David A. J. Seargent

ASTRONOMER'S POCKET FIELD GUIDE

Visually Observing Comets

Astronomer's Pocket Field Guide

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For Meg

Preface

Traditionally, comet observing/hunting and variable star observing have been widely considered the two fields of amateur astronomy where the visual observer is capable of making a true contribution to scientific knowledge. That is not to say that contributions cannot be made in other fields as well, but these two subjects were widely regarded as offering the most opportunities for users of modest equipment and were accordingly very popular with amateur astronomers.

Comets, in particular, presented some very attractive prospects. As well as being interesting objects in their own right, they had for many years been largely neglected by the professional astronomical community, and the brighter ones at least can be studied with minimal equipment.

Then, of course, there was the prospect of actually discovering a new object and the very rewarding consequence that comets were traditionally named for their discoverers. The possibility of having one's name attached to an astronomical object to be cataloged for all time was certainly an incentive to spend many hours sweeping the sky in search of these bodies! Even naked-eye discoveries, while not common, were not unknown, and large binoculars or small telescopes using low-power eyepieces were the preferred instruments of most successful comet hunters. A newspaper report of the discovery of Comet Ikeya in 1963 went so far as to describe the instrument used by (the then 19-year-old) Kaoru Ikeya as a "toy," although the journalist did at least have the courtesy to place that word in quotes. The telescope was no toy—it was a well-made 8″ (20-cm) reflector—but it had been constructed by the discoverer himself at minimal cost.

With the increasing number of professional programs employing wide-angle cameras, from the middle years of the last century, the percentage of amateur discoveries declined as objects too faint for visual detection were accidentally picked up by these programs, not that the discovery of comets was their aim. Most of the programs were set up to find minor planets or nearby stars through their large proper motion, but the extra comet discoveries still provided a welcome bonus. Around the same time, there was somewhat of revival of interest in comets among professional astronomers as the role of these objects in Solar System formation and even in terrestrial life (through the possible delivery of water and organic compounds) began to be recognized.

On the whole, however, this did not have too great an effect on amateur discoveries. Many of the comets found during the course of professional programs remained faint and would not have been discovered visually by amateurs. A visual search program by professional astronomers at the Skalnate Pleso Observatory in Czechoslovakia (now Slovakia) from the late 1940s until about 1960 proved more troublesome, as it was in direct competition with amateurs at that time; however, the number of amateur discoveries (especially by the Japanese) increased again during the 1960s following the termination of the Czechoslovakian program.

From about 1960 until the middle of the decade of the 1990s, visual discoveries by amateur astronomers were frequent. The popularity of Dobsonian telescopes made larger aperture reflectors more readily and cheaply available, and high-power binoculars having apertures of 80 mm and larger became easier to acquire. At the same time, increased interest by professional astronomers made amateur observations more in demand, and publications such as the *International Comet Quarterly* provided repositories for comet observations as well as recent professional research concerning these objects. This period became something of a golden age for visual comet observing.

All this changed in about the middle of the 1990s. A combination of automated professional programs in search of potentially hazardous near-Earth asteroids plus space-based surveys of various kinds has proved to be far more efficient at comet discovering than the photographic programs of earlier decades. These recent programs have largely been responsible for the discovery of comets many months or even years before these objects reach perihelion.

Although inevitably faint at the time of discovery, many of the comets found in this way have later brightened to within the visual range of small telescopes and would very likely have been visual discoveries had the automated programs not been operating. On the other hand, the most successful of the nonhuman comet discoverers—the SOHO extraterrestrial solar observatory—has robbed visual observers of few objects, most of these potentially visual finds having been spotted on ultraviolet images secured by the SWAN instrument. Two of the SOHO coronagraphs, LASCO 2 and 3, have found over 3000 comets at latest count (more than the total of all known comets prior to 1995!), but just three of these were sighted from the ground, and only two of these would have stood any chance of visual discovery.

In recent years, as we look through the list of new comet discoveries, we are met with names such as LINEAR, PANSTARRS, LEONOS, Siding Spring, Catalina, MOSS, ISON, SOHO, NEOWISE, and so forth. These are obviously not the names of people. They are either the acronyms of automated programs or the observatories (some space-based) from which the discoveries were made. One may look at the list and be discouraged, not just from visual comet searching but also from visually observing comets at all.

This book has been written to hopefully counter this feeling. Although it would be fanciful to think that anyone armed with nothing more than a good pair of binoculars still has as strong a chance of discovering a comet as he or she had 30 years ago, it is equally incorrect to think that a dedicated visual comet hunter no longer has any prospect of success. Moreover, it would be *very* wrong to think that comet observing with the eye instead of a CCD no longer has an important place in astronomy. As the following pages will hopefully make clear, visual observations are needed as much as they ever were.

This book is divided into three main sections. In the first of these, we take an overview of the subject, briefly covering the changing views of comets from earliest times down to the present day. We examine the main features of these objects and the reason why they display their characteristic activity while relatively close to the Sun.

Part Two deals specifically with the types of observations by which visual observers can make meaningful contributions to the study of comets. In the course of this section, we will look at the best approach to comet hunting in this age of automated programs and the types of comets that are more likely to be discoverable by visual means as well as the regions of the sky where they are more likely to be found.

As well as comet hunting, we shall look at the various types of observations that can best be undertaken by the amateur astronomer with relatively simple visual equipment.

The most important observations are those determining the total magnitude of the comet's head or coma. The various methods of estimating this value, together with the benefits and difficulties peculiar to each, are examined. The methods of estimating the diameter of the cometary coma are also discussed, together with a scale for the degree of central condensation of the coma. A chart depicting the appearance of cometary comae showing the varying degrees of condensation is provided to enable direct comparison with the image seen in the eyepiece. These measurements of diameter and estimates of degree of condensation provide an idea of how the comet appears in the eyepiece of a telescope. We will also discuss what to look for concerning the tails of comets and how the length and orientation of these features, with respect to the head, can be measured.

In addition to these quite basic observations, various unusual and at times controversial features that have been reported from time to time are mentioned. These range from the well-established coma and tail structures such as jets and envelopes in the coma, rays and striae in the tail, secondary condensations, and "satellite" comets to controversial reports such as aurora-like fluctuations and pulsations in tail brightness occurring over very brief time intervals in addition to rapid apparent motions along the tail.

Verbal descriptions of the different features are supplemented by photographs of actual examples displayed by relatively recent comets in addition to several drawings made by observers of objects seen in earlier years. These should help observers identify similar cometary phenomena observed by the naked eye or through the eyepiece of a telescope.

Part Three of this book then turns to several of the brighter and/or more interesting periodic comets predicted to appear between the end of 2016 and 2027. A brief observational history of each of the listed comets is given, together with the orbital elements for the predicted return, an ephemeris covering the period of maximum expected brightness of each comet and a chart depicting the path that the comet is predicted to follow across the sky. This information should be sufficient for observers to use in their determination of more exact ephemerides adapted to their location and time of observation. Updated orbital elements will almost certainly be available on the Web as the time of return of these comets approaches, especially following their first detection through large telescopes and while they are still distant from the Sun, and these upgrades will enable even more accurate predictions to be made in due time. Of course, it must always be remembered that comets are notoriously unpredictable, and this should especially be borne in mind with respect to the magnitude forecasts provided here. These are only approximations at best and may turn out to be wide of the mark.

Cowra, New South Wales, Australia David A.J. Seargent
July 2016

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Contents

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PART I

INTRODUCING COMETS

CHAPTER 1

COMETS THROUGHOUT HISTORY

Comets have been objects of both fascination and fear since time immemorial. Often conspicuous and spectacular in appearance, they seem to stand apart from the more usual varieties of astronomical phenomena. Even their movement across the sky is different. Like the "wandering stars" that we today know as planets, they do not remain in a set position among the fixed stars. In fact, they are even less constrained than the planets because, unlike the latter, they move at varying rates and are not even confined to the region of the zodiac. Comets can appear anywhere in the sky, move in any direction at just about any speed. Even the polar region is not exempt from their presence. It is as if these strange objects belong to a different order from the other astronomical bodies.

Records of these strange apparitions have been found on Chinese oracle bones dating back over a millennium before the time of Christ and accounts of several from the fourth century B.C. appear in the works of Aristotle. It is not clear what the ancient Chinese thought comets were, but their interest in them was more astrological than astronomical, although dividing those two approaches is somewhat anachronistic, in the true meaning of that word. Whereas these days astrology and astronomy are clearly differentiated, that was not so in ancient times, especially in cultures such as that of early China, when the sky was believed to be intimately associated with, and in effect to represent, the situation on Earth. Depending upon their appearance and location in the sky, the old Chinese astronomers/astrologers attempted to predict future events based on them. Although such beliefs have long since passed from mainstream acceptance, the incentive they gave these ancient sages to carefully note the positions, motions and appearances of the comets they observed resulted in a legacy of incalculable importance to later generations.

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Comets were noticed by other ancient cultures as well, and in most instances were regarded with fear and associated with disastrous events on Earth. Bright ones are sufficiently rare to be considered events of an unusual nature, and it is nearly always possible to find some unfortunate event (a war somewhere, a famine, the death of a benevolent national leader, etc.) happening not too far removed in time from the appearance of one such comet, for an apparent association to be found. The tendency was, therefore, to see these objects as supernatural and portentous rather than simply astronomical, although, harking back to our earlier comment that the modern schism of astrology and astronomy does not accord with ancient thinking, so likewise our sharp division between the "natural" astronomical events and celestial signs of a supernatural and portentous nature would have been foreign to early cultures.

Probably the first people to have some inkling of the nature of comets were the Babylonians, who associated them with the "wandering stars," or planets. They seem to have thought of comets as certain types of planets, albeit ones whose wanderings took them very far afield and permitted them only occasionally to become visible from Earth. This is actually pretty close to the truth, although it should be remembered that Babylonian astronomy was empirical rather than theoretical and that there is no reason for thinking that they understood, or even speculated about, the intrinsic nature of planets and comets.

It was the ancient Greeks who put forward the first "scientific" models of comets. They were, indeed, the first to apply what we today would call the "scientific method" to questions about the nature of the world, so it is only fitting that comets were included within the sweep of their scientific approach. However, there was no overriding agreement among these old sages as to what comets actually were.

Although we have no extant writings in which his ideas are presented, we have it on the opinion of later authorities that Ephorus opined comets to be somehow formed by the conjunction of planets. In support of this suggestion, he apparently made the claim that a great comet that appeared in the year 372 B.C. of our calendar split into two segments or "planets." This alleged observation was mentioned by Seneca and given by him as evidence of Ephorus' unreliability. Apparently, the thought of a comet splitting was too farfetched for Seneca, and he seems to have suspected that

Ephorus invented the observation to add support to his ideas about the nature of these objects. Today, of course, we know that splitting of comets is not an uncommon phenomenon, although none of the observed disruptions of cometary nuclei would have been visible to the naked eye. If Ephorus really did see something, like a splitting of this comet, it must have been something other than the schism of its nucleus. As we shall see, comets sometimes lose their tails, or segments of their tails, and it is possible that Ephorus witnessed something like this. In any case, and without wishing to follow Seneca in casting doubt upon his integrity, Ephorus alone mentioned the event, as far as we are aware. Aristotle and several other ancient writers mention the comet of 372 B.C., but none of the extant writings give any hint that it split.

Mention of Aristotle brings us to the first theory of the nature of comets for which the actual work of the author, and not simply handed-down reports, survived. But Aristotle's model did not see comets as truly astronomical objects. In his opinion, comets were like "slow meteors," both classes of object being "exhalations" from Earth that, upon reaching the supposedly fiery realm of the upper atmosphere, caught alight and burned. Meteors burned quickly and were consumed, quite literally, in a flash. Comets, by contrast, were only slowly consumed and could remain a feature of the sky for weeks or even months.

This comet model had certain aspects in common with the Mesopotamian opinion that comets are a sort of whirlwind. Although we have no direct access to the Mesopotamian speculations, we do have a record by Epigenes stating that they considered comets to be "a kind of eddy of violently rotating air." There is no reason to think that Aristotle was influenced by this, but the similarity is interesting. Although only speculation, we might wonder if the Mesopotamian view was influenced by the similarity of appearance between the tails of some bright comets and the funnel cloud of a tornado or waterspout, especially considering that funnel clouds have occasionally been seen to glow at night due to the intense electrical activity associated with them.

Although completely incorrect, Aristotle's model does have some observational support. Much of his writing concerning comets deals with the especially bright and spectacular object visible during the time that Alcisthenes was archon of Athens, i.e., around the year 372 B.C. This was almost certainly the same object that, according to Seneca, was described by Ephorus. Aristotle would have been a child of about 12 years of age when this object hove into view, so his descriptions are probably his own childhood recollections. Seeing this object may even have been the event that got him interested in natural science and directed him away from following his father into a career in medicine. Be that as it may, Aristotle notes that this comet first appeared low over the western horizon shortly after sunset and gradually rose higher into the sky during the following days. The tail stretched upward "like a great ribbon." It would not have taken much imagination to picture this object as something being thrown upward into the atmosphere and attaining greater altitude with each passing day. Moreover, the arrival of this comet coincided with an earthquake in Achaea and a tsunami that flooded Buris and Helice. On the one hand, that could be read as supporting the portentous nature of comets, but Aristotle may have seen these upheavals as evidence that something rather large erupted from (was "exhaled by") the ground and caught fire in the upper atmosphere.

The relegation of comets to the terrestrial air apparently had an appeal for the Western mind and came to hold sway over the earlier views of these objects as some sort of planet or even as being (somehow) formed by conjunctions of planets as Ephorus apparently believed. A good indication of what astronomers then thought of comets is given by Ptolemy in his *Almagest*. He made no mention of them at all!

Even as late as the time of Galileo (1564–1642), the idea that comets were a type of astronomical body was far from gaining universal acceptance. Galileo expressed the opinion that comets, while beyond Earth's atmosphere, are not real material bodies but, instead, merely reflections of sunlight not unlike rainbows, sundogs and many of the other spectacular light effects that grace our skies. This hypothesis met with a very favorable response from the intellectual hierarchy. So much so indeed that Galileo felt emboldened to publish his results on the moons of Jupiter and their non-geocentric orbits. That idea was not received with equal enthusiasm!

On the other hand, Galileo's younger contemporary, Johannes Kepler (1571–1630), had a very different view of comets. In his opinion, they constituted accumulations of "impurities" with tails of "filth" forced outward by the Sun's energy. Terms such as "impurities" and "filth" might seem a little pejorative, although not too inaccurate in view of what we now know about the composition of these bodies, but Kepler's understanding of comets as accumulations of space debris (in addition to the role he gave to solar energy in the formation of their tails) showed remarkable insight. Moreover, it was Kepler who first appreciated the enormous numbers of comets that must exist, remarking that he believed that there are more comets in the sky than there are fish in the oceans. On the other hand, his notion that comets moved through space along straight lines was incorrect, but we can surely forgive him this slip in view of the accuracy of his other insights.

Other ideas that began to circulate around this time included the hypothesis put forward by Johannes Hevelius (1611–1687), namely, that comets are fragments that have broken away from the Sun and planets (including the Earth itself) and subsequently propelled through space along parabolic trajectories. The orbits of many comets do indeed verge on the parabolic, and while they are not actually fragments of planets, the idea that they are solid bodies that are somehow associated with planetary formation has withstood the test of time, even if not in the form put forward by Hevelius.

Part of the difficulty in understanding the physical nature of comets concerned their sometimes odd behavior. They not infrequently failed to maintain a stable appearance (which, by the way, is a good reason for continuing visual observation of these objects!). Sudden changes of shape and brightness are not uncommon, so very different from the fixed appearance of the Sun, Moon, stars (with a very few exceptions) and planets. Even when these latter do vary (the changing brightness of Mars between opposition and conjunction for instance), they do so in a regular fashion. But comets are anything but predictable in the way they behave. Leonardo da Vinci once noted, with apparent astonishment, that "Why, this comet seems variable in shape, so that at one time it is round, at another long, at another divided into two or three parts, at another united, and sometimes invisible and sometimes becoming visible again." These were seen to be strange objects indeed!

The time had not yet arrived for the true nature of comets to be discovered, but at least by the end of the seventeenth century, an understanding of their motion through the Solar System had been reached.

CHAPTER 2

COMETS IN MOTION

We all know the story of Newton and Halley. Thanks to his discovery of the phenomenon of gravity and the formulation of its effects in the form of mathematical laws, Newton was able to demonstrate that comets obeyed the same universal law as every other physical object in the universe. Much of this work was based upon the motion through the sky of a very spectacular comet that appeared during the latter part of 1680 (Fig. 2.1). In the process, he was able to show that the bright comet that had graced the morning skies during November and early December of 1680 was actually the same as the even more magnificent apparition that emerged from the evening twilight just prior to Christmas. He also correctly demonstrated that this comet had passed unusually close to the Sun around mid-month.

The main difference between the orbits of comets and planets lay with the fact that, whereas planets followed paths that were only slightly elliptical, comets moved through space along paths that were (or were close to) a parabola. The path of the 1680 comet was either a true parabola or a very elongated ellipse. If the first alternative was correct, the appearance of 1680 was its one and only visitation. However, as nature is about as unlikely to draw a parabola as a straight line, it was more likely that the true path of this comet was an ellipse having a period of hundreds or even thousands of years.

By applying Newton's theory of gravity, his colleague, Edmond Halley (1656–1742), calculated the orbits of 24 comets that had been recorded during the preceding centuries. Although he calculated the orbits of these objects on the assumption of parabolic motion (really for simplicity sake and due to the fact that the available observations were not sufficiently precise to enable one to distinguish between a parabola and an eccentric ellipse), he was struck by the apparent similarity between some of the orbits as well as by some regularly spaced intervals separating the appearance of a few of

D.A.J. Seargent, *Visually Observing Comets*, Astronomer's Pocket Field Guide, DOI 10.1007/978-3-319-45435-1_2

Fig. 2.1 The Great Comet of 1680 over Rotterdam. (Painting by Lieve Verschur, 1627–1686)

the catalogued comets. This led him to conclude that certain comets, at least, return at regular intervals. Perhaps they all do, albeit with periods so long that their previous returns have been lost in the mists of prehistory.

Three groups of cometary apparitions were suspected by Halley as having been repeated returns of a single object. The first was a trio of objects observed in 1531, 1607 and 1682, the last of the series having been observed by Halley himself. These objects all moved along remarkably similar orbits, and Halley strongly suspected that they were simply different apparitions of the same body pursuing an elliptical path having a period of about 75 or 76 years. In apparent support of this conjecture, Halley noted that a similarly bright comet had appeared in the year 1456. Although this one was not included in his catalogue of orbits, the time interval was suspiciously close to that separating the other three. From this, he predicted that the comet would return around the year 1758 or 1759—a prediction that was gloriously fulfilled, even though Halley did not live to witness it personally. Since then, Halley's Comet, as it became

Fig. 2.2 Comet Halley in 1986 showing rays in ion tail. (Image courtesy of NSSDC Photo Gallery, NASA, image by W. Liller)

known (although its more formal title is now 1P/Halley) has been observed in 1835, 1910 and 1986 (Fig. 2.2) when it was visited by a fleet of unmanned spacecraft, and images of the active nucleus of a comet were beamed back to Earth for the first time. The comet is due back once more in 2061 and is scheduled to make a very close pass of Earth—to just 0.09 AU—during its subsequent return on May 7, 2134.

Halley also suspected that the comet he and Newton had observed in 1680 might have been a return of a very spectacular one widely observed in 1106, as well as one listed in Byzantine records for the year 530 and even the one seen at the time of the assassination of Julius Caesar in 44 B.C. This opinion was not based upon any orbital similarities of these bodies, as an orbit had been calculated for 1680 alone. Halley was basing his suspicions on the similar time intervals between the apparitions and the fact that all of these objects were bright. In contrast to his thoughts about the 1682 comet, we now know that the objects of 44 B.C., 530, 1106 and 1680 were different objects. Ironically, the 530 object was actually an early appearance of the 1682 comet!

Halley's orbit catalogues also included two other objects having similar orbital elements that Halley suspected as being separate returns of a single body. These were the bright comets of 1532 and 1661, the first having been observed by Peter Apian and represented by him in woodcuts depicting the orientation of its tail to be consistently in an anti-solar direction. This suggested identification was also incorrect, although the latter comet at least has turned out to be one of a relatively short period. It returned in 2002, at which time it was rediscovered by Kaoru Ikeya and Daqing Zhang, after whom it has now been named. Earlier apparitions of Comet Ikeya-Zhang have probably been found in the form of the comets of 1273 and 877. Although it cannot be identical with the 1532 comet, it is possible that these two have a common origin. Maybe they were once a single object that split apart near perihelion hundreds of years ago.

CHAPTER 3

TOWARD THE MODERN UNDERSTANDING OF COMETS

Nevertheless even after their motion across the sky had been tamed by Newtonian gravity, the veil of mystery shrouding comets was merely loosened rather than completely torn away. The nature of these strange objects appeared to defy a simple explanation. They clearly were not solid bodies, like the planets, nor were they similar to the Sun and other stars. Even though the heads of some comets looked relatively dense, the fact that stars were most often visible, typically with little or no dimming, implied that they must actually be composed of very rarefied material. This applied even more to the tails that accompanied many comets, especially the brighter ones. These had no known counterpart among the features of other astronomical objects. Moreover, they did not necessarily stream out behind the comet's heads, as one might imagine of a moving object. Instead, they appeared to be directed more or less away from the direction of the Sun, as noted by Chinese astronomers over 1000 years ago and again by Peter Apian in 1532.

Superficially, the appearance of the bright heads and streaming tails of large and conspicuous comets might be interpreted as something hot and burning. Indeed, it is not unusual to find mention of "heat" in nineteenth-century journal articles describing comets. An account of the Great Comet of February 1880 in one of the leading scientific journals of the day noted that "the weather was hot" during a sighting of this comet from Australia. The implication was clear: the comet was responsible for the high temperatures at the time. Needless to say, there is no need to invoke a comet to explain hot weather in Australia during February! Curiously, this idea proved to be remarkably durable in some quarters. A book on popular astronomy not that long ago stated as a given fact a comet model that understood these objects to be incandescent. According to this work, comets "caught fire" as they approached the Sun, a view it attributed to W. Olbers following his observations of the Great Comet of 1811. The book went on the say that, although Earth's passage through a comet's tail is a harmless event, an encounter with the head would surely result in a "great fire" amounting (it was implied) to a

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global conflagration. Disturbingly, even as late as 1960, at least some secondary school science teachers told their classes that "comets have a star-like head." By "star-like," some at least meant a hot molten body rather than something that simply had a star-like appearance.

A great advance in the understanding of the physical nature of comets was made following a number of interesting and at times spectacular events in the middle years of the nineteenth century. However, as sometimes happens with advances in knowledge, this also brought with it some errors of overemphasis, as we shall see.

During the early morning hours of November 13, 1833, residents across much of the United States were awakened by what must have seemed like a display of lightning. But this was no thunderstorm! The sky was filled, not with streaks of lightning but with meteors. Thousands were falling, ranging from faint shooting stars to brilliant fireballs and bolides flooding the landscape with their light. Many folk (quite understandably) viewed the spectacle with fear, thinking that the end of the world had arrived. The world did not, however, end that night. The display marked not an end but a beginning: The beginning of a new phase in the science of meteors and, ultimately, of comets.

Although a number of scientists continued to speculate that the great meteor storm was of atmospheric origin, others noted that the shooting stars appeared to radiate from a very small region of the sky located within the constellation of Leo the Lion. This actually implied that they were being caused by bodies approaching us along more or less parallel lines (rather as railway lines appear to converge in the distance and snowflakes or raindrops seem to emerge from a point above the windshield of a motor vehicle as we drive through a rain or snowstorm). This supported the view, put forward long before by Halley, that meteors were actually small objects arriving from outer space and burning up in our atmosphere through the action of friction. The meteors that arrived in enormous numbers on that early morning in 1833 were clearly traveling in more or less parallel orbits, presumably in a cloud or stream through which Earth passed at that time. Interestingly, the writings of Von Humboldt made mention of witnessing a similar phenomenon from South America in 1799. Moreover, he also noted that local residents of the area recounted seeing an equivalent event 33 years earlier, around the same time of year in 1766.

This great fall of meteors also drew attention to lesser falls that occur on an annual timescale. August had long been noted for its numbers of meteors; the so-called "tears of St. Laurence" because of their appearance around the time of the festival of this martyred saint. If the paths of these meteors are traced back, they are found to emanate from the constellation of Perseus, hence their more formal title of the Perseid meteors. Other prominent annual showers include the Lyrids of April. Even the Leonids continue to provide a certain degree of activity each year, some years stronger than others, though not reaching the tremendous levels of 1799 and 1833. Another strong meteor storm did occur in 1866, however, which, although not as intense as the one of 1833, at least demonstrated that the densest portion of the stream apparently orbited the Sun on a comet-like path, returning to the vicinity of Earth's orbit approximately every 33 years.

Before the 1866 return of the grand Leonid display, however, a number of other important developments had taken place. In 1826, a comet was discovered by W. Biela and subsequently shown to be following a small elliptical orbit and having a period of just 6.6 years. It was also found to be identical with a comet seen in 1772 and one observed in 1805 during a very close approach to Earth. The comet was duly recovered in 1832, missed due to poor location in 1839, but was found again in late 1845 accompanied, surprisingly, by a secondary comet moving in unison with it (Fig. 3.1). The two comets—by then somewhat further apart—were recovered again in 1852 (Fig. 3.2), but neither has positively been identified since.

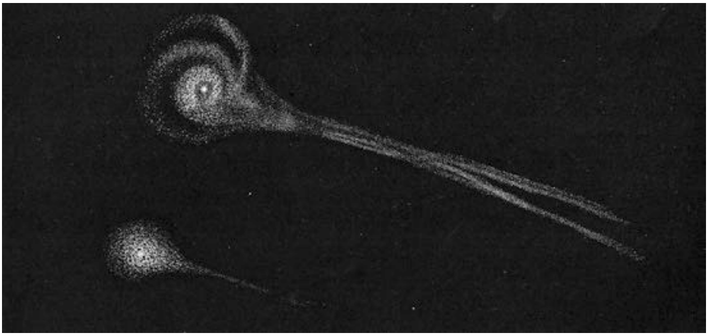

Fig. 3.1 Split comet Biela at its 1846 return. (Drawing by E. Weib)

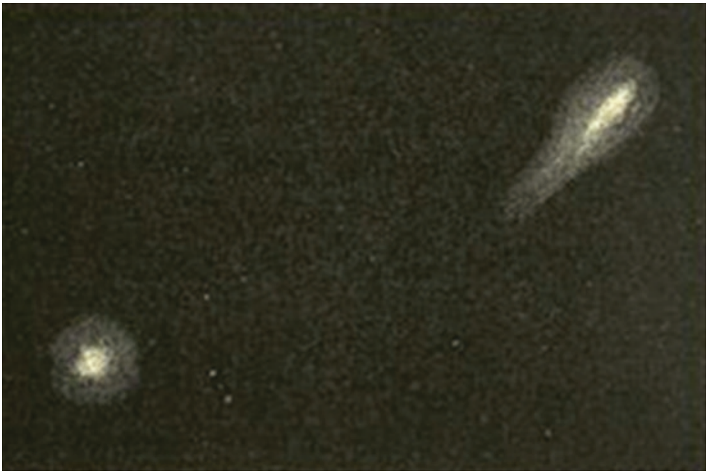

Fig. 3.2 Primary and secondary fragments of Comet Biela in 1852. (Drawing by A. Secchi)

Something remarkable happened during the computed 1872 return, but more about this shortly. Historically, the splitting and subsequent disappearance of this comet demonstrated in spectacular fashion how unstable these objects can be. Surely, they cannot be solid bodies, but instead must be something far more flimsy.

Even while the saga of Biela's Comet was unfolding, however, other discoveries were being made that contributed to the understanding of these bodies. On April 5, 1861, A. E. Thatcher discovered a comet that moved along an orbit very similar to the April Lyrid meteor stream. Then, on July 16 of the following year, a comet, which for a time became a fine naked-eye object in the northern skies, was discovered by L. Swift and, 3 days later, by H. Tuttle. Of even greater significance than its appearance was the surprising fact that its orbit turned out to closely match that of the August meteor stream, the Perseids. Finally, a comet found by W. Tempel on December 19, 1865, and secondly by H. Tuttle on January 6, 1866, turned out to be moving in the orbit of the great Leonid meteor storms. The appearance of this last comet heralded another strong Leonid display the following November.

Now, recall that Biela was also due back in 1872. It did not arrive, but instead the sky was filled with meteors coming at the rate of about 6000 per hour, on November 27 of that year!