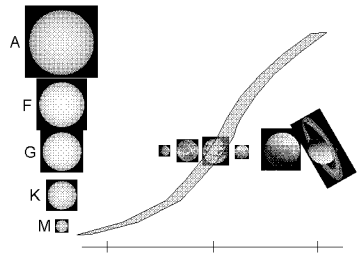
Friday, November 12

Habitable Zones of Other Stars



Problem set #3 will be due on Monday.

Habitable Zones of Other Stars
Key Concepts

1) A good place to look for life is in the Habitable Zone of low-mass main sequence stars.

2) Planets in the Habitable Zone of M stars can be tidally locked, and scoured by stellar flares.

3) Planets in the Habitable Zone of O, B, & A stars can be sterilized by UV radiation.

Requirements for Life:

Long-lived Energy Source 

Complex Chemistry 

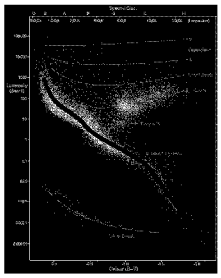
 Liquid Oceans / Solid Land

 Stable Environment

These requirements are found on rocky planets in the Habitable Zones of **low-mass main sequence stars**.

Low-mass stars (< $3M_{sun}$) have main sequence "lifetimes" of > 0.5 Gyr.

They provide a stable, long-lived energy source.

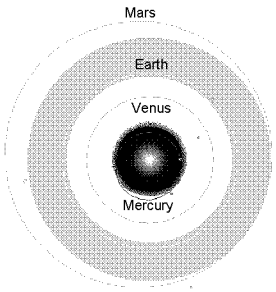


Long enough to give planets time to form, life a chance to emerge, and evolution time to act.

The Sun's Habitable Zone today:

Conservative:
0.95 – 1.4 AU

Optimistic:
0.84 – 1.7 AU



The location of a star's Habitable Zone depends on its **luminosity**.

Inner edge of Habitable Zone:

$$d_{in} = 0.95\,AU\sqrt{\frac{L}{L_{sun}}}$$

Outer edge of Habitable Zone:

$$d_{out} = 1.4\,AU\sqrt{\frac{L}{L_{sun}}}$$

Brighter stars have more distant Habitable Zones.

Examples:

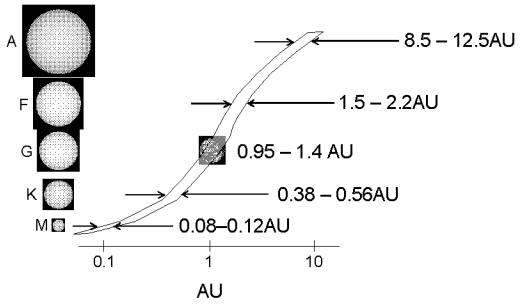
Sun (G Star): L = L_{sun}, d_{habit} = 0.95 – 1.4 AU

A Star: L = 80 L_{sun}, d_{habit} = 8.5 – 12.5 AU

M Star: L = 0.008 L_{sun}, d_{habit} = 0.08 – 0.12 AU

Brighter stars have broader Habitable Zones.

Habitable Zones of main sequence stars
(forget O&B stars; they're too short-lived.)



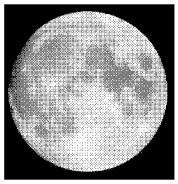
Liquid water is not enough.
Other factors also influence habitability.

Planets too close to their parent star can become **tidally locked**.

Stellar flares from the parent star can potentially wipe out life.

Excess **ultraviolet and X-ray light** can increase the likelihood of dangerous mutations.

What is tidal locking?

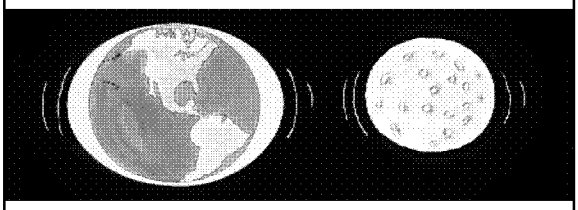


The Moon always keeps the same face turned toward the Earth.

Io, Europa, Ganymede, & Callisto always keep the same face turned toward Jupiter.

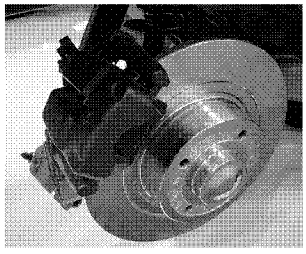
The tides of their parent planet have **tidally locked** these moons so that their orbital period is synchronized with their rotation period.

The Moon's gravity stretches out the Earth, so the Earth has two tidal bulges, on opposite sides.



The Earth's gravity stretches out the Moon, so the Moon has two tidal bulges, on opposite sides.

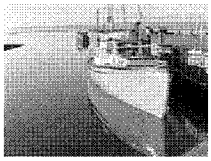
The tidal bulges of the Earth act as massive "brake pads", causing friction that slows the Earth's rotation.



The Moon's rotation has **already** slowed, to the point where it is **tidally locked**.

Tidal locking works fastest when tides are highest.

The tides on a planet are highest when it's very close to its **parent star**.

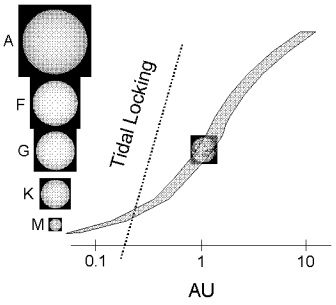


A planet will be tidally locked when it's inside the "tidal locking radius":

$$r_{lock} \approx 0.4\,AU \left(\frac{M}{M_{sun}} \right)^{1/3}$$

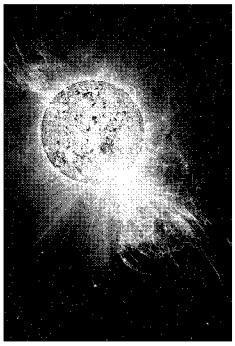
Planets in the Habitable Zone of **M** stars on the main sequence are probably tidally locked.

One side of the planet hogs all the light, and gets Too Hot; the other gets Too Cold.

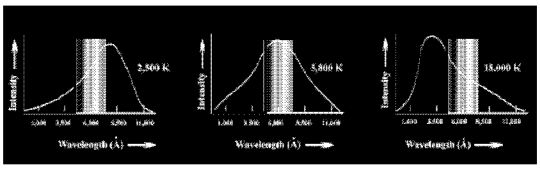


Type **M** main sequence stars are magnetically active, and can produce **stellar flares**.

Flares are large outbursts of high-energy (X-ray & ultraviolet) light; small flares cause mutations, large flares can kill.



Type **A** main sequence stars are hot enough to produce a great deal of ultraviolet (UV) light.



M star G star A star

Large doses of UV could potentially sterilize the surfaces of planets.

In our search for stars with habitable planets:

We exclude white dwarfs without an energy source.

We exclude unstable giants and supergiants.

We exclude short-lived, UV-bright O,B, & A stars.

We exclude flaring, tidal-locking M stars.

Monday's Lecture:

Exoplanets!

Next Week's Reading:

Chapter 12