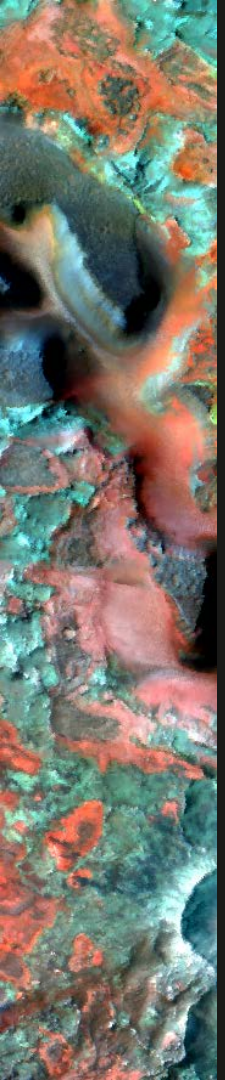


CRISM Demonstration:
Data Access, Processing, and Analysis

3rd Planetary Data Workshop

June 12, 2017
Flagstaff, AZ

MRO CRISM Science Operations Center

PDS Geosciences Node
Washington University in St. Louis

Johns Hopkins Applied Physics Laboratory

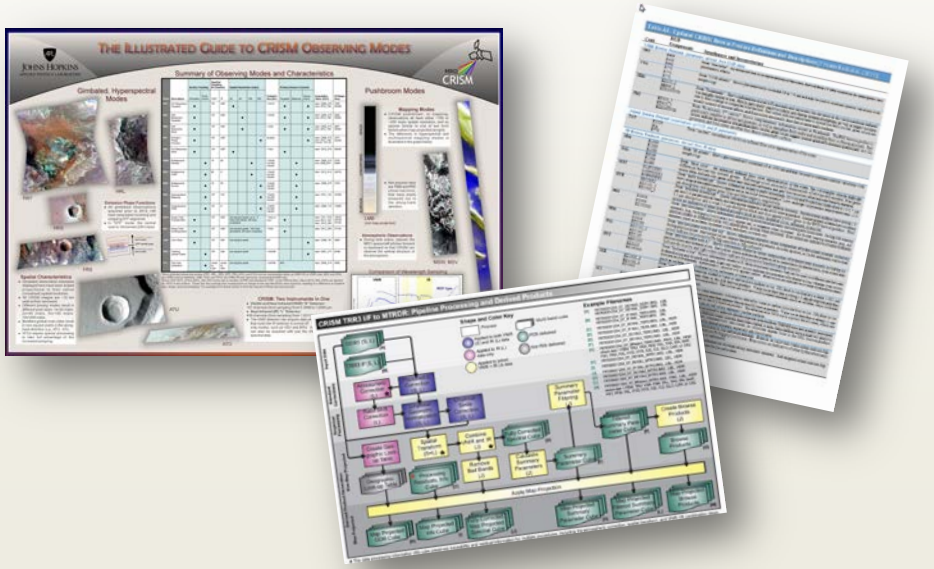
Agenda & Objectives

- **Welcome/Overview** *(2 min)*
  - **Handouts**
- **Part 0. What is CRISM?** *(5 min)*
- **Part I. Data Access** *(Demonstration; 10 min)*
  - **PDS Orbital Data Explorer (ODE)**
- **Part II. Standard Processing** *(Group Exercise; 30 min)*
  - **CRISM Analysis Tools (CAT)**
- **Part III. MTRDRs and Data Visualization** *(Show & Tell; 15 min)*
  - **Map Projected Targeted Reduced Data Records (MTRDRs)**
  - **Summary Parameters and Browse Products**
- **Part IV. Spectral Analysis** *(Group Exercise; 45 min)*
  - **Basics of spectral endmember extraction, interpretation**
- **Part V. ENVI 5.4** *(Demonstration; 15 min)*

Please Ask Questions!

Workshop materials

- **Printed handouts:**
  1. How to access data at the PDS using the ODE
  2. CRISM observing modes poster
  3. Table 3 from Viviano-Beck et al. (2014)
  4. MTRDR processing flowchart
  5. CRISM filename decoder and common tasks



- **Electronic media:**
  - **Resources**
    - Digital forms of printed handouts
    - Reference publications
    - CRISM type spectra library
  - **Data**
    - Full product suite for FRT000094F6
  - **Presentations**
    - This slide set
    - Ancillary slide sets, e.g.,
      - Filename secret decoder ring
      - History of CRISM observing modes
      - Extended MTRDR description

Part 0. What is CRISM?

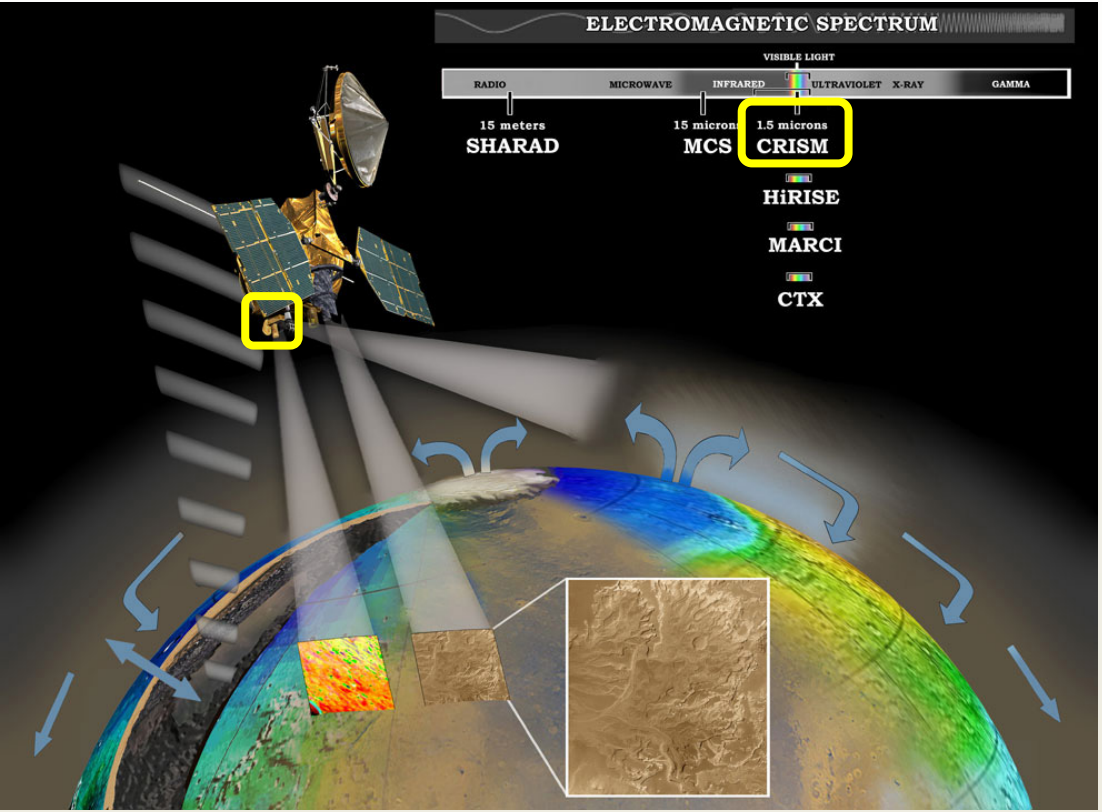
- CRISM = Compact Reconnaissance Imaging Spectrometer for Mars
- Basic instrument characteristics and observing modes

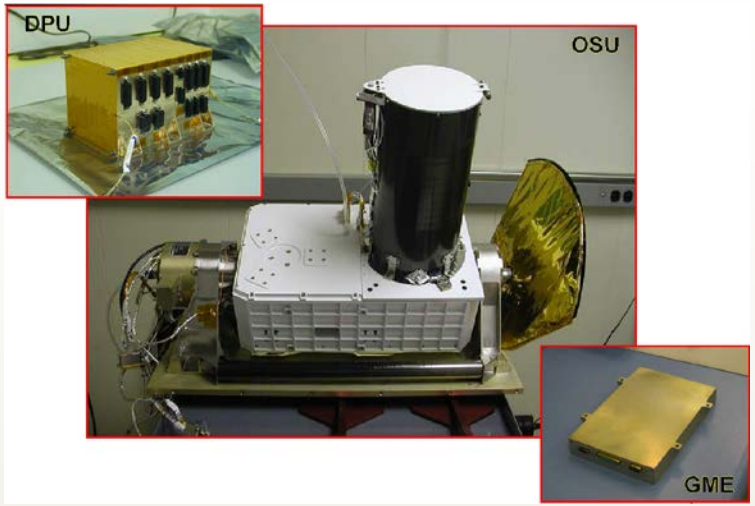
Extra information relevant to this section:

1. Resources\Publications\Murchie_JGR_2007_CRISM.pdf
2. Resources\Handouts\CRISM_observing_modes_poster_v8.png
3. Presentations\Ancillary\CRISM_Workshop2017_CRISM_obs_mode_history.pdf

What is CRISM?

- One of 6 science instruments on MRO

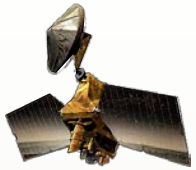


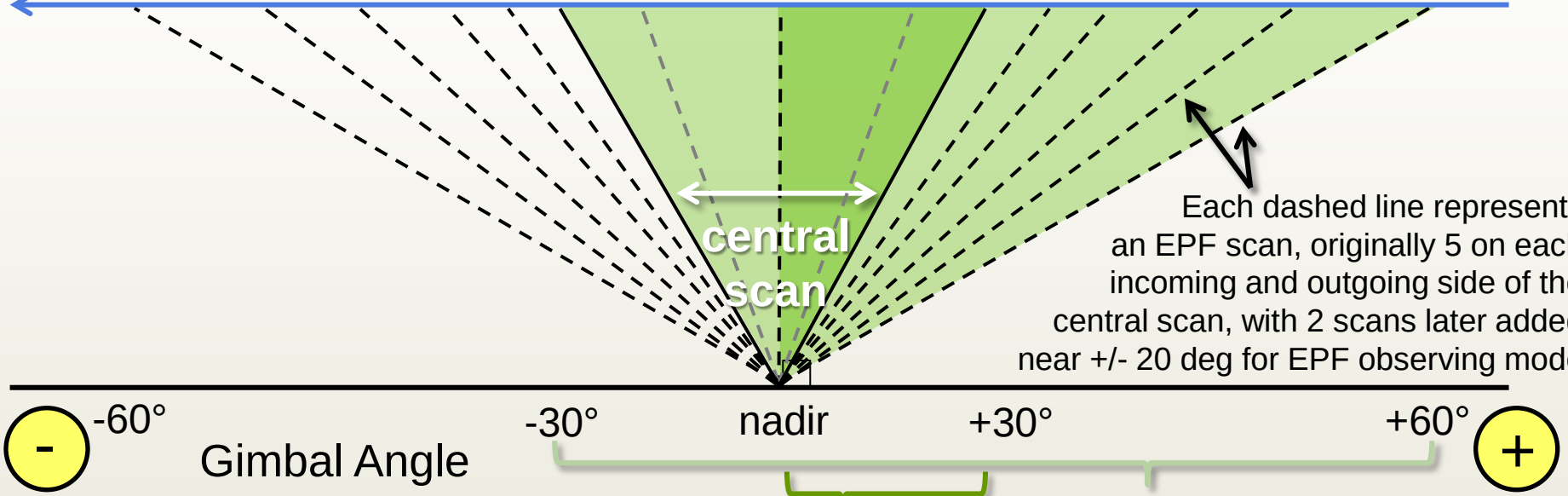


- A gimbaled, vis-near IR reflectance spectrometer
  - 544 bands from 0.4 - 3.9μm
  - 20 m/pix targeted mode
  - 100/200 m/pix mapping

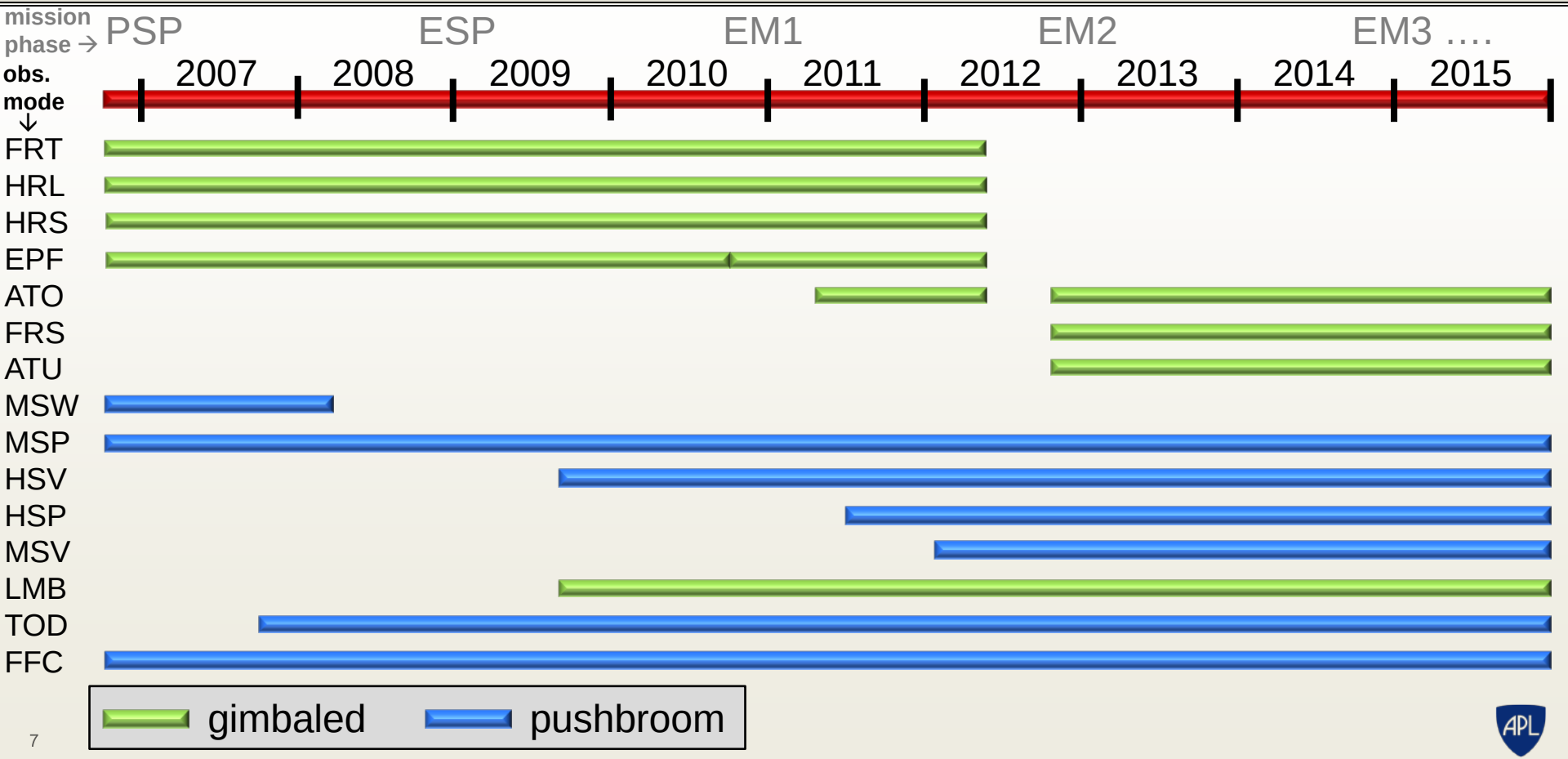
CRISM observing schematic & gimbal range of motion

Original range of gimbal motion
+60° to -60°





History of CRISM Observing Modes



Part I. Data Access Demo

- **A live demonstration of the Orbital Data Explorer (ODE) at the PDS Geosciences Node**
  - **http://pds-geosciences.wustl.edu/**

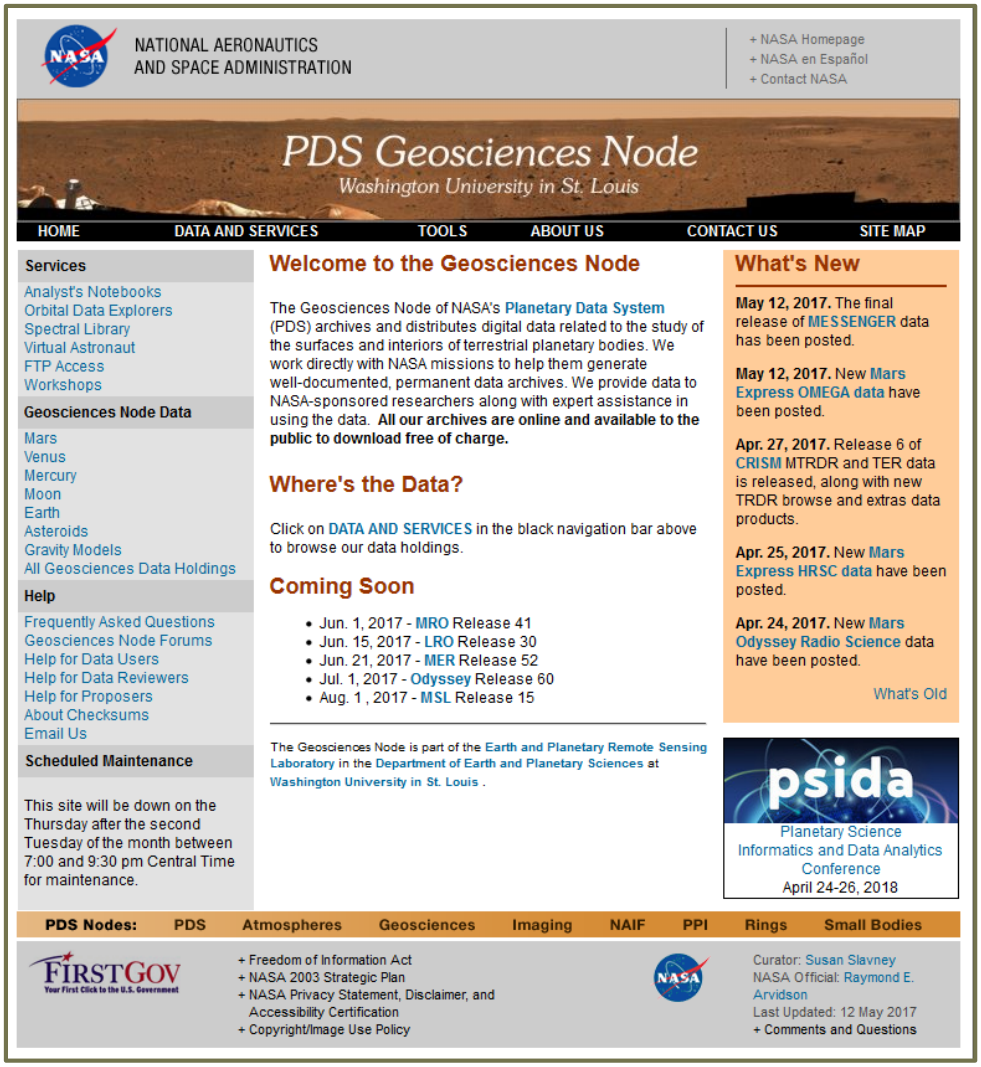
Extra information relevant to this section:

1. Resources\Handouts\Accessing CRISM Data through PDS Geo Node.pdf

What is the Planetary Data System?

- The Planetary Data System (PDS) is a NASA-funded organization that archives science data from NASA's planetary missions.
- PDS responsibilities are:
  - To help NASA missions and other data providers to organize and document their digital planetary data,
  - To collect complete, well-documented planetary data into archives that are peer-reviewed,
  - To make the planetary data available and useful to the science community,
  - To ensure the long-term preservation and usability of the data.
- PDS consists of a set of discipline nodes – the Geoscience Node handles data related to the study of the surfaces and interiors of terrestrial planetary bodies.

PDS Geosciences Node as an Example Discipline Node



- http://pds-geosciences.wustl.edu/
- Focus on Mercury, Venus, Earth's Moon, Mars
- Directed by scientist who uses the archives
- Extensive cooperation with other Nodes
- Active in PDS-wide standards development
- Participants in international development of standards
- Close coordination with missions for archive planning, validation, and delivery

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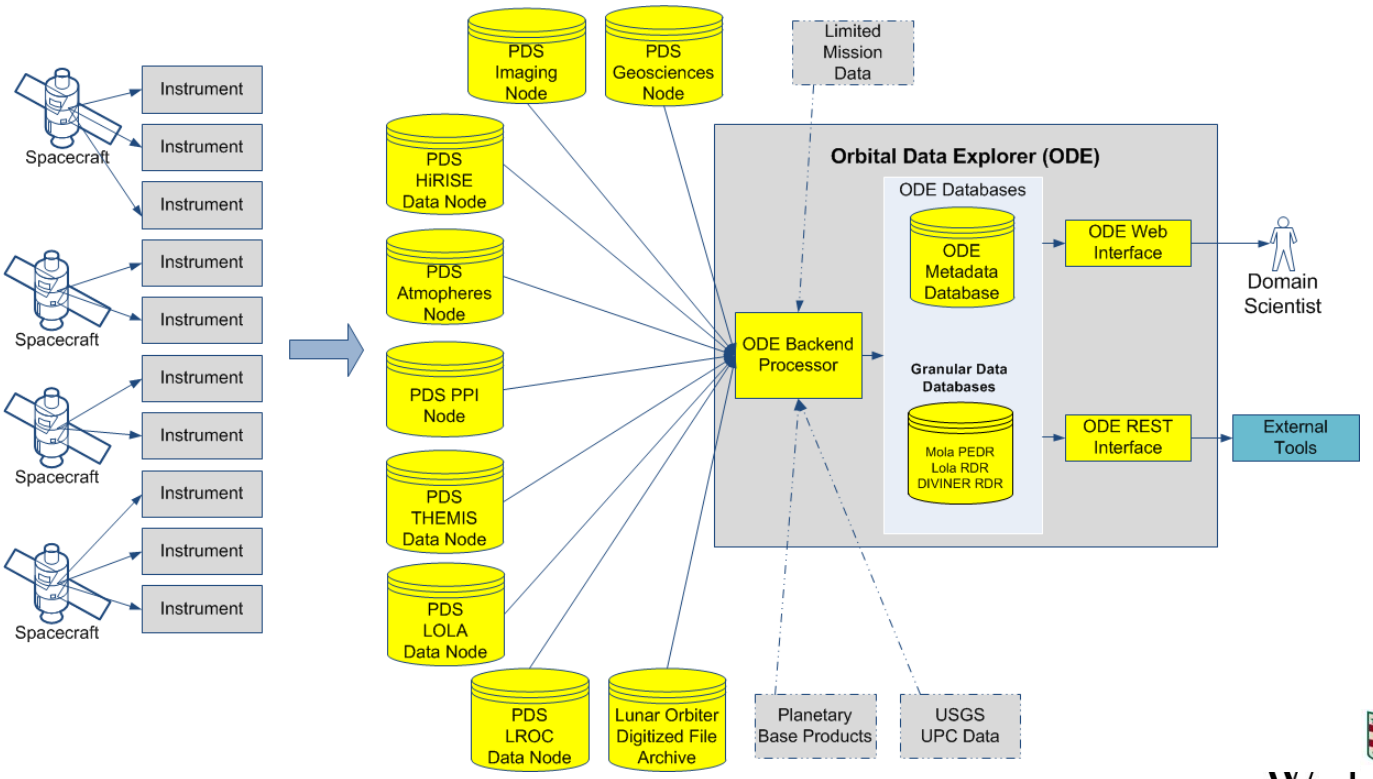
What is Orbital Data Explorer (ODE)

- A specialized PDS web tool for online search, display, and download of planetary data.
- Consists of a back-end processor, a metadata database, a granular database, a front-end web interface, and a web-based REST interface.



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ODE Data Inventory

- Provides access to data from 13 planetary missions and over 50 individual instruments
- Includes 21 million PDS data products with a volume of 1.13 petabyte

Mars Missions

MRO, * June 1, 2017- Release 41
Odyssey, * July 1, 2017 - Release 60
Mars Express, *
MGS *
Viking Orbiter *

Mercury Missions

MESSENGER, * May 12, 2017- Release 16

Moon Missions

LRO, * June 15, 2017 - Release 30
ISRO's Chandrayaan-1 *
GRAIL *
Clementine *
Lunar Prospector *
Lunar Orbiter *

Venus Missions

Magellan *

- * represents active missions
- * represents past missions

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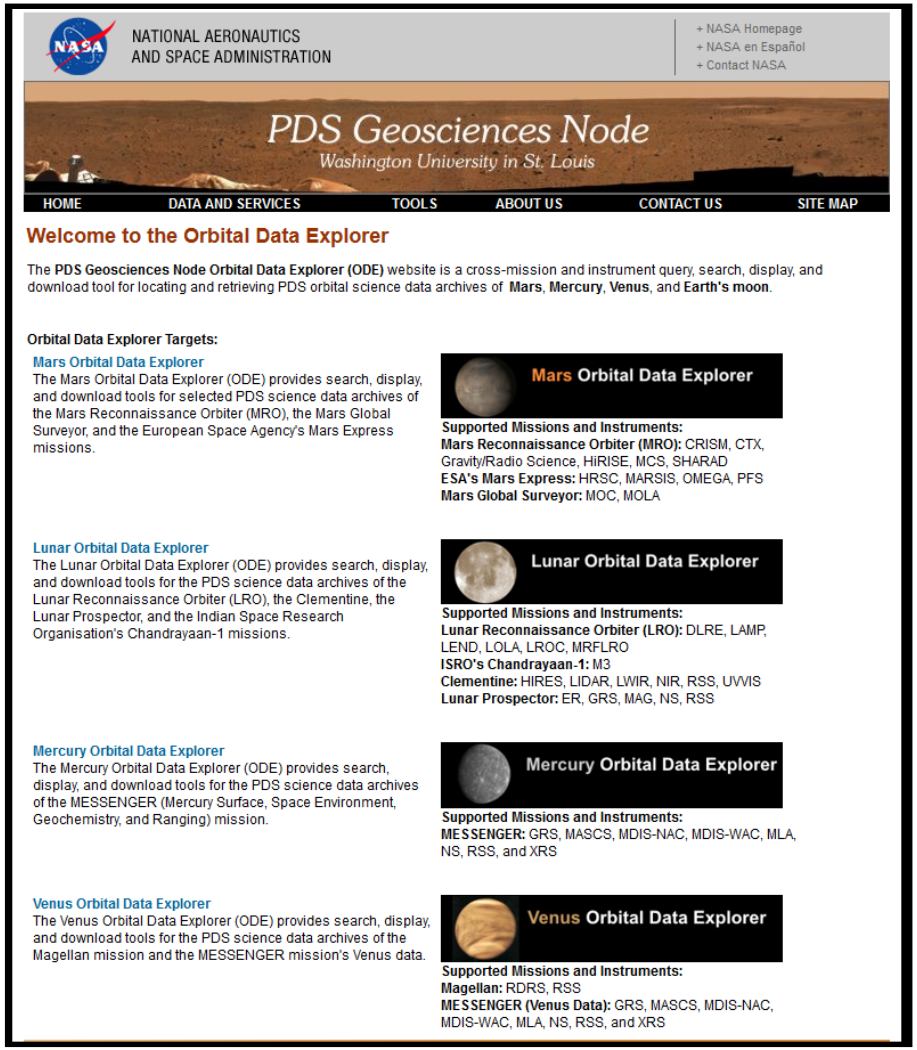
ODE http://ode.rsl.wustl.edu/



- Cross-mission and instrument searches across PDS Nodes
- Form-based, coverage-based, and map-based searches
- Feature-based searches, e.g., by crater name
- Granular data search (GDS)
- MRO coordinated observations
- Product type coverage KML files and shapefiles provided
- REST included to allow access of the ODE metadata and products
- Custom archives for delivery

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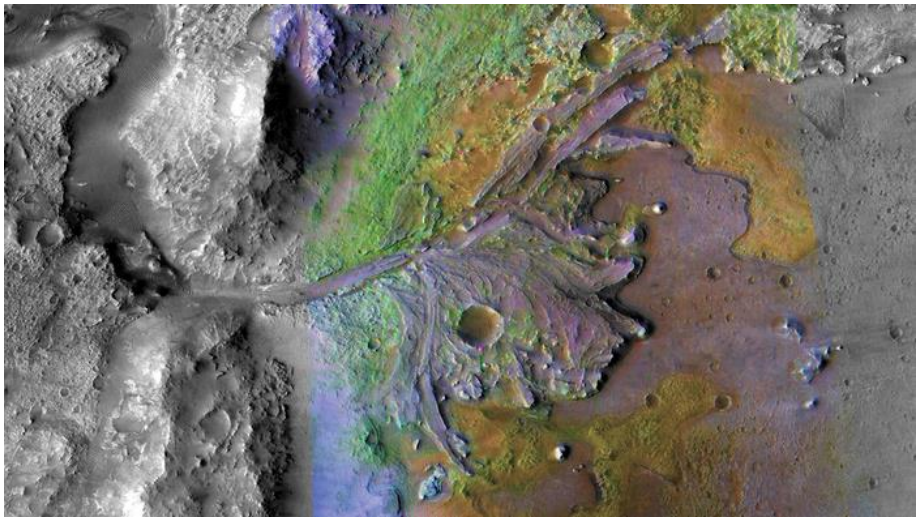
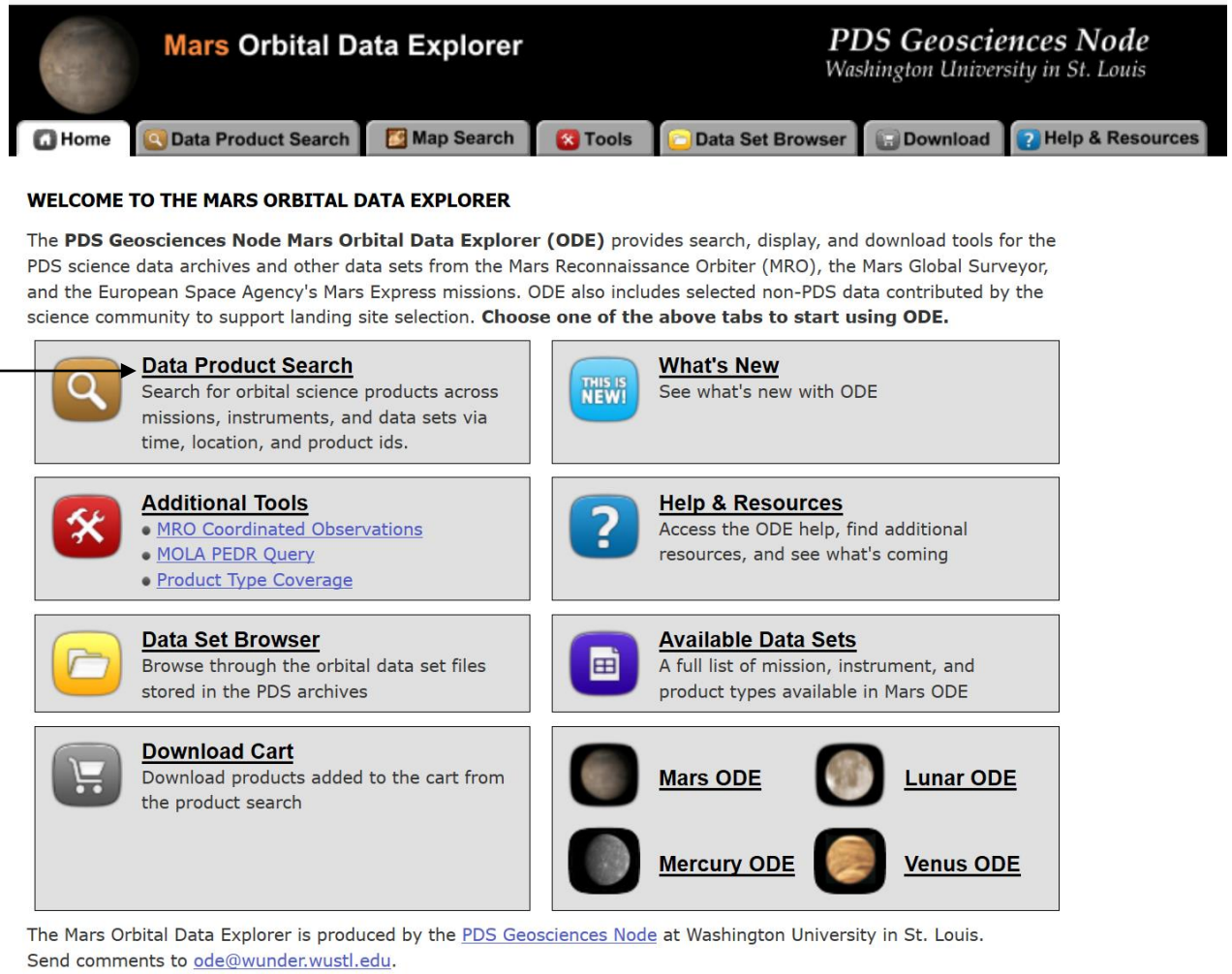
ODE Example Search and Retrieval

- Let's use ODE to find and download coordinated CRISM, CTX, and HiRISE data over Jezero Crater and its deltaic deposits, one of three candidate landing sites for the NASA 2020 Rover Mission



ODE Example Search and Retrieval



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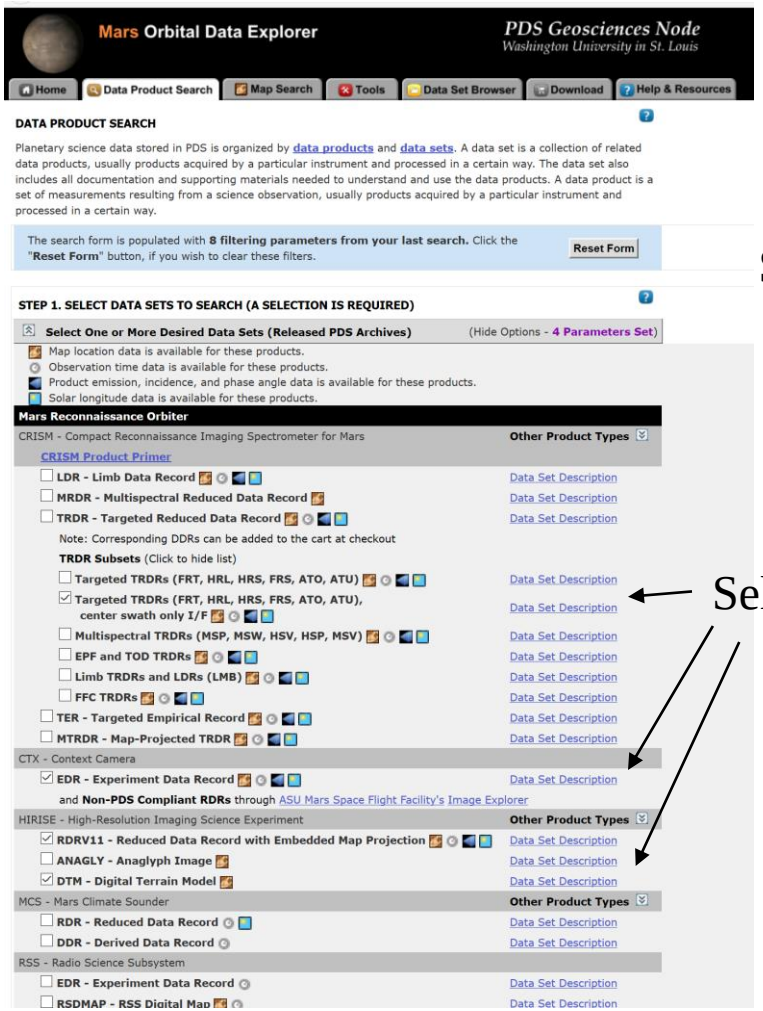
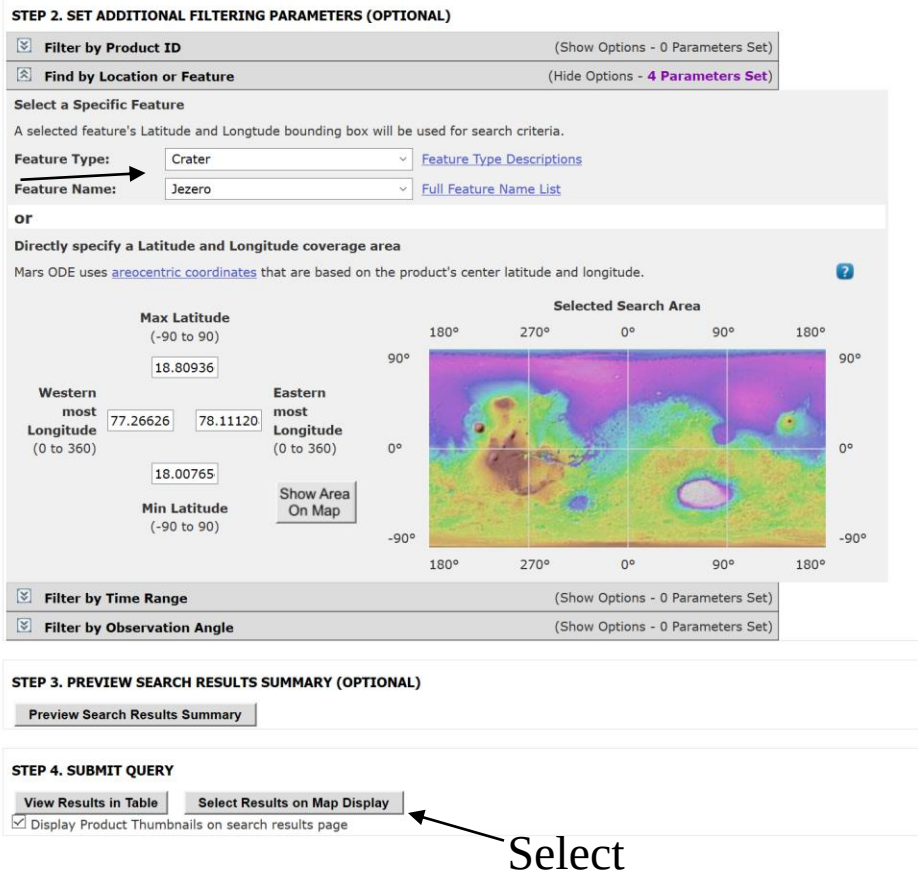
ODE Example Search and Retrieval



Select

Select



Select

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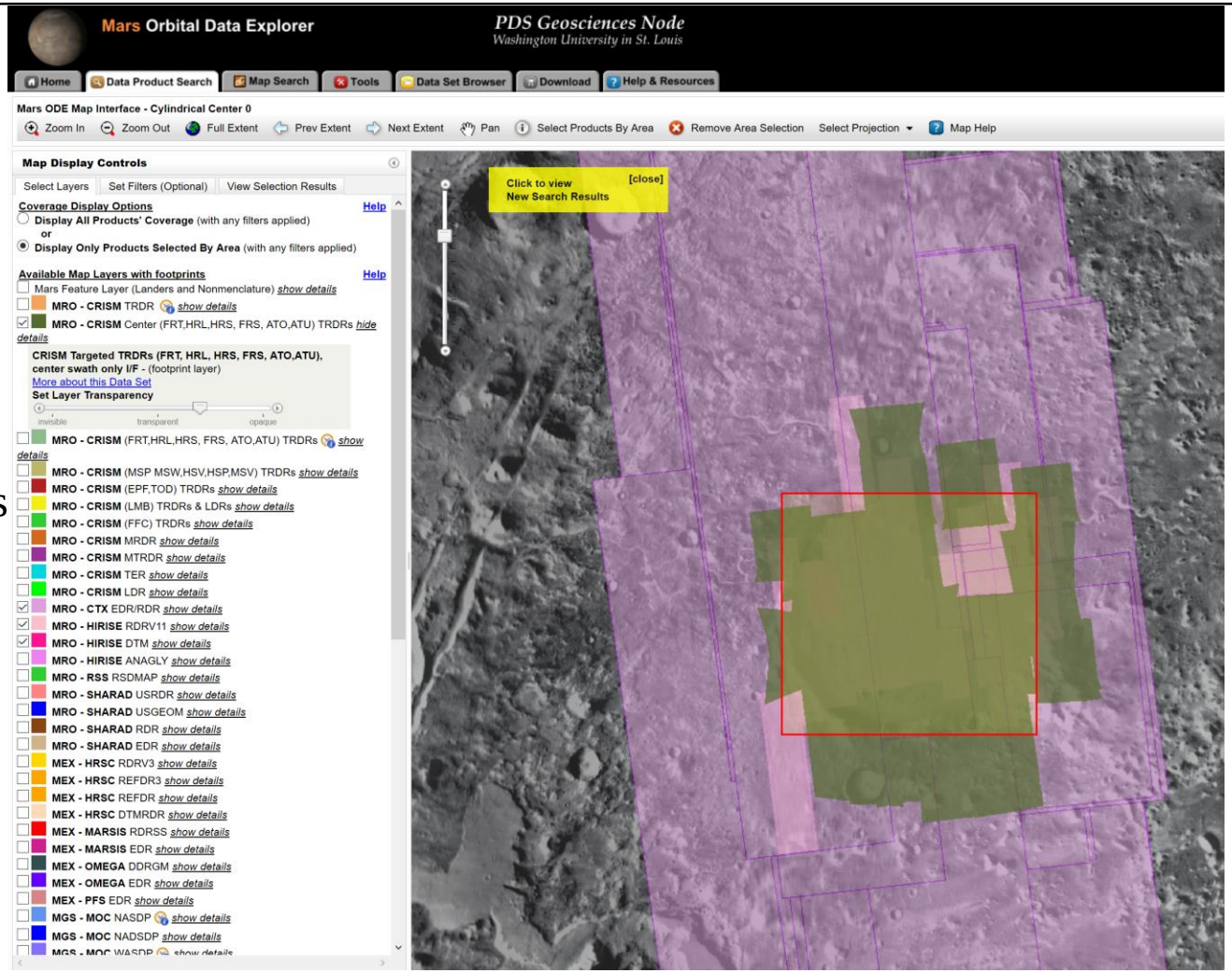
ODE Example Search and Retrieval



Layer definitions

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ODE Example Search and Retrieval

Page after "View Selections" toggled

Select

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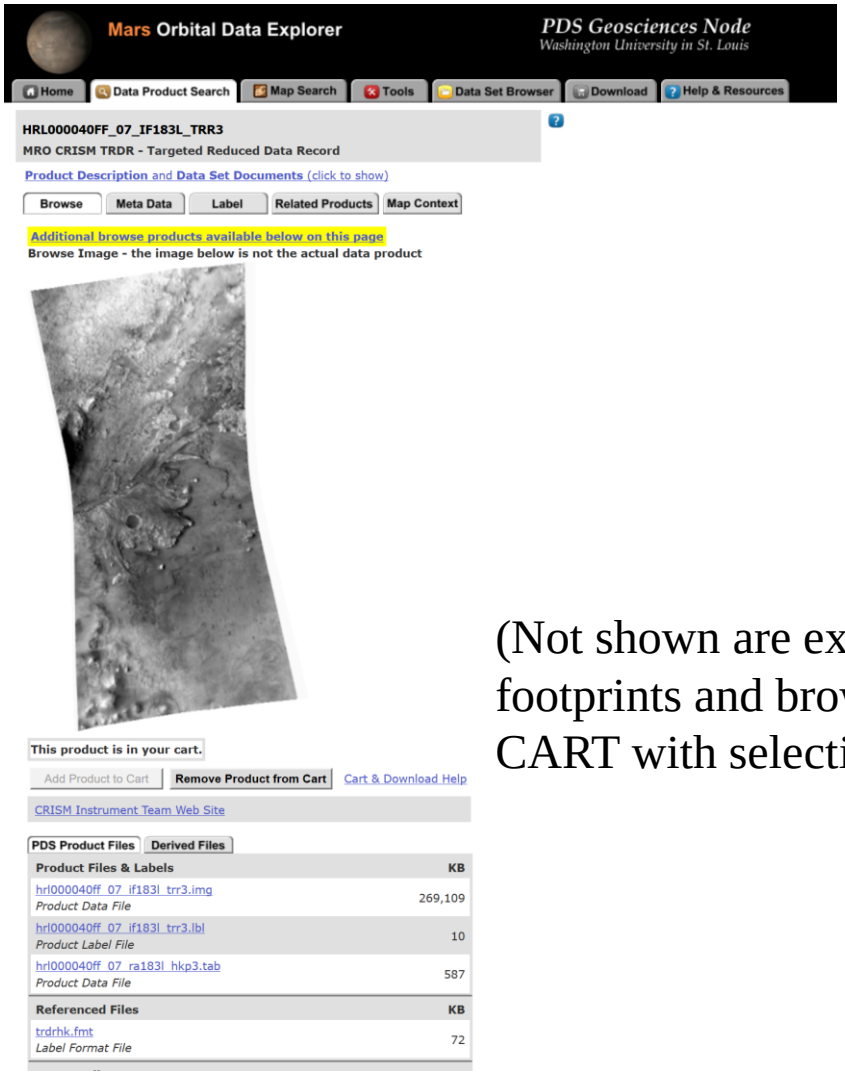
ODE Example Search and Retrieval

Shown after clicking on image thumbnail



(Not shown are examining CTX and HiRISE footprints and browse images and updating CART with selections)

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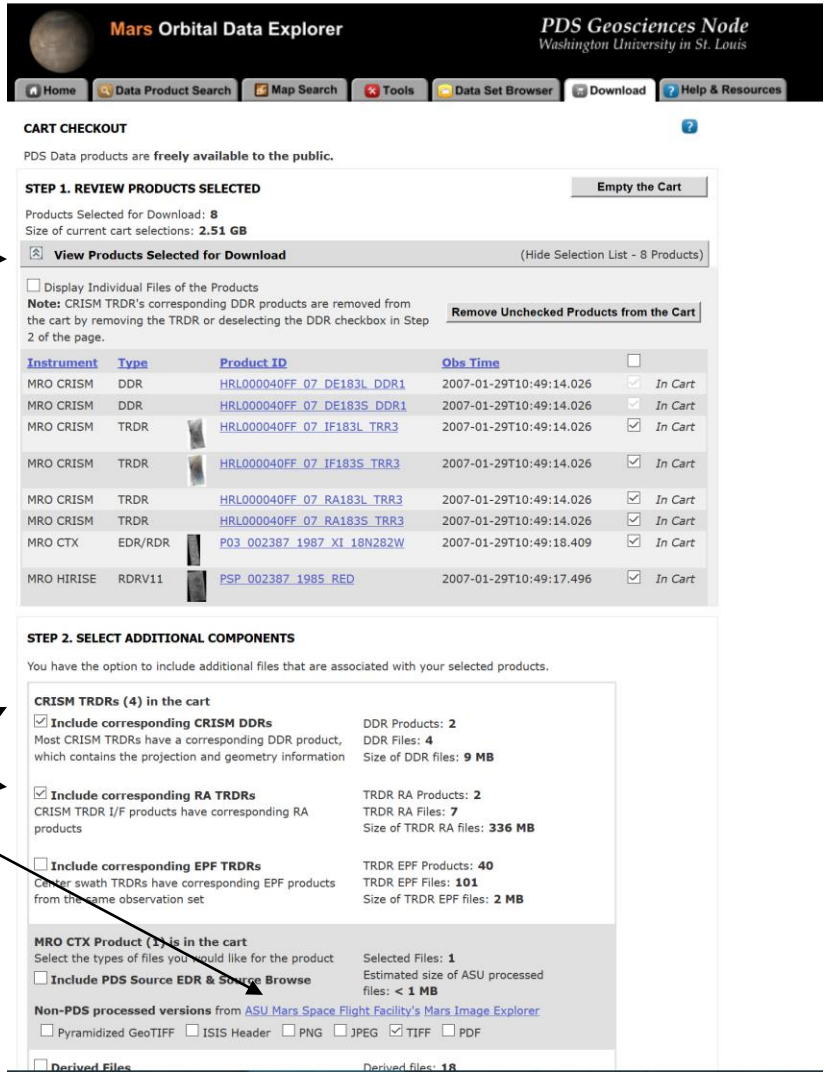
ODE Example Search and Retrieval



Select

Select

(Not shown are compression and data set organization options, along with download instructions)

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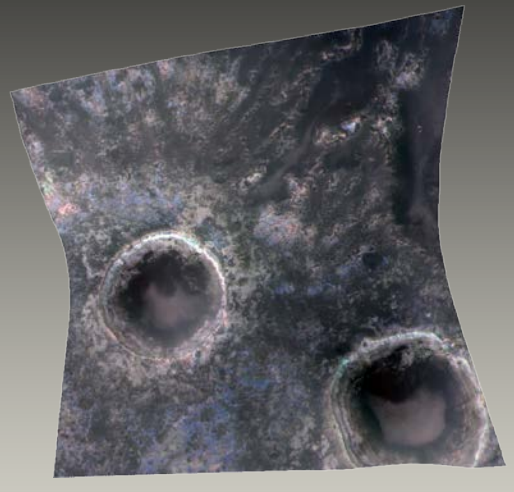
Contacts

- Send e-mails to ode@wunder.wustl.edu
- Post on the forum https://geoweb.rsl.wustl.edu/community/
- Links
  - ODE: http://ode.rsl.wustl.edu/
  - PDS Geosciences Node: http://pds-geosciences.wustl.edu/
  - The REST interface: http://oderest.rsl.wustl.edu/live/

Part II. Standard Processing

- **Real-time tutorial for how to process an example CRISM targeted observation using the CRISM Analysis Toolkit (CAT)**
- **FRT000094F6 (or scene of your choice) will be used**



Extra information relevant to this section:

1. Data\CRISM_pds_archive\...
2. Resources\Handouts\CRISM_filename_convention_and_common_ tasks.pdf
3. Resources\Publications\Viviano-Beck_JGR_2014_summary_ parameters.pdf
4. Presentations\Ancillary\CRISM_data_filetype_details.pdf
5. Presentations\Ancillary\CRISM_File_Naming_Convention.pdf

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 Harris Geospatial.

- 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.

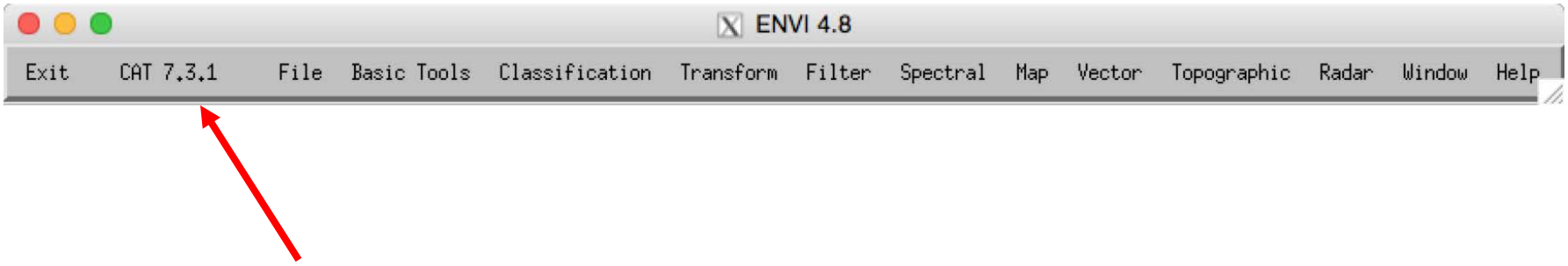
CAT Distribution: File Locations

- IDL/ENVI procedures for CAT are found under:
  - CAT_ENVI/save_add/CAT_programs
- Calibration Data Records (CDR):
  - CAT_ENVI/aux_files/CDRs/
- Ancillary Data Records (ADR):
  - CAT_ENVI/aux_files/ADR/
- User manuals, CRISM SIS:
  - CAT_ENVI/aux_files
- Default CAT output:
  - CAT_ENVI/out
- CAT temporary file output:
  - CAT_ENVI/tmp
    - Nominally CAT will clean up; files may be left in event of a crash; can be deleted after a session

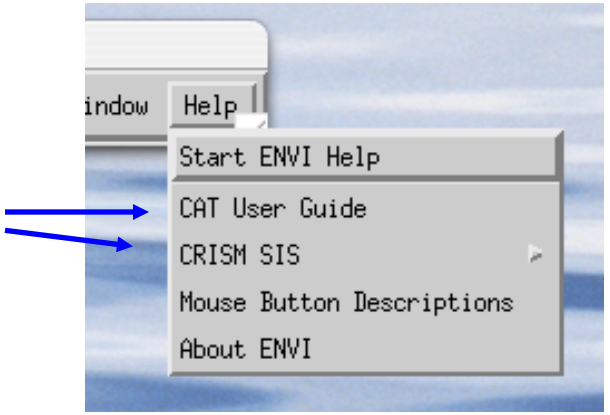
CAT Setup

- ENVI config file:
  - Need envi.cfg in CAT_ENVI
  - Can copy from one of the defaults, envi_win.cfg, envi_unix.cfg according to OS
  - Useful things it specifies: tmp file directory, default output directory, spectral library directory, default data directory (where it looks first to open files)
- CAT config file:
  - CAT_ENVI/catconfigs/crismcat*.cfg
    - Replace * with any text, or omit
    - Can have multiple configs (multiple users, customized analysis, etc)
      - **select at startup, reload during session if desired**
    - Not required
    - PDS path, aux_files path, default volcano scan

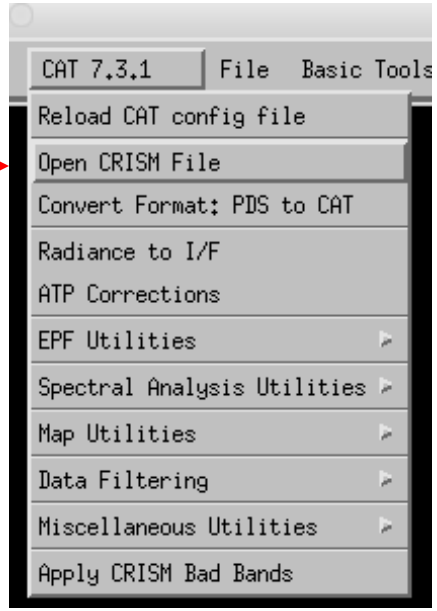
CAT Startup



- When CAT installed, ENVI starts with CAT menu added
  - includes CAT version number
- Additional CAT-specific items added under Help and Display/Tools menus



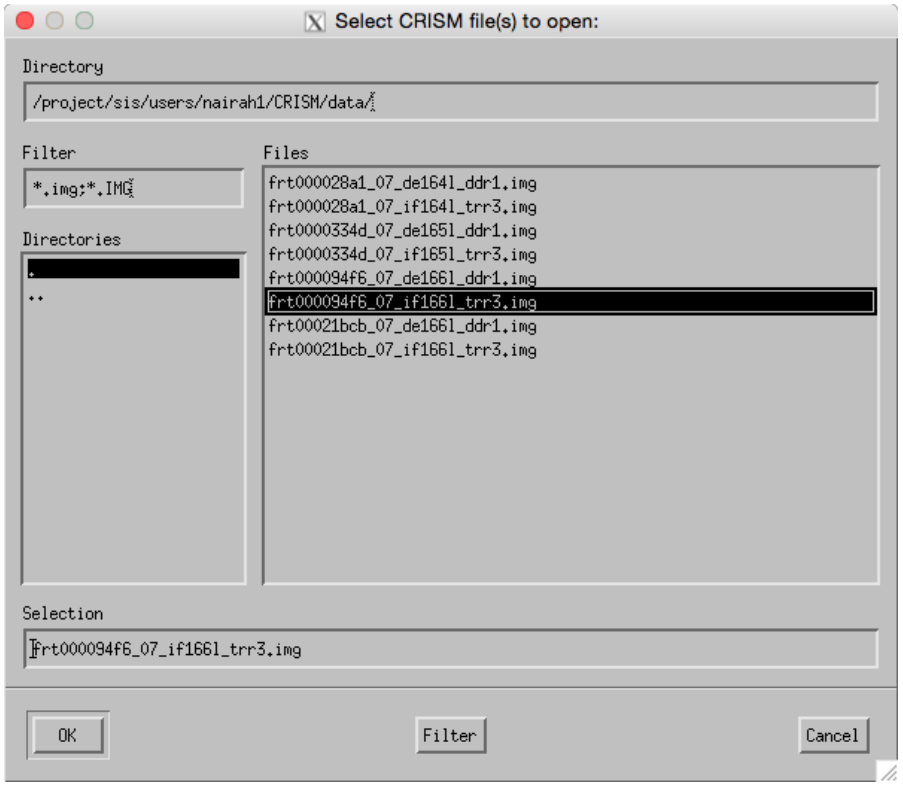
Open CRISM File



INPUT DATA:

- CRISM PDS image file (*.img)
- Corresponding PDS label (*.lbl)
  - example: frt000094f6_07_if166l_trr3.img
    frt000094f6_07_if166l_trr3.lbl

select input file in the ENVI dialog box that pops up



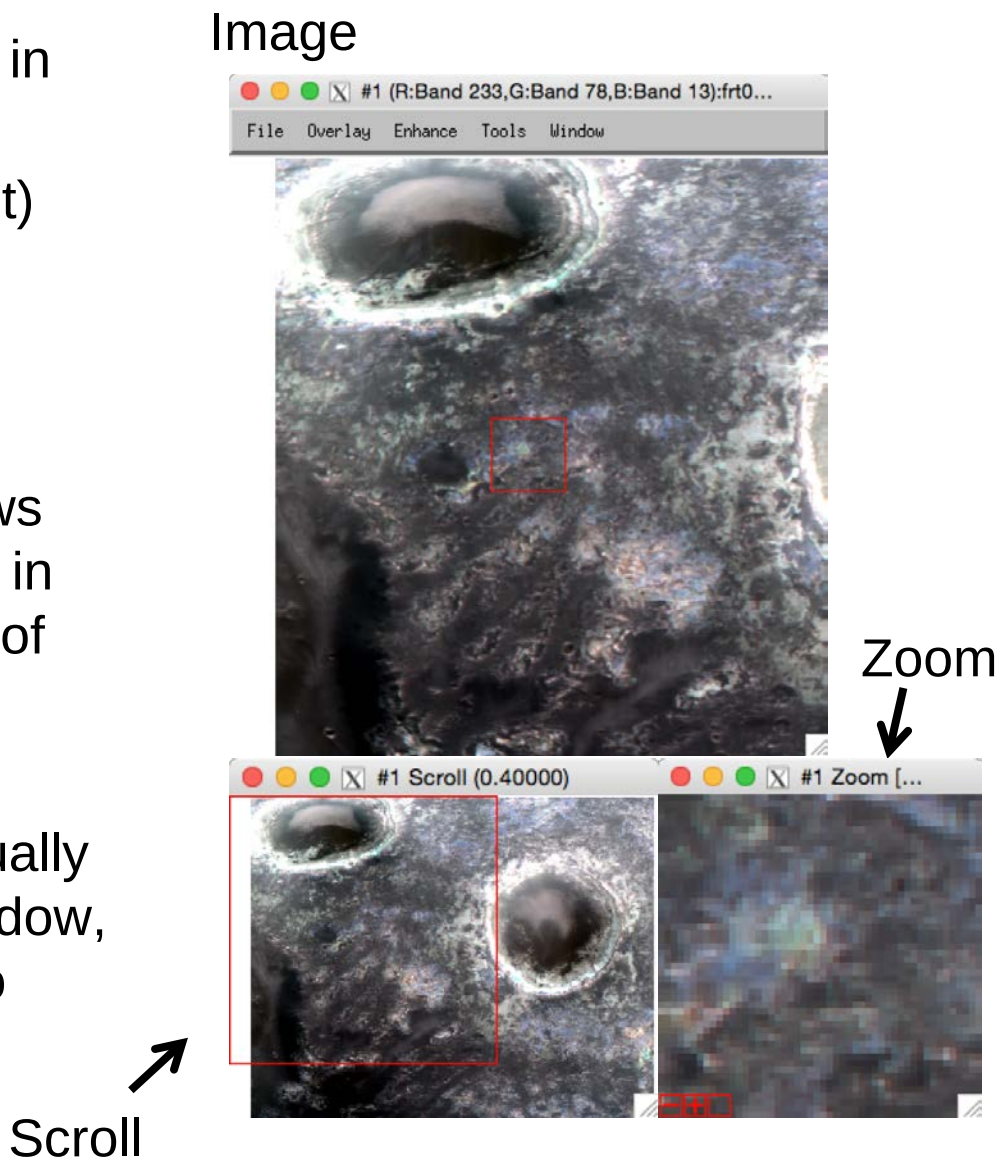
Opens CRISM data in ENVI *Available Bands* and *Display* windows

CRISM Data Files

- TRDR
  - Spectral image data
  - Filename like FRT000094F6_07_IF166L_TRR3.IMG
- DDR
  - “Backplanes” for TRDR files; geometry data including lat/lon, emission angles, elevation, other…
  - Filename like FRT000094F6_07_DE166L_DDR1.IMG
  - CAT wants to see DDRs and PDS labels along with the image data either in same directory (usual practice) or in a parallel directory structure like:
    - ...trdr/TRDR/YYYY_DDD/FRT000094F6/.IMG, *.LBL
    - ...ddr/DDR/YYYY_DDD/FRT000094F6/*.DDR, *.LBL
- MTRDR
  - Filtered TRDR data to reduce noise and correct atmospheric and photometric effects, summary parameters, join S + L cubes, map projection

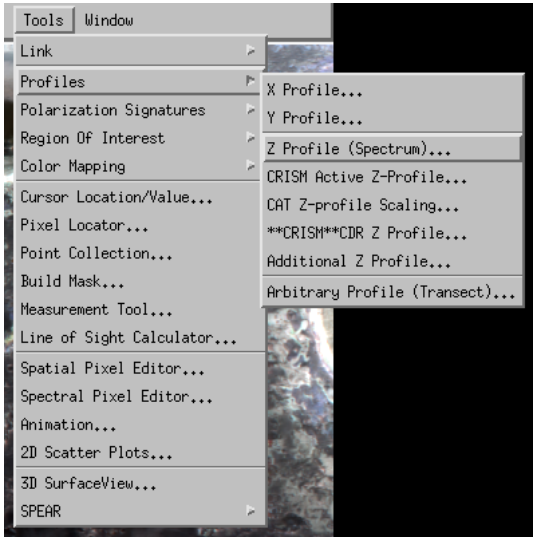
Initial Display of Image Cube

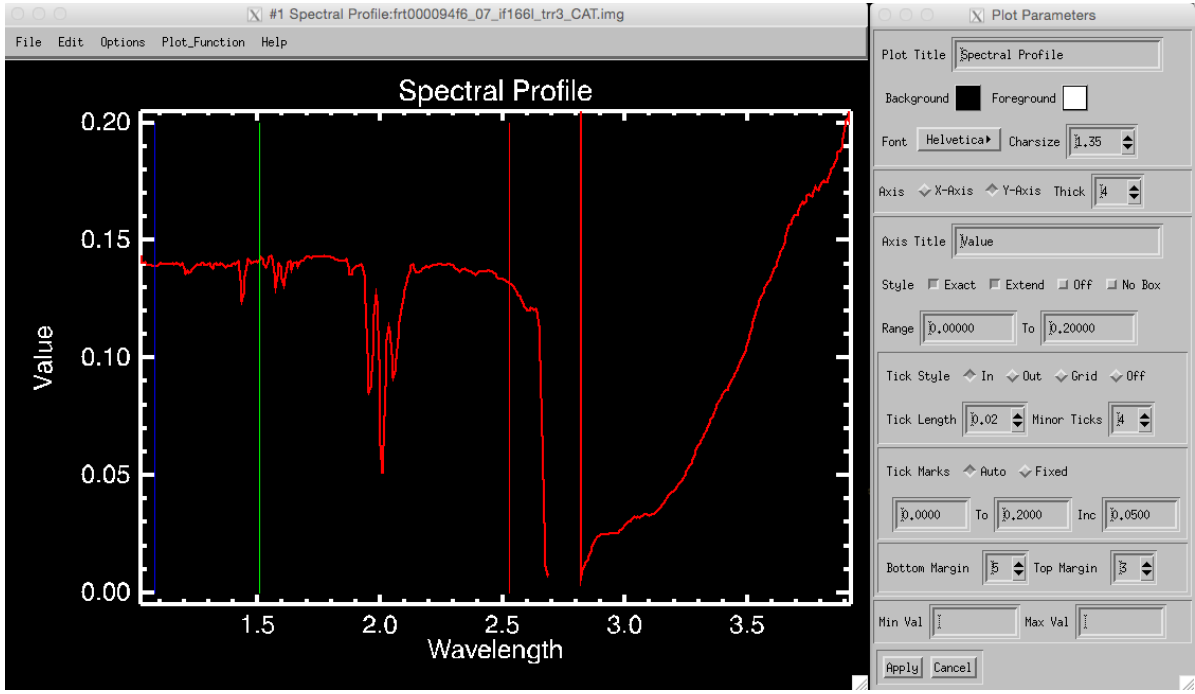
- Any image cube is initially opened in ENVI in a cluster of 3 windows.
  - Scroll (shows full spatial extent)
  - Image (full spatial resolution)
  - Zoom (4x resolution subset)
- Red box in the Scroll window shows location of Image window; red box in the Image window shows location of Zoom window.
- HINT: For CRISM images, it is usually helpful to maximize the Image window, after which the Scroll window is no longer needed.



Displaying a Spectrum

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





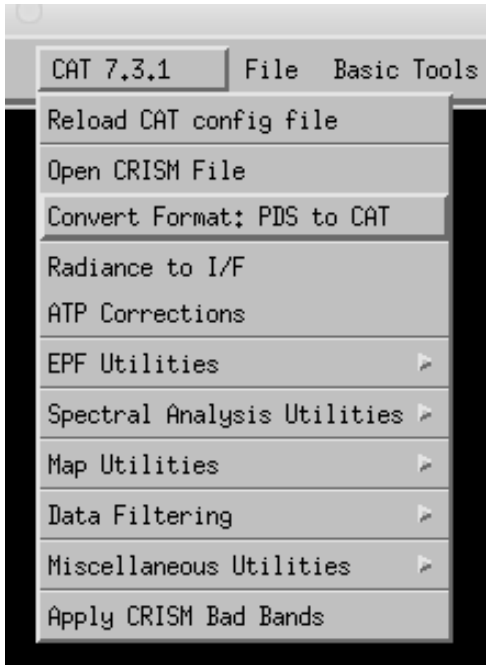
Z-profile extracted at Zoom window location.

Plot parameters can be set from Spectral Profile window, Options > Plot_Parameters

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

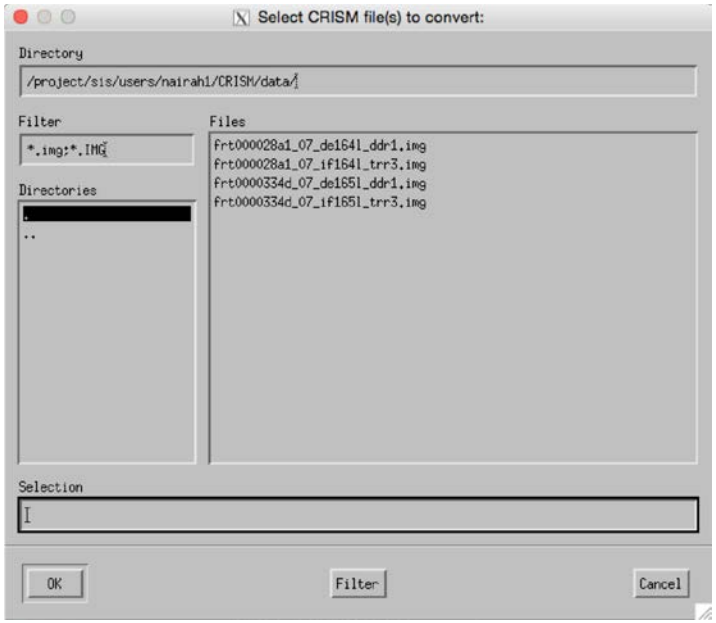
Simple Image Processing and Summary Parameters

CAT: Convert PDS to CAT



- CRISM PDS data for IR channel:
  - Spectrum stored long-to-short
  - Last wavelength 65535 (CRISM invalid data code)
- Convert Format: PDS to CAT
  - Reverses order of IR spectrum
  - Replaces the 65535 wavelength with 4.0 microns

Select input PDS file to convert here



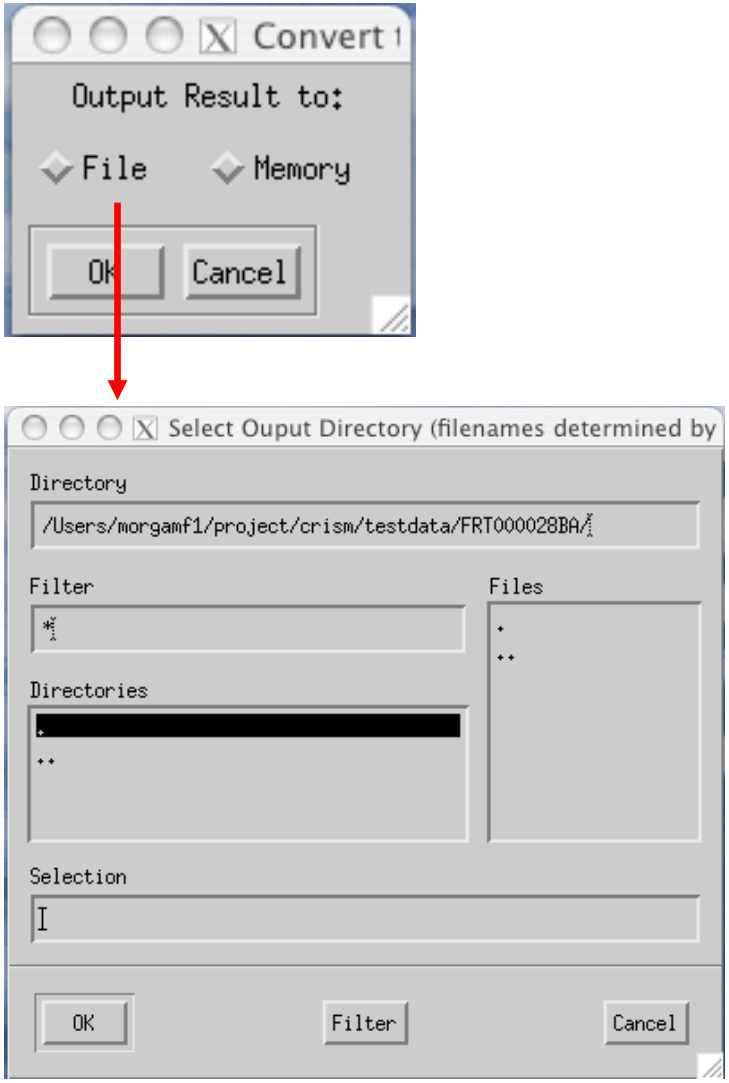
CAT: File or Memory?

Common CAT question: Output to file or memory?

Select “File,” then select an output path and, usually, filename via the ENVI dialog:

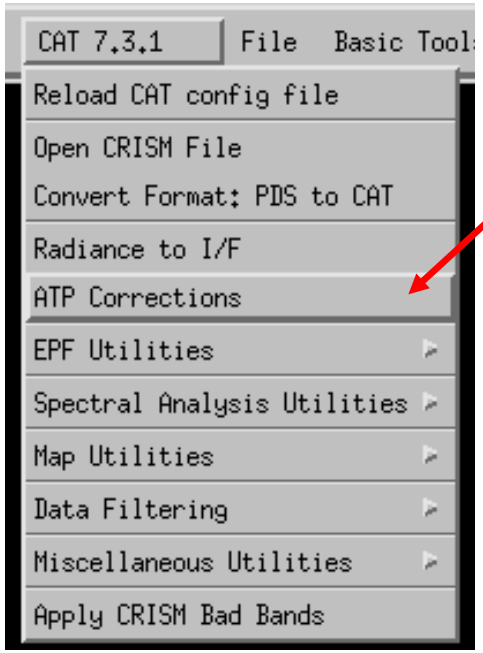
OR…

Select “Memory” and computation proceeds, with output to Available Bands and Display window

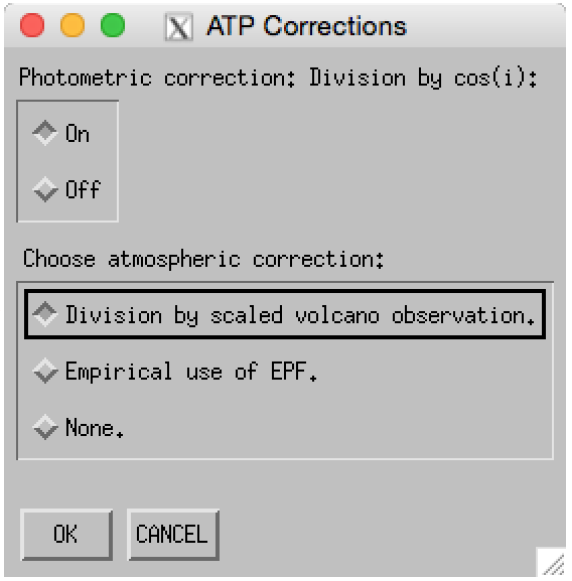


CAT: Photometric & Atmospheric Corrections

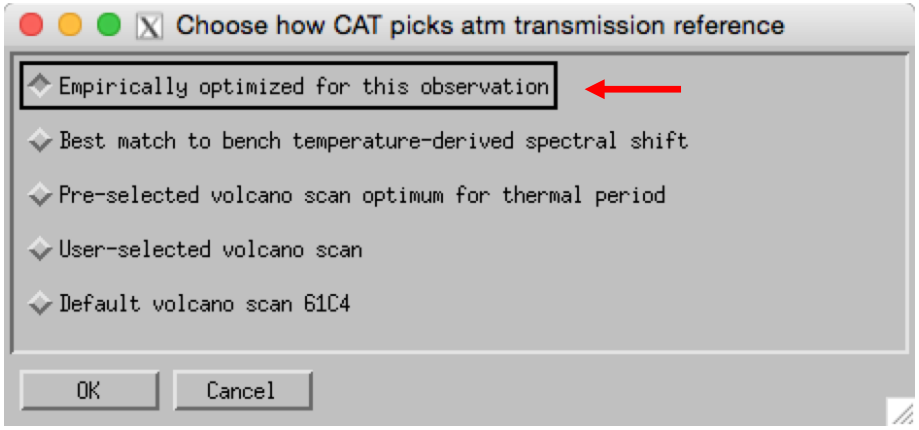
1. File selection dialog… then select corrections



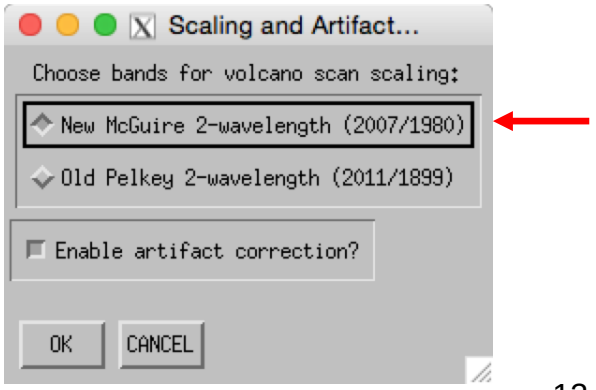
2.



3. Choose volcano scan selection method…



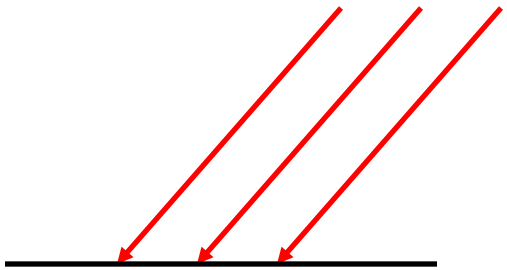
4. Select scaling wavelengths…



Photometric Correction…

First order correction to radiance for non-normal solar incidence:

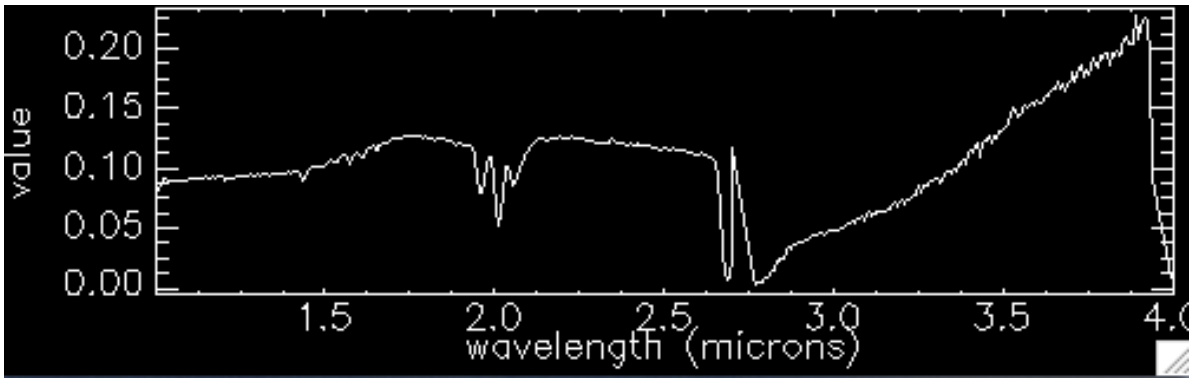
Divide by cos(incidence angle)



Get incidence angle at aeroid from DDR (ancillary data file)

CAT: Atmospheric Correction Behind the Scenes

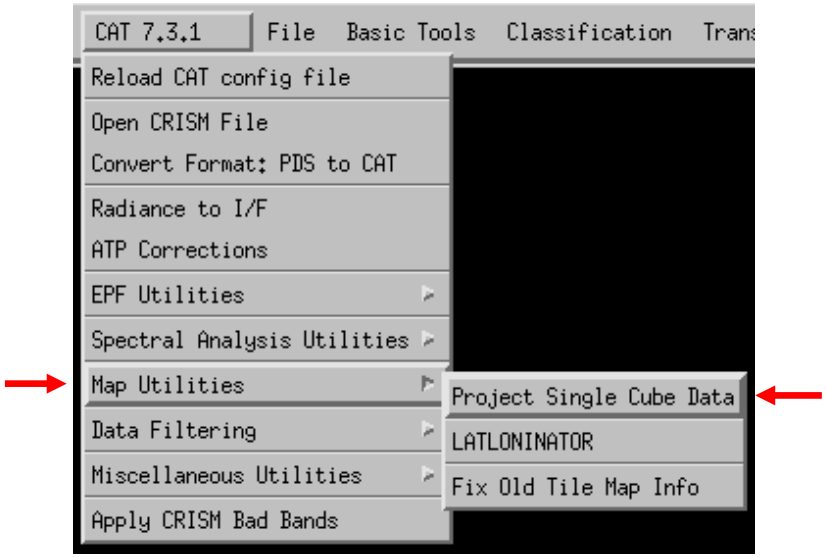
- Atmospheric Correction: Need to correct spectrum for absorption by CO_2
  - Volcano scan: special observation viewing nadir on traverse across Olympus Mons
  - Estimate atmospheric transmission =
    (base spectrum) / (summit spectrum)
  - Correct a scene spectrum by scaling the volcano scan transmission to match the scene at 2 wavelengths near the CO_2 2-micron band, then divide
    - One near absorption peak, one in wings
    - Adjusts for variable atmospheric optical depth- elevation, season…

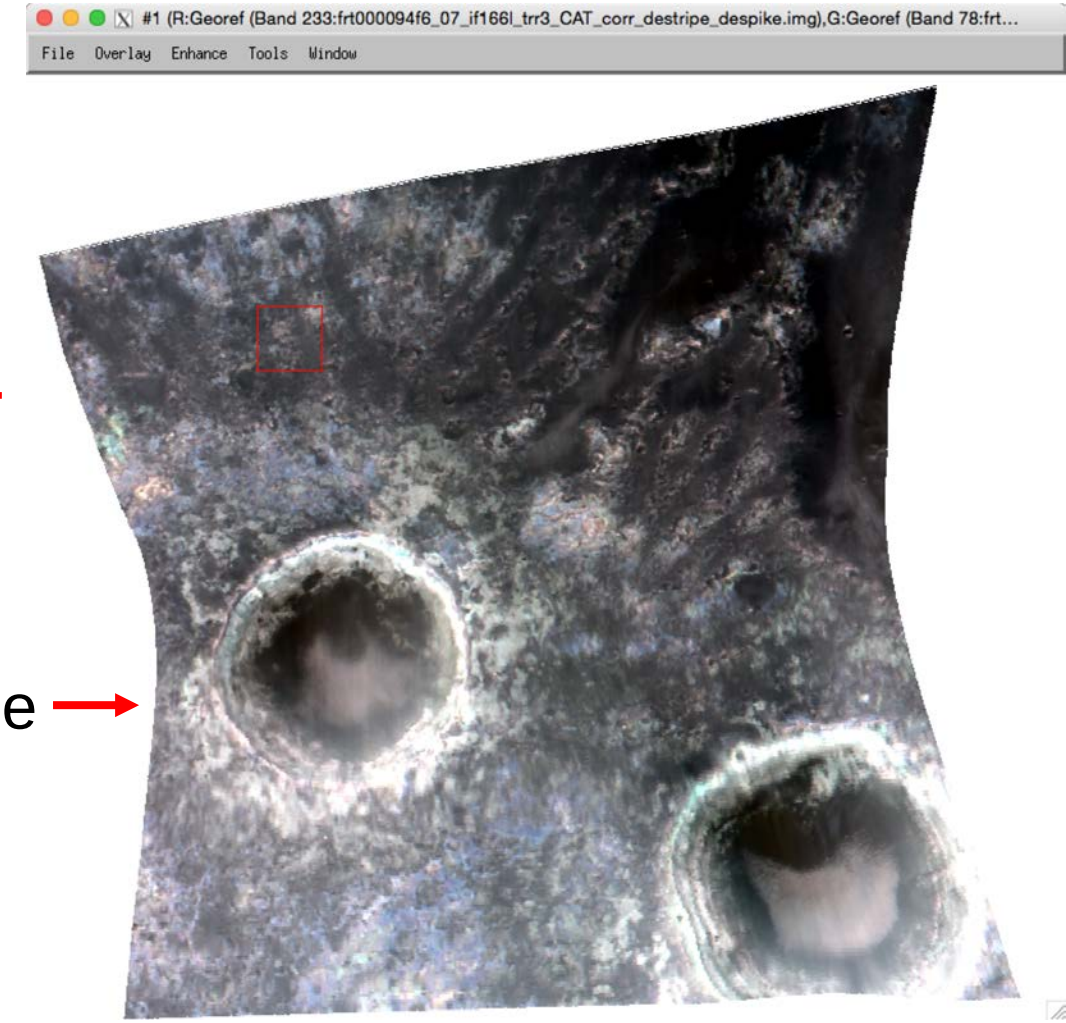


CAT: Atmospheric Correction Behind the Scenes

- Selecting scaling wavelengths: 2 options…
  - McGuire 2-wavelength (2007/1980) [recommended]
    - 2007 nm near absorption peak
    - 1980 nm in wing, but close to 2007 to reduce systematic error in presence of broad mineralogical absorptions near 2 microns
  - Pelkey 2-wavelength (2011/1899)
    - Original wavelengths in CAT
    - Closer match to OMEGA correction
    - Occasional artifacts from scaling errors caused by mineralogical abosrption affecting 2011 but not 1899

Map Projection Utilities



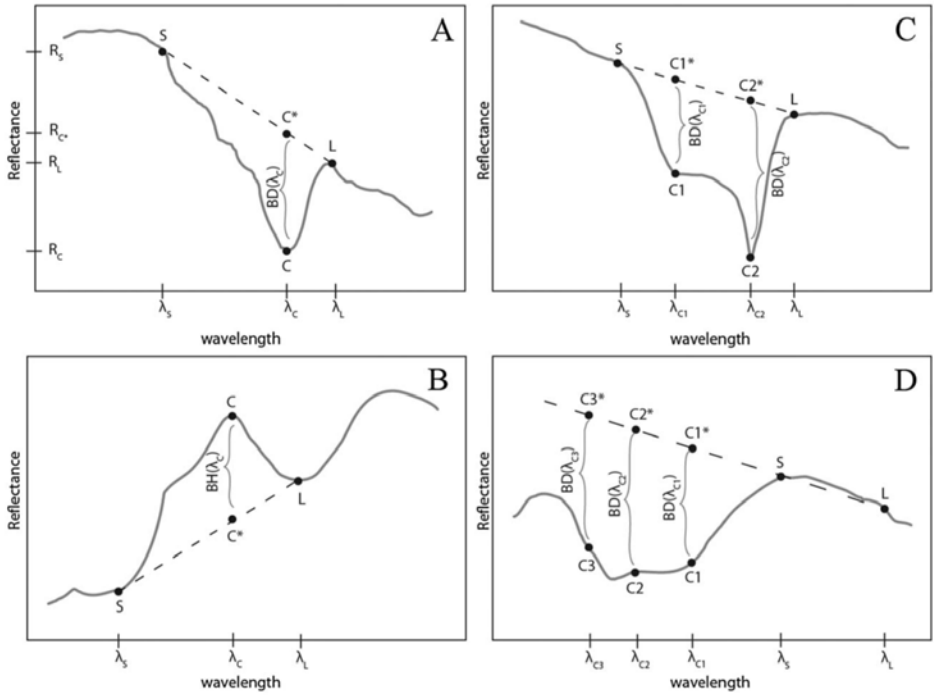


Output is map-projected cube

- Corrected spectral data
- Summary parameters

Summary Parameters

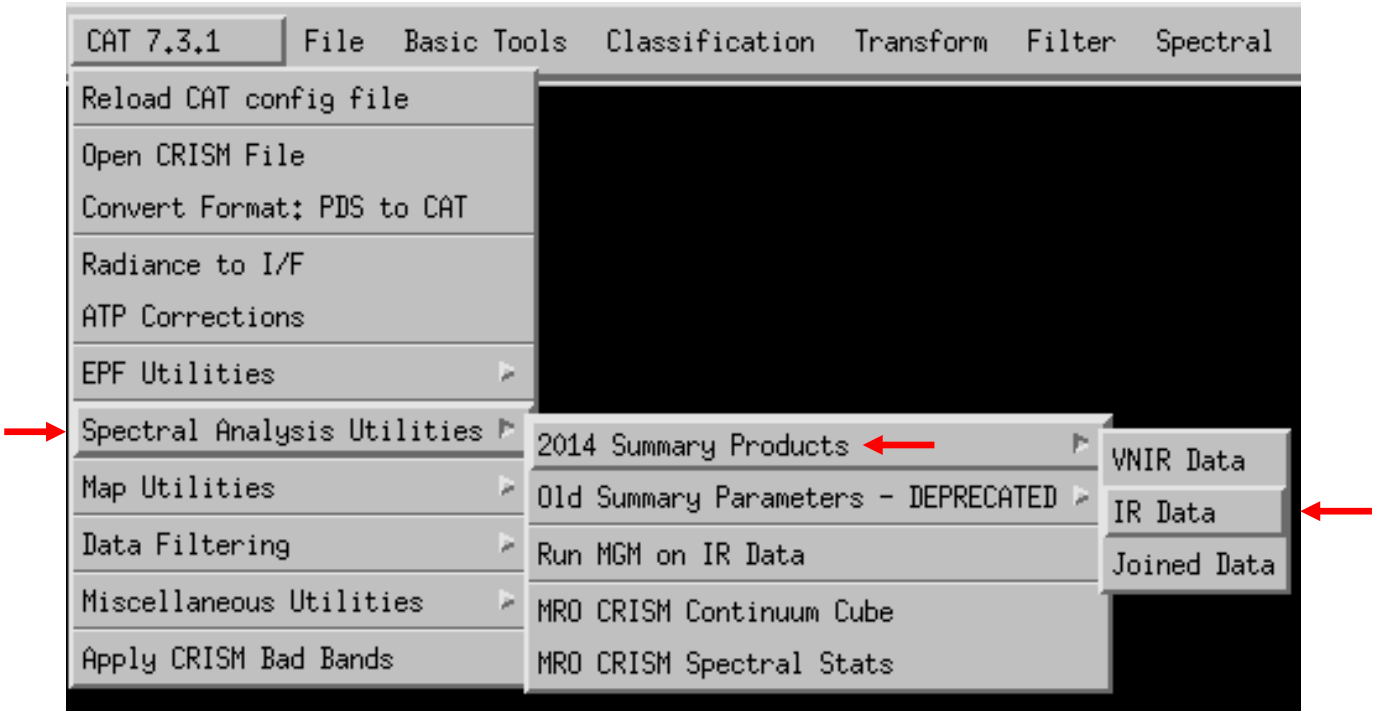
- **Summary Parameters** are algebraic measures of the strengths and positions of possible mineral absorptions

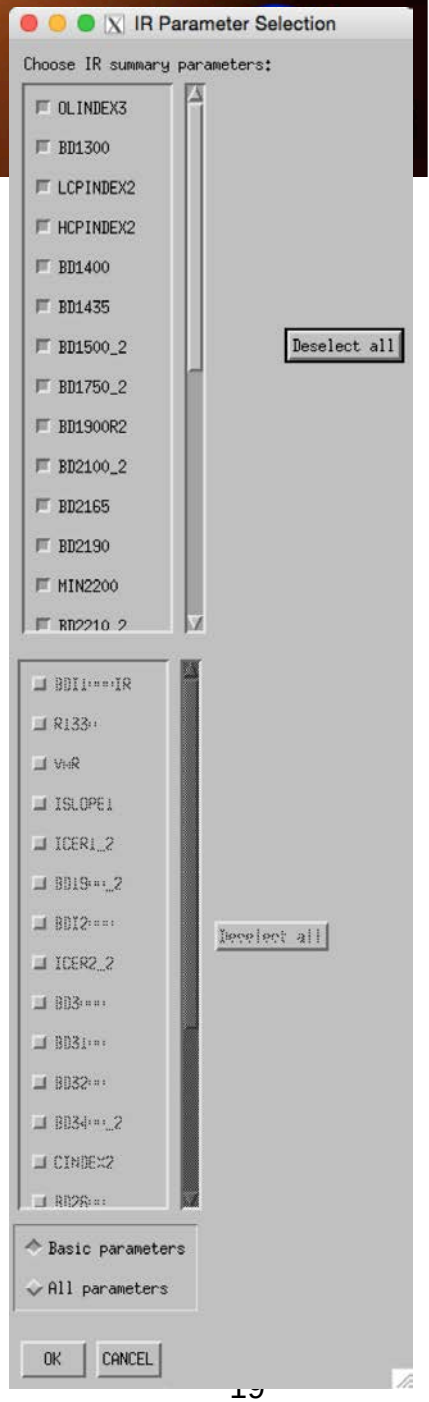


Viviano-Beck, C. E., et al. (2014), Revised CRISM spectral parameters and summary products based on the currently detected mineral diversity on Mars, J. Geophys. Res. Planets, **119**, 1403–1431, doi:10.1002/2014JE004627

Figure 7. (a–d) A visual representation of several spectral parameter formulations using idealized spectra. The solid line is a hypothetical spectrum with the generalized spectral feature superimposed on the sloped continuum. The dashed line indicates a continuum fit across the absorption band by which a reflectance point along the continuum is calculated. See sections 4.1–4.4 for a description of each formulation.

Spectral Analysis Utilities

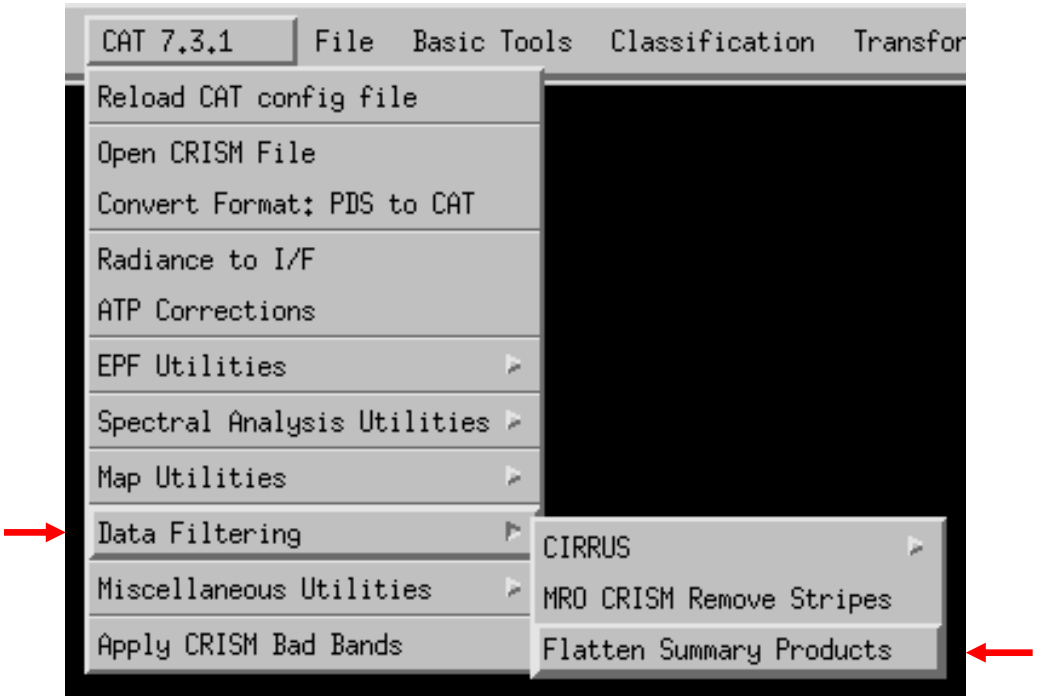




Choose ‘basic’ set or ‘all’ parameters

CAT: Data Filtering

- **Flatten Summary Products**
  - Helps mitigate column striping in summary product images



The other data filtering functions in CAT (CIRRUS despike/destripe, and Remove Stripes) are not recommended for use with TRR3 CRISM data – they were designed for use on previous calibration versions.

Part III. MTRDRs and Data Visualization

- **A brief overview of MTRDR processing and products**

Extra information relevant to this section:

1. Data\CRISM_pds_archive\...
2. Resources\Handouts\CRISM_MTRDR_processing_flowchart.pdf
3. Resources\Handouts\Viviano-Beck_etal_2014_TableA3_Browse_Products.pdf
4. Resources\Publications\Viviano-Beck_JGR_2014_summary_ parameters.pdf
5. Presentations\Ancillary\CRISM_TER_MTRDR_details_extended.pdf

Overview

- The TER/MTRDR data product suite is a set of high level analysis and visualization products that will ultimately be generated and released for the majority of CRISM classic hyperspectral targeted observations
  - FRT, HRL, HRS class types
  - New CRISM targeted observation class types (FRS, ATO, ATU) under consideration/development
- The TER/MTRDR data processing chain seeks to characterize and mitigate components of the targeted observation spatial/spectral variability that are not directly related to the surface, and accommodate instrument operational characteristics that complicate surface spectral analysis:
  - Solar illumination angle
  - Atmospheric gas absorptions (IR only)
  - Continuously varying observation geometry (gimbal motion)
  - Spectral smile (optical artifact)
  - VNIR (S-detector) / IR (L-detector) spatial reconciliation
  - Noise residuals

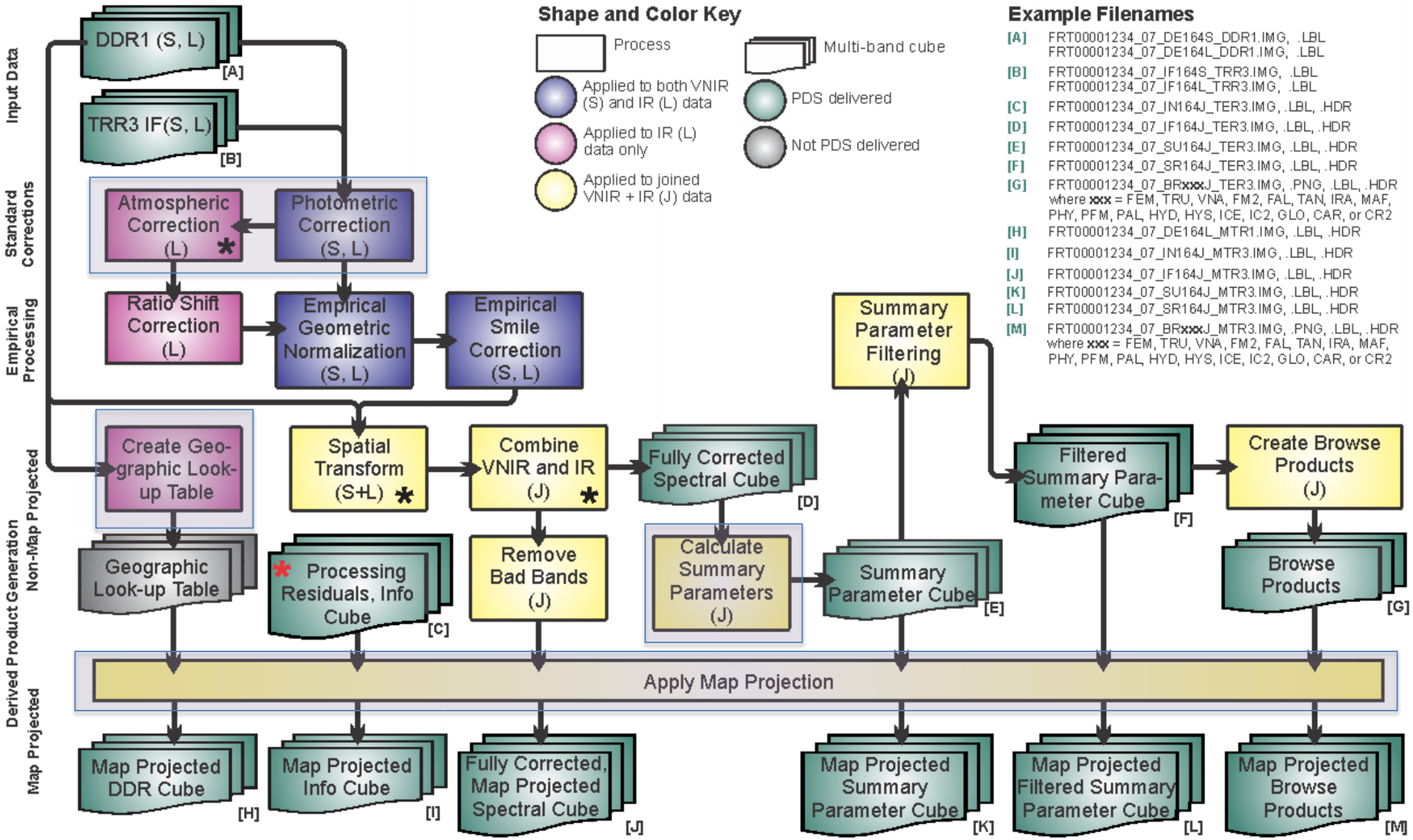
This is a superset of the typical CAT data processing workflow

- The TER/MTRDR data product suite will improve the accessibility of the CRISM hyperspectral targeted observation data set and is expected to become the main point-of-entry for the majority of the Mars science community

CRISM TER/MTRDR Workflow

CRISM CAT Functionality

CRISM TRR3 I/F to MTRDR: Pipeline Processing and Derived Products

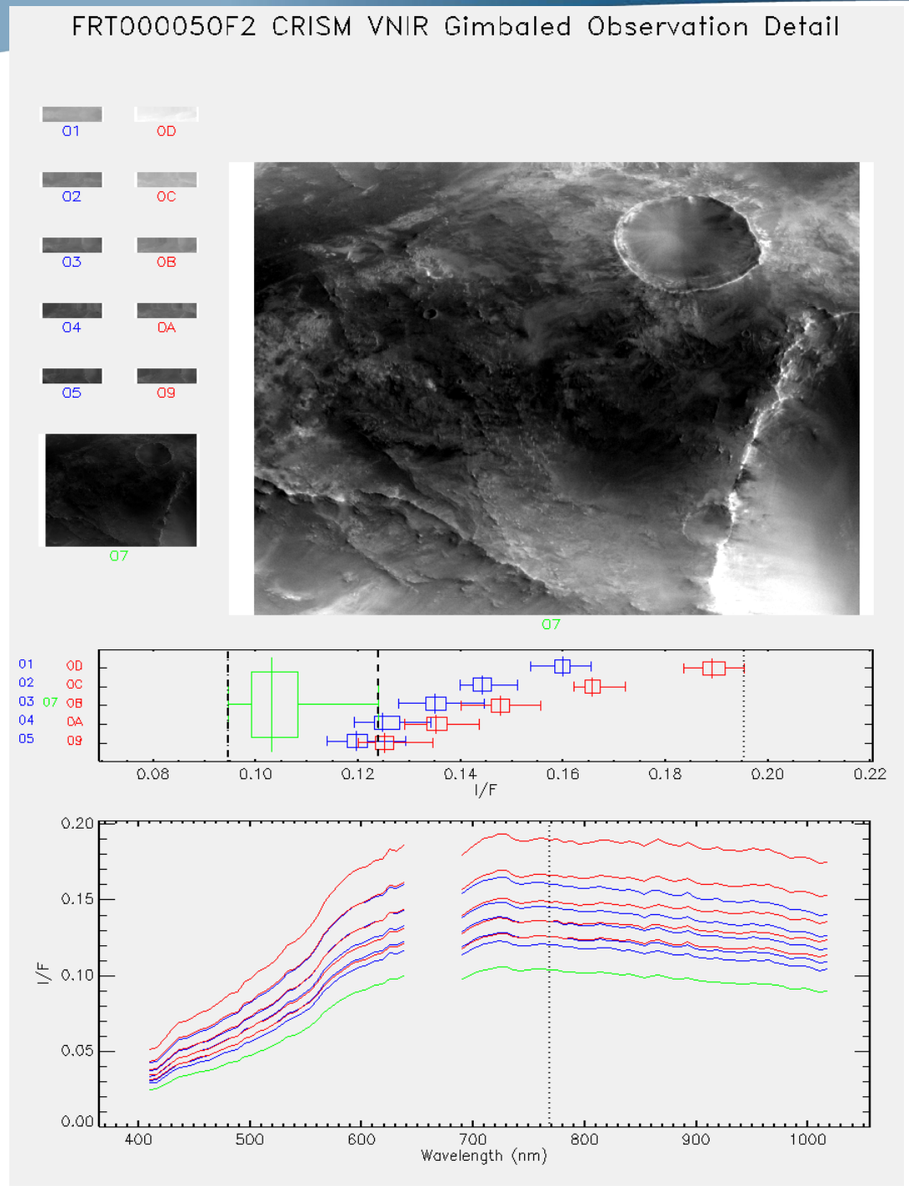


* The data processing information (IN) cube preserves traceability and residual information for multiple procedures, including the atmospheric correction, spatial transform, and VNIR+IR combination steps.

TRDR Visualizations - Gimbaled

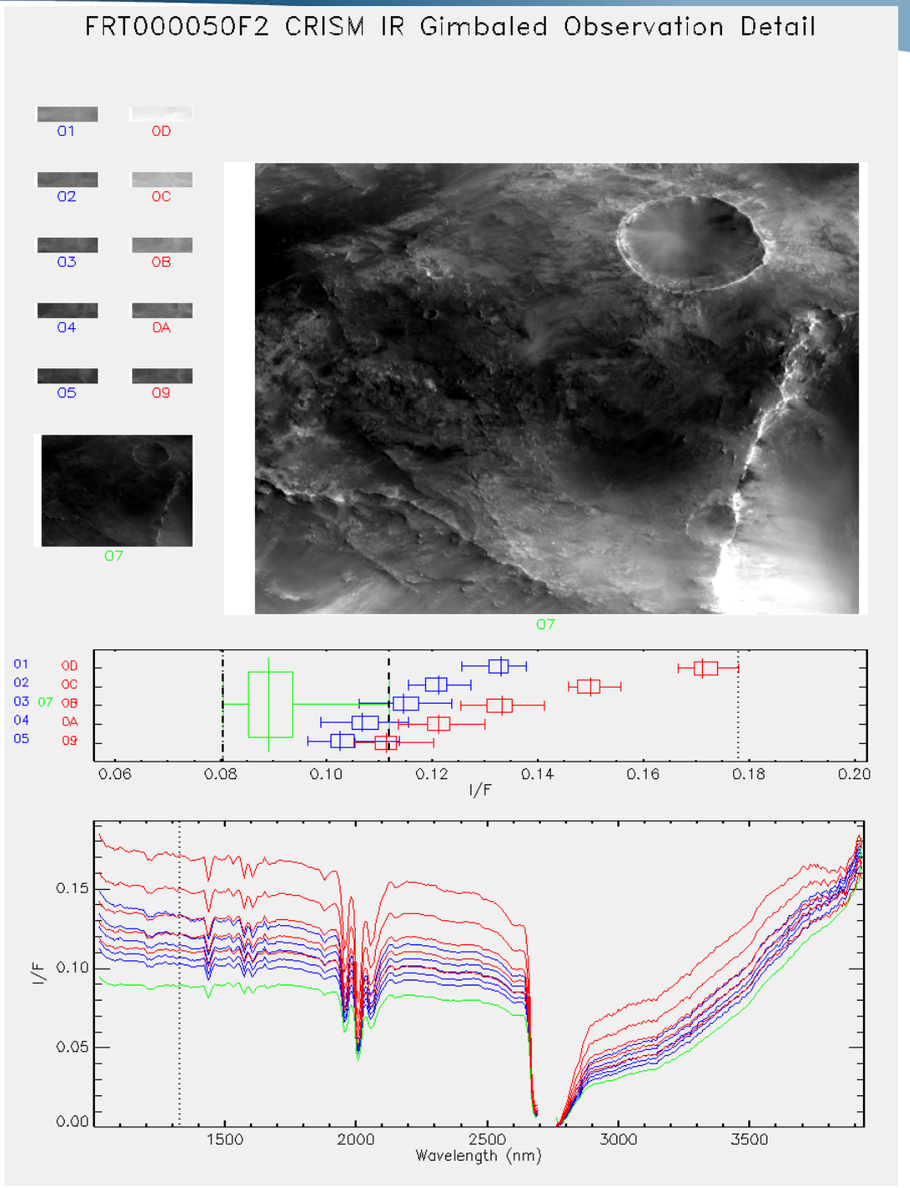
DDR1 (S, L)

TRR3 IF(S, L)



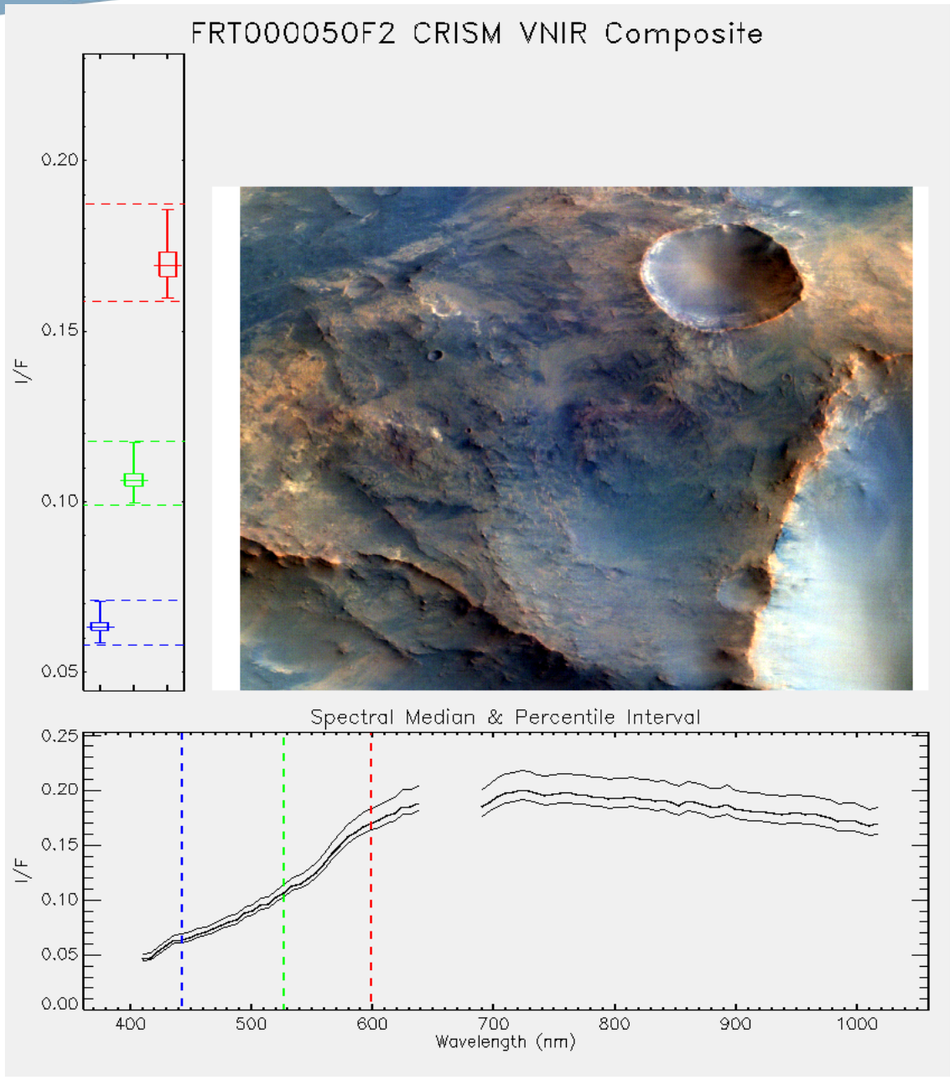
./trdr/EXTRAS/

FRT000050F2_S_TRR3_GIMBALED.PNG

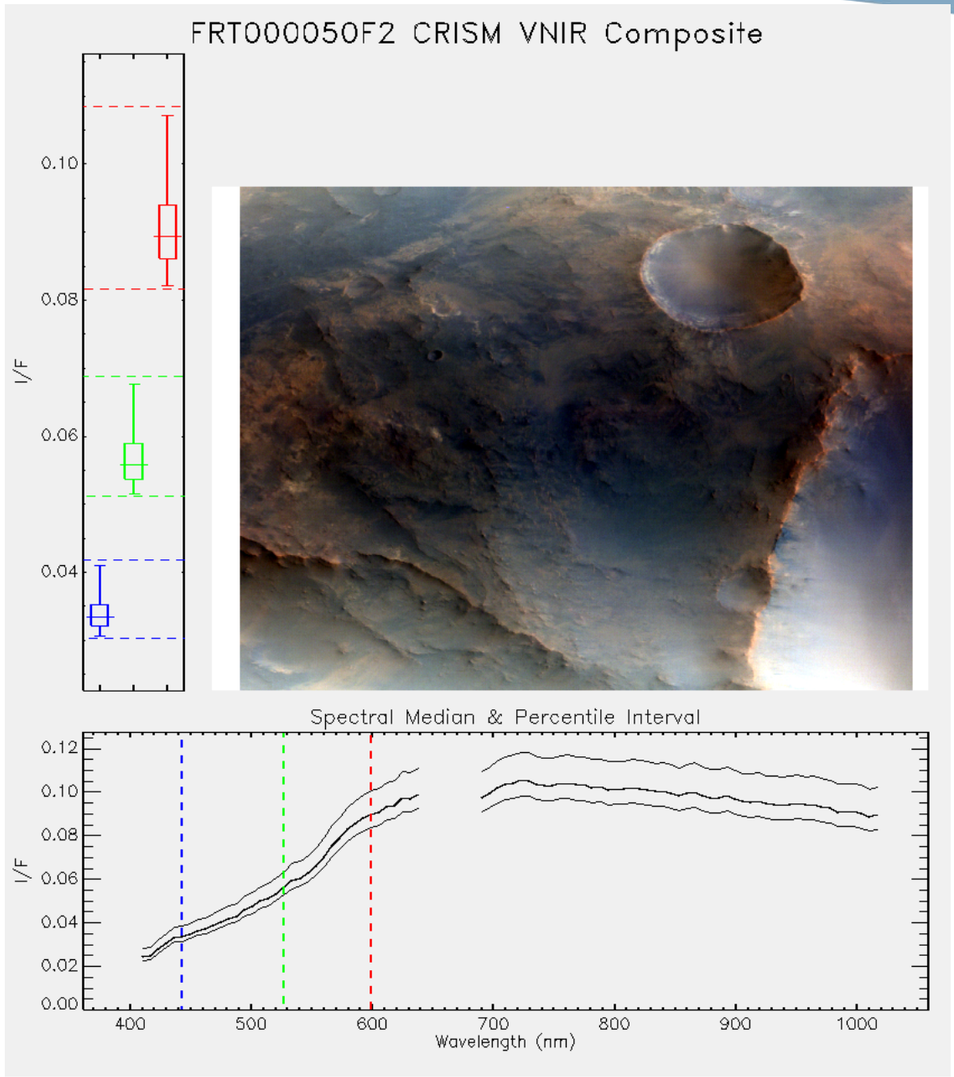


FRT000050F2_L_TRR3_GIMBALED.PNG

TER VNIR Progression – 4/4



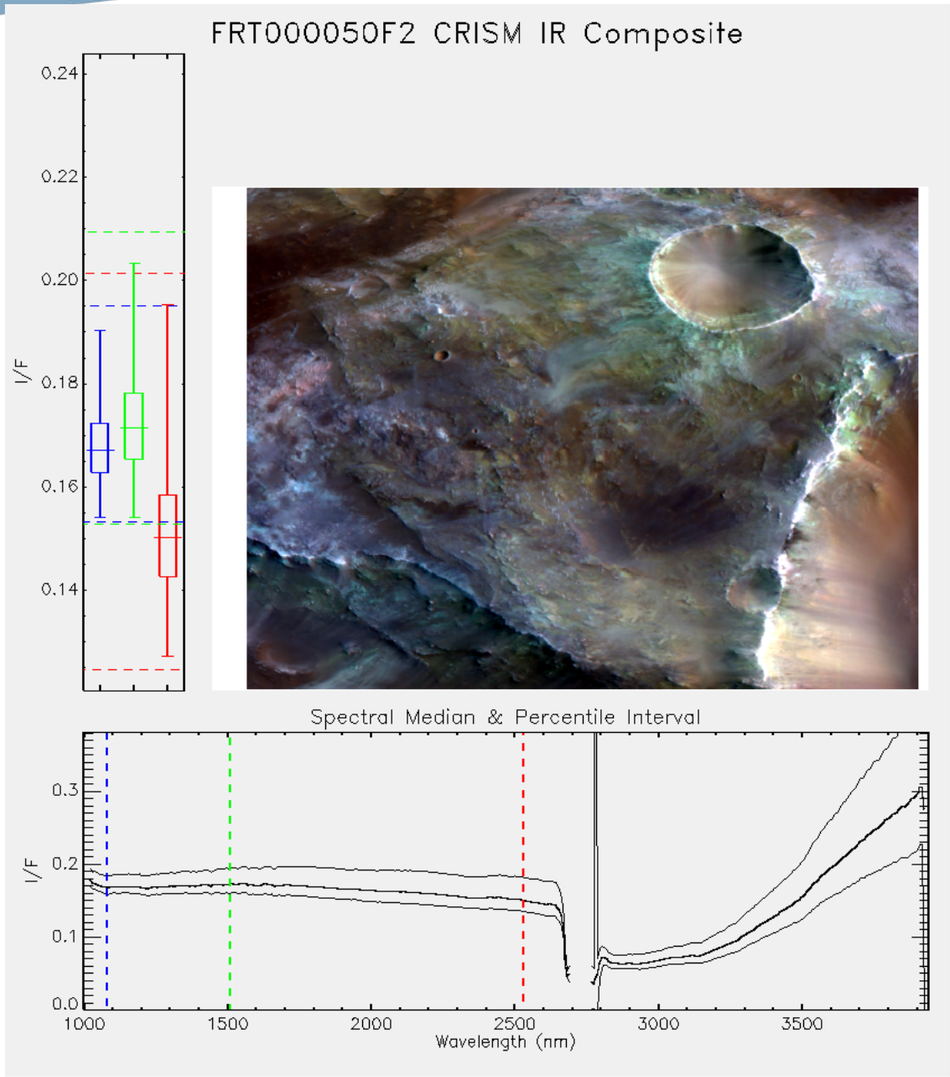
FRT000050F2_S_COMPOSITE_06.PNG



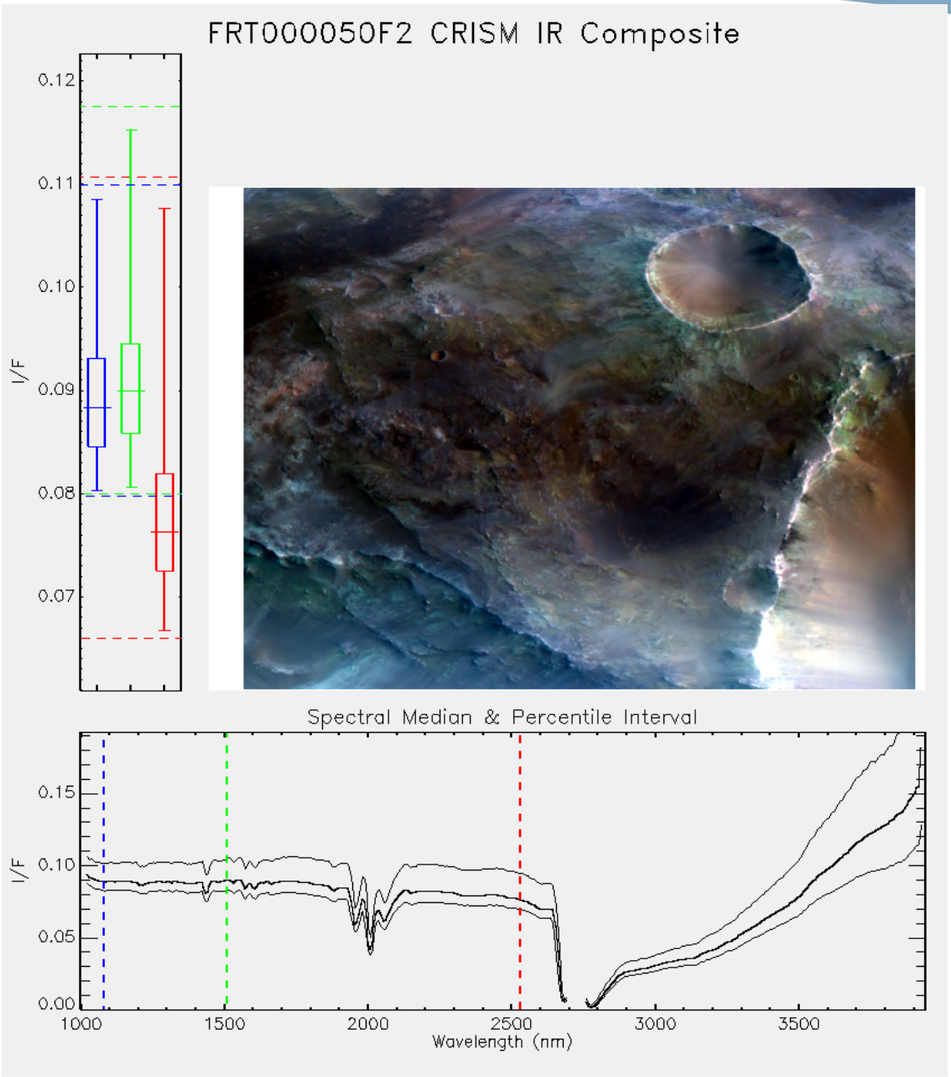
FRT000050F2_S_COMPOSITE_01.PNG

./ter/EXTRAS/

TER IR Progression – 6/6



FRT000050F2_L_COMPOSITE_06.PNG



FRT000050F2_L_COMPOSITE_01.PNG

./ter/EXTRAS/

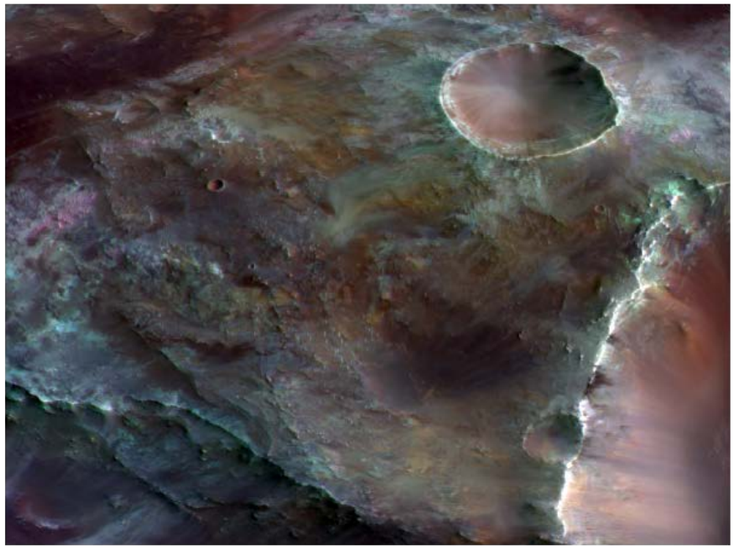
TER Spectral Summary Parameters

Calculate Summary Parameters (J)

Summary Parameter Cube

Browse Products

FRT000050F2_07_SU165J_TER3.IMG
FRT000050F2_07_SU165J_TER3.HDR
FRT000050F2_07_SU165J_TER3.LBL

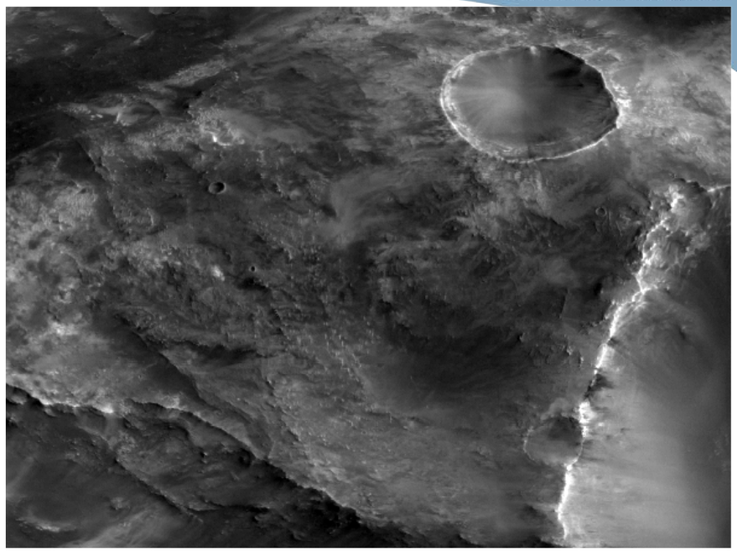


FRT000050F2_07_BUTANJ_TER3.PNG

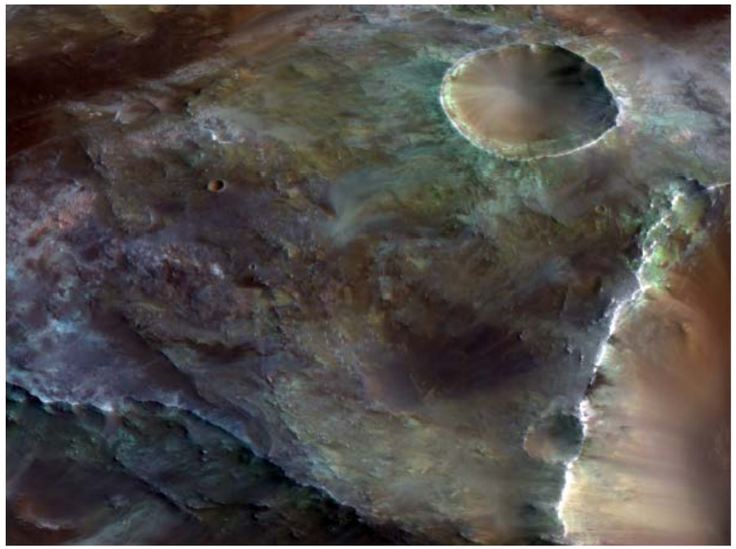
Spectral band parameters and browse products unchanged in SR/BR vs. SU/BU

./ter/TER/
./ter/BROWSE/

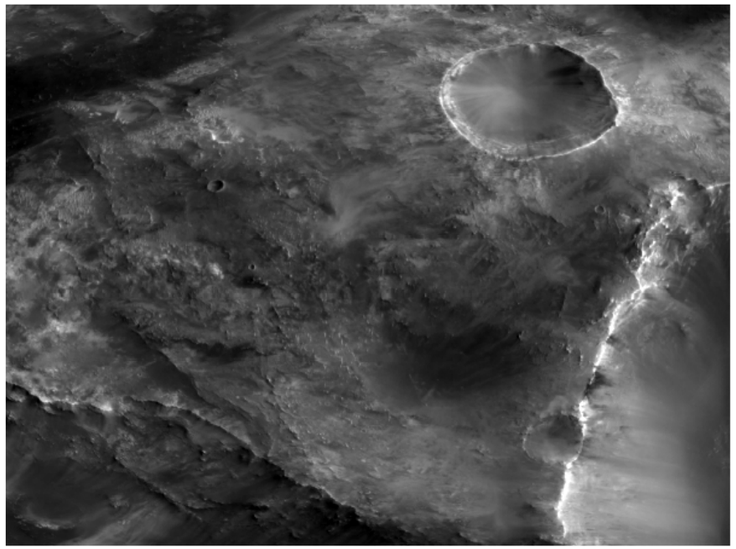
FRT000050F2_07_BUTRUJ_TER3.PNG



FRT000050F2_07_BUVNAJ_TER3.PNG



FRT000050F2_07_BUFALJ_TER3.PNG



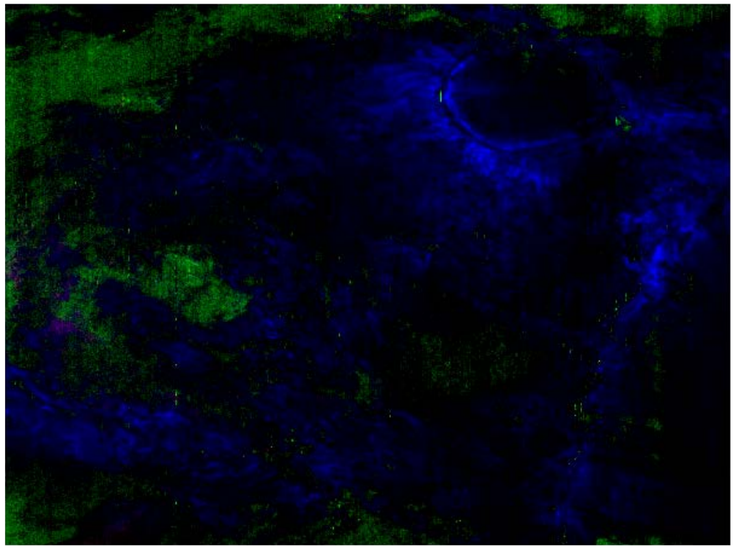
FRT000050F2_07_BUIRAJ_TER3.PNG

TER Spectral Summary Parameters

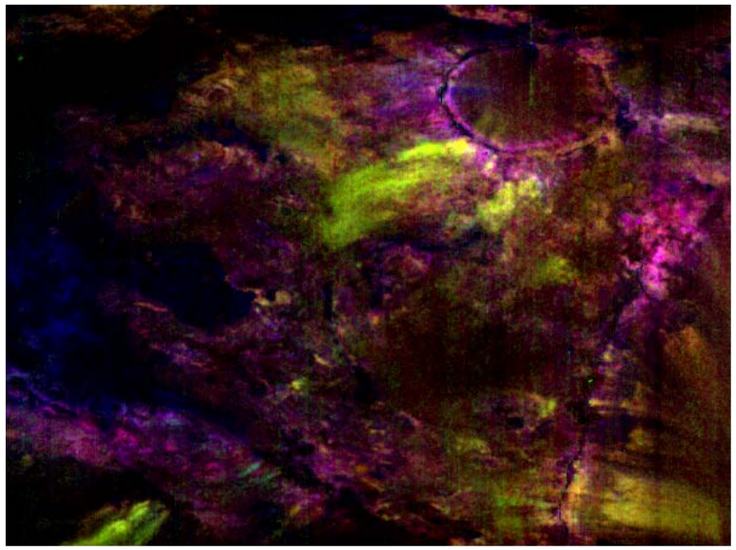
Calculate Summary Parameters (J)

Summary Parameter Cube

FRT000050F2_07_SU165J_TER3.IMG
FRT000050F2_07_SU165J_TER3.HDR
FRT000050F2_07_SU165J_TER3.LBL



FRT000050F2_07_BUHYDJ_TER3.PNG



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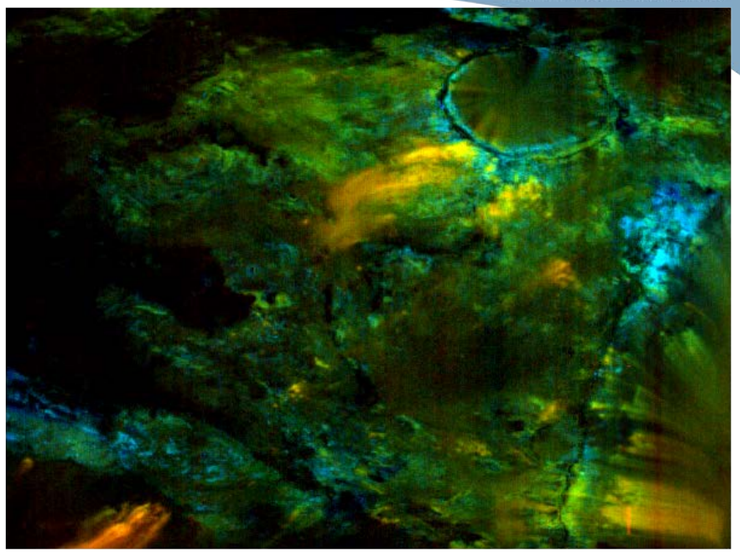
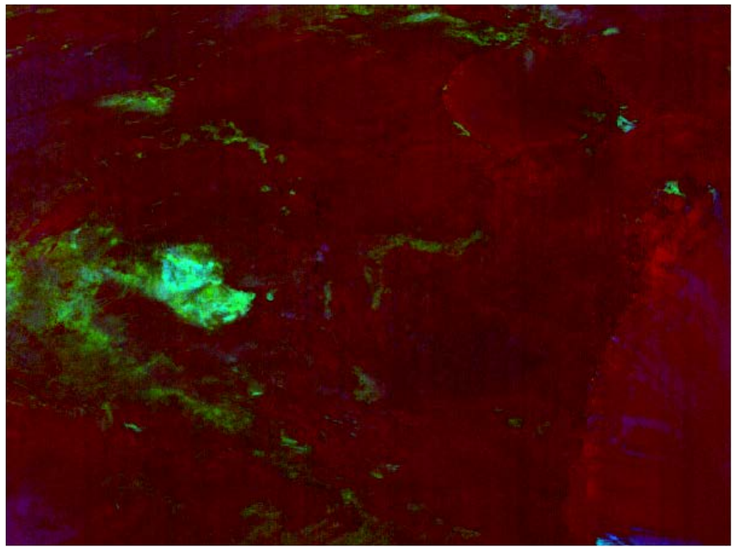
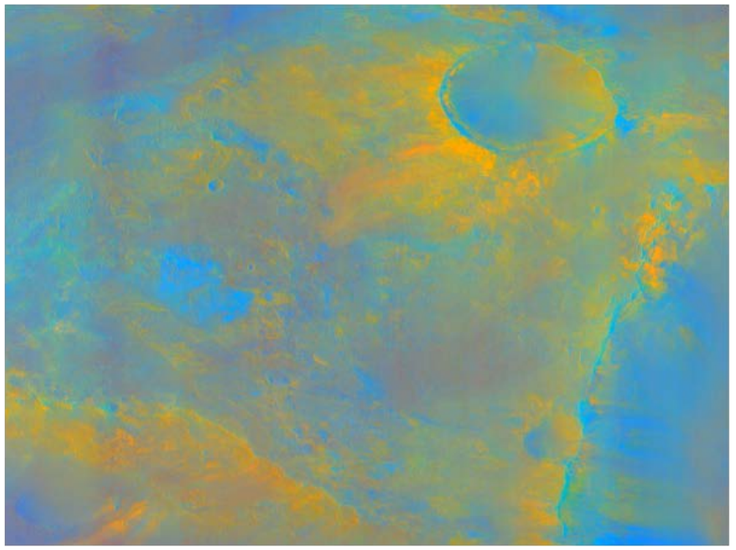


FRT000050F2_07_BUPFMJ_TER3.PNG



FRT000050F2_07_BUMAFJ_TER3.PNG



FRT000050F2_07_BUCHLJ_TER3.PNG

./ter/TER/

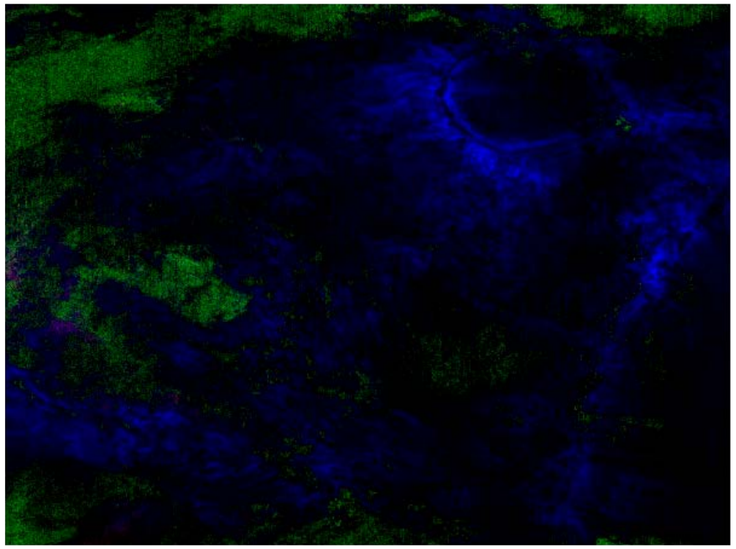
TER Spectral Summary Parameters

Summary Parameter Filtering (J)

Filtered Summary Parameter Cube

Browse Products

FRT000050F2_07_SR165J_TER3.IMG
FRT000050F2_07_SR165J_TER3.HDR
FRT000050F2_07_SR165J_TER3.LBL



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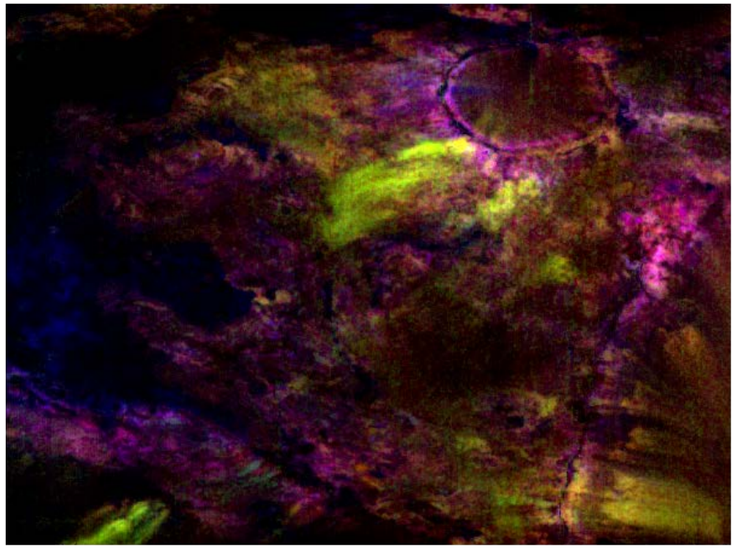
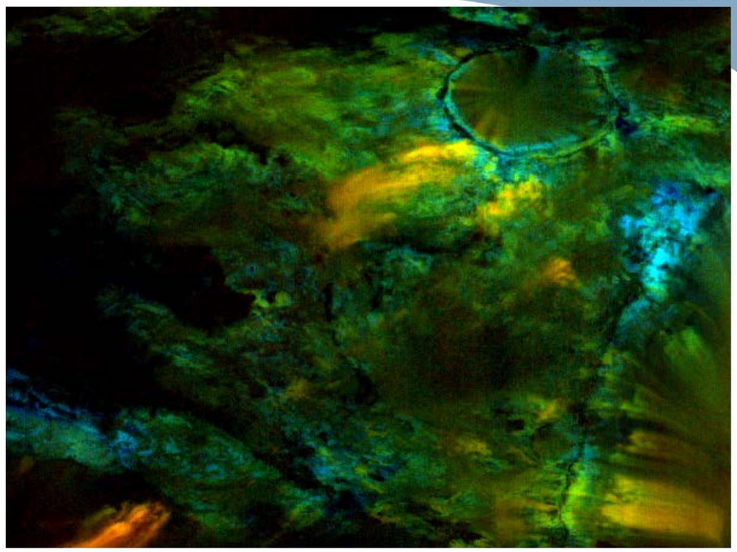
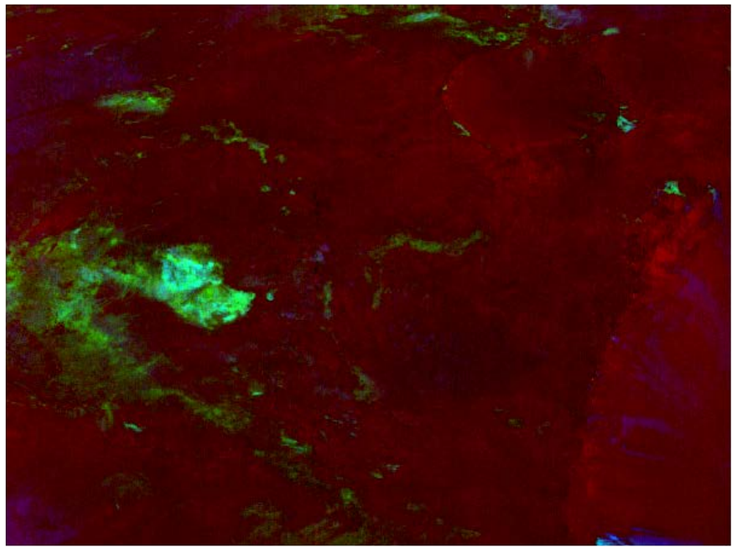


FRT000050F2_07_BRPHYJ_TER3.PNG



FRT000050F2_07_BRPFMJ_TER3.PNG



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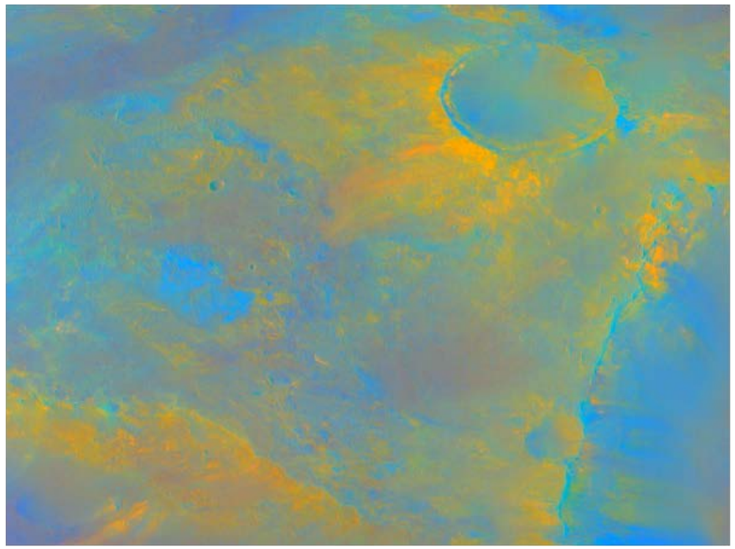
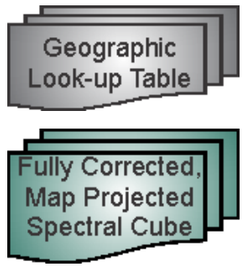


FRT000050F2_07_BRCHLJ_TER3.PNG

./ter/TER/
./ter/BROWSE/

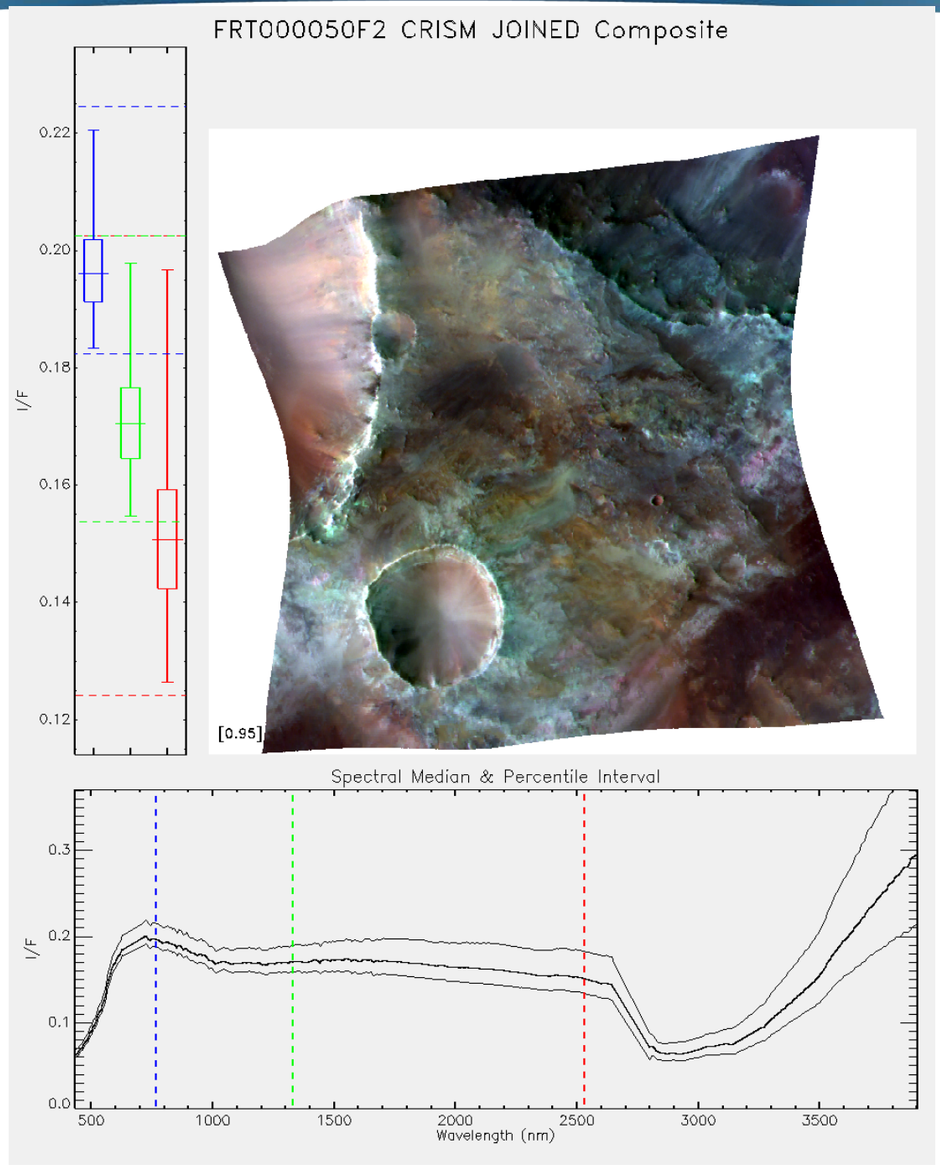
MTRDR Spectral Data Product



FRT000050F2_07_IF165J_MTR3.IMG
FRT000050F2_07_IF165J_MTR3.HDR
FRT000050F2_07_IF165J_MTR3.LBL
FRT000050F2_07_WV165J_MTR3.TAB
FRT000050F2_07_WV165J_MTR3.LBL

- MTRDR map projection adheres to MRO project standards
- ESRI PE via ENVI APIs
- GIS ready – Mars reference coordinate system string in ENVI header

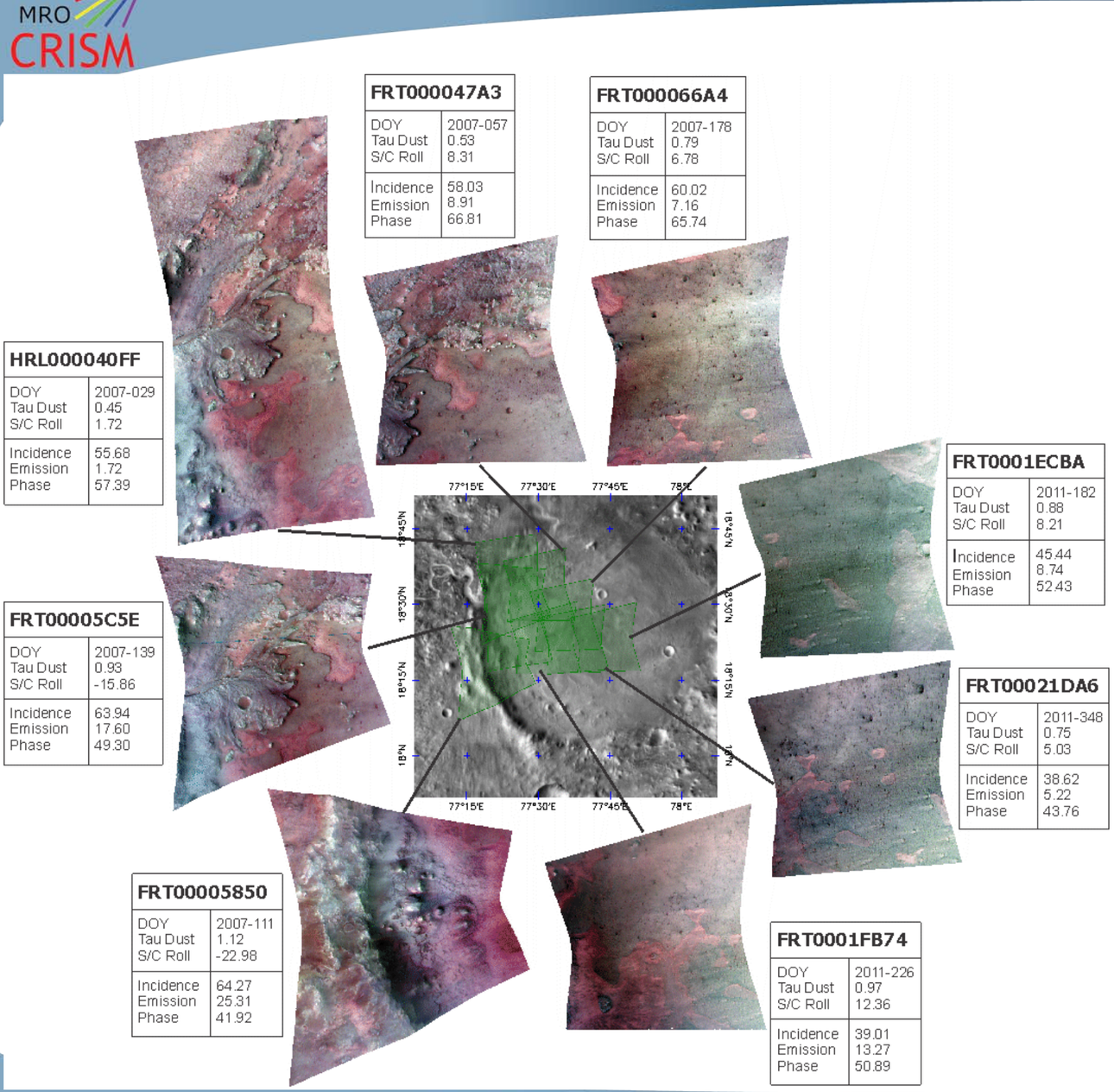
./mtrdr/TER/
./mtrdr/EXTRAS/



FRT000050F2_07_IF165J_MTR3_Composite.PNG

MTR TAN RGB Composite

TER/MTRDR Applications – MTRDR Mosaics



FRT000047A3	
DOY	2007-057
Tau Dust	0.53
S/C Roll	8.31
Incidence	58.03
Emission	8.91
Phase	66.81

FRT000066A4	
DOY	2007-178
Tau Dust	0.79
S/C Roll	6.78
Incidence	60.02
Emission	7.16
Phase	65.74

HRL000040FF	
DOY	2007-029
Tau Dust	0.45
S/C Roll	1.72
Incidence	55.68
Emission	1.72
Phase	57.39

FRT0001ECBA	
DOY	2011-182
Tau Dust	0.88
S/C Roll	8.21
Incidence	45.44
Emission	6.74
Phase	52.43

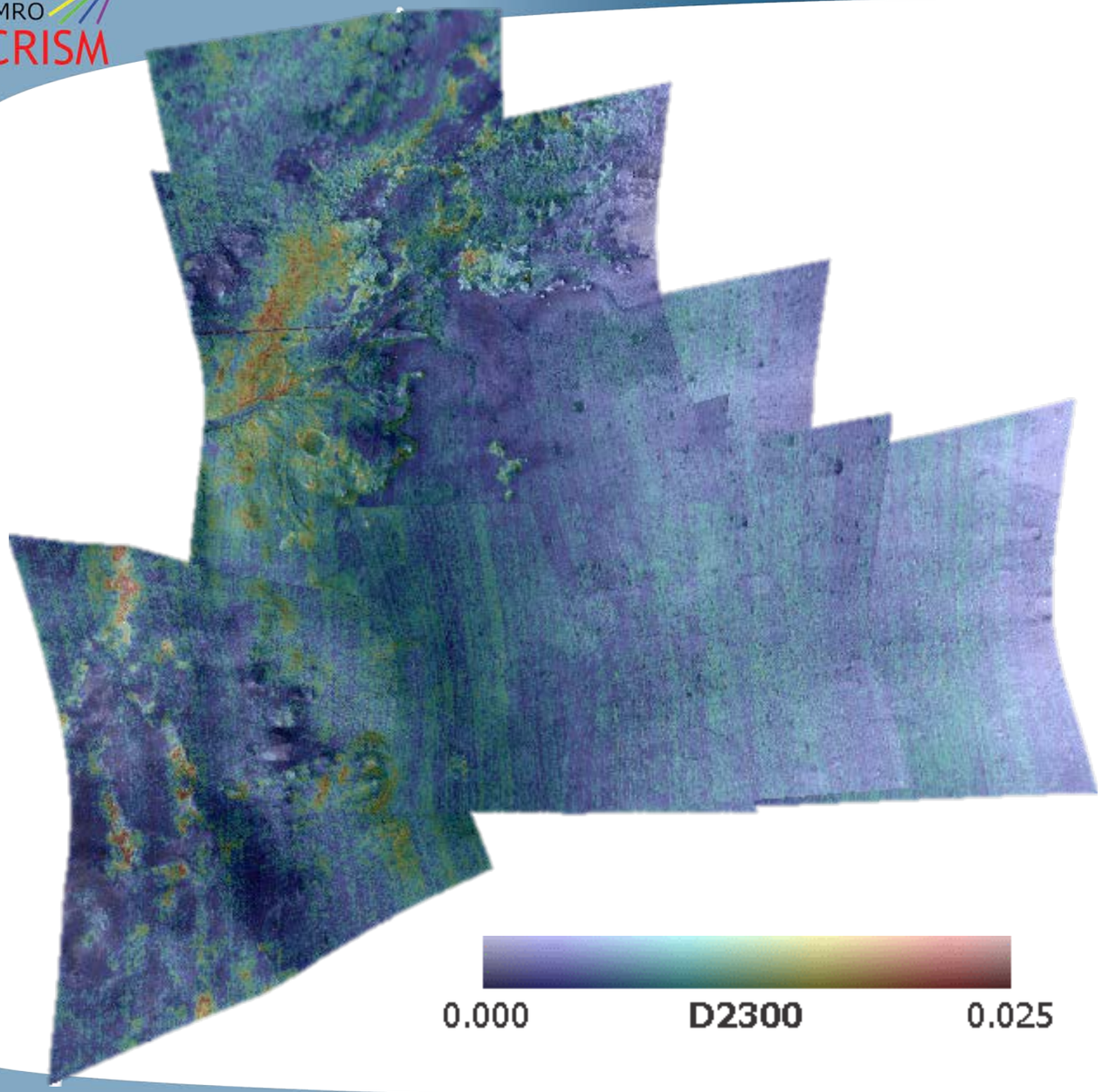
FRT00005C5E	
DOY	2007-139
Tau Dust	0.93
S/C Roll	-15.86
Incidence	63.94
Emission	17.60
Phase	49.30

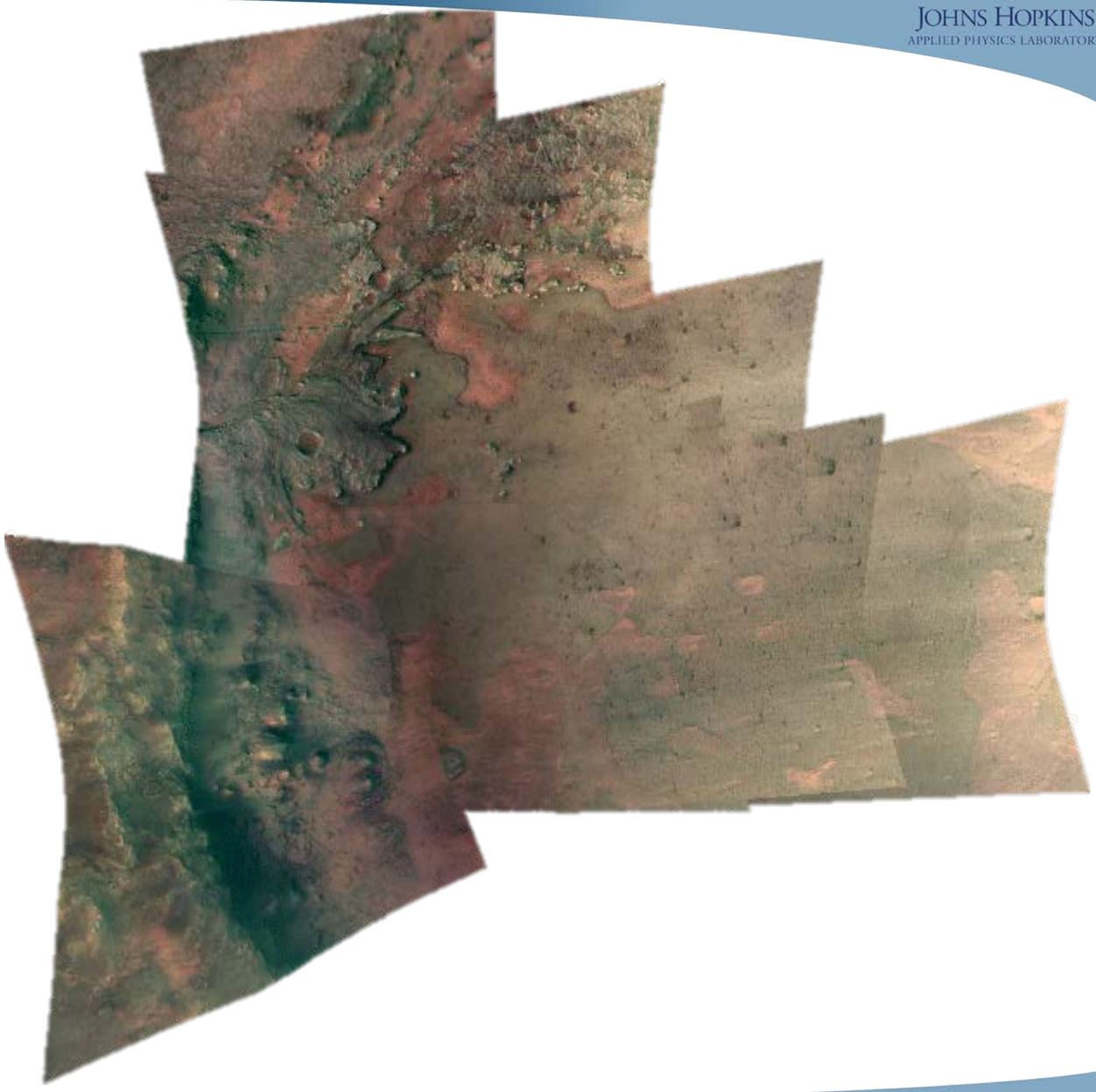
FRT00021DA6	
DOY	2011-348
Tau Dust	0.75
S/C Roll	5.03
Incidence	38.62
Emission	5.22
Phase	43.76

FRT00005850	
DOY	2007-111
Tau Dust	1.12
S/C Roll	-22.98
Incidence	64.27
Emission	25.31
Phase	41.92

FRT0001FB74	
DOY	2011-226
Tau Dust	0.97
S/C Roll	12.36
Incidence	39.01
Emission	13.27
Phase	50.89

TER/MTRDR Applications – MTRDR Mosaics





Part IV. Spectral Analysis

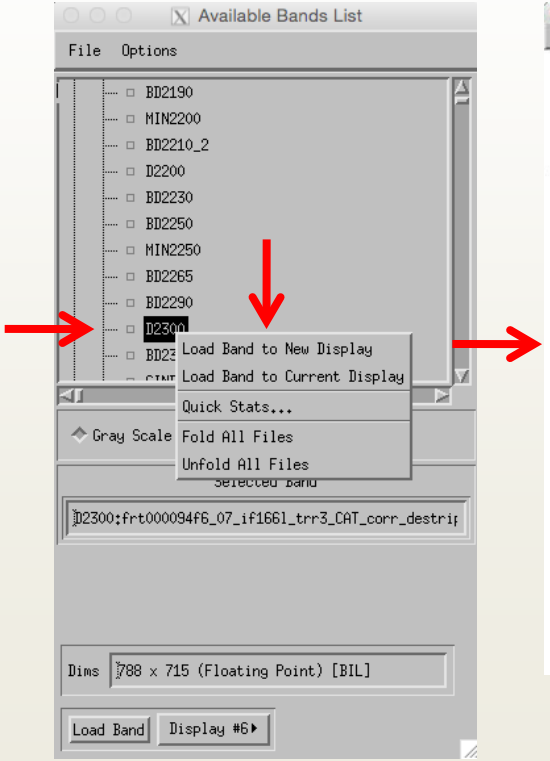
- **Real-time spectral analysis for example scene FRT000094F6 (or scene of your choice) using ENVI, covering:**
  - **Displaying, sretching, linking spectral and summary parameter cubes**
  - **Finding and extracting scene endmembers**
  - **Enhancing spectral features and interpretation**

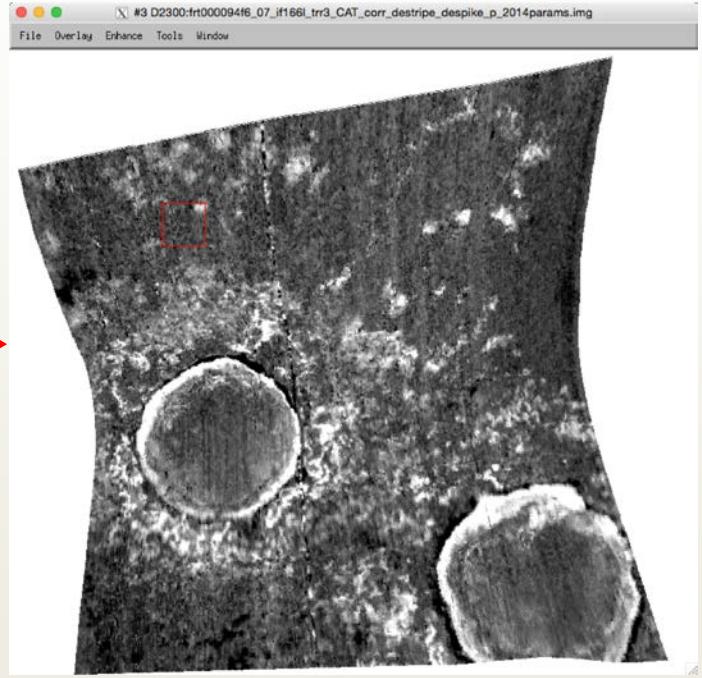
Extra information relevant to this section:

1. Data\CRISM_pds_archive\...
2. Resources\CRISM_type_spectra_library\...
3. Resources\Handouts\CRISM_filename_convention_and_common_tasks.pdf
4. Resources\Handouts\Viviano-Beck_etal_2014_TableA3_Browse_Products.pdf

Single Band Display

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

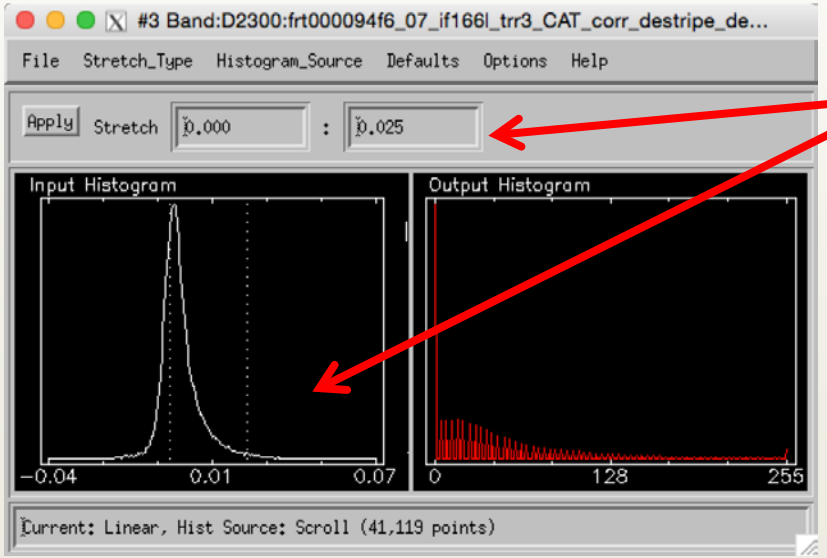




Default Linear 2% stretch includes unrealistic parameter values less than zero…

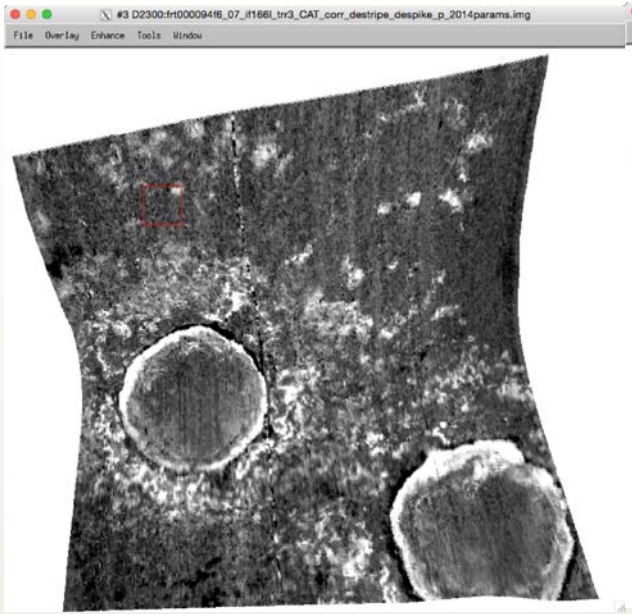
Apply Appropriate Stretch

- 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

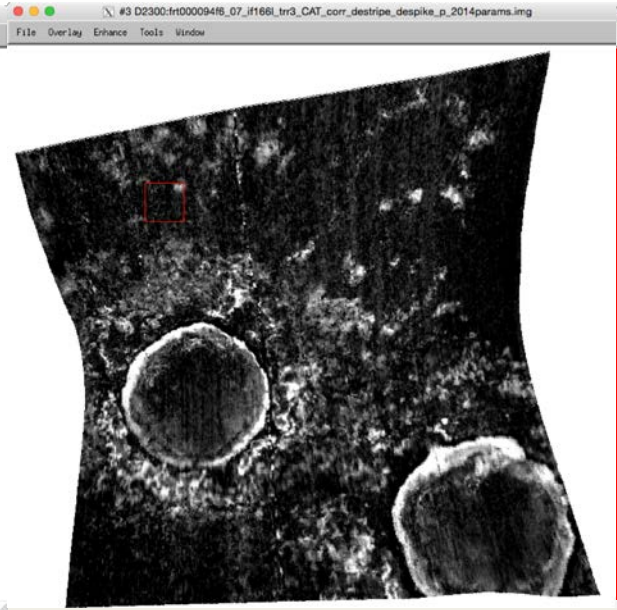


- Type min and max values or slide dashed bars until at correct percentile values (will display along bottom)
- If needed, modify the histogram binning and range under >Options >Histogram Parameters

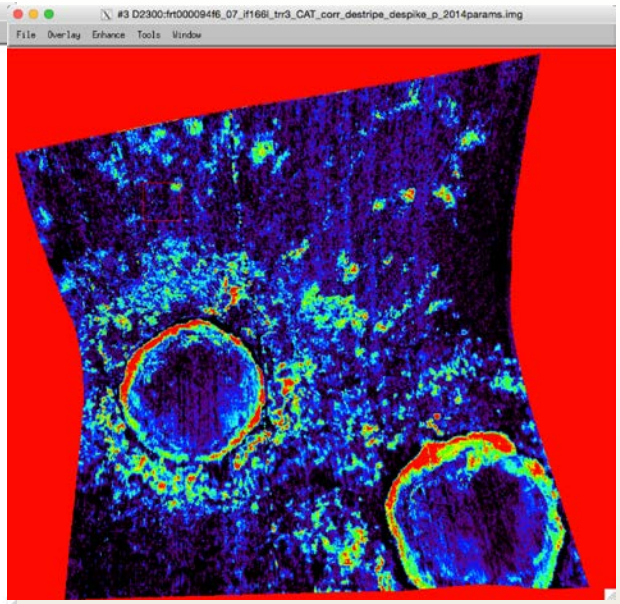
D2300 Display Comparison



Default Stretch
(-0.007 to 0.021)



Optimized Stretch,
Grayscale
(0.0 to 0.027)

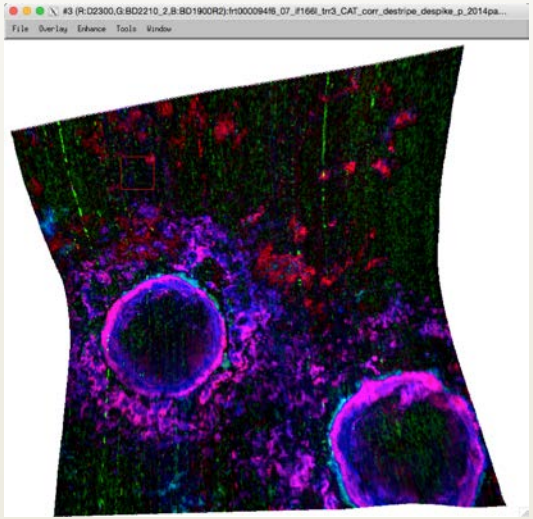


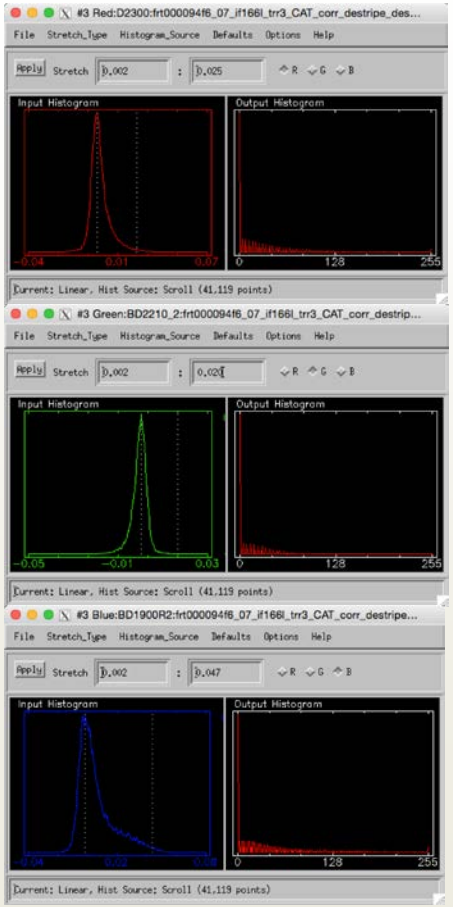
Optimized Stretch, Rainbow
Color Ramp
(0.0 to 0.027)

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

3-Parameter RGB Composite Display and Stretch

- Load PHY from Available Bands List: >Select RGB Color >click on D2300, BD2210_2, and BD1900R2 to fill in RGB fields >New Display from drop-down >Load RGB
- Optimize stretch of each band from Image window: >Enhance >Interactive Stretching





D2300

Min: 0.002 (distribution peak)

Max: 0.025 (99th percentile)

BD2210_2

Min: 0.002 (distribution peak)

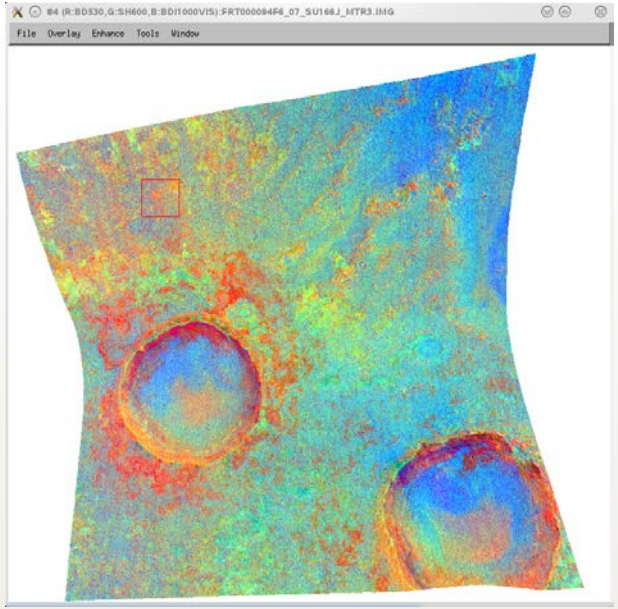
Max: 0.020 (“minimum maximum”)

BD1900R2

Min: 0.002 (distribution peak)

Max: 0.047 (99th percentile)

Other Browse Products for 94F6

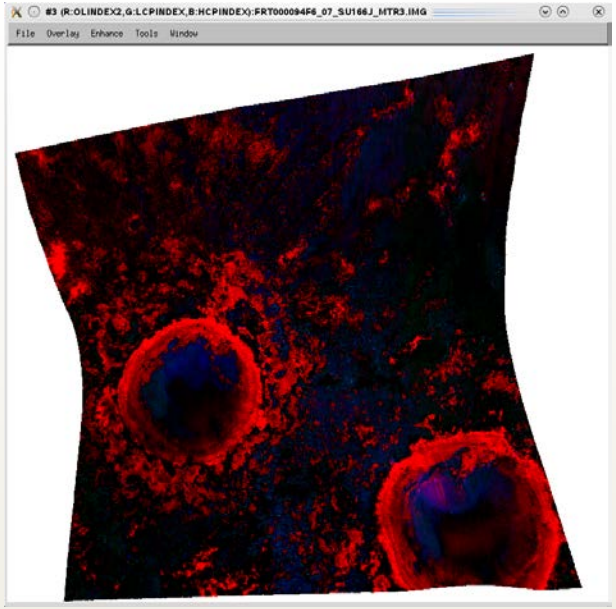


FEM

R: BD530

G: SH600

B: BD11000VIS

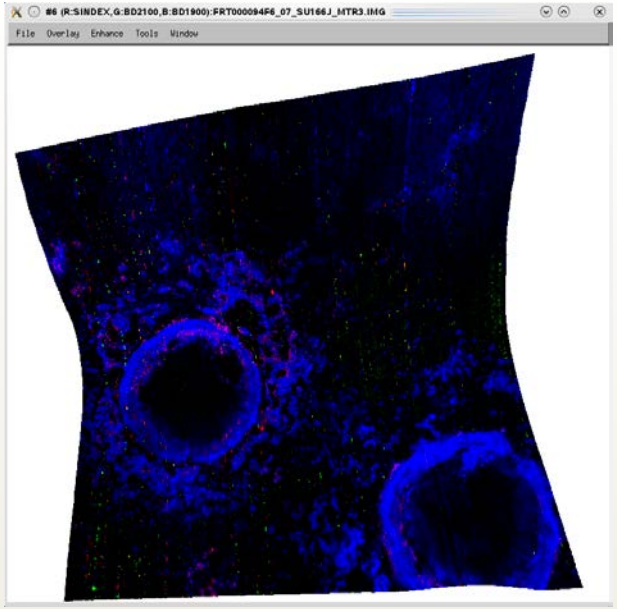


MAF

R: OLINDEX3

G: LCPINDEX2

B: HCPINDEX2



HYD

R: SINDEX

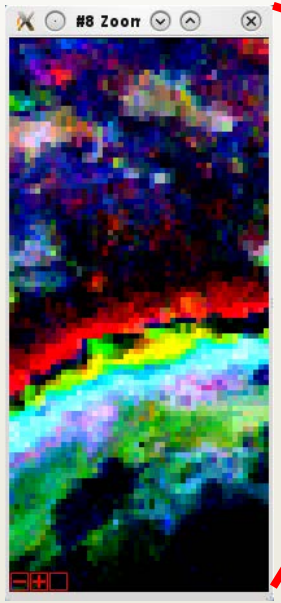
G: BD2100

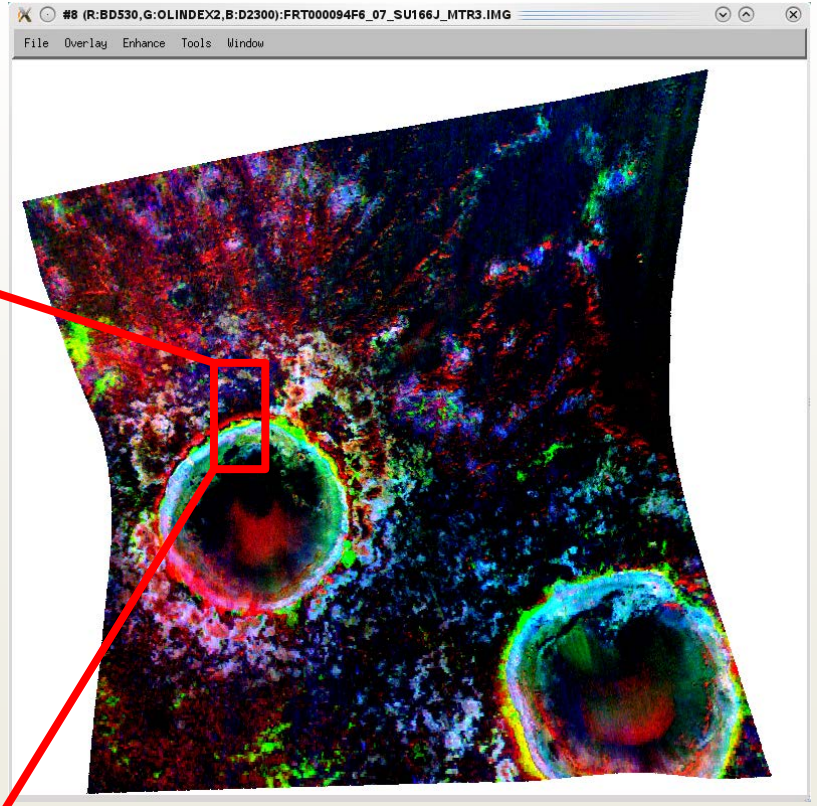
B: BD1900

Custom Composites

- Custom RGB composites and browse products can take advantage of 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…



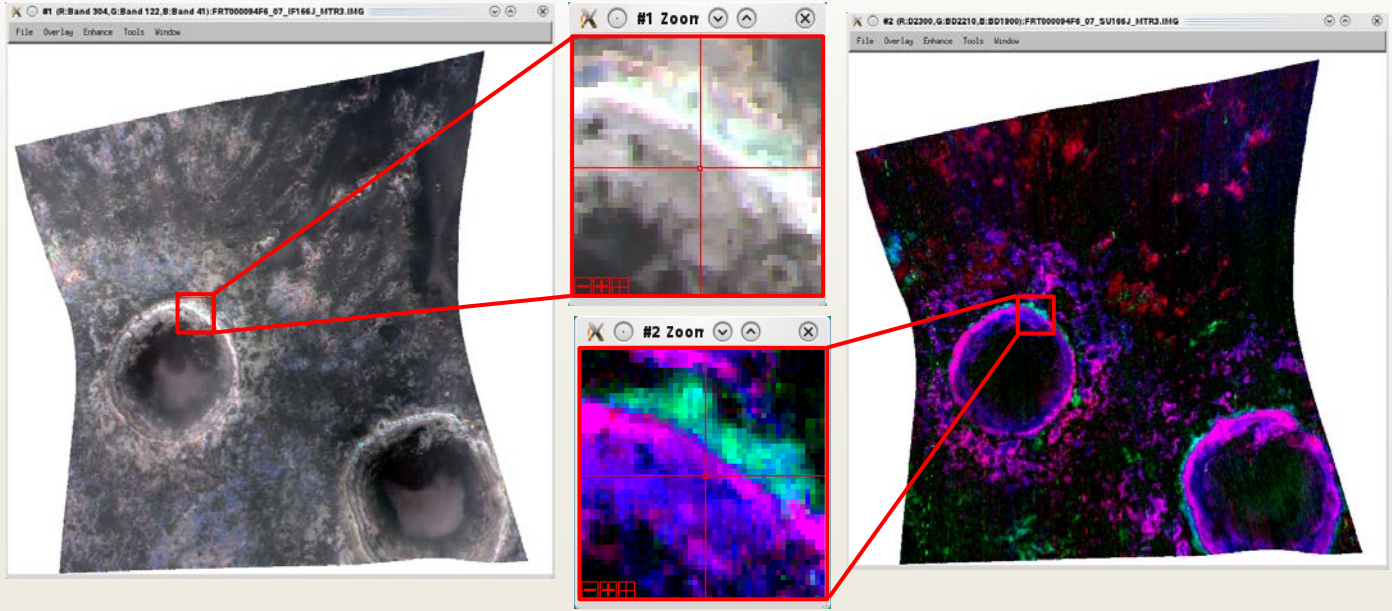


R: BD530 **G**: OLINDEX3 **B**:D2300

Linking Spectral and Summary Parameter Cubes

- From either Image window, >Tools >Link then one of
  - Use >Link Displays for pixel-location based link (requires exactly same size images; allows blinking and transparency)

  -OR-
  - Use >Geographic Link for map-projected link (can be different spatial coverage or resolutions)



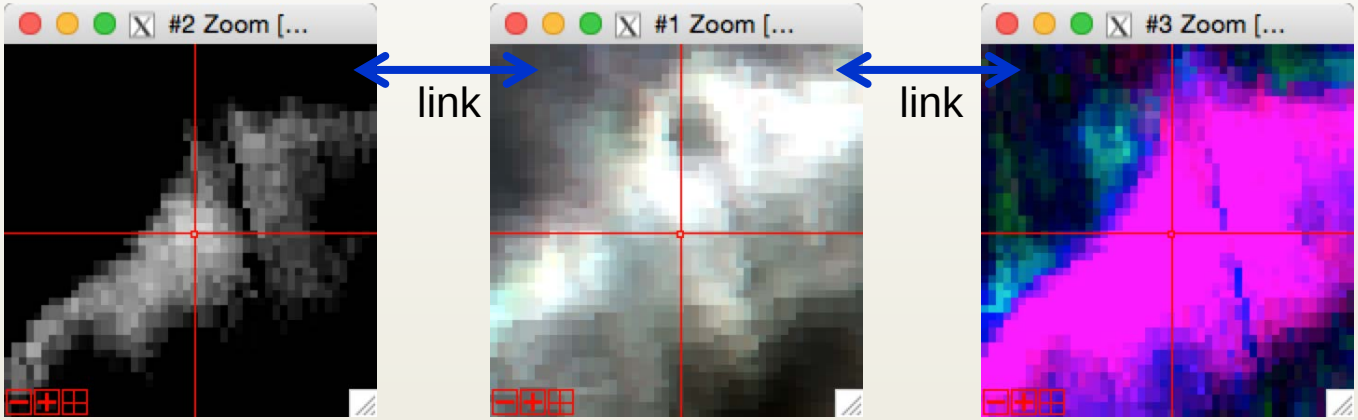
Spectral Analysis Methods

- **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 and classification tools available within the ENVI software environment or other automatic extraction and analysis programs
  - Not all of them work well with CRISM data.

Pixel-based Endmember Extraction (1 of 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)



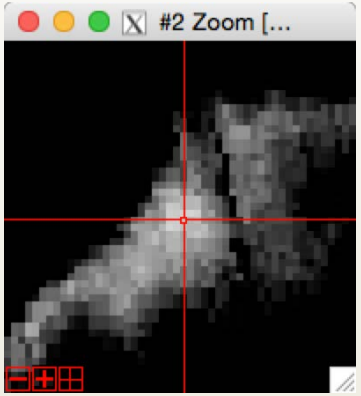
Emphasized Stretch (0.04 to 0.05)

Spectral Cube RGB

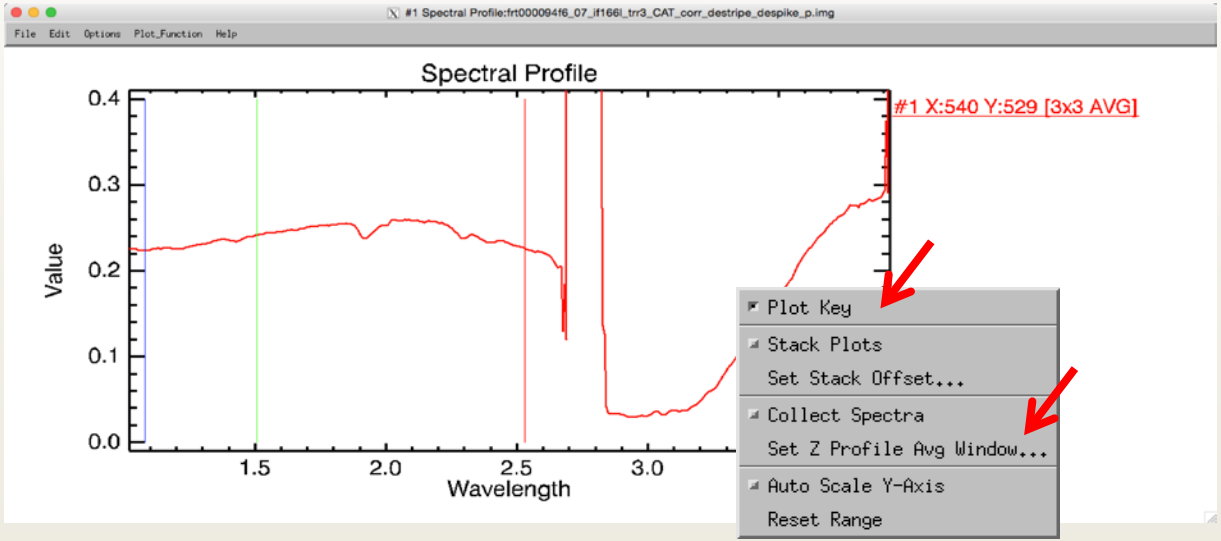
PHY Browse

Pixel-based Endmember Extraction (2 of 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…

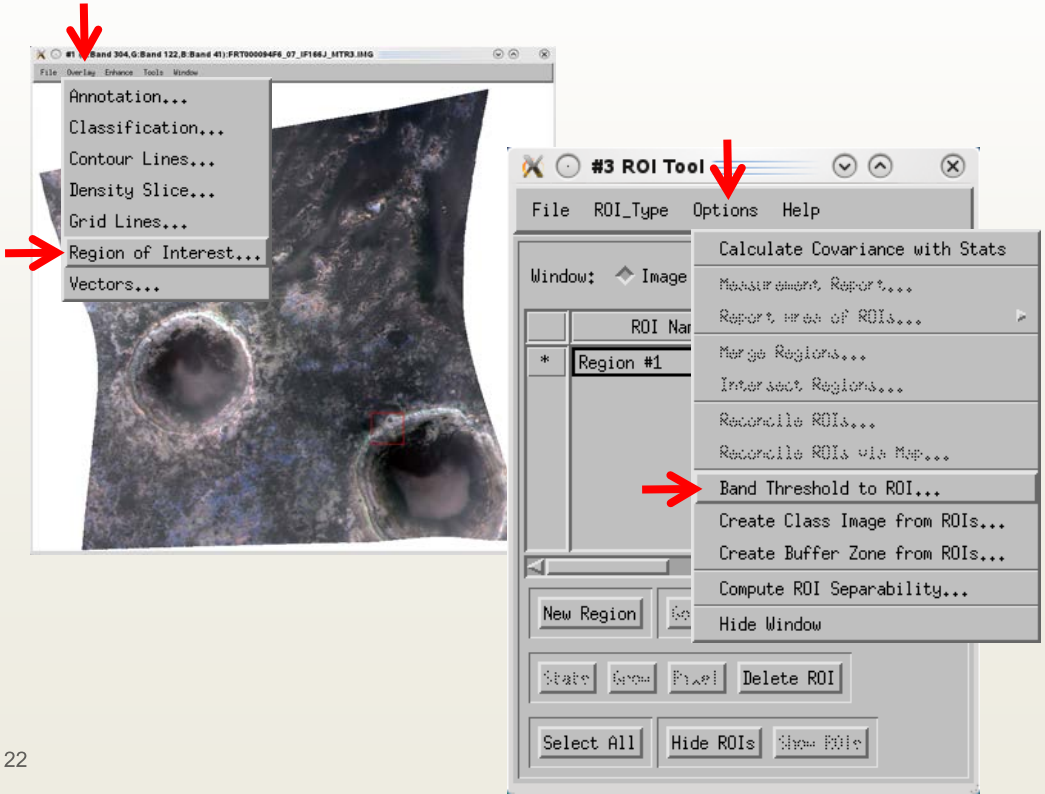


Spectral Cube RGB



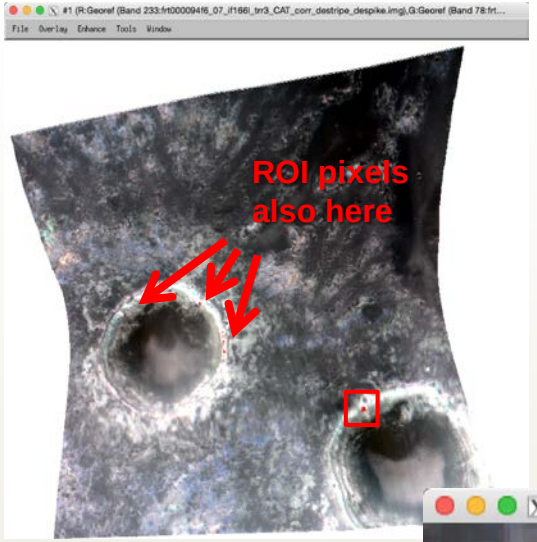
ROI-based Endmember Extraction (1 of 3)

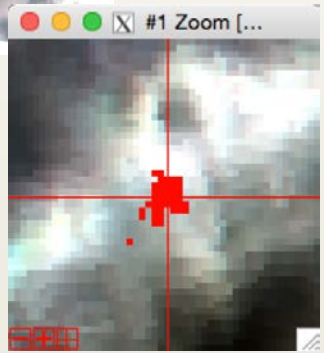
- Create a Region of Interest (ROI) from the highest D2300 values throughout the scene
- In the spectral cube Image window, go to >Overlay >Region of Interest



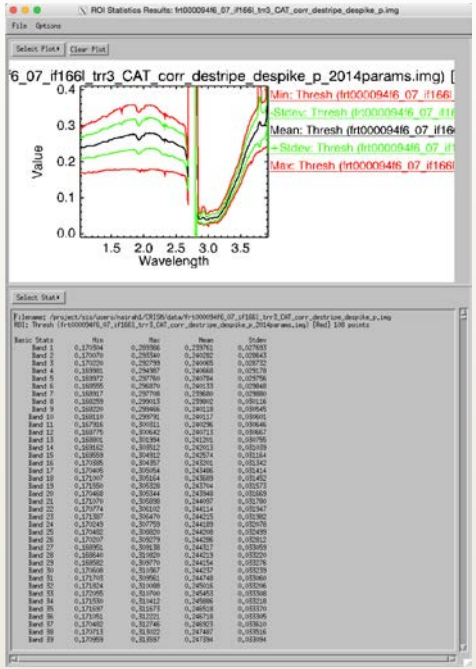
- In the ROI Tool, >Options >Band Threshold to ROI
- Select the D2300 band from the summary parameter file
- Type in min and max values of 0.04 and 0.05, respectively
- Should get a result of 108 pixels
- May want to refine threshold range to get fewer pixels

ROI-based Endmember Extraction (2 of 3)





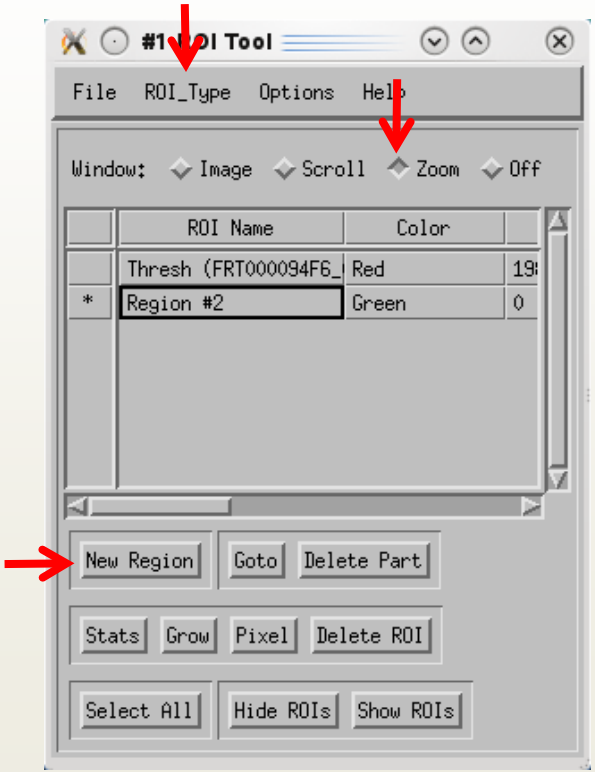
- The ROI appears as red pixels in the displayed window
- In the ROI Tool, calculate the average of the pixels by clicking >Stats



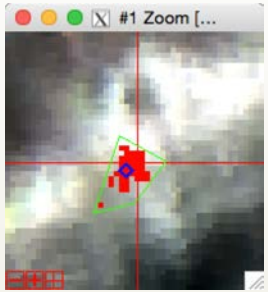
- Right click within the Stats Results plot area to adjust Plot Parameters and view Plot Key
- Click and drag the Mean spectrum to the previously-created spectral plot containing the pixel-based endmember spectrum

ROI-based Endmember Extraction (3 of 3)

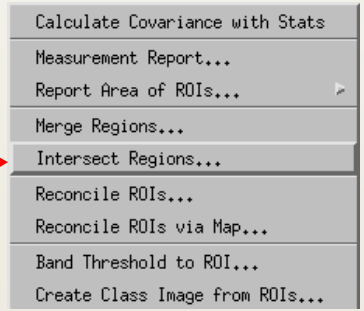
- A third method would be to define a polygon ROI…



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



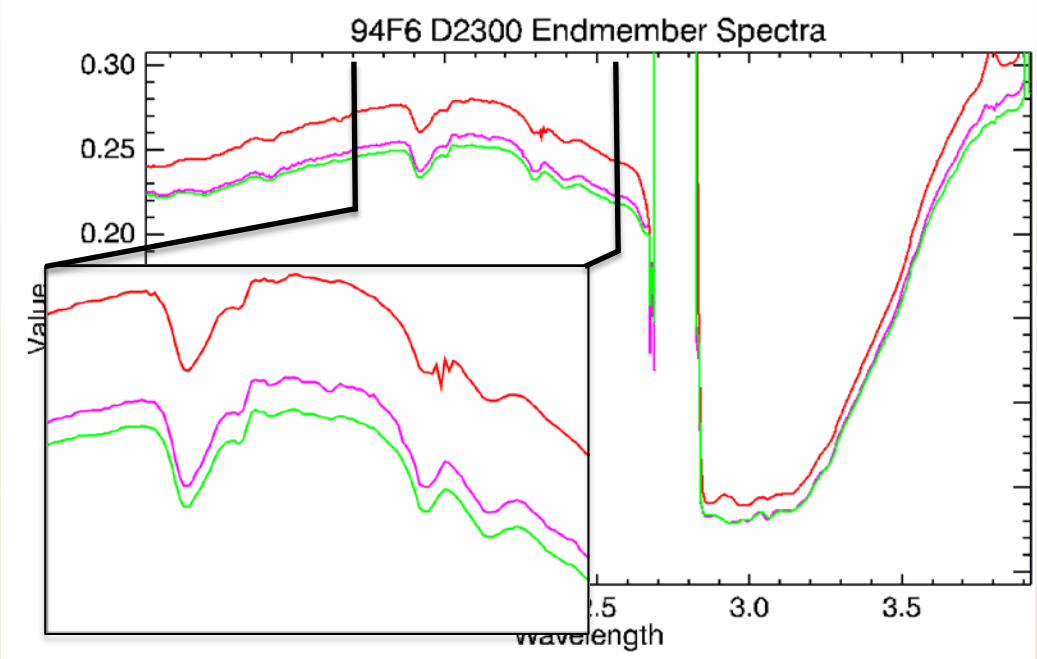
right click to finalize



- 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

- Three D2300 spectra were extracted using the methods discussed in previous slides: 1) 3x3 pixel average, 2) band threshold, and 3) polygon.
  - In this scene, there are no huge differences between the spectra.
  - In general, more pixels = less spectral noise.



3x3 AVG

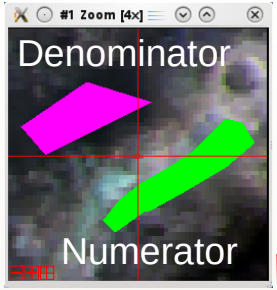
Mean: Thresh 108 points

Mean: Polygon 105 points

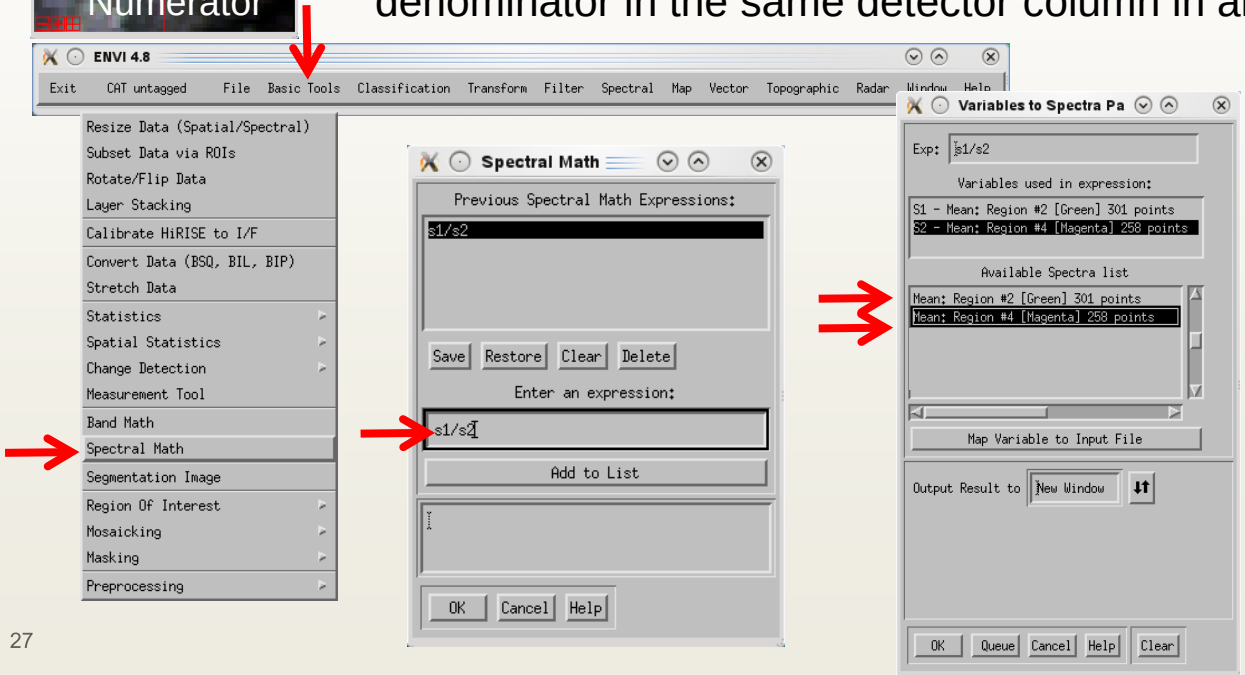
Enhancing Spectral Features

- **There are two widely accepted ways to enhance spectral features to aid with interpretation:**
  - Ratio to a spectrally neutral area in the same scene, **preferably from the same detector column in the non-map-projected cube**
  - 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 specific features

Ratioing (1 of 2)

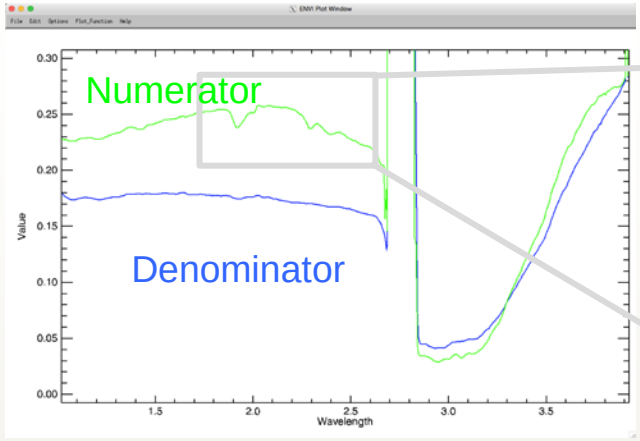


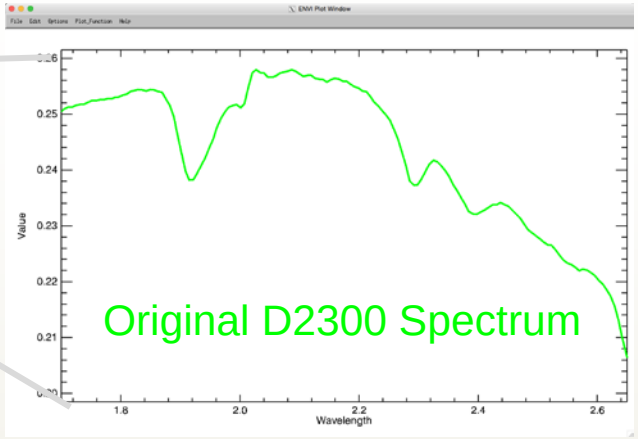
- Numerator: let's use the D2300 spectrum with the least noise - the average from the green polygon ROI.
- Denominator: Create a similar-sized polygon in the nearby spectrally bland dark material and calculate its average spectrum; it is best to use a denominator in the same detector column in an un-map-projected scene

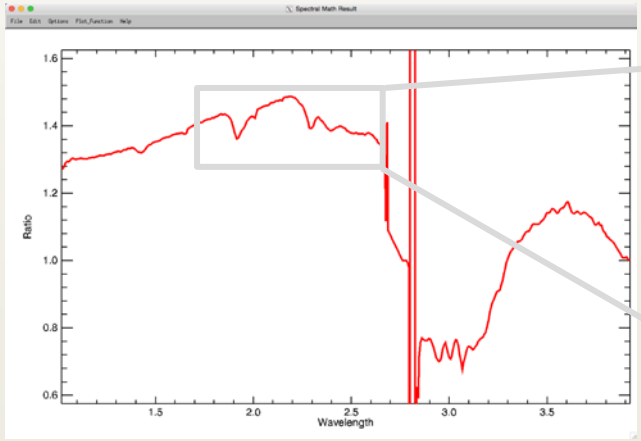


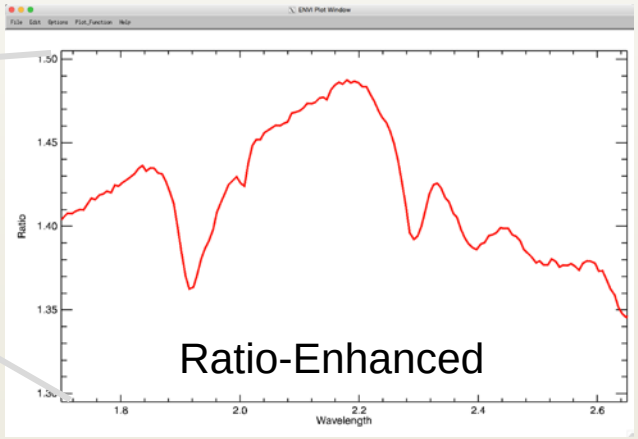
- From the ENVI main menu, go to >Basic Tools > Spectral Math
  - Enter the expression: s1/s2
  - Map the numerator (s1) and denominator (s2) to the Available Spectra List
  - Output to New Window

Ratioing (2 of 2)





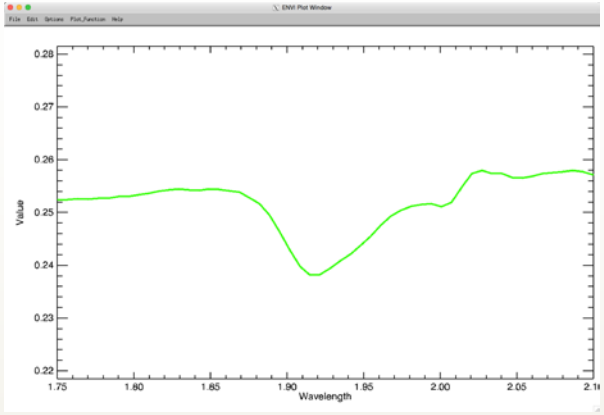




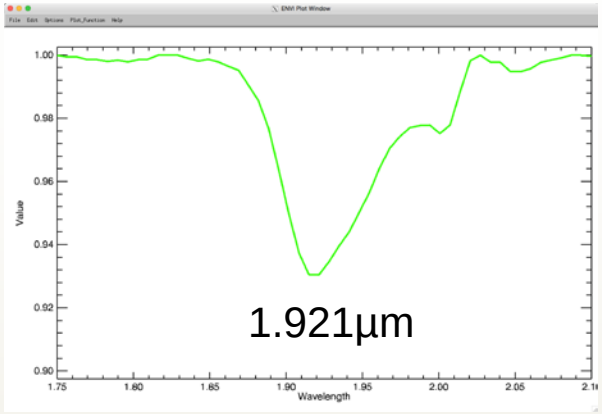
- This particular spectrum already has strong absorption features without ratioing
- Ratioing is more effective at emphasizing subtle or weak features, or at cancelling out noise or other spectral artifacts

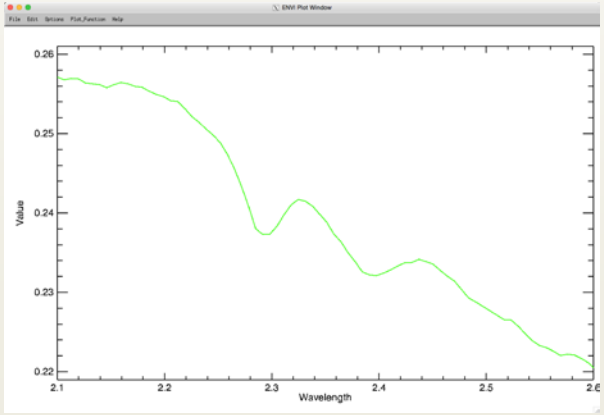
Continuum Removal

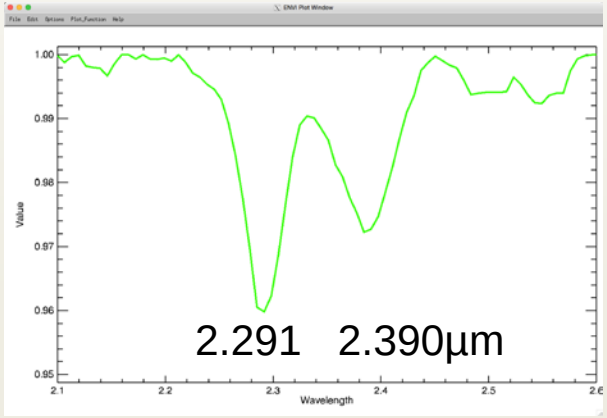
Normal



Continuum Removed

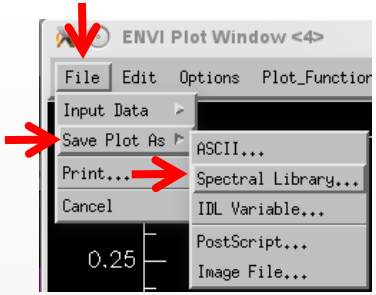




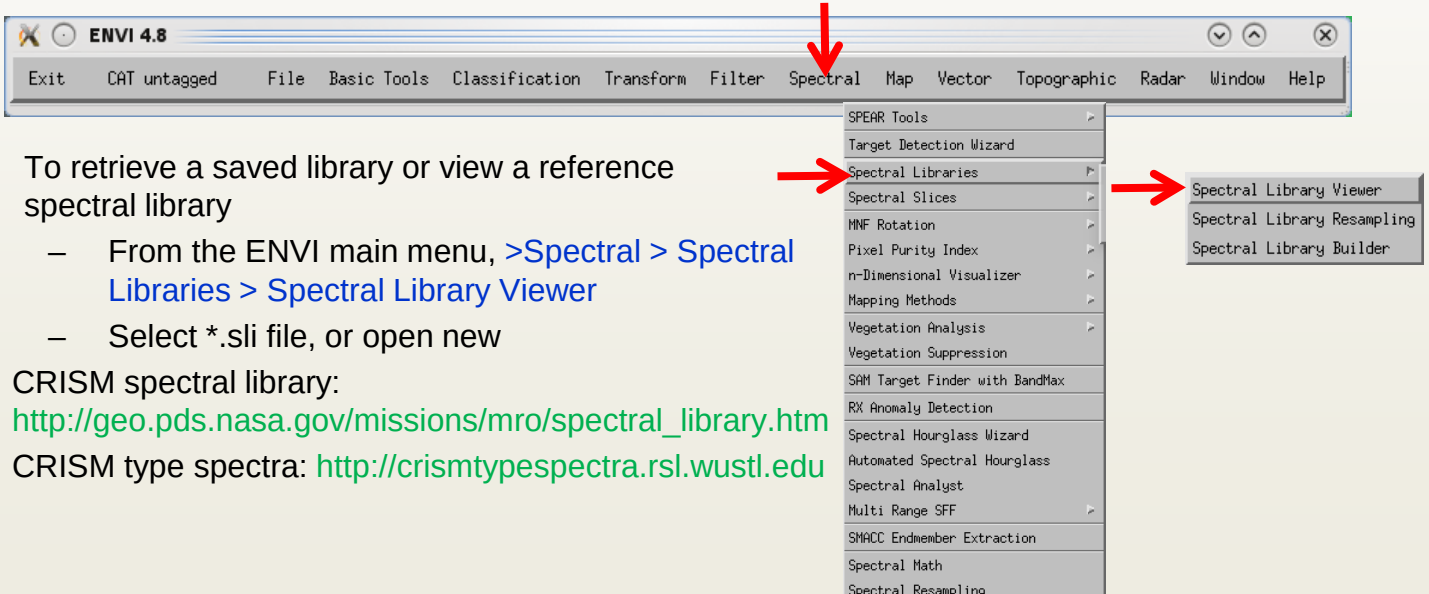


- In >Edit >Plot Parameters, subset the x-axis range to bracket the feature of interest
- Then choose Plot_Function > Continuum Removed as the display method
- You will likely have to rescale the y-axis in the continuum removed-plot

Spectral Libraries

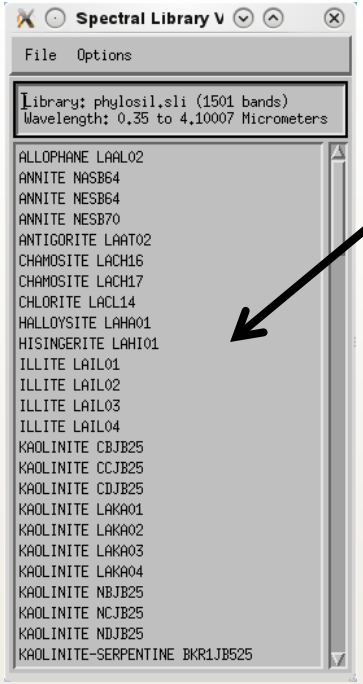


- Save spectra as ENVI spectral libraries (*.sli), or export as ASCII text file
  - From a spectral plot window, >File >Save Plot As > Spectral Library
  - HINT: Line colors are not preserved; make sure you rename the spectra appropriately



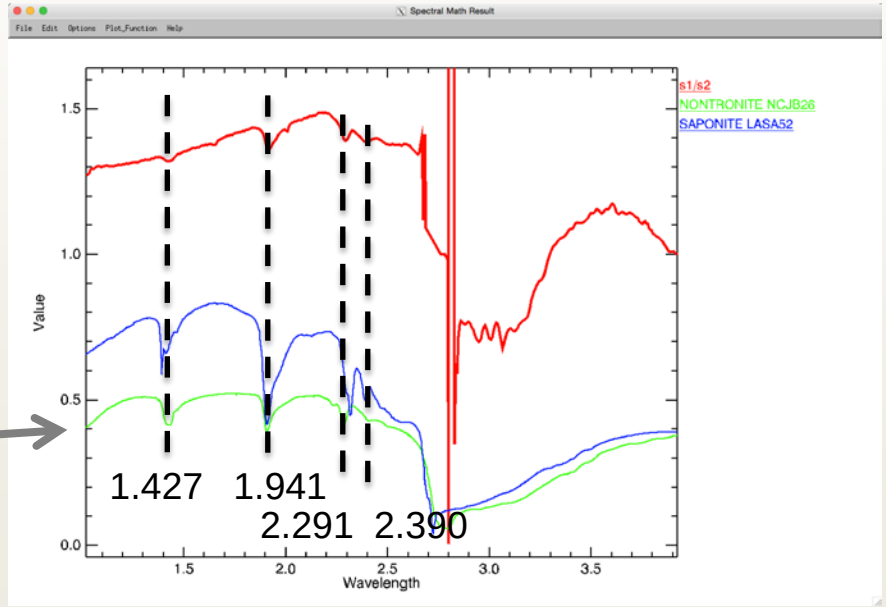
- To retrieve a saved library or view a reference spectral library
  - From the ENVI main menu, >Spectral > Spectral Libraries > Spectral Library Viewer
  - Select *.sli file, or open new
- CRISM spectral library: http://geo.pds.nasa.gov/missions/mro/spectral_library.htm
- CRISM type spectra: http://crismtypespectra.rsl.wustl.edu

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

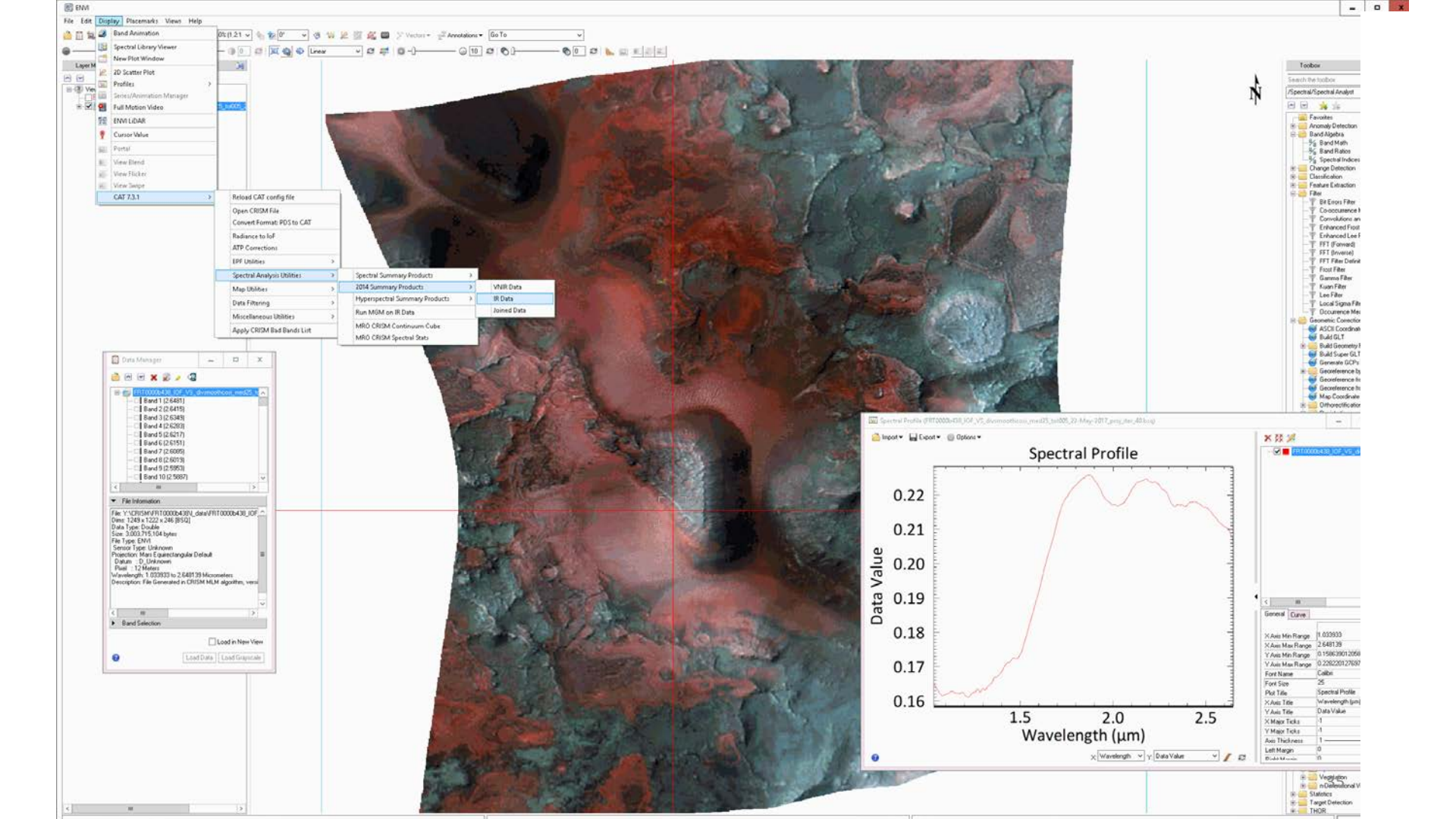
- **Common sense rules apply to spectral interpretation:**
  - All major absorption features in the spectrum of the proposed library mineral should be present or otherwise accounted for
  - Relative strengths and shapes of spectral features of the proposed library mineral should be replicated in the 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.**

Part V. ENVI 5.4 Demo

- Previous sections of this presentation depicted ENVI in “classic” mode, but more recent versions (ENVI 5+) include a more user-friendly and capable interface.
- The CAT has been updated to work with the ENVI 5+
  - Available at: http://pds-geosciences.wustl.edu/missions/mro/crism.htm
- This section will be a live demonstration of the ENVI 5.4 / CAT interface and capabilities.

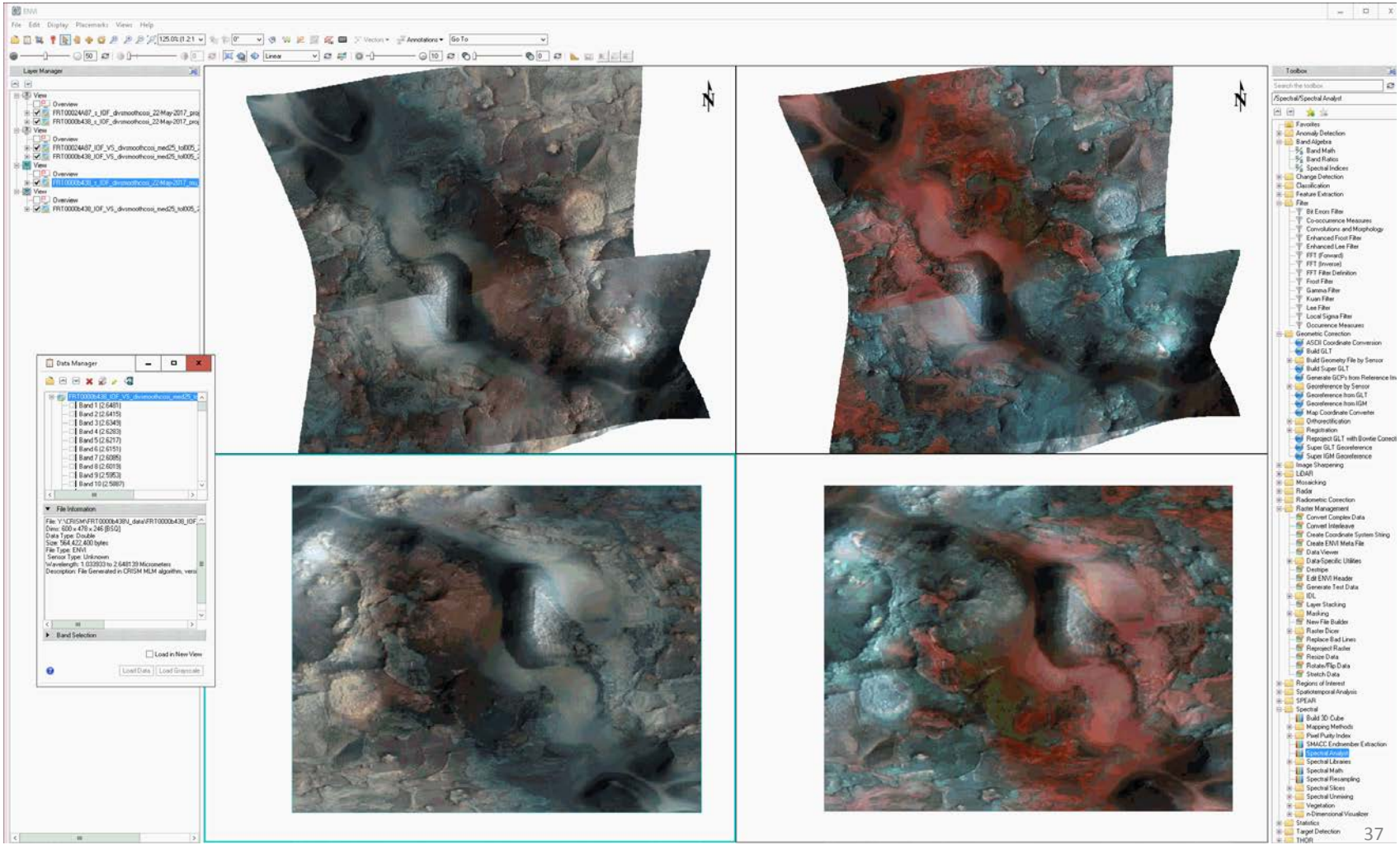
The next slide shows:

- Screenshot of ENVI 5.4 interface with CAT pulldown menu
- Example scene from Northeast Syrtis: FRT0000B438
  - Displayed: IR false color composite
  - Processing: to 12 m/pixel using log maximum likelihood procedures to retrieve best estimate of surface reflectance in presence of Poisson noise; projected views have spatial transfer function smear removed.
- CAT menu is accessed from top menu under Display.
  - Same ENVI/CAT functions are available just like in “classic” mode.
  - Pulldown is a view as if starting IR spectral parameter calculation
- Lower left: Data Manager shows hypercube wavelengths and file data structure.
- Lower right: Single pixel spectrum is displayed with location indicated by crosshair on IR false color composite image.


ENVI
File Edit Display Placemarks Views Help
Band Animation
Spectral Library Viewer
New Plot Window
2D Scatter Plot
Profiles
Series/Animation Manager
Full Motion Video
ENVI LiDAR
Cursor Value
Portal
View Blend
View Flicker
View Swipe
CAT 7.3.1
Reload CAT config file
Open CRISM File
Convert Format: PDS to CAT
Radiance to IoF
ATP Corrections
EPF Utilities
Spectral Analysis Utilities
Map Utilities
Data Filtering
Miscellaneous Utilities
Apply CRISM Bad Bands List
Spectral Summary Products
2014 Summary Products
Hyperspectral Summary Products
Run MGM on IR Data
MRO CRISM Continuum Cube
MRO CRISM Spectral Stats
VNIR Data
IR Data
Joined Data
Data Manager
Band 1 (2.6481)
Band 2 (2.6415)
Band 3 (2.6349)
Band 4 (2.6283)
Band 5 (2.6217)
Band 6 (2.6151)
Band 7 (2.6085)
Band 8 (2.6019)
Band 9 (2.5953)
Band 10 (2.5887)
File Information
Band Selection
Load in New View
Load Data
Load Grayscale
Spectral Profile
Data Value
0.22
0.21
0.20
0.19
0.18
0.17
0.16
1.5
2.0
2.5
Wavelength (µm)
Toolbox
Favorites
Anomaly Detection
Band Algebra
Band Math
Band Ratios
Spectral Indices
Change Detection
Classification
Feature Extraction
Filter
Geometric Correction
Statistics
Target Detection
THOR

The next slide shows:

- A few of the enhanced capabilities of the ENVI 5+ relative to “classic” mode.
- Example scene FRT0000B438
  - Displayed right side: VNIR false color composite (projected and un-projected)
  - Displayed left side: IR false color composite (projected and un-projected)
  - Processing: to 12 m/pixel using log maximum likelihood procedures to retrieve best estimate of surface reflectance in presence of Poisson noise; projected views have spatial transfer function smear removed.
- Corresponding false color composites of map-projected FRT00024A87 (an ATO) are overlain.



Presenters and Contact Information

- **Ray Arvidson (arvidson@wunder.wustl.edu)**
  - Washington University in St. Louis
  - Workshop co-convener, PDS Geosciences Node, CRISM Co-I
- **Frank Morgan (frank.morgan@jhuapl.edu)**
  - JHU Applied Physics Laboratory
  - CRISM uplink team, lead CAT developer
- **Frank Seelos (frank.seelos@jhuapl.edu)**
  - JHU Applied Physics Laboratory
  - CRISM Science Operations Lead Emeritus, TER/MTRDR development
- **Kim Seelos (kim.seelos@jhuapl.edu)**
  - JHU Applied Physics Laboratory
  - CRISM Science Operations Lead

- **And thank-you to the many other contributors!**
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  - JHUAPL: Debra Buczkowski, Christina Viviano-Beck, Scott Murchie