DAWN mission to Vesta and Ceres

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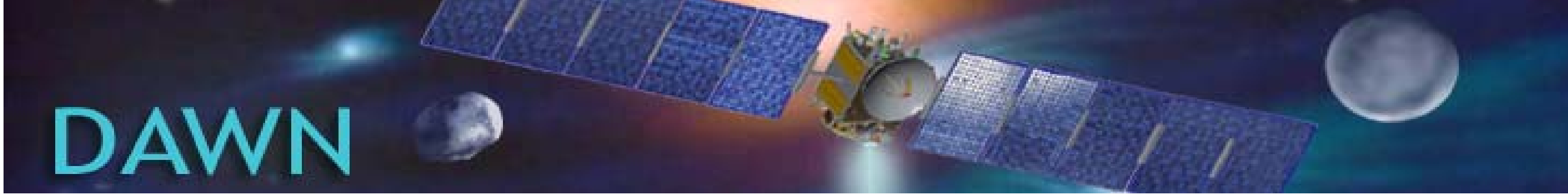

- DAWN is the ninth mission selected for the NASA Discovery program
- DAWN the first interplanetary mission that will orbit two solar system bodies – the massive main belt asteroids Vesta and the dwarf planet Ceres.
- Dawn had a beautiful launch to space on September 27.2007
- Dawn flew by Mars on 2009 February 17, successfully achieving the gravity assist it needed to help it reach the asteroid belt and its now in the way of Vesta.

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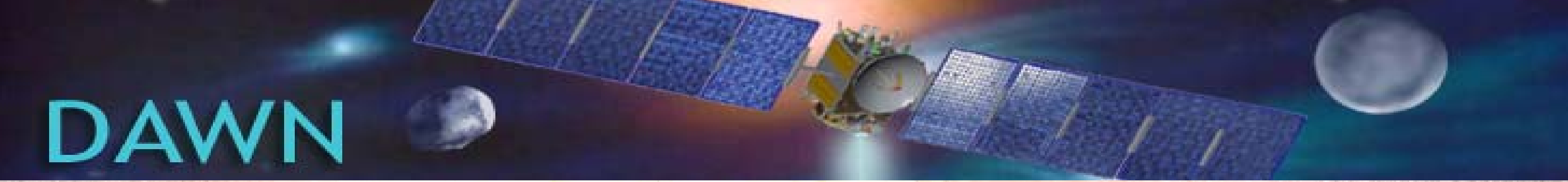
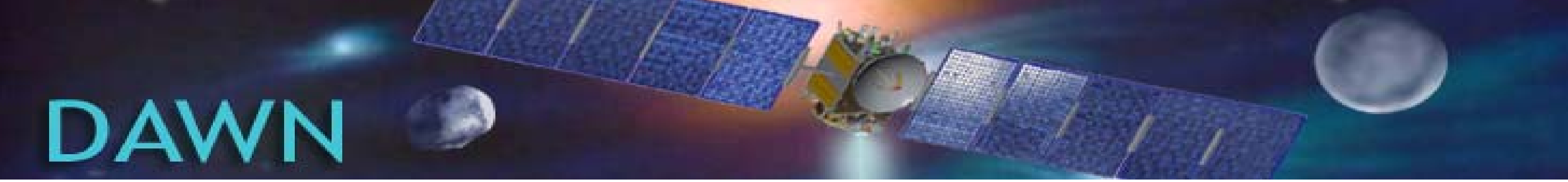


The three principal scientific drivers for the mission are:

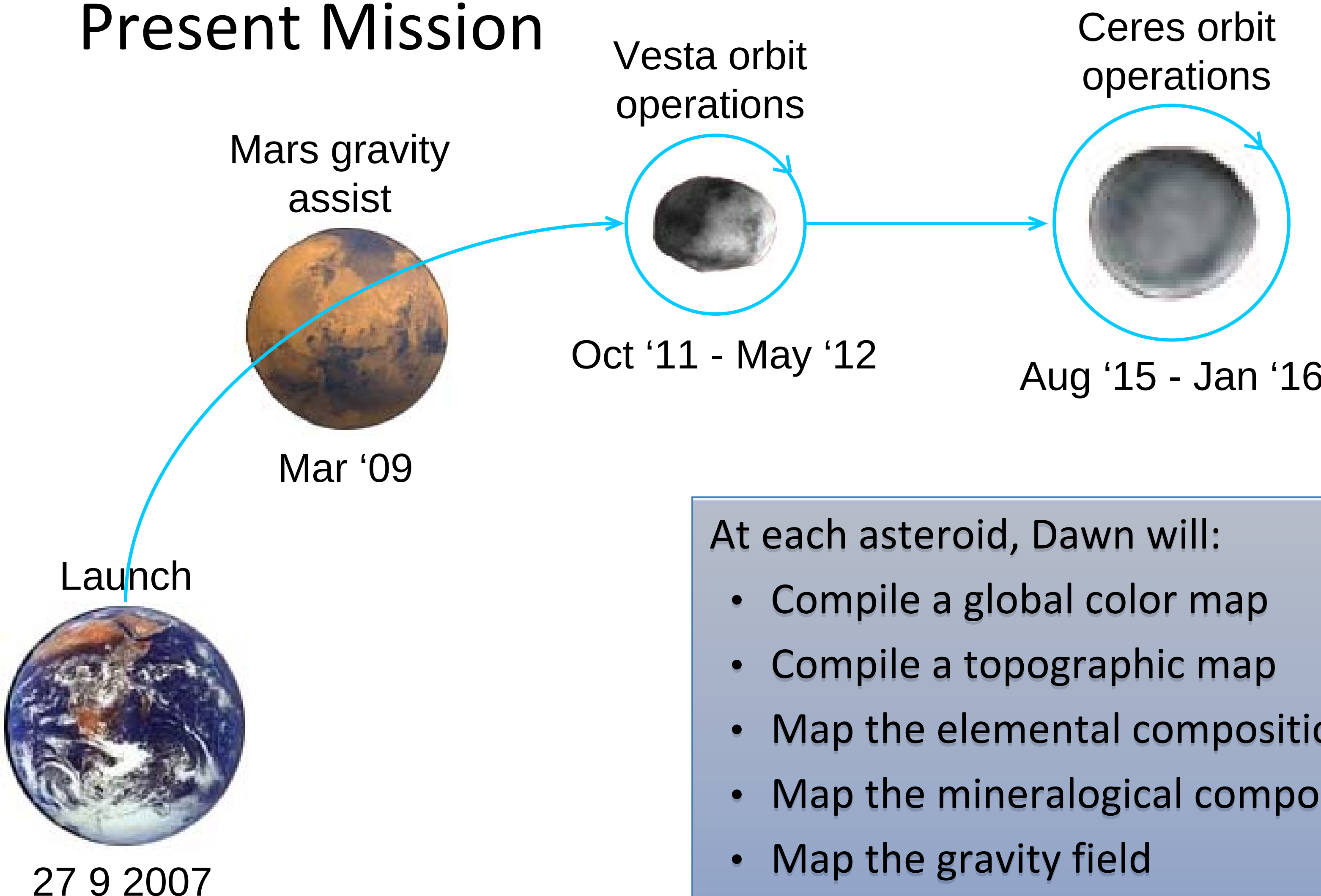
- to capture the earliest moments in the origin of the solar system enabling us to understand the conditions under which these objects formed.
- to determines the nature of the building blocks from which the terrestrial planets formed, improving our knowledge of this formation.
- to constrain the formation and evolution of two small planets, Ceres and Vesta, that followed very different evolutionary paths so that we understand what controls that evolution.

DAWN mission is very timely:

- DAWN is a journey in time back to the formation of the solar system
- It provides data on the role of water in planetary evolution and forms a bridge between the exploration of the rocky inner solar system and the icy outer solar system.

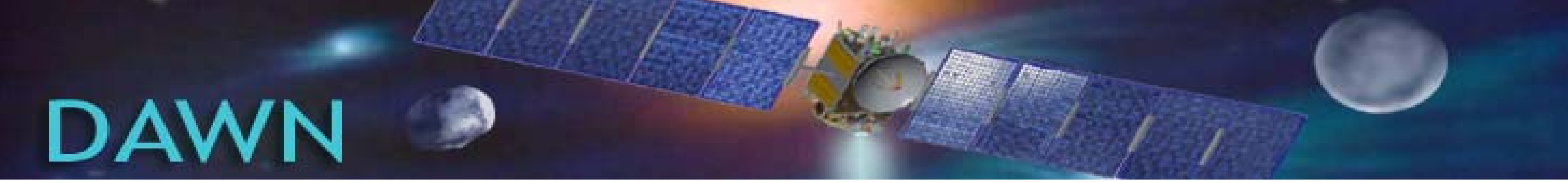


Present Mission

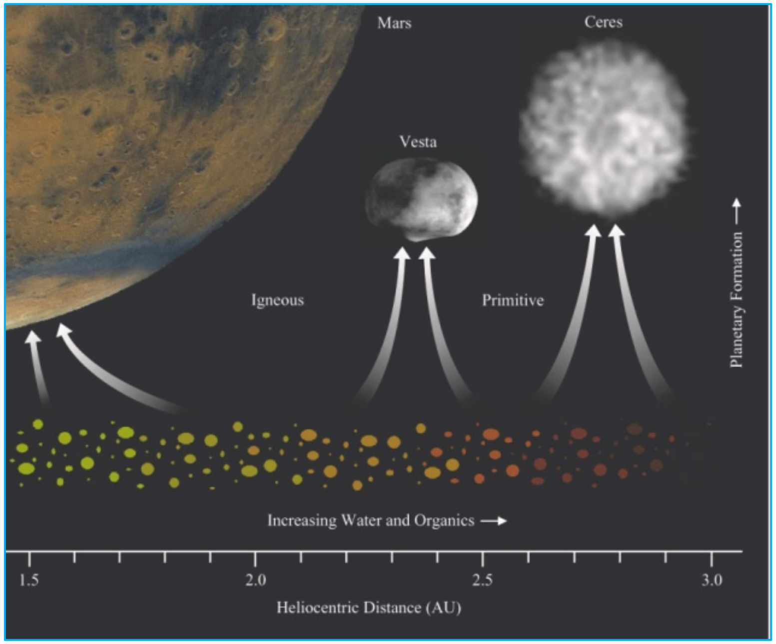


At each asteroid, Dawn will:

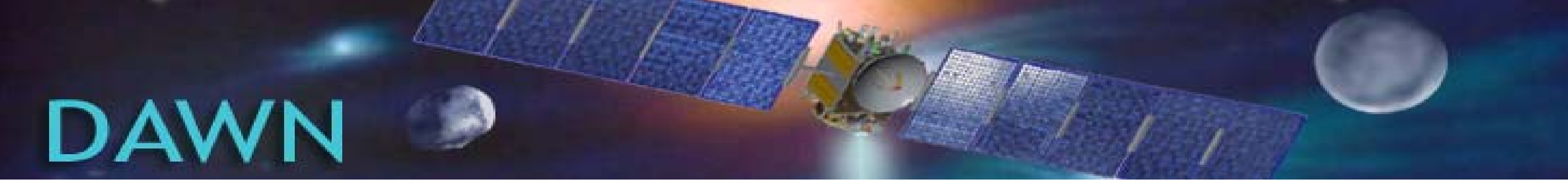
- Compile a global color map
- Compile a topographic map
- Map the elemental composition
- Map the mineralogical composition
- Map the gravity field
- Search for moons

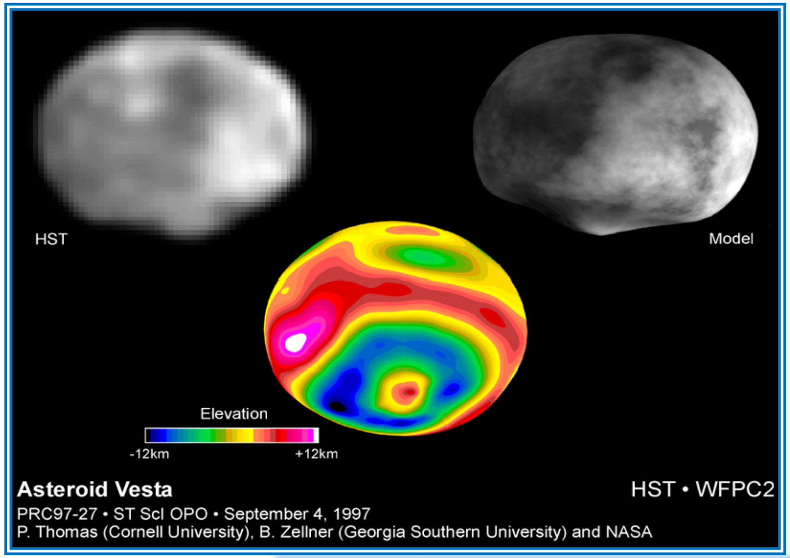


Why Vesta and Ceres ?



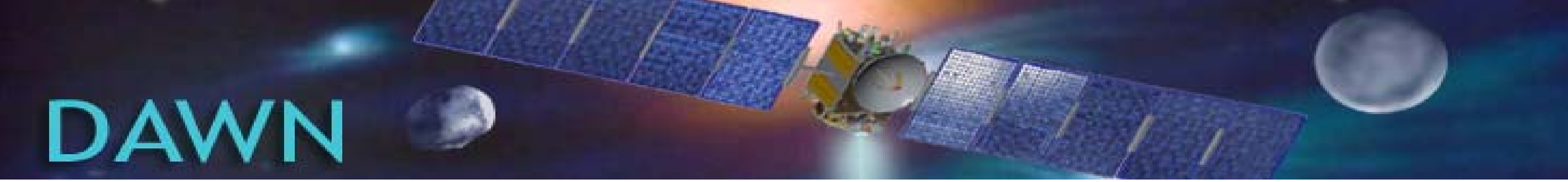
- Vesta is different from other asteroids: it is enogh massive to differentiate as terrestrial planets and it seems to be the origin of the HED suite of meteorites (Howardite, Eucrite, Diogenite)
- Ceres could be wet and primordial (?)
- Vesta e Ceres can be considered as two different and complementary protoplanets.

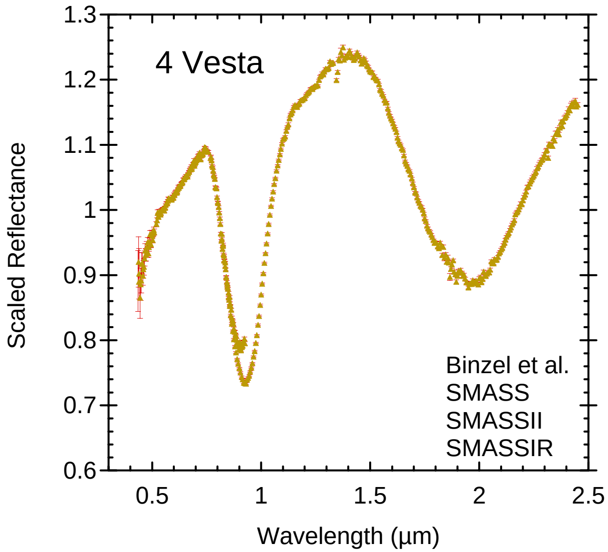


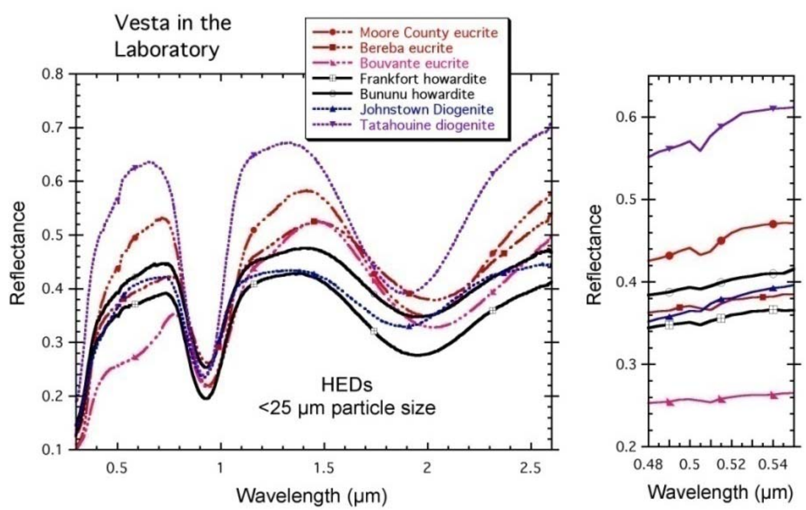


VESTA

- From HST we know that a large southern crater dominates its shape
- HST diameter measurements correspond to Vesta volume of 7.19×10^7 km^3 *(Thomas et al., 1997)*
- Vesta mass determination = 2.70×10^{20} kg *(Konopliv et al., 2006)*
- Mass/volume gives Vesta bulk density = 3.76 g/cm^3

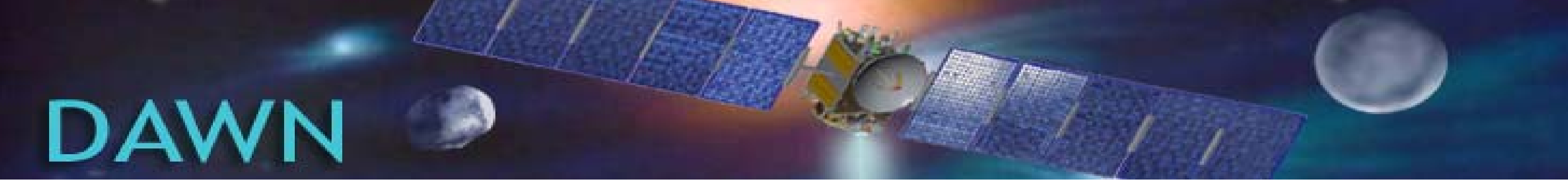




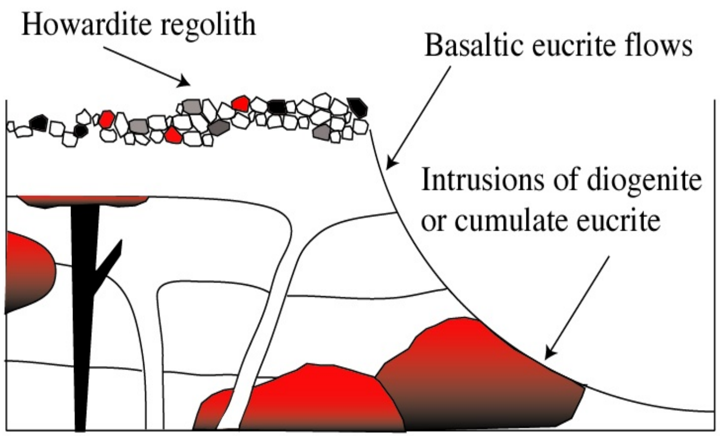


VESTA

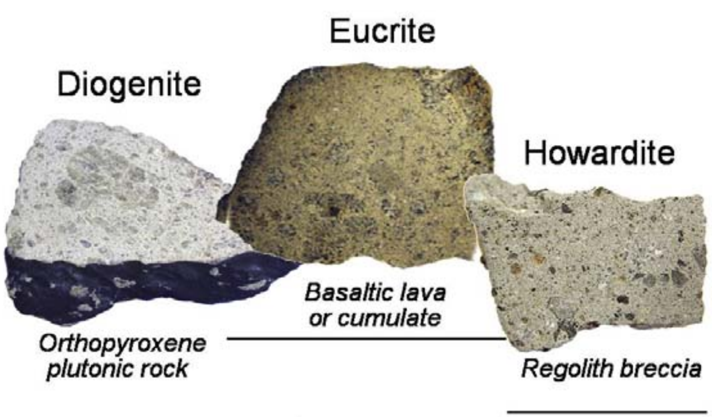
- Vesta spectra show diagnostic bands at 0.93 µm and 2.0 µ m (typical of basaltic material)
- It's basaltic surface has been associated with HED (Howardite – Eucrite – Diogenite) meteorites, due to the spectral properties
- Metallic core required by measured depletions of siderophile elements in HED and bulk density of Vesta
- Vesta is differentiated: core-mantle-crust



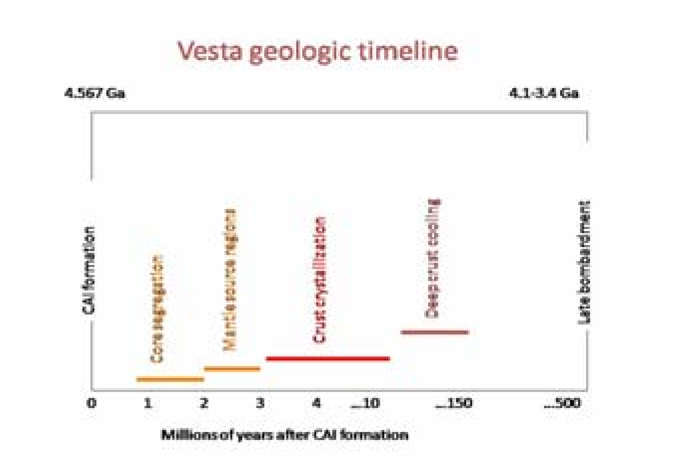
VESTA is very ancient

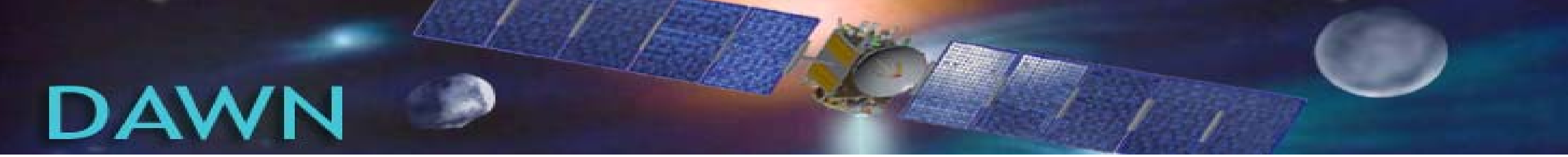


HED meteorites = Vesta samples

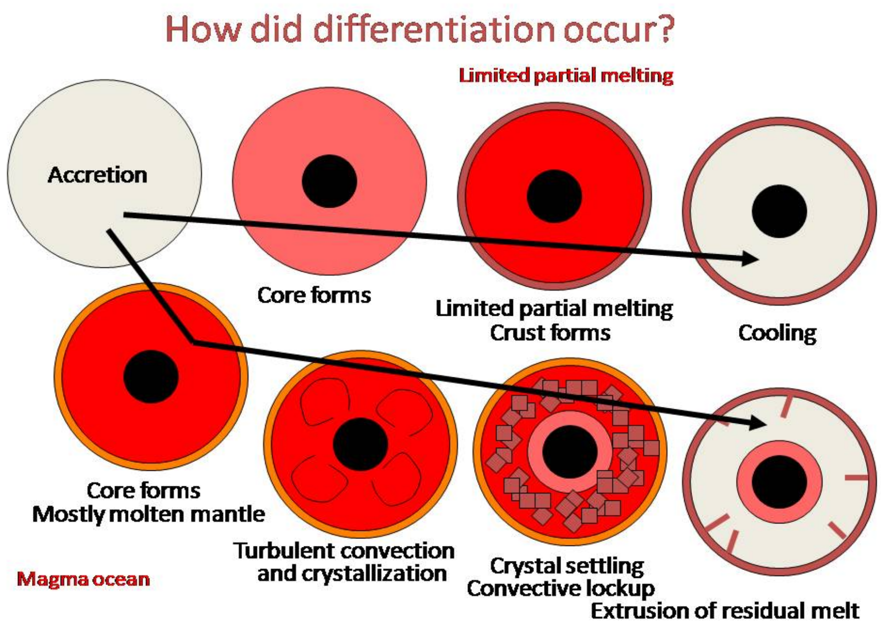


- Basaltic crust indicated by HEDs and spectral studies
- Eucrites date back to the formation of the Solar System 4.566 b.y.
- Mantle composition varies depending on whether there was a magma ocean or limited melting (could be mostly olivine)





How, when, and why did differentiation occur?

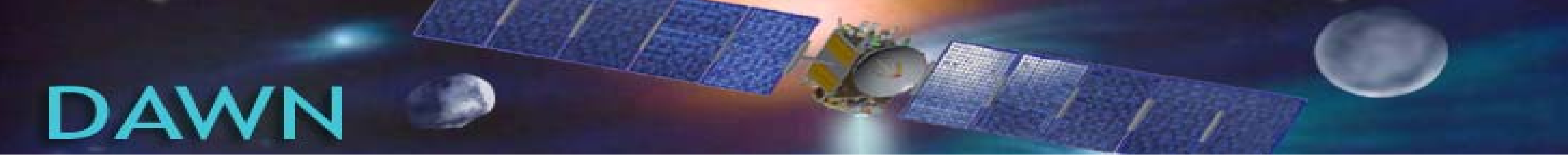


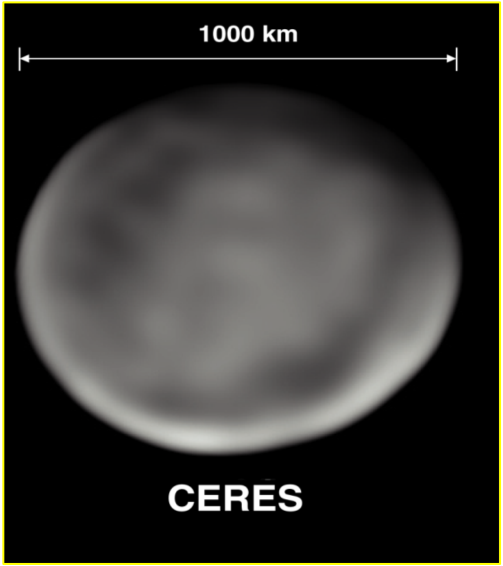
McSween, 2007

How? limited (locally ≤25%) partial melting or extensive (magma ocean) melting - as yet unresolved.

When? Differentiation to form core and mantle was rapid (within 1-3 m.y. after solar system formation). Formation of crustal rocks occurred within 3-10 m.y

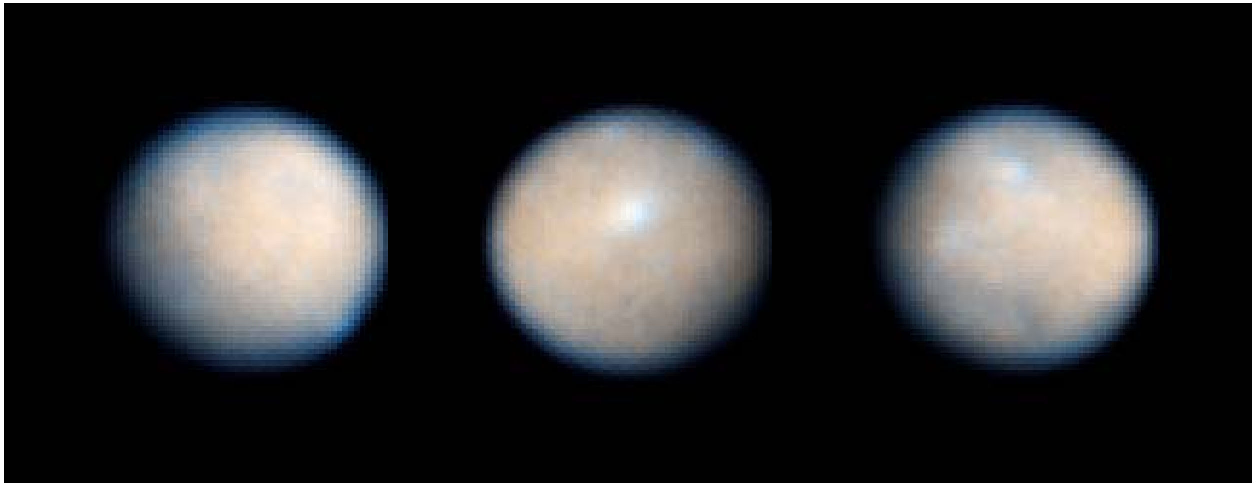
Why? Early accretion with live ^{26}Al, whose decay produced enough heat to cause differentiation and magmatic activity. A prolonged cooling interval resulted from slow thermal diffusion and perhaps exothermic core solidification.

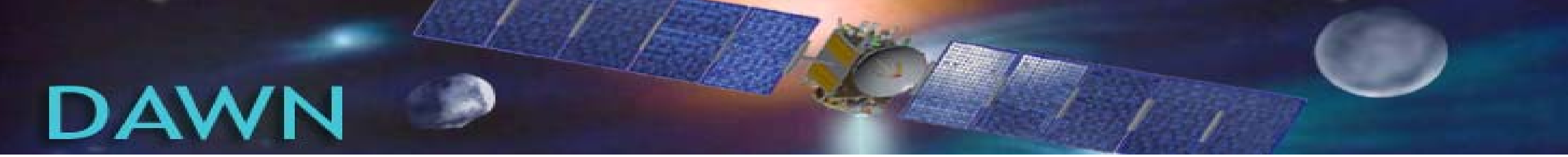


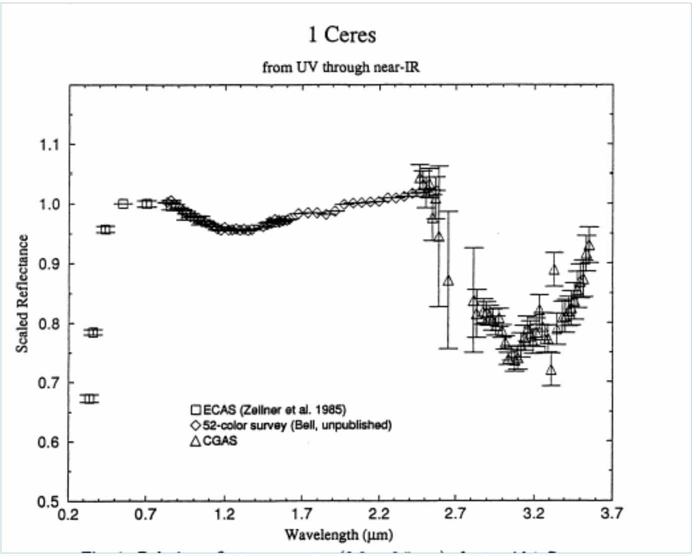


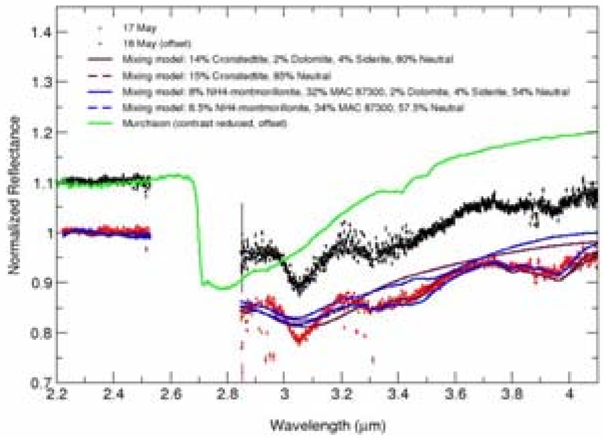
CERES

- The size and shape of Ceres, and its surface albedo were determined accurately from HST
- The surface is very dark but does have features, that could be impact craters or flows
- Very little surface relief is seen –very smooth surface
- The spheroidal shape is strongly suggestive of relaxation and thus weak surface (Thomas et al. 2005) in hydrostatic equilibrium.



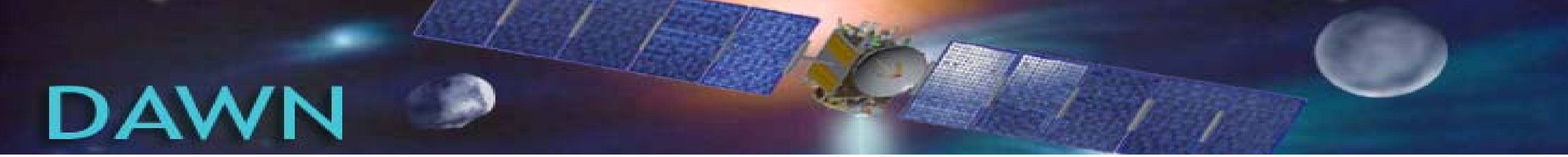


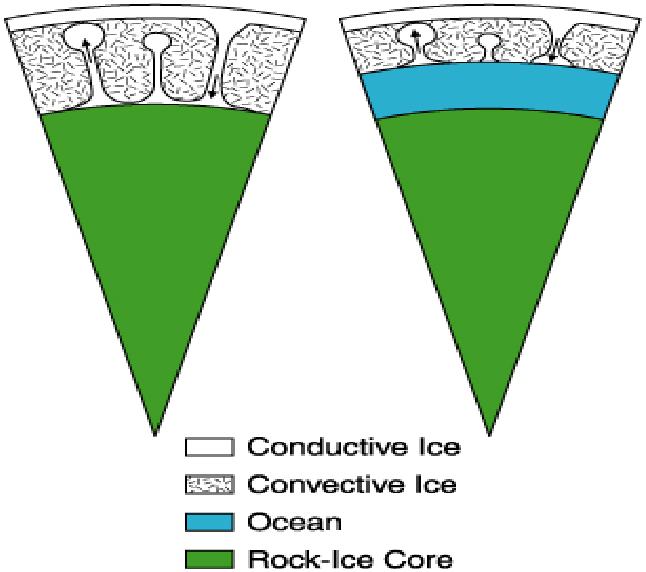


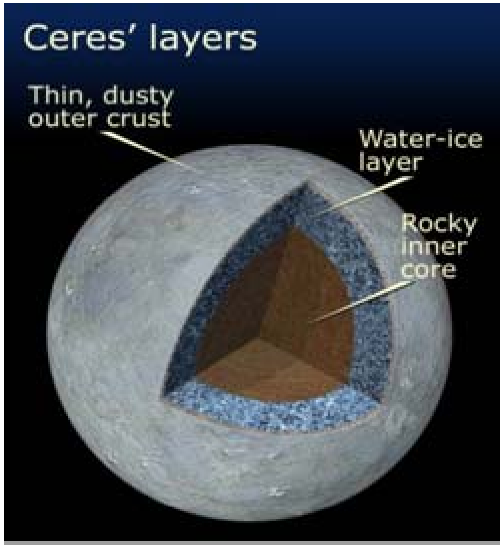


Rivkin et al. (2006)

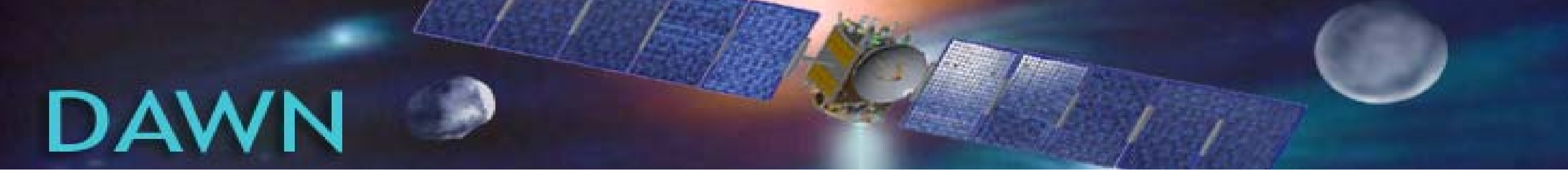
- Ceres classified as C-type, associated with carbonaceous chondrites
- UV dropoff and shallow band at ~0.6-0.7 μm- Phyllosilicates?
- Shallow but evident band from 0.9-1.8 μm
- Similar features seen in MAC 87300 and MAC 88107 (primitive, intermediate between CO&CM: Russell et al. 1995)
- Complex spectrum beyond 2.5 μm- absorptions (minima at ~ 3.9, 3.3-3.5, 3.05, < 2.85 μm)
- Not seen: olivine/pyroxene (due to opaques?), water ice
- Interpretation: Ices? NH4-bearing clays? Fe-rich clays? Irradiated organics?

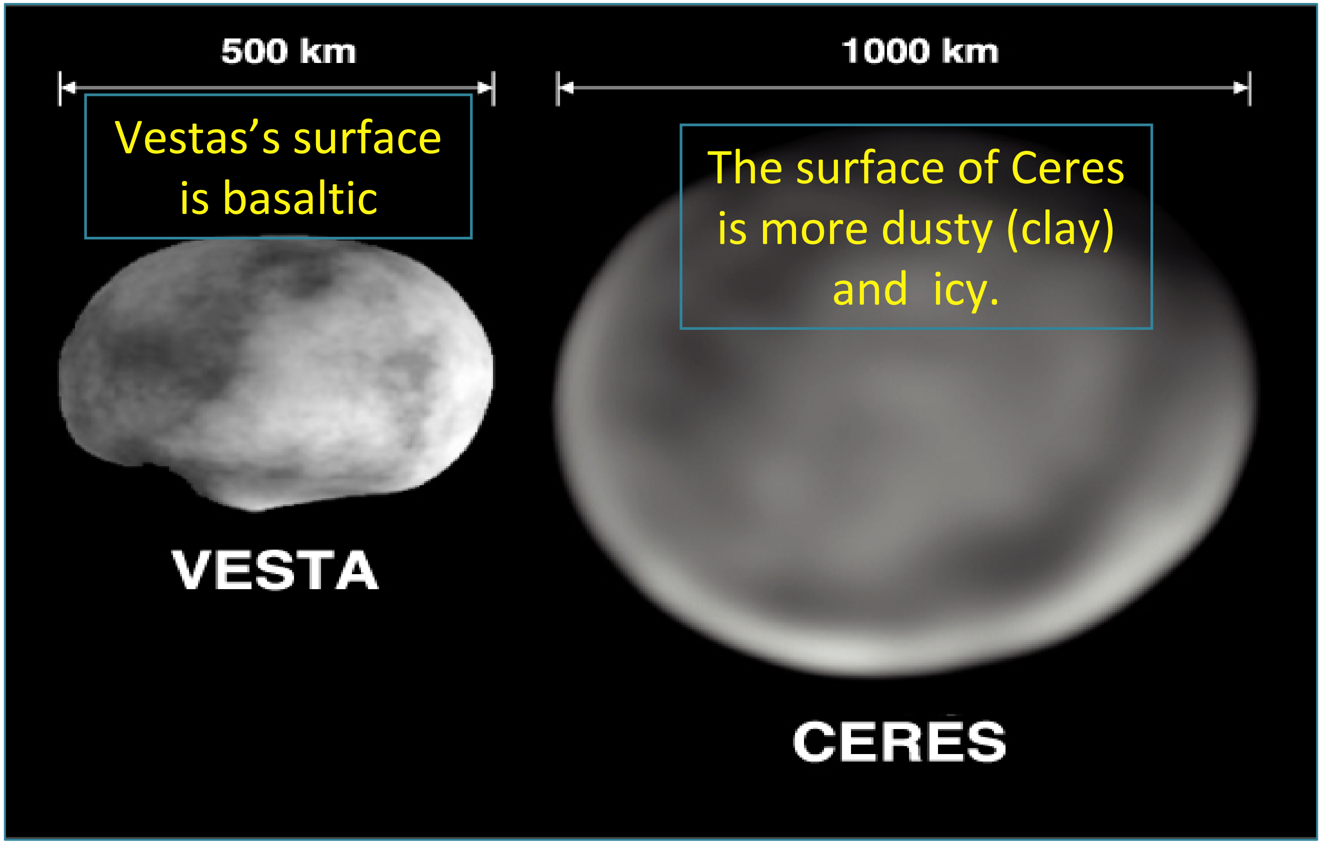




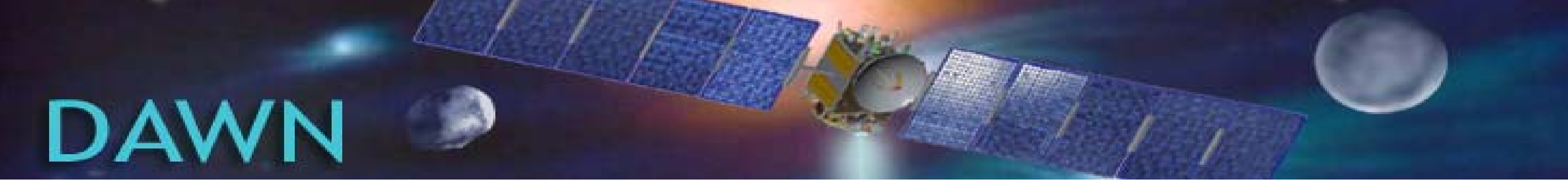


- Assuming hydrostatic equilibrium shape implies differentiation (Thomas et al. 2005)
- Thermal evolution of models of Ceres by McCord and Sotin (2005) are consistent with a rocky core, ice mantle and , possibly, ocean of water under a hard ice crust
- However, present-day ocean unlikely (unless antifreeze or reduced thermal conductivity)
- We can expect that Ceres is rich in ices and similar to icy satellites of the outer planets

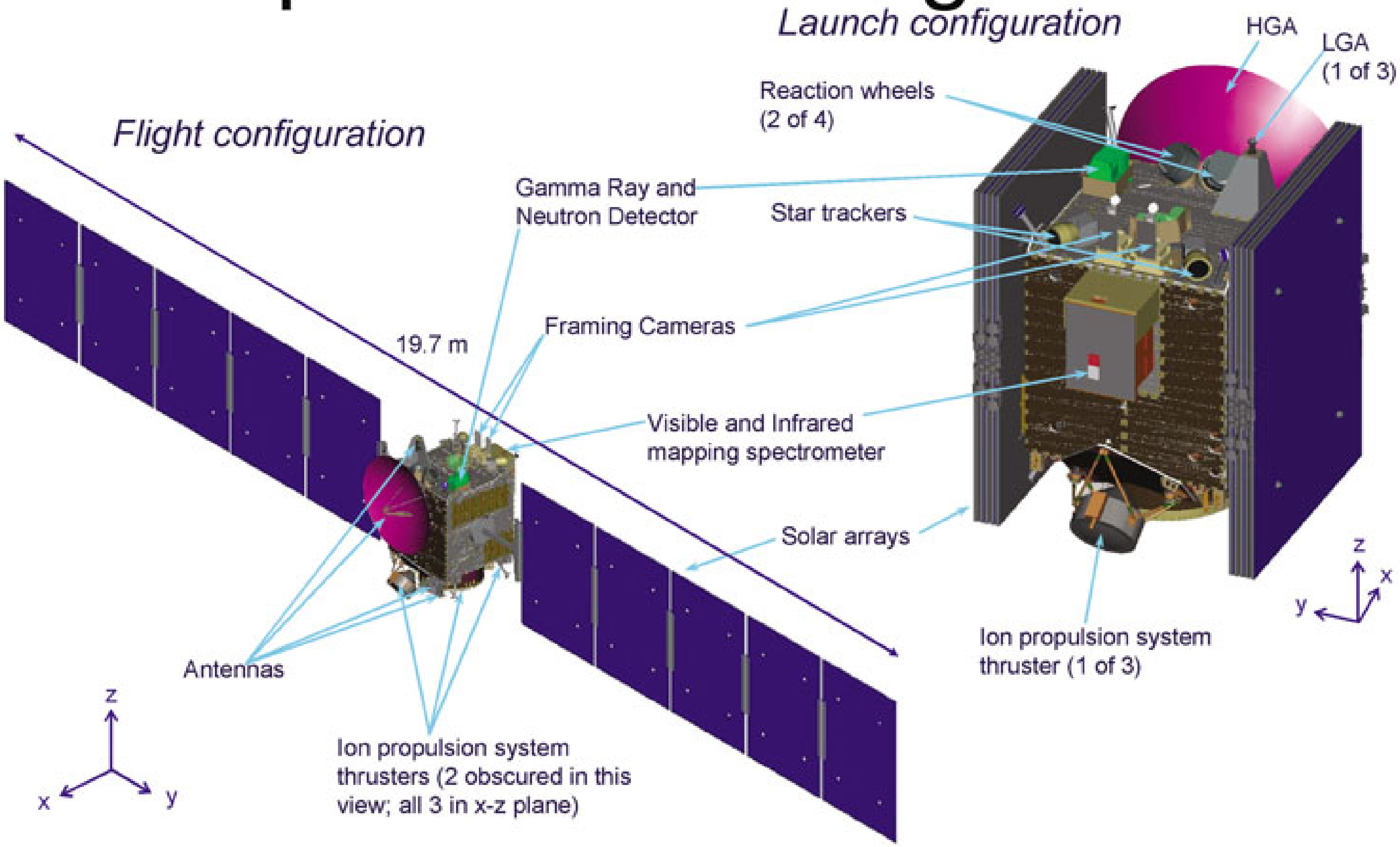


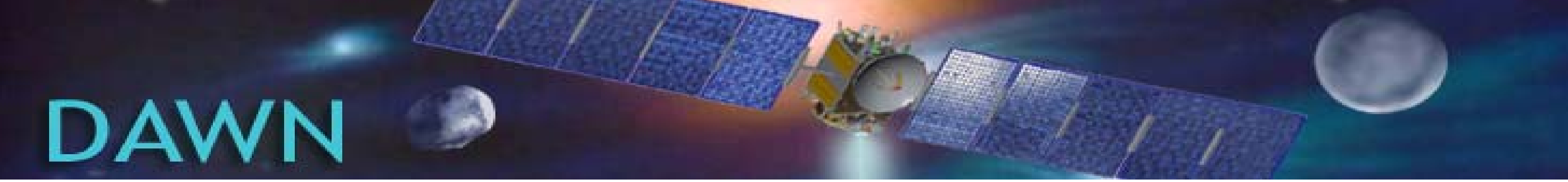


- Both bodies are very primitive
- Vesta and Ceres are the link between the rocky terrestrial planets and the icy bodies of the outer solar system



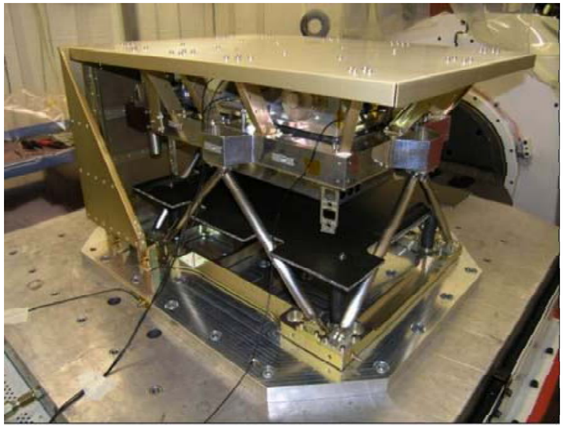
Spacecraft Configuration



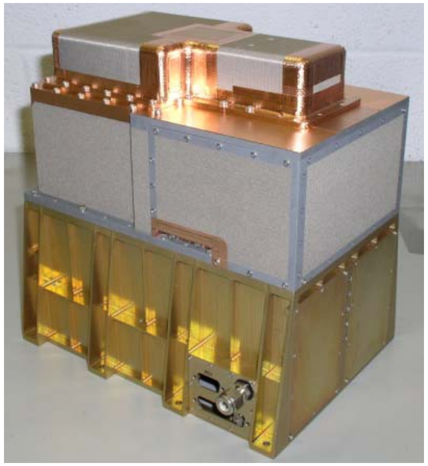


Payload

Framing Camera

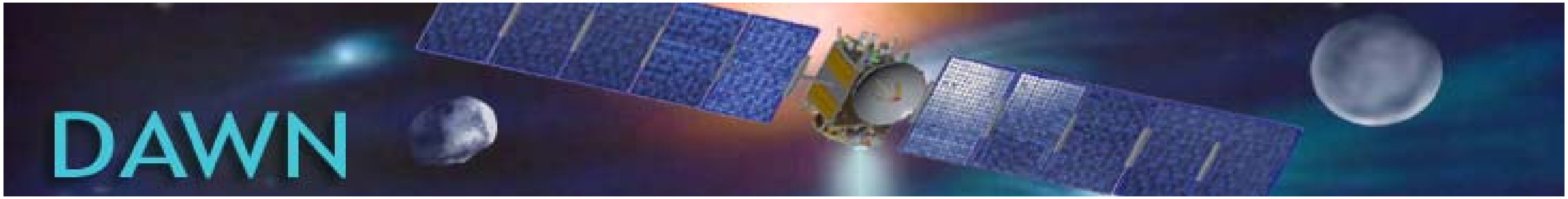


VIR



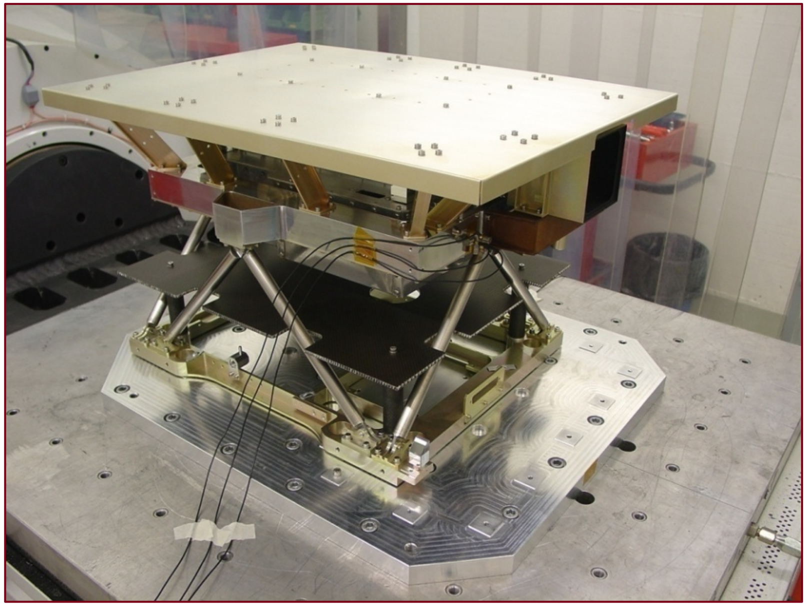
GRaND

- Dawn carries two redundant framing cameras (1024 x 1024 pixels, and 7 color filters plus clear); a visible and infrared mapping spectrometer (UV to 5 microns) and a Gamma Ray and Neutron Detector
- These are provided and managed by Germany (MPS/MPI and DLR) , Italy (ASI/INAF), and USA (LANL/PSI)
- Radiometric data provides gravity information; imaging provides topography
- The DAWN instrumentation is complete, flight- proven and similar to that used for other missions to Mercury, Mars, the Moon, and comets.

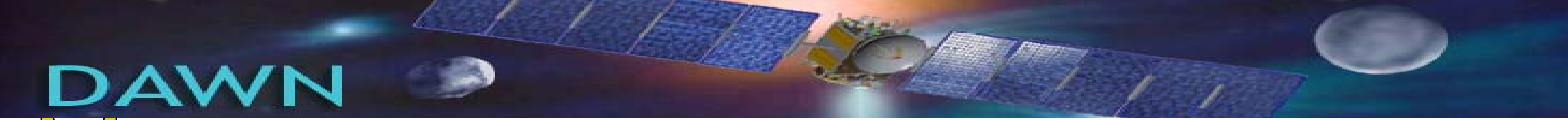


VIR Mapping Spectrometer

- VIR, Visual InfraRed Mapping Spectrometer, is an Hyperspectral imaging spectrometer operating in the visible (0.25-1 um) e infrared (0.95-5 um)
- Team Leader: A. Coradini, INAF - Contributed to Dawn by ASI and INAF
- VIR design is based on VIRTIS-M on board of Rosetta and VEx



Channel	Spectral Range	Spectral Sampling	FOV (mrad)	IFOV (mrad)	SNR	Radio. Abs.	Radio. Relat.	Det.	Matrix Dim.	Pixel pitch
VIR- vis	0.25 – 1.0	2.6 nm	64 x 64	0.25	>100	<20%	<1%	TH7896	508x1024	19 μm
VIR- IR	0.95 – 5.0	14 nm	64 x 64	0.25	>100	<20%	<1%	CdHgTe	270x436	38 μm



1997 2004 2005 2007 2011 2013

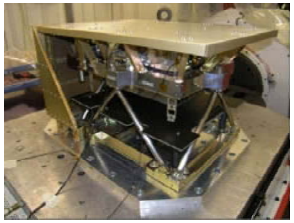
CASSINI: VIMS-V

IFOV: 166-500 µrad - FOV: 1.8° (64 samples) - Spectral range: 300-1050 nm -Spectral sampling: 1.46-7.31 nm (96 bands)

Mass (OH+PEM) 6.9 kg - Power: 23.9 W

Current status: IN FLIGHT SCIENCE-ACTIVE

More than 72.000 hyperspectral cubes (55 GB or 12 DVDs) of the Saturnian system acquired



ROSETTA: VIRTIS-M

VENUS EXPRESS: VIRTIS-M

Visible and Infrared Thermal Imaging Spectrometer (Mapping channel)

IFOV: 250 µrad - FOV: 3.6° (256 samples) – Spectral range: VIS 250-1050 nm, IR 1000-5000 nm-

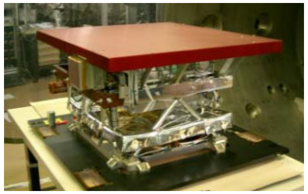
Spectral sampling: VIS 1.89 nm, IR 9.44 (432 bands each) Mass (-M, -H, ME): 29.1 kg

ROSETTA Current status: IN FLIGHT CRUISE-ACTIVE

Will reach comet 67P/Churyumov-Gerasimenko in 2014- Asteroid Steins Observed

VENUS EXPRESS Current status: IN FLIGHT SCIENCE-ACTIVE

Observing Venus since 2006, more than 300 GB (64 DVDs) hyperspectral data acquired



DAWN: VIR

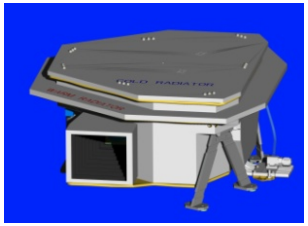
IFOV: 250 µrad - FOV: 3.6° (256 samples)

Spectral range: VIS 250-1050 nm, IR 1000-5000 nm- Spectral sampling: VIS 1.89 nm, IR 9.44 (432 bands each)

Mass (OH, ME): 20 kg - Power: 52W

Current status: IN FLIGHT CRUISE-ACTIVE

Will reach minor bodies Vesta in 2011 and Ceres in 2015.



JUNO: JIRAM

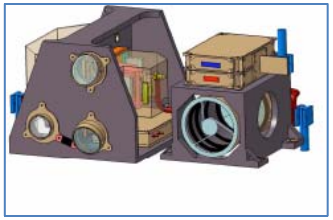
Two 256x432 HgCdTe detectors - IFOV: 237 µrad - FOV: 3.5°x6°

Spectral range: 2000-5000 nm (432 bands) - Spectral sampling: 6.9 nm - A/D converter: 16 bit RadHard design

Mass (OH, ME): 14 kg - Power: 20 W

Current status: IN DEVELOPMENT

Will be launched in 2011 to explore Jupiter atmosphere and auroras.



BEPICOLOMBO: SIMBIO-SYS/VIHI Visible Infrared Hyperspectral Imager

VIHI 256x256 HgCdTe detector - IFOV: 250 µrad - FOV: 3.6° Spectral range 400-2200 nm (256 bands)

Spectral sampling 7.0 nm - A/D converter 14 bit - RadHard design - S/C coldfinger

Mass (3 OH, ME): 9.1 kg - Power: 33 W

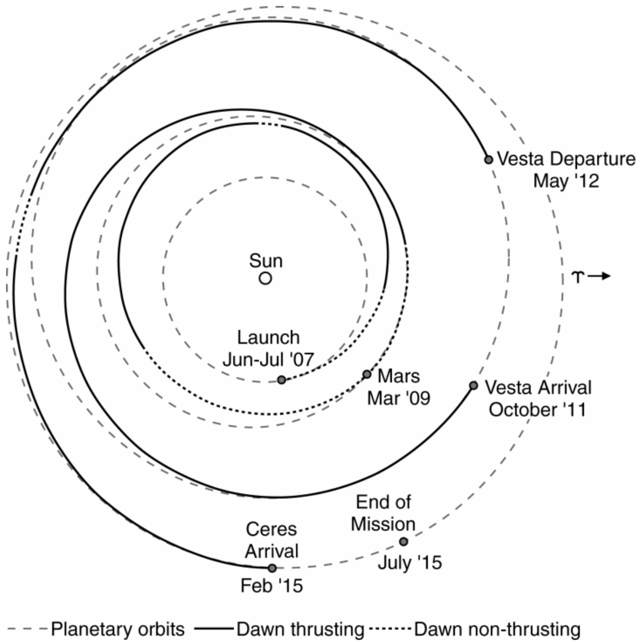
Current status: IN DEVELOPMENT

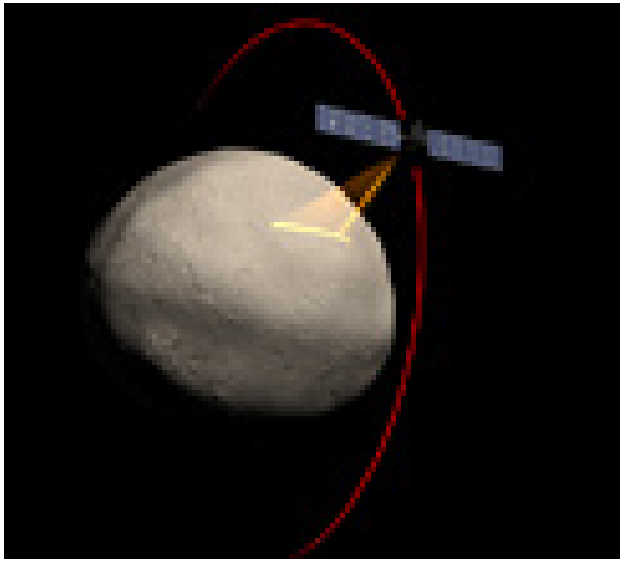
Will be launched in 2013 to map Mercury surface composition.

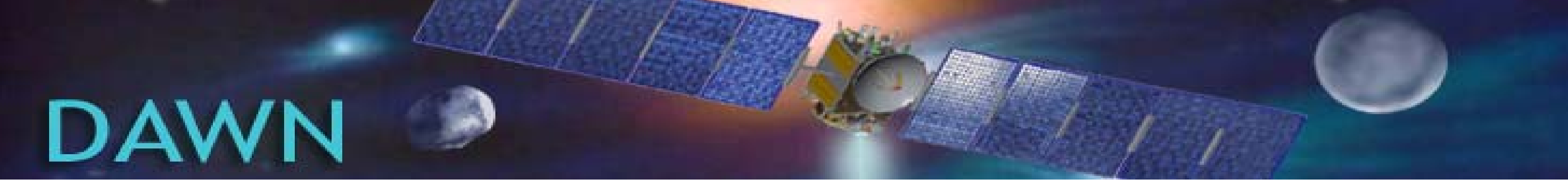
VIS-NIR IMAGING SPECTROMETERS FOR PLANETARY EXPLORATION: THE ITALIAN HERITAGE TOWARDS INNOVATION

Mission Profile

- After the gravity assist from Mars, Dawn thrusts almost continuously for 2.5 years to reach Vesta in 2011.
- After Vesta, Dawn thrusts another 2.8 years to reach Ceres in 2015
- Several months of operations are planned at Vesta and Ceres

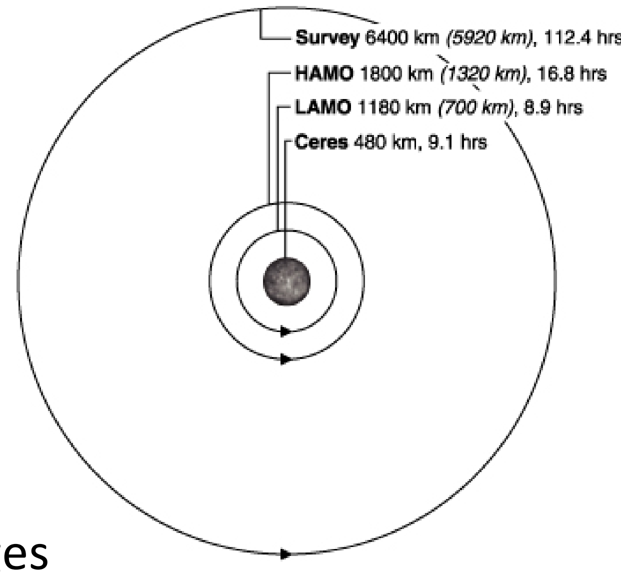




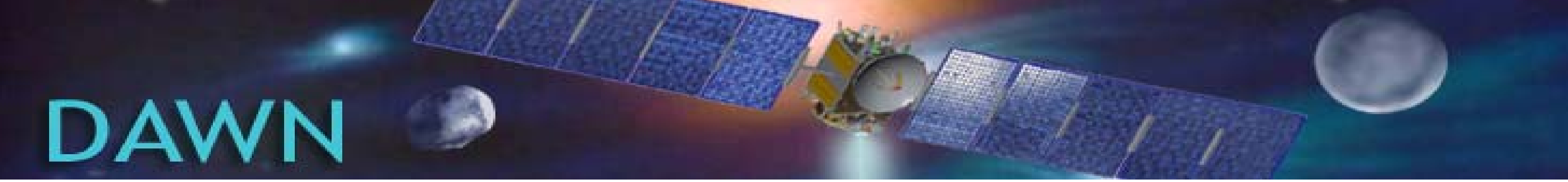


Operations

Four different phases for each target are foreseen



- **Approach phase:**
  - Rotation maps at increasing resolution
  - Dust/moon survey (high phase angle observations)
- **Survey Orbit:**
  - VIR global coverage and overlapping FC global images
- **High Altitude Mapping Orbit:**
  - High-resolution global mosaics of FC images and VIR imaging
  - Topographic mapping (off-nadir imaging)
- **Low Altitude Mapping Orbit :**
  - Gamma Ray/Neutron spectroscopy
  - Tracking for gravity science



Summary

- Dawn is on the way to explore two intriguing worlds
    - Vesta arrival in late 2011 - departure mid 2012
    - Ceres arrival in early 2015 - departure summer 2015

- Data from these two complementary massive asteroids -protoplanets will illuminate conditions and processes during the earliest epoch of formation of our solar system