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A PDS Archive for Observations of Mercury's Na Exosphere

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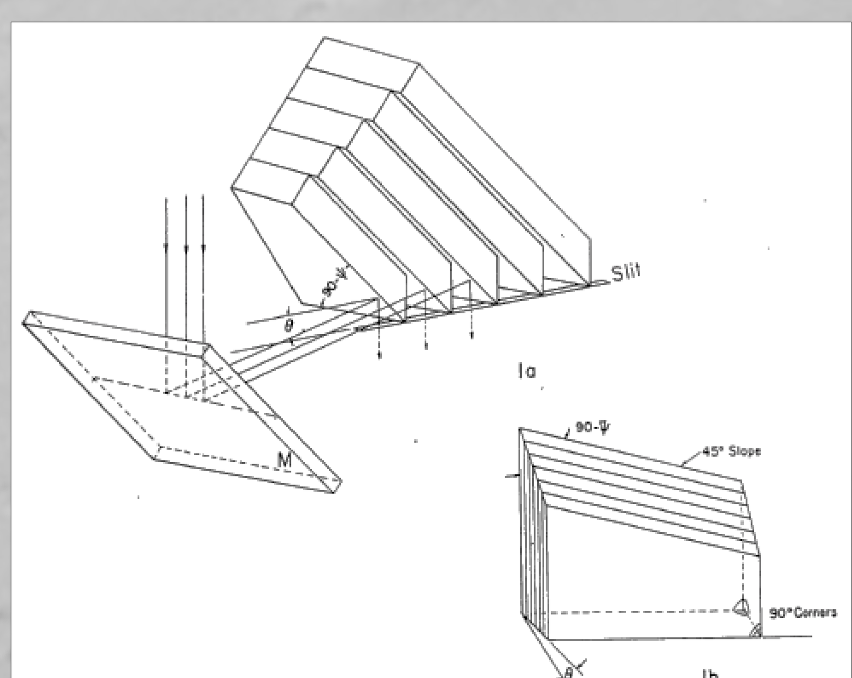
1 SCIENCE MOTIVATION

The Mercury NaD2 Data Archiving Project exists to conduct data reduction of spectral images produced from ground based images taken at the McMath-Pierce Solar Telescope and prepare the reduced images for archiving with the Planetary Database System. Twenty years of observations offer the space weather and planetary science communities the widest baseline of Mercurian Na exosphere ever taken. Reduced images and cataloged ephemeral data offer the potential for statistical analysis on the effects of extreme space weathering that are responsible for the changes in Mercury's tenuous exosphere marked by this strong sodium emission and a chance to investigate the dominant processes involved in its changes.

2 RAW DATA

DATA MAPPING w/ BOWEN IMAGE SLICER



Optical arrangement and plate stacking for Bowen Image Slicer. Credit: P.A. Keith, "Construction of a Bowen Image Slicer", Astronomical Society of the Pacific, Vol. 77, No.456, p.216, June 1965.

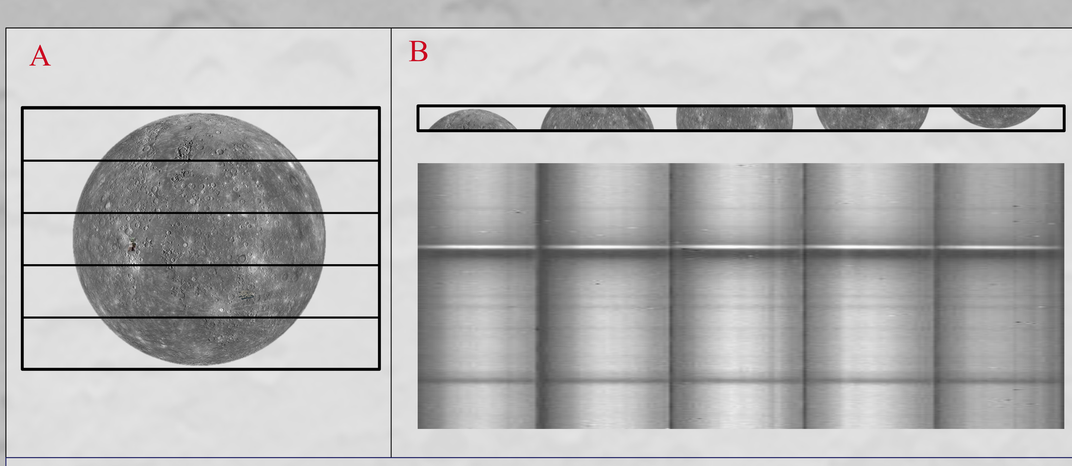


Fig 2: Image slicer is used to effectively slice (left) and rearrange (right) the planetary disk along the spectrograph slit. Light from each latitude region is dispersed into spectral slices, which can be divided into longitudinal "subslices", providing two-dimensional spatial information.

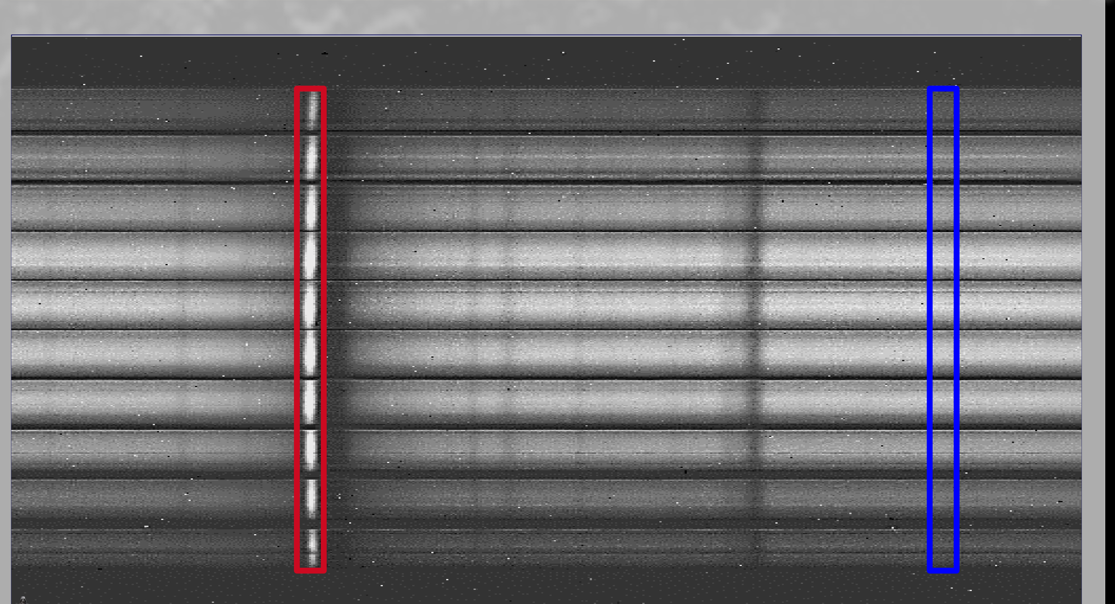


Fig 3: Reduced slicer image of Mercury centered on sodium doublet. The deep absorption features are the solar NaD2 Fraunhofers. The red area represents the spectral and spatial bounds used for field integration of the sodium emission image. The blue area represents the integration bounds for the continuum reflectance image.

3 CALIBRATIONS AND REDUCTIONS

Flat-Field

Sky spectrum is removed from raw data, used to make flat-field image, observation is divided by flat-field.

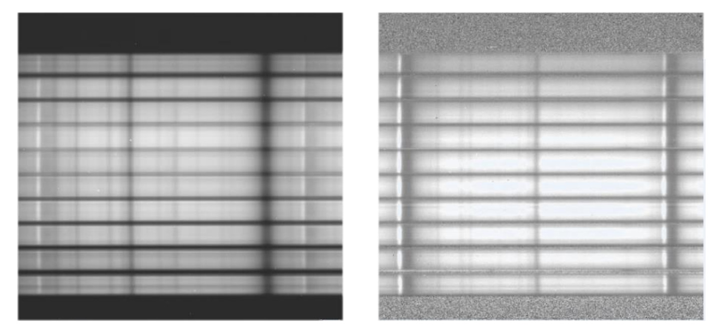
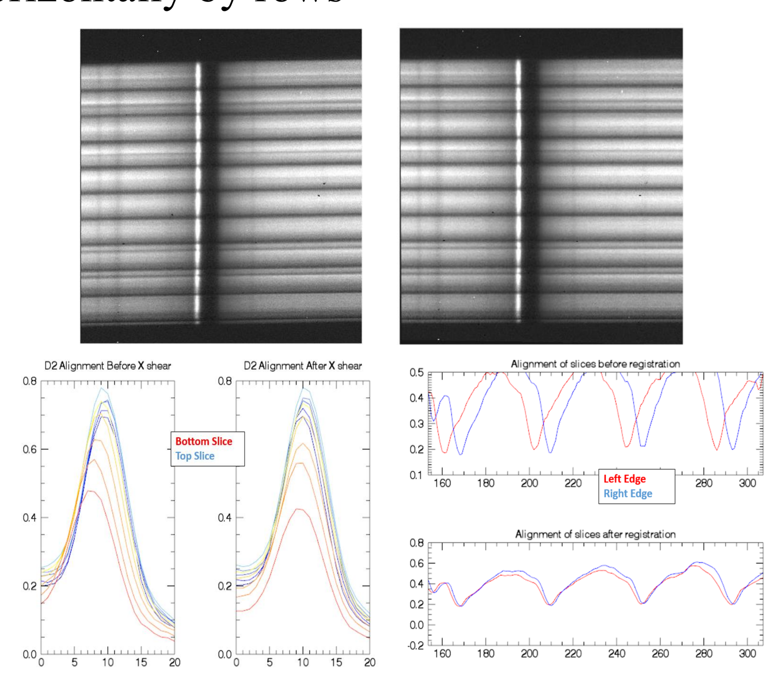


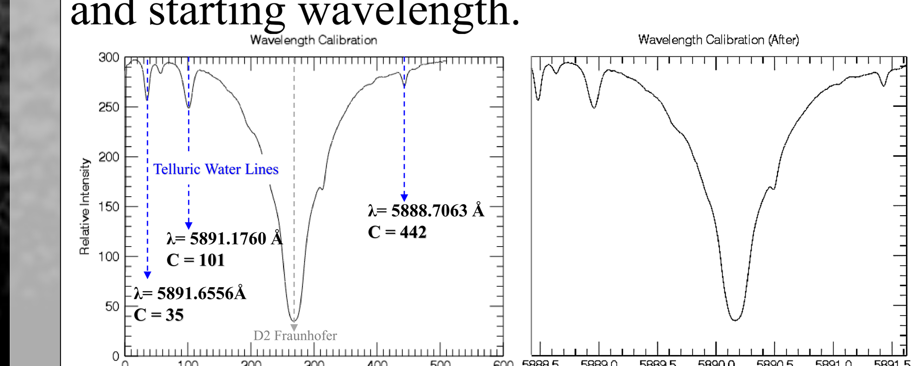
Image Registration

Image is sheared in x-direction to align spectra vertically in each slice by columns then sheared in y-direction to align slices horizontally by rows



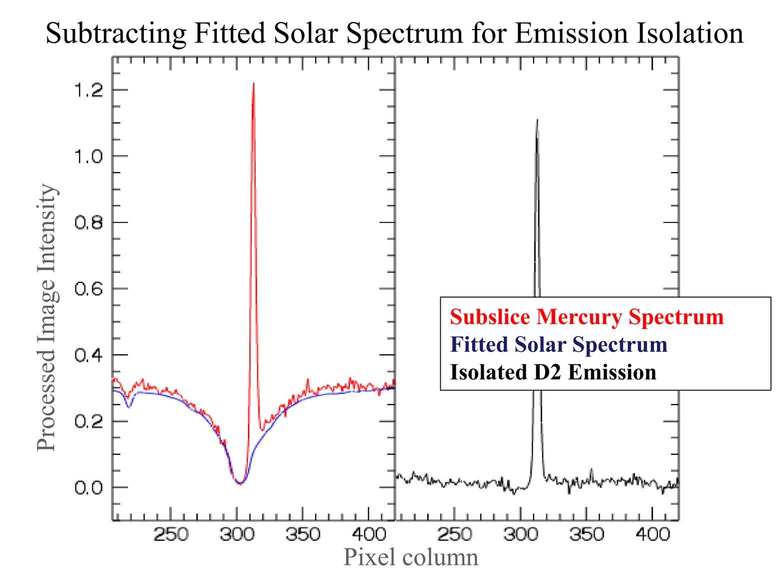
Wavelength Calibration

Telluric water lines are identified in background sky image by wavelength and column number. Fitting a line through these points gives wavelength resolution per pixel and starting wavelength.



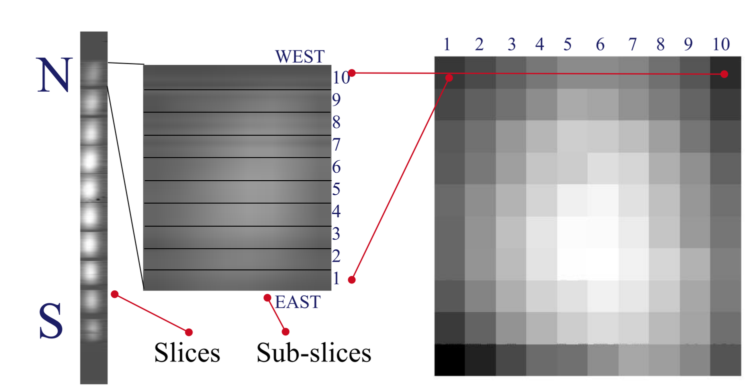
Emission Isolation

Reference hi-res solar spectrum is scaled and fit to each subslice outside emission area and subtracted from each subslice leaving only the NA D2 emission signal.



Spectral Data Mapping

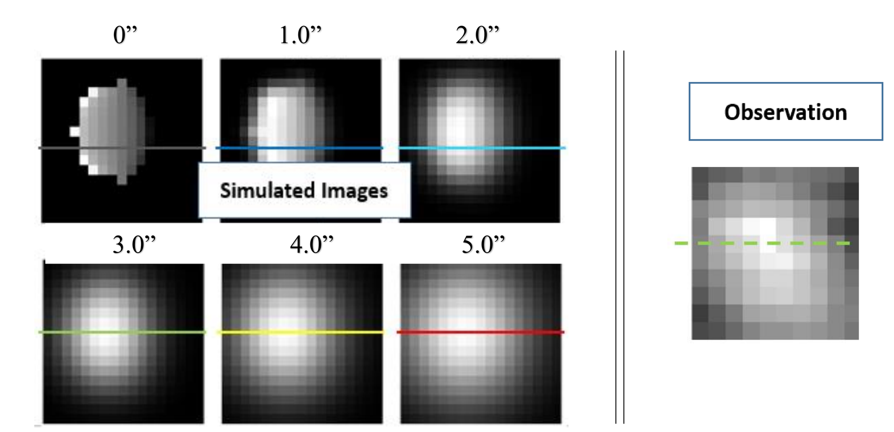
The primary advantage of the image slicer method is to enable more rapid spectral imaging of targets than traditional slit-spectroscopy. Each slice within the image which represents north-south data is subdivided into ten subslices which represent east-west data. Each subslice in the reduced image is summed to one value, then mapped to a final 10x10 pixel image (see Section 2). In these images, each slice is 0.5 arcseconds and each subslice is therefore 0.05 arcseconds. When the 10 arcsecond image slicer is used, the full Mercurian disk is covered in one image.

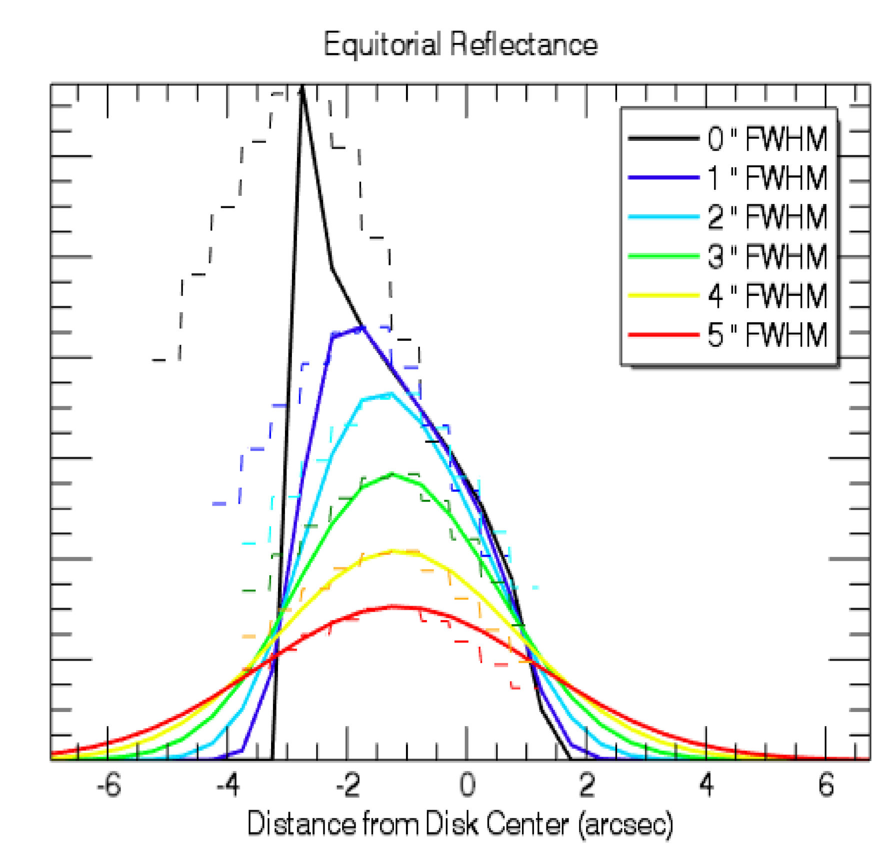


Estimating Seeing Conditions

Observation is matched to Hapke model of disk under progressively wider Gaussian blurring until the model fits the data, determining average seeing conditions over original image integration time. Kilorayleighs-per-pixel conversion is calculated which scales the pixels to light-emitted values, which is then later applied to the composite image. In this equation[1], n is a normalization constant, F is the continuum solar reflectance at Mercury, $\Delta\lambda$ is the wavelength resolution per pixel of the slicer image.

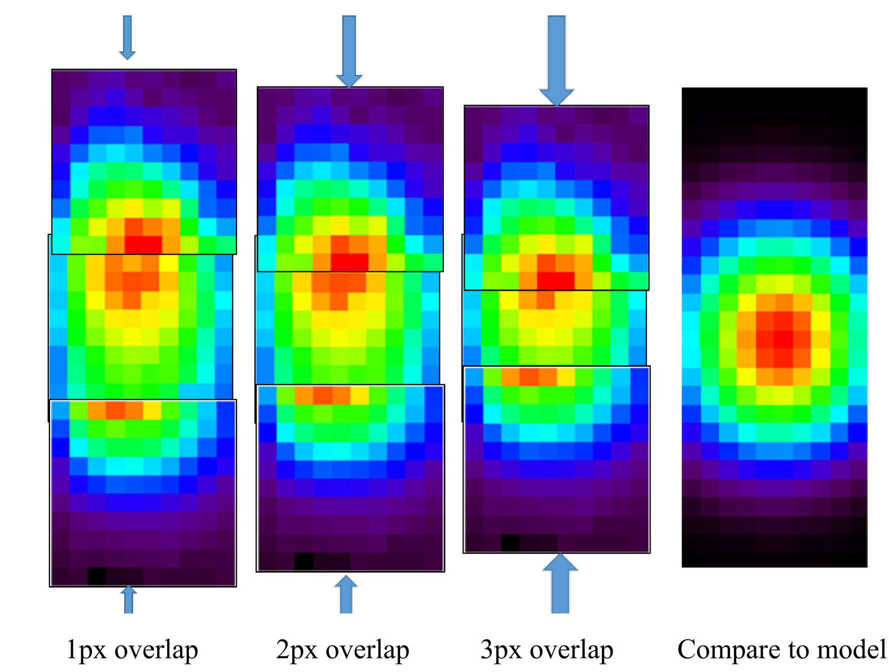
$$\frac{kR}{pixel} = n \times F \times \Delta\lambda \times 4\pi \times 10^9$$





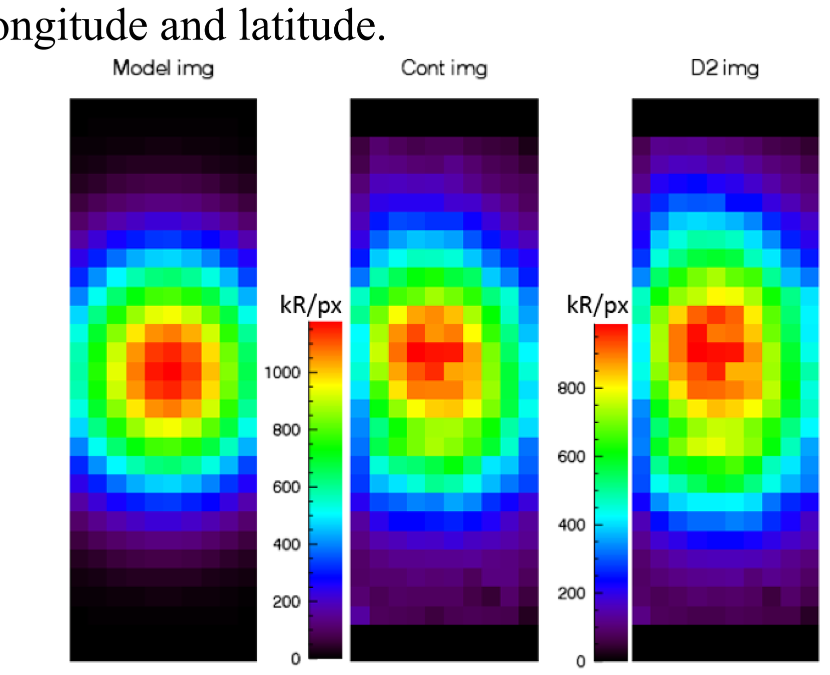
Automated Stitching of Observations

North and Center observations are overlapped until matching the northern hemisphere of model by best χ^2 fit, giving North-Center pixel overlap. North-Center image similarly overlapped with South and fitted against entire model to determine the best South-Center pixel overlap.



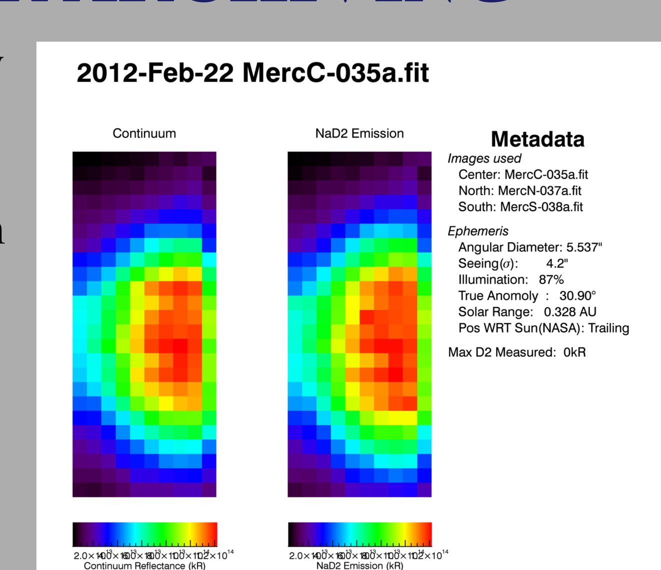
Composite Observation

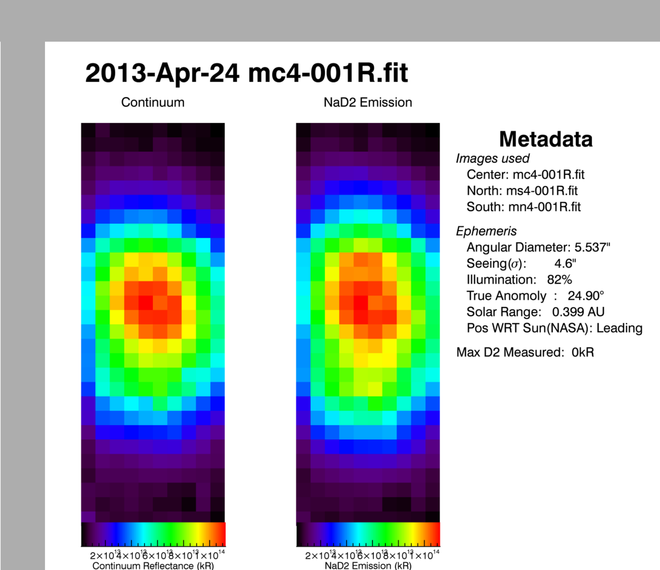
The full observed planetary crescent in D2 Emission and Reflected Continuum with values in kilorayleighs is aligned with the estimated model at the equator. The rainbow color bar is used to more easily identify the emission gradient by longitude and latitude.

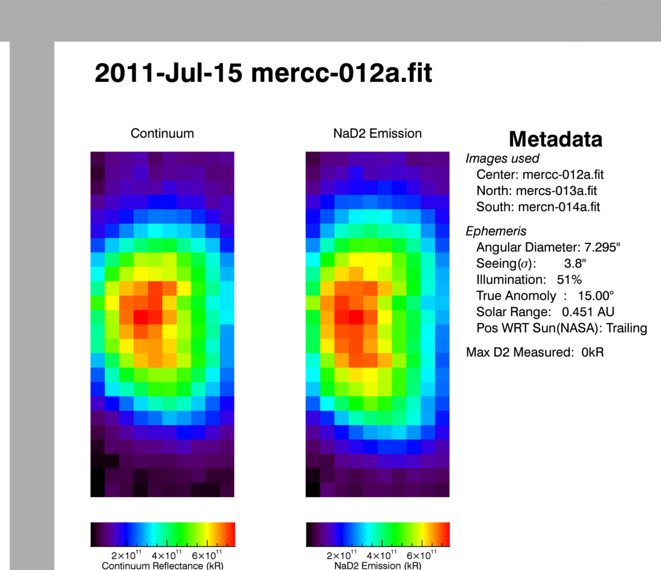


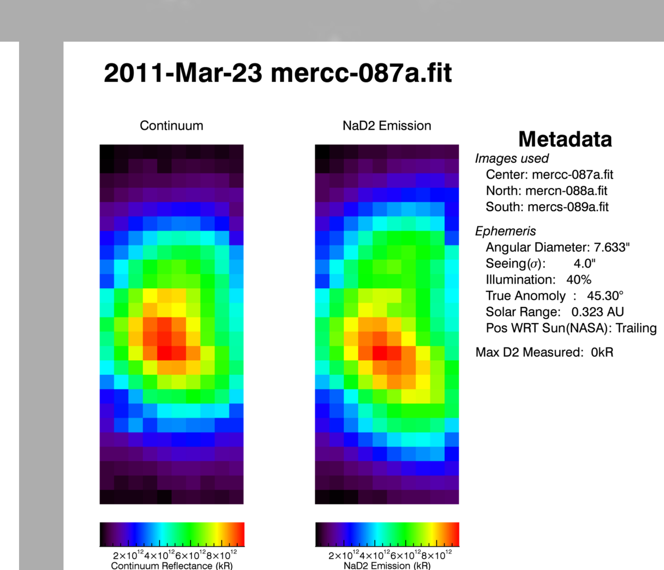
4 FINAL DATA PRODUCT FOR ARCHIVING

With the data processing pipeline for these images nearly complete, we will soon be processing all high-quality raw data. Finally we will package the data in a user-friendly format for the PDS. This product will provide an unparalleled resource for the Mercury science community – a nearly three decade long record of sodium exospheric activity. It will provide new opportunities to expand the community's understanding of exospheric dynamics, mid to high latitude exospheric emissions, and potentially space weathering.









1) Domingue, Deborah L., Ann L. Sprague, and Donald M. Hunten. "Dependence of Mercurian atmospheric column abundance estimations on surface-reflectance modeling." *Icarus* 128.1 (1997): 75-82.

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