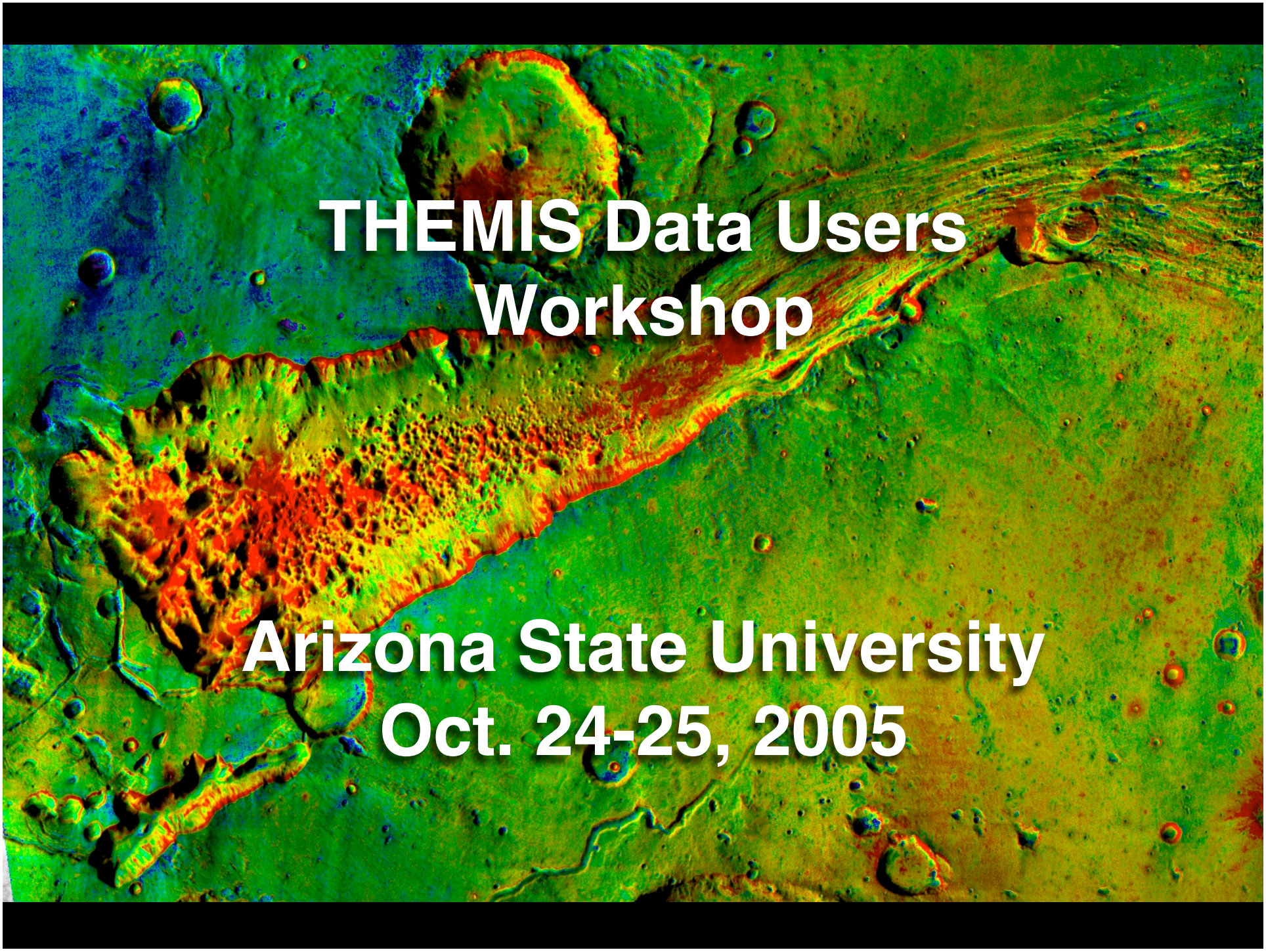
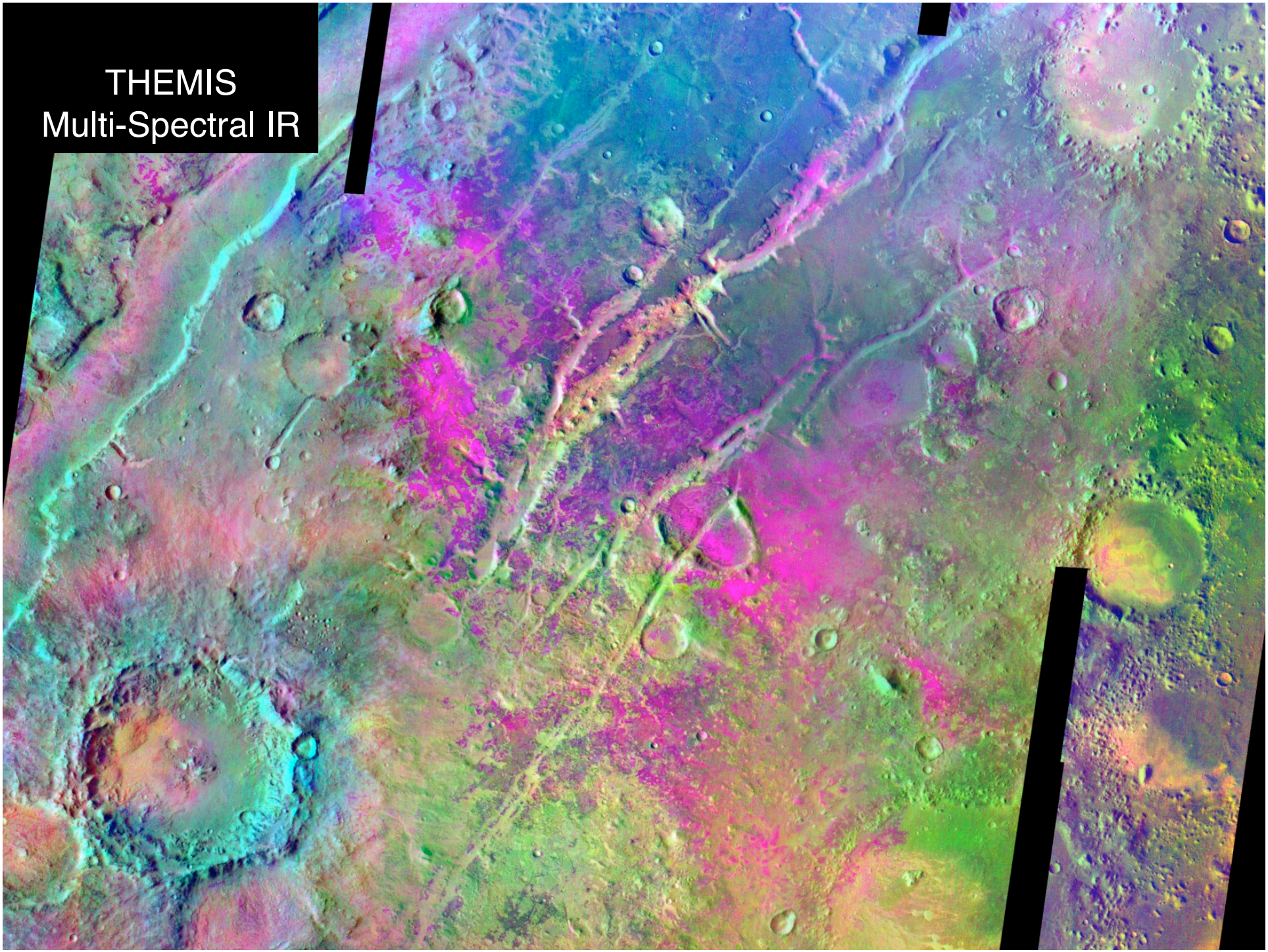

THEMIS Data Users
Workshop
Arizona State University
Oct. 24-25, 2005

# Workshop Objectives

- Send everyone home capable of producing projected multi-spectral color IR, emissivity, and temperature images

- Plan
  - Describe where and how to get THEMIS data
  - Discuss data processing and projection tools
  - Present web-based processing system
  - Give examples of science analysis using THEMIS data
  - Demonstrate THEMIS GIS tool (JMARS)
  - Provide hands-on training


THEMIS
Multi-Spectral IR

# Workshop Agenda

- Overview
- Discuss where and how to get THEMIS data
- Detailed THEMIS processing
  - Discuss each algorithm and processing step
  - Discuss problems and things to watch out for
- Output image types
- Web interface
- Science examples
  - Atmospheric correction
  - Multi-spectral analysis
  - Thermophysical properties

# THEMIS Data Users Workshop Day 1 Schedule

| | | |
|---|---|---|
| **Welcome** | Phil C. | 9:00-9:15 |
| **Overview** | Phil C. | 9:15-10:30 |
| TIR Spectroscopy Overview | | |
| Instrument Overview | | |
| Data Processing Overview | | |
| **Break** | | 10:30-10:45 |
| **Selection and Extraction of Data** | Noel Gorelick | 10:45-11:15 |
| **Image Processing Tools** | Josh Bandfield | 11:15-12:00 |
| UDDW | | |
| Rectify | | |
| Deplaid | | |
| Auto-radcorr | | |
| Unrectify | | |
| **Lunch** | | 12:00-1:15 |
| **Image Projections/Cropping** | Noel Gorelick | 1:15-1:45 |
| **Output** | | 1:45-2:15 |
| Radiance/BT/Emissivity/Tsurf | Phil C. | |
| Isis/8-bit/DCS/Backplanes | Noel Gorelick | |
| **Break** | | 2:15-2:30 |
| **Data Analysis/Display Tools** | Josh Bandfield | 2:30-2:45 |
| Decorrelation Stretch; 4-panel images | | |
| **Web Interface** | Josh Bandfield | 2:45-3:15 |
| **Science** | | |
| Atmospheric Correction/Spectral Unit Mapping | Josh Bandfield | 3;15-3:45 |
| Using THEMIS Spectral Data | Deanne Rogers | 3:45-4:30 |
| Thermophysics | Robin Fergason | 4:30-5:15 |

# THEMIS Data Users Workshop Day 2 Schedule

| | | |
|---|---|---|
| **Mosaics** | Phil | 8:30-8:45 |
| **JMARS** | Noel | 8:45-10:30 |
| **Break** | | 10:30-10:45 |
| **ENVI Software Tools** | Jen | 10:45-11:45 |
| **Lunch** | | 11:45-1:00 |
| **Hands-on Training** | | 1:00-3:00 |

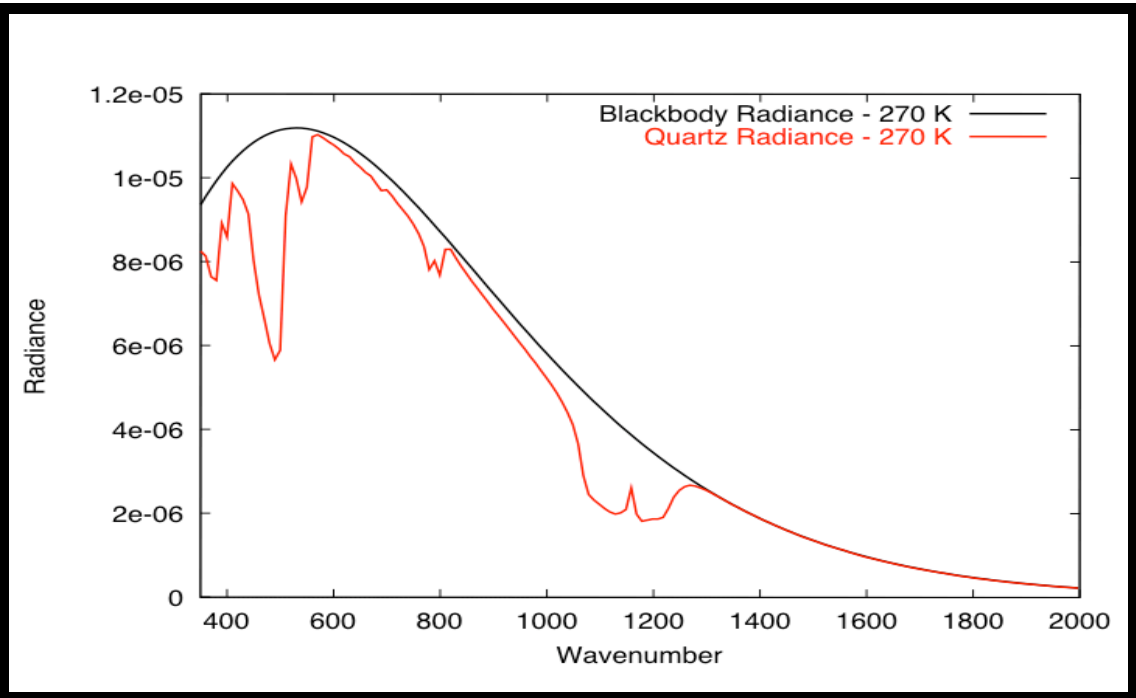
# Overview

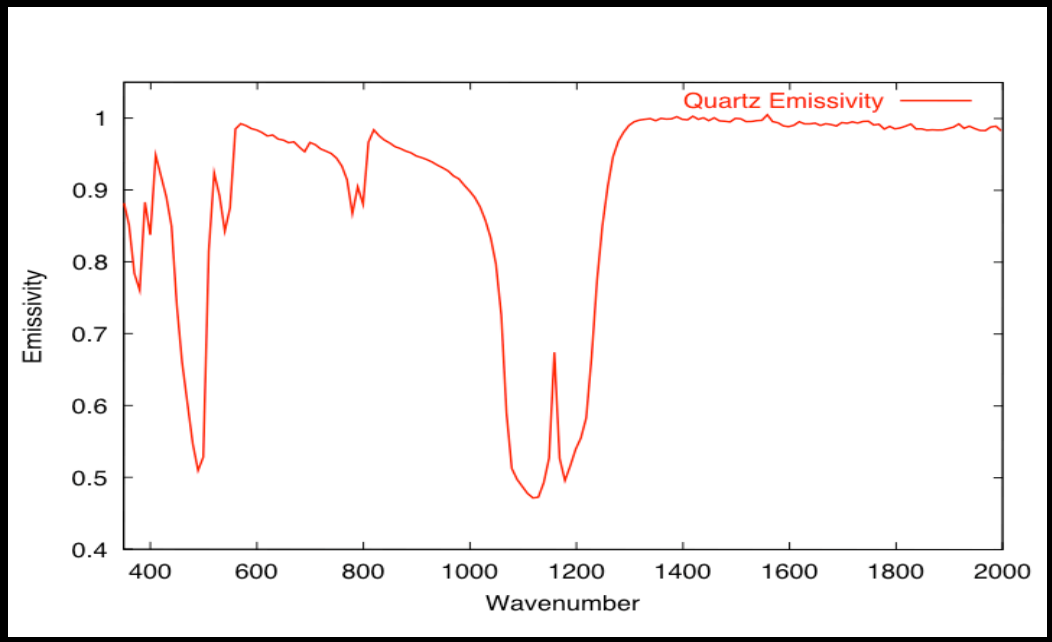
- IR spectroscopy overview
- THEMIS instrument overview
- Instrument characteristics
- Data processing overview
- Examples of THEMIS data products

# IR Spectroscopy Overview

# Glossary

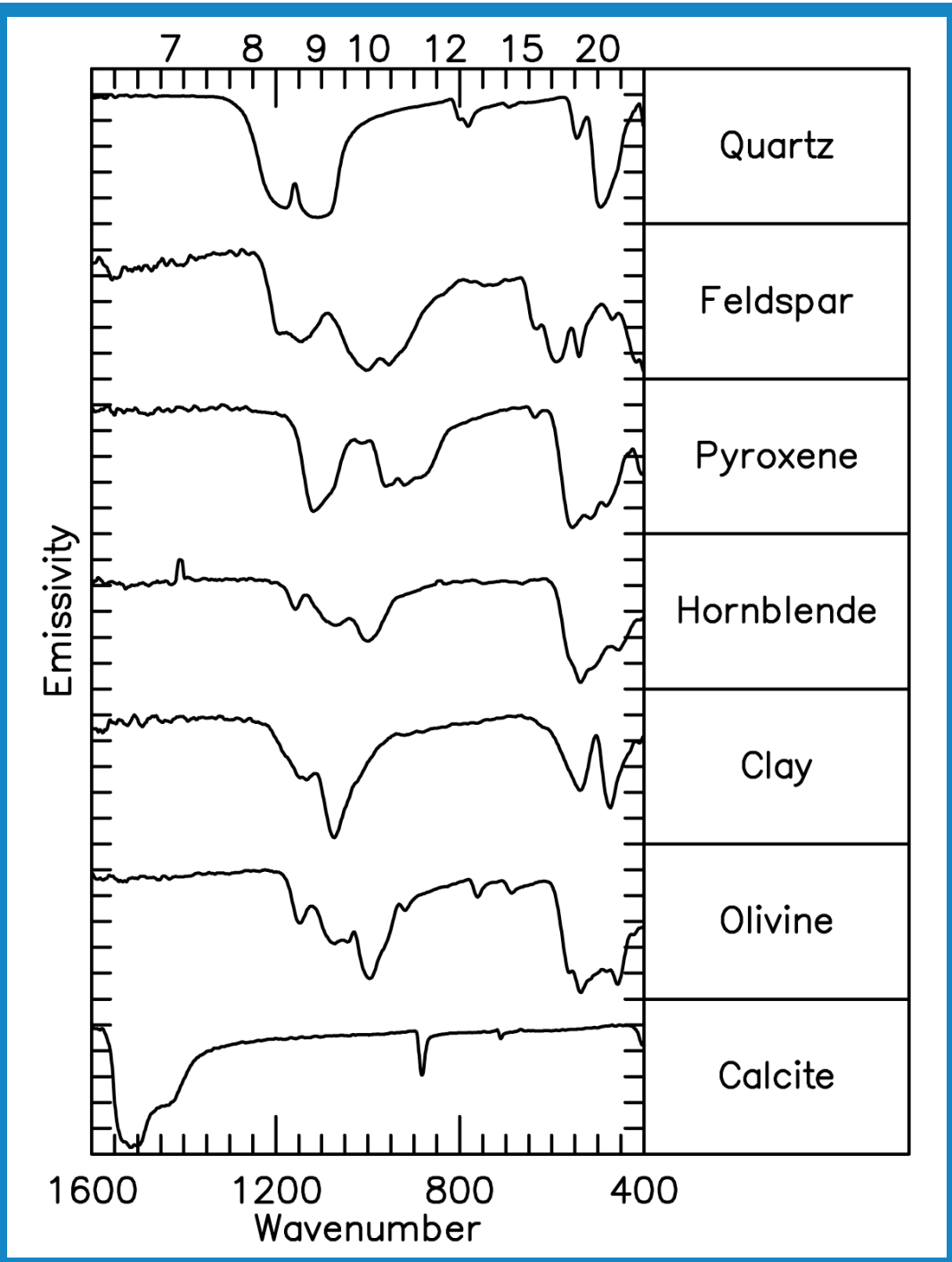
- Spectral Radiance (Radiance): $R(\lambda)$
  - Total energy emitted per unit area, angle, and wavelength
  - $W\ m^{-2}\ str^{-1}\ \mu m^{-1}$
- Blackbody
  - An ideal body that emits with maximum thermodynamic efficiency (Planck function)
- Emissivity: $\varepsilon(\lambda)$
  - Ratio of actual emitted radiance to that of an ideal blackbody

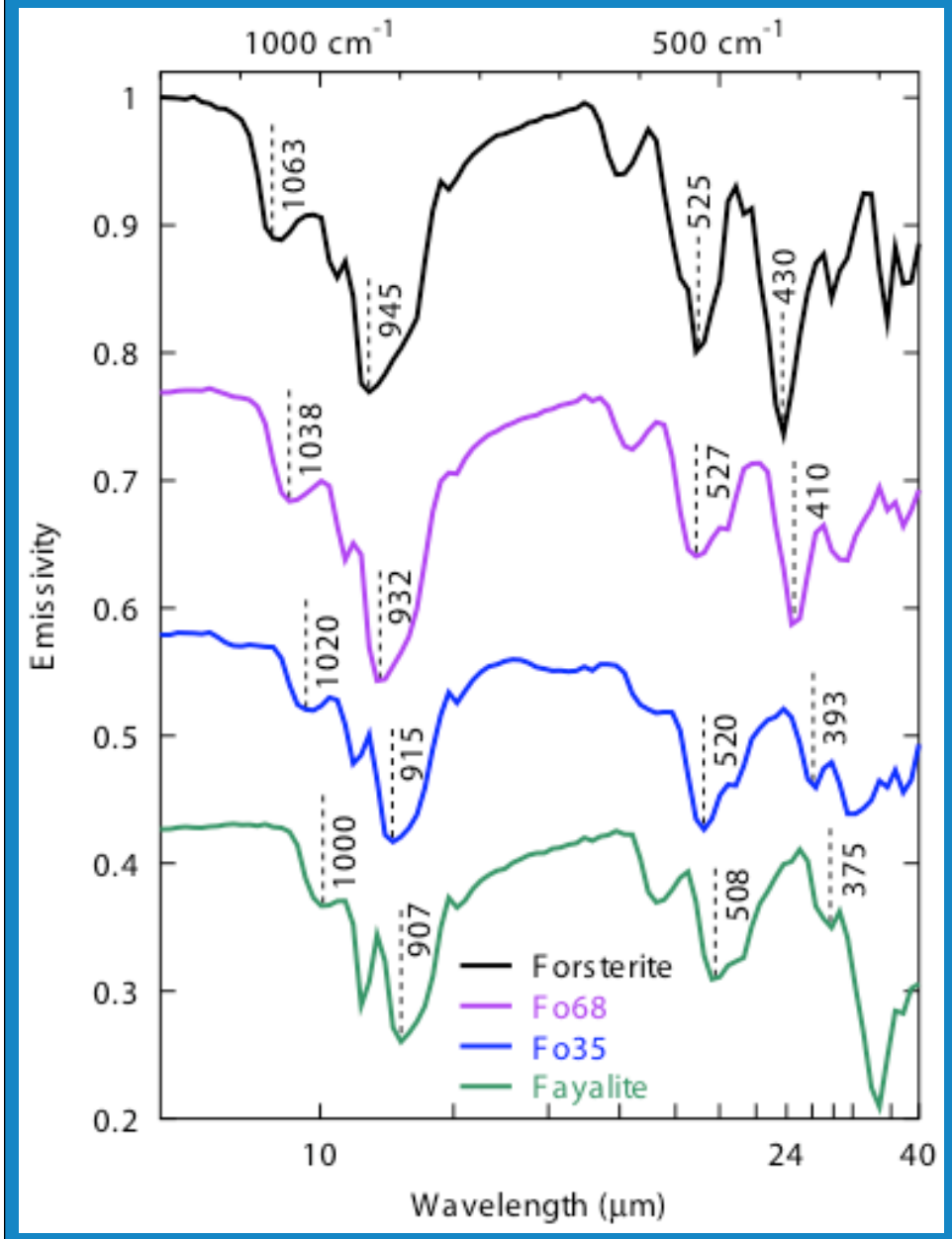

Blackbody Radiance - 270 K
Quartz Radiance - 270 K
Radiance
1.2e-05
1e-05
8e-06
6e-06
4e-06
2e-06
0
400
600
800
1000
1200
1400
1600
1800
2000
Wavenumber


Quartz Emissivity
Emissivity
1
0.9
0.8
0.7
0.6
0.5
0.4
400
600
800
1000
1200
1400
1600
1800
2000
Wavenumber

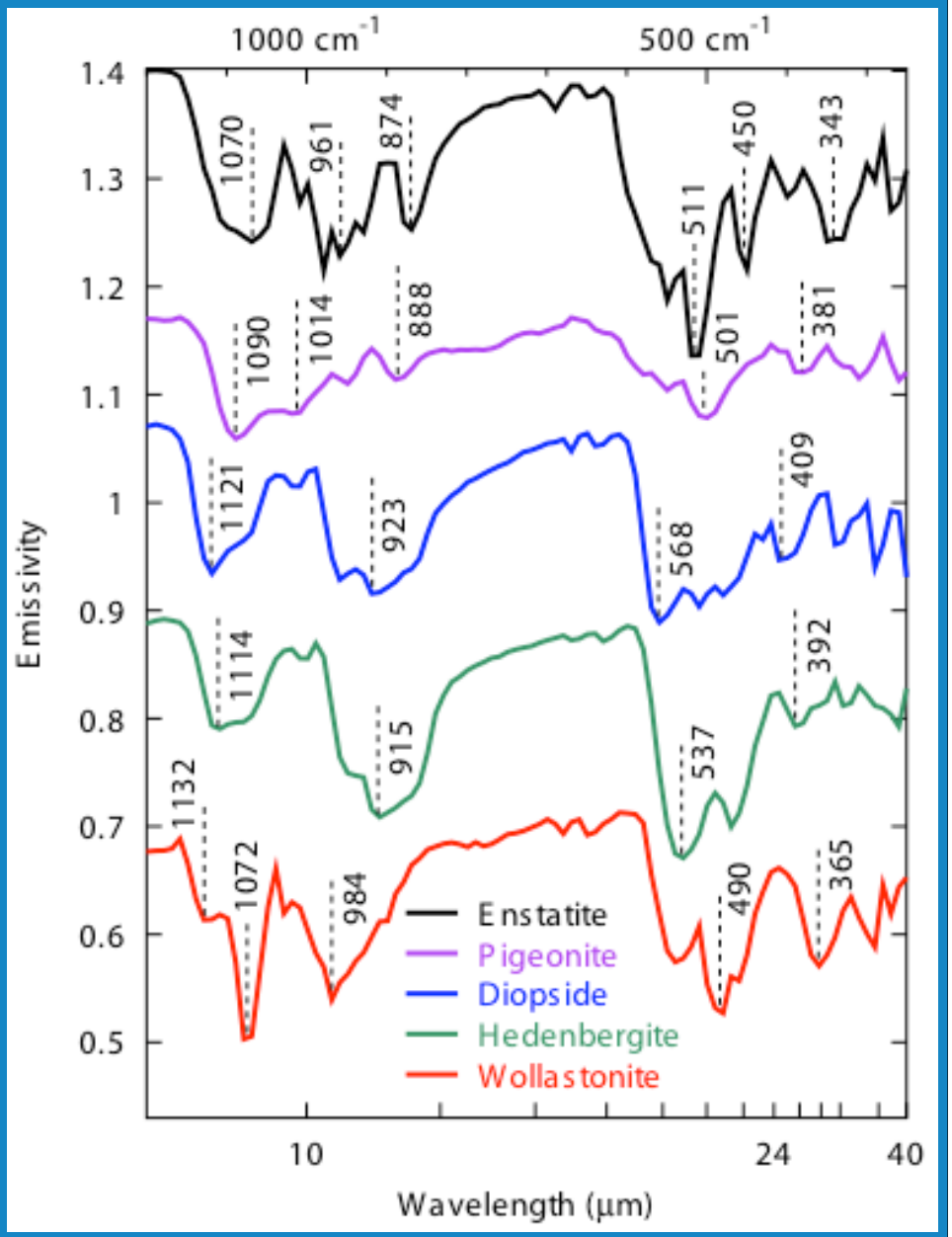
# Glossary (2)

- Brightness Temperature: $B_T(\lambda)$
  - The temperature at each wavelength of a blackbody emitting the measure radiance
- Surface (Target) temperature
  - The maximum brightness temperature over wavelength range

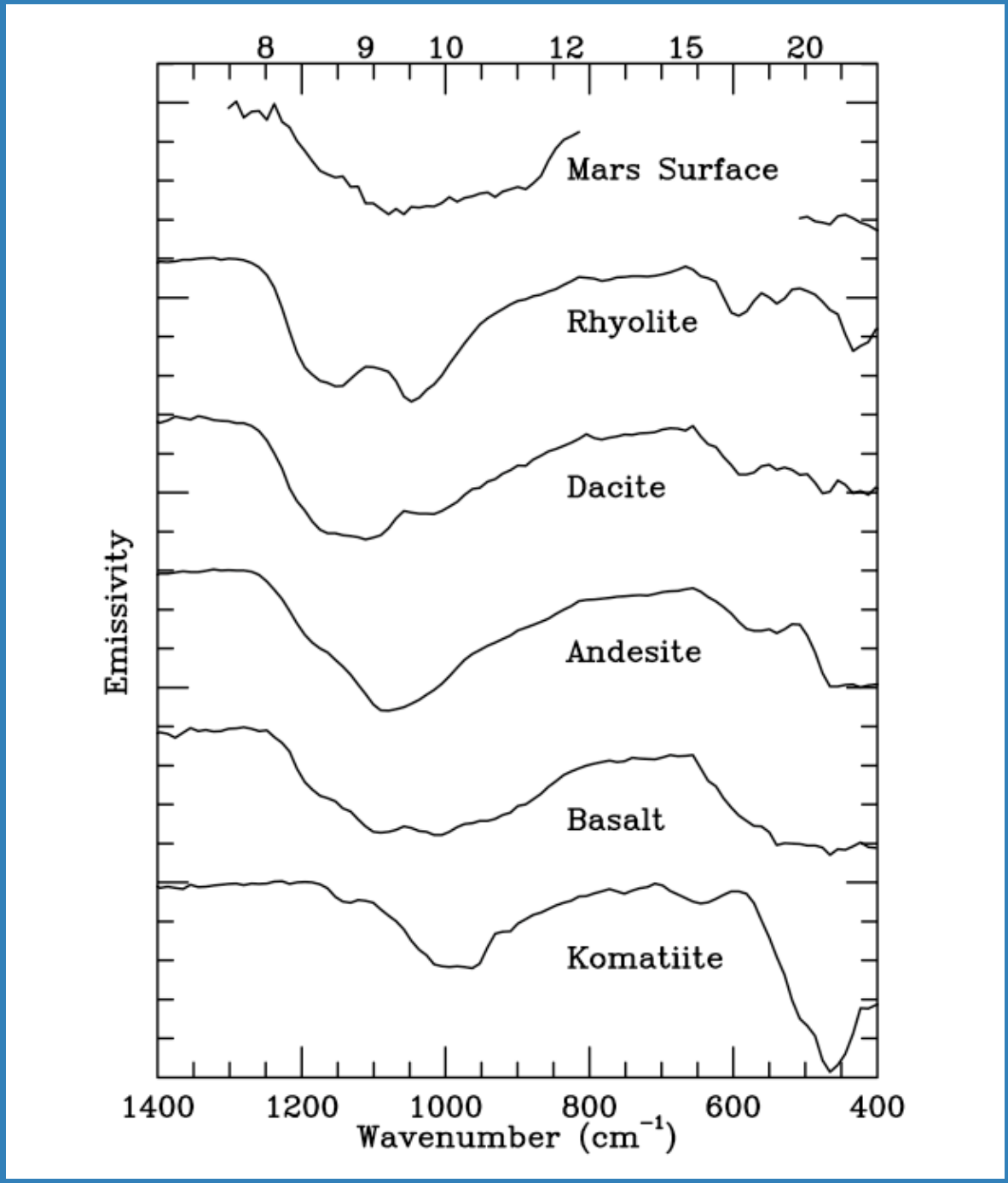

7
8
9
10
12
15
20
Quartz
Feldspar
Pyroxene
Hornblende
Clay
Olivine
Calcite
Emissivity
1600
1200
800
400
Wavenumber

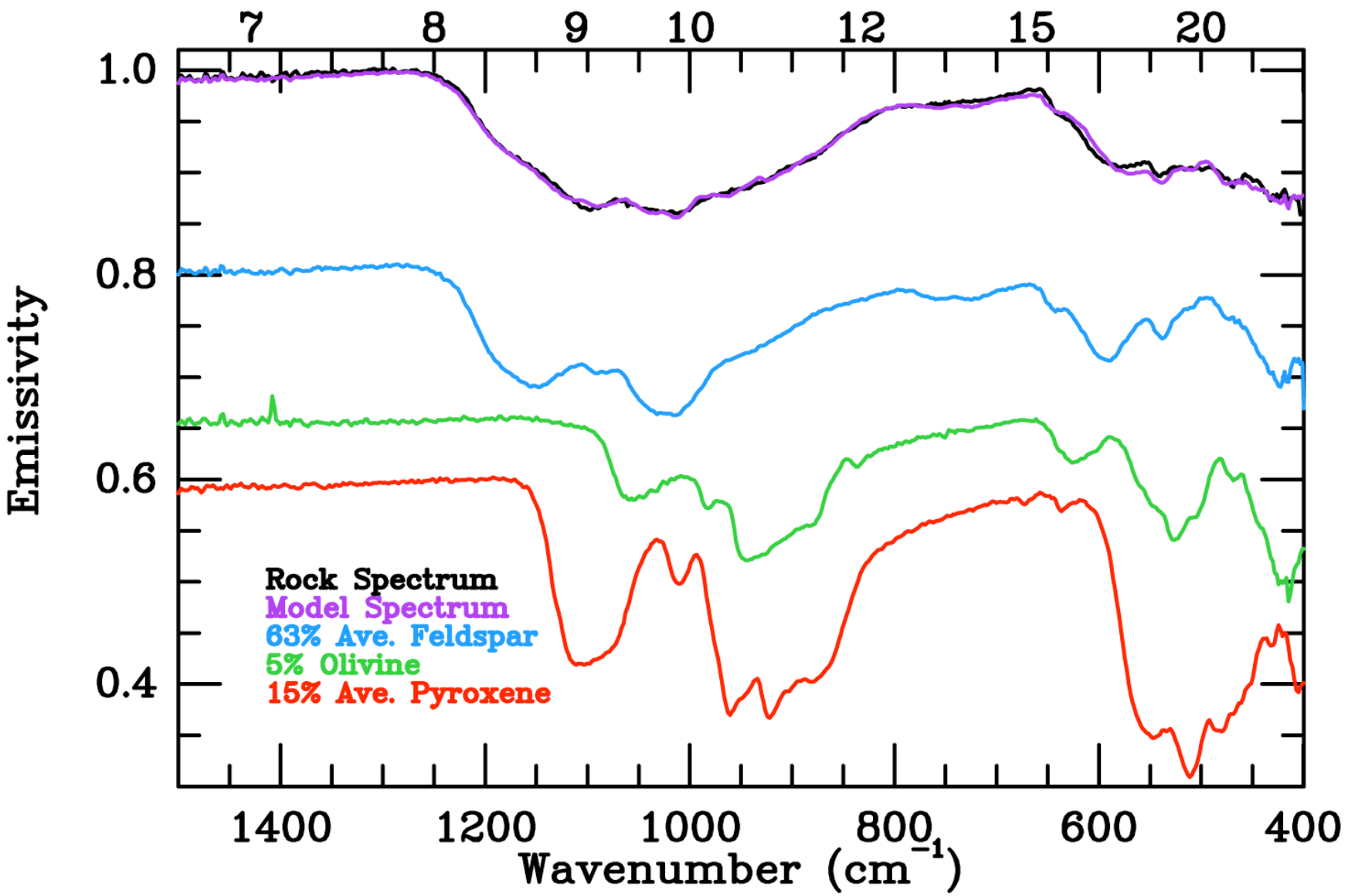



Olivines

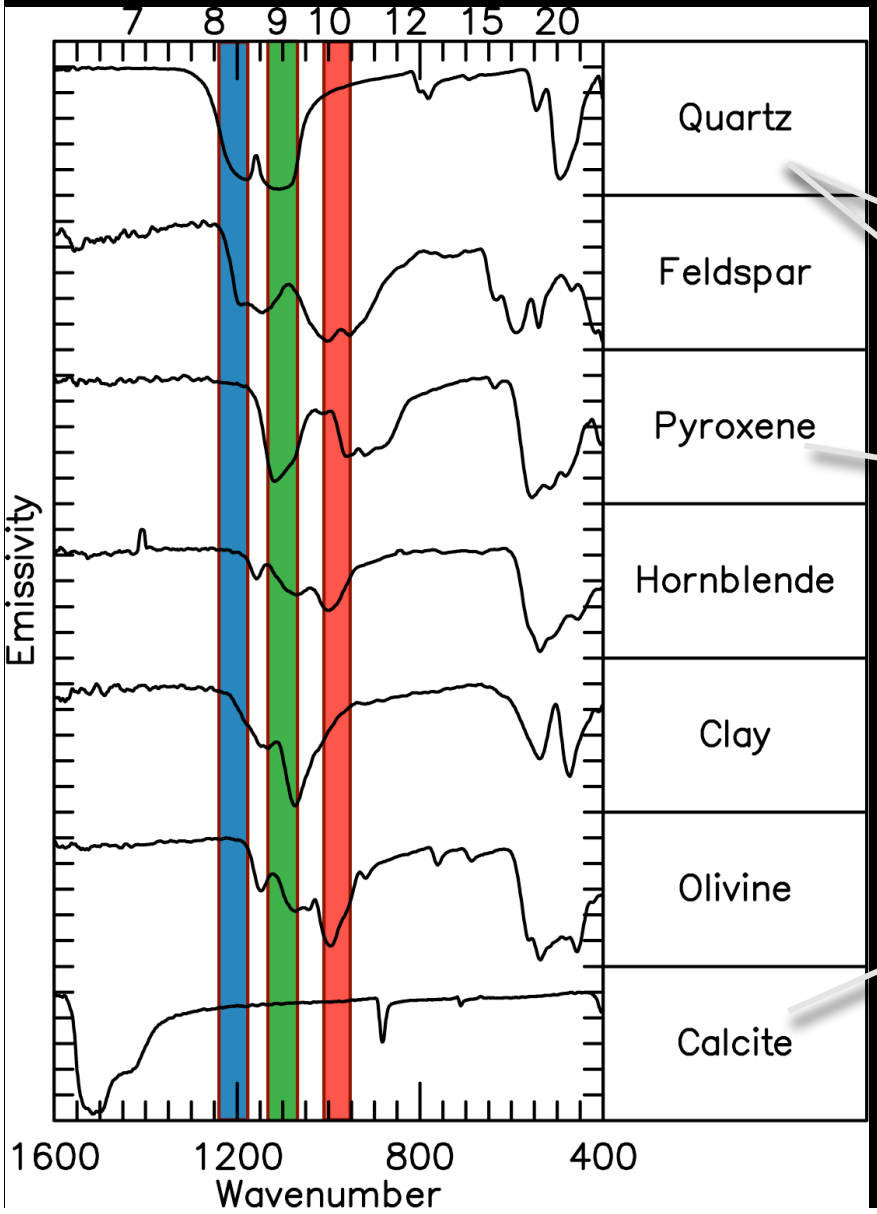


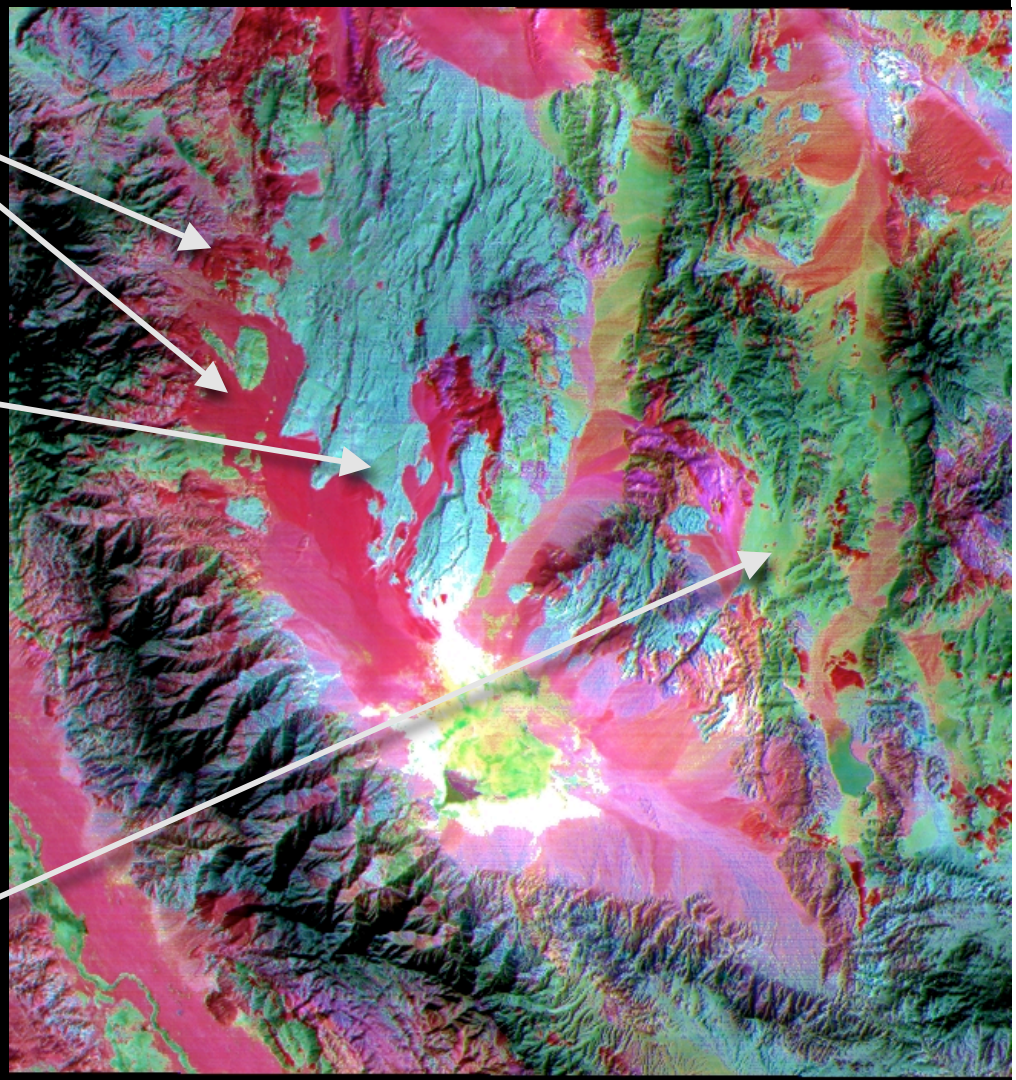

Pyroxenes


8
9
10
12
15
20
Mars Surface
Rhyolite
Dacite
Andesite
Basalt
Komatiite
Emissivity
1400
1200
1000
800
600
400
Wavenumber (cm$^{-1}$)


7
8
9
10
12
15
20
1.0
0.8
0.6
0.4
Emissivity
Rock Spectrum
Model Spectrum
63% Ave. Feldspar
5% Olivine
15% Ave. Pyroxene
1400
1200
1000
800
600
400
Wavenumber (cm$^{-1}$)

# Infrared Multi-spectral Imaging

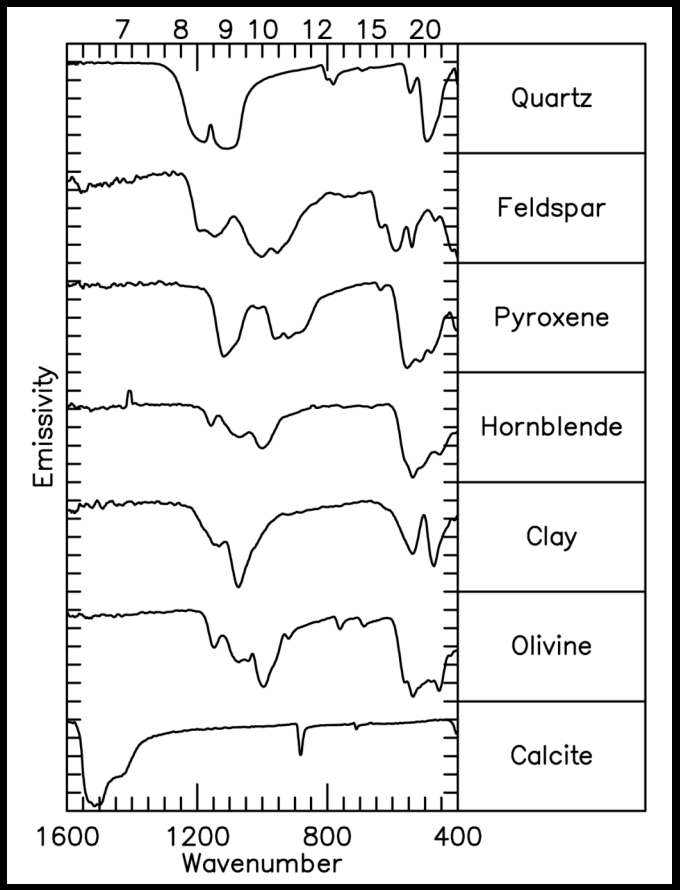


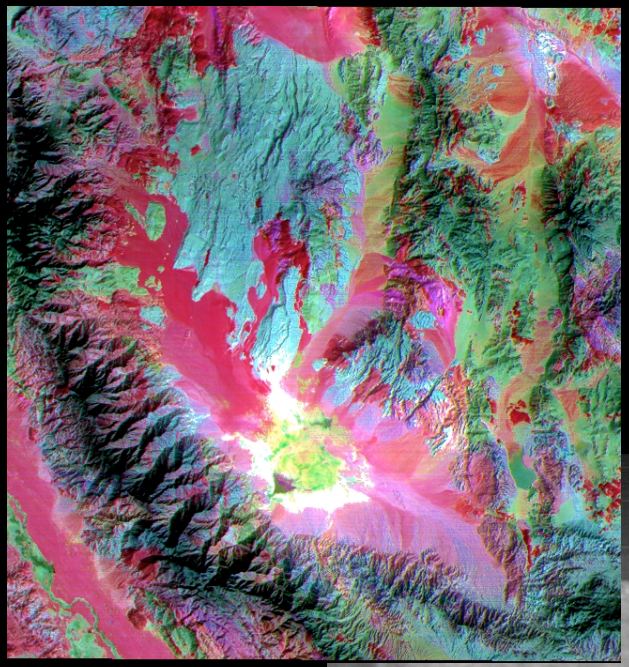
# THEMIS Instrument Overview

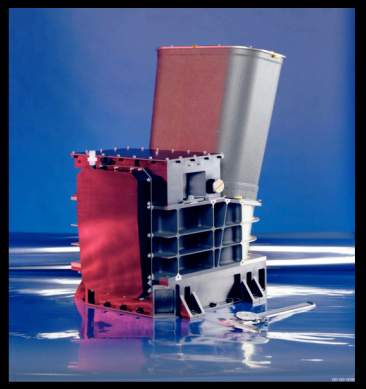
# Infrared Mapping

## Spectroscopy

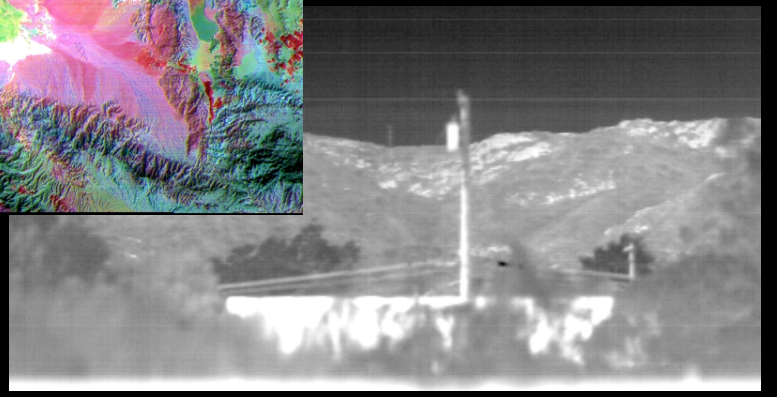


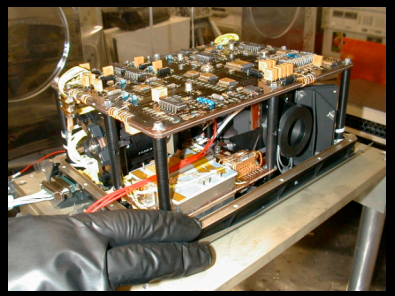

## Multi-spectral Imaging





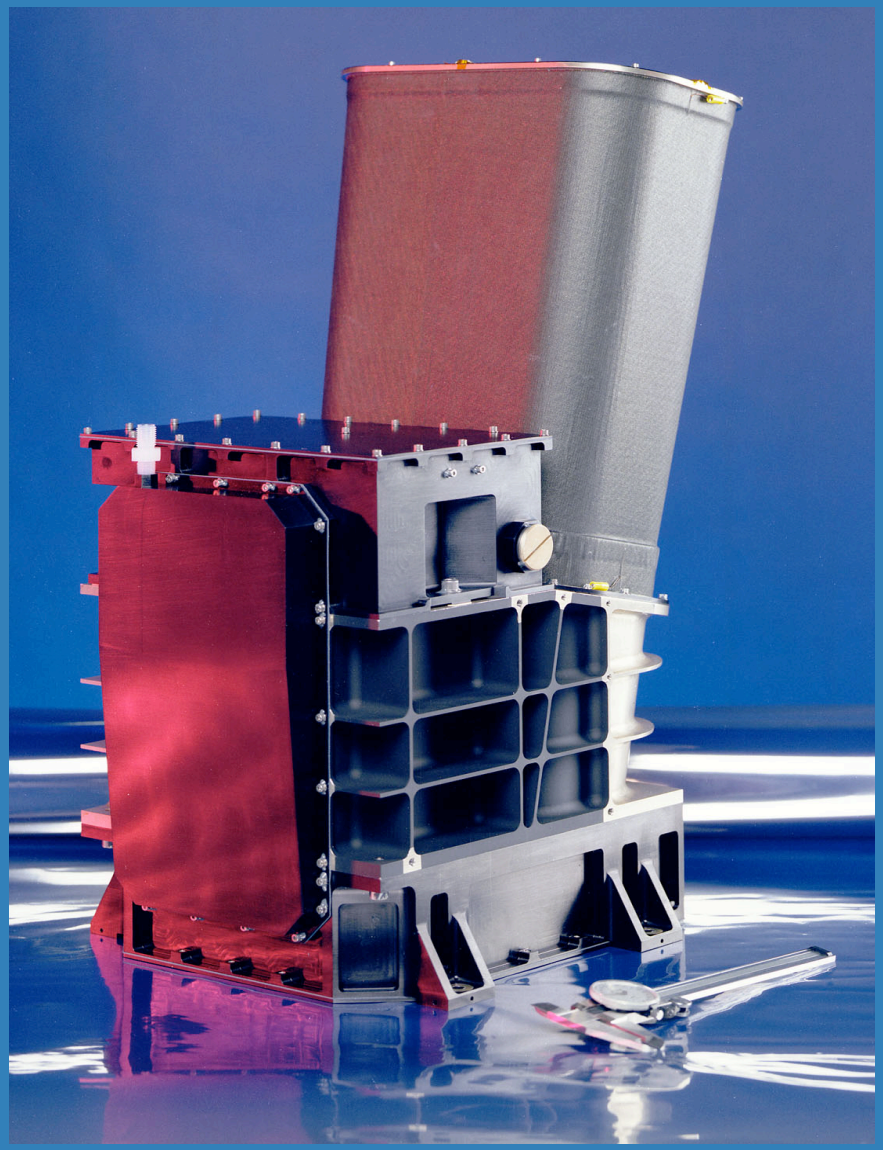
## Temperature



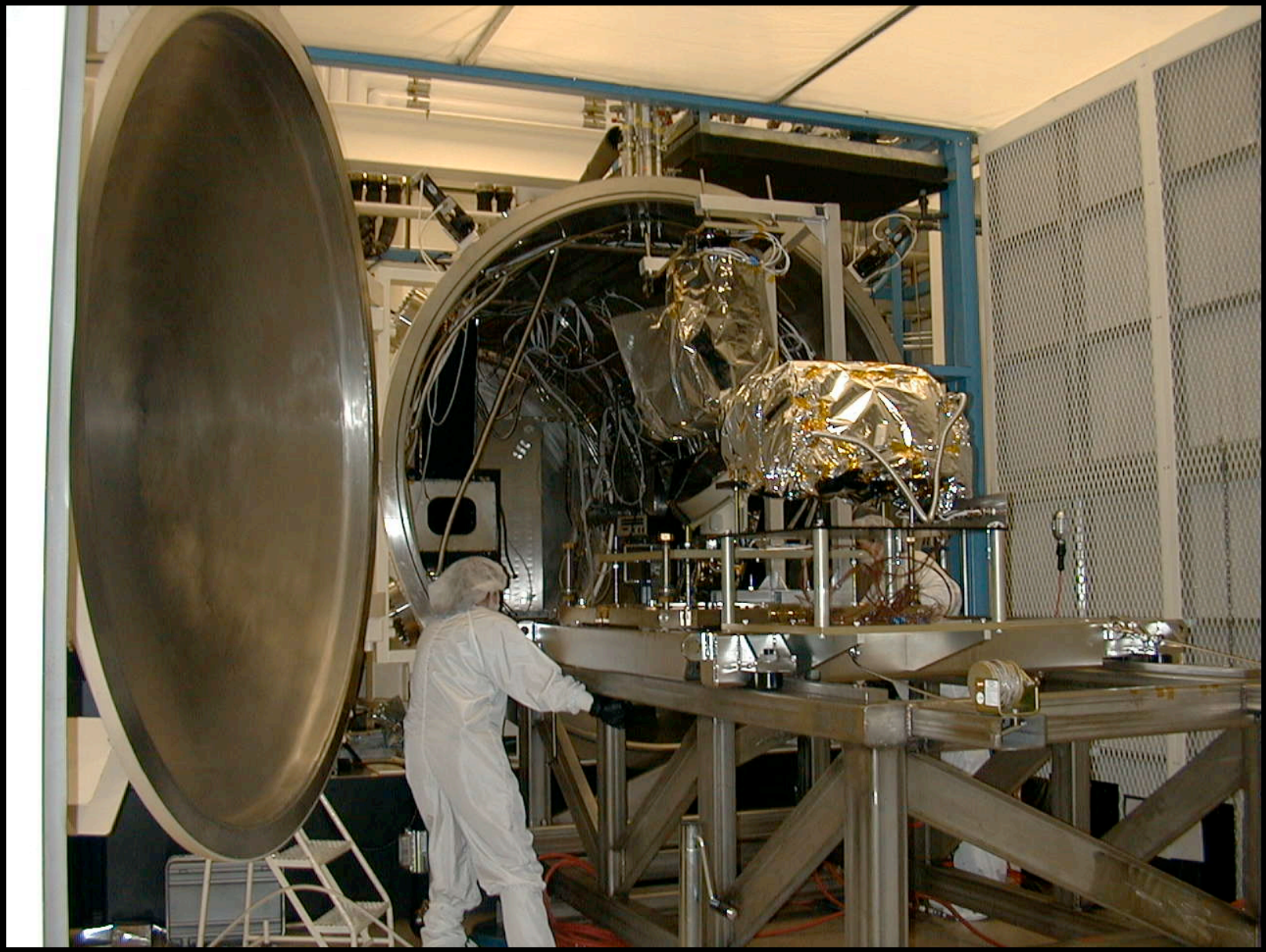


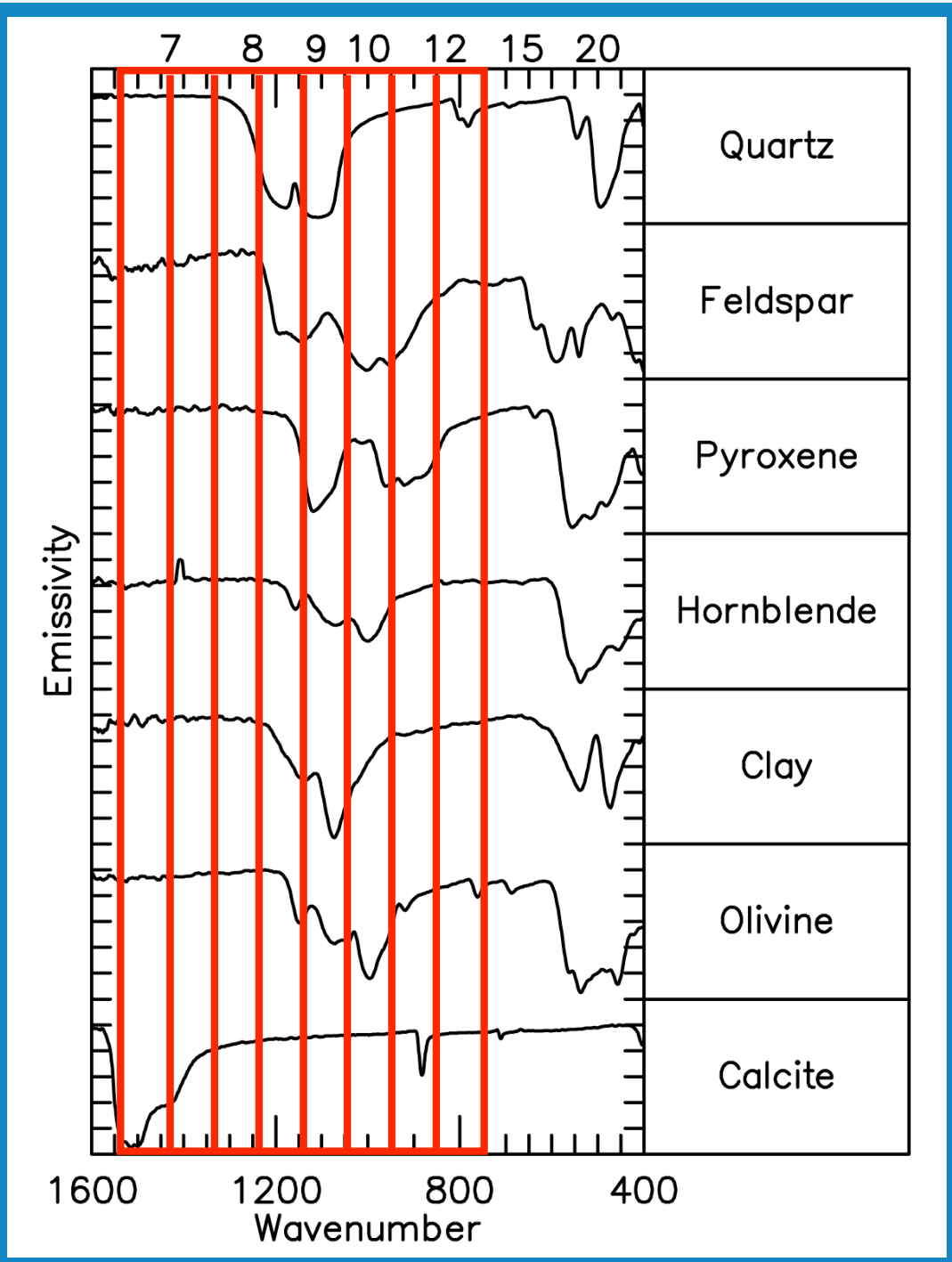
# THEMIS Investigation

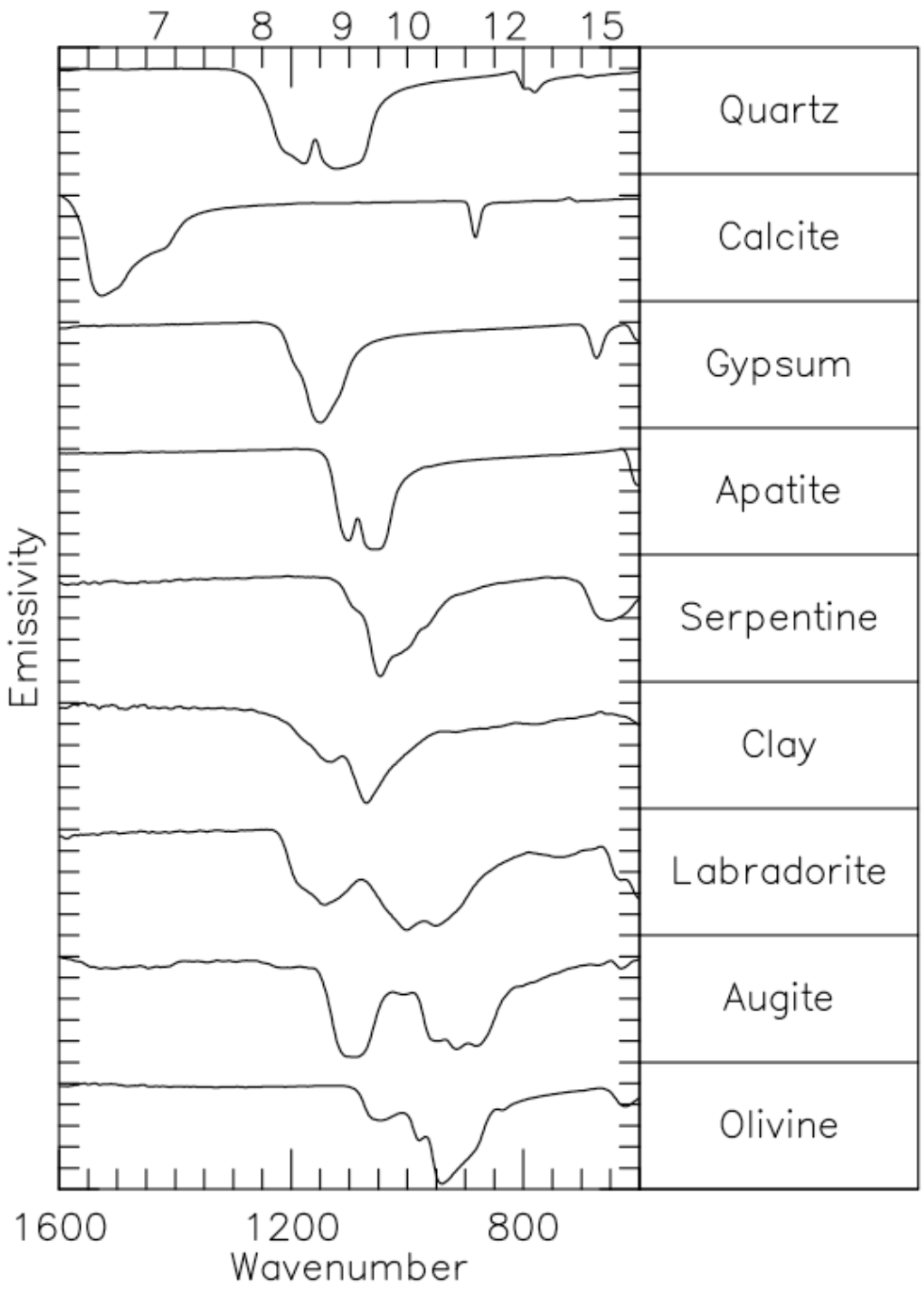
- 9-band multi-spectral IR imager
  - Uncooled microbolometer
  - 6.5-15.5 $\mu$m
- 5-band visible imager
  - 0.43-0.85 $\mu$m
- 100-m spatial resolution in IR
- 18-m spatial resolution in visible
- Global coverage in IR (day and night) and 1-band visible during primary mission
- Mass: 12.2 kg
- Size: 29 x 38 x 55 cm
- Power: 14 W

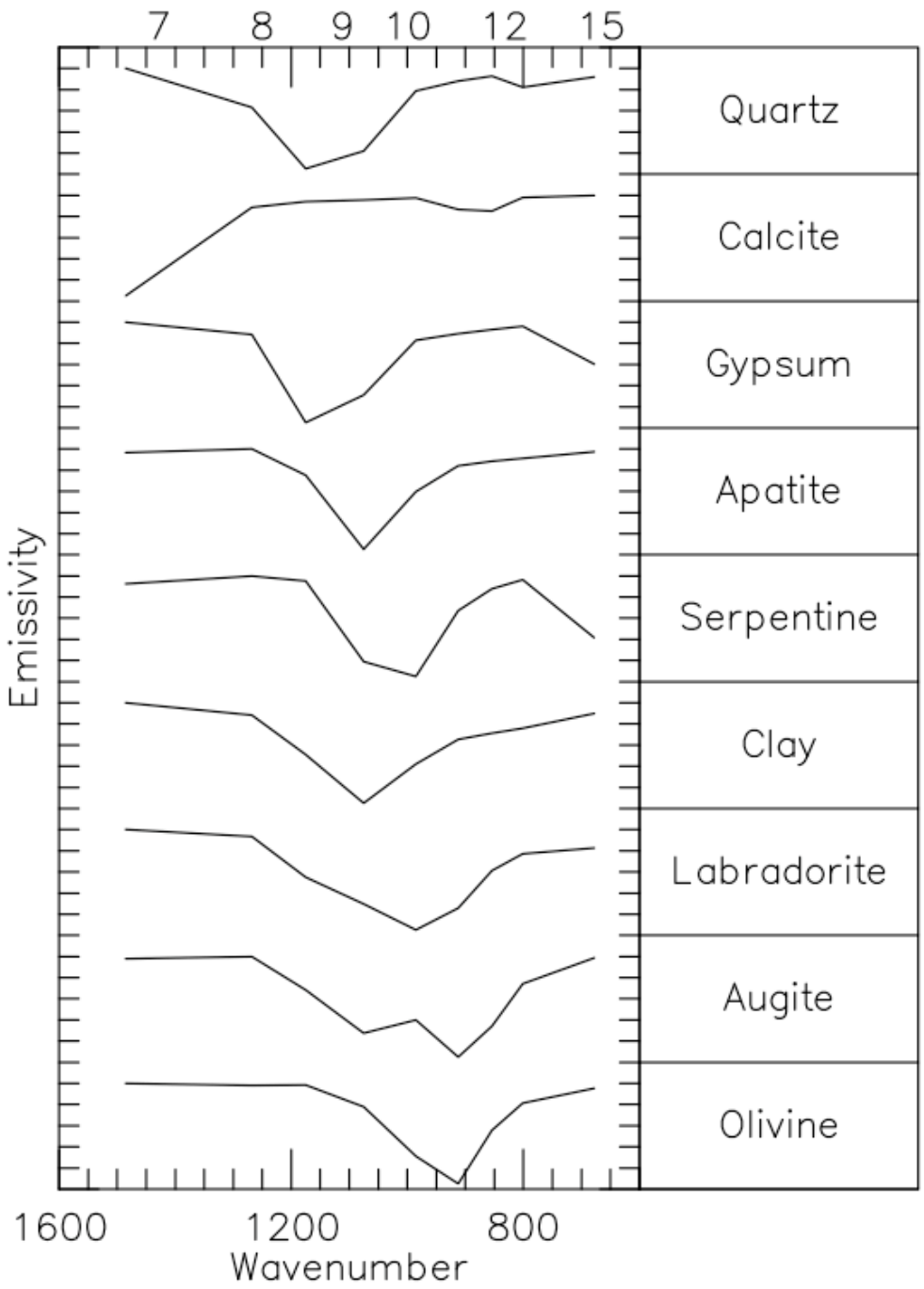


# Moving THEMIS Into Vacuum Chamber at SBRS

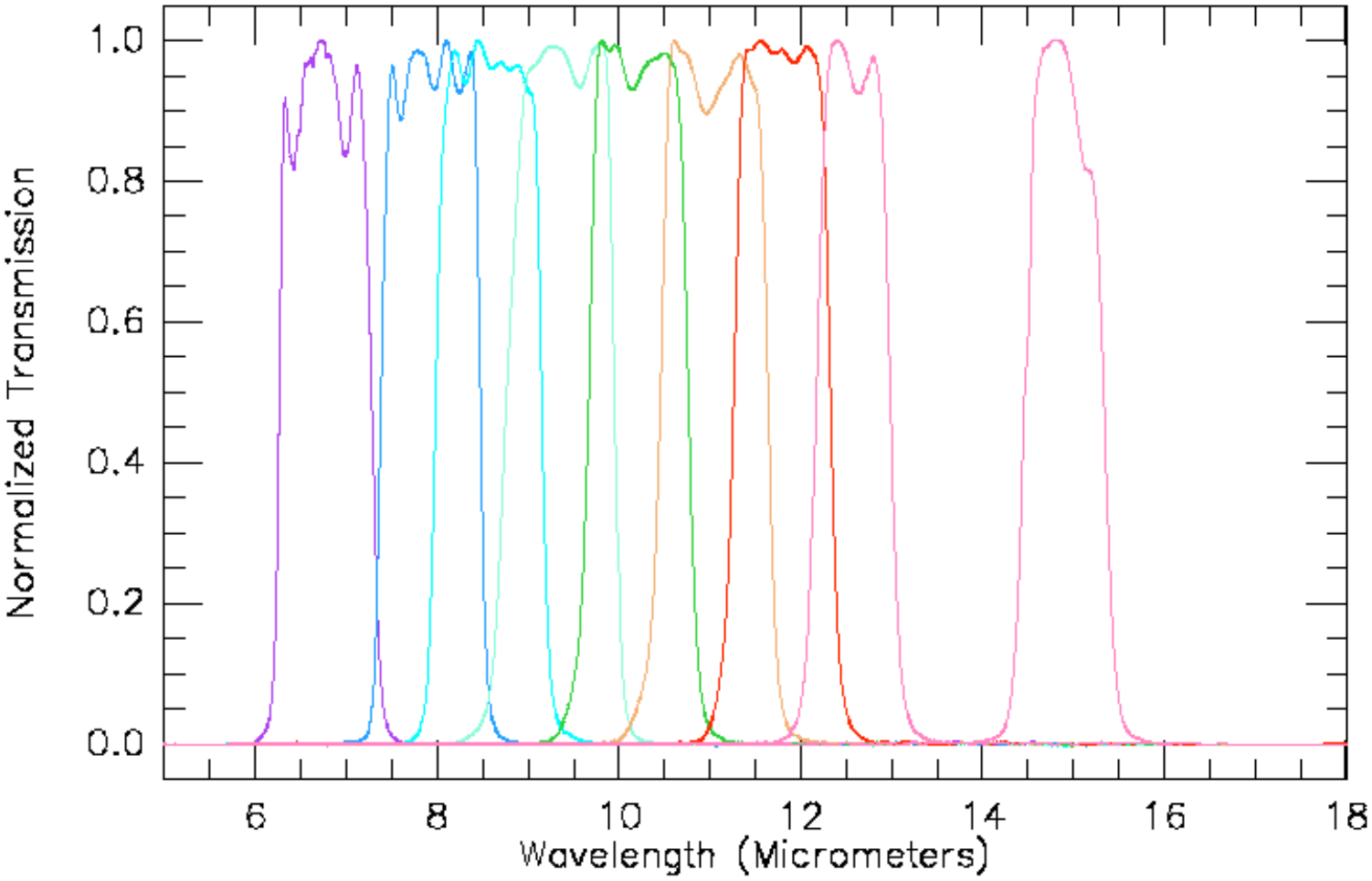



7
8
9
10
12
15
20
Quartz
Feldspar
Pyroxene
Hornblende
Clay
Olivine
Calcite
Emissivity
1600
1200
800
400
Wavenumber


7
8
9
10
12
15
Quartz
Calcite
Gypsum
Apatite
Serpentine
Clay
Labradorite
Augite
Olivine
Emissivity
1600
1200
800
Wavenumber


7
8
9
10
12
15
Quartz
Calcite
Gypsum
Apatite
Serpentine
Clay
Labradorite
Augite
Olivine
Emissivity
1600
1200
800
Wavenumber

# THEMIS IR Filters



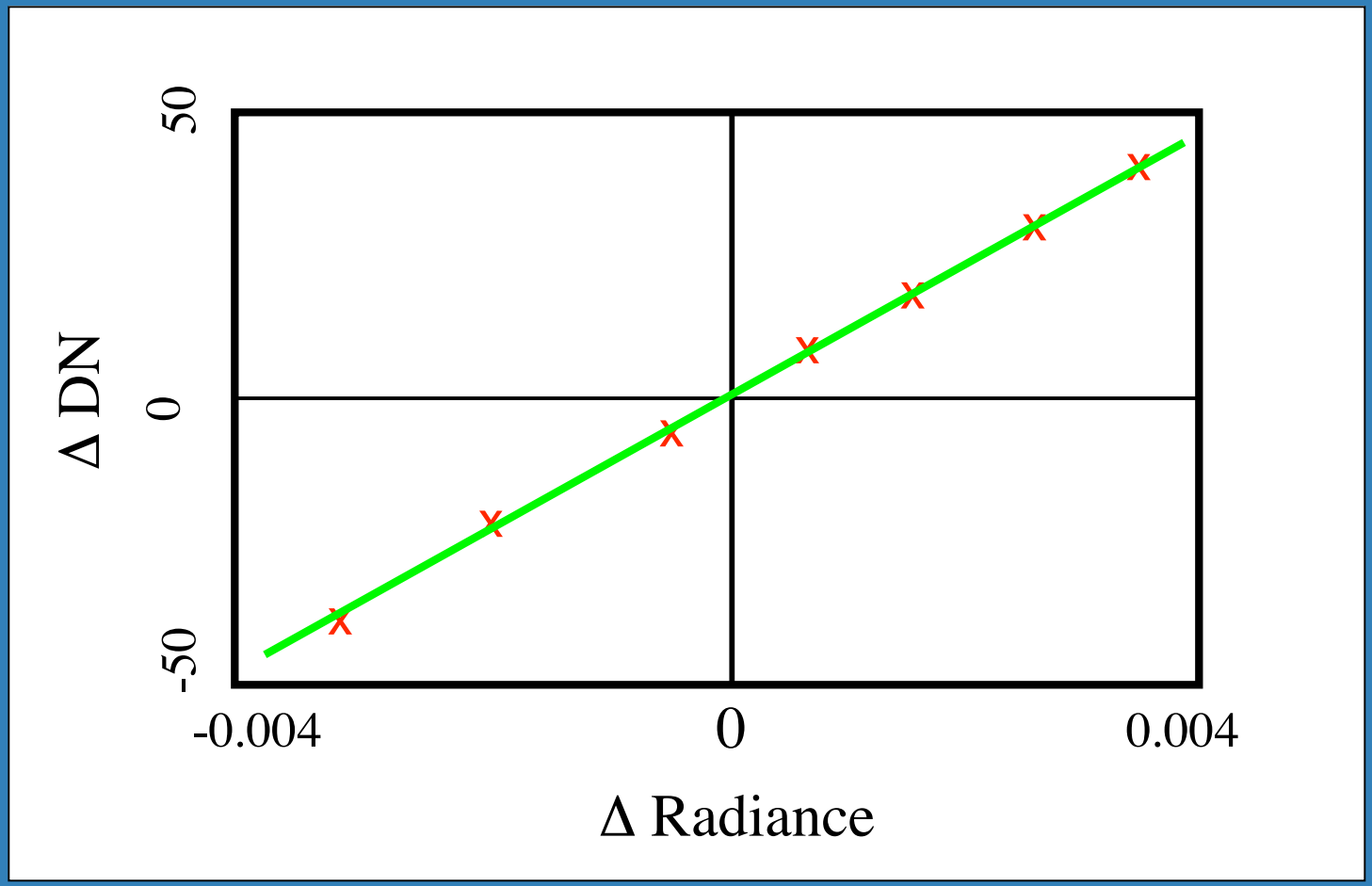
# THEMIS Spectral Bands

| IR Band | Center Wavelength | Bandwidth |
|---|---|---|
| 1 | 6.78 µm | 1.01 µm |
| 2 | 6.78 | 1.01 |
| 3 | 7.93 | 1.09 |
| 4 | 8.56 | 1.16 |
| 5 | 9.35 | 1.20 |
| 6 | 10.21 | 1.10 |
| 7 | 11.04 | 1.19 |
| 8 | 11.79 | 1.07 |
| 9 | 12.57 | 0.81 |
| 10 | 14.88 | 0.87 |
| VIS Band | | |
| 1 | 0.425 | 0.049 |
| 2 | 0.540 | 0.051 |
| 3 | 0.654 | 0.053 |
| 4 | 0.749 | 0.053 |
| 5 | 0.860 | 0.045 |

# Data Processing Overview

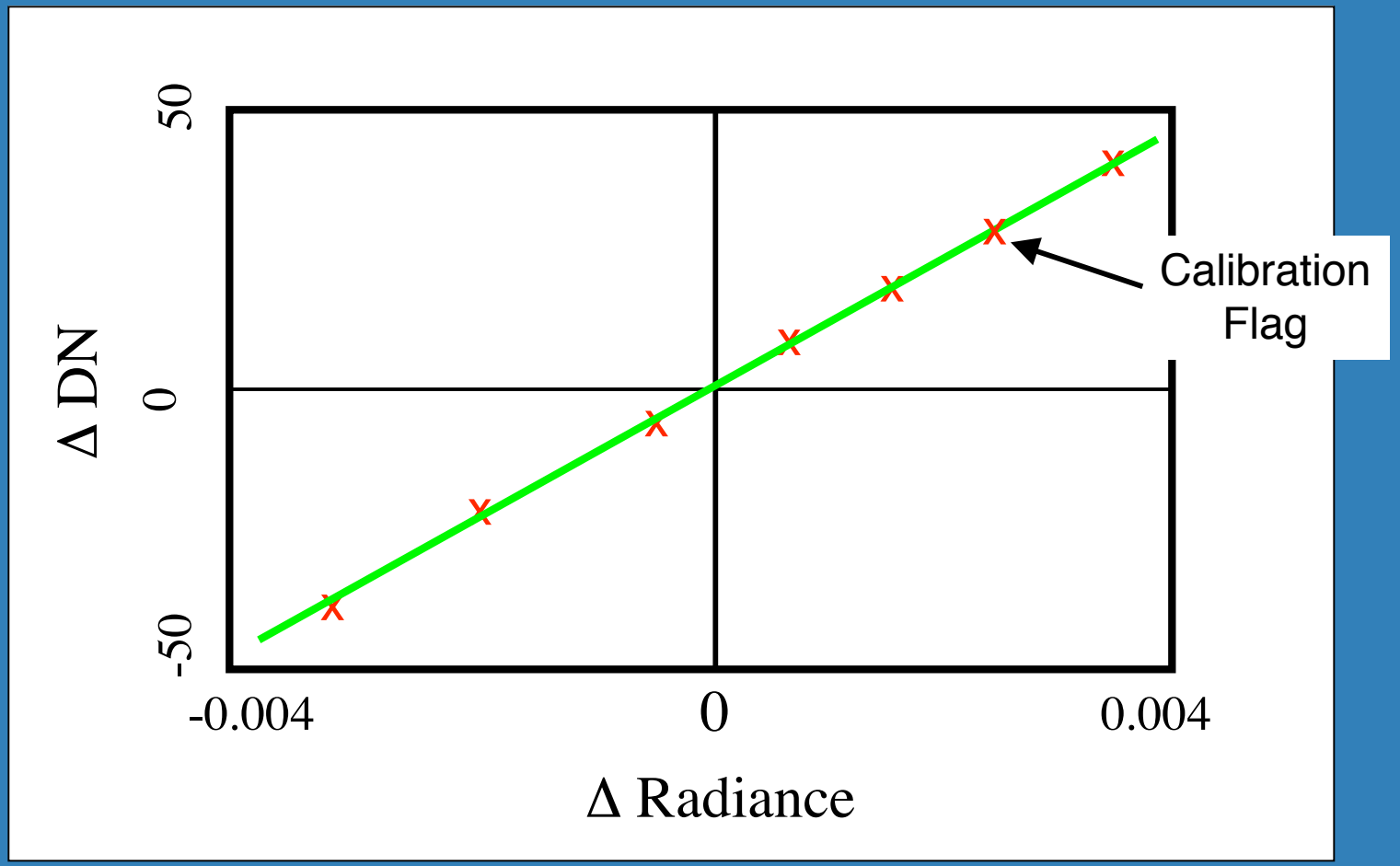
# Instrument Operation

- THEMIS measures the spectral radiance difference between the detector array and the scene



# Instrument Operation

- Measure a calibration flag - use this to determine the radiance from all the pixels in a scene



# Instrument Operation

- Close and observe the DN of the calibration flag/shutter at the start and of each IR image
  - Gives the calibration value for:

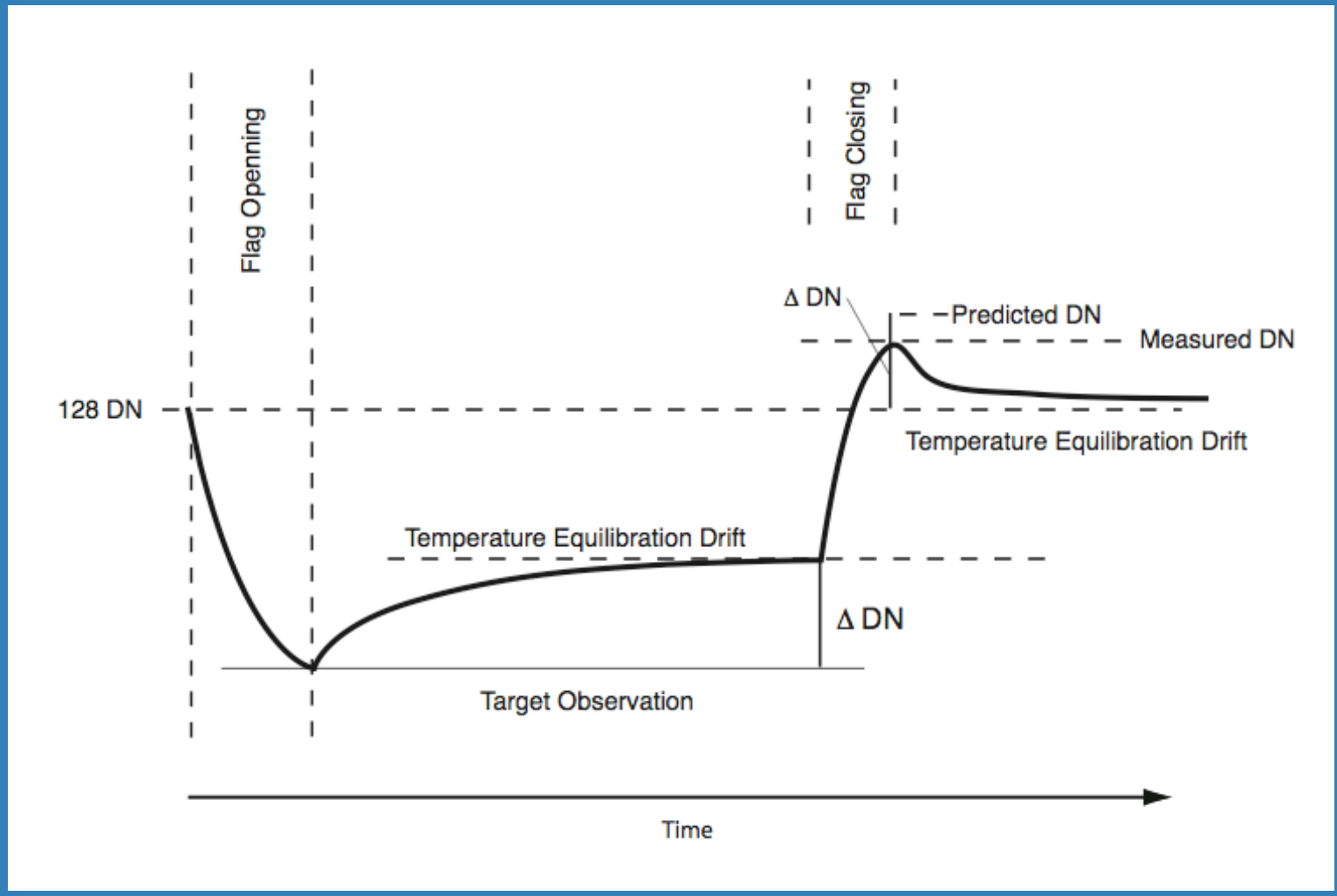
    $\Delta$ DN vs $\Delta$ radiance
  - Assume constant pre-launch gain
  - Can then compute $\Delta$ radiance for each pixel in scene
  - Use temperature (radiance) of the flag to convert $\Delta$ radiance to the actual temperature of each pixel in the scene
- However - closing the shutter subtly changes the thermal environment on the detector array

# Instrument Operation

**Issues**

- Don't directly measure the temperature of the flag.
  - Flag moves - don't want wires attached
  - Measure housing it sits next to when open
  - Assumed to be uniform temperature - it may not be
- Closing the shutter subtly changes the thermal environment on the detector array
  - Focal plane temperature controlled to ±0.001° C
  - 0.001° C temperature change produces 2-3 DN signal change
  - Changes due to scene itself
  - Produces drift in calibration along image

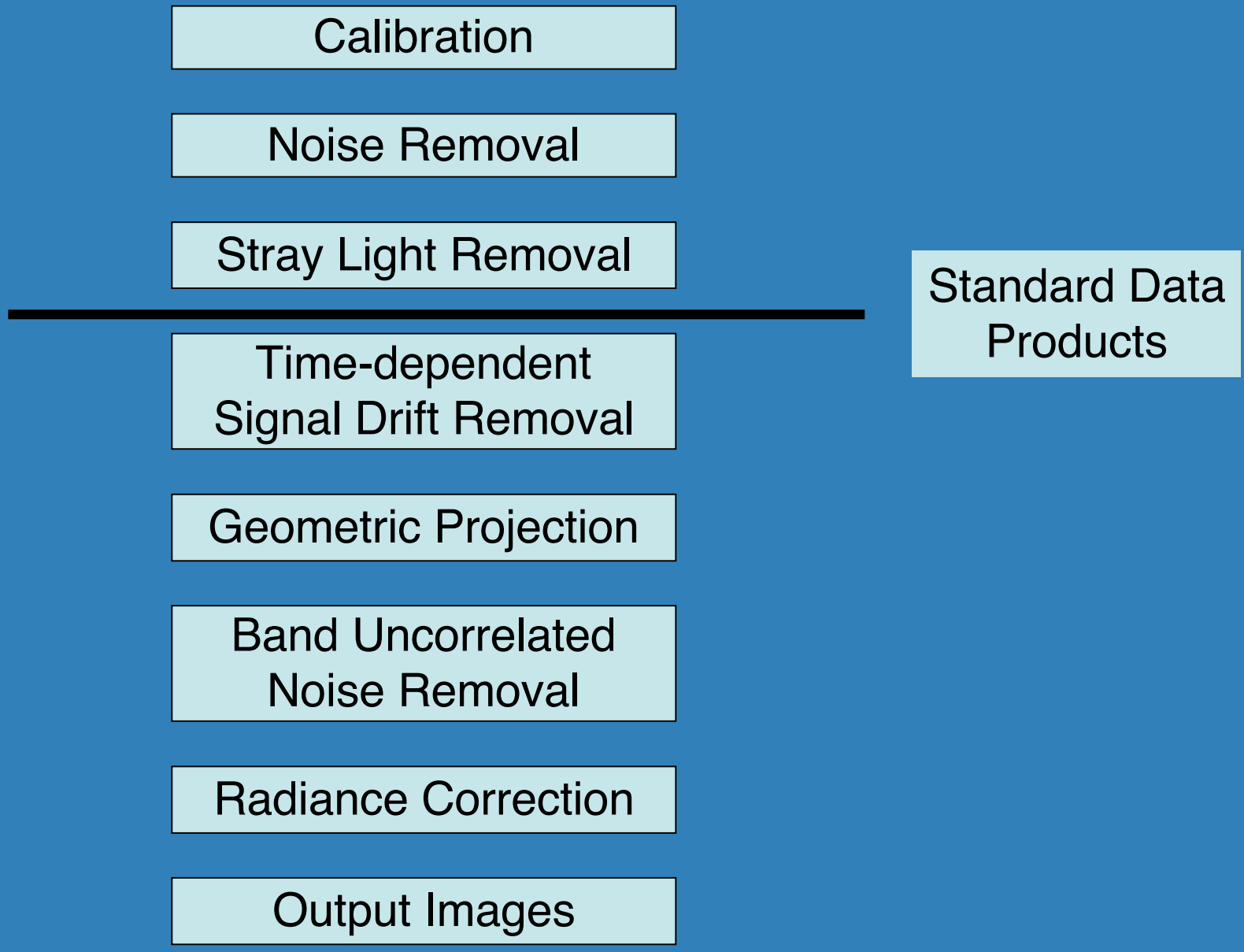
# Detector Temperature Drift



# Instrument Characteristics

- Problems and Issues
  - Normal noise
    - Greatly accentuated whenever one does a ratio or color stretch
  - Focal plane temperature drift
    - 0.001° C temperature change produces 2-3 DN signal change
    - Changes due to scene itself
  - Stray light due to bracket that holds the IR/VIS beamsplitter ("ghost")
  - Downwelling and upwelling radiance

# Data Processing Overview



# Processing Overview (con't)

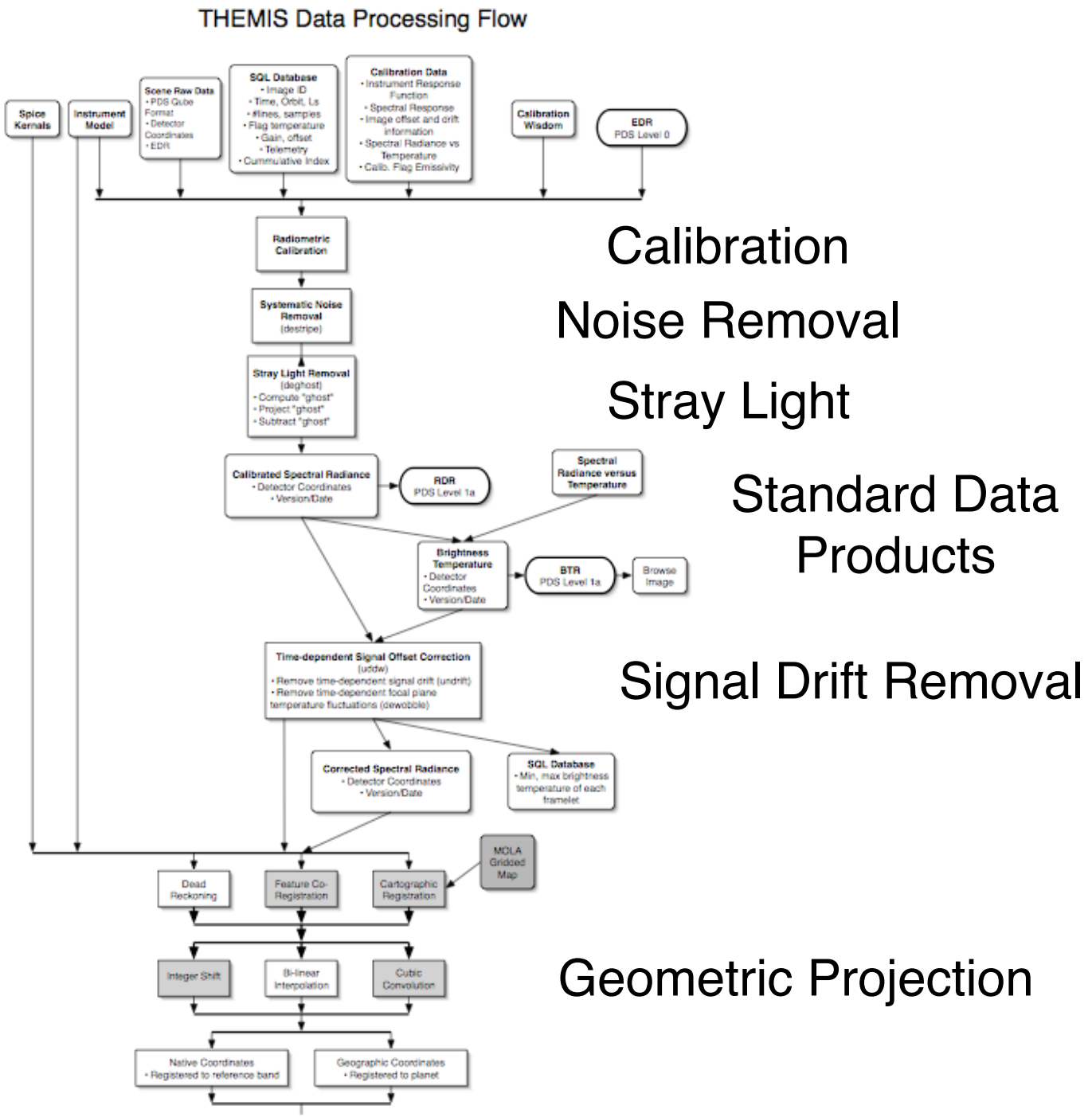
Output Images

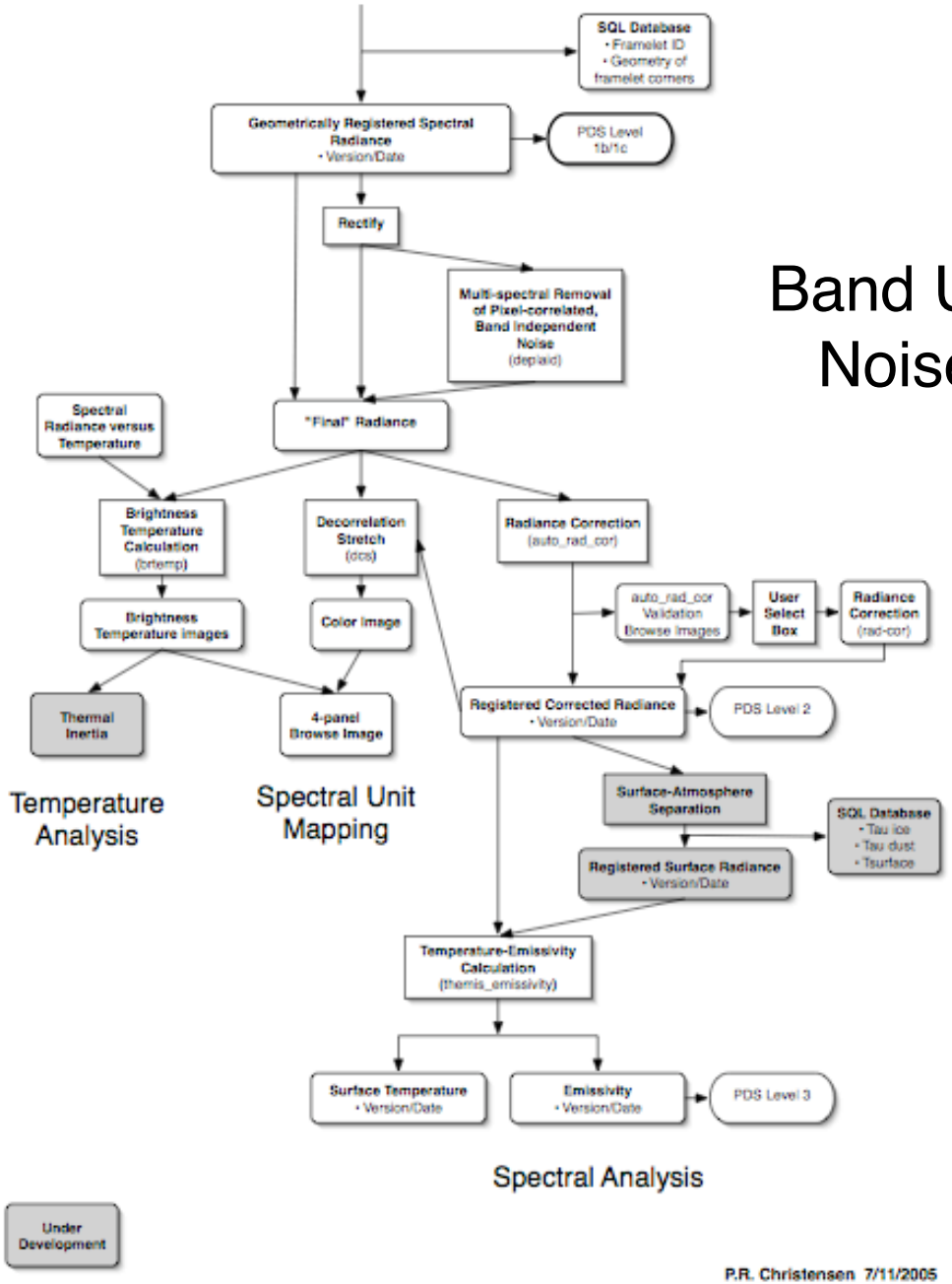
Brightness Temperature

Multi-spectral Color IR

Surface Temperature

Emissivity


THEMIS Data Processing Flow
Spice Kernals
Instrument Model
Scene Raw Data
• PDS Qube Format
• Detector Coordinates
• EDR
SQL Database
• Image ID
• Time, Orbit, Ls
• #lines, samples
• Flag temperature
• Gain, offset
• Telemetry
• Cummulative Index
Calibration Data
• Instrument Response Function
• Spectral Response
• Image offset and drift information
• Spectral Radiance vs Temperature
• Calib. Flag Emissivity
Calibration Wisdom
EDR
PDS Level 0
Radiometric Calibration
Systematic Noise Removal
(destripe)
Stray Light Removal
(deghost)
• Compute "ghost"
• Project "ghost"
• Subtract "ghost"
Calibrated Spectral Radiance
• Detector Coordinates
• Version/Date
RDR
PDS Level 1a
Spectral Radiance versus Temperature
Brightness Temperature
• Detector Coordinates
• Version/Date
BTR
PDS Level 1a
Browse Image
Time-dependent Signal Offset Correction
(uddw)
• Remove time-dependent signal drift (undrift)
• Remove time-dependent focal plane temperature fluctuations (dewobble)
Corrected Spectral Radiance
• Detector Coordinates
• Version/Date
SQL Database
• Min, max brightness temperature of each framelet
MOLA Gridded Map
Dead Reckoning
Feature Co-Registration
Cartographic Registration
Integer Shift
Bi-linear Interpolation
Cubic Convolution
Native Coordinates
• Registered to reference band
Geographic Coordinates
• Registered to planet
Calibration
Noise Removal
Stray Light
Standard Data Products
Signal Drift Removal
Geometric Projection

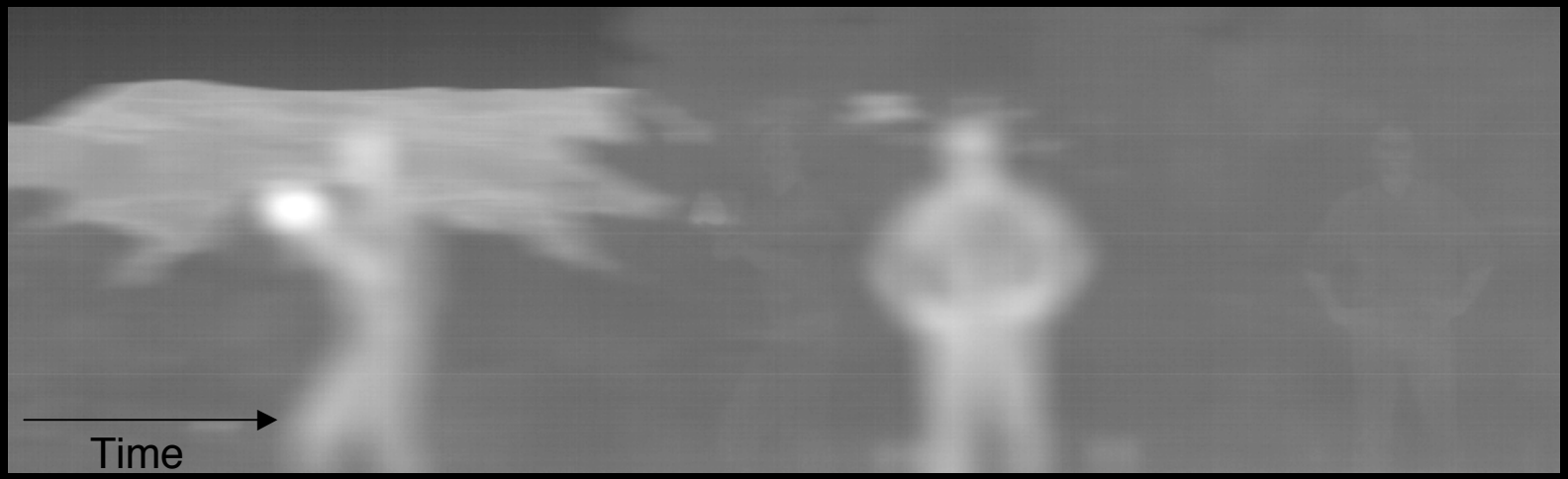


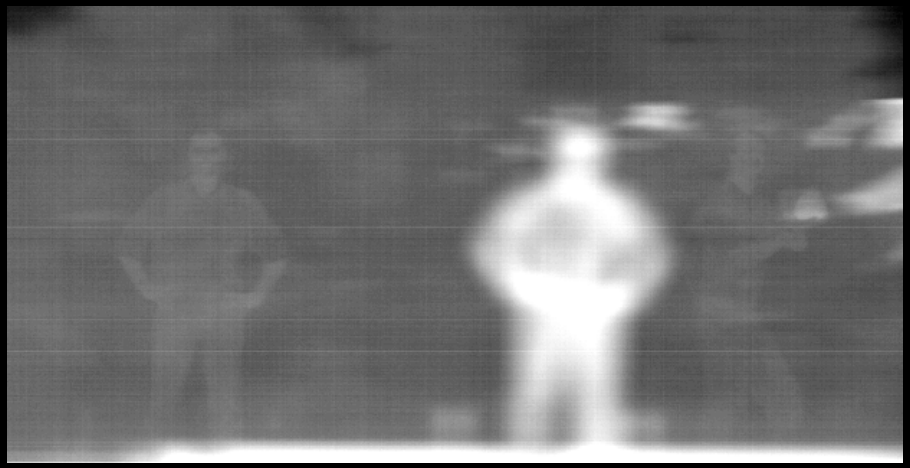

Band Uncorrelated Noise Removal

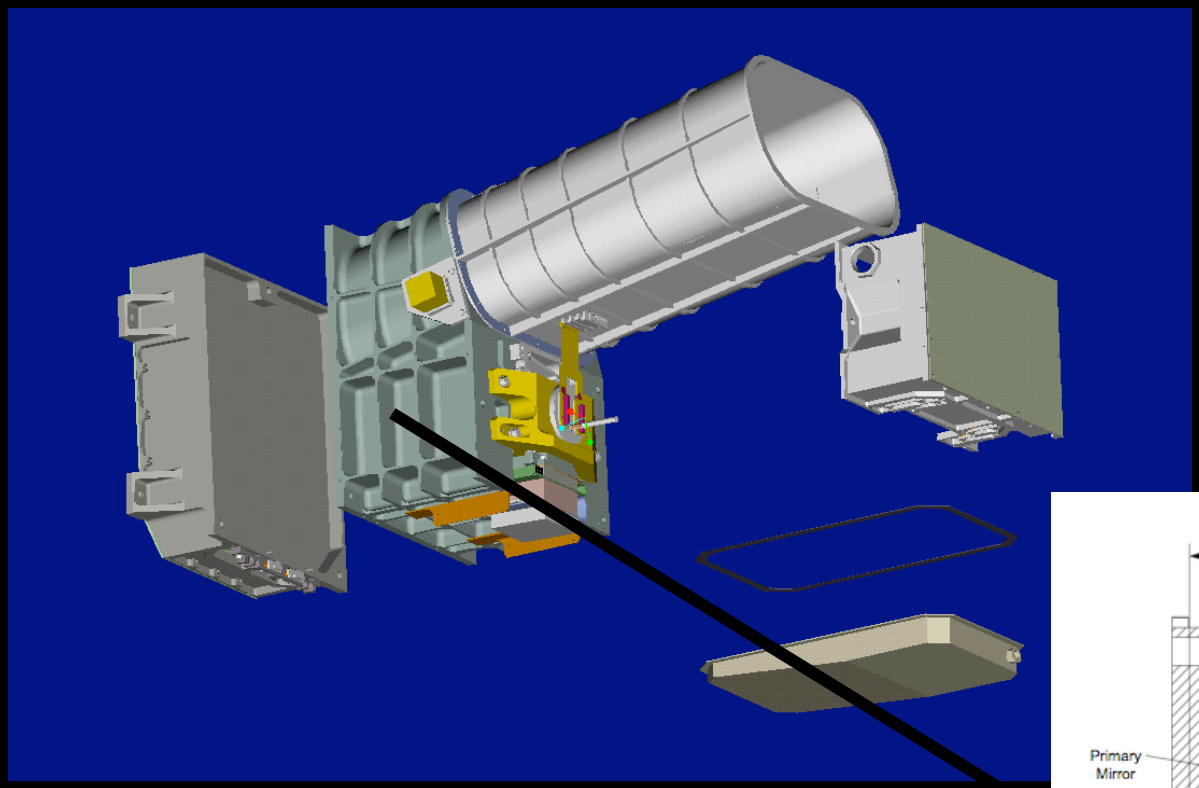
Radiation Correction

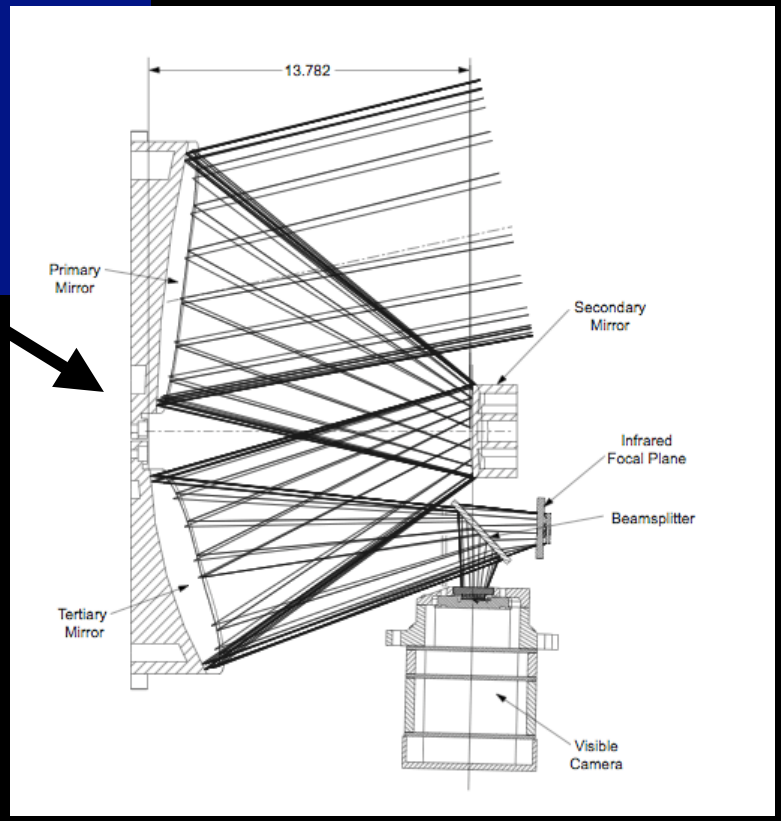
Output Images

# Reverse Scan with Focused "Ghost"

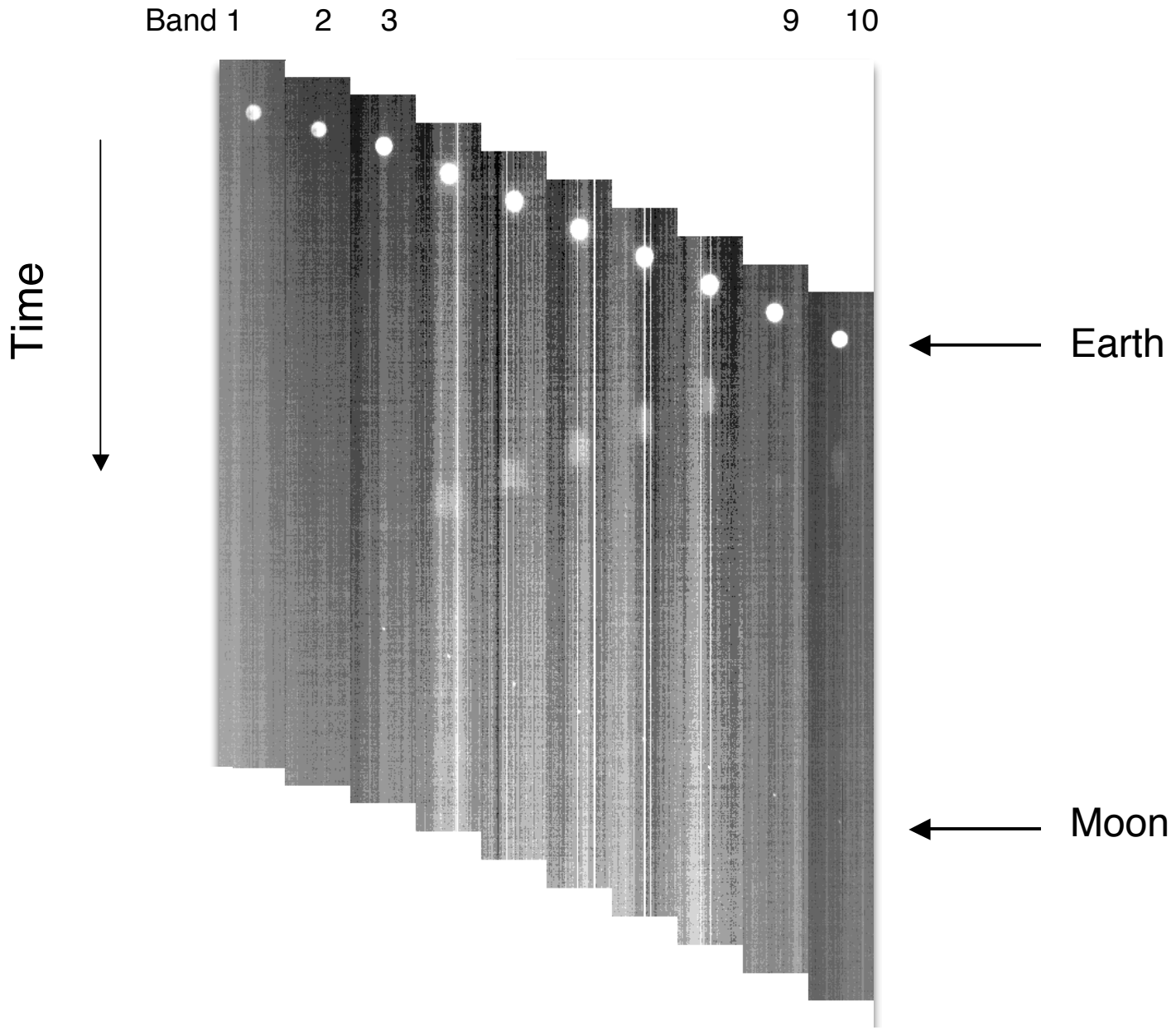


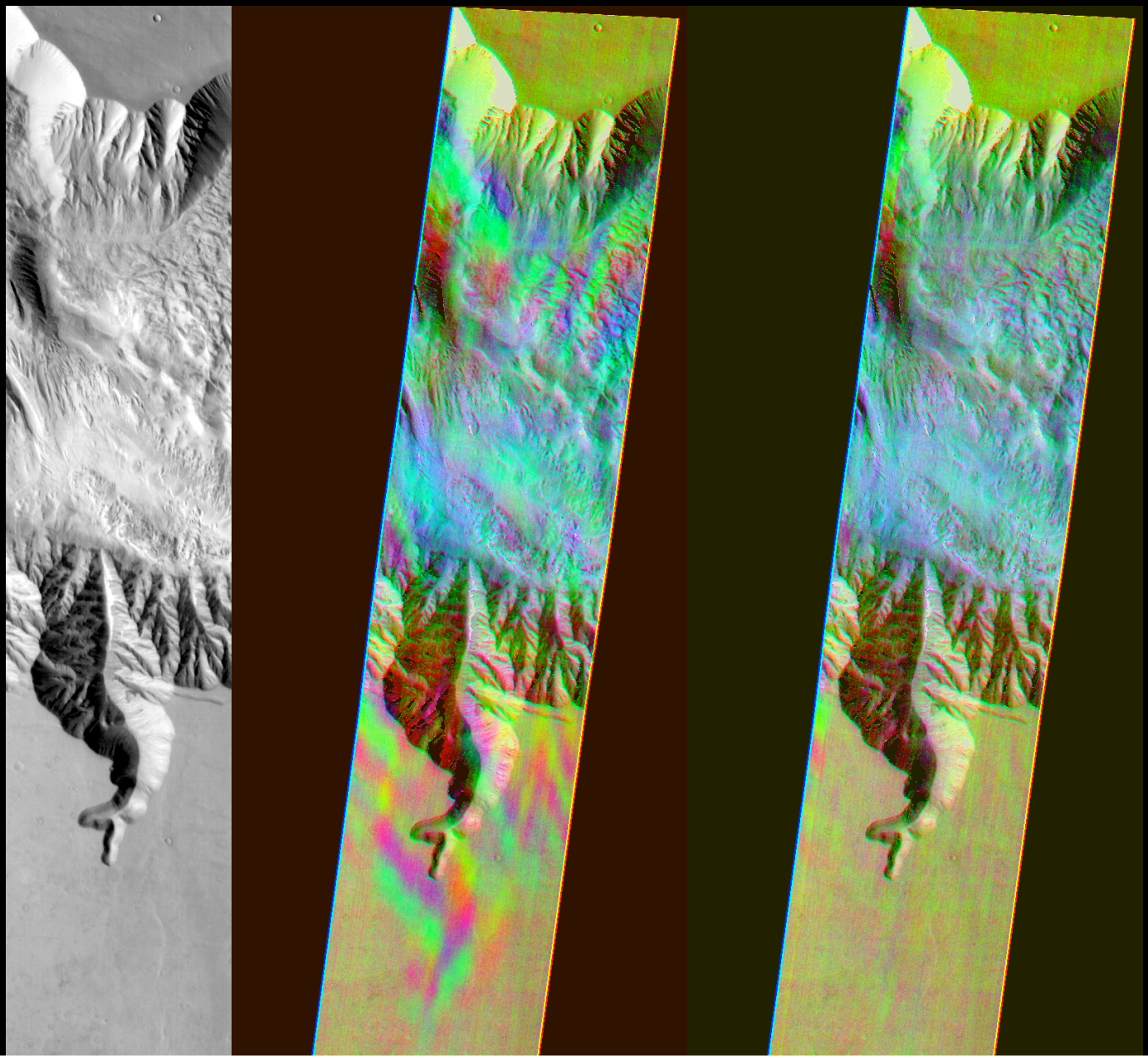



13.782
Primary Mirror
Secondary Mirror
Infrared Focal Plane
Beamsplitter
Tertiary Mirror
Visible Camera

# THEMIS IR Earth-Moon Image - Stretched

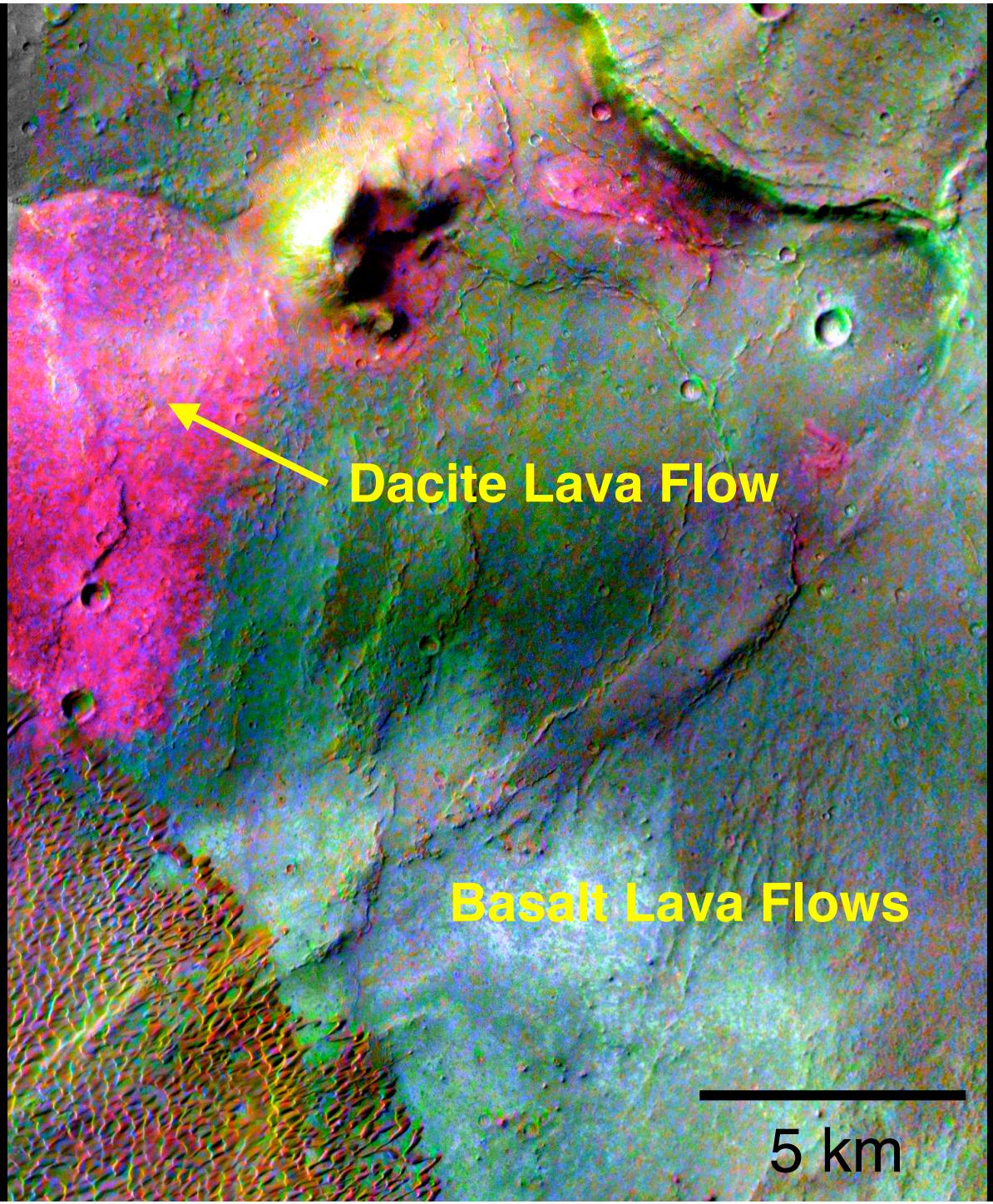


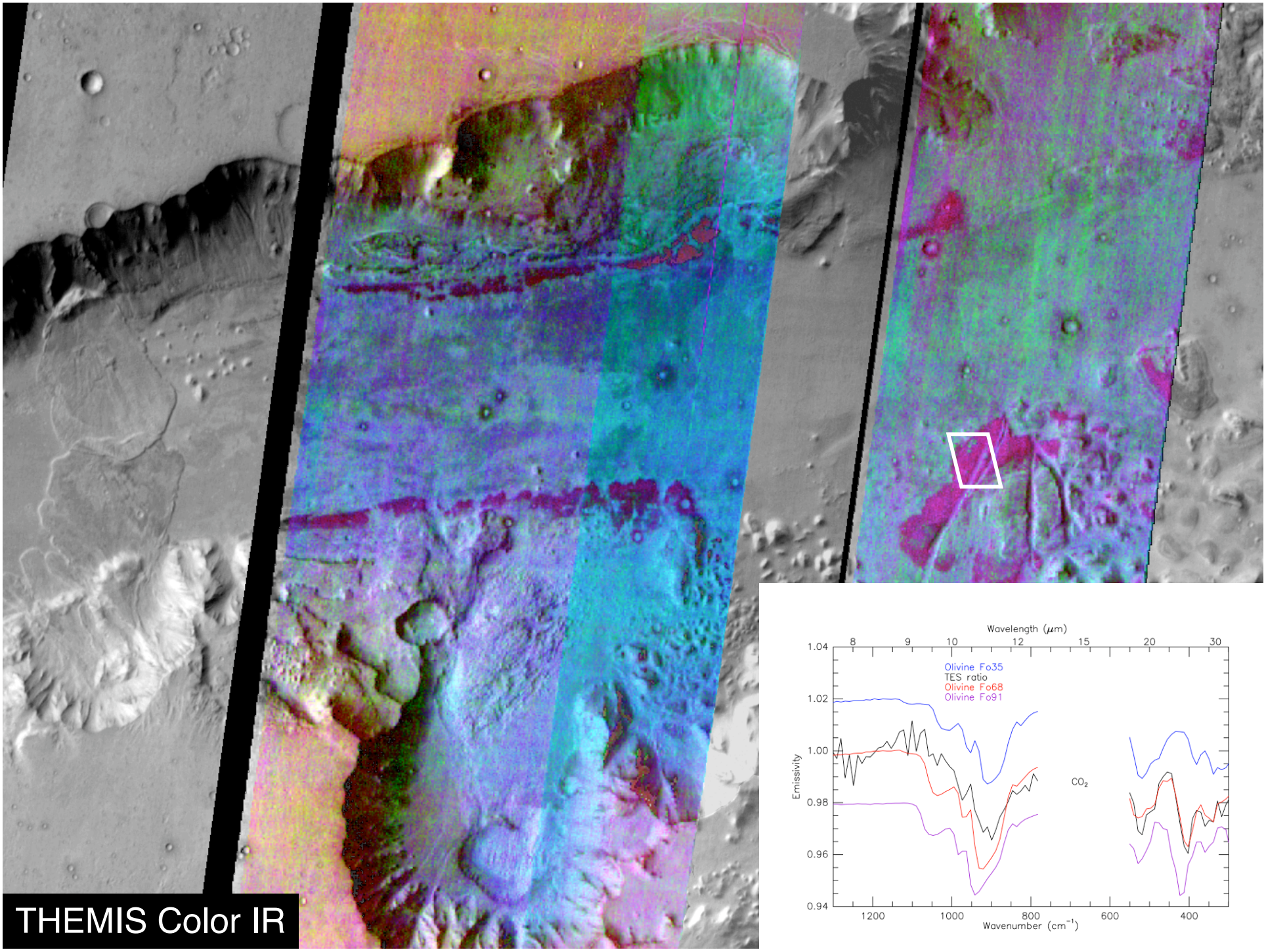
# THEMIS "Ghost"

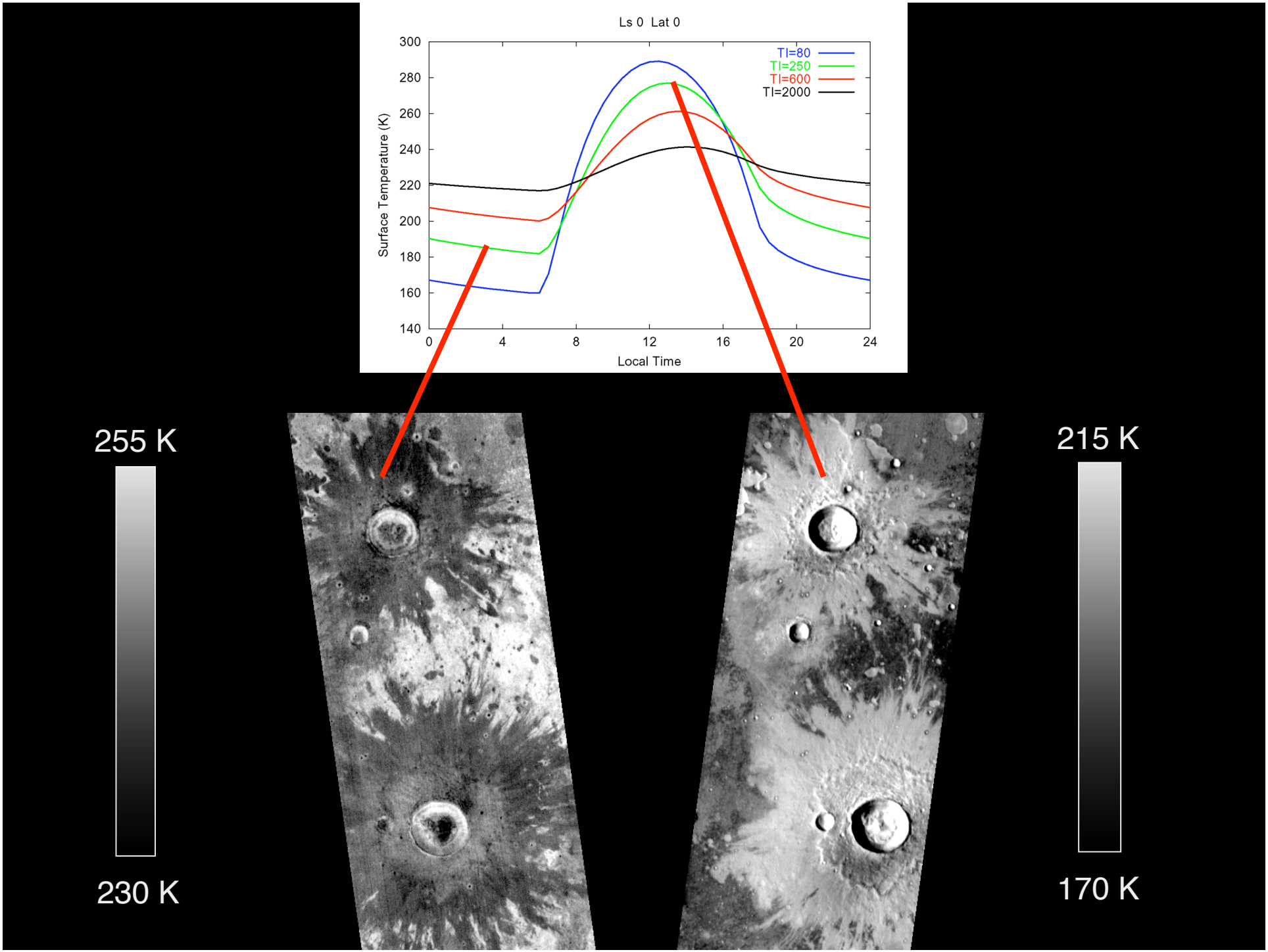


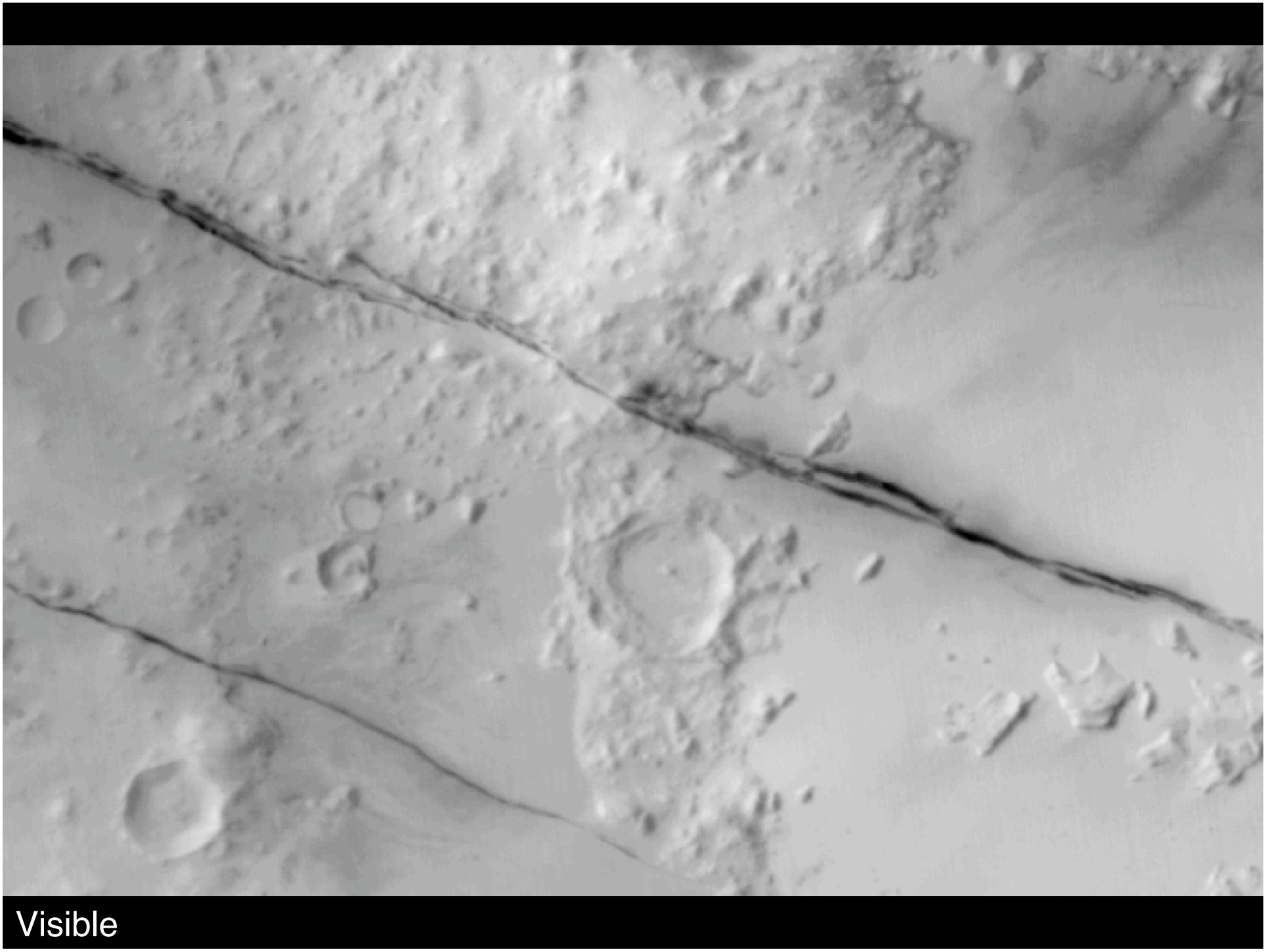
# Examples of THEMIS Data Products

THEMIS Multi-spectral IR




THEMIS Color IR
Wavelength (μm)
8
9
10
12
15
20
30
1.04
1.02
1.00
0.98
0.96
0.94
Emissivity
Olivine Fo35
TES ratio
Olivine Fo68
Olivine Fo91
CO2
1200
1000
800
600
400
Wavenumber (cm-1)


Ls 0 Lat 0
Surface Temperature (K)
Local Time
TI=80
TI=250
TI=600
TI=2000
300
280
260
240
220
200
180
160
140
0
4
8
12
16
20
24
255 K
230 K
215 K
170 K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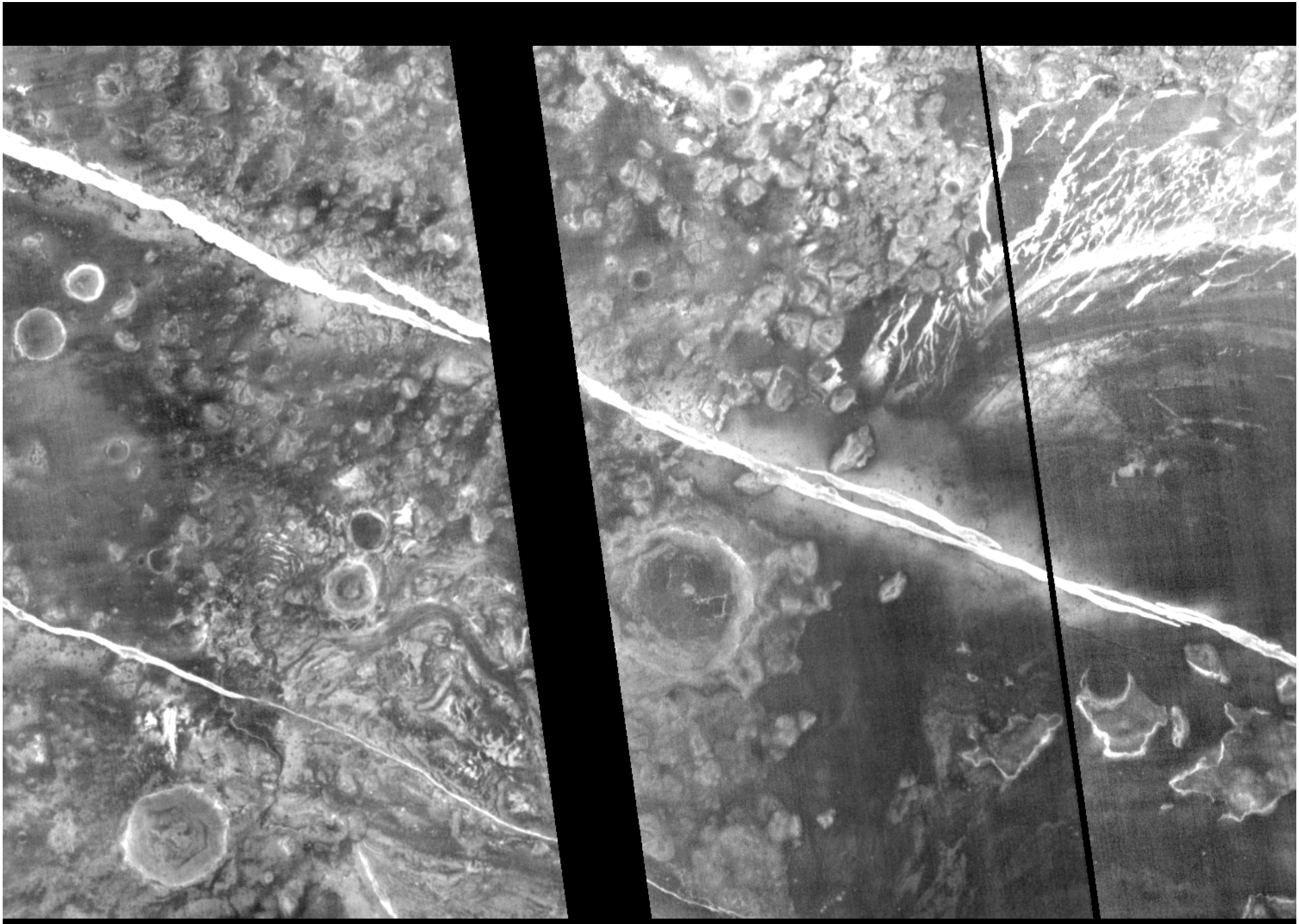
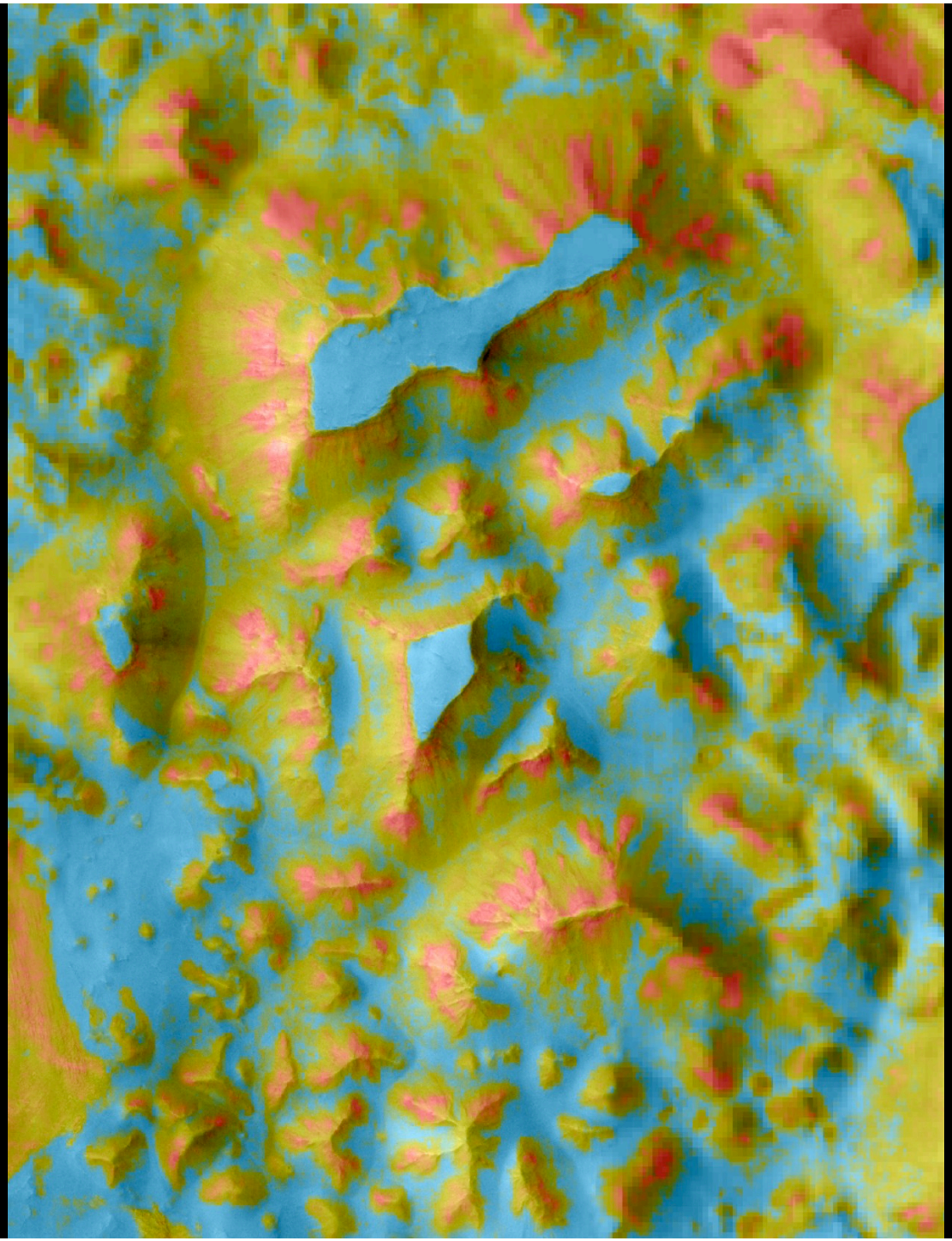
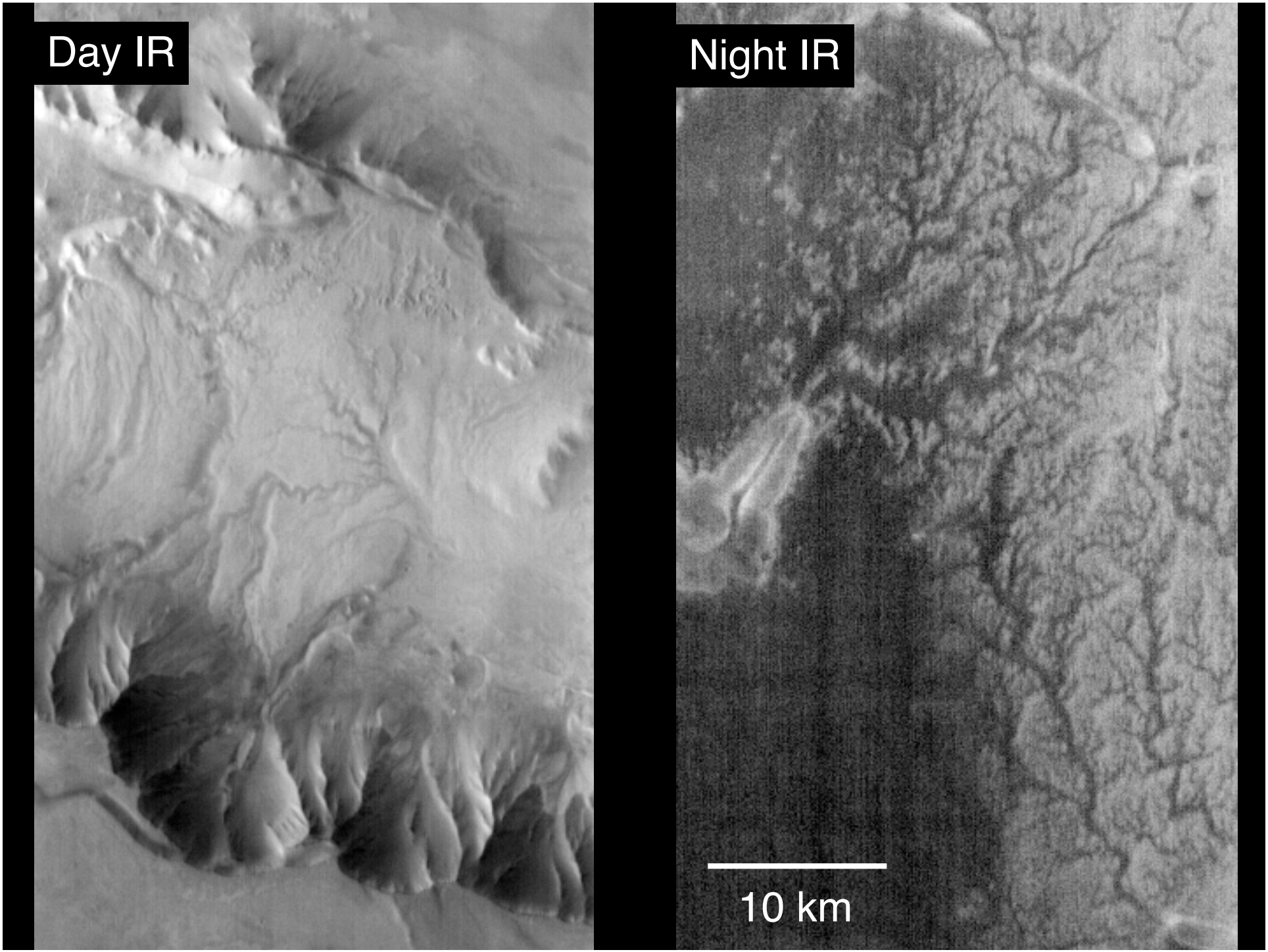

THEMIS Night IR

THEMIS
Night IR over
Day IR




Day IR
Night IR
10 km

MARS ODYSSEY MISSION

# THEMIS

THERMAL EMISSION IMAGING SYSTEM

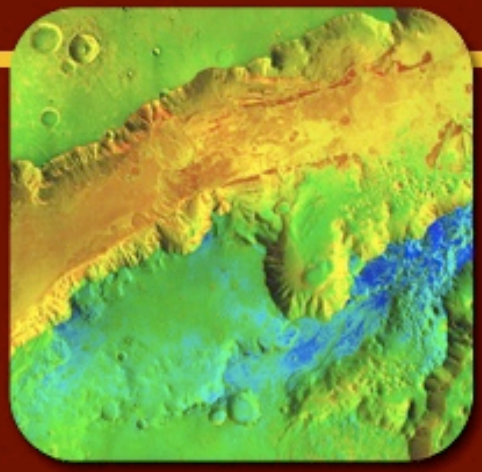
ADDITIONAL RESOURCES FOR:
STUDENTS RESEARCHERS PRESS



"LIVE" from Mars

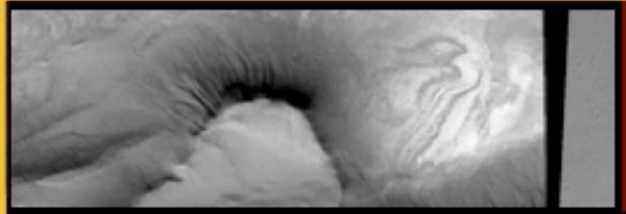
# Explore Mars

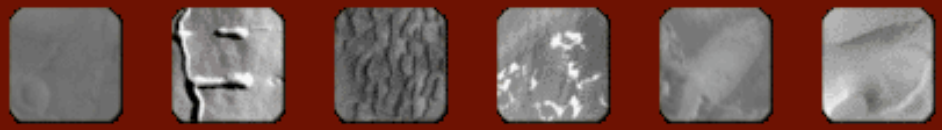
Feature of the Week



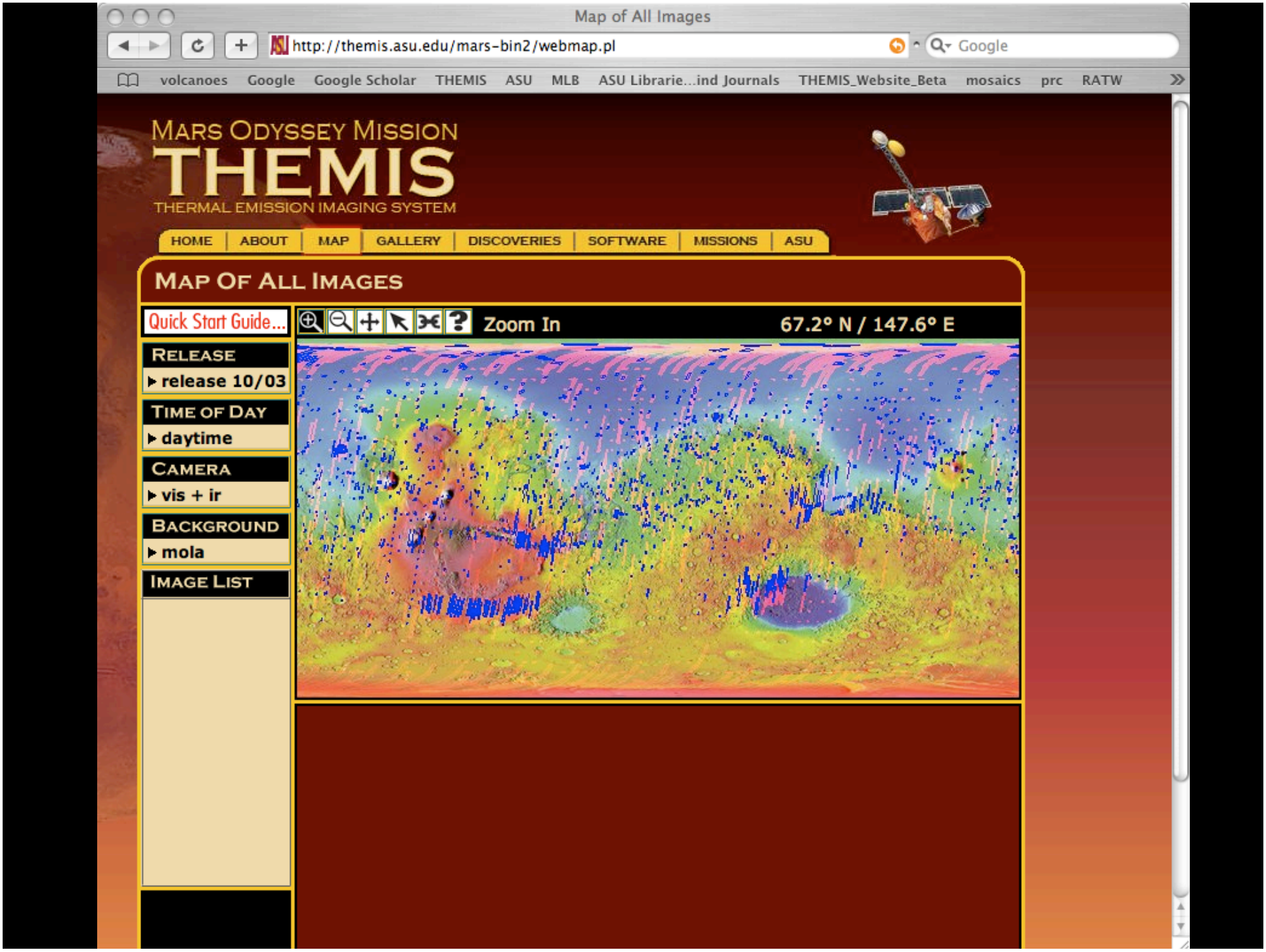
## GANGES CHASMA

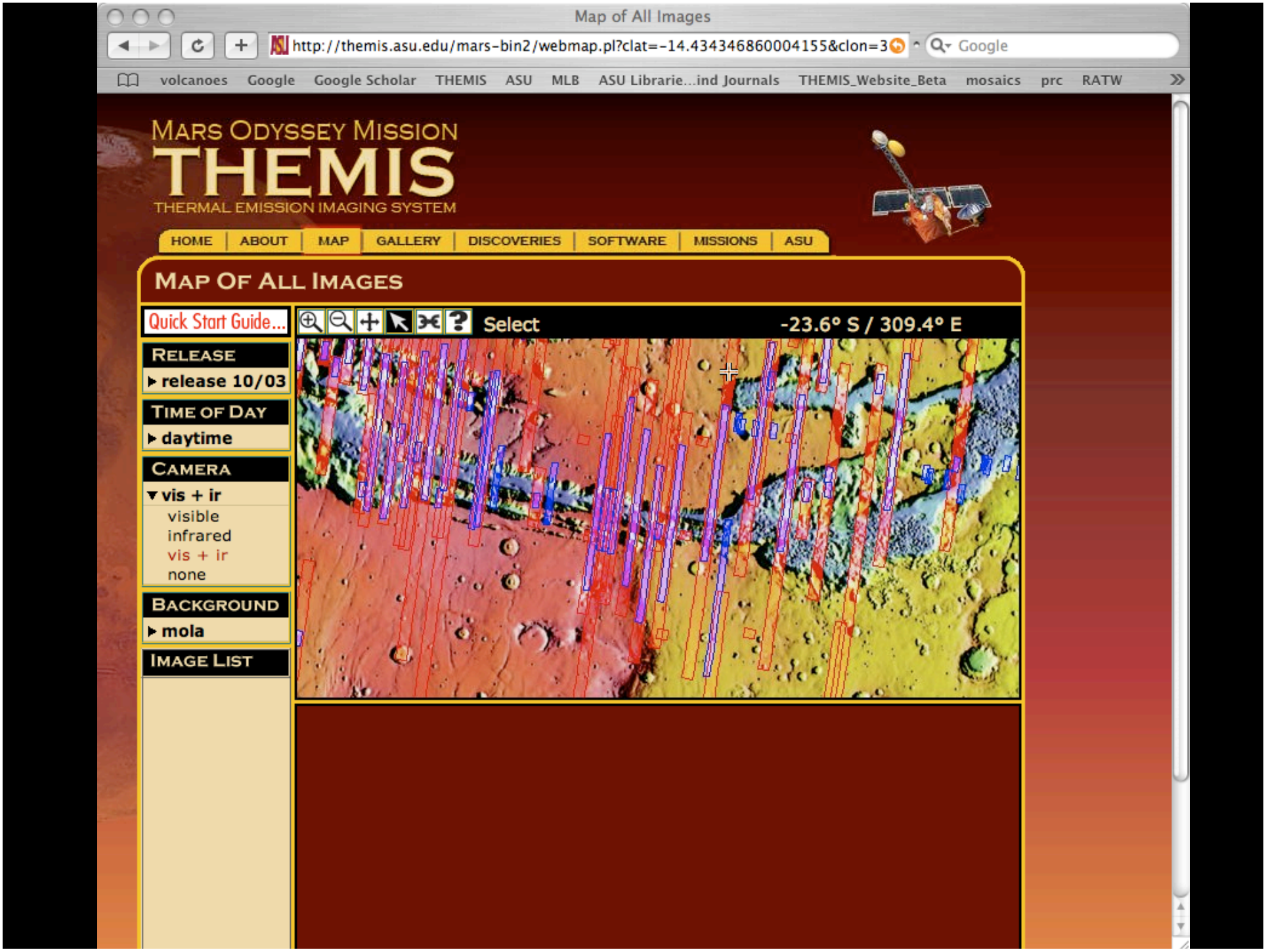
A portion of the Valles Marineris canyon system contains several enormous overlapping landslides and provides a view into the misty depths of martian geologic time.





MOST RECENT IMAGES OF THE DAY


Map of All Images
http://themis.asu.edu/mars-bin2/webmap.pl
Google
volcanoes
Google
Google Scholar
THEMIS
ASU
MLB
ASU Librarie...ind Journals
THEMIS_Website_Beta
mosaics
prc
RATW
MARS ODYSSEY MISSION
THEMIS
THERMAL EMISSION IMAGING SYSTEM
HOME
ABOUT
MAP
GALLERY
DISCOVERIES
SOFTWARE
MISSIONS
ASU
MAP OF ALL IMAGES
Quick Start Guide...
RELEASE
release 10/03
TIME OF DAY
daytime
CAMERA
vis + ir
BACKGROUND
mola
IMAGE LIST
Zoom In
67.2° N / 147.6° E


Map of All Images
http://themis.asu.edu/mars-bin2/webmap.pl?clat=-14.434346860004155&clon=3
Google
volcanoes
Google
Google Scholar
THEMIS
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MLB
ASU Librarie...ind Journals
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mosaics
prc
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HOME
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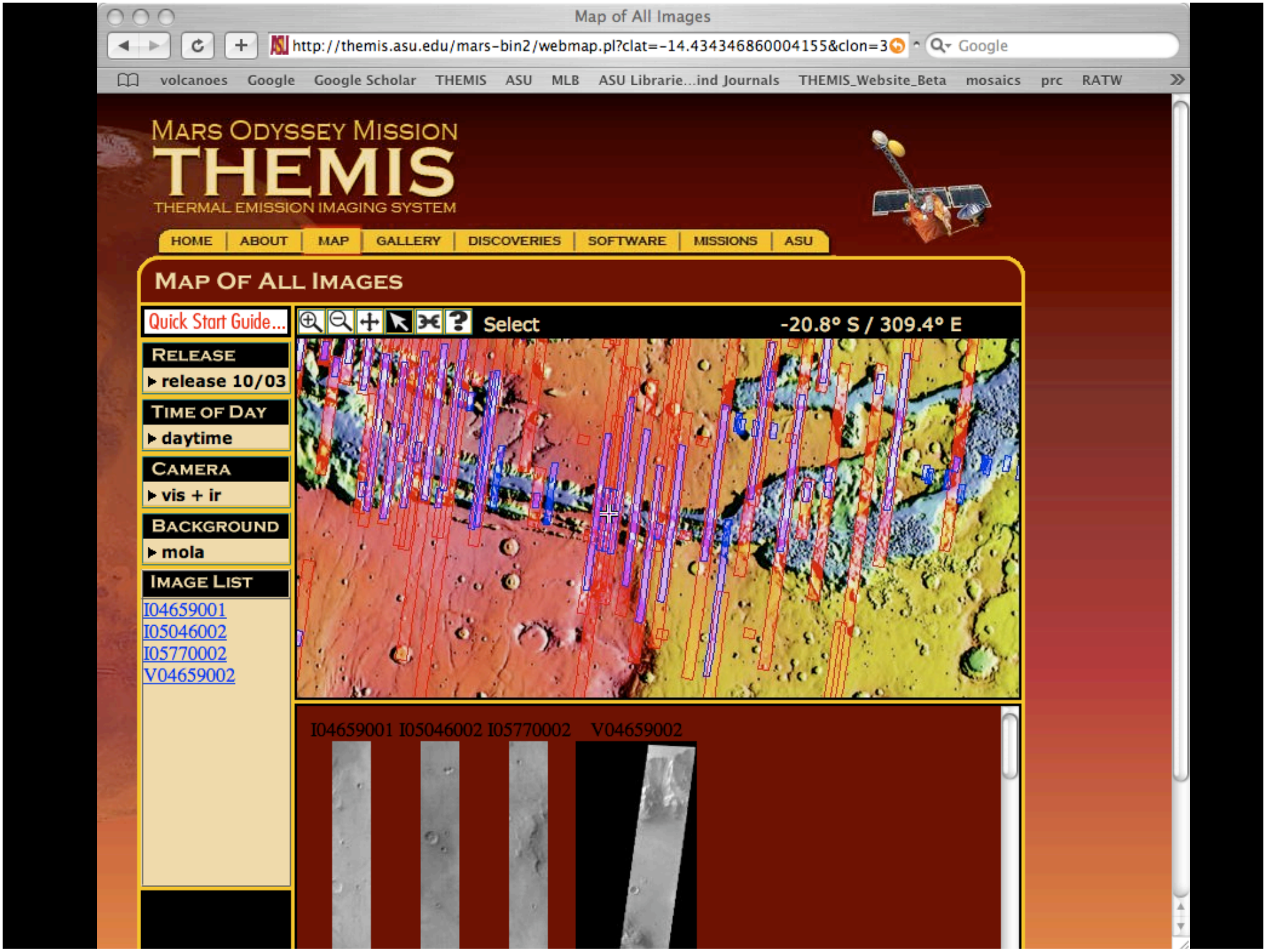
Quick Start Guide...
RELEASE
release 10/03
TIME OF DAY
daytime
CAMERA
vis + ir
visible
infrared
vis + ir
none
BACKGROUND
mola
IMAGE LIST
Select
-23.6° S / 309.4° E


Map of All Images
http://themis.asu.edu/mars-bin2/webmap.pl?clat=-14.434346860004155&clon=3
Google
volcanoes Google Google Scholar THEMIS ASU MLB ASU Librarie...ind Journals THEMIS_Website_Beta mosaics prc RATW
MARS ODYSSEY MISSION
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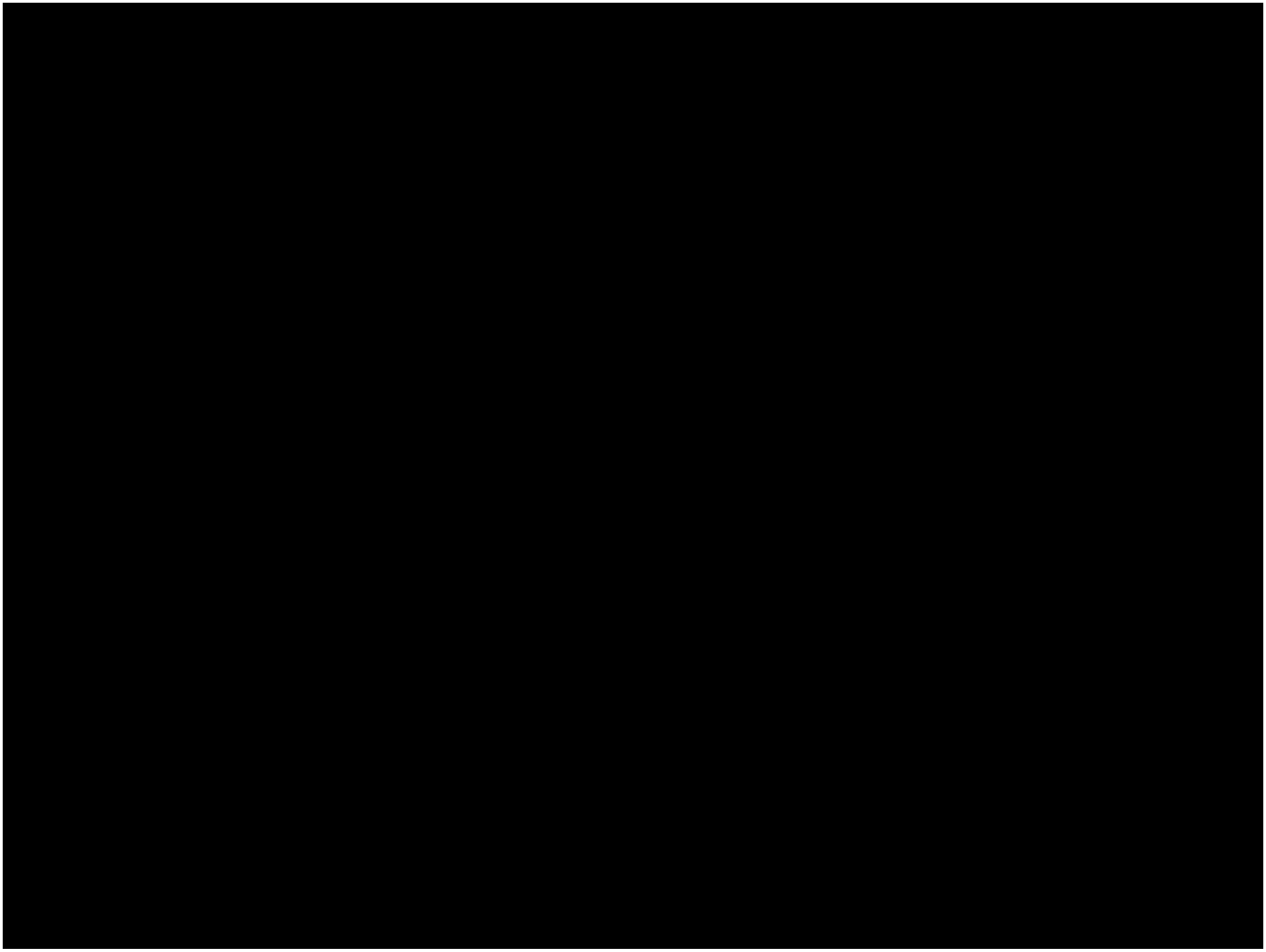
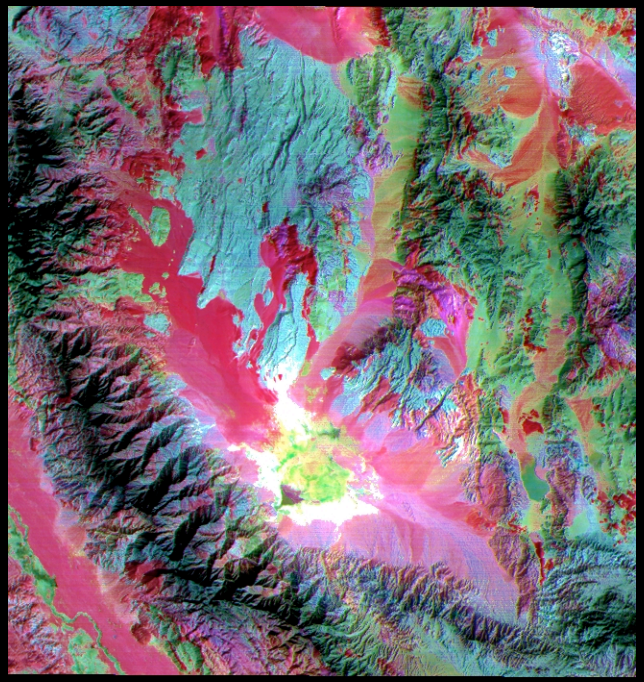
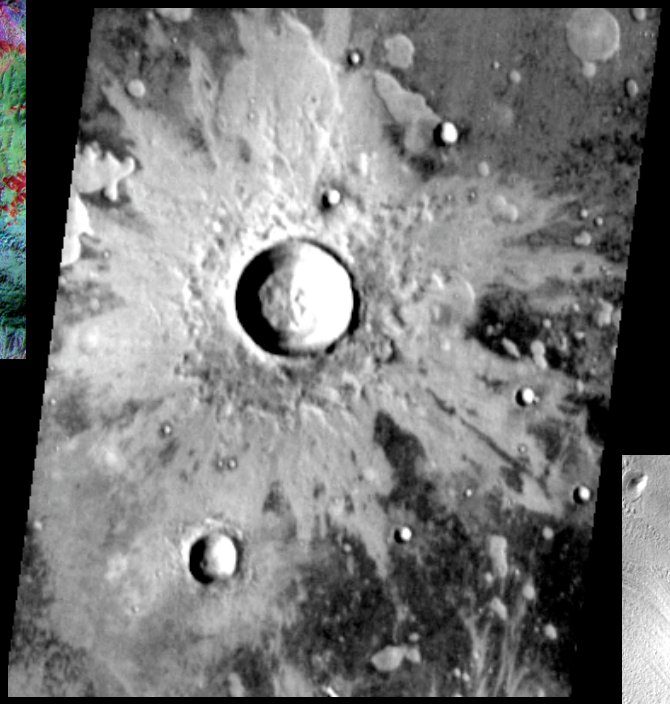
I05770002
V04659002
Select
-20.8° S / 309.4° E
I04659001 I05046002 I05770002 V04659002



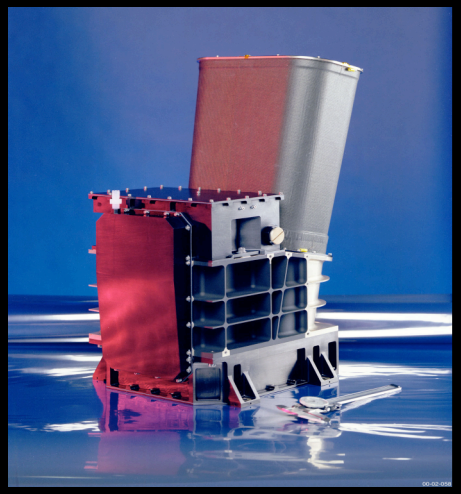
Infrared Color Imaging:
Composition



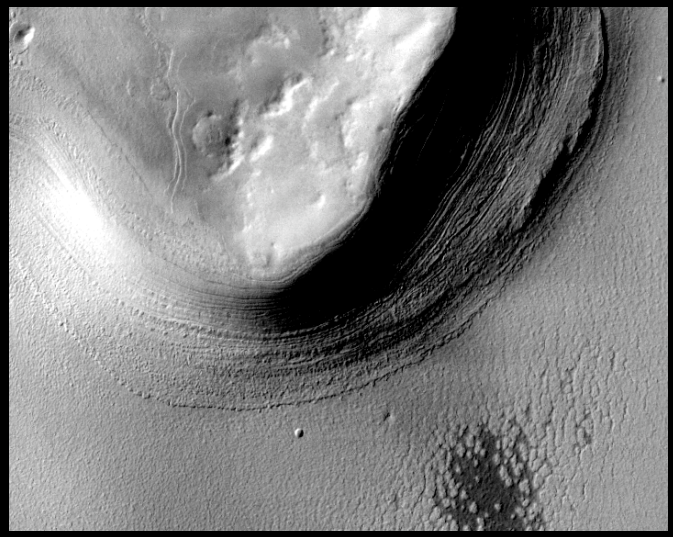
Temperature:
Physical Properties



THEMIS Camera



Visible Imaging:
Processes



# THEMIS Science Objectives

- Determine mineralogy and petrology of localized deposits, including hydrothermal or sub-aqueous environments
- Provide direct link to hyperspectral mineral mapping from MGS TES
- Study small-scale geologic processes using morphologic and thermophysical properties
- Search for thermal anomalies associated with active hydrothermal systems