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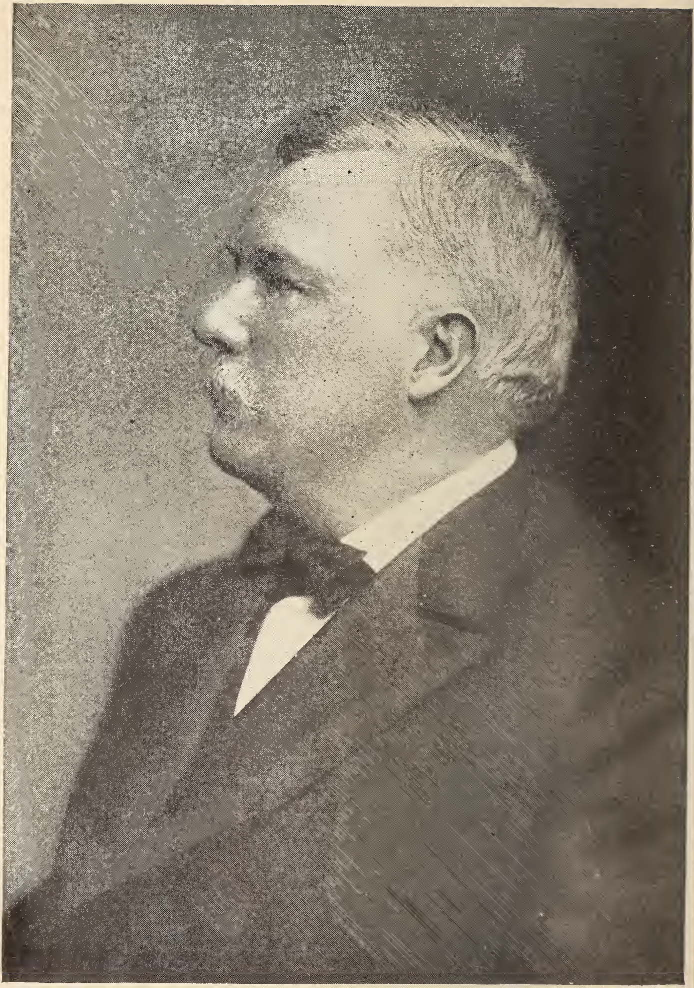
THE ROMANCE OF COMETS



Professor E. E. Barnard

The Romance of Comets

By MARY PROCTOR, F.R.A.S., F.R.Met.S.

(Daughter of the late Richard A. Proctor)
Author of "Evenings with the Stars," "Stories of Starland," "Giant Sun and His Family," "Legends of the Stars," "The Children's Book of the Heavens," Etc.

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Dedicated

TO THE MEMORY OF

my kind and helpful friend

PROFESSOR E. E. BARNARD

Contents

Illustrations

ILLUSTRATIONS

Preface

THIS book contains an account of some of the quaint ideas entertained regarding comets, meteors, and shooting stars in the days of long ago, when they were looked upon with apprehension and fear. Their appearance was supposed to herald coming disaster, until Science lifted the veil which obscured their real meaning from view. As soon as it was known that these visitants from the star-depths were composed of such airy texture that, as Sir John Herschel once expressed it, they could be easily packed in a portmanteau, tail and all, the fear of comets was at an end, and their appearance is nowadays hailed with delight.

Possibly no one appreciated this fact more strongly than the late Professor Barnard of the Yerkes Observatory, at Williams Bay, Wisconsin; and as Professor Frost, the director of the observatory, remarks, in a letter granting the author a permit for the use of several photographs of comets taken by him, "it is most appropriate that your book should be dedicated to him, as he certainly had an ardor in observing and studying comets that has seldom been equaled."

In the chapter on "Comet-hunting as a Hobby," after describing how popular it was some years ago, when cash prizes were offered to successful finders, an instance is given thereof in the story related by the late Professor E. E. Barnard, entitled "The House that was Built with Comets." As a matter of fact, it was built by means of financial aid obtained in this way. Shooting stars also come in for their due share of attention, as well as fireballs which present rather an alarming aspect until one realizes that the sudden blaze of light indicates their annihilation.

The book is illustrated with prints, charts, drawings, and photographs, and permits for their use are gratefully acknowledged to the Astronomer Royal, in connection with photographs obtained at the Royal Observatory, Greenwich; and to the directors of the Cape of Good Hope and Johannesburg Observatories in Africa, and the Yerkes Observatory in U. S. A. Also for permission kindly given by the director of Harvard College Observatory, U. S. A., to make a copy from a drawing of Donati's comet, made by Professor Bond in the year 1858.

Grateful acknowledgment is made to Mr. W.

F. Denning (Bristol) for the loan of the photograph of the Strathmore meteorite, which fell December 3, 1917, making a hole in the roof of Outh Lodge, Keithwick.

The author is specially indebted to Mr. Denning for his kindness in looking over the MS. of Chapter VIII, which deals with "Meteor Streams and Shooting Stars"; and to Dr. A. C. D. Crommelin for a like favor in connection with the chapters dealing with "Halley's Comet as Seen in 1910," and the "Origin of Comets and Meteors," the most important chapter in the book. It incorporates the views advanced by my father some thirty-five years ago, concerning the ejection theory of comets, stanchly advocated by Dr. Crommelin, as compared with the more modern capture theory. The chapter is also of special interest, as, in a way, it partly supplies the missing chapter in my father's unfinished work, *Old and New Astronomy*.

MARY PROCTOR.

LONDON, *April*, 1926.

CHAPTER ONE

COMETS AS PORTENTS

"Lo! from the dread immensity of Space,
Returning with accelerated pace,
The rushing comet to the sun descends:
And, as he shrinks below the shading Earth,
With awful train projected o'er the Heavens,
The guilty nations tremble."

—THOMSON.

CAN there be anything more awe-inspiring to the superstitious than the stealthy approach of a comet as it wends its way among the stars, finally blazing out with a marvelous train as it draws near to the sun to pay homage? As a distant relative of that luminary, it comes for an occasional visit from far-off realms, and after a brief display during which it adorns itself with a splendor befitting the momentous occasion, it withdraws into the obscurity from which it emerged. In these enlightened days a comet is greeted with enthusiasm, and the camera keeps a faithful record of its varying appearance, but in olden times it was regarded as a portent of evil.

Comets have sometimes been pictured as

dragons, and according to Pliny the shape of a comet indicated its character as a portent. Thus, some were shown as arrow heads, sea monsters, swords, lances, and flames. In A.D. 69, according to Josephus, several signs appeared in the sky announcing the destruction of Jerusalem.

> "Amongst other warnings, a comet, one of the kind called Xiphias, because their tails appear to represent the blade of a sword, was seen above the city for the space of a whole year."

Regarding the comet of A.D. 79, it is said to have preceded the death of the Roman Emperor Vespasian. When the physicians reproved the emperor for continuing to live as usual, attending to the business of the state, although attacked by a serious malady, he replied, "It is fitting that an emperor should die standing." Then perceiving some courtiers who were conversing together in a low tone of voice about the comet, gazing significantly in his direction meanwhile, he remarked: "This hairy star does not concern me; it menaces rather the King of the Parthians, for he is hairy and I am bald." Feeling his end approach, he observed, "I think that I am becoming a god."

Virgil compares a hero in his shining armor to a comet, and makes another allusion to these objects at the end of the first Georgic (Bk. I, 487-488) in the couplet thus rendered by the Rev. Canon Newbolt:

> "At no other time did more thunderbolts fall in a clear sky, nor so often did dread comets blaze."

In the natural history of Pliny we find several passages relating to the significance attached to comets by the ancients. For instance, when referring to the comet of 48 B.C., he observes:

> "We have in the war between Cæsar and Pompey an example of the terrible effects which follow the apparition of a comet. . . . That fearful star, which overthrows the powers of the earth, showed its terrible locks."

The superstitious dread in which comets were held in the Middle Ages is exemplified in the gloomy forebodings of disaster, such as wars, pestilence, and the death of kings, when these apparitions were seen in the heavens. Well known is Shakespeare's allusion to comets in Act II, Sc. 2 of "Julius Cæsar":

"When beggars die, there are no comets seen;
The heavens themselves blaze forth the death of princes."

In "Henry VI" we find the following passage in Part I, Act I, Sc. 1:

"Comets, importing change of times and states
Brandish your crystal tresses in the sky;
And with them scourge the bad revolting stars
That have consented unto Henry's death."

The comet of A.D. 451 or A.D. 453 announced the death of Attila, and the comet of A.D. 455 that of the Emperor Valentinian. So widely spread was the belief in the connection between the death of the great, and these menacing signs in the heavens, that the chroniclers of old appear to have recorded comets which were never seen, such as the comet of A.D. 814, which was supposed to have presaged the death of Charlemagne.

When the end of the world was expected in A.D. 1000, the most simple phenomena assumed terrible proportions. We are told of earthquakes, and a comet visible for nine days.

"The heavens having opened, a kind of burning torch fell upon the earth, leaving behind it a long train of light similar to a flash of lightning. Such was its light that it

> frightened not only those who were in the open country, but those who were within doors. As this opening in the heavens closed imperceptibly there became visible the figure of a dragon, whose feet were blue, and whose head seemed continually to increase."

However, this was more likely the momentary appearance of a shooting star or fireball, than the comet which the chronicler records as remaining visible for nine days.

A terrible picture accompanies the description, showing a meteor track so arranged as to resemble the outline of a dragon, and lest the resemblance might not seem convincing enough, a fearsome looking dragon to match is set beside the celestial apparition labeled "*Serpens cum ceruleis pedibus.*"

Fortunately, people were too busy in those "good old times" fighting and plundering one another to pay much heed to these omens in the sky. Moreover, with regard to the threatened end of the world, many contented themselves with the reflection that they could not be much worse off, even if the world should perish at that period. Consequently, a comet scare was averted, and we have clear evidence that, as far as the predicted catastrophe was concerned, everything went on as usual. A.D. 1000 came and went, and still the world endured.

Great importance has been attached to the seeming connection between Halley's famous comet and the portent theory, with striking events which have occurred upon the occasion of its several returns. For instance, at its return in A.D. 66 it was probably the sword of fire described by Josephus as suspended over Jerusalem not long before the destruction of that city by Titus. Its appearance in A.D. 451 coincided with the defeat of Attila at Châlons, and it was pictured in the *Nuremberg Chronicle* for A.D. 684.

It is well known in connection with the famous Bayeux tapestry into which Queen Matilda wove the story of William the Conqueror's defeat of Harold on the memorable occasion of the battle of Hastings, A.D. 1066. People are shown pointing to an object in the sky, which is labeled *Isti Mirant Stellam*, the wonderful so-called "hairy star" which supposedly heralded the success of the Conqueror.

On an adjoining panel is pictured the dejected Harold about to topple off his throne, and a solitary attendant expressing alarm at the defeated monarch's precarious position, but apparently offering no assistance of value. Thus the comet on this occasion served the double purpose, it would seem, of announcing success on the one hand and defeat on the other. Undoubtedly it caused great alarm on account of its brightness and rapid motion.

In 1456 it returned at a period of great anxiety, when the Turks, having taken possession of Constantinople three years before, now turned their attention to Belgrade, which they were besieging. It happened that the moon was passing through the crescent phase at the time, and Halley's comet presented the appearance of a sword. The crescent moon, resembling the Turkish emblem, is said to have been considered an evil omen by the Turks, contributing eventually to their defeat.

Coming to our own times, it is surprising the amount of fear and distress which was caused at the return of Halley's comet in 1910. Insanity and even cases of suicide followed at its approach, and there is a well-authenticated case of an enthusiastic young lady in New Jersey, U. S. A., who declared her intention of following the comet wheresoever it went, but was restrained by her friends, and temporary seclusion in an asylum, from this perilous pursuit.

As the time drew near for the comet to pass from the morning to the evening sky, when, according to calculations, it would cross the plane of the earth's orbit at a point exactly between the earth and the sun, fresh alarm was caused lest the earth, in plunging through the débris of the comet's train, might come to grief in consequence. A report that we should be asphyxiated by the poisonous gases, such as cyanogen, of which the train was said to be partly composed, did not tend to lessen the alarm. Cautious folk laid in a supply of bottles of oxygen to sustain life during the fatal night, and one or two of a pessimistic turn of mind actually forestalled the expected tragedy by committing suicide. Yet nothing happened, for the simple reason that on the night of the great adventure the comet obligingly spread its tail so widely apart, that we passed unharmed between two sections thereof.

Nevertheless, despite a few tragedies consequent upon fear at the comet's near approach, the lurking dread of evil it might have had in store for us was considerably less on the occasion of the return of Halley's comet in 1910, than was usual in the gloomy, prognosticating period of the Middle Ages. Yet certain events occurred which made some people wonder if there was not a kernel of truth in the so-called portents after all. For instance, during the month of January (in the

Drawn by M. Proctor

DAYLIGHT COMET 1910 A

As seen at Newcastletown Moor, January 28, by the author

eventful year 1910) the so-called Daylight comet—a totally unexpected visitor to the sun's domain—blazed out in the evening sky and the people of Paris saw its reflection in the flood which threatened to destroy their city. In May, while Londoners were watching for Halley's comet, which proved to be a very disappointing spectacle in this part of the world, the body of King Edward the Seventh lay in state at Westminster. "What wonder," as Mr. Arthur R. Hinks observes in his book entitled *Astronomy*, "that the imagination seizes upon these deplorable coincidences and the fear of comets dies hard among us?"

Tennyson thus refers to Halley's comet in his poem "Harold":

"Lo! there once more—this is the seventh night
You grimly-glaring, treble-brandished scourge of England.
. . . .
Look you, there's a star.
. . . .
It glares in heaven, it flares upon the Thames,
The people are as thick as bees below,
They hum like bees—they cannot speak—for awe,
Lord Leodwin, dost thou believe that these
Three rods of blood-red fire up yonder mean
The doom of England and the wrath of Heaven?"

Milton in "Paradise Lost" compares Satan to a comet:

"That fires the length of Ophiuchus huge
In the Arctic sky, and from his horrid hair
Shakes pestilence and war."

It has been suggested that the poet was doubtless referring to the comet of 1618, which was held responsible for the great Thirty Years' War. Milton was only ten years old at the time, but the impression made on his mind by this magnificent comet with a train 104° long (or over twenty times the distance separating the pointers in the constellation of the Great Bear), "may well have lasted until he wrote the above lines as a man of fifty."[1]

Elsewhere, in "Paradise Lost," Milton refers to a comet as the brandish'd sword of God:

". . . before them blaz'd
Fierce as a Comet: which, with torrid heat,
And vapours as the Lybian air adust,
Began to parch that Temperate clime."

According to the translation by Longfellow, Dante in his "Paradiso," Canto XXIV, refers to comets as "souls beatified."

"Thus Beatrice: and those souls beatified
Transformed themselves to spheres on steadfast poles
Flaming intensely in the guise of Comets."

[1] Chambers's *Story of the Comets*, pp. 211-212.

Turning to the *Avesta* writings, we find that the Parsees of ancient Persia classified comets as parihs, or fairies. *Pari* is the Iranian word for fairy, and is derived from the word "par," meaning to tempt, to enchant. The English word "fairy" also comes from a similar root, "fier," to enchant.

Nevertheless, these cometary fairies are not the dainty beings of English folk-lore, but are described in the *Avesta* as "ill-born fairies," their appearance in the sky inspiring terror, since they are supposed to bring disease, calamity, and death in their wake. In the picturesque language of the Persian writer, "the distress of the earth becomes as that of a sheep when a wolf falls upon it."

The following quaint account of the influence of a comet is given in the *Avesta*.

> "A hairy comet appeared in the year 662, Hijri, and the increase of the splendour of the world was in Leo. The strange thing was that it appeared to be of the proportion of the head of a big man and emitted steam from the front. It passed over the countries of Tibet, Turkestan, China, Kashgar and remained visible for 85 days. In all these

countries there arose rebellions. In Khorassan calamities of thunder and lightning and other such phenomena appeared.

"Many years and many months had passed over this event, and then in 803, a tailed comet appeared in the zenith of Constantinople. Astrologers informed Timur that from what the wise and the experienced have said, it appears that an army coming from the direction of the east will be victorious in that country, and a general from that country will assist him. Timur (literally: the illuminator of the face of fortune), who was always expecting an invasion of the country, but whose companions of poor intelligence did not acquiesce, attended to that prediction and convinced the great and small of his court, of the truth and insight of the star-seers. The learned in the mysteries of the heavens are convinced of this, that if the comet appears within the boundaries of a country, its king dies. If it is inclined towards the boundary, the country of the governor passes away from his hands, and plague and disease add to the afflictions of the country."[1]

[1] *Journal* of the Bombay Branch of the Royal Asiatic Society, vol. xxiii. Account of comets given by Mohammedan historians.

Some of the Pahlavi books refer to a comet as "the thievish Mushpar provided with tails." The comet was classified as an evil spirit in company with planets and meteors which wandered hither and thither; while the sun, moon, and fixed stars were considered good spirits, because they were always to be found at appointed times in their places in the sky.

In the mythology of China and Japan we find that comets were supposed to be celestial representatives of every country on the earth, and occupied the important position of ambassadors journeying from one celestial region to another, and giving forecasts of terrestrial events of importance. For this reason, careful records were kept of the dates of their appearance and the paths along which they traveled, thus enabling astronomers of to-day to trace back the path of Halley's comet, for instance, to a very remote era. Whatever the motive that prompted the accumulation of records, they have proved of the utmost value.

Comets are called "broom stars" in China, a name derived from the form of their tails, which have the very prosaic name of brooms (sui or soui). A comet without a tail was referred to as merely a star, or a guest star, from its visiting the provinces and taking up its abode in different places, as at an inn.

> "Their home was in the vestibule of the celestial palaces; there, under an invisible form, they awaited the order of departure," says Pingré, "the order sent, they became visible and commenced their journey. If, whilst on their way they put forth a tail, the star was said to have become a comet."

The above quotation, remarks the same author, explains:

> "the foolish and singular idea that the Chinese formed of the heavens. According to them, the heavens represented a great empire, composed of kingdoms and provinces; these provinces were the constellations; there was decided all that would happen for good or ill to the great terrestrial empire, that is, to China. The planets were the administrators or superintendents of the celestial republic, the stars were their ministers, and the comets their couriers or messengers. The planets sent their messengers from time to time to visit the provinces for the purpose of

> restoring or maintaining order, but all that was done in the heavens above was either the cause or the forerunner of what was to happen below."

The ideas of the Chinese were not more foolish than the extravagant myths of the ancients, and of the Europeans in the Middle Ages. Nevertheless, although comets are no longer regarded with superstitious awe, mystery still clings to them. For those who are unaware of the fact that astronomers can trace their paths, predict the periodic returns of these wanderers, and even analyze the substance of which they are composed, there are many problems concerning them still awaiting solution.

CHAPTER TWO

COMET-HUNTING AS A HOBBY

"I have the greatest admiration for a man or woman who discovers a comet, because I know of the hard and thorough work which the success implies."
—W. R. Brooks, the noted American comet-hunter.

TO hunt for a comet in the ocean of space is as fascinating a hobby in its way as angling for a wily fish, requiring in either case an unlimited supply of perseverance, patience, and spare time. In place of fishing tackle one requires a telescope with an aperture of four or six inches, though excellent work has been accomplished with smaller instruments. It should be erected in a position commanding a clear view of the horizon either eastward or westward, as comets travel in the wake of the rising or setting sun. During the daytime a glance at a map showing the region of the sky to be examined in the evening will save an endless waste of time, to say nothing of the disappointment when the suspected object proves to be a nebula and not a comet. On the other hand, fuzzy-looking objects resembling comets have been mistaken for nebulæ when in reality they *were* comets. For instance, in looking over Sir William Herschel's list of 1,000 nebulæ and clusters, presented by him to the Royal Society in 1786, suspicion is aroused by the following entry: "Some of the shape of a fan, resembling an electric brush, issuing from a lucid point, others of the cometic shape, with a seeming nucleus in the center, or like cloudy stars surrounded with a nebulous atmosphere." (*Philosophical Transactions*, Vol. LXXIV, p. 442.) As we shall see later on, the descriptions tally with the appearance of comets which have been photographed.

Nebulæ and clusters likely to be on the list of "suspects" have been charted in my father's *New Star Atlas*, edition 1915, containing maps of all the stars down to the sixth magnitude (that is, all stars which can be seen with the naked eye), as well as the positions of nebulæ, clusters, and fainter stars which become visible with the aid of a small telescope. It is a compact, handy volume, serving as an excellent guide for the amateur comet-hunter in his rambles through starland in search of cometary prey.

Provided with a copy of this book, and allowed the privilege of using the Brashear (name of the maker), Comet-Seeker, which is stationed on the main roof of the Yerkes Observatory at Williams Bay, Wisconsin, U. S. A., the writer spent many a delightful evening during the summer of 1910, scanning the evening sky for celestial wanderers. Unable to resist the temptation to linger by the way in admiration of double stars, clusters, and nebulæ strewn along the highways and byways of starland, comets missed recognition.[1] Nevertheless, the evenings spent with the little comet-seeker were a source of unqualified delight, though no comet hove in sight.

The telescope of six inches aperture, easily handled, is inclosed in a sort of cabin which rolls on wheels. This can be pushed backward a certain distance, leaving the instrument out in the open air. Fortunately, the width of the cabin was such that it was just possible for the writer to catch hold of the rods on each side, drawing them backward the distance required; while shutting it was an easier matter, requiring as a rule a gentle push, sending the cabin back on the rollers provided for this purpose. Before doing so, however, the telescope was leveled and carefully wrapped up to keep it free from any moisture or dampness which might penetrate from the outside, and anyone who

[1] This disposes of the story according to which, when the reporter of a Sydney newspaper asked the writer if she had discovered any comets, she modestly replied, "Yes, a few."

The Comet-seeker on the Roof of the Yerkes Observatory, at Williams Bay, Wisconsin

has passed a winter in Wisconsin knows something of the deep snowdrifts which must settle several feet deep in such an exposed site as the main roof of the Yerkes Observatory building. After the cabin has been closed, it is hooked at the sides and remains so until the services of the telescope within are once more required.

Then the cabin is reopened and the wrappings are removed from the telescope, which is turned in the direction of a specially selected star. This is kept in the center of the field of view, which is marked by the intersection of two threads made from a spider's web. As there is no clockwork attachment, the telescope is guided by means of a small screw like a miniature wheel or helm, enabling the observer to pilot his or her way through the ocean of space. Then a keen search is made in the surrounding region, and if nothing in the way of a comet "stands revealed" to the searching eye of the telescope, another region is explored, so that a more or less extended expanse of sky comes under observation during the course of the evening. On one eventful occasion a supposed comet was glimpsed and its position duly charted with regard to neighboring stars. However, on reference to the star map the fuzzy-looking object proved to be a nebula. Supposing by any possibility the suspected object *had* been a comet, this could have been proved beyond doubt by watching it for two or three evenings in succession. The presence of a comet can be detected as it slowly drifts against a background composed of the stars, while the nebula is at a distance so remote that an observer would have to watch for centuries before he detected any perceptible motion.

Nevertheless, there is a close resemblance between the hazy-looking objects known as nebulæ and comets when they emerge from obscurity. For this reason, they gave a great deal of trouble to Messier, a French astronomer of the eighteenth century. So keen was he on capturing comets that Louis XV nicknamed him "the Ferret of Comets." Consequently, we can imagine his annoyance, after discovering a supposed comet, at finding it was merely a cloudy-looking object which he termed a nebula. He kept a careful record of these "embarrassing objects," so that he might not be led astray by them again, and labeled them Messier 1, Messier 2, and Messier 3, in the order of discovery, and these are usually briefly recorded on star maps as M1, M2, M3, etc. In this way, Messier made a list of forty-five nebulæ, which he entered in a catalogue published at Paris in 1771. A century later (1871) the list had been enlarged by one hundred and three discoveries. For the listing of these "embarrassing objects," as Messier termed them, we are greatly indebted, since in recent years photography has revealed the fact that they are among the most marvelous objects in the heavens.

With the assistance of a small two-foot telescope of two and a half inches aperture, magnifying five times, and with a field of view covering four or five degrees, Messier discovered thirteen comets. His first comet dates from 1760, and another French astronomer named Pons, who discovered a comet in 1802, joined him in the pioneer work of making a systematic search for comets. It is interesting to note that Pons was a doorkeeper at the Observatory at Marseilles, and, owing to the teaching and encouragement he received from Thulis, the director, he achieved phenomenal success as a comet-hunter. A third name must be added to the list of these enterprising searchers after cometary prey, *viz.*, that of Montaigne, between whom and Messier existed a keen rivalry. The following story shows the importance attached by the latter to each comet captured.

It seems that on one occasion Messier, who had discovered twelve comets, was looking for his thirteenth, when his wife was taken seriously ill and died. While attending to her he was hindered in his search for the comet which was found by his rival, Montaigne. When some one sympathized with him about the loss he had sustained he said, "Alas! Montaigne has robbed me of my thirteenth comet!" Then realizing that he should be mourning the loss of his wife, he added the remark, "Ah! poor woman!" but he continued grieving for his lost comet.

Apparently Messier's path was beset with difficulties, for in his book entitled *Planetary Worlds* Breen tells us that on one occasion while Messier was walking in President Saron's garden he was doubtless looking up at the sky on the chance of detecting a comet, when he fell into an icehouse, and was temporarily disabled. Later on, we are told in the same book, the revolution deprived Messier of his little income and every evening he was wont to repair to the house of the noted astronomer Lalande to replenish the supply of oil for his midnight lamp. The political storm made it necessary for him to remove to another neighborhood, "where he no longer heard the clocks of forty-two churches sounding the hours during the night watchings."

Possibly his most trying experience occurred in connection with the expected return of Halley's comet in 1758. It was first observed by a farmer named Palitzsch, living at Prohlis, near Dresden, who saw it on Christmas Day, 1758, with a telescope of eight-foot focus. He was an amateur astronomer possessed of keen sight, and was in the habit of searching the heavens with the naked eye, which seems to have given rise to the statement that he found Halley's comet with the naked eye at a time when the professional astronomers were searching for it in vain with their telescopes.

Meanwhile, Messier had been carrying on a prolonged watch of the heavens, extending over the whole of the year 1758, but he did not actually get a view of Halley's comet until January 21, 1759, when he observed it regularly for three weeks. He was the first noted astronomer to do so, but according to the account given by J. Russell Hind, in his book on *The Comets* (page 41):

> "Delisle, then director of the Observatory at Paris, would not allow him to give notice to the astronomers of that city that the long-expected body was in sight, and Messier remained the only observer before the comet was lost in the sun's rays. Such a discreditable and selfish concealment of an interesting discovery is not likely to sully again the annals of astronomy. Some members of the

> French Academy looked upon Messier's observations, when published, as forgeries, but his name stood too high for such imputations to last long, and the positions were soon received as authentic, and have been of great service in correcting the orbit of the comet at this (1835) return."

The name of J. R. Hind, by the way, is the only English one included in the list of those who received a gold medal given to the discoverer of telescopic comets by Frederick VI, King of Denmark, who instituted the distribution of this award in the year 1835. The gold medal was also won by an American astronomer, Maria Mitchell, who discovered a comet, October 1, 1847, while engaged in making observations from the roof of the Nantucket Athenæum. When eighteen years old she was appointed librarian at the Athenæum, which position she held for twenty years. The roof of the building was her observatory. In 1865 she became professor of astronomy at Vassar College, a position she retained until her health permitted her to do so no longer.

The grant of the medal by King Frederick VI was discontinued after the death of his successor, Christian VIII, in 1848. The Vienna Academy of

Sciences formerly gave a gold medal to the discoverer of every new comet, but this also was discontinued in 1880. Then Mr. H. H. Warner, a wealthy American, came to the rescue and offered a prize of two hundred dollars for every unexpected comet found by an observer in Canada or U. S. A., which brings us to the story told in the autobiography of the late Professor E. E. Barnard, one of the most successful competitors. He had nineteen comets to his credit, resulting in the erection of what he quaintly termed "The house that was built with comets."

> "Times were hard in the last of the 'seventies and the first of the 'eighties, and money was scarce. It had taken all that I could save to buy my small telescope. I had been searching for comets for upward of a year with no success, when a prize of two hundred dollars for the discovery of each new comet was offered (in 1880) by the founder of the Warner Observatory through the agency of Dr. Lewis Swift, its director. Soon after this it happened that I found a new comet and was awarded the prize. Then came the question, 'What shall we do with the money?' After due deliberation it was decided that we

[referring to Mrs. Barnard] would try to get a home of our own with it. I had always longed for such a home where one could plant trees and watch them grow up and call them our own. So we bought a lot with part of the money, which was on what was afterwards called Belmont Avenue, but which was not then even a road. It was hard to find the lot after it was bought, for it was out in the open common. The place was in the midst of a scattered settlement of negro shanties, where the negroes had 'squatted' after the war, though on beautiful rising ground which I had selected in part because it gave me a clear horizon with my telescope.

"After some saving and some borrowing, and mainly a mortgage on the lot, we built a little frame cottage where my mother, my wife, and I went to live. Those were happy days, though the struggle for a livelihood was a hard one, with working from early to late for a bare sustenance (and the hope of paying off the mortgage), and sitting up all the rest of the twenty-four hours, hunting for comets.

"We could only look forward with dread to the meeting of the notes that must come due.

However, when the first note was due a faint comet was discovered wandering along the outskirts of creation, and the money went to meet the payments, and this continued after we had gone to other scenes. The faithful comet, like the goose that laid the golden egg, conveniently timed its appearance to coincide with the advent of those dreaded notes. And thus it finally came about that the house was built entirely of comets. This fact goes to prove the great error of those scientific men who figure out that a comet is but a flimsy affair after all, infinitely more rare than the breath of the morning air, for here was a strong compact house, albeit a small one, built entirely out of them. True, it took several good-sized comets to do it, but it was done, nevertheless."

In connection with the prize offered by Dr. H. H. Warner, Professor W. H. Brooks discovered twenty comets; Barnard, nineteen, as already stated; Perrine, thirteen; and Swift, eleven. Awarding this prize was given up after a while, but the idea was again revived by a wealthy American, the late Mr. J. M. Donohoe, in the year 1890, with the result that a bronze medal is now presented to the discoverer of any new comet, on the report of a committee of the Astronomical Society of the Pacific. There were two awards for the year 1923. Comet A was discovered independently by Sr. Dr. Arturo Bernard, Colmenarejo, Madrid, Spain, on October 11, 1923; and by Alexander D. Dubiago, of Kasan, Russia, on October 14, 1923. The medal was awarded to each of these two discoverers. On November 10, 1923, Mr. W. Reid, of Rondebosch, South Africa, who has been awarded several of the medals for his discoveries of comets, added another to his list of captures.

Regarding the ease with which comets may be discovered in the clear skies of America, Professor H. H. Turner, in his lecture on Halley's comet, given before the British Association in 1908 at Dublin, referred to a meeting which took place at Albany, New York, of the Board of Visitors. A discussion arose as to the value of some desk work which the director was carrying on, as compared with the discovery of a comet, which it was suggested would surely add to the reputation of the observatory. Professor Boss (the director) promptly remarked that nothing was easier, if they would sanction the outlay of certain sums of money to be used as salary for a person of average intelligence, while devoting himself to the search.

> "The challenge was accepted on the spot," remarked Professor Turner, "the money subscribed, the searcher set to work, and within the allotted time a fine comet was found. Professor Boss undoubtedly took a certain risk in undertaking to catch a comet, just as a man who would undertake to catch a fish within a definite time. But he was anxious to indicate his views of the relative importance of different kinds of work, and deserved the success he ventured to count upon."

One wonders if this was the occasion referred to when it is said that the comet-hunter, after a preliminary search for a comet, returned to the room where the Visitors were awaiting his report, announcing that he had discovered a comet in such and such a part of the sky. It was immediately claimed by Professor Barnard, who was present on this occasion, as one that had already been discovered by him last spring, or a year or so ago, as the case might be. After this had occurred two or three times, it is said, the comet-hunter remarked to Professor Barnard, "Why don't you keep your comets chained?" However, it may be as well to take this story *cum grano salis.*

The cloud-laden skies of England are not encouraging, as far as comet-hunting is concerned. It may be possible, when the moon is absent, to get a glimpse of a comet low down in the vapors after sunrise or sunset, if the chances are favorable. Then follows a week of cloud and misty skies during which period the comet has vanished. For this reason the discovery of comets in England is rare, but all the more credit to those who eventually succeed in making a capture.

Our veteran comet-hunter is Mr. W. F. Denning, of Bristol, who has specialized in the observation of comets and meteors. In his book on *Telescopic Work on Starlight Evenings* he gives an instance of two experiences he had in the year 1881, showing how he missed one comet, but succeeded in finding another, just before sunrise, when comet-hunting is not nearly as attractive, one imagines, as in the evening.

It seems that on July 11, 1881, after a night's observation of the stars, Mr. Denning, just before daylight and preparatory to ceasing work, looked in the direction of the constellation Auriga, the Charioteer. The idea occurred to him that it might be worth while to sweep the surrounding region with his comet eyepiece, but he hesitated, not thinking the prospect sufficiently inviting. There is a well-known saying that he who hesitates is lost, and on this occasion Mr. Denning undoubtedly missed an opportunity for finding a comet. Three nights later a bright comet in Auriga was discovered by Schaeberle, an American astronomer at Ann Arbor, Michigan!

That same year, on October 4, Mr. Denning had been observing the planet Jupiter before sunrise, when once more he hesitated as to the advisability of making an attempt at comet-seeking, but, profiting by his former experience, he made use of the comet eyepiece with good results. To quote his own words—

> "at almost my first sweep I alighted upon a suspicious object which afterwards proved itself a comet of short period,"

which means that it is a frequent visitor to the neighborhood of the sun. These facts are encouraging, and still more so when we remember that Kepler said, "there are as many comets in the sky as there are fishes in the sea."

The first woman to discover a comet was Caroline Herschel, the sister of the famous astronomer, Sir W. Herschel, and she had eight to her credit. In her diary, which has been most carefully preserved by Miss Francesca Herschel at Observatory House, Slough, there is an account of her first discovery which occurred on August 1, 1786. During the absence of her brother in Germany she availed herself of the opportunity to make use of a small Newtonian telescope he had given her, in "sweeping the skies." Her "sweeper," as she termed it, was of 27-inch focal length, a power of about 20, and a field of view 2° 12′.

Miss Herschel had been observing nebulæ when she saw what she believed might prove to be a comet. At one o'clock on the morning of August 2 she made the following brief note in her diary: "The object last night *is* a comet," and she wrote to Dr. Blagden of the Royal Astronomical Society, asking him to take the comet under his protection "in regard to its right ascension and declination," which correspond to latitude and longitude of a place on earth. The right ascension of a heavenly body is measured eastward along the celestial equator, from the vernal equinox to the hour circle on which the object lies. Declination of a heavenly body is its distance north or south of the celestial equator, measured on a great circle passing through the pole and the celestial body.

Caroline Herschel sent drawings she had made, showing the position of the suspected object with regard to certain stars in the same field of view, to Dr. Blagden. He was thus enabled to locate the comet and confirm her observation. When this discovery of a comet was followed by seven more, Caroline Herschel succeeded in making for herself a European reputation for what was called "her eccentric vocation."

In 1828 she received the gold medal of the Royal Astronomical Society, and in 1835 was elected an honorary member thereof. The personal interest she took in her cometary captures is evidenced by a neat little packet found among her papers after her death, containing the account of her discoveries. It was labeled "Bills and Receipts of my Comets." This also has been carefully preserved by Miss Francesca Herschel (the granddaughter of Sir William Herschel) who showed it to the writer during the summer of 1922.

Searching for comets is not part of the defined programs of observatories, as it involves an immense amount of time with results which only present themselves at intervals. However, when an amateur succeeds in discovering a comet and has made known the fact to a professional astronomer, the latter completes the work of computing its orbit and other elements, which is not usually undertaken by the discoverer, unless he has the requisite mathematical knowledge.

Yet it is advantageous, if he possesses a ring micrometer (an instrument used for the measurement of small angles), to learn how to make use of it during the first few observations, which are usually made before the comet has been seen elsewhere. These observations, if precise, will prove of the greatest value. The news of the discovery of a comet should be sent at the first opportunity to the director of the nearest observatory, who will communicate with the director (Elis Stromgren) of the Bureau Centrale Astronomique de l'Union Astronomique Internationale, Observatoire de Copenhagen, from which center it will be sent broadcast all over the world. The discoverer will then experience the delight of having a comet named after him, which he can claim forthwith as his own individual celestial treasure trove. As a matter of fact, newly discovered comets are now usually referred to by their date and order of discovery, as Comet 1, 1924, saving much confusion as to the name of the actual discoverer. This was exemplified in the case of a comet found by Pons in 1819 (III of that year), which Encke showed to be revolving in an ellipse with a periodic time of three and one-half years. Hence its name of Encke's comet. It was again renamed after Winnecke, who rediscovered it in 1858, but actually he had no more claim to the title than Caroline Herschel, who discovered it in 1795—her seventh comet—or Méchain by whom it had been previously seen in January, 1786.

The majority of comets travel in an ellipse, and those of short period, like Encke's comet, make short journeys and may be considered frequent visitors to the neighborhood of the sun. Others are long-period comets, such as Donati's (described in the following chapter), since it requires nearly two thousand years for the round trip. Finally there is a third class of adventurous comets which dash in from outer space, swinging swiftly round the sun in the focus of its curve, and darting off again with no prospect of returning, since they cannot possibly get round the other focus. Whence they have come or whither they have gone, no man knows! They are like the sparrow referred to in a simile used by a courtier in the days of King Edwin, who compared its fleeting visit to the life of a man:

"It is as a sparrow's flight through the hall when you are sitting at meat in winter tide, with the warm fire lighted on the hearth, but the icy rain storm without. The sparrow flies in at one door, and tarries for a moment in the light and heat of the hearth fire, and then flying forth from the other, vanishes into the wintry darkness whence it came."

CHAPTER THREE

THE STORY OF DONATI'S COMET

> Hast thou ne'er seen the comet's flaming flight?
> Th' illustrious stranger, passing terror sheds
> On gazing Nations, from his fiery train
> Of length enormous, takes his ample round
> Thro' depths of ether; coasts unnumbered Worlds,
> Of more than solar glory, doubles wide
> Heaven's mighty cape; and then revisits Earth,
> From the long travel of a thousand years.
>
> —YOUNG. "Night Thoughts."

WHEN a comet draws near to pay its respects to its ruler, the sun, it usually assumes a splendor befitting this momentous occasion. It adorns itself with a glittering train millions of miles in length, and composed of myriads of particles reflecting the sun's light. The head is often enveloped in a multiplicity of transparent veils, through which bright jets may be seen emanating from the star-like nucleus within. Some comets have been seen with five or six trains, spread out like that of a peacock, the camera revealing rapid and marvelous changes in their appearance, during the course of a few hours. No fair débutante, about to be presented to royalty, could vie with a comet in capriciousness regarding her raiment, nor could she equal it in splendor, even though she owned the mystic lamp of Aladdin.

The brief assumption of splendor on the part of a comet is very unlike its usual humdrum existence when it is as yet so far distant as to be not only invisible to the comet-hunter, but beyond range of the far-reaching eye of the telescope or the entrapping power of the camera. Not the slightest impression is made on the photographic plate, and as far as an observer on planet earth is concerned the comet might have ceased to exist. It is only when it begins to draw near to the sun that we are enabled to obtain a record of the marvelous changes produced in its appearance, until at its nearest approach it has sometimes been known to vibrate as though with intense excitement. For instance, in the case of Biela's comet, concerning which a special account is given further on, it was apparently so overcome at its last appearance in 1846, that it split in two and literally went to pieces.

Quite a different story is told concerning the magnificent comet which greeted us in the summer of 1858, and was first seen at Florence on the 2d of June by Giambattista Donati, after whom it was named. At the time it was merely a nebulous mass about one-twentieth the diameter of the moon, and for some weeks it retained about the same brightness except for a gradual increase in the central star-like point, the only indication of its coming splendor. At the end of August it had increased so rapidly in brightness that by September it was visible to the unaided eye, resembling a hazy-looking star adorned with a small tail.

Gradually, as it drew nearer to the sun, it increased in size and splendor, reaching its maximum brightness in October. Its train extended over an arc of forty degrees, or eight times the distance separating Alpha and Beta—the so-called pointers in the constellation of Ursa Major, the Great Bear. Its real length was then about forty-five million miles, with a width of ten million. The nucleus varied in diameter from five hundred miles to three thousand, or nearly half that of our planet earth.

The comet was kept under accurate observation for fully nine months, and during part of that time it was visible to the naked eye. Professor G. P. Bond, the director of the Harvard College Observatory, availed himself of the opportunity thus presented, of making a series of drawings of the comet which convey an excellent idea of its changing appearance, and the delicate shadings and misty outlines of this marvelous visitant from the star-depths. These drawings are of all the more value, since it will be nearly two thousand years before Donati's comet visits these realms again.

To go back to the earlier history of the comet, before these drawings were made, we find that its tail was not observed telescopically until seventy-three days after Donati's discovery. It was seen on August 14, 1858, by astronomers at Copenhagen and Vienna, but not at Harvard until the 20th of that month. The brilliancy of the comet was somewhat impaired by a strong twilight and its low altitude. This may account for the fact that it was described as ruddy in hue, and concentrated, and having a mere suggestion of a tail. On August 23 the tail was still so faint as to be easily overlooked in the moonlight, the record being: "Bright, but no trace of a tail; the sky clear, but the moon nearly at full." On August 30, according to the record in the *Times* (London), of observations made by J. Russell Hind, "The comet was just perceptible to the naked eye; its nucleus is strongly condensed and brilliant, and the tail is thrown off in the ordinary form, without bifurcation."

During the month of September the tail of the comet showed a tendency to curve, and by September 7 it was recorded as being very conspicuous to the naked eye. September 12 it had increased wonderfully in brilliancy, and on September 16 the first sketch was made by G. P. Bond, showing a view of it with the naked eye. The tail was now estimated as being 7° long, thus exceeding the distance (of 5°) separating the pointers. A tangent to the convex edge near the nucleus prolonged would pass through Delta in Ursa Major, and it was noticeable that this side was the brightest in all the sketches. A narrow dark channel extending from the nucleus up the axis of the tail was very remarkable, and its edges were surprisingly well defined, especially very near the nucleus. In fact, the comparatively sharp definition of the eastern edge of the tail was in marked contrast to the softness of outline on the western side. (See *Monthly Notices*, R. A. S., Vol. XIX, pp. 88-89.)

By September 27 the length of the tail as observed with the naked eye was about 9° or 10°. It was curved, convex toward the star Cor Caroli, being much better defined on the side near the star than on the concave side. The narrow dark stripe in the axis of the tail was still very marked, and the outline of the tail could be traced from the nucleus halfway to Delta in Ursa Major, and a degree or so further. It was now strongly curved and its upper outline well defined and bright as compared with the inner. A straight ray or secondary tail could be seen faintly suggested on the eastern side and reaching northward from the main tail.

By October 3 a marvelous change had taken place in the appearance of the comet. The train had increased in length and brightness, extending nearly as far as Eta in Ursa Major, and the straight ray or secondary train was still very much in evidence. It was supplemented by another slender ray, as shown in drawings made by Professor Bond on October 4 and 5, but it had vanished by October 6, although its position was indicated, for that date, in the faint suggestion of a ray between the main tail and the outer or secondary tail. The bright star to the left of the nucleus of the comet is Arcturus (in the constellation Boötes), over which the comet passed without perceptibly diminishing its brightness, thus showing of what airy texture the train of a comet is composed. Was it not Sir John Herschel who said that a comet could be easily packed in a portmanteau, and in the recent edition of *The Vault of Heaven* Sir Richard Gregory gives the following

Comet of Donati
Photograph taken October 10, 1858, at Harvard College Observatory

unique illustration of the insignificance of the whole mass of a comet:

> "Suppose we could take a comet, head, tail and all, and put it in one pan of a balance, and we could carve out from the air which surrounds us an object of the same size to put in the other pan, we should find that our aërial body weighed four or five thousand times more than the comet. But though a comet as a whole is lighter than air, it must not be concluded that comets consist solely of gases in a state of extreme tenuity. The head may be, and very probably is, composed of a large number of small but solid bodies; nevertheless, when a comet is taken in its entirety, the mean density is extremely low."

By October 10, the comet was receding from the neighborhood of Ursa Major, drifting across the constellation of Boötes. On this date the comet made its nearest approach to the earth. Its train now resembled that of a widely opened fan, but its outline was already growing dim. It showed strange alterations of dark and bright bands, resembling the streamers which are sometimes seen to break up the continuous outline of an auroral arch. The extreme length of the tail was nearly 64°, the greatest extent observed during the apparition of the comet. The secondary tail was still visible, but extremely faint.

October 11, the dark stripe in the tail had almost vanished, the secondary tail was no longer to be seen, and the main tail was curved like an ostrich plume. Its length was now judged to be about 30°, and the nucleus had somewhat diminished in brightness. By October 15 the comet was considerably fainter and smaller, as seen with the naked eye, and it was bent southward like a sail wafted by a celestial breeze. After the middle of October, the comet was best seen from the southern hemisphere, and the last glimpse obtained in the northern hemisphere was on October 25, when it was at an altitude of 3°, the sky fortunately being very clear. The nucleus was still bright, but the tail was only 1° long.

Its course was then followed by Maclear, Royal Astronomer at the Cape of Good Hope, who reported that on December 23 the comet was merely a faint nebulous body, about 90″ in diameter, with a slight central condensation of light and no trace of a tail. Thus, it vanished in the remote depths of space, in the same undecorated condition as when it first made its eventful début to gladden the eyes of mortals on planet earth. Its visit lasted but one hundred and seventy-seven days, from the time of its first appearance until it took its departure along a track which will not bring it within our ken again until nearly two thousand years have rolled away.

BIOGRAPHICAL NOTE.—G. B. Donati, the Italian astronomer, was born at Pisa, in 1826. At the age of twenty-six, he obtained a post in the observatory at Florence, and there by his superior abilities, acquirements, and unwearied application to duty soon gained a high reputation among the men of science of his native country. He became known to the world in 1858, by his discovery of the magnificent comet called by his name. In 1864 he was appointed director of the observatory in which he had worked so efficiently for twelve years. He then undertook the arduous task of superintending the erection of a new and more convenient observatory on the site of Arcetri, near Florence. All difficulties were conquered, the new observatory was in working condition, and the director had entered upon a new series of observations when his labors were suddenly cut short by death. He died at his home in Arcetri, September 29, 1873.

CHAPTER FOUR

COMETS IN DISTRESS

> "Thou comest whence no mortal seer can know,
> Thou goest whither nothing human dreams."
>
> —ANON.

UNTIL the photographic eyes of Science detected the peculiarities of comets, and mathematicians calculated with unerring accuracy their comings and goings, they were looked upon, as we have already seen, with more or less suspicion and dread. Nowadays, we know that these "airy nothings," as Sir John Herschel termed them, have been unjustly maligned. Were they given the power of speech, they could a tale unfold of adventurous thrills and overwhelming disasters encountered during their voyages in space, far exceeding in interest any story of terrestrial adventure. It would take the pen of a Jules Verne and an author gifted with his vivid imagination to describe the erratic career of a comet.

Take for instance the tragic fate of the headless comet of 1887, which was described by Dr. Thome of the Cordoba University as:

> "a beautiful object with a narrow, straight, sharply defined graceful tail over fifty degrees long. It was shining with a soft starry light against a dark sky, beginning apparently without a head, and gradually widening and fading as it extended upwards."[1]

Now the popular idea of a well-regulated comet is a star with a tail, but a tail without an accompanying star seems preposterous, yet a headless comet this object remained as viewed with the naked eye. The why and the wherefore of the tragedy is unknown, and whether it ever had a head and what became of it remains one of the many unsolved problems of the sky.

Still more remarkable is the career of the famous comet of Biela, from its first appearance as viewed by mortal eyes on March 8, 1772, until its final disappearance, a century later, in a veritable blaze of celestial fireworks. Its story reads like a novel, and is far more fascinating because it is fact and not fiction. The hero is a faint, insig-

[1] *Nature*, June 16, 1887.

nificant-looking object which was discovered by Montaigne of Limoges, already referred to as the comet-hunter who so indiscreetly found the thirteenth comet for which his colleague Messier was industriously searching. Little did Montaigne guess that this foggy speck of light which was so faint that it could only be seen with the aid of his small telescope would one day attract world-wide attention. Its nondescript appearance, with a tail only one-eighth the diameter of the moon, made it apparently scarcely worthy of more than passing notice. Had Montaigne concentrated his efforts on finding out its peculiarities and tracing its path, his name would have been forever connected with the little wanderer, instead of being entered in the annals of astronomy as merely the first to see it.

The introductory chapter in its story is connected with a letter written by Montaigne to the director of the observatory at Paris, announcing his discovery. This arrived in time to give the astronomers an opportunity for seeing the comet three or four times ere it vanished on its way outward bound. Little more was thought of the celestial visitor until it was glimpsed again thirty-three years later, in November, 1805, by Pons, who, as we have already seen, shared honors with Messier and Montaigne in the "eccentric vocation" of comet-hunting. The comet remained visible in the northern heavens for only a month, when it sank below the horizon and was no longer visible to observers in the northern hemisphere.

However, on this occasion the comet came very close to the earth, for we are told that it was visible to the naked eye, even in the strong twilight. Then it remained hidden from view until twenty years later, when it was again rediscovered, this time by an Austrian officer named Biela, in February, 1826. He was determined that the wily object should not be lost sight of again, as far as its orbit was concerned, and by means of careful observations and calculations he was enabled to announce that it was traveling along the same route as the comet seen by Montaigne in 1772, and that seen by Pons in 1805. Therefore, he concluded that it was one and the same comet, and predicted its return in 1832.

However, when it was announced by the great French astronomer, Arago, that the comet at this return would cross the orbit of the earth, widespread was the consternation among those who did not know what an orbit was. Possibly, imagining that it was something tangible, we can picture them looking at one another in dismay, and whispering in awed tones, "Does this mean the comet will hit the earth, and if so what will happen to us?" A possible collision with the comet was an alarming thought to the ignorant and superstitious, and the fear caused by Arago's announcement was so great that it resulted in the first of the many comet-scares. People in dread of the threatened calamity sold their goods and chattels, and thronged the churches as a fit preparation for the end of the world. There they awaited the expected crash and doubtless were surprised when nothing unusual happened. The earth still continued to roll on its appointed path, without jolt or jar to disturb the "even tenor of its way." The nervous gave a sigh of relief when the comet withdrew once more into the obscurity of space, and those who had parted with their belongings must have felt somewhat annoyed.

The so-called devout astrologers who had made use of Arago's announcement to their own advantage, when upbraided by those whom they had warned, did a skillful kind of "hedging," by stating that events announced by a comet might be postponed for one or more periods of forty years or even as many years as the comet had appeared days. Consequently, one which had appeared for six months would not produce any effect, evil or otherwise, for 180 years.[1] Thus these wise soothsayers allowed a wide margin for possible results.

To give an idea of the filmy structure of the comet, the cause of such unnecessary alarm, it was described by Sir John Herschel, who observed it on September 23, 1832, as a round hazy-looking object without a tail. It was moving in the direction of a small group of faint stars, which were undimmed when overtaken by the comet, so that it resembled a fog-like mist sprinkled with stars, this veil of cometary matter being estimated by Herschel as fifty thousand miles thick. Yet, only a month later, the remote prospect of a collision with this celestial cobweb caused a panic in Europe!

The comet was first seen on August 23, 1832, but owing to its excessive faintness was not generally observed till two months later, when at its nearest to the sun. This occurred during the month of November, within twelve hours of the time predicted by an astronomer named Santini. At its next return, in 1839, the comet was not well placed for observation, as it was too near the sun, and therefore lost in the glare of its light. As computations had shown that the comet was

[1] See Flammarion's *History of the Heavens*, p. 348.

traveling in an orbit requiring six and two-thirds of a year, it was due to return in 1845.

The first to bid it welcome was an astronomer at Rome named De Vico, on November 28 of that year. Two days later it was observed by Dr. Gallé at Berlin, but it was not generally seen until December. It appeared as a single comet on November 28, but on December 19 it was seen distinctly pear-shaped, and ten days later it amazed all observers by splitting in two. This marvelous transformation was first detected by two Americans, Mr. Herrick, then librarian at Yale College, and Mr. Francis Bradley, a clerk in the New Haven City Bank. The two were watching the comet on January 29, 1845, taking turns in looking through a telescope which had been erected in the Athenæum tower.

Suddenly one of the observers exclaimed that he could see a small comet accompanying the larger one, and we can imagine his friend making some remark concerning defective eyesight. However, when both saw the duplicity of the comet, all doubts were dispersed. But what did it mean? Had the comet a satellite, just as the earth has its accompanying moon, or had the comet actually split in two? However, the twin comets were seen two weeks later by Lieutenant Maury and Professor Hubbard at Washington, D. C., and two days later it came within the ken of European astronomers. Incidentally, three weeks before the twin comets were observed, Mr. J. Russell Hind (England) noticed a peculiar lump near the upper part of the nucleus of the main comet, which may be regarded as the first symptom indicating that something was amiss.

On January 15, Professor Challis, then director of Cambridge Observatory (England), had his suspicions aroused when he saw the complete severance of the little comet from the big one, and the description of his experience is best given in a letter he wrote to the president of the Royal Astronomical Society:

> "On the evening of January 15, when I sat down to observe it [Biela's comet], I said to my assistant, 'I see *two* comets.' However, on altering the focus of the eyeglass and letting in a little illumination, the smaller of the two comets appeared to resolve itself into a minute star, with some haze about it. I observed the comet that evening but a short time, being in a hurry to proceed to observations of the new planet."

Presumably he here refers to the search for Neptune. Alas! had he but given his whole attention to that task, instead of dispersing his energy —as it were—by pursuing a flimsy comet, England might have been acknowledged as first in the actual discovery of that planet.

Resuming his observations of the comet on January 23, Professor Challis again saw two comets, but clouds hid them from view for the next half-hour, and when they had cleared away he was convinced that the comets had moved during the interval. This suspicion was afterward confirmed, and, moreover, Professor Challis found that they had moved in unison, retaining their relative positions meanwhile. He wondered what could be the meaning of this strange procedure, and whether they were two independent comets, a double comet, or that his glass was deceiving him.

> "But I never heard of such a thing," wrote Professor Challis. "Kepler supposed that a certain comet separated in two, and for this Pingré said of him, '*Aligreando bonus dormitat Homerus.*' I am anxious to know whether other observers have seen the same thing."

In a subsequent letter he shows by his remarks that "the two comets are not only apparently, but really near each other, and that they are physically connected."[1]

[1] *Monthly Notices*, R. A. S., vol. vii, p. 73, March, 1846.

The comets continued traveling along in this sociable manner for four months, at an almost unvarying distance of about 165,000 miles, each developing meanwhile a very bright nucleus and diminutive tail half a degree in length, or one tenth the distance separating the pointers in Ursa Major. Sometimes one comet would be devoid of a tail, sometimes the other, so that one might almost imagine the tail exchanging owners, for the comets were rarely both adorned therewith at the same time.

During the latter part of February, Lieutenant Maury, at Washington, D. C., saw an arc of light extending from the large comet to the small one, forming a sort of bridge between the two, this occurring when the small comet was at its brightest. When the large comet had regained its superiority it threw out new rays, which gave it the appearance of having three tails, each adjacent tail making an angle of 120 degrees with its neighbor, one of the tails being the bridge to the new comet. This produced the effect of an arch in the heavens, through which the stars were seen to pass.

One can imagine messages passing to and fro along this bridge of light between the twin comets, and a possible farewell as they drifted further apart. At their return in August, 1852, they were separated by about one million five hundred thousand miles, and as so often happens in the case of twins it was impossible to tell which was which. The comets were not seen at their next return, in May, 1859, because they were lost in the glare of sunlight, for the same reason that we are unable to see stars in the daytime.

At the next expected visit when the comets were looked for, in January, 1866, they were nowhere to be seen. What had happened in the interval no one knows, but in 1872 the whole astronomical world was startled by a telegram from an astronomer named Klinkerfues of Göttingen, on November 30, to Pogson, the government astronomer at Madras, which read as follows:

> Biela touched earth on 27th, search near Theta Centauri.

Accordingly, a search was made, with the extraordinary result that a comet *was* found, but not *the* comet. Observations were obtained of it on December 2 and 3, but bad weather and the advance of twilight made further search impossible. When the track of the new comet, for such it proved to be, was eventually followed, it was found to be moving along a different route from the one previously followed by the comet of Biela. Nevertheless, by a remarkable coincidence it happened to be passing by or near the place where this comet was wont to wander, until he took unto himself a companion comet, which seems to have led him astray.

To be lost is interesting, especially for a comet, when one considers the vast expanse of highways and byways in starland, but the climax of the tragedy in connection with this special comet was not reached until its orbit crossed that of the earth on November 27, 1872. On that eventful night the sky seemed to be literally ablaze with meteors, which fell in swarms and showers of dazzling gleams of light, the downpour lasting from seven o'clock in the evening until one o'clock next morning, the maximum being attained at nine o'clock. We are told that the total number observed in England was estimated at a hundred and sixty thousand. They all came from the same part of the sky, radiating from a point near the beautiful double star Gamma in the constellation of Andromeda. But what was the meaning of the display? Had it been caused by an encounter of the earth with the scattered fragments of the lost comet? It certainly could not have had any connection with the comet itself, which, providing it still existed, had passed that way three months before. It was more likely the débris of its train scattered along its path after its breaking up in 1846.

There seems to be no doubt of the identity of this swarm of meteors with the comet of Biela, for on November 27, 1885, a similar encounter took place, providing a magnificent display of meteors observed all over Europe, just at the moment when the earth was due at a crossing in the former path of the comet. On that same evening, a piece of meteoric iron fell at Mazapil, in northern Mexico, during the course of the shower, and according to Professor Young, "the coincidence may be accidental, but is certainly interesting. Some high authorities speak confidently of this piece of iron *as a piece of Biela's comet itself*." (*General Astronomy*, C. A. Young.)

In 1892 and 1898, when the earth again crossed the former path of the comet, a similar display occurred, though on a minor scale, and some of the scattered cometary fragments may still be looked for on the evenings from November 17 to 27. They are recognizable from their slow motion, short trains, and from the fact that they all radiate from the second-magnitude star Gamma in Andromeda. (Incidentally, this is the star so charmingly dealt with by Dr. Holmes, in the *Poet at the Breakfast Table*, really the astronomer of the breakfast table, as suggested by conversations and correspondence between my father and Oliver Wendell Holmes.)

The star Gamma in Andromeda is easily located, as it is almost overhead between the dates November 17-27, at a convenient hour in the evening. It is in a line with Epsilon, the star at the left-hand corner of the W-shaped group in the constellation, Cassiopeia, and with Polaris, the Pole Star. The meteors radiating from this point are variously referred to as the Andromedæ, Andromedids, and the Bielids, on account of their supposed connection with the Comet of Biela. As a matter of fact it matters little what they are called, as long as we know their appearance and when and where to look for them. They may be looked upon as supplementary to the story of the comet, and possibly some of the particles may eventually find a resting-place on planet earth.

According to Dr. Crommelin of the Greenwich Observatory:

> "the career of a comet may be said to be over when its meteors have lost all their gas, or when they have been scattered by perturbations over so wide a space that its unity and visibility are lost. These disrupting causes

are most effective when a comet is fairly near the sun; therefore the oftener that a comet approaches the sun, the shorter the period of its existence as a comet. I think, therefore, that we can ascribe the great prevalence of long-period comets to the principle of the survival of the fittest."

Long-period comets are those which sometimes require hundreds of years before they return sunward, as, for instance, Donati's comet with its period of about two thousand years. Others of short period, like Encke's comet, are regular visitors to the sun, returning after a short interval of a few years along a well-known path. Once upon a time they may have been long-period comets, which have had their paths restricted, owing to the strong attractive pull of the giant planets Jupiter, Saturn, Uranus, and Neptune. As a result of the disturbances (or perturbations, as they are technically called) thus caused, according to the so-called capture theory, Jupiter has annexed fifty comets, including the Comet of Biela. Uranus and Saturn, according to the same theory, own a limited family of two, while Neptune has four, including Halley's famous comet. Its least distance from the sun is 56 million miles at its point of nearest approach, and 3,200 million miles when at the opposite end of its orbit. But the great majority of these strange bodies appear to travel in parabolas, open curves leading from infinite space to and around the sun, and thence back into the region of the fixed stars.

There is a notable instance of a comet traveling about the sun in an immense ellipse, but, like the moth, hovering around a flame which finally causes its destruction, this comet returned once too often to the neighborhood of the giant planet Jupiter, and in an encounter between a large and a small body, the latter usually comes to grief. Its path was curtailed at first, and subsequently it was shunted on to another line. Jupiter, acting as pointsman on the cometary railway, is suspected of opening the branch of the ellipse along which the comet had formerly traveled in peace and quiet, with the result that it was ignominiously side-tracked and sought for in vain.

The comet was first discovered in June, 1770, by Messier, who described it as a rather insignificant object without a tail, but resembling a nebula with a star-like nucleus. Early in July it had greatly increased in size, the nucleus and surrounding haze extending over a space more than five times the diameter of the moon. At this time it came very near the earth, remaining visible until October, when it grew small and faint, and finally faded away. Meanwhile, astronomers did their best to determine its path, notably Mr. Lexell, of the Academy of Sciences at St. Petersburg. He became so interested in clearing up the past history of this quaint little comet, that it is usually referred to as Lexell's comet. He came to the conclusion that the comet of 1770 required five years and seven months for its elliptic tour, but he was such a long time in getting at this result, that by the time he obtained it in 1778 the comet was two years overdue. Messier made a careful search for it, but without success.

Lexell was of the opinion that at the end of May, 1776, the comet came so close to Jupiter that the attractive pull of that planet was three times greater than that of the sun. When a comet rushes around the sun it has to go full speed ahead, so as to resist being drawn upon its surface, but as it recedes from the danger zone it gradually slackens its pace, with the result that by the time it is crossing the orbit along which Jupiter travels, it is going at reduced speed. Probably Jupiter was not far from the part of its orbit crossed by the comet in 1776, with the result that the unfortunate wanderer was exposed for a longer period to the powerful attraction of the giant planet. This may have caused an important change in the comet's path, with the result that it escaped from what has been termed the *sphere of activity* early in October, 1779.

At this period, according to Lexell, the comet was moving in an ellipse with a period of more than sixteen years, and at such a distance there would be no hope of our seeing it again. He finally considered the comet of 1770 as definitely lost. However, when Brooks, the famous comet-hunter of Geneva, New York, discovered a comet in 1889, which is known as Comet 1889 V, as it was the fifth comet discovered that year, it was supposed to be the long-lost Lexell comet of 1770. For that reason it is known as the Lexell-Brooks comet.

Previous to 1886, the comet discovered in 1889 was traveling around the sun in an immense ellipse, taking it out beyond the planet Uranus. Around and around the sun it went, as a moth flutters around a lamp, until in the year 1886 it came under the magic spell of Jupiter. Unable to resist this planet's persuasive influence, the path of the comet was reduced to a smaller one requiring only seven years for its completion. Apparently on this occasion the comet passed too near

Jupiter for safety, and was reduced to four fragments in consequence. When it approached the sun in 1889, and was discovered by Brooks, it may probably have been one of the four fragments; at any rate, this is the opinion of Dr. Charles Lane Poor, of New York, who made a careful and most exhaustive study of the comet and its eccentricities. It remained visible with telescopes of ordinary power until March, 1890, after which date it could only be seen with the great telescope at the Lick Observatory, at Mount Hamilton, California. With this magnificent instrument Professor Barnard followed the comet until January, 1891.

The path of its next return was calculated so accurately that when it was rediscovered on June 20, 1896, by Javelle, it was seen within a distance less than one quarter the diameter of the moon from its predicted place. By this time the comet had grown fainter, as though enfeebled by its long wanderings and the vicissitudes of its career, and it remained visible for only a few months, finally disappearing in February, 1897. For a third time the comet came near enough for us to see it, and this occurred during the summer of 1903, when it remained visible until the following January. It was then so faint, it could only be observed with the largest telescopes. The future of the comet seems as likely to be as interesting as its past.

"Unless it become wholly disintegrated by the pulling and hauling of the sun and planets, it will be seen again in 1910, and yet again in 1917," wrote Dr. Poor in 1908, but as a matter of fact it was not observed on either occasion. Dr. Poor also predicted that early in 1921 it would again come into close approach with Jupiter, "and beyond that point its history cannot be predicted. This collision will probably end its story as far as the earth is concerned, for it will undoubtedly be still further broken up, and its orbit may be so changed that it will never afterwards be seen." And we must leave it with this unsatisfactory conclusion, as it did not reappear in 1921, and nothing more has been seen or heard of this comet. By now (1925) it may be merely a derelict in space, at the mercy of any disturbing planet it may happen to pass on the way.

These instances give some idea of the dangers to which comets are subjected as they drift like frail barks on the ocean of space. Whence they have come and whither they vanish, no one knows, but it has been suggested that there is a home of comets. This has been described as a shell of nebulous matter accompanying the sun and planets, though at a distance some thousands of times greater than that of the earth from the sun, yet much closer than the nearest star. "However, we have no direct evidence of any such comet-dropping envelope," according to Professor C. A. Young.

Yet supposing it does exist, we see in imagination baby comets cradled therein in nebulous mist until they are able to take care of themselves. Then they are presumably launched forth on their perilous career, as they make their way towards their ruler, the sun, to pay their respects. Woe betide them should they cross the path of one of the giant planets at an inauspicious moment, or approach too near the sun, which would prove equally disastrous.

CHAPTER FIVE

PHOTOGRAPHY AS APPLIED TO COMETS

"With its three eyes—the eye of keenness, the eye of patient watchfulness, and the eye of artistic truth, photography promises to be a Cerberus to the science of the future, whose watchfulness will prevent the admission of error and detect truths which would otherwise escape us."

—R. A. Proctor.

THESE words written by my father, in his book entitled *The Universe of Suns*, shortly after the appearance of the comet of 1882, have since been amply confirmed, not only in connection with the sun, moon, and stars, but still more so regarding the hitherto unknown peculiarities of comets. So far we have gained some idea of the appearance of a comet as seen with the naked eye, or with the aid of a telescope, but it now remains to be shown what can be accomplished by means of photography.

Pictures of the ever-varying transformations, for instance, which took place in the appearance of the celebrated Morehouse comet of 1908, opened out new vistas in cometary wonders, hitherto beyond our ken. Successive photographs taken during the course of a night, pictured for us the unfolding of the comet's train, its spreading outward like a gigantic fan of gauze-like texture, and eventual closing up till it resembled a sheaf. By means of the revelations thus made by the camera, we became aware of the marvelous quick-change effects produced in the appearance of this comet not only from night to night, but sometimes during the brief interval of less than an hour. Nevertheless, as seen with a telescope, the Morehouse comet appeared inconspicuous and was invisible to the naked eye.

The first attempt at taking a photograph of a comet was made by Bond at Harvard College Observatory in 1858, in connection with the magnificent comet of that year, but his efforts only met with partial success. The next venture was made in 1881, by Sir William Huggins, in our country, and Dr. Henry Draper, of New York, but entirely satisfactory photographs of a comet were not obtained until 1882, when the great Daylight comet became a conspicuous object in southern skies.

This comet was first seen on September 3, by some employees of the railroad in Auckland, New Zealand, and by other persons whose duties required them to rise before daylight. The names

Photograph of Morehouse Comet, 1908 c
Taken on November 19, 6 h. 4 m., at the Royal Observatory, Greenwich

of these fortunate observers are unknown, but what a privilege to obtain the first glimpse of the comet.

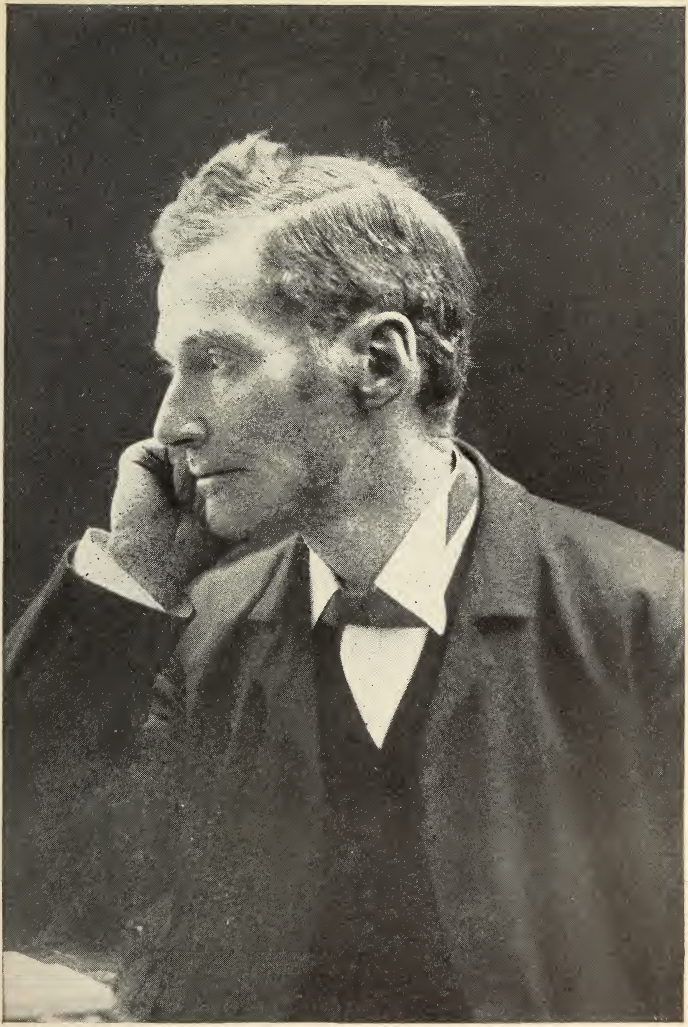
Anyone acquainted with the clear, limpid blue of the skies at dawn in New Zealand, and the brilliancy of the stars despite the near approach of sunrise, may gain some idea of the vivid appearance of the little comet in their midst as seen on this occasion. The writer, who spent a year in New Zealand (1913-14), has vivid recollections of the beauty of the dawn ushering in daylight during the course of her travels to and fro, and has almost an envious feeling with regard to those fortunate people "whose duties required them to rise before daylight," thus enabling them to obtain the first view of the comet. As in the case of the brilliant star in the East, which guided the three wise men of old to Bethlehem, doubtless they likewise "rejoiced and were exceeding glad."

The news of the discovery of a comet was soon made known, for on September 6 Dr. Gould, director of the Cordoba Observatory in South America,[1] received information that a bright comet was visible in the east before sunrise. His informant had seen it on the morning of September 5, when it was described as being as bright as

[1] See *Astronomische Nachrichten*, vol. 104, p. 129.

the planet Venus. At Reus, near Tarragona, it was bright enough to be seen at one time through a passing cloud when at a distance of only three times the diameter of the sun from its edge, or "limb," as it is technically termed. According to the report of Dr. Gould regarding the weather conditions prevailing at Cordoba, the morning of September 7 was cloudy and the eastern sky overcast on every morning during a whole week. Nevertheless, on one occasion it was thought that a part of the comet's tail could be seen. It was not until September 14 that conditions were again favorable for observing the comet.

Fortunately the link in the chain of observations was supplied by an enthusiastic amateur astronomer, Mr. John Tebbutt, who watched the comet from his observatory at Windsor, New South Wales. On September 8, he received a telegram from the Government Astronomer at Melbourne, to the effect that a large comet was reported due east at four o'clock in the morning. Other messages were received during the day from different parts of the colony, and from the information thus supplied Mr. Tebbutt was enabled to observe the comet on the mornings of September 9 and 10. By this time the nucleus of the comet was large and remarkably brilliant, and the tail about 3° or



John Tebbutt, Noted Comet-hunter of Windsor, N. S. W.

$4°$ in length, not quite the distance separating the pointers in Ursa Major.

Mr. Tebbutt had already distinguished himself as a successful comet-hunter, and in addition had vainly endeavored to form a society such as existed for comet-hunting in the northern hemisphere, but his efforts only ended in disappointment. As he wrote in his *Memoirs*, "although several astronomers owned telescopes suitable for the work, there was obviously a distaste for systematic observation." He took great pride in his miniature observatory at Windsor, actually his own handiwork, for he was his own bricklayer, carpenter, and slater combined. During a visit to the observatory in 1912 the writer was shown numberless books containing the records of fifty-five observations of the comet of 1882, extending from September 8 of that year to March 2, 1883. These observations were made by Mr. Tebbutt with his four and a half inch equatorial, with the exception of four made with the transit instrument in full sunlight. Moreover, Mr. Tebbutt was the first to see the comet in full daylight with the unaided eye.

The second series of observations of the comet in full daylight were made at the Government Observatory, Melbourne, but it was not seen in

Europe, owing to cloudy weather, until September 17, one Sunday morning. It happened that Dr. A. A. Common, the well-known amateur astronomer at Ealing, had directed his telescope to the sun for the purpose of observing sun-spots, when he had a glimpse of the comet. This was at a quarter to eleven, at which time the comet was rapidly approaching the sun. Unfortunately, clouds intervened, rendering further observations for the time being impossible.

Dr. Common sent a telegram to Dunecht (Lord Crawford's observatory near Aberdeen) so that the astronomers there might be on the lookout for the comet, with the result that it was observed by them on the following day. In England bad weather, as usual, had baffled all attempts at seeing the comet, and the clouds seemed to be in league with the powers of darkness in keeping it hidden from view. Those who can recall watching in vain in England, for Halley's comet at its return in 1910, can fully sympathize with the disappointed watchers of the sky in 1882. (In those days the writer was not nearly so enthusiastic as she should have been at the brief view of the comet obtained early one chilly morning. Admiration was slightly tinged with wonder at all the excitement over "a small white star with a train a yard long" which scarcely seemed worth the trouble of getting up for during the wee sma' hours. Nevertheless, there is comfort now in the thought, that this—her first comet—was one long afterward to be remembered.)

Day after day the comet grew in splendor, until by September 12 it was almost the cause of a momentary panic on the occasion of the attack at Tel-el-Kebir. The story is told by Colonel E. Major, somewhat as follows, in his book entitled *Lord Wolseley:* It seems that each morning Sir Garnet in the early dawn had reconnoitered the enemy's position from the high ground above their lines, and he had noticed that their pickets only came out beyond the defenses at daybreak. He therefore decided upon a night attack, which must be sudden and decisive, so that the enemy might be crushed and scattered early in the day. This would enable the cavalry to make an immediate dash for Cairo, while the infantry occupied Zagazig. After making all arrangements, we are told:

> "The troops set off in silence, no smoking or giving of orders aloud being permitted. The engineers had set up directing posts as guides in the earlier part of the march, but in the deep darkness of a moonless night

these were not easy to find. Only the North Star and the Little Bear, shining through the drifting clouds, gave the leaders some fixed point by which to find the way. Sir Garnet sent his own naval aide-de-camp, Lieutenant Rawson, R. N., who was accustomed to steer by the stars, to act as a guide with Sir Edward Hamley's division. Even with this help the flanks of the Highland Brigade in the course of the night march lost their direction after a short halt, and circled round until a crescent-like formation was the result.

"A second halt was necessary to remedy the confusion. Soon after, a strange light appeared upon the horizon, and Sir Garnet feared it was the first sign of the coming dawn. If so, the night attack had failed. But no rising sun followed that long streak of light, and later on they learned that a comet had been observed in the heavens for the first time on that eve of Tel-el-Kebir."

On September 27, the comet was seen at Vienna, according to a telegram received by the Astronomer Royal at Greenwich, but meanwhile it had been observed continuously at the Cape of Good Hope Observatory since September 8. It was seen on this date by Mr. Finlay, a member of the observatory staff, while he was going homeward after working all night at the dome. Happening to glance eastward, his attention was at once attracted by the comet. Returning hastily to the observatory, he proceeded to make the necessary measurements for recording its position with regard to a small star in its neighborhood. One can imagine the anxiety with which its reappearance was awaited next morning by Sir David Gill, the director of the observatory, and by those who may have heard the good news of a comet in the offing.

The following morning the comet was again observed, and Sir David Gill sent a telegram to Sir James Anderson, chairman of the Eastern Telegraph Company:

> Kindly tell Astronomer Royal, Greenwich, that bright comet was observed here yesterday morning by Finlay. Right ascension this morning, nine hours, forty minutes, increasing hourly, nine minutes. Declination one degree south, increasing half degree south daily.

Unfortunately, the telegram failed to reach its destination, and was doubtless delayed or mislaid in the confusion of numberless war messages. The first news that reached Europe about the comet was obtained by means of a telegram on September 12, from Dr. Cruls, director of the observatory of the Emperor of Brazil. Sir David Gill was anxious to prove Mr. Finlay's claim to priority in discovering the comet, but, as we have already seen, he had been forestalled by astronomers in Australia, and some claim should be allowed for the "early railroad workers" in Auckland, New Zealand, who were actually the first to see the comet, though their observation thereof had no practical value. For a while the comet was known as the Cruls comet, but now it is generally referred to as the great comet of 1882, or the Daylight comet. However, later on, as we have already noted, it had a rival as a Daylight comet in 1910, when a fine comet resembling the plume-like appearance of the comet of Donati was seen to advantage in England.

The great comet had another rival in popularity in the year 1882, for on May 17, when Dr. Schuster was developing photographic plates taken during a total eclipse of the sun which occurred on that date, he found a miniature comet seemingly entangled in the outer rays of the corona. This is the sun's crown of glory which can be seen only during the time the glare of sunlight is hidden from view by the moon coming directly between the sun and the earth. The consequent darkness, or totality, as it is called, can never exceed a duration of eight minutes, and on this occasion during a still briefer interval of time the little comet was captured by means of the camera. Thus, a permanent record was secured of its presence near the sun, but as it had not been seen before nor was it seen afterward, its motion must have been extremely rapid, and it may possibly have been drawn inward and consumed by the intense solar heat. Despite its small size and brief career, it is distinguished by the name of Tewfik, after the then Khedive of Egypt. It has been suggested that the comet may be kin to, or one and the same with, a comet which had its photograph taken during the total eclipse of the sun, April 16, 1893, having a period like that of the sun-spots, of about eleven years.

Possibly Sir David Gill may have had the photograph of Comet Tewfik in mind when he heard of attempts which had been made by Mr. Shoyer of Cape Town, and Mr. Simpson of Aberdeen, to photograph the comet of 1882. The results had been so far successful as to prove that the comet was capable of giving a distinct impression after sufficiently long exposure. But it was owing to the cordial and enthusiastic assistance of Mr. Allis, photographer of Mowbray, that the first pictures of the comet were obtained. When Mr.

Allis, under the direction of Sir David Gill, fastened a simple portrait camera upon the tube of one of the Cape telescopes, and pointed it at the great comet, little did he dream that the experiment would eventually lead to such great results in the future. One can imagine the thrill of triumph as the experimenter watched the gradual process of development on the photographic plate, until, as if by magic, a fine comet was revealed outlined against a starry background. Thus, three or four photographs were obtained, which excited the greatest interest among astronomers in the northern hemisphere. Possibilities were suggested with regard to the construction of a self-recording photographic star chart, thus replacing the painstaking hand-drawn star charts of the Herschels, Argelander, my father, and other astronomers at various times engaged in such work.

The gigantic undertaking was ultimately divided among nineteen observatories situated in northern and southern climes, which will eventually result in a marvelous collection of star charts. These will include millions of stars, forming a celestial library which may be consulted at leisure either now or a century hence when the makers thereof may have become a mere memory. If a supplementary set is made in the future, comparisons between the two series may result in important information with regard to star drift. (It was by comparing star charts thus made a century apart, that my father originated the star-drift theory, by his observations in connection with the five stars of Ursa Major in 1868, a theory confirmed by the spectroscopic investigations of Dr. Huggins.) Celestial photography, owing to Dr. Gill's suggestion with regard to the star-gemmed photographs of the comet of 1882, may add greatly to our knowledge in connection with such problems, the records of the past thus becoming the star-lettered volumes for the students of the future. Undoubtedly this achievement, the result of the photographs taken of the great comet of 1882, ranks high among those which make astronomy appeal so vividly to the imagination.

Now let us see how Mr. Allis went to work in obtaining the portrait of this memorable comet. To secure a perfect picture of its delicate detail, an exposure of not less than half an hour was required. To obviate the difficulty caused by the rotation of the earth, Mr. Allis attached his camera with a rapid portrait lens and sensitive dry plate to the declination axis of a large equatorial, and then turned both the telescope of the equatorial and the camera in the direction of the comet.

Matters were so arranged that in whatever direction the telescope was turned, the small camera would turn exactly with it, and thus by means of clockwork and proper small motions for delicate adjustment, the comet was kept accurately in the field of view during the whole time of exposure. The camera was therefore also pointed during the whole exposure to precisely the same point of the comet, and in this way, after one preliminary failure, three very beautiful and quite invaluable negatives of the comet were obtained. These three negatives will remain of permanent value as a scientific record of one of the most glorious comets ever seen.

To follow the progess of the comet as it increased in splendor day by day, let us return to the record of Dr. Gould, director of the Cordoba Observatory. On September 16, we are told that the brightness of the comet was such that it was visible with the finding telescope throughout the day. The next day it was so bright that it could be easily observed in full sunlight, and at eleven o'clock that morning the sun and the comet were in the same field of view. Then the comet was hidden for a while, as it passed between us and the disk of the sun.

On Monday, September 18, the brilliancy of

THE GREAT DAYLIGHT COMET, SEPTEMBER, 1882
Photograph taken at the Royal Observatory, Cape of Good Hope

the comet attracted popular attention throughout the country, and the "blazing star" near the sun was the one topic of conversation. In the small telescope it presented the aspect of a brilliant nebulous mass, having on each side curved appendages like horns or wings, nearly as large as the central body, and at their base quite as brilliant, the general form of the whole reminding one of the winged globes carved on ancient monuments. This appearance, doubtless due to the outbreak of glowing vapors from the nucleus, was also exhibited, although to less extent, on the following two days, during both of which the comet remained visible to the naked eye.

Observations made of the comet with large telescopes showed that the nucleus had separated into six or eight star-like knots strung like pearls along a luminous streak some fifty thousand miles in length. The largest of these knots was some five thousand miles in diameter, an interesting fact as compared with the size of the earth, which is 7,925 miles, according to the British Astronomical Association Handbook for 1925.

A faint straight-edged beam of light, or "sheath," accompanied the comet, enveloping the head and projecting like a hood three or four degrees in front. Besides this, three or four irregular shreds of cometary matter were detected, escorting the comet, as it were, like airplanes, at a distance of three or four degrees when first seen, but gradually receding from it, and at the same time growing fainter. The actual length of the comet's train at one time exceeded one hundred million miles, more than the distance of the sun from the earth. (If the head of the comet had rested on the earth, and its train stretched outward toward the sun, it would have extended seven million miles beyond that luminary.)

The trains of comets have been grouped under three types, *viz.*, the long straight rays as shown in the photograph of Halley's comet, though this was only one of the many outlines assumed; the second is the curved, plume-like train resembling that of the comet of Donati; and thirdly the short stubby brushes violently curved. The great Daylight comet had a greatly curved train belonging to the second type, and it was mainly composed of carbon compounds. The curvature of the train was due to matter for which the repulsive force is only a fraction of the gravitational force. The pressure of light from the sun was a most important factor in the formation of its train.

When the fierce pressure of the sun's light strikes upon the particles forming the train, it drives the particles which are of the same relative size as the particles of light along with them, just as when the waves of the sea break against a beach they tend to drive small pebbles and sand upward along the beach.

Hints for Amateur Photographers

To an amateur photographer who desires to obtain the picture of a comet which may appear perchance in the near future, their capricious appearance at unexpected periods being one of their charms, the following hints may be most acceptable. For work of this kind an equatorial telescope is used with a photographic lens and camera strapped thereon. The telescope is mounted on an axis that is parallel to the earth's axis, and is made to rotate westward by what is called a driving-clock just as fast as the earth turns to the east. It will follow the motion of the sky (which apparently drifts westward), and keep every star approximately fixed in the field of view, or on the photographic plate in the attached camera.

Otherwise, the stars will appear as trails of light, caused by the rotation of the earth as it moves onward at the rate of nineteen miles a second, which is rather disturbing to an astronomer who may be desirous of obtaining a photograph of the stars overhead. What is he to do? Here is our planet turning eastward and the stars apparently drifting westward, and unless the telescope is made to keep up with the stars by means of clockwork the results are disastrous. Consequently, the telescope is made to follow the star, comet, or whatever the desired celestial trophy may be, and it is kept in such a position that the object in view is centrally placed at the intersection of two threads obtained from a spider's web. For this reason, spiders are treated with due respect in observatories, and may explain the expression of dismay the writer saw on the face of an Indian assistant at the Kodaikanal observatory in southern India, when she nearly dispatched one of these noxious insects, which succeeded, however, in deftly eluding destruction.

The star trails shown in the photograph taken by Dr. W. J. S. Lockyer give an excellent idea of what happens to a photograph of the stars when the clockwork is allowed to run down. In this instance the telescope, with the accompanying camera, was stationary during the exposure of a little over two hours, with the result that the stars photographed are not points of light, but bright

Photograph of a Bright Meteor by Dr. W. J. S. Lockyer

and faint lines in sections of circles, since the telescope was pointed to the pole of the heavens. The interest in this photograph is increased by the fact that a meteor dashed across that part of the sky during the course of the exposure, thus resulting in one of the finest photographs of a meteor ever obtained.[1] Had the exposure lasted during twenty-four hours, and the photograph been taken in Norway some time during the course of their long winter night, the trails would have been complete circles. By this means we do not get a picture of the stars, but simply a photograph illustrating the rotation of the earth. To obtain a picture of the stars, therefore, an equatorial attachment, as above described, is an absolute necessity.

Some people have an idea that all an astronomer has to do in making photographs of a comet, or other celestial object, is to turn the telescope in the direction wanted, strap on the camera, wind up the clock, and then go homeward for a good night's rest. Unfortunately, no driving-clock has yet been devised so perfect as to move the telescope exactly with the stars. According to Profes-

[1] The camera with which the meteor was photographed by Dr. W. J. S. Lockyer is placed specially for recording meteors. It is orientated to the polar stars simply for the purpose of being able to identify the stars to deduce the path of the meteor, should one be recorded. Otherwise, no interest is attached to the polar star trails, as such.

sor E. E. Barnard, who was an expert on such matters—

> "There is always more or less irregularity of motion, all of which would be recorded on the plate, and the stars, instead of showing as merely points of light, would be elongated and blurred. The fainter ones would not show at all, because they could not be still long enough to have their pictures taken. That is why you see in the photograph the observer with his eye 'glued to the telescope,' watching a star, a guiding star which he constantly keeps behind the intersection of two illuminated spider threads in the eyepiece, by the slow-motion rods which are controlled by his hands."

Thus, every star or comet is kept immovable on the sensitive plate, and it paints its own portrait as long as the telescope is made to turn westward as fast as the earth rotates eastward. That is why a driving clock is absolutely necessary for the amateur comet photographer who is desirous of obtaining accurate results. Many hours are required in obtaining a successful photograph of such comets as the Morehouse comet, the sensitive plate requiring sometimes an exposure of many hours before it reveals satisfactory results. The observer must sit patiently hour after hour, guiding the instrument, and the writer has some idea of what this must mean, from a brief five minutes' experience at Mount Wilson in connection with the sixty-inch reflector. As a great favor she was allowed to hold the bulb in her hand which by the slightest pressure brought back an erring star which had attempted to stray momentarily from the center of the field of view of the telescope.

When one considers the hours spent by the late Professor Barnard in this nerve-racking work, the patient endurance of the astronomers who specialize in celestial photography becomes evident. It is an arduous task, and one doubtless subject to many disappointments, to avoid which Professor Barnard tried to formulate some set of rules that would be dependent on the local time and position of the comet, but these were finally rejected.

> "So much would depend on the purity of the atmosphere at the time, the size and light ratio of the lens, the kind of plate used, etc., that they would probably lead to the very errors against which we wish to guide."

The position of the comet with respect to the point of sunrise or sunset, and freedom from any form of haze in the sky, are important factors in the exposure of comet plates. Moreover, it is necessary that they should not be exposed too early in the evening or too late in the morning, in either case resulting in unsatisfactory negatives. The best of all rules is the judgment of the observer at the moment, but only long experience will warn one by a glance at the sky when there is danger of failure in this class of work. It is the few moments at the beginning or end of the exposure that will injure or ruin the plate.

With a small portrait lens (the most useful size is about six inches) essentially everything about a comet will be shown as quickly as with a larger one. The main advantage of the large lens would lie in its greater scale—which of itself is of great importance. Another source of danger is moonlight, especially in the case of a long exposure. Nevertheless, according to Professor Barnard, important results may be obtained in full moonlight, if the comet is not too near the moon. Much, however, will depend upon the clearness of the atmosphere; the purer it is the less will the moonlight affect the plate. In this case a dew-cap helps much. On an ordinary moonlit sky an exposure of half an hour with a quick portrait lens will not ruin a fast plate if the comet is not too near the moon. In full moonlight, however, a longer exposure, unless under exceptional conditions, will seriously injure or ruin the plate. With the half-hour exposure the plate will be fogged, and of course the best quality of negatives cannot be obtained therefrom. All plates should be backed to prevent halation. A backing made of sugar and burnt sienna is recommended as entirely satisfactory, and can be kept in stock.

The formula as supplied by the Cramer Dry Plate Company is as follows: Cook two pounds of granulated sugar in a saucepan, without the addition of any water, until it is nearly in the caramel or fudge stage. Then stir in one pound of burnt sienna and cook a little longer, stirring well. Do not let the backing get sticky, or it will be difficult to handle and will not soften so readily when removed from the plate. Finally add about half an ounce of alcohol to each pint as a drier. Put away in a wide-mouthed stoppered bottle or jar. When needed for use, dilute a little of this with water to the consistency of a thick but not too wet paste. Apply (not wet enough to run) to the back of the plate with a wide camel's hair brush. It is not necessary to back heavily. A sheet of soft paper (an old newspaper) pressed on the backed surface will prevent injury to the plate, which should be freshly backed when ready for use. If kept in stock a long time after being backed, an unequal fogging is likely to occur.

Before developing, remove the backing while it is still damp, with a moist piece of absorbent cotton. Should a small amount remain it will not affect the developer seriously. The plates should be carefully dusted with a broad soft camel's hair brush, after being put in the plate-holder. The camera tube should be wiped out frequently with a damp cloth to free it from dust. It should also have a tight-fitting cover at the plate end to keep it closed when the plate-holder is not in position. There should be four springs, one at each corner, on the back of the plate-holders, to press the plate forward in a constant position.

On account of its greater sensitiveness the Lumière Sigma plate is recommended by Professor Barnard, although he draws attention to the fact that this plate has frequently been found defective in having small, round, transparent and opaque spots. It is also more subject to "chemical fog" than the Cramer or Seed. Otherwise, it is a beautiful and very rapid plate.

When the comet is at its brightest, the Seed 27

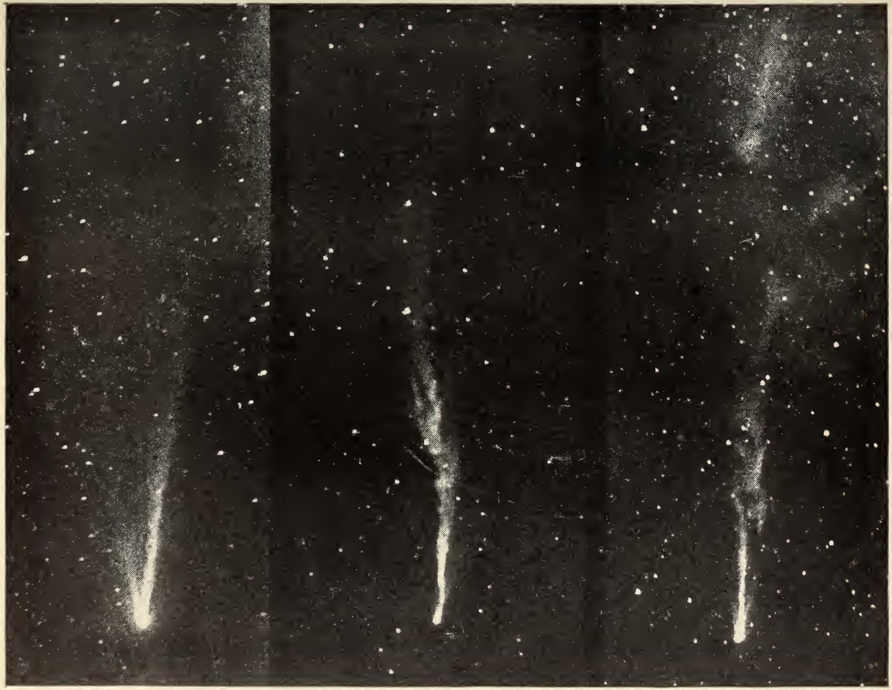
Gilt Edge plates are recommended on account of their general freedom from defects and finer grain. With these few suggestions in respect to photographing comets, made by Professor Barnard in *Popular Astronomy*, No. 170, the amateur comet-hunter is enabled to make an attempt, at any rate, at photographing those wonders of the heavens which have proved so attractive on account of their varying appearance from night to night. For those who may not have a ready access to astronomical libraries, the above condensed account from Professor Barnard's article on the subject should prove invaluable.

In an account of his life-work given by Professor Barnard during the course of an after-dinner speech in January, 1907, at Nashville, and entitled by him, "Some Unastronomical Experiences of a Lecturer," he referred to his interest in comets as follows:

> "I have always been interested in comets. These remarkable objects, which sometimes sweep across the heavens with their wonderful trains of light, and which in all ages have been objects of superstition and terror, are among the most interesting in the heavens. Little by little the mystery attached to them

is being solved. This has been done mainly through the aid of photography. Many of the physical phenomena of the tails of comets are too faint to be seen with the eye, although it may be aided by a powerful telescope; but the photographic plate secures a permanent record of these in all their complexity and beauty. These photographs show that the form and other peculiarities of a comet's tail are often utterly transformed from night to night. It is therefore highly important that a continuous series of photographs should be obtained of every active comet that can be observed, for their phenomena are as evanescent as smoke itself.

"In 1892, at the Lick Observatory, I was engaged in photographing a comet (Swift's) then visible in the morning sky just before daylight. Every morning's picture increased the interest and importance of the work. Unfortunately, I had arranged for a lecture in the Normal School at San José for the night of May 6. I did not want to disappoint the people, and I certainly could not let the comet go by unphotographed. San José was nearly a mile below us in vertical height and twenty-seven miles distant by stage road.



Comet 1893 IV Brooks

Exposures of October 21, 22, and 23, showing probable encounter with some medium which shattered the tail. Taken at Lick Observatory by Professor E. E. Barnard

The only possible way for me to secure my photograph and not disappoint my audience was to return to Mt. Hamilton that night after the lecture. At ten o'clock I hired a horse and buggy in San José and drove up that lonely mountain road, the journey taking five hours, and arrived at the summit at three o'clock in the morning, in time to make a photograph of the comet.

"The picture that I got proved to be a very important one, as the comet was then undergoing the most remarkable changes. I must say that a good many thrills passed over me during that lonely mountain ride in the dead of night—some for the chance that I might drive over into a cañon to death, and others for the possible interruption of my terrestrial existence through an encounter with some hungry, roaming mountain lion. In the main, the journey was a most impressive one. Alone in the mountains, with only the horse in front and my friends the stars above me, I doubt if my courage had not failed me entirely if the friendly stars had not encouraged me with their presence."

CHAPTER SIX

RETURN OF HALLEY'S COMET IN 1910

"It would have been a gratification to know that everyone who saw this wonderful object, did so with the same feeling of elation and wonder—one would almost say veneration—with which the average astronomer regarded this beautiful and mysterious object stretching its wonderful stream of light across the sky."

—E. E. Barnard.

WHILE Halley's comet, at its return in 1910, was undoubtedly a marvelous object as seen in the clear skies of America and in southern climes, yet it was more or less of a disappointment to watchers of the sky in England, because the view was impaired by twilight and low altitude. Nor did it come up to the expectations of those whose hopes had been aroused by the fine series of ever-varying appearances, recorded by the camera in connection with the Morehouse comet, referred to in the last chapter. Nevertheless, according to Professor Barnard, expert in photography of celestial objects, had it not been for the remarkable phenomena recorded by the camera in connection with the Brooks comet of

Halley's Comet

From photograph taken at Union Observatory, Johannesburg, May 5, 1910. Exposure 60 minutes.

1893 (see photograph), and the Morehouse comet of 1908, the numerous photographs obtained of Halley's comet would have placed it in the first rank among the records of these bodies. Yet while it lacked much of interest as seen with the eye of the sensitive plate, it left a lasting impression on the human eye, adding renewed interest to its long life history of more than two thousand years. The train of the comet reached the prodigious length of 140°, owing to its being so near the earth, and its great curvature was shown by the fact that it remained visible in the morning sky for two days after the head had become visible in the evening sky.

Halley, by whose name the comet is known, was the first definitely to establish the fact, suspected before, that certain comets are regular visitors to the domain of the sun, returning at stated intervals. For this reason they are termed periodic comets. After Halley had calculated the paths of twenty-four comets, he found that three were moving in orbits almost identical. From this he assumed that the three comets must be one and the same, just as, when a train passes through a station at regular stated intervals, one is led to infer that it must be the same train. Naturally allowances must be made for delays due to fog or stormy weather, but these factors are taken into account should the train arrive after scheduled time. In the case of a comet it may be delayed by means of the disturbing effects of the giant planets Jupiter, Saturn, Uranus, and Neptune, but in Halley's day the presence of the last two planets in the solar system was as yet unknown (Uranus was discovered in 1781, and Neptune in 1846). Therefore the following prediction made by Halley, when he was convinced that the paths of the comets which appeared in 1531, 1607, and 1682 were identical, is all the more wonderful, since only an approximate allowance had been made for these disturbing factors. Referring to the comet of 1682, he said: "If it should return according to our predictions about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman."

This was certainly the most extraordinary prediction ever made, for cometary investigations were then in their infancy, and Halley was the only man living who could have computed the orbit of this comet. Newton had his doubts regarding the suggestion that a comet seen on one side of the sun might be identical with another seen on the other side some weeks later, but Robert

Hooke, in a letter addressed to Newton in 1679, suspected that a comet could reappear after a definite period. He declared that, if gravity decreased according to the reciprocal of the square of the distance, the path of a projectile would be an ellipse.

As the year 1758 approached, one can imagine the interest aroused among astronomers, and the calculations which were made for determining as accurately as possible the disturbing effects of the larger planets within the sphere of whose influence the comet might pass. It is impossible to convey an idea of the labor involved in making the required computations of the perturbations of this comet throughout a period of two revolutions, or one hundred and fifty years. It is with a feeling of pride that the author notes the important part taken in this work by Madame Lepaute,[1] wife of one of the assistants of the great mathematician Lalande. Her work proved of inestimable value according to the following remarks made by her husband on the subject:

[1] In Rebièrés' *Les Femmes dans la Science* he writes as follows about Madame Lepaute: "A little girl of six years when taunted one day by her sister with the remark, 'I am prettier than you,' made the ready rejoinder, 'But I am wiser.' The future career of Nicole Rêine Étable de la Briére, afterwards wife of the famous clock-maker, Jean André Lepaute, proved the truthfulness of her boast."

> "During six months we calculated from morning till night, sometimes even at meals; the consequence of which was that I contracted an illness which changed my constitution during the remainder of my life. The assistance rendered by Madame Lepaute was such that without her we never should have dared to undertake the enormous labour with which it was necessary to calculate the distance of each of the two planets, Jupiter and Saturn, from the comet, separately for every degree, for one hundred and fifty years."

Amid all these difficulties, the computers toiled on, and finally, as the time was drawing near for the return of the comet, Clairaut, who was working in conjunction with Lalande, announced that the expected comet would be delayed one hundred days by the influence of Saturn, and five hundred and eighteen days by the action of Jupiter, and therefore fixed its nearest approach to the sun for April 13th, 1759. These results were presented to the Academy of Sciences on November 14, 1758, and as we have already seen in an earlier chapter of this book, on December 25th of that year the first glimpse of the long-expected wanderer was obtained by George Palitzch, a farmer of Saxony. His telescope was small, his vision keen, but the enthusiasm of a devoted amateur made up for his lack of suitable equipment. Observations were made of the comet, and astronomers were soon able to prove that the perihelion passage would take place on March 13, 1759, thirty-two days before the epoch calculated by Clairaut. Such a triumphant success of the theory produced a deep impression in the scientific world, and, as Lalande enthusiastically remarked:

> "The universe beholds this year the most satisfactory phenomenon ever presented to us by astronomy; an event which, unique until this day, changes our doubts to certainty, and our hypotheses to demonstration. . . . M. Clairaut asked one month's grace for the theory; the month's grace was just sufficient, and the comet has appeared after a period of 586 days longer than the previous time of revolution, and thirty-two days before the time fixed; but what are thirty-two days to an interval of more than 150 years, during only one two-hundredth part of which observations were made, the comet being out of sight all the rest of the time! What are thirty-two days for all the other attractions

> of the solar system which have not been included; for all the comets, the situations and masses of which are unknown to us; for the resistance of the ethereal medium which we are unable even to estimate, and for all those quantities which of necessity have been neglected in the approximations of the calculation?"

Twenty-five years before the comet was again due, its expected return in 1835 began to arouse the interest of astronomers, and prizes were offered by two academies for the most accurate forecast of its nearest approach to the sun. The successful competitors were Baron Damoiseau and M. Pontecoulant, and several astronomers undertook and completed the task of computing the planetary perturbations. Although the computers, as might be expected, differed slightly as to the time when the comet would make its nearest approach to the sun, yet the difference was not due to any defects in the methods of computation, but to the imperfections of the data employed, especially with regard to the unknown disturbing factor, the planet Neptune.

Not only was the time for the nearest approach of the comet computed, but its exact path among the stars was worked out with such accuracy that directions could be given as to the precise point toward which the telescope must be directed when the comet came within range of observation. On August 5, 1835, when M. Dumouchel, director of the observatory of the Roman College, turned his telescope in the direction indicated and looked through the tube, to his great delight he saw the comet as a faint and almost invisible stain of light on the deep blue of the heavens. Thus did science triumph in a most remarkable manner, the comet making its nearest approach within nine days of the predicted time. It appeared as a nearly circular misty object near to the predicted place, and began to develop a tail about the middle of September, which attained a length of about twenty-four degrees, or nearly five times the distance between the pointers, Alpha and Beta, in the constellation of Ursa Major. To the naked eye the head of the comet resembled a reddish star rather brighter than Antares in the constellation of the Scorpion. Bessel compared it to a blazing coal, and called attention to the peculiar fan-like haze of luminous matter forming the train, which seemed to sway to and fro like a pendulum across the radius vector, an imaginary line joining the sun and the nucleus of the comet. This oscillation took place during a period of four and three-fifths days. He came to the conclusion that a repulsive force about twice as powerful as the attractive force of gravity was responsible for the production of these remarkable effects, thus anticipating the theory according to which the very fine particles forming the train of a comet may be driven away from the direction of the sun by radiation pressure.

Meanwhile Halley's comet was passing through a remarkable series of transformations, first appearing as a nebula, then as a well-regulated comet with nucleus and train, next shining as a star, and finally dilating till it resembled a ball, then assuming paraboloidal form about May 5, 1836, after which it vanished as if melting into adjacent space through the excessive diffusion of its light. Moreover, it lost its tail previous to its arrival at perihelion on November 16, nor did it begin to recover its elongated shape until more than two months later.

At the return of Halley's comet in 1910 it was conjectured that it would probably be greatly disturbed by the influence of the planet Jupiter, and that of Uranus and the newly discovered planet Neptune. It was therefore possible for Dr. P. H. Cowell and Dr. A. C. D. Crommelin (both of the

Royal Observatory, Greenwich) to make a prediction so exact that the comet was found within six minutes of arc in R. A., and four minutes in declination of its predicted place, as shown on the first photograph obtained. This was equivalent to an angular distance in the sky less than one-quarter of the diameter of the moon. (Incidentally, a prize of 1,000 marks, which had been offered by Mr. Lindemann for the most accurate prediction of the comet's arrival at perihelion, was won and divided between the two mathematicians.) De Pontecoulant had made calculations regarding the return of the comet many years earlier which were fairly near the truth, but one month too late. It was action of Jupiter about the 1835 perihelion that had such an effect on the 1910 return. The action of Jupiter at any return does not produce a notable effect till the following return.

One of the first photographs obtained of Halley's comet at this return was due to the foresight of Herr Max Wolf of the Heidelberg Observatory, in exposing a photographic plate for several weeks beforehand, so as to entrap the wanderer at the first opportunity. It was caught at 2 A.M. in the morning of September 12, 1909, engraving its image on the photographic plate, a welcome message announcing its advent to the astronomical world. (The first photograph obtained of Halley's comet was taken at Helwan on August 24, but Herr Wolf was the first to identify the comet's image on the plate. There were also many early photographs taken at Greenwich.) For thirty-two years it had remained beyond the orbit of the outermost planet Neptune, then, obedient to the attractive power of its lord and master the sun, it had started on the return trip. Despite its enormous distance from our planet, and the fact that it was beyond reach of telescope or camera, it was possible for mathematicians to trace its path with unerring accuracy. It had approached the orbit of Neptune after the year 1888, the orbit of Uranus about ten years later, crossing that of Saturn in 1908. The following year it arrived at the orbit of Jupiter, thus bringing it within the range of both the photographic plate and giant telescopes. Its actual return to perihelion in 1910 differed by two and seven-tenths days from the prediction which can be explained only by the existence of forces which are not pure gravitation, or the possibility of another planet beyond Neptune, as yet undiscovered, acting as a disturbing factor.

When the news of Herr Wolf's success in

obtaining a photograph of the comet had been announced on September 12, it was followed on September 15 by a message from the Lick Observatory to the effect that a photograph of the comet had been obtained by Dr. Heber D. Curtis with the aid of the Crossley reflector. On Wednesday morning, September 15, Professor S. W. Burnham of the Yerkes Observatory at Williams Bay, Wisconsin, sighted Halley's comet by means of the great refractor with its forty-inch lens, while at the same time it was photographed with the two-foot reflector in an adjacent dome, by Dr. Oliver J. Lee. The comet was again detected by Professor Burnham the following morning, September 16, and it was also registered on the photographic plate by Dr. Lee.

Then came the morning of September 17, one of the most eventful in the life of the writer, who had arrived the previous day as the guest of the Barnards. That night the great refractor with its forty-inch lens was in the care of Professor Barnard, who courteously invited the writer to come to the observatory the next morning at 3 A.M., escorted by his niece, Miss Calvert, for the purpose of looking through the telescope and obtaining a view of Halley's comet. Making a first visit to the observatory in the darkness preceding dawn was an experience in itself, but the glimpse of the comet after its absence of seventy-five years is one never to be forgotten, nor is it easy to describe. For the first second or so, all seemed darkness as I gazed down the length of that great tube (63½ feet) into the opening beyond. I saw nothing, and an intense feeling of disappointment overwhelmed me as I realized and stated this fact, but Professor Barnard remarked in his whimsical way: "Surely you did not expect to see the comet with a tail?" Then he advised me to keep on looking, and even while he spoke I saw a faint, very misty outline. "Is it exactly in the center of the field of view?" queried Professor Barnard when I told him that I had seen a nebulous-looking object, and when I replied in the negative, he informed me that that faint object I was looking at *was the comet*, which eight months later I saw in all its splendor from the tower at the top of the *Times* Building in New York City.

Meanwhile, the comet had been slowly increasing in size, and by March 4, 1910, it presented the appearance shown in a remarkable photograph obtained at the Helwan Observatory. It was then suggestive of the nebulous-looking objects which had been catalogued as such by Herschel and Messier, but the latter, being more interested in comets, would soon have recognized, by means of the method already referred to, the difference as the comet slowly moved against the background of the stars. This is no reflection on the marvelous sight of Herschel, but when one reflects on the enthusiasm with which Messier hunted for comets, we may be sure any suspicious-looking object he came across was subjected to keen scrutiny before it was catalogued finally as one of those "embarrassing objects" he named "nebulæ." During the autumn of 1909 and the early part of the year 1910 the comet was photographed and observed visually at all the great observatories. At the Royal Observatory, Greenwich, a fine series of photographs were obtained despite the trying climate of our country. Up on the heights, at the Government Observatory at Kodaikanal in southern India, the progress of the comet was recorded by telescope and camera, so that our planet might be said on this occasion to have kept its Argus eye constantly directed toward the celestial visitant.

According to Professor Barnard, who made a special study of the comet, its first appearance resembled that of a small and rather faint speck of light, very much like a faint stellar nebula. The increase in brightness was not very rapid, and as late as the final observations in February, 1910, before the comet passed behind the sun, it gave very little promise of the splendid display it was destined to make later on in the month of May. However, its reappearance from behind the sun in the morning skies of April and May could not have been under more unfortunate circumstances for observation at the Yerkes Observatory. According to Professor Barnard:

> "that part of the year is always unpropitious here, and it seemed as if everything combined, on this particular occasion, to hide from us the growth of the comet and its approach to the earth. Forest fires in the northern part of the State (Wisconsin) produced a densely smoky sky, which, even when the clouds were merciful to us and would have let us see the comet, cut off with a thick yellow veil all but a glimpse of the bright head."

The comet was seen for the first time with the naked eye at the Yerkes Observatory on April 29, the nucleus being bright and of the second magnitude. The tail was visible for a couple of degrees, but with field-glasses it could be traced for four or five degrees. On May 3, at 3 h. 40 m. (civil time), the comet was seen for about one minute in a thin streak of clearer sky, but the next morning at about the same hour it was a beautiful object with a long tail streaming upward toward the right, as shown on the magnificent photograph obtained by Professor Barnard. The photograph facing Chapter VI, taken at the Union Observatory, Johannesburg, on May 5, 1910, may give some idea of what was expected but not realized by watchers of the sky in England.

When it was announced on April 29 that the comet had come within range of naked-eye observations, it occurred to the writer, who was in New York City at the time, that a desperate attempt must be made to see the comet, despite the smoke, and electric lights turning night into day. "When there's a will there's a way," and while walking along Broadway on the afternoon of April 30, wondering how these difficulties might be overcome, a glance in the direction of the *Times* Building solved the problem. On explaining to Mr. Van Anda, the assistant editor of the *Times*, what a very desirable spot the summit of the *Times* Building would be for observing the comet, a permit was obtained to be handed to the janitor the next morning at 3 A.M. on May day. It was indeed a case of "Call me early, mother dear," but an alarm clock served the purpose equally well on this momentous occasion.

Promptly at three o'clock the permit was presented to the janitor, and the writer, ascending in the lift, was transported to the twenty-third story, and escorted up a spiral staircase leading to the tower. The door was unlocked by the janitor, and the writer, stepping out on to the parapet surrounding the tower, gazed eastward for the comet, which failed to materialize, owing to a dense haze. Awaiting until dawn, the idea of seeing the comet was given up, but, nothing daunted, the same program was carried out at the same hour on May 2, and May 3, but without avail.

Then came May 4, a bitterly cold morning; but the stars shone brightly and there was every hope of the comet being visible from the tower heights. These hopes were confirmed, for on stepping out on to the parapet the writer saw the comet in all its splendor. The hazy-looking object seen on September 17, 1909, had developed into a full-grown comet with a head shining as a star of about the second magnitude, and surrounded by a nucleus. Extending outward like the beam of a searchlight gleamed the tail nearly fifteen degrees in length. Calling down to the janitor to make known the good news, the balcony was soon

Halley's Comet
Photograph taken on May 4, 1910, by Professor E. E. Barnard at the Yerkes Observatory, Williams Bay, Wisconsin

filled with eager members of the *Times* staff, who were thus enabled to obtain a view of the comet. By means of a field-glass thoughtfully provided by Mr. Van Anda, it was possible to see a further extension of the train, making it in all thirty degrees in length. Spurts of light like tiny waves seemed to flow out from the nucleus to a distance of two or three degrees. At twenty minutes to four, the writer, on looking downward at the horizon, was startled by what appeared to be a streak of flame, but as it rose higher it proved to be the crescent moon, which with the comet and the planet Venus, completed a wonderful trio. The comet remained visible, resembling a bright star with a slender stream of silvery mist trailing a few degrees after. By four o'clock it had faded in the light of approaching dawn. A glance at the photograph of Halley's comet obtained by Professor Barnard at the Yerkes Observatory on May 4 will give an idea of its splendor.

For the next few mornings observations of the comet were disappointing, owing to heavy mists in the eastern skies. The comet was almost completely hidden from view, except on the morning of May 8, when occasional glimpses were obtained of it through rifts in the clouds. On May 10, the nucleus of the comet, from which extended a diminutive train eight degrees in length and fan-like in appearance, could be seen for a few brief moments, after which it remained hidden behind clouds until dawn, making further observations impossible.

It was not until the morning of Friday, May 13, that the comet once more deigned to reveal itself to the straining eyes of the lonely watcher on the tower. The first glimpse was obtained at ten minutes past three. The comet then resembled a faint white streak drifting in the sky. A minute or so later the planet Venus came into view, gaining in brilliancy as it rose above the mists near the horizon. At twenty-five minutes past three the train of the comet was twenty degrees in length, and by half past three it extended to a distance of thirty-five degrees, or seven times the distance between the pointers (Alpha and Beta in Ursa Major). It spread out like a partly opened fan, its greatest width at the extreme end being about five degrees or more. The nucleus shone brightly as a star of the second magnitude, but by half past three it began to grow less distinct, and at twenty minutes past four the comet had faded from view on the arrival of the first few streaks of dawn.

The comet was barely visible the next few mornings, though watched for anxiously, since there was always the possibility that it might reveal itself, but these hopes were not realized. A glance at the cloudy skies on the morning of May 18 suggested the impossibility of seeing the comet, and for the first time since the morning of May 1, the writer missed her vigil at the tower.

Interest was revived, however, on learning that Professor Barnard had seen that morning

> "a narrow twilight (which later proved to be the tail of the comet) which seemed to extend along the eastern horizon. . . . The head of the comet could not be seen when it rose, with either the five-inch or the forty-inch telescope, because of the thick sky near the horizon. . . . The observations show that the tail was at least 109° long on that date. (*Astrophysical Journal*, vol. XXXIX, no 5, pp. 387-388, June, 1914.)

Now despite the fact that an astronomer at Columbia University had declared the comet would be in the evening sky, and it was useless looking for it in the morning sky of May 19, the writer decided, nevertheless, to watch for the comet at about the usual hour, and with the most gratifying results.

The parapet surrounding the tower was crowded to its utmost capacity by a favored few on the eventful evening of May 18, awaiting they knew not what, for a report had gone forth that we were scheduled to pass through the train of the comet. Below us we could see comet parties in progress on the roof gardens of some of the leading hotels. Sounds of merriment occasionally reached us, but by half past ten we—that is, Miss L., who had offered to share the lonely vigil with the writer until dawn—were the only watchers on the tower. The hush of a great silence had gradually fallen over the city, and in silence, too, we watched the eastern sky for any further trace of the comet.

Notes made by the writer on this occasion record 11.10, red flash (auroral); 11.22, flash resembling an arch of glowing white surmounted by a crest of crimson. The display occurred above a low-lying bank of mist and rose to about five degrees above the horizon. It was not of any considerable breadth, and resembled rather a glow of color against the dark background of the sky than a wide band of light. The moon, which was shining brightly, interfered seriously with the observations of auroral displays which appeared faint in its light. About 12.15 a mist appeared to spread over the city, and the air had become damp and chilly. By 1.30 the mist had cleared away. At 2 o'clock a meteor flashed across the eastern sky, downward in the direction of the star Gamma in the constellation Pegasus. It was bluish-green in color, pear-shaped in appearance, leaving a streak five degrees in length behind it as it flashed to within ten degrees above the horizon. It remained visible for about five seconds, and the display was vivid while it lasted. At 2.30 the moon, low down in the western sky, appeared of a ruddy hue as it "sank in a sea of gloom."

Turning eastward, we saw a soft glow in the sky spreading from below Pegasus and upward as far as the stars of Cassiopeia. At 2.34 a glow of grayish hue extended over the northeastern sky. At 2.43 a bright meteor was seen by Miss L., but she made no note of its direction, except that it was eastward, and a brief glimpse obtained by the writer showed its color as bluish.

At 2.45 streamers, which later proved to be the comet, were observed reaching from the eastern horizon, below Gamma Pegasi, and curving upward through Aquarius as far as Altair, and brighter in appearance than the Milky Way. At its widest part, just beneath the first-magnitude star Altair, the width of the band was about ten degrees, and throughout its length it had a brilliancy equal to that of the Milky Way, near which it terminated. The path of this band of light was very nearly that along which the comet was last seen, and the writer was convinced that it was the outer boundary of the tail through which the earth was passing. Beneath this streamer, and apparently resting along the southeastern horizon, was a secondary band resembling a haze-like misty streamer. This was not as clearly defined as was the upper band, and, moreover, it merged into the mists of the horizon.

In connection with a sketch made by the writer on this occasion, and shown to Professor Barnard, he referred to it as follows in his account of "Visual Observations of Halley's Comet in 1910," published in the *Astrophysical Journal* for June, 1914:

> "With the exception of a sketch by Miss Mary Proctor in New York City, and a newspaper account by Professor D. P. Todd of Amherst (whose observation seemed to refer to May 16th), I have seen no reference from northern observers to the second, fainter and

broader tail shown in my drawings of May 17 and 18, south of the bright beam and separated from it by a distinct dark space, perhaps ten degrees wide. The head of the comet was of course invisible, being below the horizon."

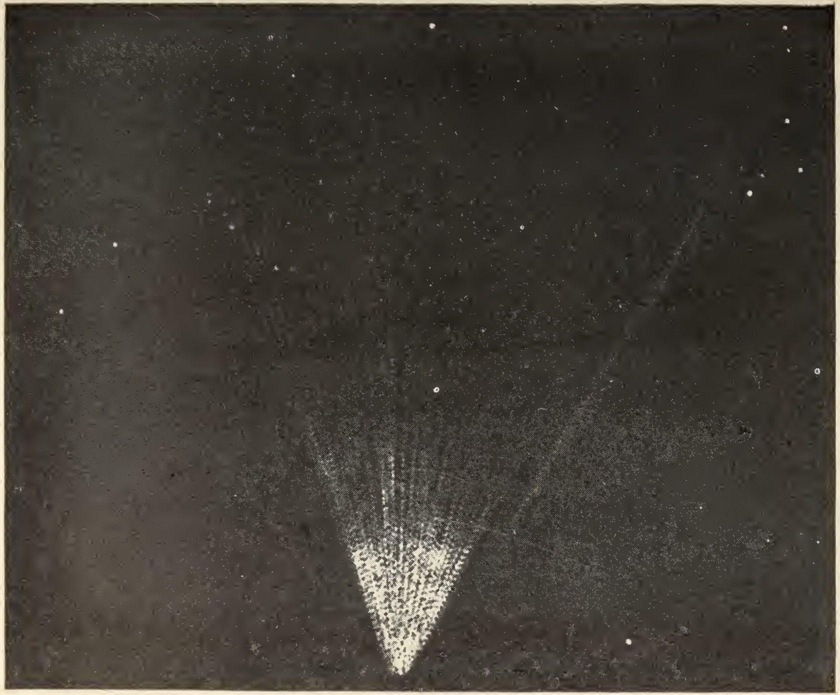
This was all the more pleasing to the writer, as doubts had been expressed in no uncertain terms by a well-known authority, according to the following statement published in an afternoon paper. "Some one thinks she saw the comet in the eastern sky, when it is really in the west." One can imagine the anxious time experienced while awaiting confirmation of the observation, but it came in due course from Yerkes, Lick, Argentine Republic, South Africa, and the writer felt rewarded for the many dreary waits in the tower during the "wee sma' hours" since May 1.

On the morning of May 20, the writer again watched from the *Times* tower, in the hope of seeing some straggling streamers trailing along the sky, denoting the presence of the comet. Between half past two and a quarter past three a ghostly apparition resembling a slender band of light was seen extending upward, though almost parallel with the northeastern horizon. It seemed to rest on a darker band of luminous haze beneath. Surely this was the last fragment of the train of the comet, outlined faintly against the dark void of space.

That same morning Professor Barnard at Yerkes detected a hazy luminous streak about five degrees broad extending from Aquilæ to the east and onward toward Alpha Pegasi. "This resembled the comet's tail," recorded Professor Barnard,

> "but was doubtless a strip of haze. I looked at it several times, taking it for a strip of haze, but it did not seem to move. There were masses of moving haze overhead toward the north. To all appearance it looked like the comet's tail of the mornings of May 18 and 19. I cannot be certain that it was not haze, but it was a singular coincidence of position, appearance, etc., if it was. It remained visible for fully fifteen or twenty minutes."

The train may have been fan-like, as in the case of the comet of 1861, discovered on May 13, by Mr. John Tebbutt of Windsor, New South Wales, already referred to in the chapter on



Comet 1861, July 2, as Seen and Drawn by R. A. Proctor
The tail of the comet was near the earth, which passed through it on this occasion

"Comet-hunting as a Hobby." In my father's book, *Mysteries of Time and Space*, he records as follows his view of that comet in connection with the drawing here given:

> "The first recorded observations (of the comet of 1861, in Europe) were made on the evening of June 30, nineteen days after it had passed its point of nearest approach to the sun. I remember well observing it on the morning of July 2, 1861. For some reason I found it impossible to sleep that morning, and getting up about three (the exact hour I do not remember, but it must have been very early), I saw in the east what looked at first like the rays of an aurora borealis. But presently I noticed that these rays proceeded (unlike those of the aurora) from a bright center, which had been hidden by clouds when my observations began. I used at that time to keep a four-inch telescope, mounted on a three-legged stand, in my bedroom. This I had quickly ready for action (noting that the object, owing to the approach of sunrise, was getting fainter every minute), and turning it on the comet, I drew a picture of the nucleus and coma, so closely resembling

that which appeared a week or two later in the *Illustrated London News*, that I might have supposed my picture had been surreptitiously sent to the office of the *Illustrated*, had I not found it resting just where I had put it in my scientific portfolio."

Returning to the discussion of Halley's comet, it was seen on May 21, at 4.30 A.M., by Professor Evershed, (then director of the Kodaikanal Observatory, Southern India), appearing no broader than on May 18, but fainter. He described it as passing centrally through the square of Pegasus, which was nearly filled with the faint light. The tail could be traced, as before, right up to the Milky Way. The star ε Pegasi was nearly in the center of the band of light, and the star α Aquilæ near its southern edge. This was the last observation Professor Evershed made before dawn. He considered it remarkable that the tail of the comet should have remained visible in the morning sky as a narrow band of light, nearly two days after the head of the comet had passed to the other side of the sun. He suggested that this might be due to the fact that the tail may have been strongly curved and very broad in the direction of the comet's motion, although narrow and straight in the direction at right angles thereto. If so, the passage of the earth through the tail, if it occurred at all, must have been delayed one or two days and probably occupied more time than a single day. There is some doubt whether the tail did actually touch the earth, for observations of its position in the sky on May 11 and 15 show that its axis was inclined very considerably northward from the direction of the radius vector, a straight line drawn from the nucleus of the comet to the sun of the comet.

In the forenoon of May 19 certain peculiarities observed suggested that our planet may have been actually immersed in the cometary débris of the train of Halley's comet. These consisted of a peculiar iridescence and unnatural appearance of the clouds near the sun, and a bar of prismatic colors on the clouds in the south. This, combined with the general effect of the sky and clouds—for the entire sky had a most unnatural and wild look—would have attracted marked attention at any other time than when one was looking, as on this occasion, for something out of the ordinary. According to the observations made by Professor Barnard at the Yerkes Observatory, the sky had been watched carefully during the forenoon of this date, but nothing unusual had appeared until close to noon, when the conditions became abnormal. Later on in June, and for at least a year afterward, slowly moving strips and masses of luminous haze were observed in the sky, which were not confined to any one part. Reports of like unusual phenomena were received from the Transvaal, and from elsewhere in southern climes.

On the evening of May 21 the comet made its first appearance in the west, as seen by watchers on the *Times* tower, but it failed to be very impressive. It was to the left and a few degrees north of the star Betelgeuse in the constellation of Orion, and it resembled a star of the third magnitude. It was surrounded by a hazy cloud-like mist that made it appear nearly as large as the space covered by the moon. To the left of it, and extending outward about three or four degrees, were three or four fan-like streamers. At 8.25 the nucleus seemed brighter and more star-like in the center, but the streamers had faded from view and the mist surrounding the nucleus had become hazy and ill-defined. Five minutes later only the star-like nucleus could be seen, doubtless owing to the combination of the glare of moonlight and the haze that reflected the city lights below.

On May 24 the comet appeared hovering for a brief interval over the western horizon, resembling a faint star enveloped in mist, and adorned with a short fan-like tail. On May 25 the comet could not be seen, owing to the mist and a drizzling rain, but on May 26 it was visible on two occasions for intervals of about five minutes. It then resembled a fairly bright star of the third magnitude, surrounded by a misty halo, but was devoid of a tail. It seemed that our chances of seeing the comet again under favorable conditions were slight, but on the evening of May 27 we were once more regaled with a fine view, which proved to be final as far as the writer was concerned.

At a few minutes past eight the nucleus of the comet appeared, as usual, hazy and ill-defined, but gradually it brightened until it equaled the glow of the first-magnitude star Regulus, in the constellation of Leo near by. Only a few degrees of tail were visible at first, but as the twilight deepened into night more and more came into view. By 8.40 P.M. it stretched outward about twenty degrees in the direction of the planet Jupiter. The train was long and slender, and not more than five degrees at its greatest width. By 9 o'clock it was clearly visible, a dark streak apparently dividing it just beyond the nucleus; the edges were more or less sharply defined for a distance of about three or four degrees. By 10.30

the train of the comet had almost faded from view; at 10.40 it had become invisible and the nucleus was barely perceptible. Within three minutes the nucleus was almost lost to sight in the haze and mist near the horizon.

Meanwhile, the moon had risen in the eastern sky, and by eleven o'clock it was several degrees above the horizon. Its arrival on the scene was the climax of an evening rich in glory, as far as the celestial display was concerned. The view of the comet on this occasion was the best that had been obtained since May 20, and settled beyond doubt the vexed question that had arisen as to whether the comet had lost its tail or had divided in two. Nevertheless, a glance at a photograph taken by Professor Barnard on June 6, shows an apparently smaller comet nestling to the left of the larger, keeping it company, as it were, in its celestial voyage outward from the neighborhood of the sun. By this time the comet had faded sadly, as Professor Barnard expressed it, and, though a noticeable object, was only the ghost of its former self.

Where is it now in its outward journey, at the present time of writing (1925)? Science can answer the question as definitely as though it were actually possessed of magic glasses, enabling it to

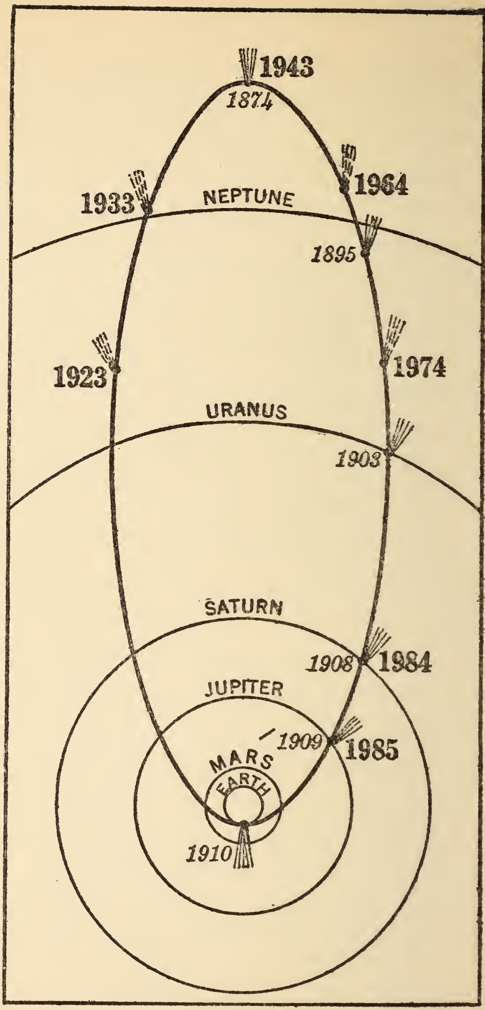
Halley's Comet

From photograph taken by Professor E. E. Barnard, June 6, 1910, at the Yerkes Observatory, Williams Bay, Wisconsin

follow the path of the retreating comet, although it has long since passed beyond our range of view. It is now approaching the orbit of the planet Neptune, crossing it in 1933, and reaches its greatest distance outward from the sun in 1943, or 3,200 million miles. In 1964 it draws near to Neptune again, and will be halfway between Neptune and Uranus in 1974, arriving at the orbit of Saturn in 1984. Once more it will gladden the eyes of mortals as it approaches the planet Jupiter, and draws near to pay its respects to its mighty ruler, the sun.

At its return in 1758 the prediction erred on the side of thirty-two days; at the return in 1835, by a margin of only two days; and in 1910, by the amount of two and one-half days. Perchance, ere it makes its next appearance in 1985,[1] the presence of another planet beyond Neptune may have been detected, explaining the disturbing factor resulting in that small discrepancy. The astronomers at that remote date (1984) may succeed, therefore, in making a prediction so exact that the comet may "swim into their ken" promptly to scheduled time. Few, if any, of the present-time readers of this book (unless it falls into the hands of a very youthful enthusiast) will be here

[1] Perihelion about February, 1986. The comet probably will be first seen during the spring of 1965.



The orbit of Halley's Comet, which it passes over in 75 to 77 years, showing where the comet is to be found now, and during its course until its next return in 1985.

to welcome the comet at its next return, and even the youthful enthusiast may have the distressing experience of the American astronomer Dr. Lewis Swift, who saw Halley's comet in 1835, and was able to welcome it at its return in 1910, but, owing to failing eyesight, was unable to see it, much to his regret.

With regard to my first visit to the Yerkes Observatory, the following facts regarding the great refractor may be of interest, as well as the incident narrated to me by Miss Calvert while we were awaiting Professor Barnard's invitation to look for Halley's comet, on that momentous occasion. The story was deferred, in my account, to the final part of this chapter, so as not to break the thread of the actual account of my first view of the comet. Following the description of the telescope, the story of a catastrophe which nearly ended its career is best told in Professor Barnard's own words, as quoted from the after-dinner speech, in January, 1907, at Nashville, already referred to in this book.

> "The tube of this instrument is about sixty-four feet long. In the farther end of this tube is placed the great object-glass, forty inches clear in aperture. When one is

looking overhead with this giant telescope, he must be at a point some thirty feet or more lower than when the tube is pointed toward the horizon. To avoid the use of a high ladder to reach the observing end of the telescope in its various positions, the floor of the dome itself is made into a giant elevator, sixty-five feet in diameter. The rising and lowering of this floor—which is done by electric motors—always keeps the observer in a convenient and safe position with reference to the eye-end. This floor is suspended by heavy steel cables which go over wheels at the tops of four towers attached to the inside walls of the dome. The floor is counterpoised by heavy iron weights at the other ends of the cables.

"Within a little over a week after the completion of the instrument and when we had seen through it only once or twice, the two south cables pulled out of their sockets and the floor fell through fifty feet to the ground and was destroyed. It was a terrible wreck. This was on the morning of May 29, 1897, at 6.30 o'clock. Mr. Ellerman and I had been working all night observing with the telescope. When we quit at daylight we left the floor at its highest point for the convenience of some workmen who were to be at work on the tube in the morning. When the floor fell there was not a soul in the building, and no one was injured. A couple of hours either way, and death in all probability would have come to one or the other of us. Only a few nights before this accident the president of the University of Chicago and thirty or more trustees and prominent men of the university had seen through the telescope, and the floor had been up and down with them on it. If it had fallen then a heavy loss of life would have been almost certain. A few days before that, Mr. Clark, who made the great glass, had unpacked the forty-inch disks on the floor at its highest point, and had put them in the cell which he finally bolted to the end of the telescope. If the floor had fallen then, the great lens would have been destroyed, with the probability that no one would be able to make another, for Mr. Clark died within a few days after he returned to Cambridge. It was providential, then, that the floor fell when it did; for the fault in the attachment of the cables made it certain that it must soon have fallen.

"But this is not the end of the story. When the floor fell, it lurched against the great iron pier of the telescope and must have given it a violent blow. There was some fear that the great glass might have been injured by the shock. It was nearly a hundred feet up in the air and could not be reached to see if it was unharmed. By climbing up on the dome (which is one hundred and ten feet high) and looking down at the glass, it was seen to be apparently uninjured. Still, the test could only be made by examining the stars through it, which was not possible until the floor was replaced by a new one. Four months were occupied in taking out the wreck and putting in the new floor.

"There was great anxiety to see the sky through the glass, and the first night available it was turned to the stars. To our consternation, there was a great, long flare of light running through every bright star we examined. This was so strong and conspicuous that it would make the instrument utterly useless. It looked as if the lens had been injured by the shock of the floor against the pier. We examined it in all positions of the instrument, but we could not get rid of the glaring defect. As I had used the glass more than anyone else before the accident, my statement that the defect did not then exist made the matter all the more serious. It was with heavy hearts that we waited for day to again critically examine the lens. The next day we all examined the great glass very carefully, but could see nothing wrong with it. Then Professor Hale noticed that just back of the glass in the tube was a thick mass of spider webs stretched across the tube, all running in the same direction. Upon comparing notes we found that the direction of the spider webs coincided with that of the flare of light seen the night before. It seemed that a spider had evidently got in the tube before the object glass was put on by Clark, and had been unable to get out; for there was no opening in the tube. During the time the tube remained at rest, while the new floor was being put in, he had climbed up to the great glass in the direction of the light; and when he found his egress barred by the great window, he spun his web, perhaps as a signal of distress, or maybe in the hope that some unlucky fly might get in through the glass that he could not get out of—anyway, with the result that he caused several astronomers the most uneasy time of their lives. When these webs were swept out by one of the astronomers climbing up in the tube with a feather duster, it was found that night, when the stars were examined, that the flare had vanished and the mighty glass was uninjured."

CHAPTER SEVEN

ORIGIN OF COMETS AND METEORS

(THEORIES ADVANCED BY THE LATE RICHARD A. PROCTOR.)

AMONG the author's most treasured possessions is a clipping from the Cincinnati *Daily Gazette* for February 18, 1874, containing a report of a lecture given by her father, on "Comets and Meteors," from which the following is an extract:

"In this lecture on comets and meteors, I promised to give some account of what is expelled from the sun when great explosions take place. If I were to say that the comets were shot out from the sun you might be startled, or if I asserted that they were also thrown out of Jupiter and Saturn. But the evidence in connection therewith is very curious. In the first place, we know that matter is shot out from the sun, with a velocity so great as to be carried away from him altogether and so would travel into space. That has only been observed a few times, but the occurrence is probably very frequent. The matter which was expelled, if it struck the earth at all, would strike in the daytime. The side of the earth facing the sun will be the illuminated side. The meteoric matter coming from the sun can only strike the illuminated part, and this can only happen in the daytime. You throw a stone at any object, and it must strike the side of the object you aim at, that is turned toward you. Humboldt affirmed that the largest number of meteoric masses had fallen in the daytime. The larger aërolites have been examined and their microscopic structure studied. Sorby of Sheffield, who examined some of them, says they consist of a number of small globules and were originally in a vaporous state before assuming their present condition. Then came a chemical analysis by Professor Graham and Chandler Roberts of London. They found in the iron of the meteoric mass more hydrogen than iron in a natural condition. Professor Graham said that in his opinion meteors certainly contained iron, and that probably they had been expelled from one of the stars that people space. He drew attention to the fact that stars contained hydrogen in their atmosphere. These are some of the facts concerned with the larger meteoric masses.

"How shall we account for those meteoric streams which travel close to the path of Jupiter? All comets of short period have paths closely approaching some of the large planets. The comet of 1680 went close to Jupiter, long before the explosive power of the sun was noticed. I call them Jupiter's family of comets. Sir John Herschel said that it was very curious that they had that relation. If we put forward the theory that Jupiter expelled these comets, we have a very startling theory, but many of the theories which have been propounded, some of the most important character and which have been proved to be true, have been the most startling. It is said that as Jupiter, Saturn, and Uranus go along their paths, they draw in the comets which travel close to them, and capture them.

"I made a calculation about the November meteors to see how close they must go to the path of Uranus in order to be captured, and found that they must approach nearly as close as the nearest satellite. Only those which came almost in contact with the planet could be captured. Now, if they were shot out when Uranus was in a sun-like condition, then it would be explained, whereas we find great difficulty in imagining that a comet coming out of space would be captured bodily by a planet like Uranus. Let us consider the matter thus: if comets are expelled from a planet, they will be carried along with the forward motion. If it could appear that some of them went backward, then we would have no evidence of the theory I have been advancing. If most of them travel forward, then we would have some evidence for the theory. Now there is the curious fact that among the comets of short period the whole of Jupiter's family travel forward. They do not travel in all directions of slope; all have a very moderate slope to the paths of the planets. They do not have the slope even of the asteroids. That is precisely what we notice —that they travel very much with Jupiter. Taking the balance between the two theories —that of expulsion and that of capture—it seems to be in favor of the more startling one—that Jupiter has had the power to expel these objects."

It is interesting, in connection with this extract from the report of a lecture given by my father some fifty years ago at present time of writing (1925), to turn to a passage in the chapter on comets, by Dr. A. C. D. Crommelin, in the *Splendour of the Heavens*, page 414, where he refers as follows to the capture theory:

> "The fact that the members of the Jupiter family (of comets) have direct motion in all cases appears to give a fatal blow to the capture theory. Practically as many comets would approach the comet with retrograde motion as with direct; there is, indeed, the point that those travelling in the same direction as the planet would remain longer in its neighbourhood, and so have more time to be perturbed, which would have some weight; but that out of some fifty comets there is not a single retrograde one is too remarkable a fact to pass over, and it clearly suggests that Jupiter played a different part from that of a mere enslaver, and was concerned with the origin of these bodies in a more intimate manner.
>
> "Many of the considerations I have brought forward were stated by Mr. R. A.

> Proctor some fifty years ago; they have therefore been accessible to astronomers, who nevertheless have been, as a rule, quite unaffected by them, so that it is time to state them afresh. The consideration that the life of a short-period comet is limited by the rapid wastage to which it is subject by the joint action of the sun and Jupiter was not, I think, so fully realised, when Proctor wrote as it is now. It serves further to invalidate the capture theory, since it prevents our assigning to these bodies such extended lives as that theory demands."

According to my father's theory, the giant planets are themselves the parents of their comet-families, and he pictured their birth as having occurred in a remote past, when the planets were more sun-like than they are to-day. We have a great amount of evidence as to the energy of the processes that are at work on Jupiter, as evidenced, for instance, by the great Red Spot (though some have hinted at the possibility of its being an early stage in the formation of a new satellite); Saturn, Uranus, and Neptune also indicate vast upheavals, though distance in their case hinders observation, and even on our own planet we have some striking instances of the power of volcanic energy, as at the eruption of Krakatoa in 1883. Sounds of the explosion were heard three thousand miles away, and a huge volume of dust was blown to the highest regions of the atmosphere, but we are entitled to expect much vaster convulsions in Jupiter, which outweighs the earth three hundred times and is in a much hotter state, judging by the deep envelope of vapours surrounding it, and the rapid changes that are constantly taking place in its appearance, on an enormous scale, as shown by the fine series of photographs which have been obtained of the planet with the giant telescopes.

Writing in his magazine, *Knowledge*, for January 1, 1887, page 64, my father states:

> "The theory of ejection was adopted as the only theory by which the chemical, physical, and microscopic structure of meteorites of all orders—from bolosiderites to asiderites—can be accounted for. They were certainly once exposed to such conditions as exist only in the interior of large orbs—suns or planets. And as certainly they have somehow come forth from such interiors. The expulsive force shown by observation to reside in the only sun-like body we can examine, indicates

the only way in which such expulsion can conceivably have been effected. Hence, I infer (for my own part I feel assured of the weight of evidence) that all orders of meteorites were expelled from some orbs at some time when such orbs were in the sun-like stage. Generalizing, I include in this theory all orders of meteors, and find all their most characteristic peculiarities explained, and all orders of meteor-systems or comets, finding their several orders thus and thus only explicable (if we include all suns now and in the past, all planets in all solar systems, in their past sun-like state, among the sources of meteors and comets). No other general theory seems to me possible."

Again, in an article in *Knowledge* for April, 1887, page 135, my father makes the following statement regarding his theory concerning comets and meteors:

"All comets and meteors are sun-born. But it is not to our own sun, nor to those other suns, the stars, that I attribute all comets and meteor systems. Many millions have come doubtless from our sun during the many millions of years he has been a sun, though few of his cometic children are known to terrestrial astronomers. Millions of millions have come from the many millions of suns in our galaxy during the many millions of years of their sunlike existence. But the giant planets were once suns,[1] and in their sun-like state, which must have lasted millions of years, they must have ejected their smaller comets and meteor systems which even now, after millions of years, have paths passing near the orbits of their parent orbs. Our earth and her fellow terrestrial planets had their sun-like stage of life, too, and it must have been while the earth was a sun that the meteors explained specially by Tschermak's theory were expelled."

According to his theory, Tschermak, noting the resemblance of structure between meteorites and volcanic products, suggests that meteors of all orders (which would include meteor streams, and therefore comets) were shot out from the earth in the days when she was young. But though this

[1] It is now thought that the temperature of such small bodies will never have been high enough to call them suns. Eddington says a mass one-eighth of that of the sun would be required for this.

is better than the other theories, in at least suggesting some sort of an origin for comets and meteors, it will not account for comets which do not approach within many millions of miles of the earth's orbit,[1] and a theory which fails for some among the comets cannot be the true general theory for meteors either.

Mr. Sorby of Sheffield, the eminent mineralogist already referred to, deduced from the microscopic structure of certain meteorites the startling theory that they had once been inside the sun; for there is evidence that their substance once existed in the form of globules of molten metal, which aggregated with large masses, which in turn were exposed to violent friction, indicating conflicting motions of very high velocities.

"Where else," wrote Sorby, in 1864, "could such conditions exist, except first in the interior, and afterwards in the immediate neighborhood of our sun!" But it is absolutely certain that the theory as thus suggested cannot possibly be true, either as a general explanation of comets and meteors, or even as an explanation of any known meteor system or comet, unless, perhaps, a few of the comets whose orbits pass very near the sun

[1] Perturbations will make very great changes in the orbits. The perihelion distance of Pons-Winnecke has increased twenty million miles or more in the past sixty years.

were sun-born, and subsequently disturbed by planetary attractions so as not to return to their parent orb.

According to my father's views on the subject:

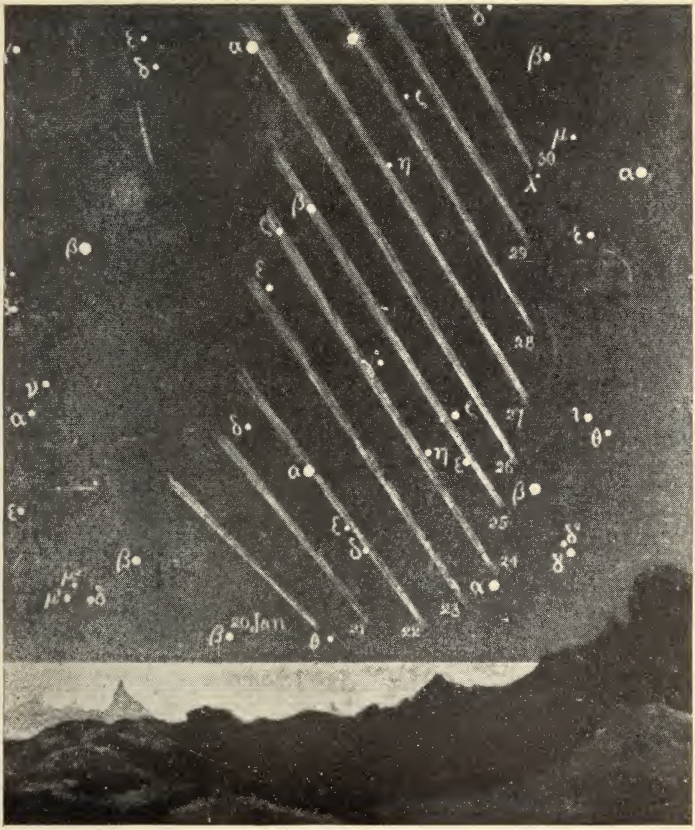
> "A flight of meteors shot out from the sun, as Sorby suggested, might have velocity enough to get away from him forever, in which case we should never see a trace of it again, even though we waited for millions of years. If, however, it could not get away, then it must return to its starting-place—that is, back to the sun's globe—unless, passing near enough to one of the giant planets, it were so far disturbed as only to return by grazing past the sun's surface. (The comets of 1843, 1880, and 1882, which all traveled in paths near the sun, almost grazing his surface, may well have been parts of a single meteor-flight shot out from his interior millions of years ago.)"

After the appearance of the new comet of 1887 in the southern skies, it was found to be following along the same track as the comets of 1843, 1880, and 1882, thus confirming my father's theory that these comets were parts of one large comet, dissipated, doubtless, some millions of years ago.

These comets were so bright when near the sun that they could be seen at noon with the naked eye. As regards the heat experienced by the comet of 1843 when near the sun, Sir John Herschel remarked:

> "Imagine a glare 25,000 times fiercer than that of an equatorial sunshine at noonday. In such a heat there is no solid substance we know of which would not run like water—boil—and be converted into smoke or vapor."

In *Knowledge* for November 1, 1887, an account is given of the remarkable southern comet first observed in January of that year, and as it is the last article on this topic written by my father for his magazine, giving a more or less detailed account of his views on the subject, the author of this book has deemed it advisable to quote it in full. It is of special interest, not only on account of its giving his theories on the subject, but for the reason that it helps to supply part of the missing chapter on "Comets and Meteors," which he had planned for his final but unfortunately unfinished work, *Old and New Astronomy*. This work had



From *Knowledge*

THE SOUTHERN COMET OF JANUARY, 1887

been in course of preparation for thirty years, and that the material for such a chapter was partially compiled the writer knows from the fact that she has a keen recollection of clippings, MSS., and notes which she saw apparently awaiting classification and arrangement, a short while before her father's departure from Florida, September 8, 1888. What became of them after his sudden death in New York a few days later, it is impossible to conjecture, unless A. C. Ranyard, who completed the book, found the chapter on comets too difficult to arrange satisfactorily. Yet even the fragments so arduously arranged and collected by my father would have been better than a missing chapter on a subject in which he was so deeply interested and to which he had devoted so much attention.

To return to my father's account of the comet of January, 1887:

> "The comet was first seen by a farmer and a fisherman of Blauwberg, near Cape Town, on the night of January 18-19. The same night it was seen at the Cordoba University by M. Thomé. On the next night Mr. Todd discovered it independently at the Adelaide Observatory, and watched it till the 27th.

On the 22d Mr. Finlay detected the comet and was able to watch it till the 29th. At Rio de Janeiro, Mr. Cruls observed it from the 23d to the 25th, and at Windsor, New South Wales, Mr. Tebbutt observed the comet on the 28th and 30th. Moonlight interfered with further observations.

"The comet's appearance was remarkable. Its tail, long and straight, extended over an arc of thirty degrees, but there was no appreciable condensation which could be called the comet's head. The long train of light, described as nearly equal in brightness to the Magellanic clouds, seemed to be simply cut off at that end where in most comets a nucleus and coma are shown.

"This comet has helped to throw light on one of the most perplexing of all the puzzles which those most perplexing of all the heavenly bodies, comets, have presented to astronomers. In the year 1668, a comet was seen in the southern skies which attracted very little notice at the time, and would probably have been little thought of since had not attention been directed to it by the appearance and behavior of certain comets seen during the last half-century. Visible for about three weeks, and discovered after it had already passed the point of its nearest approach to the sun, the comet of 1668 was not observed so satisfactorily that its orbit could be precisely determined. In fact, two entirely different orbits would satisfy the observations fairly, though only one could be regarded as satisfying them well.

"This orbit, however, was so remarkable that astronomers were led to prefer the other, less satisfactory though it was, in explaining the observed motions of the comet. For the orbit which best explained the comet's movements carried the comet so close to the sun as actually to graze his visible surface. Moreover, there was this remarkable and, indeed, absolutely unique peculiarity about the orbit thus assigned: the comet (whose period of revolution was to be measured by hundreds of years) actually passed through the whole of that part of its course during which it was north of our earth's orbit plane in less than two hours and a half! though this part of its course is a half-circuit around the sun, so far as direction (not distance of travel) is concerned. That comet, when at its nearest to the sun, was traveling at the rate of about 330 miles per second. It passed through regions near the sun's surface commonly supposed to be occupied by atmospheric matter.

"Now, had the comet been so far checked in its swift rush through those regions as to lose one-thousandth part of its velocity, it would have returned in less than a year. But the way in which the comet retreated showed that nothing of this sort was to be expected. I am not aware, indeed, that any anticipations were ever suggested in regard to the return of the comet of 1668 to our neighborhood. It was not till the time of Halley's comet, 1682, that modern astronomy began to consider the question of the possibly periodic character of cometic motions with attention. (For my own part, I reject as altogether improbable the statement of Seneca that the ancient Chaldean astronomers could calculate the return of comets. The comet of 1680, called Newton's, was the very first whose orbital motions were dealt with on the principles of Newtonian astronomy, and Halley's was the first whose periodic character was recognized.)

"In 1843, another comet came up from

the south, and presently returned thither. It was, indeed, only seen during its return, having, like the comet of 1668, been discovered only a day or two after perihelion passage. Astronomers soon began to notice a curious resemblance between the orbits of the two comets. Remembering the comparative roughness of the observations made in 1668, it may be said that the two comets moved in the same orbit, so far as could be judged from observation. The comet of 1843 came along a path inclined at apparently the same angle to the earth's orbit plane, crossed that plane ascendingly at appreciably the same point, swept round in about two hours and a half that part of its angular circuit which lay north of the earth's orbit plane, and, crossing that plane descendingly at the same point as the comet of 1668, passed along appreciably the same course towards the southern stellar regions! The close resemblance of two paths, each so strikingly remarkable in itself, could not well be regarded as a mere accidental coincidence.

"However, at that time no very special attention was directed to the resemblance between the paths of the comets of 1843 and

1668. It was not regarded as anything very new or striking that a comet should return after making a wide excursion round the sun; and those who noticed that the two comets really had traversed appreciably the same path around the immediate neighborhood of the sun, simply concluded that the comet of 1668 had come back in 1843, after 175 years, and not necessarily for the first time.

"It must be noticed, however, before leaving this part of the record, that the comet of 1843 was suspected of behaving in a rather strange way when near the sun. For the first observation, made rather roughly, indeed, with a sextant, by a man who had no idea of the interest his observations might afterwards have, could not be reconciled by mathematicians (including the well-known mathematician, Benjamin Pierce) with the movement of the comet as subsequently observed. It seemed as though when in the sun's neighborhood the comet had undergone some disturbance, possibly internal, which had in slight degree affected its subsequent career.

"According to some calculations the comet of 1843 seemed to have a period of about thirty-five years, which accorded well with the idea that it was the comet of 1668, returned after five circuits. Nor was it deemed at all surprising that the comet, conspicuous though it is, had not been detected in 1713, 1748, 1783, and 1818, for its path would carry it where it would be very apt to escape notice except in the southern hemisphere, and even there it might quite readily be missed. The appearance of the comet of 1668 corresponded well with that of the comet of 1843. Each was remarkable for its long tail and for the comparative insignificance of its head. In the northern skies, indeed, the comet of 1843 showed a very straight tail, and it is usually depicted in that way, whereas the comet of 1668 had a tail showing curvature. But pictures of the comet of 1843, as seen in the southern hemisphere, show it with a curved tail, and also the tail appeared forked toward the end, during that part of the comet's career. However, the best observations, and the calculations based on them, seemed to show that the period of the comet of 1843 could not be less than 500 years.

"Astronomers were rather startled, therefore, when, in 1880, a comet appeared in the southern skies which traversed appreciably the same course as the comets of 1668 and 1843. When I was in Australia in 1880, a few months after the great comet had passed out of view, I met several persons who had seen both the comet of that year and the comet of 1843. They all agreed in saying that the resemblance between the two comets was very close. Like the comet of 1843, that of 1880 had a singularly long tail, and both comets were remarkable for the smallness and dimness of their heads. One observer told me that at times the head of the comet could barely be discerned.

"Like the comets of 1668 and 1843, the comet of 1880 grazed close past the sun's surface. Like them it was but about two hours and a half north of the earth's orbit plane. Had it only resembled the other two in these remarkable characteristics, the coincidence would have been remarkable. But of course the real evidence by which the association between the comets was shown was of a more decisive kind. It was not in general character only, but in details that the path of the comet of 1880 resembled those on which the other two comets had traveled. Its path had almost exactly the same slant to the earth's orbit plane as theirs, crossed that plane ascendingly and descendingly at almost exactly the same points, and made its nearest approach to the sun at very nearly the same place.

"To the astronomer such evidence is decisive. Mr. Hind, the superintendent of the *Nautical Almanac*, and as sound and cautious a student of cometic astronomy as any man living, remarked, so soon as the resemblance of these comets' paths had been ascertained, that if it were merely accidental the case was most unusual; nay, it might be described as unique. And, be it noticed, he was referring only to the resemblance between the comets of 1880 and 1843. Had he recalled at the time the comet of 1668, and its closely similar orbit, he would have admitted that the double coincidence could not possibly be merely casual.

"But this was by no means the end of the matter. Indeed, thus far, although the circumstances were striking, there was nothing to prevent astronomers from interpreting them as other cases of coincident, or nearly coincident, comet paths, had been interpreted. Hind and others, myself included, inferred that the comets of 1880, 1843, and 1668 were simply one and the same comet, whose return in 1880 probably followed the return in 1843 after a single revolution.

"In 1882, however, two years and a half after the appearance of the comet of 1880, another comet came up from the south, which followed in the sun's neighborhood almost the same course as the comets of 1668, 1843, and 1880. The path it followed was not quite so close to those followed by the other three as these had been to each other, but yet was far too close to indicate possibly a mere casual resemblance; on the contrary, the resemblance in regard to shape, slope, and those peculiarities which render this family of comets unique in the cometary system, was of the closest and most startling kind.

"Many will remember the startling ideas which were suggested by Professor Piazzi Smyth respecting the portentous significance of the comet of 1882. He regarded it as confirming the great pyramid's teaching (according to the views of orthodox pyramidalists) respecting the approaching end of the Christian dispensation. It was seen under very remarkable circumstances, blazing close by the sun, within a fortnight or three weeks of the precise date which had been announced as marking that critical epoch in the history of the earth.

"Moreover, even viewing the matter from a scientific standpoint, Professor Smyth (who, outside his pyramidal paradoxes, is an astronomer of well-deserved repute) could recognize sufficient reason for regarding the comet as portentous. Many others, indeed, both in America and in Europe, shared his opinion in this respect. A very slight retardation of the course of the comet of 1880, during its passage close to the surface of the sun, would have sufficed to alter its period of revolution from the thirty-seven years assigned on the supposition of its identity with the comet of 1843, to the two and a half years indicated by its apparent return in 1882, and if this had occurred in 1880, a similar interruption in 1882 would have caused its return in less than two and a half years.

"Thus, circling in an ever-narrowing (or rather shortening) orbit, it would presently, within a quarter of a century or so, perhaps, have become so far entangled among the atmospheric matter around the sun, that it would have been unable to resist absolute absorption. What the consequences to the solar system might have been none ventured to suggest. Newton had expressed his belief that the effect of such absorption would be disastrous, but the physicists of the nineteenth century, better acquainted with the laws associating heat and motion, were not so despondent. Only Professor Smyth seems to have felt assured (not being despondent but confident) that the comet portended, in a very decisive way, the beginning of the end.

"However, we were all mistaken. The comet of 1882 retreated on such a course, and with such variation of velocity as to show that its real period must be measured not by months, as had been supposed, nor even by years, but by centuries. Probably it will not return till 600 or 700 years have passed. Had this not been proved, we might have been not a little perplexd by the return of apparently the same comet in this present year (1887). A comet was discovered in the south early in January, whose course, dealt with by Professor Kruger, one of the most zealous of our comet calculators, is found to be partially identical with that of the four remarkable comets we have been considering. Astronomers have not been moved by this new visitant on the well-worn track, as we were by the arrival of the comet of 1882, or as we should have been if either the comet of 1882 had never been seen, or its path had not been shown to be so wide ranging. Whatever the comet of the present year may be, it was not the comet of 1882 returned. No one even supposes that it was the comet of 1880, or 1843, or 1668. Nevertheless, rightly apprehended, the appearance of a comet traveling on appreciably the same track as those four other comets is of extreme interest, and indeed practically decisive as to the interpretation we must place on these repeated coincidences.

"Observe, we are absolutely certain that the five comets are associated together in some way; but we are as absolutely certain that they are not one and the same comet which had traveled along the same track and returned after a certain number of circuits. We need not trouble ourselves with the question whether two or more of the comets may not have been in reality one and the same body at different returns. It suffices that they all five were not one; since we deduce precisely the same conclusion whether we regard the five as in reality but four or three or two. But it may be mentioned, in passing, as appearing altogether more probable, when all the evidence is considered, that there were no fewer than five distinct comets, all traveling on what was practically the selfsame track when in the neighborhood of the sun.

"There can be but one interpretation of this remarkable fact—a fact really proved, be it noticed (as I and others have maintained since the retreat of the comet of 1882), independently of the evidence supplied by the great southern comet of the present year. These comets must all originally have been one comet, though now they are distinct bodies. For there is no reasonable way (indeed no possible way) of imagining the separate formation of two or more comets at different times, which should thereafter travel in the same path.

"No theory of the origin of comets ever suggested, none even which can be imagined, could account for such a peculiarity. Whereas, on the other hand, we have direct evidence showing how a comet, originally single, may be transformed into two or more comets traveling on the same, or nearly the same, track.

"The comet called Biela's, which had circuited as a single comet up to the year 1846 (during a period of unknown duration in the past—probably during millions of years), divided then into two, and has since broken up into so many parts that each cometic fragment is separately indiscernible. The two comets into which Biela's divided, in 1846, were watched long enough to show that, had their separate existence continued (visibly), they would have been found, in the fullness of time, traveling at distances very far apart, though on nearly the same orbit. The distance between them, which in 1846 had increased only to about a quarter of a million of miles, had in 1852 increased to five times that space.

"Probably a few thousand years would have sufficed to set these comets so far apart (owing to some slight difference of velocity, initiated at the moment of their separation) that when one would have been at its nearest to the sun, the other would have been at its farthest from him. If we could now discern the separate fragments of the comet, we should doubtless recognize a process in progress by which, in the course of many centuries, the separate cometic bodies will be disseminated all round the common orbit. We know, further, that already such a process has been at work on portions removed from the comet many centuries ago, for as our earth passes through the track of this comet she encounters millions of meteoric bodies which are traveling in the comet's orbit, and once formed part of the substance of a comet doubtless much more distinguished in appearance than Biela's.

"There can be little doubt that this is the true explanation of the origin of that family of comets, five of whose members returned to the neighborhood of the sun (possibly their parent) in the years 1668, 1843, 1880, 1882, and 1887. But it is not merely as thus explaining what had been a most perplexing problem that I have dealt with the evidence supplied by the practical identity of the orbits of these five comets. When once we recognize that this, and this only, can be the explanation of the associated group of five comets, we perceive that very interesting and important light has been thrown on the subject of comets generally.

"To begin with, what an amazing comet that must have been from which these five, and we know not how many more, were formed by disaggregative processes—probably by the divellent action of repulsive forces exerted by the sun! Those who remember the comets of 1843 and 1882 as they appeared when at their full splendor will be able to imagine how noble an appearance a comet would present which was formed of these combined together in one. But the comet of 1880 was described by all who saw it in the southern hemisphere as most remarkable in appearance, despite the faintness of its head. The great southern comet of the present year (1887) was a striking object in the skies, though it showed the same weakness about the head. That of 1668 was probably as remarkable in appearance as even the comet of 1882. A comet formed by combining all these together would certainly surpass in magnificence all the comets ever observed by astronomers.

"And then, what enormous periods of time must have been required to distribute the fragments of a single comet so widely that one would be found returning to its perihelion more than two centuries after another! When I spoke of one member of the Biela group being in aphelion, when another would be in perihelion, I was speaking of a difference of only three and one-third years in time; and even that would require thousands of years. But the scattered cometic bodies which returned to the sun's neighborhood in 1668 and 1887 speak probably of millions of years which have passed since first this comet was formed. It would be a matter of curious inquiry to determine what may have been the condition of our sun, what even his volume, at that remote period in history."

In view of our present knowledge of the status of the sun as a comparative dwarf in the stellar system, may it not have been a giant star at that remote period of its existence above referred to, rivaling in volume the giant star Betelgeuse with its diameter exceeding two hundred million miles.[1] At that period of the evolution of the sun, how

[1] Recent papers tend to the conclusion that the transformation from giants to dwarfs is very slow. Jeans and Jeffreys both think that the change in the sun in 1,000 million years has been slight.

terrific must have been the force of the upheavals which rent its surface, flinging forth cometic material with incalculable speed, to distances far exceeding any known in connection with the comets with which we are familiar.

Regarding the solar origin of comets, Dr. A. C. D. Crommelin writes as follows in *Splendour of the Heavens*, page 407:

> "When we note that the orbit of the great comet of 1882 almost grazes the sun's surface, there is a natural tendency to attribute a solar origin to it. We know from the phenomena of the solar prominences that the sun is continually erupting torrents of matter with very high speeds; a speed of 270 miles per second would suffice to send the matter round the sun in a circular orbit; if it rose to 382 miles per second the orbit would be parabolic; while for any intermediate speed it would be elliptic. By combining the observed speed of ascent of the prominence matter with the speed of approach or recession that is indicated by the shift of the lines in the spectrum, we conclude that speeds of this order are quite common, so that no difficulty arises on that account. I feel rather

more difficulty from the consideration that the meteoric masses that compose a comet's head could not exist in the sun in a solid state; the heat would suffice to vaporize them. The materials would solidify in the cold of space, but as they would be under no pressure, I imagine that the resulting solid particles would be microscopically small, not of the size required to form reservoirs for a large amount of gas. All objects ejected by the sun would move in orbits that intersect the sun, except in so far as their orbits are modified by planetary action. This latter might readily be large enough to change the orbit to one just outside the sun (like those of the sun-grazing comets of 1680, 1843, 1882, etc.). However, the great majority of known comets have orbits whose least distance from the sun is so large that we cannot imagine an origin for these by simple solar eruption.

"The question arises, Can the comets have existed for so long a period in view of the wastage that they undergo? According to the geologists the date of the approach of another sun to ours (as suggested in the planetesimal hypothesis) must be put at least a thousand million years ago; in such an interval, even the comets of longest period would have returned thousands of times, and I gravely doubt whether they could continue to be such compact bodies as they appear to be; I frankly admit that I have no plausible suggestion to offer for evading the difficulty; it is one of the numerous cases in astronomy (the status of the spiral nebulæ is another) in which we must be content for the present to record observed facts and suggested interpretations, leaving full understanding to come at a later date, if at all."

According to the same authority, in connection with his views on the subject, as expressed after reading the MSS. prepared for this chapter, he writes, as follows:

"I have noted a paper by A. A. Newton (see *Observatory* for 1894, page 250), in which he says, that out of 1,000 million comets approaching the sun, 126 comets will have periods reduced to 6 years, 839 to 12 years, 1,701 to 18 years, and 2,670 to 24 years. Further, of the 839 no less than 203, or a quarter of the whole, will have retrograde orbits after perturbation. I think these results go very strongly against the capture hypothesis. There would only be one short-period comet in something like 2 million years; whereas the experience of Biela's, Brorsen's (and perhaps also Tempel I and Holmes), suggests that several of them have become extinct in a century, so an equal number of new ones is required to keep up the supply. It is a matter of surprise to me that the difficulty is not more generally recognized."

The following brief abstract, condensed from an article written by Professor W. W. Payne, for *Popular Astronomy*, April, 1906, page 221, regarding "Jupiter's Family of Comets," with accompanying chart, may be of interest in connection with the matter under discussion in this chapter:

"This notable family of comets is more and more of a wonder, the further its study is pursued. It is remarkable on account of its size, and—if the capture theory be correct—of the power of Jupiter to capture comets and make them members of his family, if they, in their wild flights through space, happen to come too near to him as they sometimes do in certain parts of his orbital path around the sun. But a close study of the chart showing the paths of Jupiter's family of comets would seem to indicate that nearly all the farthest points of the comet's orbits from the sun are on one side of Jupiter's orbit. These points are marked by short cross lines. Now if Jupiter obtained his family by capture, why should he be more successful on one side of the orbit than the other?

Moreover, the motions of all these bodies about the sun, and about Jupiter, are direct, that is, contrary to those of the hands of a watch. Does not this fact of the comets traveling in the same direction, point to the supposition that they were originally ejected from the planet rather than that they were captured by Jupiter?"

CHAPTER VIII

METEOR STREAMS

Whence come these uncounted millions of bodies, rushing through space with inconceivable velocity? What purpose do they fullfil in the economy of the solar system? Are they the chips in the great workshop of Nature, the sparks which have flown from the mighty grindstone, the shreds of clay which the giant potters, Attraction and Repulsion, have cast aside as useless?

—R. A. Proctor.

SO far, we have traced the story of comets and meteors, and theories concerning their origin, but there still remains the fascinating chapter regarding those meteor streams which cross the earth's path in uncounted thousands and at regular intervals. For instance there are the great November showers unsurpassed by any, except perhaps the August meteor system. From recent investigations it has been shown that the independent particles of which these systems are composed form part of a great throng moving in orderly paths around the sun. They have proved their right to a place in the "obedient family" which Copernicus recognized as forming the solar system.

In those days meteors were regarded as a species of exhalation from the earth and consumed during some processes of change in the upper regions of the atmosphere. Later on, they had attained to the rank of volcanic missiles ejected from the moon, and ascending still higher they were said to be stones falling from the sky, not only on land, but "in the great sea, where they remained concealed."

It was not until the impressive meteoric shower of 1833 that suspicions were aroused concerning a connection between these apparently erratic wanderers in the sky and comets. When Professors Twining and Olmsted of New Haven, U. S. A., observed that the paths of all the meteors during the November shower of 1833 could be traced back to what is termed a "radiant," and Olmsted went so far as to call the densest part of the swarm a "comet," these objects attained a new interest in the astronomical world. Olmsted and Twining were the first to show that the meteors are not terrestrial and atmospheric, but bodies truly cosmical.

Could Kepler and Copernicus have revisited the former scene of their labors and listened to the discussions concerning the theories advanced in connection with comets and meteors during the latter part of the nineteenth century, they would scarcely have recognized the scheme of the solar system thus unfolded to their view! Not only has the claim of meteorites to membership in that system been firmly established, but the definite seasons for their appearance, and the well-known orbits along which certain meteor streams travel, can now be confidently predicted by astronomers. It is true, unfortunate circumstances may cause delay, as in the case of the failure of the expected return of the November meteor-shower in 1899, November 14-15, but this was undoubtedly due to the disturbing influence of Jupiter and Saturn.

However, there could be no delay and consequent disappointment at the return of this meteor swarm in 1833, which was not only totally unexpected, but furnished a scene of such splendor that words fail to convey an idea of its impressive character. We are told, by those who were so fortunate as to witness it, that the meteors fell as thickly as snowflakes. My father used to relate the following story regarding one of the planters of South Carolina who gave a most impressive account of the consternation caused among the negroes on this occasion. To quote the words of the planter:

"I was suddenly awakened by the most distressing cries that ever fell on my ears. Shrieks of horror and cries for mercy I could hear from most of the negroes of the three plantations, amounting in all to about six or eight hundred. While earnestly listening for the cause, I heard a faint voice near the door calling my name. I arose and, taking my sword, stood at the door.

"At this moment I heard the same voice still beseeching me to rise, assuring me that the world was on fire. I then opened the door, and it is difficult to say which excited me the most, the awfulness of the scene or the distressed cries of the negroes. Upward of a hundred lay prostrate on the ground, some speechless and some giving utterance to the bitterest cries. With hands upraised, they implored God to save the world and them. The scene was truly awful, for never did rain fall much thicker than the meteors fell towards the earth—east, west, north and south, it was the same."

Renewed interest was taken in the subject as the year 1866 drew near, for Professor Newton of New Haven, U. S. A., had found, after a careful examination of records in 1864, that there had been a number of great autumnal meteoric star-showers separated by periods of about thirty-three years. As a result of his investigations, he predicted that a shower would occur in 1866, and conjectured that the path along which the meteor stream would travel might have one of five different orbits; one with a period of thirty-three and a quarter years, two with periods of one year plus or minus eleven days, and two with periods of half a year plus or minus five and a half days.

Professor John Couch Adams, with the same patience and accuracy which had enabled him to discover the planet Neptune, concentrated all his efforts in tracing by means of the most laborious calculations the disturbing effects of the planets upon the November meteor stream in connection with each of the five orbits suggested by Newton. He came to the conclusion that the true orbit must be the largest, *viz.*, the one having a period of thirty-three and a quarter years. Accordingly, he confirmed the prediction that the meteoric shower was due to return in 1866, and not only was that prediction confirmed, but the meteor stream was seen again in 1867, the procession stretching out along the orbit for such a distance that it required three years to pass a given point.

Unfortunately, as far as Professor Newton and his fellow-countrymen in America were concerned, they were unable to witness the wonderful display, for on this occasion it favored our side of the world. In other words, the encounter between the earth and the dense part of the meteor stream which had caused such a spectacular display in 1833, preceded the time predicted for it only by the brief interval separating the successive passages of England and America across a given rotation space.

> "If we imagine that from some distant orb, a being were watching the event, knowing the nature of Newton's prediction and uncertain as to the result, then this being would have seen the meteor-swarm rushing onwards to the scene of encounter on the one part, and the earth sweeping towards the same point on the other. He could see that all over Europe and the western parts of Asia, and in a less degree over the foreshortened Atlantic, the meteors were already falling, the display would grow richer and richer, but after a while it would diminish in splendor. Finally, just as America began to show on the exposed hemisphere, the encounter would come to an

> end, the earth passing onwards to the relatively barren portions lying beyond the meteor orbit." (R. A. Proctor, *The Orbs Around Us*, pp. 180-181.)

Such was the occurrence which astonished the world on the nights of November 13-14, 1866, according to Sir Robert Ball's experience, which he has portrayed in such vivid language in *The Story of the Heavens:*

> "The night was fine; the moon was absent. The meteors were distinguished not only by their enormous multitude, but by their intrinsic magnificence. I shall never forget that night. On the memorable evening, I was engaged in my usual duty at that time of observing nebulæ with Lord Rosse's great reflecting telescope. I was of course aware that a shower of meteors had been predicted, but nothing that I had heard prepared me for the splendid spectacle so soon to be unfolded. It was about ten o'clock at night when an exclamation from an attendant by my side made me look up from the telescope, just in time to see a fine meteor dash across the sky. It was presently followed by another, and

then again by others in twos and in threes, which showed that the prediction of a great shower was likely to be verified.

"At this time, the Earl of Rosse (then Lord Oxmantown) joined me at the telescope, and after a brief interval we decided to cease our observations of the nebulæ and ascend to the top of the wall of the great telescope, from whence a clear view of the whole hemisphere of the heavens could be obtained. There, for the next three or four hours, we witnessed a spectacle which can never fade from my memory. The shooting stars gradually increased in number until sometimes several were seen at once. Sometimes they swept over our heads, sometimes to the right, sometimes to the left, but they all diverged from the east. All the tracks of the meteors radiated from Leo.

"Sometimes a meteor appeared to come almost directly towards us, and then its path was so foreshortened that it had hardly any appreciable length, and looked like an ordinary fixed star swelling into brilliancy and then as rapidly vanishing. Occasionally luminous trains would linger on for many minutes after the meteor had flashed across, but the great majority of the trains in this shower were evanescent. It would be impossible to say how many thousands of meteors were seen, each one of which was bright enough to have elicited a note of admiration on any ordinary night."

Soon after the remarkable display of meteors in 1866, Schiaparelli of Milan, whose interest had been aroused by the researches of Newton and Adams, published a paper upon the Perseids, or August meteors, in which he drew attention to the fact that they were moving in the same path as that of the bright comet of 1862, known as Tuttle's comet. Shortly after this Leverrier published his orbit of the Leonid meteors derived from the observed position of the radiant (within the sickle-shaped group of stars in Leo), in connection with the periodic time assigned by Adams; and almost simultaneously, but without any idea of a connection between them, Oppolzer published his orbit of Tempel's comet of 1866, and the two orbits were at once seen to be practically identical.

Now a *single* case of such a coincidence as that pointed out by Schiaparelli might possibly be accidental, but hardly *two*. Then five years later in 1872 came the meteoric shower of the Bielids, the disintegrated particles following in the track of Biela's comet, and since then scores of meteor-streams have been apparently detected with "a comet annexed," firmly establishing the theory regarding the connection between comets and meteor-streams as a well-proved fact.

The longer a comet has been in the solar system, the more widely scattered will be its accompanying meteor-stream. According to this theory, the Perseids which are scattered more or less uniformly along their orbit of enormous extent ranging far beyond the orbit of the outermost planet Neptune, are undoubtedly old inhabitants of the solar system. The Leonids, on the contrary, are comparatively newcomers introduced into the solar system (according to the calculations of Leverrier, and admitting the capture theory, though the ejection theory is far more plausible), in A.D. 126, when Tempel's comet, of which they formed part, passed very near Uranus.

Since the mystery regarding these celestial wanderers has been cleared, it might almost seem as if every comet of distinction had its own special host of meteoric attendants following closely in its wake, their number constantly increased by the addition of discarded fragments forming the train of the comet at each visit paid by it to the sun.

The following is a list compiled by Mr. W. F. Denning of the chief meteoric displays of the year.

Name of shower	*Date of maximum*	*Radiant point*	*Appearance of meteors*
		R. A. Dcl.	
Quadrantids	January 3	230° + 52°	Slowish, long paths
Lyrids	April 21	270° + 33°	Swift, streaks
η Aquarids	May 2–6	338° − 2°	Swift, very long paths
Draconids	June 28	228° + 54°	Very slow, short paths
δ Aquarids	July 28–30	339° − 12°	Slow, long paths
α Capricornids	July 25–August 4	303° − 10°	Very slow, brilliant, long
Perseids	August 11	45° + 57°	Swift, streaks
Orionids	October 19	92° + 15°	Swift, streaks
Leonids	November 14–15	151° + 23°	Very swift, streaks
Andromedids	" 17–27	25° + 44°	Very slow, short, trained
Geminids	December 11–12	110° + 33°	Swift, white, short paths

The *Lyrids* are connected with Comet 1861 I, having a period of about 415 years.

The *Perseids* are connected with Comet 1862 III, having a period of about 120 years.

The *Leonids* are connected with Comet 1866 I, having a period of 33⅓ years.

The *Bielids*, or *Andromedids*, are connected with Biela's comet, and have a period of 6¾ years.

We are now aware of meteor streams which at certain stated intervals, cross the earth's orbit.

They are regular visitors for which we may watch with every certainty that a few, if not thousands, will be captured by too near an approach to the atmospheric net encircling our planet. The whole of the solar domain may be alive with meteors, but by no possibility can we become aware of their presence until they take the fatal plunge which ultimately causes their destruction. The space actually traversed by the earth in its journey around the sun, is but the minutest fraction of that vast sphere over which the sun holds sway,

> "yet it has been estimated by Professor Newcomb of America, on grounds which are perfectly reliable, that in including telescopic meteors (that is, meteors so small as only to be visible when they happen to pass across the field of view of a telescope), no less than 146,000 millions of meteoric bodies fall each year upon the earth. If one in a thousand struck a human being the inhabitants of the earth would be decimated in a single year." (R. A. Proctor, *The Expanse of Heaven*, p. 164.)

Fortunately for us, the earth is protected by the surrounding air, which offers a most effective resistance to the swift motion of the celestial missiles with which it is bombarded from above. The swifter their motion, the more effective the resistance.

When meteors are first seen they are mostly at a height of seventy miles, vanishing at a height of about fifty miles. But the actual course they pursue through the air is nearly always much longer, because they do not descend vertically, but aslant.

Mr. Denning remarks, in his account of meteors for *Splendour of the Heavens*, "there are comparatively few astronomers, either professional or amateur, who cultivate the meteoric branch. They evidently do not regard it as an attractive study. In any case, it does not appeal to them sufficiently to enlist their sympathies, and so it has been comparatively neglected in recent years. A few ardent observers have, it is true, continued to devote themselves to the subject," and he cites instances where two English ladies, Miss A. Grace Cook, director of the Meteoric Section of the B. A. A., in 1922, and the late Mrs. Fiammetta Wilson, endeavored to arouse more enthusiasm in this field of work by both practical example and advice. As an instance of the splendid enthusiasm of the latter, she has to her credit for meteoric observations carried on during an interval of ten years, the record of about ten thousand meteors. This is an average of a thousand a year, and anyone who has attempted to keep a steady watch on a starlit night in the hope of observing an evanescent meteor will realize what such a record means. It must have required an immense amount of patience, endurance, and untiring vigilance, for the wily meteor is so apt to take us unawares.

The writer has had but one experience of the kind, and it was upon the occasion of the expected display of Leonids in 1899. The night was extremely cold, as one might expect during the month of November, when with two friends, Miss Harpham and Miss Tarbox, I stationed myself on the roof of an apartment house in New York City, on November 15, at 12.55. The record of our observations, which were continued until 6.00 A.M. at the hour of dawn, was afterward printed in *Popular Astronomy*, Vol. IX, 1901, pp. 82-83. During that time we observed sixty-eight meteors, of which, as the account shows, a few were intruders.

Never was dawn so welcome to the weary observers, who were not nearly so much chilled by the November weather, as by the disappointment at the meager display. Possibly the bright moonlight in the earlier part of the watch had dimmed the splendor of many of the Leonids, but where were the tens of thousands which were said to have fallen in 1833, or even the thousands which were observed in 1866, for not even one hundred rewarded us for our vigil in 1899? However, we were told to watch again the following year, when possibly we might meet with better luck, but our record as given in *Popular Astronomy*, Vol. IX, 1901, shows that only forty-four meteors were seen between midnight and dawn, and of these, seven were intruders. The cause of the failure of the return of the Leonids in 1899 was due to the fact that the planet Jupiter had so much disturbed the orbit of the meteor group of 1866, that from calculations made it was estimated that it would pass about two millions of miles outside of the earth's orbit, and thus escape collision with our atmosphere. For this reason, few meteors were seen in 1899 and 1900, though in 1901 and 1903 pretty brisk showers of Leonids were visible, though they were nothing like the magnificent displays of 1799, 1833, and 1866. A new shower derived from Pons-Winnecke's periodical comet was witnessed from Bristol on June 28, 1916. A very brilliant and abundant return of this display may occur during the last week of June, 1927, when the earth and comet will be exceedingly near each other.

The following suggestions may be helpful to those who may feel inclined to make a hobby of recording meteors which are far more plentiful (quite a number making their appearance on any clear night) than comets, which are, comparatively speaking, rare visitors. Practically no appliances of any kind are required. The main essential is a knowledge of the various constellations and of the stars visible to the naked eye, a knowledge soon acquired by a study of some good atlas of the heavens, such as my father's *Half Hours with the Stars*. This contains twelve charts, one for each month of the year, with accompanying letter press.

A beginner generally finds great difficulty in locating the beginning and ending of the course of a meteor, as these seldom occur close to any well-known star. It will always be found useful to have a straight rod about four feet long. This should be held up so that it seems to lie along the path of the meteor. A rapid glance along the rod, backward and forward, will generally be sufficient to enable one to detect some stars within the radius of a circle. The beginning and ending of the trail of the meteors can then be recorded, as the eye easily estimates the length of the arc between various points of the heavens. In this way one records the observation made—let us say, at 4.39, for November 15, 1899. The direction followed by the meteor was from the radiant toward Castor and Pollux, the streak remaining visible for three seconds. The meteor was very bright, meaning that it equaled a first-magnitude star, and the train was 5° in length. Though the color was not recorded at the time, yet it is possible to make a very sure guess, that it was blue, the usual color of Leonids.

It is not advisable to look for meteors very far from the radiant, as that is the main point from which they are seen to emanate. Therefore, it will be sufficient to confine the attention to a region within 30° to 40° from the radiant. Meteors appearing near the radiant have short trains, while those at a greater distance have generally longer trains. When a meteor is observed, the time, magnitude, beginning and ending of course, duration of flight, and any special characteristics should be recorded as quickly as possible, using a system of abbreviations. Possibly the writer, at the next display which is expected in 1933, may be prepared —with the assistance of a few enthusiasts—to carry out this elaborate program, but it is impossible for one or even three to make an accurate record of so many happenings regarding a meteor which may have remained on view but a second or so.

In judging the time of flight a stop-watch is very useful, but in the case of slow meteors it is easy to estimate the time approximately by counting at a certain rate, say 180 to the minute. The writer was told to recite a nursery rhyme at a certain pace, such as hickory-dickory-dock, and note the syllable or word uttered at disappearance of meteor, but in the case of the Leonids the word "hickory" had scarcely been uttered before the Leonid had vanished, so that the simpler method of counting "one, two, three," was adopted, proving entirely satisfactory, when we remembered to count!

It might be a good idea, before making the observations, to mark off on the rod, with luminous paint or radium, such as is used with watches, 3°, the distance between the three stars in the belt of Orion; 5°, the distance between the pointers in Ursa Major; 10°, the distance from Alpha to Delta in the same group of stars; 15° from Delta through Alpha; and 26° from Alpha to Eta, at the extremity of the Bear's tail, or the Dipper handle, according to the popular nomenclature used in America, where the seven stars of the

Plough, or Charles's Wain, are usually referred to as the Great Dipper.

Special attention should be given in recording very bright meteors or fireballs. In many cases fireballs may be seen by other persons, and the data supplied by any two observers situated at different places. Their combined observations are sufficient to determine the real path, radiant, etc., of the celestial object.

We have a fine illustration of this in the drift of a meteor trail which was observed by Mr. Denning at 7.33 P.M. on February 22, 1909, passing in a southwest direction over the northern coast of France. The luminous trail left in its wake persisted as a visible object for over two hours, during which time it drifted in a northwest direction at 120 miles an hour, under the influence of a violent wind in the upper atmosphere. As usual on every clear starlit night there are a number of enthusiastic observers keeping close watch of the sky, ready to trap with their cameras any unwary meteor which may flash into view. On this occasion there were at least 250 observers in different parts of the country watching the phenomenon during the whole two hours the meteor trail remained visible.

There is a branch of the British Astronomical

Association which deals with records and observations of meteors, and it is known as the. Meteor Section. "Mr. Denning has proved a faithful friend," as Miss A. Grace Cook remarks in her report of the Section for 1922, "and has encouraged the Section in every possible way." Sometime one of the enthusiastic observers in search of meteors may be rewarded by a discovery of larger prey, in the form of a comet. Imagine the delight of having a comet one could thus claim, as it were, as one's own personal property!

Fireballs differ vastly from shooting stars in exposing a larger surface to the opposing atmosphere, as they make their downward plunge from space therein. It is when they suddenly come in contact with the particles of which the air surrounding our planet is composed, that their presence is first made known to us. When a shooting star finally blazes out, owing to the friction caused by the encounter, it is at a height of from thirty to fifty-five miles above the ground. It is then dissipated in vapor, and vanishes. No wonder these balls of fire caused terror among the ignorant and superstitious in the days when their meaning was unknown. In Mr. Denning's book, *Telescopic Work for Starlight Evenings*, page 269, there is a drawing made by J. Plant of Salford, as an illustration, giving an excellent idea of the imposing aspect of a fireball, seen by this observer on November 23, 1877, as it emerged from behind a cloud. Judging from the date, it might have been one of the Bielids, provided its radiant was in the constellation Andromeda. It was, however, in Taurus.

Fireballs are usually silent, but sometimes they have been known to explode with a loud noise. The fireball which was observed (as above) in November, 1877, is said to have "given a sound like salvos of artillery, and doors and windows were violently shaken." As a rule, however, there is no audible explosion, the bright nucleus fading out until it is reduced to a mere spark before disappearing.

Occasionally fireballs have been known to give out three or four brilliant flashes before fading from view. These flashes, often of startling intensity, have been described as "coming less swiftly than flashes of lightning." They remind one forcibly of moonlight breaking through the clear intervals in passing clouds. There is always something mysterious about these luminous objects as they emerge so stealthily from the darkness, vanishing as silently as they came.

During the month of August fine meteoric displays may be looked for, between the 10th and 13th of that month. They are sometimes referred to as "the tears of St. Lawrence," since the 10th of August is dedicated to the memory of that saint. However, they are more generally known as the Perseids, their radiant being in the constellation Perseus. As this group of stars has risen tolerably high about nine o'clock in the north-eastern sky during the month of August, watching for Perseids is an easier matter than in the case of the Leonids, which do not appear at their best until "the wee sma' hours."

The meteors belonging to the Perseid family are yellow in color, moving at the rate of thirty-eight miles a second, as compared with the swift onrush of the November meteors at forty-four miles a second, the latter flashing into view with the rapidity of a skyrocket, and as swiftly disappearing. The Bielids, on the contrary, travel with medium velocity, their stately glide at ten miles per second, being in marked contrast to the speed of the Perseids or Leonids. The Bielids, also called the Andromedids, are due November 23–27, and, as already noted, may be seen to radiate from a point near Gamma in the constellation Andromeda. In the case of the Perseids, a few brilliant streaks often herald their approach, usually giving promise of an especially fine display. The August meteor showers yield the smallest shooting stars and the largest type of fireballs. Observers startled by the sudden appearance of the latter are rather apt to give exaggerated accounts of their appearance, neglecting to note the direction whence they came, the time or duration of their flight, and other necessary data, rendering the observations, in consequence, practically useless.

We now come to shooting stars, the kindergarten—as it were—of the meteoric system. Weighing practically but a few ounces at the most, they can be easily handled or put into one's pocket without discomfort. Analysis of those which have sunk to rest on our planet, as a result of successfully penetrating right through the atmospheric net surrounding our domain, has shown that they are composed of iron and many of the chemical elements, such as sodium and carbon, which are to be found on the earth.

For vast periods of time they may have been pursuing a seemingly endless voyage along the highways and byways of the solar system, wending their way in safety amid the intricate paths traversed by the planets. They have been traveling at a speed far exceeding that of the swiftest cannon ball, and doubtless with an average velocity of about twenty-five miles a second. A shooting star moving at such a rate would pass from the earth to the moon in a couple of hours, or from London to Edinburgh in about ten seconds. All goes well with the little traveler as long as it keeps at a discreet distance from the aërial torpedo net surrounding our planet, seemingly set for the purpose of entrapping such intruders. However, should the shooting star venture too near, plunging through the atmosphere at the pace which kills, it is bound to come to grief. Rubbing against every particle it meets on the way, friction is caused, resulting in the blaze of glory which makes its presence known to us, swiftly followed by its exit when it is reduced to ashes.

Some of the particles, if any are left (for usually they are dissipated in vapor in the upper regions of the air), sift down upon our planet in the form of fine dust. From the top of a high mountain Dr. Reichenbach collected dust which had never been touched by spade or pick-ax; and in analysis he found this dust to consist of almost identically the same elements as those of which meteoric stones are composed—nickel, cobalt, iron, and phosphorus. Dr. Phipson, in his interesting work on *Meteors, Aërolites, and Shooting Stars,* remarks that

> "when a glass covered with pure glycerine is exposed to a strong wind, late in November, it receives a number of *black angular particles,* which can be dissolved in strong hydrochloric acid, and produces yellow chloride of *iron* upon the glass plate."

It is a strange thought that the air which sifts in through the window, and settles on the tables and chairs, nay even the very air we breathe, may contain particles of matter which have at one time circled in meteoric form around the sun!

Should this be the case, and if, as Professor Newcomb, the American astronomer, tells us, no less than 146,000 million meteoric particles fall on the earth during the course of a year, may we not infer that this means an increase in its mass? In my father's book, *The Orbs Around Us* (page 195), he writes:

> "If we assign a single grain as the weight of each meteor visible to the naked eye, we deduce fifteen millions of grains as the earth's daily increase of weight. This is rather less

than a ton. So that in the course of about three years the earth's weight must increase (even on the very low value here assigned to a meteor's weight) by a thousand tons; and in the course of the three thousand years during which astronomy has been a science the earth's weight must have increased a million tons. This is a mere trifle compared with the earth's own weight, which is 6,000 millions of millions of times greater. Indeed, it may easily be shown that the actual increase of the earth's radius in this interval of 3,000 years, would be about the 70,000,000th part of an inch."

From time immemorial legend and superstition have interwoven themselves around these small members of the solar system as they silently and swiftly sweep across the vault of heaven, vanishing mysteriously as though extinguished by some invisible hand. Dante describes them:

"As oft along the still and pure serene
At nightfall glides a sudden trail of fire,
Attracting with involuntary heed
The eye to follow it, erewhile it rest
And seems some star that shifted place in heaven."

For the Oriental believer, the shooting stars are the fiery darts hurled by the angels at the evil spirits or genii when the latter are caught eavesdropping at the gates of heaven. This legend is to be found in the Koran, and is referred to by Moore in his "Paradise and the Peri," in the lines:

> "Fleeter than the starry brands
> Flung at night from angel hands,
> At those dark and daring sprites
> Who would climb th' empyreal heights."

According to a Lithuanian myth as told by Grimm in his *Deutsche Mythologie*, the spinstress Werpega spins the thread of a child's life at birth, and each thread ends in a star. When death approaches, the thread breaks and the star falls to earth, quenching its light.

In Galicia, the province northeast of Hungary, the peasants believe that when a star falls to earth it is at once transformed into a rarely beautiful maiden with long, glittering, golden hair. She is supposed to exert a magical influence on all who come in contact with her, but the effect is evil unless certain words are uttered ere the star falls to earth. From this superstition doubtless springs the custom of "wishing" while a shooting star is seen gliding swiftly eastwards. The wish will surely come true, it is said, if fully expressed before the star fades from view. Finally, we have the fanciful idea suggested in the following lines by Fiona Macleod:

> "A star was loosed from heaven;
> All saw it fall, in wonder,
> Where universe clashed universe
> With solar thunder."

CHAPTER NINE

DID LIFE FIRST COME TO THIS EARTH IN A METEOR?

Among the most startling suggestions recently thrown out by men of science, not one, perhaps, has seemed more amazing to the general public than the idea put forward by Sir William Thomson in the able address with which he inaugurated the meeting of the British Association (1871)—that life on the earth may have had its origin from seeds borne to our planet by meteors, the remnants of former worlds.

—R. A. PROCTOR.

THE quaint suggestion thus advanced by Lord Kelvin regarding the possibility of the first germs of life reaching our planet in the form of "a fragment of an exploded world," was taken seriously at the time by some, but was undoubtedly merely a jest on the part of the able speaker. As my father remarked in the book from which the above quotation is made (*The Orbs Around Us*): "I can scarcely bring myself to believe that the eminent professor was serious in urging his hypothesis of seed-bearing meteors. Englishmen speak sometimes of the slowness with which a Scotsman apprehends a jest; but the Scotsman may return the compliment, so far, at least, as the southern estimate of Scottish humor is concerned. For a true Scot makes his jest with a gravity and *aplomb* unequaled among Sassenach humorists. It is far from improbable that the seriousness with which the seed-bearing meteorites have been discussed proved infinitely amusing to the gathering of the clans in Edinburgh."

Nevertheless, that there were some believers who were convinced that Lord Kelvin would not have advanced such a theory without some solid basis for its foundation, was shown by the fact that the great Swedish scientist, Svante Arrhenius, considered it worth while, in his book entitled *The Life of the Universe*, to refer to the various difficulties which have made it next to impossible to establish the theory, which he compares (from the standpoint of arousing popular interest) with the problem of perpetual motion. He concluded his remarks on the subject by the statement (which has already been confirmed) that the problem of spontaneous generation in the actual form of a meteor will, "it is to be expected, be eliminated from the scientific program, just as the problem of perpetual motion has been discarded."

Nevertheless, there is something fascinating about this myth which appealed strongly, at the time it was advanced, to the imagination, though it led to queries which when answered led nowhere. If the worlds by bursting supplied space with seed-bearing meteors, how were they themselves peopled with living beings? "This circumstance of itself throws an air of doubt over the new hypothesis," according to my father's views on the subject, "as a seriously intended account of the origin of life on our earth."

It recalls the cumbersome way in which the Hindu accounted for the support of our planet in space, supposing it rested upon the back of a tortoise, but the Hindu student of science might well ask how is the tortoise itself supported? Or again, supposing life-bearing meteorites reached our planet from exploded worlds, what would be their condition by the time they were deposited on a soil favorable for their development?

According to Flammarion regarding the possibility of meteoric fragments coming to our planet from an ancient satellite of the earth which was shattered to pieces, the germs shut up in the interior of the meteorite would remain in a kind of lethargic sleep without losing any of their germinative qualities during their plunge through interplanetary space. In fact, the author lends a seductive air of plausibility to the myth, suggesting that the fragments would reach our planet fresh and cold, to be again rejuvenated and come to life, but even Flammarion is compelled to acknowledge that we have found nothing to prove such a theory true. But if this new theory should be accepted, as my father wrote in 1871, "we have reason to regard with apprehension the too close approach of one of these visitants; because, if one meteor supplied the seeds of the living things now existing on the world, another may supply myriads of seeds of undesirable living things; and perhaps the sequent struggle for life may result in the survival of the fittest."

It may seem superfluous to add that, in a collision by which a world was shivered into fragments, the seeds of life would have what may be described as a warm time, since the collision could hardly fail to vaporize the destroyed world. The fiery heat generated by the collision, followed by a voyage during myriads of millions of ages through the inconceivable cold of space, and the effect of the fierce heat which accompanies the fall of meteoric masses upon our earth, would seem so unfavorable to the germs of life that we may accept with confidence the belief that all such germs had been completely destroyed before reaching this planet.

Arrhenius reversing the seed-bearing-meteor theory in connection with a meteorite bringing the seeds of life to our planet, makes a neat calculation showing the time which would be required for a tiny particle, drawn from our planet and hurled into space, to arrive at the surface of a planet circling around the star Alpha in the constellation of the Centaur. It would be twenty days on its way to Mars (traveling at the usual rate of speed assigned to meteors, *viz.*, some twenty-six miles a second.) A year would elapse before it reached the outermost planet Neptune, which travels on the confines of the solar system, and some nine thousand years ere it plunged through the atmosphere surrounding a planet circling round the nearest star, and finally crashed on its surface. Endless are the speculations which might thus be indulged in regarding the celestial voyages of meteors through interplanetary space, but though the misguided ones which have rashly ventured too near our planet have been trapped in its atmosphere, landing on its surface before suffering complete annihilation, have been weighed, measured, and tested by chemical analysis, the past history of their excursions into space is enshrouded

Outh Lodge, Keithick, Where the Strathmore Meteorite Fell Through the Roof, December 3, 1917
Photograph of the lodge and Mr. and Mrs. Hill taken by H. Coates

in a mysterious silence as unbroken as that of the Sphinx.[1]

The writer at one time had a paper weight to which she attached great value, despite the fact that it was an apparently insignificant metallic stone weighing a few ounces, but there was a fascination in the conjecture as to where it had come from. That was the query which could never be answered, for all that was actually known of the past history of this celestial visitor dated from one eventful evening when it was seen for a few brief seconds as a momentary streak of light, revealing the course of its descent, so that a fortunate mortal here below was enabled to locate it after its swift plunge to earth. After it had cooled sufficiently to bear handling, it was carefully examined and its substance was found to be thickly interspersed with carbon particles, revealing, like so many telltale imps, that this inert mass had once known better days when its life was filled with activity until it took the fatal plunge which ended so disastrously. "If you only knew what I have seen,

[1] On rare occasions meteors have fallen on houses, as in the case of the Strathmore meteorite, photographed by H. Coates. He also took a photograph of Outh Lodge, Keithick, on which the meteorite fell, December 3, 1917. It made a hole in the roof of the house. The owners thereof, Mr. and Mrs. Hill, are included in the photograph, which was sent to the writer by Mr. W. E. Denning.

and where I have been during my wanderings in space," one could imagine the meteorite saying in reply to the numerous queries, regarding its origin, in the mind of the writer; until this fascinating little visitor in space vanished as mysteriously as it had come, through too great a confidence placed in an audience in the Far West, where the meteorite was passed round for inspection and never returned.

However, the writer was enabled to resume her study of the subject on a larger scale while visiting the famous Foyer collection of meteorites at the American Museum of Natural History, New York, where the specimens are a little too hefty for transportation. No one, for instance, would be able to depart with the Ahnighito, the great Cape York meteorite, which was found on the north coast of Melville Bay near Cape York, Greenland, by Commander Robert E. Peary, in 1894, without attracting a considerable amount of attention. It is the largest and heaviest meteorite known, weighing over thirty-six tons. It possibly weighed more up to the date of its fall, as the guide Tallakoteah, who enabled Peary to discover the meteorite, informed him that up to the early part of the nineteenth century, members of the

STRATHMORE METEORITE, ESSENDY FRAGMENT
Photograph taken December 3, 1917, by H. Coates

Eskimo tribe had found it very useful in providing them with material for knives and hatchets.

There are really three masses, the largest already referred to being ten feet eleven inches long, six feet nine inches high, and five feet two inches thick. It was called Ahnighito after the name of the daughter of the explorer. The next larger mass weighing about three tons was named "The Woman," because the shape suggested the idea of a woman seated on the ground with a babe in her arms and a shawl around her shoulders. The third and smallest mass weighing about 1,000 pounds, was called "The Dog," and the three meteorites were known as a group to the Eskimo under the name of "Saviksue," or "The Great Irons."

The Woman and The Dog were visited by Peary in 1894, and were obtained the following year after much difficulty and exciting work, an incident of which was the breaking up of the cake of ice on which The Woman had been ferried from the shore to the ship, just as the mass was about to be hoisted aboard. Fortunately there was enough tackle around the meteorite to prevent its loss. In 1895 Commander Peary visited Ahnighito, which lay on an island only four miles from the two smaller masses, but he could do little toward its removal. The next year he made another voyage for the purpose of getting the Great Iron, but was again unsuccessful. This third attempt was made in 1897, when the meteorite was brought in safety to New York in the ship *Hope.*

In the Foyer collection is also the famous Willamette meteorite, which weighs more than fifteen tons. Its height is over six feet, its width four feet, and its length ten feet. It is one of the most interesting meteoric fragments in the collection, though not the largest. Nevertheless, its appearance tells a wondrous story of the experience it must have had during its swift rush through the air. The deep hollows in its surface were probably caused by friction with the particles encountered during its swift flight through the atmosphere surrounding our planet. This resulted in the melting of part of the metallic substance of which it is composed, chemical analysis showing that it contains an admixture of iron, nickel, a small amount of cobalt, and in addition some phosphorus and sulphur. To give an idea of the depth of the hollows, the curator of the Museum showed the writer a photograph of two boys seated in two of the largest.

The Willamette was discovered in the autumn of 1902, in the forest about nineteen miles south of Portland, by a Welsh miner named Ellis Hughes. At first he thought he had discovered an iron mine, but on digging away the earth surrounding it, he found that it was a meteorite.

The miner, who was well acquainted with the handling of such masses, constructed a low wooden truck, on to which he managed to overturn the fifteen-ton mass, and then, with no other motive power than an old horse windlassing a rope round a capstan as a winch, which had to be moved and reanchored as the truck with its load was drawn up to it, he and his fifteen-year-old son, working so quietly during the winter that not even the nearest neighbor suspected what they were doing, dragged the mass three-quarters of a mile on to his own land.

Apparently this mass of iron was known before the discovery above related, as an Indian relic, revered from time immemorial by the Siwash Indians. When the Portland Land Company, who owned the land on which the meteorite was found, instituted legal proceedings in the matter, claiming the right of possession, the lawyer engaged by Ellis Hughes to plead his cause was of the opinion that the meteorite was not "real estate," but "discarded personal property," belonging to whoever might find it. In support of this statement he called a very old Siwash Indian as a witness, who testified that the mass of iron had long been known to members of his tribe, who attributed to it magic virtue. As a youth, he said, he had been conducted to it by one of the medicine-men, and informed that if arrows were dipped in the water which collected in the hollows they would always wing their way to the heart of the game shot at. However, the judge ruled that the meteorite went with the land, and an order was issued giving possession thereof to the Portland Land Company. It was purchased later on by Mrs. William E. Dodge, and presented to the Museum of Natural History in New York City.

Near the Willamette meteorite is one called the Canyon Diablo, famous chiefly on account of the fact that it contains diamonds. It was found in 1891, near Coon Butte, Arizona, in the neighborhood of the town of Canyon Diablo. The original size of the mass is not known, but thousands of fragments have been collected, varying in weight from a fraction of an ounce up to 1,087 pounds. More than sixteen tons of this material are said to have been found within a radius of two and a half miles of Coon Butte, a conical hill rising from 130 to 160 feet above the surrounding plain, and containing a crater-like hollow about three-quarters of a mile in diameter and probably originally 1,460 feet deep. The appearance of this region seems at first sight, to the casual visitor, far more suggestive of a terrific explosion at a remote period of the past, resulting in an upheaval causing the vast crater from which the meteoritic-looking masses scattered over the surrounding plain had been ejected, but Dr. Hovey is of the opinion that their presence has been caused by the downfall of an immense meteorite from above. According to his investigations of the scene, "there is no lava of any kind in Coon Butte or in its immediate vicinity, such as is found in volcanic regions." He also asserts that the main part of the mass has not yet been discovered, the fragments so far found being only the portions separated from the original mass during its passage through the atmosphere and at the time of its impact with the earth. There are two fragments of the Canyon Diablo meteorite in the Foyer collection, and the largest piece discovered is the one weighing 1,087 pounds, to which reference has already been made. A slice of the meteorite, in which a diamond was found, undoubtedly attracts the greatest amount of attention from visitors to the museum. "Diamonds falling from the sky," they have been heard to remark, "then why not make a search for the missing fragment which may be a depository of unknown wealth?" However, the possibilities are that it has buried itself to such a depth in its crash to earth, that a search for it would be a stupendous undertaking, with possibly no results as far as diamonds are concerned.

The importance attached to the discovery of diamonds in the Canyon Diablo meteorite hinges upon the well-known fact that the diamond is the purest carbon in nature. Charcoal is almost pure carbon, and, as everyone knows, common charcoal is the product of combustion, the residue from the burning of a piece of woody tissue excluded from the air. This is the everyday teaching of chemistry in the college laboratory. According to Dr. Hovey, regarding the fact that the Canyon Diablo meteorite contains diamonds, "This gem-stone diamond has been definitely proved to occur in only two meteorites, the other being a Russian fall, although many masses are known to contain carbon in the form of a soft, black powder." The discovery of diamonds in Canyon Diablo was made in 1891, by Professor G. A. Koenig of Philadelphia, and was afterward confirmed by Dr. George F. Kunz of New York, Professor Moissau of Paris, and other investigators. In 1905, Moissau dissolved a fragment of Canyon Diablo weighing several pounds, and obtained not only recognizable crystals of the diamond, but also crystals of a mineral corresponding exactly in composition to the extremely hard artificial silicide of carbon known as carborundum. The new mineral has been named Moissauite, and this is the first time that it has been found in nature.

Geology teaches us not only that charcoal and the mineral coals are different forms of that wonderful element we call carbon, but also that bituminous and anthracite coals are the transformed products of ancient vegetation, through the combined agencies of heat, enormous pressure, and the slow transmuting effect of ages. This talismanic element is ever found associated in some form with organic substance, and organic substance is life substance, animal as well as vegetable.

Hence comes the all-engrossing conclusion that wherever carbon exists there organic matter exists or has existed; and, if organic matter, then its essential companion life! Does the meteoric fragment Canyon Diablo, which fell from the sky upon our planet, come from a world now or at one time the abode of life? Seemingly, we have drifted back to the original argument, Did life first come to this earth in a meteor? and we are no nearer a solution of the problem unless—as some one facetiously remarked, an enterprising individual inclosed a message within a meteor ere it took its departure for our planet from some distant world. As Flammarion says in his book on *The Plurality of Worlds:* "The problem remains the same. We want to know how life first appeared, and this problem has not been advanced in the slightest degree by the theory adopted by Lord Kelvin and Arrhenius." But, as already stated, no one dreamed of taking the suggestion made by Lord Kelvin, seriously.

THE END