

Internal compositional structure of large primitive asteroids from spectrophotometry of asteroid families

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Introduction: An asteroid family is a group of asteroids with similar orbital proper elements (e.g., Nesvorný et al. 2005), which could be fragments formed by large impact events. The heating temperature in primordial bodies is important to form various mineralogies observed in asteroids and meteorites. Heating temperatures caused by ²⁶Al highly depend on the water-to-rock ratio (W/R) and accretion timing in the planetesimal. W/R can be a good indicator of the formation distance from the Sun. However, it should be noted that W/R can be changed by the differentiation process (Wakita et al. 2011, Kurokawa et al. 2021). The taxonomic composition of a family can be a witness to the internal structure of a primordial body, before disruption to become a collisional family. The near-ultraviolet wavelengths (NUV; 0.3-0.5 μm) and the 0.7-μm absorption band are sensitive to the presence of phyllosilicates (Feierberg et al. 1985, Vilas and Gaffey 1989). The presence or absence of the 0.7-μm band and the NUV absorption suggest a possible differentiation process.

Methods: In this study, in order to cover the NUV to visible wavelength range, using two spectrophotometric surveys, SDSS MOC4 (Ivezić et al. 2001) and ECAS (Zellner et al. 1985), for evaluation of the taxonomic configuration of family members. The asteroid family members were classified based on Tholen's taxonomy (Tholen 1984). Furthermore, the 0.7-μm band parameter (HYD) was evaluated as the slope change between the SDSS r-i filters to i-z filters.

Results and Discussions: Some of these families had been studied spectroscopically and the fraction of members with the 0.7-μm band can be obtained from the literature (Mothé-Diniz et al. 2005, Morate et al. 2016, 2018, 2019, De Prá et al. 2020). Families with negative HYD values have a majority of members with the 0.7-μm band absorption from the spectroscopic studies. Thus, we found that our HYD parameter is a good proxy for the presence of the 0.7-μm band, even though the SDSS filters are not optimized for characterizing the 0.7-μm band. Furthermore, a strong correlation (correlation coefficient of -0.69) exists between HYD and the NUV absorption, suggesting that the NUV absorption can be also used for evaluating the presence of Fe-bearing phyllosilicates. The NUV absorption strength decreases from G > C/B > F/CP > P > D classes, which is in good agreement with the percentage of objects showing 0.7-μm band found by Vilas (1994). Thus, G types might be dominated by Fe-bearing phyllosilicates in composition, while F types might be dominated by Fe-poor phyllosilicates. The figure shows the taxonomic compositions for primitive asteroid families that have more than 30 asteroid members.

- The B/C type asteroid families are mixture of presence and absence of the 0.7-μm bands and high and low NUV absorptions, suggesting a heterogeneous mixture of high and low W/R hydrated minerals. Since many of them are estimated as large parent bodies >200 km, this different W/R can be formed by the differentiation process.

- The G-type families are dominated by asteroids with the 0.7- μ m band and the deep NUV absorption, strongly suggesting the major presence of Fe-rich phyllosilicates. Noticeably, the Veritas family is composed of 80% G types. The primordial bodies of the G-type families could be formed in low W/R environments.
- The F-type families comprise more than 50% of F-type members, dominated possibly by Fe-poor phyllosilicates and magnetites. The F-type families show the most homogeneous distribution than other types. Especially, the Polana-Eulalia family comprises ~90% of F-type members. The primordial bodies of F-type families might be formed under high W/R conditions. Since they are relatively small (<100 km) and taxonomically homogeneous, they might not experience a strong differentiation process during aqueous alteration.

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