THE ROLE OF GIS IN GEOMETRIC PROCESSING OF NASA-DAWN/VIR SPECTROMETER DATA

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Introduction: Between July 2011 and September 2012, the NASA-Dawn [1] mission acquired remote sensing data of Vesta from three different orbital heights [2]. In March 2015 Dawn has successfully entered orbit at Ceres, facing a year of data acquisition over the dwarf planet. Geographic Information System, initially developed for Earth-based environmental purposes, became more and more popular in the field of Planetary Sciences in the last 15 years [3]. Within the Dawn mission, Geographic Information System have been used widely within the scientific team, allowing a versatile high-level data exchange, the production of digital geologic maps and the spatial analysis of different scientific data, from crater densities to the distribution of different terrains and mineralogic species. Herein we present the experience of the use of GIS tools for the geo-processing of the spectrometer data coming from the VIR instrument onboard NASA-Dawn.

The spectrometer onboard NASA-Dawn: The Visible and InfraRed (VIR) instrument onboard NASA/Dawn is a hyperspectral spectrometer with imaging capability [4]. The design accomplishes entirely the Dawn's scientific and measurement objectives. In particular, the primary Dawn objective is the determination of the mineral composition of surface materials in their geologic context. The nature of the solid compounds of an asteroid (silicates, oxides, salts, organics and ices) can be identified by visual and infrared spectroscopy using high spatial resolution imaging to map the heterogeneity of asteroid surfaces and high spectral resolution spectroscopy to determine the composition unambiguously. The VIR Spectrometer covers the range from the near UV (0.25 μm) to the near IR (5.0 μm) and has moderate to high spectral resolution and imaging capabilities. It is is the appropriate instrument for the determination of the asteroid global and local properties. Two data channels are combined in one compact instrument. The visible channel covers 0.25-1.05 μm and the infrared channel covers 1-5.0 μm.

The maps of spectral paramter of Vesta: Ground based studies demonstrated that Vesta's mineralogy is dominated by pyroxenes [5], thus the pyroxene-related spectral parameters are particularly useful in mapping the mineralogic differences across the surface of Vesta. The process of mapping those single spectral parameter values over large areas allow for observation of the spatial variation of the mineralogic composition across the asteroid. The combined use of the Integrated Software for Imagers and Spectrometers (ISIS) [6, 7, 8] and the Geographic Resources Analysis Support System (GRASS) GIS [9, 10] allowed to mosaic the pyroxene-related spectral parameters extracted from VIR data acquired during the orbits of the Vesta campaign [11]. Figure 1 show the variation of pyroxene band II variation across the surface of vesta through a 15-quadrangle scheme.

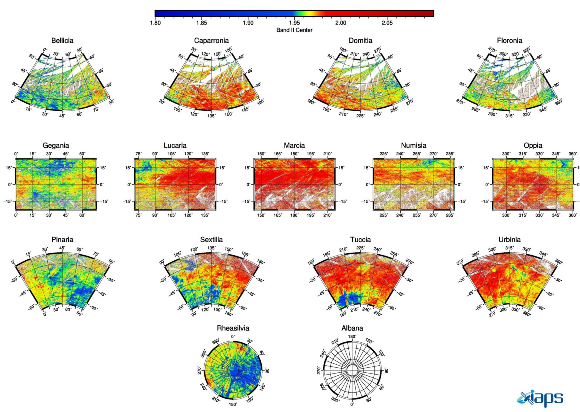
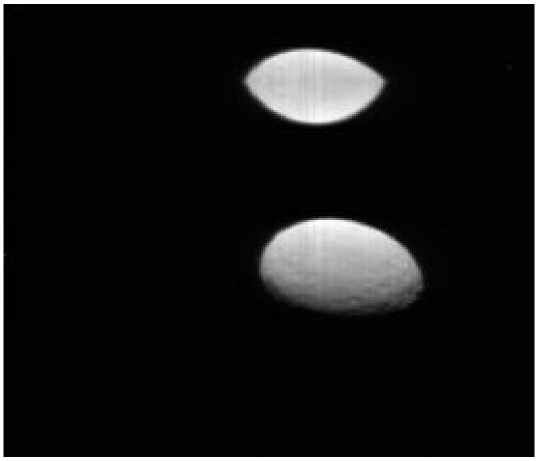
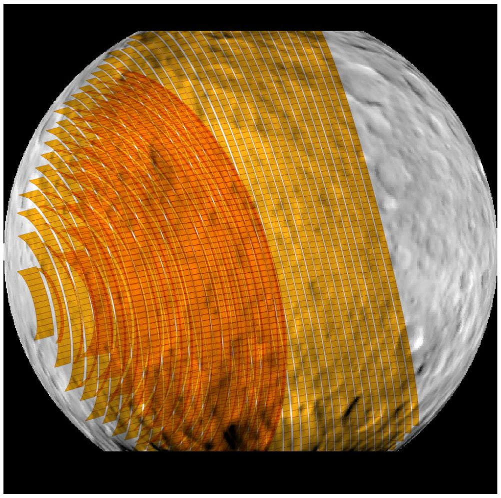


Figure 1: The pyroxene band II center maps, from the spectral parameters map of Vesta. Geoprocessing was made with ISIS and GRASS GIS. The color variation indicate clearly the mineralogic diversity across the surface of the asteroid.

VIR operations at Ceres: The data acqusition of VIR at Ceres becomes more complicated than on Vesta for two main reasons, which are closely related to each other. First of all Ceres is generally more dark than Vesta and this implies that longer exposure times are needed in order to have a sufficient signal to noise ratios. The second factor affecting the complexity of data acquisition over Ceres is that Dawn's ship orientation can not be controlled with the same accuracy used for Vesta. In fact, of four reaction wheels available on Dawn, two experienced problems during the mission, respectively in June 2010 and in August 2012 during the leave from Vesta. Since normal operations require three wheels, pointing at Ceres has to be adjusted by ion thrusting, loosing accuracy between the planned and the effective data acqusition geometries. The ion thrusting pointing adjustements affects the acquisition geometry of VIR, as shown in Figure 2.



(a) Level1B VIR data



(b) Projected VIR footprints

Figure 2: An example of VIR data acquired during thrust activation on Dawn at Ceres. (a): the Level1B data cube VIR_IR_1B_1_477629880 (band 100 of the infrared channel) shows the effect of change of pointing direction of the spacecraft. (b): the geometry of the footprints (orange) of the same data, projected over a Framing Camera image mosaic, the darker orange indicates areas with overlapping footprints. In this case we have 2 and 3-fold footprint's overlap within the same data cube.

Software improvements and the use of GIS at Ceres: The two factors indroduced above generate a special case which has to be handled specifically by the processing software. USGS's ISIS3 VIR implementation is planned to be improved, introducing a more accurate representation of the instrument footprints, taking into account the start and stop acquisition times. The change of acqusition direction during the thrusting can also cause topologic problems to some footprints. Within the VIR team we are using Geographic Information System (GIS) to handle geometries, as we did for producing spectral parameters mosaics for Vesta. This allows to geoprocess the correct geometries computed with SPICE [12] taking into account start and stop acqusition times, and to check the topology for every footprint. We develop a data model for the hyperspectral data footprints, that points to the spectra within the processed data cubes.

Discussion: Geographic Information System has been succesfully applied to various activities within the Dawn/VIR team. The range of application of geospatial processing spans from the technical/engineering operations to the scientific production. GIS-compatible digital maps are easily exchanged thanks to the use of open formats as the ones promoted by the Open Gis Consortium (OGC). After the successful use for the study of Vesta, we expect to make a more intensive use of the GIS procedures during the Ceres campaign.

References: [1] C. T. Russell, et al. (2012) *Science* 336:684 `doi`. [2] C. T. Russell, et al. (2013) *Meteoritics and Planetary Science* 48:2076 `doi`. [3] T. M. Hare, et al. (1997) in *Lunar and Planetary Institute Conference Abstracts* 515–+. [4] M. C. De Sanctis, et al. (2011) *Space Science Reviews* 163:329 `doi`. [5] T. B. McCord, et al. (1970) *Science* 168:1445 `doi`. [6] J. M. Torson, et al. (1997) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 28 of *Lunar and Planetary Institute Science Conference Abstracts* 1443–+ Houston, TX. [7] L. Gaddis, et al. (1997) in *Lunar and Planetary Institute Conference Abstracts* 387–+. [8] J. A. Anderson (2008) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 39 of *Lunar and Planetary Inst. Technical Report* 2159–+. [9] M. Neteler, et al. (2008) *GRASS GIS* chap. 9, 171–199 Springer, New York. [10] M. Neteler, et al. (2012) *Environmental Modelling & Software* 31:124 `doi`. [11] A. Frigeri, et al. (2013) *AGU Fall Meeting Abstracts* 23:1764. [12] C. H. Acton (1999) in *Lunar and Planetary Institute Science Conference Abstracts* vol. 30 of *Lunar and Planetary Inst. Technical Report* 1233.