The brighter comets of 2021

Jonathan Shanklin

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

This report describes and analyses observations of the brighter or more interesting comets at perihelion during 2021, concentrating on those for which visual observations were obtained. 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 Section visual observations web pages.

Introduction

Ninety-five comets or potential comets were assigned year designations for 2021, while 50 previously numbered periodic comets returned to perihelion. 245 comets found by the SOHO satellite, including several archival finds, and 11 from STEREO were credited during 2021. 218 of these were members of the Kreutz group, 15 were members of the Meyer group, one was of the Marsden group, none were of the Kracht group, and 22 were not associated with any known group. One of these objects was given a designation (2021 D1). One Marsden-group comet returned to perihelion and therefore could be numbered. 342P/SOHO returned to perihelion.

There were five amateur discoveries (2021 J1, L3, O1, U3, X1) for which Alain Maury, Georges Attard, Gennady Borisov and Hideo Nishimura gained the Edgar Wilson Award.[1] The awards were belatedly announced in 2024 in *MPEC* 2024-S182 with a concerned commentary in *CBET* 5451.[2]

Twenty-seven periodic comets were numbered during the year. One comet was reported as visible to the naked eye (2021 A1) and five others reached binocular brightness, though large binoculars were required for the majority of these.

The remainder of this report covers only the comets that were at perihelion. When periodic comets have visual or electronic observations at five or more returns and have not previously been analysed in detail over the past decade, the secular behaviour of the comet is considered, even though it may not qualify as a 'brighter' comet during the present return. Any evolution in behaviour is of interest, as is observation of a steady state.

Orbital elements for all the comets discovered and returning during the year can be found on the JPL Small-Body Database Browser,[3] which will also generate ephemerides. Discovery details and some information for the other comets found or returning during the year are available on the BAA Comet Section visual observations web pages,[4] which also contain links to additional background information. The raw visual observations for the year are on the same web pages in ICQ format and in the Comet Observations (COBS) database.[5] The full data set from COBS is used for the multi-return analyses presented here, but otherwise only those observations submitted to the Section – through the visual observations coordinator or through COBS – are included, along with all observations submitted to *The Astronomer* (TA) magazine. Additional images of the comets are presented in the Section image archive.[6]

The comets given a discovery designation

2020 R4 (ATLAS)

The ATLAS (Asteroid Terrestrial-impact Last Alert System) team discovered a 19th-magnitude comet in images taken with the 0.5-m Schmidt at Mauna Loa on Sept 12.50. It was posted on the Possible Comet Confirmation Page (PCCP) as A10qhkr and subsequently confirmed as cometary by several astrometrists. There

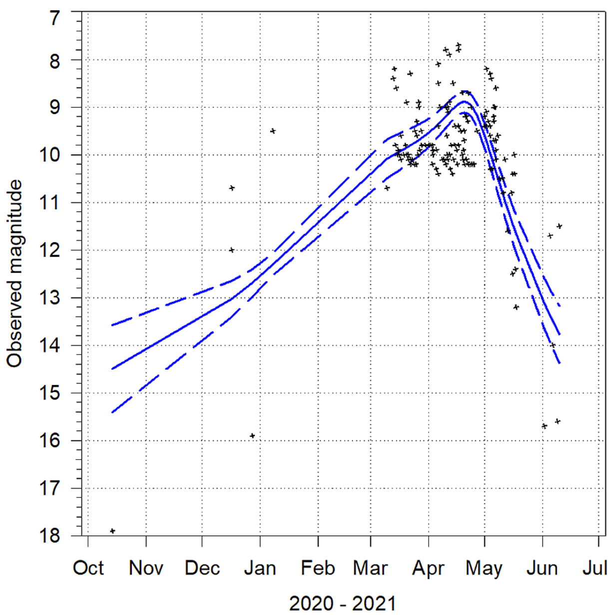

Figure 1. The observations of 2020 R4 with a standard light curve fitted to them. The dashed lines show the 95 per cent confidence limits.

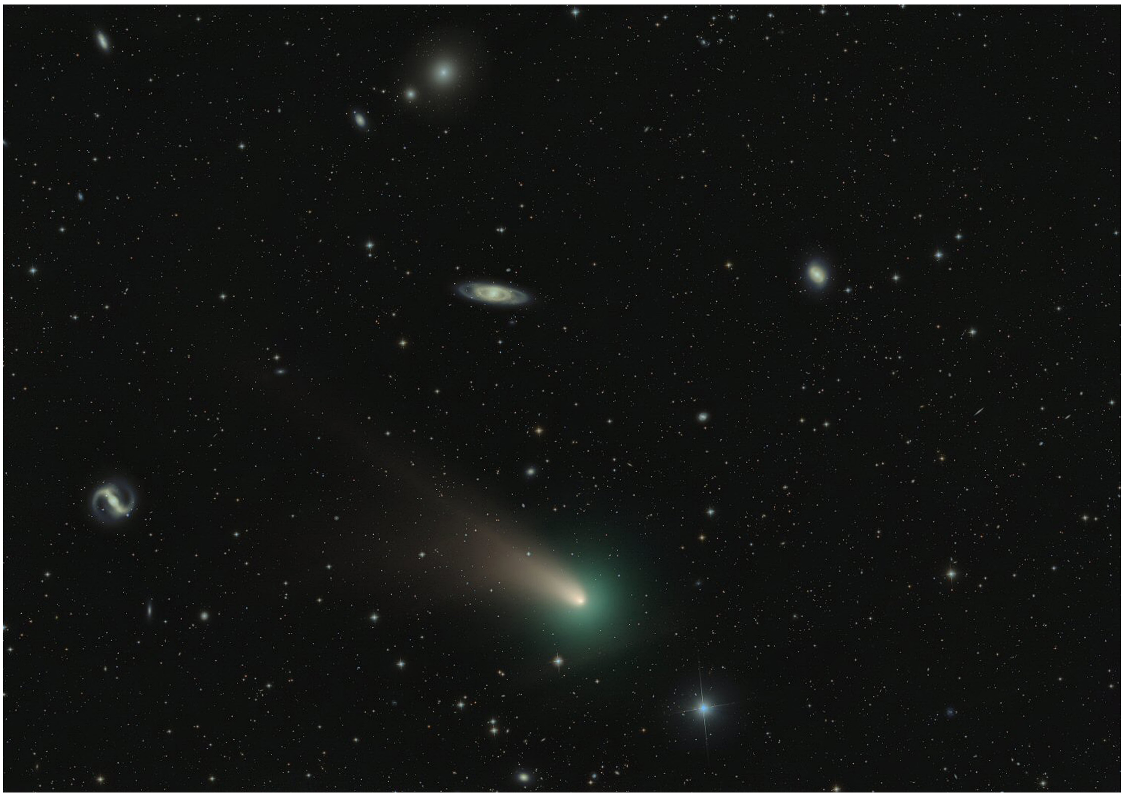

Figure 2. 2020 R4 imaged by D. Bartlett on 2021 May 9, 08:02 UT, when near the galaxies NGC 4245, 4274, 4278 and 4314. Field is 1.7 × 1.2°, N up. 124 × 90-s exposures using a ZWO ASI 294MC Pro on a Celestron RASA 11 at June Lake, California, USA.

were pre-discovery images of the comet in Catalina Sky Survey data from August and Pan-STARRS data from August and September. [*CBET* 4849, *MPEC* 2020-S33, 2020 Sept 16.] It was subsequently re-reported by ATLAS as A10wNNY and by Catalina as C23NY71 in 2021 Apr and as A10wVgj in May. These multiple postings may have been a result of the Minor Planet Center (MPC) providing out-of-date orbital elements.

The comet was at perihelion at 1.0 astronomical units (au) in 2021 Mar and has a period of around 1,000 years. Unfortunately, it was not an optimum return, though post perihelion the comet approached us to 0.5 au in late April. It was initially given a rather faint absolute magnitude, but these comets often appear brighter to visual observers. Imaging by Taras Prystavski on Dec 12 suggested that it was at least three magnitudes brighter than originally expected. J. J. Gonzalez observed it at 9th magnitude in January, though his observation is considerably brighter than the mean curve. It was observed from the UK during April, when it was around 9th magnitude. During the moderately close approach, it was a fast-moving object. It was reported to be in outburst on Apr 30, with the outburst having started about a week previously.

There is a lot of scatter in the observations, which obscures any convincing evidence of the outburst. This may therefore be an artefact of the close approach, as there is no sign of an increase

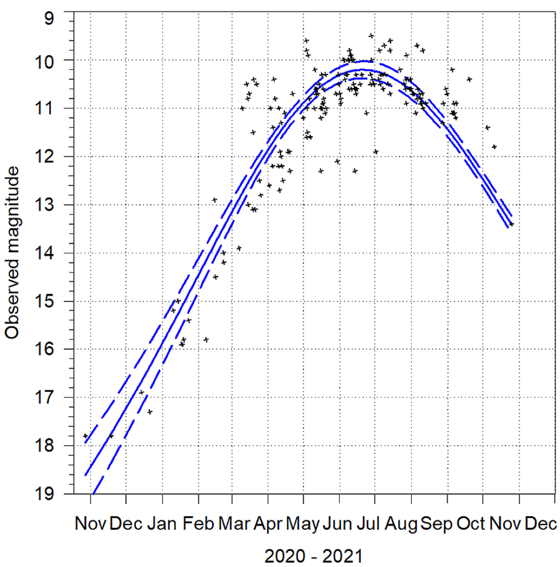

Figure 3. The observations of 2020 T2 with a standard light curve fitted to them. The dashed lines show the 95 per cent confidence limits.

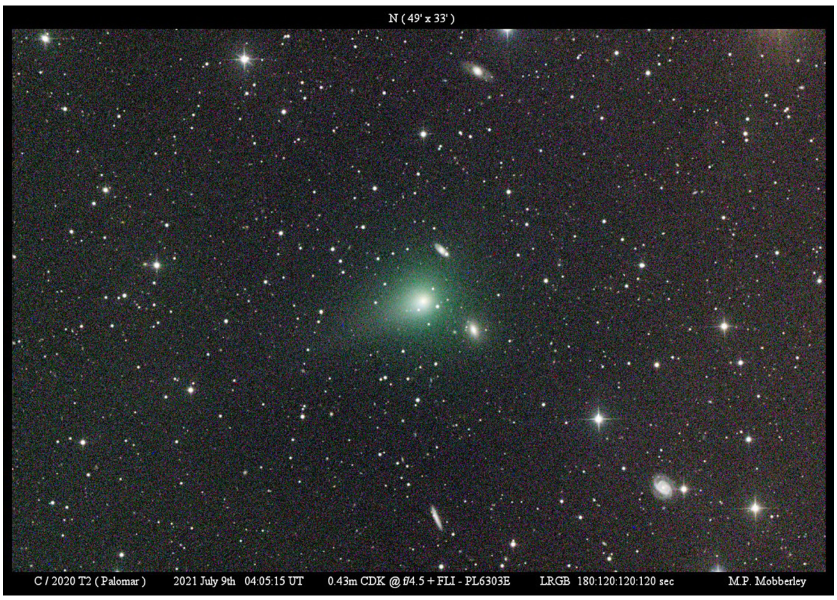

Figure 4. 2020 T2 imaged by Martin Mobberley on 2021 Jul 9, 04:05 UT, using a remote telescope. The galaxies either side of the comet are NGC 5382 and 5386.

in degree of condensation (DC), which usually accompanies an outburst. In addition, the Moon was full on Apr 27 and in the same quarter of the sky, which may also have compromised observations. After perihelion, the comet faded rapidly, and it was last seen in early June.

2020 T2 (Palomar)

Dmitry A. Duev found a comet of 19th magnitude in images taken with the Zwicky Transient Facility camera on the 1.2-m Oschin Schmidt on 2020 Oct 7.51. It was posted on the PCCP as ZTFDD01. Pre-discovery images back to 2019 Dec were found. [*CBET* 4870, *MPEC* 2020-U170, 2020 Oct 22.] It was subsequently independently discovered by the Catalina Sky Survey on Oct 22.5 and posted on the PCCP as C1G21V1. It was at perihelion at 2.1 au in 2021 Jul.

It barely qualifies as a brighter comet, just reaching 10th magnitude in 2021 Jun. Even though still relatively bright, it was not followed by BAA observers after 2021 October, when it was a southern-hemisphere object. It then remained at a poor solar elongation until 2022 Mar.

2021 A1 (Leonard)

Nick James published a preliminary report on this comet in the *Journal*.[7] This includes a fine selection of images, some showing exquisite detail in the tail. It includes observations made up to late January. Here, a summary is given, with further conclusions based on observations made subsequently.

Gregory Leonard discovered a comet of 19th magnitude in images taken with the 1.5-m reflector of the Mt Lemmon Survey on 2021 Jan 3.54. It was placed on the PCCP as C4AGJ62. There were pre-discovery observations from the Catalina Sky Survey (2020 Dec, 2021 Jan), Mt Lemmon Survey (2020 Apr, Nov), Pan-STARRS (2020 Apr, May, Jun, Aug) and the Szeged Asteroid Program, Hungary (2020 Nov). [*CBET* 4907, *MPEC* 2021-A99, 2021 Jan 10.]

The comet reached perihelion at 0.6 au in 2022 Jan. It passed 0.23 au from Earth on 2021 Dec 12 and 0.0286 au from Venus on

Table 1. Photometric observers

Observer	*Location*
Nicolas Biver	Hawaii
Denis Buczynski	Ross-shire, Scotland
Peter Carson	Leigh-on-Sea, Essex
Mike Collins	Everton, Beds.
Jose Guilherme de Souza Aguiar	Brazil
Stephen Getliffe	Haverhill, Suffolk
Marco Goiato	Brazil
J. J. Gonzalez	Asturias, Spain
Werner Hasubick	Germany
Kevin Hills	Cheshire
Nick James	Chelmsford, Essex
Timo Karhola	Sweden
Attila Kosa–Kiss	Romania
Carlos Labordena	Spain
Michael Mattiazzo	Australia
Martin Mobberley	Bury St Edmunds
Charles S. Morris	USA
Artyom Novichonok	Russia
Giuseppe Pappa	Italy
Nirmal Paul	India
Jonathan D. Shanklin	Cambridge
Sergey Shurpakov	Belarus
William C. de Souza	Brazil
Sándor Szabó	Hungary
Johan Warell	Sweden
Graham W. Wolf	New Zealand
Chris Wyatt	Victoria, Australia
Seiichi Yoshida	Japan

Many additional observers submitted their observations to the COBS archive, but for brevity only the BAA and *The Astronomer* observers, together with those who directly submitted their observations to the Section, are listed in this table.

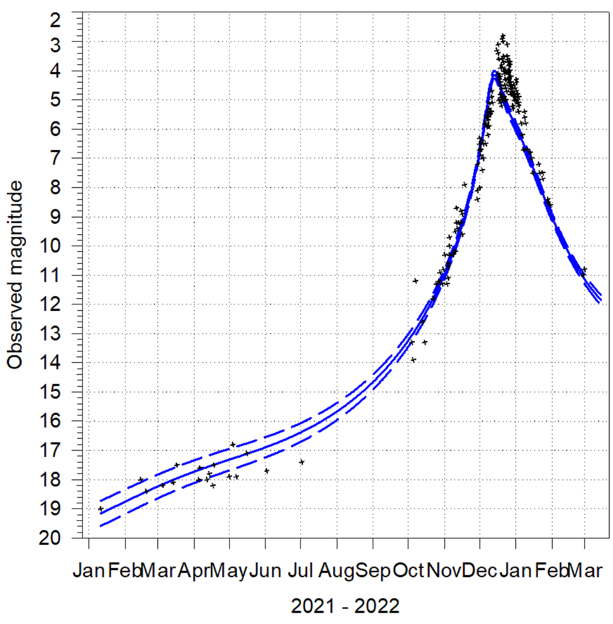

Figure 5. The observations of 2021 A1 with a standard light curve fitted to those made more than 30 days before perihelion and then extrapolated for the rest of the apparition. The dashed lines show the 95 per cent confidence limits.

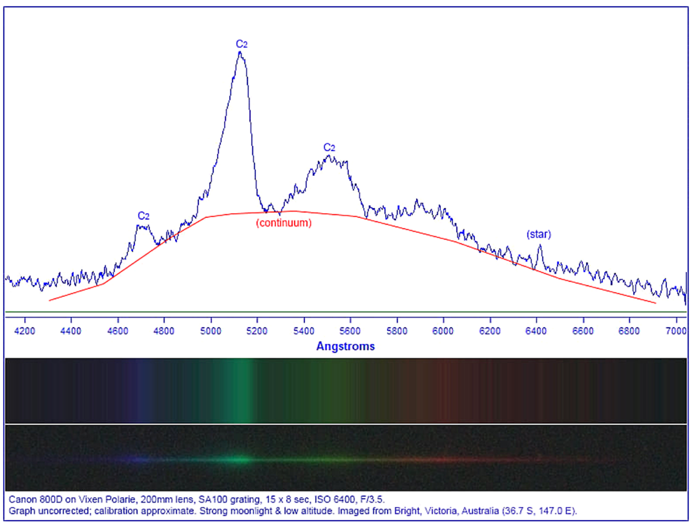

Figure 6. Low-resolution optical spectrum of 2021 A1 taken by Rob Kaufman on 2021 Dec 20, 10:55 UT. The Swan emission bands of C2 stand out. *(Created in RSpec vers. 1.9)*

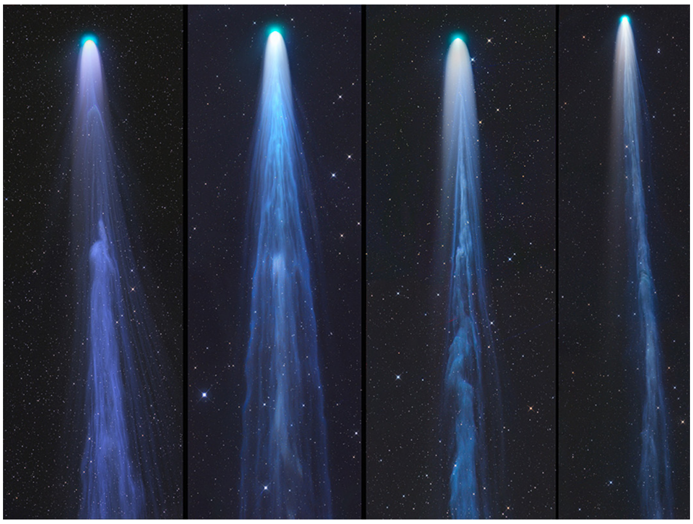

Figure 7. A sequence of images taken by Gerald Rhemann from Farm Tivoli, Namibia, showing the ion tail of 2021 A1. From left to right, the images were taken on 2021 Dec 25, 26, 28 and 2022 Jan 1. Each panel is 1.3 × 1.8°, E up. The Dec 25 image won the 2022 Astronomy Photographer of the Year competition. Features shown include disconnection events, tail rays and turbulence in the solar wind. LRGB 120/120/120/120 s, using an ASI 6200 camera on an ASA 0.30-m *f*/3.6 astrograph.

2021 Dec 18. In early October, Michael Mattiazzo suggested on the Comets Mailing List (**groups.io/g/comets-ml**) that it was a very dusty comet, although some later studies suggested that the dust-to-gas ratio was normal. He suggested that the dust could produce strong forward scattering between Dec 9 & 20 and also noted that Earth crossed the orbital plane of the comet on Dec 8, which could enhance the tail. The comet was at less than 25° solar elongation from Dec 11–17 and again from Jan 21 to Feb 18. The Moon was full on Nov 19, Dec 19, and Jan 17.

Michael Mattiazzo imaged the comet on Oct 3, estimating the *G* magnitude at 13. J. J. Gonzalez observed it visually on Oct 7, estimating it at 11.2. It was reported as being visible in SWAN images in early 2021 Nov. On Dec 2.3, it was 6.7 in 20 × 80 binoculars from central Cambridge, with a 45-arcminute tail. On Dec 8.2, it was 5.5 in 8 × 40 binoculars from central Cambridge, and was on track to reach about 4th magnitude, though some pundits suggested that it was disintegrating. The comet was rapidly moving south, and Stephen Getliffe made the last UK observation on Dec 11.22, when it was 5.4 in his 108-mm reflector.

Some imagers reported the comet being brighter than expected on Dec 14 and this might have been a result of the predicted forward scattering, although there was also a factor-of-roughly-three increase in water-vapour production at the same time. J. J. Gonzalez reported it at 3.3 in 10 × 50 binoculars from his mountain location on Dec 15.75. Observations after that became a little scattered, with much speculation about outbursts, and the comet certainly became much brighter than expected from the light curve. Activity continued to be intermittent, with the comet fading to 4.5 on Dec 22/23 (Goiato & Gonzalez), but it was 3.5 on Dec 23/24 (Amorim). Alexandre Amorim reported seeing jets in his 90-mm refractor.

Southern-hemisphere observers made naked-eye observations in early January, but the comet was rapidly fading. On Jan 28, Chris Wyatt estimated it as 8.5 in his 25-cm reflector. It was imaged in late February and early March after conjunction, and the images suggested that the comet was disintegrating, with no obvious central condensation. David Seargent then suggested that the disintegration might have already started by late January as his image on Jan 22 showed the tail more prominent than the head. Graham Wolf observed it on Feb 28, estimating it at 11th magnitude. An image taken by Nirmal Paul on 2022 Mar 31 only showed a ghostly outline of the tail.

Visual observers began to report a short tail in November and there was significant tail development during December. Several observers reported lengths of up to 9 degrees around Dec 28. The tail was still around 5 degrees long in early January, but it rapidly disappeared, leaving nothing significant to visual observers after mid-month. The degree of condensation followed a similar pattern, becoming nearly stellar in late December, before relaxing to a more diffuse coma.

Using all the observations, the standard equation produces a good fit to the observations throughout the apparition. A better fit is obtained if the observations used are restricted to those made more than 30 days prior to perihelion and this still gives a

Figure 8. The separation between the dust and gas tails of 2021 A1 increased after perihelion, as seen in this image taken by Michael Jäger on 2022 Jan 4, which also shows a tail disconnection event. Field is 6.4 × 2.2°, N up. Two-panel mosaic; LRGB composite (459/120/120/120 s); QHY600 0.20-m *f*/3 Veloce astrograph operated by Lukas Demetz.

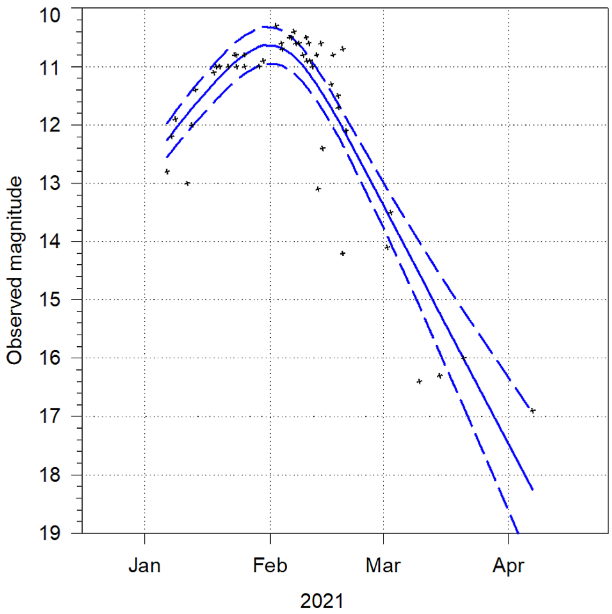

Figure 9. The observations of 2021 A2 with a standard light curve fitted to them. The dashed lines show the 95 per cent confidence limits.

Figure 10. 2021 A2, imaged by Michael Mattiazzo on 2021 Jan 18. As the image shows, the coma was very diffuse.

good fit to the observations made more than 20 days after perihelion. The comet was however systematically brighter than this curve from mid-December to early January; this encompasses the period when forward scattering might have played a part but also continues until shortly after perihelion. It seems clear that there was a series of events during this period, probably linked to enhanced outgassing. Whether this led to a complete disintegration of the nucleus or just to a shutdown of further activity is not clear. No discrete centres of condensation were reported, and images still show a gas coma as late as Jan 23, suggesting that complete disintegration had not happened up to this point. Thereafter, images show a steadily more diffuse object, disappearing rather like Lewis Carroll's Cheshire Cat.

With a well-observed comet such as this, with perihelion inside Earth's orbit, there is the opportunity to compare visual and visual equivalent magnitudes (VEMs). There were 90 VEM measurements spanning the range 0.6 to 5.0 au, whilst there were 142 visual observations spanning the range 0.6 to 1.8 au. The visual observations show an aperture effect, with the comet appearing fainter in larger apertures. The aperture correction for this comet is 0.023 ± 0.014 per centimetre of aperture, in agreement with the previously determined value of 0.033. Use of the correction improves the fit to the observations. By contrast, the derived VEM aperture correction is –0.058 ± 0.085 and does not give a significant improvement to the fit over using no correction. This is as might be expected for a purely instrumental technique. The derived absolute magnitude for the comet from the VEM measurements is 8.6 ± 0.1, whilst the visual value corrected to zero aperture is 7.8 ± 0.1. The mean aperture for the VEM measurements was 32.3 cm, and if the visual absolute magnitude was corrected to this aperture using the correction for this comet, it would give a value of 8.5. We can therefore be confident that the VEM technique is comparable to visual observation.

The result that there is no aperture effect for VEM observations does have an implication for the standard reduction technique previously used in this series of papers, where the aperture correction was applied to all observations to reduce them to zero aperture. From this paper onwards, only visual observations will be corrected and then to a standard aperture of 30 cm. This will make the magnitude parameters more useful for recovery and observation of fainter comets. For comparison with previous papers, a correction of 1.0 magnitudes to the published absolute magnitude should be applied. If a comet does reach naked-eye brightness, it will likely appear around a magnitude brighter than predicted by the standard equation.

2021 A2 (NEOWISE)

An approximately 15th-magnitude comet was discovered by the NEOWISE satellite on 2021 Jan 3.02. It was posted on the PCCP as N00ht7m. Ground-based observers confirmed the cometary nature, with Michael Mattiazzo reporting it as bright as 12th magnitude in his 0.2-m reflector. [*CBET* 4908, *MPEC* 2021-A100, 2021 Jan 10.]

It reached perihelion at 1.4 au in 2021 Jan. A southern circumpolar object at discovery, it rapidly moved north and brightened by a further magnitude, barely putting it into the brighter-comet class. For some reason, the MPC left it un-named in *MPEC* 2021-B143 [2021 Jan 31].

2021 D1 (SWAN)

Michael Mattiazzo discovered a comet on Feb 25 in SWAN images taken since Feb 19, and this was confirmed in ground-based images taken by Michael Jäger on Feb 28. The comet was near perihelion at 0.9 au and was poorly placed for visual observation, but was imageable. Nick James, Denis Buczynski, Werner Hasubick, and Richard Miles all made confirmatory images and astrometry of the comet. The MPC published an orbit and designated the comet in *MPEC* 2021-E19 [2021 Mar 4]. This gave an orbit with a period of around 75 years. *CBET* 4939 appeared five hours later on Mar 5 and gave a parabolic orbit based on a shorter arc with fewer observations, though with much more detail about the confirming observations. Further observations now suggest a period of around 1,000 years.

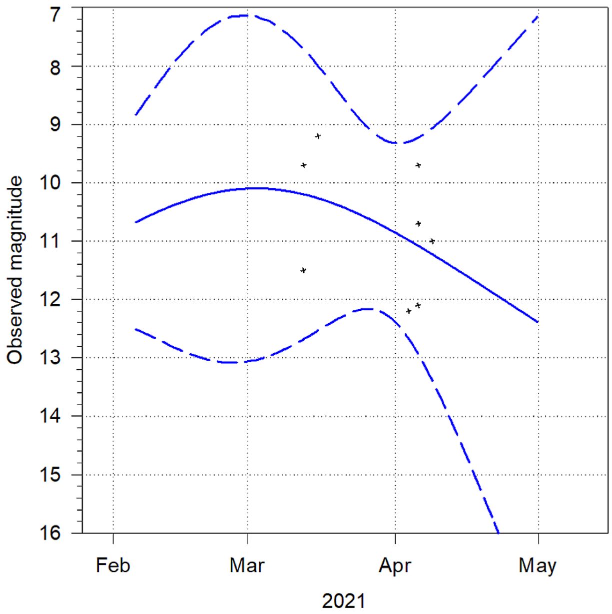

Figure 11. The observations of 2021 D1 with a standard light curve fitted to them. The dashed lines give the 95 per cent confidence limits, which show considerable uncertainty.

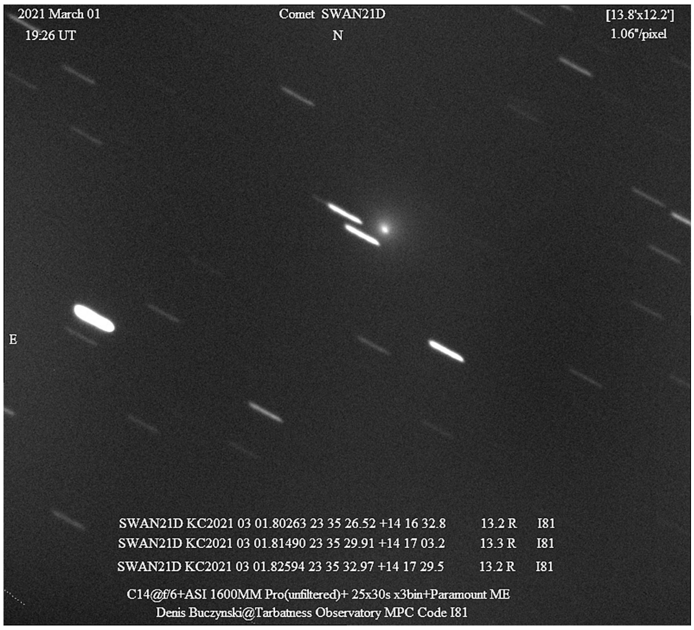

Figure 12. Confirming image and astrometry of 2021 D1, taken by Denis Buczynski on 2021 Mar 1.

Given the circumstances, few observations were made, but these suggest that the comet was observed fading from a visual peak of around 9th magnitude. The visual observations generally give a brighter magnitude than the electronic ones, and the light curve is rather uncertain.

2021 O1 (Nishimura)

Japanese amateur Hideo Nishimura, from Gansho-ji, Kakegawa, discovered a comet with a digital camera (Canon EOS 6D and 200-mm telephoto lens) on Jul 21.78. He originally thought that it might be an outburst of 8P/Tuttle. Michael Jäger was amongst those confirming the object and he gave a total magnitude of 9.2. It was placed on the PCCP as HN002. [*MPEC* 2021-O47, *CBET* 5004, 2021 Jul 25.]

The comet was at perihelion at 0.8 au in August. Unfortunately, this timing was nearly as bad as it could be, putting the comet on the far side of the Sun and at poor elongation. The comet had been at less than 30 degrees elongation since February, which probably explains why it was not picked up previously by search programmes. No observations were reported to the Section. The discovery is eligible for the Edgar Wilson Award.

The numbered periodic comets at perihelion in 2021

4P/Faye

Following its 2014 return, the behaviour of this comet was reported in the paper covering that year.[8] At the 2021 return, it reached 11th magnitude, so it was not a bright comet. A review of its behaviour will take place after the next return in 2029.

6P/d'Arrest

The discovery and behaviour of this comet was last described in the paper on the comets of 2008.[9] It made its 20th observed return in 2015, but it was a poor one, with few visual observations, and the analysis was not updated. The 2021 return was a better one and this now allows further discussion. The perihelion distance was similar at both these and the 2008 return. The next significant change in perihelion distance occurs in 2039, when a Jupiter encounter reduces it to 1.27 au.

The comet came under observation by imagers from 2021 Mar, with for example Kevin Hills estimating it at 18.2 on

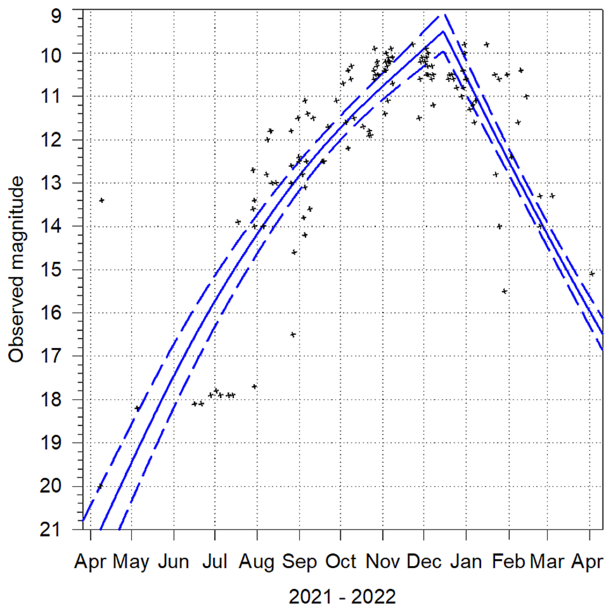

Figure 13. Observations (including all COBS observations) of 6P/d'Arrest made at the 2021 return, with a linear light curve fitted to them.

May 5. Graham Wolf estimated it at 12.0 in his 150-mm reflector on Aug 8. By October, it had reached 10th magnitude, and it remained at a similar brightness until 2022 Feb. After this, it became poorly placed for observation. For most of the period between October and February, it was best seen from the southern hemisphere. There were no observations for about 12 days when the comet was at peak brightness, with the Moon relatively close at this time.

Being able to use all the observations in the COBS database changes some of the conclusions presented in the 2008 paper. The additional data suggest that there was no significant change in the rate of brightening between 1976 and 2021, nor in perihelion distance. The delay in peak brightness has however continued to increase, from around 47 days after perihelion in 1976 to 84 days in 2021.

7P/Pons–Winnecke

Following its 2015 return, the behaviour of the comet was reported in the paper covering that year.[10] At the 2021 return, it only just reached 10th magnitude, despite a relatively close (0.44 au) approach to Earth. It approaches Jupiter to 0.64 au in 2025, in an encounter that will reduce the perihelion distance to 1.13 au. A review of its behaviour will take place after the next return in 2027.

8P/Tuttle

The discovery circumstances were described in the paper on the comets of 2008.[9] However, at that time, the archival observations

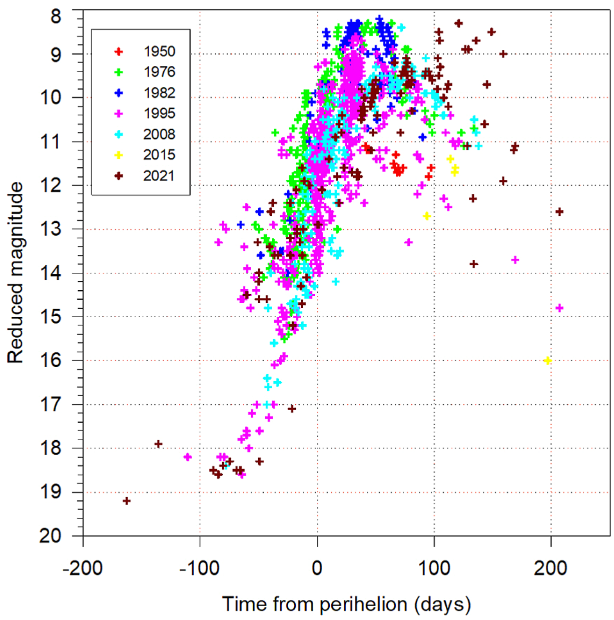

Figure 14. Composite plot showing the magnitude of 6P/d'Arrest at returns since 1950, corrected for its distance from Earth.

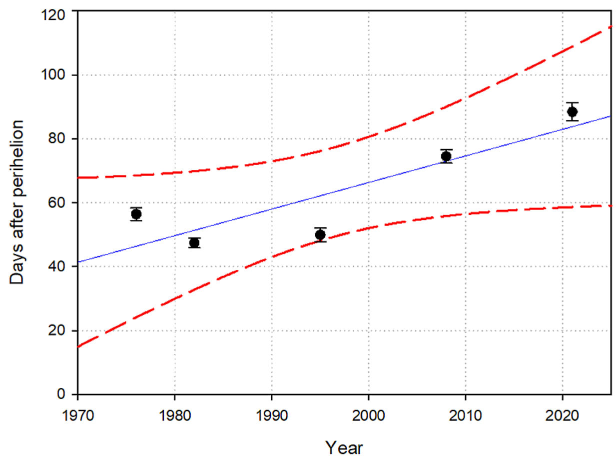

Figure 15. The change in delay of peak brightness after perihelion with time for 6P/d'Arrest. The red dashed lines show the 95 per cent confidence limits.

Table 2. Astrometric, electronic, photographic & visual imagers during 2021

Observer	*Location*	*IAU Stn. No.*
Alexander Baransky, *et al.*	Ukraine	585
Dan Bartlett	June Lake, California, USA	
Mathew Barrett	Witham, Essex	
Peter Birtwhistle	Great Shefford	J95
Michael Buechner	Germany	
Denis Buczynski	Tarbatness	I81
Montse Campas & Ramon Naves	Spain	213
Peter Carson	Leigh-on-Sea, Essex	Z10
Marc Charron	Ayrshire	
Simon Dawes	Dartford, Kent	
Terry Evans	South Australia	
Peter Gudgeon	Barx, Valencia, Spain	
Ernesto Guido, et al.	Italy	
Padraig Houlahan	Arizona, USA	
Tim Haymes	Reading	
David Hardwick	Fareham, Hampshire	
Wayne Hawley	Fiddington, Somerset	
Nick Hewitt	Northants.	
Kevin Hills	Cheshire	J22
Nick James	Chelmsford, Essex	970
Michael Jäger	Austria	
Kevin Johnson	La Palma, Spain	
Rob Kaufman	Australia	
Robin Leadbeater	Torpenhow	
Rolando Ligustri	Italy	235
Michael Mattiazzo	Australia	
Martina McGovern	Cambridge	
Andrew Mickleburgh	Cleethorpes	Z99
Richard Miles	Stourton Caundle, Dorset	F65
Martin Mobberley	Cockfield, Suffolk	
Mike Olason	Arizona, USA	
Damian Peach	Selsey	
Nirmal Paul	India	G40, W88
Mattia Piccoli	Udine, Italy	
Grant Privett	Fovant	
Gerald Rhemann	Austria/Namibia	
Richard Sargent	Chester	
Ian Sharp	Spain	
David Storey	Isle of Man	Z30
David Swan	Tynemouth	
Peter Tickner	Berkshire	
Justin Tilbrook	Australia	
Alan Tough	Elgin, Scotland	
Eric Watkins	Bradwell, Essex	K01
James Weightman	Gloucester	
Mazin Younis	Manchester	

Many additional observers submitted their images to the BAA archive, but for brevity only the BAA and *The Astronomer* observers, together with those whose images are utilised in this paper, are listed in this table.

were not available. They are now present in the COBS archive and can be used for analysis.

The 2021 return was a rather poor one, but southern-hemisphere observers recovered it in September shortly after perihelion, when it was fading from 9th magnitude. It reached 12th magnitude in December. It is slightly surprising that it was not reported in 2022, as it should have been accessible to southern imagers, and astrometric measurements were used into March for the latest JPL orbit.

When the observations from all returns are plotted, the delay in peak brightness until 26.3 ± 1.4 days after perihelion is clear. This asymmetry about perihelion should mean that the comet might be observed for longer after perihelion than it is before, however the opposite is true. It may 'switch off' very rapidly once it gets beyond 1.8 au from the Sun, possibly due to seasonal illumination of an active area. The orbit has a high inclination, with perihelion close to Earth's orbit (it is the parent comet of the Ursid meteors), and the comet is usually best seen from the northern hemisphere prior to perihelion and the southern hemisphere afterwards.

There have been no significant changes to the perihelion distance over the observed period. However, there do appear to be differences in the peak magnitude and possibly its timing. Only the 1980 and 2008 returns have observations that are adequately distributed to determine the brightness delay, and these suggest that this has increased from 13.8 ± 2.6 days in 1980 to 27.8 ± 1.6 days in 2008. When the mean rate of brightening and

Figure 16. 6P/d'Arrest imaged by Rolando Ligustri on 2021 Nov 3 from Namibia. Field is 36 × 36 arcminutes, N up. Dall–Kirkham 500/3400, CCD FLI 16803e, L = 7 × 120 s.

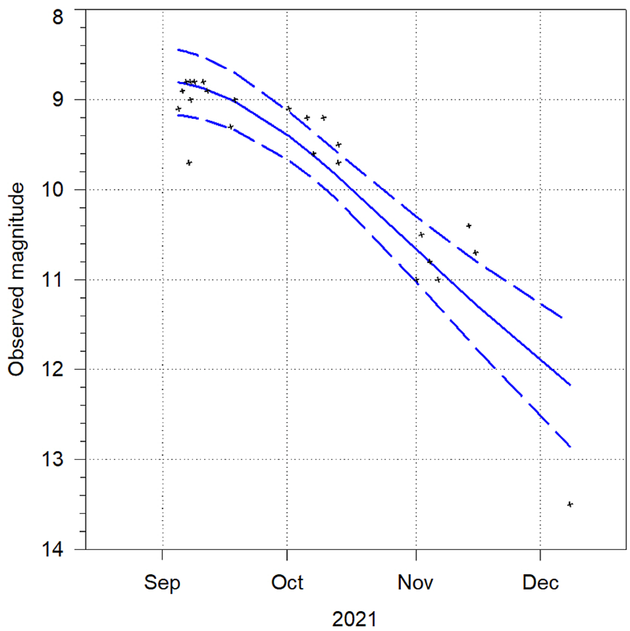

Figure 17. Observations (including all COBS observations) of 8P/Tuttle made at the 2021 return with a standard light curve fitted to them.

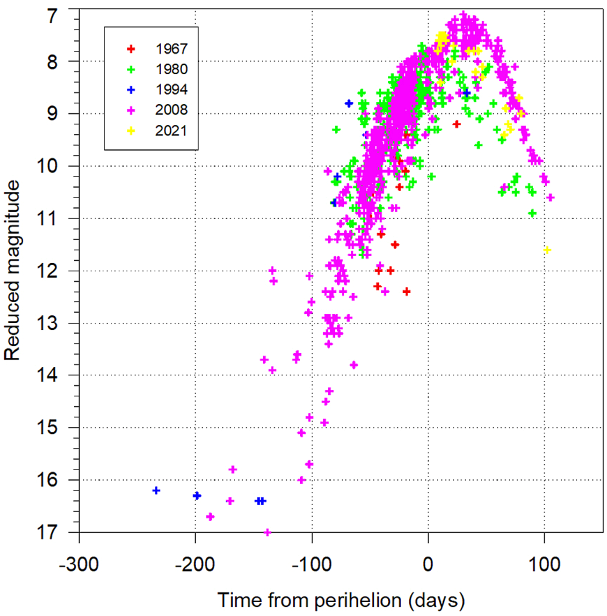

Figure 18. Composite plot showing the magnitude of 8P/Tuttle at returns since 1967, corrected for its distance from Earth.

Figure 19. 8P/Tuttle imaged by Nirmal Paul on 2021 Sept 17 from Chile. 09:18 UTC; 0.43 m, *f*/6.8. Exposure 120 s.

Table 3. Magnitude parameters of comets

a) Standard magnitude parameters

Comet	No. obs.	r (au)	H_1	K_1	H_{10}	rsqr
2016 Q2 (PANSTARRS)	1	7.1			6.4	
2018 U1 (Lemmon)	38	5.0–8.1	4.2±0.6	10.7±0.8	4.8±0.1	0.819
2019 B3 (PANSTARRS)	1	6.8			5.6	
2019 F1 (ATLAS–Africano)	52	3.6–7.4	8.3±0.4	6.6±0.6	6.1±0.1	0.696
2019 O3 (Palomar)	71	8.8–10.7	–2.1±1.5	15.1±1.5	2.8±0.0	0.595
2019 T3 (ATLAS)	24	6.0–7.0			5.3±0.1	0.276
2020 F5 (MASTER)	71	4.3–6.5	3.6±0.7	12.3±0.9	5.2±0.1	0.719
2020 F7 (Lemmon)	1	5.3			6.1	
2020 H6 (ATLAS)	74	4.8–7.0	6.2±0.6	10.0±0.9	6.2±0.0	0.648
2020 J1 (SONEAR)	80	3.4–5.3	4.4±0.7	11.5±1.2	5.3±0.1	0.535
2020 K5 (PANSTARRS)	2	1.8			15.0±0.0	
2020 M5 (ATLAS)	49	3.0–4.6			8.1±0.1	0.106
2020 N1 (PANSTARRS)	19	1.3–2.8			13.6±0.3	–1.209
2020 O2 (Amaral)	48	4.9–5.9	–1.5±2.0	20.5±2.7	6.1±0.1	0.554
2020 PV_6 (PANSTARRS)	42	2.3–3.4	3.2±0.6	26.7±1.5	10.1±0.2	0.887
2020 R4 (ATLAS)	139	1.0–2.3	9.2±0.2	13.0±1.2	9.5±0.1	0.462
2020 S8 (Lemmon)	10	2.4			12.0±0.2	
2020 T2 (Palomar)	174	2.1–3.5	1.2±0.4	25.9±1.2	6.8±0.1	0.730
2020 T3 (P/PANSTARRS)	3	1.4–1.5			16.3±0.3	
2020 T4 (PANSTARRS)	2	3.2–3.4			12.4±0.1	
2021 A1 (Leonard)	232	0.6–5.0	8.6±0.0	10.6±0.2	8.6±0.0	0.935
2021 A2 (NEOWISE)	48	1.4–1.8	5.3±0.9	46.3±5.3	11.1±0.1	0.627
2021 A4 (NEOWISE)	19	1.1–1.3			13.6±0.3	0.195
2021 A6 (PANSTARRS)	1	7.9			6.0	
2021 A7 (NEOWISE)	4	2.3–2.9			9.9±0.2	
2021 A10 (NEOWISE)	3	1.3–1.4			18.3±0.5	
2021 B2 (PANSTARRS)	1	2.6			12.7	
2021 B3 (NEOWISE)	1	2.2			13.2	
2021 C1 (Rankin)	1	3.6			10.4	
2021 C3 (Catalina)	3	2.3			13.6±0.0	
2021 C4 (ATLAS)	6	4.5–4.7			7.9±0.2	
2021 C6 (Lemmon)	1	3.9			11.5	
2021 D1 (SWAN)	8	0.9–1.1			9.5±0.3	
2021 J1 (Maury–Attard)	1	2.2			14.5	
2021 J3 (ATLAS)*	1	6.1			7.3	
2021 K1 (ATLAS)	11	2.5–3.0			10.1±0.2	–0.128
2021 K2 (MASTER)	1	5.5			7.8	
2021 L2 (P/Leonard)	1	2.1			14.2	
2021 N2 (P/Fuls)	15	3.8–4.7			8.3±0.1	0.314
2021 Q5 (P/ATLAS)	8	1.2–1.3			11.5±0.6	
2021 U1 (P/Wierzchos)	2	2.5			14.1±0.1	
4P/Faye	119	1.6–2.7	8.7±0.3	11.0±1.0	8.9±0.1	0.491
6P/d'Arrest (2021)	123	1.4–2.4	Very poor fit		9.8±0.3	–0.119
6P/d'Arrest (all)	1357	1.2–2.5	Very poor fit		10.1±0.1	–0.111
7P/Pons–Winnecke	73	1.2–2.0			12.4±0.1	0.210
8P/Tuttle (2021)	24	1.0–1.8	7.4±0.2	11.7±1.8	7.6±0.1	0.665
8P/Tuttle (all)	1216	1.0–1.8	8.9±0.1	12.3±0.5	9.1±0.0	0.306
10P/Tempel	36	1.4–3.4	5.9±0.3	22.7±1.0	9.2±0.3	0.934
15P/Finlay	35	1.0–2.4	10.7±1.8	17.6±1.7	11.2±0.2	0.774
17P/Holmes	16	2.3–4.2			10.3±0.4	0.285
28P/Neujmin	4	2.4–3.0			10.8±0.3	
52P/Harrington–Abell	1	1.8			12.2	
57P/du Toit–Neujmin–Delporte	26	1.7–3.2	5.0±1.8	27.7±6.3	9.9±0.5	0.445
67P/Churyumov–Gerasimenko	811	1.2–2.7	11.3±0.1	2.5±0.4	10.1±0.0	0.039
70P/Kojima	19	2.0–2.7			12.4±0.1	0.255
98P/Takamizawa	1	2.0			13.1	
106P/Schuster	4	1.6–1.8			13.9±0.5	
108P/Ciffréo	21	1.7–2.3	9.4±1.2	19.9±4.3	12.1±0.2	0.535
110P/Hartley	25	2.5–2.7	–9.4±3.3	59.6±8.2	10.7±0.2	0.696
132P/Helin–Roman–Alu	24	1.7–2.1	6.1±1.8	36.3±6.9	12.8±0.2	0.561
158P/Kowal–LINEAR	10	4.8–4.9			9.0±0.2	
173P/Mueller	21	4.2–5.1			8.1±0.2	–0.340
193P/LINEAR–NEAT	8	2.2–2.3			13.1±0.2	
241P/LINEAR	2	2.0			13.4±0.5	
246P/NEAT	52	2.9–3.8	5.8±1.0	14.1±2.0	7.9±0.1	0.506
252P/LINEAR	6	1.1–1.4			10.9±0.4	
282P/LONEOS (323137)	13	3.5–3.6			10.1±0.1	–0.084
284P/McNaught	6	2.3–2.6			11.3±0.3	
395P/Catalina–NEAT	2	4.2–4.3			8.7±0.7	
399P/PANSTARRS	1	2.4			15.1	
400P/PANSTARRS	1	2.2			14.2	
402P/LINEAR	11	3.9–4.4			8.1±0.1	–0.309
409P/LONEOS–Hill	28	1.8–2.2			13.5±0.1	0.456
413P/Larson	7	2.1–2.4			13.1±0.2	
414P/STEREO	2	0.6			14.8±1.3	
417P/NEOWISE	4	1.5–1.9			16.2±0.4	
418P/LINEAR	4	2.5–3.0			13.2±0.1	
419P/PANSTARRS	4	2.7–3.0			13.9±0.4	
425P/Kowalski	1	3.0			10.7	
435P/PANSTARRS	1	2.1			15.6	

(Table cont'd on p.50)

Magnitude parameters are given for all comets that were at perihelion during 2021, or which were discovered in 2021 after reaching perihelion. All quality-controlled visual and visual equivalent observations submitted to the BAA, either directly or via *TA* or COBS, were used, except when no coma diameter was given. During the process of checking, a few observations were found to be clearly incorrect and were rejected.

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 or too small an arc to calculate K_1 accurately and so a value of 10 is assumed, which gives the constant H_{10}. A correction for aperture of 0.0033 mm^{-1} has been applied to the visual observations and the H values are reduced to 30-cm aperture.

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

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

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.

For comets with more than 10 observations, a value for the coefficient of determination rsqr is normally given, which measures the goodness of fit to the standard equation. If this value is less than 0.5, the fit is unlikely to be a reliable guide and hence for some comets no fit is given. If the fit for a linear equation is better than the standard fit, this is presented in Table 3(b).

* at perihelion in 2019

perihelion delay is used to compute the absolute magnitude, this is the same for all except the 1967 return. However, if the parameters, including the rate of brightening, are changing, this approach would be invalid, and indeed the parameters do differ between the two well-observed returns.

The next close approach to Earth occurs in 2048, so we may have to wait until then to tease out the reason for the differences between the returns.

10P/Tempel

Following its 2015 return, the behaviour of this comet was reviewed in the paper covering that year.[10] At the 2021 return, it only just reached 10th magnitude. At the next return, in 2026, it approaches Earth to 0.41 au and a further review of its behaviour will then take place.

15P/Finlay

Following its 2014 return, the behaviour of the comet was reported in the paper covering that year.[8] At the 2021 return, it just reached

Table 3. Magnitude parameters of comets (Cont'd from p.49

b) Linear magnitude parameters

Comet	No.obs.	Days	H_1	K_1	ΔT	rsqr(s)	rsqr(l)
2020 M5 (ATLAS)	49	–372–276	11.5±0.1	0.0035±0.0006	–202.6±36.0	–1.128	0.469
2021 A4 (NEOWISE)	19	–40–23	11.7±0.5	0.0569±0.0165	–9.7±6.7	0.268	0.527
6P/d'Arrest (2021)	123	–163–197	8.5±0.2	0.0462±0.0021	–89.0±2.8	0.022	0.822
6P/d'Arrest (all)	1357	–163–207	8.9±0.1	0.0475±0.0013	–64.3±1.2	0.011	0.530
7P/Pons–Winnecke	73	–136–108	11.3±0.1	0.0276±0.0020	–49.6±3.6	0.366	0.805
8P/Tuttle (all)	1216	–234–105	8.0±0.1	0.0343±0.0011	–26.1±1.3	0.306	0.490
10P/Tempel	36	–385–259	6.5±0.4	0.0285±0.0017	46.5±8.9	0.927	0.940
15P/Finlay	35	–62–180	9.3±0.2	0.0438±0.0051	–10.5±4.1	0.796	0.771
57P/du Toit–Neujmin–Delporte	26	–173–293	6.9±0.7	0.0368±0.0036	–105.3±12.6	0.537	0.864
67P/Churyumov–Gerasimenko	811	–162–230	10.6±0.0	0.0181±0.0005	–59.3±1.2	0.039	0.647
108P/Ciffréo	21	–20–171	12.4±0.3	0.0180±0.0041	–7.0±15.3	0.629	0.634
132P/Helin–Roman–Alu	24	–74–131	12.4±0.3	0.0279±0.0042	–23.3±6.4	0.599	0.720

rsqr is given first for the standard equation, then for the linear equation.

10th magnitude, so it was not a bright object. A review of its behaviour will take place after the next return in 2028.

16P/Brooks

Following its 2014 return, the behaviour of the comet was reported in the paper covering that year.[8] At the 2021 return, only one observation was made. A review of its behaviour will take place after the next return in 2028.

17P/Holmes

This comet suffers outbursts, with a super one at its 2007 return and a lesser one in 2014. It was not observed until several months after its February perihelion, being poorly placed from January to June. It seems to have faded anomalously rapidly; this might imply that it had an outburst whilst in solar conjunction.

57P/du Toit–Neujmin–Delporte

This object split at its 1996 return and was found to have a secondary component in 2002.[8] It underwent an outburst at its 2021 return, suggesting a further split, which may preclude detection of any systematic trends in the comet's brightness. It had been 17th magnitude at the end of September but was reported at 12th magnitude by François Kugel on Oct 17. It remained at this brightness until the end of the year but was then lost in solar conjunction. When recovered in 2022 Aug, it was still some four magnitudes brighter than expected.

67P/Churyumov–Gerasimenko

This is an important comet, as it was extensively observed by the *Rosetta* spacecraft. The much longer period of amateur observations from the ground help put the spacecraft observations into context. An analysis of the behaviour at returns up to 2009 was given in a paper in the *Journal*.[11] Following its 2015 return, a further prediction was made for the 2021 return,[10] which suggested that the comet could reach 8th magnitude.

The 2021 return gave the comet its closest observed perihelion passage (1.21 au), and it also came relatively close to Earth (0.42 au). The first observation reported was by Peter Carson, who made an electronic estimate of the comet at 16.9 on May 24. Chris Wyatt, who specialises in attempting observation of comets when faint, made a visual observation on Jul 6, when it was 15.1 in his 0.4-m reflector under a magnification of ×261. The first European observation came on Aug 8, when J. J. Gonzalez estimated it at 12.7 in his 203-mm Schmidt–Cassegrain. As it brightened past 10th magnitude, many more observers started reporting magnitude estimates, with Mike Collins finding it to be 9.6 in his 254-mm Schmidt–Cassegrain on Oct 31. It was brightest in December, though Jonathan Shanklin, using the venerable Northumberland 0.30-m refractor of the Cambridge Observatories, estimated it at 9.8 on Dec 31. This is an example of the well-known 'aperture effect' and just a few days later, Shanklin estimated it at 8.9 in 25 × 100 binoculars. It faded quite rapidly in 2022, with the last observations coming in early June, by which time it was 16th magnitude.

When using all the available COBS observations, the data are again best fitted by a linear light curve, with a peak magnitude of 8.9 and a delay of 59.5 ± 1.3 days in reaching peak activity. The case for a brighter absolute magnitude with a smaller perihelion is not excluded by the data from this return, but it has become weaker, with the null hypothesis being the preferred one. The delay in peak brightness was significantly larger than at the previous return in 2015 (40.9 ± 4.1 days), though closer to the delay from all previous apparitions taken together (52.7 ± 2.3 days). The comet should behave similarly at the next return in 2028. A distant Jupiter encounter increases the perihelion distance a little for the 2034 return, but the observing circumstances will be nearly the same as those seen in 2021.

The analyses of the previous returns only used the BAA observations, and the analyses have been revisited using all the observations available in the COBS archive. From the plot of all observations, it is clear that the comet was brighter than average in 2009, and fainter than average in 1982. This cannot be

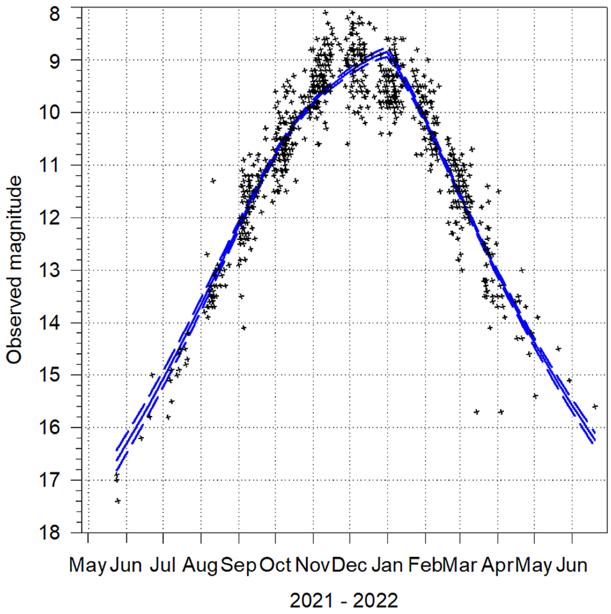

Figure 20. Observations (including all COBS observations) of 67P/Churyumov–Gerasimenko made at the 2021 return, with a linear light curve fitted to them.

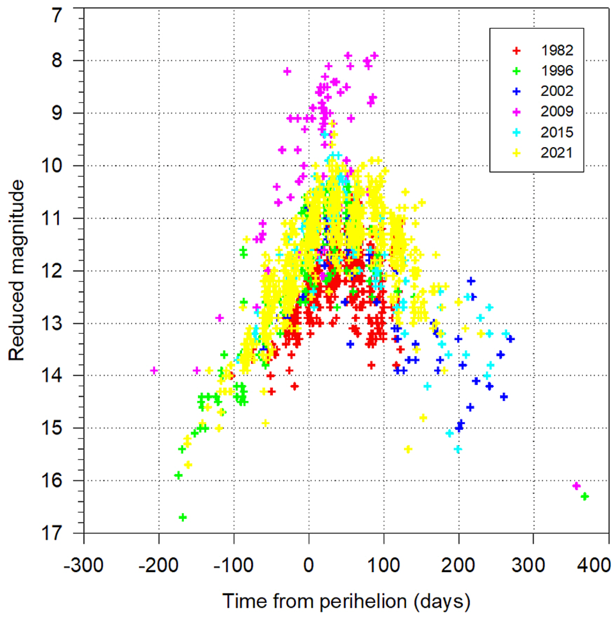

Figure 21. Composite plot showing the magnitude of 67P/Churyumov–Gerasimenko at returns since 1982, corrected for its distance from Earth.

explained by a delta effect (where the apparent size of the coma influences the magnitude) as the comet was at a similar distance from Earth at perihelion in 1982 and 2021. The three more distant apparitions of 2002, 2009 and 2015 all had relatively poor observing circumstances at perihelion, so the circumstances do not satisfactorily explain the difference either. Solar activity can be excluded as a cause: the 1996 and 2009 returns both took place during solar minimum, whilst activity was high in both 1982 and 2002. One remaining explanation is a possible rejuvenation following the perihelion distance reducing from 1.29 to 1.25 au after a distant Jupiter encounter in 2007. Finally, the in-situ observations show that the rotational period decreased from 12.76 hours prior to perihelion to 12.40 hours after perihelion in 2015. Changes in the rotation period and pole could possibly affect the cometary activity.

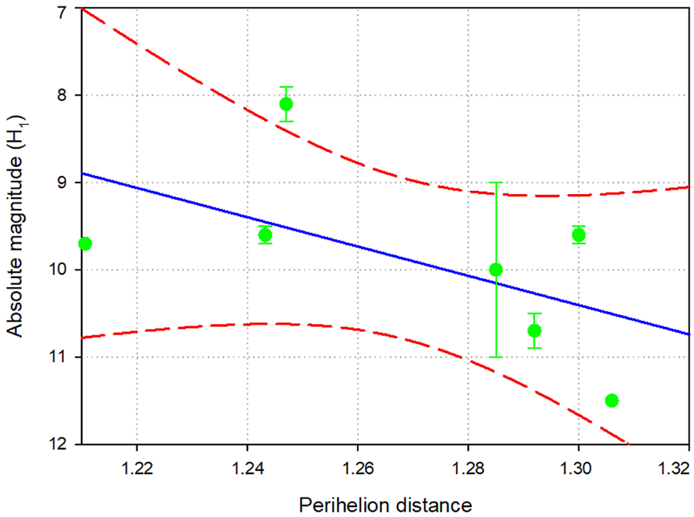

Figure 22. The variation of the absolute magnitude of 67P/Churyumov–Gerasimenko with perihelion distance. The red dashed lines show the 95 per cent confidence limits.

70P/Kojima

Following its 2014 return, the behaviour of this comet was reported in the paper covering that year.[8] The analysis concluded that further observations were required. At the 2021 return, only two observations were made, so this remains the case. A review of its behaviour will take place after the next return in 2028, which is the last prior to a Jupiter encounter in 2033. This will slightly increase the perihelion distance.

108P/Ciffréo

Following its 2014 return, the behaviour of the comet was reported in the paper covering that year.[8] At the 2021 return it only reached 14th magnitude, so it was not a bright object. A further review of its behaviour will take place after the next return in 2028.

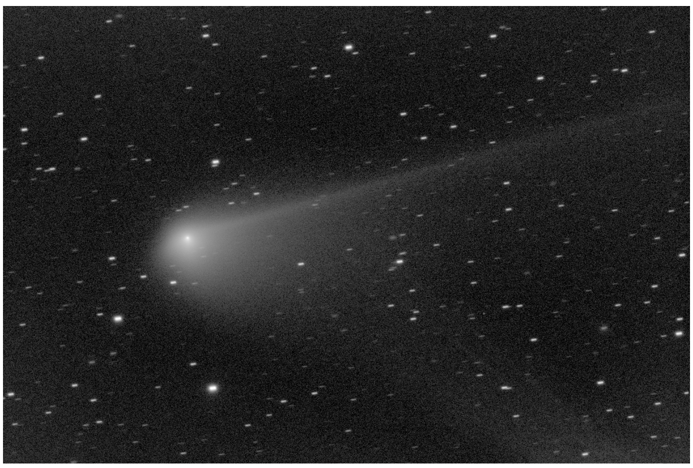

Figure 23. 67P imaged by Nick James on 2022 Jan 12, showing widely separated dust and ion tails.

110P/Hartley

Following its 2014 return, the behaviour of the comet was reported in the paper covering that year.[8] At the 2021 return, it only reached 15th magnitude, so it was not a bright object. A further review of its behaviour will take place after the next return in 2028.

414P/STEREO = 2016 J3 = 2021 A3

The discovery of this comet was described in the report on the comets of 2016,[12] which noted that the orbital period was very uncertain. On 2021 Jan 5.1, an object was discovered by the Zwicky Transient Facility and posted on the PCCP as ZTF01on. It was summarily removed on Jan 8 and noted to be P/2016 J3.

The previous evening, Maik Meyer had discovered the identity, computed a linked orbit, and informed the MPC and Central Bureau for Astronomical Telegrams (CBAT). Maik's linked orbit shows that the period is 4.67 years (much shorter than previously thought), with perihelion at 0.53 au on Jan 25. Despite this being the first comet to have an orbit computed in the year, it was not designated 2021 A1. Michael Jäger imaged it, finding it to be around 14th magnitude.

Rather belatedly, the CBAT issued *CBET* 4911 on Jan 11, with a revision coming 15 minutes later. This gives a similar account to that given here and notes that the comet will pass Jupiter at 0.9 au in 2031 Dec. It also hints that either the comet shows strong non-gravitational forces or that the 2016 positions are somewhat out. The MPC finally issued *MPEC* 2021-A157 on Jan 12. This does not give elements for the 2016 return, although the published elements for 2021 and 2025 do use observations from 2016.

Peter Carson imaged the comet on Jan 11.79, giving a visual equivalent magnitude of 13.1. J. J. Gonzalez made a visual observation on Jan 16.78 from his mountain observing site, estimating it at 9.7 in his 20-cm Schmidt–Cassegrain.

Sam Deen noted on the Comets Mailing List:

> 'It's caught in a Kozai resonance with Jupiter, that it is currently on the higher-*e*, lower-*i* leg of. I think that'll peak around 2400–2500 before cycling back. Like plenty of Earth-crossing Kozai oscillating objects, its orbit also crosses Earth sometimes, creating a potential for meteor showers. It last crossed Earth's orbit within 0.1 au in the 1300s, coming as close as 0.07 au – and it will next do so in the 2200s/2300s, coming less than 0.01 au around 2300, where it should create a fairly regular and impressive meteor shower considering that it would be even more active than it is now.'

Deen also suggested that the absolute magnitude is very faint and that it brightens rapidly, perhaps at 20 log *r*. If it does brighten at that rate, the absolute magnitude from the two observations is around 17.

Other comets observed or reported during the year

2014 UN_{271} (Bernardinelli–Bernstein)

Pedro Bernardinelli and Gary Bernstein of the Dark Energy Survey team, using the Cerro Tololo 4.0-m reflector, discovered a 22nd-magnitude asteroid in images taken between 2014 Oct 20.29 and 2018 Nov 8.24. Sam Deen was able to find prediscovery images taken with the CFHT at Mauna Kea on 2014 Aug 28. The discovery was made during an AI-assisted search for slow-moving trans-Neptunian objects. It is in a near-parabolic high-inclination orbit with perihelion at 10.9 au in 2031 Jan. [*MPEC* 2021-M53, *CBET* 4983, 2021 Jun 19/21.]

Luca Buzzi reported that cometary activity was detected on Jun 22 in images taken with the 0.51-m SkyGems Remote Telescope in Namibia. It was then quickly redesignated as a comet. [*MPEC* 2021-M83, *CBET* 4989, 2021 Jun 24.] It is the most distant comet discovery yet, being found when 29 au from the Sun. It is a comet from the inner edge of the Oort Cloud and has an absolute magnitude of 2.5, which may translate into a diameter of around 120 km. It seems to be showing variable activity, with reports of brightening by 0.7 magnitudes in less than a day on 2021 Sept 9. Although still a long way from perihelion, it is a comet that will be followed for several decades.

29P/Schwassmann–Wachmann

29P is an annual comet that has outbursts, which over the last few decades seem to have become more frequent, though this could just reflect more intense coverage. Richard Miles has developed a theory suggesting that these outbursts are in fact periodic and arise from at least four independent active areas on the slowly rotating nucleus.[13] The activity of these areas evolves with time. He also suggests that more major activity could be linked to where the comet is in its orbit around the Sun. Richard's methodology uses the magnitude of the inner coma in a 5.65-arcsecond radius window.

In 2021, visual observers noted its total magnitude as being brighter than 14 (i.e., significantly brighter than when at its quiescent level) in January, February, September, October, November, and December. It was around 10th magnitude for most of the last three months of the year.

Acknowledgements

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Address: 11 City Road, Cambridge CB1 1DP *[jdsh@bas.ac.uk]*

References

1 The Edgar Wilson Award Recipients: **http://www.cbat.eps.harvard.edu/special/EdgarWilson1.html** (accessed 2022 December)
2 Green D., *CBET* 5451: **http://www.cbat.eps.harvard.edu/iau/cbet/005400/CBET005451.txt** (accessed 2025 January)
3 JPL Small-Body Database Browser: **http://ssd.jpl.nasa.gov/sbdb.cgi** (accessed 2023 June)
4 Comet Section visual observations web page: **http://www.ast.cam.ac.uk/~jds** (accessed 2023 July)
5 Comet Observations database: **http://www.cobs.si/** (Accessed 2023 July)
6 Comet Section image archive: **http://www.britastro.org/cometobs/** (accessed 2023 July)
7 James N., 'A great display from comet C/2021 A1 (Leonard)', *J. Br. Astron. Assoc.*, **132**(2), 76 (2022)
8 Shanklin J., 'The brighter comets of 2014', *ibid.*, **129**(3), 139 (2019)
9 Shanklin J., 'The brighter comets of 2008', *ibid.*, **126**(4), 232 (2016)
10 Shanklin J., 'The brighter comets of 2015', *ibid.*, **129**(6), 341 (2019)
11 Shanklin J., '67P/Churyumov–Gerasimenko', *ibid.*, **123**(3), 163 (2013)
12 Shanklin J., 'The brighter comets of 2016', *ibid.*, **130**(1), 168 (2020)
13 Miles R., 'Observing the outbursting comet 29P/Schwassmann–Wachmann': **https://britastro.org/2019/observing-the-outbursting-comet-29p-schwassmann-wachmann** (accessed 2023 March)
14 The Comet Orbit Home Page: **http://jcometobs.web.fc2.com/index.html** (accessed 2022 December)

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