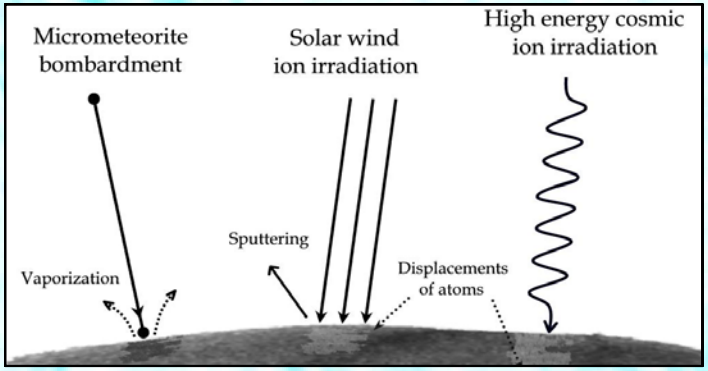
Space weathering of asteroidal surfaces

Giovanni Strazzulla[1] & Rosario Brunetto[2]

[1]INAF – Osservatorio Astrofisico di Catania, Italy
gianni@oact.inaf.it
[2]Institut d'Astrophysique Spatiale, UMR 8617, Orsay, France
rosario.brunetto@ias.u-psud.fr

Marco Polo Symposium, Paris – May 2009

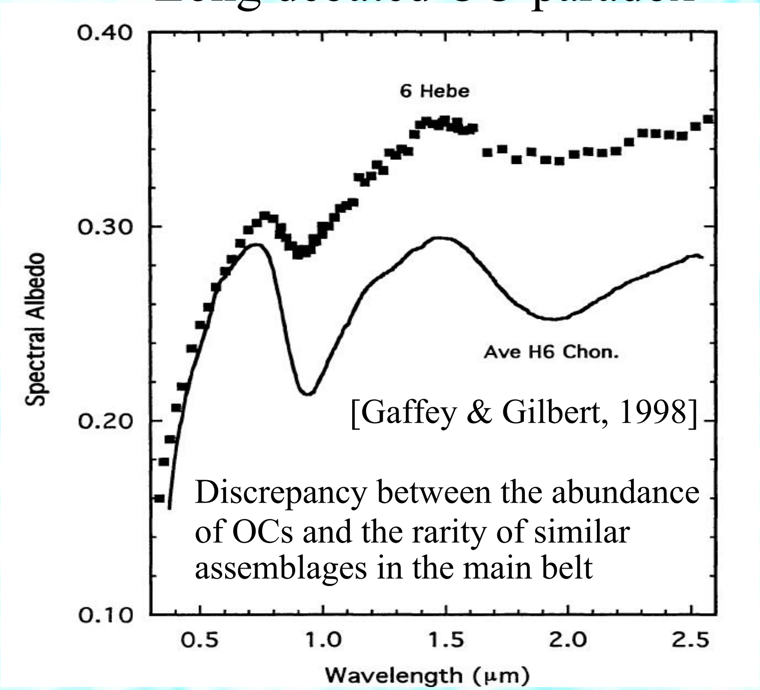
Overview



Airless bodies suffer micrometeorite bombardment, and irradiation by solar wind and cosmic ions.

Space weathering **(SW)** processes cause variations in the optical properties of the surface materials.

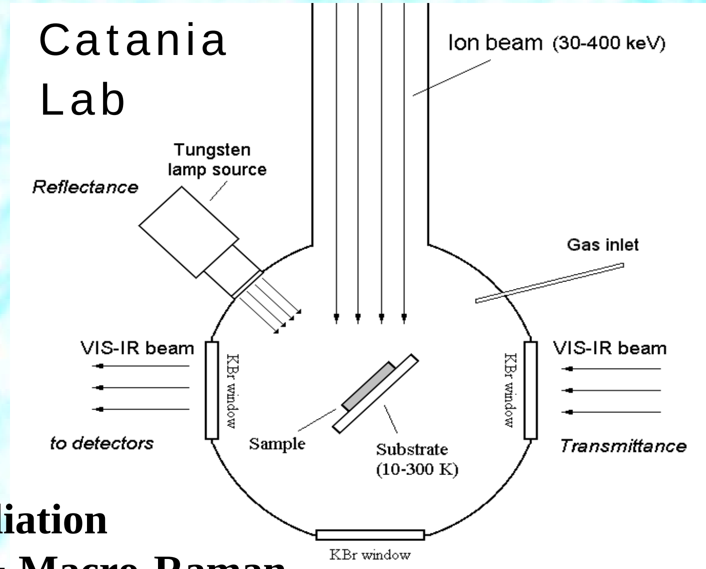
Long debated OC-paradox



[Gaffey & Gilbert, 1998]

Discrepancy between the abundance of OCs and the rarity of similar assemblages in the main belt

Catania Lab



- **Ion irradiation**
- **Micro- & Macro-Raman**
- **UV-Vis-IR Spectroscopies**

Transmittance	0.2-20 µm
Reflectance	0.2-20 µm (bidir. or diffuse)

SW of silicate-rich asteroids

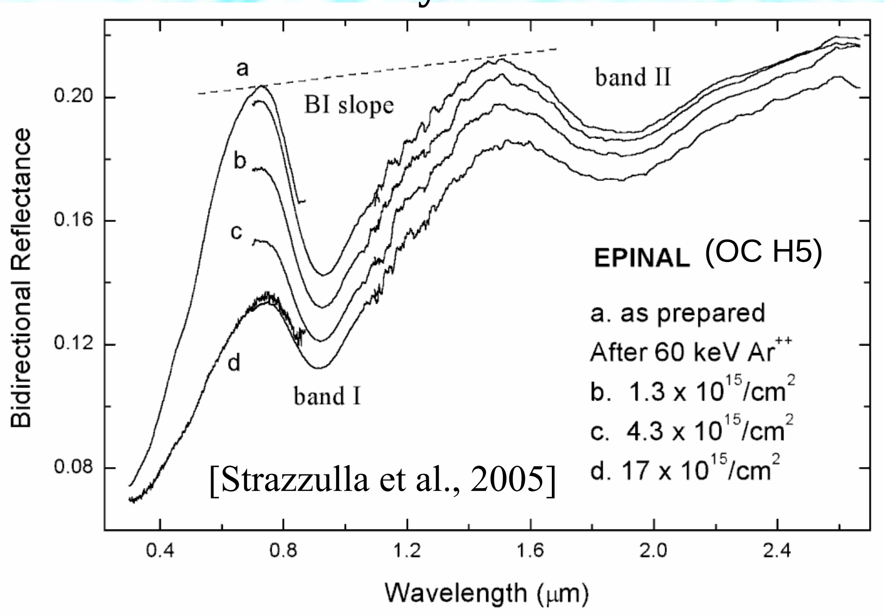
Reflectance spectra of silicate-rich surfaces become **redder & darker**

- Laser ablation (UV – IR)
- Impacts
- Ion irradiation (keV – MeV)

⇩

Timescale ~ 10^4-10^6 years

Hapke 1973 – 2001
Moroz et al. 1996
Dukes et al. 1999
Pieters et al. 2000
Sasaki et al. 2001
Demyk et al. 2001
Brunetto & Strazzulla 2005
Bentley et al. 2005
Moretti et al. 2005
Loeffler et al. 2008
etc.



Solar wind flux is the most relevant source of asteroidal SW

Exposure to solar ion irradiation:
Marchi et al. 2005
Marchi et al. 2006
Paolicchi et al. 2007

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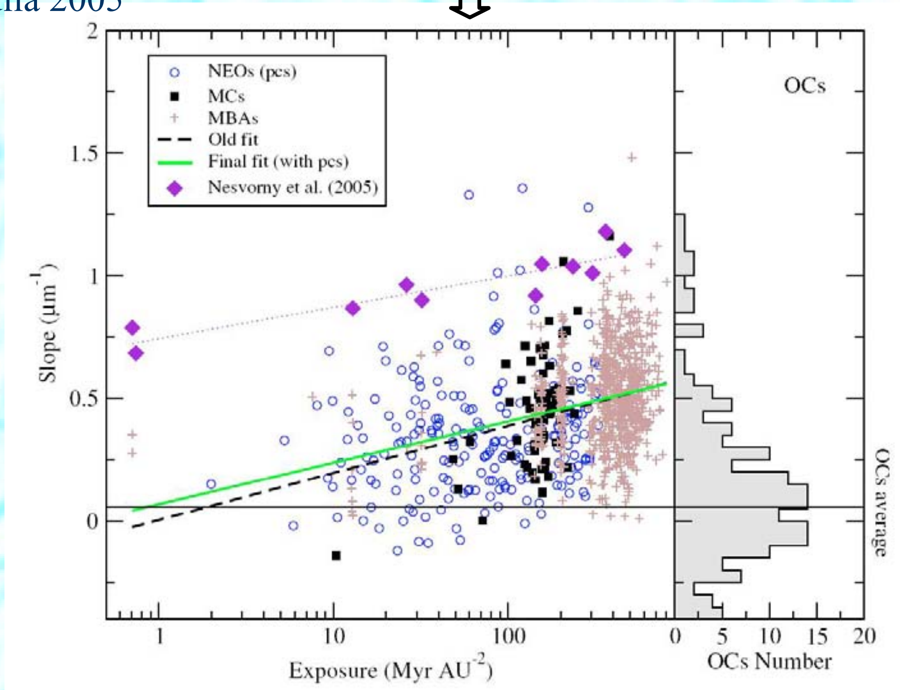
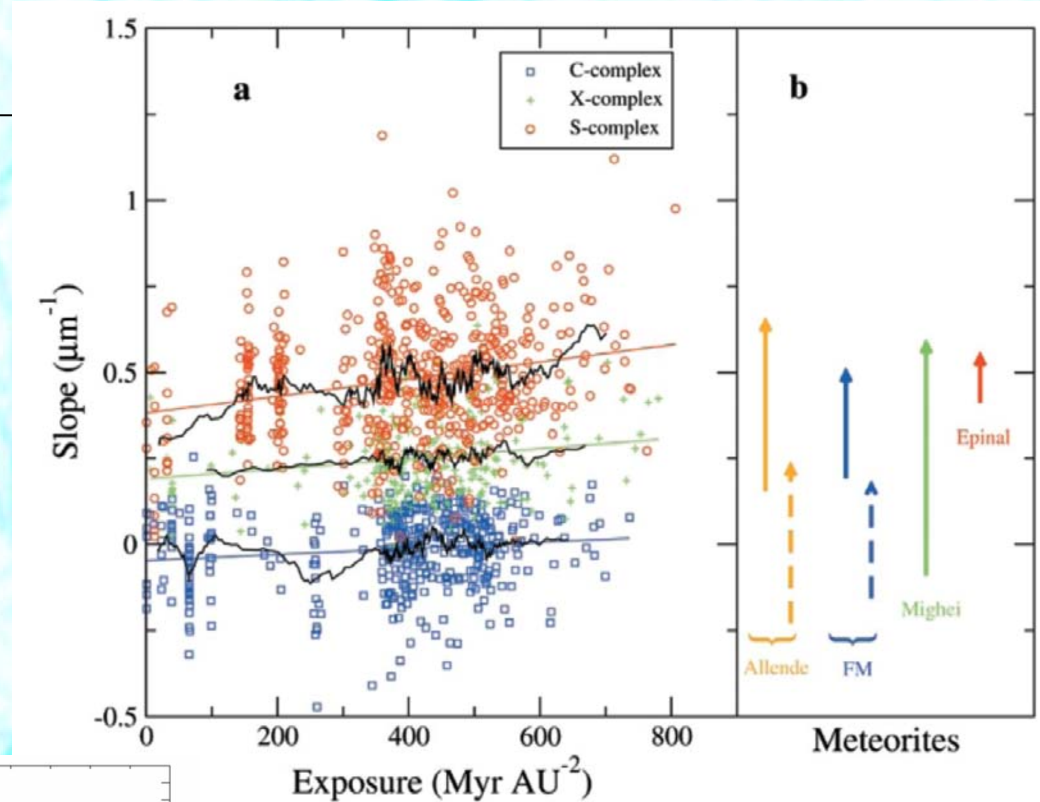


Later confirmed by studies on young asteroidal families: Willman et al. 2008, Vernazza et al. 2009

SW of ECs and CCs

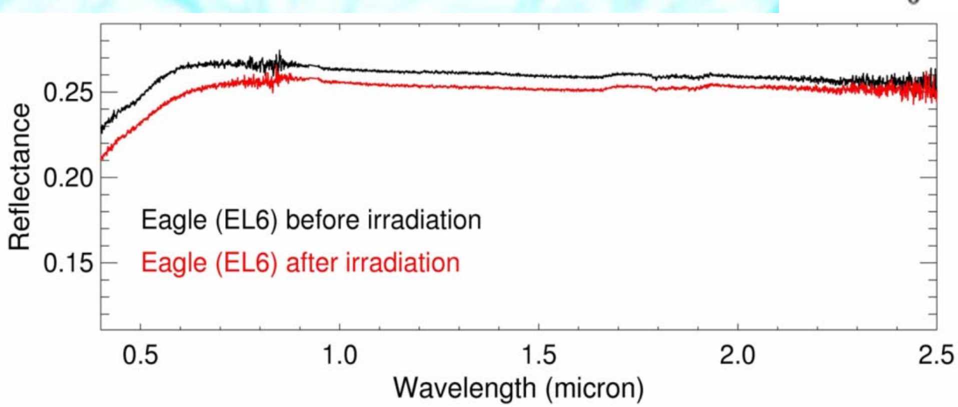
Reddening for C-type is less pronounced than for S-type asteroids

[Lazzarin et al., 2006]



For EC meteorites we observe little spectral variation → we expect little spectral difference between ECs and their parent bodies (Lutetia?)

[Vernazza, Brunetto, et al., 2009]

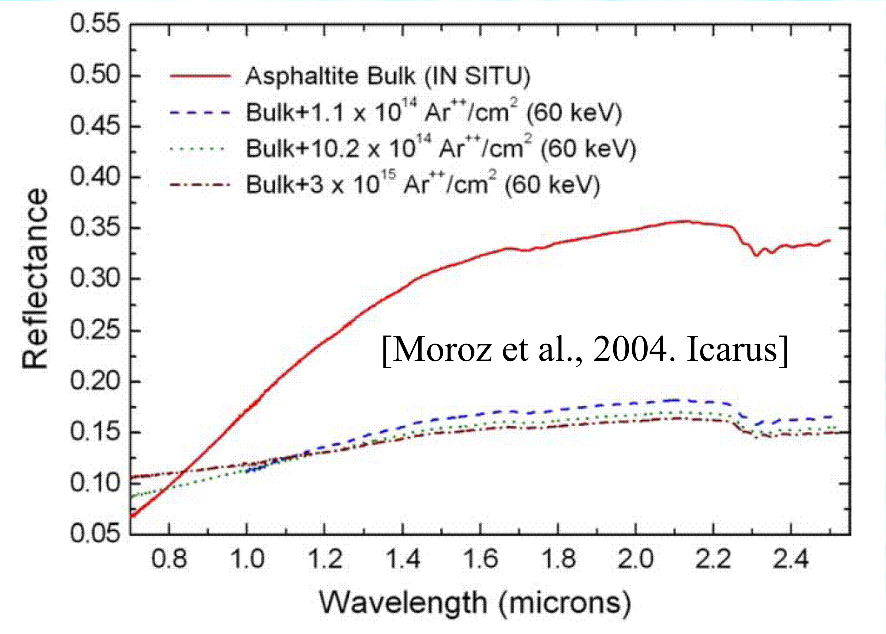


But some spectral flattening is observed in the visible in a single irradiation experiments of Tagish Lake meteorite (C2 met. from D-type asteroid?)

SW of organics and C-rich ices

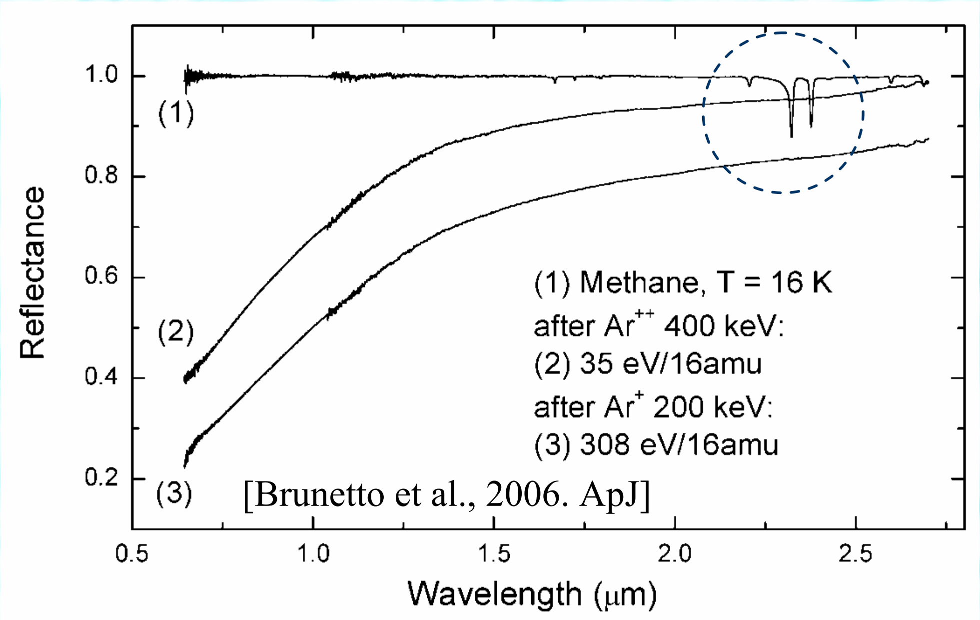
In the presence of complex organics, SW trend is not yet well established
→ dependence on the original composition.
Competition of reddening and flattening? (ex.: Jupiter Trojans show little color variations)

Flattening



Loss of hydrogen, carbonization.

Reddening (low dose) & flattening (high dose)



Formation of organic residue.

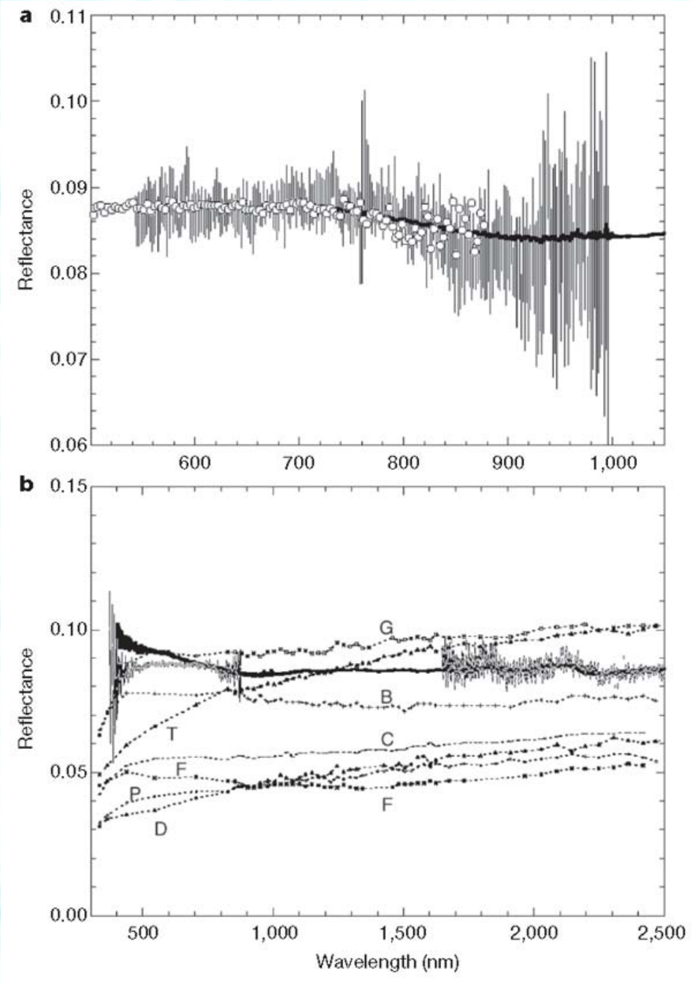
Low-albedo asteroids: the case of 2008 TC_3

October 2008: a small asteroid (2008 TC_3) hit the Earth. Later, 47 meteorites were recovered, fragments of a single body named **Almahata Sitta**.

Flat reflectance spectrum in the visible range.

(a) Meteorite reflectance spectrum compared to that of asteroid 2008 TC_3.
(b) Comparison with low albedo asteroid classes

[Jenniskens et al. 2009, Nature]



Neutral & dark visible spectra
→ strong absorption by de-hydrogenated carbons.
We expect little spectral variations due to SW.

Sample return from asteroids: space weathered layers

Slow solar wind ions:	Rp < 1 μm	high dose
Solar energetic particles: (from flares and active regions)	Rp < 1 mm	medium dose
High energy galactic ions:	Rp < 1 m	low dose

Estimated radiation doses (eV / 16-amu molecule) for ice-processing environments

Object	Distance (AU)	Dose at 1-μm Depth	Dose at 100-μm Depth	Dose at 1-m Depth
Centaur	5-35	100 - 10,000	100 - 200	30
	48-1000	100 - 500,000	100 - 30,000	30 - 50
Triton, Pluto, Charon	30-40	100	100	30
TNO	<48 ~1000	100 500,000	100 30,000	30 50
Oort cloud comet	~40,000-100,000	500,000	30,000	50

Hudson , Palumbo, Strazzulla, Moore, Cooper, Sturner, 2008, Laboratory studies of the chemistry of TNO surface materials, in: The Solar System beyond Neptune, Barucci, et al. (editors), Univ Arizona Press, Tucson, 507-523

Conclusions & perspectives

- SW processes reasonably well understood for the Moon and S-type asteroids.
- Analysis of young families, relation with exposure and dynamics → timescale measured in space approaches what estimated in the lab.
- SW processes in presence of organics are still unclear; strong dependence on the original composition.
- Lack of laboratory SW experiments on primitive meteorites.
- Sample return missions (e.g. Marco Polo): direct measure of SW?
  The first micrometer below the surface accumulates the highest dose.