PHY-465 Basics of Radio Astronomy

Credit Hours: 2-1

Prerequisite: None

Course Objective:

Astronomical observations at radio wavelengths play a key role in the discovery and study of certain classes of astronomical objects and radio observations play complementary roles in the study of nearly all objects in the Universe. Examples of the discovery role include pulsars, the cosmic background radiation, and complex molecules in space. More generally, radio wavelength observations provide insights into the very low temperature Universe (temperatures below 20 K), the highly obscured Universe (where dust obscures optical and even infrared wavelength emission) and the very high energy Universe of strong magnetic fields and relativistic particles associated with flares, neutron stars, and black holes.

Radio Astronomy is a growing field supported by state of the art ground-based instrumentation, e.g., the Jansky Very Large Array (JVLA) and the Atacama Large Millimeter Array (ALMA). The next generation radio telescope, the Square Kilometer Array (SKA) and Event Horoizon telescope (EHT) play as key participants. This course will provide an introduction to observational radio astronomy and processes in radio astrophysics.

Course Contents:

Radio Astronomy Course:

Topics will include: an introduction to radio astronomy; Basic radiative transfer; blackbody radiation and radiation from an accelerated charge; radio telescopes, receivers, and interferometers; thermal continuum sources (e.g., HII regions); nonthermal continuum sources (e.g., radio galaxies); Pulsars; and spectral-line sources (e.g., the 21 cm line, radio recombination lines, and rotational energy transitions in simple molecules).

Radio Astronomy Lab:

Analyzing and accessing the astronomical data, Calibration and analysis of radio telescope at NUST Astronomical observatory (NAO), accessing astronomical data, developing algorithms for radio astronomy, analyzing specific data for radio sources.

Detailed Course Contents:

Radio Astronomy Course:

Introduction, Atmospheric Windows, Astronomy in the Radio Window, What is special about long wavelengths?, Radio Telescopes and Aperture-Synthesis, Interferometers, The Discovery of Cosmic Radio Noise, A Tour of the Radio Universe, Radiation Fundamentals, Brightness and Flux Density, Radiative Transfer, Polarization, Black Body Radiation, Noise Generated by a Warm Resistor Cosmic Background Radiation, Radiation from an Accelerated Charge Dust Emission at Radio Wavelengths, Radio Telescopes and Radiometers Antenna Fundamentals, Reflector Antennas, Two-dimensional Aperture Antennas, Waveguides Radio Telescopes, Radiometers Interferometers, Free-Free Radiation, Thermal and Non-thermal Emission, HII Regions, Free-Free Radio Emission from HII Regions, Synchrotron Radiation, Magnetobremsstrahlung, Synchrotron Power, Synchrotron Spectra, Synchrotron Sources, Inverse-Compton Scattering, Extragalactic Radio Sources, An introduction to pulsars, Pulsars and the Interstellar Medium, Pulsar timming arrays, Recombination Lines in radio observations, Line Radiative Transfer, Excitation Temperature, Masers, Recombination Line Sources, Molecular Line Spectra, The HI 21-cm Line, Introduction to high velocity clouds in the ISM, gas and dust content in the galaxies, past and future radio observations.

Radio Astronomy Lab:

Analyzing and accessing the astronomical data, Calibration and analysis of radio telescope at NUST Astronomical observatory (NAO), accessing astronomical data, developing algorithms for radio astronomy, analyzing specific data for radio sources.

Learning Outcomes:

- Knowledge of various astronomical sources.
- Knowledge of implementing theory into observations.
- Understanding the development of algorithms for astrophysics and analysis of data.

Text Book:

- Essential Radio Astronomy by Condon & Ransom (Princeton University Press) 2015.

Radio Astronomy (Theory):

Weekly Breakdown		
Week	***Section***	***Topics***
1	CR 1.1 – 1.3	Introduction, Atmospheric Windows, Astronomy in the Radio Window, What is special about long wavelengths?
2	CR 2.1 – 2.4	Radio Telescopes and Aperture-Synthesis, Interferometers, The Discovery of Cosmic Radio Noise
3	CR 2.5 – 2.7	A Tour of the Radio Universe, Radiation Fundamentals, Brightness and Flux Density
4	CR 3.1 – 3.4	Polarization, Black Body Radiation, Noise Generated by a Warm Resistor Cosmic Background Radiation (CMB)
5	CR 3.5 – 3.6	Radio Telescopes and Radiometers Antenna Fundamentals, Reflector Antennas, Two-dimensional Aperture Antennas
6	CR 3.7 – 4.1	Radiometers Interferometers, Free-Free Radiation, Thermal and Non-thermal Emission
7	CR 4.2 – 4.3	HII Regions, Free-Free Radio Emission from HII Regions, Synchrotron Radiation
8	CR 5.1 – 5.3	Magnetobremsstrahlung, Synchrotron Power, Synchrotron Spectra, Synchrotron Sources
	Mid Term Exams	
9	CR 5.4 – 5.5	Inverse-Compton Scattering, Extragalactic Radio Sources, An introduction to pulsars
10	CR 5.6 – 5.8	Pulsars and the Interstellar Medium (ISM), Pulsar timming arrays

11	CR 6.1 – 6.3	Masers, Recombination Line Sources, Molecular Line Spectra, The HI 21-cm Line
12	CR 6.4 – 6.6	Introduction to high velocity clouds in the ISM, gas and dust content in the galaxies, past and future radio observations
13	Assigned by Tutor	A short project
14	Assigned by Tutor	A short project
15		Revisions
16	**Final Exams**	

Radio Astronomy Lab:

Weekly Breakdown	
Week	***Topics***
1	Introduction to Radio astronomical data and calibration of the radio telescope at NAO
2	Student Projects Phase I:Collecting radio data towards various radio sources from NAO
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4	
5	
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9	
10	Student Projects Phase II: Developing Algorithms, Accessing radio data of

11	EHT, and Analysis of radio data
12	
13	
14	
15	
16	**Project Presentations and Reports + Final Exam**