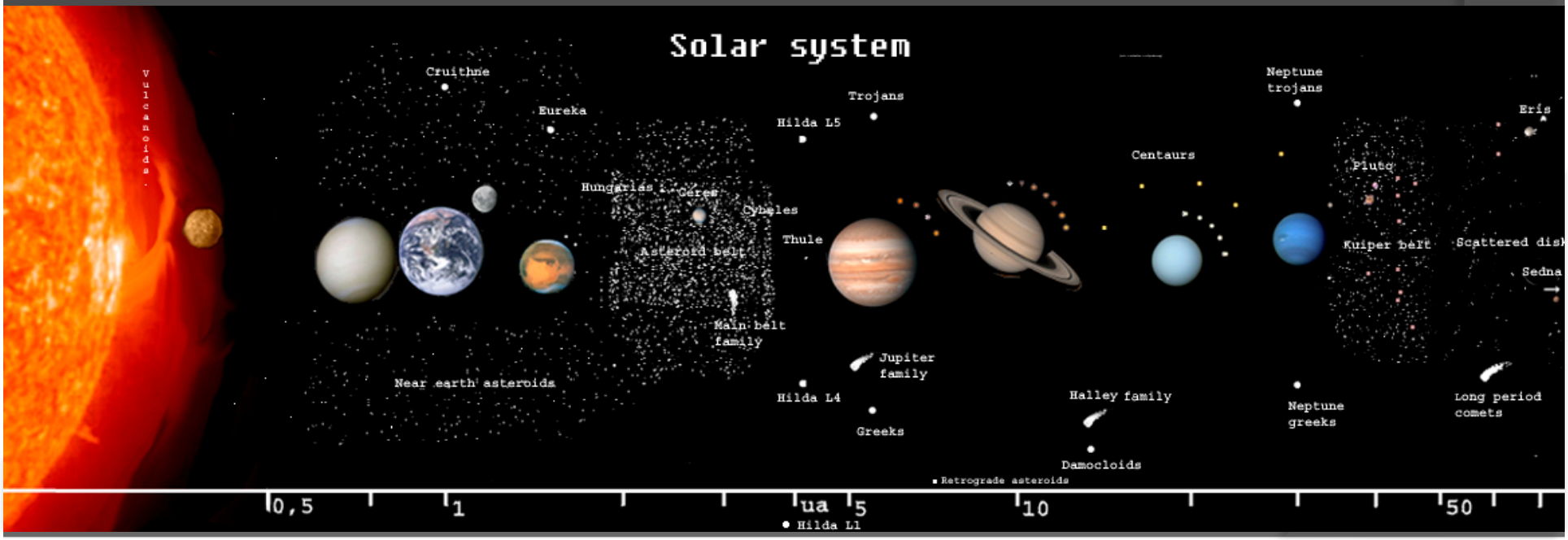
Research with Jian-Yang Li

WHAT DO I (WE) DO IN PLANETARY ASTRONOMY

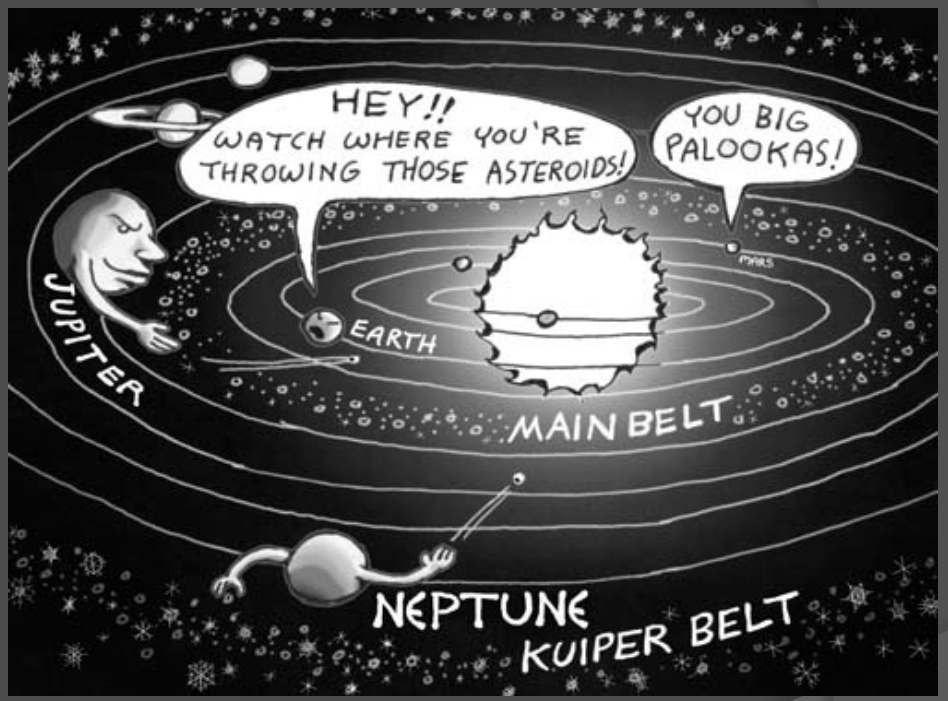
Planetary Astronomy

- Study planetary system(s)
  - Solar system formation and evolution
  - Other planetary systems

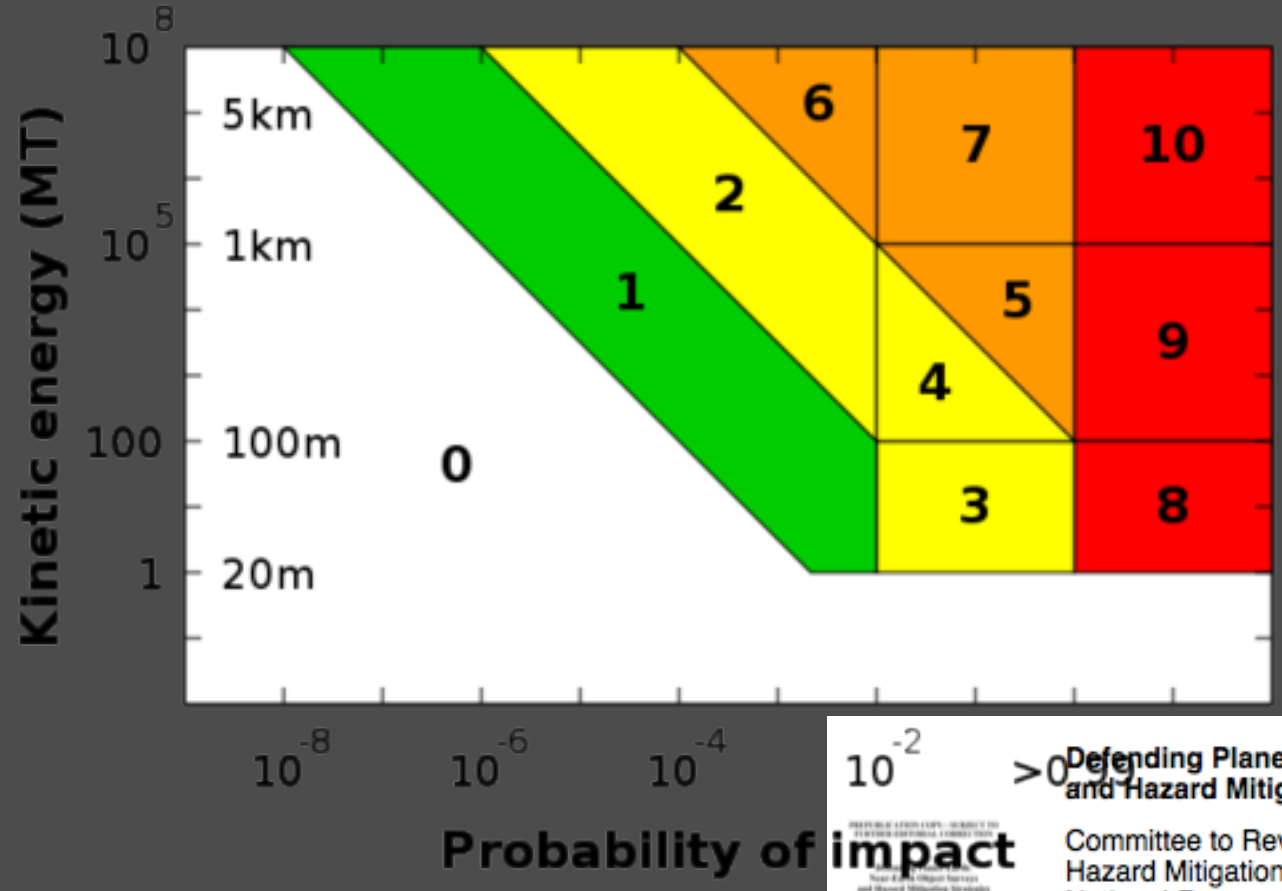


Solar system small bodies

- Building blocks of planetary system
- Vehicles of volatiles and organics
- Potential impact hazardous



Impact hazardous



99942 Apophis (350 m):

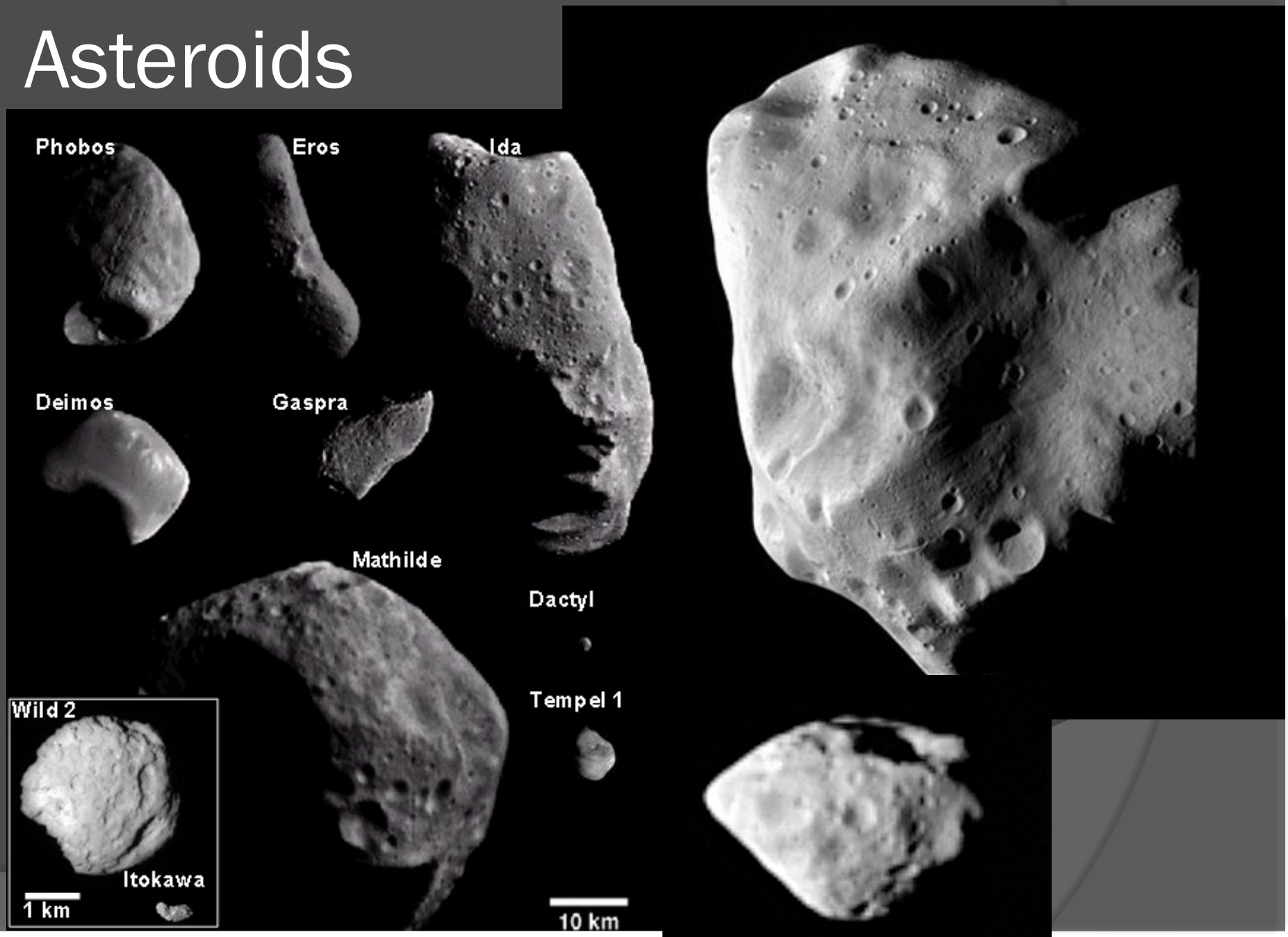
- 2 at discovery
- Upgraded to 4
- Down to 0 now

Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies: Final Report

Committee to Review Near-Earth Object Surveys and Hazard Mitigation Strategies Space Studies Board; National Research Council

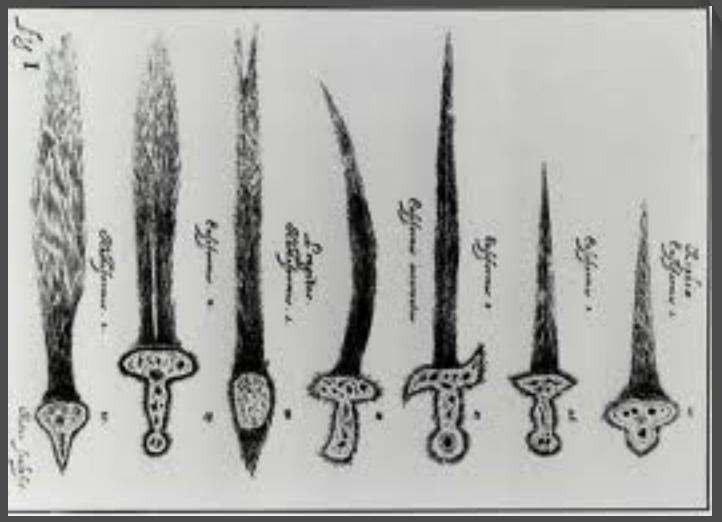
ISBN: 0-309-14969-X, 136 pages, 8 1/2 x 11, (2010)

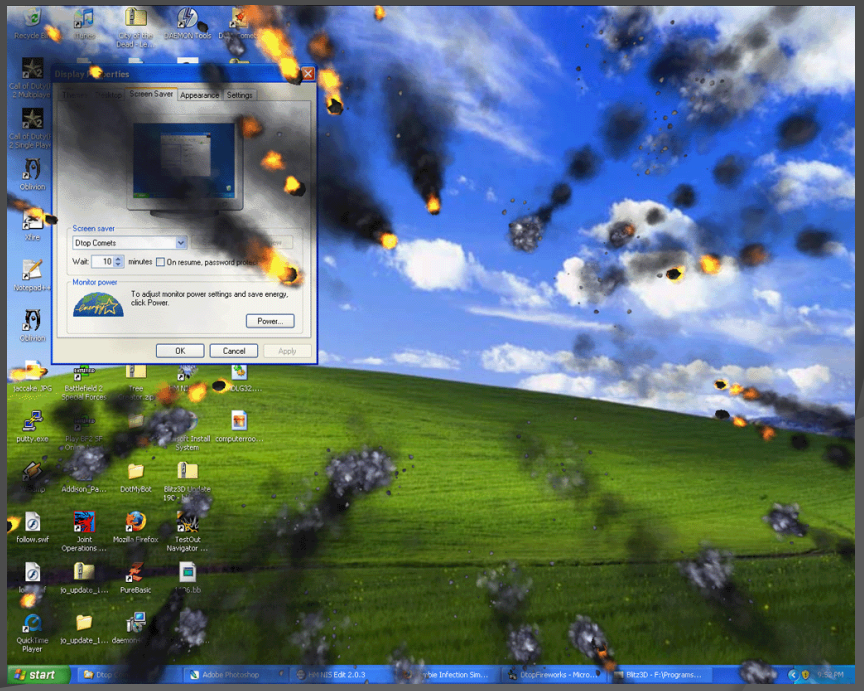
Asteroids


Phobos
Eros
Ida
Deimos
Gaspra
Mathilde
Dactyl
Tempel 1
Wild 2
Itokawa
1 km
10 km

Comets


Fundevit 1857.
L'Apparition Foudroyante et Désastreuse de la Comète du 13 Juin 1857

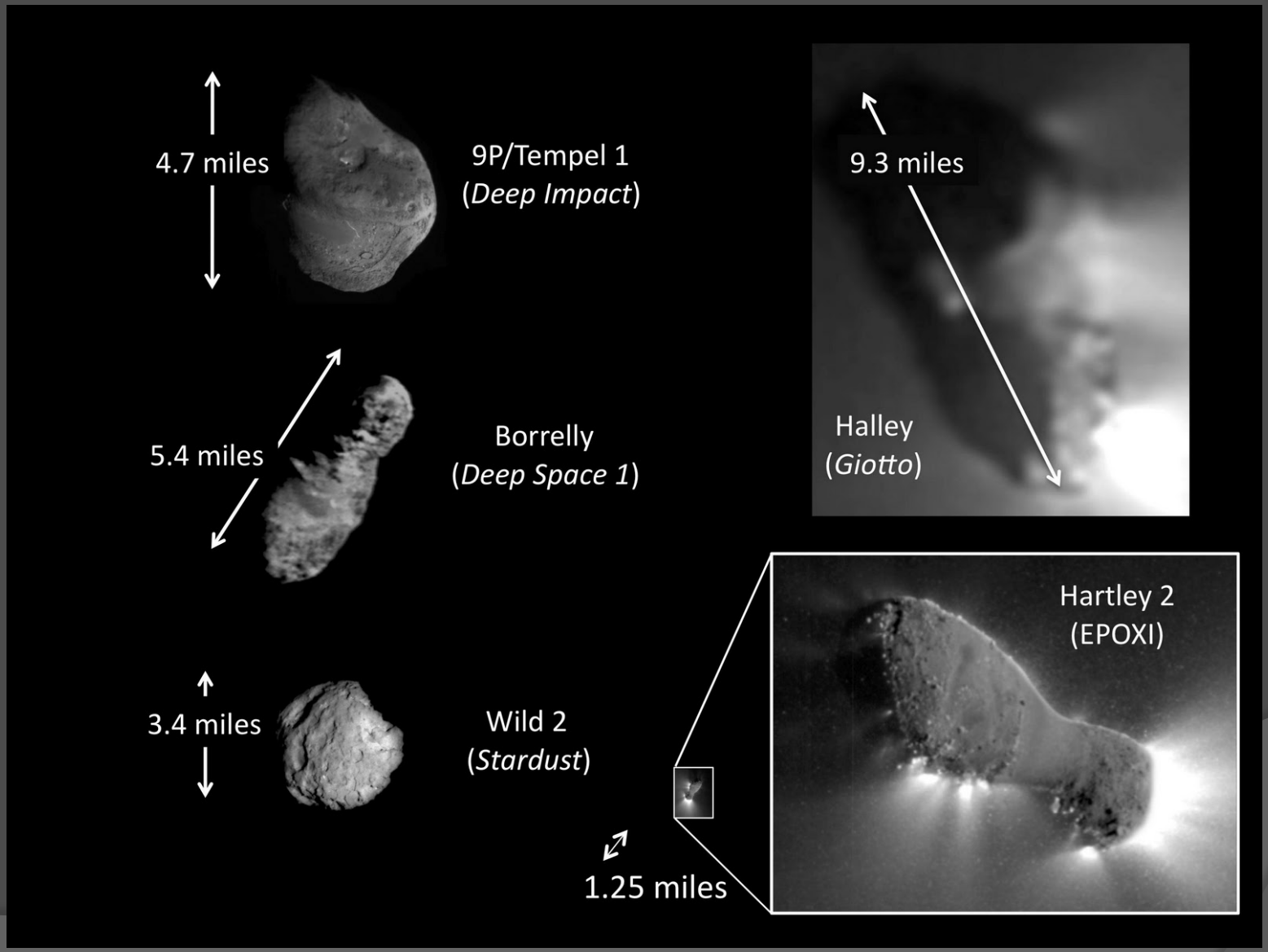



Display Properties
Screen Saver
Appearance
Settings
Screen saver
Dtop Comets
Wait: 10 minutes
Monitor power
To adjust monitor power settings and save energy, click Power.
Power...
OK
Cancel
Apply
start

Comets

Photo credit: Hannes Pieterse, Astronomical Society - Bloemfontein
© Hannes Pieterse, Bloemfontein, South Africa
e-mail: pieterse@polka.co.za
Comet C/2006 P1 McNaught 20 km West from Bloemfontein.
Friday, 19/01/2007; 20:39. 30 Second exposure.

Comets


4.7 miles
9P/Tempel 1
(*Deep Impact*)
9.3 miles
Halley
(*Giotto*)
5.4 miles
Borrelly
(*Deep Space 1*)
3.4 miles
Wild 2
(*Stardust*)
Hartley 2
(EPOXI)
1.25 miles

NASA Discovery Missions

Eleven Discovery Missions have been chosen to date.

Five Discovery Missions of Opportunity have been selected.

NEAR

On February 17, 1996, **Near Earth Asteroid Rendezvous**, **NEAR** was the first Discovery Program spacecraft to be launched and it became the first ever to orbit and land on an asteroid.

More on NEAR...

Mars Pathfinder

The **Mars Pathfinder** mission demonstrated a low-cost method of delivering a set of science instruments and the first free-ranging rover to the surface of Mars.

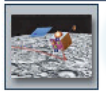
More on Pathfinder...

ASPERA - 3

ASPERA-3 (Analyzer of Space Plasma and Energetic Atoms), an instrument flying on the Mars Express spacecraft, is studying the interaction between the solar wind and the Martian atmosphere.

More on ASPERA-3...

MOON MINERALOGY MAPPER



The **Moon Mineralogy Mapper, or M3**, will fly aboard India's first deep space mission, Chandrayaan-1, and will characterize and map the mineral composition of the Moon at high resolution.

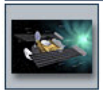
More on M3...

Lunar Prospector

The science data returned from **Lunar Prospector** has enabled scientists to create detailed maps of the gravity, magnetic properties and chemical composition of the Moon's entire surface.

More on Prospector...

Stardust



The **Stardust** spacecraft collected interstellar dust and comet dust during a close encounter with Comet Wild 2 and returned the particles to Earth for analysis by scientists worldwide.

More on Stardust...

EPOXI

EPOXI is an extension of the Deep Impact mission that will search for planets around other stars and observe a new comet.

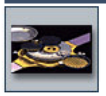
More on EPOXI...

Stardust-NExT

The **Stardust New Exploration of Tempel 1, or NExT**, mission will use the Stardust spacecraft to revisit Comet Tempel 1, the target of the Deep Impact mission.

More on Stardust-NExT...

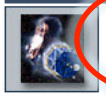
Genesis



The **Genesis** spacecraft spent two years collecting atoms of solar wind before returning them to Earth in September 2004 for detailed analysis.

More on Genesis...

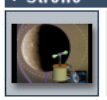
CONTOUR



The **Comet Nucleus Tour**, or **CONTOUR**, mission was going to encounter and study two diverse comets during their periodic visits to the solar system.

More on CONTOUR...

Strofio



Strofio will use a unique mass spectrometer to study the atoms and molecules that compose Mercury's atmosphere to reveal the composition of the planet's surface.

More on Strofio...

MESSENGER

MESSENGER (**ME**rcury **S**urface, **S**pace **EN**vironment, **GE**ochemistry, and **R**anging) mission is a scientific investigation of the planet Mercury.

More on MESSENGER...

Deep Impact

The **Deep Impact** mission propelled a large copper projectile into the surface of a comet, creating a huge crater and yielding new information about the internal composition and structure of a comet.

More on Deep Impact...

DAWN

The Dawn mission is on its way to the oldest and most massive asteroids in our solar system, to give us a glimpse of conditions and processes at the dawn of our solar system.

More on Dawn...

Kepler

Kepler will use a unique telescope to search for Earth-size habitable planets around stars beyond our solar system.

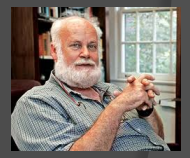
More on Kepler...

GRAIL

The **Gravity Recovery and Interior Laboratory**, or GRAIL, mission will put twin satellites into orbit around the Moon to map the Moon's interior and variations in its gravitational pull & to reconstruct its thermal history.

More on GRAIL...

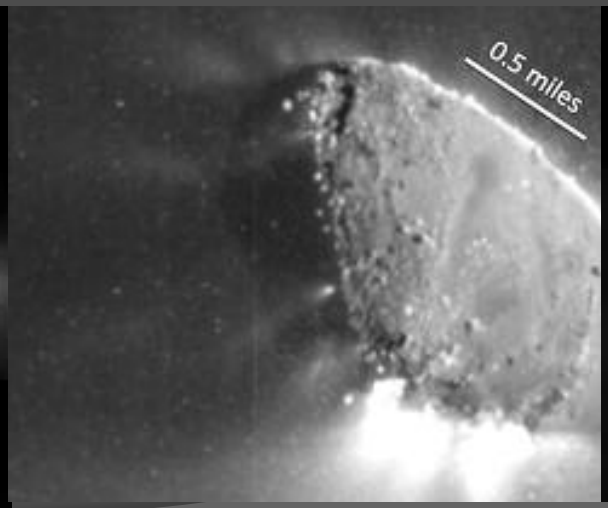
Led by

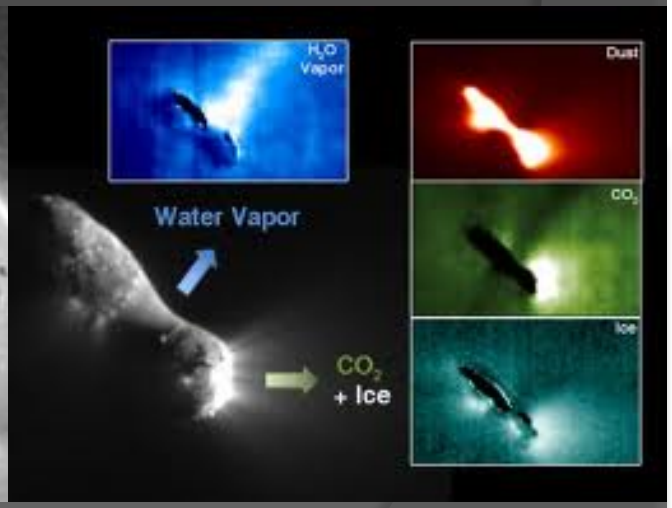


We are

EPOXI

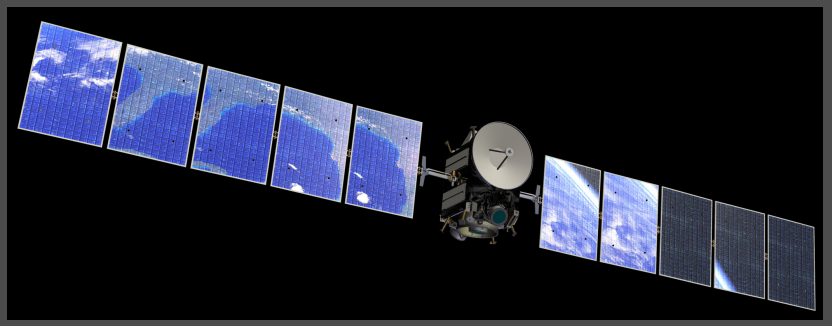
- Epoch
  - Drake Deming (last week?)
- DIXI
  - Jessica Sunshine (next week?)



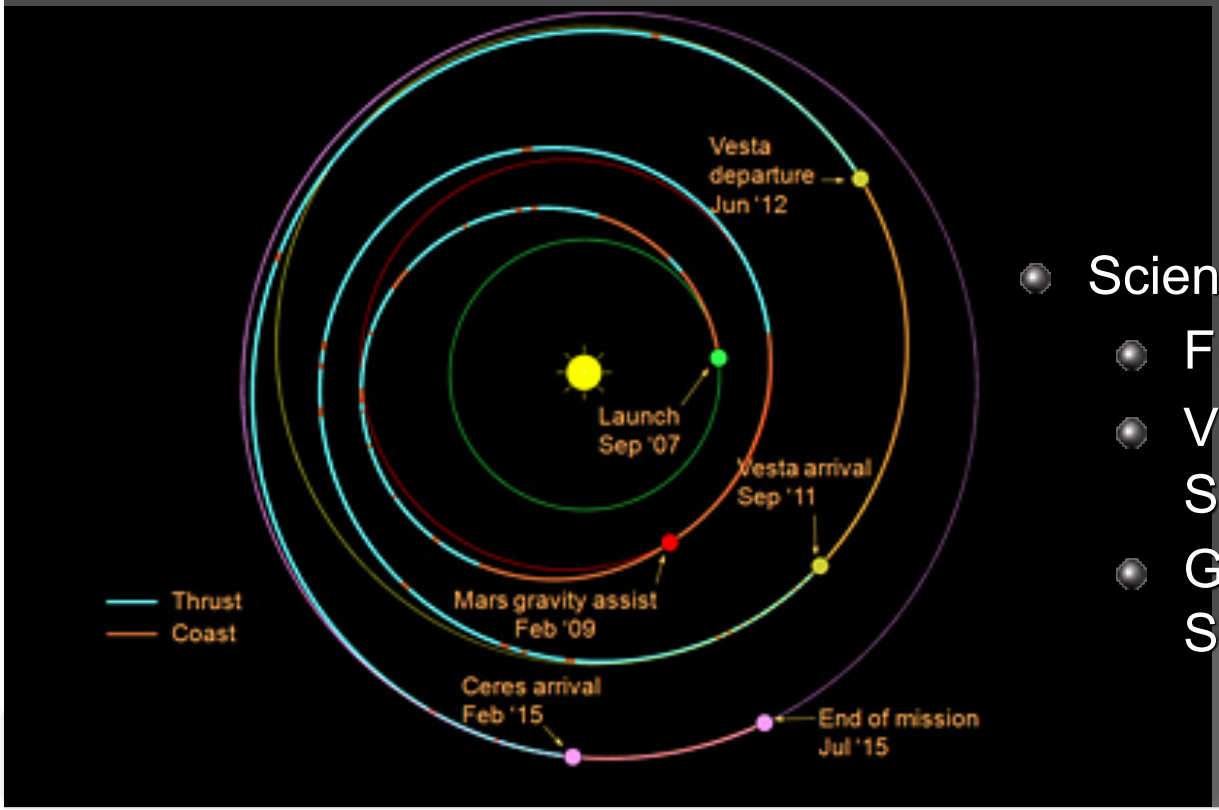


Dawn Mission

Dawn Mission



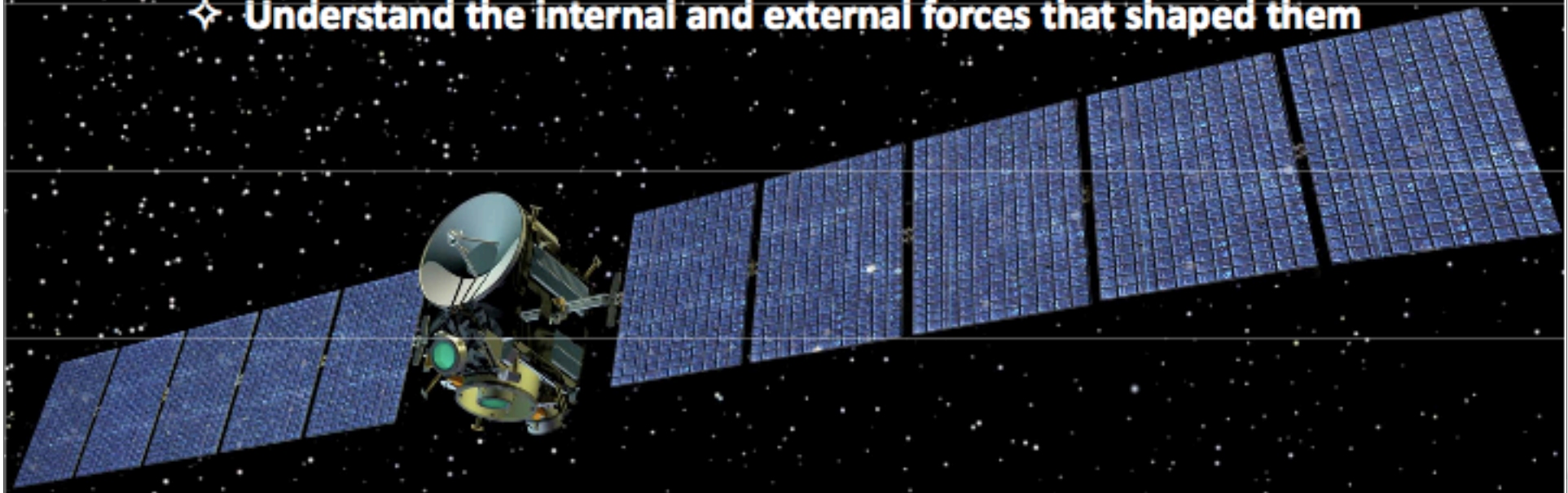
•Double-rendezvous: Vesta and Ceres



- Science Payload:
  - Framing Camera (visible)
  - Visible Infrared Mapping Spectrometer (0.25 – 5 μm)
  - Gamma Ray and Neutron Spectrometer

Dawn will characterize the surfaces of two complementary protoplanets, Vesta and Ceres, and probe their internal structure

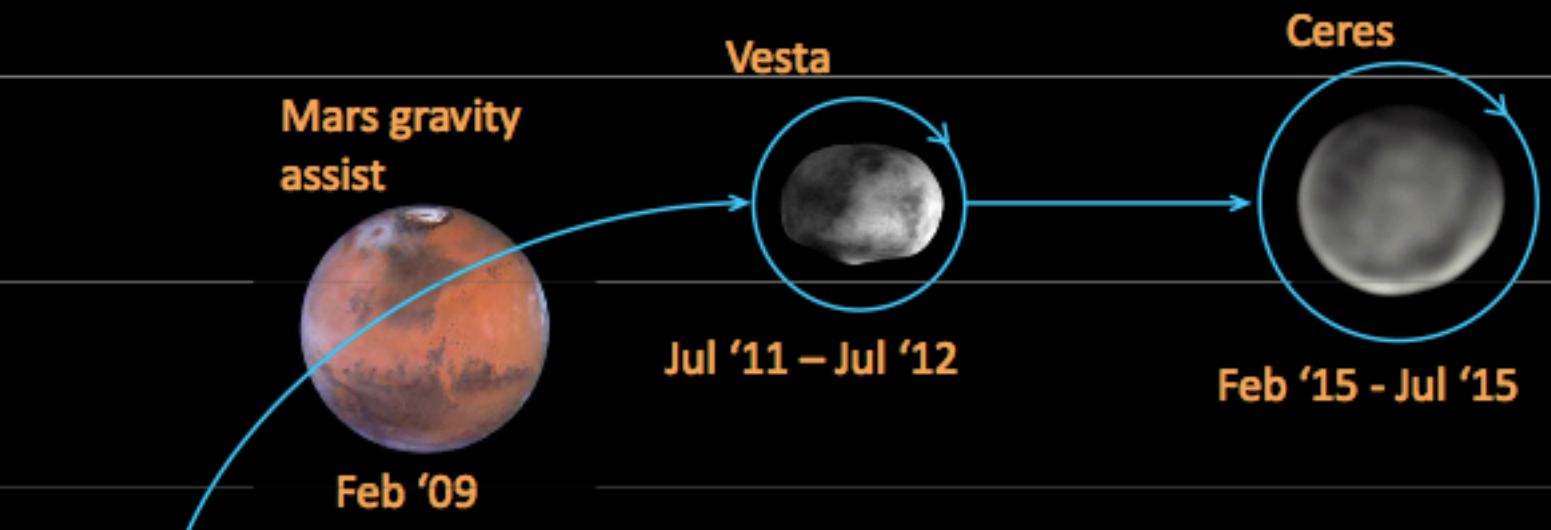
- Map the geologic units
- Create detailed shape models
- Determine how and when the bodies formed
- Understand the internal and external forces that shaped them



Dawn uses ion propulsion to explore the main asteroid belt

- 425 kg of xenon imparts a Δv of 11 km/s
- IPS operates for > 50000 hrs during mission

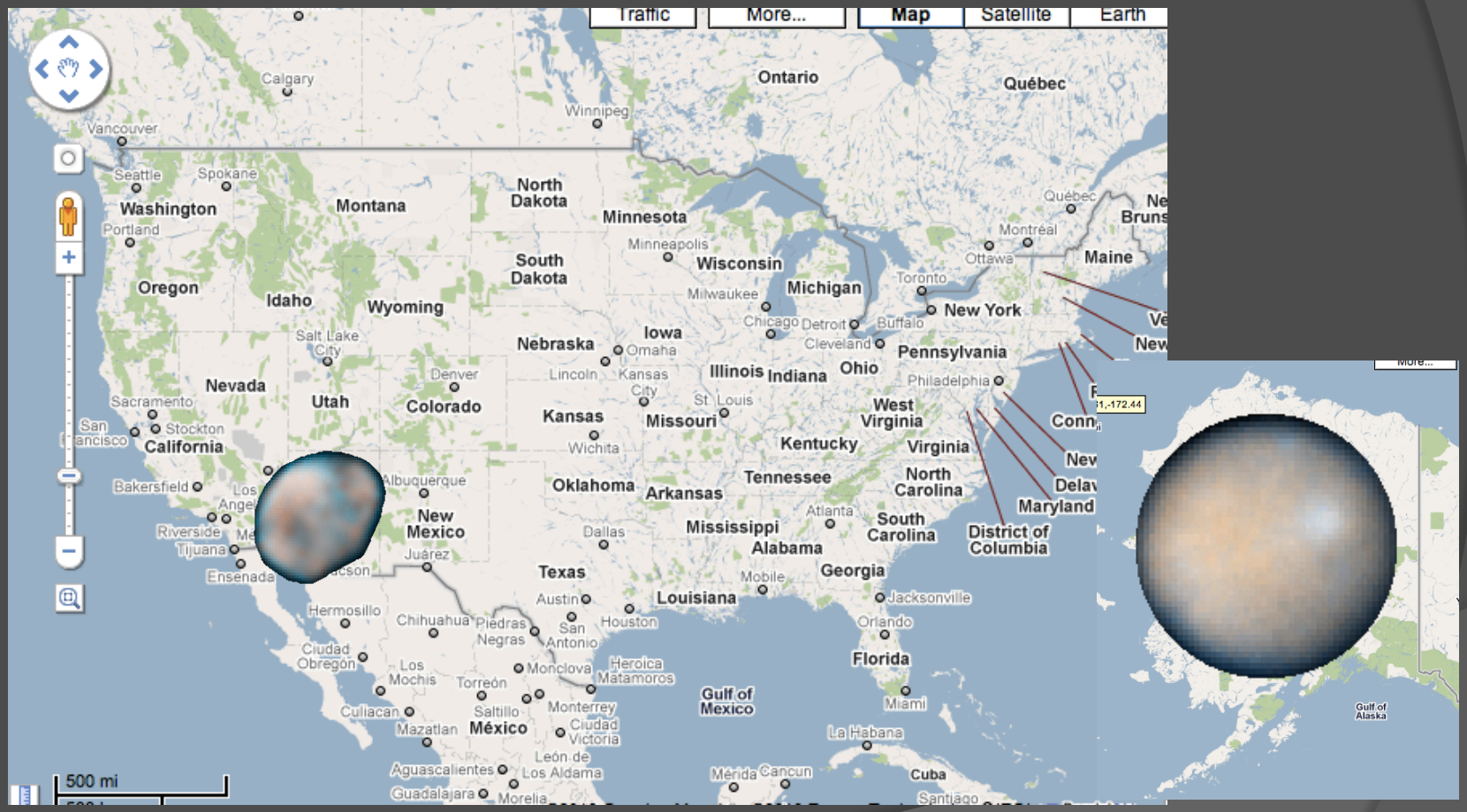
Mission Itinerary



At each target, Dawn will:

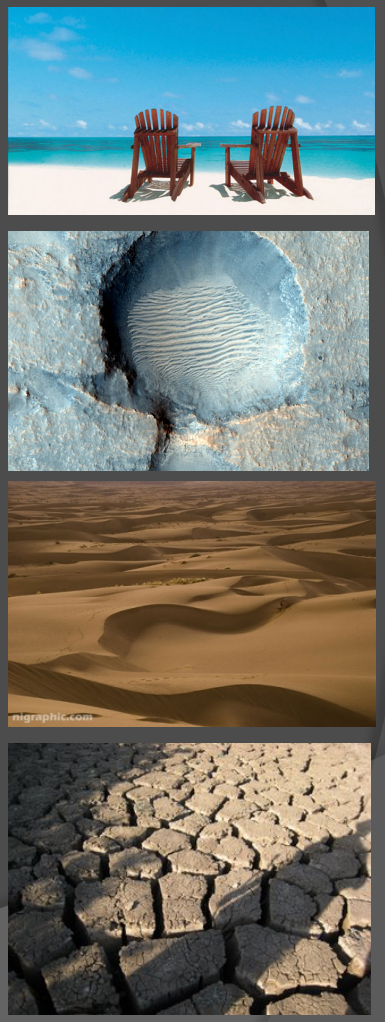
- Acquire color photographs
- Compile a topographic map
- Map the elemental composition
- Map the mineralogical composition
- Measure the gravity field

Vesta and Ceres



Vesta and Ceres

- Ceres is wet
  - Show evidence of compositional water (25%)
  - Phyllosilicates, carbonates, magnesium hydroxide
  - Water has played an important role in its evolution
- Vesta is dry
  - Undergone intense heating, driven out all volatiles
  - Differentiation, basaltic surface
  - Source of HED meteorites
- Two objects have distinctively different formation environments and paths
  - Ceres more like outer solar system small bodies and icy bodies
  - Vesta more like inner solar system terrestrial planet – the smallest terrestrial planet

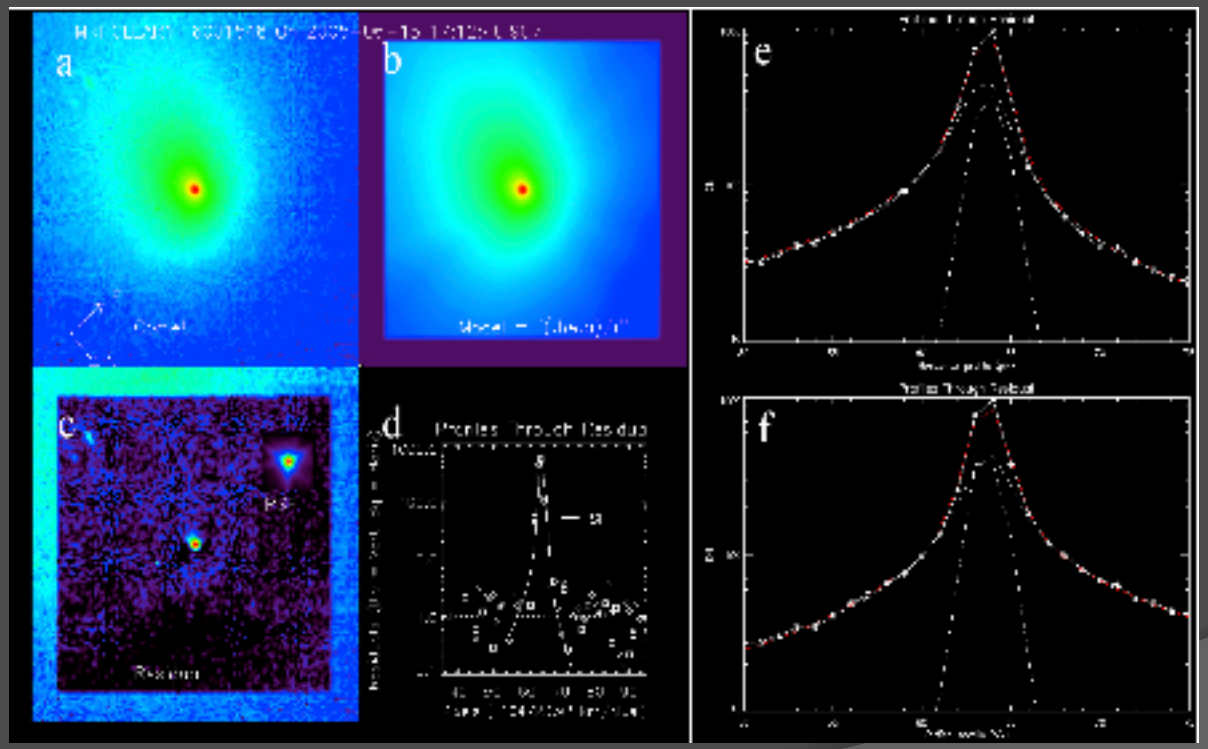


Potential projects

- Phase function of cometary nuclei
  - Separation of cometary nuclei and coma
  - Construct and model phase function
- Vesta surface mapping
  - Develop general mapping tool (not from scratch)
  - Map Vesta with low-resolution Dawn data
- Vesta rotation
  - Precisely measure the rotation of Vesta using Dawn data
- High-contrast imaging on asteroids
  - Search for companions
  - New for extended sources

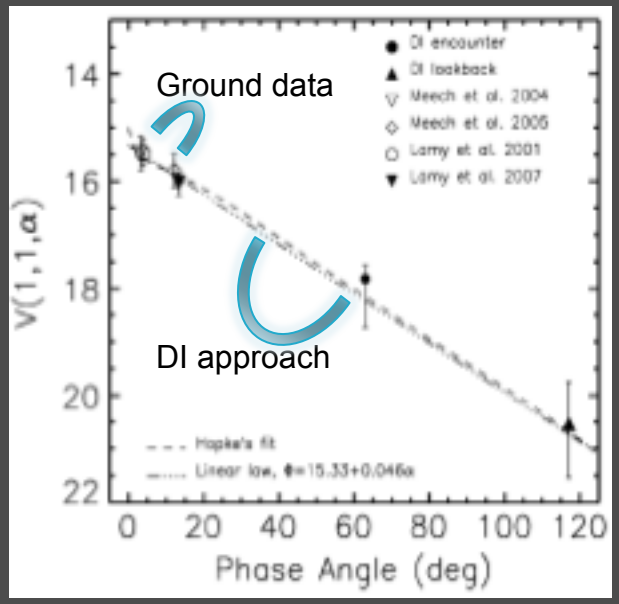
Photometry of cometary nuclei

- Separation of nucleus from coma

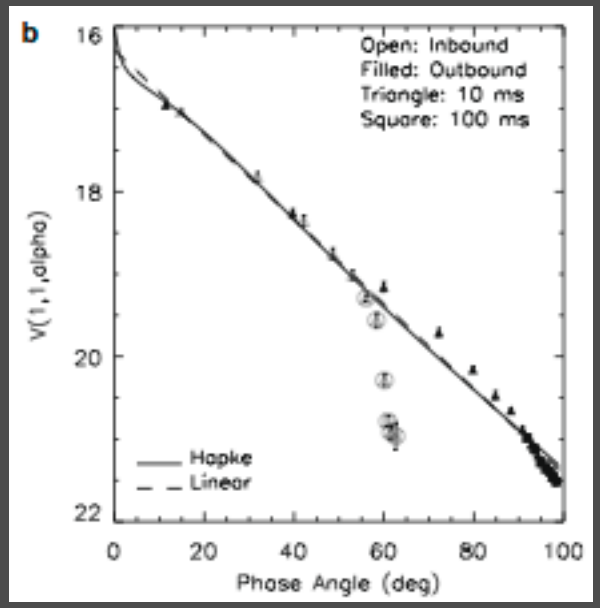


Photometry of cometary nuclei

- Construct and model the phase function



Tempel 1 (Li et al., 2007)



Wild 2 (Li et al., 2009)

Vesta mapping

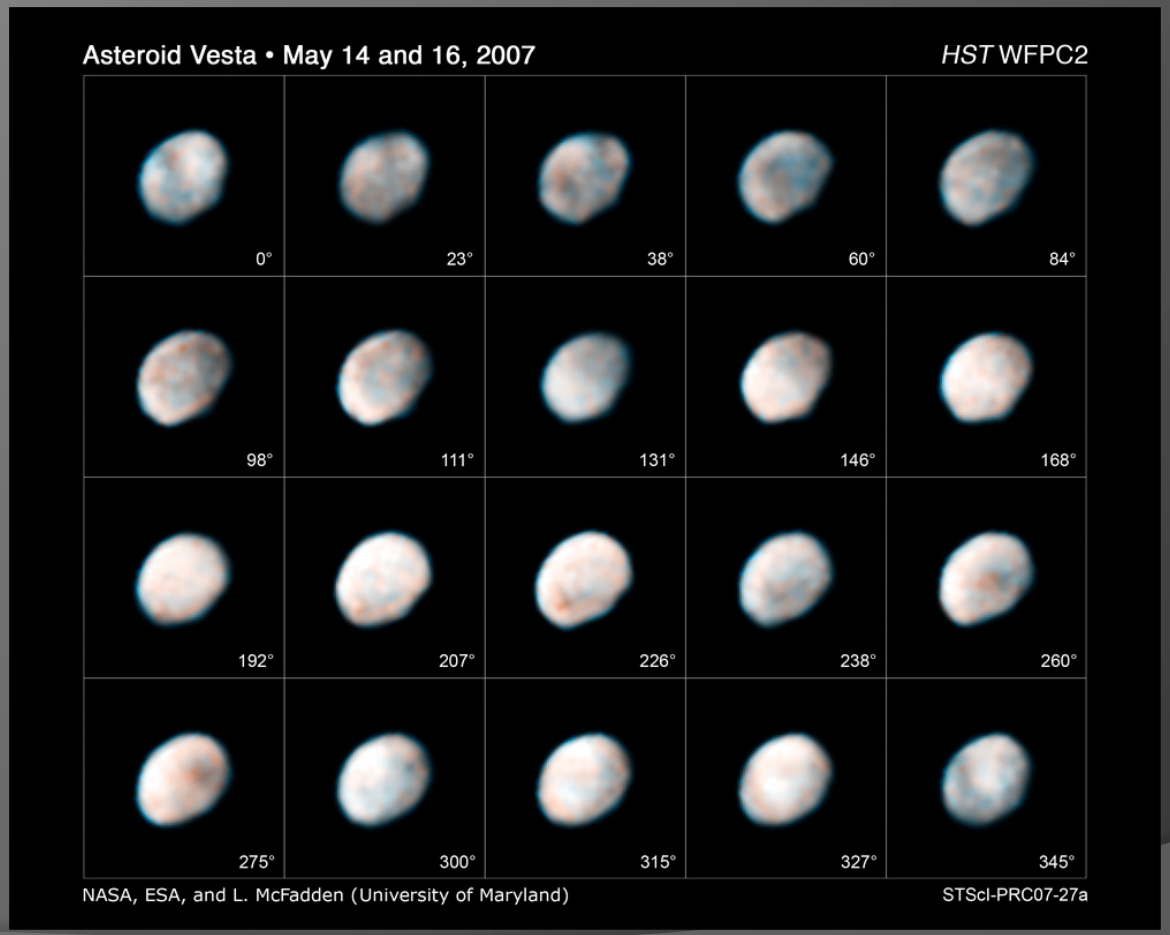
- Photometric properties of Vesta
  - How reflectance changes with illumination and viewing geometry
  - Fundamental properties of the surface, albedo, particle impurity, roughness
  - Photometric mapping (albedo/color, roughness)
- Mission support
  - Photometric correction for images and spectra
  - Data archive

Naked-eye Asteroid

Wikipedia (http://en.wikipedia.org/wiki/Image:Asteroid_Vesta.jpg), by Mila Zinkova

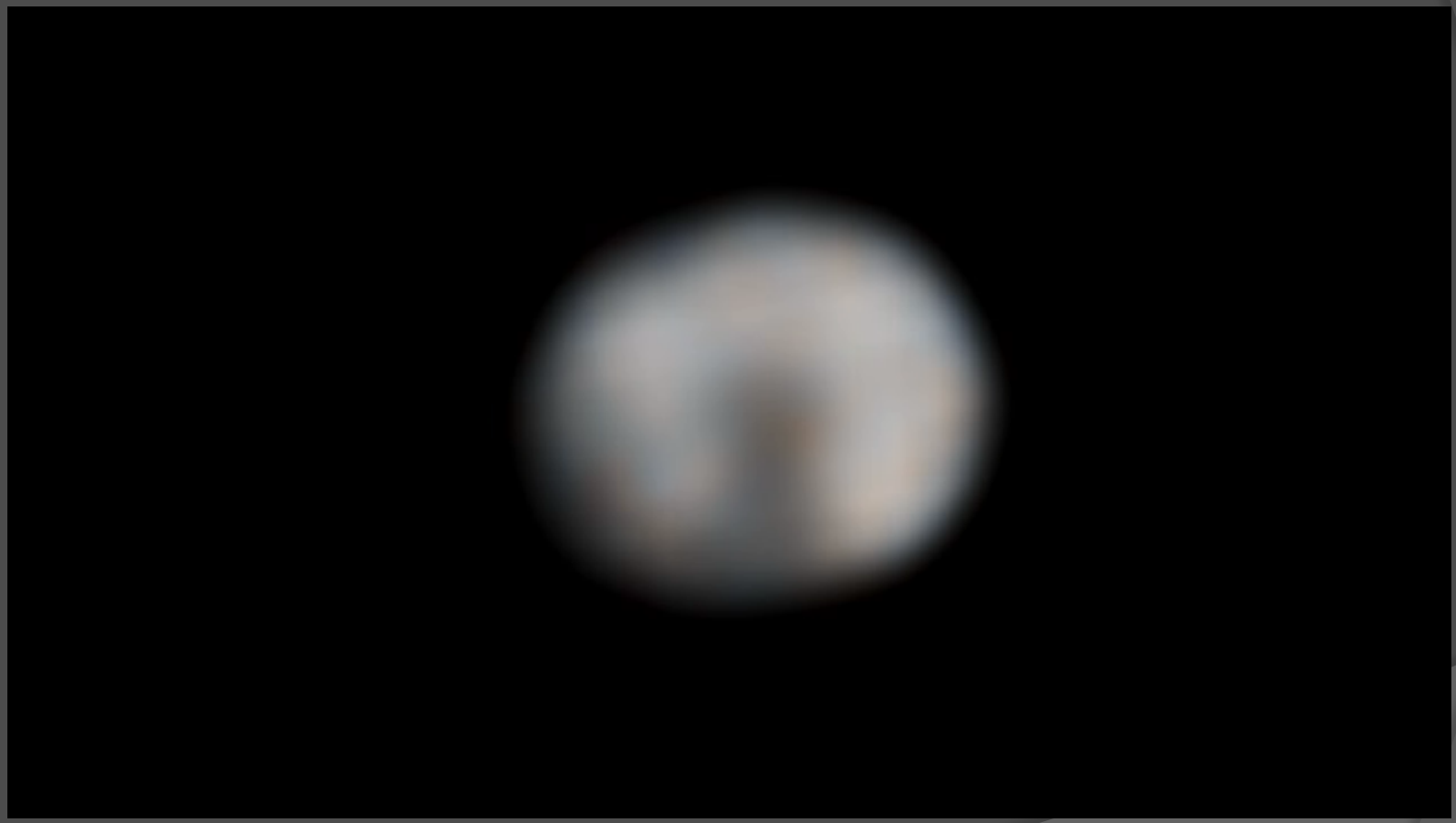
Will be 5.6 mag in Aug 2011 during Dawn's arrival in the constellation of Capricornus

HST/WFPC2 2007



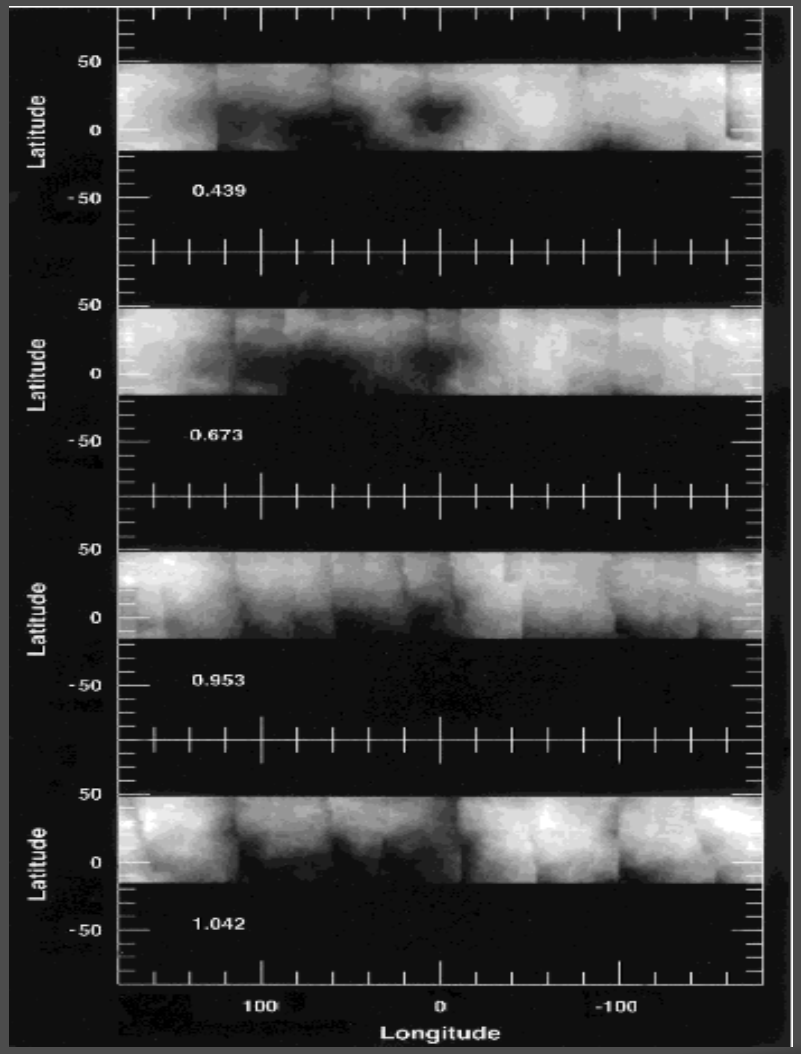
http://hubblesite.org/newscenter/archive/releases/2007/27/

HST/WFC3 2010

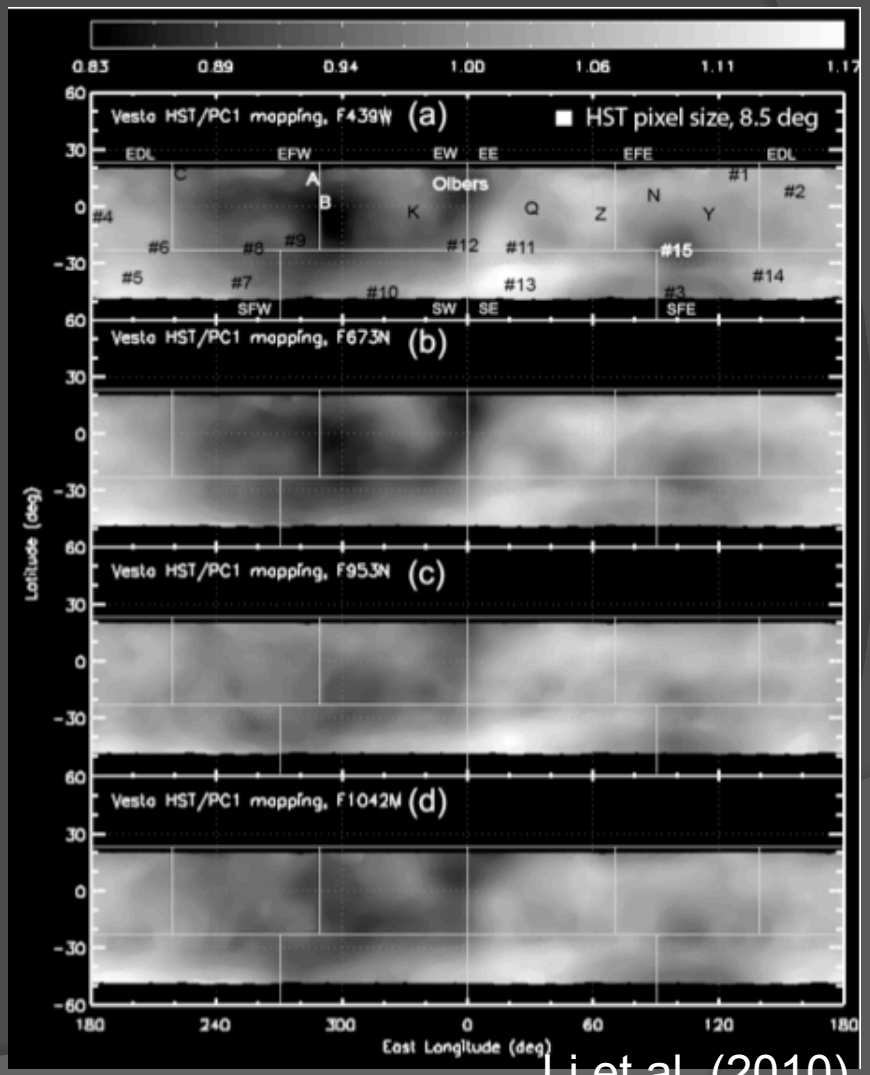


http://hubblesite.org/newscenter/archive/releases/2010/33/image/

Current maps



Binzel et al. (1997)



Li et al. (2010)

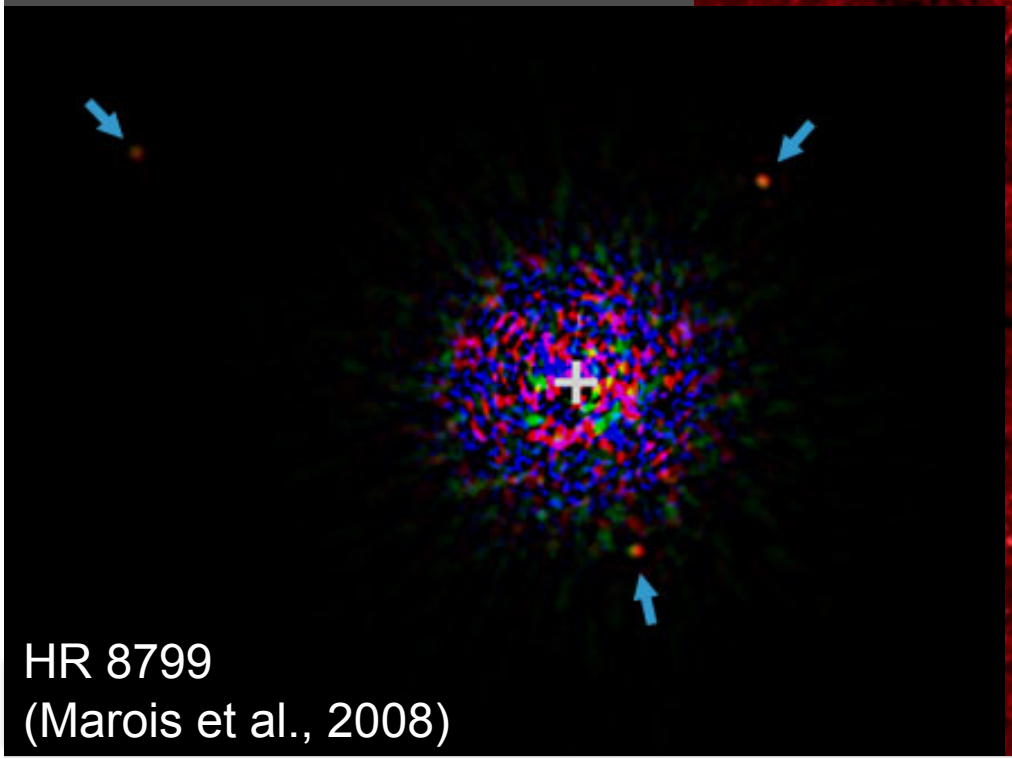
Vesta rotation

- Revised recently from all available data (Li et al., Icarus in press)
  - Limited by spatial resolution
  - Uncertainty 1.5º in Dec and 3º in RA
  - Statistically significant
- Precise measurement from Dawn
  - Pixel scale down to 25 m (0.006º on Vesta)
  - One year time baseline
  - Precisely measures the pole and potentially wobble (nodding)
  - Rotation evolution
- Data available from June 2011

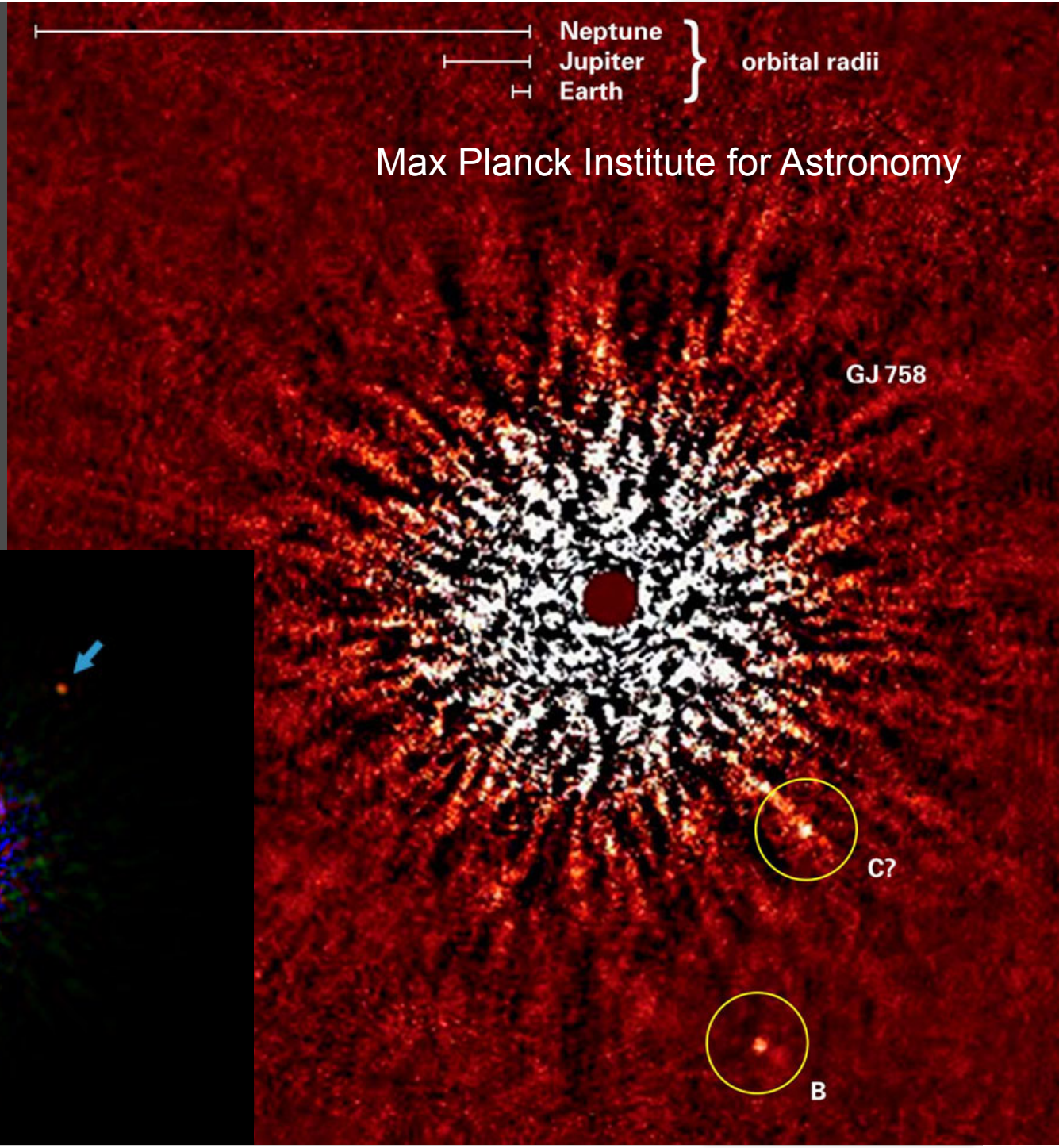
High-contrast imaging

- Adaptive optics
  - Decrease the size of point spread function (PSF)
  - Put diffraction pattern back into the central lobe
  - Stable PSF
- Coronagraph
  - Block the light from the center
  - Suppress speckles
- Post-processing
  - Remove speckles
  - Enhance contrast

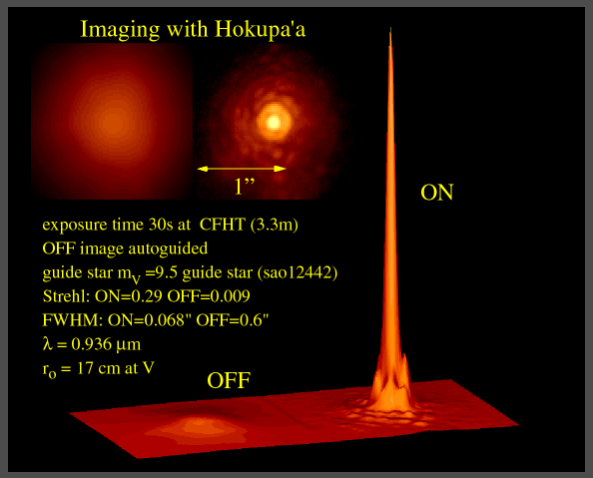
Technique for direct imaging of exoplanets

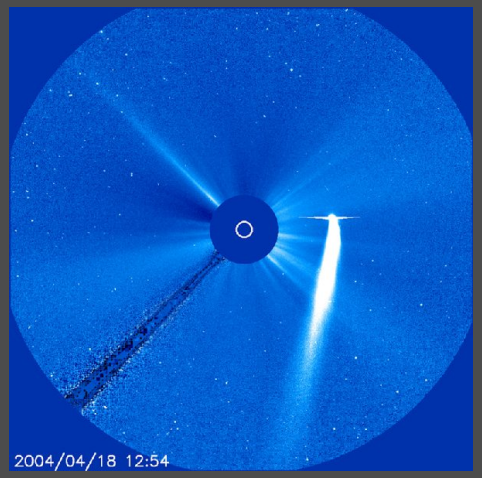


HR 8799
(Marois et al., 2008)



Adaptive optics + coronagraph

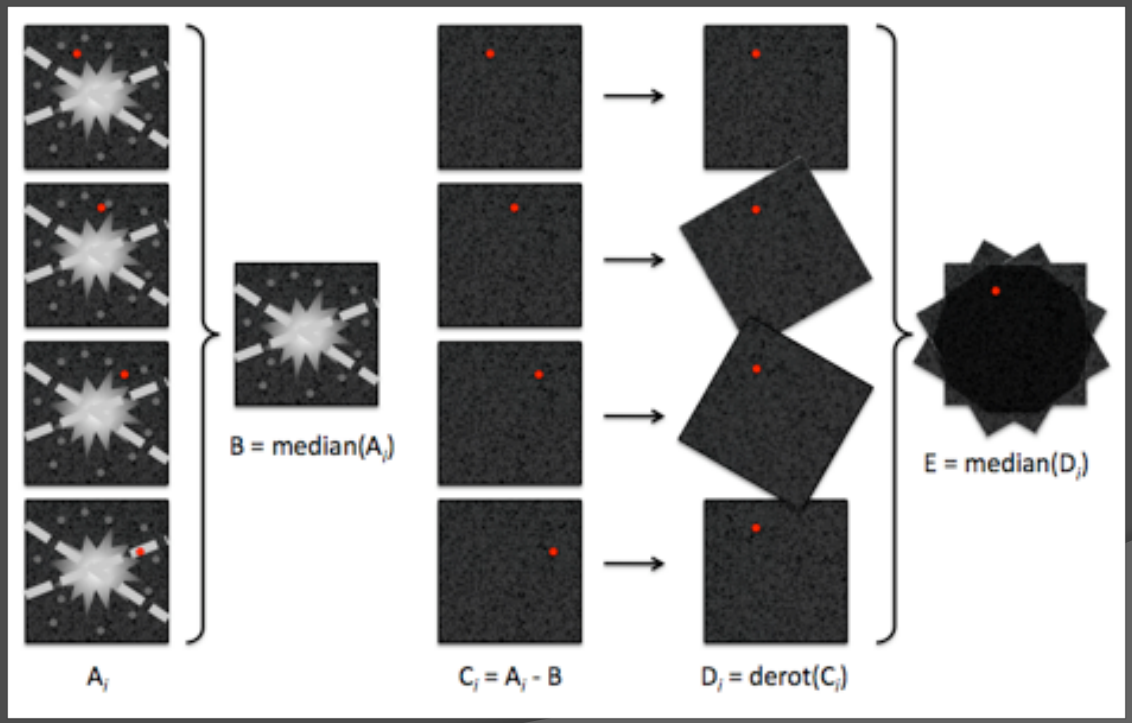




- Use a disk to block the light from center source
- Use funny shapes and transparency patterns to suppress diffraction patterns
  - Band-limited mask
  - Phase mask
  - Optical vortex mask

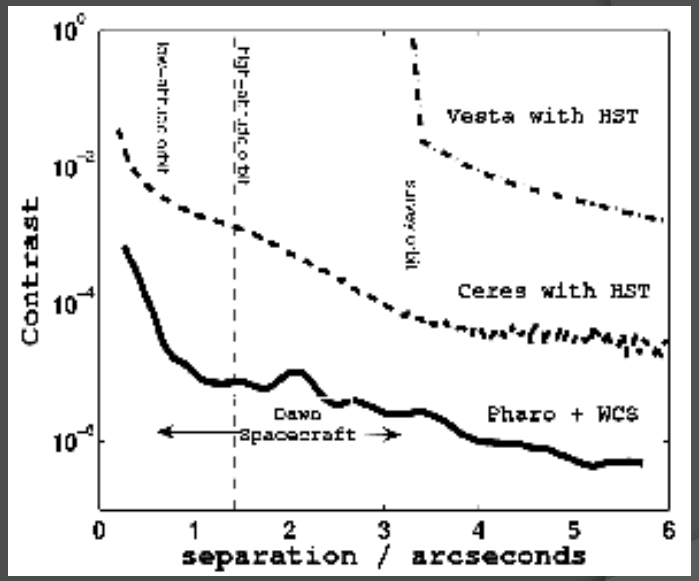
Post-processing

- Direct speckle subtraction
- Angular differential imaging



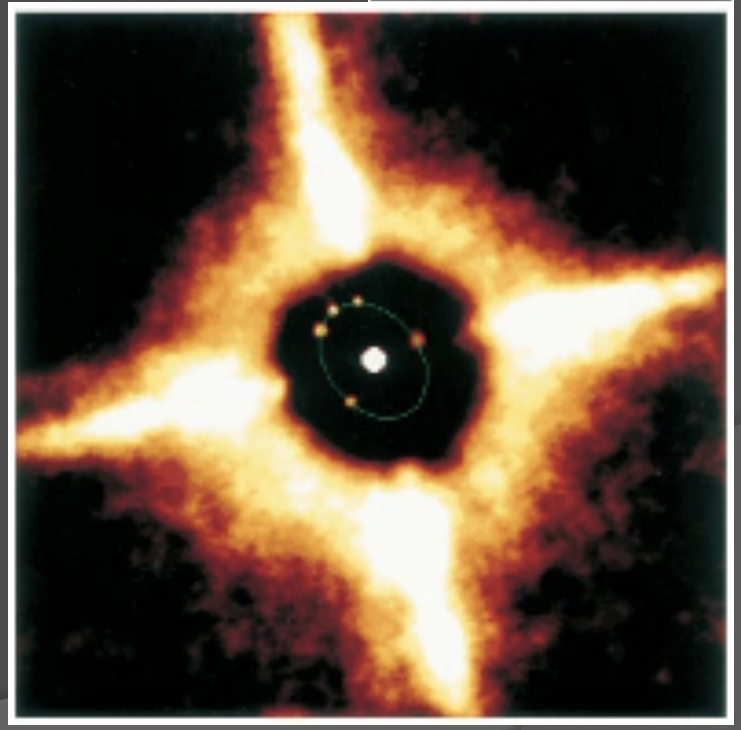
High-contrast imaging for asteroids

- Only the brightest ones
- Large angular size (!)
- Irregular shape
- Fast moving companions



Eugenia – Two known satellites

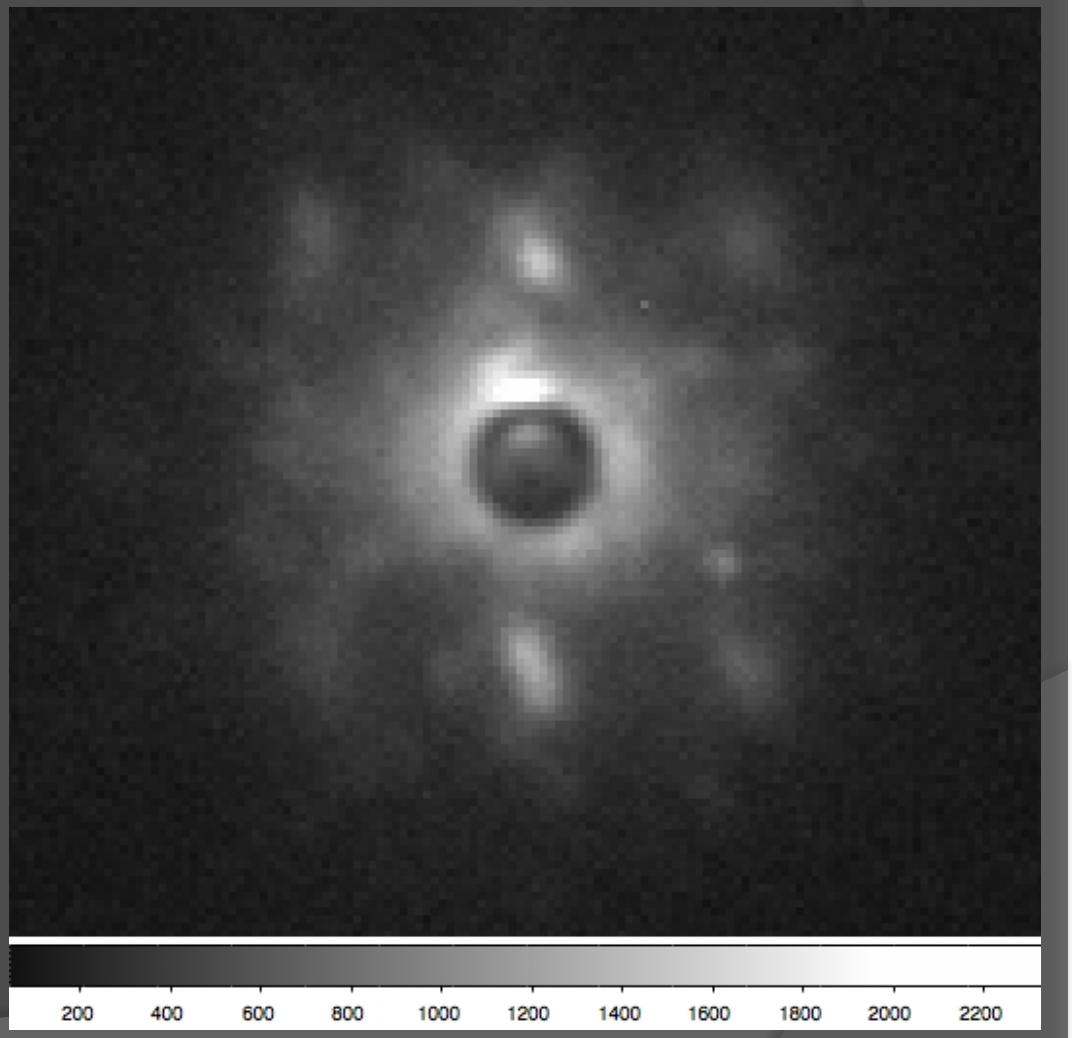
- Petit-Prince
  - Discovered in 1998 by CFHT AO, first time by ground-based telescope
  - Diameter 13 km
  - Semi-major axis 1184 km, or 11 radii of Eugenia
- S/2004 (45) 1
  - Discovered in 2004 by VLT
  - Diameter 6 km
  - Semi-major axis ~700 km(?)



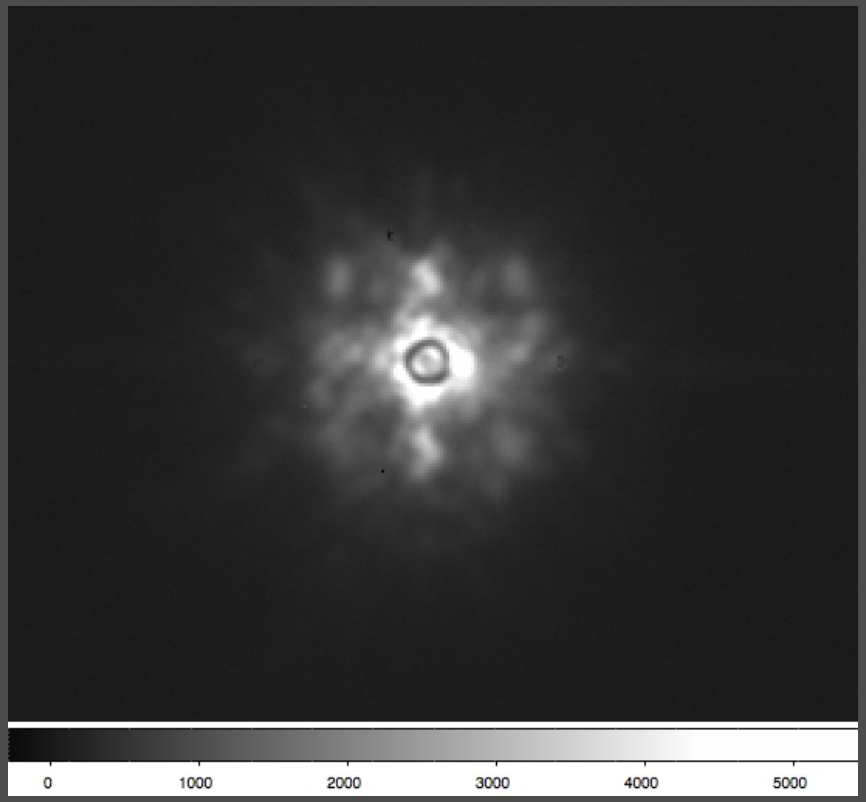
Merline et al. (1998)

Eugenia

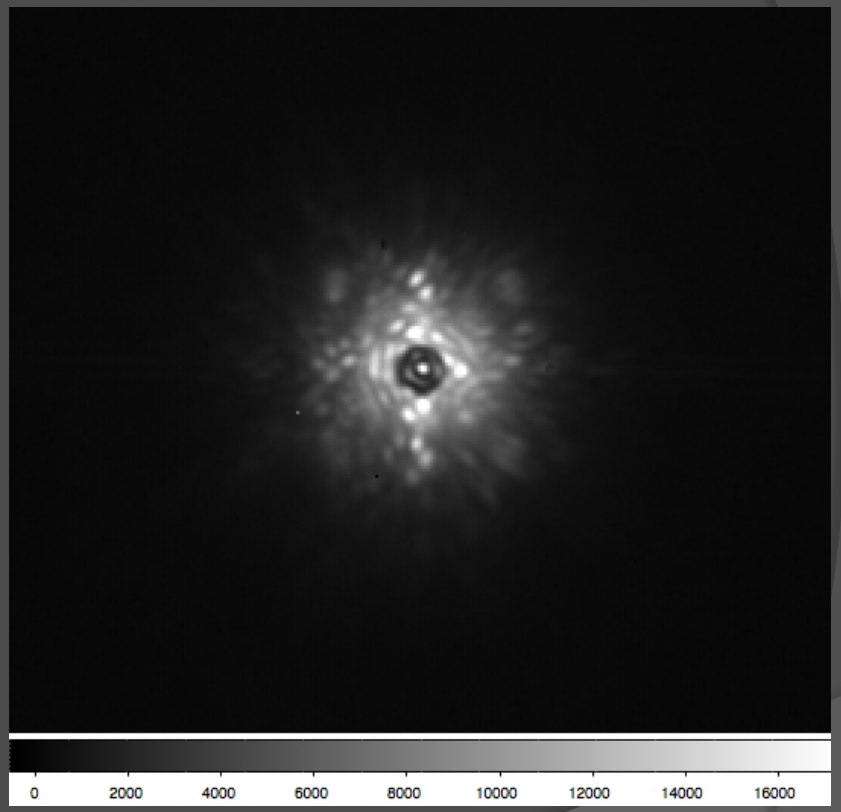
- V=12.5 mag, Ang. Diam=0.130”
- No calibration star was taken
- Remove speckle using Adeona (V=11.8, Ang. Diam=0.126”



Metis – occulted

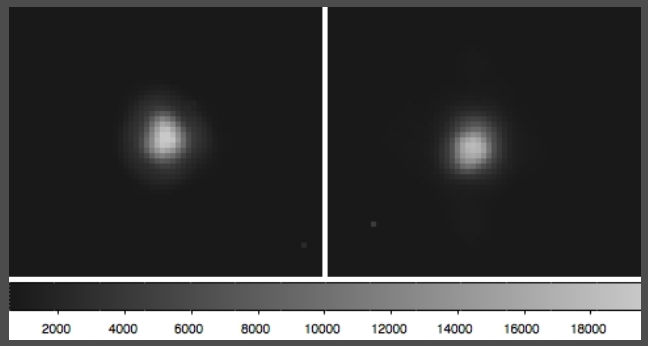


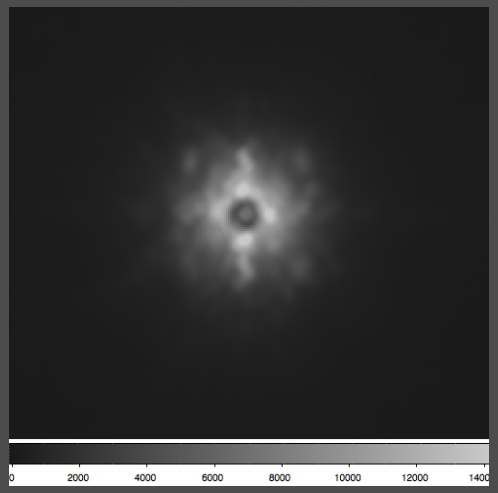
Metis

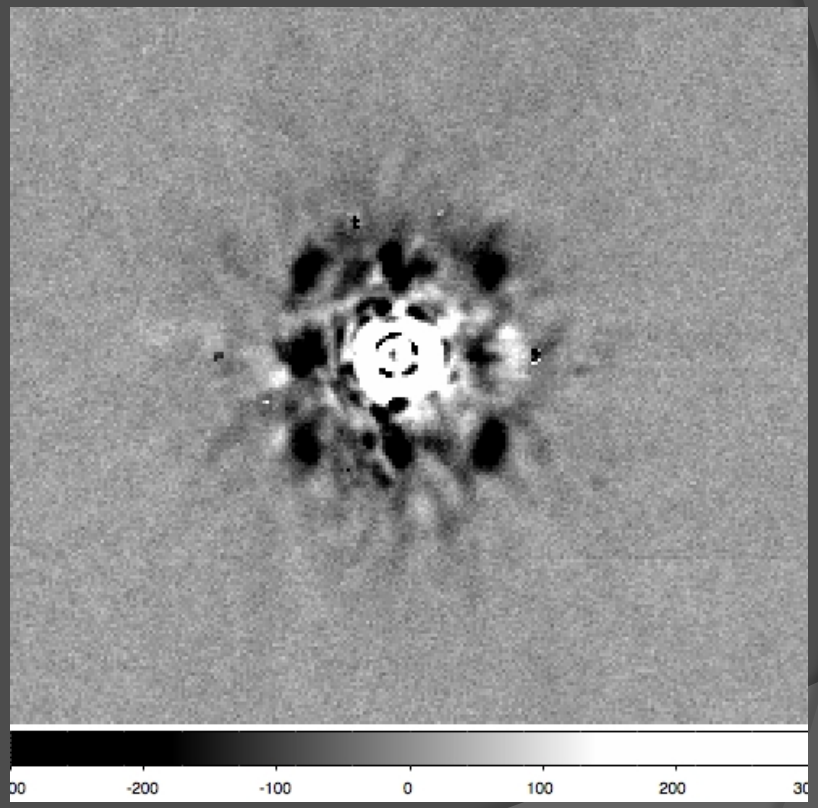


Calibration star

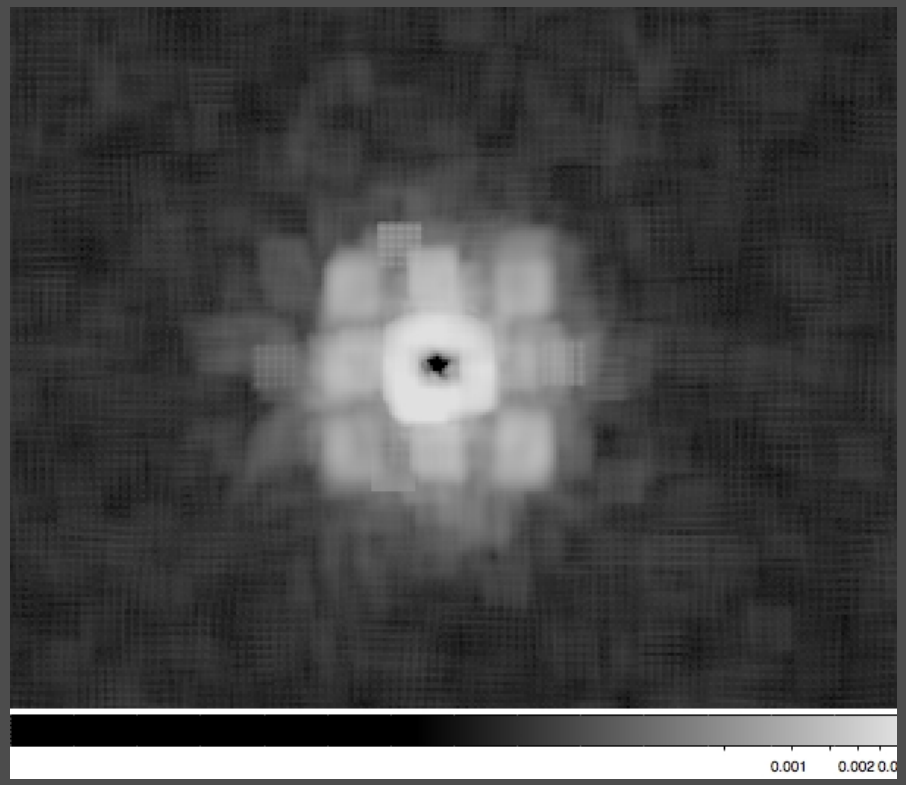
Convolve PSF with target disk and subtract



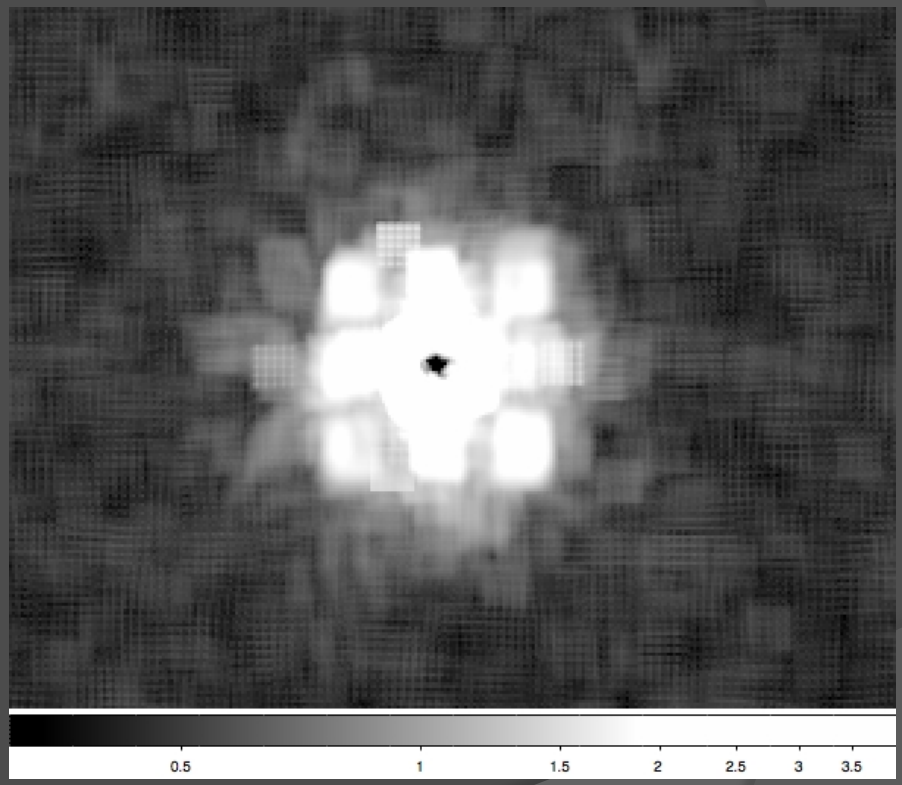




Contrast ratio and limiting size

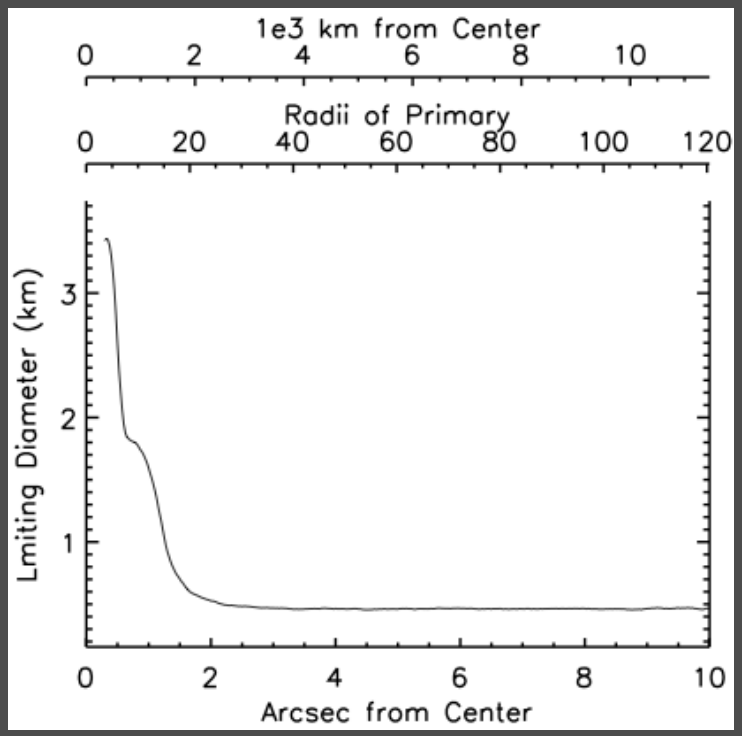


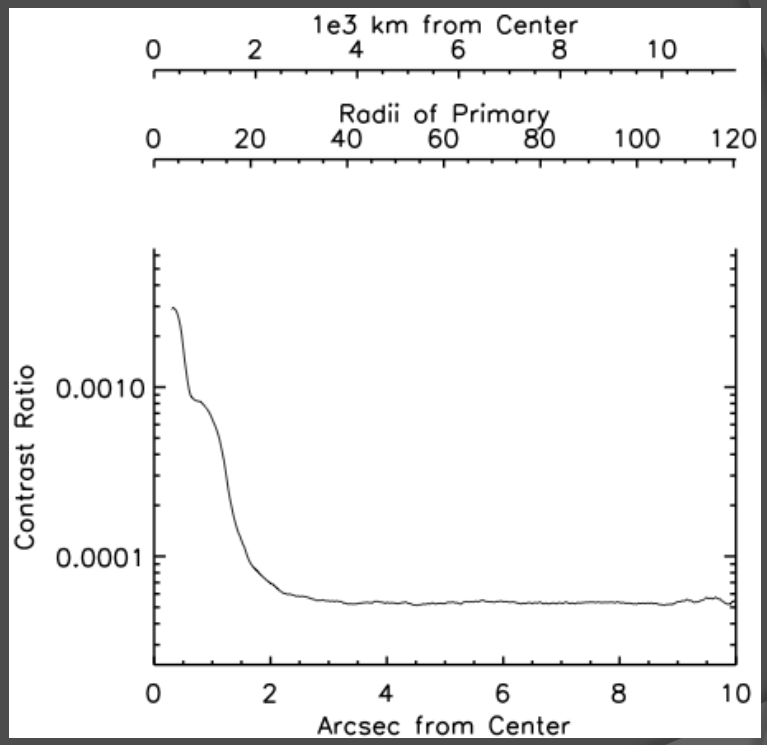
Contrast ratio map



Limiting size map

Limiting size





Ks-band