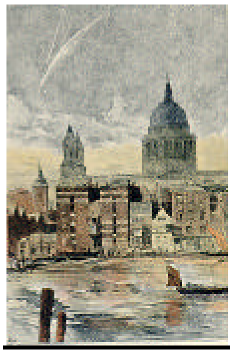

THE COMET'S TALE

Newsletter of the Comet Section of the British Astronomical Association

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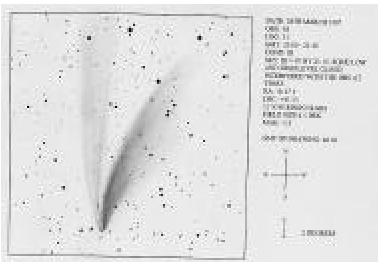
A Brief History of Comets II (1950-1993)

The following text 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)

This is the second part of a brief historical review, covering the period from 1950 to 1993, i.e. until just before the crucial years 1994-1997 that saw the impact of Comet Shoemaker-Levy 9 on Jupiter (1994), the apparition of Comet Hyakutake that passed only 15 million km from the Earth (1996), as well as the bright Comet Hale-Bopp that was discovered in 1995 and put on a marvellous display when it passed perihelion in early 1997. 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.



Hale-Bopp 1997 March 28 Robert Bullen

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.

1952 - 1984: The modern era Following the break-throughs in 1950-51, the entire concept about comets had to be revised. This process was a gradual one, as new observational facts were collected, and also because these observations were becoming increasingly quantitative, allowing a progressively more detailed verification of the new ideas. Although number density estimates for cometary comae had been derived since the time of Wurm's investigations in the 1930's, the figures obtained were rather uncertain and their reliability was limited by the lack of quantitative studies about the excitation mechanisms of the light. Thus it is not too surprising that, continuing the earlier investigations by Swings and McKellar, most spectroscopic studies between 1950 and 1970 were devoted to a never-ending attempt at discovering and identifying new emission lines and bands, as well as at unraveling the structure of the rotational and vibrational bands of the comet radicals and ions. A special reference must here be made to the numerous and important contributions from the Liege school, reviews of which are given by Swings (1956) and Arpigny (1965). During this epoch rather complete models were made of the fluorescence of the CN, CH, OH, and C_2 radicals. The advent of high resolution spectroscopy in the late 1950's allowed the identification of many unknown lines, most of which were due to C_2 and NH_2. It is worth mentioning here that this effort has never been carried through to completion and many observed cometary spectral lines have still not been assigned an emitter; the most likely are CO^+, CO_2^+ and C_3 in the near-UV, C_2 and NH_2 in the optical and NH_2 and H_2O^+ in the IR.

The following Sections, divided according to the main areas of investigative thrust during this period, illustrate how cometary research over the most recent decades has vindicated the ideas put forward in 1950-51.

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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 write this introduction on my way home from Antarctica at the end of March. My visit this year was a relatively short one, and my work went very smoothly. With it approaching autumn in Antarctica the nights became darker and longer throughout my stay. Although a generally cloudy summer, we did have a few clear nights in which to experience the grandeur of the southern skies. Surprisingly light pollution is a problem about the station, as there are a number of badly designed floodlights which create considerable glare. However once you are over a bluff overlooking the station the skies are truly dark, the milky way is bright enough to cast shadows and on most moonless nights the faint glow of the diffuse aurora is visible to the south. Unfortunately there were no comets to observe, but I was able to spend time on the voyage north typing in the some more archival observations from TA for 1980 to 1989. This was over 2200 observations, bringing the total number up to over 28,000.

My success in discovering one SOHO comet was followed by two more before my departure for the Antarctic. The first of these was a faint non Kreutz group object, whilst the second was a moderately bright Kretuz group member. This discovery prompted Michael Oates to have a go and he soon spotted one, though it turned out to have already been discovered. Nothing daunted he has continued searching and has found several more, including a couple in archived SOHO observations. On my return from Antarctica I found another whilst in the process of compiling material for this issue of The Comet's Tale.

Comet LINEAR 1999 S4 offers the hope of a naked eye comet over the summer. Do make every effort to observe it, but when you send the observations up please try to submit them by email in either the ICQ format to me or the TA format to Guy. Try to get it exactly right as we both have more than enough to do without having to edit observations. There is a template for both formats on the section web page, so copy this if you are uncertain. Don't worry if you don't have email – paper copy is still acceptable, but send your observations to me as the program that I use to enter the archival data allows me to quickly enter more recent observations.

I hope to have the Section guide on comet observing reprinted during the autumn. If anyone has suggestions for additions or other improvements do let me know. The Tycho catalogue is the best source of magnitude information and this has recently been upgraded and now has fainter stars than in the first edition. I have added a section on reporting discoveries, as it is important to follow the correct steps if you think you have made one. I plan to drop the CCD and photographic reporting forms because no-one has ever used them.

I would like to develop a standard for submitting CCD images in order to make it easier to archive images from many observers. The standard needs to allow for the name of the comet, the name of the observer, the date and time of the image, the telescope and camera details, the scale of the image and different image types (gif, jpeg etc). It is good practice to include much of this information on the image, but if this is not possible an auxiliary file may be needed.

A possible suggestion would be to name image files as comet_yyyymmddl_obs.img and auxiliary files as comet_yyyymmddl_obs.txt, where comet is the comet identifier, yyyymmdd is the date, l the image number taken by the observer on that date, obs the first three letters of the observers surname, and img the image format. As an example 1999s4_19991128a_mob.jpg would be the first jpeg image that Martin Mobberley took of 1999 S4 on that date and if he felt that further information was needed there would be a supporting file 1999s4_19991128a_mob.txt. The second gif image of 141P/Machholz 2 by David Strange on the same date would be 141p_19991128b_str.gif. The advantage of the sequence comet_date_observer is that it allows sequential sorting. I have canvassed opinion from regular imagers, but other comments are welcome.

Since the last newsletter observations or contributions have been received from the following BAA members: Len Entwisle, Werner Hasubick, Guy Hurst, Nick James, Martin Mobberley, Michael Oates, Gabriel Oksa, Roy Panther, Jonathan Shanklin, David Storey, David Strange, Cliff Turk and Alex Vincent

and also from: Jose Aguiar, Alexandr Baransky, Nicolas Biver, John Bortle, Jean-Gabriel Bosch, Reinder Bouma, Nicholas Brown, Paul Camilleri, Jose Carvajal, R Ferrando, Stephen Getliffe, Bjorn Granslo, Andreas Kammerer, Heinz Kerner, Atilla Kosa-Kiss, Martin Lehky, Rolando Ligustri, Maik Meyer, Antonio Milani, Andrew Pearce, Stuart Rae, San, Seg, Oddleiv Skilbrei and the Ageo Survey Team (KenIchi Kadota and Seiichi Yoshida) (apologies for any errors or omissions). Without these contributions it would be impossible to produce the comprehensive light curves that appear in each issue of *The Comet's Tale*.

Comets under observation were: 4P/Faye, 10P/Tempel 2, 37P/Forbes, 50P/Arend, 59P/Kearns-Kwee, 74P/Smirnova-Chernykh, 63P/Wild 1, 84P/Giclas, 106P/Schuster, 114P/Wiseman-Skiff, 141P/Machhol 2, 1995 O1 (Hale-Bopp), 1997 BA6 (Spacewatch), 1999 E1 (Li), 1999 H1 (Lee), 1999 H3 (LINEAR), 1999 J2 (Skiff), 1999 J3 (LINEAR), 1999 K8 (LINEAR), 1999 L3 (LINEAR), 1999 N2 (Lynn), 1999 S3 (LINEAR), 1999 S4 (LINEAR), 1999 T2 (LINEAR), 1999 T3 (LINEAR), 1999 U1 (Ferris), 1999 U3 (P/LINEAR), 1999 U4 (Catalina-Skiff), 1999 XS87 (P/LINEAR), 1999 Y1 (LINEAR).

Many of the fainter comets were observed by the AGEO team of KenIchi Kadota and Seiichi Yoshida who are using a CCD camera on an 18 cm reflector to very good effect. I hope to begin using the Cambridge Observatories 3-mirror telescope designed by Roderick Wilstrop for some astrometric and photometric observations over the coming months and so may be able to contribute some observations. Perhaps the Supernova searchers would like to add the odd comet to their list - they might discover one in outburst!

Jonathan Shanklin

Tales from the Past

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

150 Years Ago: A large number of astrometric observations of Gambart's (Biela's) comet from the Cape of Good Hope were published in November. [Biela actually discovered it ten days before Gambart] T Maclear comments in his notes "This comet is perhaps the most interesting on record, on account of the appendage, which was probably a portion of the original mass." [The comet had split just before its 1845 return, and its next return was its final one, though remains were seen in the form of meteors for another 50 years or more.] In January a paper by J R Hind on the past history of Halley's comet was published. Here he traced past apparitions of the comet and made new links for several apparitions, including that of 1066. In March Mr Hind informed the Society about computations on the comet of 1264 and 1556 which was thought due to return. He had computed search ephemerides, but on hearing from Mr Hind that recent calculations suggested a delay in the return of several years, the Editor did not publish them. In April Norman Pogson gave a note about the comet observed by Pons in Marseilles in 1818. He noted that the elements computed from three positions were almost identical to those of a comet seen in 1772, which was supposed to have been that of Biela. [The comet of 1772 was Biela's, but that of 1818 was Crommelin's].

100 Years Ago: The November Journal has a note: Biela's Comet - The discovery of this comet was reported from Santiago, Chile at the end of October, but no confirmation has been obtained of the report, and no credence should be attached to it. In December John Tebbutt wrote to say that he had made astrometric measurements of 10P/Tempel 2 on 43 nights, which he hoped would be useful in determining the mass of the giant planet Jupiter. No 5 has a list of comets seen since 1889 compiled by A C D Crommelin. Interestingly only the periodic comets were "named". He did not include the comet seen at the total eclipse of 1893 April 16 as it was not seen again.

50 Years Ago: The December Journal includes a review of "Comets in Old Cape Records" by Donald McIntyre. At the January meeting Dr Merton spoke about comets. 1949 had been a quiet year, particularly the second half when only two observations were received. The March Journal has a paper on "The Statistics of Comet Orbits" by Harley W Wood. He concluded: 1) 77% of comets have parabolic orbits. 2) No comets have certainly hyperbolic orbits on approach to the Sun. 3) None have hit the Sun. [No longer true, I discovered another one that did shortly before I compiled these notes!] 4) The elements, particularly a and e are affected by planetary perturbations. 5) Comets are subject to wastage. 6) Their origin and history must account for the presence of volatiles.

A Brief History of Comets II (1950-1993)

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The ultraviolet, infrared and radio windows were explored in the early 1970's, the emissions of H I, O I and OH were observed and the dissociation products of the main volatile constituent of the nucleus were finally detected observationally. The first radar detection of a comet in 1980 (P/Encke, Kamoun et al. 1982), and the first recording of an image of a comet nucleus in 1986 convinced the last sceptics that Whipple was correct. From refined studies of the orbital motion of comets it was demonstrated that Oort's distant reservoir was fully justified, even though some shortcomings of the theory are only now being overcome and have led to new and exciting developments. Above all, however, a wealth of quantitative data became available, making truly comparative studies of comets possible. In a not too distant future this should enable us to learn whether the differences we observe between individual comets are the results of evolutionary processes or rather reflect intrinsic diversity.

Water as the main constituent of comets In 1958, high resolution spectroscopy allowed the separation of the terrestrial oxygen lines from the cometary ones and also led to the definitive confirmation of the presence of the isotopic lines of 13C, long suspected to be present in comets. The detection of the [O I] red lines in comet Mrkos (1957 V) (Swings and Greenstein 1958) created a completely new problem: it was soon shown by Wurm (1963) that if fluorescence is at the origin of the emission, then very large amounts of oxygen are implied, much larger than those of for instance C2. It seemed preferable to assume another emission mechanism and Wurm proposed corpuscular excitation. The idea that some coma species may be produced directly into an excited state can be traced back to McKellar (1943), but this suggestion was not explored in detail until 1964 (Biermann and Trefftz 1964). Their work led to the prediction that photodissociation of parent molecules is the main production mechanism and that not only oxygen but also hydrogen atoms must exist in large amounts in comets, with resulting production rates of e.g. log Q (mol s-1) ~ 30 for a bright comet, or much larger than those of the parents of CO+, CN or C2. In some sense, the discovery in 1970 by the Orbiting Astronomical Observatory (OAO-2) and the Orbiting Geophysical Observatory (OGO-5) of huge Lyman-alpha haloes of neutral hydrogen (1.5 x 107 km) around comets Tago-Sato-Kosaka (1969 IX) and Bennett (1970 II) did not come as a complete surprise. However, the origin of these hydrogen atoms was not yet known with certainty.

While the OH emission band at 3090 AA was first identified in comet Cunningham (1941 I) by Swings, the first quantitative OH abundance measurements only date from the early 1970's (Code et al. 1972; Blamont and Festou 1974; Keller and Lillie 1974). The analysis of the Lyman-alpha isophotes of comet Bennett (1970 II) revealed that the velocity of the H-atoms was about 8 km s-1 (Bertaux et al. 1973). Following an investigation of the photolysis of water molecules by sunlight, this led these authors to speculate about the possibility that the majority of the observed H-atoms were coming from the dissociation of OH radicals. To prove this assertion, Blamont and Festou (1974) measured both the then unknown scalelength of OH and the production rate of that radical in comet Kohoutek (1973 XII). They proposed for the first time, on a quantitative basis, that water was the parent of most of the hydrogen atoms and the OH radicals. Horst Uwe Keller and co-workers reached similar conclusions in a series of independent papers: Keller (1971) discussed the possibility that the observed H-atoms in comet Bennett might arise from the direct dissociation of water and later (Keller 1973a, 1973b) developed these ideas further. His investigation though, as well as that of Bertaux et al. (1973), was limited by the fact that the parameters governing the water photolysis were not well known at that time. Keller and Lillie (1974) also measured the scalelength of OH (in comet Bennett) and found a value in complete agreement with that found for comet Kohoutek. The definitive clue that H2O was the main source of both the H-atoms and the OH radicals came when the velocity of the H-atoms was measured directly from COPERNICUS observations (Drake et al. 1976) and, indirectly, from the analysis of H I Lyman-alpha observations (cf. the review by Keller 1976), and was found to be compatible with the water photolysis scheme. This was confirmed by the direct observation of water in P/Halley in 1986.

After the discovery of the 18 cm maser emission of OH (Biraud et al. 1974; Turner 1974), OH radio observations became routine and the evidence for the ubiquitous presence of water in comets was overwhelming. The emission of an unknown ion was observed in comet Kohoutek (1973 XII) by Herbig (1973) and Benvenuti and Wurm (1974). Herzberg and Lew (1974) had just obtained the first laboratory spectra of the H2O+ ion and tentatively identified this ion as the source of the new cometary emission. The same emission was later found in cometary spectra recorded as early as 1942 (Swings et al. 1943). Although the water ion might be an abundant species in comet tails, its presence there is not conspicuous: this is a clear indication that the ion is lost rapidly, unlike the other tail ions. Aikin (1974) showed that the main loss mechanism is a charge exchange reaction with water molecules leading to the formation of the H3O+ ion, and this latter is likely to be destroyed in electron recombination reactions. H3O+ was indeed found to be one of the main ions in the comae of P/Giacobini-Zinner and P/Halley.

Quantitative studies and comparative cometology Many parameters for the OH radical were derived from radio observations at 18 cm. The detailed mechanism by which comets emit photons at that wavelength was investigated by Despois et al. (1981). The methodology for determining OH velocity profiles was worked out by Bockeee-Morvan and Gerard (1984). An overview of the production rate and velocity determinations is given by Bockelee-Morvan et al. (1990). Beginning with comet Bradfield (1979 X), a long series of high quality observations of the UV spectrum of comets was obtained by the International Ultraviolet Explorer (IUE), from which a self-consistent set of water production rates was derived (e.g. Festou and Feldman 1987). The radio and UV determinations of these rates do not agree perfectly, because the models used in the interpretation of the data differ markedly. Schloerb (1988) and Gerard (1990) have discussed this problem.

The 1970's saw the development of quantitative observations of comet emissions, mainly by means of narrow-band photoelectric filter photometry through diaphragms encompassing a more or less large part of the coma. A review of the early observations and the observing techniques is given by A'Hearn (1983). One of the shortcomings of standard photoelectric photometry is the contamination by an underlying continuum and by gaseous emissions in the wings of the spectral transmission curve defined by the filter. It was therefore not surprising that spectrophotometry developed rapidly in the early 1980's when linear detectors and image intensifier tubes became available; see the review by A'Hearn (1982). This method provided both a good separation of the band or line emissions and also spatially well-resolved information about the distribution of coma species. In parallel, numerous theoretical studies, aimed at calculating the fluorescence efficiencies of the coma radicals and ions, resulted in the establishment of reliable conversions of observed surface brightness into column densities of the different species. The last step in the data analysis process is then the derivation of gas production rates.

The data accumulated during the last 20 years or so by many dedicated observers, using both ground- and space-based instruments, have made possible the comparison of the relative abundances in comae of different comets. As direct sources of detailed information and for additional references on this subject as well as the radio OH measurements quoted above, we refer the reader in particular to the papers by A'Hearn and Millis (1980), Cochran (1987), Newburn and Spinrad (1989) and Osip et al. (1992). A list of all individual observations made with the IUE until late 1989 and a discussion of the resulting comparative cometology have been published by Festou (1990). The most striking observational fact is that, at first sight, all comets look alike (Cochran 1989). There are just a few well-known objects for which the chemical composition of the coma departs notably from that of an average comet, e.g. a few CO+ rich comets or those that seem to contain only one or a few of the actual compounds of comet comae. For instance, P/Giacobini-Zinner is C2 and C3 depleted (Cochran 1989), while comet Yanaka (1988 XXIV) seems to be made almost exclusively of NH2 and water (Fink 1992). As suggested by the direct inspection of optical (Swings 1948) and UV spectra (Festou 1990b), the main difference between individual comets is the continuum to gas emission ratio. Observations of P/Halley in 1986 added an interesting piece to the puzzle: CO and some other observed gases require an extended source in the coma. A key issue is now to determine the relationship between this source and the dust particles. The general picture beginning to emerge is that all comets basically have similar molecular abundances and that the observed differences might only reflect a variable dust to gas production ratio. It remains to be determined whether this ratio is an intrinsic property or the result of an evolutionary (i.e. ageing) process.

Dynamical evolution From the point of view of cometary dynamics, the modern era is first of all distinguished by the advent and development of efficient and powerful computers. This allowed, for the first time, extensive numerical simulations of the orbital evolution resulting from repeated close encounters with Jupiter and other planets. It also revolutionized the work on orbit determination and linkage of past apparitions for observed comets as well as the preparation of ephemerides for upcoming apparitions, even for long-lost comets.

Whereas Oort had been working on a small sample of comets to build his theory, Marsden et al. (1978) improved the earlier statistics by using 200 well-determined long-period orbits. They found a concentration of inverse semimajor axes corresponding to an average aphelion distance of about 45,000 AU, only about half as remote as Oort's original distance. A major problem remained the apparent overabundance of Jupiter family comets. Edgar Everhart (1972) found a possible route of direct transfer from the Oort cloud via Jovian perturbations at repeated encounters with the planet, beginning with a special type of initial orbits with perihelia near Jupiter's orbit and low inclinations. However, some authors questioned the efficiency of this transfer or the fit of the orbital distribution of the captured comets. An alternative scenario came from orbital integrations of the observed comets by Elena I. Kazimirchak-Polonskaya (1972): the comets might not be captured by Jupiter alone, but rather by a stepwise process involving all the giant planets.

The ideas about the long-term dynamics of the Oort cloud evolved considerably. While passages of individual stars were mostly considered in earlier investigations, the tidal effects of the Galaxy as a whole, preliminarily modelled by Chebotarev (1965), have become recognized in recent years as the prime mechanism to provide new comets from the outer cloud. The dramatic effects that might follow upon close encounters with massive perturbers, such as giant molecular clouds (Biermann and Luest 1978), also received a great deal of attention. In particular, the question of the stability of the outer, classical regions of the Oort cloud over the age of the solar system has been debated.

A major step forward taken during this period dealt with the modelling of nongravitational effects in cometary motions. Based on Whipple's concepts, Brian Marsden (1969) introduced a nongravitational force into the Newtonian equations of motion with simple expressions for the radial and transverse components in the orbital plane. These involved a function of the heliocentric distance r expressing a standard `force law', multiplied by a coefficient whose value was determined along with the osculating orbital elements by minimizing the residuals of the fit to positional observations. The radial coefficient was called A1 and the transverse A2. It was realized that the model might not be physically realistic and that more meaningful parameters might be derived from a generalized formalism, but attempts in this direction were not successful (Marsden 1970). The final update of the model was made in 1973 (Marsden et al. 1973), stimulated by calculations of the H2O sublimation rate as a function of r (Delsemme and Miller 1971). This was taken as the model force law, expressed as an algebraic function g(r) whose parameters were chosen to fit Delsemme and Miller's results. Eventually more realistic models were constructed for the jet force as resulting from asymmetric H2O outgassing, including the heat flow in the surface layers of the nucleus (Rickman and Froeschle 1983). As a result it was found that the true force law might be very different from the g(r) formula, and hence there should be room for an improved model.

The long-term variations of the nongravitational forces were found to involve a wide range of behaviour. Thus the well-determined A2-values found over different periods of time for the same comet usually vary in a more or less regular fashion, often including changes of sign. This was generally interpreted in terms of spin axis precession, which in turn may be caused by the torque associated with the jet force of outgassing. An early suggestion of such a scenario was made for P/Kopff (Yeomans 1974). Quantitative models were first derived by Whipple and Zdenek Sekanina (1979) to fit the secular decrease of the nongravitational perihelion shift of P/Encke. These models, and similar ones developed later on for a number of other comets (Sekanina 1984-85; Sekanina and Yeomans 1985), led to predictions of some physical parameters of the nuclei - in particular, the orientations of the spin axes. They treated the jet force in a physically more realistic way than the g(r) formula. However, the results were still dependent on model assumptions and thus questionable (cf. Sekanina 1988).

Cometary origin The introduction of the basic concepts of the Oort cloud and the icy conglomerate nucleus have naturally influenced modern ideas about the origin of comets. Oort (1950) already paid attention to the problem of formation of the cloud and hypothesized that it could have originated as a result of Jovian perturbations after the explosion of a planet-sized body in the asteroid belt. Thereby the asteroids and comets would have a common origin, the former being devolatilized variants of the latter. However, this revival of Olbers' old idea did not gain wide acceptance, partly due to the growing evidence that meteorites, obviously part of the same complex of minor bodies, have nearly solar elemental abundances and can not originate from a planet-sized parent body.

Around 1950, the Kant-Laplace nebular hypothesis for the origin of the solar system was also reconsidered in the light of the chemical compositions of the planets and their variation with heliocentric distance. Edgeworth (1949) and Gerald P. Kuiper (1949, 1951) argued that it is unlikely for the solar nebula to have ended abruptly at the position of Neptune's orbit, and thus a large population of planet precursors with a generally icy composition would have existed outside the giant planets. Kuiper (1951) claimed that such bodies could be identified with Whipple's cometary nuclei and suggested that Pluto's gravitational action (its mass was then thought to be in the 0.1 - 1 Earth-mass range) might have scattered the objects into Neptune's zone of influence, whereupon ejection into the Oort cloud would ensue. In particular, outside Pluto's orbit, the population might still remain intact.

During the following decades, Lyttleton (1952, 1974) challenged both basic concepts (the solid nucleus and the Oort cloud), arguing instead for cometary formation by aggregation of dust during the Sun's passages through interstellar clouds. Cometary origin thus would not be coupled to the origin of the solar system but to capture events throughout its lifetime. This scenario never received as much support as the one due to Kuiper, since it faced obvious difficulties, e.g. in explaining the cometary 1/aorig distribution and nongravitational effects. As both Oort's and Whipple's concepts have been consolidated in recent years, the basis for Lyttleton's picture has now virtually disappeared.

However, the idea of interstellar comets embraces many different scenarios that are subject to continued investigations. Aspects that have attracted particular attention are the distribution of aphelion directions of long-period comets and the possible signature of the solar apex, the mechanisms for formation of cometary nuclei under interstellar cloud conditions, the role of comets in galactic chemical evolution, and the significance of the fact that no hyperbolic comets have as yet been observed.

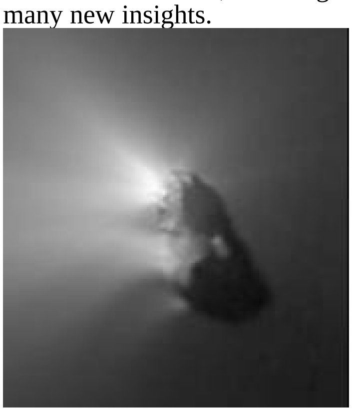
The standard concept of the solar nebula was criticized by Alfven and Arrhenius (1970, 1976), who argued for the importance of electromagnetic forces in the collapsing cloud, leading to a different picture of the radial arrangement of orbiting material and a different scenario for the accretion of larger bodies. In particular, the formation of comets was considered to occur by longitudinal focussing produced by self-gravitation and inelastic collisions in narrow streams of particles, so-called jet streams. This idea has not gained general acceptance, however. An eruptive origin of comets continued to attract attention as well. Van Flandern (1977, 1978) proposed, based on the distribution of orbits of long-period comets, that comets and asteroids originate from the break-up of a 90 Earth-mass planet in the asteroid belt only 5.5×10^6 years ago. This suggestion did not gain support, mainly on physical grounds (see the discussion following Van Flandern 1977). It was in stark disagreement with the picture building up during the 1970's and 80's, according to which minor bodies in general, and comets in particular, represent undifferentiated, pristine solar system material (Delsemme

1977). Sergej K. Vsekhsvyatskij (1972, 1977) continued to favour a variant of the Lagrange ejection hypothesis, involving the satellites of the giant planets, but he remained quite isolated in a community dominated by the view of comets as primordial bodies probing the solar nebula. The idea is fraught with many problems of different nature - let us mention here only that of explaining the abundance of long-period comets.

1985 - 1986: Encounters with P/Giacobini-Zinner and P/Halley Following the enormous increase of interest for comets in the late 1970's, another giant leap in our understanding of comet phenomena occurred in March 1986 when six spacecraft (henceforth `S/C') observed P/Halley in situ, and future cometary scientists will undoubtedly speak about the pre- and post-Halley eras, much as historians describe the transition from the dark ages to the renaissance period. However, the first cometary encounter took place already six months earlier on September 11, 1985, when the ISEE-3 spacecraft, released from its earlier task of monitoring the Earth's radiation belts and, renamed as the International Cometary Explorer (ICE), passed through the tail of P/Giacobini-Zinner, about 8000 km from the nucleus. The main results were the confirmation of the plasma tail model, indications about the ion composition and the detection of a neutral current sheet at the center of the tail. ICE flew on to register the effects of P/Halley on the interplanetary medium from a distance of 28 x 10^6 km sunward.

The detailed results from the extraordinary P/Halley campaign during the 1985-86 apparition fill many volumes - it will here suffice to give a very condensed overview of the main results.

Five spacecraft encountered P/Halley in early 1986: Vega 1 (closest approach on March 6 at 8890 km distance), Suisei (March 8; 150,000 km); Vega 2 (March 9; 8030 km), Sakigake (March 11; 7 x 10^6 km) and Giotto (March 14; 600 km). At the same time, an unequalled long-term Earth-based observational effort was coordinated by the International Halley Watch (IHW) (Newburn and Rahe 1990); the IHW Archive with more than 25 Gbytes of data was released in December 1992 (IHW 1992) and the associated Summary Volume (Sekanina and Fry 1991) contains detailed information about the data obtained within the various IHW Networks. The observations were carried out in all wavebands from the UV at 120 nm to the radioband at 18 cm, by professionals and amateurs. It has proven particularly fruitful to combine space- and Earth-based observations for calibration and long-term monitoring purposes. In general, the earlier developed cometary models were confirmed and could now be quantified by in situ measurements, leading to many new insights.



Comet Halley's Nucleus. Credit: Halley Multicolour Camera Team, Giotto, ESA ©: MPAE

The nucleus was observed at close distance for the first time; it was found to be larger (equivalent radius about 5.5 km) and darker (albedo about 4 percent) than expected. Surface features (craters, ridges, mountains etc.) and the emitting vents were observed. The coma was found to be highly structured on all scales (jets, shells, ion streamers, etc.) and the gaseous component (parent molecules, radicals, ions and atomic species) was analyzed in situ; H2O was confirmed to be by far (about 85 percent by weight) the most abundant constituent in the gas phase. A cavity devoid of magnetic field was detected within about 5,000 km of the nucleus. The dust was analyzed by size and composition; there was an unexpectedly high fraction of very small grains, down to the sensitivity limit (about 10^{-19} kg). In addition to those of possibly chondritic composition, carbonaceous `CHON' particles were seen for the first time; they may be a new source of gas. Atomic masses from 1 to 100 amu. were detected by mass spectroscopy, and the likely presence of large organic polymeric molecules was indicated. The maximum measured production rates were larger than 10^4 and about 3 x 10^4 kg/sec for dust and gas, respectively, i.e. a dust/gas ratio larger than 0.3. The integrated mass loss experienced by the nucleus at this passage, of the order of about 4 x 10^{11} kg (but very uncertain) was about 0.5 percent of the total mass of the nucleus, estimated at 1 - 3 x 10^{14} kg. The brightness of the central condensation appears to be varying with pseudo-periods of about 2 and 7 days, but it was not possible to determine unambiguously the rotational state of the nucleus. The various predicted plasma effects were confirmed, including the existence of a bow shock and the adjacent interplanetary medium was found to be kinematically and magnetically extremely turbulent. Several disconnection events in the ion tail were observed, also at the time of the encounters, and the suspected connection with magnetic field reversals was partly confirmed.

1986 - 1993: P/Halley follow-up Much of the period after the Halley encounters has been spent reducing the enormous amount of data on this comet. Ground-based observations of a number of other bright comets, including Wilson (1987 VII), Austin (1990 V), P/Brorsen-Metcalf (1989 X) and Levy (1990 XX), have served for comparison and have also resulted in several important discoveries, for instance of some new parent molecules, e.g. H2CO, H2S and CH3OH. Thanks to improved instrumentation and reduction techniques, it has become possible to observe fainter and more distant comets than ever before. To some surprise it has been found that several comets continue to be active many years after perihelion passage, in some cases at heliocentric distances well beyond 10 AU; this has implications for the models of the nuclei.

Another space encounter with a comet took place on July 10, 1992, when the Giotto spacecraft flew through P/Grigg-Skjellerup during the Giotto Extended Mission (GEM), cf. Schwehm and Grensemann (1992). A preliminary overview of some of the early results was published by Boehnhardt et al. (1992). The foremost virtue of GEM has been to provide direct comparison between a very active and a supposedly less active comet and to search for the underlying causes. However, P/Grigg-Skjellerup was found to be at least as active as expected, and the first presence of cometary ions was detected at a distance of about 6 x 10^5 km, while a magnetic disturbance resembling a bow shock or wave was passed at about 1.5 x 10^4 km distance. A few dust impacts occurred just after the closest approach which took place at about 200 km from the nucleus.

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.

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

Companion to comet Grigg-Skjellerup discovered using Giotto data? (ESA Press Release)

On 13/14 March 1986, the European Space Agency's Giotto spacecraft obtained the first close-up pictures of a comet nucleus during its close flyby of Halley's Comet. An historic second comet encounter followed on 10 July 1992 when Giotto flew within 200 km of Comet Grigg-Skjellerup.

Seven years later, continuing analysis of data from Giotto's Energetic Particle Detector (EPONA) has led to the conclusion that a second comet, possibly a fragment of the main nucleus, may have been accompanying Grigg-Skjellerup. The new results have been obtained by Professor Susan McKenna-Lawlor, the Irish Principal Scientific Investigator for the EPONA instrument, and Russian scientist Dr. Valeri Afonin. Their discovery is based on fluctuations in the energetic particle data recorded by EPONA.

One of the most important aspects of the Grigg-Skjellerup encounter was that it enabled scientists to use the same instruments to compare the fairly inactive Grigg-Skjellerup with Comet Halley, its much larger, more active cousin. A number of experiments on board Giotto were functioning during both encounters.

One of these was EPONA, which has the capability to record charged particles -- protons and heavier ions -- with energies ranging from several tens of keV to several tens of MeV. Characteristic fluctuations in the energetic particle records allowed EPONA to detect the same cometary boundaries at Halley and Grigg-Skjellerup as Giotto's other particles and fields experiments.

Recent, detailed analysis of EPONA data by McKenna-Lawlor and Afonin, (described in the journal Planetary and Space Science Vol. 47, p. 557-576 and Circular No. 7243 Central Bureau for Astronomical Telegrams IAU, 1999 August 25), has revealed a complex particle enhancement in the energy range 60-100 keV. This increase was recorded by EPONA some 90,000 km beyond Grigg-Skjellerup. Several possible explanations for this flux enhancement were considered, but the overall conclusion was that it constituted the signature of a 'companion' comet, three to four times smaller than Grigg-Skjellerup and with a correspondingly lower gas production rate. It is unlikely that these two objects have existed side by side from the beginning of their existence. A more probable explanation is that the smaller object broke away from Grigg-Skjellerup shortly before the Giotto encounter. Splitting of cometary nuclei is a well known phenomenon that can occur even at large distances from the Sun.

200 TRANSNEPTUNIAN OBJECTS Brian G. Marsden Harvard-Smithsonian Center for Astrophysics (CfA), Cambridge, Massachusetts, U.S.A.

Hard on the heels of the announcement last week of the discovery of the 200th potentially hazardous asteroid, the announcement was made today of the discovery of the 200th member of the Transneptunian Belt. Also known as the Kuiper Belt or the Edgeworth-Kuiper Belt, the Transneptunian Belt is a collection of bodies orbiting the sun generally at distances somewhat larger than that of Neptune.

As with the PHA discoveries, the rate of TNO discoveries has increased very dramatically recently. Fully half of the TNOs have been found during just the last 12 months, with the first discovery having been in 1992 or 1930, according as to whether one does not or does choose to consider Pluto to be a member. Whether one does or does not include Pluto does not affect today's milestone, because the seven new objects being announced take the count well over 200.

While the rate of new TNO discoveries is gratifying, this greatly increases the problem of obtaining enough follow-up observations to ensure a reliable prediction for the next opposition--and then ensuring that recovery observations are then made. Some 61 percent of the TNOs with an opportunity so far for recovery have in fact been observed at a second opposition. Such success is actually quite encouraging, given that the observations at the discovery opposition have often been extremely meagre, and that the orbit solutions are almost invariably complete guesswork. Although a second opposition is necessary for a reliable orbit determination, it is hardly sufficient, and continued occasional monitoring is very much in order. The recent recovery announcement of 1998 UU43 consisted of data on two consecutive nights last week of an object observed last year on one night in October and another in December. At least one of the presumed multiple-opposition TNOs, 1995 YY3, now appears to be lost.

It has been usual to separate the TNOs into two principal groups, namely, what are called the "classical Kuiper Belt objects", or "cubewanos" (this name arising from the designation 1992 QB1 of their prototype), with orbits of rather low eccentricity (though with inclinations up to 30 degrees or so) and mean distances between 42 and 47 AU from the sun (Neptune being at a distance of 30 AU); and the "plutinos" (Pluto itself being the prototype), their mean distances of 39 AU giving them orbits having revolution periods that are three-halves that of Neptune, this resonance in fact preventing close approaches to Neptune, even though orbital eccentricities up to more than 0.3 mean that these objects can cross Neptune's orbit. Almost 50 percent of the objects with good orbit determinations are cubewanos, and almost 40 percent are plutinos. It also seems that 5 percent or so have revolution periods that are twice that of Neptune, so they have mean distances of 48 AU, the rather large orbital eccentricities again allowing these objects to approach Neptune's orbit--but not Neptune itself. There are also a couple of resonant objects with revolution periods that are four-thirds and five-thirds that of Neptune.

The remaining well-observed TNO, 1996 TL66, ranges in distance between 35 AU and 135 AU from the sun. There are certainly other objects of this type, sometimes called "scattered-disk objects", although only four of the single-opposition objects, all of them discoveries in February 1999, have officially been assigned scattered-disk orbits. It is highly probable that several of the lost TNOs are actually in this category--which would help explain why they are lost, because scattered-disk status would very considerably augment the amount of sky needed to be searched to guarantee their recovery.

One can argue that the count of PHAs is arbitrary because the rules defining a PHA are also arbitrary. But we can at least be sure that the accepted PHAs meet those rules. Given that only 34 percent of the currently known TNOs have been observed at more than one opposition, we cannot really provide a satisfactory definition for a TNO that we can guarantee will be met by the majority of the objects that have been classed as TNOs. Certainly, we seem to be on reasonably firm ground when it comes to the established cubewanos and plutinos (and also perhaps the other resonant objects), but beyond that there is a problem.

Part of the problem is that there is at some level really no dynamical distinction between a scattered-disk object and a centaur. A centaur is an object that in some way moves in the general range of the giant planets. Although Chiron, which in 1977 was the first such discovery, currently moves rather neatly between the orbits of Saturn and Uranus, close approaches to these planets can change this. But half of the 16 objects classified as centaurs actually have their farthest points from the sun beyond the orbit of Neptune--i.e., into the domain of the TNOs. One of these objects, 1995 SN55, is currently well beyond Neptune, at 39 AU from the sun. Its classification as a centaur is quite arbitrary, and it could equally well be classified as a TNO: it is probably not a plutino or other "regular" TNO, but it could easily have been classified as a scattered-disk TNO. So if we are going to consider scattered-disk objects as part of the TNO population, we really should also include at least part of the centaur population.

The combined population therefore has well over 200 members--more than 220 if all the centaurs are included. Then there is the recent 1999 TD10, which we know to be currently just beyond the orbit of Saturn, well inside the "centaur region", but that at its farthest from the sun is quite akin to 1996 TL66 and the other scattered-disk objects. It is "both" a centaur and a TNO, but it is currently being classified as neither.

Finally, there is the matter of the comets. We know that Chiron shows cometary attributes, and it is classified both as a centaur, with the asteroid number (2060), and a comet, with the designation 95P/Chiron. It is widely believed that the centaurs and TNOs generally are protocomets. There are other comets, such as 29P/Schwassmann-Wachmann 1 and 39P/Oterma, with current orbital characteristics that could also allow them clearly to be classified as centaurs. Furthermore, less than half a century ago, the orbit of 39P/Oterma, then inside the orbit of Jupiter, was much like those of many of the other short-period comets, notably, D/1993 F2 (Shoemaker-Levy 9), the string of objects that crashed into Jupiter in 1994.

So we can indeed celebrate and claim that today we acquired our 200th known TNO. But we don't know what that means.

A Progress Report on the Lincoln Near Earth Asteroid Research Project R. M. Elowitz, G. H. Stokes, M. Bezpalko, M. S. Blythe, J. B.. Evans, E. C. Pearce, R. W. Sayer, F. C. Shelly, H. E. M. Viggh (MIT Lincoln Laboratory)

The Lincoln Near-Earth Asteroid Research (LINEAR) project is a MIT Lincoln Laboratory effort cooperatively sponsored by the United States Air Force Office of Scientific Research (AFOSR) and the National Aeronautics and Space Administration (NASA). The objective of the LINEAR project is to substantially contribute to the NASA goal of cataloguing 90 percent of the Near Earth Asteroids (NEAs) with sizes larger than 1 km, within the next 10 years.

Since March 1998, the LINEAR project has been hosted on a 1-meter telescope located at the Lincoln Laboratory Experimental Test Site (ETS) on the White Sands Missile Range near Socorro, New Mexico. Beginning in October 1999, the LINEAR system added a second 1-meter telescope to routine operations, thus doubling the search capacity. Each telescope is equipped with a large format 2560x1960 back-illuminated frame-transfer CCD along with associated camera/processing elements developed by MIT Lincoln Laboratory for United States Air Force space surveillance applications. Since March of 1998, LINEAR has contributed 70% of the world wide discoveries of NEAs. As of January 1, 2000 the LINEAR project has discovered 74 Potentially Hazardous Asteroids (also referred to as PHAs), 22 Atens, 150 Apollos and 140 Amors. In addition, LINEAR has discovered 33 comets since the project began [I made it 35], and the first two asteroids with retrograde orbits that show no indication of cometary activity. Future plans for the LINEAR project include further automation of operations and processing enhancements that will increase the already impressive discovery rate of the LINEAR program.

NASA BEGINS BUILDING NEXT MISSION TO STUDY COMETS (NASA Press Release)

NASA's Comet Nucleus Tour, or CONTOUR, mission took a giant step closer to its launch when the project received approval to begin building the spacecraft. Planned for a July 2002 launch, CONTOUR is expected to encounter Comet Encke in November 2003 and Comet Schwassmann-Wachmann-3 in June 2006. The mission has the flexibility to include a flyby of Comet d'Arrest in 2008 or an as-yet undiscovered comet, perhaps originating from beyond the orbit of Pluto. Such an unforeseen cometary visitor to the inner solar system, like Comet Hale-Bopp discovered in 1995, would present a rare opportunity to conduct a close-up examination of these mysterious, ancient objects which normally reside in the cold depths of interstellar space.

RADAR OBSERVATIONS OF COMETS J. K. Harmon, D. B. Campbell, S. J. Ostro, M. C. Nolan: PLANETARY AND SPACE SCIENCE, 1999, Vol.47, No.12, pp.1409-1422

Seven comets have been detected by Earth-based radars during the period 1980-1995. All but one of these gave a detectable echo from the nucleus, while three of the comets also showed a broad-band echo from large (similar to cm-size) grains in the inner coma. Although all observations have been of the CW (continuous-wave) type, which precludes direct size measurement, the radar cross sections are consistent with nucleus diameters averaging a few kilometers and varying over a range of ten. Comparisons with independent size estimates indicate relatively low radar albedos, implying nucleus surface densities of 0.5 to 1 g/cm(3). The surfaces of comet nuclei appear to be as rough as typical asteroid surfaces, but are considerably less dense. Analysis of coma echoes indicates that some comets emit large grains at rates (similar to ton/s) which are comparable with their gas and dust production rates. There is also some indirect evidence for grain evaporation or fragmentation within a few hundred to a few thousand kilometers of the nucleus. The highest priority of future radar observations will be to obtain delay-Doppler images of a nucleus, which would give direct size and shape estimates as well as a more reliable albedo. Delay-Doppler or interferometric imaging of the coma echo would also help to better characterize the grain halo. Ten short-period comets are potentially detectable during the next two decades, although the best radar opportunities may well come from comets yet to be discovered. © 1999 Elsevier Science Ltd.

R.R. Weissman: **Diversity of comets: Formation zones and dynamical paths.** SPACE SCIENCE REVIEWS, 1999, Vol.90, No.1-2, pp.301-311

The past dozen years have produced a new paradigm with regard to the source regions of comets in the early solar system. It is now widely recognized that the likely source of the Jupiter-family short-period comets (those with Tisserand parameters, $T > 2$ and periods: P, generally < 20 years) is the Kuiper belt in the ecliptic plane beyond Neptune. In contrast, the source of the Halley-type and long-period comets (those with $T < 2$ and $P > 20$ years) appears to be the Oort cloud. However, the corners in the Oort cloud almost certainly originated elsewhere, since accretion is very inefficient at such large heliocentric distances. New dynamical studies now suggest that the source of the Oort cloud comets is the entire giant planets region from Jupiter to Neptune, rather than primarily the Uranus-Neptune region, as previously thought. Some fraction of the Oort cloud population may even be asteroidal bodies formed inside the orbit of Jupiter. These comets and asteroids underwent a complex dynamical random walk among the giant planets before they were ejected to distant orbits in the Oort cloud, with possible interesting consequences for their thermal and collisional histories. Observational evidence for diversity in cometary compositions is limited, at best. © 2000, Institute for Scientific Information Inc.

NEW ORBIT VISUALISATION TOOL ONLINE

A new Orbits section has been added to JPL's Near-Earth Object home page. The highlight is a cool visualization tool. It is an interactive 3D orbit viewer written in Java, and you can view the orbit of any asteroid or comet. You can rotate the orbits around and zoom in, move around the solar system and "play" the orbits backwards and forwards like a movie. It resides at:

http://neo.jpl.nasa.gov/orbits

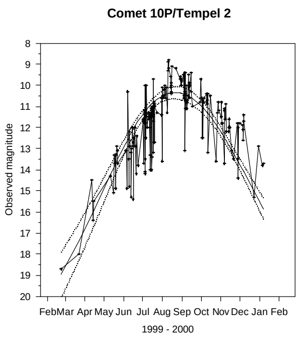
You'll have to select an object of interest first, by either entering the asteroid/comet's name (wildcards are allowed), or making a selection from the table of Potentially Hazardous Asteroids provided.

Review of comet observations for 1999 October - 2000 March

The information in this report is a synopsis of material gleaned from IAU circulars 7281 – 7399 and The Astronomer (1999 October – 2000 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 by the AGEO team of Seiichi Yoshida and KenIchi Kadota by CCD in November when it was 16th magnitude.

10P/Tempel 2 continued to fade, and was generally too far south for observation from the UK. It was last seen in early January at 14th magnitude. Overall the comet was well observed, however there is considerable scatter in the observations.



The preliminary uncorrected light curve m = 5.4 + 5 log d + 32.3 log r is only a fair fit to the 200 observations.

A couple of further observations of **50P/Arend** were received, but the comet was never brighter than 14th magnitude. At its best ever return the comet reached a similar magnitude and this apparition was not a good one.

59P/Kearns-Kwee had a rather unfavourable return and was another comet which didn't become brighter than 14th magnitude. It was around this brightness during the autumn.

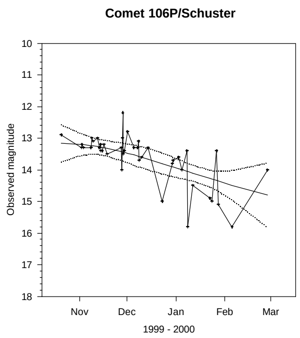
63P/Wild 1 Nakano reported observations made by T. Kojima, Chiyoda, on October 24.83 of this 13-year-period comet, missed at its 1986 return. These observations confirm a single-night detection at mag 22.4 by Hergenrother (1.5-m Catalina reflector) on February 14. The prediction on MPC 27082 requires correction by Delta T = -0.35 day. Further details were given on MPEC 1999-V18. Kojima (0.25-m f/6.3 reflector) reported the comet at m1 = 16.5 and as diffuse without a tail on October 24, at m1 = 15.9 and diffuse with condensation and a coma diameter of 30" on November 4. [IAUC 7302, 1999 November 6]. The comet brightened and reached 12th magnitude in January. Moving south, it was lost to view from the UK, but Southern Hemisphere observations continued. The 25 observations received so far give a preliminary light curve of m = 10.6 + 5 log d + 7.5 log r, however the fit to the observations is not good.

Close encounters with Jupiter in 1955 and 1963 changed the orbit of **74P/Smirnova-Chernykh** drastically and it was discovered in 1975, though it had been earlier given the minor planet designation 1967 EU. For a few years around 2025 it will be captured by Jupiter and then a further encounter with the planet at the end of the century will move the perihelion distance outside that of Jupiter. Due to the low eccentricity of its orbit the comet is visible even at aphelion but it is faint at about magnitude 16. At this return it doesn't reach perihelion until January 2001, however the AGEO team are imaging it and it has reached 15th magnitude.

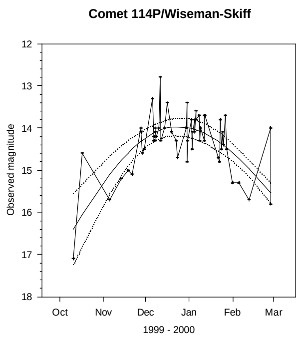
76P/West-Kohoutek-Ikemura makes a close approach to Mars on June 5, passing only 0.043 AU from the red planet. The apparition is not a good one for earth based observers, but if we were on Mars the comet would be around mag 7.5 in a dark sky, although very close to Jupiter and Saturn. From Earth it is nine magnitudes fainter and not surprisingly is close to Mars, which is at an elongation of only 7° from the Sun.

84P/Giclas made its fourth observed return since its discovery in 1978 by Henry Giclas of the Lowell Observatory. The perihelion distance is fairly constant at present and Jupiter encounters only make significant changes to the angular elements. However around 2300, a low velocity close encounter with Jupiter will transfer the comet to an orbit outside that of the planet. It was yet another faint comet, which perhaps reached 14th magnitude in the autumn.

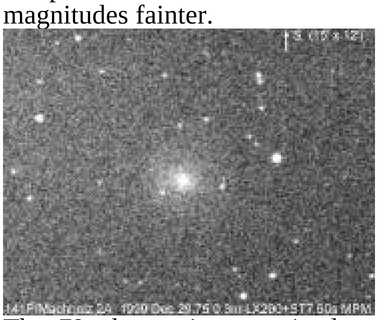
106P/Schuster was discovered in 1977 October at La Silla, though a month earlier it had been recorded as an asteroid. It was not seen at its second return, which was unfavourable. The orbit is relatively stable. This was its third observed return and it remained at 13th - 14th magnitude from late October into January. The light curve is indeterminate from the observations received so far.



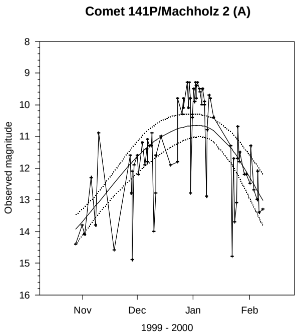
114P/Wiseman-Skiff had a favourable apparition and also reached 14th magnitude in December and was still this bright in January. The 55 observations give an uncorrected preliminary light curve of m = 8.9 + 5 log d + 28.9 log r.

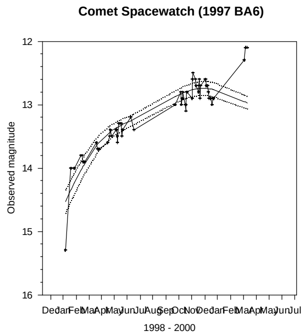


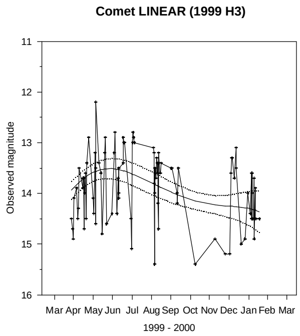
141P/Machholz 2 (1999 P1) put on a disappointing performance and never reached the brightness achieved at the last return. This was not entirely unexpected as the comet had fragmented last time round and this undoubtedly boosted its performance. It was never well placed from the UK and was difficult to observe. Two components were recovered. Component A peaked at 9th magnitude in early January and component D was at least two magnitudes fainter.



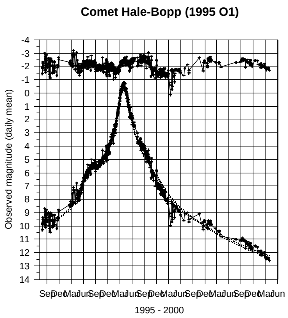
The 79 observations received so far give a preliminary, uncorrected light curve of m = 13.6 + 5 log d + 11.8 log r.







Hale-Bopp (1995 O1) is still being observed from the Southern Hemisphere, but it will soon be too faint for further visual observation. The observed arc now covers 1712 days with observations made on 796 days. The equation -0.64 + 5 log d + 7.53 log r fits the aperture corrected 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 close to the value indicated by the equation.



The residuals on the fitted curve are shown above.

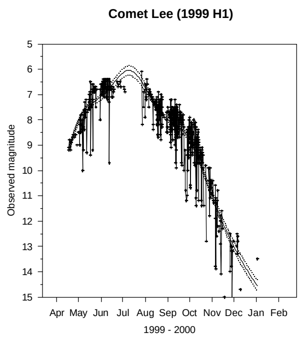
Spacewatch (1997 BA6) reached perihelion at 3.4 AU in late November and as expected was around 12th magnitude. First observed visually in 1998 December it will be around for most of this year, but only for Southern observers. The comet is currently a little brighter than expected from the uncorrected preliminary light curve, which was a good fit to m = 4.5 + 5 log d + 10.0 log r from 68 observations.

Only a few further observations of **LINEAR (1998 M5)** were received as the comet faded past 15th magnitude. The observations give an uncorrected preliminary light curve of 6.0 + 5 log d + 10.2 log r

The AGEO team made a couple of further observations of **1999 E1 (Li)** as it faded.

1999 H1 Lee reached peak brightness in early October, but became markedly harder to observe later in the month. The comet continued to fade and was last seen in early January by Andrew Pearce.

546 observations give an uncorrected preliminary light curve of 6.7 + 5 log d + 11.5 log r



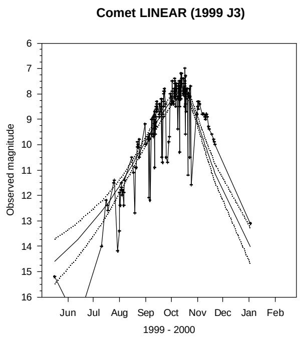
1999 H3 LINEAR is in a distant parabolic orbit and hasn't become much brighter than 13^{m}. It was in conjunction with the sun during November and December, albeit at an elongation of 40° and therefore fairly difficult to observe. It faded rapidly during the early spring as its distance from Earth increased.

100 observations give a somewhat indeterminate uncorrected preliminary light curve of -1.1 + 5 log d + 21.9 log r

1999 J2 Skiff is slowly fading and has now reached 16th magnitude.

1999 J3 LINEAR peaked in brightness at around 7^{m} in mid October. Thereafter it faded and was last seen in late November by Andrew Pearce at 10th magnitude in 20x80B.

197 observations give an uncorrected preliminary light curve of 9.0 + 5 log d + 11.8 log r

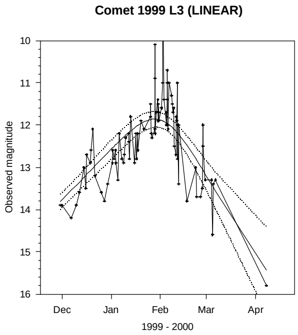


1999 J6 was a SOHO comet (SOHO-109), though not a member of the Kreutz group and was discovered by Michael Oates on 2000 March 20 using archival images on the SOHO website.

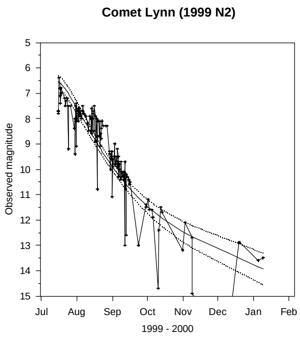
Scattered observations of **1999 K8 LINEAR** have continued, with observers estimating it at around 14th magnitude. Reaching perihelion in April, it will continue to be observable for some time.

49 observations give an uncorrected preliminary light curve of -1.4 + 5 log d + 18.7 log r but this is a poor fit.

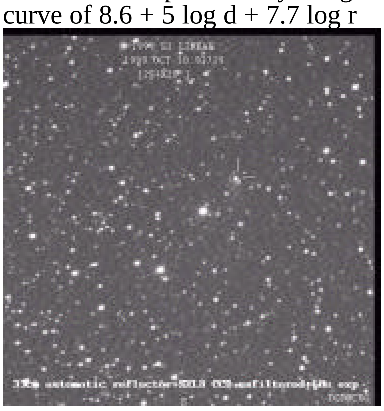
1999 L3 LINEAR brightened to within visual range at the end of November. It peaked at around 11th magnitude in early February, with several observers following it.



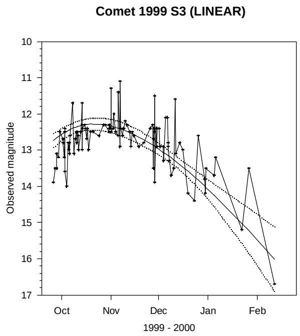
1999 N2 Lynn became difficult to observe after late Autumn, but became better placed as its elongation increased in the new year. Observations by Jonathan Shanklin suggested a magnitude around 13 in early January, but no other observers reported seeing it.



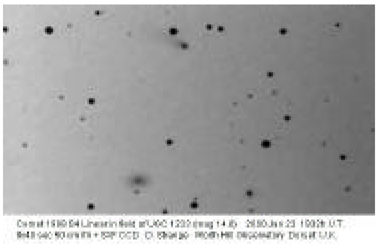
150 observations give an uncorrected preliminary light curve of 8.6 + 5 log d + 7.7 log r



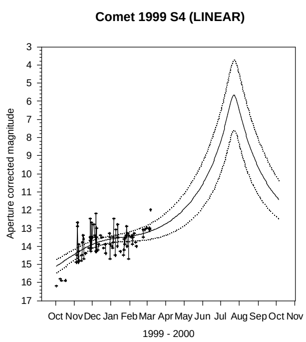
1999 S3 LINEAR reached around 12th magnitude in November and early December and was quite well followed. The preliminary light curve from 106 observations is m = 0.7 + 5 log d + 39.8 log r



1999 S4 LINEAR has brightened quite slowly, which seems to be a feature of 'new' comets. Astrometric observations show that it is making its first visit to the inner solar system and may well behave in a similar fashion to comet Kohoutek.



It is currently in conjunction, but after conjunction it should brighten rapidly and will become visible in the northern sky. The best fit light curve prior to conjunction, using observations corrected for aperture is m = 8.5 + 5 log d + 5.9 log r. This suggests that it could reach at least 5m, and the first observations after conjunction will be important in making the final predictions. The light curve shows the observations and the range of possible extrapolation. At its best the comet could have a tail a few degrees long.



1999 T1 McNaught-Hartley Robert H. McNaught, Research School of Astronomy and Astrophysics, Siding Spring Observatory, reported his discovery of a 15th magnitude comet on a plate taken by Malcolm Hartley with the 1.2-m U.K. Schmidt Telescope on October 7.64. The strongly condensed comet showed a 8" coma and a very faint 1' tail in p.a. 320°. Additional astrometry was published on MPEC 1999-T42. I. P. Griffin, Auckland Observatory, reported a condensed coma of diameter 7" on CCD exposures taken on October 11.4 UT (0.5-m telescope). A. Becker and C. Stubbs, University of Washington; and J. Perez, Cerro Tololo Interamerican Observatory (CTIO) noted a tail in p.a. 328° on a CCD exposure taken with the CTIO 0.9-m telescope on Oct. 11.19. [IAUC 7273, 1999 October 11].

This comet may reach binocular brightness, though there are insufficient observations to make an accurate prediction. Initially at far southern declinations it will come within range of large apertures in July and binoculars in October. It moves far enough north for observation by UK observers in December when it reaches perihelion and moves through Hydra, Virgo and Libra.

1999 T2 LINEAR F. Shelly reported the discovery by LINEAR of an 18th magnitude comet on October 14.16. Additional observations were reported following posting on the NEO Confirmation Page [IAUC 7280, 1999 October 14]. The 7 observations suggest that the absolute magnitude is around 5.5, but don't place any constraint on the slope parameter. The comet will reach perihelion in November 2000 and may reach 13th magnitude or a little brighter, in the late summer.

1999 T3 LINEAR Linkage at the Minor Planet Center of observations by LINEAR on several nights during October 3.34 - 21 revealed an 18th magnitude object with a nearly-parabolic retrograde orbit. This orbit also represented a single-night detection of an object by E. W. Elst and S. Ipatov at Uccle on October 18. Following placement of an ephemeris on The NEO Confirmation Page further observations were made on October 24 and 25. In response to enquiries, Elst remarked that the object was diffuse and had a possible tail to the north; J. Ticha and M. Tichy, Klet, reported the object as slightly more diffuse than stars of comparable brightness and deduced a coma size of 9"; and D. Durig, Sewanee, TN, in poor conditions (strong wind, full moon), also noted the object's diffuse appearance. [IAUC 7289, 1999 October 25]. The comet is a distant one and will not get any brighter.

A/1999 TD10 Details of a distant asteroid discovered by Spacewatch on October 3.19 were announced on MPEC 1999-T46 [1999 October 11], with further observations and a new orbit given on MPEC 1999-V07 [1999 November 2]. The 19th magnitude asteroid is in an unusual high eccentricity orbit, which has perihelion at 11.6 AU, and a nominal semi-major axis of 155 AU giving a period of 1900 years.

1999 U1 Ferris LONEOS (0.59-m Schmidt + CCD) reported the discovery of a 17th magnitude comet on October 18.38. Additional observations were reported following posting on the NEO Confirmation Page [IAUC 7283, 1999 October 18]. The comet was at perihelion last year and will fade.

1999 U2 SOHO Doug A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reported observations of a comet (not a Kreutz sungrazer) discovered independently by S. Gregory (Stanford University) and by J. D. Shanklin (Comet Section, British Astronomical Association) in SOHO/LASCO C3 data. The comet is very faint, and not visible in very many frames. It was first visible on October 25.21 and remained visible until October 25.74. [IAUC 7292 and MPEC 1999-U29, 1999 October 28] I made the co-discovery on October 26.35.

1999 U3 P/LINEAR R. Huber reported the discovery by LINEAR of an 18th magnitude comet on October 30.32. Additional observations were reported following posting on the NEO Confirmation Page [IAUC 7295, 1999 October 31]. It is past perihelion and will fade from 16th magnitude.

1999 U4 Catalina-Skiff On October 31 T. B. Spahr, Lunar and Planetary Laboratory, reported the discovery by the Catalina Sky Survey on October 31.25 of a slow-moving 17th magnitude object that was independently discovered on November 1.28 by B. A. Skiff (measurer B. W. Koehn) of the LONEOS survey. In response to Skiff's alert, R. L. Millis and L. H. Wasserman, on a 5-min R-band exposure with the Perkins 1.8-m reflector, detected a coma extending 8" southeastward from the nucleus. After a posting in The NEO Confirmation Page, M. Tichy and Z. Moravec, Klet, also reported that the object had an 8" coma [IAUC 7298, 1999 November 1]. The object is very distant, but could brighten to 14th magnitude when at perihelion in 2001.

4 observations received so far give an uncorrected preliminary light curve of 4.6 + 5 log d + [10] log r

A/1999 UG5 Details of another unusual asteroid, discovered by the Catalina sky survey on October 29.25, were given on MPEC 1999-V09 [1999 November 3]. This 18th magnitude object has a perihelion distance of 6.6 AU and a period of 65 years.

1999 V1 Catalina C. W. Hergenrother, Lunar and Planetary Laboratory, reported the discovery of another comet of 18th magnitude by the Catalina Sky Survey on November 5.44. [IAUC 7302, 1999 November 7] The comet is close to perihelion and in a distant orbit. It will remain at a similar brightness until early next year, then fade.

1999 WJ7 P/Korlevic An apparently asteroidal 18th magnitude object discovered on November 28.94 by Korado Korlevic at Visnjan with a 0.41-m f/4.3 reflector + CCD was indicated on some of his December images to be possibly "fuzzy", and the cometary nature has been confirmed by C. Hergenrother and S. Larson, Lunar and Planetary Laboratory, who found a 13" coma elongated in p.a. 80 deg on a 600-s co-added R-band exposure taken on 2000 Feb. 7.25 UT with the 1.54-m Catalina reflector. The comet has a perihelion distance of 3.2 AU and a period of ten years. [IAUC 7368, 2000 February 18]

P/1999 X1 Hug-Bell Amateurs Gary Hug and Graham E. Bell, Eskridge, KS, reported their discovery of a 19th magnitude comet on December 10.33, showing a faint tail in p.a. 285° on CCD images taken with a 0.3-m Schmidt-Cassegrain reflector during the course of their minor planet search and follow up program. Following posting on the NEO Confirmation Page, L. Sarounova (Ondrejov, 0.65-m reflector) obtained observations on December 11.2 UT showing a tail 20" long in p.a. about 300°. C. Hergenrother, Lunar and Planetary Laboratory, reports that a co-added 1200-s R-band image obtained with the 1.54-m Kuiper telescope on December 11 shows a 15" coma and a slightly curved tail 1' long in p.a. 280°. All of the available astrometry (including prediscovery observations on October 10 and December 7 by LINEAR) gives elliptical orbital elements, with perihelion in 1999 June and a perihelion distance of 1.9 AU. [IAUC 7331, 1999 December 11]. The comet will fade.

A/1999 XS35 Details of another unusual asteroid, discovered by the LONEOS program on December 2.42, were given on MPEC 1999-X19 [1999 December 9]. This 17th magnitude object has a perihelion distance of 0.95 AU and a period of 79 years. The orbit approaches very close to the Earth at the ascending node, so the object is classed as a PHA. The orbital miss distance is only 0.008 AU from the Earth and the asteroid passed this point only 2.9 days ahead of the Earth. If it produced a meteor shower, slow meteors would have been seen by Southern Hemisphere observers on or around November 11.1, with a radiant point of RA 17h 55m, Dec -70. Next year the shower would be expected around November 10.3.

1999 XB69 P/LINEAR An apparently asteroidal, 18th magnitude object discovered by LINEAR on December 7.29, with a cometlike orbit has been observed by C. Hergenrother, Lunar and Planetary Laboratory, on February 27 with the Catalina 1.54-m reflector to show a 5" coma and a 10" tail in p.a. 80°. The comet is intrinsically faint, with a perihelion distance of 1.6 AU and a period of 9.4 years. [IAUC 7370, 2000 February 29]

1999 XS87 P/LINEAR An object that was assumed to be asteroidal was found by LINEAR on 1999 December 7.38 and 8, and it was later linked to observations by LINEAR on 2000 January 6 and 7 by G. V. Williams, Minor Planet Center. Following a request from the Minor Planet Center after seeing that the orbit appeared comet-like, M. Tichy and Z. Moravec obtained observations at Klet on January 11 and 12 that showed this object to be diffuse with a coma diameter of 15". [IAUC 7344, 2000 January 12] The comet is in a long period orbit (73 years) and was at perihelion in 1999 August at 2.8 AU.

1999 XN120 P/Catalina An apparently asteroidal, 17th magnitude object discovered on December 5.19 by the Catalina Sky Survey, with a cometlike orbit was also observed by Hergenrother on February 27 with the 1.54-m reflector to show a 12" coma but no tail. The comet has a perihelion distance of 3.29 AU and a period of 8.5 years. [IAUC 7370, 2000 February 29]

1999 Y1 LINEAR A 17th magnitude object with unusual motion and reported as asteroidal by LINEAR on December 20.22 was found to be cometary in appearance following posting on the NEO Confirmation Page. Z. Moravec, Klet, reported that the object appeared slightly diffuse with a possible coma of diameter about 10" on images taken in poor seeing on December 21 and 22. G. Billings, Calgary, AB, reported an apparent nebulosity of diameter about 12" on December 23 CCD images taken with a 0.36-m reflector, and he noted a faint tail about 20" long in p.a. 70° on December 27. S. Nakano, Sumoto, Japan, reported that H. Abe (Yatsuka, 0.26-m reflector) found the comet to be evidently diffuse, T. Kojima (Chiyoda, 0.25-m reflector) found a 10" coma and a short tail toward the northeast, and T. Oribe (Saji Observatory, 1.03-m reflector) found a 20" coma and a 30" tail in p.a. 60°, all on December 27. A. Nakamura, Kuma, Japan, found coma diameter 0'.35 and a faint tail in p.a. 60° on December 27 (0.60-m reflector). The initial orbit is parabolic with perihelion in March 2001. [IAUC 7338, 1999 December 27] The comet could reach 13th mag at the end of the year.

1999 Y2 SOHO Kazimieras Cernis, Vilnius, Lithuania, discovered an apparent comet at magnitude about 5 on SOHO images taken on 1999 December 28.28 that were posted on the SOHO website. D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reported that the comet was visible on both LASCO C2 and C3 images and that no tail was detected. Astrometric measurments by Biesecker and D. Hammer (University of Maryland), reduced by Marsden, appeared on MPEC 2000-A36, together with parabolic orbital elements (q = 0.048 AU, i = 111.4 deg), showing that the comet is not a Kreutz sungrazer. Magnitude reductions by Biesecker and Hammer show that the comet faded from magnitude 6.1 to 6.8 during December 28.58-28.79, and thence from view while still in the C3 field. [IAUC 7343, 2000 January 10]. The comet should have still been brightening at this point, implying that its volatiles had probably been exhausted.

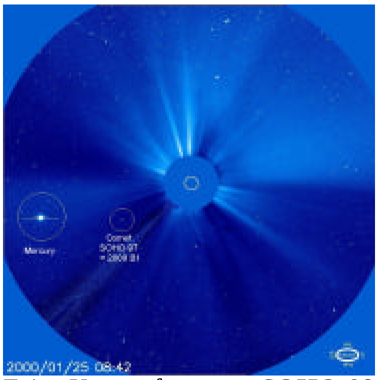
Kazimieras provided the following information about the discovery: I discovered this comet due to your two discoveries and information which helped me for looking at CCD images. The object at C2 was difficult for detecting at 1024x1024 too. I say that because I detected independently SOHO-94 with a bright tail after A. Vourlidas without problem on December 21. C/1999 Y2 was without tail and its brightness was similar to Sgr24 in orange filter (about 5 mag). Then I discovered SOHO-95 at C3 images (from December 27 23 hours) and sent more than 20 positions to B. Marsden. D. Biesecker did not reply me for 6 days. It was a holidays. If the comet has absolute magnitude about 18, it could be detectable with CCD in the evening sky as 15.5 mag with elongation about 40 deg these days before bright moonlight coming.

1999 E2 SOHO (IAUC 7377, 2000 March 09)
1999 O1 SOHO (IAUC 7367, 2000 February 15)
1999 O2 SOHO (IAUC 7376, 2000 March 07)
1999 O3 SOHO (IAUC 7376, 2000 March 07)
1999 P3 SOHO (IAUC 7367, 2000 February 15)
1999 P4 SOHO (IAUC 7376, 2000 March 07)
1999 P5 SOHO (IAUC 7376, 2000 March 07)
1999 Q1 SOHO (IAUC 7376, 2000 March 07)
1999 Q2 SOHO (IAUC 7376, 2000 March 07)
1999 Q3 SOHO (IAUC 7376, 2000 March 07)
1999 R3 SOHO (IAUC 7376, 2000 March 07)
1999 R4 SOHO (IAUC 7383, 2000 March 17)
1999 S5 SOHO (IAUC 7383, 2000 March 17)
1999 S6 SOHO (IAUC 7383, 2000 March 17)
1999 S7 SOHO (IAUC 7383, 2000 March 17)
1999 U5 SOHO (IAUC 7386, 2000 March 24)
1999 W1 SOHO (IAUC 7386, 2000 March 24)
1999 Y3 SOHO (IAUC 7386, 2000 March 24)
2000 B1 SOHO (IAUC 7349, 2000 January 24)
2000 B5 SOHO (IAUC 7386, 2000 March 24)
2000 B6 SOHO (IAUC 7386, 2000 March 24)
2000 B7 SOHO (IAUC 7386, 2000 March 24)
2000 C6 SOHO (IAUC 7364, 2000 February 12)
2000 D1 SOHO (IAUC 7370, 2000 February 29)
2000 D3 SOHO (IAUC 7386, 2000 March 24)
2000 E1 SOHO (IAUC 7376, 2000 March 07)
2000 F1 SOHO (IAUC 7393, 2000 April 04)

were discovered with the SOHO LASCO coronographs and have not been observed elsewhere. They were sungrazing comets of the kreutz familly and were not expected to survive perihelion. Some of these comets show no tail at all and it is possible that some supposed observations of Vulcan were actually tiny Kreutz group comets.

SOHO 74 (1999 O1) and SOHO-76 (1999 P3). D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, repored measurements of two apparent Kreutz sungrazing comets (both tailless) discovered with the LASCO C3 coronagraph aboard SOHO on 1999 July 31.51 and August 3.24 [IAUC 7367, 2000 February 15]. 1999 O1 was found by T. Lovejoy in movies posted at the SOHO website. 1999 P3 was found by D. Lewis.

I discovered **SOHO-97 (2000 B1)** on January 24. I had to leave work early on January 24 in order to pick up my car which had been in for servicing (an expensive business as several repairs were needed) and went straight home afterwards as it was clear and I wanted to grab a bite to eat before it got dark. I then cycled out to the Cambridge Observatories and got out the great Northumberland refractor at around 17:50. I observed 141P/Machholz 2 (a bit iffy at 13^{m}), 114P/Wiseman-Skiff (glimpsed with averted vision at 14^{m}) and 1999 S4 (LINEAR) (not seen and [13.8). I could see clearly several galaxies catalogued at 13^m. I also observed a few binocular variables and then thought about going bell-ringing (one of my other hobbies) at 19:30, though as the practice started at 19:00 I would be late. However, I decided to have a quick look at the SOHO images first on the IOA Starlink system. As soon as the java loop had downloaded it was obvious that a Kreutz fragment was heading in towards the sun. I immediately emailed Doug and Brian Marsden, though this one was so obvious that I was sure there would have been prior claims. It turned out that there weren't and Doug posted the discovery on his web page and quickly got the positions for Brian to compute the orbit, which appeared on IAUC 7349 at 23:10. The comet peaked in brightness at around 5th magnitude on the morning of January 25, and began to grow a tail, but also to fade. It disappeared from the C3 frames but a ghostly image was visible for a couple of hours on the C2 frames between 16:06 and 18:30.



Faint Kreutz fragment **SOHO-98 (2000 B6)** was discovered by Maik Meyer on January 29, however an independent discovery was made by Michael Oates of the SPA on January 30. He had heard a talk that I gave on January 29 about my discovery of SOHO-97 and decided to try it himself. He wasn't aware of the real time movie loops and so downloaded individual high resolution frames and made a movie himself. Looking at the sequence he spotted the moving image of the Kreutz fragment, however he was beaten to it by Maik Meyer. Terry Lovejoy also spotted the object. I was quite surprised therefore to get some credit on IAUC 7386 as I thought that I had only confirmed the discovery.

SOHO-99 (2000 B7) was also discovered by Maik Meyer, and almost simulataneously by Terry Lovejoy.

Three more comets, including SOHO-100 were discovered between February 3 and 5, moving in similar trajectories diagonally across the upper left quadrant. There seems to be a swarm of these objects, with a fourth discovered by Michael Oates and visible on the C2 images from 18:54 - 20:44 on February 7.

SOHO-104 (2000 C6) was a Kreutz fragment discovered by Terry Lovejoy on February 9. **SOHO-105 (2000 D3)** was another Kreutz fragment.

SOHO-106 (2000 D1) D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reports observations of an evident Kreutz sungrazing comet with a tail discovered by D. Lewis in SOHO/LASCO C3 data on February 28.57. Biesecker provides apparent magnitudes brightening from V = 7.4 +/- 0.2 on Feb. 28.971 to 5.8 +/- 0.1 on Feb. 29.404 UT. [IAUC 7370, 2000 February 29]

SOHO-107 (2000 E1) D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reports that several people browsing the SOHO Web site (including M. Meyer, M. Boschat, T. Harincar, and M. Oates) noted another Kreutz sungrazing comet in SOHO LASCO data on March 4.40. Observed in both the C2 and C3 telescope data, this object showed a tail of length about 10'. [IAUC 7376, 2000 March 7]
On the same IAUC Biesecker also reported observations (measures by D. Hammer and himself, reductions by B. G. Marsden) of some older Kreutz sungrazing comets seen in SOHO C3 data; full astrometry and parabolic orbital elements appear on the MPECs indicated below. Comet C/1999 O2 developed a short tail, C/1999 O3 had a short tail evident, C/1999 Q3 showed a tail, and C/1999 R3 showed evidence for a tail; the other four comets showed no evident tail. Comets C/1999 O2 and C/1999 P4 were discovered by D. Lewis, C/1999 P5 by A. Vourlidas, C/1999 Q2 and C/1999 R3 by K. Schenk, and C/1999 Q3 by Biesecker, while comets C/1999 O3 and C/1999 Q1 were first noted by T. Lovejoy via the SOHO Web page.

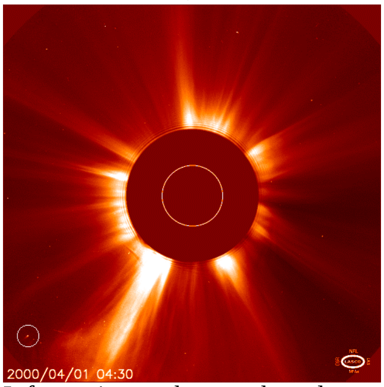
SOHO-108 (1999 E2) D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reported that M. Oates, Manchester, England, found another Kreutz sungrazing comet in archival SOHO LASCO C3 Web data from **1999** March 2.51. [IAUC 7377, 2000 March 9]

On IAUC 7383 [2000 March 17], D. A. Biesecker reported observations (measures by D. Hammer and himself, reductions by B. G. Marsden) of four more tailless, Kreutz sungrazing comets seen in SOHO C3 data, during 1999 September, which were discovered by K. Schenk, except for C/1999 R4, which was first noted by T. Lovejoy via the SOHO Web page.

On IAUC 7386 [2000 March 24] D. A. Biesecker reported observations (measures by D. Hammer and himself, reductions by B. G. Marsden) of four more comets seen in 1999 SOHO data, all but C/1999 J6 being presumed Kreutz sungrazers. Comets C/1999 J6 (visible in both C2 and C3 data) and C/1999 U5 (visible in only the C3 telescope) show no tail. However, C/1999 W1 and C/1999 Y3, which were both visible with only the C2 telescope, did show tails. Selected V magnitudes from Biesecker for C/1999 J6: May 10.750 UT, 8.1; 10.833, 7.3; 10.935, 6.5; 11.088, 5.9; 11.269, 5.5, 11.338, 4.9; 11.462, 5.1. Comet C/1999 J6 (SOHO-109) was first noted by M. Oates in archival data via the SOHO Web page on ? 2000 March 20; C/1999 U5 and C/1999 W1 were discovered by Biesecker, and C/1999 Y3 was discovered by A. Vourlidas of the SOHO team.

On the same IAUC Doug Biesecker also reported observations of four additional Kreutz sungrazing comets detected by SOHO in the first few months of 2000. Comet C/2000 B5 was discovered by Biesecker; the other three comets were found by several people browsing the SOHO web site, as follows: C/2000 B6, M. Meyer, T. Lovejoy, J. Shanklin, and M. Oates; C/2000 B7, Meyer and Lovejoy; C/2000 D3, Meyer and K. Cernis. C/2000 D3 was visible with both the C2 and C3 telescopes and showed a short tail; the other three comets showed no apparent tail and were visible only in the C3 data.

I discovered **SOHO-110** (1999 F1) on April 1 at 09:09 UT whilst compiling material for this issue of Comet's Tale at the Institute of Astronomy. I'd looked at the C3 frames and seen nothing and whilst waiting for the C2 frames to download I was updating the web pages and collating notes from the Journals. I thought that I glimpsed a moving object on the bit of the movie that I could see and on checking it was an obvious Kreutz fragment, visible from 04:30 to 07:31. I immediately emailed the search team and almost instantly got a message from Maik Meyer saying that he had also found it.



Information about the latest discoveries is available from Doug Biesecker who is a member of the SOHO team. To mark SOHO-100 ESA issued a Press release and more information and images are on NASA hotshots.

SOHO was launched on 1995 December 2. It experienced a malfunction on 1998 June 25 and contact with it was lost. It was located by radar on July 29, communication was established in early August and it resumed pointing at the Sun in mid September. The LASCO cameras were reactivated in October but further problems were encountered and the spacecraft did not return to action until February 1999. Further control problems were encountered from time to time during the winter of 1999/2000.

There are three LASCO (Large Angle Spectroscopic Coronographs) on the SOHO spacecraft, which orbits the sun at the earth's L1 Lagrangian point, 1.5 million km ahead of the earth. C1 has a field from 1.1 to 3 solar radii, C2 from 1.5 to 6 and C3 from 3.5 to 30. Brighter objects are often discovered in the real time data, but the fainter ones have to wait for the archival data to be searched which runs three or four months behind. SOHO has now discovered 110 comets (109 with LASCO), of which the majority are all members of the Kreutz group of sungrazing comets. So far, only 13 are not Kreutz group sungrazers. Further background information on the SOHO comets can be found on Doug Biesecker's web pages. The LASCO images are downloaded every half an hour and you can view them individually or as movies on the web.

2000 A1 Montani J. Montani, Lunar and Planetary Laboratory, reported his discovery of a faint 19^{th} magnitude comet on CCD images taken with the 0.90-m Spacewatch telescope at Kitt Peak on January 12.33. The comet shows a coma with diameter 5"-6", slightly elongated in p.a. 245-250°. An R CCD image taken by S. Kern with the 2.3-m Steward telescope on January 13 shows the comet to be clearly extended toward the southwest, and she derived mag 18.1. W. Shook found the object to be nonstellar with a 2".6 tail toward the southwest on an image taken with the 3.5-m WIYN telescope on January 13. [IAUC 7346, 2000 January 14] The comet is very distant (9.8 AU) and close to perihelion. The perihelion distance is the largest on record for a confirmed comet, though Trans-Neptunian-Objects (for example 1999 DP8) have greater perihelion distances.

A/2000 AB229 Details of an unusual asteroid with a 400 year period, a high inclination orbit and a perihelion distance of 2.3 AU were given on MPEC 2000-B20. The 18^{th} magnitude object was discovered by LINEAR on January 5.38 and was just past perihelion. The next MPEC gave details of another unusual object 2000 AC229, which has a period of 8.8 years, an inclination of 53 degrees and a perihelion distance of 1.8 AU. This was discovered by LINEAR on January 8.24.

2000 B2 LINEAR A 19^{th} magnitude object with unusual motion and reported as asteroidal by LINEAR on January 29.24 was found to be cometary in appearance following posting on the NEO Confirmation Page. CCD observations by P. Kusnirak (Ondrejov, 0.65-m f/3.6 reflector) and by M. Tichy and Z. Moravec (Klet, 0.57-m f/5.2 reflector) indicate that the object appears slightly diffuse. [IAUC 7354, 2000 February 1] The comet is a distant one, past perihelion and will fade.

2000 B3 P/LINEAR A 19^{th} magnitude object with unusual motion that was reported as asteroidal by LINEAR on January 27.24 was found to be cometary in appearance following posting on the NEO Confirmation Page. CCD observations by P. Kusnirak (Ondrejov, 0.65-m f/3.6 reflector) on Feb. 1 show a coma diameter of 6" and a faint tail in p.a. 120 deg, and F. Zoltowski (Edgewood, NM, 0.3-m f/3.3 reflector) reports a small faint tail about 30" long in p.a. 100 deg and a dense coma about 10" across. The comet is near perihelion. [IAUC 7356, 2000 February 2]

2000 B4 D/LINEAR Another apparently asteroidal object, of 19^{th} magnitude, was reported by LINEAR on January 29.25 and posted on the NEO Confirmation Page. This object has the orbit of a centaur and was noted as appearing perhaps slightly diffuse (P. Kusnirak, Ondrejov, 0.65-m reflector, February 10) and 'soft' and slightly larger than star images (D. Balam, Victoria, 1.82-m reflector, Feb. 11). The perihelion distance is 6.8 AU and the period 77 years [IAUC 7368, 2000 February 18]

A/2000 BD19 MPEC 2000-C09 reports the discovery by LINEAR of a sun-approaching asteroid on January 26.26. The 18^{th} magnitude object has a period of 0.8 years, and a perihelion distance of 0.09 AU. If entirely asteroidal it would be 12^{th} magnitude at perihelion, but if it shows cometary activity it could reach 6^{m} and be visible on SOHO LASCO images. It was last at perihelion on 1999 Oct 17.3 and will next be at perihelion in 2000 August.

2000 C1 P/Hergenrother Carl Hergenrother, Lunar and Planetary Laboratory, reported a 17^{th} magnitude object on 2000 February 4.46 that showed an 11" tail in p.a. 300 deg on one of four CCD images taken with the 0.41-m Schmidt telescope at Catalina.

Following posting on The NEO Confirmation Page, numerous CCD observers reported cometary appearance: February 5.3 UT, coma diameter about 12", brighter 60" tail in p.a. 290 deg, extending more faintly to 180" (J. E. McGaha, Tucson, AZ, 0.62-m reflector); February 5.5, tail about 12" long toward the northwest (G. Billings, Calgary, AB, 0.36-m reflector); February 5.7, slightly diffuse with very faint tail about 10" long to the northwest (G. J. Garradd, Loomberah, N.S.W., 0.45-m reflector); February 6.1, coma diameter 0'.1, tail 0'.3 long in p.a. 290 deg (P. Pravec and P. Kusnirak, Ondrejov, 0.65-m reflector); February 6.4, faint tail < 10" long in p.a. about 290 deg (D. T. Durig, Sewanne, TN). Prediscovery observations by LINEAR on January 4 and 8 have also been identified. [IAUC 7357, 2000 February 6] The comet is intrinsically quite faint and has perihelion at 2 AU. It will brighten a little.

2000 C2 SOHO 2000 C3 SOHO 2000 C4 SOHO 2000 C5 SOHO 2000 C6 SOHO D. A. Biesecker, SM&A Corporation and Goddard Space Flight Center, reported measurements of five comets observed with the coronagraphs aboard SOHO. Only C/2000 C6 appears to be a Kreutz sungrazer; it was first noticed by Terry Lovejoy on SOHO web images on February 9.22, and Biesecker notes that its brightness ranged from V = 8.7 on February 9.43 to 7.7 on February 9.68 UT, and the comet showed a tail at 13 solar radii on C3 images. The other comets showed no tail. C/2000 C2 (SOHO's 100th comet) first noted by Kazimieras Cernis on February 3.70, remained relatively stable in brightness (V = 6.5-6.9) during February 3.70-3.84. C/2000 C3, found by Biesecker on February 4.56, brightened from V = 6.7 on February 4.59 to 5.9 on February 4.79, before fading to V = 7.0 on February 5.09. C/2000 C4, found by Maik Meyer on February 5.16, was on a trajectory closely following that of C/2000 C3, and it was assumed that the orbits are identical with a difference Delta(T) = 0.60 day. C/2000 C4 brightened from V = 5.9 on February 5.17 to 4.9 on February 5.30, before fading to V = 6.7 on February 5.67. C/2000 C5, found by Michael Oates on February 7.79, was at V = 7.5-8.0 on February 7. Comets C/2000 C2 and C/2000 C5 may also be related to each other. [IAUC 7364, 2000 February 12]

2000 CT54 LINEAR Yet another apparently asteroidal LINEAR object, of 19^{th} magnitude, discovered on February 2.44, that was posted on the NEO Confirmation Page was noted to have a 15"-16" tail toward the north-northwest on February 12 by J. G. Ries, McDonald Observatory (0.76-m reflector). The comet reaches perihelion at 3.1 AU in 2001 June [IAUC 7368, 2000 February 18]

2000 D2 LINEAR An apparently asteroidal object of 18^{th} magnitude, discovered by LINEAR on February 25.20 and posted on the NEO Confirmation Page was observed to be cometary by F. B. Zoltowski (Edgewood, NM; very diffuse image on February 28.1 UT; 12" tail in p.a. 270 deg on March 1.1) and by C. Hergenrother (Catalina 1.54-m reflector; 8" coma and very faint 15" tail in p.a. 105 deg on March 1.3). The comet was near perihelion at 2.3 AU. [IAUC 7372, 2000 March 1]

A/2000 DG8 The third asteroid with retrograde motion was announced on MPEC 2000-E07. It has a perihelion distance of 2.19 AU and a period of 32.5 years.

A/2000 DQ110 and **A/2000 EB107** are another two asteroids with orbits similar to those of short period comets. Details of the orbits of these and other unusual asteroids are on the iau web page at http://cfa-www.harvard.edu/iau/lists/Others.html

2000 ET90 P/Kowal-Mrkos MPS 11479 contained observations on March 9.30 and 13 by LINEAR of an apparently asteroidal, 19^{th} magnitude object presumed to have a moderately eccentric orbit in the inner part of the main belt. Linkage by G. V. Williams to LINEAR observations on April 4 and 8 demonstrated the cometary nature of the orbit, and the object was placed in The NEO Confirmation Page. Isolated observations from LINEAR on February 7, from the Catalina Sky Survey on March 1 (when observer T. B. Spahr had in fact drawn attention to the object's "slowish" motion) and from LONEOS on April 2 were then also linked. Neither these observers nor those responding to the Confirmation Page made a definite remark about the object's cometary appearance, even in response to specific enquiries from the Central Bureau (although strong moonlight has recently been a factor). Following a suspicion by Brian Marsden and an independent suggestion by C. W. Hergenrother, 2000 ET90 has been definitively identified with comet D/1984 H1 = 1984 JD (Kowal-Mrkos) = 1984n (IAUC 3988, 4001) = 1984 X, for which current predictions (ICQ Comet Handbook for 2000, p. H87; OAA Comet Handbook for 2000, p. 37) require correction by Delta T about -125 days. The comet passed only 0.16 AU from Jupiter in March 1989. There was an unobserved return with T = 1991 Aug. 2. [IAUC 7403, 2000 April 15] The original orbit was based on only eight observations, so it is perhaps not surprising that the prediction was somewhat in error.

2000 G1 LINEAR F. Shelly, for the Lincoln Near-Earth Asteroid Research project, reported, in connection with the discovery on April 7.45 of a fast-moving 18th mag object, that Lisa Brown-Manguso noticed that the object showed clear cometary activity. It is very likely that the comet is short period (with current geocentric distance 0.24 AU), though the initial elements are parabolic, with q 1.01 AU and T 2000 March 9.02. [IAUC 7396, 2000 April 8] The parabolic orbit suggests that the comet would have passed 0.15 AU from the Earth in early March, reaching 15^{th} magnitude, but was at high southern declination.

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

NOVEMBER 1999 : Until three years ago, the search for Near-Earth Objects (NEO's) was carried out in both the Northern and Southern Hemispheres. Then, in 1996 the Australian government stopped the funding so the Southern Hemisphere search was shut down. In the meantime the Northern Hemisphere increased its search capabilities, especially with the addition of LINEAR, in New Mexico, about a year ago. Now the Southern Hemisphere search has been re-funded and should begin soon. Robert McNaught will manage it and all the equipment is being updated.

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

ICWA II : METHOD-RELATED BRIGHTNESS ESTIMATE DIFFERENCES, AND THE DELTA EFFECT

Joseph N. Marcus

The Comet's Tale editor is to be commended for his extraordinary efforts which made the Second International Workshop on Cometary Astronomy such a success. Not only was Jonathan Shanklin key in organizing and administrating the program and its finances, but he turned out a great synopsis of the goings-on in issue 12 of *The Comet's Tale* (1) that arrived in the U.S. mail only six weeks after the event! At such a pace it was perhaps inevitable that an error or two may have crept into the summary. I should like to correct one that occurred in the discussion of Charles Morris' presentation ("Why you don't get your papers published in the ICQ and other rants") and offer some clarifying remarks.

Contrary to what was reported on p. 12, I did not comment "…that the extensive work by the Dutch Comet Section did demonstrate the delta effect." Instead I noted that the Dutch Comet Section had studied differences in brightness estimates between the the Sidgwick and Bobrovnikoff methods. My remarks addressed the misimpression that arose during the discussion period that these differences were not documented – a point over which Morris took some ribbing, as Shanklin noted.

In fact, the Dutch Comet Section had long ago published in the English language literature an analysis of methods-related brightness estimate differences in their observations of two comets in 1981-2 (2). For 64P/Swift-Gehrels, a faint, large, diffuse comet, the "…Morris and Sidgwick estimates were essentially the same, but the Bobrovnikoff estimates were considerably fainter," by 0.9 magnitude. For C/1982 M1 (Austin), which was condensed, the difference was considerably smaller, about 0.2-0.25 magnitude. The author, the venerable comet observer Reinder Bouma, further wrote: "From these two examples it is clear that there is a real difference between Bobrovnikoff and Sidgwick estimates. The size of the difference appears to be a function of the coma's brightness, size, and degree of condensation." He warned that absolute magnitude m_o and slope n value of a cometary light curve can be systematically affected by the type of method used in the analysis. Don Machholz, a participant in the Cambridge IWCA, was actually the first to present hard data on methods differences in *Comet News Service* (3), only two years after the Morris method was published in the Western literature (4,5). Machholz had found the same thing for 1980 apparitions of comets 38P/Stephan-Oterma, 8P/Tuttle, and 2P/Encke – the Sidgwick method yields brighter estimates than the Bobrovnikoff, with the Morris method in-between (3). In summary, Morris' assertion about methods-related brightness estimate differences is supported by published literature. There is no need to attribute the claim solely as a "personal communication."

The "delta effect" is an artifact in which the outer part of the coma, magnified by near-earth distance, is lost to human vision as its contrast gradient falls below threshold, leading to an underestimate in coma diameter and brightness. Named after the Greek letter Δ, which is used to connote the earth-object distance, it can be studied through the formula

1) $m_1 = m_o + 2.5\,k \log D + 2.5\,n \log r$

where m_1 is the observed magnitude of the comet, r is comet-sun distance, D is the absolute magnitude (reduced to $D = 1$ AU $= r$), and k and n are the indices of variation of m_1 with log D and log r, respectively. Normally k is taken to be 2, i.e., it is assumed that comet brightness varies as D^{-2}, the familiar inverse square law of distance, but in a delta effect, $k < 2$. Eq. (1) is in the general form

2) $a_0 + a_1 x_1 + a_2 x_2 = 0$

where x_1 (= 2.5 log D) and x_2 (= 2.5 log r) are independent variables and a_0 (= m_o), a_1 (= k) and a_2 (= n) are unknown coefficients that can be solved for through multiple linear regression (6) on a data set of m_1, r, and D values.

In his talk at IWCA II, Morris implied that doing multiple linear regression on comet light curves in the above manner is not legitimate because r and D are always "statistically correlated." This implication is not correct. Certainly r and D are always *mathematically related* by the cosine law

3) $r^2 = D^2 + R^2 - 2RD \cos q$

where R is the sun-earth distance and q is the elongation. Morris confuses the concept of "mathematical relationship" with that of "statistical correlation." *r* and *D may* or *may not* have a significant statistical correlation depending on the geometry of the apparition and the distribution of the m_1 observations. If, say, the comet is a periodic reaching a close perigee at the time of its perihelion, then *r* and *D* have a high degree of covariance, and it would be difficult or impossible to do useful regression. However, if a comet reaches close perigee at a time when it is solely on the heliocentric inbound or outbound legs of its orbit, then the covariance may be minimal and legitimate regression would be possible. Such was the case for near earth-approaching comets 1P/1909 R1 (Halley), C/1975 T2 (Suzuki-Saigusa-Mori) and C/1979 Y1 (Bradfield), for which delta effect *k* values were found by multiple regression to be 1.41 ± 0.07, 1.61 ± 0.12, and 1.37 ± 0.09, respectively (7-9). The covariance between *r* and *D* can be assessed in two related ways. One is to compute the correlation coefficient between them directly using the variance-covariance matrix in the regression formula (6). For the Bobrovnikoff data set (10) for P/Halley in 1910, the correlation coefficient between log *D* and log *r* can be computed as -0.047 – almost no correlation at all! A second way, less direct but more utilitarian, also employing the variance-covariance matrix, is to look at the sizes of the standard deviations on *k*. The greater the co-correlation between log *D* and log *r*, the larger the standard deviation, and the less determinate the solution for *k*. For the m_1 data sets analyzed for these three comets, the SDs on *k* are small enough so that when assessed by Student t-test, all 3 *k* values are significantly different from *k* = 2, with the level of probabilities that the differences can be due to chance being much less than p = 0.05 in all three cases.

It should therefore be accepted that multiple linear regression to obtain m_0, *n*, and *k* values for comet light curves is possible and that it is a legitimate method when judiciously applied. It would be unfortunate if Morris' "rant," in his word, at the Cambridge IWCA should deter analysts from employing it for fear of having a paper rejected by the *International Comet Quarterly*, of which he is Associate Editor, or any professional astronomical journal. Charles' choice of the word "rant" in the title of his talk was amusing and appreciated for its self-deprecating good humor. However, he should realize that one of the definitions entered for it in the Oxford English Dictionary (apologies, Cambridge!) is "empty declamation." I think that it can be fairly concluded that it is this entry which most accurately characterizes his specific rant against regression on log *D* and log *r* in comet light curves because they are "correlated."

This being said, Charles and I would probably agree that the best way to look for a delta effect in a comet light curve is not, paradoxically, through the light curve itself. After all, comets can and quite often do behave irregularly in brightness, in such a manner as to violate the assumption of linear behavior of heliocentric magnitude with log *r*. It is this criticism of *any* log *r* regression analysis which is most cogent in my view. Ideal analyses of delta effect in light curves should take into account such potential irregularities by comparing m_1 observations with independent data sets, such as dust and gas production rate photometry, which may be less prone to a delta effect. Such analyses have never been done, to my knowledge. And analyses for delta effect (and of comet light curves in general) are further complicated by the need to adjust for systematic errors arising from the type of magnitude estimation method employed – discussed above – as well as for other error sources, such as instrument magnification – noted below.

In my view, the best evidence for delta effect is the well-documented artifact of underestimated coma diameter and brightness with increasing instrument magnification, also referred to as "aperture effect" (10, 11). Charles Morris helped to define it (11), and the effect is beautifully seen in his observations of C/Bradfield 1979 Y1 (12). In the paradigm that each is an artifact of human vision, "aperture effect" and "delta effect" are identical in that the underestimation artifact introduced by observing a comet at, say, twice the magnification in an instrument twice the aperture is physically equivalent to observing the comet in the original instrument if the comet-earth distance were to be halved. This symmetry is so direct that it should be no leap at all to accept that "delta effect" exists if "aperture effect" exists.

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Observations of Comet 109P/Swift-Tuttle

Alex Vincent

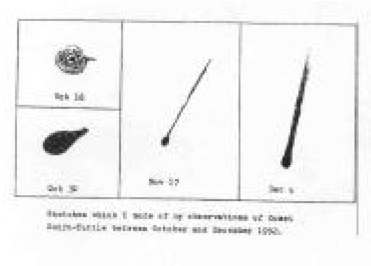
Comet Swift-Tuttle was discovered by Lewis Swift and Horace Tuttle in 1862 and came to perihelion in the same year. It was calculated to have a period of 120 years and was due to return in 1982, but it never came. Some astronomers thought that it came and went unseen while others thought that it had a longer period.

Its period is between 130 and 135 years and it last reached perihelion on 1992 December 12. T Kiuchi recovered it on 1992 September 27. Comet Swift-Tuttle is the parent comet of the Perseid meteor shower, which is seen in August each year.

The comet will return again in 2126 and will make a very close approach to the Earth to just over 1 million kilometres and its tails will stretch half way across the sky. The comet may be seen in daylight. I'd sure like to see that rascal!

I made a number of observations of comet Swift-Tuttle, the first was on 1992 October 16 through a 20cm Celestron telescope and it appeared as a large fuzzy smudge with a short tail. My next observation was on October 30 where its tail was longer and the comet more elongated. I took several photographs of it on a camera platform.

I made observations of it on November 6 through a Celestron 20cm and it looked great with its tail. My next observation of it on November 17 was down on the beach. The comet's tail was thin as viewed through a x2 teleconverter attached to a camera lens through which I took some photographs.



Sketches of Comet Swift-Tuttle made between 1992 October and December.

My best observation of the comet was on 1992 December 4, again through the 20cm Celestron, and again it looked impressive with its tail. The comet was of 5th magnitude and I took several photographs with the camera piggybacked on the telescope. My last look at it was on December 5 down at the beach with the naked eye also taking a number of photographs with my camera on a tripod.