Taurids 2015 - spectra and structure diversity by AMOS

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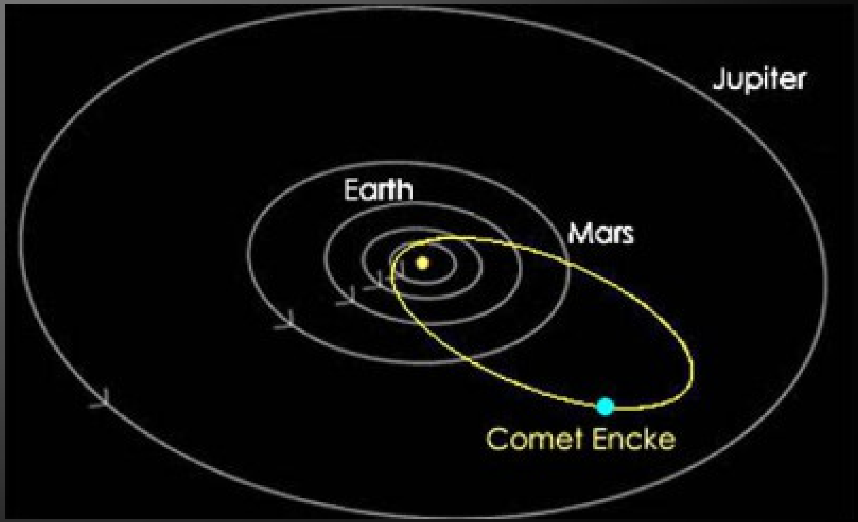
Taurid meteor complex

- Extensive complex of meteoroid streams
- Member streams: N. and S. Taurids, Piscids, chi-Orionids, Daytime beta Taurids, Daytime zeta Perseids, …
- Low inclinations, perihelia 0.2 – 0.5 AU
- Center of the stream related to 2P/Encke
- Proposed relation to over 20 Apollo asteroids (Babadzhanov, 2001; Porubčan et al., 2006), particularly 2004 TG_{10}
- Orbits similar to asteroids evolving from the *ν*6 resonance (Valsecchi et al., 1995)

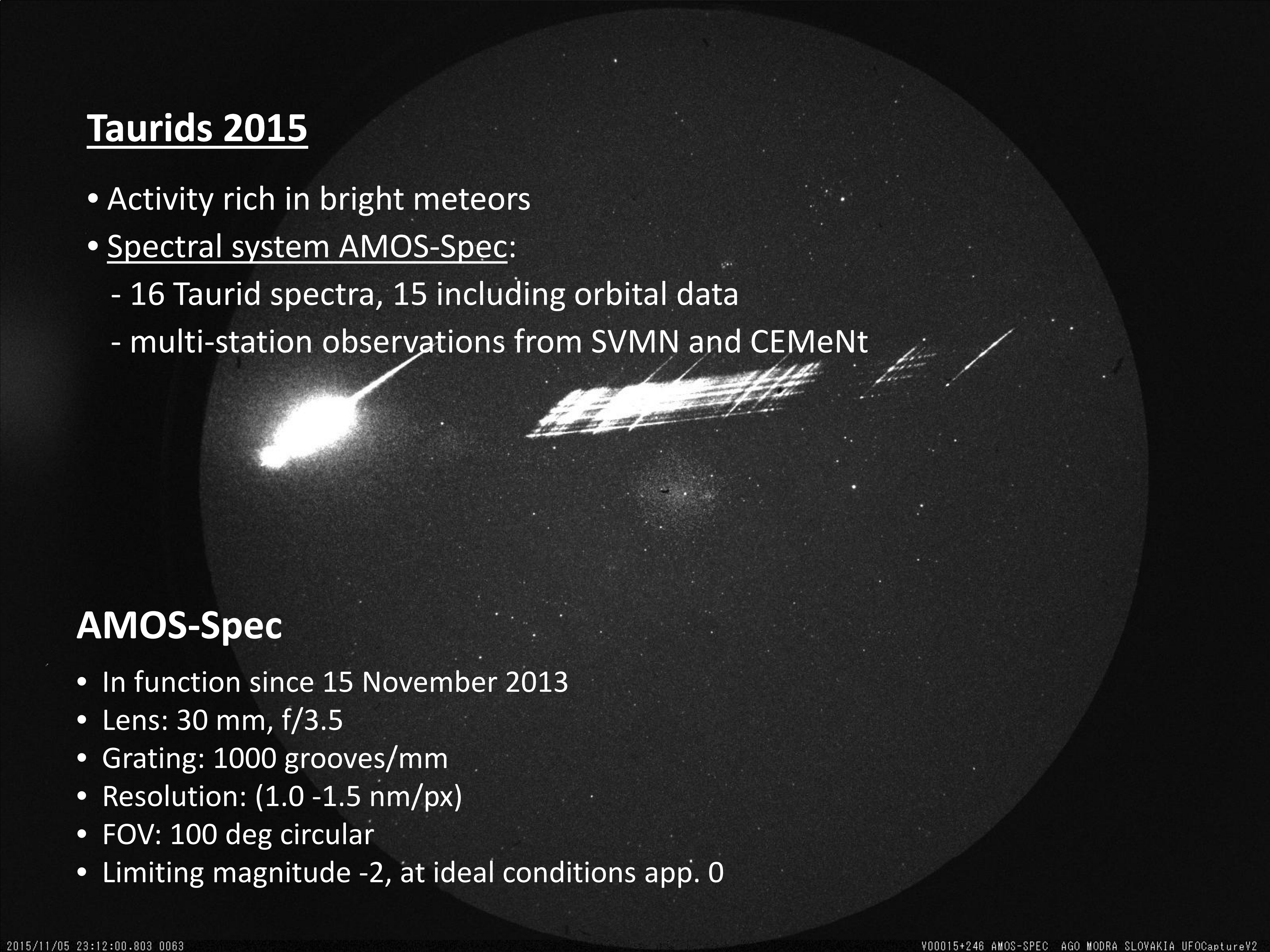


Taurids 2015

- Activity rich in bright meteors
- Spectral system AMOS-Spec:
  - 16 Taurid spectra, 15 including orbital data
  - multi-station observations from SVMN and CEMeNt

AMOS-Spec

- In function since 15 November 2013
- Lens: 30 mm, f/3.5
- Grating: 1000 grooves/mm
- Resolution: (1.0 -1.5 nm/px)
- FOV: 100 deg circular
- Limiting magnitude -2, at ideal conditions app. 0




AMOS-Spec
Nov. 5, 2015, 23:12:00 UT
2015/11/05 23:12:00.803 0063
V00015+246 AMOS-SPEC AGO MODRA SLOVAKIA UFOCaptureV2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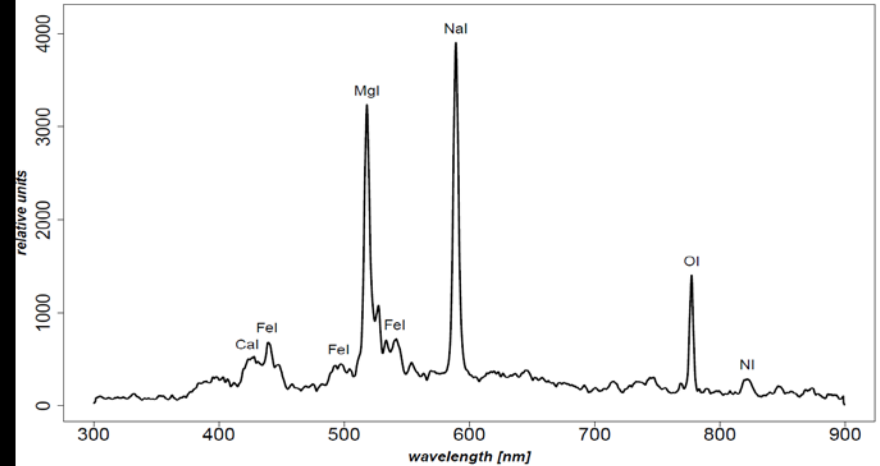

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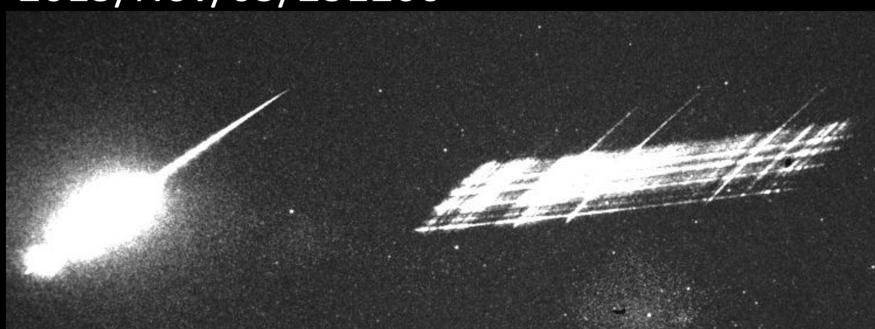

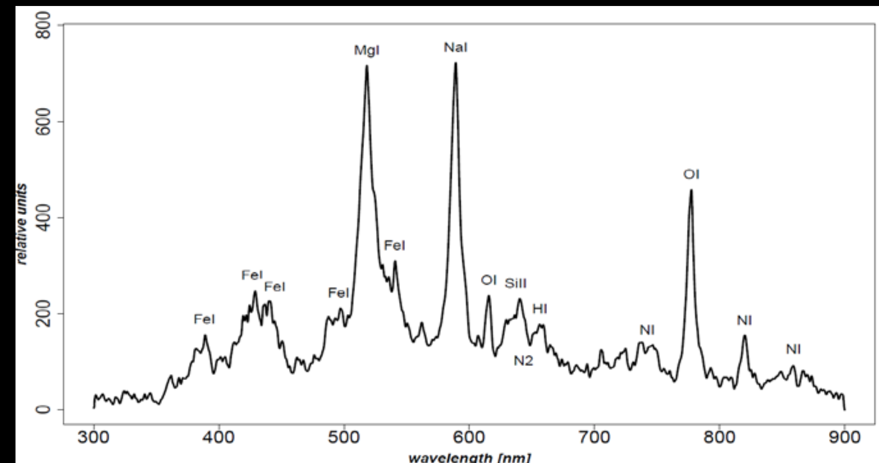

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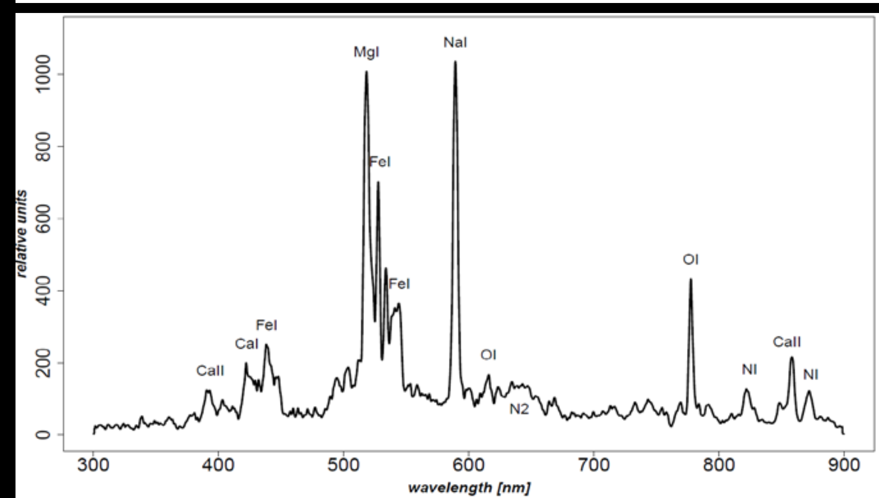
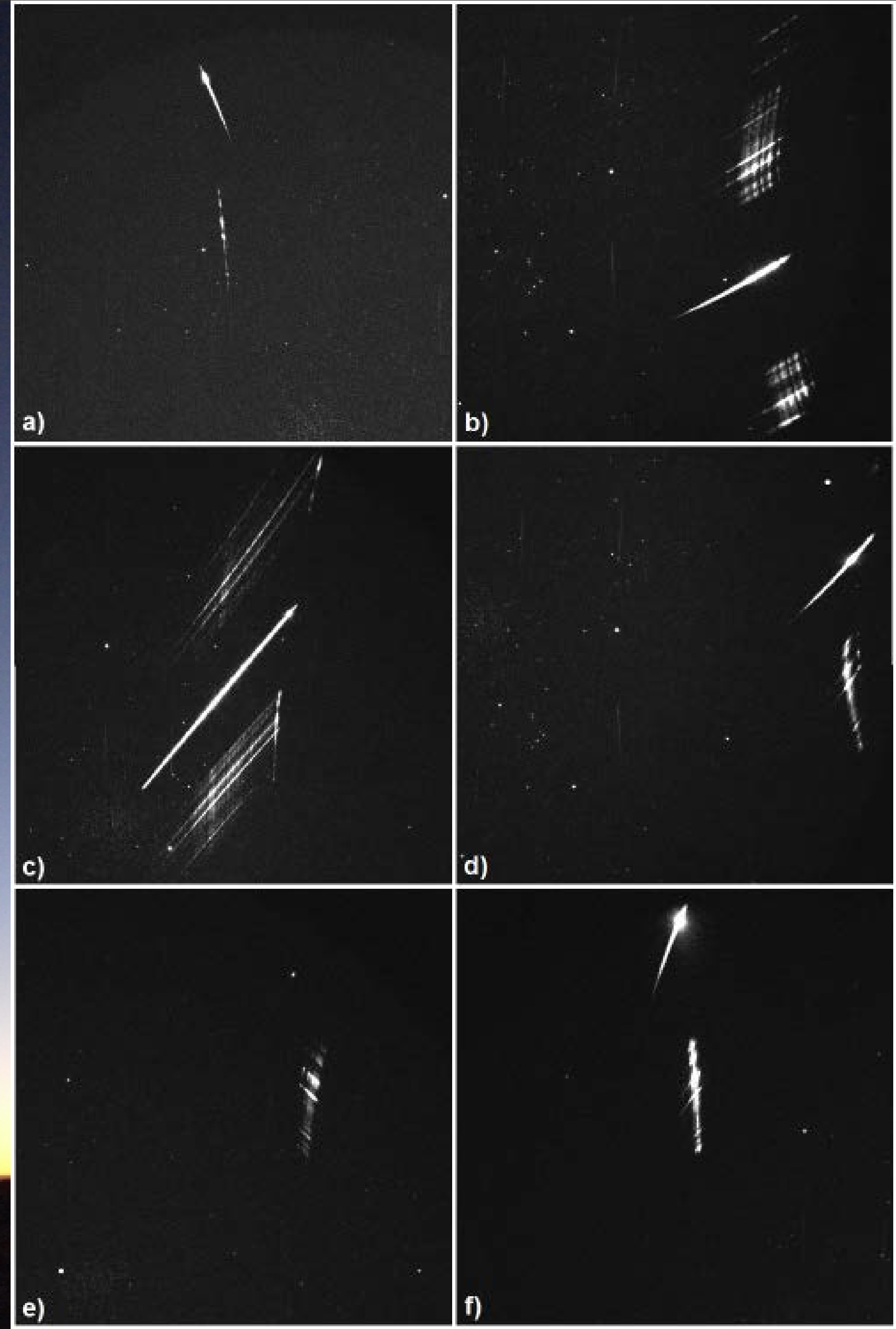


Taurids 2015

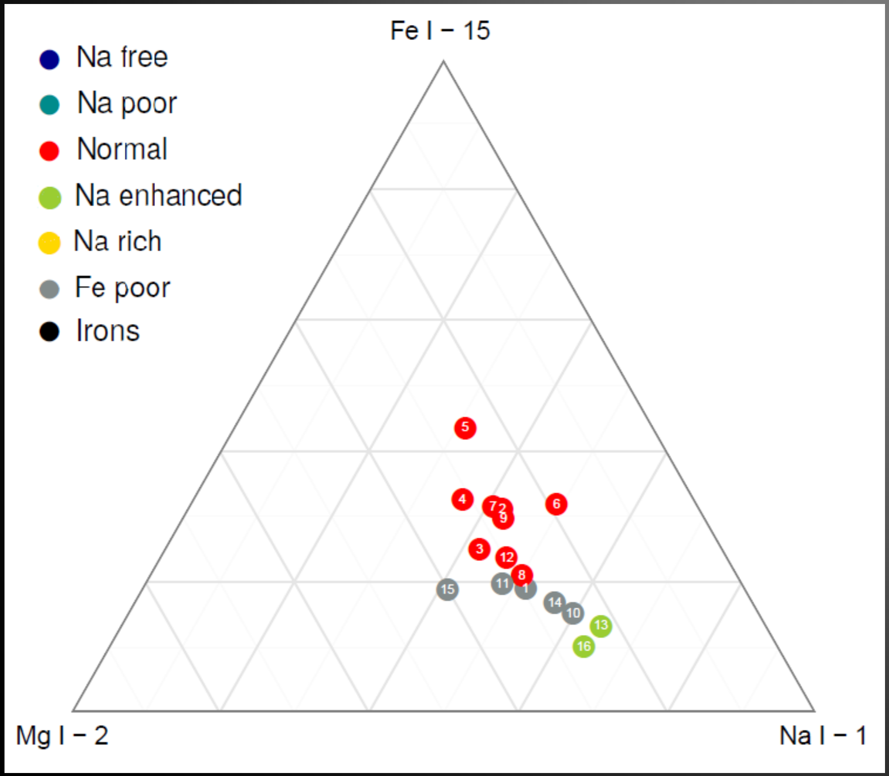
- Testing system during expedition in Chile
- 17 single-station Taurid meteors with spectra (500 grooves/mm)



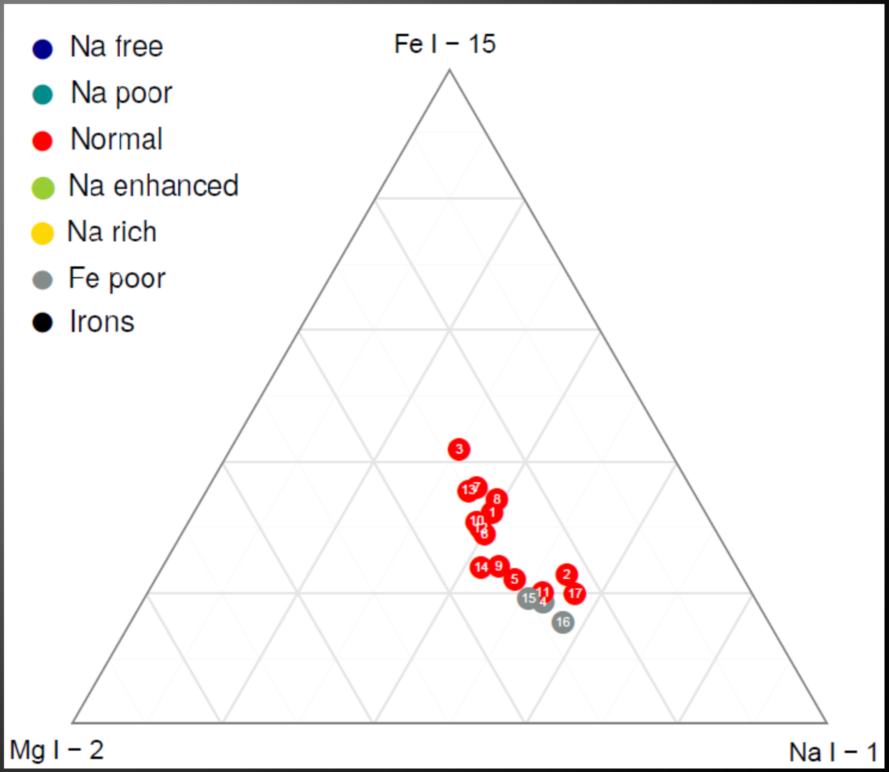
Spectral classification – Taurids 2015

- Mostly normal type spectra
- Relative intensities of Na, Mg, Fe close to chondritic values
- Slight enhancement of Na mainly in fainter Taurid spectra

Taurids - AGO



Taurids - Chile



The role of Na in cometary and asteroidal meteoroids

- Na - tracer of volatile phases associated with cometary origin

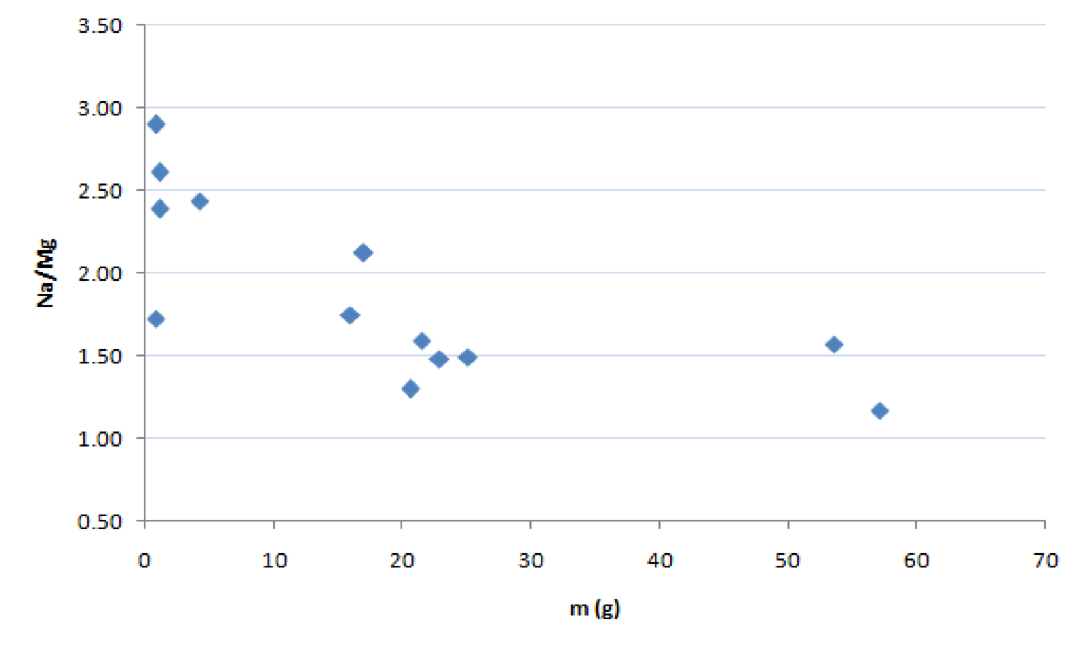
- Observed depletion in Na for meteoroids as a function of exposure to solar radiation - asteroidal debris will be Na-poor materials (Borovička et al., 2005; Trigo-Rodriguez, 2007)

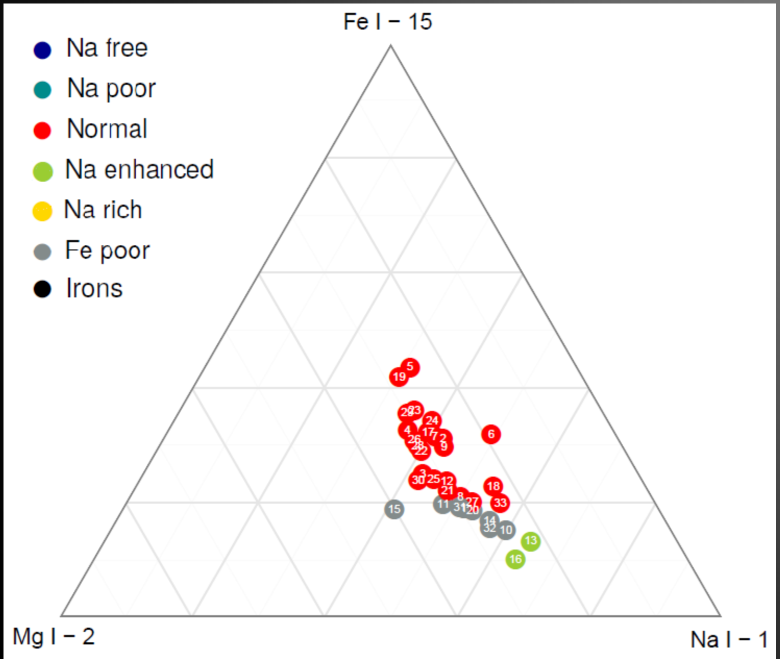
- Three populations of Na-free meteoroids (Borovička et al., 2005): irons, small perihelia orbits (thermal desorption), Halley-type orbits (cosmic radiation)

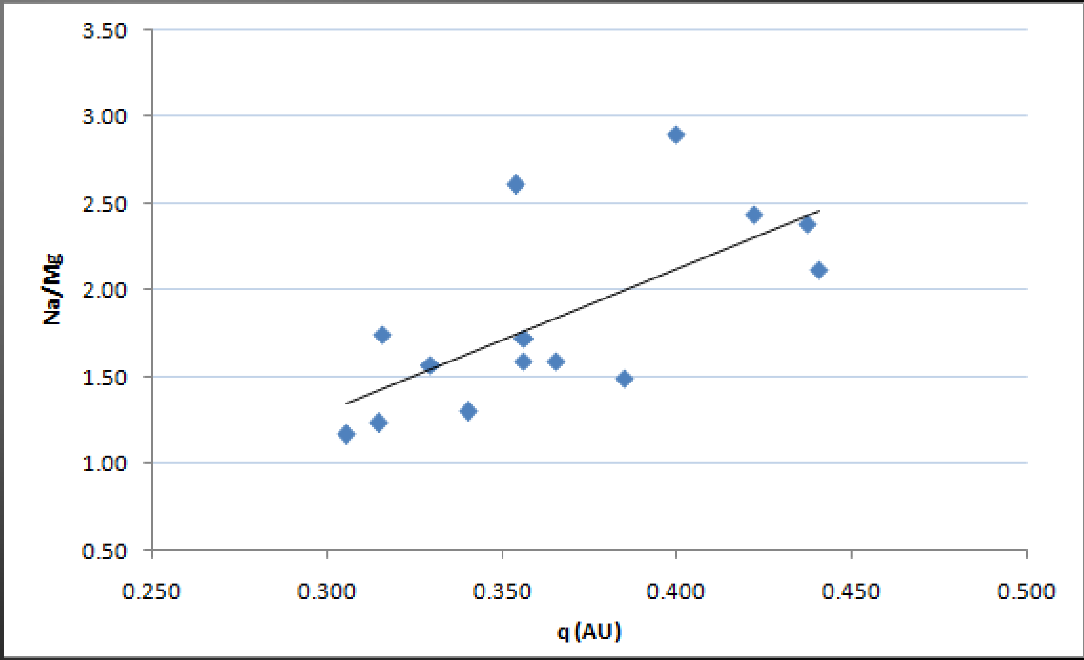
- Na/Mg ratio speed dependent below 40 km/s (Borovička et al., 2005)

- Low excitation of Na line (2.1 eV) compared to Mg line (5.1 eV)

- Clear trend of Na/Mg increase with perihelion distance

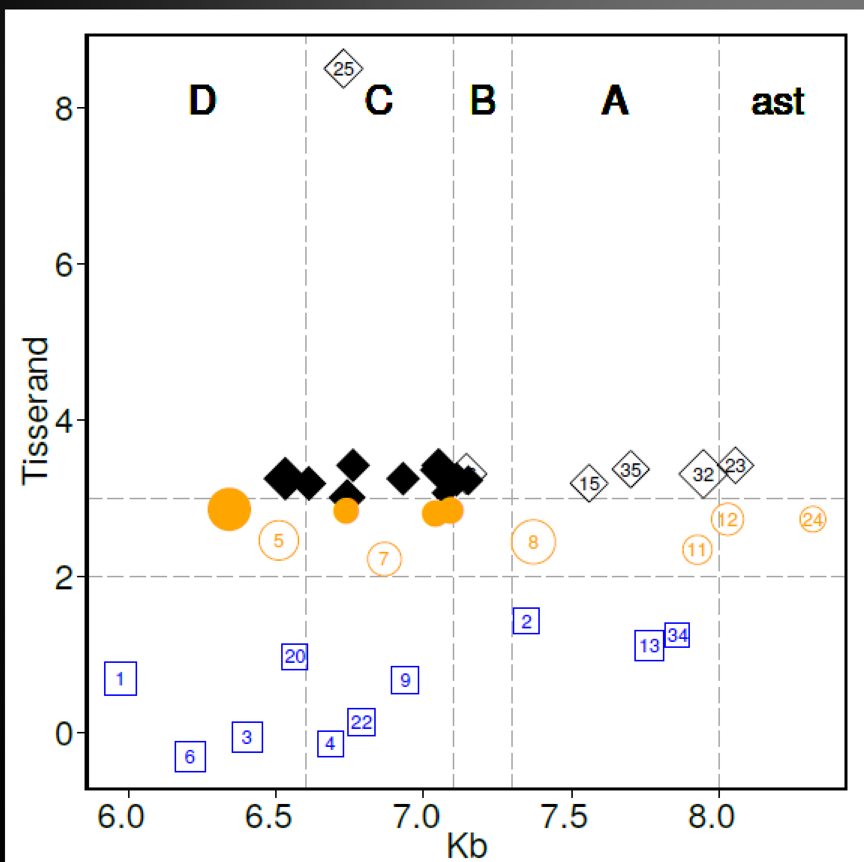


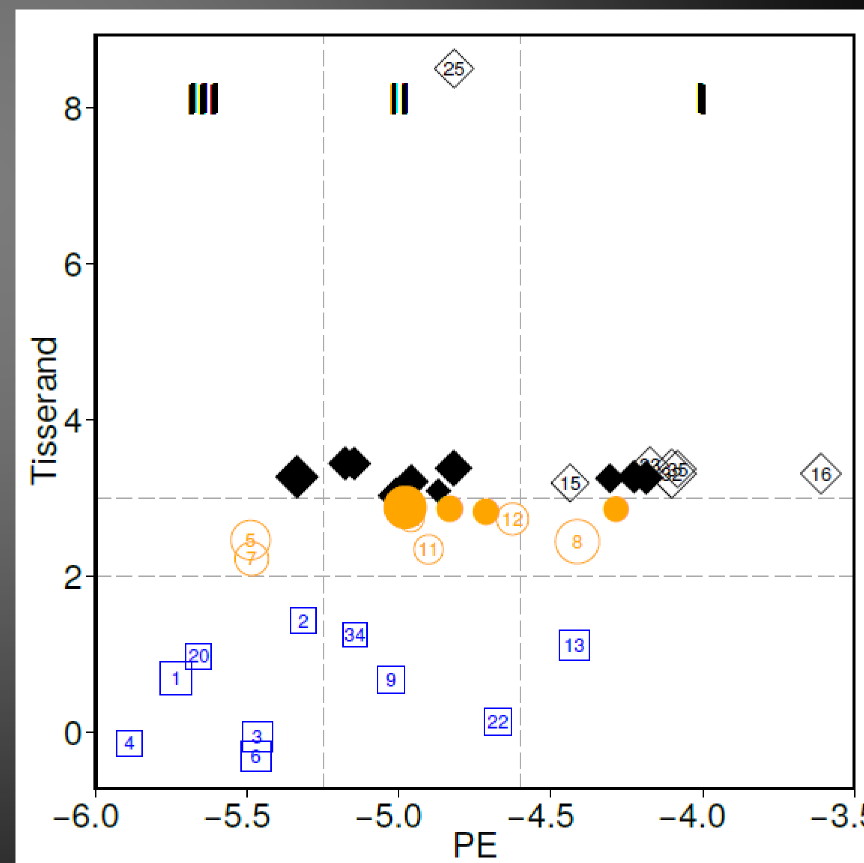




Material strength vs. Tisserand parameter

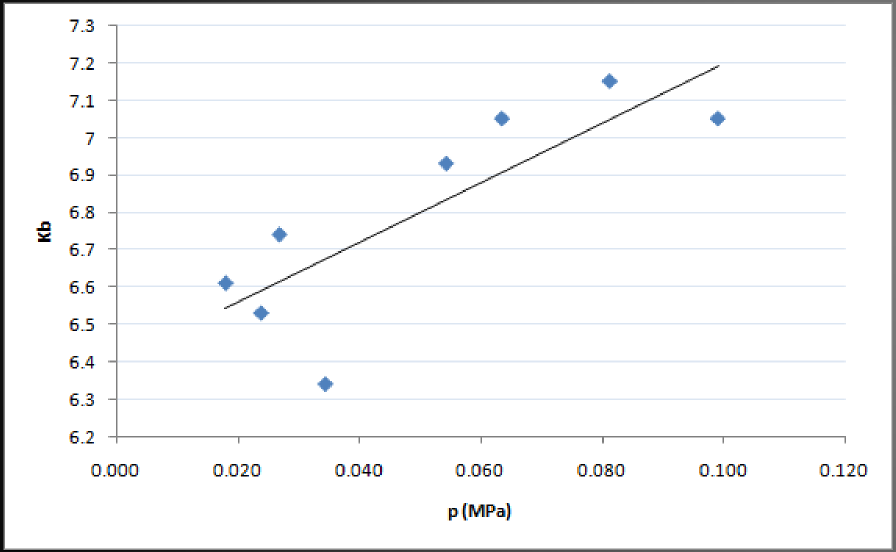
- dynamically decoupled from Jupiter, some exceptions …
- Kb typical for cometary bodies
- PE closer to values typical for carbonaceous bodies

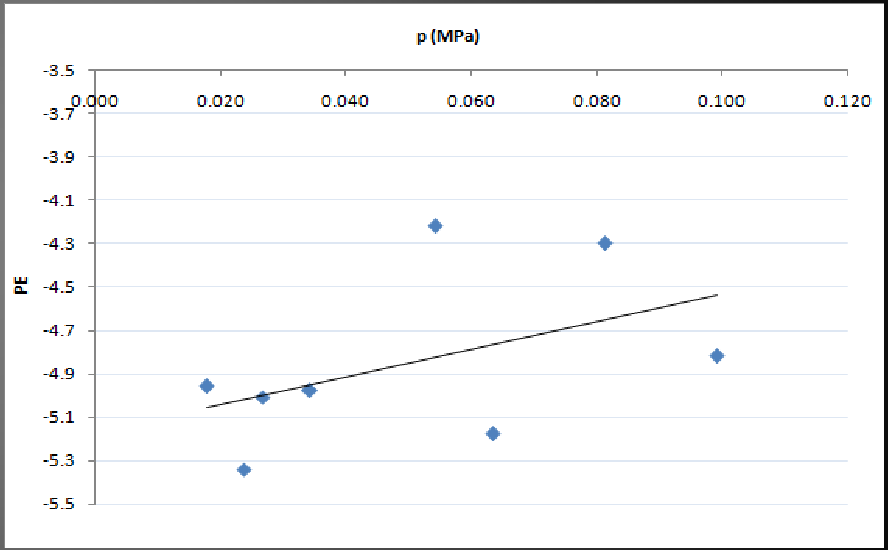




Dynamic pressure vs. Kb and PE

- Dynamic pressure 10^{-2} - 10^{-1} Mpa
- The lower dynamic pressure, weaker material parameters Kb, PE





Mechanical strength derived from dynamic pressure

- Popova et al. (2011): low strengths of meteoroids from observed meteorite falls
- Estimated strengths on entry characteristically 10^{-1} - 10^{-2} times the tensile strengths of recovered samples
- 0.1 - 1 MPa on first breakup, 1 - 10 MPa maximal strength
- Taurids 2015: 0.01 - 0.1 MPa

				Measured strength of similar meteorites		First breakup		Maximum strength at breakup	
Bolide event	Weight expected (kg)	Weight recovered (kg)	Fragments number	Compressive (MPa)	Tensile (MPa)	Inferred bulk strength (MPa)	Altitude (km)	Inferred bulk strength (MPa)	Altitude (km)
Příbram	80[a]	6[a]	4[a]	77–247	31–42	0.9	44	–	–
Lost City	25[b]	17[b]	4[b]	77–247	31–42	0.7	41	2.8	28
Innisfree	5[c]	4.6[c]	9[c]	20–450	(2–62)	0.1	55.6	3	23.7
Peekskill	?	12.4[l]	1[l]	163–327	–	–	41.6		36
Tagish Lake	100–1000[d]	16.3[d]	~500[d]	–	–	0.3	48	2.2	32
Morávka	100[a]	1.4[a]	6[a]	77–327	31–42	<0.9	>46	5	29.3
Neuschwanstein	20[e]	6.2[k]	3[k]	–	–	3.6	34	9.6	20.8
Park Forest	>45[f,g]	30[f,g]	>100[f,g]	20–450	2–62	0.03	70	7	29
Villalbeto de la Peña	?	4.4[h,j]	33[h,j]	63–98	6–31	–	–	5.1	24
Bunburra Rockhole	1.1[n,m]	0.339[n,i]	3[n,m,i]	–	–	0.1	54.8	0.9	33.9
Almahata Sitta	?	~5[o]	>300[o]			0.2–0.3	46–42	1	33
Jesenice	10–30[p]	3.6[p]	3[p]	63–98	6–31	0.3	46	3.9	23
Grimsby	5[q]	0.215[q]	13[q]	77–327	31–42	0.03	70	3.6	30

Source: [a]Borovička and Kalenda (2003); [b]Ceplecha (1996); [c]Halliday et al. (1978); [d]Hildebrand et al. (2006); [e]Spurný et al. (2002, 2003); [f]Simon et al. (2004); [g]Brown et al. (2004); [h]Llorca et al. (2005); [i]This paper; [j]Trigo-Rodríguez et al. (2006); [k]Oberst et al. (2004); [l]Brown et al. (1994); [m]Bland et al. (2009); [n]Spurný et al. (2009); [o]Jenniskens et al. (2009); [p]Spurný et al. (2010); [q]Brown et al. (2011).

Conclusion

- Spectral characteristics typical for cometary material with variations of Na and Fe content

- Na/Mg line ratio > 1 for all Taurids, function of the perihelion distance, slight dependence on material strength

- Slight Na enhancement expected for cometary particles at 28 $km.s^{-1}$

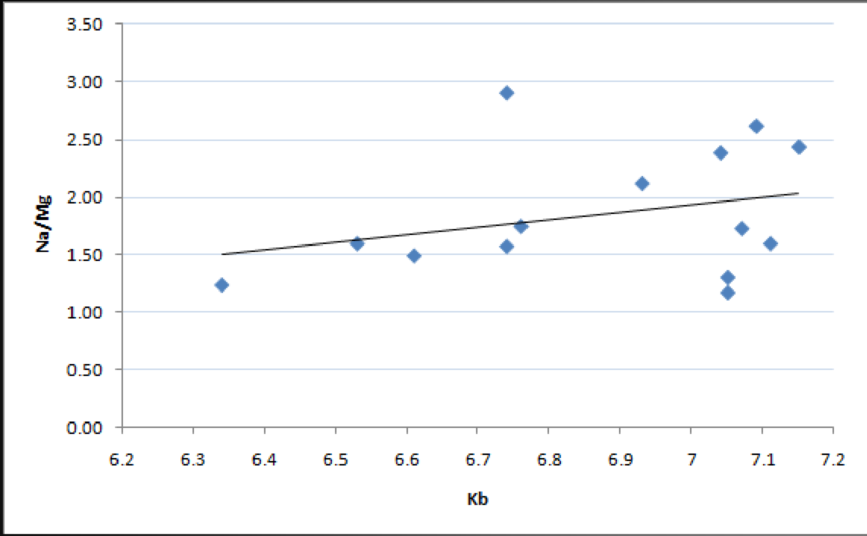
- Material strength Kb typical for cometary bodies, PE classification closer to values typical for carbonaceous bodies –> structural or material heterogeneity

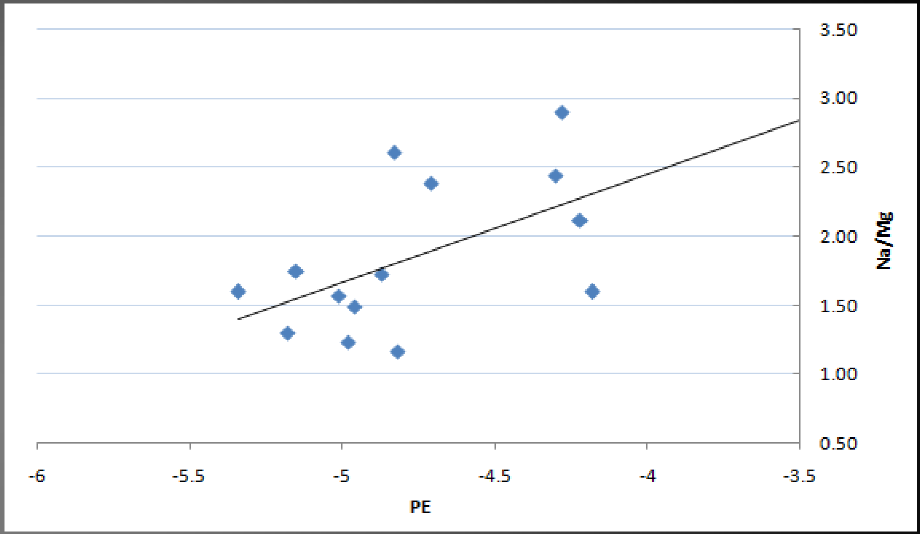
- Low mechanical strength derived from dynamic pressure 0.01- 0.1 MPa

- Studied Taurid meteoroids show cometary characteristics, physical properties of several particles similar to carbonaceous chondrites

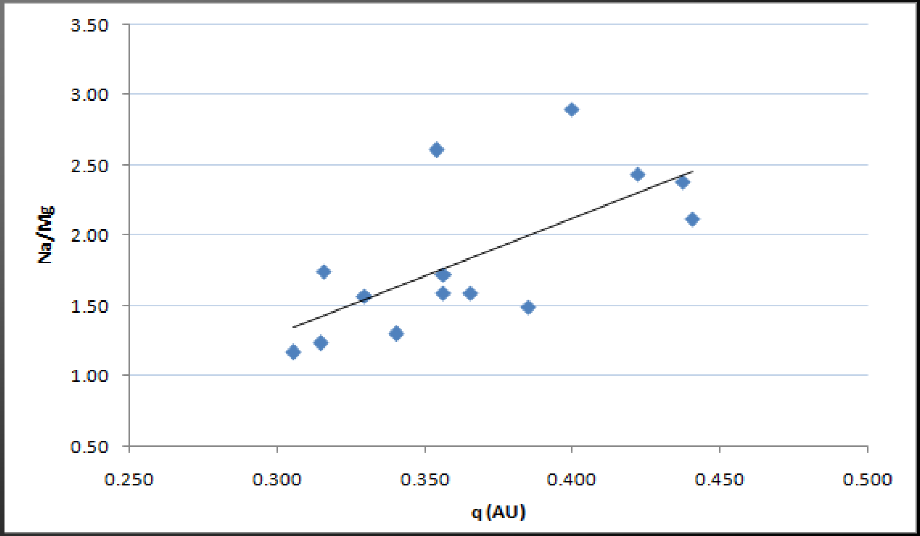
Thank you for your attention

Na/Mg vs. material strength

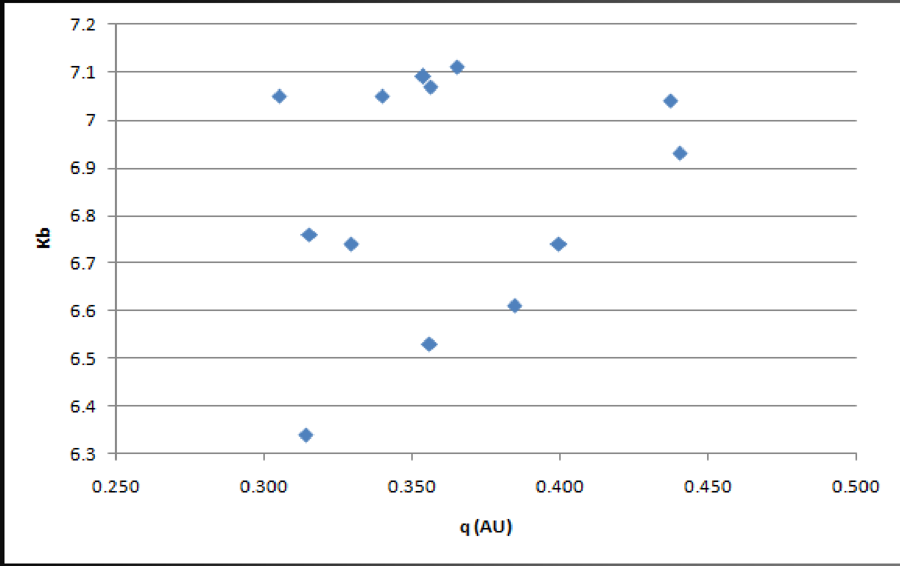


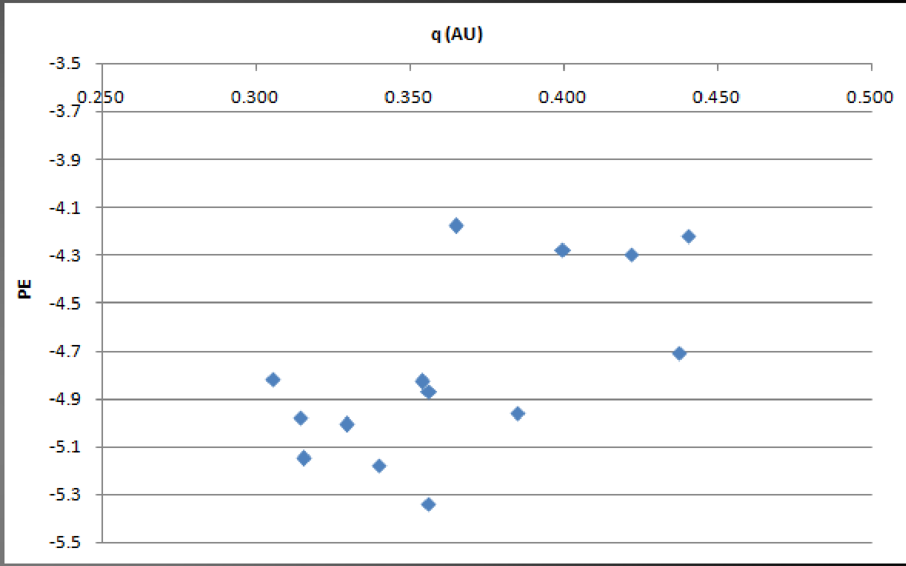


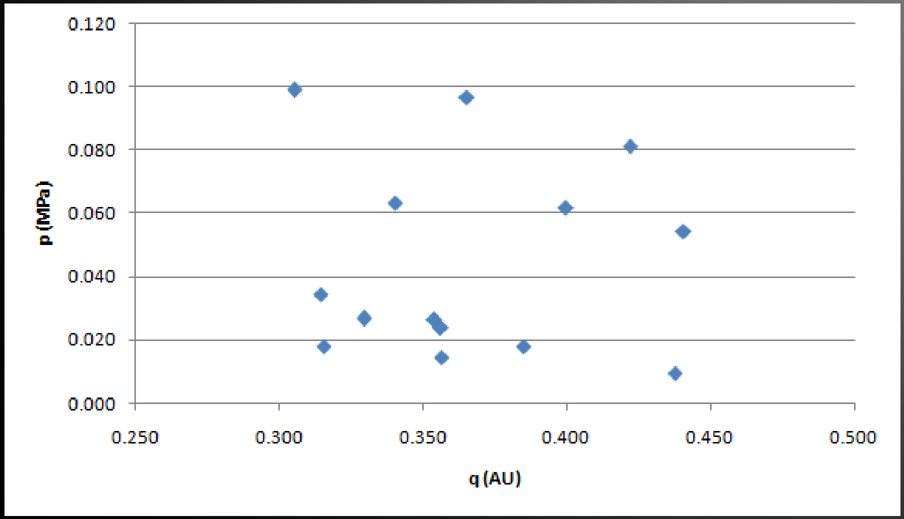
• Na enhancement in cometary material suggests weaker exposure to solar radiation



Material strength vs. perihelion distance







Material strength

• Material strength parameters K_B and PE
(Ceplecha and McCrosky, 1976; Ceplecha, 1988)
- Based on beginning and terminal heights H_B and H_E
- Distinguishes fragile cometary particles from strong asteroidal material

$$K_B = \log \varrho_B + 2{\cdot}5 \log v_\infty - 0{\cdot}5 \log \cos z_R$$

$$P_E = \log \varrho_E - 0{\cdot}42 \log m_\infty + 1{\cdot}49 \log v_\infty - 1{\cdot}29 \log \cos z_R$$

("ast"):	$8{\cdot}00 \leqq K_B$
group A:	$7{\cdot}30 \leqq K_B < 8{\cdot}00$
group B:	$7{\cdot}10 \leqq K_B < 7{\cdot}30$; $q \leqq 0{\cdot}30$ A.U.
group C1:	$6{\cdot}60 \leqq K_B < 7{\cdot}10$; $a < 5$ A. U. ; $i \leqq 35°$
group C2:	$6{\cdot}60 \leqq K_B < 7{\cdot}10$; $a \geqq 5$ A. U.
group C3:	$6{\cdot}60 \leqq K_B < 7{\cdot}10$; $a < 5$ A. U.; $i > 35°$
group D:	$K_B < 6{\cdot}60$

group I:	$-4{\cdot}60 < P_E$
group II:	$-5{\cdot}25 < P_E \leqq -4{\cdot}60$
group IIIA:	$-5{\cdot}70 < P_E \leqq -5{\cdot}25$;
group IIIAi:	$-5{\cdot}70 < P_E \leqq -5{\cdot}25$; $a \geqq 5$ A. U.
group IIIB:	$P_E \leqq -5{\cdot}70$

• Atmospheric density from MSIS-E-90 Atmospheric Model (Hedin, 1991)

Dynamical and physical properties

- dynamically decoupled from Jupiter
- Kb typical for cometary bodies
- PE closer to values typical for carbonaceous bodies
- Dynamic pressure 10^{-2} - 10^{-1} MPa

No.	Shower	Meteor	Mag	m_p (g)	v_g (km/s)	H_B (km)	H_E (km)	a (AU)	q (AU)	e	i (deg)	ω (deg)	Ω (deg)	T_J	type	K_B	type	P_E	type	p (Mpa)	m_dens (g.cm-3)
1	STA	M20151102_020949	-4.7	16	28.74	103.95	70.10	1.868	0.316	0.831	5.51	120.19	39.10	3.45	AST	6.76	C1	-5.32	IIIA	0.018	1.94
2	NTA	M20151102_024553	-4.5	22	27.62	99.17	52.68	2.037	0.365	0.821	3.32	293.69	219.16	3.27	AST	7.11	B	-4.36	I	0.097	2.5
3	STA	M20151103_212219	-5.1	21	27.98	99.10	69.26	1.887	0.340	0.820	4.74	117.32	40.90	3.44	AST	7.05	C1	-5.35	IIIA	0.063	2.43
4	STA	M20151103_212454	-6	57	29.27	99.69	60.65	1.900	0.305	0.839	6.59	121.13	40.90	3.39	AST	7.05	C1	-4.98	II	0.099	2.44
5	NTA	M20151105_205304	-8.1	456	30.12	108.79	56.58	2.346	0.314	0.866	1.80	298.08	222.95	2.89	JFC	6.34	D	-5.13	II	0.034	1.32
6	STA	M20151105_215813	-2.1	1	28.98	99.29	72.16	2.392	0.354	0.852	4.33	113.45	42.92	2.88	JFC	7.09	C1	-5	II	0.026	2.48
7	STA	M20151105_220109	-5.6	23		92.40	69.12									7.97	A	-4.87	II		
8	STA	M20151105_220251	-1.8	1	28.34	99.15	73.44	2.171	0.356	0.836	3.72	114.04	42.92	3.10	AST	7.07	C1	-5.04	II	0.015	2.47
9	STA	M20151105_231200	-8.4	597	27.94	105.98	60.45	2.020	0.356	0.824	4.86	114.78	42.98	3.28	AST	6.53	D	-5.51	IIIA	0.024	1.58
10	STA	M20151105_235959	-1.9	1	26.59	99.31	68.50	2.546	0.438	0.828	0.82	103.60	42.92	2.83	JFC	7.04	C1	-4.9	II	0.010	2.41
11	STA	M20151108_234416	-5	25	27.27	104.87	63.74	2.091	0.385	0.816	5.46	111.17	46.01	3.22	AST	6.61	C1	-5.14	II	0.018	1.7
12	NTA	M20151109_041942	-5.5	54	29.30	104.35	68.10	2.213	0.330	0.851	1.01	296.74	226.32	3.04	AST	6.74	C1	-5.17	II	0.027	1.93
13	STA	M20151111_220940	-1.3	1	27.71	103.03	62.76	2.450	0.400	0.837	5.12	108.00	48.96	2.87	JFC	6.74	C1	-4.46	I	0.062	1.92
14	STA	M20151116_193459	-3.9	17	25.51	99.75	54.48	2.080	0.441	0.788	4.87	104.98	53.88	3.28	AST	6.93	C1	-4.42	I	0.054	2.23
16	NTA	M20151123_012004	-2.9	4	26.06	98.08	57.04	2.080	0.422	0.797	2.96	286.88	240.24	3.26	AST	7.15	B	-4.49	I	0.081	2.54
																					2.1
																					0.4

Spectral classification of meteors, AMOS-Spec results:

(Borovička et al., 2005)