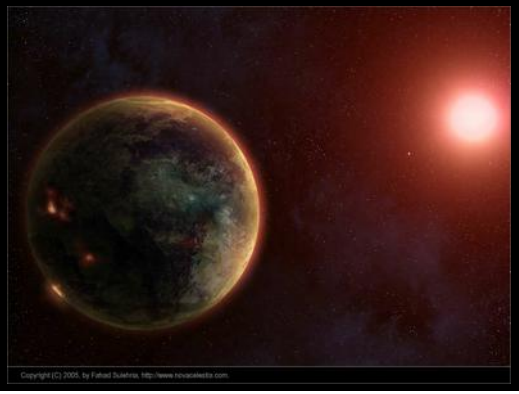
# The Search for Extraterrestrial Life



# The Fermi Paradox

***Q:*** *One of the "big" questions: Are we alone?*

• Enrico Fermi, 1950: "*So where is everybody?*"

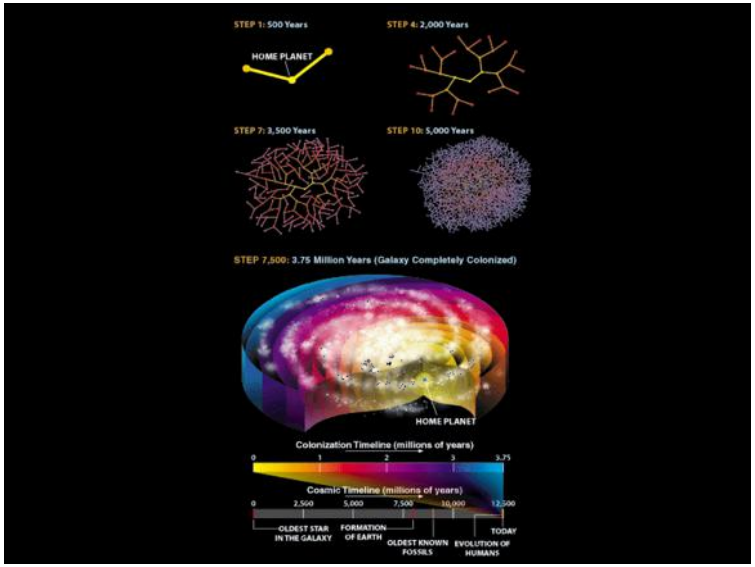
• if Earth-like worlds are even *somewhat common*, there could be *many civilizations* in our galaxy

• even at *sub-light speeds*, a civilization could "colonize" most of galaxy in ~ *millions of years*
***(eg)*** *How much have humans done in 100 years?*

• colonize *even faster*: *Von Neumann machines*
• *we're* already doing this! ***(eg)*** *MER, Voyager*

• ***Fermi Paradox***:
(1)If we are ***not*** unique, galaxy ***should*** be colonized
(2)We see ***no evidence*** of this

• so where ***is*** everybody?



• several solutions to ***Fermi Paradox***

**(1)** we are ***unique & alone in the universe***

**(2)** civilizations exist ***but do not travel far in space***
***Q:*** *Why not?*

• *technological problems*
• *sociological issues* ***(eg)*** *NASA funding cuts*
• *self destruction (!)*

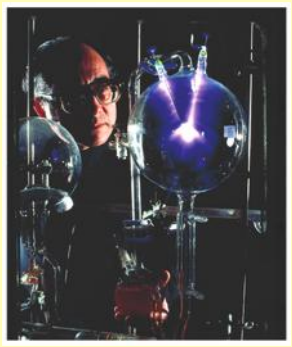
**(3)** civilizations exist ***but don't interfere***
• "***The Prime Directive***" - avoid primitive cultures

# Life on Earth

• *microscopic fossil* evidence of life ~ ***3.5+ Gy*** ago

• ***some meteorites & comets*** *contain organic molecules*

• *primitive atmosphere:* $CH_4$, $H_2$, $H_2O$
• ***Miller-Urey experiment***

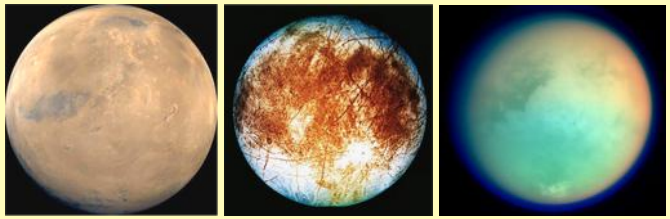


• life arose fairly ***quickly*** – *but is it likely?*

***DVD:*** Cosmos-"Miller-Urey"

# Life in the Solar System

• ***Mars***, ***Europa*** & ***Titan*** all have conditions which approximate "*extremophile*" regions on ***Earth***



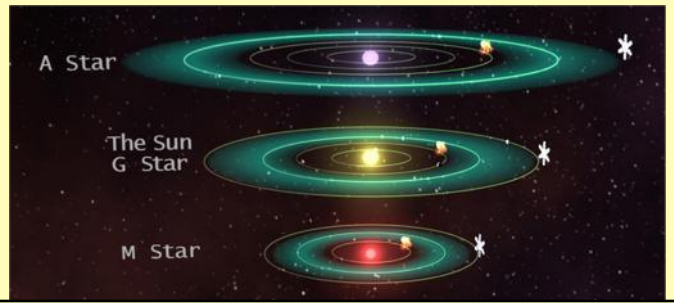
• *in the past*, ***Mars*** was likely *much more hospitable*

# Habitable Zone

***Q:*** *How common are planets that can support life?*

• ***habitable***: can sustain life ***as we know it*** (*water*)

• depends on ***parent star***, ***elements available***, ***orbits***



# Life in the Universe


- look for ***life*** beyond our solar system

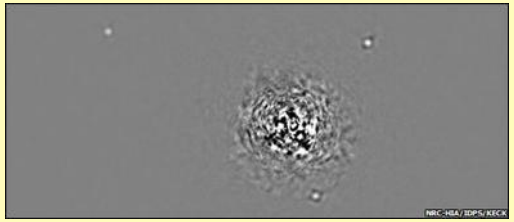
***Q: Where*** *do we start?* ***How*** *do we look?*

- look for *planets* around a star *like Sol*

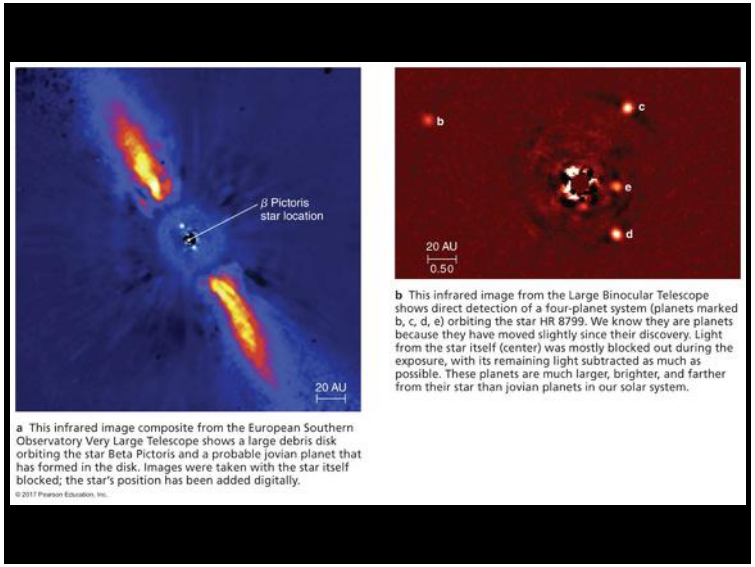
***Q:*** *How? Why are extrasolar planets hard to see?*

# Finding Extrasolar Planets

- viewing extrasolar planets ***directly*** is a challenge



- most search for planets ***indirectly*** using *position*, *spectrum* or *brightness* of parent star
- since 1995, ~400 *extrasolar planets (pre-Kepler)*
- early exoplanets tended to be *large* & *close*

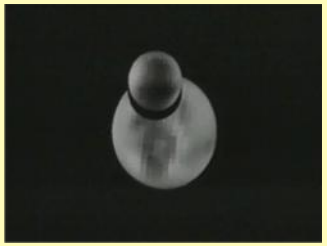



**a** This infrared image composite from the European Southern Observatory Very Large Telescope shows a large debris disk orbiting the star Beta Pictoris and a probable jovian planet that has formed in the disk. Images were taken with the star itself blocked; the star's position has been added digitally.

**b** This infrared image from the Large Binocular Telescope shows direct detection of a four-planet system (planets marked b, c, d, e) orbiting the star HR 8799. We know they are planets because they have moved slightly since their discovery. Light from the star itself (center) was mostly blocked out during the exposure, with its remaining light subtracted as much as possible. These planets are much larger, brighter, and farther from their star than jovian planets in our solar system.

# Astrometric method

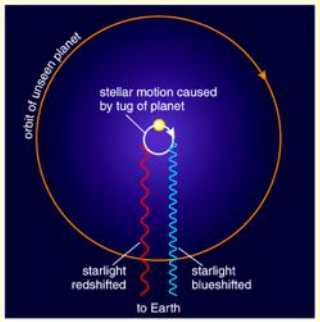
- *carefully* view the *position* of a star over time as it ***orbits about the center of mass of its solar system***
- *"wobble"* results from *planets' gravitational pull*
- best for *massive planets* far enough away to result in larger "*wobbles*"

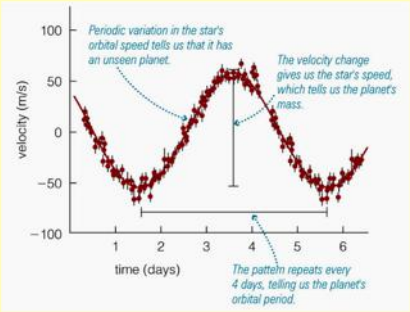


***(eg)*** Sun @ 10 ly away has 12 year wobble due to Jupiter of ~ 1/1,000,000° (*a hair seen from 5 km*)

# "Radial Velocity" method

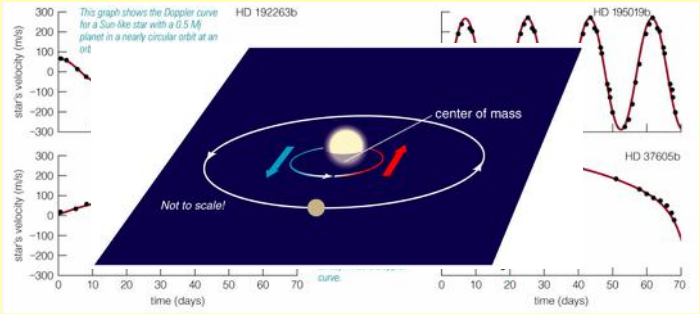
- most common technique
- view *spectrum* of a star over time



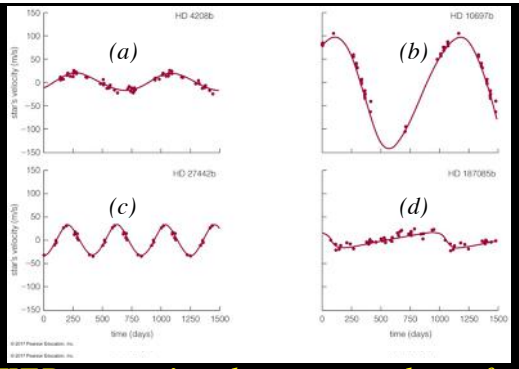

- best for *massive planets* close to the parent star

- doppler shift curve gives *mass, orbit period/shape*




- only works if orbit ***at least slightly*** "edge on"
- *underestimates* velocity (& thus mass) of planets

***(eg)*** Jupiter causes a wobble of ~13 m/s in the Sun; Earth 0.1 m/s; we can readily detect ~ 1 m/s.




***CLICKER: assuming*** *the same sized star for each graph above, which curve above shows:*

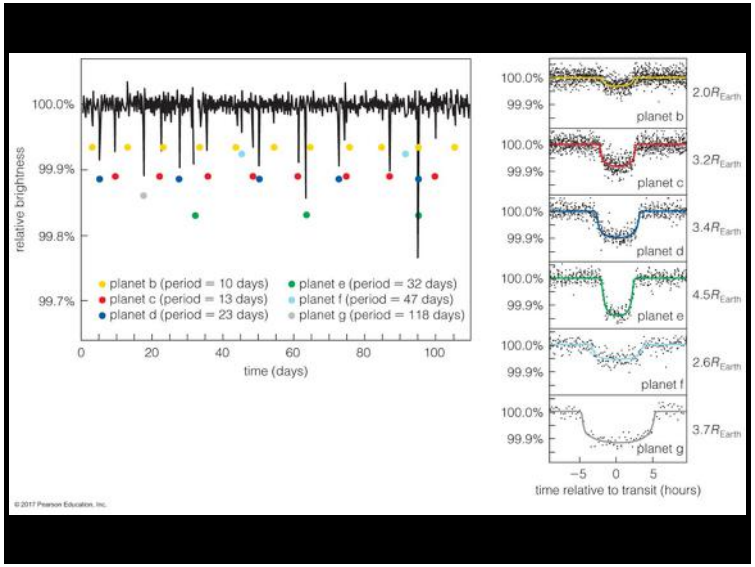
- ***the planet with the fastest orbit***
- ***the planet with the most elliptical orbit***
- ***the planet with the largest mass***

# "Light Curve" method

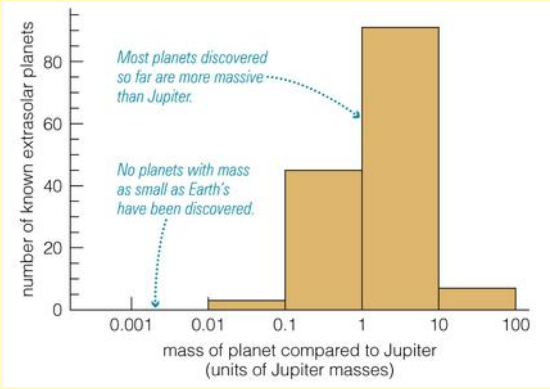
- aka "***transit photometry***" method

- ***amount*** of light blocked: ***size of planet***
- ***time*** between transits: ***orbital period***
- ***duration*** of transit: ***orbital velocity***
- *only* viewpoint to yield *correct mass* ***Q:*** Why?

***(eg)*** Jupiter transiting Sun results in about a *1% reduction in brightness; can detect ~ 0.01% drop*

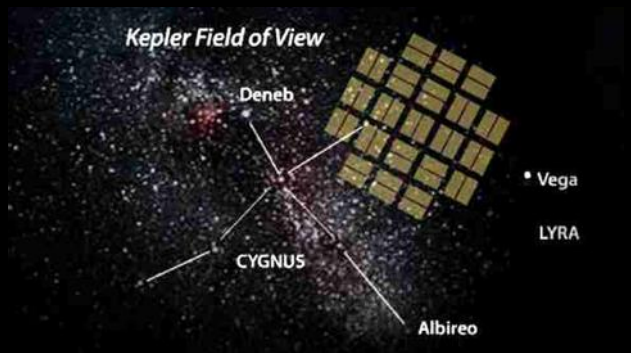



# *Pre-Kepler findings…*

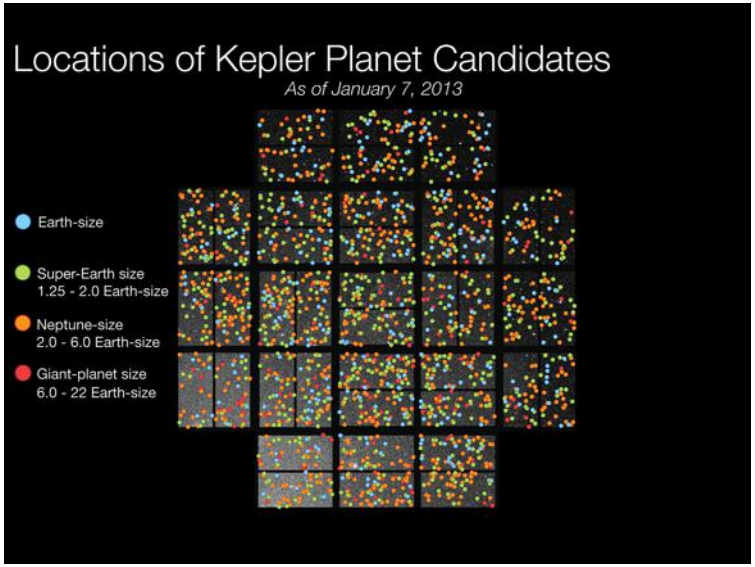



- ***biased*** to detect ***more massive planets; Why?***

# *Kepler (2009-2018)*

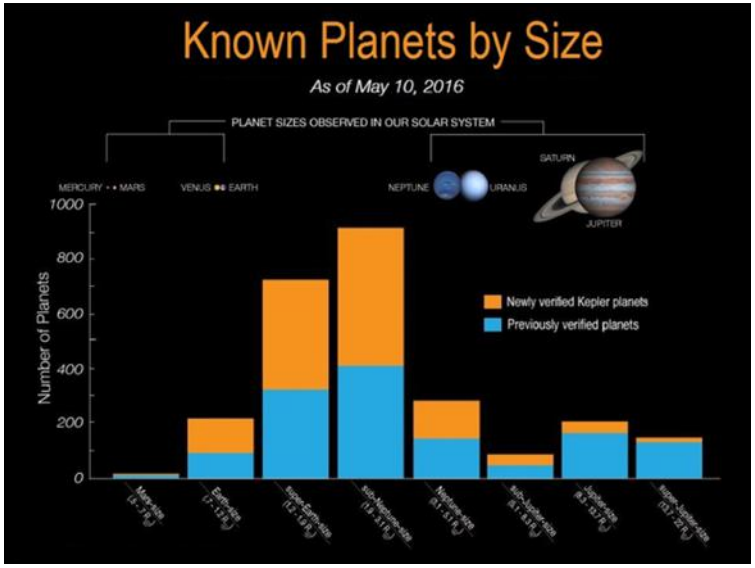


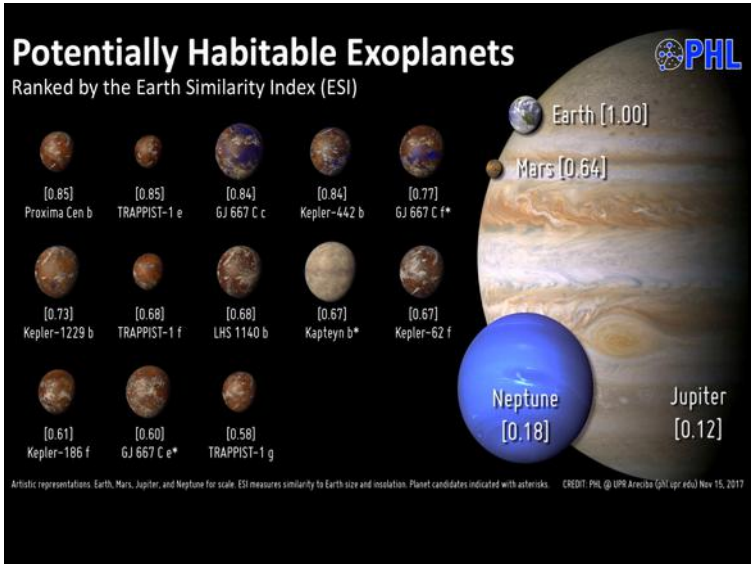

- ***transit method*** for 100,000 systems in ***Cygnus***
- ***"K2" mission extension 2014 - 2018***



## *TESS (2018-)*

- *2 year "all sky" widefield version of Kepler*




## The Drake Equation

*Q: How many technological societies exist?*

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

- $R_*$ = *rate* at which *suitable stars form*
- $f_p$ = *fraction* of stars with *planets*
- $n_e$ = *number* of planets (per star) in *habitable zone*
- $f_l$ = *fraction* of planets in zone which *evolve life*
- $f_i$ = *fraction* of those which evolve *intelligent life*
- $f_c$ = *fraction* of those which evolve *technology*
- L = *lifetime (in years)* of the civilization

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

$$= 10 \times 1 \times 0.1 \times 0.1 \times 0.1 \times 1 \times 10000$$

$$N = 100$$

• if spread ***equally*** throughout the ***Milky Way***, the nearest civilization would still be *100's of ly away*

***GIGO!***

# The Language of Aliens

• Egyptian hieroglyphics: *a message through time*
***Q:*** *Would a message from space be easier?*

• *we can't even talk to dogs!!!*

***Q:*** *How might aliens contact us? Why?*

• any alien communication (*to* or *from*) should be:

• *easy* for even *young cultures to discover*
• *inexpensive* to use
• *fast*
• *obvious*

• ***radio*** (***astronomy***) *fits the bill!*

• *largest radio telescope:* ***Arecibo*** (***Puerto Rico***), *300 m diameter*
• *two such scopes could "talk" over 15,000 ly apart*

# SETI

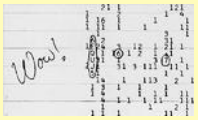
• ***Search for Extra Terrestrial Intelligence***

• *interstellar spaceflight* difficult

• so *wait for the aliens to show up* or *call them*

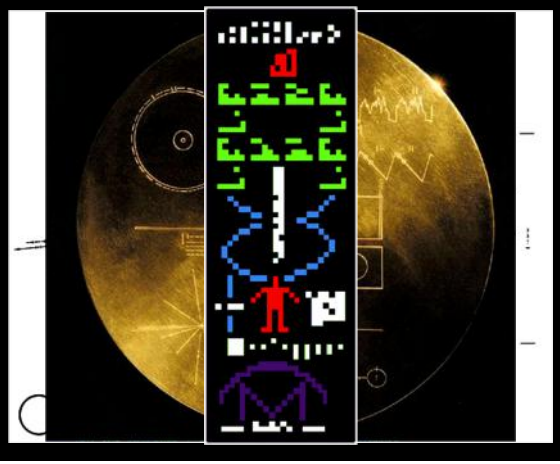
• msg to ***M13*** (25,000 ly away) by *Arecibo* in 1974

• ***listen*** at *frequencies ~ 1400 MHz*




• so far: no *extraordinary*, *repeating* signal found
• "Big Ear" @ Ohio State, 1977 - *"Wow"* signal

## Pioneer, Voyager & Arecibo



## Interstellar Travel

• it appears *intelligent life* will probably exist ***outside*** our solar system, so we'll have to travel

• **Project Orion**: dropping ***H bombs behind ship***…
• *current tech*; get us to nearest stars *in a century*

• **Interstellar Ramjet**: scooping up ***H gas***…
• saves weight (fuel) but *has to be big (why?)*

• ***matter/antimatter engines***: 100% efficient *but*…

## Immensity…

• we've discussed searching for intelligent civilizations in our galaxy - our "*backyard*"

• the ***universe*** is a big place
***Q:*** *How* ***likely*** *is it that we are alone in it?*

• ***HST*** spent *150 hours* photographing an "*empty*" part of the sky *near the Big Dipper for* ***HDF***

• ***HST*** spent *11 days* photographing an "*empty*" part of the sky *near Eridanus/Fornax for* ***HUDF***

## *Review*: ET Life

• ***Fermi Paradox: "Where is everyone?"***

• outside Earth, our solar system ***appears lifeless***

• we have discovered ***hundreds*** of extrasolar worlds
• ***astrometric, radial velocity, light curve methods***

• ***Drake Equation*** calculates # of alien civilizations

• despite ***SETI, UFO claims*** we are still "alone"…
• …but the universe is a ***big place***