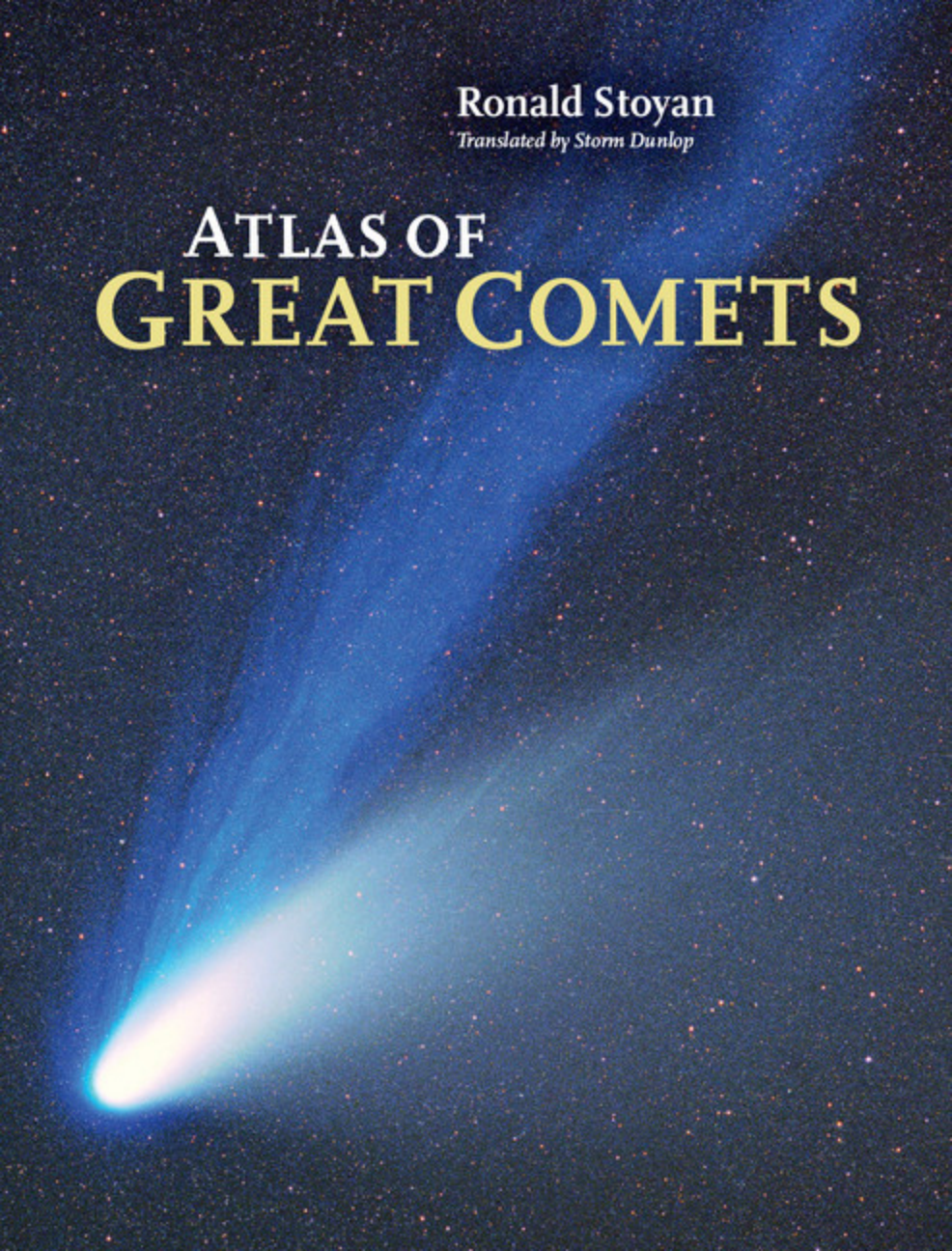
Ronald Stoyan
Translated by Storm Dunlop

Atlas of Great Comets



Atlas of Great Comets

Throughout the ages, comets, enigmatic and beautiful wandering objects that appear for weeks or months, have alternately fascinated and terrified humanity. The result of five years of careful research, *Atlas of Great Comets* is a generously illustrated reference on thirty of the greatest comets that have been witnessed and documented since the Middle Ages. Special attention is given to the cultural and scientific impact of each appearance, supported by a wealth of images, from woodcuts, engravings, historical paintings and artifacts, to a showcase of the best astronomical photos and images.

Following the introduction, giving the broad historical context and a modern scientific interpretation, the Great Comets feature in chronological order. For each, there is a contemporary description of its appearance along with its scientific, cultural and historical significance. Whether you are an armchair astronomer or a seasoned comet-chaser, this spectacular reference deserves a place on your shelf.

RONALD STOYAN is Editor-in-Chief of *interstellarum*, and the proprietor of the independent German publisher Oculum-Verlag, which specialises in amateur astronomy books. He is the founding director of the German deep-sky organisation 'Fachgruppe Deep-Sky' and has authored or co-authored twelve books on practical astronomy, including *Atlas of the Messier Objects* and *The Cambridge Photographic Star Atlas*.

STORM DUNLOP is an experienced writer and lecturer on astronomy. He is author of *Collins Night Sky* (2011), a Fellow of the Royal Astronomical Society, and a past president of the British Astronomical Association.

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Atlas of Great Comets

Ronald Stoyan

Translated by Storm Dunlop

Cambridge University Press

for Renate

Comet Hyakutake 1996. *Kent Wood*

Foreword

Throughout the ages, comets, those extraordinary, wandering celestial objects that, without warning, shine in the heavens for weeks or months, have impressed mankind. The ancient Greeks called them κομήτης, which meant 'with long hair' or 'hair stars'. In other languages they were known as 'broom stars' (in English), or 'tailed stars' ('staartster' in Dutch). The German word 'Schweifstern' ('stars with tails') summarizes their diverse appearance.

The debate about these celestial bodies has been beset with errors and confusion, great ideas and amusing anecdotes. Beliefs and superstitions, art and science have all been influenced by the appearance of great comets. They reflect humanity's development and its search for explanations for appearances in the heavens.

The history of this development is described in this book though the descriptions of the 30 greatest comets from early modern times to the twenty-first century. In choosing these events, astronomical points of view were not the only criteria. The aim was to describe the strange ideas that had the greatest influence on people in former centuries.

This book would not have been possible without the help of numerous individuals. In particular, three people have had a great influence: great thanks are due to Hans Gaab, an expert on the astronomical history of Nuremberg, who placed extensive materials, books and copies at my disposal. His help was particularly valuable in the chapters on antiquity, the Middle Ages and early modern times.

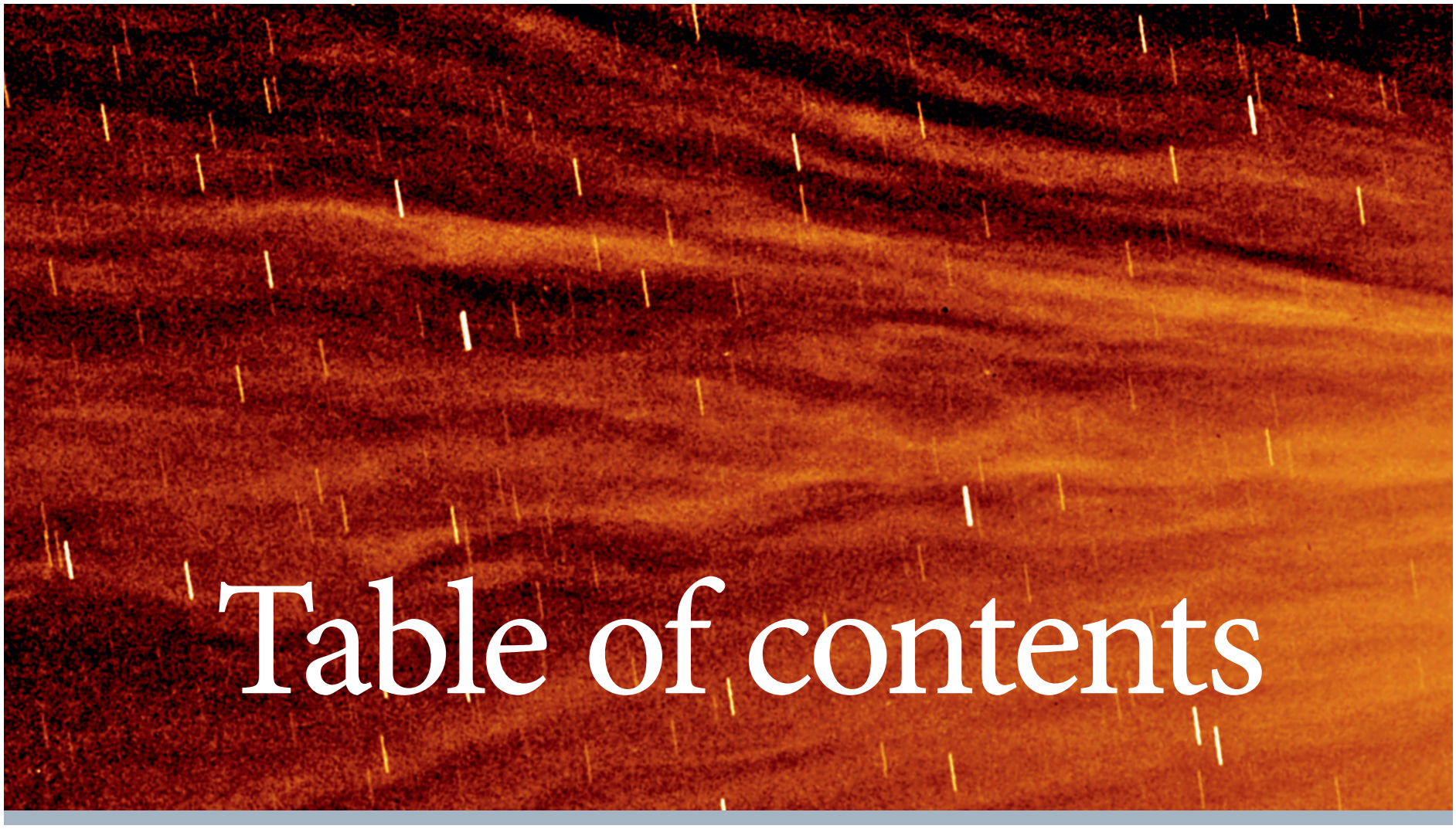
Maik Meyer, who holds the record for the most comets discovered with the SOHO solar probe, and co-author with Gary W. Kronk of the multi-volume *Cometography* series of books, the world's most comprehensive documentation on comets, provided extremely significant help on discovery data and discovery statistics. Burkhard Leitner, the expert on comets on the editorial board of *interstellarum* magazine, provided the charts of the individual comet apparitions.

This illustrated work would not have appeared in such an opulent edition without the wonderful support from numerous astrophotographers. These included Stefan Binnewies, Karl Brandl, Rudolf Dobesberger, Dirk Ewers, Philipp Keller, Michael Kobusch, Bernd Koch, Bernd Liebscher, Jürgen Linder, Norbert Mrozek, Christoph Ries, Gerald Rhemann, Jim Shuder, Wolfgang Sorgenfrey, Peter Stättmayer, David Thomas and Uwe Wohlrab. For their assistance in obtaining picture material, I would also like to thank Prof. Helmut Meusinger (Tautenburg Observatory), Dr Holger Mandel (Heidelberg Observatory), Dr Uwe Reichert and Dr Axel Quetz (*Sterne und Weltraum* magazine) as well as Rainer Mannoff and Wolfgang Sorgenfrey.

I wish to thank Dr Harald Krüger and my editorial colleague Daniel Fischer for their critical checking of the chapter on the modern-day interpretation of comets. Dr Michael Wenzel checked the sections on the history of art. And, by no means last, for their correction of the manuscript I want to thank Dr Winfried Neumann, Susanne Schwab, Angela Hensel and my wife Renate, who has continually sustained me throughout five years of research.

Erlangen, October 2014
Ronald Stoyan

Storm Dunlop, this edition's translator, wishes to acknowledge the help of Chris Caron (on mediaeval German), Françoise Launay (on early French observatories), and Jonathan Shanklin and Steve Edberg (on cometary science).



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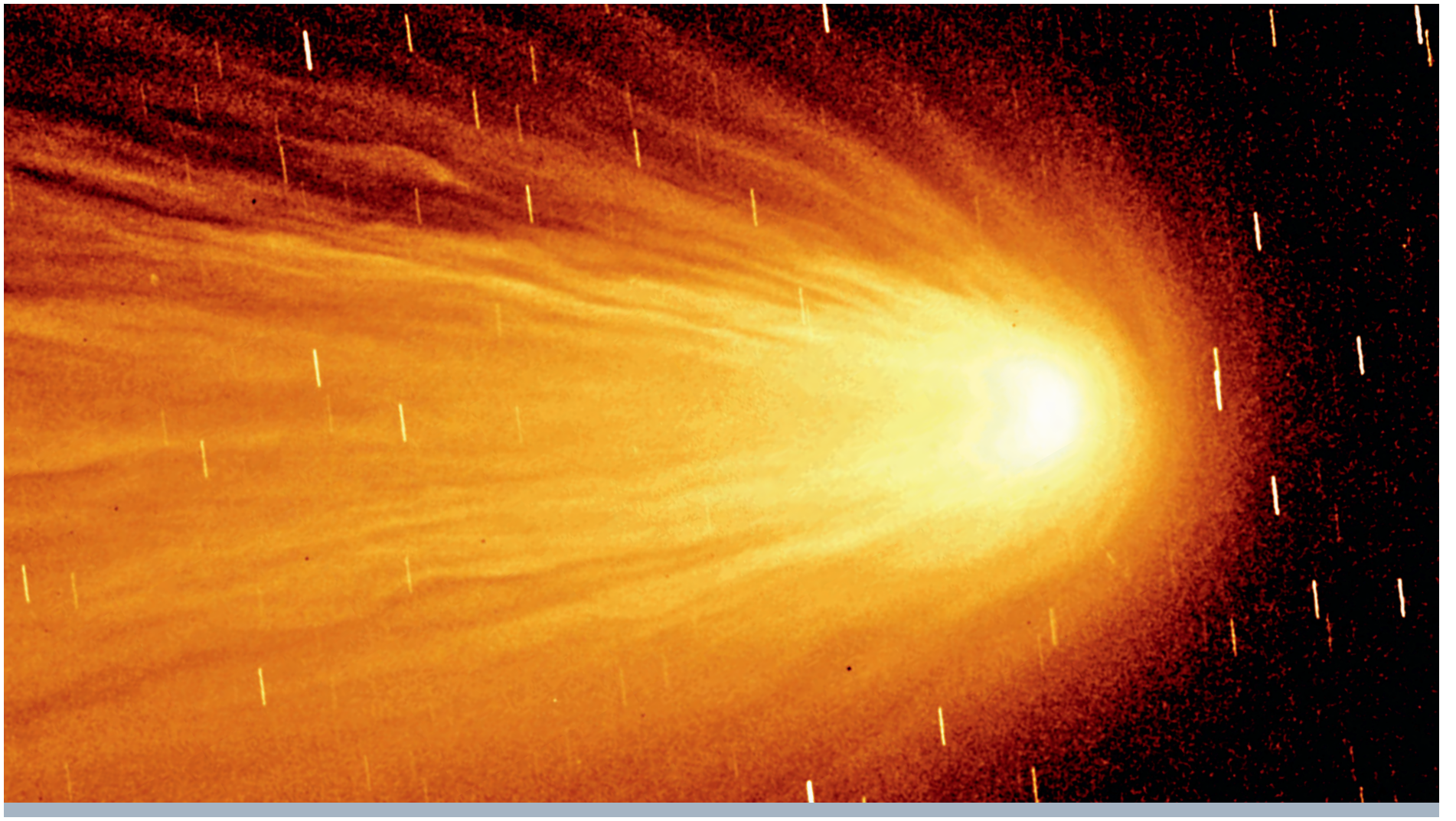


Appendix

Using this book

Text

The apparitions of 30 comets have been chosen for detailed description in this book. With one exception, individual appearances of these celestial bodies are discussed, but Comet Halley is included no fewer than seven times: every one of its apparitions between 1532 and 1986 is individually described.

The text concerning each comet is divided into three sections:

- Orbit and visibility. In this section the apparent path of the comet as seen from Earth is described. The changing position of the comet against the background of the constellations and the conditions under which it was visible to Earth-bound observers are reconstructed. In addition, specific features of its actual path in space are noted.
- Discovery and observation. The circumstances and the date of the discovery of the comet as well as the subsequent observational accounts by various authors are described and summarized. This is where details of the magnitude and length of the tail are to be found, and which, for the most part, rely on estimates by visual observers. Because, in most cases, it is not possible to calculate any objective values, such information may be contradictory. In general, the longer in the past the observations were made, the more critically the information should be viewed. A list of the sources employed is given in the appendices.
- Background and public reaction. This section deals with the scientific findings that relate to each comet, as well as its effect on the general public. Technical terminology is used sparingly, but is, however, not completely avoided. A glossary of the most important concepts is given on page 218.

Data

A table gives the most important astronomical data for each individual comet:

- Designation: The current official designation of the comet
- Old designation: The designation of the comet that was historically employed
- Discovery data: The first sighting of the comet, according to current knowledge (up to 1580 in the Julian calendar, and from 1581 in the Gregorian calendar)
- Discoverer: The first to observe the comet, again according to current knowledge
- Perihelion date: Date of closest approach to the Sun (up to 1580 in the Julian calendar, and from 1581 in the Gregorian calendar)
- Perihelion distance: Distance of closest approach to the Sun in Sun-Earth units (astronomical units, 1 AU = 149 million kilometres)
- Closest approach to Earth: Date of the closest approach to the Earth (up to 1580 in the Julian calendar, and from 1581 in the Gregorian calendar)
- Distance from Earth: Distance of closest approach to Earth in Sun-Earth units (AU)
- Maximum magnitude: The maximum magnitude of the comet according to present-day calculations
- Maximum length of tail: The greatest observed length of the comet's tail
- Longitude of perihelion: The angle between the vernal equinox and the ecliptic longitude of perihelion
- Longitude of the ascending node: The angle between the vernal equinox and the ecliptic longitude of the ascending node of the comet's orbit
- Orbital inclination: The inclination of the comet's orbit relative to the ecliptic
- Eccentricity: The deviation of the comet's orbit from a circular form: 0° = circle; > 0 < 1 = ellipse; 1 = parabola; > 1 = hyperbola.

Charts

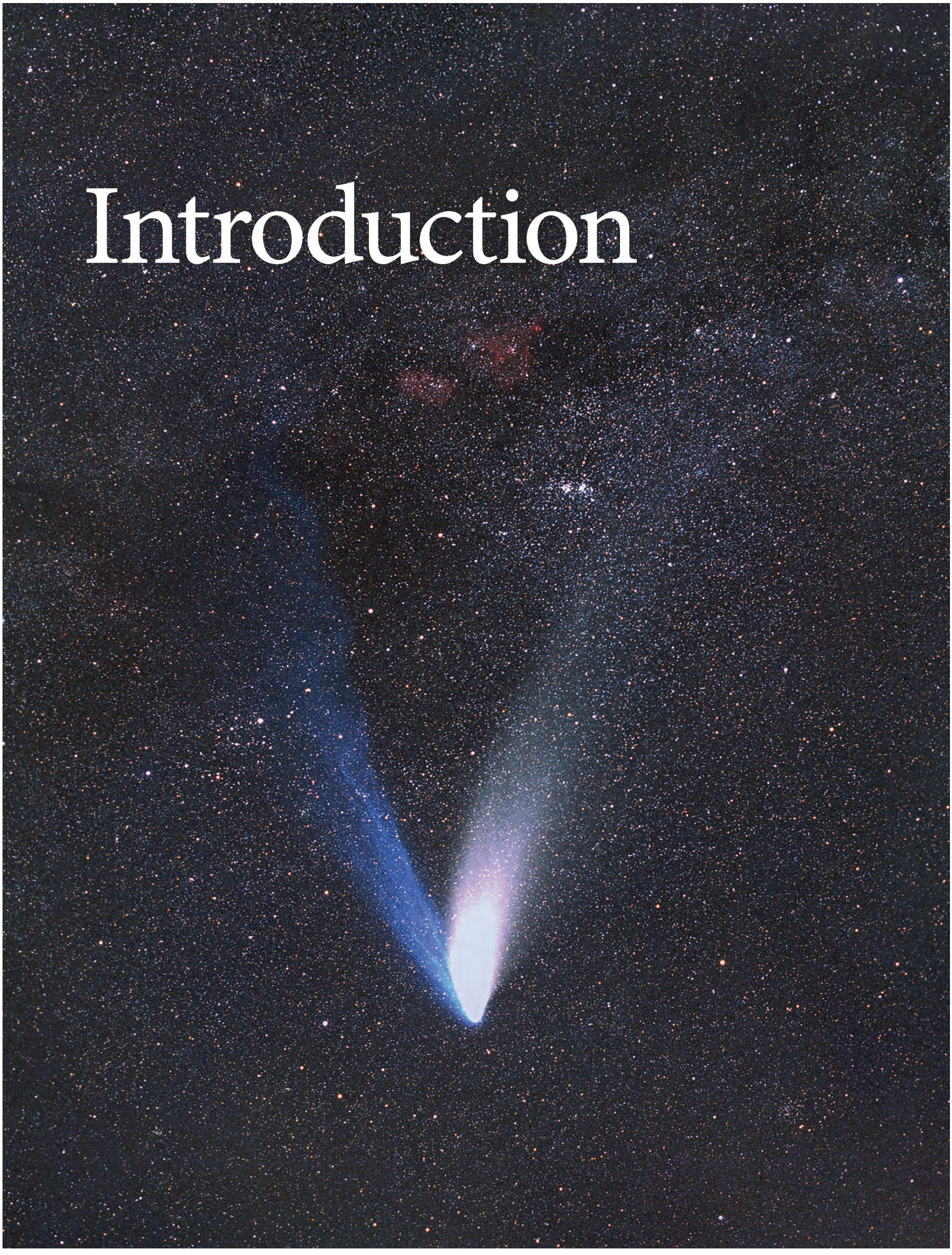
Each appearance of a comet is illustrated with a chart. This shows the course of the object against the sky. The comet's positions and the direction of the tail are shown at fixed intervals. In addition, the beginning of every calendar month is indicated.

The charts also show the position of the comet at its discovery (d), at perihelion (P), closest approach to Earth (E) as well as the final observation (f). The position of the Sun at perihelion is also indicated.

For some comets the whole path across the sky between discovery and last observation cannot be shown. In these cases, the diagrams concentrate on an interval around perihelion and closest approach to the Earth.

Dates are given in the Julian calendar up to 1580, and in the Gregorian from 1581.

Introduction



Cometary beliefs and fears

Ancient ideas

During its changes throughout the year, the starry sky always shows the same set of constellations. The Moon and the planets follow their regular paths. The laws that govern these were discovered early on, so they could then be predicted. Comets, by comparison, arrive and then disappear again. Unlike the planets, they suddenly appear and are unpredictable. They are only ever visible in the sky for a short period of time, whether a few weeks or months, and may move over long distances in a short time. So they are a chaotic, disruptive element in the night sky, which disturbs the orderly procession of the normal movements in the sky.

According to the Roman philosopher Seneca, the Babylonians had already recognised comets as being unique phenomena about 5000 years ago. They saw them as being fiery bodies or planets. Pythagoras, in the sixth century BC, assumed that there was only a single comet, that returned, like a planet, and which also belonged to the planetary sphere and consisted of the mysterious fifth element ('quintessence'). Hippocrates of Chios agreed. According to him, the tail arose through moisture drawn from Earth, which simply reflected sunlight. If the comet appeared in the damp north, then it formed a bright tail, and if in the dry south, by contrast, none. The Greek philosophers Democritus and Anaxagoras held that comets arose by planetary conjunctions. Heraclides Ponticus held, on the other hand, that comets were high clouds reflecting sunlight.

The Greek astrologer, Epigenes, in the second century BC, distinguished two types: the lower, that were created by eddies in the air, and those that arose from vapours. But Apollonius of Myndus believed that comets were planets that came from distant regions of the universe, and were visible over only part of their path. He also assumed that there were very many of them.

Aristotle comprehensively eliminated the many competing and contradictory theories. His conception of comets, which he created about the year 350 BC, was held for 2000 years to be the answer to everything. Aristotle promoted a finite universe. Within the innermost four spheres lay the Earth, surrounded by spheres of water, air and fire. Above these lay the spheres of the Moon, the Sun and the planets. Above everything was the unchanging sphere of the fixed stars.

Comets, according to Aristotle, were part of the lowermost spheres, and thus were not part of the heavens, but were to be considered as weather phenomena ('meteors'). They were created by vapours from the Earth, that rose when warmed by the Sun and were linked with the evaporation of water. If they reached the fourth sphere, they were ignited by friction, and were dragged into a circular path around the Earth. Shooting stars were comets that were particularly easily ignited.

As comets arose from moisture from the Earth, storms and droughts followed their appearance. Aristotle maintained that most comets appeared in the Milky Way, because this would favour terrestrial 'exhalations', whereas the Sun and planets prevented them from forming near the ecliptic. While most authors in antiquity and the Middle Ages followed Aristotle, there were contradictory ideas. In his *Naturales quaestiones* Seneca opposed Aristotle's view. He also rejected Apollonius's planetary nature of comets, because they appeared far from the ecliptic and were not brightest when they were closest to

In all ages and in all cultures, comets engendered anxiety and fear. Deptictions from c.1707–1710. *Anonymous (left), Christoph Weigel (right)*

the Earth. He envisaged comets, however, as long-lasting bodies that were on closed paths, and recommended long-term observations to determine their return.

During the Middle Ages, Aristotle's views persisted, because they were adopted by the Church and were advanced as the expert opinion by influential theologians such as Albertus Magnus (Albert of Cologne). The translation of the Greek text of *Meteorologica* into Latin around 1156 also contributed to this. In this connection, in the thirteenth century, Robert Grosseteste thought that comets were vaporized fire, attracted from the planets as if by a magnet. Around 1350, Conrad of Megenberg held that comets were not just moisture from the Earth, but also arose from people's blood, who would thus be dried out and 'heated'. John of Legnano (Giovanni da Legnano) said that comets made people choleric in nature.

Cometary astrology in antiquity

Among the Babylonians, astronomy was not considered separate from astrology, and this was even more applicable to the interpretation of comets in antiquity. Seneca himself said "If a rare and extraordinarily formed fiery phenomenon becomes visible, then everyone wants to know what it means. Everyone forgets everything else, and asks whether the newcomer should be treated as a marvel or something to be feared. Prophets soon arise, who generally proclaim it as an ominous sign, and the thirst for knowledge and the wish to discover the truth follows them, as to whether it is a sign of foreboding or merely a heavenly body."

The belief was widespread that comets were human souls rising from the Earth to Heaven, but that only those with power and authority shone so brightly that they could be seen from Earth. An example was the comet that appeared after the death of Caesar. Shakespeare drew on this for his famous words "When beggars die, there are no comets seen."

Pliny the Elder, in his *Naturalis Historia*, gave detailed instructions regarding the astrological interpretation of comets. According to his account they generally appeared to the north of the Milky Way. Some comets move. Their significance may be drawn from the constellation in which they lie, the direction of their tails, and their shape. Ten different types of comet may thus be distinguished, which are (in Wittstein's translation):

- Pogonias: bearded stars, because hanging below them is a long beard like those of men
- Acontias: these are called arrow stars because they move swiftly, and their prognostications are swiftly fulfilled
- Xiphias: sword stars. These are the faintest of all stars, and they shine like a sword and throw off small rays
- Disceus: disc stars, which, as the name suggests, are disc-like in shape, have a bright yellow colour and give off very few rays
- Pitheus: have the shape of a barrel, with a smoky light within them
- Ceratis: horn stars, appearing like a horn
- Lampadias: torch stars, resembling a burning torch
- Hippeus: horse stars, horses' manes that circle them extremely rapidly
- Argenteus: white comets, with silvery tails, and so brilliant that it is hardly possible to look at them; which reveal an image of the Divine in a human face
- Hircus: others are rough like wool, and surrounded by a cloud.

The most influential astrological work was undoubtedly the four volumes published by Claudius Ptolemy, known as the *Tetrabiblos*. They formed a complete summary of Greek astrology, supplemented by Ptolemy's own astrological findings. According to this, all appearances in the heavens – and thus not just comets – could be attributed to the planets according to their colour. A dark tint was linked to Saturn, white to Jupiter, red to Mars, yellow to Venus and changes in colour to Mercury. The astrological significance then corresponded to that of the appropriate planet.

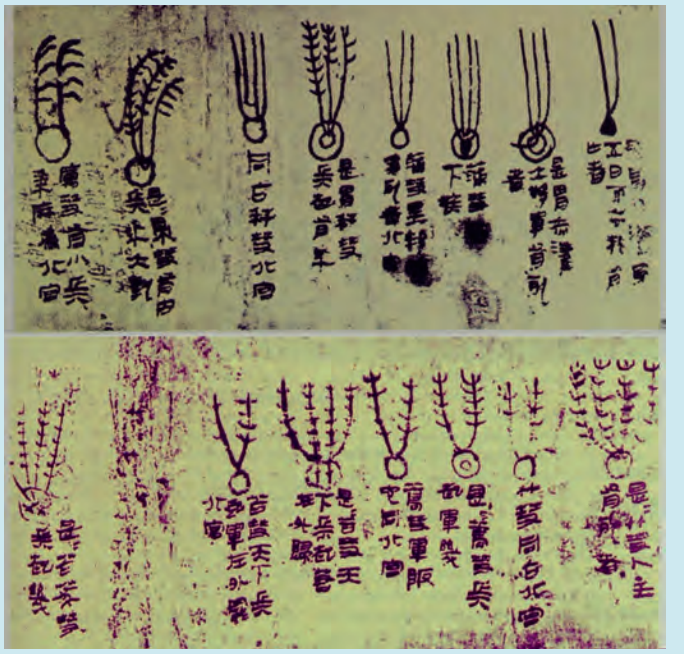
Comets were generally associated with Mercury and Mars. As a result they portended wars, hot weather and rebellion. The regions of the Earth that would be affected could

A comet was also viewed as a negative sign by the Aztec emperor Montezuma. He may have predicted his fall in a comet of 1519–1520. *Diego Duran*

Chinese ideas about comets

In China comets also had a great astrological significance, because heavenly phenomena were supposed to presage the country's fate. The Chinese emperor maintained court officials who were both astronomers and astrologers, who constantly observed the heavens and who interpreted the signs as advice for the emperor.

Because the traditional Chinese sky was divided into 283 constellations, which were much smaller than their western counterparts, accurate reconstruction of cometary paths is possible. The positions of comets were additionally given in terms of 28 lunar 'houses', whose boundaries were fixed relative to specific reference stars. Chinese cometary observations are, until early modern times, the most reliable source of information about cometary apparitions. Chinese cometary notes before 213 BC were largely destroyed.



According to Chinese cometary lore, the types of tails enabled conclusions to be drawn about the influence of comets. Most tail forms were given a negative interpretation.

In China, too, the astrological significance of comets was distinguished by their shape. A list of 29 different types of 'broom stars' was given in one source, said to date from 168 BC, but the content of which probably originates in the fourth century AD. Every shape is linked to specific consequences – for example: wars, epidemics, crop failures, famine and revolt. Only two forms are reserved for positive outcomes, which predict the return of the army and a good harvest.

The severity of the consequences was determined by the length of the tail and the comet's lunar house. Chinese astronomers established, by the seventh century at the latest, that comets' tails always pointed away from the Sun, and that comets themselves were non-luminous bodies. The accumulated Chinese knowledge about comets was superior to the European view until the fourteenth century, but always came with an astrological connotation. This has persisted in Chinese popular culture until this day. An allegedly unlucky person – and this characteristic is often ascribed to daughters-in-law who are disliked – is, as a result, described as 'comet'.

be determined from the zodiacal sign in which they occurred, and these signs were indicated by the direction of the tail. In addition, the shape of the head and the tail could predict the type of misfortune. The duration of their appearance, and their closeness to the Sun would, additionally, indicate the beginning and length of the events. Comets appearing in the east therefore led to rapid events, whereas those shining in the west to prolonged ones.

Comets as portents of disaster

In antiquity, in parallel with the astrological interpretation, the idea arose that comets were a sign of negative changes. For one thing, they were seen as prodigies, disturbances of order, that had to be re-established by the general public. But a comet could also be an omen affecting a particular person or event. Then intervention was required to avert the disaster.

Even Pliny believed that comets were terrifying signs, 'punishment' that was difficult to avoid: "It is thought that their influence depends on the region they rush across; the strength of which star they absorb; what objects they look like; and where they appear. If they appear like flutes, they are related to music; but to obscene matters when they appear in the private parts of the constellations; to understanding and learning if they form 3- or 4-sided equiangular figures with nearby fixed stars; to the making of poisons when they appear in the head of the northern or southern Serpent."

The Comet Egg

A particularly absurd product of cometary beliefs even involved the Paris Academy of Sciences: In Rome, on 11 November, according to later reports on 2 December 1680, a hen, which had never before laid an egg, had 'with great noise' laid an egg that carried a comet-like design – just at the time when the Great Comet of 1680 stretched across the sky.

Because it was calculated that the 'wonder' had appeared at the seat of the Pope, the Protestant pamphleteers, in particular, saw it as an urgent warning to Catholics to renounce their old-fashioned beliefs. It was thus eagerly taken up and widely depicted. Even in Paris, this grotesque idea was accepted even though it was explained scientifically that it was in no way to be taken as a likeness of the comet – nevertheless people in France widely viewed hens as cometary prophets. The event recurred just two years later, when a hen in Marburg laid a 'comet egg' at the return of Halley's Comet.

A contemporary representation of the 'comet egg' and its source.

The rulers' court astronomers, however, did look for positive indications from comets, because it was not always clear whether comets should be considered part of, or a disturbance of, the divine order. Seneca, in his *Naturales questiones* opposed the interpretation of comets as presages of disaster. He viewed them as part of the divine order, that could not be understood by humans.

In most other cultures around the world, occurrences of comets were interpreted as negative signs. Independently of one another, the celestial appearances were linked to drought, enemies, illness and death.

The Australian aborigines, for example, became worried at the appearance of a comet. It was seen as a bad sign that might portend death, malevolent spirits or evil magic. The New Zealand Maoris called comets 'Auahi-roa' or 'Auahi-turoa', which meant 'long smoke'. Among the Aztecs, too, who called them 'citalinpopoca' ('smoking stars'), comets were taken as a sign of disaster. Allegedly, a comet appeared in 1517 or 1519 before the Spanish invasion. It was, however, initially interpreted as a portent of the fall of the Aztec culture.

The Christian fear of comets

Based on astrological tradition, as well as the belief in portents that were held in antiquity, towards the end of the Middle Ages an interpretation of comets developed that was based on Christianity. Calling on biblical references, comets were interpreted as a sign from God of the imminent end of the world. In the Gospel according to Luke, we have: "... there will be great earthquakes, and famines and plagues in many places; in the sky terrors and great portents." (Luke 21:11) And in the Revelations of John there are suggestions of comets in the description of the end of the world: "... and a great star shot from the sky, flaming like a torch ..." (Revelations, 8:10).

In the sixteenth century, driven by the discovery of printing and the increasing literacy of the general public, the peak of Christian cometary literature occurred. Tidings of new comets in the sky were distributed on broadsheets and pamphlets, most equally accompanied by a scriptural interpretation. These news items fell on fertile soil at a time of turmoil and many changes, shaped by the Reformation and the discovery of America. They also reflected the increasing curiosity about phenomena in the heavens, after the 'Dark' period of the Middle Ages. However, the foundation for the comet literature was still the heliocentric Aristotelian/Ptolemaic System, in which a comet was interpreted as a short-term disturbance of the unchanging heavenly spheres, and as such a special sign.

In German-speaking countries, the broadsheets were, in general, printed in the great evangelical centres such as Nuremberg, Augsburg, Leipzig and Frankfurt. The authors, frequently priests, gained their living partially from the distribution of these writings, which offered excellent possible earnings for little expenditure. In most ca-

A German coin showing the Great Comet of 1618.
Obverse (*left*): The threat of a comet (around rim); A sign will appear: Lu(ke) 21 (beneath image).
Reverse (*right*): God grant that the Comet star may teach us to better our lives.

Astrological comet types

Pliny had already developed a classification scheme that was employed until well into modern times. According to Girolamo Cardano there were various types, from the appearance of which one could derive the consequences on Earth:

- Vera: This is very long and thin, accompanies the Sun, is terrible and is a mixture of the natures of Saturn and Mercury; it destroys crops and states and kills noblemen and princes.

- Coenaculum: Another is very large, long and broad, and is of the nature of the Moon and signifies general evil.

- Pertica: The third is large and very long (like the first), but not as wide (as the second). Both of these two have their tails directed away from the Sun, but the third has a thick, dense and rounded tail and signifies a shortage of water and infertility. If it is also linked to Saturn, then deaths follow among the general populace and among old people; if with Jupiter, they will be among rulers and high priests; with Mars, great wars and many deaths; with the Sun, famous rulers will be struck; with Venus, great drought and infertility; with Mercury, deaths by mysterious means or secret acts; with the Moon, deaths among the general populace. It is like the nature of Mars with the Sun or Mercury.

- Miles: The fourth has a great brilliance like the Moon and affects the whole Zodiac through which it passes, and it signifies the formation of sects and parties. It has the nature of Venus and also means great drought and infertility and affects the female sex and those of youthful age.

- Asconas: The fifth is unprepossessing, of the colour of the sky, with a long tail and is of the nature of Mercury. It signifies war, the death of outstanding men, serious illnesses and, similarly, treachery and violence, bad times, denunciations and similar ills.

- Aurora: The sixth is red and has a long red tail, but not so great as the fifth (Asconas) and is of the nature of Mars and signifies heat and drought, famine, war, conflagrations, and generally applies in the hot regions.

- Argentum: The seventh is like pure silver, it flashes so much that it may be seen with the eye only with great difficulty. It is of the nature of Jupiter and means changes in reigns and in public life, which are good, but which are linked to great confusion, and its size signifies rich harvest and foodstuffs, mighty winds and a healthy composition of the air.

- Rosa: The ninth is also large and fashioned like a man, and its colour is a mixture of the sixth (Aurora) and the seventh (Argentum). It signifies the death of noblemen and the mighty, changes for the better and is of the nature of the Sun. And if comets appear at a great solar eclipse, then they very particularly signify strange consequences.

ses, the observational report was accompanied by a biblical quotation, followed by an interpretation of the phenomenon. Characteristically, they ended with a call for penance, because these were promoted by evangelical authors, given that Martin Luther saw comets as 'the work of the Devil'. But Catholic sources also fostered anxiety about comets.

The broadsheets catered for the readers' mood in a way similar to modern sensational journalism. So, on the one hand, they fed anxiety over the negative consequences of comets, and on the other, simultaneously, fulfilled the desire for entertainment. In the end, curiosity about the meaning of inexplicable events was also satisfied. According to circumstances, however, a mixture of scriptural and astrological interpretations was also present, if they fitted in with the author's conception of the world.

On the broadsheets, comets were described as 'the scourges of punishment' or 'torches of wrath'. They were a sign from God to Man and required penance and changing one's ways. David Herlitz, one of the most active authors of the broadsheets, wrote in 1619: "So this comet is like an obvious sign that Almighty God has displayed or revealed, in which He shows us the scourge and the threat of his wrath, with which He will strike all those that do not perform a true penance, and whom he will cast into the Fire." Other signs in the sky such as fireballs, halo phenomena and polar aurorae were similarly viewed. Cometary apparitions, however, remained the most significant signs, because they appear to everyone at the same time and are visible for a few days or weeks. Alongside the broadsheets, cometary sermons were delivered and peals of bells were sounded, to assuage God's wrath.

Astrological (*top*) and Christian (*bottom*) themes regarding fear of comets. Whereas astrology saw in a comet itself the cause of a disaster, in the Christian interpretation it was taken with other celestial signs as a warning of the approaching Apocalypse. *S. Lubinietzky (top), Anonymous (bottom)*

The peak of Christian fears focussed on comets in Germany was reached at the time of the Thirty Years' War. Three bright comets were in the sky in the year it began, 1618. They were initially seen as a sign of the defeat of the opposing side, and only after the war were they taken as a portent for the war as a whole.

In the second half of the seventeenth century, comets were strongly regarded as omens of new evils. After 1577 and 1618, the great comets of 1664 and 1680 produced a major response. In this, the troubled times played a large part, such that it was claimed that the danger from the invading Turks was indicated by comets. In the broadsheets, comets were often depicted in the form of a scimitar. In 1680 the Great Comet hung over the besieged city of Vienna. It was alternately taken at a sign of the downfall of the Ottomans or the menacing danger of war, which could be lifted by penance and amendment. Even extraordinary phenomena such as the appearance of a hen's egg that showed the image of a comet, were seen in the light of a Christian interpretation.

It was not until the eighteenth century that these publications about such marvels came to an end, thanks to the results of astronomical research, which increasingly unlocked the nature of these mysterious comets. By the predicted return of Halley's Comet in 1759, they had largely died out.

Early modern astrological interpretations

Cometary astrology, based on Ptolemy's *Tetrabiblos* reached a peak in early modern times. The view was widespread that comets signified a change, which was dependent on the constellations in which they appeared and through which they passed. The interpretations were thus similar to those concerning the planets. Classification depended on their colour or the star near which they were discovered. Red comets were particularly popular, which were identified with Mars, or comets with dark, yellowish tails, which were identified with Saturn. Individual cometary phenomena had particular influence on countries that were ruled by the corresponding zodiacal sign.

Factors of astrological significance:

- *magnitudo*: the brighter a comet, the greater its effects
- *color*: an indication of the corresponding planet
- *splendor*: the greater its brightness, the greater its effects
- *forma*: the shape of the comet according to Pliny
- *diuturnitas*: the duration of visibility would be crucial for the duration of its effects, consequently various conversion factors were given
- *locus*: the constellation in which the comet appeared. Earth signs led to drought; water signs to floods; air signs signified revolts; and fire signs war
- *motus*: the direction and velocity of the comet indicated the regions affected
- *habitus ad solem*: the position of the comet relative to the Sun indicated the start of its effects: these arrived quickly with comets to the east of the Sun, and slowly for those west of the Sun
- *situs orbi*: the projection of the comet's path onto the Earth indicated the regions affected

Kepler, who alongside his pioneering astronomical discoveries, also practised as an astrologer, summarized the multitude of factors involved: "standstill or velocity; location of the tail; colour; brightness or darkness; an orderly or irregular motion; how and also from which heavenly house or sign it emerges; whither it is headed; where it vanishes; which constellations were at its beginning and end; how long it persisted; the locations over which the head passed, and which locations or birth horizons coincide with its path, together with all other such things." Kepler did not see comets as completely deterministic, but rather as a disruption of heavenly harmony. Comets were sent by God. Generally speaking, it could be held that 'Comets, wars, pestilence, price rises, earthquakes, droughts (or on the other hand, floods) commonly arrived together.'

The astrological view contradicted and was openly in conflict with Christian teaching, in which God alone could foreordain fate, and not phenomena in the heavens, and also that a man's actions had an influence on his fate. Nowadays, comets have hardly any significance in astrology. The German astrological portal astrowiki.de states: "The significance of comets as a fascinating heavenly phenomenon is probably greater than their astrological relevance."

Many astrologers, however (even today), view comets as a sign of changes on the personal and political level. Comet Kohoutek in 1974 was linked to the coup d'etat in Chile, for example, as indicated by its discovery in the constellation of Sagittarius. Its influence was also seen as negative for Portugal, because the 'national sign' of Pisces, together with the location of the comet, determined the loss of the colonies. In 1986, Comet Halley was linked to the Chernobyl disaster. With Hale-Bopp in 1997, astrologers drew parallels with Dolly, the cloned sheep.

Modern conspiracy theories

Even after the decline of astrological interpretations and of the belief in marvels, there are still rather daring claims made about comets. In 1773, for example, there was a mass panic in Paris, after the rumour went around that the astronomer Jérôme Lalande had predicted the impact of a comet in a talk that he gave. In 1910, there was panic and suicides when the Earth passed through the tail of Comet Halley, and the cyanide compounds that had been discovered in it shortly before were thought to be likely to kill people. And, sadly, it is still fresh in our memory with the mass suicide of members of the Heaven's Gate sect, who interpreted Comet Hale-Bopp as the divine vehicle to carry them to the beyond, after American conspiracy fanatics maintained that the comet was being followed by a Saturn-like spaceship, shown on photographs – however, this was simply a diffraction effect caused by the optics that were used.

Comets in art

In contrast to the popular perception by which the appearances of bright comets were particularly significantly regarded in all ages, when it comes to comets as a motif in the visual arts, they appear only occasionally. This apparent contradiction is based on the clear restriction of their role as harbingers of disaster and portents, by which comets were regarded until early modern times. Their significance as negative signs was so strong that they could not be represented in any other context.

Back in antiquity, comets were not shown in art, being firmly linked, in iconological terms, to astrology. The few representations of comets were stylized images on coins that were struck at the death of Julius Caesar. Other rulers also had coins struck with comets as a motif.

The Middle Ages

In the Middle Ages, comets, because of their negative connotations, were excluded from art. In particular, they could not be employed to symbolize the Star of Bethlehem. In many sources the few representations of the Star of Bethlehem as a comet were condemned, despite it not being possible to substantiate this assertion. Among these representations is one on an ivory panel on the throne of Maximian, Bishop of Ravenna, dated to the years 540–545 AD. There, a very stylized representation of the Star may be seen above the scene of Christ's birth. It looks more like a flower than a comet. Because the 'tail' is also an apparent ornament on other panels, and the connotation associated with a cometary subject contradicts the intended significance, we can be fairly certain that a comet is not intentionally depicted here.

A similar case applies to the set of mosaics by Pietro Cavallini (1250–1330) in the church of Santa Maria at Trastevere (in Rome), which have been dated to 1291. Here the Star is depicted with three rays pointing towards the Christ-child. This is probably intended as a symbol of the Trinity. Because rays around stars in paintings from the Middle Ages should not be taken as physical features, but instead have an iconographical significance, again this should not be seen as the image of a comet.

The famous depiction of Halley's Comet on the Bayeux Tapestry, which has been dated to 1291, should be seen in a quite different light. The Tapestry, 70 m long and 50 cm wide, illustrates events surrounding the Battle of Hastings in 1066, when the Norman, William the Conqueror, wrested the English throne from the Anglo-Saxon

◀ A Roman denarius with the image of the Emperor Augustus and a depiction of the comet of 44 BC, symbolic of the divinity of the Julian family.

▼ The Bayeux Tapestry (detail) with the representation of Halley's Comet of 1066 (*left*). In contrast to this the star shown on the Maximian Throne in Ravenna is nothing like a comet (*right*).

king, Harold. A highly stylized comet is depicted on the join between panels 32 and 33, representing Harold's downfall. The inscription above reads "Isti mirant stella" ('they marvel at the star'). The representation of the comet is notable, because there is a gap between the head and the tail. Is this showing one of Comet Halley's typical breaks in the tail? (See, for example, the photos on page 182.)

The first true, not stylized, representation of a comet is found in the famous fresco Adoration of the Magi by Giotto di Bondone (1266–1337), which forms part of the decoration of the Arena Chapel (Cappella degli Scrovegni) in Padua. It has been dated to 1303–1306. Giotto is rightly regarded as the person who revived the art of painting. For the first time he showed the Star of Bethlehem as a comet. The comet is shown with naturalistic features, which may be ascribed to Giotto's own observation of Halley's Comet in 1301. This representation contradicted the biblical interpretation as a 'good star', because comets were seen as bad omens. A copy of this scene, also with the depiction of a comet, is found in the church of St Francis in Assisi. The scene of the Nativity (or the Adoration) was reproduced here in 1315.

Halley's Comet in 1456, a tempura miniature illustration from the *Lucerne Chronicle*, 1507–13. *Diebold Schilling*

Early modern times

One of the few additional works of religious art that depicts a link with comets is the oil painting The Birth of Christ by Hans Baldung (a.k.a. Hans Baldung Grien, 1484–1545). This shows a stylized small comet above the thatched roof of the Nativity's stable. The tail points towards the Christ-child's head. This representation definitely originated as a result of the influence of the Great Comet of 1471. The oil painting The Flight from Egypt in the Schottenkirche in Vienna, by some unknown master, dates from the same period. This depicts another naturalistic representation, which is probably also related to the Great Comet of 1471.

This is in contrast to the ordinary artistic depiction of comets. One of the most famous works is Melencolia I of 1514 by Albrecht Dürer (1484–1545). Dürer adhered closely to the astrological interpretation current in his time. According to this, melancholy was a property of Saturn. The comet in the background is exemplary in showing its connection to that planet. It is thus rather pale and hangs above the sea, which symbolizes the water sign ruled over by Saturn. Its location under the rainbow, however, refers to Christianity's superiority to astrology. In addition, Dürer depicted the comet in a stylized manner.

At about this period between 1507 and 1513, tempera miniatures appeared in the *Lucerne Chronicle*, painted by Diebold Schilling (c. 1460—1515). These harked back to the *Nuremberg Chronicle*, which depicted the comet of 1471 (although in popular form), and showed four differing images with comets. They depicted cometary phenomena for 1400 (the image shows the crusade against the Turks in 1394 as well as the outbreak of the plague); for 1456 (the earthquake at Naples is shown and a rain of blood over Rome, with the birth of monstrosities being additionally shown in the foreground); for 1471 (the theme here is drought and war, with the depiction of a funeral procession); and for 1506 (floods, landslides and ruined harvests are shown). The depiction of the comets is stylized, but at the same time very imaginative. The tails always point down towards the ground, to emphasize the link with the Earthly events below. All link comets with negative events. In Schilling's drawings we can see the rendering of popular beliefs and a precursor of the later comet broadsheets.

These arose with the introduction of printing towards the end of the fifteenth century. The appearances of bright comets were turned into a sort of sensational literature, with astrological or Christian significance. On them, comets were more-or-less stylized or distorted as a sword or 'scourge of God', to convey this message. Comets also gained popularity as a typical theme for depictions of the Apocalypse and in the iconology of vanity. As a result, they are hardly ever found in any other setting in art from the fifteenth to the eight-

▶ The Adoration of the Magi, a fresco in the Arena Chapel in Padua, 1303–06. *Giotto di Bondone*

The Comet of 1680 over Rotterdam. Oil painting, 1681. *Lieve Verschuier*

eenth centuries, and were, in addition, not suitable for the subject of the Star of Bethlehem in the religious context. These broadsheets persisted until the middle of the eighteenth century. From this period on, the accuracy of the depictions of cometary form increased and, simultaneously, stylization decreased.

Comet. Oil painting, c. 1711. *Donato Creti*

The Enlightenment and Romantic periods

From the second half of the seventeenth century, in parallel with the scientific discoveries, the topic of comets broke free from its astrological significance. In the oil painting of the Great Comet of 1680 over Rotterdam by Lieve Verschuier (1634–1686), there is no longer any symbolic content in the foreground, but rather an impression of the celestial phenomenon itself. Curiosity about the comet predominates rather than fear. The observers in the foreground are holding cross-staffs, which were used for the determination of astronomical positions – a symbolic indication of comets as celestial bodies subject to scientific examination. Verschuier's painting is not an exact reproduction, however, but a form of summary of features that the comet showed at various times. They were subsequently reproduced in the painting.

In an oil painting, produced in 1711, by Donato Creti (1671–1749), a remnant of the fear of comets is seen in the demeanour of the woman in the foreground. Otherwise there is rather a relaxed feeling to the painting. This work cannot be ascribed to any particular comet.

From the eighteenth century, the treatment of comets in caricatures is observed. Commercial artists used this form of image, above all, to make fun of political events. Such images were sold in some shops, and at festivities and meetings. Comets thus served simply as a symbol for a political context, in particular in connection with Napoleon, where the classical meaning of comets was employed ironically, with the comet predicting his downfall. The Great Comet of 1811, however, served as a motif of its own. Some caricaturists used it to poke fun at comet hysteria. The publication of caricatures continued for the comets of 1842 and 1858, but at the same time, with the appearance of widespread copying, they assumed a rather romanticized form. The

▲ Melencolia I. Engraving, 1514. *Albrecht Dürer*

▲ Donati's Comet on 5 October 1858. Watercolour, 1858. *William Turner of Oxford*

◀ Donati's Comet. Watercolour, 1858. *Unknown Artist*

▲ Pegwell Bay, 5 October 1858. Oil painting, 1858. *William Dyce*

▶ Donati's Comet over Dartmoor (detail). Water-colour, 1859. *Samuel Palmer*

Three typical caricatures from the 'comet-mad' nineteenth century. *Anonymous (top left), Honoré Daumier (top right), Thomas Rowlandson (bottom)*

satirical postcards of the 'end of the world' on the occasion of the 1910 return of Halley's Comet, however, revived this tradition.

Donati's Comet of 1858, which must be numbered amongst the most beautiful comets in history, and which was visible for a long time, was adopted as a favourite motif by the Romantic movement. In the watercolour by William Turner of Oxford (1775–1851) the comet is in the very centre of the depiction, and the foreground serves merely as a frame for the phenomenon. In the watercolour of the comet by Samuel Palmer (1805–1881), which was painted in 1859, the comet is depicted in a particularly romantic setting over the hills of Dartmoor. Palmer prepared the sketch for his painting on 5 October 1858. The position of the star Arcturus is, in contrast to the rather stylistic sky shown by William Turner, very accurately reproduced.

William Dyce (1806–1864) set Donati's Comet over Pegwell Bay in southeast England in his oil painting. The almost photographic reproduction in the Pre-Raphaelite style, shows the link between the foreground (stooping, individual women) in contrast to the massive background (weathered cliffs) as a metaphor for life's perils. The pale comet above the scene serves as a symbol of the extrater-

restrial forces in the sky that drive fate that cannot be influenced by human beings.

Modern times

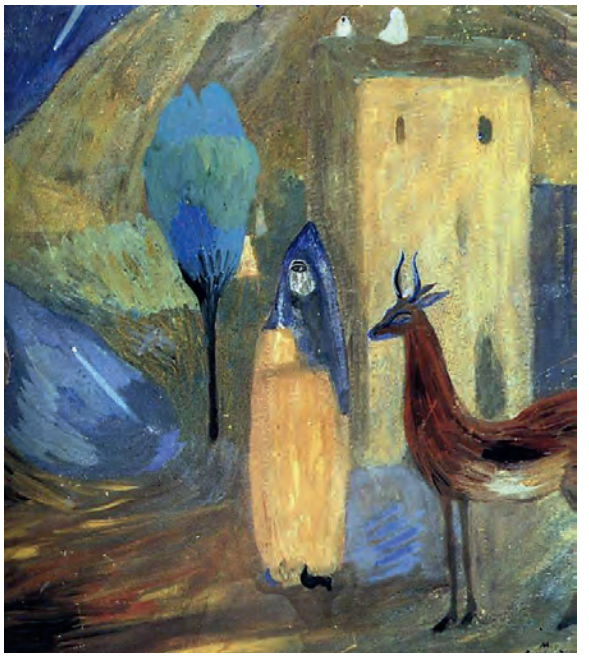
From the beginning of the twentieth century, representations of comets increasingly diverged from one another. The less the motif of comets was seen in astrological or romantic terms, the more freely images could be employed. Painting thus became ever more individualistic.

A wave of comet pictures comparable with that caused by Donati's Comet in 1858 was unleashed by Halley's Comet in 1910. This fell on fertile ground with the early Expressionists. In his painting Comet, Vassily Kandinsky (1866–1944) showed a bright yellow tail over seemingly Christmas scenery, whereas the Armenian Martiros Sarjan (1880–1972) created something reminiscent of an oriental/magical landscape, in which the motif also appears in a reflection. The Ukrainian painter Georgii Narbut (1886–1920), in contrast, depicted a cold Art Nouveau landscape, in which the bright comet appears almost threatening, whereas with Walter Ophey (1881–1930) the theme dissolves entirely into individual points of light.

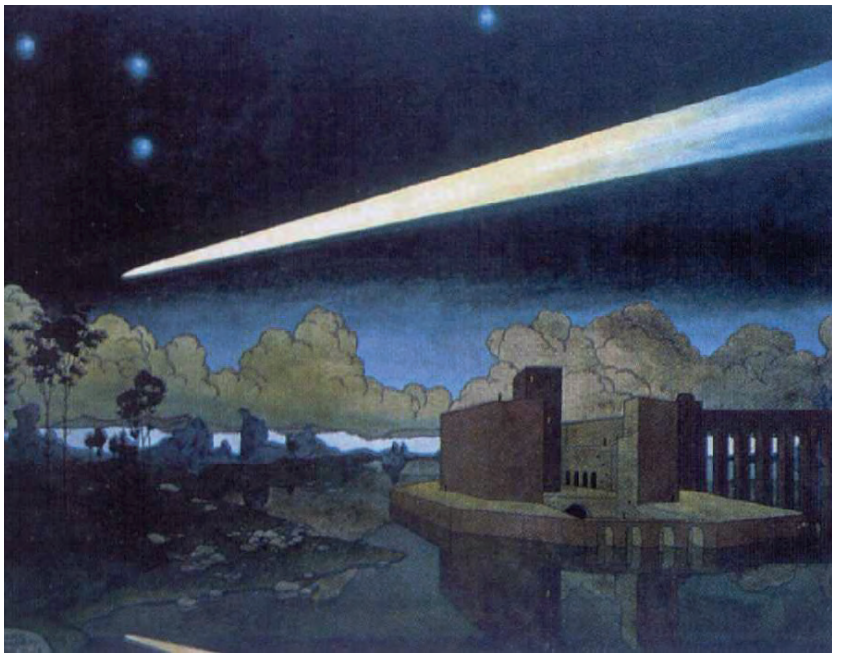
▲ Comet. Watercolour and gold bronze powder, 1900. *Vassily Kandinsky*

▶ Comet. Oil painting, 1910. *Walter Ophey*

▼ Comet. 1907. *Martiros Sarjan*



▼ Landscape with comet. 1910. *Georgii Narbut*



Comets in literature and poetry

Just as in art, for a long time the comet motif in literature was bound up with negative astrological meaning. Only with the Enlightenment did it become possible to employ comets in a metaphorical sense in other contexts. Since the second half of the nineteenth century, comets have been a central motif in science fiction.

Early modern times

"When beggars die there are no comets seen / the heavens themselves blaze forth the death of princes." This famous verse from the second act of Shakespeare's tragedy 'Julius Caesar' dates from 1599. Shakespeare compressed the entire literary role of comets into one sentence, which he put into the mouth of Calpurnia, Caesar's wife. The statement is quite in accord with the ancient astrological interpretation.

Until well into the eighteenth century, it was no different in German-speaking countries. Among many similar tales, the 'Kometspiegel' ('Comet mirror') of Thomas Hartmann, written in Halle in 1606, has become famous, and which, in a mixture of Christian fear of comets and astrological interpretation, lists the threats to mankind posed by a comet:

"All comets indeed give evidence / of a lot of bad luck, affliction, peril and danger / and a comet never appears / to be cares without evil meaning / in general eight kinds of affliction occur / when a comet burns in the air:

1) Much fever, illness, pestilence and death,
2) Difficult times, shortages and famine,
3) Great heat, droughts and infertility,
4) War, rapine, fires, murder, riots, envy, hatred and strife,
5) Frost, cold, storms, weather and lack of water,
6) Great increase in people going into decline and death,
7) Conflagrations and earthquakes in many places,
8) Great changes in government.

But for us to do penance from the heart, God afflicts us with disasters and pains."

The Enlightenment and Romanticism

About the middle of the eighteenth century, in parallel with the scientific revelations about comets, the literary point of view also changed. Authors during the Enlightenment discovered comets as an ideal motif. First, however, they had to be freed from the astrological restrictions. In 1742, the French philosopher Pierre Louis Moreau de Maupertuis wrote that "these stars, after having been the world's terror for a long time, have suddenly become discredited, so that they are able to cause no more than a cold in the head."

August Wilhelm Iffand (1759–1814), in his farce 'The Comet' likewise dealt with the overwhelming fear of comets. In a comical fashion this recounts how a charlatan, who as a result of the supposed end of the world threatened by a comet, attempts to gain material and personal advantages, until his fraud is finally exposed in a humiliating and hilarious scene.

Comet Flaugergues of 1811 was immortalized in the famous novel War and Peace by Leo Tolstoy (1828–1910). In it, Pierre, one of the two main characters, sees it "Above the dirty, ill-lit streets, above the black roofs, stretched the dark starry sky. ... Almost in the centre of it, above the Prechistenka Boulevard, surrounded and sprinkled on all sides by stars but distinguished from them all by its nearness to the earth, its white light, and its long uplifted tail, shone the enormous and brilliant comet of 1812 – the comet which was said to portend all kinds of woes and the end of the world." To Pierre, however, the sight, 'invigorated and strengthened' him: "joyfully, he gazed at this bright comet." However, the Russian author got the year wrong, because by 1812 Comet Flaugergues was no longer visible to the naked eye!

Science fiction

Edgar Allan Poe (1809–1849) did not live long enough to experience the brightest comets of the nineteenth century. In the *Conversation of Eiros and Charmion* (1839), the American author was inspired by the end-of-the-world mood of the Adventists in the USA in the 1830s. In it, two dead people discuss the end of the world, which has been caused by a comet that has poisoned the Earth's atmosphere.

Jules Verne (1828–1905) in the story *Hector Servadac* (published in English as *Off on a Comet*) used a comet as a vehicle for his protagonists. The tail, which brushed the Earth, carries various people away with it, and carries them on a tour of the Solar System. Jules Verne's comet 'Gallia' consists, remarkably, of metals – a large fraction being gold – and has active volcanoes. The space-tourists land safely, using two air-balloons, when the comet returns to Earth.

In the novel *In the Days of the Comet* by H.G. Wells (1866–1946), the tail of a comet causes humanity to be 'exalted' into a utopian, peaceful community without property. The author's predictions are amazing; he both foreshadows the forthcoming First World War, as well as the passage of the Earth through the tail of Halley's Comet in 1910. A similar theme is adopted by the German author Hannes Stein, in his German-language book of 2013, *Der Komet*, he describes a world without the catastrophes of the twentieth century.

Nowadays, apocalyptic scenarios involving the impact of a comet are popular. This is reflected by the numerous films on the topic such as the 1998 Hollywood blockbusters *Deep Impact* and *Armageddon*.

Comets in science

Fifteenth and sixteenth centuries

For centuries the nature of comets was not a matter for consideration. Astrological theory was too strongly entrenched. It was only at the beginning of modern times that the fundamental question came to be posed: "Are comets meteorological or astronomical phenomena?" "Are they sublunar, being situated under the Moon, or are they supralunar, lying beyond it?"

These questions should have been answered by the determination of the distance of comets. The principle of distance determination rests on parallax, that is, on the apparent spatial shift in the positions of comets in front of a more distant background (the starry sky), based on viewing the comet from different angles. If comets were closer than the Moon, as Aristotelian doctrine held, then when comets were viewed from two different locations they should appear at different positions on the sky. Similarly, parallax should have been detected with observations from a single, fixed position over a period of some hours, if the comet were closer to the observer than the whole firmament, which was rotating around the Earth.

Before the discovery of the telescope in 1610, people tried to determine the positions of comets with the naked eye. In the Middle Ages, the instruments available were the torquetum and the cross-staff (or Jacob's staff). In early modern times, quadrants were also used, and the larger they were, the more accurate their determinations of positions. Astrolabes and armillary spheres were also employed.

The Italian geographer Paolo Toscanelli (1397–1482), famous for his (inaccurate) chart of the Atlantic Ocean that led Columbus to believe that a shorter route to India lay to the west, was one of the first people to determine the positions of comets. He followed six comets between 1433 and 1472 and recorded their motions across the sky. His notes were not rediscovered until the nineteenth century.

The Austrian astronomer Georg von Peuerbach (1423–1461), was the first to undertake an attempt to determine parallax with Comet Halley in 1456. Because of the shift in the position of the comet relative to the stars over a few weeks, he came to the conclusion that the parallax was less than that of the Moon, and thus that the comet was more distant than the Moon. The method used by Peuerbach was very inaccurate, because the proper motion of the comet itself was not taken into account. The actual parallax of most comets was not capable of being determined with contemporary methods.

The mathematician and astronomer Johannes Müller, known as Regiomontanus (1436–1476), born in Königsberg in Franconia (now Bavaria), a pupil of Peuerbach's, refined the method of determining the parallax of comets. However, he also neglected the comets' proper motion and was therefore only able to give imprecise details, which left open the question of the sub- or supralunar location.

In 1531, Peter Bienewitz, known as Apian (1495–1552), found, following position determinations of Halley's Comet and subsequent comets, that cometary tails are always directed away from the Sun. Apian was famous for the *Astronomicum Caesareum*, a monumental work on astronomy that he published and printed himself.

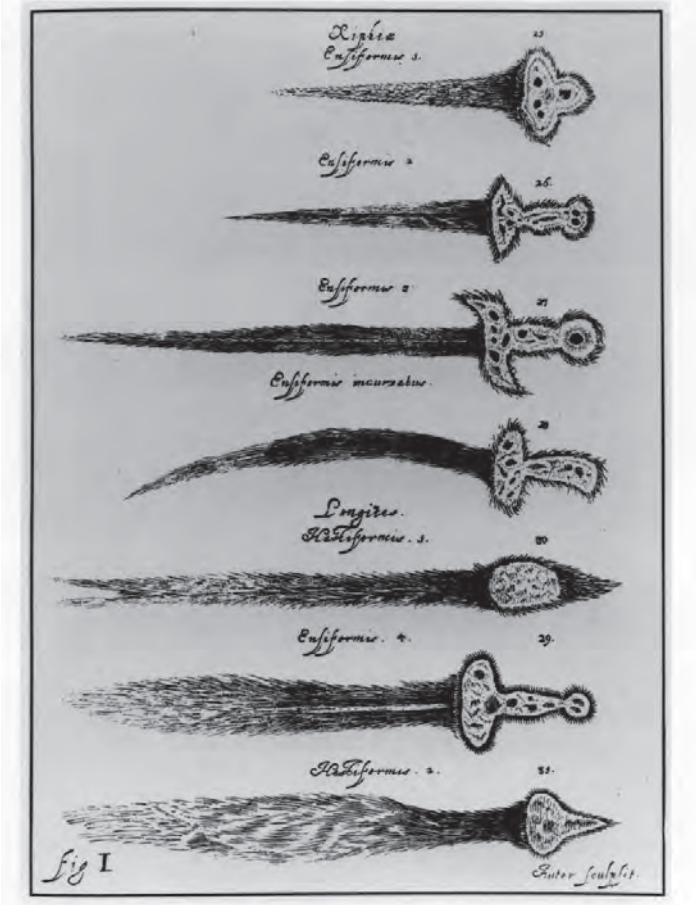
The Italian astronomer and astrologer Girolamo Cardano (1501–1576) compared the rate at which Comet Halley 1531 and another comet of 1532 moved, with that of the Moon and found them less. Consequently, he located the comets in the supralunar sphere. Cardano believed that comets were in the shape of a lens and were illuminated by the Sun, with the tail being formed by the optical effect of the lens. Cardano is also known for his horoscope of Jesus, for which he was taken into custody by the Inquisition in 1570.

The Danish astronomer Tycho Brahe (1546–1601), famous for his accurate determinations of position, followed the Great Comet of 1577 and obtained the longest and most accurate series of positions secured up to that time. He succeeded in determining the parallax of the comet over a period of three hours, as did Thaddaeus Hagecius (Tadeáš Hájek, 1525–1600) in Prague and Cornelius Gemma (1535–1578) in Leuven. Tycho obtained an angle of 15' as a maximum, and concluded that the comet had to be at least 230 Earth radii distant. He also rejected Copernican theory and believed in a mixed geocentric/heliocentric universe. He accepted an oval heliocentric orbit for the comet. Like many of his contemporaries, however, he also believed in its astrological significance.

The Schwabian theologian and mathematician Michael Mästlin (1550–1631), a student of Apian's son, Philipp (1531–1589), also followed the Great Comet of 1577 and was unable to determine any perceptible parallax. As a result he viewed it as being a celestial object and calculated a circular heliocentric orbit. So at the end of the sixteenth century, the view became established that comets, like the planets, lay beyond the Moon.

The seventeenth century

Previously, straight-line or circular orbits were taken as the starting point for comet movements. During the course of the seventeenth century, however, it was realised that this approach could not describe the motion of comets on the sky. The newly invented telescope was of assistance in this. However, the often poor optical quality did not really allow any detailed ideas about the appearance of comets to be obtained.



Johannes Kepler (1572–1630), who revolutionized understanding of the orbital motions of the planets, had difficulty in describing cometary orbits. He observed Halley's Comet of 1607 and, a little later, was one of the first to undertake telescopic observations of comets. He published a study *De Cometis Libellis Tres* in 1618, in which he took straight-line cometary orbits as his starting point – in contrast to the elliptical 'Keplerian' orbits of the planets. His conclusions were based on inadequate determinations of position, whereas his deciphering of the motion of the planets had been assisted by the precise position determinations by Tycho Brahe.

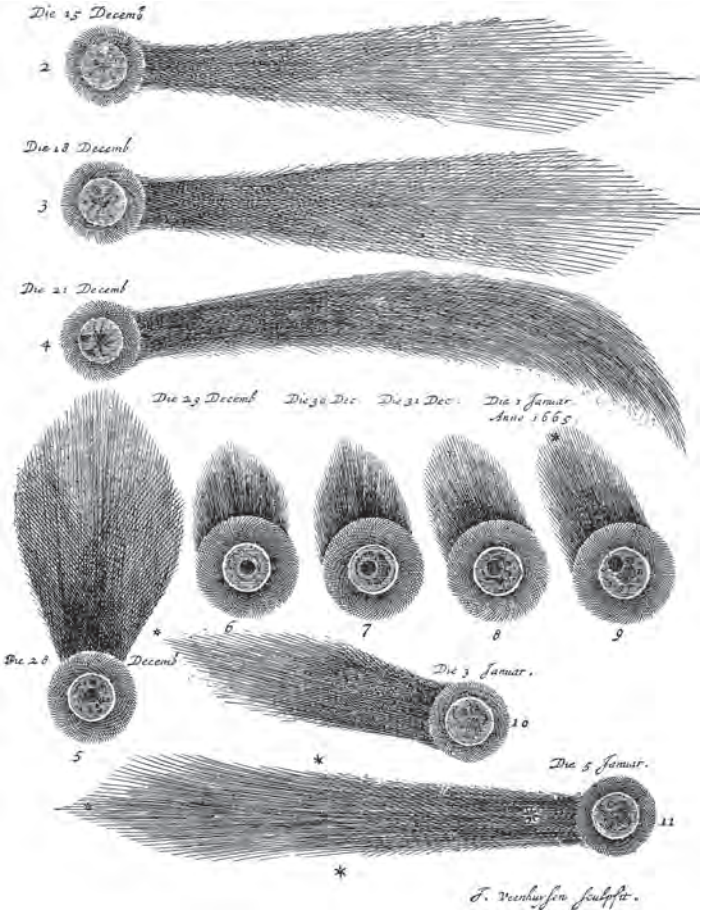
In the interpretation of the nature of comets, Kepler was still trapped in the old ways of thought. He believed that comets arose spontaneously out of the 'ether', and were guided by a spirit that was created and disappeared with them. Yet he rightly believed that the tail consisted of cometary particles that were dragged away from the Sun, and that sunlight was reflected from them. Kepler explained the curvature of a comet's tail as the refraction of rays from the Sun. Kepler also produced numerous astrological predictions about comets, and he was convinced that the passage of the Earth through a comet's tail would give rise to poisonous vapours.

Neither was Galileo Galilei (1564–1642), the 'father of observational astronomy', able to make any sense of comets. He thought that comets moved at right-angles to the surface of the Earth – but this could be due to the fact that most comets were first discovered at or after perihelion, so that only a portion of their orbits was observed. Galileo himself did not propose any theory of his own to explain comets, but was indefatigable in attacking his contemporaries on the subject.

The Danzig brewer and astronomer Johannes Hevelius (1611–1687), in his monumental work *Cometographia* of 1668, discussed comets thoroughly and brought the various theories that previously existed into a single overall picture. His own observations between 1652 and 1665 were included in the work, which also contained a catalogue of historical comets from the Biblical times to 1665. Like Kepler, Hevelius initially adopted a linear motion, but later established that curved paths must be involved, and that comets moved fastest when near the Sun. He took parabolas or hyperbolas as the probable form of orbit.

Hevelius supported the view that comets themselves were disc-shaped and lay at right-angles to the Sun. They arose in the atmospheres of Jupiter and Saturn by the transpiration of vapours – a reflection of the then common view that such vapours were to be found on many heavenly bodies: as spots on the Sun, for example. Hevelius chose Jupiter and Saturn on the basis of the colour of comets. The tail was formed from particles ejected from the core of the comet, and which were then swept away from the head by the Sun.

Title page (*top*) and sample page from *Cometographia*, the most influential tome on cometary astronomy in the seventeenth century. *Johannes Hevelius*



Title page (*top*) and sample page from *Theatrum Cometicum*, the second influential volume on cometary astronomy in the seventeenth century. *Stanislaus Lubinietzky*

At the same time as the work by Hevelius, a masterpiece by another Pole appeared. Lubinietzky was a historian who described in more than 800 pages, in his *Theatrum Cometicum* of 1666–68, the history of 415 comet appearances from antiquity to 1665. Numerous illustrations and charts meant that his book was frequently cited.

The Great Comet of 1680 brought about a considerable advance in cometary research. The German astronomer Gottfried Kirch (1639–1710) discovered it accidentally with a telescope. It was the first comet discovery made in this manner. A theologian from Plauen, Georg Samuel Dörffel (1643–1688) showed that with the comet of 1680, the path could be described by a parabola, with the Sun at the focus. His conclusion was, however, based on just a few position determinations, and it was not an accurate orbital determination. This was provided by Isaac Newton (1643–1727). He initially believed that the comet of 1680 consisted of two separate bodies before and after perihelion, which, moreover, moved on straight-line orbits. However, he rejected this idea years later in his *Principia* (*Philosophiæ Naturalis Principia Mathematica*), when he developed his method of determining orbits. This semi-graphical method allowed him to determine the shape of the orbit and the velocity of the comet from observations that were separated in time.

Newton recognized that the Sun's gravity was the fundamental cause of the motion of comets. He considered comets to be solid bodies that produced vapours because of heating by the Sun, and he explained the curvature of the tail as being caused by the comet's own motion.

Edmond Halley (1656–1742) seized on Newton's method and calculated the orbits of 24 comets seen between 1337 and 1698. In doing so, he discovered that the comets of 1531, 1607 and 1682 followed similar elliptical orbits, and therefore had to be repeated appearances of one and the same body. The differences between the periods which were not precisely equal between apparitions were correctly explained by Halley as caused by Jupiter's gravitational effects. Halley later extended the series of comet apparitions to the comets of 1456, 1380 and 1305. However the last two are incorrect, because Halley's Comet did return in 1378, but was seldom observed.

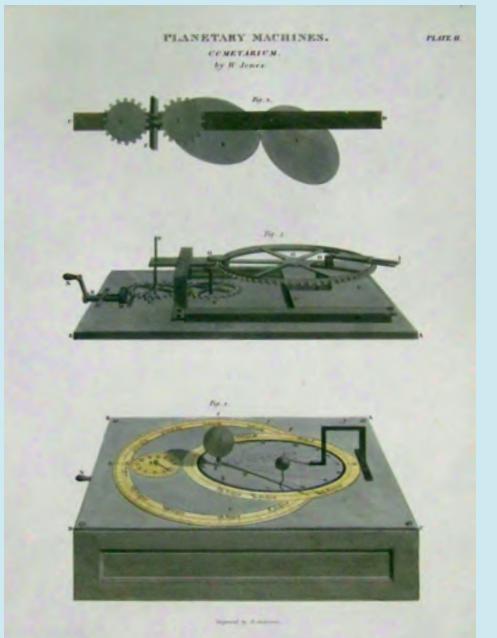
In 1705, Halley predicted a return of this comet for 1758, but later shifted the date to the turn of the year (1758–1759) because of orbital perturbations by Jupiter. In addition, he maintained that there was agreement between the comets of 1532 and 1661. He also determined a return period of 575 years for the comet of 1680, and identified it with comet apparitions in 1106, 531 and 44 BC. Whereas Halley hit the nail on the head with the comet now named after him, the second identification has, however, not proved to be correct.

With his epoch-making identification of the comet appearances of 1531, 1607 and 1682, and his prediction for 1758, Edmond Halley revolutionized cometary research.

The cometarium

People in the eighteenth century were fascinated by the ability to calculate cometary orbits and to predict the apparitions of comets. The path of a comet around the Sun could be visualized with a cometarium, as it was known. This was a mechanical device, which demonstrated the motion of a comet around the Sun, and in particular the faster motion at perihelion. Kepler's Second Law was thus directly visible.

The first such device was described by the French-born, British scientist John Theophilus Desaguliers in 1730, however this depicted the orbit of the planet Mercury. The first mechanism specific for comets was built by Benjamin Martin around 1740. Between 1750 and 1850 many devices appeared, particularly by English manufacturers. Nowadays surviving cometariums are rare collectors' items.



The eighteenth century

The successful prediction of the return of Halley's Comet, thoroughly destroyed all irrational ideas associated with these celestial bodies. Comets were now seen as part of predictable celestial mechanics and as one of the most persuasive examples of Newtonian physics. In the eighteenth century, astronomers made the first deliberate searches for these celestial bodies.

The Swiss mathematician Leonhard Euler (1707–1783) refined the method of orbit determination through the use of what are now known as Euler approximations. Moreover, it was now possible to obtain the orbit of a comet, or another celestial body, from just three positions, at short intervals, with sufficient accuracy to find it again at a later date.

The Frenchman, Charles Messier (1730–1817) was the first astronomer to specifically search for comets. The French king gave him the nickname of 'The ferret of comets'. The trigger for this obsession was the search for Comet Halley that he undertook starting in 1757. The early date that was adopted (when compared with the original date), was based on the erroneous assumption that the period of Halley's Comet was decreasing. In his telescopic search, Messier came across many comet-like nebulous spots in the sky. The confusion of the Crab Nebula, nowadays designated as M1 (Messier 1), with a faint comet, gave him the impetus to compile the Messier Catalogue, which lists the brightest star clusters, nebulae and galaxies, and which is extremely popular among amateur astronomers today. Messier first found Halley's Comet in January 1759, after it had been sighted on 24 December 1758 by the Saxonian 'peasant astronomer' Johann Georg Palitzsch (1723–1788). However, Messier was not put off and went on subsequently to discover 12 comets, among them the Great Comet of 1769, which brought him international fame.

In 1797, Heinrich Wilhelm Olbers (1758–1840) published a practical method of calculating orbits, which is still used. In 1801, Carl Friedrich Gauss (1777–1855) produced yet another method.