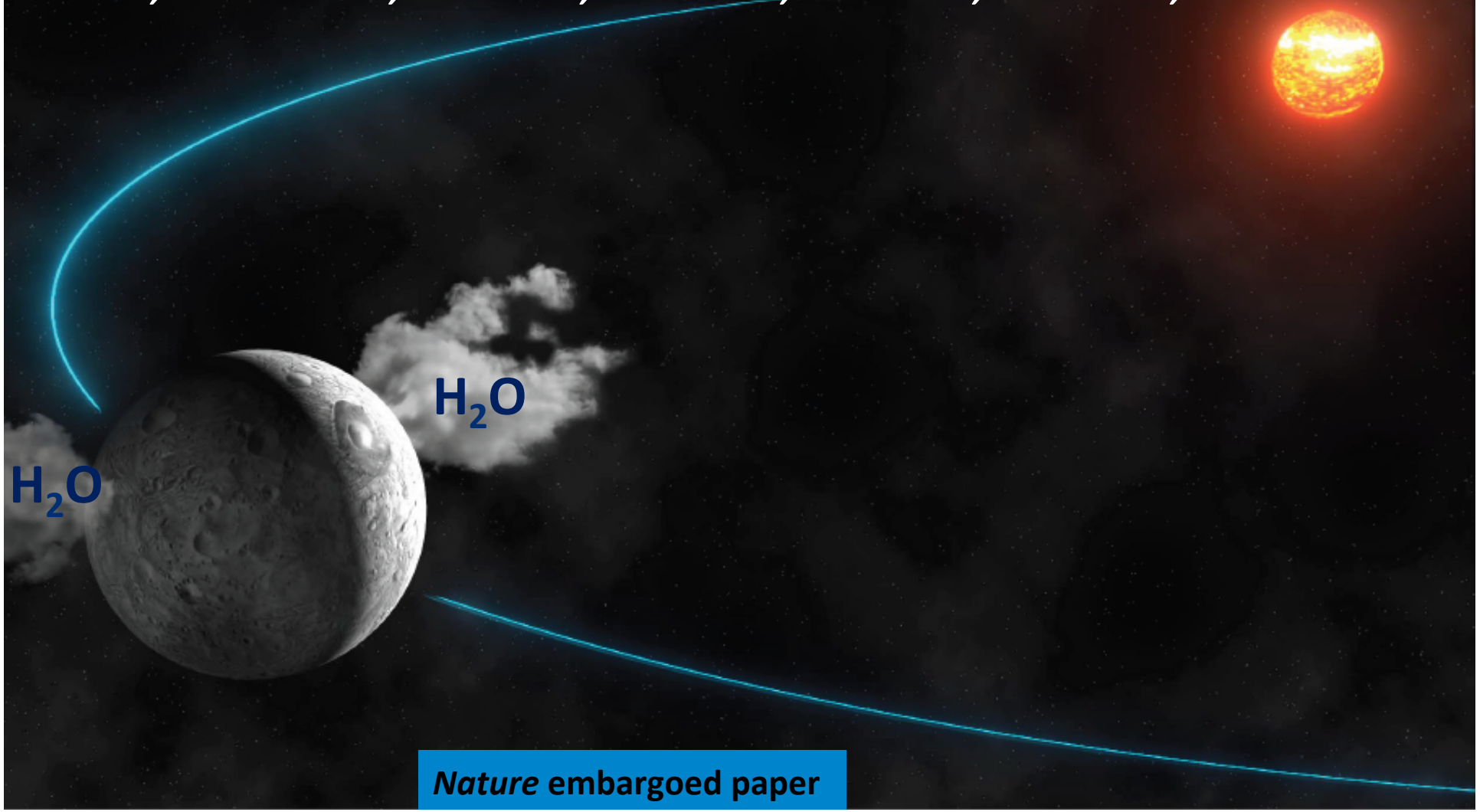
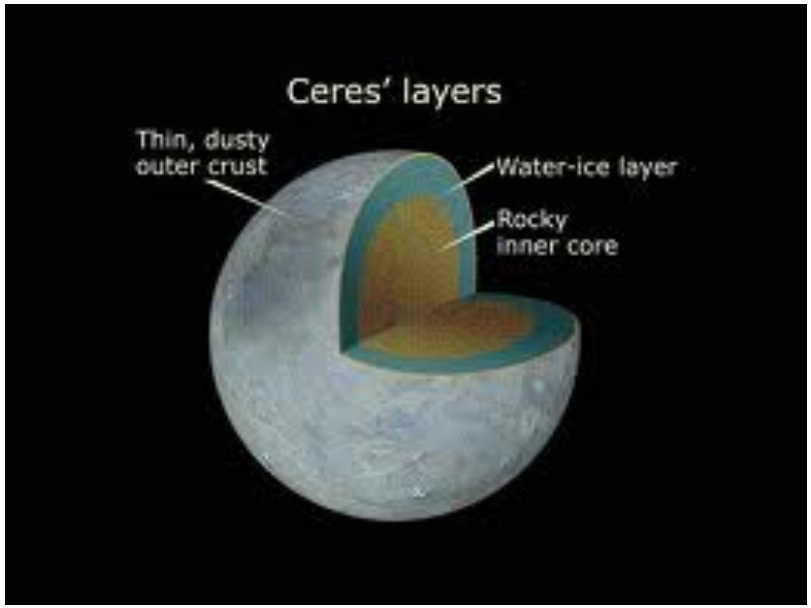
The water regime of dwarf planet (1) Ceres

M. Kueppers, L.O'Rourke, B. Carry, D. Bockelée-Morvan, V. Zakharov, D. Teyssier, S. Lee, M. Van Allen, T. Marson, J. Crovisier, T. Mueller, R. Moreno, A. Barucci



***Nature* embargoed paper**

Introduction: H_2O in Ceres

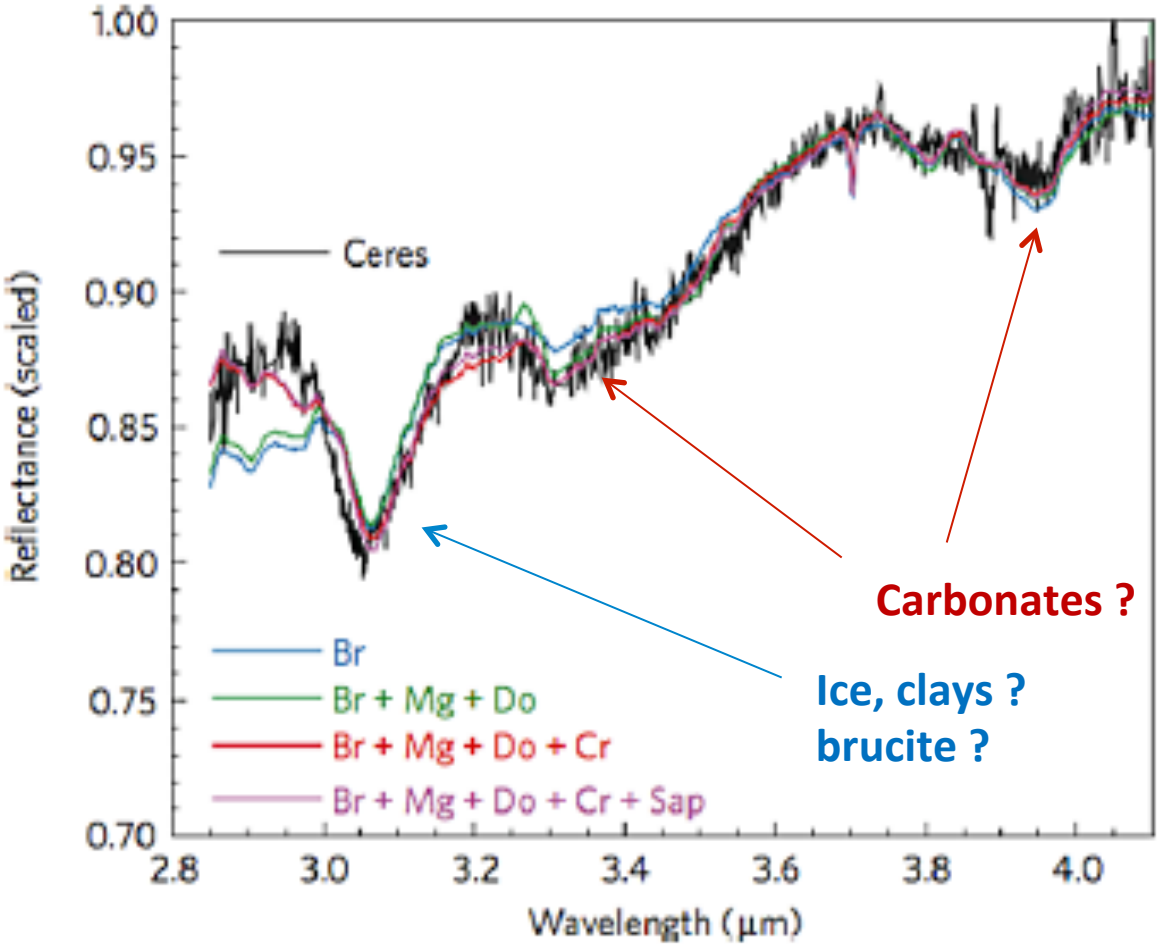


Ceres
- the largest asteroid (dwarf planet)
- diameter: 974 km
- density: 2,08 g/cm^3
- orbits between 2.54 et 2.98 AU
- type C, albedo = 0.09

- Differentiated body (from the shape: polar radius ~ 30 km smaller than equatorial radius)
- Models of the thermal evolution of Ceres and its low density suggest an icy mantle (30-80 km) under the surface regolith (a few 10 m), and possibly liquid water.

  ~25 % of water ice
- Smooth surface: suggests past (current ?) global-scale resurfacing by hydrothermal activity.
- Ice is not expected at the surface (dark object, and ice sublimates rapidly)
- IR spectra: hydrated minerals at the surface

IR spectrum of Ceres



small rotational variations correlated with albedo

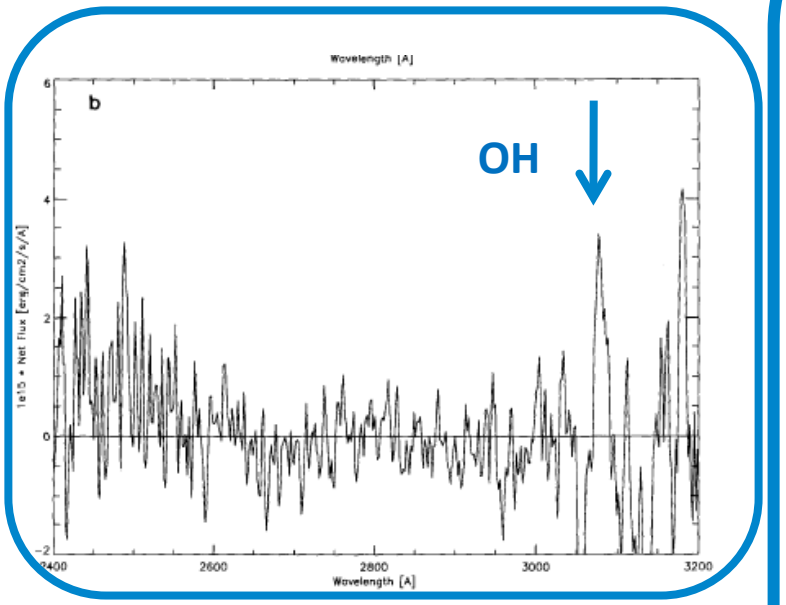
(smaller band depth on bright regions)

Vernazza et al. 2005: water ice & hydrated silicates

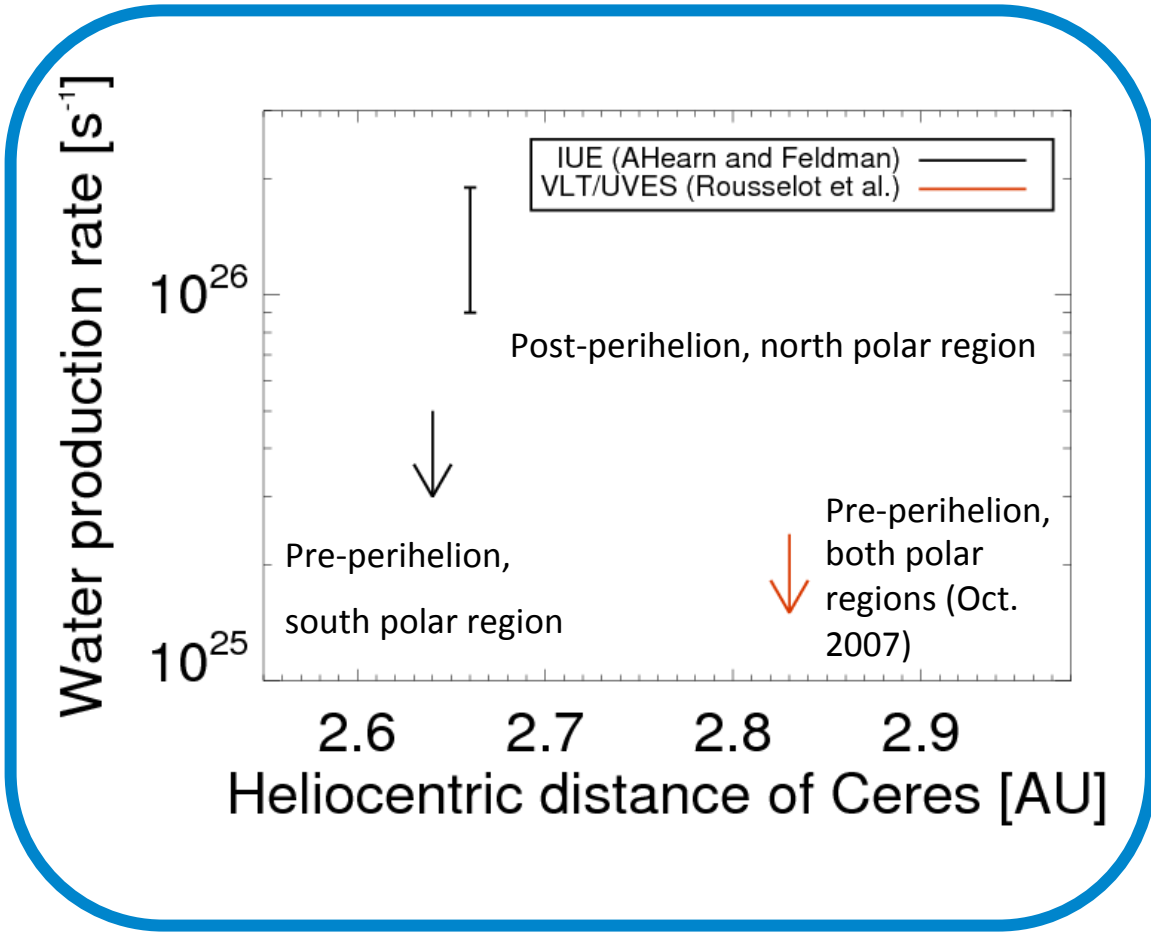
Mullinen & Rivkin 2009 : brucite $Mg(OH)_2$ and carbonates

Observations of OH in UV

29 mai 1991



A'Hearn et al. 1992



The marginal detection of OH by IUE suggests the presence of water vapour around Ceres

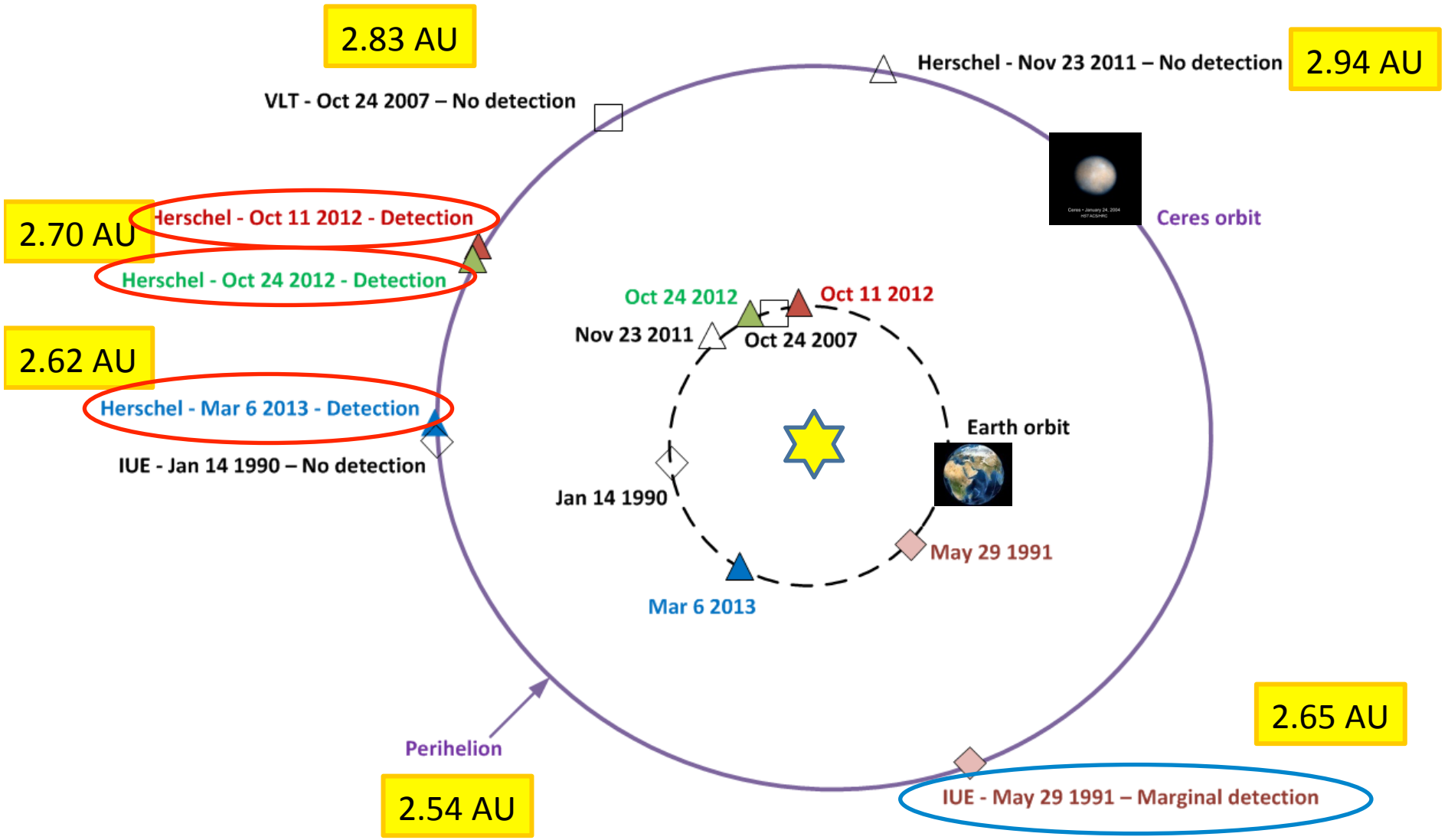
H_2O observations of Ceres with HIFI

- MACH 11 guaranteed time program (PI: L. O'Rourke)
  + DDT Kueppers et al.

- Fundamental 1_{10} -1_{01} H_2O line at 557 GHz
- Dual beam-switching
- Observations in band 1b receiver, except in March 2013 (band 1a)

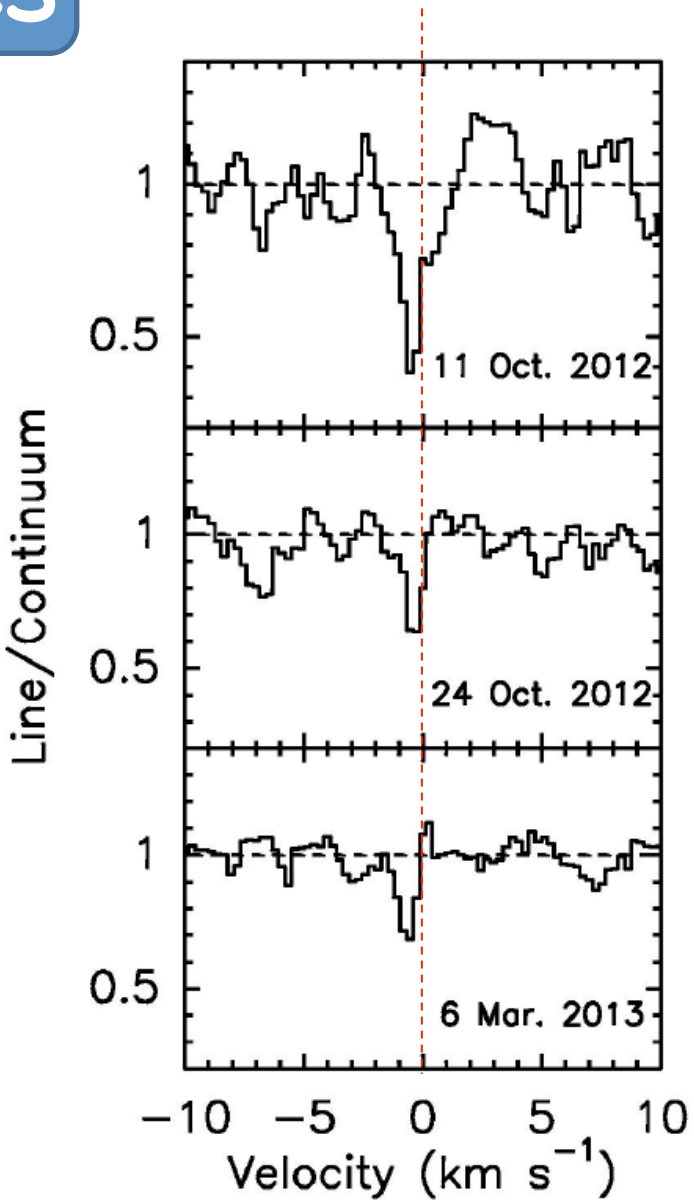
- **23 November 2011** at 2.94 AU from Sun, pre-perihelion (integration time: 1.1 h)
- **11 & 24 October 2012** at ~2.7 AU (integration time: 2.4 h)
- **Continuous observations on 6 March 2013** at 2.6 AU
  (10 h, a little more than Ceres rotation period of 9.07 h)

Detection of H_2O gas

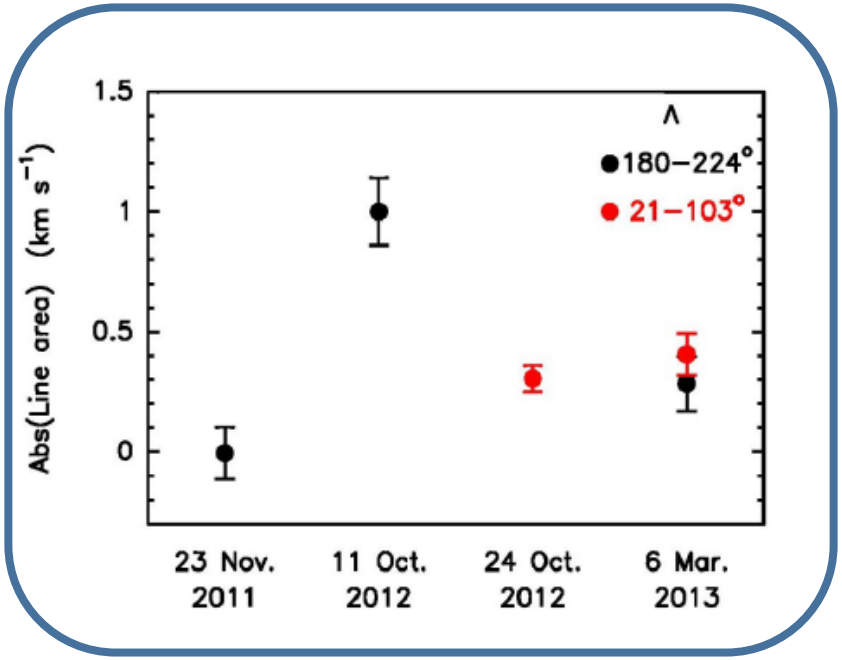


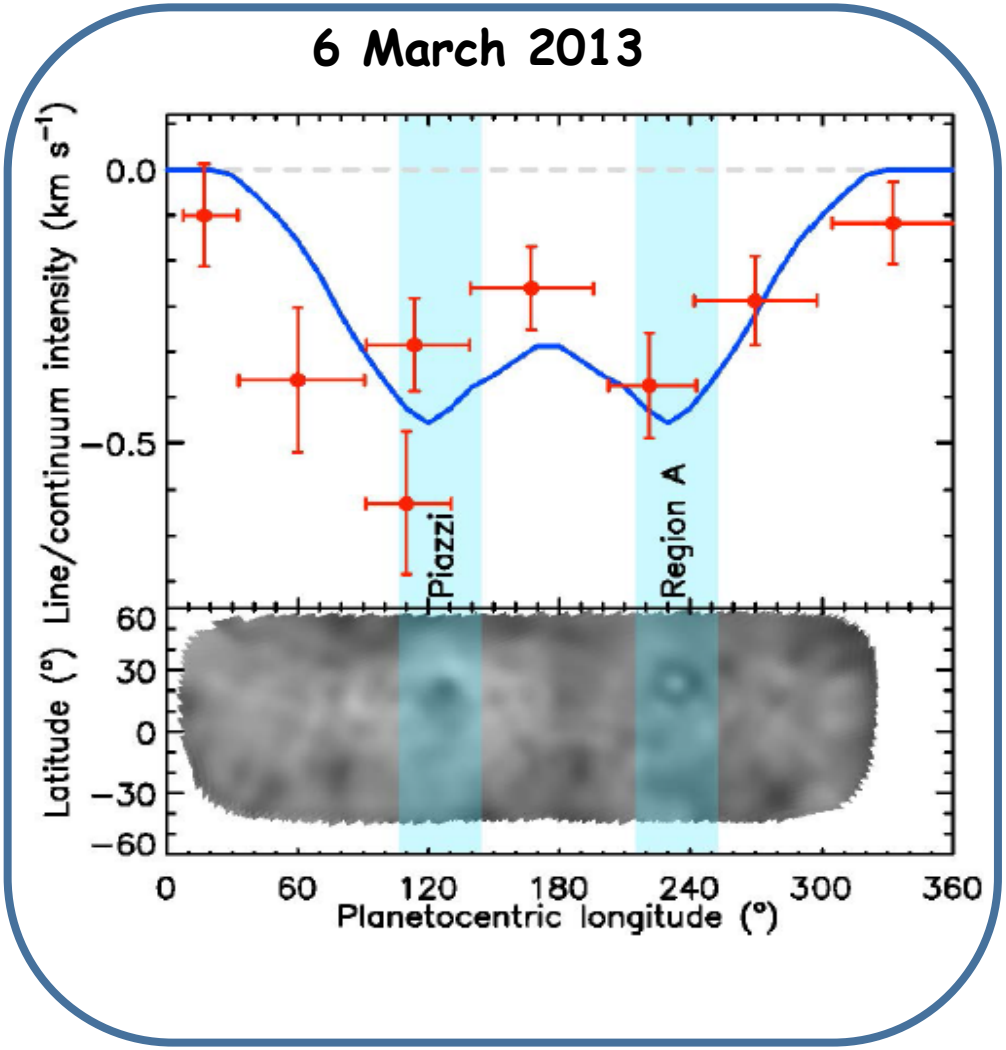
H_2O Spectra in Ceres

- H_2O line detected in absorption against Ceres thermal continuum (~ 10 Jy)
- Blueshifted absorption line (-0.7 to -0.3 km/s)
- Marginal detection of an emission feature at positive velocities
- Absorption signal variable on small and long time scales



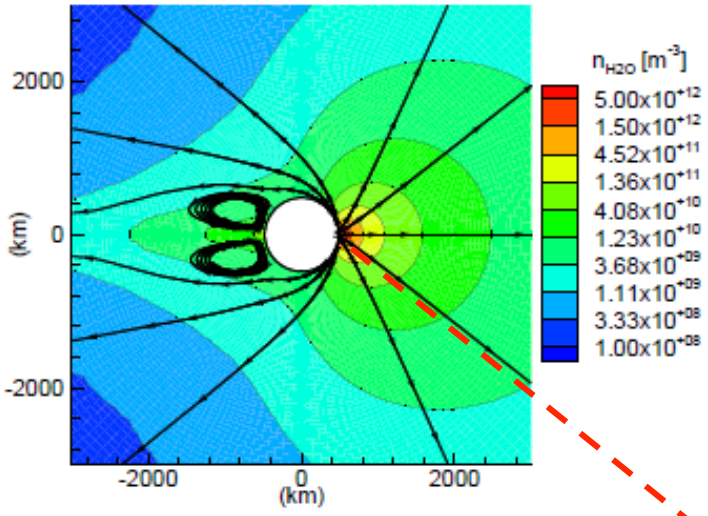
Time variation of the absorption line



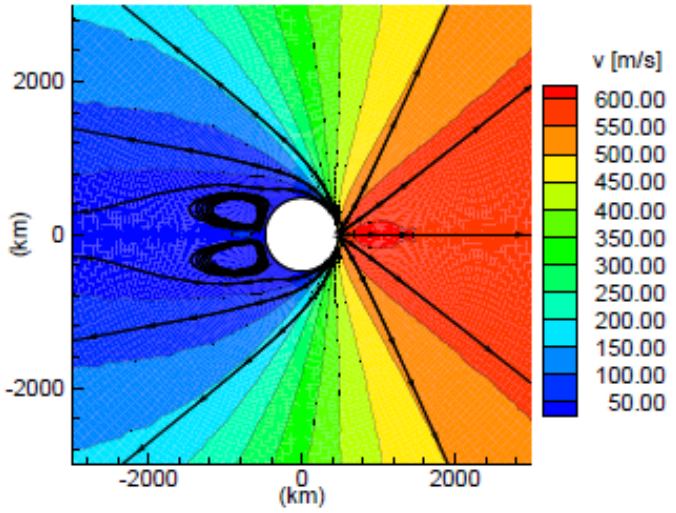


2D- Monte Carlo Simulations of Ceres's exosphere

Density

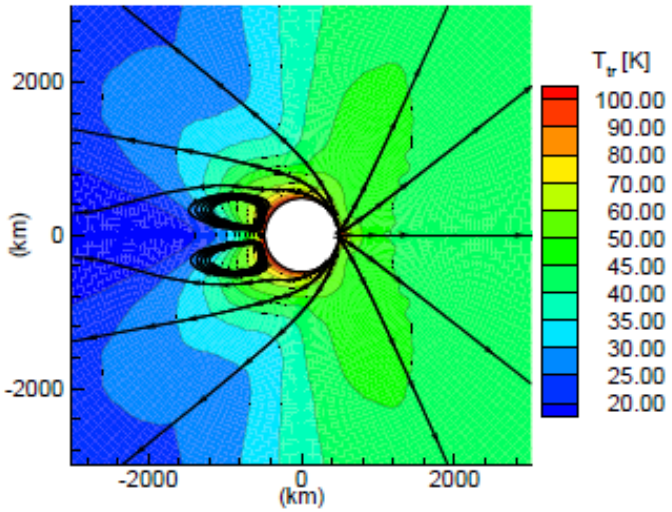


Velocity



Pressure ~ 1 mBar

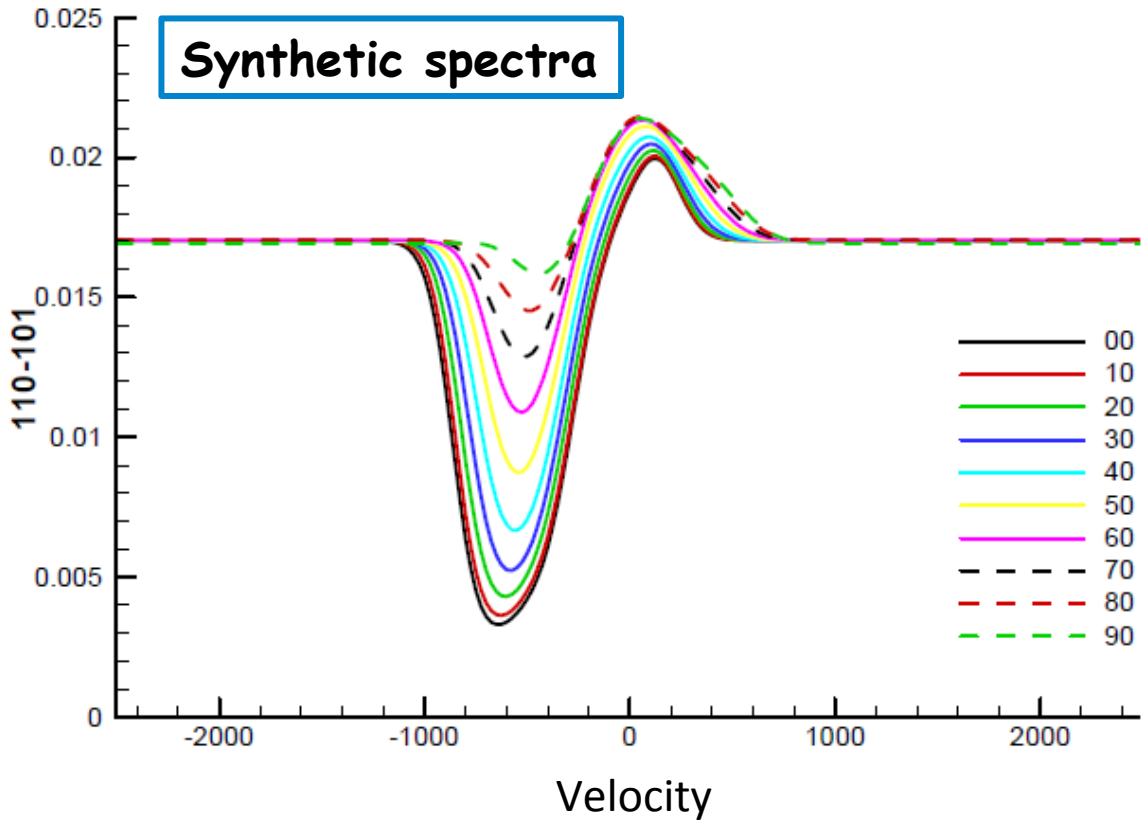
Temperature

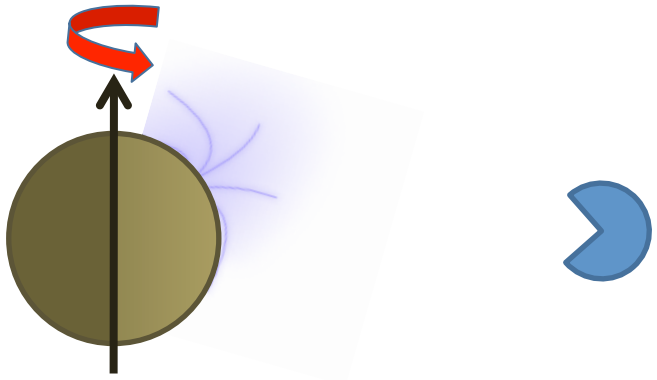


- Model including gravity
- $Q(H_2O) = 10^{26}$ mol/s from a region of 75 km diameter
- Tsurf : 235 K (sub-solar) to 168 K

Excitation model and radiative transfer (Monte Carlo)

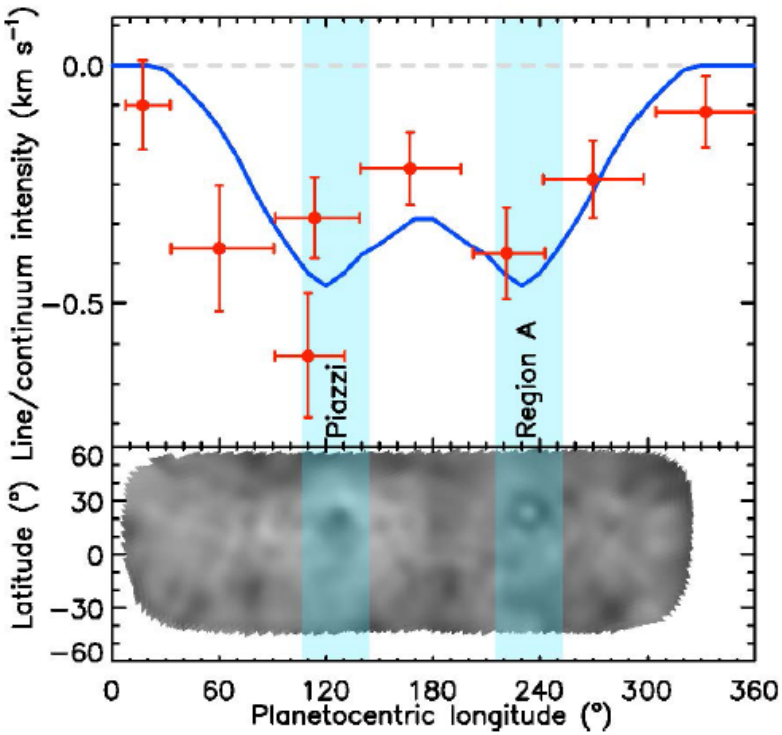
- Model including H_2O-H_2O collisions, excitation of IR bands by the solar radiation, and excitation by the Ceres thermal radiation

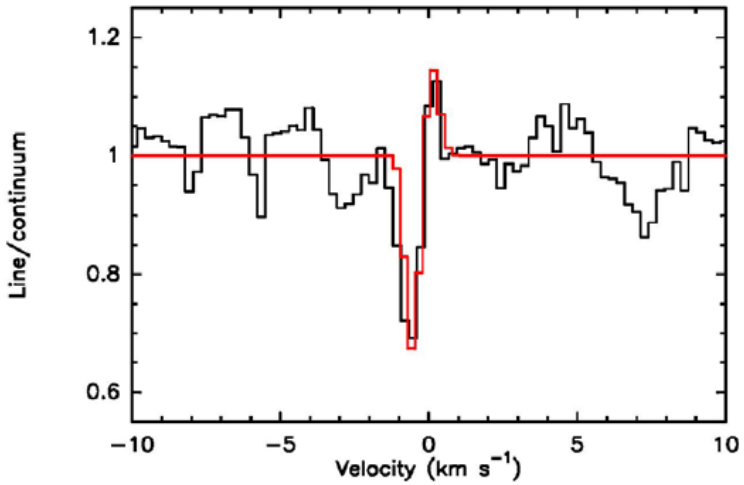




Sub-Earth point position wrt source position (degree)

Model with 2 sources for March 2013





- For each source: $Q(H_2O)$ = 10^{26} mol/s (3 kg/s)
- Sources permanently active
- Corresponds to ~0.6 km^2 of ice at the surface

= > 10^{-7} of Ceres surface and 10^{-5} of source regions

Summary

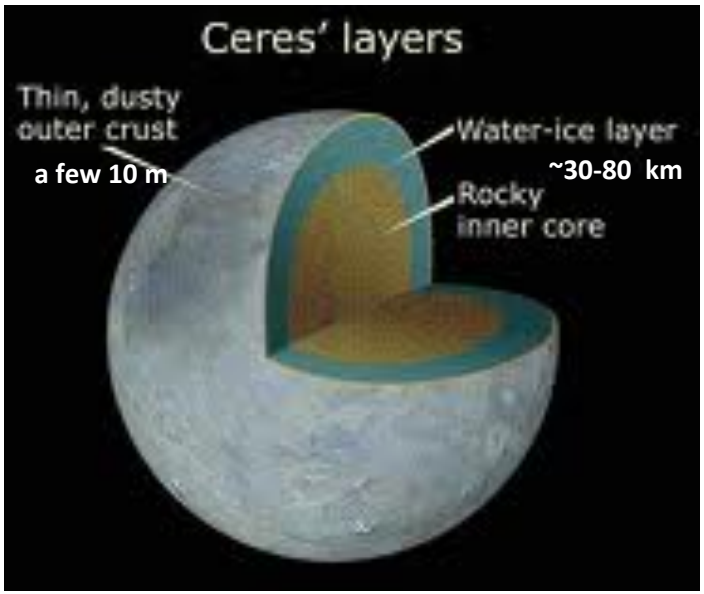
- Detection of an exosphere around Ceres – weak outgassing (3 kg/s)
- Water outgassing from mid-latitudes
- Seems associated to two dark regions (20 deg N) : Piazzi et region A

Cryovolcanism or comet-like activity

- More activity near perihelion: **comet-like activity with near-surface ice**

Inconsistent with ice stability: *« Ice could be present within a few meters below the surface at mid latitudes (tens of meters at equator), and near the poles (Shorghofer et al. 2009) »*

Recent impacts exposing underneath Ceres ice ? Ice-rich body impacts ?

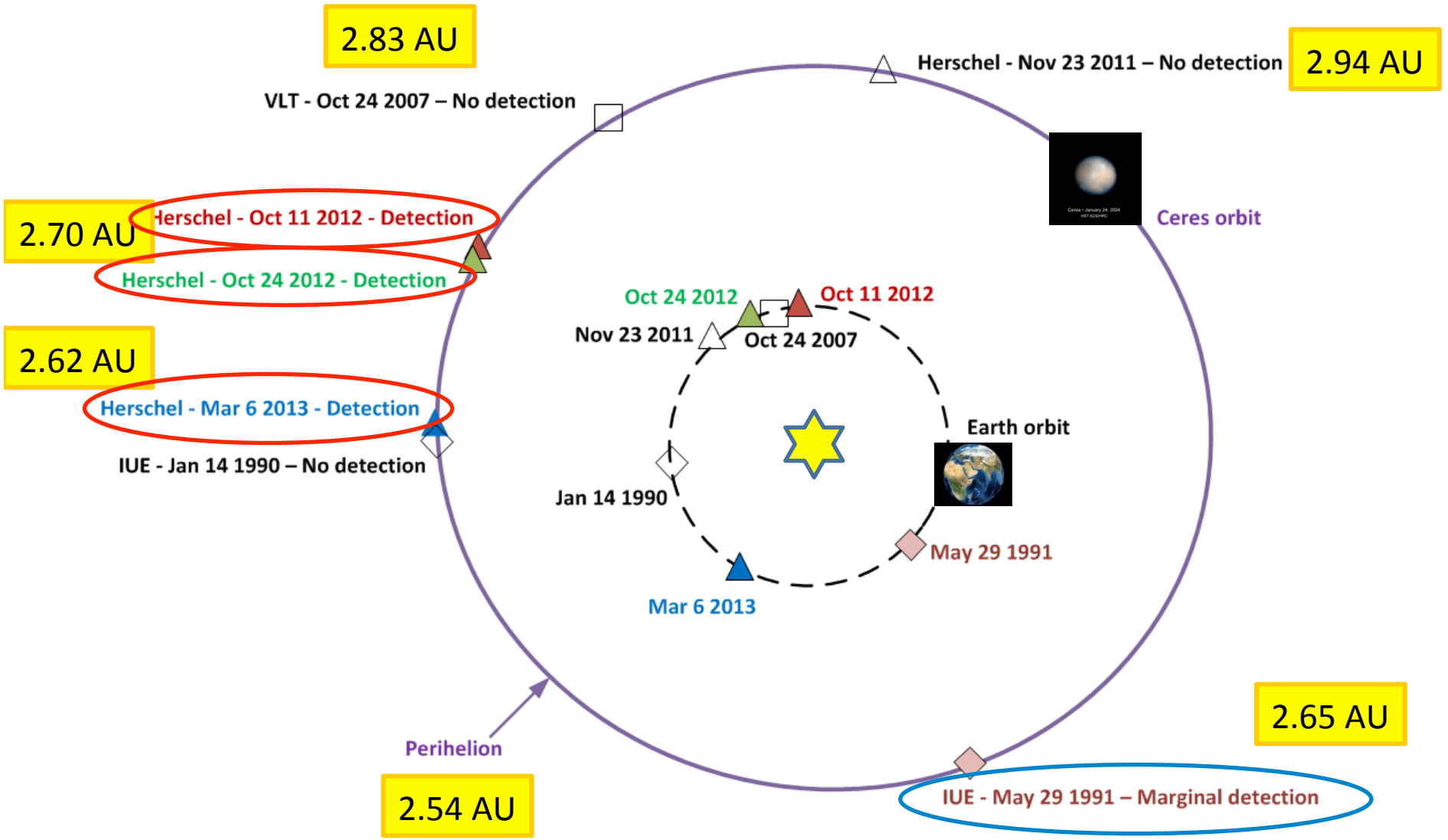


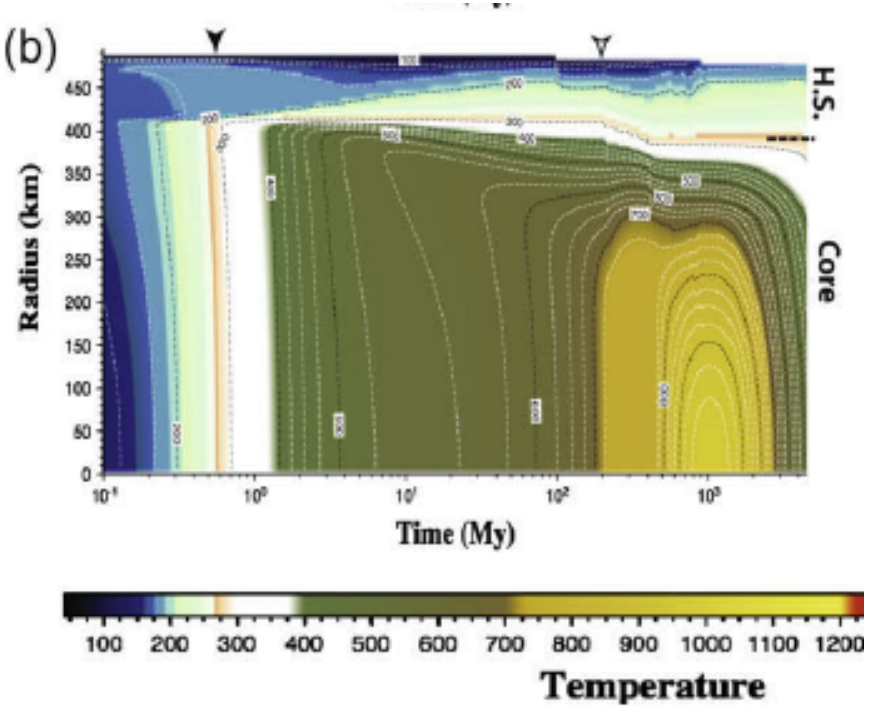
Hydrothermal activity ?

- Homogeneous surface: recent hydrothermal activity
- High temperature of the hydrosphère predicted (~170 K at equator)
- The small thickness of the hydrosphere favours exchanges with the surface

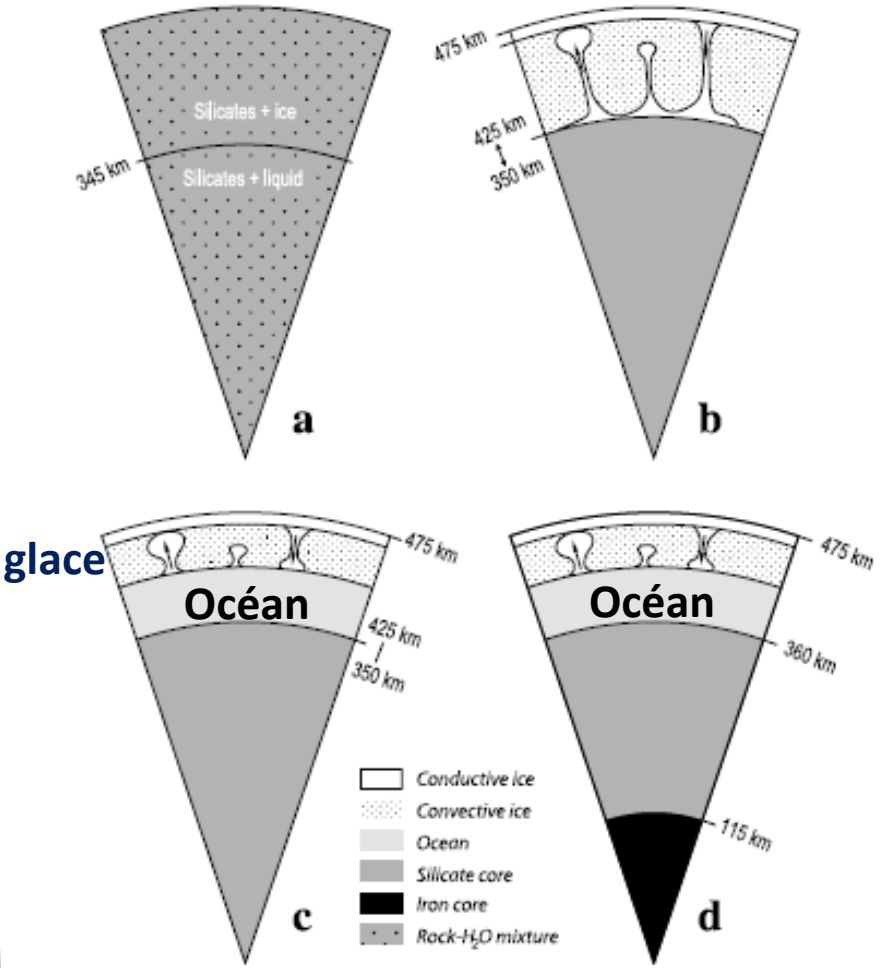
Dawn Mission is arriving at Ceres in 2015

Detection of H_2O gas





Castillo-Rogez & McCord 2010



McCord & Sotin 2010

End


TCHIK
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Comet or Asteroid ?
That is the question !
Thanks to Gö
for suppor