Australian Astronomy ASA Factsheet No.17

Comets

Few sights of the night sky are as spectacular as a bright comet with a long tail. Long ago, they were seen as mysterious, frightening objects than were often thought of as bad omens. Today, we know a good deal about comets, but there is still much to learn.

GENERAL INFORMATION ABOUT COMETS

Comets are objects composed of ices and dust particles. They move on paths — called *orbits* — around the Sun, and are therefore members of our Solar System. Comets typically move in quite elongated (oval-shaped) orbits, which is why we normally see a comet easily for only part of its orbit — when it is in the inner part of the Solar System, where the Earth is located.

We do not actually see the relatively solid central part of the comet, called the *nucleus*, which is typically a few kilometres across. The classic view we have of a bright comet in the inner Solar System is a diffuse patch of light called the *coma*, sometimes with a *tail*. The coma is formed around the nucleus when the comet is relatively near the Sun. There, the higher temperature makes the nucleus less stable, resulting in material being ejected as the comet heats. The *tail* forms as this material is 'blown away' by a stream of particles from the Sun called the *solar wind* and also by the Sun's light; the tail of a comet is directed away from the Sun regardless of the direction of the comet's motion.

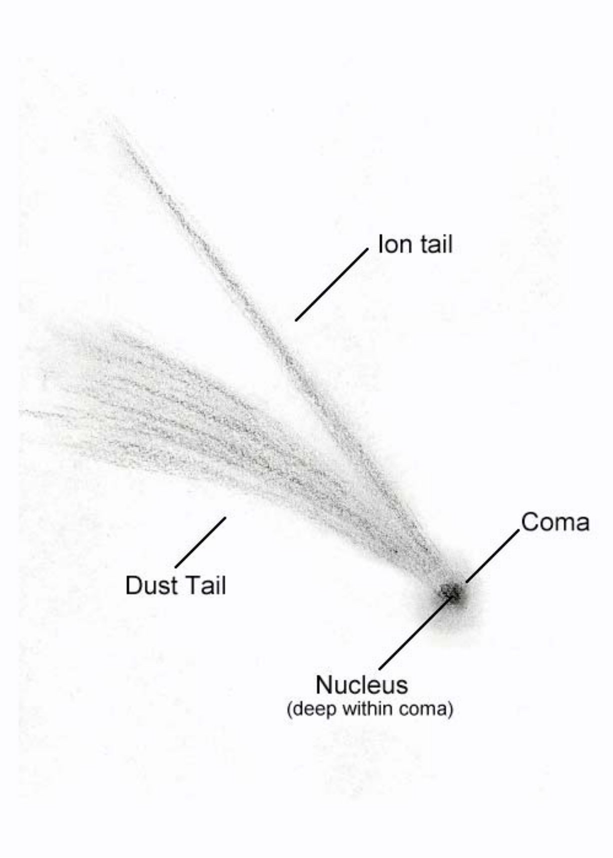


Fig.1
Structure of a typical comet when in the vicinity of the Sun. In this diagram, the Sun would be to the lower right. Only the position of the small nucleus is shown. The diagram is produced in negative form for clarity.

The volatile nature of comets sometimes results in their disintegration. A famous case of this was Comet Biela, which was seen to split into two parts in 1846. Other well-known comets that have broken up are Comet West (1976) and Comet Schwassmann-Wachmann 3 (1995).

Comets shine both by reflecting sunlight and by emitting their own light after absorbing energy from the Sun. The most well-known example of a comet is Comet Halley, which was seen in our part of the Solar System in 1986 but is now too far away to see even using powerful telescopes.

Fig.2
Comet Halley — the most famous comet of all. Photographed the morning of 21 March 1986 by Martin George, Launceston Planetarium, Tasmania.

THE ORBITS OF COMETS

All objects moving around the Sun move on orbits that are oval-shaped — called *ellipses*. The orbits of most of the planets are very nearly circles, but comets typically move on paths that are quite elongated. At one extreme, they can pass quite close to the Sun, but at the other they can be very distant indeed. A number of comets, called *periodic* comets, are on orbits small enough that they are seen regularly, as they repeatedly move through the section of their orbit that brings them close to the Sun and Earth. Such comets that return after periods of less than 200 years are called *short-period* comets. Comet Halley is the only one of these that is always seen clearly with the unaided eye; the others require binoculars or telescopes. Comet Halley's orbital period is about 76 years. Its orbit brings it closer to the Sun than the orbit of Venus and, at the other extreme, to a point farther out than Neptune. The comet with the shortest known period is Comet Encke, which moves around the Sun every 3.3 years.

Some comets that we see, however, are on such large orbits that their next return to the inner Solar System — if indeed they do return — will be in the distant future, as they may take thousands of years to complete each revolution. Fine examples were Comet Hyakutake in 1996 and Comet Hale-Bopp in 1997. Even though in some cases such comets may have been seen thousands of years ago, they are effectively all ‘new’ discoveries, and we sometimes have very little warning of their upcoming appearance in our night sky. Such comets’ orbits are so elongated that the ellipse is open-ended, or very nearly so. An ellipse that is open-ended is called a *parabola*. If a comet is on a truly parabolic orbit, it will never return.

Close approaches to the planets can significantly affect the orbits of Comets.

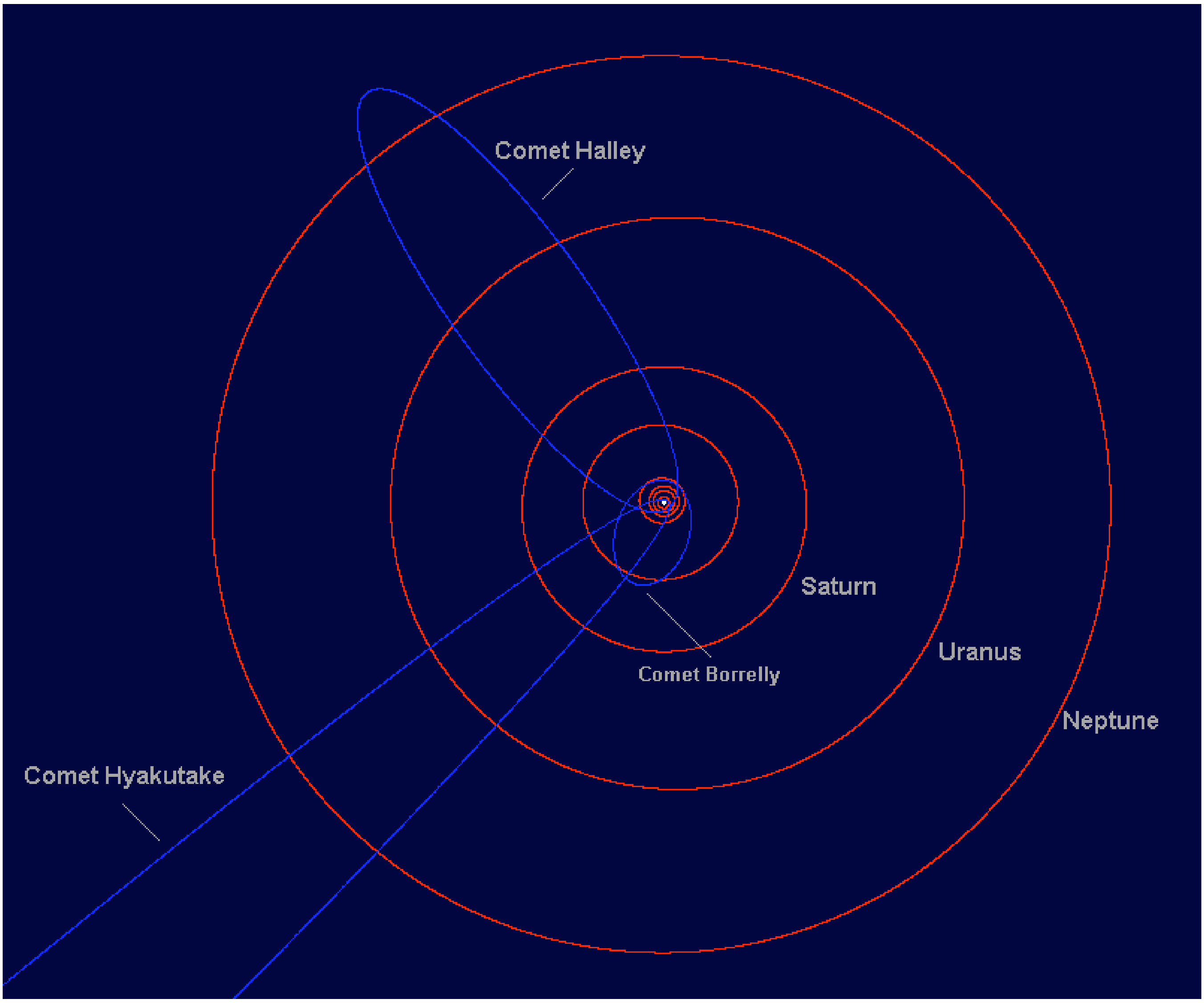


Fig.3
The orbits of three comets — Comet Borrelly, Comet Halley and Comet Hyakutake — as seen from the northern side of the Solar System. Their orbital periods are 6.8 years, 76 years, and about 12,000 years, respectively.

ARE WE AT RISK?

It is possible for comets and asteroids to collide with the Earth. The impacts of large objects which pose a serious risk to civilisation are relatively rare, but the topic is taken very seriously because of the great devastation that such an event could cause.

A total of about 26 periodic comets are known to approach the Sun at least as closely as the Earth's orbit, but none of these is on an orbit that can cause it to collide with the Earth for at least many centuries; indeed, none of these may ever collide with the Earth.

In the case of long-period comets, an estimation of the risk is very difficult. A typical such comet, if it has an orbit bringing it at least as far in as the Earth's orbit, has a typical probability of less than one in 100 million of impacting Earth during each orbit. Coincidentally, research suggests that the annual probability of a *large* comet impacting Earth and causing a global catastrophe is about the same: somewhat less than one in 100 million.

The closest known approach of a comet to Earth was that of Comet Lexell in 1770, which came to within about 2.3 million kilometres. A comet designated as C/1491 B1 may have come to within 1.4 million kilometres — less than four times the distance to the Moon — 20 February 1491, but its orbit is rather uncertain. Comet Halley can also approach us fairly closely; its record minimum distance was 5 million kilometres in the year 837.

A famous cometary impact occurred in 1994, when more than 20 fragments of the broken-up Comet Shoemaker-Levy 9 collided with Jupiter, yielding dark impact sites that could be seen even in quite small telescopes.

Fig. 4
Comet Hyakutake, which passed within 15 million kilometres of Earth in 1996, was a spectacular sight all over the world. From the southern hemisphere, it upstaged Comet Hale-Bopp, which was seen at its best during the following year.

This picture was taken on the morning of 24 March 1996 by Martin George of the Launceston Planetarium, Tasmania.

THE ORIGIN OF COMETS

Modern opinion is that comets are remnants of Solar System formation billions of years ago, and that they formed in the cold outer reaches of the Solar System in the region of the planet Neptune. The gravity of the outer planets then caused them to be thrown out into more distant orbits beyond Neptune. It is thought that, today, there is a huge ‘reservoir’ of distant comets, named the *Oort Cloud* after the Dutch astronomer Jan Oort. Many comets never recorded before, on parabolic or very nearly parabolic orbits, are thought to come directly from this region and to return there — after a brief passage into the inner Solar System where they swing rapidly around the Sun. In recent years, astronomers have confirmed the existence of a closer group of icy objects orbiting at Pluto's distance and beyond. This is called the *Kuiper Belt* (after the astronomer Gerard Kuiper, who proposed its existence). It is likely that comets with shorter orbital periods originate from this region.

THE COMPOSITION OF COMETS

Research on comets over the years, conducted using telescopes and spacecraft, has given astronomers a good deal of information about their composition. In broad terms, a comet can be likened to a 'dirty snowball'. The nucleus of a comet consists of ices of various compounds of carbon, hydrogen, oxygen and nitrogen; water ice appears to be a major constituent. In addition to the ice, there is a good deal of 'dust' in the form of grains containing silicon, magnesium and other heavier elements. This dust, mixed in with the ice, results in the nucleus of a comet being rather dark. Photographs of the nucleus of Comet Halley, about 15 kilometres across, showed most of it to be very dark indeed.

Comets' comas and tails contain both gas and dust, and have offered important clues to the composition of the nucleus itself; 80% of the molecules in the coma of Comet Halley are water molecules, while much of the remainder consist of molecules of carbon monoxide and carbon dioxide.

The gas and dust in comets' tails are blown away from the comet via different mechanisms. The gas tail, more correctly called the *ion* tail, is composed of many different types of ionised molecules being drawn away from the coma by the *solar wind* — the stream of electrically charged particles moving outwards from the Sun at a speed of hundreds of kilometres per second. The dust particles, however, are removed by interaction with the *light* of the Sun. Typically, the ion tail will be almost straight, whereas the dust tail will exhibit a curve. This means that a comet's ion and dust tails are separated, and are often seen as such, especially in photographs.

DISCOVERING COMETS

Comets tend to be discovered when they are on their way towards the inner Solar System, while they are still relatively faint — much too faint to be seen with the unaided eye.

Many new comet discoveries are made by experienced amateur astronomers using telescopes or binoculars. This is largely because their professional counterparts are normally heavily involved in specific projects, while amateurs are more free to choose their activities. In Australia, there are many serious amateurs involved in this work. The most well known in Australia is Bill Bradfield in South Australia, who has discovered eighteen comets, all of which have been named after him.

To perform this work, a thorough knowledge of the night sky is essential, as many distant star clusters, nebulae (clouds of gas and dust in space) and galaxies can resemble the fuzzy comas of comets.

Comets can also be discovered by their appearance on images of the night sky taken by both amateur and professional astronomers. In recent years, comets have been increasingly found using instruments designed to image the sky as part of the study of Near-Earth Asteroids, or NEAs.

Comets are generally named after their discoverers, although sometimes two observers find a new comet independently within a short time and the object is named after them both. There are even cases of triple-barrelled names! A comet may be named after the observing programme that was involved in its discovery — for example, those found by the *Near-Earth Asteroid Tracking Survey* are called NEAT. A numbering and lettering system is also used.

OBSERVING COMETS

Despite their appearance — especially when they have a long tail — comets do not 'dash' across the sky. Like the planets, they appear in slightly different positions each night with respect to the background stars. A comet passing very close to the Earth, however, can appear to move quite dramatically from night to night, as did Comet Hyakutake in March 1996.

Most comets are observable only with optical aid (binoculars or telescopes); only occasionally does one become visible to the unaided eye. The brightness of a comet is often difficult to predict in advance, especially if it has never been seen before.

When there is a fine ‘naked-eye’ comet in the sky, the best view is usually obtained with binoculars, rather than with a telescope. For this purpose, it is advisable to have a pair with lenses at least 50mm across, such as ‘7x50’ binoculars (the second number is the lens diameter in mm).

Like many features of the sky, such as the Milky Way, comets are much more clearly visible from dark, country locations away from city lights. The 'Light pollution' of cities is an increasing problem around the world. Comet Halley, for example, was seen far more clearly in 1910 than in 1986 largely because of the increase in city lighting over the 76-year period.

Indeed, country dwellers with binoculars in 1986 obtained a very good view of Comet Halley; many people living in cities, ignoring all of this advice, failed even to notice it at all!

It is also important to wait outside for some time (at least ten minutes, but preferably longer) to allow your eyes time to get used to the darkness.

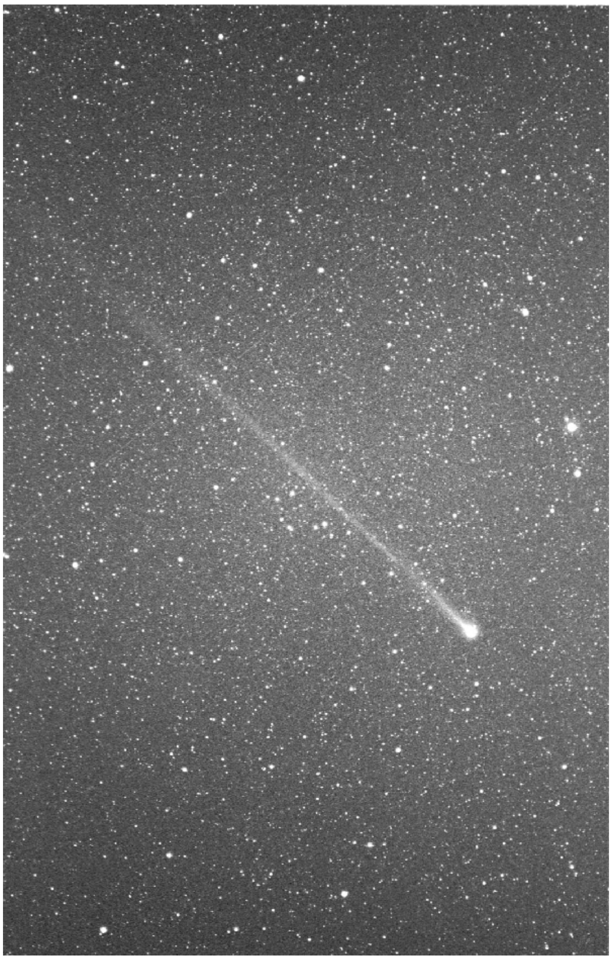


Fig.5
Comet LINEAR (not the 2004 comet), photographed on the evening of 19 May 2001. Photograph by Martin George, Launceston Planetarium, Tasmania.

PHOTOGRAPHING COMETS

Even if optical aid is used, time-exposure photography (or electronic imaging) shows faint objects more clearly than does direct observation with the human eye. Because of this, comets — especially the fainter parts of their comas and tails — show up far more easily on such images.

If using film, it is advantageous to ensure that it is relatively fast (ISO 400 or more); this has the effect of cutting down the necessary exposure time. Exposure times with the camera lens at its widest aperture setting (i.e. with the lowest f/number) are typically a few minutes to a few tens of minutes. A rare, bright comet such as Comet Hyakutake can be recorded — complete with part of its tail — in this way in one or two minutes.

It is important to remember, however, that during a time exposure, the Earth will rotate. This results in the image of the comet and background stars being 'trailed', especially with the longer exposures. Better images can be made by carefully guiding the camera to counteract the Earth's rotation using an *equatorial mount*; a simple arrangement is to 'piggyback' the camera on a telescope on such a mount.

In order to obtain the *best possible* images of comets, there is a further refinement to bear in mind — especially for comets that are relatively close to the Earth and so appear to move fairly rapidly from night to night. In addition to using the equatorial mount to counteract the Earth's rotation, the camera must be continually re-aimed *at the comet itself*, using fine adjustments on the mount. This is why some images of comets have 'star trails' in the background: they are an indication of the movement of the *comet* during the exposure.

Fig.6
Comet Hale-Bopp, photographed from Tasmania on 31 May 1997 by Martin George, Launceston Planetarium, Tasmania.

COMETS AND METEORS

Comets and *meteors* are quite different. A typical meteor — also called a 'shooting star' — is a glow of light formed when a small object called a *meteoroid* enters our atmosphere at great speed and burns up. It *does* appear to move rapidly across the sky, because of its proximity to us.

There is a connection, however, between meteors and comets: most of the small objects entering our atmosphere are thought to be tiny pieces of cometary debris. In particular, material remaining in the comet's orbit can produce regular, yearly 'meteor showers' at predictable times as the Earth moves through it.

Larger, rocky objects, some of which reach the ground, are more related to asteroids.

A BRIEF HISTORY OF COMET OBSERVATIONS

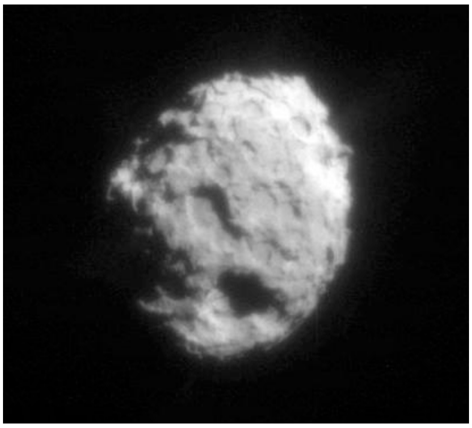
Long ago, nobody knew the true nature of comets. The Chinese called them, among other things, 'broom stars' or 'bushy stars'. Comets were often thought to be bad omens, being wrongly associated with such events as the deaths of important people or with natural disasters such as earthquakes. The appearance of Comet Halley in 1066 was thought to relate to the Battle of Hastings, and its presence in the sky then is depicted on the Bayeux Tapestry. The timing was, of course, completely coincidental!

Although there were many different ideas about comets, a major early theory was that comets were atmospheric phenomena — in other words, that they existed within Earth's atmosphere, making them very close to us. In 1577, however, a breakthrough was made by the famous astronomer Tycho Brahe: he showed that the bright comet that appeared in that year must have been at least four times as distant as the Moon.

During the seventeenth century, it became clear that comets orbit the Sun. Appearances of the comet that was later to be known as Comet Halley led to the realisation that some comets do, in fact, return periodically. Edmond Halley noted that the comets seen in 1531, 1607 and 1682 had similar orbits, and suggested that they were one and the same comet. He correctly predicted that it would reappear in 1758, but died before he could see his prediction come true. The next comet to be identified as periodic, early in the nineteenth century, was Comet Encke, with its first predicted return in 1822 being observed from Parramatta Observatory in New South Wales. We now know of over a hundred such comets that orbit over periods of less than 200 years.

By the late 1800s, scientists had discovered that the light emitted by different substances — for example, when burned in a flame — produces different spectra (a *spectrum* is the pattern we see when light is split up into its constituent colours). Astronomers therefore examined the spectra of the light of comets in order to try to understand their composition. It was not until several decades later, however, that scientists had a fairly good understanding of which molecules were responsible for the features in the comet spectra.

Better instrumentation over the decades has told us much more about comets, in particular the many different kinds of molecules present.



In 1986, several spacecraft passed very close to Comet Halley, with the European Space Agency's *Giotto* craft returning the first-ever picture of a cometary nucleus. It was shown to be elongated and irregular, with many bright and dark patches. Since then, the nucleus of Comet Borrelly has been imaged by NASA's *Deep Space 1* craft; in January 2004 another NASA craft, called *Stardust*, returned spectacular images of the nucleus of Comet Wild 2 and collected material which will be returned to Earth for close study.

Fig.7
The nucleus of Comet Wild 2, images by NASA's Stardust spacecraft in January 2004. Courtesy NASA.

The study of comets is very important in order to develop our understanding of the history of the Solar System. They are very old, and because of their frozen state contain material that has changed little since their formation.

BRIGHT COMETS SEEN SINCE 1900

1901 The Great Comet of 1901 (Viscara's Comet). First seen on 12 April 1901, low in the morning twilight. Faded from naked-eye view in late May.

1910 The Great January Comet ('The Daylight Comet'). The brightest comet of the twentieth century. First seen by miners in South Africa on 12 January 1910. Seen with the unaided eye for several weeks, and visible for a time in daylight. Often confused with Comet Halley, which appeared in the same year.

1910 Comet Halley. Often confused with the Great January Comet. Located photographically on 11 September 1909. First seen with the unaided eye on 11 February 1910, and visible until June.

1927 Comet Skjellerup-Maristany. First seen in November 1927 and visible in daylight during December.

1947 'Southern Comet'. First seen on 8 December 1947, but visible with the unaided eye for only about two weeks.

1948 The 'Eclipse Comet'. Discovered during a total eclipse of the Sun on 1 November 1948, in which totality was seen from central and eastern Africa. The comet was seen with the unaided eye in the morning twilight until early December.

1957 Comet Arend-Roland. Discovered photographically on 6 November 1956 and a spectacular object during April 1957.

1965 Comet Ikeya-Seki. Discovered on 18 September 1965. Seen with the unaided eye during October and November. Passed very close to the Sun on October 21.

1970 Comet Bennett. Discovered on 28 December 1969. Seen with the unaided eye from early February to early May 1970.

1976 Comet West. Discovered in November 1975, on photographs taken in September. Visible with the unaided eye from January until April 1976, and was a spectacular object during March from the northern hemisphere.

1996 Comet Hyakutake (The Great Comet of 1996). Discovered in January 1996. Visible with the unaided eye from early March until mid-June. A spectacular object during late March when it passed only 15 million kilometres from Earth, and was seen from all over the world.

1997 Comet Hale-Bopp (The Great Comet of 1997). Discovered in July 1995 when it was still over 1,000 million kilometres from the Sun. Visible with the unaided eye from late 1996 until late 1997. It was a spectacular object from the northern hemisphere in April 1997; southern hemisphere observers missed out on the very best views.

Fig.8
Comet Hale-Bopp, photographed from northern Thailand on 4 April 1997 by Martin George, Launceston Planetarium, Tasmania.

More information

Sky & Telescope - Comets	http://skyandtelescope.com/observing/objects/comets/
The Nine Planets - Comets	http://www.nineplanets.org/comets.html
JPL Comet Observation page	http://encke.jpl.nasa.gov/
Observable Comets Ephemerides	http://cfa-www.harvard.edu/iau/Ephemerides/Comets/

This information was prepared for the ASA by Martin George of Launceston Planetarium (http://www.qvmag.tased.edu.au/planetarium.html) and Nick Lomb of Sydney Observatory (http://www.sydneyobservatory.com.au). This sheet may be freely copied for wide distribution provided the Australian Astronomy and ASA logos are retained.

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