

ASTR 1120: Stars & Galaxies



Prof. Juri Toomre TA: Ben Brown
Lecture 43 Wed 27 Apr 05
zeus.colorado.edu/astr1120-toomre

Today's Events

- Last two lectures look at Possibilities of Life Elsewhere – and Extra-Solar Planets
- Final Exam Review tonight by Ben Brown, here, 7-9pm. Final review sheet available.
- Extra-credit observing projects due today
- Homework 10 returned + answers
- Overview read Chap 24: Life beyond Earth
- Course evaluation today at end of class

Life in the Milky Way galaxy

Which do you think is most likely?

- A. life of any kind is present only on Earth
- B. primitive life exists elsewhere (Mars, other planetary systems), intelligent life is unique to Earth
- C. intelligent life developed elsewhere, but has since died out
- D. other civilizations exist, but are rare
- E. other civilizations are very common

WHAT IS LIFE ?

What is LIFE ?

- ORGANIZES AND INCORPORATES ENVIRONMENT TO SUSTAIN ITSELF
- o METABOLISM (ENERGY SOURCE)
 - GROWTH
 - o SELF-REPRODUCING

KEY TO SUCCESS MAY BE COMPLEXITY!

Complex, complicated, delicate

LIFE ON EARTH IS SUPERCOMPLICATED, WITH DELICATELY BALANCED CHEMICAL REACTIONS

↑ UNDER WHAT CONDITIONS CAN THIS DEVELOP?

Building blocks for life forms

(PLAUSIBLE) REQUIREMENTS FOR ANY LIFE FORM

1. BASED ON ELEMENT WITH COMPLEX CHEMISTRY

MOST ABUNDANT	C	CARBON, 6 PROTONS
	Si	SILICON, 14 P
	Ge	GERMANIUM, 32 P
2. SOME KIND OF LIQUID WITH GOOD BONDING PROPERTIES

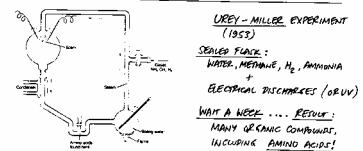
H₂O MOST ABUNDANT, MAYBE METHANE?
AMMONIA (ON TITAN)
3. MODERATE TEMPERATURES (~ 300 K) TO ALLOW CHEMICAL REACTIONS (ULTIMATE ENERGY SOURCE)
4. MAYBE SOME UV RADIATION, ELECTRICAL DISCHARGES TO GET THINGS STARTED

How does life start ?

HOW DOES LIFE START ?

1. DIVINE INTERVENTION POSITIVE, BUT AN TERRIBLE SCIENTIFIC PROBLEM POSED
2. PANSPERMIA EARTH WAS "SEEDED" BY SPORES
(BUT BEST QUESTION OF HOW LIFE STARTS ANYWHERE)
ORGANIC COMPOUND ARE FOUND IN METEORITES, BUT UNLIKELY LIFE COULD DEVELOP IN SPACE
3. SPONTANEOUS SELF-ORGANIZATION OF CHEMISTRY FOLLOWED BY "EVOLUTION" THROUGH NATURAL SELECTION

Three propositions



BUT WE DO NOT KNOW PROBABILITY FOR THIS "BRAIN SOUP" TO DEVELOP INTO LIFE.
CHEMICAL EVOLUTION ? BIOLOGICAL EVOLUTION

Life on Earth: 4 ingredients

Proteins: complex DNA - RNA encoding

LIFE ON EARTH

- CARBON-BASED** COMPLEX OF COMPLICATED CHEMISTRY
- REQUIRES H₂O** FURTHER REACTIONS, STABILIZES CONDITIONS
- ALL LIFE BASED ON PROTEINS** MADE OF 20 AMINO ACIDS, EACH WITH 13-27 ATOMS OF C, H, O, N
- COMPLEXITY COMES FROM GENETIC CODING** OF NUCLEIC ACIDS: DNA PROKARYOTIC AND RNA

DNA: RNA
 C.C. BACKBONE
 G.C. PAIRS
 A.T. PAIRS
 U.A. PAIRS

DOUBLE-STRAND BACKBONE CHAIN: PHOSPHATE DEOXYRIBOSE (SUGAR)

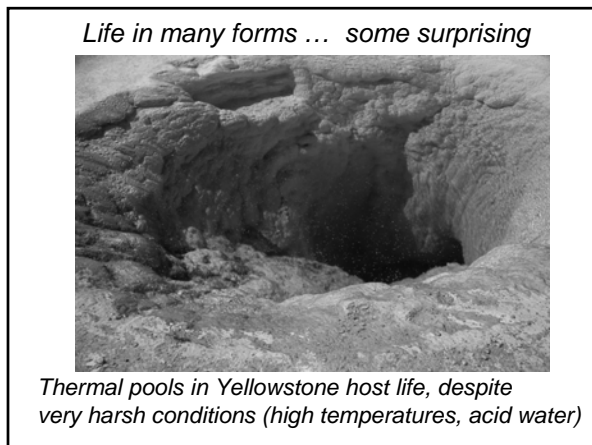
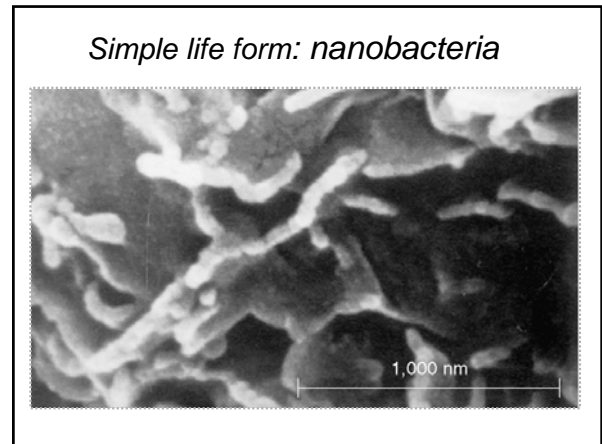
DNA STRAND BECOMES AN RNA

CODING FOR CONSTRUCTION OF PROTEINS:

4 "BASES" IN PAIRS
 ... (A) (T) (C) (G) ...

IN ANY ORDER, TAKEN 3 AT A TIME "TRIPLET CODE"
 = 64 POSSIBILITIES
 MORE THAN ENOUGH TO CODE 20 AMINO ACIDS

TRIPLET NATURE OF CODE PROVIDED BY STOPPAGE SIGNAL!



Zones of habitability: requirements for carbon-based life (ecospheres)

REQUIREMENTS FOR HABITABILITY (CARBON-BASED LIFE)

PLANETARY CONDITIONS:

- LIQUID WATER
- TEMPERATURE BETWEEN FREEZING AND BOILING (AT LEAST SOME OF THE TIME)
- ALSO NO FREE OXYGEN IN ATMOSPHERE TO START WITH!

IN OUR SOLAR SYSTEM, CORRESPONDING TO

ZONE OF HABITABILITY ("ECOSPHERE")

Ecospheres to nurture and sustain life (on planets)

HABITABLE PLANETS AROUND OTHER STARS?

REQUIREMENTS:

- STABLE PLANETARY ORBIT FOR > FEW BILLION YEARS => NOT BINARY STAR
- LONG ENOUGH MAIN SEQUENCE LIFETIME FOR LIFE FORMS TO DEVELOP => "LATER" THAN MAIN SEQUENCE ~ F2
- HOT ENOUGH SO ECOSPHERE IS NOT TOO SMALL TO CONTAIN AT LEAST ONE PLANET => "EARLIER" THAN K5

SPECTRAL TYPE	ECOSPHERE (AU)	LIFETIME	NUMBER IN MILKY WAY
M	0.02 - 0.06	> 10 ¹⁰ yr	> 3 x 10 ¹¹
G (SUN)	0.8 - 1.6	10 ¹⁰ yr	3 x 10 ¹⁰
B	100 - 200	10 ⁷ yr	< 10 ³

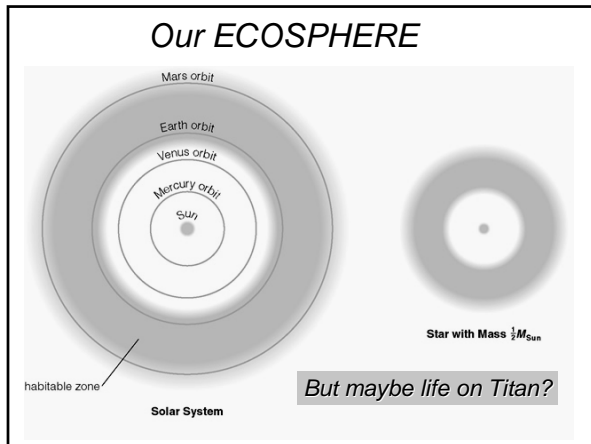
SUN IS JUST RIGHT!

ECOSPHERES AROUND STARS

Varying zones of habitability around stars

A-type stars favorable, but lifetime on MS?

SPECTRAL CLASS



Requirement for liquid water defines a habitable zone: range of distances from a star where the surface temperature is between freezing and boiling

Not known observationally how often a rocky planet occupies the habitable zone

Thought on theoretical grounds that habitable planets should be common

Course Evaluation

More on hunting for extra-solar planets and estimating chances for life in ultimate lecture: plus winners for 'finest crib sheets'