Spectral data of asteroids revealing the mineralogy of surfaces

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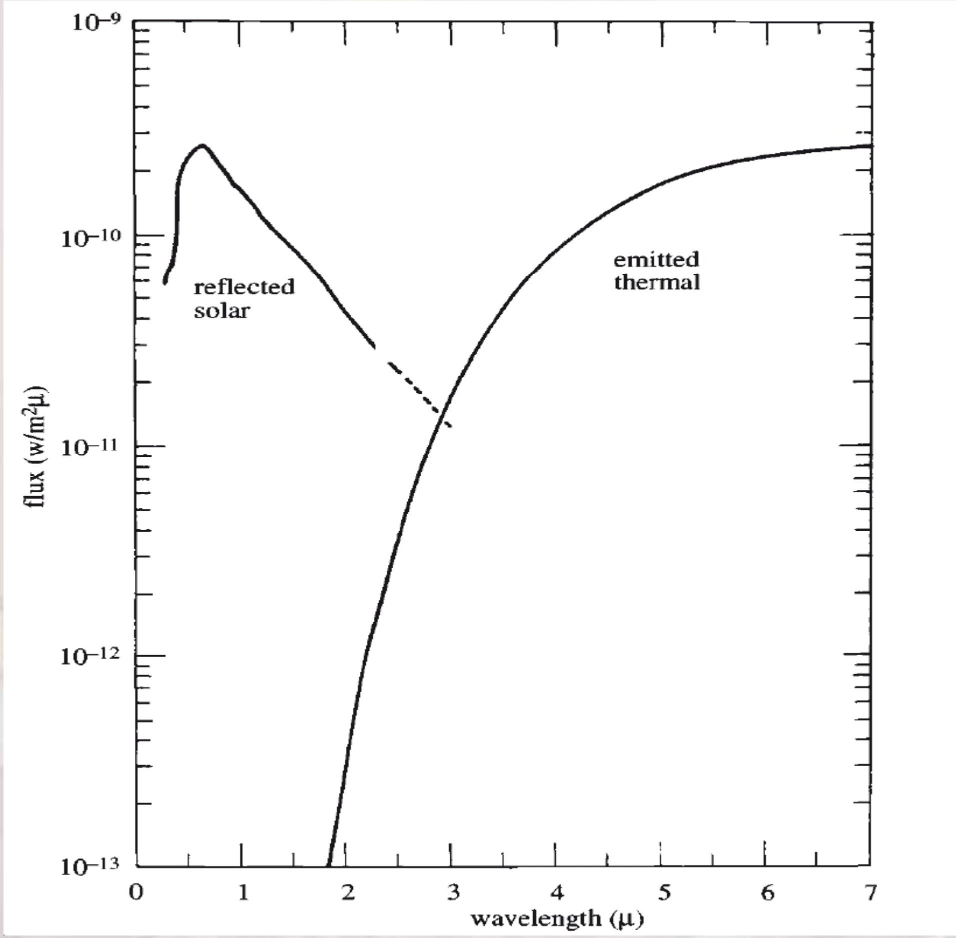
CONTEXT

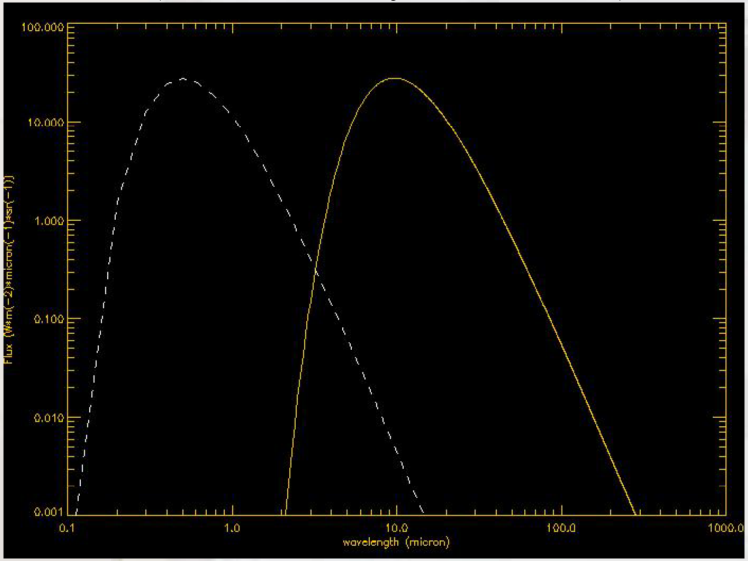
he spectral flux received on Earth from a square ilometre of sunlit mare basalt on the Moon's surface.



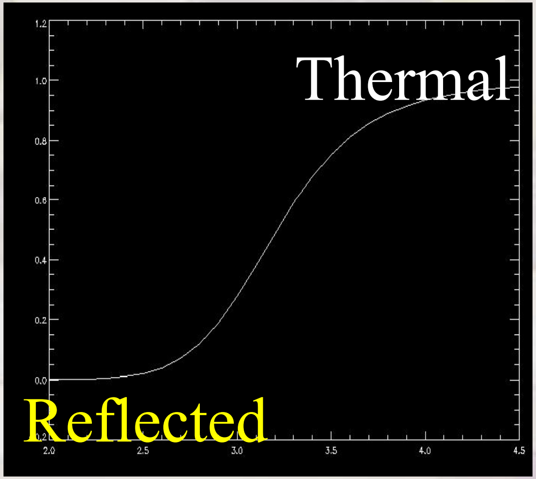
McCord & Adams, 1977 (***Use of ground-based telescopes in determining the composition of the surfaces of solar system objects.***)

Asteroid

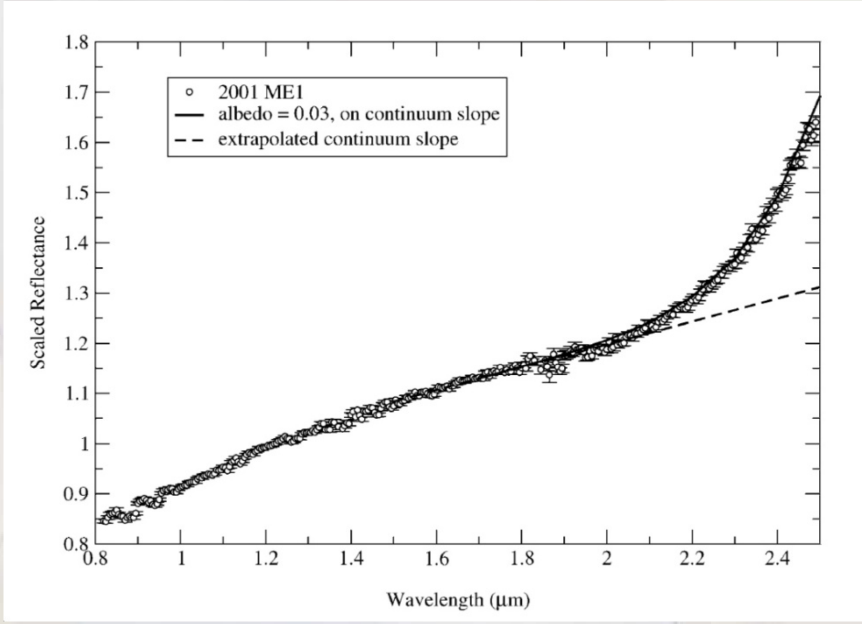
(Black Body, T=200K)

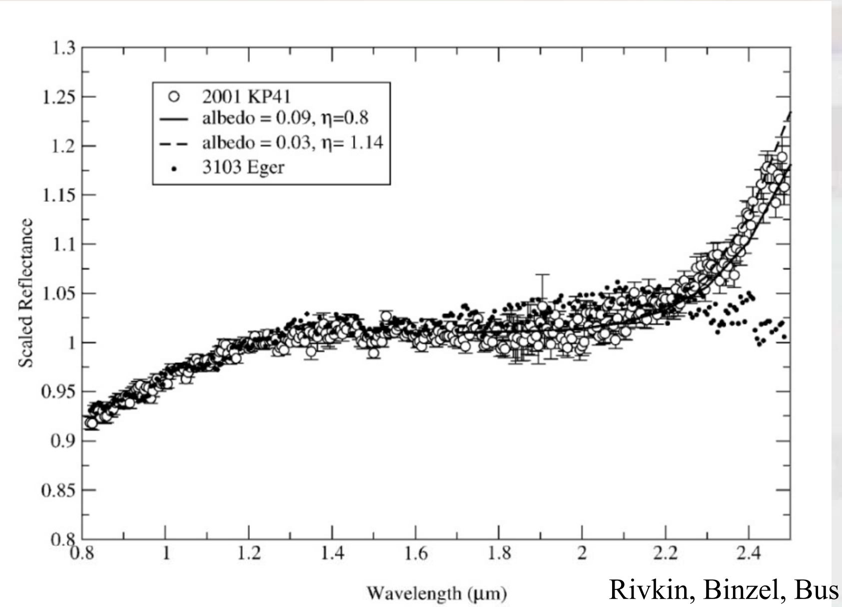


Balance Ref/Therm



TWO EXAMPLES (NEAs)





Rivkin, Binzel, Bus
Icarus 175, 2005

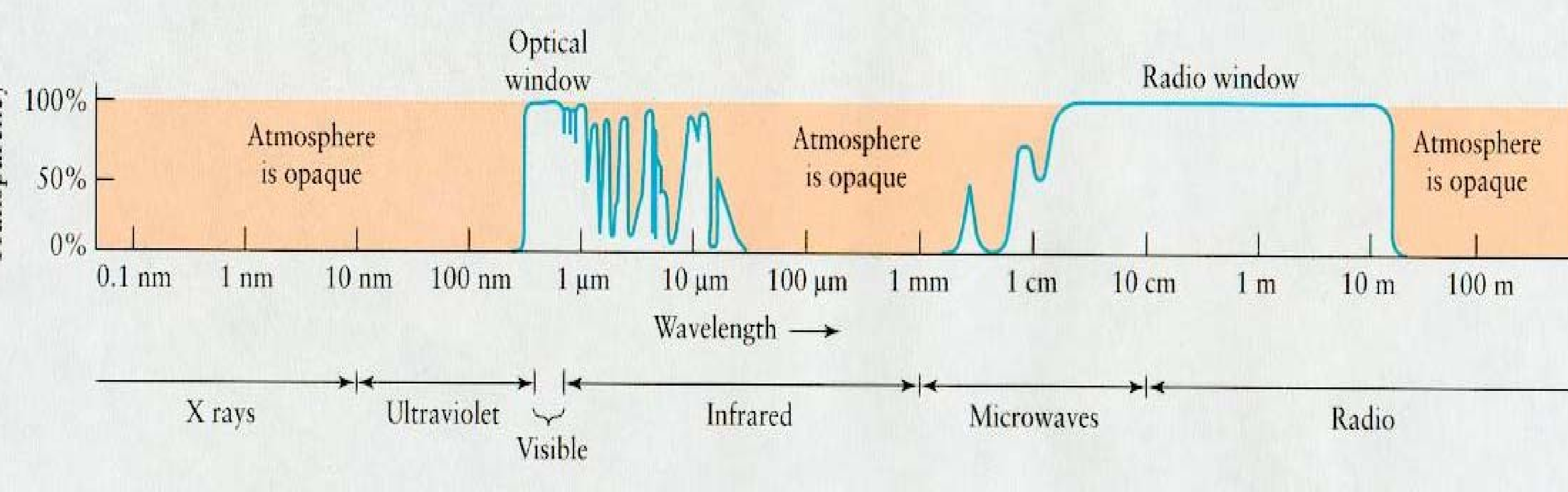
IN FACT:

MBAs – **spectrum of reflectance** in the interval 0.4 – 4.0 µm

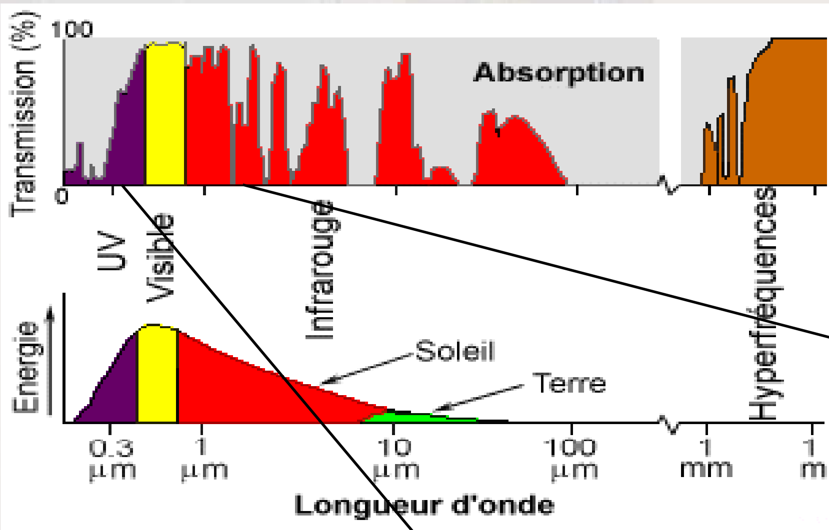
Reflectance spectroscopy is the result of a thin layer at the surface of atmosphereless body.

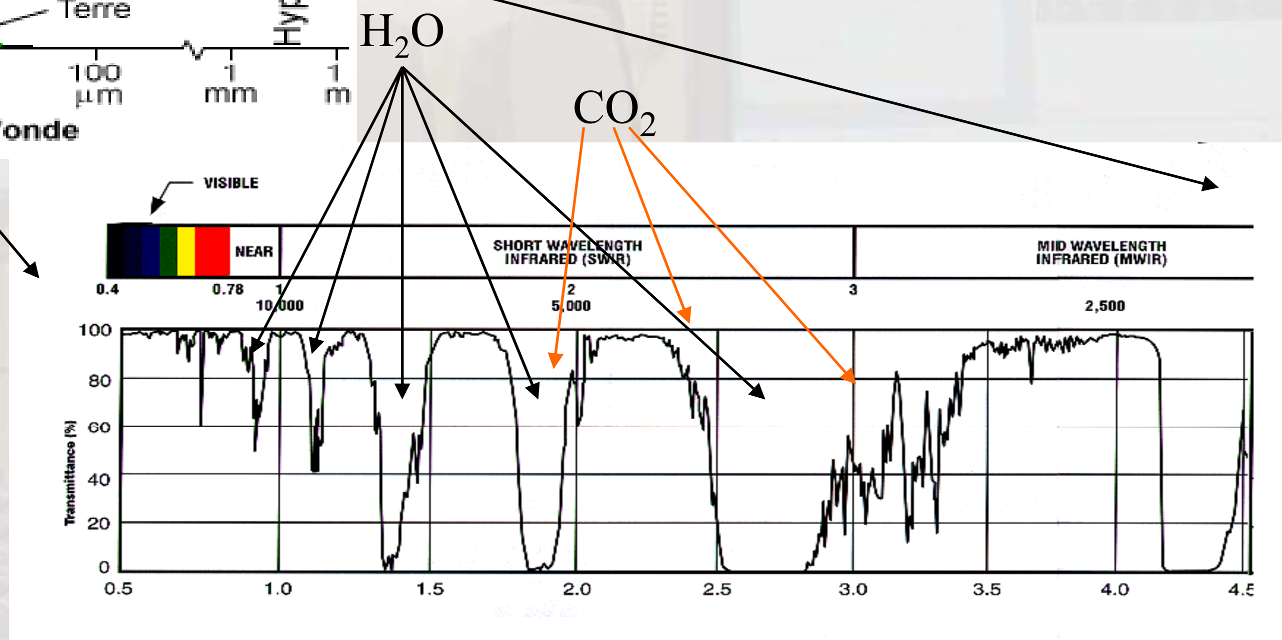
REMOTE SPECTROSCOPY

ATMOSPHERIC TRANSPARENCY

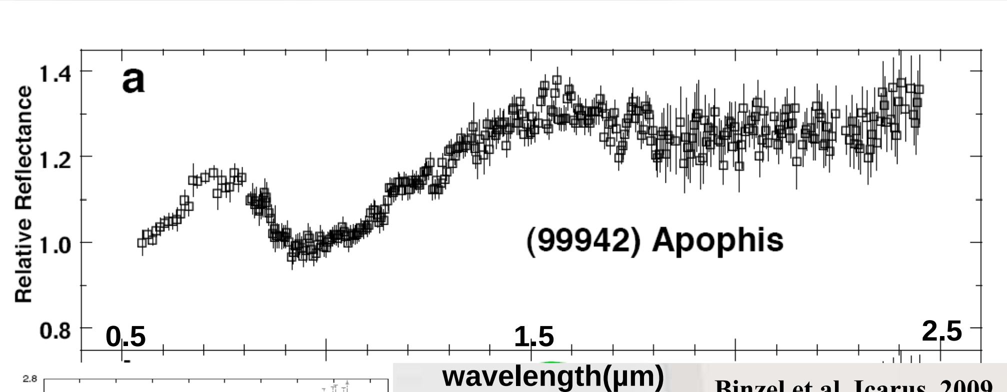


Atmospheric Molecules:
H_2O, O_3, CO_2, O_2, NO_2,

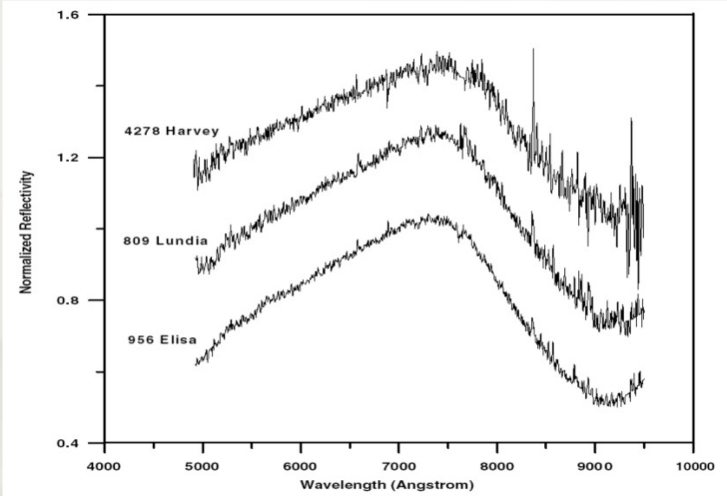




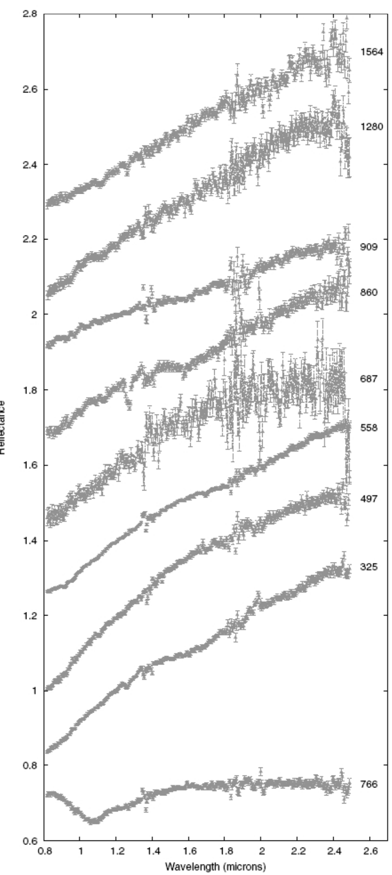
Visible and V+NearInfraRed spectra

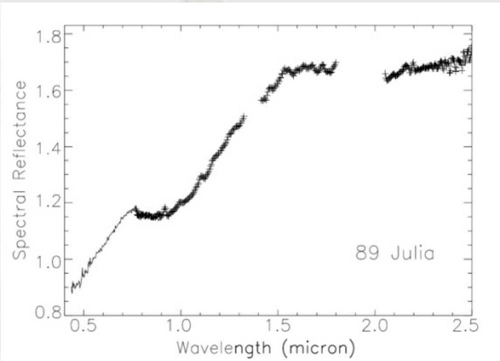


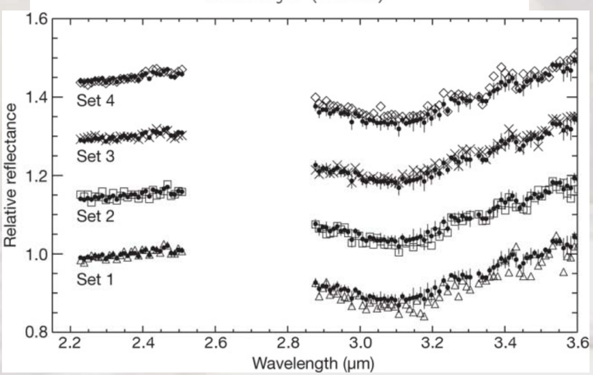
Binzel et al, Icarus, 2009



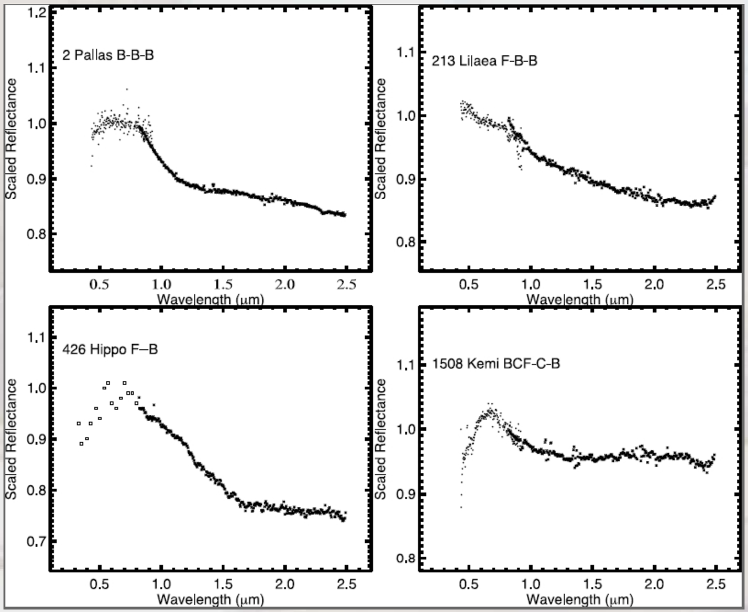
Florczak et al, Icarus, 2002





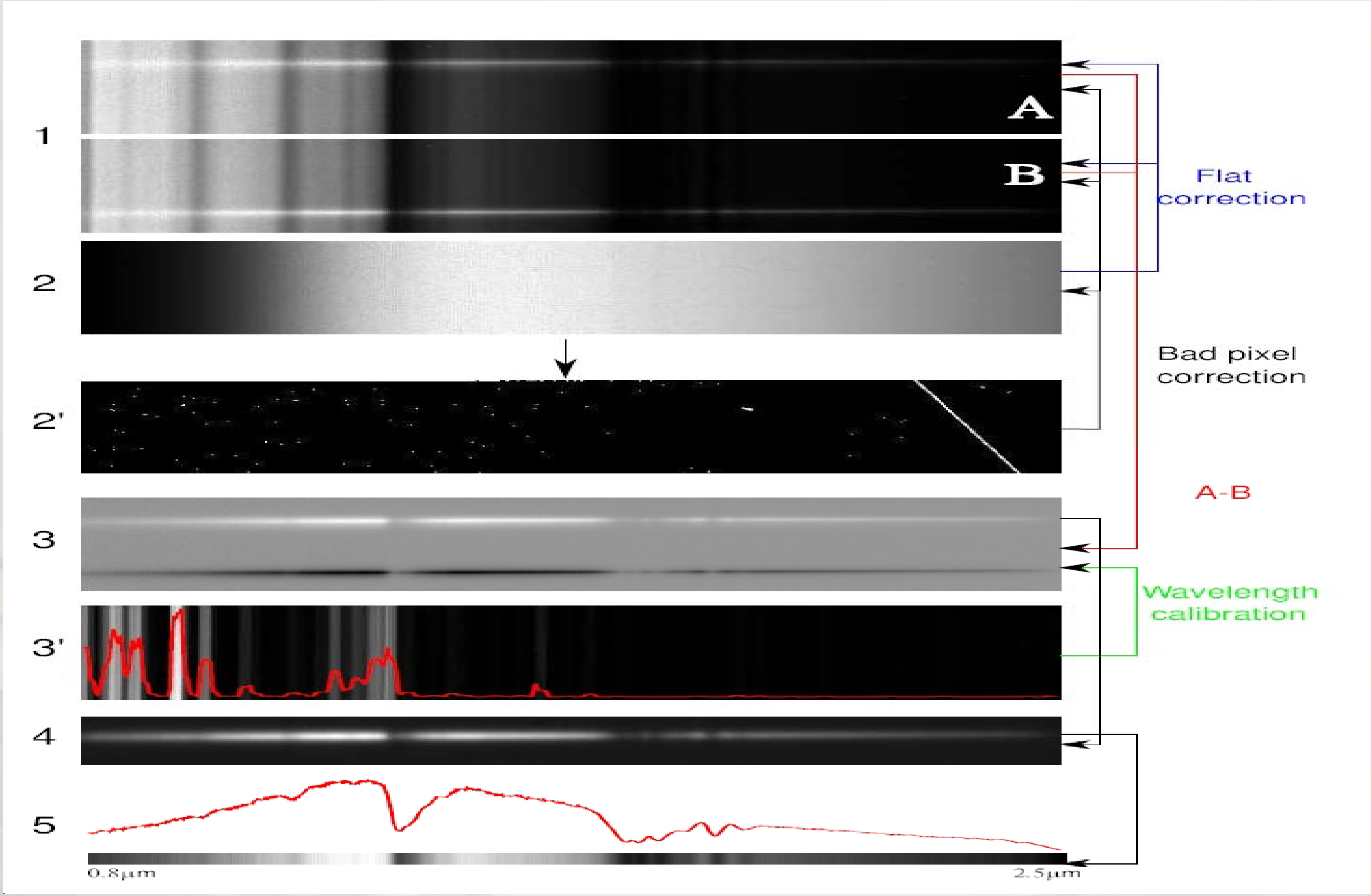


Campins et al, Nature, 2010

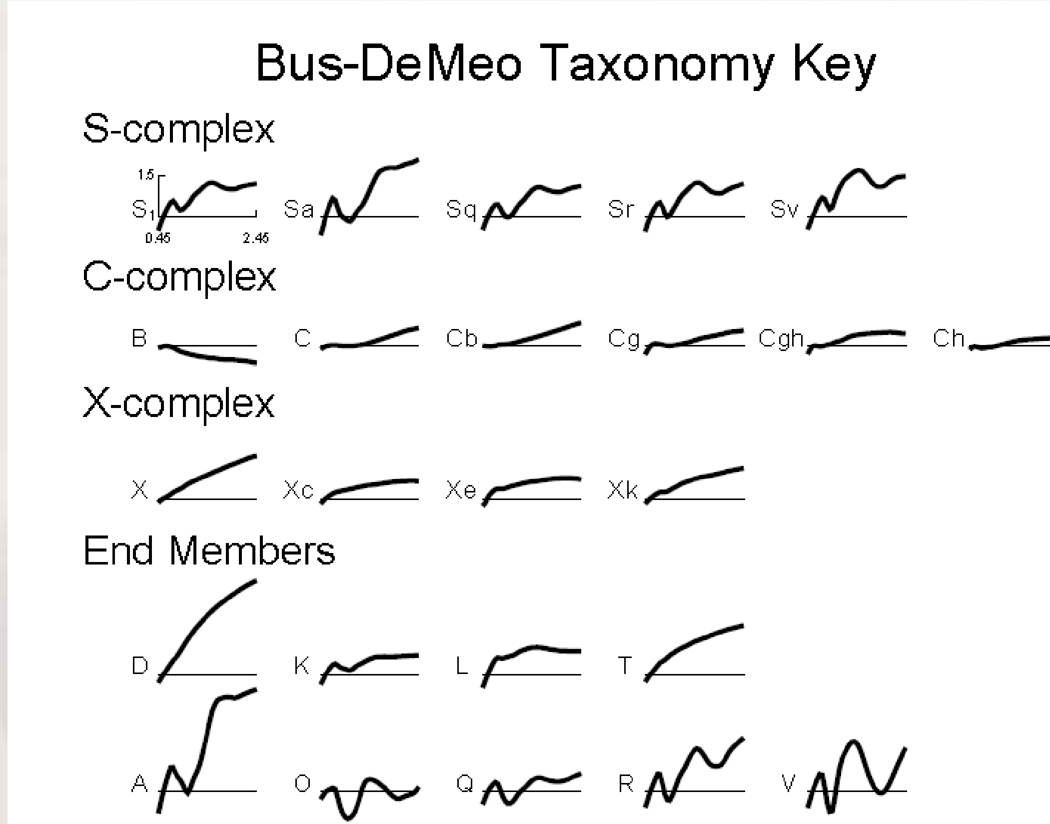


Clark et al, JGR, 2010

Near InfraRed DATA REDUCTION COOKBOOK



Asteroid classification

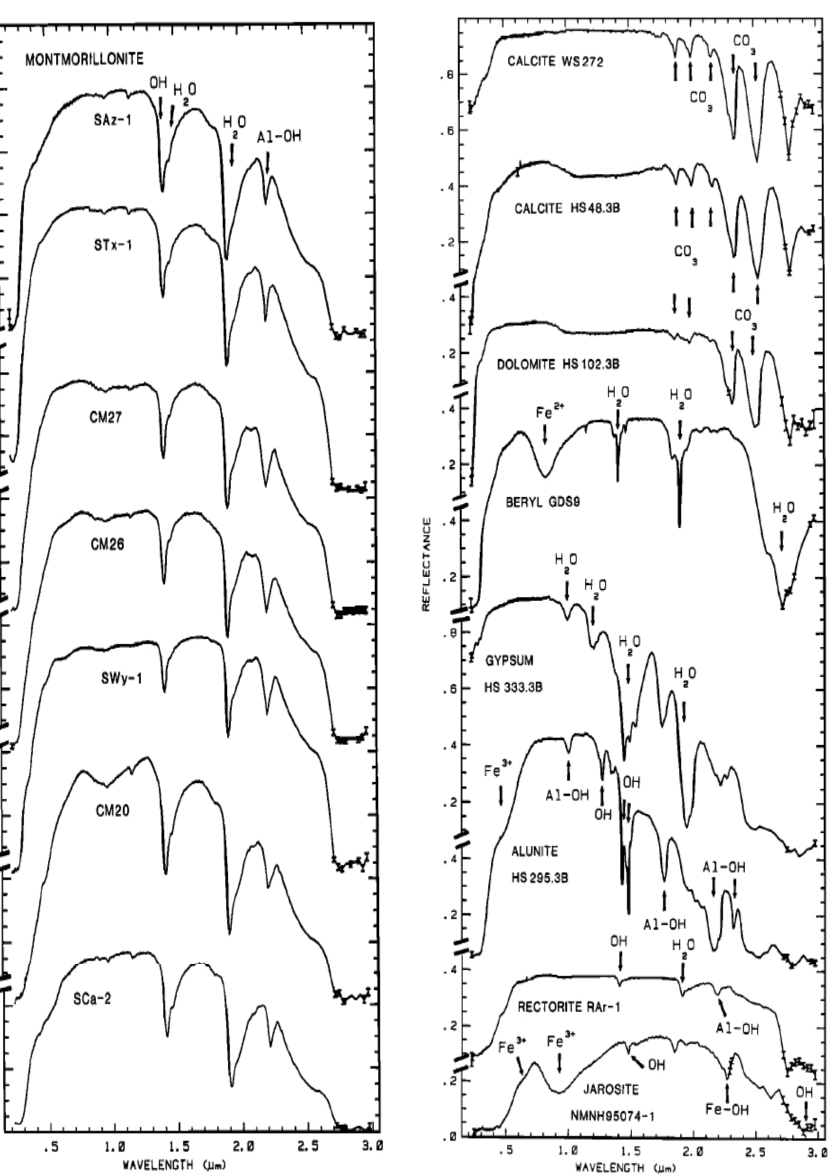


DeMeo et al, Icarus, 2009

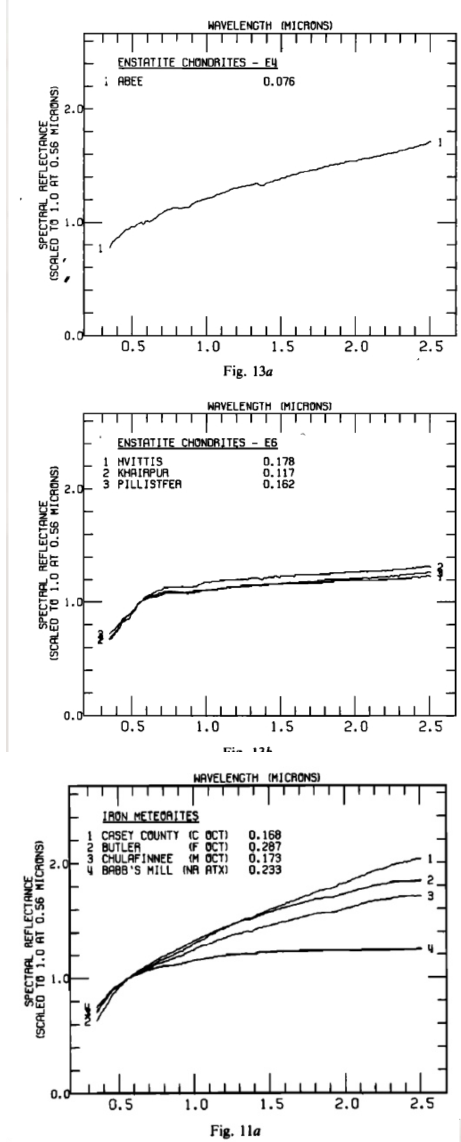
Asteroid Taxonomy ⇔ Bird taxonomy

Establish the DNA of asteroids via comparative planetology

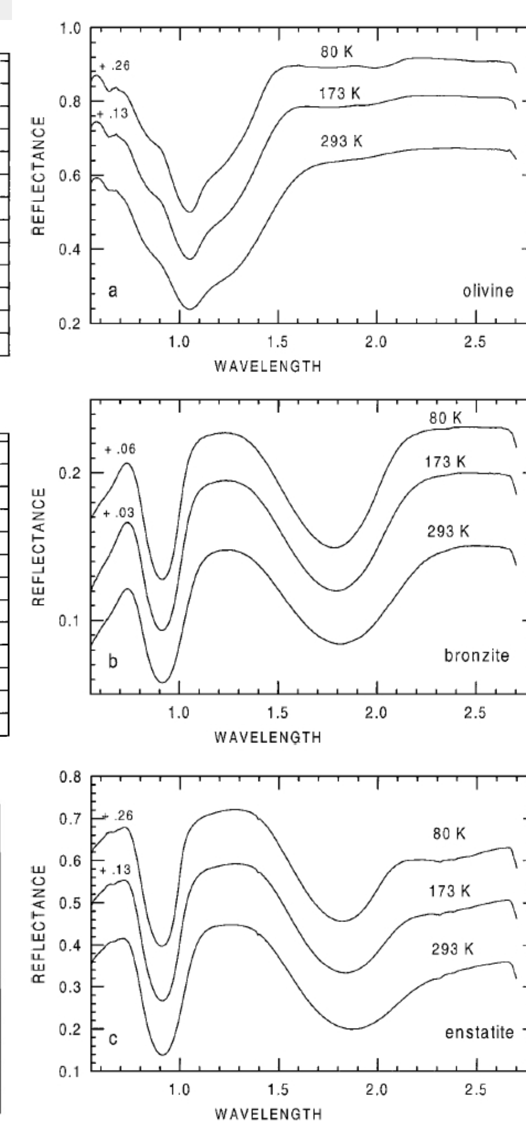
LABORATORY SPECTRA (EXAMPLES)



Clark, JGR 1990



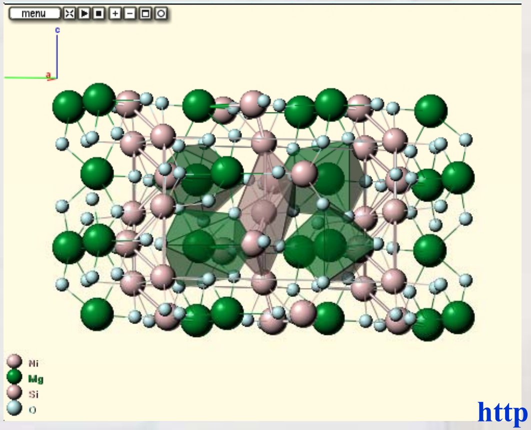
Gaffey, JGR 1976



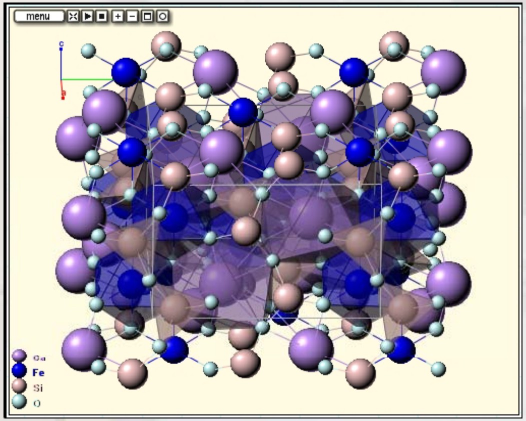
Moroz et al, Icarus 200

Comparative Planetology
Made the right choice of minerals…

- The mineral must be cosmochemical representative (ex: Ol



OPx, CPx



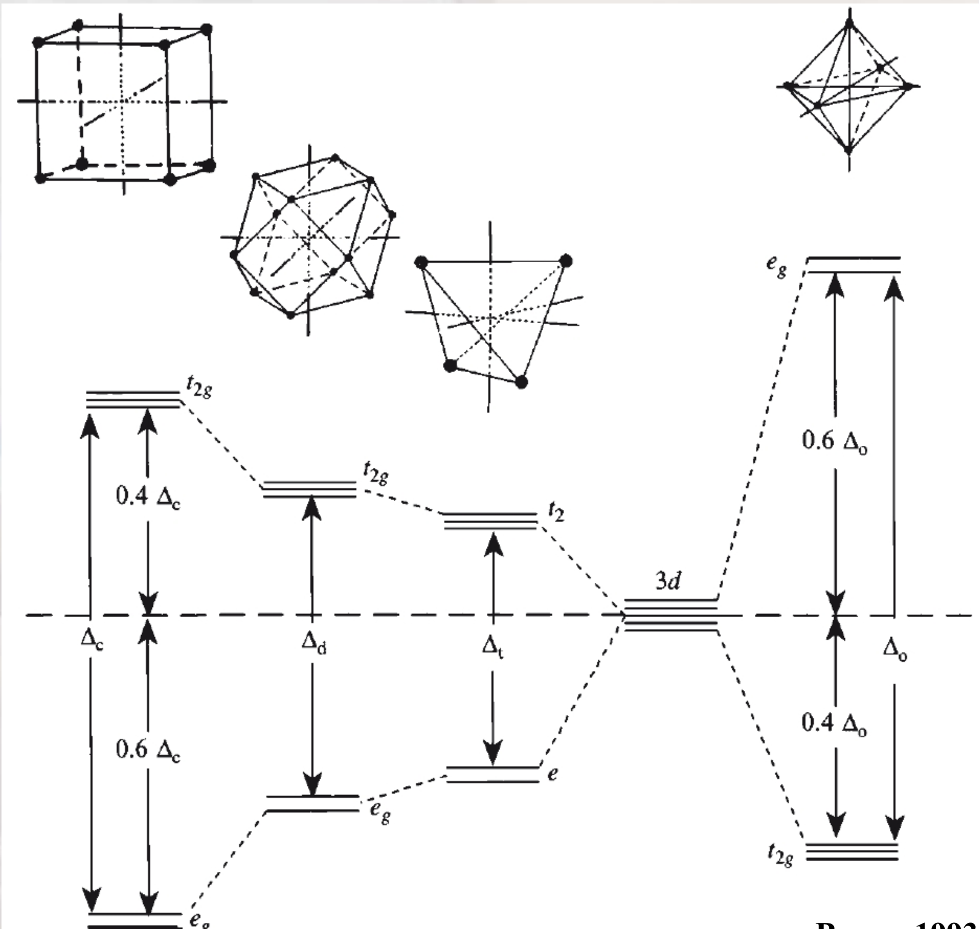
http://webmineral.com/data

- Spectral signature outside the telluric bands (OH stretch ≠ 1.4, 1.9, 2.7,…µm)

- Spectral signature large/deep enough to be detected by telescopic observations.

Results based on Crystal Field Theory

Origin of absorption bands associated to the transition elements (*d, f* orbitals)

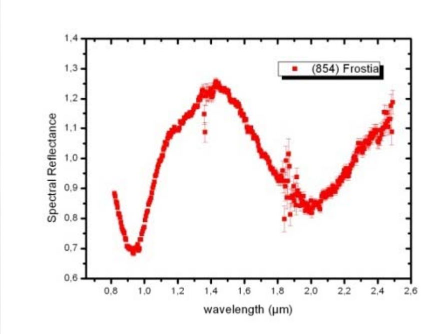


Burns, 1993

	Atomic number	Element
	19	K
	20	Ca
first-series transition elements	21	Sc
	22	Ti
	23	V
	24	Cr
	25	Mn
	26	Fe
	27	Co
	28	Ni
	29	Cu
	30	Zn
	31	Ga
	32	Ge

Ions: Fe^{2+}, Fe^{3+}, Cu^{2+}, Ca^{2+}, Mn^{2+},…

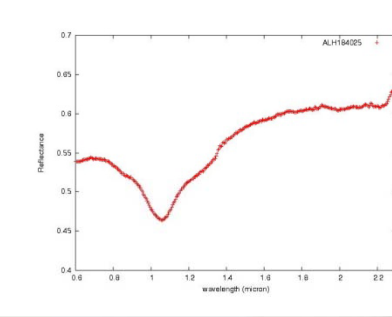
Absorption band envelope



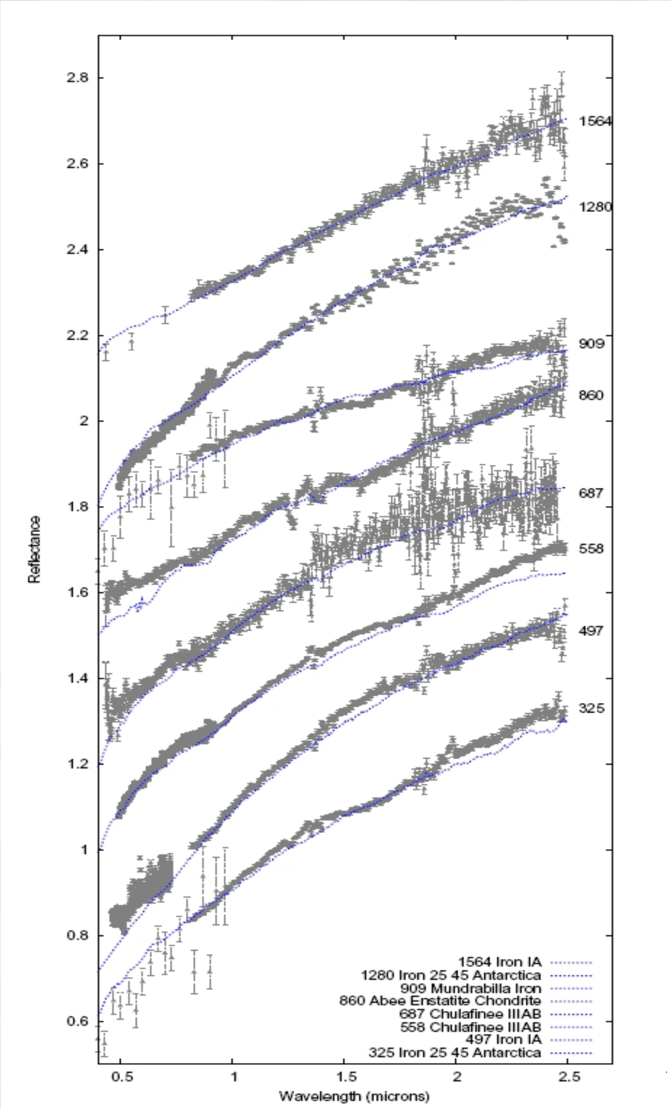
Following Burns (1993)

FWHM between $10^{-3} \div 10$ µm

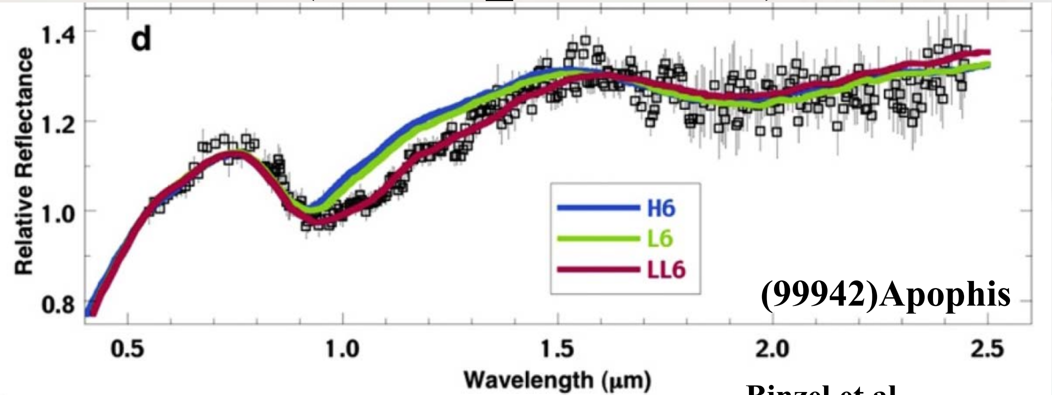
- ***Correlations with energy level diagrams***
- ***The dynamic Jahn-Teller effect (distorted polyhedron)***
- ***Effects of multiple site occupancies***
- ***Vibrational interactions***



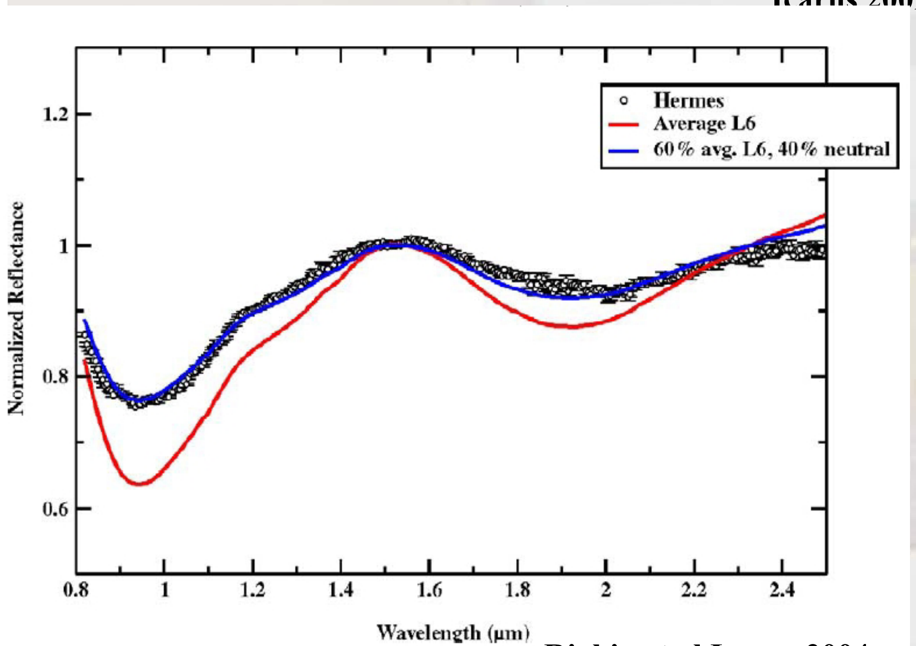
Example ONE (simple fit)



Birlan et al, A&A 2007



Binzel et al, Icarus 2009



Rivkin et al Icarus 2004

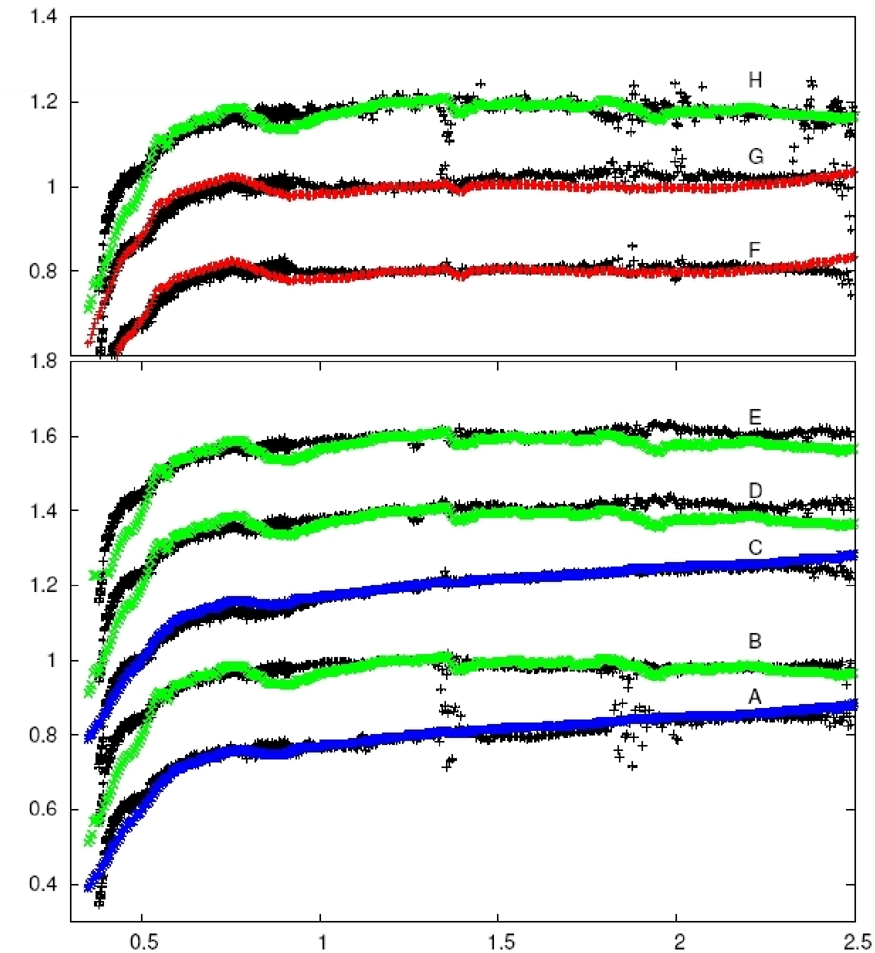
Hermes
S-type

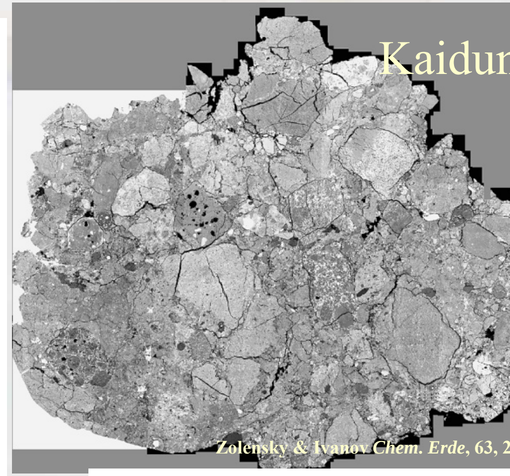
Test χ^2 Lutetia/météorites

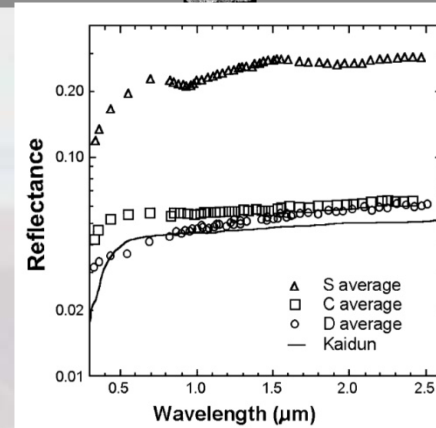
$$\chi^2 = \frac{1}{N_w} \sum_{i=1}^{N_w} \frac{(R_i - f(w_i))^2}{f(w_i)}$$

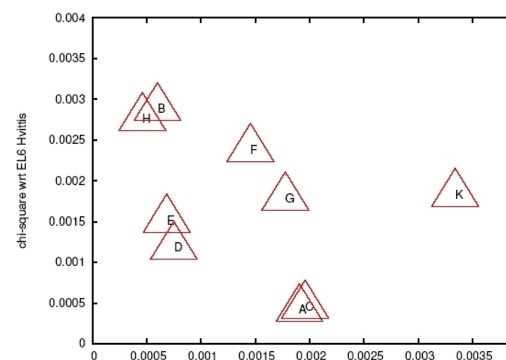
Nedelcu, et al, *A&A*, 2007

Spectrum	Meteorite	Type	χ^2 ($\times 10^6$)
A	Hvittis	EL6	416
	Hvittis	EL6	504
	Pillistfer	EL6	629
	Sevrukovo	L5	633
	Kainsaz	CO3	860
B	Orgueil	CI1	599
	Orgueil	CI1	656
	Grosnaja	CV3	742
	Vigarano	CV3	1015
	Kainsaz	CO3	1355
C	Hvittis	EL6	460
	Hvittis	EL6	471
	Pillistfer	EL6	624
	St. Mark's	EH5	768
	Khairpur	EL6	840
D	Orgueil	CI1	749
	Orgueil	CI1	774
	Kainsaz	CO3	1046
	Vigarano	CV3	1137
	Hvittis	EL6	1180
E	Orgueil	CI1	684
	Orgueil	CI1	720
	Vigarano	CV3	854
	Kainsaz	CO3	897
	Grosanaja	CV3	1008
F	Vigarano	CV3	319
	Kainsaz	CO3	533
	Grosnaja	CV3	559
	Felix	CO3	687
	Warrenton	CO3	936
G	Vigarano	CV3	530
	Kainsaz	CO3	576
	Grosnaja	CV3	1003
	Felix	CO3	1088
	Warrenton	CO3	1237
H	Orgueil	CI1	460
	Orgueil	CI1	515
	Grosnaja	CV3	721
	Vigarano	CV3	1071
	Kainsaz	CO3	1336

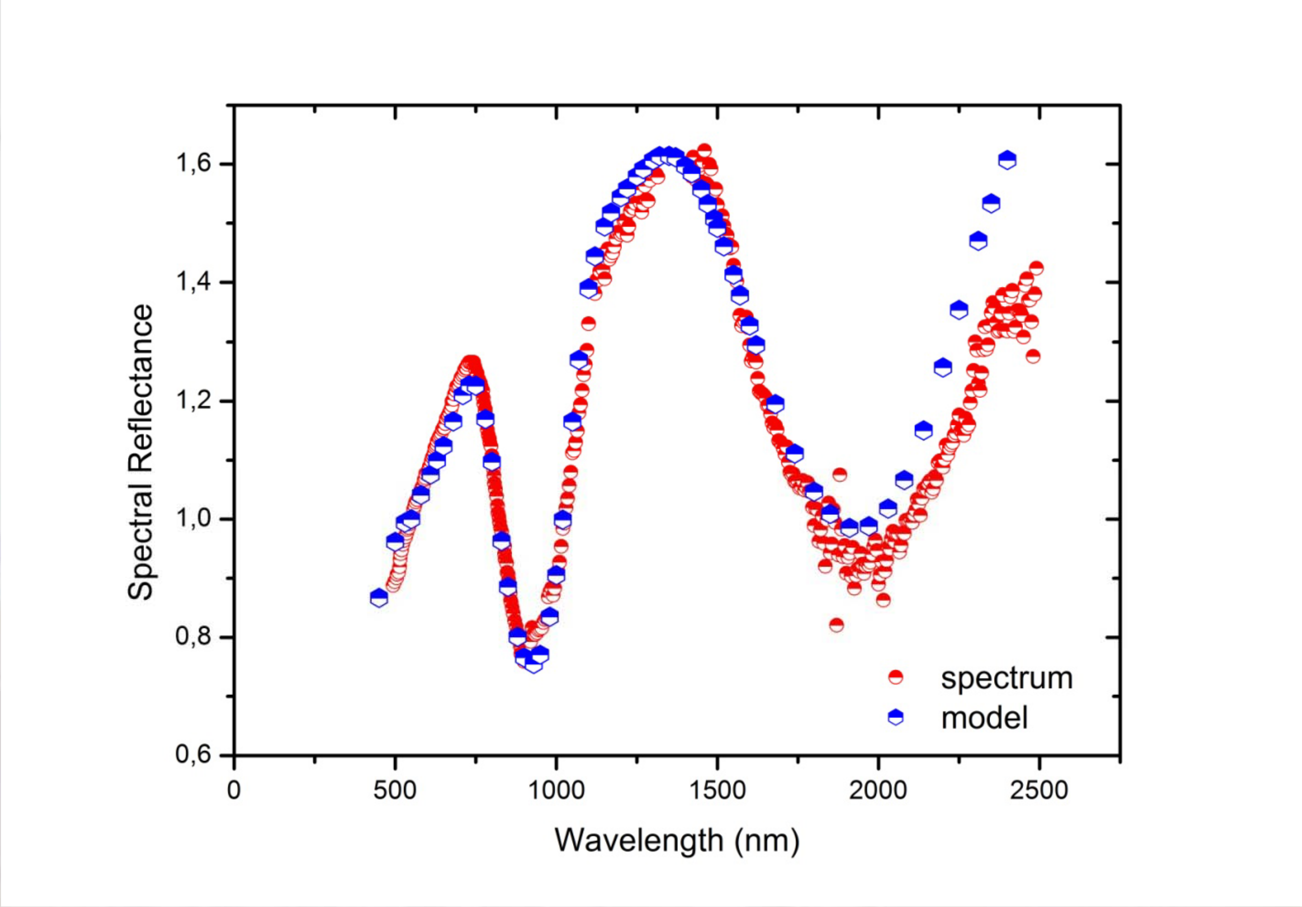








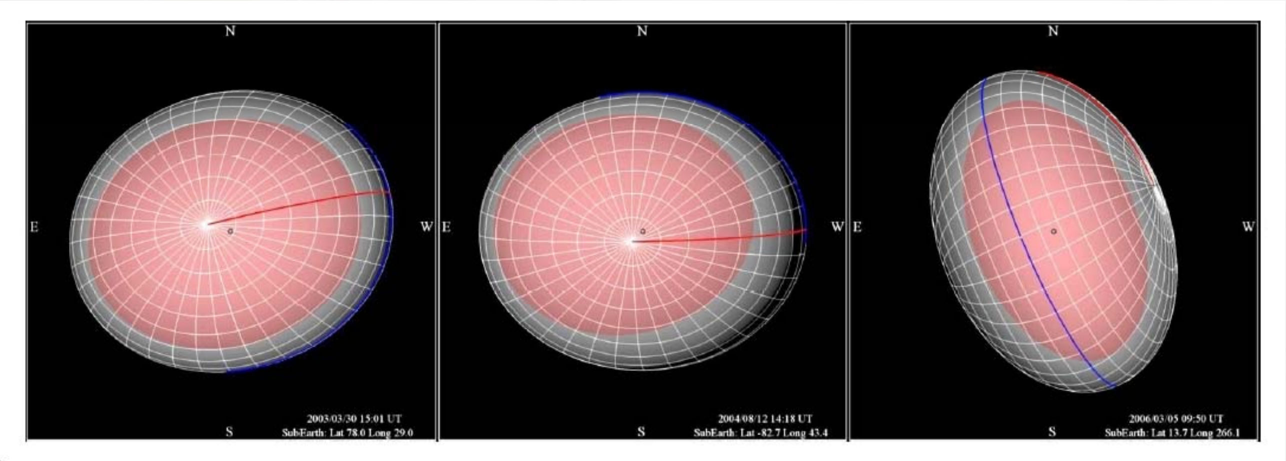
Example TWO
(mixtures and scattering laws)



(809) Lundia modelled with 77% of OPx and 23% of feldspar using Shkuratov/Akimov/Kharkow law.

Example THREE

(spectra/mixtures+ scattering law + physical ephemeris)



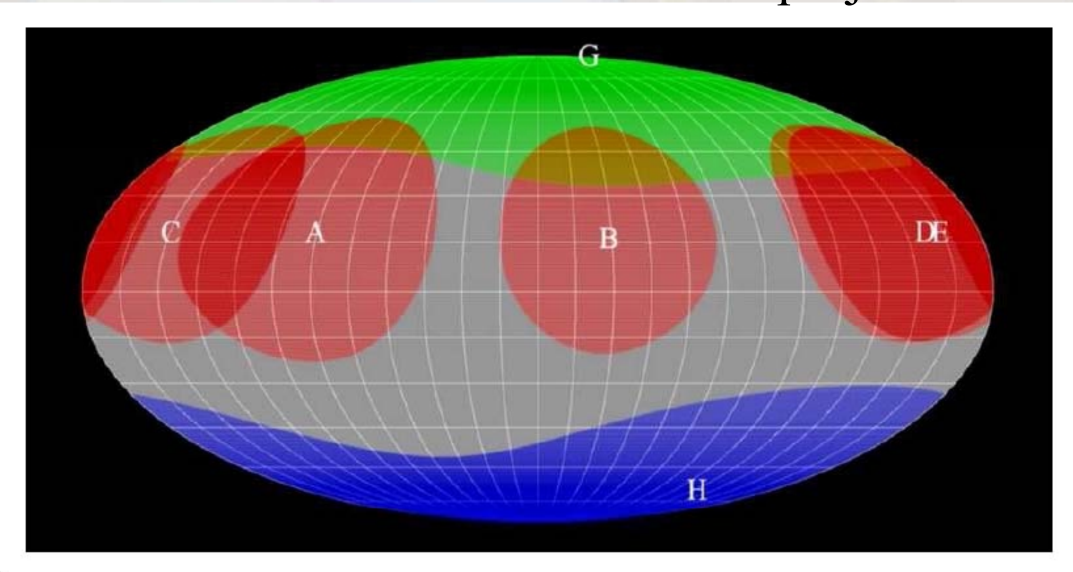
21 Lutetia

2003 – North Pole

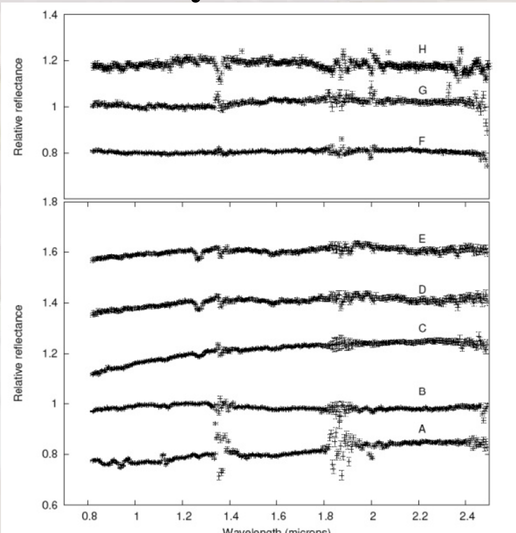
2004 – South Pole

2006 – Eq aspect

21 Lutetia in Mollweide-Babinet projection



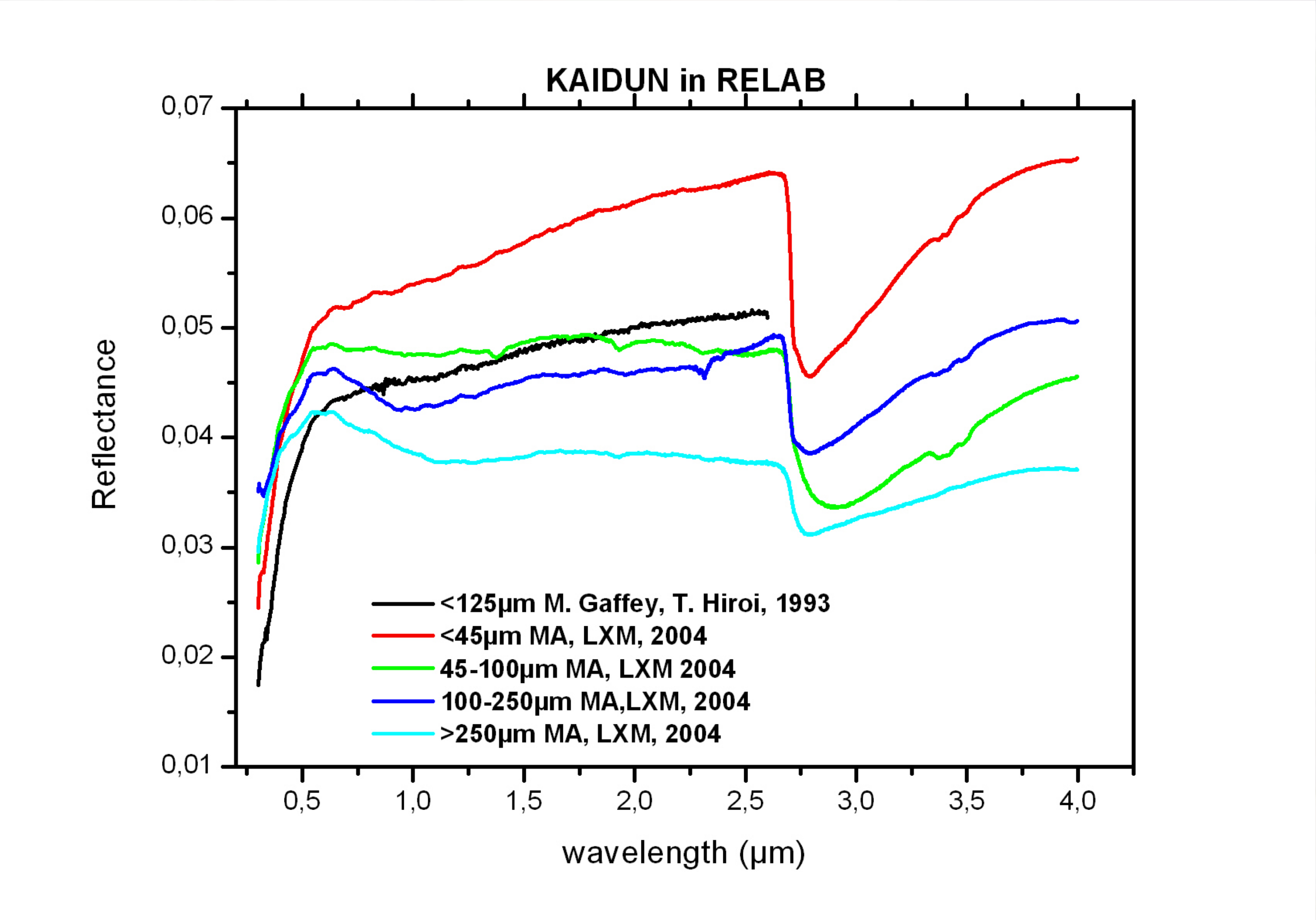
Consistency between spectra D&E obtained 1 mth appart; Dichotomy with B one



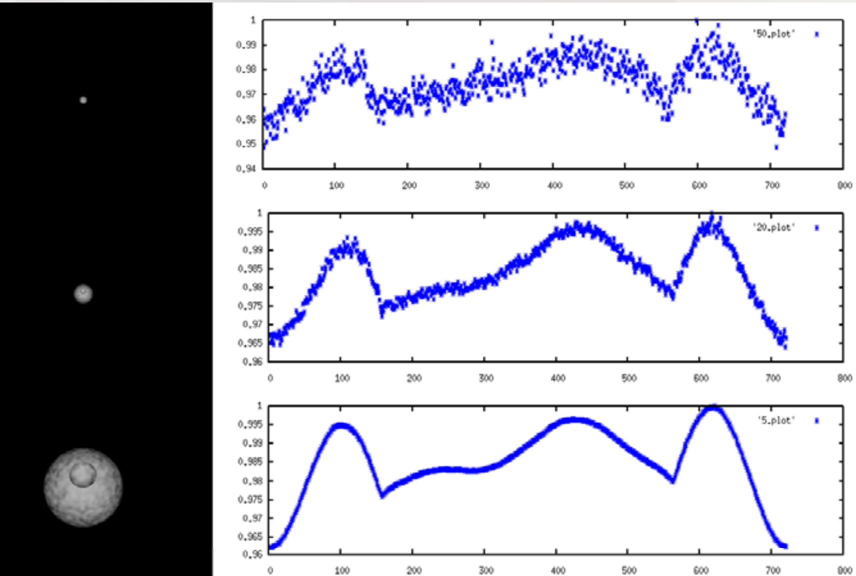
Limitations of method

- Multiple(degeneracy) of mineralogical solutions
- Ambiguous definition of continuum
- Highly dependence of spectra wrt lab sample
- Relative values (normalized to V or J values for instance)
- Magnitude will limit the S/N for a reasonable observing time
  - Spectral resolution

Limitations



Limitations



@Alin Nedelcu

Numerical simulation of a lightcurve

Laboratory		Telescope
$\Delta\lambda / \lambda$	$>$ $>>$	$\Delta\lambda / \lambda$

$$\Phi'(\lambda) = F(\lambda) * \Phi(\lambda)$$

$F(\lambda)$ instrument/transfer function

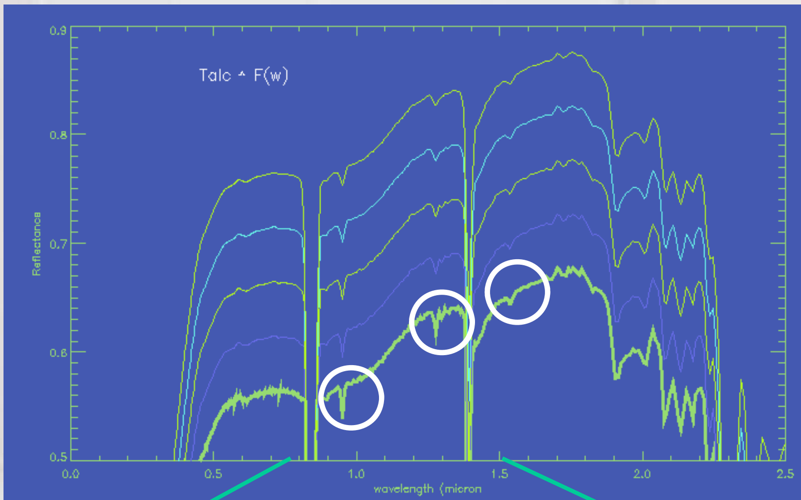
$\Phi(\lambda)$ incident flux

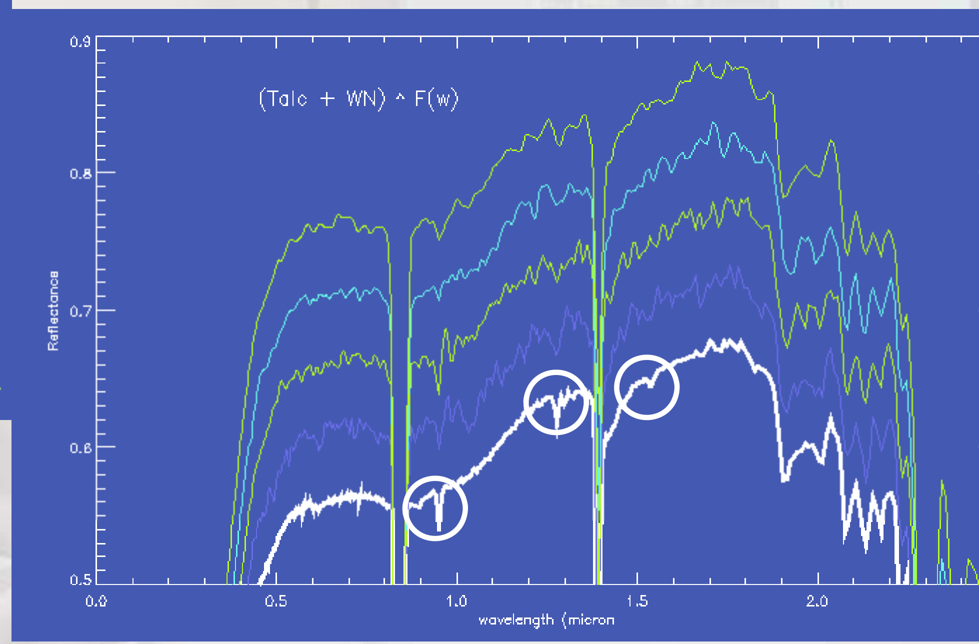
$\Phi'(\lambda)$ recorded flux

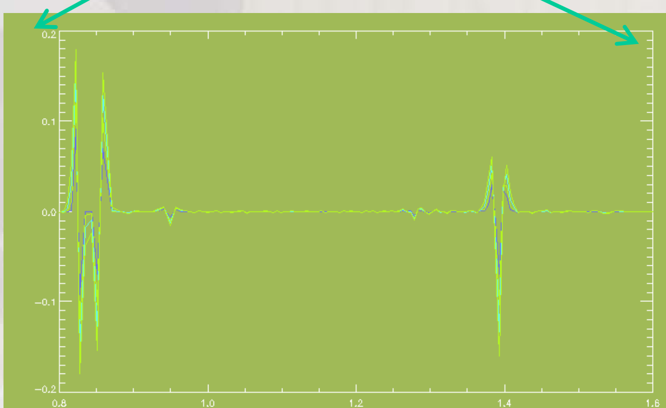
Exercise : reproduce the lab spectrum in a telescope/instrument conditions

- spectrum of talc from UGSC (talc_gds23.6471.asc)
- Res_lab = 4 x Res_tel (i.e. IRTF/SpeX)
- White noise (0.5%)

$F(\lambda)$ Gaussian function stretching up to 20 pts(pixels)







Q: How representative for the bulk mineralogy of asteroid (segregation, space weathering,…) the surface is?