ASTR 1120: Stars & Galaxies

Arecibo Radio Dish

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Lecture 44 Fri 29 Apr 05

zeus.colorado.edu/astr1120-toomre

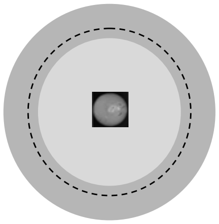
The ULTIMATE Lecture

- *Look at intense hunts for Extra-Solar Planets (and revisit Homework 9 with Ben)*
- *Advice about preparing for Final Exam*: go carefully over prior 3 mid-terms + answers, plus the review sheets (they sample the course well)
- *Final review sheet* still available; *crib sheet* competition winners announced today
- Overview read *Chap 24: Life beyond Earth*

Now winners of the great

Crib Sheet Competition

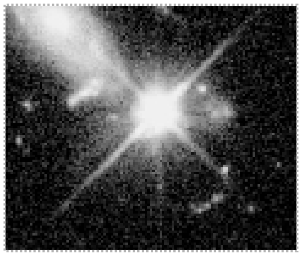
Requirement for liquid water defines a habitable zone (ecosphere): range of distances from a star where the surface temperature is between freezing and boiling



Not known observationally how often a rocky planet occupies the habitable zone

Though on theoretical grounds such habitable planets should be common

How many stars host planetary systems?



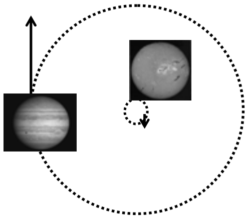
Extremely hard to form images of extra-solar planets: faint, very close to bright host star

Jupiter is ~10^9 times fainter than Sun as seen by distant observer

Most extra-solar planets detected by radial velocity method, some by looking for transits

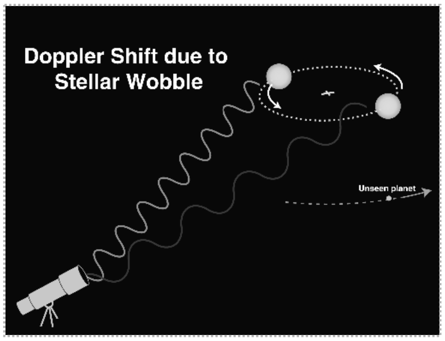
Radial velocity searches for planets

Sun wobbles slightly in response to the gravity from orbiting planets (mostly from Jupiter):

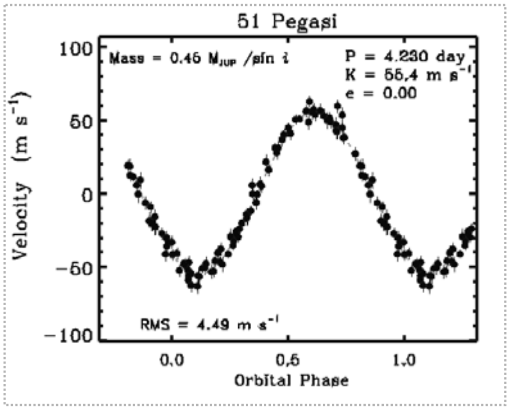


Small effect - Sun's wobble due to Jupiter has a speed of about 10 ms^{-1}

But detectable by looking at Doppler shift of spectral lines in stellar spectrum



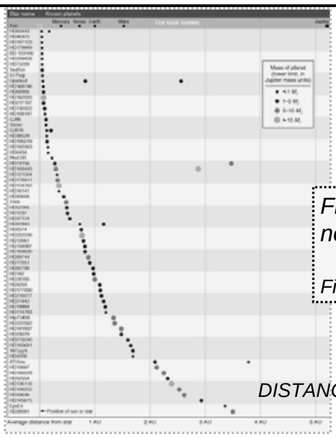
Light is slightly blue-shifted when star moves toward us, red-shifted when it moves away



Searches by several teams show that ~10% of stars similar to Sun host giant gas planets

Smaller extra-solar Earths are not yet detectable

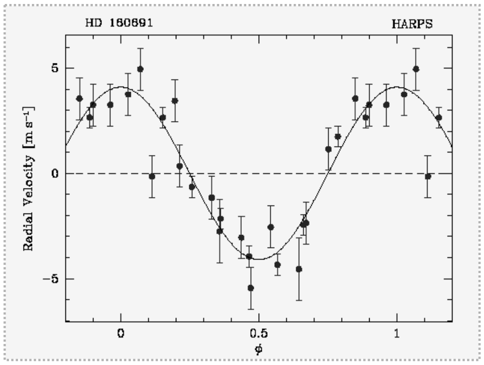
STAR



DISTANCE

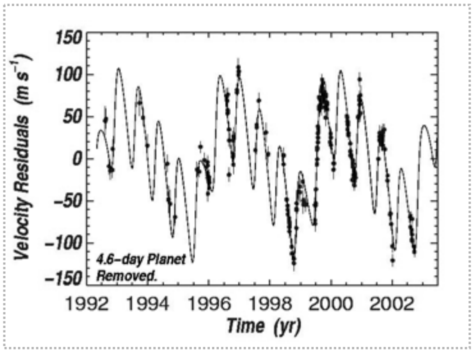
First 77 planets, now about 130+

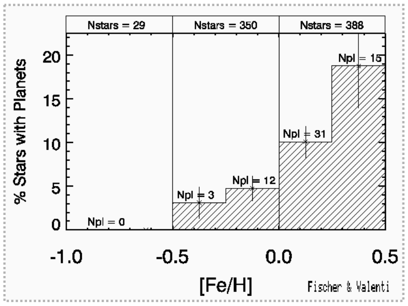
Fig 9.17



Neptune mass planet in short period orbit

Multiple massive planets in Upsilon Andromeda





Found that the planet frequency increases with the metallicity (i.e. the fraction of elements heavier than helium) of the star - presumably reflects more raw material for planet formation

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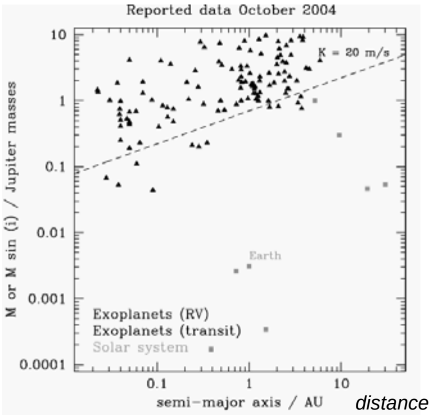
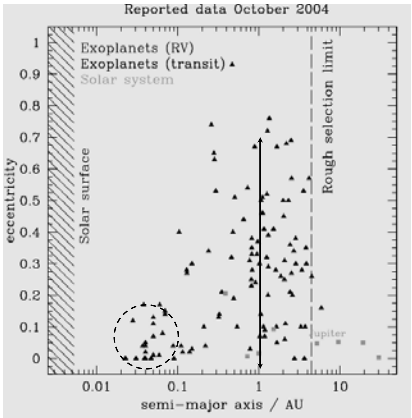
Jupiter masses



distance



Hot Jupiters:
a < 0.1 AU
P as low as 1.2 dy,
circular orbits

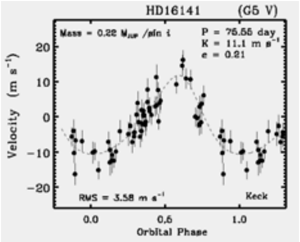
Broad range of eccentricity for all other planets

No real overlap with Solar System

Planet frequency is ~5 % in sample

Observables

- *planet mass x sin(i)*
- *period / semi-major axis*
- *eccentricity*



Biases

$$K \propto m_p a^{-1/2}$$

fixed sensitivity, minimum detectable planet mass scales as square root of orbital radius

Weak bias against finding e ~ 1 planets

Now turn to subtler issues with

Planet Finder

Homework Set 9

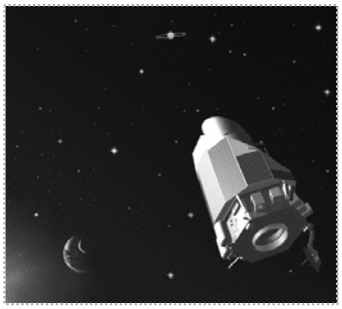
What fraction of stars with planets have habitable planets?

What makes a planet habitable?

A. oxygen atmosphere
B. solid surface
C. liquid water
D. presence of a moon to create tides
E. magnetic field to shield solar storms

Solid surface (i.e. rocky rather than gas giant planet) and liquid water seem most fundamental

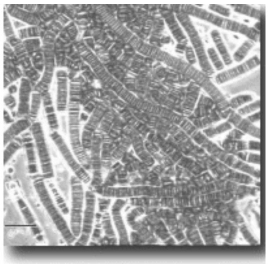
NASA's <u>Kepler</u> mission (2007) will detect and measure the frequency of habitable planets



Very probably: habitable planets are common

Timescale for emergence of life

First evidence for life on Earth dates from about <u>3.8 billion years ago</u>



Simple, <u>single-celled</u> organisms

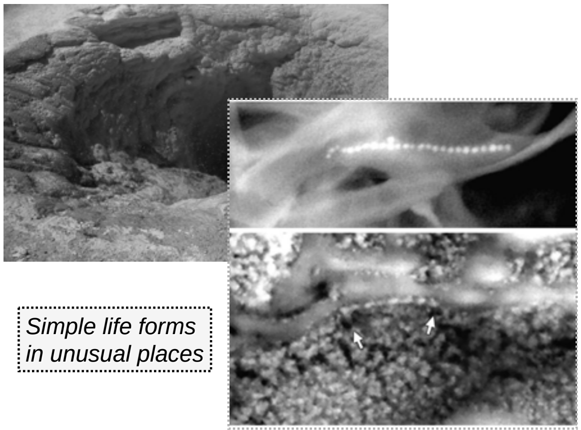
This was ~ 1 billion years after Earth formed, <u>but</u> then planet was repeatedly impacted by large asteroids etc …

`The late heavy bombardment'

Late heavy bombardment ended about 3.8 billion years ago

Primitive life got started on Earth quickly once conditions allowed

One interpretation: expect life to start on any planet with the basic ingredients (liquid water, a source of energy)



Simple life forms in unusual places

Probability of more complex life emerging

On Earth, the first evidence for <u>multi-celled organisms</u> dates back about <u>1 billion years</u>

For <u>3 billion years</u> (significant fraction of Sun's lifetime) there were only <u>single-celled</u> organisms

Modern <u>humans</u> and (especially) <u>technology</u> are only recent developments (only ~ <u>last million</u> years)

Impossible to infer from this the probability that <u>simple life would evolve</u> into a species capable of technology (and communication)

The Drake equation

How many planets in Galaxy evolved intelligent life ?

$$N = N_* \times f_{\text{planets}} \times f_{\text{habitable}} \times f_{\text{life}} \times f_{\text{intelligent}}$$

- N_* **is number of suitable stars in the Galaxy, say 100 billion (10^{11} stars)**
- $f_{planets}$ **is *fraction* of those that have planets**
- $f_{habitable}$ **is fraction of planetary systems that include habitable planets**
- f_{life} **is fraction of habitable planets on which life of any sort gets started**
- $f_{intelligent}$ **is fraction of planets on which life becomes `intelligent'**

How many civilizations are there?

Let’s estimate (guess!) some numbers:

$$N = N_* \times f_{\text{planets}} \times f_{\text{habitable}} \times f_{\text{life}} \times f_{\text{intelligent}}$$

$$= \underbrace{10^{11} \times 0.1 \times 0.5}_{\text{`astronomical parameters'}} \times 1 \times 10^{-6}$$

life is common but the chance of it becoming intelligent is very small

Gives N = 5000… our Galaxy should be teeming with intelligent life!

Milky Way galaxy is about 10 billion years old -- or 5 billion years older than the Sun

Many of those other civilizations could be millions or billions of years more advanced than us

So … why is not ET (or ET’s robot) here by now ?

Some Thoughts on Civilizations

A. **intelligent life is *really* rare (10^{-9}), or even unique**

B. **civilizations are fragile - if they last only 1 million years, 5000 could have gotten started but at any time only one survives**

C. **ET has better things to do than waste time communicating with primitive species (us)**

D. **ET is keeping us in quarantine**

E. **life of *any* kind is rare**

We wish you good fortunes with the Final Exam on Tuesday (1:30pm here) -- please bring pencils, crib sheets, ID

… and we hope you’ve enjoyed this course that has touched the universe