

Water in Solar System

Fly By

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Overview

- ★ *Water is present on our planet in three different states: vapour, liquid and solid*
- ★ *In its liquid form, it has played an essential part in the appearance, development and maintenance of terrestrial life*
- ★ *In its gaseous and solid forms, water is omnipresent in the Universe: in the most distant galaxies, among the stars, in the Sun, in its planets and their satellites and ring systems, and in comets.*

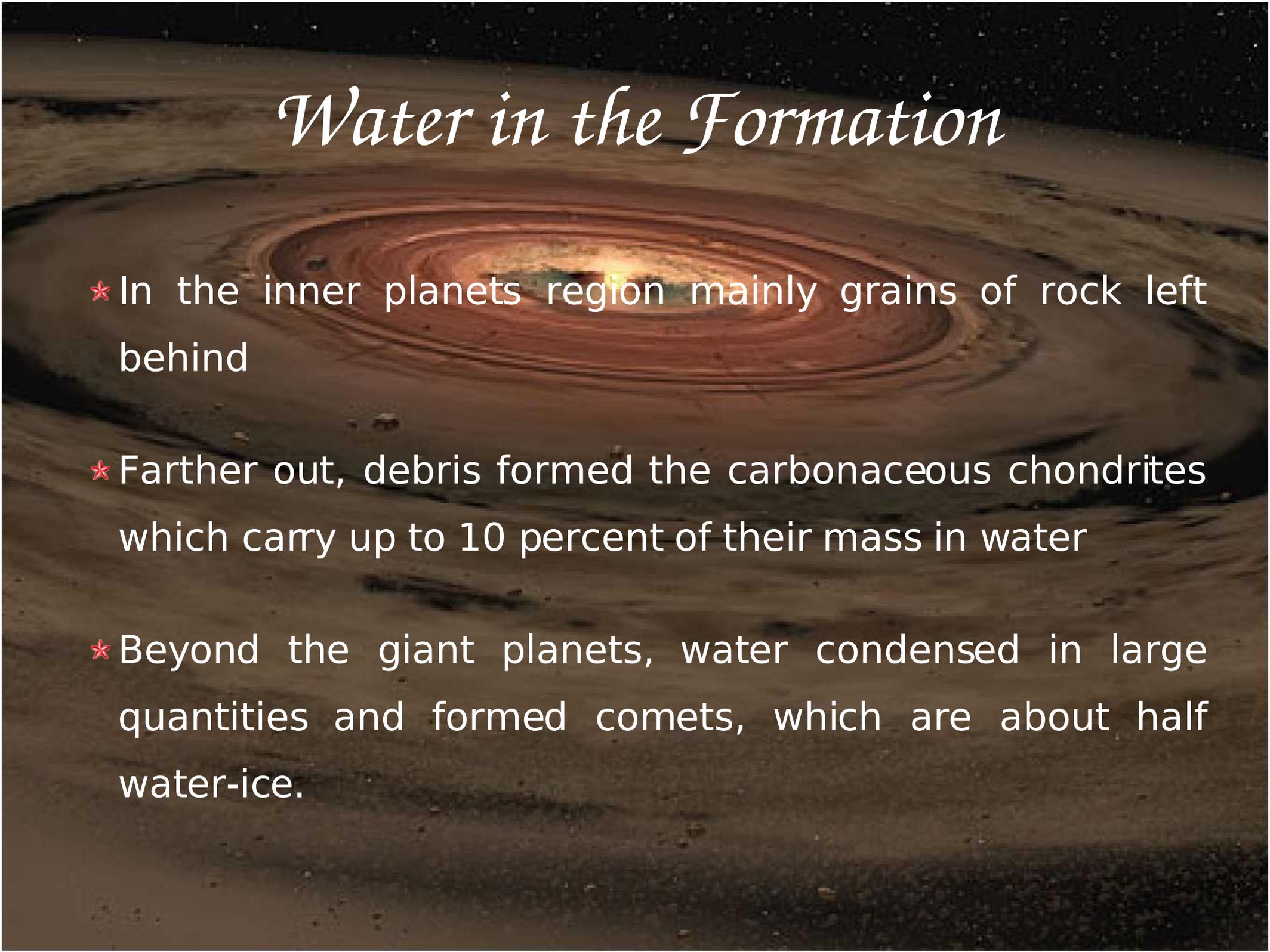
Questions About Water

**How can we get warm water in the shower here?*

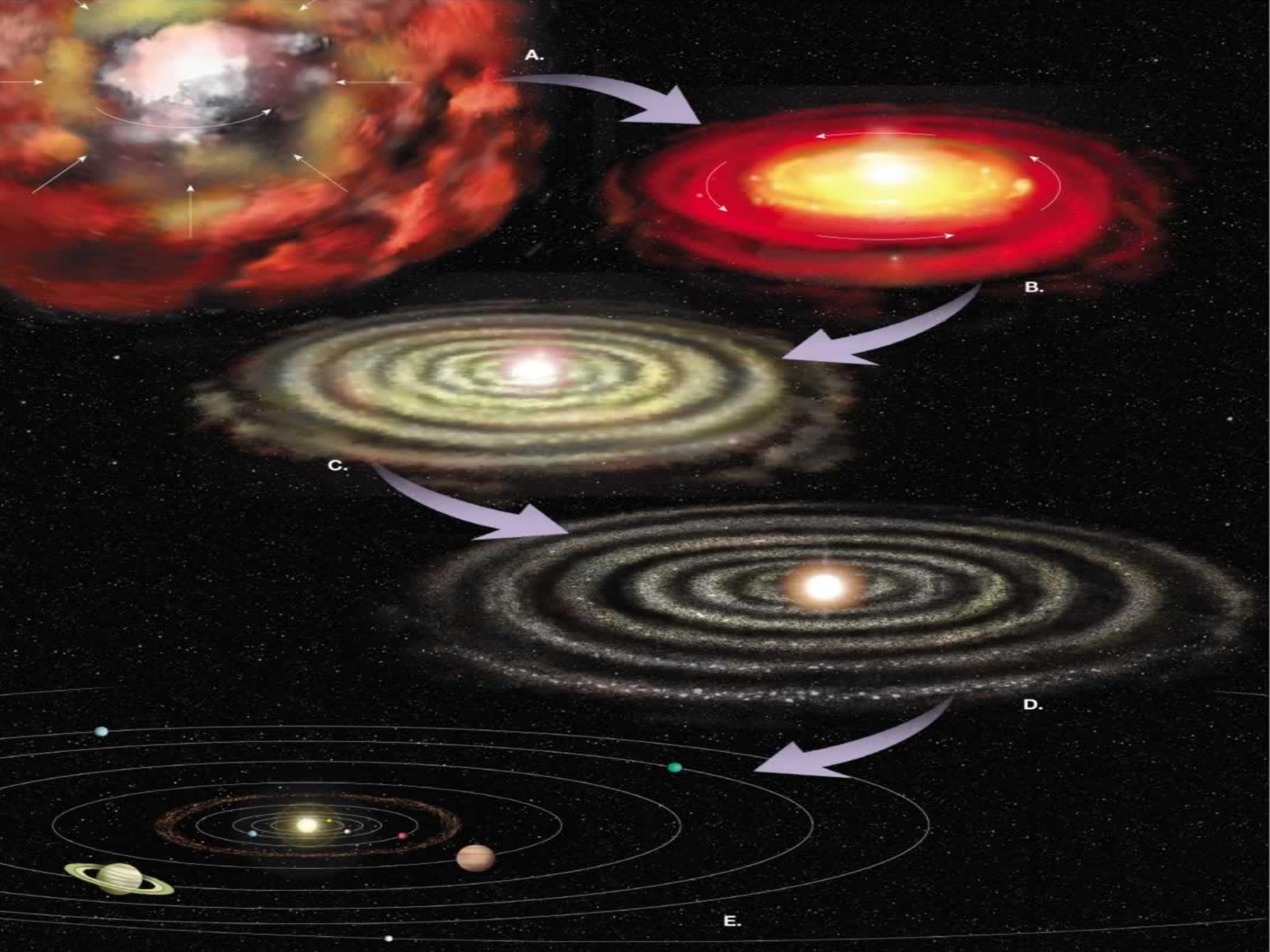
Questions About Water

- * How was water distributed in the formation of the Solar System?*
- * Earth has substantially more water than could be expected at 1 AU from the Sun. So, how did Earth come to possess its seas?*
- * What about other celestial bodies?*

Water in the Formation

A protoplanetary disk (proplyd) is shown, consisting of a central star surrounded by a disk of gas and dust. The disk is composed of concentric rings of material, with the innermost rings being the hottest and the outermost being the coldest. The central star is a bright yellow-orange color, and the disk is a mix of brown and orange hues, with some darker regions. The background is a dark, starry space.

- * In the inner planets region mainly grains of rock left behind
- * Farther out, debris formed the carbonaceous chondrites which carry up to 10 percent of their mass in water
- * Beyond the giant planets, water condensed in large quantities and formed comets, which are about half water-ice.



Search for Real Data



Search for Real Data

★ PDS Text Search: “Water”

Search for Real Data

★ PDS Text Search: “Water” => 117 results

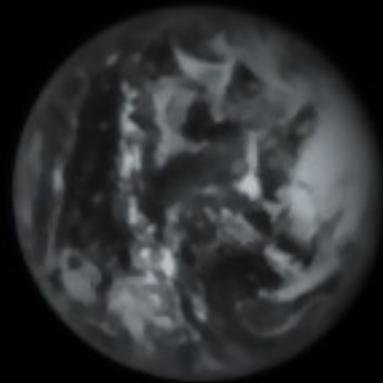
- ◆ 60 *Datasets*

- ◆ 48 *Instruments*

- ◆ 5 *Missions*

- ◆ 3 *Instrument Hosts*

- ◆ 1 *Target*



Earth

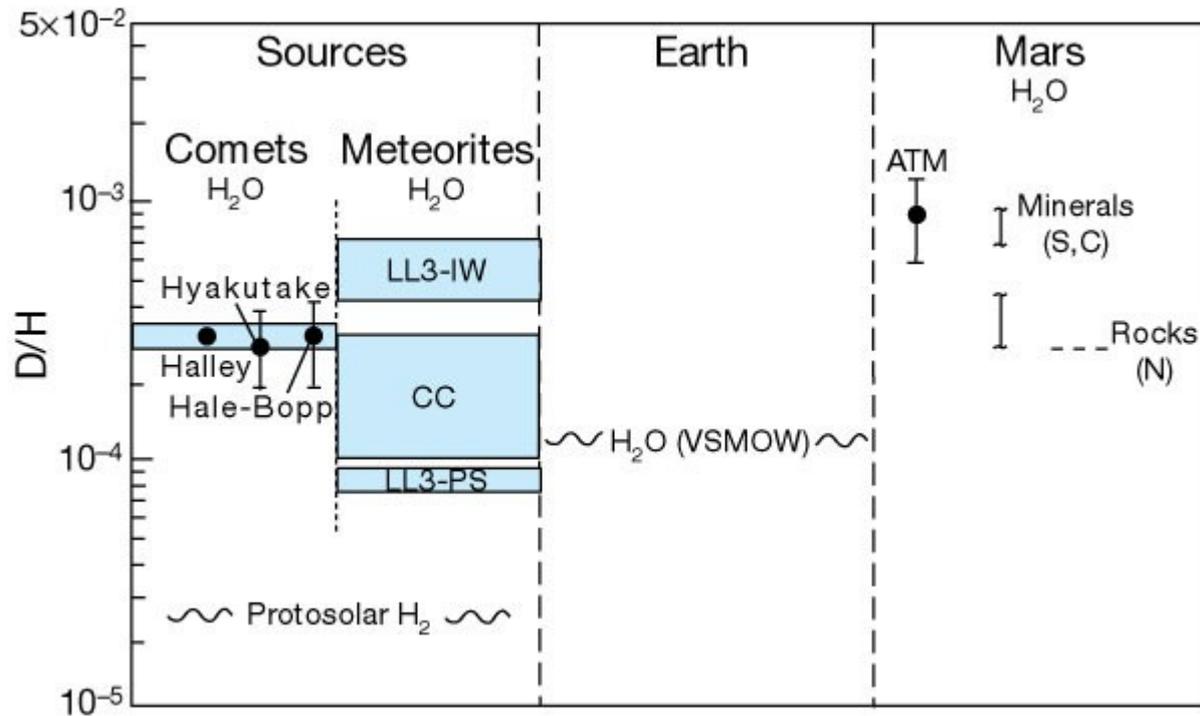
Source: Hayabusa Project Science Data Archive

Earth

- ★ Total amount of water is about 10(?) terrestrial oceans *
- ★ About 0.02 percent of Earth's water mass is in its oceans, other amount sits beneath the surface
- ★ Possible sources can be divided into endogenous and exogenous
- ★ Among discriminators, the D/H ratio discriminator has most data available.

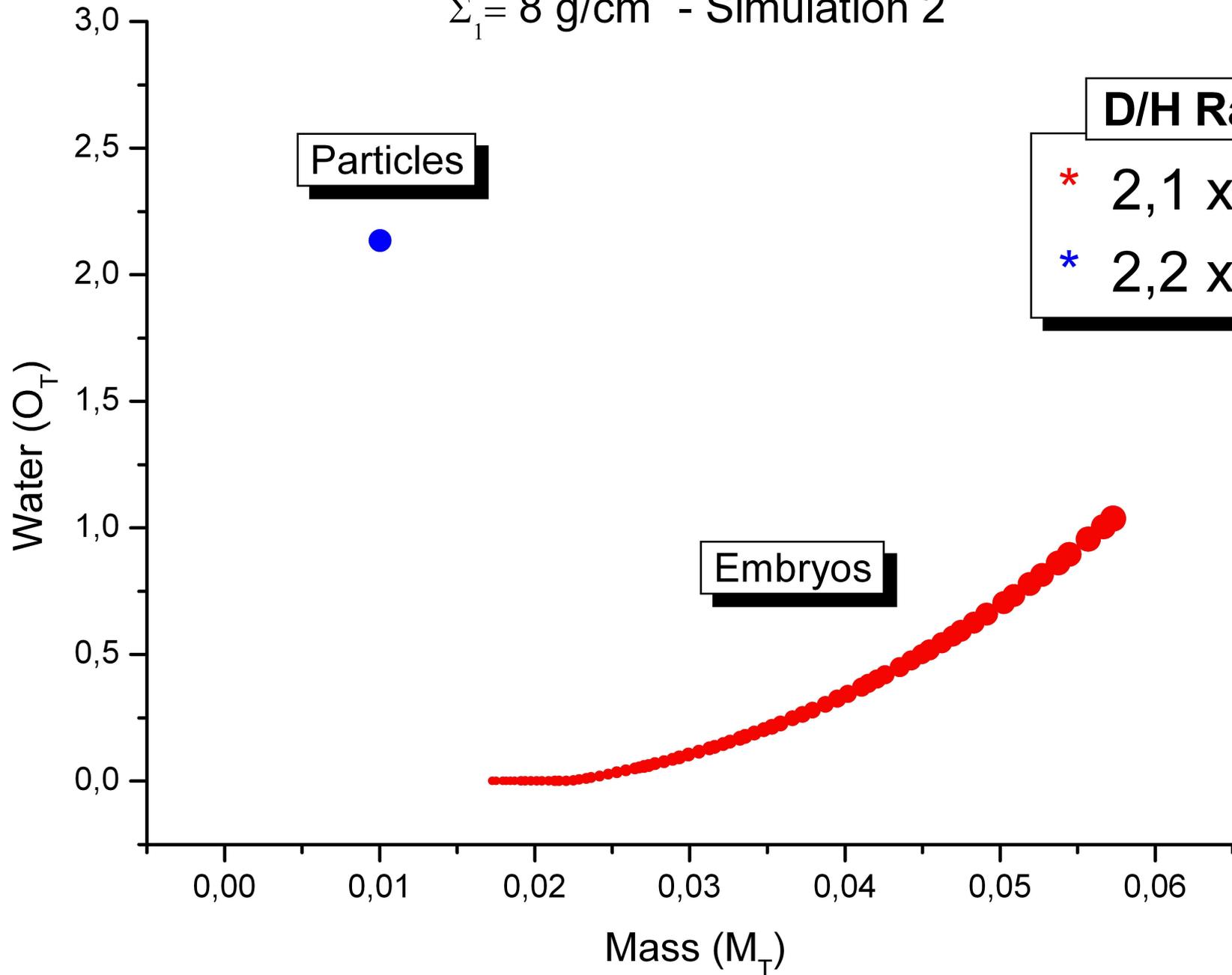
* $1 O_T = 1.4 \times 10^{24}$ g of water

Known D/H Ratios

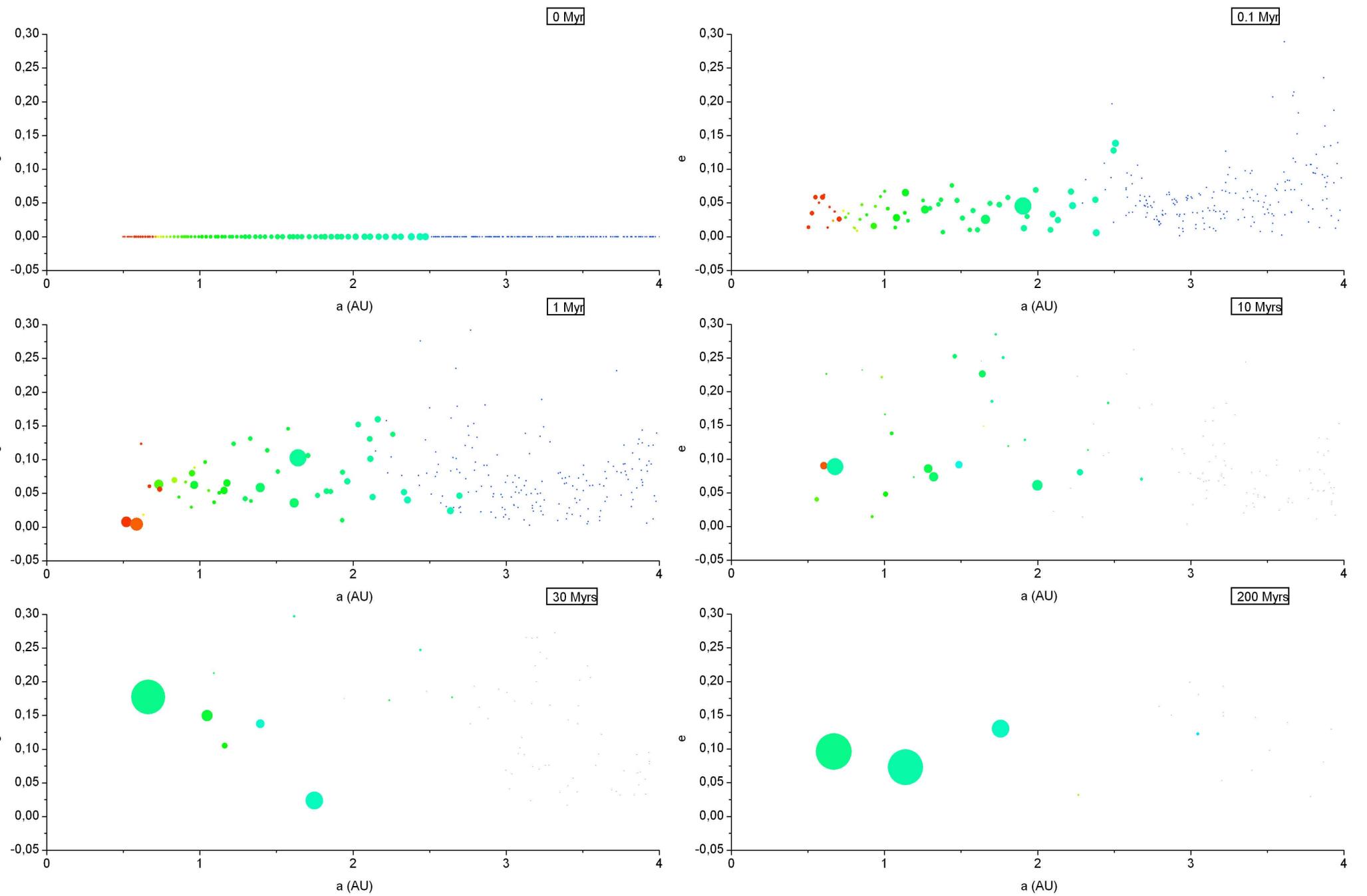


Initial Conditions

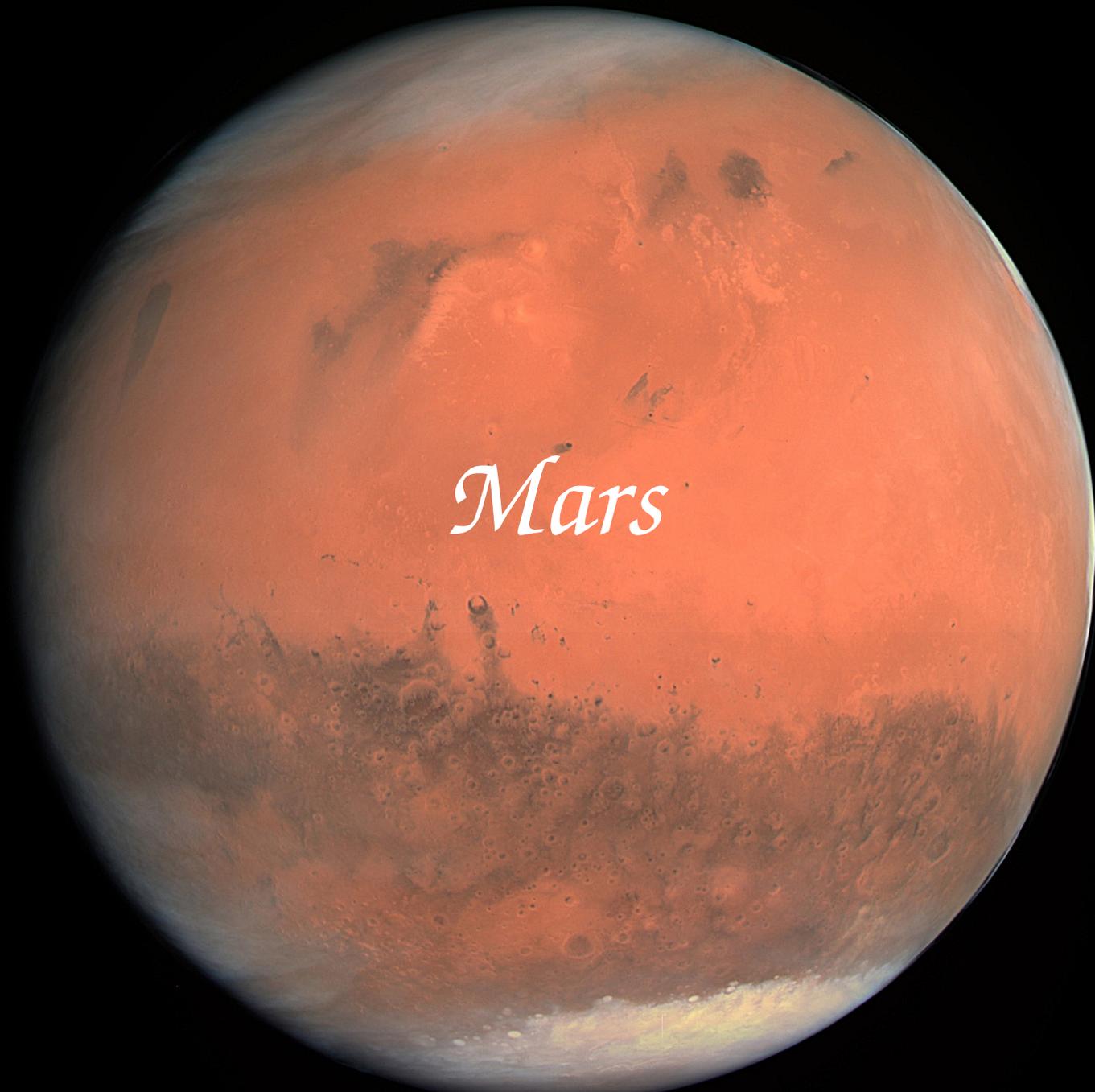
$\Sigma_1 = 8 \text{ g/cm}^2$ - Simulation 2



$\Sigma_1 = 8 \text{ g/cm}^2$ - Simulation 2

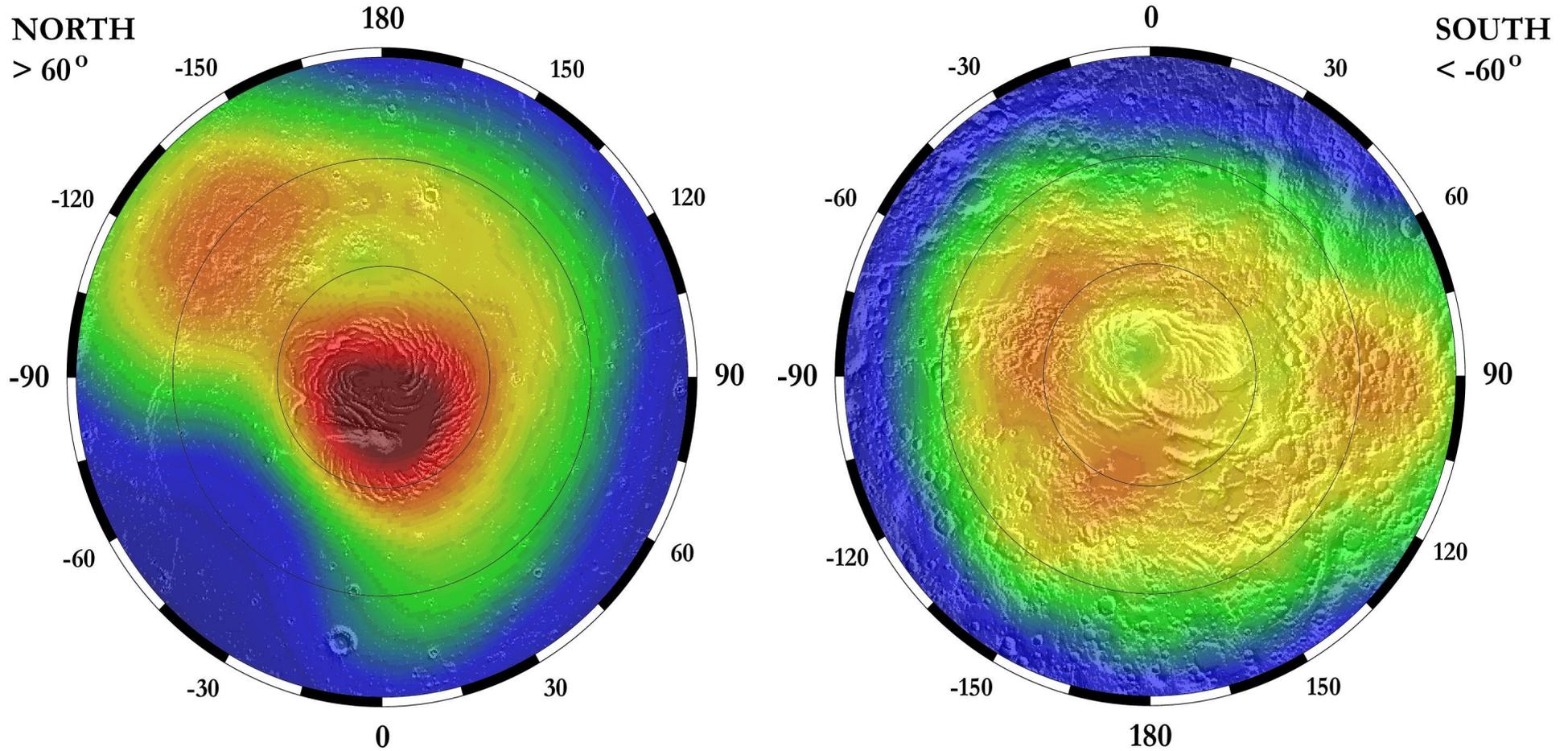
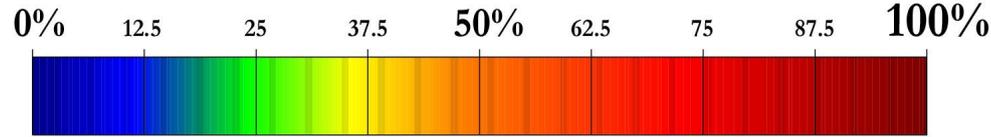


-5,250 -4,740 -4,230 -3,720 -3,210 -2,700 -2,190 -1,680 -1,170 -1,000



Source: ESA/MPS - 24 February 2007 during Rosetta's swing-by of Mars (OSIRIS)

Water Equivalent Hydrogen Abundance



Distribution of Water on Mars: Overlay of water equivalent hydrogen abundances and a shaded relief map derived from MOLA topography. Mass percents of water were determined from epithermal neutron counting rates using the Neutron Spectrometer aboard Mars Odyssey between Feb. 2002 and Apr. 2003.

These data were generated by the Planetary Science Team at Los Alamos: B. Barraclough, D. Bish, D. Delapp, R. Elphic, W. Feldman, H. Funsten, O. Gasnault*, D. Lawrence, S. Maurice*, G. McKinney, K. Moore, T. Prettyman, R. Tokar, D. Vaniman, and R. Wiens. * Also at Observatoire Midi-Pyrenees, France

Reference: Feldman W. C., T. H. Prettyman, S. Maurice, J. J. Plaut, D. L. Bish, D. T. Vaniman, M. T. Mellon, A. E. Metzger, S. W. Squyres, S. Karunatillake, W. V. Boynton, R. C. Elphic, H. O. Funsten, D. J. Lawrence, and R. L. Tokar, The global distribution of near-surface hydrogen on Mars, *JGR-planets*, submitted July 2003.

The neutron spectrometer aboard Mars Odyssey, a component of the Gamma-ray Spectrometer suite of instruments, was designed and built by the Los Alamos National Laboratory and is operated by the University of Arizona in Tucson. The Mars Odyssey mission is managed by the Jet Propulsion Laboratory.

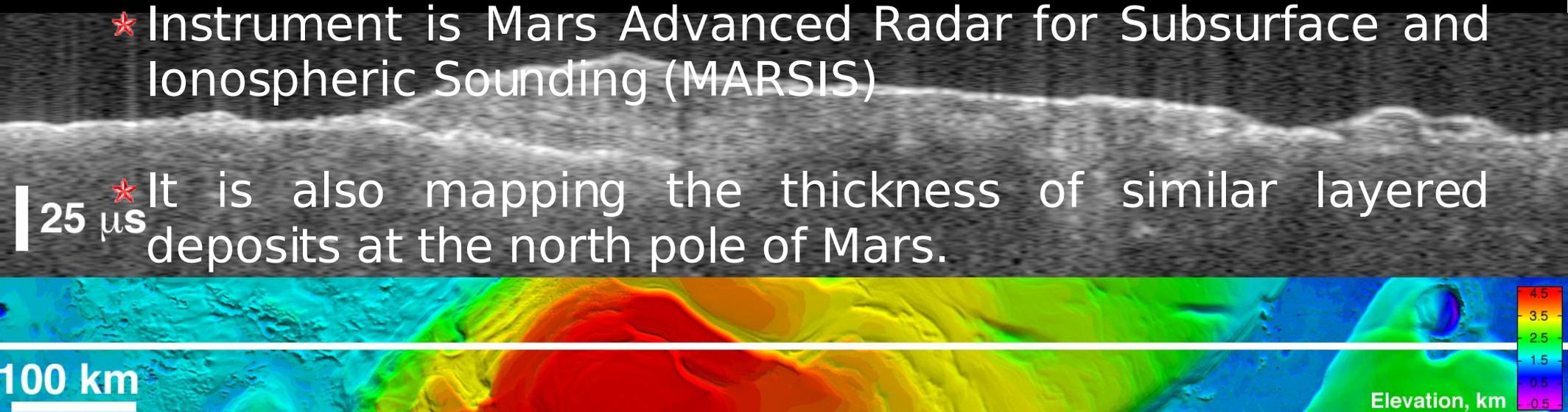
Mars

A high-resolution stereo image of the Louth crater on Mars. The crater is a large, roughly circular depression in the reddish-brown Martian surface. At the center of the crater floor, there is a prominent, bright, circular patch of white material, which is residual water ice. The surrounding terrain is textured with various shades of brown and red, indicating different mineral compositions and erosion patterns. The word "Mars" is written in a white, cursive font at the top center of the image.

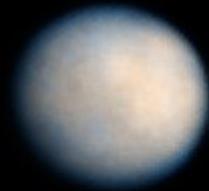
- ★ High Resolution Stereo Camera (HRSC) on ESA's Mars Express in 2 February 2005
- ★ Louth crater located on Vastitas Borealis, at approximately 70.5° North and 103° East
- ★ The circular patch of bright material located at the centre of the crater is residual water ice
- ★ Colours are very close to natural.

Mars

- ★ Mapping the thickness of ice in south polar region revealed ice layers as deep as 3.7 kilometres below the surface
- ★ The amount of water trapped in frozen layers is equivalent to a liquid layer about 11 metres deep covering the planet
- ★ Instrument is Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS)
- ★ It is also mapping the thickness of similar layered deposits at the north pole of Mars.



Bright lower echo from Mars' south-polar layered deposits. Source: ESA Space Science (15 March 2007)

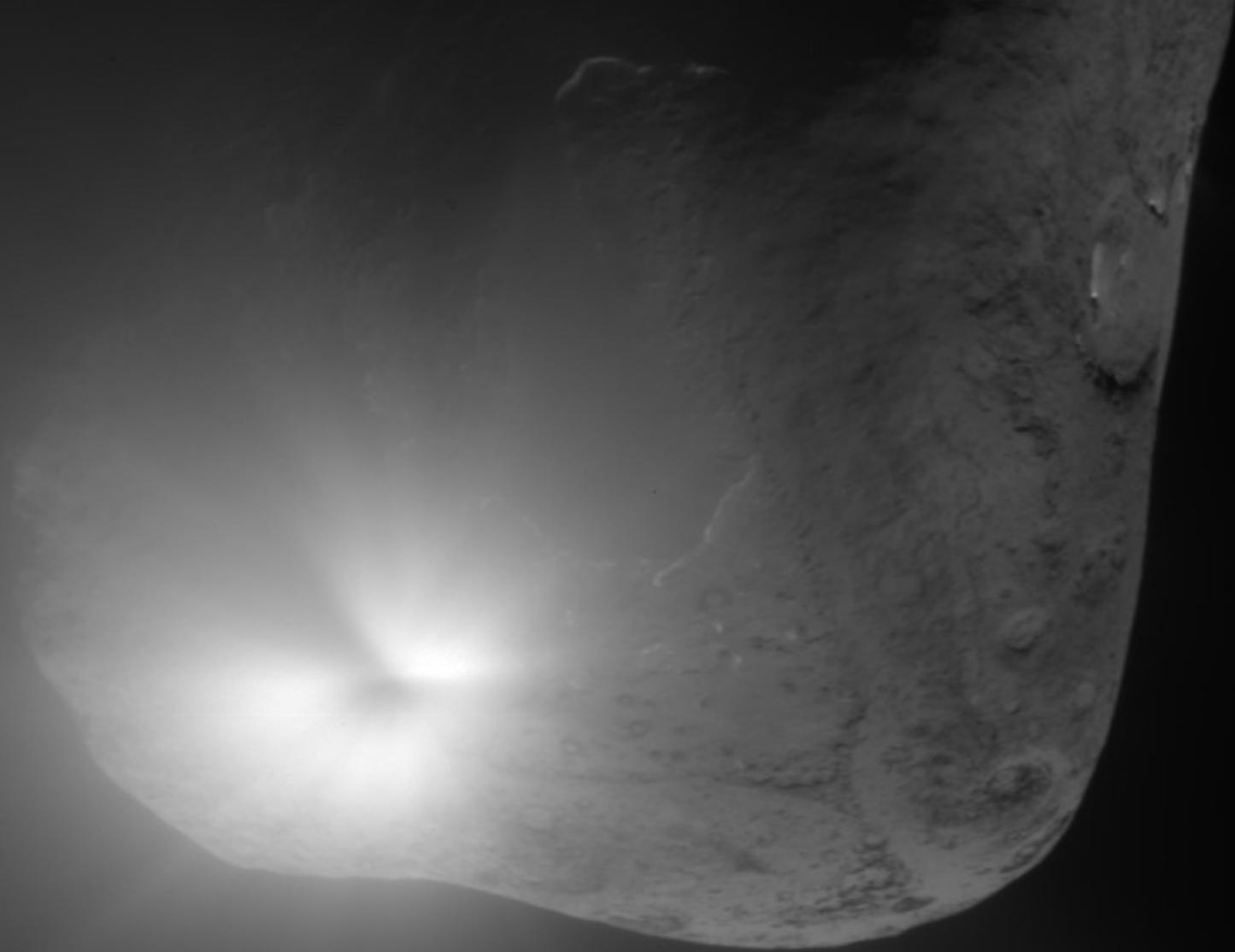


Ceres

Source: hubblesite.org

Ceres

- ★ Previous attempts to match with meteorite spectrum were unsuccessful: type is unique
- ★ Water content expected between 17% and 27% by Mass
- ★ Close inspection by Dawn Mission in Feb-July 2015



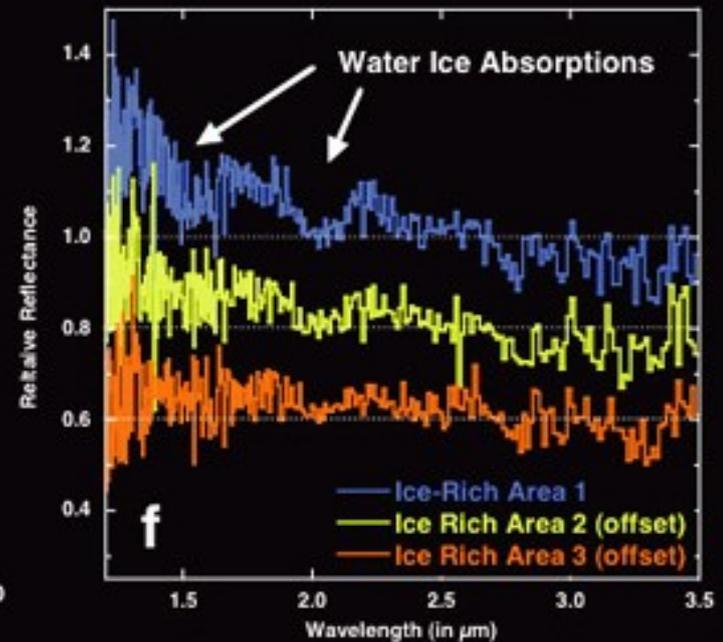
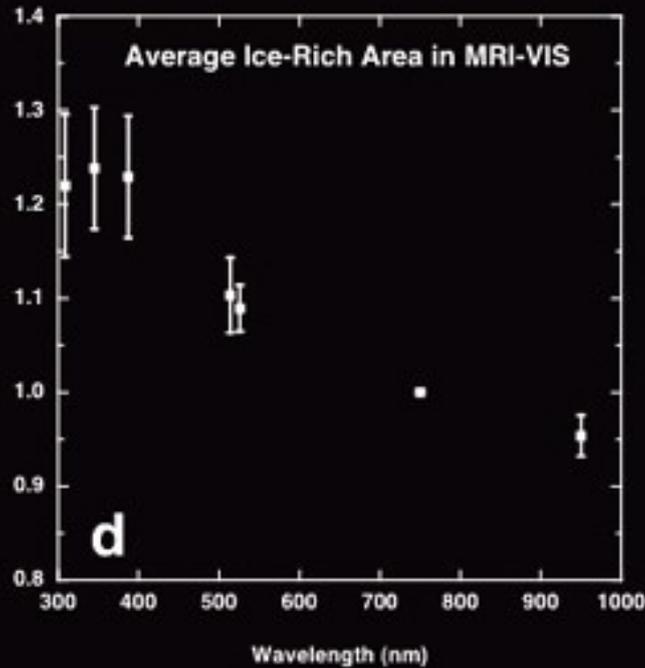
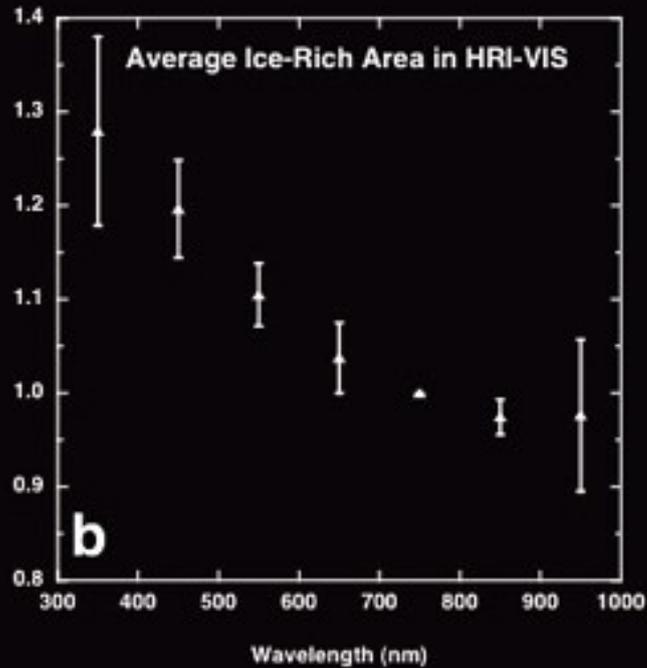
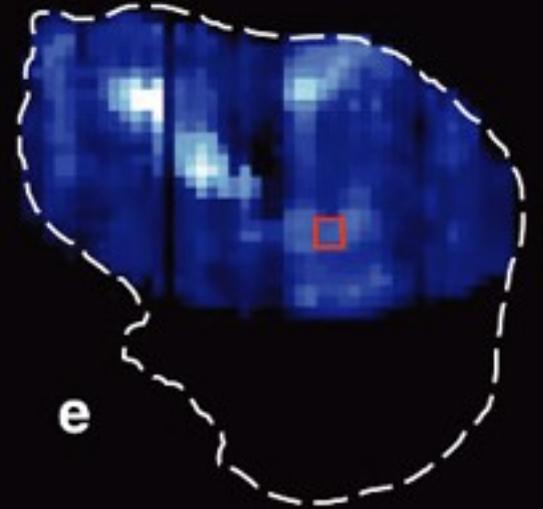
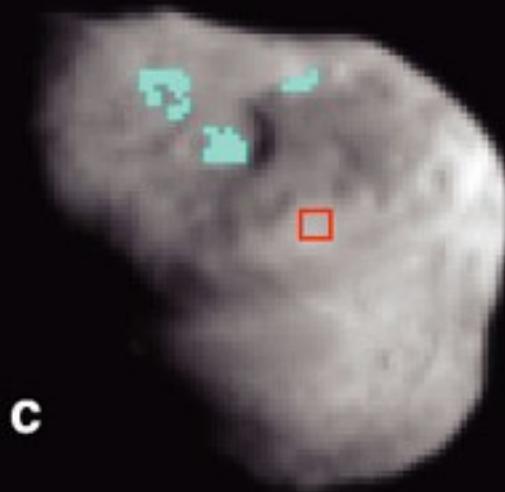
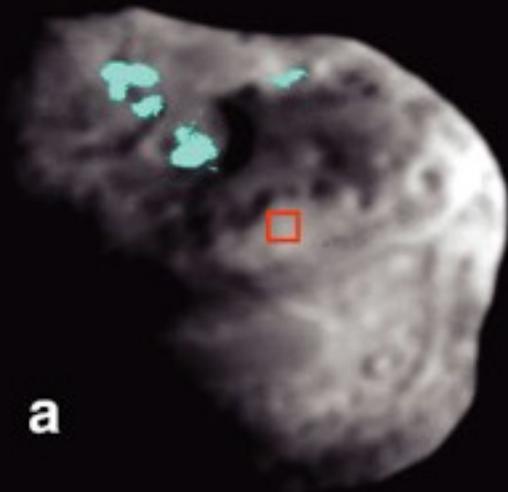
Comet 9P/Tempel 1

Source: PDS – Small Bodies Node – Deep Impact

Comet 9P/Tempel1

- ★ Deep Impact spacecraft encountered Comet 9P/Tempel 1 on July 4th, 2005
- ★ Prior to the impact event, the coma was monitored and gaseous water are detected (HRI-IR spectrometer)
- ★ Water gas was detected in the pre-impact ambient coma as well as in the impact ejecta 
- ★ First time water ice has been directly detected on the surface of a comet.

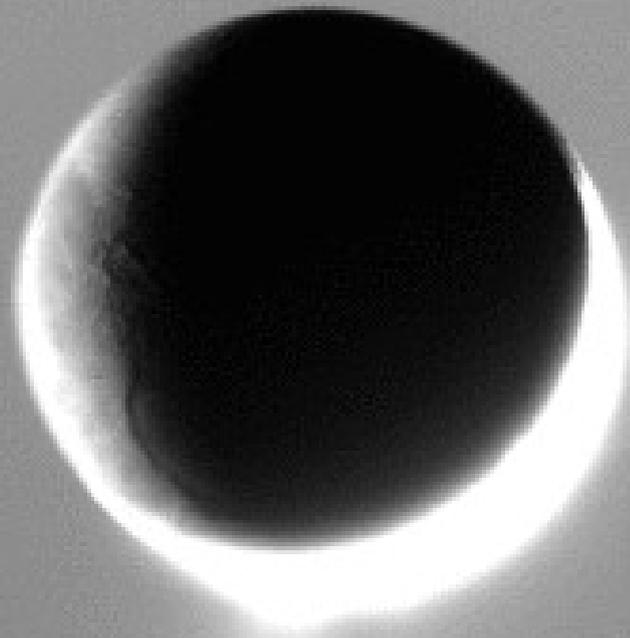
Comet 9P/Tempel1



Comet 9P/Tempel1

- ★ The quantity of hot water detected in the vapor plume is considerably greater than the water in the ambient coma
- ★ Water ice is present in the interior at least to the maximum depth ejected by the impact, ~10 to 20 meters
- ★ Total amount of water ice is not quantified yet.

Enceladus

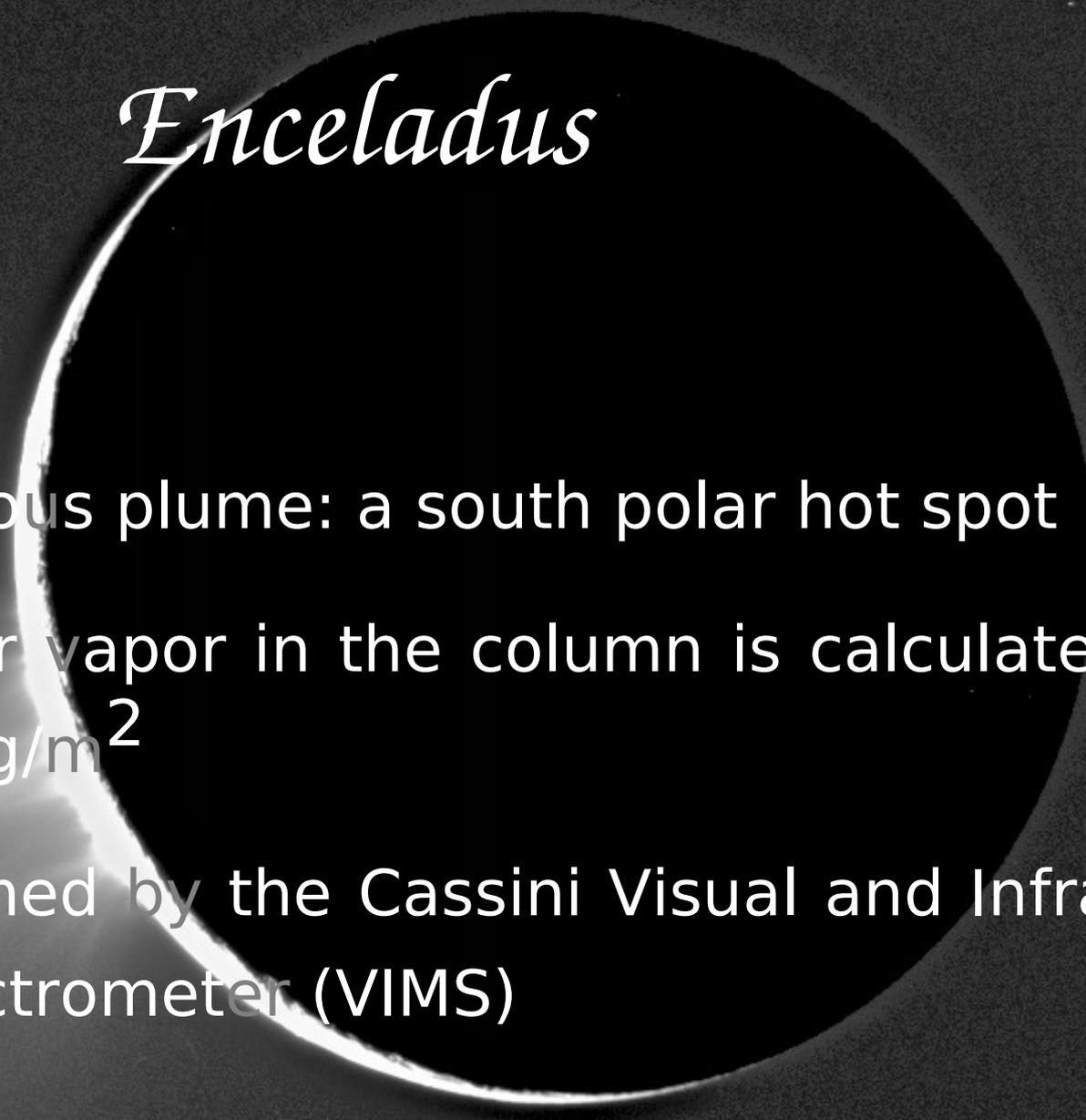


Source: PDS Data System – Enceladus

Enceladus

- ★ One of the most geologically dynamic objects in the solar system
- ★ Imaged by the Cassini spacecraft in February 2005
- ★ Surface temperature is about 73 kelvins
- ★ But plumes arise from near-surface pockets of liquid water at temperatures of 273 kelvins or more

Enceladus



- ★ Watery, gaseous plume: a south polar hot spot
- ★ Mass of water vapor in the column is calculated in $7.16 \times 10^{-6} \text{ kg/m}^2$
- ★ Water confirmed by the Cassini Visual and Infrared Mapping Spectrometer (VIMS)

Enceladus

- ★ Surface of Enceladus is bright and is mostly water ice
- ★ Surface marked by deep canyons and thick flows
- ★ Only the third known solid planetary body – after Earth and Io – that is sufficiently geologically active for its internal heat to be detected by remote sensing (by Cassini's Composite Infrared Spectrometer – CIRS)
- ★ Unique among Saturn's medium-sized icy satellites, because its surface includes sizable crater-free areas that have been resurfaced by endogenic forces.

A large, bright yellow sun with a textured surface of solar flares and sunspots. A small planet, resembling Jupiter with its characteristic bands, is visible in the distance, partially obscured by the sun's glow. The background is a deep blue and black space filled with numerous stars of varying colors and sizes.

“Is the truth out there...?”

HD 209458 b

- ★ First transiting extrasolar planet discovered, the first extrasolar planet known to have an atmosphere
- ★ In April 10 2007 is announced evidence that the atmosphere contained water vapor
- ★ By combination of previously Hubble Space Telescope measurements and new theoretical models
- ★ Hypothesis is still being investigated for confirmation.

Acknowledgments

- ★ Ceres: Lucy A. McFadden*
- ★ Mars: Angelo Pio Rossi*
- ★ Tempel1: Mike A'Hearn*
- ★ Enceladus: Mark Showalter*