28. A SEARCH FOR ENCKE'S COMET IN ANCIENT CHINESE RECORDS: A PROGRESS REPORT

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Abstract. The catalog by Ho Peng Yoke lists ancient Chinese observations of 581 transient astronomical objects of which some 300 might conceivably have been P/Encke, between the years -156 and $+1600$. Using the Gauss-Hill method it was possible to establish roughly the plane of the orbit and the direction of perihelion for P/Encke over this interval of time. All but about 40 of the objects could be eliminated by comparing the observed locations with possible locations of P/Encke. Several more could be eliminated on the basis of their calculated magnitudes and general observability. Large uncertainties in the non-Newtonian motion as yet prevent our certain identification of P/Encke among the remaining possibilities.

The extended and torroidal character of the Taurid-Arietid meteor complex in space (Whipple and Hamid, 1952) and its dynamical relationship with Encke's Comet (Whipple, 1940) demonstrate that this periodic comet has been active in contributing meteoroids for at least hundreds and probably for thousands of revolutions. Observations, general logic, and specifically the icy comet model (Whipple, 1950) support the concept that the intrinsic brightness of a comet should progressively decrease with time. Hence P/Encke, which has probably moved in much its present orbit throughout all historic time, should generally have been brighter in earlier centuries than during recent apparitions. The rate at which comets systematically change in brightness with age is not established satisfactorily on either an observational or a theoretical basis. Hence it is highly desirable to establish whether P/Encke, frequently a naked-eye object during the past 180 years, was sufficiently bright in ancient times to attract the attention of the systematic Chinese observers. Identification of P/Encke in the ancient records could also give us valuable information about its past nongravitational motion and perhaps a clearer idea of how it attained its present unusual orbit. The extremely valuable *Ancient and Medieval Observations of Comets and Novae in Chinese Sources* by Ho Peng Yoke (1962) provides an unparalleled source in which to search for possible observations of P/Encke. For most of the 581 observations listed, Ho Peng Yoke includes a date, a direction in the sky and frequently detailed information on the appearance of the object plus additional observations of its motion.

The long intervals between probable observations of P/Encke in the past and its known variable period (see e.g., Marsden, 1969) preclude the possibility of meaningful predictions of the comet's position for apparitions predating its discovery in 1786. On the other hand, the position of the orbital plane and the line of apsides can be predicted approximately over long periods of time by computation of the secular perturbations, even though the phase relationship of the comet in its orbit has become completely uncertain. Thus for any given date in the past twenty centuries one can ascertain with some confidence whether an observed comet in the sky at a given date

Chebotarev et al. (eds.), The Motion, Evolution of Orbits, and Origin of Comets, 152–154. *All Rights Reserved.*

could reasonably be attributed to P/Encke at some position in its orbit as seen from the Earth.

Before beginning such calculations we eliminated some 280 objects from Ho Peng Yoke's catalog because of their previous identification with Halley's Comet, with novae, with fireballs, or because of lack of specific information on the date or position in the sky. Many of the sky positions were rather vague because of their location by means of Chinese constellations, some of which extend for over great distances on the sky.

We calculated the orientation of the orbit of Encke's Comet in space by numerical integration of the equations of motion defining the secular perturbations through the Gauss-Hill method. The positions of the planets in the past were obtained from the Brouwer-van Woerkom (1950) theory. The small errors in numerical results obtained from this theory as noted by Sharaf and Budnikova (1967) are trivial with respect to the much larger observational uncertainties in the comet positions.

At 100-yr intervals, from the calculated position of the orbit of Encke's Comet, we derived the directions as seen from the Earth at 10-day intervals for all positions around the Earth's orbit and around the comet's orbit from 140 days before the perihelion to 130 days after. For each recorded cometary observation we searched in the ephemeris of the orbital plane nearest in time to ascertain whether or not P/Encke could have been seen in the stated direction at the given time, errors in direction up to 20° being allowable. For each allowable observation, an approximate date of perihelion could be determined. More than 40 cometary observations remain from Ho Peng Yoke's catalog in the interval -156 to $+1600$ after the application of this geometrical exclusion.

A number of these possible observations of Encke's Comet can be eliminated by the criterion that $r^{-4}\Delta^{-2} > 16$, where r and Δ (in AU) are the solar and geocentric distances at the time of observation. This three-magnitude enhancement of the brightness from that at unit distance from the Sun and Earth might be relaxed as a criterion among the earlier observations should clear evidence be found for an intrinsic brightening of Encke's Comet in ancient times. Some observations can be questioned because of close proximity of the observed position to the Sun. Furthermore, some of the Chinese comets were too bright or lasted too long to have been Encke's Comet.

A few observations might be added tentatively to the list of possibilities should a clear-cut sequence of identification of Encke's Comet be established in the abridged list. The process of searching for possible identifications is being continued, although the sequences so far found appear to be the result of chance. The number of revolutions between widely separated possible observations is, of course, unknown, depending on the nongravitational effects.

References

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Discussion

G. A. Chebotarev: Can one be sure that the orbit of P/Encke has not undergone large changes during this time?

F. L. Whipple: The general turning of the orbital plane is rather well established, but there is uncertainty in the semimajor axis and period, of the order of a few percent, because of the non-gravitational forces.

L. Kresák: The present mean value of the semimajor axes of the shower meteors associated with P/Encke is definitely smaller than that of the comet. Do you think that this difference is due to the past history of the comet's orbit, or to the nongravitational effects acting on the meteoroids?

F. L. Whipple: I believe that unknown forces act to reduce the semimajor axes of meteor orbits and therefore that the semimajor axes of associated meteor streams do not give useful information about the past history of the comet orbit.