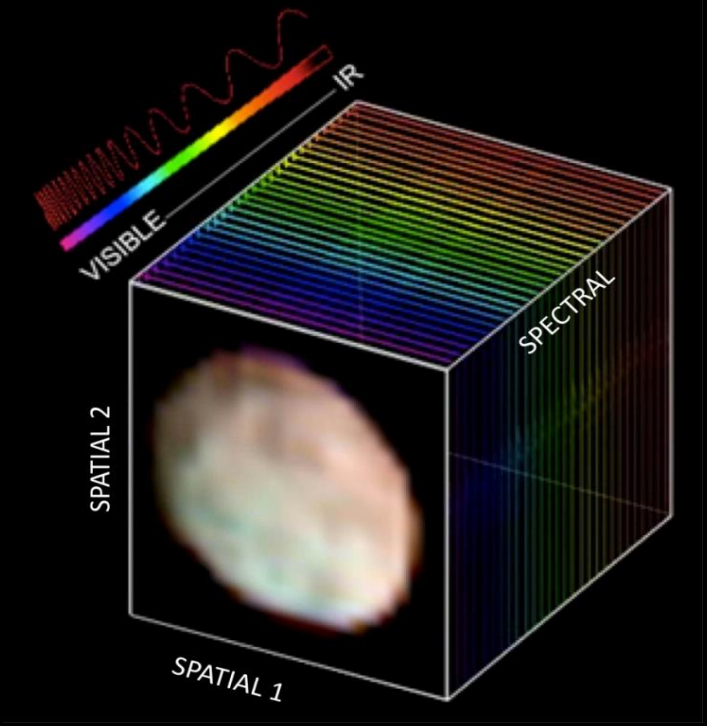
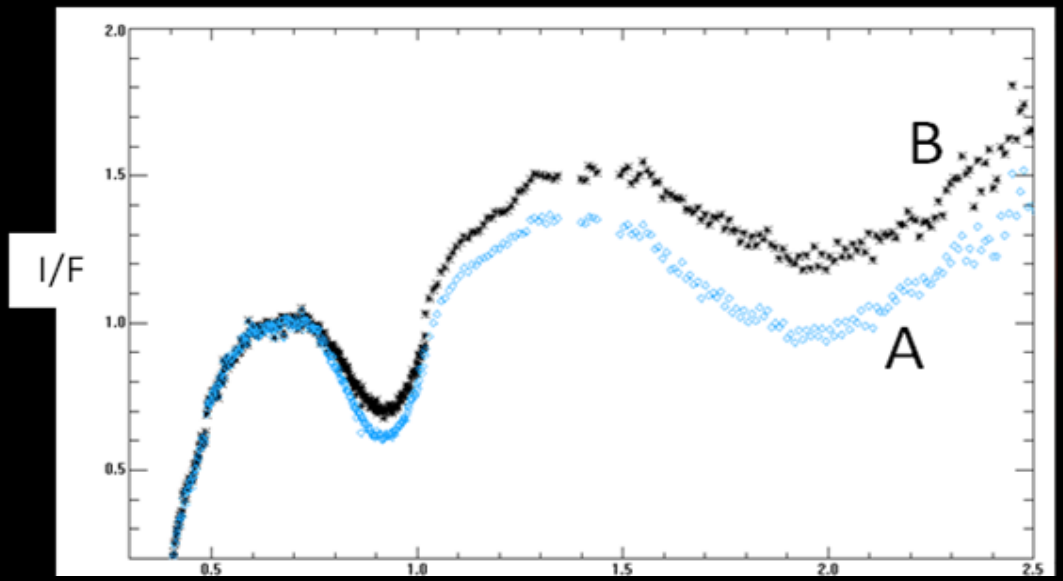
Hyperspectral Vesta: exploring composition and evolution

E. Palomba(1), M.T. Capria, C.T. Russel, C.A. Raymond, E. Ammannito, F. Capaccioni, U. Christensen, M.C. De Sanctis, B. Feldman, R. Jaumann, H.U. Keller, T. McCord, L. McFadden, H. McSween, S. Mottola, A. Nathues, G. Neukum, C. Pieters, T. Prettyman, H. Sierks, M. Sykes, M. Zuber and the international Dawn team

1) Istituto di Astrofisica e Planetologia Spaziale, INAF, Italy,

Mineralogy of Vesta from VIR





- VIR obtains an image cube of spectral information from visible to infrared, enabling minerals to be identified from absorption lines in two spatial dimensions.
- The two main absorption bands of pyroxene vary in position and depth as the pyroxene changes from eucritic to diogenitic composition.

VIR highlights and discoveries

- Vesta composition is dominated by pyroxenes
- Vesta is consistent with being the HED parent body: eucrite/diogenite crust and an olivine mantle, around an iron core
- Vesta spectral dicotomy: Northern regions more eucritic, Southern more diogenitic

1. Discovery of dark material units
2. Discovery of OH rich areas highly correlated with dark material units
3. Discovery of few large deposits of Olivine in the northern terrains

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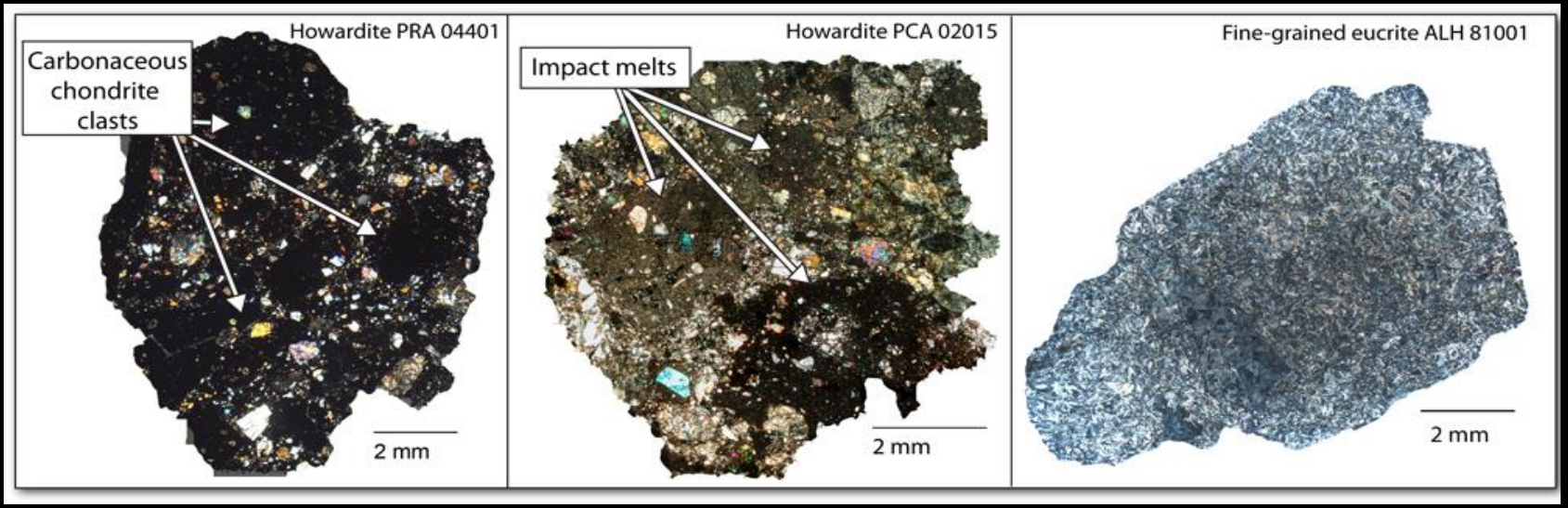
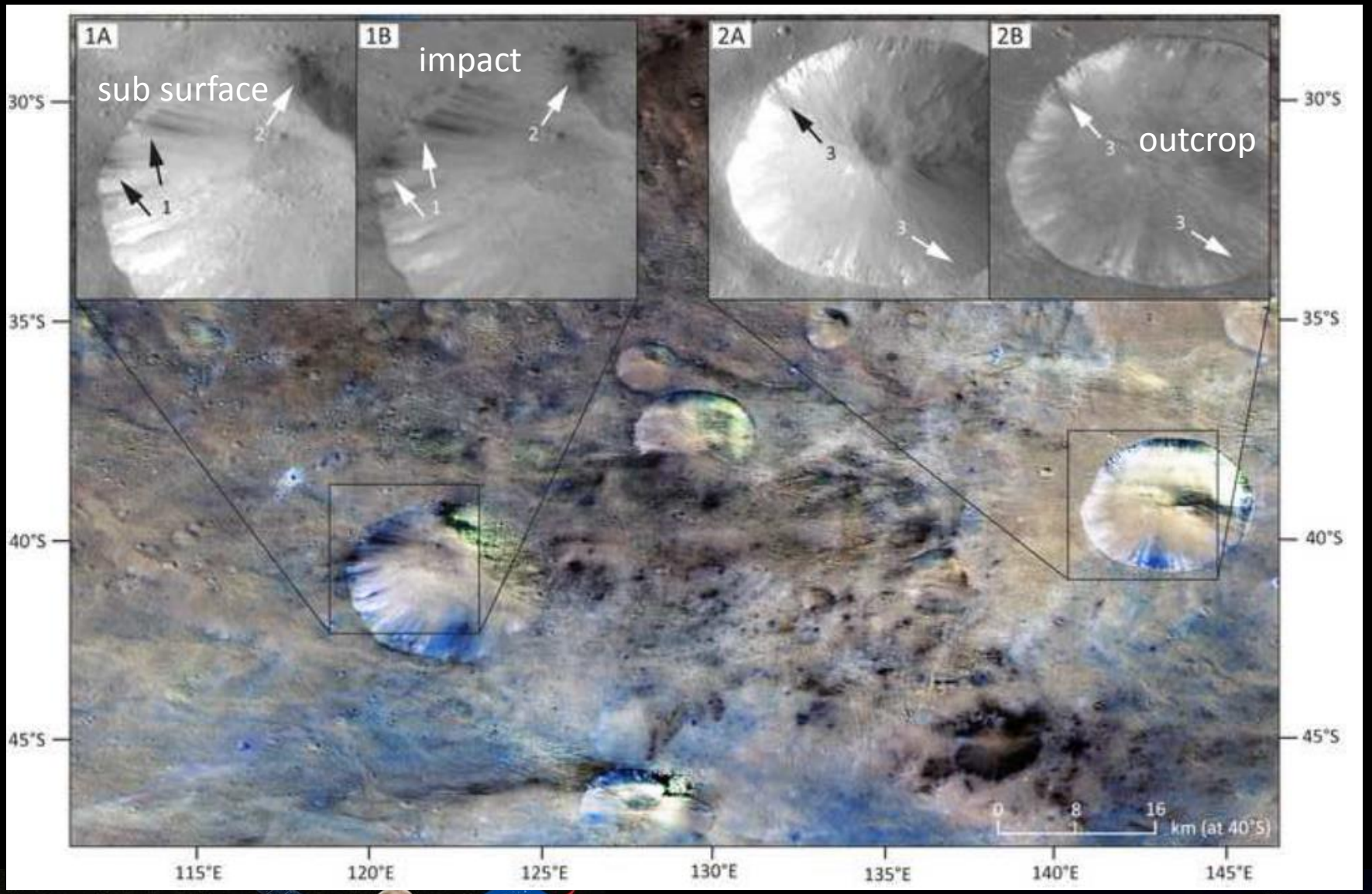
1. Discovery of dark material units

Dark Material in HED Meteorites

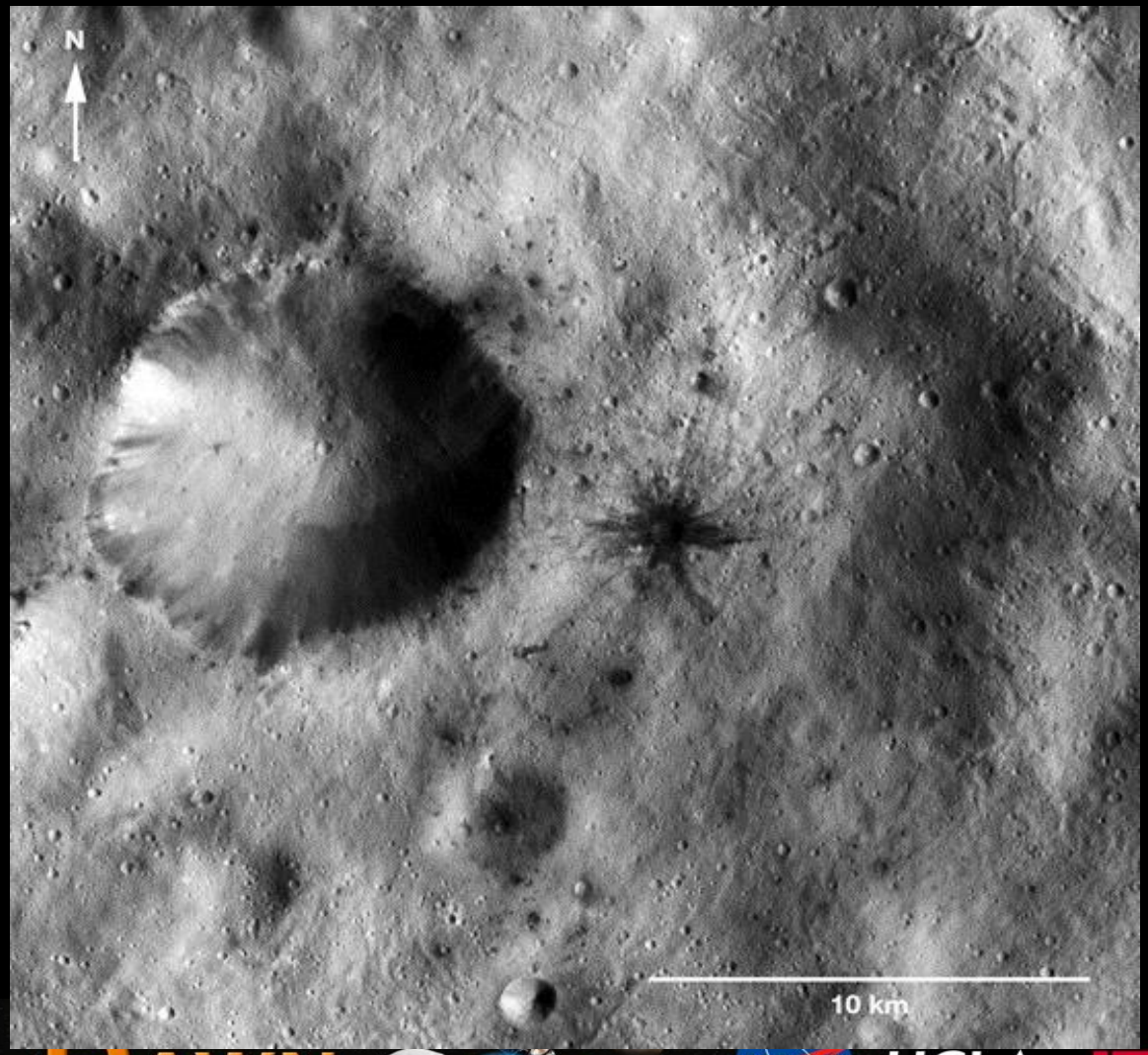


- Impact melt glasses are dark because of dispersed fine-grain opaques.
- Fine-grained eucrites appear dark primarily because of their texture.
- Carbon not expected to be found native in a differentiated body like Vesta.
- Carbonaceous chondrites contain highly absorbing organic phases.
  - Average impact velocities in Main Belt are lower than at Moon or Mercury, so preservation of impactor material may occur.

Vesta Dark Material



Small-Scale Dark Impactor Residue ?

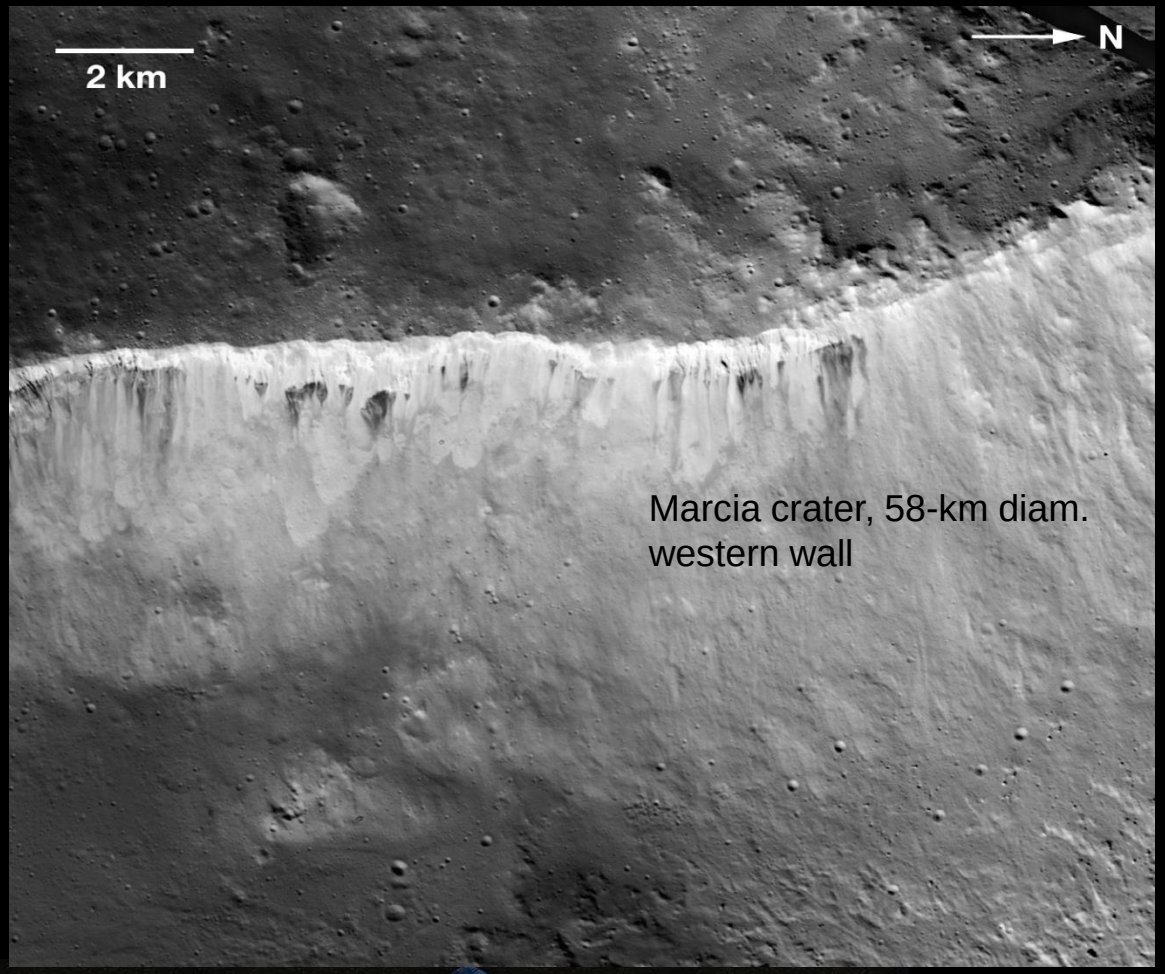


Sextilia quadrangle. Image FC21A0016892

- The dark-rayed crater and dark spots could have come from a small carbonaceous body that broke up and struck Vesta at relatively low speed.

- Alternatively, this location could consist of a thin higher-reflectance surface layer that overlies a regional dark deposit. Small impacts punch through and expose the underlying dark material.

Example of Vesta Dark Material



- Similar morphology to lunar Diophantus.
- Potentially pyroclastics, but
  - Pyro beads not seen in HED meteorites
  - Modeling by Wilson & Keil suggests that vestan pyroclasts would fall hot and coalesce into lava flows.
- So might be
  - Paleo-regolith
  - Dark lavas / intrusion
  - Impact-modified material

Mosaic of FC21A0014665 and FC21A0016872

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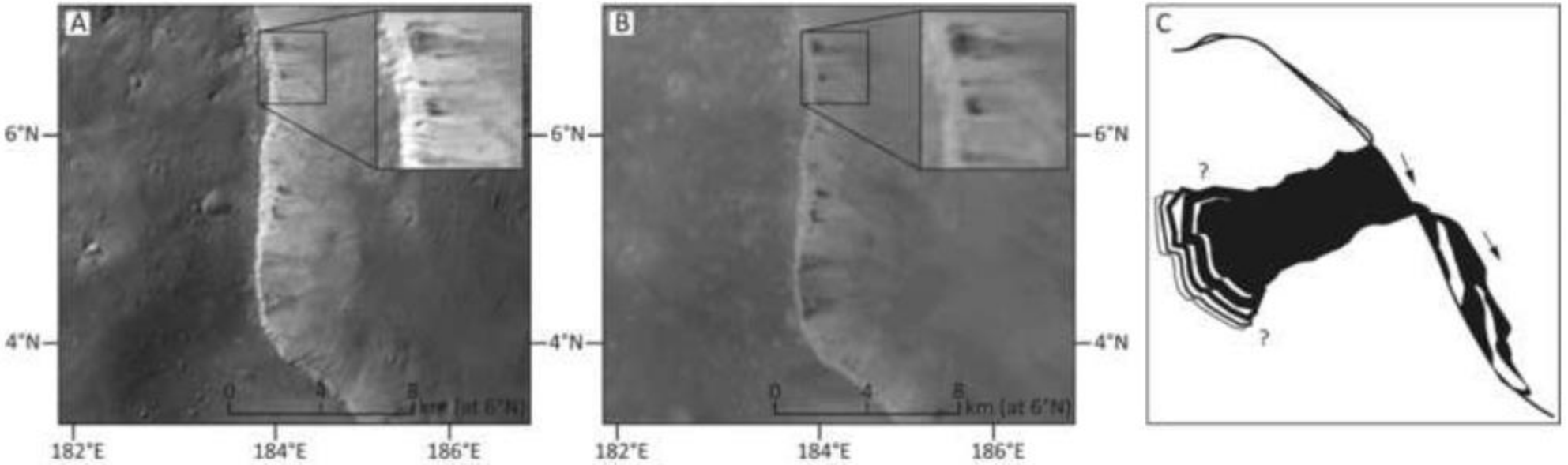
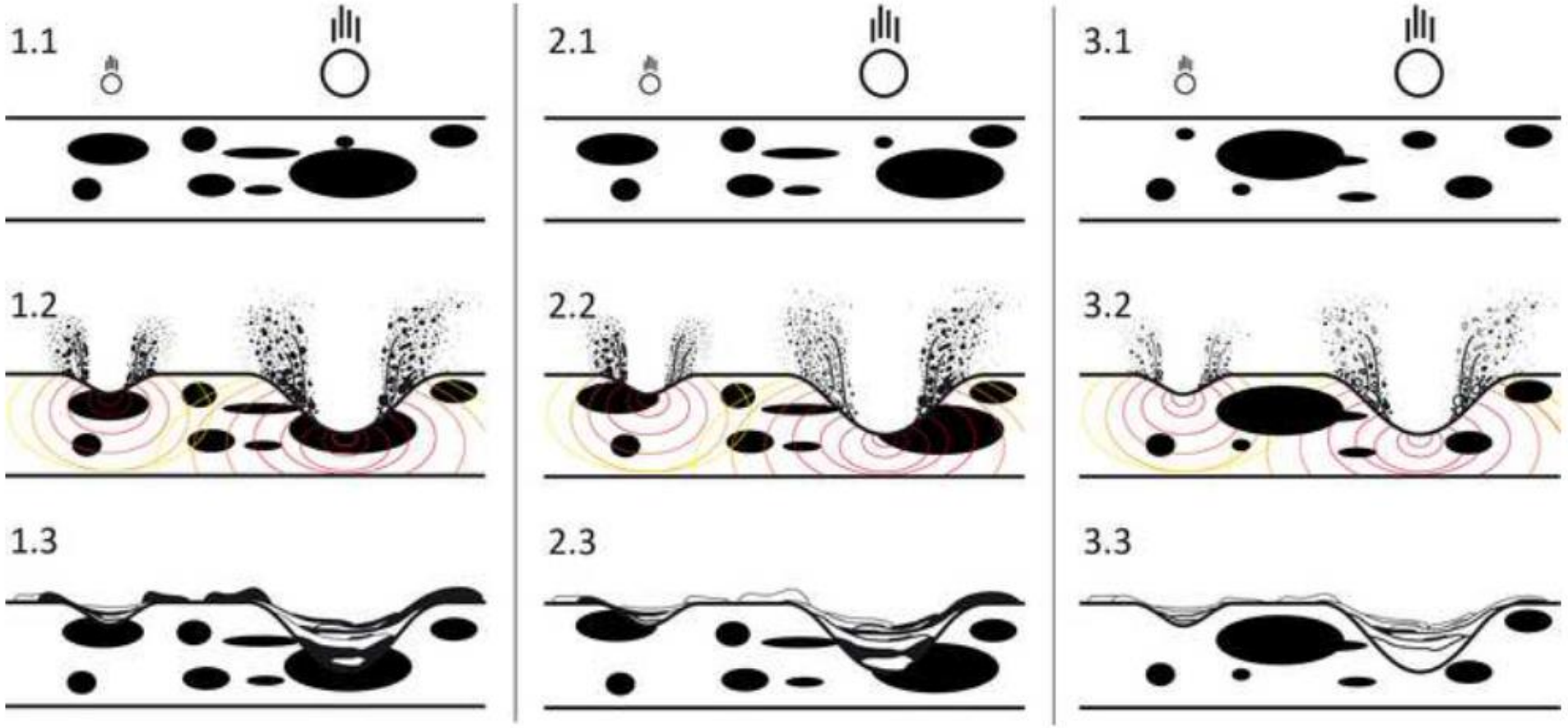


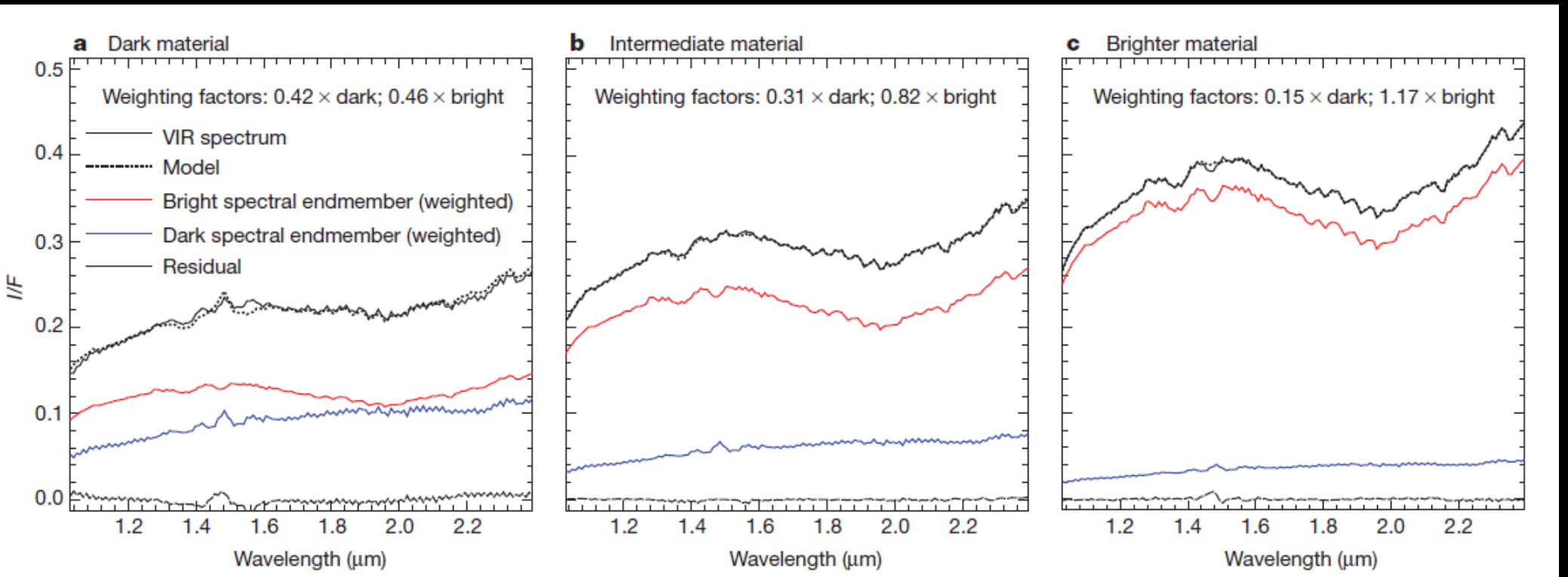
Mosaic of FC21A0014665 and FC21A0016872

Vesta Dark Material: formation models



Mosaic of FC21A0014665 and FC21A0016872

Spectral analysis of Vesta Dark Material



McCord et al., 2012 Nature

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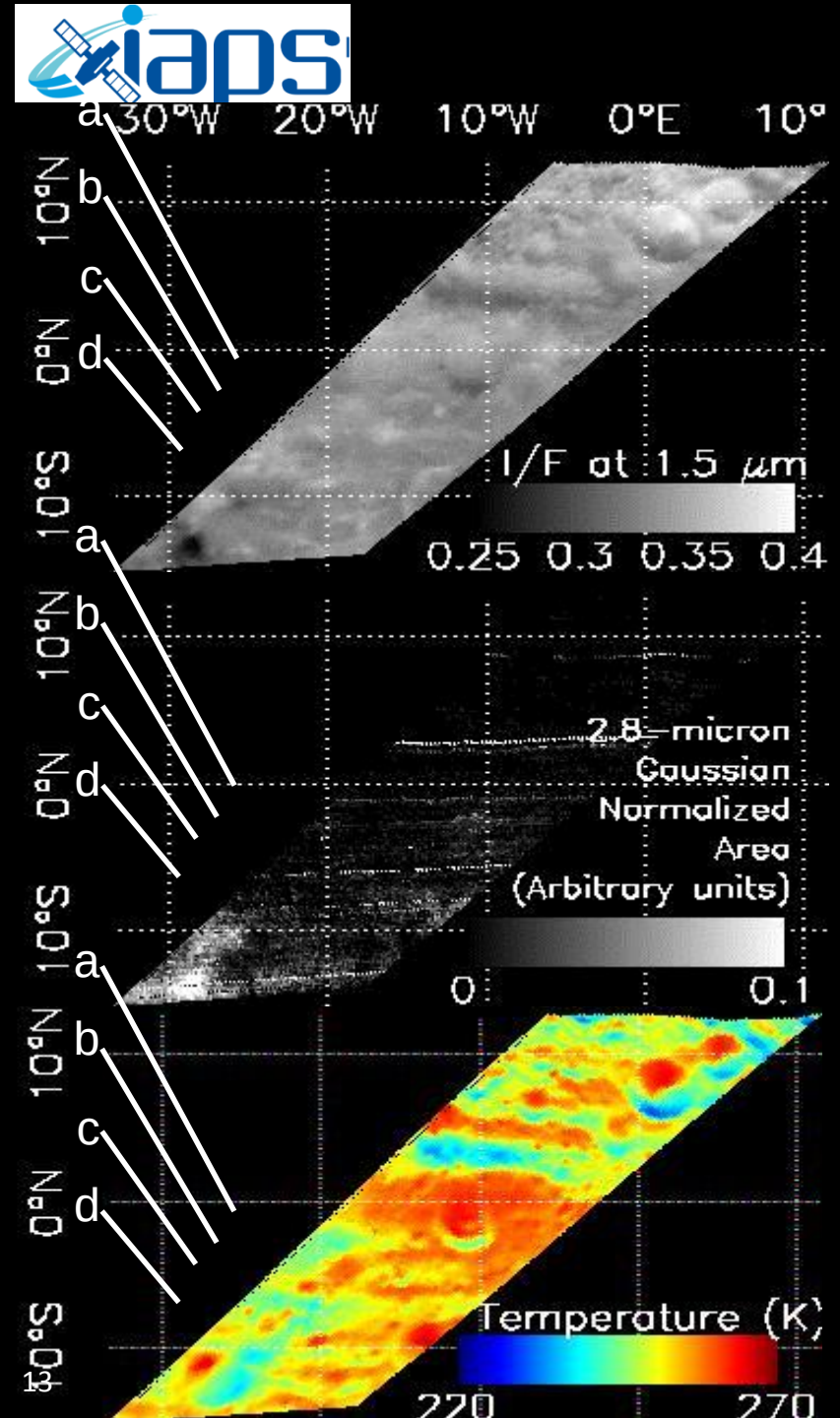
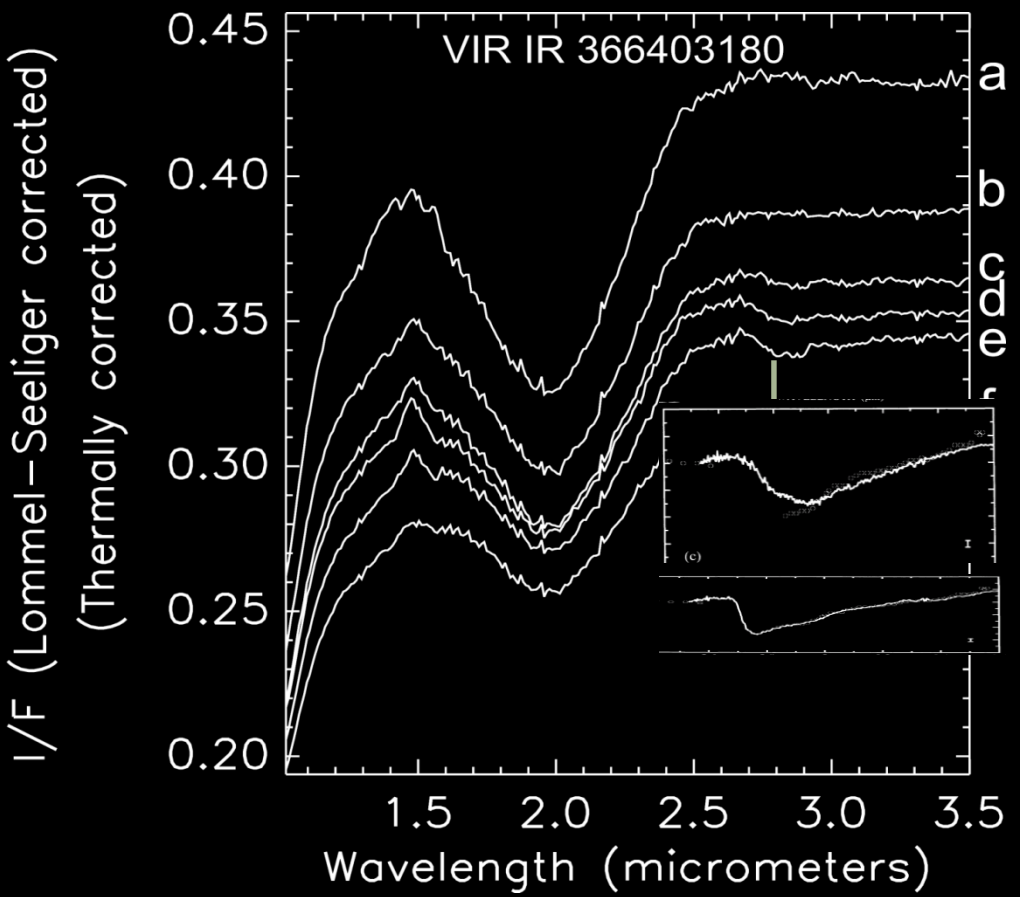
VIR Spectral Analysis: 2.8-μm Variations

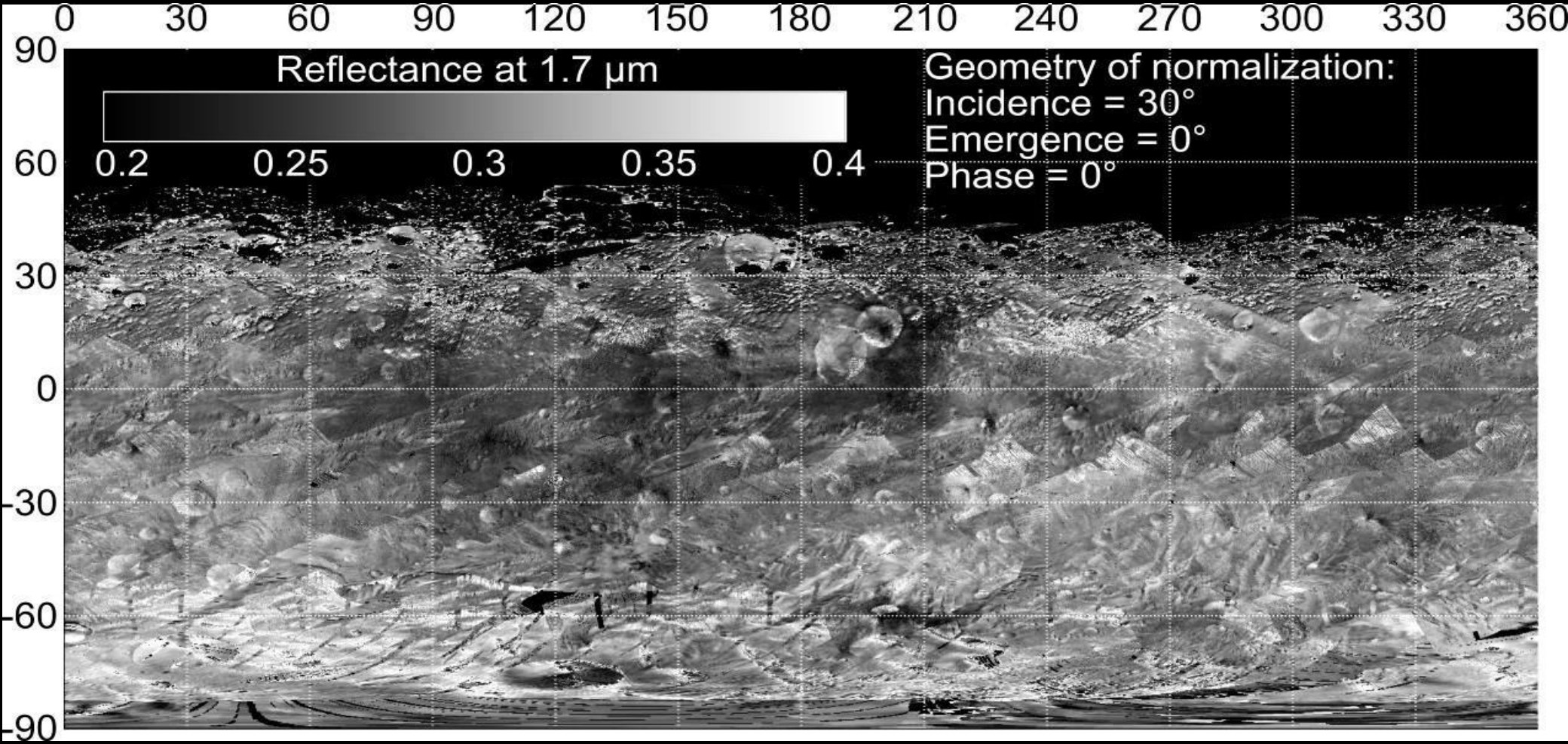




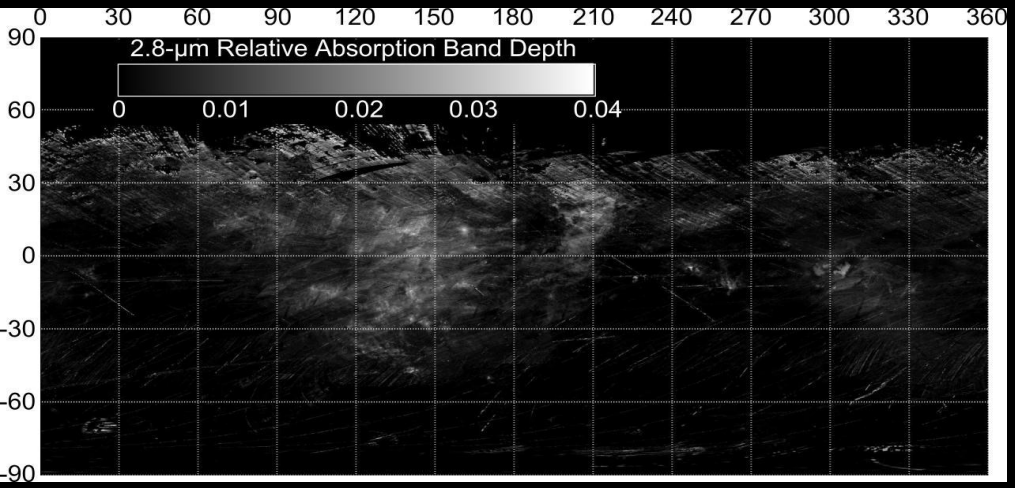
→Variations at 2.8 μm are spatially coherent

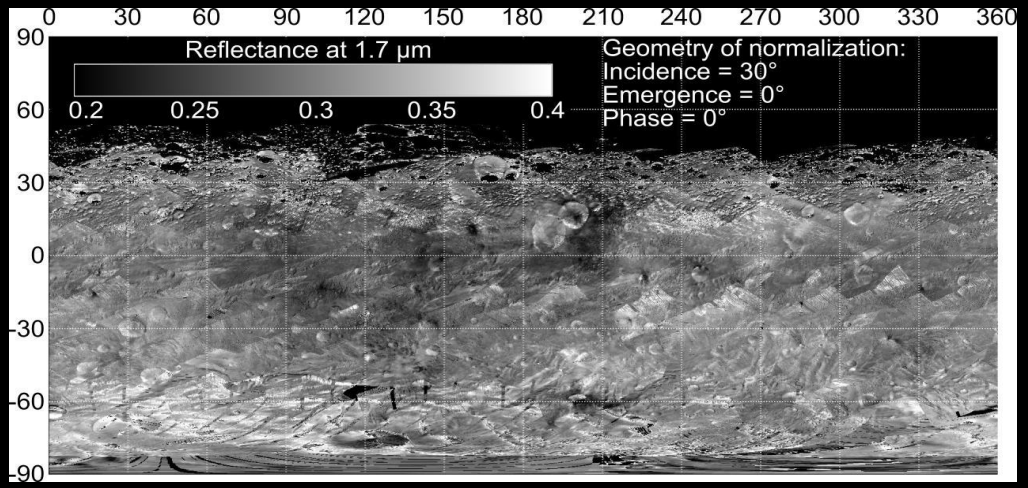
→Darker material have deeper 2.8-μm absorption band

2.8-μM Absorption Band



Anti-Correlation With Albedo

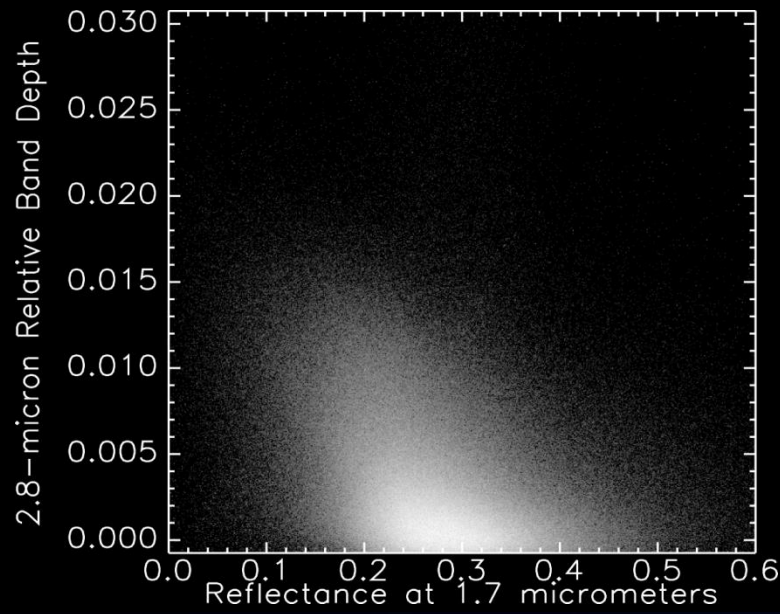




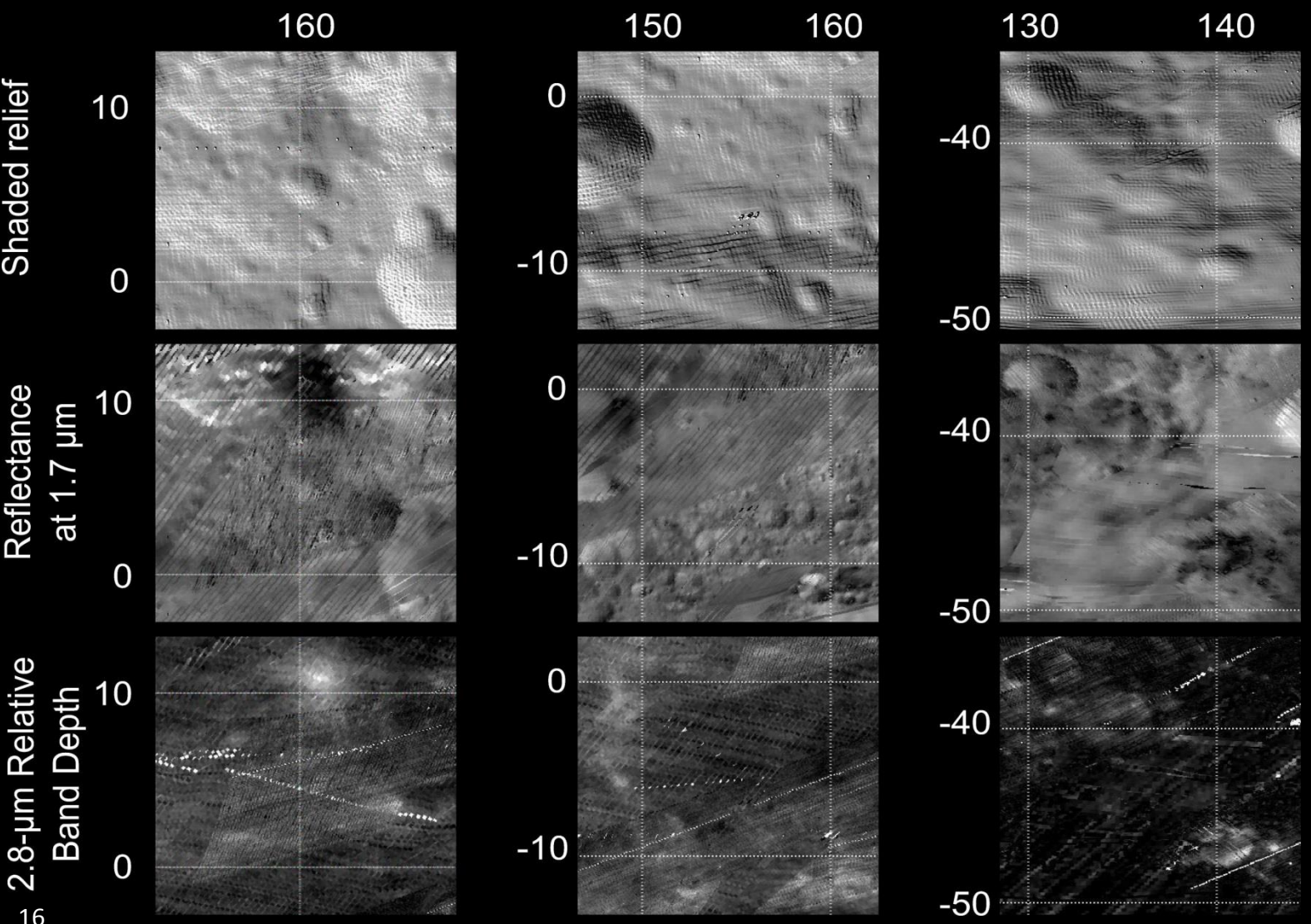
Stronger 2.8-μm band associated with darker materials at large scale

→*Does not support the hypothesis of infalling carbonaceous chondrites*

→*May correspond to a different composition of the crust*



2.8-µm Absorption on Dark Materials

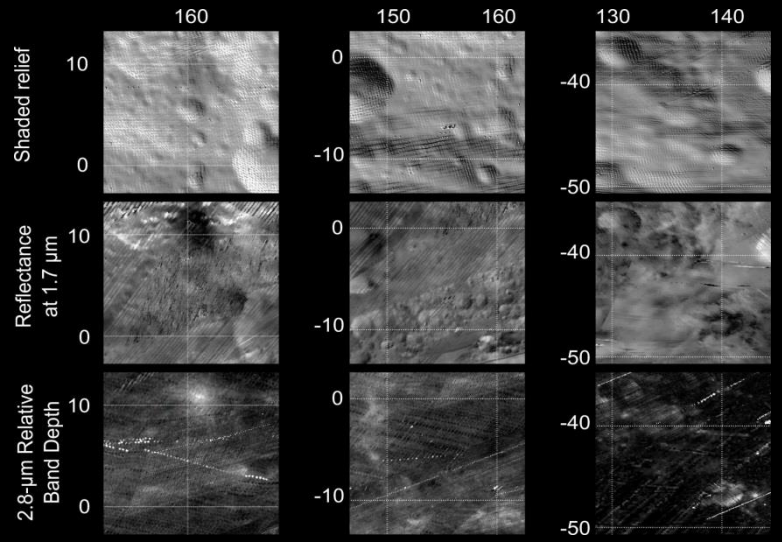


Stronger 2.8-µm band associated with spots of dark materials

→*Maybe impacts by dark-material rich meteorites*

→*May support the hypothesis of infalling carbonaceous chondrites*

Origin of Dark materials



Dark material are exogeneous

Maybe impacts by dark-material rich meteorites May support the hypothesis of infalling carbonaceous chondrites

Two scenarios:

A Few big ancient impacts with Carbonaceous asteroids (Reddy et al, 2012)

B Many micro impacts with CC particles up to cm in size (De Sanctis et al., 2012)

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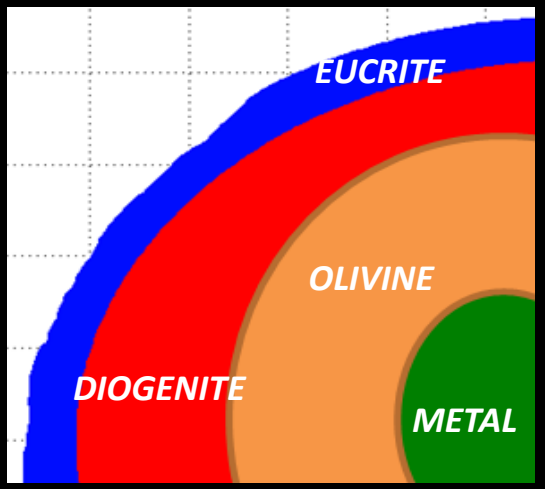
Olivine on Vesta

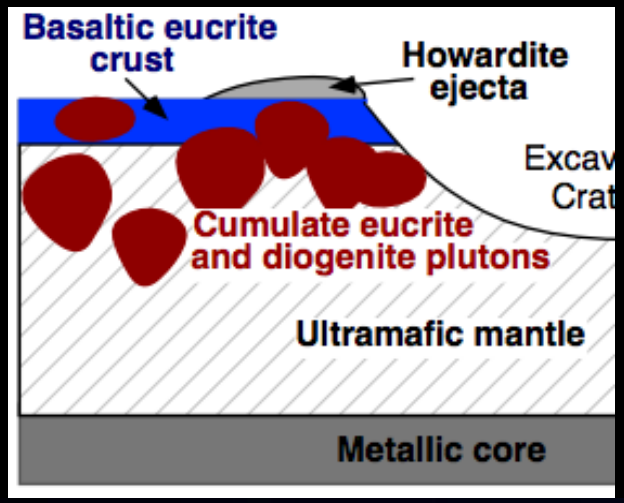
- The presence of Olivine on Vesta has been postulated by several observers from rotationally-resolved ground-based spectra and HST data, but the results were contradictory (Gaffey, 1997, Thomas et al. 1997; Binzel et al. 1997, Reddy et al. 2010, Li et al., 2010).
- Few HEDs contain small amount of olivine
- Two main petrogenic models can be applied to Vesta for olivine formation:
  - **Magma ocean**
  - **Fractionation in multiple crustal plutons**

Petrogenetic models

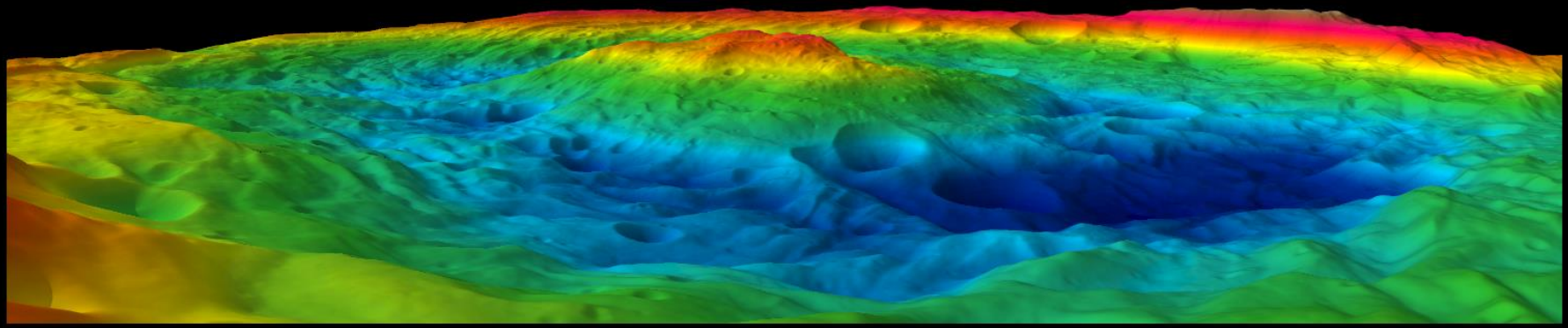
- **Magma ocean:** heavier elements and minerals sank in the mantle, while lighter material floated to the surface and solidified into the crust (Righter and Drake, 1997; Ruzicka et al., 1997; Toplis et al., 2013) . Vesta should be layered, with a thick eucritic crust overlying a layer of diogenites and at greater depth, **olivine rich mantle** rocks and a metal core are expected.

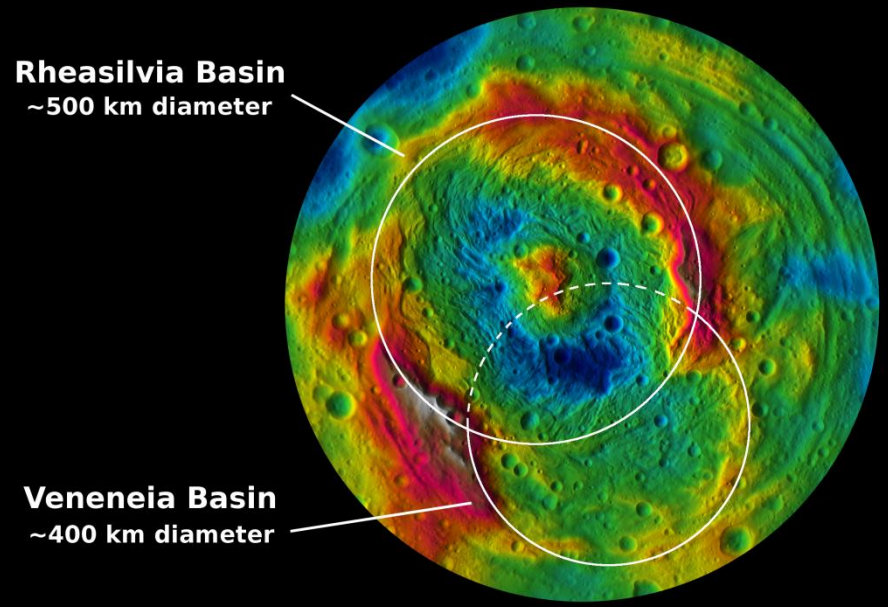


- **Plutons:** If olivine-rich lithologies formed via fractionation in multiple crustal plutons, more heterogeneously distributed and relatively shallow and ferroan olivine-rich diogenites are expected



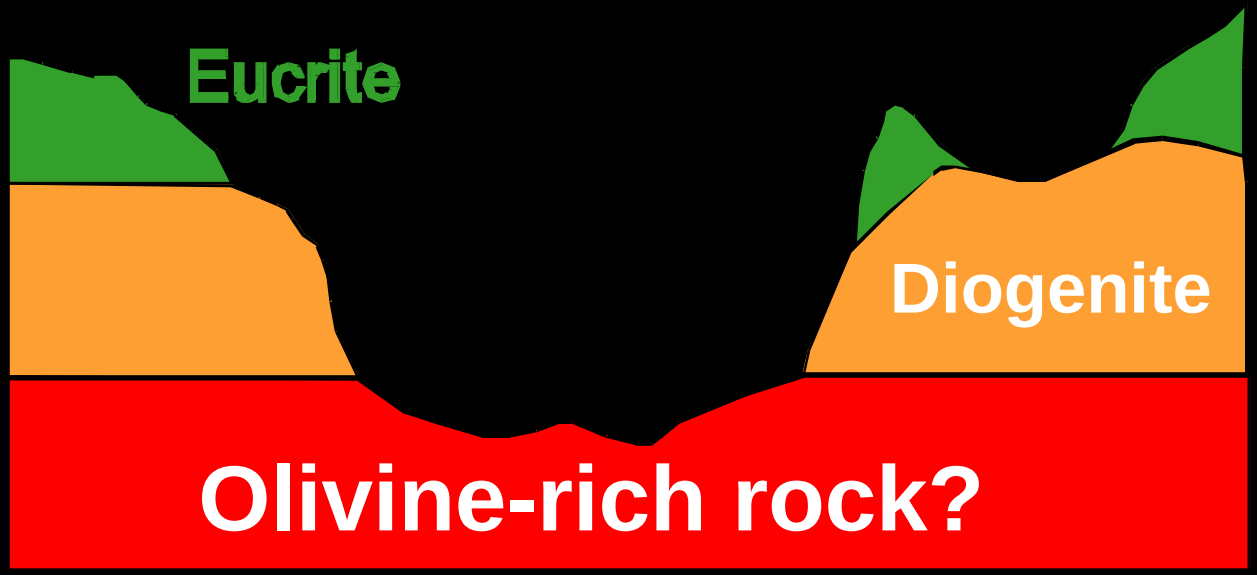
Search for olivine

- 



Search for olivine

- The mapped mineralogical distribution, with diogenitic rich material prevalently exposed in the deeply excavated southern hemisphere, is broadly consistent with magma ocean models for Vesta's differentiation.



Search for olivine

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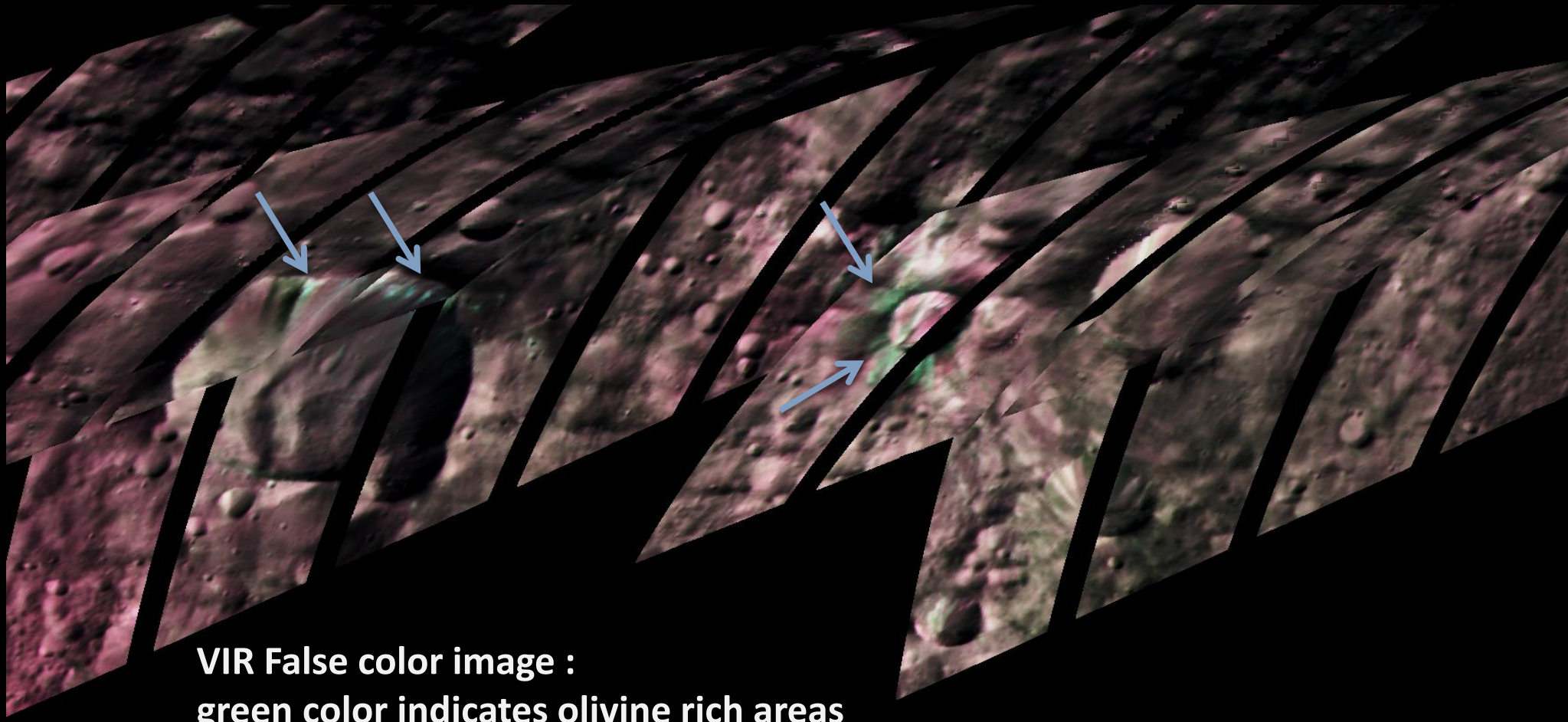
- Because of these models, a search was made for olivine in the southern deeply excavated basins and their ejecta, without success.
- However, olivine-bearing diogenites cannot be easily spectrally distinguished from olivine-free diogenites (Beck et al., 2011), so they may be actually present in small amount on the surface of Vesta but below our ability to detect them.

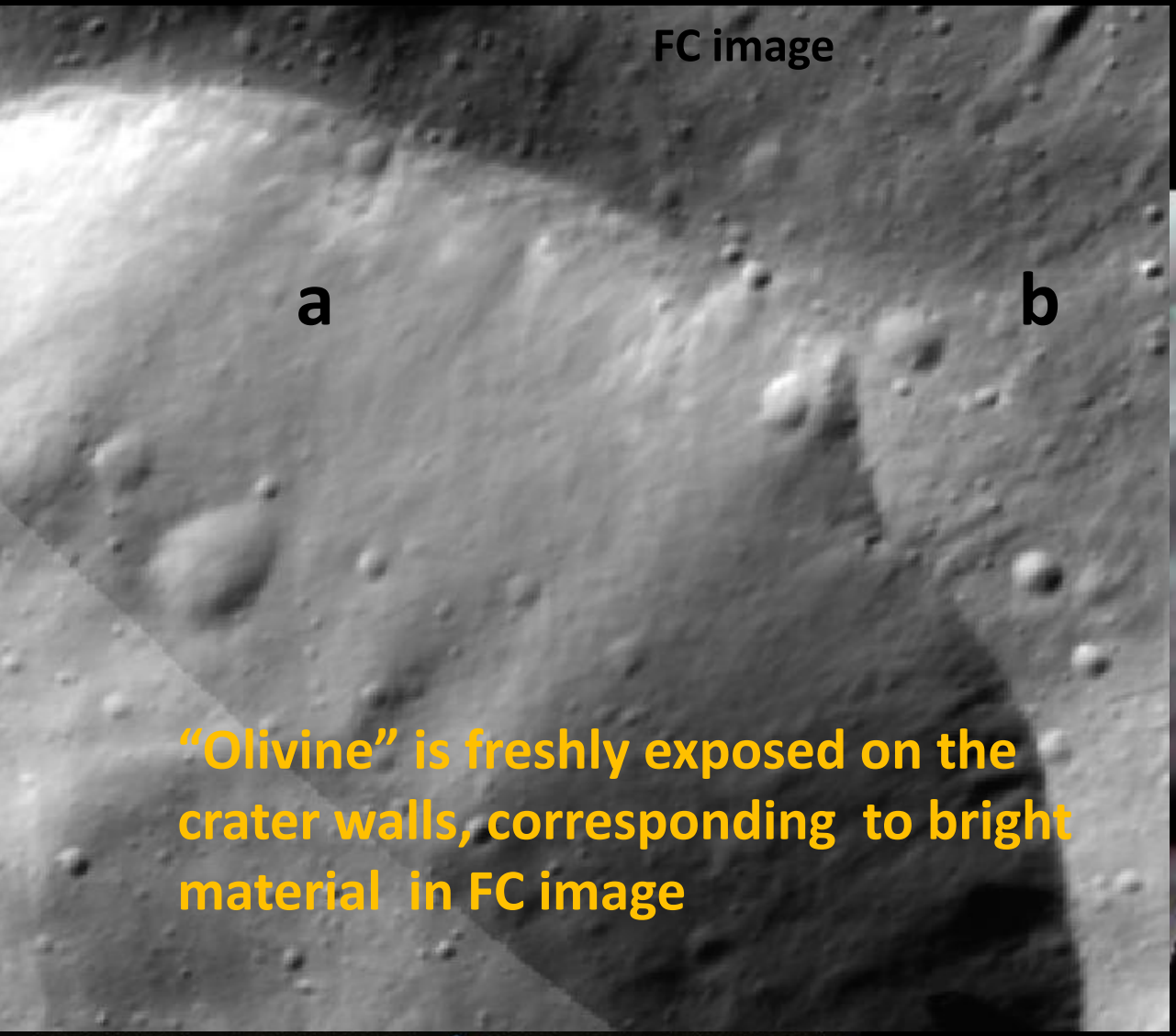
VIR data mosaic

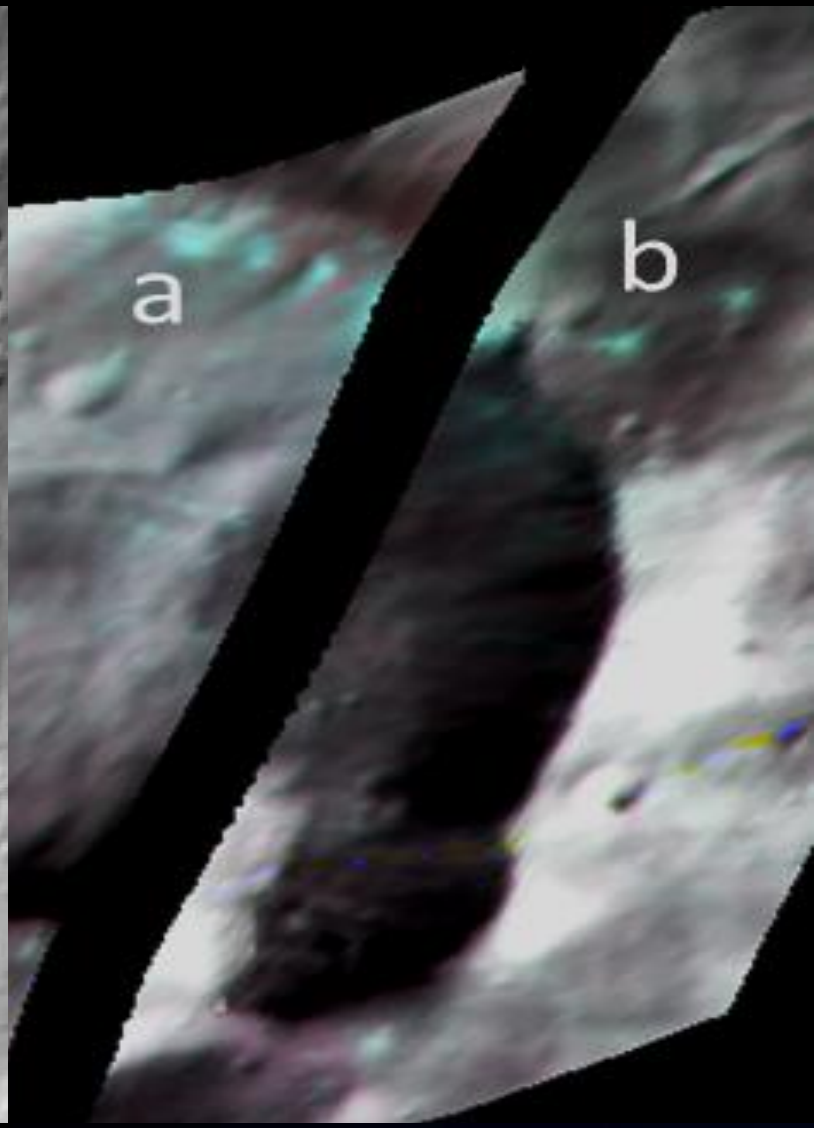
- VIR data indicate the possible presence of olivine in two locations in the northern hemisphere relatively close each other



VIR False color image :
green color indicates olivine rich areas

FC and VIR

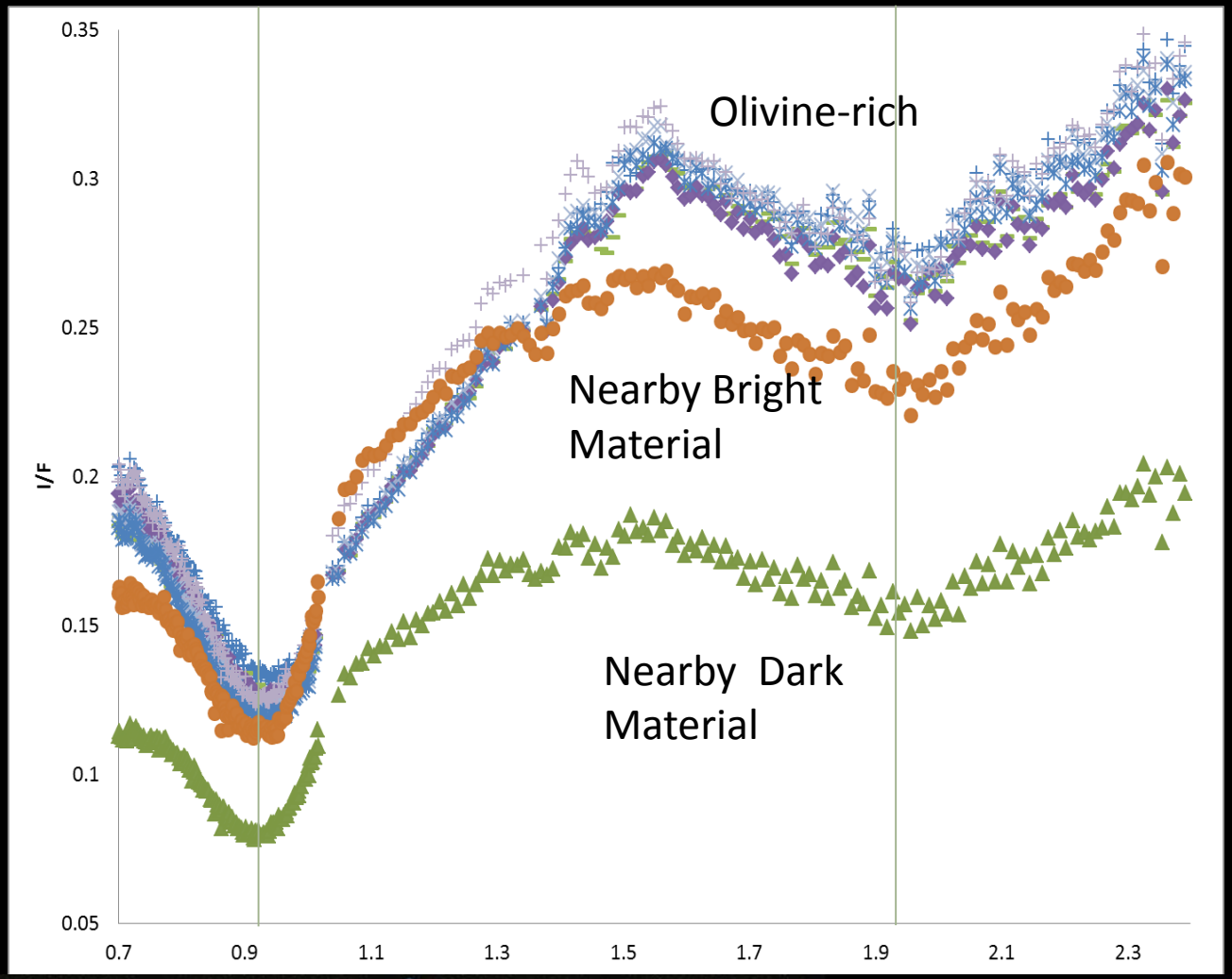




“Olivine” is freshly exposed on the crater walls, corresponding to bright material in FC image

DAWN UCLA JPL Orbital DLR MPS

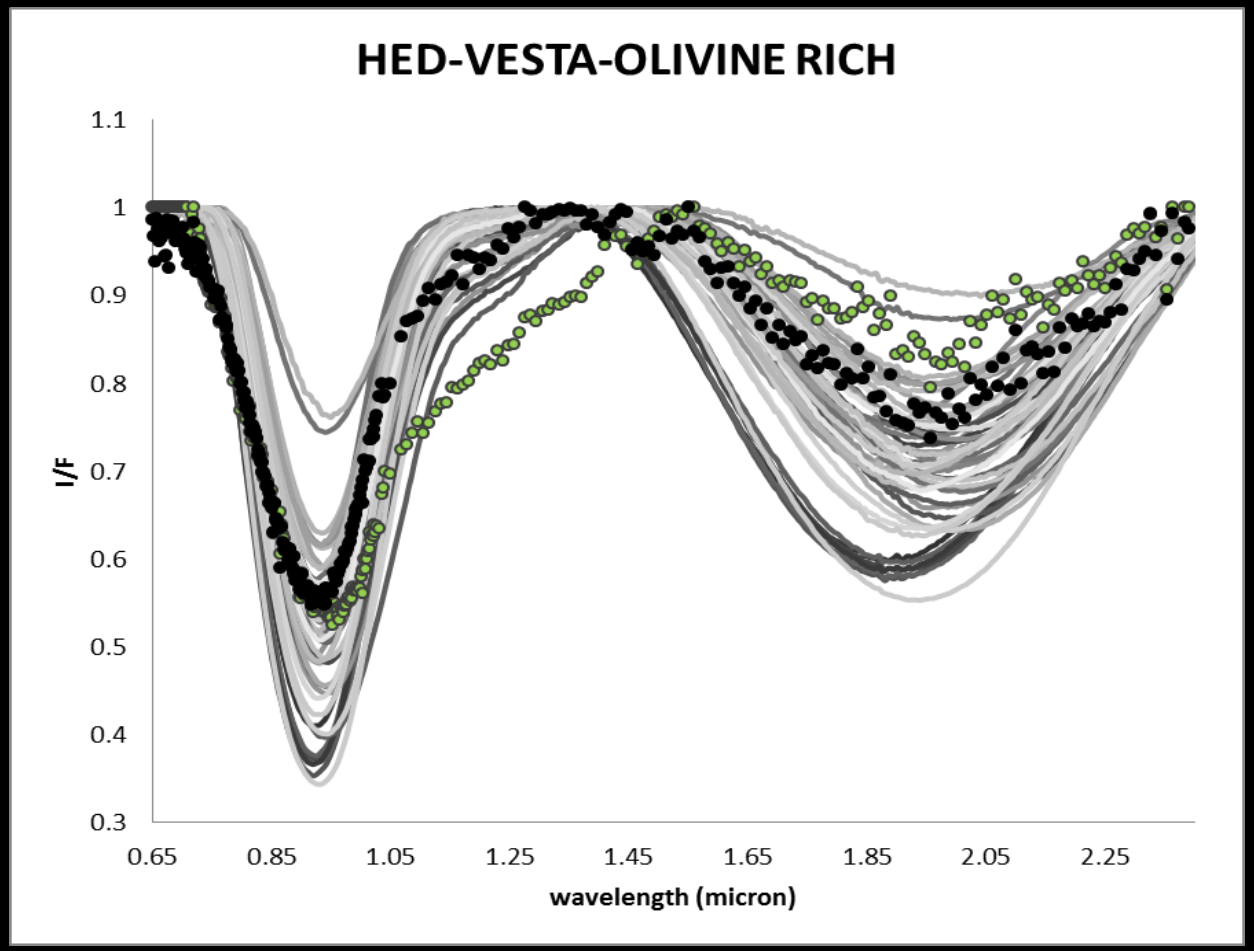
Olivine rich areas spectra



Olivine rich:

- High reflectance
- BI center at longer wavelengths
- The overall spectrum has a greater positive slope.

HED-Vesta- Olivine rich



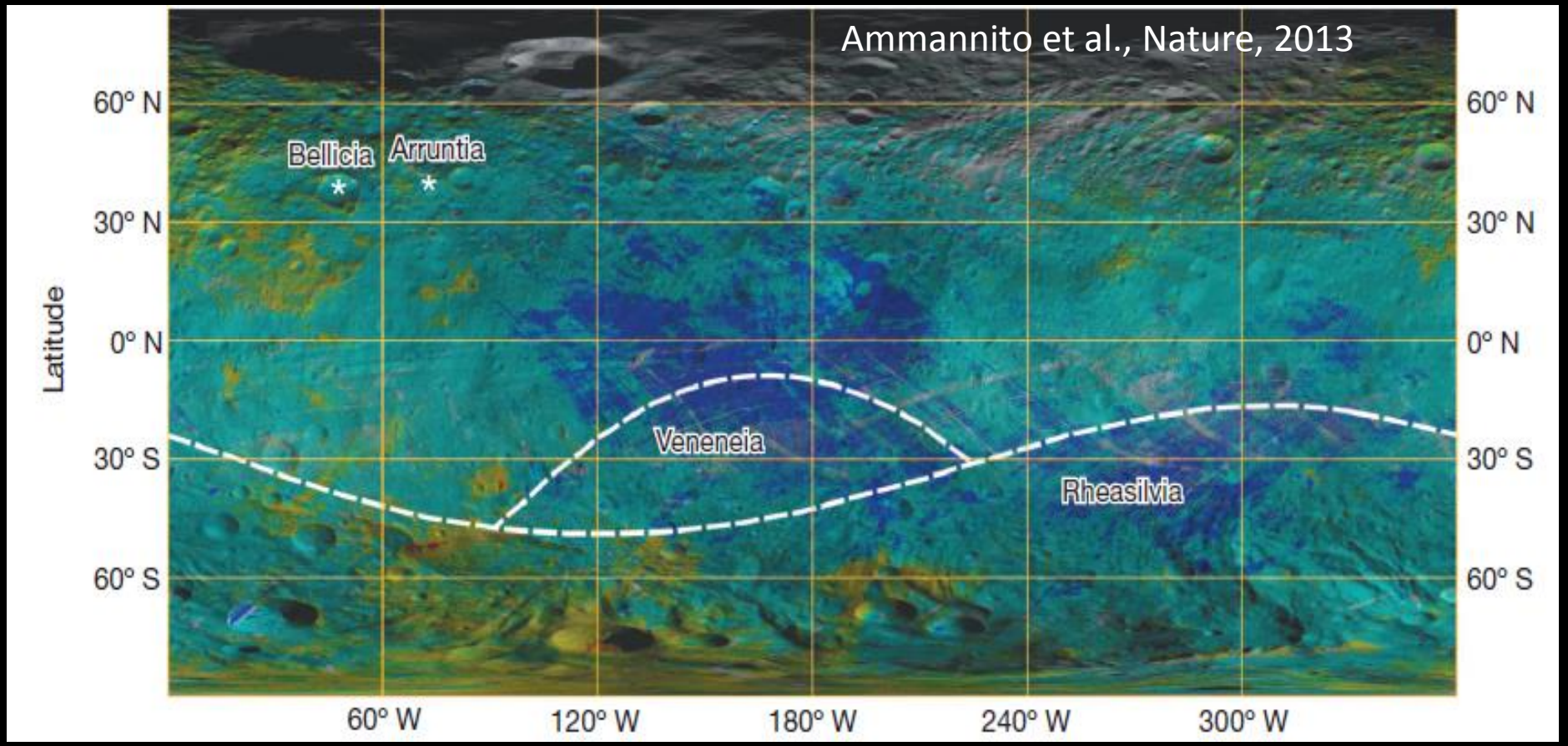
Olivine rich spectra differ from HED spectra :

- Broad and asymmetric band at 1 µm with a shallow depression at 1.3 µm
- BI at longer wavelengths with respect HEDs

Mixture of HED with olivine

Rheasilvia ejecta

- In the magma-ocean model, the Rheasilvia basin, could have excavated and redistributed mantle material across Vesta.
- The equator-south mineralogical diversity indicates that the lower-crust/upper-mantle, dominated by diogenitic material, was exposed by these impacts, and was deposited as an extensive area of ejecta in the north-west direction, but most likely not extending to the Bellicia-Arruntia region.



Clues for the Vesta interior

- The **large exposures of olivine-rich material** and their **association with howardite** may favor a **magma-ocean model** for the origin of the olivine.
- However, the **apparent absence of olivine concentrations in Rheasilvia** may suggest that the **internal distribution of lithologies was heterogeneous**, perhaps supporting the **pluton model**, or that the crust-mantle boundary was deeper in the region excavated by Rheasilvia than in the Arruntia-Bellicia region.
- In any case, the lack of pure olivine in the southern deeply excavated basins and its unexpected discovery in the northern hemisphere of Vesta indicate a more **complex evolutionary history** than inferred from pre-Dawn models.