Habitability Outside the Solar System

A discussion of Bennett & Shostak
Chapter 11
HNRS 228
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Chapter Overview

• Distant Suns (11.1)
  - Life cycle of stars and their habitability zones

• Extrasolar Planets: Discoveries and Implications (11.2)
  - detection methodologies

• The Possibilities that Earth is Rare (11.3)

• The Process of Science in Action: Classifying Stars (11.4)
Are Habitable Planets Common?

• Really two questions
  - Are planets common?
  - How many exoplanets are habitable?

• Review formation of stars and planets
  - evidence from HST
Habitability Zone Around Other Stars in Our Galaxy

• Use the range from our solar system as a basis for analysis
  - In our solar system, 4 rocky planets that orbit the Sun from 0.4 to 1.4 AU and spaced 0.4 AU apart

• If typical, likelihood of other solar systems having continuous habitability zone is just width of the zone divided by the typical spacing
  - $0.2/0.4 = 0.5$
  - Probability of 50%
  - Discuss this probability
Habitability Zone in Our Galaxy

• Other factors also relevant
  - Several stars in our galaxy with planets the size of Jupiter within terrestrial zone from their sun
  - Mass of star
    • Larger mass, greater luminosity, shorter life
    • Most abundant stars in galaxy are least luminous and longest-lived (red dwarfs)
Habitability Zones Elsewhere in the Galaxy
Different Stars - Different Habitable Zones

Athena Andreadis, in *Astronomy*, Jan. 1999, illus. by Terri Field
Another View of Habitability
iClicker Question

• Compared to a star of spectral type K, a star of spectral type A is generally
  - A hotter, more luminous, and more massive.
  - B hotter, more luminous, and less massive.
  - C cooler, dimmer and less massive.
iClicker Question

- Stars of types O and B are unlikely to have planets with life because
  - A they have short stellar live.
  - B their intense ultraviolet light would sterilize any planets.
  - C they don’t have enough heavy elements.
  - D Both A and B above are true.
  - E A, B, and C above are true.
iClicker Question

• How does the habitable zone around a star of spectral type M compare to that around a star of spectral type G?
  - A It’s larger and farther from its star.
  - B It’s hotter and brighter.
  - C It’s smaller and closer to its star.
How to Find an Extrasolar Planet

- Think about how a planet effects the star around which it orbits
  - light seen from star
  - gravitational effects
    - translate into visual effects
  - spectroscopic effects
    - translate into observed spectroscopic observations
    - remember Doppler Effect
Four Main Ways to Find an Extrasolar Planet

• Photometrically
  - light from star blocked by planet decreasing light seen from star in concert with orbit

• Astrometrically
  - change in position caused by “dance with planet”

• Spectroscopically
  - Doppler Effect on spectral lines due to “dance with planet”

• Gravitational Microlensing
  - large gravitational force effecting light path
Transit Detection of Exoplanets

Photometric Light Curve
Change in position of Sun due to Jupiter as seen from 10 parsecs distant

Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.
Remember Doppler
Applying Doppler
Applying Einstein

Gravitational Microlensing

Light from a distant star is bent and focused by gravity as a planet passes between the star and Earth.
Extrasolar Planet Detection Capability
They are everywhere!

55 Cancri
HD 114762
70 Virginis
47 Ursae Majoris
τ Bootis
υ Andromedae
β Coronae Borealis
16 Cygni B
51 Pegasi
Gliese 876
14 Hercules
Considerations for Habitability

- Distance from sun
- Luminosity of sun
- Planet size
- Atmospheric loss processes
- Greenhouse effect and gases in the atmosphere
- Source of energy (internal/external)
- Presence of water
- Presence of carbon biomolecules
- Biota
Phases of Water and $CO_2$

![Diagram showing the phase transitions of water and $CO_2$](image)
Planetary Spectra
Planet Size Questions

- Tectonics: why important
- Magnetosphere and solar winds
- Gravity and tectonics
Atmospheric Loss Processes to Consider

• Solar winds of charged particles
  - Sweeps away atmosphere in episodic wind events
• Planet’s magnetic field (magnetosphere)
  - Deflect solar winds
  - Earth and Mercury have magnetospheres
  - Mars and Venus do not have magnetospheres
• Atmospheric loss processes
  - Escape velocity of gases
iClicker Question

• About how many extrasolar planets have been detected to date?
  - A  between 10 and 100
  - B  between 100 and 1000
  - C  more than 1000
iClicker Question

• How have we detected most extrasolar planets discovered to date?
  - A  Transits
  - B  Hubble Space Telescope images
  - C  the Doppler related technique
iClicker Question

• Which technique will the Kepler mission use to search for Earth size planets around other stars?
  - A Transits.
  - B The astrometric technique.
  - C The Doppler related technique.
  - D Gravitational lensing.
iClicker Question

- Nearly all the extrasolar planets discovered to date are
  - A terrestrial-like planets.
  - B jovian-like planets.
  - C large, icy worlds.
Is Earth Rare?

• What are the odds?
  - Location, location, location
  - Special events

• What are the odds of any special event?
  - Example of coin toss