

The brighter comets of 2006

Jonathan Shanklin

A report of the Comet Section (Director [1990–2015]: J. D. Shanklin)

This report describes and analyses observations of the brighter or more interesting comets discovered or at perihelion during 2006, concentrating on those with reported visual observations. Magnitude parameters are given for all comets with observations. Information on other comets seen during the year may be found on the Section Web pages.

Introduction

During the year 62 comets were assigned year designations and 16 previously numbered periodic comets returned to perihelion. 170 comets were discovered from the SOHO satellite; of these 154 were members of the Kreutz group, eight were members of the Meyer group, two of the Marsden group and six were not associated with any known group. There were two amateur discoveries, those of 2006 OF₂ by John Broughton and 2006 T1 by David Levy, for which they gained the Edgar Wilson Award. Nine periodic comets were numbered. Four comets were reported as visible by the naked eye during the year.

Orbital elements for all the comets discovered and returning during the year can be found on the JPL Small-Body Database Browser,¹ which will also generate ephemerides. Discovery details and some information for the other comets found or returning during the year are available on the Comet Section web pages,² which also contain links to additional background information. Further images of the comets are presented in the Section image archive.³

The comets given a discovery designation

2006 A1 (Pojmanski)

Grzegorz Pojmanski, of Warsaw University Astronomical Observatory, discovered a comet on All Sky Automated Survey (ASAS) images taken with a 180mm focal length f/2.8 telephoto lens (+V

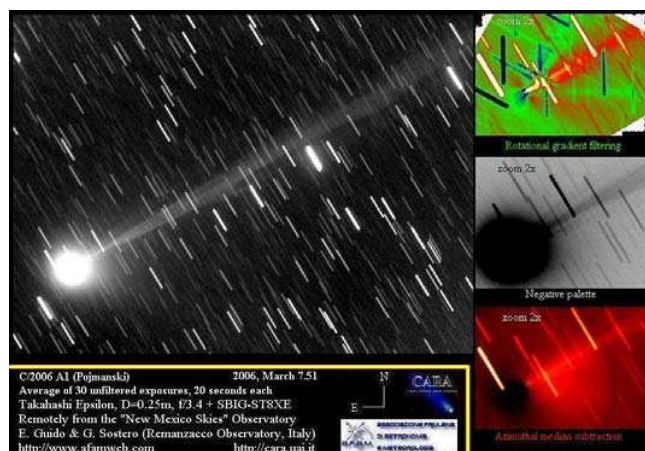


Figure 1. 2006 A1 (Pojmanski) imaged by Ernesto Guido & Giovanni Sostero on 2006 March 7.51.

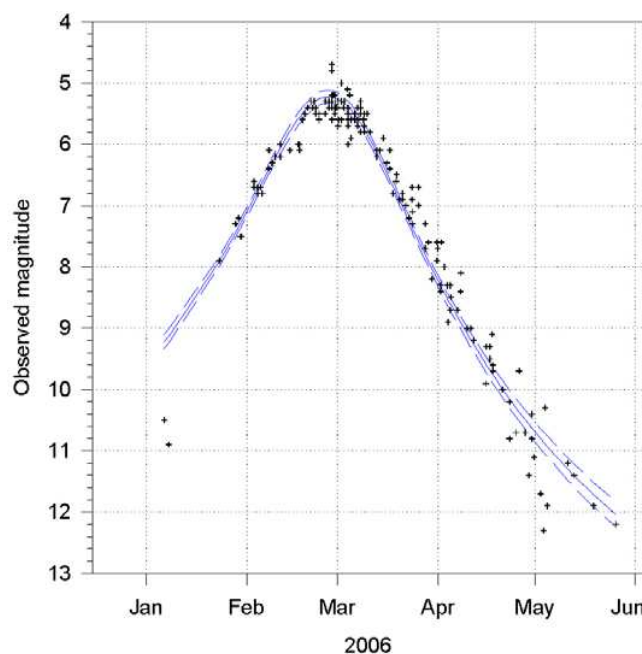


Figure 2. The lightcurve of 2006 A1 (Pojmanski). The dashed lines indicate the 99% confidence limits.

filter) at Las Campanas on January 1.04. The discovery was confirmed as a comet on Jan 4 by Santiago Roland from Montevideo, and Pojmanski subsequently found the comet in pre-discovery images from 2005 Dec 29. Some seven hours after Pojmanski, Kazimieras Cernis reported an object in SWAN imagery, and this had the same motion as the new comet.

The comet was at perihelion at 0.6 au in late February. The orbital data suggests that it had made a previous visit to the inner solar system, although the period is over 100,000 years. It was initially a southern hemisphere object, but became visible from the UK in late February.

Michael Mattiazzo imaged the comet on Jan 7 and estimated the magnitude as 10.5 in his 20cm reflector. It brightened quite rapidly, with his estimating it as 7.9 in 25×100B on Jan 23.5, with a 3' DC5 coma. Jonathan Shanklin was able to observe the comet on Feb 8.05 from on board the Fishery Protection Vessel MV *Sigma* at 54°S 39°W with 10×50B and made it 6.1. For the next three weeks he was at Bird Island, a notoriously cloudy location, but on Feb 17/18 the skies remained clear and he estimated the comet at mag 5.6 in 10×50B, DC8 on Feb 18.21.

Once in view from the UK, imagers reported a 5° ion tail in early March. Stephen Getliffe, observing on Mar 3.21 with 7×50B estimated the comet at magnitude 5.3 and highly condensed at DC7. It faded rapidly and by early April it had faded, with James Abbott estimating it at 8.4 in his 0.30m reflector on April 1.87.

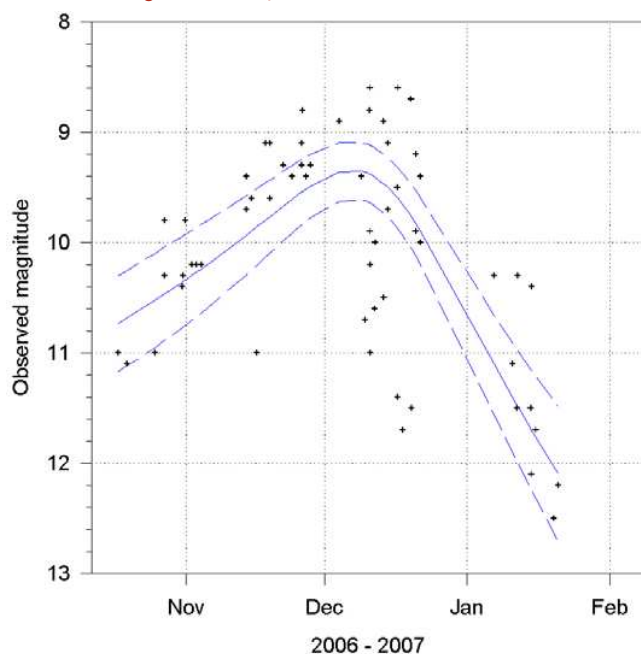


Figure 3. The lightcurve of 2006 L1 (Garradd).

Observations by Seiichi Yoshida in early May suggest that further rapid fading occurred as the comet was around 12th magnitude. The final observations were made by Juan José Gonzalez towards the end of the month.

2006 L1 (Garradd)

Gordon Garradd discovered his first comet on June 4.38 during the course of the Siding Spring Survey. The object was 18th magnitude at discovery and reached perihelion at 1.5 au in 2006 October. The comet became brighter than expected and peaked at around 9th magnitude in early December when it was closest to the Earth. It faded quite rapidly and became quite diffuse.

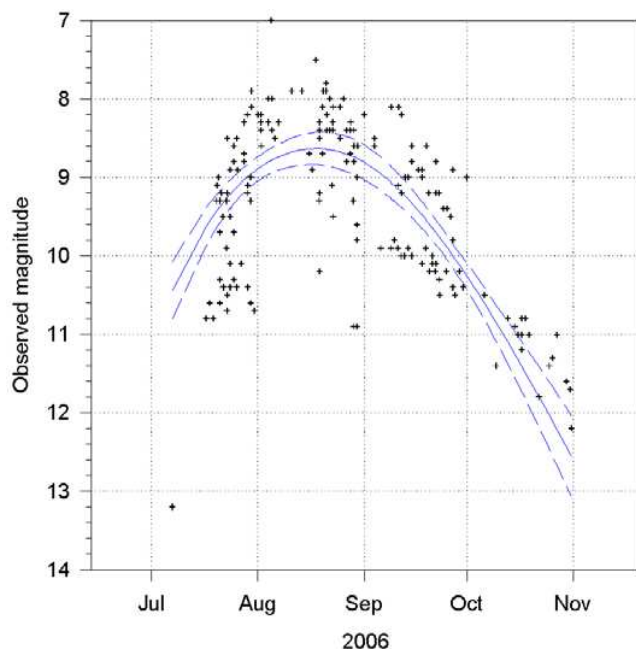


Figure 4. The lightcurve of 2006 M3 (177P/Barnard).

2006 M3 (177P/Barnard)

A 17th magnitude asteroidal object found by LINEAR on June 23.26 was shown to have cometary characteristics following posting on the Near Earth Objects Confirmation Page (NEOCP). Dan Green suggested that it might be a return of comet 1889 M1 (P/Barnard) and Brian Marsden confirmed the identification. Edward Emerson Barnard had discovered the comet whilst hunting with a 0.16m refractor at the Lick Observatory. At brightest it was around magnitude 9.5. Observations made over a 45-day arc at the discovery return had suggested a period of around 130 years.

Despite this being a more favourable return than at discovery, the comet seemed unlikely to exceed 14th mag based on its recovery brightness. However, as is often the case, early magnitude estimates by CCD observers were approximating to m_2 rather than their published m_1 and by mid-July the comet was reported at around 10th magnitude. It was however very diffuse, so much harder to see than the magnitude suggested. It peaked at around mag 8 in August, with for example Jonathan Shanklin making it 8.6 in 25×100B on Aug 1.98. By September it was fading, though aperture made quite a difference to the reported magnitude of the diffuse comet. Stephen Getliffe observing on Sept 21.84 with 7×50B made the comet 8.8, but the next night James Abbott and Shanklin, both using 0.3m reflectors, made it around 10.4. Seiichi Yoshida made the final observation at the end of October, when the comet was mag 12.2. Both linear and conventional (the fit shown here) magnitude parameters are given, though neither give very good fits to the observations.

2006 M4 (SWAN)

Michael Mattiazzo & Rob Matson found an object in the Solar Wind Anisotropies (SWAN) satellite images from late June, which was also found on images taken by Terry Lovejoy on June 30. The comet was confirmed with images taken by Rob McNaught with the Uppsala Schmidt on July 12. It passed through the SOHO LASCO coronagraph field between Aug 11 and the end of the month, but was barely visible. The comet reached perihelion in late September at 0.8 au. The orbital data suggest that it was a 'new' comet from the

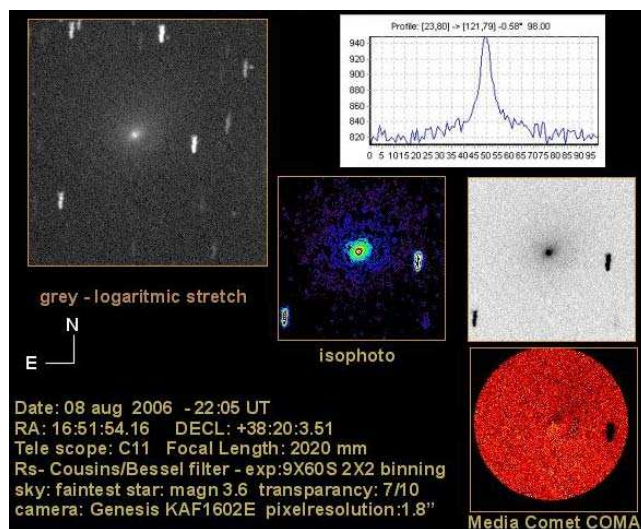


Figure 5. 2006 M3 (177P/Barnard) imaged by Erik Bryssinck on 2006 August 8.92 showing the use of a variety of image processing techniques.



Figure 6. 2006 M4 (SWAN) imaged by Michael Jager and Gerald Rhemann on 2006 October 10. The images, taken only 10 minutes apart, show significant changes in the tail structure.

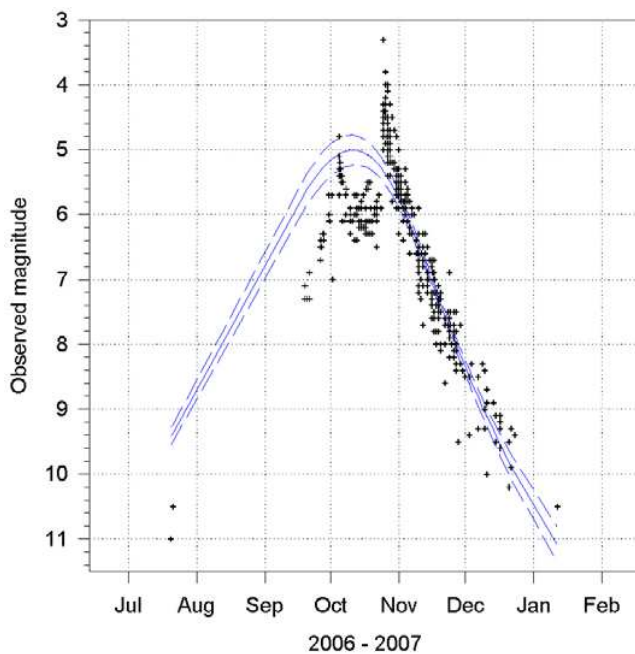


Figure 7. The lightcurve of 2006 M4 (SWAN).

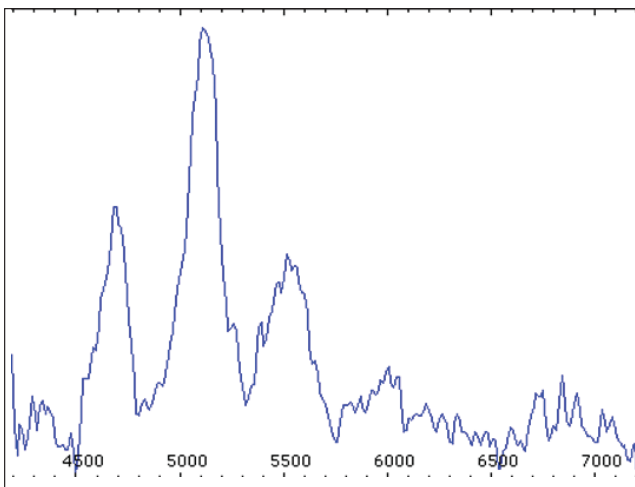


Figure 8. Spectrum of 2006 M4 (SWAN) by Robin Leadbeater on 2006 October 15.

Shanklin: The brighter comets of 2006

Oort Cloud. It emerged from conjunction in mid-September as an 8th magnitude object in the morning sky.

David Storey recovered the comet from the Isle of Man on Sept 15. His image showed the comet well condensed and about 8th magnitude. Martin McKenna observing from Northern Ireland on Sept 26 in a morning observing session reported a naked eye observation and saw a 30' tail in binoculars. Observing with 20×80B from near Dorchester on Oct 4.80 Jonathan Shanklin noted the comet as 5th magnitude, appearing much like a globular cluster. This appears to have been a short lived outburst as a few nights later it was back to mag 6. A second outburst occurred around Oct 24, and that evening Shanklin was surprised to find it at around mag 4.5 with a short tail. Infrared observations on Nov 7, made with the MMT suggested the presence of a secondary condensation, perhaps originating in the Oct 24 outburst. Thereafter the comet faded predictably until it entered solar conjunction in early January.

2006 OF₂ (Broughton)

An unusual asteroid, of 18th magnitude, was discovered by John Broughton with his 50cm reflector at Reedy Creek on July 17.66. It was reported to be in a highly eccentric orbit with a period of over 4000 years and perihelion was at 2.6 au in 2008 November. It was 7.6 au from the Sun at discovery. [MPEC 2006-O13, 2006 July 21, 32-day orbit]. Shanklin speculated on the Section web page that it might develop cometary activity as it approached the Sun. The object did



Figure 9. John Broughton with the telescope used to discover 2006 OF₂. (M.P. Mobberley).

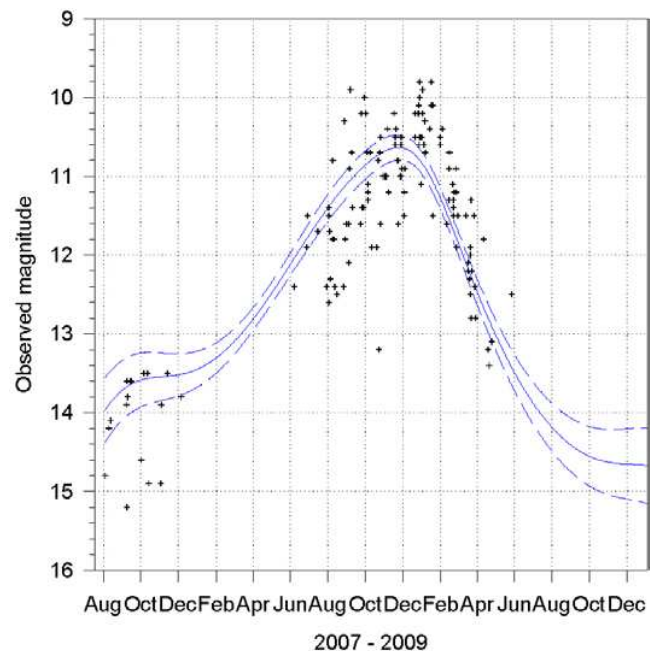


Figure 10. The lightcurve of 2006 OF₂ (Broughton).

Shanklin: The brighter comets of 2006

grow a coma, which was detected by Carl Hergenrother on CCD frames taken with the 1.54m reflector at Catalina on 2006 Sept 20.11. The final orbit is slightly hyperbolic with perihelion at 2.4 au in 2008 September.

The comet emerged from solar conjunction in 2008 June as a 12th magnitude object and peaked at around mag 10 in November. It had a long period of visibility with visual observations from 2007 August to 2009 May.

2006 P1 (McNaught)

A preliminary report on this Great Comet was presented in the *Journal*⁴ and covered observations until early 2007 February. Three points were made in that report that needed further investigation: that the absolute magnitude of the comet appeared to be signifi-



Figure 11. 2006 P1 (McNaught) imaged by Jamie Cooper on 2007 January 10.

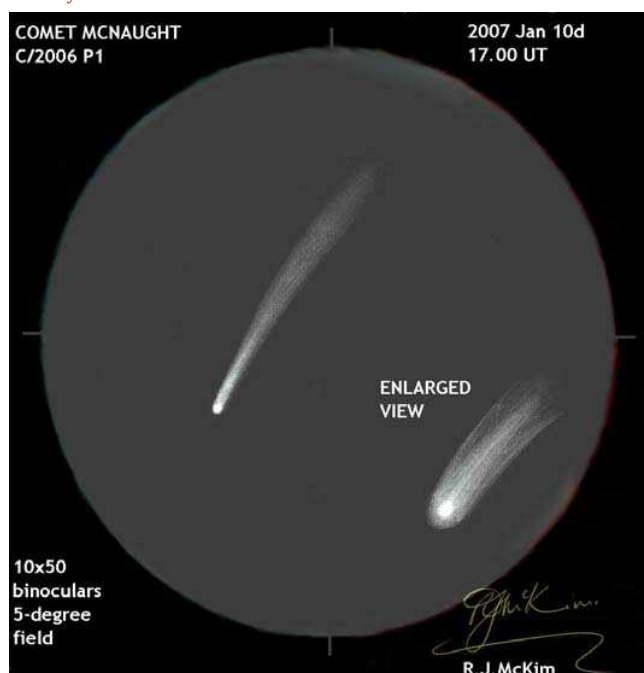


Figure 12. 2006 P1 (McNaught) drawn by Richard McKim on 2007 January 10.



Figure 13. 2006 P1 (McNaught) imaged by Rudi Vavra on 2007 Jan 20.

cantly brighter post-perihelion than it was pre-perihelion; that forward scattering needed to be considered, and that a specific aperture correction was needed for this comet.

Subsequent observations confirm that the absolute magnitude of the comet was about 1.2 mags brighter after perihelion. This could be explained by seasonal effects on the comet's nucleus, or by the intense solar radiation at the perihelion distance of 0.17 au initiating a greater area of cometary activity on the nucleus. Forward scattering in comets generally⁵ and for 2006 P1 specifically⁶ was extensively discussed by Joe Marcus in the *International Comet Quarterly*. The comet was at a small scattering angle (or equivalently a large phase angle) between Jan 11 and 18, and this was smallest at around 31.8° around Jan 14. His model suggests that this gave a brightness enhancement of 2.3 magnitudes at this time, which is in good agreement with the observations.

In the light of this theory, tables giving periods when comets are due to reach large phase angles or show opposition brightness enhancements are given on the Section web page. Finally, the observations show that a larger than usual aperture correction of 0.060 ± 0.008 compared to the standard 0.033 improves the fit of the lightcurve, however for consistency the standard parameter fit is also given.

2006 Q1 (McNaught)

Rob McNaught discovered his 32nd comet on August 20.74, during the course of the Siding Spring Survey. The comet was 18th

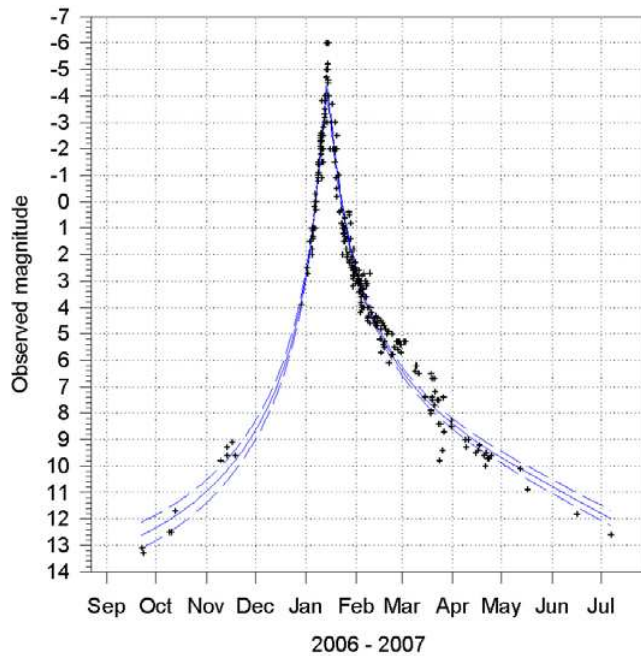


Figure 14. The lightcurve of 2006 P1 (McNaught).

magnitude and still over 6 au from the Sun. This discovery by Rob equalled the record for individually named comet discoveries with the Shoemakers. In other respects it was a fairly average telescopic comet, reaching 11th magnitude in 2008.

2006 S3 (LONEOS)

A 19th magnitude comet was discovered by LONEOS on September 19.32 and when posted on the NEOCP was confirmed as cometary by Peter Birtwhistle, Richard Miles and others. Perihelion was near 5.1 au in 2012 April. The comet was under visual observation from 2010 to 2014 and reached mag 12 near the time of perihelion. There is considerable scatter in the magnitude estimates.

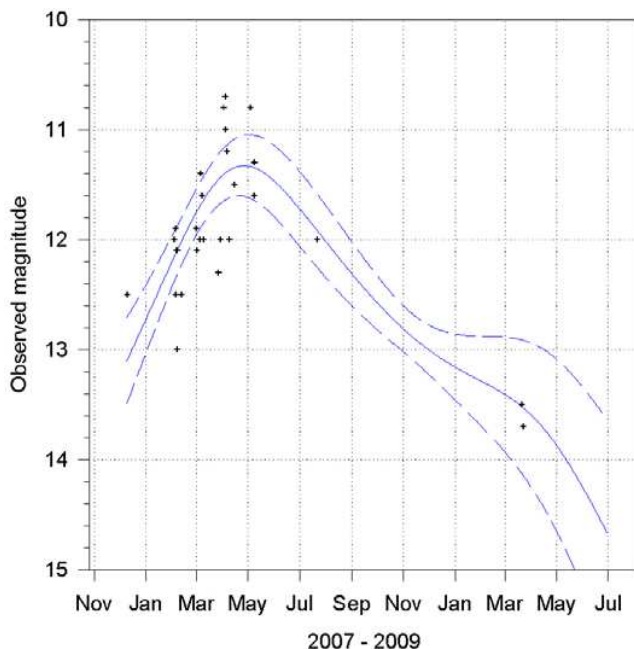


Figure 15. The lightcurve of 2006 Q1 (McNaught).

2006 T1 (255P/Levy)

David Levy made a visual discovery of a comet on October 2.50. Observing near Saturn with his 0.41m reflector he noted a diffuse object of magnitude 10.5. The cometary nature of the object was confirmed by Peter Birtwhistle and Richard Miles amongst others. The Japanese comet hunter Shigeki Murakami made an independent discovery of the comet on Oct 4, but by this time the object had been placed on the NEOCP and an *IAUC* issued.

The comet can approach Venus, the Earth and Jupiter within 0.2

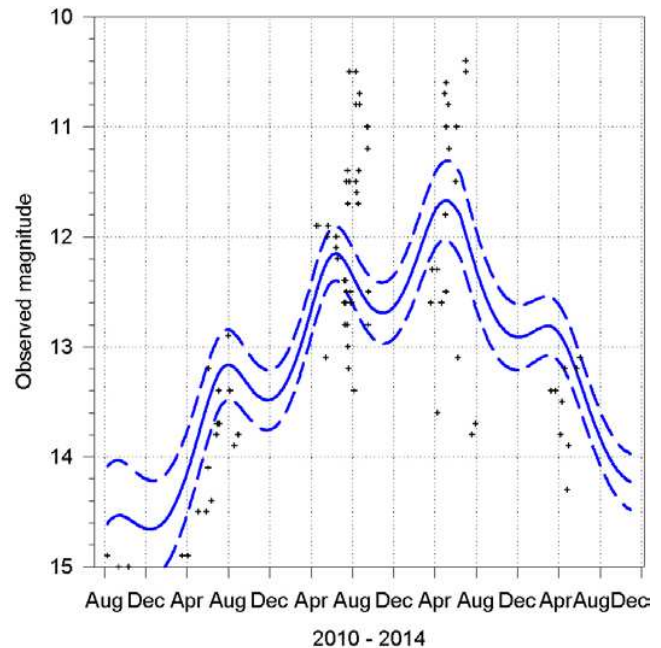


Figure 16. The lightcurve of 2006 S3 (LONEOS).

Table 1. Photometric observers, 2006

James Abbott, Witham, Essex	Attila Kosa-Kiss, Romania
Alexandre Amorim, Brazil	Carlos Labordena, Spain
Alexandr Baransky, Ukraine	Martin Lehky, Czech Republic
Nicolas Biver, Hawaii	Antonio Lepardo, Italy
Reinder Bouma, The Netherlands	Tom Lloyd-Evans, St Andrews
Sergiy Borysenko, Ukraine	Jose Carvajal Martinez, Spain
Tim Cooper, South Africa	Michael Mattiazzo, Australia
Matyas Csukas, Romania	Giannantonio Milani, Italy
Haakon Dahle, Norway	David Moore, Dublin, Eire
Jose G. de Souza Aguiar, Brazil	Richard Miles, Dorset
Roger Dymock, Clanfield, Hants.	Artyom Novichonok, Russia
Len Entwisle, Elland, West Yorks.	Gabriel Oksa, Slovak Republic
Sergio Foglia, Italy	Roy Panther, Walgrave, Northants.
James Fraser, Alness, Rossshire	Mieczyslaw Paradowski, Poland
David Frydman, London	Andrew Pearce, Australia
Michael Gainsford, Burbage, Leics.	Jan Qvam, Norway
Antonio Giambersio, Italy	Stuart Rae, New Zealand
Marco Goiato, Brazil	Maciej Reszelski, Poland
J. J. Gonzalez, Asturias, Spain	Juan M. San Juan, Spain
Bjoern Haakon Granslo, Norway	Toni Scarmato, Italy
Stephen Getliffe, Haverhill, Suffolk	Jonathan Shanklin, Cambridge
Virgilio & Mario Gonano, Italy	Oddleiv Skilbrei, Norway
Ernesto Guido, Italy	Giovanni Sostero, Italy
Werner Hasubick, Germany	William C. de Souza, Brazil
Roberto Haver, Italy	David Storey, Oxfordshire
Michael Hendrie, W. Bergholt, Essex	Magda Streicher, South Africa
Kevin Hills, Tarporley, Cheshire	Janet Simpson, Furnace, Argyll
Guy Hurst, Basingstoke, Hants.	Melvyn Taylor, Wakefield, Yorks.
Michael Hezzlewood, Burnley	Koos van Zyl, South Africa
Albert F. Jones, New Zealand	Graham Wolf, New Zealand
Andreas Kammerer, Germany	Seiichi Yoshida, Japan
Mark Kidger, Canary Islands	

Table 2. Astrometric, electronic, photographic and visual observers

Observer	Site	IAU Stn No
David Arditti	Edgware, Middlesex	
Alexandr Baransky	Ukraine	585
Peter Birtwhistle	Great Shefford	J95
Jean-Gabriel Bosch	France	
Ian Brantingham	Keith, Scotland	
Massimo Calabresi	Italy	157
Jeremy Calderwood	Bournemouth	
Russell Cockman	Australia	
Jamie Cooper	Piddington, Northants.	
Rodney Cuff	Guisborough, Cleveland	
Haakon Dahle	Norway	
J. A. Emerson	Middlesborough	
Terry Evans	Ipswich	
John Fletcher	Mount Tuffley, Gloucs.	J93
Maurice Gavin	Worcester Park, Surrey	
Antonio Giambersio	Italy	
Alex Gifford	Australia	
Virgilio & Mario Gonano	Italy	473
Bjoern Granslo	Norway	
Ernesto Guido	Italy	H06
Werner Hasubick	Germany	215
Roberto Haver	Italy	157
Morton Henderson	Australia	
Guy M. Hurst	Basingstoke, Hants.	
Michael Jaeger	Austria	
Nick James	Chelmsford, Essex	970
Barry Keenan	Wereham, Norfolk	
Ken Kennedy	Dundee, Scotland	
James Lancashire	Bristol	
David Layland	Ticknall, Derbyshire	
Robin Leadbeater	Wigton, Cumbria	
Martin Lehky	Czech Republic	048
Rolando Ligustri	Italy	235
Pepe Manteca	Spain	170
Richard McKim	Upper Benefield, Northants.	
Martin McKenna	Maghera, N. Ireland	
Haldun Menali	USA	
Cliff Meredith	Prestwich, Manchester	
Richard Miles	Dorset	J77
Duncan Miller	Hartpury, Gloucs.	J68
Arthur Missira	Alston, Cumbria	
Martin Mobberley	Cockfield, Suffolk	480
Fabrizio Montanucci	Italy	
Phil Moore	Bristol	
Bob Neville	Greens Norton, Northants.	967
Chris Newsome	Derby	
John O'Neil	Rush, N. Ireland	
John Owen	Aberdeen, Scotland	
Andrew Pearce	Australia	
Danilo Pivato	Italy	
Steve Quirk	Australia	
Kevin Reeves	Waterlooville, Hants.	
Gerald Rhemann	Austria	
Gordon Rogers	Long Crendon, Bucks.	
Derek Ryan	Tarves, Scotland	
John Sanford	USA	
Vincenzo Santini	Italy	473
Toni Scarmato	Italy	
Robin Scagell	High Wycombe, Bucks.	
Jonathan Shanklin	Cambridge	
Giovanni Sostero	Italy	473
David Storey	Isle of Man	987
David Strange	Worth Matravers, Devon	
Rikki Swenson	USA	
Helen Taylor	South Georgia, S. Atlantic	
Peter Thomas	Australia	
John Thorpe	Australia	
Alan Tough	Elgin, Scotland	
Vince Tuboly	Hungary	
Rudi Vavra	Australia	
Alex Vincent	Worthing, Sussex	

Note: Many observers contributed images of 2006 P1 (McNaught) and those who submitted images over several days are included here. All the images are shown on the Section Web pages.

au. The encounters with Jupiter make significant changes to the orbital elements; one in 1972 reduced the perihelion distance from 1.2 to 1.0 au, and another in 2020 will reduce it further to 0.8 au. Maik Meyer suggested a possible link with 1743 C1, which made a close approach to Earth in 1743 January, however the Jupiter encounters make this possibility difficult to confirm. Several people, including Cédric Bemer, have suggested the possibility of a meteor shower from the comet around Dec 31/Jan 1. The near-chaotic orbit makes meteoritic activity less likely, however if the comet is fragmenting it may be more likely to have a significant dust trail present. It is highly likely that the comet was discovered in outburst, as the absolute magnitude at the 2012 return was considerably fainter.

2006 VZ₁₃ (LINEAR)

An unusual object of 20th magnitude, originally classed as an Amor asteroid, was discovered by LINEAR on November 13.13. [MPEC 2006-W03, 2006 Nov 16] It had a period of 40 years, and a retrograde orbit with perihelion at 1.33 au, suggestive of a comet. Richard Miles noted that his astrometric images appeared slightly softer than stellar images and this was confirmed by Carl Hergenrother using the University of Arizona's

1.54m Kuiper reflector at the Catalina station on Dec 1 and 2. The cometary orbit is parabolic, with perihelion at 1.02 au. The comet came into visual range in 2007 June and reached mag 7 in July. The BAA imaged the comet with the remotely-operated Liverpool Telescope during the Exhibition Meeting on 2007 June 30.

Cédric Bemer noted that the Earth would pass 0.005 au inside the comet's orbit on 2008 May 27.1 (solar longitude 66°) and that there might be a possibility of a meteor shower. The radiant is around RA 330 +16. Interestingly Peter Jenniskens⁷ lists the gamma Delphinid shower, which has a broadly similar orbit and is active from June 1–20 from a radiant around RA 320 +12. Jenniskens gave a possible outburst on 2013 June 11.

2006 W3 (Christensen)

Eric Christensen discovered an 18th magnitude comet on Nov



Figure 17. 2006 T1 (255P/Levy) imaged by Peter Birtwhistle on 2006 October 3.



Figure 18. 2006 VZ₁₃ (LINEAR) imaged near M102 by Rolando Ligustri on 2007 July 13.

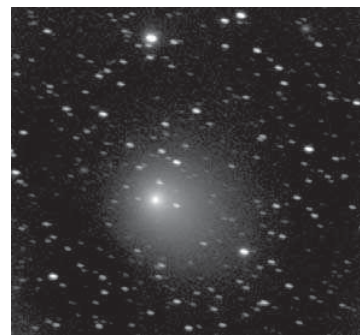


Figure 19. 2006 W3 (Christensen) imaged by Nick James on 2009 July 10.

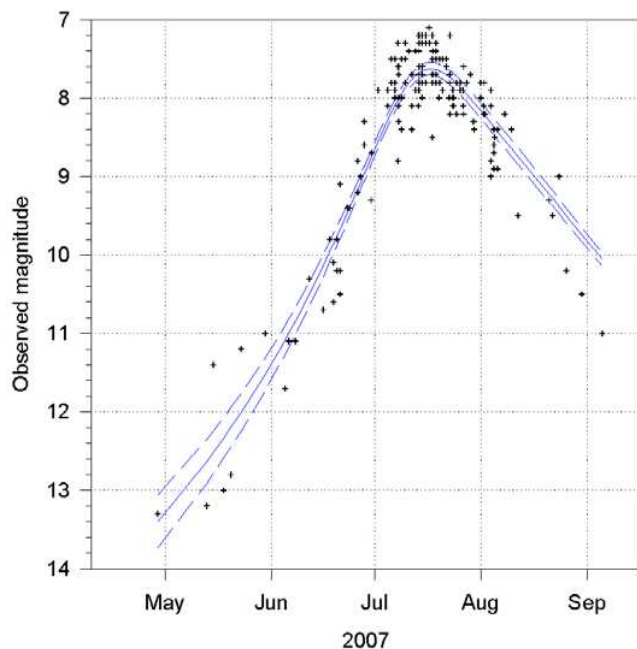


Figure 20. The lightcurve of 2006 VZ₁₃ (LINEAR).

18.40 during the course of the Catalina Sky Survey with the 0.68m Schmidt telescope. Peter Birtwhistle was among those making confirming observations. With a bright absolute magnitude and a relatively far perihelion distance of 3.1 au it had a long period of visibility, although it only reached mag 8 when at its brightest in 2009.

The numbered periodic comets at perihelion in 2006

4P/Faye

Hervé A. Faye discovered 4P/Faye in 1843 during a visual search with a small telescope at the Paris Observatory. At that return it reached mag 5, though this has never been reached at subsequent returns. It is possible that this was a one-off caused by a slight reduction in perihelion distance from 1.8 to 1.7 au follow-

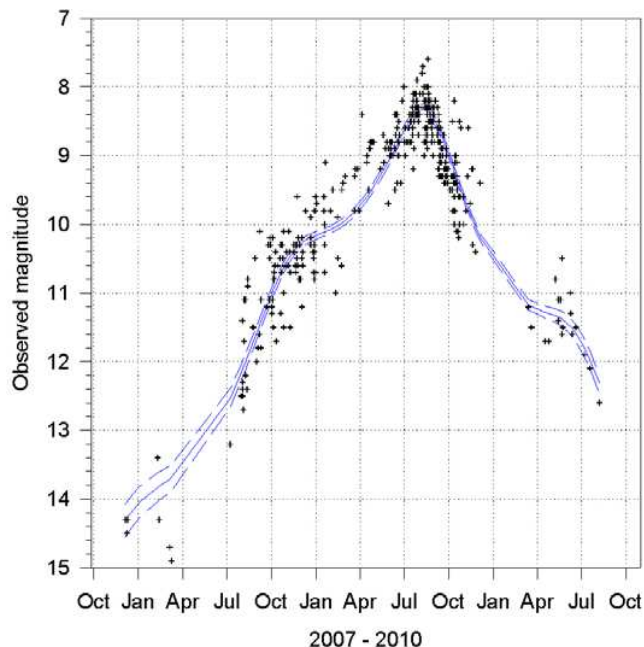


Figure 21. The lightcurve of 2006 W3 (Christensen).

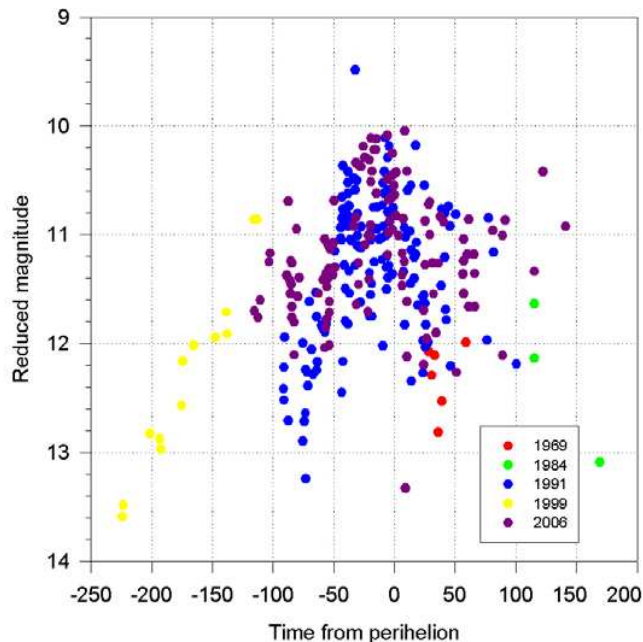


Figure 22. The composite lightcurve of 4P/Faye.

ing a close encounter with Jupiter in 1841.

Several authors have suggested that the absolute magnitude of the comet is declining rapidly, but it has reached a similar magnitude at all apparitions observed by the BAA since 1969. This return was very similar to the 1991 return, when it reached 10th magnitude. The comet behaved much as predicted and was at its brightest in early November 2006 at just brighter than mag 10.



Figure 23. 4P/Faye imaged near M74 by Rolando Ligustri on 2006 Aug 26.

41P/Tuttle–Giacobini–Kresak

Horace Tuttle discovered 41P/Tuttle–Giacobini–Kresak in 1858, when he found a faint comet in Leo Minor. Nearly 50 years later, Prof Michel Giacobini discovered a mag 13 object whilst comet hunting, which was observed for a fortnight. Andrew C. D. Crommelin linked the apparitions in 1928 and made predictions for future returns, but the comet wasn't recovered and it was given up as lost. In 1951, Lubor Kresak discovered a mag 10 comet with 25×100 binoculars whilst participating in the Skalnaté Pleso Observatory's program of routine searches for comets. After further observations the comet was identified with the lost comet and a better orbit computed.

The comet underwent a series of encounters with Jupiter in the sixteenth century, which reduced the perihelion distance from around 1.5 au to 1.0 au. At the 1973 return, which was similar to that of 1907, it underwent a major outburst and reached mag 4, before fading and then undergoing a second outburst. Alternate returns are unfavourable. At this return nothing remarkable occurred and the comet reached around 10th magnitude.

The BAA has observations over five returns. At the first, in 1962,

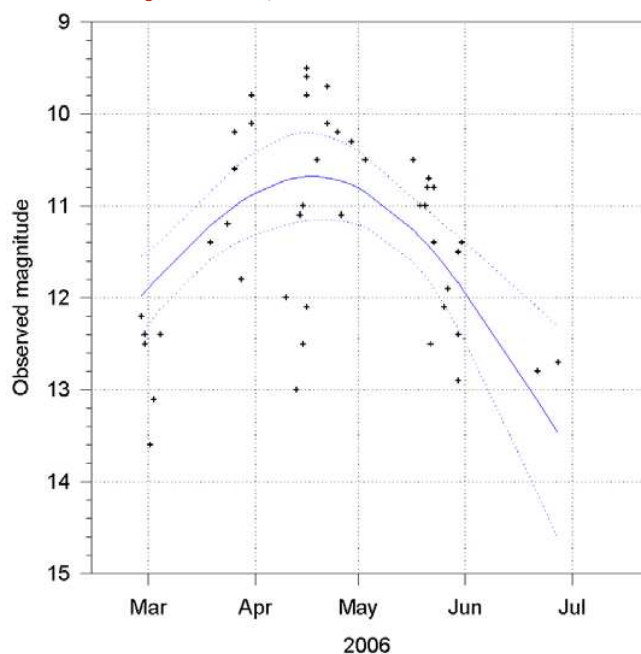


Figure 24. The lightcurve of 41P/Tuttle–Giacobini–Kresak.

the comet had a slightly greater perihelion distance than the other four and this perhaps explains why it was fainter then. The cumulative lightcurve confirms the hypothesis presented in the paper on the comets of 2001⁸ that there was an outburst in mid-December 2000, and perhaps suggests an outburst at the 1995 return.

71P/Clark

Michael Clark of Mt John Observatory, New Zealand, discovered this comet on a variable star patrol plate in 1973 June. At discovery it reached 13th magnitude, but alternate returns are unfavourable and it is then 5 magnitudes fainter, though it hasn't been missed. An encounter with Jupiter in 1954 put it into its present orbit, which is such that it can approach quite closely to Mars, passing within 0.09 au in 1978 October. As might be expected from the discovery, it is usually best seen from the Southern Hemisphere. The nucleus of the comet is estimated at 1.4km in diameter.

The comet was recovered at the 2006 return by several observers, including Ernesto Guido, an Italian amateur astronomer. He provided the following details: *'At the end of November I started the project to try to recover the comet 71P. The first attempt was unsuccessful, probably the comet was fainter than 19 magnitude that was my limiting magnitude. On December 29 I tried again and this time I found the 71P at 7' away from the nominal position roughly at 18.5 magnitude. On December 30 I was able to obtain a second night as requested from MPC.'*

It was quite well covered by observers at this return and their observations are best fitted by a linear form of lightcurve.

73P/Schwassmann–Wachmann

Prof Arnold Schwassmann & Arno Arthur Wachmann of Hamburg Observatory discovered their third periodic comet, on minor planet patrol plates taken on 1930 May 2. Initially of magnitude 9.5 it brightened to nearly mag 6, thanks to a very close approach to

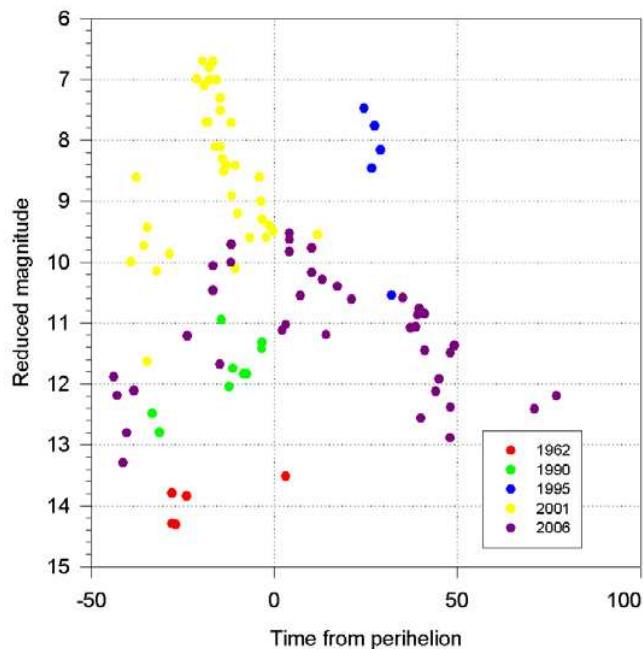


Figure 25. The composite lightcurve of 41P/Tuttle–Giacobini–Kresak.

Earth (0.062 au on May 31.7). This approach to Earth is, at the time of writing in late 2014, tenth closest on the list of well-determined cometary approaches to our planet.

The initial orbit was a little uncertain and the comet wasn't found at succeeding apparitions until 1979. The comet passed within 0.75 au of Jupiter in 1953, and 0.28 au in 1965. In 1979 August, Michael Candy reported his discovery of a comet on a plate taken by John Johnston & Michael Buhagiar while searching for minor planets; this had the motion expected for 73P/Schwassmann–Wachmann, but with perihelion 34 days later than in a prediction by Brian Marsden. Although missed at the next return, it has been seen at every return since.

Around 2006 May 12.4 it made another close approach to Earth (0.079 au), and will make further moderately close approaches in 2054 and 2070. This small miss distance makes it a convenient spacecraft target, and the *Contour* mission was scheduled to intercept it, as well as comets 2P/Encke and 6P/d'Arrest, however the spacecraft was destroyed following a rocket motor failure. The

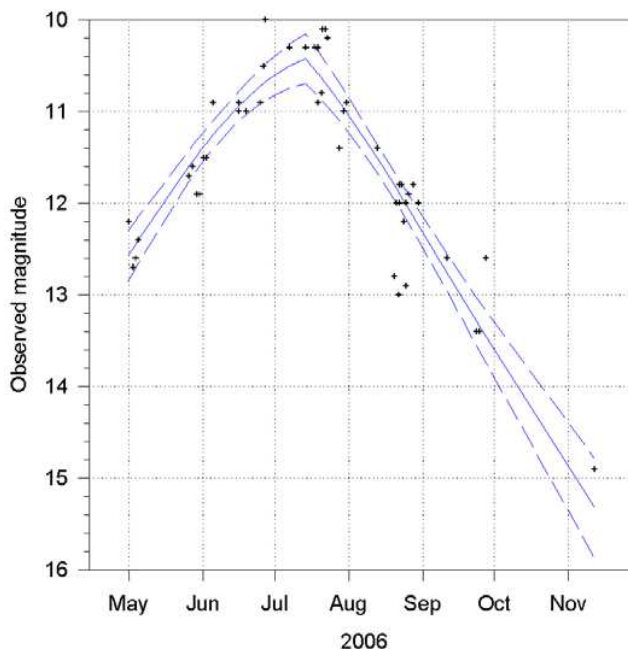


Figure 26. The lightcurve of 71P/Clark.

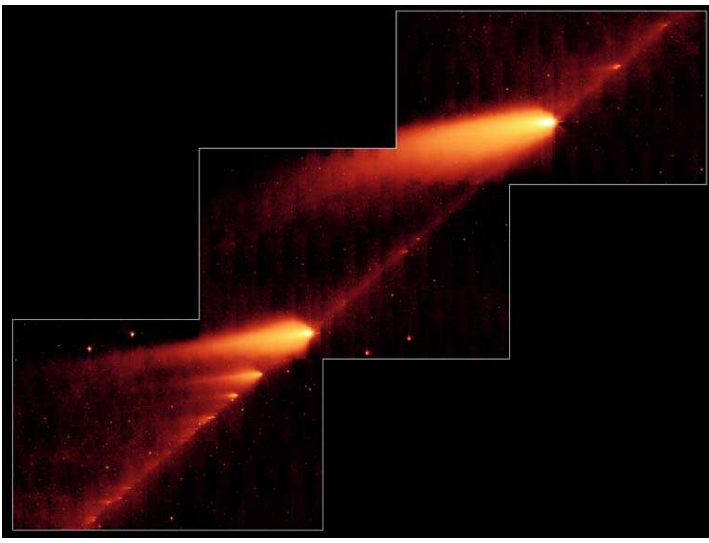


Figure 27. 20 micron infrared image from NASA's Spitzer Space Telescope showing fragments of 73P/Schwassman–Wachmann, each with tails, while a dusty trail links the fragments.

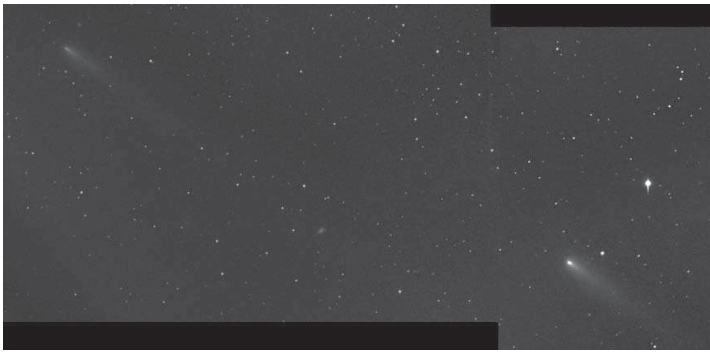


Figure 28. Components 'B' (top left) and 'C' of 73P/Schwassmann–Wachmann imaged by Mike Holloway on 2006 June 3.

mission was designed to view a diversity of comets with 73P/Schwassmann–Wachmann expected to show fresh cometary surfaces following the major outburst and fragmentation in 1995,⁹ while 2P/Encke is an old comet and 6P/d'Arrest an average one.

With the comet orbit approaching so closely to the Earth, an associated meteor shower might be expected, and the comet has

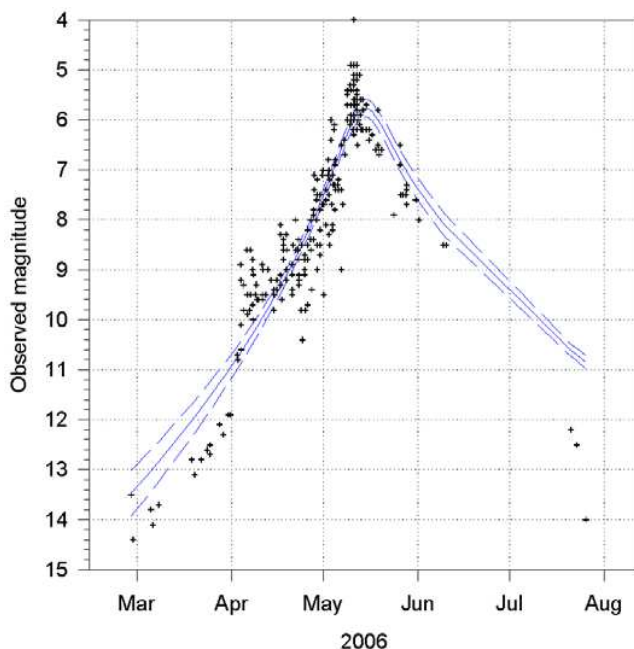


Figure 29. The lightcurve of 73P/Schwassmann–Wachmann component 'B'.

been linked to the Tau Herculis shower of late May and early June, though the radiant now lies in the Bootes–Serpens region. Strong activity was observed in 1930 by Kaname Nakamura at Kwasan Observatory in Japan, but little has been seen since then, though video meteor observations showed marginal activity in 2006. Weak displays are expected in 2022 and 2049, though these are due to encounters with dust released in the nineteenth century and are not connected with the recent activity.

A paper by Zdenek Sekanina¹⁰ on the 1995 splitting of the comet had identified a fragmentation cascade involving five major fragments. The main comet was recovered on 2005 Oct 22.49 by Carl Hergenrother. As the object continued to approach the Earth more and more fragments were reported in the *IAUC* with 66 finally being given orbits in the JPL database. The Spitzer Space Telescope imaged the comet in the 24-micron band (Figure 27) and showed major and minor fragments with tails, linked by a continuous dust trail. Visual observers mostly saw fragments 'B', 'C' and 'G', though a few others were also detected.

The main body of the comet was fragment 'C'. Visual observations in early 2006 March put it at 12th magnitude. It brightened rapidly, and by early April had reached 10th magnitude and was easily visible in large binoculars. On April 3.95 Jonathan Shanklin observed 'B' and 'C' in 20×80B and found that 'B' was noticeably brighter than 'C', with an estimate at around mag 9. Despite a bright Moon they were easily visible in large binoculars from urban Cambridge. By early May, component 'C' was being reported as visible to the naked eye; it was well condensed with a short tail and an easy object in binoculars. Martin McKenna made one such report on May 3:

'I had a great look at these two comet fragments last night. In my 0.22m telescope fragment 'C' was a proper comet with stellar central condensation, well condensed coma (it has grown larger) and a long dust tail 30' long pointing SW with faint slender spine and numerous ion streamers radiating away from the coma. Fragment 'B' also sported a bright stellar condensation (in outburst again) with very short stubby 10' long dust tail pointing SW. Both comets were large bright objects in

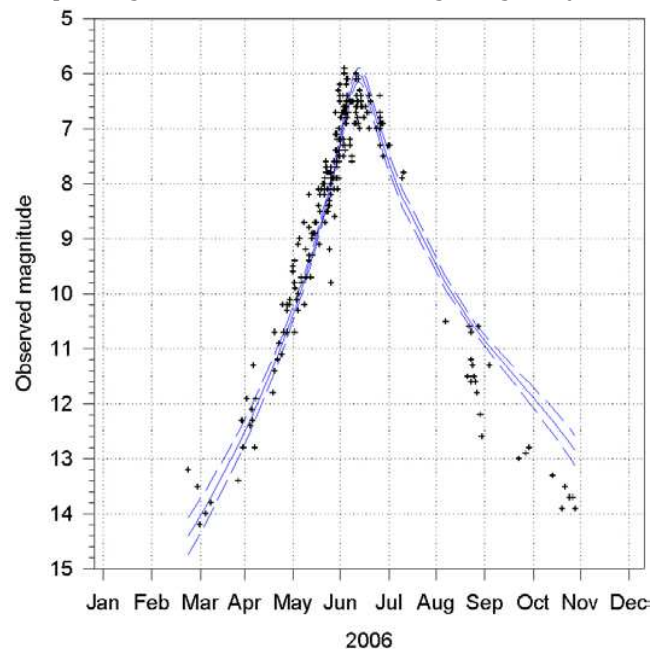


Figure 30. The lightcurve of 73P/Schwassmann–Wachmann component 'C'.

10×50B with ‘C’ showing a long slender tail and ‘B’ sharing the same field of view as M13. I got to experience ‘aperture effect’ first hand tonight! Using my 8×22B both comets were remarkably larger and brighter compared with the view in the 10×50s. Fragment ‘C’ was a very easy naked eye object tonight that looked like a large grey fuzzy patch with the coma and tail combination extending at least 15’ in diameter although I suspect it is much larger! I also spotted fragment ‘B’ with the naked eye using averted vision as a small soft stellar source that was

quite easy to see, and I reckon it was magnitude 6.5–6.7 with ease! In fact with the naked eye I could see fragment ‘C’, M13 and ‘B’ all at the same time.’

Following closest approach the comet rapidly moved south and faded. Although the formal errors on the lightcurve parameters are fairly small, there may be bias caused by the close approach and the wide range of instruments used for observation. Forcing a larger value for K brings the mean curve closer to the observations towards the end of the apparition and only makes a small difference elsewhere.

The brightest of the other fragments was ‘B’ and whilst this shows a broadly similar basal lightcurve to fragment ‘C’, it exhibits several outbursts, suggesting that the body was still actively fragmenting. It was reported in outburst on April 2, and subsequent analysis of the photometry by Giovanni Sostero suggested that the outburst began a few days previously. It changed in appearance from day to day, but was generally more diffuse than the main body. Observations showed a major new outburst around May 8, making the fragment an easy object under light polluted skies. It showed quite an extreme aperture effect, being faintly visible to the naked eye, yet nearly two magnitudes fainter in 20×80B.

Fragment ‘G’ was clearly a minor fragment, with an absolute magnitude some four magnitudes fainter than the major components.

Other comets and objects observed during the year

29P/Schwassmann–Wachmann

The comet was discovered in 1927 and is in a near-circular orbit, just outside that of Jupiter. Occasional encounters, the next in 2037, mostly affect the angular elements. In 1931 images of the comet were found on archival plates taken in 1902. It was at perihelion in 2004 when it was in almost continuous outburst.

This comet has frequent outbursts and for a number of years seems to have been more often active than not. Historically it rarely got brighter than mag 13 in outbursts, however even this is remarkable for an object that is more distant than Jupiter from the Sun. The outbursts may be due to a thermal heat wave propagating into the nucleus and triggering sublimation of CO inside the comet. Richard Miles has recently developed an alternative model^{11,12} for the activity of the comet, which most importantly makes predictions for future outbursts. The comet is an ideal target for those equipped with electronic imagers and it should be observed at every opportunity.

The comet was in solar conjunction in 2006 May and at opposition in Perseus towards the end of November. Observation was possible in the first three months of 2006 and the second half of the year and positive visual observations were made

Table 3. Magnitude parameters of the comets of 2006

a. Standard magnitude parameters

Comet	No. obs.	r (au)	H ₁	K ₁	H ₁₀
A1 (Pojmanski)	168	0.6–1.9	7.3±0.0	7.1±0.2	7.6±0.0
F1 (Kowalski)	1	4.5			5.8
HR ₃₀ (P/Siding Spring)	28	1.2–1.9			11.1±0.2
K4 (NEAT)	2	5.7–5.8			5.0±0.1
L1 (Garradd)	59	1.5–2.0	6.9±0.5	11.9±2.2	7.2±0.1
L2 (McNaught)	17	2.0–2.7	3.9±1.1	15.9±2.7	6.2±0.1
M4 (SWAN) (Post outburst)	182	1.0–2.0	5.5±0.1	9.4±0.5	5.4±0.0
O2 (Garradd)	1	1.6			11.8
OF ₂ (Broughton)	136	2.4–4.8	6.4±0.3	5.2±0.6	4.2±0.1
P1 (McNaught)					
(Standard model)	287	0.2–3.3	4.2±0.1	9.7±0.1	4.2±0.0
(Pre-perihelion)	73	0.2–2.4	5.6±0.1	10.9±0.2	5.1±0.1
(Post-perihelion)	214	0.2–3.3	4.0±0.0	10.3±0.1	3.9±0.0
(Specific aperture correction)	287	0.2–3.3	3.9±0.1	9.4±0.1	4.8±0.0
Q1 (McNaught)	35	2.8–4.9	5.2±0.8	8.0±0.6	4.2±0.1
S1 (P/Christensen)	4 c	1.4–1.5			15.3±0.2
S2 (LINEAR)	1 c	3.7			7.1
S3 (LONEOS)	87 c	5.1–6.9			0.7±0.1
S4 (P/Christensen)	2 c	3.2			7.9±0.1
S5 (Hill)	18 c	2.6–4.9	8.8±0.4	5.5±0.8	6.5±0.2
S6 (P/Hill)	3 c	2.4			10.9±0.1
U6 (Spacewatch)	1	3.9			5.8
VZ ₁₃ (LINEAR)	169	1.0–1.9	8.1±0.0	9.2±0.5	8.0±0.0
W3 (Christensen)	388	3.1–6.1	0.3±0.2	11.6±0.4	1.2±0.0
WD ₄ (Lemmon)	2	3.1			4.6±0.1
XA ₁ (LINEAR)	6	2.0–2.4	7.8±1.2	7.9±3.7	7.1±0.1
4P/Faye	179	1.7–2.3	7.6±0.4	11.1±1.5	7.8±0.0
41P/Tuttle–Giacobini–Kresak	48	1.0–1.4	9.8±0.2	12.1±3.2	10.0±0.1
71P/Clark	48	1.6–2.1	10.0±0.5	6.8±2.5	9.3±0.1
73P/Schwassmann–Wachmann					
B	255	0.9–1.8	11.3±0.1	6.9±0.9	11.2±0.0
C	353	0.9–2.1	11.3±0.0	3.0±0.5	10.8±0.0
G	25	1.1–1.3			14.7±0.3
76P/West–Kohoutek–Ikemura	2 c	1.6–1.7			12.9±0.7
84P/Giclas	2 c	1.9–2.2			9.8±0.9
98P/Takamizawa	1 c	2.1			10.7
177P/Barnard	169	1.1–1.5	9.1±0.1	17.4±1.7	9.7±0.1
181P/Shoemaker–Levy	4	1.1			11.1±0.0
249P/LINEAR	1 c	1.2			15.6
255P/Levy	18 c	1.0–1.1	8.7±0.1	50.1±7.5	9.0±0.2
278P/McNaught	1	2.1			11.7
287P/Christensen	1 c	3.1			8.7

b. Linear magnitude parameters

Comet	No. obs.	Days	H ₁	K ₁	ΔT
S3 (LONEOS)	87c	–616–704	7.3±0.2	0.0022±0.0003	–424±87
71P/Clark	48	–37–158	11.0±0.1	0.0133±0.0027	–36.9±4.4
177P/Barnard	169	–64–64	9.5±0.1	0.0352±0.0032	–5.7±1.4

The magnitude of the comets can be calculated from the equation: $m = H_1 + 5.0 * \log(\Delta) + K_1 * \log(r)$. For many comets there are insufficient visual observations to calculate K_1 accurately and so a value of 10 is assumed, which gives the constant H_{10} . Some comets do not follow the standard equation and are better fitted with a linear equation: $m = H_1 + 5.0 * \log(\Delta) + K_1 * \log(t - T + \Delta t)$, where t is the Julian Date, T the Julian Date of perihelion and Δt an offset. If Δt is positive the comet is intrinsically brighter prior to perihelion.

CCD observations have been used to determine the magnitude parameters of comets with insufficient visual observations; these are indicated by c after the no. of observations. A correction for aperture of 0.0033/mm and the observer corrections derived in previous papers^{14,15} have been applied and the H values are reduced to zero aperture.

in January, February, July, August, September, October, November and December. Clearly defined outbursts occurred in July and October, with less well defined events in the other months. The outbursts followed the usual pattern with an initially high degree of condensation steadily becoming more diffuse. At brightest it reached around 11th magnitude.

174P/Echeclus = (60558) = 2000 EC₉₈

A cometary coma was detected around the Centaur asteroid (60558) 2000 EC₉₈ on 2005 Dec 30.50. At discovery by *Spacewatch* in 2000 the object was 21st magnitude, but the development of a coma caused it to brighten by at least 3 magnitudes. Visual reports suggested it could be even brighter, and Seiichi Yoshida reported it at 14.4, with a 0.5' coma and DC3 in his 0.4m reflector on Jan 8.78. He suggests that this may be the most distant visual detection of a comet, as the object was 13 au from the Sun.

The object is in a 35-year orbit, and not due to reach perihelion until 2015, when it will be at 5.9 au. Subsequent observations of a secondary body in early 2006 suggest a fragmentation event, and a further significant outburst was reported in 2011. Systematic observations by Kevin Hills and Roger Dymock during 2014 showed a slow brightening during the first half of the year, followed by a sudden fade in September. This behaviour is rather different from that of 29P, but hopefully continued systematic observation will throw some light on it.

The nomenclature is similar to the case of Chiron, which is designated as (2060) 95P/Chiron. It will be interesting to see whether the full resolution data from the *New Horizons* spacecraft shows a tail or coma on Pluto, though even if it does the political ramifications of a further change in status are unlikely to be welcomed.

Hill Comets

BAA member Rik Hill discovered four comets during the course of the Catalina Sky Survey this year. These were **2006 D1 (P/Hill)**, **2006 S5 (Hill)**, **2006 S6 (P/Hill)** and **2006 W4 (195P/Hill)**.

Acknowledgments

Thanks are due to Guy Hurst for preparing cometary material for publication in *The Astronomer* magazine. Acknowledgment is also given to the British Antarctic Survey and the Institute of Astronomy, Cambridge for the use of computing facilities. Information on comet orbits was also obtained from internet pages by Kazuo Kinoshita.¹³

Address: 11 City Road, Cambridge CB1 1DP. [jds@ast.cam.ac.uk]

References

- 1 JPL Small-Body Database Browser, <http://ssd.jpl.nasa.gov/sbdb.cgi> (Accessed 2015 January)
- 2 BAA Comet Section web page <http://www.ast.cam.ac.uk/~jds> (Accessed 2015 January)
- 3 BAA Comet Section image archive <http://www.britastro.org/cometobs/> (Accessed 2015 January)
- 4 Shanklin J. D., '2006 P1 (McNaught) – a Great Comet', *J. Brit. Astron. Assoc.*, **117**(2), 57 (2007)
- 5 Marcus J. N., 'Forward-Scattering Enhancement of Comet Brightness. I. Background and Model', *ICQ*, **29**(2), 39 (2007)
- 6 Marcus J. N., 'Forward-Scattering Enhancement of Comet Brightness. II. The Lightcurve of C/2006 P1 (McNaught)', *ibid.*, **29**(4), 119 (2007)
- 7 Jenniskens P., *Meteor showers and their parent comets*, Cambridge University Press, 2006
- 8 Shanklin J. D., 'The comets of 2001: Part 2', *J. Brit. Astron. Assoc.*, **124**(1), 29 (2014)
- 9 Shanklin J. D., 'The comets of 1995', *J. Brit. Astron. Assoc.*, **110**(6), 311 (2000)
- 10 Sekanina Z., 'Comet 73P/Schwassmann–Wachmann: Nucleus Fragmentation, Its Light-Curve Signature, and Close Approach to Earth in 2006', *ICQ*, **27**(4), 225 (2005)
- 11 Miles R., 'Predicting outbursts of comet 29P/Schwassmann–Wachmann', *European Planetary Science Congress Abstracts* 9, EPSC2014-200 (2014)
- 12 Miles R. *et al.*, 'Discrete sources of cryovolcanism on the nucleus of comet 29P/Schwassmann–Wachmann', submitted to *MNRAS* (2014)
- 13 The Comet Orbit Home Page, <http://jcometobs.web.fc2.com/index.html> (Accessed 2015 January)
- 14 Shanklin J. D., 'Comet Levy 1990c', *J. Brit. Astron. Assoc.*, **105**(6), 295 (1995)
- 15 Shanklin J. D., 'Comet Shoemaker–Levy 1991a₁', *J. Brit. Astron. Assoc.*, **106**(1), 19 (1996)

Received 2014 October 19; accepted 2015 March 25

BAA Membership

The subscription rates for the 2015–2016 session are as follows:

Young Persons' membership (22 years of age or under on 1st August) £19.00
Ordinary Members (23–64) £47.00
Senior Members (65 or over) £34.00
Affiliated Society £47.00

Members with 50 or more years' continuous membership (Honorary Members), no charge

Family Membership:
Where both members are under 65 on 1st August £51.00
Where one or both members are 65 or over £36.00

Family Membership is available for two people living at the same address. Only one *Journal* and *Handbook* will be sent although both may attend meetings and have a vote.

Paper Circulars, 4 issues (if required):
UK & Europe £6.00
Rest of World £12.00

Postage

Overseas postage by surface mail for the *Journals* and *Handbook* is included in the above rates. To avoid postal delays and losses use of airmail is strongly recommended. Please add the following for airmail:

Europe (incl. Canary Is. & Turkey) £14.00
Rest of World £21.00

Overseas members may send a sterling cheque, arrange payment in sterling on a UK bank, or pay by credit card using the BAA's secure website www.britastro.org. Please note that we do not currently hold a continuous credit card payment authority, so your payment must be renewed every year.

UK members are particularly asked to save administrative costs and time by paying their subscriptions by Direct Debit: please contact the Office for the necessary form.

Gift Aid

UK Income Tax payers are urged to complete a Gift Aid certificate for their subscriptions and other donations. To claim Gift Aid you must pay an amount of UK income tax and/or Capital Gains tax at least equal to the tax which we reclaim on your donations in the tax year (currently 25p for each £1 you donate).

Please request a Gift Aid form from the Office if you have not previously completed one. The BAA can claim a tax refund at any time during the year.