The Place of Humans in the Cosmos

Life in the Universe

Fate of the Universe

Our Place in Space

- As we explored in Lecture 2, the Universe is unimaginably big
  - even in the solar system, earth is only a grain
  - earth mass is <0.0003% of solar system mass
  - and humans are tiny compared to the earth
- We are not at the center of:
  - the solar system
  - the galaxy
  - the universe
  - attention

Our Place in Time

- Modern humans have been around maybe 200,000 years
- This is about 0.001% the age of the universe
  - $2\times10^5/2\times10^{10} = 10^{-5}$
  - flash in the pan
- Compared to distance scale, this is sort-of like the size of a galaxy compared to the size of the whole universe
- Feeling Insignificant?

Are We Alone?

- Hard to believe that we are
- Assumptions (restrictive version):
  - must have solid planet to start life
  - planet must be in habitable zone (liquid water)
  - >10% of stars have planets
    - already see >5%, and just getting started
  - life forms given energy input and non-destructive environment
    - no supernovae nearby, no heavy comet bombardment, etc.

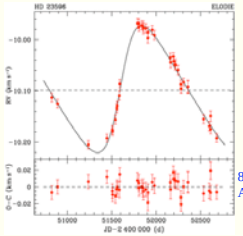
The Numbers

- 100 billion stars in Milky Way
- 10% with planetary systems
  - 10 billion planetary systems
- Say 1% of planetary systems have habitable planets
  - 100 million planets
- Pick very long odds for life formation: one-in-a-million
  - now 100 life-bearing planets in Milky Way
- Now multiply by 100 billion galaxies in *visible* universe
  - 10 trillion life-bearing planets in visible universe
- How many have (or have at one time had) *intelligent* life?
  - very difficult to know—related question: how long does intelligent life persist?
- Why don't they visit?
  - were you paying attention to the description of the vastness of space??

Planetary systems known to date

- 230 planetary systems discovered since 1995
  - 287 planets total
  - 20 multi-planet systems known
- Discovered by seeing star wiggle under gravitational influence of planet
  - tends to find BIG planets CLOSE to the parent star (biased)

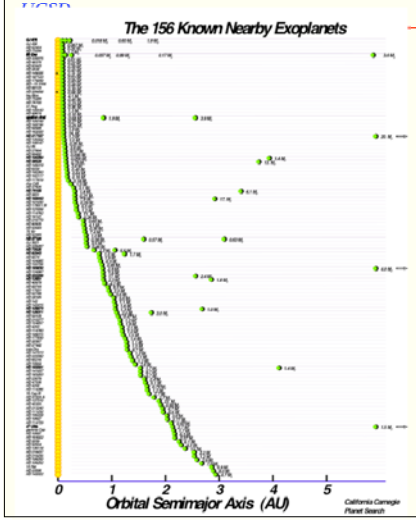
sun's path in 65 years



red points are individual measurements (with error bars)

black line is best-fit elliptical orbit

8 M_{JUP} at 2.88 A.U., 0.29 ecc.



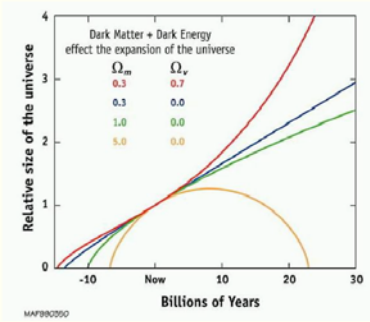
See http://exoplanets.org/ for the latest stats

Ultimate Fate of the Universe

- Three classical possibilities:
  - eventual re-collapse (enough matter to halt expansion)
  - eternal expansion (not enough matter to halt expansion)
  - Goldilocks scenario: perfect balance between
    - expand forever, but come to rest at infinite time
- Before dark energy, one-to-one correspondence to geometry of space
  - closed geometry: ultimate re-collapse
  - open geometry: eternal expansion
  - flat geometry: Goldilocks

"Trajectory" of Expansion

- Orange: Closed; re-collapse
- Green: Flat; teeter
- Blue: Open; eternal expansion
- Red: our universe; flat, but accelerated



what we know at present is the *slope*—which is why the curves above all have same "Now" slope

The New Picture

- Dark Energy messes up this picture
  - though at critical *energy* density, not all in form of matter
  - not enough gravity to halt expansion
  - being *accelerated* to boot!!
- Best guess as of now: eternal, accelerating expansion
  - shrinking horizon (ultimately less of universe visible)
  - called the "cold death"—universe continues to cool as it expands

References and Assignment

- More on extra-solar planets
  - http://exoplanets.org
- Calculating the probability for life: the Drake Equation
  - http://en.wikipedia.org/wiki/Drake_equation
- Fate of the Universe
  - http://science.hq.nasa.gov/universe/science/expanding.html
- Assignments:
  - Read Hewitt Chapter 11 through Quarks
  - Homework Exercises for Friday (4/11):
    - Hewitt 1.R.15, 1.R.18, 1.E.7
    - Additional (required) questions on course website
  - Question/Observation due 4/11 via WebCT