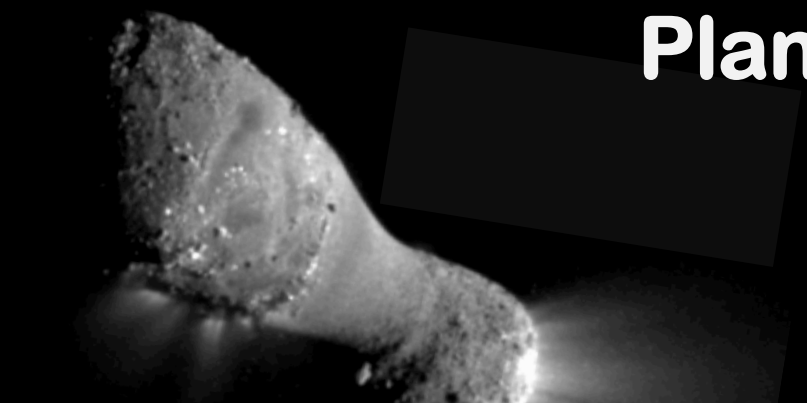
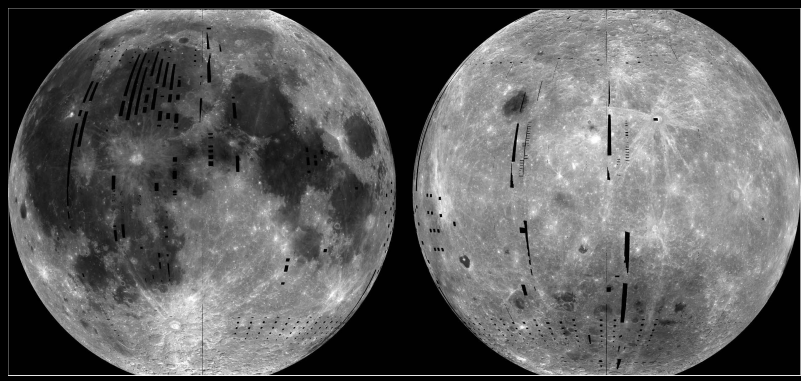
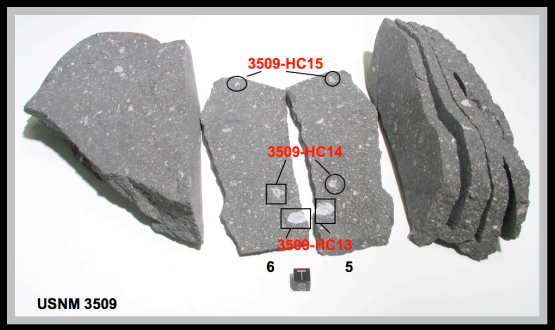
Composition from IR Spectra: Comets, Asteroids, Meteorites, and the Moon

Prof. Jessica M. Sunshine
Planetary Group







"Upstairs" Planetary People

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

Scientific Focus

- **Origin & evolution of the solar system**
  - Larger bodies are dominated by evolution
  - Small bodies preserve an early record
    - How do we separate primordial conditions from evolutionary effects?

- **Study asteroids, comets, and the Moon with wide variety of techniques**
  - To understand origin AND evolution

Functional Activities

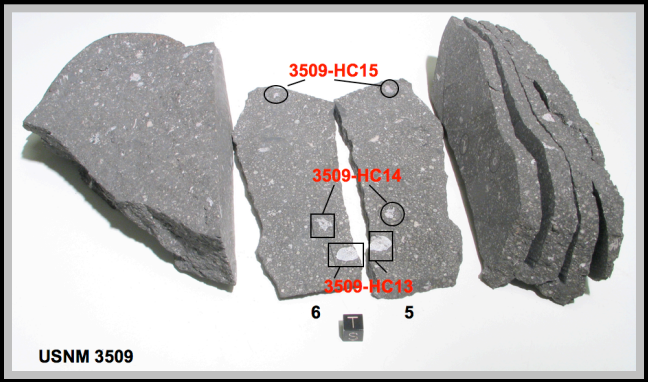
- **Planetary Data System**
  - Small bodies node located at UM
    - A'Hearn, Kolokolova, Farnham, Feaga
  - Direct connection to research on the data
    - Modest science supported, major science enabled
  - Direct connection to many missions
    - DI, EPOXI, NExT, NEAR, Dawn, Chandrayaan, Rosetta
- **EPO Programs**
  - Feaga, Warner
  - College Park Scholars, amateur astronomers
  - EPO lead for DI, EPOXI
- **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

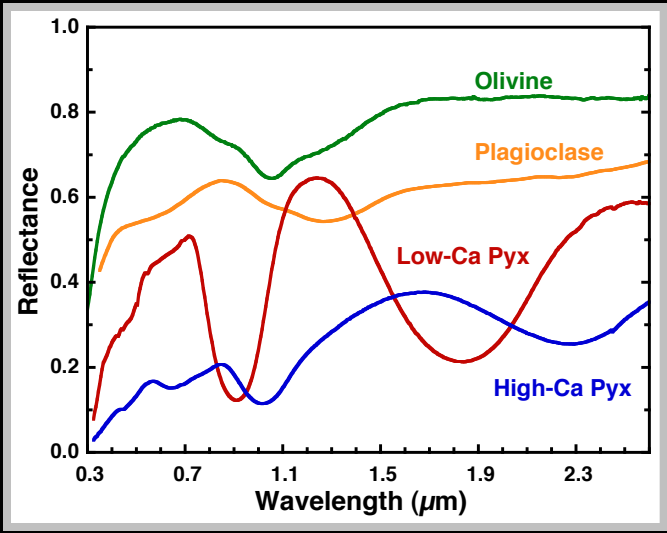
History & Evolution of the Early Solar System

Study of the least processed surfaces w/ Spectroscopy

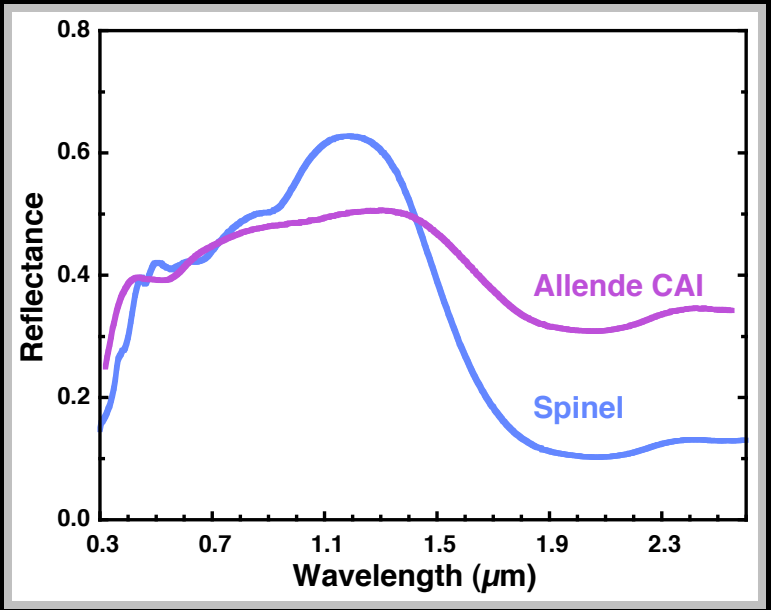
- **Comets**
  - Composition: primordial vs. evolutionary
  - Mixing within early Solar System
    - continued analysis of Deep Impact (ice, solids, surface)
    - extended mission (DIXI) to Hartley 2 and return to Tempel 1 (NeXT)
- **Asteroids and Meteorites**
  - Composition: timing and nature of accretion 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



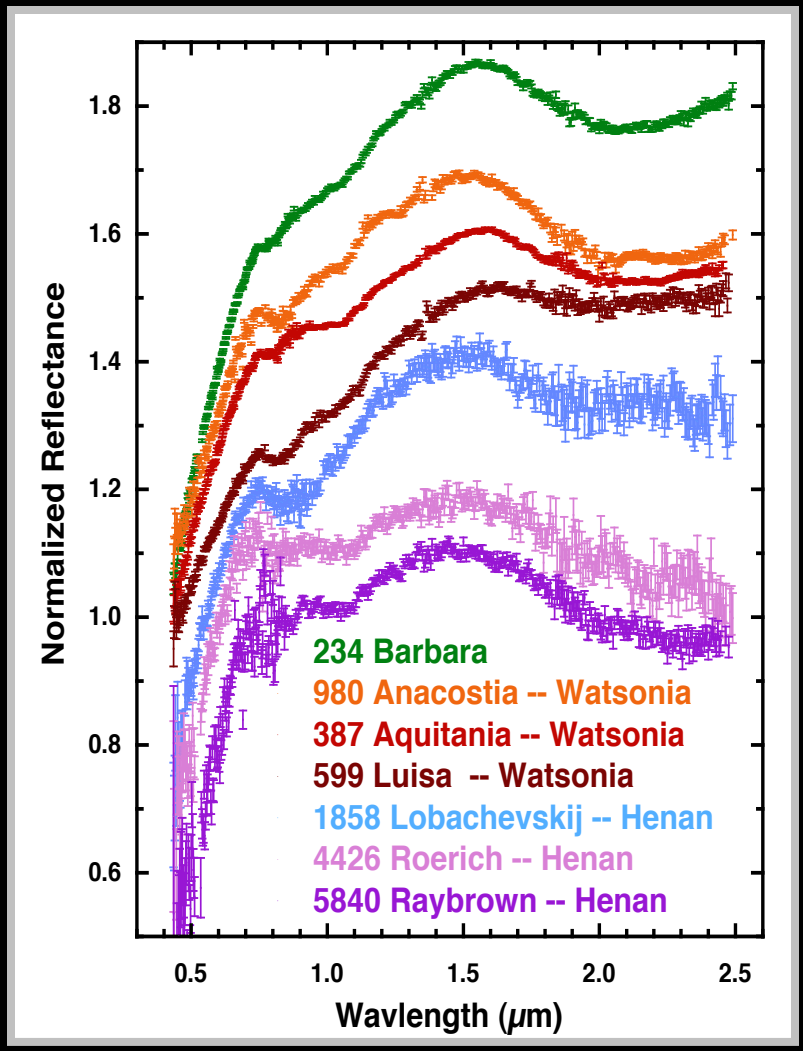


- **Oldest known rocks**
  - mineralogy predicted for first nebular condensates
  - date the start of the Solar System
  - occur in all classes of chondrites
- **Spectrally dominated by spinel hercynite: $[Fe,Mg]Al_2O_4$**
  - strong 2 μm absorption
  - absent or weak 1 μm bands



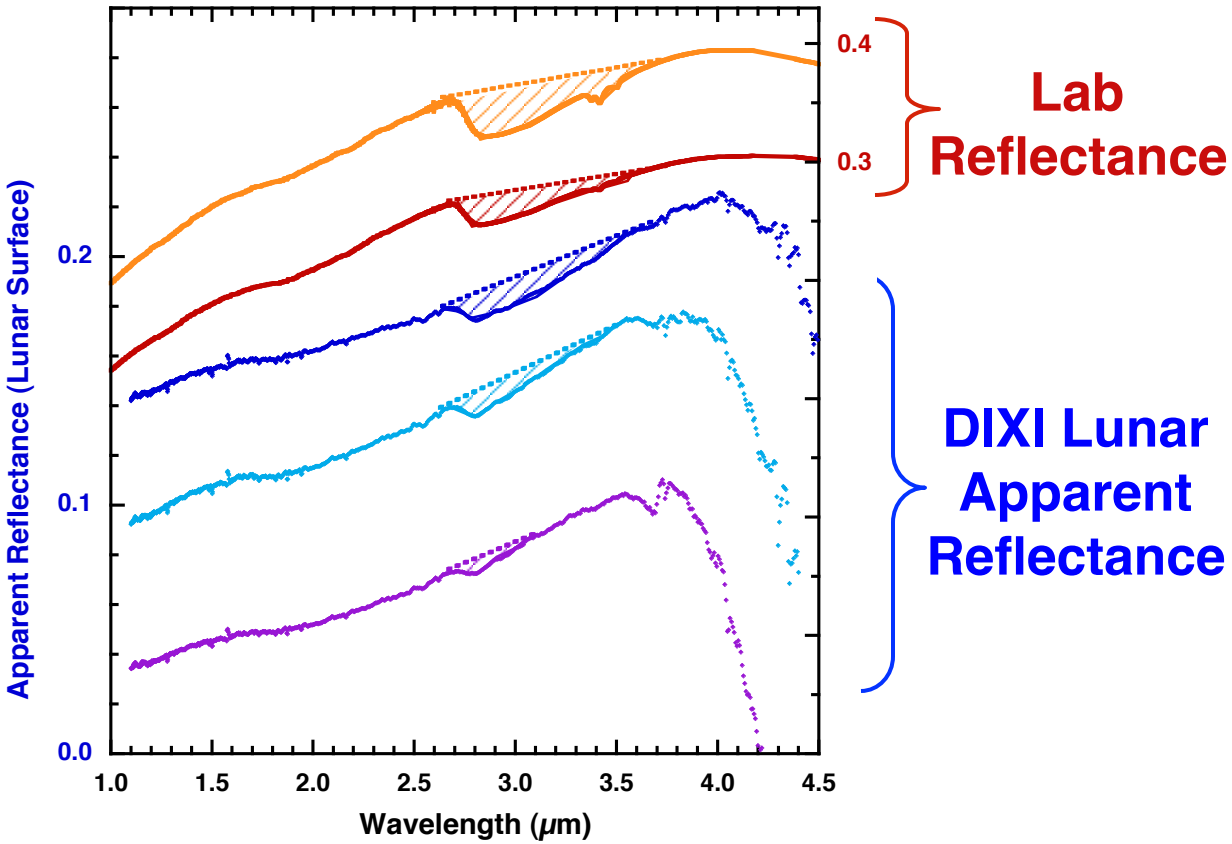
Calcium-Aluminum-Rich Asteroids

- **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 ?

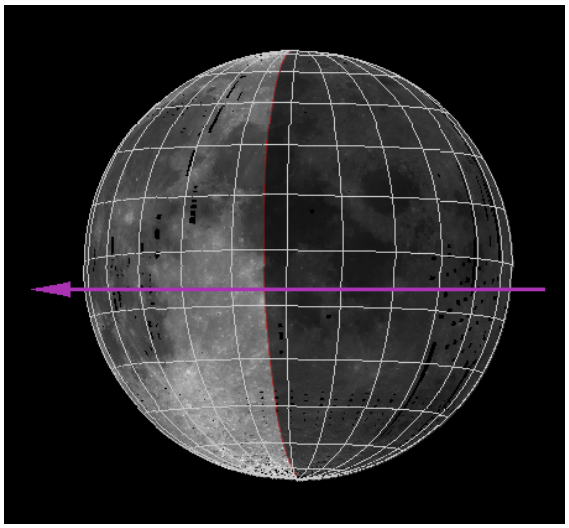


Water on the Lunar Surface

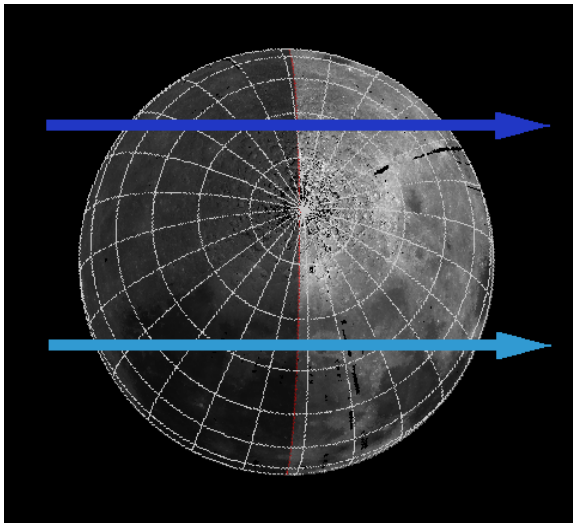
Adsorbed OH and H_2O



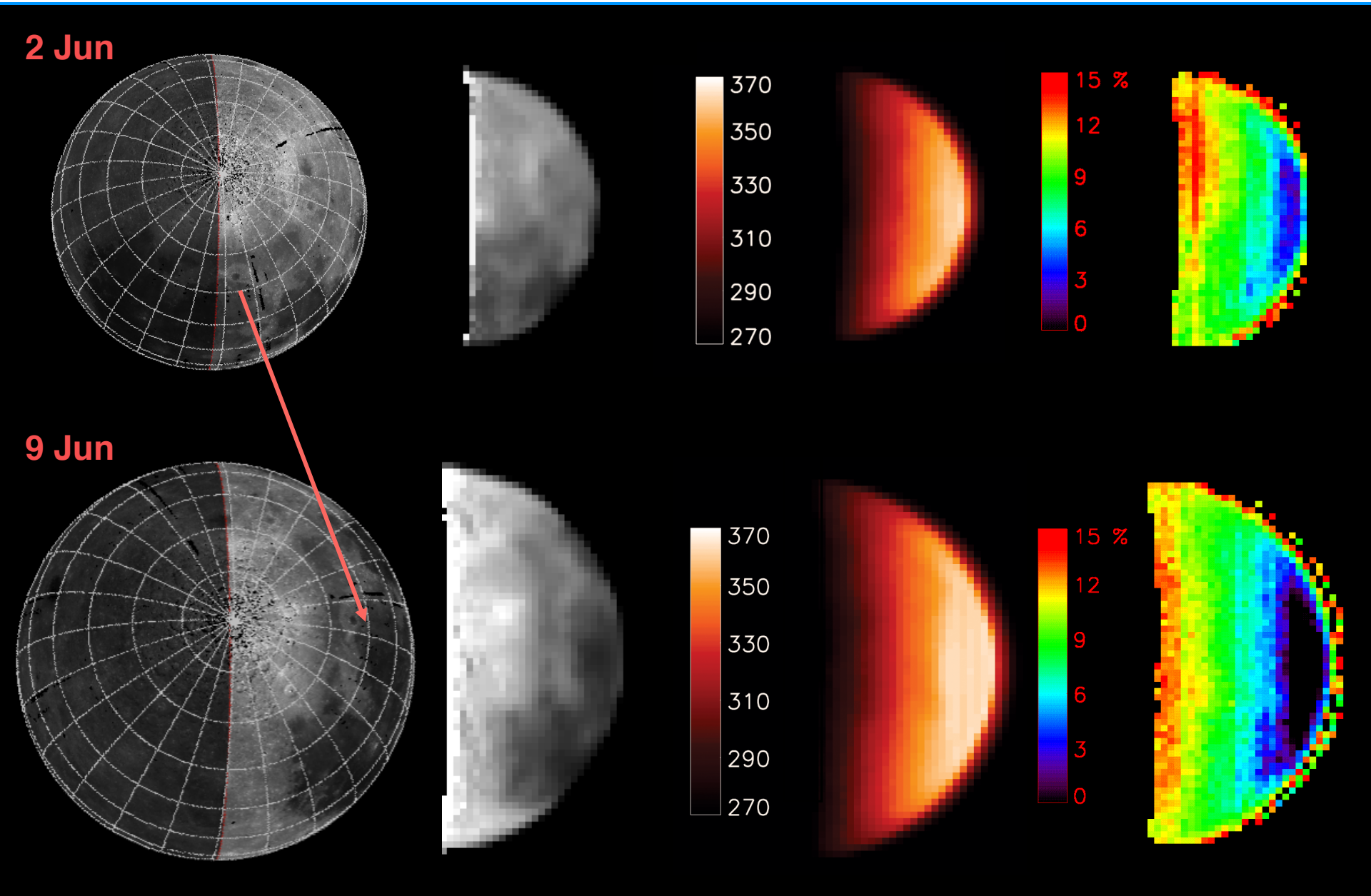
Dec 2007



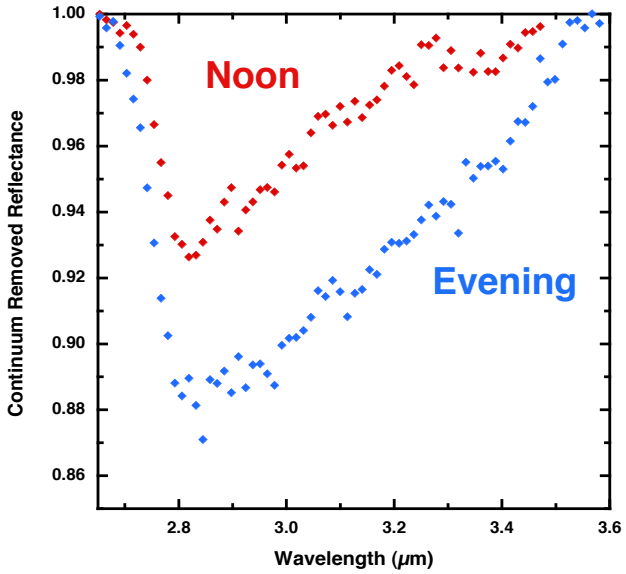
June 2009

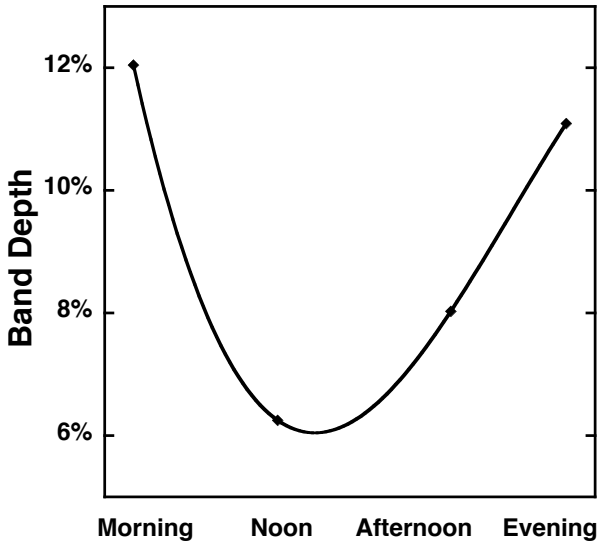


North Pole: 2nd & 9th Jun ‘09



Daytime Cycle

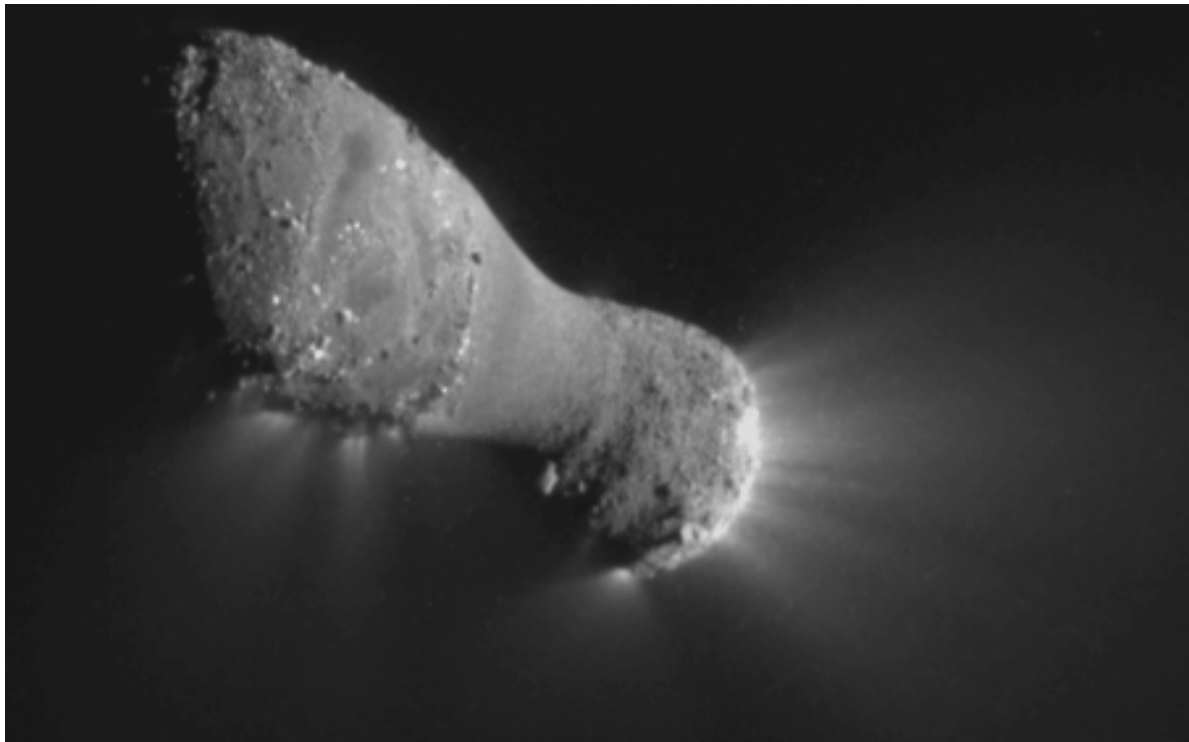


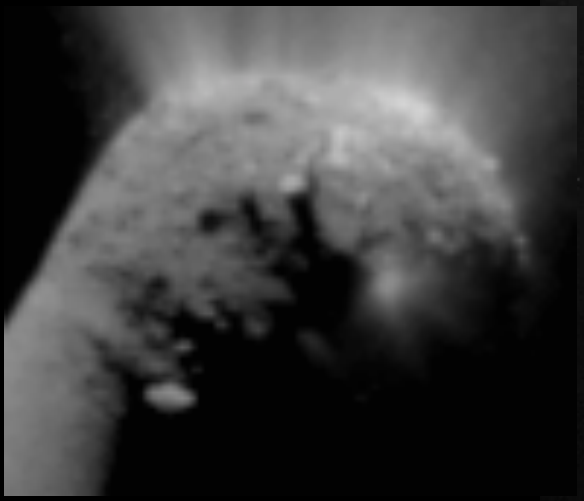


- **Diurnal change**
  - suggests surface effect
- **Entire surface is hydrated**
  - during at some part of the lunar day
- **Change in shape of absorption**
  - preferential loss of H_2O vs. OH
- **Loss toward noon, recovery back to morning values by evening**
  - entirely in daylight
    - not condensation
  - 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

Why/how is Hartley 2 active over >100% of it's surface?

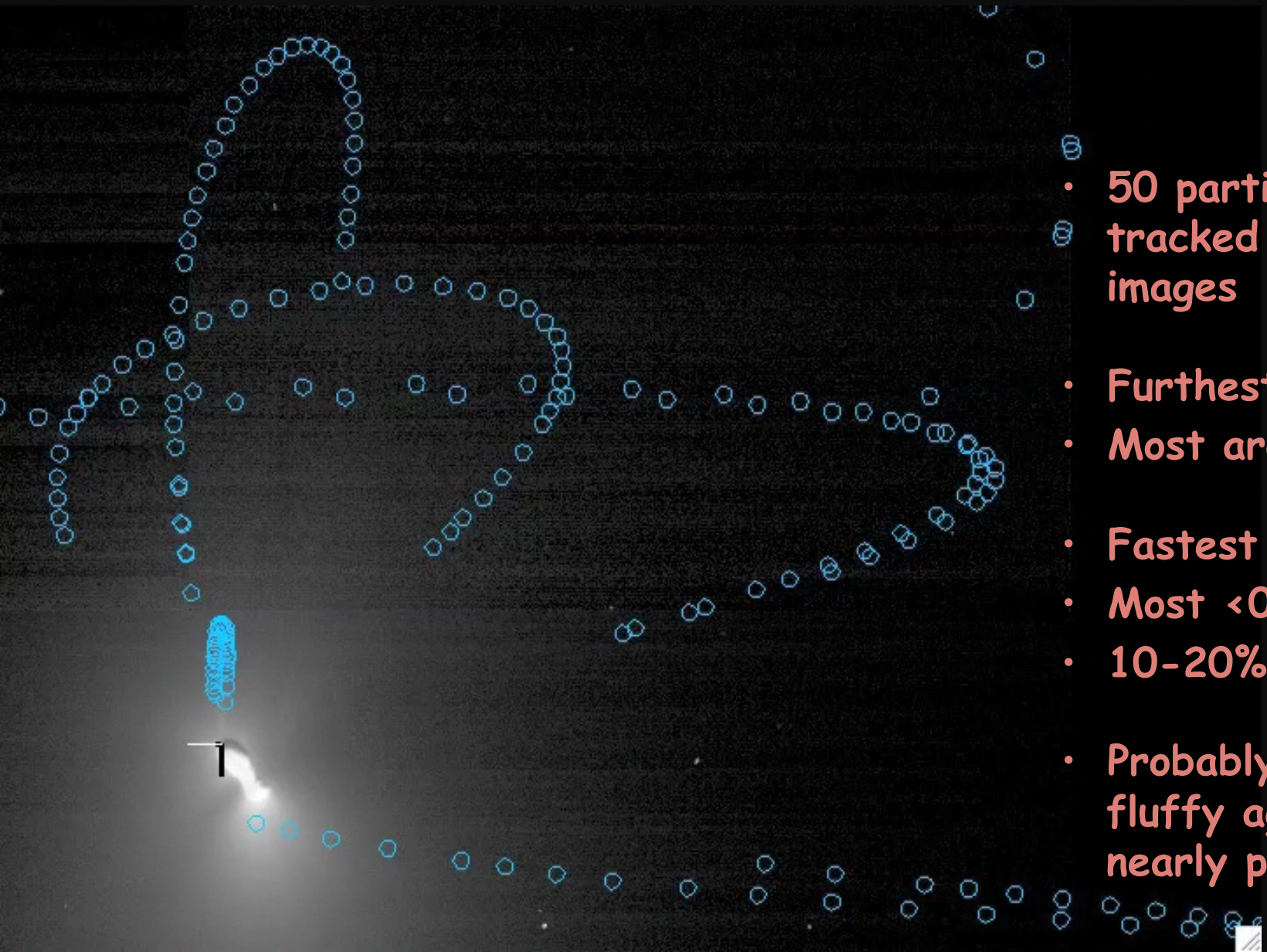




Sun is Up

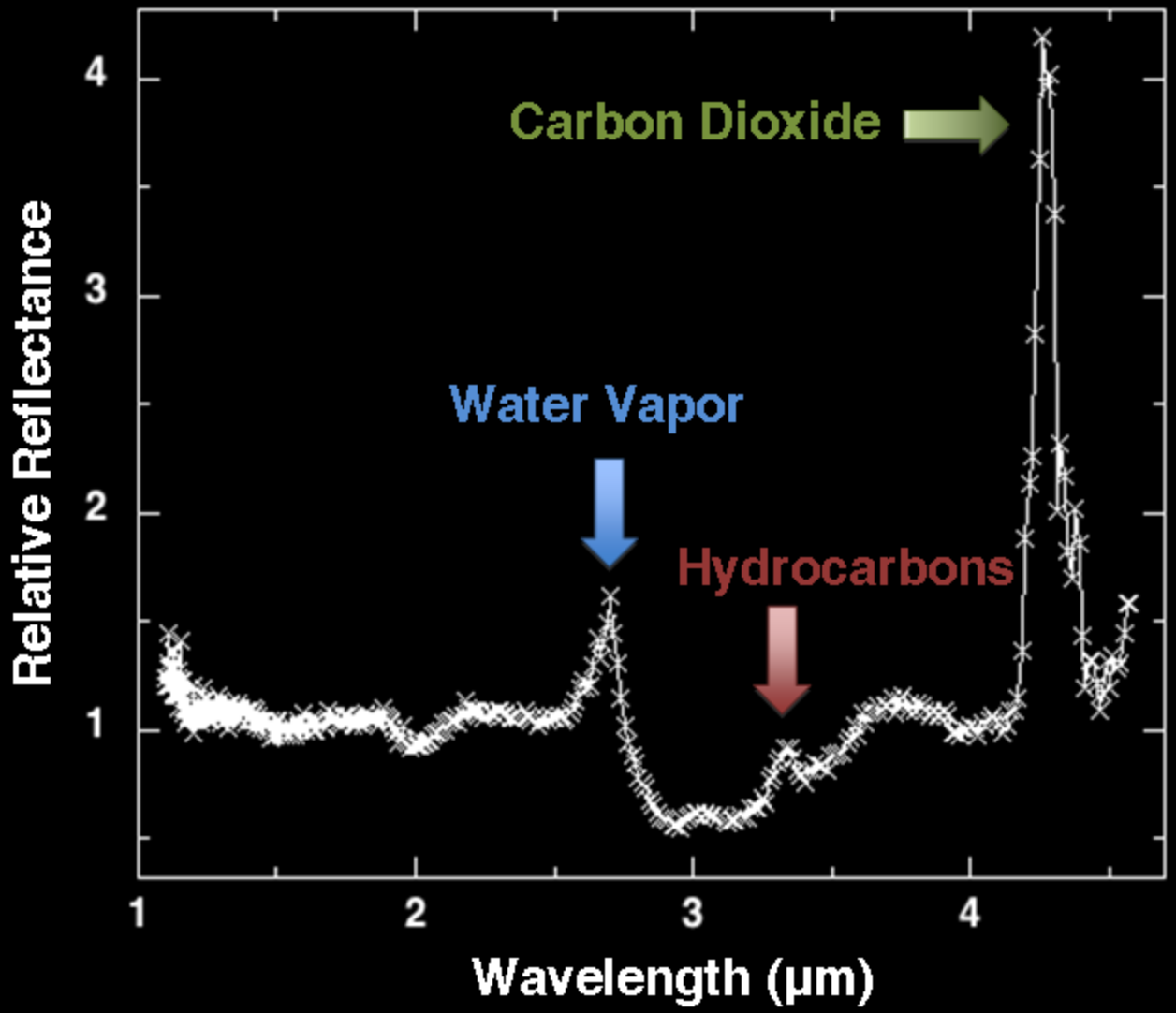
Ice Chunks, Spires, Depressions

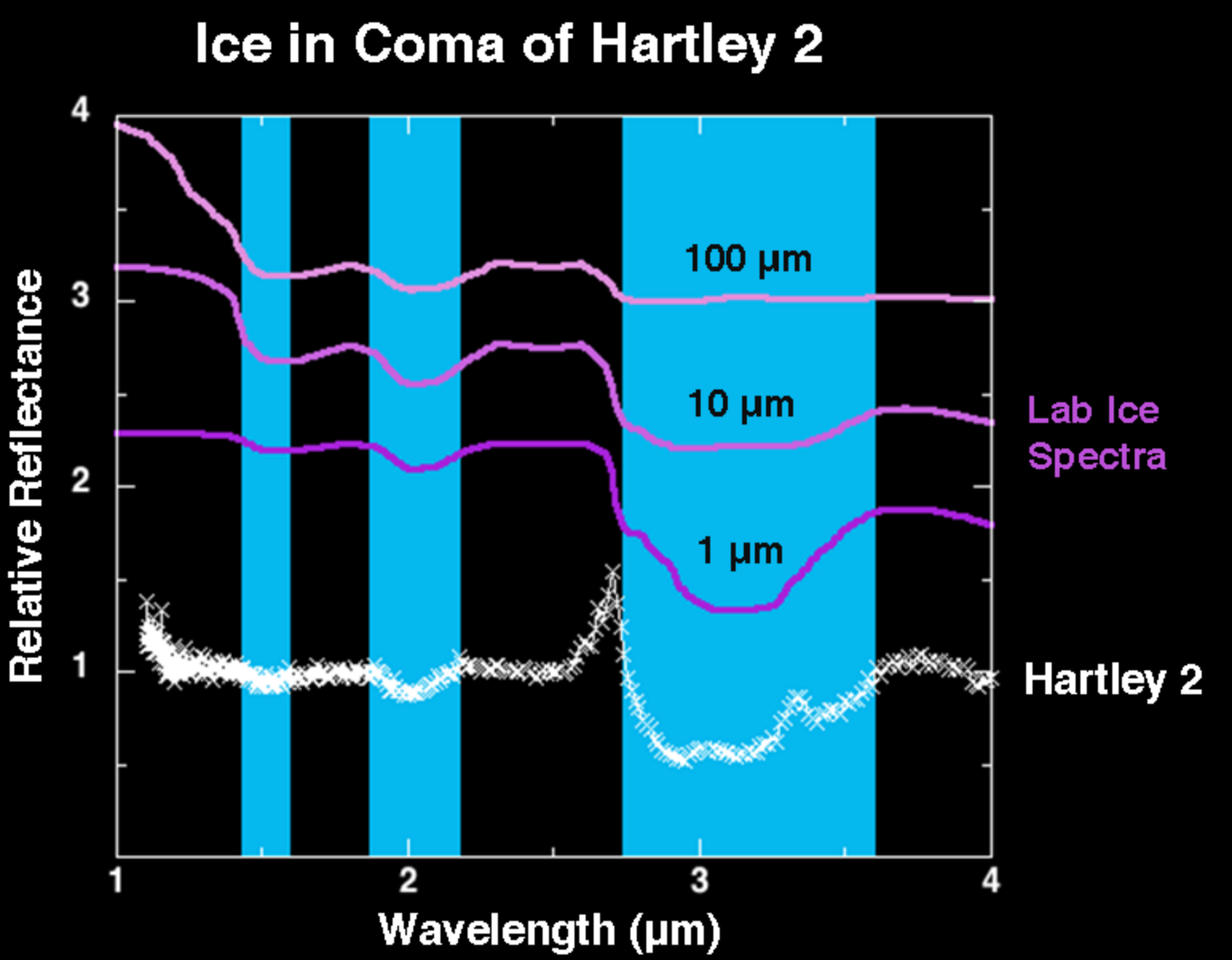
Chunk Motion

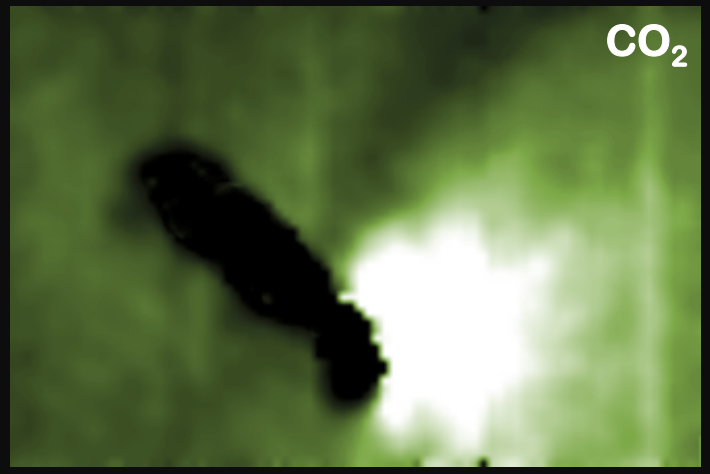


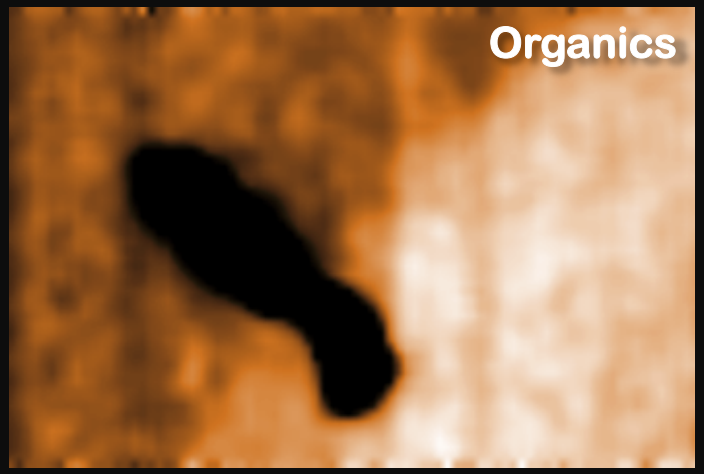
- 50 particles tracked in 10s of images
- Furthest is 28 km
- Most are <15 km
- Fastest <2 m/s
- Most <0.5 m/s
- 10-20% < v_{esc}
- Probably porous, fluffy aggregates, nearly pure

Gases in Coma of Hartley 2




Ice in Coma of Hartley 2
Relative Reflectance
Wavelength (μm)
1
2
3
4
100 μm
10 μm
1 μm
Lab Ice Spectra
Hartley 2

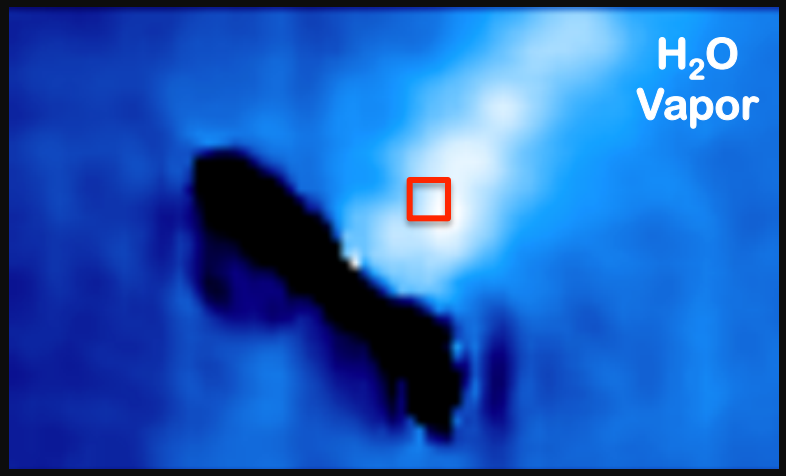


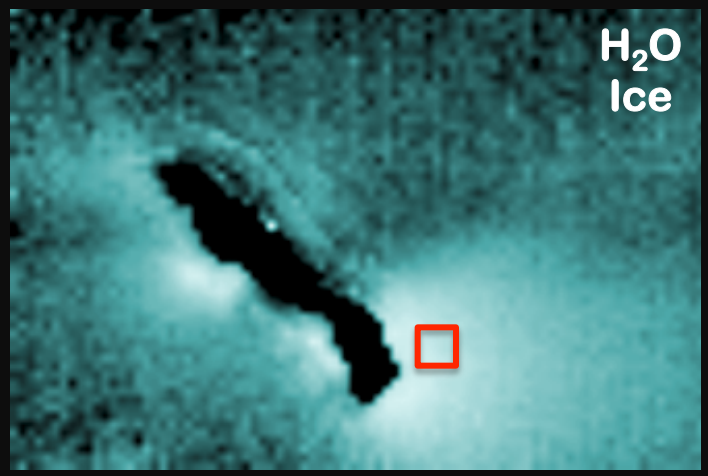


CO_2 3x Ice 10x H_2O 1.5x CO_2:H_2O 3x

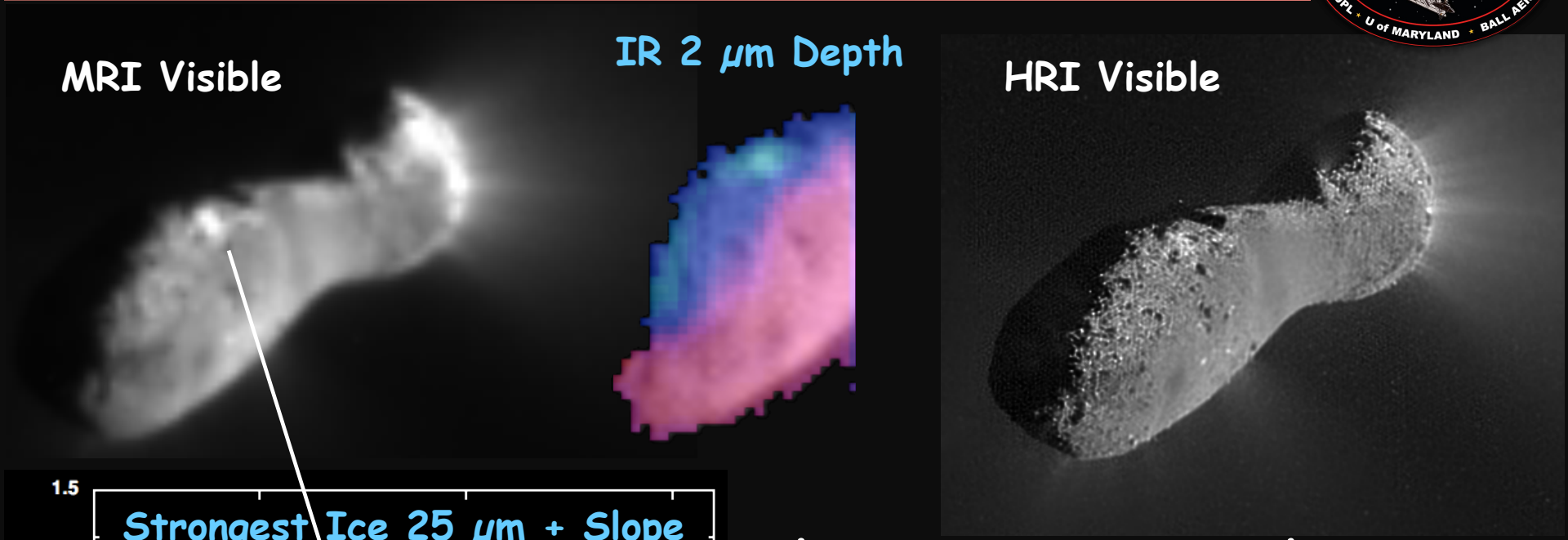
CO_2 ~20% of H_2O at peaks; 10% at minima

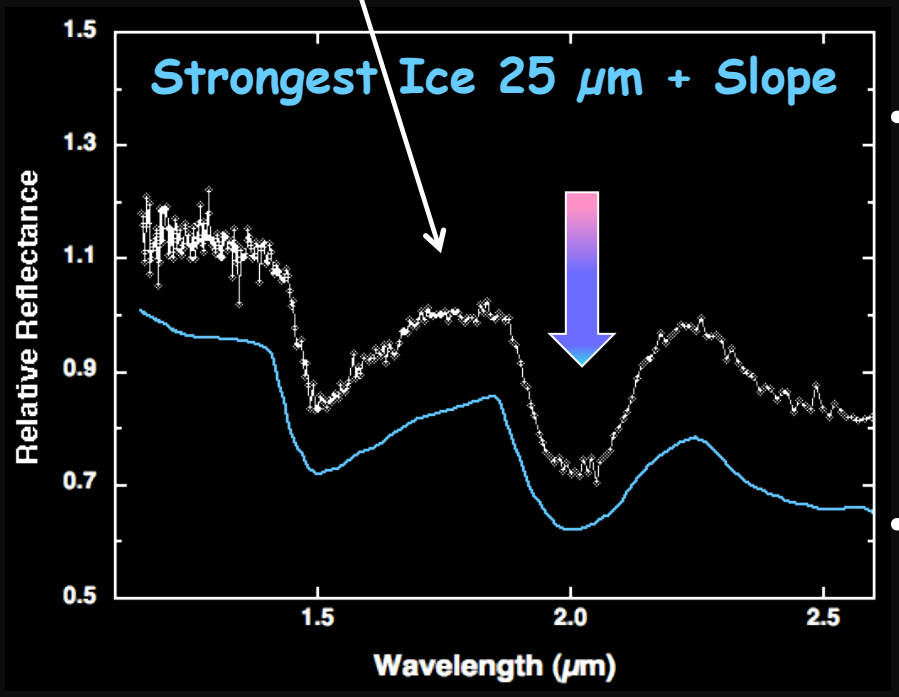
CO <~0.3% (from HST)





Ice in Highest Resolution IR

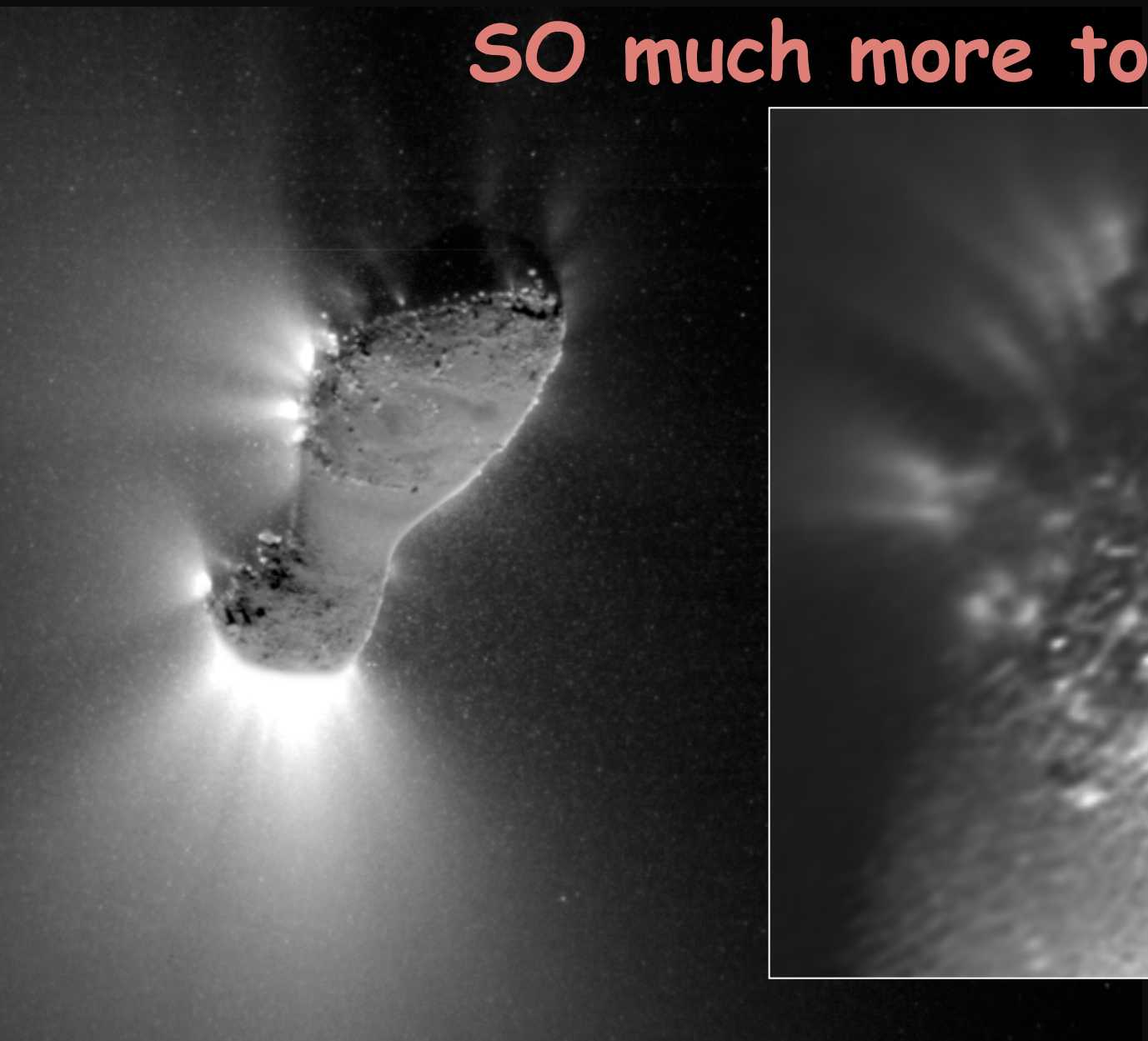


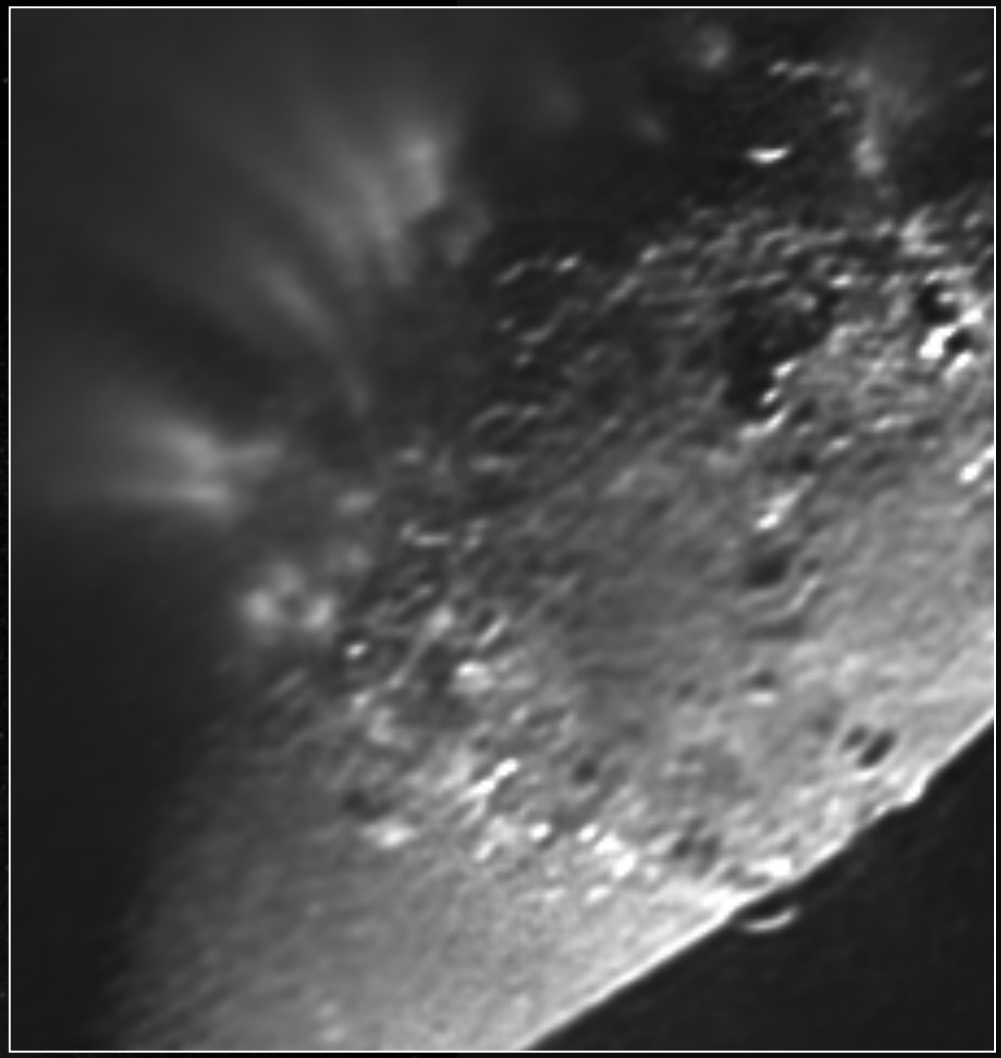


- Clear association with brighter, rougher surface
  - sharp contact
  - topography could provide shading preferentially retain ice
- Long term deposit or short-term re-deposition?

Jet Sources on H2

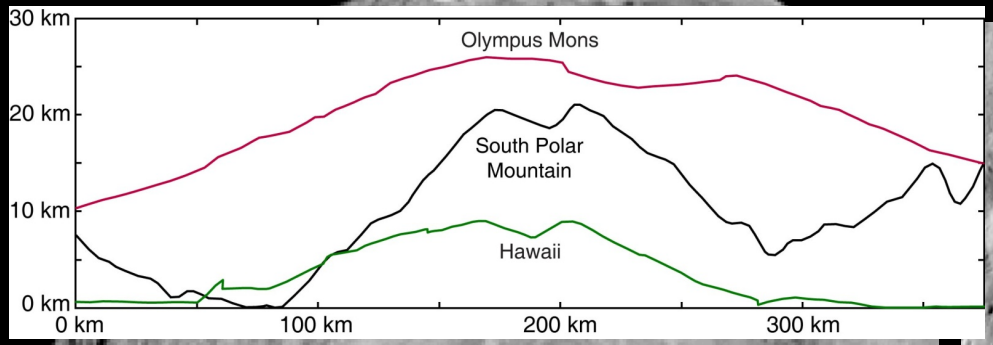
SO much more to do !!

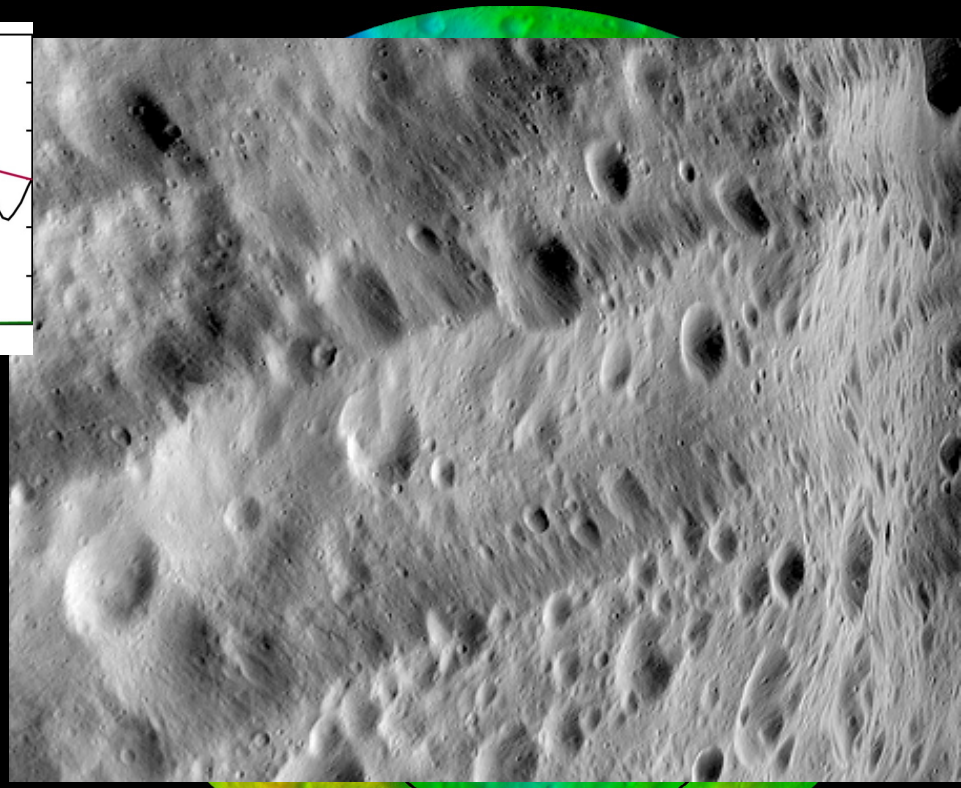




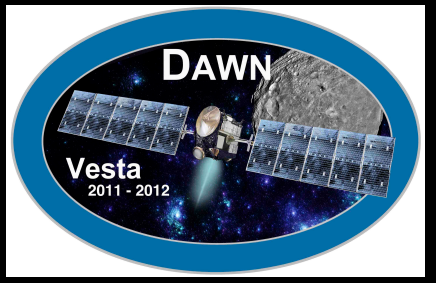
4 Vesta: *Dawn*

- Southern pole has TWO giant impact basins
  - Rheasilvia ~500 km – ~90% of diameter of asteroid!
  - Central mound is one of largest mts. in Solar System
    ~ 22 km from floor of crater
  - Two sets of troughs; impact debris on fast (5.5 hour) rotating body

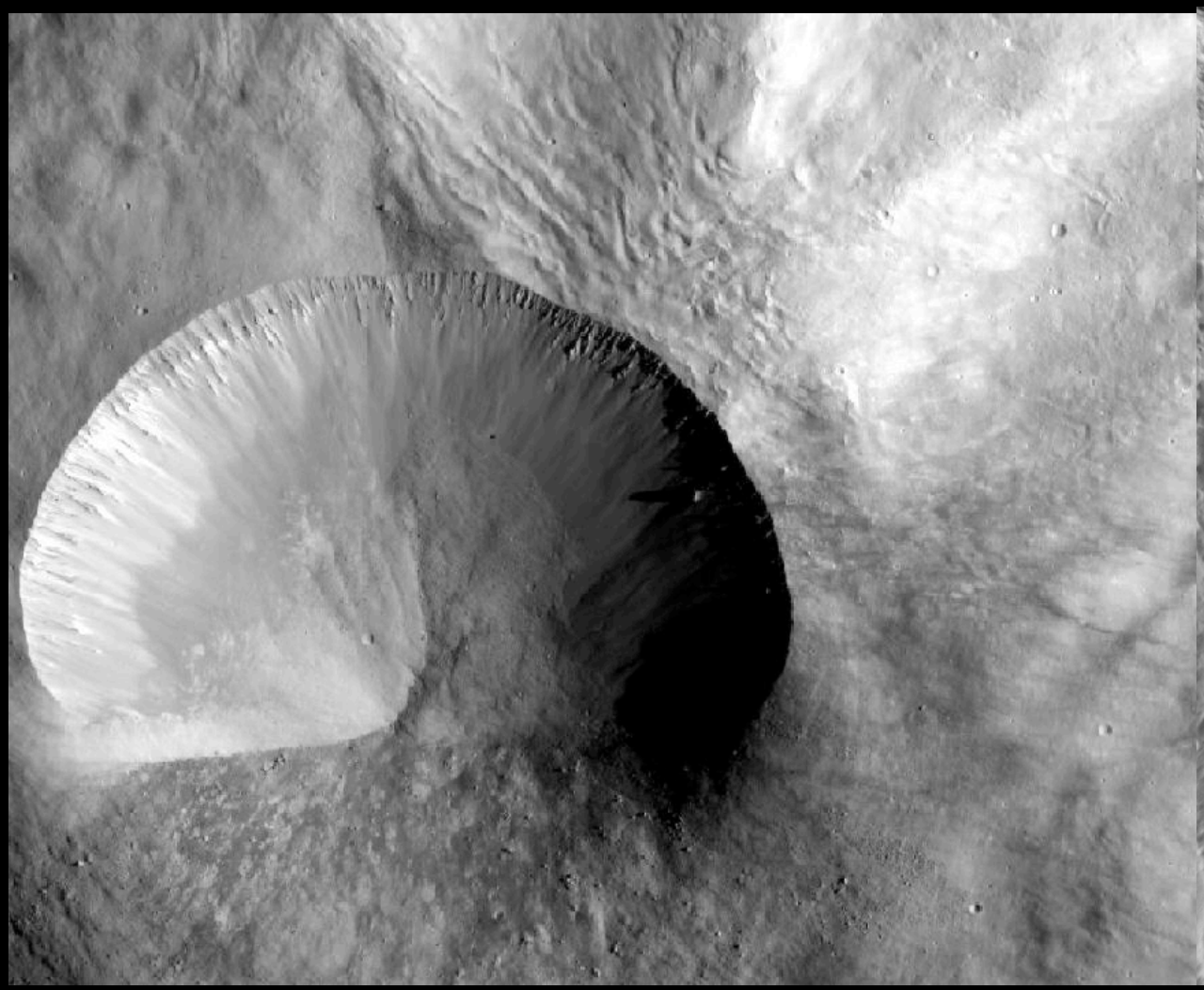


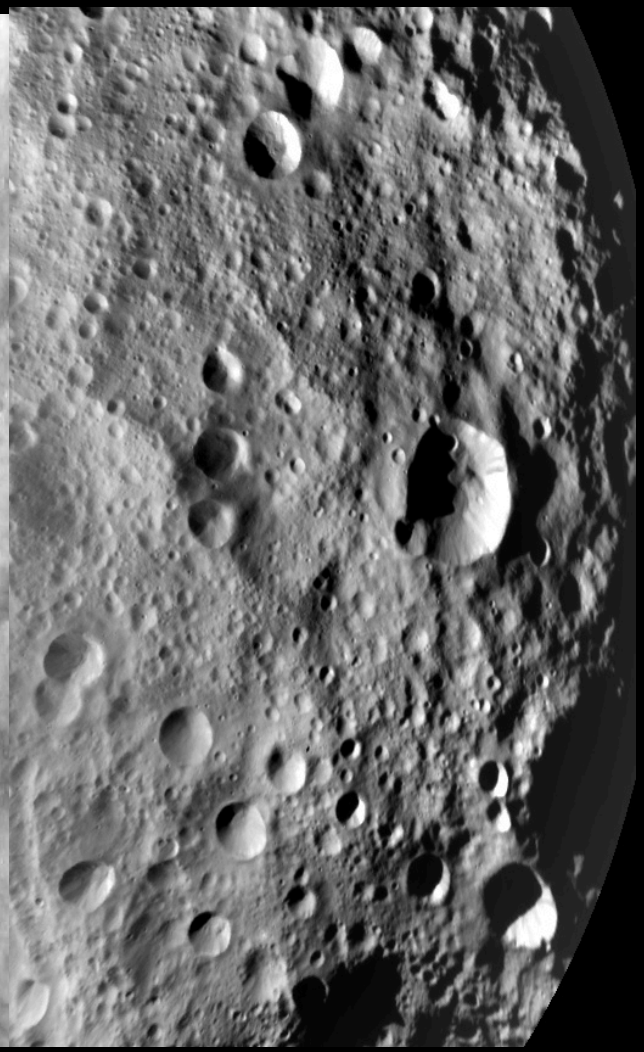


4 Vesta: *Dawn*



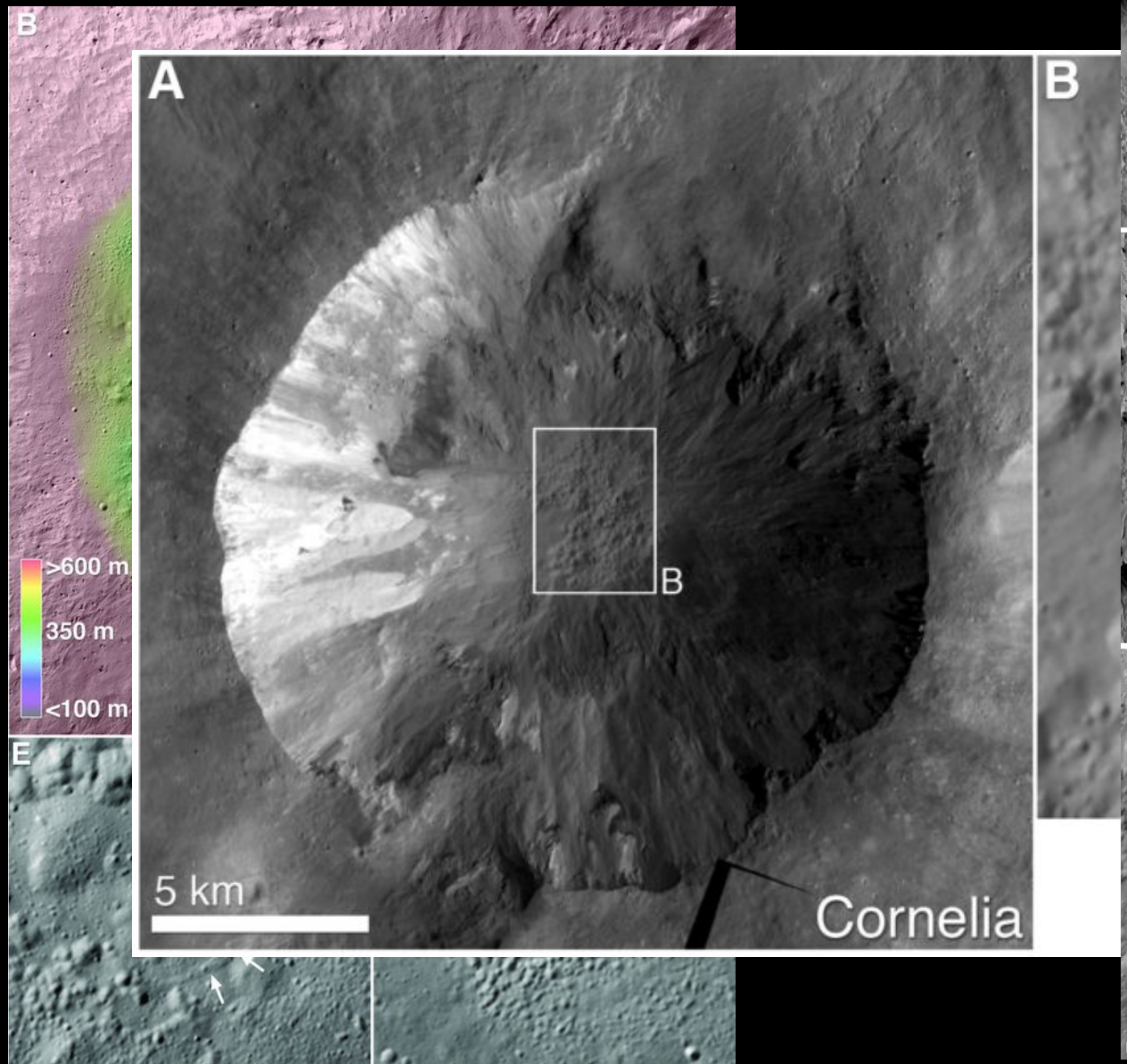
- Gravity shows 100 km core: differentiated body
- Craters in all states – fresh to degraded
- Downslope movement/slumping

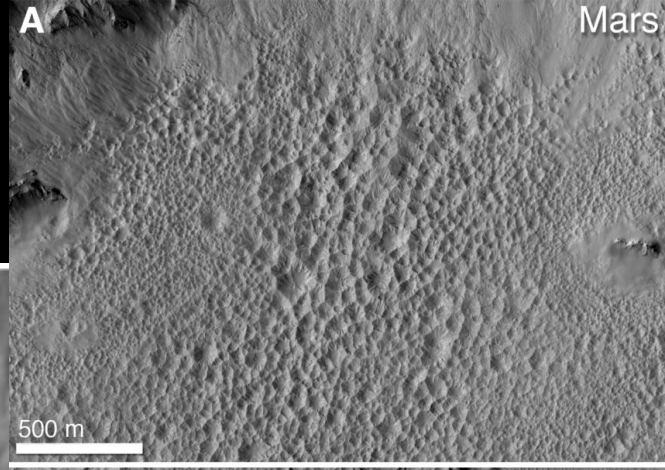


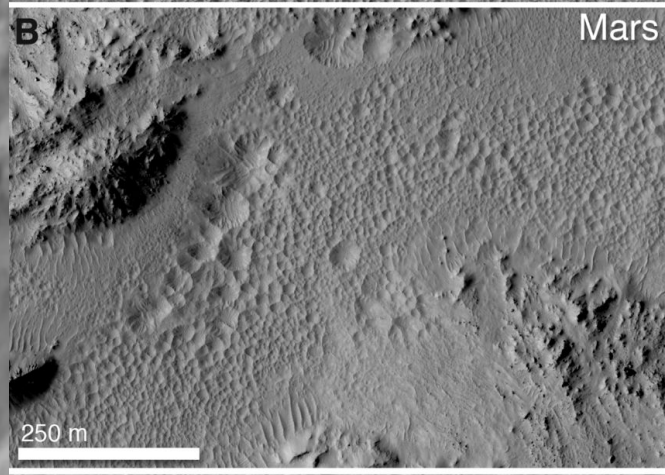


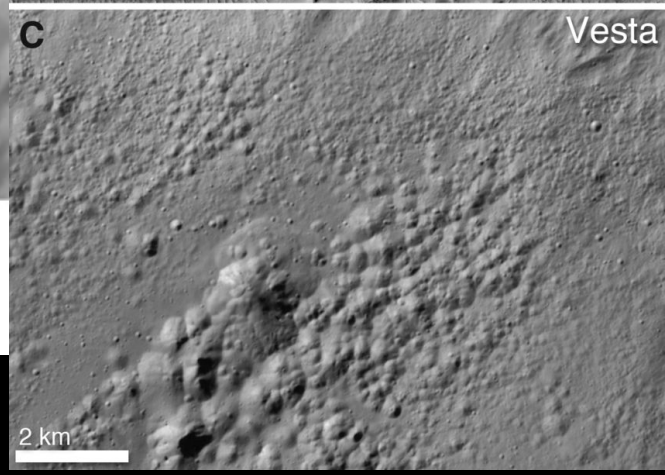
4 Vesta: *Dawn*

- Pitted terrain and water!! (*Science*, 2012)









B W Denevi et al. Science 2012;338:246-249

Colorizing the Solar System