"Dark Matter"

Dark Matter: The Oldest Unsolved Problem in Physics.

Tuesdays: 1:30 PM to 3:00* PM for 5 weeks (09/26/17 - 10/24/17)

Facilitator: John Anderson – andrdap@msn.com or phone 303-770-9360

Course Description:

Scientists know that galaxies and clusters of galaxies are held together by what they call "dark matter". This mysterious stuff can't be seen yet it comprises five times as much of the universe as all the ordinary matter that makes up our world, our bodies, the sun, etc. What is it really?

Physicists have several distinct ideas which we will discuss along with some novel technical jargon. This is a priority problem at the frontier of physics and cosmology.

At the first class, we will view the feature length movie "Particle Fever" which shows the behind the scenes story of the Large Hadron Collider in Switzerland where the Higg's particle (Nobel Prize 2013) was discovered. The LHC is currently searching for clues as to what dark matter is.

Today's Research: We will highlight some of the many laboratories where the search for dark matter is underway. Different approaches include 1) creation and detection of dark matter particles at the LHC, 2) direct detection of dark matter particles in deep underground facilities where rare interactions of dark matter particles with atoms of exotic substances like xenon should be detectable, 3) indirect detection via gamma rays coming from regions of high dark matter concentration where annihilations of dark matter may occur.

The Scientists as People:

Adding interest are the personal stories of the scientists as we will see in the movie "Particle Fever" which shows some of the key people who discovered the Higgs Boson at work at the Large Hadron Collider in Geneva Switzerland.

Clues to Physics Beyond the Standard Model (i.e. major breakthroughs):

Dark matter is definitely beyond our knowledge base today.

- Is Dark Matter a collection Weakly Interacting Massive Particles or WIMPs?
- Is Dark Matter a collection Massive Astrophysical Compact Halo Objects or MACHOS? (Things like dim stars, planets, asteroids, black holes, etc.)
- Is Dark Matter a pool of supercooled axions in which galaxies are immersed?
- Will the LHC find new Supersymmetric particles?
- Is there a fourth type of neutrino that is very massive?
- Is Modified Newtonian Dynamics an alternative given the evidence seen in the Bullet Cluster?

Course Schedule by Week (subject to revision):

	Videos/Lectures	Reading from Freese's *Cosmic Cocktail:*
Week 1, Tuesdays. September 26th 1:30 to 3:30 PM *** NOTE:** 30 min. longer	• Special 2 Hour Movie Screening • "Particle Fever", 99 min movie about the discovery of the Higgs Boson at CERN in Geneva, Switzerland, which is now searching for Dark Matter.	None Available on Netflix
Week 2 October 3rd 1:30 to 3:00 PM	• Introduction to Dark Matter (Academy Website) • Video, "What Holds Each Galaxy Together: Dark Matter" – Dr. Don Lincoln, Fermilab, 30 minutes	Freese Chapter 1 - 3: Pages 1- 66 Source: Great Courses, The Theory of Everything
Week 3 October 10th 1:30 to 3:00 PM	• Review what we know well: The Standard Model (Academy Website) • Video, "Confronting the Invisible Universe" - by Jesse Thaler, MIT given at Aspen Center for Physics, Runtime 1:04:32	Freese Chapter 4 - 6: Pages 68 - 122 Video Link: https://www.youtube.com/watch?v=QNmSNY8VenQ
Week 4 October 17th 1:30 to 3:00 PM	• Online Video: World Science University – Justin Khoury, U Penn. "New Ideas About Dark Matter". (Four parts: 12:08, 11:19, 12:56, 19:36. Total 56 minutes) • Brief Introduction to Supersymmetry (no slides)	Freese Chapter 7 - 8: Pages 123 - 182 Link for video: http://www.worldscienceu.com/
Week 5 October 24th 1:30 to 3:00 PM ***Last Week***	• More explanations. • Sterile neutrinos, if they exist. Don Lincoln. • Super Symmetry, the Lightest Supersymmetric Particle – Don Lincoln, 30 Minutes. • Primordial Black Holes – Scientific American	Freese Chapter 9: Pages 183 – 213 For a short introduction to dark energy Link Seesaw: Sterile Neutrinos https://www.youtube.com/watch?v=bgg32f6wl4o

Biographical information for Don Lincoln (our first video presenter):

Don Lincoln is a Senior Scientist at Fermi National Accelerator Laboratory (Fermilab). He is also a Guest Professor of High Energy Physics at the University of Notre Dame. He received his Ph.D. in Experimental Particle Physics from Rice University.
Dr. Lincoln's research has been divided between Fermilab's Tevatron Collider, until its close in 2011, and the CERN Large Hadron Collider, located outside Geneva, Switzerland. The author of more than 1,000 scientific publications, his most noteworthy accomplishments include serving on the teams that discovered the top quark in 1995 and confirmed the Higgs boson in 2012. He is a fellow of the American Physical Society and the American Association for the Advancement of Science.
His writing at a popular level includes many articles as well as four books: Understanding the Universe, The Quantum Frontier, The Large Hadron Collider, and Alien Universe. His enthusiasm for science education earned him the 2013 Outreach Prize from the High Energy Physics Division of the European Physical Society.
Dr. Lincoln has given hundreds of lectures on four continents to a broad range of audiences. He is a blogger for the website of the PBS television series NOVA, and he also writes a weekly column for the online periodical Fermilab Today.

Biographical information for Jesse Thaler

Jesse Thaler joined the MIT Physics Department in 2010, and is currently an Associate Professor in the Center for Theoretical Physics. From 2006 to 2009, he was a fellow at the Miller Institute for Basic Research in Science at the University of California, Berkeley. He received his Ph.D. in Physics from Harvard University in 2006, and his Sc.B. in Math/Physics from Brown University in 2002. He was awarded an Early Career Research Award from the U.S. Department of Energy in 2011, a Presidential Early Career Award for Scientists and Engineers from the White House in 2012, a Sloan Research Fellowship from the Alfred P. Sloan Foundation in 2013, and a Harold E. Edgerton Faculty Achievement Award from MIT in 2016.

Biographical information for Justin Khoury

Undergraduate Chair of Physics & Astronomy, University of Pennsylvania (2014-)
My research interests lie at the interface of particle physics and cosmology. A central theme of my research program is the possibility that the dark sector includes new light degrees of freedom that couple not only to dark matter but also to baryonic matter. Part of my research efforts over the last few years have focused on the development of screening mechanisms, such as chameleon and symmetron, to explain why such scalars, if light, have escaped detection from laboratory/solar system tests of gravity.

Books for Class (First book strongly recommended:)

- ***The Cosmic Cocktail: Three Parts Dark Matter***, Katherine Freese, Princeton University Press, 2014, ISBN 978-0-691-15335-3, Pages (250). Thorough but no math and little particle physics. New idea: dark stars. Lots of experiments and many collocated with neutrino experiments. Breezy style of writing. Several Colorado connections.
- ***Nature's Blueprint – Supersymmetry and the search for a Unified Theory of Matter and Force***, Dan Hooper, Smithsonian Books, Harper Collins Publishers, 2008, ISBN 978-0-06-155836-8, Pages (230). An overview of modern particle physics. First 100 pages is standard stuff. Overview of supersymmetry. Predictions of early LHC findings were wrong. Clearly written.

I hope you enjoy the course.

Your course leader,

John Anderson