ASTR/GEOL-2040: Search for life in the Universe: Lecture 33

- Exoplanets
- Extraterr. Intelligence
- Quiz questions etc

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)
The next two weeks

• Review Quiz #2 model solutions (D2L)
• HW7 on Wednesday, due Dec 8
  – only the 5 best ones count
• How to find life on exoplanets
  – Chapter 8, pp. 261 – 280
• How to find extraterrestrial intelligence
  – Chapter 9, pp. 281 – 302
• Review of all material for the final
Plot reading

A. Need to be 2 times closer
B. 4 times closer
C. 16 times closer

What if star is 4 times dimer?

To have Earth-like conditions, we …

(a) Mark the points on the black line on the left plot where the temperature is 90 K (two points), 80 K (two points), and 70 K (only one point).
See the blue points in the figure above.
(b) Read off the corresponding pressures on each of the five points and write them in the empty fields in Table 1. See the blue numbers in the table below.
### Horizontal Lines

A. Need to be 2 times closer
B. 4 times closer
C. 16 times closer

### Star Dimmer

What if star is 4 times dimmer?

To have Earth-like conditions, we …
(c) Mark all the five points in the phase diagram above with dots.
See the blue points.
(c) Mark all the five points in the phase diagram above with dots.
See the blue points.
(d) Determine the phase for all five points. Write the corresponding answer in the five corresponding fields of Table 1. Use S for solid, L for liquid, and G for gas.

See the blue and orange points.

[2pts]
(e) Where in the atmosphere do you expect methane in the gas phase?

In the upper layers which is denoted by “Tholin haze”, see the orange dot in the figure below.

<table>
<thead>
<tr>
<th>temperature</th>
<th>pressure (1st point)</th>
<th>phase?</th>
<th>pressure (2nd point)</th>
<th>phase?</th>
</tr>
</thead>
<tbody>
<tr>
<td>90K</td>
<td>1000</td>
<td>S</td>
<td>30</td>
<td>G</td>
</tr>
<tr>
<td>80K</td>
<td>300</td>
<td>S</td>
<td>50</td>
<td>S</td>
</tr>
<tr>
<td>70K</td>
<td>100</td>
<td>S</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
Life elsewhere in the Universe?

• To many: most important question…
  – Profound religious & philosophical implications
  – Cannot answer (right now)

• But can pose & answer related questions
  – What can science tell us?

• One of the early approaches:
  – Number N of civilizations in our galaxy broadcasting their existence into space
Life elsewhere in the Universe?

• Drake’s equation: \( N = R_b \ t \)

  Rate (number per unit time) at which broadcasting civilizations appear in our galaxy

  - \( N = ? \) (at least 1) = us on Earth
  - \( t = ? \) > 50 yr … 100 yr
  - \( R_b > 0.02 \text{ yr}^{-1} \)
The number of civilisations in our galaxy in which communication might be possible.

\[ N = R^* \times f_p \times n_e \times f_i \times f_l \times f_c \times L \]

- \( R^* \): The fraction of stars with planets
- \( f_p \): The fraction that can go on to support intelligent life.
- \( n_e \): Length of time such civilisations release detectable signs into space.
- \( f_l \): The fraction of civilisations that develop a technology detectable from space.
- \( f_i \): The average number of planets that can potentially support life (per star with planets.)
- \( f_c \): The average rate of star formation per year in our galaxy.
- \( L \): The Drake Equation.
Drake (1960)

- $R^* = 1 \text{ yr}^{-1}$
- $f_p = 0.2 \ldots 0.5$
- $n_e = 1 \ldots 5$
- $f_1 = 1$
- $f_i = 1$
- $f_c = 0.1 \ldots 0.2$
- $L = 10^3 \ldots 10^8$
- $N = 10^3 \ldots 10^8$
Nowadays: more accuracy

- $R^* = 1 \text{ yr}^{-1}$
- $f_p = 0.4$
- $n_e = 0.005$
- $f_i = 1$
- $f_i = 1$
- $f_c = 0.1 \ldots 0.2$
- $L = 10^3 \ldots 10^8$
- $N = 10^3 \ldots 10^8$

Psychology and sociology: choose not to broadcast…
**Planets with biosignatures**

- $N^* = \text{number of M stars in sample}$
  - $= 30,000$
- $F_Q = \text{fraction of quiet stars} = 0.2$
- $F_{HZ} = \text{rocky planets in HZ} = 0.15$
- $F_O = \text{observable} = 0.001$
- $F_L = \text{fraction with life} = 1$
- $F_S = \text{fraction with spectroscopic signatures} = 0.5$
- $N = 2$

Sara Seager
Back to exoplanets: what can we observe?

- Potential for habitability
  - Oceans, land/ocean ratio, clouds, seasons
- Surface/subsurface life?
- Eventually: atmospheric composition
  - Abundance & combination of gases
How to find biospheres

• Galileo: find life on Earth
  – fly-by on Earth (→ Challenger disaster)

• Near infrared spectrometer (NIMS)

• Large amount of O₃
  – Hard to explain abiologically
  – Also CH₄: this, together with O₃, important
  – Readily oxidized to give…
Ozone?

A. Like benzene
B. Like chlorine
C. Like fluorine
D. No odour
California Beaumont Zone of Ozone City

A. Like benzene
B. Like chlorine
C. Like fluorine
D. No odour
Ozone?

A. Like benzene
B. Like chlorine
C. Like fluorine
D. No odour
Odor of ozone?

A. Like benzene
B. Like chlorine
C. Like fluorine
D. No odor
Ozone?

A. Like benzene
B. Like chlorine
C. Like fluorine
D. No odour

Smell? ozein (ὄζειν), the Greek verb for smell
Source of ozone layer

A. Xerox machines
B. Lightning + oxygen
C. UV radiation + oxygen
D. Airplanes
E. Forest fires
Ozone cycle

O₂ + hv → 2O·

UV-B
UV-C
100-315 nm
photolysis

O· + O₂ → O₃

- autocatalysis
- cycle
Source of ozone on Earth

A. Xerox machines
B. Lightning + oxygen
C. UV radiation + oxygen
D. Airplanes
E. Forest fires
How to find biospheres

• Galileo: find life on Earth
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  – Readily oxidized to give…
Methane + Oxygen = ?

A. Water
B. Carbon dioxide
C. All of the above
Methane + Oxygen = ?

A. Water
B. Carbon dioxide
C. All of the above

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]
Next time

- Planetary atmospheres
- Starshade

- Rothery et al. 262 – 280
- Longstaff: pp 366 – 375
- BS: 380 – 395