

# Introduction to Comets

## Comets and Cometary Concepts in History

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## Foundations of Modern Astronomy

Can be traced to two main factors:

- Advances in general science and understanding that began in the Renaissance, i.e. the few centuries up to the Industrial Revolution;
  - These advances provide a **backdrop** against with to 'read' the literature on comets in the 17th–19th century and earlier;
  - End of the 18th century** as a kind of '**watershed**' between an older pre-scientific view of the natural world, and the modern 'scientific' view'.
- A more or less **continuous** strand of interest in comets and cometary debris, from the earliest times right up to the present day, viz:
  - The physical and societal impact of comets;
  - Comets as **agents of destruction** (catastrophism) versus celestial bodies that convey(ed) **ingredients necessary to sustain 'Life'** on Earth;
  - The **rejection and rediscovery** of cometary catastrophism.

**New paradigm**, namely **Earth in touch** with its **near-space environment**.

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## Why Astronomy?!

Three main strands of interest:

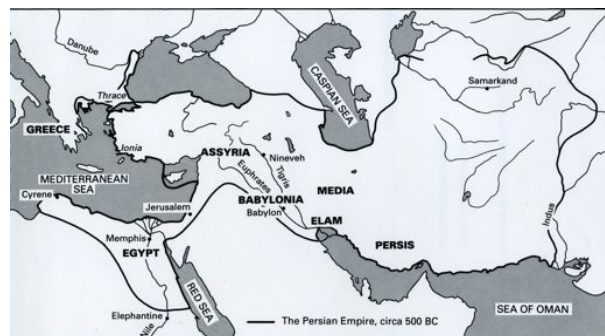
- The broadly cosmological, 'quasi-religious' strand, going back thousands of years — the quest **to understand our 'Origins', Man's place in the Universe etc.**;
- The 'practical' strand, i.e. the commercial, military, and economic 'spin-off' from astronomy, nowadays including education and the arts — e.g. **the calendar; navigation; celestial mechanics; Earth observation; image processing; the 'inspiration of astronomy' and its technical 'spin-off'**;
- The strand of pure science or 'Astrophysics' — the project **to understand the nature, contents and interactions of all the objects in the entire Universe . . .**

We live in a Golden Age, where the three strands have come together in a rare conjunction of activity: hence **unprecedented advances in both observations and theory**, the former almost always leading the latter!

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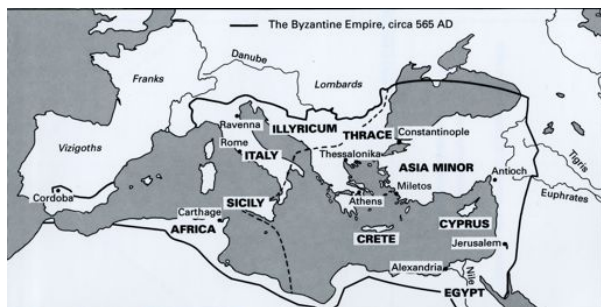
## Cradle of Civilization: Eastern View



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## Cradle of Civilization: Western View



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## Ancient Greek Views: Anaximander's Jets of Fire

- Earth** as a short, squat cylinder three times as wide as long, surrounded by air and floating freely at the centre of the observable Universe in an infinite space.
- Sun, planets, stars** are enclosed circular hoops of fire; they only become visible due to holes in their enclosing hoops, which allow the fiery substance to leak out and become visible. No direct evidence of his thoughts about comets; but note the hoops of fire lie **below** the Sun and Moon.

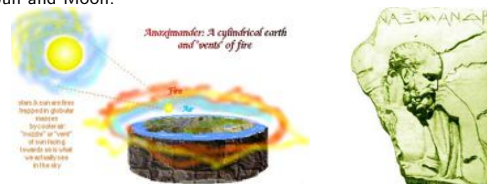


Image credit: Tony Mendes

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## Table of Babylonian/Greek/Roman Theories of Comets

Date	Broad Type	Originator	Brief Description
c.2000 BC	Celestial	Babylonians	Earthy bodies akin to planets
c.2000 BC	Celestial	Babylonians	Fiery celestial phenomena
c.575 BC	Celestial	Anaximander	Jets from fiery celestial hoops
c.550 BC	Atmospheric	Xenophanes	Burning clouds
c.450 BC	Celestial	Anaxagoras	Planetary 'conjunctions' on sky
c.450 BC	Celestial	Pythagoreans	Rare sighting of a planet
c.430 BC	Celestial	Hippocrates	A kind of planet
c.430 BC	Atmospheric	Pythagoreans	Reflected sunlight
c.430 BC	Celestial	Diogenes	Chains of rocky bodies (stars)
c.400 BC	Celestial	Artemidorus	Chains of unseen planets
c.350 BC	Atmospheric	Aristotle	Fiery atmospheric phenomena
c.350 BC	Atmospheric	Heracleides	Reflections from high clouds
c.330 BC	Atmospheric	Metrodorus	Influx of Sun into clouds
c.330 BC	Celestial	Apollonius	Celestial bodies
c.300 BC	Celestial	Zeno	Conjunctions of stars
c.290 BC	Celestial	Strato	Stars enveloped by cloud
c.130 BC	Atmospheric	Panaetius	False images of stars
c.100 BC	Atmospheric	Böethus	Violent, fiery winds
c.50 AD	Celestial	Seneca	Celestial bodies

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## Early Developments of Astronomy

Four broad phases can be identified:

- Judicial Astrology (≈3000–1000 BC)
  - Events in sky self-evidently influence events on Earth.
  - Celestial 'order' transmitted to Earth by sky-gods or deities.
  - ⇒ a powerful 'motive' to **observe** the sky and **interpret** the celestial 'omens'.
  - The sky gods are 'announcing' events on Earth, for example through the appearance of a bright comet or meteor, or by the fall of a meteorite or thunderbolt hurled by the sky-god Jupiter etc.
- Zodiacal Astrology (≈1000–400 BC)
  - A slow transformation from Judicial Astrology to an increasing focus on the important part of the sky associated with the principal sky-gods, i.e. the **Zodiac**.
  - The sky divided into sections, each with a different perceived 'influence' on people or events on Earth.

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### Later Developments of Astronomy

3. Horoscopic Astrology (≈400 BC to ≈1600 AD)
  - ▶ Based on the entirely false premise that wandering stars ('planets') exert a distant controlling influence on human affairs.
    - ▶ Provides an early example of a powerful, but 'magical' scientific concept, i.e. 'action at a distance'.
  - ▶ Motivates careful observations of the planets; their paths against the fixed stars; their periods of revolution etc; all linked to predictions.
    - ▶ Demonstrates growing understanding and an increasingly 'scientific' approach to observations of the natural world;
  - ▶ Nevertheless, the focus on unimportant chance alignments of planets and stars, planetary conjunctions etc. (e.g. 'Star of Bethlehem'), and on the 'random' appearance of an occasional bright comet etc. ultimately proves to be a cul-de-sac for science.
  - ▶ Despite this, the idea of horoscopic astrology has proved remarkably hard to shift: it's still believed by upwards of 25% of the population!
4. Scientific Astronomy (≈1600 AD to present)

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### Comets and Meteors as Omens or Prophecies

1. Precise astronomical observations were the key to prophecies; and the omen literature always took the form "If [astronomical observation] then [terrestrial effect]." E.g., quoted by Bjorkman (*Meteoritics*, 8, 91, 1973): "If a shooting star flashes as bright as a light or as a torch from east to west and disappears on the horizon, then the army of the enemy will be slain in its onslaught"
2. Some early cometary observations are quoted by Olivier (in "Comets", 1930). Thus, on a Babylonian tablet dated around 1140 BC and referring to a military campaign, we read: "a comet arose whose body was bright like the day, while from its luminous body a tail extended, like the sting of a scorpion." And in Diodorus Siculus's account of the expedition of Timoleon (344 BC): "On the departure of the expedition of Timoleon from Corinth to Sicily the gods announced his success and future greatness by an extraordinary prodigy. A burning torch appeared in the heavens for an entire night, and went before the fleet to Sicily."

What could have led to these ideas? Seneca (c.4 BC – 65 AD) gives some insight. Referring to the 'difference' between us Romans and Etruscans, he remarks, "... We believe that lightning is caused by clouds colliding, whereas they believe that clouds collide in order to create lightning. Since they attribute everything to the gods, they are led to believe not that events have a meaning because they have happened, but that they happen in order to express a meaning."

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### Atlantic View: Megalithic Astronomy



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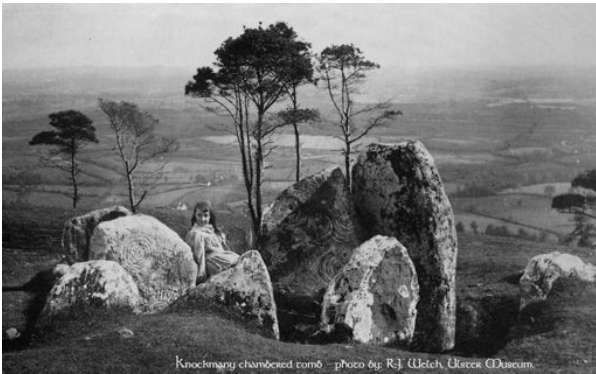
### Rock Art at Knockmany Chambered Tomb, Co. Tyrone



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### View of Knockmany in Nineteenth Century



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### Rock Art and Megalith in Scotland



Megalithic markings on a rock from Traprain Law, Midlothian, Scotland; and the huge megalith at Beacharr, Argyle Peninsula, Scotland

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### Further Examples of Rock Art in UK and Ireland



Distribution of significant rock art in UK and Ireland (after C. Mansell); and examples from Loughcrew, Donegal, Scotland and Northumberland

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### Commonly Occurring Motifs in British Rock Art

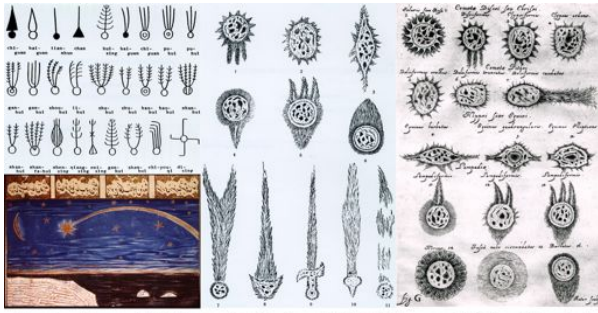


Frequently occurring designs in British rock art. Left: In Argyll, Scotland (after Ronald Morris, 1977). Right: In Northumberland, England (after Stan Beckensall, 1983)

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### Chinese/Greek/Roman Classification of Comets



Cometary forms. Left: Chinese classification c.168 BC (Xi Ze-song, 1984) and Comet of 1577 (M. Dizer, Kandilli Observatory). Centre and Right: Greek and Roman classification schemes for comets (Hevelius 1668)

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### Comet Images from Fifteenth to Nineteenth Century



Halley's Comet (674; from Nuremberg Chronicle 1497); Comet Holmes (1892 November 9/16); Donati's Comet 1858 and Great Comet 1861; and Comet 1527

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### Great Comet of 1910: Drawing versus Photograph



The Great Comet of 1910: drawing by Ellison Hawks and photograph around same time

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### Comets of 1577 and 1995 Hale-Bopp (Two Prints)

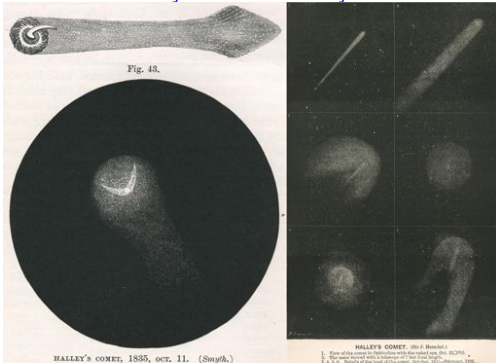


Artistic renditions of two comets drawn 400 years apart: the Great Comet of 1577, and Comet Hale-Bopp produced by S. Farrington in 1997.

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### 17th and 19th-Century Views of Halley's Comet



Halley's Comet in 1683 (Hevelius) and in 1835/36 (Smyth/Herschel)

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### Impacts Occur: 20th Century Examples



Left: The c.10 Mt Tunguska event in Siberia on 1908 June 30 (Kulik), compared with the tree-fall pattern superimposed over London (J. Tate). Right: Sikhote-Alin meteorite (Courtesy Russian Academy of Sciences).

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### Effects of Impacts: Great and Small



Impacts can produce effects ranging from mass-extinctions of life (e.g. K/T boundary c.65 Myr ago) to merely local damage (e.g. Sikhote-Alin meteorite, 1947). They can also lead to new mythology and superstition (e.g. the erection of a totem pole at the Tunguska ground-zero to Agby, the Siberian god who brings fire to the forest).

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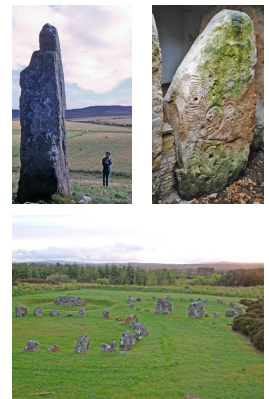
### Short-Term Implications

Ancient societies appear to be obsessed by the sky:

- ▶ e.g. early astronomical interest in 'the sky'; evidence of megalithic monuments/prehistoric 'rock art'.
- ▶ Neugebauer: "... ancient 'astrology' can be much better compared with weather prediction from phenomena observed in the sky than with astrology in the modern sense of the word." Suggests knowledge of direct link between sky and Earth.
- ▶ Consistent with more "activity" in the sky in the distant past.

Suggests that some solar-system phenomena may change on much shorter time-scales than we normally consider possible.

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## Ancient Greek Mysteries

Ancient Greek "mysteries": **Problem of Milky Way ... Zodiacal Light?**

- ▶ **Anaximander**: describes stars as like lighted jets of gas spurting out of a punctured hoop of fire.
- ▶ **Aristotle**: believes the Milky Way to lie in the sublunary zone, a hot accumulation of the disintegration products of many comets.
- ▶ **Anaximander, Parmenides, Leucippus**: the 'stars' lie below the Sun and the Moon.
- ▶ **Metrodorus and Oenopides of Chios**: the Milky Way is the **former** path of the Sun.
- ▶ **Anaximander and Democritus**: the Milky Way lies in the shadow of the Earth.



Image of Milky Way (A. White); Leonid meteor storm; and zodiacal light.

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## Debating Origin of Comets in Mid-17th Century



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## Scientific Advances: Sixteenth Century and Beyond

1. **Aristotelian dogma**: Comets are atmospheric phenomena; the Earth is the centre of the Universe; the Moon, Sun and planets revolve around the Earth, as too do the fixed stars. **The dogma persisted nearly 2000 years.**
2. **Renaissance**: Rediscovery that comet tails always point away from the Sun (Apian et al.). **Showed that comets not totally unpredictable!**
3. **Distance**: Comet of 1577 shown to be at least 6 times farther than Moon (Tycho) — helps to undermine the Aristotelian theory.
4. **Orbits**: Gradual acceptance of heliocentric theory (Copernicus, Galileo) together with Kepler's and Newton's insights into planetary motion leads to new questions about comets. **Are they 'solar system' or 'interstellar' objects; are they 'gravitating'; and what 'risk' do they pose to Earth in its orbit?**
5. **Halley's Comet**: Halley shows that the orbits of the comets seen in 1456, 1531, 1607 and 1682 are closely similar. **Predicts the comet's return in 1759, a prediction confirmed.** Demonstrates that comets are indeed 'gravitating' matter, and at least one has a **periodic orbit**.

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## New Theories for Old: Decline of Catastrophism

18th century sees contrast between an older 'astrological' view, with comets as **portents of doom** potentially disastrous for life on Earth; and a new 'teleological' view developed by Newton and his disciples, with emphasis on the **providential** characteristic of comets. Thus:

1. Comets supply the "**most subtle and active parts of our air, upon which the life of things chiefly depends**" (Pemberton 1728); and comprise a "**pure, elementary fire, of absolute necessity for the life and being of all things**" (Hill 1754).
2. Stars and planets are inhabited by living things, and **comets** — in moving from one stellar system to another — **provide the means by which stars and planets can replenish their day-to-day losses** (Herschel 1790).

In contrast, the older, 'astrological' view persists amongst the general public:



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## "Lines To A Comet" — I (William Carleton c.1835) Unpublished poem inspired by Halley's Comet, 1835

Hail to the **Seraph** glowing  
In burning car through heaven's high concave  
borne  
His youthful **locks** of heavenly light **unshorn**  
In **terrible beauty** flowing  
How rapid through the blue and boundless  
space  
He flashes on his bright careering race!  
His **fiery Seal** of red destruction shewing.

Be dim each trembling star,  
God's dread portentous messenger appears.  
The diadem of glory which he wears  
Shines fearful, fierce and far (Transcends your  
brightness far).  
See from his vengeful hand in ire he hurls  
The fate of empires and the fall of worlds  
**Scattering** around **plague, pestilence and war**.

Allusions to the comet as a member of the highest order of angels; as 'long-haired'; and to the second of the four horses of the apocalypse in the Book of Revelations, the red horse that was given the power (i.e. given with the approval of God) to take peace from the Earth and to make men slay one another by the sword ...

The second verse has further allusions to the *Book of Revelation*, and end-times; to Homer's *Iliad* (The helmet of Achilles shone), rendered by Pope as: "Like the red star, that from his flaming hair; Shakes down diseases, pestilence, and war"; and to Milton's *"Paradise Lost"* as: "Satan stood; Unterrified, and like a Comet burn'd; That fires the length of Ophiuchus huge; in th'Arctick sky, and from its horrid hair; Shakes pestilence and war".

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## Lines To A Comet — II (William Carleton c.1835)

But did death-flag so bright  
**Before** o'er falling empires **ever wave?**  
Gives heaven a sign that man should be a  
slave?  
No it is **freedom's light**  
Streaming on high a signal for the brave  
And shines **not** to destroy mankind **but save**  
Guiding the oppressed to **victory** and right

The tyrant may grow pale  
The light that chains the slave to him in gloom  
'Twas **thy bright beam** that **wrote Belshazzar's**  
doom:

**Angel** of freedom hail!  
When Michael's host with thy first victory  
rung  
**Thine was the Battle-banner** o'er them flung  
**Triumphant** floating on the heavenly gale —

Rembrandt's *Belshazzar's Feast* (c.1635)  
Wikipedia Commons

Allusions to the *periodic* nature of cometary orbits, especially that of P/Halley; introduces the 'Enlightenment' or Newtonian view of comets, i.e. that they are basically benevolent 'angels' that help to sustain life on Earth and all things good ...

The fourth verse returns to catastrophism, the *Book of Revelation* and end-times, e.g. the 'writing on the wall' that foretold Belshazzar's doom, but ultimately all's well with 'good' triumphing over evil.



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## Lines To A Comet — III (William Carleton c.1835)

Then not — Thou art like some **mighty mind**  
That runs a bright irregular career.  
In solitary grandeur **through its sphere**  
Too strong for laws to bind  
Again I hail thee **mystic prince** of night  
**Throwing** so proudly every star of light  
From thy own orb of splendour far behind

Or art though some **great Power**  
Or high **Arch-angel** fallen still in quest  
With **troubled spirit** of thy long lost rest  
Whom awful thoughts devour  
Alas! what splendid misery is thine  
With **ruin'd peace** how brightly dost thou shine  
Though thy fate passed th'irrevocable hour.

Allusions to comets lying beyond the Moon, as in that of 1577, i.e. passing through the 'crystalline spheres'; and to comets as one of three principal celestial bodies (stars, planets, comets) identified by the ancients, i.e. stars, planets and comets ...

The sixth verse returns to the idea of a comet as a fundamentally benevolent being, a member of the highest order of angels — although tragically destined to die and decay



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## Lines To A Comet — IV (William Carleton c.1835)

Thus **Byron** rose and passed;  
**Like thee** along his devious way he shone  
Looking for peace **unhappy and alone**  
His course as bright as fast  
Imagination thinks she still can view  
Where he his parting blaze of glory cast.

The **Eagle** too of **France**  
And terror of a **world Napoleon**  
**Like thee** shook guilty tyrants on their throne  
With **king-dismaying** — compelling glance  
He made of states and kingdoms mighty  
wrecks  
And planted freedom on their prostrate necks  
Shiv'ring their sceptres with his **bolt-like lance**.

The personification of the comet; allusions to a 'meteoric', but ultimately troubled, career

Finally comets signify changes in world order, exemplified by Napoleon's belief that the comet of 1811 presaged success in his invasion of Russia (when it arguably had the opposite effect!). Despite benevolent tendencies, comets have a powerful influence on terrestrial affairs and remain a capricious force capable of throwing thunderbolts, and therefore of continuing concern to emperors and kings.



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## Summary: Comets in Literature and Poetry

1. Virgil *"At no other time did more thunderbolts fall in  
A clear sky, nor so often did dread comets blaze."*  
Georgica, Book 1.
2. Homer *"Like the red star, that from his flaming hair  
Shakes down diseases, pestilence, and war."*  
The Iliad.
3. Shakespeare *"Comets importing change of times and states  
Brandish your crystal tresses in the sky,"*  
Henry VI.
4. Milton *"Satan stood  
Unterrified, and like a comet burn'd  
That fires the length of Ophiuchus huge  
in th'Artick sky, and from its horrid hair  
Shakes pestilence and war."*  
Paradise Lost.

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## Summary: Comets as Portents, Presaging Death of Kings

1. Shakespeare: *"When beggars die, there are no comets seen; The Heavens  
themselves blaze forth the death of Princes."*  
Julius Caesar.
2. Seneca: [after death of Demetrius, king of Syria] *"... there appeared a comet as  
large as the Sun. Its disc was at first red, and like fire, spreading sufficient light to  
dissipate the darkness of night; after a little while its size diminished, its brilliancy  
weakened, and at last it entirely disappeared."*  
146 BC.
3. Suetonius: [after death of Julius Caesar] *"A hairy star was then seen for seven  
days under the Great Bear. ... It rose at about five in the evening, and was very  
brilliant, and was seen in all parts of the Earth. The common people supposed  
that the star indicated the admission of the soul of Julius Caesar into the ranks of  
the immortal gods."*  
44 BC.

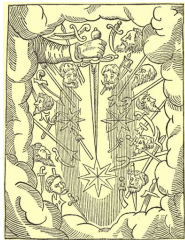


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## Comets as Horror-Movies: "Monstriferus" (Pliny)

Ambrose Paré (1510–1590), the father of French surgery: *"The comet was so horrible, so  
frightful, and it produced such terror in the vulgar, that some died of fear and others fell  
sick. It appeared to be of excessive length and was the colour of blood. At the summit  
of it was seen the figure of a bent arm, holding in its hand a great sword, as if about to  
strike. At the end of the point there were three stars. On both sides of this comet were  
seen a great number of axes, knives, blood-coloured swords, among which were a great  
number of hideous human faces, with beards and bristling hair."*



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## Table of Cometary Theories from c.1600–1800

Originator and Date	Theory and Broad Type
Tycho (c.1600)	Comets are <b>exhalations from planets</b> : a 'halfway house' between the 'celestial' and 'atmospheric' theories
Kepler (c.1600)	Comets are <b>interstellar</b> objects; move on rectilinear paths and populate the 'heavenly air' in great numbers. Form from the celestial fires by process akin to cloud formation
Galileo (c.1600)	Last genuinely ' <b>atmospheric</b> ' theory: comets are a form of reflected sunlight, akin to rainbows, parhelia etc.
Sir William Lower and Henry Percy (c.1610)	Comets are <b>celestial</b> objects; orbits elongated ellipses
Anon. (c.1620)	Comets are <b>exhalations from Sun</b> : the cindery refuse from great solar conflagrations
Hevelius (c.1680)	Comets are <b>vapours</b> that condensed in <b>planetary atmospheres</b> ; ejected by violent whirlwinds into parabolic orbits
Cassini (c.1680)	Comets are <b>interstellar</b> objects: vapours ejected from stars
Halley/Newton (c.1680)	Comets are <b>gravitating</b> solar-system objects; <b>akin to planets</b>
Buffon (c.1745)	Comets <b>akin to planets</b> ; formed as part of solar system through collision of a comet with the Sun
Kant (c.1755)	<b>Nebular Hypothesis</b> : comets, like planets, form by condensation in protosolar nebula; comets <b>akin to planets</b>

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## Summary Up to 18th-Century Watershed

1. **Comets** sometimes the most prominent objects in sky: as bright as the brightest stars. **Appear unpredictably** but **move like planets** . . .
2. Comets and associated meteoric phenomena scrutinized as '**omens**' to predict events on Earth; **observations go back millennia**.
3. **Mankind's** puzzling '**fear**' of comets still **not adequately explained**. Historical evidence suggests '**the sky**' may have been **significantly different** in proto-historic times.
  - ▶ Suggests actual experience of **Earth as an 'open' system**: in touch with its near-space celestial environment.
  - ▶ But is **astronomical change** on such historical timescales **possible**?
4. Two thousand years of '**atmospheric**' ideas finally superseded by a correct '**celestial**' picture for comets.
5. Later — and modern — debates focus on '**interstellar**' versus '**solar system**' ideas, and whether comets are **distinct objects** in their own right, or objects with an origin **more akin to planets**.

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