

Enigmas of the Universe

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Overview: Astronomy has seen tremendous progress in the past century. Large telescopes on the ground and in space now give us views of the universe across the electromagnetic spectrum. Powerful computers can handle exponentially increasing volumes of data and they allow simulations of remote objects and extreme astrophysics. We know how stars work, how many galaxies there are, and how to find exoplanets. Yet there is much we don't know, and areas where our physical understanding is weak. This course is a report from the frontiers of astronomy and physics research on five aspects of the universe where profound questions remain unanswered.

Meetings: Typical structure is a 50 minute lecture, then a 10 minute break, a 40 minute lecture, then 20 minutes for questions and discussion. Short descriptions of the five topics follow.

- **The Big Bang.** How did the universe begin? There's ample observational support for the idea that the universe expanded from a hot, dense state billions of years ago. But the nature of dark matter and dark energy are unknown and the situation just after the big bang is shrouded in mystery.
- **Black Holes.** What happens in extreme regions of space-time? Nature can make black holes ranging from ten to ten billion times the Sun's mass and the recent detection of gravitational waves confirms that black holes exist. However, gravity theory is challenged in trying to explain black holes.
- **The God Particle.** Where does mass come from? The detection of the Higgs particle filled in the missing piece of the Standard Model of particle physics. But having a mechanism for mass doesn't explain the "zoo" of elementary particles, and there appears to be a deeper level of structure in nature.

- **Life Beyond Earth.** Are we alone in the universe? Astronomers have found 4000 exoplanets, ranging from hot Jupiters to Earth-like worlds. But they are struggling to be able to detect life on any of these distant planets, and they don't know how biology might operate in other parts of the universe.
- **How It Ends.** What is the fate of the universe and its contents? It appears that the universe will expand forever, and the cycle of star birth and death will cease. But there are unanswered question about the distant future of astronomical objects like galaxies and black holes, and the universe itself.

Background Reading List: Those recommended for the five topics are starred. A set of shorter articles that are required reading will be available as pdf downloads.

How It Began, by Chris Impey, 2012, Norton, 448 pages *

The Big Picture, by Sean Carroll, 2017, Dutton, 480 pages

Black Hole Blues, by Janna Levin, 2017, Anchor, 256 pages

Einstein's Monsters, by Chris Impey, 2018, Norton, 304 pages *

Beyond the God Particle, by Lederman/Hill, 2013, Prometheus, 325 pages *

The Grand Design, by Hawking & Mlodinow, 2012, Bantam, 208 pages

The Living Cosmos, by Chris Impey, 2011, Cambridge, 411 pages

The Planet Factory, by Elizabeth Tasker, 2017, Bloomsbury, 336 pages *

Astrobiology: Short Introduction, by David Catling, 2014, Oxford, 160 pages

How It Ends, Chris Impey, 2010, Norton, 352 pages *

Instructor Bio: Chris Impey is a University Distinguished Professor of Astronomy and Associate Dean of the College of Science at the University of Arizona. He has over 180 refereed publications on observational cosmology and his research has been supported by \$20 million from NASA and NSF. He has won eleven teaching awards and he teaches online classes with over 180,000 enrolled. Impey is a past Vice President of the American Astronomical Society, NSF Distinguished Teaching Scholar, Carnegie Council's Arizona Professor of the Year, and recently, a Howard Hughes Medical Institute Professor. He's researched science literacy, instructional technology, and online teaching, and has published 60 papers on those subjects. He's written more than 50 popular articles on cosmology and astrobiology, two introductory textbooks, a novel called *Shadow World*, and eight popular science books: *The Living Cosmos*, *How It Ends*, *Talking About Life*, *How It Began*, *Dreams of Other Worlds*, *Humble Before the Void*, *Beyond: The Future of Space Travel*, and *Einstein's Monsters: The Life and Times of Black Holes*.