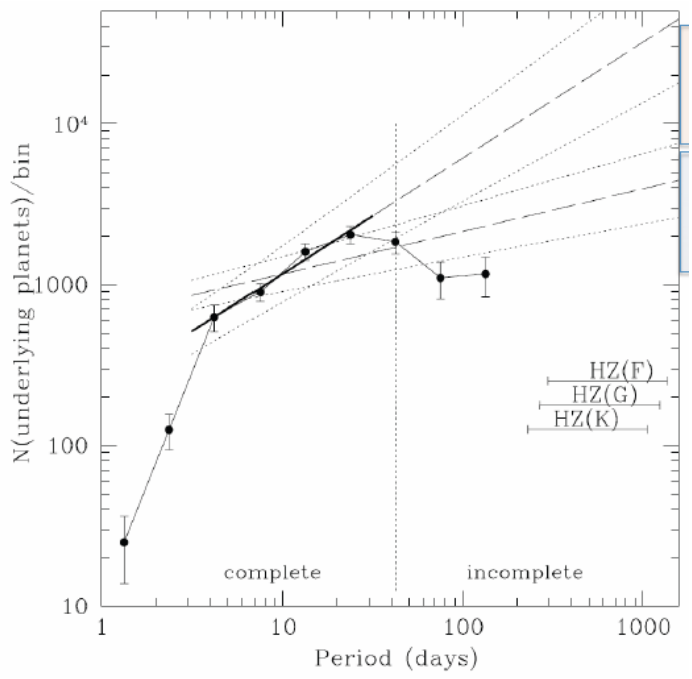
The Hubble Ultra Deep Field is the deepest look we've ever taken into the universe. It showed 10,000 galaxies in one tiny slice of the sky. You would need 13 million Hubble Ultra Deep Fields to cover the whole sky. Use this information to estimate how many galaxies there are in the observable universe.

Not all of the stars in the universe are created equally! We give stars "Spectral Classifications", which follow the pattern OBAFGKM from most massive to least, hottest to coolest, largest to smallest and rarest to most common. A good way to remember this is to use the pneumonic "Oh Be A Fine Guy/Girl, Kiss Me", or you can come up with your own (tell a counselor if you come up with a good one!).

The table below lists the average mass (in solar masses, or multiples of the mass of our sun), temperature (in degrees Kelvin) and something we've called "Relative Proportion", which you should interpret as answering the question, "for every O star that the universe creates, how many B, A, F, G, K and M stars does it create?" For your reference our sun is a G2 star, slightly hotter (6,000K) and more massive (1 solar mass) than the "average" G star.

Spectral Type	Average Mass (solar masses)	Temperature (Degrees Kelvin)	Relative Proportion
O	40	38,000	1
B	6.5	16,400	72
A	2.1	8,620	1,018
F	1.29	6,540	3,199
G	0.93	5,610	6,901
K	0.69	4,640	13,917
M	0.21	3120	227,838

Use the table above to start thinking about how the environment around a star determines where habitable planets are located relative to the star. Would a planet in a "habitable" location around an O star still be habitable if it were moved to around a G star? What other factors might affect where life will develop and how long it will survive for?



The graph above is a brand new scientific result derived from Kepler data. It's complicated, so let's break it down. The black points represent the number of planets discovered with certain orbital periods. Close-in planets are on the left and distant planets are on the right. In the center of the graph is a dotted line separating "complete" from "incomplete" samples. What this basically means is that we are not very good at detecting planets that are very far from their host stars, so our sample out there is "incomplete" – there are likely many more planets at those distances than the ones we've found currently. On the righthand side of the graph, the Habitable Zones of F, G and K stars are marked. These are the planets we're really interested in discovering, but notice that they're within the "incomplete" sample. What the creators of this graph have done is extrapolate the trend that they see in the complete sample into the incomplete one. Their most optimistic and pessimistic extrapolations are shown by the long dashed lines – higher and lower respectively. They use these to predict that in the most optimistic case, 44.8% of stars have Earth-like habitable terrestrial planets around them. Their "worst-case-scenario" pessimistic estimate is that only 7% of stars have this type of planet around them. Which do you believe or do you think it's somewhere in between? What if you throw habitable moons of giant planets into the mix?

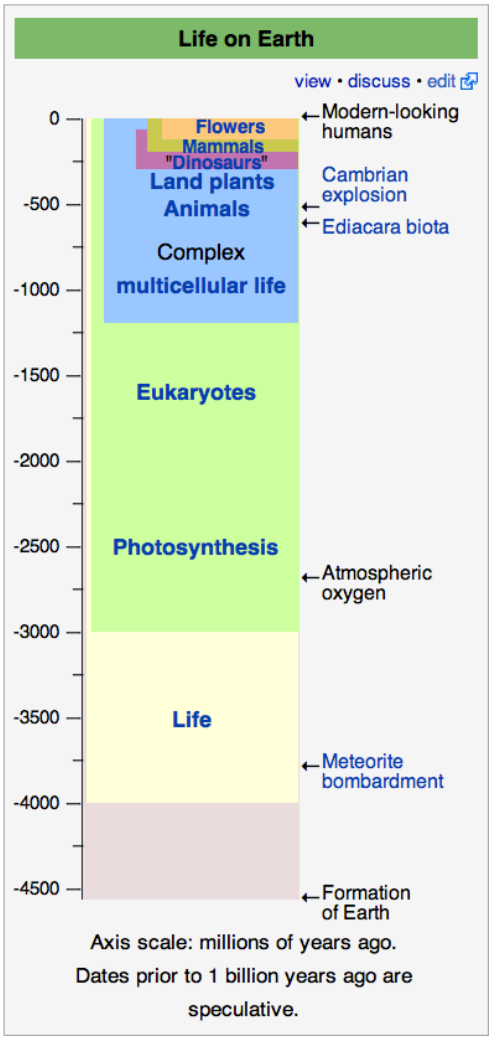
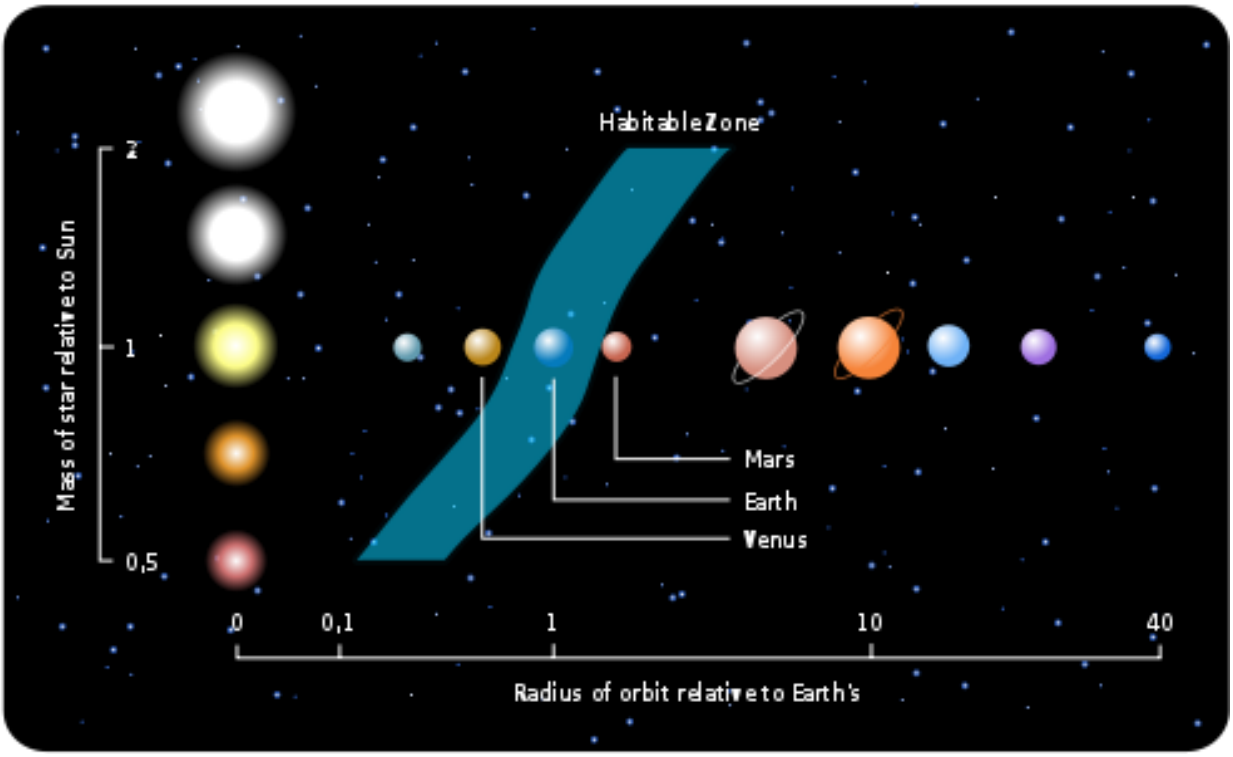


Table 11-1
Main-Sequence Lifetimes

Mass ($M_\odot$)	Surface temperature (K)	Luminosity ($L_\odot$)	Time on main sequence (10^6 years)	Spectral class
25	35,000	80,000	3	O
15	30,000	10,000	15	B
3	11,000	60	500	A
1.5	7,000	5	3,000	F
1.0 (Sun)	6,000	1	10,000	G
0.75	5,000	0.5	15,000	K
0.50	4,000	0.03	200,000	M



The table above shows the "Habitable Zone" of different types of stars in blue. The HZ is defined as "the region around a star where temperatures are sufficient for the existence of liquid water". Our solar system is shown next to the G star for your reference. Which of our solar system planets (or potentially moons of those planets) would be habitable if our solar system were moved to around a much smaller, cooler star? A bigger, hotter one?