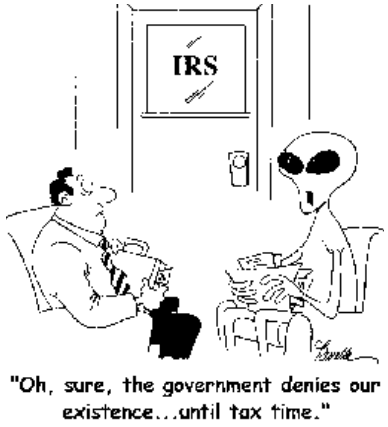
Astronomy 330

TR 1300-1420

134 Astronomy Building



This class (Lecture 7):

Origin of planets
Darcy Barron
Margaret Hutton

Next Class:

Nature of Solar Systems
Michael Johnson
Ross Thompson:

HW 2 is due today.

Music: *Planet of Sound* – Pixies

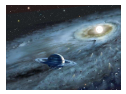
Outline

- Extrasolar planets: watch them wobble.
- Not exactly what we expected.
- What to expect in the future.
- What is f_p?

Drake Equation

Frank Drake








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

N	R_*	f_p	n_e	f_l	f_i	f_c	L
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	15 stars/ yr	systems/ star	planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

What Are We Looking For?

General Predictions of Solar Nebula Theory

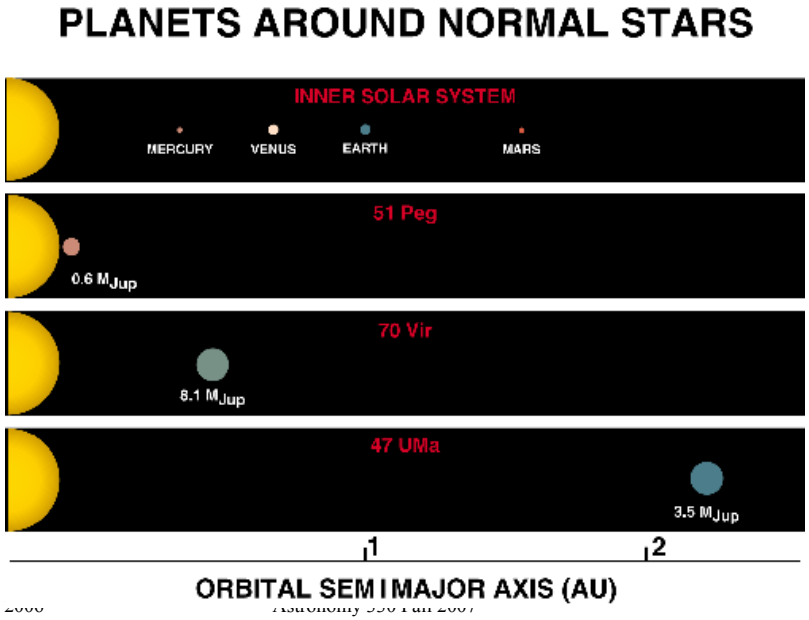
☺ Are interstellar dust clouds common? ***Yes!***

☺ Do young stars have disks? ***Yes!***

? Are the smaller planets near the star?

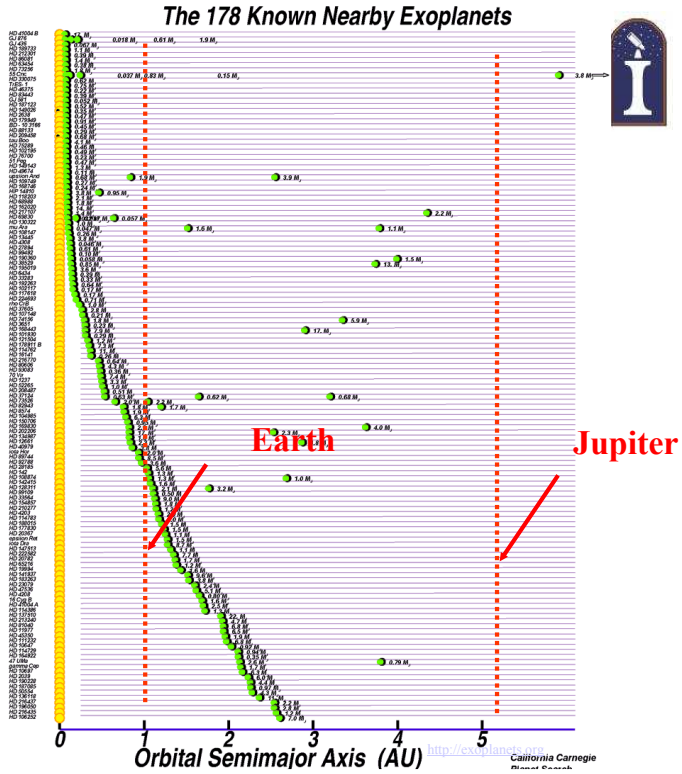
? Are massive planets farther away?

Early Discovery-- 1996

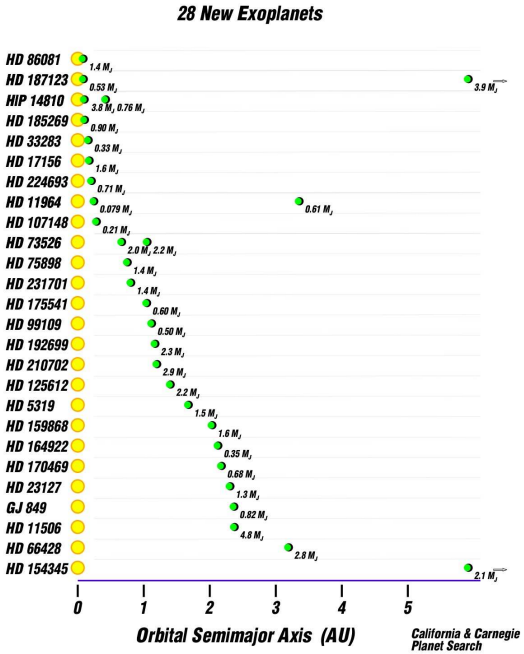


Hear all about it.

As of today, there are 236 planets known around nearby stars.



Recent Ones

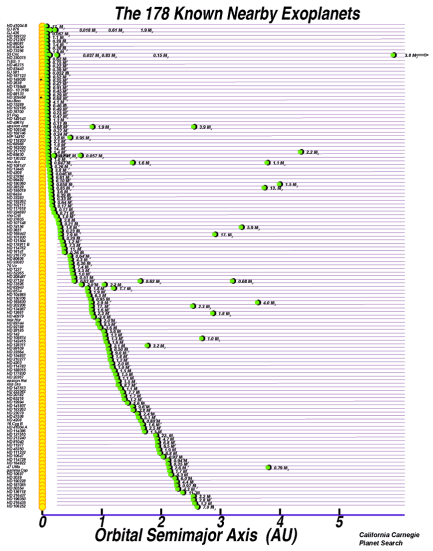


Exoplanets: Results to Date

Over 236 planets detected so far

- More than 23 times the number in our Solar System!

- By measuring the wobble variation:
  - With time, gives the planet distance: Kepler's 3rd law
  - The orbital speed of the star gives masses: the bigger the wobble amplitude, the heavier the planet



Exoplanets: Results to Date

At least 20 multi-planet systems!

Note: Jupiter is 318 time the mass of Earth or

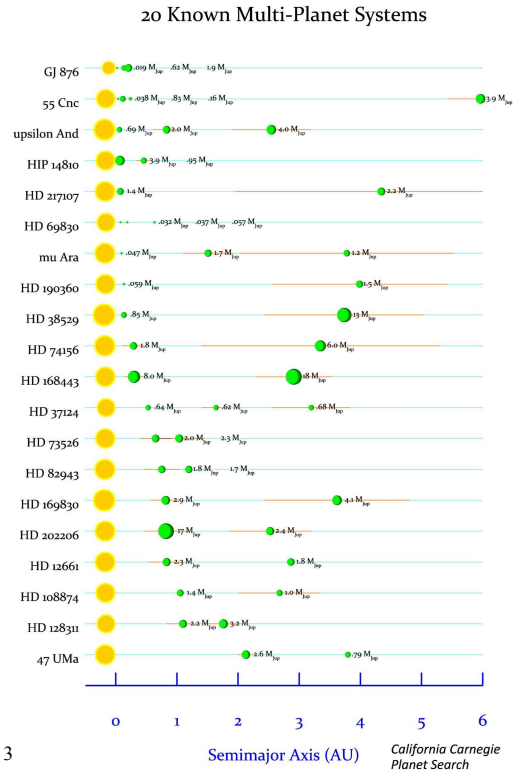
$M_E = 0.003\ M_J$

$M_J = 0.001\ M_{Sun}$

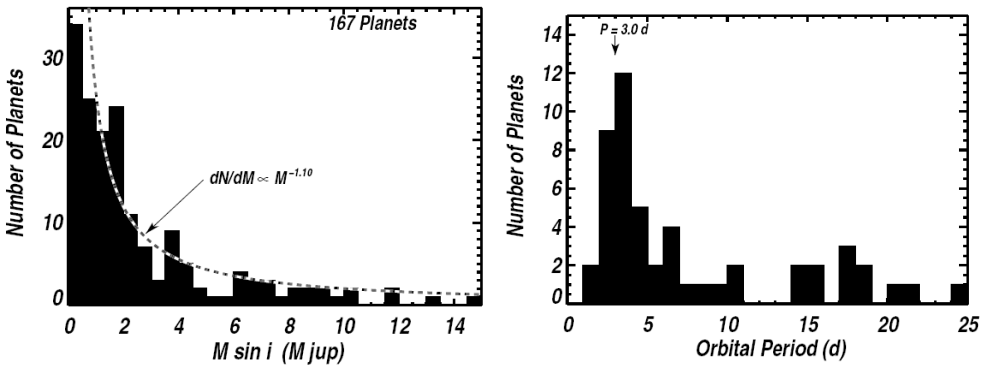
$M_{red\ dwarf} = 80\ M_J$

$M_{brown\ dwarf} = 18\ M_J$

$Period_J = 12$ years



Masses/Periods of Extrasolar Planets



http://exoplanets.org

List

http://exoplanets.org/

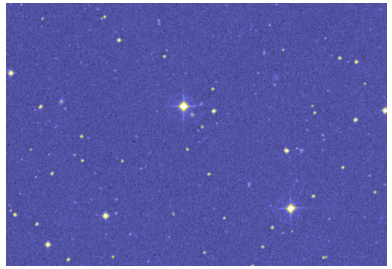
Other Planets, Other Stars

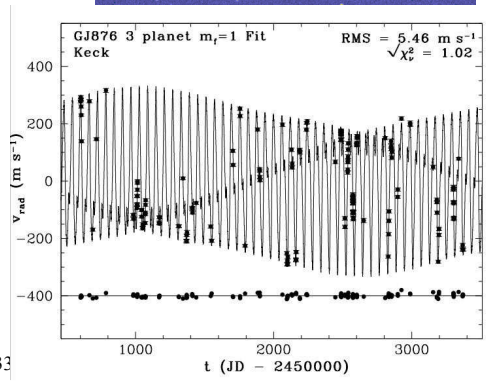
47 Ursae Majoris System– 51 light years away (near the Big Dipper). 13 years of data has shown 2 planets– 1 Jupiter like and 1 Saturn like.

Wow! Among the most similar to our own system

The Lowest Mass to Date

GJ 876 – a Red Dwarf that is 15 light years away (in Aquarius). Has three planets! 2 Jupiter-like and one that is 6-8 Earth masses! But all are inside 1 AU!





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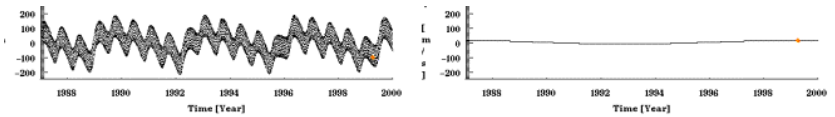
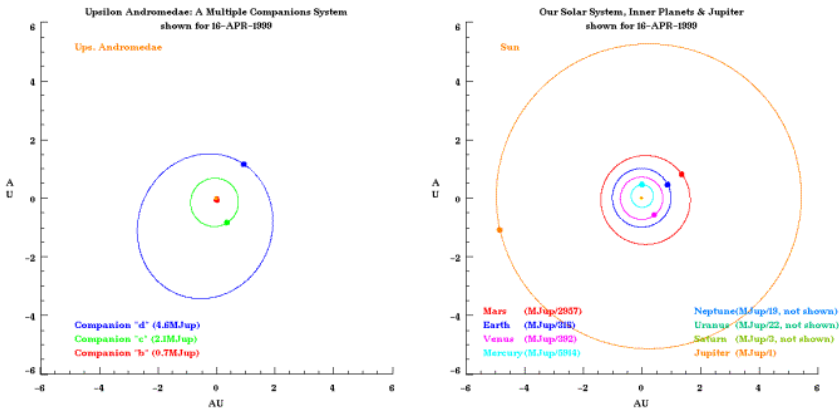
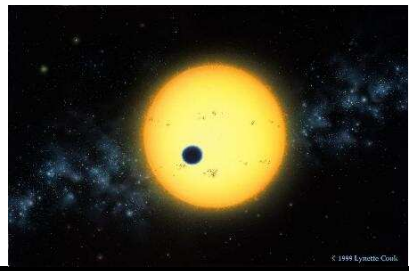
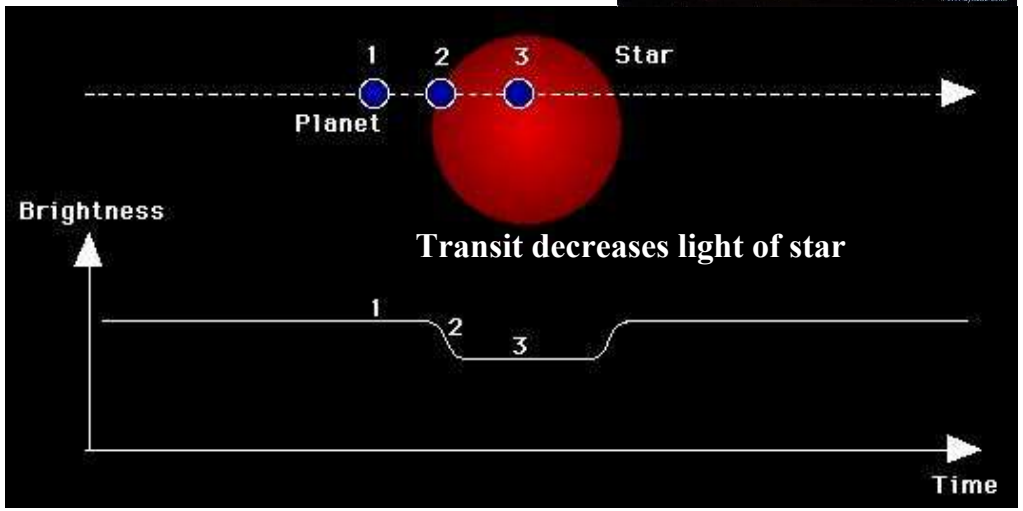
Detecting the Solar System





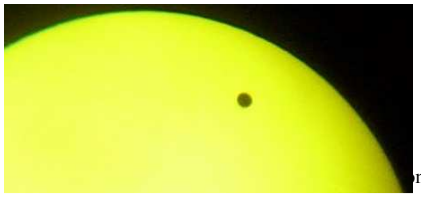
Planet Transits

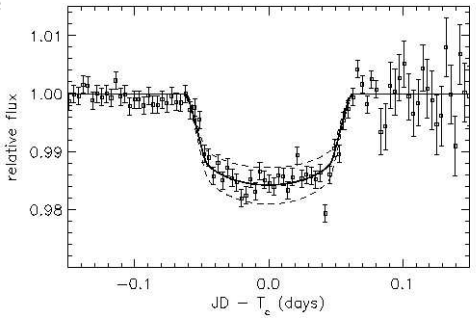


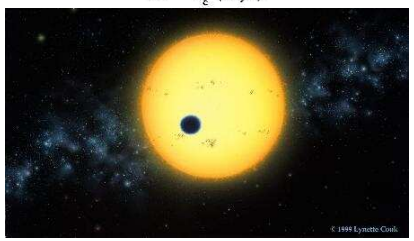


Transits

- The planet passes in front of the star– like Venus 2004.
- Can find planet radius
- Best chance of finding Earth-like planets
- Requires the extrasolar planet's orbital plane to be pointed at Earth
- http://www.howstuffworks.com/planet-hunting2.htm







Direct Detection?

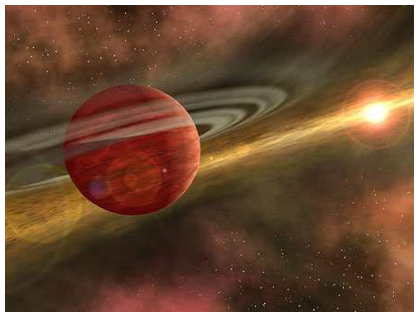
- The race is on to directly image a planet in the IR, it is still difficult to determine the stellar mass.
- Best example so far is an adaptive optic image from April, so planet or brown dwarf?

The Sub-Stellar Companion to GQ Lupi
(NACO/VLT)

Results to Date

No surprise

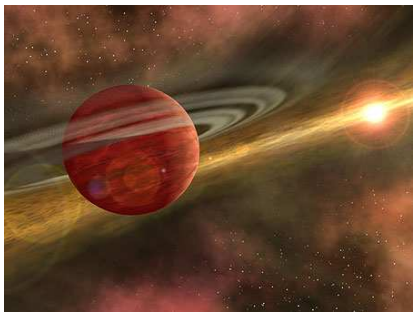
- ✓ New planets are massive
- ✓ Why? Big planets make a big wobble
- ✓ If not massive, we could not have found them
- ✓ About 3-5% of all stars have some type of planet.



Results to Date

Big surprises

- ? Most periods of only *a few days!*
- ? Most planets are very near their stars!
- ? τ Bootes' planet is 3.6 times Jupiter's mass, but it's orbit smaller than Mercury's!
- ? If a Jupiter-like planet formed close in, perhaps that prevents terrestrial planets from forming.



What Are We Looking For?

General Predictions of Solar Nebula Theory

☺ Are interstellar dust clouds common? ***Yes!***

☺ Do young stars have disks? ***Yes!***

? Are the smaller planets near the star?

Not the ones found so far! Haven't found smaller planets yet!

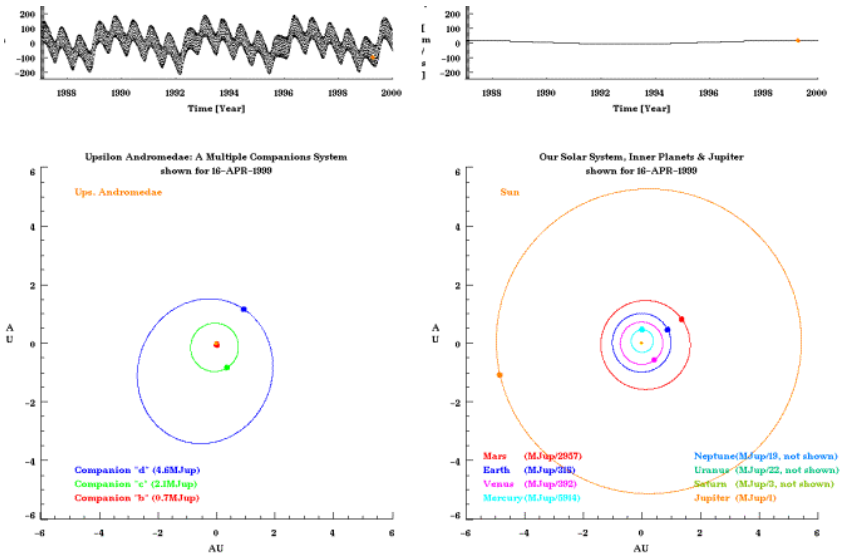
? Are massive planets farther away?

Not most of the ones found so far!

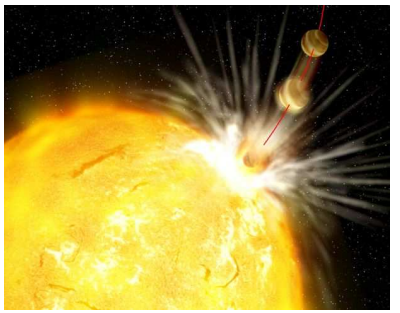
Important Caveat

- Our current observations of extrasolar planets do **not** exclude planetary systems like our solar system
- Current instruments are most sensitive to large planets close to their stars
  - Big planet - big wobble
  - Close planet - fast wobble
- We only have a little over 10 years of data – 1 orbit's worth for Jupiter
- To find solar-type systems, we need more sensitive equipment

Detecting the Solar System



Exoplanets: Implications



Solar Nebula **Theory**:
- Giant planets born far from star

Exoplanet Data:
- Giant planets found very close

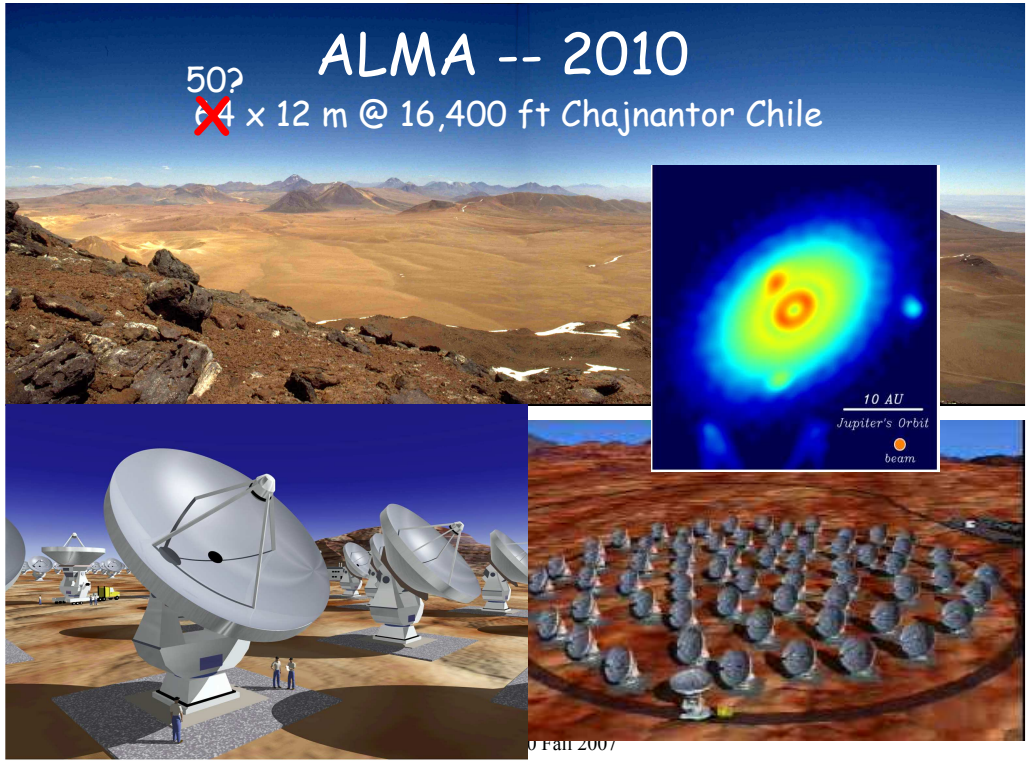
Theory is *incomplete/wrong*!

New questions:
? Who is normal: Them or us?
? Are giant planets born close in?
? Are some giant planets born far out, move in?
"planet swallowing"!?!

Anyway: Planets are common!
✓ Good news in search for life elsewhere...maybe

Future Projects

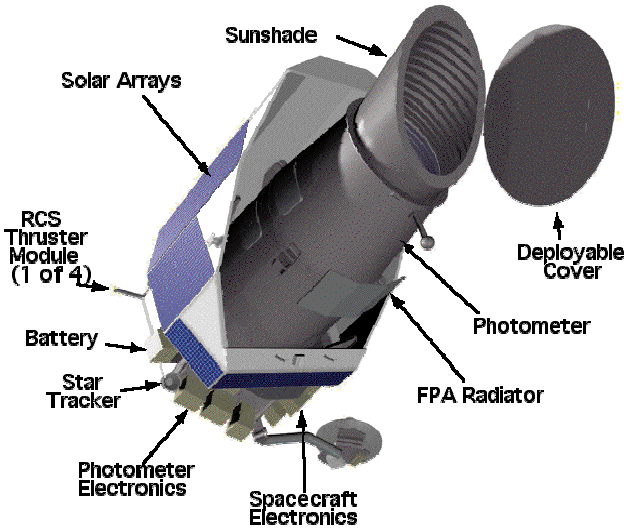
- Atacama Large Millimeter Array (ALMA): 2010
  - mm interferometer:
    direct detection of young gas giants
- Kepler: 2008
  - Planet Transits
- Next Generation Space Telescope
  James Webb Space Telescope (JWST): 2013
  - Direct imaging of forming gas giants?
- Space Interferometry Mission (SIM): 2015?
  - Astrometry
- Terrestrial Planet Finder (TPF): Mission 1: 2014
  - Coronagraph
  - IR interferometer
- Terrestrial Planet Finder (TPF): Mission 2: 2020
  - A large-baseline infrared interferometer. Imaging extrasolar Earths!!!!



Kepler

1.4 meter mirror, measuring accurate brightness of stars.

A terrestrial-sized Earth-like planet would dim the star's light by 1/10,000th – comparable to watching a gnat fly across the beam of a searchlight.

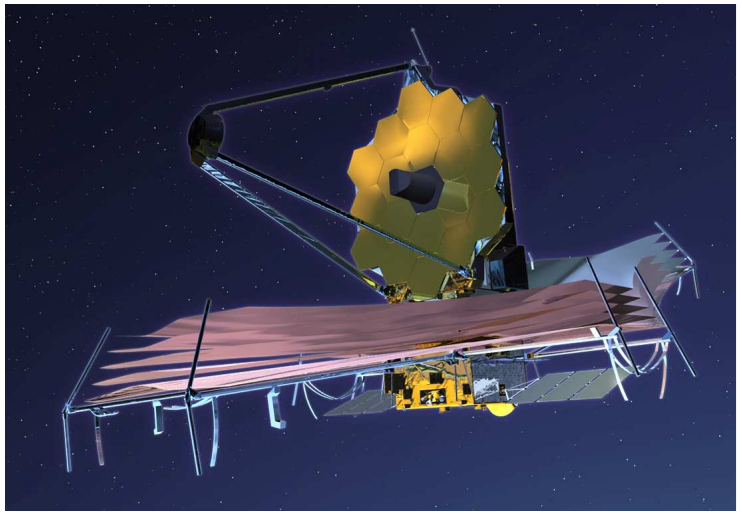


JWST

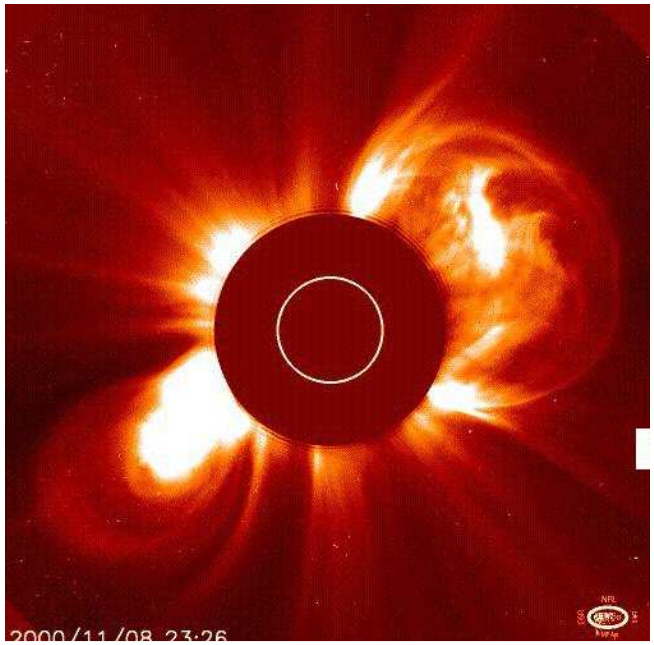
James Webb Space Telescope: Successor to HST

6.5 meter observatory

Working in the infrared with a coronagraph.



The Coronagraph Advantage



Space Interferometry Mission

Accurately measure location of stars to micro-arcseconds.

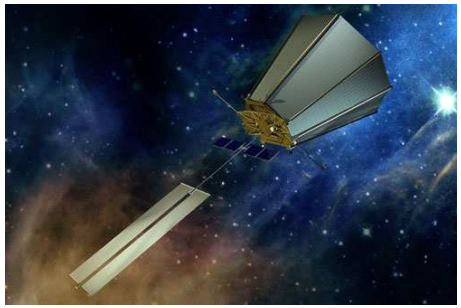
Need to know relative location of components to 50 pm.

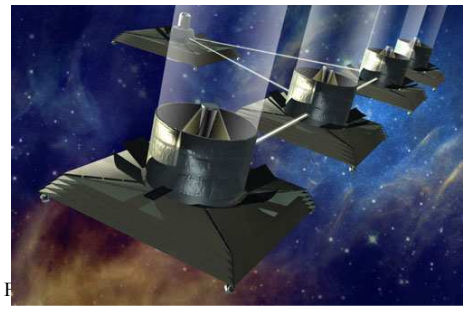
Funding in question.

http://planetquest.jpl.nasa.gov/SIM/sim_index.html

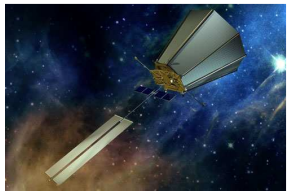
Terrestrial Planet Finder Mission: Two Telescopes

- Survey nearby stars looking for terrestrial-size planets in the "habitable zone"
- Follow up brightest candidates looking for atmospheric signatures, habitability, or life itself
- Then, the ultimate: image the little blue dots

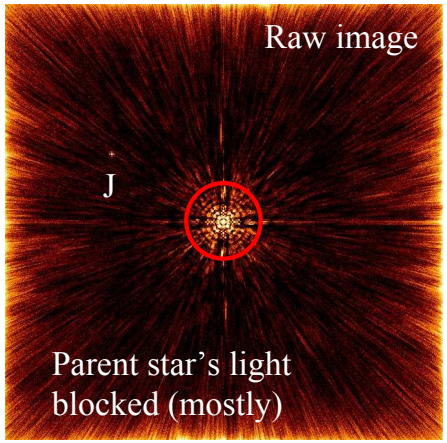


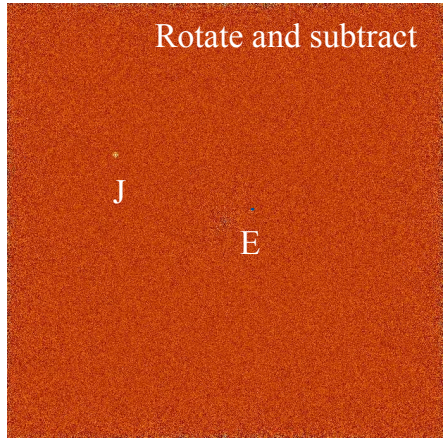


TPF



Visual wavelength `coronagraph'
- Find Earth-like planets
- Characterize their atmospheres, surfaces
- Search for bio-signatures of life (O_2, H_2O, etc)





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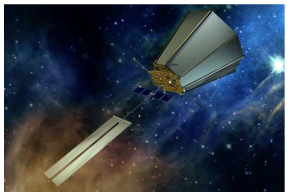

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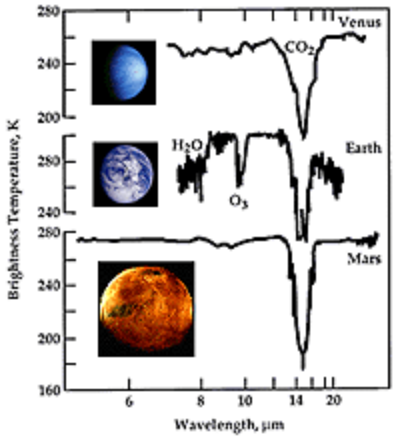
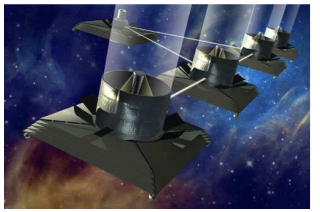


TPF: Step 2

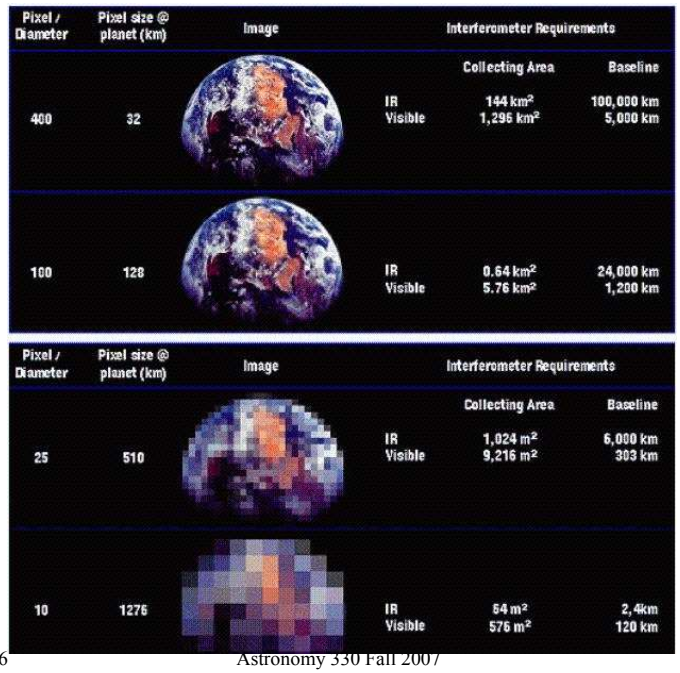


The goal of imaging an Earth-like planet.

5 platforms of 4 eight meter interferometer in space.

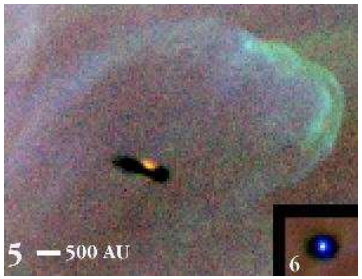
spider.ipac.caltech.edu/staff/jarrett /talks/LiU/origins/openhouse30.html

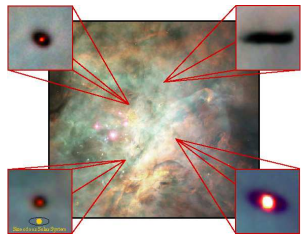
TPI -- Scales



Now, for f_p

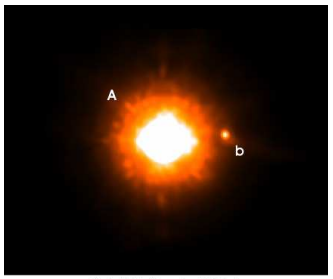
- About 2/3 of all stars are in multiple systems.
  - Is this good or bad?
- Disks around stars are very common, even most binary systems have them.
- Hard to think of a formation scenario without a disk at some point– single or binary system.
- Disk formation matches our solar system parameters.
- We know of many brown dwarves, so maybe some planets do not form around stars.
  - There might be free-floating planets, but…





Now, for f_p

- Extrasolar planet searches so far give about $f_p \sim 0.03$, but not sensitive to lower mass systems.
- Maximum is 1 and lower limit is probably around 0.01.
- A high fraction assumes that the disks often form a planet or planets of some kind.
- A low fraction assumes that even if there are disks, planets do not form.
- This is not Earth-like planets, just a planet or many planets.



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