Astro 41: The Invisible Universe
by Prof.Sajina
TTh 9:00-10:15AM
Room CLIC 204

Contact info:

Instructor — Anna Sajina
email: Anna.Sajina@tufts.edu
office: CLIC 312F
Office hours: TTh right after class, Wednesday 1-2pm, or by appointment

TA — TBD

Learning goals:

1. Understand how the ability to detect radiation across the electromagnetic spectrum as well as detect high energy particles and more recently gravitational waves has dramatically improved our understanding of a wide range of astrophysical phenomena including blackholes, supernovae and neutron stars. We have thus gained insights ranging from the early Universe to the formation of planets such as our own. Beyond astrophysics, such `multi-messenger' observations allow us to address questions in fundamental physics as well as the origin of life.

2. Improve your understanding of fundamental physics by presenting applications of concepts you would have learned (or will learn) about in detail from other classes.

3. Gain a deeper understanding of the detectors and telescopes needed for the above studies. Appreciate the role of fundamental science in driving technological development.

4. Improve your lifelong learner skills by making you an active participant in the class. There will be readings before class and in-class discussion and exercises. The class includes a term project on a topic of your own choosing which is presented to the class near the end of term.

Prerequisites:

At a minimum, the first year Physics sequence (Physics 11 and 12) is needed because it provides an introduction to mechanics and electromagnetism. If you have also taken Physics 13 (Modern Physics) discussion re special relativity and quantum mechanics are going to be easier — but I will provide some very basic introduction thereof so as to make this a recommendation rather than a requirement. The sophomore astrophysics classes (Astro 31 "Stellar Astrophysics" and Astro 32 "Galactic and Extragalactic Astrophysics") are certainly helpful but again not required. There are a few lectures reviewing the relevant astrophysics build-into this class. The emphasis during homework and exams is on concepts rather than heavy mathematical manipulation.

Reference books:

This class does not have an assigned textbook. Your primary study materials will be the posted lecture notes and posted assigned readings.

I draw some material from the following reference books — these are therefore recommended for those of you who want to read further on these topics.

1) Fundamentals of Radio Astronomy- Observational Methods and Astrophysics by Ronald Snell, Stanley Kurtz and Jonathan Marr (CRC Press Series in Astronomy and Astrophysics)
2) Introduction to Particle and Astroparticle Physics by Alessandro De Angelis and Mario Pimenta (Springer)
3) Astrochemistry from the Big Bang to the Present Day by Claire Vallance (World Scientific)

Grading:

- Participation 5% (in class and/or on Canvas Discussion boards)
- Homework 25%
- 4 Minitests 40% (these take up to 20min of class time, and take the place of the usual midterm+final)
- Term projects 30%

Academic Integrity:

Tufts holds its students strictly accountable for adherence to academic integrity. The consequences for violations can be severe. It is critical that you understand the requirements of ethical behavior and academic work as described in Tufts' Academic Integrity handbook. If you ever have a question about the expectations concerning a particular assignment or project in this course, be sure to ask me for clarification. The Faculty of the School of Arts and Sciences and the School of Engineering are required to report suspected cases of academic integrity violations to the Dean of Student Affairs Office. If I suspect that you have cheated or plagiarized in this class, I must report the situation to the dean.

Course outline:

Module I Background (2 lectures)

Sept 3 — Lecture 1 Course overview
Sept 5 — Lecture 2 Overview of stars and stellar evolution

Module II Radio astronomy (5 lectures)

Sept 10 — Lecture 3 Brief review of electromagnetism
Sept 12 — Lecture 4 Key processes and astrophysical sources
Sept 17 — Lecture 5 Radio telescopes, Part I
Sept 19 — Lecture 6 Radio telescopes, Part II — **Reading #1 due**
Sept 24 — Lecture 7 Some key results and frontiers in radio astronomy
Homework #1 due
Minitest #1 (Radio astronomy)

Module III Infrared/mm astronomy (5 lectures)

Sept 26 - Lecture 8 Brief review of the infrared astronomy/key astrophysical sources
Oct 1 — Lecture 9 Infrared telescopes and detectors
Oct 3 - Lecture 10 Molecules in the interstellar medium
Oct 8 - Lecture 11: Astrochemistry and the origin of life — **Reading #2 due**
Oct 10 - Lecture 11 continued, & IR astronomy module review
Homework #2 due
Minitest #2 (Infrared astronomy)

Module IV High-energy astronomy (6 lectures)

—————————————————————

Oct 15 - **Minitest #2 (Infrared astronomy)** start Lecture 12 Brief review of particle physics
Oct 17 - Lecture 12 continued & Lecture 14 Key processes and astrophysical sources
Oct 22 - Neutrinos and how to detect them - **guest lecture by Prof.Wongjirad**
Oct 24 - Lecture 14 continued & Lecture 15 X-ray and Gamma-ray detectors
Oct 29 - Lecture 15 X-ray and Gamma-ray detectors
Oct 31 - Lecture 16 Cosmic Rays & High-energy astronomy module review
Reading #3 due
Homework #3 due

Module V Gravitational wave astronomy (4 lectures)

————————————————————————-

Nov 5 - NO CLASS — Presidential Election Day
Nov 7 - **Minitest #3 (High-energy astronomy)** & start Lecture 17 Brief review of cosmology and general relativity
Nov 12 - NO CLASS - Substitute Monday's schedule on Tuesday
Nov 14 - Lecture 17 continued & Lecture 18 Gravitational waves (GW) and GW detectors
Nov 19 - Lecture 21 GW sources and their EM counterparts - **Reading #4 due**
Nov 21 - **Guest lecture from NANOGrav group at Tufts**
Homework #4 due

Module VI: Topics for further exploration (w/ student presentations)

——————————————————————————————-

Nov 26 — Minitest #4 (Gravitational wave and multi-messenger astrophysics) — class takeaways summary

Nov 28 - NO CLASS - Thanksgiving break
Dec 3 - Student presentations and discussion
Dec 5 - Student presentations and discussion
Dec 10 - Student presentations and discussion

Student term projects:

Students are going to be be working in groups of ~2 on a topic of their choice. Below are some suggestions. You're free to pursue your own topics as well, subject to prior approval. More details on the format and requirements for the term projects will be included in a separated PDF document.

Example project topics for student presentations:

1) The intergalactic medium — studying the baryons in between galaxies

2) Dark matter or Dark energy — theories and methods of detection/study

3) Intermediate mass black holes

5) Solar cycle/solar wind — effects on the Earth

6) The 21cm emission from the Dark Ages

7) Any future observatory — design/science goals