Astronomy 162, Week 4
Planets, Life, SETI

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Planets, Life, SETI
Refer to Ch. 8-4, 8-5, 8-6, 30

- How could we detect planets around other stars?
- Is there life elsewhere in the universe?
- How could we detect extraterrestrial life?

Planets

- Planets formed differently from stars
- Recall dusty accretion disk around a forming star
- Likely that planets built up through collisions and accumulation of material in disk
- Beta Pic is a good example

Can we detect planets around other stars?

- This is a grand question for science and indeed humanity
- In the 1990s, we developed the technology to detect extrasolar planets
- Since then, nearly 200 extrasolar planets have been detected
- This is now one of the most active and exciting research areas in astronomy

How to detect planets?

- Planets around nearby stars very faint compared to the stars, also very close in separation
- Planets weigh so little that motion of parent star is hardly affected
- How to detect them?

- As with so many advances in science, s significant advances in instrumental capability were key:
  - Timing of pulsars
  - Ability to measure radial velocities of stars to 10s of meters/sec
  - Ability to measure brightnesses for millions of stars to better than 0.01 magnitude

Current methods for detecting planets around stars like our Sun

- Radial velocities - also very difficult, but apparently successful
- Transits (eclipses)
- Microlensing (Prof. Gould of our dept. is a world expert on this)

Future methods and programs to detect extrasolar planets

- Astrometric measures (as for visual binaries) from space missions
  - NASA's Space Interferometry Mission (SIM)
    - http://planetquest.jpl.nasa.gov/SIM/new_worlds.cfm
  - ESA's GAIA mission
    - http://www.esa.int/esaSC/120377_index_0_m.html

- Photometric measures of transits (as for eclipsing binaries)
  - NASA's Kepler mission
    - http://kepler.nasa.gov/

The Discovery of Extrasolar Planets

- 1993, Aleksander Wolszczan, a planet around a pulsar from very accurate timing
- 1995, Mayor and Queloz, a planet around the star 51 Peg from radial velocity variations (like a spectroscopic binary)
- Since then, Marcy and Butler have discovered many more planets from radial velocity variations

Surprising results

- Detected planets appear to
  - have masses of 1/2 to 8 times Jupiter
  - be as close as 0.05 AU to parent star
- Results very unexpected from theoretical ideas about how planets form

Upsilon Andromedae

- Butler et al. 1997
  - Evidence for 4.6 day period,
  - Jupiter mass companion
  - 0.06 AU orbit
- Further obs. show evidence for two more planets w. masses of at least
  - 2 Jup. mass at 0.8 AU
  - 5 Jup. mass at 2.5 AU

New Result on Planet Formation

- See www.jpl.nasa.gov/releases/2002/ release_2002_4.html
- Report on new radio observations of a protostellar disk
  - Find that the methanol molecules are distributed in a disk shape
  - Think this is evidence for a shock zone where planets are born

- Note that methanol (wood alcohol) is an organic molecule
- Interesting that it appears in zone where planets are believed to form

Reference Web Sites

- General Article
  - http://en.wikipedia.org/wiki/Extrasolar_planet
- The Extrasolar Planets Encyclopedia
  - Catalog of currently known planets
  - http://vo.obspm.fr/exoplanetes/encyclo/catalog.php

Recent Discovery of a Planet via Microlensing

- OSU Prof. Andrew Gould and team
  - http://researchnews.osu.edu/archive/suprerth.htm
  - New planet has 13 times the mass of the Earth
  - 2.7AU from parent star
  - Microlensing offers best current chance to find earth-mass planets around other stars

Life in the Universe (Ch. 30)

- Recall the many interstellar molecules
  - including organic ones
- Amino acids are found in meteorites
- Lab. experiments show how lightning might form amino acids
- What is chance there is life elsewhere?

Astrobiology

- A newly emerging subject
- As yet, there is no definitive evidence for life outside the Earth
- Possibilities in solar system
  - Mars
  - Europa, the satellite of Jupiter heated by tidal interactions

Exoplanets

- The discovery of extrasolar planets and increasing power of telescopes plus instruments is opening up new possibilities
  - Need to isolate and observe such planets
  - Need enough light gathering power and resolution to detect potential biological signatures via spectroscopy

Terrestrial Planet Finder

- Major future NASA mission to find and study Earth-like planets around other stars
  - http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm

Drake equation (Ch. 30-4)

- A way to estimate chance of life elsewhere
  - $N = R_* f_p n_e f_l f_i f_c L$
  - N is number of other advanced civilizations
  - R_* is rate at which sun-like stars form in Galaxy
  - f_p is fraction of stars that have planets
  - n_e is number of Earthlike planets
  - f_l is fraction with intelligent life
  - f_c is fraction with communications technology
  - L is lifetime of the advanced civilization

How many stellar systems with advanced life may exist?

- In our galaxy, from Drake equation
  - anywhere from 1 (us) to many
- Note that there could be many more with some form of (primitive) life
  - there could be a billion stars like the Sun in our galaxy
  - chances of advanced life seem much smaller
- What do you think?

SETI

- Search for extraterrestrial intelligence
- How could we search for evidence of life outside solar system?
- Listening for radio emission is the best way
- Radio waves can penetrate dust in galaxy
- Our own radio/TV signals have now traveled 50-100 light years out in space

- With current technology, our signals could be detected over most of that distance
- We should be able to detect signals from nearby stars
- What's the best way to listen in?
- Megachannel receivers
- Recall "Contact" by Carl Sagan

UFOs

- Unidentified flying objects
- Are there sightings without good explanations?
- Yes
- Does that mean they are caused by extraterrestrials?
- No

Make up your own mind

- Ch. 30 gives an extensive discussion.
- Consult web sites such as
  - www.seds.org (look for SETI link)
  - www.seti.org (SETI Institute)
  - www.skypub.com/news/special/seti_toc.html (Sky&Telescope Magazine)
- Read for your own interest, let me know what you think

SETI on your PC

Connection between star formation and SETI

- Recall the conditions where stars are forming:
  - cold (10°K), dense, dusty, molecular clouds
- Also, cold, dusty clouds favor the formation of interstellar molecules, especially the more complex ones
- Note the connection between the two: complex molecules and star formation

Questions

- Do you think life of any kind may exist elsewhere in the universe? Why?
- Do you think there could be life elsewhere that is as advanced as on Earth? Why?

- If yes, what do you think the chances are that they could communicate with us?
- Do you think we been visited by extra-terrestrials? Why or why not?

Astronomy 162, Week 4
Begin Structure of Sun

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The structure and evolution of the stars

- Topics for next two weeks
- Begin with the nearest star, our sun
  - Its source of energy
  - Nuclear reactions
  - Structure of sun, theory and observations
- Next, evolution of stars
  - Use of star clusters to guide and test theory

The Sun (Ch. 18)

- Sun is on main sequence
  - is no longer contracting
  - has achieved stability
  - Why? How?
- Basic questions
  - What makes the sun shine?
  - What is its source of energy?

- Recall that some source of energy must be keeping the sun hot.
- Otherwise it would cool, just as a toaster does when the electricity is disconnected

Energy and Power

- Luminosity (power output) of sun is enormous - 4 x 10^{26} watts
- Earth receives 1.4 kilowatt per sq. meter from sun
- Power - energy emitted per second
- Energy - the ability to do work

- Types of energy
  - Gravitational
  - Thermal
  - Radiative
  - Mechanical
- Energy is conserved
  - Can be transformed but not created or destroyed

So, what could power the sun?

- Unsolved mystery of the last century
  - Ordinary burning doesn't work
  - Sun would only last ten thousand years
- Geological studies were showing age of earth was very long
  - Now known to be at least 3.9 billion years

A real problem

- Helmholtz and Kelvin noted possibility of gravitational energy (like protostars)
  - Sun would contract to replenish energy lost at surface
  - But gravitational energy would only work for about 20 million years
  - Mystery continued until 1930s

Einstein's famous equation

- $E = m c^2$
  - E is energy
  - m is mass of object
  - c is speed of light
- Equation demonstrates
  - Energy content of matter is enormous

- Mass can be converted to energy and vice versa
- Mass and energy are conserved

What does this mean for the sun?

- A solution to the lifetime problem
  - if some of solar mass could be converted to energy, easy to account for age of earth (and sun)
- Solar luminosity means 4 million (metric) tons of matter are being converted to pure energy every second
  - equiv. to 100 billion hydrogen bombs per sec

How can matter be converted to energy?

- Not by chemical reactions
- Nuclear physics turned out to give the answers
- Advances in astrophysics and nuclear physics in 1st half of 20th century
  had tremendous impact

Nuclear Energy

- Nuclei of atoms:
  - extremely dense
  - held together by very strong forces
  - have large amounts of potential energy
- Nuclear fission
  - splitting nuclei of heavy atoms (Uranium)
  - can release much energy
  - powers nuclear reactors on earth

Nuclear Fusion

- Binding together (fusing) of light nuclei
- Why does fission or fusion release energy?
  - Need to consider the masses of the nuclei and the particles they're made of
- Eddington noted in 1920s that a helium nucleus weighed 0.7% less than 4 hydrogen nuclei

- If hydrogen could somehow be transformed to helium, energy could be released
- To understand nucleus and possible reactions better, consider its different components

Parts List

Particle	Mass	Charge
Proton	$1.7\text{x}10^{-27}$	+1
Neutron	$1.7^{+}\text{x}10^{-27}$	0
Electron	$9\text{x}10^{-31}$	-1
Neutrino	0	0
Positron[1]	$9\text{x}10^{-31}$	+1
Gamma rays[2]	0	0

[1]Anti-matter

[2]High-energy radiation

- Remember that nuclei consist of protons and neutrons and are surrounded by electrons
- But in the various nuclear reactions, electrons, positrons, neutrinos, and gamma rays can also play a part

Nuclear reactions in sun

- 1930s - Bethe showed that energy source of sun was fusion of 4 hydrogen atoms to form 1 helium atom
- 0.7% of rest mass is released as energy
- (Recall Eddington's observation)

What conditions are needed?

- High temperature
  - more than 10 million degrees
- High pressure
- Both occur at center of sun (and stars)
- Provide chance for hydrogen nuclei to collide and overcome electrical repulsion
- Very hard to produce such conditions in labs on the earth

Proton-proton reaction

- Main reaction in sun
  - $^{1}H + ^{1}H \rightarrow ^{2}H + e^{+}$ + gamma ray + neutrino
  - $^{1}H + ^{2}H \rightarrow ^{3}He$ + gamma ray
  - After 1. and 2. happen twice
  - $^{3}He + ^{3}He \rightarrow ^{4}He + ^{1}H + ^{1}H$

Proton – Proton Reaction (continued)

- See Fig 18-2 and discussion in book for more information
- Note that several steps are involved
- Net result - 4 H atoms converted into 1 He atom, 0.7% of rest mass converted to energy
  - because He has 0.7% less mass than 4 H atoms
- This is the main energy source for the Sun