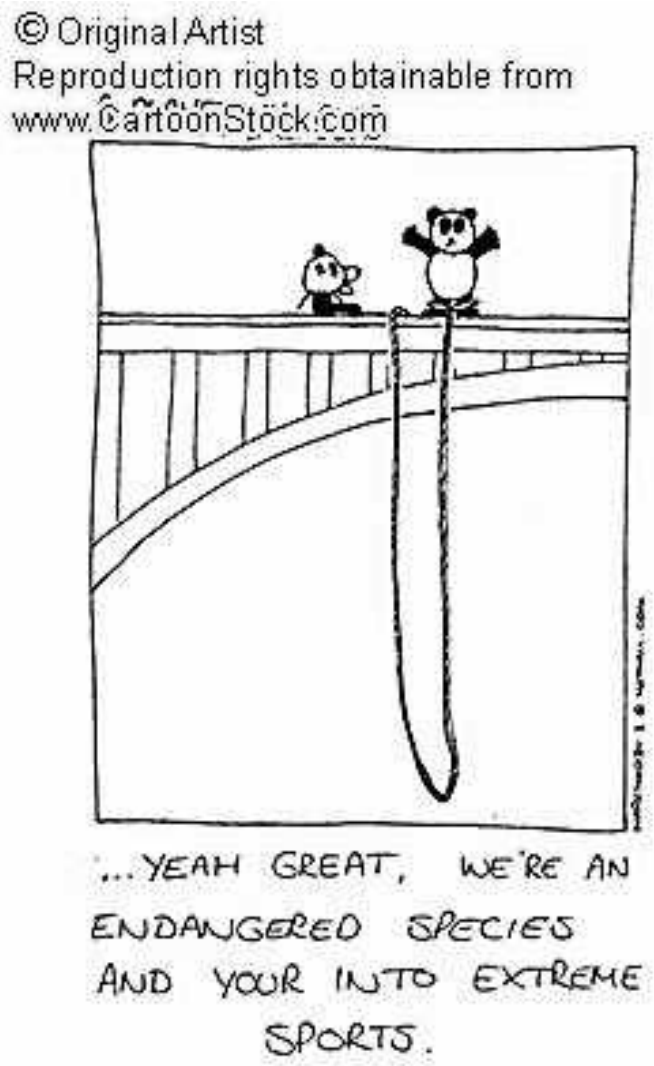
Extreme Life and Life at the Extreme



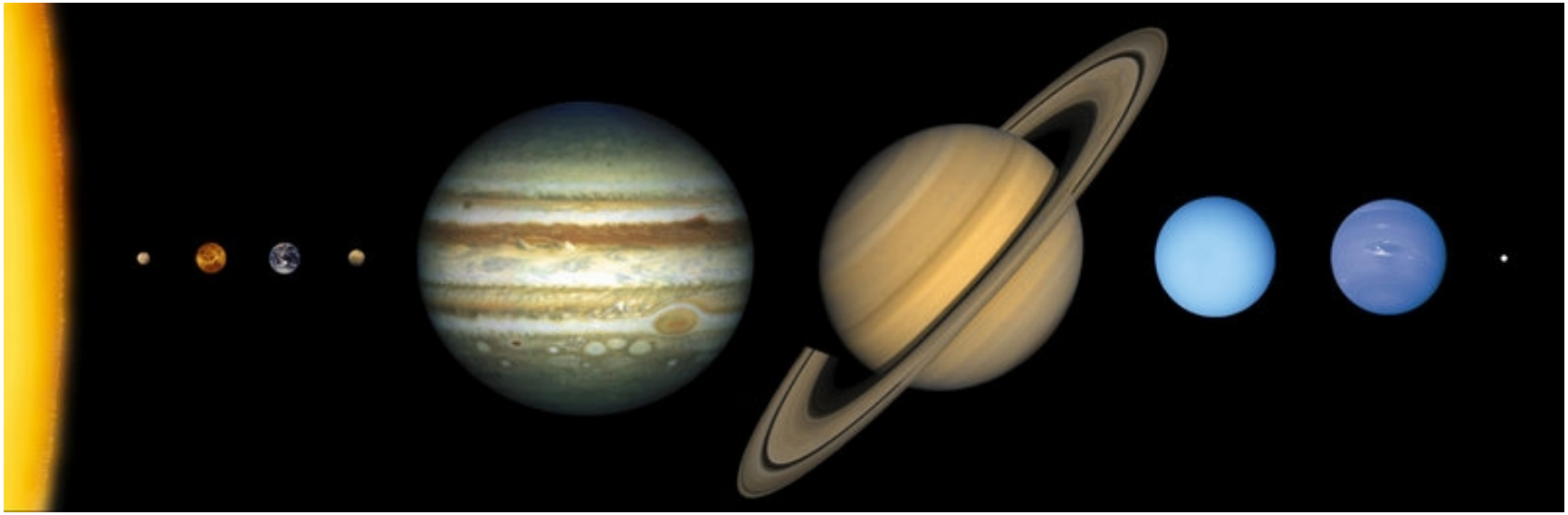

Planetary Orbital Period (Yr)
Stellar Mass (M$_\odot$)
B
A
F
G
K
M
2 yr. Orbit
Stellar Radi and Planetary Orbital Semi-
1
0
1
0.1
0.00
1
0.0
1
0.1
1

Why does life need tectonics?

- Tectonics involve huge chunks of the planet's surface float atop an ocean of boiling magma
- And then spread apart, and crash into one another, lifting up gigantic mountain ranges
- This process enables complex chemistry and recycles carbon dioxide, which acts like a blanket to keep the Earth warm and hospitable for life
- Carbon dioxide is locked into rocks, and then returned to the atmosphere when the rocks melt,
- Without this cycle, carbon dioxide would get locked away in rocks forever.

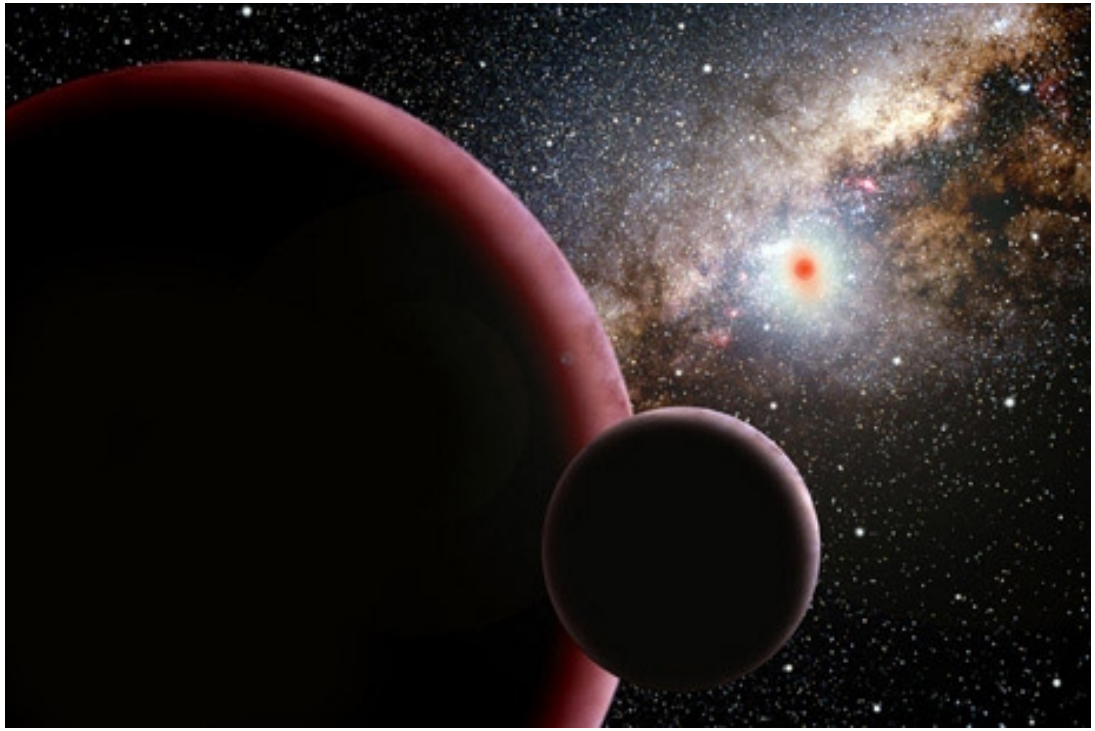
Is the size important?

- If you get a planet with more than one Earth mass, the plate tectonics really get rolling, and the carbon cycle becomes really active.
- Any bigger than 10 Earth mass you start to get a gas planet.
- Earth itself is at the lower limit of how big a planet can be and still have the plate tectonics system needed to stabilize temperatures enough for life, and therefore, is barely habitable.
- Conclusion:
  - Astronomers searching for habitable worlds might do best to look for rocky planets several times larger than Earth



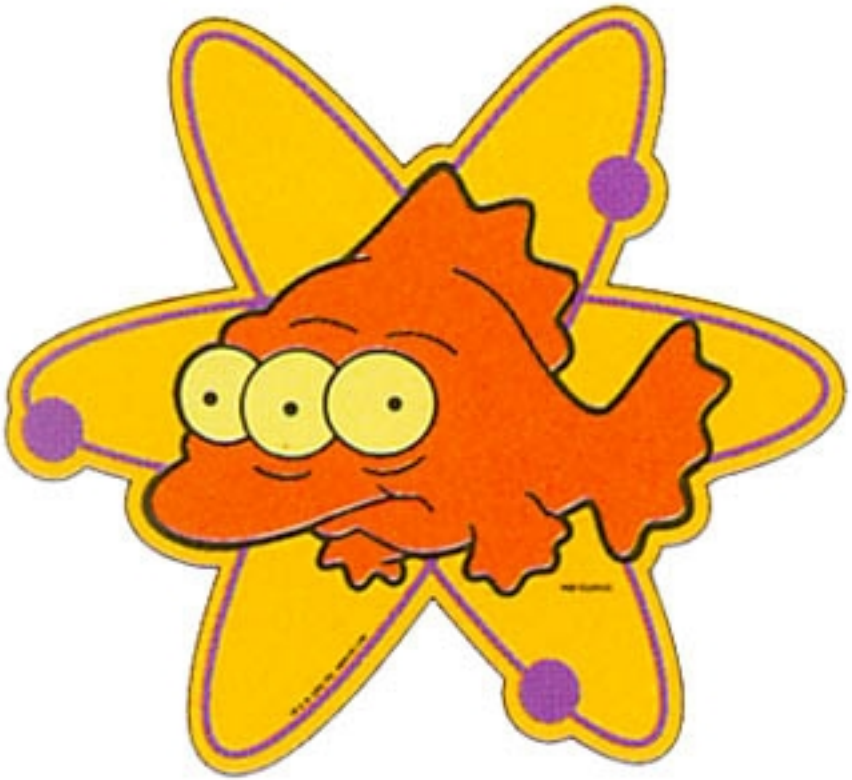
We need a Super-Earth!

- A Super-Earth is a planet 2-10 Earth's size.
  - Can have globe-spanning rings of fire, bursting with hot springs and geysers
  - Life has every opportunity to get started.
- Super-Earth OGLE-2005-BLG-169Lb
  - icy, rocky planet
  - about 13 Earth mass
  - orbits the outer region of its solar system, around a red dwarf star that is about half as big as our sun.
  - its distance from its star chills it to -201ºC, making it too cold for liquid water and, presumably, life.



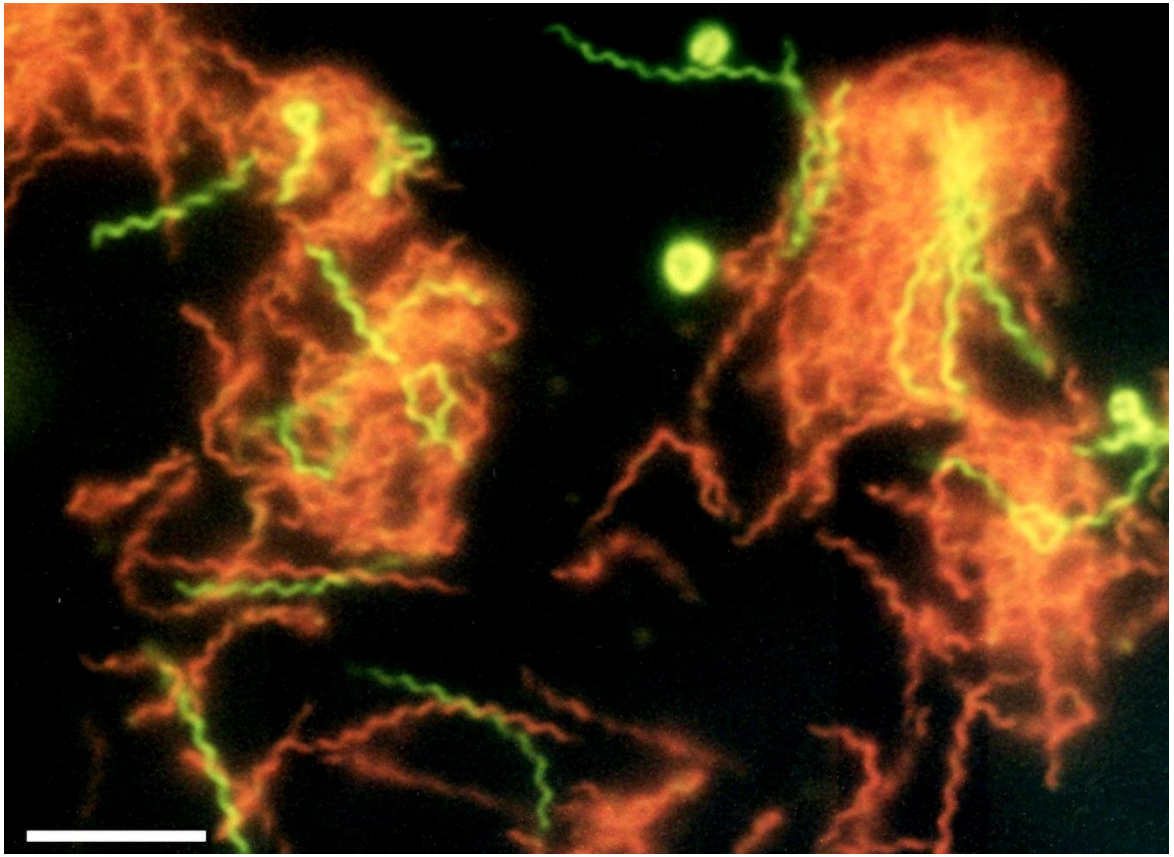
Do we need it to be perfect?

- We don't have to have a perfect temperature, a certain pH level, and so forth, for life to thrive.
- Extremophiles can live in
  - ice
  - boiling water
  - nuclear reactors
  - and may in fact be the norm for life elsewhere in the cosmos.
- microbes found in an Antarctic extremely alkaline lake Untersee could survive the coldest temperatures and the salty water on Mars.
- Conclusion:
  - the liquid found beneath Mars' surface could harbor microbial life
  - that life could exist elsewhere in the solar system and galaxy



The power of life

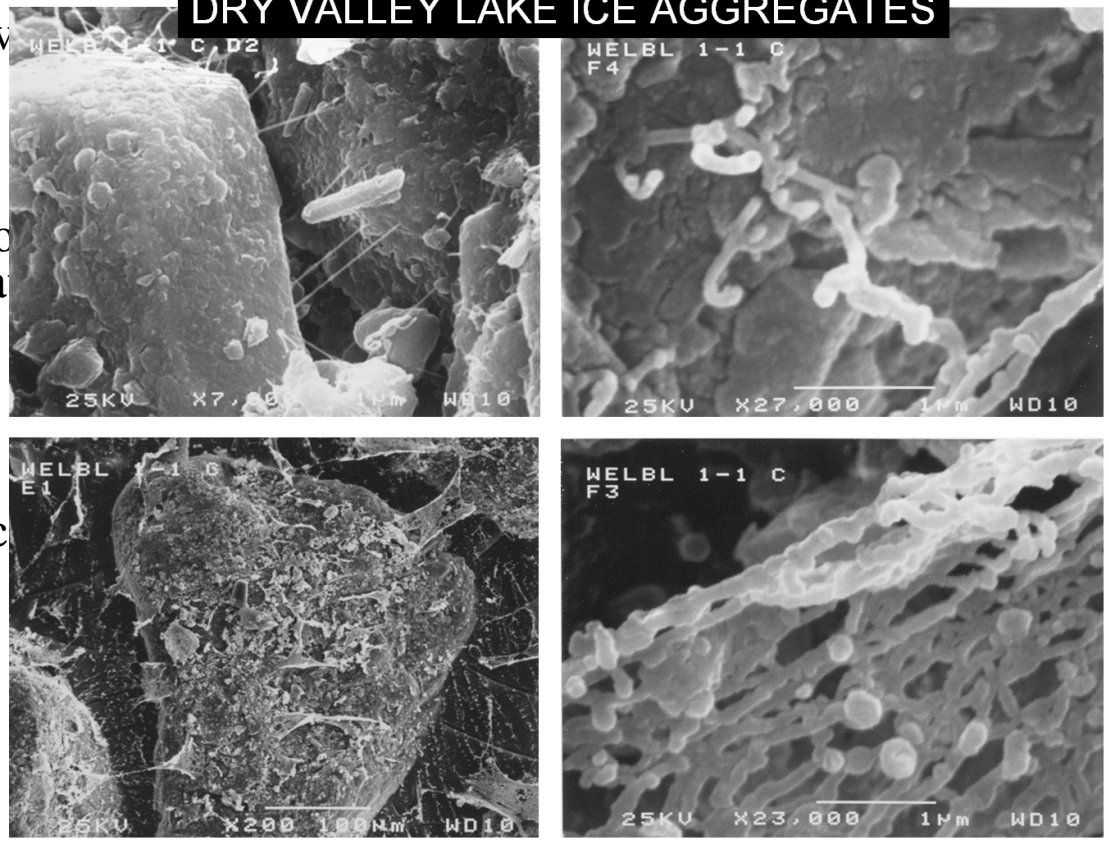
- *H. lacusprofundi* can possibly thrive in the salty water which can remain liquid at temperatures well below 32 degrees Fahrenheit.
- *M. burtonnii* can survive on without oxygen
- Both can survive at the temperature range on present-day Mars and it's salty soil.



The power of life

- H*alophiles* and *methanogens* liv
  hot springs, acidic fields, salty
  lakes, and polar ice caps
- have DNA repair systems to pro
  them from extremely high radia
  doses
- capable of growth on simple
  compounds like hydrogen and
  carbon dioxide for energy and c
  turn their waste into methane
- highly adaptable: at low
  temperatures, form cellular
  aggregates, providing ways of
  survival as a population

DRY VALLEY LAKE ICE AGGREGATES



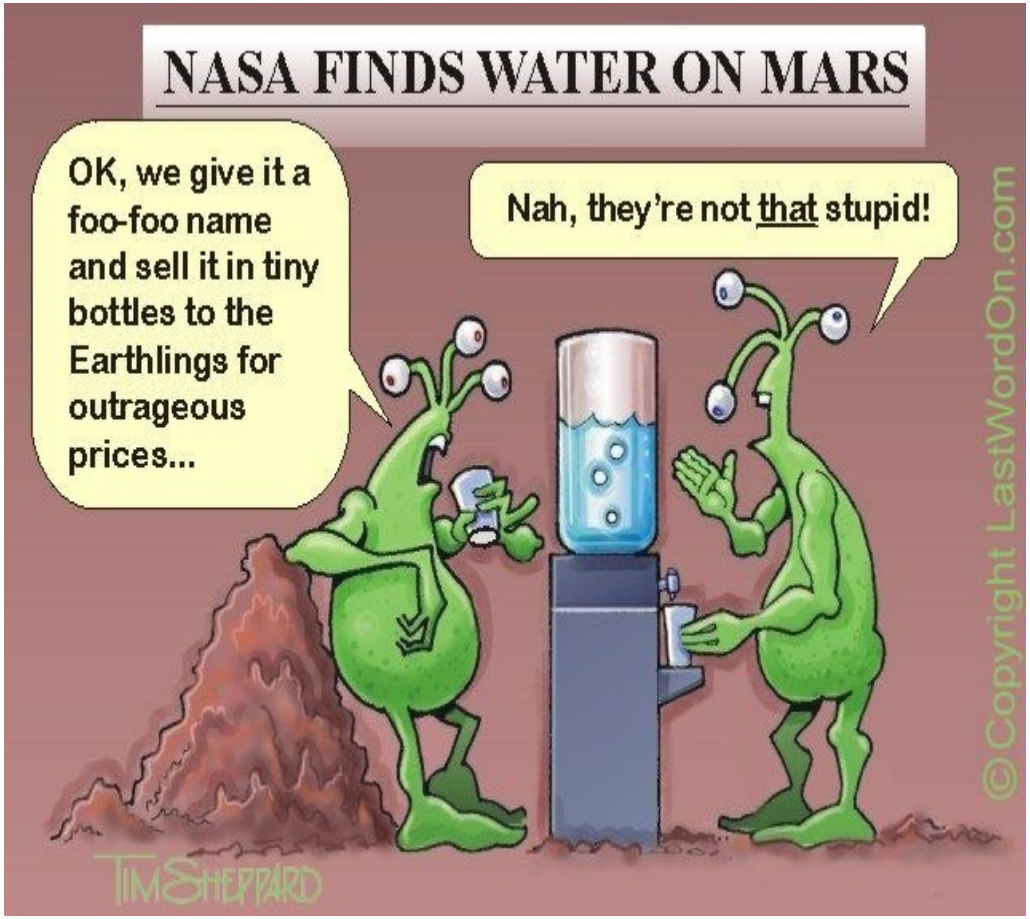
The power of life

- Some Mammouth Hot Springs cyanobacteria live in waters as hot as 76° C.
  - At this temperature they are usually yellow, but become orange, rust or brown as the water cools.
- Between 45° and 55° C, other species may appear which modify the colors even more.
- Yellow or pink strands of bacteria sometimes appear in water as hot as 92° C, just below the boiling point (water boils at 93° C at this elevation)

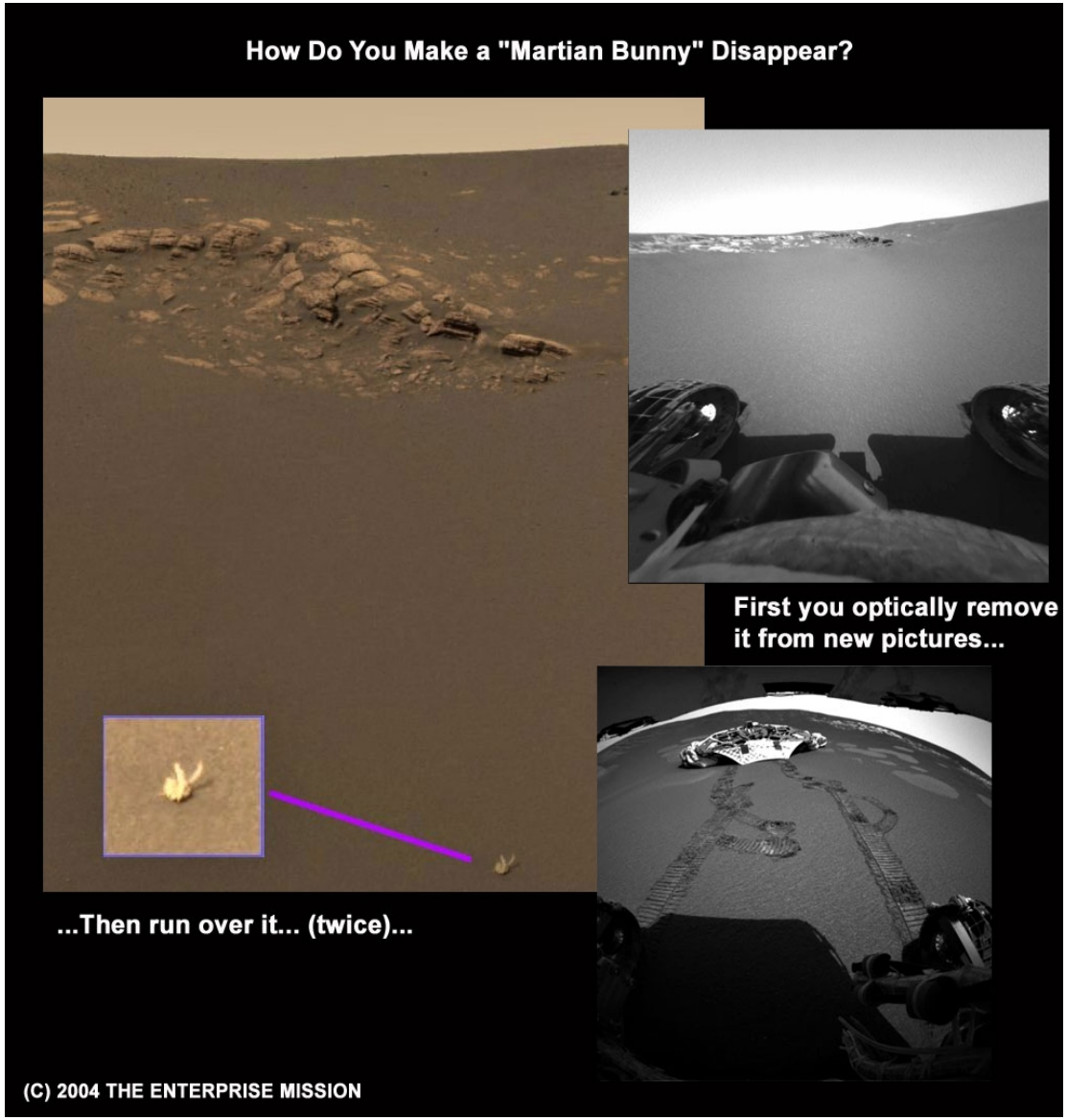
Mars: too salty for life?

- So far, the Mars Exploration Rover Mission has turned up very little evidence that there is, or was, life on the Red Planet.

- Even more bad news is on the way from data sent back from NASA rovers Opportunity and Spirit - the water on Mars has been always "too salty" for even the toughest organisms on Earth

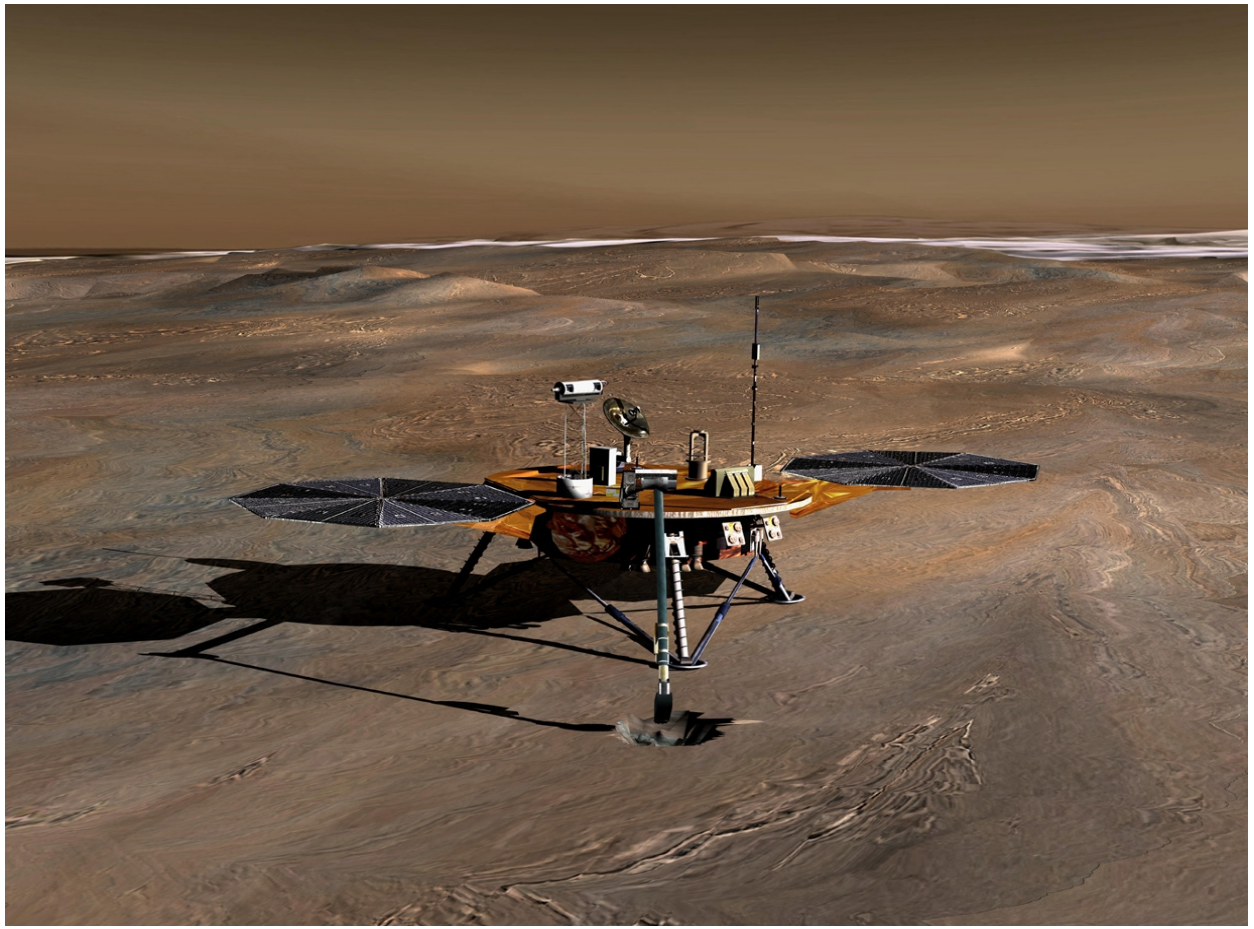


Not for the Martian bunnies!



Phoenix Mission

- Currently en-route to Mars and one of its objectives is to carry out advanced analysis for Martian life.
- Phoenix lands on May 25 of this year to hunt for life in the frozen North Pole.
- Mars Science Laboratory is expected for launch in 2009 and will continue the hunt for organic compounds in the Martian regolith.



Life - what are we looking for?

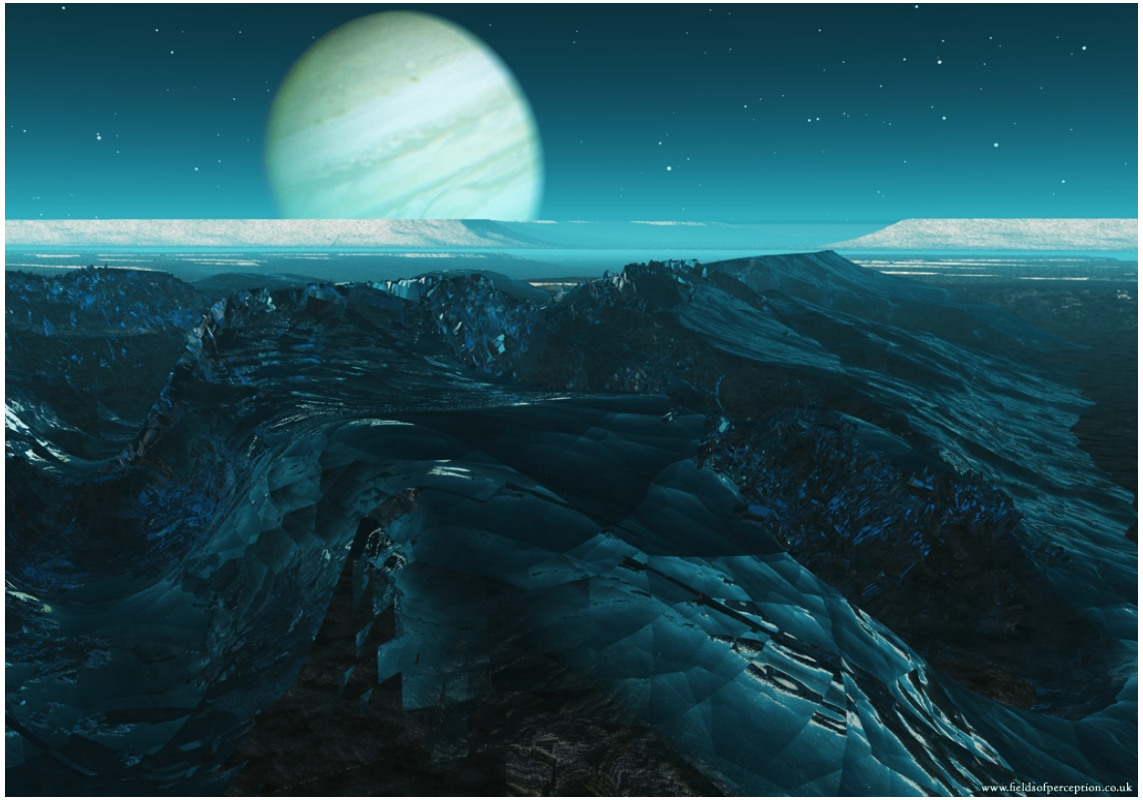
- It is critical to know what to look for in the search for life
- The search so far has focused on Earth-like life because that's all we know
- But life that may have originated elsewhere could be unrecognizable compared with life here.
- The basic requirements for life might not be as concrete as we thought.
- NASA is to expand its search for life in the Solar System to include non-carbon forms of life.

Europa – a frozen wilderness?

- At first glance, it looks like a dead, frozen wilderness with its entire surface cloaked in a layer of ice.
- Yet, photographs of the moon taken by the Galileo probe revealed a complex web of lines criss-cross the globe.
- Only one other place in the solar system looks like that - the frozen Arctic seas on Earth.
- It is believed that the icy surface of Europa could be floating on a vast liquid ocean, with all the ingredients for life likely present.

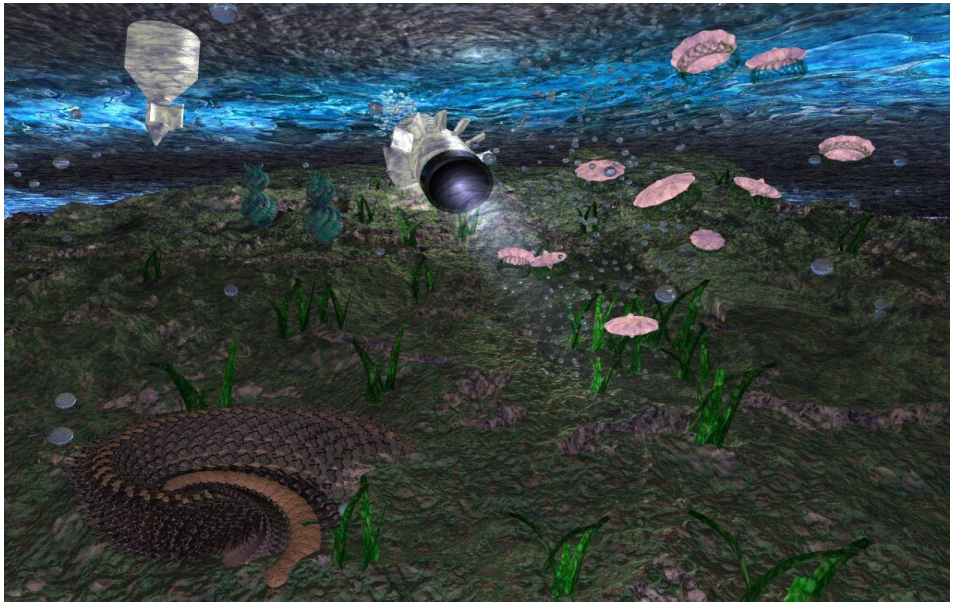
Oceans of Europa

- The combination of tidal processes from Jupiter and its other moons, warms the waters
- The periodic surface exposure may be enough not only to warrant life, but also to encourage evolution.
- It's even possible that the ocean floor may contain hotspots called 'hydrothermal vents' rich in life.



Oceans of Europa

- There is strong evidence that the ocean below the ice is connected to the surface through cracks and melting, at various times and places.
- As a result, the biosphere, if there is one, includes not just the liquid water ocean, but it extends through the ice up to the surface where there is access to oxidants, organic compounds, and light for photosynthesis.
- The physical setting provides a variety of potentially habitable and evolving niches. If there is life there, it would not necessarily be restricted to microorganisms.

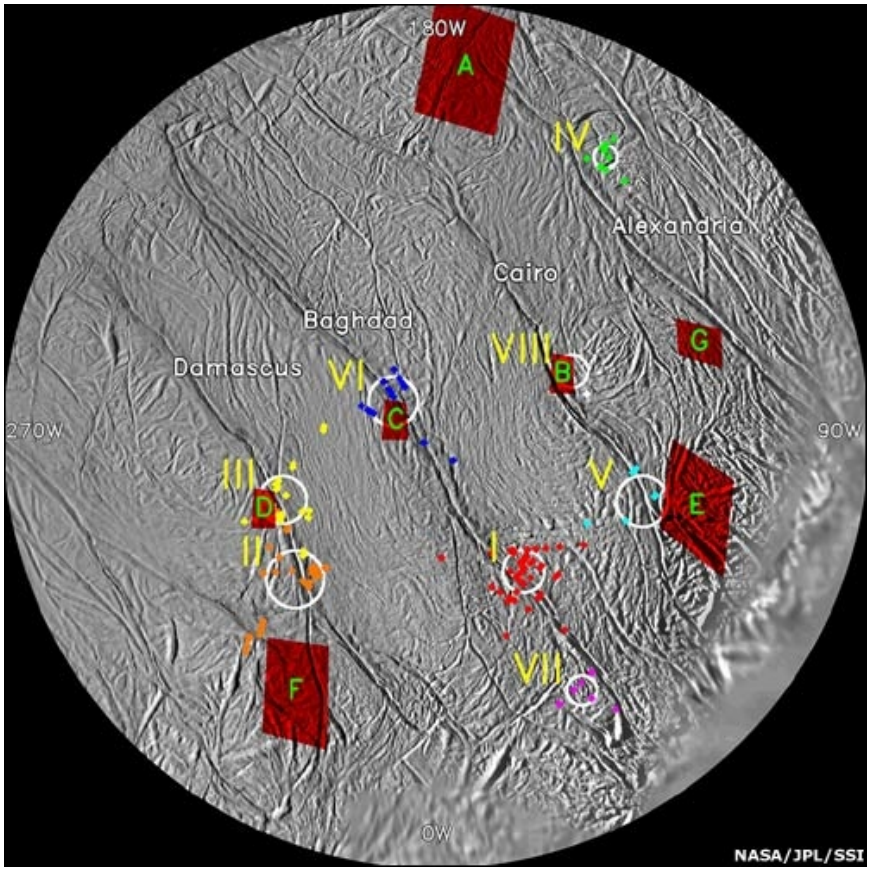


DepthX mission

- The future NASA DepthX mission to Europa, scheduled for 2019, is a mushroom-shaped machine, an underwater hydrobot.
- DepthX is currently undergoing tests in one of the world's deepest flooded cave systems -the El Zacaton cave complex in Mexico- to simulate penetrating the Europa's ice-covered seas.
- The craft sent to Europa would use nuclear power to melt through the 10 km of ice that cover the moon's ocean.
- The mission will be one of the most complex ever attempted by the American space agency NASA.

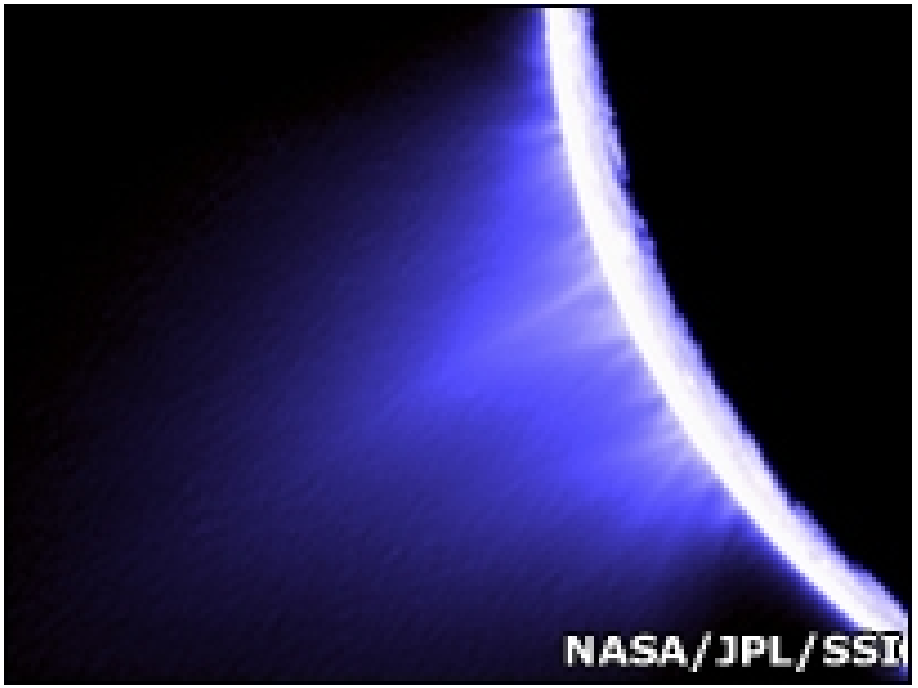
Enceladus’es jets of life?

- South polar region:
  - elaborate arrangement of fractures
  - intense heat radiation
  - geyser-like plumes consisting of ice crystals and gases such as methane, nitrogen and carbon dioxide
- The plumes erupt from vents located in large fractures called "tiger stripes"
- The first model proposed to explain the plumes suggested they tap into shallow pockets of liquid water in a water-ice shell.
- Another, that the plumes originate in the dissociation of certain stiff compounds of ice, which may cover Enceladus to a depth of tens of kilometers.
- The fountains on Enceladus tantalise scientists by suggesting an ocean beneath the moon's icy crust - an ancient sea is the best bet for where life might evolve off Earth, scientists say.



Or just fireworks?

- A new study concludes that an ocean is not the source of the jets emanating from Saturn's moon Enceladus
- A chemical analysis of Enceladus failed to detect sodium, an element which should be in a body of water that has had billions of years of contact with rock.
- Spectral analysis with the Keck Telescope found no sodium in the plumes or in the vapour that's in orbit around the moon.
- Conclusion: the source of the plumes is either very, very pure water, clean ice, melt water or clathrates - a crystal of water, carbon dioxide and ammonia.

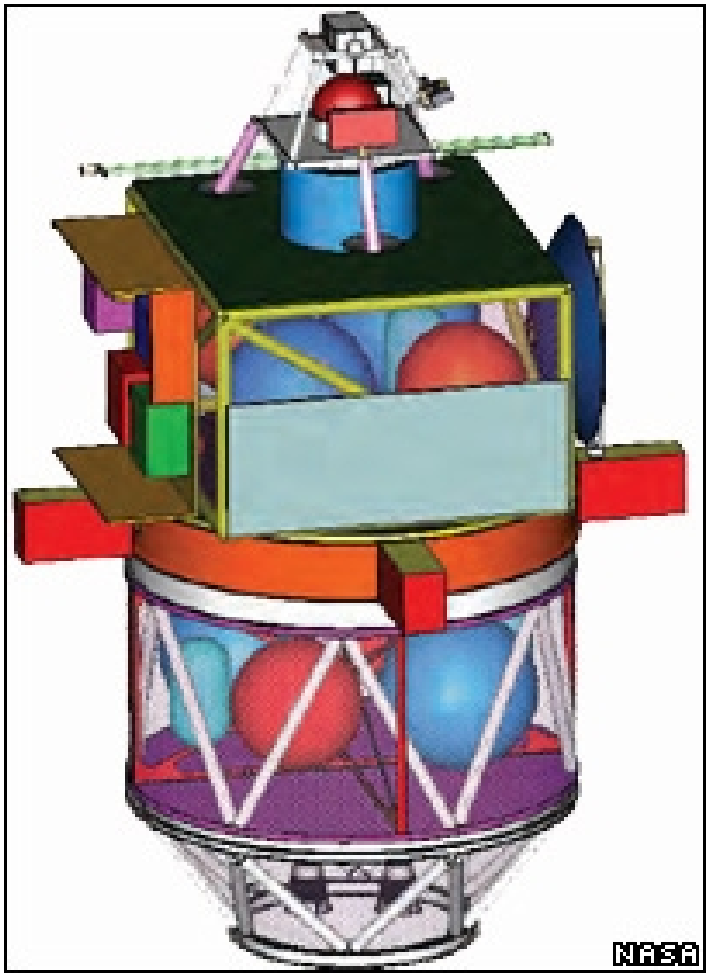


Sodium should be everywhere

- Sodium is quite abundant in the Solar System. Therefore, the question is: can you hide it?
- One way is to put it in a salt crystal. If a sodium atom were tied up in a solid form, the Keck Telescope would not detect it.
- "If you took salt from a salt-shaker and threw it into the air, the telescope wouldn't see any sodium, even though half the salt is sodium”

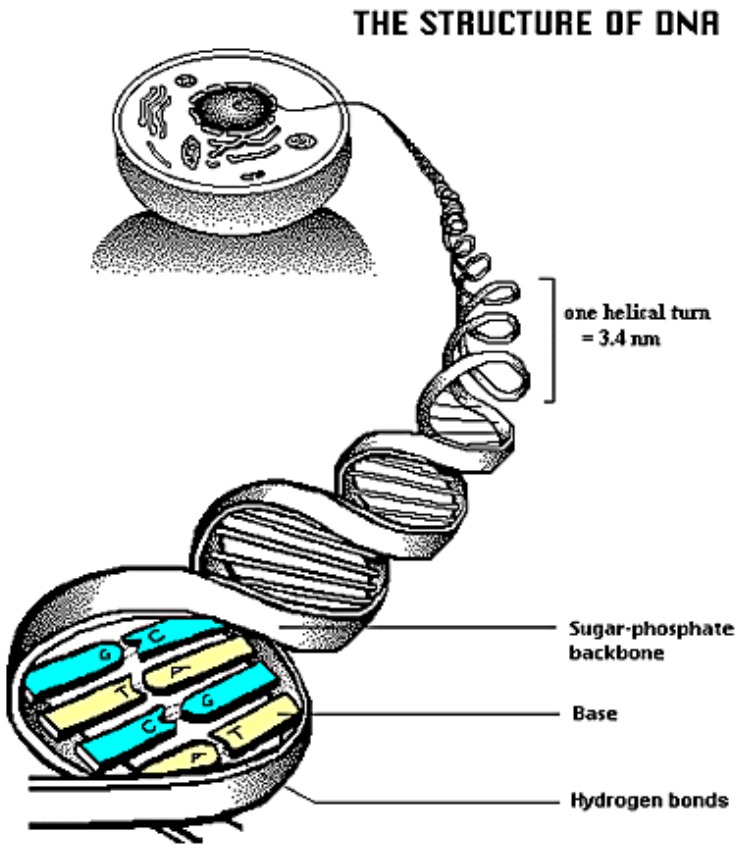
Enceladus – space mission

- A spacecraft designed to sample the water directly and run tests to detect the presence of alien microbes.
- Difficult and expensive - the data is not obtainable at altitude and a lander has to be put on the icy surface to reach it.
- The Enceladus flagship mission is one of four - along with those to Europa, Titan and Jupiter - competing for funding and currently under review by NASA.
- NASA is scheduled to select which flagship missions will advance at the end of December.
- The concept that eventually emerges in the process will launch no earlier than 2015.



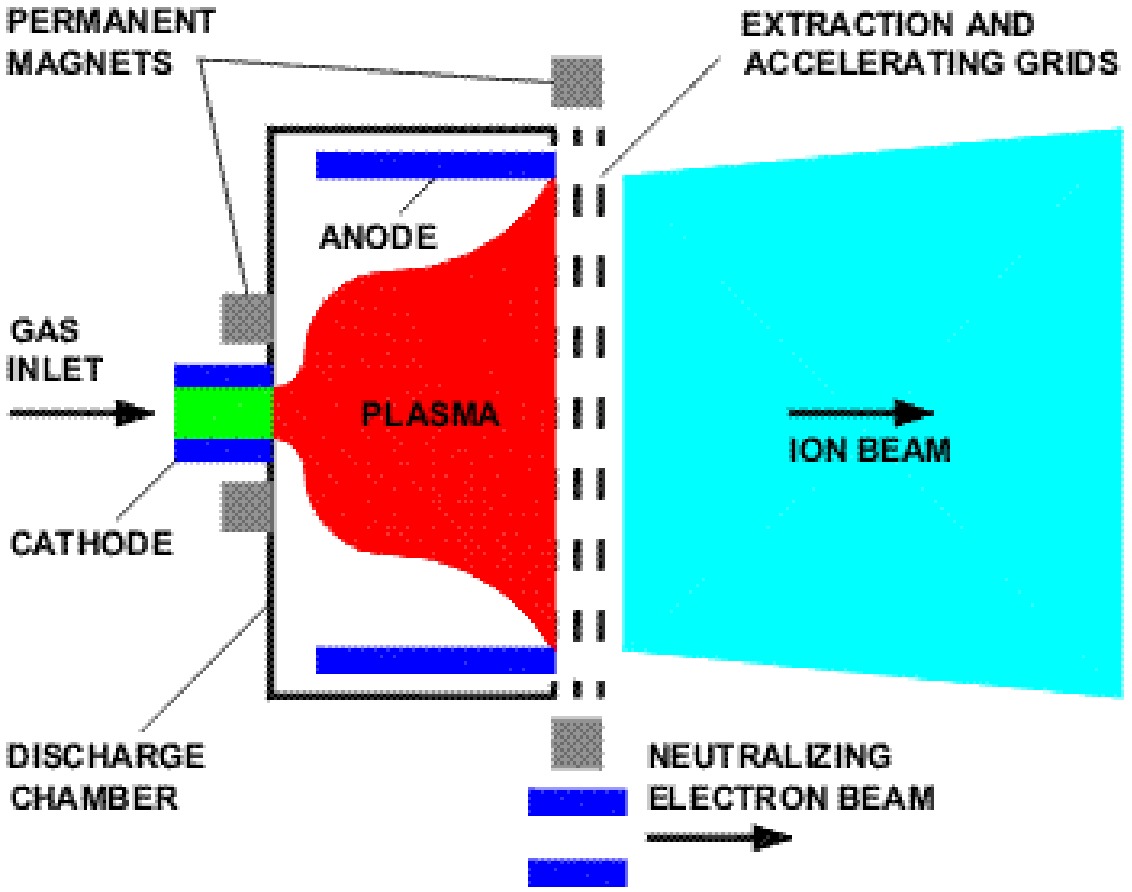
The life of dust

- „From plasma crystals and helical structures towards inorganic living matter” V.N. Tsytovich et al. 2007
- May naturally self-organize into stable interacting helical structures
- Exhibit all the necessary properties of candidates for inorganic living matter that may exist in space, provided the natural evolution is allowed
  - bifurcations that serve as ‘memory marks’
  - self-duplication
  - metabolic rates in a thermodynamically open system



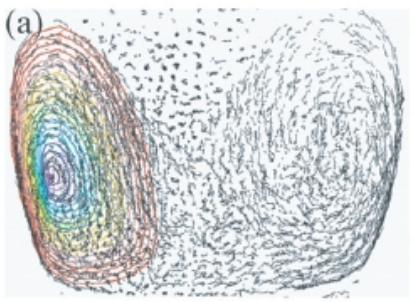
The life of dust

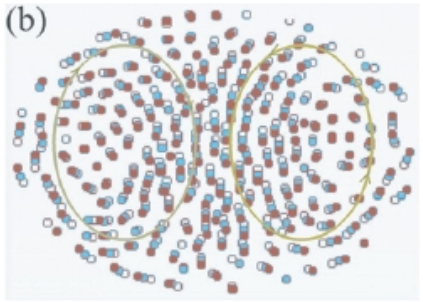
- Helical dust structures sim
  DNA can be considered as
  separated flat structures wi
  constant rotation angle bet
  planes
- The whole structure looks
  'worm', hollow inside (hav
  dust void inside) and movi
  cylindrical surfaces around
  of discharge.
- The central part of the heli
  structure of the 'worm' is c
  from the traces left of the s
  on the wall of the discharg
  chamber, the grains are loc
  the surfaces of a few cylin
  inside each other

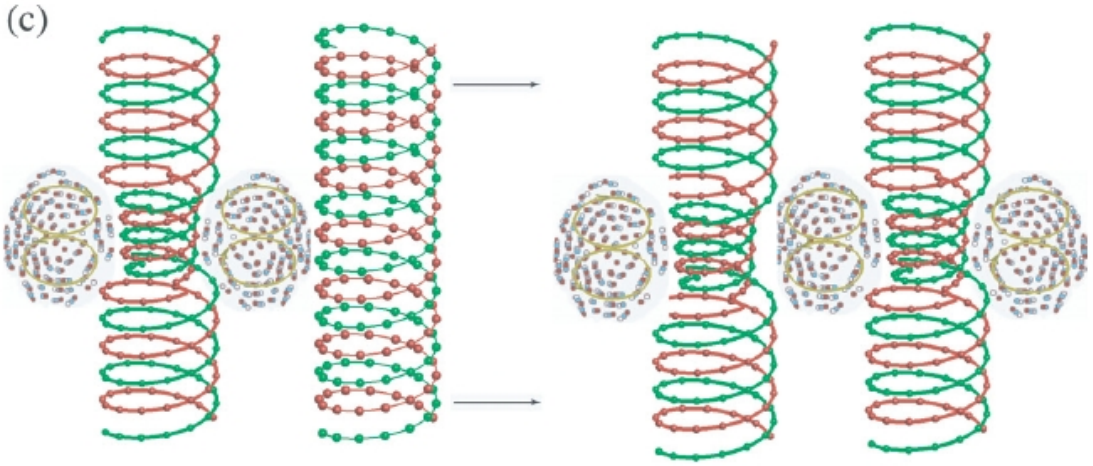


The life of dust

- (a) The observed grain convection surrounding the cylindrical grain crystal.
  - different colours correspond to different grain velocities.
  - from about 0.4 cm s−1 (blue)
  - up to 1.5 cm s−1 (red)
- (b) The dust convection obtained in numerical simulation
- (c) Sketch of the model for helical structure duplication (reproduction).







Expedition for the sake of humanity