Total Eclipse of the Moon

April 15, 2014

Mid-Eclipse - 12:46 am PDT

Earth's Penumbra

North

Earth's Umbra

Partial Eclipse Ends

02:33 am

Total Eclipse Begins

01:25 am

Mid-Eclipse

12:07 am

Total Eclipse Ends

10:58 pm*

Partial Eclipse Begins

Moon's Motion Relative to Earth's Shadows

* Eclipse begins on night of April 14

All times are in Pacific Daylight Time

Courtesy of Fred Espenak
www.MrEclipse.com
The Search for Extraterrestrial Intelligence (SETI)

Our goals for learning

- What is the Drake equation?
- How many habitable planets have life?
- How many civilizations are out there?
- How does SETI work?
How many civilizations are out there?

The Drake Equation

Number of civilizations with whom we could potentially communicate

\[ N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \]

\( N_{HP} = \text{total \# of habitable planets in galaxy} \)
\( f_{\text{life}} = \text{fraction of habitable planets with life} \)
\( f_{\text{civ}} = \text{fraction of life-bearing planets with civilizations at some time} \)
\( f_{\text{now}} = \text{fraction of civilizations around now} \).
How many Habitable Planets in Milky Way?

\[ N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \]

Best estimates come from Kepler observations:
How many Habitable Planets in Milky Way?

\[ N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \]

Initial *extrapolations* from Kepler observations:

\[ N_{\text{stars}} \text{ in the Galaxy with planets} \sim 100 \text{ billion} \]
What fraction of our Solar System in Habitable Zone?

Solar System Habitable Zone from 0.7 – 3.0 AU
Orbit of Neptune (farthest planet) is ~ 30 AU

Area of H.Z. \[ \pi (3^2 - 0.7^2) \]

Fraction of H.Z. = \[ \frac{\text{Area of H.Z.}}{\text{Area of Sol. Sys.}} \] = \[ \frac{\pi (3^2 - 0.7^2)}{\pi 30^2} \] \approx 0.01
How many Habitable Planets in Milky Way?

\[ N_{\text{HP}} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \]

Initial extrapolations from Kepler observations:

\( N_{\text{stars}} \) in the Galaxy with planets \( \sim 100 \text{ billion} \)

But if only \( \sim 1:100 \) of those stars has a planet in a Habitable Zone (perhaps a pessimistic estimate!)

\[ N_{\text{HP}} \sim 1 \text{ billion} \]
How many Habitable Planets have life?

$$N_{HP} \times f_{life} \times f_{civ} \times f_{now}$$

To date, we only know of 1 example:

Most Pessimistic Estimate:

$$f_{life} \sim 1 / 1 \text{ billion}$$
Solid surface with atmosphere conducive to life

40% of Kepler-discovered planets are Super-Earths or smaller
However - Moon of Gas Giants Could be Habitable
Development of life happened in few 100 million years
Earth was heavily bombarded with rocks/comets
Possible sterilization of biogenesis
Impacts may have sterilized early Earth shortening time for biogenesis?
Is Biogensis Common??

If yes, then optimistic estimate:

\[ f_{\text{life}} \sim 0.5 - 1 \]
Water is *common* in all Star-Forming Regions
Need enough time for Biogenesis

High mass limit of 2 times solar mass for lifetime to be at least 1 billion years for development of life.
Red dwarfs are most numerous stars in Milky Way (~90%) But they have the smallest Habitable Zones

The less massive the star is, the smaller the habitable zone.
Tidal locking can occur with strong interaction (being close)

Same side of Moon always faces Earth
Tidal locking should occur for planets close to stars.

Planets in H.Z. around red dwarfs may have the same face always facing the star = potentially bad for life?
Stellar Flares can be detrimental to life

Fast rotating large planets can have strong, protective magnetic field

Red dwarf are more active than solar-type stars
Earth’s Moon has stabilized tilt of orbital axis
Mars has no moon to stabilize its rotation axis.

Climatic variability – how does this affect life?
Earth has plate tectonics which cycles Carbon

Plate tectonics favor larger planets?
More evidence size matters: retaining an atmosphere

Neither hydrogen nor water will escape from a planet as long as their temperature and gas speed are below respective lines. Below the dotted line for hydrogen, it escapes due to gravity. Below the dotted line for water, it escapes due to gravity.

- **Retains hydrogen**: Above the dotted line for hydrogen (H₂), the gas speed is too high for gravity to hold it, and it escapes.
- **Retains water**: Above the dotted line for water (H₂O), the gas speed is too high for gravity to hold it, and it escapes.

**Gas Speed (km/s)**

**Temperature (K)**
How many Habitable Planets have life?

\[ N_{HP} \times f_{life} \times f_{civ} \times f_{now} \]

Bottom line is that we don’t know and the answer could be anywhere between \(~ 0 \) and \( 1 \)

Most Pessimistic Estimate:

\[ f_{life} \sim 1 / 1\text{billion} \]

Is Biogensis Common ?

If yes, then Optimistic Estimate:

\[ f_{life} \sim 0.5 - 1 \]
How many planets with life develop intelligence?

\[ N_{\text{HP}} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \]

To date, we only know of 1 example and it took 4.5 billion years:
How many planets have intelligent life now?

$$N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}}$$

Major extinction events have occurred in the past
How many planets have intelligent life now?

$$N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}}$$

Ends of civilizations may be self-inflicted
We do not know the values for the Drake Equation

\[ N_{HP} : \sim 1 \text{ billion (estimates will improve next few yrs)} \]
\[ f_{life} : \text{???} \quad \text{Hard to say (near 0 or near 1)} \]
\[ f_{civ} : \text{???} \quad \text{It took 4.5 billion years on Earth} \]
\[ f_{now} : \text{???} \quad \text{Can civilizations survive long-term?} \]

For “optimistic” values of the factors, the proximity of aliens depends on the longevity of their civilizations.
How many planets have communicating civilizations?

$$N_{HP} \times f_{\text{life}} \times f_{\text{civ}} \times f_{\text{now}} \times f_{\text{communicate}}$$

Humans have had radio communication for only ~ 100 years
We’ve even sent a few deliberate signals ourselves…

Earth to globular cluster M13: Hoping we’ll hear back in about 50,000 years!
How does SETI work?

Looking for *deliberate* signals from E.T.
Best Frequency to search is in **Radio**

Lowest “noise”
Your computer can help! SETI @ Home: a screensaver with a purpose, looking for signals in radio data (mostly just noise).