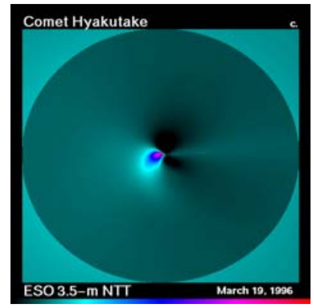
(Modified from an illustration by Larry Koehn. http://www.shadowandsubstance.com)



Jets and Rotation Rate - Observations during early March, 1996 from the European Southern Observatory (ESO; Chile), Pic-du-Midi in France, and other sites showed spectacular curved dust jets which were time-variable. Both the jets and observations made through narrow bandpass filters to isolate the light from either the dust or specific molecules showed that comet Hyakutake's brightness was changing on a timescale of 6.3 hours, probably due to nucleus rotation, and a single strong jet. The image at the right shows a false color image of the comet's inner coma which shows a prominent jet. The image was obtained with the ESO New Technology Telescope on March 19, 1996 (ESO Press Photo 25c/96). See larger version.

Fragmentation - During March, 1996, strong dust jets were reported in the inner coma of comet Hyakutake, and telescopes from sites with high resolution capabilities were reporting "knots" or "flakes" of material o moving away from the nucleus at velocities of 10-20 meters/sec. This type of behavior had not been seen before, but was interpreted as small pieces of the comet's surface flaking off. The image at the left from the Hubble Space Telescope taken on March 25, 1996 shows an image 3340 km across. Pieces which have broken off the comet and are forming their own tails are seen at upper left. Individual fragments could be traced from night to night in the images from the different observatories. See larger version.

Molecule Detection - Perhaps some of the most exciting discoveries with comet Hyakutake were the detections of many new molecules in the coma using radio telescopes and infra-red telescopes. Among the molecules discovered include a large suite of organic compounds such as methanol (CH_3OH), methyl cyanide (CH_3CN), hydrogen cyanide (HCN), formaldehyde (H_2CO), methane (CH_4), ethanol and ethane (C_2H_6). The ethane discovery was particularly exciting as this molecule had never before been seen on a comet. The relative abundance of ethane and methane were consistent with thermodynamic equilibrium, and suggested that they formed in a warm high-pressure region, which is inconsistent with our ideas of how comets formed. It is possible that maybe these comet constituents formed near the giant planets, say in a sub-nebula near Jupiter. However, if this interpretation is not possible, then a revision of the current astrochemical models may be needed since production of these molecules is believed to be inhibited in the ISM.

The Table below highlights some of the observed gases on comet Hyakutake and compares them to what we know about other comets and the ISM. The study of the abundance of many of these molecules, possible only with bright comets in many cases, is contributing greatly to our understanding of the origins of comets.

Comet and ISM Composition Comparison

Species	T_s*	ISM-Gas	ISM-Dust	Most Comets	P/Halley	Hyakutake	Hale-Bopp	Implications
H_2O	152	100	100	100	100	100	100	-
CH_3OH	99	4-5	1	1-5	1.5	0.023	0.049	Consistent with grains in ISM cloud cores
HCN	95	2	-	0.02	0.1	-	-	-
NH_3	78	1	10	0.1-2	0.1-2	0.25	-	Consistent with molecular clouds
CO_2	72	10	0-3	-	2-4	5	-	-
H_2CO	64	0.2-1	-	0.5	0-5	0.002	-	Variable in P/Halley
CH_4	31	0.2-7	0-5	0.02	-	0.7	-	First good detection in Hyakutake
CO	25	1000	13	1-7	7	5-5.8	6.4	Distributed source and nuclear source in Halley
N_2	22	10-1000	-	0.1	5	-	-	-
S_2	20	-	-	0.03	-	0.01	-	Seen in only 1 comet before
C_2H_6	-	-	-	-	-	0.4	0.13	Could be a lower limit
CH_4:CO	-	0.001-0.003	0.13-2.4	-	-	0.12	-	-

* T_s = Sublimation Temperature

Observing Plans for Comet Hale-Bopp

Because the comet is expected to be very bright, a large number of astronomers are planning observations of the comet. When a comet is bright, a large number of different observing techniques in different wavelength regimes may be used to investigate different aspects of cometary physics. Below are selected programs from some of the major teams which routinely observe bright comets.

At the Lowell Observatory astronomers D. Schleicher, B. Millis and T. Farnham are undertaking an extensive long-term observing campaign of comet Hale-Bopp. Schleicher and Millis are experts in the photometric observation of bright comets, and were key observers in the campaign to determine the rotation period of comet P/Halley when it was near perihelion in 1986.

- Narrowband Photometry every 2 weeks to measure how much dust and how much of each of several gas species is being produced as a function of time. This will help astronomers determine if there are differences in composition and amount of gas produced when compared to other well-observed comets.

- Narrowband CCD imaging every 10 days will be used to study the structure in the coma. In particular they will be looking for the number and location of active areas called jets, and will use these observations to try to determine a rotation period for the comet.

A team of comet scientists, lead by M. Mumma (Goddard) has been very active at looking at comets in the infra-red wavelengths to try to discover the composition of the parent molecules in the comet. The team (consisting of: N. Dello Russo, M. DiSanti, M. Fomenkova, K. Magee-Sauer, B. Novak, D. Reuter, and Y. Pendleton) plans to use the NASA Infrared Telescope on Mauna Kea in late January, late February and mid-April to do the following:

- Detection and monitoring of the abundance of organic species and water molecules, as well as CO. The first detections of CO were made in June of 1996, and organics in September of 1996.

- Mumma and Vladimir Krasnopolsky have also been studying X-rays from the comet in an ongoing program to try to understand the mechanism which produces the X-rays.

Astronomer Harold Weaver, at the Johns Hopkins University has specialized in the observation of bright comets using the Hubble Space Telescope (HST) Facility. Since 1995 Weaver and his collaborators have been monitoring the comet with the HST which can achieve superior resolution compared to ground-based instruments, which allows astronomers to study jets in the inner coma. His specific observing plans include:

- In collaboration with M. A'Hearn, C. Arpigny, J. Brandt, P. Feldman and A. Stern, Weaver plans to resume his monitoring of the comet beginning in late-August 1997. It will not be possible to observe the comet near perihelion because the HST has solar elongation exclusion limits of 50 degrees. Originally the team had hoped to get an exception to this limit and point the telescope closer to the sun during the first two weeks of March, 1997, but it is unlikely that these will be allowed.
- In addition, Weaver will be collaborating with others (T. Brooke, G. Chin, S. Kim and J. Davies) to use the NASA Infrared Telescope Facility in early march to search for organic molecules (acetylene - C_2H_2, ethylene - C_2H_4, and methane - CH_4). The presence of these organic materials are strong indicators as to how much of the original interstellar matarial is preserved in the comet.

References

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Mumma, M. *et al.*, 1996, *Science*, in press.

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PLANETARY SCIENCE RESEARCH PSRD Discoveries

Hot Idea posted February 14, 1997 (updated March 11, 1997)

1997 Apparition of Comet Hale-Bopp
Observing Comet Hale-Bopp

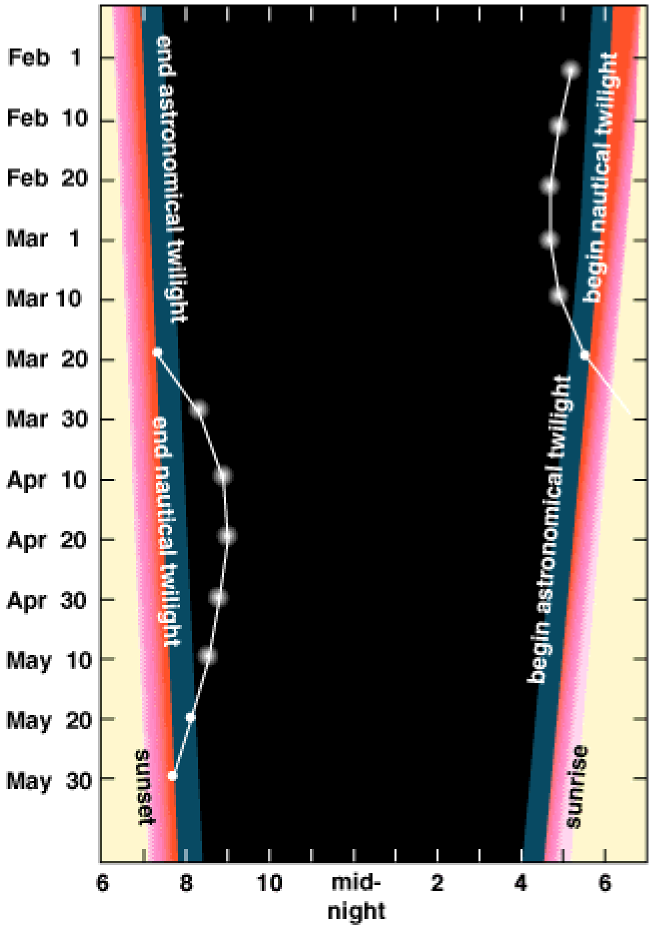
by Karen Meech

Binocular and naked-eye views of the sky from the darkest location possible should result in some satisfying comet-watching. Consult local astronomy groups and newspapers for details on viewing comet Hale-Bopp where you live. Or link now to **PSR Discoveries** visibility tables for Denver or New Orleans.

A Comet Hale-Bopp Positions generator [was] also available on-line from the United States Naval Observatory, Astronomical Applications Department. The position of the comet during twilight can be obtained for any location in local time.

Observing Opportunities from Hawaii

The comet moves fairly far north when it is at its brightest, and will not therefore be optimally placed for viewing from Hawai`i, however, it should be visible in the morning skies in February and March, and in the evening skies during April and May. The figure and table, below, show the visibility from Hawai`i.



(Karen Meech, Univ. of Hawaii.)

In the figure, solid circles indicate when the comet rises (in the morning) and sets in the evening. The sunrise and sunset on each date are shown as heavy lines, and the other 2 lines represent the beginning (in the morning) or end (evening) of [nautical twilight](#) (NTwi) and the beginning (morning) or end (evening) of [astronomical twilight](#) (ATwi). The comet should be easily visible during the astronomical twilight, and may be visible well into the nautical twilight (note, civil twilight is not plotted).

The table indicates that the comet will not be very high above the horizon while the sky is quite dark, *i.e.* during astronomical twilight. The best time to see the comet from Hawai`i from this point of view will be near Feb 20 in the morning (between 5-5:30) and again in mid April in the evening at the end of twilight. The times in the table should be accurate to about 5 minutes, but will depend on the geometry of the observer's horizon. The magnitudes were based on an early extrapolation of the lightcurve. However, after the brightness seemed to stagnate from July through October 1996, again brightening in November, some astronomers are being more conservative in the maximum brightness prediction, suggesting it may reach between -0.5 and -1.0.

Visibility of Comet Hale-Bopp from Hawaii

(revised on 11 March 97)

* see below for other localities

Date	**Comet Rise**	**Beg ATwi**	**Altitude**	**Beg NTwi**	**Altitude**	**Sunrise**	**Mag**
Feb 01	5:15 am	5:41 am	11.4 deg	6:07 am	17.4 deg	6:47 am	
Feb 10	4:58 am	5:39 am	14.8 deg	6:05 am	20.8 deg	6:45 am	
Feb 20	4:44 am	5:33 am	16.0 deg	5:59 am	21.7 deg	6:39 am	
Mar 01	4:42 am	5:29 am	15.1 deg	5:54 am	20.2 deg	6:33 am	
Mar 10	4:54 am	5:22 am	10.7 deg	5:48 am	15.5 deg	6:25 am	-0.1
Mar 20	5:32 am	5:14 am	-	5:40 am	06.7 deg	6:17 am	-0.5
Mar 30	-	5:03 am	-	5:30 am	-	6:09 am	-0.6
Date	**Comet Set**	**End NTwi**	**Altitude**	**End ATwi**	**Altitude**	**Sunset**	**Mag**
Mar 20	7:14 pm	7:21 pm	-	7:46 pm	-	6:41 pm	-0.5
Mar 30	8:14 pm	7:23 pm	12.8 deg	7:50 pm	08.3 deg	6:46 pm	-0.6
Apr 10	8:48 pm	7:28 pm	19.5 deg	7:53 pm	14.6 deg	6:47 pm	-0.4
Apr 20	8:55 pm	7:31 pm	21.1 deg	7:58 pm	15.5 deg	6:51 pm	0.0
Apr 30	8:43 pm	7:35 pm	18.8 deg	8:03 pm	12.9 deg	6:53 pm	0.5
May 10	8:25 pm	7:39 pm	14.5 deg	8:07 pm	08.2 deg	6:57 pm	1.1
May 20	8:02 pm	7:45 pm	08.1 deg	8:14 pm	-	7:02 pm	1.7
May 30	7:36 pm	7:49 pm	-	8:20 pm	-	7:07 pm	2.2

Visibility of Comet Hale-Bopp from Denver or New Orleans

Where to Find Comet Hale-Bopp

Click on the buttons below to bring up the finder chart for the desired month.

February. The comet should reappear after solar conjunction in the morning skies in late January. It will be difficult to observe during early February, accessible only during the early morning twilight hours. At the beginning of the month, the comet will have a declination of only +15 degrees, and be found just north of the constellation Aquila. During the month the comet will brighten rapidly and move north.

March. During the month of March, the comet will brigthen to something easily accessible to the general public, as it moves closer to the sun. It will move toward being visible in the evening sky late in March. The comet will be passing south of the prominent constellation of Cygnus towards Andromeda. On the date of its closest approach to Earth, March 22, the comet will be just NW (by several degrees) of the Andromeda nebula (M31) which will just be rising in the twilight.

April. During late March and early April the comet will be visible in the northwest sky just after sunset, and it should be approaching its maximum brightness. During the month, the comet will move from Andromeda to Perseus and Taurus, and during the last week it will be located just east of the star cluster the Pleiades. During late April the moon will interfere with observations as the comet fades.

May. The dust tail development should peak during May and June, but the comet will probably be lost to observation by the general public during the month. The comet begins to move south, by late June passing south of the celestial equator. During the fall, the comet will be accessible by binocular or small telescope to southern hemisphere observers only, as it reaches a maximum southern declination of -65 degrees during January 1998.

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