How Common Is Life?

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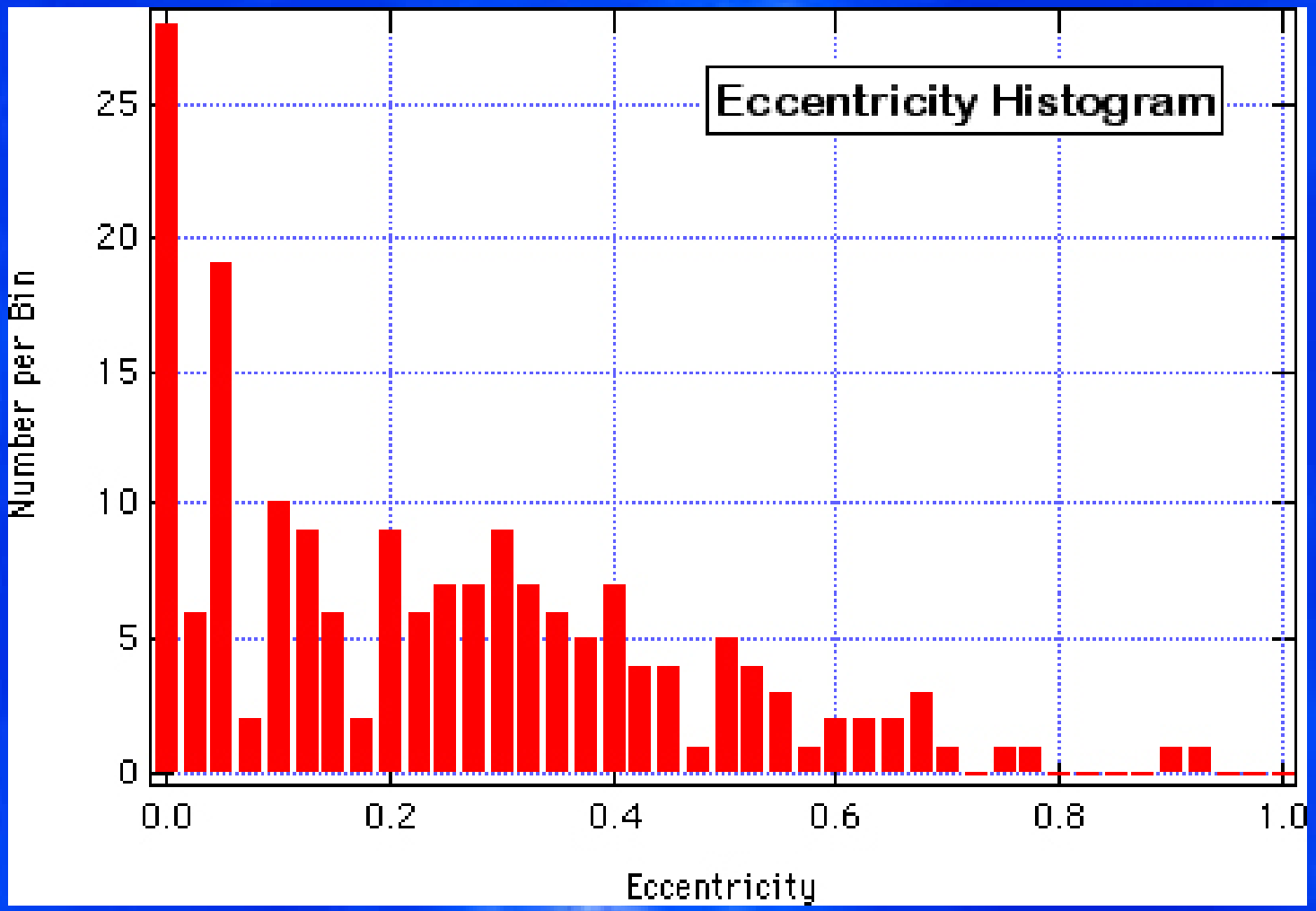
Summary from Last Time

- **We have found hundreds of planets around other stars**
- **Overwhelming majority are massive gas giants, many close to their parent star**
- **This is because they are easiest to find with the Doppler technique**
- **Have found: multiple planet systems (20+); planet atmospheres; some low-mass (probably solid) planets**
- **So far, only a few gas giants in the HZ; no solid planets; maybe moons could host life (??)**
- **Future searches will be sensitive to Earth-mass planets in the HZ**

Eccentricity

- **Exo-planets have a wide range of eccentricity**
- **Many have eccentricity MUCH higher than Pluto**



Eccentricity Effects

- **Why is eccentricity bad for life?**

Eccentricity Effects

- **Why is eccentricity bad for life?**
- **Planet moves in and out of the Habitable Zone**
- **Many of these are giant planets**
  - **Strong gravitational pull disrupts orbits of smaller planets nearby**
  - **So … even if the small planets have e=0, they are affected by this**
  - **Giant planets also seem to bring asteroids, meteors along with them – so … ???**

How Common Is Life?

- **Important questions:**

- **How many stars are there in the Galaxy?**
- **How many of them are suitable for Life?**
- **How many of those stars have suitable planets?**
- **How many of those suitable planets around suitable stars produce Life?**

How many stars are there in the Galaxy?

- **Well …**
- **Galaxy mass is 100 billion solar masses**
- **But, average star mass is about 0.3 solar masses**
- **Why? LOTS of M dwarfs!**

- **So … about 300 billion stars**

What fraction of them are suitable for Life?

- **Well …**
- **Need high metal abundance**
- **Late F, G, K stars are only ones with right Habitable Zone stable for >4 billion years**
- **Cannot have giant planets with eccentric orbits, or even circular orbits <5 AU**

- **So … from exo-planet surveys, we estimate that about 1/200 (??) stars is suitable**

How many suitable planets per suitable star?

- **Well …**
- **This one is tougher**
- **We don’t KNOW any suitable planets in other solar systems yet**
- **Does this mean they don’t exist? No**
- **Does this mean they are uncommon ???**

What fraction of those suitable planets around suitable stars produce Life?

- Well …
- This one is even tougher
- We don't KNOW any suitable planets in other solar systems yet, so we only have one example (Earth)
- Positive attitude: 1 for 1 $\Rightarrow$ life is common!
- Negative attitude:
  - By definition we live on a "successful" planet
  - Maybe it is one in a billion (and we are the one)!
  - Would imply that Life is rare

What fraction of those suitable planets around suitable stars produce Life?

- On the other hand …
- Clear evidence of Life popped up on Earth just after the Early Heavy Bombardment ceased
- Could imply that life forms easily in a suitable place

- On the other hand …
- All life on Earth is VERY similar in chemical makeup
- All use same “handedness” of amino acid isomers
- Could imply that life originated only ONCE

The Drake Equation

- **First proposed by Cornell astronomer Frank Drake**
- **Actual mathematical formula for estimating number of intelligent civilizations currently in the Galaxy**

$$N = N_* f_p n_e f_l f_i f_c f_L$$

N_* = The number of stars in the Milky Way Galaxy.

f_p = The fraction of those stars that have planetary systems around them.

n_e = The average number of planets in a given planetary system that are suitable for the deveopment of life.

f_l = The fraction of those planets on which life actually arises.

f_i = The fraction of those planets with life on which intelligent life appears.

f_c = The fraction of those planets with intelligent life that develop a technological civilization.

f_L = The fraction of the life of a planet that a technological civilization survives.

N, the solution, is the number of advanced technological civilizations in the Milky Way galaxy.

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What about number of planets with life?

- $N_{life} = N_* f_P n_e f_l$
- So …
- $N_* = 3 \times 10^9$ stars
- f_P = 1/200 fraction of "suitable stars" (an educated guess)
- n_e =1 suitable planets per suitable stars
- f_l = fraction of these planets where life forms

What about number of planets with life?

- $N_{life} = N_* f_P n_e f_l$

- $N_{life} = 3 \times 10^9$ stars * 1/200 * 1 * f_l
- = 15 million * f_l
- If f_l =1 , then we have **15 million** life-bearing planets in the Galaxy
- If f_l =1 in a million, then we have **15** life-bearing planets in the Galaxy
- If f_l =1 in a billion, then we are on the **ONLY** life-bearing planet in the Galaxy

Summary

- **Rarity/prevalence of life in the Galaxy depends on several factors**
  - **How many stars are there in the Galaxy?**
  - **How many of them are suitable for Life?**
  - **How many of those stars have suitable planets?**
  - **How many of those suitable planets around suitable stars produce Life?**

- **We can calculate an estimate of the number of civilizations in the Galaxy using the Drake Equation**
- **A shorter version tells us how many planets have any life at all**
- **Current estimates: as high as 15 million, as low as 1 (us!)**
- **Next time: Extraterrestrial Intelligent Life**