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Comparison of photometric phase curves resulting from various observation scenes

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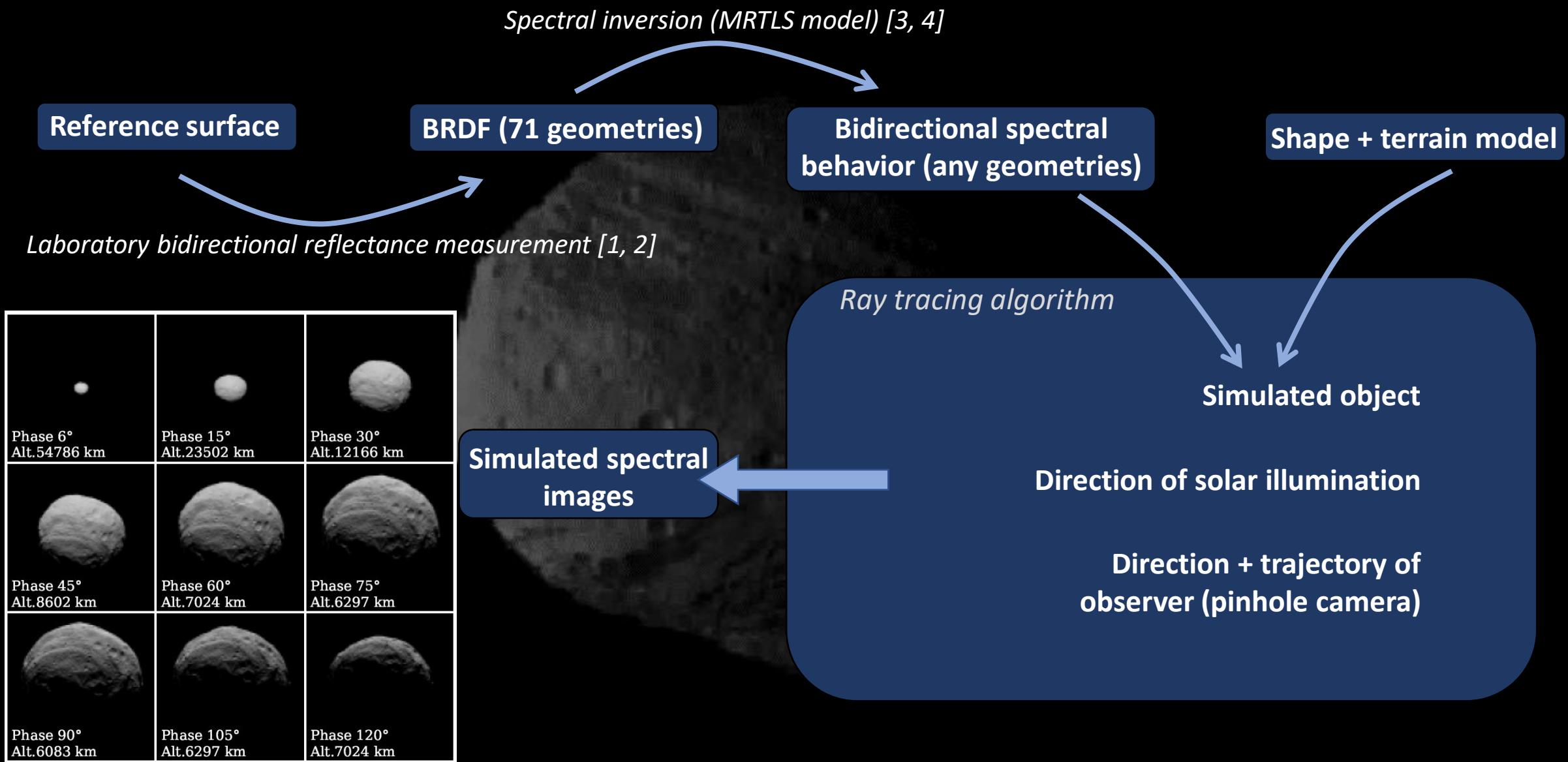


Introduction and context

The Solar System small bodies can be observed from ground-based or Earth orbiting telescopes but only span over a few pixels on the images due to their distance to the observer, their small size and atmospheric conditions blurring the images. The highest spatial resolution on the surface is achieved by in-situ observations by spacecrafts orbitting their target.

- *To which extent unresolved topography, roughness and the overall shape of asteroids are going to control their reflectance spectra depending on the geometrical acquisition conditions?*
- *Under which conditions is it possible to interpret asteroid spectra using reference reflectance spectroscopy of samples in the laboratory?*

Simulation of planetary observations - Methodology



Simulated observations of (4)Vesta resulting from the polar fly-by. The intensity of the grey scale corresponds to the radiance at 400nm [5]

Simulation of planetary observations – Fly-bys of (4)Vesta

Simulation of the asteroid (4)Vesta homogeneously covered with a fine powder of howardite and virtual observations during 3 different scenarii:

Spot-pointing

- Camera observes the same point on the surface
- Phase angles generated by moving illumination
- Observations during waxing and waning phases

Reflectance modified by:

- **Increasing casted shadows** on the surface due to the topography with increasing phase angle

Equatorial fly-by

- Fixed illumination direction
- Camera follows a linear trajectory along the equator of Vesta, going away from the light source

Reflectance modified by:

- **Increasing casted shadows** on the surface due to the topography with increasing phase angle
- + *Variation of the observed surface*

Polar fly-by

- Fixed illumination direction
- Camera follows a linear trajectory from north to south

Reflectance modified by:

- **Increasing casted shadows** on the surface due to the topography with increasing phase angle
- Variation of the **observed surface**
- + *Variation of the observed shape*

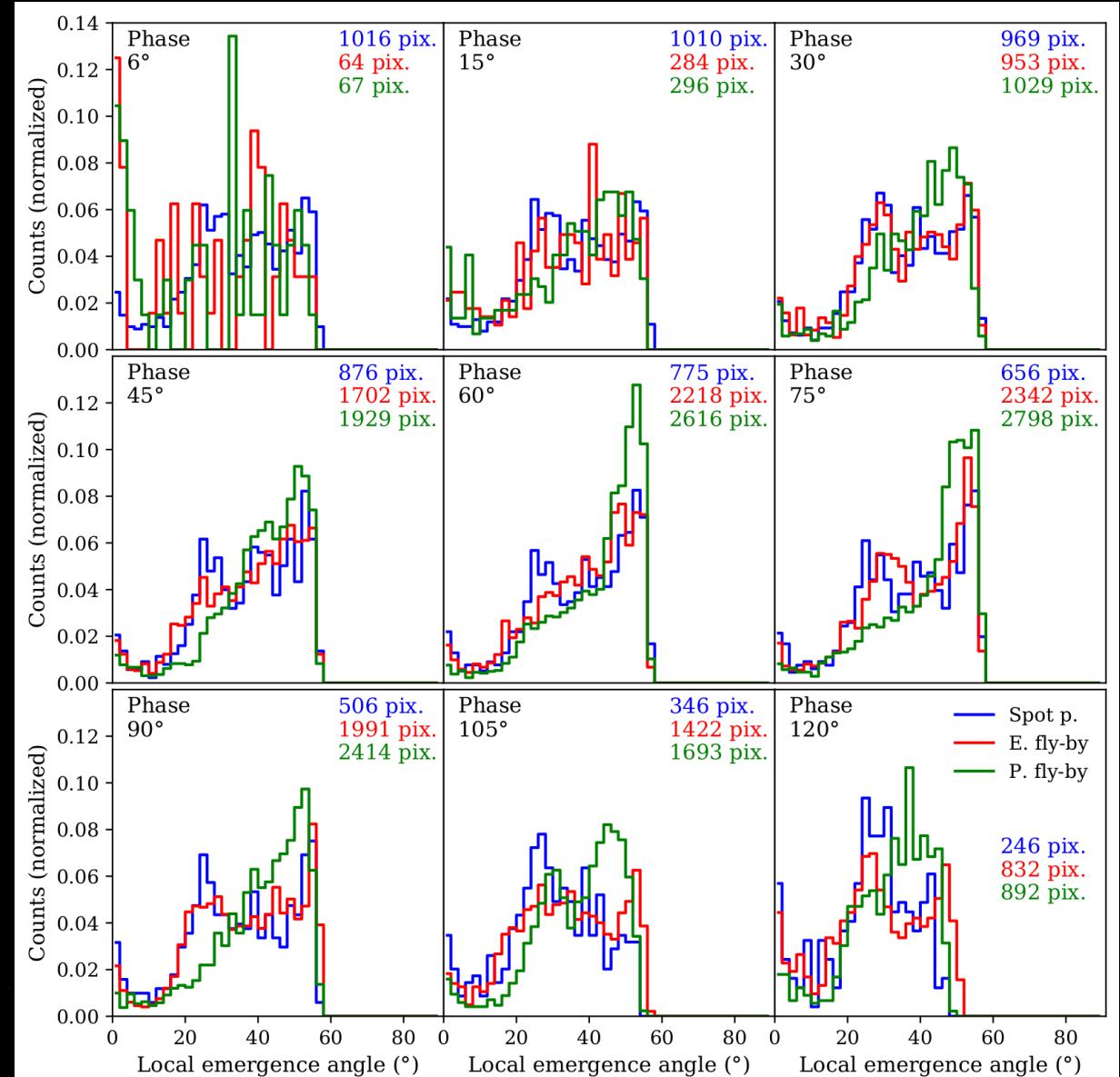
Unresolved observation of the simulated object obtained by averaging the reflectance over the observed surface

Variations of local incidence and emergence angles

A spherical body shape induces a triangular shape of the histograms with the **maximum of population met at the highest values of local angles** (grazing geometries). This is due to the high number of facets forming the sides and limbs of the observed half-sphere, compared to the low amount of facet forming the subsolar and sub-observer points with local incidence and emergence angles near 0° .

A **non-spherical shape and the surface topography modifies the distribution of the local angles**, as seen in this example as the increase of population around 25° and the decrease of population in the wide angles for the spot-pointing and equatorial fly-by. All these variations will impact the averaged reflectance spectroscopy collected by the observer.

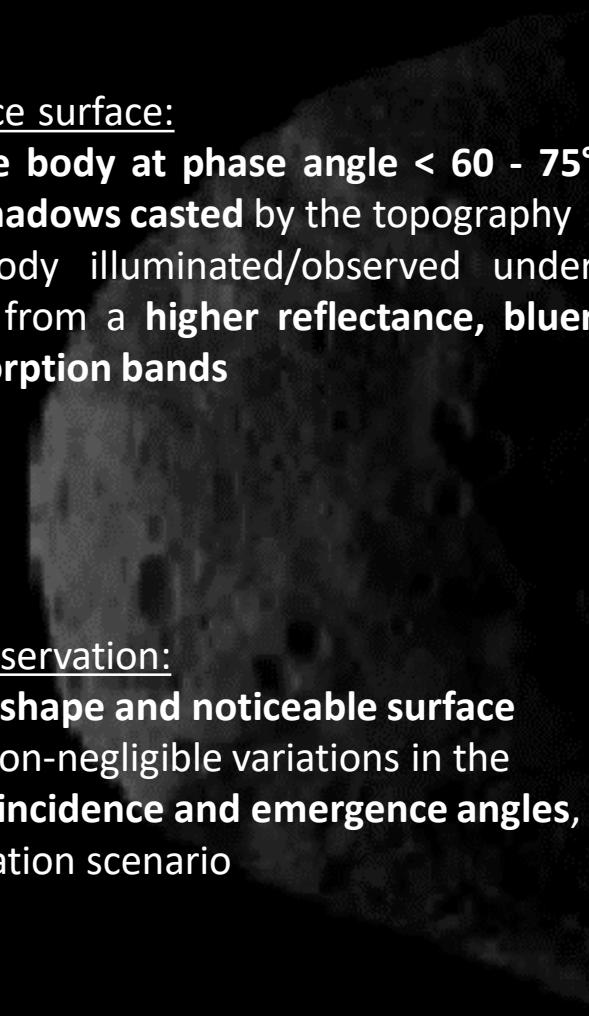
Histograms of the local emergence angles resulting from the spot-pointing (blue), equatorial fly-by (red) and polar fly-by (green) around Vesta. Each panel represents a phase angle. The angles are considered with respect to the normal to the surface (nadir = 0°). The counts have been normalized to the area under the histogram, so the total number of pixels illuminated and observed in the images. This number of pixels is indicated on each panel for the spot-pointing (blue), equatorial fly-by (red) and polar fly-by (green) [5]



Comparison between the various phase curves and the reference surface

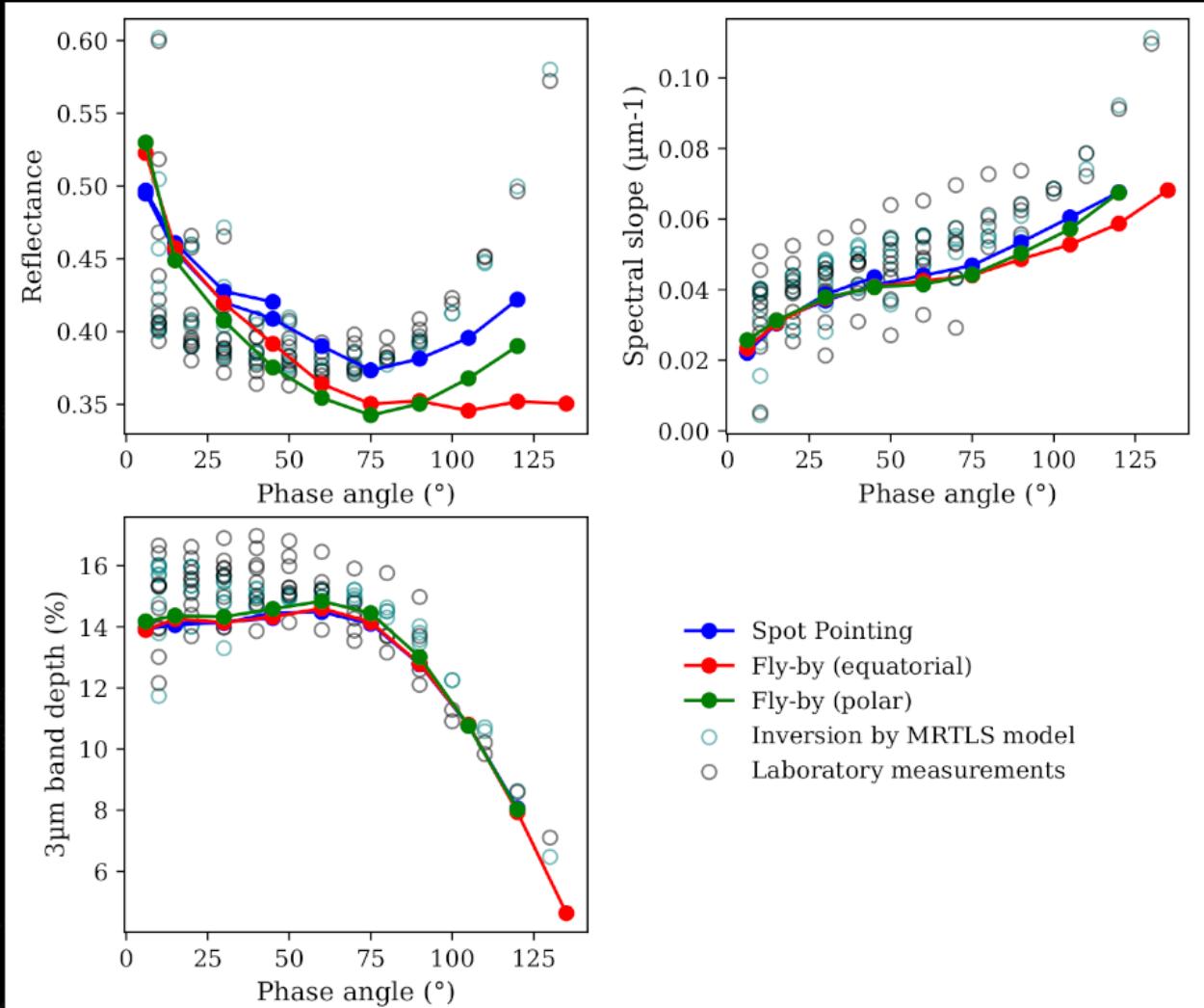
Differences from the reference surface:

- Due to the **shape of the body at phase angle < 60 - 75°** then by the **increasing shadows casted** by the topography
- Wide region of the body illuminated/observed under grazing angles, resulting from a **higher reflectance, bluer slope and shallower absorption bands**



Differences between each observation:

- Due to the **non-spherical shape and noticeable surface topography** that induce non-negligible variations in the **distributions of the local incidence and emergence angles**, depending on the observation scenario



Spectral phase curves resulting from the simulated spot-pointing (blue), equatorial fly-by (red) and polar fly-by (green) around Vesta, compared to the spectral parameters of the reference surface calculated on the measured spectra (black circles) and resulting from the inversion by the MRTLS model (blue circles) [5]

Conclusion

- ✓ At low phase angle, the reflectance spectra of a planetary body tends to be **brighter, bluer and showing fainter absorption features** compared to the reference surface. These differences are due to the high area of the global shape of the planetary body presenting **near grazing local incidence and emergence angles** and the strong backscattering behavior of the reference powdered surface.
- ✓ **The value of reflectance is the most impacted parameter**, while the phase curves of the spectral slope and amplitude of the absorption bands approach and sometimes match the laboratory measurements. These variations are due to the local incidence and emergence angles induced by the shape of the simulated Vesta coupled with its varying surface topography
- ✓ Unregarding the composition, surface texture and geometry of observation, the shape and topography of the planetary body will impact its unresolved reflectance spectroscopy and **generate noticeable differences with the reflectance spectroscopy of its surface alone**.

References

- [A] Potin et al. 2018, *Applied Optics*, 57, 8279-8286
- [B] Potin et al. 2019, *Icarus*, 333, 415-428
- [C] Wenner et al. 1995, *Journal of Geophysical Research*, 100, 21077-21089
- [D] Kugler et al., in press, *Statistics and Computing*
- [E] Potin et al., *under review*



The laboratory BRDF of the reference surfaces are freely available to the community and stored in the SSHADE database

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