

## **ASTRONOMY 107—LIFE BEYOND EARTH**

**Professor Tom Bania**

**Fall 2015**

About 10% of the planets in our Milky Way galaxy are like Earth in size and material composition. The same physical laws operate everywhere so extraterrestrial life may be both common and technologically advanced. Where is Everybody?

*Life Beyond Earth* (LBE) satisfies the CAS Natural Science non-laboratory general education requirement. LBE requires no prerequisite courses; all essential material is covered in lectures and assigned readings in texts and websites. LBE only requires mathematical skills at the level of high school algebra and geometry.

**LECTURES:** Tuesdays (T) and Thursdays (R) in CAS 213 from 11:00 a.m. to 12:30 p.m.

### **LIFE BEYOND EARTH:**

#### **A Consideration of Extraterrestrial Civilizations from Without and Within**

The history of Humankind shows a profound relationship between resources, technology, and population. Through the development of technology, our species has continuously increased the available resources while the population expanded. The resources of any single planet, however, are finite. No individual planet can support unlimited growth. To continue to grow, every advanced civilization must sooner or later move away from its home planet to gather the needed energy and material resources. We already have the technology to begin the colonization of space. The first large, closed-cycle colonies will be manufacturing centers that will process raw materials from the Moon and the asteroids. Once Humankind begins this sort of technological exploitation of our solar system's resources, it is inevitable that large human populations will be living off-planet in very large space habitats. Part of Humankind will be living in space permanently; many human generations will spend their lives in space.

Once people have become accustomed to living in space habitats, it makes no difference where these colonies are. Some colonies will eventually be used as multi-generational starships. If Humankind follows this path, our exploitation of the resources of the entire Milky Way Galaxy will be profound. Within the next century, a contingent of human beings can be living in colonies away from the Earth. Within a few centuries the entire Solar System can be colonized. Using design concepts already in existence, multi-generational ships can be built that will be capable of reaching the stars. Furthermore, people used to living in space colonies will find life aboard such ships to be rich, rewarding, and perfectly normal. With quite conservative assumptions, the time it will take for Humankind to colonize the entire Galaxy is about 50 million years.

Our Milky Way Galaxy is about 10 billion years old. Any technological civilization should be able to go through this same process of expansion. If there are a significant number of advanced civilizations in the Galaxy, then at least one colonization front should have reached us by now.

### *Where are they?*

In 1950, during a casual conversation with colleagues about the possibility of extraterrestrial intelligence, the great physicist Enrico Fermi is reputed to have immediately asked: "Where is Everybody?" This conundrum, known as the Fermi Paradox, provides the focus for LBE.

**OFFICE HOURS:**

Professor Bania's office is in CAS 514G (x3-3652)(bania@bu.edu). His office hours are on Tuesday/Thursday, 2–3:30 pm and Wednesday, 1–2 pm. The best way to contact him is via email.

Ms, Kerry Hensley is the AS 107 Teaching Assistant (TA), Kerry will conduct the weekly Discussion Sections. Her office is in CAS room 524 (x3-6554)(khens@bu.edu). Her office hours are Monday, 11am–12pm, Wednesday, 11am–12:30pm and Friday 2–3pm.

Please make an appointment if you wish to see us at other times.

**REQUIRED TEXTS:**

Should be available at the BU bookstore. If you choose to purchase online be sure to get the right editions. Electronic books are sufficient, but be warned that "The High Frontier" eBooks that I see are *not* the 3rd Edition.

- *The Living Cosmos: Our Search for Life in the Universe (Updated Edition)*, by Chris Impey, ISBN 978-0-521-17384-1 ("LC" hereafter for reading assignments)
- *If the Universe is Teeming with Aliens... Where is Everybody?*, by Stephen Webb, ISBN 978-0-3879-5501-8 ("WIE" hereafter)
- *The High Frontier: Human Colonies in Space*, Third Edition, 2000, Gerard K. O'Neill. ISBN 978-1896522678 ("HF" hereafter)

**WEBSITES:**

- The LBE web site can be found at <http://learn.bu.edu/> with the name **15fallcasas107\_a1** N.B. You **must** have an ACS account to access BlackBoard Learn. All LBE lectures will be available on this site as Portable Document Format (.pdf) files. N.B. As of 2 September 2015, this web site is still a work in progress.
- [https://www.cfa.harvard.edu/~ejchaisson/cosmic\\_evolution/](https://www.cfa.harvard.edu/~ejchaisson/cosmic_evolution/) Eric Chaisson's *Cosmic Evolution* site is a fundamental resource. ("CE" hereafter)
- *Life Beyond the Earth: A Consideration of Extraterrestrial Civilizations from Without and Within*, by Robert T. Rood, Thomas M. Bania, & James S. Trefil will also be used for LBE. This book draft will be available online at a location TBD. ("LBE" hereafter)
- Numerous external web sites will be identified during lectures.

**RECOMMENDED BOOKS:**

These are useful references. They are *not* required and so are *not* available at the BU bookstore. Consider used texts and sharing.

- *Life in the Universe*, Third Edition, 2012, Bennett & Shostak, Addison Wesley. ISBN-10 0-321-68767-1
- *Are We Alone? The Possibility of Extraterrestrial Civilizations*, by Robert T. Rood and James S. Trefil, Scribners. Long out of print you will only be able to find it online or in a library.

**GRADES:** Your final semester grade will be based upon performance in the following: (1) Two In Class Exams (25% each; dates TBD); (2) a comprehensive Final Exam (25%); and (3) discussion section (25%). Discussion section grades will be based on attendance, weekly quizzes, bi-weekly homework, and participation.

**FINAL EXAM:** The Final Exam will be held on Thursday, 17 December 2015, between 12:30 p.m. and 2:30 p.m. in room CAS 213.

## **LIFE BEYOND EARTH TOPICS**

**(Order subject to change)**

Reading assignments are listed in *THIS FONT*. You are expected to read the LC, WIE, and HF texts in their entirety. See page 1 for definitions of LC, WIE, HF, CE, and LBE. Here, “ch” means “chapter”, “pp” gives a page range, and “ep” is the Epoch number in the CE website.

### **Week 1 — Life Beyond Earth Overview**

The Galactic Year. The Drake Equation. The Future of Humankind. Fermi Paradox.

LC: pp 264–271; WIE: ch 1&2; HF: pp 1–2;7 CE: ep 1, summary only LBE: ch 1, “Interlude”

### **Weeks 2 & 3 — The Universe: What We Know and How We Know It**

Scientific Method. Four Forces in Nature. Electromagnetic Spectrum. Atoms and Molecules. Spectroscopy. Doppler Effect.

LC: ch 1; CE: ep1, Age Controversies only; LBE: ch 9

### **Week 4 — Our Place in the Universe: The Milky Way Galaxy**

Milky Way Formation and Age. Giant Molecular Clouds. Star Clusters.

CE: ep 2; lecture

### **Week 5 — Star Formation and Evolution**

Formation and Evolution of Stars. Stellar Nucleosynthesis. We are star stuff.

CE: ep 3; LBE: ch 2, 3, & 4

### **Week 6 — Planet Formation and Evolution**

Formation of the Solar System. Earth’s Origin and Evolution. Greenhouse Effect and Climate.

LC: pp 138–169, ch 5; CE: ep 4

### **Week 7 — Life, Intelligence, Technology, and Planetary Civilization**

Origin of Life. Rise of Mammals and the Storage of Information. Evolution of Societies.

LC: ch 2,3 pp 170–181, 284–294; CE: ep 5, 6, & 7; LBE: ch 5 & 6

### **Week 8 — Finite Resources and Limits to Growth**

*“Is the surface of a planet really the right place for an expanding technological civilization?”*

— G. K. O’Neill Malthus, Overpopulation, and *The Club of Rome*.

HF: pp 28–44, 104–114; CE: ep 8; LBE: ch 12

### **Week 9 — Future of Humankind: Interstellar Travel and Interstellar Colonization**

*“If you get to low-Earth orbit you are halfway to anywhere.” — R. A. Heinlein*

Resources from Space: Mining the Sky. Getting up here: Rockets, Project Orion, and the Space Elevator. Space Colonies. Lunar Colonies. Interstellar Travel. Interstellar Colonization.

HF: pp 45–103, 115–171; CE: ep 8; LBE: ch 13 & 14

### **Week 10 — SETI: Search for Extraterrestrial Intelligence**

History: Project OZMA, NASA SETI, Project Phoenix, and the SETI Institute. Search strategies. SETI vs CETI (Communication with Extraterrestrial Intelligence).

LC: pp 295–310; CE: ep 8; LBE: ch 10

### **Week 11 — The Drake Equation: Reprise**

Principle of Mediocrity. Anthropic Principle. Extra-solar planets.

How many extra-terrestrial civilizations might there be?

LC: pp 222–246, 272–283; CE: LBE: ch 8

### **Weeks 12 & 13 — The Fermi Paradox: Where are They?**

Solutions to the Fermi Paradox: (1) “They” are already HERE. (2) “They” exist, but are not here. Yet. (3) “They” do not exist.

WIE: ch 3 through 7; HF: CE:

**DISCUSSION SECTIONS:** Weekly discussion sections are held in CAS B04. **You must attend one of the discussion sections:**

| Section | Day | Time            | Current Enrollment (Limit is 16) |
|---------|-----|-----------------|----------------------------------|
| A2      | T   | 03:30pm–05:00pm | 16                               |
| A3      | W   | 03:30pm–05:00pm | 13                               |
| A4      | F   | 12:30pm–02:00pm | 9                                |

**The first section meets on TUESDAY, 9 September 2015.**

This means that **all** new section activities will start on Tuesdays. Your performance in discussion section will comprise 25% of your final grade. You will be graded on: (1) Attendance (mandatory); (2) Weekly quizzes; (3) Bi-weekly homework; and (4) Participation. Below is an outline of the Discussion Section schedule. Further details will be forthcoming during section.

**HOMEWORK:** My goal is to exercise and improve your critical inquiry and research skills. The broad ideas in LBE are particularly amenable to straightforward, but interesting “back of the envelope” quantitative calculations (“Fermi numbers”).

#### **DISCUSSION SECTION SCHEDULE (Subject to Change)**

**Week 1** — “Textbook” Planet

**Week 2** — Introduction. Videos: *Powers of Ten*. Fermi numbers. The Drake Equation.

**Week 3** — Scientific Method. Forces of Nature. Periodic Table.

**Week 4** — Properties of Light. Atoms and Molecules. Spectroscopy

**Week 5** — Milky Way. Molecules in Space. Stellar Nucleosynthesis. Review for Exam No. 1

**Week 6** — Earth Formation. Video: *Planet Earth: The Climate Puzzle*

**Week 7** — Origin of Life. Biological Evolution. Societal Evolution.

**Week 8** — Video: *Other Worlds? The Search for Habitable Planets*

**Week 9** — **Review for Exam No. 2**

**Week 10** — The Lotus Mark V Ecohabitat.

**Week 11** — Movie: *What is E.T. Made Of?*

**Week 12** — **NO SECTIONS! Fall Recess week!**

**Week 13** — Video: *The Fermi Paradox*

**Week 14** — **Review for Final Exam**

## **ABSENCES:**

**Attendance is expected at all meetings of the course.**

In the case of personal illness, first and foremost, please take good care of yourself. Do what you need to do to regain your health. Please contact me as soon as you are able so that we can work together to help get you back on track insofar as AS 107 course work is concerned. Absences due to other reasons — religious holidays, team sports, family issues, etc. — must be discussed with me **before** the absence occurs, if at all possible. Emergencies will be dealt with on a case by case basis.

It is your responsibility to make up for any course related issues that result from your absence. We shall help where we can. For logistical reasons, in some cases discussion section events simply cannot be reproduced.

## **LATE WORK:**

Without a valid excuse or prior arrangement, late work will be subject to the following policy: (1) less than 24 hours late: forgiven the first time, –10% for subsequent infractions; (2) 24 hours to one week late: –50%; and (3) more than 1 week late: no credit.

## **ACADEMIC CONDUCT:**

It is your responsibility to know and understand the Boston University Academic Conduct Code: <http://www.bu.edu/academics/resources/academic-conduct-code/>

Misconduct involves more than just cheating on the exams. All work handed in for credit must be your own. I encourage you to study together, but to submit the homework assignments separately. You may help each other to find out how to solve a problem, but you must present your own discussion and steps needed to achieve the solution. You must take care not to work so closely with a classmate that your answers are nearly identical. I **MUST** refer all cases of suspected academic misconduct to the Dean's Office. I will assign a punitive grade (usually an "F" or 0) for any assignment that was judged by the Dean to be plagiarized. Note that any such decision is made after a hearing before a faculty/student Academic Conduct panel.

## **IMPORTANT ACADEMIC DATES:**

For Fall 2015 the following dates control the add/drop process. I cannot alter any of these dates.

**16 September 2015**, is the last date that a student can enroll ("ADD") into AS 107 for the Fall 2015 semester.

**7 October 2015**, is the last date that a student can withdraw from ("DROP") a class without receiving a "W" (withdrawal) on their transcript.

**6 November 2015**, is the last date that a student can drop a class. Student will receive a "W" on their transcript.

**1 December 2015**, is the last day to officially take a leave of absence or withdraw from the University.