Processing of Hayabusa AMICA and NIRS data of Itokawa

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Mineralogy

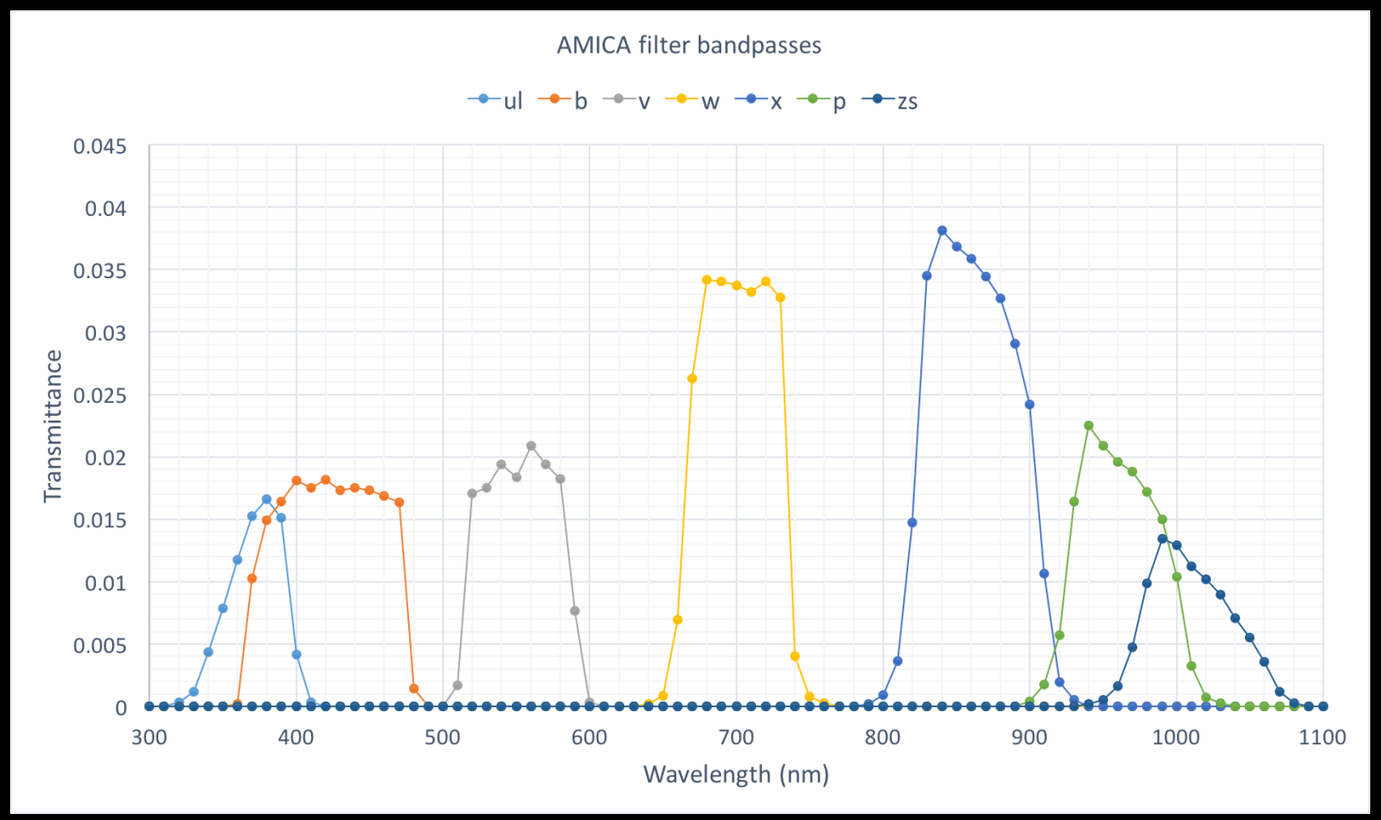
- The goal of our work is to restore data from the Hayabusa spacecraft that is available in the Planetary Data System (PDS) Small Bodies Node.

- More specifically, our objectives are to radiometrically calibrate and photometrically correct AMICA (Asteroid Multi-Band Imaging Camera) images of Itokawa. The existing images archived the PDS are not in reflectance and not corrected from the effect of viewing geometry.

- Calibrated AMICA color images will be useful for combining with the NIRS spectral range for a complete spectrum of Itokawa.

Itokawa

- Target of Hayabusa Sample Return Mission
- Apollo Near-Earth Asteroid
- Surface Composition similar to LL Chondrite (mostly olivine and pyroxene)
- Subtle albedo variations seen in AMICA color images



System efficiency of AMICA 7 color filters

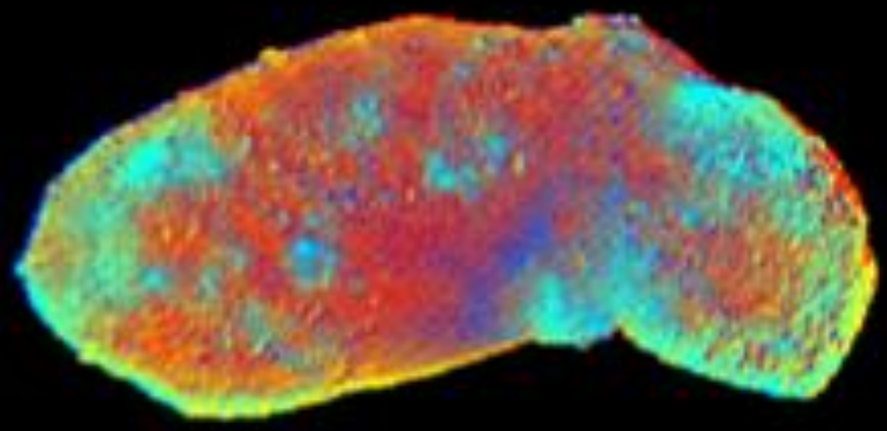
Animation showing rotation of Itokawa using sequential AMICA color images

Itokawa

True Color Image (R=700 nm; G=553 nm; B=429 nm)

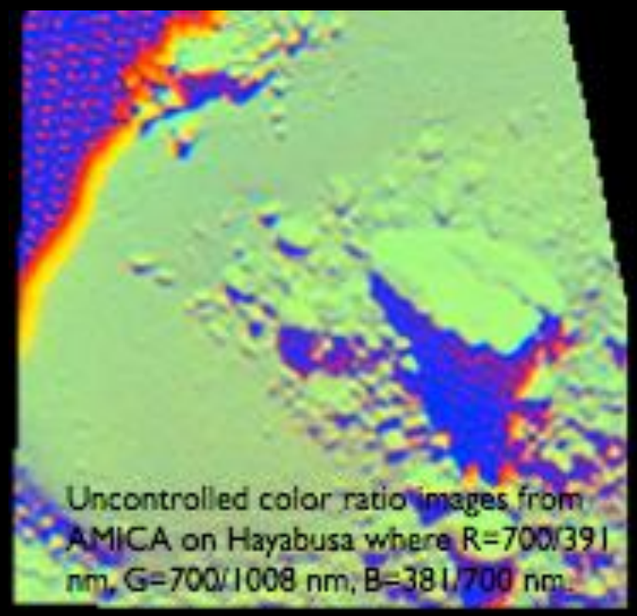
False Color Image (R=700 nm; G=429 nm; B=381 nm)

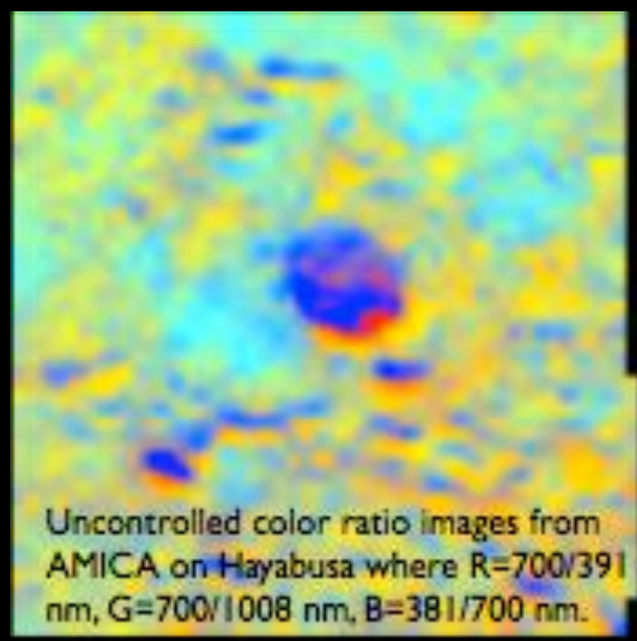
False Color Image (R=700 nm; G=960 nm; B=1008 nm)



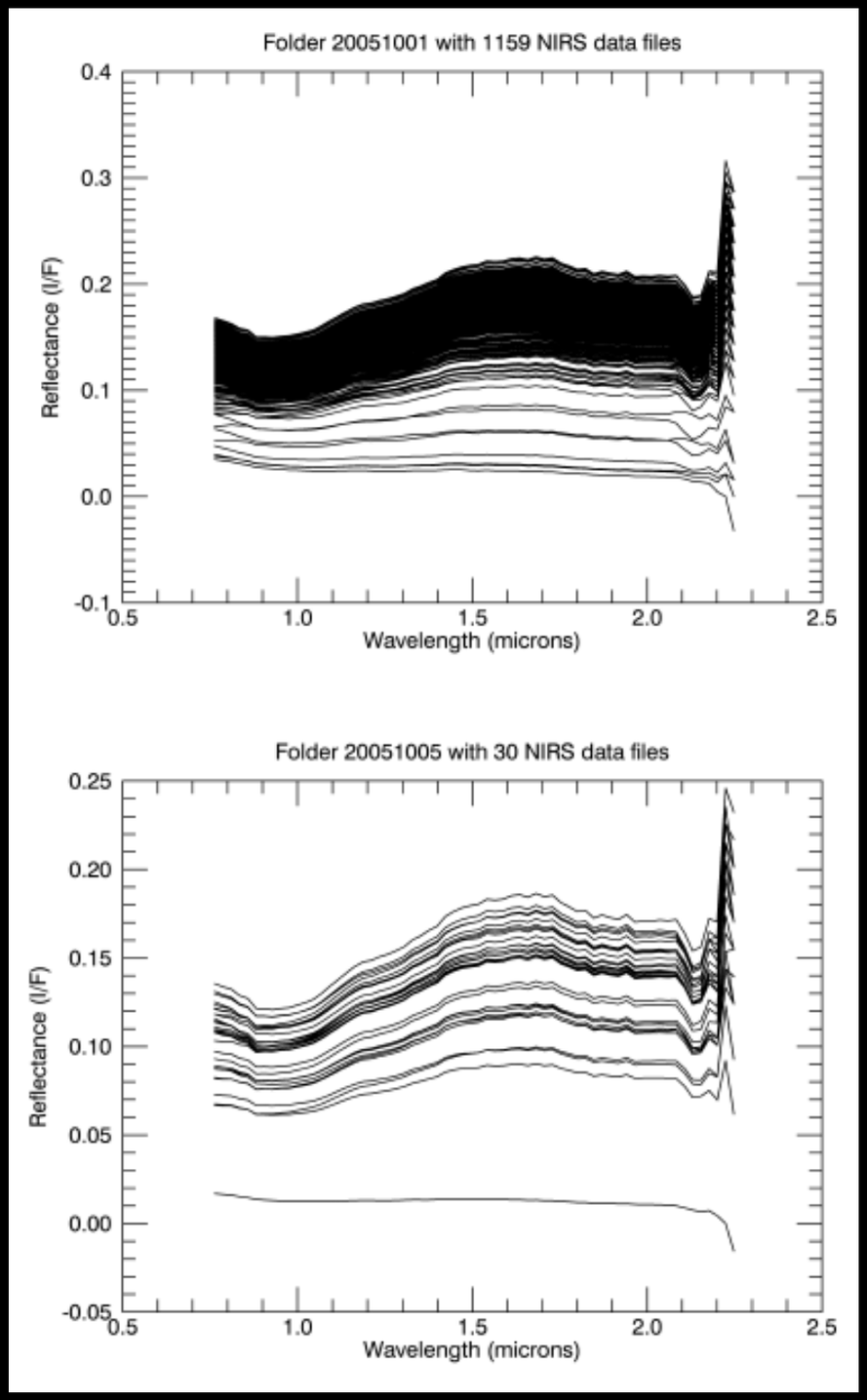
Clementine Color Ratio

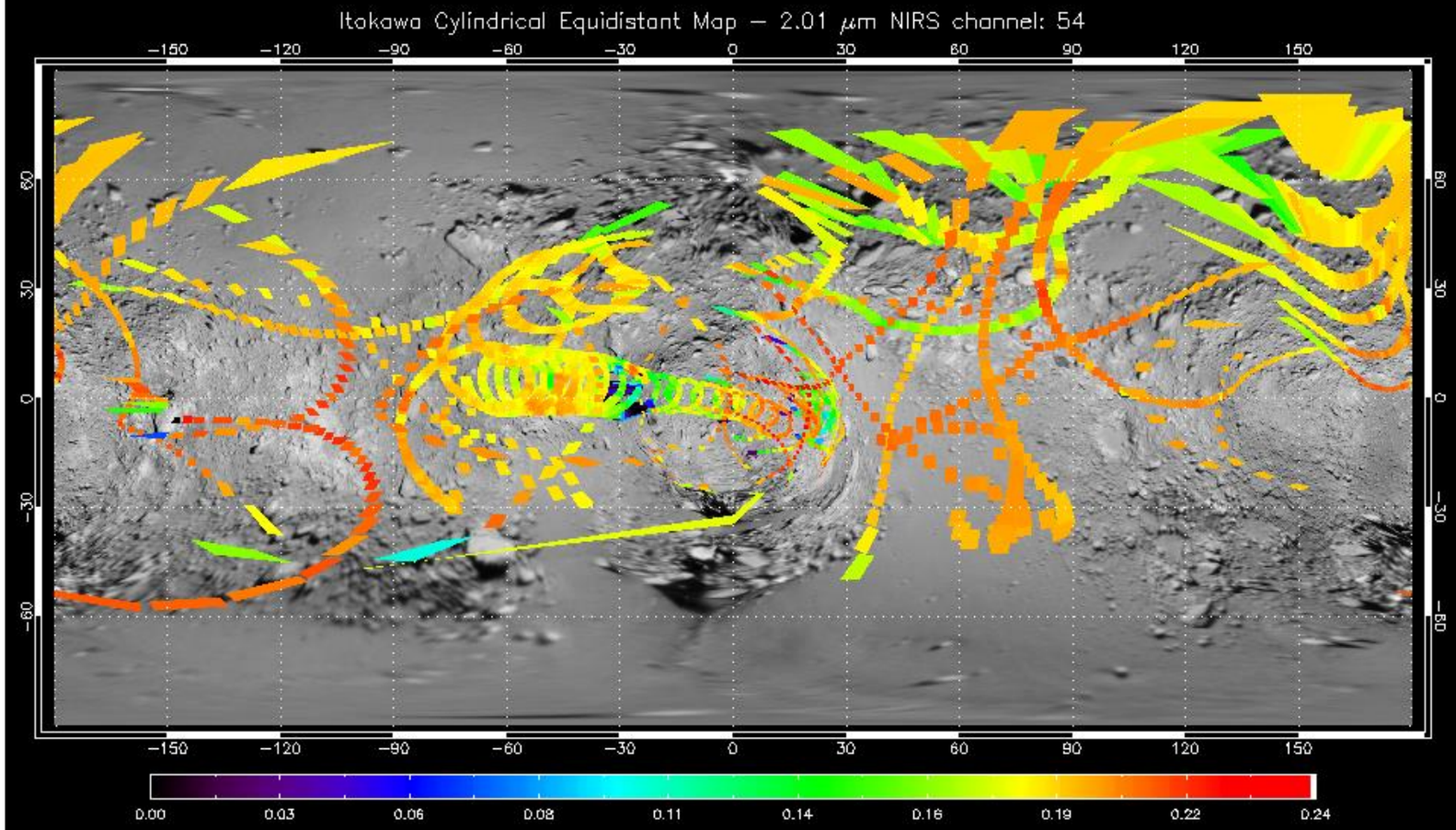
Uncalibrated Data





NIRS spectral data





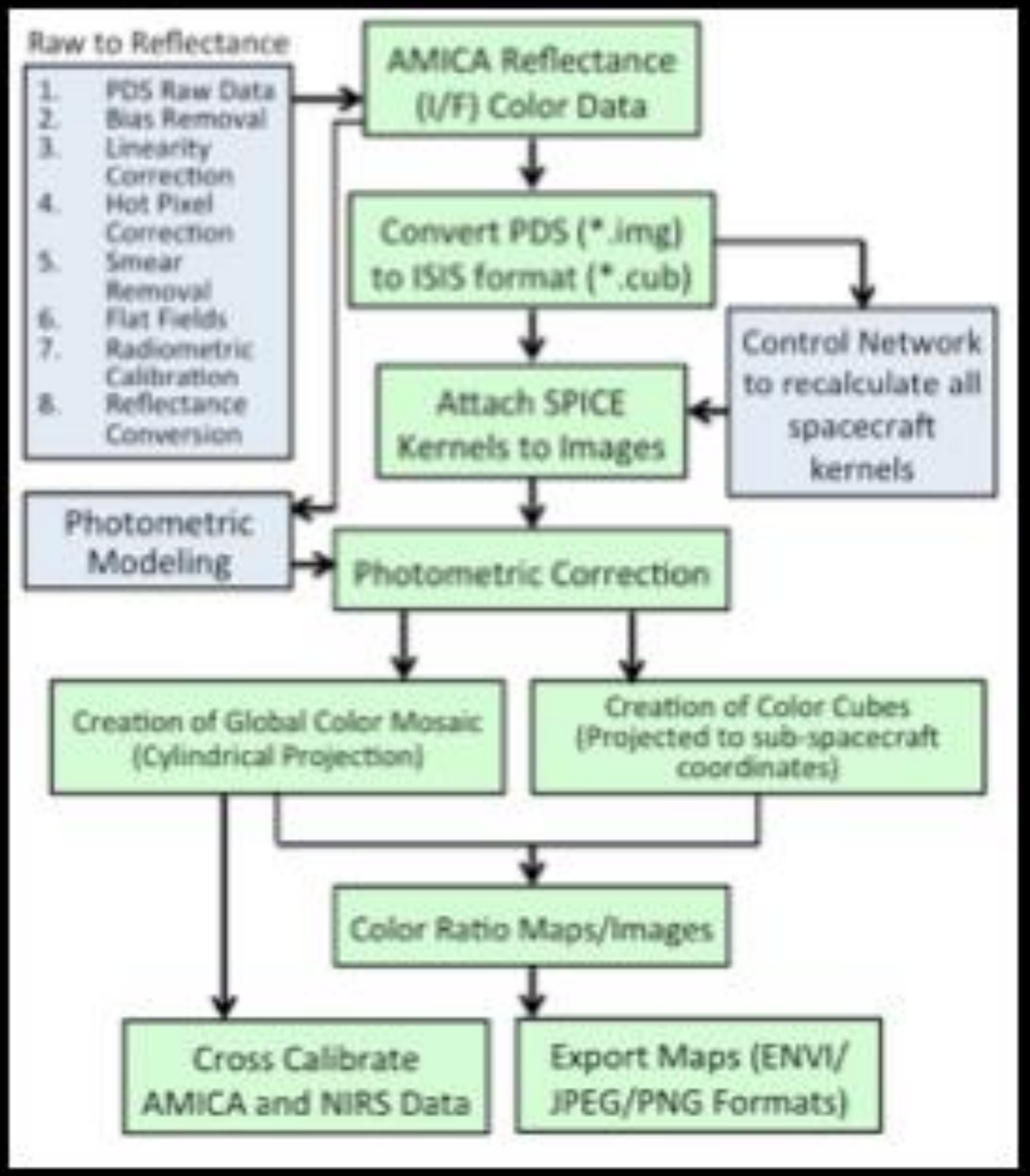
- NIRS is a point spectrometer ranging from 0.8 to 2.2 µm
- We implemented an ISIS application NIRS2ISIS to import NIRS PDS data in ISIS.
- NIRS camera model to reproject the data

AMICA Processing

- AMICA data processing is done using ISIS (Integrated Software for Imagers and Spectrometers), which is developed and maintained by U. S. Geological Survey (USGS) Astrogeology Science Center to support NASA spacecraft missions.
- We developed and implement new ISIS routines for processing AMICA images. All these routines will be distributed via USGS ISIS releases.
- Processing steps:

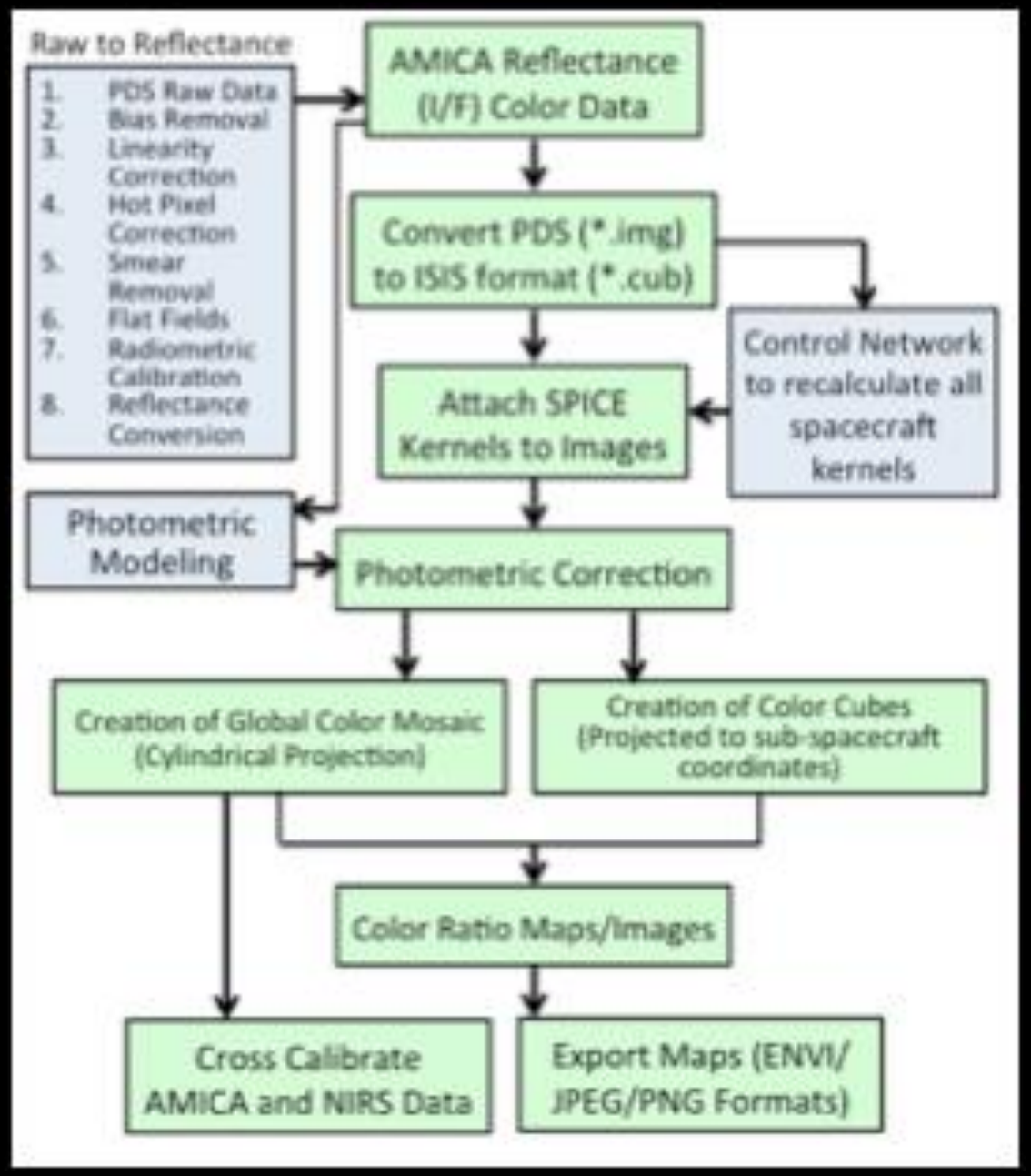
✓ 1) Ingestion of images in ISIS using *amica2isis* (New Application)

✓ Update the AMICA start time with *sumspice* (New Application)



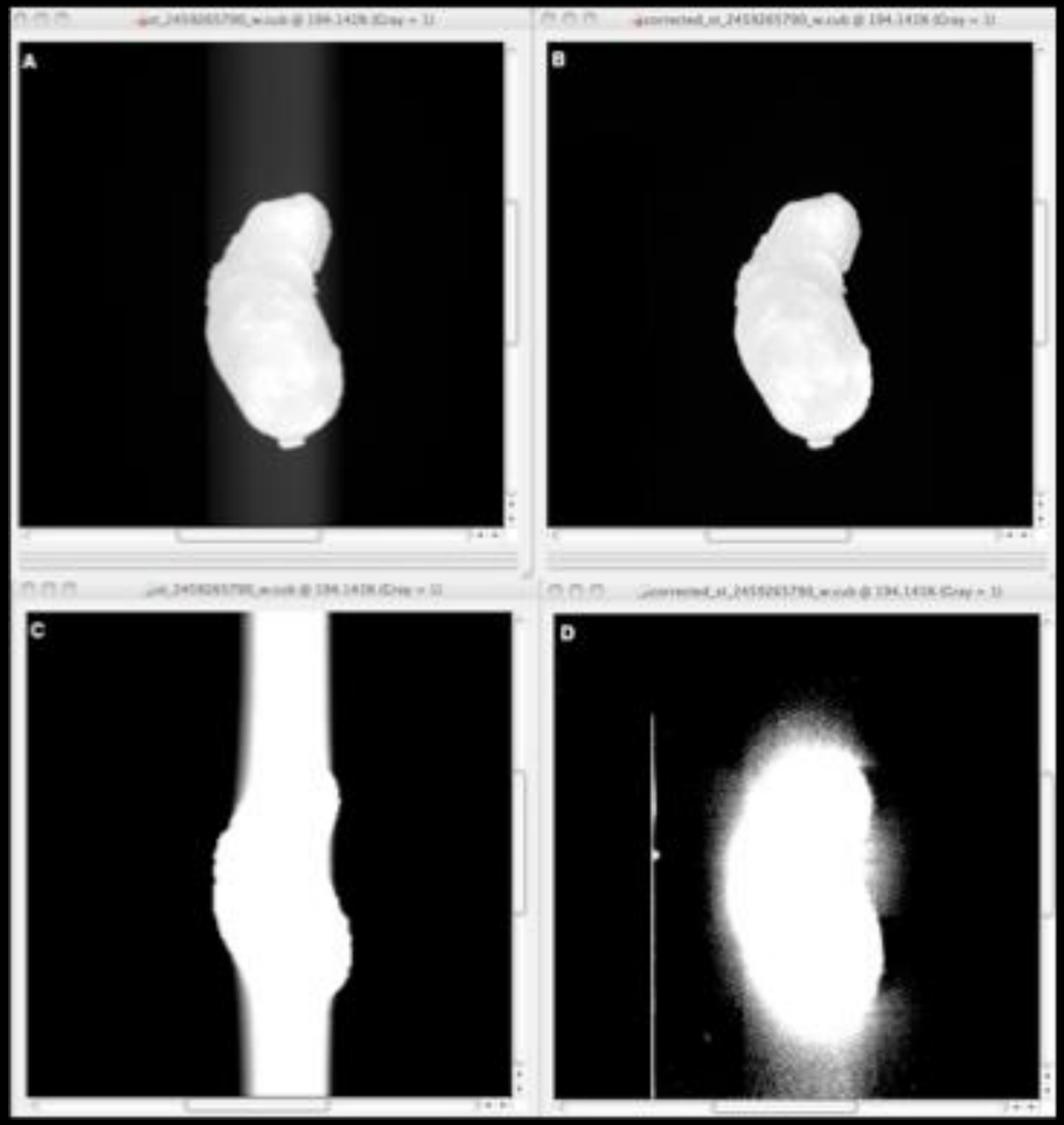
AMICA Processing

- ✓ DNs by 16 for lossy data, substraction of the bias, linearity correction, removal of hot pixels, read out smear removal (smear correction was processed correctly onboard until Oct. 2005), division by flat field, conversion to radiance and reflectance. We are currently testing the latest Point Spread Function (Ishiguro et al. 2014) that includes the effect of scattered light affecting mostly the three last filters. Scattered light can add 10% of signal in zs, p images.
- ✓ *Amicacal* can be applied to subframes and binned images. It has an option to remove the pixels corresponding to the polarized filters.
- ✓ Applying SPICE ephemeris, adjusting control using Gaskell SUMFILEs from SPC using the sumspice routine (next slides).



Examples

- Results of radiometric calibration applied to the sub-sampled (binned) image st_2459265790_w: Image A shows the raw unprocessed image. Image B is the calibrated image. To demonstrate the smear removal aspect of the calibration, Image C shows a hard stretch of the raw image that highlights the smear component of the data. Image D shows the results after the processing.

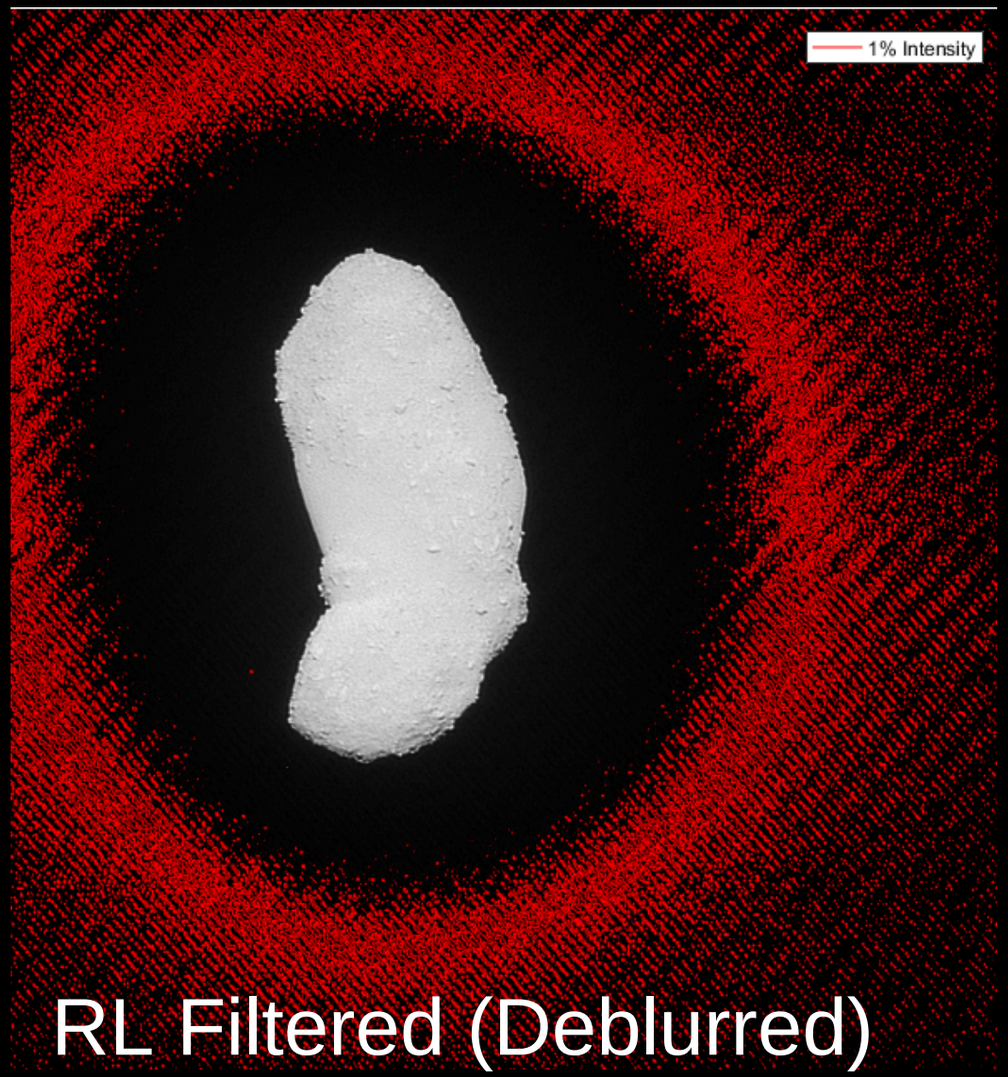


Examples

- Results of radiometric calibration applied to the image st_2460318038_p. Left image shows the raw unprocessed image with effects from read out smear and scattered light. Middle image is the calibrated image with read out smear correction. Right image shows the same as the previous one but with PSF correction applied.

R-L algorithm

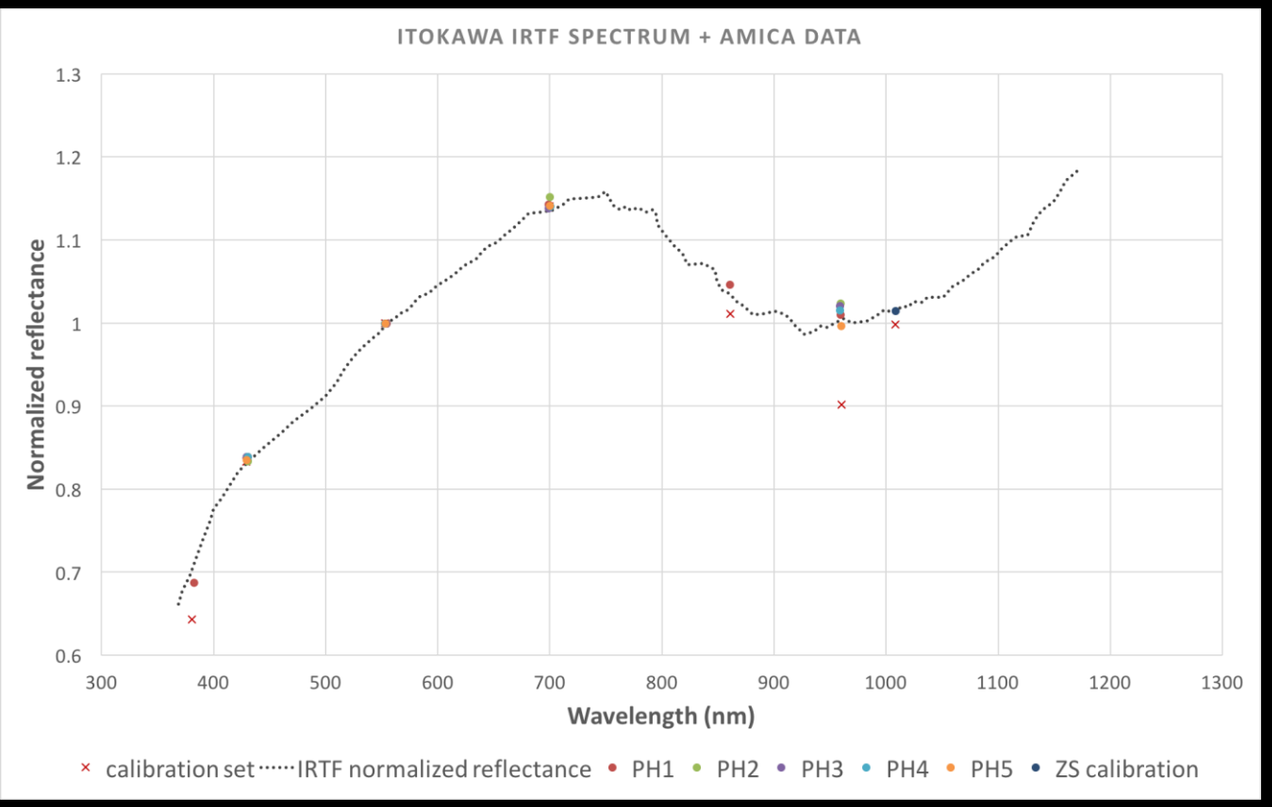
Original

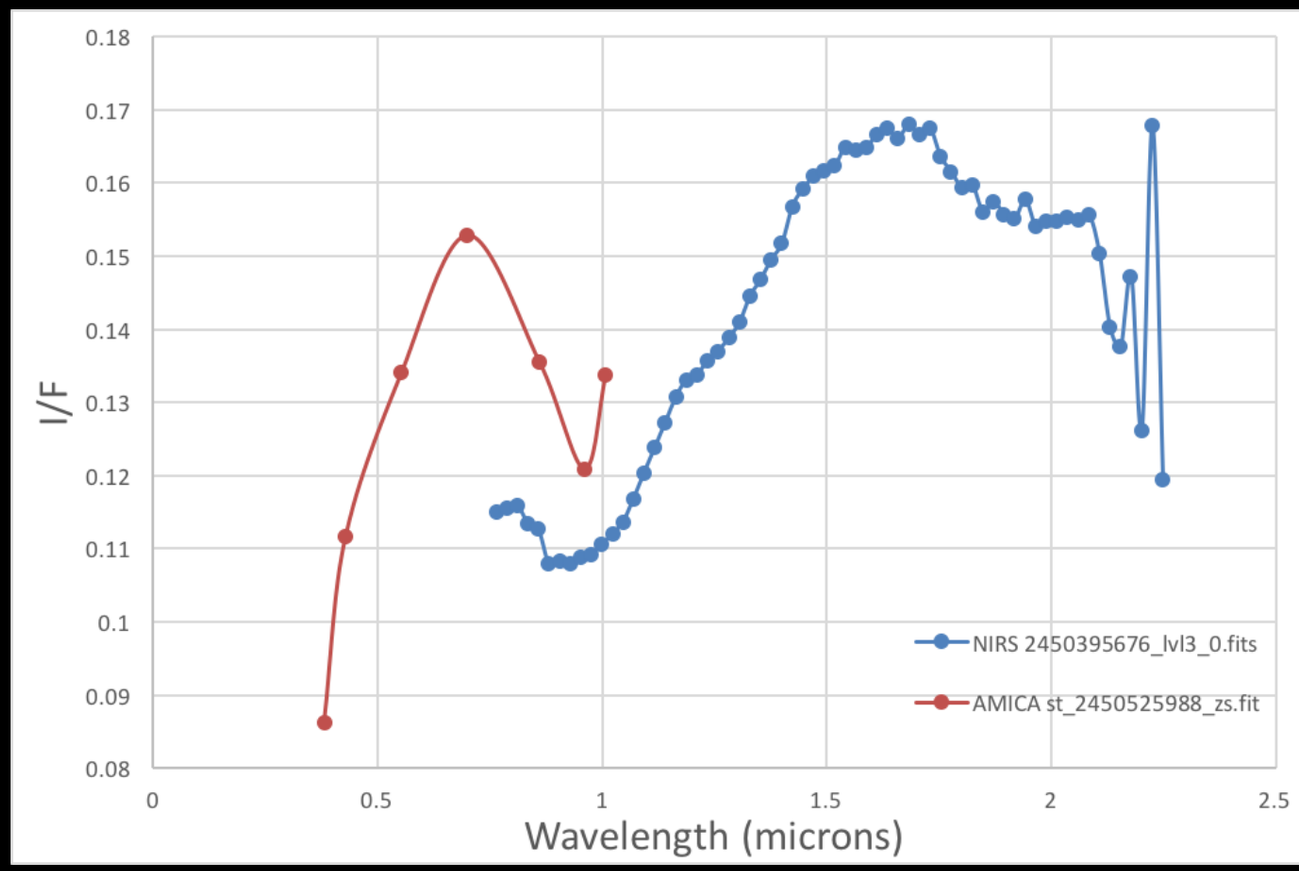


RL Filtered (Deblurred)

- (Left) Original image after basic calibration showing the level of brightness in the sky background due to scattered light.
- (Right) Image after scattered light removal and sharpening.

AMICA I/F





- Conversion factors for 6 filters from Ishiguro et al. to get I/F values from DN/s using ECAS data obtained from ground-based observations
- We tried determining zs conversion factor using IRTF spectrum but scattered light still to be corrected here.

- Comparison of a color image set from AMICA to a NIRS observation from the same data and viewing conditions
- However NIRS footprint much smaller on Itokawa than the AMICA frame (global Itokawa)
- Good matching for AMICA/NIRS

Updating Pointing/Trajectory

- The *sumspice* application has been completed and distributed to the community in the ISIS 3.4.12 release. This application was developed to apply ephemeris pointing and spacecraft position data to individual images using Gaskell SUMFILEs, a byproduct of digital elevation modeling (DEM) processes.

- It has been designed to also apply timing corrections contained within the SUMFILEs to image observation start times. We found a discrepancy while evaluating geometric alignment with the Itokawa DEM. This issue was resolved with additional functionality added to *sumspice* to apply the start times in the Gaskell SUMFILEs to each image and is a selectable user option in the application.

- The routine *sumspice* was tested on Hayabusa AMICA images using SUMFILEs from Bob Gaskell and the routine successfully improved the matching of geometric backplanes with the corresponding raw images from the PDS.

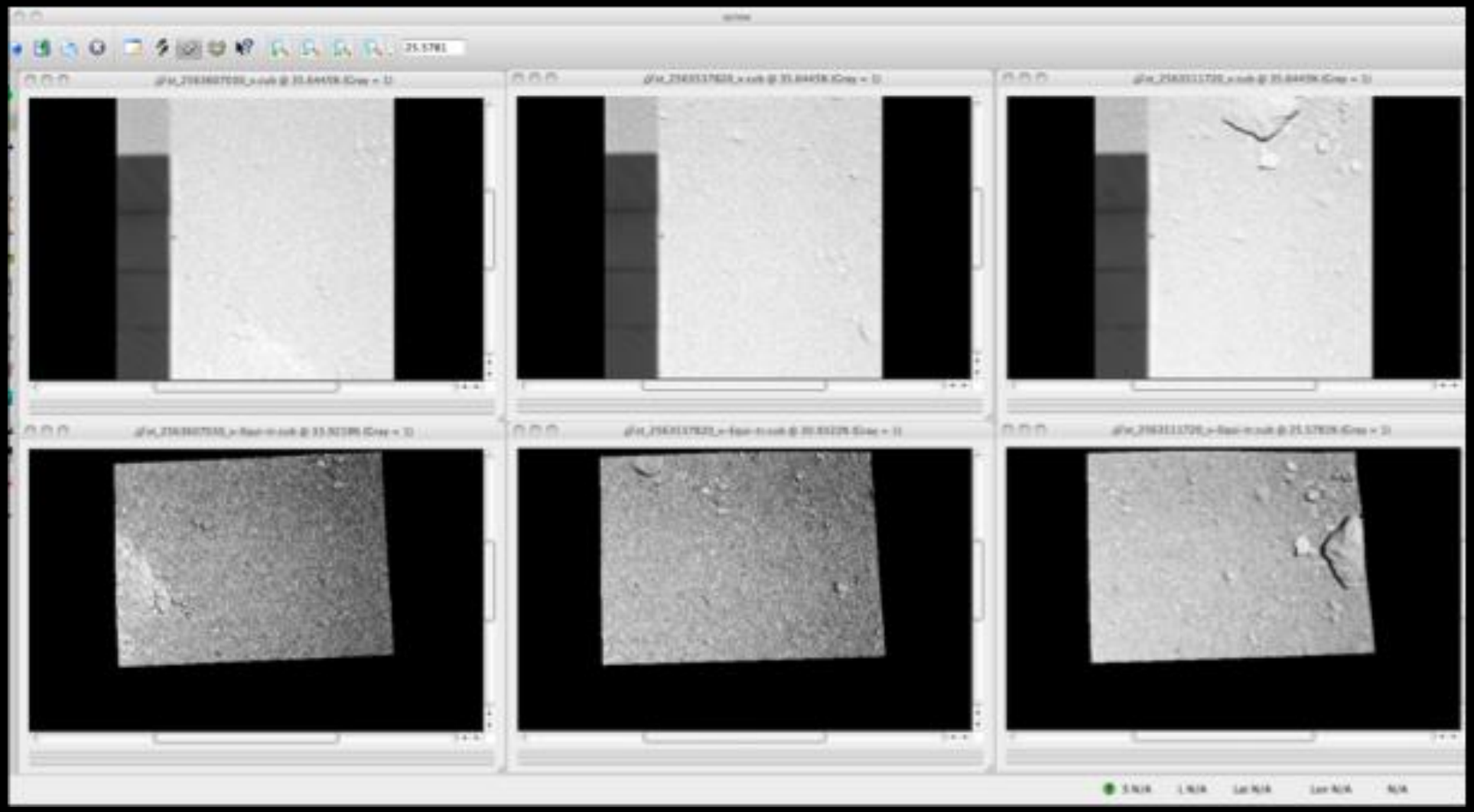
Updating Pointing/Trajectory

- Also validated using Dawn Framing camera color images and Gaskell SUMFILEs generated during the construction of the Vesta shape model.

- Our goal is to create controlled mosaics for these objects and produce updated CK and SPK kernels that can be applied directly to the images without sumspice.

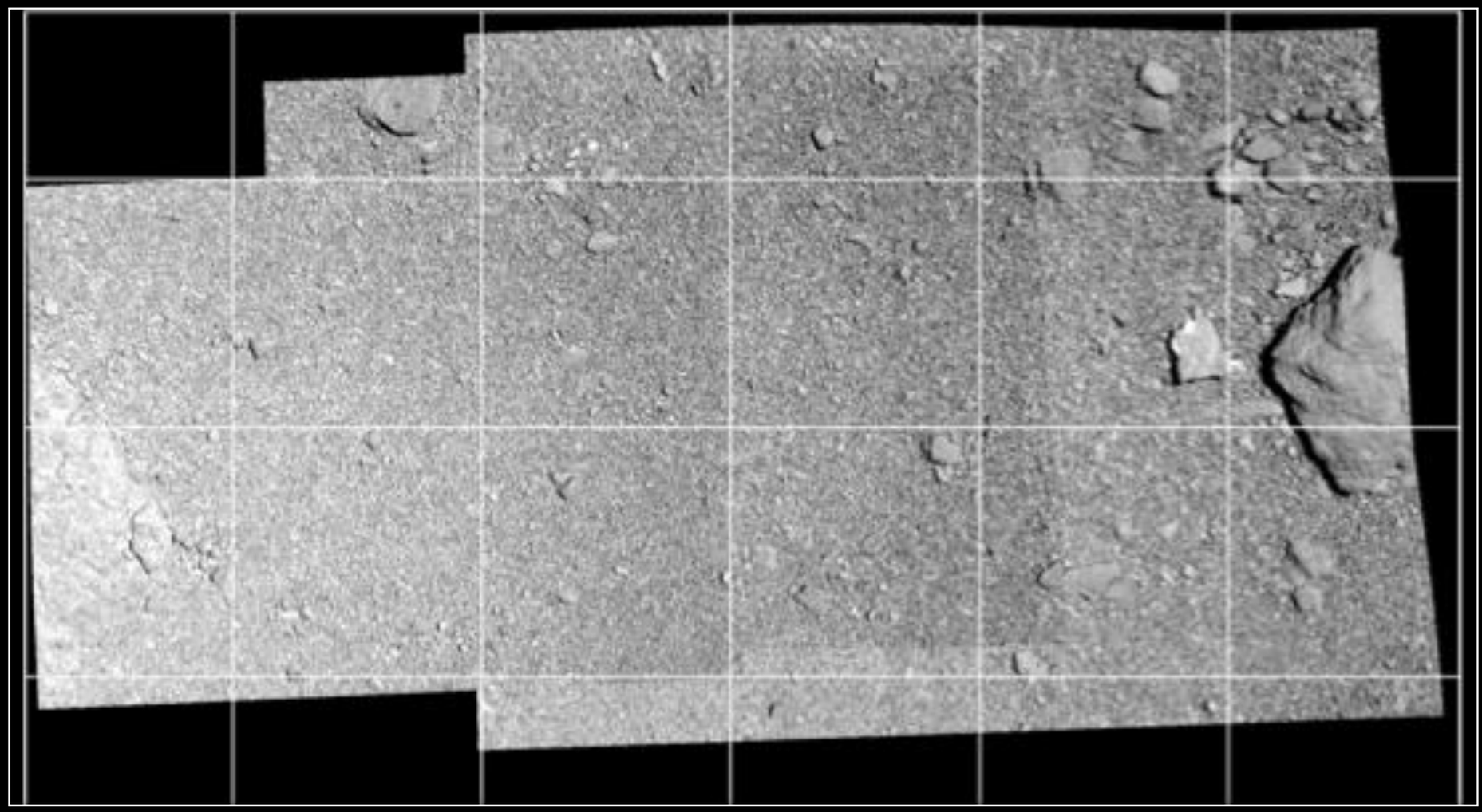
- This process to register images works as long as sumspice is able to find the correct SUMFILE for each image.

Reprojection



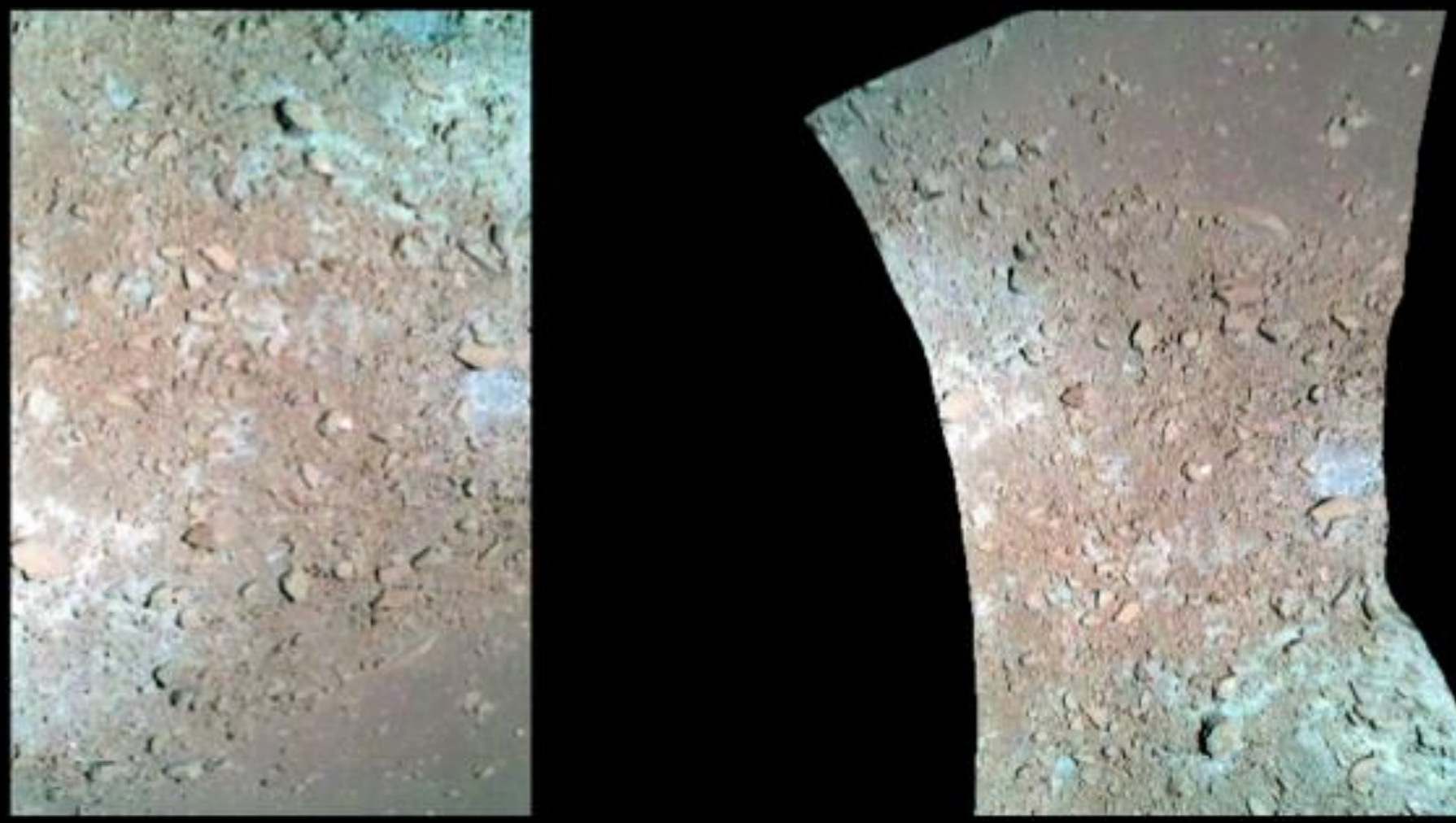
- The three files shown at the top are raw images from the PDS. At the bottom, each image was processed with the *amicacal* routine and projected. This routine has the option to trim the left edge that contains the polarized filters.

Reprojection



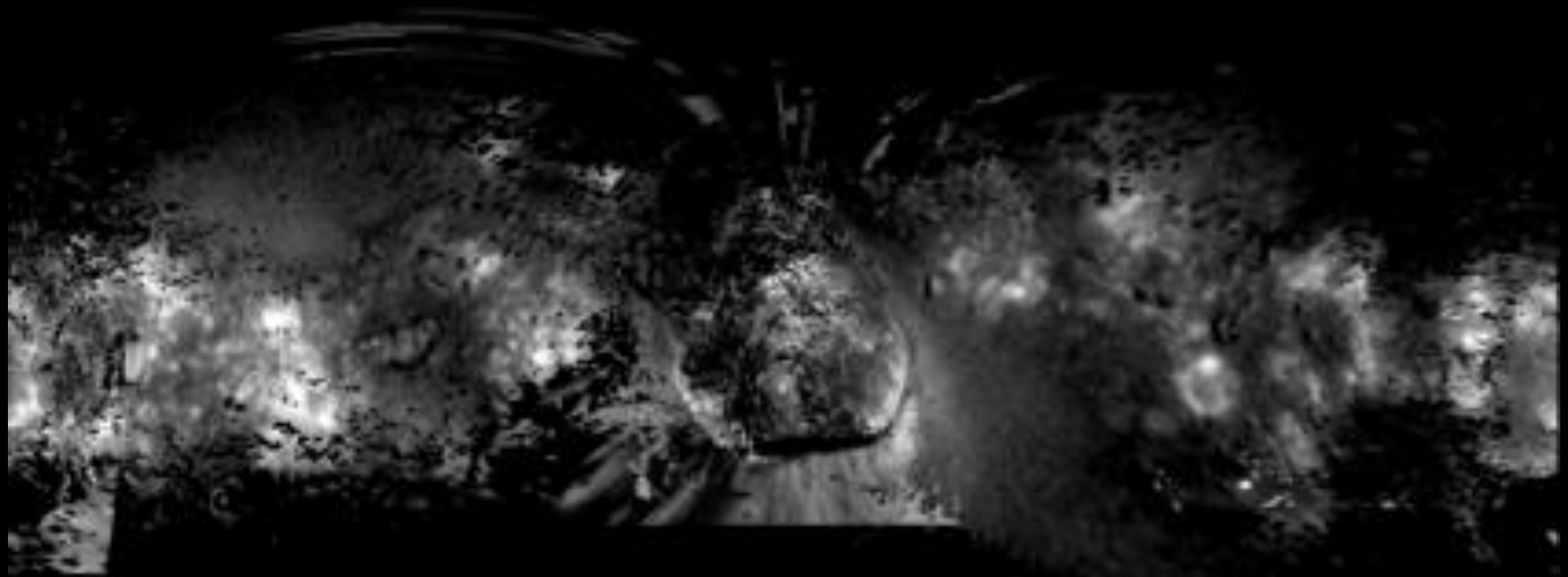
- Projection of images using *cam2map* (including orthorectification with the DEM or DSK)
- The mosaic of the three images in previous slide. The mosaic is an equirectangular projection at 5.3 cm/pixel, some of the highest resolution images in the Hayabusa dataset.

Reprojection

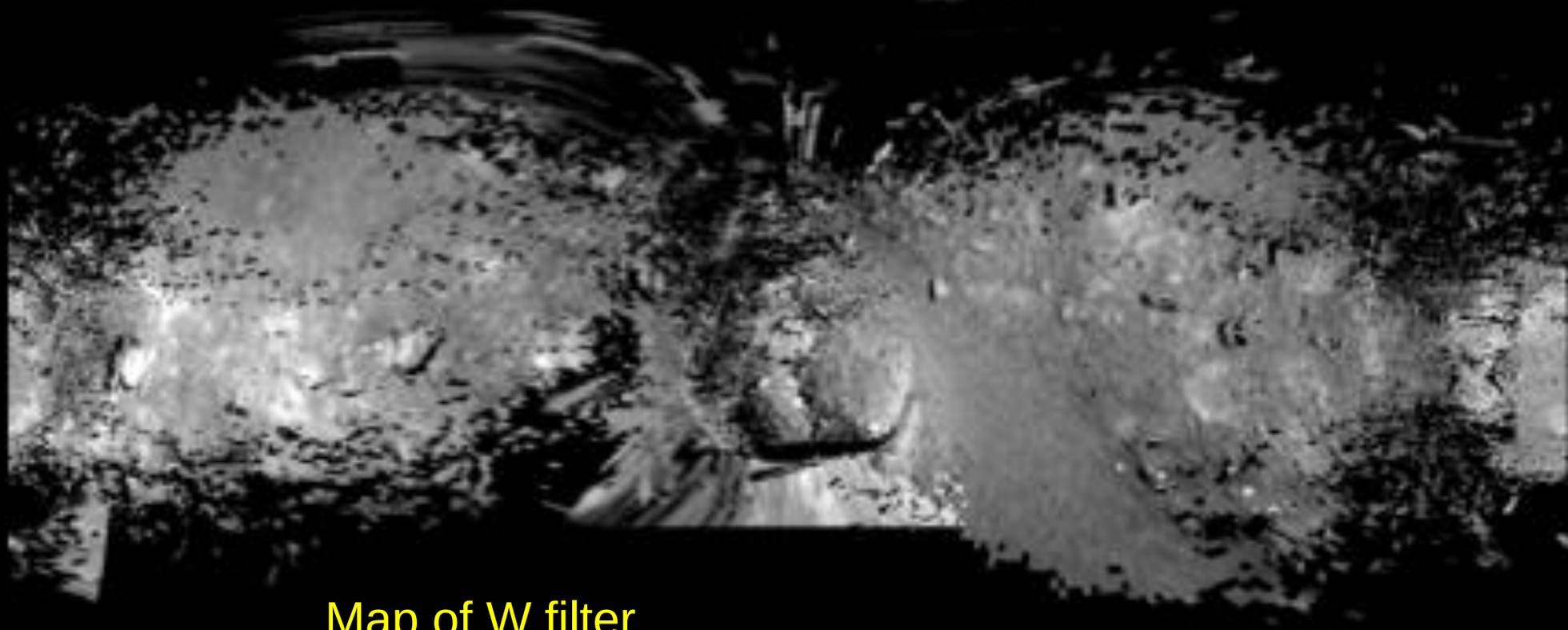


- Left image is unprojected and right image is projected data of the combined color composite of the P (960 nm), W (700 nm) and V (553 nm) AMICA filters in RGB channels. Right image is an orthorectified equirectangular projection at 181 cm/pixel. Both images are not radiometrically calibrated.

Global Mosaics



Map of UL filter



Map of W filter