CRISM 2012 Data Users' Workshop

MTRDR Data Analysis Walk-Through

K. Seelos, D. Buczkowski, F. Seelos,
S. Murchie, and the CRISM SOC
JHU/APL

Goals

- Familiarize CRISM data users with the new MTRDR data set and products.
- Learn how to...
  - open and browse files
  - create and analyze spectra
  - create custom visualization products
- All material provided online as a take-home exercise.

Outline

1. Basics
    1. CRISM Analysis Toolkit (CAT) installation
    2. Opening and displaying an MTRDR spectral cube
    3. Displaying spectra
    4. Opening and displaying an MTRDR summary parameter cube
    5. Linking and browsing
2. Spectral Analysis
    1. Selecting a region of interest (ROI)
    2. Calculating statistics
    3. Enhancing features
    4. Interpretation
3. Visualization
    1. Custom RGB products
    2. 3-Dimensional views
    3. Mosaicking

Walk-Through Section 1

BASICS

CRISM Analysis Toolkit (CAT)

- The CRISM Analysis Toolkit (CAT) is a series of custom IDL procedures packaged as a plug-in to ENVI, a proprietary remote sensing software available through ITT Exelis.

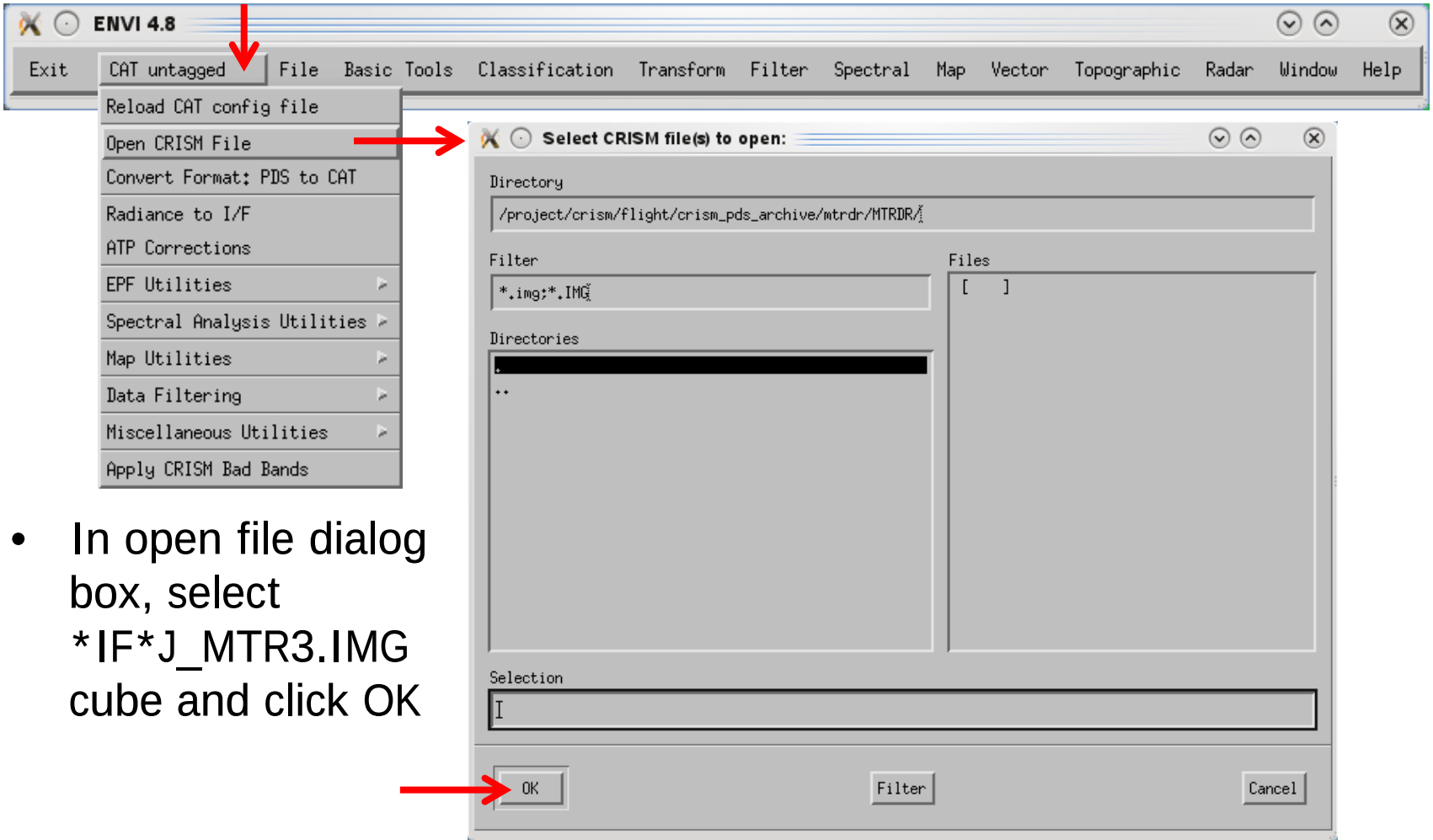
- To download and install the CAT, go to

http://pds-geosciences.wustl.edu/missions/mro/crism.htm

- You will need CAT Version 7.0 or better to utilize the MTRDRs and related data products.

Opening an MTRDR cube

- Start IDL/ENVI, with CRISM Analysis Toolkit (CAT) installed
- On the main menu bar, go to >CAT >Open CRISM File



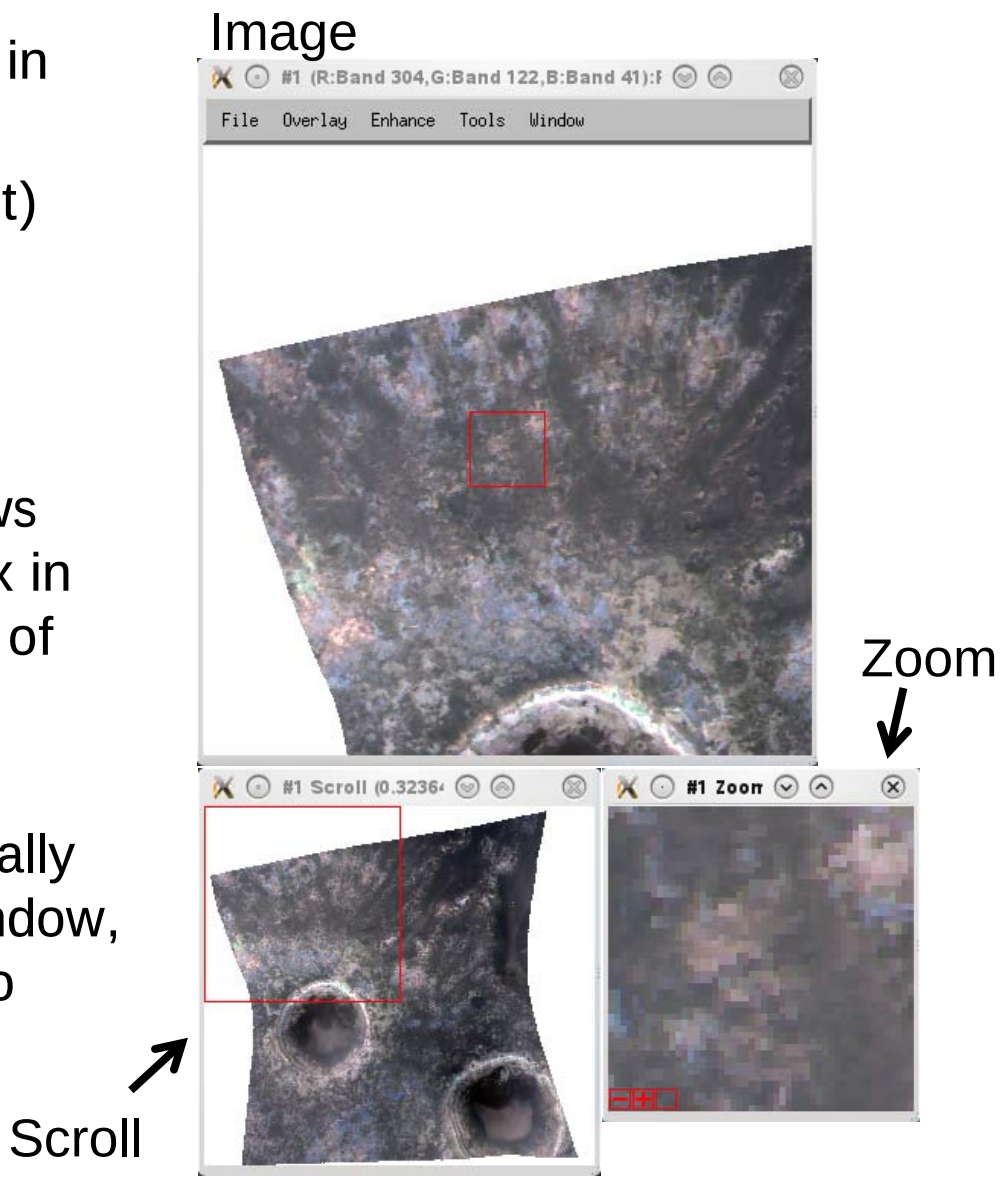
- In open file dialog box, select *IF*J_MTR3.IMG cube and click OK

Initial Display of MTRDR cube

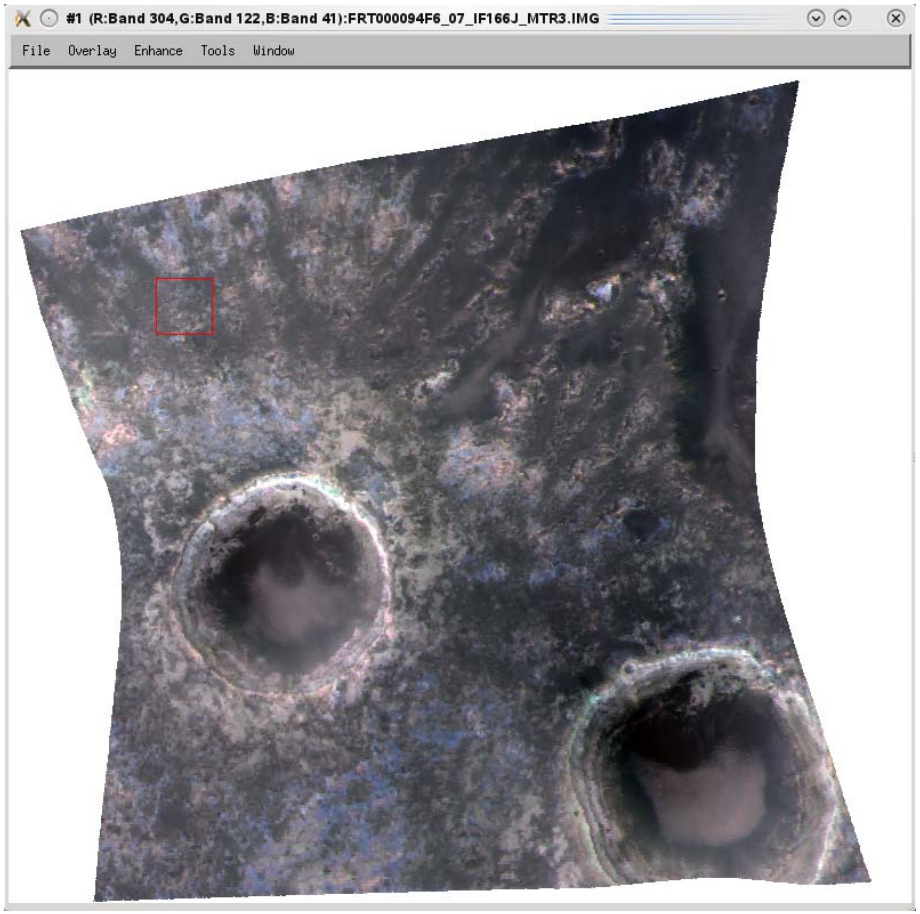
- Any image cube is initially opened in ENVI in a cluster of 3 windows.
  - Scroll (shows full spatial extent)
  - Image (full spatial resolution)
  - Zoom (4x resolution subset)

- Red box in the Scroll window shows location of Image window; red box in the Image window shows location of Zoom window.

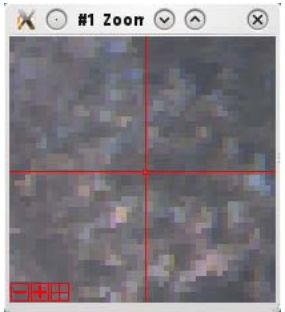
- HINT: For CRISM images, it is usually helpful to maximize the Image window, after which the Scroll window is no longer needed (see next slide).



Default RGB Stretch for MTRDR



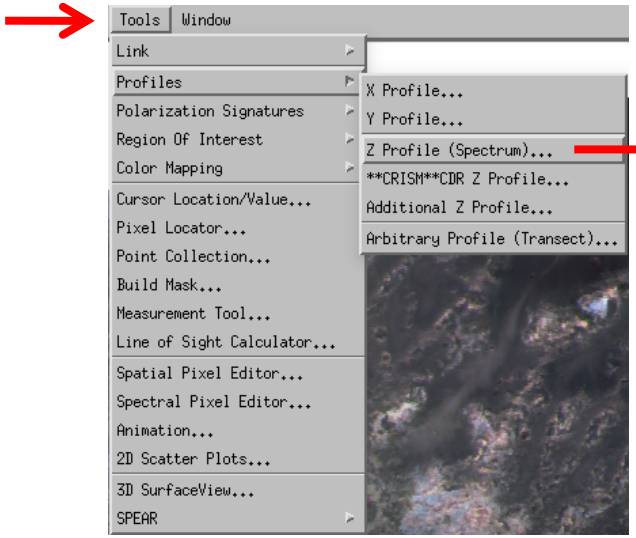
Change Zoom window size or magnification level, or turn crosshairs on here

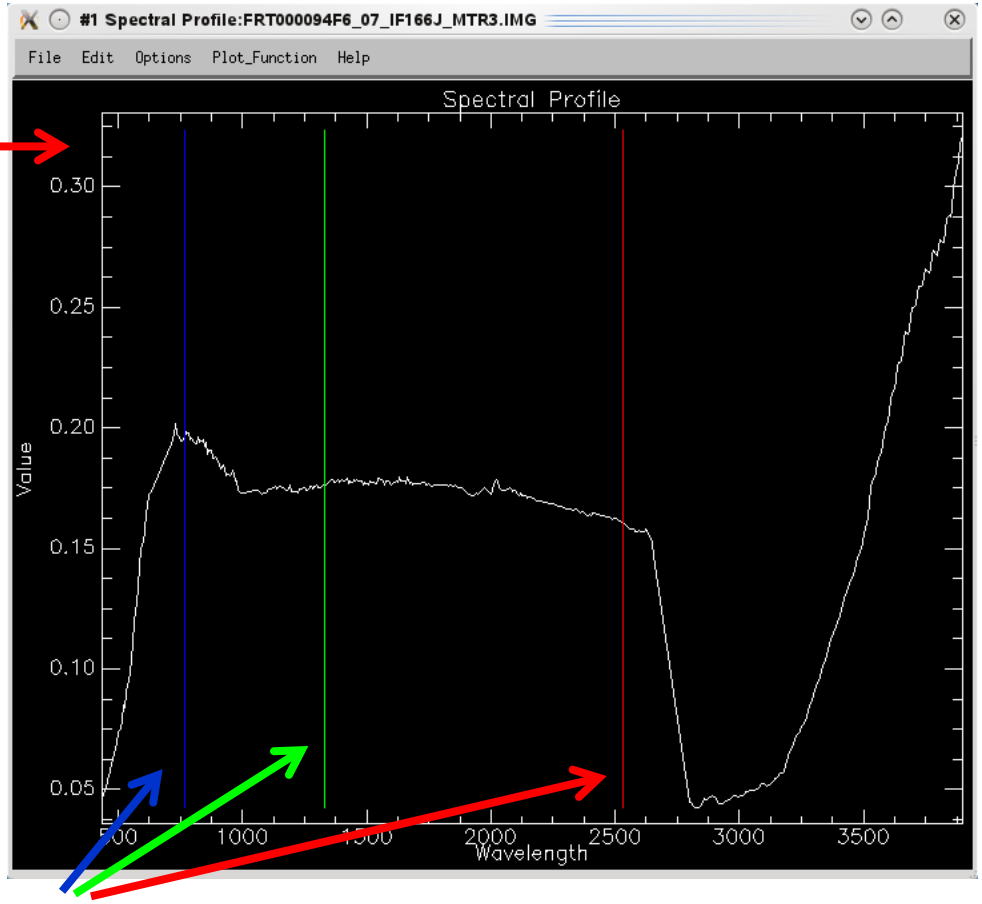


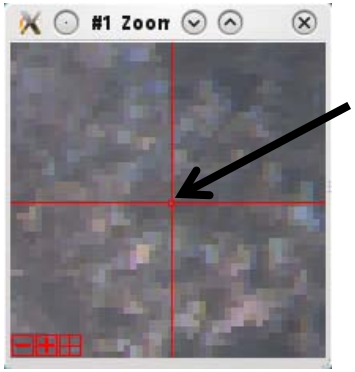
- The default bands for an MTRDR are
  - R: Band 304 (2529.51 nm)
  - G: Band 122 (1329.21 nm)
  - B: Band 41 (768.40 nm)
- Equivalent to TAN browse product
- All bands are listed in the Available Bands List and you can load any combination.
- By default, ENVI applies a 2% Linear stretch to each band independently; a 1% Linear stretch is shown at left.

Displaying a MTRDR Spectrum

- From the Image window menu, >Tools >Profiles >Z Profile (Spectrum)



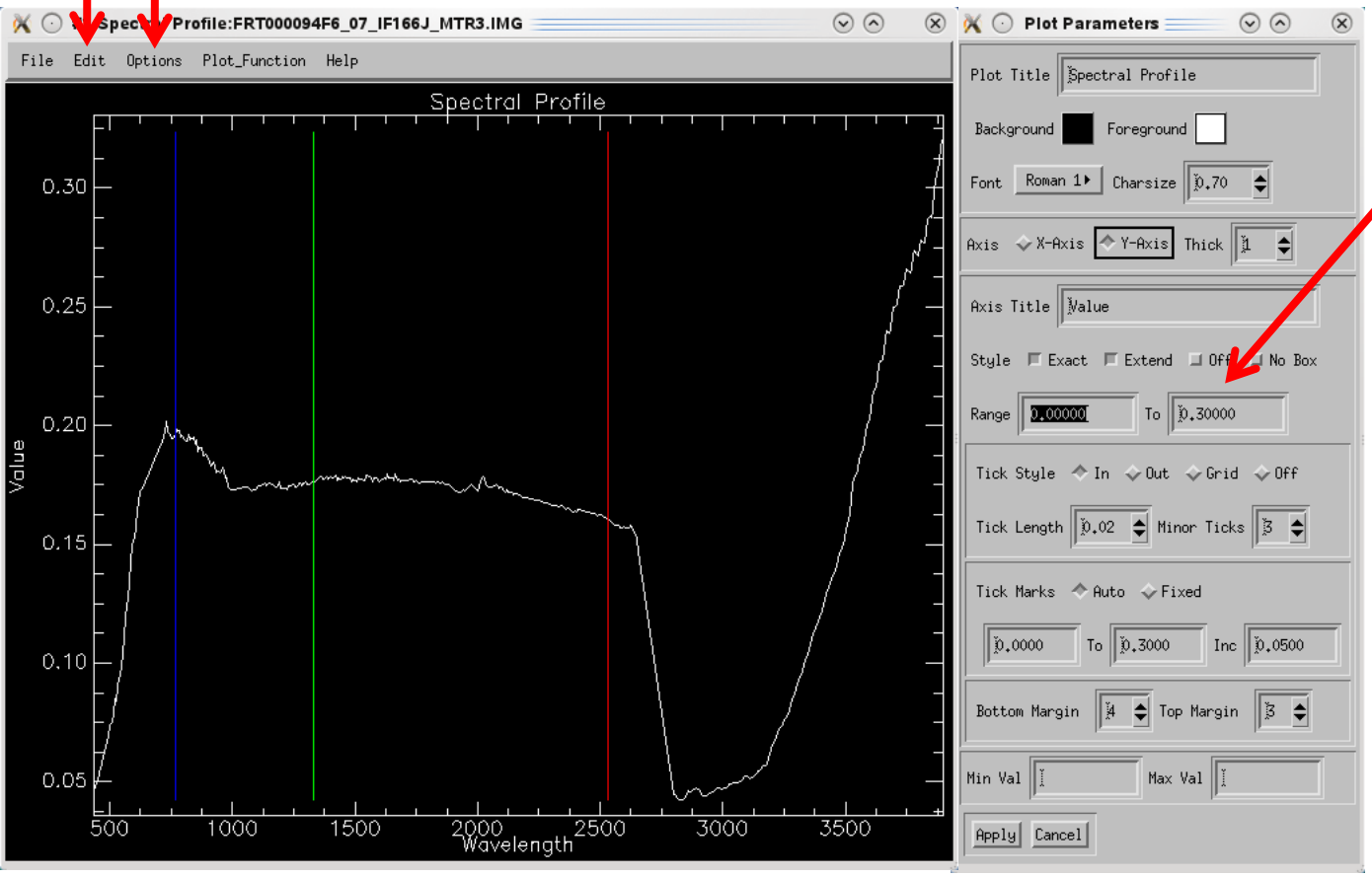




Z-profile extracted at Zoom window location.

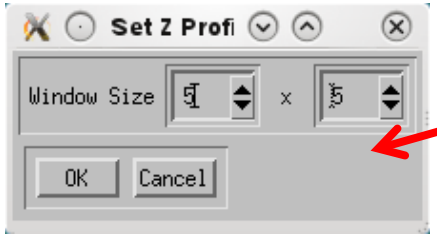
Colored vertical lines on spectral plot indicate RGB wavelength positions – can adjust, reload new combination in Image window.

Adjusting the Spectral Plot



- Go to >Edit >Plot Parameters to set the x- and y-axis ranges, change plot labels, colors, etc.

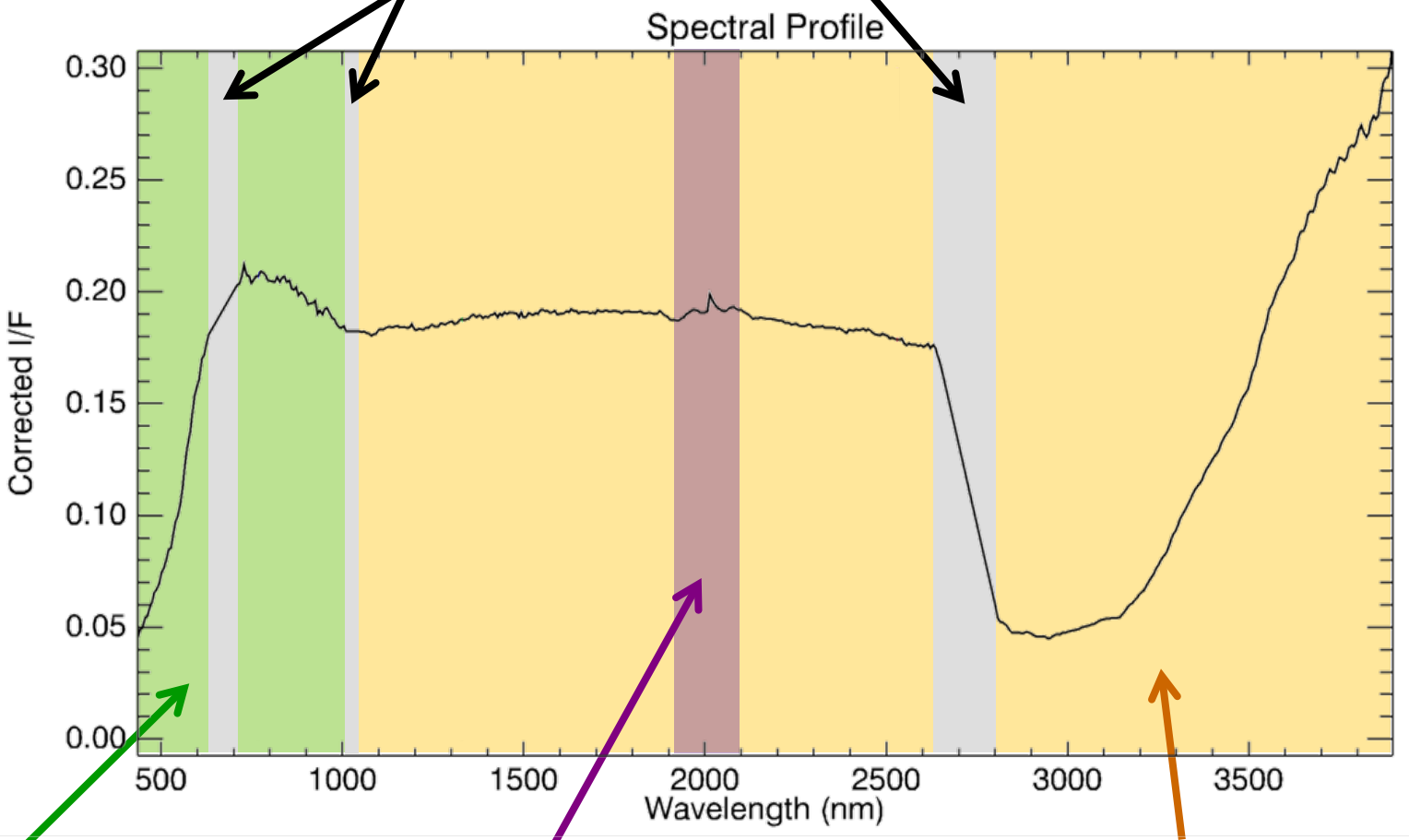
- HINT: Leaving this dialog box open will keep the axis range from changing as you browse the scene.



- Go to >Options >Set Z Profile Avg Window to change the number of pixels averaged together for the displayed spectrum.

Anatomy of a MTRDR Spectrum

Location of bad bands at detector and filter boundaries



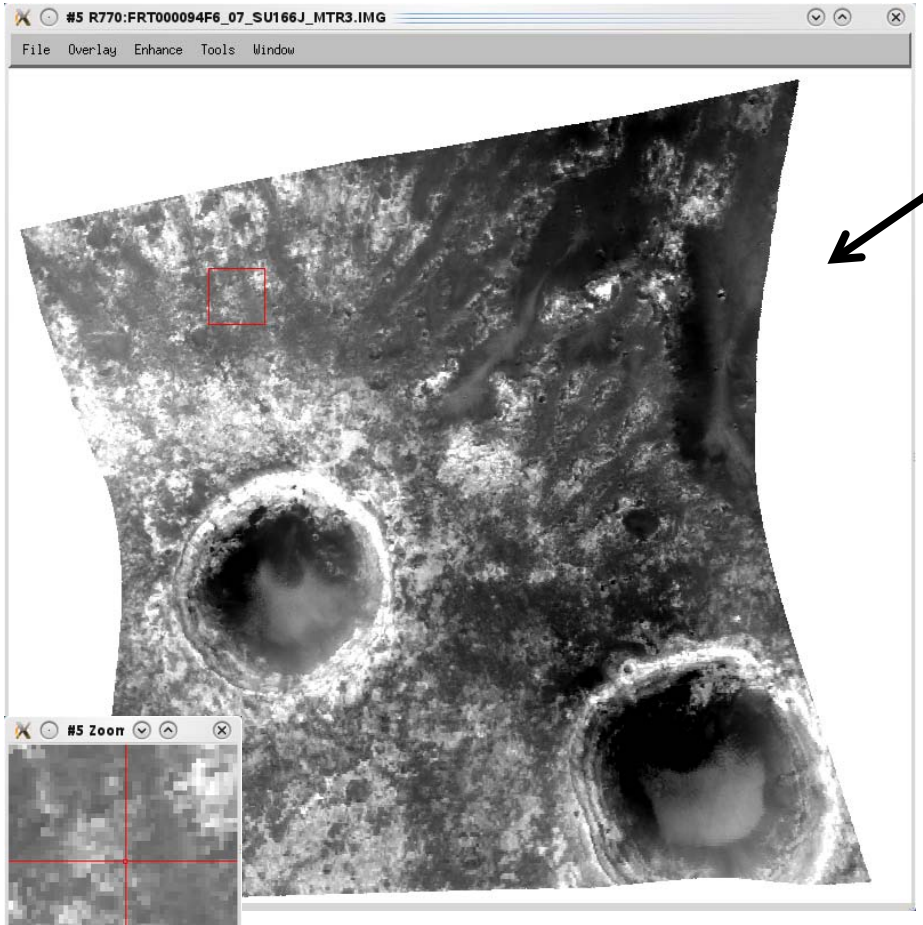
VNIR detector wavelengths (0.4-1µm)

2-micron atmospheric correction residual

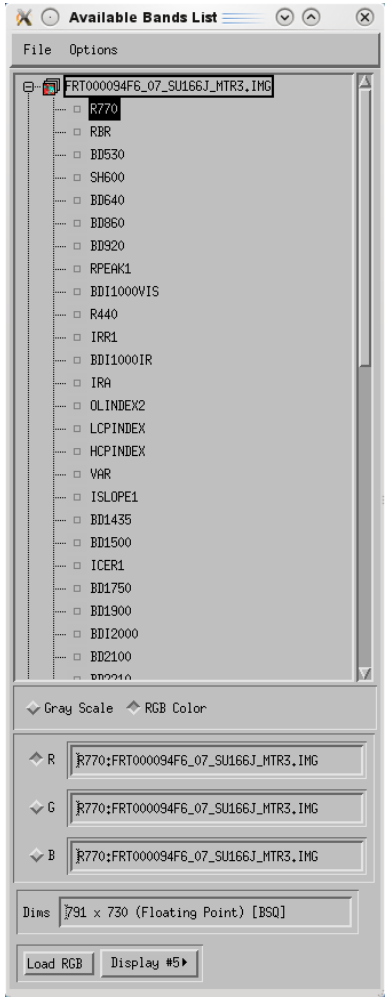
IR detector wavelengths (1-4 µm)

Opening an MTRDR Summary Parameter cube

- Same procedure as before... On the main menu bar, go to >CAT >Open CRISM File
- Choose *SU*J_MTR3.IMG file and click OK

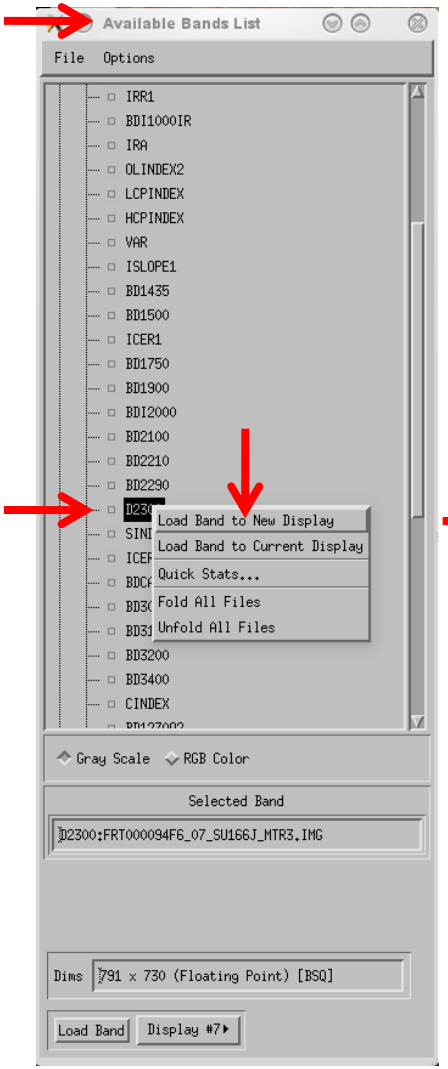


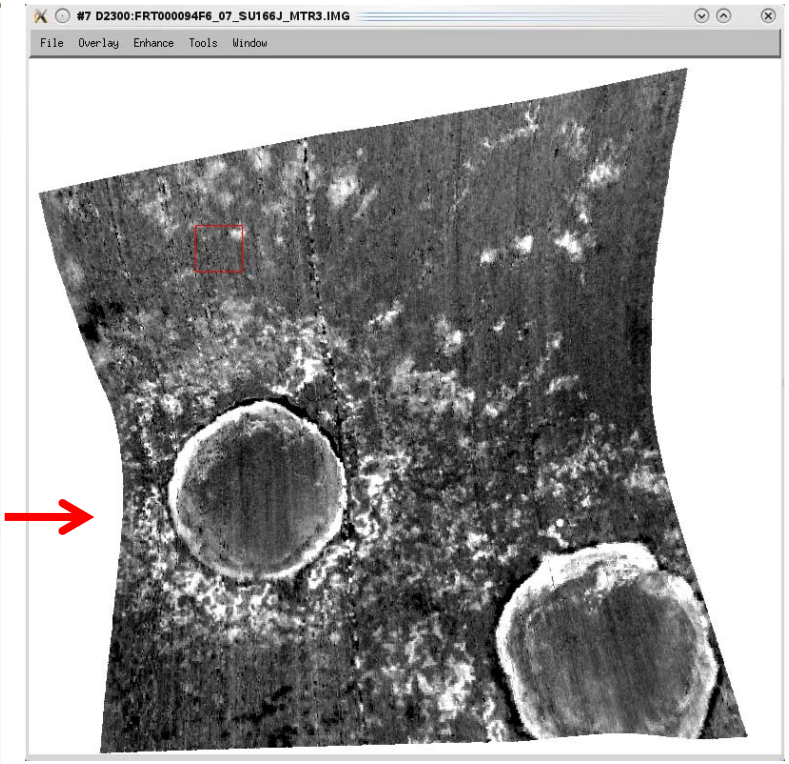
- R770 loaded by default
- All SU bands (parameters) displayed in Available Bands List

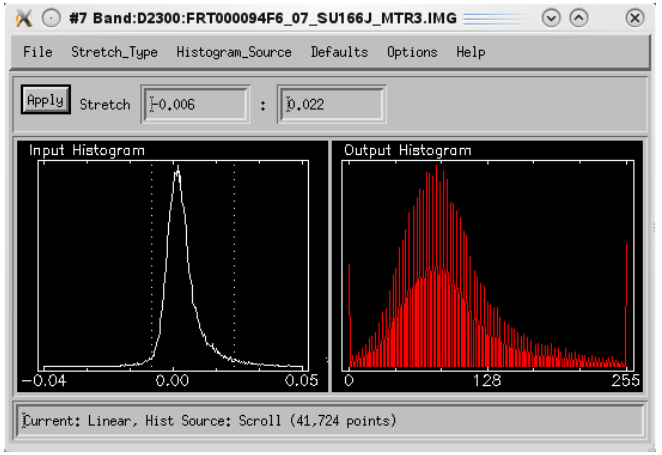


SU MTRDR: Single Band Display

- Load the D2300 parameter: from Available Bands List, right click on D2300 and select Load Band to New Display



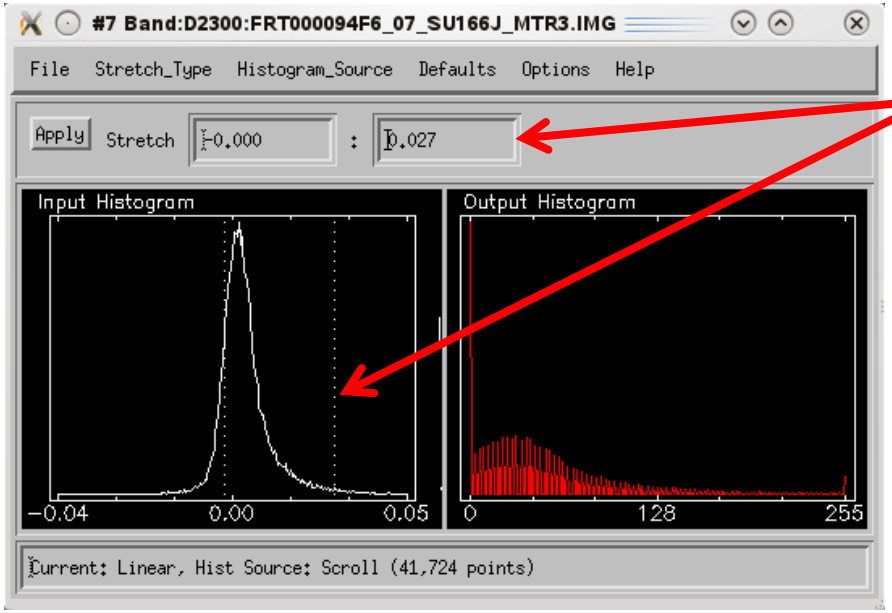




- Default Linear 2% stretch includes unrealistic parameter values less than zero

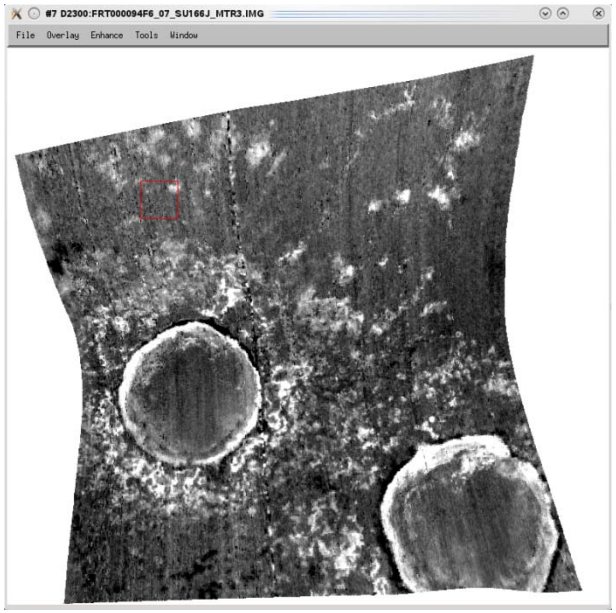
SU MTRDR: Apply Appropriate Stretch

- For most band depth and similar measures of absorption,
  - Zero is the minimum realistic value
  - The 99th percentile is typically a good maximum, although there is a empirically-determined “minimum maximum” that varies by parameter (e.g., 0.02 for D2300)
- From Image window, go to >Enhance >Interactive Stretching

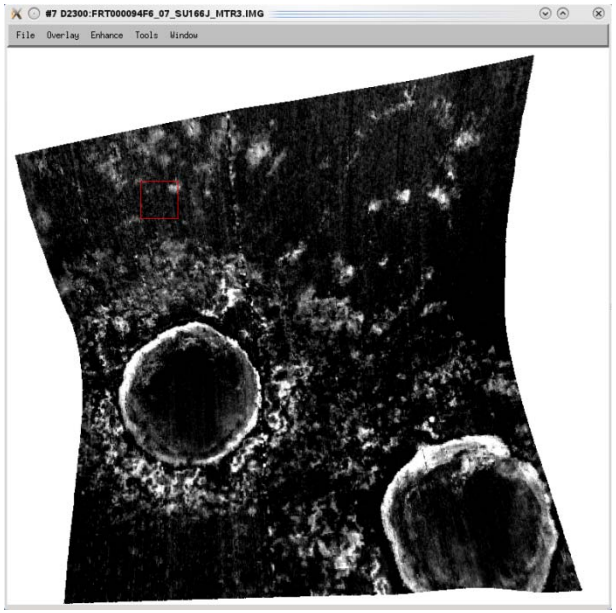


- Type min and max values or slide dashed bars until at correct percentile values (will display along bottom)
- If needed, modify the histogram binning and range under >Options >Histogram Parameters

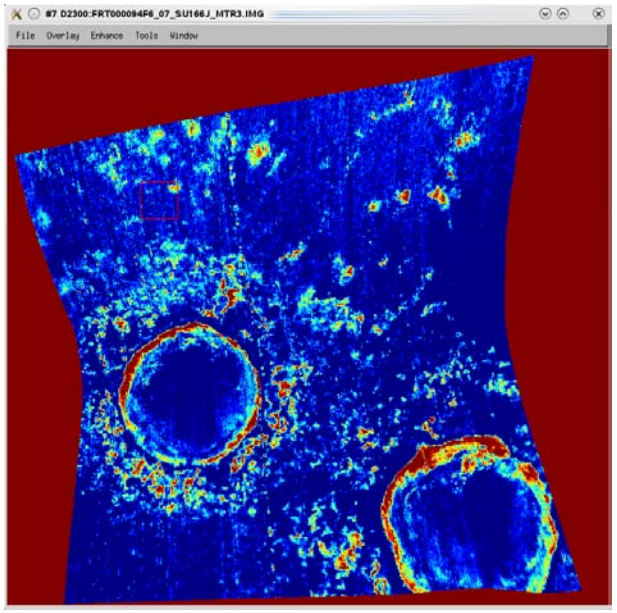
SU MTRDR: D2300 Display Comparison



Default Stretch
(-0.006 to 0.022)



Optimized Stretch,
Grayscale
(0.0 to 0.027)



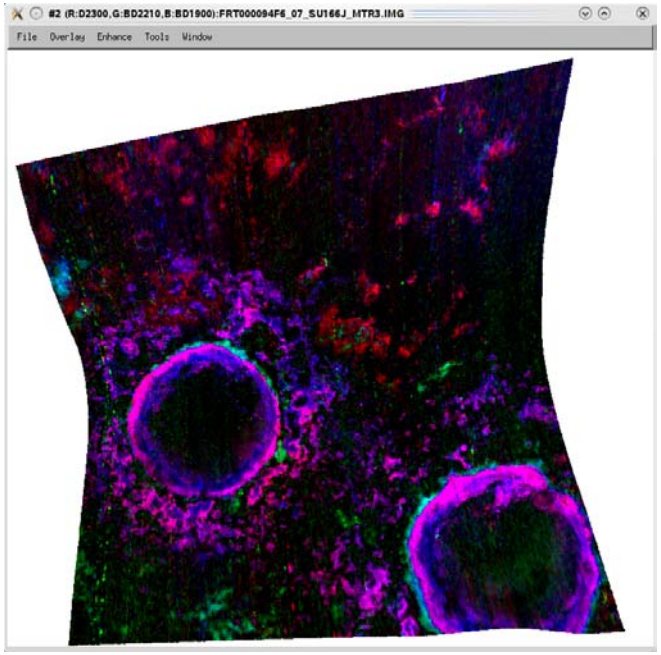
Optimized Stretch,
Blue-Red Color Ramp
(0.0 to 0.027)

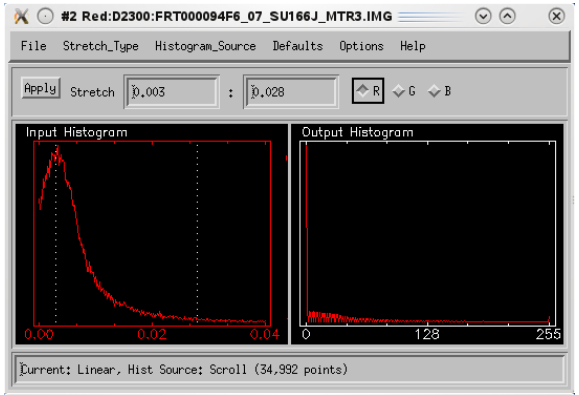
- To apply color ramp, go to >Tools >Color Mapping > ENVI Color Tables

SU MTRDR: RGB Display and Stretch

- Load PHY from Available Bands List: >Select RGB Color >click on D2300, BD2210, and BD1900 to fill in RGB fields >New Display from drop-down >Load RGB
- Optimize stretch of each band from Image window: >Enhance >Interactive Stretching

PHY Browse Product Result:

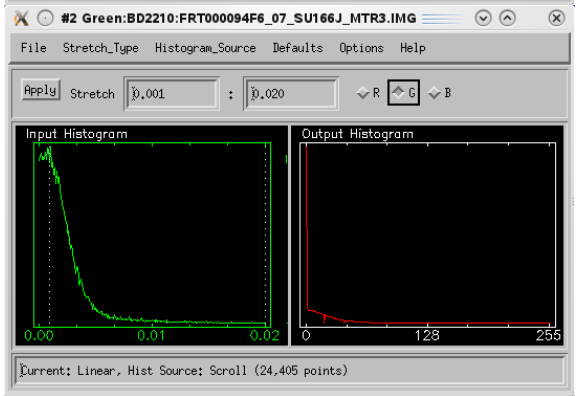




D2300

Min: 0.003 (distribution peak)

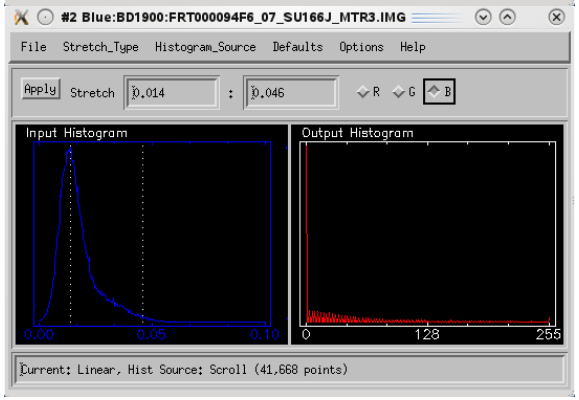
Max: 0.028 (99th percentile)



BD2210

Min: 0.001 (distribution peak)

Max: 0.020 (“minimum maximum”)

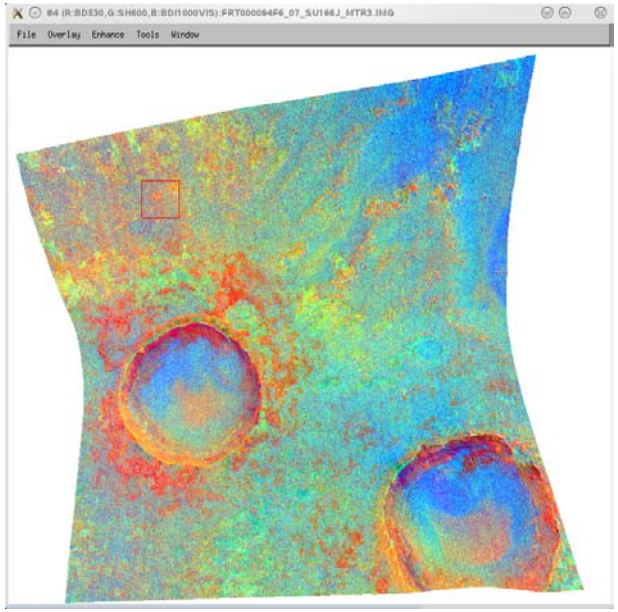


BD1900

Min: 0.014 (distribution peak)

Max: 0.046 (99th percentile)

Other Browse Products for 94F6

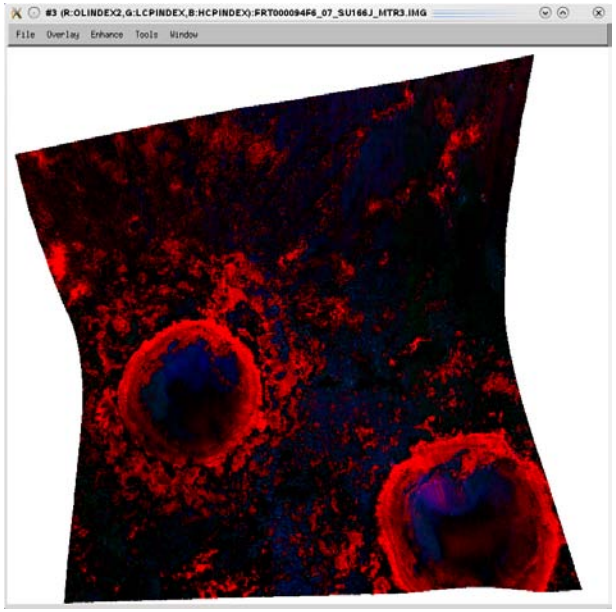


FEM

R: BD530

G: SH600

B: BD11000VIS

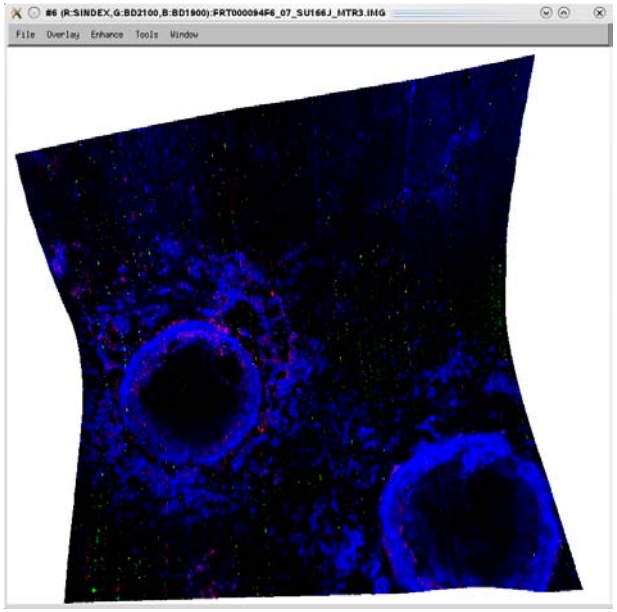


MAF

R: OLINDEX2

G: LCPINDEX

B: HCPINDEX



HYD

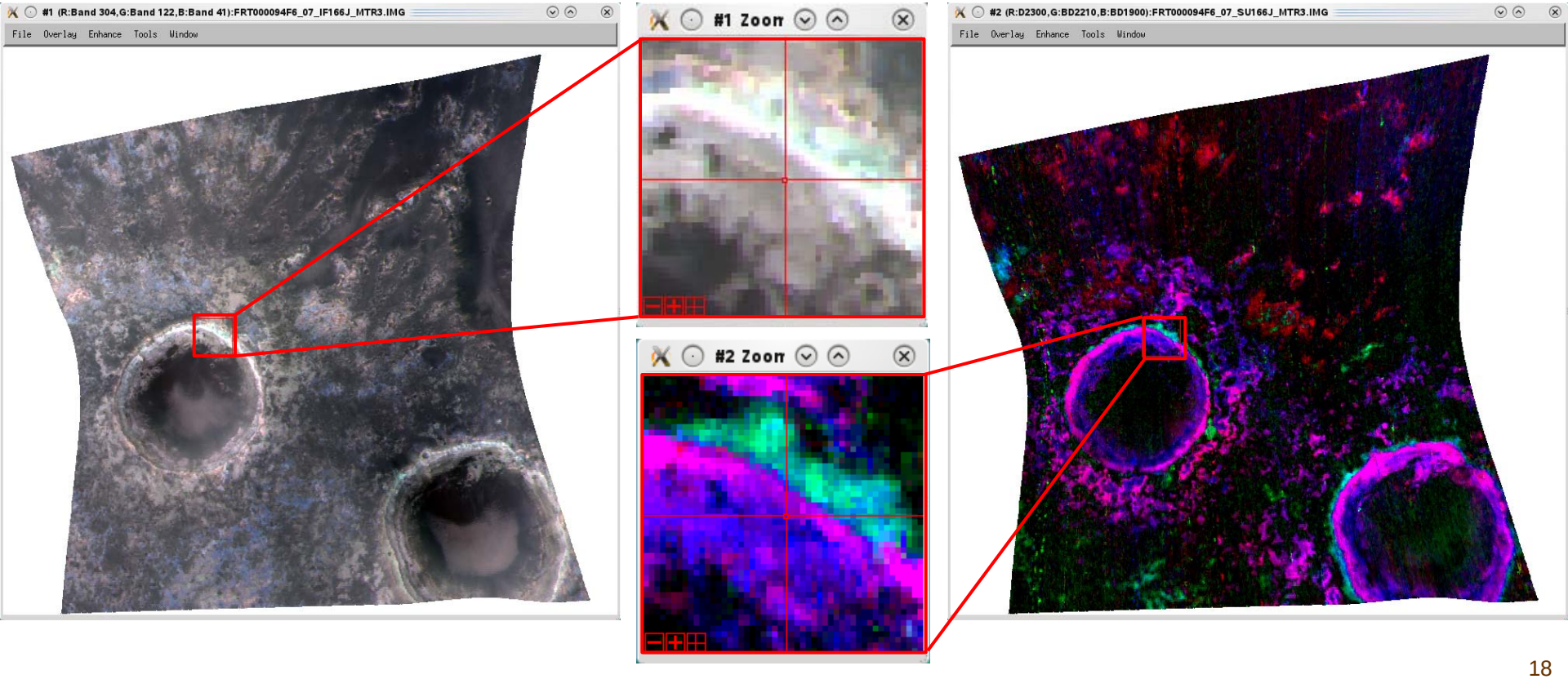
R: SINDEX

G: BD2100

B: BD1900

CRISM Linking Spectral and Summary Parameter Cubes

- From <u>either</u> Image window, >Tools >Link then one of
  - >Link Displays for pixel-location based link (requires exactly same size images; allows blinking and transparency), -OR-
  - >Geographic Link for map projected link (can be different spatial coverage or resolutions)



Walk-Through Section 2

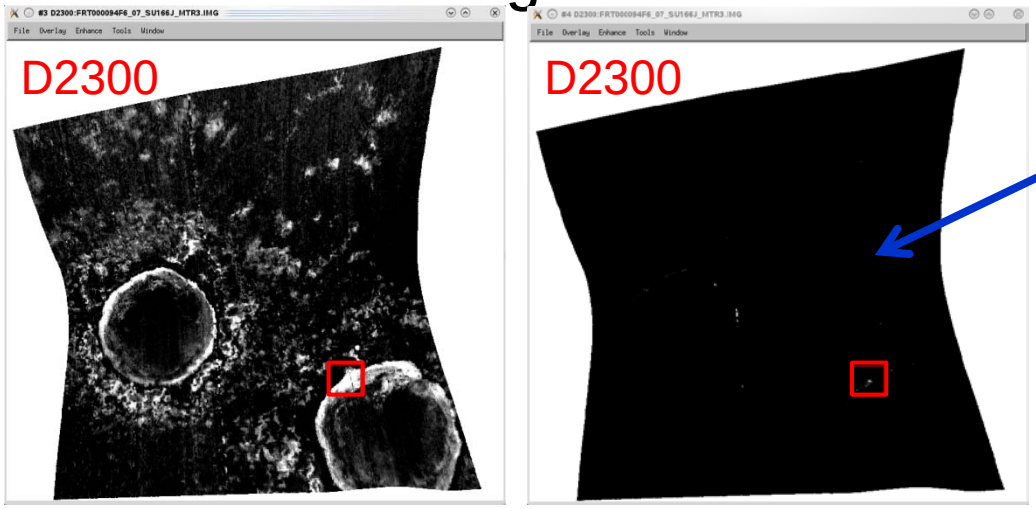
SPECTRAL ANALYSIS

Spectral Analysis Methods

- In general, there are 3 steps to spectral analysis:
  1. Locate interesting material(s)
     - Summary parameters are a good start
  2. Collect best possible spectra (scene “endmembers”)
     - Pixel average, Region of Interest (ROI), etc.
  3. Interpret endmember spectra
     - E.g., comparison to laboratory mineral spectra
- This is what ENVI is designed to do...
  - There are many analysis tools/options available within the ENVI software environment.
  - Not all of them work well with CRISM data.

Pixel-based Endmember Extraction (1/2)

- As an example, let's find an endmember spectrum for the D2300-bearing material in FRT000094F6.



- Load D2300 as single band and stretch to emphasize highest realistic D2300 values.
- Link D2300 with MTRDR spectral cube and PHY browse (optional, but useful)

Nominal Stretch (0.0 to 0.022)

Emphasized Stretch (0.04 to 0.05)

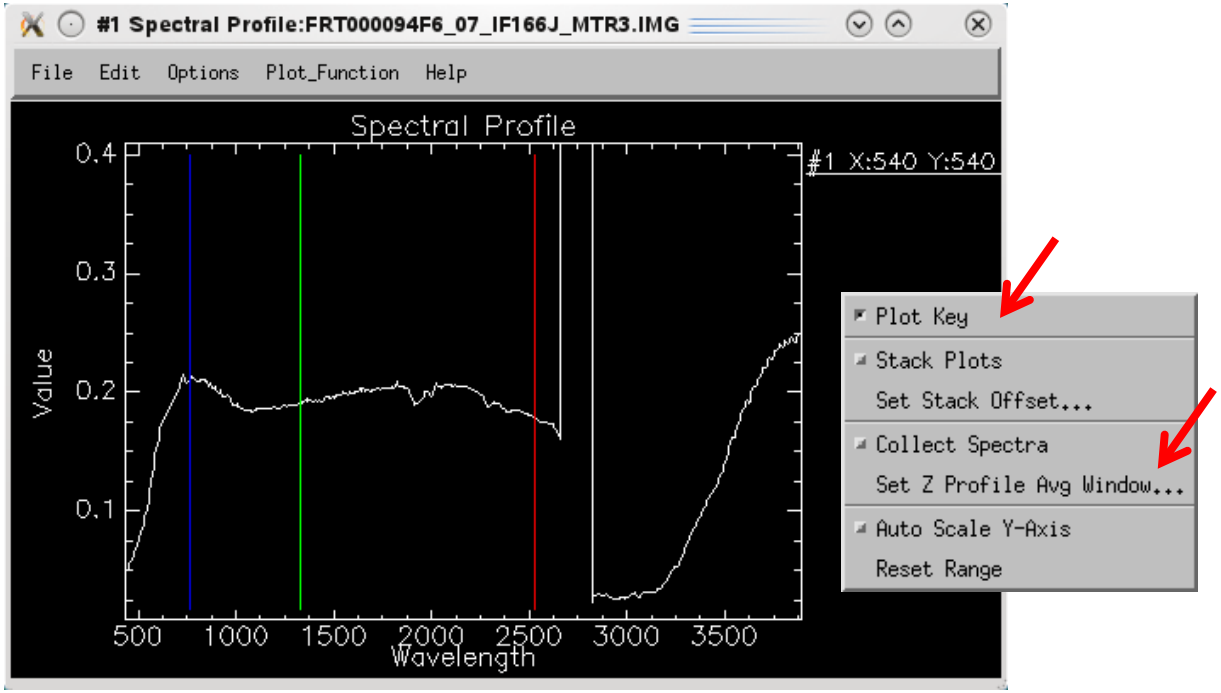
Spectral Cube RGB

PHY Browse

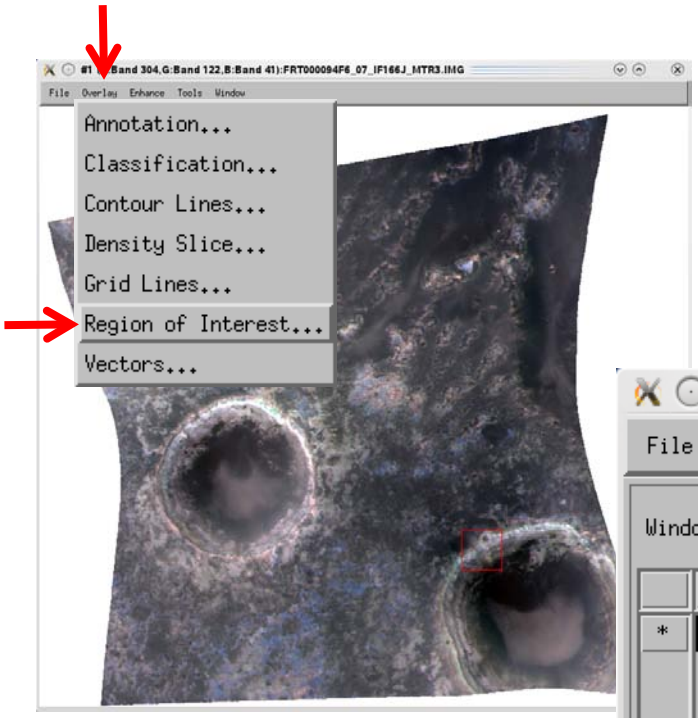
Pixel-based Endmember Extraction (2/2)

- From the linked spectral cube Image window, extract a Z-profile (Spectrum)
- In the spectral plot window
  - Go to >Edit >Plot Parameters to adjust y-axis (65535 values skew the range)
  - Right click anywhere to view Plot Key and set Z-profile Avg Window to 3x3 pixels
  - Preserve this spectrum for later use under >Options >New Window: with Plots...

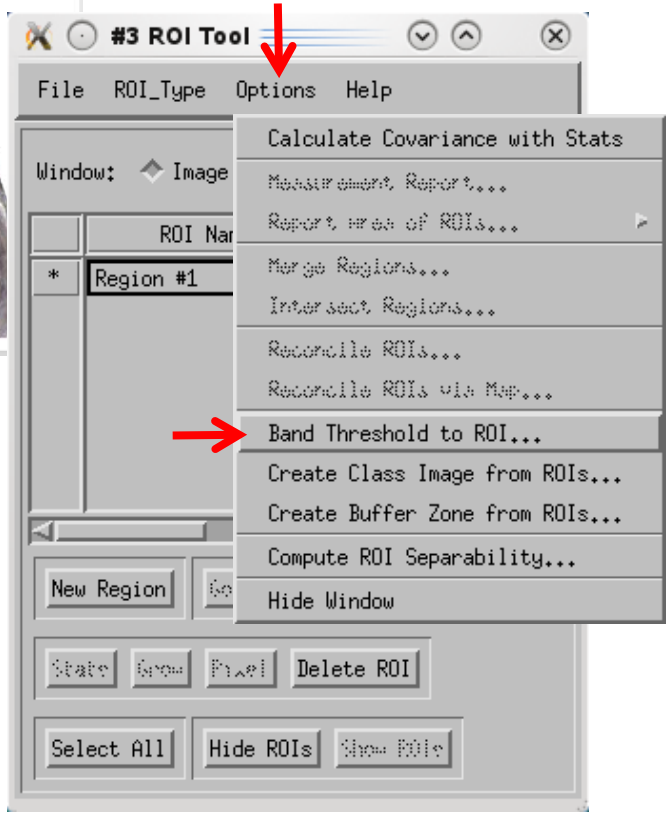
Spectral Cube RGB



ROI-based Endmember Extraction (1/3)

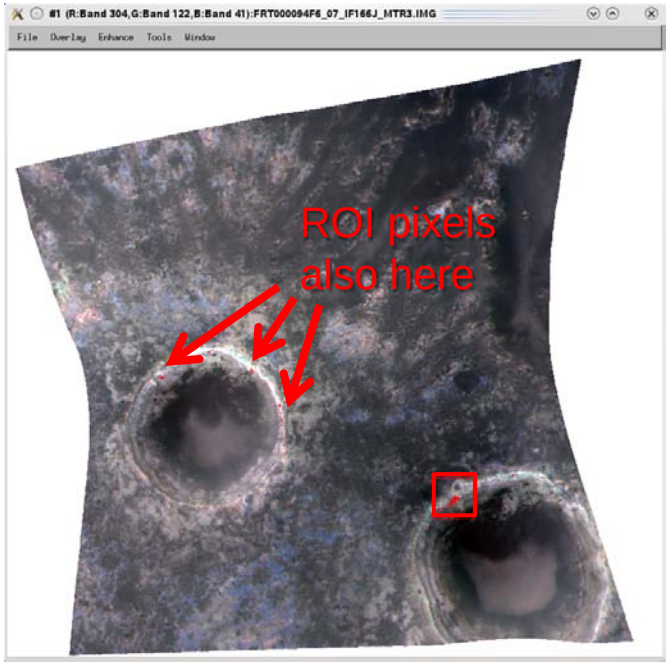


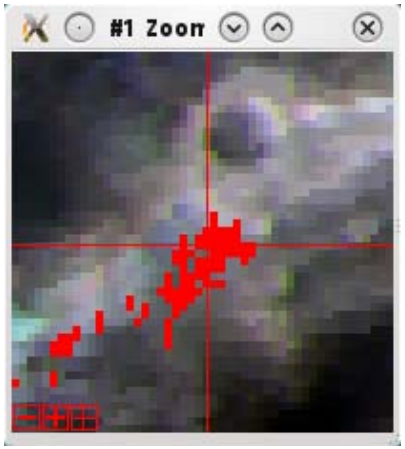
- Create a Region of Interest (ROI) from the highest D2300 values throughout the scene
- In the spectral cube Image window, go to >Overlay >Region of Interest



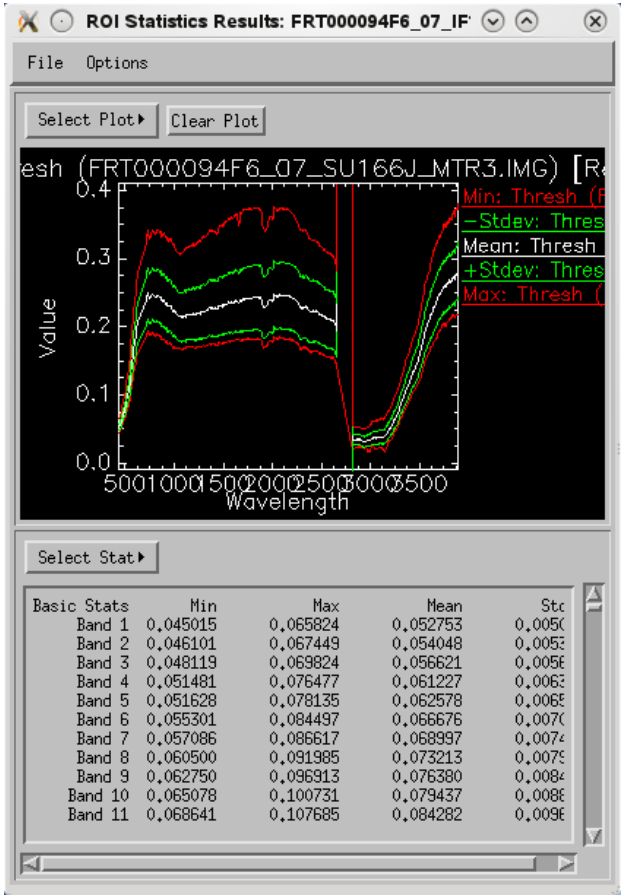
- In the ROI Tool, >Options >Band Threshold to ROI
- Select the D2300 band from the SU MTRDR file
- Type in min and max values of 0.04 and 0.05, respectively
- Should get a result of 198 pixels
- May want to refine threshold range to get fewer pixels

ROI-based Endmember Extraction (2/3)





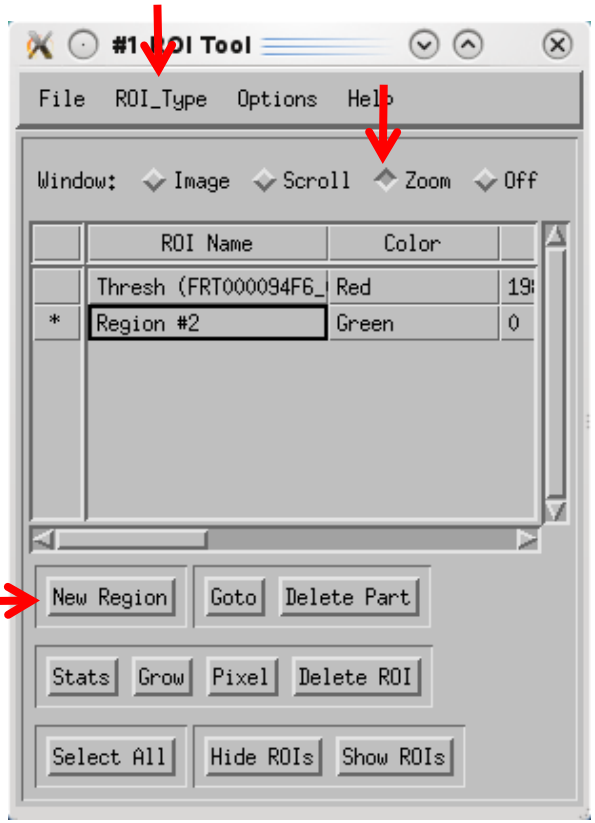
- The ROI appears as red pixels in the displayed window
- In the ROI Tool, calculate the average of the pixels by clicking >Stats



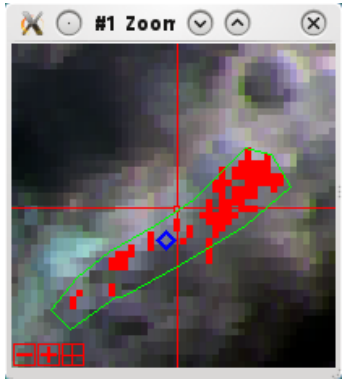
- Right click within the Stats Results plot area to adjust Plot Parameters and view Plot Key
- Click and drag the Mean spectrum to the previously-created spectral plot containing the pixel-based endmember spectrum

ROI-based Endmember Extraction (3/3)

- A third method would be to define a polygon ROI…

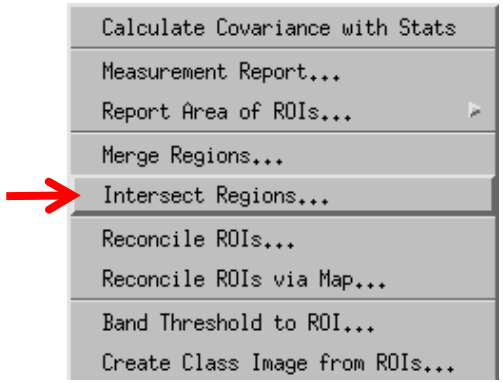


- In the ROI Tool, select >ROI_Type >Polygon
- Create New Region and select Zoom as the active window



right click to finalize

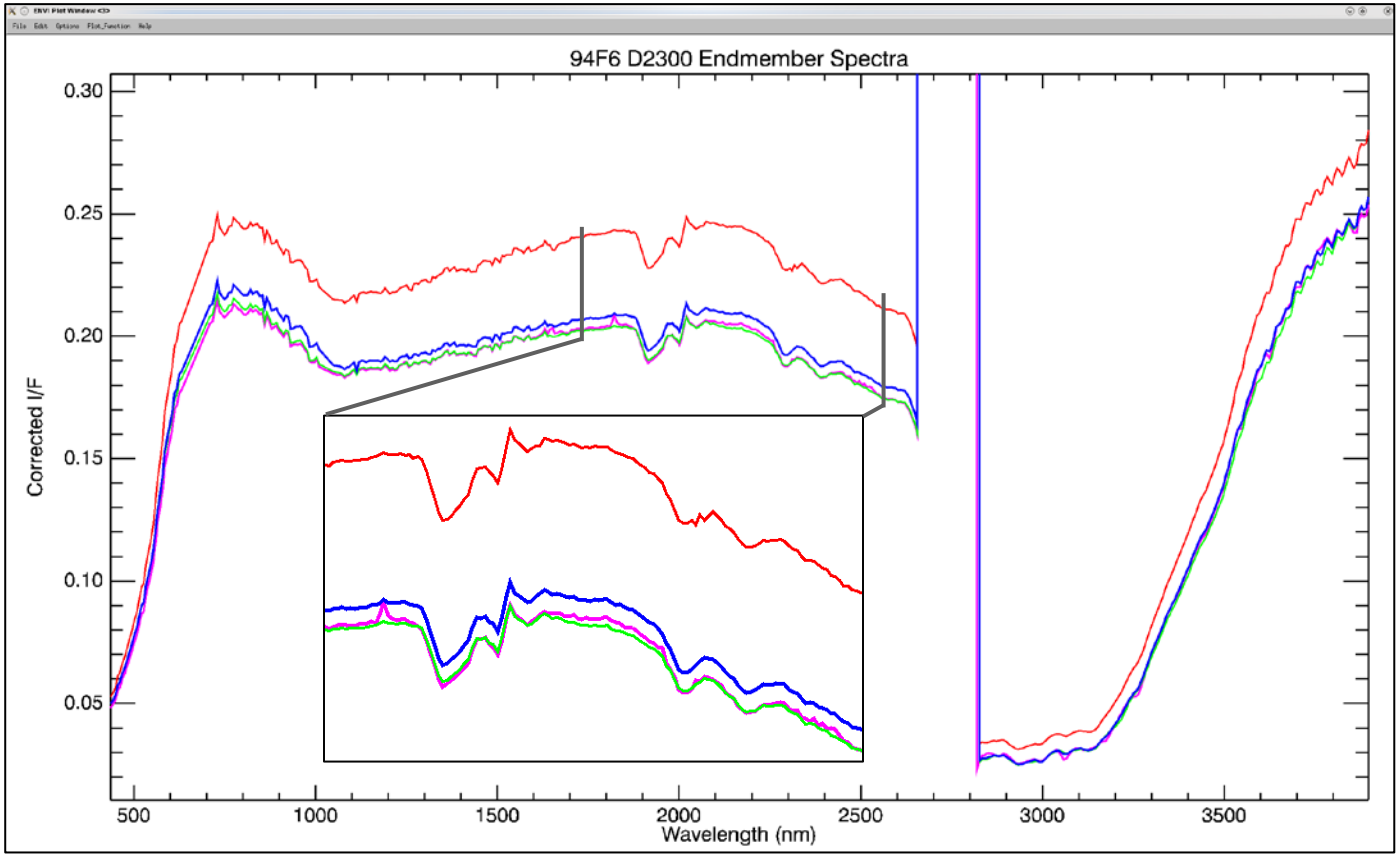
- Calculate statistics on the polygon-ROI as before
- The polygon ROI can be used alone or (e.g.) to spatially constrain the band threshold ROI: >ROI Tool > Options >Intersect Regions



Example Endmember Spectra – D2300

- Four D2300 spectra were extracted using the methods discussed in previous slides: **1)** 3x3 pixel average, **2)** band threshold, **3)** polygon, and **4)** band threshold-polygon intersection.

- In this scene, there are no huge differences between the spectra.
- In general, more pixels = less spectral noise.



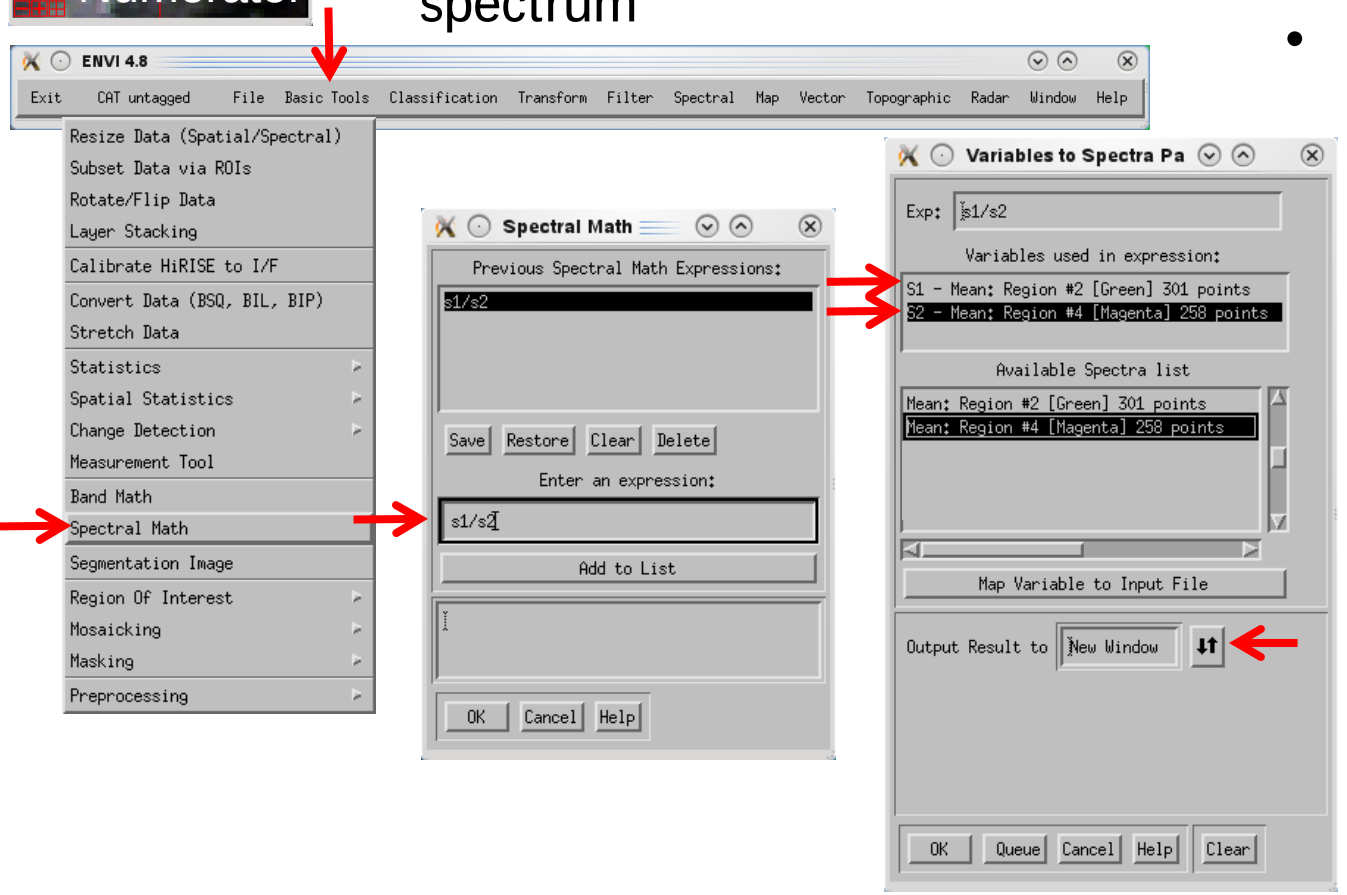
#1 X:540 Y:540 [3x3 AVG]
Mean: Thresh [Red] 198 points
Mean: Region #2 [Green] 301 points
Mean: Thresh [Red] 198 points AND Region #2 [Green] 301 points [Blue] 93 points

Enhancing Spectral Features

- There are two widely accepted ways to enhance spectral features to aid with interpretation:
  - Ratio to a spectrally neutral area in the same scene
  - Continuum removal
- Benefit to using a ratio is that you may cancel out detector noise or spikes
- However, if your denominator spectrum is not truly neutral you may introduce unintended spectral shape, e.g., from:
  - Broad features from mafics like olivine or pyroxene
  - Spectral slope
  - VNIR variability from ferric oxide-related features
- Continuum removal is not recommended over the entire CRISM wavelength range, either
  - Best results when focused on relatively narrow range bracketing the feature(s) of interest

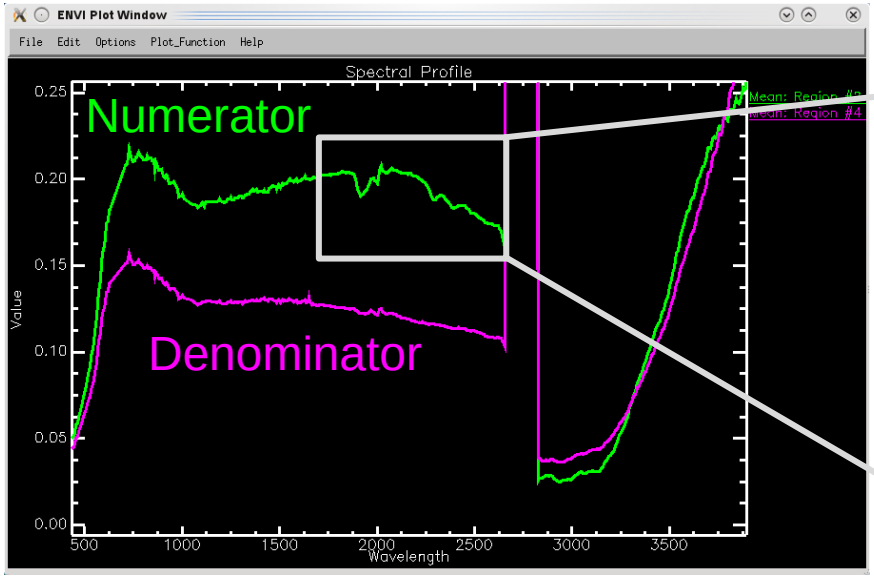
Ratioing (1/2)

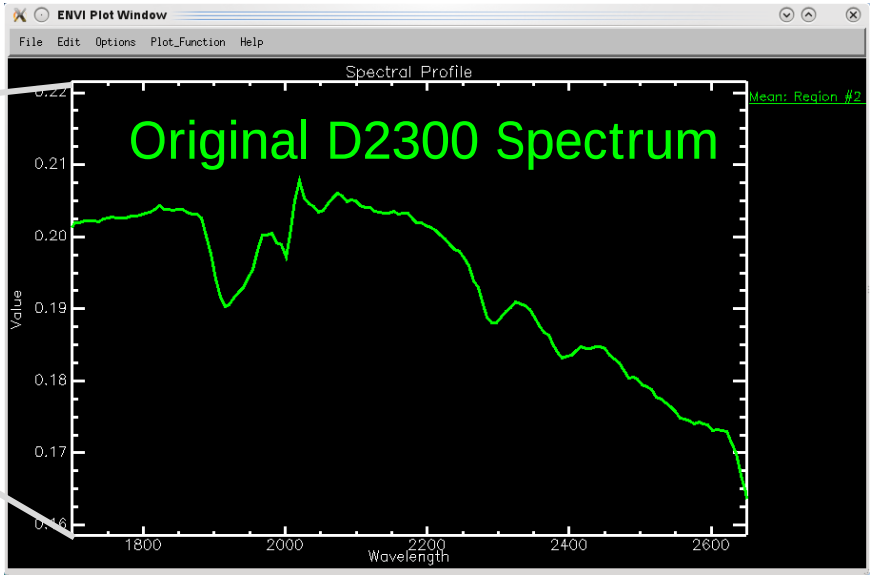
- Numerator: let's use the D2300 spectrum with the least noise - the average from the green polygon ROI.
- Denominator: Create a similar-sized polygon in the nearby spectrally bland dark material and calculate its average spectrum

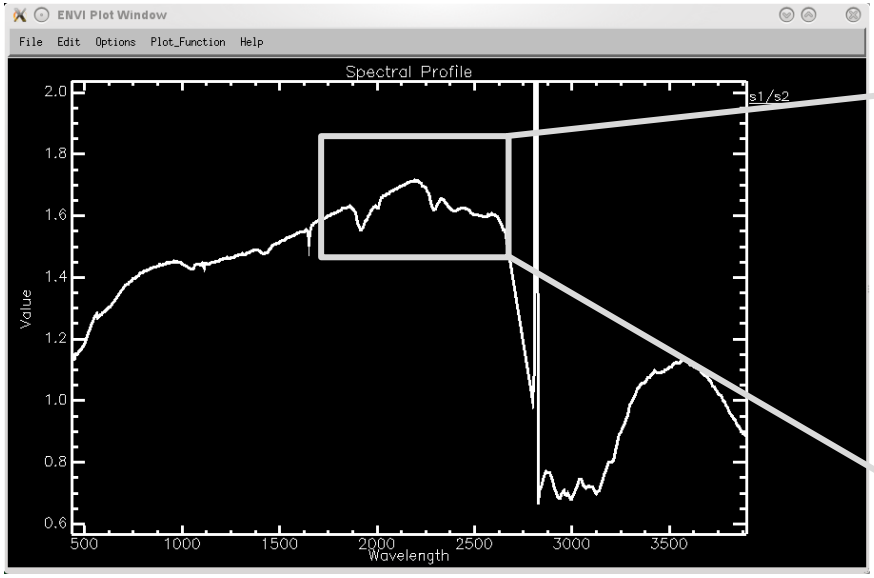


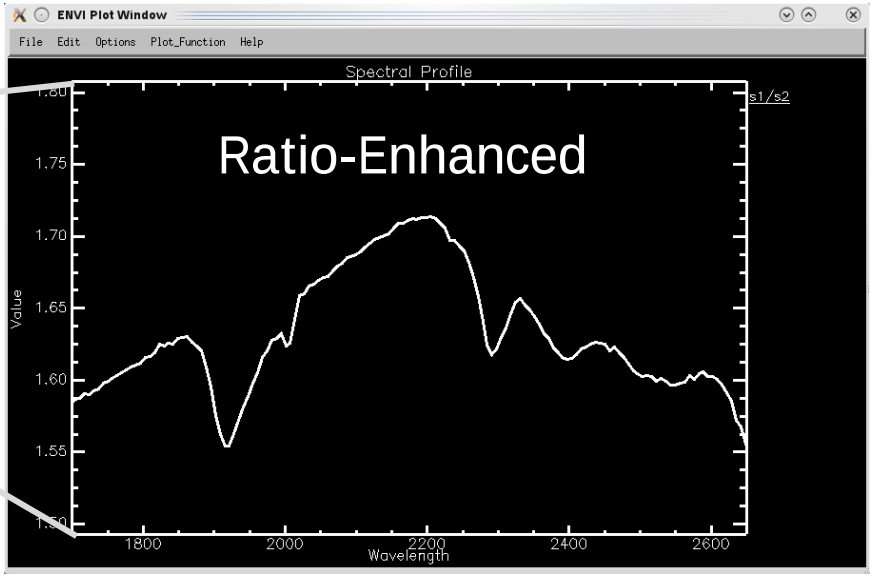
- From the ENVI main menu, go to >Basic Tools > Spectral Math
  - Enter the expression: s1/s2
  - Map the numerator (s1) and denominator (s2) to the Available Spectra List
  - Output to New Window

Ratioing (2/2)


ENVI Plot Window
File Edit Options Plot_Function Help
Spectral Profile
Numerator
Denominator
Mean: Region #2
Mean: Region #4
Value
Wavelength

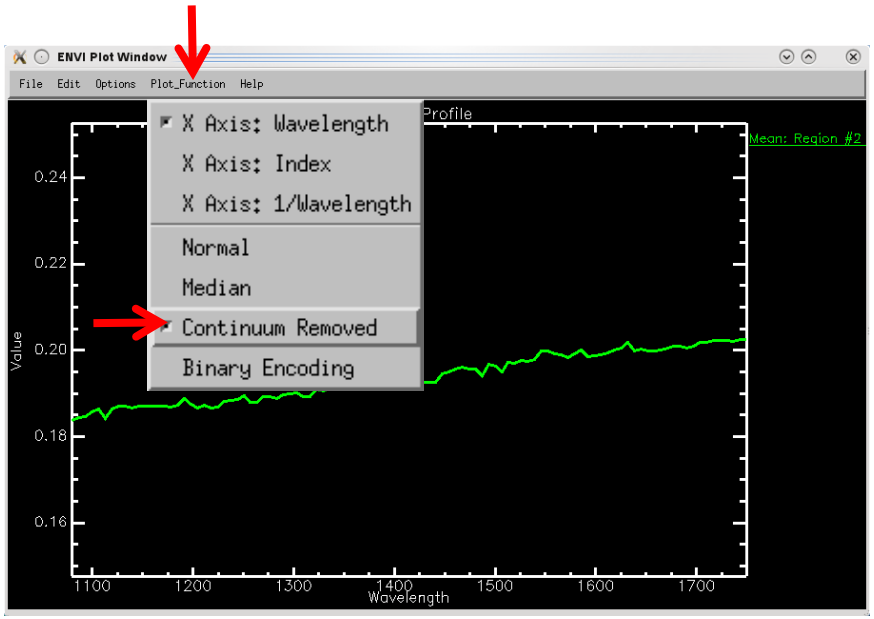

ENVI Plot Window
File Edit Options Plot_Function Help
Spectral Profile
Original D2300 Spectrum
Mean: Region #2
Value
Wavelength


ENVI Plot Window
File Edit Options Plot_Function Help
Spectral Profile
s1/s2
Value
Wavelength


ENVI Plot Window
File Edit Options Plot_Function Help
Spectral Profile
Ratio-Enhanced
s1/s2
Value
Wavelength

Continuum Removal (1/2)

- Examine 3 wavelength regions independently: ~1.4, ~1.9, and ~2.3 µm.
- In >Edit >Plot Parameters, subset the x-axis range to bracket the feature of interest
- Then choose Plot_Function > Continuum Removed as the display method
- You will likely have to rescale the y-axis in the continuum removed-plot



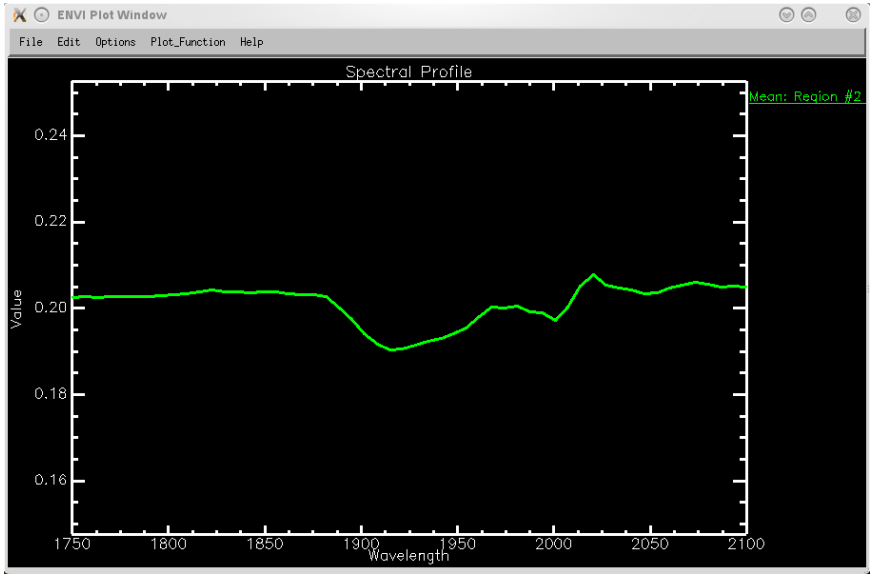
Normal

Continuum Removed

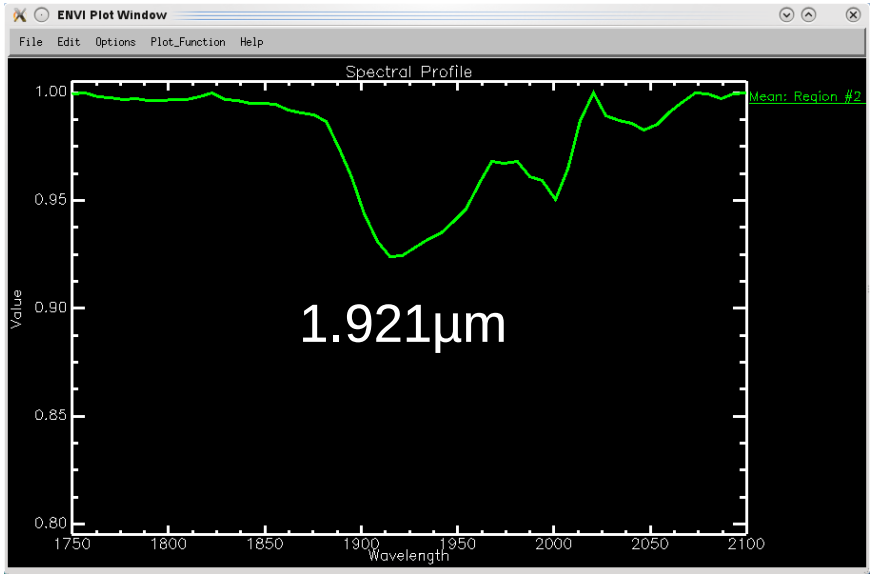
The 1.4 band is better-emphasized by the ratio!

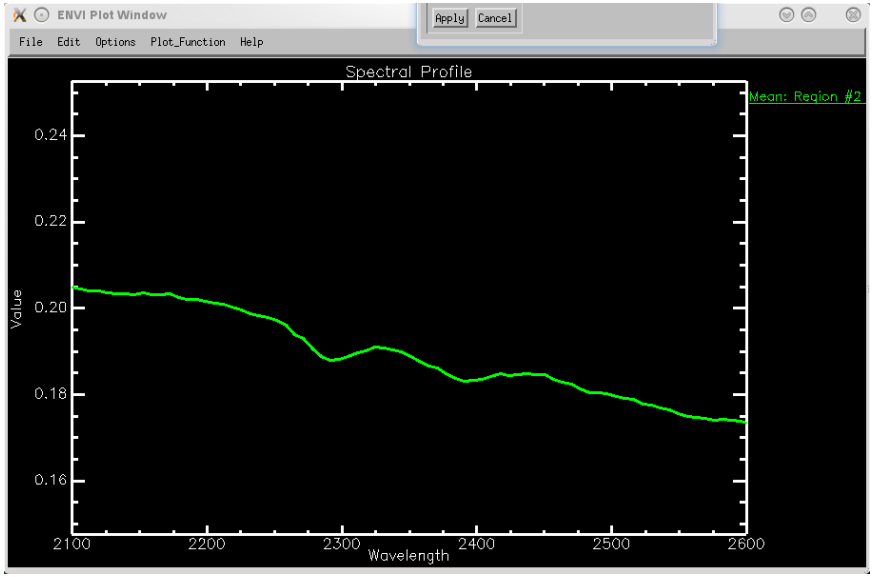
Continuum Removal (2/2)

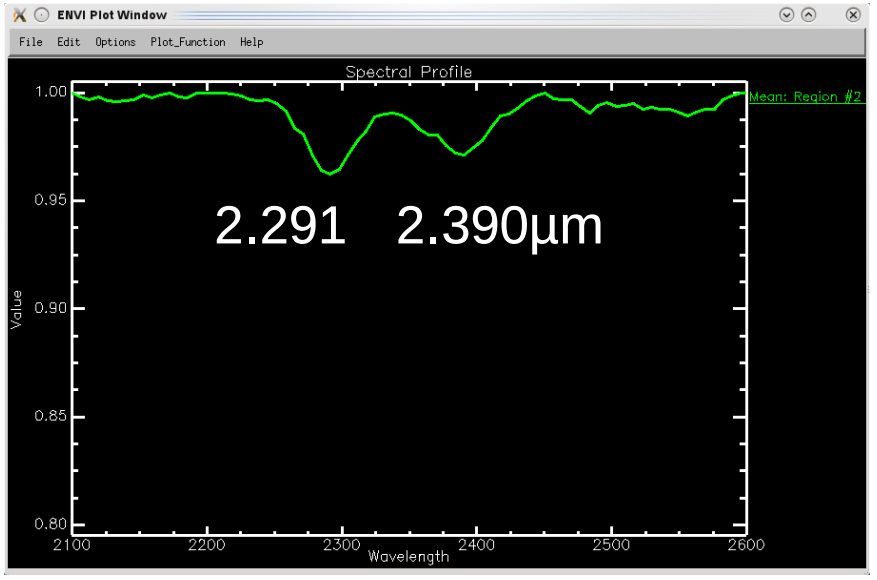
Normal



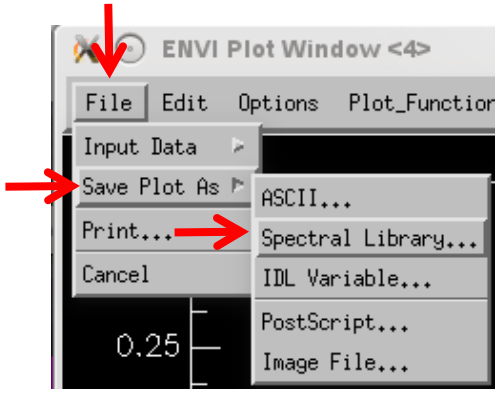
Continuum Removed



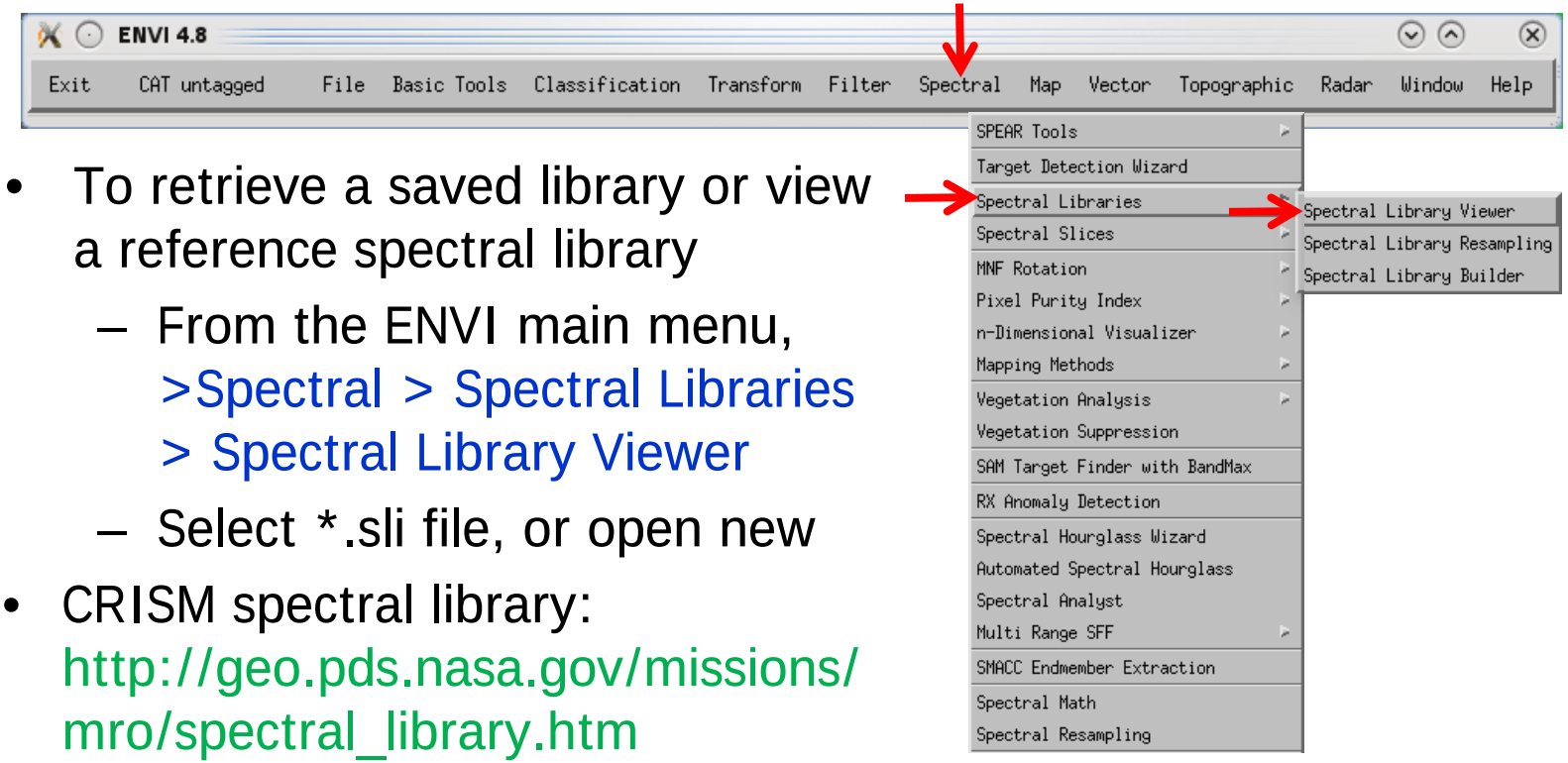




Spectral Libraries

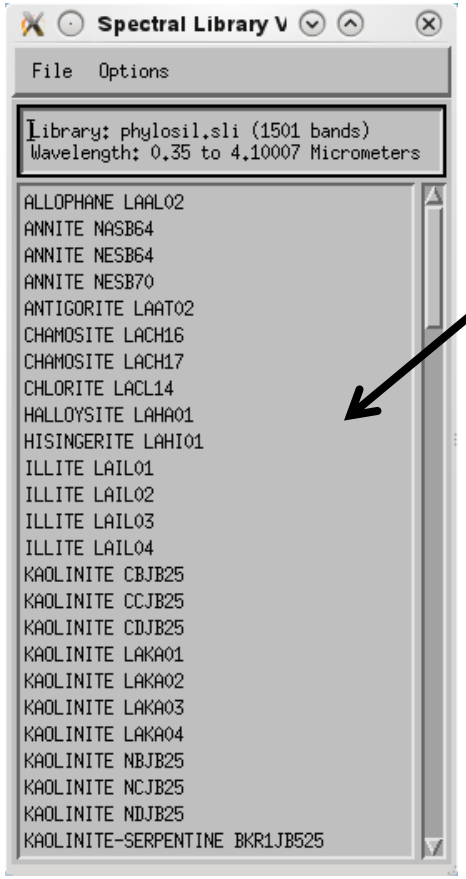


- Save spectra as ENVI spectral libraries (*.sli), or export as ASCII text file
  - From a spectral plot window, >File >Save Plot As > Spectral Library
  - HINT: Line colors are not preserved; make sure you rename the spectra appropriately

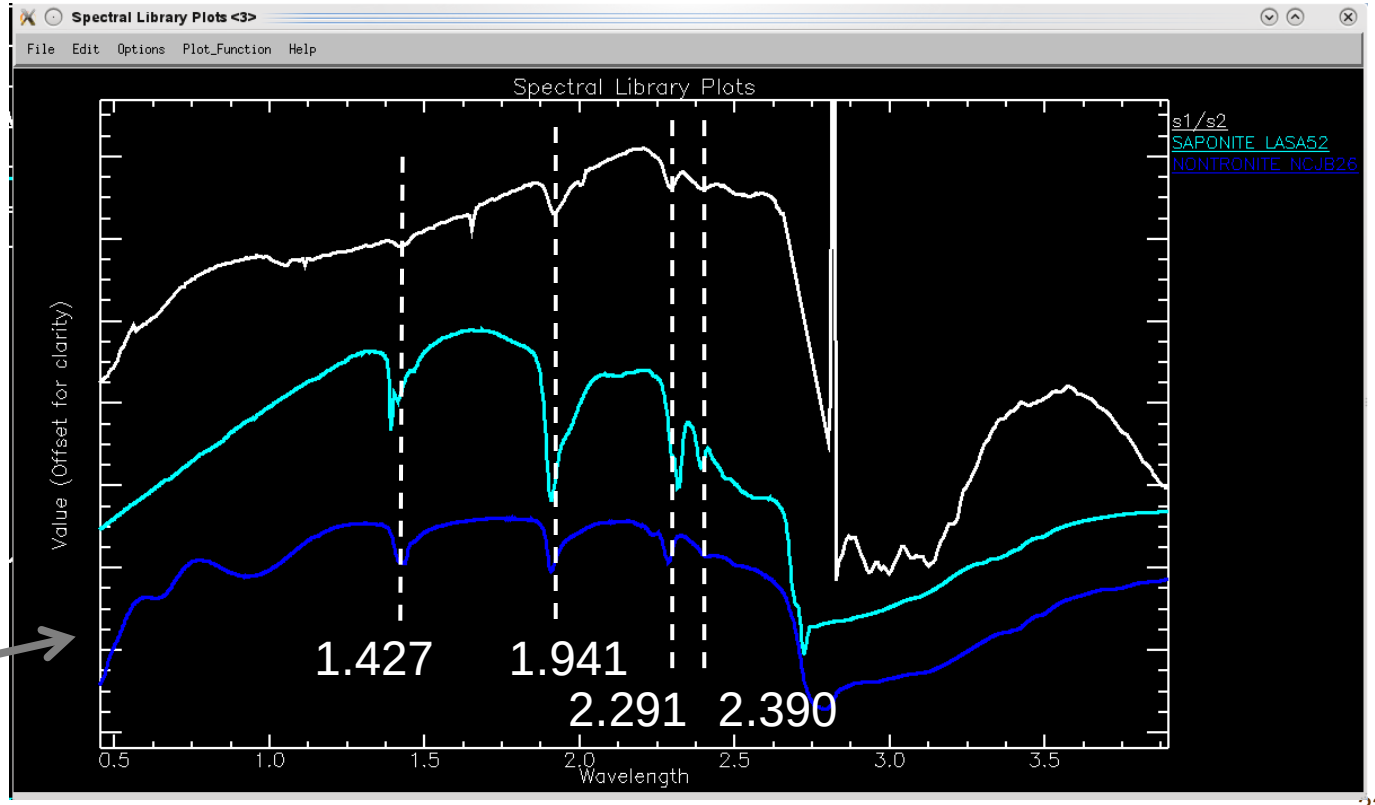


- To retrieve a saved library or view a reference spectral library
  - From the ENVI main menu, >Spectral > Spectral Libraries > Spectral Library Viewer
  - Select *.sli file, or open new
- CRISM spectral library: http://geo.pds.nasa.gov/missions/mro/spectral_library.htm

Interpretation



- Compare the enhanced spectra to laboratory reference spectra to locate the best mineralogic match(es).
- For the D2300 endmember example, open a library containing phyllosilicate spectra and load candidate reference spectra to examine absorption band positions in detail...



Diagnostic bands match best with nontronite.

Interpretation Guidelines

- Common sense rules apply to spectral interpretation:
  - All major absorption features in the spectrum of the proposed reference mineral should be present or otherwise accounted for
  - Relative strengths and shapes of spectral features of the proposed reference mineral should be replicated in the CRISM spectrum
- Even a single CRISM pixel (~20m) is unlikely to comprise a single pure mineral, i.e.,
  - Spatial mixing is likely
  - Intimate mixtures can also occur
  - Geochemically intermediate phases are also possible
- So, simple explanations are usually best, but complexity happens. It's real geology, after all!

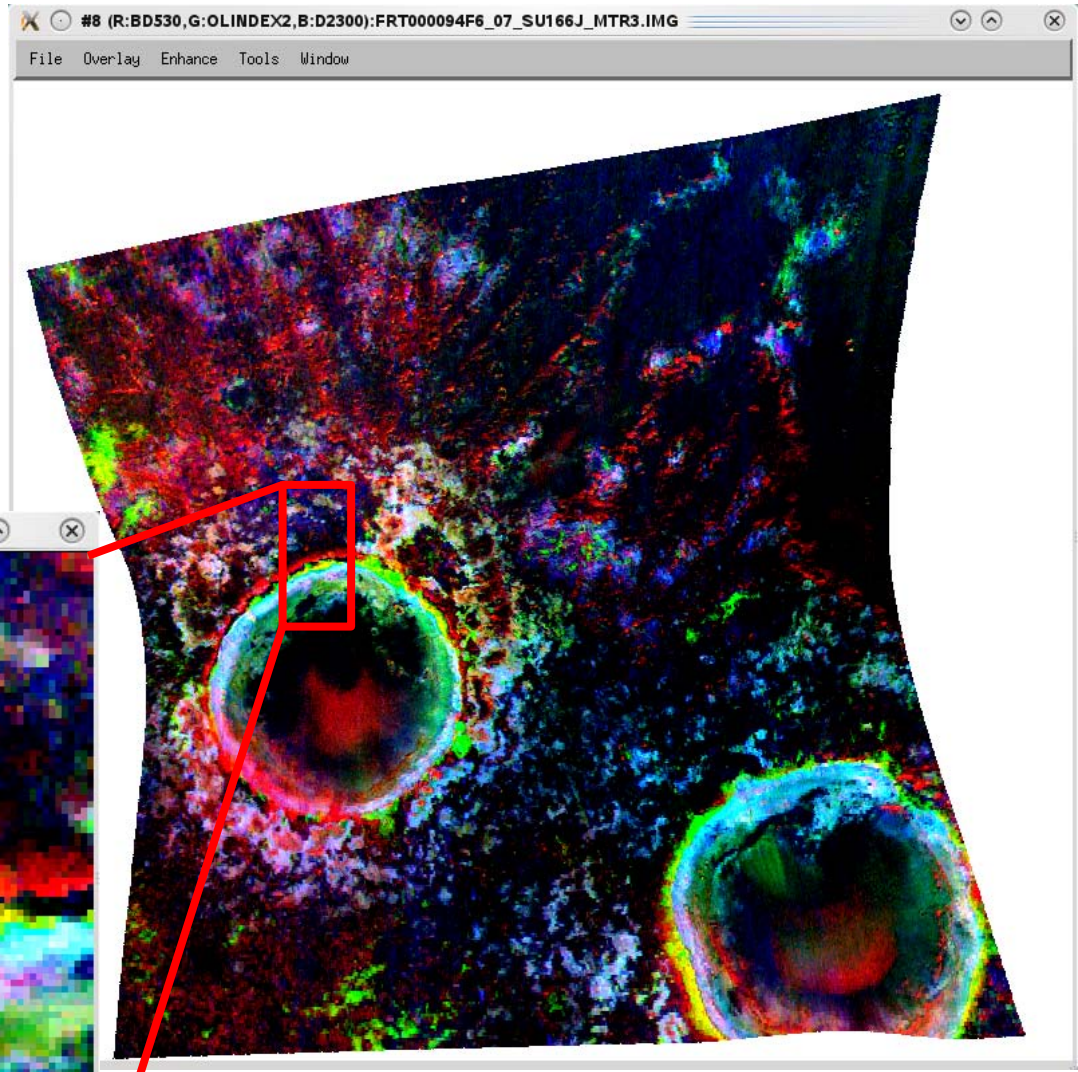
Walk-Through Section 3

VISUALIZATION

Custom Composites

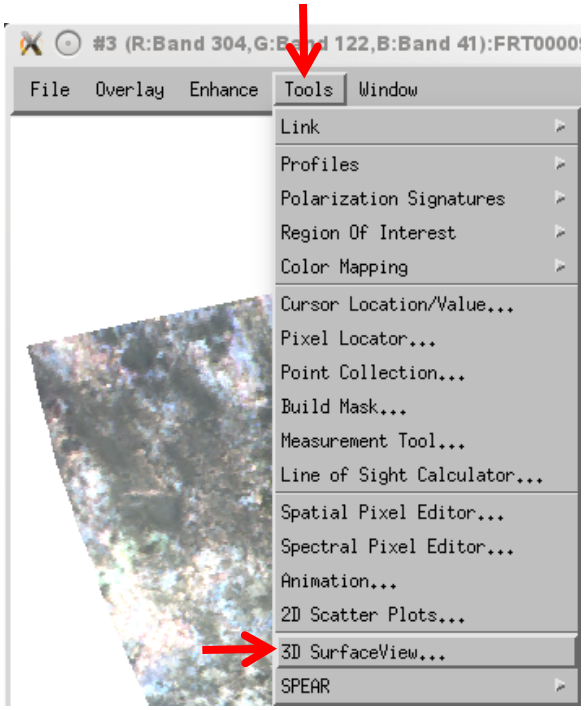
- Custom RGB composites and browse products can take advantage the joined nature of the MTRDR summary parameter cube.

- Example at right shows ferric, ferrous, and clay variability.
- MANY color units to follow-up on!!



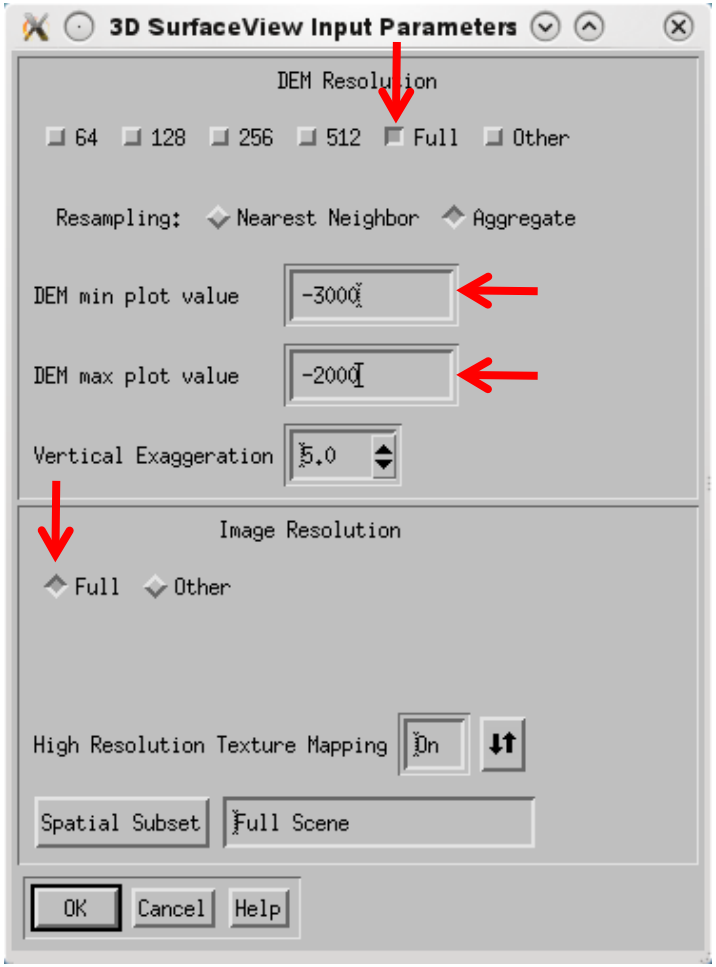
3-D Rendering (1/3)

- 3-D visualization can be helpful for understanding relationships between different units.
- First, open the map projected DDR cube (*DE*L_MTR1.IMG) and load the Elevation band
  - Highest resolution MOLA gridded data is oversampled to match CRISM spatial scale; co-registration is good but interpolation in sparse areas can lead to feature mismatch
  - Note the approximate elevation range under >Enhance >Interactive Stretching (you'll need this later)
- Load and stretch the band or RGB composite that you want to view in 3D
- From the Image window, go to >Tools >3D Surface View



3-D Rendering (2/3)

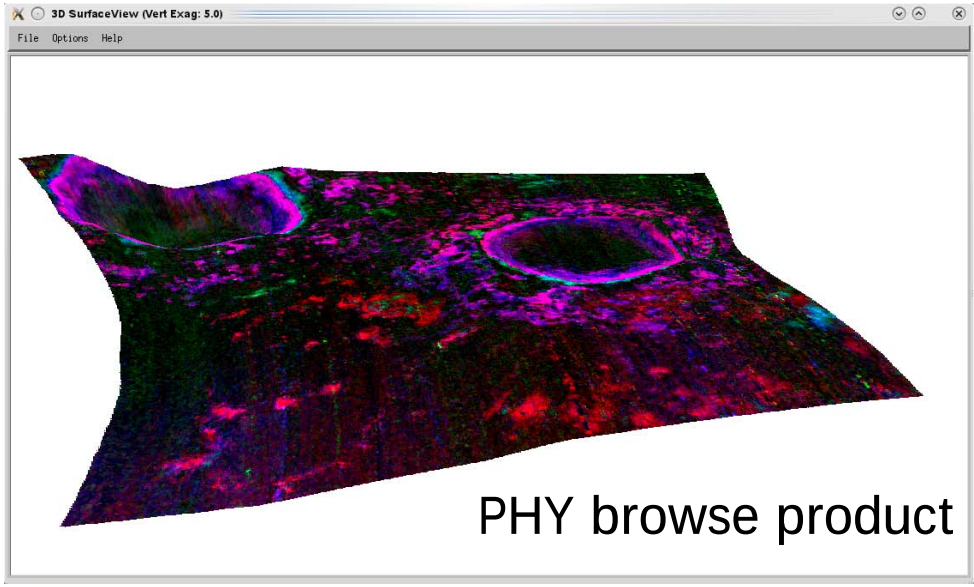
- In the 3D SurfaceView Input dialog
  - Indicate Full DEM Resolution
  - Type in min and max elevation values that bracket the actual range
  - Indicate Full Image Resolution



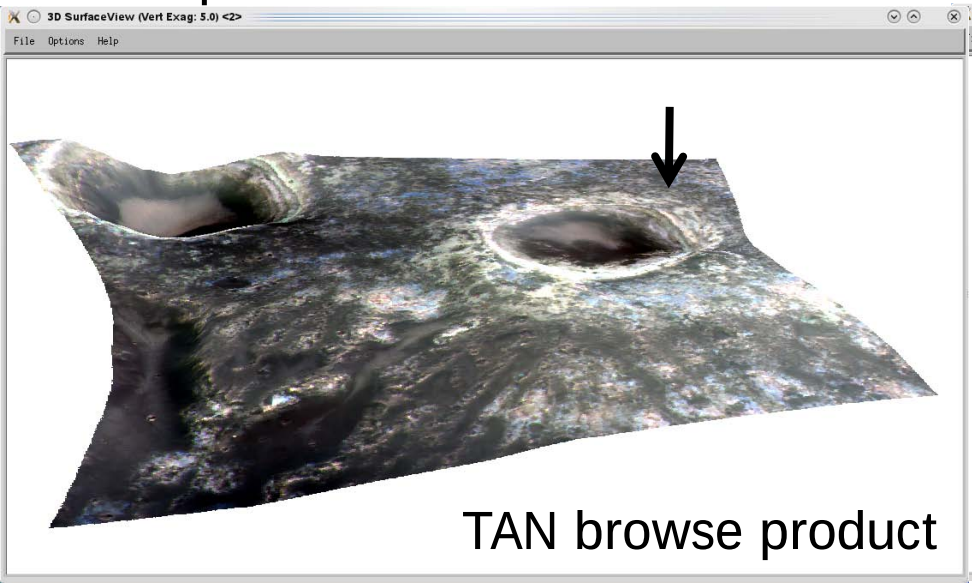
Initial 3D view

3-D Rendering (3/3)

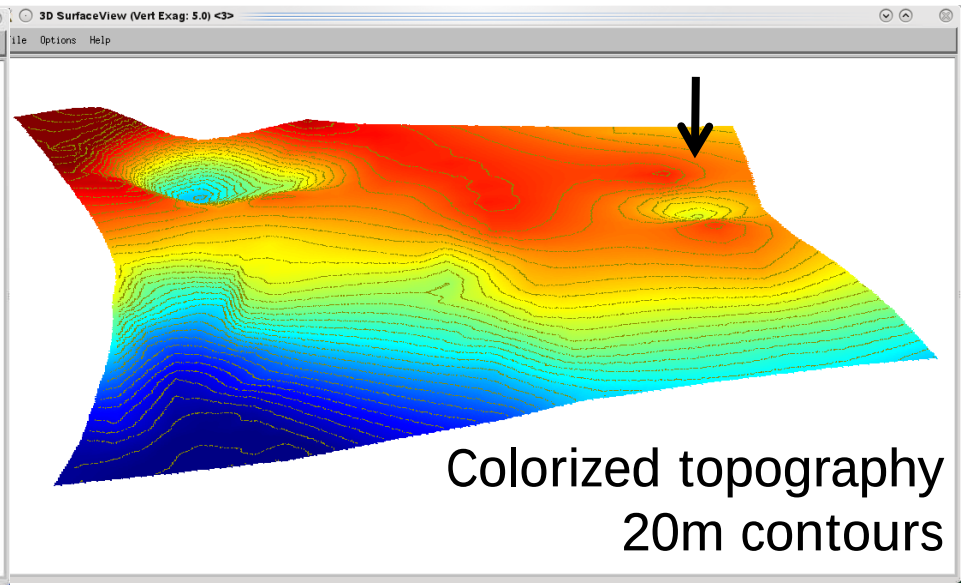
- Use mouse buttons to navigate, or use >Options >Surface Controls
- Perspective view here is looking south (5x vertical exaggeration)
- Note that the lowest point for the western crater (right side, arrows) is offset from the crater's center due to sparseness of the interpolated MOLA tracks



PHY browse product



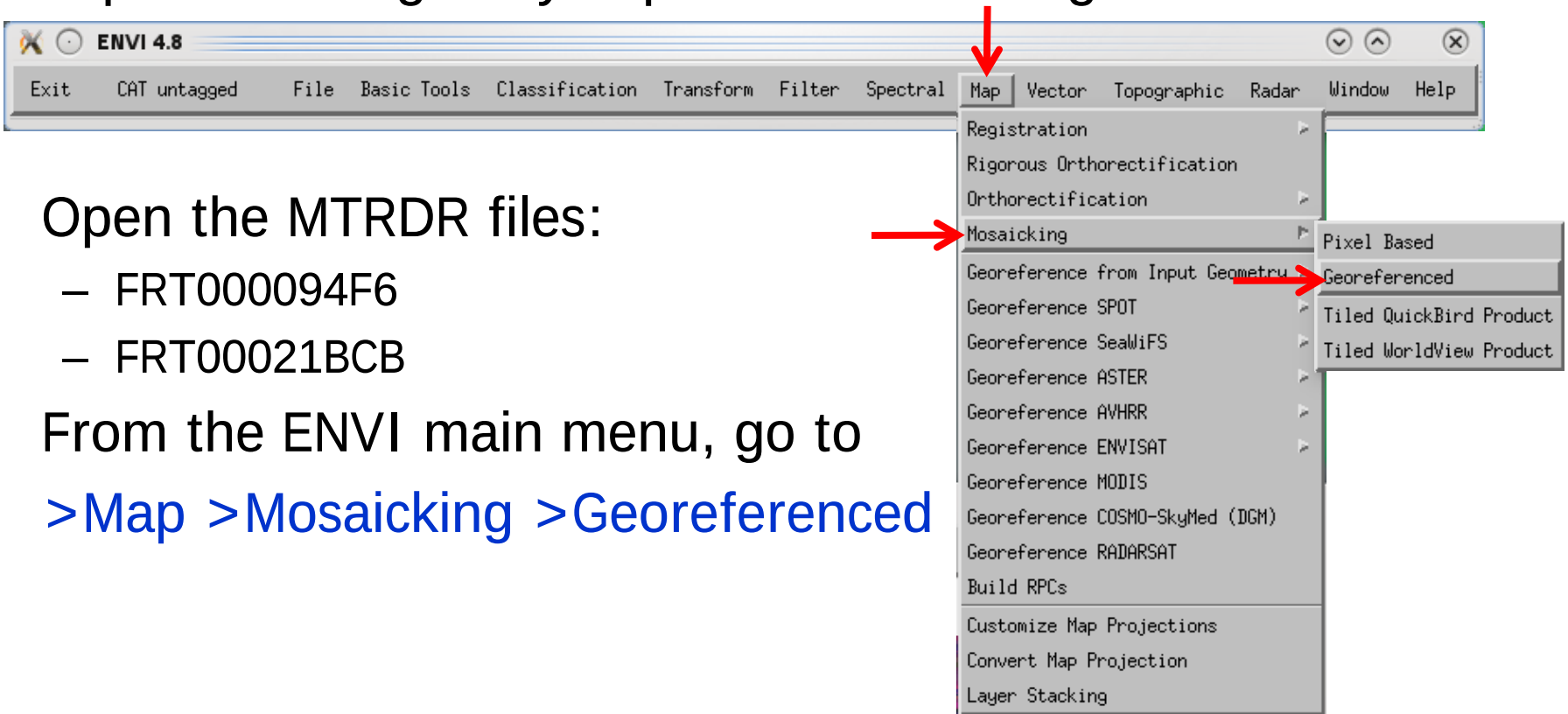
TAN browse product



Colorized topography
20m contours

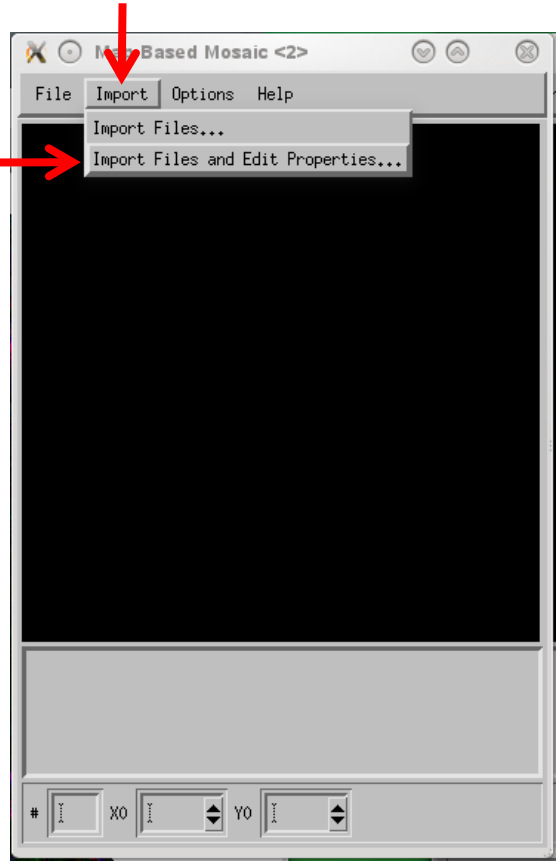
Mosaicking (1/4)

- Mosaicking multiple CRISM cubes together allows broader geographic context for inferred mineralogy.
  - Can mosaic map-projected spectral, summary parameter, or DDR cubes
- MTRDR empirical correction of scene-specific geometric dependencies greatly improves mosaicking results.



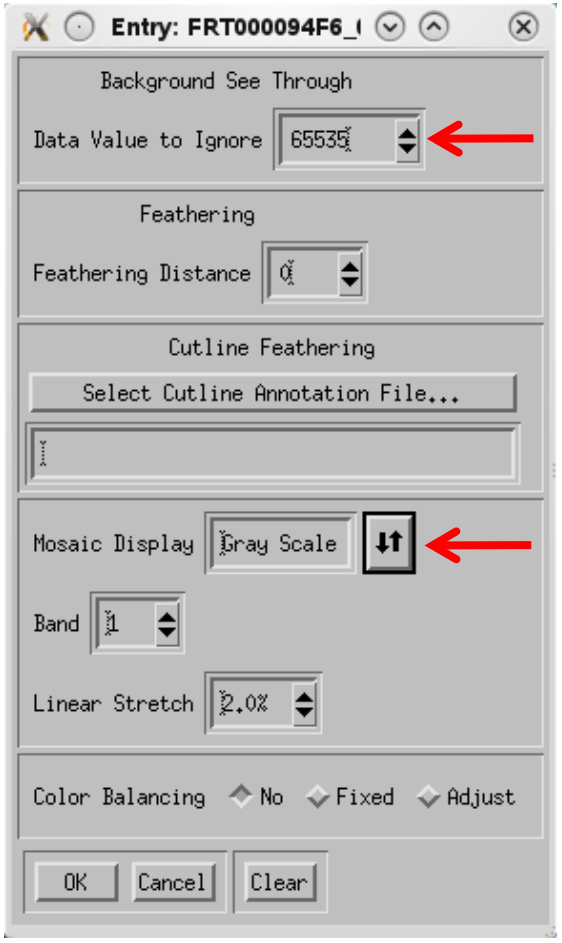
- Open the MTRDR files:
  - FRT000094F6
  - FRT00021BCB
- From the ENVI main menu, go to
  >Map >Mosaicking >Georeferenced

Mosaicking (2/4)

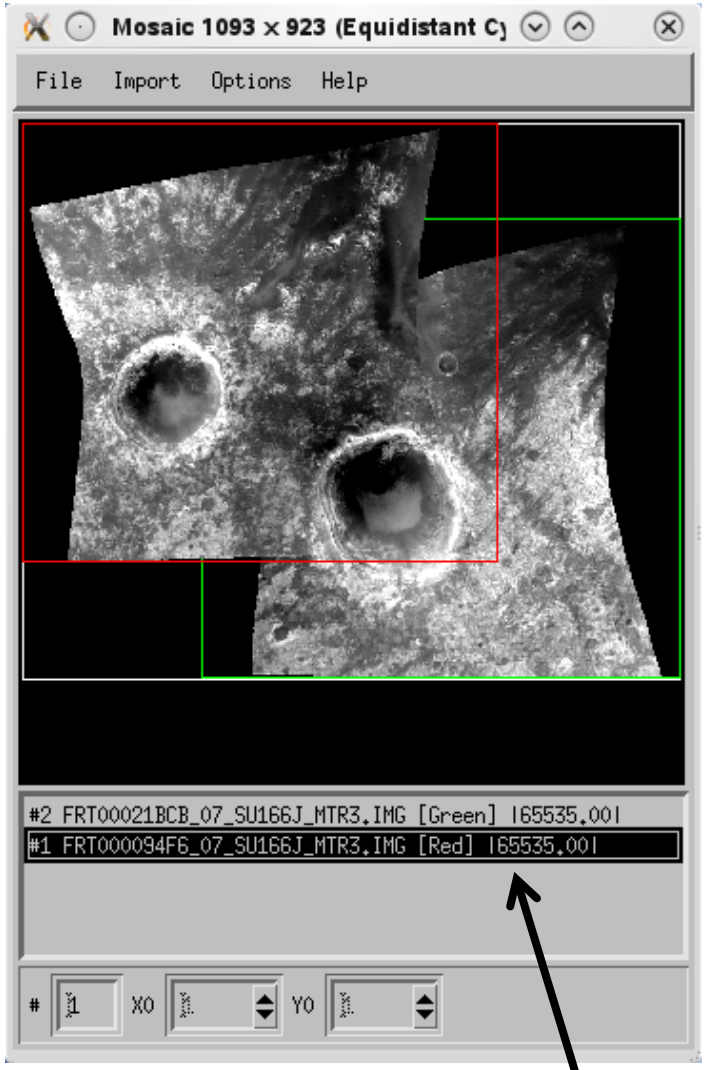


- In the Mosaic dialog box, go to >Import >Import Files and Edit Properties
  - Select the two cubes you wish to mosaic

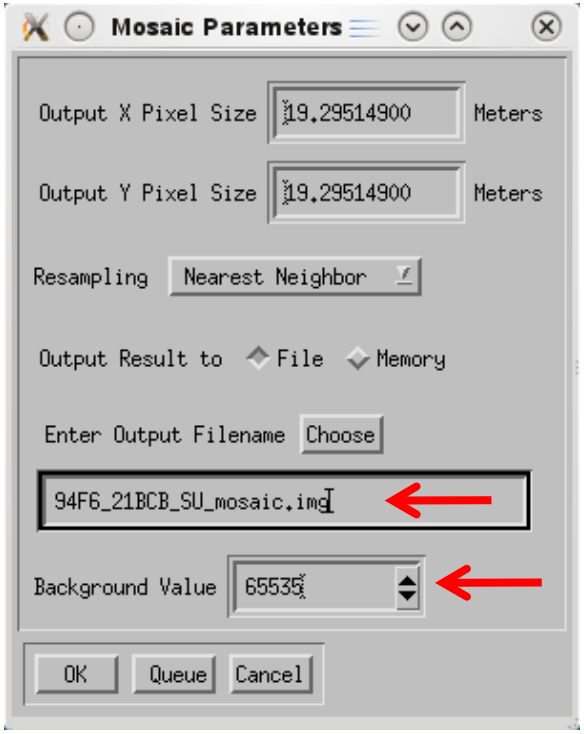
- For each file, indicate a Data Ignore Value of 65535 and Mosaic Display of Gray Scale, Band 1 (you can change this later).



Mosaicking (3/4)



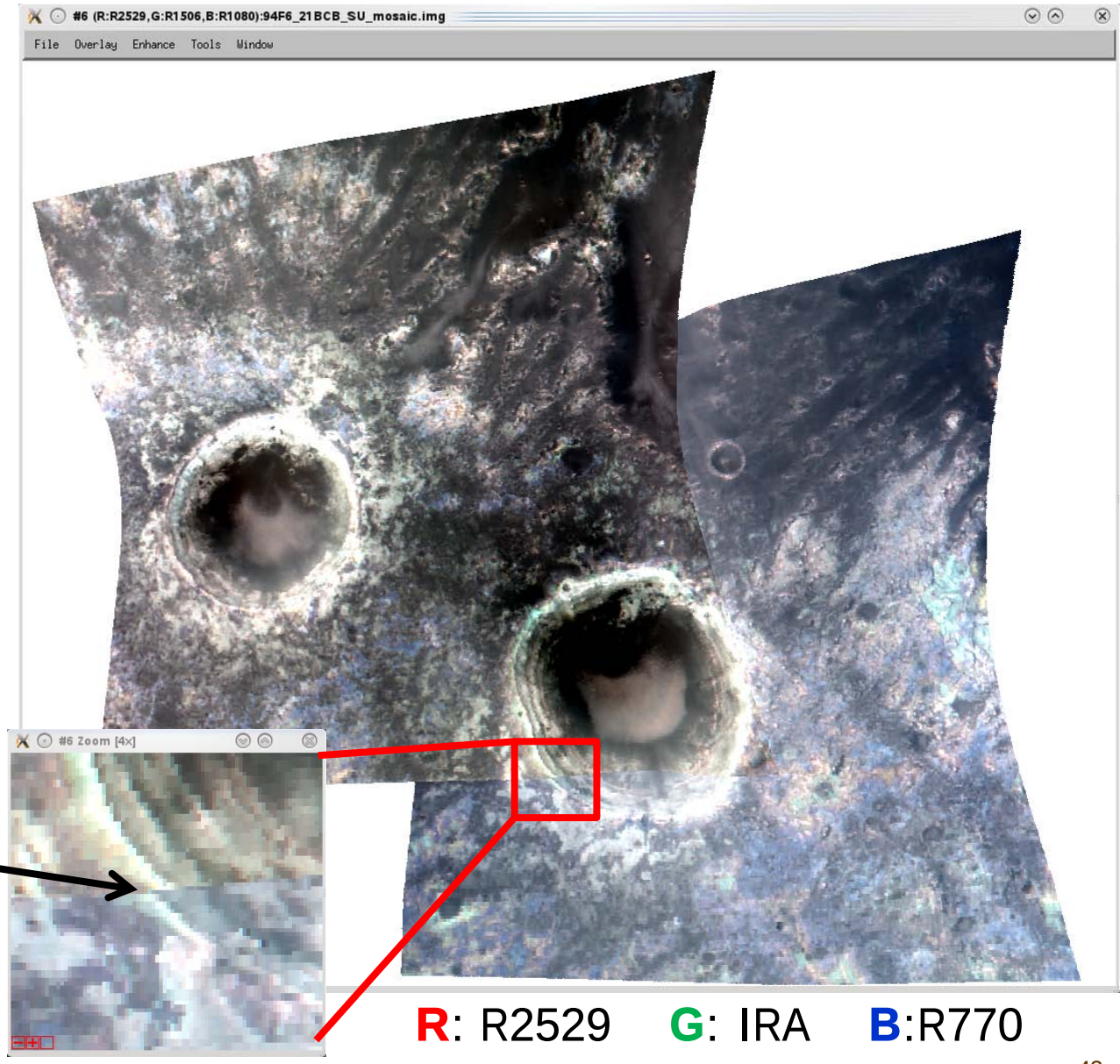
- You should see the indicated band (1: R770) appear in the mosaic window for each cube.
- To save, go to >File >Apply
  - Indicate filename and include a background value of 65535.



To adjust layering order or edit display properties, right click on filename here

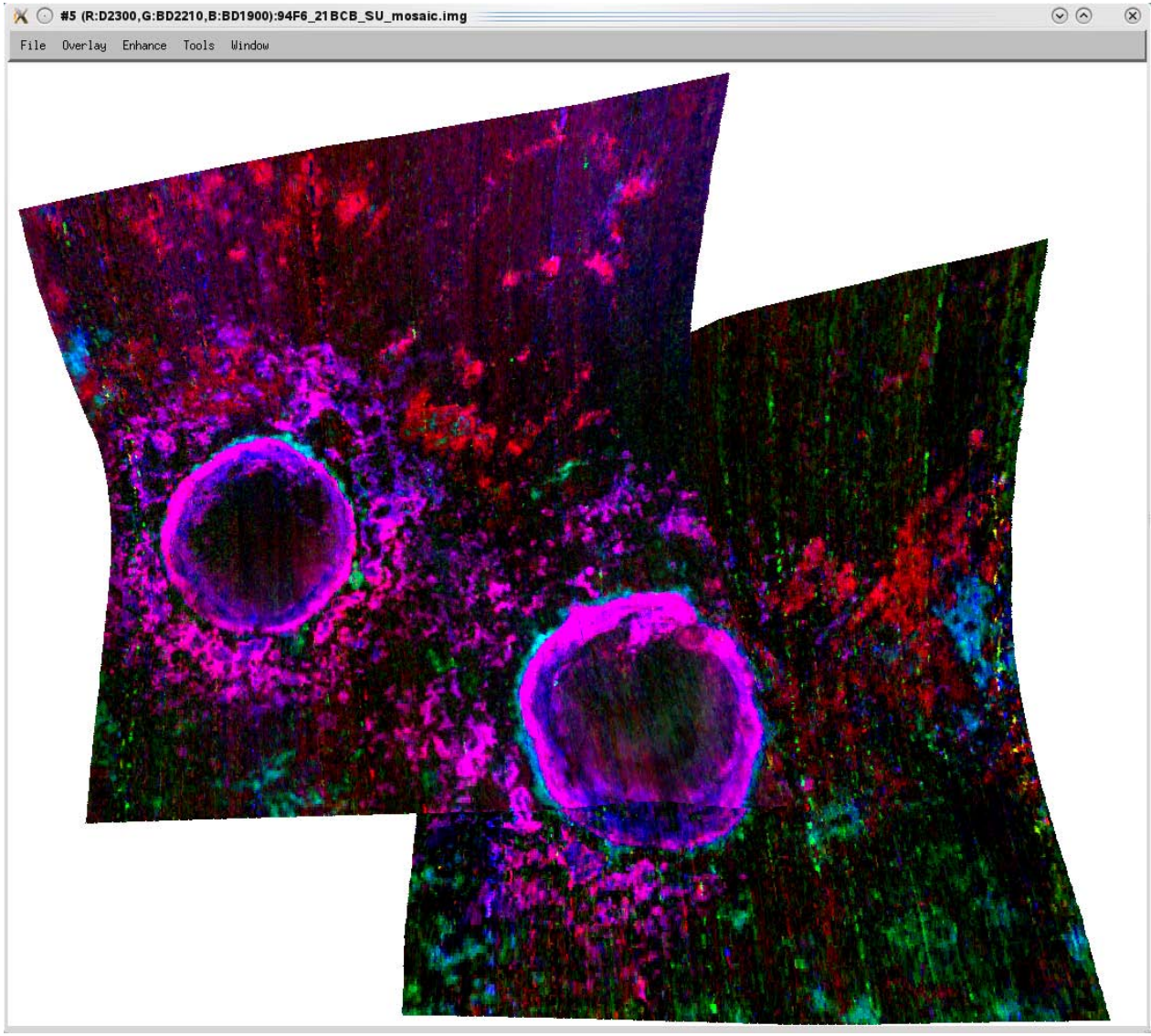
Mosaicking (4/4)

- Load a mosaic just like any other file
- Go to >File >Edit ENVI Header to set Data Ignore Value (65535) and reapply band names if desired
- TAN browse product at right →
  - **No** histogram matching
  - Some seams visible, and a few pixel offset on slopes where the MOLA shape model is perhaps inadequate



More Mosaic Results

- PHY browse product →
- Some parameters mosaic better than others due to the nature of their formulation
  - More noise is apparent in FRT00021BCB (right image) as a result of the 125K detector temperature



R: D2300 **G**: BD2210 **B**:BD1900

QUESTIONS?

Please also visit the PDS forum:
http://geoweb.rsl.wustl.edu/community/index.php?/forum/20-mrocrism-data-users-workshop-2012/