HALLEY'S COMET AND ITS CELESTIAL SISTERS

ΟΜΙΛΙΑ ΤΟΥ ΑΝΤΕΠΙΣΤΕΛΛΟΝΤΟΣ ΜΕΛΟΥΣ κ. ZDENEK KOPAL

Mr. President, distinguished Members of the Academy, Ladies and Gentlemen,

Permit me to commence this first address of mine before the Academy of Athens by expressing to you my sincere appreciation for having elected me in 1976 your Corresponding Member, and for granting me today the honour of addressing you in your midst — in the city so intimately connected with the cradle of our civilization. I only regret that my linguistic shortcomings do not permit me to do so in Greek — the language of Plato, the founder of the first institution of many whose name has become a household word in any civilized language. For according to tradition, the Academy of which you made me a member derives its name from the hero Academos, on whose land it opened its doors in 387 B.C. to last (with ups and downs) for 916 years, until it was closed in A.D. 529 on the orders of the Emperor Justinian. My only justification of addressing you in the language which Plato would have considered barbaric is the topic of my lecture, which no doubt would have been of interest to Plato, and even more to his pupil Aristotle. Although the ashes of both the teacher and the pupil have long been scattered to the four corners of the land, their spirits continue to dwell among us; and may they do so also in the future!*

Indeed, the known past history of the comet about to visit us once more is almost (though not quite) as long as that of the city of Athens itself — reaching from 240 B.C. when the first records of its appearance came down to us from China (cf. Stephenson and Walker, 1985), to its impending closest approach to the Sun which is to take place on 9 February 1986. Julius Caesar was a boy of 13 when this comet did the same in 87 B.C.; Dzhingiskhan saw it in 1222 A.D.; and Johannes Kepler in 1607 before Edmond Halley realized in 1682 the periodic nature of its re-appearance every 76.1 years (see Figure 1).

**It is my understanding that Plato's Academy was located in a quarter of modern Athens now called Astryphos (Hagios Tryphon). Its place is open to visitors; though no monument commemorates its original purpose (cf. p. 397 of Sarton, 1953).*

This comet — which has carried Halley's name ever since — became the first known periodic comet revolving around the Sun; and remained the only one of this type for more than a century — until J. F. Encke established in 1819 that other (less conspicuous) comets observed in 1786 by Mechain, 1795 by Caroline Herschel, or by Pons in 1805 and 1818 were one and the same object, trevolving around the Sun in a much shorter period (3.30 years). Unlike Halley's Encke's comet is a purely telescopic object; which recently attracted especial attention when Kresak (1978) proved that a chip (about 3 per cent of its total mass) collided with the Earth on 30 June 1908 to produce the Tunguzka crater in the Siberian taiga. However, by its celestial appearance Encke's comet can in no way compete with Halley's which, on some past occasions (such as in 837 A.D., when it approached the Earth to a distance of a mere 5 million kms; and the lenght of its tail visible to the naked eye — its "broom", as the Chinese described it — exceeded 80°) must have been very spectacular indeed.

The apparitions of bright comets in the sky in pretelescopic age used to attract much attention, and were connected with all kinds of superstition. "When beggars die, there are no comets seen. The Heavens themselves blaze forth the death of princes", proclaimed William Shakespeare in his tragedy on Julius Caesar († 44 B.C.; when incidentally, no bright comet appeared). However, coincidences between terrestrial and cometary events worked better in other cases; thus, in the 14th century A.D., Charles IV, King of Bohemia and Holy Roman Emperor (1316 - 1378) died at Prague Castle on 29 November — only 19 days after Halley's comet passed through its perihelion that year. And this was not for the last time that a significant contribution to cometary astronomy emanated from Prague. In 1577, another great comet appeared in the sky, which Tycho Brahe observed with care at Uraniborg in Denmark. A subsequent comparison of his observations with those made by Tadeas Hajek (Hagecius) in Prague at the same time led to a parallax which placed this comet outside the sub-lunar sphere; and the right of this (and other) comets to be considered as denizens of interplanetary space was firmly established.*

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Since that time (coinciding roughly with the advent of telescopic astronomy) the number of comets discovered in the sky began to grow by leaps and bounds.

** It was closest to the Earth on October 3rd of that year, and passed not far from the zenith in Prague; nut no contemporary chronicle seems to have made a point of this coincidence.*

Thus in 1984 alone the discovery of no less than 21 comets was reported by different observers (though some of these proved identical with those previously detected); and of a total of 735 comets observed up to that time, only 132 (i.e., 18 %) turned out to revolve around the Sun in periods of less than a hundred years. These totals mean, however, very little except as a measure of the number of astronomers active in this particular branch of their science: already at the beginning of the 17th century Johannes Kepler expressed an opinion that "there are more comets in the sky than fish in all the waters of the Earth"; and nothing that we learned has weakened the validity of this simile — except, perhaps, for the fact (unforeseen by Kepler) that pollution of our waters can exterminate fish more rapidly that the solar heat can dissolve comets.

As is well known, the anatomy of the individual comets can be divided into a core, its coma, and the tail. In spite of deceptive appearances, it is the inconspicuous cometary core which really matters — although no one has yet seen it! For whenever a comet — any comet — happens to transit across the disc of the Sun, it vanishes in projection completely out of sight — which could not be true of any solid body larger than a few kms in size[1]*. Its mass must likewise be minute; for even at closest approach all comets have so far failed to disturb the motion of any celestial body to measurable extent*[2]*. From a lack of evidence to the contrary we conclude that the masses of cometary cores do not, on the average, exceed* 10^{17} - 10^{18} *g; and their densities are of the order 0.1 to 1 g/cm*^{3}.

Far away from the Sun — in the domain inhabited by the major planets where prevailing ambient temperatures are 100°K or less — the whole comet consists only of such a core, whose mean density indicates that it represents nothing else but a floating iceberg of volatile compounds (mainly water!), contaminated but little by heavier rocks accreted on its journey through space — thus "hitch-hiking a ride" on the core as long as the latter remains solid, though they can be shaken off its surface when the latter begins to melt. In the "cold storage" of the outer parts of the solar system (generally outside the orbit of Jupiter) this is not

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1. This was verified by radar contacts with comet Encke in 1980, or comet Araki-Alcock in 1983.

2. For example, comet Brooks of 1889 passed between Jupiter and its time 5th satellite (Amalthea) and was split for its audacity into not less than four parts; though Amalthea itself (a body akin to a small asteroid, less than 100 km across) did not acknowledge the presence of the interloper by the least nod of its motion.

the case; and the cometary cores behave there like bodies shining in scattered sunlight. However, when a comet enters the asteroidal belt or gets inside the orbit of Mars, sublimation of its surface material under the influence of sunlight begins to surround the cometary head by a coma and, eventually, gives rise to tails which are the chief title to fame of this class of celestial bodies. The 20th century has been, in general, poor on conspicuous comets. However, the 19th century produced several — like those of 1811 (presaging, according to some, Napoleon's invasion of Russia), 1848 (a year of many political upheavals in Europe), 1858, or 1861 and 1882 — which stretched their tails over a large part of the sky; and Chéseaux's comet 1744 — that peacock of the cometary tribe — spread out not less than six tails at the same time to the admiration of countless onlookers.

Cometary tails represent, we may add, the only part of the anatomy of these celestial bodies which is characterized by a certain degree of physical complexity. A part of the radiation emitted by them is nothing but the light of the Sun, scattered on solid particles of interplanetary dust (the dimensions of which are large in comparison with the wavelength of incident sunlight) whose pressure aligns them in the direction of the cometary radius-vectors. As most of this dust is released by a gradual melting of the cometary core, the geometric characteristics of such tails depend on the angles between the Sun, the Earth, and the comet; and can be foreseen with tolerable accuracy.

However, another constituent of cometary tails is gases ionized by the solar ultraviolet light flux; and their characteristics are then at the mersy of magnetic fields frozen in the puffs of solar corpuscular radiation (the "solar wind"), the existence of which was predicted by Biermann (1951), and subsequently confirmed by man-made space probes. These no longer have to point always away from the Sun; and the resultant are the tails — often variable in space and time — which we observe from case to case. One essential feature is, however, common to them both: namely, that whatever their nature or size, they represent matter which — once "unstuck"— is irretrievably lost to the comet, and bound to bring about its eventual dissipation.

Astronomically speaking, comets are indeed but shortlived denizens of our skies — the more so, the closer they can approach the Sun. For instance, Halley's comet — the core of which has been estimated to 10 km in size — loses in this way a surface layer about 2m deep and cannot, therefore, survive more than about 10^4 years; this mass loss being sufficient to account for the observed delay each successive perihelion passage of approximately 4 days.

As it transpires from the foregoing remarks, we have learned already a good deal about Halley's comet in the past: but still very little in comparison to what we can expect with confidence to learn in the next several months. There are several reasons for this optimistic prognosis; and virtually all are due to vastly improved methods of observation.

At the time of the last appearance of Halley's comet in 1910 — which may still be remembered by some senior members of this Academy — the photographic plate still remained the principal tool of exploration. As the next approach was drawing near, photoelectronic devices already in current use (CCD) permitted astronomers of the Mount Palomar Observatory to pick up with their 5-m telescope the comet already on 16 October 1982 as a starlet of 24th apparent magnitude, when the comet was still 1211 days before its perihelion passage, at a distance of more than 10 astronomical units (i.e., outside the orbit of Saturn); and it has never been lost sight of since that time.

Modern computers (how primitive were those at the disposal of our ancestors around 1910!) enabled us from the observed positions of the comet in the sky to predict its future motion with great accuracy (necessary for subsequent space work) as Halley's comet was heading for the Sun: in January 1984 it entered inside the orbit of Jupiter; and in late September of that year (rather abruptly) the cometary core began to develop a coma (accompanied by the appearance of molecular bands of CN in its spectrum) even before the comet approached more closely to Mars. Now — one year later — the comet has become visible in smaller telescopes; though on photographs taken these weeks no tail has made an appearance (because it happens to be oriented in a direction parallel with the line of sight).

Another radically different instrument of observation — now at our disposal, which as not available to our ancestors in 1910 — is the International Ultraviolet Explorer (IUE) — a synchronous satellite (revolving around the Earth at an altitude of km above the surface of the Earth in the period of one day) which for the first time has permitted us to study the spectra of all celestial objects (including the comets) to almost the Lyman limit of the hydrogen spectrum. It is this tool that has already permitted us to establish (from the UV spectrum of the ionized H_2O molecules) that cometary cores consist predominantly of ice.

Third, large enough radio telescopes have been erected in recent years to enable us to observe the occultations of background radio-sources by cometary tails — observations which have enabled us to establish the electron densities prevalent in such tails at different distances from the Sun.

But it is not only our current ability to observe Halley's comet outside our atmosphere in extreme domains of the spectrum that is bound to make its 1986 opposition a milestone in the study of this venerable denizen of our sky. The ultimate triumph of the times is the fact that — for the first time in history — Halley's comet can be observed, not only outside the atmosphere, but from a close proximity of the comet itself! As we are met together in Athens these days, a veritable armada of not less than six man-made spacecraft — two of Japanese origin ("Sakigake" and "Suisei"), two Soviet ("Vega"), and one European ("Giotto") in addition to the American ("International Comet Explorer") are heading for their respective rendezvous with Halley's comet in the first half of 1986.

Of these, the European collaborative project carrying the code name of Giotto[1] *should really have been described as "kamikadze"; for it is destined to collide with the core of Halley's commet on 13 March 1986 to suffer complete destruction. All others are fly-by's; and some had already other work to do en route to their ultimate goals. Thus the Soviet Vegas (acronym for the Venus-Halley mission) paid already close calls on our sister-planet Venus; and parts of them soft-landed (on 10 June 1985) on its surface to advance further our knowledge of its physics as well as chemistry; while the American ICE spacecraft explored the plasma physics of the tail of the comet Giacobini-Zinner or 11 September 1985 (see Fig. 2); and must still do what it can to reach Halley in March 1986.*

In the meantime, our space armada is well underway: the Vega spacecraft is due to rendez-vous with Halley's comet on 6 and 9 March 1986; Suisei on 8 March; and Giotto, on 13 March. In addition, a manned U.S. Astro 1 mission is to be lifted in circum-terrestrial orbit on 6 March 1986 to study Halley's comet aboard a space-shuttle for the available observing "windows" during each orbit from the distance of the Earth, but well outside of the terrestrial atmosphere.

It is clear from these data that the month of March 1986 will keep the cometary students more busy than they were ever before in their lives. Our time is too short to survey fuller details of all these objectives, and of the ways in which these are to be accomplished. There is, however, no doubt that their joint outcome will revolutionize our knowledge of the cometary world no less than the Apollo and

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1. So called after the medieval Florentine painter Giotto di Bondone, who immortalized the return of Halley's comet in 1301 in his famous painting of the Adoration of the Magi in the Scrovegni chapel of Padua which (painted in 1303) identified that comet with the Star of Bethlehem.

other missions of the 1960's revolutionized the knowledge of our Moon. With such prospects now only months in the future, was it not worth-while for the veterans of the 1910 opposition of Halley's comet (of whom there are some still present among us) to await its return 76 years later?

We may perhaps conclude by saying that this would indeed be a very good idea; for the appearance of the comet this week (as seen on the accompanying Fig. 3) may be regarded by some as a disappointment. It could, however, hardly have been otherwise; for the present approach of Halley's comet to the Sun is not favourable for terrestrial observations. At the time of the perihelion passage the comet will be on the opposite side of the Sun and, therefore, invisible to us on Earth. At the next passage through the perihelion (on 28 July 2061) the situation will be much more favourable; and even more so one revolution afterwards (27 March 2134), when Halley's comet will approach the Earth at a distance of mere 13.9 million kms — closer than at any other time since in 837 A.D.. In the 22nd century of our era Halley's comet may, therefore, recover at least some of its past glory in the sky; but, unfortunately, it will be only our grandchildren's grandchildren who may benefit from its renaissance.

REFERENCES

L. Biermann, *Zeit. f. Astrophys.*, **29**, *274 - 286, 1951.*

L. Kresák, *Bull. Astron. Inst. Czechoslovakia*, **29**, *129 - 134, 1978.*

G. Sarton, *A History of Science I: «Ancient Science through the Golden Age of Greece», Oxford University Press, London, 1953.*

F. R. Stephenson, and C. B. F. Walker, *Halley's Comet in History, British Museum Publ. Ltd., London, 1985.*