NAROO-AST

Precovery observations and impact predictions of Near Earth Asteroids

A.-C. Perlbarg [1][2], V. Robert [1][2], J. Desmars [1][2], D. Hestroffer [1]

(1) Institut de Mécanique Céleste et de Calcul des Éphémérides (IMCCE), Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ Paris 06, Univ. Lille, 77 avenue Denfert-Rochereau 75014 Paris (France)
(2) Institut Polytechnique des Sciences Avancées (IPSA), 63 bis boulevard de brandebourg 94200 Ivry-sur-Seine (France)

Abstract

Near Earth Asteroids represent a danger for the Earth. An impact of a Potentially Hazardous Asteroid could have catastrophic consequences. The knowledge of the current dynamic of Potentially Hazardous Asteroids is essential for the purpose of an international program of planetary defense. In this respect, accurate astrometric measurements acquired over a large time span are crucial to provide reliable orbits and impact predictions and to detect small accelerations such as Yarkovsky effect.

The NAROO digitization centre is dedicated to the digitization and the analysis of old astronomical observations with astrophotographic plates. Digitizations are realized with a high precision digitizer composed of high-resolution camera and a plate holder mounted on an air-bearing table moving on granite based out of vibrations. Glass plates up to 35 cm wide can be digitized. The resulting digitization has an accuracy better than 65 nm for the measurements.

Astrophotographic plates form a source of old observations of Solar System objects including Potential Hazardous Asteroids. Some of these old observations are precovery observations of these objects. The existing databases gather all the metadata of the past observations such as date, hour, right ascension, declination and exposure time which are essential to retrieve all the objects present in the observation. New orbit solutions of a selection of Potential Hazardous Asteroids were done from their positions on astrophotographic plates. It was made thanks to the identification of their old and/or precovery observations among databases and to their new reduction with Gaia catalog. It shows an improvement of the accuracy of their new ephemeris 2 to 10 times better depending on the asteroid hence the interest of using these old observations.

Next step will not be only to detect and to quantify small perturbations affecting asteroids such as Yarkovsky effect, but also to refine accurate impact predictions thanks to these new orbital solutions.

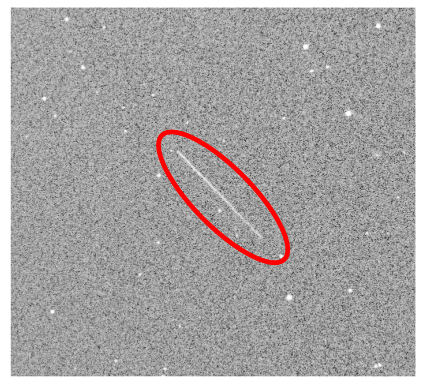
Old observations

Astrophotographic plates form a source of old observations of Potentially Hazardous Asteroids (PHAs) of the XX^th century. They could have been observed even if it was not the purpose of the original observation. The existing databases gather all the metadata of the past observations such as date, hour, right ascension, declination and exposure which are essential to retrieve all the objects present in the observation using SkyBoT (Berthier et al. 2006). SkyBoT provides the list of Solar System objects into a field of view of given celestial coordinates and radius at a given epoch.

Such an analysis has been carried out on the database of the Observatoire de la Côte d'Azur (OCA) – Caussols. It gathers 3600 Schmidt plates made between 1978 and 1996 with a large field of view and a long exposure time. Hence, objects with a maximum apparent magnitude up to 20 can be measured, particularly PHAs. 217 PHAs with an apparent magnitude below 20 have been identified with SkyBoT among 427 plates, including 328 precoveries. Precoveries are very interesting as they are observations made before the discovery date of the object never used for orbit determination. Finally 12 PHAs have been identified among 24 plates, including 7 precoveries after looking at the plates. Indeed, sometimes the plate was lost or broken or the object was too faint due to its large apparent motion. The older precovery found was made 25 years before the discovery of the PHA 2015 UM67.

All the old observations found in the OCA Caussols database have been digitized with the NAROO digitizer to enable the analysis. The astrometric reduction is in progress.

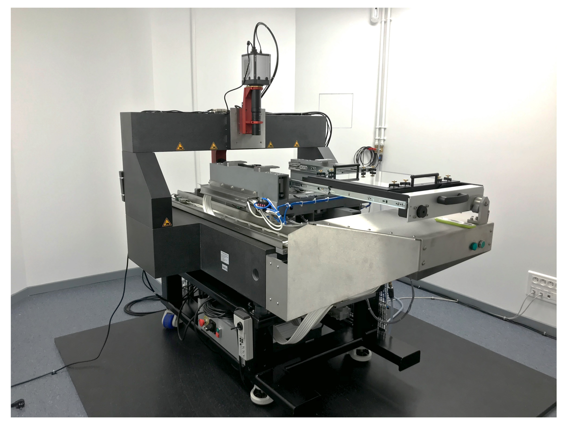
©NAROO – 2015 UM67 (1990)



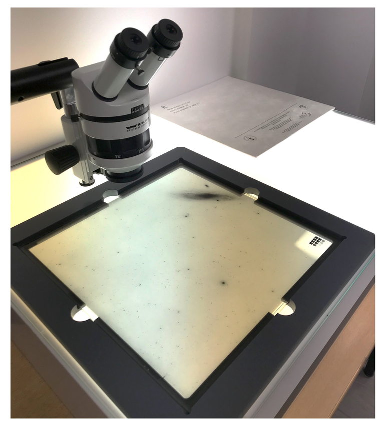
©NAROO – 2006 SU49 (1982)

NAROO digitization centre

The **N**ew **A**stronomical **R**eduction of **O**ld **O**bservation digitization centre of Paris Observatory - Meudon is dedicated to the digitization and the analysis of old astronomical observations with astrophotographic plates. Digitizations are realized with a high precision digitizer in a temperature and humidity stabilized ISO-5 clean room to ensure the best digitizing conditions. It is composed of high-resolution sCMOS camera on Z axis and a plate holder mounted on an air-bearing XY positioning table. The whole is supported by a granite based out of vibrations thanks to dynamic feet. Glass plates up to 35 cm wide can be digitized. The resulting digitization has an accuracy better than 65 nm for the measurements. Futhermore, the archive room already contains plate collections of Paris Observatory and also enables the storage of plate loans for collaborations or for Call for Proposals. (V. Robert et al., 2021, in press).



©NAROO – Digitizer



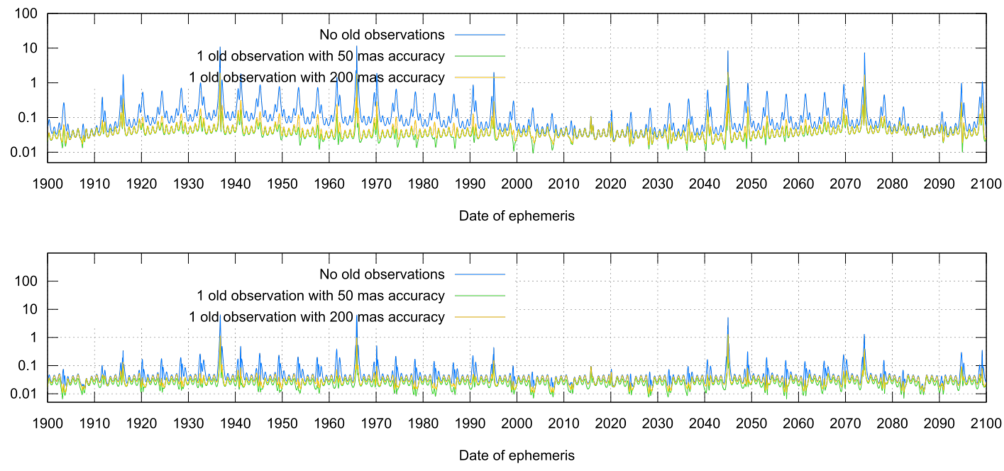
©NAROO - Plate

©NAROO – Plate archives

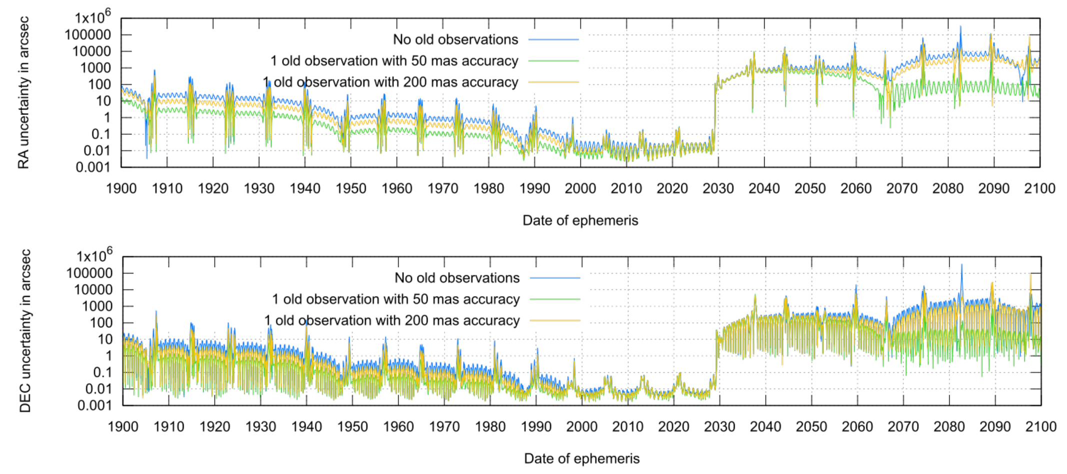
Orbital solutions

The **N**umerical **I**ntergration of the **M**otion of an **A**steroid (J. Desmars, 2015) provides orbit determination and ephemeris with their precisions by using observations from the Minor Planet Center (MPC), and their estimated uncertainties (J. Desmars et al. 2009). The previous old observations were added to the MPC dataset in order to estimate the improvement of the precision of the ephemeris for the simulations as the astrometric reduction is in progress. The object ephemeris on the observation was used for the simulations with an astrometric precision of 200 mas and 50 mas, representing the level of precision expected with the NAROO digitizer and the Gaia catalog.

Simulations were realized with the PHAs 2015 OL35 and the well-known Apophis. 2015 OL35 was discovered on 2015-07-23 and its observational period goes from 2015-07-23 to 2020-04-28. One precovery was identified in the OCA Caussols database in 1995. Apophis was discovered on 2004-06-19 and its observational period goes from 2004-03-15 to 2020-11-15 before its observation campaign of 2021. One precovery was identified in the OCA Caussols database in 1989. The figures show the estimated precision of the ephemeris in equatorial coordinates. The addition of the precovery shows a significant improvement in the ephemeris precision over the complete period, for both an astrometric precision of 200 mas and 50 mas. Same results were obtained for other PHAs with an improvement 2 to 10 times better. These simulations reveal that few old observations reduced with the NAROO digitizer and the Gaia catalog are enough to significantly improve the ephemeris precision and so, the orbit.



©NAROO – Simulation of the evolution of the precision of the ephemeris of 2015 OL35 from 1900 to 2100



©NAROO – Simulation of the evolution of the precision of the ephemeris of Apophis from 1900 to 2100

Perspectives

A new reduction of old observations with Gaia catalog is necessary as most of them were reduced with old star catalogs affected by systematic errors (V. Robert et al., 2016). The observational periods will also be completed with recent observations and Gaia observations in order to estimate the benefit between old and new observations.

Then, accurate astrometric measurements acquired over a large time span are crucial not only to provide reliable orbits and impact predictions, but also to detect and measure small accelerations such as Yarkovsky effect. The final model will help to calculate accurate impact predictions.

Further information

Anne-Charlotte Perlbarg
1^st year PhD Student
anne-charlotte.perlbarg@obspm.fr

The NAROO Project webpage
https://omekas.obspm.fr/s/naroo-project

References

J. Berthier et al., 2006, ADASS XV, Vol. 351, 367
J. Desmars et al., 2009, A&A, 499, 321
J. Desmars, 2015, A&A, 575, A53
V. Robert et al., 2016, A&A, 596, A37
V. Robert et al., 2021, A&A, in press