Compositional properties of the “small” near-Earth asteroids: results from the NEOShield-2 project

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European Commission
Horizon 2020
European Union funding
for Research & Innovation

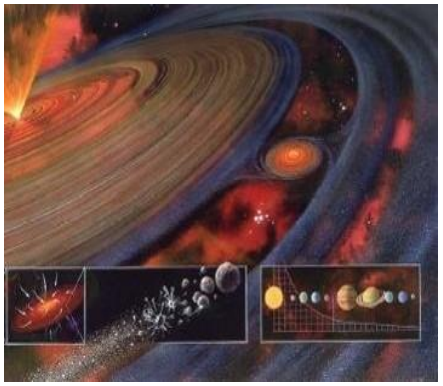
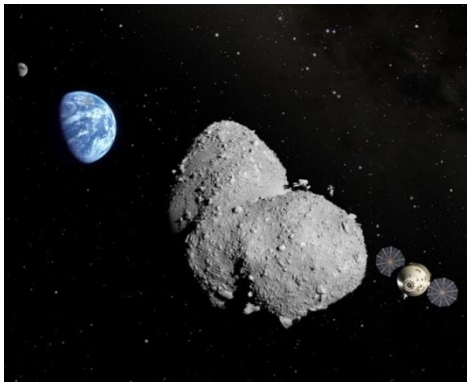
NEOShield-2

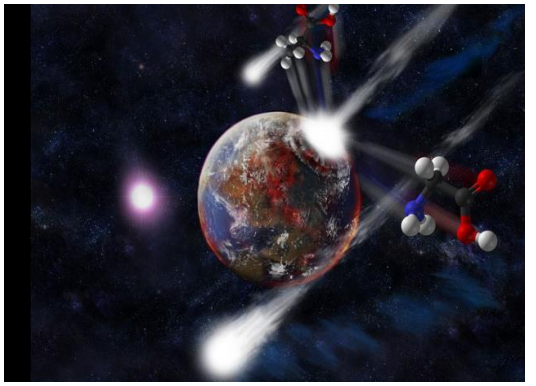
Why near-Earth asteroids do matter

- The closest building blocks of the solar system
  - ✓ Relevant for the origin of prebiotic material on the early Earth
  - ✓ Study of small-sized asteroids

- Accessible targets for space missions
  - ✓ Science
  - ✓ Water/mineral resources

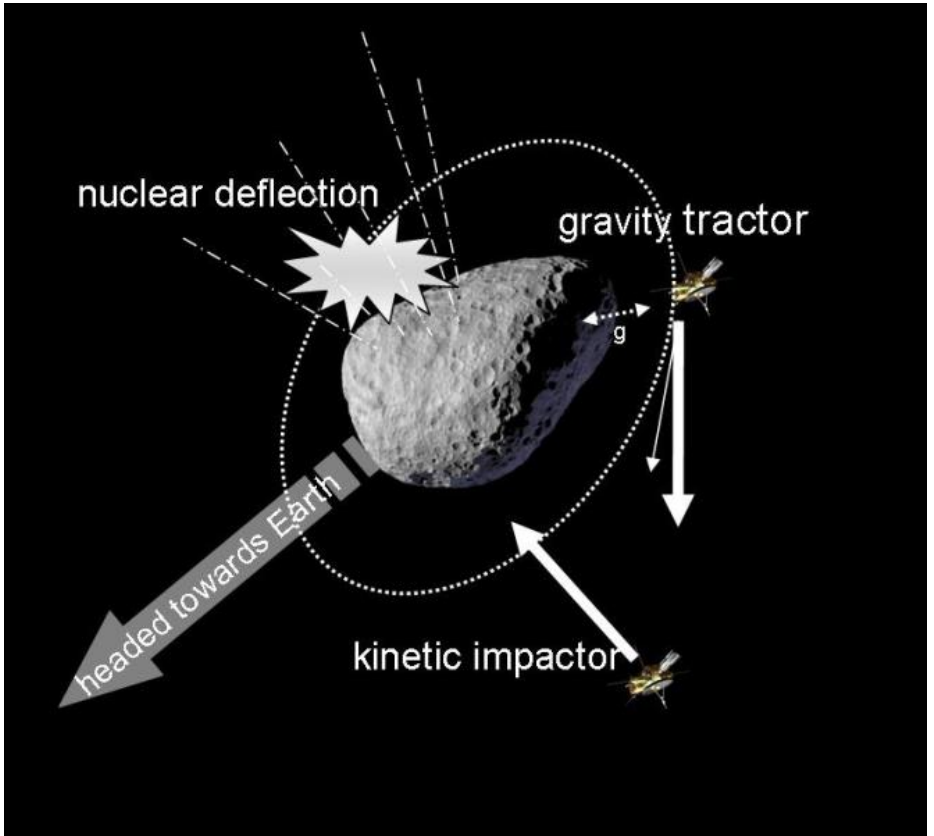
- Planetary defense



The first NEOShield project (Jan 2012 – May 2015)

- Consortium of 13 partners from 6 countries
- Response to the European Commission's FP7 call "Prevention of impacts from near-Earth objects (NEOs) on our planet"
- Funding by the European Commission: 4.0 Meuro
- Science, technology development, response planning
- Detailed study of 3 deflection techniques:



Participant organisation	Country
DLR, Berlin *Coordinating partner*	Germany
Observatoire de Paris (LESIA and IMCCE)	France
CNRS (Obs. Côte d'Azur)	France
Open University	UK
Fraunhofer – EMI	Germany
Queen's Univ. Belfast	UK
Airbus D&S	Germany France UK
Deimos Space	Spain
Carl Sagan Center, SETI Inst.	USA
TsNIIMash (Roscosmos)	Russia
Univ. of Surrey	UK

The NEOShield-2 project (Mar 2015 – Sep 2017)

Horizon 2020
European Union funding
for Research & Innovation

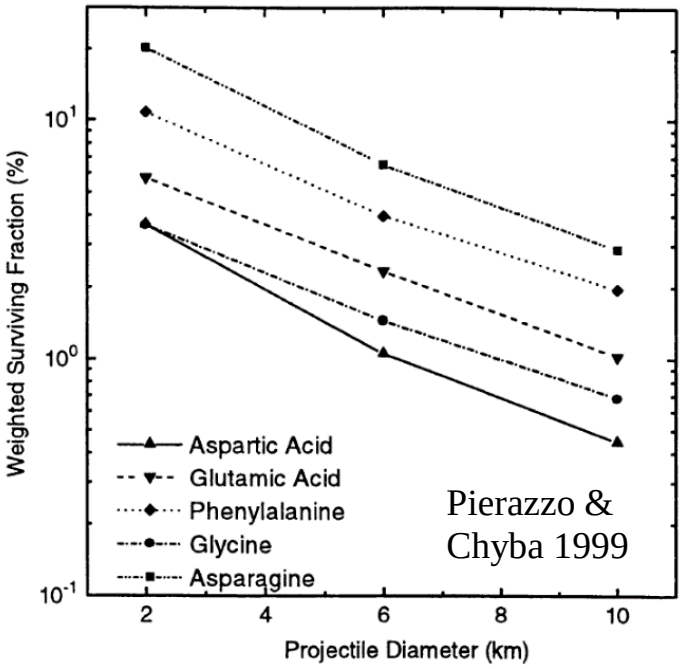
- Consortium of 11 partners from 5 countries
- Response to the European Commission's H2020 call "Access technologies and characterisation for Near Earth Objects (NEOs)"
- Funding by the European Commission: 4.2 Meuro
- Two specific challenges:
  - ✓ Technology development for GNC and material sampling
  - ✓ Physical characterization of NEOs (in particular, 50-300 m size range)
    - WP10: NEO Observations and data reduction/analysis

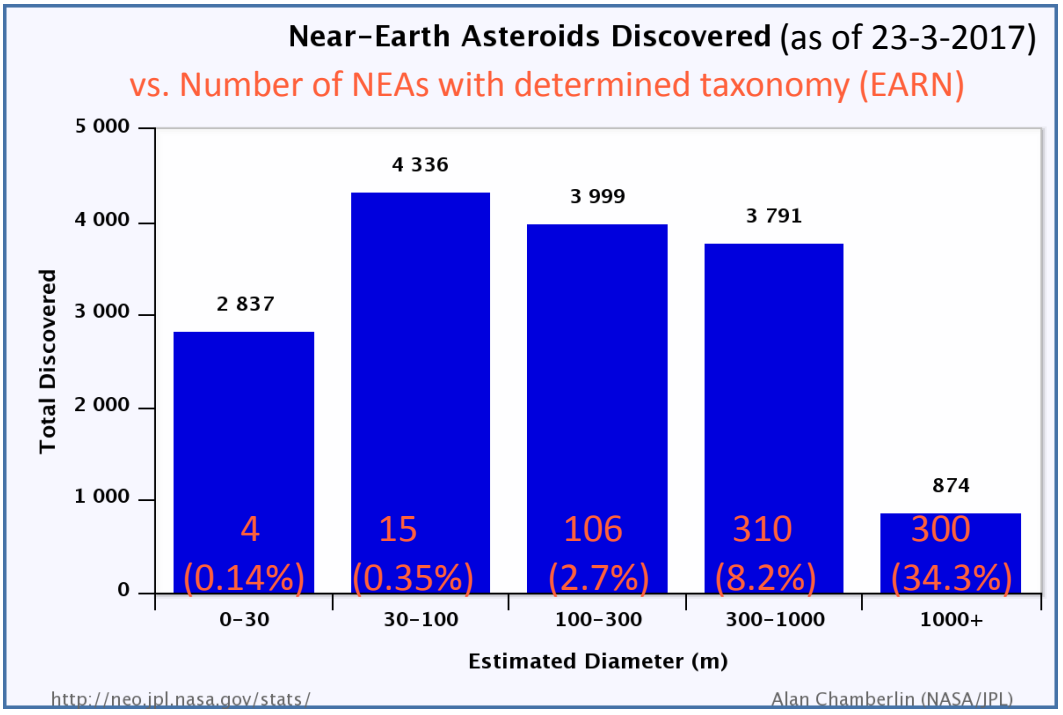
      LESIA: Reflectance spectroscopy
      INAF: Photometric colours & phase functions
      IMCCE: Light-curves
      CNRS: Thermal IR
      QUB: Precovery
      DMS: Support tools / Database

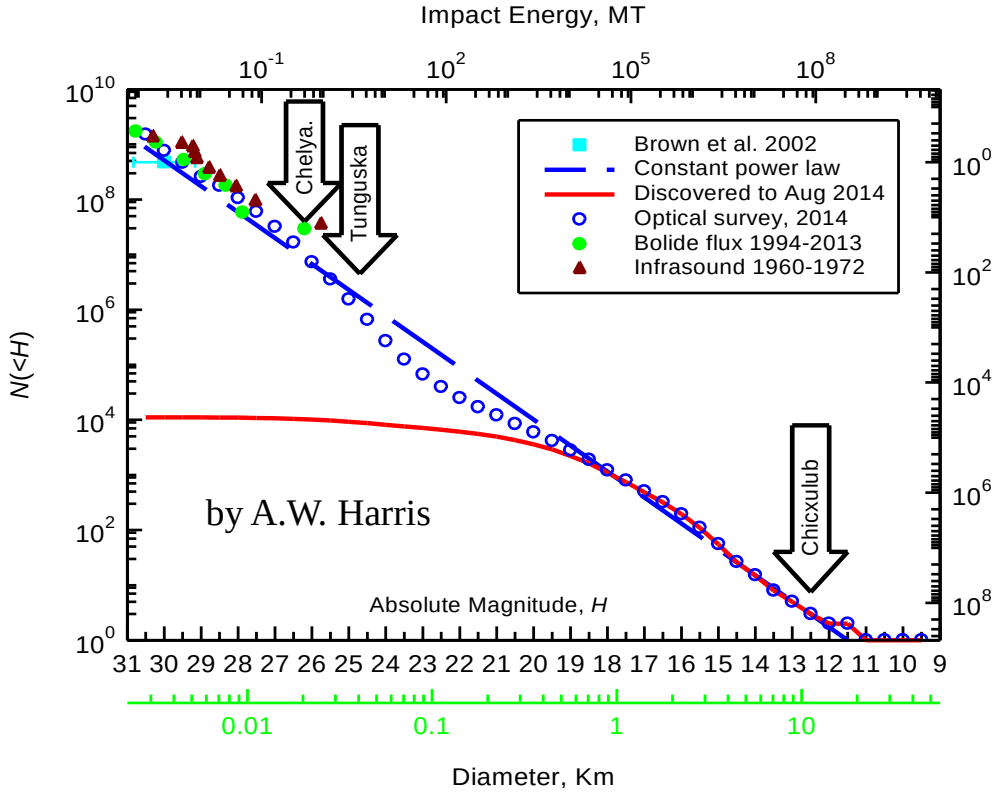
Participant organisation	Country
Airbus D&S *Coordinating partner (D)*	Germany France UK
DLR, Berlin	Germany
Observatoire de Paris (LESIA and IMCCE)	France
CNRS (Obs. Côte d'Azur)	France
INAF	Italy
Fraunhofer – EMI	Germany
Queen's Univ. Belfast	UK
Deimos Space	Spain
GMV A&D	Spain

Why to study the small NEA population?

- Most probable hazard in the near future
- Water and organics better preserved in “small” impacts
- Opportunity to study size-dependent physical properties
- Extremely poorly known
  (characterized << discovered << estimated)

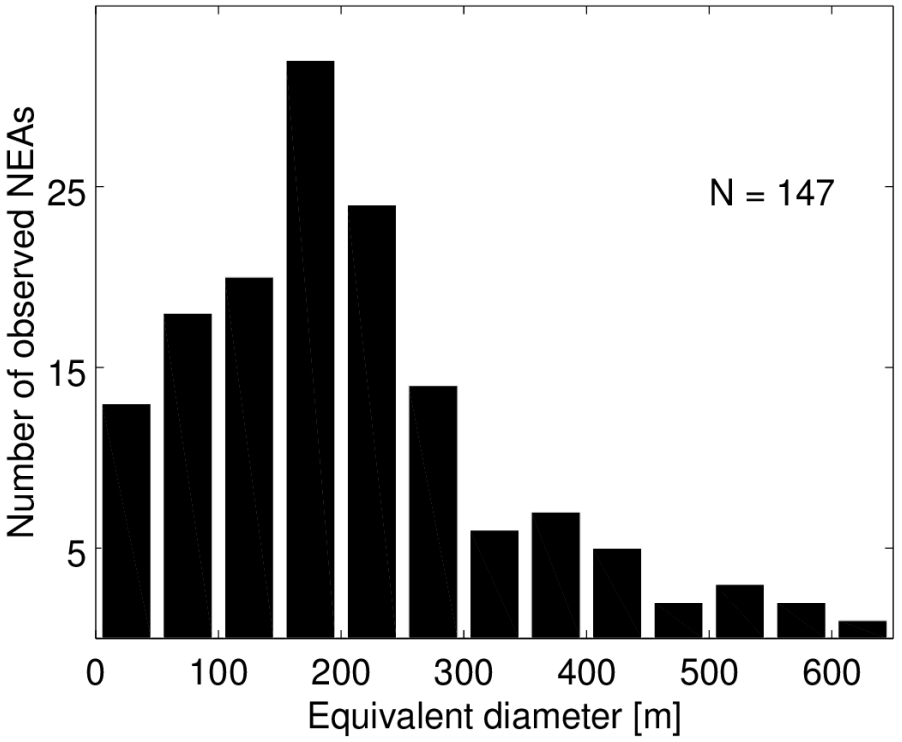




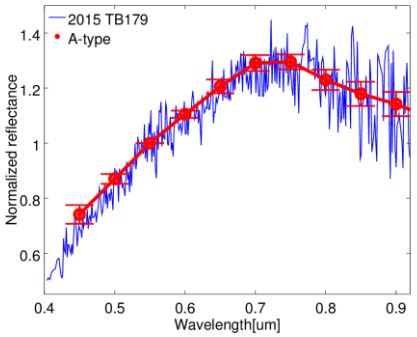


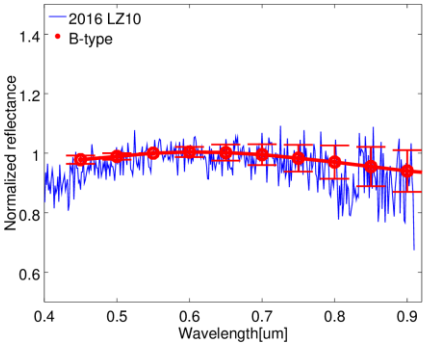
Guaranteed Time Observations of small NEAs @ ESO-NTT

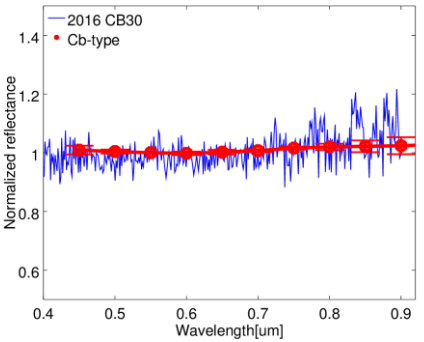
- 30 observing nights over 4 semesters (4/2015 – 3/2017)
- Most of our targets were observed soon after their discovery
- 147 small NEAs characterized by visible spectroscopy (homogeneous sample!)

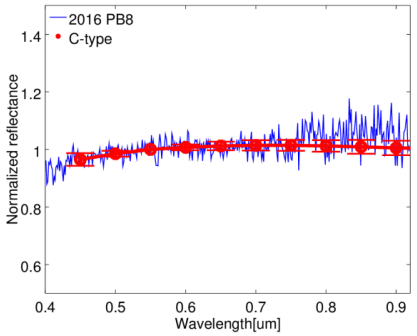


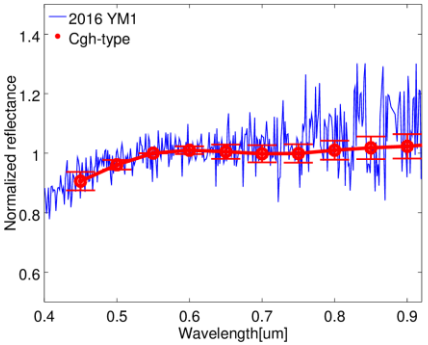
Small NEAs @ ESO-NTT: taxonomic classification

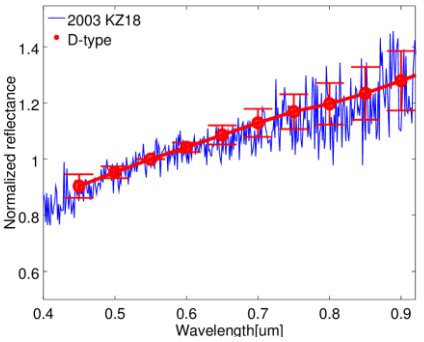


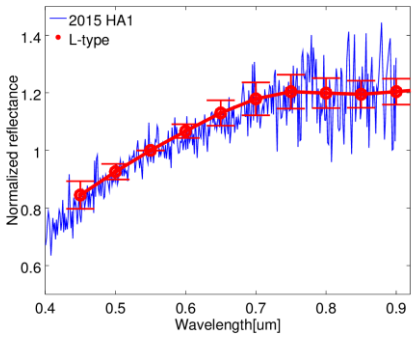


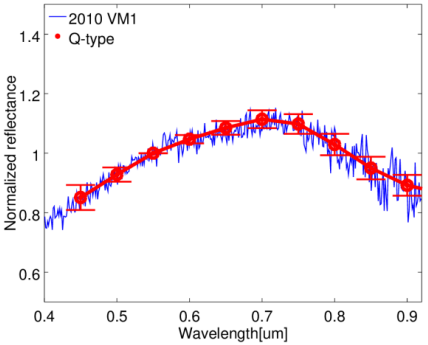


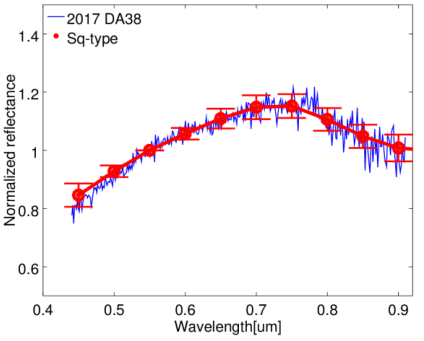


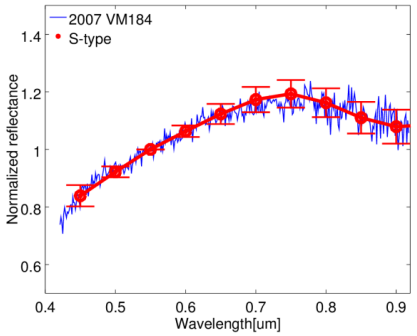


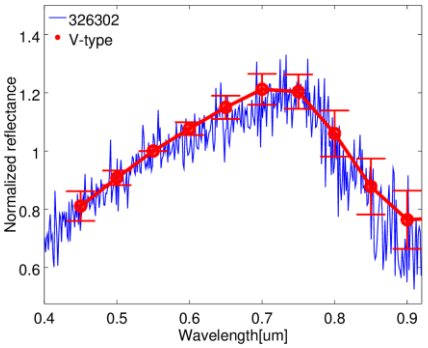


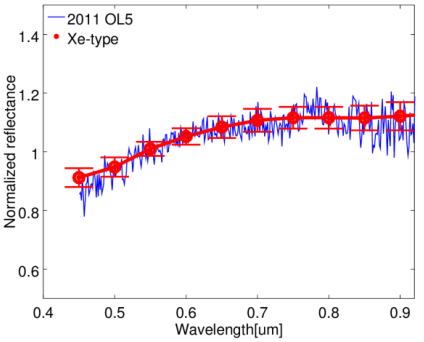




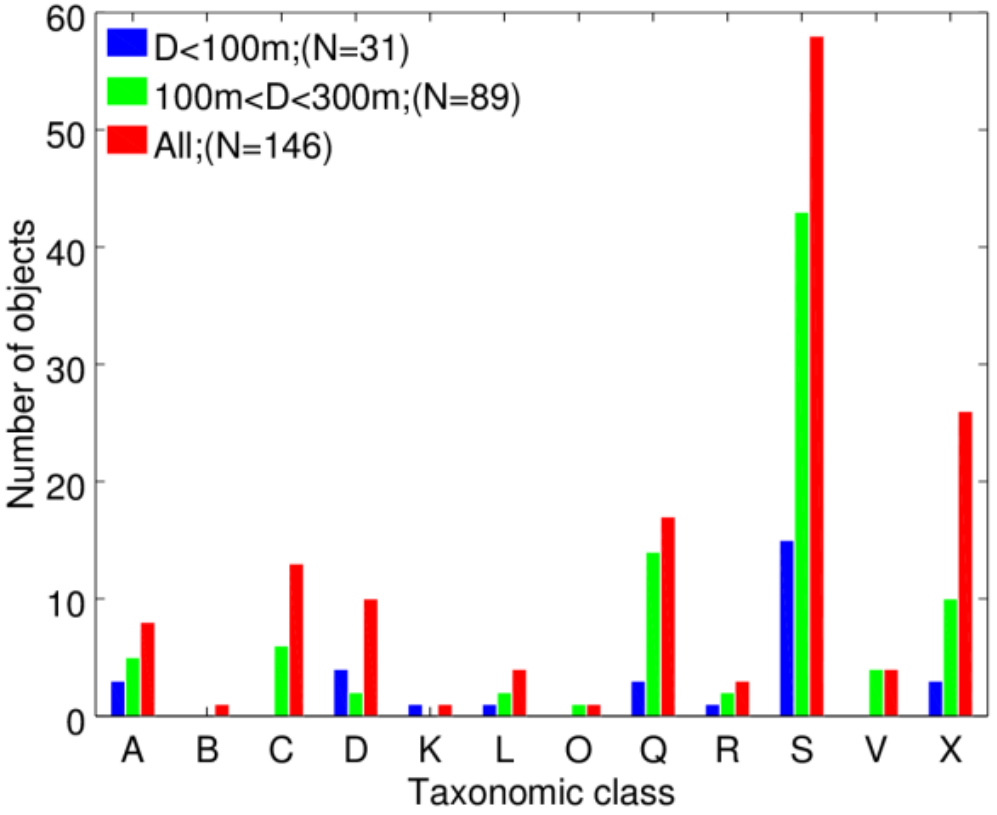


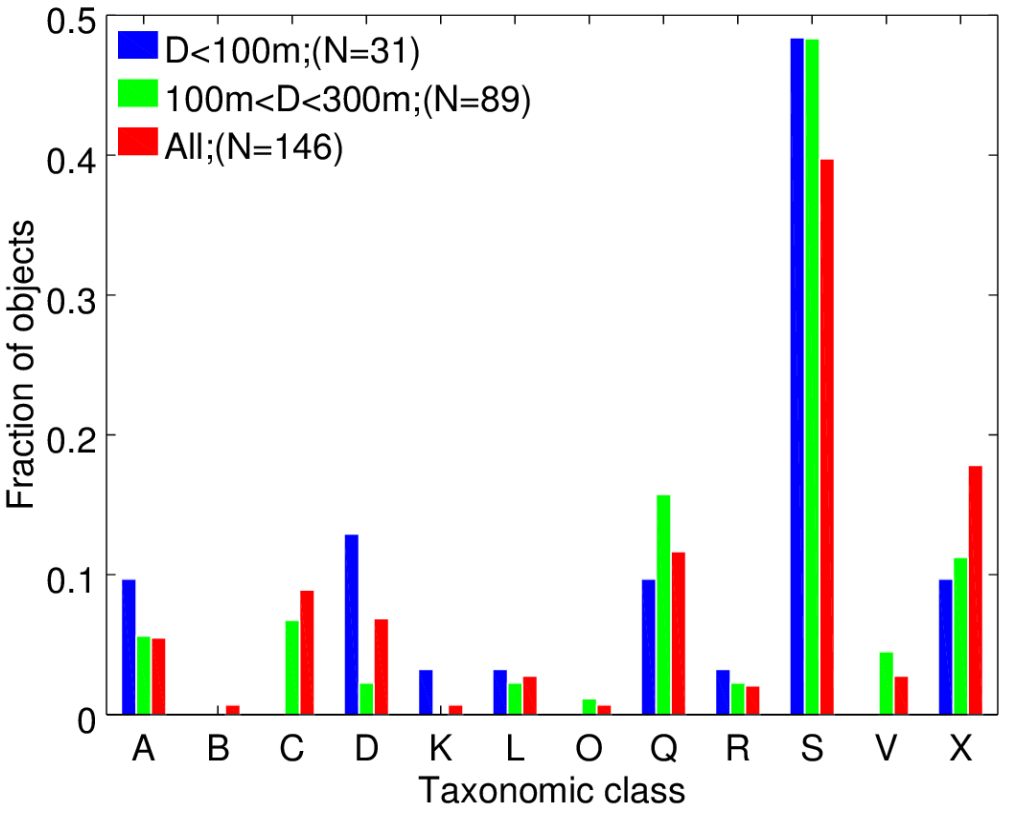






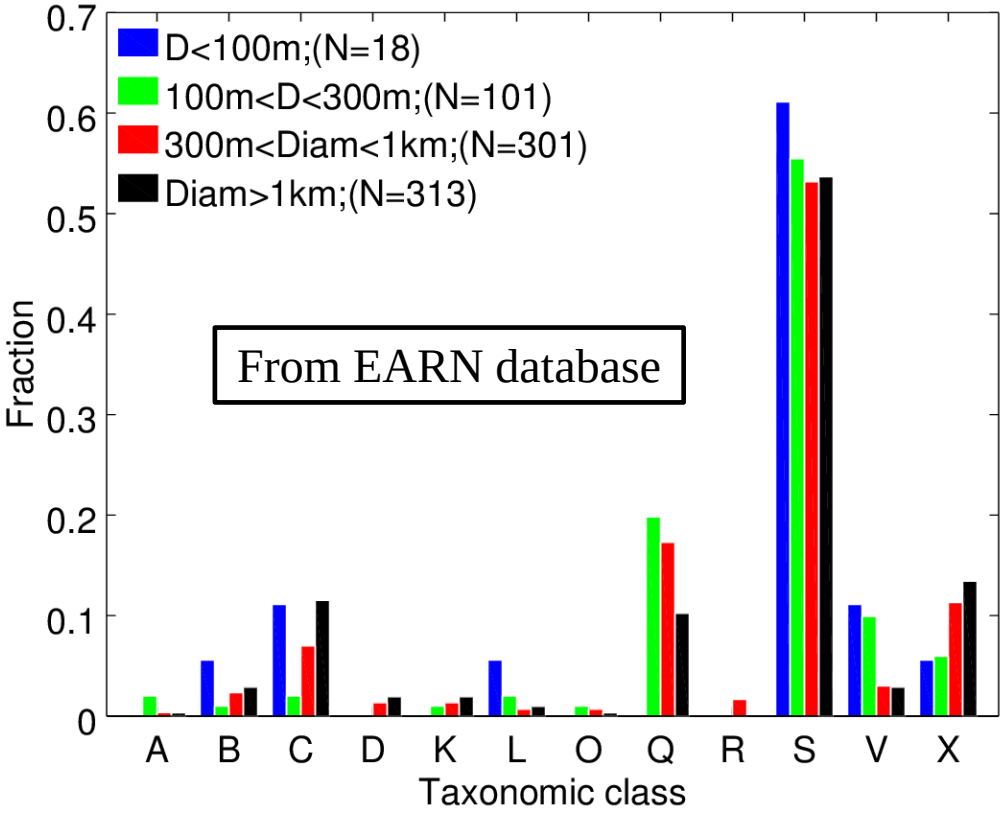
Small NEAs @ ESO-NTT: taxa distribution

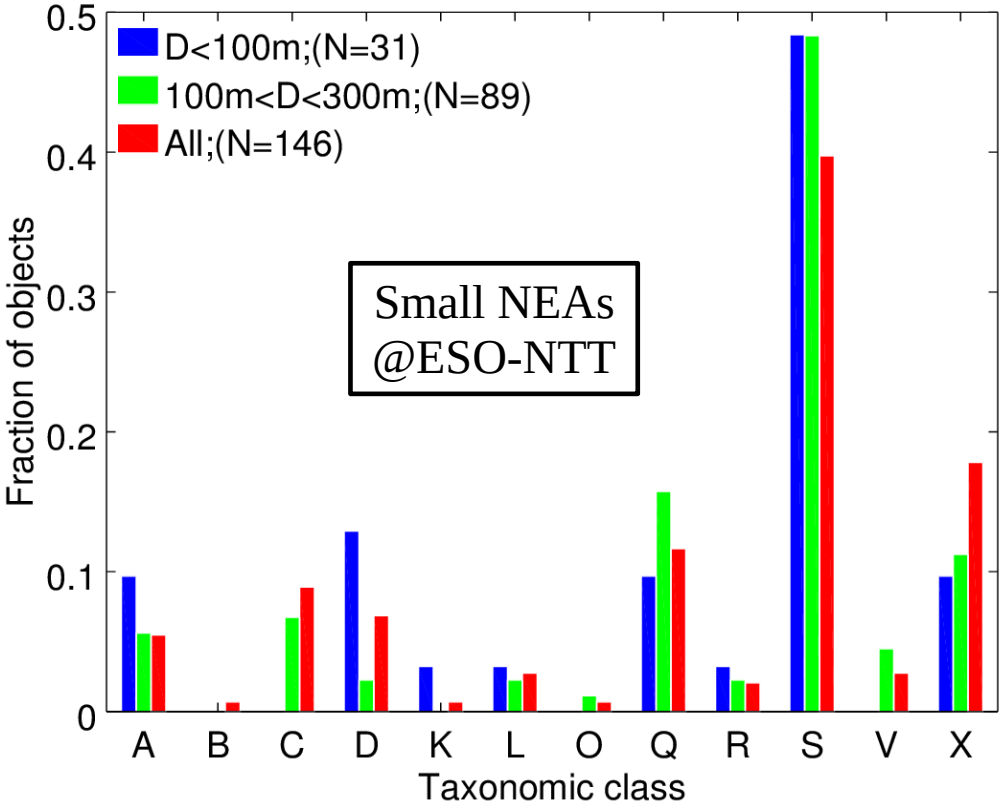




- Targets selected by H ≥ 20 → Larger objects are low albedo ones
- Bias against very small low albedo objects

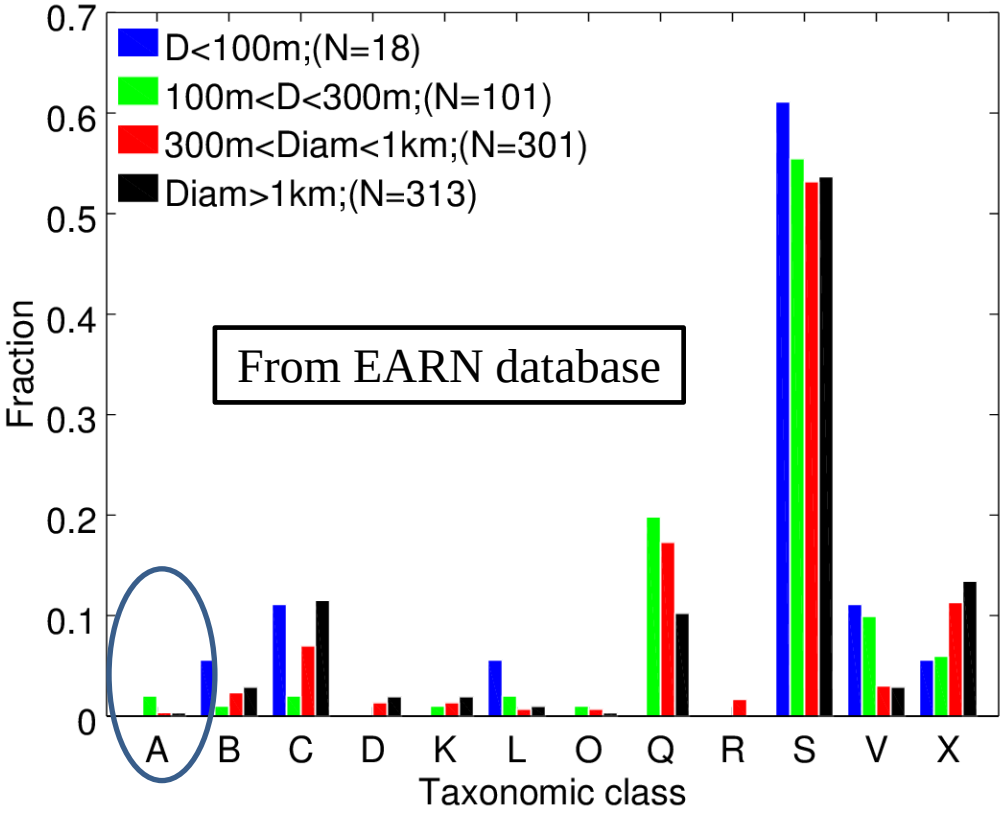
Small NEAs @ ESO-NTT: taxa distribution (vs. literature)

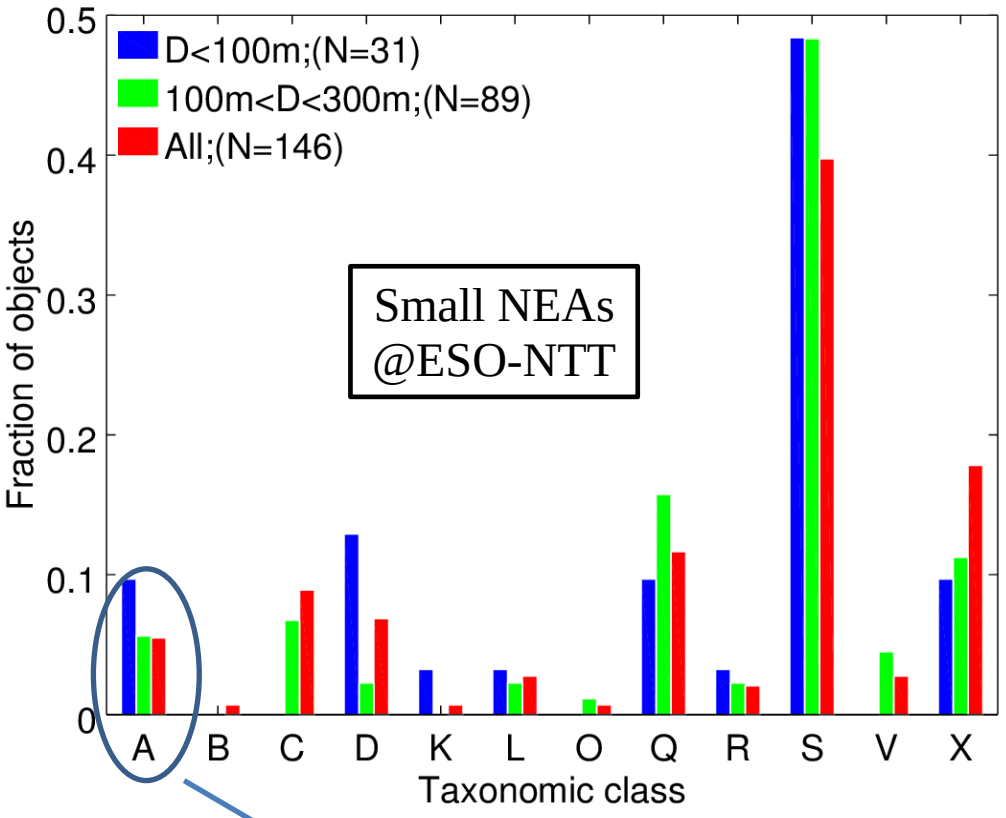




Taxon	A	B	C	D	K	L	O	Q	R	S	V	X
Our sample (%)	5.48 (8/146)	0.68 (1/146)	8.90 (13/146)	6.85 (10/146)	0.68 (1/146)	2.74 (4/146)	0.68 (1/146)	11.64 (17/146)	2.05 (3/146)	39.73 (58/146)	2.74 (4/146)	17.81 (26/146)
146-unit random samples from EARN database (%) [±1σ]	0.47± 0.56	2.45± 1.27	8.38± 2.26	1.38± 0.97	1.49± 0.99	1.09± 0.87	0.54± 0.61	14.23± 2.86	0.68± 0.67	53.94± 4.11	4.10± 1.62	11.25± 2.61
Deviation (σ)	+8.9	-1.4	+0.2	+5.6	-0.8	+1.9	+0.2	-0.9	+2.0	-3.5	-0.8	+2.5

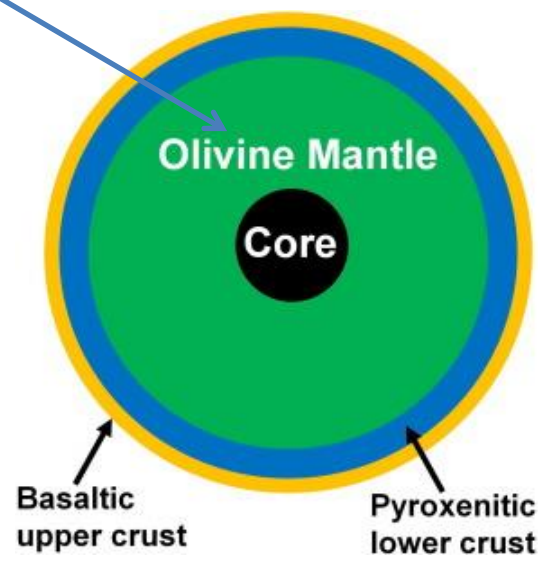
Small NEAs @ ESO-NTT: taxa distribution (vs. literature)



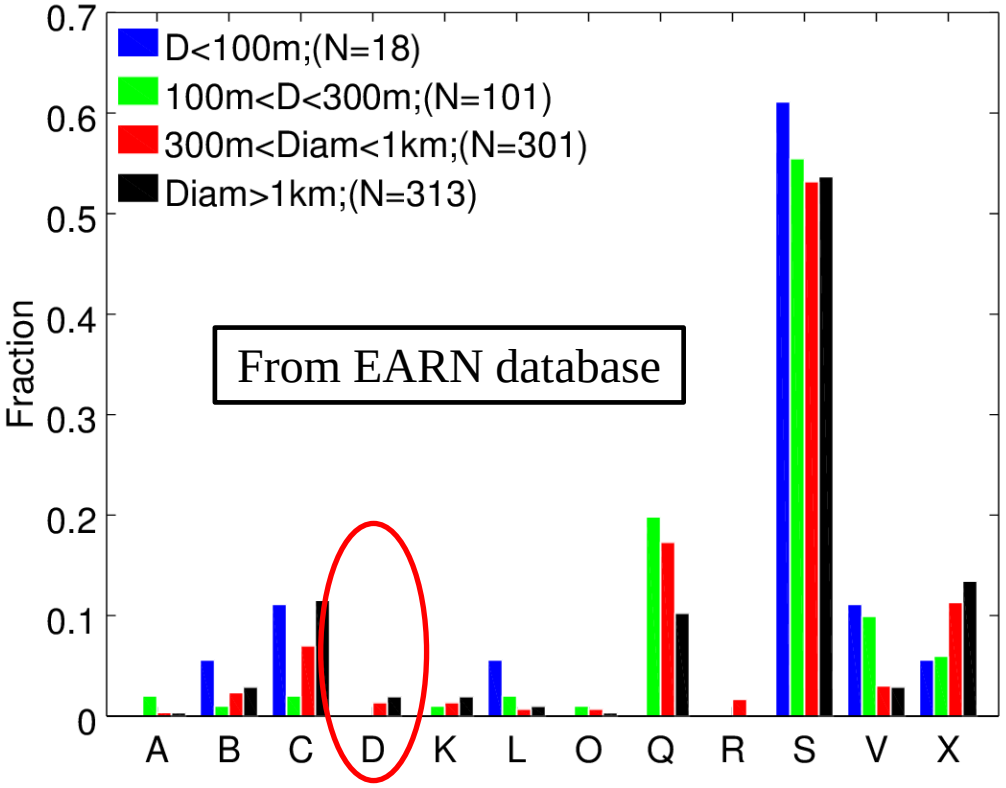


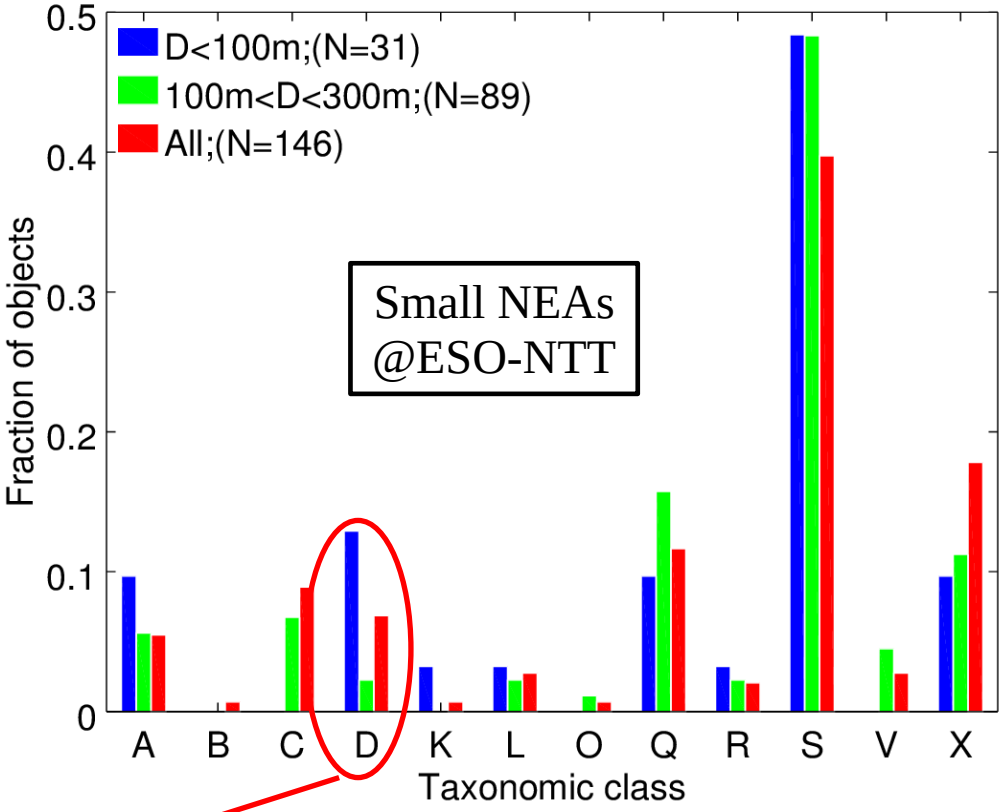
Could support:

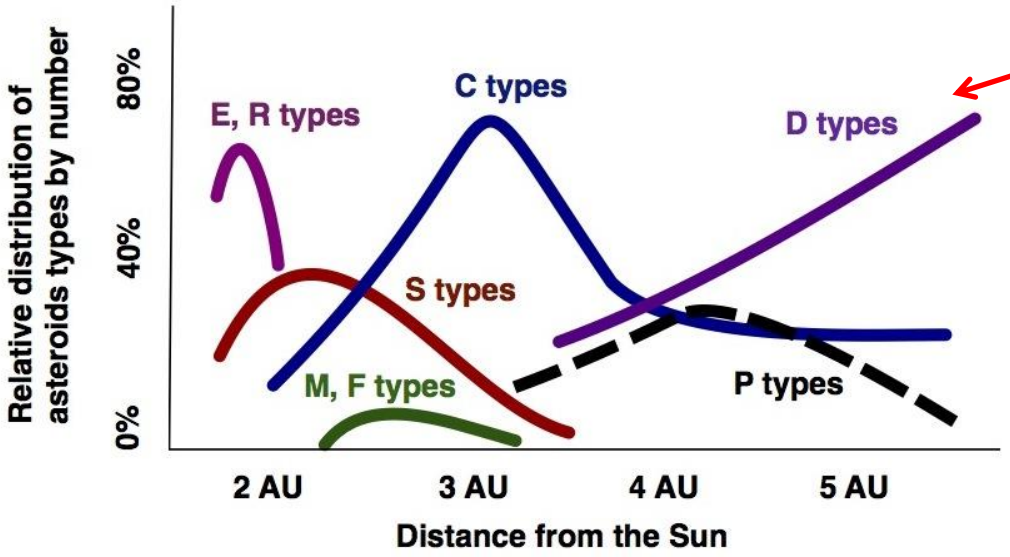
- "Battered to bits" scenario (e.g., Burbine et al. 1996)
- Exogenous origin of olivine outcrops on Vesta (e.g., Turrini et al. 2016)



Small NEAs @ ESO-NTT: taxa distribution (vs. literature)

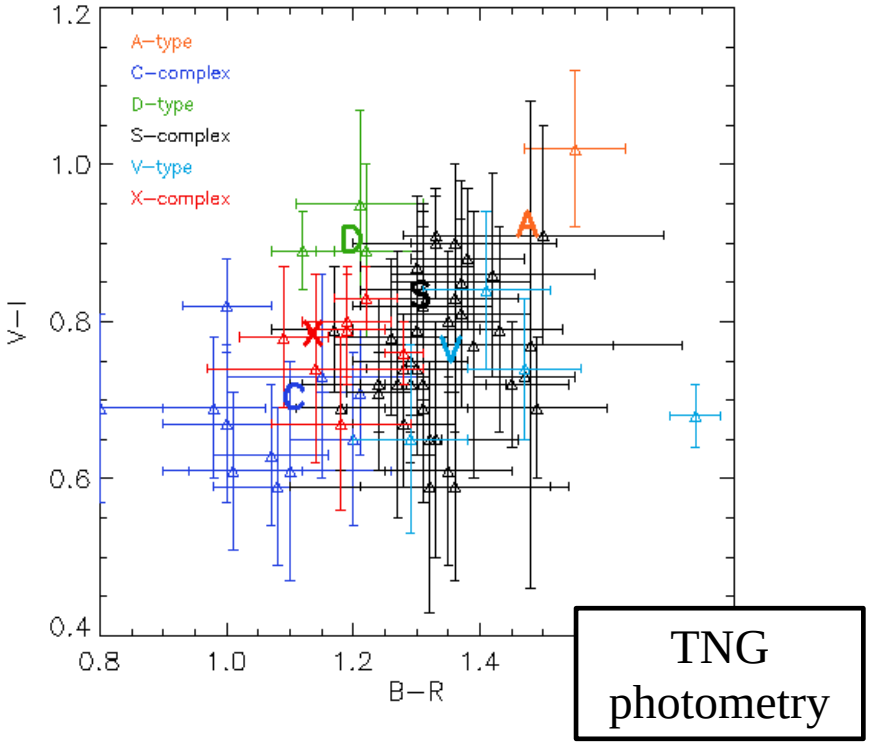


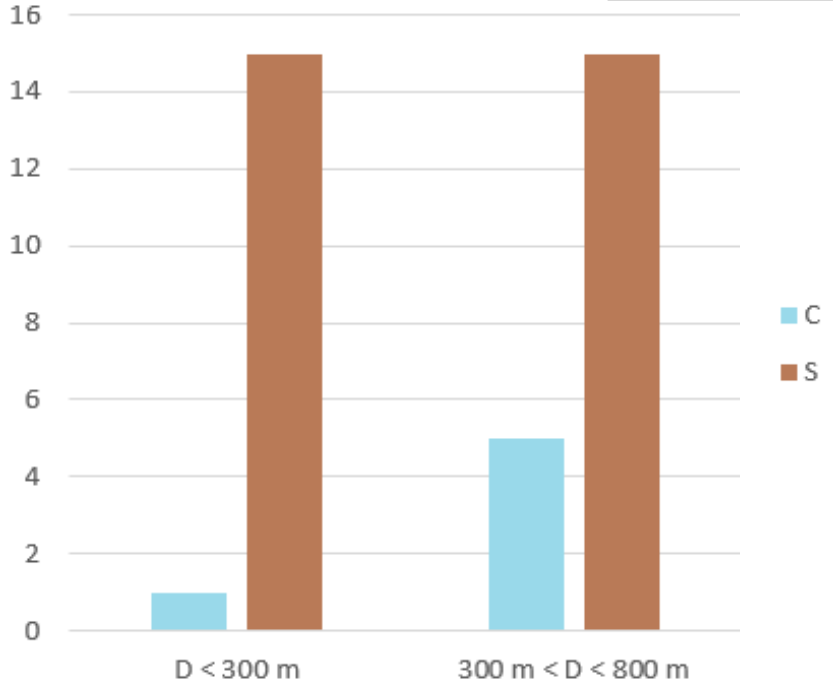


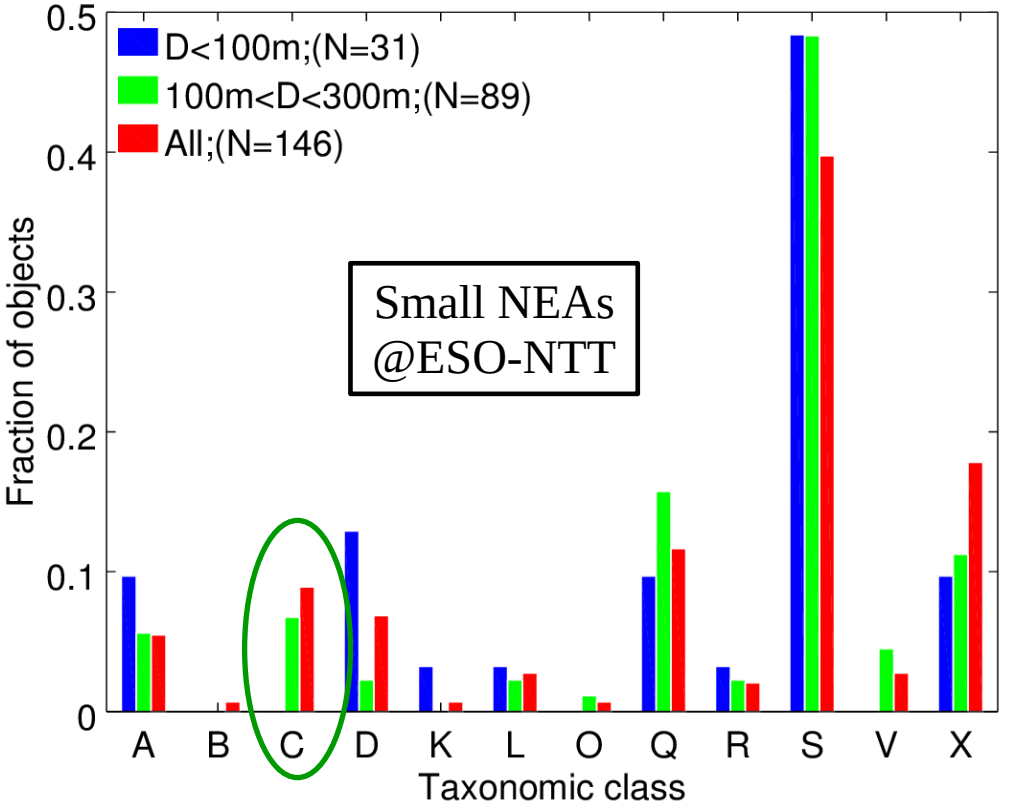


- Asteroidal contribution to the terrestrial prebiotic material could be even more important than foreseen
- Waiting for a sample return mission from a D-type asteroid…

Few small C-types

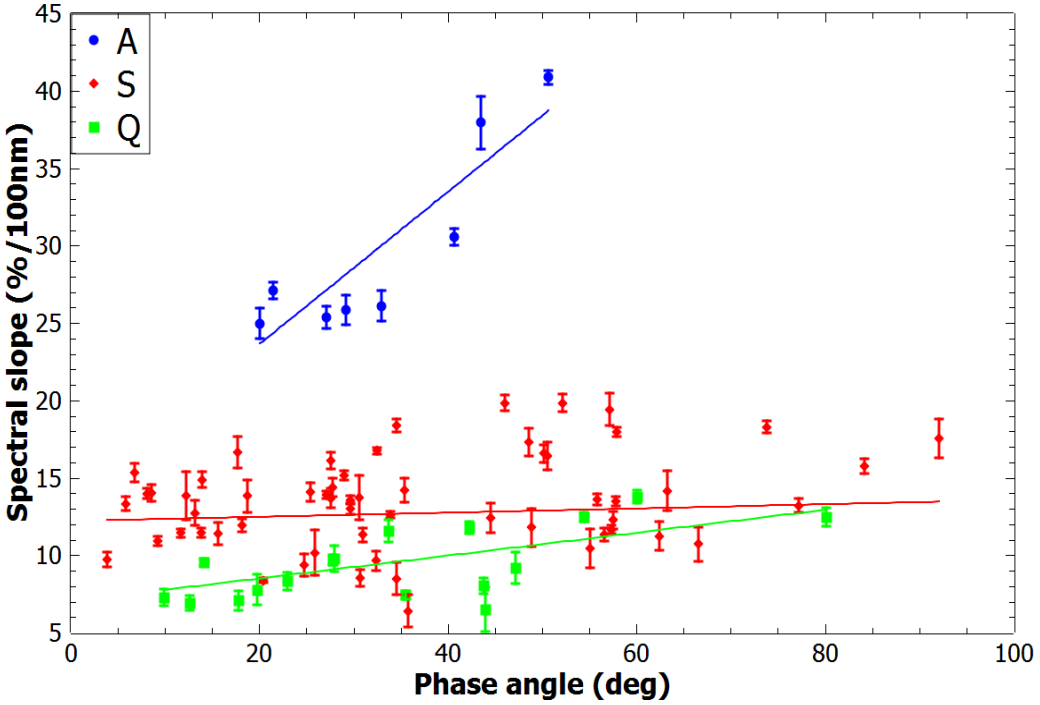


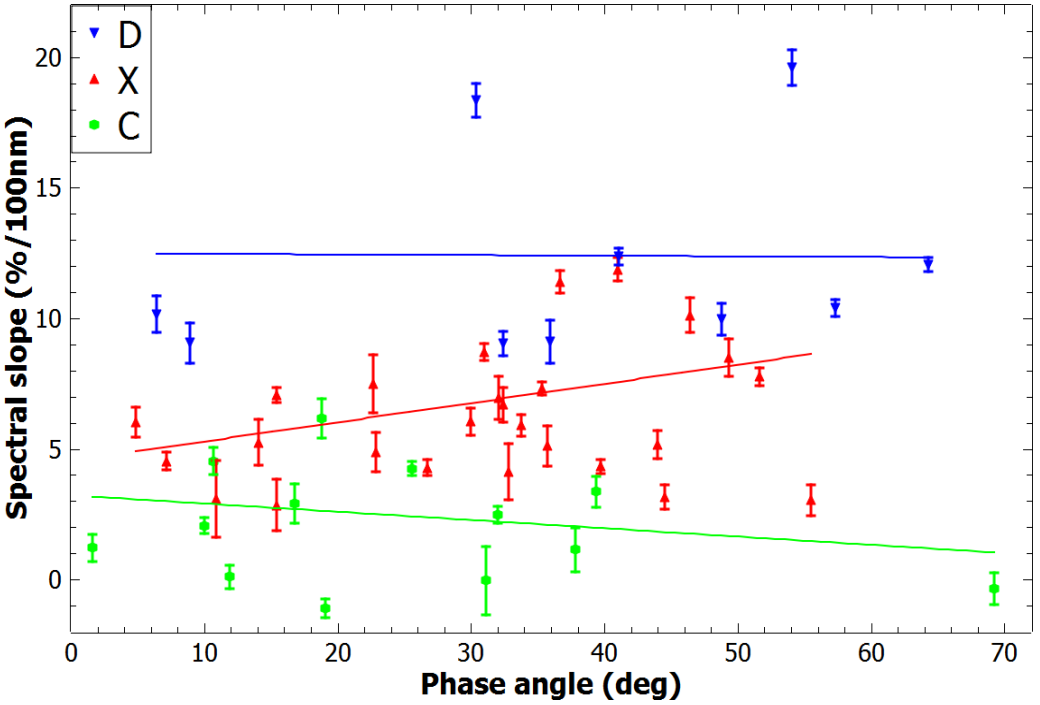




- Just an observational bias?
- YORP-induced disaggregation of small rubble piles?
  - ✓ Scheeres (2017): S-types could fragment more into “monolithic constituents” than C-types (possible dryness effect)

Small NEAs @ ESO-NTT: phase reddening





Taxon	Phase angle range (deg)	Number of objects	γ (%/100 nm/deg) [0.44-0.65 μm]
A	20-51	8	0.492±0.072
Q	10-80	17	0.074±0.018
S	4-92	58	0.013±0.009
X	5-56	26	0.074±0.021
D	6-64	10	-0.024±0.027
C	2-69	13	-0.032±0.030

Summary

Within the "small" NEA population we find:

- Many A-types (towards a solution of the "missing olivine problem"?)
- Many D-types (potential source of prebiotic material?)
- Few C-types (less efficient YORP-induced fragmentation?)

- Distinctive phase reddening for different taxonomic types

For more information:

- Perna et al. 2017, A&A 597, A57
- Perna et al. 2018, P&SS, under revision
- Popescu, Perna et al. 2018, MNRAS, under revision
- Barucci, Perna et al. 2018, MNRAS, under revision
- Ieva, Dotto, Mazzotta Epifani, Perna et al. 2018, A&A, submitted

(and further papers will follow…)

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