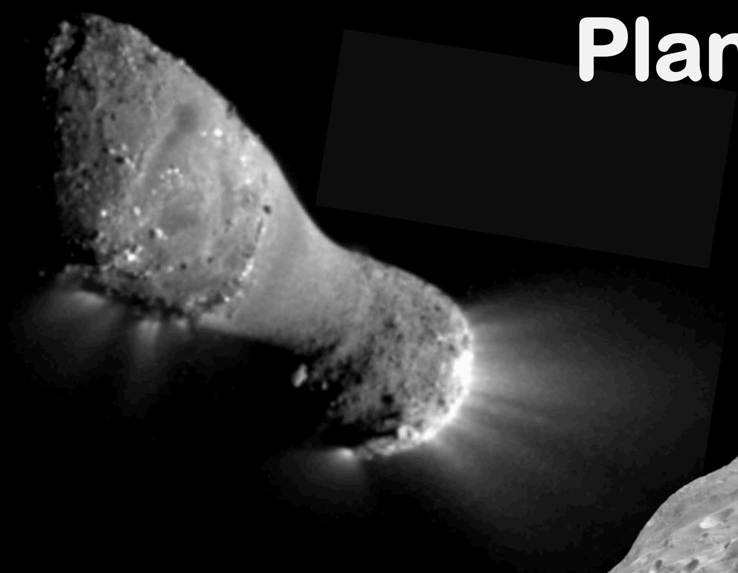
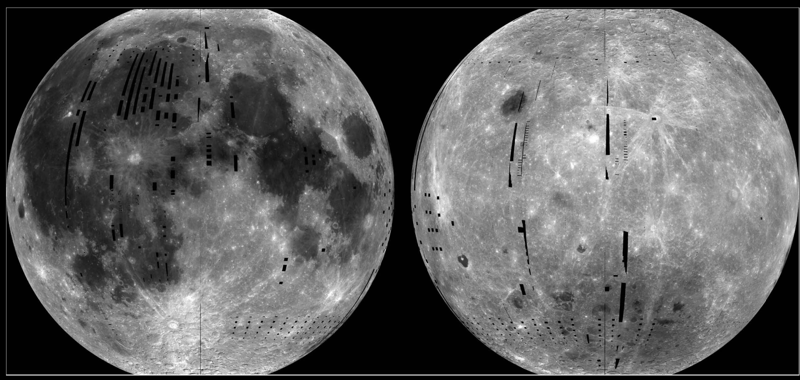
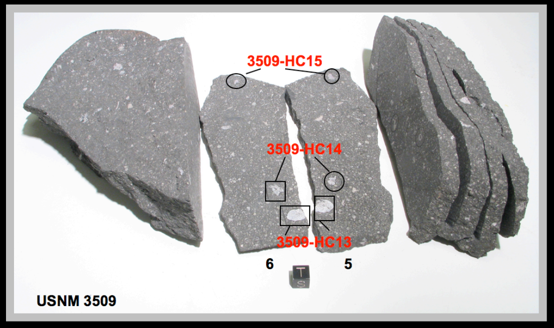
Composition from IR Spectra: Comets, Asteroids, Meteorites, and the Moon

Prof. Jessica M. Sunshine

Planetary Group







"Upstairs" Planetary People

- **Professorial faculty**
  - » Sunshine
- **Research "faculty"**
  - » A'Hearn (emeritus), Farnham, Feaga, Kolokolova, Bodewits, Kelley, Li
- **Other PhD researchers**
  - » Besse, Protopapa, Wellnitz
  - » At least 1 post-doc positions to be filled
- **Technical support**
  - » Williams, Barnes, McLaughlin, Ritchie, Raugh, Warner
- **Students**
  - » Typically 2-4 grad students and 2-4 undergrad students
  - » Some students joint with GSFC *via* NAI

Scientific Focus

- "Where did we come from?" (decadal survey)
- Origin & evolution of the solar system
  - » Larger bodies are dominated by evolution
  - » Small bodies preserve an early record
    - How do we separate primordial from evolutionary?
- Study asteroids, comets, Moon, Mercury with wide variety of techniques to understand origin AND evolution

Functional Activities

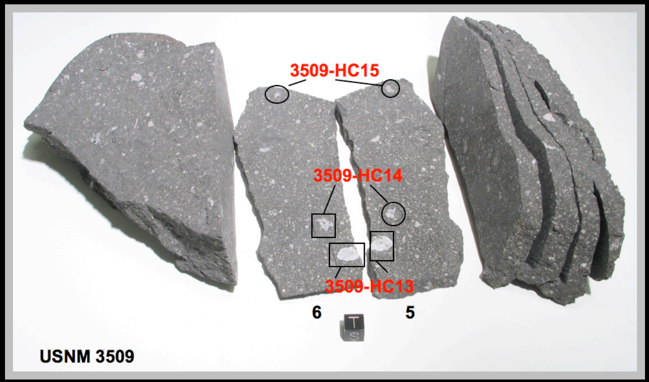
- **Planetary Data System**
  - Small bodies node located at UM
    - A' Hearn, Kolokolova, Farnham, Feaga
  - Direct connection to research on the data
    - Modest science supported, major science enabled
  - Direct connection to many missions
    - DI, EPOXI, NExT, NEAR, Dawn, Chandrayaan, Rosetta
- **EPO Programs**
  - Feaga, Warner
  - College Park Scholars, amateur astronomers
  - EPO lead for DI, EPOXI, CHopper
- **Regular users of telescopes**
  - Ground based telescopes
    - Kitt Peak, Mauna Kea, Lowell, CTIO, BIMA (CARMA and DCT in future)
  - Space-Based telescopes
    - IUE, HST, Spitzer, SWIFT

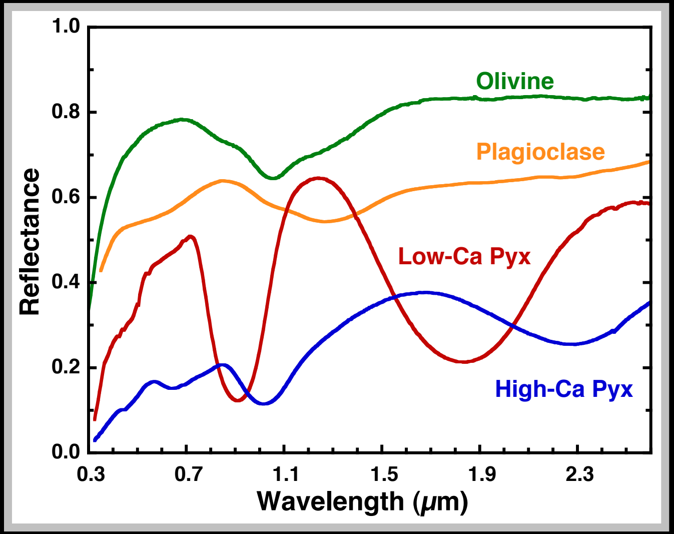
History & Evolution of the Early Solar System

Study of the least processed surfaces w/ Spectroscopy

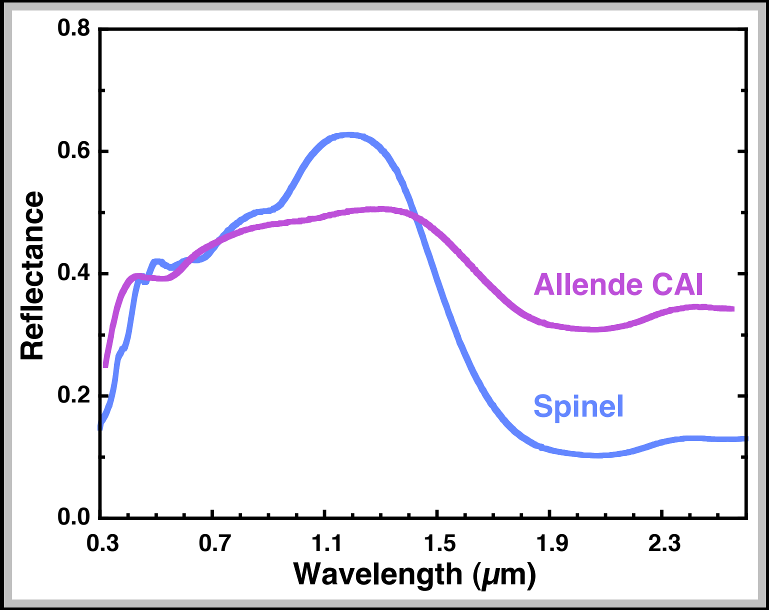
- **Comets**
  - Composition: primordial vs. evolutionary mixing within early Solar System
    - continued analysis of Deep Impact (ice, solids, surface)
    - extended mission (DIXI) to Hartley 2 and return to Tempel 1
- **Asteroids and Meteorites**
  - Composition: timing and nature of accretion and alteration (igneous, aqueous, metamorphic, impact)
    - laboratory analysis (Smithsonian)
    - asteroid surveys (telescopic, SPEX)
    - DAWN mission to mainbelt Asteroid 4 Vesta
- **The Moon**
  - Composition in a geologic context. Formation and relation to Earth and subsequent igneous and impact evolution; H_20/OH
    - Moon Mineralogy Mapper (M^3) on-board Chandrayaan-1

Calcium Aluminum-Rich Inclusions: CAIs



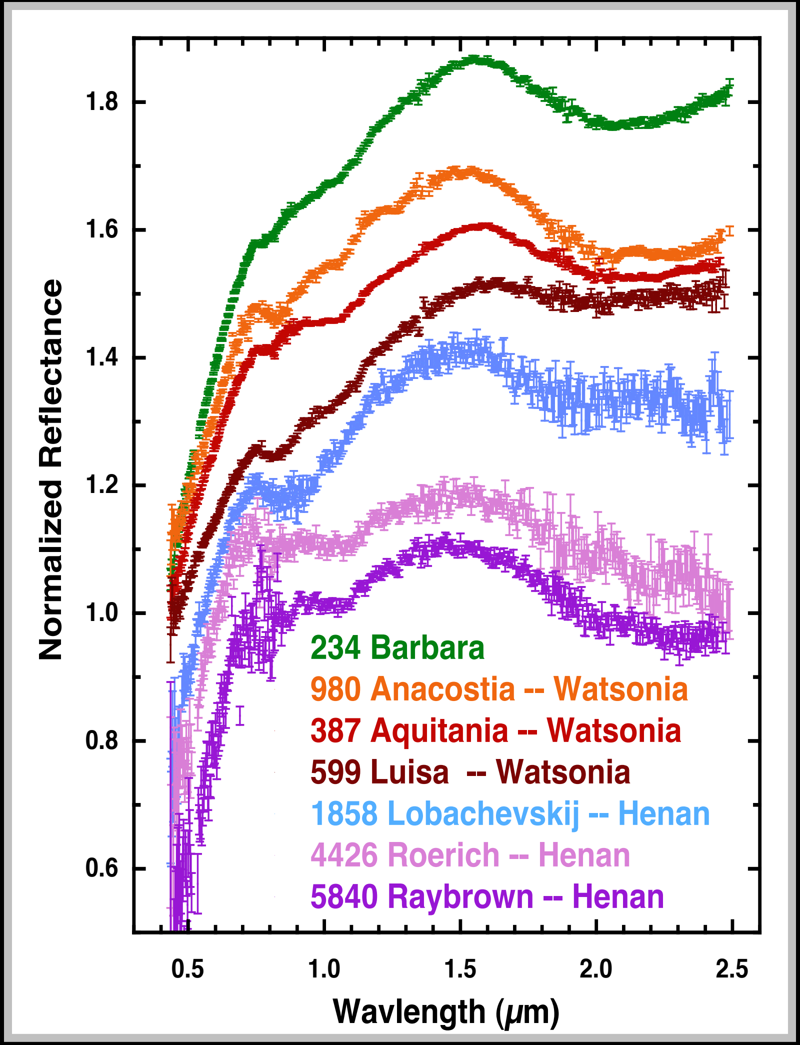


- **Oldest known rocks**
  - » mineralogy predicted for first nebular condensates
  - » date the start of the Solar System
  - » occur in all classes of chondrites
- **Spectrally dominated by spinel hercynite: $[Fe,Mg]Al_2O_4$**
  - » strong 2 μm absorption
  - » absent or weak 1 μm bands



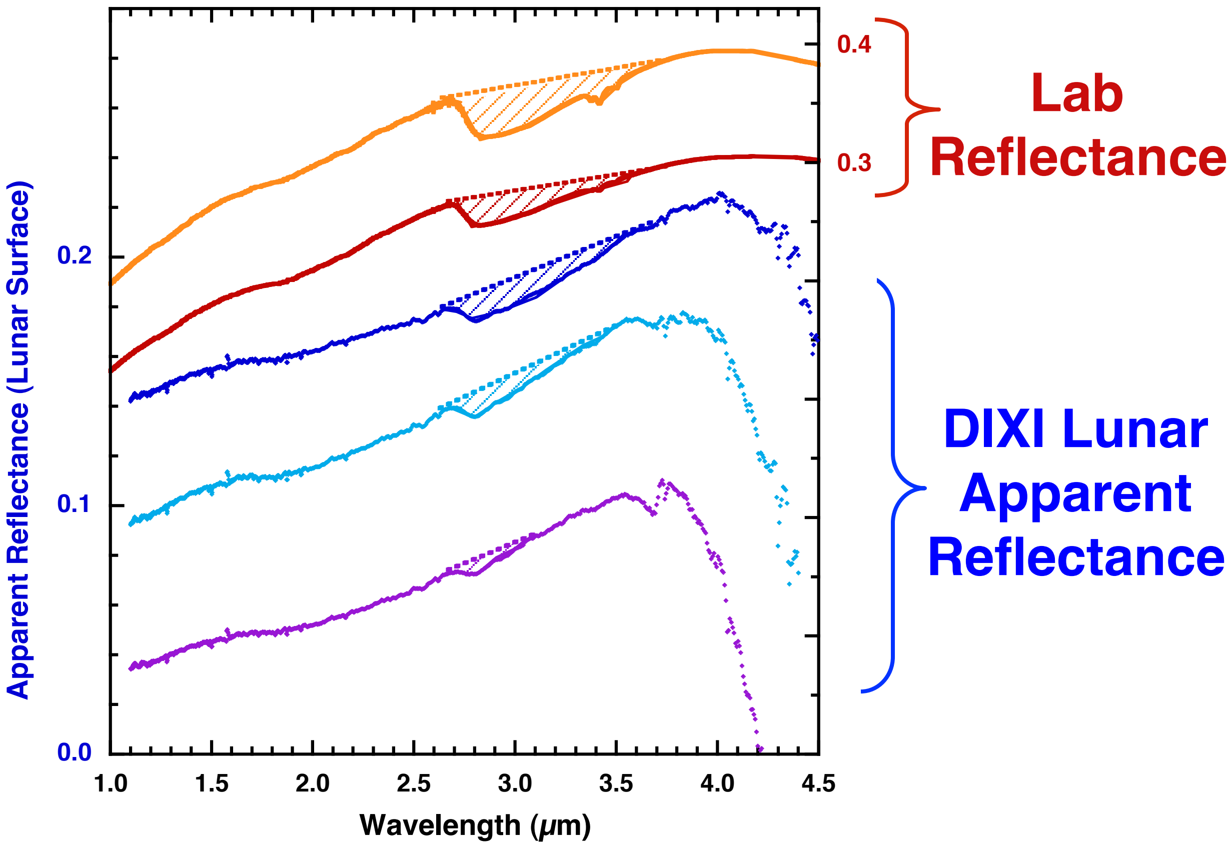
Calcium-Aluminum-Rich Asteroids

- **3 distinct parent bodies**
  - 234 Barbara;
    Watsonia and Henan Families
- **Spectral models: 2x-3x > CAIs then any known meteorite**
  - implies very ancient
  - early accretion
- **Survived as large bodies**
  - d = 50-100 km
- **if Al-rich why didn't the melt?**
  - perhaps, pre-date Al^{26} injection into solar system ?

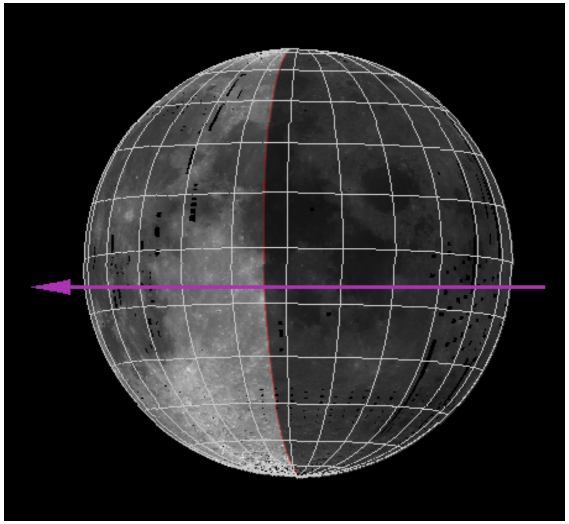


Water on the Lunar Surface

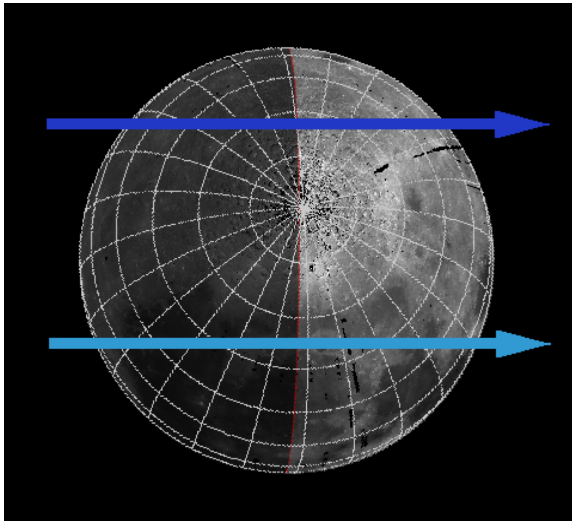
Adsorbed OH and H_2O



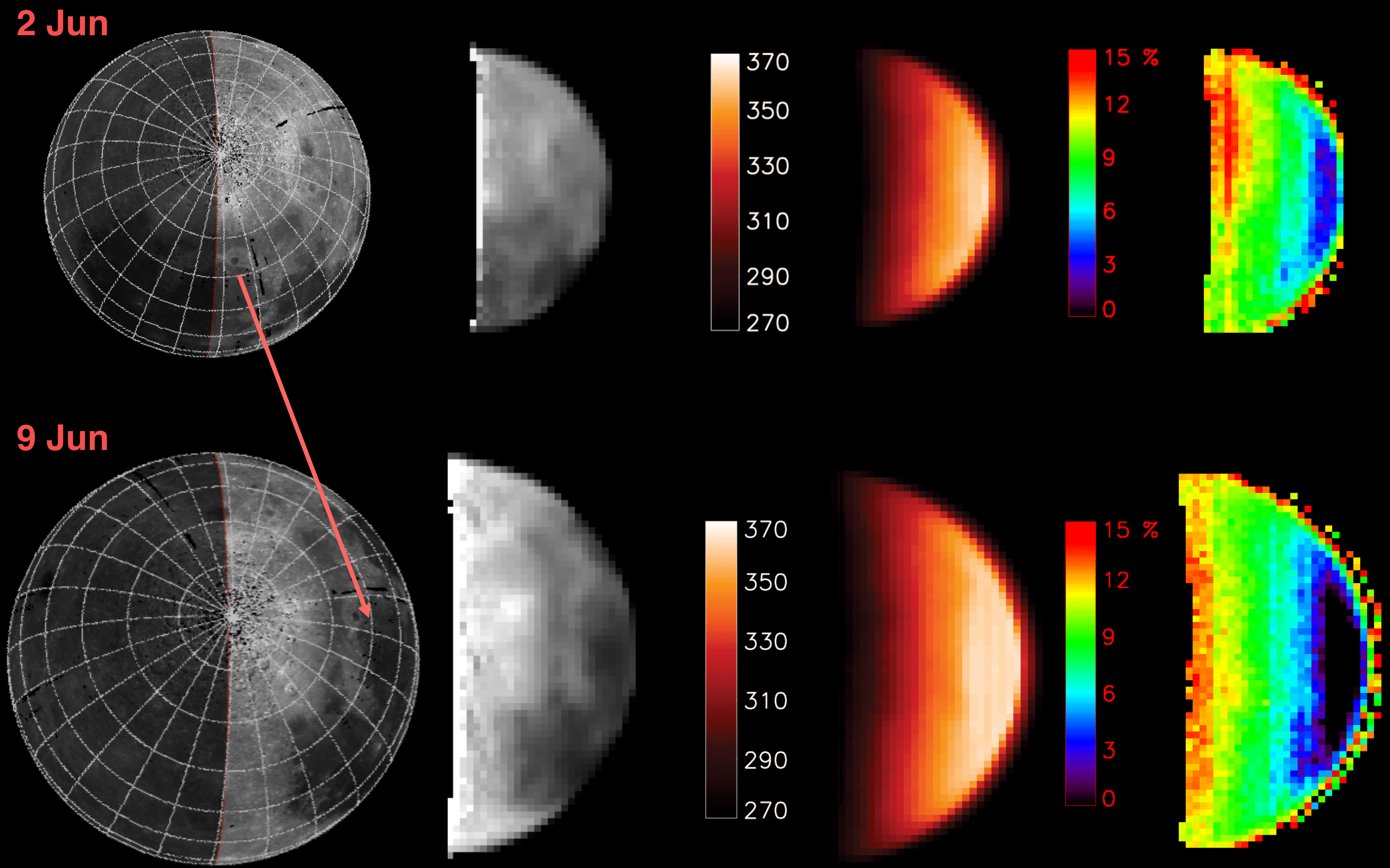
Dec 2007



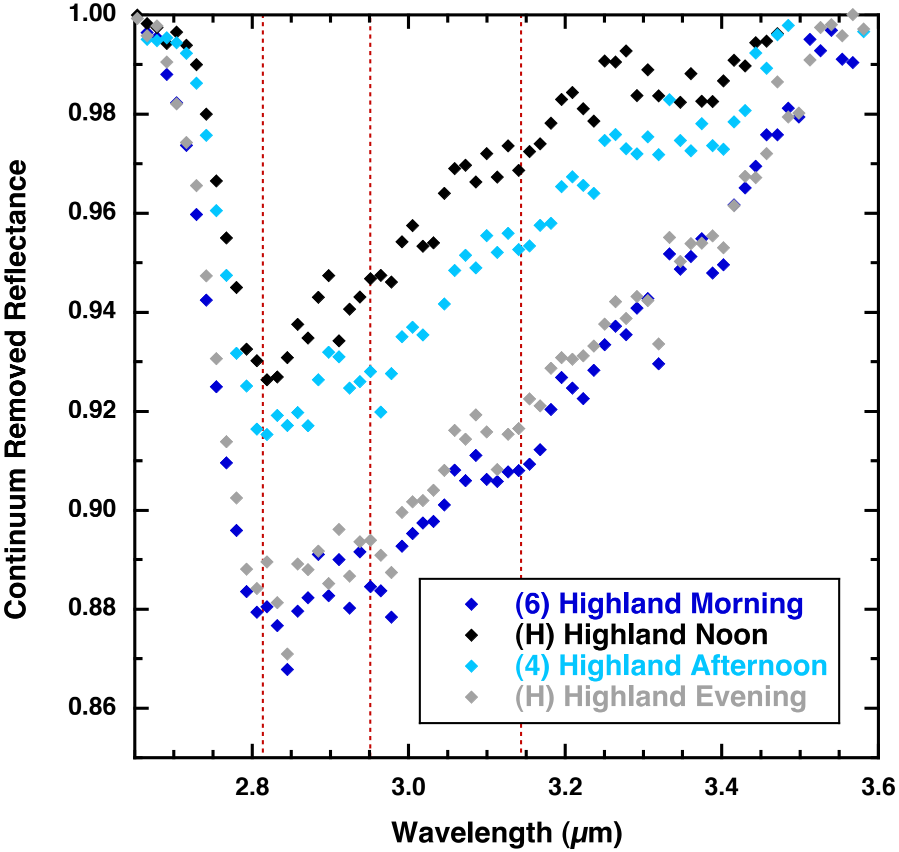
June 2009



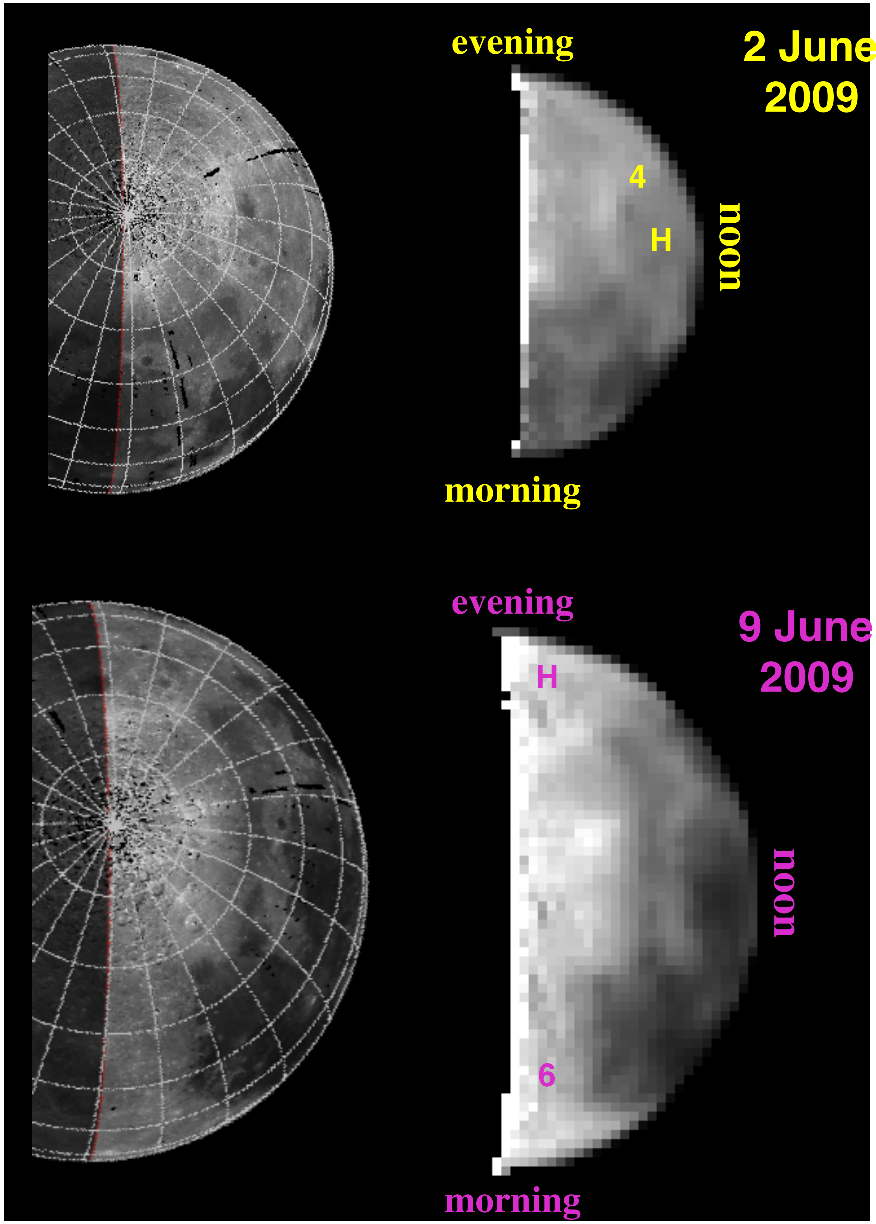
North Pole: 2nd & 9th Jun '09



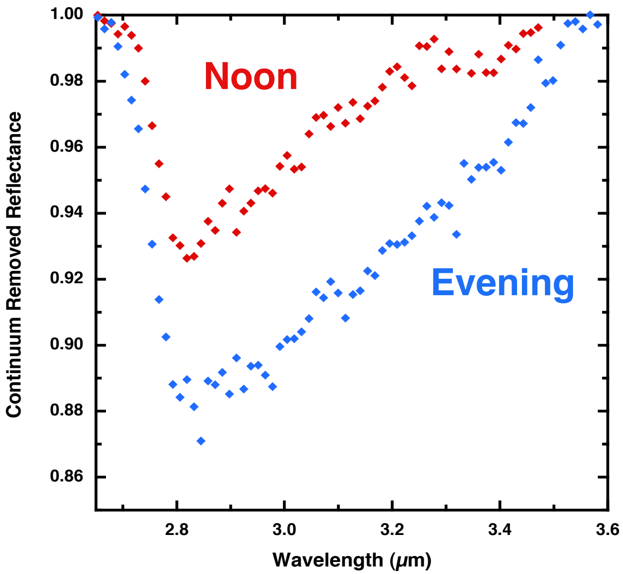
Change with Time of Day

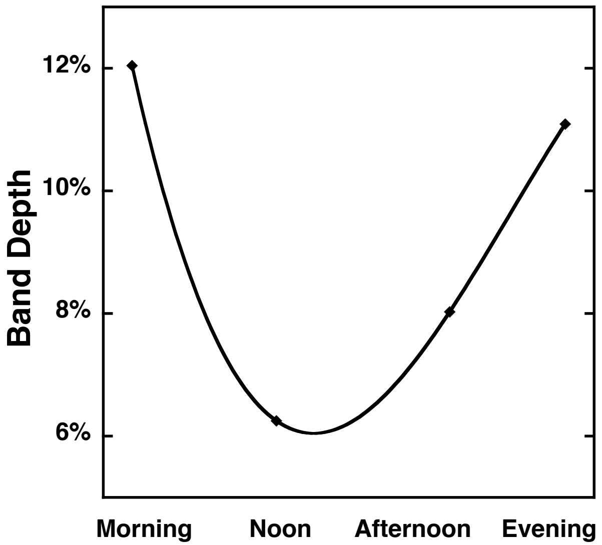


Comparing highland units
- morning equals evening
- noon/afternoon weaker and shape change



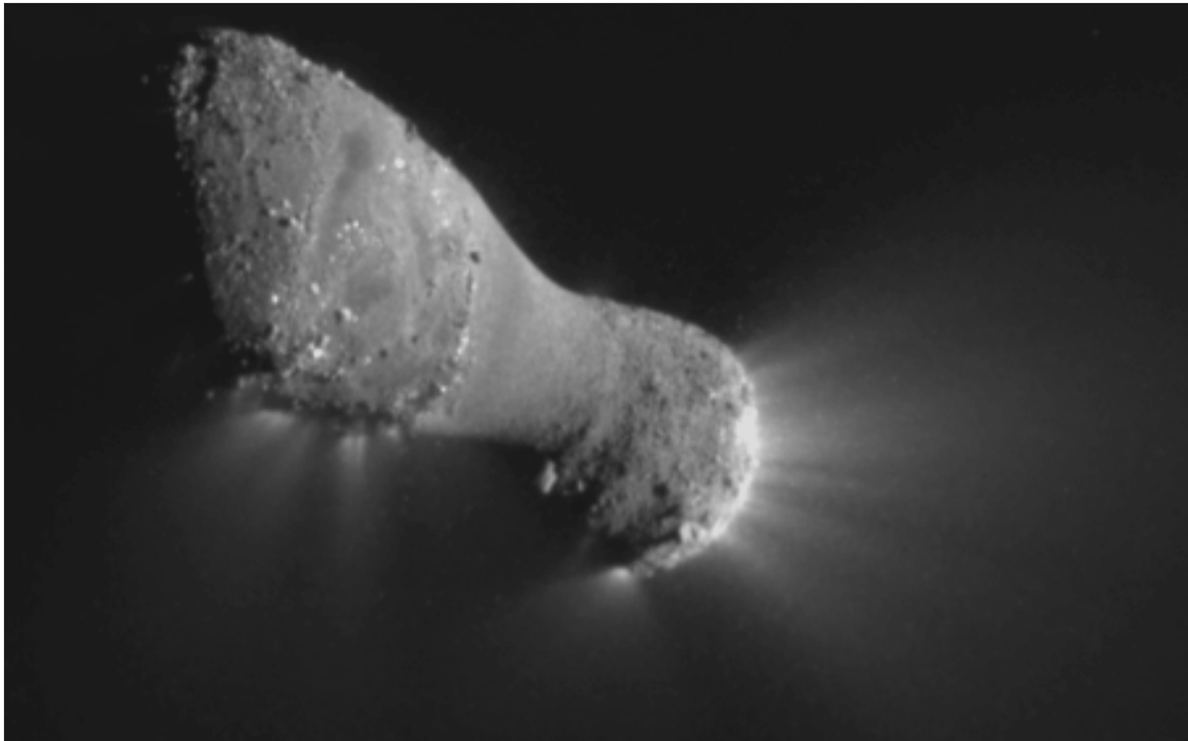
Daytime Cycle



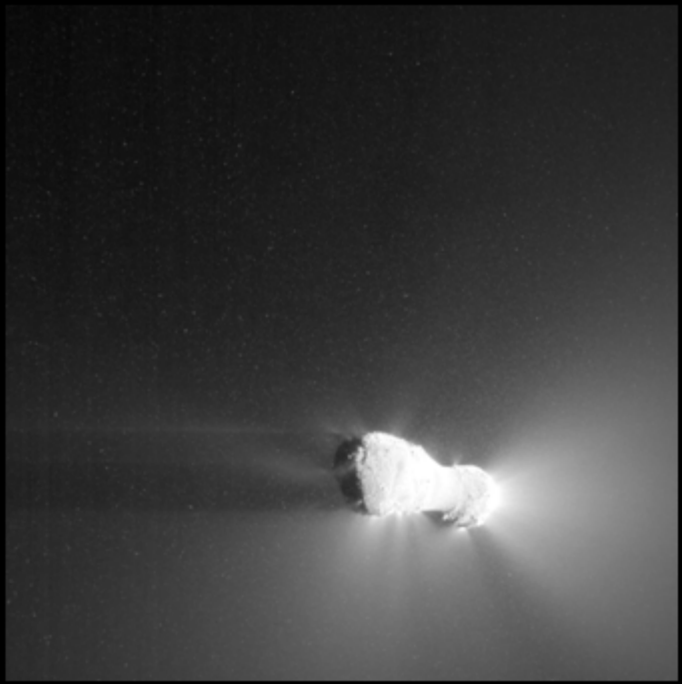


- **Diurnal change**
  - » suggests surface effect
- **Entire surface is hydrated**
  - » during at some part of the lunar day
- **Change in shape of absorption**
  - » preferential loss of H_2O vs. OH
- **Loss toward noon, recovery back to morning values by evening**
  - » entirely in daylight
  - » not condensation
  - » rapid photodissociation of H_2O ?
  - » short term migration?
  - » ready source?
- **Consistent with Solar Wind**
  - » H^+ reacts with O in lunar soil

Deep Impact eXtended Investigation to Comet Hartley 2



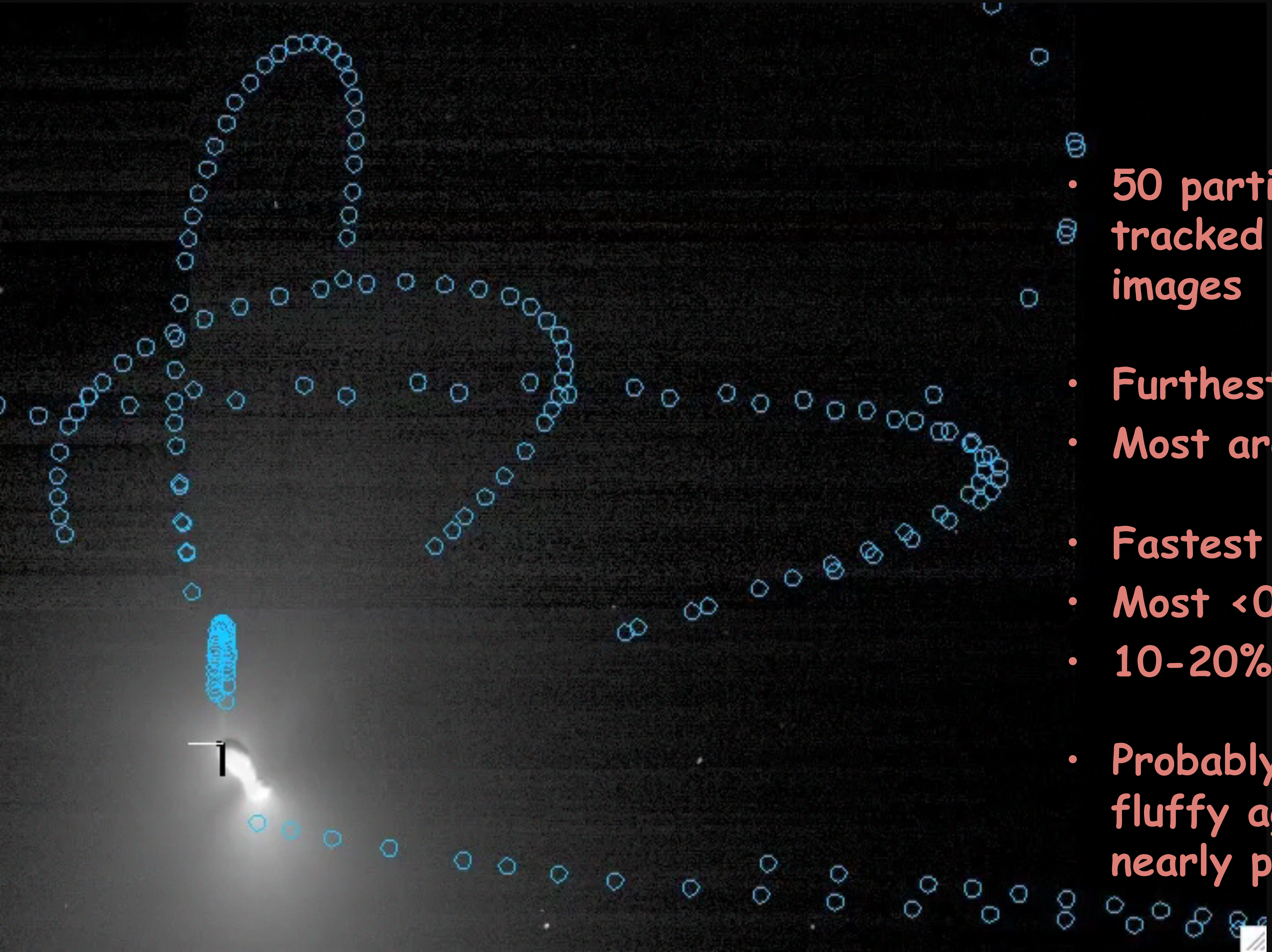
MRI Camera View of Nucleus and Inner Coma



context view

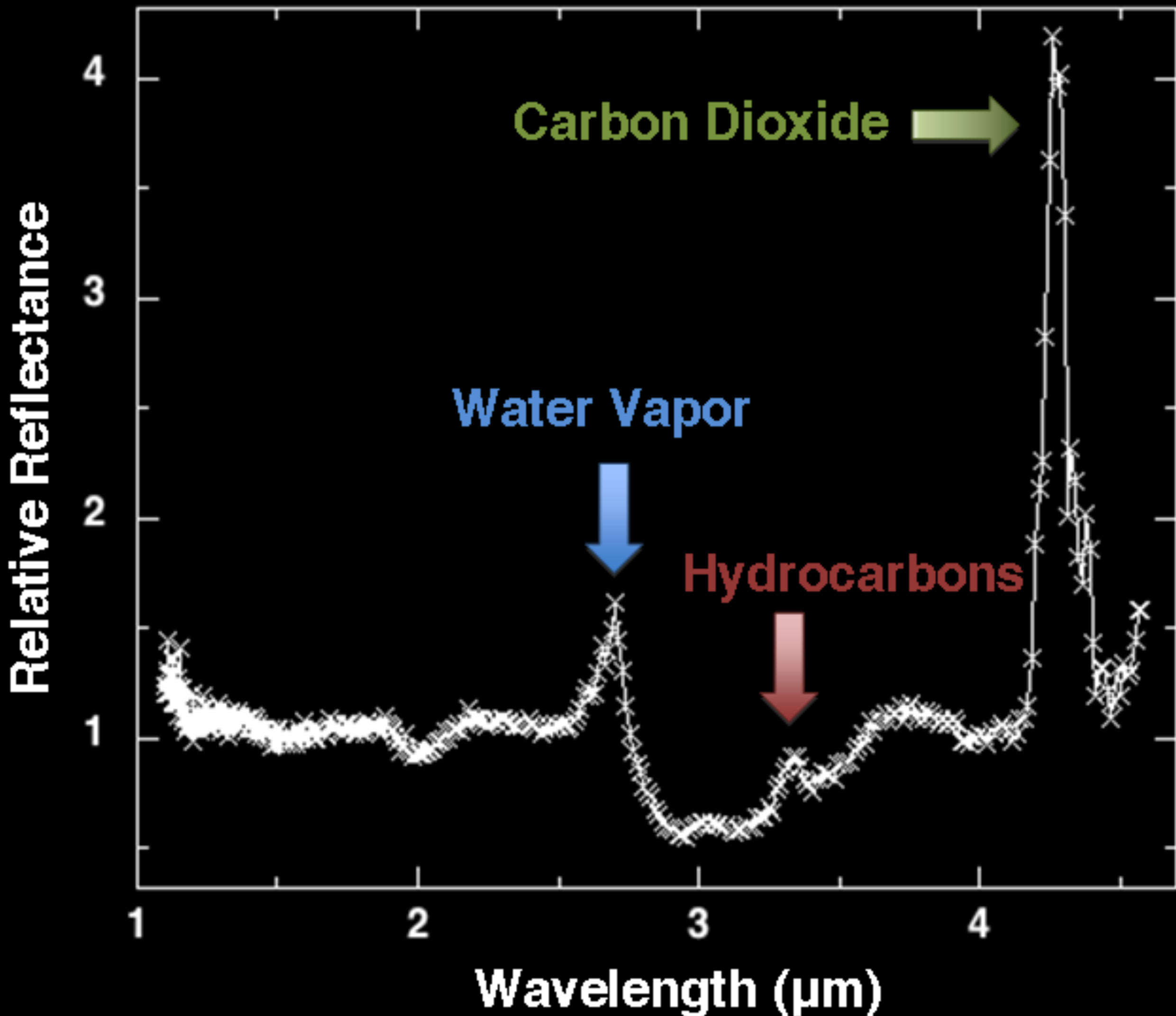
enlarged view

Chunk Motion

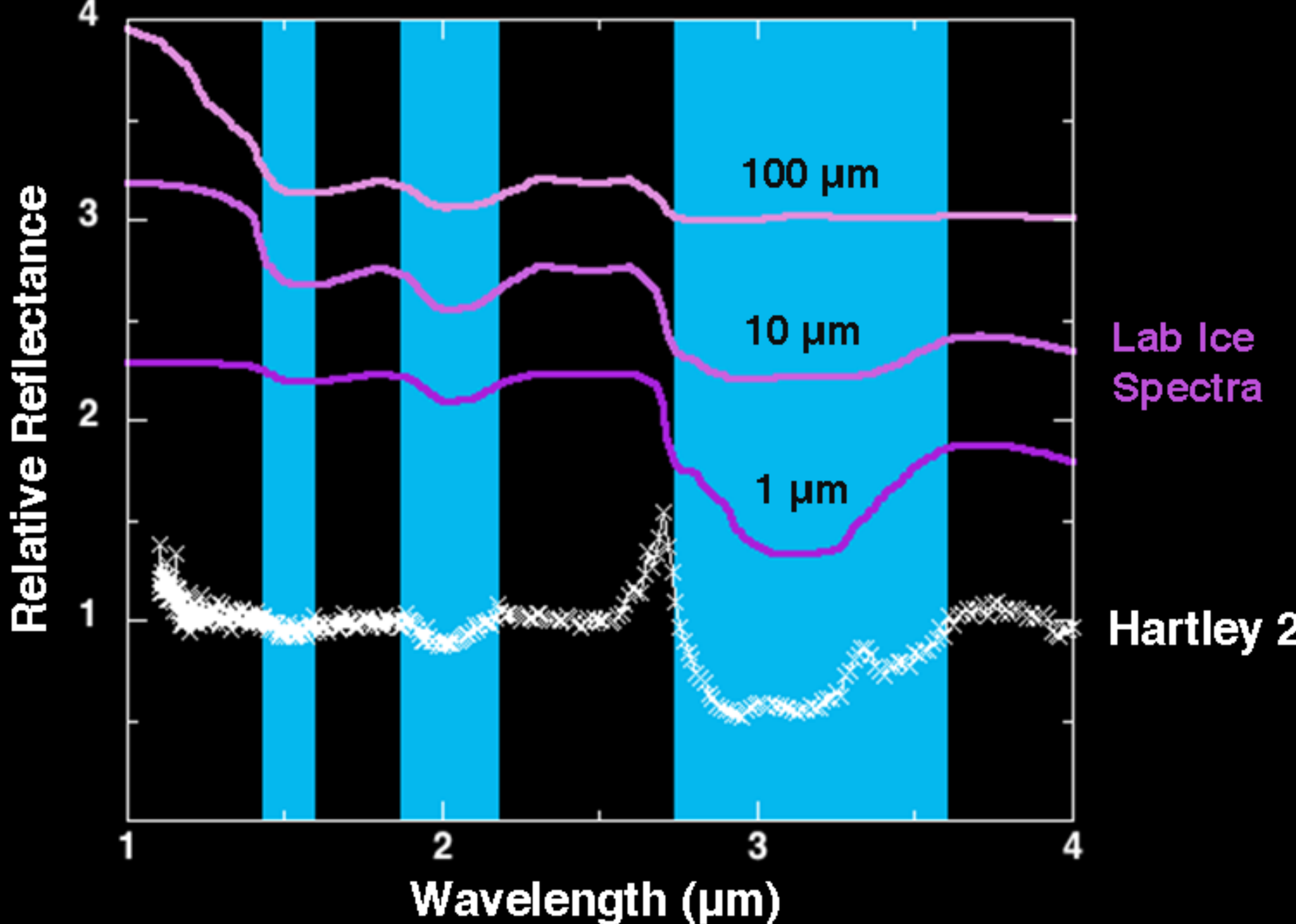


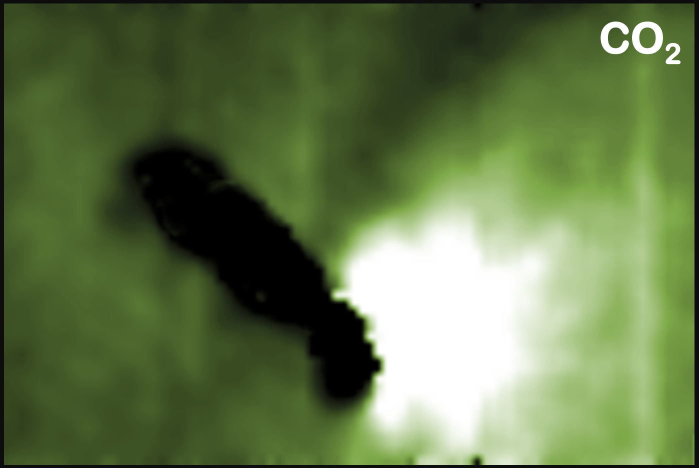
- 50 particles tracked in 10s of images
- Furthest is 28 km
- Most are <15 km
- Fastest <2 m/s
- Most <0.5 m/s
- 10-20% < v_{esc}
- Probably porous, fluffy aggregates, nearly pure

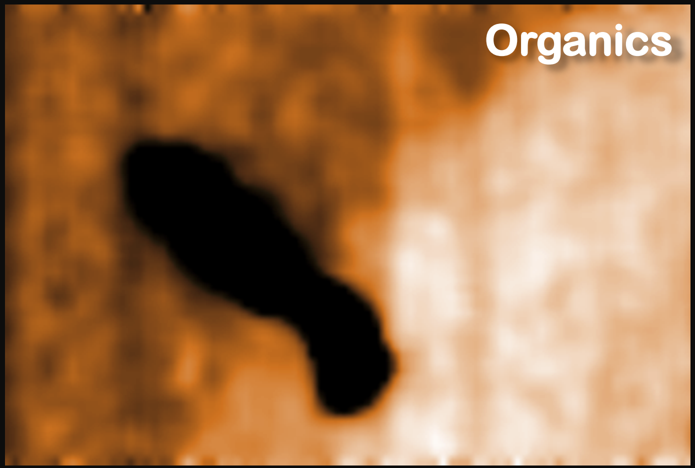
Gases in Coma of Hartley 2



Ice in Coma of Hartley 2



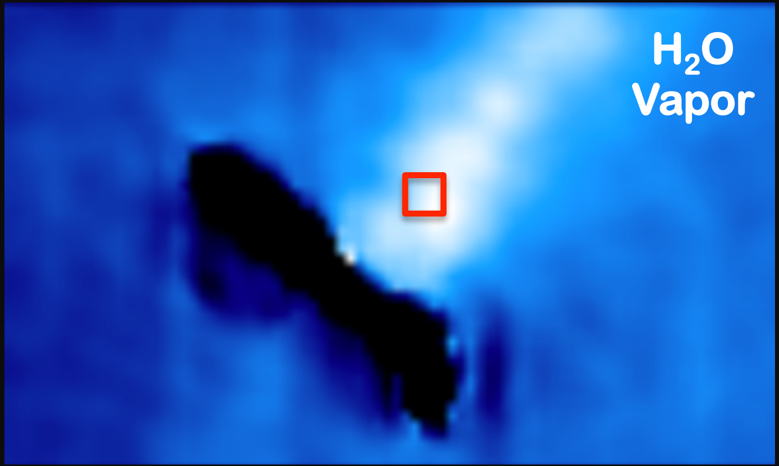


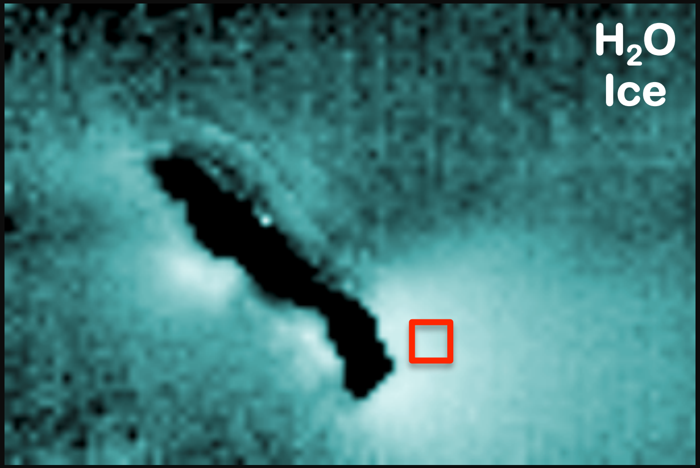


CO_2 3x Ice 10x H_2O 1.5x $CO_2:H_2O$ 3x

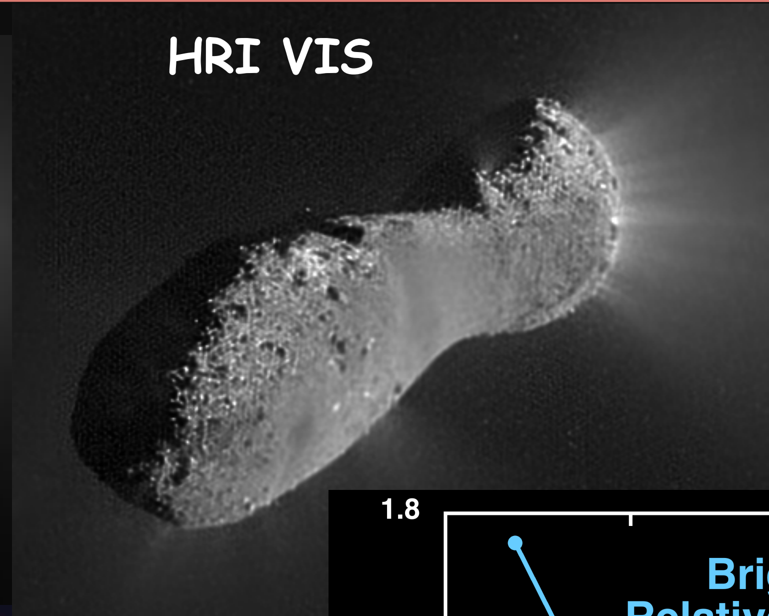
CO_2 ~20% of H_2O at peaks; 10% at minima

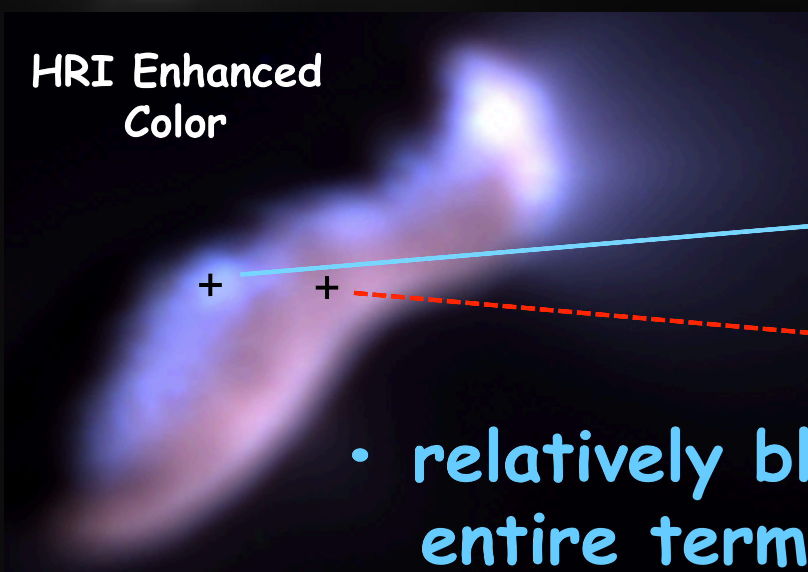
CO <~0.3% !! (from HST)

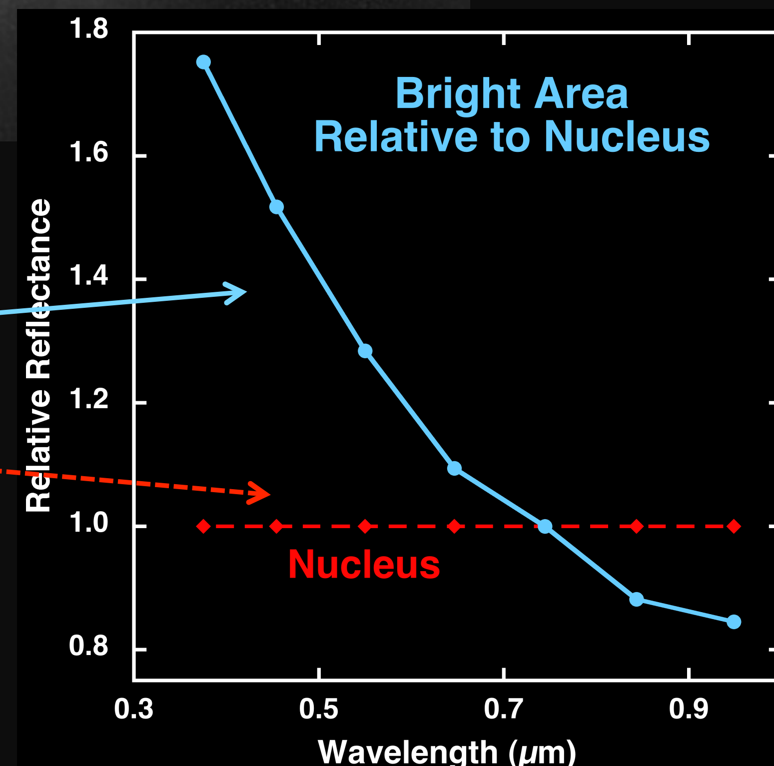




Surface Ice on Nucleus: Inbound

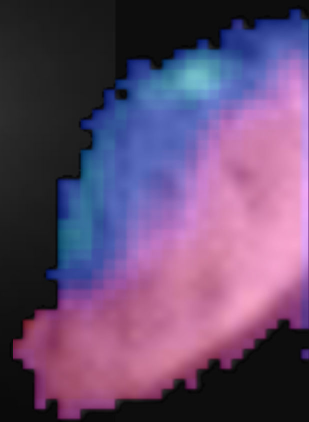


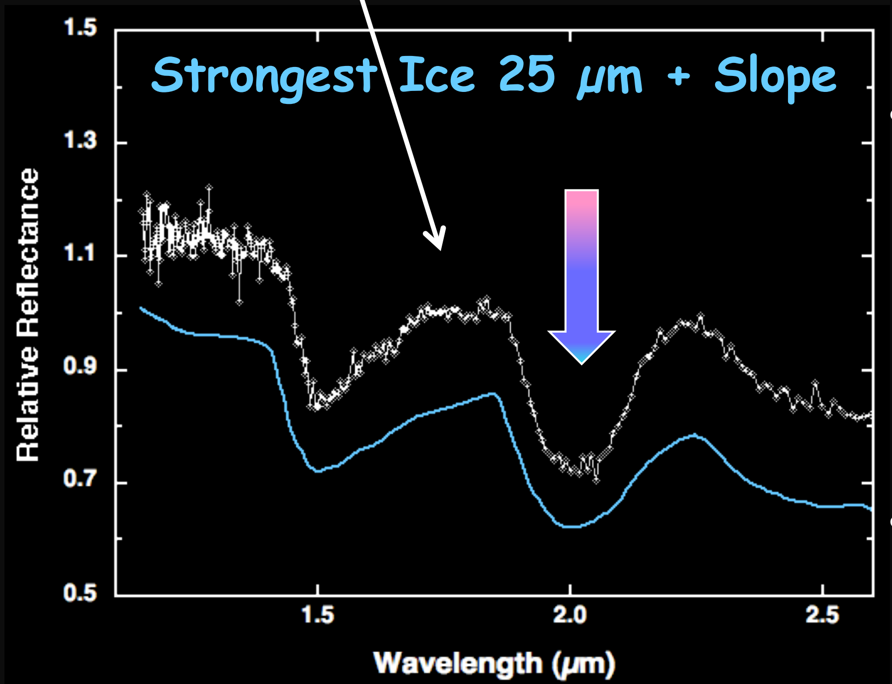




- relatively blue along entire terminator

Ice in Highest Resolution IR

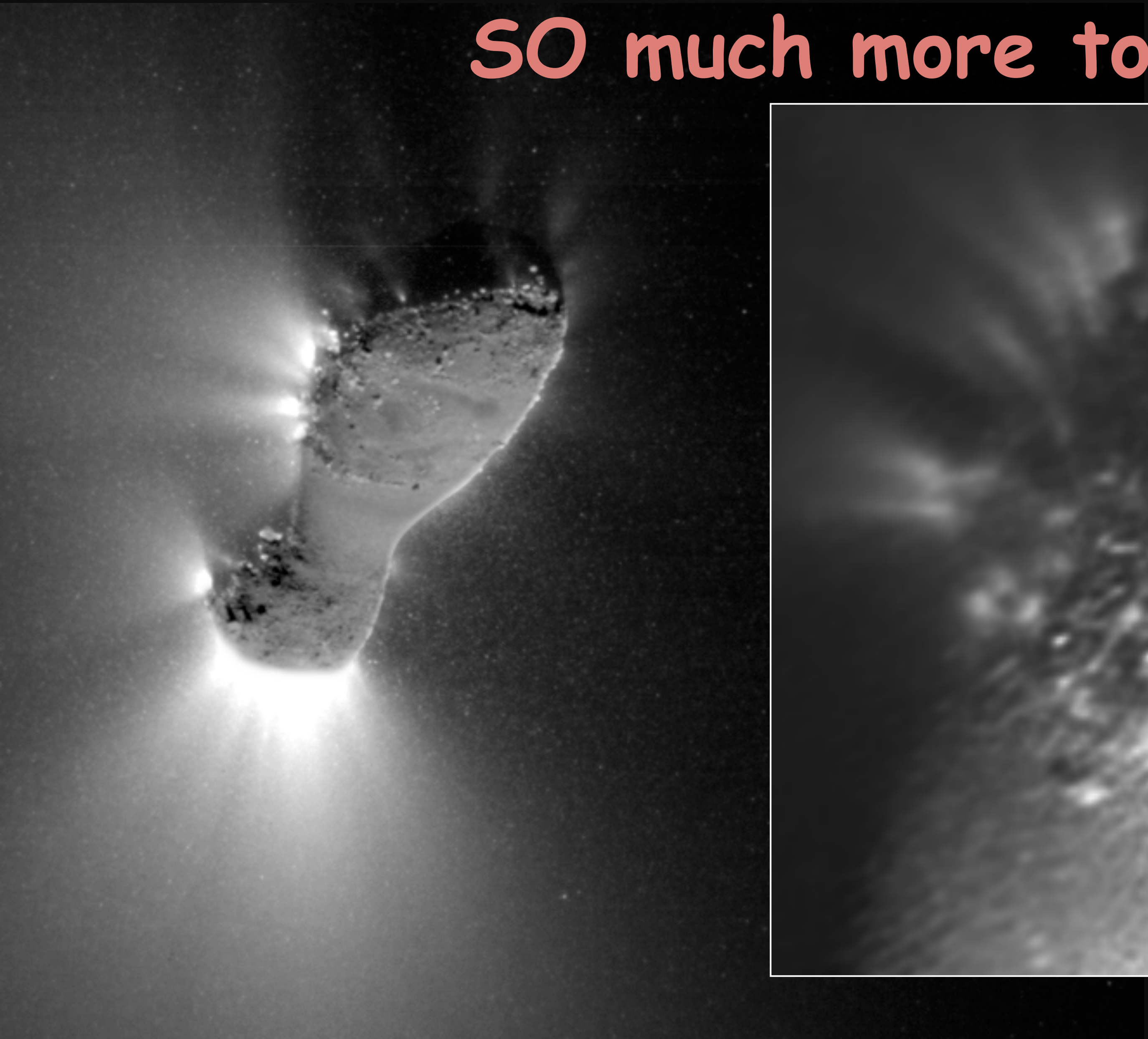


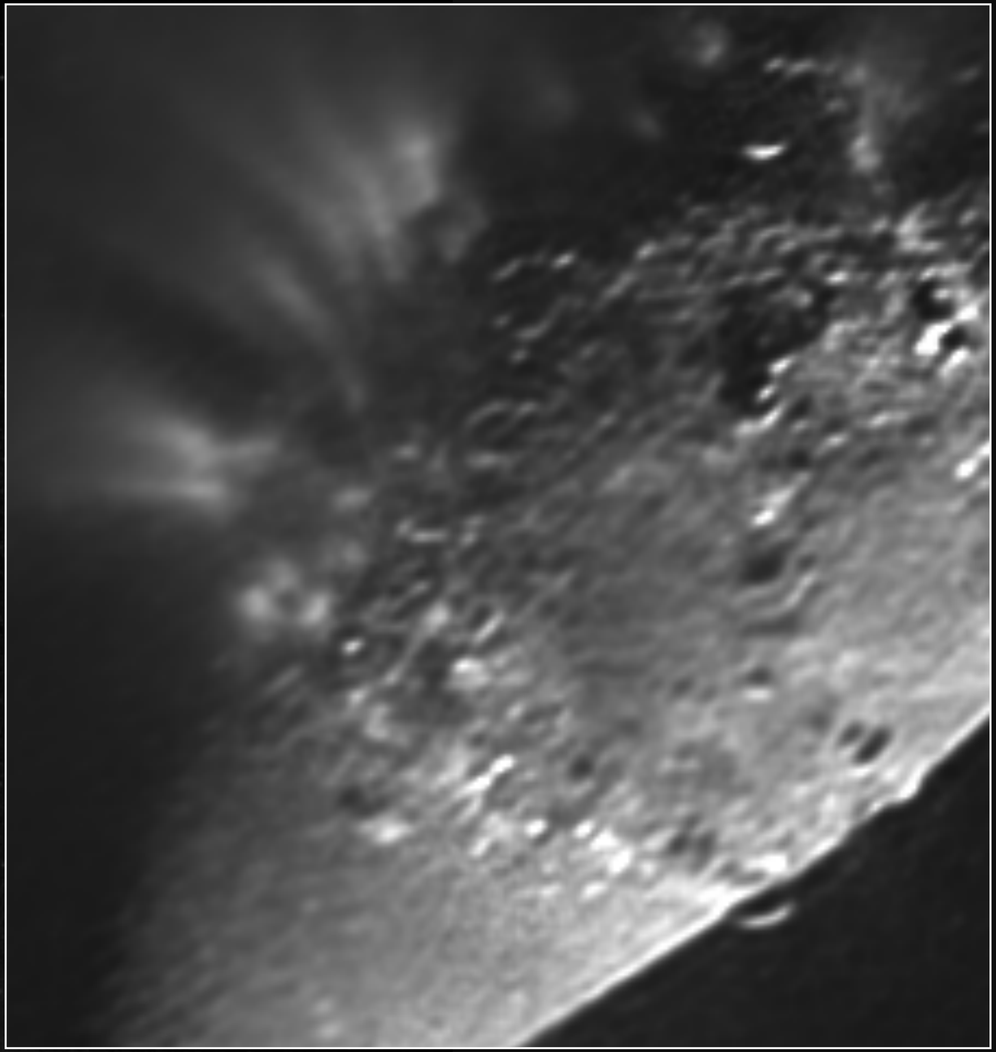


- Clear association with brighter, rougher surface
  - sharp contact
  - topography could provide shading preferentially retain ice
- Long term deposit or short-term re-deposition?

Jet Sources on H2

SO much more to do !!



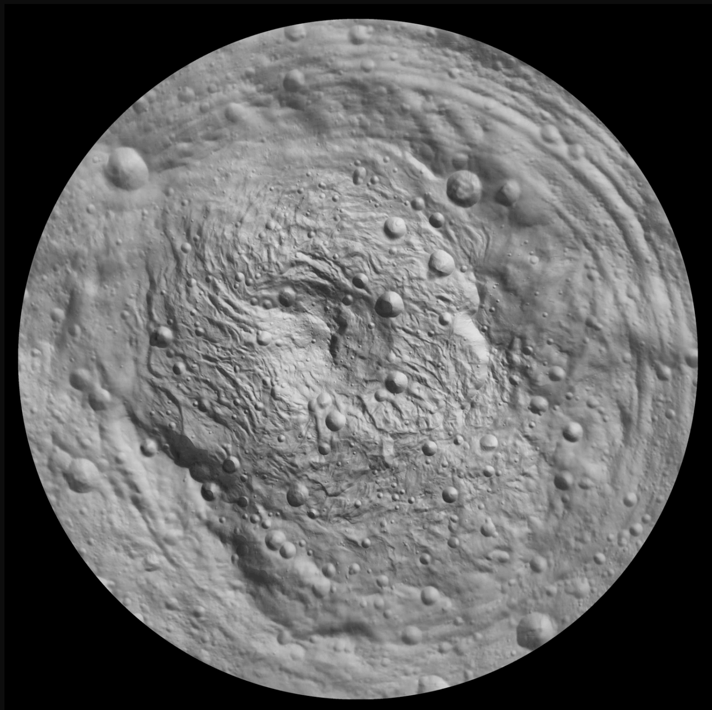


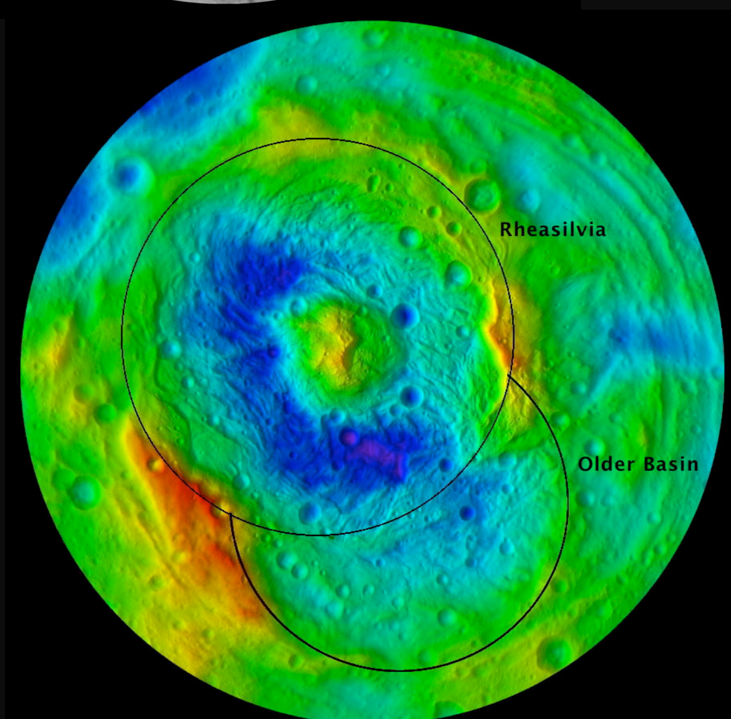
Dawn at Vesta

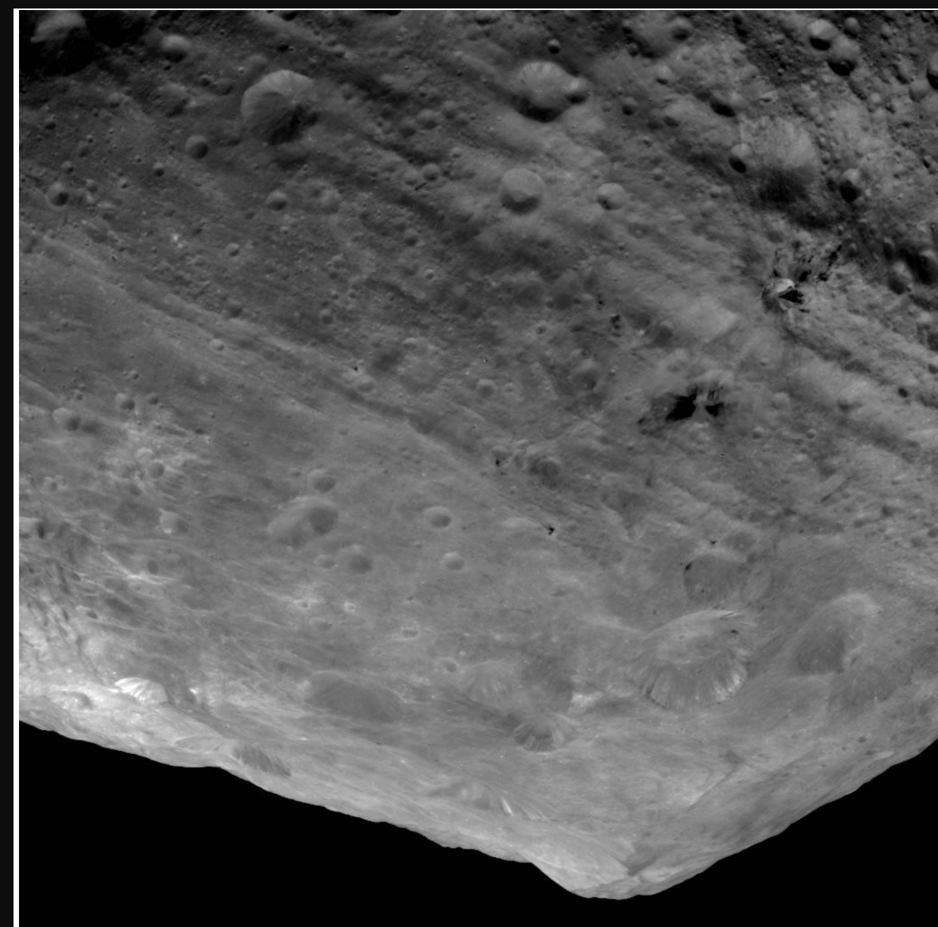
What did we expect:

According to the chronology of HEDs, melting and fractionating occurred in the early stage (4.56 Ga) of Vesta's geologic history, during which the asteroid is thought to have completely differentiated and formed a silicate-bearing crust

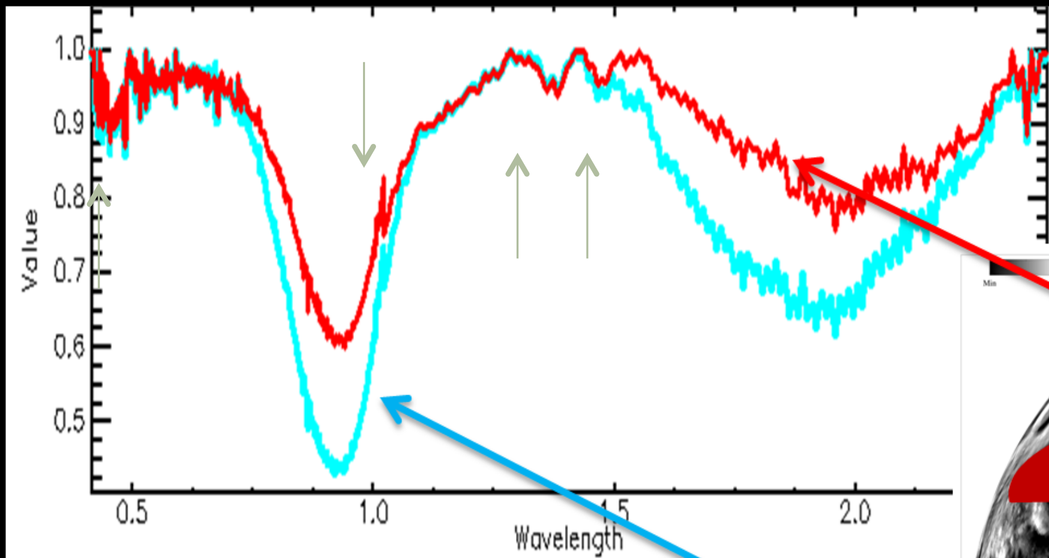
DAWN
Vesta
2011 - 2012



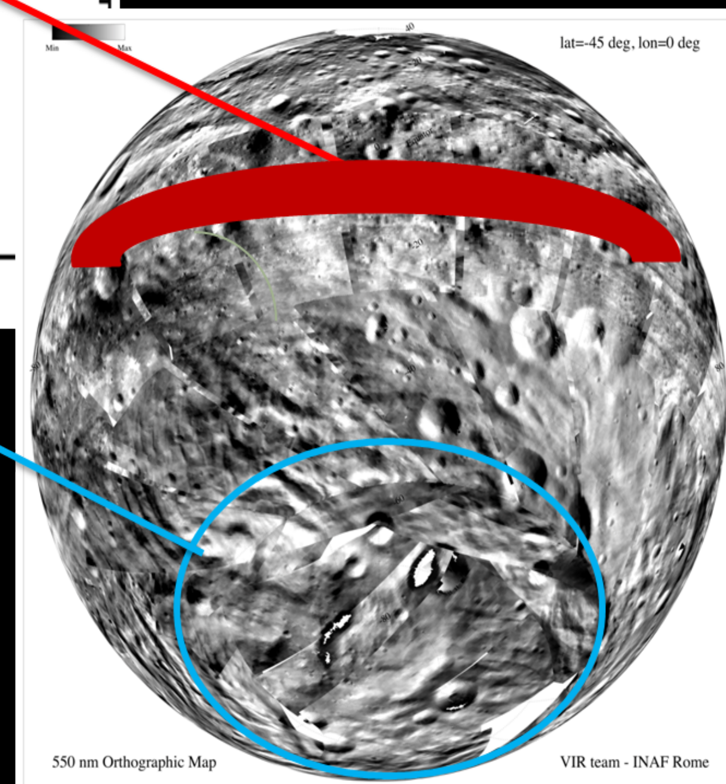




Spectral differences south / equator



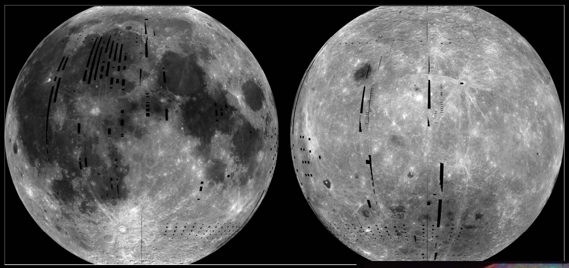
Arrows indicate calibration residuals

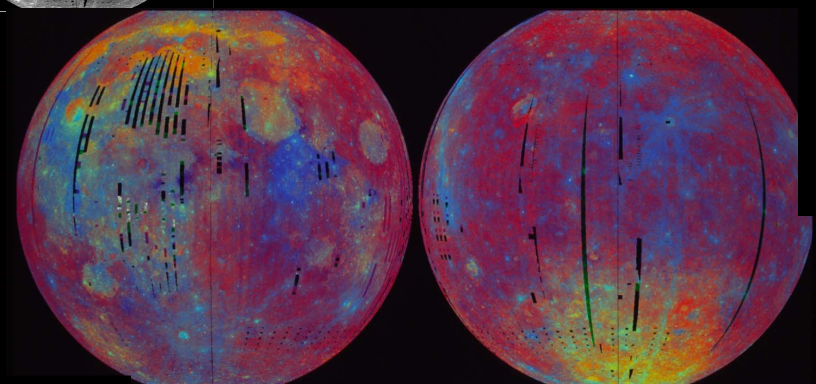


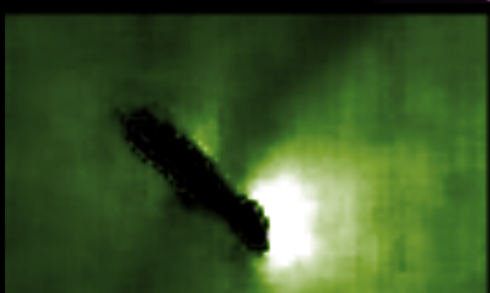
Southern regions show:

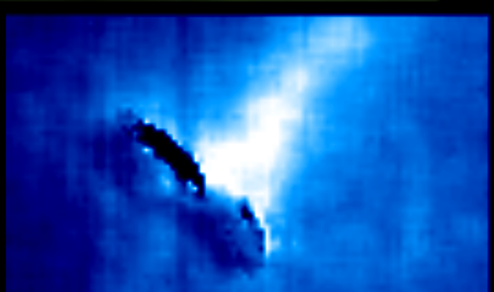
- Larger band depths
- Larger band widths
- Different shapes (2 µm)

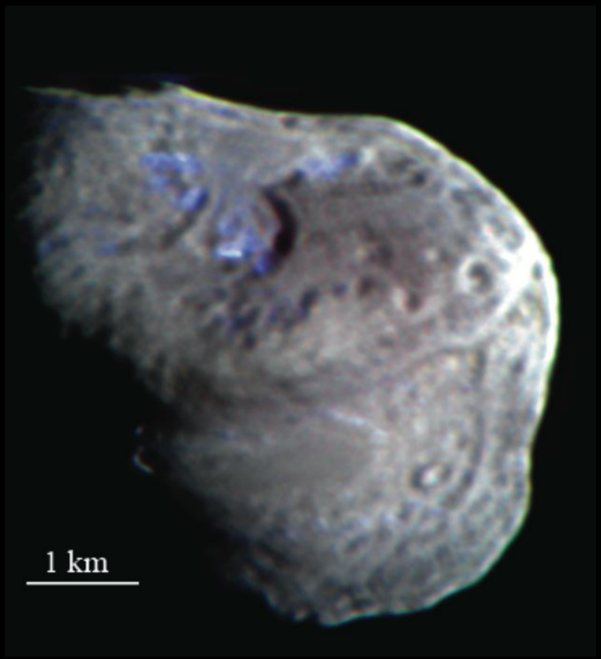
Colorizing the Solar System



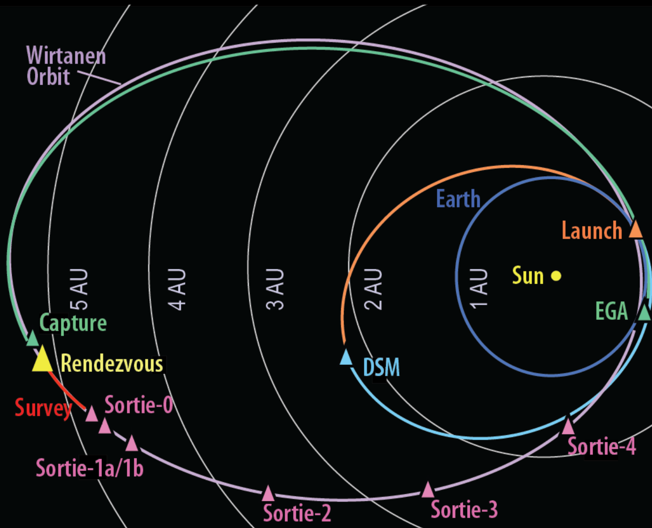








Comet Hopper (CHopper)



Key Event	Date	Comments
Launch	Dec. 31, 2016	34-day window
DSM	Mar 25, 2018	620 m/sec
EGA	Nov 26, 2018	319 km flyby
Capture	Apr 14, 2022	1201 m/s
Mapping	May-Jul 2022	4.8 to 4.7 AU
Sortie 0	Sep 2022	4.6 AU
Sortie 1a	Oct 2022	4.5 AU
Sortie 1b	Nov 2022	4.5 AU
Sortie 2	May 2023	3.5 AU
Sortie 3	Oct 2023	2.5 AU
Sortie 4	Mar 2024	1.5 AU
EOM prime	Apr 2024	Baseline + 1 mo.