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Astrometric observations of natural satellites and orbit update

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Abstract:
This paper reports on our observing campaign of nature satellites and orbit update in last 30 years. In following work, besides the regular observation, we will begin our digital research of photo plates.

1 Research History
In 1985, we start our research on natural satellites, and successfully took the first photo plate in Sheshan station in 1987. Till 1994, we had obtained hundreds of photo plates, which were the almost exclusive observations on natural satellites in those decades. In favor of Chinese Digital Project, we have an opportunity to digitize some of them, re-measure them with high precision catalogue. The results will be very interesting.
Motivated by CCD achievement, we observed the planet satellites in successful implement since 1994. Because of the small field of the primary CCD and the shortage of high precision catalogue, we had a lack of reference stars in each CCD frames so that, the classical astrometric reduction was invalid. In order to determine the orientation and scale of the CCD chip, we used bright moon of target planets or bright stars, for instance double star or cluster, as calibration reference, whose positions are derived from very well known ephemeris data (Harper et al., 1997). Actually this method should introduce some systematic errors into satellites’ position, and just can be used in only if a classical astrometric reduction is not possible (Shen et al., 2001), but also it is an efficacious calibration way in that time.
However, after 2002, as the publication of UCAC2 and the using of big field CCD chip which be equipped in Sheshan station, our ongoing works are benefited from the improvement of the technique. Generally 15-20 reference UCAC2 stars are available in each frame. It means the increase of the precision.
Last year, we equipped a 14 inch aperture telescope mounted an electron cooling CCD for the observation of satellites’ occultation.

2 Astronomic Observation and Orbit Update
Observation is the first and most important part of our work. From 1980s, we have obtained thousands of frames and photos of the satellites of Saturn, Neptune, Uranus, and Jupiter. Most of those frames have not been published. In last decade, we observed more faint satellites than before, which are difficult to be observed for their more than 12 magnitude. In use of CCD image processing, some inner faint satellites can be separated from the bright primary’s halo light. The valuable measurements of faint satellites were used to improve their theories.
2.1 Saturnian satellites
We began our observation on Saturn’s eight major satellites in 1987. The first successful observations were commenced on the 1.0 meter reflector at Yunnan observatory. The following photo plates were obtained in 1988 and 1993 at Sheshan station. All these astrometric data has been collected into “A catalogue of ground-based observations of eight major satellites of Saturn, 1874-1989” (Strugnell et al., 1990). The observations from 1994 to 1996, including 451 measurements of positions with a small field CCD at Sheshan station, achieved better results in position to photo plates, which enhanced us very much. We collected 3000 CCD observations in 1990-1997, which obtained by Beurle et al. (1993), Harper et al. (1997, 1999), and our group (Qiao et al. 1999), to compare four different astrometric reduction methods for the calibration of a CCD target. During 1997-2000, we obtained 1167 positions of the eight major satellites of Saturn, and published them. The observation of the eight major satellites from 2002-2008 is amending. Due to the large quantity of data, it takes us a lot of time in reduction. We project to publish these positions in the end of this year.

Orbit update is another important part of our works. We calculated the secular and long-period perturbation for each of the elements for Iapetus in the 200 years. The residual of existing motion theories were consistent in limited time span with available data, but had large differences in a long period calculation.

Compared with the other eight satellites, the 9th satellite, Phoebe is more difficult to observe for its irregular distribution. We had published its observation two times, the 115 frames from 2003-2004, and 1173 frames from 2005-2008. In 2005, we determined Phoebe’s orbit again, and distributed the observations on Phoebe orbit projected on the Earth’s mean equator J2000. Our orbit leaded to significantly lower residuals than ever before. In 2007, we improved the orbit of Phoebe by numerical integration via fitting 686 available data covered 1905-2006, and yielded a new determination of the total mass of Saturnian system. Last year, with 105 years’ observation, 1904-2009, the accuracy of orbit updated of Phoebe had been improved to about 0.1arcsec.

2.2 Uranian satellites
Our observations of the five major Uranian satellites were paralleled by the observation of Saturnian satellites. The bright moon method also was used in calibrating Uranian satellites effectively, based on the GUST86 theory. We have published 122 CCD frames and 864 positions from 1995 to 1997 of the five major Uranian satellites. The precision lay between 0.03 and 0.05 arcsec. The article to publish our observations from 1998-2007, will be finish soon.

2.3 Neptune’s satellites
We took Image processing in our reduction of the 1996-2006 observations of Triton, using a third-degree polynomial to simulate sky background. That improved the residuals to about 0.04arcsec. Nereid is a very faint satellite, which magnitude is 18.7. It is very difficult to observe, that usually need big aperture telescope and long-time exposure, sometime more than 20mins, with good weather condition. From 2006 to 2007, we obtained 112 CCD astrometric positions of Nereid. Because of high accuracy stars catalogue UCAC2, we get a higher precision in reduction than ever before.

2.4 Galilean satellites
Recently years, we start our research in the eclipses and occultation of Galilean satellites. In July 2009, we obtain successful observations of the mutual eclipses and occultation of Galilean satellites.
3 Summary

In the past, our works were benefited for the high precision catalogue, such as UCAC2. As the public of UCAC4 and GAIA catalogue, to reduce the old CCD frames with new, high accuracy catalogue will be very imperative. We cooperate with Shanghai Observatory in the Chinese photo plate digital project. In our ongoing work, we will re-measure the photo plate, analysis the effect coming from digit, and compare the reduction results with our primary conclusion. We determined the beginning and end times, as well as the mid-light time when the light flux of the eclipsed satellite dropped to the minimum during the event.

4 Thanks

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5 References


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