## Stars, Galaxies & the Universe Announcements

- **Reading Quiz #14**– today in class
- ACE Forms – please take seriously and give feedback
- **HW #12 due on Friday (12-10) by 5 pm; available now!**
- **Final Exam review materials posted by end of week**
- **Final Exam will be cumulative; Thursday 16 Dec @7:30 am in VAN LR 1; 150 points – 50 questions @3 pts each! We will have a review session sometime during Finals Week.**
- **REVIEW: Tuesday (12-14) evening @ 7 pm in LR70 – bring a question to get in.** ☺

## Stars, Galaxies & the Universe Lecture Outline

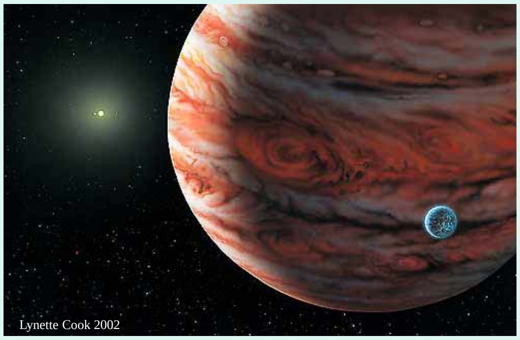
**Life in the Universe (Chapter 27)**

(1) Additional techniques for finding exoplanets
(2) Search for Intelligent Life

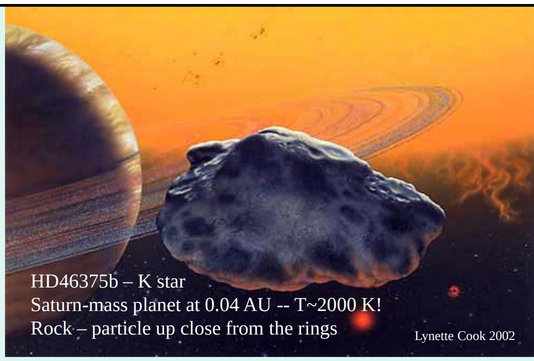
### The Doppler Technique

*Caveats* of this method:

1. Planets of Jupiter mass and bigger are the most easily detectable
2. Planets closer to the star are easier to detect
   *- gravity is stronger, "wobble" bigger*
3. Planets less massive than Jupiter (like Earth, Mars) are very difficult to detect (undetectable)
   *-mass, gravity weaker; "wobble" miniscule*
4. If the plane of planet orbit is not aligned with our sight-line, then "wobble" not detected
   *- Doppler effect for toward/away from motion*
   *- not side to side*




55 Cancri – triple planet system!
3x Jupiter mass at 5.5 AU from star
One of the most similar to our SS

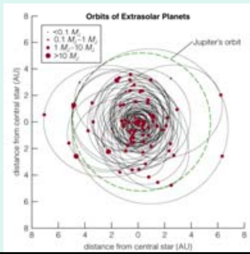


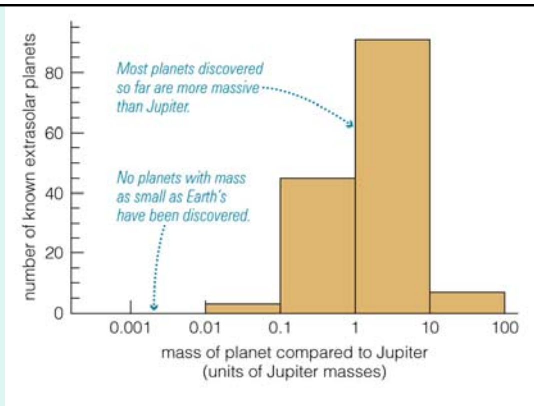


Upsilon Andromeda b
4 day orbital period
0.7 Jupiter masses – tidally locked to star

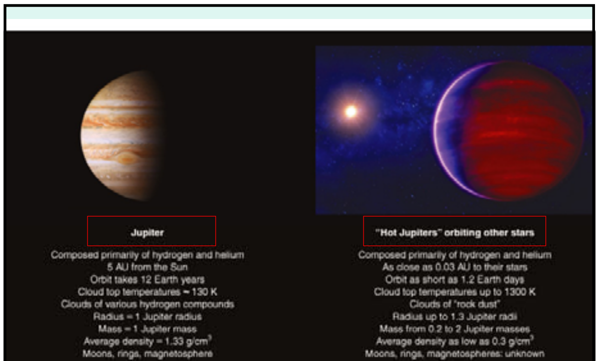
## Most of the detected planets are ***not*** like our Solar system

- Most systems have planets within 0.2 AU of star and large mass
  - These planets will have orbital periods of days, weeks
- Theoretical work shows that it is impossible for a gas giant like Jupiter to form so close to star
  - Will have to have formed further out, drifted inwards



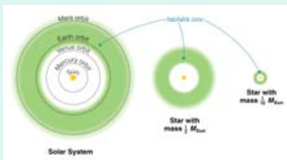





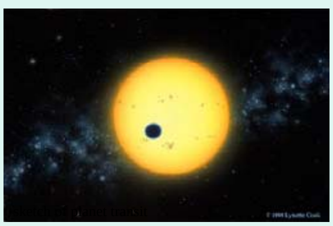
## Life around other stars?

- Planets detected so far by Doppler method don't seem to be "habitable" – i.e., too hot (too close to star) and Jovian-like
- Terrestrial-type planets may be there, but undetectable now
- What properties must a star have to harbor a "habitable" planet?
  - → old enough to have life evolve on its planet (i.e. billions!)
  - → star must have stable orbits (not be binary or multiple)
  - → size of habitable zone – temperature allowing liquid water/ice

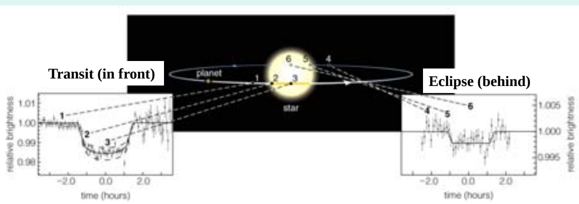



## II. Planet Transits & Eclipses (Indirect)

planet crossing in front of star may cause brightness change
repeated observations b/c stars can vary their brightness
- can get direct measure of SIZE



- depends on parameters of how planet would be orbiting
- backyard astronomers are monitoring for such fluctuations



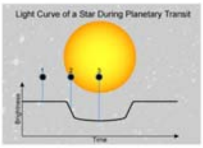

**Visual light signal decreases when planet moves in front of star (b/c planet is blocking some of the visual light from star)**

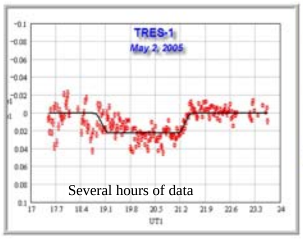
**Infrared light signal decreases when planet moves behind star (b/c planet radiates mostly in IR)**

→Can figure out size by how much light decreases and for how long

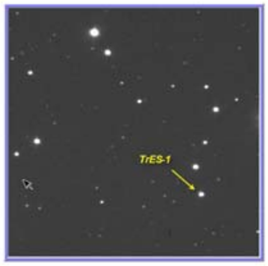
→Can figure out thermal emission of planet by studying drop in IR light

**Data taken with the Iowa Robotic Telescope**



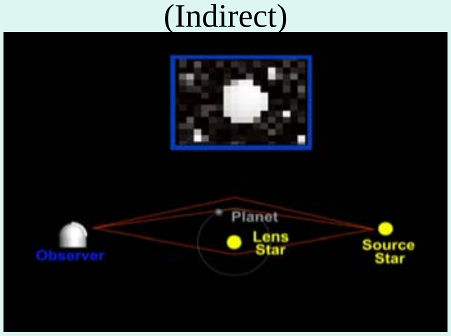




Several hours of data

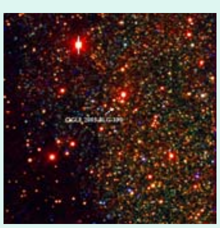



Star a little cooler than
our Sun – K star

## III. Extrasolar Microlensing (Indirect)




## III. Extrasolar Microlensing



**Distant star appears to change in brightness as star system with planet in the foreground bends the light around as it passes by**

**2005 and 2007 – first microlensed star-planet systems event were detected: 5-7 Earth masses**

**Indirect Methods of Extrasolar Planet Detection:**

*1. Doppler Technique*
- Looking for slight changes "wobbles" in star's position

*2. Planet Transit*
- Looking for slight changes in brightness of star due to planet crossing in front of star

*3. Microlensing*

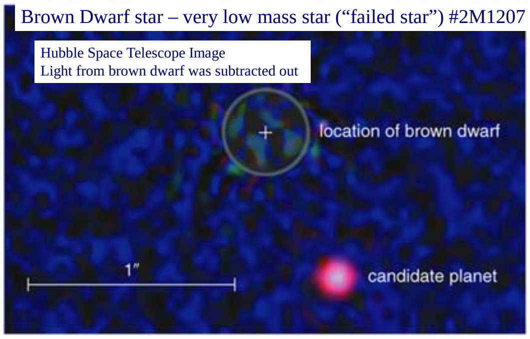
→ Learn orbital properties, size, mass

**Direct Method of Extrasolar Planet Detection:**

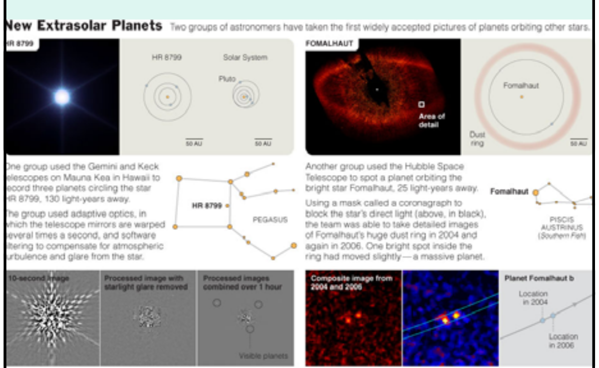
*1. Directly detecting the planet!*
- emission from the star drowns out signal from planet
- some hope if you look in IR, where planets are strong

Brown Dwarf star – very low mass star ("failed star") #2M1207

Hubble Space Telescope Image
Light from brown dwarf was subtracted out



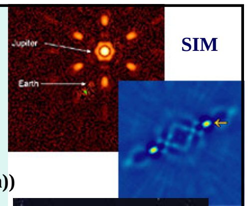


**NASA is planning several new spacecraft missions to search for Earth-sized (!) planets:**

**-Space Interferometry Mission (SIM)**
**-Terrestrial Planet Finder (TPF-I (interferometry) or TPF-C (coronagraph))**

**SIM**



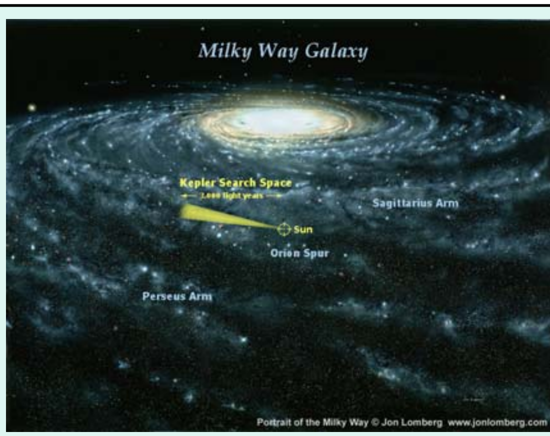



Kepler Mission : to try to find Earth-like extrasolar planets

- telescope of 0.95 meter diameter
- 430-890 nm (visible)

- will monitor 100,000 solar type stars and measure very small changes in brightness (planet transits)

- ~ 85 days until launch!
- 6 March 2009

**How many stars in our Galaxy may have a life-bearing planet around them?**

• Can make some assumptions:

1. suppose 1/10 stars have life-bearing planet (optimistic)

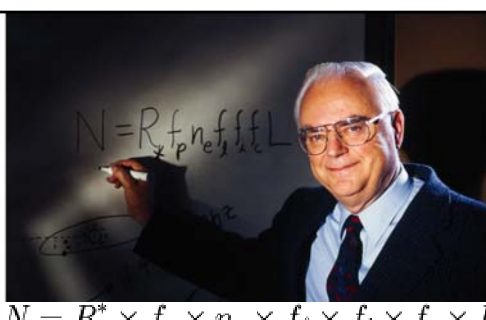
2. suppose life lasts for ~1 million years on a planet in a stellar system that lasts ~10 billion years

   - life would last 1/10,000$^{th}$ of the star's lifetime
   - means only 1 in 10,000 stars have a planet currently with life

3. translate that to the 100 billion stars in our Galaxy

   → 1 million stars with life-bearing planet

**pessimistic approach: life is so rare and special, we are alone**


$$N = R^* \times f_p \times n_e \times f_\ell \times f_i \times f_c \times L$$

N = number of civilizations with which we might hope to communicate

R = rate of formation of stars

L = lifetime of intelligent civilization in years

$f_p$ = fraction of stars with planets

$n_e$ = number of planets per system

$f_l$ = fraction of those planets which may support life

$f_{i,c}$ = fraction of those to go to develop intelligent life; fraction who are technically capable

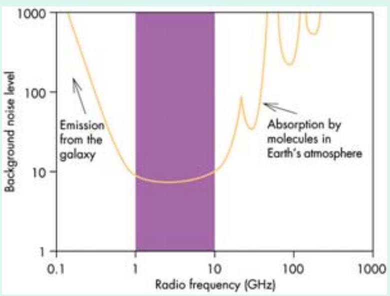
**The Search for Extra-terrestrial Life Elsewhere...**

**"Listening" across the EM spectrum**

*What is the best frequency to tune into?*

• radio frequencies 1-10 x $10^9$ Hz are most promising

→ relatively "empty" part of the radio spectrum




**"Listening" across the EM spectrum**

*What is the best frequency to tune into?*

• some possibilities in the radio spectrum

→ radio frequency of 1.4 x $10^9$ GHz
spectral line of atomic hydrogen – HI – spin flip!
since 90% of interstellar material is hydrogen

→ radio frequency of 1.4 x $10^9$ GHz * $\pi$ = 4.4 GHz
universal number * hydrogen spectral line

• want to use very narrow spectral windows
to discover strong, "beamed" signals, beacons

**SETI**
**Search for Extraterrestrial Intelligence Program**

Program criteria for success/challenges:

1. large collecting area (big dish)
2. dedicated telescope constantly scanning sky
3. adequate funding – both gov't & private
4. removal of interference from tv, radio, cellphones, satellite communications
5. processing HUGE amounts of data

As of recently, SETI is using two telescopes:

1. Arecibo radio telescope (308 m) in Puerto Rico

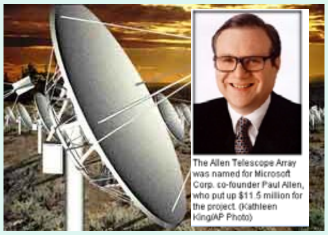
2. Parkes radio telescope (64 m) in Australia → Southern Sky

## Current SETI search: Project Phoenix

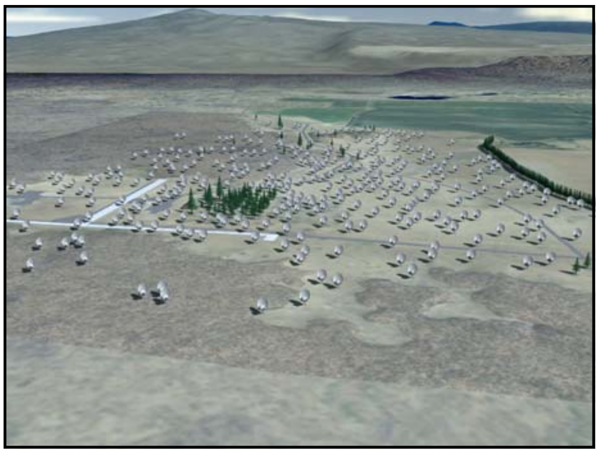
- Examining ~1,000 nearby stars
- Uses over 1 billion channels (1 Hz wide)
- Currently at Arecibo Radio telescope (Puerto Rico)
- About ½ of target stars already examined.

SETI
Search for Extraterrestrial Intelligence Program

The Future: Allen Telescope Array



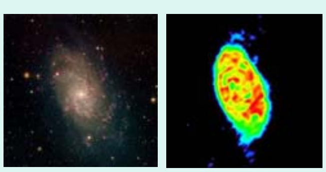

- money donated by Paul Allen, one of the Microsoft founders
- dedicated telescope for SETI
- ~350 6 meter telescopes like backyard satellite dishes



**Allen Telescope Array**

science Operations started October 2007

simultaneous SETI search and also radio surveys of sky and known objects

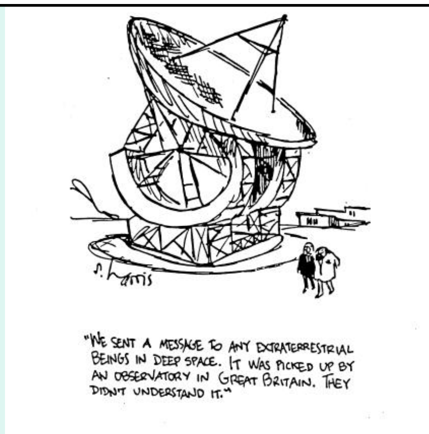


←
(M33 in optical and in HI radio emission)

http://www.seti.org/Page.aspx?pid=503

Have *we* broadcasted anything into space on purpose for communication?

In 1974 we also sent a beamed radio signal to the globular cluster M13 (21,000 ly) from Arecibo in Puerto Rico

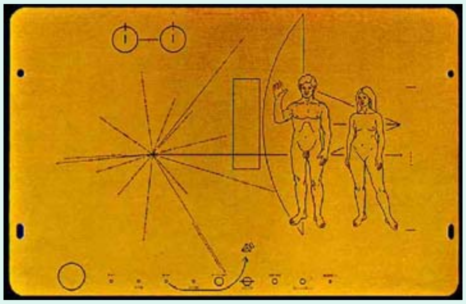



**How easy would it be for us to *travel* to another planetary system to find life?**

- interstellar travel has been drastically dramatized!
  - sci-fi movies, books, etc.
  - travel near the speed of light is impossible
- interstellar travel will likely never happen
  - the distances are just too great
  - spacecraft just can not travel fast enough
- even fastest *VOYAGER* spacecrafts are moving slowly
  - travel at 20 km/s (less than 1% the speed of light)
  - it will take 60,000 years to get to nearest star!

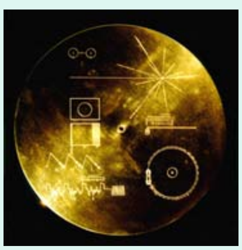
**Pioneer 10 & 11 – launched in 1973, 74**

- exploring the Solar System beyond Mars
- first spacecraft to get to the Asteroid belt
- currently they are ~60-70 AU



**Voyager 1 & 2 – launched in 1977**

- explore beyond Jupiter
- made first good images of Saturn, Uranus Neptune
- included a visual message & audio recording
- currently Voyagers beyond Pioneer at > 100 AU!



**Even at the speed of light, there are still complications...**

- energy required to get a spacecraft to speed of light is <u>enormous</u>
  - *– fuel would be heavy, expensive*
  - *- very inefficient mode of communication*

-Energy needed to accelerate a ship like the "Enterprise" in *Star Trek* to just 0.5c would use more than 2000x the annual energy budget of the Earth!

- at such speeds, interstellar particles (gas, dust, atoms) *would become deadly for craft, passengers*

## Scene from Movie *Contact*

- http://www.youtube.com/watch?v=vPOZsdp6_Dg