KING COMET

BHASKAR DATTA
J C BHATTACHARYYA

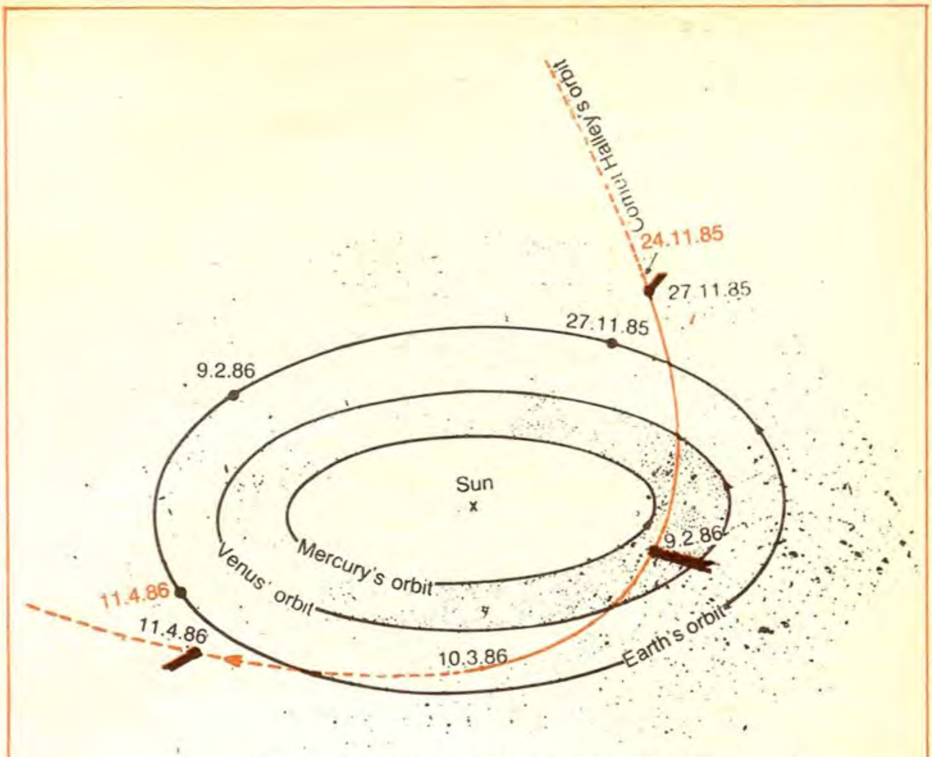
Comet Halley taken in 1910.

THE WORLD is waiting and preparing — astronomers, astrophysicists and all — for the king among comets — Halley's. After 75 years, it will once again make its appearance in the sky towards the end of this year.

The word comet comes from "cometes" — the Latin equivalent for long-haired. To the unaided eye, a comet seems like a faint and narrow strip of cloud. Though Halley's comet has a periodicity of about 76 years, comets themselves are not that rare. Routine sky surveys with telescopes usually always manage to spot a few almost all round the year. They are generally very faint objects and cannot be spotted by a random look at the night sky. Once in a while, however, a relatively bright comet comes along, and it draws public attention, albeit temporarily. Over the past two decades, four relatively bright comets — like Ikeya-Seki (1965), Bennett (1970), Kohoutek (1973) and West (1976) — were seen. They were bright enough to have been seen with the naked eye.

Halley's comet belongs to the same class but it carries a somewhat special status. The appearances of the four bright comets were all unexpected. There is no mention of their earlier arrival, if any, in the history of recorded astronomy. In contrast, the more or less regular appearance of Halley's comet has been amply recorded. Astronomical archives definitely establish that for the past two thousand years or so this great visitor has appeared in the Earth's vicinity at a regular interval of approximately seventy six years. There are a few other comets which show up periodically, but all of them happen to be extremely faint objects and can be seen only through a telescope; hence there is no trace of them in the astronomical records of the pre-telescope era. With Halley's comet, the situation is different; every time it has made its appearance over the last couple of millenia, it has attracted the attention of sky-watchers, and has been chronicled for posterity. Today we see the record in various forms — folk-tales, artists' impressions on paintings, tapestries or just carvings on stone faces or clay tablets.

Although the comet of 239 BC was vaguely identified with Halley's, there was no reliable evidence of its history before 12 BC. Now scientists in Britain and Austria, studying inscriptions on Babylonian clay tablets kept in the British Museum, have confirmed its appearances in 87 BC and 164 BC. This takes the comet's history further back than Chinese records.



Perspective view of passage of Comet Halley 1985-1986

Astronomers tell us that there exists a regular pattern for the changes in the location and brightness of planets (and their satellites) in our solar system in relation to the distant stars, which are almost stationary as far as we are concerned. There do exist a few "variable" or large proper motion stars, but their changing positions and luminosities are well known and are charted in the ephemerides. Somewhere among these stars, a faint point of light marks the initial appearance of a comet.

In a few week's time, the point of light gradually becomes brighter and its position in the sky shows a variation like that of planet. Most comets remain in that stage, then gradually disappear from view. But some stay on longer, gaining both in brightness and apparent size. Telescopically, at this stage they present a more nebulous appearance than planets. Some characteristic features can be noticed: a somewhat stretched appearance, one end being relatively denser (the head of the comet) and the other end diffuse (its tail). The comet can be seen (provided the relative positions of the Sun, Earth and the comet are favourable) to grow at a rapid rate. To the naked eye it appears like a streak of faint light against the dark sky. The infinite variety of the physical features of comets becomes noticeable at this stage.

For instance, the shape of the head may be round or sharply pointed, and the tails may vary widely — some very short, others quite long with curved and twisted appearances, some are widely divergent. Then there are comets with two distinct tails. Tails are always directed away from the Sun. Hence, it follows the comet as it approaches the Sun but precedes it as it recedes.

The point on the trajectory at which the comet is closest to the Sun is called its perihelion point, and here it attains its maximum brightness. At the perihelion point a comet becomes invisible to the naked eye, because it rises and sets in the sky at the same time as the Sun does, and the comet is usually fainter than the day sky.

Very few comets have been seen in the day sky, but one that deserves mention is Ikeya-Seki which appeared in 1965, with a perihelion point very close to the Sun. Special photographs of this comet, taken from the Nobeyama Solar Observatory in Japan, revealed that its head had split into three distinct parts.

As a comet recedes from the solar system, its brightness as well as the length of its tail gradually diminish. However, as seen from the Earth, this need not always be the case. The reason is that as the comet approaches the Sun, its proximity to the Earth increases too. At this stage, the apparent brightness of the comet depends critically on its distance from the Earth. It may happen that the comet's trajectory brings it closer to the Earth at times other than its perihelionic passage; in that case the comet may appear as brighter and bigger at those epochs rather than during perihelion. Halley's comet is expected to display such phenomena during its forthcoming apparition.

Rough estimates of the appearance and location of comets in ancient times are to be found mainly in incidental literature or paintings or sculptures. These indicate the constellation or the bright star near which the comet had been sighted and perhaps its passage on subsequent nights. But such information is too meagre to figure out the trajectory. From the extensive observations of planets recorded by the Danish astronomer Tycho Brahe during Europe's Renaissance, his student Johannes Kepler was able to formulate the general laws that govern the motions of planets in the solar system. The law of gravitational attraction was proposed by Isaac Newton in 1682, and it could correctly explain Kepler's formulations of the laws of planetary motions. These principles of the gravitational force and planetary motions now enable astronomers to calculate cometary orbits accurately.

The comet and the telescope

The year 1682 saw the appearance of a bright comet in the sky. Instruments for astronomical studies were well developed by that time, and it was demonstrated by Edmund Halley, who was twenty-six years old at that time, that the orbit of this comet was quite different from the planetary orbits, being more nearly parabolic instead of elliptical. This implied that the comet had a highly eccentric orbit. From his calculations, Halley predicted that the same comet would make a reappearance seventy-six years later, that is, in 1758. He also claimed that, further back in time, the comets that had appeared in 1607 and 1532 were in fact this same comet in its previous rounds.

Halley's assertions were not readily accepted by his contemporaries. Some even went to the extent of calling it a hoax, especially since 76 years later Halley would not be alive to face the likelihood of a disgraceful error. Halley lived to be 86 years and his detractors were eventually proved wrong when the comet did appear at Christmas time in the year 1758, as predicted by him. It was named after him in recognition of his work. Since then, Halley's comet has made its appearances, in 1834 and 1910. The next perihelion passage, that is the forthcoming one in February 1986, will be its fourth since the young astronomer's prediction, and the thirtieth if we dig into its recorded history of apparitions as early as 239 BC.

Can we then say that Halley's comet is a permanent member of the solar system, like the planets and their satellites, the only difference being that it has a highly eccentric orbit? To answer the question, one has to consider cometary science in a little more detail.

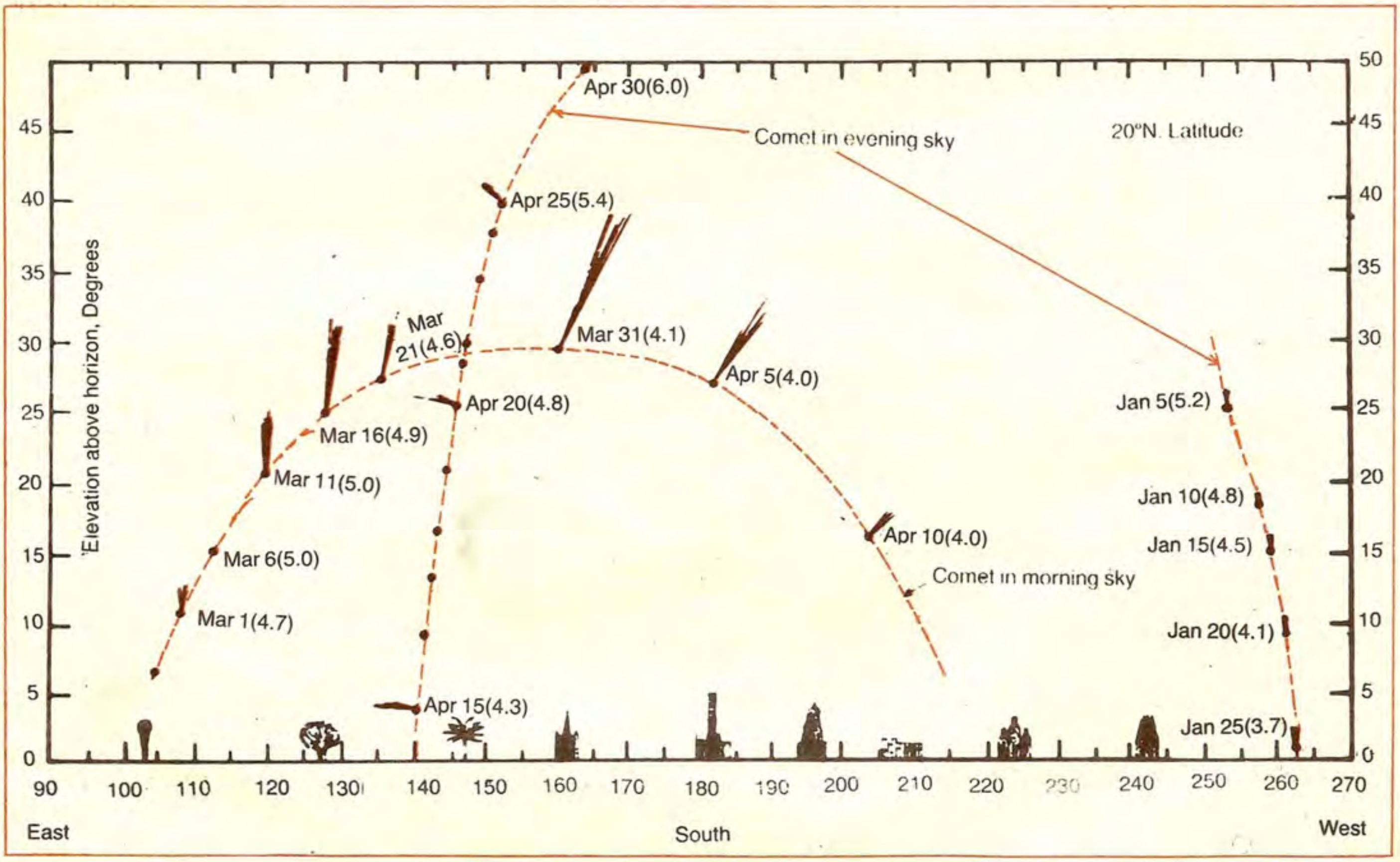
Scientific studies of comets suggest two broad classifications. The first group comprises periodic comets, that is, the ones that show up at roughly regular intervals of time. Their orbits are elliptical, with the Sun situated at one focus, and follow Kepler's laws of planetary motion. They attain their largest orbital speeds at their perihelion points and the lowest speeds at their aphelion. It may be noted that if a relatively light object is thrown (within a limiting velocity) towards a heavier object, the former will go in a stable orbit around the latter in the manner described above. (This principle is widely used while launching artificial satellites around the Earth.)

The second category of comets comprises those which have been sighted only once. Their orbits are either parabolic or hyperbolic. Of the approximately thousand comets observed from the Earth so far, most belong to this category. However it is possible that some of these have extremely elongated elliptical orbits with very large periods so that it takes an enormous amount of time between their two successive visits to the inner solar system.

This category may include those which had a path too close to the Sun so as to suffer (at least partial) disruption due to solar gravitational tidal forces. Comet Ikeya-Seki is of this type. It got partially destroyed but the remaining part gradually faded away like any other comet.

So we can say that comets are objects external to our solar system, scattered in the interstellar space in the Milky Way galaxy. All stellar objects are in motion. During the course of their random motions, comets stray into the gravitational arena of the solar system. The Sun, being the dominant source of gravity in this system, then determines the path and speed of the comet, the orbit of which can be any one of the following: open ended, such as a parabola or a hyperbola. In either case, the comet returns to interstellar space after going around the Sun, or alternately breaks and falls on to the Sun. (Such comets are "single event" phenomena.) Or the orbits can be bound, or elliptical (provided the comet's velocity is within appropriate limits). A comet with such an orbit returns near the Sun at regular intervals of time, and so belongs to the class of periodic comets.

A comet in an elliptical orbit is, however, not guaranteed to return periodically to the solar system for all time to come. The reason for this is that a part of its constituent material gets "lost" through evaporation as it

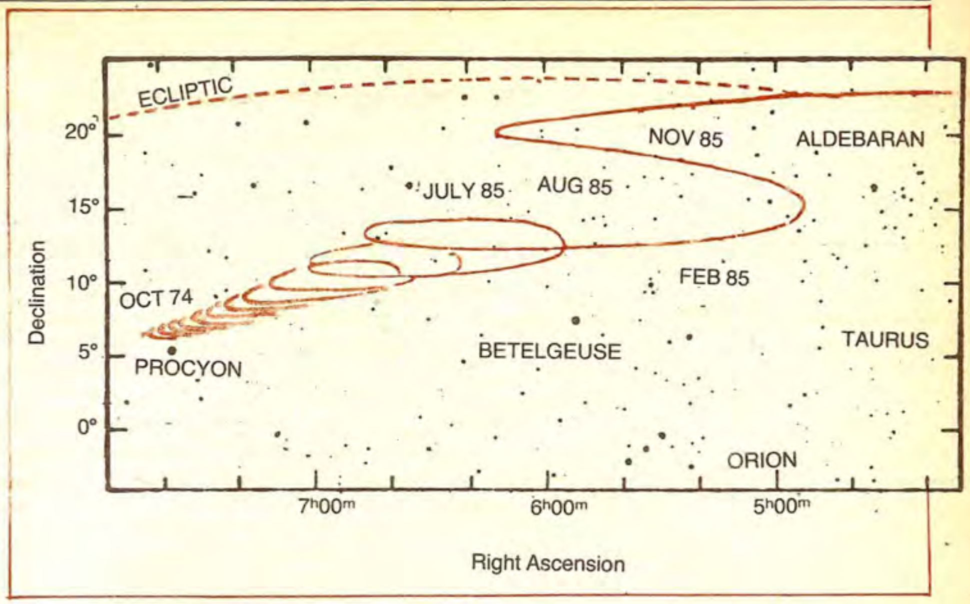


goes by the Sun, leading to a mass loss which, in turn alters its orbit. The eventual fate of the comet is then either to fall on to the Sun (or a planet) or to resume an indefinite journey into outer space.

A study of periodic comets shows that their aphelion points lie slightly beyond the orbit of the planet Neptune. At the aphelion point, the comet's speed is relatively slow. Hence there is a general cluster of comets at that region, which is referred to as the comet belt. At present we do not understand why the comet belt should be located around the orbit of Neptune. Maybe it has something to do with the limiting speed of the comet that gives it an elliptical orbit. It should be mentioned here that the location of the comet belt is not based on any direct observation but inferred from studies of cometary orbits close to the Sun.

The planets of the solar system all lie approximately in the same plane, which is called the ecliptic plane. Cometary orbits do not lie in this plane, which may be a hint that comets are external to the solar system. Usually cometary orbits intersect the ecliptic plane at two nodes in the course of their journey around the Sun. Halley's comet will also follow such a pattern. However, the sense of its direction of motion around the Sun will be opposite to that of planets. It may be mentioned here that such "counter-directional" comets are more likely to be bound in an elliptical orbit. This also suggests that comets originate outside the solar system.

The compositions of comets have certain characteristics which confirm this theory. There are objects in the solar system (such as the asteroid types Aten and Apollo) whose orbits go pretty close around the Sun. However, they never develop tails. Tails are peculiar to comets only, and start forming even when the comet is fairly distant from the Sun. The spectroscopic analysis of asteroids indicates that the composition is mainly iron and stone. The spectral analysis of comets, on the other hand, suggests that these are made up of frozen gases such as methane and carbon dioxide, and ice. Roughly speaking, it has been found that comets develop their tails at two astronomical units, that is, when they are about twice as distant from the Sun as the Earth-Sun distance. This suggests the existence of substantial amounts of volatile materials in comets. In the solar system, such materials are found within or in the vicinity of a few planets. On the other hand, spectral analysis of light from far-away stars indicates the presence of many ice fragments plus silicate and graphite in interstellar space. There seems to exist a similarity between the composition of comets and the swarm of interstellar grains which are extensively spread out in the plane of the Milky Way. The planets and their satellites have been influenced by solar radiation over the last few billion years (1 billion = 1, 000,000,000 . As a result, the volatile materials in them, if any, have mostly disappeared except for trace amounts surrounding some of them. It is possible, of course, that such materials exist in a solidified form (due to enormous pressures) in the interiors of the major planets. However, in the vast interstellar space where intensities of stellar thermal radiations are feeble, the matters that exists will be fairly representative of the primordial matter that formed not too long after the creation of the universe. Comets can, therefore, be presumed to be made up of such primordial matter.



An interesting question is: Are comets basically meteoroids or asteroids with layers of volatile material? Such a model cannot explain the occurrence of the fairly long-lived tails of comets. Spectral analysis of the tails suggests the presence of substantial amounts of dust, with the head being the likely source of origin. In other words, along with the vaporisation of the volatile material, dust particles also get scattered away from the head. So it can be speculated that comets are big chunks of ice-coated dusty material, the ice and the dust having coalesced to form large balls. As the comet approaches the Sun, the Sun's radiation induces evaporation, releasing vapour and dust. The rate of dissipation of such lumps has been estimated. An average sized comet with a well-developed tail will survive to make about a hundred rounds around the Sun. This will lead to a gradual diminution in the brightness of the comet. It will eventually disappear into outer space or merge on to the surface of the Sun or some other large object in the solar system.

This kind of evolutionary trend is noticeable in the case of Halley's comet too. Its brightness magnitude has shown a progressively diminishing trend with the passage of time (Table 1).

Table 1. Fall in the luminosity of Halley's comet

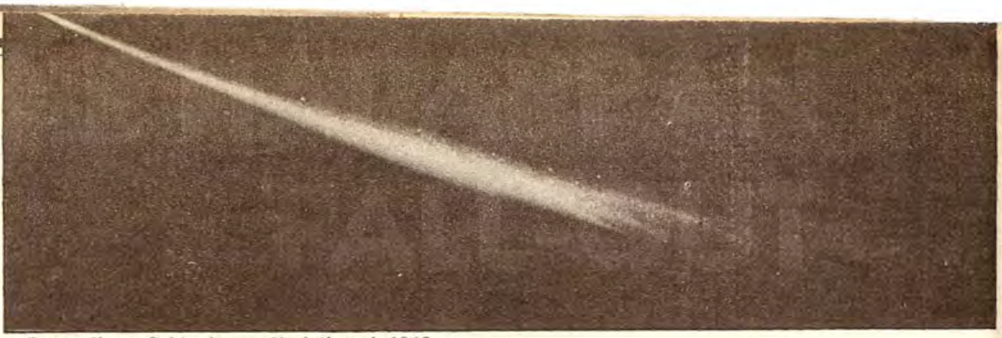
Year (A.D.)	Standard visual magnitude *	Relative brightness
760	2.0	100
1607	3.5	25
1682	4.0	16
1835	4.4	11
1910	4.6	9

* Estimated visual magnitude when comet's distance is 1 astronomical unit (AU) from the Sun and when viewed from the Earth, also 1 AU away from the comet.

Now what about the forthcoming appearance of Halley's comet? Its aphelion will lie in the constellation of Cancer at a distance of about 36 astronomical units and close to the orbit of Neptune. At this position, the comet is out of bounds for Earth-based telescopes.

Since the time it went around the Sun in 1910, the comet continued to recede from the Sun for about four decades. In 1949, it reversed its journey and started moving towards the Sun. In 1983, its faint image was seen through the 200-inch telescope at Mt Palomar, USA.

During November 1985, Halley's comet will be located slightly to the north of the constellation of Taurus. Any attempts to see it at that time will require a pair of binoculars or a small telescope. It will become visible to the unaided eye around the new year of 1986; when it will be located near the celestial equator and in the constellation of Capricorn. However, because of the proximity of the Sun, the actual visibility will be restricted only to a brief period after sunset. On 9 February 1986, the comet will reach its perihelion point and will be invisible in the bright day sky for about a fortnight. It will "reappear" slightly in the south of constellation of Sagittarius, towards the end of February


Indian Institute of Astrophysics

Comet Ikeya-Seki taken at Kodaikanal, 1965.

1986 to the beginning of March 1986. During this period, Halley's comet will be at its biggest and brightest. After that, till about the middle of April 1986, the comet will be positioned in the lower part of the southern sky. After passing close by the bright star Alpha Centauri, the comet will drift northwards and diminish in brightness rather rapidly. During May 1986, it might be barely visible to the unaided eye. After that it will assume a gradually contracting helical path towards its point of aphelion. The initial part of this outward journey may be traceable with the help of telescopes.

What scientific investigations of Halley's comet are being planned? Just as the most advanced instruments of the time have been used for this in the past, on this occasion too, the possibilities of exploring newer frontiers exist because of great technological advances. It is now feasible to send up a spacecraft that can fly close by the comet and make revealing close-range observations.

Observatories around the world have made extensive plans for ground-based observations. Several spacecrafts, fitted with special detector devices, have been launched into space for rendezvous with the comet. in 1910 it was inconceivable that observations in wavelengths other than those of visible light could be possible. Today, it is possible to make detailed observations of all celestial objects over a wide spectrum of wavelengths, starting from high energy gamma rays to long wavelength radio waves. Consequently, many new features of comet Halley are expected to be revealed this time.

Dr Datta is at the Indian Institute of Astrophysics, Bangalore. His research interest is in theoretical astrophysics.

Prof Bhattacharyya, director, Indian Institute of Astrophysics, Bangalore, has been associated with astronomical research since the late fifties. He has a D Phil from Calcutta University and has specialised in instrumentation and techniques for astrophysics.

Comet viewing

THE MOST important information the interested viewer needs is the comet's position in the sky and its movements. These will naturally depend on the part of the globe where the viewer is situated. The most favourable viewing conditions will be for observers in the southern hemisphere, because that is where the comet will be high up in the sky during its brightest phase.

For viewers in India and nearby regions, the general situation will be as follows: As early as August 1985, the comet was visible (through a big telescope) in the eastern sky about an hour before sunrise. After about two months, its position will drift towards a location where it can be seen almost all through the night. At its longest phase it will rise about an hour after sunset; at dawn it will be slightly above the western horizon. But still it will not be bright enough to be visible to the naked eye. Around the beginning of January 1986, the comet will be seen during the evenings in the western sky.

It will then be quite bright with a well-developed tail, and will be visible to the naked eye. Around this time, its position will undergo rapid changes. Towards the end of January 1986, it will rise and set almost simultaneously with the Sun, and so will be out of sight. Towards the end of February 1986, it will be seen again during the early hours of the mornings in the eastern sky. The brightness of the comet and tail length will increase daily, attaining their maximum values towards the end of March 1986. At the maximum, the tail length will have an angular dimension of about 20°. To get an idea of this length we may remember that the Sun and Moon have angular sizes of about half a degree. Around the middle of April 1986, the comet will cross over from the eastern sky to the western sky, and will be visible in the evenings near the western horizon. It will gradually recede from the Sun, but continue to be visible for several hours in the evenings. Soon afterwards, its brightness and tail length will start dwindling. After the middle of May 1986, it will cease to be visible to the naked eye. However, scientific observations using telescopes can still be continued for about a month thereafter, but in India the advent of the monsoon will draw the final curtain on the comet.

The movements of Halley's comet, seen from the Earth, will appear to be somewhat complex, crossing horizons and apparently going around the Sun several times. All these complications are due to the Earth's own motion around the Sun. Observed from outside the solar system, the comet will go around the Sun only once. The approach of the comet will be from the southern sky. After crossing the ecliptic plane, it will end its voyage around the Sun slightly to the north of this plane, and after a few days will go down to the south of the ecliptic plane. During this span of time, the Earth will have travelled half way around in its orbit.

The three important dates regarding apparition of the comet Halley this time are: November 27, 1986 — when the comet will be at its closest to the Earth on its incoming path; February 9, 1986 — the comet will be at its closest to the Sun and April 11, 1986 — when once more it will approach close to the Earth on its way out. This point will be closer to us than the first one; the Earth-comet separation at that time will be 63 million km (about 42 per cent of the Earth-Sun separation).

Unlike during the 1910 apparition, this time comet Halley and the Earth will be placed on two opposite sides of the Sun at the time of perihelion. In 1910, the tail of Halley's comet happened to lie close to the Earth; this time the tail will look much shorter.