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THE NAROO PROGRAM

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Abstract. The NAROO program has been created at Paris Observatory, Meudon, as a unique centre dedicated to the digitization and the analysis of old astro-photographic plates for scientific purposes, only. The NAROO digitizer consists of a granite-based Newport-Microcontrol open frame air- bearing XY positioning table, a scientific sCMOS camera, and a telecentric optical system. The machine is placed in an overpressure, air-conditioned, ISO-5 clean room to maintain its positioning stability better than 15 nm, and its accuracy better than 65 nm.

The renewed interest about photographic plates concerns the expansion of the database of transient objects evolving in time, since digitization now makes it possible to measure images with a high level of accuracy and to identify all the available objects. The information extracted from such materials can be of an astrometric, photometric, and spectroscopic nature, when not purely imaging, with consequences in planetology, Near-Earth Asteroid risk assessment, astrophysical phenomena, and general relativity, to mention but a few. Since we invite researchers to use our facilities and digitize their collection (free of charge), we give examples of current and upcoming uses for the community.

Keywords: Instrumentation: high angular resolution – Techniques: image processing

1 Introduction

The NAROO program has been created at Paris Observatory, Meudon, as a unique centre dedicated to the digitization and the analysis of old astro-photographic plates for scientific purposes, only. It is build around a digitizer consisting of a granite-based Newport-Microcontrol open frame air- bearing XY positioning table, a scientific sCMOS camera, and a telecentric optical system. The machine is placed in an overpressure, air-conditioned, ISO-5 clean room to maintain its positioning stability better than 15 nm, and its accuracy better than 65 nm that is to say below 1 mas. The renewed interest about photographic plates concerns the expansion of the database of transient objects evolving in time, since digitization now makes it possible to measure images with a high level of accuracy and to identify all the available objects. The information extracted from such materials can be of an astrometric, photometric, and spectroscopic nature, when not purely imaging, with consequences in planetology, Near-Earth Asteroid risk assessment, astrophysical phenomena, and general relativity, to mention but a few.
As we detailed in Robert et al. (2021), we have started working on internal and external scientific programs, since we invite researchers to use our facilities and digitize their collection (free of charge). Some of them are detailed in next sessions as examples of use for the community.

2 Dealing with old observations

Following the newest improvements of the astrometric accuracy with the availability of the Gaia catalogs (Gaia Collaboration et al. 2016, 2021), we have warned the community that most of the observations used in the adjustments (catalogs, proper motions, dynamics...) have been reduced with references in the range 100-1000 mas in positioning accuracy. However, old observations obviously remain essential for the modelization of transitory phenomena and for the dynamics of moving objects.

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First, the framework is to re-reduce old observations using Gaia reference stars. It allows us to expand the sampling up to one century and to decrease the mean accuracy from 1 arcsec to some tens of mas. Second, we have to clearly define what is meant by "old observation", and the consensus is to consider observations realized before Gaia (1880-2016). Thus, and expect for the CCD observations realized from the end of the 90's, the materials used were astro-photographic plates, essentially.

A new analysis is essential to improve the accuracy of old observations already reduced, to analyze original observations, and to express all the data in the same reference system, eliminating biases. Dealing with photographic plates: either the measurements are still available (and accurate enough), or we need to digitize the original materials and the availability of the metadata (date, location, exposure time...) is crucial. By the end, we can assess a huge observational tank (1890-1998) allowing a new analysis (improvement) and/or a first analysis (originality).

3 The NAROO center

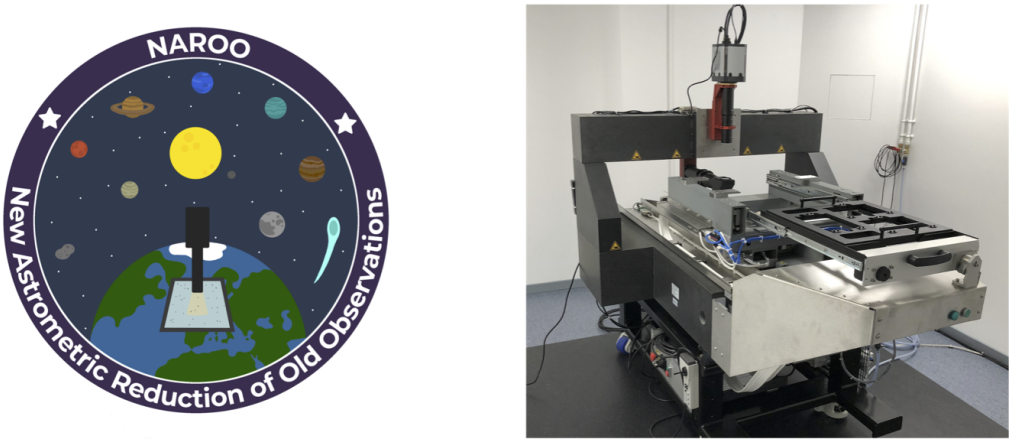

Fig. 1. The NAROO logo (left). and digitizer (right).

A unique digitization center dedicated to the sub-micrometric analysis of old astro-photographic plates, mainly for science purposes. Figure 1 shows the logo of the program (left) and the digitizer as of April 2020 (right). Figure 2 shows examples of digitizations realized for different topics: Planetology, Small bodies of the Solar System, Solar science, Deep sky study.

3.1 Facilities

The NAROO center is housed in 100 m2, at Paris Observatory, Meudon site. It is build around computing, archive, and machine rooms. The machine room is an ISO-5 regulated clean room with 20°C±0.1°C and 50% RH±10% RH. The machine comes from a Newport-Microcontrol XY-table 3 μm air-bearing system, with the capability to digitize plates up to 35 cm x 35 cm that is to say up to the tallest available formats without loss. The orthogonality, tilts and flips are constrained by Heindenhain 1nm encoders. The camera for digitization is an Andor sCMOS Neo 5.5 with pixels of 6.5 μm.

The Newport stability was measured below 10 nm. The Newport repeatability was measured below 40 nm. With real data, we were able to produce measurements with positioning stability below 15 nm, and a positioning repeatability below 65 nm. This is the overall accuracy we guarantee for the digitization final products. The FOV is isotropic with an error below 5 nm. The optical system was manufactured by the Instrument Pole of Paris Observatory with no tilt or distorsion contributions.

3.2 Operation and Call

Table 1 shows the operation ratio of the NAROO digitizer. Most important, the NAROO Call every 6 months is an invitation for researchers to use our facilities and digitize their collection, and is free of charge !

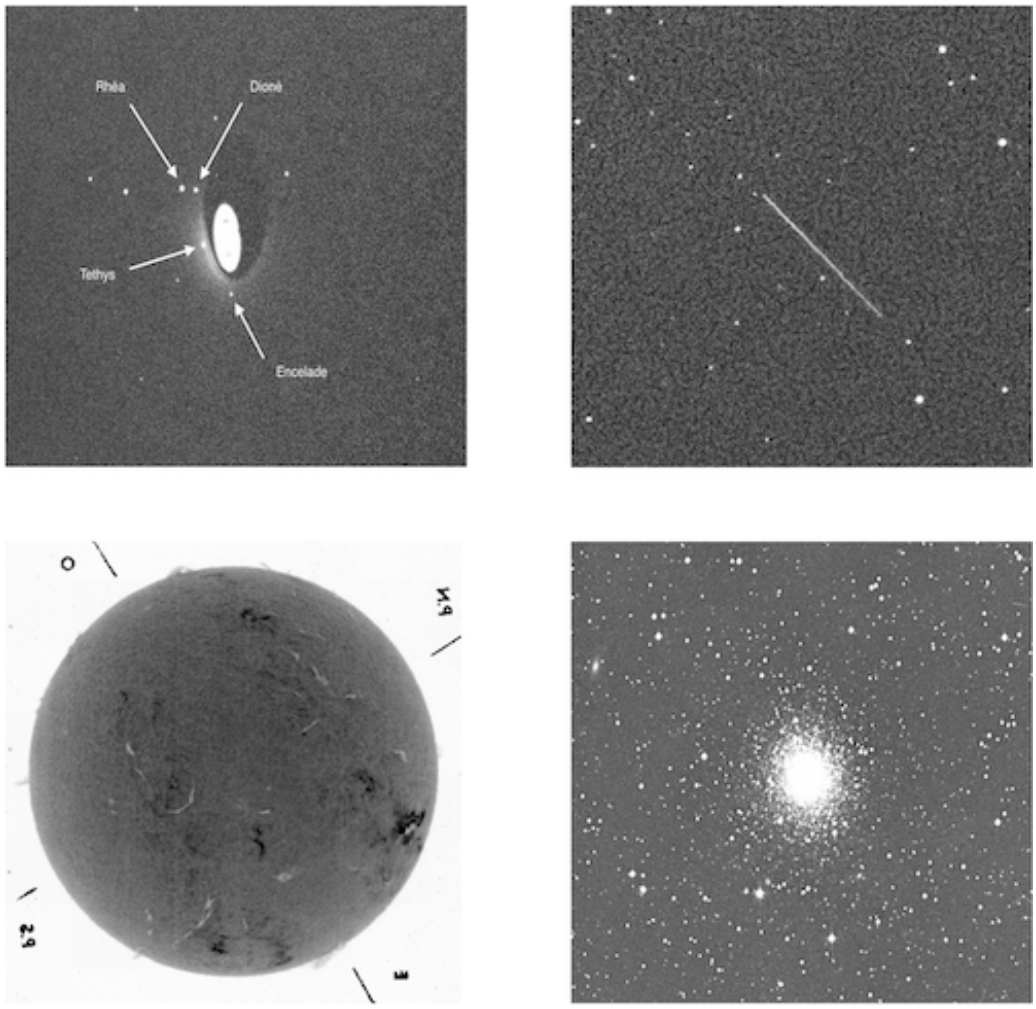

Fig. 2. Examples of digitizations realized for Planetology (top left), Small bodies of the Solar System (top right), Solar science (bottom left), Deep sky study (bottom right).

Table 1. Operation ratio of the NAROO digitizer.

Item	Maintenance	Call	Teaching	Discretionary
Quota	10%	60%	10%	20%

We received 4 proposals for the 2021B (starting) and 2022A Calls, each, and 5 proposals for the 2022B Call. All informations are available on our website (`https://omekas.obspm.fr/s/naroo-project/`) and regularly communicated within internal and (inter)national mailing lists.

3.3 Current and upcoming programs

We give some examples of current and upcoming uses for the community:

- **USNO Jovian plates**— A set of about 550 USNO photographic plates (1967-1998, Pascu) of Jupiter resulting in 2500 individual observations. First analysis was realized 10 years ago and only a demonstrator subset was published (Robert et al. 2011). At this epoch we determined intersatellite positions of the Galilean satellites with an overall accuracy of 30 mas (90 km at Jupiter), that is to say 3 times better in accuracy than the previous measurements. We determined equatorial positions for the first time with these materials with an overall accuracy of 70 mas (210 km at Jupiter), better in accuracy than more actual observation programs. We just reanalyzed the complete series with Gaia-DR3 for new improvements. The results will be submitted by October, 2022.

- **SAAO Saturnian plates**— A set of about 1300 SAAO photographic plates (1926-1945, Alden & O'Connell) of Saturn resulting in 1200 individual observations. We are determining spherical coordinates of the planet and the main satellites to improve the most recent dynamical models of the system, especially in regard to the datation of the observation. The results will be submitted by December, 2022.
- **SAF Juvisy/Flammarion plates**— A set of photographic plates realized by Quénisset and Flammarion (1903-1923) resulting in 1500 individual observations. We are using such very old observations for the comparison between measured star proper motions and those deduced from Gaia-DR3 propagation for an external characterization of the catalog accuracy. The results will be submitted by February, 2023.
- **NAROO-AST / Precoveries of PHAs**— From existing databases, we identified precovery observations of Potentially Hazardous Asteroids which were fortuitous observations made before their discovery. We added the positioning results to observation dataset to define new orbital solutions and detect the Yarkovsky effect with NIMA (Desmars 2015). Figure 3 shows the example of 2014 WV363 discovered in 2014, and that we observed on POSSI Schmidt plates in 1954, that is to say 60 years before the official discovery. The results will be submitted by March, 2023.

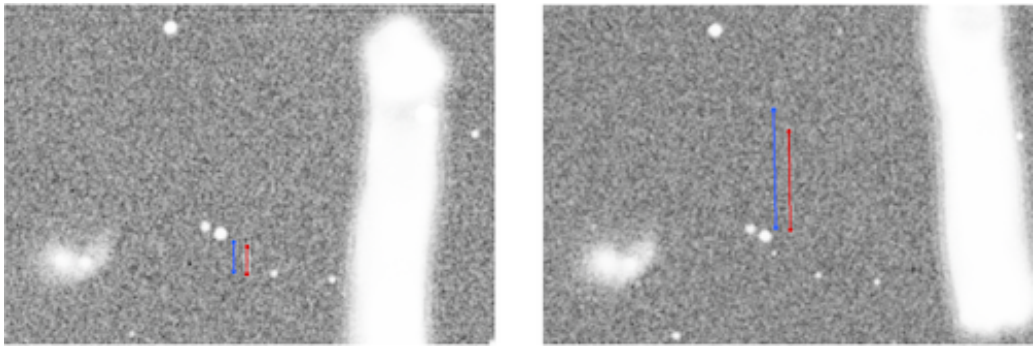

Fig. 3. Digitizations of observations of 2014 WV363 from POSSI R-band survey (left) and POSSI B-band survey (right). Red line denotes the measurement, blue line denotes the theoretical progagation.

4 Conclusion

The contribution of the observatories in the archiving of the materials is essential if we want to use original data and to avoid losing them. Then, the digitization and the analysis of astro-photographic plates consist in a huge challenge but contribute to many topics in Astronomy and Astrophysics. The information extracted from such materials can be of an astrometric, photometric, and spectroscopic nature, when not purely imaging.

In this framework, the NAROO machine is available for researchers to digitize their own collections for scientific purposes, since digitization time is reserved for external users within our call for proposals that is issued every six months via our project website.

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