Harvard College Observatory
60 Garden Street
Cambridge, MA 02138-1516

Freshman Seminar 21C: "Cosmic Explosions"

Wednesdays 1:30-3:30pm
Harvard-Smithsonian Center for Astrophysics
60 Garden Street, Cambridge
Room B105

Somewhere in the Universe a massive star ends its life in a supernova explosion every second (you can count: "1 supernova, 2 supernova, 3 supernova…"). These supernovae, and other types of cosmic explosions like them, play a critical role in shaping the Universe. They are responsible for the synthesis and dispersal of all the chemical elements heavier than hydrogen and helium, and therefore provide the building blocks for the next generations of stars, planets, and ultimately life. These cosmic explosions also give birth to exotic objects such as neutron stars and black holes. Finally, the explosions are so powerful that they can influence the formation of new stars within their galaxies. In this Freshman Seminar we will explore how different types of cosmic explosions occur and how they influence the Universe and life in it. Equally important, we will actually use telescopes in Cambridge and in Arizona to study a new supernova explosion during the semester.

Each topic covered in this seminar will include readings from the peer-reviewed literature (specific selections from the papers listed below), including review papers and new results "hot off the presses". The course will include weekly reading assignments, a short (at least 2-page) summary of each reading, and discussions led by the students on a rotating basis. The course will also include final individual written and oral presentations on a topic related to the course material, chosen by each student in consultation with the instructor. The students will also utilize the Astronomy Lab's Clay Telescope on the roof of the Science Center to monitor a new supernova explosion discovered during the semester. The manager of the Astronomy Lab and Clay Telescope, Ms. Allyson Bieryla, will assist the students in obtaining and analyzing the observations. The students will be responsible for providing a written summary of the results of their observations. We will also use data from the Harvard-Smithsonian Center for Astrophysics 1.2-m and 1.5-m telescopes at Whipple Observatory in Arizona to study and classify newly discovered supernovae on a weekly basis (these observations will be carried out remotely).

Topics and Readings

Week 1+2 *Diversity of stars and the various phases of stellar evolution from birth to death, with a particular focus on massive stars.*

Selections from "An Introduction to Stellar Evolution" by LeBlanc
Selections from "An Introduction to Modern Astrophysics" by Carroll & Ostlie
Smartt, S. 2009, Annual Reviews of Astronomy & Astrophysics, 47, 63

Week 3 *Supernova discovery and zoology: from Type I to II and everything in between*

Baade, W. & Zwicky, F. 1934, Proceedings on the National Academy of Science of the

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United States, 20, 254
Filippenko, A. 1997, Annual Reviews of Astronomy & Astrophysics, 35, 309

Week 4 *Normal core-collapse and thermonuclear supernova explosions*

Woosley, S. & Weaver, T. 1986, Annual Reviews of Astronomy & Astrophysics, 24, 205
Hillebrandt, W. & Niemeyer, J. 2000, Annual Reviews of Astronomy & Astrophysics, 38, 191

Week 5 *Superluminous supernovae, pair-instability supernovae, and other exotica*

Gal-Yam, A. 2012, Science, 337, 927

Week 6 *The compact remnants of supernova explosions: black holes, neutron stars, and magnetars*

Heger, A., et al. 2003, Astrophysical Journal, 591, 288

Week 8+9 *Gamma-ray bursts: The most extreme cosmic explosions*

Gehrels, N., et al. 2009, Annual Reviews of Astronomy & Astrophysics, 47, 567
Berger, E. 2014, Annual Reviews of Astronomy & Astrophysics, 52, 43

Week 10 *Neutron star and black hole binary mergers, and their aftermath*

Narayan, R., et al. 1992, Astrophysical Journal Letters, 395, 83
Hughes, S. 2009, Annual Reviews of Astronomy & Astrophysics, 47, 107
Faber, J. & Rasio, F. 2012, Living Reviews in Relativity, 15, 8

Week 11 *Nucleosynthesis of elements in supernova explosions: The origin of the iron-peak and lighter elements*

Hoyle, F. 1954, Astrophysical Journal Supplement, 1, 121
Arnett, D. 1995, Annual Reviews of Astronomy & Astrophysics, 33, 115

Week 12 *Nucleosynthesis of elements in neutron star binary mergers: The origin of the heaviest elements*

Goriely, S., et al. 2011, Astrophysical Journal Letters, 738, 32
Berger, E., et al. 2013, Astrophysical Journal Letters, 774, 23

Week 13+14 Student presentations on individual topics

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Grading

Grading in the course will be based on class participation, weekly summaries of the reading assignments, participation in the supernova observations, and the final presentations. The breakdown will be as follows:

Class participation + leading a weekly discussion:	30%
Weekly summaries of reading materials:	20%
Supernova observations + classifications:	20%
Final written and oral presentation:	30%

Grading will be on a SAT/UNSAT basis: A SAT grade is equivalent to a range of A to C- (60-100%), while a lower score will result in a grade of UNSAT.

Policy on Collaboration

Students are encouraged to collaborate on discussions of the reading materials out of class, as well as on preparation for in-class discussion points and materials. The course format is ideal for student interaction and peer learning. Students are also allowed to collaborate on the supernova observations, although each student should submit their own individual reports written independently. Similarly, students are not allowed to collaborate on the classification of new supernovae – each student should provide their own best assessment of the classification and we will review the results in class. Final reports and presentations will be provided and performed individually.