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Asteroids observations from the ground and space: implications for our understanding of the main belt and of asteroid families

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1. Asteroid surveys

Telescopes on the ground, such as the Catalina Sky Survey (CSS) and Pan-STARRS [1] and in space (NEOWISE) [2] discover everyday new asteroids and track the orbits of the known ones. Their data are organised by Minor Planet Center (MPC), which provides quick and accurate access for those who query their databases to obtain the final products: orbits and asteroid ephemerides. Photometric information from these telescopes are also used to obtain basic properties, such as rotation periods, shapes, and the direction of the rotational poles [3].

However, the information in these *databases of orbits* does not tell us what an asteroid actually is, because they do not contain physical properties such as albedo, size, mass, composition, and shape. Values for these physical parameters are obtained from different groups, using different techniques and different telescopes from ground and space.

For insatnce WISE, AKARI, IRAS, MMX, and Spitzer space telescopes [2] have provided infrared observation in the thermal infrared on which our knowledge of sizes and albedos is nowadays based (totalling to more than 140,000 asteroids).

On the other hand to study the composition of asteroids, spectra of the solar light reflected by these bodies are acquired with several different ground based telescopes (IRTF, TNG, Magellan...), analysed and compared to the millions of laboratory spectra of minerals and meteorites (see e.g smass.mit.edu). Spectrophometirc data from the SDSS [4] is used for the faintest asteroids.

2 Connecting physics & dynamics

Massively obtaining published data of asteroids, combining the physical and dynamical properties is key to future asteroid science, as it has been demonstrated in the case of interpreting of the compositional gradient of the Main Belt in term of the different events that sculpted our Solar System, [5] and in the discovery of asteroid families [6, 7, 8, 9].

However, this massive data exploitation is a problem. Hundred thousand of values for several physical properties exist, but are spread in numerous literature works or in other archives throughout the world [10, 11, 12, 13, 14, 15, 16, 17], usually hosted by the relevant space telescope internet sites or by the institutes of the scientists who obtained the values or even in supplementary materials of scientific publications [9].

One answer to this problem is the attempt of the Observatoire de la Côte d'Azur to develop and hosts an online, publicly open tool, the *Minor Planet Physical Properties Catalogue (mp3c.oca.eu)* that stores and distribute massive asteroid data. MP3C is also part of the *Virtual Observatory*.

3 The structure of the Main Belt

What are the original asteroids – those that formed as planetesimals by direct accretion of dust and pebbles in the protoplanetary disk ? Which asteroids are instead those of new generations – members of families of fragments created by the catastrophic fragmentation of the original parents bodies ? We need to identify all these possible families and remove them from our view in order to understand what were the sizes and the composition of the planetesimals that formed our planets. In the past, families have been identified as many tight clusters of asteroids on closely related orbits; this identification was performed solely on the basis of the orbits of the asteroids [18]. But this family identification was very conservative. New methods [19] based on the combination of dynamical and physical properties are very promising as they revealed ancient [6] and

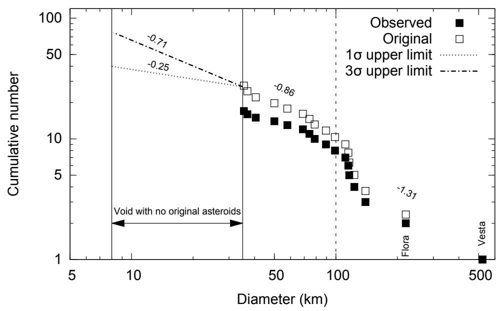

Figure 1: **Example of cumulative size distribution of original asteroids**. The cumulative size distribution of those asteroids that are outside families of the inner Main Belt (filled squares) is corrected for the maximum number of objects that were lost, due to the collisional and dynamical evolution, in order to obtain an upper limit for the distribution of the planetesimals (open squares). Functions of the form $N(>D) = N_0 D^{\beta}$, where N is the cumulative number of asteroids, are fitted piecewise in the size ranges $D >$ 100 km, $35 < D < 100$ km, and $8 < D < 35$ km. For the original planetesimals size distribution, we obtain the values of β reported by the labels in the plot. In the range of sizes between 8 and 35 km, we give the 1σ and the 3σ upper limits on the planetesimals size distribution. Adapted from [9]

primordial families [9], that, when removed, allowed us to identify the original planetesimals in a very restricted area of the Main Belt.

4 Future perspectives

ESA mission Gaia just released (DR2 on 25-04-18) the first milli-arcsec precise asteroid astrometry and in 2020 with the DR3 massive Gaia astrometry and spectroscopy will be released. The LSST first light in 2019 will provide an enourmous boost to asteroids physical characterisation, in particular for km-sized and smaller Main Belt objects: it will provide 5-band colour data, astrometry and photometry.

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