= Comet Hale ? Bopp =

Comet Hale ? Bopp (formally designated C / 1995 O1) is a comet that was perhaps the most widely observed of the 20th century and one of the brightest seen for many decades . It was visible to the naked eye for a record 18 months , twice as long as the previous record holder , the Great Comet of 1811 .

Hale ? Bopp was discovered on July 23 , 1995 , at a great distance from the Sun , raising expectations that the comet would brighten considerably by the time it passed close to Earth . Although predicting the brightness of comets with any degree of accuracy is very difficult , Hale ? Bopp met or exceeded most predictions when it passed perihelion on April 1 , 1997 . The comet was dubbed the Great Comet of 1997 .

= = Discovery = =

The comet was discovered independently on July 23 , 1995 by two observers , Alan Hale and Thomas Bopp , both in the United States .

Hale had spent many hundreds of hours searching for comets without success , and was tracking known comets from his driveway in New Mexico when he chanced upon Hale ? Bopp just after midnight . The comet had an apparent magnitude of 10 @.@ 5 and lay near the globular cluster M70 in the constellation of Sagittarius . Hale first established that there was no other deep @-@ sky object near M70 , and then consulted a directory of known comets , finding that none were known to be in this area of the sky . Once he had established that the object was moving relative to the background stars , he emailed the Central Bureau for Astronomical Telegrams , the clearing house for astronomical discoveries .

Bopp did not own a telescope . He was out with friends near Stanfield , Arizona observing star clusters and galaxies when he chanced across the comet while at the eyepiece of his friend 's telescope . He realized he might have spotted something new when , like Hale , he checked his star maps to determine if any other deep @-@ sky objects were known to be near M70 , and found that there were none . He alerted the Central Bureau for Astronomical Telegrams through a Western Union telegram . Brian G. Marsden , who had run the bureau since 1968 , laughed , " Nobody sends telegrams anymore . I mean , by the time that telegram got here , Alan Hale had already e @-@ mailed us three times with updated coordinates . "

The following morning , it was confirmed that this was a new comet , and it was given the designation C / 1995 O1 . The discovery was announced in International Astronomical Union circular 6187 .

The comet may have been observed by ancient Egyptians during the reign of pharaoh Pepi I (2332 ? 2283 BC) . In Pepi 's pyramid in Saqqara is a text referring to an " nhh @-@ star " as a companion of the pharaoh in the heavens , where " nhh " is the hieroglyph for long hair .

= = Early observation = =

Hale ? Bopp 's orbital position was calculated as 7 @.@ 2 astronomical units (AU) from the Sun , placing it between Jupiter and Saturn and by far the greatest distance from Earth at which a comet had been discovered by amateurs . Most comets at this distance are extremely faint , and show no discernible activity , but Hale ? Bopp already had an observable coma . An image taken at the Anglo @-@ Australian Telescope in 1993 was found to show the then @-@ unnoticed comet some 13 AU from the Sun , a distance at which most comets are essentially unobservable . (Halley 's Comet was more than 100 times fainter at the same distance from the Sun .) Analysis indicated later that its comet nucleus was 60 ± 20 kilometres in diameter , approximately six times the size of Halley .

Its great distance and surprising activity indicated that comet Hale ? Bopp might become very bright indeed when it reached perihelion in 1997 . However , comet scientists were wary ? comets can be extremely unpredictable , and many have large outbursts at great distance only to diminish in brightness later . Comet Kohoutek in 1973 had been touted as a ' comet of the century ' and turned

out to be unspectacular .

= = Perihelion = =

Hale ? Bopp became visible to the naked eye in May 1996 , and although its rate of brightening slowed considerably during the latter half of that year , scientists were still cautiously optimistic that it would become very bright . It was too closely aligned with the Sun to be observable during December 1996 , but when it reappeared in January 1997 it was already bright enough to be seen by anyone who looked for it , even from large cities with light @-@ polluted skies .

The Internet was a growing phenomenon at the time , and numerous websites that tracked the comet 's progress and provided daily images from around the world became extremely popular . The Internet played a large role in encouraging the unprecedented public interest in comet Hale ? Bopp .

As the comet approached the Sun , it continued to brighten , shining at 2nd magnitude in February , and showing a growing pair of tails , the blue gas tail pointing straight away from the Sun and the yellowish dust tail curving away along its orbit . On March 9 , a solar eclipse in China , Mongolia and eastern Siberia allowed observers there to see the comet in the daytime . Hale ? Bopp had its closest approach to Earth on March 22 , 1997 at a distance of 1 @.@ 315 AU .

As it passed perihelion on April 1 , 1997 the comet developed into a spectacular sight . It shone brighter than any star in the sky except Sirius , and its dust tail stretched 40 ? 45 degrees across the sky . The comet was visible well before the sky got fully dark each night , and while many great comets are very close to the Sun as they pass perihelion , comet Hale ? Bopp was visible all night to northern hemisphere observers .

= = After perihelion = =

After its perihelion passage , the comet moved into the southern celestial hemisphere . The comet was much less impressive to southern hemisphere observers than it had been in the northern hemisphere , but southerners were able to see the comet gradually fade from view during the second half of 1997 . The last naked @-@ eye observations were reported in December 1997 , which meant that the comet had remained visible without aid for 569 days , or about 18 and a half months . The previous record had been set by the Great Comet of 1811 , which was visible to the naked eye for about 9 months .

The comet continued to fade as it receded , but is still being tracked by astronomers . In October 2007 , 10 years after the perihelion and at distance of 25 @.@ 7 AU from Sun , the comet was still active as indicated by the detection of the CO @-@ driven coma . Herschel Space Observatory images taken in 2010 suggest comet Hale ? Bopp is covered in a fresh frost layer . Hale ? Bopp was again detected in December 2010 when it was 30 @.@ 7 AU away from the Sun , and on August 7 , 2012 at a 33 @.@ 2 AU distance from the Sun . Astronomers expect that the comet will remain observable with large telescopes until perhaps 2020 , by which time it will be nearing 30th magnitude . By this time it will become very difficult to distinguish the comet from the large numbers of distant galaxies of similar brightness .

= = Orbital changes = =

The comet likely made its previous perihelion 4 @,@ 200 years ago . The comet 's orbit is almost perpendicular to the plane of the ecliptic , which ensures that close approaches to planets are rare . However , in April 1996 the comet passed within 0 @.@ 77 AU of Jupiter , close enough for its orbit to be measurably affected by the planet 's gravity . The comet 's orbit was shortened considerably to a period of roughly 2 @,@ 533 years , and it will next return to the inner Solar System around the year 4385 . Its greatest distance from the Sun (aphelion) will be about 370 AU , reduced from about 525 AU .

Over many orbits , the cumulative effect of gravitational perturbations on comets with high orbital

inclinations and small perihelion distances is generally to reduce the perihelion distance to very small values . Hale ? Bopp has about a 15 % chance of eventually becoming a sungrazing comet through this process .

It has been calculated that the previous visit by Hale ? Bopp occurred in July 2215 BC . The comet may have presented a similar sight to people then , as the estimated closest approach to Earth was 1 @.@ 4 AU , but no records of it have survived . Hale ? Bopp may have had a near collision with Jupiter in early June 2215 BC , which probably caused a dramatic change in its orbit , and 2215 BC may have been its first passage through the inner Solar System .

The estimated probability of Hale @-@ Bopp 's striking Earth in future passages through the inner Solar System is remote , about 2 @.@ 5 × 10 ? 9 per orbit . However , given that the comet nucleus is around 60 km in diameter , the consequences of such an impact would be apocalyptic . Weissman conservatively estimates the diameter at 35 km ; an estimated density of 0 @.@ 6 g / cm3 then gives a cometary mass of 1 @.@ 3 × 1019 g . At a probable impact velocity of 52 @.@ 5 km / s , impact energy can be calculated as 1 @.@ 9 × 1032 ergs , or 4 @.@ 4 × 109 megatons , about 44 times the estimated energy of the K @-@ T impact event .

= = Scientific results = =

Comet Hale ? Bopp was observed intensively by astronomers during its perihelion passage , and several important advances in cometary science resulted from these observations . The dust production rate of the comet was very high (up to 2 @.@ 0 × 106 kg / s) , which may have made the inner coma optically thick . Based on the properties of the dust grains ? high temperature , high albedo and strong 10 ?m silicate emission feature ? the astronomers concluded the dust grains are smaller than observed in any other comet .

Hale ? Bopp showed the highest ever linear polarization detected for any comet . Such polarization is the result of solar radiation getting scattered by the dust particles in the coma of the comet and depends on the nature of the grains . It further confirms that the dust grains in the coma of comet Hale ? Bopp were smaller than inferred in any other comet .

= = = Sodium tail = = =

One of the most remarkable discoveries was that the comet had a third type of tail . In addition to the well @-@ known gas and dust tails , Hale ? Bopp also exhibited a faint sodium tail , only visible with powerful instruments with dedicated filters . Sodium emission had been previously observed in other comets , but had not been shown to come from a tail . Hale ? Bopp 's sodium tail consisted of neutral atoms (not ions) , and extended to some 50 million kilometres in length .

The source of the sodium appeared to be the inner coma , although not necessarily the nucleus . There are several possible mechanisms for generating a source of sodium atoms , including collisions between dust grains surrounding the nucleus , and ' sputtering ' of sodium from dust grains by ultraviolet light . It is not yet established which mechanism is primarily responsible for creating Hale ? Bopp 's sodium tail , and the narrow and diffuse components of the tail may have different origins .

While the comet 's dust tail roughly followed the path of the comet 's orbit and the gas tail pointed almost directly away from the Sun , the sodium tail appeared to lie between the two . This implies that the sodium atoms are driven away from the comet 's head by radiation pressure .

= = = Deuterium abundance = = =

The abundance of deuterium in comet Hale ? Bopp in the form of heavy water was found to be about twice that of Earth 's oceans . If Hale ? Bopp 's deuterium abundance is typical of all comets , this implies that although cometary impacts are thought to be the source of a significant amount of the water on Earth , they cannot be the only source .

Deuterium was also detected in many other hydrogen compounds in the comet . The ratio of

deuterium to normal hydrogen was found to vary from compound to compound , which astronomers believe suggests that cometary ices were formed in interstellar clouds , rather than in the solar nebula . Theoretical modelling of ice formation in interstellar clouds suggests that comet Hale ? Bopp formed at temperatures of around 25 ? 45 Kelvin .

= = = Organics = = =

Spectroscopic observations of Hale ? Bopp revealed the presence of many organic chemicals , several of which had never been detected in comets before . These complex molecules may exist within the cometary nucleus , or might be synthesised by reactions in the comet .

= = = Detection of argon = = =

Hale ? Bopp was the first comet where the noble gas argon was detected . Noble gases are chemically inert and highly volatile , and since different noble elements have different sublimation temperatures , they can be used for probing the temperature histories of the cometary ices . Krypton has a sublimation temperature of 16 ? 20 K and was found to be depleted more than 25 times relative to the solar abundance , while argon with its higher sublimation temperature was enriched relative to the solar abundance . Together these observations indicate that the interior of Hale ? Bopp has always been colder than 35 ? 40 K , but has at some point been warmer than 20 K. Unless the solar nebula was much colder and richer in argon than generally believed , this suggests that the comet formed beyond Neptune in the Kuiper belt region and then migrated outward to the Oort cloud .

= = = Rotation = = =

Comet Hale ? Bopp 's activity and outgassing were not spread uniformly over its nucleus , but instead came from several specific jets . Observations of the material streaming away from these jets allowed astronomers to measure the rotation period of the comet , which was found to be about 11 hours 46 minutes .

= = = Binary nucleus question = = =

In 1997 a paper was published that hypothesised the existence of a binary nucleus to fully explain the observed pattern of comet Hale ? Bopp 's dust emission observed in October 1995 . The paper was based on theoretical analysis , and did not claim an observational detection of the proposed satellite nucleus , but estimated that it would have a diameter of about 30 km , with the main nucleus being about 70 km across , and would orbit in about three days at a distance of about 180 km . This analysis was confirmed by observations in 1996 using Wide @-@ Field Planetary Camera 2 of the Hubble Space Telescope which had taken images of the comet that revealed the satellite .

Although observations using adaptive optics in late 1997 and early 1998 showed a double peak in the brightness of the nucleus , controversy still exists over whether such observations can only be explained by a binary nucleus . The discovery of the satellite was not confirmed by other observations . Also , while comets have been observed to break up before , no case has previously been found of a stable binary nucleus . Given the very small mass of this comet , the orbit of the binary nucleus would be easily disrupted by the gravity of the Sun and planets .

= = UFO claims = =

In November 1996 amateur astronomer Chuck Shramek of Houston , Texas took a CCD image of the comet , which showed a fuzzy , slightly elongated object nearby . When his computer sky @-@ viewing program did not identify the star , Shramek called the Art Bell radio program Coast to Coast AM to announce that he had discovered a " Saturn @-@ like object " following Hale ? Bopp . UFO

enthusiasts , such as remote viewing proponent Courtney Brown , soon concluded that there was an alien spacecraft following the comet .

Several astronomers , including Alan Hale , claimed the object was simply an 8 @.@ 5 @-@ magnitude star , SAO141894 , which did not appear on Shramek 's computer program because the user preferences were set incorrectly . Later , Art Bell even claimed to have obtained an image of the object from an anonymous astrophysicist who was about to confirm its discovery . However , astronomers Olivier Hainaut and David J. Tholen of the University of Hawaii stated that the alleged photo was an altered copy of one of their own comet images .

A few months later , in March 1997 , 39 members of the cult Heaven 's Gate committed mass suicide with the intention of teleporting to a spaceship they believed was flying behind the comet .

Nancy Lieder , a self @-@ proclaimed contactee who claims to receive messages from aliens through an implant in her brain , stated that Hale ? Bopp was a fiction designed to distract the population from the coming arrival of " Nibiru " or " Planet X " , a giant planet whose close passage would disrupt the Earth 's rotation , causing global cataclysm . Although Lieder 's original date for the apocalypse , May 2003 , passed without incident , predictions of the imminent arrival of Nibiru continued by various conspiracy websites , most of whom tied it to the 2012 phenomenon .

= = Legacy = =

Its lengthy period of visibility and extensive coverage in the media meant that Hale ? Bopp was probably the most @-@ observed comet in history , making a far greater impact on the general public than the return of Halley 's Comet in 1986 , and certainly seen by a greater number of people than witnessed any of Halley 's previous appearances . For instance , 69 % of Americans had seen Hale ? Bopp by April 9 , 1997 .

Hale ? Bopp was a record @-@ breaking comet ? the farthest comet from the Sun discovered by amateurs , with the largest well @-@ measured cometary nucleus known after 95P / Chiron , and it was visible to the naked eye for twice as long as the previous record @-@ holder . It was also brighter than magnitude 0 for eight weeks , longer than any other recorded comet .