Variegated chemical and physical properties of the surface of TNOs

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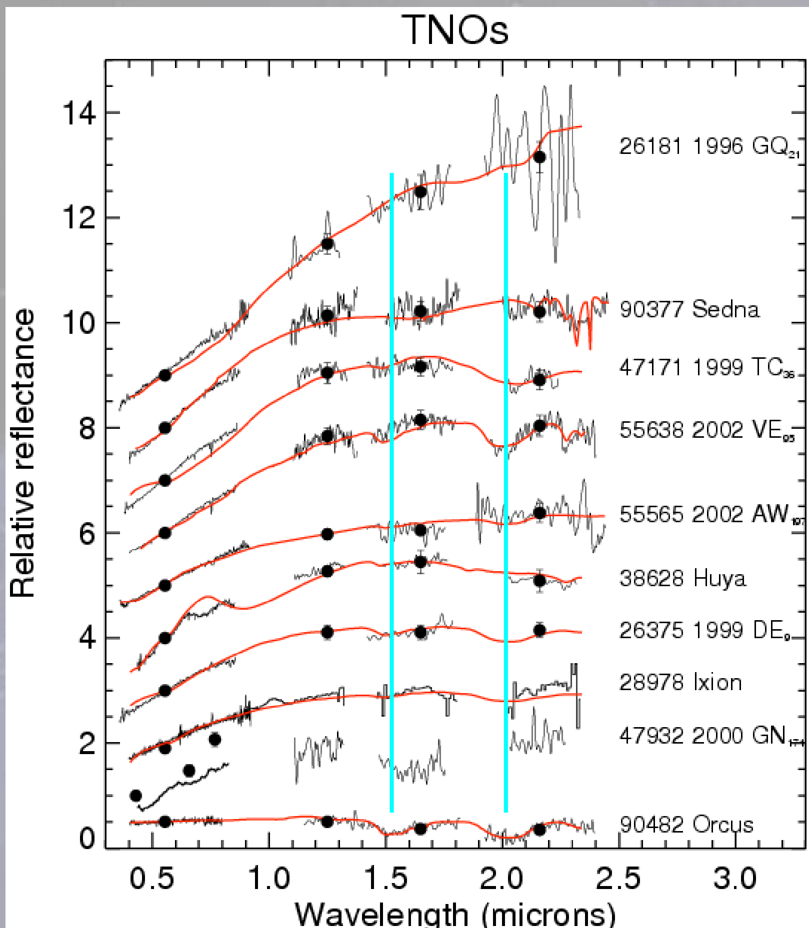
Regolith on solar system bodies, December 2nd, 2010.

TNOs: Main surface characteristics



→ Spectral diversity - Visible, nIR

→ Neutral and red objects from the visible

→ Absorption features, usually related to water ice

TNOs: Main surface characteristics

→ Link between the color and the irradiation level of a surface

→ Different surface properties (ices, dust, refractory layer, etc.)

→ Different radiation sources (UV, high energetic particles)

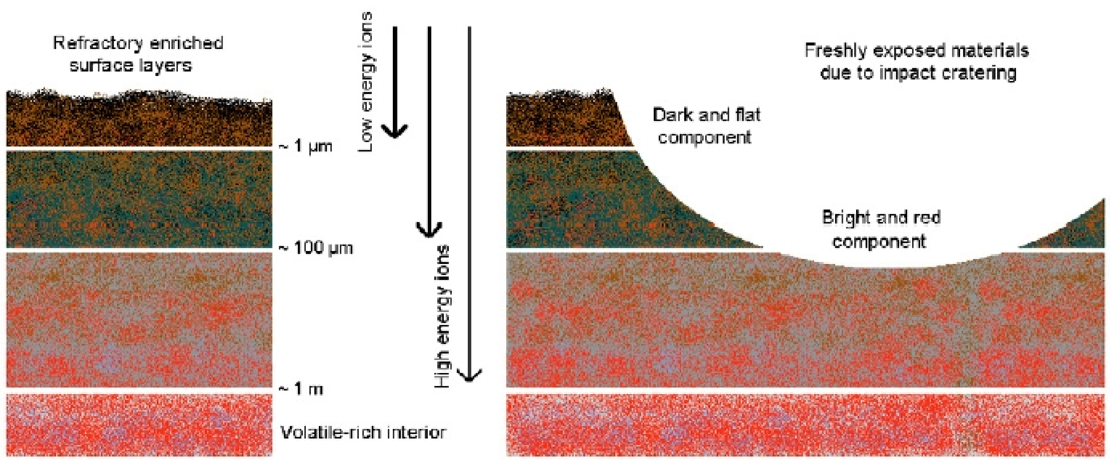


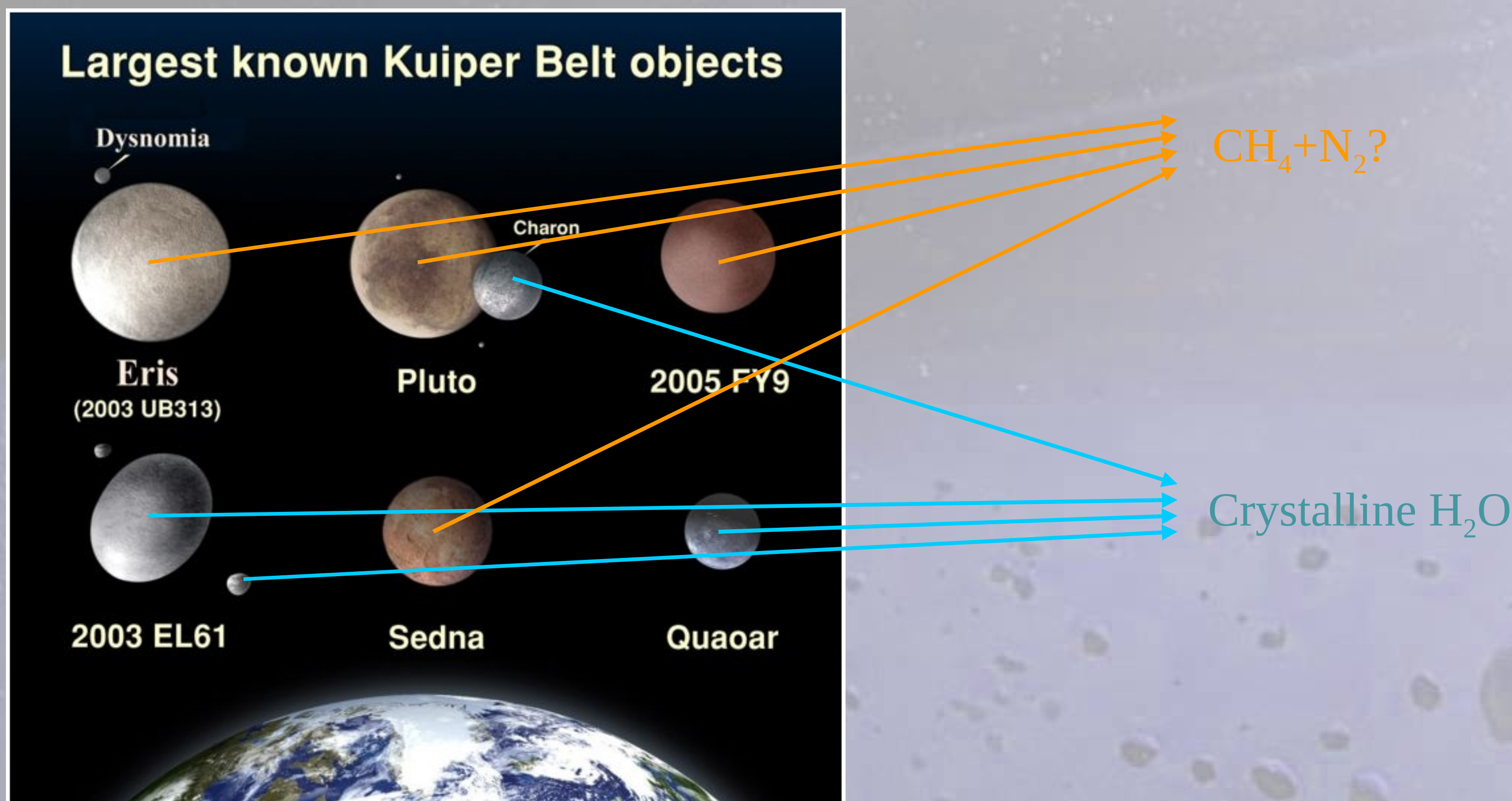
Illustration of particle irradiation by different energies.

Guilbert et al. (2009)

S/N limited!!!

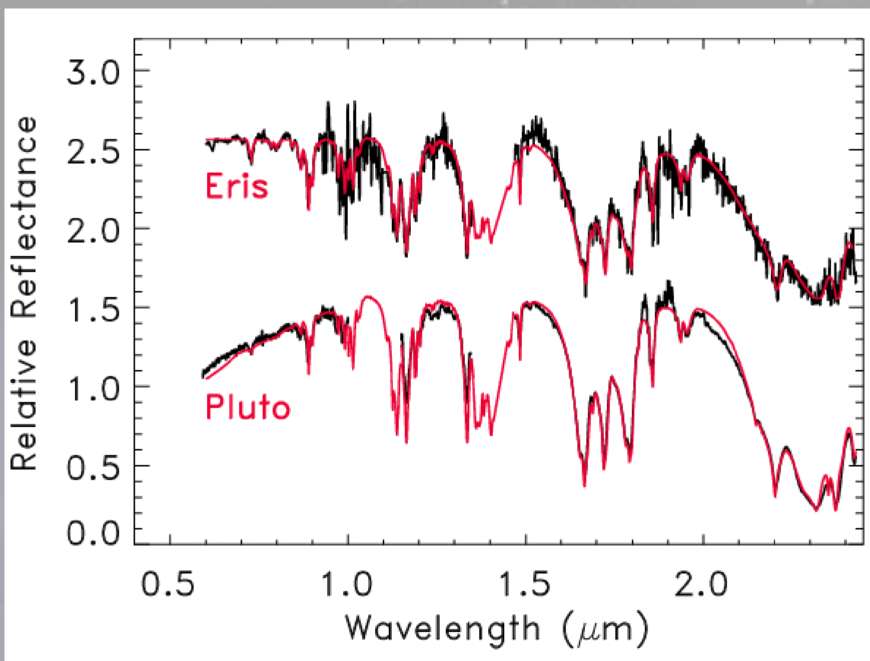
TNOs: The biggest ones

→Focus our analyses on the he brightest objects.

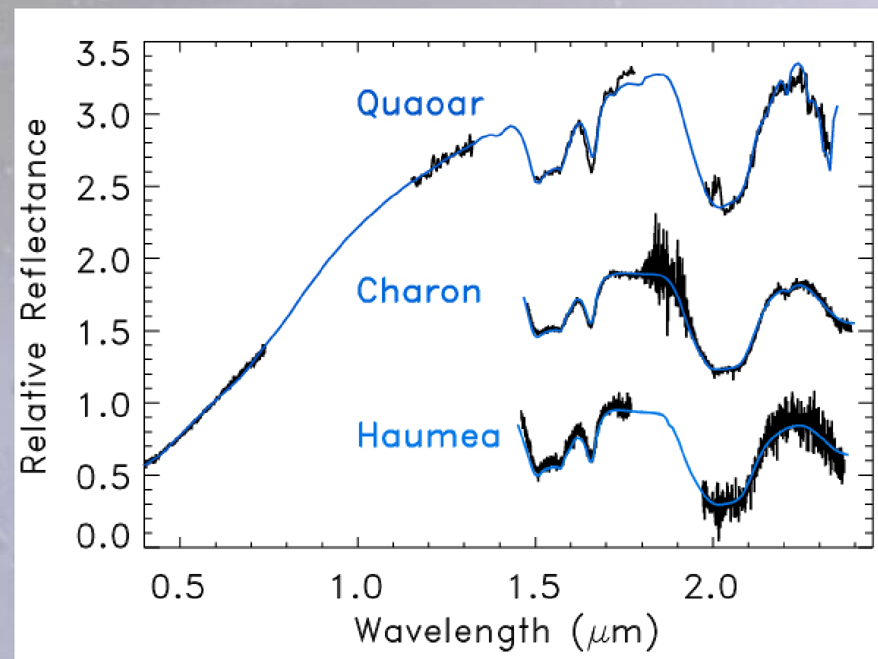


TNOs: The biggest ones

All objects have a diameter close or larger than 1000km.



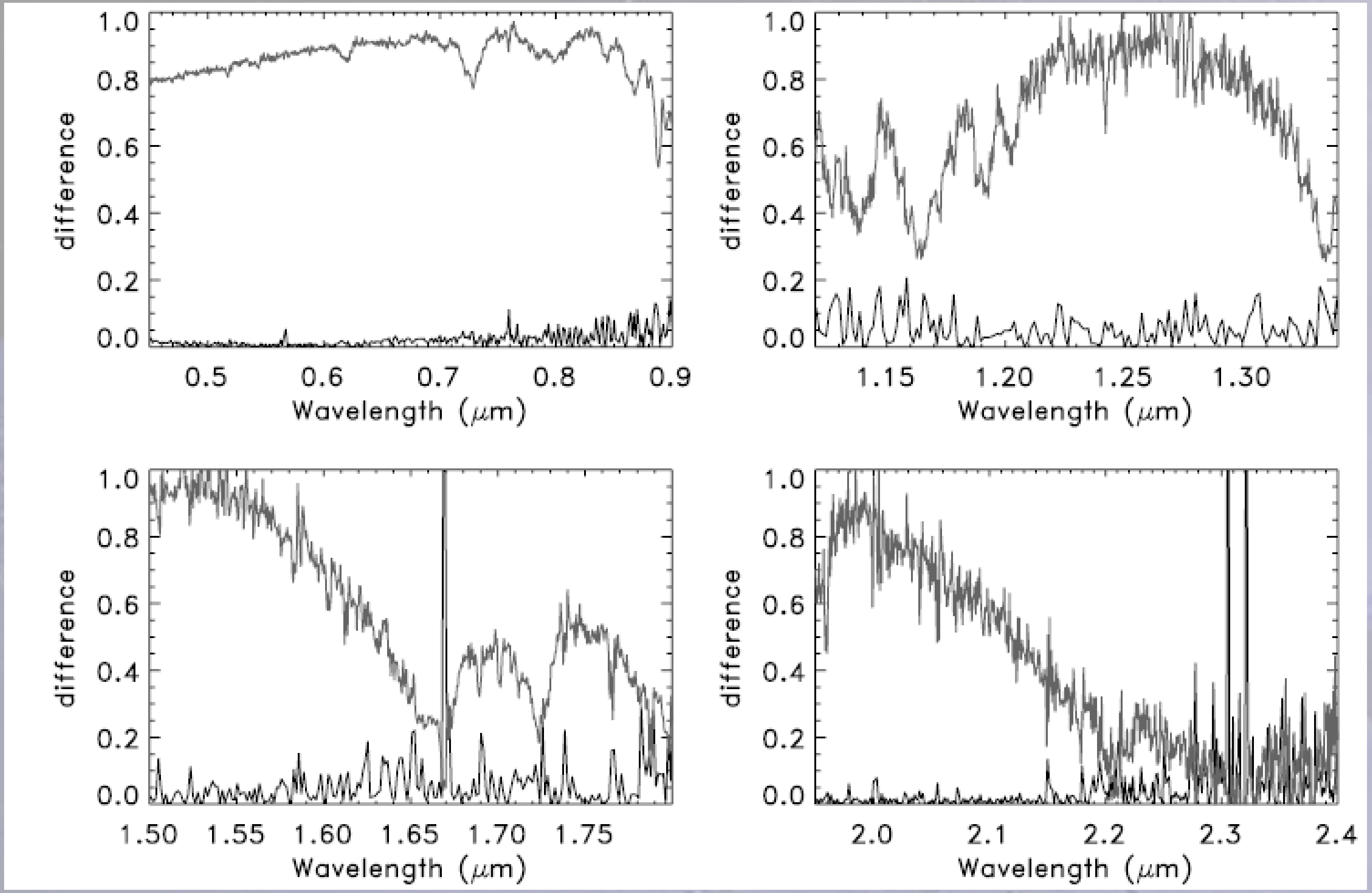
N_2, CH_4



H_2O, NH_3:H_2O

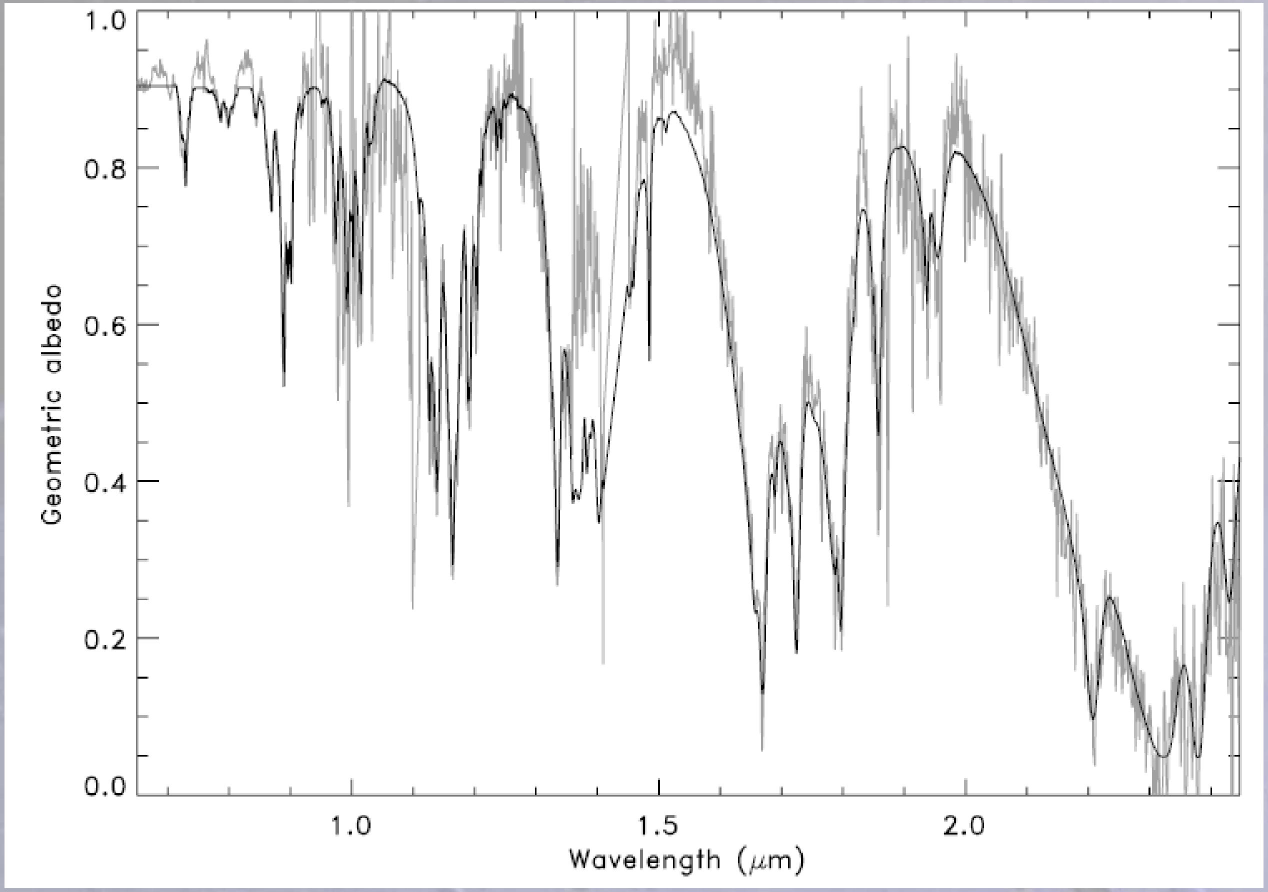
TNOs: The case of Eris

Diameter : >2000 km, Albedo: >0.8 in V band
Composition : CH_4 (Brown et al. 2005)



TNOs: The case of Eris

Spectral modeling

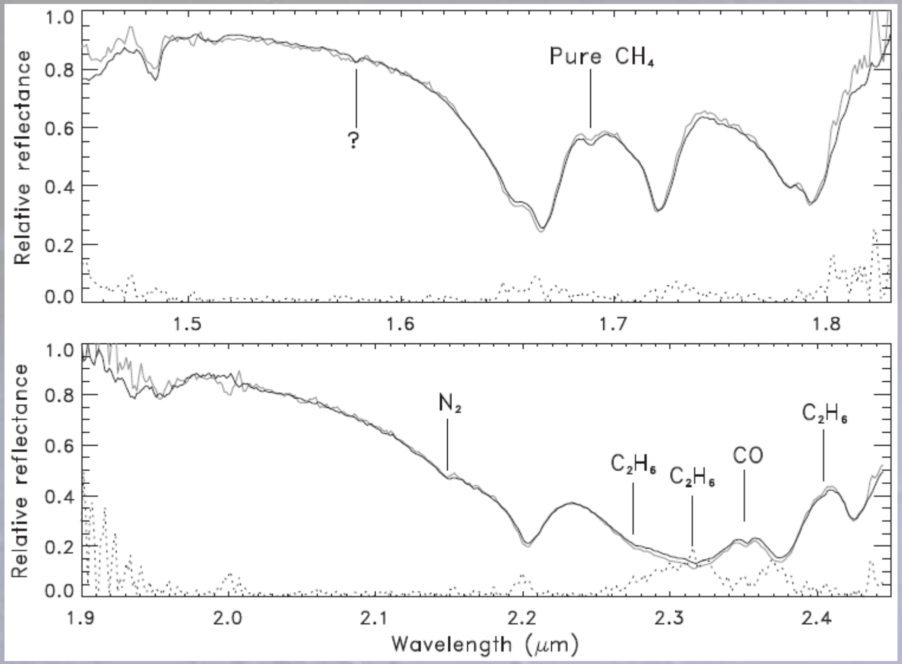


Mixture of methane ice (diluted and pure with at least 3 different sizes from 0.1mm to 2cm) + Titan Tholin (up to 10%).

→ Large particule imply slow cooling

TNOs: The case of Pluto

Diameter : 2150 km, Albedo: 0.53 in V band
Composition :
N_2, CH_4, CO (Cruikshank et al. 1976, Owen et al. 1993)



N_2 mainly in Beta phase. This implies T>35.6K (Doute et al. 1999)
Pure and diluted CH_4 (Douté et al. 1999, Olkin et al. 2007)
N_2 and CH_4 in the thin atmosphere (Young et al. 1997, Lellouch et al. 2009)

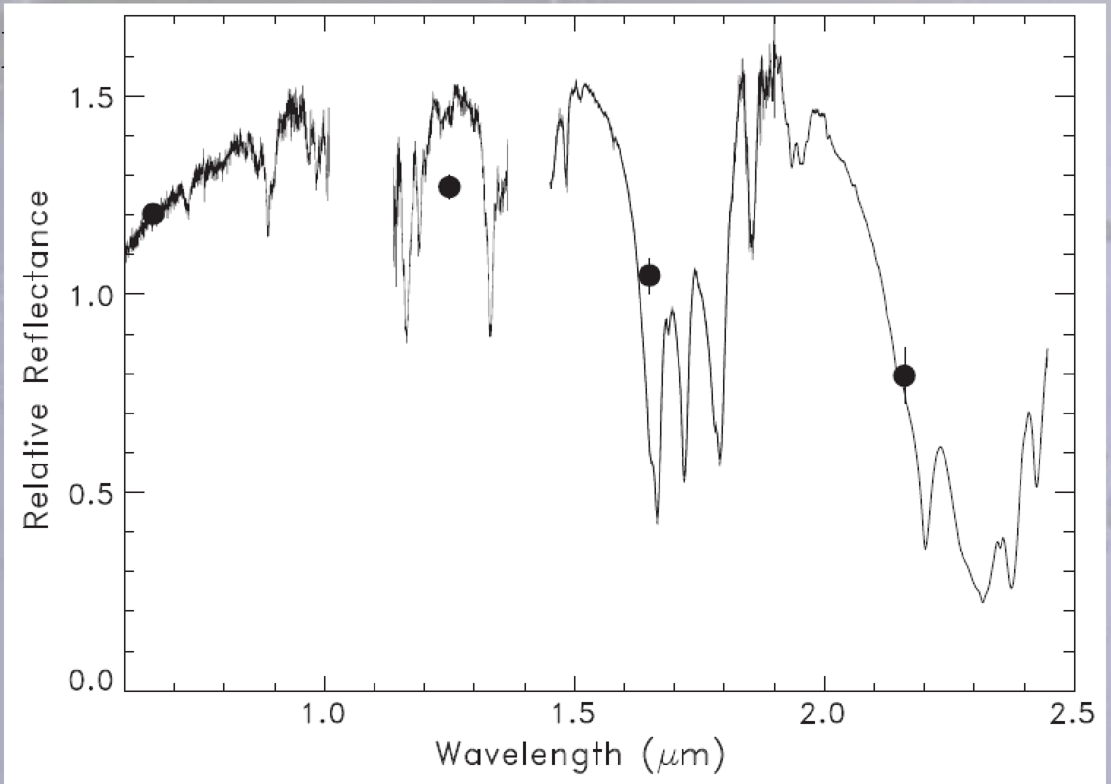
TNOs: The case of Pluto

From photometric data of the entire couple (ISAAC) and the relative flux of each other from disentangle data (SINFONI in H and K bands). Assuming the composition in J band = that reported in H+K bands, Hapke model can be used to derive mJ:

Photometric results for 2008 April 13.

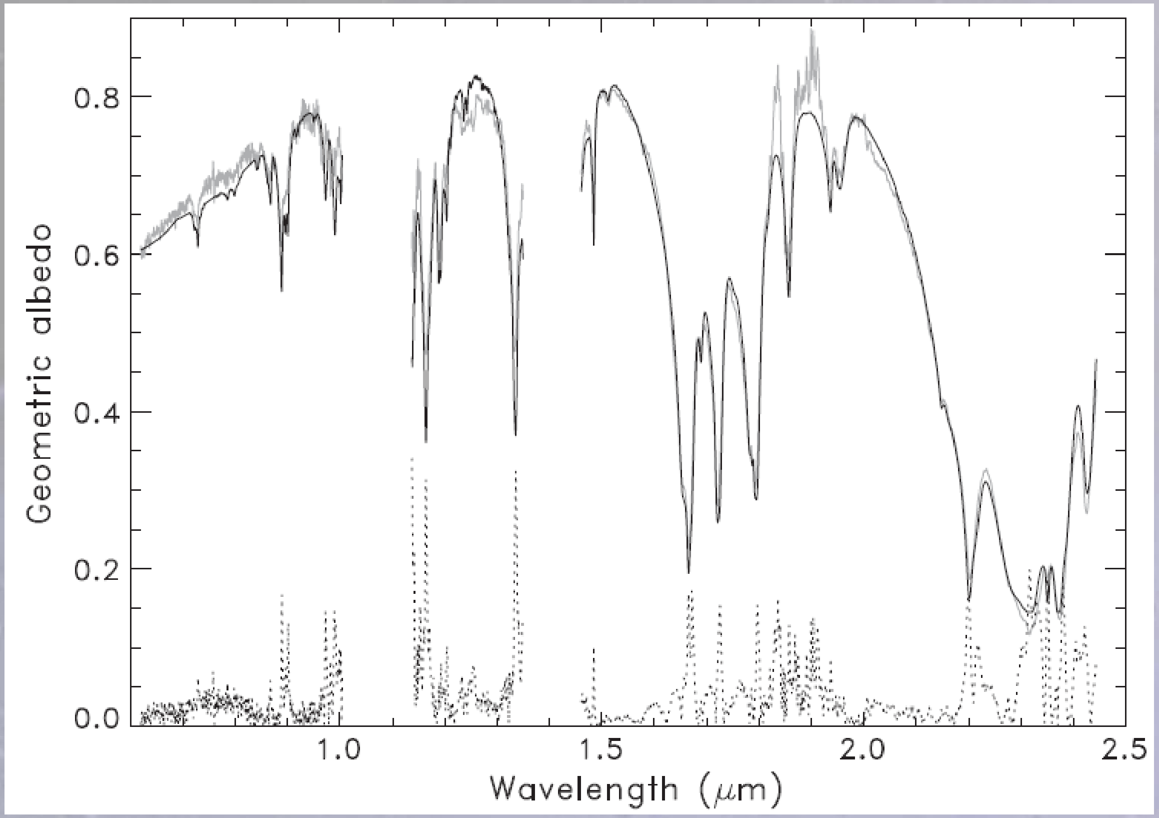
Band	J (1.25 μm)	H (1.65 μm)	Ks (2.2 μm)
Pluto	13.14 ± 0.04	13.05 ± 0.04	13.29 ± 0.05
Charon	15.16 ± 0.05	15.14 ± 0.05	15.21 ± 0.06

Final reflectance s



TNOs: The case of Pluto

Spectral modeling



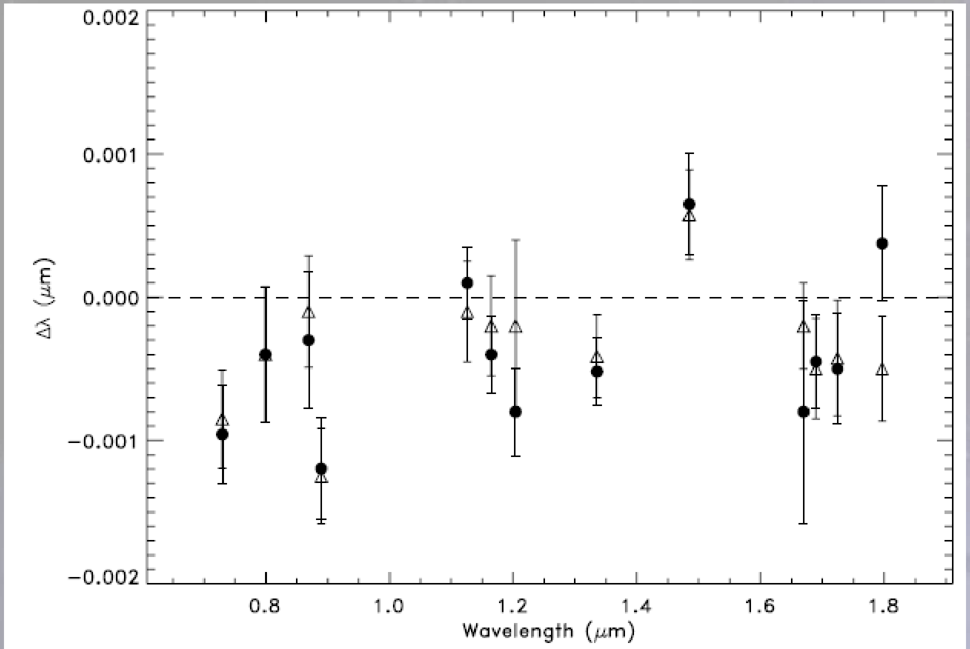
Two geographic areas:

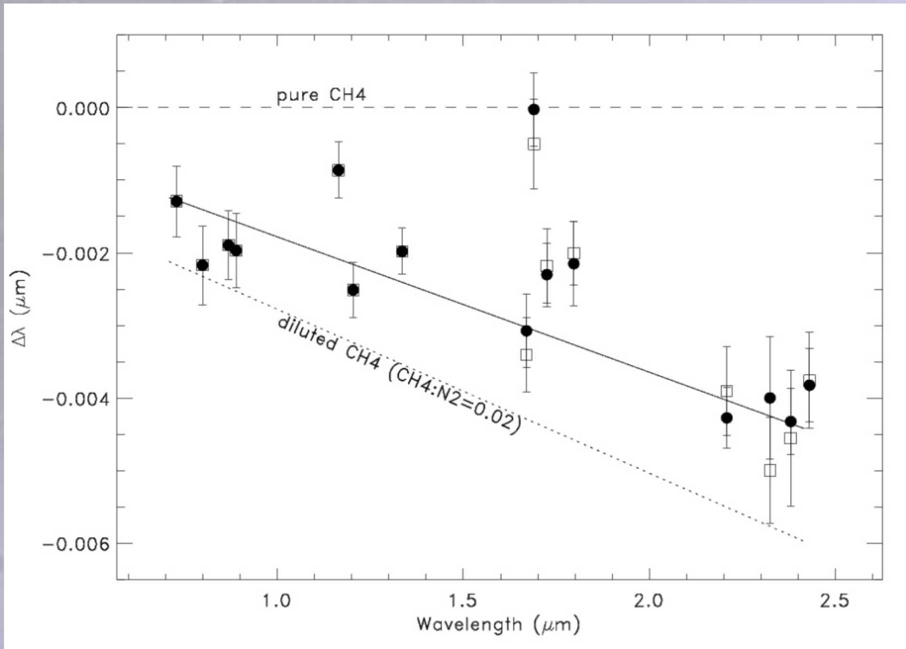
Zone 1 (15%) : 79% CH_4 pure (mm/cm) + 19% Titan Tholin (2.5μm) + 2% carbon

Zone 2 (85%) : 79% CH_4 diluted (cm) + 19% Titan Tholin (2.5μm) + 2% carbon

TNOs: Dilution state of methane ice on Eris and Pluto

Position of the absorption bands of methane ice compared to pure methane ice. (Measured by Cross correlation with a synthetic spectrum of pure methane ice)





Eris: Peak positions agree with pure methane ice, except in the visible for the deepest bands.
→ Stratification of the pure and diluted methane ice (thin layer of pure methane ice on the top of a layer of diluted one)

Pluto: The wavelength shift is wavelength dependent
→ The stratification state of the methane ice seems less obvious, but pure and diluted methane ice patches are present on the surface.

TNOs: Dilution state of methane ice on Eris and Pluto

→ CH_4/N_2 ratio on Pluto is different than that of Eris (N_2 is not directly detectable on Eris)

→ The variation of the CH_4/N_2 ratio is horizontally more important than vertically for Pluto, it seems the contrary for Eris.

→Temperature on Eris should be cold (~15-20K). We do not expect to have an atmosphere, even very thin. The temperature shouldn’t exceed 40K on the surface (at perihelion)

BUT

→ Stratification of diluted methane ice, bright surface and moderate red slope suggest the formation of a temporal atmosphere for Eris able to rejuvenate the surface.

TNOs: Volatile transport on Pluto

Comparison with previous data and results:

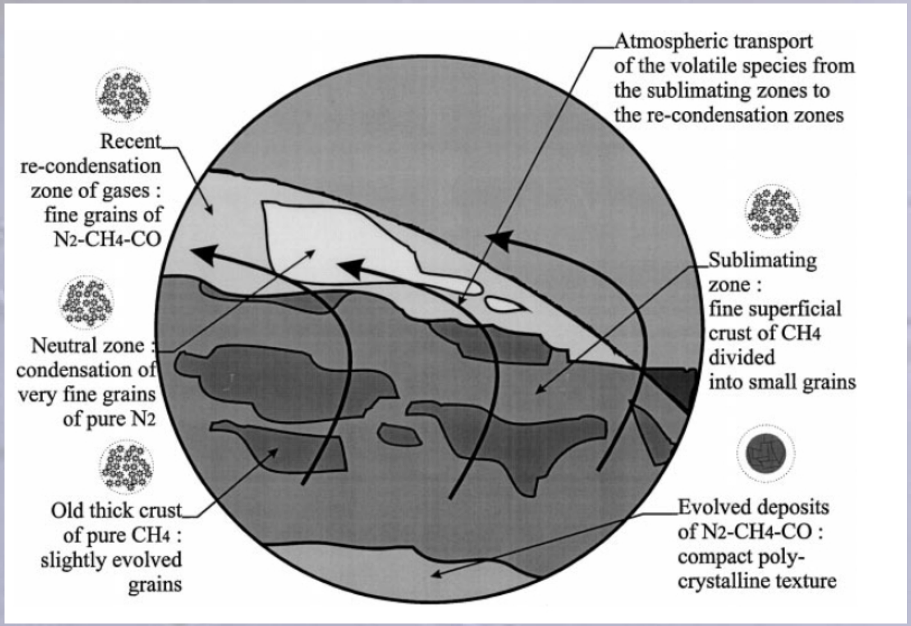
Doute et al. (1999) observed Pluto at a longitude = 66°

From this observation, we almost observe the same area (85-90% of the surface is similar with that looked on April 12th 2008). The main difference is the inclination of Pluto (the planetocentric latitude varied from -16° to -41°)

From both results, we see variation of the wavelength shifts of the absorption bands of methane ice (=different dilution state).

→ Temporal variations seem probable on Pluto even if spatial variation can't be completly ruled out.

→ This could confirm the hypothesis of volatile transport deduced by Doute et al. from spatial variation only.

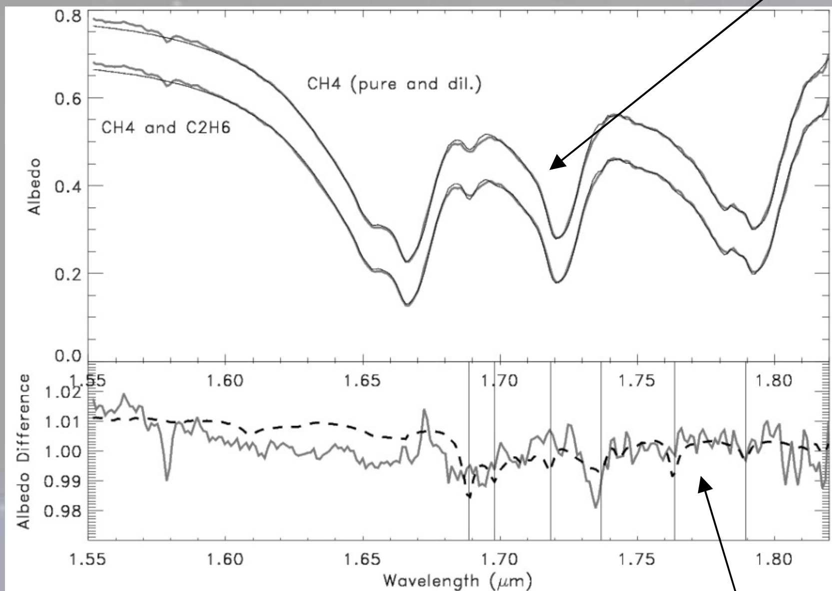


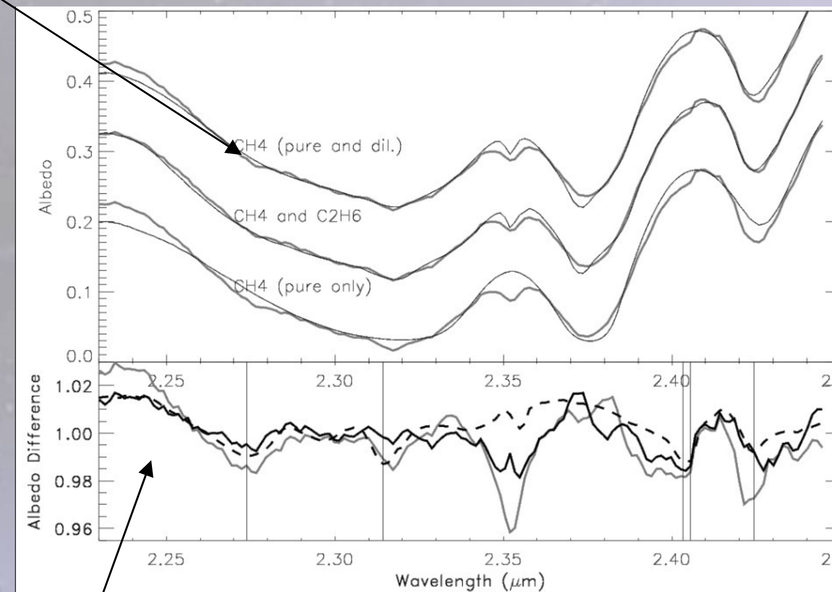
Douté et al.(1999)

TNOs: Search for irradiated products on Eris and Pluto

Detection of Ethane on Pluto?

Models





Difference = object spectrum – synthetic spectrum

H Band : 3% K Band : 5%

Ethylene is not reported →If confirmed, this observation suggests that irradiation on Pluto is driven by UV photolysis or protons irradiation.

From the wavelength location of the ethane bands, it should be in its amorphous or metastable state (This implies that T_{Ethane} never exceeds 60K, below P)

TNOs: Search for irradiated products on Eris and Pluto

Detection of Ethane on Eris?

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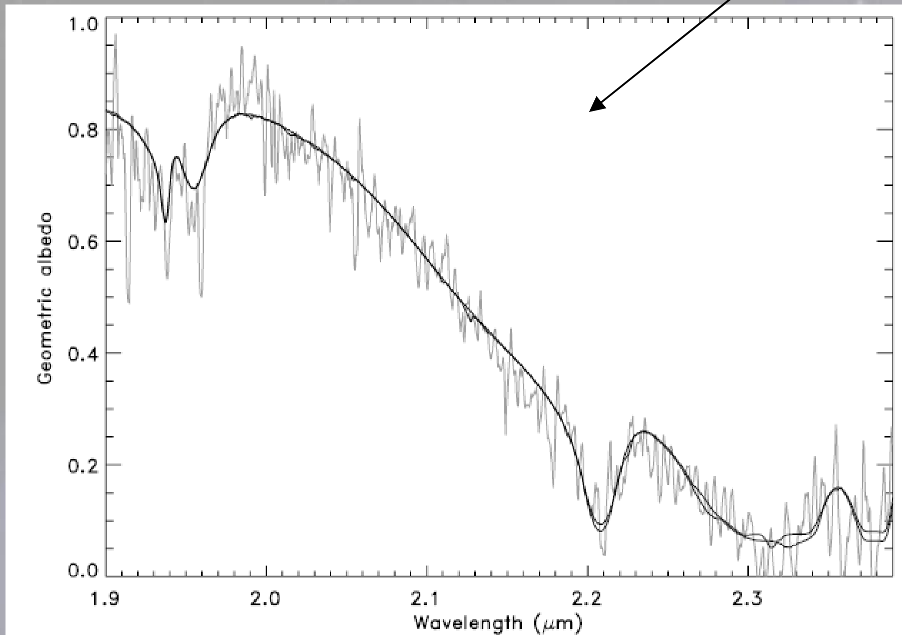

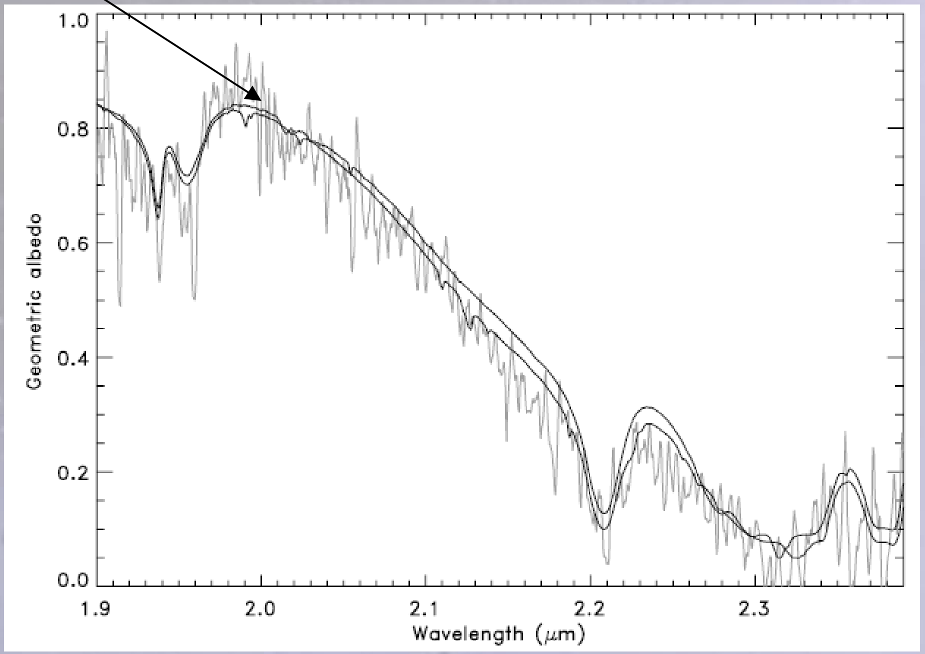

K Band : 3% better χ^2

10% Upper limit

Ethane is less obvious on Eris compared to Pluto (some noise) → Need spectral models

TNOs: Main conclusions

→ Big TNOs have large amounts of ice on their surface
Several phenomena can act to preserve/rejuvenate the surface from space weathering
Water ice is common (70%)

→ Other ices have been detected
Methanol, nitrogen, ammonia…

→ Methane ice is present for objects larger than 1500km
Escape velocity seems to be the main factor.

→ The regolith on these object is subject to change at the time scale of an orbit
(248 – 557 years for Pluto and Eris)

→ Some evidences of the presence of Ethane on Pluto and Eris
This compound can be formed by irradiation of methane ice (formed by the space weathering effect).

TNOs: Prospects

→Complete coverage of the surface of Pluto and Eris

Dissociate spatial and temporal variation

Confirm the presence of Ethane and map it (crudely)

→ New laboratory measurements.

New optical constants especially for icy mixtures and dirty mixtures.

Constrain the temperature and dilution effects on wavelength shifts

Constrain the space weathering effects on thick layers of icy mixtures

→Define the albedo of these objets.

In order to give some clues on the presence or abscence of ice when limited S/N