INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: C**

Period AOT39 (April 2019 – September 2019) **Submit using: www.tng.iac.es/submit.html**

1. Title

Spectroscopic survey of Merxia and Agnia family, a closer look to early differentiation in the Solar System

2. Abstract

Dynamical asteroid families resulting from catastrophic disruptions offer an unprecedented tool to investigate the interiors of their former parent bodies. The classic differentiation model from a chondritic parent body is expected to form an object with a metal core, a olivine-rich mantle, and a basaltic crust. However, most asteroid families tend to show similar spectra among the members. At the same time spectra of metal-like materials and olivine-dominated assemblages have not been so common in asteroid families in the Main Belt and the expected mantle material is missing from both meteorite records and asteroid surveys. Up to now, the Vesta family has been identified as the only one in the main belt coming from a large differentiated body, with evidence of a thick basaltic crust, a homogeneous family and two large basin in the south pole. It has been suggested that several large differentiated bodies has been "battered to bits". We propose to obtain visible spectra of asteroids within the Merxia and Agnia S-type families, two poorly investigated families that has been connected with extensive differentiation, to search for compositional variations that are indicators of differentiation.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
9						

3b. Observing modes

TNG:	x	Visitor	x	Service		ToO
REM:		Rapid Response		Queuing		ToO

4a. Preferred months

first choice: April second choice:

4b. Other scheduling constraints (use also box 14)

The month for observations was chosen in order to maximize the number of bright targets already observed in the near-infrared range.

5a. Past and future of the project

a) Hours already awarded to the project: 18

b) Hours foreseen to complete the project: 9
(not including this request)

6. Principal investigator

Name Simone Ieva

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7. Co-investigators (name and institution)

E. Dotto, INAF - OAR, Italy
E. Mazzotta Epifani, INAF - OAR, Italy
D. Perna, INAF - OAR, Italy
E. Perozzi, ASI, Italy
M. Micheli, ESA NEOCC

8. Status of the project

Telescope	Instrument	Date	Hours	Notes
TNG	DOLORES + NICS	12/11/2018-13/11/2018	9+9	Visible observations with DOLORES were not performed due to bad weather conditions.

Description

Near-infrared spectra for 13 objects belonging to the Merxia and Agnia family were acquired during the only night of observations performed during AOT38. Since the acquisition of visible spectra is fundamental to constrain the mineralogy of these bodies we ask for a night in April 2019 to characterize in the visible range some of the targets already observed in the near-infrared during AOT38. The remaining targets will be observed during a night in AOT40, ideally close to January 2020.

Publications

Once obtained the spectral coverage for both the visible and the near-infrared part, necessary to a proper taxonomic classification, a publication will be foreseen.

9a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

9b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

10. Description of the programme (max. 3 pages, including references, tables, and figures.)

A) Scientific rationale Asteroid families are the remnants of catastrophic collisions between asteroids and represent the most striking evidence of the collisional evolution of the asteroid belt since its formation. Their analysis not only provides important clues about how this evolution happened but also about the long term dynamics of asteroid orbits. From the physical properties (like size distribution, albedo and reflectance spectrum) of the asteroids belonging to families it has been possible to estimate certain parameters, like the age of the families (Marzari et al. 1996, 1999) and the size of the parent bodies (Tanga et al. 1999) that originated them. Due to their formation processes, asteroid families provide us with the opportunity to probe the interiors of the former parent bodies. Differentiation of a large initially chondritic parent body is expected to result in an ''onion shell" object with an iron-nickel core, a thick olivine-dominated mantle, and a thin plagioclase/pyroxene crust (Gaffey et al. 2002). Spectroscopic studies have observed a paucity of metal-like materials and olivine-dominated assemblages within Main Belt asteroid families.The deficit of olivine-rich mantle material in the meteorite record and in asteroid observations is known as the ''missing olivine" problem (Sanchez et al. 2014, Popescu et al. 2018).

Up to now, the only family connected to a differentiated parent body has been the Vesta family. It is assumed that this family originated from an impact crater excavated on the basaltic surface of Asteroid 4 Vesta (Thomas et al. 1997). Such basaltic crust indicates that 4 Vesta must be a differentiated body indeed, the only one identified up to now (McCord et al. 1970). However, most of the members of the Vesta family with known spectra are basaltic V-type objects (see Ieva et al. 2016 for a review) and there is no single evidence about the presence of olivine rich members that should come from the mantle of the parent body (Burbine et al. 2000). Surprisingly, the only olivine deposits found on Vesta has been found in the northern hemisphere, far away from the two giant south pole basins where they were expected (Ammannito et al. 2013).

The lack of other large bodies with a basaltic crust has led to the idea that other differentiated parent bodies were "battered to bits" very early in the Solar System and the olivine-rich material was collisionally broken down over time. However, several asteroid families have been connected with differentiation processes: Eunomia (Reed et al. 1997, Nathues et al. 2005), Eos (Mothé-Diniz et al. 2008, Huaman et al. 2014), Merxia and Agnia (Sunshine et al. 2004).

The most promising cases of asteroid families linked to a differentiated body are represented by Merxia and Agnia: these two families, located in the middle main belt, are predominantly composed by S-type bodies. However, Sunshine et al. (2004) have established that these bodies are best explained as mixtures of high-calcium pyroxene (HCP), low-calcium pyroxene (LCP) and plagioclase, with relative amount of olivine (less than 20%). The high HCP/ (HCP + LCP) found require relatively extensive differentiation of these asteroids and/or their primordial parent body. This is comparable with the degree of melting that produces the eucrites, a group of meteorites connected to Vesta, suggesting a similar thermal and geological history for these asteroids and their parent body and the eucrites and Vesta.

The analysis of reflectance spectra is currently the main tool to assess the surface mineralogy of asteroids. A direct interpretation of asteroid mineralogy based on reflectance spectra is only possible if mineralogically diagnostic features are present in the spectrum, which ideally must have a high signal-to-noise ratio and spectral coverage extending from the visible to the near infrared. This kind of analysis may provide us with information about asteroid interiors, geological differentiation of asteroids, space weathering, and other physical processes that may modify the mineralogical properties of asteroids along their life. Unfortunately, only a few members of the Merxia and Agnia family have been spectroscopically characterized up to now in the Vis-NIR range (see Fig. 1), resulting in a prevalent S-complex taxonomy.

B) Scientific aim Here we propose to perform a visible spectroscopic survey of the Merxia and Agnia family members already observed during AOT38 in the NIR range, in order to investigate the idea that these two parent bodies have experienced extensive differentiation. If the prevailing S-complex composition of the family members should be confirmed by our observations, this could imply that both Agnia and Merxia represent secondary families from the breakup of the original basaltic fragment. Another possibility is also that these asteroids have experienced an impact history that has homogenized their surfaces, as suggested by Michel et al. (2001). However, if we should find more thermally evolved asteroids among their family members (i.e. A- and V-type, representatives of the olivine mantle and the basaltic crust, respectively) we could confirm the presence of another differentiated family not connected to Vesta, due to its location in the main belt. Dynamical simulations has shown that the probability for an asteroid to evolve from the Vesta family and cross over the 3:1 resonance, reaching a stable orbit at the current location of Merxia and Agnia, is almost 1% (Roig et al. 2008, Brasil et al. 2017, see Fig. 2).

The presence of other differentiated families could alter our vision on the frequency of these processes in the early Solar System. Differentiation was most likely driven by the presence of ^{26}Al and ^{60}Fe, two radioactive isotopes. Bottke et al. (2006), based on the ^{26}Al and ^{60}Fe half-life period and their original location in the solar nebula, theorized that early differentiation could have been occurred only in the inner main belt ($a < 2$ au). The proof of the existence of another basaltic parent body beyond the 3:1 resonance, located at 2.5 au, could alter the current paradigma of differentiation processes, implying that the extension of the temperature gradient in the protosolar nebula at the epoch of planetary formation was different than always thought, in order to reach the right amount of heat able to sustain differentiation at solar distances $a > 2.5$ au.

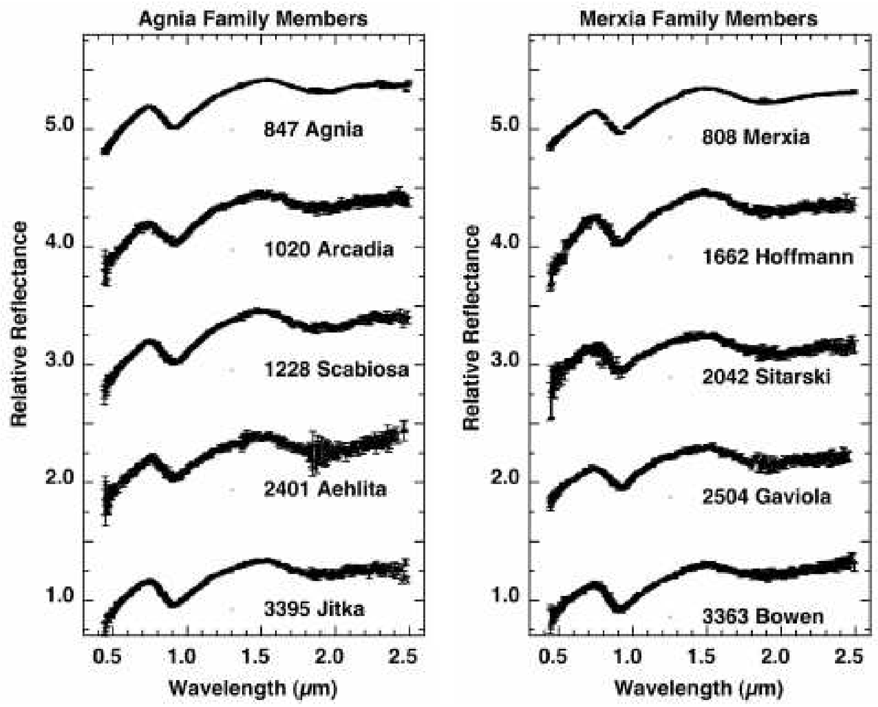

Figure 1: Visible and near-infrared spectra of Agnia and Merxia family members to date. From Sunshine et al. (2004). Note the spectral similarity within and between these two families.

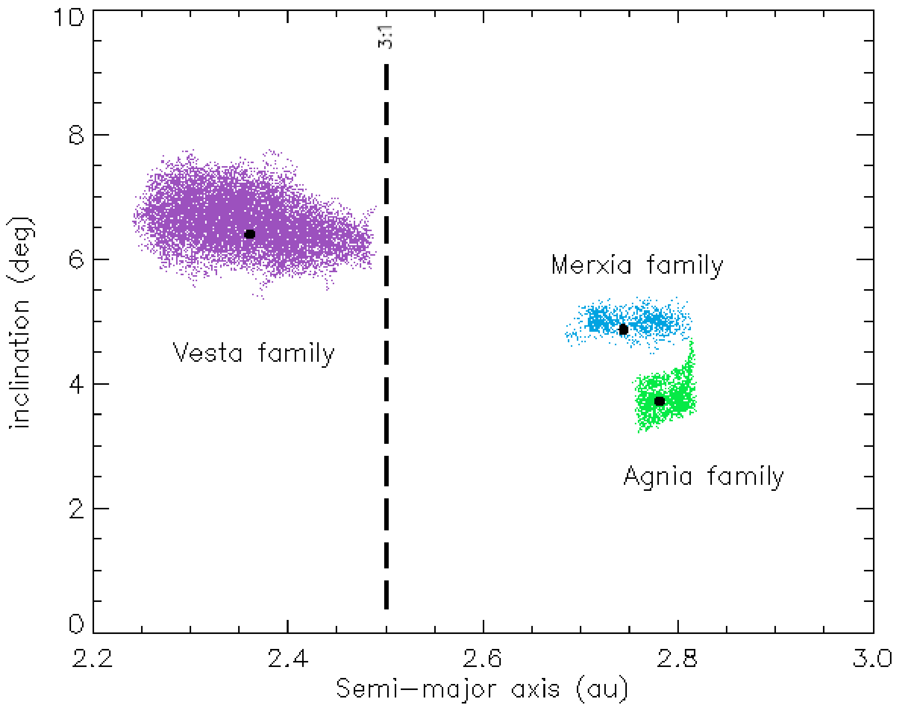

Figure 2: Proper semi-major axis vs inclination for the Vesta, Merxia and Agnya family. Also plotted is the 3:1 mean motion resonance with Jupiter. Dynamical simulations has shown that the probability that an object from the Vesta family cross it and reach a stable orbit beyond 2.5 au is below 1%. The confirmation of their differentiation will therefore establish a second differentiated family in the Solar system, challenging our current models of early differentiation.

References:

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Thomas, P. C., Binzel, R. P., Gaffey, M. J. et al. 1997, Science, 277, 1492

11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
(13723)	11 54 33.7	-03 14 30	J2000	V 18.7	20'	Merxia family
(14169)	14 48 55.0	-11 54 27	J2000	V 18.8	20'	Merxia family
(21575)	12 28 19.5	+07 51 24	J2000	V 16.8	10'	Merxia family
(21981)	08 32 55.9	+26 23 14	J2000	V 18.1	15'	Merxia family
(25118)	13 47 19.4	-04 21 15	J2000	V 18.7	20'	Merxia family
(25775)	13 10 31.1	-02 32 54	J2000	V 18.2	15'	Merxia family
(41339)	14 00 09.1	-03 57 47	J2000	V 18.7	20'	Merxia family
(3491)	09 58 26.0	+12 28 26	J2000	V 17	10'	Agnia family
(4496)	16 58 29.0	-16 42 22	J2000	V 17.9	15'	Agnia family
(6077)	06 32 30.6	+27 33 58	J2000	V 18.3	20'	Agnia family
(7728)	06 45 58.1	+25 32 46	J2000	V 18.3	20'	Agnia family
(9471)	08 14 23.5	+19 14 27	J2000	V 18.4	20'	Agnia family
(12906)	09 21 46.1	+15 33 09	J2000	V 18.3	20'	Agnia family
(23171)	17 37 55.4	-19 29 10	J2000	V 18.3	20'	Agnia family
(23876)	10 49 45.9	+15 07 44	J2000	V 17.5	15'	Agnia family
(24864)	11 50 16.9	+00 55 21	J2000	V 18.3	20'	Agnia family

12. Observational strategy and justification of requested time, including overheads.

To compile the above list we took all the asteroids belonging to the Merxia and Agnia families, and we selected the ones with a $m_V < 19$ during April 2019. Ephemerids are computed for Apr 5, 2019 The list here proposed is tentative, since the final targets would be selected according to the day chosen for the observations eventually assigned.
We would perform visible observation with DOLORES. Based on our previous experience of observation and reduction, a S/N of at least 30 is necessary to properly characterize the diagnostic features and combine the visible range with the near-infrared part obtained with NICS. With a seeing of 1.2", slit of 2" we expect to reach

- a S/N $\sim$ 30 for $m_V = 19$ with an integration time of about 20 min.
- a S/N $\sim$ 50 for $m_V = 18$ with an integration time of about 15 min.
- a S/N $\sim$ 75 for $m_V = 17$ with an integration time of about 10 min.

To remove the contribution of a strong fringing that it is intrinsically present after 0.8-0.85 μm when using the LR-R grism, for each target we will acquire at least three spectra in different positions.
Counting the pointing, overhead time and the acquisition of at least 6 solar analogues we ask for a total amount of 9 hours. The combination of visible spectra taken with DOLORES and near-infrared spectra already taken with NICS during AOT38 is required to reach the proper wavelength coverage in the 0.4-2.5 μm, so to obtain the mineralogical diagnostic features needed to confirm or reject the family differentiation.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	Dolores	1x1	none	2.0	LR-B	4.5hr	
2	Dolores	1x1	none	2.0	LR-R	4.5hr	

14a. Moonlight constraints

Max. # of days from new moon $\boxed{7}$

14b. Scheduling constraints, special requirements and other remarks
(please include justification of constraints in 14a)

In order to maximize the number of bright asteroids, we prefer to observe our targets in April 2019. We do not have any preference between visitor and service mode, although the visitor mode has the intrinsic advantage to allow us to adjust in real time the observational strategy.

15. Observational background of the applicants

Name of the observer(s) at TNG: Simone Ieva

Experience of the observer(s) with the requested TNG instrument(s)
Data acquired at TNG by the proposers were recently published in:

- Mazzotta Epifani, E., Perna, D., Dotto, E., Palumbo, P., Dall'Ora, M., Micheli, M., Ieva, S. et al. ''Nucleus of the active Centaur C/2011 P2 (PANSTARRS)" 2017, A&A, 597, 59
- Perna, D., Hromakina, T., Merlin, F., Ieva, S. et al. ''The very homogeneous surface of the dwarf planet Makemake" 2017, MNRAS, 466, 3594
- Hromakina, T., Perna, D., Belskaya, I., Dotto, E. et al. ''Photometric observations of nine Transneptunian objects and Centaurs" 2018, MNRAS, 474, 2536
- Perna, D., Bott, N., Hromakina, T., Mazzotta Epifani, E., Dotto, D. et al. ''Rotationally resolved spectroscopy of Jupiter Trojans (624) Hektor and (911) Agamemnon" 2018, MNRAS, 475, 974
- Ieva, S., Dotto, E., Mazzotta Epifani, E., et al. "Photometry of 67 Near-Earth Objects" 2018, A&A, 615, A127.
- Ieva, S., Dotto, E., Lazzaro, D., Fulvio, D., Perna, D., Mazzotta Epifani, E. et al. ''Basaltic material in the main belt: a tale of two (or more) parent bodies?" 2018, MNRAS, 479, 2607
- Mazzotta Epifani, E., Dotto, E., Ieva, S. et al. "2013 UL10: the first active red centaur", accepted in A&A

Experience of the observer(s) with other telescopes/instruments
The proposers have a proven experience in observations of Solar System small bodies, with several telescopes (mainly ESO-VLT, ESO-NTT, NOT, CAHA and LBT) and in their data reduction and analysis. The data will be reduced using the MIDAS and IDL packages.