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Spectroscopy of "small" and faint small-bodies with Gemini telescopes: results and perspectives

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Introduction

- **Investigation of Solar System bodies such as asteroids and comets allows us to understand better the formation of the Solar System, and its further dynamical and physical evolution. Visible and near-infrared spectroscopy is a good and consolidated tool for acquiring some knowledge on how such evolutionary processes took place, through the study of the possible mineralogical features in the spectra of the small bodies, in comparison with our knowledge about minerals found on Earth and on meteorites. Silicates like pyroxene and olivine are among the most common material found in asteroids, and present very clear, broad and deep absorptions around 1.0 and/or 2.0 microns. According to the slope of the visible continuum and the characteristics of the absorptions, spectra of asteroids are classified into taxonomic classes. At the same time, according to dynamical properties, they can be grouped into "families", which are the result of the breakup of a larger body and, as so, its members are expected to share spectroscopic properties compatible with either a differentiated or a primitive parent-body.**

Introduction (cont.)

- **Amongst the biggest problems in solar system research is the topic of finding the asteroid spectroscopic proxies for the most common class of meteorites which fall on Earth: the Ordinary Chondrites (OC hereafter). The apparent lack of OC material among asteroids have been attributed to the space weathering effect - which is the time-dependent modification of an asteroid's surface, caused by effects like micrometeorite impacts or solar wind particles implantation - acting on the most common class of asteroids in the main-belt, the S-types. The smallest of the asteroids are, in its majority, results of more recent collisions, and had less time to expose their surfaces to space weathering effects. Therefore, observing objects of very small sizes (< 5 km) and families recently formed, was necessary to look for more "fresh" surfaces.**

Introduction (cont.)

- **Here, the spectroscopic data obtained with the GMOS spectrographs at GEMINI South and North are presented, and three interesting results examined. These data were obtained under the programs GS-2007A-C-6, GS-2007B-Q-7, GN-2007B-Q-67, which were awarded a total of 3 nights in classical mode, and 14 hours in queue mode. One night of the classical mode was lost due to technical problems with the instrument. Nevertheless, exciting results were achieved, and the first spectra similar to OC mineralogies were found in the Main Belt of asteroids, among extremely young asteroid families (Mothé-Diniz & Nesvorný, 2008a). Another result concerns the surface characterization of one asteroid family in the outer main belt, Tirela Family (Mothé-Diniz & Nesvorný, 2008b). Another part of the data from these programs belongs to the search for OC mineralogies among small sized-asteroids. The spectra have been analysed, and a paper is under preparation. The results are reported here and the perspectives discussed.**

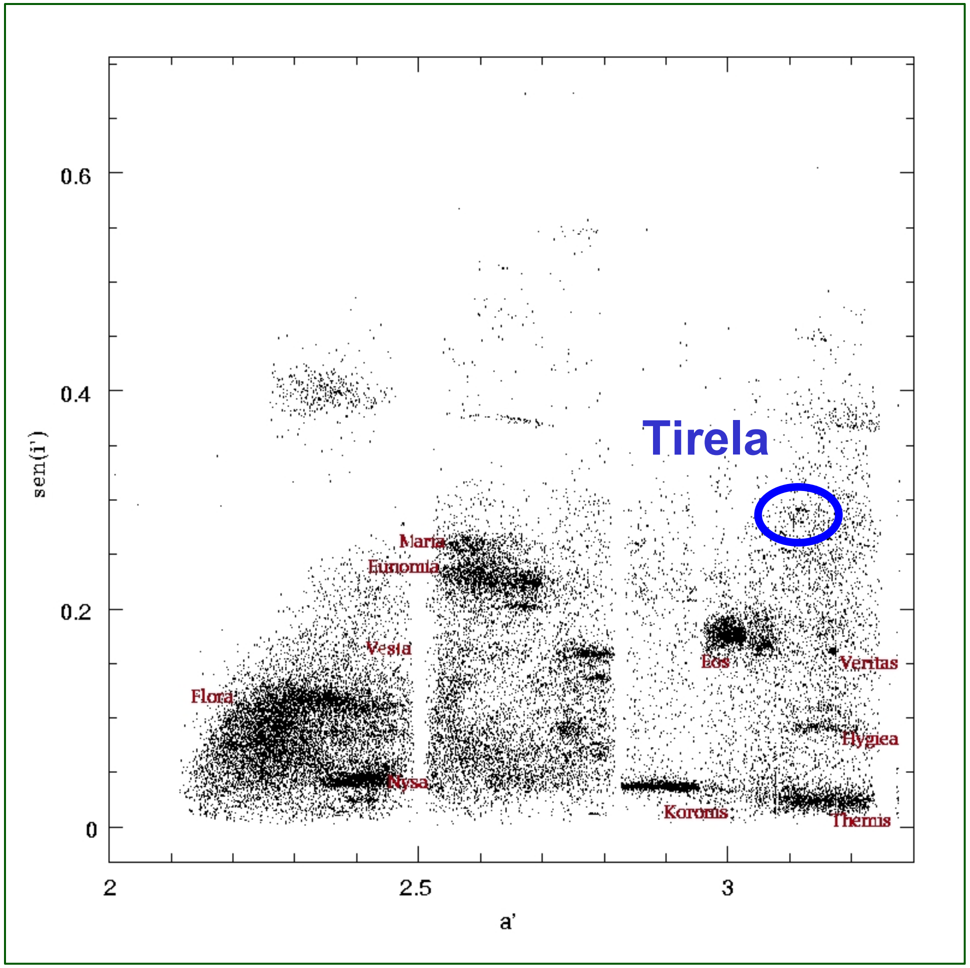
Observations

- GMOS, in long-slit mode, with a slit of 1.5".
- Filter GG455-G0305 => wavelength interval ⩾ 460 nm + effective wavelength ⩾ 550 nm.
- Grating R150+G5306 for GN & R150+G5326 for GS => simultaneous coverage of 1071nm, with R=631.
- Asteroids + Solar Analogues for removal of the Solar Flux.
- Reduction of the data:
  - Asteroids and Solar Analogues were reduced using standard procedures, with the package “gmos” for IRAF.
  - Asteroid spectra are then divided by the spectrum of the solar analogue to obtain reflectance spectra.

Project 1: Tirela Family

- Motivation: Study the only possible D-type asteroid in the main belt
  - Levison and Bottke (2008) suggest that some objects were implanted in the MB from beyond 15 AU.
  - Among asteroids: P, D- types are possible cometary analogs
  - (1400) Tirela (D) + Family => Possible "implanted" object in outer main belt?

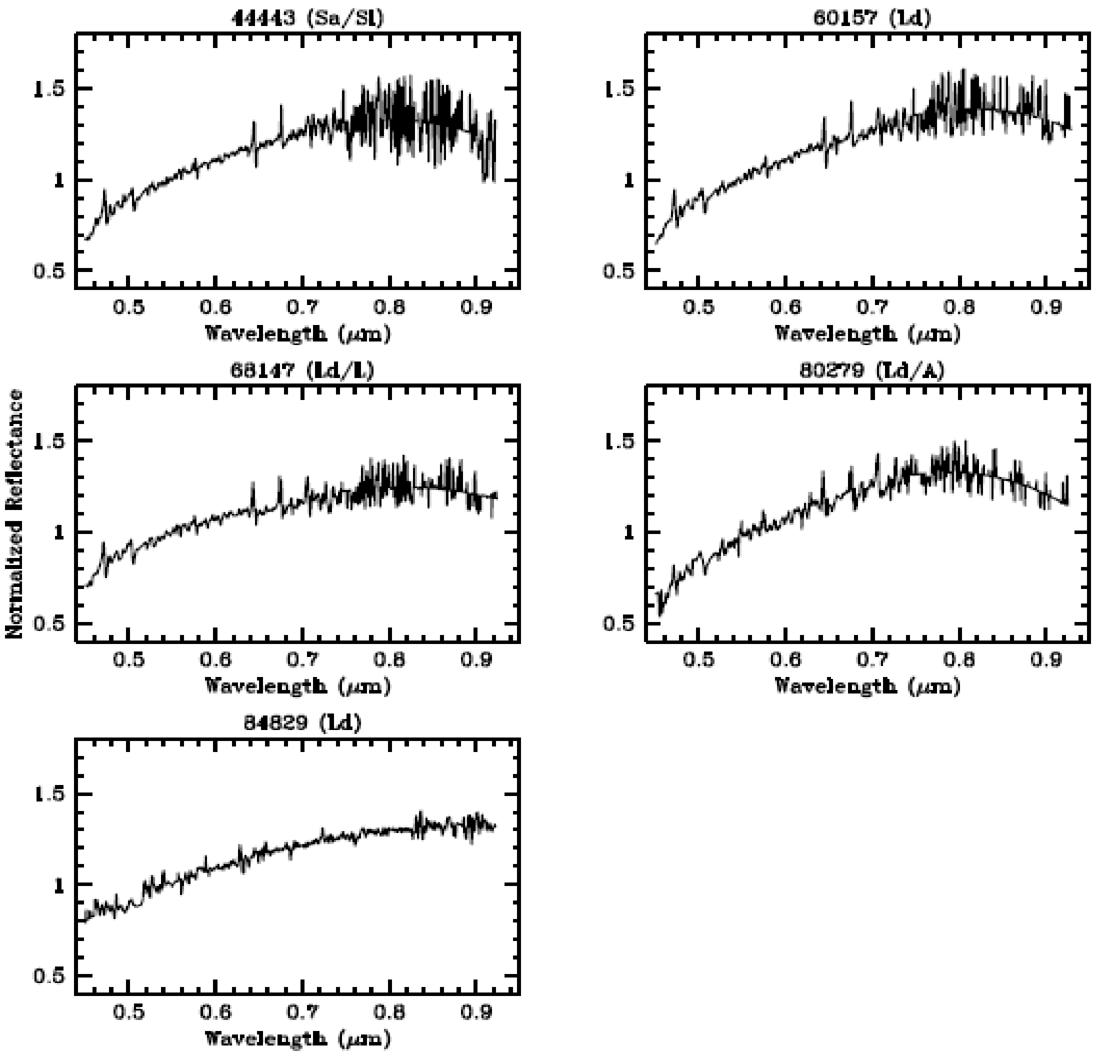
– Characteristics:
- Location: outer main belt
- a = 3.12, e = 0.19, i = 17^{o}
- Aprox. 400 members.
- Very faint objects for spectroscopy (Mv > 20)



Observed objects

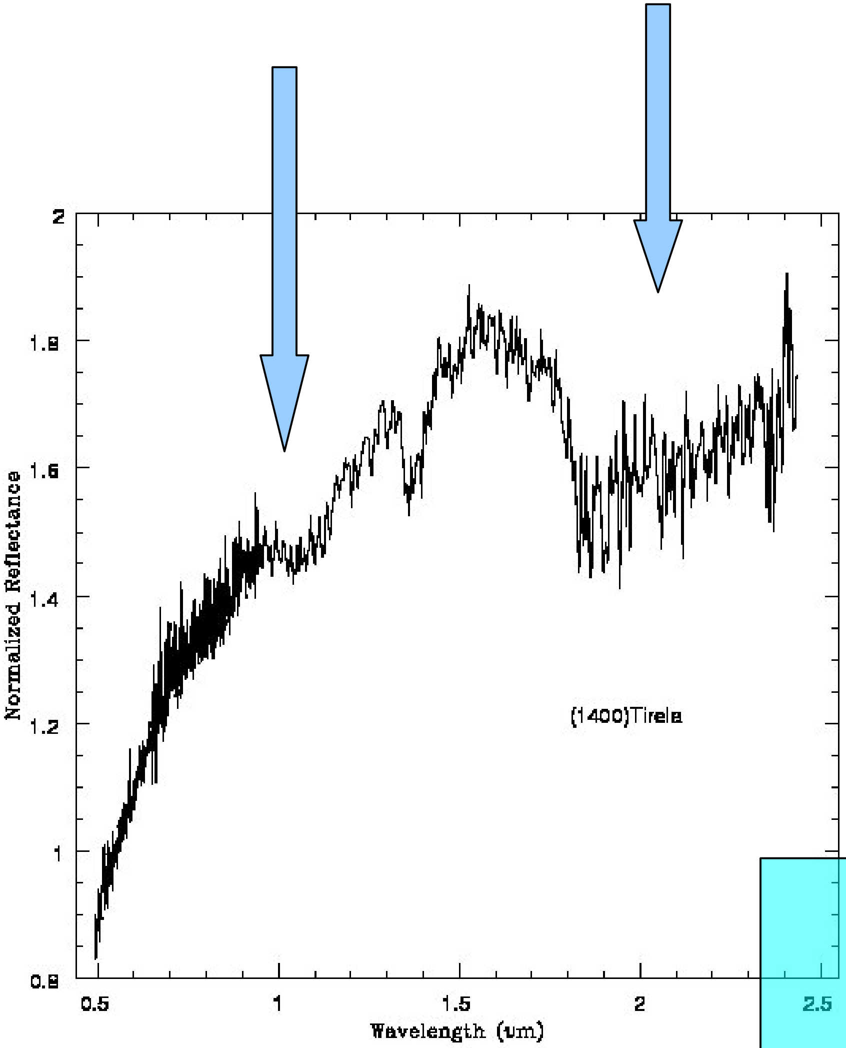
Asteroid	*SpectralRange/ Telescope*	*UTdate*	*Exposure (sec)*	*Mean airmass*	*PhaseAngle (deg)*	*Mag.(V)*	*Solar Analogue*	*Class*
(1400)*Tirela*	*NIR/IRTF*	20 – *Jun* – 2006	120	1.23	13.8	15.9	*SA*107684	*Ld*
(9222)1995*YM*	*Vis/TNG*	16 – *Dec* – 2006	1500	1.07	4.8	16.3	*SA*115271	*B*
(13150)*Paolotesi*	$Vis/GEMINI_S$	15 – *Mar* – 2007	6x300	1.01	18.8	18.36	*SA*104335	*Ld*
(31704)1999*JZ*44	$Vis/GEMINI_N$	3 – *Jan* – 2008	4x250	1.04	14.6	19.4	*SA*92501	*Ld/D*
(43343)2000*RY*81	*Vis/TNG*	16 – *Dec* – 2006	1500	1.02	7.7	16.3	*SA*115271	*Ld*
(44443)1998*UY*19	$Vis/GEMINI_S$	17 – *Mar* – 007	4x210	1.03	22.2	16.6	*SA*104335	*Sa/Sl*
(60157)1999*UT*23	$Vis/GEMINI_S$	17 – *Mar* – 2007	6x250	1.03	8.5	17.9	*SA*104335	*Ld*
(68147)2001*AW*44	$Vis/GEMINI_S$	17 – *Mar* – 2007	6x210	1.08	4.9	17.5	*SA*104335	*Ld/L*
(80279)1999*XP*33	$Vis/GEMINI_S$	17 – *Mar* – 2007	8x260	1.78	25.4	19.0	*SA*104335	*Ld/A*
(84829)2003*AN*	$Vis/GEMINI_N$	16 – *Nov* – 2007	4x250	1.27	9.9	18.5	*SA*98682	*Ld*
(97768)2000*JP*69	*NIR/IRTF*	20 – *Jun* – 2006	4x120	1.25	20.5	17.6	*SA*107684	?

Some Gemini/Gmos spectra



Object	Class
1400	Ld
9222	B
31704	D/Ld
43343	Ld
44443	D
60157	Ld
68147	Ld
77828	??
84829	Ld

Results



Tirela family is mostly Ld/D-type

=> compatible with the idea that its parent-body was an “implanted” object from the outer solar system (cometary origin)

- ... but this is ruled out by silicate bands in the NIR!

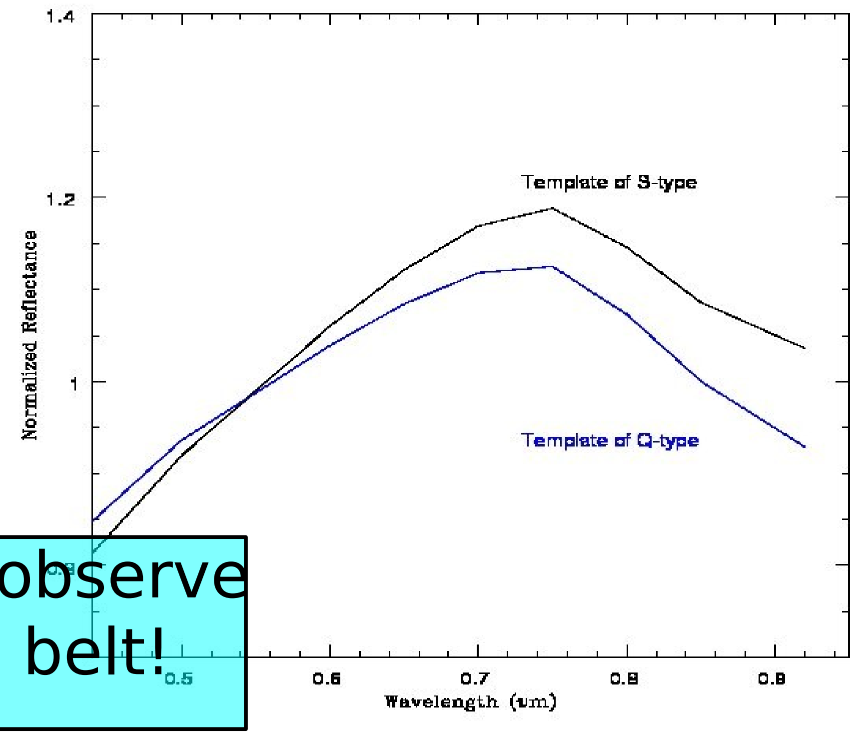
  Perhaps even a differentiated parent-body?

This is a good example on how important is the Near Infrared for studies of minor bodies.

Project 2: The Ordinary Chondrite "Paradox"

- There seems to be no good match to OCs in the main belt.
  - Best matches are S-class objects:

- Redder slopes + shalower 0.95 µm band
- => "Space Weathering"
- Idea: smaller asteroids might have "fresher" surfaces (less or no weathering)



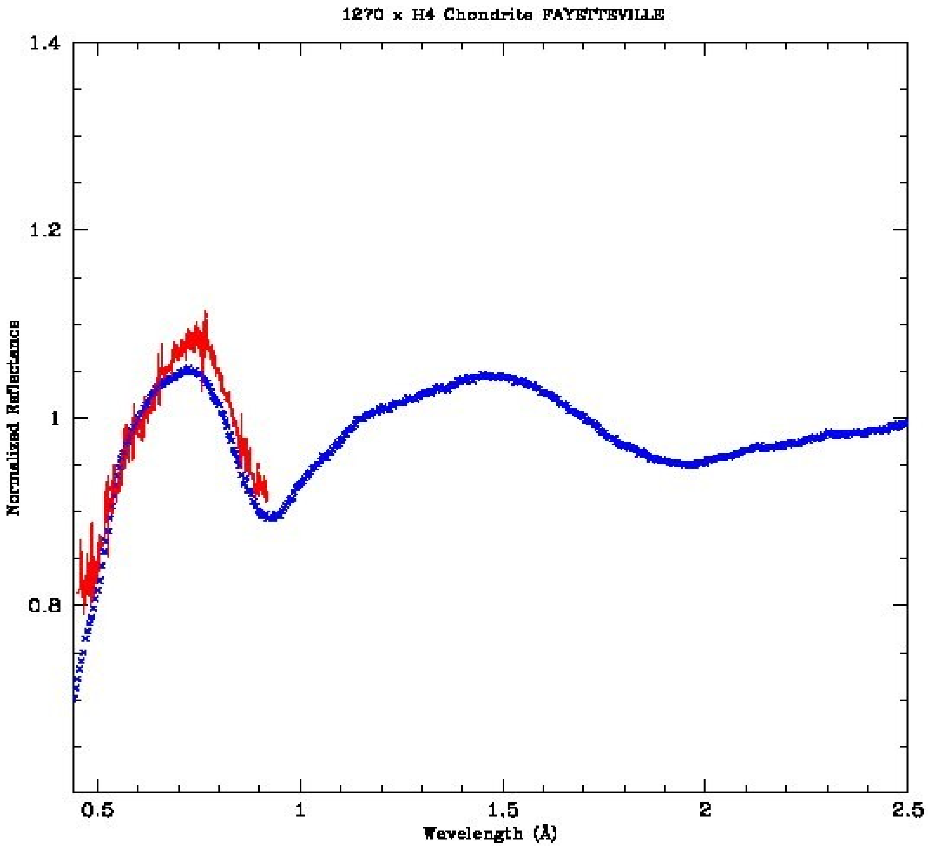
GEMINI with gmos can observe small asteroids of the main belt!

Observed objects

Asteroid	*UT date*	*Exposure (sec)*	*Mean airmass*	*PhaseAngle (deg)*	*Mag.(V)*	*Solar Analog*	*D*	*Class*	*Dyn.Family*
(12210)(1981*EA*42)	16 – *Mar* – 2007	6*x*250	1.30	13.2	18.76	*SA*104335	11		*Datura*
(16598)(1992*YC*2)	17 – *Aug* – 2007	4*x*300	1.28	17.2	20.30	*SA*1112093	2.3	*V*	–
(30173)(2000*GG*72)	17 – *Mar* – 2007	6*x*250	1.20	8.5	18.42	*SA*104335	2.8	*Sq*	(16598)
(31991)(2000*HK*35)	15 – *Mar* – 2007	6*x*250	1.65	10.9	18.68	*SA*104335	2.6	*S*	–
(36305)(2000*JZ*56)	17 – *Mar* – 2007	8*x*300	1.43	12.4	19.25	*SA*104556	2.2	*Sk*	–
(46690)(1997*AN*23)	16 – *Mar* – 2007	6*x*220	1.63	24.9	18.85	*SA*104335	1.7	*Sk/S*	–
(48732)(1997*CM*4)	17 – *Mar* – 2007	8*x*260	1.76	22.3	20.00	*SA*104556	2.7	*V*	–
(49985)(2000*AX*1)	15 – *Mar* – 2007	8*x*240	1.66	21.1	19.06	*SA*104335	2.1	*S/Q*	–
(52349)(1993*FK*15)	17 – *Mar* – 2007	6*x*280	1.10	21.8	19.06	*SA*104335	2.1	*Sq*	–
(53769)(2000*EU*85)	15 – *Mar* – 2007	6*x*250	1.06	18.8	18.70	*SA*104556	2.0	*S/Sl*	–
(54184)(2000*HJ*67)	15 – *Mar* – 2007	6*x*250	1.27	5.3	19.03	*SA*104556	2.2	*Sl*	–
(55373)(2001*SE*240)	17 – *Mar* – 2007	6*x*290	1.38	10.5	19.03	*SA*104556	1.8	*L/S*	–
(56447)(2000*GR*76)	17 – *Mar* – 2007	8*x*250	1.20	16.2	19.09	*SA*104335	1.5	*S*	–
(57409)(2001*RT*120)	15 – *Mar* – 2007	8*x*240	1.07	14.2	19.20	*SA*104556	1.9	*S*	–
(60151)(1999*UZ*6)	15 – *Mar* – 2007	4*x*360	1.80	19.8	20.50	*SA*104335	1.9	*S*	–
(60645)(2000*FU*38)	15 – *Mar* – 2007	8*x*250	1.60	15.3	19.24	*SA*104335	1.7	*Sk*	*Datura*
(80279)(1999*XP*33)	17 – *Mar* – 2007	8*x*240	1.80	25.4	19.03	*SA*104456	2.2	*S*	–
(85715)(1998*SB*54)	17 – *Mar* – 2007	8*x*250	1.27	2.3	19.23	*SA*104335	2.4	*Sl*	–
(86863)(2000*HY*14)	17 – *Mar* – 2007	8*x*310	1.00	20.1	19.73	*SA*104335	1.8	*S*	–
(90127)(2002*XE*81)	16 – *Mar* – 2007	10*x*280	1.90	19.1	19.40	*SA*104335	2.1	*X*	–
(90265)(2003*CL*5)	15 – *Mar* – 2007	2*x*250 + 8*x*300	1.20	8.2	19.30	*SA*104335	1.9	*V*	–
(203370)(2001*WY*35)	02 – *Sep* – 2007	4*x*300	1.09	29.9	21.50	*SA*1112093	2.1	*Sq*	*Datura*
(209570)(2004*XL*40)	20 – *Aug* – 2007	4*x*280	1.28	15.6	20.40	*SA*1112093	0.8	*O/Q*	*Datura*
							1.0	*Sq*	*Lucascavin*

Results

- Q-type objects found in very young asteroid families, and among small asteroids



They had their surfaces "refreshened" in recent break-ups (times smaller than the space weathering timescales)

- OC mineralogies seem as frequent in NEAs as in the small sizes (~ 30 %)

But this needs confirmation from NIR!

Conclusions

- Studies of minor bodies of the Solar System broadly benefit from observations made with GEMINI telescopes, as now we urge to study smaller objects (D < 5 km), and/or objects which are far away.
- With GEMINI we can observe small bodies up to M_V 23!
- What do we need: Low Resolution spectroscopy
  - GMOS Visible spectra helps to taxonomically classify objects, but...
  - ... **Low resolution NEAR-INFRARED spectra (0.8 – 2.5 microns) is essential to determine mineralogy!**

Publications with GEMINI + Gmos data:

- Mothe-Diniz & Nesvorný. 2008. Tirela: an unusual asteroid family in the outer main belt. A&A. 492, 593
- Mothe-Diniz & Nesvorný. 2008. Visible spectroscopy of extremely young asteroid families. A&A 486L, 9.
- Mothe-Diniz et al. 2009. Search for OC mineralogies among small main belt asteroids. (in preparation)