# IF THE EARTH ISN'T WORTH SAVING, CONSIDER THE ALTERNATIVES.


**Source: The Environment Challenge Fund**

# What We Will Learn Today

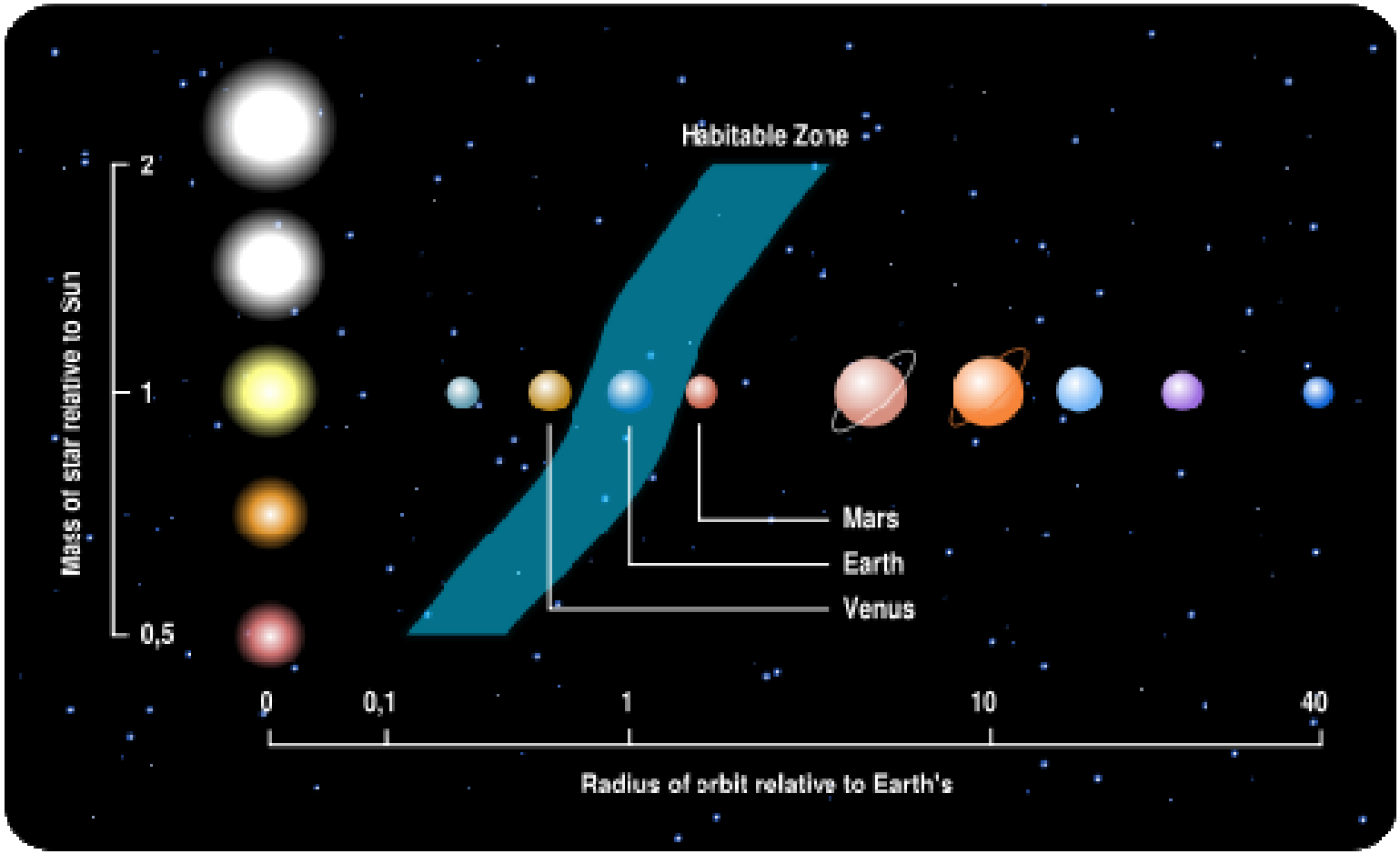
- What places in the Solar System might harbor life?
- What is the habitable zone?
- How does SETI search for intelligent alien life?

# Requirements for Life

- A source of nutrients from which to build living cells
- Energy to fuel the activities of life
- A solvent liquid to carry nutrients to all part of the organism
  - Liquid water is abundant, remains liquid over a wide temperature range and a great solvent

# The Habitable Zone

- The distance from the Sun/Star at which temperatures support liquid water



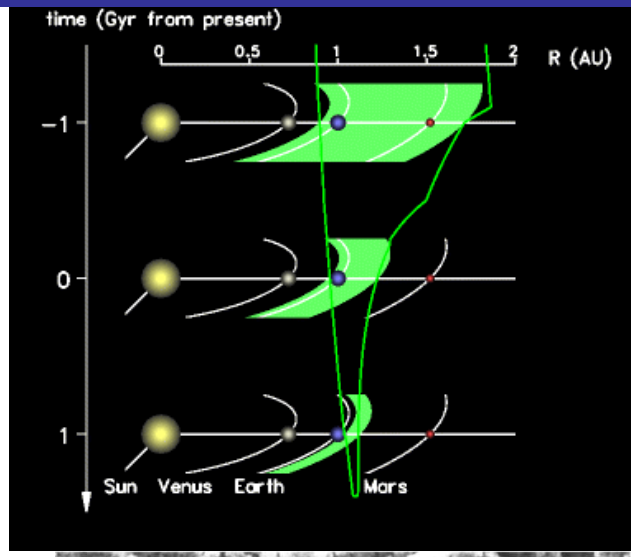

Source: Prof. Chris Done, Durham University

# Life Outside the Habitable Zone

- Other factors could support liquid water
  - Greenhouse effect
  - Local sources of energy, i.e. tidal heating
  - What's so special about water, anyway?
    - Liquid ammonia is as good a solvent as water
    - Liquid methane might also support life
    - Remember the parallels between Titan and Earth?

# Possible Life on Mars

- Had liquid water in the past
- Might have liquid water underground or near volcanoes
- Methane seen in the atmosphere
- Meteorite ALH84001
  - 4.5 billion years old
  - Blown off Mars and landed in Antarctica about 13,000 years ago
  - Contains layered carbonate minerals and PAHs
    - Associated with life on Earth
  - Rod-shaped structures seen
    - Similar to nanobacteria on Earth
  - However
    - Can be formed by non-biological processes
    - Contamination from Earth bacteria also seen



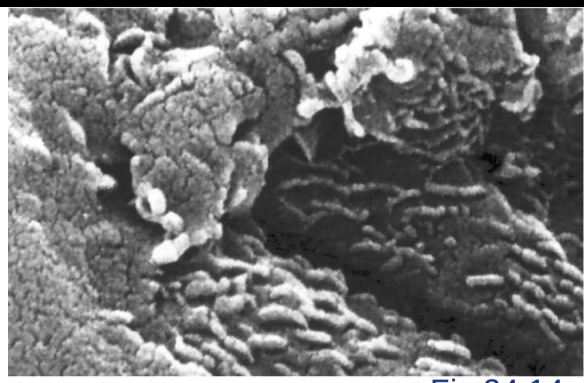
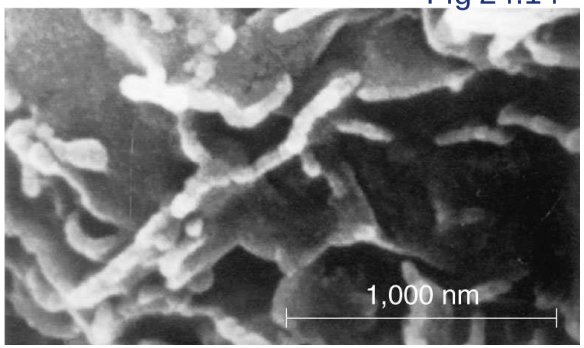



Fig 24.14



# Possible Life on Jovian Moons

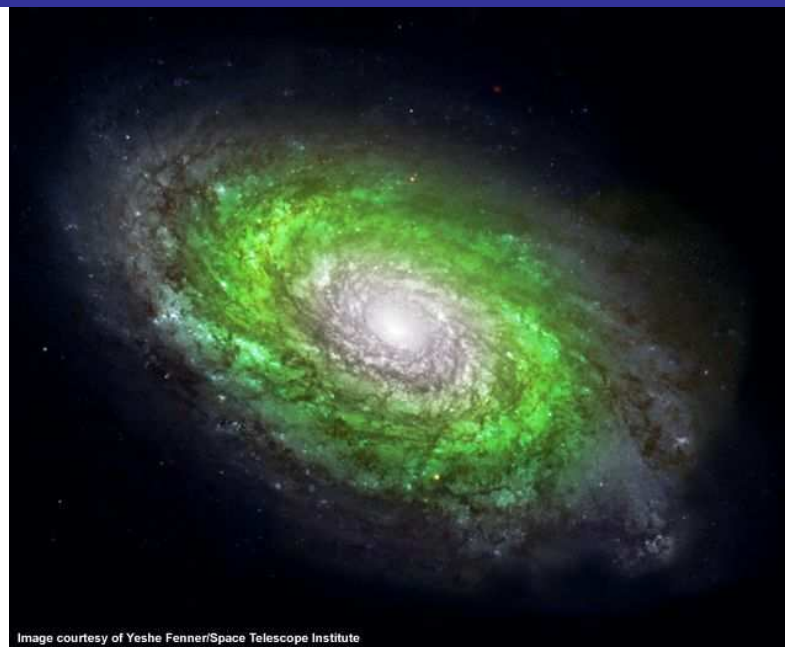
- Europa (and possibly Ganymede and Callisto)
  - Lots of $H_2O$
  - Tidal heating provides source of energy
  - Induced magnetic field is evidence of conductive liquid interior – most likely salt water
  - Likely has underwater vents
    - Earth has plenty of life at its ocean vents, why not Europa?
- Titan
  - Parallels to Earth (liquid methane, water rock & lava)
  - Has all the necessary components to allow organic life forms

# Which Stars Could Harbor Life

- Massive stars live short, violent life
  - The most massive stars only live a few million years
  - Planet formation and life formation unlikely
  - Planets more than a few times Sun's mass are unlikely candidates
  - Rules out only 1% of all stars
- Some scientists think binary stars (about half of all stars) are not good candidates
  - Current evidence (remember Two Suns?) shows that this is not a good assumption

# The Galactic Zone

- Too close galactic center
  - Higher supernova rates
  - More frequent harmful radiation
  - However
    - Atmosphere could protect life
    - Radiation could speed up mutation hence, evolution




- Too far from galactic center
  - Metallicity levels drop as you move farther out in the disk
  - Lower metallicity could imply fewer or no terrestrial planets
  - However
    - Earth's mass is 1/330,000 times mass of the Sun
    - Not much material required to make Earths

# Other Factors

- Protective Jupiter in outer orbit
  - Shields Earth from many impacts
- Stable climate
  - Plate tectonics
  - Large Moon
- But are these necessary or merely desirable?

# The Drake Equation

$$N = R_* f_p n_e f_l f_i f_c L$$

N = Number of civilizations communicating with us now!

$R_*$ = Star formation rate in Galaxy (number of stars/year)

$f_p$ = Fraction of stars with planets

$n_e$ = Number of habitable planets per star

$f_l$ = Fraction of stars with planets that will develop life

$f_i$ = Fraction of stars wit life that develop intelligent life

$f_c$ = Fraction of intelligent civilizations wanting to communicate

L = Duration (in years) that the civilization remains communicative