



CRISM Demonstration: Data Access, Processing, and Analysis

3RD PLANETARY DATA WORKSHOP

June 12, 2017
Flagstaff, AZ



PDS Geosciences Node
Washington University in St. Louis

The logo consists of a small red and white shield-shaped crest with a cross and other heraldic symbols, followed by the text 'Washington University in St. Louis'.

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

The logo features a blue shield with the white letters 'APL' inside, positioned above the text 'JOHNS HOPKINS' and 'APPLIED PHYSICS LABORATORY'.

Agenda & Objectives

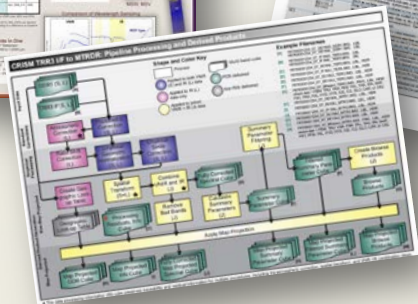
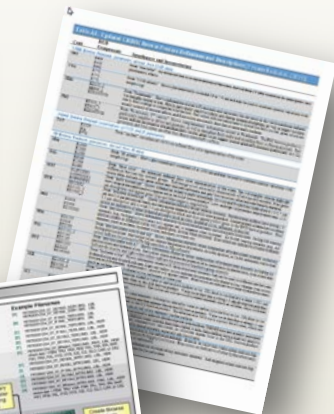
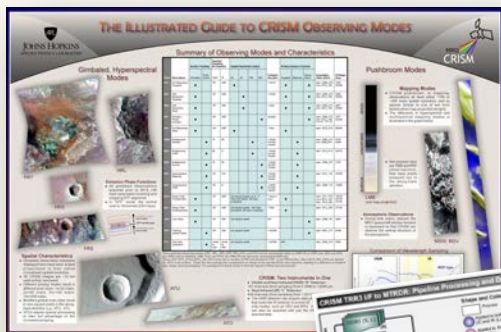
- **Welcome/Overview** (2 min)
 - Handouts
- **Part 0. What is CRISM?** (5 min)
- **Part I. Data Access** (Demonstration; 10 min)
 - PDS Orbital Data Explorer (ODE)
- **Part II. Standard Processing** (Group Exercise; 30 min)
 - CRISM Analysis Tools (CAT)
- **Part III. MTRDRs and Data Visualization** (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?

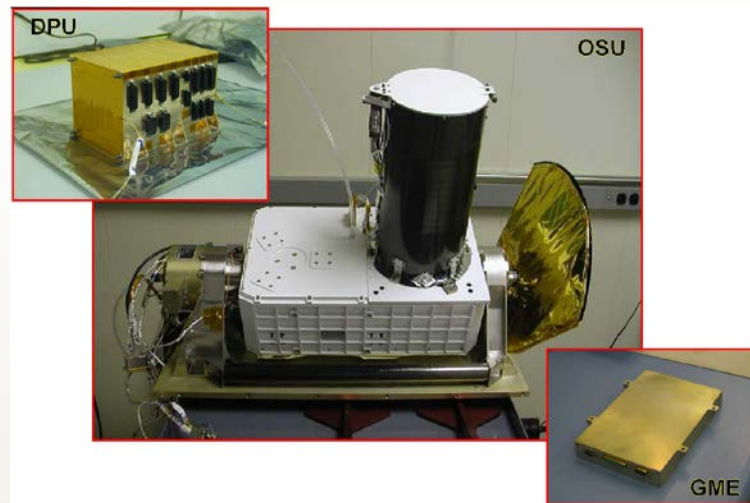
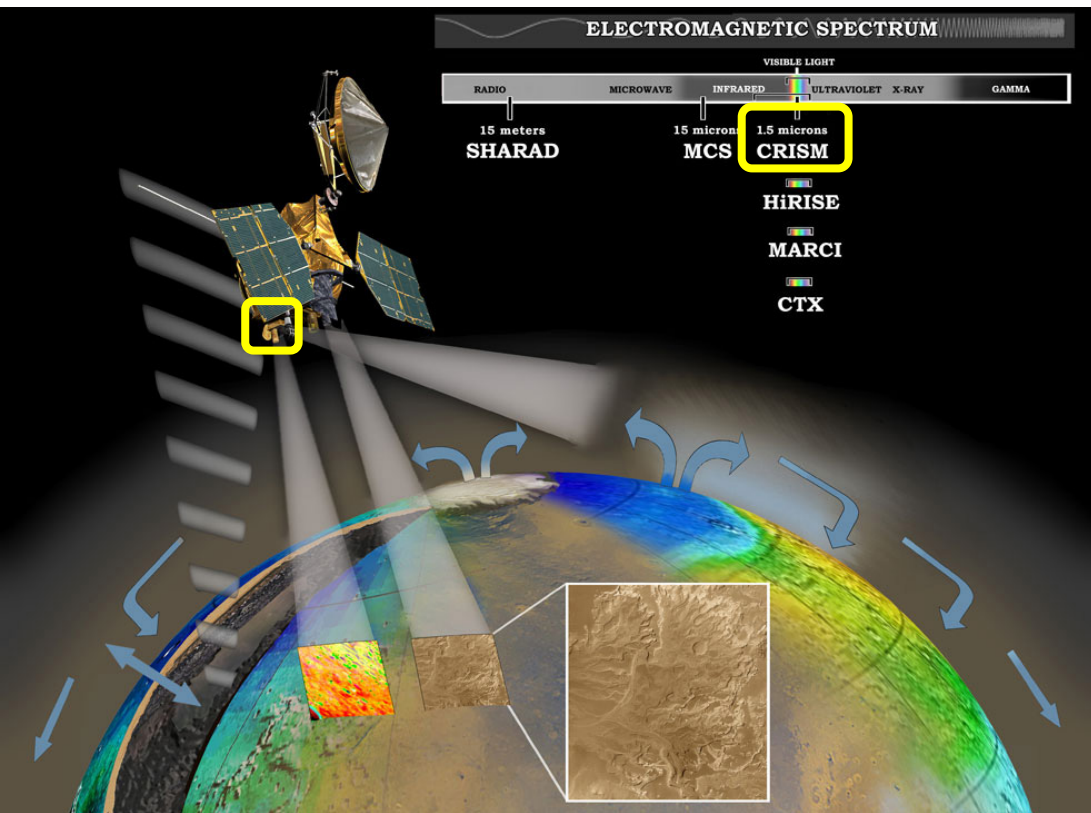
- CRISM = **C**ompact **R**econnaissance **I**maging **S**pectrometer for **M**ars
- Basic instrument characteristics and observing modes

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

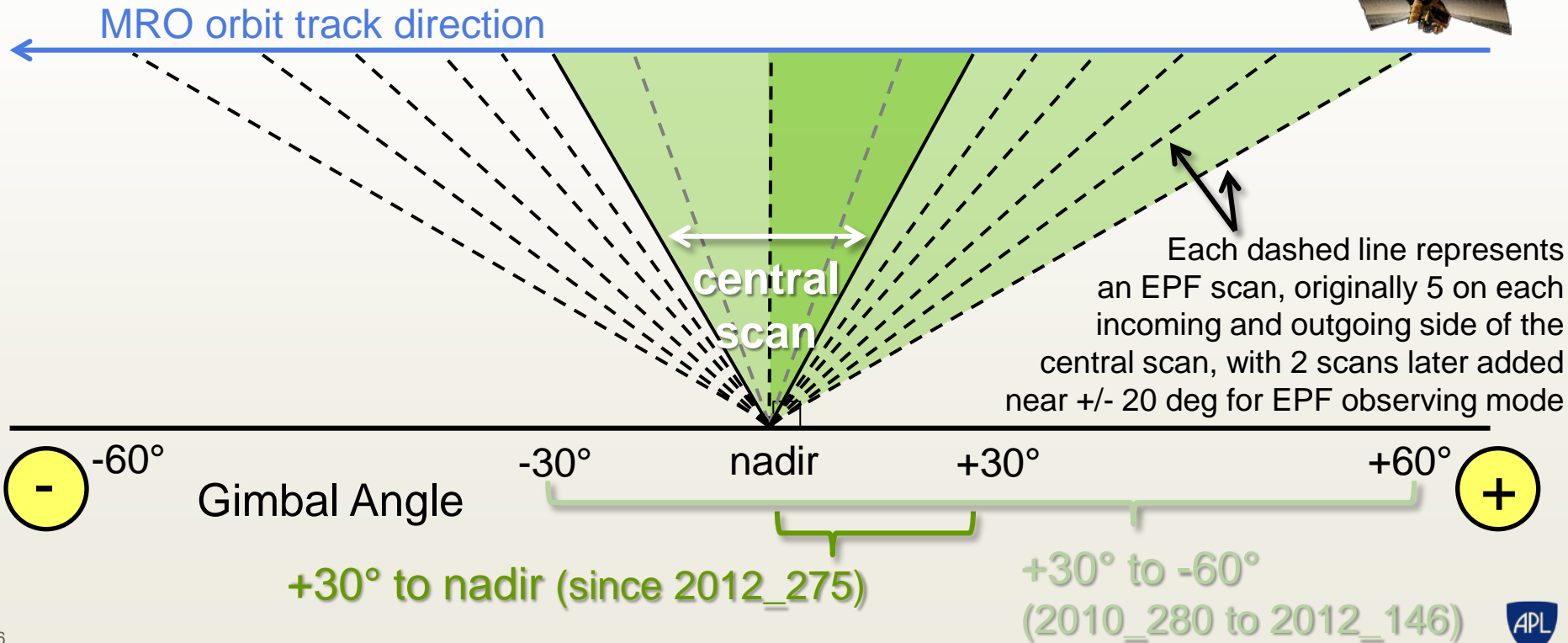


- A gimbaled, vis-near IR reflectance spectrometer
 - 544 bands from 0.4 - 3.9 μ m
 - 20 m/pix targeted mode
 - 100/200 m/pix mapping

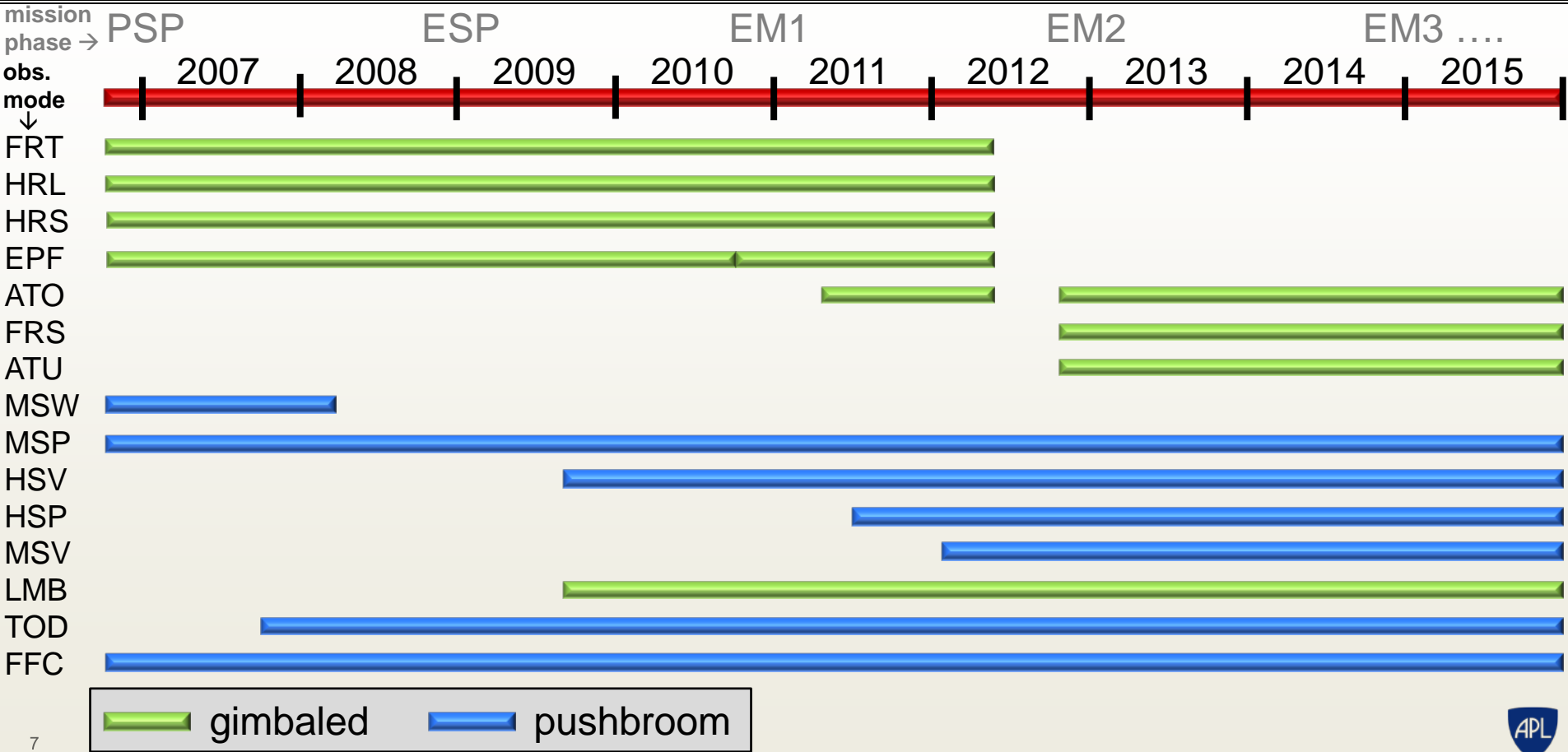
CRISM observing schematic & gimbaling range of motion

Original range of gimbaling 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

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

+ NASA Homepage
+ NASA en Español
+ Contact NASA

PDS Geosciences Node

Washington University in St. Louis

HOME DATA AND SERVICES TOOLS ABOUT US CONTACT US SITE MAP

Services

- Analyst's Notebooks
- Orbital Data Explorers
- Spectral Library
- Virtual Astronaut
- FTP Access
- Workshops

Geosciences Node Data

- Mars
- Venus
- Mercury
- Moon
- Earth
- Asteroids
- Gravity Models
- All Geosciences Data Holdings

Help

- Frequently Asked Questions
- Geosciences Node Forums
- Help for Data Users
- Help for Data Reviewers
- Help for Proposers
- About Checksums
- Email Us

Scheduled Maintenance

This site will be down on the Thursday after the second Tuesday of the month between 7:00 and 9:30 pm Central Time for maintenance.

Welcome to the Geosciences Node

The Geosciences Node of NASA's **Planetary Data System** (PDS) archives and distributes digital data related to the study of the surfaces and interiors of terrestrial planetary bodies. We work directly with NASA missions to help them generate well-documented, permanent data archives. We provide data to NASA-sponsored researchers along with expert assistance in using the data. **All our archives are online and available to the public to download free of charge.**

Where's the Data?

Click on **DATA AND SERVICES** in the black navigation bar above to browse our data holdings.

Coming Soon

- Jun. 1, 2017 - **MRO** Release 41
- Jun. 15, 2017 - **LRO** Release 30
- Jun. 21, 2017 - **MER** Release 52
- Jul. 1, 2017 - **Odyssey** Release 30
- Aug. 1, 2017 - **MSL** Release 15

What's New

May 12, 2017. The final release of **MESSENGER** data has been posted.

May 12, 2017. New **Mars Express OMEGA** data have been posted.

Apr. 27, 2017. Release 6 of **CRISM** MTRDR and TER data is released, along with new TRDR browse and extras data products.

Apr. 25, 2017. New **Mars Express HRSC** data have been posted.

Apr. 24, 2017. New **Mars Odyssey Radio Science** data have been posted.

What's Old

psida

Planetary Science Informatics and Data Analytics Conference
April 24-26, 2018

PDS Nodes: PDS Atmospheres Geosciences Imaging NAIF PPI Rings Small Bodies

FIRSTGOV
Your First Click to the U.S. Government

+ Freedom of Information Act
+ NASA 2003 Strategic Plan
+ NASA Privacy Statement, Disclaimer, and Accessibility Certification
+ Copyright/Image Use Policy

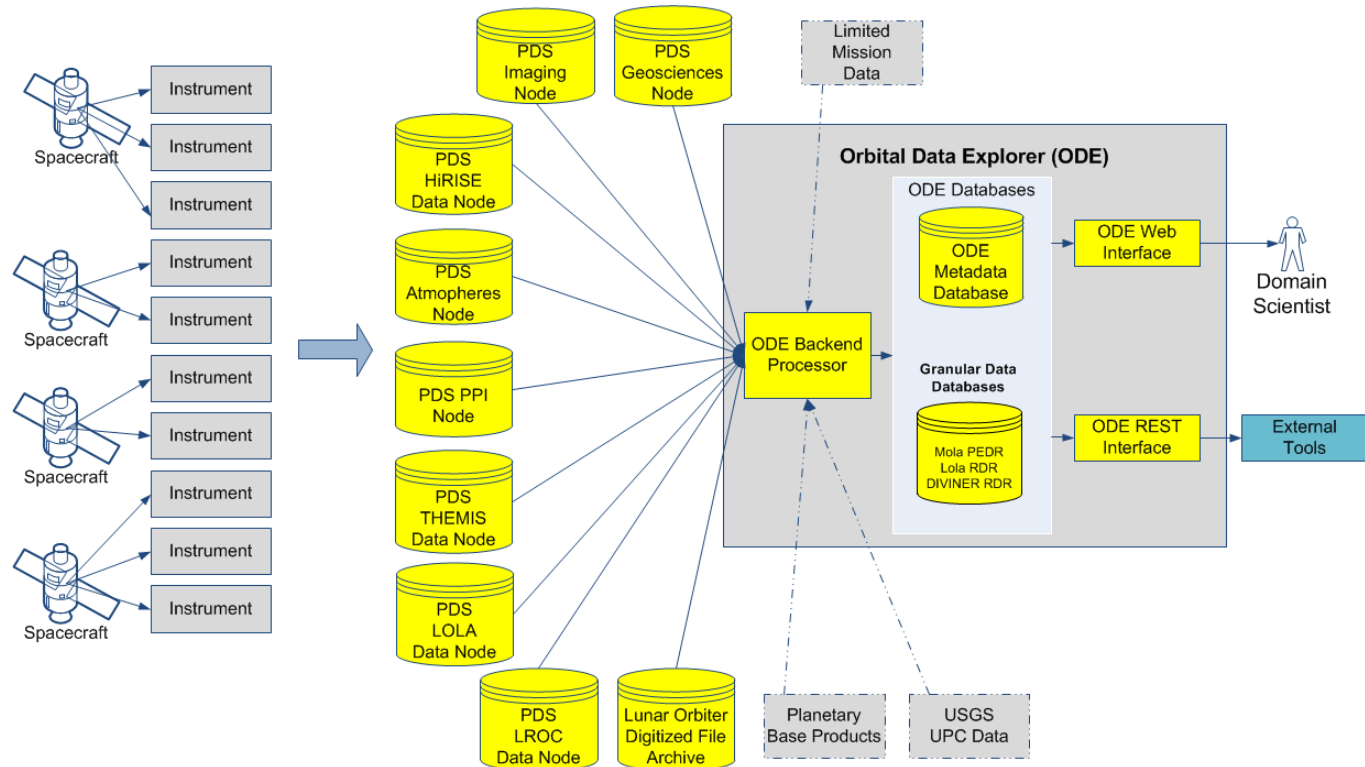
NASA

Curator: Susan Slavney
NASA Official: Raymond E. Arvidson
Last Updated: 12 May 2017
+ Comments and Questions

- <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

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.



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

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

The screenshot shows the homepage of the PDS Geosciences Node. At the top left is the NASA logo and the text "NATIONAL AERONAUTICS AND SPACE ADMINISTRATION". To the right are links: "+ NASA Homepage", "+ NASA en Español", and "+ Contact NASA". Below this is a banner image of a Mars rover with the text "PDS Geosciences Node" and "Washington University in St. Louis". A navigation bar contains links: "HOME", "DATA AND SERVICES", "TOOLS", "ABOUT US", "CONTACT US", and "SITE MAP".

Welcome to the Orbital Data Explorer

The PDS Geosciences Node Orbital Data Explorer (ODE) website is a cross-mission and instrument query, search, display, and download tool for locating and retrieving PDS orbital science data archives of **Mars, Mercury, Venus, and Earth's moon.**

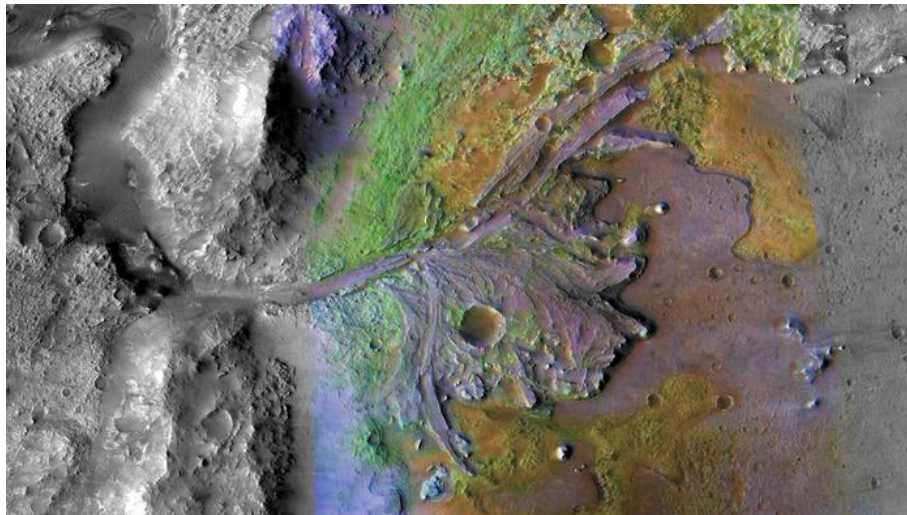
Orbital Data Explorer Targets:

- Mars Orbital Data Explorer**
The Mars Orbital Data Explorer (ODE) provides search, display, and download tools for selected PDS science data archives of the Mars Reconnaissance Orbiter (MRO), the Mars Global Surveyor, and the European Space Agency's Mars Express missions.
Supported Missions and Instruments:
Mars Reconnaissance Orbiter (MRO): CRISM, CTX, Gravity/Radio Science, HiRISE, MCS, SHARAD
ESA's Mars Express: HRSC, MARSIS, OMEGA, PFS
Mars Global Surveyor: MOC, MOLA
- Lunar Orbital Data Explorer**
The Lunar Orbital Data Explorer (ODE) provides search, display, and download tools for the PDS science data archives of the Lunar Reconnaissance Orbiter (LRO), the Clementine, the Lunar Prospector, and the Indian Space Research Organisation's Chandrayaan-1 missions.
Supported Missions and Instruments:
Lunar Reconnaissance Orbiter (LRO): DLRE, LAMP, LEND, LOLA, LROC, MRFLRO
ISRO's Chandrayaan-1: M3
Clementine: HIRES, LIDAR, LWIR, NIR, RSS, UUVIS
Lunar Prospector: ER, GRS, MAG, NS, RSS
- Mercury Orbital Data Explorer**
The Mercury Orbital Data Explorer (ODE) provides search, display, and download tools for the PDS science data archives of the MESSENGER (Mercury Surface, Space Environment, Geochemistry, and Ranging) mission.
Supported Missions and Instruments:
MESSENGER: GRS, MASCS, MDIS-NAC, MDIS-WAC, MLA, NS, RSS, and XRS
- Venus Orbital Data Explorer**
The Venus Orbital Data Explorer (ODE) provides search, display, and download tools for the PDS science data archives of the Magellan mission and the MESSENGER mission's Venus data.
Supported Missions and Instruments:
Magellan: RDRS, RSS
MESSENGER (Venus Data): GRS, MASCS, MDIS-NAC, MDIS-WAC, MLA, NS, RSS, and XRS

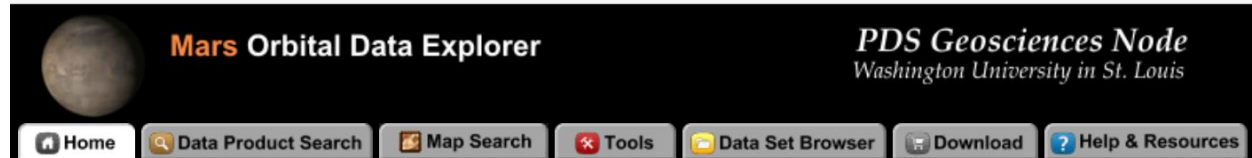
- ❑ Cross-mission and instrument searches across PDS Nodes
- ❑ Form-based, coverage-based, and map-based searches
- ❑ Feature-based searches, e.g., by crater name
- ❑ Granular data search (GDS)
- ❑ MRO coordinated observations
- ❑ Product type coverage KML files and shapefiles provided
- ❑ REST included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

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



WELCOME TO THE MARS ORBITAL DATA EXPLORER

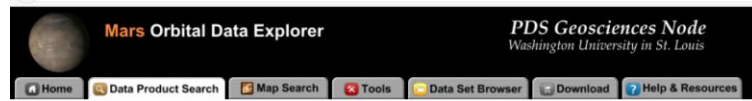
The **PDS Geosciences Node Mars Orbital Data Explorer (ODE)** provides search, display, and download tools for the PDS science data archives and other data sets from the Mars Reconnaissance Orbiter (MRO), the Mars Global Surveyor, and the European Space Agency's Mars Express missions. ODE also includes selected non-PDS data contributed by the science community to support landing site selection. **Choose one of the above tabs to start using ODE.**

Select

 Data Product Search Search for orbital science products across missions, instruments, and data sets via time, location, and product ids.	 What's New See what's new with ODE
 Additional Tools <ul style="list-style-type: none">• MRO Coordinated Observations• MOLA PEDR Query• Product Type Coverage	 Help & Resources Access the ODE help, find additional resources, and see what's coming
 Data Set Browser Browse through the orbital data set files stored in the PDS archives	 Available Data Sets A full list of mission, instrument, and product types available in Mars ODE
 Download Cart Download products added to the cart from the product search	 Mars ODE  Lunar ODE  Mercury ODE  Venus ODE

The Mars Orbital Data Explorer is produced by the [PDS Geosciences Node](#) at Washington University in St. Louis. Send comments to ode@wunder.wustl.edu.

ODE Example Search and Retrieval



DATA PRODUCT SEARCH

Planetary science data stored in PDS is organized by [data products](#) and [data sets](#). A data set is a collection of related data products, usually products acquired by a particular instrument and processed in a certain way. The data set also includes all documentation and supporting materials needed to understand and use the data products. A data product is a set of measurements resulting from a science observation, usually products acquired by a particular instrument and processed in a certain way.

The search form is populated with 8 filtering parameters from your last search. Click the "Reset Form" button, if you wish to clear these filters.

[Reset Form](#)

STEP 1. SELECT DATA SETS TO SEARCH (A SELECTION IS REQUIRED)

Select One or More Desired Data Sets (Released PDS Archives) (Hide Options - 4 Parameters Set)

- Map location data is available for these products.
- Observation time data is available for these products.
- Product emission, incidence, and phase angle data is available for these products.
- Solar longitude data is available for these products.

Mars Reconnaissance Orbiter

CRISM - Compact Reconnaissance Imaging Spectrometer for Mars

Other Product Types

CRISM Product Primer

- LDR - Limb Data Record [Data Set Description](#)
 - MRDR - Multispectral Reduced Data Record [Data Set Description](#)
 - TRDR - Targeted Reduced Data Record [Data Set Description](#)
- Note: Corresponding DDRs can be added to the cart at checkout
- TRDR Subsets (Click to hide list)
- Targeted TRDRs (FRT, HRL, HRS, FRS, ATO, ATU) [Data Set Description](#)
 - Targeted TRDRs (FRT, HRL, HRS, FRS, ATO, ATU), center swath only I/F [Data Set Description](#)
 - Multispectral TRDRs (MSP, MSW, HSW, HSP, MSV) [Data Set Description](#)
 - EPF and TOD TRDRs [Data Set Description](#)
 - Limb TRDRs and LDRs (LMB) [Data Set Description](#)
 - FFC TRDRs [Data Set Description](#)
 - TER - Targeted Empirical Record [Data Set Description](#)
 - MTRDR - Map-Projected TRDR [Data Set Description](#)

CTX - Context Camera

- EDR - Experiment Data Record [Data Set Description](#)
- and Non-PDS Compliant RDRs through [ASU Mars Space Flight Facility's Image Explorer](#)

HIRISE - High-Resolution Imaging Science Experiment

Other Product Types

- RDRV11 - Reduced Data Record with Embedded Map Projection [Data Set Description](#)
- ANAGLY - Anaglyph Image [Data Set Description](#)
- DTM - Digital Terrain Model [Data Set Description](#)

MCS - Mars Climate Sounder

Other Product Types

- RDR - Reduced Data Record [Data Set Description](#)
- DDR - Derived Data Record [Data Set Description](#)

RSS - Radio Science Subsystem

- EDR - Experiment Data Record [Data Set Description](#)
- RSDMAP - RSS Digital Map [Data Set Description](#)

Select

Select

STEP 2. SET ADDITIONAL FILTERING PARAMETERS (OPTIONAL)

Filter by Product ID (Show Options - 0 Parameters Set)

Find by Location or Feature (Hide Options - 4 Parameters Set)

Select a Specific Feature

A selected feature's Latitude and Longitude bounding box will be used for search criteria.

Feature Type: [Feature Type Descriptions](#)

Feature Name: [Full Feature Name List](#)

or

Directly specify a Latitude and Longitude coverage area

Mars ODE uses [areocentric coordinates](#) that are based on the product's center latitude and longitude.

Max Latitude

(-90 to 90)

Western most Longitude

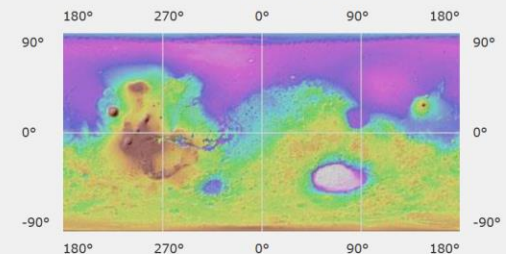
(0 to 360)

Min Latitude

(-90 to 90)

[Show Area On Map](#)

Selected Search Area



Filter by Time Range (Show Options - 0 Parameters Set)

Filter by Observation Angle (Show Options - 0 Parameters Set)

STEP 3. PREVIEW SEARCH RESULTS SUMMARY (OPTIONAL)

[Preview Search Results Summary](#)

STEP 4. SUBMIT QUERY

Display Product Thumbnails on search results page

Select

ODE Example Search and Retrieval

Mars Orbital Data Explorer
PDS Geosciences Node
Washington University in St. Louis

Mars ODE Map Interface - Cylindrical Center 0

Map Display Controls

Select Layers Set Filters (Optional) View Selection Results

Coverage Display Options

Display All Products' Coverage (with any filters applied)

or

Display Only Products Selected By Area (with any filters applied)

Available Map Layers with footprints

- Mars Feature Layer (Landers and Nonmenclature) [show details](#)
- MRO - CRISM TRDR [show details](#)
- MRO - CRISM Center (FRT,HRL,HRS, FRS, ATO,ATU) TRDRs [hide details](#)

CRISM Targeted TRDRs (FRT, HRL, HRS, FRS, ATO,ATU), center swath only IF - (footprint layer)
[More about this Data Set](#)

Set Layer Transparency

MRO - CRISM (FRT,HRL,HRS, FRS, ATO,ATU) TRDRs [show details](#)

- MRO - CRISM (MSP MSW,HSV,HSP,MSV) TRDRs [show details](#)
- MRO - CRISM (EPF,TOD) TRDRs [show details](#)
- MRO - CRISM (LMB) TRDRs & LDRs [show details](#)
- MRO - CRISM (FFC) TRDRs [show details](#)
- MRO - CRISM MRDR [show details](#)
- MRO - CRISM MTRDR [show details](#)
- MRO - CRISM TER [show details](#)
- MRO - CRISM LDR [show details](#)
- MRO - CTX EDR/RDR [show details](#)
- MRO - HIRISE RDRV11 [show details](#)
- MRO - HIRISE DTM [show details](#)
- MRO - HIRISE ANAGLY [show details](#)
- MRO - RSS RSDMAP [show details](#)
- MRO - SHARAD USRDR [show details](#)
- MRO - SHARAD USGEOM [show details](#)
- MRO - SHARAD RDR [show details](#)
- MRO - SHARAD EDR [show details](#)
- MEX - HRSC RDRV3 [show details](#)
- MEX - HRSC REFDR3 [show details](#)
- MEX - HRSC REFDR [show details](#)
- MEX - HRSC DTMRDR [show details](#)
- MEX - MARSIS RDRSS [show details](#)
- MEX - MARSIS EDR [show details](#)
- MEX - OMEGA DDRGM [show details](#)
- MEX - OMEGA EDR [show details](#)
- MEX - PFS EDR [show details](#)
- MGS - MOC NASDP [show details](#)
- MGS - MOC NADSDP [show details](#)
- MGS - MOC WASDP [show details](#)

Layer definitions

ODE Example Search and Retrieval

Page after
“View
Selections”
toggled

The screenshot displays the Mars Orbital Data Explorer (ODE) interface. At the top, it features the logo for the PDS Geosciences Node at Washington University in St. Louis. Below the logo is a navigation bar with buttons for Home, Data Product Search, Map Search, Tools, Data Set Browser, Download, and Help & Resources. The main interface is titled "Mars ODE Map Interface - Cylindrical Center 0" and includes a toolbar with options like Zoom In, Zoom Out, Full Extent, Prev Extent, Next Extent, Pan, Select Products By Area, Remove Area Selection, Select Projection, and Map Help.

On the left side, there is a "Map Display Controls" panel with a table of search results. The table has three columns: "Select Layers", "Set Filters (Optional)", and "View Selection Results". The results are listed as follows:

Select Layers	Set Filters (Optional)	View Selection Results
TRDR	FRT0001EAE0_07_IF166S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001ECBA_07_IF166L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001ECBA_07_IF166S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001F0D2_07_IF127S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001F7EA_07_IF126S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001FB74_07_IF166L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT0001FB74_07_IF166S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT00021DA6_07_IF166L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT00021DA6_07_IF166S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT00022212_07_IF126S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	FRT00023BAD_07_IF126S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL000040FF_07_IF183L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL000040FF_07_IF183S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL00010963_07_IF183L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL00010963_07_IF183S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL000116C6_07_IF183L_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL000116C6_07_IF183S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL0001F26F_07_IF195S_TRR3	<input type="checkbox"/>
MRO CRISM TRDR	HRL0001F43A_07_IF195S_TRR3	<input type="checkbox"/>
MRO CTX EDR/RDR	B05_011630_1986_XN_18N281W	<input type="checkbox"/>
MRO CTX EDR/RDR	B17_016219_1978_XN_17N282W	<input type="checkbox"/>
MRO CTX EDR/RDR	B17_016364_1978_XN_17N282W	<input type="checkbox"/>
MRO CTX EDR/RDR	B17_016443_1978_XN_17N282W	<input type="checkbox"/>

The main map area shows a grayscale image of Mars with several colored overlays: a large purple rectangle, a green rectangle, and a red rectangle. A white arrow labeled "Shown" points to a small gray rectangle within the green area. A yellow tooltip box above the map says "Click to view New Search Results [close]".

Select

ODE Example Search and Retrieval

Mars Orbital Data Explorer

PDS Geosciences Node
Washington University in St. Louis

Home Data Product Search Map Search Tools Data Set Browser Download Help & Resources

HRL000040FF_07_IF183L_TRR3

MRO CRISM TRDR - Targeted Reduced Data Record

[Product Description and Data Set Documents \(click to show\)](#)

Browse Meta Data Label Related Products Map Context

Additional browse products available below on this page

Browse Image - the image below is not the actual data product

This product is in your cart.

Add Product to Cart Remove Product from Cart Cart & Download Help

[CRISM Instrument Team Web Site](#)

PDS Product Files		Derived Files
Product Files & Labels		KB
hrl000040ff_07_if183l_trr3.img	Product Data File	269,109
hrl000040ff_07_if183l_trr3.lbl	Product Label File	10
hrl000040ff_07_ra183l_hkp3.tab	Product Data File	587
Referenced Files		KB
trdrhk.fmt	Label Format File	72

Shown after
clicking on
image thumbnail

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

ODE Example Search and Retrieval

Select →

Mars Orbital Data Explorer PDS Geosciences Node
Washington University in St. Louis

Home Data Product Search Map Search Tools Data Set Browser Download Help & Resources

CART CHECKOUT

PDS Data products are freely available to the public.

STEP 1. REVIEW PRODUCTS SELECTED Empty the Cart

Products Selected for Download: 8
Size of current cart selections: 2.51 GB

[View Products Selected for Download](#) (Hide Selection List - 8 Products)

Display Individual Files of the Products
Note: CRISM TRDR's corresponding DDR products are removed from the cart by removing the TRDR or deselecting the DDR checkbox in Step 2 of the page. [Remove Unchecked Products from the Cart](#)

Instrument	Type	Product ID	Obs Time	
MRO CRISM	DDR	HRL000040FF_07_DE183L_DDR1	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CRISM	DDR	HRL000040FF_07_DE183S_DDR1	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CRISM	TRDR	HRL000040FF_07_IF183L_TRR3	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CRISM	TRDR	HRL000040FF_07_IF183S_TRR3	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CRISM	TRDR	HRL000040FF_07_RA183L_TRR3	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CRISM	TRDR	HRL000040FF_07_RA183S_TRR3	2007-01-29T10:49:14.026	<input checked="" type="checkbox"/> In Cart
MRO CTX	EDR/RDR	P03_002387_1987_XI_18N282W	2007-01-29T10:49:18.409	<input checked="" type="checkbox"/> In Cart
MRO HIRISE	RDRV11	PSP_002387_1985_RED	2007-01-29T10:49:17.496	<input checked="" type="checkbox"/> In Cart

STEP 2. SELECT ADDITIONAL COMPONENTS

You have the option to include additional files that are associated with your selected products.

CRISM TRDRs (4) in the cart

Include corresponding CRISM DDRs
Most CRISM TRDRs have a corresponding DDR product, which contains the projection and geometry information
DDR Products: 2
DDR Files: 4
Size of DDR files: 9 MB

Include corresponding RA TRDRs
CRISM TRDR I/F products have corresponding RA products
TRDR RA Products: 2
TRDR RA Files: 7
Size of TRDR RA files: 336 MB

Include corresponding EPF TRDRs
Center swath TRDRs have corresponding EPF products from the same observation set
TRDR EPF Products: 40
TRDR EPF Files: 101
Size of TRDR EPF files: 2 MB

MRO CTX Product (1) is in the cart
Select the types of files you would like for the product
Selected Files: 1
Estimated size of ASU processed files: < 1 MB

Include PDS Source EDR & Source Browse

Non-PDS processed versions from [ASU Mars Space Flight Facility's Mars Image Explorer](#)

Pyramitized GeoTIFF ISIS Header PNG JPEG TIFF PDF

Derived Files
Derived files: 18

Select →

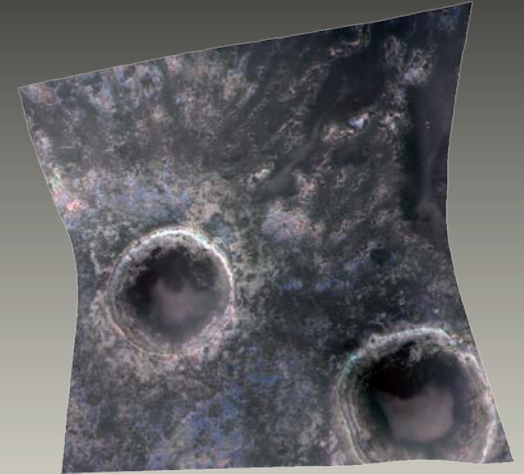
(Not shown are compression and data set organization options, along with download instructions)

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



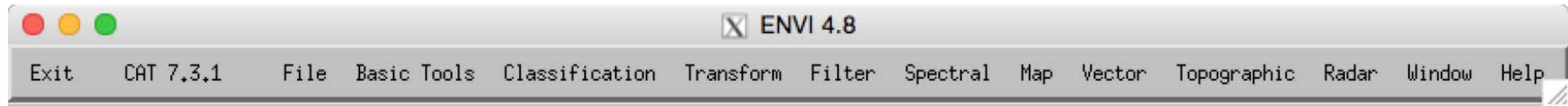
Extra information relevant to this section:

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

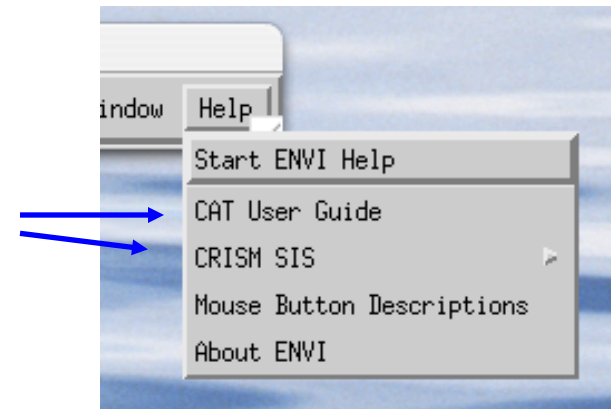
- The CRISM Analysis Toolkit (CAT) is a series of custom IDL procedures packaged as a plug-in to ENVI, a proprietary remote sensing software available through Harris Geospatial.
- To download and install the CAT, go to <http://pds-geosciences.wustl.edu/missions/mro/crism.htm>
- You will need **CAT Version 7.0** or better to utilize the MTRDRs and related data products.

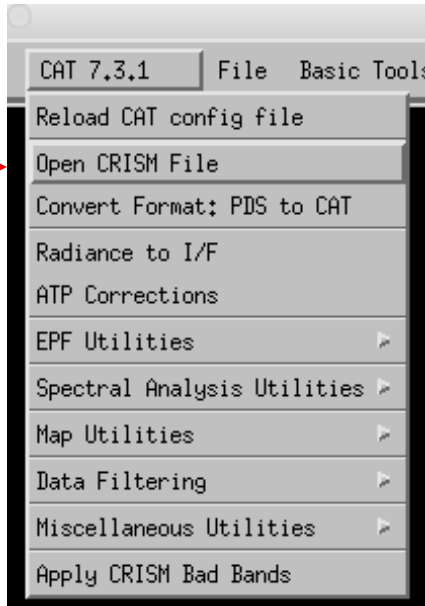
- IDL/ENVI procedures for CAT are found under:
 - CAT_ENVI/save_add/CAT_programs
- Calibration Data Records (CDR):
 - CAT_ENVI/aux_files/CDRs/
- Ancillary Data Records (ADR):
 - CAT_ENVI/aux_files/ADR/
- User manuals, CRISM SIS:
 - CAT_ENVI/aux_files
- Default CAT output:
 - CAT_ENVI/out
- CAT temporary 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

- 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



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

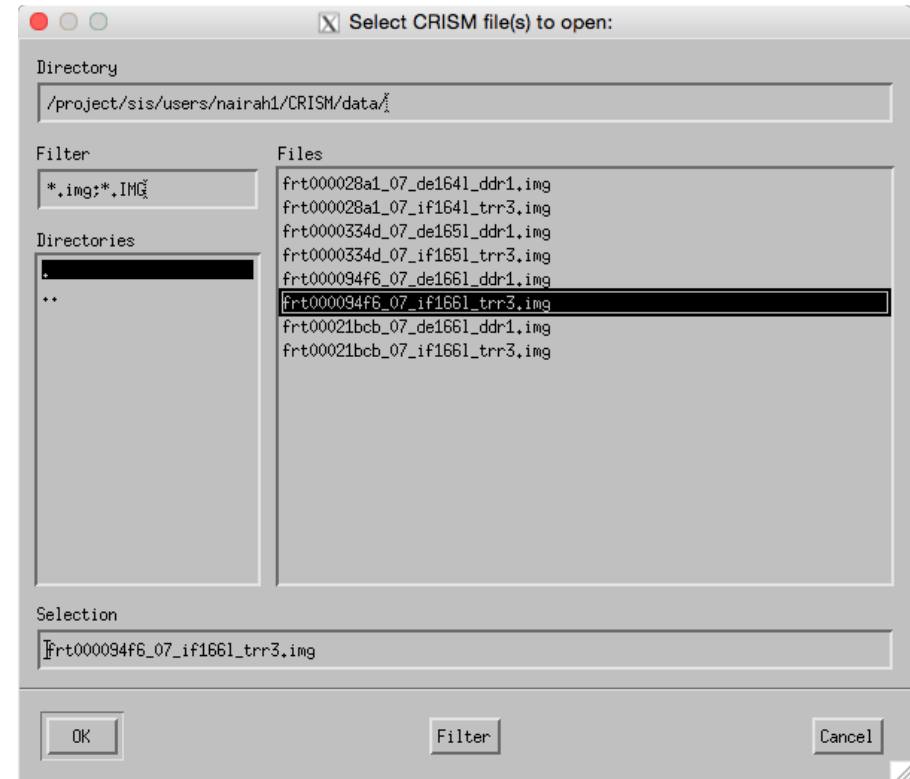




INPUT DATA:

- 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

- TRDR

- Spectral image data
- Filename like FRT000094F6_07_IF166L_TRR3.IMG

- DDR

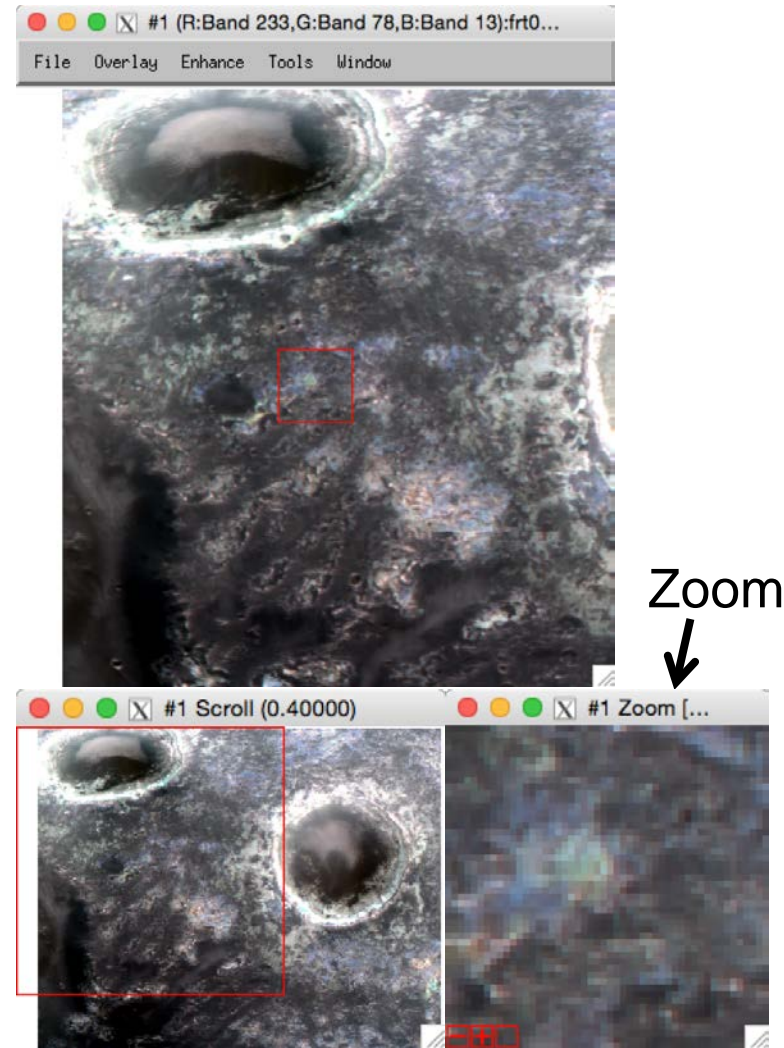
- “Backplanes” for TRDR files; geometry data including lat/lon, emission angles, elevation, other...
- Filename like FRT000094F6_07_DE166L_DDR1.IMG
- CAT wants to see DDRs and PDS labels along with the image data either in same directory (usual practice) or in a parallel directory structure like:
 - ...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

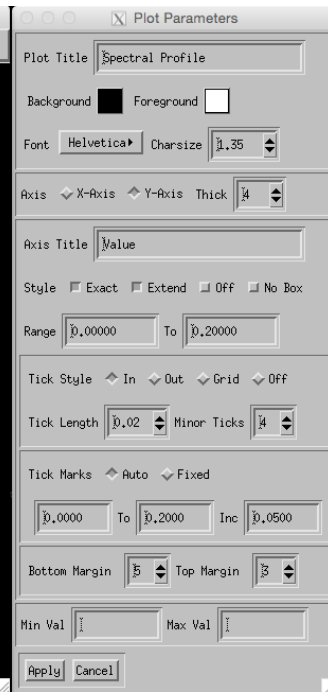
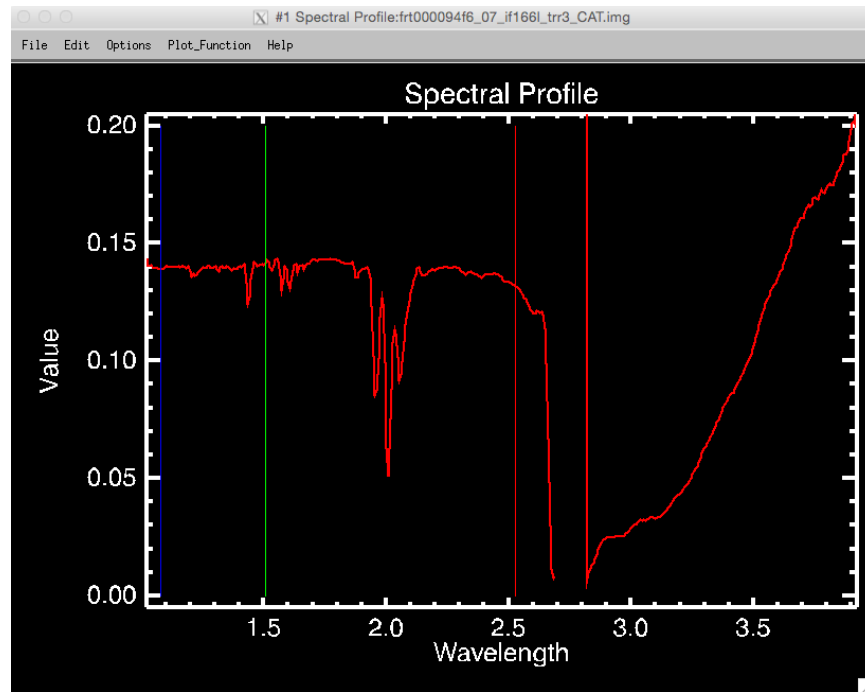
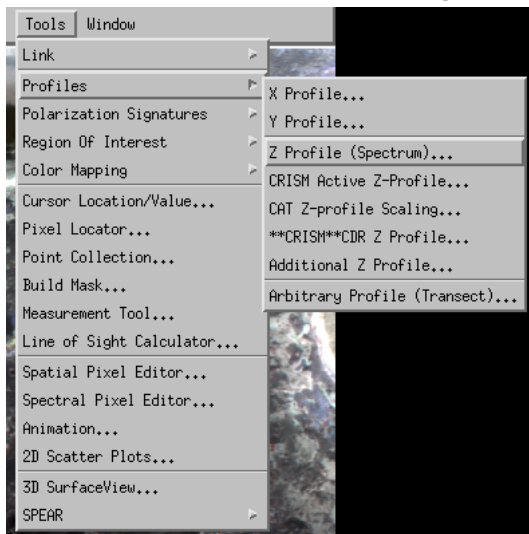
- Any image cube is initially opened in ENVI in a cluster of 3 windows.
 - Scroll (shows full spatial extent)
 - Image (full spatial resolution)
 - Zoom (4x resolution subset)
- Red box in the Scroll window shows location of Image window; red box in the Image window shows location of Zoom window.
- HINT: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

Image



Scroll

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

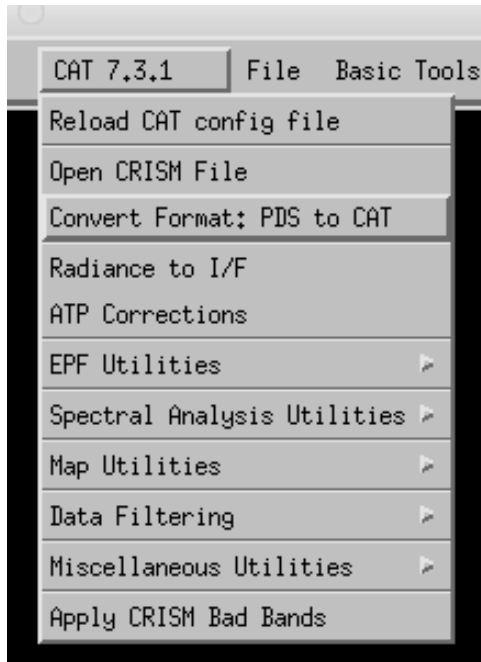


Z-profile extracted at Zoom window location.

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

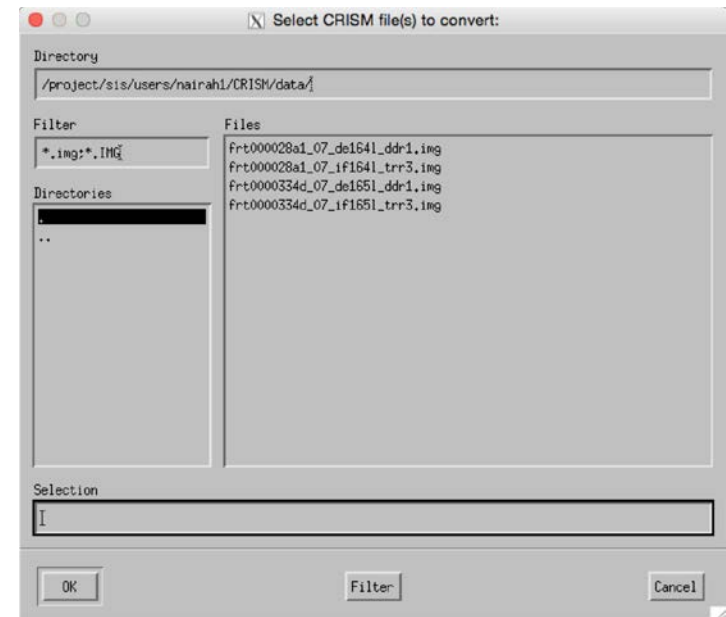
Colored vertical lines on spectral plot indicate RGB wavelength positions – can adjust, reload new combination in Image window.

Simple Image Processing and Summary Parameters



- 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

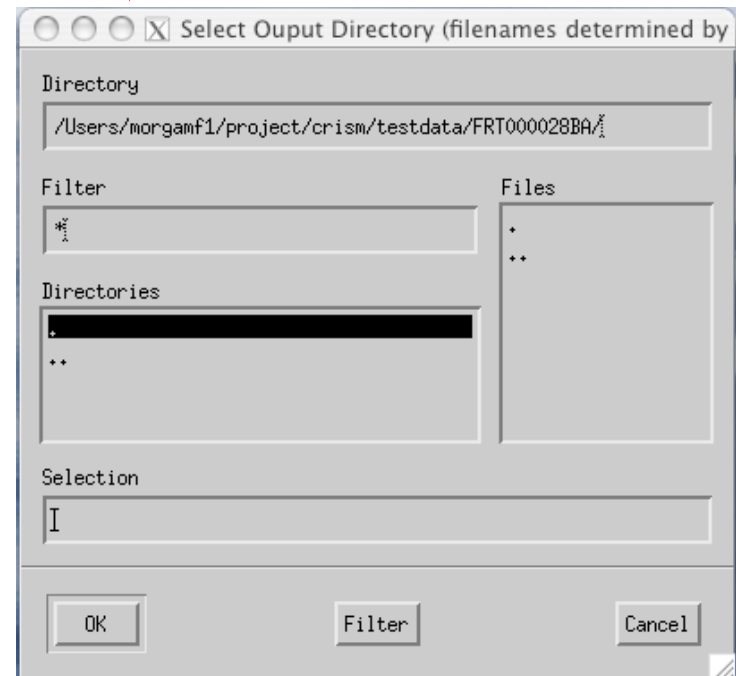
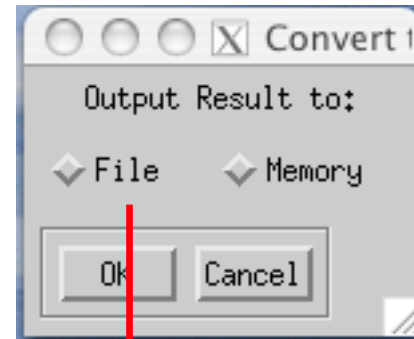


Common CAT question: Output to file or memory?

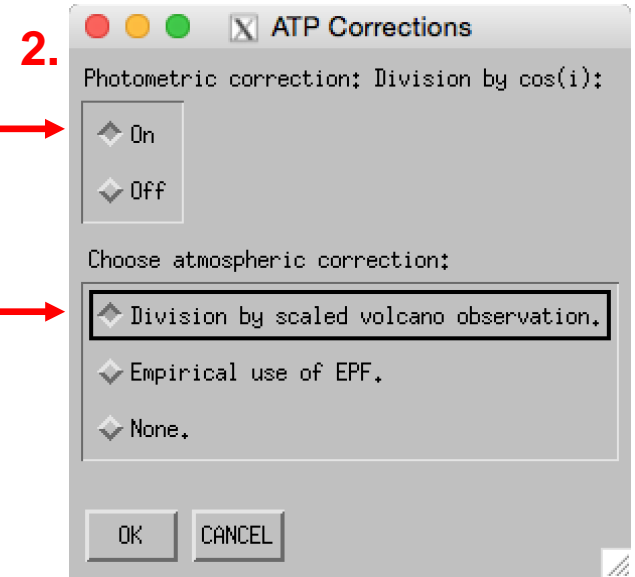
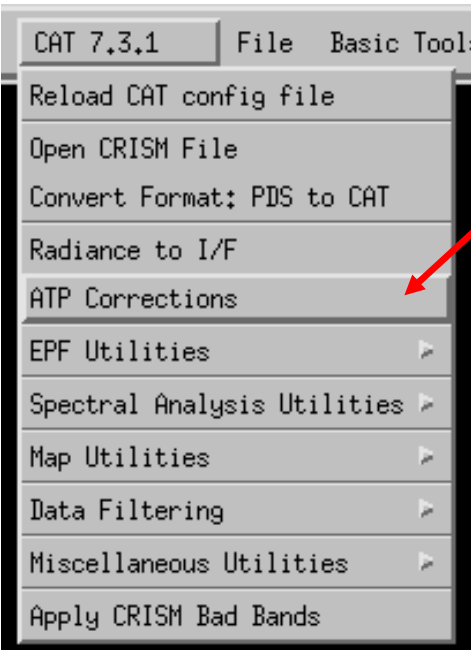
Select “File,” then select an output path and, usually, filename via the ENVI dialog:

OR...

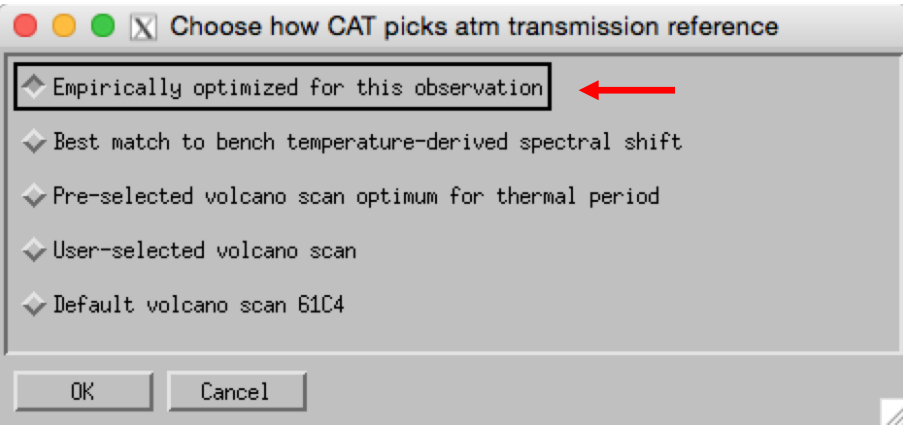
Select “Memory” and computation proceeds, with output to Available Bands and Display window



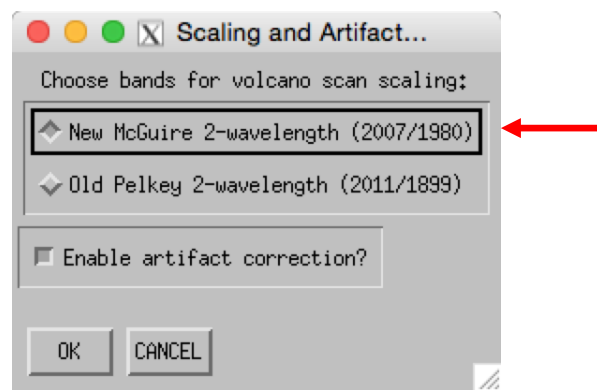
1. File selection dialog... then select corrections



3. Choose volcano scan selection method...



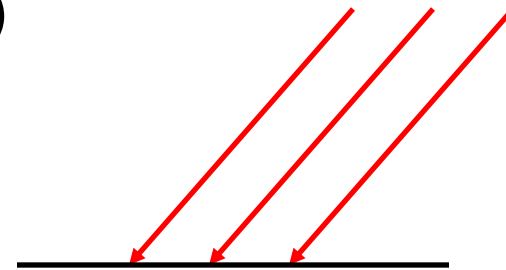
4. Select scaling wavelengths...



Photometric Correction...

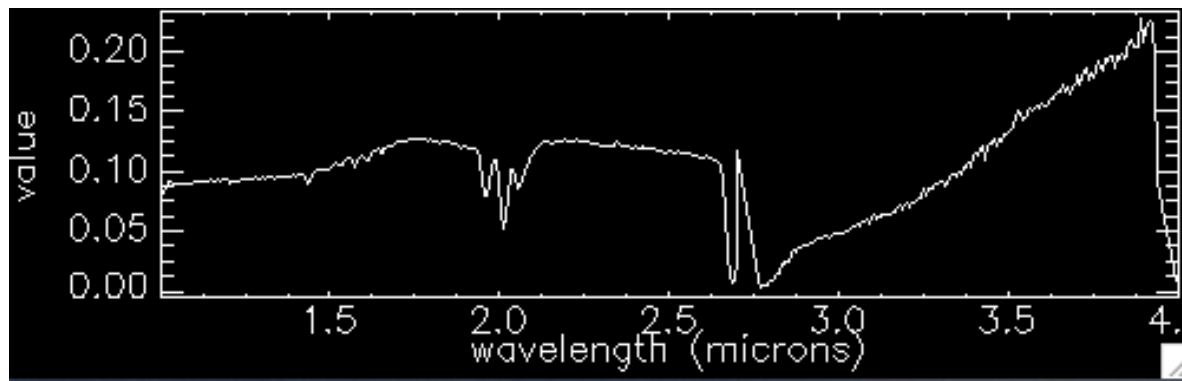
First order correction to radiance for non-normal solar incidence:

Divide by $\cos(\text{incidence angle})$

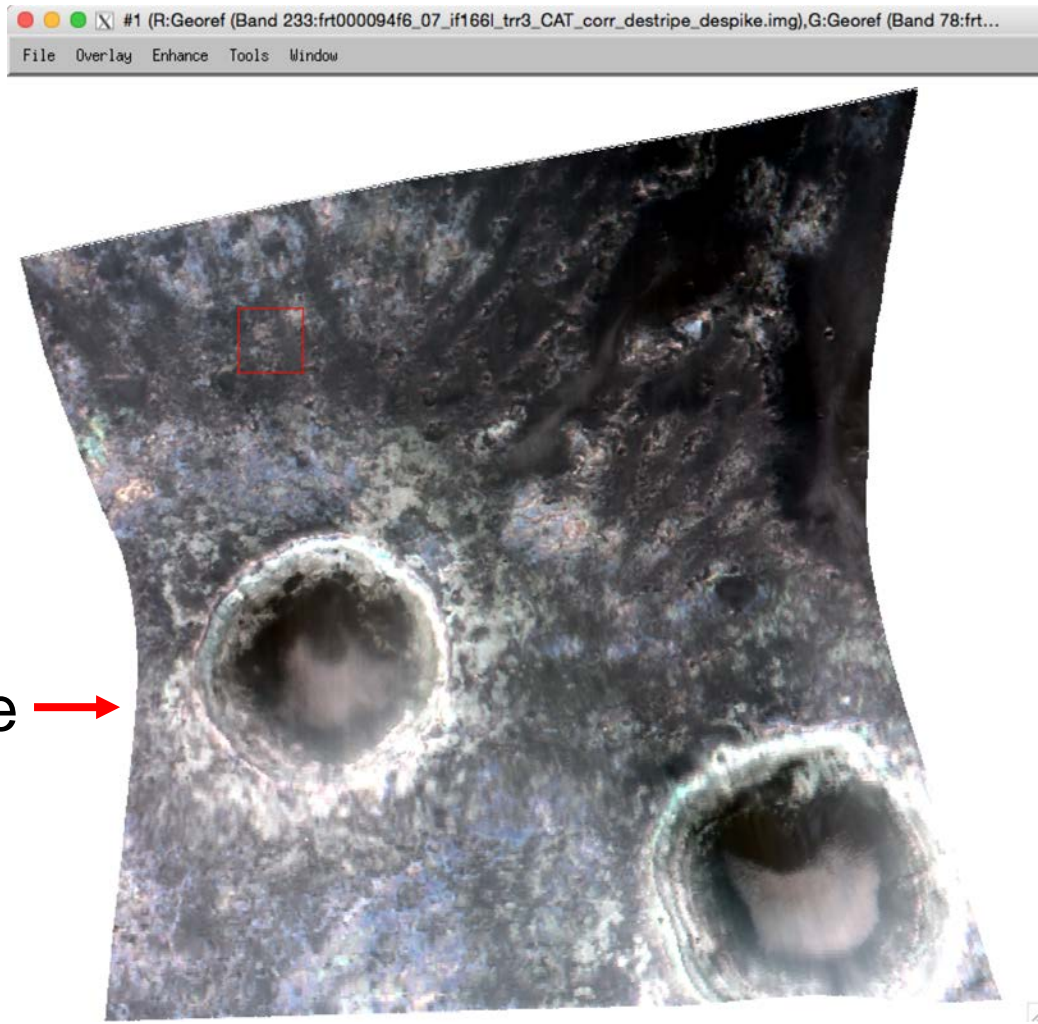
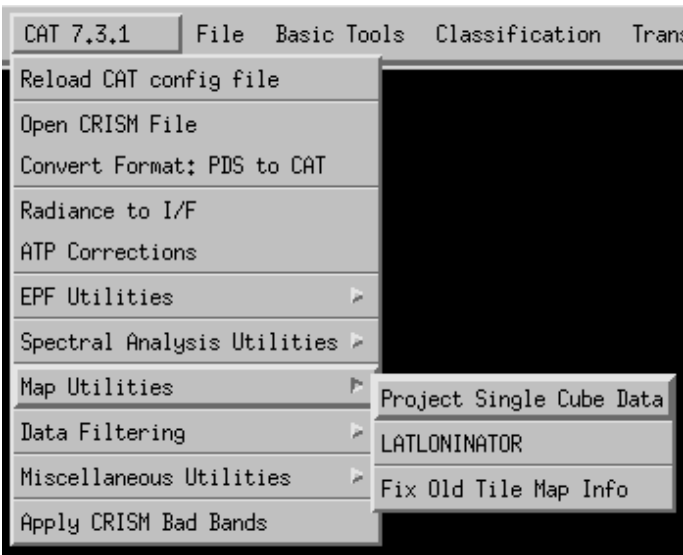


*Get incidence angle at aeroid from DDR
(ancillary data file)*

- Atmospheric Correction: Need to correct spectrum for absorption by CO₂
 - 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 CO₂ 2-micron band, then divide
 - One near absorption peak, one in wings
 - Adjusts for variable atmospheric optical depth- elevation, season...



- 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 absorption affecting 2011 but not 1899



Output is map-projected cube →

- Corrected spectral data
- 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

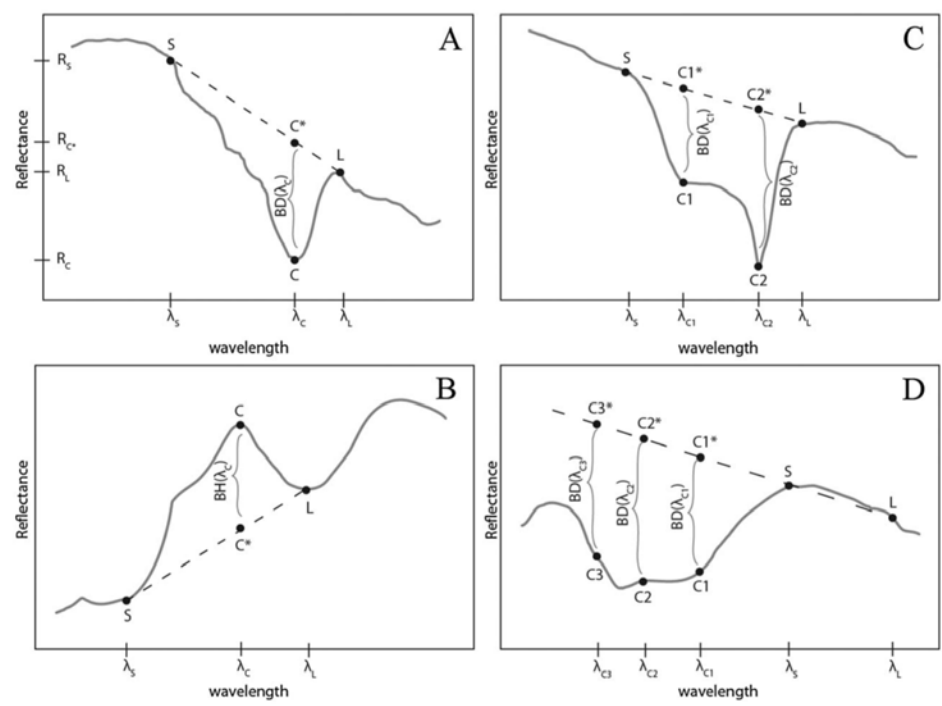
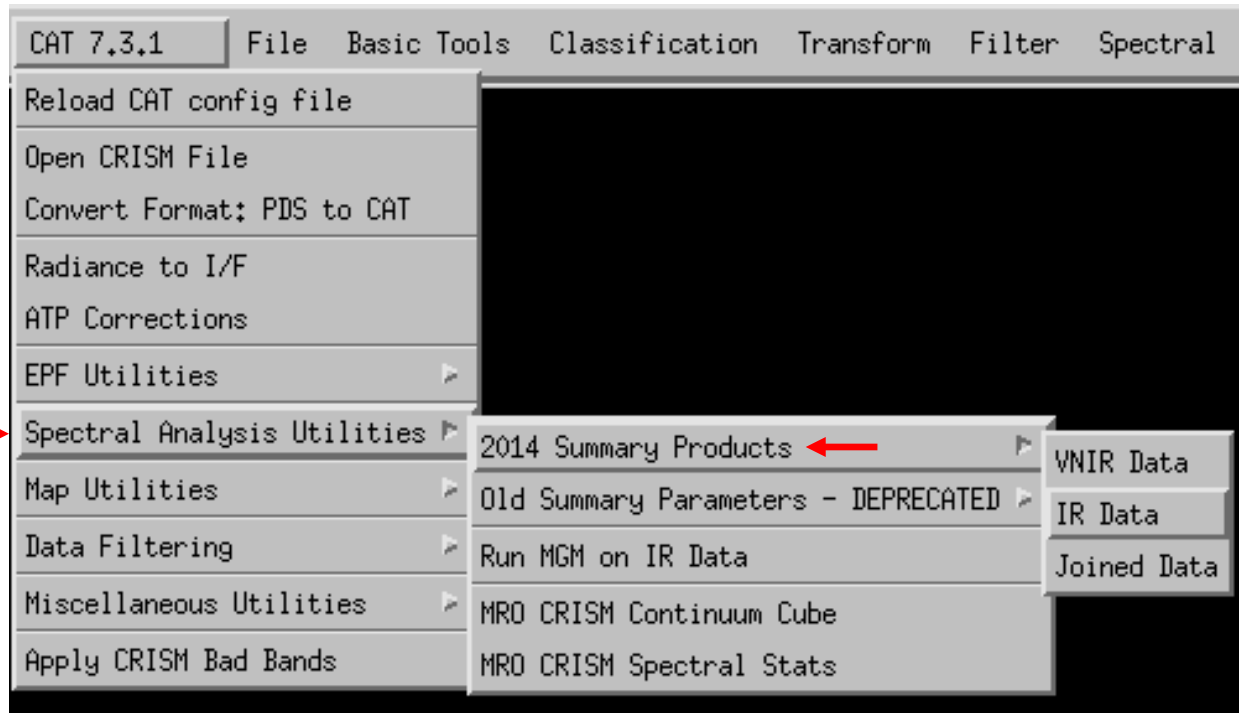


Figure 7. (a–d) A visual representation of several spectral parameter formulations using idealized spectra. The solid line is a hypothetical spectrum with the generalized spectral feature superimposed on the sloped continuum. The dashed line indicates a continuum fit across the absorption band by which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

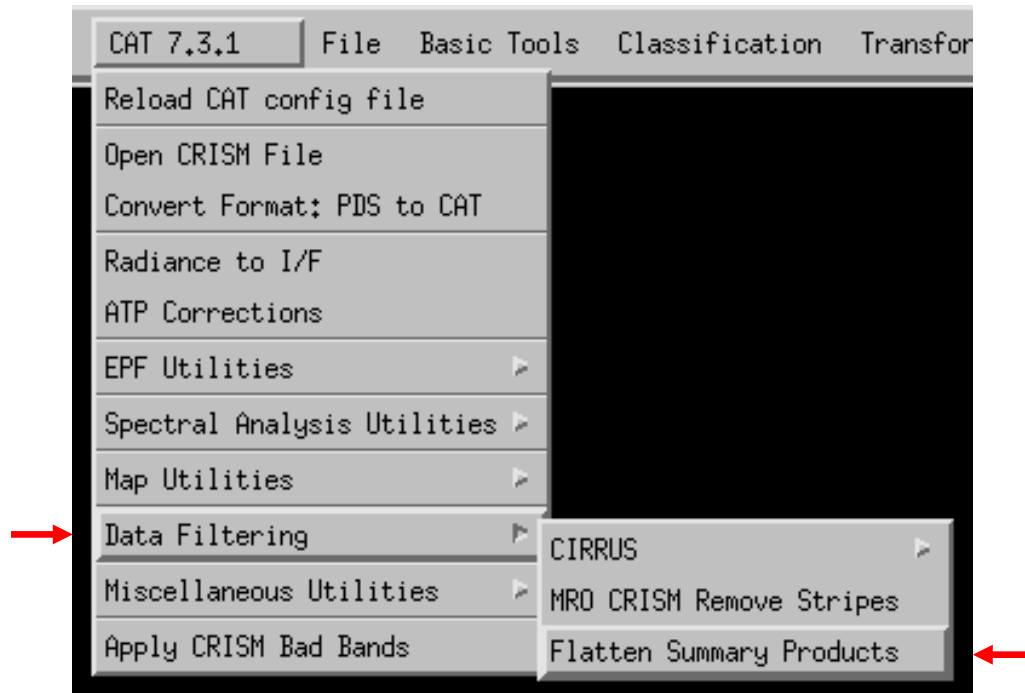
Spectral Analysis Utilities



Choose 'basic' set or 'all' parameters

- **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

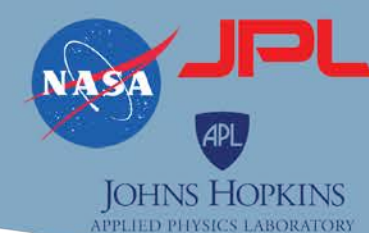
Extra information relevant to this section:

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

- 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
 - 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
- This is a superset of the typical CAT data processing workflow

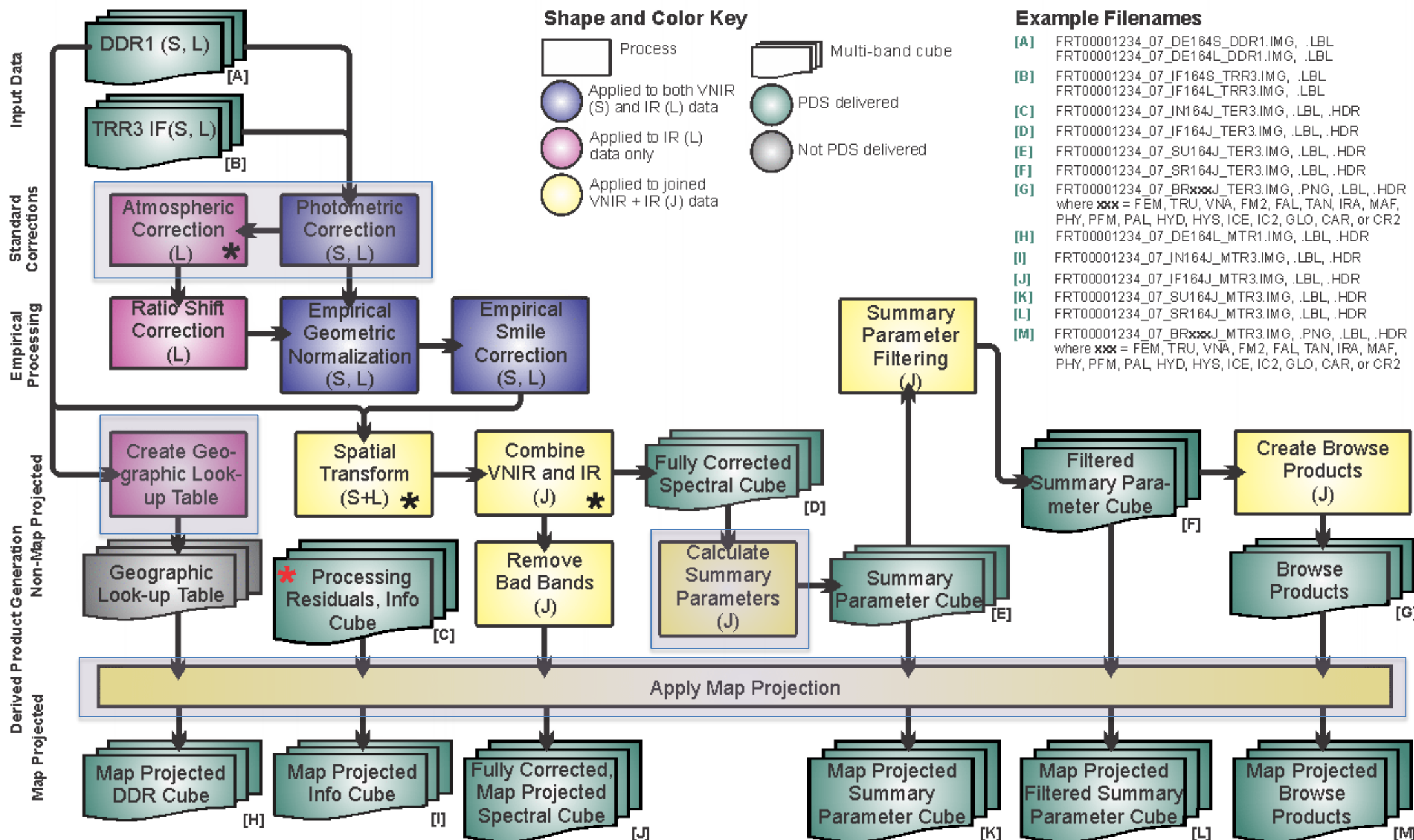


CRISM TER/MTRDR Workflow



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

CRISM CAT Functionality



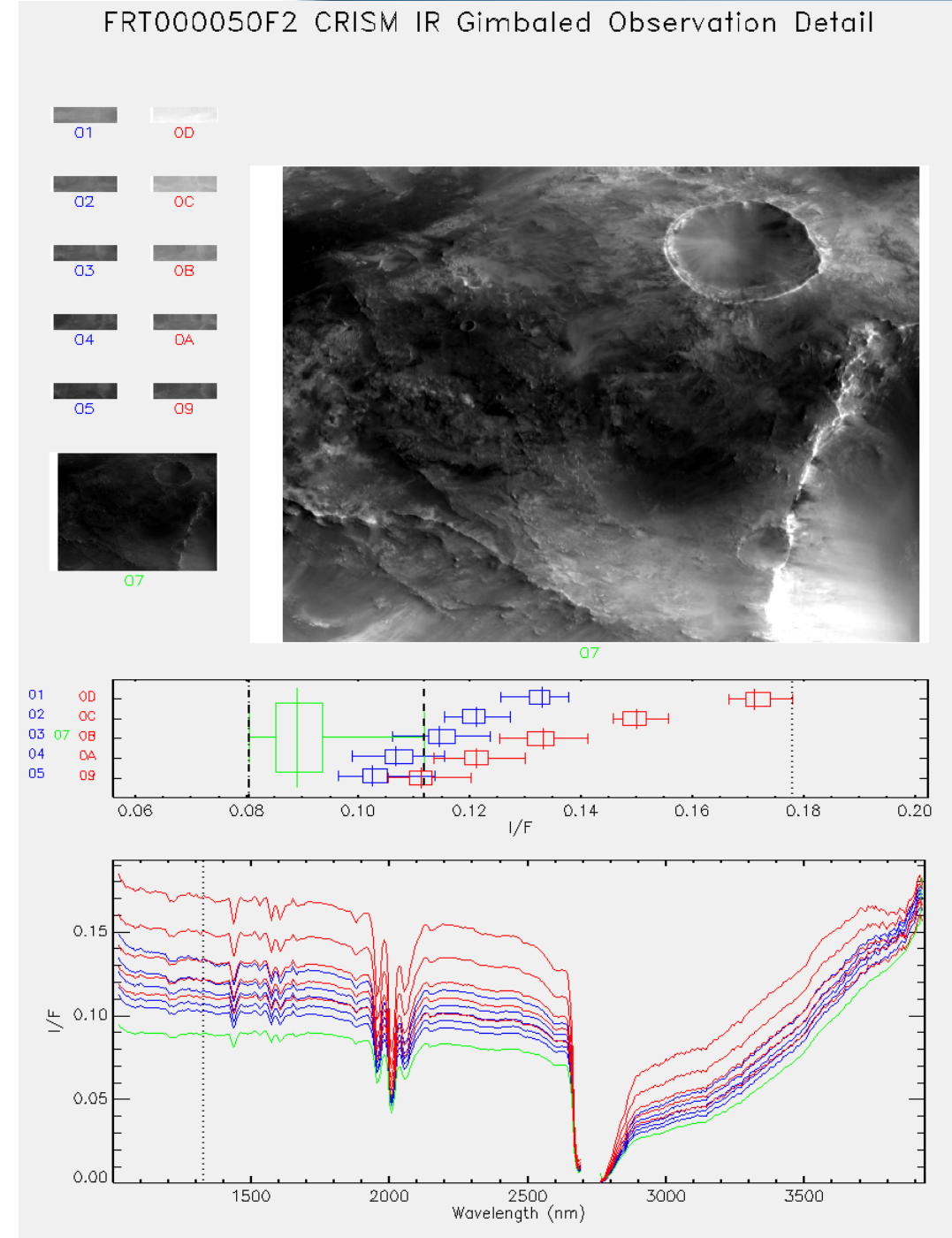
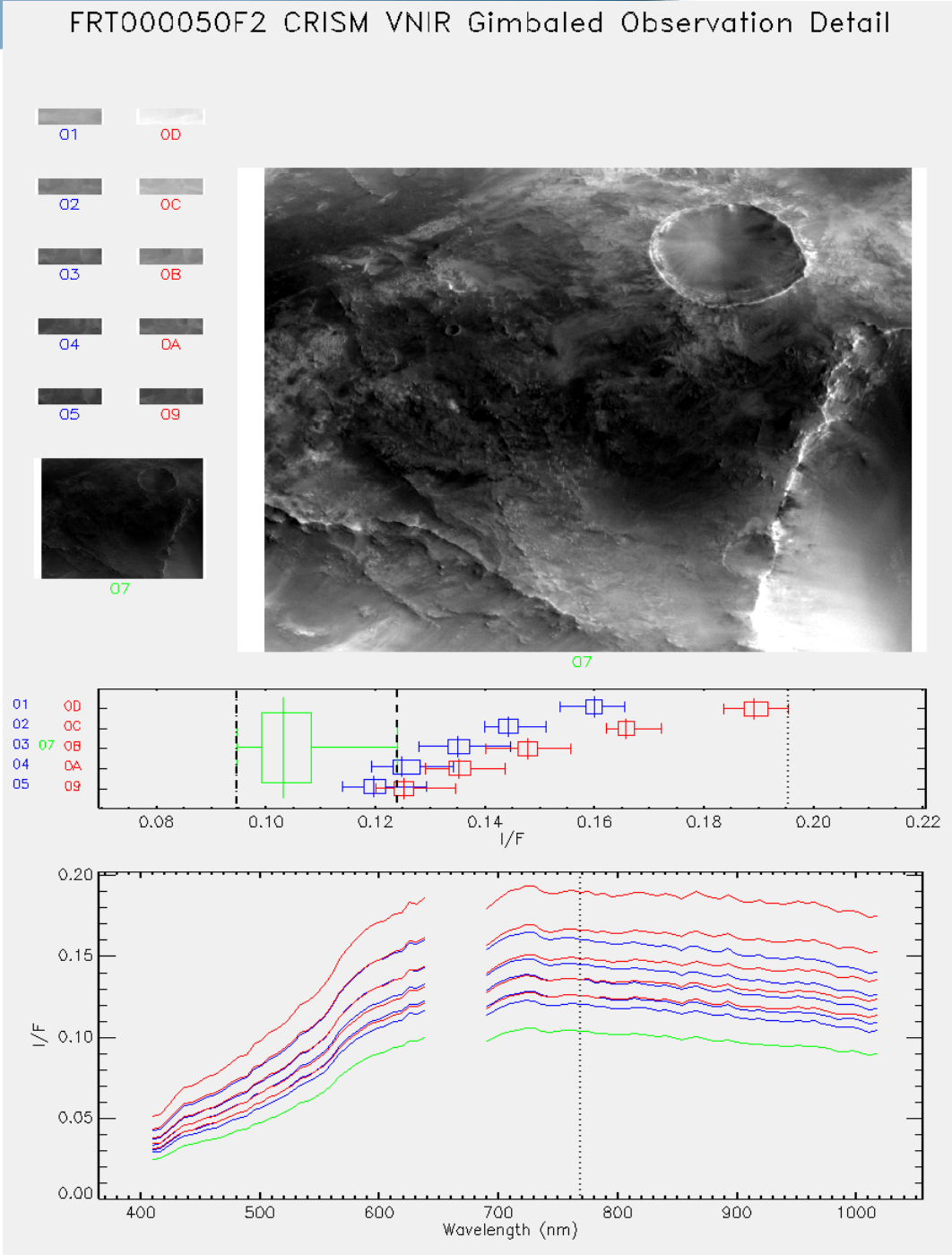
* The data processing information (IN) cube preserves traceability and residual information for multiple procedures, including the atmospheric correction, spatial transform, and VNIR+IR combination steps.



TRDR Visualizations - Gimbaled



DDR1 (S, L)
TRR3 IF(S, L)

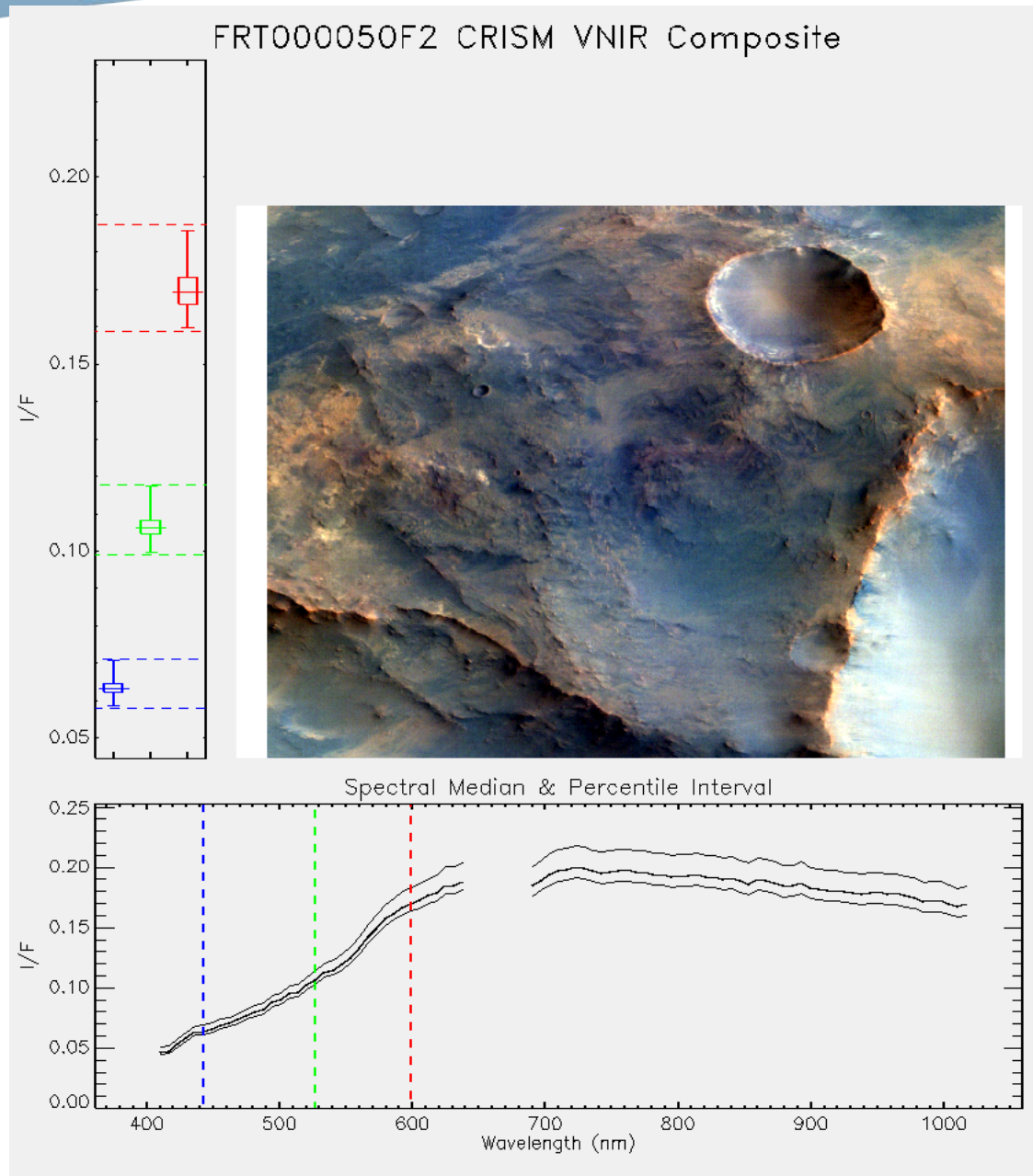


./trdr/EXTRAS/

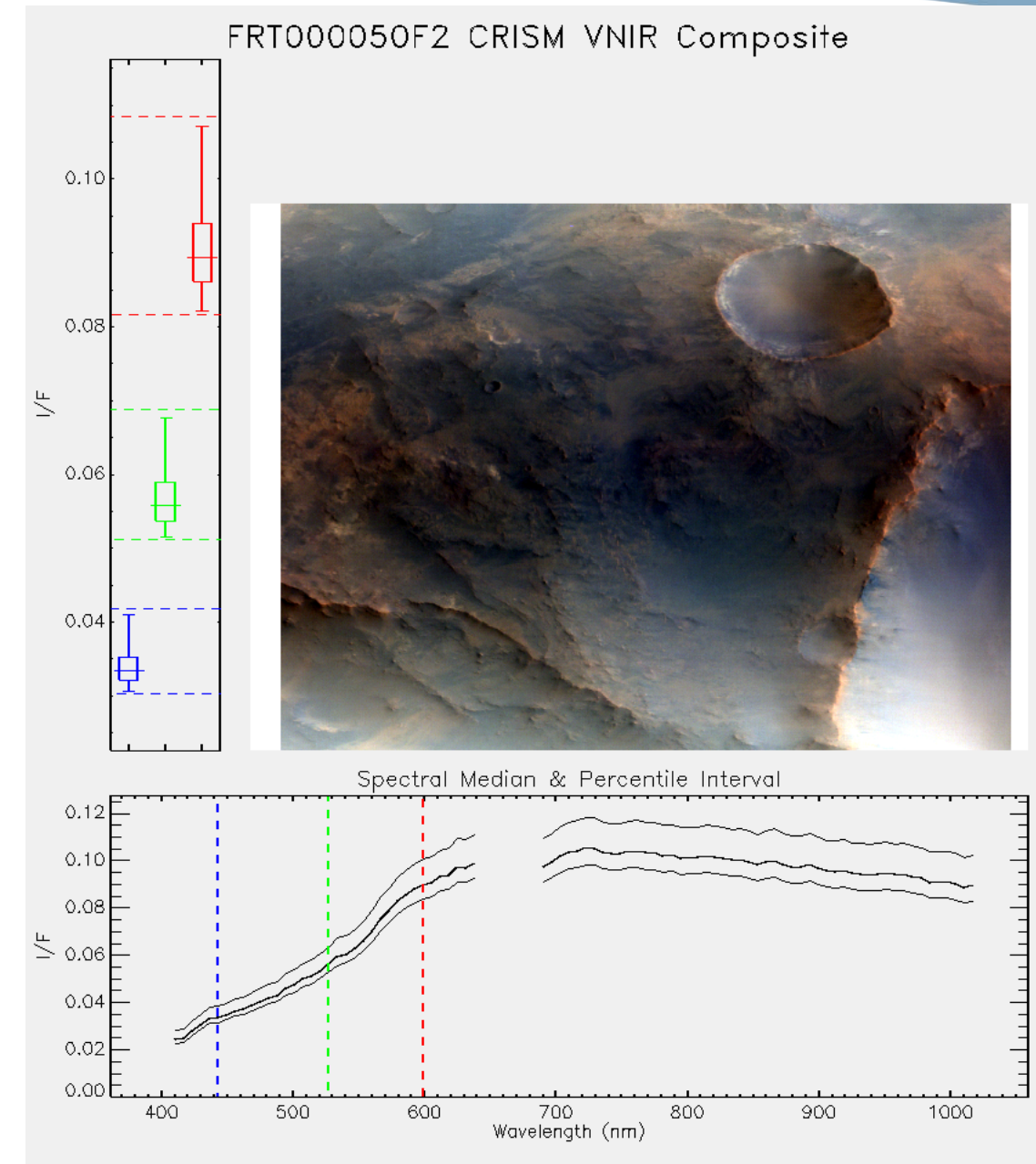
FRT000050F2_S_TRR3_GIMBALED.PNG

FRT000050F2_L_TRR3_GIMBALED.PNG

TER VNIR Progression – 4/4

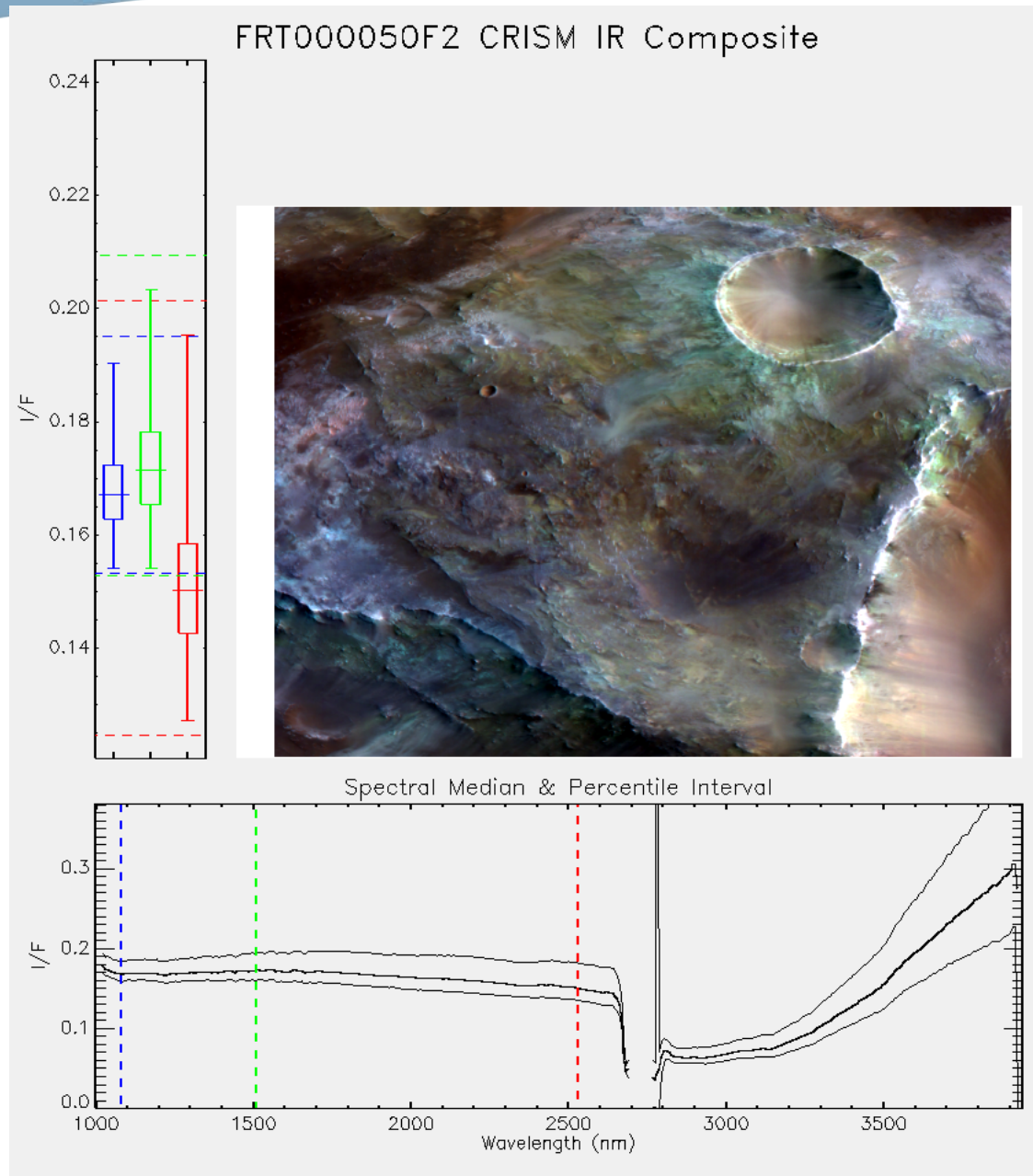


FRT000050F2_S_COMPOSITE_06.PNG

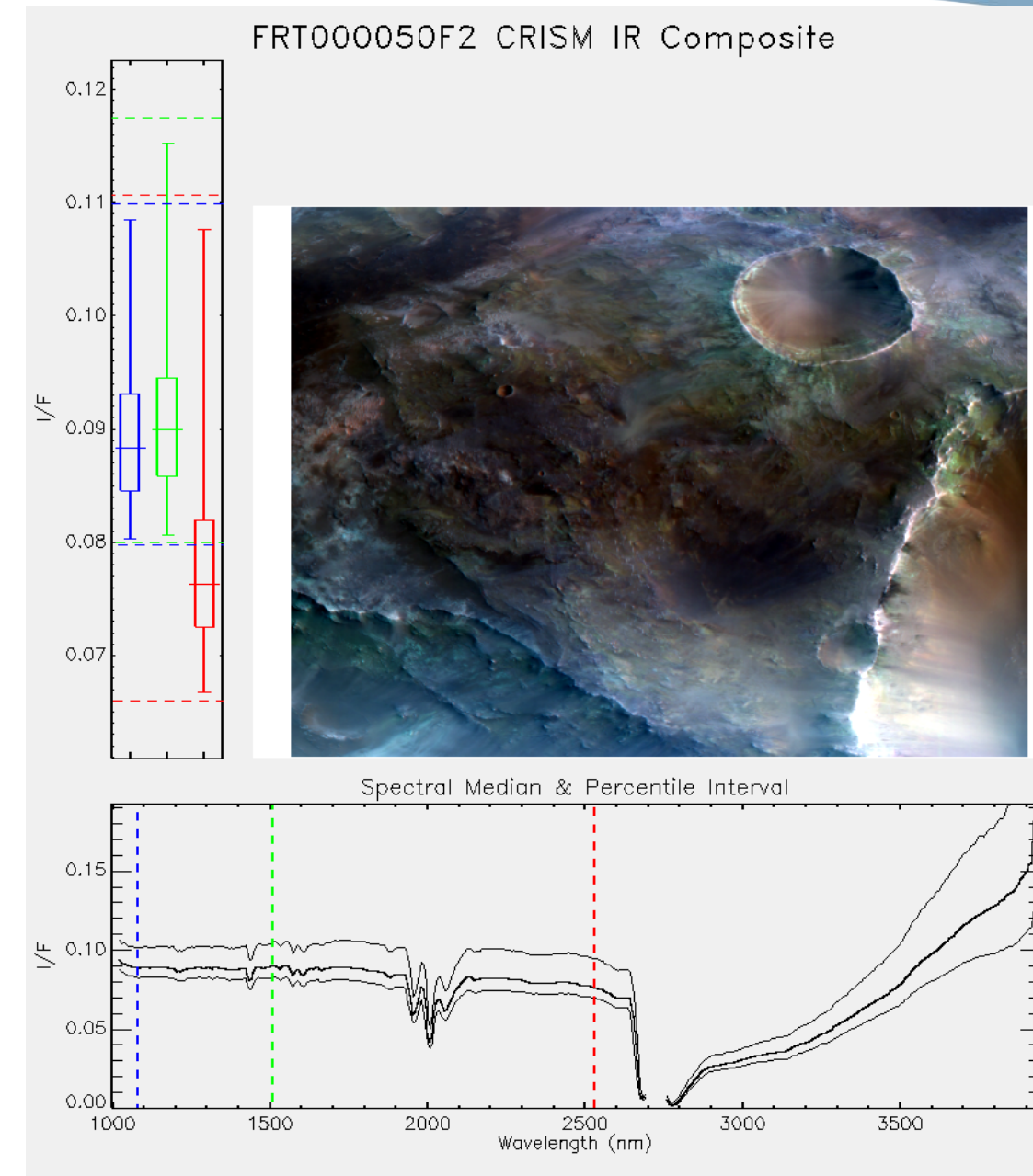


FRT000050F2_S_COMPOSITE_01.PNG

TER IR Progression – 6/6



FRT000050F2_L_COMPOSITE_06.PNG



FRT000050F2_L_COMPOSITE_01.PNG



TER Spectral Summary Parameters

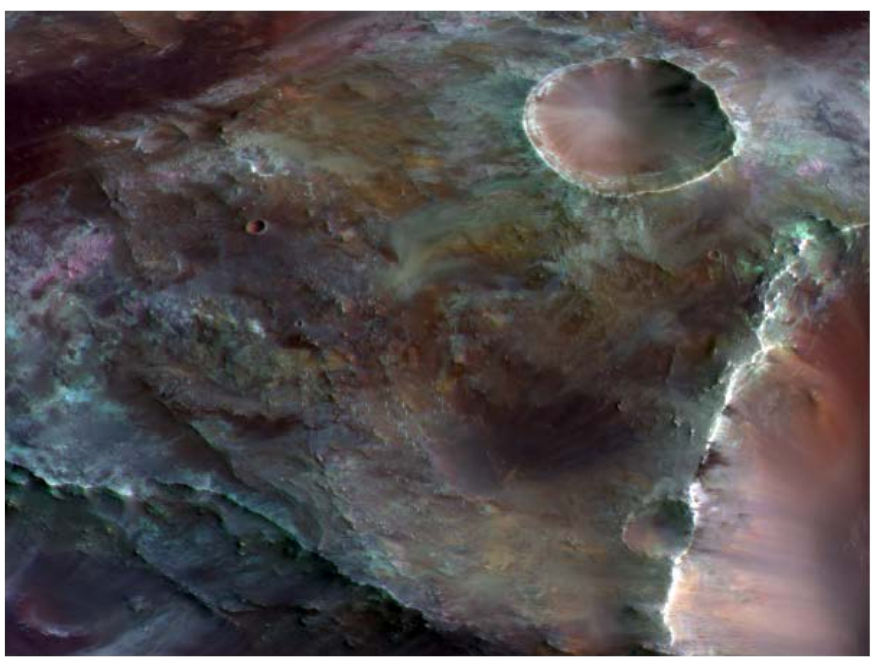


FRT000050F2_07_SU165J_TER3.IMG
FRT000050F2_07_SU165J_TER3.HDR
FRT000050F2_07_SU165J_TER3.LBL

Calculate
Summary
Parameters
(J)

Summary
Parameter Cube

Browse
Products

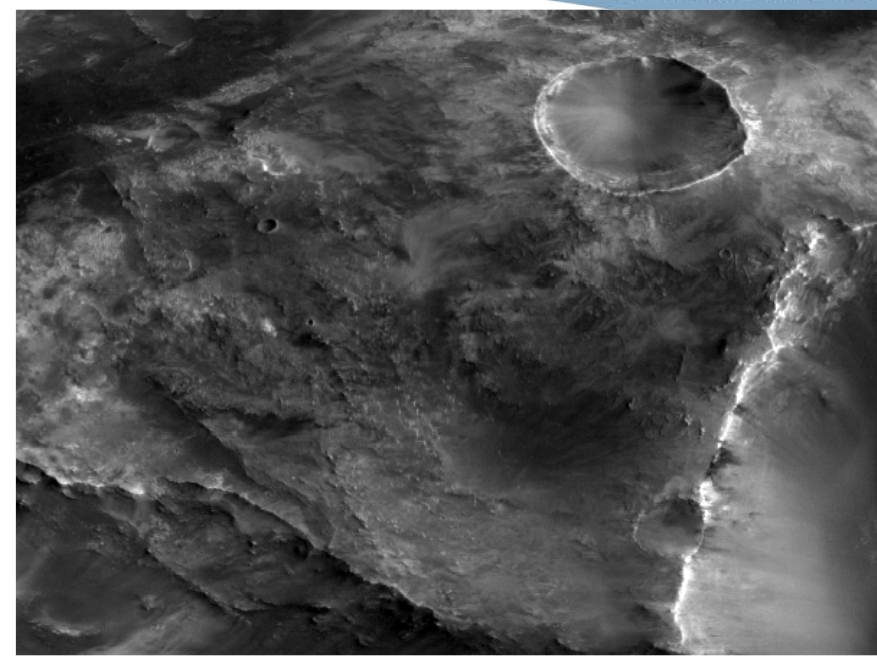


FRT000050F2_07_BUTANJ_TER3.PNG

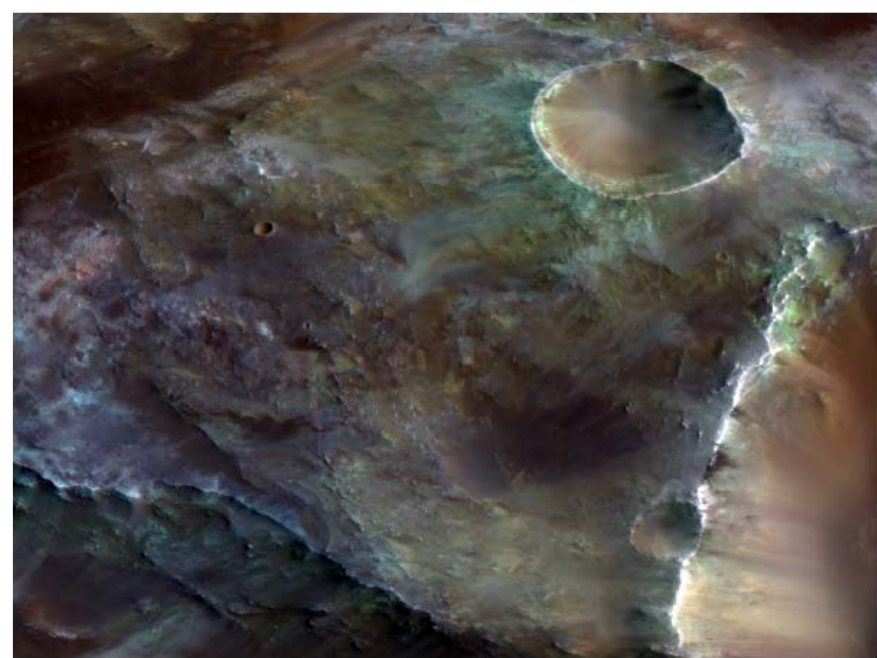
Spectral band parameters and browse
products unchanged in SR/BR vs. SU/BU



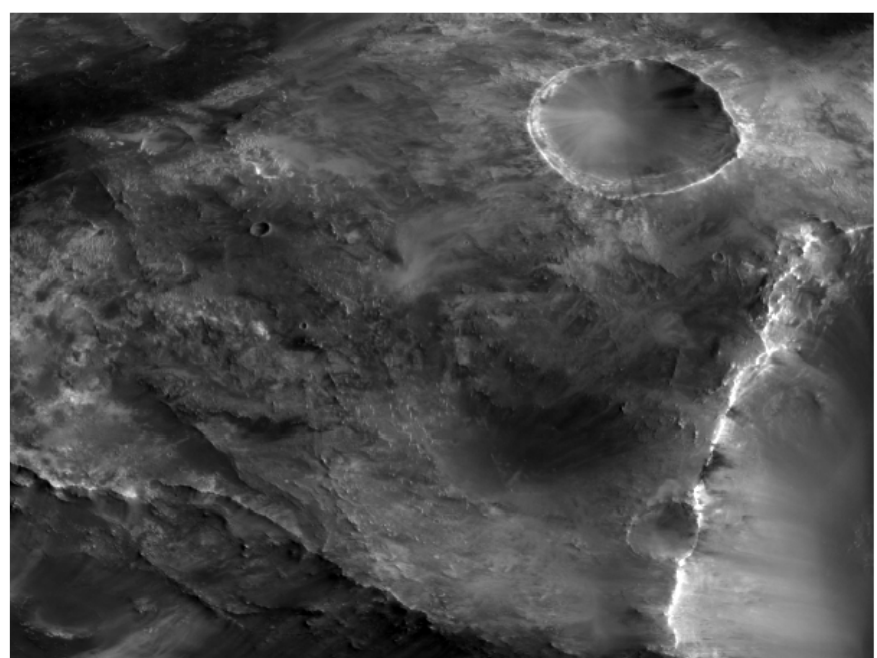
FRT000050F2_07_BUTRUJ_TER3.PNG



FRT000050F2_07_BUVNAJ_TER3.PNG



FRT000050F2_07_BUFALJ_TER3.PNG



FRT000050F2_07_BUIRAJ_TER3.PNG

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



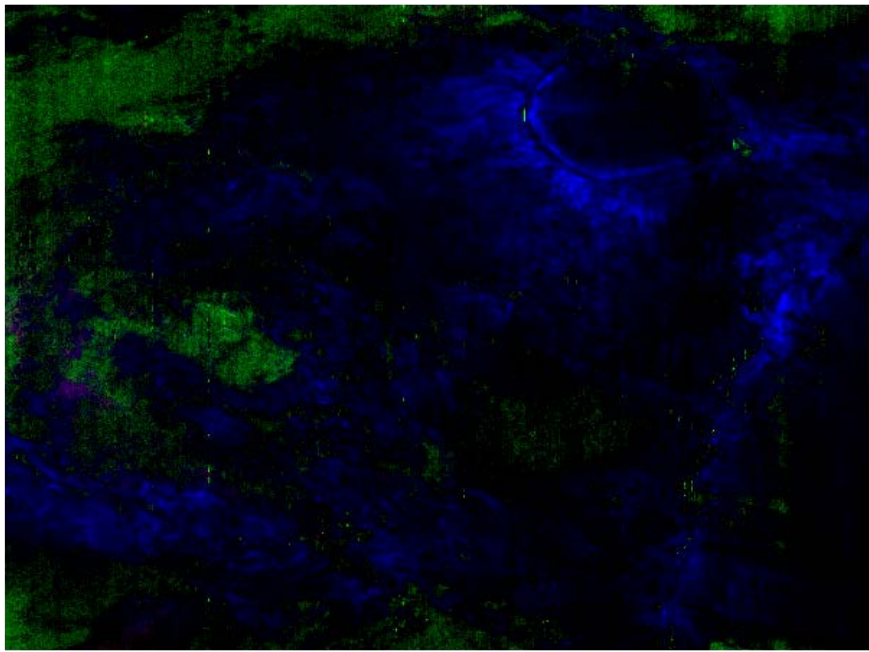
TER Spectral Summary Parameters



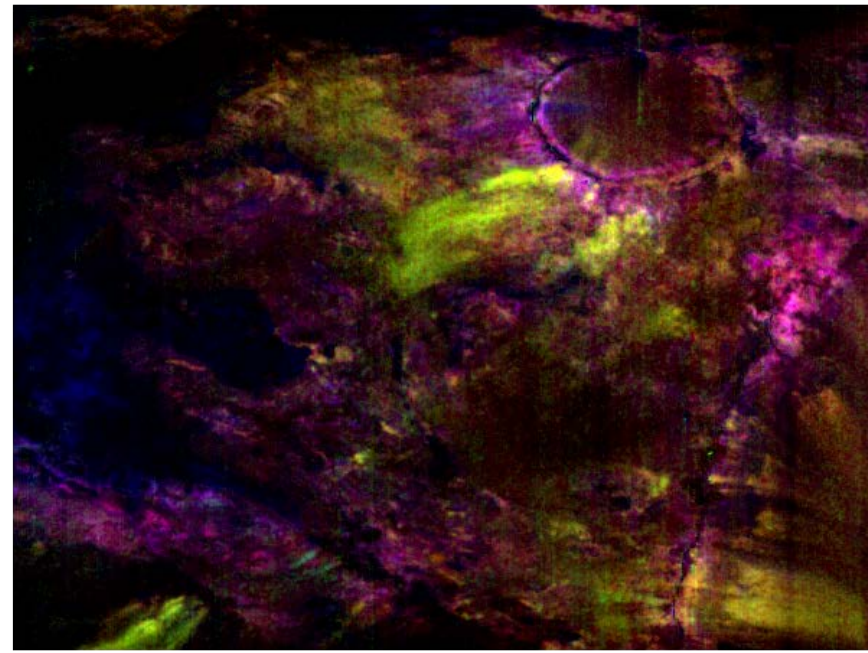
FRT000050F2_07_SU165J_TER3.IMG
FRT000050F2_07_SU165J_TER3.HDR
FRT000050F2_07_SU165J_TER3.LBL

Calculate
Summary
Parameters
(J)

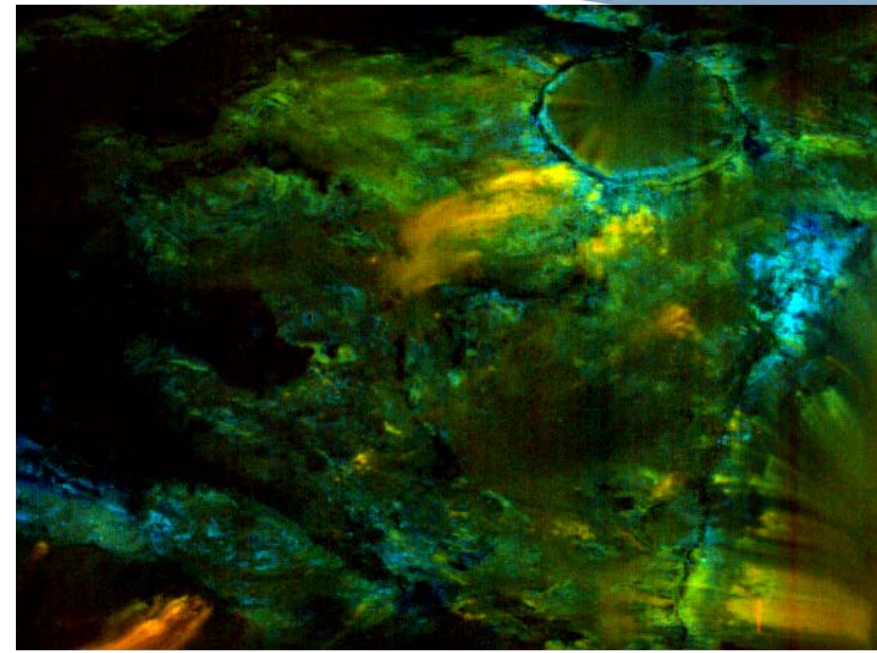
Summary
Parameter Cube



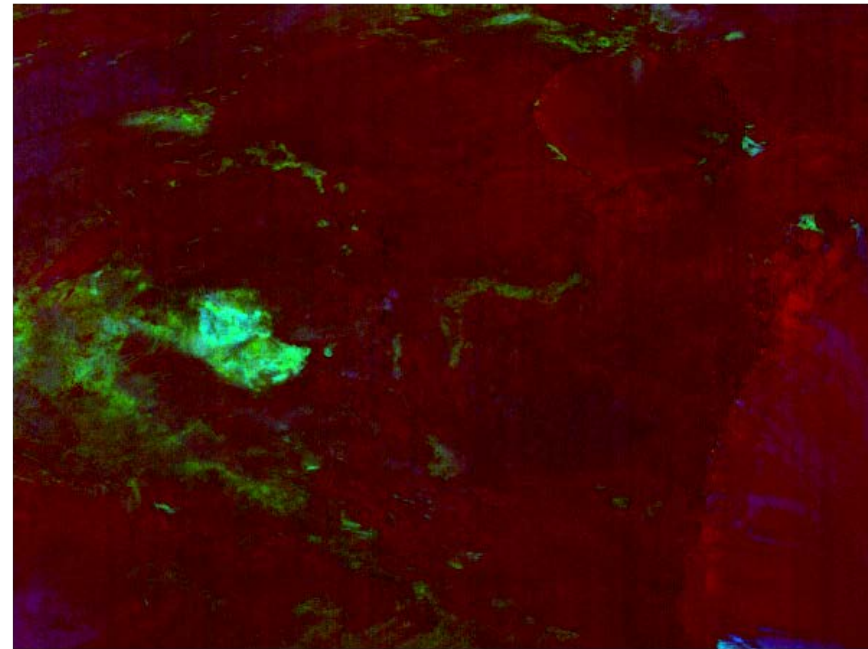
FRT000050F2_07_BUHYDJ_TER3.PNG



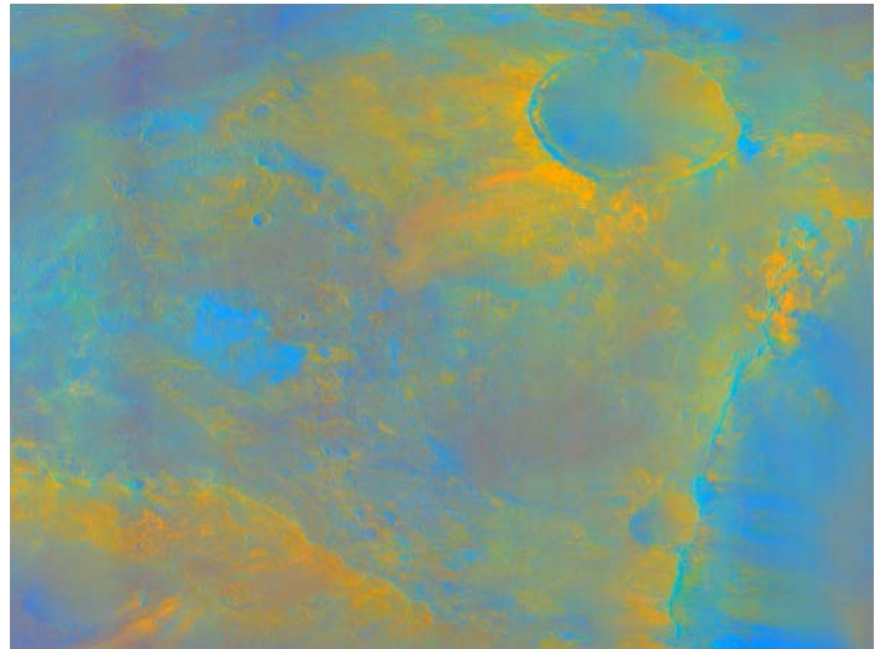
FRT000050F2_07_BUPHYJ_TER3.PNG



FRT000050F2_07_BUPFMJ_TER3.PNG



FRT000050F2_07_BUMAFJ_TER3.PNG

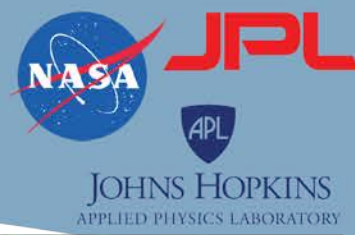


FRT000050F2_07_BUHLJ_TER3.PNG

./ter/TER/



TER Spectral Summary Parameters

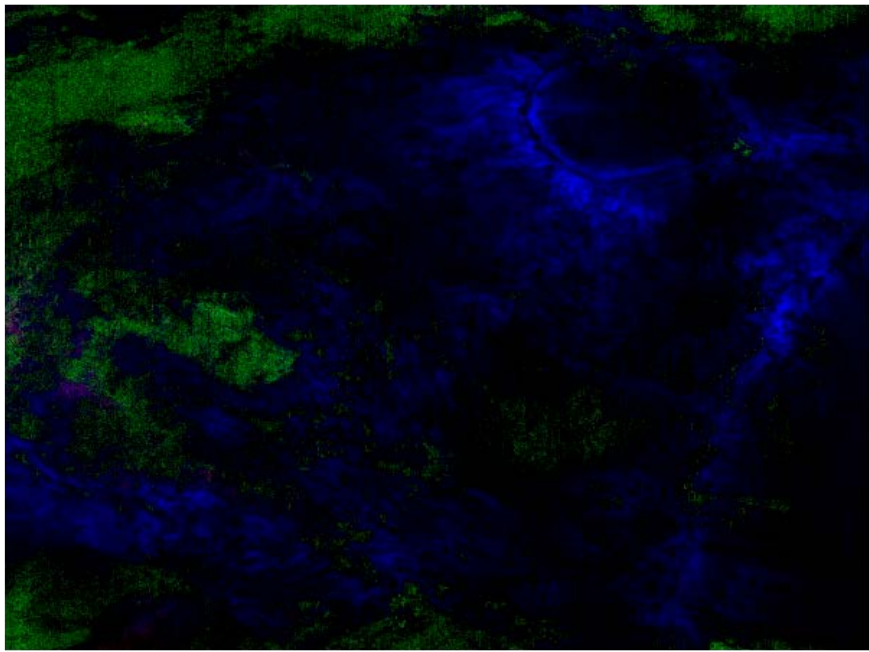


FRT000050F2_07_SR165J_TER3.IMG
FRT000050F2_07_SR165J_TER3.HDR
FRT000050F2_07_SR165J_TER3.LBL

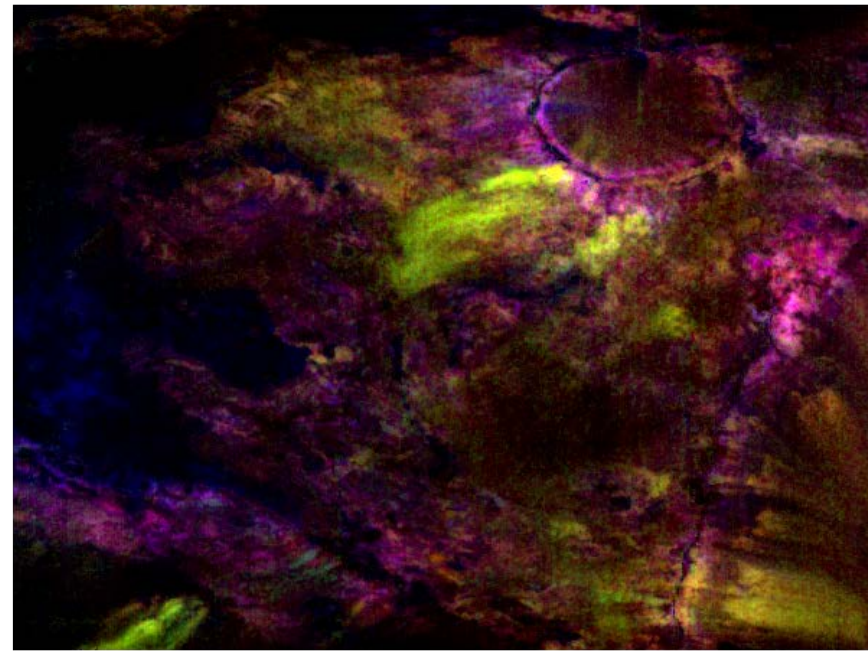
Summary
Parameter
Filtering
(J)

Filtered
Summary Para-
meter Cube

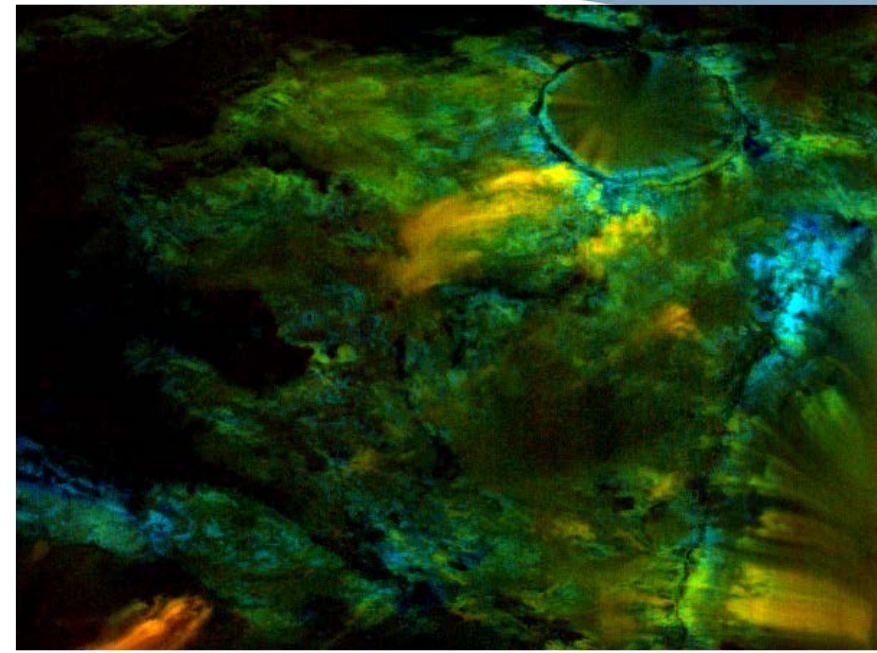
Browse
Products



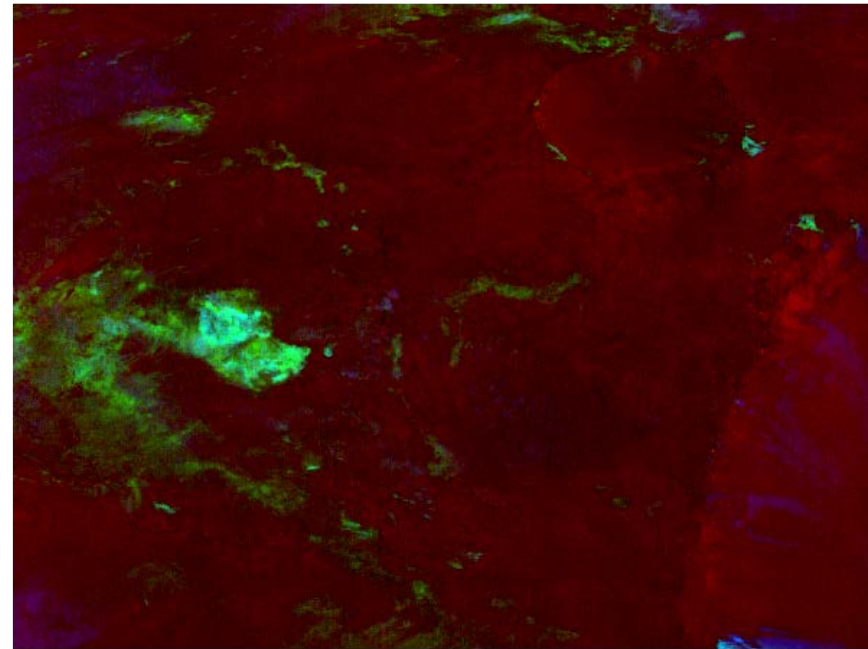
FRT000050F2_07_BRHYDJ_TER3.PNG



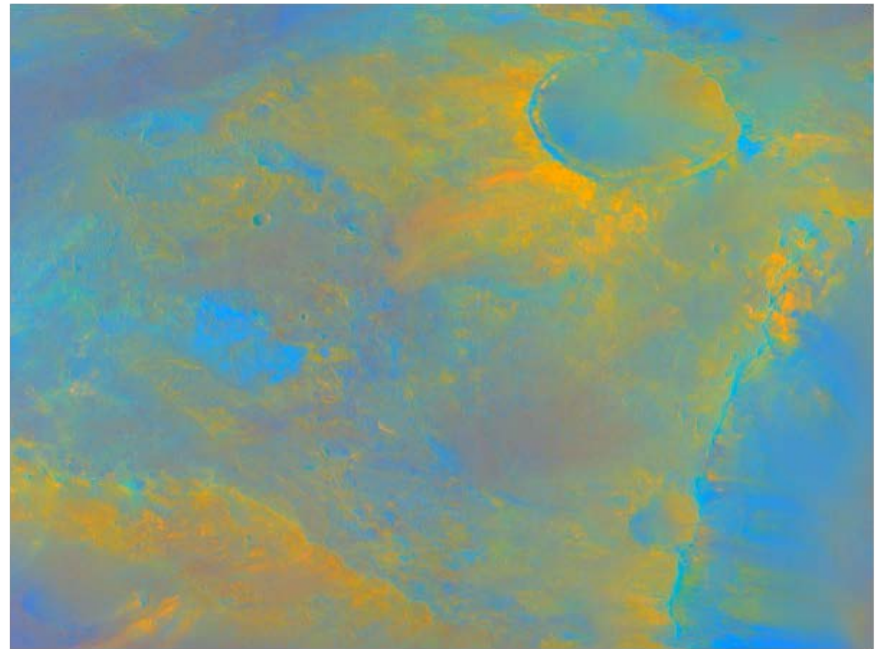
FRT000050F2_07_BRPHYJ_TER3.PNG



FRT000050F2_07_BRPFMJ_TER3.PNG



FRT000050F2_07_BRMAFJ_TER3.PNG



FRT000050F2_07_BRCHLJ_TER3.PNG

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



MTRDR Spectral Data Product

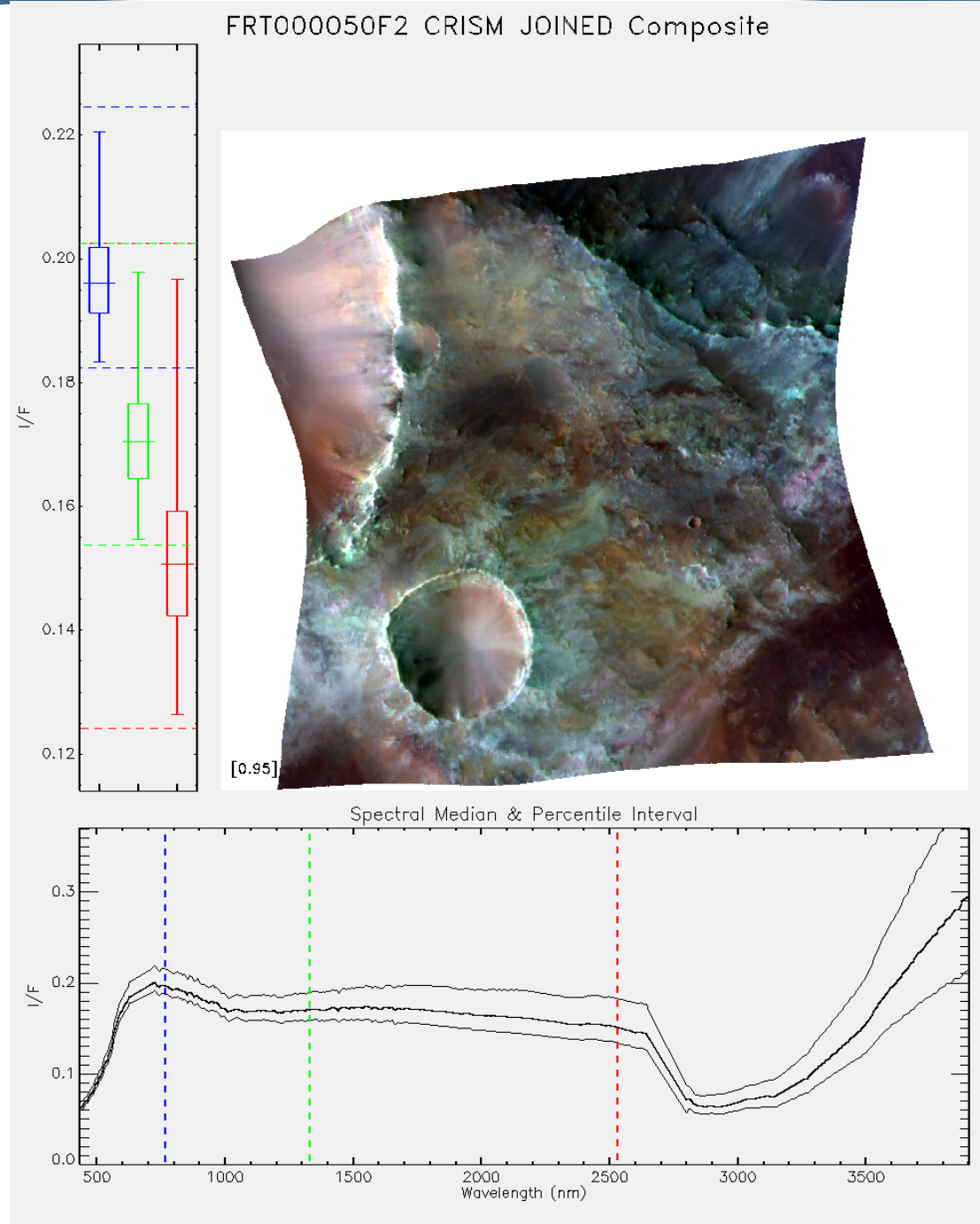


- Geographic Look-up Table
- Fully Corrected, Map Projected Spectral Cube

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

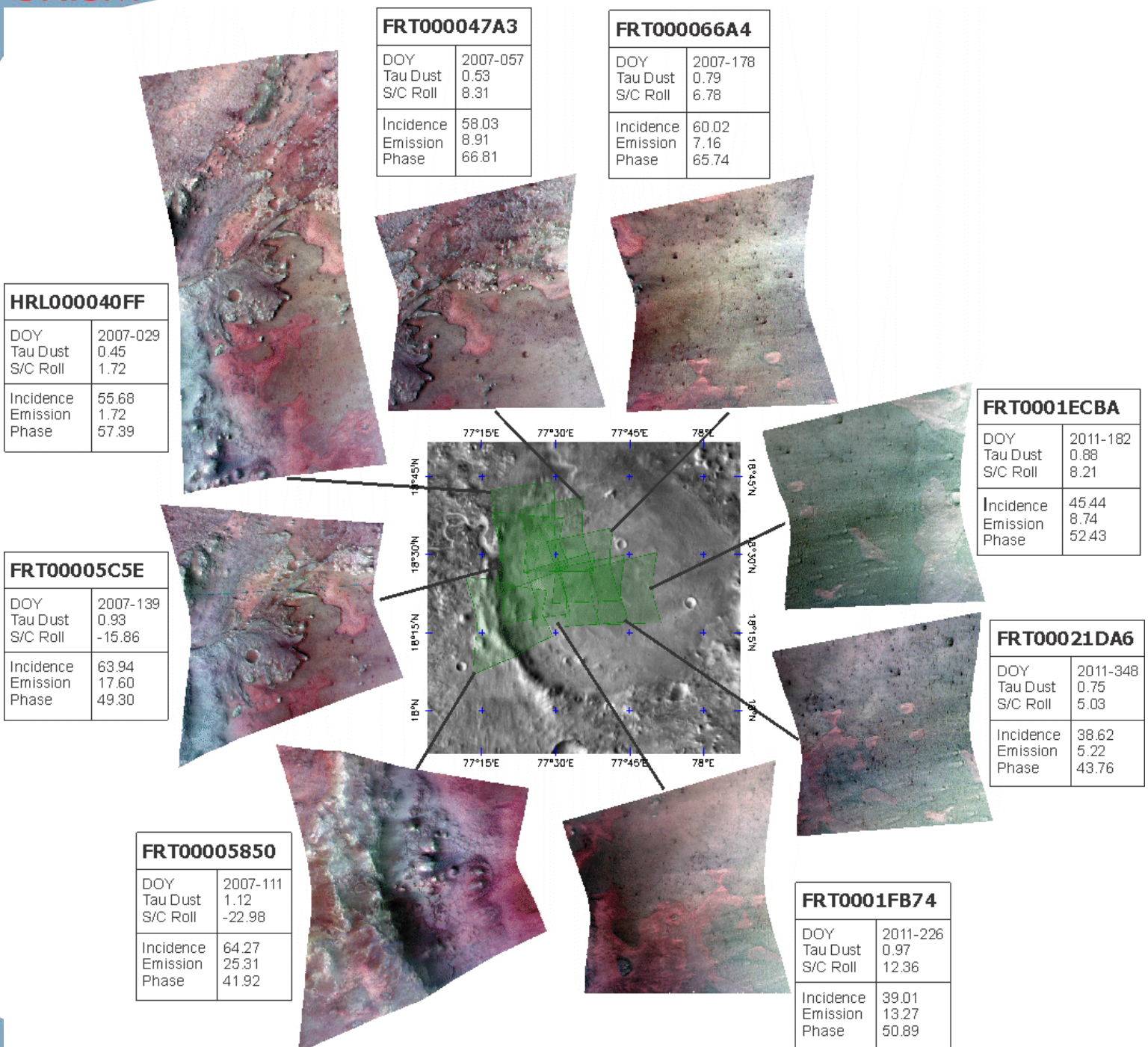
- MTRDR map projection adheres to MRO project standards
- ESRI PE via ENVI APIs
- GIS ready – Mars reference coordinate system string in ENVI header

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



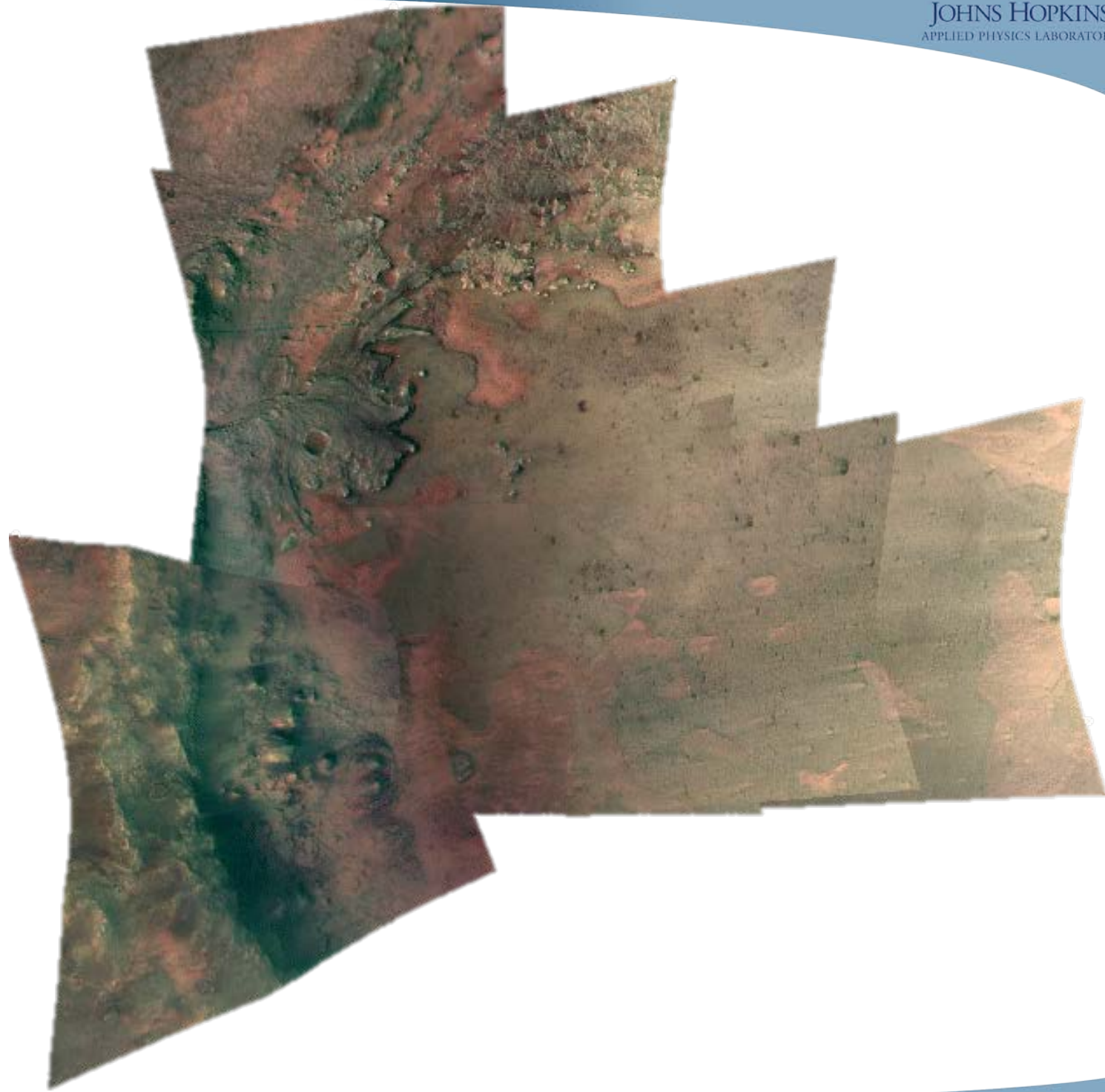
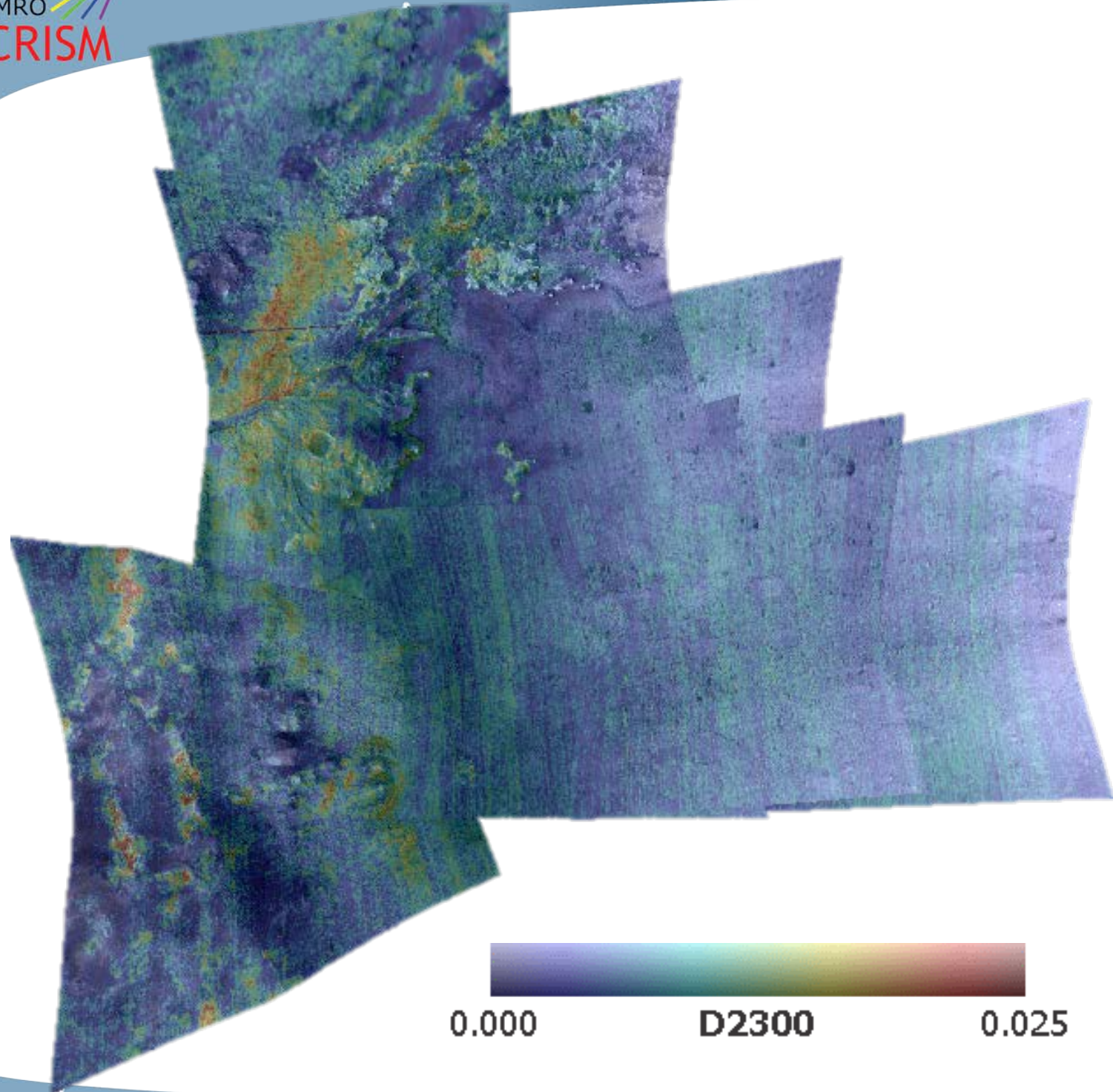
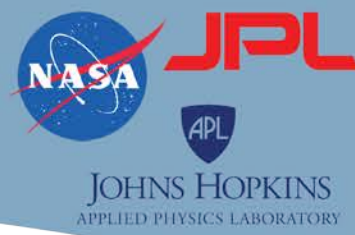
MTR TAN RGB Composite

FRT000050F2_07_IF165J_MTR3_Composite.PNG





TER/MTRDR Applications – MTRDR Mosaics



Part IV. Spectral Analysis

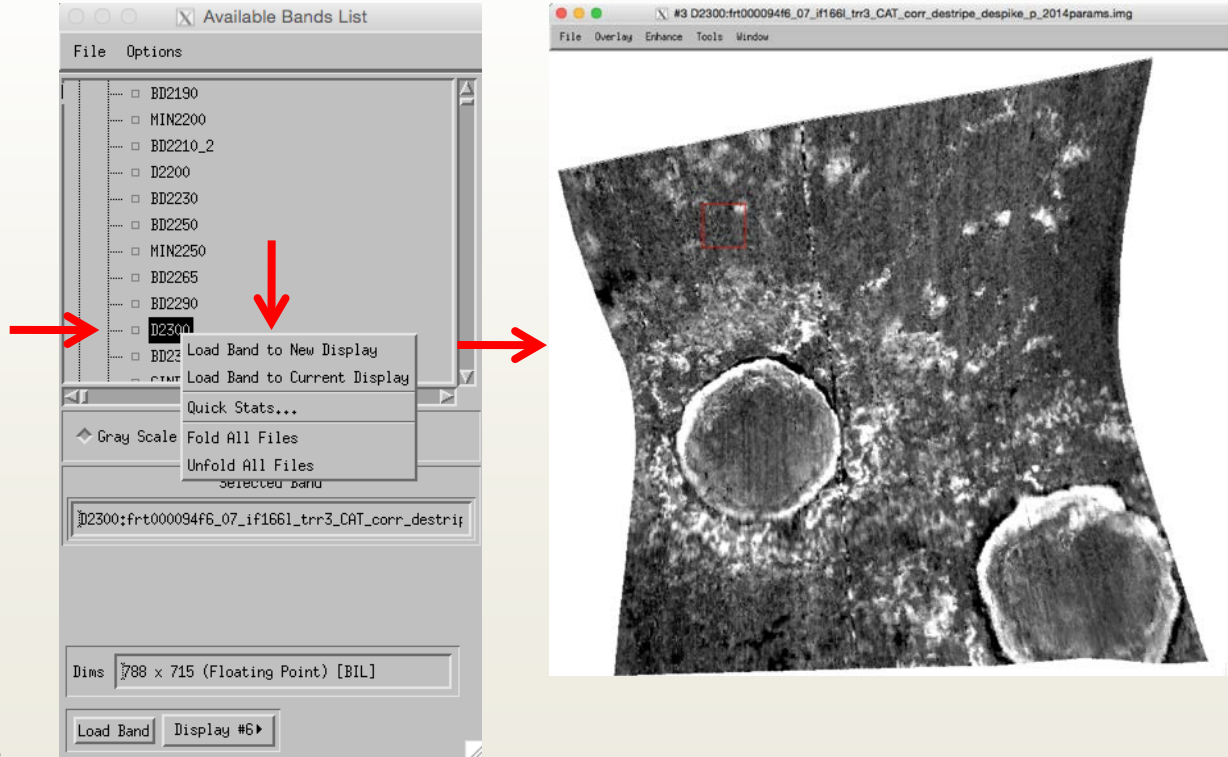
- Real-time spectral analysis for example scene FRT000094F6 (or scene of your choice) using ENVI, covering:
 - Displaying, stretching, linking spectral and summary parameter cubes
 - Finding and extracting scene endmembers
 - Enhancing spectral features and interpretation

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

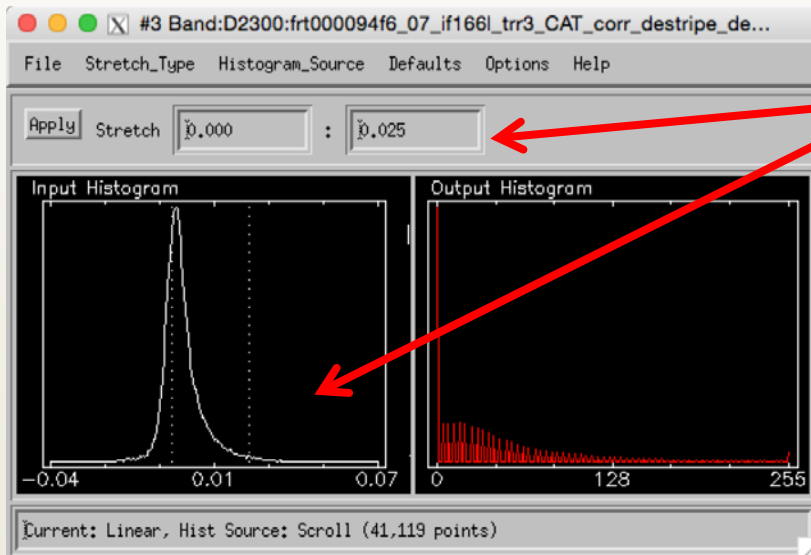
- Load the D2300 parameter from Available Bands List, right click on D2300 and select Load Band to New Display



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

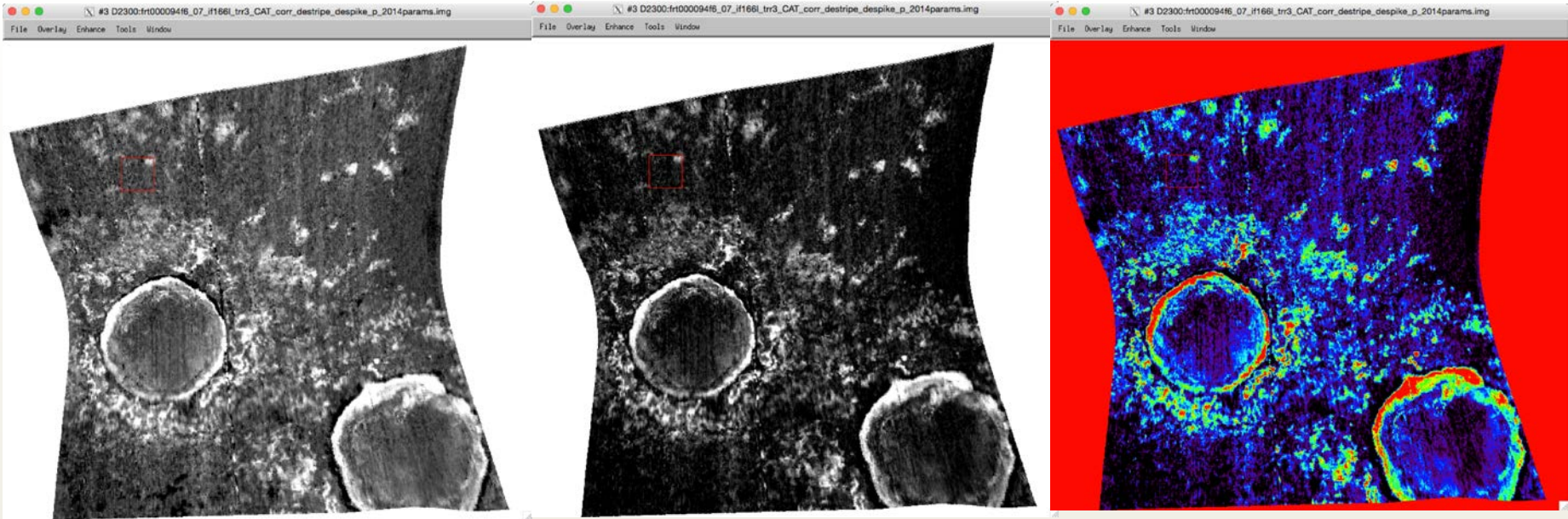
Apply Appropriate Stretch

- 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 an 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)

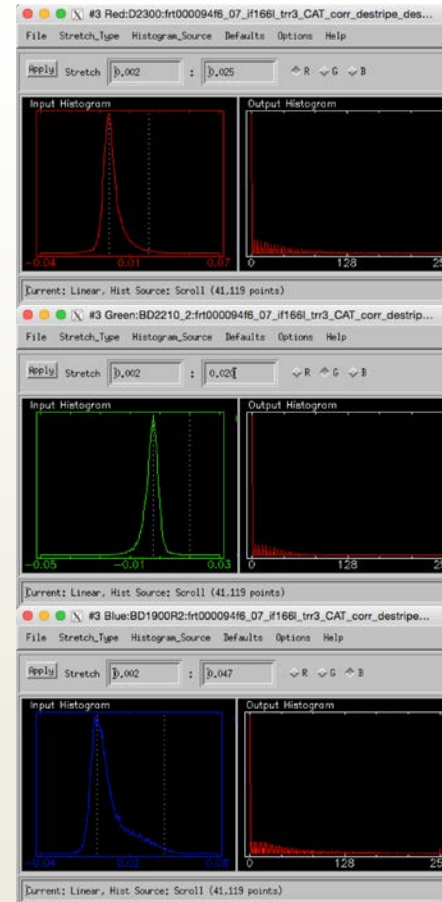
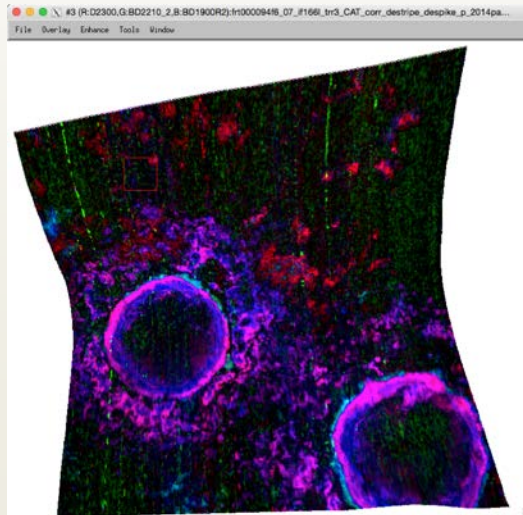
Optimized Stretch,
Grayscale
(0.0 to 0.027)

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)

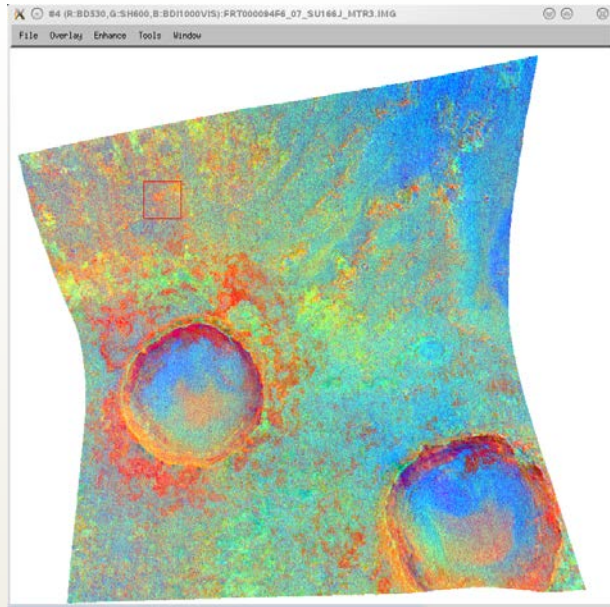
Max: 0.020 (“minimum maximum”)

BD1900R2

Min: 0.002 (distribution peak)

Max: 0.047 (99th percentile)

Other Browse Products for 94F6

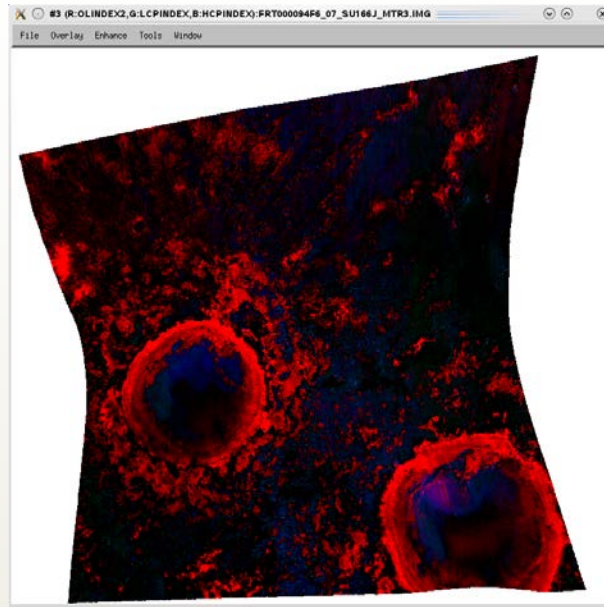


FEM

R: BD530

G: SH600

B: BD11000VIS

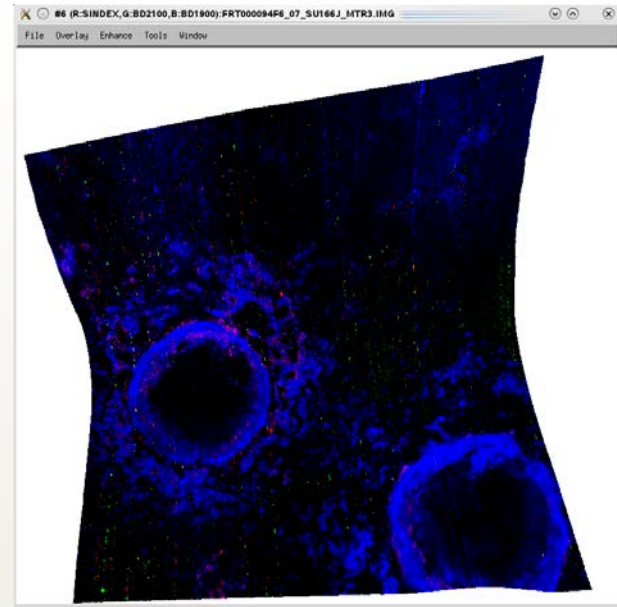


MAF

R: OLINDEX3

G: LCPINDEX2

B: HCPINDEX2



HYD

R: SINDEX

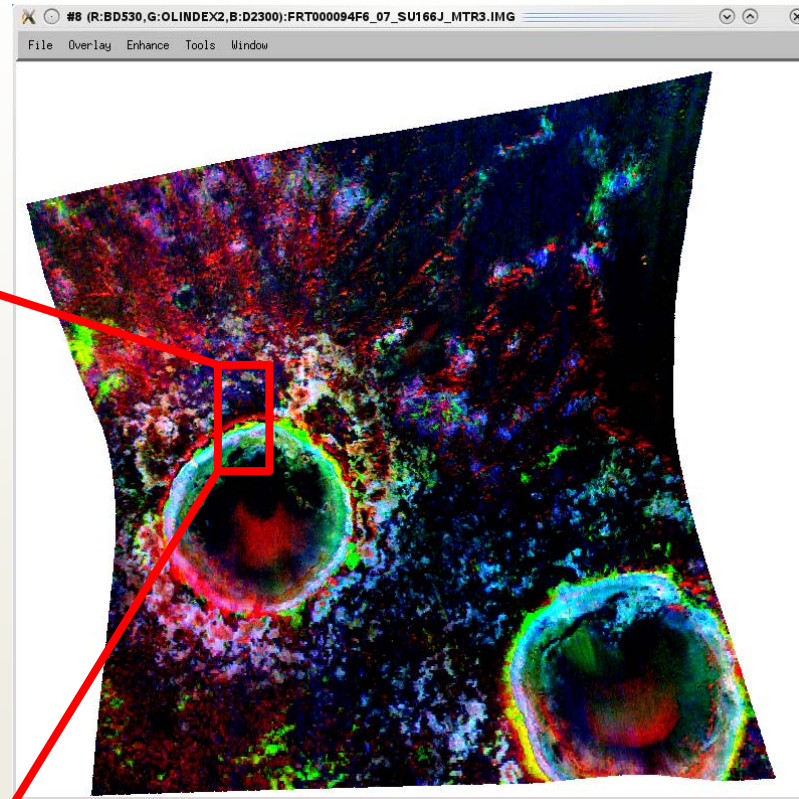
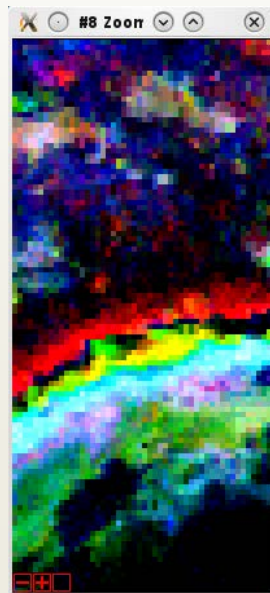
G: BD2100

B: BD1900

Custom Composites

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

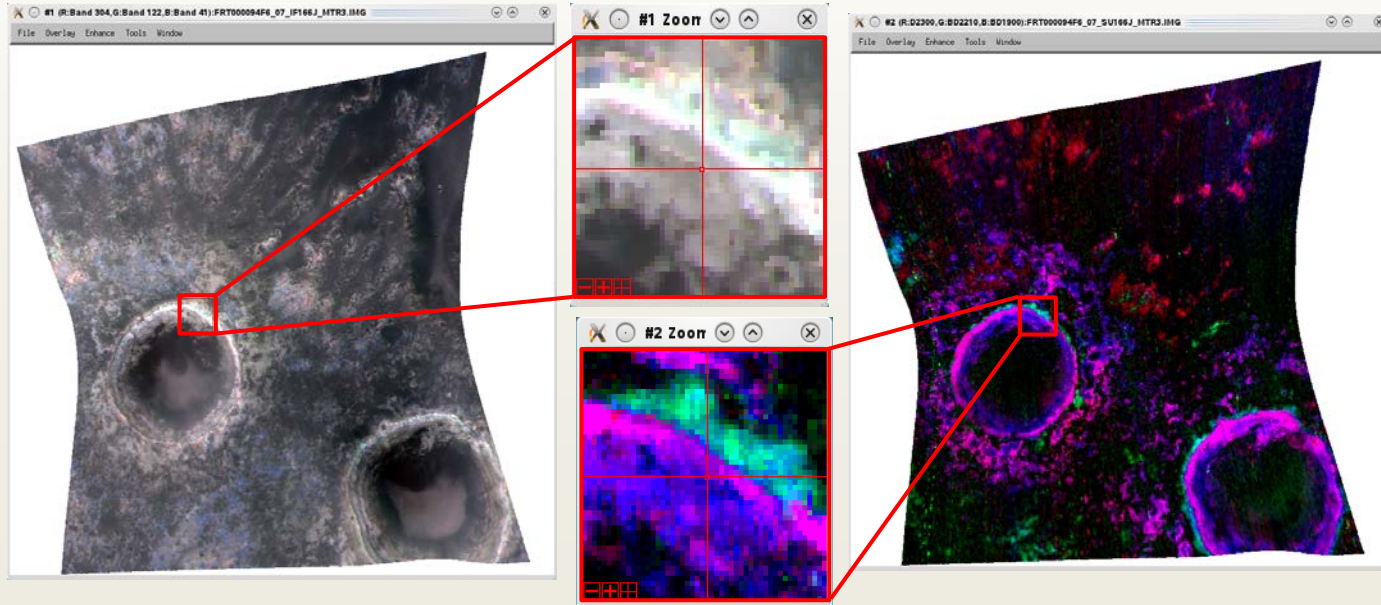
- Example at right shows ferric, ferrous, and clay variability.
- MANY color units to follow-up on...



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

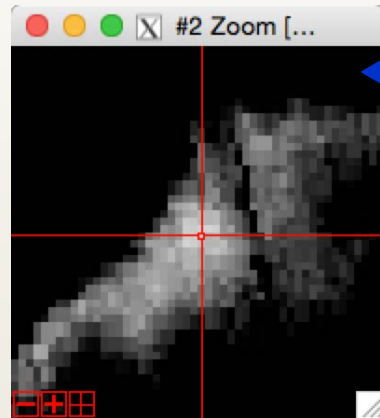
- **In general, there are 3 steps to spectral analysis:**
 1. **Locate interesting material(s)**
 - Summary parameters are a good start
 2. **Collect best possible spectra (scene “endmembers”)**
 - Pixel average, Region of Interest (ROI), etc.
 3. **Interpret endmember spectra**
 - E.g., comparison to 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)

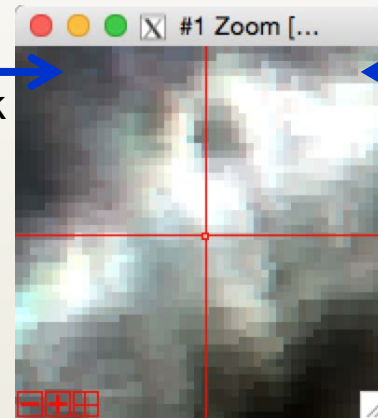
- As an example, let's find an endmember spectrum for the D2300-bearing material in FRT000094F6.



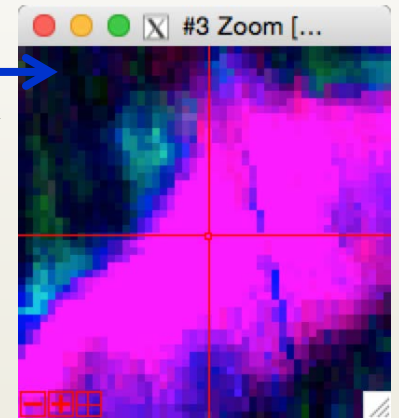
- Load D2300 as single band and stretch to emphasize highest realistic D2300 values.
- Link D2300 with MTRDR spectral cube and PHY browse (optional, but useful)



Emphasized Stretch
(0.04 to 0.05)



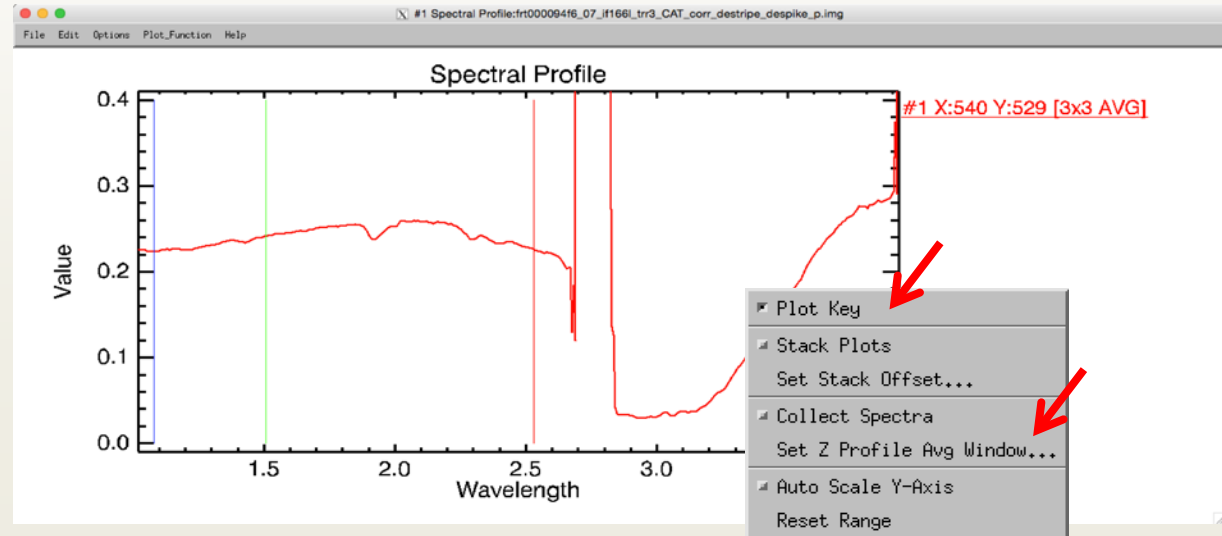
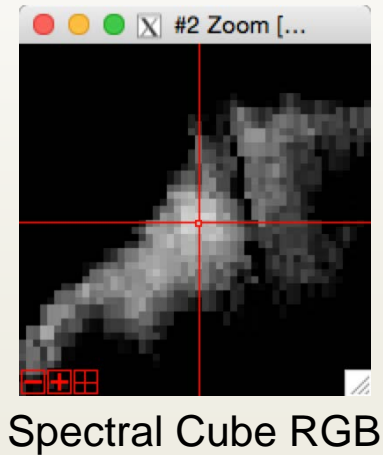
Spectral Cube
RGB



PHY Browse

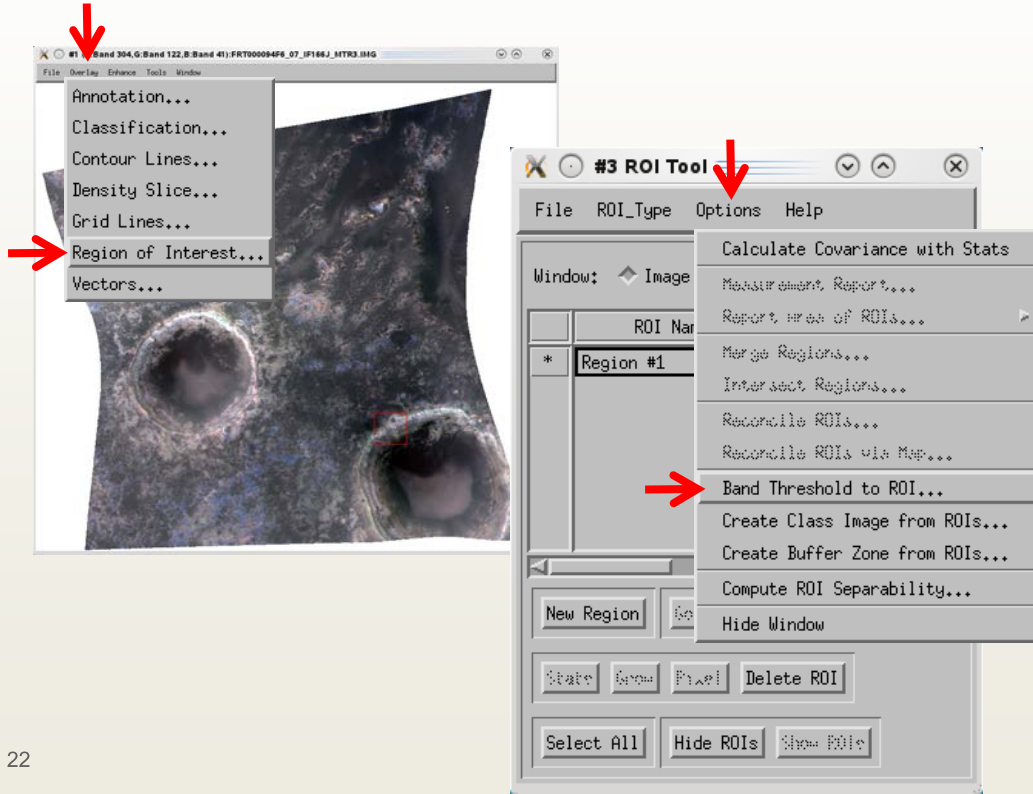
Pixel-based Endmember Extraction (2 of 2)

- 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...**



ROI-based Endmember Extraction (1 of 3)

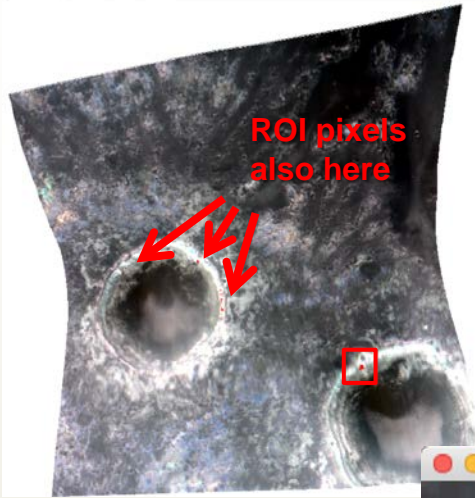
- Create a Region of Interest (ROI) from the highest D2300 values throughout the scene
- In the spectral cube Image window, go to **>Overlay >Region of Interest**



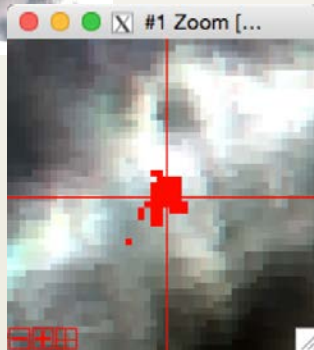
- In the ROI Tool, **>Options >Band Threshold to ROI**
- Select the D2300 band from the summary parameter file
- Type in min and max values of 0.04 and 0.05, respectively
- Should get a result of 108 pixels
- May want to refine threshold range to get fewer pixels

ROI-based Endmember Extraction (2 of 3)

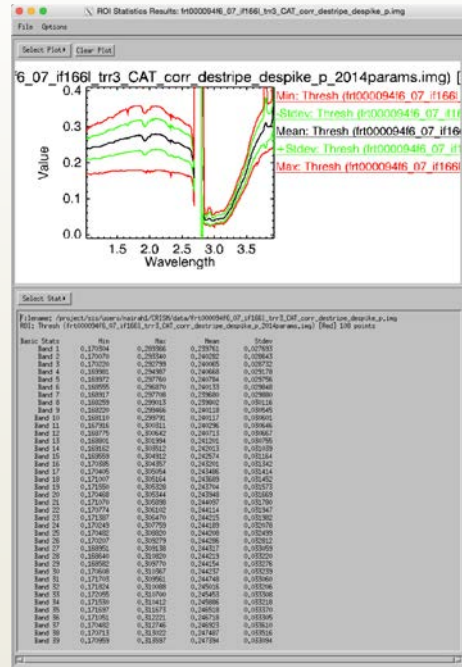
#1 (R:Georef (Band 233-910009416_07_#166)_tr3_CAT_corr_destripe_destripe.img,G:Georef (Band 78:fr...



ROI pixels
also here



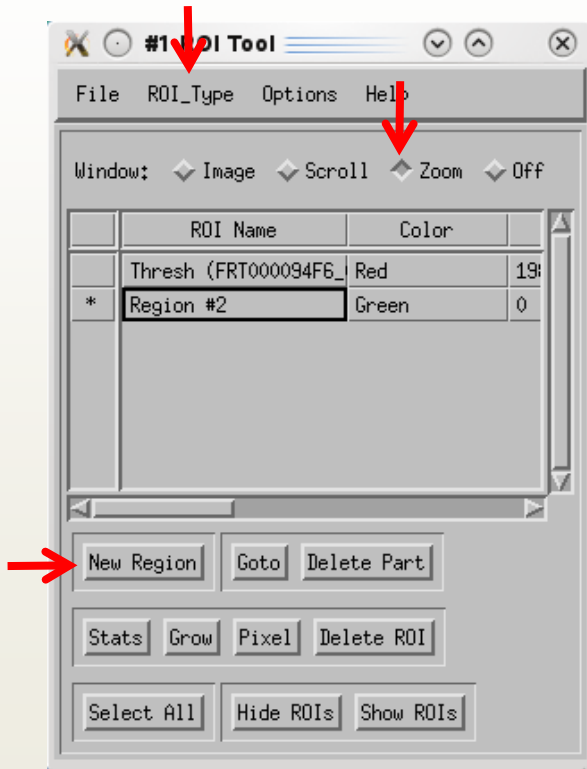
- The ROI appears as red pixels in the displayed window
- In the ROI Tool, calculate the average of the pixels by clicking **>Stats**



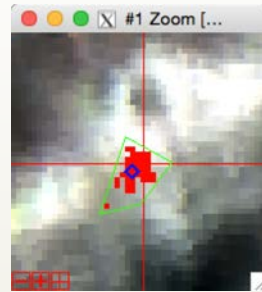
- Right click within the Stats Results plot area to adjust **Plot Parameters** and view **Plot Key**
- Click and drag the Mean spectrum to the previously-created spectral plot containing the pixel-based endmember spectrum

ROI-based Endmember Extraction (3 of 3)

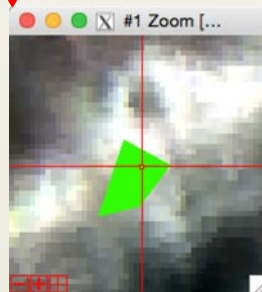
- A third method would be to define a polygon ROI...



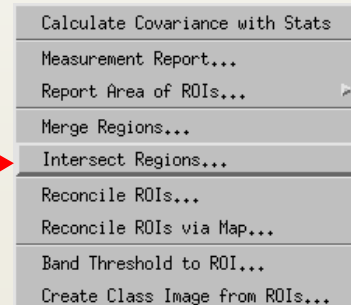
- In the ROI Tool, select **>ROI_Type >Polygon**
- Create **New Region** and select **Zoom** as the active window



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**



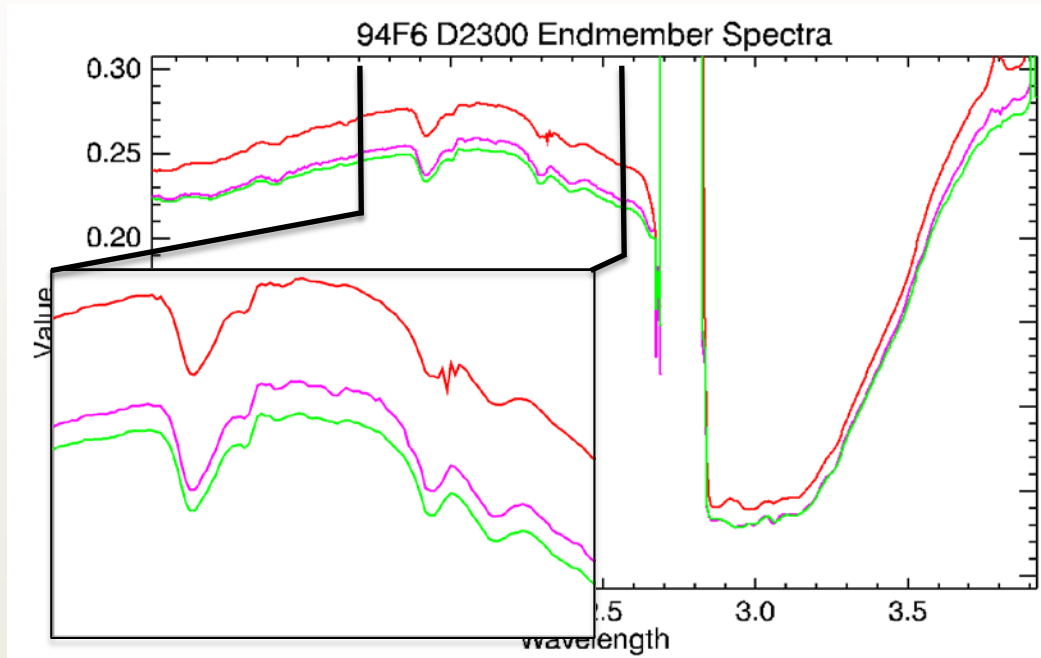
Example Endmember Spectra – D2300

- 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

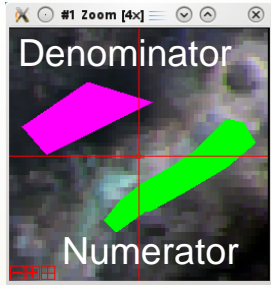
Mean: Polygon 105 points



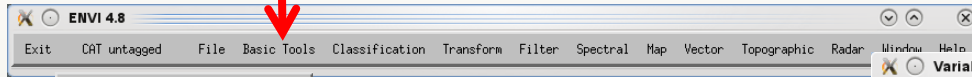
Enhancing Spectral Features

- **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

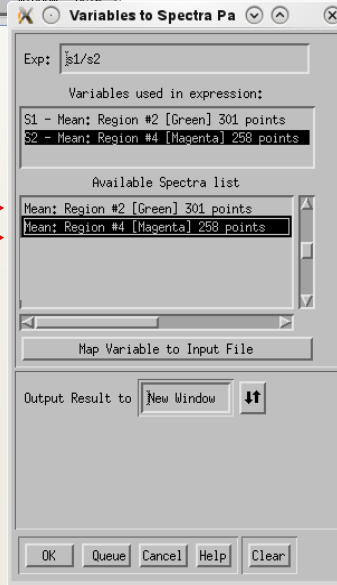
Ratioing (1 of 2)



- 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

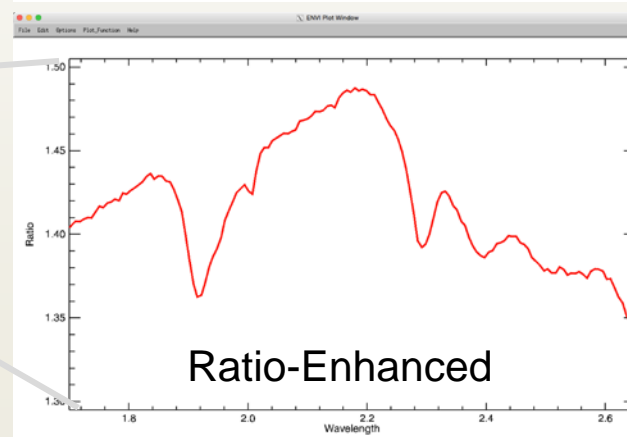
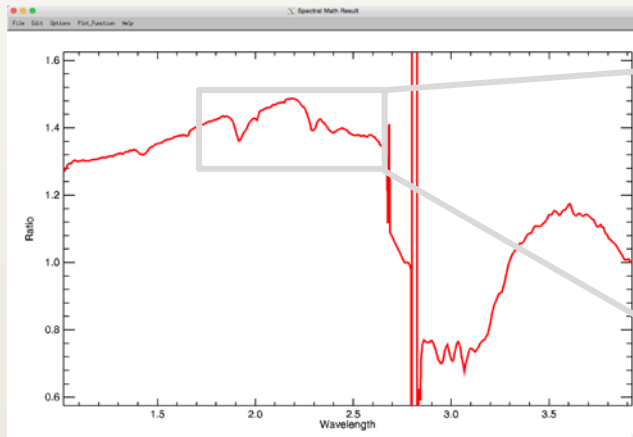
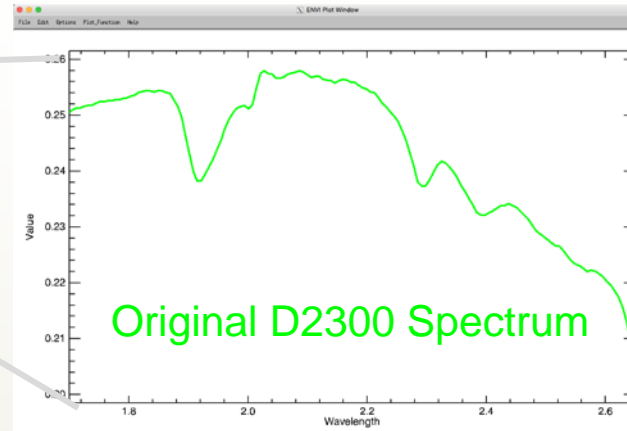
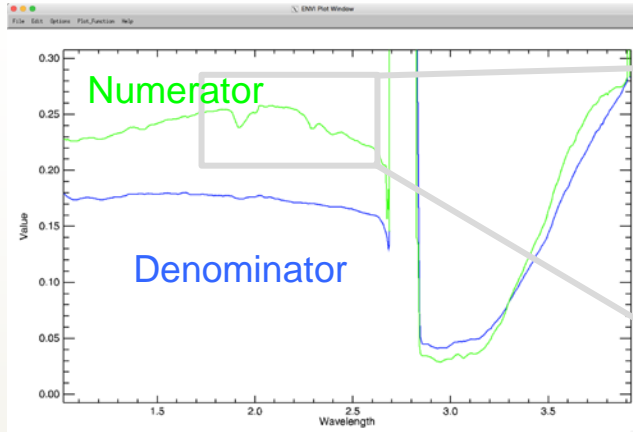


- Resize Data (Spatial/Spectral)
- Subset Data via ROIs
- Rotate/Flip Data
- Layer Stacking
- Calibrate HiRISE to I/F
- Convert Data (BSQ, BIL, BIP)
- Stretch Data
- Statistics
- Spatial Statistics
- Change Detection
- Measurement Tool
- Band Math
- Spectral Math
- Segmentation Image
- Region Of Interest
- Mosaicking
- Masking
- Preprocessing



- 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

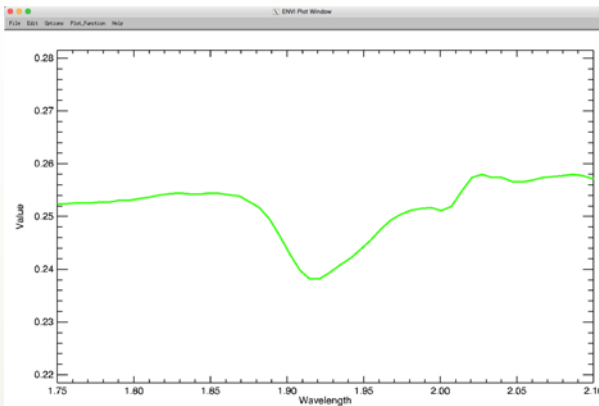
Ratioing (2 of 2)



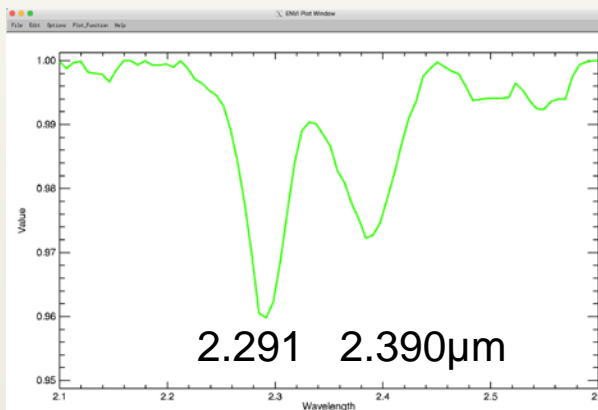
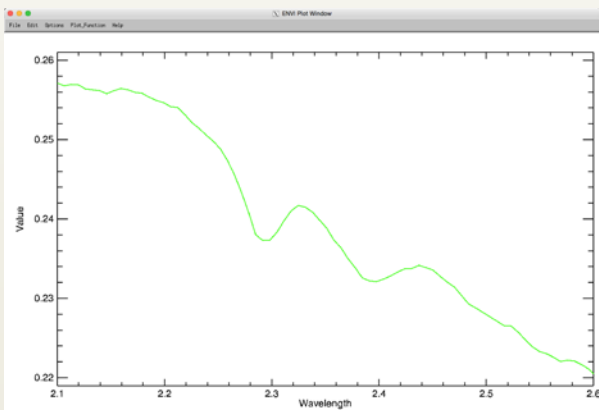
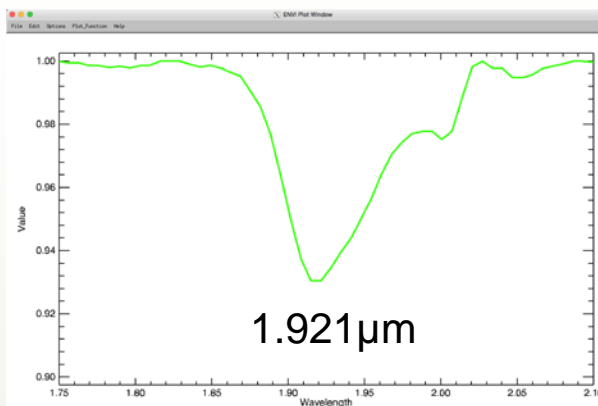
- This particular spectrum already has strong absorption features without ratioing
- Ratioing is more effective at emphasizing subtle or weak features, or at cancelling out noise or other spectral artifacts

Continuum Removal

Normal

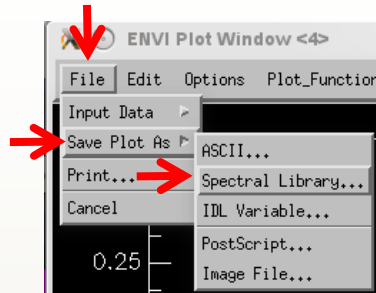


Continuum Removed

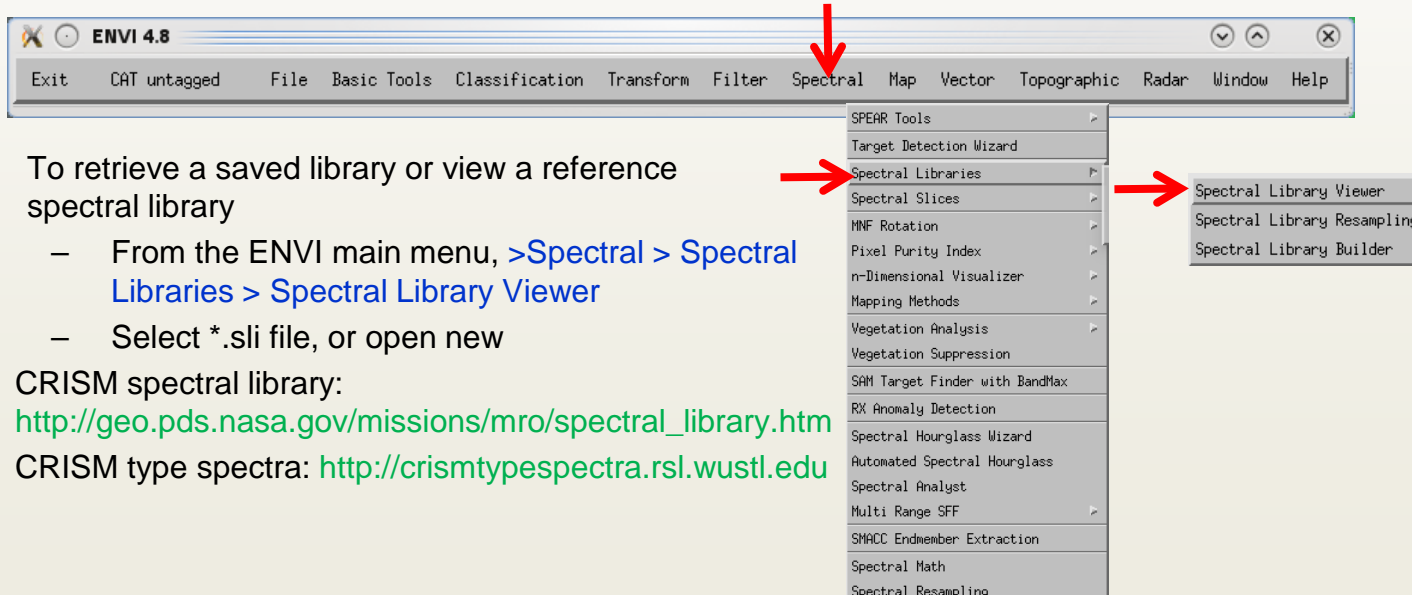


- In **>Edit >Plot Parameters**, subset the x-axis range to bracket the feature of interest
- Then choose **Plot_Function > Continuum Removed** as the display method
- You will likely have to rescale the y-axis in the continuum removed-plot

Spectral Libraries



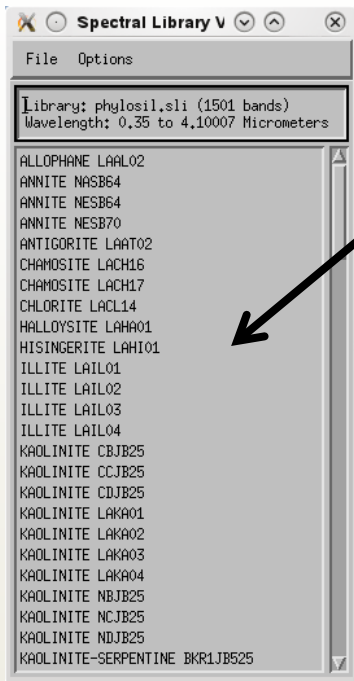
- Save spectra as ENVI spectral libraries (*.sli), or export as ASCII text file
 - From a spectral plot window, >File >Save Plot As > Spectral Library
 - HINT: Line colors are not preserved; make sure you rename the spectra appropriately



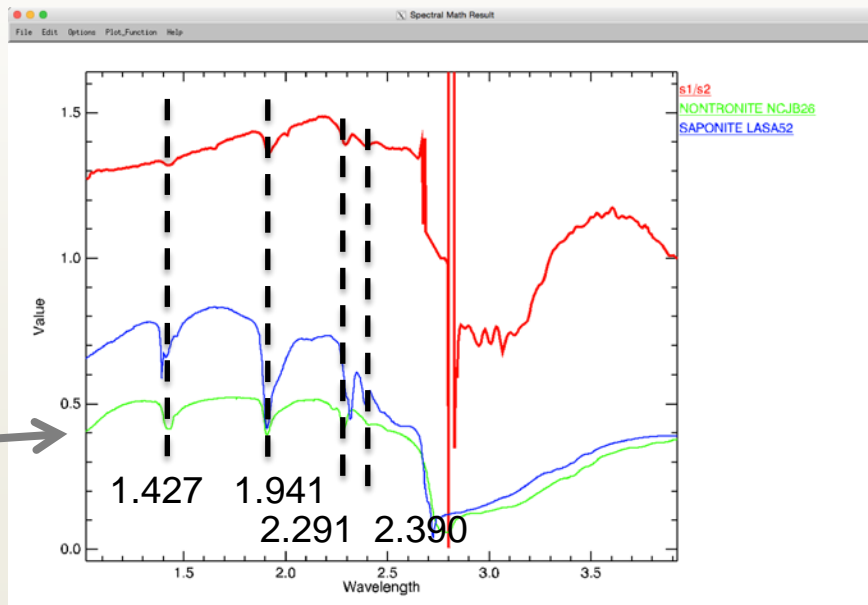
- To retrieve a saved library or view a reference spectral library
 - From the ENVI main menu, >Spectral > Spectral Libraries > Spectral Library Viewer
 - Select *.sli file, or open new
- CRISM spectral library: http://geo.pds.nasa.gov/missions/mro/spectral_library.htm
- CRISM type spectra: <http://crismtypespectra.rsl.wustl.edu>

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:

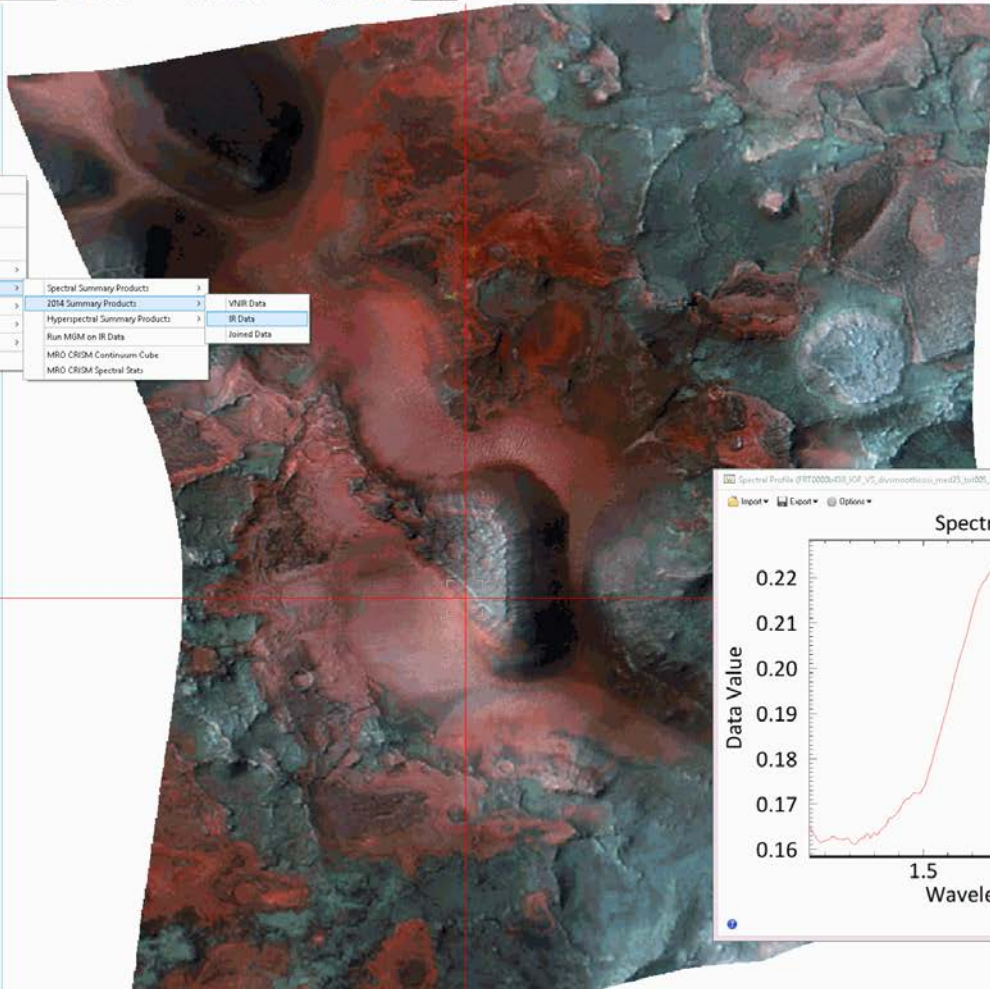
- **Screenshot of ENVI 5.4 interface with CAT pulldown menu**
- **Example scene from Northeast Syrtis: FRT0000B438**
 - **Displayed: IR false color composite**
 - **Processing: to 12 m/pixel using log maximum likelihood procedures to retrieve best estimate of surface reflectance in presence of Poisson 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 Placemaps View Help

Band Animation
Spectral Library Viewer
New Plot Window
2D Scatter Plot
Profiles
Select Annotation Manager
Full Motion Video
ENVI LIDAR
Cursor Value
Portal
View Blend
View Flicker
View Swipe
CAT 7.3.1

Reload CAT config file
Open CRIM File
Convert Format: PDS to CAT
Radiance to Iof
ATP Corrections
EPF Utilities
Spectral Analysis Utilities
Spectral Summary Products
2014 Summary Products
Hyperspectral Summary Products
Run MIM on BI Data
MRO CRIM Continuum Cube
MRO CRIM Spectral Stats
Map Utilities
MUP Data
Data Fitting
Miscellaneous Utilities
Apply CRIM Bad Bands List
WHR Data
IR Data
Joined Data



Data Manager

ERT10000430_IOP_VS_data\mrocrim\mrocrim

- Band 1 (2.6481)
- Band 2 (2.6419)
- Band 3 (2.6348)
- Band 4 (2.6293)
- Band 5 (2.6217)
- Band 6 (2.6151)
- Band 7 (2.6095)
- Band 8 (2.6019)
- Band 9 (2.5963)
- Band 10 (2.5887)

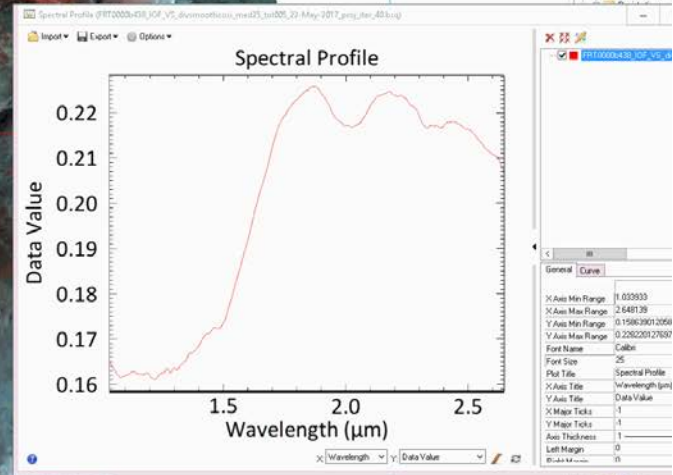
File Information

File: Y:\CRISM\FRT10000430_data\FRT10000430_IOP_VS
Date: 1249 x 1222 x 246 [85Q]
Data Type: Double
Size: 3,003,715,104 bytes
File Type: ENVI
Sensor Type: Unknown
Projection: Mercator/Angular Default
Datum: Unknown
Pixel: 12 Meters
Wavelength: 1.023933 to 2.648193 Micrometers
Description: File Generated in CRISM MLM algorithm, version 1.0

Band Selection

Load in New View

Load Data Load Grayscale



Toolbox

Search the toolbox

/Spectral/Spectral Analyst

- Band Algebra
- Band Ratios
- Spectral Indices
- Change Detection
- Classification
- Feature Extraction
- File
 - BI Error Filter
 - Co-occurrence
 - Convolution
 - Enhanced Edge
 - Enhanced Lee Filter
 - FFT (Forward)
 - FFT (Inverse)
 - FFT Filter Detail
 - Float Filter
 - Gamma Filter
 - Gauss Filter
 - Lee Filter
 - Local Sigma Filter
 - Co-occurrence Measure
- Geometric Corrector
- AOI Coordinates
- Build GLT
- Build Geometry 1
- Build Super GLT
- Generate GCPs
- Georeference to
- Georeference to
- Map Coordinates
- Orthorectifier

Vegetation
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.**

ENVI

File Edit Display Placemarks Views Help

1:25.00 (1:2.1)

Linear

Layer Manager

- View
 - FR10004487_1_OF_drvsmoohcsi_22_May2017_pnl
 - FR10004487_1_OF_drvsmoohcsi_22_May2017_pnl
- View
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
- View
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
- View
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
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 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
- View
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2
 - FR10004487_OF_VS_drvsmoohcsi_med05_ib005_2

Data Manager

File Information

File: Y:\ENVI\ENVI100004487_1_of_drvsmoohcsi_22_May2017_pnl\FR100004487_OF_VS_drvsmoohcsi_med05_ib005_2

Size: 364,622,400 bytes

File Type: ENVI

Compression Type: Unknown

Wavelength: 1.022023 to 2.648233 Micrometers

Description: File Generated in ORFEM MLU algorithm, vers

Band Selection

Load in New View

Load Data Load Grayscale

Toolbox

Search the toolbox

Spectral/Spectral Analyst

- Favorites
- Anomaly Detection
- Band Algebra
- Band Math
- Band Ratio
- Spectral Indices
- Change Detection
- Classification
- Feature Extraction
- Filter
 - 3x3 Median Filter
 - 3x3 Convolution and Morphology
 - Enhanced Fract Filter
 - Enhanced Lee Filter
 - FFT Forward
 - FFT Filter Dilation
 - Fract Filter
 - Gamma Filter
 - Kuise Filter
 - Lee Filter
 - Local Sigma Filter
 - Occurrence Measures
- Geometric Correction
 - ASCI Coordinate Conversion
 - Build GLT
 - Build Geometry File by Sensor
 - Build Super GLT
 - Generate GCPs from Reference In
 - Georeference by Sensor
 - Georeference from GLT
 - Georeference from GAT
 - Map Coordinate Converter
 - Orthorectification
 - Registration
 - Preproject GLT with Bowtie Control
 - Super GLT Georeference
 - Super GAT Georeference
 - Image Smoothing
- LMAR
- Mosaicking
- Radix
- Radiometric Correction
- Raster Management
 - Convert Complex Data
 - Convert Inteleview
 - Create Coordinate System String
 - Create ENVI Meta File
 - Data Views
 - Data Specific Utilities
 - Driftline
 - ENVI ENVI Header
 - Generate Test Data
 - IDL
 - Layer Stacking
 - Masking
 - New File Bubble
 - Raster Dice
 - Replace Bad Lines
 - Reproject Raster
 - Reslice Data
 - Rotate File Data
 - Stretch Data
- Regions of Interest
- Spatiotemporal Analysis
- SPEAR
- Spectral
 - Build 3D Cube
 - Mapping Methods
 - Pixel Flatly Index
 - SNACC Endmember Extraction
 - Spectral Analyst
 - Spectral Math
 - Spectral Recampling
 - Spectral Slices
 - Spectral Smoothing
 - Vegetation
- Statistics
- Target Detection
- THOR

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