# The Themis-Beagle families: Investigation of space-weathering processes on primitive surfaces

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In the past 20 years, enormous progress has been reached in the study of space-weathering (SW) effects on silicates and silicate asteroids. The so-called ordinary chondrite paradox, that is, lack of asteroids similar to the ordinary chondrites, which represent 80 % of meteorite falls, has been solved. These meteorites are now clearly related to S-type asteroids, as proved also by the direct measurements of the NEAR and HAYABUSA missions on the near-Earth asteroids Eros and Itokawa. Spectral differences between S-type asteroids and ordinary chondrites are caused by space-weathering effects, which produce a darkening in the albedo, a reddening of the spectra, and diminish the silicate absorption bands on the asteroids surfaces, exposed to cosmic radiation and solar wind. On the other hand, our understanding of space-weathering effects on primitive asteroids is still poor. Only few laboratory experiments have been devoted to the investigation of SW effects on dark carbonaceous chondrites and on complex organic materials. Irradiation of transparent organic materials produces firstly redder and darker materials that upon further processing turn flatter-bluish and darker (Kanuchova et al. 2012; Moroz et al. 2004).

The Themis family is a natural laboratory to study primitive asteroids and space-weathering effects. The Themis family is located between 3.05 and 3.24 au, beyond the snow line, and it is composed of primitive asteroids. Themis is one of the most statistically reliable families in the asteroid belt. First discovered by Hirayama (1918), it has been identified as a family in all subsequent works, and it has 550 members as determined by Zappalà et al. (1995) and more than 4000 as determined by Nesvorny et al. (2010). The family formed probably about 2.3 Gyr ago as a result of a large-scale catastrophic disruption event of a parent asteroid 400 km in diameter colliding with a 190-km projectile (Marzari et al. 1995). Several Themis family members show absorption features associated to hydrated silicates, and, recently, water-ice and organics features have been detected on the surface of (24) Themis (Campins et al. 2010, Rivkin & Emery 2010). Hydrated silicates are produced by the aqueous-alteration process, which require low temperature ($< 320$ K) and the presence of liquid water in the past. The Themis family may be an important reservoir of water ice. Moreover, the main-belt comets 133P, 238P, and 176P seem to be related to the Themis family because of orbital proximities and spectral properties analogies. Within the old Themis family members, a young sub-family, Beagle, formed less than 10 Myr ago, has been identified. This sub-family has 65 members up to 2 km of diameter (Nesvorny et al. 2008). So, the Themis family is very important to shed light on the asteroid-comet continuum, to constrain the abundances of water ices in the outer part of the main belt, and to probe space-weathering effects on old Themis and young Beagle families' members. To investigate all these aspects, we carried out a spectroscopic survey in the visible and near-infrared range at the 3.6-m Italian telescope TNG (La Palma, Spain) during 6 nights in February and December 2012. We got new spectra of 8 Beagle and 22 Themis members using the DOLORES (with the LR-R and LR-B grisms) and the NICS (with the Amici prism) instruments. To look for possible coma around the targets, we also performed deep imaging in the R filter.

Data are currently under analysis, and the results will be presented at the ACM meeting. None of the investigated spectra show water-ice absorption features at 1.5 and 2 microns, while few Themis members have visible absorption bands associated with hydrated silicates. The best meteoritic analogues to both Themis and Beagle members are the carbonaceous chondrites, especially CM2. The spectra of Beagle and Themis asteroids show significant differences: 'old' Themis members exhibit a wide range of spectra, including asteroids with blue/neutral and moderately red spectra (relative to the Sun), while the young Beagle members investigated are bluer and brighter than the Themis ones. These preliminary results seem to indicate that the SW effects on primitive asteroids are similar to those observed on silicate asteroids, that is, they produce reddening of the spectra and moderate darkening of the surface.

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**References:** Kanuchova et al. 2012, Icarus 221, 12; Moroz et al. 2004, Icarus 170, 214; Marzari et al. 1995, Icarus 113, 168; Nesvorny et al. 2008, AJ 679, 143; Nesvorny et al. 2010, EAR-A-VARGBDET-5-NESVORNYFAM-V1.0. NASA Planetary Data System; Hirayama 1918, AJ 31, 185; Zappala' et al. 1995, Icarus 116, 29; Campins et al. 2010, Nature 464, 320; Rivkin & Emery, 2010, Nature 464, 1322.