Core Curriculum Scientific Inquiry 30.01: Cosmology.

3 hours lecture; 3 credits

Profs. Micha Tomkiewicz – michatom@brooklyn.cuny.edu *Fall, 2007*
Monday – Thursday 12:15 – 1:30 *2127N*

Text: William K. Hartmann & Chris Impey: Astronomy – The Cosmic Journey – 2002 Publisher – Brooks/Cole

Bulletin Description: Organization and evolution of the universe that includes topics such as methods of inquiry over large cosmological distances, the structure of space and time, lifecycle of stars, the origin of chemical elements and attempts to address the issue if we are alone in the Universe.

Prerequisite: Junior standing or completion of all lower tier requirements in the same category.

Discussion:
This course takes the students through a journey that will lead to exposure to our current understanding of the structure of the Universe that is consistent with the principles of a Scientific method that are anchored on experimental observations. Students will be able to practice working with available raw astronomical data and demonstrate that the data are consistent with some of the key observations.

Course Outline:

- Week 1 – The Scientific Method and How Science Works: The size of the Universe; Estimation, logic and mathematics; Measurements; Observational science and experimental science; Alternative methods of acquiring knowledge.
- Week 2 – Religion, Mythology and Science: Ancient observations; Keeping track of seasons, calendars and time; Early Greek thinkers; Geocentric and Heliocentric models of the Universe.
- Week 3 – The Copernican Revolution: Copernicus, Brahe, Kepler, Galileo and Newton; The Copernican Revolution and the Scientific Method; Kepler's three laws and working with formulas and units; Galileo's observation; Newton's laws of motion and Newton's law of gravitational attraction.
- Week 4 – Matter and Energy in the Universe: The structure of atoms and molecules; Energy and the two laws of thermodynamics; Temperature; Wien's law and Stefan Boltzmann's law.
- Week 5 – Detecting Radiation from Space: Nature of light and spectrum of electromagnetic radiation; Waves and Particles; Emission and absorption of lines as fingerprints of atoms; The Doppler effect; Standard candles to measure distance; Other methods to measure distance.
- Week 6 – Our Sun - The Nearest Star: Simple observations of the solar systems; Properties of the Sun and how do we measure them; Evidence that the Sun is not powered by fossil fuels; Nuclear Fusion; The Suns interior; logarithmic scales to describe the structure of the Sun.
- Week 7 – How Planetary Systems Form: Archeology of the solar system; The conservation of angular momentum and Helmholtz contraction; The process of accretion and the origin of the planets; Formation of the moon; Alternative theories and how do we know who is right; Resulting Geology.

- Week 8 – Properties of Stars: Distance, chemistry, mass, luminosity, temperature and chemical composition and how do we measure them; The H-R diagram; Main sequence stars and off-main sequence stars; Explaining the H-R diagram; Giants and dwarfs; Constructing the H-R diagram.
- Week 9 – The lifecycle of stars and the evolution of chemistry; Stars life span; The birth and death of stars; The battle with gravity; Quantum theory; The uncertainty principle; The exclusion principle; Degeneracy pressure; Alternative fusion mechanisms; The periodic table of chemical elements and how do they form; White Dwarfs, Supernova, Neutron Stars and Black Holes.
- Week 10 – Einstein – Gravitation and the nature of space and time: The two postulates of Special Relativity; Redefinition of space and time coordinates; Proof of $E=MC^2$ from the postulates; The need for alternative theory of gravity; The General Theory of Relativity; Matter determines the shape of space-time and the shape of space-time determines the behavior of matter; Black Holes and the ultimate victory of gravity; Formation of "something from nothing" near Black Holes.
- Week 11 – The expanding Universe: The experimental observations – the red-shift of galaxies and the Hubble relation and the discovery of the cosmic background radiation; The Big Bang model and alternative models; The Cosmological Principle; Curvature of space and mean density of space; The future of the Universe.
- Week 12 – The first three minutes: What do we know about the evolution of the Big Bang and how do we know it; What can we prove and what do we believe; The need for inflationary expansion; The mechanism of the inflationary expansion.
- Week 13 – The cycle closes – the quest for a unified theory of all four forces: Why do we need a unified theory; A short history of the attempts to develop a unified theory; String theory; Negative energy and dark matter.
- Week 14 – Life in the Universe: Are we alone? What will it take to find out; Short explanation of life on earth; Our current understanding of the evolution of life on earth; The Drake equation; Communication.

Common Goals Addressed by Core Course:

1. To acquire the tools that are required to understand and respect the natural universe. *(includes OARM Goals 5& 18)*

2. To develop the ability to think critically and creatively, to reason logically, and to reason quantitatively**.** *(includes OARM Goals 2, 5 & 10)*

3. To understand what knowledge is and how it is acquired by the use of differing methods in different disciplines. *(includes OARM Goals 2& 17)*

4. To produce informed and responsible citizens. *(includes OARM Goal 8)*

5. To establish a foundation for life-long learning and the potential for leadership. *(includes OARM Goal 29)*

Objectives of Core Course:

1. Students will be able to understand cosmological observations in terms of few physical laws that can be independently tested.

2. Students will be able to differentiate between explanations that are based on the Scientific Method and explanations that are based on other belief systems.

3. Students will be familiar with reading and constructing graphs using logarithmic scales.

4. Students will be able to use algebraic equations that represent physical laws, to represent physical observations.

5. Students will be able to differentiate between facts, hypothesis and theory (*from OARM Goal 18).*

6. Students will be able to apply cosmological, holistic, approaches to "earthy" experiences and future learning.

Outcomes for this Core Course:

1. Students will explain how observations support particular conclusions.

2. Student will identify questions that remain unresolved based on prior research in Astronomy (*from OARM Goal 10).*

3. Students will use units, convert between units and work with different scales.

4. Students will read and construct graphs using logarithmic scales.

5. Students will perform simple calculations based on algebraic equations.

6. Students will explain "personal experiences" such as seasons, climate, day-night, calendars, etc.. in terms of astronomical observations and cosmological principles.

Methods of Evaluation: There will be a midterm exam (20%), final exam (40%) and two projects. In one project (project A – 10%) the students will write a short report on direct observational experience either through following the sky or visiting the planetarium. The other project (project B – 20%) will involve extraction of stars and galaxies data from TheSky CD-ROM and confirming or trying to refute some fundamental key observations. Class participation will count for 10%.

Methods of Assessment:

Assessment will be based on the following mechanisms:

1. Students will be asked how a given set of observations are being explained in terms of a particular cosmological models.

2. Students will be asked about unresolved questions based on class material and outcome from project A.

3. Students will be asked to extract information from algebraic equations and convert between relevant units.

4. Students will "read" logarithmic scale graphs throughout the course; asked to interpret them in the examinations. Project B will be largely based on reading logarithmic-scale information and constructing logarithmic-scale graphs.

5. Students will perform simple calculations on algebraic equations that represent physical laws.

6. Students will be asked to explain "personal experiences" such as seasons, climate, day-night, calendars, etc.. in terms of astronomical observations and cosmological principles.

Bibliography:

Recommended Textbook: A recent edition or equivalent of:

William K. Hartmann & Chris Impey: Astronomy – The Cosmic Journey – 2002 Publisher – Brooks/Cole

Additional Reading:

- Edwin A. Abbot: *Flatland,* Dover Publications (1992).
- Albert Einstein: *Relativity,* Three Rivers Press (1961).
- Brian Green: *The Elegant Universe,* Random House (2000)
- Stephen Hawking: *The Universe in a Nutshell,* Bantam Books (2001).
- Robert P. Kirshner: *The Extravagant Universe,* Princeton University Press (2002)

Electronic Tools:

- Data retrieval from TheSky CD-ROM that comes with the textbook.
- "Reality checks" with the NASA websites.