Science & Science Fiction

Major Question 4:
Are we alone in the universe?

Today…

Finding habitable planets;

Conditions necessary for intelligent life

- **Exploration Paper 4 due Friday, Nov. 10**
  - **Topics on Extraterrestrial Intelligence**
  - **Details on Canvas**

Announcements for Wednesday, Nov. 8

SciAm Special Collector's Edition, August 2022

Choose any article in this issue and explore the topic further, or just write about one of the original topics on Canvas

Additional choices for Exploration Paper on Extraterrestrial Intelligence…

33-120 Science & Science Fiction

- Quiz 5 next Monday, November 13
  - Ch. 5 + lectures this week
  - Given on Canvas, 25 points possible

Next week…

- **How do we decide what to look for?**
  - **Why do we only search for life *as we know it*?**
  - **What conditions are necessary for life *as we know it* to exist?**
- **How do we begin the search?**

Last time…
Systematically searching for signs of extraterrestrial intelligence

Drake Equation

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Assumptions made (1960) to justify the SETI Project:

R^* = rate of star formation in the galaxy = 10 per year
f_p = fraction of stars with planets (<1)
n_e = number of Earth-type planets per star (>1)
f_l = fract'n of planets capable of supporting life (=1)
f_i = fract'n of habitable planets w/ intelligent life (=1)
f_c = fract'n of intelligent civ. w/ radio com. (=1)
L = lifetime of radio-communicating species (= 10^4 y)

Systematically searching for signs of extraterrestrial intelligence…
The Drake Equation and the SETI Project (1960)

Finding habitable planets in other star systems

Conditions necessary for intelligent life to exist

The science behind the systematic search for extraterrestrial intelligence

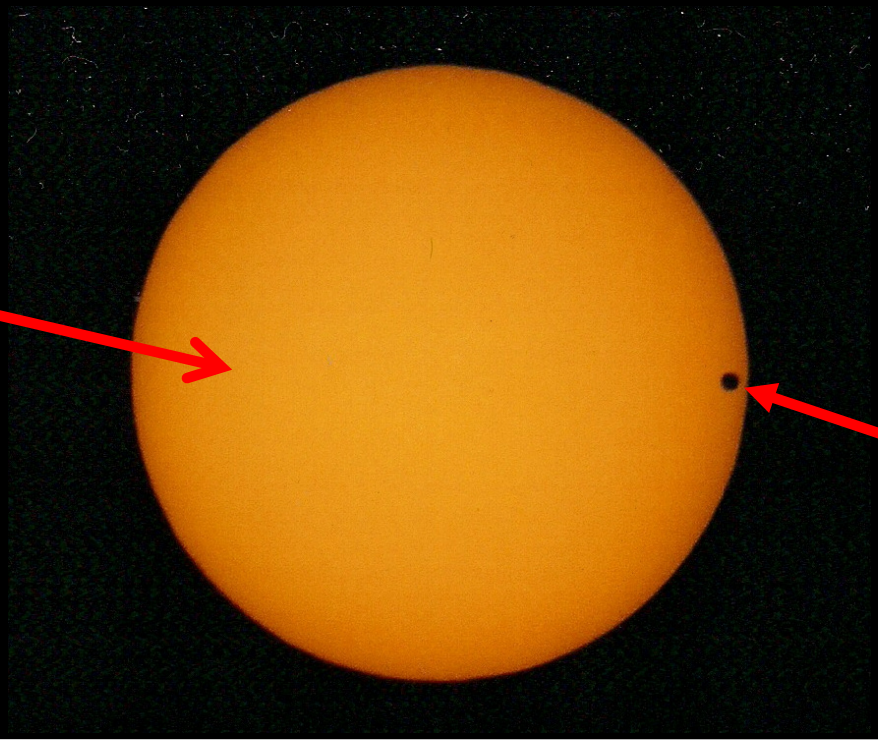
Today…

Three standard methods plus one brand new one:

1. **Transit method** (periodic dips in light intensity)
2. **Doppler spectroscopy** (red-shift or blue-shift in wavelengths of light, due to motion of star)
3. **Wobble method** (shift in position in the sky)
4. **Direct photography** (image of actual planet)

Finding planets in other star systems

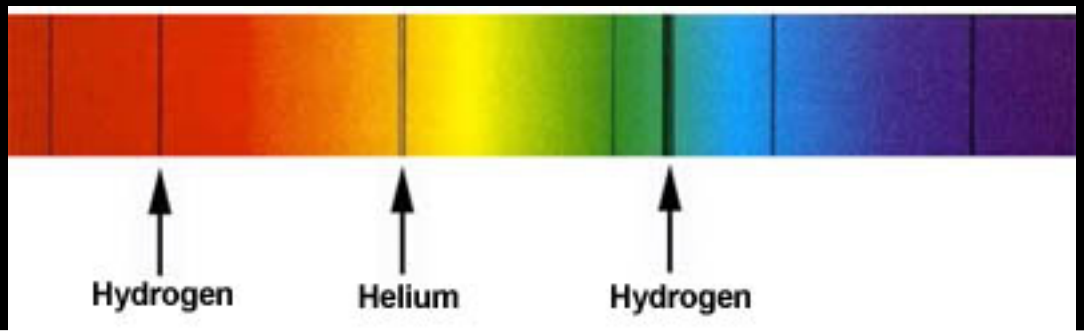
Transit of Venus (2004)



The Transit Method:
Monitor periodic change in light intensity as planet passes in front of star.

The Doppler Effect:
Fractional shift in wavelength = velocity of star over speed of light

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$



Doppler Spectroscopy:
Red-shift or blue-shift in light from star

When Worlds Collide

Directed by Rudolph Maté

Paramount (1951)

Finding planets in other star systems:
Movie illustration of the Wobble Method
(plus a method that didn't exist until 60 years later)

The Wobble Method:
Precise photographic measurement of shifts in star position due to gravitational tug from orbiting planet

New method predicted in Sci-FI:
Direct photographic imaging of a planet
Impossible until very recently!

Finding planets in other star systems:
another standard method + a brand new one

For Extra Credit
(up to 10 points)

How many *exoplanets* are known to exist, based on *actual observational data*?

Based on know data, how many stars in our galaxy are likely to have planets?

Include references.

Opportunity for Extra Credit
Finding Exoplanets
Send me email by class time on Friday, Nov. 10

- **Conditions necessary for habitable planet ("Goldilocks Zone", atmosphere, moon/tides)**

- **Conditions necessary in the star system (age of star, habitable planet, gas giants)**

- **Conditions necessary in the universe (apparent fine-tuning of physical constants)**

What conditions are necessary for life (as we know it) to exist?

- **Conditions for a planet to be *habitable***

1. **Orbits star in “Goldilocks Zone”**
   - **Too close = too hot for liquid water**
   - **Too far = too cold for liquid water**

What conditions are necessary for life (as we know it) to exist?

- **Conditions for a planet to be *habitable***

2. **Moon big enough to make tides**
   - **Calm tidal pools for life to evolve**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the star system**

1. **Star must be old enough…**
   - **Too young = not enough time for life to evolve on planets**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the star system**

2. **Star system should have *gas giants***
   - **Protect habitable planets from collision by comets**
   - **Example: Comet Shoemaker-Levy collision with Jupiter (1994)**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the Universe:**
  apparent fine-tuning of physical constants

1. **Cosmological flatness (expansion of the universe not too fast or slow)**
   - **If too fast, then no formation of stars and galaxies.**
   - **If too slow, then universe would gravitationally collapse.**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the Universe:**
  apparent fine-tuning of the physical constants

  2. **Small imbalance of "matter" over "antimatter" (1 excess proton for every 10^{10} proton-antiproton pairs)**
     - **If smaller imbalance (even fewer protons), then not enough matter to form stars and galaxies**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the Universe:**
  apparent fine-tuning of the physical constants

  2. **Small imbalance of "matter" over "antimatter" (1 excess proton for every 10^{10} proton-antiproton pairs)**
     - **If greater imbalance (even more protons), then too much matter… gravitational collapse of universe.**

What conditions are necessary for life (as we know it) to exist?

- **Conditions necessary in the Universe:**

  apparent fine-tuning of the physical constants

  3. **Mass of neutron about 1 part in 1000 greater than mass of proton.**
     - **If greater difference, then too much beta decay (n → p) and not enough stable elements.**
     - **If smaller difference, then too much positron decay (p → n)**

What conditions are necessary for life (as we know it) to exist?

CONTACT

Directed by Robert Zemeckis

Warner Brothers (1997)

(opening scene 0:02:29)

The science behind the search for ET…
Age and intensity of radio transmissions versus distance from source

CONTACT

Directed by Robert Zemeckis

Warner Brothers (1997)

(Arecibo 0:03:38)

SETI and radio astronomy:
World's (2nd) largest single-dish radio telescope, Arecibo, Puerto Rico

- 305 m dish
- Completed 1963
- World's largest for 53 years
- Surpassed by China's 500 m *FAST* 2016
- Collapsed Dec. 1, 2020

World's (2nd) largest single-dish radio telescope, Arecibo, Puerto Rico

- 305 m dish
- Completed 1963
- World's largest for 53 years
- Surpassed by China's 500 m *FAST* 2016
- Collapsed Dec. 1, 2020

World's (2nd) largest single-dish radio telescope, Arecibo, Puerto Rico

The Drake Equation Revisited

The Science Behind the SETI Project

Next time…