

Revitalize Your Introductory Courses with Modern Topics such as SETI

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Modern Physics

American Association of Physics Teachers president Ruth Howes stated in a recent editorial:

"We [physics teachers] have assumed that ordinary folk like chemists and biologists, to say nothing of lawyers and journalists, should learn only the well-established basics. We have kept the exciting stuff to ourselves and our chosen followers. ...Our courses almost never discuss anything newer than the development of quantum mechanics and relativity in the first decades of the last century." (Howes 2000)

It is paradoxical that introductory physics courses, the only physics that most of our students will ever learn, fail to present the current scientific view of the physical universe. Students learn, instead, how to solve problems using methods of Newtonian physics, and if the course is a good one they learn the great principles of 17th, 18th, and 19th-century physics. But classical physics, which applies to only a relatively small fraction of physical reality, and then only approximately, is seriously and fundamentally flawed both quantitatively and qualitatively.

Furthermore, contemporary physics is the more popular thing to teach! For example: What kinds of physics books do non-scientists pick up voluntarily? Recently, many have picked up Brian Greene's *The Elegant Universe*, a sophisticated presentation of general relativity, quantum field theory, and string theory, without algebra and without oversimplification, in language that non-scientists can grasp. People are fascinated by physics, but they want, and deserve, to learn *today's* physics. It is surprising that, at a time of declining enrollments, we throw away our most exciting resource, namely modern physics.

We can take a tip from astronomy, a field that is popular both in the classroom and in the bookstores. Unlike most physics courses, most introductory astronomy courses are contemporary and conceptual (non-algebraic). One fascinating and physics-packed modern topic that is usually included in astronomy courses but unfortunately ignored by physics courses, is SETI: the search for extraterrestrial intelligence.

SETI

I will outline the two SETI lectures in my one-semester physics course for non-scientists (for further details see Hobson 1999). Their purpose is to present SETI, to apply the principles of energy, thermodynamics, electrodynamics, and special relativity (these have already been presented by this point in the course), to illustrate scientific methodology, and to consider a social implication known as "Fermi's question."

Because of all the pseudoscientific nonsense surrounding extraterrestrial life, we begin by separating science from pseudoscience. I present an article from a popular tabloid newspaper that is strong on astonishing claims but weak on evidence and scientific principles. During class discussion, it becomes clear that little or no real evidence is offered for such claims as alien visitations, miraculous predictions, communications with the dead, etc.

"Pseudoscience" can be defined as the dogmatic belief in an appealing idea that purports to be scientific but that is not supported by scientific methods. Such beliefs generally lack objective evidence, and may contradict widely-accepted scientific principles such as the laws of thermodynamics. I list some examples: parapsychology, levitation, alien invasions, dianetics, astrology, creationism (a real threat in the United States)--the list goes on and on.

A poll of the class usually reveals that most students believe there is life beyond Earth. Upon inquiring into their *reasons* for this belief, many students reply that "Earth is surely not unique in this respect." This leads into a discussion of the "Copernican Principle," the notion that "there are no special places." After all, physics seems to be the same everywhere. So why, indeed, should Earth be unique?

Most of our class time is occupied with the standard analysis carried out by such SETI pioneers as Frank Drake and Carl Sagan, an analysis that follows naturally from the Copernican Principle. We divide the SETI question into four parts: (1) What is the expected number of Earth-like planets? (2) For Earth-like (capable of supporting life) planets, what is the likelihood of life arising? (3) If life arises, what is the likelihood that it will develop intelligence? (4) If intelligent life arises, then what is the likelihood that it will develop technology (radio

transmitters, for example)? We need to add question (4) if we want our SETI quest to have observable content, because intelligent life will probably be undetectable by us unless it can communicate across space, for instance via radio technology.

Question (1) leads to lots of contemporary astronomy and physics. This is the great age of planetary discovery! We should bring this adventure into our classrooms. Not only the discoveries themselves, but also the physics-based methods of observation, are fascinating. Other topics include star and planet formation, the formation of our solar system, the types of stars that could have Earth-like planets, the possibility of past or even present life on Mars, the extent of our galaxy, the extent of the known universe.

Question (2) has been the subject of many biochemical investigations, leading to the hypothesis of a chemical origin of life on Earth. The 1953 Miller-Urey experiment, showing that amino acids and nucleic acids form spontaneously under a variety of conditions thought to simulate early Earth conditions, is worth describing.

When we come to questions (3) and (4), observations and experiments are sparse. These questions can stimulate worthwhile speculation, but conclusions must be very tentative.

With each of the four questions, I include a plausible numerical estimate, while always reminding the class that such estimates are highly speculative. To focus the discussion, we restrict it to our Milky Way galaxy, with the remark that there are at least billions of galaxies in our universe. Most scientists who have spent much time considering SETI believe there may be a billion or more Earth-like planets in our galaxy. Furthermore, the ease with which biological precursor molecules form, and the plausible mechanisms for further "chemical evolution," lead most scientists to conclude that on a significant fraction (such as 10%) of these Earth-like planets, life arose.

Thus, it is quite plausible that life arose in millions or billions of places, in our galaxy alone! Although speculative, this is a highly significant hypothesis. It implies that life, while existing around only a small fraction of stars, is nevertheless abundant throughout the universe! Life is a characteristic feature of the cosmos.

Our speculation has led us to two plausible hypotheses, namely that Earth-like planets and life are abundant, and to a framework for asking such questions. Beyond this, the uncertainties make speculation difficult. Such uncertainty is expected whenever we explore new territory. Despite the uncertainties, some scientists have always been willing to carry the speculation further. One of these was Enrico Fermi.

Fermi's Question: Where Is Everybody?

Fermi was conversing with physicists Edward Teller, Herbert York, and others over lunch one day at Los Alamos in 1950. The talk turned to possible modes of interstellar travel. All agreed that Earth had not been visited by alien spacecraft. Then Fermi asked "Don't you ever wonder where everybody is?" He followed this up with a series of calculations, similar to the four steps outlined above, leading to the conclusion that we should have been visited long ago and many times over. He further concluded that the reason we have not been visited might be that interstellar travel was impossible, or that it is always judged not to be worth the effort, or that technological civilization doesn't last long enough for it to happen. (Kuiper and Brin 1989).

Fermi's reasons for the absence of visitations are worth discussing. Teller, Freeman Dyson, and others have outlined several modes of interstellar travel that seem feasible for a civilization that has possessed technology for at least many centuries (Hobson 1999). Perhaps unknown dangers prevent this (Fermi's first suggestion), or perhaps advanced civilizations judge the effort as not worthwhile (Fermi's second suggestion).

Fermi's third suggestion is sometimes called the "short lifetime hypothesis." Do civilizations survive their own technology? Our only example is us. Humans (bipedal hominids) have been here for 5 million years, and became technological (with radio) a mere century ago. Will we survive, as a technological society capable building devices such as radios?

The evidence is not encouraging: Organized killing between members of our own species continues all over the world. Already 6 billion strong and a strain on Earth's resources, we continue growing exponentially. Other known problems that could destroy the hope of a prosperous future society include poverty, illiteracy, superstition, deforestation, animal and plant extinctions, global warming, resource exhaustion, new epidemics, and many more. The unknown problems are anybody's guess. Whether one agrees with Fermi or not, the great physicist's third suggestion is a sobering perspective on the sustainability of our own civilization.

All in all, SETI is an intellectual feast that we should be eager to share with our students.

References and notes

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