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Connection between apparent and real orbits of a binary system

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In a binary system, each body describes about the other an elliptical apparent orbit which is the projection of the real orbit on the tangential plane. Following Kepler's first law (the primary is at one of the ellipse focus), and with a suited choice of the two angles needed to define the orientation of the orbital plane in the space, we can get in a closed form a simple expression in a polar representation, of the apparent orbit as a function of the keplerian elements of the real orbit. In case where the orbital plane of the secondary has a zero inclination over the equatorial plane of the primary, these angles stand for the sub–Earth point latitude and the position angle of the pole of the primary with respect to the north celestial pole. These angles are generaly well known for solar system bodies and are given by the physical ephemerides.

In reality, none system follows exactly the Kepler's first law owing to the gravitational perturbations due to primary's oblateness and by the massive bodies — especially the giant planets and the Sun. However their effects become noticeable only after a couple of days. On the other hand, depending on the distance to the Earth, the apparent aspect of the orbit will change as the Earth will travel on its path. Therefore, if we have some observations performed over a few consecutive days (case of a solar system body), we can safely consider that they are distributed over a same projected Keplerian orbit which is the osculating orbit defined as the orbit that would be followed if the perturbing force were instantaneously turned off.

Our method can then be used to provide a prelimary orbit determination. This always provides two solutions that are symmetric (one direct and one retrograde), since the inclination of the orbital plane (or the direction of the angular momentum vector) cannot be determined unambiguously from a single epoch observation. Initial estimates of the five orbital elements involved are easily found and convergence is achieved after a few iterations with a fitting algorithm based on the Levenberg–Marquardt technique.

Thanks to the adaptive optics technique, we can now detect more and more close binary systems among asteroids and TNO but also close faint satellites of planets, not separable so far. In such systems the secondary orbits so quickly the primary that we can apply our method provided that observations are well distributed over the orbit. Moreover if we have at least two epochs of observation, we can derive for each of them the location of the pericenter in the orbit and consequently directly measure the apsidal rate which is mainly related to the non–spherical shape of the primary.

This method has been succesfully applied to a small satellite of Uranus, Puck [1], and to the satellite of the asteroid 22 Kalliope [2] (fig. 1). It has been adapted to the case of the binary stars as well.

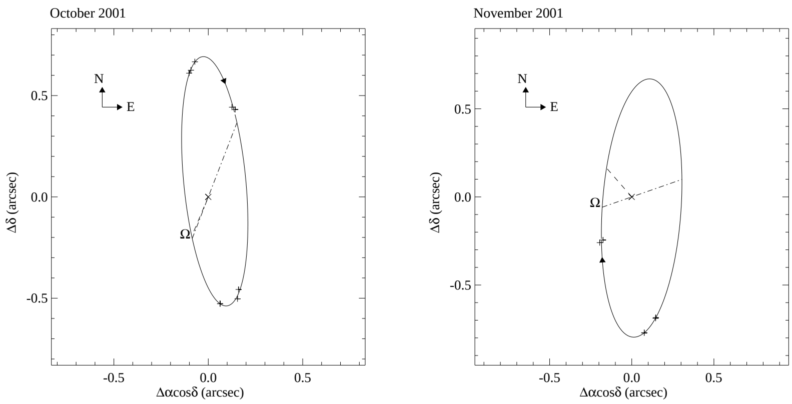

Fig. 1. Orbit of the secondary of (22) Kalliope on October and November 2001. Nodal line and location of the pericenter are plotted.

References

1. Descamps P., Marchis F., Berthier J., Prangé R., Fusco T., Le Guyader C. First ground–based astrometric observations of Puck. C.R. Physique, 2002, **3**, 121–128.

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