The brighter comets of 2015

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A report of the Comet Section. Director: N. D. James

This report describes and analyses observations of the brighter or more interesting comets discovered or at perihelion during 2015, concentrating on those visually observed. Magnitude parameters are given for all comets with observations. Any evolution in the magnitude parameters of those periodic comets with multiple returns is discussed. Additional information on the comets discussed here, and on other comets seen or at perihelion during the year, may be found on the Comet Section's visual observations web pages.

Introduction

83 comets were assigned year designations for 2015 and 40 previously numbered periodic comets returned to perihelion. 228 comets from the SOHO satellite were credited during 2015, including five returning objects. 188 were members of the Kreutz group, 22 were members of the Meyer group, three of the Marsden group, two of the Kracht group and 15 were not associated with any known group. There were at least six amateur discoveries (2015 D4, F2, F4, Q2, VL_{62} and X4) for which Gennady Borisov, Rafal Reszelewski; Michal Kusiak, Marcin Gedek and Michal Zolnowski; Cristóvão Jacques, Eduardo Pimental, Bill Yeung and Leonid Elenin may gain the Edgar Wilson Award (though there has been no formal announcement to date).

13 periodic comets from the year were numbered. One comet (2014 Q2) was reported as visible to the naked eye during the year. In a change from previous practice, the behaviour of comets that were discovered during 2015 but will only become bright enough for visual observation several years in the future will be analysed during the year of perihelion.

Orbital elements for all the comets discovered and returning during the year can be found on the Jet Propulsion Laboratory (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 Section visual observations web pages,[2] which also contain links to additional background information. The raw visual observations for the year are on these pages in ICQ format and in the Comet Observations (COBS) database.[3] The full dataset from COBS is used for the multi-return analyses presented here, but otherwise only those submitted to the Section are used. Additional images of the comets are presented in the Section image archive.[4]

The comets given a discovery designation

2015 C2 (SWAN)

Rob Matson reported a comet in SWAN images taken between Feb 15 & 22. Michael Mattiazzo and Vladimir Bezugly reported the same object. Terry Lovejoy imaged the comet on Feb 25.4, estimating it at 11th magnitude. Michael Mattiazzo also imaged the comet and was able to observe it visually at magnitude +11.5. The comet was at perihelion at 0.7au in early March [*CBET* 4068, *MPEC* 2015-D110, 2015 Feb 27]. It remained at a poor solar elongation.

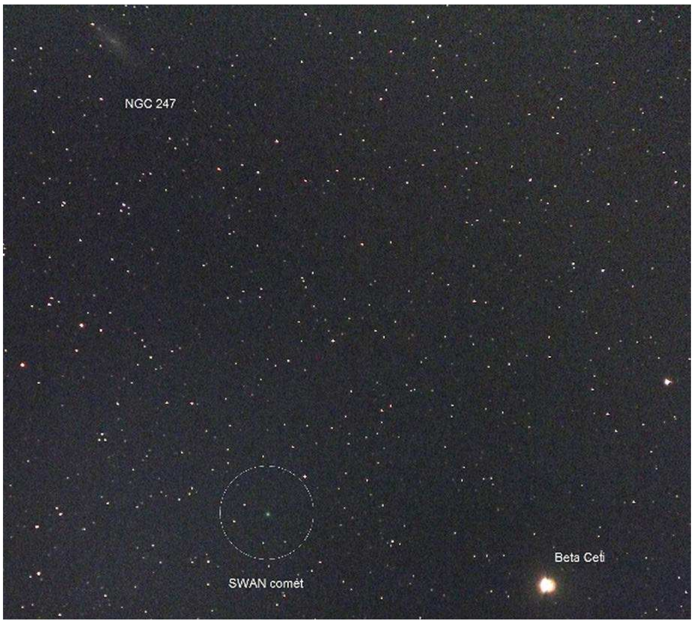

Figure 1. Image taken on 2015 Feb 25 at 10:30 UT using a Canon 60Da with Sigma 200mm lens; 10×20s stack. The field of view is three degrees. *Michael Mattiazzo*

Rob Matson provides some discovery details:

> 'I first spotted the comet in SWAN imagery on Sunday, Feb 22, when composite images were available for Feb 15, 16, 17, 18 & 19. It wasn't bright enough to be reportable yet (particularly the Feb 15 image), but I was pretty confident it was real so started the process of converting raw pixel coordinates to RA/Dec and grabbing SOHO satellite ephemeris data for the dates in question. I could find no other known comets predicted to be at that location, so I computed a preliminary orbit. It didn't take long to realise that my chances of acquiring it in 20×110 binoculars from southern California were poor, due to the low solar elongation combined with northern hemisphere winter. It would take more aperture and darker skies.

'By Tuesday I had the comet in eight images; it was time to find someone on the ground who could confirm it, and to report rough positions to Dan Green and Gareth Williams. I made my usual epoch assumption for SWAN composite images (12 UT), figuring that an uncertainty of ±12h is better than the alternatives. In reality, SWAN composites are stitched together from much smaller images collected over a roughly 24-hour period, so different parts of the celestial sphere are imaged at different times. (I've never been able to find information about SWAN's scan pattern, or if there is ancillary data that provides the epoch of each pixel.) I sent the eight positions to Dan and Gareth.

'I explained that my +10 estimate for the magnitude was just an educated guess based on the comet's moderately easy detectability in the last several images. I computed a preliminary parabolic orbit and generated search ephemerides for Terry Lovejoy and Rob McNaught, which I sent to them just prior to e-mailing Dan and Gareth. The comet appeared to be moving at about 1.6 degrees-per-day (°/d), so I advised Terry and Rob that the position could be off by ±0.8° (mostly in declination) just based on the SWAN timing uncertainty alone, and more like ±1° when SWAN's coarse angular resolution is folded in.

'Terry got back to me almost immediately, mentioning that he was concerned it might be too low for him and with the possibility of local obstructions, but that weather permitting he'd give it a try. At 01:39 Wednesday morning (Pacific Time), Terry e-mailed me to say he'd found it close to the predicted position – estimating the magnitude at +11 with a 2′ coma – and said it had a short, stubby tail. At this time he informed me that Michael Mattiazzo also contacted him shortly after I had, which wasn't surprising as Michael and I have shared discovery credit on a number of prior SWAN comets. Once the *CBET* was out, I saw that Vladimir Bezugly (another veteran SWAN comet-finder) had also spotted the comet.

'It will be interesting to see if the comet turns out to be periodic; when I combined ground-based astrometry with SWAN positions I got solutions that seemed to favour a 100-to-200-year orbit, depending on how much I shifted the epoch times of the SWAN positions.'

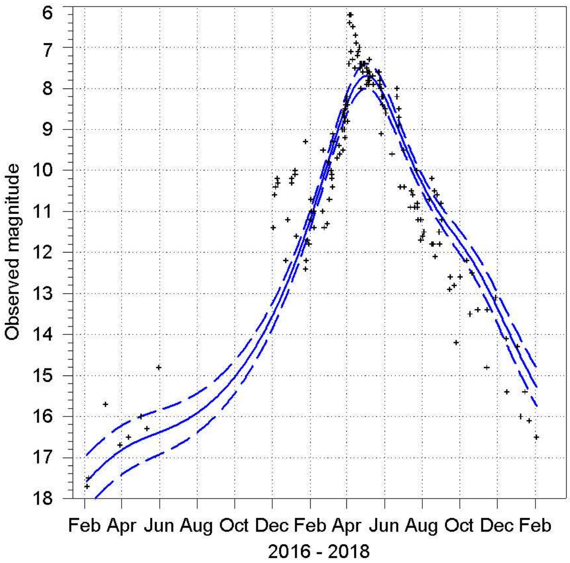

Figure 2. The observations of 2015 ER_{61} (PanSTARRS) with a standard light curve fitted to them. The dashed lines show the 95% confidence limits.

2015 D1 (SOHO)

Worachate Boonplod discovered a comet in SOHO/LASCO C3 images taken at 07:06, 07:18 & 07:30 UT on Feb 18.

Karl Battams noted that the comet appeared tiny at first (just above the noise at about 9th magnitude) and gradually brightened as it neared the Sun. He was surprised to see that it then dramatically brightened to a magnitude of about +1.5 as it crossed into the C2 field of view, when a short, faint tail appeared (Feb 19). It remained visible for the rest of the comet's observable passage (fading to around magnitude +6 by the time it left LASCO's field of view on Feb 21.77).

Matthew Knight (Lowell Observatory) analysed the SOHO images and reported that the comet was first visible late on Feb 17, right at the detection limit in C3 (about magnitude +9.5 to +10), and peak brightness occurred around Feb 19.9 at an apparent visual magnitude of about +1.3. It had a much more cometary appearance during the second half of the visible apparition, with the tail seeming more distinct as it was fading.

Table 1. Photometric observers

James Abbott, Witham, Essex
Alexandre Amorim, Brazil
Alexandr R. Baransky, Ukraine
Denis Buczynski, Tarbatness, Ross-shire
Paul Camilleri, Australia
Peter Carson, Leigh-on-Sea, Essex
Jakub Cerny, Czech Republic
Mike J. Collins, Everton, Bedfordshire
Roger Dymock, Waterlooville, Hampshire
Stephen Getliffe, Haverhill, Suffolk
Marco Goiato, Brazil
Juan J. Gonzalez, Spain
Virgilio Gonano, Italy
Ernesto Guido, Italy
Werner Hasubick, Germany
Kevin Hills, Cheshire
Nick James, Chelmsford, Essex
Andreas Kammerer, Germany
Heinz Kerner, Germany
Carlos Labordena, Spain
Martin Lehky, Czech Republic
Artyom Novichonok, Russia
Mieczyslaw L. Paradowski, Poland
Nirmal Paul, India
Jonathan D. Shanklin, Cambridge
Giovanni Sostero, Italy
William C. de Souza, Brazil
Sándor Szabó, Hungary
Johan Warell, Sweden
Graham W. Wolf, New Zealand
Seiichi Yoshida, Japan

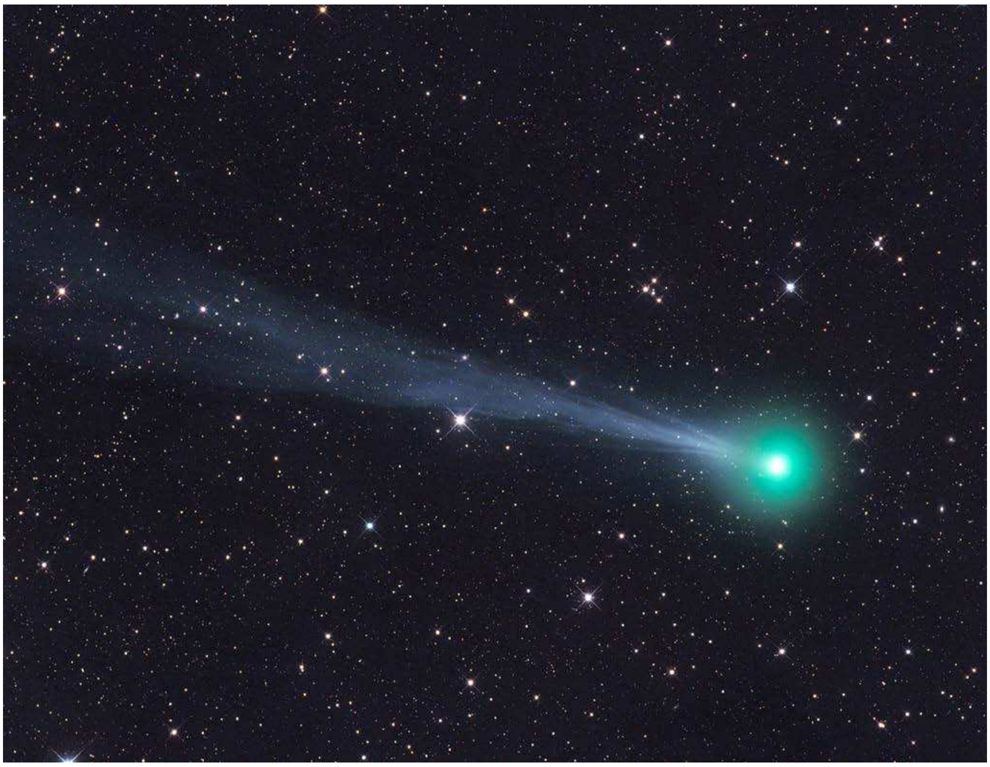

Figure 3. 2015 ER_{61} (PanSTARRS), imaged on 2017 Apr 6 at 03:34 UT from Farm Tivoli, Namibia, SW Africa. ASA 300mm f/3.6 telescope, FLI PL 16200 camera & ASA DDM85 mount; Exposure time LRGB 12/5/5/5min. *Gerald Rhemann*

Pre- and post-perihelion solutions were required to fit the observations; considering the appearance of the tail near perihelion and rapid brightening, it is possible that some large physical change (perhaps splitting) occurred around that time [*CBET* 4067, *MPEC* 2015 D73, 2015 Feb 24].

The *CBET* gave the discovery time as Feb 18.004. No error bars were given for their orbit solutions. As there is a relatively small arc and the SOHO positions are of low accuracy, it is not clear how significantly different the pre- and post-perihelion orbits are. The JPL orbit, based on a three-day arc, classes it as a Jupiter-family comet with a period of around 11 years.

The comet was observed from the ground, however it only showed as a dusty streak on images taken by Justin Cowart.

2015 ER_{61} (PanSTARRS)

Pan-STARRS 1 discovered a 21st magnitude asteroid in images taken with the 1.8m Ritchey–Chrétien on 2015 Mar 14.37. Peter Birtwhistle contributed, confirming astrometry [*MPEC* 2015-F124, 2015 Mar 27]. The object, originally classified as an Amor-type NEO but in a near-parabolic orbit, reached perihelion at 1.1au in 2017 May. The orbit has a Tisserand criterion with respect to Jupiter of 1.27, a Jupiter minimum orbit intersection distance (MOID) of 0.029au and an Earth MOID of 0.10au. Unfortunately, the object itself did not approach the Earth particularly closely.

Observations in 2015 December and 2016 January showed that the object had cometary features and a coma was then noted in images from 2015 June. It was therefore re-designated as a comet on *MPEC* 2016-C01 [2016 Feb 1]. A secondary component was detected by Belgian amateur Erik Bryssinck, on 2017 Jun 13.41.

Juan José González recovered the comet after solar conjunction on 2016 Dec 6.25, at magnitude +10.4. The comet brightened fairly slowly, but underwent a short-lived outburst in early April when it briefly reached 6th magnitude. Overall, it peaked at 7th magnitude in early May. It faded slightly more rapidly after perihelion than it had brightened beforehand; this was probably an effect of the outburst. The comet showed a short tail that was best (0.7°) at the time of the outburst.

2015 F3 (SWAN)

Rob Matson reported a comet in SWAN images taken in March. It was soon confirmed by ground-based observers, including Peter Birtwhistle [*CBET* 4084, *MPEC* 2015-F122, 2015 Mar 27]. The comet reached perihelion at 0.8au in early March. The orbital parameters are close to those of 1988 A1 (Liller) and 1996 Q1 (Tabur). Visually, it was around 10th magnitude in late March and early April.

1996 Q1 was discovered by Australian amateur Vello Tabur on 1996 Aug 19.70. After reaching naked-eye brightness in mid-October, the comet suddenly faded dramatically. The orbit is very similar to that of 1988 A1 (Liller), which reached perihelion on 1988 Mar 31. It seems likely that these two comets separated at their last perihelion passage, about 2,900 years ago. The comet is one of those known to have undergone nuclear splitting according to a list by Marcos & Marcos (2018).[5] They link 2015 F3

Table 2. Astrometric, electronic, photographic & visual imagers during 2014

Observer	*Site*	*IAU Stn. No*
Paul Abel	Leicester	
David Anderson	Girvan, Ayrshire	
Tony Angel	Spain	Z85
David Arditti	London	
Chris Baddiley	Malvern, Worcestershire	
Alexander Baransky, *et al.*	Ukraine	585
Peter Birtwhistle	Great Shefford	J95
Roberto Bonello	Malta	
David Boyd	Wantage, Oxfordshire	
Erik Bryssinck	Belgium	B96
Denis Buczynski	Tarbatness	I81
Montse Campas	Spain	213
Peter Carson	Leigh-on-Sea, Essex	K02
José Chambó	Spain	
Mike Crook	Essex	
Paul Curtis	Andover, Hampshire	
Rob Davey	Essex	
David Davies	Cambridge	
Sean Dean	Isle of Wight	
Alfons Diepvens	Belgium	C23
Roger Dymock	Clanfield, Hampshire	G68, Q65
John Drummond	New Zealand	
Dave Eagle	Higham Ferrers, Northants	
John Fletcher	Mount Tuffley, Gloucestershire	J93
James Fraser	Alness, Ross-shire	
Mike Glenny	Gloucestershire	
Ernesto Guido, *et al.*	Italy	Q62
Carl Hergenrother	USA	Q65
Nick Howes, *et al.*	Hawaii / La Palma	J13, Q62
Kevin Hills	Cheshire	J22
Dale Holt	Hertfordshire	
Michael Jaeger	Austria	
Nick James	Chelmsford, Essex	970
Richard Jones	Cheshire	
Manos Kardasis	Greece	
Hisayoshi Kato	Chile	
Rob Kaufman	Australia	
Rolando Ligustri	Italy	235
Gordon Mackie	Caithness	
Glyn Marsh	Ramsey, Isle of Man	
Michael Mattiazzo	Australia	
Andrew Mickleburgh	Cleethorpes	Z99
Richard Miles	Dorset	F65
Martin Mobberley	Cockfield, Suffolk	480
T. Moran	Whitley Bay	
Neil Morrison	Crawley, West Sussex	
Arto Oksanen	Finland	
Mike Olason	USA	
Guiseppe Pappa	Italy	
Nirmal Paul	India	470, H06, I89, Q62
Damian Peach	Selsey	
Terry Platt	Binfield, Berkshire	
Danilo Privato	Italy	
Jan Qvam	Norway	
Gerald Rhemann	Austria/Namibia	
Andrew Robertson	Broome, Norfolk	
Omar Salah	Egypt	
John Savage	Sturminster Newton, Dorset	
Chris Schur	USA	
Ian Sharp	Chichester, West Sussex	
David Storey	Isle of Man	987
David Strange	Worth Matravers, Dorset	
Alan Tough	Elgin, Scotland	
Adriano Valvasori	Italy	
Graham Winstanley	Liverpool	
Simon White	Kendal, Cumbria	

with 1996 Q1, but do not mention 1988 A1.

2015 F4 (Jacques)

Cristóvão Jacques discovered a 16th magnitude comet on images taken with the SONEAR Observatory 0.28m astrograph on Mar 27.21 [*CBET* 4085, *MPEC* 2015-F159, 2015 Mar 31]. The comet had perihelion at 1.6au in 2015 August, when it was near opposition. It was 12th magnitude when observed by Juan José González on Jun 18.08 and brightened to 10th magnitude in mid-August.

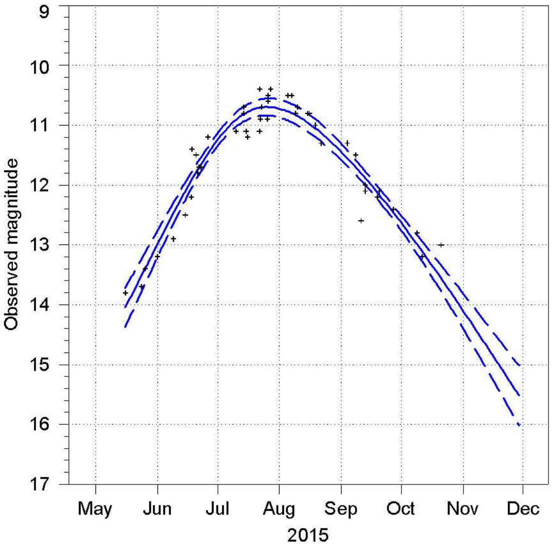

Figure 4. The observations of 2015 F4 (Jacques) with a standard light curve fitted to them.

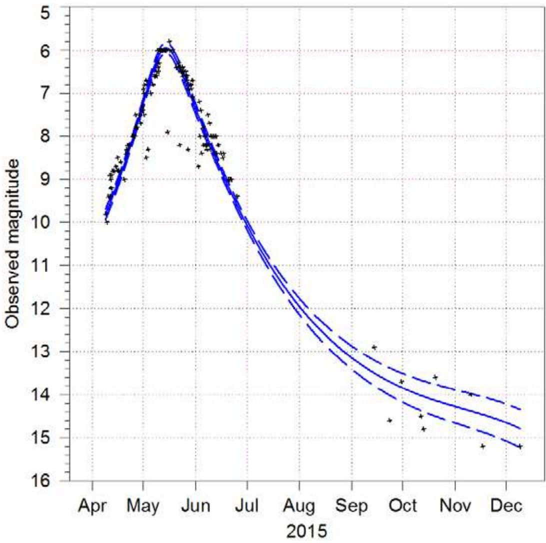

Figure 5. The observations of 2015 G2 (MASTER) with a standard light curve fitted to them.

2015 F5 (SWAN–Xingming)

Several people, including Szymon Liwo, Worachate Boonplod, Michael Mattiazzo and Rob Matson, reported a comet in SWAN images taken between Mar 29 & Apr 1. It was independently found by Guoyou Sun in images taken in twilight on Apr 4.9 by Xing Gao with a 0.11m *f*/5 refractor, in the course of the Xingming sky survey. It appeared on the Minor Planet Center's Possible Comet Confirmation Page (PCCP) as XMAAGS, prior to being designated as 2015 F5.

The comet reached perihelion at 0.3au at the end of March and has a period of around 60 years. It faded quite rapidly, from 8th magnitude in early April to 11th magnitude at the end of the month.

2015 G2 (MASTER)

Denis Denisenko reported a comet in R-band images taken by P. Balanutsa *et al.*, with the MASTER (Mobile Astronomical System of Telescope-Robots) 0.4m *f*/2.5 reflector at the South African Astronomical Observatory on Apr 7.13. Rob Kaufman from Australia noted the comet in pre-discovery images taken on Mar 30.80. The object was on the PCCP as M503ujx [*CBET* 4092, 2015 Apr 10; replaced by *CBET* 4104, issued on May 23].

The comet reached perihelion at 0.8au in May, when it brightened to around 6th magnitude. No significant tail development was reported. The electronic observations in May are rather discordant when compared to the visual ones, suggesting that the reduction technique used at that time did not work well on bright, extended objects. Visual observers often reported a coma diameter three times that measured in the image reduction.

Figure 6. 2015 G2 (MASTER) imaged on 2015 Jun 8. Planewave 20″ CDK *f*/4.4 reflector & FLI PL09000 camera (L:1×180 Bin1 + RGB:1×60 Bin2). Remotely obtained from Siding Spring (Australia). *José Chambó*

2015 O1 (PanSTARRS)

A 20th magnitude comet was discovered in Pan-STARRS 1 images, taken with the 1.8m Ritchey–Chrétien on Jul 19.47 [*CBET* 4119, *MPEC* 2015-O34, 2015 Jul 21]. The comet reached perihelion at 3.7au in 2018 February. This was the 100th comet discovered by Pan-STARRS.

2015 P3 (SWAN)

Michael Mattiazzo identified a possible comet in SWAN images from August 3 & 4, and confirmed it with an image he took on Aug 9.38 from Castlemaine, Australia. This was also confirmed by other astrometrists and observed visually at around 12th magnitude. The comet was near perihelion at 0.7au in late July [*CBET* 4136, *MPEC* 2015-P25, 2015 Aug 11].

Hirohisa Sato suggests that the comet is in a long-period orbit, with aphelion at around 500au. The elongation of the comet improved, although it faded quite quickly. Visual observations put the comet at around magnitude +10.5 in mid-August.

2015 V2 (Johnson)

Jess A. Johnson discovered a 17th magnitude comet in Catalina Sky Survey images obtained with the 0.68m Schmidt on Nov 3.44 [*CBET* 4161, *MPEC* 2015-V44, 2015 Nov 5] The comet reached perihelion at 1.6au in 2017 June.

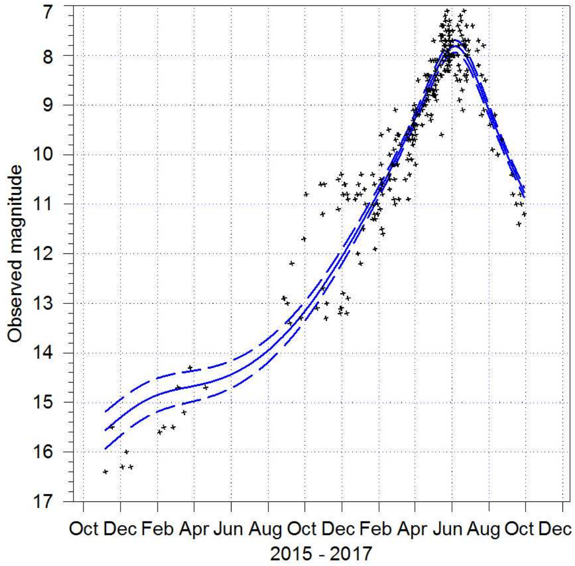

Figure 7. The observations of 2015 V2 (Johnson) with a standard light curve fitted to them.

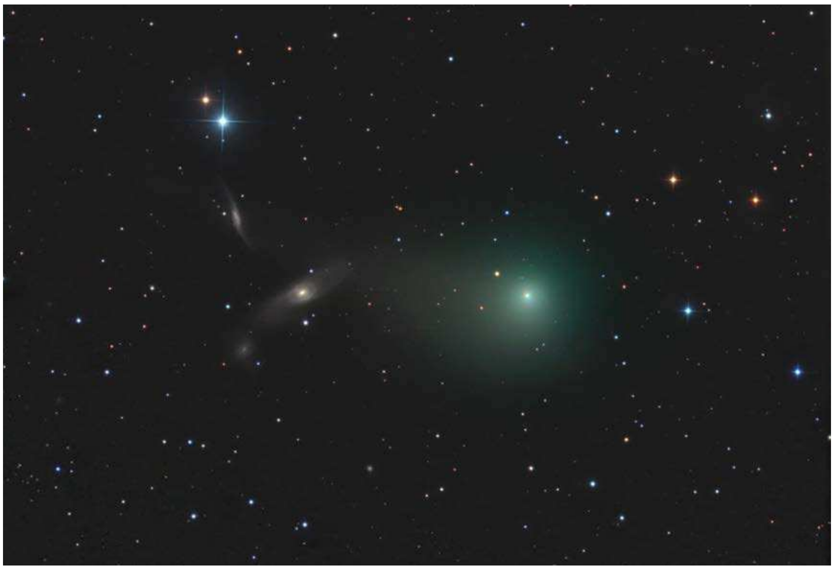

Figure 8. 2015 V2 (Johnson) imaged on 2017 Jun 18 at 05:09 UT. 20″ CDK with FLI camera. LRGB, 30min total. *Damian Peach*

JPL figures give an Earth MOID of 0.6au and classify the comet as a hyperbolic one. Juan José González picked it up at 12th magnitude in early 2016 September – much earlier than expected, though consistent with extrapolation of electronic observations by Kevin Hills. The comet brightened quite slowly, but became a good binocular object in the spring and early summer of 2017.

2015 VL_{62} (Lemmon–Yeung–PanSTARRS)

A 20th magnitude comet was discovered in Pan-STARRS 1 images, taken with the 1.8m Ritchey–Chrétien on 2016 Jan 23.30. After posting on the PCCP it was linked first to asteroid 2015 YY_6 – discovered in December by Bill Yeung – and then to asteroid 2015 VL_{62}, discovered in early 2015 November from Mount Lemmon [*CBET* 4247, *MPEC* 2016-B85, 2016 Jan 29].

The comet is in a retrograde hyperbolic orbit and had perihelion at 2.7au in 2017 August. It will approach Jupiter to 0.9au in 2018 November, on its way out of the solar system. It reached around 13th magnitude at the time of perihelion.

The numbered periodic comets at perihelion in 2015

6P/d'Arrest

The comet made its 20th observed return in 2015, but it was a poor one with few visual observations. These are unfortunately insufficient to allow updating of the analysis presented in the paper on the comets of 2008.[6] The 2021 return will be a good one.

7P/Pons–Winnecke

This comet was last described in the paper on the comets of 2002.[7] It was faint at both the 2008 & 2015 returns, and there are not enough observations in the COBS database to give a consistent overall light curve. The comet appears to have been brighter at

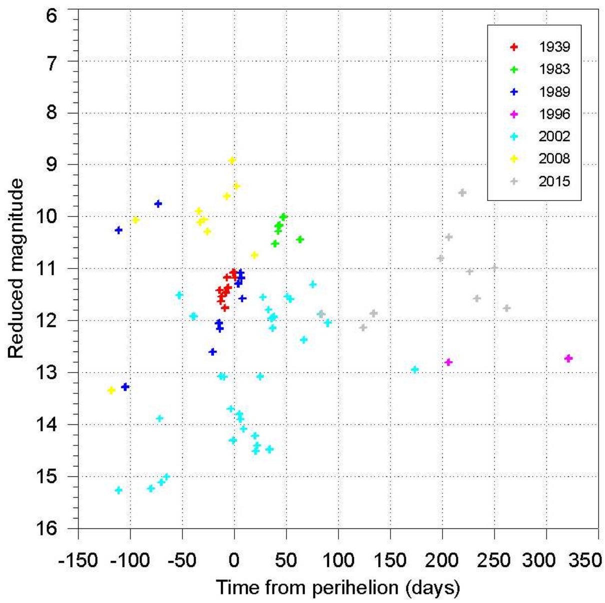

Figure 9. Composite plot showing the magnitude of 7P/Pons–Winnecke at returns since 1939, corrected for the distance from the Earth.

the 2008 return than it was at the 2002 return, but the perihelion distance was similar. In 2015 the comet was only observed after perihelion, and appears to have faded relatively slowly.

Overall, observations over the seven apparitions in the database suggest that the comet is usually brighter several months after perihelion and that it fades more slowly than it brightens. The 2021 apparition should be a relatively good one; the comet then encounters Jupiter in 2025 and again in 2037, pushing the perihelion distance inside the Earth's orbit.

10P/Tempel

Previous observations were analysed in the report on the comets of 2010,[8] with a prediction made for the return of 2015. This was based on a relationship between the delay in peak output and the perihelion distance. Because most of the observations in 2015 were made before the peak output of the comet, the exact timing

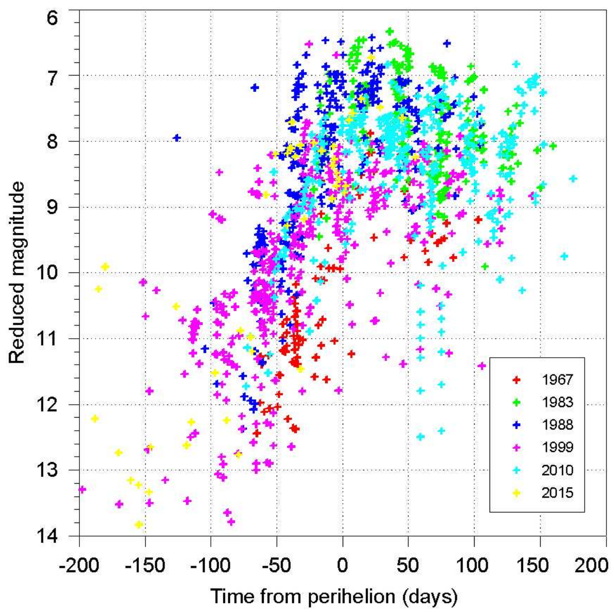

Figure 10. Composite plot showing the magnitude of 10P/Tempel at returns since 1967, corrected for the distance from the Earth.

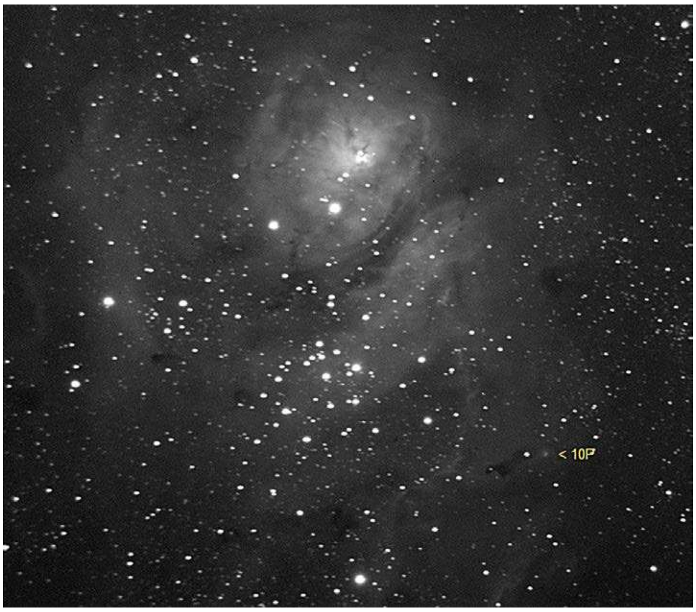

Figure 11. 10P/Tempel, imaged from Denver, Colorado on 2015 Nov 2 at 01:28 UT when it was close to Messier 8. 300s; 6″ SCT; *f*/10; STF-8300. FOV 42×32′. *Mike Olason*

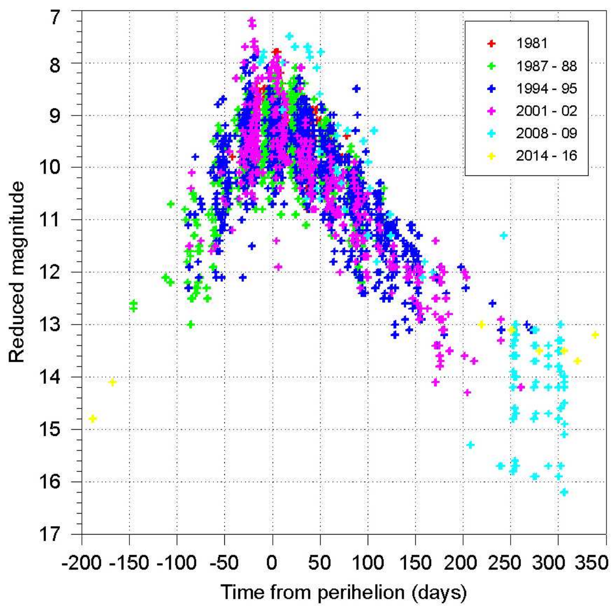

Figure 12. Composite plot showing the magnitude of 19P/Borrelly at returns since 1981, corrected for the distance from the Earth.

of the peak is not well-defined, but it was broadly in line with the prediction at 39 ± 10.3 days after perihelion. Unfortunately, the next few returns all have similar perihelion distances, so will only add points at the same place in the relationship.

The comet makes a relatively close pass to the Earth in 2026, when it has a perihelic opposition and could reach 7th magnitude. It is one of those comets suspected to have undergone nuclear splitting, according to the list of Marcos & Marcos (2018).[5] They link it to 2015 T3 (P/PanSTARRS).

19P/Borrelly

Previously described in the paper on the comets of 2001,[9] this comet will approach Jupiter during 2019 in an encounter that will reduced the perihelion distance to 1.31au: its smallest on record.

The 2015 return of the comet was a poor one, as was that of the previous return in 2008. However, there are enough observations in the COBS database to allow an analysis over multiple returns. These show that the comet has been very consistent over the six apparitions since 1981. There are no trends with respect to perihelion distance, or to time.

22P/Kopff

The comet was well observed prior to perihelion in 2015 and the observations from the return were used in the analysis presented in the paper on the comets of 2009.[10] The parameters given here for all the returns include additional observations from 1943, 1951 & 2015.

44P/Reinmuth

This comet was previously described in the paper on the comets of 2001.[9] There are enough observations in the COBS database over multiple returns to allow further analysis of its behaviour; they are however insufficient to determine any trends. The collective observations are slightly better fitted by a standard light curve, but they are quite scattered.

51P/Harrington

The comet split at its 1994 return and did so again at that of 2001, the latter being described in the paper on the comets of that year.[9] Whilst there are some further observations from 2008 & 2015, the relatively recent split means that a multiple return analysis is not yet warranted.

57P/du Toit–Neujmin–Delporte

This is another split comet; it last became so in 1996 and was found to have a secondary component in 2002.[7] Whilst there are

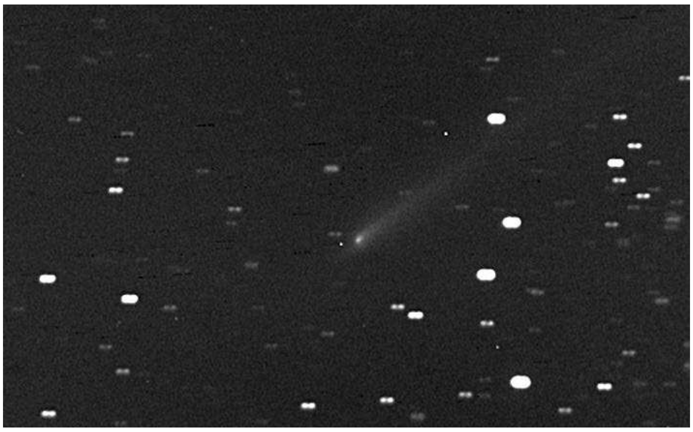

Figure 13. 19P/Borrelly, imaged on 2015 Dec 11 at 03:45 UT. The Earth was close to the orbital plane of the comet at this time, and a sunward-directed spike can just be discerned in the image. 9×120s; C14; *f*/6; SBIG ST9XE; Paramount ME. *Denis Buczynski*

Figure 14. 22P/Kopff, imaged on 2015 Sep 17 when it was around 11th magnitude and showing a greenish coma. 20″ CDK with FLI CCD. LRGB: 16/2/2/2min. *Damian Peach*

some further observations from 2015, the relatively recent split means that a multiple return analysis is not possible.

61P/Shajn–Schaldach

The comet was previously described in the paper on the comets of 2001.[9] There are now enough observations in the COBS database over multiple returns to allow some analysis of its behaviour, which shows clear effects due to perihelion distance.

Prior to 1946, the comet had a perihelion distance of 4.3au, but an encounter with Jupiter reduced this to 2.23au. It was much brighter at the 1949 return than at any subsequent one, suggestive of the sublimation of short-lived volatile species. The comet was fainter at the returns of 1993 & 2001 – which had a perihelion distance of 2.3au – than it was at the returns of 2008 & 2015, which had a perihelion distance of 2.1au. The 2022 return is a fraction more distant, so the comet is likely to be slightly fainter.

67P/Churyumov–Gerasimenko

Visual observers and electronic imagers extensively observed the comet, which was the subject of a major pro-am campaign in support of the *Rosetta* mission. An analysis of the behaviour at returns up to 2009 was given in the paper 'The brightness of 67P/Churymov–Gerasimenko'.[11]

In 2015 it was again intrinsically brightest around 40 days after perihelion, but its absolute magnitude was fainter than expected. There are clear differences between the absolute magnitudes of the various returns, with the comet being brightest in 2009 and fainter in 2015. Although the best-fit lines still show a trend with both perihelion distance and time, the null hypothesis of no change has become more likely. This then leads to the prediction that the comet will at best reach 8th magnitude in 2021.

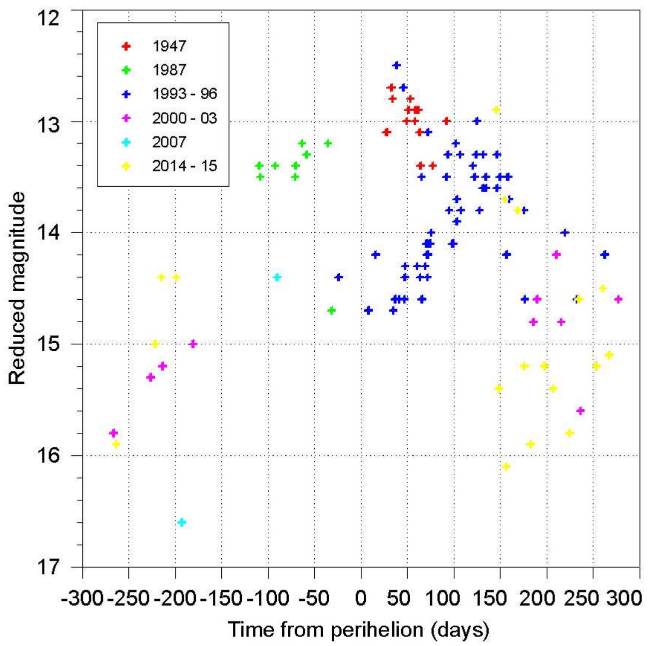

Figure 15. Composite plot showing the magnitude of 44P/Reinmuth at returns since 1947, corrected for the distance from the Earth.

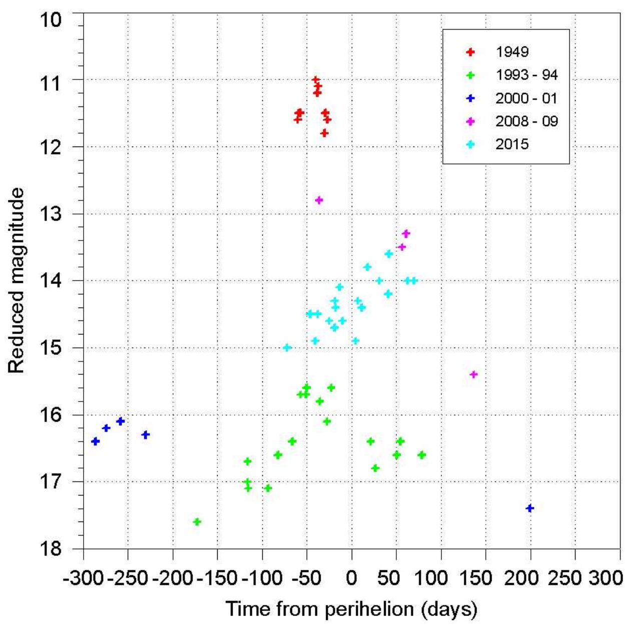

Figure 16. Composite plot showing the magnitude of 61P/Shajn–Schaldach at returns since 1949, corrected for the distance from the Earth.

Table 3. Magnitude parameters of the comets of 2015

a) Standard magnitude parameters

Comet	No. obs.	r (au)	H_1	K_1	H_{10}
C2 (SWAN)	4	0.7–1.5	7.8±0.5		
D1 (SOHO)	1	0.7	9.0		
ER$_{61}$ (PanSTARRS)	158	1.0–5.7	6.6±0.1	7.6±0.4	6.1±0.1
F1 (PanSTARRS)	11	2.5–2.7	9.8±0.2		
F2 (Polonia)	3	1.2–1.3	12.2±0.8		
F3 (SWAN)	12	0.9–1.3	9.4±0.2		
F4 (Jacques)	88	1.6–2.3	8.1±0.5	10.9±2.0	8.4±0.1
F5 (SWAN–Xingming)	6	0.5–0.9	11.7±0.2		
G2 (MASTER)	134	0.8–3.2	7.8±0.0	6.6±0.3	7.9±0.1
GX (PanSTARRS)	3	2.1–2.3	9.2±0.1		
O1 (PanSTARRS)*	50	3.7–8.1	4.2±0.7	8.2±1.0	3.1±0.1
P3 (SWAN)	10	0.8–0.9	11.2±0.1		
Q1 (Scotti)	13	1.8–2.2	11.5±0.3		
R1 (PanSTARRS)	7	2.3–3.6	11.0±0.2		
R2 (PanSTARRS)	2	2.6	12.3±0.3		
R3 (PanSTARRS)	1	6.6	3.9		
T4 (PanSTARRS)	5	3.1–3.5	7.8±0.4		
TP$_{200}$ (LINEAR)	9	3.4–3.5	6.7±0.2		
V1 (PanSTARRS)*	21	4.3–5.6	8.6±1.7	3.5±2.5	4.3±0.1
V2 (Johnson)	270	1.6–6.5	6.9±0.1	3.8±0.3	4.9±0.1
VL$_{62}$ (Lemmon–Yeung–PanSTARRS)	22	2.7–4.5	8.7±1.1	4.5±2.1	6.0±0.2
W1 (Gibbs)	3	2.5–2.9	8.7±0.9		
W2 (Catalina)	3	2.7–2.8	10.8±0.2		
WZ (PanSTARRS)	15	1.4–1.8	8.5±0.3		
X4 (Elenin)	3	3.4–3.5	7.6±0.4		
X7 (ATLAS)	4	3.9–4.2	6.6±0.2		
X8 (NEOWISE)	2	1.5–1.7	9.2±0.2		
Y1 (LINEAR)	2	2.5–2.6	8.3±0.3		
6P/d'Arrest	2	1.8–1.9	7.9±0.1		
7P/Pons–Winnecke (2015)	10	1.6–2.9	9.6±0.3		
7P/Pons–Winnecke (all)	81	1.1–3.3	10.7±0.2		
10P/Tempel (2015)	49	1.4–3.2	5.1±0.5	26.7±2.2	8.7±0.3
10P/Tempel (all)	1511	1.4–4.1	6.8±0.1	16.6±0.7	8.1±0.0
19P/Borrelly (2015)	15	1.8–3.4	5.7±0.1	13.2±0.4	7.0±0.0
19P/Borrelly (all)	2727	1.3–3.4	7.1±0.1	11.7±0.3	7.4±0.0
22P/Kopff (2015)	108	1.6–3.0	5.5±0.4	17.5±1.1	7.8±0.1
22P/Kopff (all)	1889	1.5–3.7	6.0±0.1	14.5±0.5	7.0±0.0
44P/Reinmuth (2015)	18	2.4–2.9	9.2±0.2		
44P/Reinmuth (all)	117	1.9–4.5	10.1±0.4	7.6±1.1	9.3±0.1
51P/Harrington	5	1.7–1.8	13.5±0.4		
57P/du Toit–Neujmin–Delporte	12	1.8–2.4	9.9±0.2		
61P/Shajn–Schaldach	19	2.1–2.2	9.6±0.1		
67P/Churyumov–Gerasimenko (2015)	100	1.2–2.9	9.2±0.2	7.1±1.1	8.7±0.1
67P/Churyumov–Gerasimenko (all)	1132	1.2–2.9	9.8±0.2	4.8±1.0	9.0±0.1
88P/Howell (2015)	184	1.4–3.2	5.7±0.1	13.6±0.5	6.5±0.1
88P/Howell (all)	661	1.4–3.8	5.4±0.1	18.3±0.5	7.2±0.1
141P/Machholz (2015)	41	0.8–1.3	12.9±0.3	14.3±3.7	12.6±0.2
141P/Machholz (all)	541	0.7–1.4	11.9±0.1	22.3±1.3	10.9±0.1
162P/Siding Spring	15	1.3–3.0	11.2±0.2		
174P/Echeclus**	164	5.8–13.0	2.9±0.2		
180P/NEAT	6	2.5–2.7	8.8±0.4		
201P/LONEOS	12	1.3–1.9	11.8±0.2		
204P/LINEAR–NEAT	9	1.9–2.3	11.2±0.2		
205P/Giacobini	8	1.9–2.3	8.6±0.2		
218P/LINEAR	14	1.2–2.0	13.0±0.3		
220P/McNaught	6	1.7–2.0	12.6±0.6		
230P/LINEAR	20	1.5–1.8	11.9±0.2		
299P/Catalina–PanSTARRS	16	3.1–3.6	8.4±0.2		
318P/McNaught–Hartley	12	2.4–2.6	7.0±0.2		
319P/Catalina–McNaught	8	1.2–1.8	13.7±0.4		
327P/Van Ness	2	1.6	12.3±0.9		
329P/LINEAR–Catalina	4	1.7	11.0±0.5		
332P/Ikeya–Murakami	9	1.6	12.9±0.2		

Explanatory notes for this table are given with its continuation on p. 350

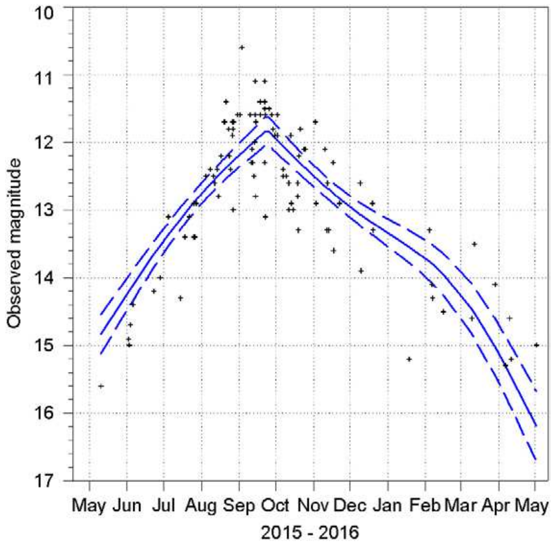

Figure 17. The observations of 67P/Churyumov–Gerasimenko at the 2015 return, with a linear light curve fitted to them.

86P/Wild

The comet was last described in the paper on the comets of 2001.[9] There were no further observations at the 2008 or 2015 returns.

88P/Howell

Well observed in 2015, observations from this comet's return were used in the analysis presented in the paper on the comets of 2009.[10]

141P/Machholz

Donald Machholz discovered the comet at magnitude +10 with his 0.25m reflector in 1994 August. It had multiple components and was almost certainly found after a major fragmentation event. The comet was around three magnitudes fainter in absolute terms at the 1999 return. Although the data are scattered, it seems to have behaved in a broadly similar manner at each of the subsequent returns.

174P/Echeclus (60558)

A cometary coma was detected around the centaur asteroid (60558) Echeclus (= 2000 EC$_{98}$) on 2005 Dec 30.50. At discovery by Spacewatch in 2000 it was 21st magnitude, but the development of a coma caused it to brighten substantially. The object is in a 35-year orbit, and reached perihelion at 5.9au in 2015.

Since the last report,[12] the comet has undergone further major outbursts. Paul Camilleri caught the comet in outburst on 2016 Aug 28.68, finding it had brightened by about two magnitudes. Juan José González was able to see it visually at +14.8. An outburst occurred again in 2017 December, with the

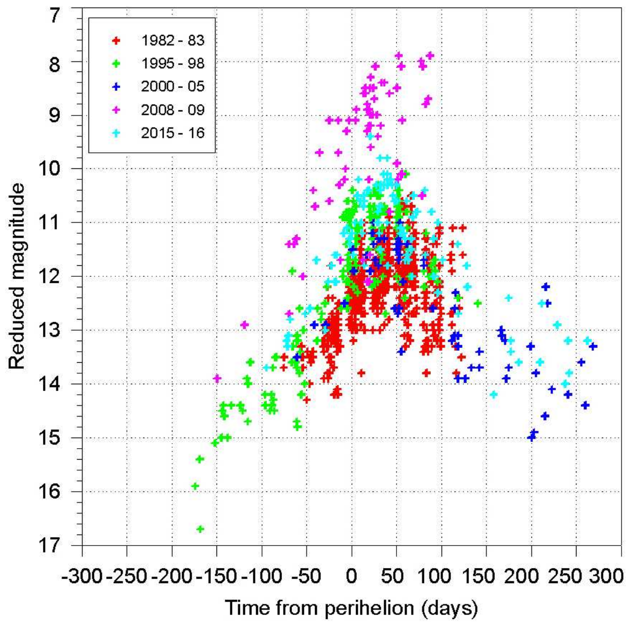

Figure 18. Composite plot showing the magnitude of 67P/Churyumov–Gerasimenko at returns since 1982, corrected for the distance from the Earth.

comet brightening by around four magnitudes. Nick James analysed electronic observations, finding that the coma expanded at about 3.4arcsec/d from around Dec 6.5, corresponding to an expansion speed of 95m/s. His analysis of the total magnitude suggested a fading of 0.011 magnitudes per day.

332P/Ikeya–Murakami = 2010 V1 = 2015 Y2

A comet was discovered visually by Japanese amateur observers Kaoru Ikeya and Shigeki Murakami in 2010 November. It was 47 years since Ikeya had discovered his first comet (1963 A1). The object was in outburst at the time of discovery. Further details were given in the paper on the comets of 2010.[8]

A 21st magnitude comet discovered in Pan-STARRS 1 images taken with the 1.8m Ritchey–Chrétien on 2015 Dec 31.52, and briefly on the PCCP, was identified with 2010 V1 (P/Ikeya–Murakami). A secondary component was also discovered. The comet returned to perihelion in 2016 March at 1.57au and has a period of 5.4 years. The indicated correction to the prediction by Gareth Williams in *MPEC* 2013-O31 was Δ(T)= +7.0d [*CBET* 4230, *MPEC* 2016-A10, 2016 Jan 2]. The secondary component was designated 2010 V1-B [*CBET* 4231, *MPEC* 2016-A36, 2016 Jan 5], though there were no reports of it at the 2010 return. Further components identified as C–J were also discovered. The brightest fragment reached 12th magnitude.

Detailed computations by Zdenek Sekanina, JPL, shed some light on the comet's behaviour and suggest that the 2010 outburst had more severe consequences for the comet's evolution than its accompaniment of a single fragmentation event. In *CBET* 4250, 2016 Feb 3 he suggested that fragment C was the main body, but had been largely inactive. Fragment A probably separated from it in early 2012 November (with an uncertainty of ±2 months) at a rate of 0.36 ± 0.04m/s, and was subjected to a differential non-gravitational deceleration of 5.2 (±0.6) × $10^{-5}g_\odot$ ($g_\odot$ = solar gravitational acceleration). It might be sufficiently massive to be seen at the next perihelion in 2020.

Figure 19. 88P/Howell, imaged remotely from Siding Spring, Australia on 2015 Apr 1. The 10th magnitude comet shows a greenish coma of 5′ diameter and a short ion tail toward the south-west. Technical details: Planewave 20″ CDK *f*/4.4 reflector with FLI PL09000 camera (L:1×120 Bin1 + RGB:1×60 Bin2). *José Chambó*

For companion B a very tentative solution, based only on the observations of Jan 11–29, suggests that it may have split off in the second half of 2013 or the first half of 2014. The observations of B from Jan 8 leave systematic residuals of 2–4′ from this solution, and a more recent origin of B is plausible. It is possible that the Jan 8 astrometric positions of B refer instead to D, in which case component D would have separated only in 2015 mid-October; some 150 days before perihelion. Being subjected to a deceleration of about 25 × $10^{-5}g_\odot$, this would be a short-lived fragment. He concludes that the 2010 event triggered a fragmentation process that continued over an extended period of time after the outburst (and apparently is still continuing) – a fairly common phenomenon among split comets that is referred to as 'cascading fragmentation'.

The comet is one of those known to have undergone nuclear splitting, according to the list by Marcos & Marcos (2018).[5] They consider that the multiple fragments are linked to 2010 B2 (P/WISE).

Other comets observed during the year

29P/Schwassmann–Wachmann

The comet was at opposition in July and in solar conjunction at the beginning of the year. Observation was difficult for around six weeks either side of conjunction. It was at 25° southern declination when at opposition. Significant outbursts occurred in May, July and September, with additional minor events. A few outbursts followed the usual pattern, with an initially high degree of condensation steadily becoming more diffuse; most were not so clear-cut however. At its brightest, in May, the comet reached around 11th magnitude.

Further background on the comet was given in previous papers and is not repeated here.

Acknowledgements

Thanks are due to Guy Hurst for preparing cometary material for publication in *The Astronomer* magazine. Acknowledgement 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 web pages by Kazuo Kinoshita.[13]

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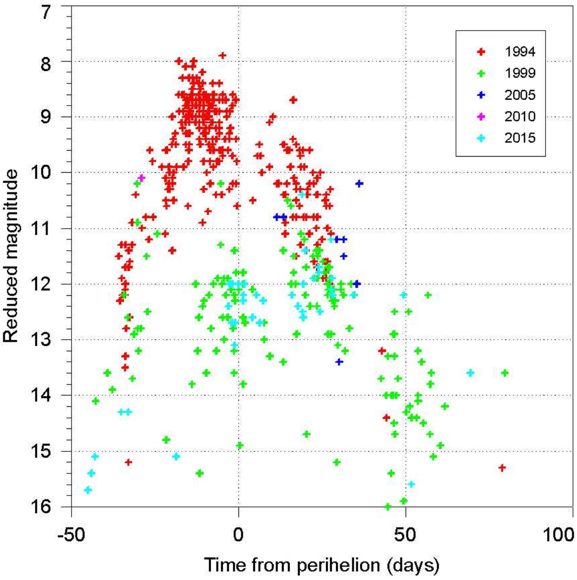

Figure 20. Composite plot showing the magnitude of 141P/Machholz at returns since 1994, corrected for the distance from the Earth.

Table 3. Magnitude parameters of the comets of 2015 (cont'd from p. 348)

b) Linear magnitude parameters

Comet	No. obs.	Days	H_1	K_1	ΔT
10P/Tempel (2015)	49	–201–349	7.7±0.4	0.0311±0.0021	–39.0±10.3
10P/Tempel (all)	1511	–583–349	8.6±0.1	0.0231±0.0007	–36.1±1.5
67P/Churyumov–Gerasimenko (2015)	100	–95–263	9.5±0.1	0.0173±0.0017	–41.9±5.3
67P/Churyumov–Gerasimenko (all)	1132	–174–269	9.9±0.1	0.0157±0.0016	–49.6±4.0
88P/Howell (2015)	184	–344–249	7.3±0.1	0.0182±0.0008	–8.6±3.5
88P/Howell (all)	661	–344–471	7.6±0.1	0.0231±0.0007	–22.0±2.0

Notes on Table 3

* Comet is still under observation
** Mean, including outbursts

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 observations to calculate K_1 accurately and so a value of 10 is assumed, which gives the constant H_{10}. CCD observations approximating to visual, which include a measure of the coma diameter, are used to augment the light curves of those comets with insufficient visual observations. A correction for aperture of 0.0033mm^{-1}, and the observer corrections derived in previous papers,[14,15] have been applied and the H values are reduced to zero aperture.

Some comets do not follow the standard equation and are better fitted with a linear equation:

$$m = H_1 + 5.0 \log(\Delta) + K_1 \operatorname{abs}(t - T + \Delta t)$$

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.

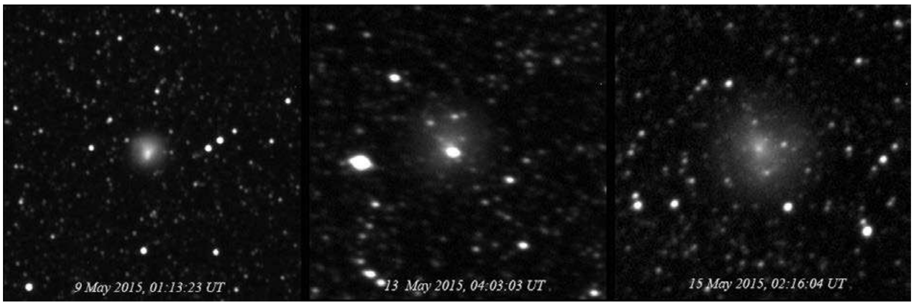

Figure 21. A sequence of images of 29P/Schwassmann–Wachmann showing the development of the May outburst. Planewave 27″ (0.7m) CDK700WF *f*/6.8 reflector with FLI PL09000 camera; 120s exposures obtained remotely from Siding Spring, Australia. FOV 2.7×2.7′. *Manos Kardasis*

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Received 2018 March 18; accepted 2018 September 5