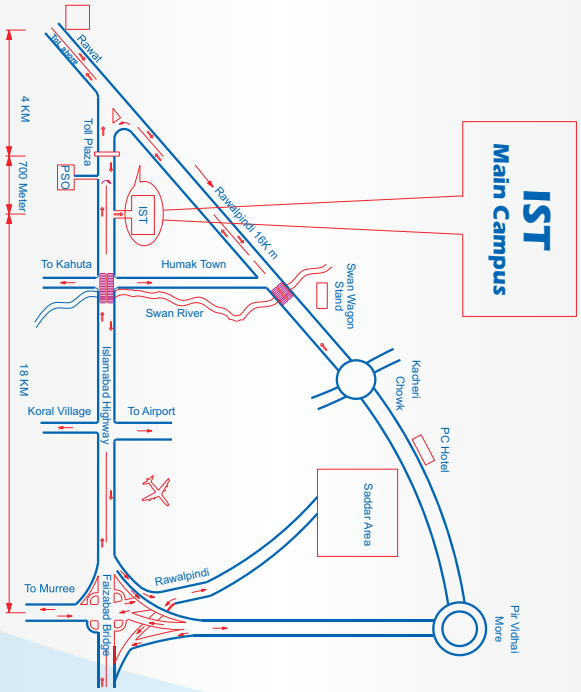
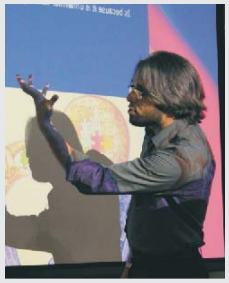
## Workshop outline (Timings: 0900 hrs - 1600 hrs)

- Current Issues in Radio Astronomy
- Next Generation Radio Telescopes
- The Big Picture
- Radio Astronomy Data Processing Tutorial
- Radio Astronomy Fundamentals
- Science with Radio Astronomy
- Radio Observatory Overview
- Radio Telescopes
- Radio Astronomy Backends
- Introduction to Radio Interferometry
- Radio Interferometry Signal Processing
- Radio Imaging
- Telescope Access
- Proposal Writing
- Observation Strategies
- Planning and Execution




## About the Resource Person



**Dr. Aquib Moin**
New York University

Dr. Aquib Moin is a Research Fellow at the Astrophysics Division of New York University (NYU), New York, USA / Abu Dhabi, UAE, and a Research Associate with NASA's Goddard Space Flight Centre / Jet Propulsion Lab (JPL) and the Harvard-Smithsonian Centre for Astrophysics in the USA. At NYU, he acts as a Principle investigator in the area of observational radio astronomy and he is leading major projects on themes related to AGN, Pulsars and GRBs and also responsible for radio astronomy operations. At NASA, he is core team member of a large international Maser survey project and the scope of his work involves instrument commissioning, science observations, data analysis and interpretation formulation. He is also affiliated with NASA's James Webb Space Telescope project. He previously worked as a Postdoctoral Research Fellow at Shanghai Astronomical Observatory, Shanghai, China and led a number of astrophysics projects and conducted research on themes related to AGN, X-ray binaries and GRBs. He did his PhD in Astrophysics from the International Centre for Radio Astronomy Research, Curtin University, Australia. During his PhD, he was a part of collaboration involved in the development of world's largest radio telescope called the Square Kilometre Array (SKA). He also worked as a VLBI operations team member at Australia Telescope National Facility, Australia. He had been involved in the VLBI/e-VLBI experimental setup and initialization, observation and monitoring, trouble-shooting and problem identification in Australia for over four years.

## Workshop Secretariat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Institute of Space Technology

# Workshop on Radio Astronomy

Dr. Aquib Moin
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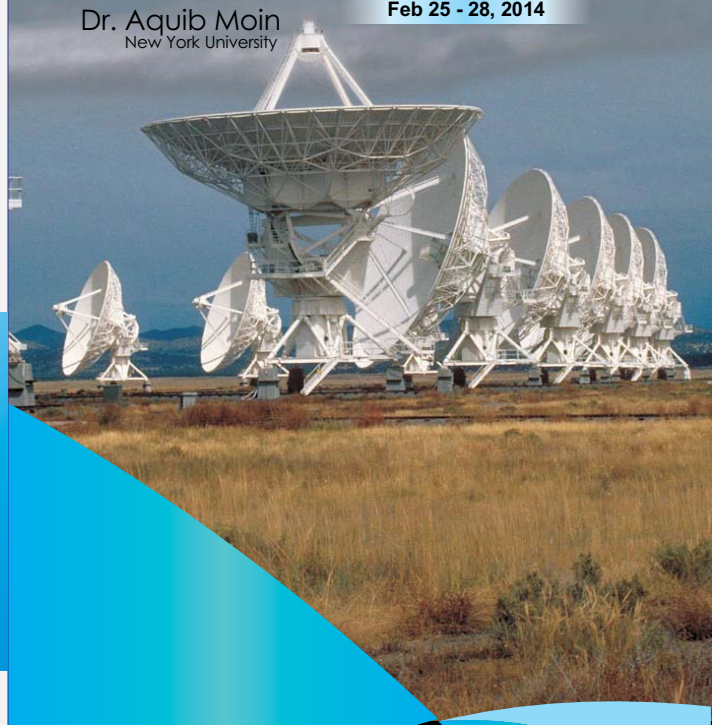
**Feb 25 - 28, 2014**

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### About Institute of Space Technology

Institute of Space Technology (IST) was established in 2002 as an educational institution that would impart specialized education in space and related science in Pakistan. In 2002 the institute started offering undergraduate degree programs in Aerospace Engineering and Communication Systems Engineering followed by undergraduate programs in the field of Material Science and Engineering and Space Science. IST is also offering PHD/MS programs in these disciplines. In addition of these indigenous programs IST is collaborating with Beihang University, Northern Polytechnic University, China and University of Surrey, UK to offer linked programs in several more area as well. The programs offered by IST are approved by Higher Education Commission (HEC) and accredited by Pakistan Engineering Council. Over the past decade, IST has developed state of the art facilities that enhanced research in all educational and training programs. IST is ranked amongst Top 5 engineering universities of Pakistan by HEC.

### Introduction to Radio Astronomy

Radio Astronomy is a sub-branch of astronomy in which the nature, origin and properties of celestial objects, astronomical events and phenomena, astrophysical processes and mechanisms are studied at radio wavelengths using various kinds of radio telescopes. The primary difference between other branches of astronomy (e.g. optical/infrared) and radio astronomy is that the equipment, instruments and the observational setup used for radio astronomy is very similar to the one which would be used for radio science and engineering. The elements of the radio observation system broadly include radio antennas, receiver systems, signal acquisition and processing chain, I/O systems and a data storage, processing and analysis system. The entire facility where the radio observation system is installed and deployed is known as a radio observatory or a radio astronomy facility.

## Science Themes at a Radio Observatory

### 1. Astronomy & Astrophysics

Radio Astronomy provides a very powerful framework carry out to astronomical and astrophysical research. Since it deals with the long wavelength part of the electromagnetic spectrum, it provides a window to the "invisible" Universe. That is, there are a number of astrophysical processes, mechanisms that can only be studied using radio astronomy techniques since they are undetectable and untraceable at any other wavelength. Well-planned, comprehensive observational and monitoring of those processes holds the key to the characterization and better understanding of various astrophysical mechanisms associated with a number of objects and events. The main themes that can be covered within the framework of radio astronomy include but are not limited to: ·

- **Galactic microquasars**
- **Relativistic jets**
- **Pulsars**
- **Compact objects (Black Holes Active Galactic Nuclei White Dwarfs, Neutron Stars)**
- **Gamma-Ray Burst afterglows**
- **Early Universe and star formation**
- **HI (neutral hydrogen)**
- **Cosmic Microwave Background mapping**

### 2. VLBI

A radio telescope can also be used in another mode of operation called "Very Long Baseline Interferometry (VLBI)". In the VLBI mode, the radio telescope becomes a part of a network or an array of telescopes, which observes a target simultaneously. The entire array of telescope act as a large aperture the diameter of which is equivalent to the longest distance between a pair of telescopes in the array. The VLBI technique enables to achieve exceptionally high resolution and precision for the observations which is not possible when the telescope is used as a single instrument due to structural limitations. A radio observatory which is a part of the international VLBI networks can participate in very large programs in the areas of astronomy, geodesy and spacecraft tracking. VLBI operations also allow to build very effective international collaborations and engage in advanced, mainstream research and development.

### 3. Aeronomy & Atmospheric Studies:

A well-equipped radio astronomy facility can also support aeronomy and atmospheric research. These studies allow to probe the upper layers of Earth's atmosphere, so as to understand the properties of the contents of those layers, the interaction between them and their behavior as a function of time. Another very important activity that can be carried out within this domain is the monitoring of solar events, which can interact with various layers of Earth's atmosphere causing the properties and observational signatures to change. Observational study of such processes enables to better understand the conditions and the environment around the Earth.

### 4. Spacecraft Tracking

A well-equipped radio observatory setup can play a major and crucial role in supporting space related activities. Non-geosynchronous spacecraft of various kinds are needed to be tracked and communicated with along the course of their entire orbit. A single tracking station cannot follow a spacecraft all along because of the field-of-view and visibility limitations. Since a radio telescope is essentially a large and sensitive dish antenna, radio observatories can therefore, function as tracking stations for any space vehicle as it comes within its range. A radio observatory can not only track the spacecrafts belonging to the host country, it can also provide its tracking services to any client around the world who would need its spacecraft to be tracked when it passes overhead. A radio telescope can track a spacecraft both in single-dish and VLBI mode. Spacecraft tracking in VLBI mode enhances the accuracy and precision of the positioning manifolds due to higher angular resolution.

### 5. Geodesy

Another scientific discipline that can be regarded as a key research area at a radio observatory is Geodesy. This branch of science deals with naturally occurring geodynamical earth systems such as tectonic motion, gravitational variations, orientation parameters, tides and dynamics of mineral displacement etc. As part of the geodetic studies, very precise (cm to mm level) measurements of the movement of Earth's tectonic plates can be carried out using the VLBI technique. Just as the accurate position of an astronomical source can measured using a VLBI array of known parameters, the variation in the distance between two VLBI stations can also be determined by observing a distant astronomical source with known parameters. This measurement in turn, gives the motion of tectonic plates and the variation as a function of time. This also helps in accurate position determination on the ground. Another application of Geodetic VLBI is the estimation of Earth's rotation and orientation parameters which are useful for all kinds of navigation and positioning. Supplementing geodetic instruments such as GPS receivers, SLR equipment can also be installed at a radio observatory for additional geodetic work.

### 6. Radio Science & Engineering Laboratory

A radio observatory can also house a radio science and engineering lab, which serves as a research and development incubator for the instruments, subsystems, devices related to radio science. The science and technology requirements can promote the development of receivers, special-purpose amplifiers and filters, I/O systems, database systems, dedicated signal and data processing systems and various other hardware/software interfaces. This lab at a radio observatory not only fulfills the requirements of the host institute but the spin-offs and innovative system solutions can also be supplied to other interested organizations.

### 7. Miscellaneous Functions of a Radio Observatory

In addition to the aforementioned benefits of establishing a radio observatory, a number of other civilian as well as defense applications can be explored and necessary equipment can be deployed to take advantage of a dedicated radio observatory. For instance, surveillance and monitoring systems, dedicated and secure communication links and other equipment of importance can be operated from a radio observatory as and when required. It can also function as a support station for the emerging satellite navigation systems such as Beidou, Galileo and GLONASS.