

COSMOS, LIFE, AND CIVILIZATION: Are We Alone?

Lecturer

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1. Course Outline

In this course you are to confront the following questions about life in the Universe: 1) What had happened to allow the Universe to support life? 2) How did life originate and evolve on Earth, and how differently might it do elsewhere? 3) Where else might life have arisen in the Galaxy, what might it be like, and how can we find it? These questions are of the fundamental importance to the past, present and future of the life and civilization on Earth. In answering them we have no choice other than to make a full use of our current knowledge of the terrestrial life, no matter how incomplete it may be.

We take the solar system as an example of exo-planetary ones, if they exist in the Galaxy, and examine whether life and civilization are natural outcomes of the cosmic evolution over some billion years. The evolution of matter in the Universe is first followed from the big bang to the formation of heavy elements *via* nucleosynthesis in the very cores of massive stars. Elements heavier than helium are the chemical ingredients that are essential for the makings of earth-like rocky planets harboring life.

We follow the dynamical evolution of interstellar cloud from the stage of its gravitational collapse to the formation of rotating disk, wherein rocky planets are expected to form. This will lead us to conclude that planets are to be found around many stars at least in our Galaxy. We then analyze orbits of the exo-planets so far detected in a view point of finding counter parts of the solar terrestrial planets.

The existence of extra-solar planetary systems does not necessarily mean that every exo-planet could harbor life at any level of sophistication. We will examine the chemical and biological evolutionary paths the Earth has gone through over the last 4.6 billion years. This will tell us that the same path may hold true for extra-solar rocky planets as well. If that is the case, there must be exo-planetary civilizations so highly advanced that could have visited Earth. But we have no concrete evidence for such visits so far. This will be discussed in a view point of the curve-of-growth for the terrestrial civilization and also for exo-planetary ones.

We may now ponder upon the following quote from the German philosopher, Karl T. Jaspers(1883-1969):

Ein mittelalterlicher Spruch lautet: Ich komme, ich weiss nicht woher. Ich bin, ich weiss nicht wer. Ich sterb, ich weiss nicht wann. Ich geh, ich weiss nicht wohin."
--- 『Der philosophische Glaube angesichts der Offenbarung』, Piper, München-Zürich, 3e., 1984, 28-29 ---

By the time you finish this course, you may be qualified to change the part 'Ich weiss nicht ...' in the above quotation to a clause like 'I do know at least partially ...', after the subject 'Ich' in each sentence having been replaced by one of 'human beings', 'Earth', 'the terrestrial life', and 'the Earth civilization.'

2. Text Books

- Kevin W. Plaxco and Michael Gross 2006, *ASTROBIOLOGY: A Brief Introduction* (The Johns Hopkins University Press: Baltimore), pp 259, ISBN 0-8018-8367-9
- Lewis Dartnell 2007, *Life in the Universe* (Oneworld Publications: Oxford), pp 202, ISBN-13: 978-1-85168-505-9

3. Course Schedule

1) July 6 - 10: Cosmic Settings for Life

what is life - astrobiology; definition of life;

bing bang & nucleosynthesis - primordial H and He; stellar nucleosynthesis of heavy elements; a habitable universe

from cloud to planet - gravitational collapse of interstellar cloud; formation of star, proto-planetary disk, and planets; a habitable planet; heavy bombardment

primordial soup_1 - Miller-Urey Chemistry; synthesis of amino acids

Reading Assignments of the Week July 6:

- Plaxco & Gross 2006, pp. 1~91.
- Dartnell 2007, iix~29, 53~86.
- Carl Sagan 1973, *The Cosmic Connection, An Extraterrestrial Perspective* (Dell Pub: N.Y.), pp. vii~72

➤ Take the first quiz.

➤ Fix the topic of expository essay.

2) July 13-17: Origin and Evolution of Life

- *primordial soup_2* - non-Miller-Urey sources of life's building blocks; pre-biotic chemistry; spark of life; earliest evidence of the existence of life

- *from molecules to cells* - RNA as encoder and catalyst; formation of DNA; precursors to RNA; vesicle formation; precursors to cells

- *first complex ecosystem* - ecosphere; LUCA; photosynthesis & oxygen revolution;

advent of aerobic metabolism; eukaryotes; bigger and better cells

- *a brief history of earth-life* – Darwin evolution; Cambrian explosion; snowball earth; explosions of life; extinctions of life

Reading Assignments of the week July 13:

- Plaxco & Gross 2006, pp. 92~170.
- Dartnell 2007, 86~108.
- Carl Sagan 1973, *The Cosmic Connection, An Extraterrestrial Perspective* (Dell Pub: N.Y.), pp. 73~166.

➤ Take the second quiz.

➤ Submit the progressive report on the expository essay in a written form.

3) July 20-27: Search for Extraterrestrial Life and Civilization

- *Mars & Venus* – Goldilocks problem; water everywhere; direct evidence of liquid water; evolution of Martian life; environmental collapse; terraforming the planets
- *elsewhere in the Solar system* – snow line; tidal evolution; tidal heating; Europa; Titan
- *extra-solar planets* – detection methods; hot jupiter; statistics; habitable zone; stars like Sun; red dwarf
- *signatures of life* – Gaia & OhnSaengMyung; spectroscopic signatures of life
- *alien worlds* - what would an alien look like; classification of cosmic civilizations; Fermi paradox; curve-of-growth theory; signatures of alien civilizations; search strategy for detecting extraterrestrial intelligence; interstellar radio communication; interstellar travel; friendly or hostile?

Reading Assignments of the Week July 20 :

- Plaxco & Gross 2006, pp. 192~249.
- Dartnell 2007, 109~184.
- Carl Sagan 1973, *The Cosmic Connection, An Extraterrestrial Perspective* (Dell Pub: N.Y.), pp. 167~267.

Take the final quiz.

Submit the final report on the expository essay in a written form.

Present the final report on the expository essay to the class with a ppt.

4. Topics and Primary References for the Expository Essay

1) Inventory of Carbon on Earth

- Falkowski, P., Scholes, R.J., Boyle, E., Canadell, J., Canfield, D., Elser, J., Gruber, N., Hibbard, K., Hogberg, P., Linder, S., Mackenzie, F.T., Moore, B., Pedersen, T., Rosenthal, Y., Seizinger, S., Smetacek, V., and Steffen, W. 2000, The Global Carbon Cycle: A Test of our Knowledge of Earth as a System, *Science*, 290, 291-296.

2) Comets and Life on Earth

- Allamandola, L.J., d'Hendecourt, L. 2004, A tribute to the Life and Science of J. Mayo Greenberg, in *Astrophysics of Dust*, ASP conf. ser. Vol 309, eds. A.N. Witt, G.C. Clayton, B.T. and Draine, p. 1

3) Water as an Element of Life

- Kasting, J.F. and Catling, D. 2003, Evolution of a Habitable Planet, *Annual Review of Astronomy & Astrophysics* **41**, 429-463

4) The Origin of Water on Earth

- Mottl, M., Glazer, B., Kasiser, R. and Meech, K. 2007, Water and Astrobiology, *Chemie der Erde/ Geochemistry* **67**, 253-282

5) Comets as Sources of Terrestrial Water

- Chyba C.F. 1990, Impact Delivery and Erosion of Planetary Oceans in the Early Inner Solar System, *Nature*, 343, 129-133.
- Delsemme, A. 1996, The Origin of the atmosphere and of the oceans, in *Comets and the Origin and Evolution of Life*, eds. P.J. Thomas, C.F. Chyba, C.P. McKay, (Springer: N.Y.), p. 29.

6) Extremophiles and the Span of Terrestrial Biotic Environments

- Lunine, J.I. 2005, *ASTROBIOLOGY: A Multidisciplinary Approach* (Pearson Education, Addison Weley: N.Y.), 305-328.
- Kevin W. Plaxco and Michael Gross 2006, *ASTROBIOLOGY: A Brief Introduction* (The Johns Hopkins University Press: Baltimore), pp. 171-191.
- Lewis Dartnell 2007, *Life in the Universe* (Oneworld Publications: Oxford), pp. 30-52.

7) External and Internal Influences in the Evolution of Life

- Lunine, J.I. 2005, *ASTROBIOLOGY: A Multidisciplinary Approach* (Pearson Education, Addison Weley: N.Y.), 514-545.

8) Evolution of Intelligence and the Persistence of Civilization

- Lunine, J.I. 2005, *ASTROBIOLOGY: A Multidisciplinary Approach* (Pearson Education, Addison Weley: N.Y.), pp. 546-567.

5. Grading

class participation : quiz : expository essay = 10 : 45 : 45

6. Further Reading

- Dick, S.J., and Strick, J.E. 2005, *The Living Universe, NASA and the Development of Astrobiology* (Rutgers Univ Press: New Brunswick, N.J.), pp. 308.
- Gargaud, M. Martin, H. and Claeys, P. (eds) *Lectures in Astrobiology* vol I (Springer: N.Y.), pp. 530.
- Gargaud, M. Martin, H. and Claeys, P. (eds) *Lectures in Astrobiology* vol II (Springer:

- N.Y.), pp. 669.
- Gluckman, P. and Hanson, M. 2006, *Mismatch, Why our World No Longer Fits our Bodies* (Oxford Univ Press: Oxford, UK), pp. 285.
- Horneck, G. and Retterg, P. (eds) *Complete Course in Astrobiology* (Wiley-VCH: Weinheim), pp. 412.
- Kauffman, S.A. 1995, *AT HOME IN THE UNIVERSE, The Search for Laws of Self-Organization and Complexity* (Oxford Univ Press: N.Y.)
- Kauffman, S.A. 2008, *Reinventing the Sacred, A New View of Science, Reason, and Religion* (Brockman, Inc. : N.Y.) pp. 321.
- Kwok, S. 2016, *Stardust, The Cosmic Seeds of Life* (Springer: N.Y.), pp. 267.
- Lovelock, J. 1995, *Gaia, A New Look at Life on Earth* (Oxford Univ Press: Oxford, UK), pp. 148.
- Lunine, J.I. 2005, *ASTROBIOLOGY: A Multidisciplinary Approach* (Pearson Education, Addison Weley: N.Y.), pp. 586.
- Monod, J. 1971, *CHANCE AND NECESSITY* (Alfred A. Knopf : N.Y.), pp. 199.
- Sagan, C. 1973, *The Cosmic Connection, An Extraterrestrial Perspective* (Dell Pub: N.Y.), pp. 267.
- Sagan, C. 1980, *COSMOS* (Random House: N.Y.), pp. 365.
- Schrödinger, E. 1967, *What is Life? : The Physical Aspect of the Living Cell* (Cambridge Univ Press: Cambridge, UK), pp. 1-96.
- Scharf, C.A. 2009, *Extrasolar Planets and Astrobiology* (University Science Books: Sausalito, CA, USA), pp. 470.
- Trefil, J. 1997, *Are We Unique? A Scientist Explores the Unparalleled Intelligence of the Human Mind* (John Wiley & Sons: N.Y.), pp. 242.
- Websites of Some Interest:
<http://www.astrobio.net/>
<http://www.astrobiology.com/>
<http://www.seti.org/>
<http://www.space.com/>

How did life get started? How did our fantastically complex civilization develop? When will we encounter other civilizations out there, if ever? This book will explore our history and place in the Universe, examine why Earth is so hospitable for life and civilization, and consider the likelihood for life to exist on other worlds, some that may be far more different than our own. Our world is rare enough that we may appreciate it just as much as if we are in fact alone. Recent studies have shown that, while life's ingredients are common throughout the Universe, the exact quantity and assortment of chemicals and minerals that make up Earth are unlikely to exist elsewhere. In other words, given the enormous amount of real estate in space, aliens are sure to exist. So why haven't we found any? I don't dispute this straightforward idea because, after all, it underpins the search for extraterrestrial intelligence (SETI). But not everyone agrees. A recent paper by three researchers at the University of Oxford is throwing shade on those who feel confident that the cosmos is thick with extraterrestrials. The Oxford academics were addressing a puzzle known as the Fermi Paradox, which describes the disconnect between our expectation of many worlds swarming with aliens and the fact that we are alone. Are humans unique and alone in the vast universe? This question--summed up in the famous Drake equation--has for a half-century been one of the most intractable and uncertain in science. But a new paper shows that the recent discoveries of exoplanets combined with a broader approach to the question makes it possible to assign a new empirically valid probability to whether any other advanced technological civilizations have ever existed. And it shows that unless the odds of advanced life evolving on a habitable planet are astonishingly low, then human kind is not the universe's first technologi