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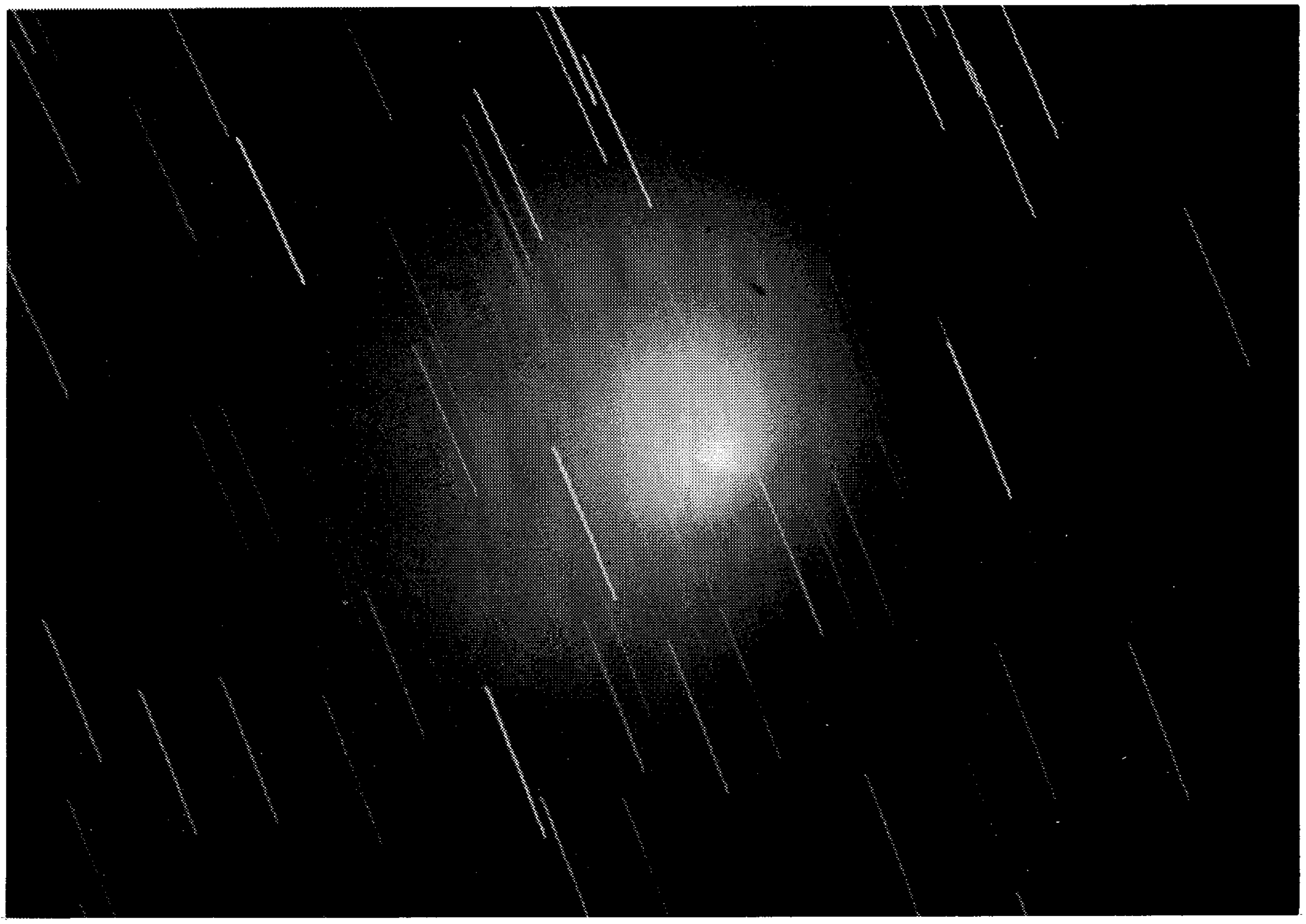

COMET IRAS-ARAKI-ALCOCK 1983d: Photo by A. Mrkos (Klet Observatory, Czechoslovakia), 20-minute exposure beginning May 9.97193 UT. North is to the right.

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INSIDE THIS ISSUE

The Interaction of Comets with Solar Radiation and the Solar Wind. I. ...51
by D. A. Mendis and Harry L. F. Houpis

Recent Visual Observations of Nuclear Outbursts in P/Kopff 1982k..........59
by John E. Bortle

The Light Curve of Periodic Comet d'Arrest 1983e, by John E. Bortle.......61

Tabulation of Comet Observations..64
(Comets Kohler 1977 XIV, Meier 1978 XXI, Bradfield 1979 X, Meier 1980 XII, Panther 1981 II, Austin 1982g, IRAS-Araki-Alcock 1983d, Sugano-Saigusa-Fujikawa 1983e, Černis 1983l, P/Pons-Winnecke 1983b, P/Tempel 1 1982j, P/Tempel 2 1982d, P/d'Arrest 1983e, P/Kopff 1982k, P/Johnson 1983h, P/Churyumov-Gerasimenko 1982f, P/Gunn, P/Russell 3 1983i, P/Schwassmann-Wachmann 1, P/Stephan-Oterma 1980 X)

Recent News Concerning Comets, by Daniel Green...........................75

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All cometary observations should be sent to C. S. Morris; R.D. 2, Box 96; Harvard, MA 01451, U.S.A. Back issues are available from Dr. T. L. Rokoske, Dept. of Physics and Astronomy; A.S.U.; Boone, NC 28608, U.S.A.

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FROM THE EDITOR

Readers are asked to note the address change for our Associate Editor:

Charles S. Morris
Prospect Hill Road
R.D. # 2, Box 96
Harvard, MA 01451, U.S.A.

Special notice should also be given to our request for proper reporting of observational data (see p. 64). Improper reporting procedures by many observers causes considerable delays, not only in the publication of such observers' specific data, but in the publication schedule of the ICQ as a whole. Our added individual attention to observations that lack certain necessary data (such as comparison star reference, magnitude estimation method, etc.) takes time of the ICQ Staff away from more important tasks.

--Daniel Green, 1983 August 10
Cambridge, Massachusetts

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UNIVERSAL TIME (UT): This time based on the Greenwich meridian is used throughout the ICQ; it is 24-hour time, from midnight to midnight. In North America, add the following numbers to standard times to convert to UT: EST, 5; CST, 6; MST, 7; PST, 8. For daylight savings time, add 4, 5, 6, and 7 hours, respectively.

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

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I. INTRODUCTION

Due to their small sizes, which are typically on the order of a kilometer, cometary nuclei do not possess sufficient internal pressure and temperature to cause differentiation* and other physico-chemical changes that are manifest in the larger solar system bodies such as planets and satellites. It is therefore generally recognized that comets probably constitute the most pristine objects in the solar system. Furthermore, during each passage around the sun, the outer skin of the cometary nucleus is removed, exposing fresh material for analysis. Consequently, knowledge of the physical structure and chemical composition of the cometary nucleus should provide us with basic information about both the physical and chemical conditions that existed during the earliest stages of planetary formation, as well as the physico-chemical processes that led to their formation.

Unfortunately, by the time a comet is first visible even with the largest telescopes, the cometary nucleus is already shrouded by a thick atmosphere of gas and dust. As the comet approaches the sun, it may also begin to develop long tails composed of dust and ionized gases. All these phenomena are associated with the interaction of solar radiation and the solar wind with comets, and therefore it is necessary to clearly understand the nature of these interactions if one is to make reliable deductions about the nucleus from the observations.

While this provides a strong motivation for the study of cometary atmospheres and tails, they are highly interesting phenomena in their own right. For instance, while the atmospheres of the planets exhibit an enormous diversity in their chemical composition and physical properties, they have two important properties in common. With the exception of small seasonal variations and insignificant exospheric losses of lighter molecules, they are constant and they are gravitationally bound to their parent planets.

Cometary atmospheres differ from the planetary atmospheres in both these essential aspects. On the one hand, as comets approach the sun in highly elliptical orbits, they continuously develop more and more extensive atmospheres. On the other hand, due to the negligible gravity of the small cometary nucleus, this atmosphere flows radially outward with velocities on the order of 1 km/s. Also, this outflowing gas carries a large quantity of dust with it, and the dynamic and thermodynamic coupling between the gas and the dust adds several novel features to this dynamic atmosphere, making it, in particular, transonic. Finally, it appears that the cometary nucleus varies not only in size, but more importantly in chemical composition and surface structure. As a result, the atmospheric activity varies widely from one comet to another. While many comets which are presumably rich in volatiles such as CO_2 and CO exhibit atmospheric activity at large heliocentric distances ($r \geq 3$ AU), a class of comets whose sublimation seems to be controlled by H_2O shows significant activity only much closer to the sun ($r \leq 2$–3 AU).

The nature of the solar wind interaction with comets is also highly variable. For instance, in the case of an average-sized ($R_n \sim 1$ km) H_2O-dominated cometary nucleus, the sublimated atmosphere beyond $r \geq 4$ AU will be so tenuous that it will present a negligible obstacle to the solar wind, which will flow directly onto the surface. Also, since

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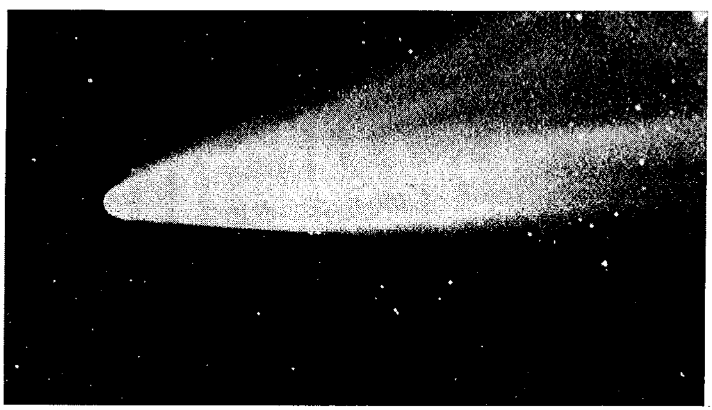
* development from the simple to the complex

the solar wind proton gyro-radius at this distance is much larger than the nuclear size, while the electron gyro-radius is also larger or comparable to it, the solar wind flow past the comet is 'free-particle'. Consequently, the comet will not disturb the solar wind flow either upstream or downstream from it. When such a comet is close to the sun ($r < 1$ AU), however, the rapid sublimation and outward expansion results in an extensive atmosphere which interacts with the solar wind over a scale which is 5-6 orders of magnitude larger than the size of the nucleus.

Also, while comets are not expected to possess intrinsic magnetic fields, this interaction of the magnetized solar wind with the cometary atmosphere and ionosphere is expected to drive large currents in the cometary head and plasma tail, and give rise to a huge, purely-induced magnetosphere.



(a)

(b)

Fig. 1. Photographs of comet West 1976 VI obtained from a rocket on March 5, 1976, and printed to the same scale: (a) visual light photograph (P. D. Feldman, Johns Hopkins University), (b) Lyman-α photograph showing the hydrogen cloud (C. B. Opal and G. R. Carruthers, Naval Research Laboratory). [from Comets: Readings from SCIENTIFIC AMERICAN, J. Brandt, Editor, 1981]

In this connection, we should also point out the important role of comets as natural free probes of the interplanetary medium. Indeed, it was the orientation of the plasma tail of comets which led to the discovery, by Ludwig Biermann in 1951, of the continuous outflow of corpuscular radiation from the sun, which we now call the solar wind. In this role, comets have not been entirely superceded by the more recent artificial space probes, because while the latter are confined to regions close to the ecliptic plane, comets approach the sun at all inclinations and a few of them get closer to the sun than any artificial probe has or will in the foreseeable future.

It should also be clear from the above discussion that the study of the interaction of the solar radiation and the solar wind with comets is not only uniquely interesting in itself, but would contribute significantly to the important new discipline of comparative planetology. However, while an impressive body of knowledge now exists about planetary atmospheres and magnetospheres, this is not the case with comets. Due to their infrequent occurrences and transient natures, they are not well suited to well-planned programs of careful observation. Consequently, although the accumulated knowledge of comets is not insignificant, it is highly fragmentary.

Spectrophotometry, both from the ground and, more recently, from earth-orbiting satellites, gives the most quantitative observations of comets. Unfortunately, the direct information which the observations provide pertains almost exclusively to the photolytic neutral molecular fragments and ions present in the extended outer atmosphere and plasma tails. Very little data exists on the stable molecules that must dominate the inner atmosphere (or coma) and are the 'parents' of the highly chemically unstable molecular fragments that are observed in the outer coma.

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

II. SPECTROPHOTOMETRY OF THE COMETARY ATMOSPHERE AND TAIL

All the chemical species identified to date are shown in Table I. This is a composite list -- not all being observed in all comets. While Na is observed at moderate distances from the sun, the other metals are observed only in sun-grazing comets, and probably come from the vaporization of dust grains.

TABLE I. SPECTRAL IDENTIFICATIONS IN COMETS.

H, O, C, S, Na, K, Ca, V, Mn, Fe, Co, Ni, Cu, C_2, $^{12}C^{13}C$, CH, CN, CO, CS, NH, OH, C_3, NH_2, H_2O*, HCN, CH_3CN, S_2.

C II, Ca II, CO II, CH II, CN II, N_2 II, CO_2 II, H_2O II.

*This identification is tentative.

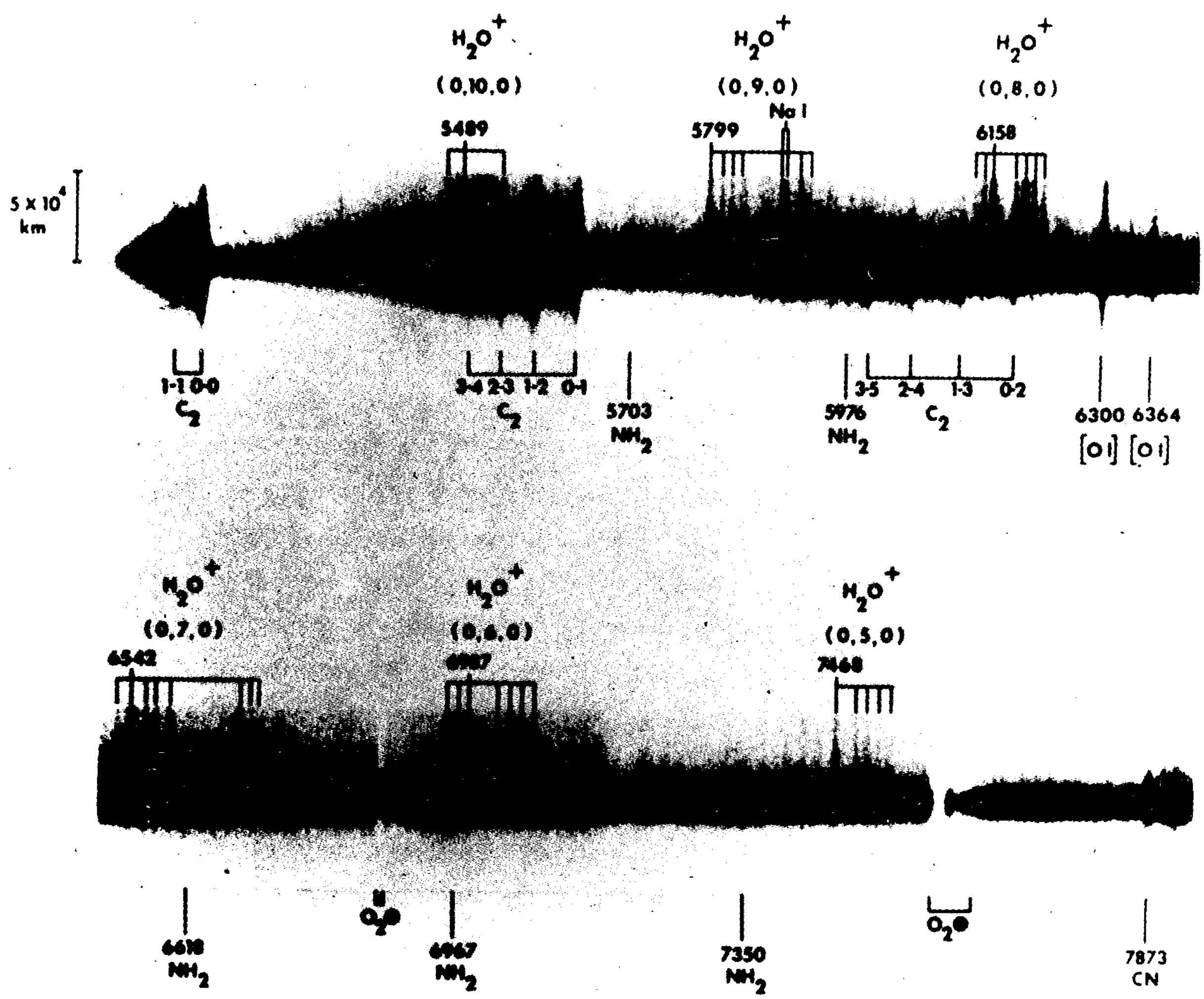


Fig. 2. Spectrogram of comet Kohoutek 1973f, taken 1974 Jan. 10.7 UT (r = 0.51 AU) with the Cassegrain spectrograph of the 1-m reflector at Wise Observatory using an ITT F-4089 image tube (S-25 photocathode). The image of the coma was centered on the spectrograph slit, which was oriented along the comet's tail. The tail spectrum is above the strong continuum of the coma. The H_2O^+ bands are identified by the designations of their upper-vibronic levels, the lower state being in all cases (0,0,0) of the ground electronic state. Only the strongest band heads (or lines) of C_2, CN, and NH_2 in the coma are marked. The reciprocal dispersion in the original spectrum was 15.0 nm/mm. Exposure was 15 min on Kodak 103a-D plate (from Wehinger et al. 1974, Ap. J. 190, L43).

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

Cometary observations now span the entire range of electromagnetic radiation. While most of the neutral radicals, metals, and ions have been detected in the optical range, the contribution of recent radio and vacuum-UV observations have been most significant.

The stable molecules such as HCN and CH_3CN were observed for the first time in the radio via their ground state vibration-rotation transitions at millimeter wavelengths. H_2O has also been reportedly detected via a ground state rotation-vibration transition at centimeter wavelengths, but this identification must be considered tentative at this time. The important neutral species, H, C, O, and S, have been detected via their resonance lines by vacuum-UV detectors in earth-orbiting spacecraft and high-flying rockets. The N resonance line is weak and is hidden in the wing of the hydrogen Lyman-α line, which makes its detection very difficult, and probably explains its absence from the list in Table I.

Besides the emission bands and lines of the molecules and atoms, there is also continuum emission from the cometary head and dust tail. Below about 2 microns (μ), this is largely sunlight reflected by dust. Beyond this is thermal re-radiation with broad features around 10μ and 20μ, which are generally attributed to silicates, although organic polymers have also been suggested as alternative candidates. In fact, if all the metallic species seen in sungrazers did come from the vaporization of the dust grains which are generally believed to be silicates, the non-observance of the strong Si I line at 390.5 nm is puzzling.

The neutral species are seen only in a more or less spherical region around the nucleus. This has typical dimensions ~ 10^5 km at a heliocentric distance of ~ 1 AU, for all species except atomic hydrogen, whose Ly-α emission extends over a region which is more than an order of magnitude larger (see Fig. 1). The ions are seen both in the coma and in the plasma tail. Figures 2 and 3 show two spectrograms of comets, one in the optical and near-infrared region, and the other in the vacuum-ultraviolet. Notice the extensions of the emissions normal to the spectral dispersion. It is clear that ionic emissions are strongly extended in the tail direction, while the neutral emissions are concentrated around the nucleus.

For a typical comet, the neutral atmosphere is first seen when $r \leq 3$ AU. The (0-0) band of CN near 388.9 nm is the first to appear, and defines the greatest extension of the neutral coma. It also defines the 'photographic diameter' of a comet. The 'visual diameter' as well as the color of the coma are

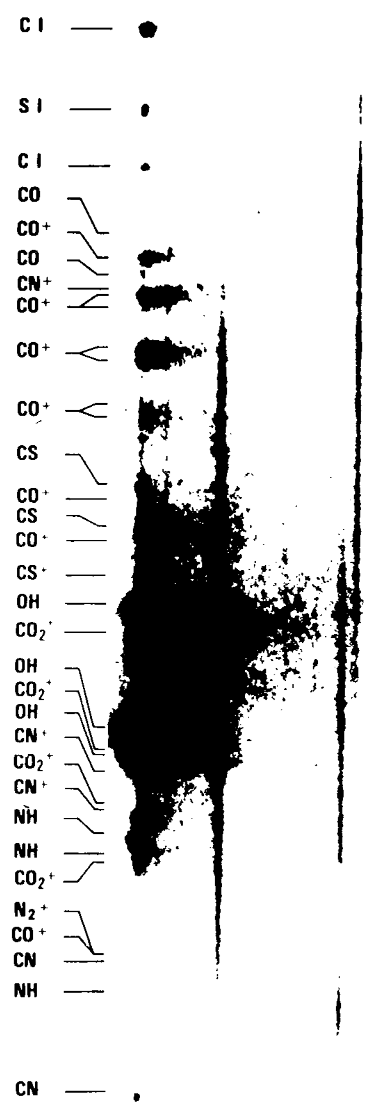


Fig. 3. Ultraviolet spectrum of comet West 1976 VI obtained from a rocket-borne instrument flown on March 10, 1976. The coma images are at the left, with the tail images, particularly in CO^+ and CO_2^+, stretching to the right. (A. M. Smith and T. P. Stecher, Laboratory for Astronomy and Solar Physics, NASA Goddard Space Flight Center) [from Brandt 1981, Comets (ibid.)]

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

generally determined by the Swan bands of C_2 ($\geq$ 436.0 nm), which appear somewhat later ($r \leq 2$ AU) and which extend to a slightly smaller distance. The C_3 and NH_2 emissions appear somewhat earlier, but are generally less extended than the C_2. The OH emission bands lie close to the ground-based limit of observation and are difficult to observe at large zenith distances, due to absorption by terrestrial ozone. However, they represent some of the strongest and most extended emissions to the detectors on orbiters outside the earth's atmosphere. The [O I] lines and the D-line of atomic Na typically appear only when $r \leq 1$ AU, while the elements of the iron group (Cr, Mn, Fe, Co, Ni, Cu), as well as K and Ca, are seen essentially only in sungrazers (when $r \leq 0.02$ AU).

The isophotes of the neutral molecular emissions are generally quite spherical, with slight flattening toward the sunward side. The isophotes of the metallic lines are much more asymmetric, and for the D-lines of Na they are 2 to 3 times longer on the tailward side of the nucleus as on the sunward side. This asymmetry results from the effects of radiation pressure, which, due to the larger oscillator strength for the sodium excitation than for typical molecular excitations, is more pronounced in this case. The long, tailward extension of the ions is due to their strong interaction with the solar wind, and this will be discussed later.

III. ATMOSPHERIC ABUNDANCES AND PRODUCTION RATES

While the first step in the quantitative study of cometary atmospheres is to estimate the abundances of the various species that have been detected spectroscopically, the amount of reliable measurements on the emission line and band strengths is rather limited. Early monochromatic emission rates determined from photographs were quite rough, and were also complicated by aperture effects when the whole comet was not in the field of view. Reliable quantitative measurements of line emission rates, using both multi-aperture narrow band photometry and digital spectrophotometry, both in the optical and in the UV, have become routine only in comparatively recent times.

If the projected aperture of an instrument is considerably larger than the projected scale length against decay of a given species, and if the atmosphere is assumed to be optically thin, the total number of molecules, N, in the coma responsible for a particular emission is given by

$$N = 4\pi\Delta^2 F/g, \qquad (1)$$

where Δ is the geocentric distance, F is the measured flux in the line, and g is the flouresence efficiency (which is the probability of scattering a solar photon of that frequency per unit time per molecule). This 'g-factor' depends on the oscillator strength* of the transition, the branching ratio, and the solar flux at that frequency.

Traditionally, instead of the atmospheric abundance of a given species, what is generally given is the production rate, Q, of that species, which, under steady-state conditions, is related to N by

$$Q = N/\beta, \qquad (2)$$

where β is the lifetime of the species, and is determined either empirically (i. e., from observations of the comet itself) or by calculation.

In calculating β, the various destruction processes for the species, together with their branching ratios, must be known, and the relevant cross-sections as functions of the wavelength must be known. Usually only photodestruction (dissociation and ionization) are considered and solar wind interactions are ignored.

In order to calculate β empirically, one requires a suitable dynamic mod-

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* a quantum-mechanical term specifying the luminous intensity of the atom in units of the luminous intensity of a classical oscillator

el of the cometary atmosphere. The one that has been generally adopted is the exospheric model of L. Haser, where both the parent and daughter molecules move radially with constant velocities. The continuity equation then gives the number-density profile, and an integration of this along the line of sight gives the column-density profile and therefore the brightness profile, since the atmosphere is assumed to be optically thin. Fitting the model profile to the observations, one gets the destruction scale lengths ($v\beta$) for the daughter and the parent molecules. With some assumed value of the outflow velocity (typically ~ 1 km/s), one then obtains β. The values of β derived this way have been systematically shorter than the calculated values, particularly for the parent molecules. Recently several authors have made essential improvements to the Haser model. All of these treatments have taken into account the random directions of ejection of the daughter products during photo-destruction.

Despite these improvements, the application of the Haser model to obtain the destruction scale-lengths and time-scales must be viewed with considerable caution. The most serious difficulty is the fact that, while the Haser model describes free-molecular flow, collisions dominate within a circumnuclear region of radius r_c, and the proper description of the flow is as a fluid. For a typical H_2O-dominated, medium-bright comet at a heliocentric distance of 1 AU, $r_c \sim 10^4$ km, whereas for comets dominated by more volatile species such as CO_2 or CO, it is considerably larger. Particularly in cases where the inferred photo-destruction scale-lengths of the parent molecules are comparable to or smaller than r_c, they must be regarded with skepticism.

Also, the single time-scale for destruction is applicable only for the case of photo-destruction. In the case of removal by chemical reactions, such as is the case for the ions (e.g., by fast ion-molecule reactions, dissociative recombinations, etc.), the time-scale depends on the product of the densities of the species partaking in the reaction as well as the temperature, and these vary drastically within the cometary coma. Therefore, a special word of warning is in order against the application of this method in determining the destruction time-scales or length-scales of various cometary ions. The situation is complicated further in the case of the ions, because their distribution is determined not only by their production and destruction rates, but also by their flow, which is expected to have strong discontinuities, such as a tangential discontinuity surface (separating the cometary ions created within it from the inflowing contaminated solar wind), and an 'inner' shock (which causes a transverse diversion of the ion flow).

Production rates for the three species CN, C_2, and C_3 based on homogeneous sets of observations have been determined for several comets observed in the middle- and late-1970s. The production rates of the atomic species C, O, and H, as well as some radicals and molecules (OH, CO), have recently been obtained from UV observations of some comets. The production rates of several species observed in the UV in comets Kohoutek 1973 XII and West 1976 VI are shown in Table II.

These production rates give us information about the composition of the nucleus or at least its upper few meters. It is interesting to note that

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TABLE II. THE PRODUCTION RATES OF COMETS KOHOUTEK 1973 XII AND WEST 1976 VI FROM ULTRAVIOLET (UV) OBSERVATIONS

Species	Wave-length (nm)	Comet 1973 XII (r = 0.34 AU)	Comet 1976 VI (r = 0.38 AU)
H I	121.6	5.4×10^{29}	3.2×10^{30}
O I	130.4	1.4×10^{29}	1.1×10^{30}
C I	165.7	1.2×10^{29}	3.1×10^{29}
OH	309.0	0.8×10^{29}	9.6×10^{29}
CO	151.0	$\leq 7.1 \times 10^{29}$	4.2×10^{29}
CO	289.0	$\leq 1.1 \times 10^{30}$	$\leq 2.3 \times 10^{29}$

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

the production rates of C and CO are comparable to that of H and OH. For instance, in comet 1976 VI, Q(CO) ~ 0.3 Q(OH). Also, since the production rates of H and OH are comparable, it is reasonable to assume that H_2O is the parent molecule of both OH and H; in that case, Q(CO) ~ 0.3 Q(H_2O), since the main photo-destruction pathway for H_2O is dissociation into OH and H. The idea that the chemical composition of the volatile component of the cometary nucleus is a clathrate hydrate, where all other volatile species are entrapped in the H_2O ice lattice, proposed by Armand Delsemme and Pol Swings over 30 years ago, explains a number of cometary phenomena, including the almost-simultaneous activity of the cometary coma in nearly all the observed species. However, the clathrate hydrate can hold a maximum of one guest molecule for every six H_2O molecules. So the above observation that Q(CO) ~ 0.3 Q(H_2O) clearly contradicts this model. Due to the inherent uncertainties in the production rate estimates discussed earlier, it is perhaps still a bit premature to use them to either support or rule out the clathrate hydrate model. More reliable estimates based on more realistic models are needed for that purpose.

On the other hand, there do seem to exist comets whose chemical composition is not a clathrate hydrate of H_2O; these are the ones such as the recent comet Bowell 1980b that show strong continuum (dust) activity at large (r ≥ 4 AU) heliocentric distances.

IV. MODELLING THE COMETARY ATMOSPHERE

As we have pointed out earlier, most of the species observed in the extended cometary atmosphere are chemically unstable radicals which are clearly photo-destruction products of more stable 'parent' molecules, as first recognized by Karl Wurm over 40 years ago. All subsequent modeling efforts of the cometary atmosphere, including the ionosphere, have started with an assumed chemical composition of the nucleus and attempted to fit the observed distributions. Besides photo-dissociation and photo-ionization, fast exothermic reactions involving molecules and the newly-produced ions result in a reshuffling of chemical species in the inner coma. Consequently, even if one starts with a small number of initial nuclear constituents (parent molecules), the number of neutral and ionic species in the coma becomes substantial.

Simultaneously with the chemistry, one has also to consider the dynamics

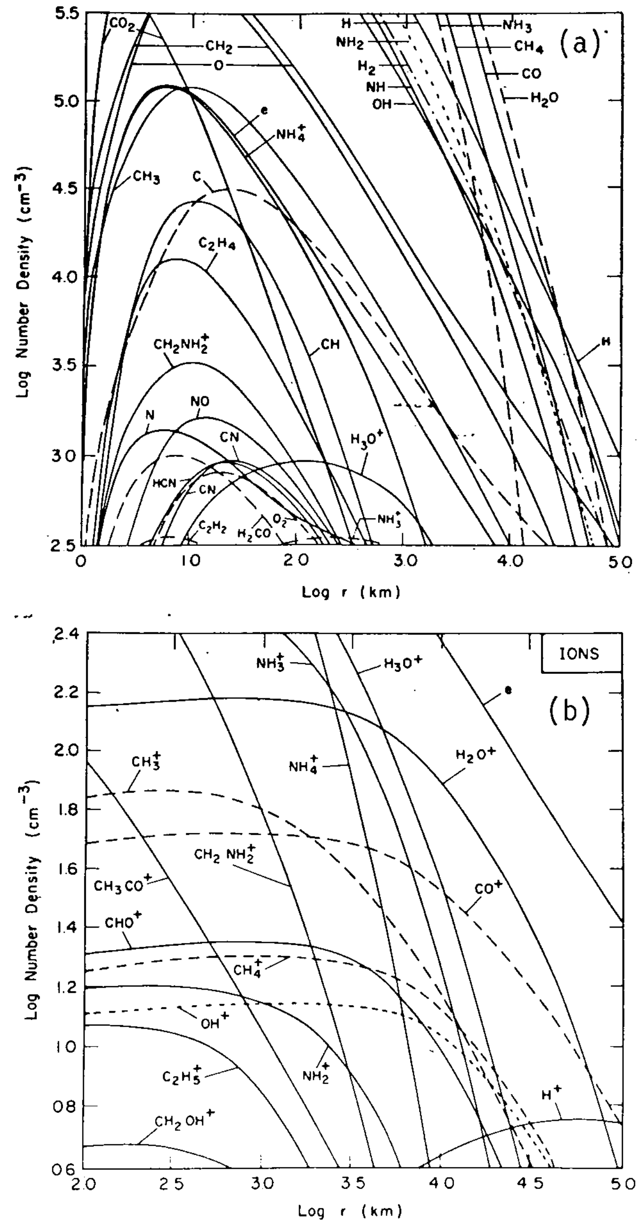

Fig. 4. The density profile of the cometary atmosphere resulting from a nucleus composed largely of H_2O, CO, CH_4, and NH_3. (a) Neutrals and some of the dominant ions, (b) the other ions (from Huebner and Giguere 1980, Ap. J. 238, 753).

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

and thermodynamics of this multispecies atmosphere. The presence of dust, which is both dynamically and thermodynamically coupled to the gas, further complicates the problem. Finally, one has also to consider the transfer of both the solar UV radiation (which is responsible for the photolytic processes), as well as the solar visual and near-infrared radiation (responsible for the heating of the nucleus), through this expanding dusty atmosphere.

Clearly this problem is not simple, and, as a result, a strong dichotomy exists in the theoretical models of the cometary atmosphere. One class of models has concentrated on the chemistry while oversimplifying the dynamics and thermodynamics. These models generally assume a constant expansion velocity for all the species as well as a constant temperature. They also ignore the effects of dust. The results of a calculation of this type, which assumes an initial composition dominated largely by H_2O, CO_2, NH_3, and CH_4, are shown in Figures 4a and 4b. Notice that, in the inner coma, ions such as H_3O II (hydromium) and NH_4 II seem to dominate. These have not been observed in comets yet, but _in situ_ mass spectroscopy during the flybys of Halley's Comet in 1986 should be able to detect them if they do exist.

The neglect of the dynamics and thermodynamics is a serious drawback in these models. Many of the chemical processes -- in particular, the dissociative recombination process which is the main sink for the electrons -- are highly temperature sensitive, and therefore the quantitative predictions of the models are highly suspect. In fact, all these models have greatly underproduced CO II vis-a-vis H_2O II.

The opposite approach, which is to minimize the chemistry and restrict oneself to the probable dominant parent molecules (e.g., H_2O, CO_2, N_2, etc.), while concentrating on dynamics and thermodynamics, has been pursued by several authors. Very recently, a self-consistent multifluid model of the dynamical and thermal structure of a two-phase dusty-gas atmosphere of a dirty clathrate ice nucleus containing H_2O, CO_2, and N_2 has been contructed by M. L. Marconi and the first author. This was done by solving the simultaneous set of differential equations representing conservation of number density, momentum, and energy, together with the transfer of solar radiation in streams responsible for the major photolytic processes and heating of the nucleus. The heliocentric distance of the comet is taken as 1 AU. The dust makes the flow transonic, with a very thin subsonic region of about 50 meters around the nucleus (in this case, assumed to be of radius 2.5 km). The flow is supersonic in the rest of the collision-dominated atmosphere, although the Mach number decreases to ~ 2 in the outermost region due to rapid heating (see Fig. 5). This multifluid model also reproduces an important observation, namely the fast (18 km/s) component of the neutral hydrogen seen in the outer coma. This is represented by the curve marked U_H* (Fig. 5).

One of the most interesting predictions of this model is the overall temperature profile, shown in Figure 6. It is seen that there are 4 different temperatures within the atmosphere. While the dust temperature remains almost constant throughout the atmosphere, the temperature of all the other species (the heavy neutrals and the ions (R), the photo-produced hydrogen (H), and the electrons), go through a strong inversion close to the nucleus due to the

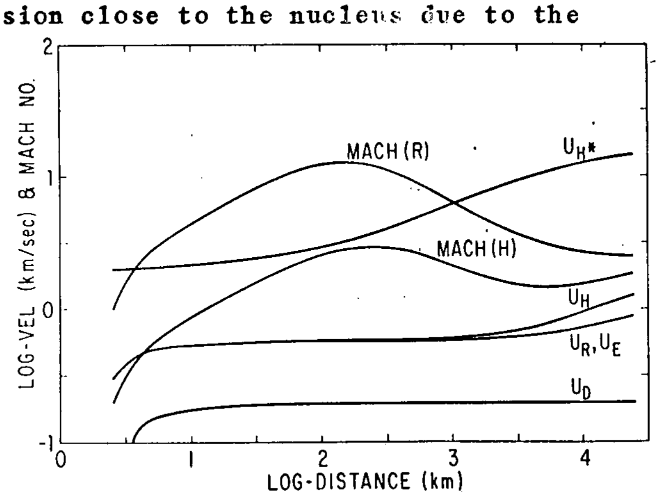

Fig. 5. The radial profiles of the velocity and Mach number of the various species in the cometary atmosphere: D, R, H, and E stand, respectively, for the dust, the heavy neutrals and ions, the thermalized hydrogen, and the electrons, while H* stands for the unthermalized photo-produced hydrogen (from Marconi and Mendis 1983, _Ap. J._, in press).

THE INTERACTION OF COMETS WITH SOLAR RADIATION AND THE SOLAR WIND. I.

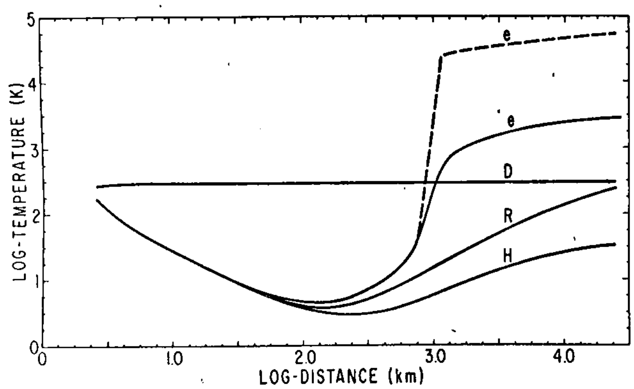

Fig. 6. The radial profiles of the temperatures of the various species in the cometary atmosphere. The broken curve represents electrons when their thermal conductivity is neglected (from Marconi and Mendis 1983, *ibid*.).

rapid infrared cooling by H_2O and the adiabatic cooling due to rapid expansion. Also, in the outer regions, the electron temperature -- which is largely controlled by thermal conductivity -- increases to about 2700 K (degrees Kelvin). The dashed lines give the electron temperature in the absence of thermal conductivity. The high electron temperature in the outer coma has a strong effect on the electron density profile. It makes the removal of electrons by dissociative recombination less efficient, leading to the prediction of higher electron densities in the outer coma.

What is clearly required in the modeling of cometary atmospheres in the future is a combination of the two approaches discussed above.

All these atmospheric models assume the simplest geometry: spherical symmetry. Implicit here are the assumptions that the nuclear surface is more or less spherical, homogeneous in chemistry, and has a fairly uniform temperature distribution. Rapid rotation of the nucleus is generally expected to result in such a temperature distribution. Even so, this assumption is of restricted validity. While it is generally valid for neutrals in $r_c \leq 10^5$ km (r = 1 AU) where the effects of solar radiation pressure are negligible, it is valid for ions only up to a certain point. As we saw earlier, not only the neutrals, but also the ions, expand supersonically. The interaction of this supersonically-expanding ionosphere with the supersonic solar wind stream causes shocks to form both in the solar wind and the cometary ionosphere, while the two flows are separated by a contact surface. The 'inner shock' in the cometary ionosphere is responsible for the deceleration of the outflowing ions and their diversion into the tail. The overall size and shape of both the contact surface and the inner shock has been calculated by a couple of authors. It appears that at 1 AU, the nuclear distance of the inner shock is less than about 10^4 km. Consequently, the assumption of spherical symmetry for the ions is only valid up to this distance. Even this is true only if the cometary ionosphere is not penetrated by the interplanetary magnetic field. In fact, if the recent observations of the Venusian ionosphere are a reliable guide, this may not be the case, at least during disturbed solar wind conditions. [The final part of this article will appear in the October issue.]

RECENT VISUAL OBSERVATIONS OF NUCLEAR OUTBURSTS IN P/KOPFF 1982k

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Periodic comet Kopff (1982k) has exhibited some extraordinary nuclear outbursts recently. These are quite the most striking of events, and overall are very reminiscent of those I have observed in P/Schwassmann-Wachmann 1, albeit on a much smaller scale. At the initiation of each outburst, a bright, completely stellar nucleus appears. Within a few days, this feature, while remaining very dense in appearance, becomes decidedly non-stellar and progressively spreads across the coma. As it does so, the area of greatest condensation grows slowly weaker, dropping several units

RECENT VISUAL OBSERVATIONS OF NUCLEAR OUTBURSTS IN P/KOPFF 1982k

in Degree of Condensation. A minute stellar or near-stellar nucleus does seem to persist throughout each of the outbursts, however, and this, too, brings to mind the P/Schwassmann-Wachmann 1 flares. The following notes from selected nights document the outbursts. All were made using a 32-cm f/5.6 Newtonian reflector.

April 18.20 UT. The coma's diameter is 2.2′ and total visual magnitude (mag) is 10.6. The central region is devoid of any nucleus and the DC is rated as 1. The coma is significantly condensed over perhaps the central 30 percent of its disk.

May 5.15. The comet's total brightness has increased half a magnitude, which in itself is not surprising. However, at the center of an otherwise almost-totally diffuse coma is a bright, stellar object of mag 11.5. When viewed at 110x, it is as sharp and hard as a star of similar brightness just north of the comet. Were it not for this bright nucleus, the DC would be rated as 1. The coma is 2.3′ in diameter.

May 6.13. The 2.7′ coma displays an intense knot of bright material at its center. The knot is tiny, but clearly non-stellar, some 0.2′ in size. A minute, stellar nucleus of about mag 12.5 occupies its center. Overall, the coma's DC is rated as 7, and the total mag has increased strikingly to 9.2.

May 10.13. The coma's DC has decreased drastically, now being rated at only 2. The knot of outburst material subtends about 0.3′ and is much less intense than previously. The total mag is 9.2.

May 13.12. The coma appears circular and not particularly condensed, DC 4. There is still a tiny knot of material at the coma's center subtending less than 0.3′; total mag is 9.1.

May 18.13. A new outburst is in progress. Within the 3.1′ coma, at the center of the area of greatest condensation, is a very dense, non-stellar nucleus of mag 11.6, less than 0.1′ in size. Undoubtedly, the outburst is a day or two old, judging by the size of this feature. While the total mag is unchanged, the coma's DC has risen to 6 due to the outburst.

June 12.13. The 5.0′ coma quite suddenly condenses near its center; DC rated as 5. At 110x, there is a mag 12.8 stellar nucleus within the dense, bright center of the coma. Outer portions of the coma are very vague and diffuse. The total mag is 8.4.

July 1.10. Yet another new outburst is evident! At 110x, one can clearly see a sharp, hard starlike body of mag 11.4 at the coma's center. The region immediately surrounding the nucleus is not particularly condensed, so the outburst must have begun only hours ago. Neglecting the bright stellar feature at the coma's center, the DC of the 6′ coma is only 3.

July 4.10. The coma is much more centrally condensed than on July 1, its DC now 5-6. At 110x, there is a very dense region not more than 1′ in diameter, itself within the 5.5′ coma. The outer half of the coma is totally diffuse. Contained within the condensation is a not-quite-stellar nucleus of mag 12.7, some arc seconds east-northeast of the precise center of the condensed region. It is heavily involved with the cometary material that seems to be issuing westward from it.

July 8.11. The coma is at least 6′ in diameter, but has grown steadily less-condensed over the past few nights, the DC now being 4-5. The coma condenses almost steadily from the edges of the center. An almost-stellar nucleus of mag 12.9 still occupies the coma's center and is surrounded by a tiny knot of bright material. With 10x50 binoculars, the total mag has reached 7.6.

[Ed. note: Other observers, including myself, have noted these nuclear outbursts. -- C.S.M.]

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THE LIGHT CURVE OF PERIODIC COMET D'ARREST 1983e

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Discovered in 1851, periodic comet d'Arrest had made 13 appearances prior to 1982, the last in 1976. The 1982 return was moderately favorable, with perihelion occurring in mid-September. During the apparition, the comet's negative declination favored observers in the southern hemisphere.

In a 1976 article (Marsden and Bortle), this writer examined the observational history of the comet and, for the first time, the unique character of its light curve was demonstrated. Predictions for the 1976 apparition were made and subsequently were largely fulfilled, with the comet first brightening dramatically, then stabilizing and thereafter fading slowly under the careful watch of both professional and non-professional astronomers.

An analysis of the 1976 photometric data (Bortle 1977) confirmed an essentially linear rise in brightness stretching from the initial observations up to $(t-t_o)$ = +25 days, where $(t-t_o)$ is the time from perihelion, designated as Stage I; a period of apparently constant brightness extending from $(t-t_o)$ = +25 to +60 days, or Stage II; and, finally, the slow decline, Stage III. The variations in the total magnitude during the first 2 stages seem to have been completely unrelated to the comet's heliocentric distance.

ANALYSIS OF THE 1982 DATA

Predictions for the 1982 return were available in several publications and it was expected that the comet might reach 8th magnitude and be visible in small-aperture instruments. By the end of the apparition, more than 100 observations had been made and subsequently published in the ICQ. Of these, a total of 100 observations from 7 observers were selected for analysis. By comparison, the 1976 light curve of P/d'Arrest was based on 110 observations from 4 individuals.

Typically, total magnitude estimates of comets are empirically corrected to a standard aperture prior to analysis. This technique accounts for the fact that comets appear fainter in larger instruments. As pointed out in the 1977 paper (Bortle), P/d'Arrest requires a much larger aperture correction than is normally assumed. To properly analyze the data, observer-specific corrections had to be derived. For convenience, a standard aperture, or zero-point, of 2 inches (about 5 cm) was chosen, rather than the usual 2.67 inches (or 6.78 cm). For the present study, it was again necessary to derive individual corrections. A standard aperture (or zero-point) of 5 cm was chosen to be consistent with the 1976 light curve.

The individual contributing, by far, the largest body of data in 1982 was Andrew Pearce, who obtained a long series of magnitude values using 6.5-cm binoculars. These were so near in size to the primary instrument employed in the 1977 study that they were considered for the zero-point of the current light curve. A comparison with the writer's own 31.7-cm reflector data, corrected to 5.0 cm, using the correction factor derived in the 1977 study, showed an almost perfect overlap, removing any question concerning the choice of Pearce as the primary observer.

Listed in Table I is the correction factor for each of the observers, with regard to the various instruments they used. As in the case of the 1976 observations, the corrected data provided a very coherent light curve for P/d'Arrest. Once the basic zero-point correction had been applied to all the data, no further adjustments to "improve" the data, or forcing of results, were made.

These data were subsequently sorted into 3 groups corresponding to Stages I, II, and III. After correcting for changing geocentric distance, the data were subjected to a linear regression analysis to determine the relationship between heliocentric magnitude and time (i.e., $t-t_0$). Similar analyses were performed for the Stage-II and -III data. A power-law solution for the Stage-III data was also derived for comparison with 1976 figures.

MAGNITUDE FORMULAE

For the observations made during Stage I of the light curve, there was a very obvious correlation between heliocentric brightness and time, but none with regard to heliocentric distance. Based on 22 data points between $(t-t_0) = -23$ and $+25$ days, the comet's apparent brightness could be expressed in terms of the formula

$$m_1 = 10.03\ (\pm\ 0.057\ \text{p.e.}) - 0.071\ (\pm\ 0.004\ \text{p.e.})(t-t_0) + 5 \log \Delta,$$

where Δ is the comet's geocentric distance and the errors are probable errors (indicated by p.e.).

In 1982, a total of 51 observations were obtained during Stage II of the light curve, the more-or-less flat period of maximum brightness. This was considerably more data than had been secured over the same time span in 1976. At that previous apparition, it had been assumed that the comet's brightness had remained completely unchanged during the period $(t-t_0) = +25$ to $+60$ days. The author is not quite so confident about this after examining the more numerous 1982 data. These values seem to show a very slow continued rise in brightness, peaking near t + 60 days. For this reason, the Stage-II data were reduced in two ways: first, assuming the brightness remained constant during this period, and, second, that the magnitude had some correlation with time since perihelion. The results for Stage II can be expressed as follows, based on these assumptions:

$$m_1 = 8.35\ (\pm\ 0.103\ \text{p.e.}) + 5 \log \Delta$$

or

$$m_1 = 8.59\ (\pm\ 0.064\ \text{p.e.}) - 0.006\ (\pm\ 0.0015\ \text{p.e.})\ (t - t_0) + 5 \log \Delta.$$

Here again, t is the number of days elapsed since perihelion.

While a power-law formula had been used to represent the 1976 photometric data during Stage III (the decline), re-evaluation now suggests that the decline may have been actually related to time rather than heliocentric distance, just as with Stages I and II. Since there remained some question as to which of these interpretations is correct, both linear and power-law solutions were determined.

A total of 27 observations were made during Stage III of the light curve and extend from $(t-t_0) = +60$ to $+111$ days. The coverage almost precisely matches that for 1977. Reduction of the data to produce both a power-law and a simple linear solution resulted in the following formulae:

$$m_1 = 5.67\ (\pm\ 0.179\ \text{p.e.}) + 16.44\ (\pm\ 0.924\ \text{p.e.}) \log r + 5 \log \Delta$$

and

$$m_1 = 6.71\ (\pm\ 0.119\ \text{p.e.}) + 0.028\ (\pm\ 0.0015\ \text{p.e.})\ (t - t_0) + 5 \log \Delta,$$

where r is the comet's heliocentric distance.

CONCLUSIONS

By comparing the photometric formulae derived at the 1976 and 1982 apparitions, one is immediately struck by their almost exact coincidence. Magnitudes obtained from the 1976 formulae and their counterparts of 1982 are consistently in agreement to within 0.1 magnitude for the period $(t-t_0) = -50$ to better than $+100$ days.

For comparison, the results of the 1976 and 1982 apparitions are presented below side-by-side. There are some very slight differences in the 1976 figures presented here and those

THE LIGHT CURVE OF PERIODIC COMET D'ARREST 1983e

TABLE I*

OBSERVER	INSTR.	CORR.	NO.
A. Pearce	6.5 B	0.0	30
	15.0 L	-0.2	
M. Clark	25.0 L	-0.4	24
J. Bortle	31.7 L	-0.95	17
D. Seargent	8.0 B	-0.8	18*
T. Lovejoy	20.0 L	-1.1	8
C. Morris	25.0 L	-1.0	5
V. de Assis Neto	7.0 B	-1.2	4

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* Seargent's observations of Sept. 18, Oct. 6, 7, and 8 appear quite discordant and were not included in the analysis.

** Columns 2, 3, and 4, are: (2) Instrument aperture and type, as given in normal ICQ Tabulations; (3) Correction factor to 5.0 cm; (4) Total No. of Observations used

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appearing in the 1977 study. These changes are the result of the correction of a few copying errors in the originally published data. A $(t-t_o)$ formula for the 1976 Stage-III data is presented here for the first time. All the formulae are for heliocentric magnitudes.

Stage I :

1976: $m = 9.96 - 0.070\ (t-t_o)$

1982: $m = 10.03 - 0.071\ (t-t_o)$

Stage II :

1976: $m = 8.28$ 1982: $m = 8.35$

Stage III :

1976: $m = 6.75 + 0.027\ (t-t_o)$

1982: $m = 6.71 + 0.028\ (t-t_o)$

While the almost-coincident results from the two apparitions should not be taken too literally, recalling the vague appearance and large aperture-correction of this object, they do seem to indicate that, photometrically, they must have been at least very similar. Clearly demonstrated is the fact that P/d'Arrest's unique light curve is repeated faithfully at each return. The results thus lay to rest the question of whether the comet was anomalously bright in 1976. Obviously, the sizeable aperture-corrections, called for in cases where this comet was observed with large telescopes, was responsible for the low magnitudes reported at the earlier return.

In the final analysis, P/d'Arrest can be regarded as the prototype of a very small group of periodic comets that display decided perihelia asymmetry and aberrant light curves. The latter are characterized by a very steep rise or surge in brightness shortly before perihelion passage, culminated by a protracted maximum phase whose midpoint occurs several weeks after perihelion and is followed by a decline less precipitous than the rise. While the situation is not clear for other members of the group, P/d'Arrest appears to reach maximum coma diameter about the time of maximum brightness (about 5' at unit distance in early November 1982). Aperture correction, at least in the case of this comet, is considerably higher than the average figure, seemingly by a factor of two or three.

Another primary example of the P/d'Arrest-class of comets is P/Tempel 2, which is currently visible. Its current return is moderately favorable and all observers are urged to monitor its brightness and appearance over as great a time span as possible. A direct comparison of photometric and physical propertires of these two objects could prove interesting indeed. [Ed. note: Mr. Bortle has also published a less-detailed analysis of P/d'Arrest's 1982 light curve in _Sky and Telescope_ _65_, 565 (1983).]

REFERENCES

Bortle, J. E. (1977). _Sky and Tel_. _53_, 152.

Marsden, B. G.; and J. E. Bortle (1976). _Sky and Tel_. _52_, 10.

NOTICE TO OBSERVERS

The Editors of the INTERNATIONAL COMET QUARTERLY wish to draw attention to the fact that this effort is entirely volunteer. As such, in our efforts to compile and publish photometric observations of comets, we ask that ALL individuals reporting observations send them legibly printed or typed on copies of the ICQ report form (published in the April issue, page 47; additional copies available from the Editor). Failure of many observers to send their observations via this report sheet, or to include all required information, causes problems for the ICQ Staff on two counts: 1) Missing data must be obtained by writing back to the observer and requesting additional information, thus considerably slowing the publication schedule of specific observations and taking the time and energies of our volunteer Staff from more useful tasks; and 2) Data not submitted to the ICQ in our specified, formatted columns considerably slows the entering of observations into the computer, again placing more demands on the Staff's time and increasing the possibilities for errors to creep into our data files.

PLEASE HELP US TO PLACE OUR ENERGIES INTO MORE EFFICIENT USES, AND RECORD YOUR OBSERVATIONS PROPERLY. THANK YOU!

TABULATION OF COMET OBSERVATIONS

As can be seen here, the recent observations of comets have kept us extremely busy, again delaying observations made more than 3 or 4 years ago. Note that all of the observations by Charles S. Morris for comet 1983d in the April issue were published incorrectly; they are corrected here.

Again, we ask all observers contributing observers to check their data once it has been published in the ICQ. We take every effort to avoid errors, but in an undertaking this large, some errors are inevitable.

NEW OBSERVER TO THE OBSERVER KEY (cf. ICQ 5, 16 and 39):
WAR ROBERT WARREN, IN, U.S.A.

NEW INSTRUMENT TO THE INSTRUMENT KEY:
S = Schmidt-Newtonian telescope

CHANGES IN REFERENCE KEY:
RA = Annual Ephemeris of the Royal Astronomical Society of Canada (not recommended, even for bright comets)
UR = old RC

NEW ADDITION TO MAGNITUDE METHODS KEY:
G = Naked eye estimate, with glasses used to defocus comparison stars (for bright comets only)

Comet Kohler (1977 XIV = 1977m)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1977 10 05.01	S	8.6	AC	15	L	8	51	3.0				DEY
1977 10 07.02	S	8.4	AC	15	L	8	51	3.0				DEY
1977 10 15.00	S	7.7	AC	15	L	8	51	3.4				DEY
1977 10 18.02	S	7.6	AC	15	L	8	51	3.2				DEY
1977 10 21.01	S	7.5	AC	15	L	8	51	3.3				DEY
1977 10 22.02	S	7.4	AC	15	L	8	51	3.6				DEY
1977 10 29.02	S	7.3	AC	15	L	8	51	4.2				DEY
1977 10 30.01	S	7.1	AC	5.0	B		7	4.6				DEY
1977 10 31.02	S	7.0	AC	5.0	B		7	4.9				DEY
1977 11 02.01	S	6.8	AC	5.0	B		7	4.6				DEY
1977 11 12.00	S	6.9	AC	15	L	8	51	4.8				DEY
1977 11 13.03	S	7.0	AC	15	L	8	51	4.7				DEY
1977 11 14.00	S	6.9	AC	15	L	8	51	5.4				DEY
1977 11 15.00	S	7.0	AC	15	L	8	51	5.6				DEY

Comet Meier (1978 XXI = 1978f)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1978 06 01.10	S	10.2	AC	15	L	8	51	1.8				DEY
1978 06 10.12	S	10.0	AC	15	L	8	51	1.5				DEY
1978 06 14.11	S	10.0	AC	15	L	8	67	1.3				DEY
1978 06 15.10	S	9.9	AC	15	L	8	67	1.2				DEY

Comet Bradfield (1979 X = 1979l)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1980 01 29.98	* S	6.3	AC	5.0	B		7	10.0				DEY
1980 02 03.02	* S	6.6	AC	5.0	B		7	8.1				DEY
1980 02 05.01	* S	6.9	AC	5.0	B		7	7.6				DEY
1980 02 08.06	* S	7.3	AC	5.0	B		7	6.6				DEY
1980 02 11.01	* S	7.6	AC	15	L	8	51	6.2				DEY
1980 02 12.03	* S	7.8	AC	15	L	8	51	6.1				DEY
1980 02 13.03	* S	7.9	AC	15	L	8	51	6.0				DEY
1980 02 14.00	* S	8.0	AC	15	L	8	51	5.0	7			DEY
1980 02 18.02	S	8.4	AC	15	L	8	51	4.5	5			DEY
1980 02 19.04	S	8.5	AC	15	L	8	51	4.5	4			DEY
1980 03 04.04	* S	11.0	AC	15	L	8	67	3.5	2			DEY

Comet Meier (1980 XII = 1980q)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1980 11 13.02	S	10.5	AC	15	L	8	51	& 2.5	2			DEY

Comet Panther (1981 II = 1980u)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1981 04 02.61	B	8.5	S	12	L	8	33	6	4			SAK
1981 04 07.61	B	8.7	S	12	L	8	33	5	4			SAK
1981 04 10.59	B	8.7	S	12	L	8	33	5	5			SAK
1981 04 20.58	B	8.5	S	12	L	8	33	4	4			SAK
1981 04 21.42	B	8.6	S	12	L	8	33	4	3			SAK
1981 04 24.55	B	9.0	S	12	L	8	50	3	4			SAK
1981 04 25.54	B	9.4	S	12	L	8	50	3	3			SAK
1981 04 30.55	B	9.2	S	12	L	8	50	3	3			SAK
1981 05 01.50	B	9.6	S	12	L	8	50	2	3			SAK

Comet Austin (1982g)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1982 08 18.08	S	4.7	AA	3.5	B		7	8.5		1.0		MOR03
1982 08 19.07	S	4.9	AA	3.5	B		7	6				MOR03
1982 08 21.08	S	5.0	AA	3.5	B		7	5.5		0.4		MOR03
1982 08 22.07	S	5.1	AA	3.5	B		7					MOR03
1982 08 22.08				15	R	5	31	5		1.35	32	MOR03
1982 08 24.06	S	5.0	AA	3.5	B		7					MOR03
1982 08 26.06	S	5.2	AA	3.5	B		7					MOR03
1982 08 28.06	S	5.5	AA	3.5	B		7					MOR03
1982 08 29.06	S	5.7	AA	3.5	B		7					MOR03
1982 09 05.04	S	6.4	AC	3.5	B		7					MOR03
1982 09 09.05	S	6.7	AC	3.5	B		7					MOR03
1982 09 19.03	S	7.9	AC	3.5	B		7					MOR03
1982 10 02.01	S	8.6	AC	6	R	15	36	& 3				MOR03
1982 10 05.01	S	9.1	AC	6	R	15	36	3				MOR03
1982 10 11.01	S	9.4	AC	15	R	5	31	4				MOR03
1982 10 17.43	S	9.6	AC	15	R	5	31	2.5				MOR03
1982 10 24.42	S	9.9	AC	15	R	5	31	4.5				MOR03

Comet IRAS-Araki-Alcock (1983d)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 04.20	* M	5.9	AA	4.0	R		12	15	4			MOR
1983 05 04.22	* M	6.0	AA	4.0	R		12					MOR
1983 05 05.20	* S	6.0	AA	4.0	R		12	15	2			MOR
1983 05 05.23	S	6.1	S	3.5	B		7	21	3			MAR01
1983 05 06.27	* M	5.8	AA	4.0	R		12	16	4			MOR
1983 05 06.92	S	5.3	NO	5.0	B		10	20	3			CAV
1983 05 07.12	* M	5.0	AA	4.0	R		12	18				MOR
1983 05 07.13	* S	4.8	AA	1.5	B		6	24				MOR
1983 05 07.28	* S	4.7	AA	0.0	E		1					MOR
1983 05 07.28	* M	4.9	AA	4.0	R		12					MOR
1983 05 07.40	S	4.5	SP	0.9	E		1					KEE
1983 05 08.34	* M	4.7:	AA	4.0	R		12	&20				MOR
1983 05 08.35	S	4.2	SP	0.9	E		1					KEE
1983 05 09.17	S	3.6	SP	0.9	E		1					KEE
1983 05 09.27	S	2.9:	AT	0.7	E		1					MAR01
1983 05 09.27	B	4.6	S	3.5	B		7	36	4			MAR01
1983 05 09.30	S	3.4	SP	0.9	E		1					KEE
1983 05 09.85	S	2.0	AT		E		1	95	3			CAV
1983 05 10.17	* S	2.9	AA	4.0	R		12					MOR
1983 05 10.17	* B	2.9	AA	0.0	E		1	129				MOR
1983 05 10.19	S	2.9	SP	0.9	E		1	120				KEE
1983 05 10.29	* B	2.8	AA	0.0	E		1	142				MOR
1983 05 11.17	S	2.1	SP	0.9	E		1					KEE
1983 05 11.18	* M	2.3	AA	0.0	E		1	193	2			MOR
1983 05 12.08	* M	1.7	AA	0.0	E		1	180				MOR
1983 05 12.38	S	1.5	A		E		1	96	4			SEA
1983 05 13.40	S	2.1	A		E		1					SEA
1983 05 14.44	S	4 :	A	2.5	B		2	42				SEA
1983 05 14.44	S	3.2	A		E		1					SEA
1983 05 14.66	S	4.4:	AA		E		1					CLA
1983 05 15.38	S	3.4	A		E		1					SEA
1983 05 15.38	S	3.8	A	2.5	B		2	30				SEA
1983 05 15.51	S	4.7	AA		E		1	35				CLA

Comet IRAS-Araki-Alcock (1983d) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 15.52	S	5.1	AA	15.2	L	5	30	25	5			CLA
1983 05 15.52	S	4.8	AA	3.0	R		6					CLA
1983 05 15.53	S	5.4	AA	41	L	4	86	25	5			CLA
1983 05 15.53	S	4.8	AA	6.5	B		20	28				CLA
1983 05 16.42	S	5.3	A	2.5	B		2	16				SEA
1983 05 16.42	S	4.8	A		E		1					SEA
1983 05 16.51	S	5.0	AA		E		1					CLA
1983 05 17.53	S	5.4	AA	3.0	R		6					CLA
1983 05 17.53	S	5.2	AA		E		1					CLA
1983 05 17.56	S	5.7	AA	15.2	L	5	30	18	5			CLA
1983 05 17.57	S	6.0	AA	41	L	4	86	20	5			CLA
1983 05 18.47	S	6.2	AA	41	L	4	86	16	6			CLA
1983 05 18.48	S	5.6	AA	3.0	R		6					CLA
1983 05 18.48	S	5.4	AA		E							CLA
1983 05 19.70	S	6.1	AA	12.0	R	5	21	12.0	5			CAM
1983 05 19.75	S	6.0	AA	8.0	B		11	15.0	5			CAM
1983 05 20.70	S	6.1	AA	12.0	R	5	21	10.0	5			CAM
1983 05 21.45	S	7.8	AA	41	L	4	86	7	6			CLA
1983 05 21.45	S	6.6	AA	3.0	R		6					CLA
1983 05 28.33	S	7.2:	A	8.0	B		15	& 5	4			SEA
1983 05 28.69	S	8.0	AA	12.0	R	5	21	6.0	3			CAM
1983 05 29.33	S	7.4	A	8.0	B		15		4			SEA
1983 05 29.70	S	8.1	AA	12.0	R	5	21	6.0	3			CAM
1983 05 30.35	S	7.6	A	8.0	B		15					SEA
1983 05 30.70	S	8.2	AA	12.0	R	5	21	6.0	3			CAM
1983 05 31.42	S	7.5	A	8.0	B		15					SEA
1983 05 31.76	S	8.7	AA	12.0	R	5	21	5.0	2			CAM
1983 06 01.67	S	8.8	AA	12.0	R	5	21	3.0	2			CAM
1983 06 02.69	S	9.0	AA	12.0	R	5	21	3.0	2			CAM
1983 06 04.41	S	8.1	A	8.0	B		15					SEA
1983 06 04.69	S	8.8	AA	12.0	R	5	21	3.0	4			CAM
1983 06 05.67	S	8.8	AA	12.0	R	5	21	3.0	4			CAM
1983 06 07.95	B	8.5	S	7.0	B		10	1.4				DEA
1983 06 08.38	S	8.3	A	8.0	B		15	& 4	4			SEA
1983 06 08.69	S	9.5	AA	12.0	R	5	21	2.5	2			CAM
1983 06 09.69	S	9.9	AA	12.0	R	5	21	2.5	2			CAM
1983 06 11.68	S	10.3	AA	12.0	R	5	21	2.0	2			CAM
1983 06 12.92	B	9.2	S	7.0	B		10					DEA
1983 06 13.35	S	9.6	A	8.0	B		15		2			SEA

Comet Sugano-Saigusa-Fujikawa (1983e)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 18.02	B	7.8	S	15.0	L	5	25	4.3	4	0.14	293	MER
1983 05 22.06	B	8.3	S	15.0	L	5	25	5.5	4	0.10	326	MER
1983 05 23.09	B	8.7	S	15.0	L	5	25	5.4	4			MER
1983 06 01.31	S	9.5:	AA	25	L	7	68	& 5	0			MOR
1983 06 03.00	B	8.8	S	15.0	L	5	25	5.0	2/	0.08	259	MER
1983 06 04.01	B	8.4	S	15.0	L	5	25	7.5	2/	0.09	275	MER
1983 06 05.02	B	8.2	S	15.0	L	5	25	9.0	2	0.09	252	MER
1983 06 06.43	S	6.9	S	15.0	R	6	29	13	1			MAC
1983 06 07.81	S	7.5:	A	8.0	B		15	&20	1			SEA
1983 06 08.77	S	7.7	A	5.0	B		10	16	0			SEA
1983 06 09.24	S	7.4	S	4.0	R		12	24	0/			MOR

Comet Sugano-Saigusa-Fujikawa (1983e) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 06 09.29				32	L	6	55	9	2			BOR
1983 06 09.29	S	7.2	NO	5.0	B		10	25	0/			BOR
1983 06 09.32				7.0	B		10	14				DEA
1983 06 09.43	S	7.1	S	15.0	R	6	29	8	1			MAC
1983 06 09.77	S	7.6	A	5.0	B		10	&12	0			SEA
1983 06 10.40	S	6.0	S	15.0	R	6	29	14	1			MAC
1983 06 10.77	S	6.8	A	5.0	B		10	>16	0			SEA
1983 06 10.97	B	7.0	S	5.0	B		7	30.0	0/			MER
1983 06 11.29	S			8.0	B		20	30				MOR
1983 06 11.29	S	6.5:	S	4.0	R		12	20	0/			MOR
1983 06 11.29	S	7.5:	AA	8.0	B		20		0/			GRE
1983 06 11.30	S	6.0	S	7.0	B		10	19				DEA
1983 06 11.39	S	5.9	SP	3.5	B		7					KEE
1983 06 11.39				0.9	E		1	60				KEE
1983 06 11.69	S	6.8	A	5.0	B		10	26	0			SEA
1983 06 12.08	B	6.6	S	5.0	B		7	25.0	0			MER
1983 06 12.19	S	5.9	S	7.0	B		10	18				DEA
1983 06 12.28	S	6.0	AA	5.0	B		12	30	1			MOR
1983 06 12.29	S	5.8	NO	5.0	B		10	37	0			BOR
1983 06 12.29	S	5.6	NO	5.0	R		6	41	0			BOR
1983 06 12.29					E		1	&60	0			BOR
1983 06 12.39	S	7.3	S	15.0	R	6	29	15	1			MAC
1983 06 12.40				0.9	E		1	60				KEE
1983 06 12.40	S	5.6	SP	3.5	B		7					KEE
1983 06 12.52	S	6.4	A	5.0	B		10	&35	0			SEA
1983 06 12.57	S	6.3	A	5.0	B		10	&43	0			SEA
1983 06 13.04	S	6.2	S	7.0	B		10					DEA
1983 06 13.46	S	6.8	A	5.0	B		10	39	0			SEA
1983 06 14.36	S	6.2	SP	3.5	B		7	60				KEE
1983 06 14.46	S	6.5	A	5.0	B		10	34	0			SEA
1983 06 15.30	S	6.9	S	15	L	3	17					KEE
1983 06 16.54	S	7.8	A	5.0	B		10	17	0			SEA

Comet Černis (1983l)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 22.33	M	10.5	AC	25	L	7	103	2.0	5			MOR
1983 07 22.46	S	11.3	S	15.0	R	6	29	1.2	3			MAC
1983 07 23.33	M	10.4	AC	25	L	7	68	1.8	5/			MOR

Periodic Comet Pons-Winnecke (1983b)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 16.87	S	12.3	VN	41	L	4	86	1.2	2			CLA
1983 05 19.82	S	12.1	VN	41	L	4	86	2	2			CLA

Periodic Comet Tempel 1 (1982j)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 03 03.88	S	12.9	AC	26.0	L	6	63	2.5	2			MER
1983 03 07.94	S	12.9	AC	26.0	L	6	130	2.5	3			MER
1983 03 08.92	S	12.8	AC	26.0	L	6	130	& 4	3		343	MER
1983 03 10.90	S	12.7	AC	26.0	L	6	130	2.5	2			MER
1983 03 13.00	S	12.7	AC	26.0	L	6	130	2.5	3			MER
1983 03 20.03	S	11.8	AC	26.0	L	6	63	2.9	1/	0.03	105	MER

Periodic Comet Tempel 1 (1982j) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 04 11.56	S	11.4	A	41	L	4	86	1.25	7			CLA
1983 04 11.80	S	11.1	AC	15.2	L	5	30	1.5	6			PEA
1983 04 11.80	M	11.0	AC	15.2	L	5	30					PEA
1983 04 12.78	M	11.0	AC	15.2	L	5	30					PEA
1983 04 12.78	S	11.1	AC	15.2	L	5	30	1.5	6		310	PEA
1983 04 13.58	S	11.3	A	41	L	4	86	1.5	7			CLA
1983 04 13.76	S	11.0	AC	15.2	L	5	30	1.5	6/			PEA
1983 04 14.69	S	11.3	A	41	L	4	86	1.5	7			CLA
1983 04 14.75	S	11.0	AC	15.2	L	5	30	1.5	6/			PEA
1983 04 15.76	S	10.9	AC	15.2	L	5	30	1.5	7			PEA
1983 04 16.76	S	10.8	AC	15.2	L	5	30	1.75	7			PEA
1983 04 17.75	S	10.8	AC	15.2	L	5	30	1.5	7			PEA
1983 04 18.72	S	11.2	A	41	L	4	86	2	6			CLA
1983 04 19.75	S	10.7	AC	15.2	L	5	30	1.3	7			PEA
1983 05 03.43	S	10.3	A	11	L	5	20					SEA
1983 05 03.53	S	10.5	A	41	L	4	86	3	6			CLA
1983 05 06.44	S	10.3	A	11	L	5	20		1			SEA
1983 05 09.24	S	10.0	A	20.0	C	10	81	1.0	4			SPR
1983 05 09.51	S	10.3	AC	41	L	4	86	3.5	6			CLA
1983 05 10.22	S	10.2	A	20.0	C	10	81	1.0	4			SPR
1983 05 10.48	S	9.6	A	8.0	B		15	4	1			SEA
1983 05 10.50	S	9.4	A	5.0	B		10		0			SEA
1983 05 11.23	S	10.2	A	20.0	C	10	81	1.0	5			SPR
1983 05 11.54	S	9.5	A	8.0	B		15		1			SEA
1983 05 12.47	S	9.6	A	8.0	B		15					SEA
1983 05 13.24	S	9.9	A	20.0	C	10	81	1.0	5			SPR
1983 05 15.42	S	9.4	A	8.0	B		15					SEA
1983 05 15.56	S	9.8	AC	41	L	4	86	4.5	7	0.05	168	CLA
1983 05 16.44	S	9.4	A	8.0	B		15					SEA
1983 05 16.45	S	9.2	A	5.0	B		10					SEA
1983 05 17.59	S	9.7	AC	41	L	4	86	4.5	7	0.05	168	CLA
1983 05 17.87	S	9.9	AC	26.0	L	6	39	& 3.0	3	0.05	174	MER
1983 05 29.86	S	9.6	AC	26.0	L	6	63	3.7	2			MER
1983 05 30.40	S	9.4	A	8.0	B		15		1			SEA
1983 05 31.44	S	9.4	A	8.0	B		15		1			SEA
1983 06 01.10	S	9.3	A	32	L	6	68	3.3	3			BOR
1983 06 02.91	S	9.4	AC	26.0	L	6	39	4.7	1/	0.05	159	MER
1983 06 03.93	B	9.4	S	26.0	L	6	39	5.0	1/			MER
1983 06 04.22	S	10.2	A	20	C	10	102	1.0	4			SPR
1983 06 04.42	S	9.3	A	8.0	B		15					SEA
1983 06 04.94	B	9.3	S	26.0	L	6	39	5.1	1/			MER
1983 06 06.10	S	9.3	AC	25	L	7	68	3.75	2/			MOR
1983 06 06.22	S	10.4	A	20	C	10	102	1.5	3			SPR
1983 06 06.37	S	9.8	S	15.0	R	6	29	4	2			MAC
1983 06 07.21	S	10.0	A	20	C	10	81	1.5	4			SPR
1983 06 08.23	S	10.1	A	20	C	10	81	1.5	4			SPR
1983 06 08.46	S	9.4	A	8.0	B		15					SEA
1983 06 09.09	S	9.7	AC	25	L	7	68	3.9	3			MOR
1983 06 09.11	S	9.4	A	32	L	6	68	2.8	4			BOR
1983 06 09.11	S	9.4	AC	8.0	B		20	8	1			MOR
1983 06 10.93	S	9.4	AC	26.0	L	6	39	6.4	1/			MER
1983 06 11.11	S	9.6	AC	25	L	7	68	4.4	2/			MOR
1983 06 11.14	S	9.3	AC	8.0	B		20	8	1			MOR
1983 06 11.17	M	9.4	AA	20.3	L	6	68		2			GRE
1983 06 12.11	S	9.4	A	32	L	6	68	3.1	4			BOR

Periodic Comet Tempel 1 (1982j) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 06 12.13	S	9.4	AC	8.0	B		20	8	1			MOR
1983 06 13.21	S	10.2	A	20	C	10	81	1.0	2			SPR
1983 06 13.91	S	9.8	AC	26.0	L	6	39	4.6	2/	0.05	190	MER
1983 06 14.20	S	10.4	A	20	C	10	81	1.25	2			SPR
1983 06 14.90	S	9.7	AC	26.0	L	6	39	5.3	2/	0.07	200	MER
1983 06 15.92	S	9.7	AC	26.0	L	6	39	5.7	2			MER
1983 06 27.91	S	9.7	AC	26.0	L	6	63	& 4	3			MER
1983 06 28.93	S	9.8	AC	26.0	L	6	63	& 4	2/			MER
1983 06 30.10	S	9.4	AC	25	L	7	68	4.6	1/			MOR
1983 07 01.08	S	9.4	AC	25	L	7	68	4.6	0/			MOR
1983 07 01.11	S	10.0	A	32	L	6	68	1.8	1/			BOR
1983 07 02.90	S	10.2	AC	26.0	L	6	63	4.1	2	0.07	157	MER
1983 07 03.90	S	10.3	AC	26.0	L	6	63	& 3.5	3	0.07	172	MER
1983 07 08.08	S	9.6	AC	25	L	7	68	5.1	0			MOR
1983 07 08.10	S	9.7	A	32	L	6	68	2.8	1			BOR
1983 07 10.08	S	9.7	AC	25	L	7	68	& 5	0			MOR
1983 07 11.11	S	9.6	A	32	L	6	68	3.3	1			BOR
1983 07 13.92	S	10.2	AC	7.0	R	12	28	7.5	2			MER
1983 07 14.08	S	9.6	AC	25	L	7	68	4.5	0/			MOR
1983 07 14.10	S	9.7	A	32	L	6	68	3.0	2			BOR

Periodic Comet Tempel 2 (1982d)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 10.84	S	10.8	VN	41	L	4	86	1.5	2			CLA
1983 05 16.86	S	10.4	VN	41	L	4	86	3.5	3			CLA
1983 05 19.81	S	10.2	VN	41	L	4	86	4	3			CLA
1983 06 08.13	S	9.8	AA	12.0	R	5	21	5.0	3			CAM
1983 06 09.15	S	9.3:	AA	8.0	B		20	& 5	0/			GRE
1983 06 09.32	S	10.5	S	32	L	6	68	2.0	2			BOR
1983 06 09.46	S	8.7	S	15.0	R	6	29	5	2			MAC
1983 06 11.31	S	9.5:	S	20.3	L	6	72	& 2	0			GRE
1983 06 12.45	S	8.6	S	15.0	R	6	29	6	3			MAC
1983 06 16.31	B	9.0	S	7.0	B		10					DEA
1983 06 17.14	S	9.7	AA	12.0	R	5	21	4.0	4			CAM
1983 06 17.45	S	8.3	S	15.0	R	6	29	5	4			MAC
1983 06 20.10	S	9.8	AA	12.0	R	5	21	3.5	2			CAM
1983 06 22.14	S	9.9	AA	12.0	R	5	21	3.0	3			CAM
1983 06 23.15	S	9.9	AA	12.0	R	5	21	3.5	4			CAM
1983 07 07.44	S	8.2	S	15.0	R	6	29	6	2			MAC
1983 07 10.09	B	9.0	S	7.0	R	12	28	7.3	2			MER
1983 07 10.31	S	9.0	AA	25	L	7	68	3.8	2			MOR
1983 07 10.32	S	8.7	AA	8.0	B		20	7.6	1			MOR
1983 07 11.12	B	9.1	S	7.0	R	12	28	& 7	3			MER
1983 07 11.31	S	9.0	A	8.0	B		20	5	1/			BOR
1983 07 11.31	S	9.5	A	32	L	6	68	3.5	2			BOR
1983 07 12.12	B	9.2	S	7.0	R	12	28	& 7	3			MER
1983 07 13.09	B	9.2	S	7.0	R	12	28	10.6	3			MER
1983 07 14.31	S	8.8	A	8.0	B		20	5.5	1			BOR
1983 07 14.31	S	9.3	A	32	L	6	68	3.3	3			BOR
1983 07 14.32	S	9.6	AA	25	L	7	68	3.3	3			MOR
1983 07 17.30	S	9.5	A	32	L	6	68	3.9	3			BOR
1983 07 17.30	S	9.0	A	8.0	B		20	7	1/			BOR
1983 07 20.43	S	8.8	S	15.0	R	6	29	6	4			MAC

Periodic Comet Tempel 2 (1982d) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 21.32	S	9.8	AC	25	L	7	68	3.8	3			MOR
1983 07 21.32	S	9.4	AA	8.0	B		20					MOR
1983 07 22.30	S	9.8	AC	25	L	7	68	3.8	1/			MOR
1983 07 22.46	S	8.8	S	15.0	R	6	29	7	4			MAC

Periodic Comet d'Arrest (1982e)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1982 11 07.01	S	9.6	S	7.0	B		10	2.0				DEA

Periodic Comet Kopff (1982k)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 03 13.06	S[	12.5	AC	26.0	L	6	130					MER
1983 03 20.09	S	12.7	AC	26.0	L	6	130	1.5	3			MER
1983 04 11.60	S	12.0	A	41	L	4	86	1.5	0			CLA
1983 04 12.84	S	11.8	A	41	L	4	86	2	1			CLA
1983 04 13.60	S	11.8	A	41	L	4	86	2	2			CLA
1983 04 13.79	S	11.5	AC	15.2	L	5	30	1.8	3			PEA
1983 04 14.70	S	11.8	A	41	L	4	86	2	2			CLA
1983 04 14.79	S	11.4	AC	15.2	L	5	30	1.75	3			PEA
1983 04 15.78	S	11.3	AC	15.2	L	5	30	1.75	3			PEA
1983 04 16.78	S	11.3	AC	15.2	L	5	30	1.8	3			PEA
1983 04 17.76	S	11.3	AC	15.2	L	5	30	2	4			PEA
1983 04 18.73	S	11.6	A	41	L	4	86	2	3			CLA
1983 04 19.77	S	11.2	AC	15.2	L	5	30	2	4			PEA
1983 04 23.86	S	10.8	AC	15.2	L	5	30	2.25	5			PEA
1983 04 23.86	M	10.9	AC	15.2	L	5	30					PEA
1983 04 24.88	S	10.7	AC	15.2	L	5	30	2.2	5			PEA
1983 05 03.54	S	10.7	AC	41	L	4	86	2.5	5			CLA
1983 05 04.52	S	9.0	A	11	L	5	20	9	3			SEA
1983 05 05.45	S	9.2	A	8.0	B		15					SEA
1983 05 06.45	S	9.1	A	8.0	B		15	6	4			SEA
1983 05 08.48	S	8.8	A	8.0	B		15	6	4			SEA
1983 05 08.49	S	8.6	A	5.0	B		10					SEA
1983 05 09.23	S	10.5	A	20.0	C	10	81	1.5	1			SPR
1983 05 09.56	S	9.8	AC	41	L	4	86	4	7			CLA
1983 05 10.24	S	10.8	A	20.0	C	10	81	1.0	1			SPR
1983 05 10.46	S	8.5	A	8.0	B		15	5	6			SEA
1983 05 11.24	S	10.5	A	20.0	C	10	81	1.0	1			SPR
1983 05 12.51	S	8.3	A	8.0	B		15	7	4			SEA
1983 05 13.22	S	10.1	A	20.0	C	10	81	1.0	3			SPR
1983 05 14.50	S	8.1	A	5.0	B		10	6	3			SEA
1983 05 14.68	S	9.0	AC	15.2	L	5	30	3.5	6			CLA
1983 05 15.55	S	9.3	AC	41	L	4	86	4	6			CLA
1983 05 16.50	S	8.1	A	8.0	B		15					SEA
1983 05 16.50	S	8.0	A	5.0	B		10		5			SEA
1983 05 16.82	S	9.1	AC	41	L	4	86	4.5	7			CLA
1983 05 16.83	S	8.8	AC	15.2	L	5	30	5	7			CLA
1983 05 17.60	S	9.1	AC	41	L	4	86	5	6	0.17	255	CLA
1983 05 17.89	S	9.4	AC	26.0	L	6	39	& 3.0	4			MER
1983 05 19.75	S	8.9	AC	41	L	4	86	5	6			CLA
1983 05 21.88	S	9.4	AC	26.0	L	6	63		4			MER

Periodic Comet Kopff (1982k) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 05 21.90	S	9.2	AC	15.0	L	5	75					MER
1983 05 29.88	B	8.9	S	26.0	L	6	39	4.8	4	0.06		MER
1983 05 29.89	B	8.7	S	9.0	L	9	28					MER
1983 05 30.38	S	7.7	A	8.0	B		15	7	3			SEA
1983 05 31.43	S	7.8	A	8.0	B		15		4			SEA
1983 05 31.87	S	9.7	AA	12.0	R	5	21	3.0	5			CAM
1983 06 01.19	M	8.9	AA	25	L	7	68	3.4	6			MOR
1983 06 02.86	S	9.8	AA	12.0	R	5	21	3.0	4			CAM
1983 06 02.89	B	8.8	S	26.0	L	6	39	6.3	3/	0.05	312	MER
1983 06 02.94	B	8.7	S	9.0	L	9	28	11.7	2			MER
1983 06 03.90	B	8.7	S	26.0	L	6	39	6.3	3/	0.05	322	MER
1983 06 03.91	B	8.6	S	9.0	L	9	28					MER
1983 06 04.21	S	9.4	A	20	C	10	81	2.75	3			SPR
1983 06 04.41	S	7.7	A	8.0	B		15		4			SEA
1983 06 04.92	B	8.6	S	26.0	L	6	39	6.5	3/			MER
1983 06 04.94	S	9.9	AA	12.0	R	5	21	3.0	5			CAM
1983 06 05.69	S	9.9	AA	12.0	R	5	21	3.0	4			CAM
1983 06 06.14	M	8.7	AA	25	L	7	68	4.4	4			MOR
1983 06 06.22	S	9.5	A	20	C	10	81	2.5	3			SPR
1983 06 06.33	S	8.5	S	15	L	3	17					KEE
1983 06 06.37	S	8.6	S	15.0	R	6	29	6	6			MAC
1983 06 06.85	S	9.9	AA	12.0	R	5	21	3.0	3			CAM
1983 06 07.22	S	9.3	A	20	C	10	81	2.75	4			SPR
1983 06 07.88	S	9.9	AA	12.0	R	5	21	3.5	3			CAM
1983 06 08.00	B	9.0	S	7.0	B		10	4.6				DEA
1983 06 08.23	S	9.2	A	20	C	10	81	3.0	4			SPR
1983 06 08.45	S	7.5	A	8.0	B		15	7	4			SEA
1983 06 08.83	S	9.8	AA	12.0	R	5	21	3.5	3			CAM
1983 06 09.12	S	8.1	A	8.0	B		15	8	3			BOR
1983 06 09.13	M	8.5	S	25	L	7	68	5.2	6			MOR
1983 06 09.14	S	8.1	AA	8.0	B		20	9	4			MOR
1983 06 09.36	S	8.4	S	15.0	R	6	29	7	6			MAC
1983 06 09.89	S	9.8	AA	12.0	R	5	21	3.5	3			CAM
1983 06 10.33	S	8.0	S	15	L	3	17					KEE
1983 06 10.92	B	8.8	S	26.0	L	6	39	7.0	3/			MER
1983 06 11.12	M	8.5	S	25	L	7	68	4.6	6			MOR
1983 06 11.17	S	8.3	AA	8.0	B		20	7	3			MOR
1983 06 11.19	M	8.3	AA	8.0	B		20	&10	2			GRE
1983 06 11.38	S	8.0	S	15	L	3	17					KEE
1983 06 11.94	S	9.7	AA	12.0	R	5	21	3.5	3			CAM
1983 06 12.06	B	8.8	S	26.0	L	6	39		4			MER
1983 06 12.07	B	8.6	S	15.0	L	5	25		3			MER
1983 06 12.13	S	8.1	A	8.0	B		15	7				BOR
1983 06 12.13	S	8.4	A	32	L	6	55	5.0	5			BOR
1983 06 12.15	M	8.5	S	25	L	7	68	4.6	6			MOR
1983 06 12.15	S	8.3	AA	8.0	B		20	9	4			MOR
1983 06 12.38	S	8.3	S	15.0	R	6	29	9	5			MAC
1983 06 13.11	S	8.3	AA	8.0	B		20	8				MOR
1983 06 13.22	S	9.2	A	20	C	10	81	3.0	4			SPR
1983 06 13.81	S	9.5	AA	12.0	R	5	21	4.0	3			CAM
1983 06 13.88	B	8.7	S	26.0	L	6	39	& 5.0	3			MER
1983 06 14.20	S	9.1	A	20	C	10	81	3.0	4			SPR
1983 06 14.38	S	7.8	S	15	L	3	17					KEE
1983 06 14.88	B	8.7	S	26.0	L	6	39	& 5.0	3/			MER
1983 06 14.88	S	9.6	AA	12.0	R	5	21	4.0	3			CAM

Periodic Comet Kopff (1982k) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 06 15.31	S	7.7	S	15	L	3	17					KEE
1983 06 15.89	B	8.6	S	26.0	L	6	39	6.0	3/			MER
1983 06 15.90	S	9.6	AA	12.0	R	5	21	4.0	3			CAM
1983 06 16.39	S	8.1	S	15.0	R	6	29	6	5			MAC
1983 06 16.87	S	9.6	AA	12.0	R	5	21	4.0	3			CAM
1983 06 16.91	S	9.7	AA	15.0	L	6	40	3.5	4			CAM
1983 06 26.69	S	9.6	AA	12.0	R	5	21	3.0	3			CAM
1983 06 27.22	S	8.5	A	14	S	4	20	6.5	3			SPR
1983 06 27.77	S	9.7	AA	12.0	R	5	21	3.5	3			CAM
1983 06 27.89	B	8.4	S	26.0	L	6	39	& 5	3			MER
1983 06 28.21	S	8.6	A	14	S	4	20	6.0	3			SPR
1983 06 28.90	B	8.4	S	26.0	L	6	39	& 5	2	0.06	276	MER
1983 06 28.92	B	8.4	S	9.0	L	9	28		2			MER
1983 06 29.27	S	8.2	S	15.0	R	6	29	9	6			MAC
1983 06 29.74	S	9.3	AA	12.0	R	5	21	5.0	4			CAM
1983 06 30.14	S	8.0	AA	8.0	B		20	10	6			MOR
1983 06 30.14	M	8.5	S	25	L	7	68	4.1	7			MOR
1983 06 30.21	S	8.4	A	14	S	4	20	7.5	3			SPR
1983 06 30.78	S	9.4	AA	12.0	R	5	21	4.5	4			CAM
1983 07 01.10	S	8.0	AA	8.0	B		20	10	5			MOR
1983 07 01.10	S	7.7	A	5.0	B		10	8	3			BOR
1983 07 01.10	M	8.5	S	25	L	7	68	4.4	7			MOR
1983 07 01.31	S	8.1	S	15.0	R	6	29	7	6			MAC
1983 07 01.91	B	8.3	S	26.0	L	6	39	& 5	3			MER
1983 07 02.92	B	8.5	S	26.0	L	6	39	6.7	3		114	MER
1983 07 02.94	B	8.4	S	9.0	L	9	28		2			MER
1983 07 03.22	S	8.3	A	14	S	4	20	6.0	4			SPR
1983 07 03.91	B	8.4	S	26.0	L	6	39	6.7	3	0.07	155	MER
1983 07 04.10	S	7.7	A	5.0	B		10	10	3			BOR
1983 07 04.90	B	8.5	S	26.0	L	6	39	& 6	2/			MER
1983 07 05.22	S	8.0	A	14	S	4	20	5.5	3			SPR
1983 07 06.20	S	8.3	A	14	S	4	20	5.0	2			SPR
1983 07 06.35	S	8.2	S	15.0	R	6	29	9	5			MAC
1983 07 07.10	S	7.6	A	5.0	B		10	15	3			BOR
1983 07 07.12	S	7.8	AA	8.0	B		20	13	5			MOR
1983 07 07.12	M	8.3:	S	25	L	7	68	5.0	7			MOR
1983 07 08.11	S	7.6	A	5.0	B		10	14	3			BOR
1983 07 08.14	S	7.6	AA	8.0	B		20	13	6			MOR
1983 07 09.21	S	8.1	A	14	S	4	20	5.0	2			SPR
1983 07 09.97	B	8.5	S	7.0	R	12	28	12.2	3			MER
1983 07 10.14	S	7.6	AA	8.0	B		20	13	5			MOR
1983 07 10.95	B	8.6	S	7.0	R	12	28	& 8	3			MER
1983 07 11.12	S	7.6	A	5.0	B		10	12	2			BOR
1983 07 11.12	S	7.8	A	8.0	B		20	9	3			BOR
1983 07 11.14	S	7.6	AA	8.0	B		20	12	5/			MOR
1983 07 11.25	S	8.1	S	15	L	3	17					KEE
1983 07 11.98	B	8.4	S	7.0	R	12	28	& 8	3			MER
1983 07 12.92	B	8.2	S	7.0	R	12	28	& 8	3/			MER
1983 07 13.96	B	8.2	S	7.0	R	12	28	& 8	3			MER
1983 07 14.11				25	L	7	68	4.1				MOR
1983 07 14.11	S	7.7	AA	8.0	B		20	10	5/			MOR
1983 07 14.12	S	7.7	A	8.0	B		20	11	3			BOR
1983 07 14.12	S	7.5	A	5.0	B		10	14	2			BOR
1983 07 15.10	S	7.7	A	8.0	B		20	10	2			BOR
1983 07 15.10	S	7.5	A	5.0	B		10	12	0/			BOR

Periodic Comet Kopff (1982k) Cont.

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 15.11				25	L	7	68	3.6	6			MOR
1983 07 15.11	S	7.9	AA	8.0	B		20	10	4			MOR
1983 07 17.14	S	7.9	AA	8.0	B		20	8				MOR
1983 07 30.23	S	9.0	A	25	L	5	38	4.0	3			SPR
1983 07 31.22	S	8.6	A	20	C	10	64	4.5	4			SPR

Periodic Comet Johnson (1983h)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 10.04	P	17.0	UP	60.0	L	4		0.4	2			MER

Periodic Comet Churyumov-Gerasimenko (1982f)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1982 10 17.42				15	R	5	62	1.7				MOR03
1982 10 17.42	S	10.9	AC	15	R	5	31					MOR03
1982 10 24.20	S	11.2	AC	15	R	5	62	1.1				MOR03
1982 10 26.39	S	11.2	AC	15	R	5	62	1.1				MOR03
1982 10 30.43	S	11.5	AC	15	R	5	62	0.9				MOR03
1982 11 10.40	S	10.4	AC	15	R	5	62	1.7				MOR03
1982 11 17.41				15	R	5	62	1.4				MOR03
1982 11 17.41	S	11.0	AC	15	R	5	31					MOR03
1982 11 22.13	* S	10.4	AC	25.4	L	4	79	2.0	6/			CAV
1982 11 27.40	S	10.3	AC	15	R	5	62	1.7				MOR03
1982 12 07.40	S	10.2	AC	15	R	5	62	1.9				MOR03
1982 12 12.16	S	10.1	AC	15	R	5	62	1.9				MOR03
1982 12 13.39	S	10.2	AC	15	R	5	62	1.7				MOR03
1982 12 17.38	S	9.9	AC	15	R	5	62	1.9				MOR03
1982 12 18.07	S	9.7	AC	15	R	5	62	1.9				MOR03
1983 03 02.85	S	12.8	AC	26.0	L	6	130	& 1.0	0			MER
1983 03 03.85	S	13.0	AC	26.0	L	6	130	& 1.5	0			MER
1983 03 07.85	P	13.5:	UP	26.0	L	6		& 1	3			MER
1983 03 08.88	P	14.0:	UP	26.0	L	6		& 1	3			MER

Periodic Comet Gunn

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 11.06	P	15.0	UP	60.0	L	4		0.2	7			MER

Periodic Comet Russell 3 (1983i)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 07 13.04	P	13.5	UP	60.0	L	4		1	5	0.02	235	MER

Periodic Comet Schwassmann-Wachmann 1

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1983 02 19.06	S	12.0	AC	26.0	L	6	130	1.6	3/			MER
1983 02 20.03	S	11.9	AC	26.0	L	6	130	1.7	3			MER
1983 03 06.02	P	12.5:	UP	26.0	L	6		& 1	2/			MER
1983 03 13.07	S	[12.5	AC	26.0	L	6	130					MER
1983 05 12.93		[11.9		20	R	14	40					SHA02
1983 07 12.88	P	13.5	UP	60.0	L	4		1	3			MER
1983 07 13.88	P	14.0	UP	60.0	L	4		1	2			MER

Periodic Comet Stephan-Oterma (1980 X = 1980g)

DATE (UT)	MM	MAG.	RF	AP.	T	F/	PWR	COMA	DC	TAIL	PA	OBS.
1980 11 11.14	S	9.6	AC	15	L	8	51	2	3			DEY
1980 11 13.14	S	9.8	AC	15	L	8	51	2	5			DEY

NOTE: Asterisks (*) after the dates of specific observations indicate that those observations are revisions of data published in previous issues of the INTERNATIONAL COMET QUARTERLY. --Editors

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RECENT NEWS CONCERNING COMETS

The past two months have seen the discoveries of four hitherto-unknown comets. Indeed, no less than 9 comets have been discovered or recovered in the last three and a half months! Two of the latter 4 objects are newly-found short-period comets: P/Russell 3 was found by Kenneth S. Russell from plates exposed June 14-15 with the 1.2-meter Schmidt telescope at Siding Spring, Australia; the object had a short tail and was at total magnitude 16. P/IRAS, the third of four comets discovered since late April by the Infrared Astronomical Satellite, was around magnitude 15 at discovery in late June. These two periodic comets -- designated 1983i and 1983j, respectively -- have orbital periods of 7.4 and 13.3 yrs and perihelion distances of 2.52 (1982 Nov. 22) and 1.70 (1983 Aug. 23), respectively (cf. MPC 8052).

P/Russell 3 is fading as it recedes from the inner solar system, but comet 1983j may attain a total magnitude slightly brighter than 14 in September, as it passes within 0.8 AU of the earth. A third new discovery, also discovered by IRAS, and so named, was designated comet 1983k. This 18th magnitude object has been very poorly observed, due in part to its southern location in the sky. Parabolic orbital elements by Brian G. Marsden indicate perihelion occurred at some 2.4 AU last April 28. It, too, is fading.

The brightest of the new comets was discovered by Kazimeras Černis, observing apparently visually from the Soviet Union; he was also a co-discoverer of comet 1980 IV = 1980k. Comet 1983l was discovered at around magnitude 11 on July 19, and was at total visual magnitude 10.5 some 3 days later, according to Charles S. Morris. Parabolic orbital elements by Marsden show that this object will be well-placed for viewing as it brightens slowly by half to a full magnitude during the next month. An ephemeris accompanies this column. Comet 1983l is intrinsically very bright, with an absolute magnitude of 2 or 3; it was more than 3 AU from both the sun and earth at discovery.

We have received many drawings and photographs of comet IRAS-Araki-Alcock, some of which appear in this issue. Especially interesting are the drawings by J.-C. Merlin and S. O'Meara. This comet (1983d) was certainly the best naked-eye comet since comet West 1976 VI; it isn't often that a comet becomes one of the brightest objects in the night sky -- more than 50 or 60 degrees in elongation from the sun. Comet 1983e (Sugano-Saigusa-Fujikawa) was also a faint naked-eye object to some observers with dark skies, but many individuals had great difficulty in locating the extremely diffuse comet in the dense Milky Way region near the time of closest approach in June.

One astronomer studying the rotation rate of the nucleus of comet 1983d announced his findings at this summer's American Astronomical Society meeting. Fred Whipple gives his "current preliminary" results, based on visual-wavelength observations (mostly

RECENT NEWS CONCERNING COMETS

from CCD images obtained by R. Schild with the 24-inch telescope at Mount Hopkins in Arizona): the nucleus appears to be rotating retrograde with respect to its motion around the sun. He finds a period of 8 hr 42.5 min.

Our southern hemisphere observers are becoming quite prolific, as attested by observations of such recent comets as IRAS-Araki-Alcock and Sugano-Saigusa-Fujikawa elsewhere in this issue. Observers worldwide have been following the three periodic comets brighter than 10th magnitude: P/Tempel 1, P/Tempel 2, and P/Kopff.

Readers will likely find John Bortle's record of his observations of P/Kopff 1982k quite interesting (see page 59 of this issue).

The IRAS group has released news of a 20-million-mile-long and 200,000-mile-wide, dusty, infrared tail observed of P/Tempel 2 (1982d). The tail was originally discovered as what IRAS observers thought to be a large number of individual objects near comet 1982d, moving with motion similar to the comet. Near the nucleus, the tail appears to be a few arc minutes wide, with a total length of some 10 degrees, according to John Davies of the University of Leicester, England. This novel discovery is sure to have a large impact on the physical studies of comets. The only visual observer reporting a tail recently has been J.-C. Merlin of Le Creusot, France. His drawings show tail structure extending no more than 4′ from the nuclear region.

Very few astrometric observations have been made of P/Tempel 2 at this apparition. E. Everhart, observing near Denver, Colorado, has observed it in the past month, along with comets P/Gunn and Bowell 1980b. The latter 2 comets are quite faint. Jim Gibson continues to follow some of the fainter comets which would likely otherwise go unobserved. On April 2, he photographed comet Elias (1981 XV) with the large Schmidt Palomar telescope, noting it to be well-condensed with a faint coma and a short tail. On the same night, he found comet Austin (1982g) at total magnitude 20, as it was moving southwestward in Lynx. Everhart's photograph of P/Bowell-Skiff (1983c) on May 16 shows an image of total magnitude 19.

NASA has revealed serious plans for a satellite rendezvous with a periodic comet sometime in the early- to mid-1990s, with comets P/Honda-Mrkos-Pajdušáková, P/Tempel 2, and P/Encke leading the list of likely candidates (though not necessarily in that order). Funding and other feasibility factors will ultimately decide how far these plans will get.

Readers are reminded again of the second American Workshop on Cometary Astronomy, co-sponsored by the ICQ and the International Halley Watch, to be held on Saturday, October 1st, in Pasadena, California. An active slate of talks is scheduled. Further information can be obtained from: S. Edberg, Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109, USA.

-- Daniel Green, 1983 August 8

EXTENDED EPHEMERIS FOR PERIODIC COMET TEMPEL 2 (See ICQ 5, 28):

Date ET	R. A. (1950)	Decl.	Delta	r	Elong.	Mag.
1983 09 23	03 14.36	-05 47.4	0.989	1.807	130.2	11.5
1983 09 28	03 12.41	-06 29.3				
1983 10 03	03 09.46	-07 08.8	0.992	1.869	139.3	11.7
1983 10 08	03 05.60	-07 44.5				
1983 10 13	03 01.00	-08 15.0	1.011	1.931	148.0	11.9
1983 10 18	02 55.86	-08 38.9				
1983 10 23	02 50.36	-08 55.4	1.050	1.994	154.5	12.1
1983 10 28	02 44.74	-09 03.9				
1983 11 02	02 39.17	-09 04.2	1.111	2.058	156.3	12.4

EXTENDED EPHEMERIS FOR PERIODIC COMET TEMPEL 2 (See ICQ 5, 28):

Date	ET	R. A. (1950)	Decl.	Delta	r	Elong.	Mag.
1983 11	07	02 33.88	-08 56.2				
1983 11	12	02 29.02	-08 40.4	1.194	2.122	152.5	12.7
1983 11	17	02 24.73	-08 17.4				
1983 11	22	02 21.10	-07 48.0	1.300	2.187	145.4	13.0
1983 11	27	02 18.18	-07 13.1				
1983 12	02	02 16.00	-06 33.7	1.427	2.251	137.0	13.3
1983 12	07	02 14.56	-05 50.5				
1983 12	12	02 13.86	-05 04.3	1.571	2.314	128.3	13.6
1983 12	17	02 13.86	-04 15.8				
1983 12	22	02 14.52	-03 25.6	1.730	2.378	119.8	14.0

PARABOLIC ORBITAL ELEMENTS FOR COMET CERNIS 1983l, BY B. G. MARSDEN.
(From IAUC 3848; angles for argument of perihelion, node, and inclination are equinox 1950.0)

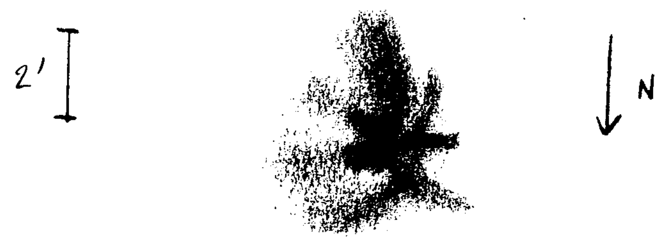
T = JD 2445539.696 = 1983 July 24.196 ET
ω = 186°.918 i = 134°.808
Ω = 208.877 q = 3.31349 AU

Date	ET	R. A. (1950)	Decl.	Delta	r	Elong.	Mag.
1983 07	20	02 42.95	+11 32.6	3.439	3.314	74.4	10.4
1983 07	25	02 42.44	+10 31.9				
1983 07	30	02 41.44	+09 25.2	3.245	3.314	84.9	10.3
1983 08	04	02 39.90	+08 12.0				
1983 08	09	02 37.77	+06 51.7	3.052	3.317	96.1	10.1
1983 08	14	02 35.00	+05 23.8				
1983 08	19	02 31.54	+03 48.0	2.868	3.322	107.9	10.0
1983 08	24	02 27.35	+02 03.9				
1983 08	29	02 22.39	+00 11.5	2.704	3.331	120.4	9.9
1983 09	03	02 16.62	-01 49.0				
1983 09	08	02 10.03	-03 56.8	2.570	3.342	133.2	9.8
1983 09	13	02 02.64	-06 10.8				
1983 09	18	01 54.47	-08 29.2	2.478	3.355	145.6	9.7
1983 09	23	01 45.60	-10 49.9				
1983 09	28	01 36.12	-13 10.4	2.437	3.371	154.9	9.7
1983 10	03	01 26.16	-15 27.9				
1983 10	08	01 15.87	-17 39.6	2.452	3.390	156.1	9.7
1983 10	13	01 05.45	-19 43.1				
1983 10	18	00 55.09	-21 36.4	2.523	3.411	148.2	9.8
1983 10	23	00 44.96	-23 18.1				
1983 10	28	00 35.24	-24 47.8	2.644	3.434	136.6	10.0
1983 11	02	00 26.08	-26 05.2				
1983 11	07	00 17.59	-27 10.9	2.805	3.460	124.1	10.1
1983 11	12	00 09.85	-28 05.7				
1983 11	17	00 02.93	-28 50.6	2.996	3.488	111.9	10.3
1983 11	22	23 56.82	-29 26.8				
1983 11	27	23 51.53	-29 55.4	3.204	3.518	100.3	10.5
1983 12	02	23 47.04	-30 17.5				
1983 12	07	23 43.31	-30 34.2	3.421	3.551	89.4	10.7
1983 12	12	23 40.31	-30 46.3				
1983 12	17	23 37.97	-30 54.8	3.638	3.585	79.1	10.8
1983 12	22	23 36.26	-31 00.3				
1983 12	27	23 35.10	-31 03.4	3.848	3.621	69.4	11.0

On these pages are drawings by Jean-Claude Merlin (Le Creusot, France) and Stephen J. O'Meara (Cambridge, Massachusetts) of comets in recent months, from visual observations. Below are 4 drawings by Merlin of P/Kopff, and on the following two pages are drawings of comet IRAS-Araki-Alcock 1983d by O'Meara. Many more drawings and photos we've received will be published in future issues.

P/Kopff - 1982 K.

10 Juin 1983 - T260 - 130x - 23h45 TU



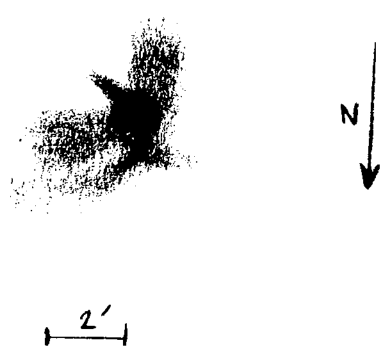
13 Juin 1983
21h20 TU

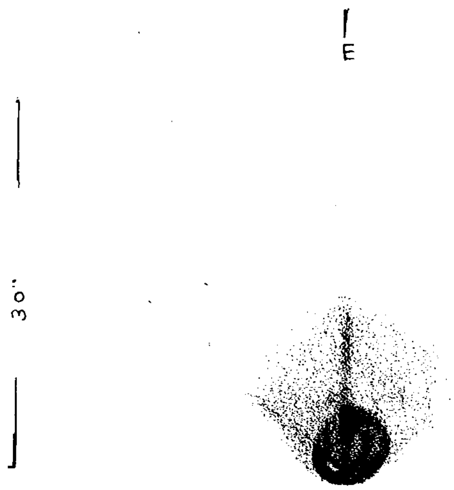
T260 - 130x

14 Juin 1983
21h25 TU

15 Juin 1983
21h30 TU

T260
130x
312x





3'' of arc

O'Meara

5/5/83
5:30 U.T.

O'Meara

5/6/83
7:30 U.T.

O'Meara

5/7/83
3:50 U.T.

25 cm Refl.

O'Meara

5/10/83
2:30 U.T.

O'Meara

3:30 U.T.

3' of arc

5/10/83
4:30 U.T.

15-cm Clark

O'Meara

Oak Ridge

5/10/83
[illegible] U.T.

15-cm [illegible]

O'Meara

Oak Ridge

5/10/83
6:00 U.T.

15-cm Clark

Oak Ridge

[illegible]

15-cm Clark

O'Meara

[illegible]

5/11/83
3:30 U.T.

15-cm Clark

O'Meara

Oak Ridge

5/12/83
2:30 U.T.

15-[illegible]

O'Meara

[illegible]