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The Themis-Beagle families: clues into space weathering processes on primitive asteroids

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Abstract

The Themis family is a natural laboratory to study the asteroids-comets continuum and space weathering effects. Recently water ice and organics were detected on 24 Themis indicating that the Themis family may be an important reservoir of ice. Moreover, some main belt comets may be related with 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. Thus 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.

1. Introduction

Themis is one of the most statistically reliable family in the asteroid belt. First discovered by Hirayama (1918), it has been identified as a family in all subsequent works, and has 550 members as determined by Zappalà et al. [1]. The Themis family is characterized by asteroids with $3.05 \leq a \leq 3.22$ AU, $0.12 \leq e \leq 0.19$, and $0.7^o \leq i \leq 2.22^o$ [2] and spectrally dominated by primitive C- and B-type asteroids, as reported by spectroscopic investigation in the visible range of some members [3,4]. The family formed probably $\sim$ 2.3 Gyr ago as a result of a large-scale catastrophic disruption event of a parent asteroid $\sim$ 400 km in diameter colliding with a 190 km projectile [5]. Interestingly, recent observations by Rivkin and Emery [6] and Campins et al. [7] found spectroscopic evidence of the presence of water ice and organics on the surface of asteroid Themis. Analyzing the infrared spectrum of the asteroid, Rivkin and Emery [6] concluded that the surface of Themis contains very fine water frost, probably in the form of surface grain coatings, and that the infrared spectral signatures can be fully explained by a mixture of spectrally neutral material, water ice, and organics. Contemporaneously, Campins et al. [7] derived that water ice is evenly distributed over the entire Themis surface using spectra obtained at four different rotational phases. Nevertheless the nature of the 3.1 μm feature on 24 Themis is still a matter of debate, and very recently Beck et al. [8] proposed the hydrated iron oxide goethite as alternative interpretation of this feature. However, Jewitt & Guilbert-Lepoutre [9] stress that goethite, when found in meteorites, is a product of aqueous alteration in the terrestrial environment and that extraterrestrial goethite in freshly fallen meteorites is unknown.

The discovery of the presence of water ice and/or hydrated minerals such goethite on 24 Themis indicates that Themis family may be an important reservoir of ice and that possibly ice may exists in the members of the family. Indeed, absorption band in the visible region related to hydrated silicates have been detected on the surface of 15 Themis family members [4]. These materials are produced by the aqueous alteration process, that is a low temperature (< 320 K) chemical alteration of materials by liquid water [10]. The presence of hydrated minerals implies that liquid water was once present on these asteroids, and suggest that post-formation heating took place. Furthermore the Themis family seems to be the source of the main belt comets (MBC) 133P, 238P, 176P, and P/2006 VW139. Nesvorny et al. [11] propose that 133P could potentially be one member of the younger (< 10 Myr) Beagle sub-family of the Themis group. This subfamily has 65 members up to 2 km of diameter.

2. Results

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

R filter.

All the objects investigated belong to the C or B types. None of the investigated spectra show water ice absorption features at 1.5 and 2 micron, but five Themis members have visible absorption bands associated with hydrated silicates and thus they have experienced the aqueous alteration process in the past.
Spectra of the Themis family members show a range of spectral slope much wider than the Beagle members: '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 than the Themis one. The analysis of the spectral slope versus the albedo of the objects, derived from the WISE data, indicates that the young Beagle members are also brighter than most of the old Themis members.
To explain these differences, we propose two possible scenarios: a) The Themis/Beagle family parent body was heterogeneous in composition, and the diversity we see nowdays reflects different source regions in the parent body; b) the family parent body was homogeneous and the spectral variability we see is related to space weathering effects. In the second scenario, our observations imply that on the Themis/Beagle primitive asteroids the space weathering processes acts in a similar way than in silicate rich asteroids, producing a reddening of the spectra and a darkening of the albedo. The analysis of our observations will be presented, and compared to the results of recent laboratory experiments on irradiation of carbonaceous chondrite meteorites.

Acknowledgements

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