

# Comet C/1996 B2 (Hyakutake): The Great Comet of 1996

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*A joint report of the Comet Section (Director, Jonathan Shanklin) and The Astronomer magazine (Editor, Guy Hurst)*

A preliminary report on this comet has already appeared in the *Journal*<sup>1</sup> and a more detailed set of observations has been published by *The Astronomer*.<sup>2</sup> This paper records those observations submitted to *TA* and the BAA up to the end of 1996 October. Whilst there is some analysis here it is not extensive. It is hoped that a final report will be published as a *Memoir* at a later date. Many of the observations and images have been archived electronically on a CD-ROM. A selection of these observations is also available on the Internet.<sup>18</sup> The visual observations were converted to electronic format and have been forwarded to the *International Comet Quarterly*.

## Discovery

Comet C/1996 B2 was discovered by the Japanese amateur Yuji Hyakutake<sup>3</sup> on 1996 January 30. It was discovered visually using a pair of 25×150 binoculars and at the time it was an eleventh magnitude object in Libra. On the day of its discovery Rob McNaught in Australia described the comet as moderately condensed and of around magnitude 10 with a four arc-minute diameter coma.<sup>6</sup> There was no hint that this was anything other than a run-of-the-mill faint comet.

CCD astrometry of the comet quickly followed the discovery announcement and on 1996 February 3 the first parabolic orbital elements were reported.<sup>7</sup> A total of 33 astrometric observations over a four-day arc indicated that the comet would reach perihelion on 1996 May 2.8 at a distance of only 0.22 AU. A close perihelion distance was remarkable enough but the elements also indicated that the comet would approach to within 0.11 AU of the Earth in late 1996 March. Given the brightness at discovery it was possible that it could reach first magnitude at close approach. Comet Hyakutake

had the potential to become a spectacular object. Shortly after the discovery Marsden commented: 'The comet is unique in its close passage to the Earth and subsequent small perihelion distance. If the brightness holds it will be intrinsically the brightest comet to pass so close to the Earth since 1556'.<sup>9</sup>

## The orbit

Comet C/1996 B2 moves in the highly inclined, retrograde orbit shown in Figure 1. This figure shows the orbits of the comet and the Earth from a point 0.3 AU above the ecliptic plane. Very soon after discovery it was apparent that the orbit was an ellipse rather than a parabola. The periodic orbit was encouraging since it meant that this comet was not a new visitor to the inner solar system. New comets tend to be relatively active far from the Sun but often fail to come up to expectations as they move into the inner solar system. Older comets have a more uniform performance and are less prone to early outbursts.

Figure 1 was generated by a computer program using the osculating orbital elements in Table 1. In this table  $T$  is the time of perihelion passage in Terrestrial Time (the modern successor to Ephemeris Time and 62 seconds ahead of UT in 1996);  $e$  is the orbit's eccentricity,  $q$  is the perihelion distance (in AU),  $\omega$  is the argument of perihelion,  $\Omega$  is the longitude of the ascending node and  $i$  is the inclination. The epoch is the time at which the osculating elements are valid. Away from this time the elements change due to gravitational perturbations and rocket effects caused by outgassing from the nucleus. The parameters  $A_1$  and  $A_2$  represent the radial and tangential components of the accelerations due to these rocket effects and they are defined in units of  $10^{-8}$  AU/day<sup>2</sup>. The radial non-gravitational acceleration is quite large in this case and this implies that the mass of the comet is small. The orbit in Table 1 was the latest available from the Minor Planet Center (MPC) at the time of writing (1997 April). There have been significant problems fitting an orbit to post-perihelion observations and later element sets from other sources should be treated with caution.

The osculating elements can be used as the basis of an orbit integration. This numerical integration takes into

**Table 1. Orbital elements from 703 observations, 1996 January 31–May 23.<sup>12</sup>**

|                                                      |                       |           |  |
|------------------------------------------------------|-----------------------|-----------|--|
| Epoch: 1996 April 27.0 (JD <sub>T</sub> = 2450200.5) |                       |           |  |
| $T$ = 1996 May 1.39500 TT                            | $\omega$ = 130°.17725 |           |  |
| $e$ = 0.9997576                                      | $\Omega$ = 188°.04538 | $J2000.0$ |  |
| $q$ = 0.2302210 AU                                   | $i$ = 124°.92332      |           |  |
| $A_1$ = +2.76                                        | $A_2$ = +0.0716       |           |  |

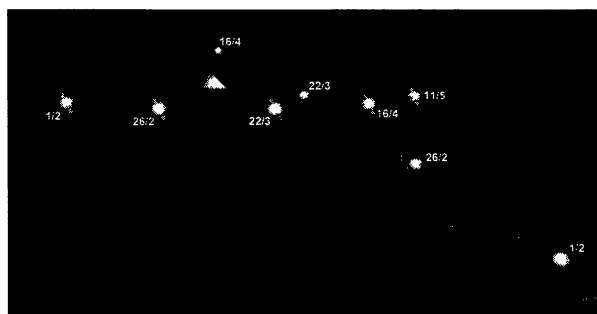


**Figure 1.** The orbit of Comet Hyakutake seen from a position 0.3 AU above the ecliptic plane.

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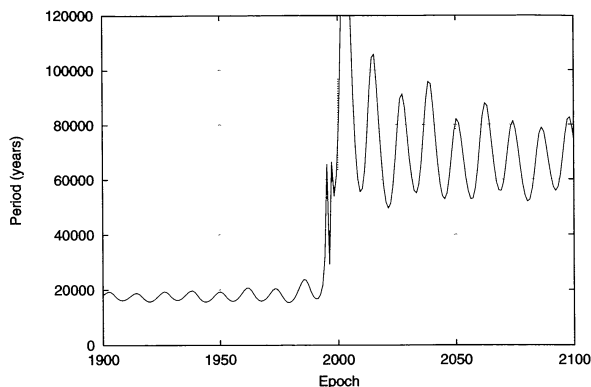
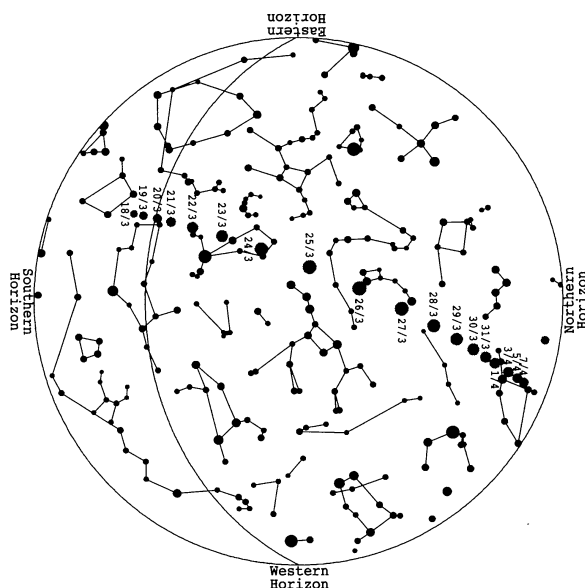


**Figure 2.** The orbital period at various times in the past and future obtained by integrating the osculating elements given in Table 1 using the RADAU integrator.

account the perturbations caused by the gravitational influences of the planets and the non-gravitational forces. These perturbations tend to change the osculating elements of the orbit over time. Of particular interest is the orbital period since this tells us when Comet Hyakutake was last in the inner solar system and when it will next visit the Sun. Figure 2 shows the instantaneous orbital period of the comet for 200 years before and after perihelion. This graph was obtained using the RADAU integrator<sup>14</sup> with the osculating elements and non-gravitational parameters given in Table 1. It is most likely that the comet was last in the inner solar system 17,000 years ago but it will not visit again for 70,000 years. These numbers are, of course, very approximate since they depend on elements derived from only four months of observation.

### Circumstances of the apparition

The circumstances of this apparition were especially favourable as can be seen from Figure 1. Comet Hyakutake was discovered at the end of January when it was well below the



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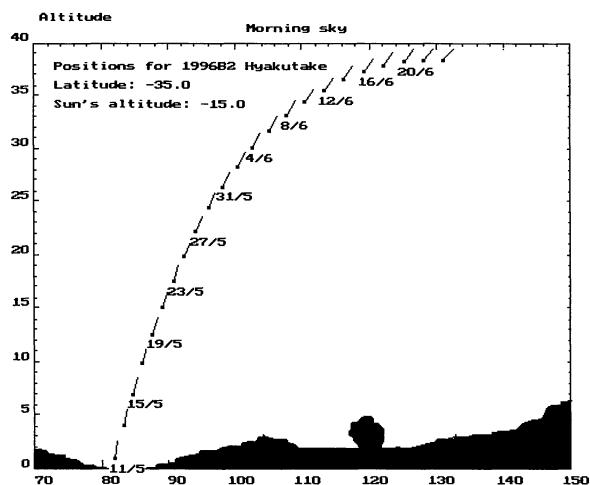


Figure 5. The appearance of the comet in the southern hemisphere morning sky post-perihelion.

year before its discovery the comet was at about  $95^\circ$  elongation in Centaurus. At this time it was about 6.3 AU from the Sun and Earth and, if the magnitude law presented later in this paper was valid, it would have been about magnitude 16. For several months in early 1995 Comet Hyakutake would have been a relatively easy object, however the only pre-discovery image was obtained by Takamizawa on 1996 January 1.<sup>8</sup> Reduction of this photograph was hampered by the comet's low altitude but it showed a  $1'$  diameter coma at approximately magnitude 13.3.

### Early observations

In 1996 February the comet was a southern hemisphere object at a declination of  $-24^\circ$  and it was difficult to obtain observations from the UK. Shanklin first saw the comet on 1996 February 11.08 from the Falkland Islands. At that time the comet was of about eighth magnitude and estimates of the coma diameter ranged from two to seven arcminutes. The first UK visual observation on record was obtained by Bullen (Bognor Regis) on February 14.24. Imaging the comet would prove difficult due to the southerly declination but south-coast photographer David Strange was the first

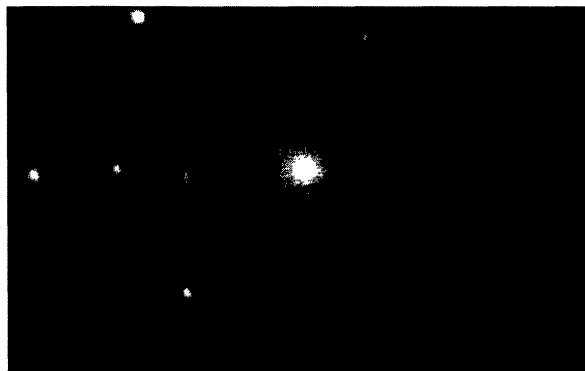


Figure 6. The first CCD image from the UK was obtained on 1996 February 15 at 05.20 UT. This is a  $4 \times 40$ s exposure using a 50cm  $f/4$  Newtonian with an SX CCD. South at top,  $7^\circ \times 5'$  field. David Strange

British observer to submit an image (Figure 6). His CCD frame taken in the early morning hours of 1996 February 15 showed a bright central condensation slightly offset to the west in a diffuse coma. This despite the comet's position only  $7^\circ$  above his southern horizon.

The brightness of the comet was increasing rapidly and by February 20 it had reached seventh magnitude. Visual coma diameter estimates ranged from  $12'$  to  $22'$  and Mikuz reported a  $1^\circ$  tail in p.a.  $290^\circ$  using a 0.20m reflector, a V filter and a CCD. In addition to the southerly latitude UK observers had to contend with very cloudy conditions so observations are sparse during this period. The first reported tail sighting from the UK was made by Getliffe on 1996 February 21.18. He reported a  $0^\circ.1$  tail in p.a.  $314^\circ$  from his observing site at Haverhill.

During a brief gap in the gloom Mobberley obtained a CCD image of the comet on 1997 February 27 (Figure 7). This confirmed the rapid increase in brightness but it would be the last time that he would see the comet until March 16! By February 29.18 Shanklin reported that the tail had grown to  $1^\circ.8$  in p.a.  $305^\circ$ . He was using  $7 \times 50$  binoculars at a dark site in North Wales and estimated the magnitude as 6.4. Proctor also saw the comet that morning from Torquay. It was low in the horizon haze and only just visible in  $10 \times 40$  binoculars.

As February drew to a cloudy end the comet was still well south of the equator but it was already a naked-eye object at fifth magnitude and the tail had become more prominent. It had now come far enough north that British observers had a chance to observe it but at just about this time the British weather seemed to become permanently overcast. Observations from the UK are very sparse in the leadup to close approach and we have to rely on overseas observers to record what we missed.

On March 13.41 Spratt, from Canada, reported the magnitude as 4.3 and wrote: 'The coma is slightly elongated east-west. It is very large with a bright, round, globular-like centre with filamentary hoods or veils sweeping back to form a multi-structured three part tail. One tail is narrow and extends  $0^\circ.25$  in p.a.  $295^\circ$ ; the main tail extends for  $1^\circ.5$  in p.a.  $285^\circ$ , with another thin, narrow section of tail of length  $1^\circ.0$  in p.a.  $260^\circ$ .'

The comet was developing rapidly and only two days later the same observer wrote: 'A small  $1^\circ$  plasma tail extends



Figure 7. 1996 February 27, 04.19 UT. 0.49m Newtonian + Starlight Xpress CCD. North is at the top, east to the left in this  $10' \times 6'$  frame. Martin Mobberley

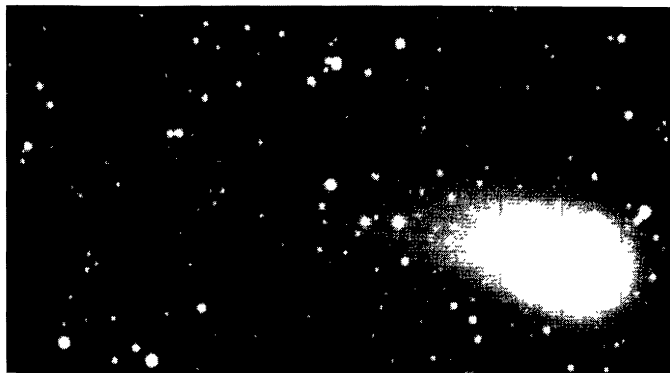


**Figure 8.** 1996 March 17, 01.01 UT, 4×80s, SX camera and 135mm, f/2.8 telephoto. SSW at top. *David Strange*

outwards in p.a.  $250^\circ$ , the main tail extends for  $2^\circ.5$  at p.a.  $270^\circ$ . The tail structure is much changed from the mornings of March 13.41 and 14.40. In 11×80B the coma shows a very bright centre, a filamentary, very broad tail with a very bright narrow central part within the main section which extends some  $2^\circ.5$  in p.a.  $270^\circ$ . A smaller ( $60'$ ) thin plasma tail extension at p.a.  $255^\circ$  was also very evident. Through an 8cm OG f/3.7 ( $\times 19$ ) the coma has a very bright solid centre with a small veil extension of  $8'$  on the NE side.' On 1996 March 19.04 Bullen, observing from Sussex, confirmed that the tail had two components, the south side being the brighter of the two (Figure 8).

The frustration of many UK observers who read these descriptions in the nightly flow of e-mail was immense. By now several had drawn up escape plans as fleeing the country seemed to be the only option. Mobberley, Marsh and James headed for Tenerife,<sup>4</sup> Rogers for southern Spain and McKim managed to combine a pre-arranged skiing trip in the Italian Alps with observations of the comet at close-approach.

### The close approach

By March 20, when the comet passed into the northern hemisphere, it had brightened to second magnitude and was a beautiful naked-eye sight to those lucky enough to have clear skies. The coma was already larger than  $1^\circ$  and an ion tail of up to  $20^\circ$  had been reported by some observers. The comet was now moving quickly across the sky as it approached the Earth.

The tailward jet reported by Spratt had now become very prominent. On 1996 March 22.94 Granslo (Eina, Norway) reported: 'A most spectacular sight. The coma is blue-

green. In 10×50B the tail showed several streamers and structures, including an elongated ion cloud which was  $1.5\times 4^\circ$  and about  $10^\circ$  from the head of the comet. In the 25cm f/6 refl. at  $\times 61$   $m2=8.0$ . There is a prominent jet  $2'$  long towards the SW.'

This jet was confirmed by Zanotta observing from 2000m elevation in the Italian Alps on March 23.02: 'In 7×42B there is also a slightly curved tail or ray just south of the main tail with which it merges before joining the coma; the main tail shows a delicate spine and several hints of ray structures. In the 40cm L, f/4.5 at  $\times 183$  a bright star-like false nucleus and a bright, narrow and sharp jet at PA  $240^\circ$  (bright for nearly  $2'$ ) can be seen. There is also a yellow fan,  $150^\circ$  wide, less than  $1'$  long in the sunward direction'.

On the early morning of March 23 Mobberley, James, Marsh and Kidger were packed into a small car on their way to a coastal observing site on the extreme north-eastern tip of Tenerife. It was very difficult to concentrate on the road since a spectacular comet, complete with tail, could be seen out of the windows. On that morning the comet had a distinctive 'spring-onion' appearance. Arcturus was embedded in the tail and the consensus was that the comet was about 0.5 magnitudes fainter than that star. The tail was visible for over  $20^\circ$  and in 11×80B the coma showed a stellar nucleus surrounded by a classic hood. The coma diameter was at least  $1^\circ.5$ . (Figure 9).

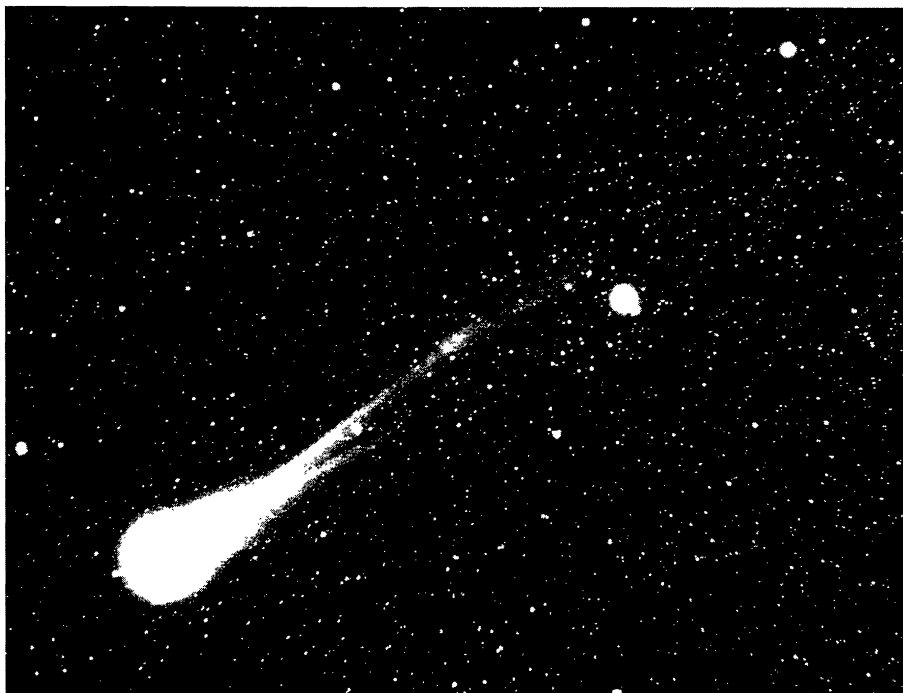


**Figure 9.** 1996 March 23, 0247–0251 UT. 85mm, f/1.8 lens, Gas hypered Tech Pan. The field of view is  $16^\circ \times 12^\circ$ . Arcturus is visible in the tail. *Mobberley, James, Marsh*

Observing from Stormville, USA, on March 23.34 Bortle wrote: 'In the 41cm refl. at  $\times 57$ –114 the nucleus appears as a hard and brilliant star with a slightly tawny hue, which is shared by the immediately surrounding coma. Otherwise the comet's head is essentially bluish. From the nucleus issues an incredibly intense jet, probably the root of the ion tail,

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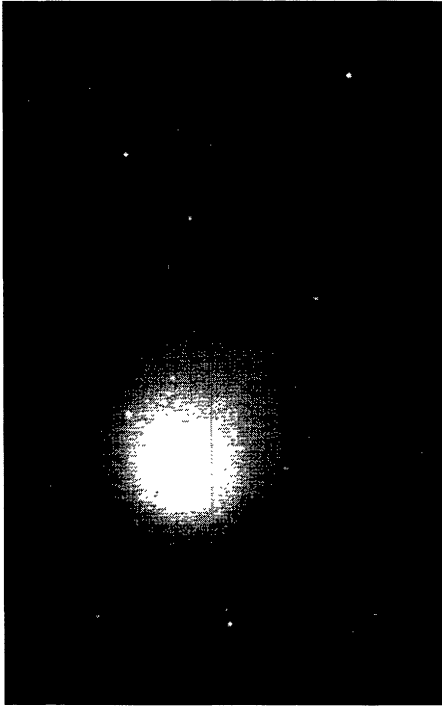


**Figure 10.** 1996 March 23, 23.50–23.58. North is at top, east left in this  $162' \times 109'$  image. *Mark Armstrong*

stretching back to the southwest for some minutes of arc. Sunward there is an ill-defined bright fan about  $90^\circ$  in PA wide with a bright jet at its northern boundary. The comet's head far exceeds the field of view of the low power Erfle eyepiece. Several times there is the impression that the entire head is composed of countless overlying veils of material.'

By the evening of March 23 the tail had changed dramatically. That night McKim found himself onboard a cross-channel ferry. Despite light pollution and smoke from the funnels he could see  $4^\circ$  of tail with the naked eye and wrote: 'the comet is one of the most conspicuous objects in the

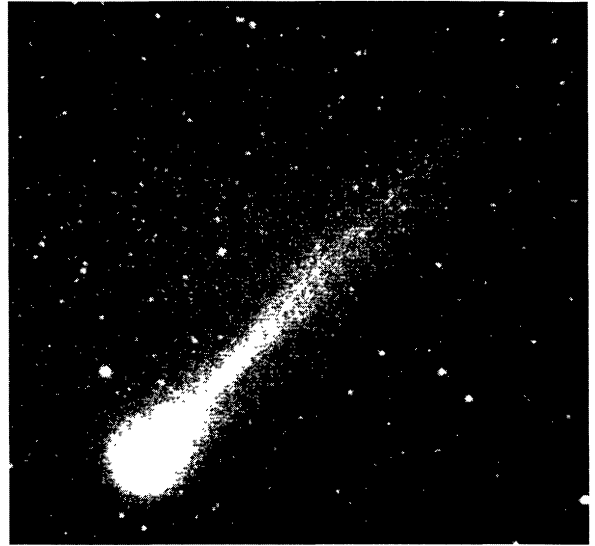


**Figure 12.** 1996 March 24, 01.12. 1 minute exposure on Scotch Chrome 1000. The field of view is  $13^\circ \times 11^\circ$ .  $\gamma$  Boo is the bright star near to the head. *Gerald North*

night sky with a huge coma and a distinct tail'. Mark Armstrong in Kent was one of the few UK observers to submit an image on that night (Figure 10). Later, at 03:00 on March 24, McKim had arrived in Rheims. With 10×50B he reported a  $1^\circ$  diameter coma with a nearly stellar nucleus. At about the same time Mobberley, Marsh and James were freezing in a high gale at 2,000m near the Izana observatory on Tenerife. They were lying on their backs in the shelter of some rocks and the comet was a spectacular sight at the zenith. The tail was less well defined but the coma was slightly brighter than the previous day. Rogers, observing from Albarracin, Spain, also had good conditions. He estimated a tail length of approximately  $21^\circ$  but complained of light pollution from the Gegenschein! From southern England Gerald North was lucky with the weather and glimpsed the comet through a gap in the clouds (Figure 12).

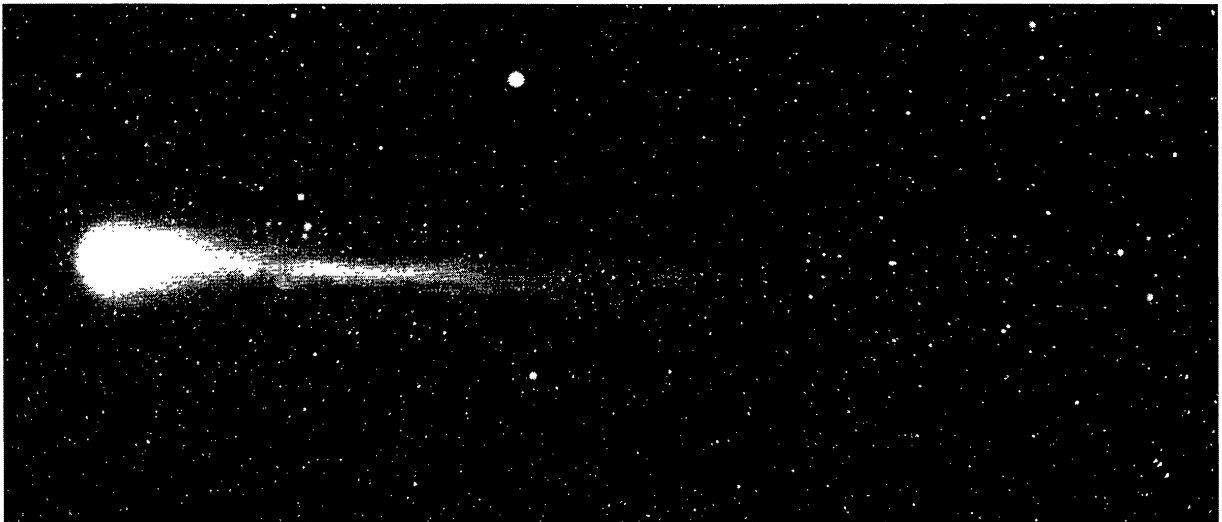


**Figure 11.** 1996 March 25, 00.19–00.23. 85mm, f/1.2L lens at f/1.8. Gas hypered Tech Pan film. The negative was scanned and processed to remove a small amount of vignetting and then log-stretched to bring out the tail without saturating the coma. The field of view is  $24^\circ \times 10^\circ$  and  $\eta$  UMa is the bright star near the top centre. Chipeque, Tenerife. *James, Mobberley, Marsh*



Figure 14. 1996 March 26, 03.50. 50mm, f/1.8 lens. Nick Martin

At its closest on the morning of March 25 the comet approached zero magnitude and the tail stretched from Ursa Major, through Boötes and possibly as far as the bowl of Virgo. Fortuitously, the comet became most active right at the time of closest approach and the tail detail visible on the night of March 24/25 was astounding. Mobberley, Marsh and James were at 1,600m on Mount Teide and the sky was perfect from dusk until dawn. Early in the observing session the thin crescent moon caused some problems but the comet and its tail were spectacular as they rose over the trees surrounding the observing site. Once the moon had set the tail was visible for at least  $25^\circ$  with direct vision and well over  $40^\circ$  with averted vision (Figure 11). In  $11\times 80B$  the bright, tailward pointing spike was very prominent and the main disconnection event was clearly visible with the naked eye. On that night the comet totally dominated the sky and many of the best photographs were taken. Some particularly impressive colour pictures were obtained from dark sites (Figure 13, on the cover).

Unfortunately it was almost totally overcast in the UK at the time of closest approach. One of the few observers to see the comet from Britain at that time was Vetterlein in Orkney. He had clear skies on the early morning of March 25 and reported a  $35^\circ$  tail visible to the naked eye.

The exact time of close approach was 1996 March 25.3. The comet now began to recede from the Earth as it headed in towards the Sun. The viewing geometry meant that the apparent tail-length was expected to grow as the comet moved away from the Earth. Simple geometry (Figure 15) shows that, assuming the tail is an extension of the solar radius vector, its theoretical maximum length is dependent on the Solar phase angle. The phase angle at close approach on March 25 was  $57^\circ$  and on March 26 it was  $70^\circ$ . The phase

Figure 13. (Cover, top). 1996 March 25, 03.51 – 03.54. 85mm, f/1.2L lens at f/1.8. Fuji Super-G800 film. From Chipeque, Tenerife. Mobberley, James, Marsh

angle reached a maximum of  $111^\circ$  on April 6.

On March 25.88 Spratt wrote: 'The coma is very bluish and the brightest portion of the tail is visible for  $15^\circ$ . There is faint evidence of a multiple tail or a nearly parallel spine structure. The west side is more diffuse and slightly more extended than the east side which was straighter in its inner portion and somewhat better defined. In the 10cm OG at  $\times 14$  the coma is at least  $2^\circ.5$  in diameter and has a definite blue colour. The nuclear condensation is displaced sunward of centre, and the area immediately surrounding it was yellowish. A very noticeable  $15'$  long, fan-shaped down-tail spike

is visible. At  $\times 80$  the nuclear condensation is non-stellar and about  $1'$  across. There are no signs of any secondary nuclei.'

In the early morning hours of March 26 Mobberley, Marsh and James were making their final trip to observe the comet from Tenerife. The tail had again changed considerably from the day before and it was indeed longer, possibly up to  $50^\circ$  with averted vision (Figure 14). The comet was now near to Kochab in Ursa Minor. At 04.00UT from Alarcon, Spain, Rogers wrote: 'Standing on the castle ramparts above a canyon; earlier, lightning was flashing on the horizon beyond the dark tower, with the Great Comet visible in gaps in the clouds. Now viewed through better breaks in clouds with variable limiting magnitude. Tail might have extended  $37^\circ$  to Cor Caroli? Width  $1^\circ.0$  at base fanning out to  $3^\circ.5$  at  $26^\circ$  from head. No distinct ray.' He estimated the head magnitude as 0.0.

The weather in the UK improved as Hyakutake moved away from the Earth with the first partially clear night occurring on the evening of March 26/27. The comet reached its maximum northern declination of  $+86^\circ.5$  at 03h on March 27. At this time astrophotographers could take quite long time exposures with short lenses without much trailing

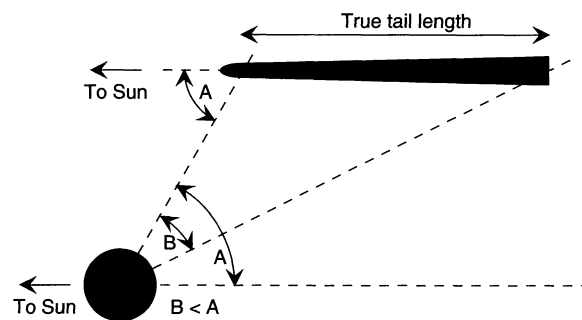


Figure 15. If the tail is radial to the Sun its apparent angular size, B, must be less than the phase angle, A.



**Figure 17.** 1996 March 27, 22.36. SX CCD + 50cm Newtonian. This 6'×6' field is processed to show the nuclear jet. *David Strange*

(Figure 16, page 171). In Essex Abbott had clear skies and saw a 23° long tail in p.a. 130°. He commented: 'A sharp-edged second tail of length 3° in PA 150 is visible. A third tail in PA 115 is only visible as a stub with the naked eye. The primary gas tail widens to 1°.8 at its far end.' John Rogers had returned from Spain and his view from Linton was hampered by some clouds. He could follow the tail for 26° in magnitude 5.8 skies. He noted that the brightness gradient was not as strong as he had observed in Spain and the tail was, in fact, easier to see. The head was getting noticeably smaller as the comet moved away from the Earth and had faded back to first magnitude.

By the evening of March 27 the comet had faded to between magnitude 0.5 and 1.0, the coma diameter was reported to be around 1° and tail lengths of up to 70° were being reported.<sup>10</sup> The night was clear over much of the UK and many observers got their first good view of the comet. Hurst wrote: 'The coma and tail filled the whole field of view. A fan-shaped tail from PA 030 to 130. Very bright jet 3.5' long in centre of tail extension. Nuclear region contains bright slightly elongated star-like centre. At ×120 (Nagler) star-like centre just separated in fleeting moments of good seeing into two components. The brighter, offset in PA 025 mag 12.5 (GSC) and the fainter offset PA 205 mag 13.0 (GSC).' At the same time Stewart Moore reported that: 'The nucleus is elongated and of two different intensities, the northern component is considerably brighter [than the southern]'. These double-nucleus observations were not confirmed by other observers but the features were near to the seeing limit. It is possible that this was a contrast effect in the very complex, bright inner coma.

Strange obtained a high resolution CCD image at 22.36 on March 27 (Figure 17) but it is saturated near to the nucleus and so it does not shed light on the observation of Hurst and Moore. What it does show is the spectacular tailward-pointing ray. Strange comments that visually in his 50cm reflector there was a brilliant 120° fan extending from

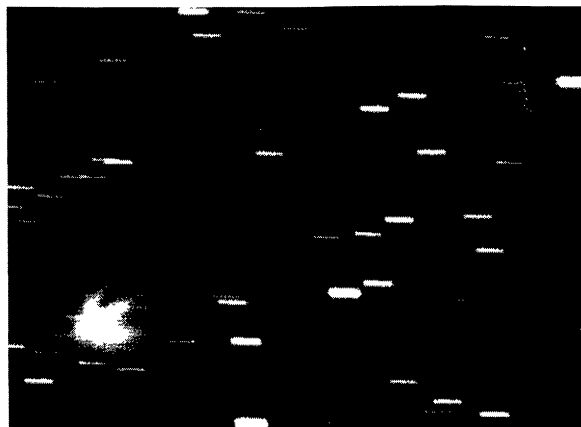


**Figure 18.** 1996 March 27, 20.44–20.59 (30×20s). SX CCD + 135mm f/2.8 lens. The 2°.4 × 1°.8 image has been processed with a median unsharp mask to show features in the coma and tail. *Nick James*

the stellar nucleus. There are at least three fountains visible in the CCD image. He also noted that the tail was distinctly blue in 10×50B. A wider-field image taken by James at about the same time (Figure 18) has been processed to show radial details in the coma and tail.

Graham Keitch on Dartmoor had a particularly good view of the comet in the early morning hours of March 28 and he summed up the awe that most people felt when looking at this amazing object: 'It is one of the brightest objects in the sky. A truly remarkable and eerie sight despite a rather indifferent sky. One could easily sense the awe and fear that would have struck the hearts of previous inhabitants of Foxworthy back in the Middle Ages had they chanced upon an object such as this'. At about the same time, Proctor, observing in the dark skies of Saddle Tor, Dartmoor reported that the tail stretched as far as  $\alpha$  UMa (about 40°) using averted vision.

By March 29 the Moon had started to become a problem



**Figure 20.** 1996 April 5, 20.31–20.51. Zeiss Triplet, FL 1200mm, f/7. T-Max 400 10"×8" sheet film. This is a detail from the original negative and has a field of view of 6°×4°. *Glyn Marsh*



**Figure 21.** 1996 April 5, 21.00–21.10. 20cm, f/6.5 Wright Camera, hydrogen hypered Tech Pan.  $1^{\circ}.5 \times 3^{\circ}$  field. *Brian Manning*

in the evening sky and visual estimates were being hampered by the strong moonlight. Despite a combination of the Moon and passing cloud Alcock managed to draw the comet from Peterborough using 15×80B and 20×60B. As the comet moved away from the Earth and towards the Sun the diameter of the coma was shrinking but the tail had become better defined.

The comet was bright enough to allow relatively simple equipment to capture a spectrum. One such was obtained by Gavin on 1996 April 1 (Figure 19, page 171). The coma shows reflected sunlight and two prominent carbon molecule emission lines in the cyan and green parts of the spectrum. Two fainter emission lines are visible in the blue and yellow and absorption lines due to Earth's atmosphere are visible in the red. The tail is much fainter and only the reflected solar continuum is visible.

### Towards perihelion

In early April the comet stabilised at about second magnitude as the effects of moving away from the Earth were compensated by an increase in its total luminosity as it was warmed by the Sun. Whilst the comet was outside of the Earth's orbit the tail had

consisted mainly of ionised gas, and any dust tail had been very faint. As the comet moved towards the Sun in early April it was hoped that a prominent dust tail would develop. This would ensure that the comet would become a spectacular object in the early evening sky.

A lunar eclipse on the morning of April 4 allowed observers an additional moon-free period to observe the comet and during totality a tail of up to  $18^{\circ}$  was reported.<sup>11</sup> Rogers reported: 'The full Moon disappears, giving an exotic spectacle, a dark sky with the eclipsed Moon high in the south and the comet low in the north'. Unfortunately most UK observers had difficulty in seeing any tail during the eclipse due to the comet's low altitude.

By the end of the first week of April the Moon was no longer a problem as the comet sank lower into the northwest on its way to perihelion. By April 5 the large format cameras of Marsh (Figure 20) and Manning (Figure 21) could be brought to bear on the comet at last. These images show a very well developed ion tail containing a considerable amount of detail. A curved dust tail was beginning to form but it was by no means prominent.

By April 9 Zanotta reported a  $15^{\circ}$  tail in p.a.  $45^{\circ}$  from 2,000m altitude in the Italian Alps. He commented: 'A small coma with a disk-like central condensation was visible with the naked eye. In 7×42B a parabolic coma of diameter nearly  $10'$  was seen. It had a star-like nuclear region and broad tail very slightly curved towards the south. In 25×150B there were traces of a sunward fan nearly  $90^{\circ}$  wide in the coma.'

On the evening of April 10 McKim was observing from Hay-on-Wye. The sky was very clear and dark and he had a spectacular view of the comet with the naked-eye and 10×50B. He reported that the tail was very prominent: 'The first  $7^{\circ}$  is very easy, steadily fading for the next  $5^{\circ}$  or so but obvious using averted vision' (Figure 33). With the naked eye he estimated the tail length of at least

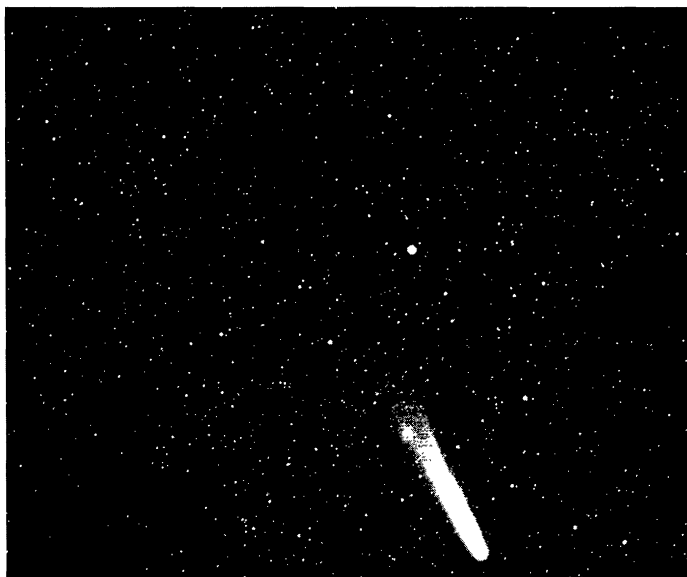


**Figure 22.** 1996 April 13, 21.30–21.40 UT. 135mm, f/3.5 lens on hypered Tech Pan. *Karl-Gustav Andersson, Riala, Sweden*

## Comet C/1996 B2 (Hyakutake)

18° but at this point the tail was getting lost in the bright Milky Way. The coma was now only 20' across and no features or jets were seen in the binoculars.

A prominent dust tail finally began to appear around April 10 although it never surpassed the ion tail. Many observers had been reporting that the bright inner part of the tail had a bluish tint. This is what would be expected for an ion tail fluorescing under the influence of solar radiation. The dust tail would be more diffuse and would have a yellowish colour since it shines by reflected sunlight. On April 11.90 Granslo, Norway, commented: 'There is an apparent stellar central condensation of magnitude 3.4. The

brighter inner parts are yellow, there is an easy green hue to the border region of the parabolic envelope, the outer halo is fluorescent blue and the tail begins sharp and white!'

The tail now had a classic appearance (Figure 22) with a sharp ion tail and a diffuse dust tail. Photographs taken with Schmidt cameras reveal exquisite detail and many streamers are visible in the tail (Figure 23). Colour images clearly separate the ion (blue) and dust (yellow) tails (Figure 24, page 171).

Observers in southern England were treated to a superb view of the comet on the evening of April 17. As the Sun set it was apparent that the night ahead offered the prospect of very transparent skies. In the early twilight the comet was visible in binoculars and as the sky darkened its tail could be seen with the naked eye stretching for at least 10° through Perseus. Rogers observing from Linton describes a 'spectacular panorama in a beautiful clear twilight with Mercury, Pleiades, Venus to the left. The comet is much fainter than the planets but in binoculars (10×50B) the tail is obvious even in blue twilight, becoming very impressive as it darkens.' At almost the same time Hurst wrote: 'The tail is absolutely superb! 6° long and intensely bright and broadening with increasing distance from coma. Tail far brighter than at the earlier close approach to the Earth.' At about this time Dinham recorded the scene in southern Spain (Figure 25).

On the following night Doherty recorded the naked-eye view in a superb painting (Figure 26) and Sefton photographed the inner tail from Lancashire (Figure 27). The comet was now becoming more difficult to observe as it sank into the evening twilight. It was still about second



**Figure 23.** 1996 April 16, 19.57 UT. 200/220/300 Schmidt, 4 min exposure on hypered Tech Pan. Lennart Dahlmark, St. Etienne les Orgues, France

tail was seen for 12° and was visible to near the fine open cluster NGC 1528. The western edge is more sharply defined (gas component?) than the eastern side (dust tail?).'

Meanwhile jet activity in the coma continued and on April 13.20 Spratt reported 'In the 0.20m at ×185 the comet continued to show considerable jet activity. The tailward jet was still evident but very weak, leading directly to main part of tail. Three other areas of jetting activity were noted. The most prominent was on the sunward side.' Some observers at good sites reported prominent colours in the coma. On April 15.82 Zanotta reported: 'In 25×150B the coma is filled with colours as never seen before. The nuclear region and

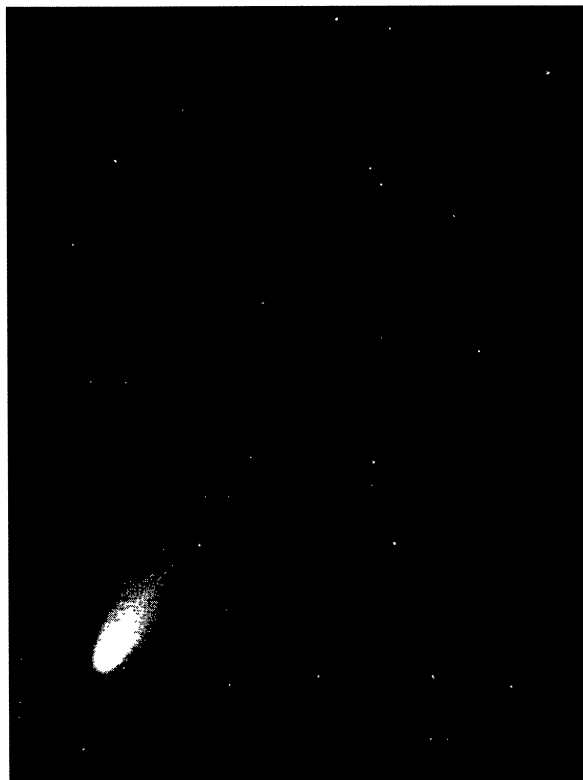


**Figure 27.** 1996 April 18, 21.50. 130mm, f/6 Astrophysics refractor. 5 min exposure on lightly hypered Ektachrome 320 Tungsten slide film. Andy Sefton

**Figure 25.** (Cover, bottom left). 1996 April 17. 20.10. 50mm, f/2.8 lens. 60s exposure on Fujicolor Super Plus 400. Eric Dinham, Spain

**Figure 26.** (Cover, bottom right). 1996 April 18. 20.58–21.15, 8×40B. This watercolour painting of the comet was made by Paul Doherty from his original observations. It gives a very good impression of the visual appearance of the comet in the late evening twilight. P. B. Doherty

Comet C/1996 B2 (Hyakutake)

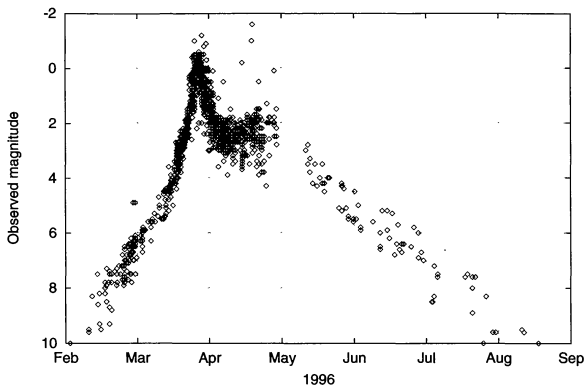


**Figure 29.** 1159 visual magnitude estimates plotted against date. The comet's peak apparent magnitude occurred at close approach and it was then around zero. The break in observations at the start of May was due to conjunction.

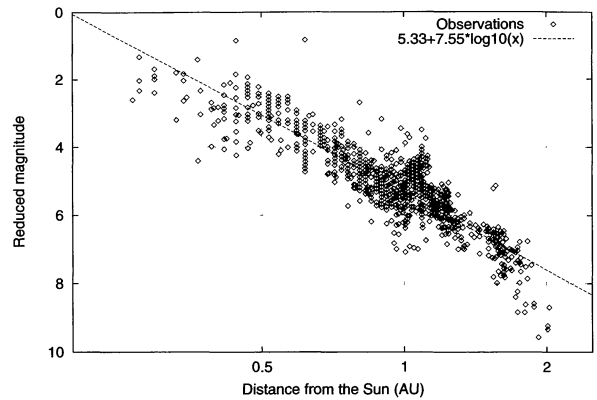


**Figure 30.** The pre-perihelion visual magnitude estimates corrected for the comet's distance from the Earth are plotted against the log of the comet's distance from the Sun. The best fit magnitude law is  $5.31 + 5 \log \Delta + 7.69 \log r$ .

magnitude but the scatter in estimates had become quite large. One of the last photographs received was from Vincent on the 20th (Figure 28, page 171). It shows the comet low above the horizon in nautical twilight.

On the evening of April 24 Rogers estimated the magnitude as 2 but commented: 'The magnitude is a guesstimate only. Venus and the Moon are high to the left. Binoculars showed Pleiades next to Mercury and the comet deepest in twilight, a stellar 'nucleus' and only a little tail. The comet's head was just glimpsed with the naked eye before it sank into the haze.'

Comet Hyakutake was last seen visually by northern hemisphere observers a few days prior to the perihelion passage. By April 27 the magnitude was somewhere between 2 and 3 but it was very difficult to estimate since the comet was seen against such a bright sky. Buczynski, Marsh, Mobberley and James saw it for the last time on the evening of April 27. Observing from Catforth the comet was just visible in 25×105B a few degrees above the horizon in very bright twilight. It was distinctly non-stellar and more fuzzy on its upper edge but it was not easy to see. The early predictions of a naked-eye, daylight comet had not materialised.

### Post-perihelion

As the comet moved towards the Sun it entered the field of the LASCO C3 coronagraph on board the SOHO satellite. Images of the comet at perihelion were obtained by this instrument but terrestrial observers had to wait until May 9 for the comet to reappear from the Sun's glare. By this time it was a southern hemisphere morning object and was around third magnitude.

The comet faded rapidly as it moved away from the Sun. Garradd picked it up on May 9.82 and estimated it to be of third magnitude. A day later Lovejoy reported a 1° tail in strong twilight. By May 18 the comet was visible in a darker sky but the coma had faded to fourth magnitude. As compensation Lovejoy reported that a 6° tail was visible to the

naked eye. The comet faded past sixth magnitude around June 10 and by this time the tail had shrunk to less than 1°.

On June 20 Pearce described the tail as broad and diffuse of length 0°.9 in PA 201°. By the end of July it had faded below eighth magnitude and on August 24 Pearce estimated the magnitude as 10.6. He commented: 'Very vague, diffuse and ill-defined coma. Quite difficult to see in a fairly crowded starfield.' No tail was seen.

### The visual magnitude law

Over 90 observers submitted 1159 visual magnitude estimates to the TA and BAA coordinators. These observations have been stored electronically in the TA/ICQ format and are available online.<sup>19</sup> These estimates have been analysed by Shanklin,<sup>15</sup> following the procedures given in his paper on analysing comets.<sup>16</sup> Despite the impression that the comet faded substantially after closest approach, the light curve (Figure 29) is surprisingly consistent, though the comet does seem to have brightened more rapidly in the month after discovery. Apart from this, there is no significant difference between pre- and post-perihelion behaviour. The same observations are plotted corrected for geocentric distance in Figure 30. The mean light-curve gives a peak magnitude of +0.5 at closest approach, however there is considerable scatter reflecting the difficulty in estimating the brightness of a large, bright, diffuse object. The best-fit magnitude law from the raw observations is given by the first row of Table 2:

$$m_1 = 5.31 + 5 \log \Delta + 7.69 \log r$$

Since the comet was so well behaved it is possible to analyse the light curve in greater detail. The first step is to

**Table 2. Magnitude parameters from an analysis of the visual observations**

|           | <i>H</i> 1 | <i>K</i> 1 | <i>P</i> 1( <i>mm</i> <sup>-1</sup> ) | <i>Q</i> 1    | <i>S</i> 1 ( <i>arcmin</i> <sup>-1</sup> ) |
|-----------|------------|------------|---------------------------------------|---------------|--------------------------------------------|
| Raw       | 5.31±0.02  | 7.69±0.11  |                                       |               |                                            |
| Corrected | 5.33±0.01  | 7.55±0.09  |                                       |               |                                            |
| Aperture  | 5.17±0.02  | 7.21±0.08  | 0.0031±0.0003                         |               |                                            |
| Ap + coma | 5.30±0.03  | 7.32±0.09  | 0.0026±0.0003                         |               | -0.0039±0.0006                             |
| Mag.      | 5.25±0.02  | 7.31±0.09  |                                       | 0.0068±0.0007 |                                            |
| Mag+coma  | 5.39±0.02  | 7.44±0.09  |                                       | 0.0052±0.0008 | -0.0048±0.0006                             |

Table 3. List of observers.

(Corr. is the systematic magnitude estimate correction which has been applied to each observer's estimates; Obs. are the number of estimates included in the analysis and SD is the standard deviation of the corrected estimates.)

| Observer       | Corr. | Obs. | SD  | Location              | Type & Equipment                  | Observer        | Corr. | Obs. | SD  | Location                              | Type & Equipment                                 |
|----------------|-------|------|-----|-----------------------|-----------------------------------|-----------------|-------|------|-----|---------------------------------------|--------------------------------------------------|
| Abbott J.      | 0.2   | 9    | 0.4 | Witham                | V E, 10×50B                       | Lehky M.        | 1.7   | 1    | 0.0 | Czech Republic                        | V 200R                                           |
| Aguiar         | -0.1  | 19   | 0.2 | Brazil                | V 11×80B                          | Lourencon R.    | -0.2  | 9    | 0.2 | Brazil                                | V 20×80B, 7×50B                                  |
| Alcock G.E.D.  | 0.9   | 1    | 0.0 | Peterborough          | V 15×80B, 20×60B                  | Lovejoy T.      | 0.1   | 2    | 0.2 | Australia                             | V 10×50B                                         |
| Aldridge J.    | 0.5   | 1    | 0.0 | Cambridge             | V E                               | Manning B.      | -     | -    | -   | Stakenbridge                          | P 200W                                           |
| Andrews F.     | 0.1   | 8    | 0.2 | New Zealand           | V 150R, 11×80B                    | Marsden B.      | 0.0   | 2    | 0.3 | USA                                   | V E                                              |
| Armstrong M.   | -     | -    | -   | Rolvenden             | C 200T                            | Marsh G.        | -     | -    | -   | Catforth & Tenerife                   | P 1200A                                          |
| Baransky A.R.  | -0.1  | 37   | 0.4 | Ukraine               | V E, 110L, 30R, 12×80B            | Martin N.       | 0.1   | 3    | 1.0 | Ayr                                   | V E                                              |
| Baroni S.      | -0.5  | 17   | 0.4 | Italy                 | V E, 7×50B, 20×80B                | McKim R.J.      | -0.1  | 15   | 0.3 | Oundle                                | V E                                              |
| Beaumont S.    | -0.5  | 15   | 0.6 | Windermere            | V E, 125R                         | McNaught R.     | 0.8   | 1    | 0.0 | Scotland & Australia                  | V 20×120B                                        |
| Bembrick C.S.  | 0.9   | 1    | 0.0 | Australia             | V 11×80B                          | Menali H.I.     | 1.5   | 1    | 0.0 | Turkey                                | V E                                              |
| Binder L.      | 0.5   | 1    | 0.0 | USA                   | V 7×35B                           | Merlin J.-C.    | -0.1  | 7    | 0.2 | France                                | V 7×50B, P                                       |
| Bortle J.E.    | 0.0   | 44   | 0.4 | NY, USA               | V E, 10×50B, 20×80B, 15×80B, 406R | Mikuz H.        | 0.1   | 20   | 0.4 | Slovenia                              | V E, 200T, 7×50B, 3×12B; P                       |
| Bouma R.J.     | -0.5  | 5    | 0.2 | Netherlands           | V E                               | Milani G.       | -0.1  | 10   | 0.3 | Italy                                 | V E, 20×80B                                      |
| Bullen R.      | 0.1   | 23   | 0.5 | Bognor Regis          | V E, 11×80B, 210L, 30R, 35R, C    | Miles R.        | 0.5   | 3    | 0.2 | Wadebridge                            | V E, 7×50B                                       |
| Caldwell P.    | -0.4  | 2    | 0.1 | Australia             | V 10×50B, 250L                    | Mobberley M.P.  | 0.2   | 5    | 0.2 | Tenerife, Chelmsford, Bury St Edmunds | V E; P 85P; C 490L, 150T                         |
| Camilleri P.   | -0.5  | 21   | 0.4 | Australia             | V E, 20×80B, 200L                 | Moore D.        | 0.2   | 3    | 0.3 | Dublin                                | V N, 20×80B, 7×50B, 355L                         |
| Canepari F.    | 0.3   | 12   | 0.4 | Italy                 | V E                               | Moore S.        | 0.3   | 3    | 0.7 | Fleet                                 | V E, P 50P                                       |
| Cernis K.      | -0.0  | 22   | 0.4 | Lithuania             | V E, 7×50B, 20×110B               | Morrison N.     | -0.0  | 15   | 0.5 | Crawley                               | V E, 8×23B, 15×80B                               |
| Clegg D.H.     | -1.3  | 7    | 0.5 | Hull                  | V 10×50B, 20×80B, 250T            | Niechoy D.      | -1.1  | 6    | 0.5 | Germany                               | V E, 100L                                        |
| Collins M.     | 0.4   | 12   | 0.4 | Everton, Beds         | V E, 103R, 7×50B                  | O'Halloran B.   | -0.3  | 21   | 0.4 | Maynooth                              | V E, 10×50B                                      |
| Colombo E.     | 1.6   | 6    | 0.2 | Milan, Italy          | V 7×50B, 8×40B                    | Oksa G.         | -0.0  | 13   | 0.2 | Slovak Republic                       | V E, 20×80B                                      |
| Csukas M.      | 0.4   | 11   | 0.5 | Romania               | V 8×30B                           | Pearce A.R.     | -0.1  | 24   | 0.4 | Australia                             | V E, 20×80B                                      |
| Dahle H.       | -0.3  | 11   | 0.3 | Canada                | V E, 200R, 10×50B                 | Platt T.C.      | -1.5  | 3    | 0.5 | Binfield                              | V E; P C                                         |
| Dinham E.L.    | 0.5   | 1    | 0.0 | Plymouth              | V 9×63B                           | Richardson P.   | 0.1   | 5    | 0.3 | Leigh                                 | V 10×50B                                         |
| Doherty P.B.   | 0.5   | 1    | 0.0 | England               | V E, 8×40B, 150L                  | Rogers J.H.     | 0.0   | 15   | 0.4 | Cambridge                             | V E, 10×50B                                      |
| Ewen-Smith B.  | -0.3  | 1    | 0.0 | Portugal              | V 7×50B                           | Sanford J.      | 1.1   | 1    | 0.0 | USA                                   | V 10×50B                                         |
| Fischer D.     | 0.5   | 1    | 0.0 | Germany               | V 11×70B                          | Shanklin J.     | 0.1   | 44   | 0.5 | Cambridge                             | V E, 20×80B, 14×100B, 7×50B                      |
| Fleet R.       | 0.8   | 2    | 0.2 | Reading               | V E                               | Skilbrei O.     | -0.4  | 38   | 0.4 | Norway                                | V E 7×50B, 10×50B                                |
| Foulkes M.     | -0.0  | 10   | 0.3 | Hatfield              | V E                               | Skjaeraasen O.  | 0.0   | 1    | 0.0 | Norway                                | V 7×35B                                          |
| Fraser J.      | 0.1   | 13   | 0.6 | Alness, Scotland      | V E, 8×30B, 10×50B, 10×42B        | Spratt C.E.     | 0.1   | 21   | 0.4 | Canada                                | V 11×80B, 7×50B, 6×50B                           |
| Gainsford M.J. | 0.2   | 9    | 0.3 | Hinckley              | V E, 11×80B                       | Stanley P.      | -0.2  | 2    | 0.3 | Crawley                               | V E                                              |
| Garradd G.     | -0.0  | 2    | 0.1 | Australia             | V 250L, 10×50B                    | Stomeo E.       | 0.4   | 4    | 0.1 | Italy                                 | V E                                              |
| Gavin M.       | -     | -    | -   | London                | C 85P                             | Storey D.       | -0.6  | 10   | 1.1 | Oxford                                | V E, 20×80B, 7×50B                               |
| Getliffe S.    | -0.1  | 7    | 0.3 | Haverhill             | V 108L                            | Strange D.      | -     | -    | -   | Swanage                               | C 500L                                           |
| Giuntoli M.    | 0.1   | 10   | 0.3 | Italy                 | V 10×50B, 8×22B                   | Tanti T.        | 0.3   | 17   | 0.4 | Malta                                 | V E, 254T, 30R, 12×50B, 20×70B                   |
| Granslo B.H.   | -0.3  | 56   | 0.3 | Norway                | V E, 10×50B, 60R, 203T            | Taylor M.D.     | 0.6   | 13   | 0.3 | Wakefield                             | V 8×40B, 10×50B, 16×70B                          |
| Hasubick W.    | 0.5   | 5    | 0.2 | Germany               | V 25×100B, 10×50B                 | Thorvaldsen S.  | 0.1   | 9    | 0.4 | Norway                                | V 150L, 60R, 7×50B                               |
| Haver R.       | -0.2  | 13   | 0.3 | Italy                 | V E, 10×50B, 15×80B               | Topping B.D.    | -0.7  | 3    | 0.1 | Watford                               | V 7×50B                                          |
| Heath A.W.     | 0.2   | 2    | 1.3 | Nottingham            | V E                               | Vanmunster T.   | 0.6   | 1    | 0.0 | Belgium                               | V E                                              |
| Heen L.T.      | -0.1  | 6    | 0.4 | Norway                | V E, 7×50B                        | Ventura F.      | -0.1  | 23   | 0.6 | Malta                                 | V E, 10×50B                                      |
| Henshaw C.     | 0.3   | 4    | 0.3 | Saudi Arabia          | V E                               | Verde D.        | -1.1  | 1    | 0.0 | Tenerife                              | V E                                              |
| Hillestad T.   | -0.1  | 19   | 0.4 | Norway                | V E                               | Vetterlein J.C. | -0.4  | 15   | 0.4 | Orkney                                | V 7×50B, 20×80B; P 36A                           |
| Hurst G.M.     | 0.1   | 29   | 0.5 | Basingstoke           | V E, 10×50B, 15×80B, 5×25B, 440L  | Wolf G.W.       | 0.1   | 151  | 0.4 | New Zealand                           | V E, 200T, 250L, 180L, 150L, 120R, 20×50B, 7×50B |
| James N.D.     | 1.1   | 1    | 0.0 | Chelmsford & Tenerife | P 55P, 85P, 205P C 300L, 135P     | Zanotta M.      | -0.1  | 21   | 0.5 | Italy                                 | V E, 25×150B, 7×42B; P                           |
| Jones A.F.     | 0.3   | 43   | 0.4 | New Zealand           | V 317L, 78R, 45R 7×50B, 2×23B     |                 |       |      |     |                                       |                                                  |
| Kammerer A.    | 0.1   | 16   | 0.4 | Germany               | V E, 203T, 9×63B                  |                 |       |      |     |                                       |                                                  |
| Kato T.        | -0.4  | 2    | 0.2 | Japan                 | V E                               |                 |       |      |     |                                       |                                                  |
| Keitch G.      | 0.1   | 10   | 0.5 | Foxworthy             | V E                               |                 |       |      |     |                                       |                                                  |
| Kerner H.      | -0.0  | 13   | 0.4 | Germany               | V E, 7×50B                        |                 |       |      |     |                                       |                                                  |
| Kidger M.      | -0.6  | 4    | 0.8 | Tenerife              | V E                               |                 |       |      |     |                                       |                                                  |
| Kiernan N.S.   | -2.1  | 5    | 1.2 | Pulborough            | V E, 8×30B, 10×50B                |                 |       |      |     |                                       |                                                  |
| Kosa-Kiss A.   | 0.4   | 19   | 0.8 | Romania               | V 63R, 7×50B                      |                 |       |      |     |                                       |                                                  |
| Kvaloe J.      | 0.5   | 2    | 0.0 | Norway                | V E                               |                 |       |      |     |                                       |                                                  |
| Lancashire J.  | 0.6   | 6    | 0.4 | Cambridge             | V E, 11×63B                       |                 |       |      |     |                                       |                                                  |

Key: V=Visual, P=Photographic, C=CCD.  
Instrument codes: E=naked-eye, L=Reflector, R=Refractor, T=Catadioptric, SC=Schmidt camera, W=Wright camera, FF=flat-field camera, B=Binoculars, A=astrophotographic lens, P=photographic lens. Telescopes and binoculars are defined by their apertures in mm, photographic lenses (P) by their focal length in mm.



**Figure 31.** These three photographs have been printed to the same scale and orientation to show how the tail developed on the morning of 1996 March 25. At the time these images were taken two disconnection features are visible in the tail. A & B are 85mm lens + TP2415, C is 55mm lens + TP2415. *James, Mobberley and Marsh*

correct for the systematic variation between observers.<sup>16</sup> Once the systematic error has been determined it is applied to each observer's magnitude determinations (Table 3). This significantly improves the fit but does not greatly change the magnitude parameters (Table 2, second row). After this, the aperture correction, P1, can be derived and this gives a value of  $0.0031 \pm 0.0003 \text{ mm}^{-1}$  which is similar to that found for comet Levy 1990c (1990 K1).<sup>17</sup> The value of the magnification parameter, Q1, is much smaller than that found for comet Levy, perhaps reflecting the very different visual appearance which generally required the use of a lower magnification. The magnification used by an observer has slightly less significance than the aperture. The correction for variation in observed coma diameter between observers, S1, although marginally significant, is sufficiently small that it does not greatly improve the fitted light curve. It is given in Table 2, rows 4 and 6, for reference.

### Tail development

One of the most impressive features of this comet was its tail. Since Hyakutake made such a close approach its tail aspect changed rapidly from the end of March to mid-April. The development of the tail over several weeks is illustrated by the CCD images of Platt (Figure 32) and the drawings of McKim (Figure 33).

In addition to the daily changes this comet was un-

usual in that it was possible to observe major changes in the tail structure over periods measured in hours. We do not normally have the opportunity to do this since comets with large tails are usually only visible in a dark sky for a short period. Hyakutake had the unusual property that, at the time of close approach, its massive tail was visible for the entire night.

The development of the tail on the night of close approach was captured by Mobberley, James and Marsh (Figure 31). The three images have been printed to the same scale. The scale bar shows the scale at the distance of the comet normal to the line of sight. At the time the phase angle was  $57^\circ$  and so, assuming the tail follows the projected solar radius vector the scale parallel to the tail is increased by  $1/\sin 57^\circ$ . Two disconnection features are visible in the tail. The most prominent, marked a, is moving away from the head at approximately 52 km/s. The fainter feature, b, is roughly 4.5 million km down the tail and is receding at approximately 32 km/s. At the time the comet's heliocentric velocity along its orbit was 41 km/s.

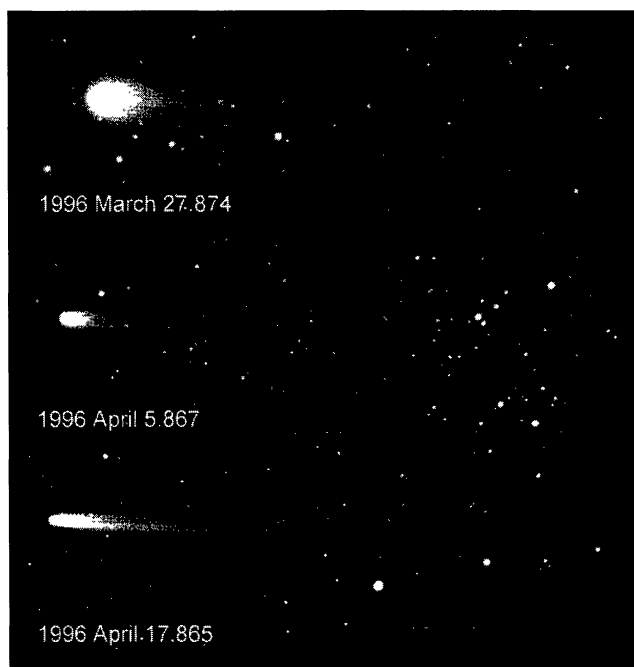


**Figure 32.** These three CCD images are printed to the same scale and orientation to show how the tail developed from just after close approach (March 27) to near perihelion (April 17). The size of the coma reduces as the comet moves away from the Earth and a dust tail becomes apparent on April 17. 50mm f/2.8 lens + SXL8 CCD. *T. C. Platt*

## Comet C/1996 B2 (Hyakutake)

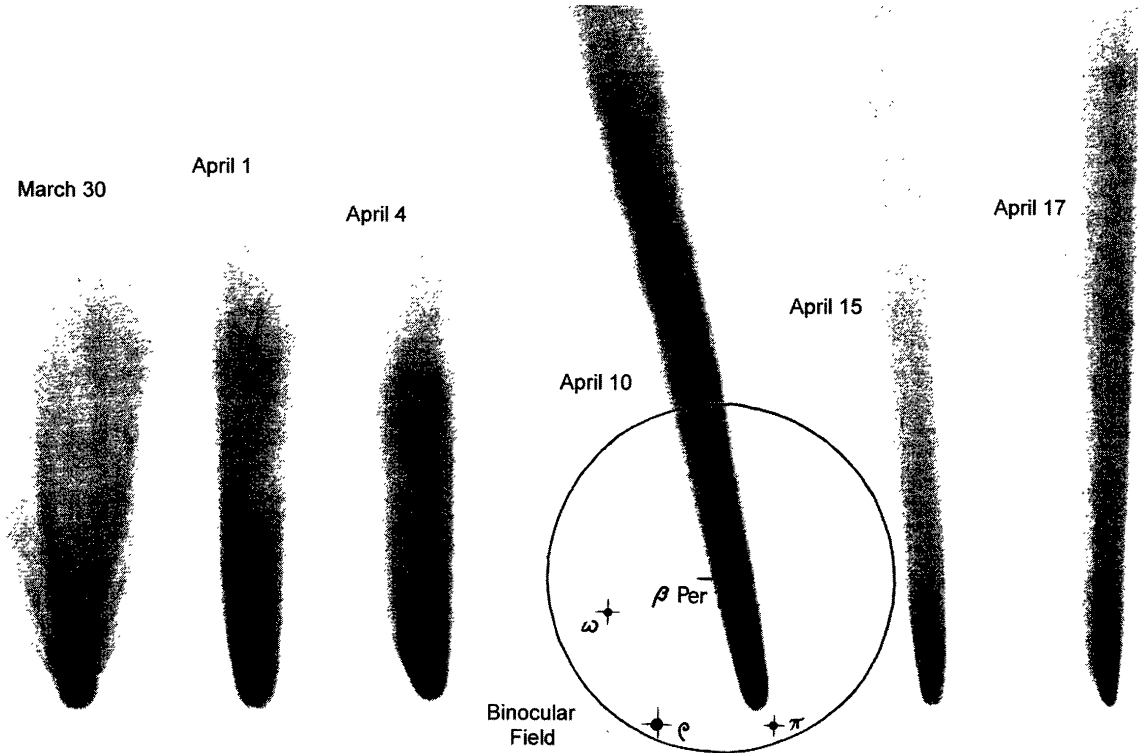


Figure 33. Drawings showing the development of the tail. *Richard McKim*

### The inner coma

Since Hyakutake made such a close approach to the Earth it was possible to see considerable detail in the inner coma with amateur-sized telescopes. This was also the first bright comet to make a close approach since CCD cameras became widely available in the amateur community. Photographers have never been particularly successful in reproducing the details visible in the inner coma of comets since the wide variation in light levels exceeds the available range of printing papers. The ability of CCD cameras to operate over a very large range of brightness levels meant that they could record the fine detail in the inner coma which in former times was only available to visual observers. Advanced processing techniques such as unsharp masks and radial filters can be applied easily to electronic images and some of the amateur CCD results are stunning.

Comet Hyakutake showed many interesting features close to the nucleus. Of particular importance were the sunward fan and the very intense tailward-pointing jet that was seen around close approach. CCD images of this jet show condensations moving away from the nucleus (Figure 17).

Hyakutake's nucleus was barely 3km in diameter and even the Hubble Space Telescope was unable to resolve it directly. Despite the small nuclear diameter many observers, both visual and CCD could infer its rotation rate from observations of features in the inner coma. A sequence of drawings by Rogers, observing on the night of March 29/30 with his 25cm telescope, shows up to four jets. These jets changed form and

orientation over a three-hour period. Even more extraordinary was the sequence of CCD images made by Terry Platt on 1996 April 1 (Figure 34). He used an SX camera to obtain an image of the central region of the coma at thirty minute intervals from 19.40 to 23.41 UT. The images were short exposures to ensure that the CCD did not saturate on the

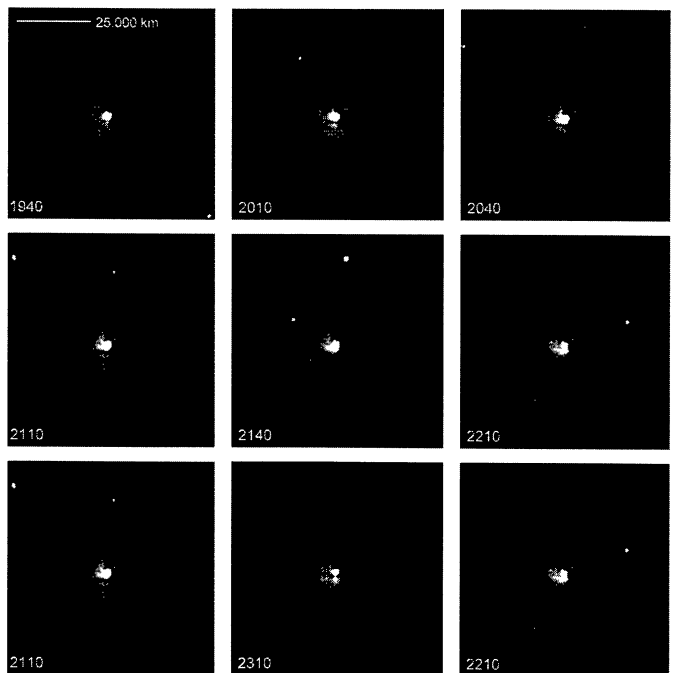


Figure 34. Images of the inner coma taken on 1996 April 1 show a clear anti-clockwise rotation over a period of four hours. Changes in the tailward pointing jet are also visible. *T. C. Platt*

bright inner coma. Each image was processed with an unsharp mask to bring out details in the inner coma. The nine frames clearly show the anti-clockwise rotation of various features. The effect is particularly strong when the frames are processed into a movie. This movie is available in MPEG format on the World Wide Web.<sup>20</sup> Early professional results from Pic du Midi gave a most likely nuclear rotation rate of 6.0 hr.

### Professional results

Comet C/1996 B2 was the first Great Comet that could be observed using modern techniques and professionals made the most of their opportunities during the few short weeks of the apparition. Some of the highlights are listed below.

Spectra from the IUE satellite indicated that Hyakutake's molecule production rate was significantly higher than that for Comet Halley. A number of emission lines were seen and the most important were those for C<sub>2</sub>, CS, CO<sub>2</sub><sup>+</sup>, NH, C, O, CO and S. The IUE results indicated that water production reached a temporary maximum around closest approach as small pieces broke off the nucleus exposing fresh surfaces. The Hubble Space Telescope (HST) tracked these small fragments as they moved away from the nucleus at around 11.5m/s. The high activity at close-approach was particularly fortunate since it made the tail so spectacular.

Observers using the James Clark Maxwell mm-wave telescope on Hawaii detected continuum emissions from the comet on March 23 and 24 which were the strongest ever detected from a comet. The estimated dust mass in the 19" diameter telescope beam (1,700km at the comet) was 10<sup>8</sup> kg. Assuming a dust outflow velocity of 10m/s the comet was producing dust at the considerable rate of around 1,200kg/s.

Radar contact with the comet was achieved by the Goldstone X-Band (8.5GHz) dish on March 24. A few dozen 480kW pulses were directed towards the comet and the echoes were received 107 seconds later. Steve Ostro of JPL reported that the radar results implied a very small nucleus of 1–3km diameter surrounded by a dense cloud of pebble-sized objects. Optical observations by the NTT at La Silla with a resolution of 18km/pixel had shown that the dense central gas and dust condensation had a diameter of 70km but these observations did not resolve the nucleus.

The first ever detection of X-rays from a comet was reported by a team of observers using the ROSAT satellite. Observations took place on nine separate occasions from March 26–28. The brightest parts of the comet in X-rays were diffuse and crescent shaped, offset sunwards by about 6' from the nucleus (about 30,000km). The X-rays were strongly time-variable over periods of hours and the observed levels were around 100 times those expected. A number of theories were proposed to explain the discrepancy. Possibly solar X-rays were absorbed by molecules in the coma causing them to fluoresce. Alternatively the X-ray emission could have been caused by violent collisions between solar wind particles and the coma.

### Concluding remarks

Comet Hyakutake put on an amazing show throughout 1996 March and April. Unfortunately, the weather in the UK was very poor at the critical time of close approach. This, and the gradual deterioration of observing conditions due to light pollution, meant that many did not consider that the comet was worthy of the adjective 'Great'. Those observers who were lucky enough to see the comet at its best under dark skies will certainly not have any problems with this description. They will remember the Great Comet of 1996 for many years.

### Acknowledgments

Most of the visual observations used in this paper had to be entered manually into a computer database. This is a major task, particularly when a Great Comet is in the sky, and I would like to thank Guy Hurst who performs this task for TA and the BAA. With the growing availability of e-mail it is possible to submit observations electronically. This is helpful but it is still a major task to enter them into the database if they are in the wrong format. TA has a standard format which is close to the one used by the *ICQ* and Guy's life would be made much easier if observers could submit their observations in this format.<sup>5</sup>

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- 2 James N. D. (Ed.), *The Great Comet of 1996*, The Astronomer, 1996. This book is still available from TA but only in an electronic format.
- 3 *ibid.*, p12. Hyakutake's name means 100 Samurai or Chivalry. In this note he says: 'I am a bit perplexed by the attention paid to me when it is the comet that deserves the credit'.
- 4 *ibid.*, pp21–26
- 5 *ibid.*, pp31–28
- 6 International Astronomical Union, *Circulars*, (IAUC) 6299, 1996 January 31. This circular contains the discovery announcement and the first observations by McNaught.
- 7 *IAUCs* 6303 & 6304 (1996 February 3)
- 8 *IAUC* 6311 (1996 February 10)
- 9 *IAUC* 6329 (1996 February 29)
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- 18 <http://www.demon.co.uk/astronomer/>
- 19 <http://www.ast.cam.ac.uk/~jds/1996b2.obs>
- 20 The complete movie consisting of nine frames in MPEG format is available online at [http://www.demon.co.uk/astronomer/images/1996b2\\_960401.mpg](http://www.demon.co.uk/astronomer/images/1996b2_960401.mpg)

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**Figure 16.** 1996 March 27, 03.26. 4min exposure on ISO 200 film, 50mm, f/2. The comet is very close to the Pole. *James Abbott*

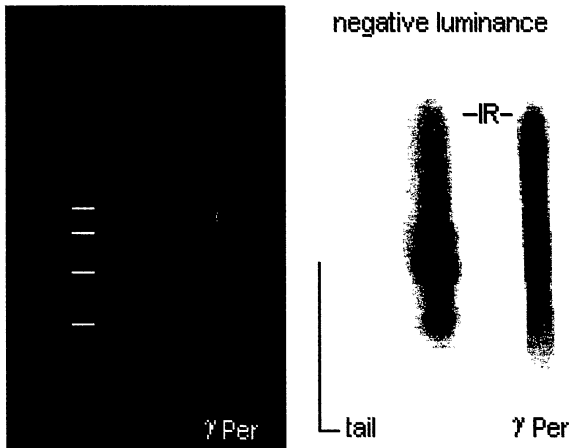


**Figure 19.** Spectrum of Comet Hyakutake taken on 1996 April 1. 85mm f/2 lens + prism + SX colour CCD. This spectrum shows the prominent Carbon molecule emission lines. *Maurice Gavin*

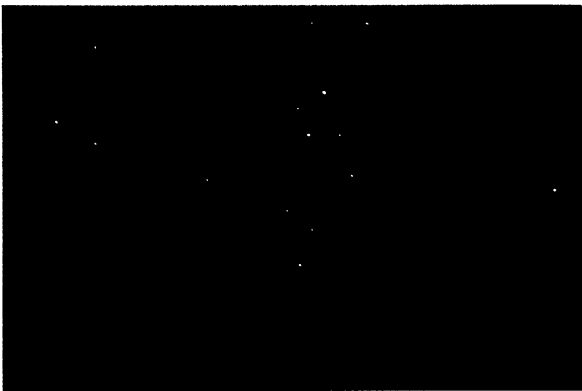


**Figure 28.** 1996 April 20, 21.10. 50mm. 30s exposure. *Alex Vincent*



**Figure 24.** 1996 April 17. 19.46 UT. 190/255/435 Schmidt. 4 min exposure on Kodak Gold Pro 400 film in 120 format. The different colours of the gas and dust tails are obvious. *Gerald Rhemann, Ebenwaldhöhe, Austria*