# MW-Gaia STSM

## Physical characterization of Small Solar System Bodies using Gaia DR3 data complemented by data from other sources

Dr. Alberto Cellino from Osservatorio Astrofísico di Torino spent two weeks (28/08-09/09/2019) at the Observatoire of the Côte d'Azur (Nice) thanks to a GP3 STSM grant to collaborate with Prof. Paolo Tanga.

The goal of this STSM was to improve and optimize the scientific output of the asteroid data obtained by the Gaia space mission of the European Space Agency (ESA). This data was published on June 2022 in the third Gaia Data Release (GDR3). The activities carried out during this STSM took also profit of the presence in Nice in the same days of Prof. Karri Muinonen, from Helsinki University. As in the case of Cellino and Tanga, Prof. Muinonen is also deeply involved in the activities of the international Data Processing and Analysis Consortium (DPAC), which is responsible of the processing and interpretation of Gaia data.

The activities carried out in this STSM included the following:

- Dr. Cellino is one of major world experts in the field of asteroid polarimetry. He is co-PI of the Calern Asteroid Polarimetric Survey (CAPS), a research project in collaboration between the Astrophysical Observatory of Torino (Italy) and the Observatoire of the Côte d'Azur (OCA). During his staying at OCA, Dr. Cellino gave a seminar about CAPS and its role in modern asteroid polarimetry, with the presence of many colleagues and students. In particular, he pointed out the role played by polarimetric data in determining some properties of the layer or surface regolith on asteroid surfaces that are difficult to obtain by means of other techniques. He stressed also the possibility provided by polarimetric data to identify special classes of objects, including very primitive asteroids and candidates to be extinct comets. CAPS has already obtained a relevant part of all the available database of asteroid polarimetric measurements, which make it possible to derive reliable phase – polarisation curve for about 200 asteroids. One important goal of this STSM was to discuss the possibility to carry out a new and updated calibration of the existing relations between different polarimetric parameters and the geometric albedo, in order to update and improve the most recent work in this field, published by Dr. Cellino and colleagues in 2015. A very important agreement was established with the OCA colleagues (Dr. Benoit Carry and co-workers), who are developing a massive effort to derive from the whole data-set of currently existing asteroid data the most reliable values of some physical parameters, including the size obtained from star occultation data, the absolute magnitude, the spectral reflectance properties, for thousands of asteroids. According to their agreement, Dr. Carry was to provide in mid-October the most reliable parameter determinations for a large number of objects, including many present in the CAPS database. In this way, a new calibration of the relations between the albedo and different polarimetric parameters would be produced based on CAPS polarimetric data. The following step would be to use

the set of physical properties derived by polarimetric data as a constraint in the analysis of spectroscopic and photometric Gaia DR3 data.

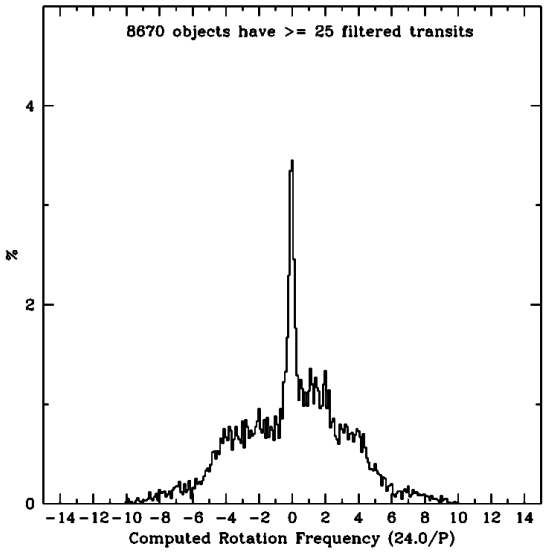
- During this STSM, most time was devoted to the preliminary results of photometric inversion of Gaia photometric data, making use of the genetic algorithm developed by Dr. Cellino. This algorithm is devoted to deriving, from Gaia sparse photometric data obtained at different epochs, the most reliable estimates of the spin properties (rotation period, orientation of the rotation axis), of the overall shapes and of some properties of the surface regolith. The analysis of the results obtained for a large set of about 25000 objects observed by Gaia led to the discovery of an important consequence of the properties of the Gaia sky scanning law, namely an effect producing in a non-negligible number of cases some spurious results of photometric inversion. These effects tend to produce particular values of the resulting rotation period and of the error bars affecting these determinations. This is an important result, because it allowed us to design and implement some changes in the algorithm of photometric inversion, and set up some rejection filters aimed at minimizing the number of unreliable results.
- The analysis of the spin properties obtained from GDR3, after the elimination of suspect photometric inversion solutions as explained in previous item, made it possible to build a first list of spin properties for asteroids present in the GDR3 database. It is important that this database includes the first determination of spin properties for tens of thousands asteroids, mostly small and faint ones, never observed before. Comparisons of the results obtained in GDR3 with those obtained in the past by means of ground-based observations for a much smaller subset of objects listed in GDR3 made it possible to estimate the most likely uncertainties of the photometric inversion solutions. The role played by the still incomplete sampling of viewing conditions for asteroids listed in the GDR3 database could be better evaluated. This is also useful to predict the improvement of the quality of the expected results from the photometric inversion of following Gaia data releases, including a much larger number of observations and a much better sampling of the space of possible viewing conditions.
- The general activities described in previous item also include some studies of particularly interesting cases. Among them, worth mention the cases of asteroids apparently displaying very long spin periods, to be interpreted in terms of collisional histories (including the possible formation of binary objects), thermal radiation effects, and the possible effects of a tumbling rotation state. Moreover, a very preliminary analysis of the properties of the phase – mag curves obtained from Gaia GDR3 photometry suggested some procedures to implement the possibility to use photometric data also for the purposes of a preliminary estimate of the albedo of different taxonomic classes, derived from Gaia spectroscopic data. The general lines of this work was only sketched due to the short available time, but the developments will certainly take profit of the activities and results of this STSM.

Summarizing, the results obtained during this STSM are important, and indicate both specific and more general directions for future developments in the scientific exploitation of Gaia asteroid data.

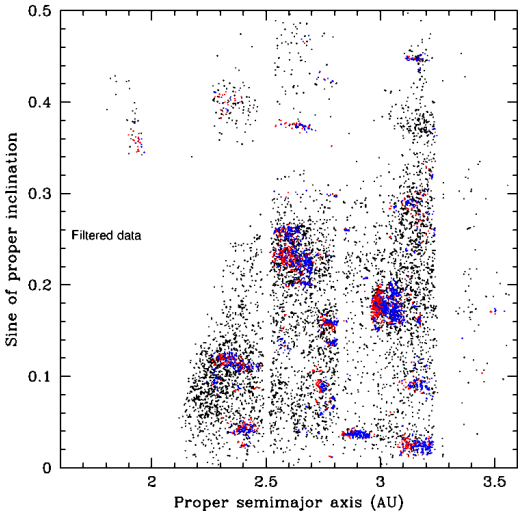
**Main achievements**

There are a couple of papers produced using input obtained during A. Cellino STSM in Nice on September 2022:

- ✓ “Gaia Data Release 3. The Solar System Survey.” Tanga, P. et al., A&A 674, A12, 2023
- ✓ “Gaia Data Release 3. Reflectance spectra of Solar System small bodies.” Gaia Collaboration, A&A 674, A35, 2023
- ✓ “Asteroid spin and shape properties from Gaia DR3 photometry.” Cellino et al. A&A submitted 2023




This plot shows the rotation frequency distribution for the sample of 8670 asteroids having at least 25 recorded transits in the Gaia FOV at the epoch of the 3rd release of Gaia data (GDR3), after removing low-quality data.




This plot shows a sin(orbital inclination) vs. semimajor axis for Main Belt asteroids, in which objects found to have prograde rotation are plotted in blue, and asteroids having retrograde rotation are shown in red. The clusters of objects correspond to asteroid dynamical families. The sense of rotation data has been computed based on analysis of GDR3 photometric data, after filtering out low-quality data.

The collaborations with the host continue regularly, in spite of the fact that A. Cellino is currently retired. He is still very active in the investigations carried out in the framework of the COST STSM.