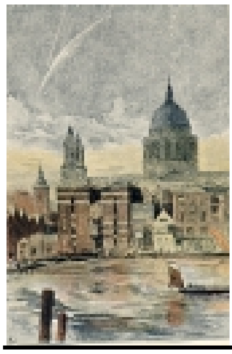

THE COMET'S TALE

Newsletter of the Comet Section of the British Astronomical Association

Volume 6, No 1 (Issue 11), 1999 April

INTERNATIONAL WORKSHOP ON COMETARY ASTRONOMY

The BAA Comet Section is very pleased to be hosting the second International Workshop on Cometary Astronomy. This will be held at New Hall Cambridge from August 14 to 16. The meeting aims to bring together professional and amateur observers and as many comet discoverers as possible.

The first IWCA was held at Selvino, Italy in February 1994 and details appeared in the Comet's Tale for 1994 May. Four previous American Workshops on Cometary Astronomy had been held in the U.S.A., but had not attracted much attention in Europe.

The 1994 meeting marked the 15th anniversary of the ICQ and attracted a good attendance of active observers. Presentations on the work of various national observing groups were given, along with talks by individuals on their own particular programs. Of greater importance were sessions which focussed on observing methodologies and these lead to significant improvements in the quality of observations.

Since then we have had two very bright comets which presented new problems in observation. There has been a huge growth in the Internet, enabling rapid dissemination of observations and the suspicion that this may bias observers. Planetarium programs using the Guide Star Catalogue now give observers precise finder charts enabling them to observe much fainter comets than in the past.

These new problems need new solutions and hopefully discussion at the meeting will lead to some conclusions that further improve our observing standards. However, observers generally have very fixed views so expect some heated arguments!

Although many amateurs observe comets for their own satisfaction, it can add enjoyment if you know that your observations are contributing to the scientific understanding of comets. To this end a number of leading professionals will be at the meeting, explaining how our observations are used and what additional observations would help with their research.

Bearing all this in mind the meeting has three main goals: 1) improving the acquisition of cometary information. 2) increasing understanding as to what science can be gained through observing comets by both amateurs and professionals. 3) providing a forum in which cometary astronomers can meet others from distant geographical locations and discuss various issues.

The format of the meeting will be to have selected invited talks, open panel discussions, contributed talks and poster sessions. Speakers scheduled to appear include Doug Biesecker (SOHO comets), Nicolas Biver (visual magnitudes and CO outgassing beyond 3 AU), Stephane Garro (French archival observations), Dan Green (comet photometry), Eleanor Helin (comet searching/discovery at Palomar and with NEAT), Gary Kronk (Cometography), Brian Marsden (amateur contributions), Herman Mikuz (CCD photometry), Charles Morris (possibly on web issues), Mahendra Singh (comet spectroscopy).

The college bar will be open in the evenings for informal discussion. If it is clear there will be opportunity to use the two historic refractors at the University Observatory.

Cambridge has many sites of astronomical interest and there will be free time for participants to explore at their leisure. Many famous scientists with comet connections studied at Cambridge including Newton, Herschel, Challis and more recently Lyttleton.

To conclude the meeting I have arranged a trip to Stonehenge on the Monday evening, when we will be allowed in to the inner circle to view the stones close up. There have been some suggestions that Stonehenge was first constructed as either a comet or meteor observatory! Numbers for this visit have to be restricted and those attending the meeting will have priority.

A registration form is enclosed, so take the time to fill it in now and come and enjoy what should be a very interesting meeting. The latest details will be posted on the Section web page.

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Subscription to the Section newsletter costs £5 for two years, extended to three years for members who contribute to the work of the Section in any way. Renewals should be sent to the Director and cheques made payable to the BAA. Those due to renew should receive a reminder with this mailing.

Section news from the Director

Dear Section member,

I returned from my 11th visit to the Antarctic in March. It was a very busy stay at Halley station where I was forecasting for our aircraft operations in addition to my expected tasks of installing a new automatic weather station and carrying out an inspection and calibration of the instrument which measures ozone. The forecasting was quite successful and we had no aborted flights during the 8 weeks of operations.

On the flight down to Antarctica I had a window seat (thanks to a kindly RAF airman) and was able to see the spectacular return of the Leonids. At its best we saw one fireball every 10 seconds and I logged over 300 meteors. The peak was much earlier than predicted by the experts so who knows where the best location for the 1999 return will be.

I saw a number of other interesting phenomena during my stay: a brilliant halo display which included Hevelius' parhelia, the parhelic circle and a circumzenithal arc with supernumery colours, a fogbow, miraging, iridescence on clouds, a 40 knot blizzard and a very weak aurora.

On passage I was able to complete drafts for papers on the comets of 1995, 1996 and 1997 and an outline of 1998 which will appear in the Journal in due course. I also entered another 2267 observations into the Section database, this time of the long period comets of the 1980s. This task is now almost completed and I only have to enter the observations of these long period comets which solely appeared in TA. I have not typed up all the observations in the files because some had already been sent to the ICQ by Michael Hendrie and I did not want to duplicate his typing. I suspect, however, that I may not hold all the observation forms from some observers and that they may have gone missing before I took over as Director. If anyone wants a list of magnitude observations that I hold, please let me know.

The computer archive currently has over 26,000 visual magnitude observations by 617 observers at 338 cometary apparitions. 117 observers have made only one observation, 376 fewer than 11 and only 54 have made more than 100. Major contributions include 2433 from myself, 884 from Albert Jones, 549 from Roy Panther, 504 from Tony Tanti, 370 from Guy Hurst, 351 from Werner Hasubick, 225 from Melvyn Taylor, 224 from Michael Gainsford, 171 from Gabriel Oksa, 151 from Michael Hendrie, 136 from Frank Ventura, 125 from Sally Beaumont, 104 from George Alcock and 98 from James Fraser. Over the years many non and former BAA Members have also contributed observations, in particular TA contributors and the Australian comet section, including Andrew Pearce (1187), John Bortle (989), Martin Lehky (697), Herman Mikuz (625), Alexandr Baransky (621), Bjorn Granslo (481), David Seargent (475), Graham Keitch (460), Vittorio Zannotta (410), Graham Wolf (406), Jose Aguiar (375), Reinder Bouma (364), Atilla Kosa-Kiss (334), Chris Spratt (316) and Paul Camilleri (281). For most observers these are not the full total that they have made as it excludes those sent to the ICQ prior to the commencement of the archive. If any readers would like to add to their totals by sending me observations in ICQ format either via email or on floppy disc I'll be very pleased to include them.

As described on the front page, we are hosting the International

Workshop on Cometary Astronomy in August, and I hope to see as many of you there as possible. Don't miss it, who knows where the next one will be!

Visitors who have indicated that they will be coming include Jose Aguiar (Brazil), Alexandr Baransky (Ukraine), Doug Biesecker (USA/UK), Giuseppe Canonaco (Belgium), Jose Carvajal (Spain), Tim Cooper (South Africa), Stephane Garro (France), Dan Green (USA), Werner Hasubick (Germany), Michael Jager (Austria), Gary Kronk (USA), William Liller (Chile), Don Machholz (USA), Brian Marsden (USA), Herman Mikuz (Slovenia), Charles Morris (USA), Andrew Pearce (Australia), James Scotti (USA), David Seargent (Australia), Chris Spratt (Canada), Patrick Stonehouse (USA), Kesao Takamizawa (Japan).

Since the last newsletter (which was incorrectly numbered volume 6 instead of 5) observations or contributions have been received from the following BAA members: Sally Beaumont, David Briggs, Denis Buczynski, David Clegg, Werner Hasubick, Guy Hurst, Nick James, John Lewis, John Mackey, Gabriel Oksa, Jonathan Shanklin, David Strange, Melvyn Taylor and Alex Vincent

and also from: Alexandr Baransky, Sandro Baroni, John Bortle, Reinder Bouma, Stephen Getliffe, Roberto Haver, Aymen Mohamed Ibrahem, Andreas Kammerer, Heinz Kerner, Atilla Kosa-Kiss, Martin Lehky, Jean-Claude Merlin, Herman Mikuz, Andrew Pearce and Seiichi Yoshida (apologies for any omissions or miss-classifications).

Comets under observation were: 4P/Faye, 10P/Tempel 2, 21P/Giacobini-Zinner, 29P/Schwassmann-Wachmann 1, 37P/Forbes, 52P/Harrington-Abell, 59P/Kearns-Kwee, 60P/Tsuchinshan 2, 65P/Gunn, 74P/Smirnova-Chernykh, 88P/Howell, 93P/Lovas 1, 95P/Chiron, 139P/Vaisala-Oterma, 140P/Bowell-Skiff, Hale-Bopp (1995 O1), Spacewatch (1997 BA6), Meunier-Dupouy (1997 J2), Mueller (1998 K1), LINEAR (1998 K5), LINEAR (1998 M2), Larsen (1998 M3), LINEAR (1998 M5), Williams (1998 P1), LONEOS-Tucker (1998 QP54), P/LINEAR-Mueller (1998 S1), LINEAR (1998 T1), P/Mueller 6 (1998 U2), P/Jager (1998 U3), LINEAR (1998 U5), Spahr (1998 W1), LINEAR (1998 W3), P/ODAS (1998 X1), P/LINEAR (1998 Y1), P/Li (1998 Y2), Tilbrook (1999 A1), Hermann (1999 D1) and Li (1999 E1).

Many of the fainter comets were observed only by Seiichi Yoshida who is using a CCD camera on an 18 cm reflector to very good effect. I hope to see many more CCD observations from UK observers in the next edition, though I can't set an example as my camera has been 'borrowed' to help test equipment for Gemini!

Jonathan Shanklin

Tales from the Past

This section gives a few excerpts from past RAS Monthly Notices, BAA Journals and Sky & Telescope.

150 Years Ago: Francis De Vico died on 1848 November 15. He discovered 6 comets and was awarded the King of Denmark's Gold Medal four times in 1846 for his telescopic discoveries. He died of typhus on a visit to England and was buried in the cemetery of the Roman Catholic chapel in Chelsea.

100 Years Ago: An interim report on Brooks' comet 1898I appears in the December Journal. It was conspicuous in early November and the reports suggest that it was a little fainter than M13. [*only Messier objects were used for comparisons, a practice that is not recommended today.]*. In the January Journal Mr Crommelin reported that plates taken to determine the Leonid radiant had also revealed a new comet. Ten comets were observed in 1898, a record, beating that of 1858 when eight were observed. In March a review of "Remarkable Comets" by W T Lynn, noted that comets were probably attracted into the orbit of meteor swarms, rather than the meteors forming from comets. At the Conversazione (an evening exhibition meeting) Mr Crommelin gave a lecture on comets and recommended more use of photography in the observation and discovery of comets. In the intervals between lectures, the Blue Anglo-Hungarian Band played music and there was the chance to view the exhibits. A note on comet seeking recommends the use of one eye for solar observing and the other for comets and nebulae, and never looking at strong light such as the sun or electric arcs.

50 Years Ago: The November meeting had several reports on the eclipse comet, which was one of the brightest of the century (further reports appeared in Sky & Telescope). Next month, Dr Merton gave a talk on comets. In response to a question he commented "We do need careful observations of its magnitude. Most of those who sent the first reports appear to have been so moved at the splendid sight this comet made that they omitted to record precise information of physical details." The January Journal contains an abstract of a paper on cometary statistics which appeared in Bulletin No 283 of the New South Wales branch. Details of this also appeared in Sky & Telescope. The March Journal has a report of a lecture given by Dr J G Porter to the Newcastle-on-Tyne Astronomical Society. At this time the 'sandbank' theory of comets was popular and he suggested that Halley's comet might consist of 3×10^{13} tons of blocks of meteoric material scattered over a space about 20 miles in diameter. [*Giotto showed that the comet was a single nucleus x miles long, weighing some x tons]*. Sky & Telescope was running a series of articles entitled 'Terminology Talks'. Several of these focussed on comets. In December there was a short article on the great comet of 1882, including some recollections from Americans who had seen it. [*Perhaps older readers would like to contribute recollections of the Eclipse comet, or other bright comets seen over 25 years ago]*. An explanation of comet terminology again likened the comet's nucleus to a swarm of meteorites extending over a few thousand miles, with considerable space between the individual particles. Finally 1948 equaled the record number of comets with 14.

Professional Tales

Many of the scientific magazines have articles about comets in them and this regular feature is intended to help you find the ones you've missed. If you find others let me know and I'll put them in the next issue so that everyone can look them up.

Jonathan Shanklin

The following abstracts (some shortened further for publication) are taken from the Cambridge Conference Network (CCNet), which is a scholarly electronic network devoted to catastrophism, but which includes much information on comets. To subscribe, contact the moderator Benny J Peiser at <b.j.peiser@livjm.ac.uk>. Information circulated on this network is for scholarly and educational use only. The abstracts, taken from daily bulletins, may not be copied or reproduced for any other purposes without prior permission of the copyright holders. The electronic archive of the CCNet can be found at http://abob.libs.uga.edu/bobk/cccmenu.html

M. Fulle, G. Cremonese, C. Bohm: **The preperihelion dust environment of C/1995 O1 Hale-Bopp from 13 to 4 AU.** ASTRONOMICAL JOURNAL, 1998, Vol.116, No.3, pp.1470-1477

Two UK Schmidt plates of comet Hale-Bopp dust tail taken in 1996 May are analyzed by means of the inverse dust tail model. The dust tail fits are the only available tools providing estimates of the ejection velocity, the dust-loss rate, and the size distribution of the dust grains ejected during years preceding the comet discovery. These quantities describe the comet dust environment driven by CO sublimation between 1993 and 1996, when the comet approached the Sun from 13 to 4 AU. The outputs of the model are consistent with the available coma photometry, quantified by the Af rho quantity. The dust mass loss rate increases from 500 to 8000 kg s(-1), these values being inversely proportional to the dust albedo, assumed here to be 10%. Therefore, the mass ratio between icy grains and CO results is at least 5. Higher values of the dust-to-gas ratio are probable, because the model infers the dust-loss rate over a limited size range, up to 1 mm sized grains, and because the power-law index of the differential size distribution ranges between -3.5 and -4.0, so that most of the dust mass was ejected in the largest boulders that Hale-Bopp was able to eject. The dust ejection velocity close to the observations, between 7 and 4 AU, was close to 100 m s(-1) for grains 10 mu m in size, much higher than that predicted by R. F. Probstein's theory, thus confirming previous results of Neck-Line photometry. This result is an indicator of CO superheating with respect to a free sublimating CO ice, in agreement with the high observed CO velocity. The fundamental result of the paper is that such a high dust velocity remained constant between 13 and 4 AU, thus providing a strong constraint to all models of the GO-driven activity of the comet during its approach to the Sun: CO superheating must have been active since 13 AU from the Sun. It might be provided by the abundant dust itself, or by seasonal effects heating the subsurface layers, as was suggested for comet 29P/Schwassmann-Wachmann 1. Another similarity between the two comets is provided by the power-law index of the time-averaged size distributions: -3.6 +/- 0.1 for C/1995O1 and -3.3 +/- 0.3 for 29P/SW1. However, other characteristics of the dust environments are very different, so that, in general, it is impossible to distinguish a CO-driven comet from a typical water-driven one.

P.L. Lamy, I. Toth, H.A. Weaver: **Hubble Space Telescope observations of the nucleus and inner coma of comet 19P/Borrelly.** ASTRONOMY AND ASTROPHYSICS, 1998, Vol.337, No.3, pp.945-954

The nucleus of comet 19P/Borrelly was detected using the Planetary Camera (WFPC2) of the Hubble Space Telescope (HST). During the time of our observations, the comet was 0.62 AU from the Earth, 1.40 AU from the Sun, and had a solar phase angle of 38 degrees. The high spatial resolution of the HST images allowed us to discriminate clearly between the signal from the nucleus and that from the coma. The lightcurve of the nucleus indicates that it is a highly elongated body rotating with a synodic period of 25.0 +/- 0.5 hr. Assuming that the nucleus has a geometric albedo of 4% and is a prolate spheroid with a rotational axis pointing in the direction determined by Sekanina (1979), we derive that its semi-axes are 4.4 +/- 0.3 km and 1.8 +/- 0.15 km. The corresponding fractional active area of similar to 8% suggests a moderately active comet. The highly anisotropic coma is dominated by a strong sunward fan, and the dust production rate exhibited signs of temporal variability throughout our observations.

W. Waniak, S. Zola: **Dust emission for Comets Shoemaker-Levy 1991a1 and McNaught-Russell 1993v**. ICARUS, 1998, Vol.136, No.2, pp.280-297

We present CCD photometric results for the dust comae of the dynamically new Comet Shoemaker-Levy 1991a1, carried out at heliocentric distances from 1.2 to 0.8 AU pre-perihelion, and the high-eccentricity, long-period Comet McNaught-Russell 1993v obtained at a heliocentric distance close to 1.0 AU post-perihelion. Maps of the directional distribution of the dust emission rate from these cometary nuclei were obtained using the directional deconvolution method (Waniak 1994, Icarus 111, 237-245). For Comet Shoemaker-Levy the prominent region of enhanced dust production was situated between the solar terminator and the nucleocentric meridian opposite the subsolar point. Activity in this region on the night side of the nucleus may be explained both by the heating of the nucleus' surface by scattered visible and reemitted infrared radiation, which is produced by the dust coma, or by non-solar radiation sources of energy, such as chemical reactions or phase transitions. During the period of observations the dust emission rate for this region decreased in comparison with that of another region of enhanced dust production situated on the

subsolar hemisphere. For Comet McNaught-Russell two active regions were also visible, although the subsolar region was much more active than that on the night side of the nucleus. For both comets, dust was emitted from the entire surface of the nucleus at a level no lower than 30% of the maximum value for the active regions. The total (integrated over a 4 pi solid angle) dust emission rate for Comet Shoemaker-Levy changed as r(h)(-2.3) for the observed range of heliocentric distance r(h). For both comets, the ejection velocity of submicron dust particles was of the order of 0.1 km sec(-1) and the power-law size distribution of dust particles (a(-n)) had a mean value of exponent n equal to 2.9. The power-law dependence of the ejection velocity upon the beta parameter (nu similar to beta(k)) was specified by a mean value of k close to 0.18.
(C) 1998 Academic Press.

P. Wiegert & S. Tremaine: **The evolution of long-period comets.** ICARUS, 1999, Vol.137, No.1, pp.84-121

We study the evolution of long-period comets by numerical integration of their orbits, a more realistic dynamical approach than the Monte Carlo and analytic methods previously used to study this problem. We follow the comets from their origin in the Oort cloud until their final escape or destruction, in a model solar system consisting of the Sun, the four giant planets and the Galactic tide. We also examine the effects of nongravitational forces as well as the gravitational forces from a hypothetical solar companion or circumsolar disk. We confirm the conclusion of Oort and other investigators that the observed distribution of long-period comet orbits does not match the expected steady-state distribution unless there is fading or some similar physical process that depletes the population of older comets. We investigate several simple fading laws, We can match the observed orbit distribution if the fraction of comets remaining observable after m apparitions is proportional to m(-0.6+/-0.1) (close to the fading law originally proposed by Whipple 1962); or if approximately 95% of comets live for only a few (similar to 6) returns and the remainder last indefinitely, Our results also yield statistics such as the expected perihelion distribution, distribution of aphelion directions, frequency of encounters with the giant planets and the rate of production of Halley-type comets.
(C) 1999 Academic Press.

P. Gronkowski & J. Smela: **The cometary outbursts at large heliocentric distances**. ASTRONOMY AND ASTROPHYSICS, 1998, Vol.338, No.2, pp.761-766

A model is presented explaining changes in cometary brightness during an outburst at large heliocentric distances. It is shown that a combination of the following effects can explain the main characteristics of outburst at large heliocentric distances: the specific exothermic processes in cometary nucleus (as the HCN polymerisation and the crystallization of the water amorphous ice, connected with the ejection of the large quantities of dust) and the sublimation of CO or CO2 from the comet's nucleus. The obtained results are in good agreement with observations.
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Z. Sekanina: **A double nucleus of comet Evans-Drinkwater (1996 J1).** ASTRONOMY AND ASTROPHYSICS, 1998, Vol.339, No.1, pp.L25-L28

The nucleus of comet C/1996 J1, whose duplicity was first detected in early May 1997, similar to 4 months after perihelion, is found to have split nontidally similar to 70 days before perihelion at 1.65 AU from the Sun. The secondary nucleus, discovered when in outburst and subsequently observed for 8-1/2 months, had separated from the primary nucleus at a rate of 1.7 m/s and drifted away from it with a radial nongravitational deceleration of similar to 31 x 10(-5) the Sun's attraction, typical for the short-lived companions. At the time of splitting, this dynamically new comet was near conjunction with the Sun and therefore unobservable from Earth. In late 1997 and early 1998, when last seen, the companion was greater than or similar to 100 times fainter relative to the primary component than it had been when first reported.
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A. Brunini & M.D. Melita: **On the existence of a primordial cometary belt between Uranus and Neptune**. ICARUS, 1998, Vol.135, No.2, pp.408-414

The existence of stable orbits in the interplanetary region between Uranus and Neptune over the lifetime of the Solar System has been reported by Holman (1997, Nature 387, 785-788). A long-term integration of test particles in that zone resulted in a number of surviving bodies with semimajor axis roughly between 24 and 27 AU, and eccentricities and inclinations smaller than 10(-2) and 1 degrees, respectively. According to up-to-date surveys, the total mass of this putative belt has been estimated as less than or equal to 10(-3) M+ and it would be composed of objects with radius smaller than 50 km. In this work we assess the plausibility of the existence of a real population of objects in such a belt. Time-reversal arguments rule out the possibility of capture in such long-term stable orbits, for example, of objects escaped from the Kuiper belt. So if a real population exists nowadays, it should have undergone the conditions of planetesimal accretion in the region. Hence, we have studied the orbital evolution of test particles under different kinds of plausible primordial scenarios. The conditions considered were mutual collisions and gravitational encounters, planetary migration and the presence of an adjacent Pluto-sized object. Under none of these conditions have we obtained a surviving substantial population on the reported belt region, from which it is concluded that, at present time, it would be very unlikely to find a substantial number of primordial objects in those long-term stable orbits.
(C) 1998 Academic Press.

Z. Sekanina: **Multiple fragmentation of comet P/Machholz 2 (1994 P1).** ASTRONOMY AND ASTROPHYSICS, 1999, Vol.342, No.1, pp.285-299

Discovered in August of 1994, periodic comet Machholz 2 consisted of five condensations, A-E, of which D later became double. They were lined up along their common heliocentric orbit (with A being the leading and brightest component) and connected by a trail of material, suggesting that the comet's nuclear fragmentation was accompanied by a copious release of large dust particles. The earliest breakup is found to have occurred in late 1987, similar to 600 days before the comet's 1989 perihelion, giving birth to fragment B and the grand precursor of A. The precursors of A and D and fragments A and C appear to have originated, respectively, similar to 5 days prior to and right at perihelion. The last breakup episode during that same return to the Sun was the separation of E, probably from the precursor of D, similar to 600 days after perihelion. The division of D into D-1 and D-2 is the only event analysed in this paper that occurred one revolution later, in 1994. The circumstances and implications of this fragmentation sequence are examined in detail and predictions are presented for 1999/2000.

Review of comet observations for 1998 October - 1999 March

The information in this report is a synopsis of material gleaned from IAU circulars 7030 – 7138 and The Astronomer (1998 October – 1999 March). Note that the figures quoted here are rounded off from their original published accuracy. Lightcurves for the brighter comets are from observations submitted to The Astronomer and the Director. A full report of the comets seen during the year will be published in the Journal in due course.

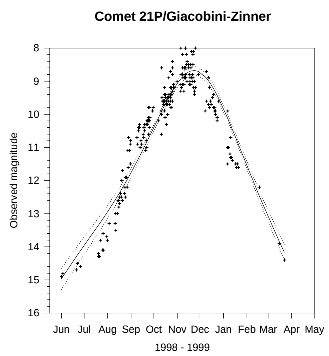
4P/Faye was observed several times over the winter as it slowly brightened to around 13th mag. Perihelion is not until May, but this is a poor return and further observations are unlikely, though observers with large apertures may glimpse it in the autumn.

10P/Tempel 2 makes its 20th observed return since its discovery by William Tempel (Milan, Italy) as a 9th magnitude object in 1873. Several unfavourable returns were missed in the earlier years. The orbit is very stable, which is one reason why it is a favoured target for planned spacecraft missions. In 1983 the IRAS satellite detected an extensive dust trail behind the comet.

Traditionally the light curve is regarded as highly asymmetric with a late turn on. There is a rapid rise in brightness as perihelion approaches, which continues more slowly for a couple more weeks after perihelion, followed by a slow decline until activity switches off. An alternative view is that the light curve is linear with a peak about a month after perihelion, which at this return occurs in early September.

With a 5.5 year period alternate returns are favourable and this is one of them. A CCD observation by Seiichi Yoshida in late March put it at 18th mag. The comet may be picked up in large telescopes in April when it is in Ophiuchus and it should reach 10th magnitude in June. It is closest to the Earth in July (0.65 AU) when it could be 9th magnitude and UK observers should be able to follow it until August, but it then moves too far south. More southerly observers may be able to observe it until the end of the year as it fades.

21P/Giacobini-Zinner, the parent comet of the October Draconid meteors, remained visible until March, though most observers lost it in December. Observations show the comet brightened very rapidly with distance from sun and earth changing in step. The 214 observations give a light curve of 8.3 + 5 log d + 11.4 log r.



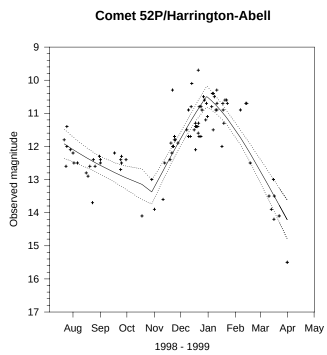
29P/Schwassmann-Wachmann 1 has frequent outbursts and over the past couple of years seems to be more often active than not, though it rarely gets brighter than 12m. It is possible that its pattern of behaviour is changing. This year Andrew Pearce detected a major outburst at the end of March.

It is at opposition in May on the borders of Hydra and Libra and reaches solar conjunction in November. Observers are encouraged to check the comet at every opportunity over the apparition, although it will remain at low altitude for UK observers for several years to come. It is worth monitoring with CCD cameras on a regular basis.

37P/Forbes will be 13m between April and June. Andrew Pearce picked up the comet at 13.5 in the second half of March.

52P/Harrington-Abell was discovered in outburst at 12th magnitude by Alain Maury, Observatoire de la Cote d'Azur, on CCD images taken on July 21.1. It slowly faded, but then underwent a second outburst in October that peaked some 29 days before perihelion, which was in late January. This is the seventh observed return of the comet since its discovery in 1954 and it has never became brighter than 17th magnitude at previous returns. Normally it would have been expected to get no brighter than 15th magnitude at this return, but peaked near 10th magnitude at the turn of the year.

Observations received so far (90) give an uncorrected preliminary light curve for the second outburst of 10.9 + 5 log d + 0.0299 abs(t - T + 28.5)



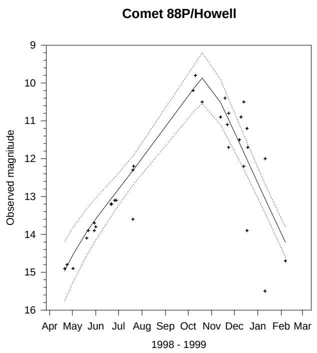
59P/Kearns-Kwee was observed by Werner Hasubick in January at 15th mag. This is rather brighter than expected and it could reach 12th mag towards the end of the year.

60P/Tsuchinshan 2 is yet another faint object imaged by Seiichi Yoshida at 16th mag, which is as bright as it will get.

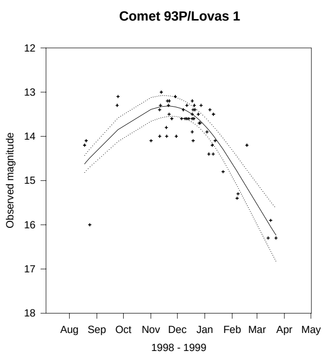
65P/Gunn remains on view to CCD observers, although it is only 17th mag.

Another faint object is **74P/Smirnova-Chernykh** which doesn't reach perihelion until January 2001 but has already been imaged by Seiichi Yoshida at 16th mag.

88P/Howell reached a peak magnitude of around 10 in the autumn, but was essentially a southern hemisphere object. The 33 observations received so far give a preliminary light curve of 8.8 + 5 log d + 0.0319 abs(t - T - 27.8)

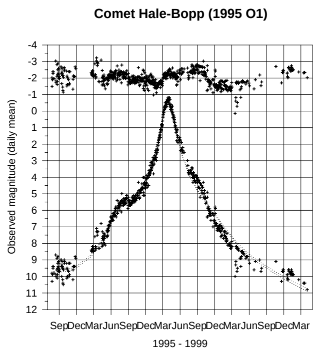


93P/Lovas 1 was quite well observed and faded from 13th mag at the turn of the year. The 53 observations give a preliminary light curve of 9.3 + 5 log d + 13.8 log r

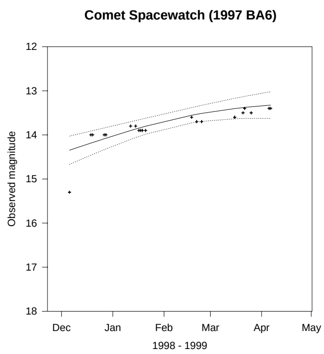


Comet/Asteroid **95P/Chiron** will be 16m when at opposition in late May in Libra. Seiichi Yoshida imaged it near 17th mag in the first quarter of the year.

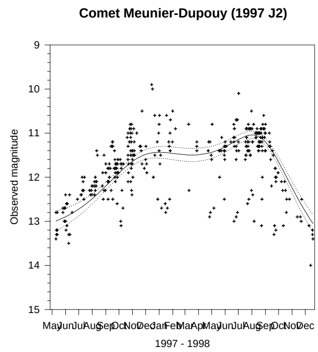
Hale-Bopp (1995 O1) is now a telescopic object, but still well placed for Southern Hemisphere observers as it loops round the Large Magellanic Cloud. Somewhat to my surprise I was able to glimpse it in 20x80 binoculars from the Falkland Islands in mid November at 10.5 but it will reach 13th mag by the end of this year. The observed arc now covers 1349 days with observations made on 734 days. The equation -0.69 + 5 log d + 7.66 log r fits daily means very well, but there are long period variations about this mean light curve of around a magnitude, which are shown plotted with an offset of -2. It is currently a little brighter than indicated by the equation.



Spacewatch (1997 BA6). The orbit of this comet is very eccentric, with a period near 4500 years and a semi-major axis of several hundred AU. Currently it is 13th mag and is at high southern declination. It is heading for perihelion at 3.4 AU in 1999 December when it may be around 12th mag.



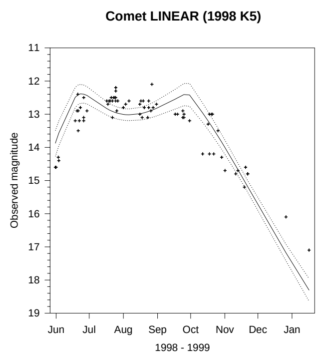
Meunier-Dupouy (1997 J2) faded away and no observations were received after December. The 359 observations received so far suggest a preliminary light curve of 5.1 + 5 log d + 5.8 log r.



Mueller (1998 K1) was imaged by Seiichi Yoshida over the winter, but is now fainter than 18th mag.

LINEAR (1998 K5) was a little fainter and a little more diffuse in mid October compared to the early autumn. By the end of October it was still 14th mag, but becoming larger and more diffuse and faded rapidly in November. The light curve is very unusual and the comet's absolute magnitude seems to have peaked some 73 days after perihelion. The combination of changing distance from earth, with the late peak in brightness kept the magnitude nearly constant from July to October.

The 71 observations analysed give a preliminary light curve of 13.1 + 5 log d + 0.0298 abs(t - T - 73.0).

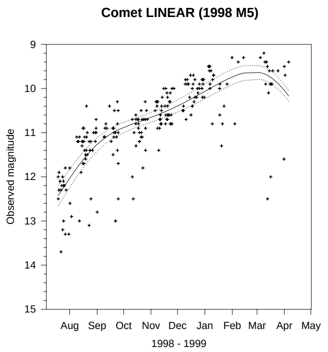


LINEAR (1998 M2) was imaged a couple of times by Seiichi Yoshida over the winter, but was too faint for most other observers.

Larsen (1998 M3) was also imaged by Seiichi Yoshida, this time at 18th mag.

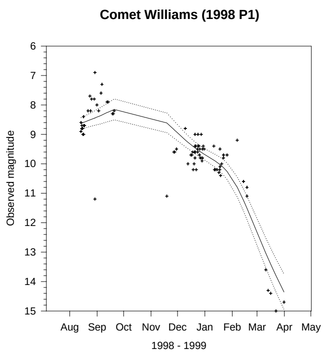
LINEAR (1998 M5) was at perihelion in January at around 10th magnitude and moved north from Lyra, passing very close to the pole in mid March. At this point its motion effectively cancelled out the earth's rotation and imaging was possible with a fixed mounting. Heading south it passes through Camelopardalus and Lynx, reaching Cancer mid year when it will have faded to 13th magnitude. It will then be too faint and close to the sun for further observation.

Observations received so far (225) give a preliminary light curve of 6.2 + 5 log d + 7.4 log r



Williams (1998 P1) was recovered after perihelion by Andrew Pearce in late November but its rapid fade had already begun and it was nearly 10th mag. This fade continued, though some observers reported surprisingly bright magnitudes as late as March.

The 82 observations received so far give a light curve of 5.1 + 5 log d + 15.5 log r.



LONEOS Tucker (1998 QP54) was another target for Seiichi Yoshida, and was recorded at 16th mag in December. Martin Lehky and Werner Hasubick also recorded it visually at near 15th mag earlier in the autumn.

P/LINEAR-Mueller (1998 S1) faded from 14th mag in November to 16th mag in February.

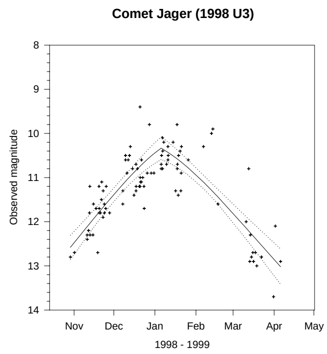
LINEAR (1998 T1) was discovered during survey work whilst still a long way from perihelion. Several observers recorded it over the winter whilst near 14th mag. The light curve is not very well defined yet, but it should reach 9th magnitude when it is at perihelion in June, though it will not be visible from the UK.

LINEAR (1998 U1) is yet another comet discovered by LINEAR. The object, discovered on October 18, was reported as asteroidal and fast-moving, and a request for further observations was placed on The NEO Confirmation Page. From the confirmatory observations, made at four observatories on October 20 and 21, it quickly became clear that the object had a retrograde, nearly parabolic orbit. Referring to the observations made with the 0.65-m f/3.6 reflector at the Ondrejov Observatory on October 20.9 UT, P. Pravec noted that a faint tail was visible on individual 3-min exposures with a clear filter. The tail, extending 16" in p.a. 60 deg, was confirmed on co-addition of six frames. [IAUC 7033, 1998 October 21]. The comet is faint and distant and past perihelion.

P/Mueller 6 (1998 U2) was discovered by Jean Mueller on plates taken by herself on Oct 21.3 (and with K. Rykoski on Oct. 22) with the 1.2-m Oschin Schmidt Telescope in the course of the Palomar Outer Solar System Ecliptic Survey. The comet had a strong condensation and a short, faint tail to the southeast. [IAUC 7035, 1998 October 22]. Prediscovery images from September 14 were found in LONEOS data and the comet is an intrinsically faint periodic object found at a favourable opposition. Seiichi Yoshida made a single observation in December when it was 17th mag.

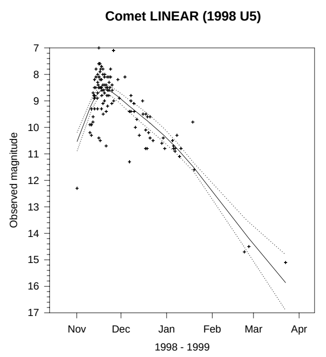
P/Jager (1998 U3) was discovered by TA correspondent Michael Jager on 16- and 9-min Technical Pan film exposures with a 0.25-m f/2.8 Schmidt camera. The comet had a 1'-2' coma with condensation and a tail several arcmin long in p.a. 275-281 deg and was around 12th mag. [IAUC 7038, 1998 October 25]. Nick James imaged the comet on October 26. I observed it on October 29.1, making it around 12.5 in the Northumberland refractor x105, DC s3 and diameter around 1'. It reached a very broad peak of 10th mag between December and February.

Observations received so far (94) give a preliminary light curve of 9.8 + 5 log d + 0.0201 abs(t - T + 27.8). This suggests that it will now fade quite rapidly.



P/Spahr 1 (1998 U4) was discovered by Timothy B Spahr of the University of Arizona on October 27.4 on CCD images taken with the Catalina Sky Survey 0.41-m f3 Schmidt. It was 17th mag and was confirmed by Spacewatch Telescope images. [IAUC 7042, 1998 October 29]. The preliminary orbit is a distant elliptical one and the comet did not become any brighter.

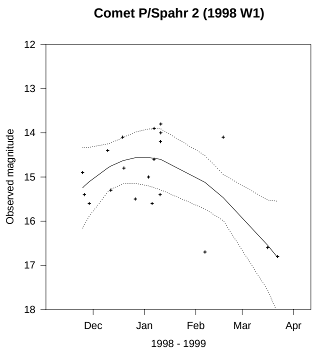
LINEAR (1998 U5) was another object discovered by LINEAR that was later identified as a comet. [IAUC 7044, 1998 October 31]. On November 1.18 I estimated it at 12.3, rather brighter than 1998 U3. It brightened explosively and reached 8th mag just over a fortnight later.



Observations received so far (119) give a preliminary light curve of 6.1 + 5 log d + 28.9 log r. Although it faded quite quickly, very few observations were made after December

P/LINEAR (1998 VS24). On further examining the Nov. 10-11 observations, published on MPS 3154, of an apparently unremarkable asteroidal discovery from the LINEAR program, G. V. Williams made identifications with isolated sets of observations from Visnjan on Oct. 24, 28 (the latter having been published on MPS 2894 as one of two objects that were both erroneously identified with 1998 UD19) and Nov. 26. The resulting orbit was very cometary in form, with a period of 9.6 years. Furthermore, he recognized that the object had made an extremely close approach (< 0.01 AU) to Jupiter in Oct. 1971, with additional approaches to 0.5-0.7 AU in both 1983 and 1995. It is a distant intrinsically faint object, so of no concern for the moment.

P/Spahr 2 (1998 W1) Timothy B Spahr of the University of Arizona discovered another comet on November 16.4 on CCD images taken with the Catalina Sky Survey 0.41-m f3 Schmidt. It was 16th mag but there was no visible tail, with the round coma 18" in diameter [IAUC 7052, 1998 November 17]. It reached perihelion in January and was no brighter than 15th mag on CCD images, but visual observers made it as bright as 14th mag.



P/Hergenrother (1998 W2) C W Hergenrother found a comet on CCD images obtained by Timothy B. Spahr on Nov. 22.10 in the course of the Catalina Sky Survey. The comet was 17th magnitude and will fade. The comet was a short period one, almost at perihelion. [IAUC 7057, 1998 November 23]

LINEAR (1998 W3) The LINEAR Team discovered an object that had unusual motion on November 25.3 and placed the information in The NEO Confirmation Page. On reporting astrometric follow-up, G. Hug, Farpoint Observatory, Eskridge, KS, noted the object's appearance was probably cometary, a point confirmed by other observers on request from the Central Bureau, and by the near-parabolic retrograde orbit, which showed it to be a distant object. [IAUC 7063, 1998 November 28]. Seiichi Yoshida was able to image it on several occasions and Martin Lehky also recorded it visually near 15th mag.

139P/Vaisala-Oterma (1998 WG22) Precise positions of 1939 TN, an apparently asteroidal object discovered by Y. Vaisala at Turku on 1939 Oct. 7 and observed by him and L. Oterma on three more nights over a 35-day arc, were published in 1979 in Turku Obs. Report R10 and on MPC 4811. The orbit computation by Oterma suggested to her that the object was a comet, and in a communication to the Minor Planet Center in 1981 she remarked that a careful reexamination of the plates suggested that the object was perhaps somewhat diffuse. The introduction to the 1982 edition of the Catalogue of Cometary Orbits quotes her conclusion that the object was probably a comet, but the object was not actually listed as one. On MPEC 1998-X19, the object is identified by S. Nakano, Sumoto, with 1998 WG22, a 19th mag apparently asteroidal object observed by the LINEAR program on Nov. 18.26 and 21:

Fortuitously, this object was located only 4' from the result of integrating forward from 1939 the orbital elements by Brian Marsden on MPC 6815. Further LINEAR observations were made on Nov. 24. On observing the object with the 1.8-m reflector at the Dominion Astrophysical Observatory on Dec. 6.3 UT, D. Balam noted (in FWHM 3".1 seeing) an 8" coma and a tail extending 18" in p.a. 260 deg. On Dec. 7.1 W. Offutt, Cloudcroft, observing between clouds, also remarked on a tail (or antitail) extending 17" in p.a. 257 deg, but no coma was noted. M. Tichy, observing in poor conditions at Klet on Dec. 7.9, remarked on a possible 6" coma.

The object's cometary nature seems now reasonably assured and it has a period of 9.55 years [IAUC 7064, 1998 December 7]. Seiichi Yoshida was able to observe it at 18th mag shortly after discovery.

P/ODAS (1998 X1) The Observatoire de la Cote d'Azur-Deutsches Zentrum fur Luft und Raumfahrt Asteroid Survey (ODAS) discovered an 18th magnitude comet on December 15.17 with the 0.90-m Caussols Schmidt camera. The orbit is of short period (6.8 years), with perihelion having occurred in July. [IAUC 7067, 1998 December 17]. Once again Seiichi Yoshida successfully imaged it.

140P/Bowell-Skiff (1998 X2). G. V. Williams, Minor Planet Center, rediscovered comet P/1983 C1 (= 1983c = 1983 II) in the course of his processing of two-night "asteroid" data obtained by the LINEAR program on Dec. 14 and 17. The indicated correction to the prediction on MPC 27081 (ephemeris on MPC 32547) was Delta T = +17.3 days. [IAUC 7076, 1998 December 28]. Seiichi Yoshida has again been successful at imaging it, at around 16th mag and it could brighten a little further.

D/LINEAR (1998 Y1) LINEAR discovered another faint periodic comet on December 22.31 [IAUC 7072, 1998 December 24]. Perihelion occurred a month earlier and it is not due to return for over 100 years. Because it is a one apparition comet with a period which is a substantial fraction of the notional upper limit of 200 years it has been given a D/ designation. Seiichi Yoshida was able to observe it on several occasions between discovery and early February.

P/Li (1998 Y2) Weidong Li, Department of Astronomy, University of California at Berkeley, reported his discovery of a comet in the course of the Lick Observatory Supernova Search (cf. IAUC 6627; with the participation of M. Papenkova, E. Halderson, M. Modjaz, T. Shefler, J. Y. King, R. R. Treffers and A. V. Filippenko). The object was found automatically by the Katzman Automatic Imaging

Telescope in the field of NGC 1041, but it was immediately recognized as a comet by Li, who then used the equipment to make a deliberate confirmatory observation, as well as follow-up observations on the following night. [IAUC 7075, 1998 December 28]. The comet is periodic with a period of about 15.2 years. Seiichi Yoshida has imaged it on several occasions at around 16th mag. Martin Lehky observing visually made it over two magnitudes brighter.

Tilbrook (1999 A1) Justin Tilbrook (Clare, South Australia) discovered a second comet on January 12.49 with his 0.2-m f6 reflector x70. [IAUC 7084, 1999 January 13]. Although it had perihelion inside the earth's orbit and was relatively close, it was intrinsically quite faint and faded after discovery. Andrew Pearce made some early observations, reporting it at a little fainter than 10th magnitude. Moving south, it will not be visible from the Northern Hemisphere.

SOHO (1999 C1). Having been restored to operation in October SOHO was quickly disabled again by gyro failures. Ground controllers managed to get round the problems and it returned to the fray in early February when it quickly discovered another Kreutz group fragment.

Hermann (1999 D1) S M Hermann of the LONEOS team discovered a comet on images taken on February 20.4 [IAUC 7111, 1999 February 20]. It is an intrinsically faint short period comet. It faded after discovery, but not before it had been imaged by Seiichi Yoshida.

Li (1999 E1) Weidong Li and M. Modjaz, Department of Astronomy, University of California at Berkeley discovered a 17th mag comet in the course of the Lick Observatory Supernova Search on March 13.18 [IAUC 7126, 1999 March 16]. The object was found automatically by the Katzman Automatic Imaging Telescope (KAIT), recorded by Modjaz as a supernova candidate, and recognized by Li as a comet. Li then used the equipment to make confirmatory observations three nights later. The comet shows an apparent tail in p.a. about 120 deg. It is in a distant parabolic orbit and will fade, though Seiichi Yoshida imaged it at 15th mag just over a week after discovery.

P/Machholz 2 has not yet been recovered, though recovery is not really expected until late spring. It may reach 7th magnitude in the late autumn. This comet split into several fragments at its discovery return in 1994 and both the ephemeris and expected magnitude are a little uncertain. The date of perihelion is uncertain by up to a day and more accurate ephemerides will be published when the comet is recovered. UK observers should be able to observe it from November at 10th magnitude, though more southerly observers may find it a month earlier.

For the latest information on discoveries and the brightness of comets see the Section www page: http://www.ast.cam.ac.uk/~jds
or the CBAT headlines page at http://cfa-www.harvard.edu/cfa/ps/Headlines.html

Comet Hunting Notes

Don Machholz

JULY 1998: **At what declination (number of degrees north or south of the equator) do amateur astronomers visually discover comets**? The finds range from +72 degrees to -62 degrees. From 1975 to the present, of the 43 comets found in the Northern Hemisphere, seven were found north of +45 degrees. Sixteen were between +20 and +45 degrees and the remaining 20 were found between the celestial equator and +20 degrees. As for the 34 southern comets, five were found south of -45 degrees while 16 more were between -20 and -45 degrees. The remaining 13 Southern Hemisphere comets were found between the celestial equator and -20 degrees.

AUGUST 1998: The Edgar Wilson Award has been announced for amateurs who discover comets. A cash award of about $20,000 will be distributed each June 12 among those finding comets during the previous year. The rules are few. The comet must be named after you and you must be using your own equipment in an amateur capacity. The discovery may be made by visual, photographic, or electronic means. The amount an individual receives depends upon the number of comet finds during the year. For example, in the past twenty years, any individual who found a comet would have received between $1500 and $20,000 for that comet find.

SEPTEMBER 1998: While comet hunting I've always recorded the number of meteors I happen to observe passing through my field of view. On June 16 of this year I recorded my 10,000 telescopic meteor. The span of time was 6314 hours over the course of 23 years. The number of meteors I see per hour in the morning sky averages 1.9 while the evening sky averages 0.9. I also record the number of artificial satellites I see. The hourly rates for these has increased, and now exceeds the meteor rates. I made my 10,000 satellite sighting about a year ago.

OCTOBER 1998: Williams' comet discovery on August 10 brings the total number of Australian visual comet discoverers to five, this is now half the number of Americans (10) who have visually found comets since 1975. There are only two other Southern Hemisphere comet discoverers: Austin of New Zealand and Campos of South Africa. All 24 comets found by these seven men were discovered south of the celestial equator, 23 being found by only one discoverer. Peter Williams is the first person to qualify for the Edgar Wilson Award: a cash sum of about $20,000 to be divided up among all the amateurs who discover comets before June 11, 1999.

NOVEMBER 1998: **As seen from the earth, how far are comets from the sun when first discovered**? This angle, called elongation, has been calculated for the 78 comets found visually by amateurs since 1975. It ranges from 22 to 171 degrees. Over half of the comets have been found within 58 degrees of the sun. Seventy of the seventy-eight were found within 92 degrees of the sun. Why are they found at such small elongations? Not only do comet hunters concentrate their searches on areas near the sun, but comets generally become brightest in those regions.

DECEMBER 1998: Williams, Jager and Tucker are all now eligible for the Wilson Comet award. Each amateur used a different methods to find "their" comets: visual, photographic and CCD.

JANUARY 1999: Father Leo Boethin of the Philippines passed away on Sept.15. He was the discoverer of Periodic Comet Boethin (85P/) on Jan. 4, 1975. It orbits the sun every eleven years.

FEBRUARY 1999: **In which month do amateur astronomers visually discover the most comets**? Of the 79 comets found in the past 24 years, 12 were found in July while 10 were found in January. In last place is both February and April with three finds each.

MARCH 1999: Five of the last seven visual discoveries (covering 2.5 years) have been made by Southern Hemisphere observers, all from Australia, and all five comets being found south of the celestial equator. Two were accidental finds (by Williams and Tilbrook), with Tilbrook then finding one more and Tabur finding two.

APRIL 1999: Of the 79 visual comet discoveries since 1975, 30 (38%) have been made in the first half of the year, with 49 finds in the second half. Subdividing the year into quarters, the first quarter has 18 discoveries, the second has 12, the third has 26 and the last three months of the year yields 23 finds.

Don's Comet Hunting Hours:

Comet Hunting Hours 1975-1998: 6468.00

Hours January through February 1999: 26.25

Total hours at last discovery (10-8-94): 5589.00

Least hours in any month since he began comet hunting on 1/1/75: 4.00 (02/98), 4.50 (01/86), 5.50 (02/80)

Most hours in any month since he began comet hunting: 69.25 (05/76), 63.00 (05/78)

These notes are taken from Comet Comments by Don Machholz, which is published on the Internet.

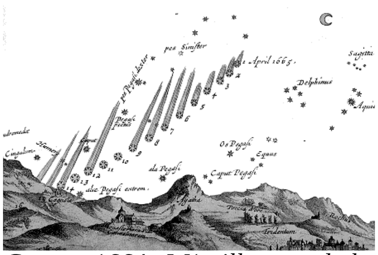
A Brief History of Comets I (until 1950)

The following text is taken from the ESO web page and is adapted from a major review on Comets, prepared by Michel C. Festou (Observatoire Midi-Pyrenees, Toulouse, France), Hans Rickman (Astronomiska Observatoriet, Uppsala, Sweden) and Richard M. West (European Southern Observatory, Garching, Germany) and published in the review journal Astronomy & Astrophysics Reviews (A&AR) (Part I, Vol. 4 pp. 363-447, 1993)

The present account deals with the period up to around 1950. It includes some references to major papers in this period (by author of year of publication), but the original version of this review in Astronomy & Astrophysics Reviews must be consulted for the full details about these.

Introduction The history of cometary astronomy is naturally divided into five major periods, the transitions being marked by important new insights. Before 1600, comets were essentially considered to be heavenly omens and were not yet clearly established as celestial (astronomical), rather than meteorological phenomena in the terrestrial atmosphere. Then followed two centuries of mostly positional measurements with emphasis on the motions and the orbits, lasting until the early 19th century, when the era of cometary physics was inaugurated, in particular by the passage of P/Halley in 1835. The next major step forward occurred in 1950 with the sudden emergence of the modern picture of comets as being essentially very old solar system objects made of primordial ice and dust, generally in unstable orbits and intensively interacting with the solar electromagnetic and corpuscular radiation. Finally, the space missions to P/Giacobini-Zinner in 1985 and especially to P/Halley in 1986 provided the first in situ observations of comets and dramatically widened our scientific horizon, but also posed many new questions which are yet to be answered.

Before 1950: The main events The word comet, now used in all European languages, comes from Greek (kometes= `the hairy one'), but the earliest extant records of cometary observations date from around -1000 in China and probably from about the same time in Chaldea (on the territory of present-day Iraq). Ideas about the true nature of comets are available from the time of the rise of Hellenistic natural philosophy at about -550 when the Pythagoreans considered comets to be a kind of (wandering) planets that were seen rather infrequently and mostly near the horizon in the morning or evening sky. Aristotle in his Meteorology (ca. -330) relegated comets to the lowest, `sublunar' sphere in his system of spherical shells and described them as `dry and warm exhalations' in the upper atmosphere. There is no mention of comets in Ptolemy's Almagest, presumably because they were not considered of celestial origin, but he described them in astrological terms in his Tetrabiblos. The Aristotelian view on comets was dogmatically upheld during the following millennium; the first doubts seem to have been expressed by Thomas Aquinas and also by Roger Bacon in his Opus Tertium from 1267, but like their predecessors they strongly believed comets to be evil omens.



Comet 1664 W1 illustrated by Stanislaw Lubieniecki in the Theatrum Cometicum, published in 1667. Observations of it lead to many advances in cometary science. It also presaged the plague of London.

Finally, Paolo Toscanelli observed P/Halley in 1456 and several other comets between 1433 and 1472 with improved accuracy, inaugurating the renaissance of European observational astronomy after the long period of dormancy. The decisive demonstration was delivered by Tycho Brahe (and confirmed by a few other observers, especially Michael Mästlin), on the basis of extensive observations of the bright comet which first appeared in late 1577. He showed that the horizontal parallax of this comet was certainly smaller than 15 arcmin, corresponding to a distance in excess of 230 Earth radii, or four times the distance to the Moon. The question of how comets move arose as a natural consequence and in 1610, the amateur Sir William Lower proposed that they do so in very elongated ellipses, while Robert Hooke and Giovanni Borelli suggested that cometary orbits may be parabolic. Georg Dörffel was the first to specifically state that the two bright comets seen in 1680 and 1681 are one and the same before and after its perihelion passage, and that it moved along a parabola with the Sun in the focal point. Isaac Newton in Principia (1687), applied his new theory of gravitation to show that the 1680 comet moved in an elliptical, albeit very nearly parabolic orbit and that it passed only about 0.0016 AU above the surface of the Sun. Edmond Halley (1705) computed the orbits of a dozen well-observed comets and demonstrated the periodical nature of the bright comet of 1682. `Halley's Comet', as it was from now on called, was telescopically recovered in December 1758 by Johann Palitzsch; this proved conclusively the validity of Newton's law of gravity out to the distance of the aphelion at 35 AU, more than three times the distance of Saturn, the outermost planet known at that time.

18th century cometary astronomy is characterised by the gradual development of improved methods for orbital computations and at the beginning of the 19th century, this had become a straightforward, if still somewhat arduous task, in particular when planetary perturbations were taken into account by means of iterative corrections. Some basic features of the orbital distribution of comets were established, e.g. the extremely broad range of orbital periods, over which the different objects are scattered. While some comets turned out to have orbits virtually indistinguishable from parabolas, others were confined to the inner solar system in the vicinity of Jupiter's orbit or inside of it. As time passed, a concentration of comets moving in similar orbits with fairly low inclinations and with aphelia close to Jupiter's orbit became more and more obvious; this concentration became known as the Jupiter family. It either called for a continuing ejection from Jupiter or for a mechanism of dynamical evolution, called `capture', whereby the comets would become concentrated into such orbits. It was realized that comets in general, and Jupiter family members in particular, suffer by far the largest orbital perturbations due to the action by Jupiter, and the restricted three-body problem (Sun-Jupiter-comet) therefore offered an interesting approximation for the study of their dynamical behaviour.

After Halley, Johann F. Encke was the second to successfully predict the return of a comet (in 1822) which as a consequence now carries his name. It turned out to have, and still has, the shortest period of all known comets, 3.3 years, and it was soon found to arrive systematically about 0.1 days earlier at perihelion than predicted, even when taking all planetary perturbations into account. Inspired by his observations of an asymmetric distribution of luminous matter in the head of P/Halley in 1835, Friedrich W. Bessel interpreted this as a Sun-oriented asymmetric outflow and suggested that a non-gravitational effect might arise due to the rocket-type impulse imparted by such an outflow. As a consequence, such perihelion shifts as observed for P/Encke might arise.

During the next decades, progressively more sophisticated instrumentation became available and the road was opened for a more physical approach to the study of comets. Comet tails were explained by Heinrich W.M. Olbers (1812) and Bessel (1836) by assuming that they were made of solid particles on which was acting a repulsive force directed anti-sunward. The close connection between comets and meteors was demonstrated by Giovanni Schiaparelli (1866, 1867) who found that the orbits of the Perseid and the Leonid meteor streams coincide with those of comets P/Swift-Tuttle (1862 III) and P/Tempel-Tuttle (1866 I), respectively. In 1835, P/Halley became the first comet in which detailed structures were extensively observed, in particular by John Herschel, Bessel and Friedrich G.W. Struve, who described jets, cones and streamers, cf. the Atlas by Donn et al. (1986). This led Bessel (1836) to postulate the ejection of material in the direction of the Sun which was then somehow forced back in the opposite direction by an unknown repulsive force. Feodor A. Bredikhin (quoted by Jaegermann, 1903) further developed this interpretation into the Bessel-Bredikhin' mechanical model which remained in use until the late 1950's. Sir Arthur Eddington (1910), introduced the fountain model of particle ejection in which the parabolas represent the outer envelopes of particle trajectories emitted from the sunlit hemisphere of the nucleus or surfaces of high density of matter. One of the repulsive forces acting on the dust was identified by Svante Arrhenius (1900) as the radiation pressure by sunlight. The corresponding theory was further developed by Karl Schwarzschild (1901) and extended to molecules by Peter Debye (1909).

The Section archives contain many reprints, some dating back to the early 19th century. This drawing of comet Donati was made by G P Bond on 1858 October 2 using the great refractor at Harvard Observatory and is from the Mathematical Monthly of December 1858.

The first spectroscopic observations of comets were made by Giovanni Donati (1864) and by Sir William Huggins (1868) who visually compared the spectrum of comet Winnecke (1868 II) with flame spectra and found that the bands seen in the comet and in the flame, now known as the `carbon' or `Swan bands', were similar. Subsequent observations showed that these bands were present in all comet spectra and that carbon was therefore an important constituent of comets. Spectroscopy soon became the standard technique for studying the light of comets and new emissions were discovered at an increasing rate; Baldet (1926) published a detailed description of the spectra of about 40 comets, obtained since 1864, together with a complete bibliography of all comets observed until that time by spectroscopy. Schwarzschild and Kron (1911) studied the intensity distribution in P/Halley's straight tail during the 1910 passage and suggested that the emission could be explained by the effect of absorption of solar light, followed by re-emission, i.e. fluorescence. Polydor Swings (1941) solved the long-standing problem of why the violet CN bands (3875 A) in cometary spectra did not resemble CN laboratory spectra and varied in appearance: because of the crowding of absorption lines in the solar spectrum, the intensity at the exciting wavelengths critically depends on the doppler shift caused by the comet's motion relative to the Sun and so determines the strength of the fluorescence emission lines in the comet's spectrum; this is now known as the Swings effect.

1950 - 1951: Two crucial years

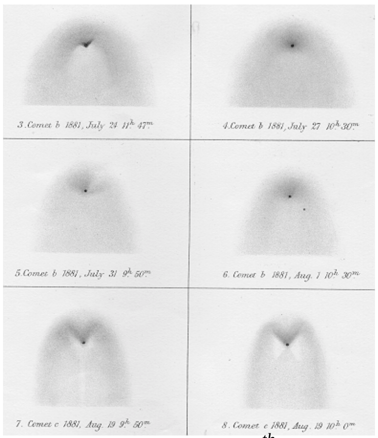
A major revolution in cometary science took place in 1950-51, with the formulation within a short time span of three fundamental ideas: 1) the icy conglomerate (`dirty snowball') model of the cometary nucleus by Fred Whipple (1950), 2) the identification from kinematic studies of the existence of a distant reservoir of comets, now known as the Oort cloud, by Jan Hendrik Oort (1950), and 3) the explanation of the motions in cometary plasma tails as due to interaction with the solar wind by Ludwig Biermann (1951). Interestingly, none of these ideas resulted directly from new observational evidence, and important parts of them had been proposed earlier, but it was the first time that the known facts were effectively combined to reveal the new picture.

The icy conglomerate nucleus

Karl Wurm, in a series of enlightening papers published between 1932 and 1939, suggested that, because the observed cometary radicals and ions are not chemically stable, these species must be created by pure photochemistry of more stable molecules residing inside the nucleus, cf. for instance the reviews by Wurm (1943) and Swings (1943). In the 1940's, Swings contributed significantly to the development of ideas along Wurm's line of thinking and his key role appears to have been overlooked in the later literature. The presence of CO, C2N2, CH4, CO2, N2 and NH3 was invoked on the basis that CO+, CN, CH, CO2+, N2+ and NH were identified in comet spectra, respectively. Swings proposed many possible and reasonable candidates as parent molecules, among others CH4 since CH2 was held responsible for the emission recorded in the 4000-4100 A interval, as well as H2O, following the discovery of the OH 3090 A ultraviolet emission in 1941 by Swings, and despite the fact that the low vapor pressure of water was considered a serious problem when explaining the observed presence of the OH emission far from the Sun. In 1948, he came very close to actually proposing an icy model for the nucleus by suggesting that the mentioned molecules could exist in the solid state in the nucleus.

Swings (1942) also suggested that molecules similar to those found in meteorites were possibly stored in the nucleus by occlusion. This idea was quantitatively (and most probably, independently) explored by Boris Yu. Levin (1943), who developed the desorption theory of outgassing from the surface of meteoritic material to demonstrate that his sand bank model for the nucleus had a solid basis. However, although the average desorption heat, about 6000 cal/mole, as deduced empirically from the observed brightness/heliocentric distance relation, was in agreement with the laboratory values for the cometary molecules mentioned above, the amount of material that could be desorbed from a sand bank with an expected cometary mass fell far short of explaining the persistence of comae over several months at single passages, or indeed, the survival of comets like P/Halley or P/Encke for many apparitions.

Since the mid-19th century, a great deal of research had concentrated on understanding the nature of the central source of gas and dust in comets. Transits of comets across the solar disk had never shown any dark silhouette, proving the absence of any extended, optically thick object. Seeing-limited observations of comets passing near the Earth showed a central, unresolved light source of dimensional upper limits in the 10-100 km range (Nicolaus B. Richter, 1963). Upper limits to cometary masses had been estimated for instance from the absence of evidence for mutual gravitational attraction of the components of P/Biela in 1846 or of any influence on the Earth's orbit at very close passages like that of P/Lexell in 1770; in the end, masses in the 1012 - 1017 kg range were estimated (Whipple 1961). Comets were obviously small and light bodies, possibly even without a solid nucleus at the center. At the end of the 1940's, the nature of the nucleus was still a subject of much speculation and no consensus had been reached. In an attempt to put together all known facts about the cometary nucleus, and with particular attention to the long-standing problem of explaining the non-gravitational perihelion shifts, Whipple (1950, 1951) laid the foundations for the model of an icy conglomerate, solid nucleus. Building on the idea dating back to Pierre S. de Laplace (1813) and Bessel (1836), Whipple described the nucleus as a mixture of ices from which the gases in the coma are produced by sublimation in increasing quantities as the comet approaches the Sun and the nucleus surface temperature rises, and meteoritic dust that is released from the nucleus when these ices evaporate. This model had the virtue of explaining at once several observed features: 1) the large gas production rates, for which the desorption model was totally inadequate, 2) the observed jet-like structures in the coma and the erratic activity, impossible to produce if the nucleus were a cloud of particles, 3) the observed non-gravitational forces by means of momentum transfer by the outflow of gas from the nucleus, the net effect on the orbital motion being dependent, among others, on the sense of the nuclear spin and the direction of the spin axis, 4) the fact that most comets which pass extremely close to the Sun, e.g. the Kreutz sungrazing group, apparently may survive such approaches intact and with little change after perihelion, and 5) the fact that comets are the sources of meteor streams. Items 2-4 gave particularly strong arguments for a solid nucleus rather than a sand bank structure.



Many of the late 19th century comets showed intricate structure near to the nucleus. These illustrations of 1881 K1 and 1881 N1 were made by Otto Boeddicker using the 3 foot reflector of the Earl of Rosse at Birr Castle, which is perhaps better known for deep sky observations. This reprint is from the Scientific Transactions of the Royal Dublin Society for August 1882.

The Whipple model quickly won general acceptance and was gradually refined during the following decades. It had, however, some shortcomings; the main one was pinpointed by Whipple himself as being the large difference between the latent heats of vaporization of the various ices. As a consequence the highly volatile material should be rapidly removed from the surface layer of the nucleus long before perihelion, in contradiction to the observation of radicals and ions like CH and CH+ near the Sun. This objection was tentatively removed when Armand Delsemme and Swings (1952) noticed that almost all parent molecules (except NH3) required to explain the observed radicals and ions in comets could co-exist in the nucleus in the form of solid clathrate hydrates. In this way, the highly volatile material does not disappear too rapidly and is also freed together with less volatile molecules; this explains why the spectrum remains more or less similar throughout the comet apparition.

The Oort Cloud Many orbital studies of individual comets with particular attention to the influence of planetary perturbations were carried out at several observatories during the first decades of the 20th century. They were naturally followed by statistical considerations about the distribution and dynamical origin of comets, including the question of whether or not some comets have `original' hyperbolic orbits (reciprocal semi-major axis 1/aorig < 0) and are therefore of interstellar origin. The work at the Copenhagen Observatory by Elis Strömgren (beginning in about 1910) and his associates is typical of such studies and showed the absence of originally hyperbolic orbits, all observed orbits of this type having been caused by planetary perturbations. Sinding (1948) produced a list with the values of 1/aorig for 21 long-period comets which together with the work by van Woerkom (1948) formed the basis for Oort's famous paper (1950) on the existence of a cometary reservoir in the outer reaches of the solar system. The idea of a cloud of distant hypothetical comets, stable against stellar perturbations, and its necessity in case many observed comets would have 1/aorig 10000 AU, had been expressed earlier by Ernst J. Öpik (1932).

Based on van Woerkom's (1948) theory of the orbital diffusion caused by planetary perturbations, Oort found that the number of comets with very small values of 1/aorig is much larger than one would expect, when comparing with the neighbouring, long-period elliptical orbits. This suggested that many of the comets become unobservable after their first passage through the inner solar system. In a subsequent study, Oort and Schmidt (1951) distinguished between `new comets' (those coming directly from the Oort cloud, making their first visit near the Sun) and `old comets' (those returning on elliptic orbits). The former appeared to be dustier and brighten more slowly than the latter. These tentative conclusions have later been revisited and modified, and the role of stellar perturbations in providing new comets has been reconsidered. However, the basic concept of the Oort cloud as an outer halo of the solar system has been substantiated by later studies, based on improved samples of cometary orbits.

The solar wind The tails of comets have been the objects of many investigations. It is exactly these appendices that make comets so impressive to the layman, and astronomers of all times have been struck by the fact that the tails may vary so dramatically from one object to another. In the early 20th century, perhaps the strangest characteristic was the enormous repulsive force found to act on straight comet tails in the anti-solar direction.

Already in 1859, Richard Carrington (1859) suspected a physical connection between the major solar flare observed in the morning of Sept. 1, and enhanced magnetic activity on the Earth some hours thereafter. Ideas about the possible existence of a stream of particles from the Sun, perhaps electrically charged, emerged towards the end of the 19th century, in particular to explain the excitation of molecules and ions observed in cometary comae. It was also found that cometary ion tails (formerly Type I) develop closer to the Sun than dust tails (formerly Type II). However, it was only 50 years later that Cuno Hoffmeister (1943) provided the crucial observations of a gas tail aberration of about 6o, i.e. the angle between the observed tail and the anti-solar direction. This was correctly interpreted by Biermann (1951) in terms of interaction between the cometary ions in the tail and the solar wind, a stream of electrically charged particles from the Sun with velocities of several hundred km/sec. His derived plasma densities were unrealistically high, since electrons were thought to accelerate the cometary ions, but Hannes Alfven (1957) settled this problem by introducing the notion of an interplanetary magnetic field which is carried along with the solar wind. Its existence was soon thereafter confirmed by experiments onboard some of the first spacecraft launched after the space age opened in late 1957 (Lunik I and II, Explorer X, Mariner II, etc.). Still, for quite some time, cometary ion tails were the only well-distributed solar wind probes in interplanetary space and they remain so outside the ecliptic. Another important result of Alfven's study is that an ion tail must be considered as part of the comet since it is magnetically connected to the cometary head.

To be continued