DRAFT SYLLABUS

Astronomy/Physics/Engineering 256 – The Search for Extraterrestrial Intelligence (SETI): Scientific and Technical Fundamentals

Course Instructor: To be determined
Lectures: Twice a week of one hour duration
Office Hours: To be determined

General Information:

This course is intended to be an elective for first year graduate students in Astronomy, Physics or Engineering, and advanced undergraduates meeting the prerequisites are also welcome. The purpose of the course is to acquaint the student with the modern concepts of SETI, including the ability to understand the scientific and technical SETI research literature. No previous SETI knowledge is assumed, as all needed concepts will be developed in the course. The topics and their emphasis during the course are subject to change, depending upon the student's backgrounds and interests. Student discussion and interaction during the lectures is encouraged.

After successfully completing the course, the student will achieve a fundamental understanding of the following topics:

1) The science and technology that pertains to conducting a SETI project
2) The physics related to the transmission and reception of electromagnetic waves through interstellar space
3) Practical engineering aspects of telescope design, phased arrays, signal processing and space communication
4) ETI search strategies, their merits and deficiencies
5) An informed personal opinion about the prospects for the success of SETI
6) Scientific and technical publications about SETI
7) Humanity's place in the universe through the use of scientific processes

The prerequisites are physics including Maxwell's equations and introductory quantum mechanics, and math up to and including the theory of complex variables and solution of partial differential equations, and basic computer programming skills. Familiarity with basic astronomy and electrical circuit design concepts helpful but not required.

All information about this course will be available and maintained on a website, including schedule, assignments, and documents.

Textbook:

There is no textbook covering the material to be presented, but lecture notes will be available. Supplemental reference material, including research literature, will be documented or available for download at the course website.

Course Grading:

The course grade will be based on the following:

1) Homework Problem Sets: these will count for 60% of the grade and thus will be the most important component. Homework will be assigned about every two weeks.
2) Class Participation: student participation, leading to active discussion about each SETI related topic, is encouraged for 10% of the grade
3) Midterm Exam: 10%
4) Final Exam: 20%

Topics:

Here is a partial list of SETI topics to be discussed. Others may be added based on student participation and preference. Guest lecturers who conduct SETI investigations or research in SETI associated disciplines will also be invited.

What is SETI? Is it a science? What are the reasons that SETI can succeed or fail? Scientific arguments that ETI could be either abundant or rare in our galaxy. Common arguments supporting the "Fermi Paradox", including the feasibility of galactic colonization, and their rebuttal.

The nature of the detected signal, benefits to society, SETI cost estimates.

Historical Background – survey of scientific and technical literature, the nature and limitations of initial sporadic attempts. The merits and benefits of coordinated searches such as HRMS, Phoenix, SERENDIP, SETI@Home, Breakthrough Listen and with the Allen Telescope Array (ATA). Examples of false positive SETI events, and methods to assess the importance of a candidate SETI signal.

The physical nature of our universe – cosmology, physical laws, origin and distribution of stars and planets, distance scales, constraints imposed by nature on contact with ETI

Techniques for detecting extrasolar planets capable of supporting terrestrial life, summary of current results and planned investigations

The prospects for extraterrestrial life in the universe – biological evolution, cultural evolution, development of intelligence

Estimating the number of ETI – derivation of the Drake equation. Other estimate methods.

Possible methods of contact – interstellar travel, probes, exotic space propulsion methods

Communication by electromagnetic waves – fundamentals, information theory, message composition

Effects of the interstellar medium and cosmic background radiation on the efficiency of electromagnetic communication. The detectability of signal types, information and bandwidth considerations.

Properties of radio and optical telescopes, antennas and receivers

Optical SETI – principles, technology, current efforts

Exotic ETI detection techniques – using stars as gravitational lenses, the FOCAL mission, Dysonian SETI, and the possibility of non-EM methods such as neutrinos or gravitational waves.

Engineering considerations for practical SETI

Signal Processing methods and algorithms – Fast Fourier Transform (FFT), Karhunen–Loève transform (KLT), "Taylor Tree" and so on. The practicality of implementing these algorithms with representative examples. How SETI could take advantage of advances in conventional computing (Moore's law) or new technologies such as quantum computers.

Search Strategies – targeted, all-sky, and combination "targeted-sky surveys" enabled by synthesized beams using a radio telescope array. Search strategies that offer effective SETI and radio astronomy to take place simultaneously. The respective merits of searching for narrow-band vs. moderate to wide bandwidth signals. Searches based on the timing of natural processes and events, such as the relative position of Earth and exoplanets.

SETI beacons – feasibility, engineering considerations

The Allen Telescope Array (ATA) – history, funding, technical capabilities, SETI and results from ATA observations. A review of the motivations for the design of the ATA. How did its purpose for SETI observations influence its design? Specific topics to be discussed: Antenna size vs. total cost, advantages of multiple beams, and possibilities for the SKA.

Other uses of SETI systems technology and algorithms: astronomy with SETI systems, space debris detection, and commercial applications.

The effects of radio frequency interference (RFI) – mitigation, the optimal location for receiver placement. Sources and characteristics of RFI encountered in SETI. Methods for mitigation: Two-star strategy, pseudo-interferometry, using multiple beams. Exotic locations for SETI antennae, such as the lunar far side or in space. Design considerations

in SETI electronics to preserve signal integrity and shielding techniques to prevent self-interference.

Current and near term large radio telescopes and arrays for SETI: Green Bank Telescope, Arecibo, Parkes, FAST, Square Kilometre Array (SKA), and others. Their sensitivity and effectiveness to reduce spurious signals caused by radio frequency interference (RFI) from terrestrial sources.

SETI priority in both public and private funding. Benefits and obstacles to carrying out a full scale search.

Prepared by Larry Lesyna, 1 Dec 2014 LXL Technology
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seti@lxltech.com
+1 702 518 4131