Primitive Material in the Solar System
Physical Characterization of Small Bodies
in the TNG era

Elisabetta Dotto (INAF-OAR)

Elena Mazzotta Epifani (INAF-OAR), Simone Ieva (INAF-OAR),
Davide Perna (Obs. Paris, INAF-OAR)

INAF Osservatorio Astronomico di Roma

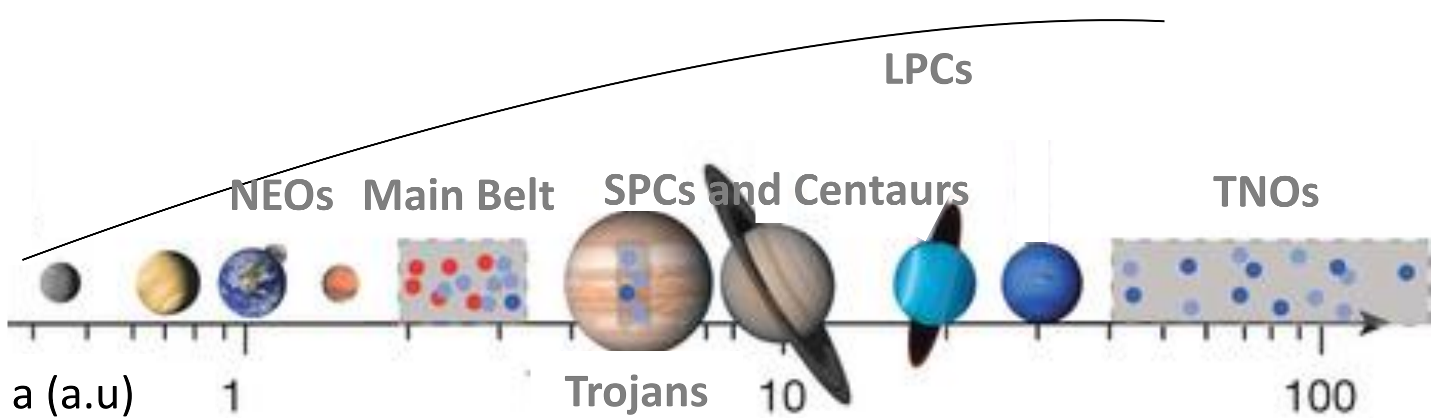
1-3 March - Padova

10-years of Observations

V+NIS photometry and spectroscopy (Dolores+NICS/Amici)

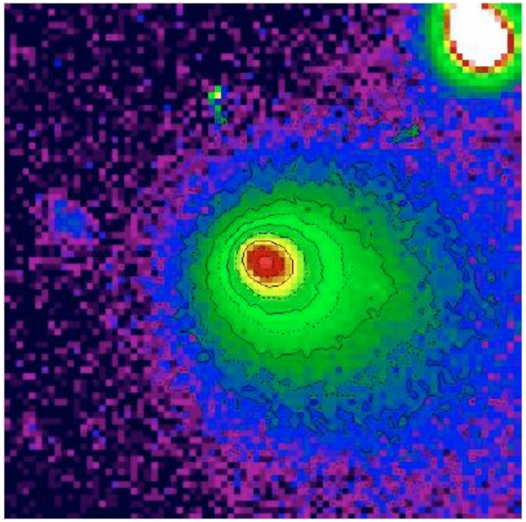
- Long Period Comets
- Trans-Neptunian Objects
- Short Period Comets
- Centaurs (active & no-active)
- Jupiter Trojans
- Main belt asteroids – Asteroid targets of space missions
- NEOs

~ 35 papers: observations, interpretation, models, “big picture”

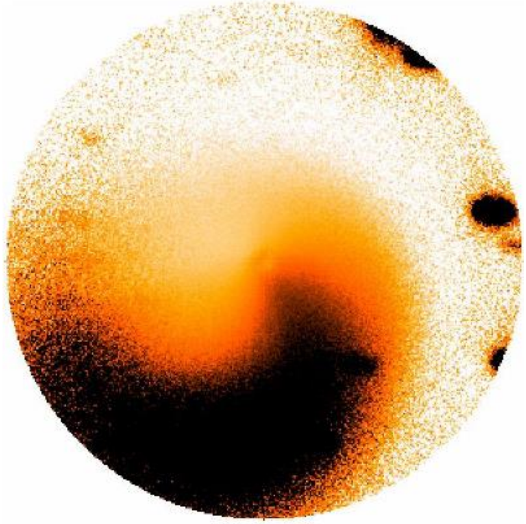


The activity of the Long Period Comets (EME10, EME14, EME16)

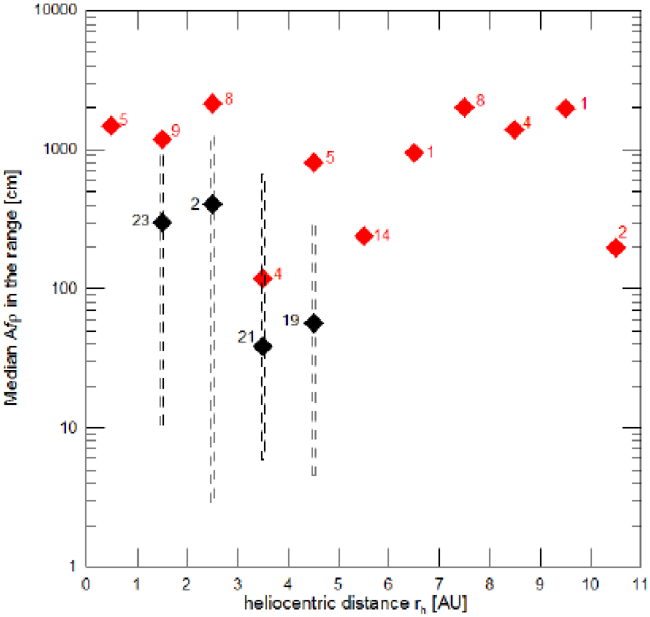
A program (18h) to investigate the differences of activity levels for Long Period Comets (LPCs), in particular for Oort Cloud Comets, wrt older comets, in order to obtain further constraints on evolutionary differences resulting from distinct dynamical histories.



C/2007 D1 (LINEAR) @ 10 au



Complex coma morphology of C/2005 L3 (McNaught) @ 7 au



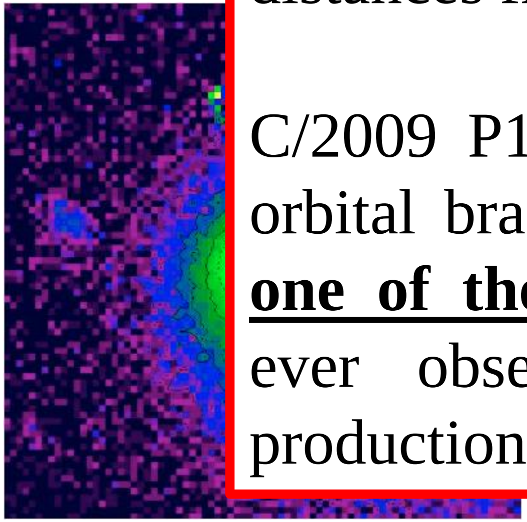
Activity level for SPCs and LPCs

The activity of the Long Period Comets (EME10, EME14, EME16)

A program (18h) to investigate the differences of activity levels for Long Period Comets (LPCs), in particular for Oort Cloud Comets, wrt older comets, in order to obtain further constraints on evolutionary differences resulting from distinct dynamical histories.

"New" comets are intrinsically more active at large distances from the Sun than the periodic ("old") ones.

C/2009 P1 (Garradd) was observed along its inbound orbital branch until its perihelion and was detected as **<u>one of the most active and "dust producer"</u>** LPCs ever observed, with repeated outbursts in water production.



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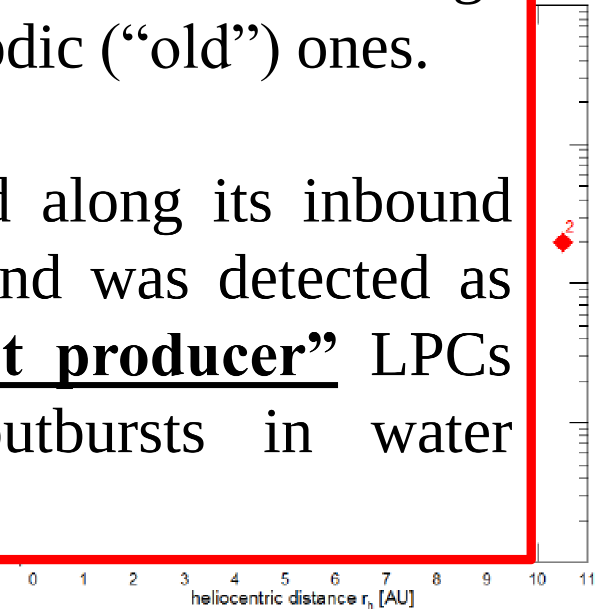

Activity level for SPCs and LPCs

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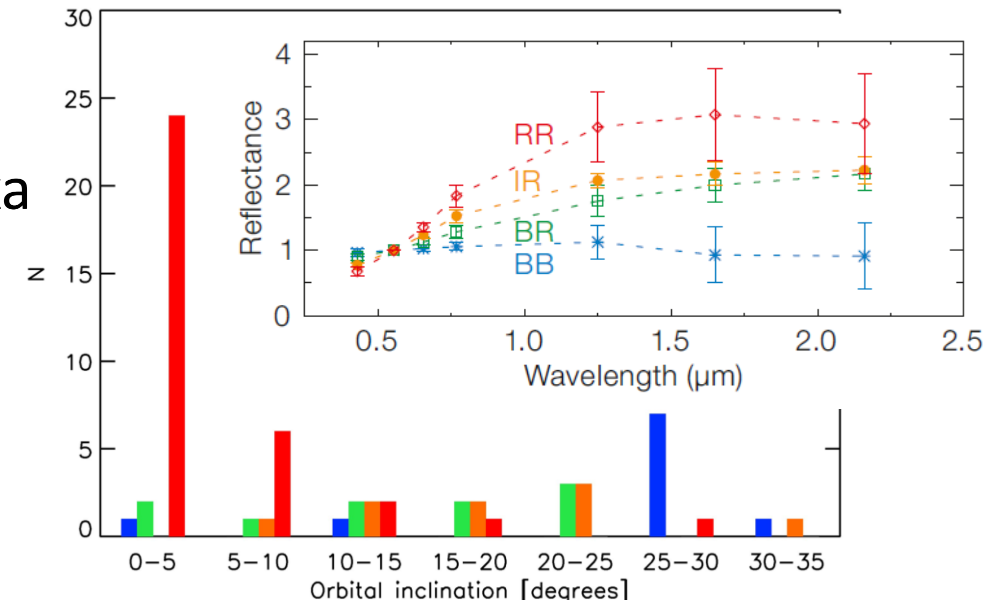
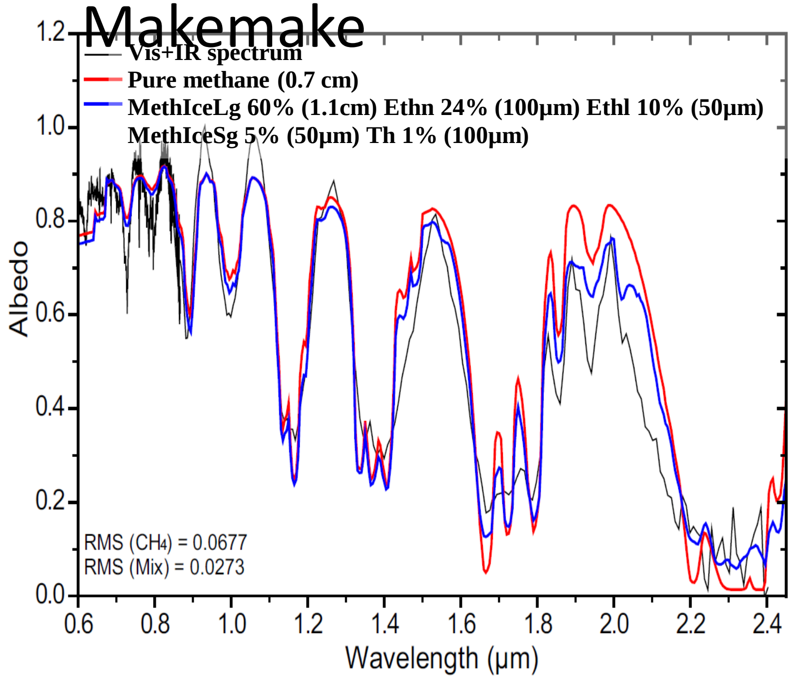
TNOs: photometry and spectroscopy (DP13, DP17)

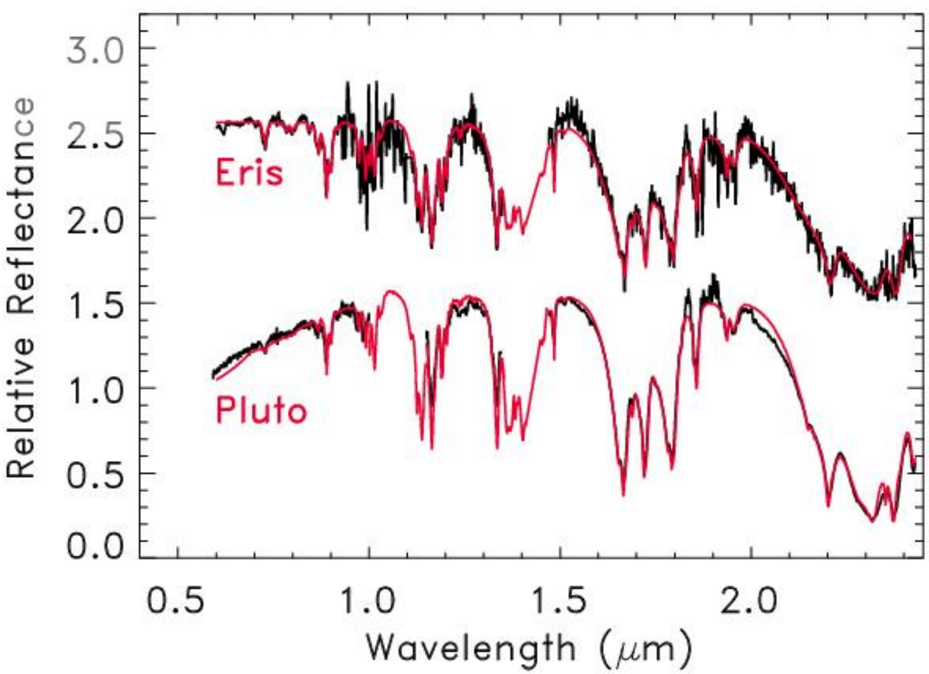
Photometry: color indices – taxa

Hershel program (EV12, TLL10, EL10, TGM10, TGM09)



Spectroscopy: composition of Makemake

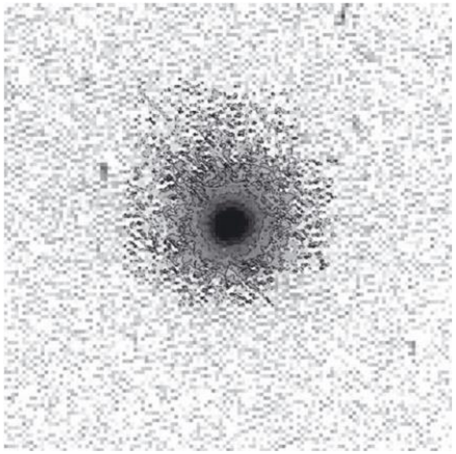




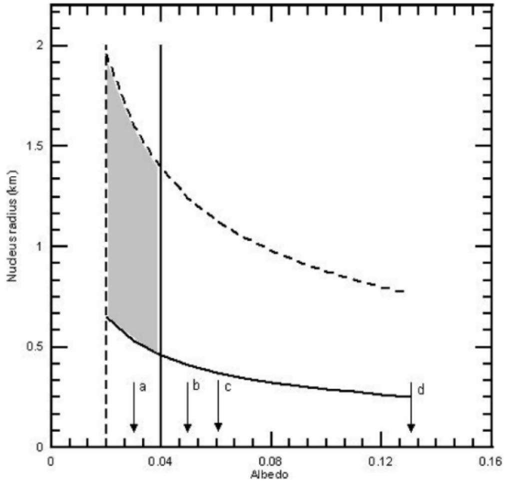
The distant activity of the Short Period Comets (SPCs)

(EME07, EME08, EME09)

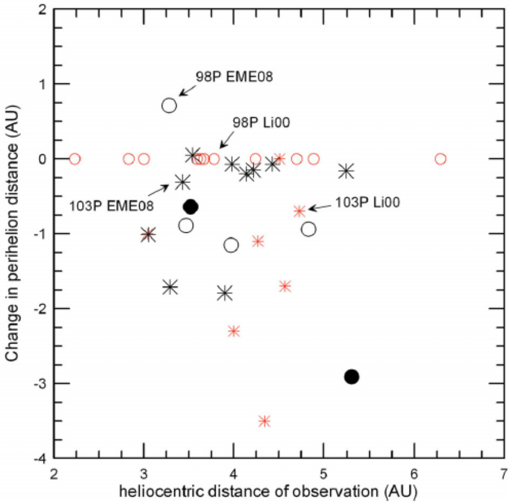
A program (27h) to investigate the complexity of the transition between bare nucleus and the presence of a well-developed coma in SPCs, to compare activity levels and to obtain information concerning evolutionary differences resulting from distinct dynamical histories.



103P/Hartley 2 @ TNG (DOLORES)



«radius curve» for 111P/H-R-C



distant activity vs recent dynamical history

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The distant activity of the Short Period Comets (SPCs)

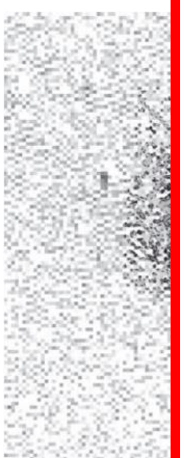
(EME07, EME08, EME09)

A program (27h) to investigate the complexity of the transition betwee... na in SPCs, ... ation concer... nical histori...

SPCs resulted more likely to be active post-perihelion than pre-perihelion.

There is a weak trend of comets with increasing perihelion distance to be more likely active at large heliocentric distance.

The hypothesis of distant activity 'induced' by higher temperature owing to perihelion lowering cannot be unequivocally invoked for SPCs.



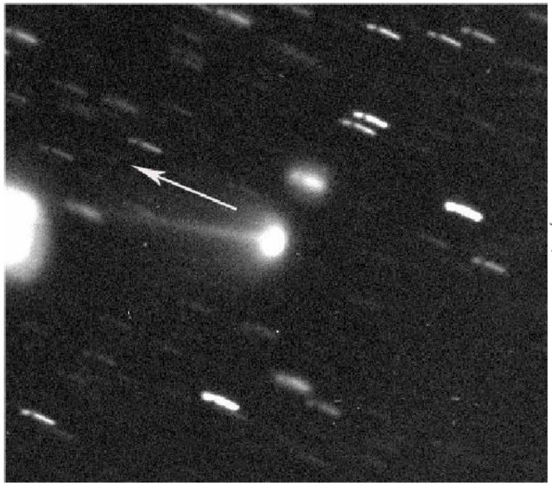
103P/Hartley

distant activity vs recent dynamical history

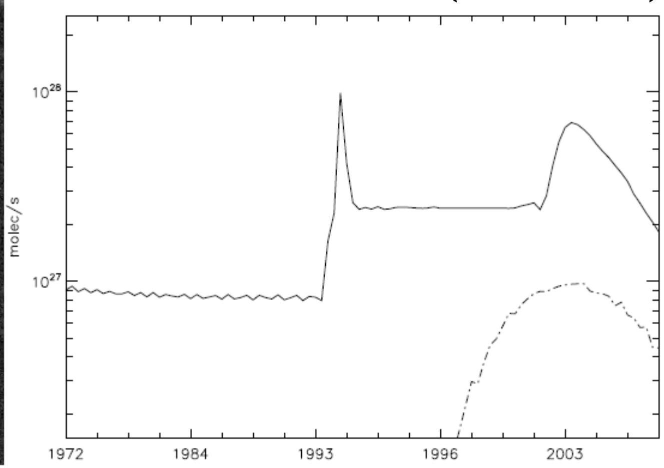
The active Centaurs (I) (EME06, MTC09, EME11)

A program (13h) to study the comet-like environment of single active Centaurs, a very scarcely populated subgroup of the Centaur class

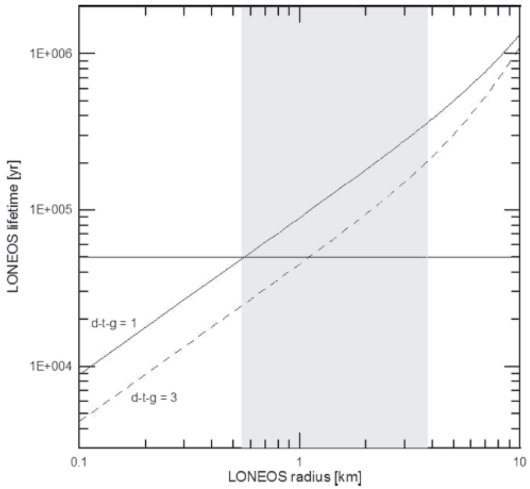
Centaur P/2004 A1 (LONEOS)



P/2004 A1 @ 5.5 au



modeled CO and CO_2 gas fluxes



nucleus region derived from modelled lifetime

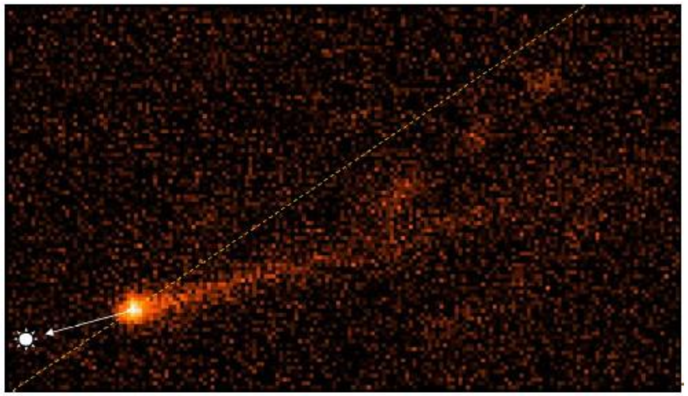
Centaur P/2004 A1 (LONEOS) has revealed as a CO-driven comet-like environment, able to release large (above 1-10 cm) particles and significantly contributing to the replenishment of the interplanetary dust complex in the region among the gas giants.

Its nucleus has been modelled together with its recent dynamical history (close encounter with Saturn that injected it in a closer orbit); its nucleus size (1-3 km) is closer to the average SPC than to the average Centaur.

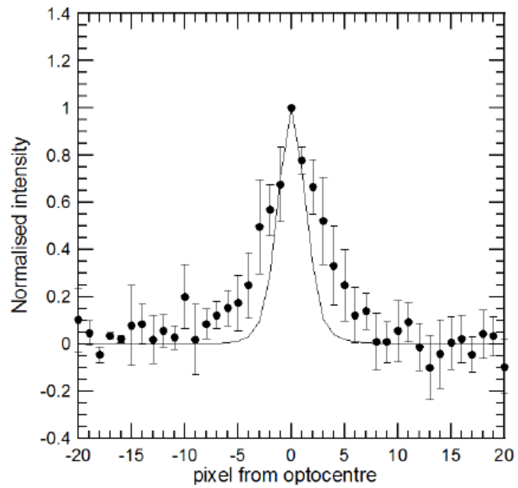
The active Centaurs (II) (EME14, EME17)

A program (12h) to study the comet-like environment of single active Centaurs, a very scarcely populated subgroup of the Centaur class

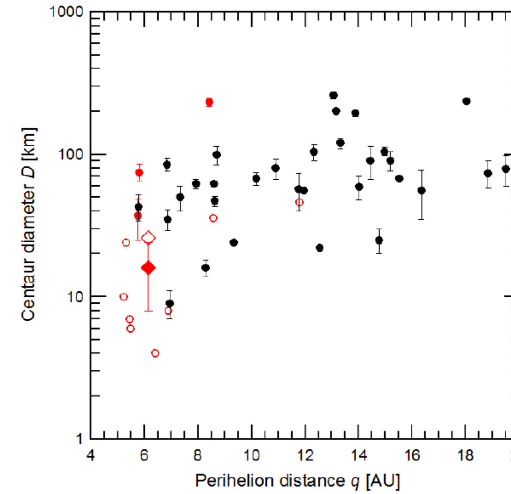
Centaurs P/2010 C1 (Scotti) and C/2011 P2 (PANSTARRS)



P/2010 C1 @ 5 au



Very weak activity detected for C/2011 P2 @ 9 au



Diameter of active and inactive Centaurs

Centaurs P/2010 C1 (Scotti) revealed as the «quintessentially» transitional object: a small (r ~ 4 km), weakly emitter (Q_d ~ 1-10 kg/s) Centaur, recently injected on its orbit in the inner region, evolving towards its SPC status.

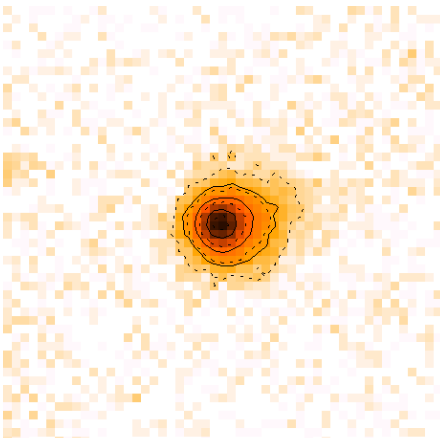
Centaur C/2011 P2 (PANSTARRS) revealed unexpectedly active @ 9 a.u. (Q_d ~ 4 – 40 kg/s).

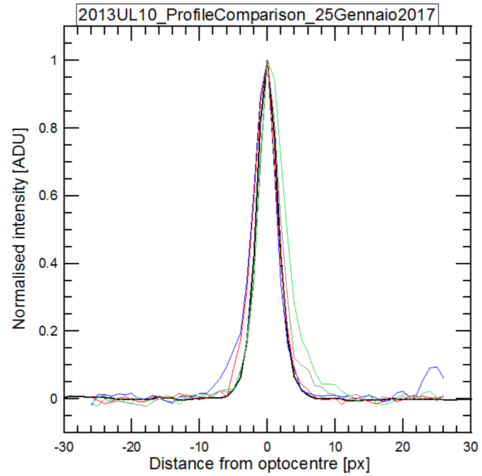
Despite the still few data available, two general trends seem to emerge for the still immature general picture: Centaurs with smaller q tend to be smaller than those which remain farther from the Sun during their orbital path, and active Centaurs tend to be smaller than inactive ones.

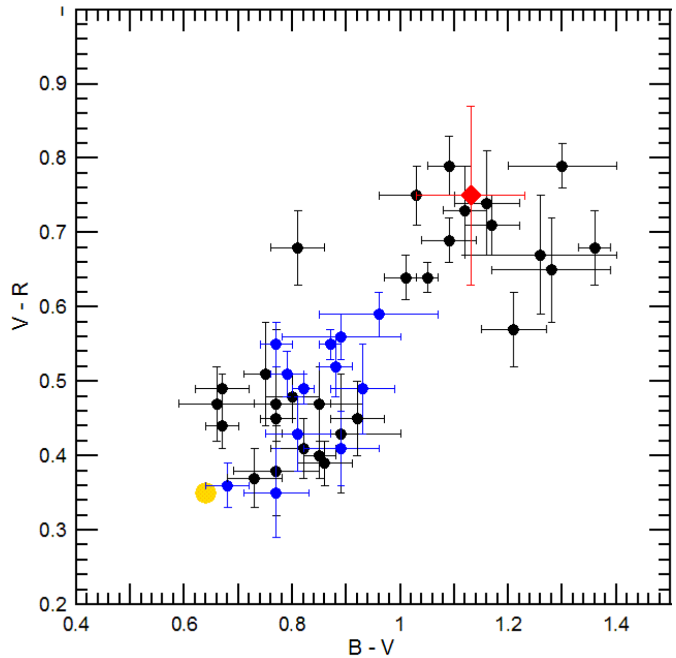
The Centaurs: any hidden activity out there?

A pilot program (analysis presently ongoing) to start a systematic color survey of inactive Centaurs, preferentially orbiting in the potential activity region, in order to obtain a taxonomic classification, more detailed characterization of surface properties (colours, dust activity…), and a more reliable study of the correlations with orbital parameters

6h + 25h observing time (+ more time at CAHA telescopes)
1 paper submitted + 2 papers in preparations

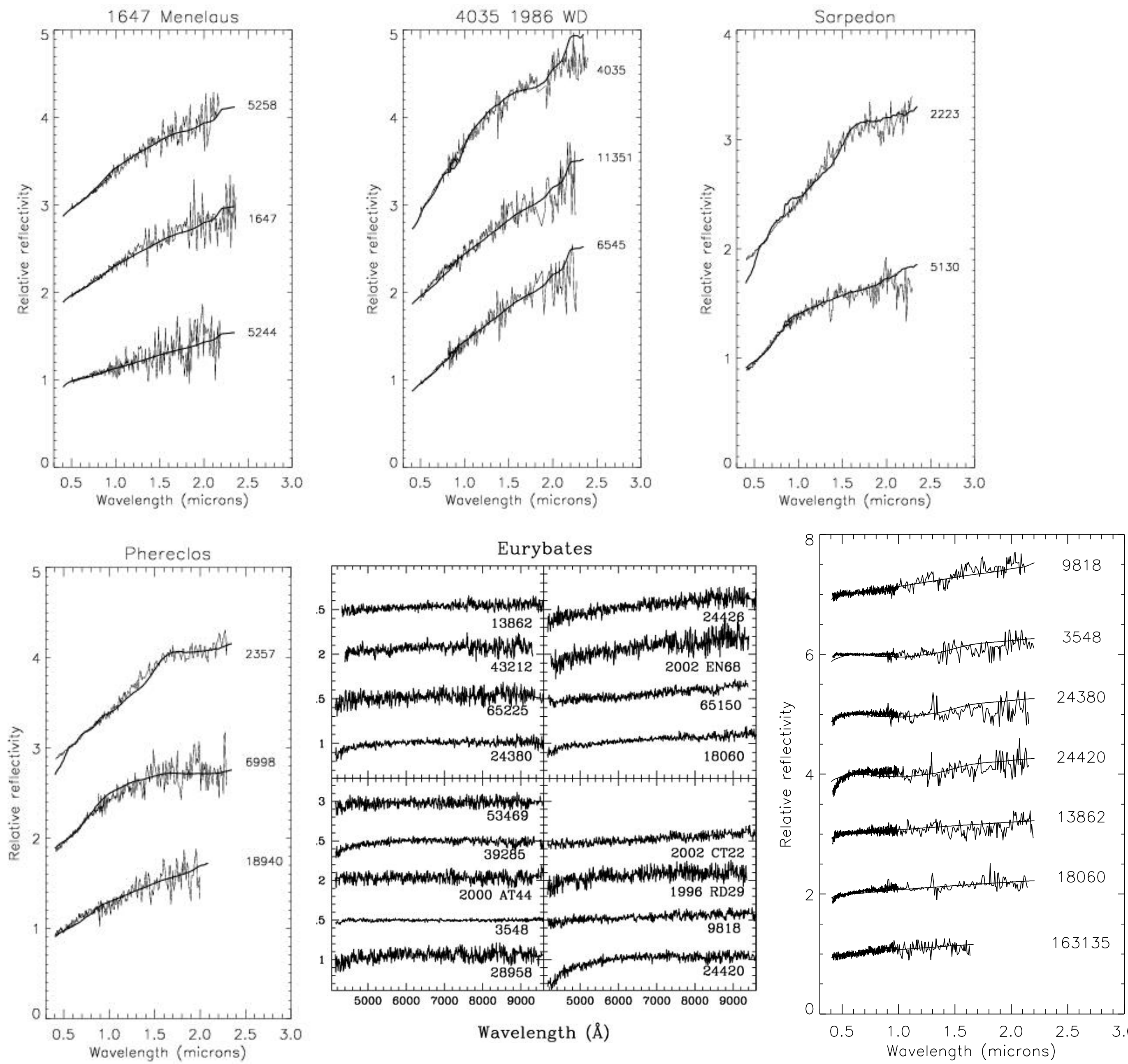




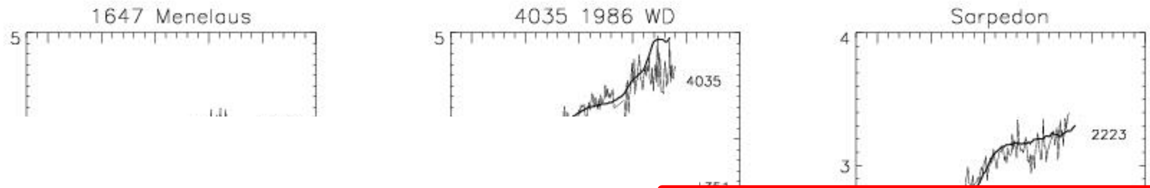


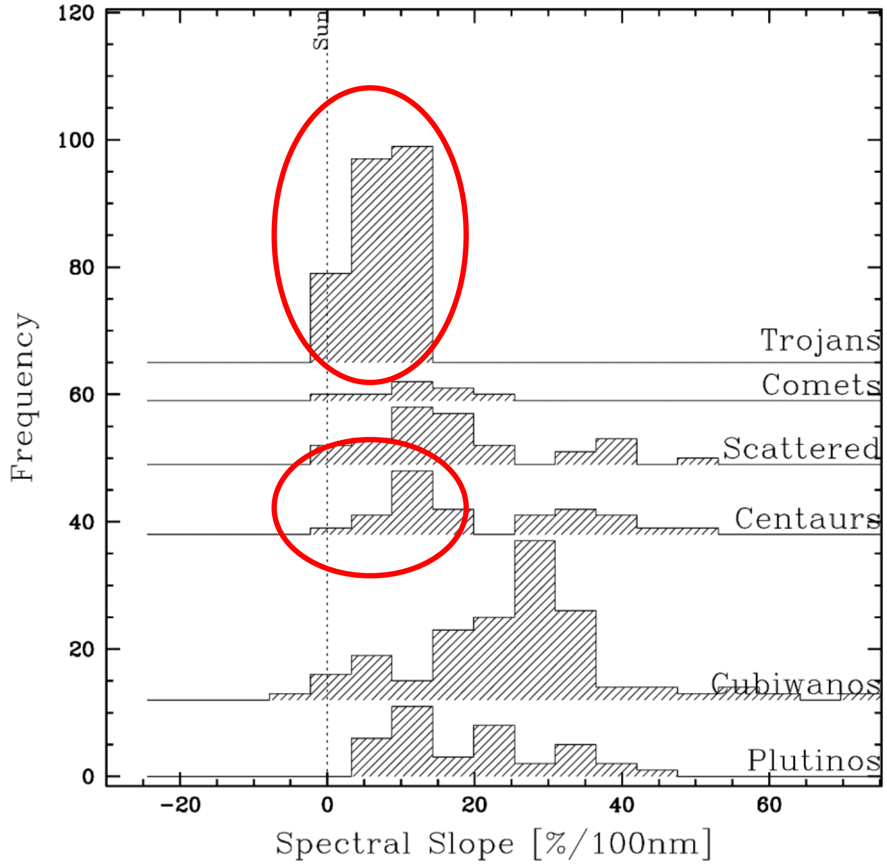
<u>2013 UL10: the first red active Centaur detected</u>.
Is the comet-activity induced resurfacing (and bluishing) a short time-scale process?
Are we observing a young, transient, comet-like process of «transformation while moving» ?

Jupiter Trojans (ED08, SF07, SF08, FDL10)



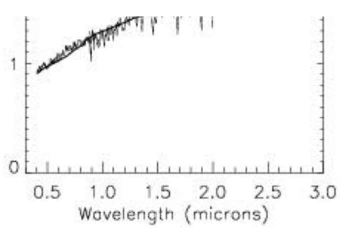
Jupiter Trojans (ED08, SF07, SF08, FDL10)

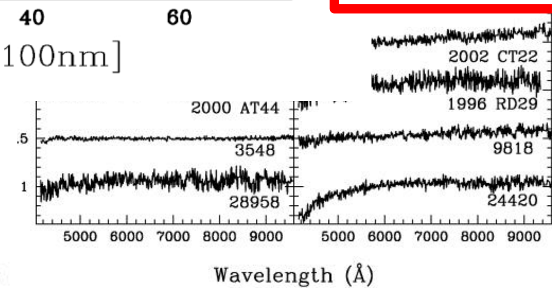


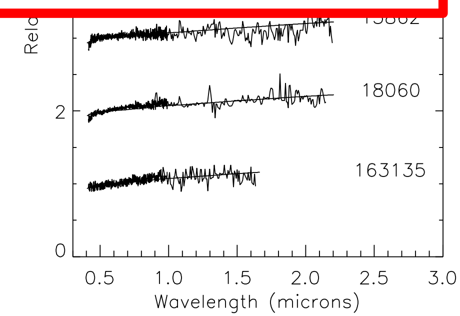


Spectral slopes of Jupiter Trojans are similar to those of short period comets and neutral Centaurs.

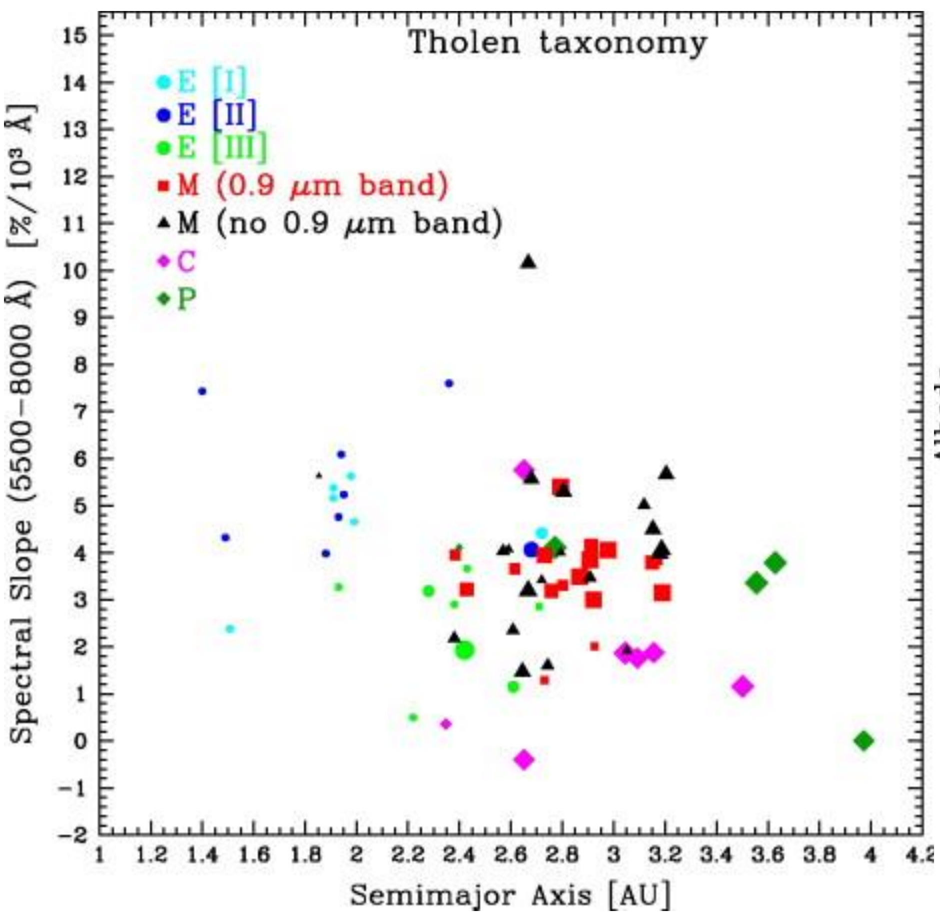
It seems that Jupiter Trojans are more similar to the active and post-active bodies.

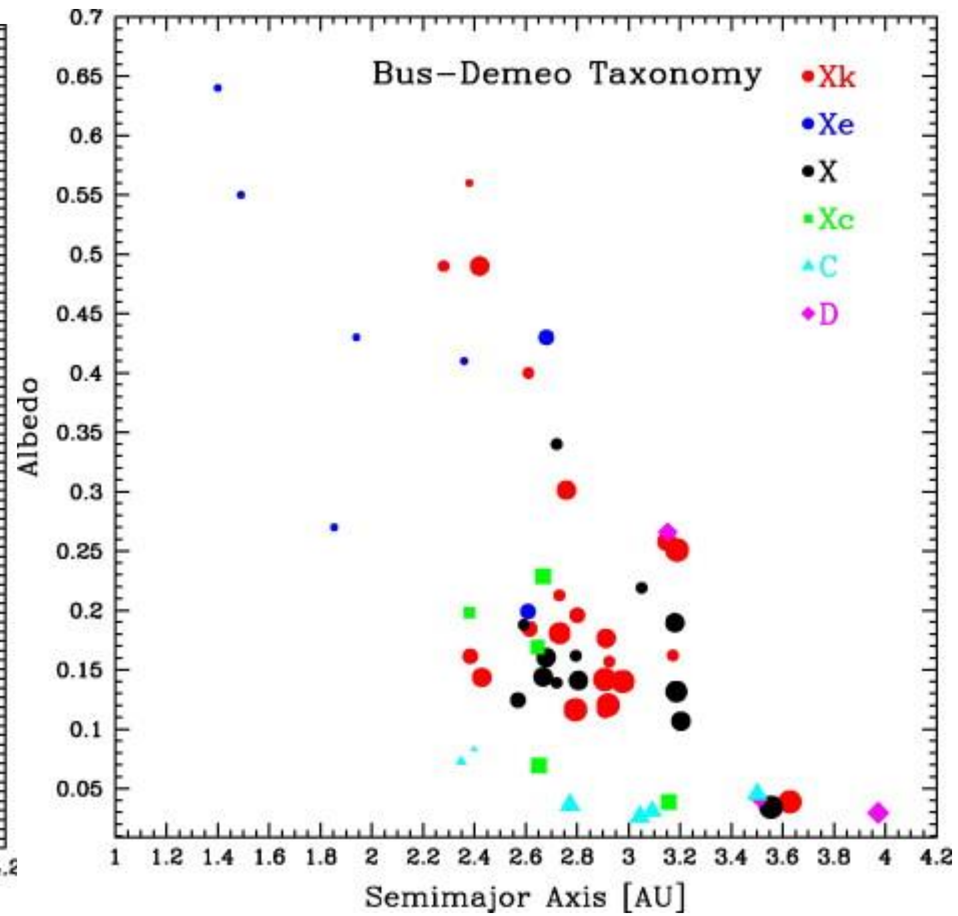






Main Belt Asteroids: E, M, X-types (SF08, SF10, SF11)





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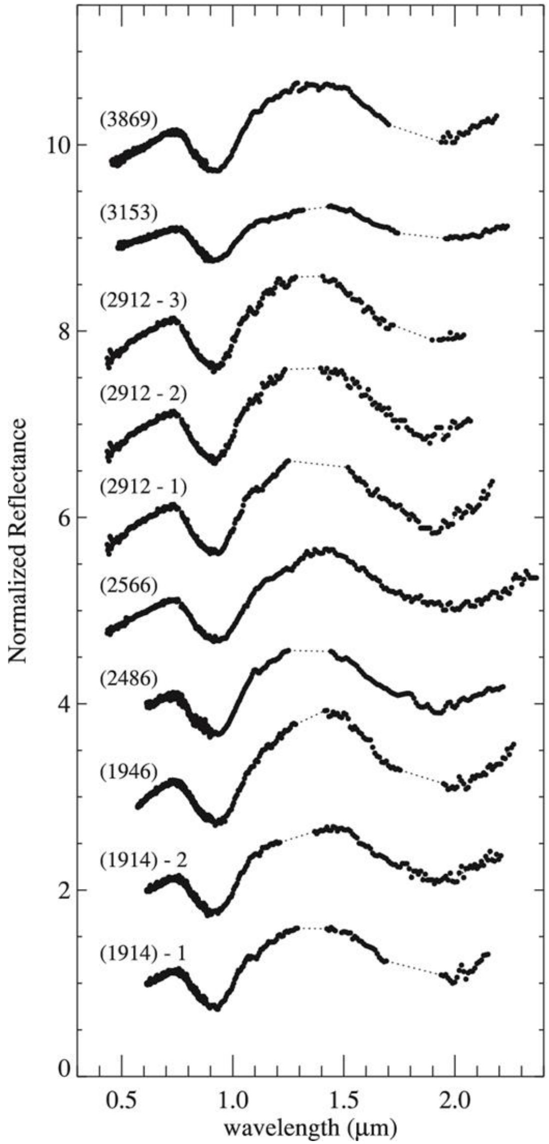
Main Belt Asteroids: E, M, X-types (SF08, SF10, SF11)

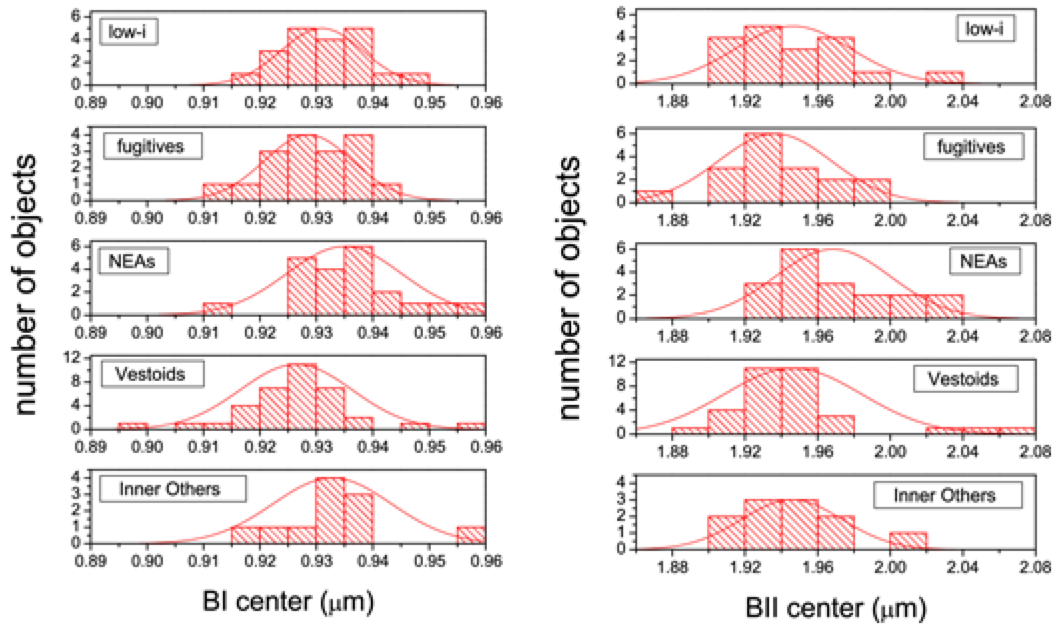
The X complex in the Tholen taxonomy comprises the E, M and P classes with similar spectral features.

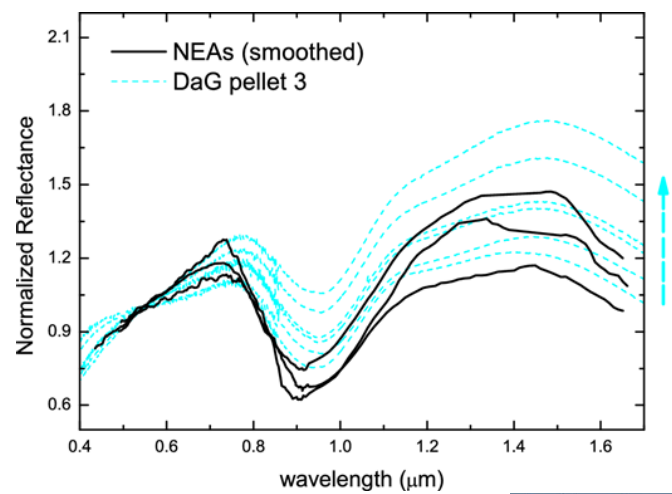
We analysed a large sample of MBA, taking into account the albedo values (by Tedesco et al. 2002), looking for their surface composition and meteorite analogs.

Our analysis has clearly shown that, although the mean visible spectral slopes of M-, E- and P-type asteroids are very similar to each other, the differences in albedo indicate major differences in mineralogy and composition.

Main Belt Asteroids: V-types (SI16, DF16)







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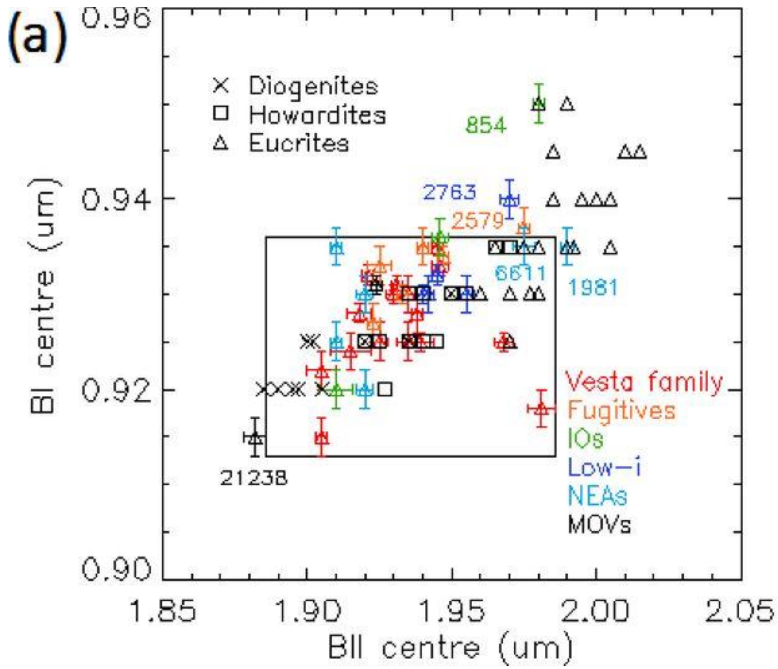
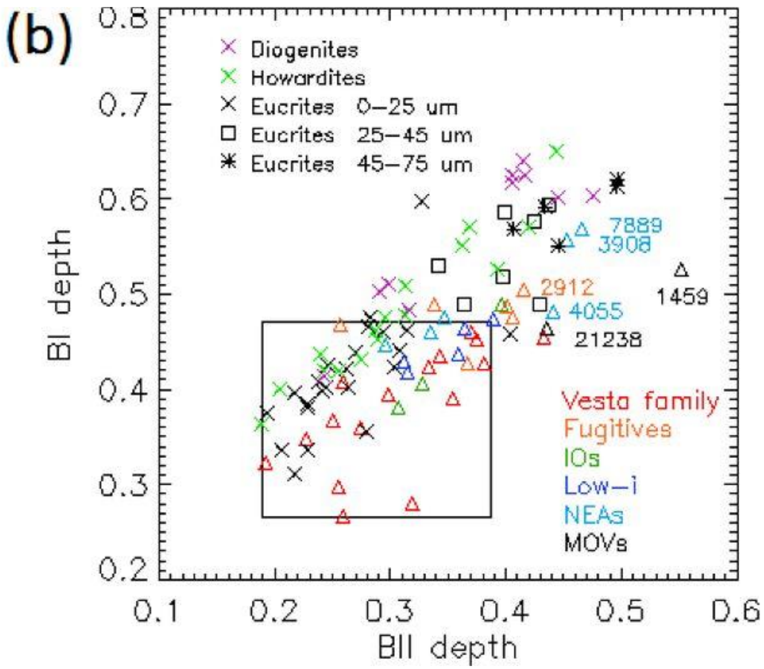
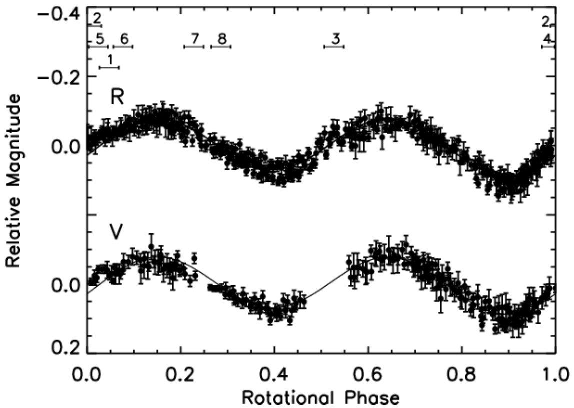
Main Belt Asteroids: V-types (SI16, DF16)

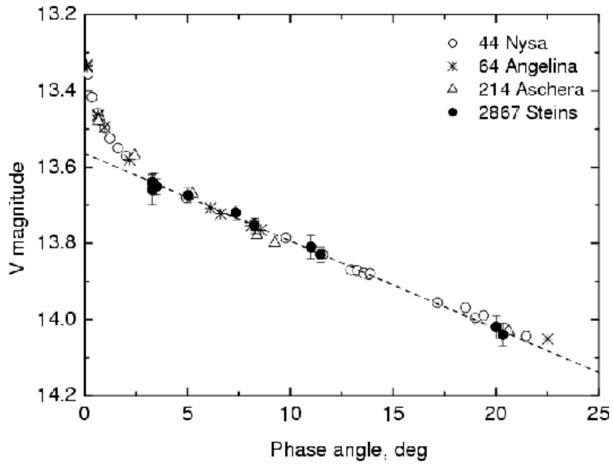


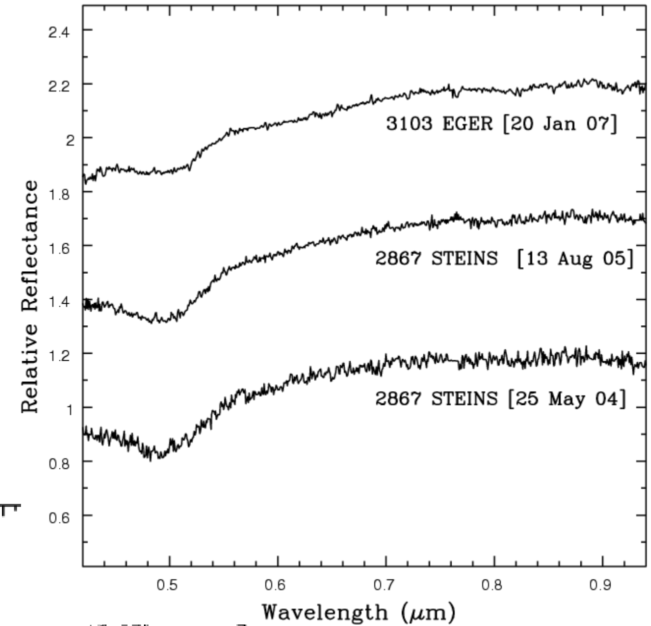


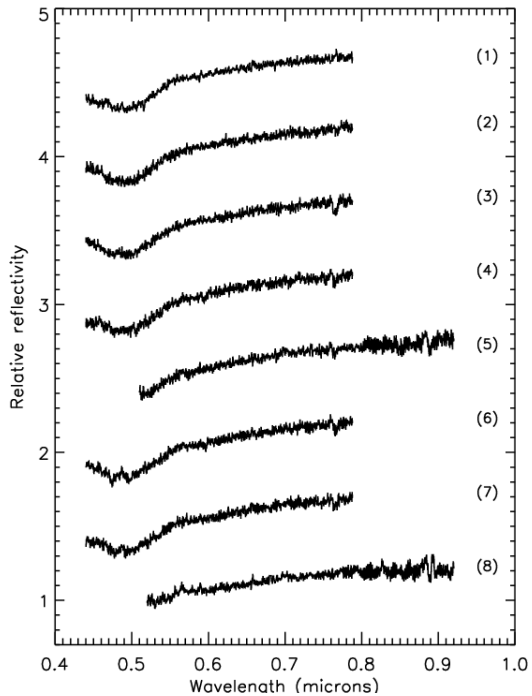
Our analysis shows that, although most of the V-type asteroids in the inner main belt do have a surface composition compatible with an origin from Vesta, this seem not to be the case for V-types in the middle and outer main belt and for NEAs.

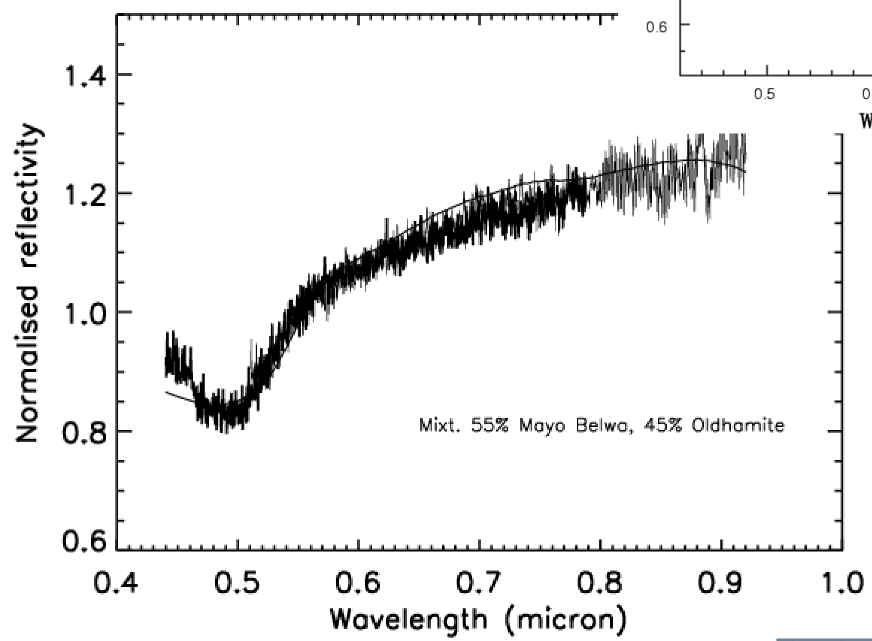
Space mission targets: Steins (SF07, ED09)



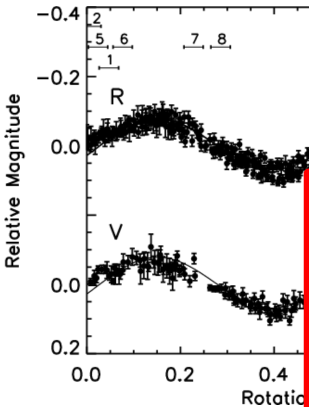


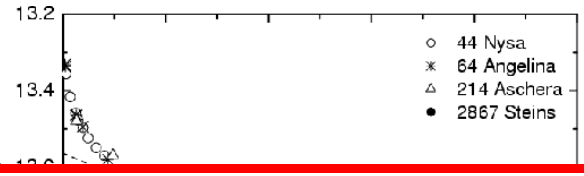


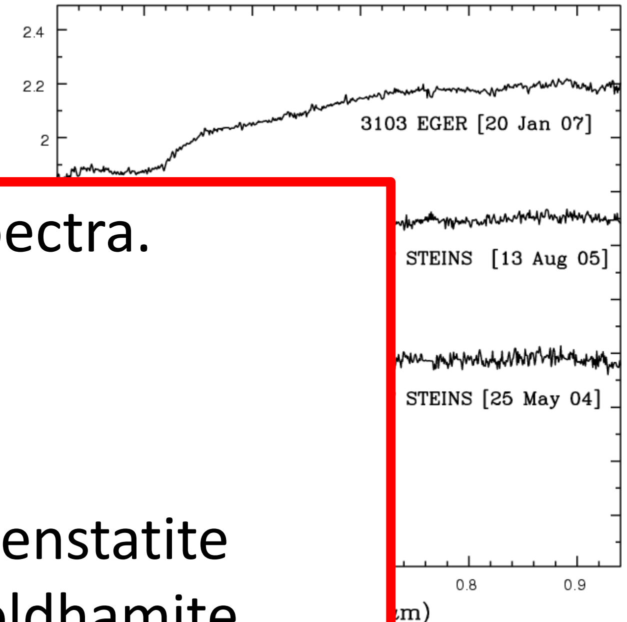




Space mission targets: Steins (SF07, ED09)



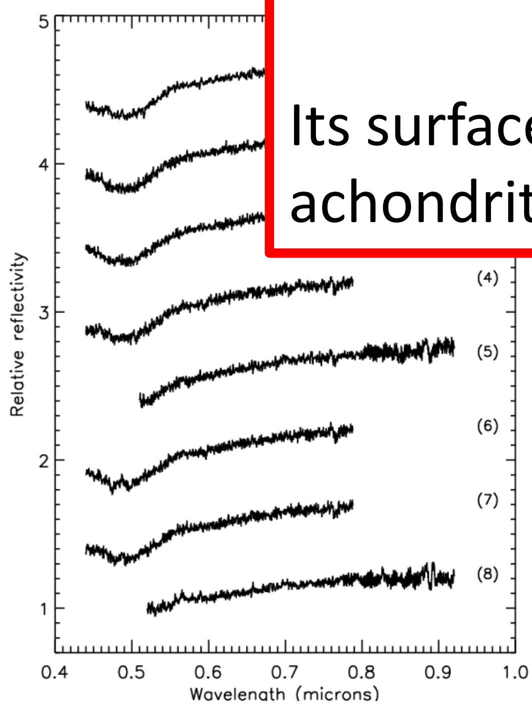


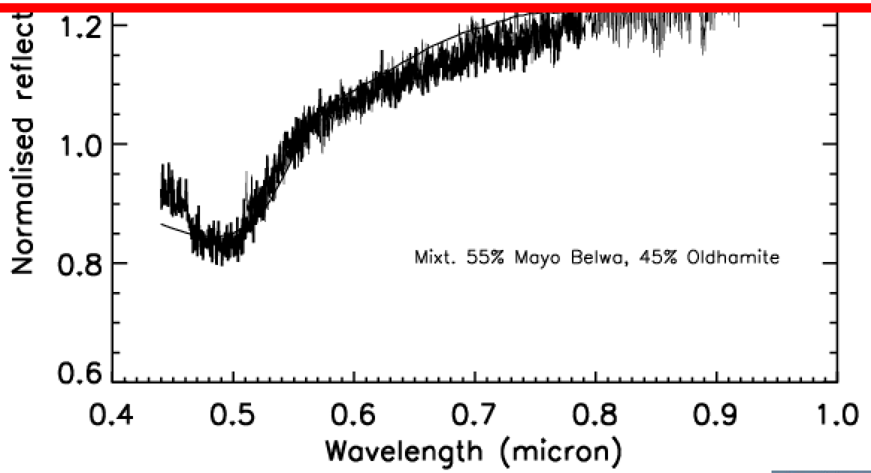


Rotational period, phase curve, 8 spectra.

Steins is an E-type asteroid.

Its surface composition is similar to enstatite achondrite meteorites enriched in oldhamite.





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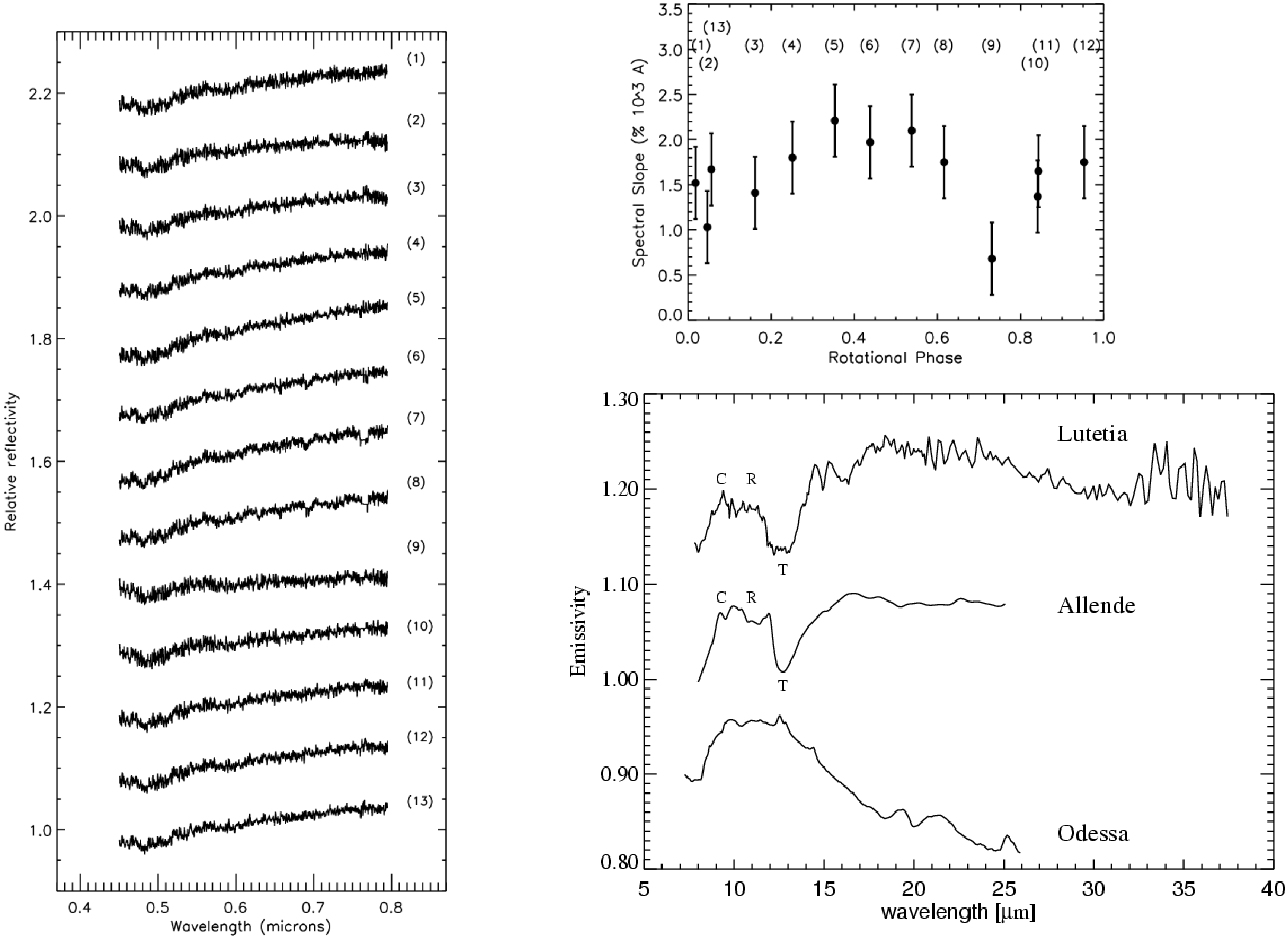
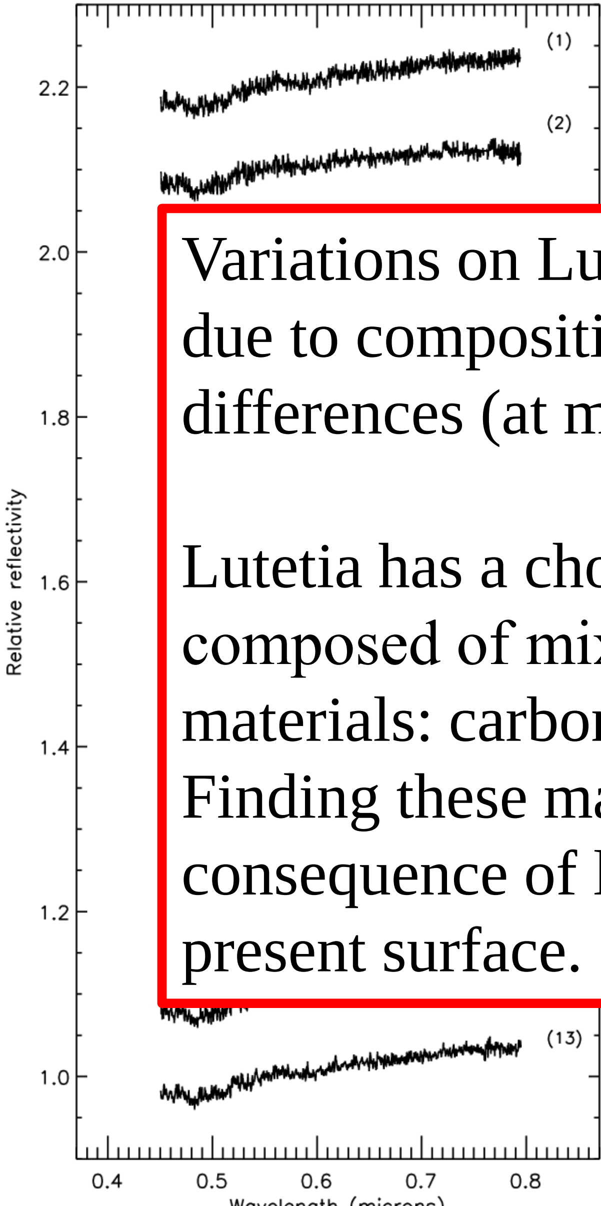
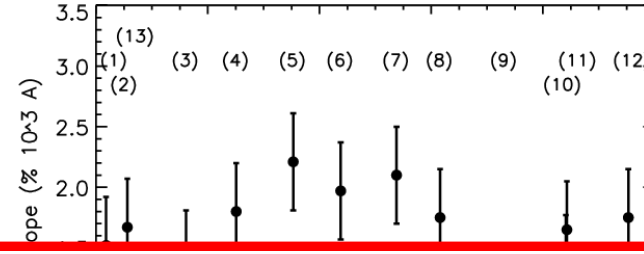
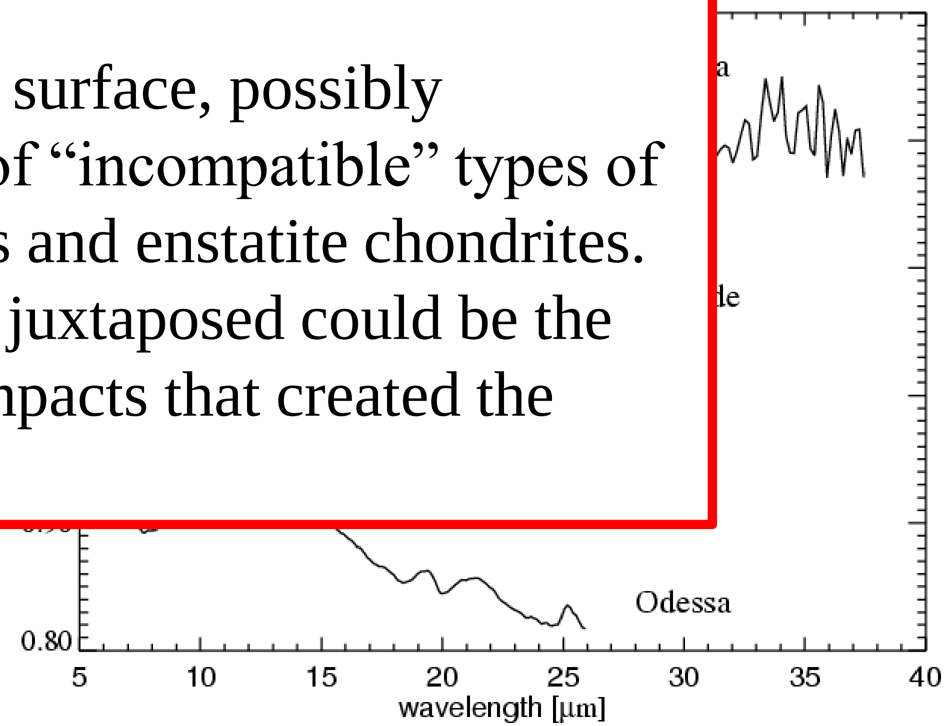
Space mission targets: Lutetia (MAB05, DP10)



Space mission targets: Lutetia (MAB05, DP10)



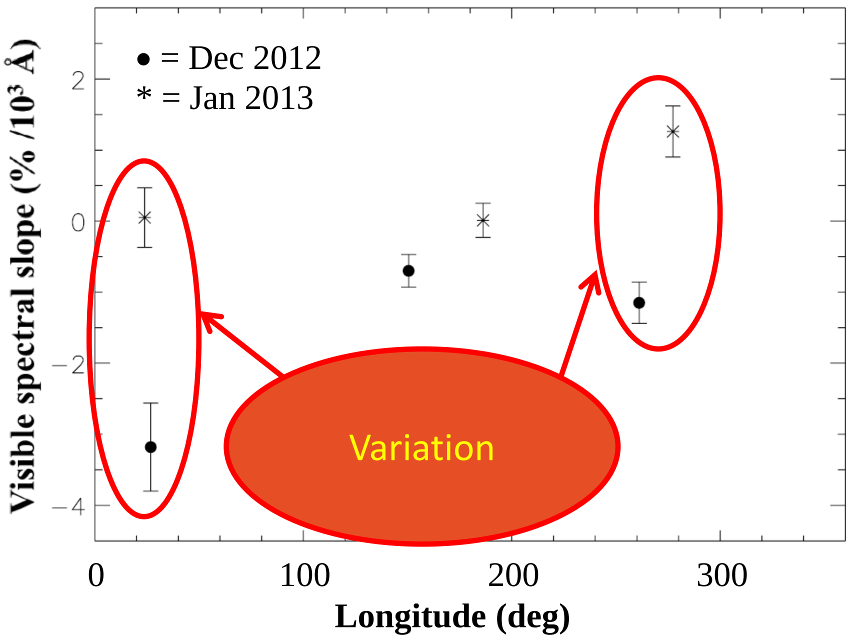


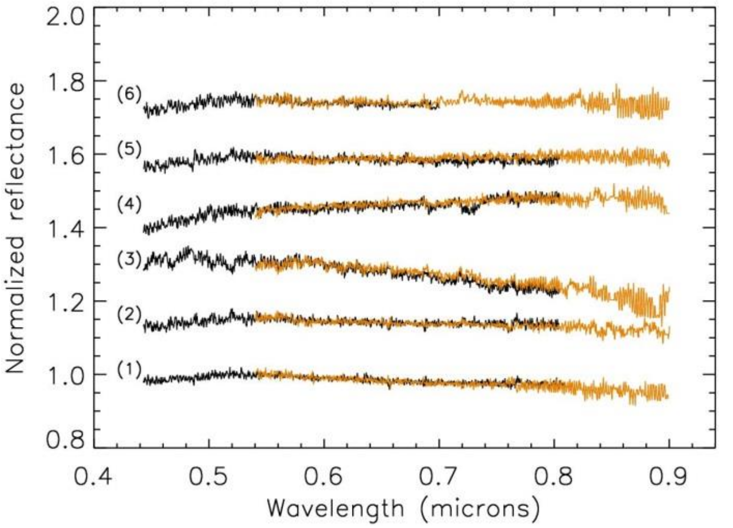


Variations on Lutetia's surface are inferred to be due to compositional and morphological differences (at macro and micro scales).

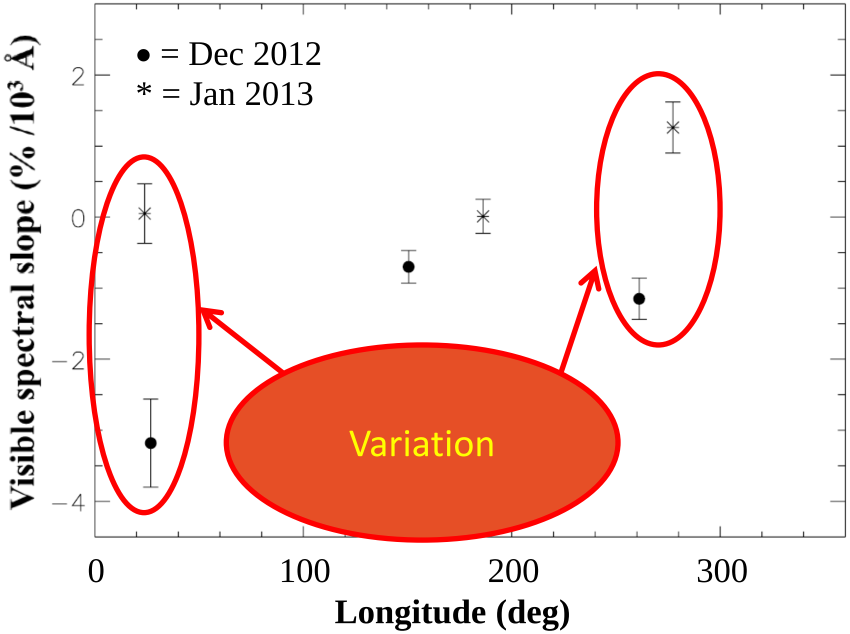
Lutetia has a chondritic surface, possibly composed of mixtures of “incompatible” types of materials: carbonaceous and enstatite chondrites. Finding these materials juxtaposed could be the consequence of large impacts that created the present surface.

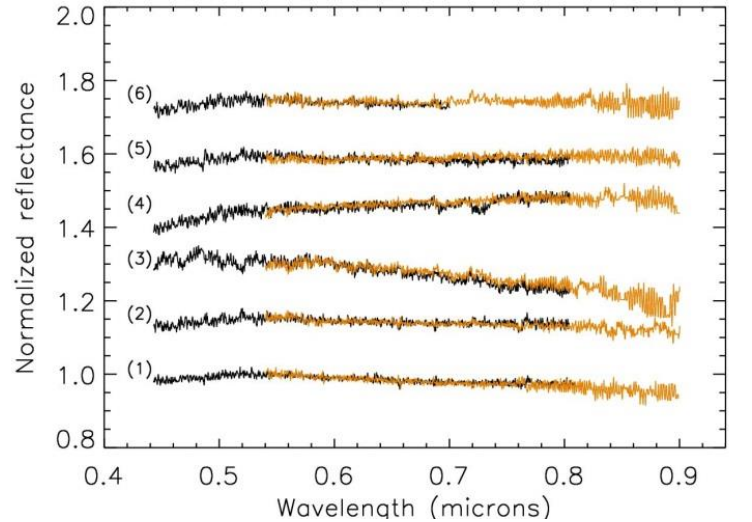
Space mission targets: Ceres (DP15)

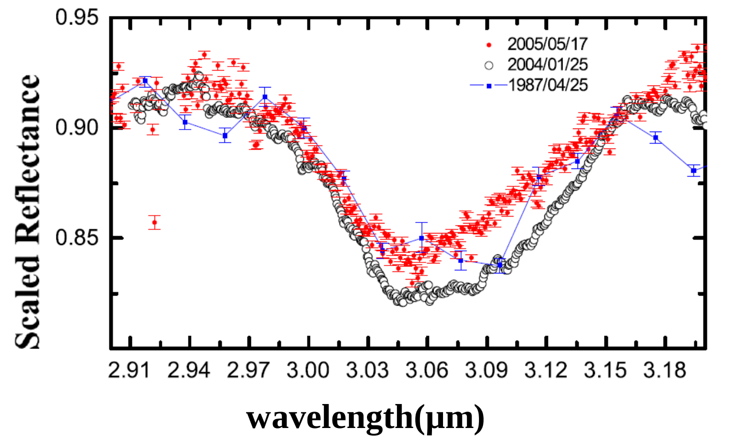


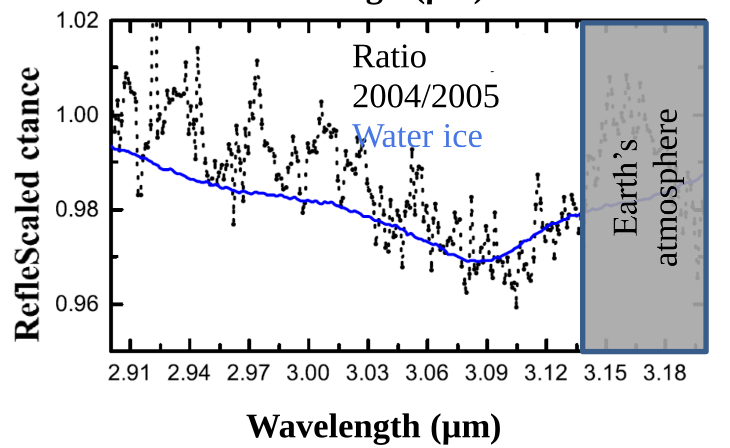


Space mission targets: Ceres (DP15)

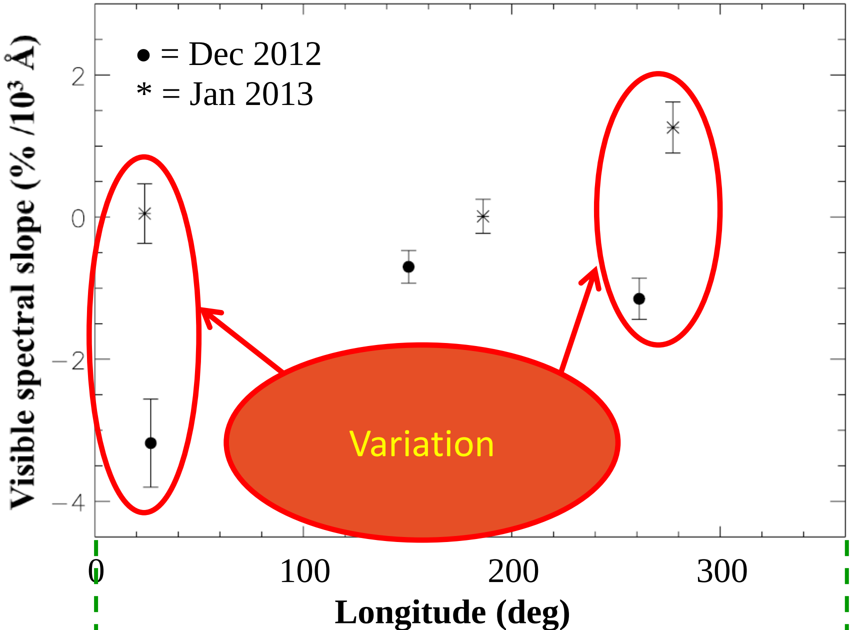


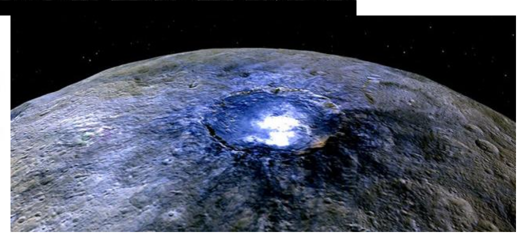


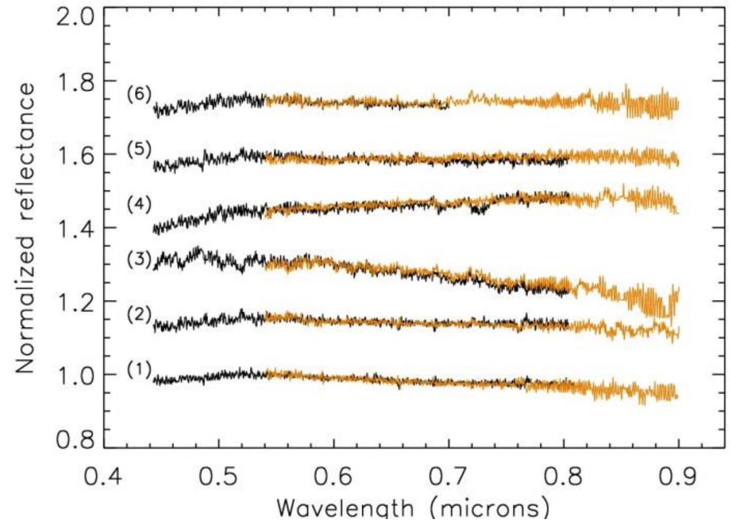


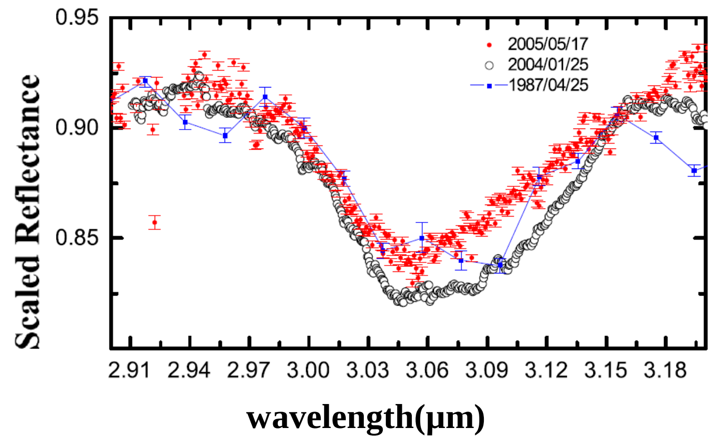


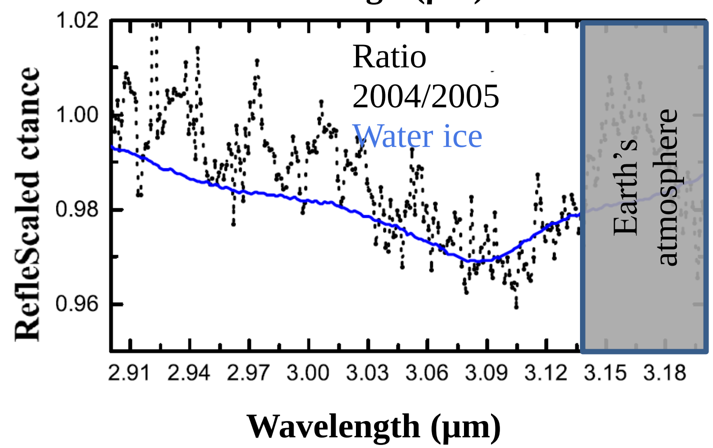
Space mission targets: Ceres (DP15)



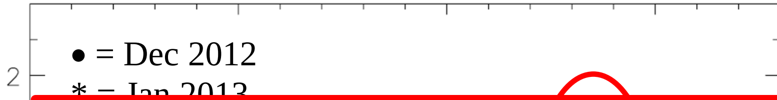


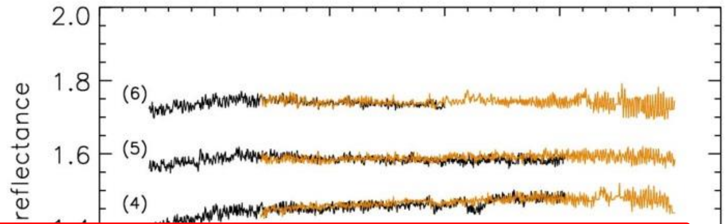






Space mission targets: Ceres (DP15)



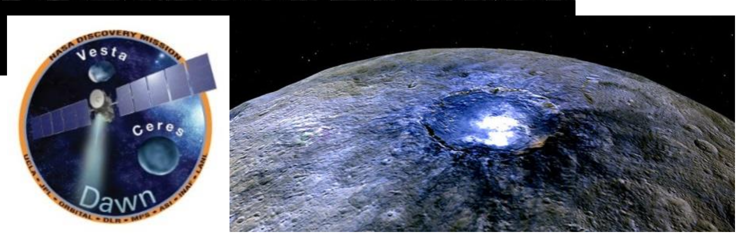


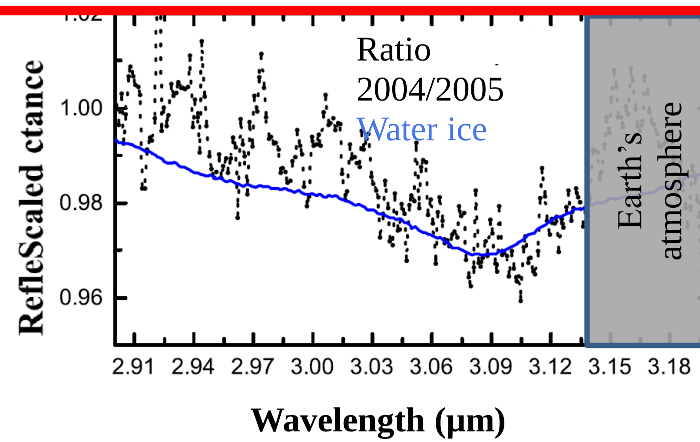
Visible spectra exhibit a remarkable short-term temporal variability.

NIR spectra exhibit a changing shape of the 3 μm band.

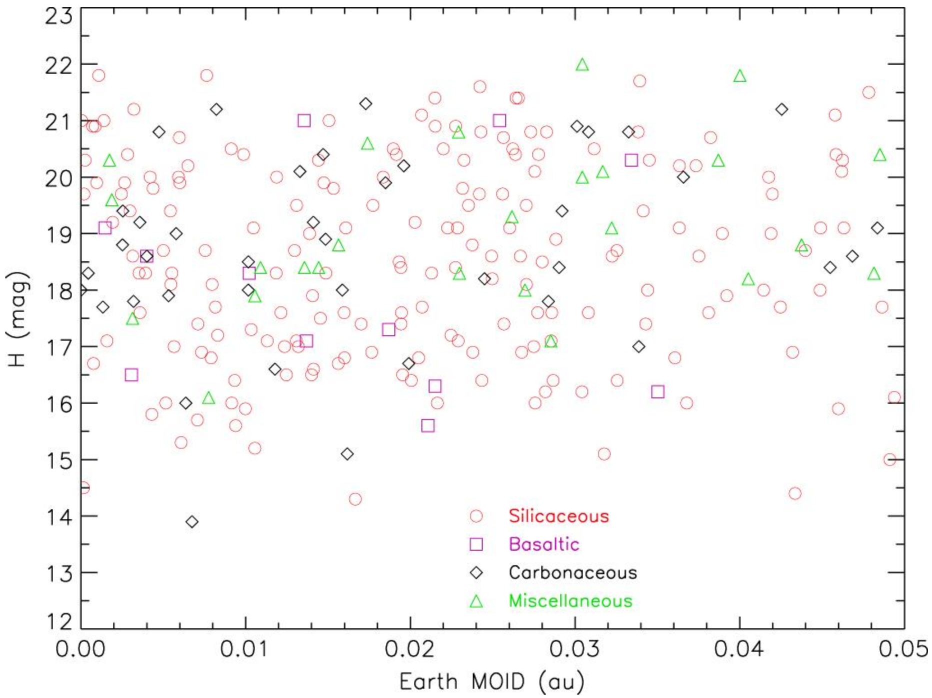
These spectral features can be hints of different amounts of water ice exposed on the surface of Ceres.

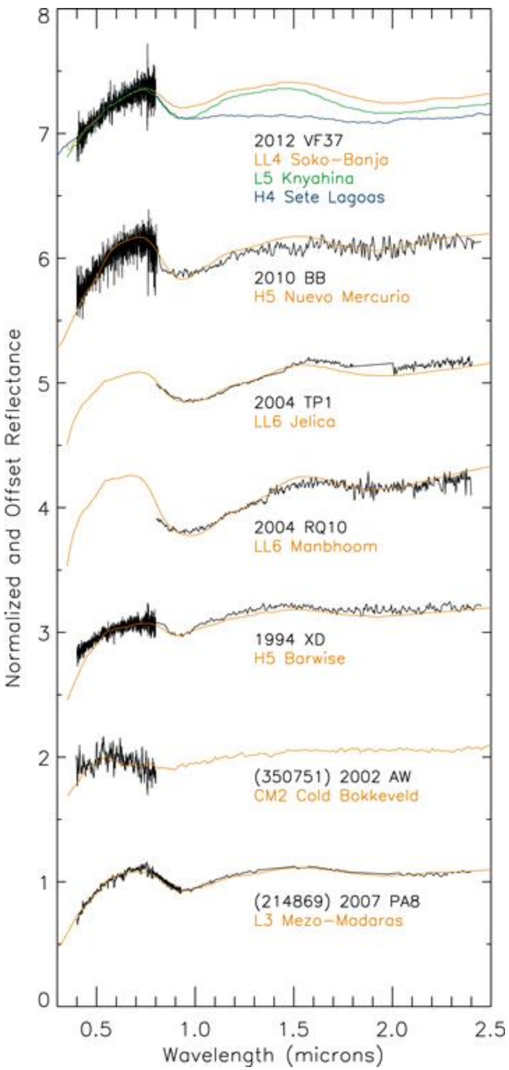
We can hypothesize that Ceres is still undergoing extended resurfacing processes (probably due to cryovolcanism).





Near Earth Objects: PHA (DP13, DP16)

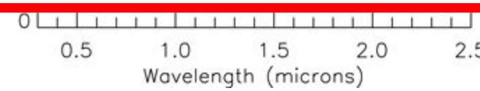




Near Earth Objects: PHA (DP13, DP16)

The primitive, carbonaceous asteroids seem to pose a special danger to our planet since:

- ✓ the most mature techniques for deviating an asteroid from a hazardous orbit are less efficient for such objects;
- ✓ their low MOID and inclination values indicate that they will have close approaches with the Earth more frequently than those belonging to the other groupings.



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Near Earth Objects: the EU NEOShield-2 program

The NEOShield-2 (2015-2017) project has been approved by the European Commission in the framework of the Horizon 2020 programme with the aims;

- to study specific technologies and instruments to conduct close approach missions to NEOs or to undertake mitigation demonstration,

- <u>to acquire in-depth information of physical properties of the population of small NEOs</u>, in order to design mitigation missions and assess the consequences of an impact on Earth.

Participant organisation	Leading personnel	Country
DLR, Berlin	A. W. Harris	Germany
Observatoire de Paris (LESIA and IMCCE)	M. A. Barucci, D. Hestroffer	France
CNRS (Obs. Côte d'Azur)	P. Michel	France
Fraunhofer – EMI	F. Schäfer	Germany
Queen's Univ. Belfast	A. Fitzsimmons	UK
Astrium *Supervisory interface for technical WPs*	A. Falke	Germany France UK
Deimos Space	J. L. Cano	Spain
GMV - Aerospace	G. Binet	Spain
INAF	E. Dotto	Italy

- Kick-off: March 2015
- Duration: 2.5 years

Near Earth Objects: the EU NEOShield-2 program

Our contribution to the project

Task 10.2.1 (INAF): Colours and Phase functions

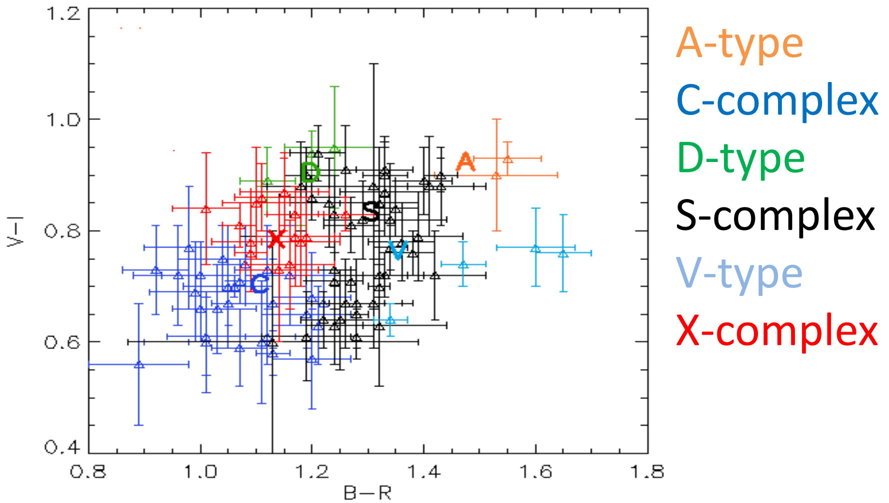
- Submissions and execution of proposals for time allocation to INAF medium and large telescopes (TNG, LBT)

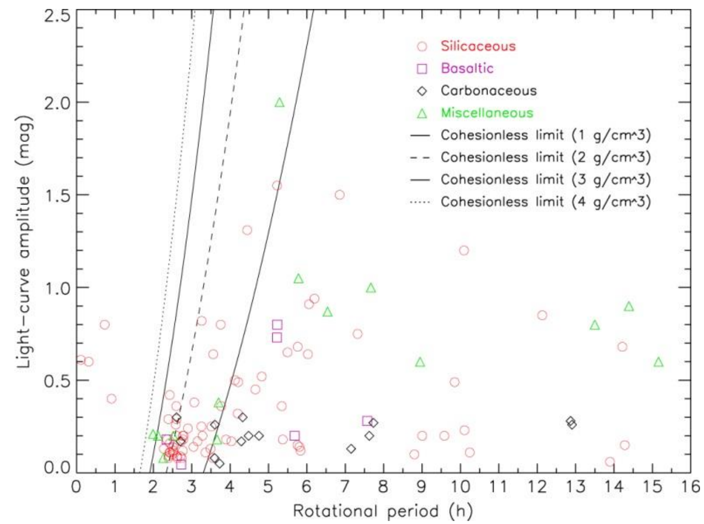
- Data reduction and analysis in order to obtain information on i) surface physical properties (regolith, albedo…); ii) surface colour variation and iii) preliminary taxonomic type of the observed objects (interface with task 10.3)

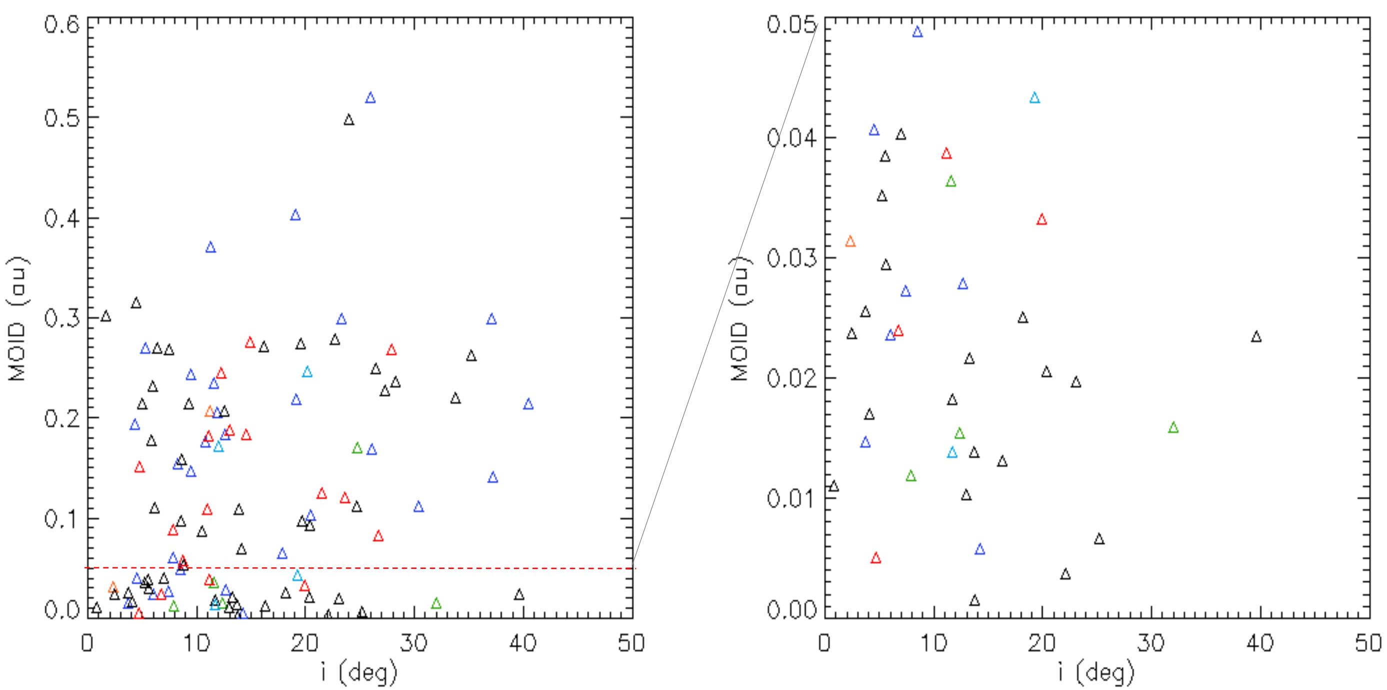
- Interface with task 10.4 (combine with thermal-IR information in order to determine albedo and diameter).

Near Earth Objects: the EU NEOShield-2 program (SI17)

During the first year (48h) we have observed and classified 105 NEOs.







Near Earth Objects: the EU NEOShield-2 program (SI17)

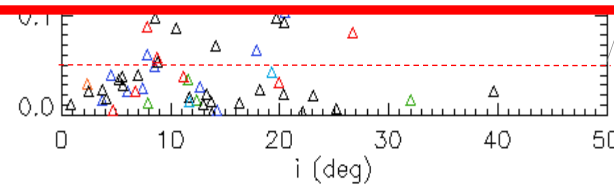
During the first year (48h) we have observed and classified 105 NEOs.

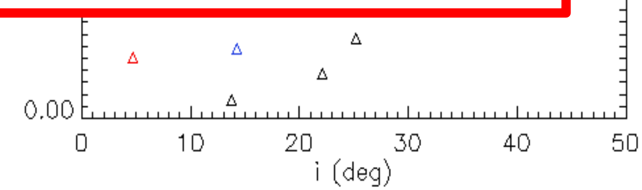
We can confirm that the primitive, carbonaceous, C- and D-type NEOs seem to pose a special danger to our planet since (low MOID and high inclination)

The size distribution of our sample shows that C-complex material becomes underrepresented in the small size range (D<200-250 m):

- bias effect ?
- or a weaker mechanical resistance of more fragile carbonaceous asteroids ?

More observations are needed.





Conclusion and future works

Small bodies of the Solar System are usually considered to be "closest" to the formation era of the planetary system.

Ground-based observations are essential to provide characterizing information on a large sample of objects of different dynamical families and groups.

On-ground V+NIR photometric and spectroscopic observations are needed to improve our knowledge of these objects.

TNG (Dolores-NICS/Amici) is fundamental to obtain important results on the physical properties of small bodies of the Solar System.