

Week 5: Advanced course on search for Life in the Universe

Objective:

This advanced course aims to deepen participants' understanding of the Search for Extraterrestrial Intelligence (SETI), focusing on the fundamental aspects of SETI research. Students will explore various methods used to detect potential signs of life, with a particular emphasis on technosignatures and their implications for discovering intelligent life in the universe.

Prerequisite:

Participants should have completed a basic course on Life in the Universe, which would have covered essential topics such as the conditions necessary for life, Drake's Equation, and the basics of finding and characterizing extrasolar planets.

Day 1: The Landscape of SETI Research

Motivation to search for life in the Universe (5 minutes: slides 1 to 7):

1. Exoplanet discoveries
2. Likelihood of Earth-like planets
3. Introduction to Astrobiology
4. Detection of life in extreme environment on Earth

Technosignature (20 minutes: slide xx to xx):

1. Searching for evidence biosignatures from extrasolar planets
2. Limitation of biosignatures to only search life within a few pc distance from us.
3. What are technosignature?
4. Types of technosignatures:
 - a. Physical artifacts by technologically-advanced life (potential example: von Neumann probes)
 - b. Exo-engineering projects such as Dyson spheres
 - c. Technosignature through electromagnetic waves
5. Differences between biosignatures and technosignatures.

Technosignature at Electromagnetic Waves (20 minutes)

1. Nanoseconds Optical pulses
2. Coherent narrowband optical spectral lines
3. Radio waves

In-class MCQ:

Question 1: What is the primary difference between biosignatures and technosignatures?

- A) Biosignatures indicate the past presence of technology.
- B) Technosignatures are derived from geological formations.
- C) Biosignatures are natural markers of life, while technosignatures indicate the presence of technology.
- D) Technosignatures can only be found on Earth.

Question 2: Which type of electromagnetic wave is commonly searched for in SETI due to its ability to travel long distances through space without significant attenuation?

- A) Infrared radiation
- B) Gamma rays
- C) Radio waves
- D) Ultraviolet radiation

Question 3: What would a detection of narrowband spectral lines most likely indicate in the context of SETI?

- A) Natural astronomical phenomena
- B) Indications of biological life processes
- C) Evidence of technologically produced signals
- D) All of the above

Home Assignment for Day1

- Write a 500-word essay on one type of technosignature discussed during the session. Describe its potential to provide evidence of extraterrestrial technology and discuss the technological and observational challenges associated with detecting such signatures.

Day 2: Technosignature searches at radio waves around the world

History of SETI (10 minutes)

1. Project Oma
2. The Big Ear Radio Observatory and Wow! signal
3. SETI@home
4. Harvard-Smithsonian Optical SETI searches
5. Allen Telescope Array and SETI Institute

Current on-going SETI searches around the world (30 minutes)

1. Optical wave-bands
 - a. VERITAS searches for nanosecond pulses
 - b. Automated Planet Finder (APF) at Lick Observatory: Looking for narrowband optical lasers.
2. Radio wave-bands:
 - a. Breakthrough Listen: The largest ongoing SETI effort, including searches from the Green Bank Telescope, Parkes Telescope, and MeerKAT.
 - b. LOFAR (Low-Frequency Array): Searching for technosignatures at low radio frequencies.
 - c. FAST (Five-hundred-meter Aperture Spherical Telescope): The world's largest radio telescope focusing on narrowband signals.

Search Challenges and Breakthroughs (10 minutes):

1. Challenges of sifting through large amounts of data.
2. The importance of differentiating natural signals from artificial ones.

Activity (10 minutes):

- Case study: Review the Wow! signal, discussing its implications and the methods used to analyze it.

Home Assignment (Due on Day 3):

- Write a 500-word report on the strengths and weaknesses of using radio wave-bands for SETI searches. Include a case study of an ongoing search.

In-class MCQ:

Question 1: Which of the following was the first modern SETI experiment that searched for extraterrestrial radio signals?

- A) The Big Ear Radio Observatory
- B) Harvard-Smithsonian Optical SETI
- C) Project Ozma
- D) Allen Telescope Array

Questions 2: Which telescope is currently the largest radio telescope in the world, being used for SETI searches, especially for narrowband signals?

- A) LOFAR
- B) Green Bank Telescope
- C) MeerKAT
- D) FAST (Five-hundred-meter Aperture Spherical Telescope)

Question 3: What was the Wow! signal detected by the Big Ear Radio Observatory most likely considered to be?

- A) A technosignature from an advanced civilization
- B) A glitch in the telescope equipment
- C) A natural astronomical phenomenon
- D) A satellite signal interference

Day 3: Searching for Narrowband Signals from Extraterrestrial Intelligence

Narrowband Signal Detection (15 minutes):

1. Why narrowband signals?: They are less likely to be natural and more likely to indicate technological origins.
2. Examples: Historical searches (e.g., Cocconi & Morrison 1959) and modern breakthroughs (e.g., Breakthrough Listen).

Tools and Techniques for Narrowband Searches (15 minutes):

1. turboSETI: A tool for narrowband signal detection.
2. Machine Learning in SETI: How AI is helping sift through large datasets (Ma et al. 2023).
3. HyperSETI: A more sensitive search tool currently being developed.

Review of SETI Algorithms (15 minutes):

1. Explain how different algorithms (e.g., turboSETI, HyperSETI) work.
2. Review of current data-processing methods used in Breakthrough Listen.

Questions 1: Why are narrowband signals of particular interest in SETI searches?

- A) They are typically produced by natural cosmic phenomena.
- B) They are more likely to be of technological origin than broadband signals.
- C) They are easy to detect in noisy environments.
- D) They are commonly emitted by stars.

Question 2: Which tool is most commonly used in SETI to search for narrowband radio signals?

- A) SETI@home
- B) turboSETI
- C) HyperSETI
- D) OpticalSETI

Question 3: What is one challenge of using narrowband signals to detect extraterrestrial intelligence?

- A) Narrowband signals are highly likely to be natural in origin.
- B) Narrowband signals are difficult to distinguish from Earth-based interference.
- C) Narrowband signals can only be detected in the optical spectrum.
- D) Narrowband signals are too weak to be detected over large distances.