Asteroid orbits and ephemerides: Towards higher-fidelity predictions

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Since the discovery of the first minor planet Ceres, astronomers have faced the problem of determining asteroid orbits and providing reliable ephemeris predictions. Though the theoretical algorithms to solve this problem are well consolidated, we still have to face several challenges when estimating asteroid trajectories.

The computation of an asteroid orbit is determined by the optical and radar astrometric observations available. Thus, the observation error model is crucial for providing reliable orbits and uncertainty information. The presence of systematic errors in asteroid optical astrometry is a known issue that we have to deal with. Therefore, we show how to correct for star catalog biases due to star position and proper motion errors by using the PPMXL catalog as reference. Moreover, since the quality of observations from different observatories and different observing programs is uneven, we apply individual data weights to each observation according to the expected quality. We also discuss how to mitigate the possible correlations arising between observations from the same observatory that are closely spaced in time.

Beside the treatment of the astrometry, the dynamical model is an essential component when computing asteroid orbits. For a very well constrained orbit, even small accelerations can be required in order to fit the observational dataset and to make reliable predictions. We account for the gravitational attraction due to the Sun, the planets, the Moon, and Pluto as well as that due to the 16 most massive bodies in the main asteroid belt. We also include a relativistic model that account for both Solar and relativistic terms. Non-gravitational perturbations may be a relevant component of the dynamical model and they are difficult to model since they depend on the considered asteroid's physical properties, which are typically unknown. We discuss how to estimate non-gravitational perturbations and the resulting uncertainty by either determining them as free parameters during the orbital fit or using the available information on the asteroid's physical properties.

One of the most important applications of asteroid predictions is the hazard assessment for impacts on Earth. Though there are two automated systems, JPL's Sentry and NEODyS, routinely scanning for possible impacts in the next hundred years, we need additional care when pushing forward the horizon for impact predictions and in presence of strong scattering encounters. Under these circumstances, the accurate mapping of the uncertainty and the handling of nongravitational perturbations become critical for a reliable risk assessment. We discuss how to capture the uncertainty due to both astrometry and dynamical model and how to use keyholes to compute reliable impact probabilities.