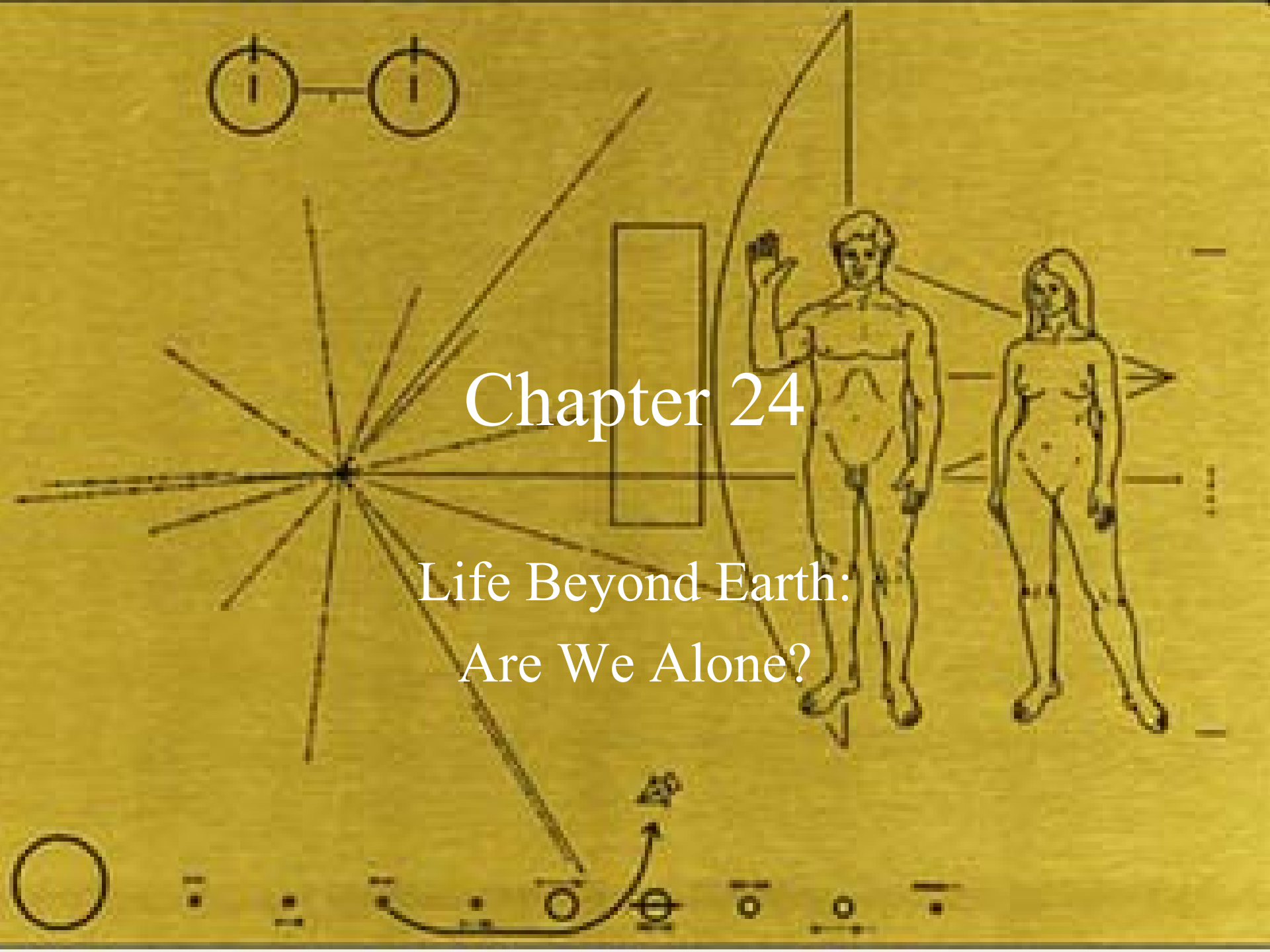


# Chapter 24

Life Beyond Earth:  
Are We Alone?



# Two Ways to Approach Question

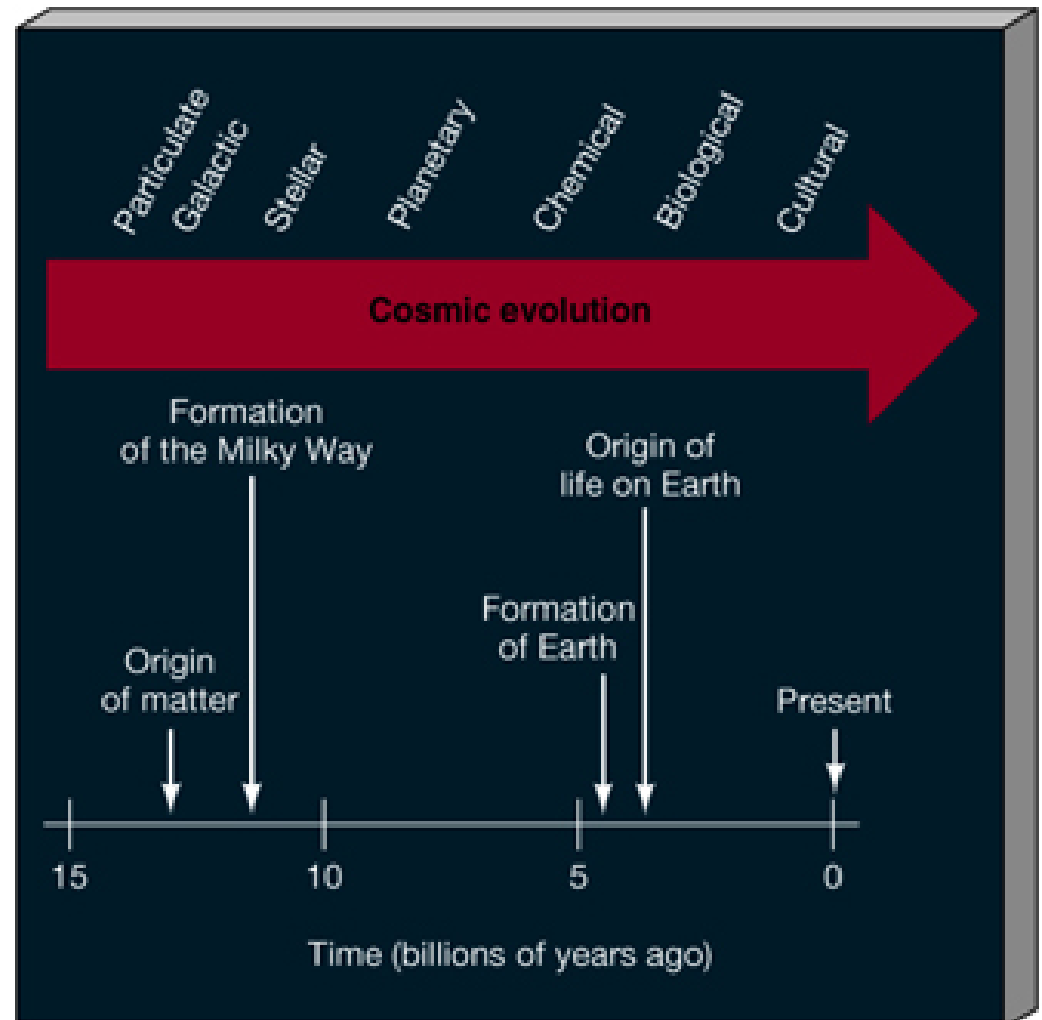
- Philosophical/Religious
  - beliefs outway facts
- Scientific
  - facts inform beliefs (theories)
- Fact is, Earth is the only place we know of in the Universe where life exists

# Topics

- Cosmic Evolution
- Life on Earth (abbreviated)
- Life in the Solar System
- Intelligent Life in the Galaxy
- Search for Extraterrestrial Intelligence

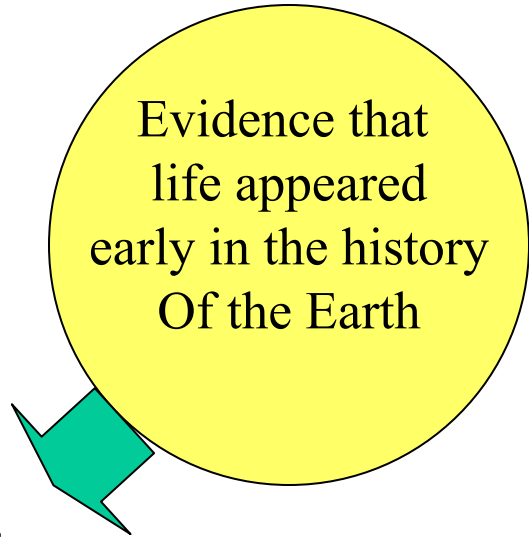
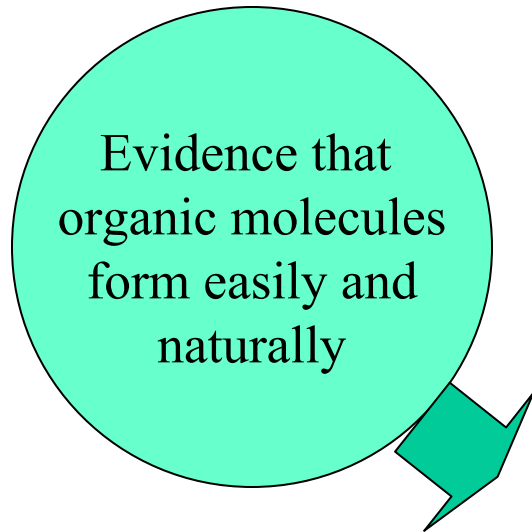
# Cosmic Evolution

- Evolution = change
- Seven principal stages
- Trend: from simplicity to complexity

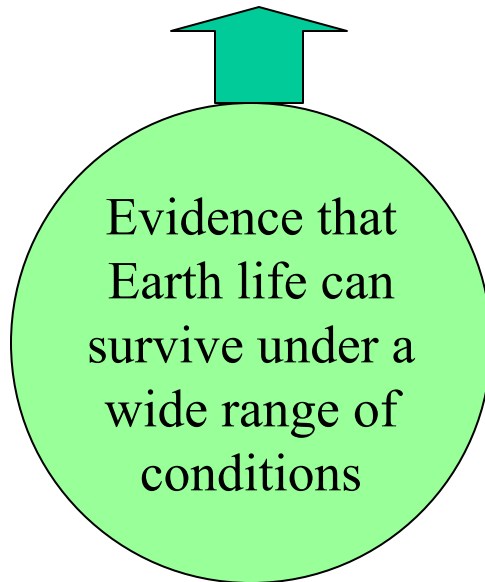


# Two Scientific Views on Origin of Life in Universe

- Natural and inevitable given right circumstances and enough time
  - *universe should be teeming with life*
- Product of a series of extremely fortunate accidents
  - *we may be a fluke*



*Biology  
may be common  
in the universe*

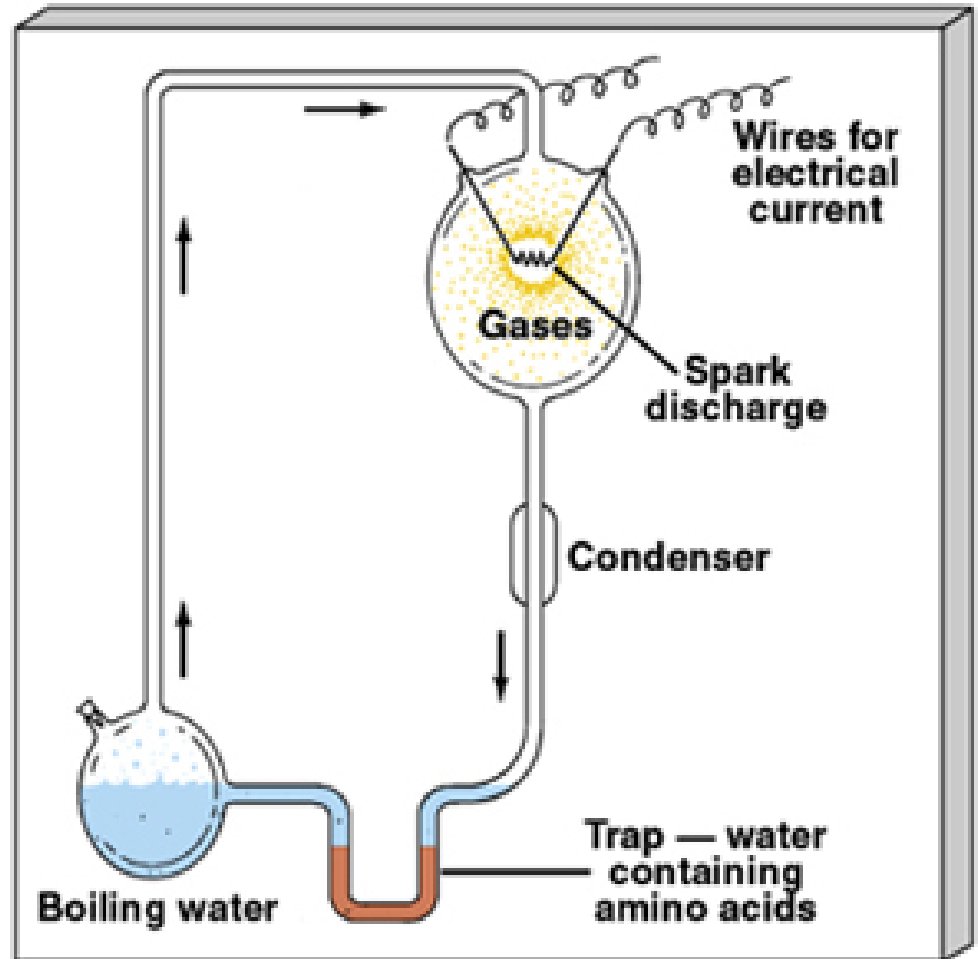


# Organic Molecules in the Universe

- Organic molecules
  - CO, CO<sub>2</sub>, HCN, CH<sub>4</sub>
- Detected in:
  - Comets, asteroids, and meteorites
  - Atmospheres of Jovian planets
  - Atmosphere of Titan
  - Star-forming molecular clouds in MW and other galaxies
- Significance
  - Easily converted into amino acids by natural processes

# Miller-Urey Experiment (1953)

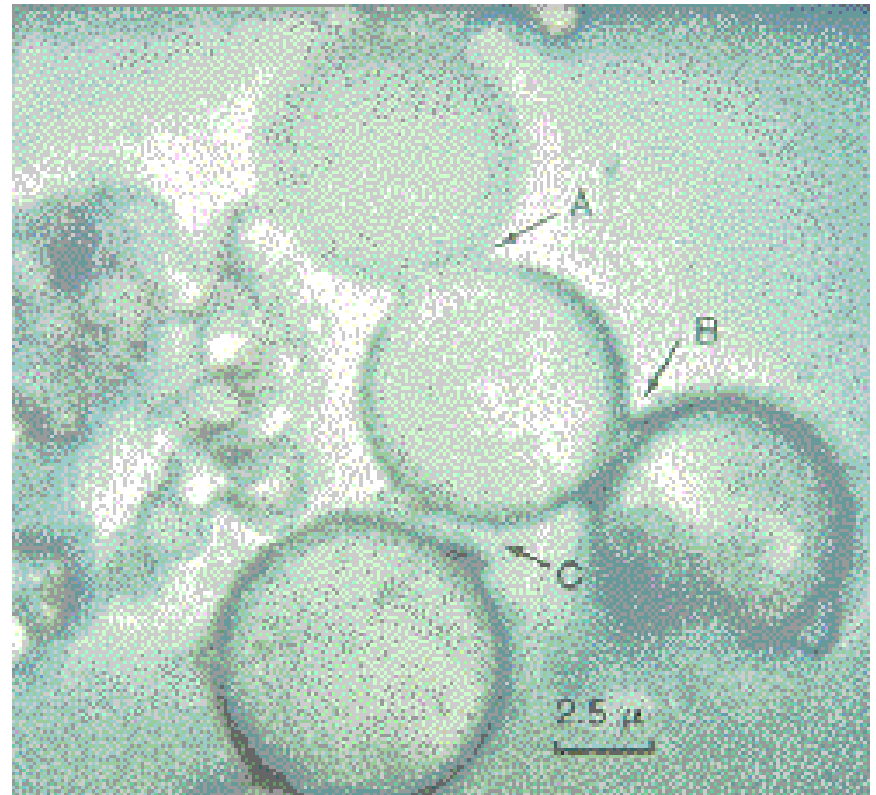
- An electric discharge is passed through gas mixture similar to Earth's primordial atmosphere ( $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{NH}_4$ ,  $\text{CH}_3$ )
- amino acids are produced
- building blocks of DNA and proteins



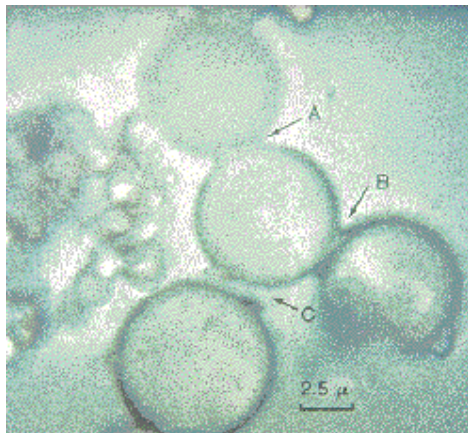


# Microspheres: First Step to Cellular Life?

- M-U expt. proves biological molecules are produced naturally
- more advanced expts. Produce protein microspheres
- similar to cell membranes
- permeable to small molecules, not large



# Comparison with Single Cell Organisms



microsphere



fossil bacteria

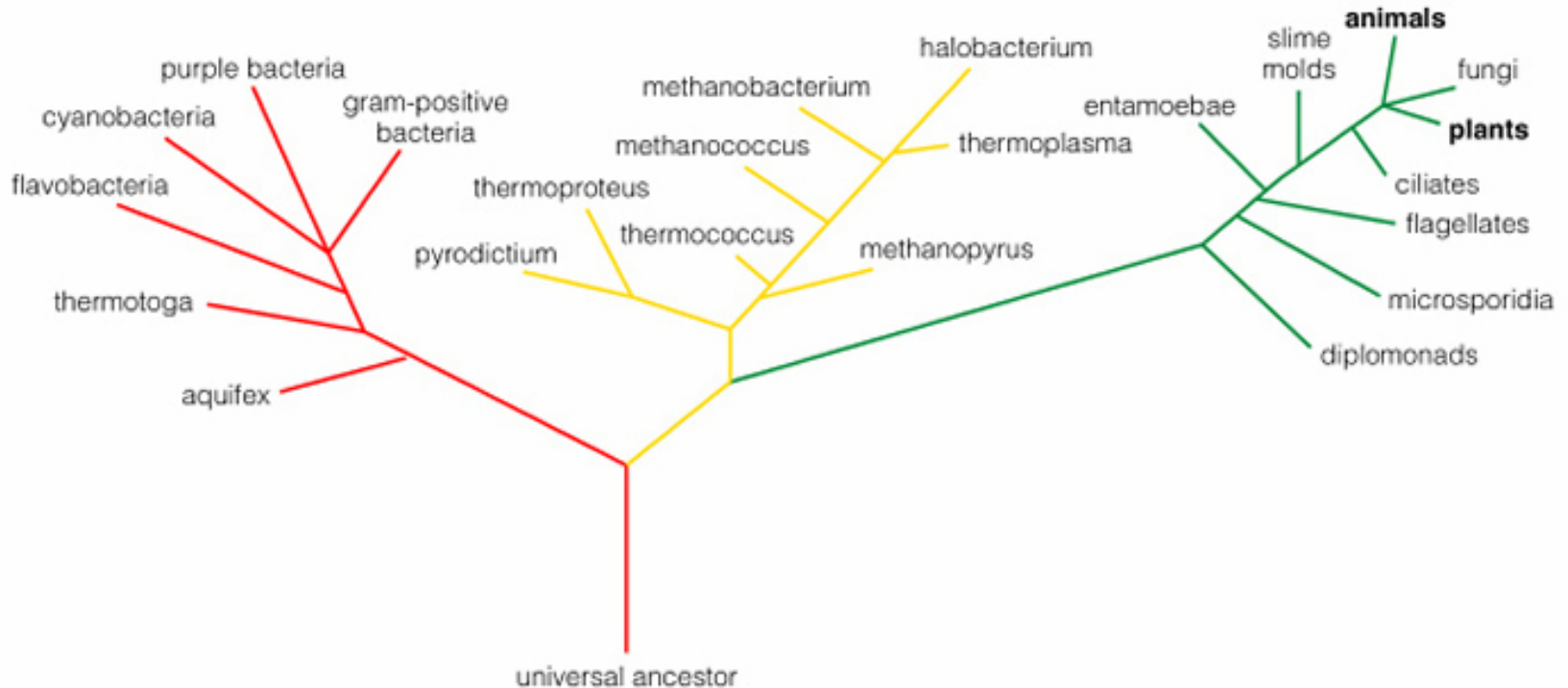


modern algae

# Life on Earth

- Life as we know it:
  - is carbon-based
  - first simple single cell organisms (algae) appeared 3.5 Byr ago (1 Byr after Earth formed and 0.5 Byr after bombardment ceased)
  - complex single cell organisms (amoeba) appeared 2.5 Byr ago
  - multi-cell organisms appeared 1 Byr ago
  - Cambrian explosion 600 Myr ago
  - humanoids appeared 4 Myr ago

# Tree of Life



Note: all plants and animals are only two branches

# Life in the Solar System

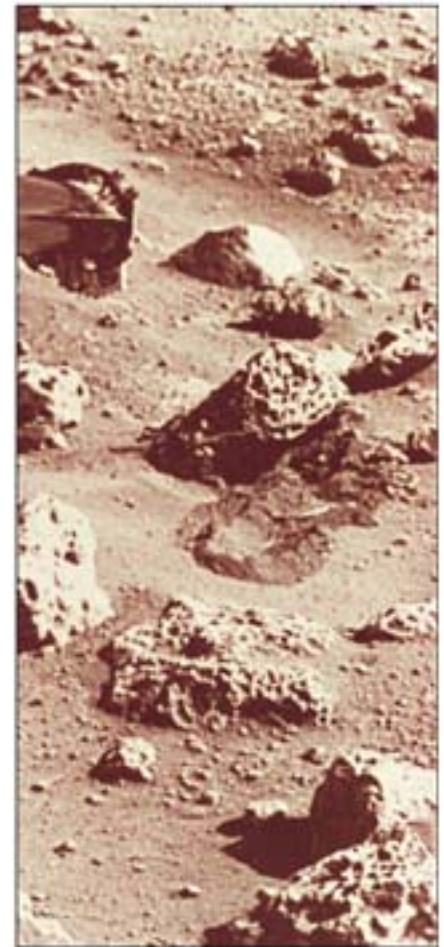
- Where else could life as we know it have found conditions similar to Earth?
  - liquid water
  - protective atmosphere
  - not too hot or cold
  - billions of years for life to evolve
- Mars, but lost most of atmosphere after 1 Byr
  - many missions will look for archeo-life
- Jovian moons Europa and Titan

# Life on Mars?

- Thin atmosphere and absence of liquid water makes life very unlikely today
- could microbial life have thrived earlier when atmosphere and water were more abundant?
- Viking lander (1976) gave ambiguous result

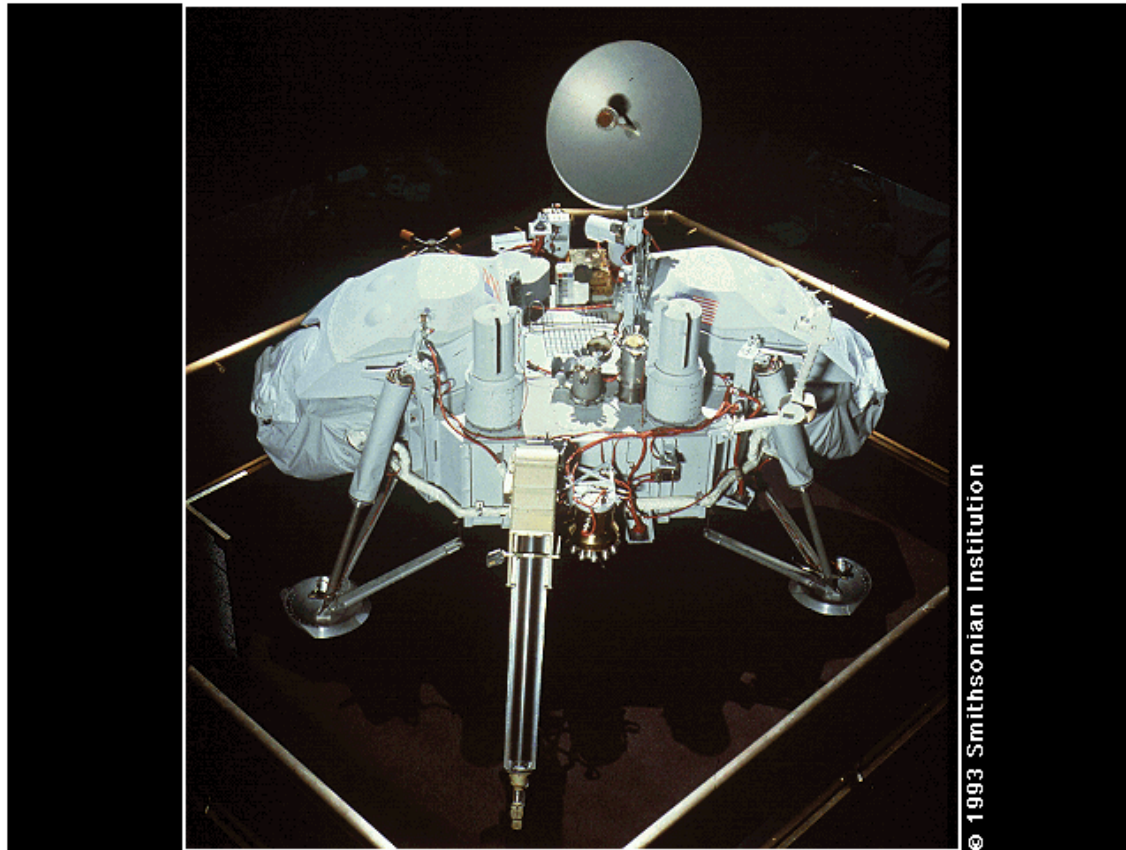


(Before)



(After)

# Viking Mars Lander (1976)



Purpose: analyze Martian soil for microbial life



# Smoking Gun? ALH84001

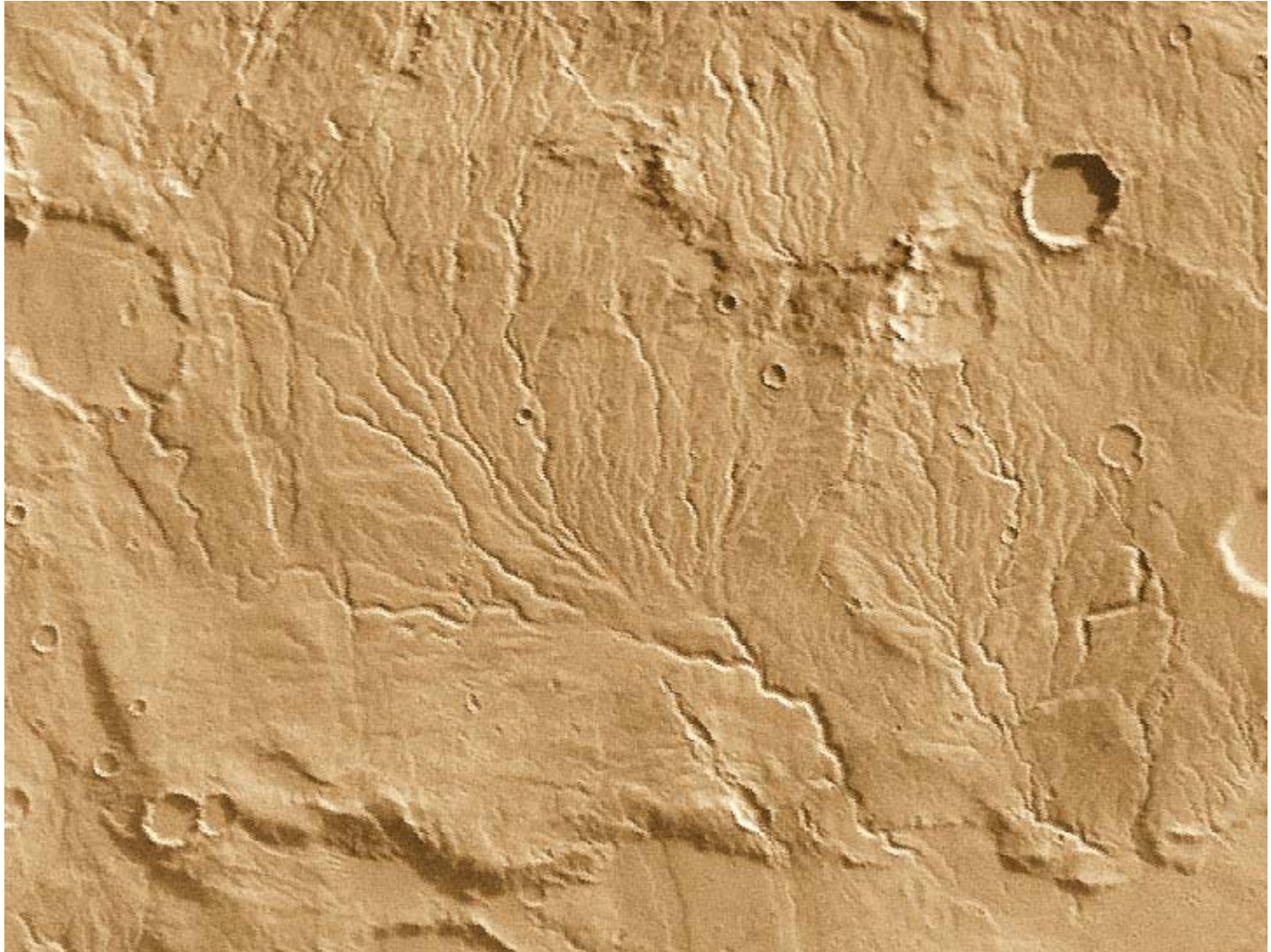
Top science news story of 1996



Fossil bacteria or mineral features?



# Water on Mars?

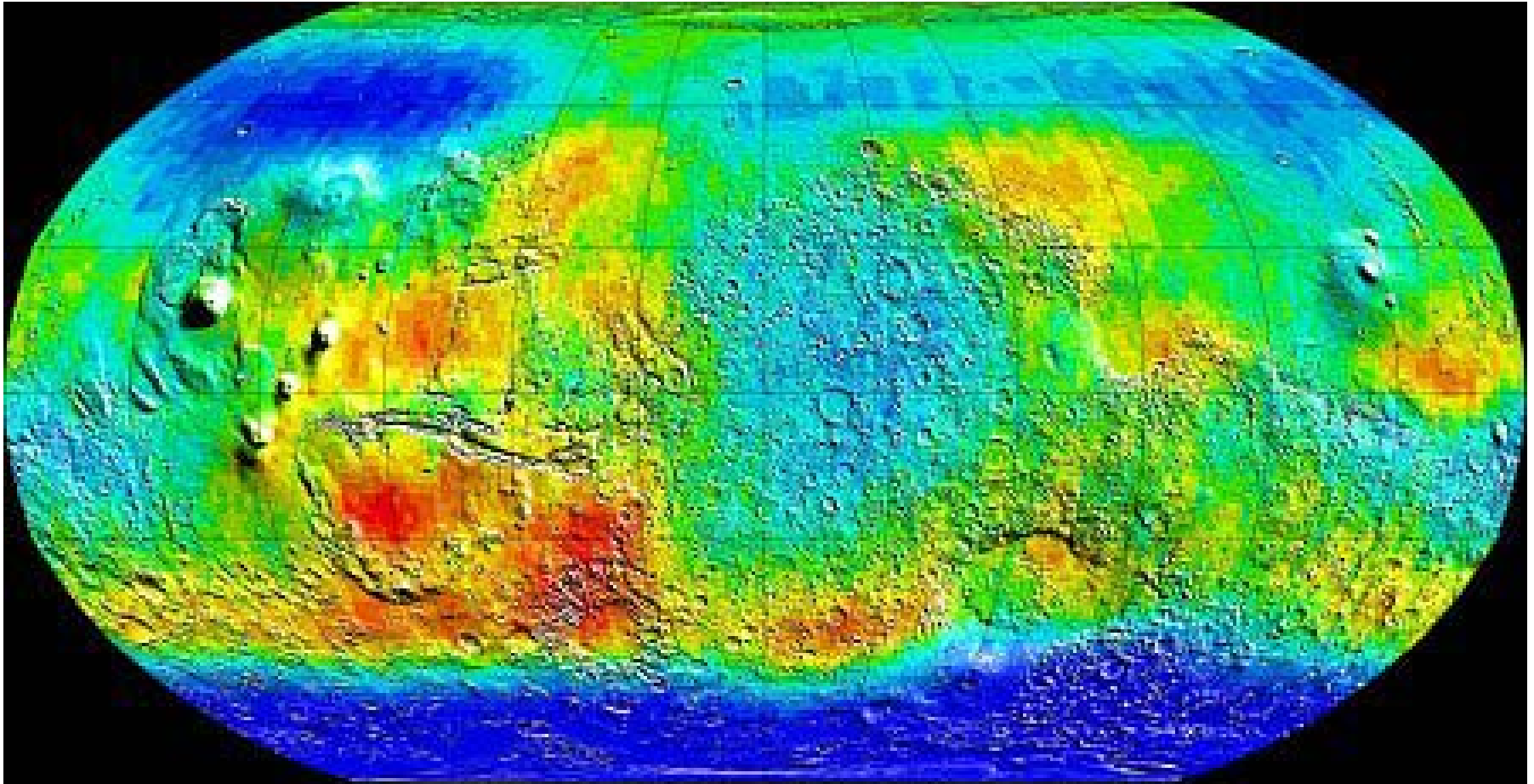


NASA/MGS

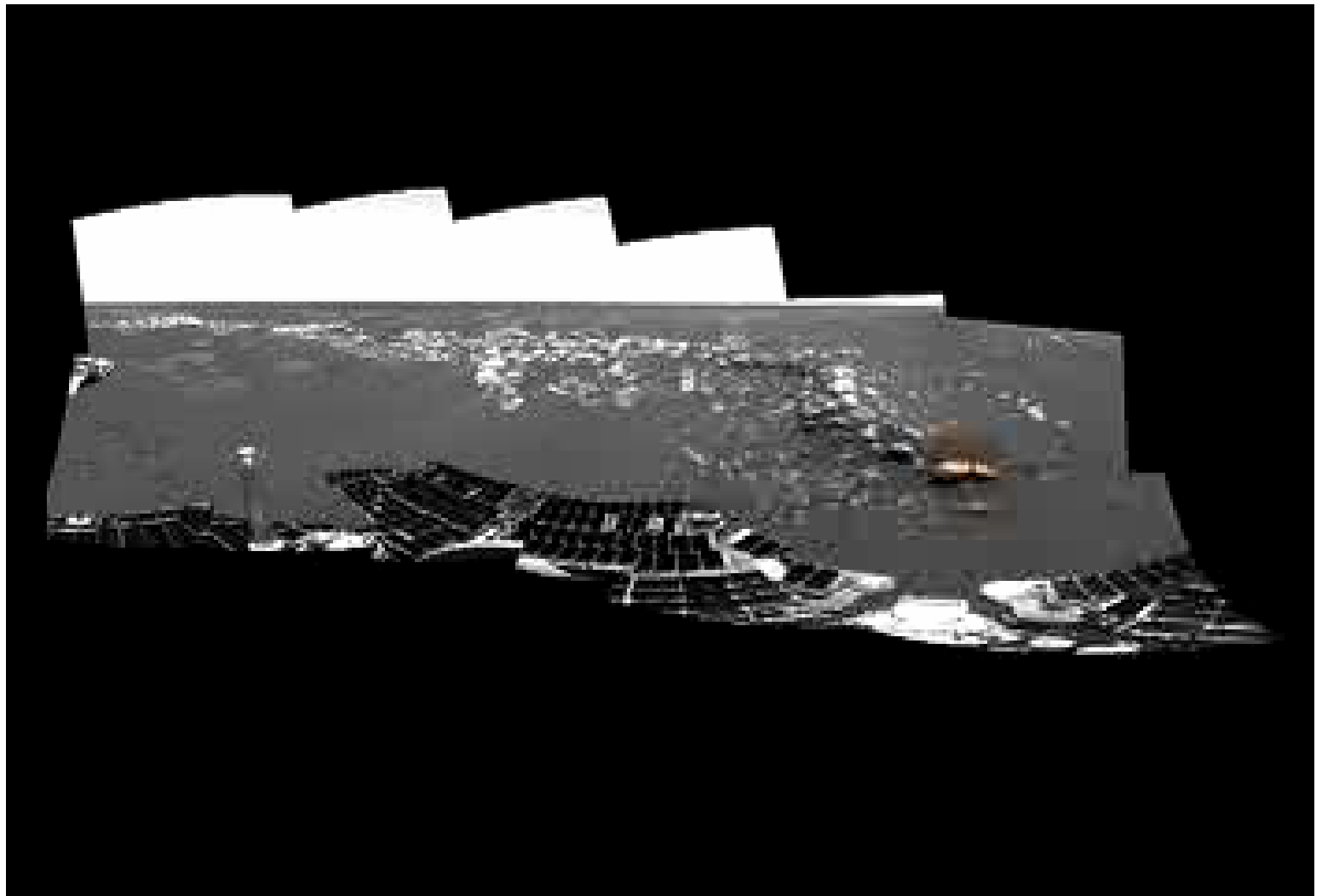
# Water Ice on Mars

- Discovered May, 2002
- Gamma-ray spectrometer aboard Mars Global Surveyor has detected surface hydrogen coming from N and S poles
- Inference is water ice just below the surface “permafrost”
- Amount: enough to fill Lake Michigan twice (est.)
- maybe more deeper

# Map of Ice Concentration

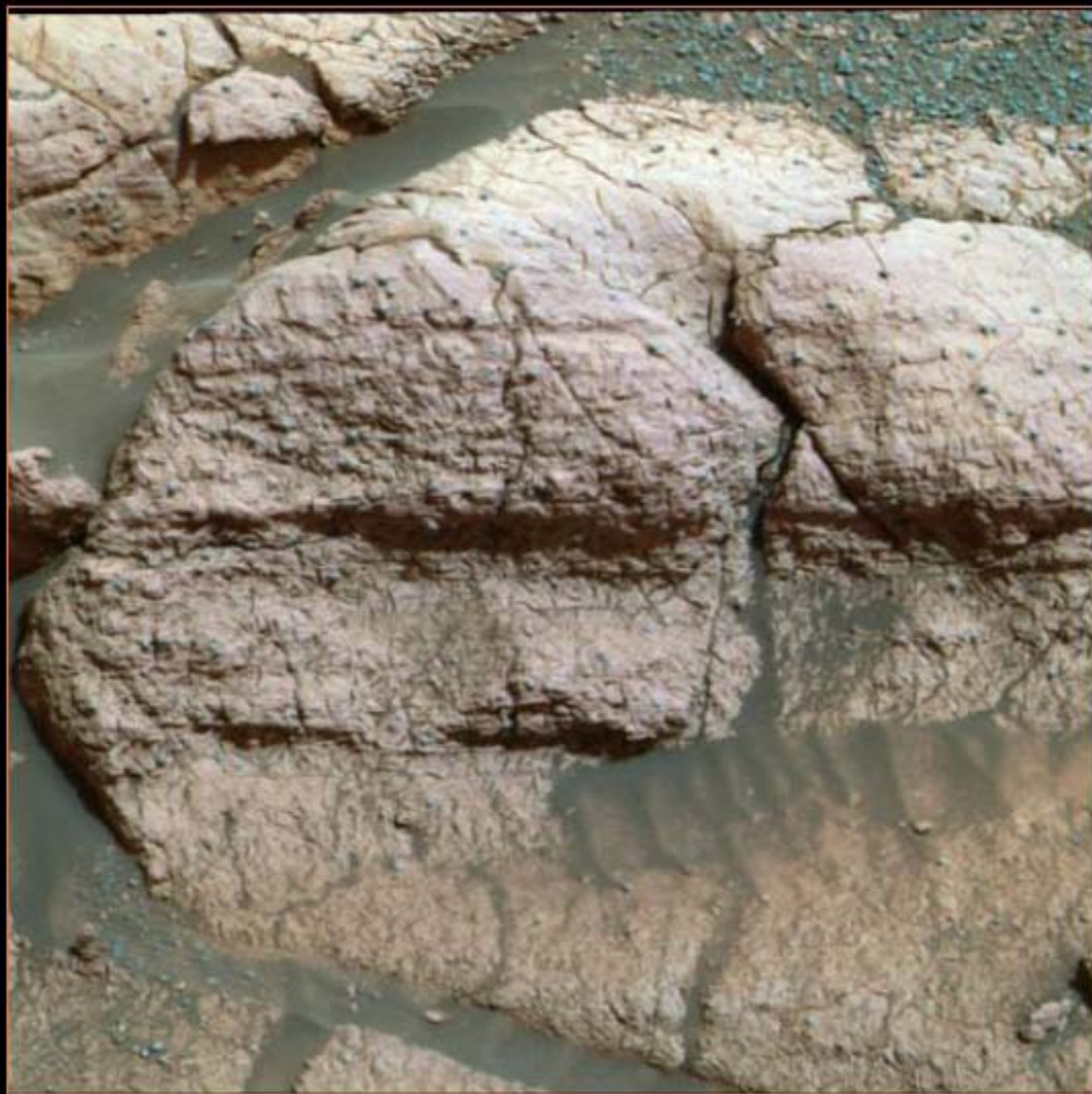


Color indicates hydrogen concentration; Red=low, Blue=high



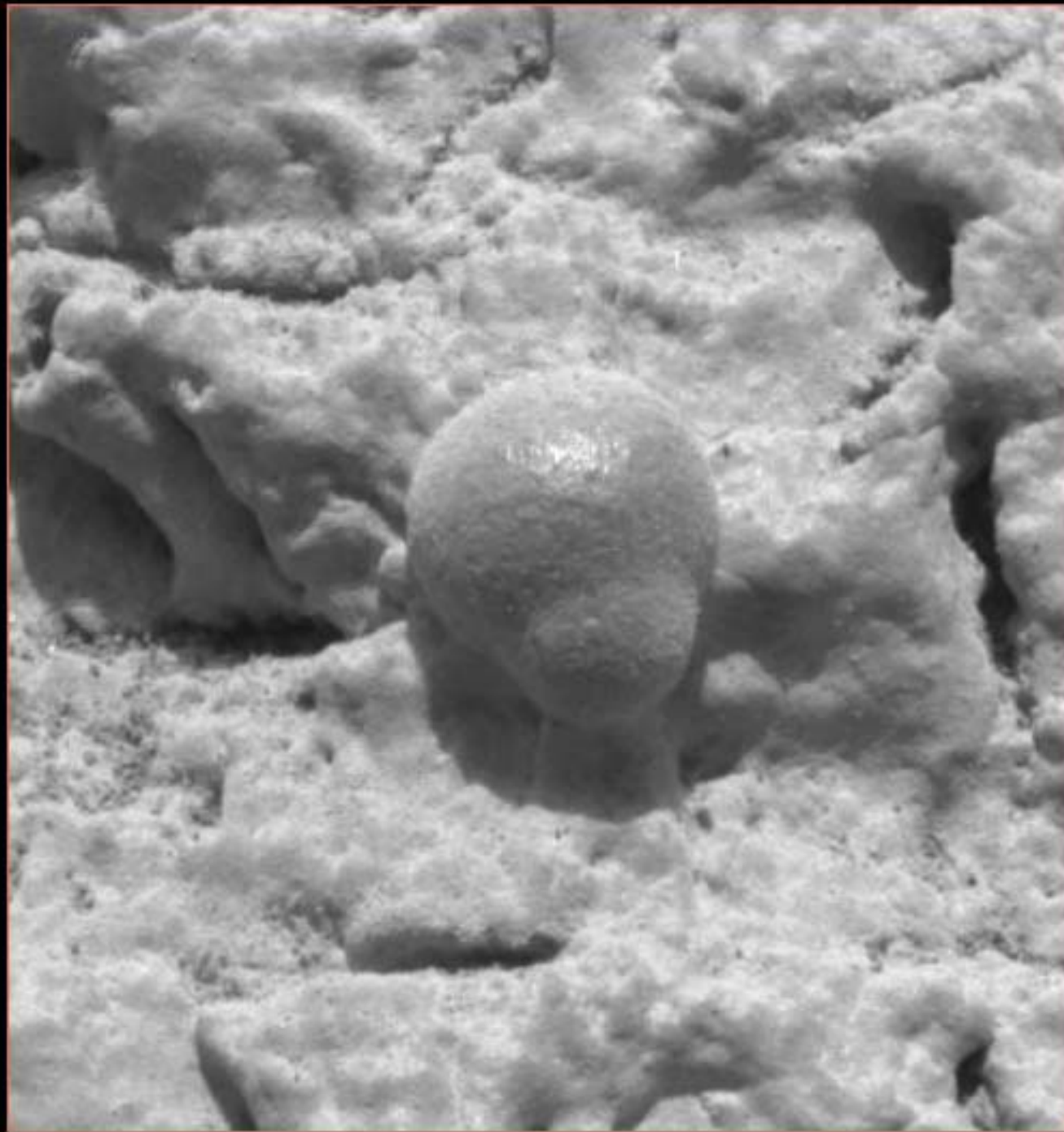
Opportunity at Eagle Crater





Opportunity  
03/02/04

Discovery would come at the site named "El Capitan," where 4 details point to a water-soaked past on Mars.



Opportunity  
03/02/04

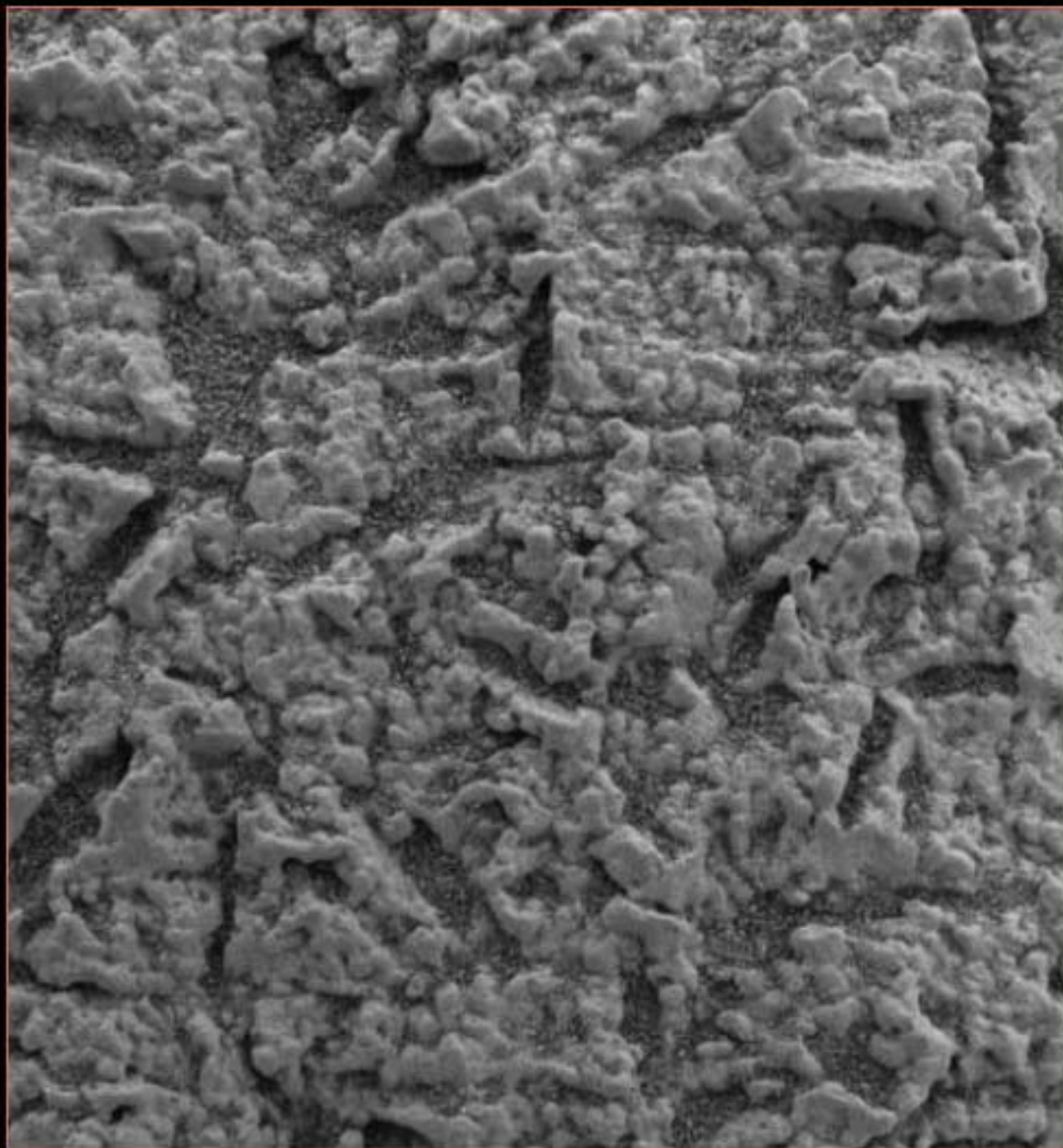
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### Water Sign #1: SPHERULES

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This close-up, microscopic image of El Capitan reveals one of many “BB-sized” spherules found in the rock outcrop. They may be accretions of minerals that formed in porous, water-soaked rocks.





Opportunity  
03/02/04

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## Water Sign #2: "VUGS"

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On earth, this texture occurs when crystals of salt minerals form within rocks sitting in briny water. At El Capitan, small cavities called "VUGS" may be voids left when the crystals disappeared. Water may have dissolved them over time.



Opportunity  
03/02/04

---

### Water Sign #3: CROSSBEDDING

---

Angled, layered  
patterns  
(crossbedding)  
give clues to the  
rock's formation.

The rock called "Last  
Chance" has concave,  
small-scale, rippled  
layers that may  
have formed in  
moving water.





Opportunity  
03/02/04

---

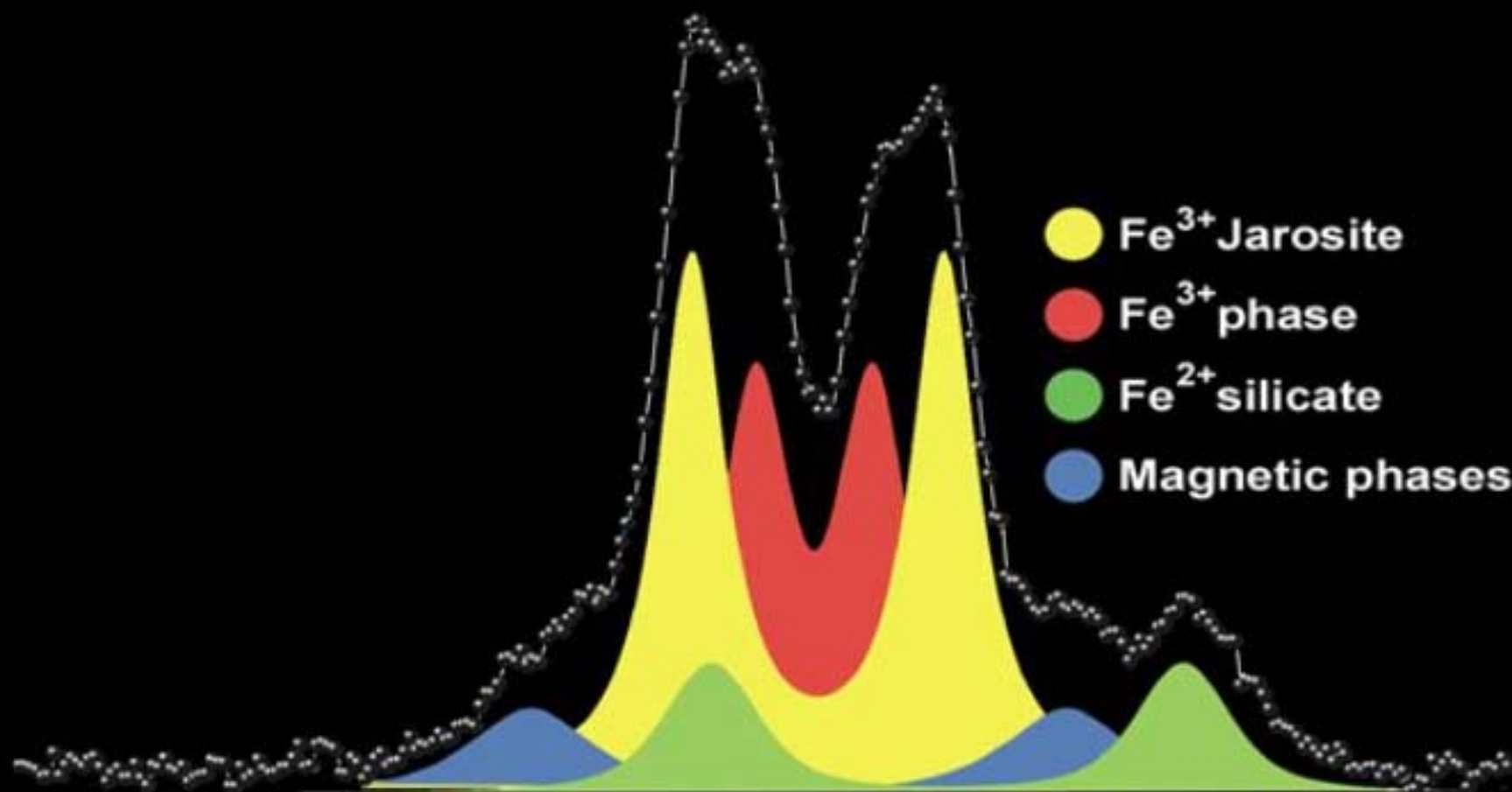
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## Water Sign #4: MINERAL ANALYSIS

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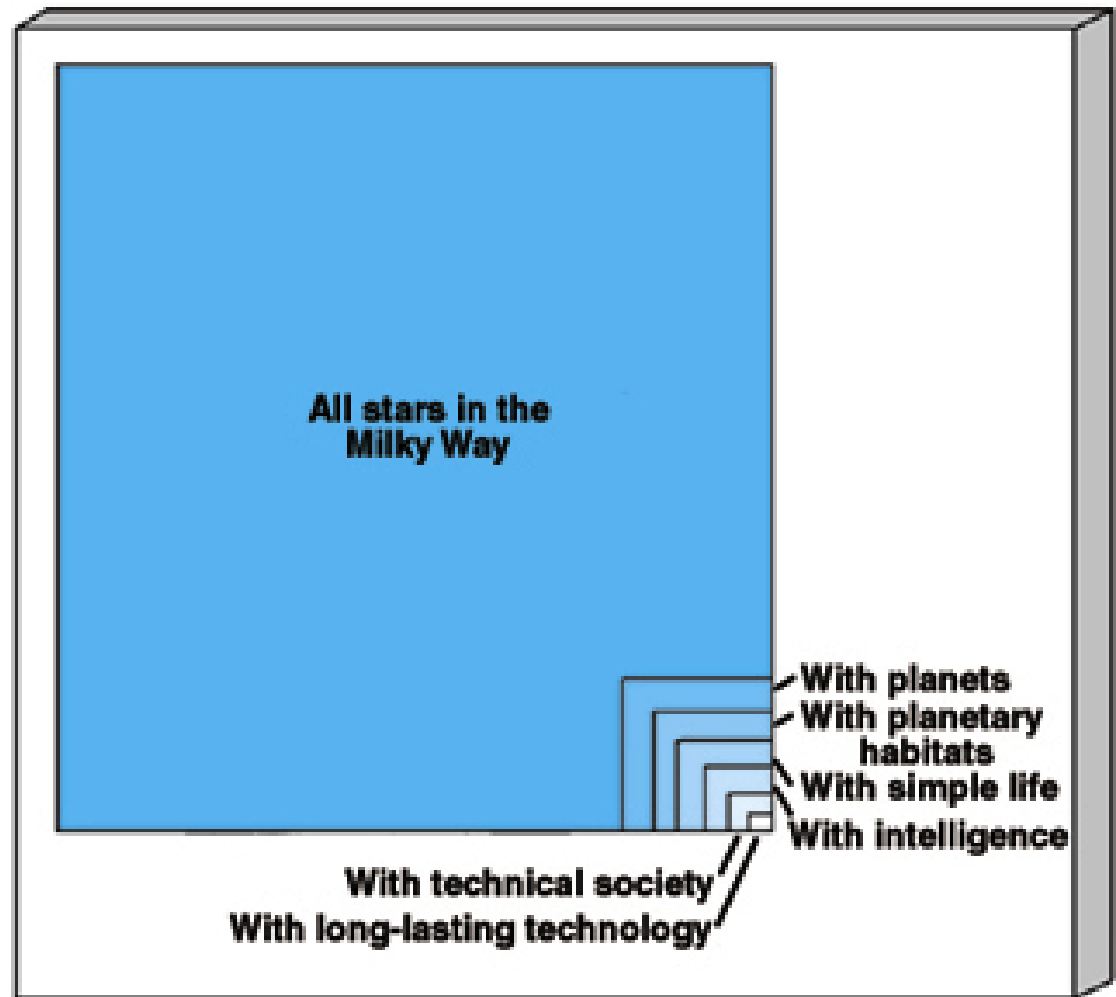
Spirit detected the presence of an iron-bearing mineral called jarosite. On Earth, jarosite forms in dilute sulfuric acid in ground water.



# Intelligent Life in the Galaxy: The Drake Equation



Frank Drake  
Cornell University



# How Many Intelligent Civilizations?

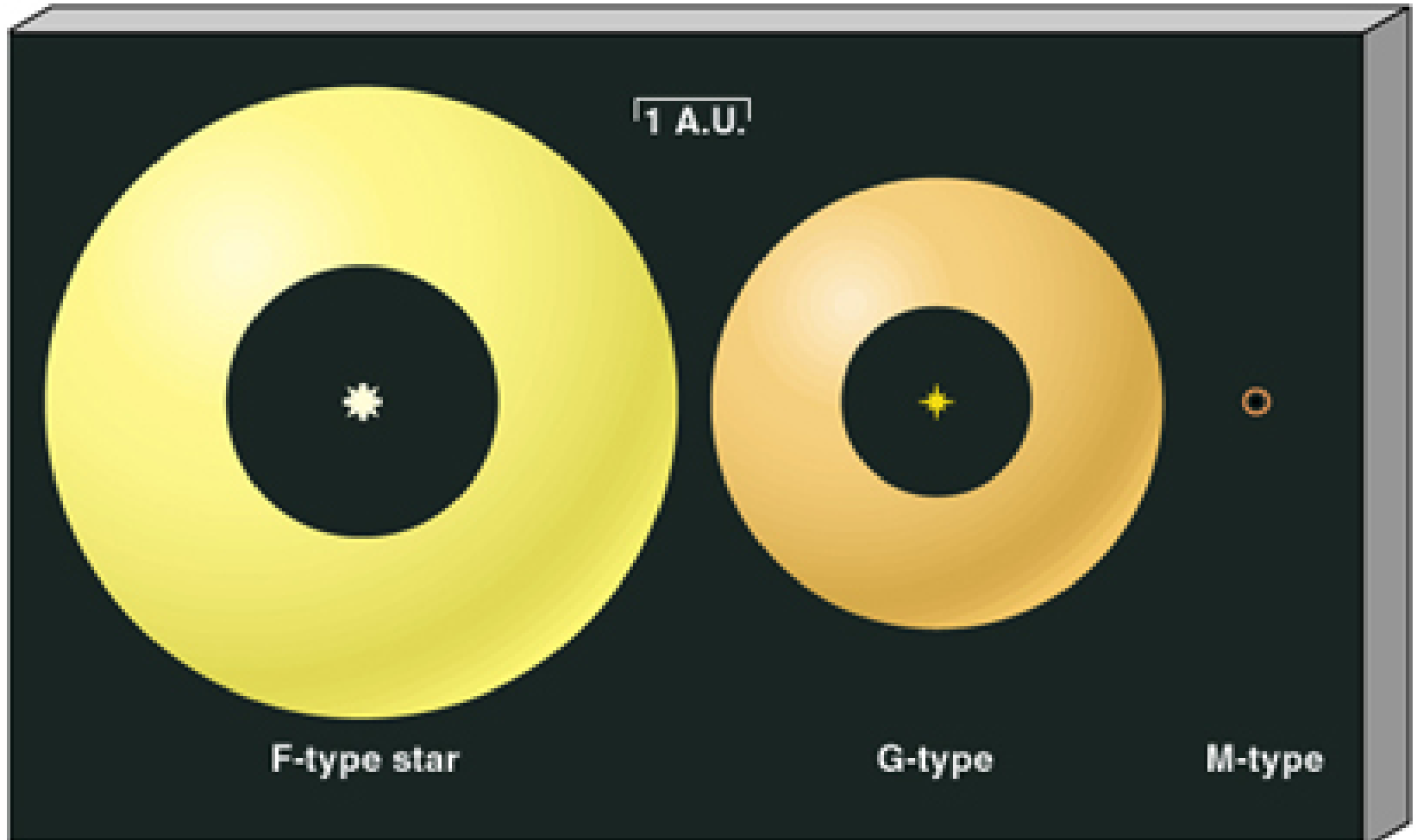
## The Drake Equation

Number of technological, intelligent civilizations in the Milky Way galaxy

= Rate of star formation, averaged over the galaxy  $\times$  Fraction of stars having planetary systems  $\times$  Average number of habitable planets per system  $\times$

Fraction of those with life  $\times$  Fraction of those which evolve intelligent life  $\times$  Fraction of those which develop technological society  $\times$  Average lifetime of a technologically competent civilization

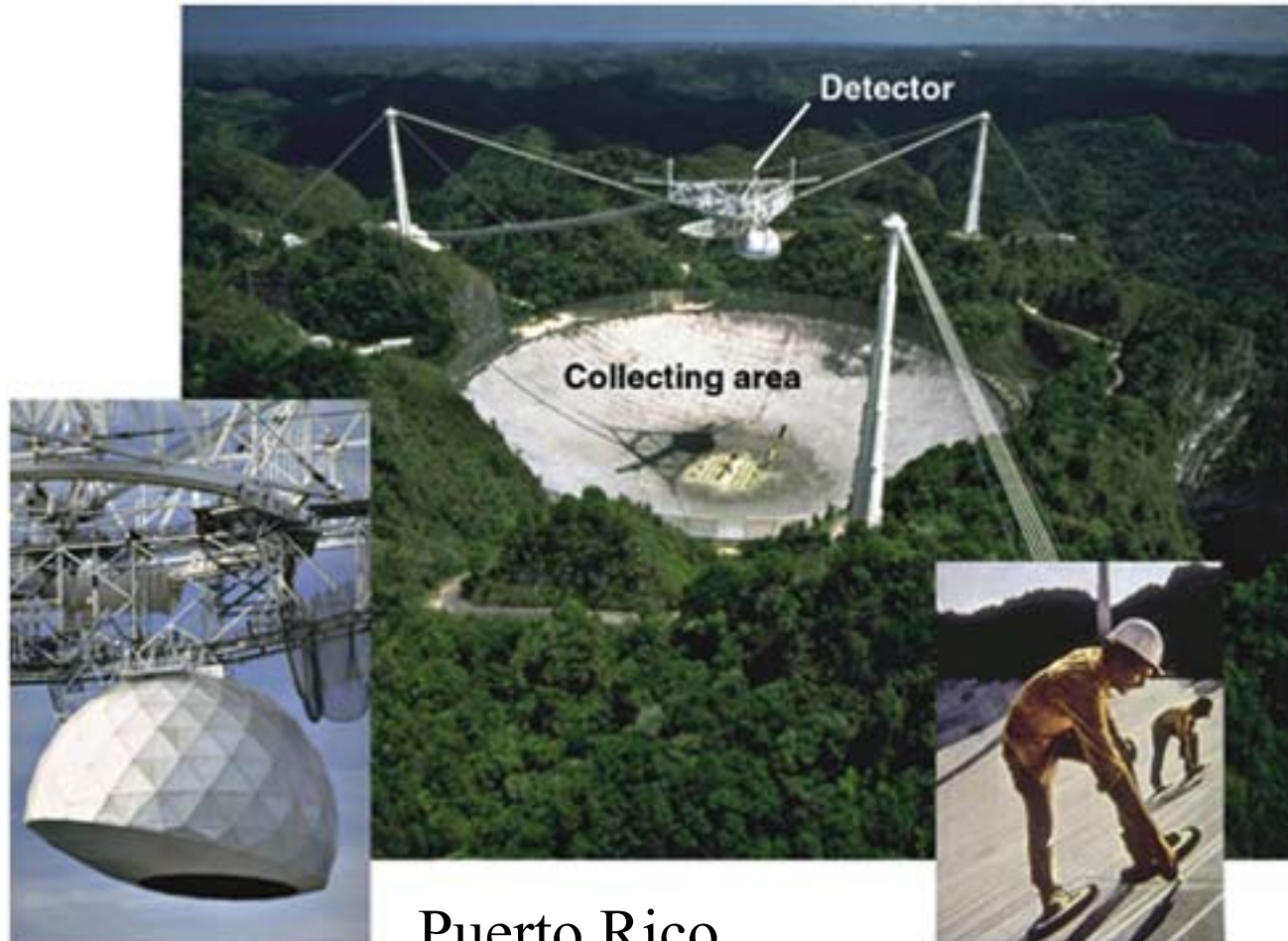
# The Habitable “Goldilocks” Zone



SETI:  
Search for Extraterrestrial  
Intelligence

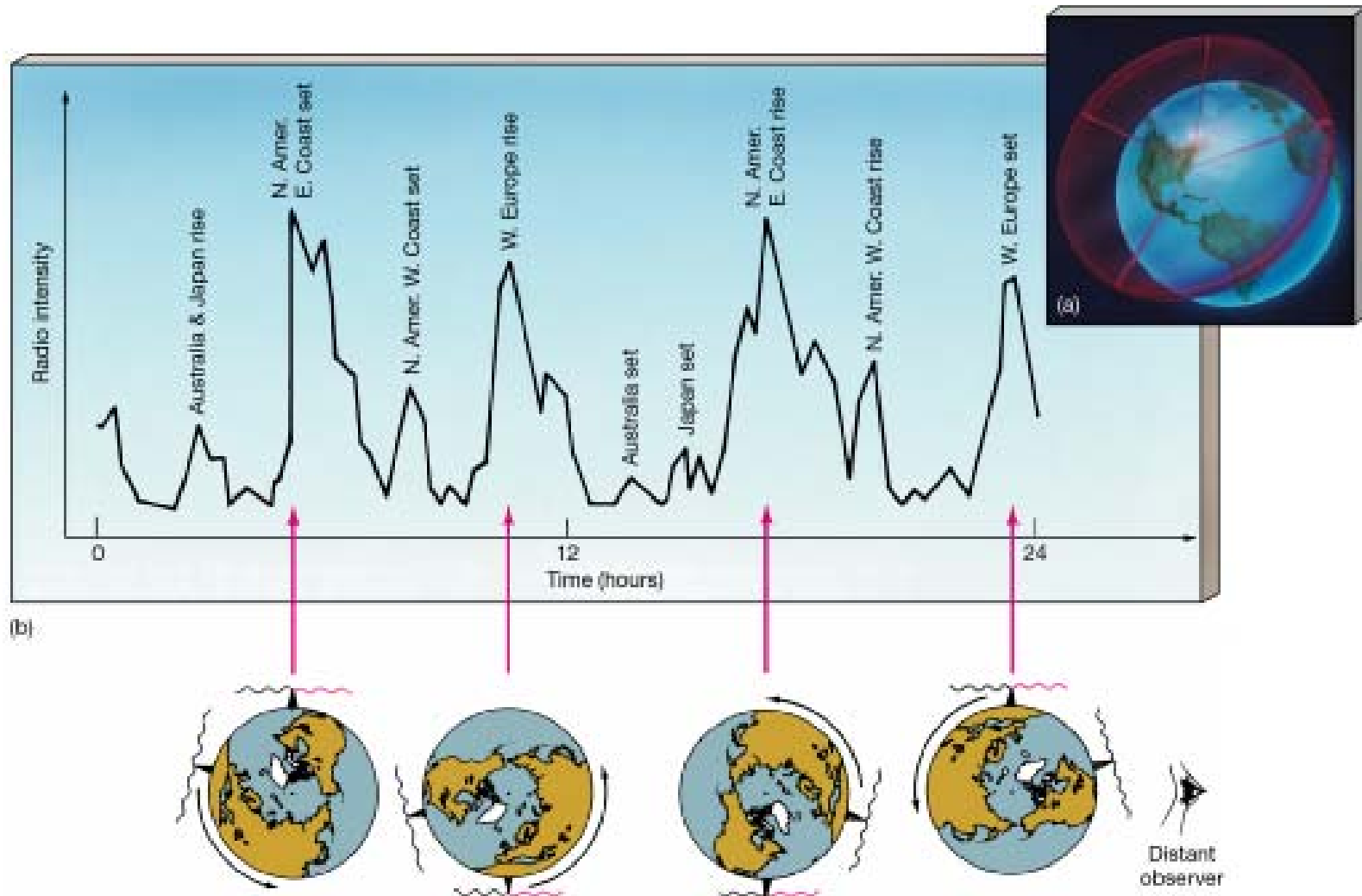
# Arecibo Radio Observatory

D=300 m aperture

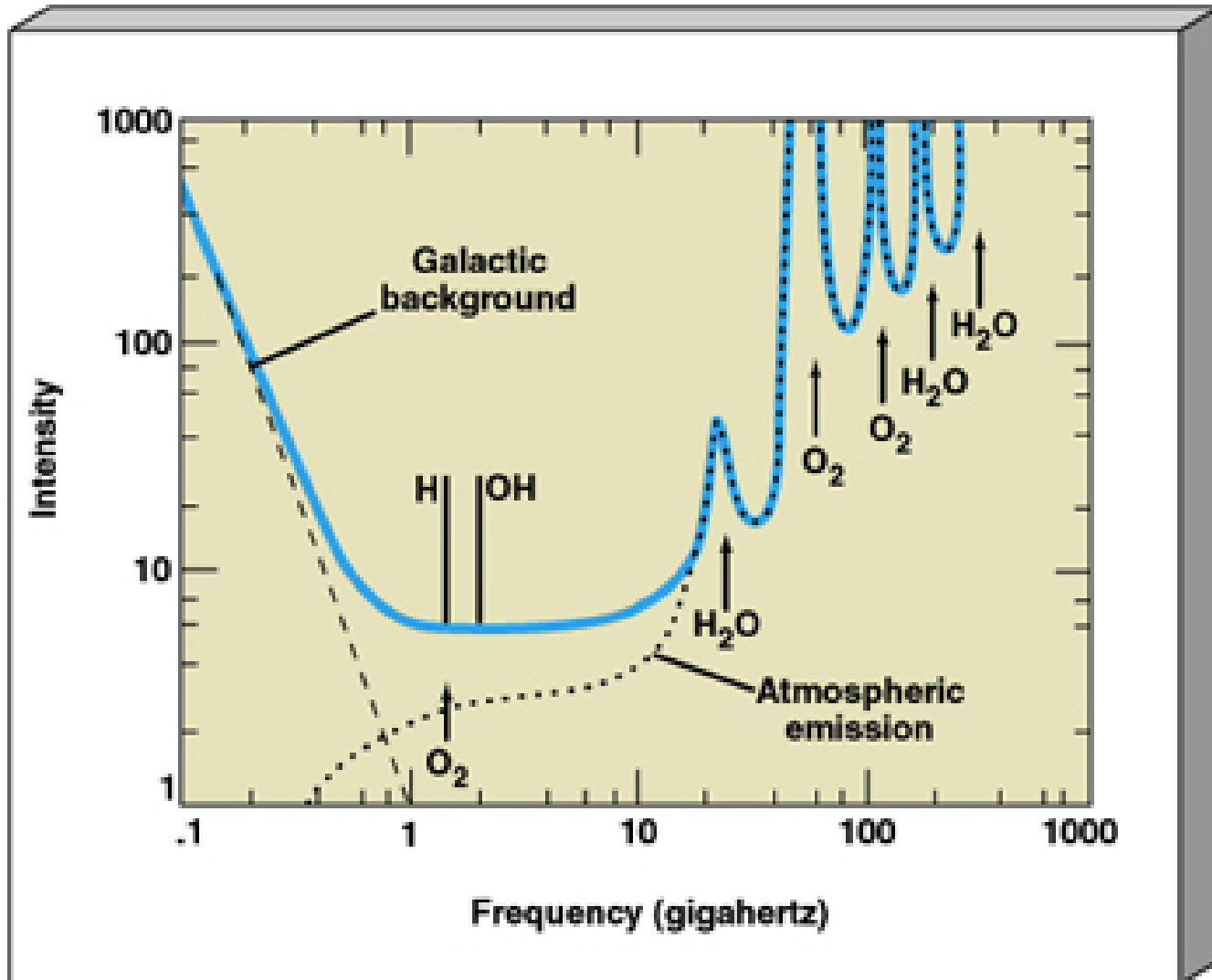


Puerto Rico

# Earth's Radio Leakage



# SETI: The Water Hole







SETI INSTITUTE

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WWW www.seti.org

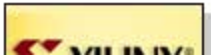
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Nov. 13 - Dec. 12, 2003

### [Arecibo Diaries](#)

What is it like to live and work at the Arecibo Observatory? Project Phoenix staff members share their experiences at the big dish during the SETI Institute's fall observing session.



[Events Calendar](#)



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[SETI Institute's Are We Alone?](#) - a weekly science radio program  
This Sunday: **Live From Arecibo: Talk from the telescope**

## Announcements

www.seti.org

# Project Phoenix



**Project Phoenix Observations** Arecibo, Puerto Rico, Fall 2003



**Features**  
**SETICam**  
**Background/History**

## SETICam B



[Launch floating window Cam B](#)

- >> Switch to Cam A
- >> SETICam B
- >> Star Map [Live data]
- >> Web log
- >> Star log - Recently Observed Targets
- >> Observing Schedule
  
- >> Observers
- >> Glossary
  
- >> Jodrell Bank Cam



# The Search for Extraterrestrial Intelligence At U.C. Berkeley

**SETI@Home**: Why let your home computer waste millions of CPU cycles running a screen saver when it could be analyzing SETI data? Computer users from around the world are able to participate in this major scientific experiment.

**SERENDIP**: The SERENDIP SETI program is a search for radio signals from extraterrestrial civilizations; it is currently conducting a sky survey at the world's largest radio telescope.

**Optical SETI**: Instead of listening for radio signals, this new project searches for pulses of light from thousands of nearby stars.

**Southern SERENDIP**: A sky survey conducted by our colleagues at the Parkes radio telescope in Australia.

<http://seti.ssl.berkeley.edu/>