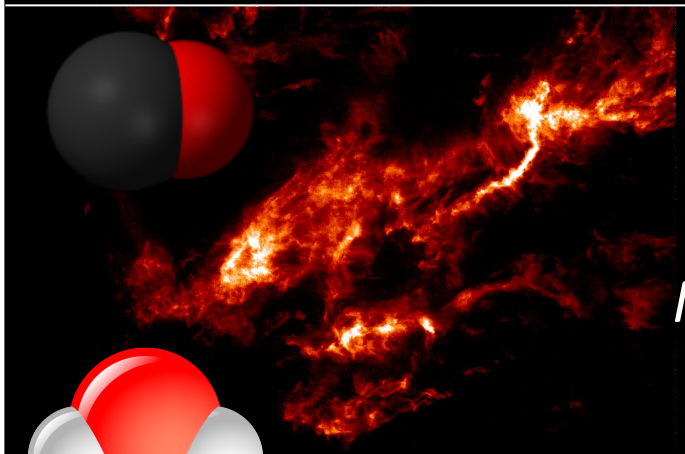
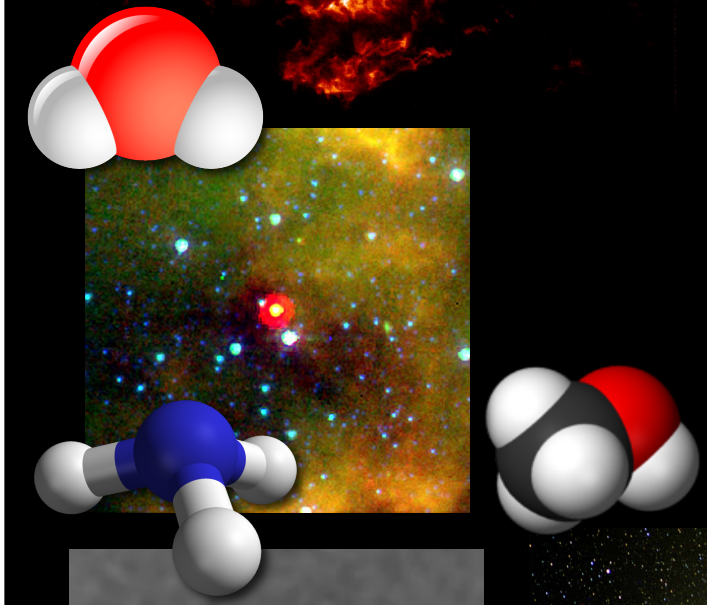
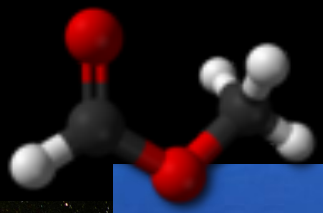
Our Astrochemical Origins

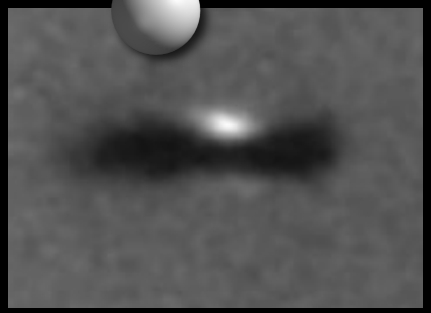


Paola Caselli

Center for Astrochemical Studies
Max-Planck-Institute for Extraterrestrial Physics





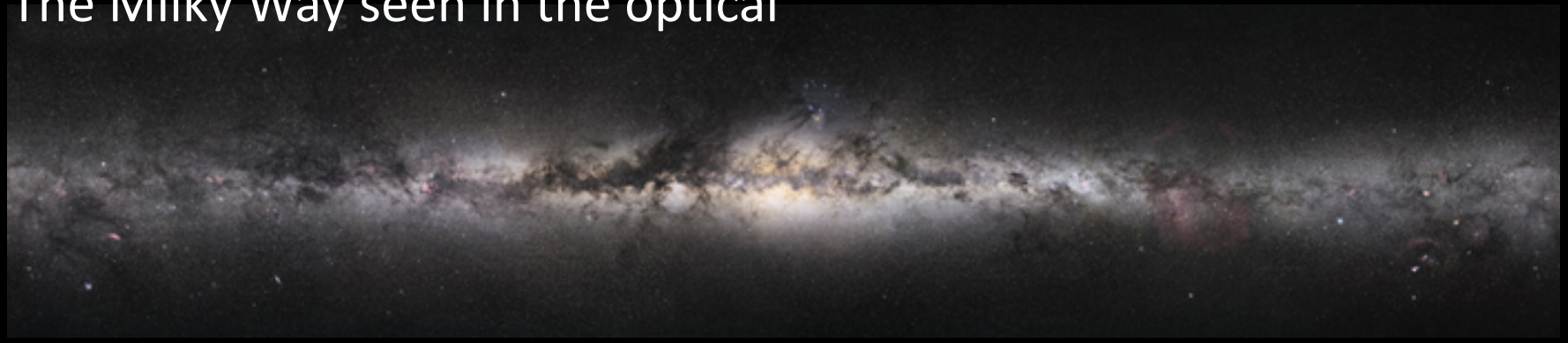


Outline

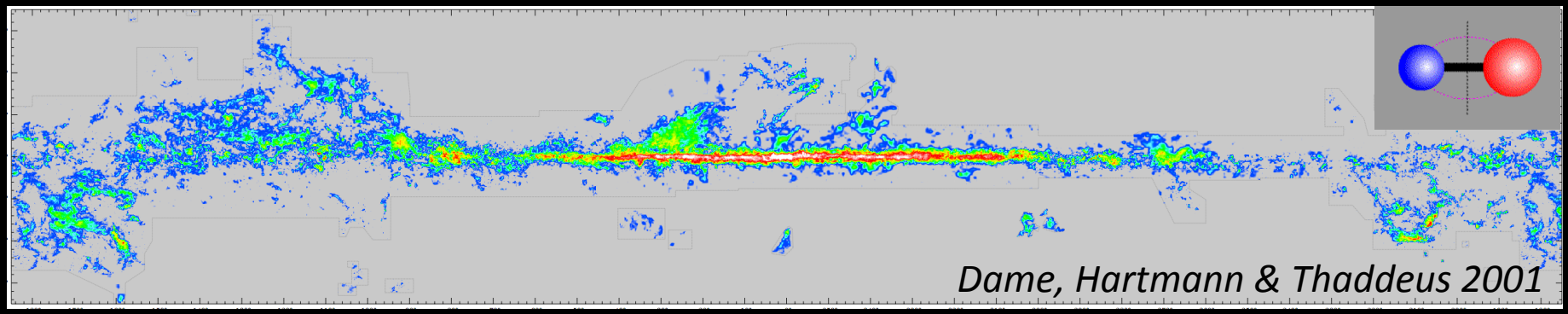
- Interstellar clouds and the seeds of life
- Just before stellar birth: pre-stellar cloud cores
- The birth of stars
- The assemblage of planets
- Towards the origin of life

Interstellar clouds and the seeds of life

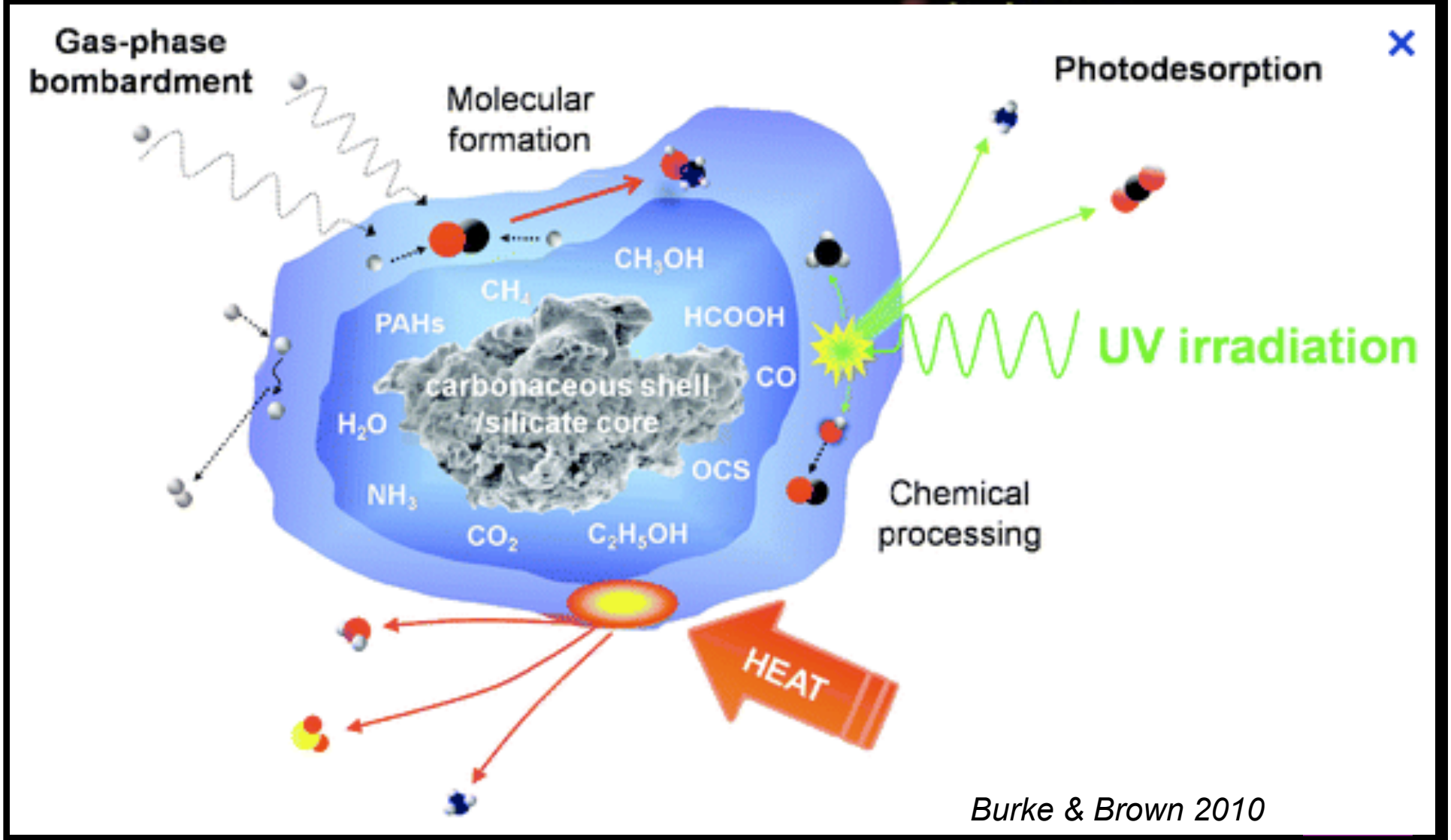
The Milky Way seen in the optical



The Milky Way seen at 2.6 mm (CO 1-0)

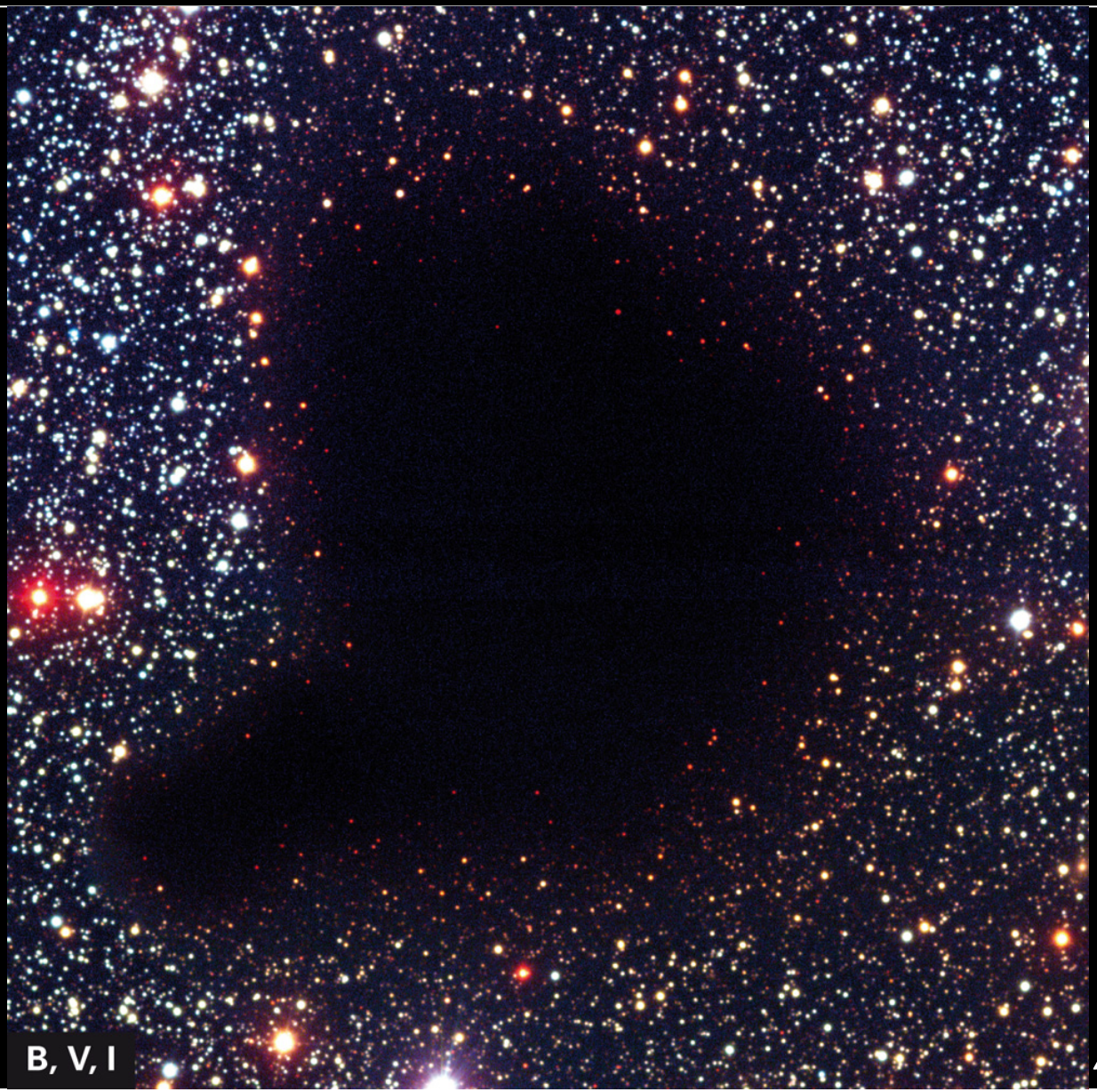


Interstellar clouds and the seeds of life



Burke & Brown 2010

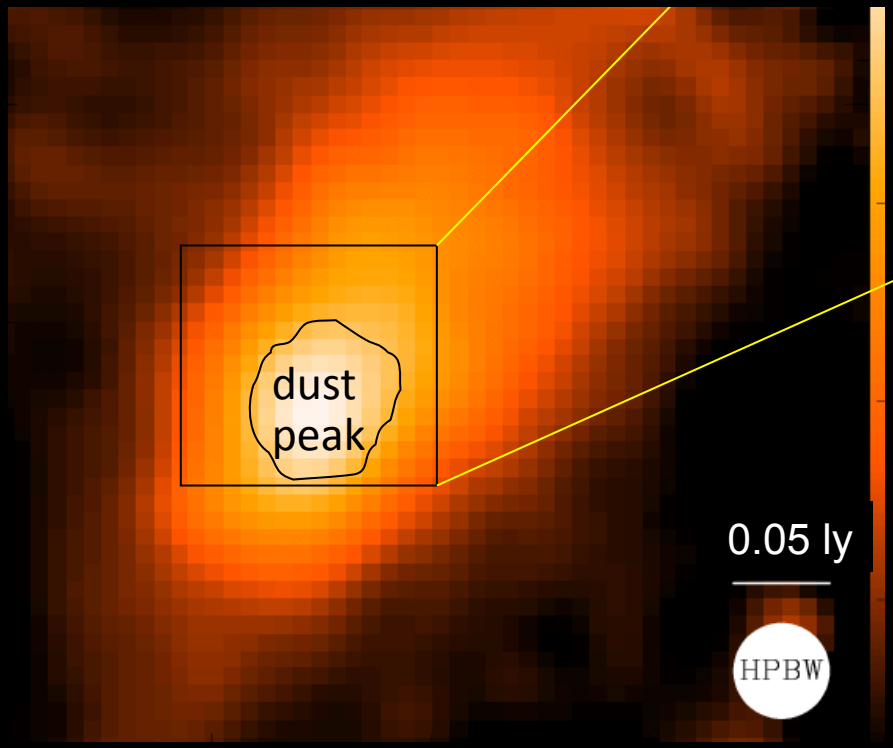
Just before stellar birth: pre-stellar cores

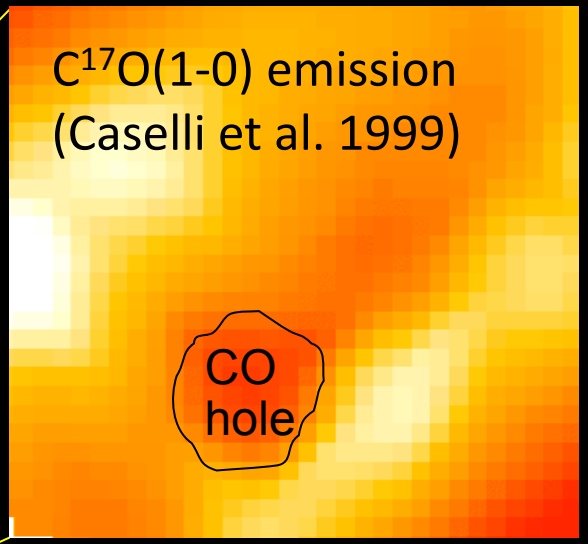


Alves et al. 2001

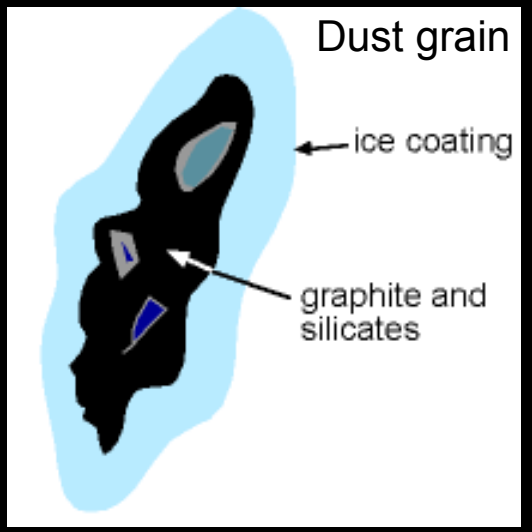
Just before stellar birth: pre-stellar cores

Dust emission in a pre-stellar cloud

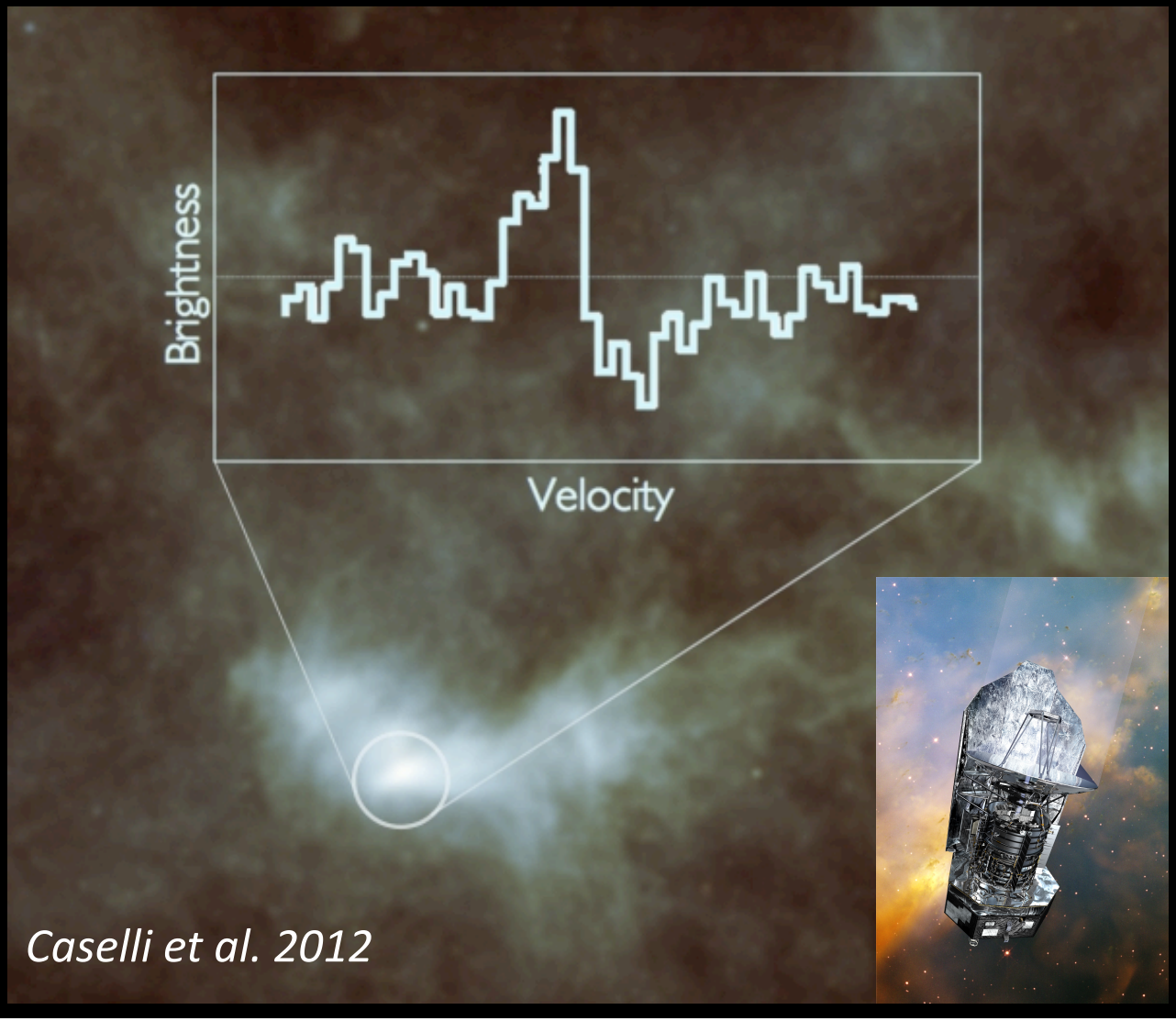




Molecules freeze out onto dust grains in the center of pre-stellar cores ➔



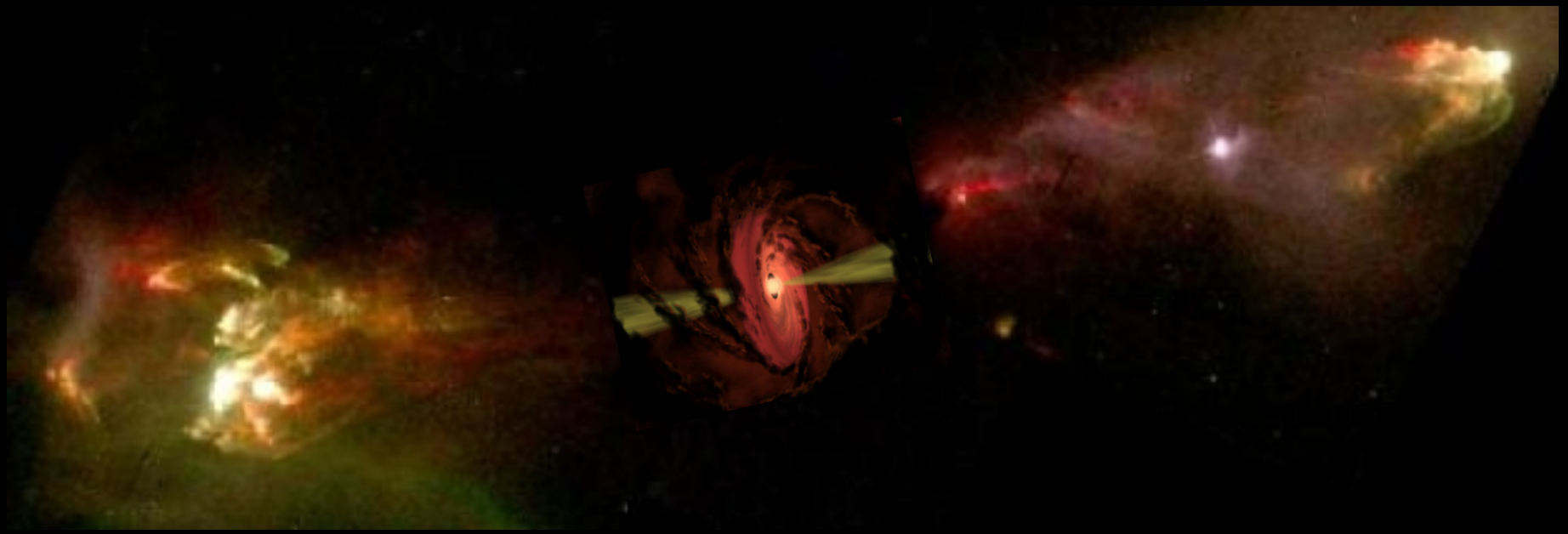
Large water reservoir and complex organics at the dawn of stellar birth



With Herschel, we measured 2000 Earth's oceans in the gas phase and 3 million frozen oceans on the surface of dust grains !

Plenty of water to seed future planets and moons …

The birth of stars: outflows and disks

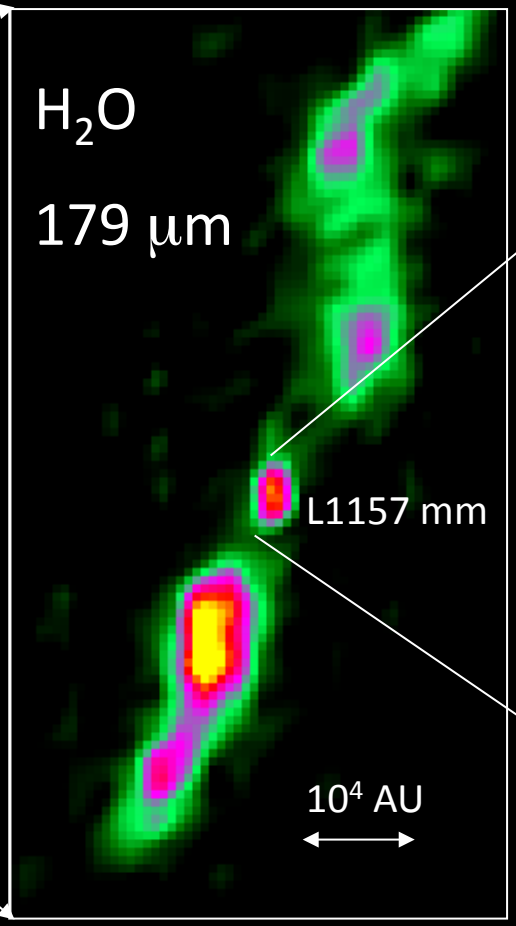


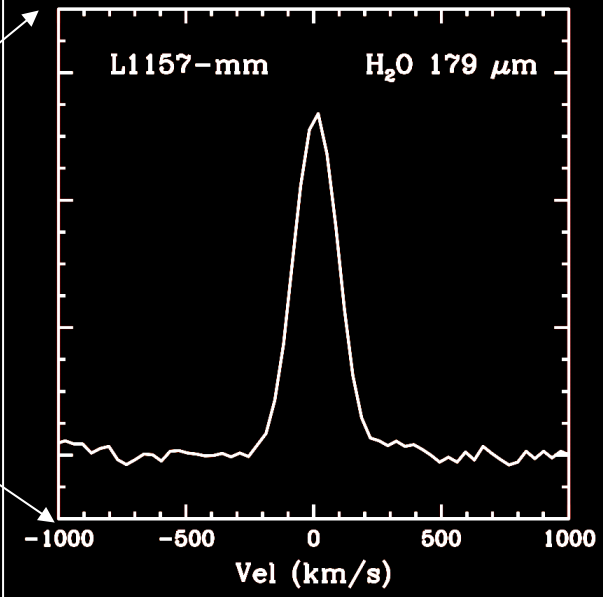
Hubble/WFPC2 – http://hubblesite.org/gallery/album/entire/pr1995024c/web/npp/16/

The birth of stars: outflows

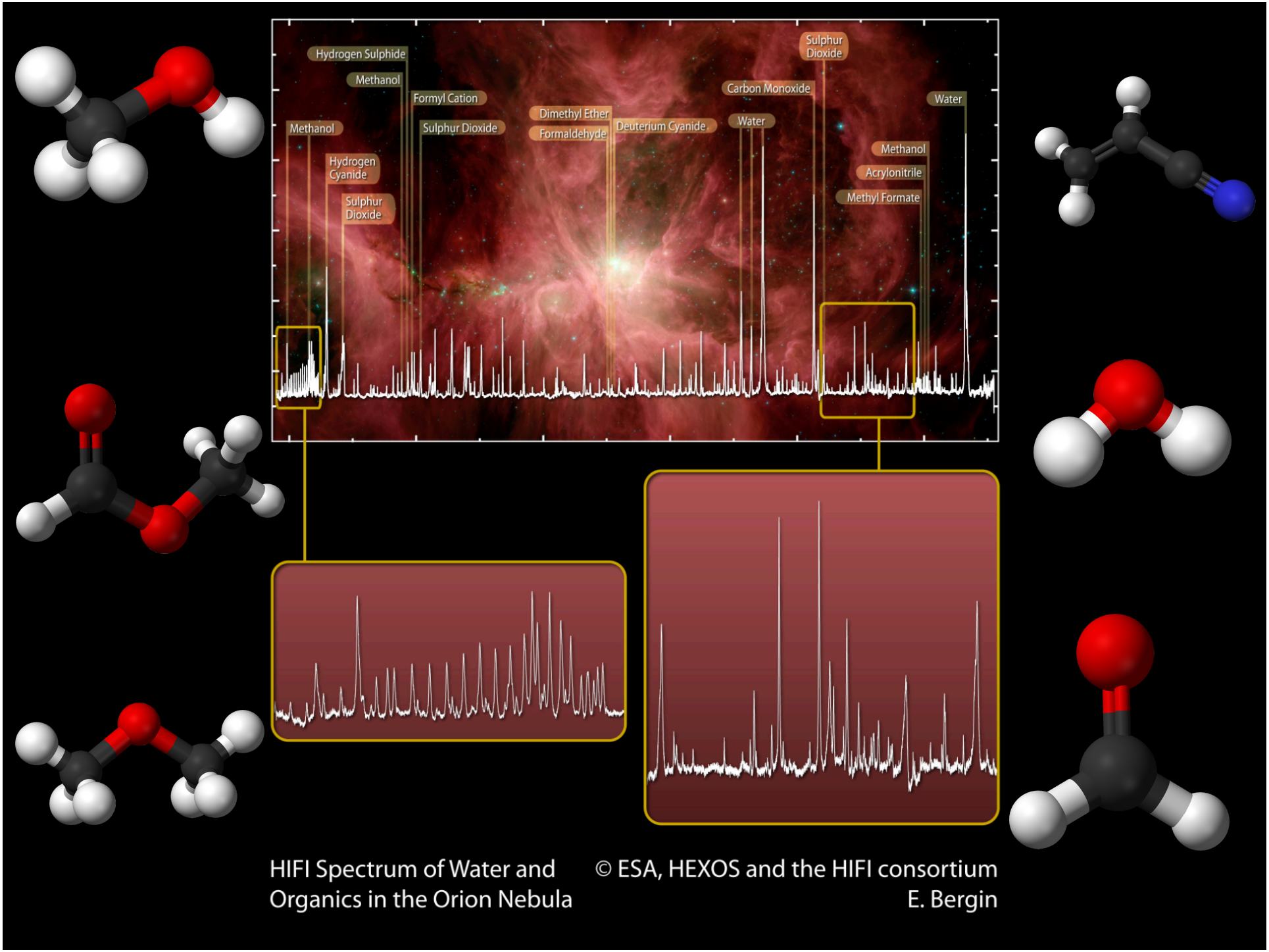
Spitzer IRAC

Herschel PACS





Nisini et al. 2010

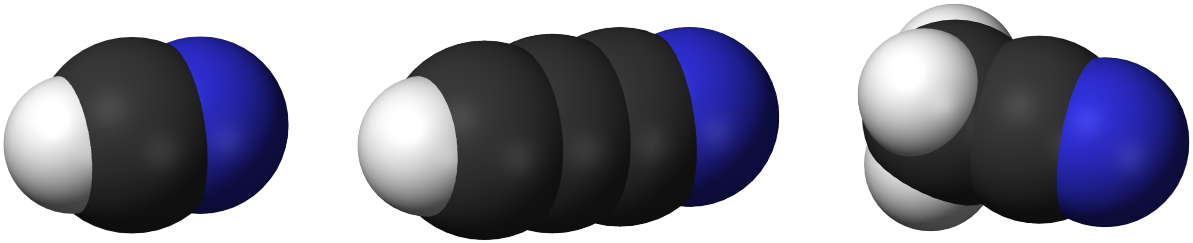


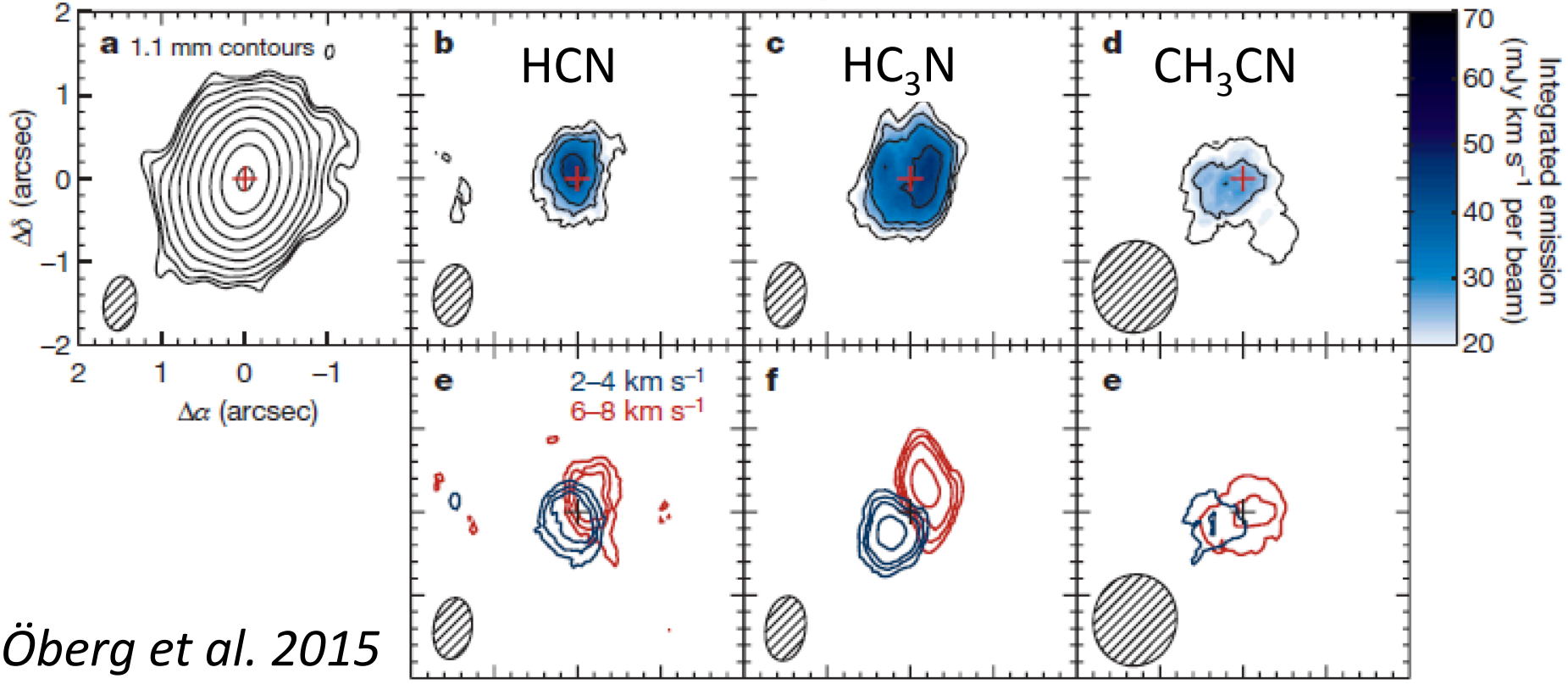
HIFI Spectrum of Water and Organics in the Orion Nebula

E. Bergin

http://www.eso.org/public/news/eso1436/

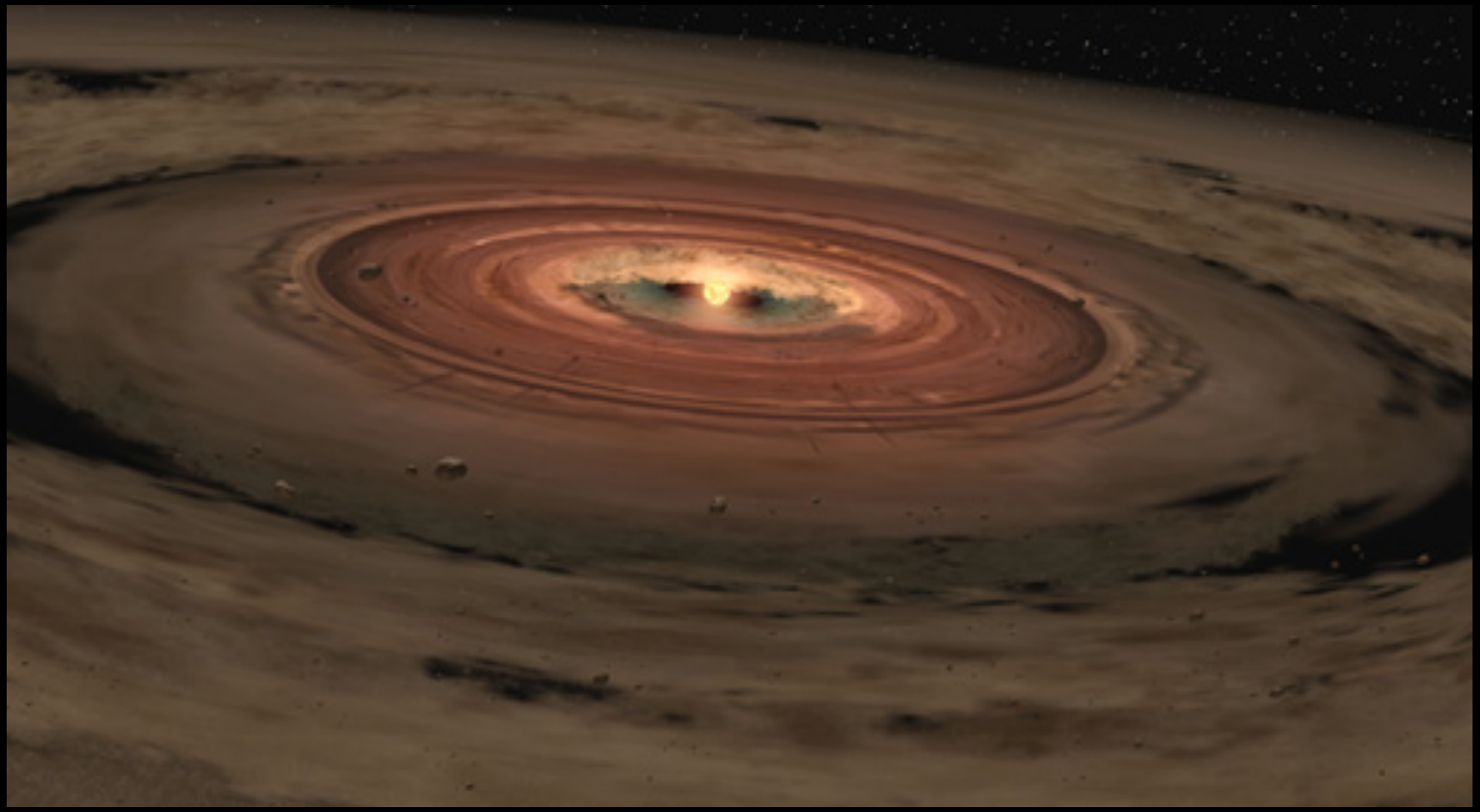
Complex cyanides and the comet-like composition of a protoplanetary disk

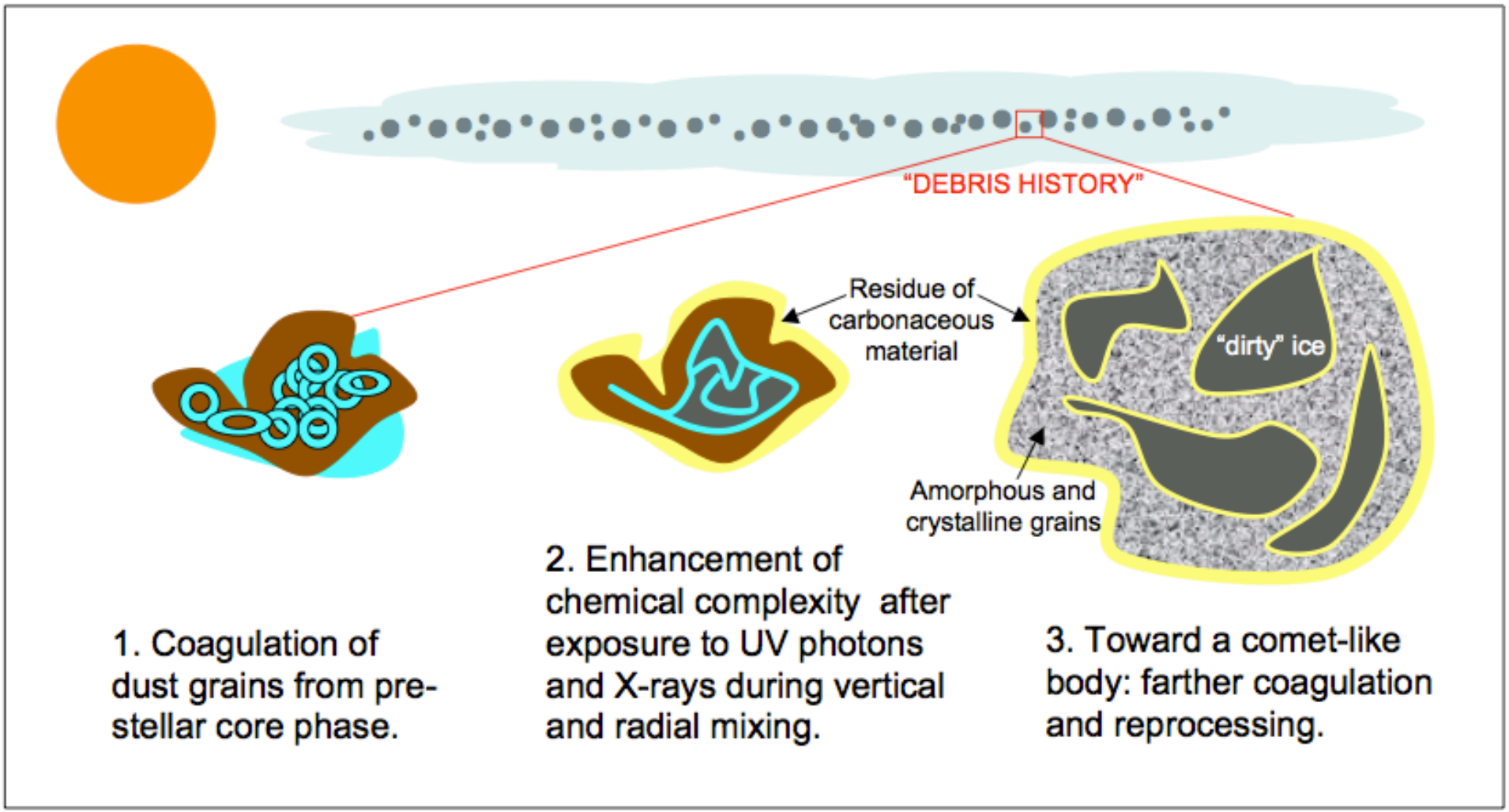




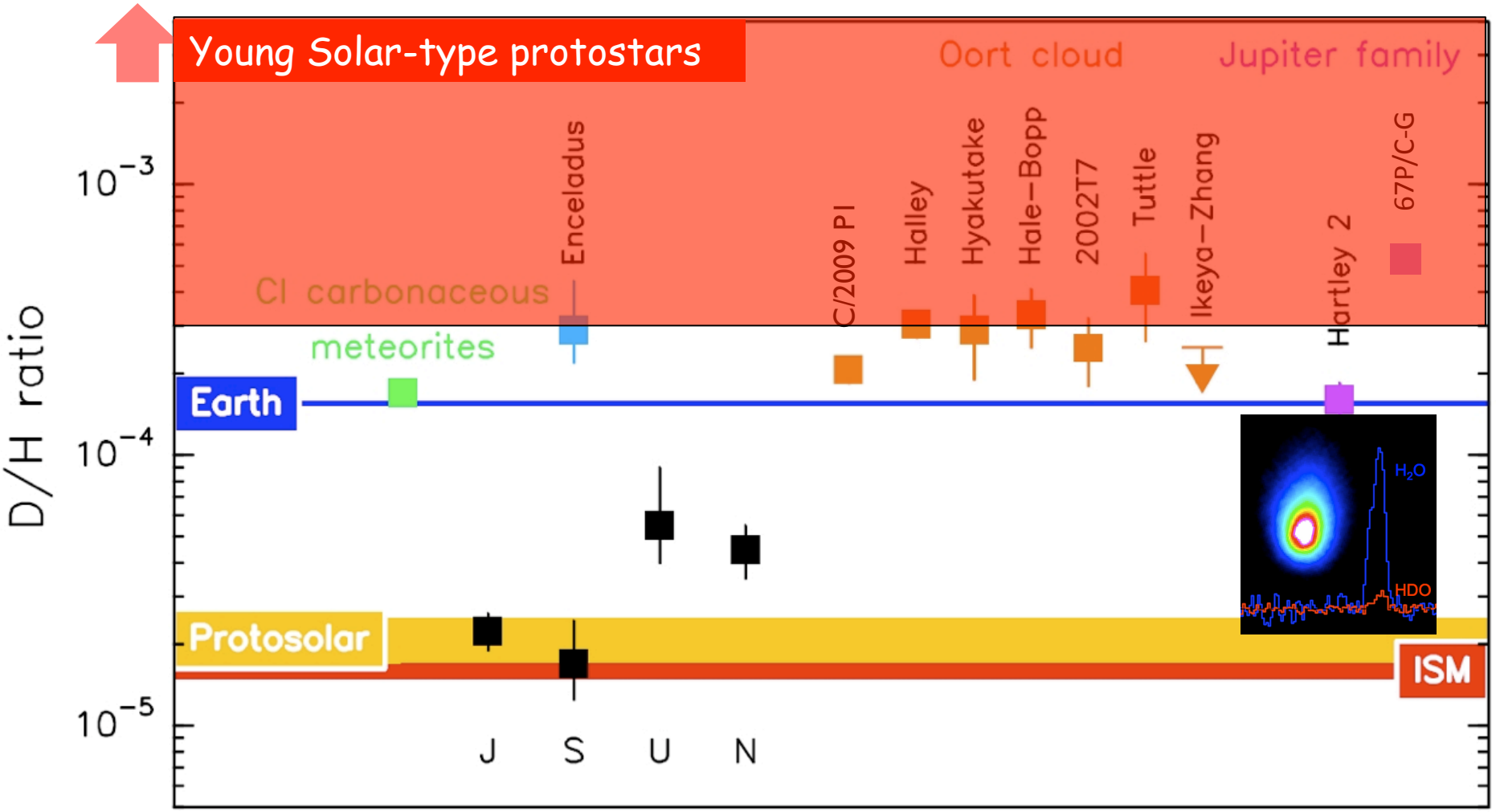
Öberg et al. 2015

The assemblage of planets





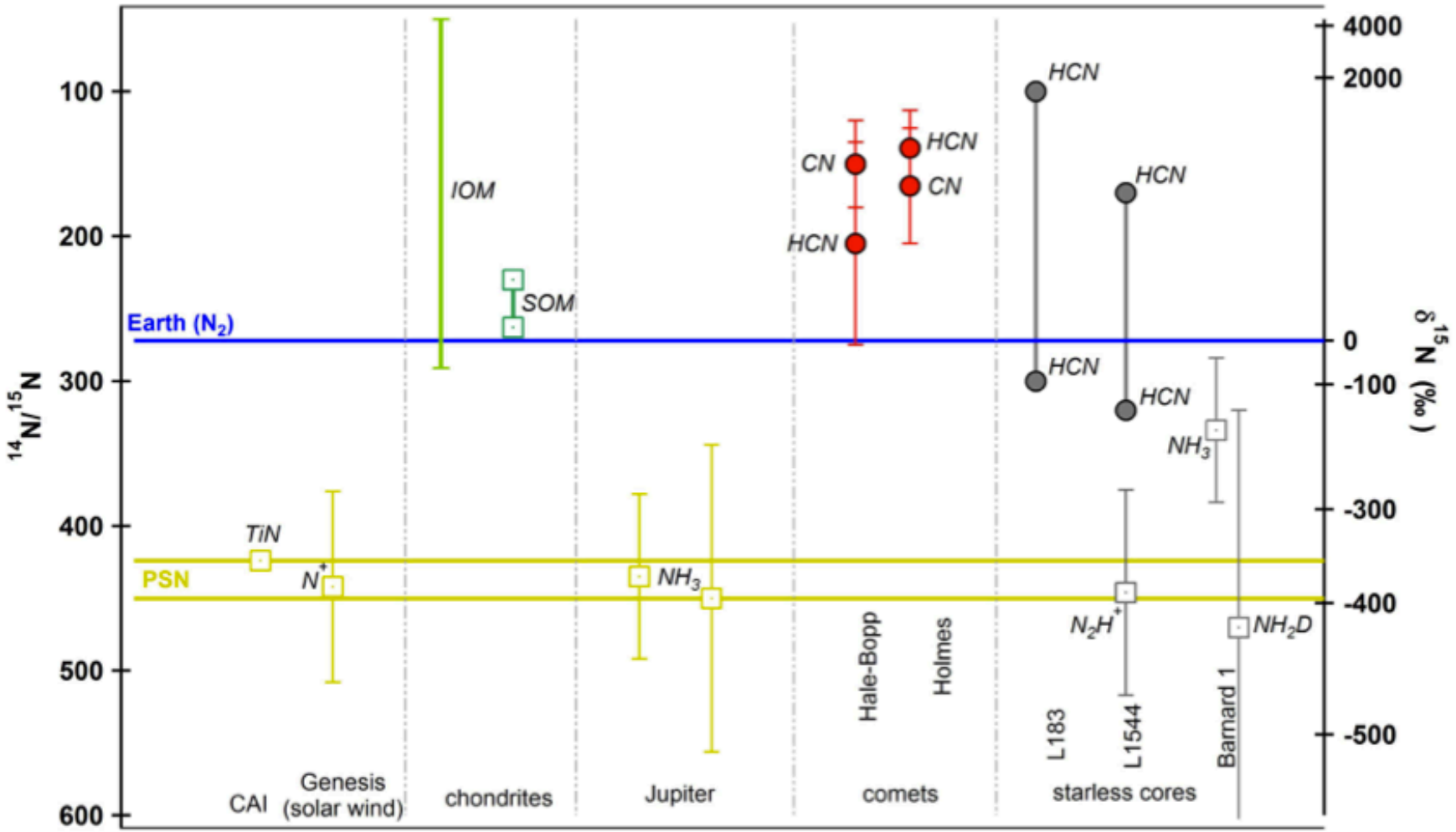
Caselli & Ceccarelli 2012



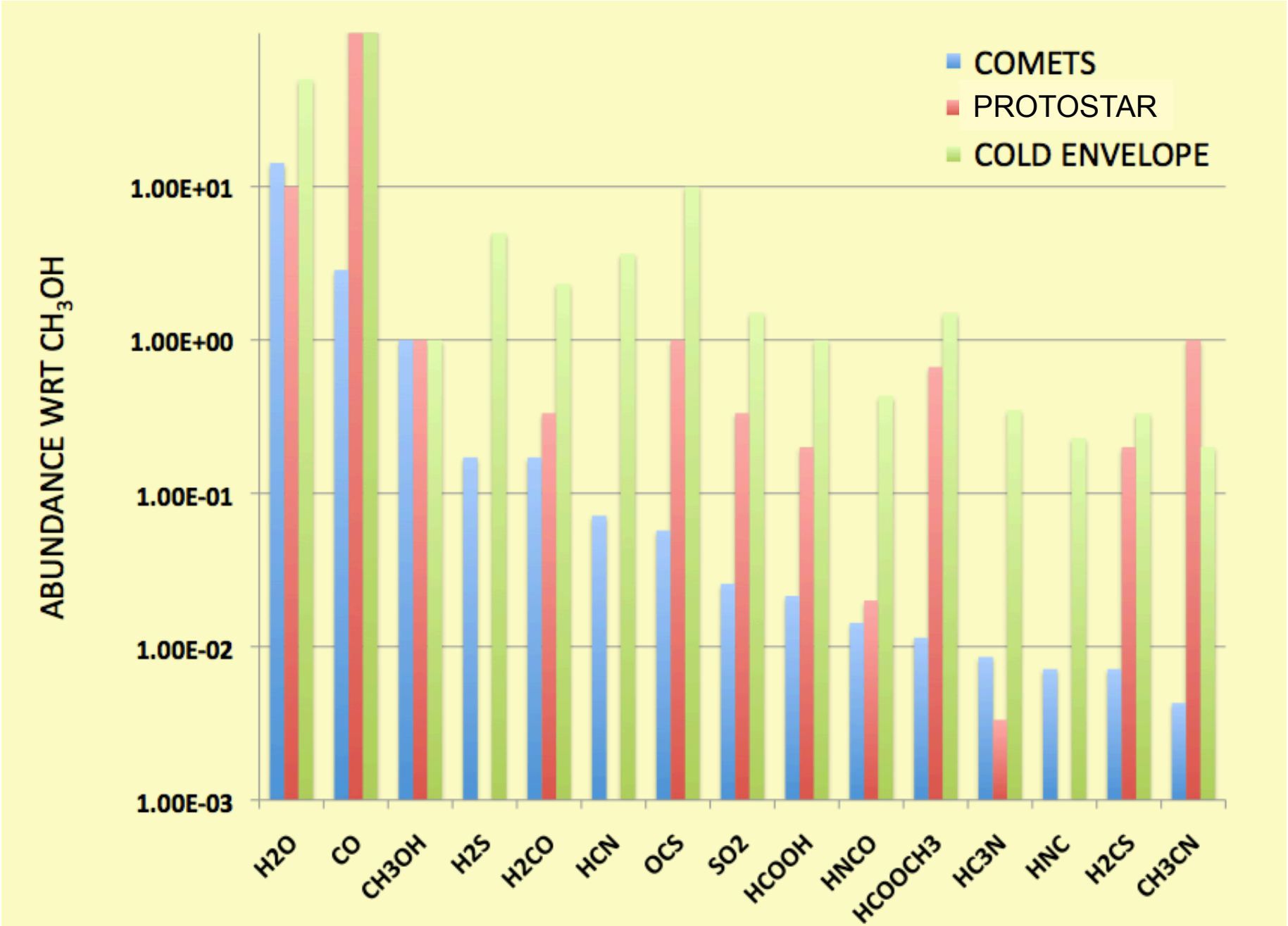
HDO/H_2O in Jupiter family comet = HDO/H_2O in oceans !

Hartogh et al. 2011
Bockelee-Morvan et al. 2012
Altwegg et al. 2014

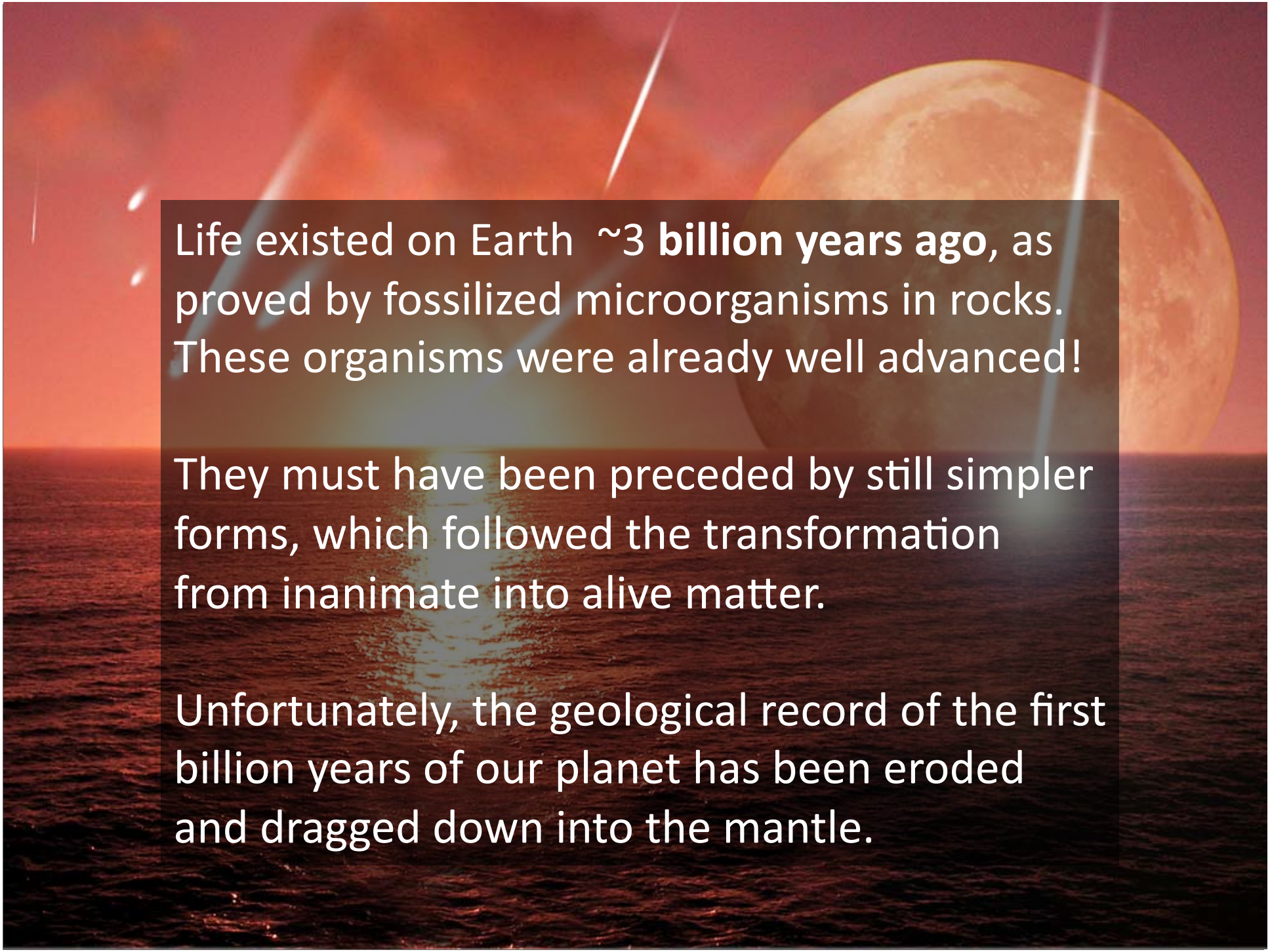
Differential ^{15}N enhancement between nitrile- and amine-bearing interstellar molecules.



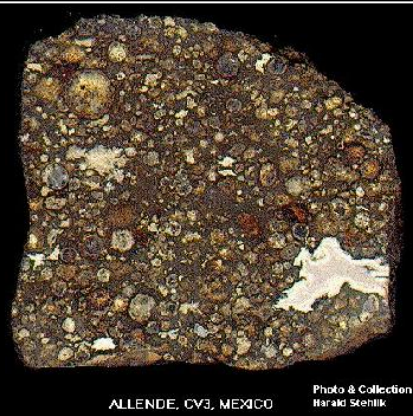
Hily-Blant et al. 2013, Wampfler et al. 2014, Fontani et al. 2015



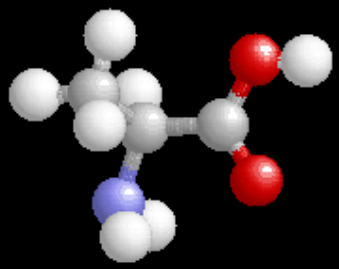
Caselli & Ceccarelli 2012 (see also Mumma & Charnley 2011 for cometary ices)


Life existed on Earth ~3 **billion years ago**, as proved by fossilized microorganisms in rocks. These organisms were already well advanced!
They must have been preceded by still simpler forms, which followed the transformation from inanimate into alive matter.
Unfortunately, the geological record of the first billion years of our planet has been eroded and dragged down into the mantle.

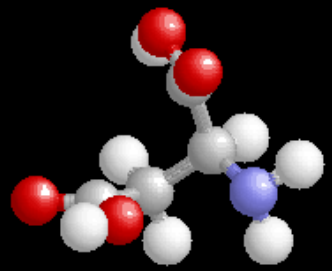
Towards the origin of life



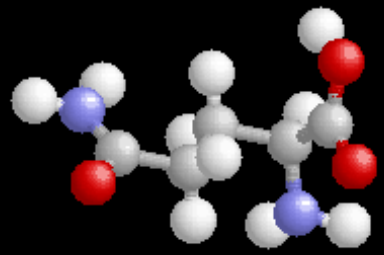
>200 amino acids have been identified in meteorites;
20 of these are used in life.



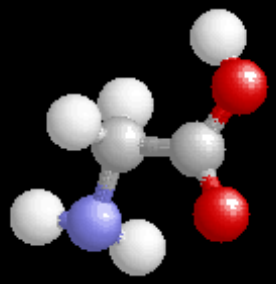
L-Alanine



L-Aspartic Acid



L-Glutamine



Glycine

Towards the origin of life

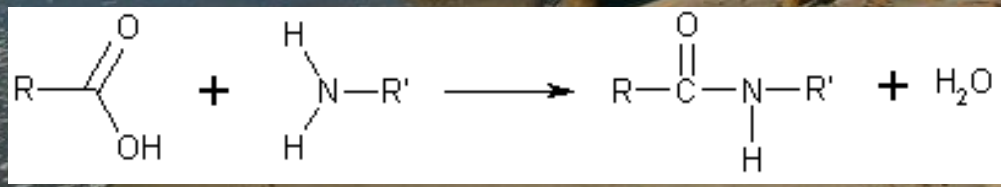
How to assemble these components into much larger molecules ?

How to get molecules to join together in a repetitive fashion (polymerization process) ?

We do not know ! No one has been able to generate RNA or DNA spontaneously…

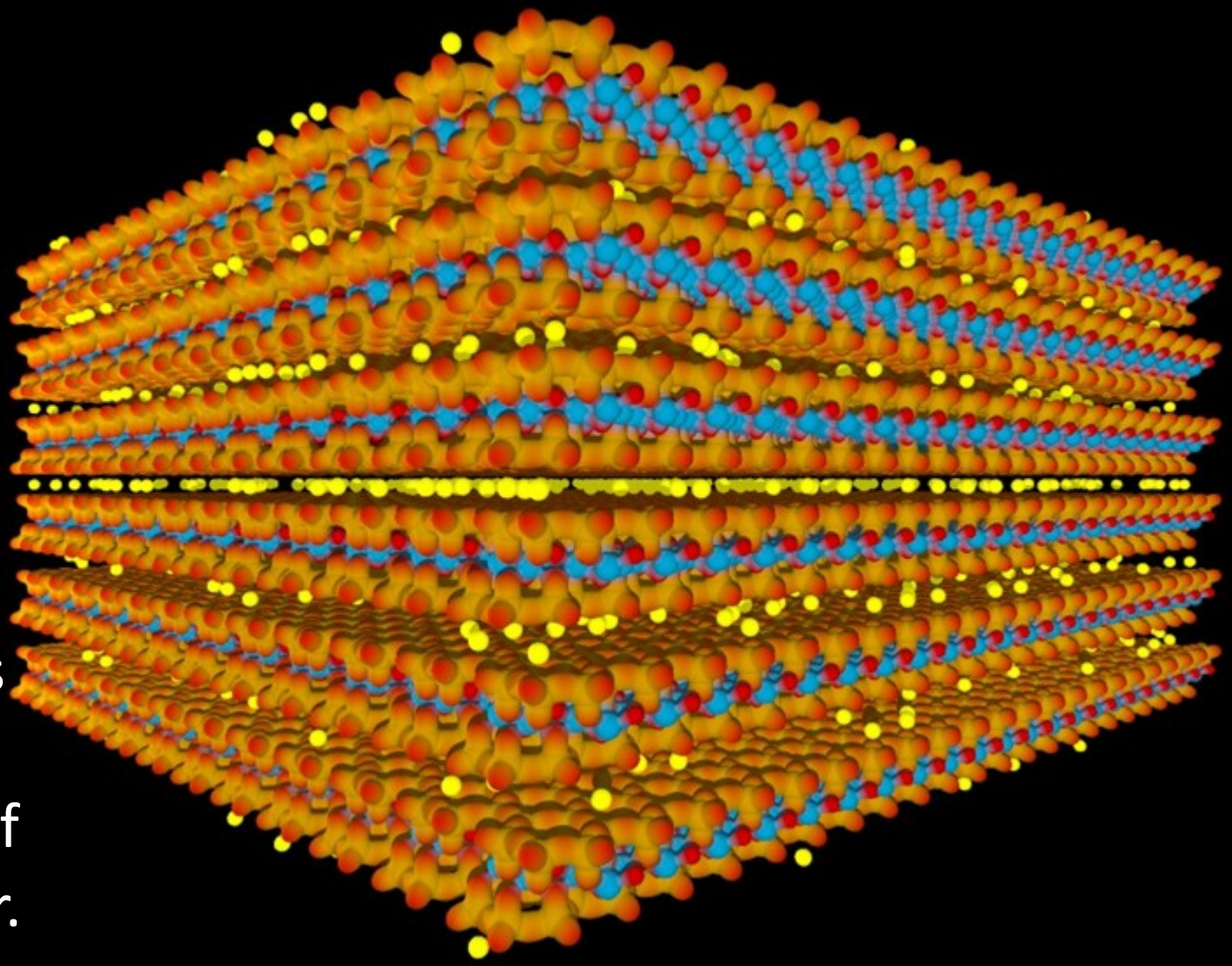
Towards the origin of life

Clays have large surface areas and help to concentrate organic molecules and to absorb the water released during polymerization.



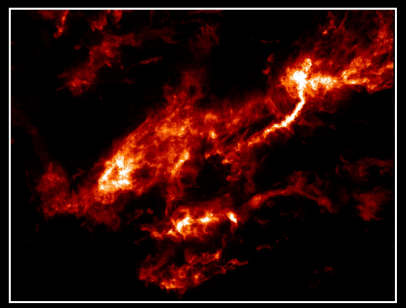
Towards the origin of life

Clay minerals consists of atoms arranged in organized lattices, which might have served as the first templates for the organization of organic matter.

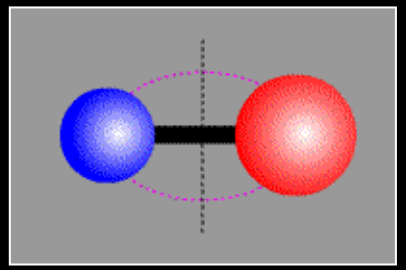


Summary

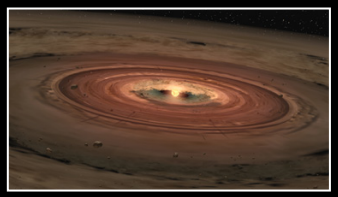
• Stars are made in interstellar clouds, which contain **organic** molecules, building blocks of life.



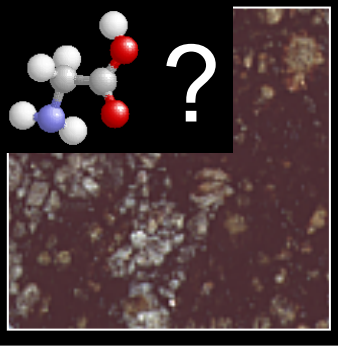
•Planets are made in dusty discs rotating around newly born stars.



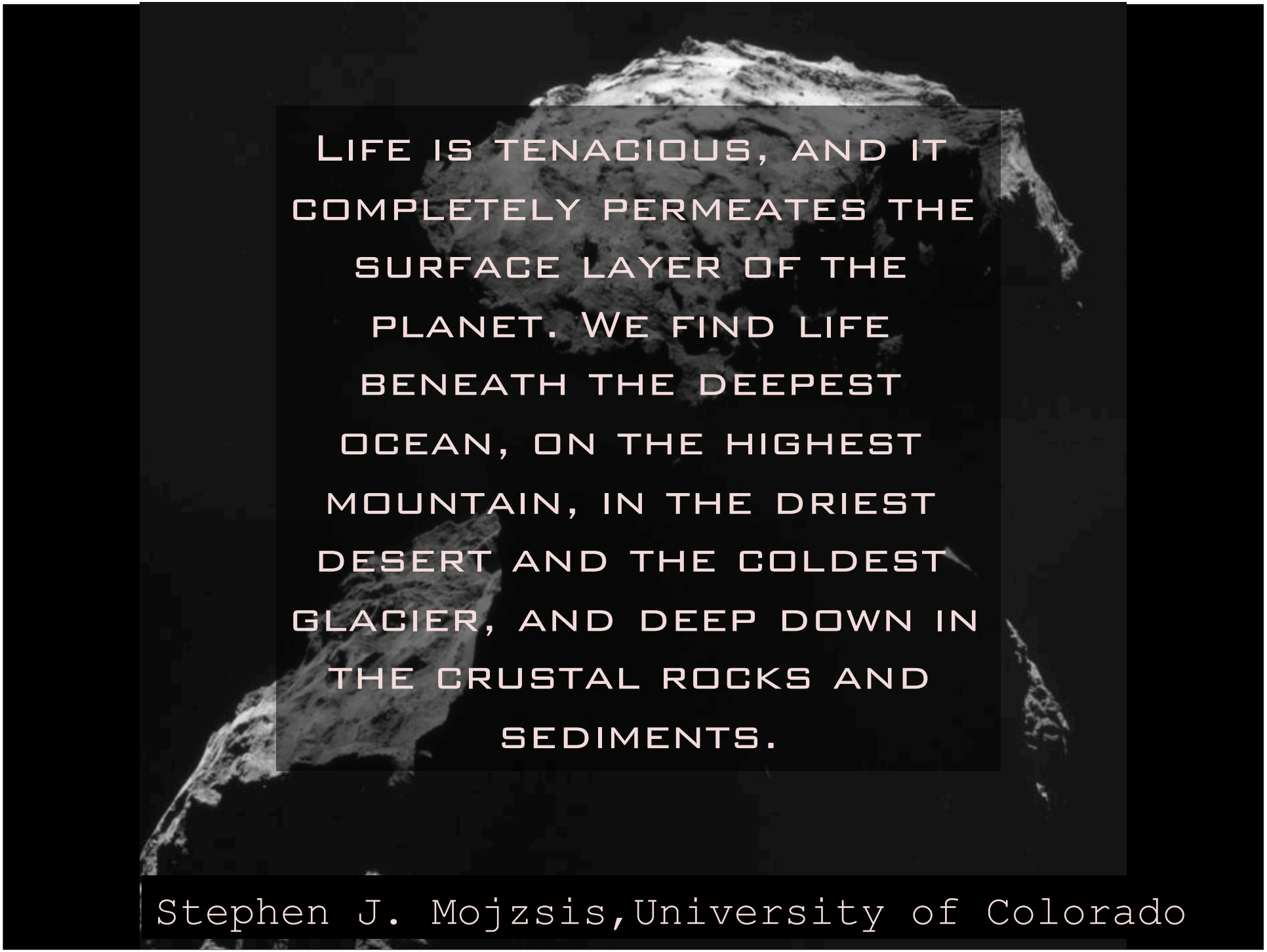
• In discs, icy dust grains stick together forming pebbles and planetesimals.



• The star heats the pebbles/rocks and an active chemistry occurs (amino acids, nucleotides and fatty acids are found in meteorites).



• Astronomers, chemists, physicists, geochemists and biologists need to work together !


Life is tenacious, and it completely permeates the surface layer of the planet. We find life beneath the deepest ocean, on the highest mountain, in the driest desert and the coldest glacier, and deep down in the crustal rocks and sediments.
Stephen J. Mojzsis,University of Colorado