NOW THAT COMET HALLEY IS OUT OF HIDING

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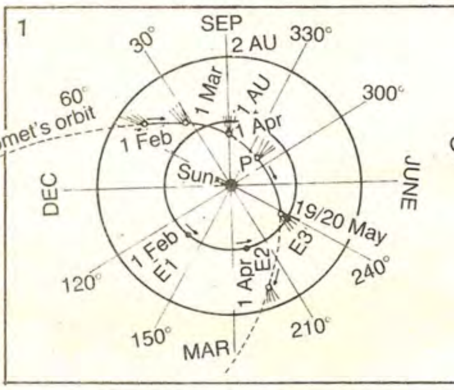
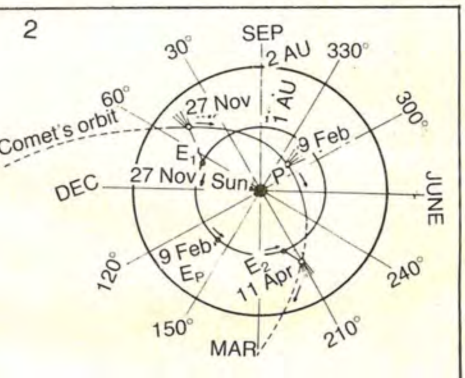
BEFORE THE advent of photographic plates, comets used to be drawn by hand. The drawings, based on observations through telescopes were done by the observers themselves. Some of these drawings show remarkable details of jets or fountains spouting from the bright nucleus in the coma and are as good as some of the best photographs obtained with large telescopes. Beginning with the first spectroscopic observations of Comet Tempel by Donati in 1864, we have valuable contributions from pioneering stellar spectroscopists like Sir William Huggins. In 1868, he identified the strong bands in the cometary spectrum with Swan bands of carbon (C_2) known in the laboratory. That was long before the appearance of Comet Halley in 1910. The instruments that observed it in 1910 were naturally more sophisticated but few then could have predicted the sophistication of the observational instruments we have now.

The first attempt to recover (catch the first glimpse of) Comet Halley during its present apparition succeeded in October, 1982. Astronomers saw it through the 200-inch telescope at Mt Palomar. At that time it was very faint and beyond the orbit of Saturn. Keeping track of Halley's comet is important as it is the only short-period comet that is known to display all their interesting phenomena — like the large dense coma, both ionic and dust tails, and many varieties of tail phenomena. It has a well-determined orbit and is the only comet which has been well documented earlier (1910).

Astronomers of the Indian Institute of Astrophysics, Bangalore; Uttar Pradesh State Observatory, Nainital; Osmania University, Hyderabad; Physical Research Laboratory, Ahmedabad; Tata Institute of Fundamental Research, Bombay and the Positional Astronomy Centre, Calcutta, have evolved a well co-ordi-





Path of Comet Halley along its orbit during 1909-1910. The open circles along this orbit represent the positions of the comet on 1 February, 1 March, 1 April and May 19/20 of 1910. P is the perihelion on 20 April 1910. Filled circles E_1, E_2 and E_3 represent the positions of the earth in its orbit 1 AU away from the Sun. Notice the favourable position on May 19/20 1910, when the Earth was downstream from the comet and passed through its tail. Also the comet was just in the plane of the Earth's orbit which made the relative positions more favourable.

Path of Comet Halley for 1985-1986. Notice that the comet is close to the Earth at two positions — 27 November 1985 and 11 April 1986. E_1 and E_2 are the positions of the Earth on these dates. The Earth will be a E_P when the comet is at the perihelion (P) on 9 February 1986. Notice the relative unfavourable positions of the comet and the Earth with the Sun in between. On 11 April the comet is already below the plane of the Earth's orbit (hence dotted line for the comet's orbit) and in addition the tail is directed away from the Earth.

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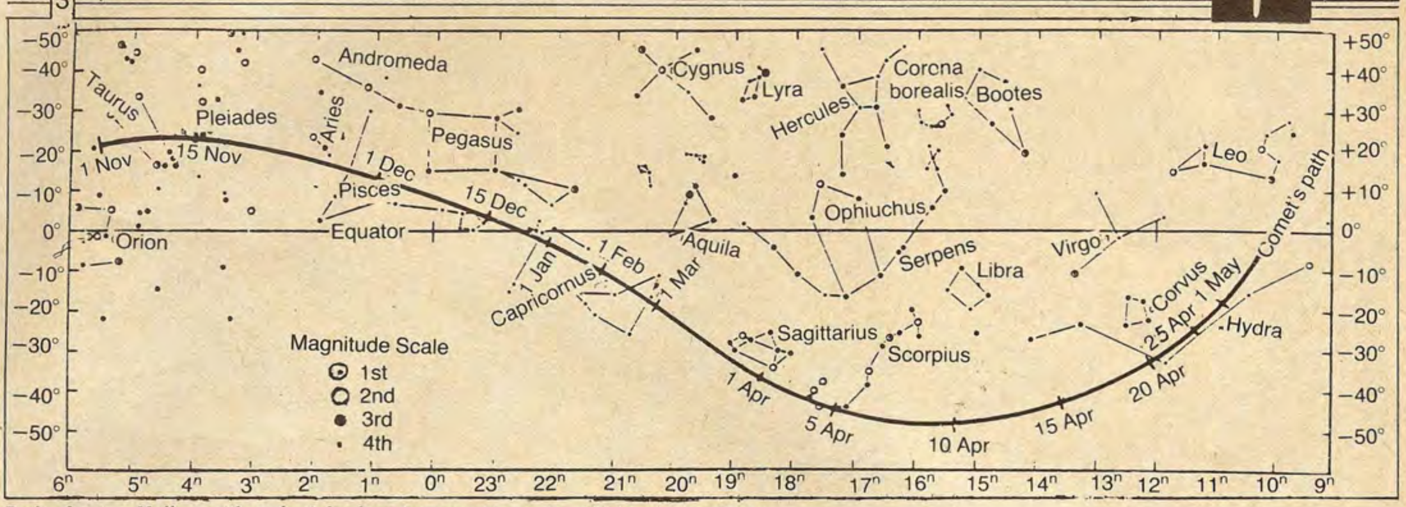

Path of Comet Halley on the celestial sphere between November 1985 and May 1986.

nated observational programme on a national level to be run from the observatories in India. Called the Indian Halley Observation Programme (IHOP), it is organised to cover several observations:

1. *The interaction of the ionic tail and the solar wind.* A series of photographs of the entire comet with a wide field camera through proper filters to separate the ionic tail from the dust tail will provide the necessary material for this study. When an interesting phenomenon like tail disconnection takes place, a series of photographs covering the entire event is ideal data, helping us to understand the nature of the plasma interaction causing such events. Photographs using wide-field telescopes will be obtained from all the observatories involved. Also, precise measurements of the speeds of flow of the ionic stream in the tail, which is so vital for any interpretation of tail phenomena, are planned jointly by the Physical Research Laboratory and the Indian Institute of Astrophysics scientists using a Fabry-Perot interferometer system (designed and got ready by the former) in conjunction with the 1-metre telescope at Kavalur.

2. *Well-exposed large-scale photographs of the coma.* From these the velocity of dust and gas molecules can be measured and the way they differ from the development of the coma can

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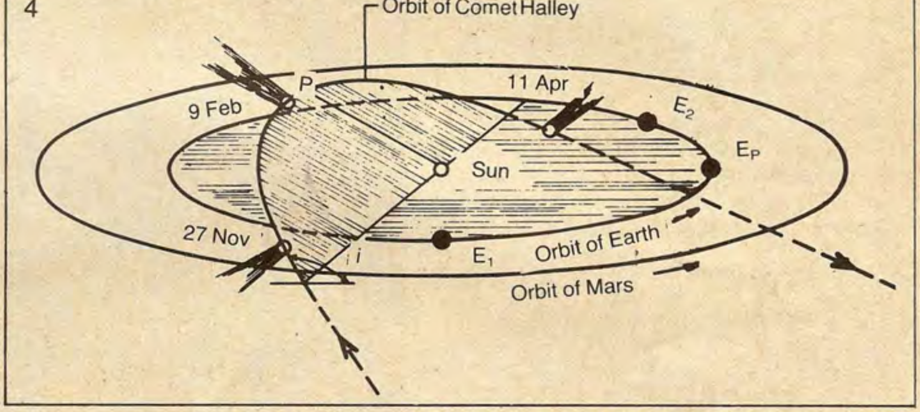

Artist's conception of the path of Halley in 1985-1986. The orbit of Mercury and Venus are not shown to avoid crowding in the diagram. For explanation of E_1, E_2, E_P and the dates see figures 1 and 2

Catch it if you can

AN AREA where amateurs can contribute a great deal is cometary photography. Since the study of the changing forms of the tail would depend entirely upon a continuous series of photographs obtained in quick succession, any gap due to poor weather and the limited number of professional astronomers engaged in photography can be augmented by amateur efforts. Black-and-white photographs are more useful for scientific study as these can be calibrated. On the other hand, colour photographs are more spectacular and could form valuable aids for instruction to the interested public.

A fine grain emulsion like Kodak 2415 Technical Pan Film is recommended when the comet is at its brightest phase. When not so bright it would be advisable to use Kodak medium speed films or ORWO NP22 or their equivalent. Tail photography through blue and orange filters would be highly rewarding and can be done with high speed films like Double-X or Kodak 2485 or even Tri-X. Photographs taken through a blue filter would isolate the ionic tail, whereas the ones with an orange filter would predominantly show up the dust tail. A sequence of unfiltered—blue-filtered—orange-filtered photographs is recommended. These filters can be placed in front of the camera lens or in front of the objective of the telescope as the case may be. For the best results, the peak transmission band for the blue filter should be centered around 4500 A and for the orange filter around 6200 A. Kodak gelatin filters 47 A and 2B would meet these specifications. For the blue a combination of 47 A with 2 B would be ideal. When there are signs of tail activity, amateurs should take successive photographs at the rate of two to three per hour so that these would portray the changing forms in the tail completely.

Other details which can help amateurs get good results are being published serially in *Communications on Comet Halley,* a special ISRO publication distributed to many amateur astronomers' associations and similar groups in the country.

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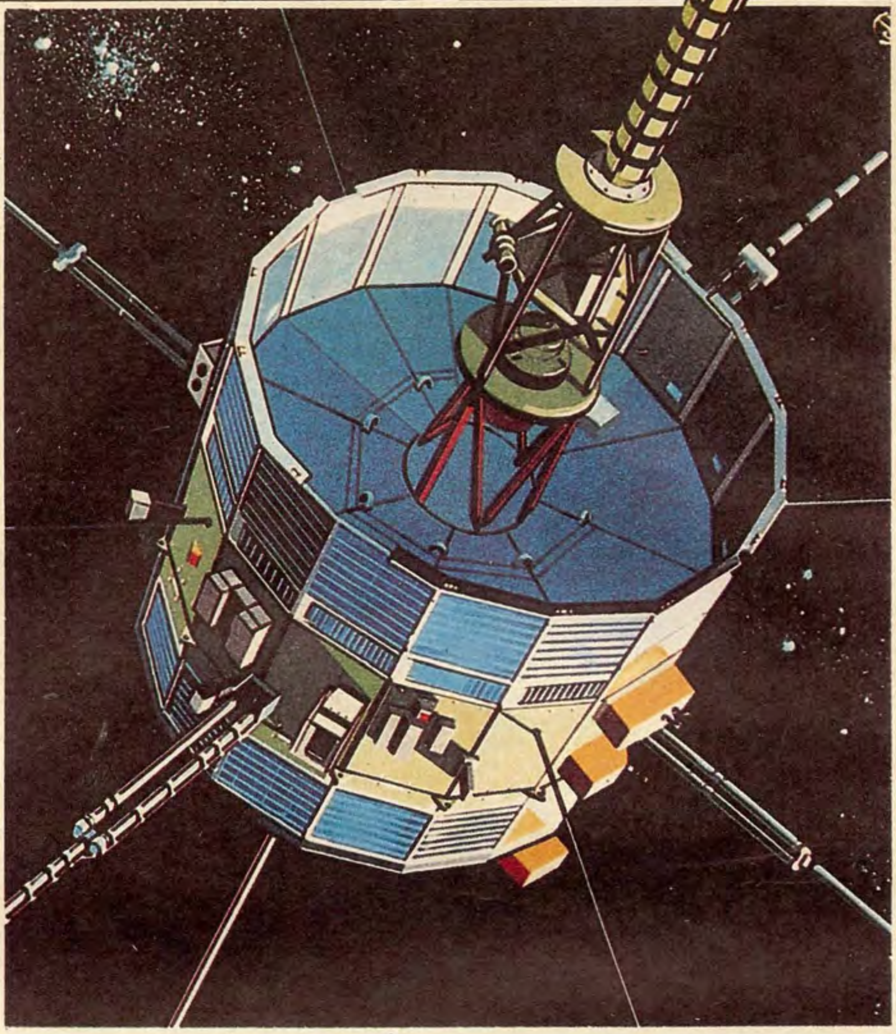
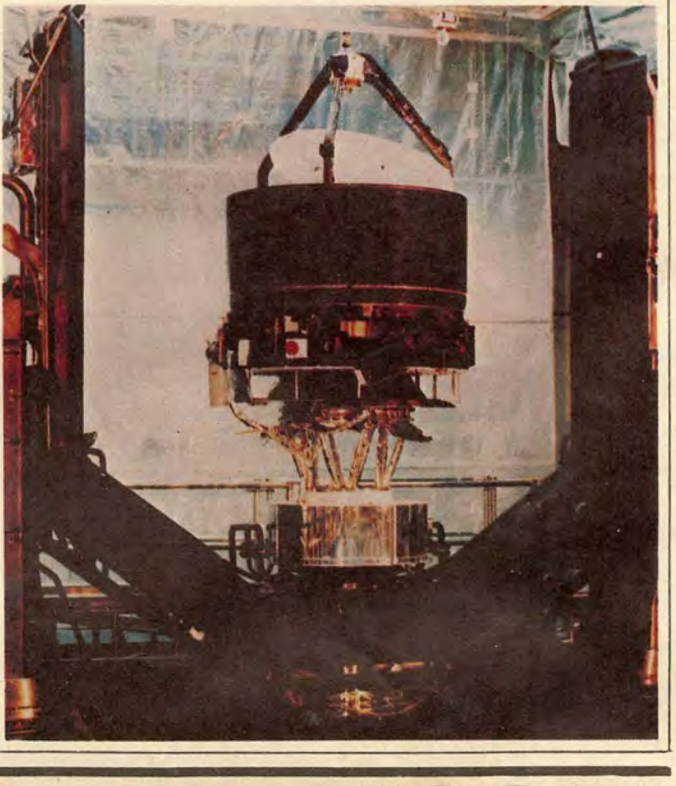
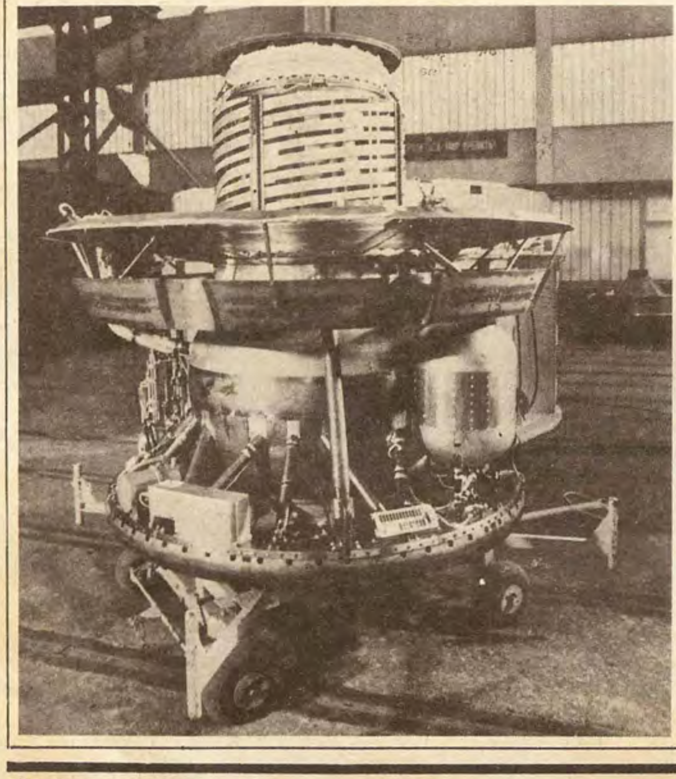
be studied. Also, the spectacular changes in the configuration of the coma associated with sporadic outbursts from the nucleus can be studied from such data. High resolution photographs will be obtained for this purpose.

3. *Spectroscopic observations.* Essentially all the information on chemical composition comes from spectroscopic observations which are the most reliable means of segregating various components like cometary dust, neutral molecules and ions. These observations will provide clues to the composition of the coma and the tail, the origin and loss of molecules and dust from the cometary nucleus and the tail. Spectroscopy on Comet Halley will be done in the entire visible region (3600 Å to 7500 Å) using all the three 1-metre class telescopes in India. The spectra should reveal the presence of hitherto unknown molecules, if any, in the comet.

4. *Photometry*. The comet has both continuous radiations and radiation concentrated in certain bands. These can be isolated using optical filters. The flux radiated by each of the







The comet seekers. Clockwise from below: Giotto—the European Space Agency's craft that is to meet Halley's comet, the Soviet Union's Halley probe, VEGA and the International Cometary Explorer (ICE) that has already encountered a comet, Giacobini-Zinner molecular species from the entire cometary surface can be measured by photometric techniques. From this the total number of molecules of each species can be derived. The nature, composition and the quantity of dust in the coma, can be derived from the flux of continuous radiation. Using special photometers, this study will be carried out for all the colours in the visible region and in the near infra-red.

5. *Stellar observations*.The cometary tail is tenuous and allows bright stars in the background to shine through it. But it dims their light. The amount of dimming can be calculated by measuring the brightness of a star when viewed through the tail and when it is outside it. The nature and composition of the material in the tail can be inferred from such measurements.

The density of electrons in the plasma tail is an important quantity which can be measured with a good radio telescope. The radio telescope at Ooty will be used to view the radio sources in the sky when they are occulted by the plasma tail of Halley's comet. A radio source scintillates when viewed through the plasma tail and this is caused by the density variations within the tail. For measurements of the scintillations, electron densities in the tail can be measured

6. *Chemical studies.* Comets also contain complex molecules and their presence has been detected using radio telescopes. It is going to be thrilling to look for complex molecules in Comet Halley.

NASA has organised a wide net of observing centres on a global scale by involving as many observatories as possible. This is the International Halley Watch (IHW) programme. The Indian observatories which are members of this watch have an important role to play. The gap between the observatories of Japan and China on the one hand and those of East Europe on the other is a vast one and can only be covered by India.

Public interest to see comet Halley is already very high. It was photographed on 29 August and 3 September with the 1-metre telescope at Kavalur and will be closest to the Sun (perihelion) on 9 February 1986 when it will be at a distance of 0.59 AU from the Sun and 1.55 AU from the Earth. It will make close approaches to the Earth on 27 November 1985 during its inbound journey and on 11 April 1986 on its exit from the neighbourhood of the Sun.

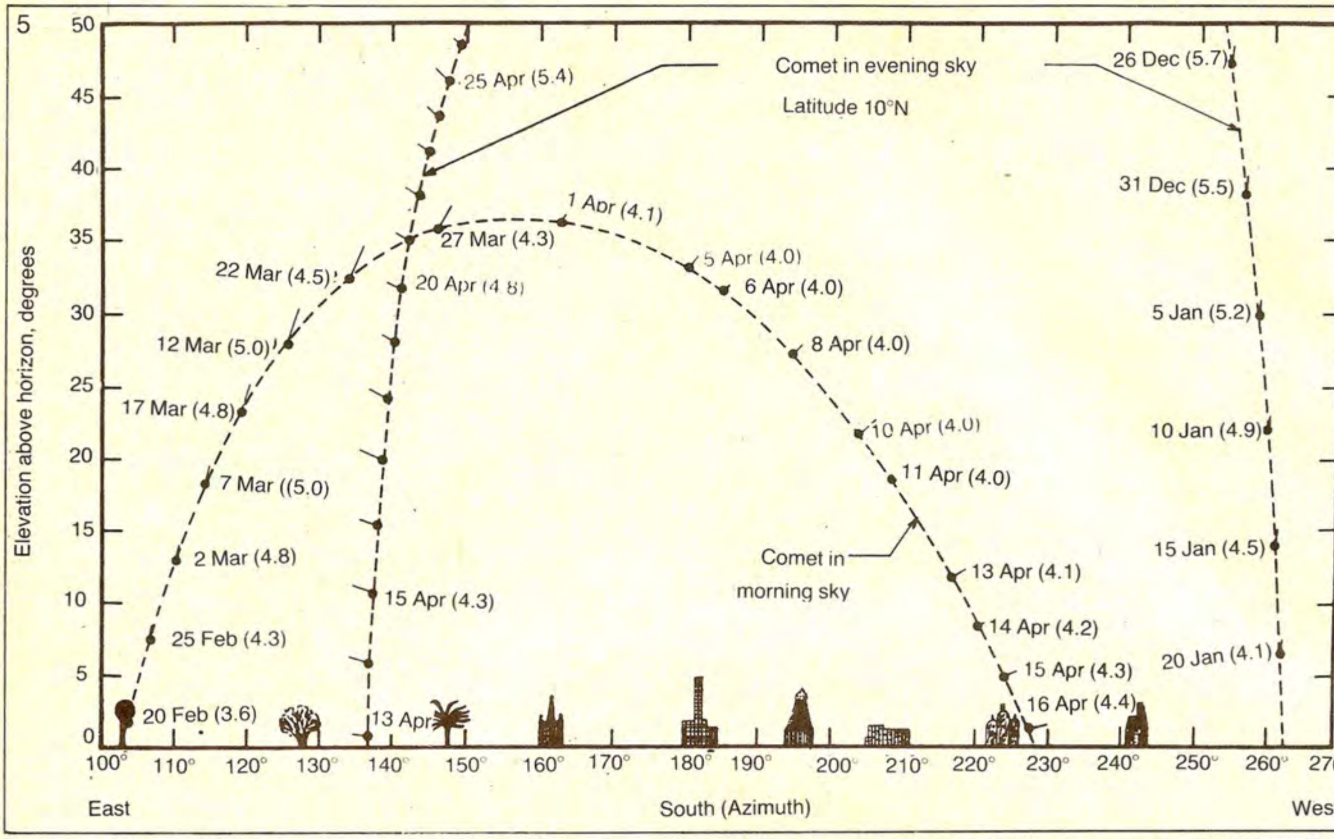
When exactly a comet becomes a spectacular sight depends upon its position in relation to the Sun and the Earth around the time of perihelion. In general, a comet is brightest when it is at perihelion. It would be ideal for viewing if the comet and the Earth were as close to each other as possible at this time.

In 1910, at perihelion, (20 April) the comet was 0.59 AU from the Sun and 1.18 AU from the Earth. The corresponding distances in 1986 will be more or less similar, but viewers in 1910 were more fortunate. By 18/19 May 1910, a month after perihelion, when the comet continued to be at its best, both the comet and the Earth were on the same side of the Sun. Also, they moved so close to each other that the tail of the comet swept past the Earth a day or two later. (Figs 1 and 2).

This time, unfortunately, the comet

When Comet Halley appeared in 1466 the European Christians fighting the Turks were on the losing side. So they thought God had gone over to the Turks. Ninety-one years later, when the Great Comet appeared (shown here as represented by a Turkish artist) the Turks once again stole a march on the Europeans. They used the occasion to found the Istanbul observatory.

The 16th century Aztec emperor Moctezuma II observing a bright comet. Did he feel it foretold the end of his empire? The invading Cortez captured and killed him soon after.



Positions of Comet Halley before the morning twilight and after the evening twilight as seen from a place 10°N latitude on the Earth from December 1985 to April 1986. Numbers within the brackets after the dates are the expected brightnesses of the comet on the magnitude scale.

will be unfavourably located. Not only will it be farther away from the Earth at the time of perihelion, but during the first three weeks of February 1986 when it will be at its brightest, the comet and the Earth will be on opposite sides of the Sun, making it virtually impossible for ground-based observers to sight it. Although it will be close to Earth twice, on both occasions the tail will be oriented away from the Earth and will appear shorter than it really is, due to projection effects. This will be more so on the second occasion (11 April 1986) as the comet will already be below the plane of the ecliptic (Figs 3 and 4). All these unfavourable factors will most likely make the comet unimpressive to the common viewer irrespective of where he chooses to observe it from. Light pollution in the urban areas will make the situation worse.

The comet will be a northern hemisphere object till late 1985 (24 December) and will then transit to the southern hemisphere and remain

How bright is it?

EVERYONE HAS noticed how some stars appear brighter than others. The brightnesses of stars are described by their apparent magnitudes. The magnitude scale used in astronomy has developed over the years into a well defined, but somewhat arbitrary scale. The brightest stars in the sky are more or less first magnitude; the faintest stars visible to someone with good eyesight and ideal observing conditions (no clouds, city lights, or air pollution) is sixth magnitude. The brighter a star, the lower the numerical value of its magnitude. The brightest stars in the constellations Orion, Bootes, and Lyra (Rigel, Arcturus, and Vega) are extremely bright. These stars are zero magnitude objects.

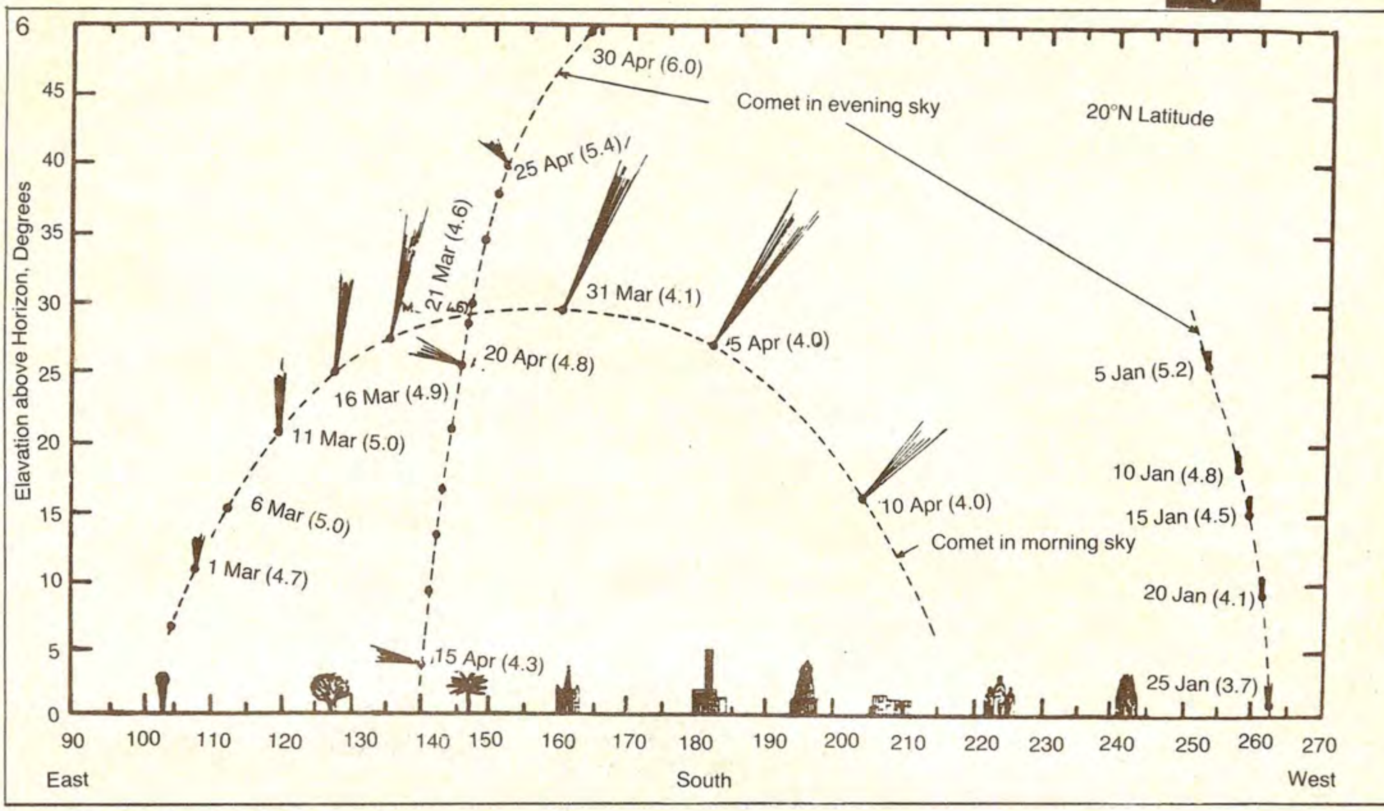
First magnitude stars are very bright. The brightest stars in Scorpius, Cygnus, and Virgo (Antares, Deneb, and Spica) are a few examples. The second magnitude stars such as Polaris, the pole star, are moderately bright and can be easily identified. Third magnitude stars are still fainter. On a misty night these are usually the faintest stars that one can see. The fourth magnitude stars are visible on a moonlit or hazy night. Fifth and sixth magnitude stars are visible only under the most ideal conditions. If you are used to the kinds of skies you see around cities, you can be confused by a very clear sky. If you were to go to a high mountaintop in the southwest on a superclear night there seem to be so many stars in the sky that it takes a minute or so to find the constellations. Figure 18 is a sketch of the Little Dipper, with the magnitudes of the stars indicated. Since the stars are magnitudes 2, 3, 4 and 5, it makes a good reference in the sky. You can also get a feeling for the viewing conditions on a given night by checking the Little Dipper. If you can see all the stars clearly, it is a fairly good night.

How long is its tail?

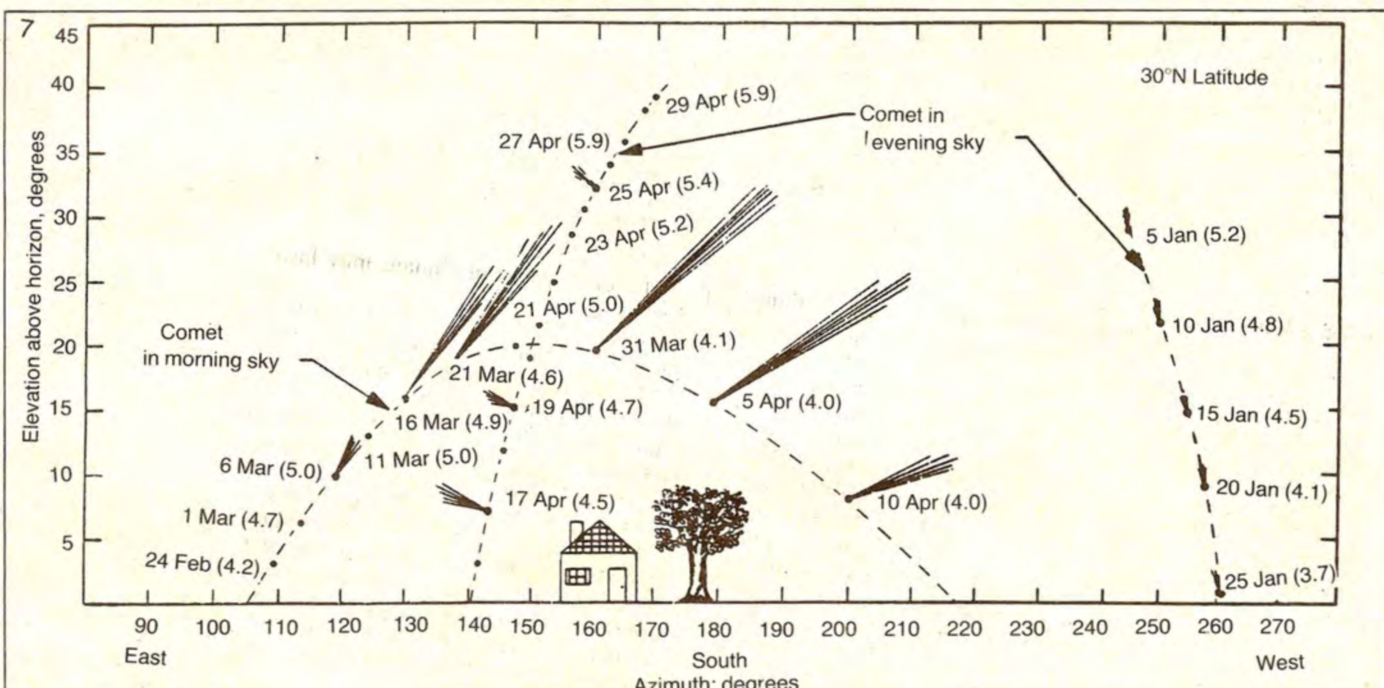
MEASURING ANGLES in the sky is not very difficult. There are several good angle reference points in the sky. For instance, the Moon is about one-half degree in diameter. The pointer stars in the Big Dipper are 5° apart, while the stars on the top of the bowl of the Dipper are 10° apart

Courtesy: National Aeronautics and Space Administration (NASA), USA.

COME



Same as Fig 5 for latitude 20°N.



Same as Fig 5 for latitude 30°N.

there until it fades from view by mid-1986 (Fig 5-6-7). So it will be best placed for observers in the northern hemisphere after perihelion. Further, if the comet turns active after perihelion, as is usually the case, observers in the southern hemisphere will get the best view during this period.

Comet viewers located about 30°N latitude will see the comet low in the horizon after perihelion. So observers in India, particularly those in the south, will have the advantage of a good view of the comet, both when it is in the northern as well as in the southern celestial hemisphere. The tail will appear to be at its longest some time between 20 March and 10 April. At this time, the comet will still seem spectacular from India although, at places above 30°N, the comet will

Ulka and Dhumketu

IN INDIA, the vedic science of stars is called Jyotish. Jyotish is known as Vedanga — that is, one of the limbs or constituents of the Vedas.

Ancient Indian astronomers seem to have known the difference between a meteor and a comet. The former was called ulka and the latter dhumketu. Meteors were popularly believed to be sparks produced when the vehicles of the gods clashed against one another. They were also held to be the excreta dropped either by a water-bird or by Garuda, the favourite eagle and vehicle of Vishnu. It was believed that it was impossible to get hold of these droppings, but if ever they could be got hold of, applying them on the eyes of a blind man would restore his eyesight. Applied on a leper, his skin would be restored to a golden lustre. It was commonly believed — and the belief still prevails amongst villagers and tribals — that meteors are the spirits of the righteous and they fall because of the curse of Indra. They subsequently assume the highest human forms on Earth.

"Dhumketu" is derived from *dhuma* which means smoke, vapour, mist or flame. Dhumketu means a smoke-marked star. Its first proper reference is seen in the Atharva Veda (19.9). By the time we come to the 6th century AD a lot of "research" seems to have been done. Varahamihira, the well-known astronomer of this age, devotes one full chapter on the course of comets in his famous Brhat-Samhita (see page 6).

The appearance of a comet over a country is believed to bring some dire calamity to the head of the nation. It also threatens all tailed animals with destruction. Children born when a comet appears are supposed to turn out to be bad characters. In short, its appearance is popularly regarded as symptomatic of a coming evil, like a great war, a great famine, or epidemics throughout the length and breadth of a country. In the Vishnu Dharmottara Purana there is a story which tells us about the birth of this Dhumketu.

The population on the Earth had increased so mucn that Brahma got worried. So he created a damsel whom he named Mrityu and asked her to spread death amongst the population. When Mrityu came to know about the assignment she shuddered at the idea and cried bitterly. Tears rolled down her cheeks. From these tears originated various kinds of diseases. When she saw these diseases, she could not control herself. She left her place and took penance. When Brahma saw this, he blessed her and said, "Well, you won't be the cause of death... Nobody will die because of you." Hearing this, she heaved a great sigh of relief... and from this big sigh was born Dhumketu.

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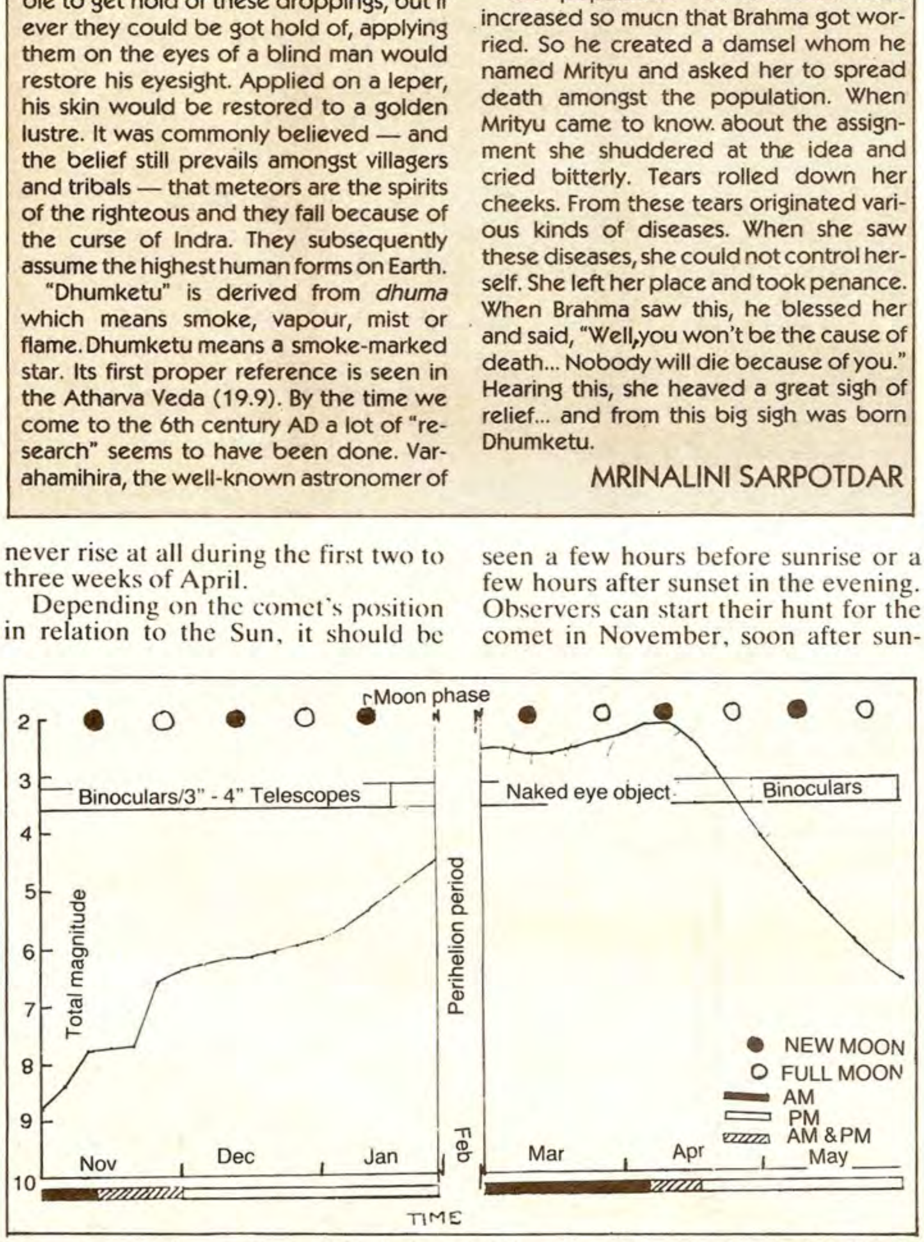
never rise at all during the first two to three weeks of April.

Depending on the comet's position in relation to the Sun, it should be seen a few hours before sunrise or a few hours after sunset in the evening. Observers can start their hunt for the comet in November, soon after sunset. A pair of binoculars or a small telescope will help them see it then when it will be around seventh magnitude in brightness. There are periods when it will be visible in the Indian skies for a long time. In November, it will be seen in the dark for nearly eight hours, tapering down to about four hours in December. By January it will have brightened to fourth magnitude and will be visible in the evening skies for 3 to 4 hours after sunset. During February, it will be behind the Sun and close to it and will be visible only by the end of the month. It rises again after perihelion and becomes available from two hours in March to about eight hours in late April/early May 1986. For those viewers located below 20°N latitude (south India) the comet will look splendid in the morning sky throughout March and until mid-April, especially through binoculars or a telescope. Those planning photography will find this time most rewarding (see P 45). Also, the greatest tail lengths will occur sometime in late March or early April 1986. The comet is expected to become a naked eye object by late December this year and continue through January next year. After perihelion it will also be visible in March. Amateurs will be able to view the comet from November 1985 till May 1986 and make observations

Observations by amateurs could include: visual estimates (by well-trained amateurs) of the brightness of the coma and the central condensation and the times at which abrupt changes in brightness occur. Using binoculars or small aperture telescopes, the brightness can be estimated in terms of the known brightness of stars and if the observer is experienced, such magnitude estimates can be made very reliable. The diameter of the coma and its changes over the entire apparition period is another important parameter which an amateur could measure.



The total magnitude of Comet Halley in the period November 1985 to May 1986 during which the comet can be seen either with binoculars or a small telescope or with the naked eye in either the late evening sky, early morning sky or during night. Moonless nights facilitate comet observations

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