Spectral properties of near-Earth asteroids on cometary orbits

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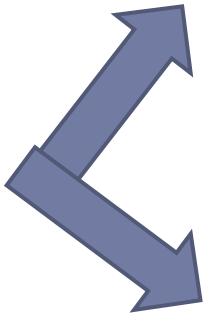
Asteroids or comets?

- The asteroids in cometary orbits (ACOs) are observationally asteroids and dynamically comets.
- The active, dormant and dead comets are very dark, often reddish, objects , with spectra similar to D, P, and C-type asteroids of the outer Solar System with albedo and colors probably controlled by carbonaceous dust containing reddish organic compounds.

Dynamically (e.g. Kresák 1967, Vaghi,1973):

$$T_J = \frac{a_J}{a_{\rm obj}} + 2\cos(i_{\rm obj})\left[\frac{a_{\rm obj}}{a_J}\left(1-e_{\rm obj}^2\right)\right]^{1/2}$$



TJ>3 – most asteroids

TJ<3 – most comets

TJ - Tisserand's parameter with respect to Jupiter

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Cometary orbit

To avoid objects with stable dynamical evolution incompatible with the chaotic dynamics of comets, Tancredi (2014) presented an extended criterion to identify ACOs.

It ensures the selection of objects with a dynamical evolution similar to the population of periodic comets. Tancredi's criterion is based on:

i. Tisserand's parameter

ii. the MOID among the giant planets

iii. some information regarding the aphelion and perihelion distances

iv. does not include objects in mean-motion resonances

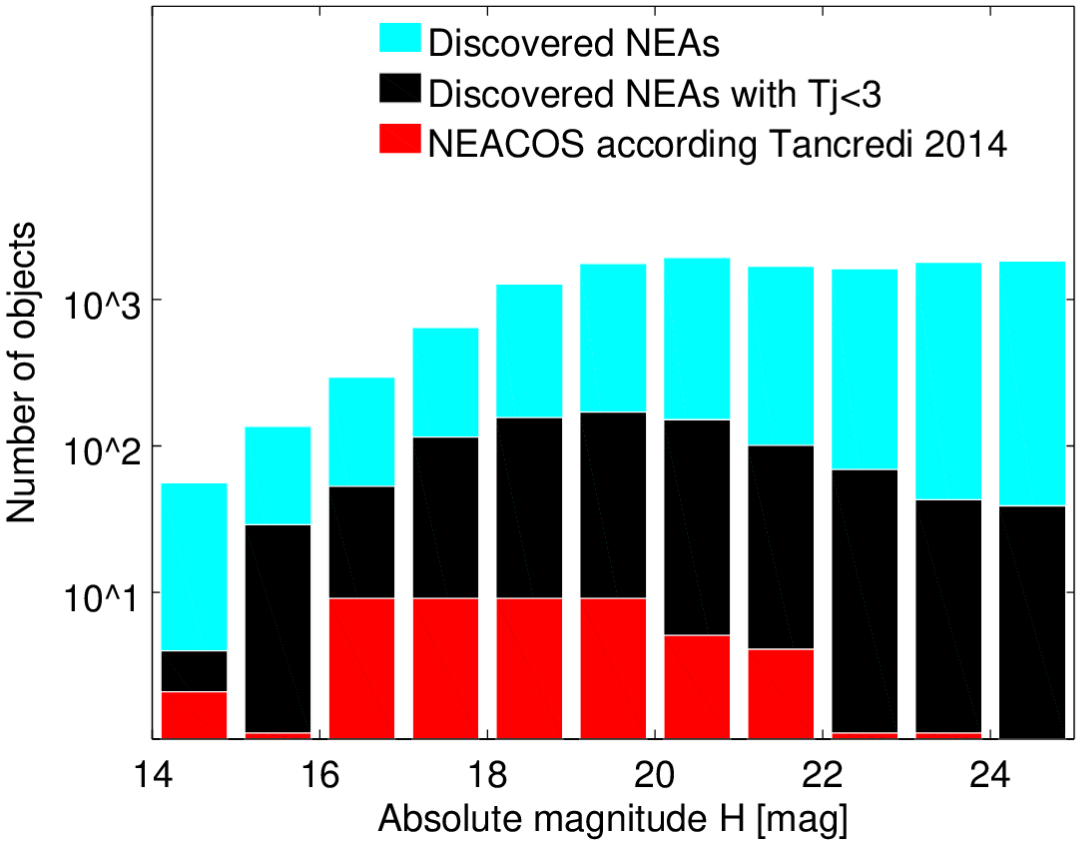
v. does not include objects with large TJ uncertainties

Near-Earth Asteroids with TJ<3

We aim to characterize the spectral properties of near-Earth asteroids with TJ<3. We seek to correlate these properties with their dynamical behavior.

Key questions:

- how many end-state comets are among the NEAs population?
- what are the source regions for this peculiar population?
- how space-weathering affects these objects on very elongated orbits?



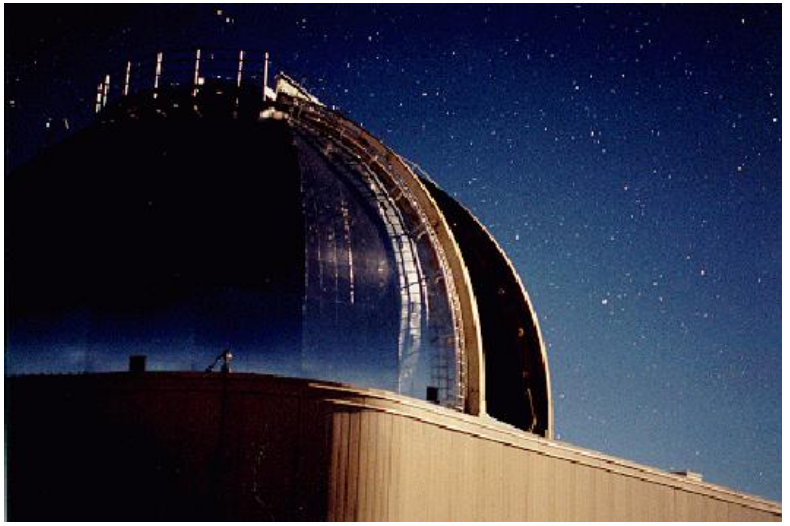
New spectral observations

- Visible spectra (0.4-0.9 μm)

Isaac Newton Telescope (INT)
IDS longslit spectrograph with the R150V diffraction element and the RED2+ camera.

- Near-infrared spectra (0.8-2.5 μm)

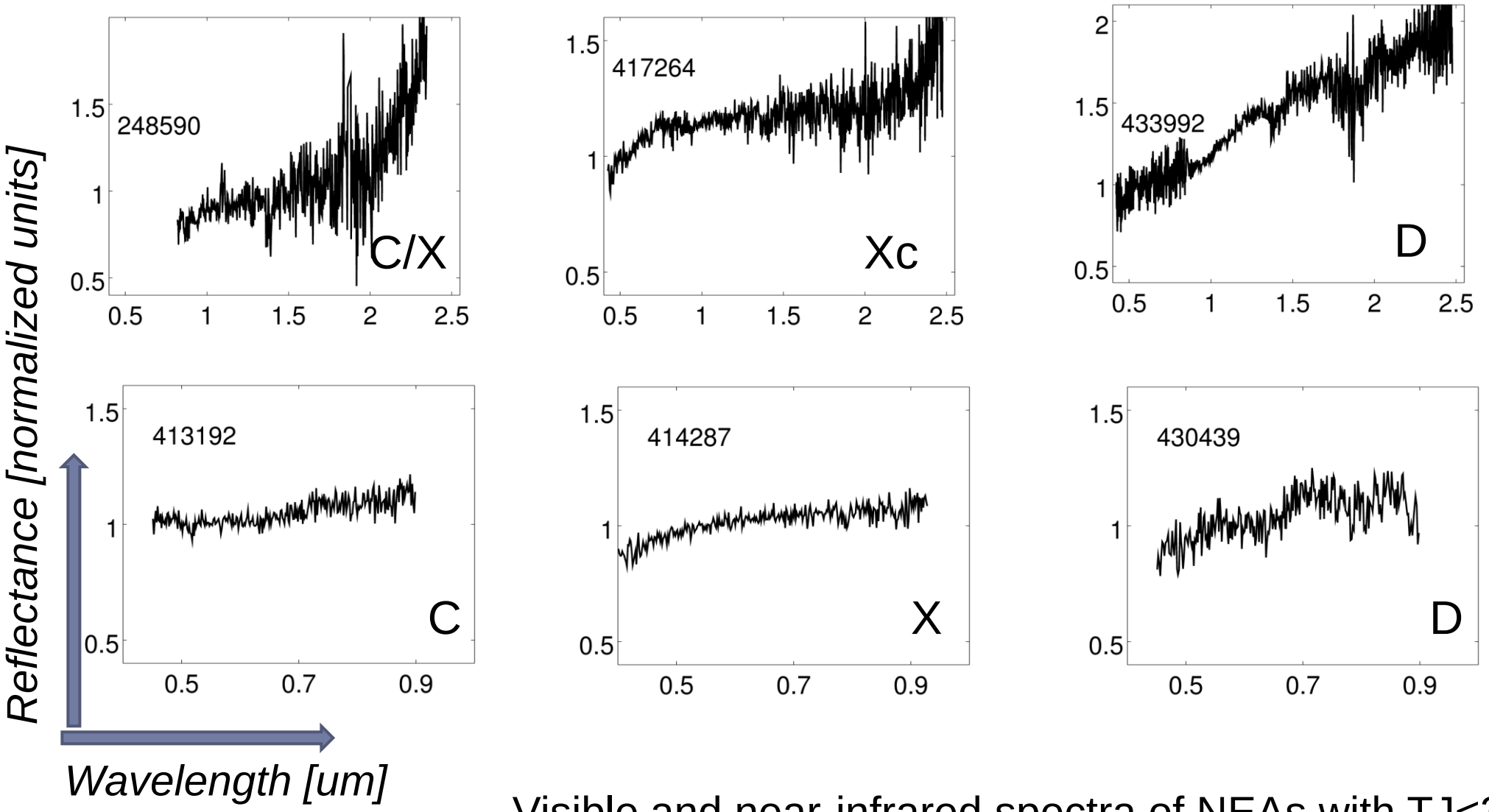
NASA Infrared Telescope Facility (IRTF) / SpeX instrument, with the 0.8x15" slit, in the low resolution prism mode



Results

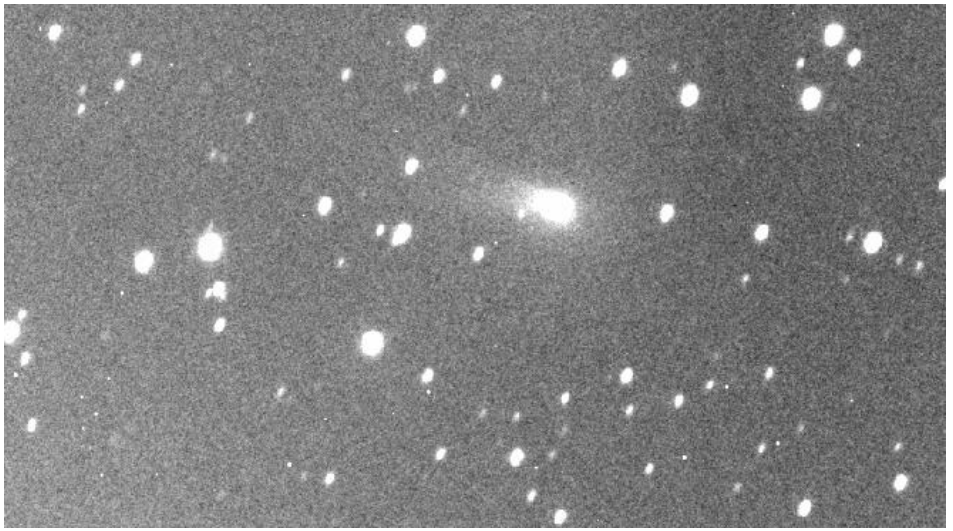
Number	TJ	Spectrum	Tax. Type	pv	H	q[AU]	Q[AU]	i[°]
2007VA85	0.418	nir	D	-	-	1.12	7.33	132
466130	2.367	nir	R/Sr	-	18.2	0.98	4.00	75
248590	2.441	nir	C/X	0.02	16.5	0.88	4.94	52
433992	2.566	vis+nir	D	0.16	18.0	1.17	4.66	49
414287	2.619	vis+nir*	X	-	17.7	0.78	5.64	14
450160	2.689	nir	S	-	16.7	0.81	4.06	57
413192	2.779	vis	C	0.02	16.8	1.11	5.38	9
1998 GL10	2.788	vis	X	-	19.0	1.05	5.29	9
442037	2.816	vis+nir*	Cg	0.07	19.3	0.92	4.94	18
2015 XB379	2.820	vis+nir	L	-	19.1	1.15	5.24	8
214088	2.845	vis+nir	Sq	0.25	15.3	0.88	4.89	13
2015 WH9	2.880	vis	Xk	-	18.6	1.30	5.03	11
430439	2.929	vis	D	-	19.8	1.21	4.71	16
9400	2.940	vis	Sq	-	14.9	1.09	4.09	36
293054	2.945	vis	S	-	18.4	0.59	4.48	6
2015 CA1	2.960	vis	T	-	20.6	1.10	4.64	11
2011 YB40	2.985	vis	Q	-	19.1	1.05	4.08	33
416071	2.993	vis+nir	Sr	-	17.9	1.02	4.32	22
417264	2.997	vis+nir	Xc	-	17.2	1.09	4.33	21

Cometary-like spectra: 11/19 NEAs(58%)

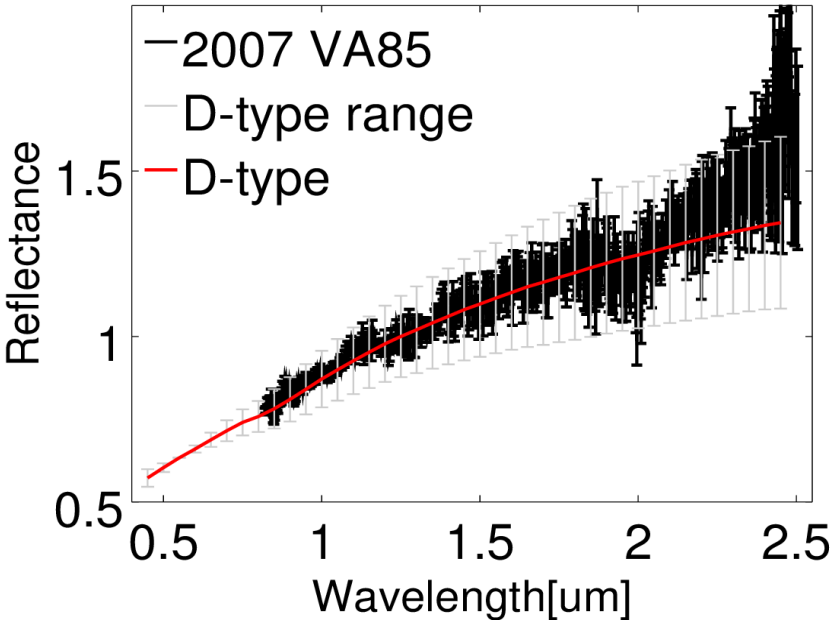


Visible and near-infrared spectra of NEAs with TJ<3

2007 VA85 - 333P/LINEAR



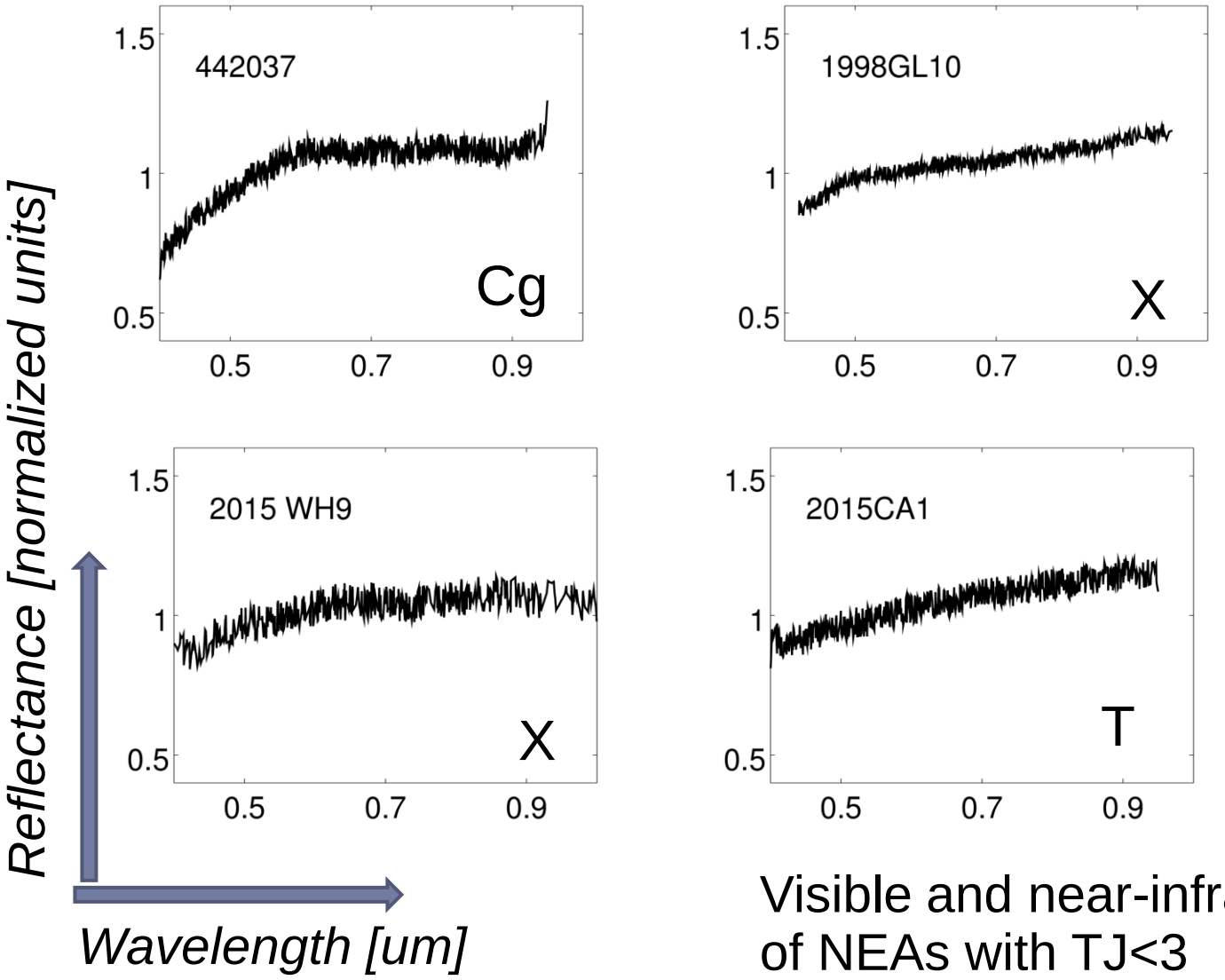
2007 VA85 observed at T1m/ Pic du Midi on 2016-04-06



- Discovered as asteroid 2007 VA85
- Cometary activity detected on early 2016
- TJ = 0.418, retrograde orbit
- D-type spectrum

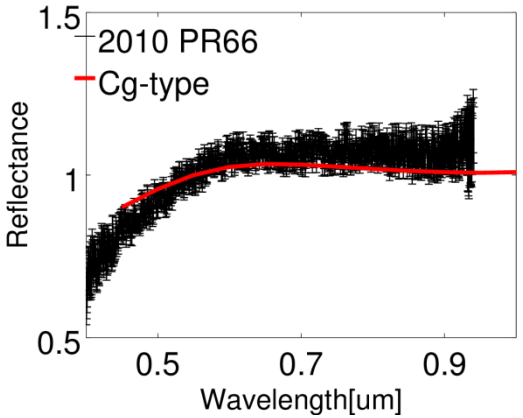
Paper in preparation

Cometary-like spectra: 10/19 NEAs(53%)

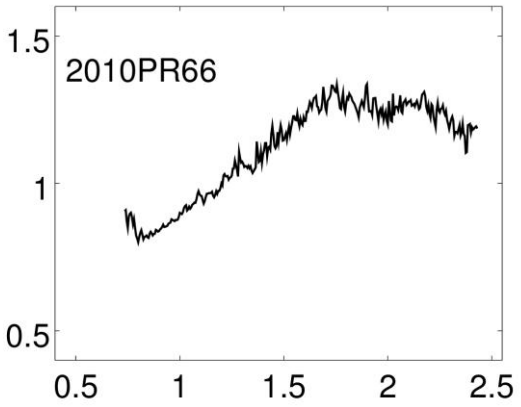


Visible and near-infrared spectra of NEAs with TJ<3

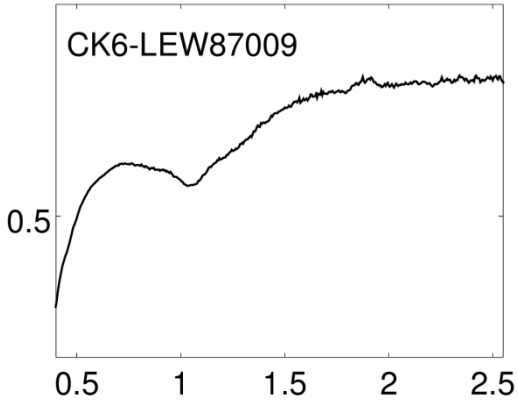
A strange spectrum: 442037(2010 PR66)



Visible spectrum acquired with INT/IDS



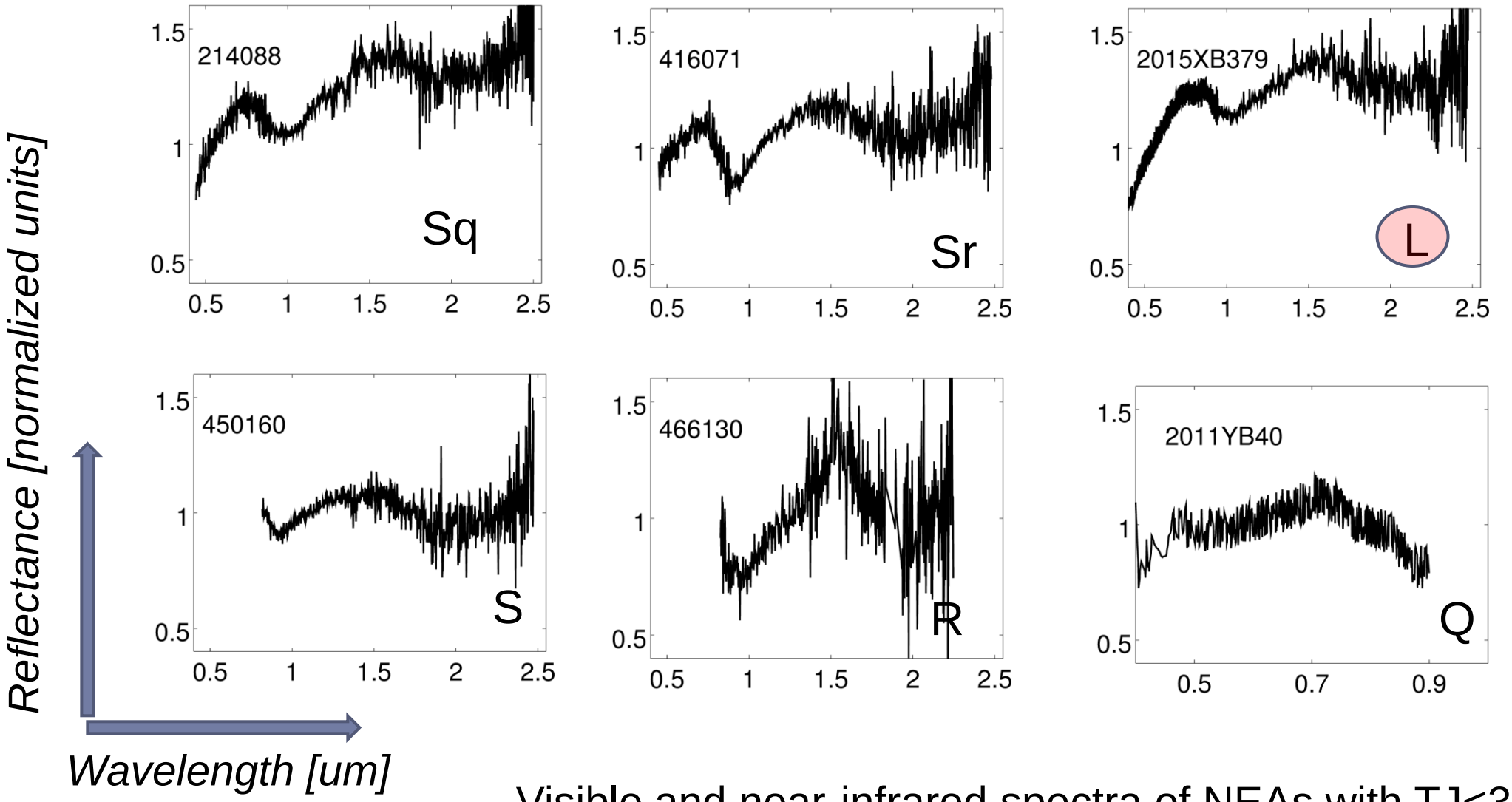
Near-infrared spectrum acquired by MIT-UH-IRTF



Possible meteorite analogue (Relab)

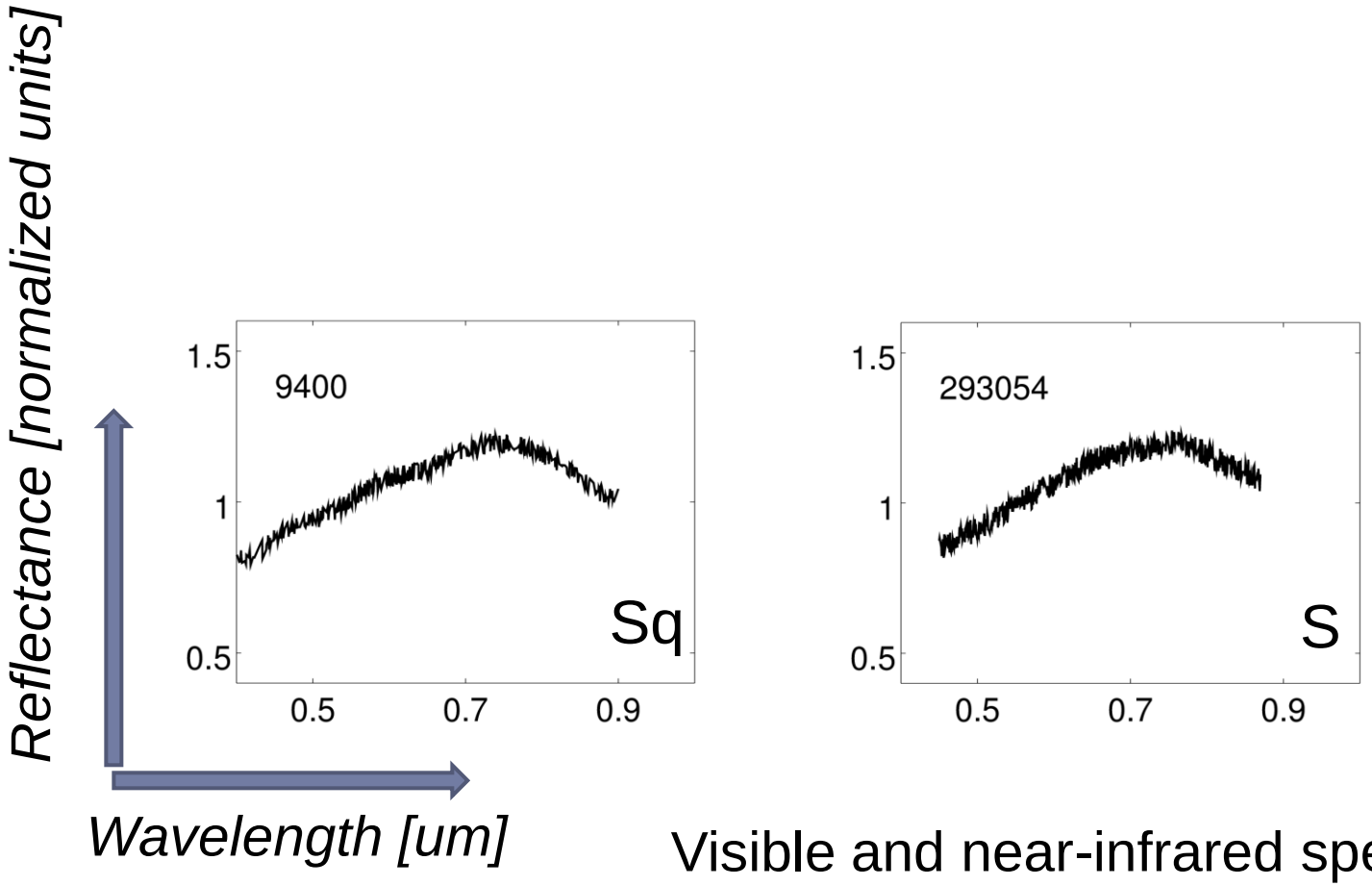
- Large drop in the blue region – Cg / G-type
- Unusual NIR data
- Similar spectra of meteorites: Carbonaceous chondrites CK (Karoonda)

Silicates compositions:8/19 NEAs(42%)



Visible and near-infrared spectra of NEAs with TJ<3

Silicates compositions:8/19 NEAs(42%)

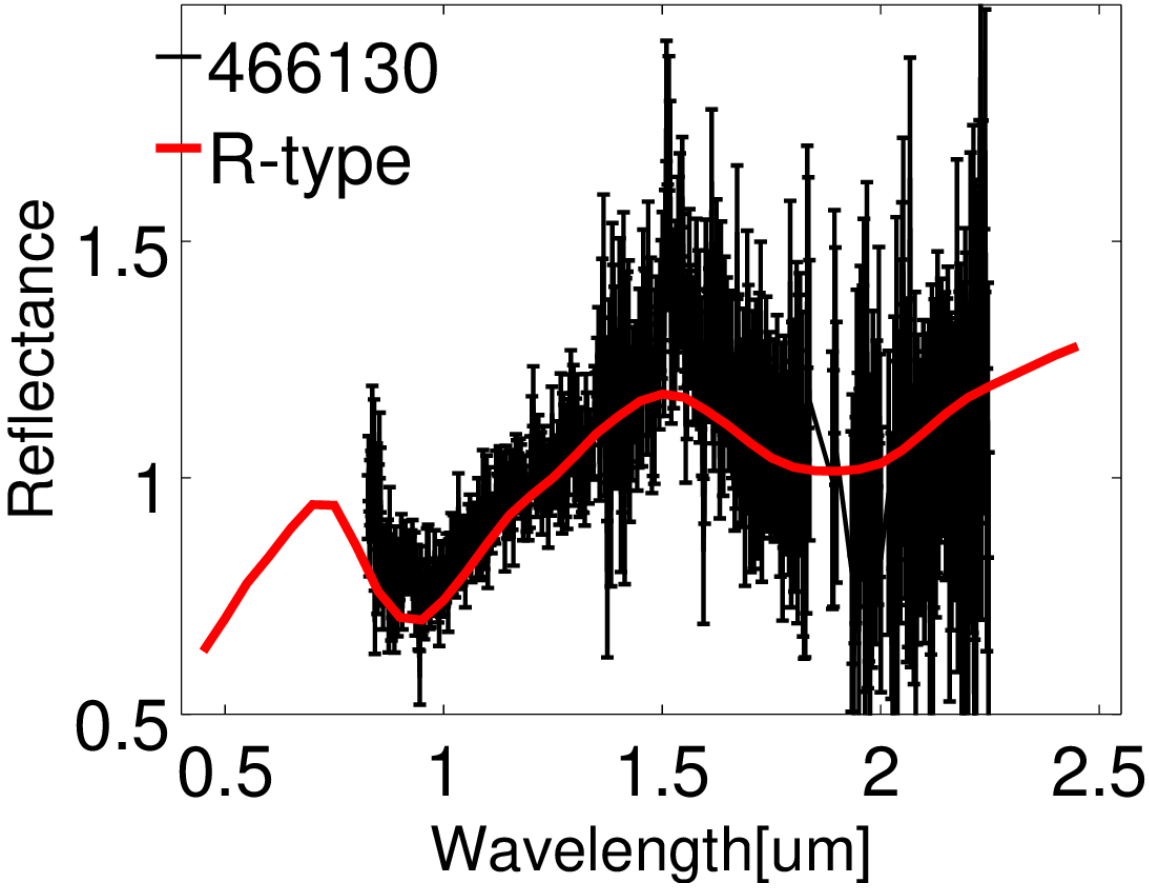


Visible and near-infrared spectra of NEAs with TJ<3

An extreme case: (466130) 2012FZ23, a R type at TJ = 2.367

Orbital elements: a = 2.490 AU: Q = 4.004 AU: q = 0.975 AU: i = 75 deg

- R-type - uncommon spectral class, the most representative member is (349) Dembowska
- Its spectrum resembles that of basaltic body, with the distinctive 1 and 2 μm pyroxene absorption bands
- H = 18.2 => D~600 m (pV~0.26)



Spectral data of (466130) 2012 FZ23 compared with R-type taxonomic type.

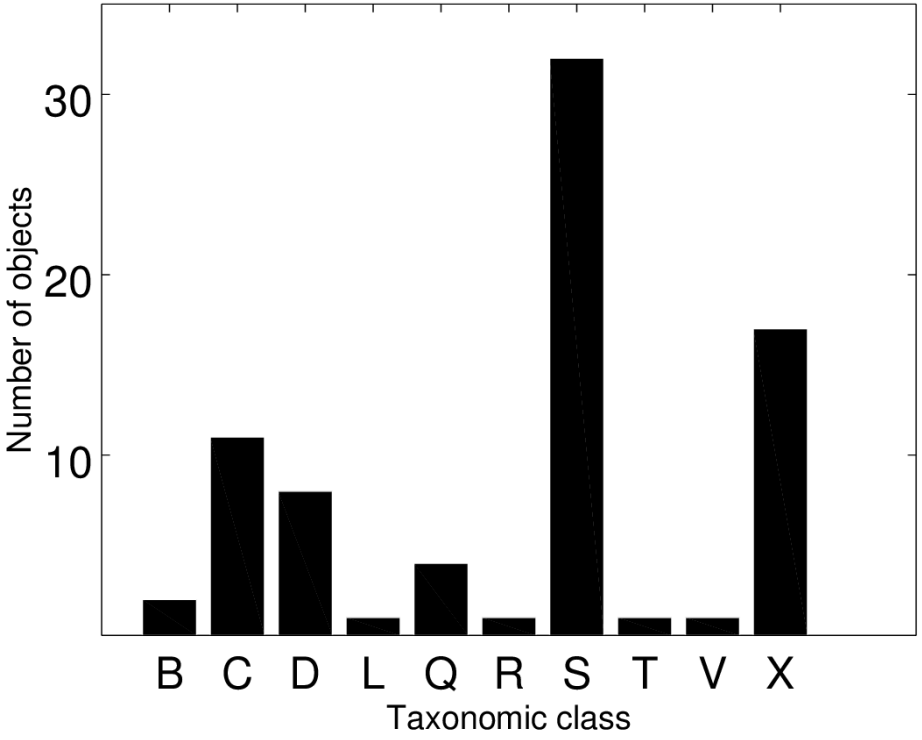
Gathering more data

We retrieved taxonomic classification for another 57 objects from EARN - DLR database. Therefore, we studied the taxonomic distribution of 75 asteroids, out of which 49 are numbered asteroids.

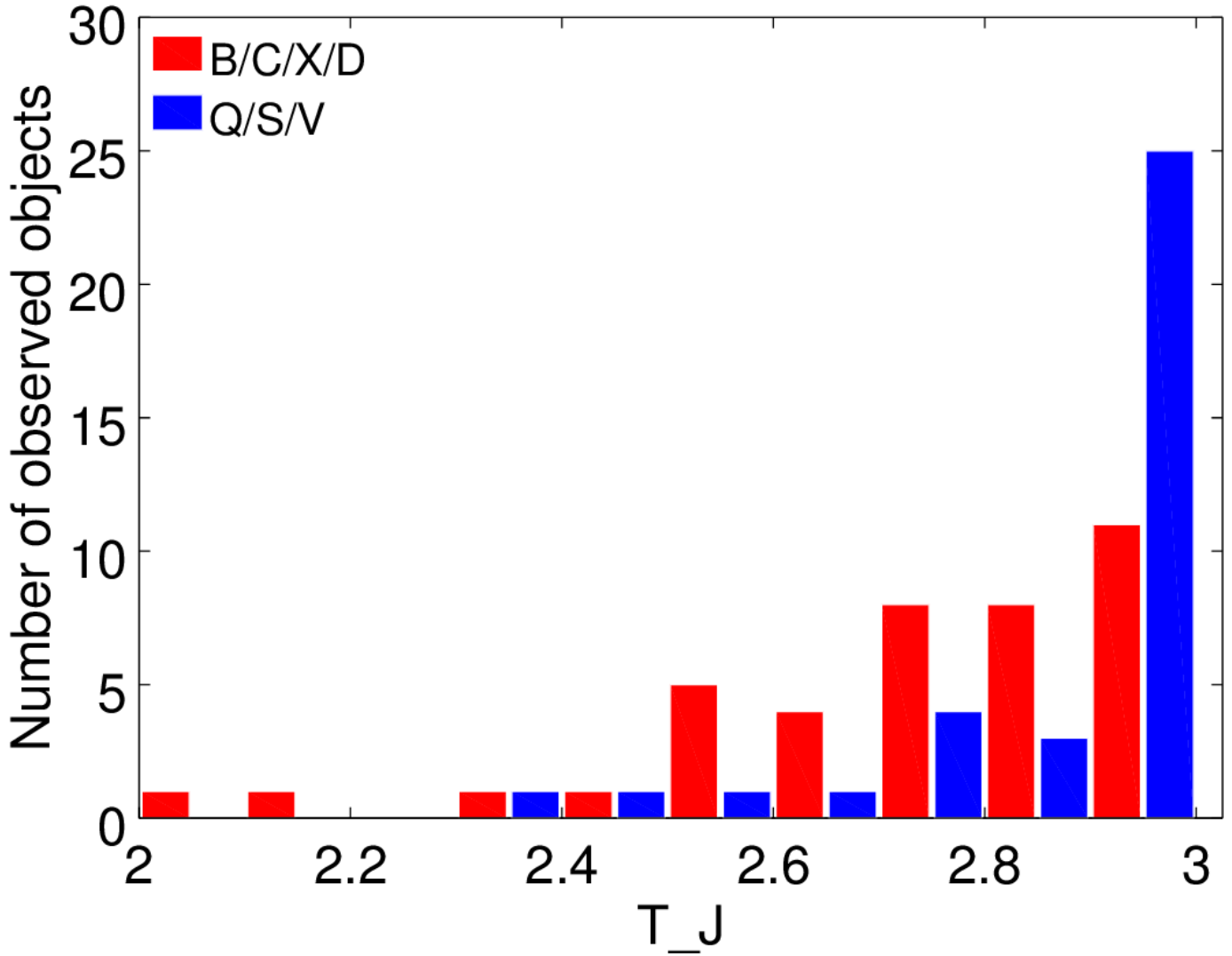
- Cometary-like spectra
  - B/C/D/T/X: 39 (52 %)
- Silicate spectra
  - Q/R/S/V: 36 (48 %)

Licandro et al.2008: 11/17 NEAs with TJ<3 have featureless spectra and 6/17 have bands similar with ”ordinary S-types”.

DeMeo et al. 2008: "54 ± 10% of NEAs with TJ<3 are viable as “comet candidates."



Taxonomic distribution vs TJ



NEACOS from Tancredi's list

Desig.	Tj	Taxon	Albedo	H	q[AU]	Q[AU]	i
3552	2.31	D	0.03	12.9	1.240	7.278	31
248590	2.44	C	0.02	16.5	0.878	4.944	52
1999 LT1	2.59	C	-	17.6	1.080	4.931	43
85490	2.66	D	-	14.7	1.267	6.254	3
2000 WL10	2.72	Xc	-	18.1	0.890	5.396	10
455157	2.77	C	-	17.1	1.115	5.472	4
455185	2.84	D	-	17.3	1.266	4.810	25

- 6/50 have taxonomic classification
- all six belong to taxonomic classes compatible with a cometary-like spectra.
- this taxonomic distribution is in agreement with the one of JFC-ACOs characterized so far - 11 objects (55%) are D-types, 8 (40%) X-types and 1 (5%) T-type. (Licandro et al 2017, paper in preparation)

Conclusions

- Near-Earth asteroids with TJ<3 cover a wide spectral diversity
- The taxonomic distribution is dominated by S-types for TJ~2.9 and by primitive types for TJ<2.8
- Extreme cases can be found, such as 2012 FZ23 a R type at TJ = 2.367
- Initially identified as NEACOs 2007 VA85 showed cometary activity on its apparition in 2016
- The spectral properties fully confirm as possible dormant/inactive comets the NEACOS from Tancredi 2014 list. The conclusion is supported by other findings - albedo distribution (Licandro et al 2016).
- 0.5 - 8 % end-state comets are NEAs population

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