A NOTE ON THE ASTROMETRIC PRECISION OF MINOR PLANET OBSERVATIONS

D. PASCU
U. S. Naval Observatory
Washington, DC 20392-5100
U.S.A.

ABSTRACT. For years, interest in precise positions of minor planets has centered on tying the dynamical reference frame with the stellar frame and determining catalog zone errors. Photographic methods are generally used in obtaining observed spherical equatorial coordinates (R.A., Dec.) or crossing-point observations. Estimates of the external precision of the equatorial coordinates are overly pessimistic, while those for crossing-point observations, too optimistic.

It is estimated that equatorial positions for the brighter ($m < 11$) minor planets can be determined with an external precision not worse than +/-0.2 arcsec (m.e.), and perhaps as low as +/-0.1 arcsec (m.e.), depending on the reference catalog zonal errors.

Intersatellite observations are a type of crossing-point observation in which the images of two different objects appear in the same exposure. This is the most precise type of crossing-point observation and gives an estimate for the lower limit to the external precision of this observation type. Recent studies of satellite observations indicate that this lower limit is in the +/-0.05 to +/-0.08 arcsec (m.e.) range.

1. Introduction

The history of the use of minor planets for the improvement of the celestial coordinate system has been well documented by Orelskaya (1974), Pierce (1978), Hemenway (1980) and Whipple et al. (1988). Following IAU resolutions presented at Brighton (Trans. IAU XIVB, 1971) several

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programs of photographic observation were begun/continued for a selected list of minor planets. Estimates of the external precision (accuracy) of these observations were often made by redetermining positions for catalog reference stars and comparing these positions to the catalog values. This method simply returned the (accidental) catalog error for the epoch and did not adequately allow for the benefit gained from using many reference stars. Large external errors were often attributed to catalog zone errors. To eliminate zone errors, Hemenway (1980) and Whipple et al. (1988) have advocated the use of crossing-point (x-pt) observations. The external errors involved in these two techniques are discussed below.

2. Spherical Equatorial Coordinates

A better estimate of the external error can be found from the expression (see Pascu and Schmidt 1990):

$$e^2_t = \frac{e^2_{*c} + S^2 e^2_{*o}}{(n-m)} + (S e_{po})^2$$

where e_t is the total, single-image external error in position of an object p near the center of a photographic plate; e_{*c} is the mean catalog error of the reference stars (arcsec); e_{*o} is the mean, total observational error of the reference stars; e_{po} is the total observational error of object p (in mm); S is the plate scale (in arcsec/mm); n is the number of reference stars used in the plate solution; and m is the number of degrees of freedom--the number of constants determined in the plate solution. In this expression, the first term represents the accidental error due to the reference frame (catalog and observational), while the second term is due to the plate and night errors for object p. Note that this formulation does not account for zone errors in the reference catalog, nor for some unmodelled observational effects.

Using AGK3 parameters and current values for the other quantities, the expected external precision is between +/-0.1 and +/-0.3 arcsec (m.e.), depending on instrumental focal scale. A telescope with a focal scale of about 30 to 40 arcsec/mm will provide the optimum precision with these parameters. To this value must be added the systematic portion due to the zone errors of the catalog. These numbers are supported by photographic observations of Saturn (Pascu and Schmidt 1990) and agree with the assessment of E. Hog (quoted by Hemenway 1980), and indicate that AGK3 zone errors may not be greater than about 0.1 arcsec at epoch 1980 along the northern ecliptic.

With the introduction of the new high density, high precision photographic catalogs (see de Vegt 1988), the error interval on e_t will decrease further to (+/-0.06 to +/-0.2 arcsec m.e.), the advantage then lying with the long-focus instruments. It is clear that the systematic catalog errors will be the limiting factor in the use of these catalogs for this application.

3. Crossing--Point (X-Pt) Observations

Whipple et al. (1988) define a x-pt observation as "the observed angular separation between two minor planets as measured against the same stellar background". This observation type has the advantage that systematic catalog errors are eliminated. Usually, the observation of each minor planet is made on different plates and on different nights. However, should both objects appear on the same plate, such observations would be the most precise because the observational errors due to the reference stars would also be eliminated. Intersatellite observations are this type of x-pt observation if reference stars are used to reduce the plates. Thus, discussions of this observation type can yield a value for the lower limit to the external error for x-pt observations.

Taylor and Shen (1988) recently analyzed a very large dataset of the intersatellite observations of the eight brightest moons of Saturn. Their Table 3 shows no individual dataset with an external mean error smaller than +/-0.10 arcsec for all satellite/Titan pair observations taken together. Taylor (1985,1986) also computed external mean errors for individual satellite/Titan pairs. The smallest external mean error was +/-0.08 arcsec for the Rhea/Titan observations made with the 26-inch refractor at the Naval Observatory. There was also an indication in Taylor's computations that image density or magnitude difference contributed to this error and that a lower limit, say +/-0.05 arcsec (m.e.), was reasonable.

4. Conclusions

Recent studies of the external precision of photographically obtained equatorial positions for Saturn (Pascu and Schmidt 1990) and photographic intersatellite observations of the Saturnian moons (Taylor and Shen 1988, Taylor 1985, 1986) yield important information on the expected external precision of astrometric observations of minor planets. For bright ($m < 11$ mag), slow-moving minor planets, photographic spherical equatorial coordinates can be obtained with an external precision of +/-0.25 arcsec (m.e.) along the northern ecliptic using the AGK3 catalog and a long-focus refractor. With the introduction of the modern high-density reference star catalogs (Douglass and Harrington 1990, de Vegt 1988) this precision can be increased to +/-0.1 arcsec (m.e.). Meanwhile, x-pt observations can be obtained with an external precision not much better than +/-0.08 arcsec (m.e.). Considering the value of the spherical equatorial coordinates in fixing the minor planet orbit in space (Whipple et al. 1988), x-pt observations should only be made when systematic catalog errors larger than 0.1 arcsec are suspected.

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