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Gaia's view of hydrated asteroids

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We analyze Gaia DR3 asteroid reflected light spectra in an attempt to detect the shallow absorption band around 0.7 μm, which is indicative of primitive aqueous alteration.

Gaia DR3 contains reflectance spectra for 60 518 asteroids (Gaia Collaboration et al., 2023). We analysed these spectra in an attempt to detect the feature around 0.7 μm which indicates that in the asteroid's parent body liquid water was present at some point (e.g. Fornasier et al., 2014). In combination with the asteroid orbital elements, an analysis of this feature can provide insights into where hydration (i.e. water) was present in the primitive solar system.

We used machine learning to identify asteroids with a 0.7 μm band. All Gaia DR3 reflectance spectra were used as input data. The normalized reflectance at the bluest wavelengths was corrected as described in Tinaut-Ruano et al. (2023). Literature classifications were collected for a sample of 1134 asteroids. The classifications were verified by JB and MB on the basis of spectra from the literature. This resulted in 315 C-type asteroids, of which 140 asteroids have the 0.7 μm band and in 139 the band is not present (the remaining C-types being dubious cases). Furthermore there are 569 S/X/Other type asteroids and 233 asteroids of unknown or doubtful taxonomic class. The asteroids with literature classifications were used to train a two-stage machine learning algorithm (scikit-learn's multilayer perceptron classifier[1]) which first separates C-type asteroids from the rest and then identifies asteroids with a 0.7 μm band from among the C-types. The observational uncertainties were accounted for by running the classification algorithm on multiple random realizations of the data (assuming Gaussian uncertainties). In both classification steps asteroids with mean class probabilities above 0.8 and a scatter in the probabilities of less than 0.1 were retained as C-type and hydrated asteroids, respectively. Some 2200 C-type asteroids were identified of which 230 feature the 0.7 μm band, $\sim$ 400 have no h-band, and the rest could not be confidently classified. Figure 1 shows the fraction of C-type asteroids with the 0.7 μm band as a function of proper semi-major axis and H-magnitude (Asteroid physical properties were obtained from https://mp3c.oca.eu/). The fractions are significantly lower than those found by Rivkin (2012), and should be seen as lower limits. No hydrated asteroids were identified for $a_p < 2.1$.

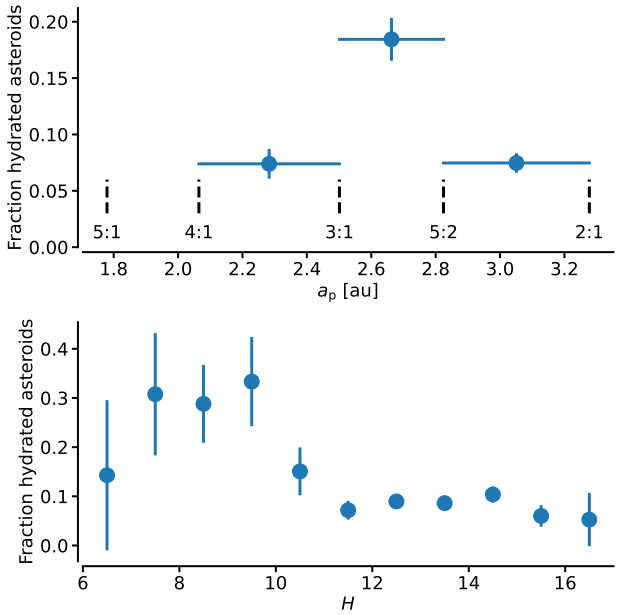

Figure 1. Hydrated asteroid fraction with respect to all C-types vs. semi-major axis (top) and H-magnitude (bottom). The fractions as a function of semi-major axis are for ranges in a_p in between the indicated mean motion resonances. The error bars refer to Poisson uncertainties.

[1] https://scikit-learn.org/stable/

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The results are still very preliminary. Future work will focus on improving the identification of asteroids with the 0.7 μm feature in their reflectance spectra and accounting for selection effects.

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