National Research Foundation | HartRAO Hartebeesthoek Radio Astronomy Observatory

# AVN Training HartRAO 2017

**Welcome to HartRAO - we hope that you have an enjoyable and interesting visit.**

***Radio transmitters may interfere with science operations. All cell phones must be switched OFF inside the security fence. The use of wireless mice, wi-fi and blue-tooth is NOT permitted. If you do not know how to turn off wireless and bluetooth on your laptop please ask us.***

**Please note:**

- All the **Lectures** will take place in the **Lecture room**
- **Invited Talks** will take place in the **Library**
- **Tea and Coffee** will be served in the **Foyer**
- **Lunch and Dinner** will be served in the **Visitors Center**

## Monday 06 March: Welcome and Introduction

- 08:30 – 09:00: Registration (Foyer)
- 09:00 – 10:00: Welcome and Introduction (the Newton Project) – **(LC)**
    - Logistics (catering and accommodation) – **(GC)**
    - Health and Safety – **(PS)**
    - Logistics (programme) – **(AdW)**
    - Computers (instructions) – **(RB)**
- 10:00 – 10:15: My AVN Experience - Invited Talk **(AN)**
- 10:15 – 11:00: Participants to introduce themselves
- 11:00 – 11:30: Tea/ Coffee break
- 11:30 – 13:00: Tour of the facility – **(AdW/PS/RB/LC)**
- 13:00 – 14:00: Lunch
- 14:00 – 14:45: Historical Background of Radio Astronomy I – Lecture **(KE)**
- 15:00 – 15:45: Historical Background of Radio Astronomy II – Lecture **(KE)**
- 16:00 – 16:30: Tea/Coffee break
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Tuesday 07 March: Introduction to Radio Astronomy

- 09:00 – 10:00: Introduction & Overview – Lecture **(AdW/RB)**
- 10:00 – 11:00: Radiometer Equation & Signal Flow – Lecture **(AdW)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Radio Antennas – Lecture and Demonstration **(GN)**
- 13:00 – 14:00: Lunch
- 14:00 – 16:00: Equipment & Instrumentation Introduction – Demonstration **(GN)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 17:30: Scientific Methods vs Serendipity – Invited Talk **(GM)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Wednesday 08 March: History of Radio Astronomy in SA

- 09:00 – 10:00: History of Radio Astronomy in South Africa:
  From Sputnik to the SKA – Talk **(GN)**
- 10:00 – 10:30: Tea/Coffee break
- 10:30 – 13:00: Half day tour to SANSA – **(EA)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: History of the AVN – Talk **(GM)**
- 15:00 – 16:00: The square Kilometre Array:
  Big Telescope, Big Science, Big Data – Talk **(RT)**
- 16:00 – 16:30: Tea/Coffee break
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Thursday 09 March: Coordinate and Timing Systems

- 09:00 – 10:00: Overview of Coordinate Systems – Lecture **(AdW)**
- 10:00 – 11:00: Overview of Coordinate Systems – Exercises **(AdW)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 12:00: Continue with exercises **(AdW)**
- 12:00 – 13:00: Timing Systems – Lecture **(LC)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Telescope Pointing – Lecture **(JQ)**
- 15:00 – 16:00: Travels of a Scientist – Invited Talk **(LC)**
- 16:00 – 16:30: Tea/Coffee break
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Friday 10 March: Microwave Receiver Systems

- 09:00 – 10:00: Microwave Receiver Systems – Lecture **(PS/GN/RM)**
- 10:00 – 11:00: Tour of the workshop **(PS/GN/RM)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Microwave Receiver Systems – Practical **(PS/GN/RM)**
- 13:00 – 14:00: Lunch
- 14:00 – 16:00: Microwave Receiver Systems – Exercises **(PS/GN/RM)**
- 16:00 – 16:30: Tea/Coffee break
- 18:30 – 20:00: Dinner/Cultural event [labs will close at 18:00]

## Saturday 11 March: Computer Skills for Astronomy

- 10:00 – 11:00: Basic Introduction to Linux & IPython Notebook – Practical **(KE)**
- 11:00 – 12:00: Basic Introduction to Spreadsheets – Practical **(AdW)**
- 12:00 – 13:00: Additional help using Linux, Python and spreadsheet **(KE&AdW)**
- 13:00 – 17:00: Excursion: Boat trip (Buses depart at 13:00)
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Sunday 12 March: No class, free time

- 13:00 – 14:00: Lunch at HartRAO
- 18:30 – 21:00: Dinner [labs will be closed]

## Monday 13 March: Astronomy with a small Radio Telescope and Amateur Radio

- 08:30 – 10:00: Calibrating a Small Radio Telescope – Practical **(AdW)**
- 10:00 – 11:00: Measurement Errors – Lecture **(GM/AdW)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Measuring the Brightness Temperature of the Sun – Exercises **(AdW)**
- 13:00 – 14:00: Lunch
- 14:00 – 16:00: Amateur Radio Astronomy – Invited Talk & Demonstration **(TV)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 18:00: Continue with exercises **(AdW)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Tuesday 14 March: Single-Dish Continuum Observations

- 09:00 – 10:00: Radio Continuum Observations – Lecture **(AdW/PS)**
- 10:00 – 11:00: Drift Scan Observations and Calibration – Lecture & Demonstration **(AdW/PV)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Drift scan Observations and Calibration – Exercise **(AdW/PV)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Radiometer, square law detector – Lecture & Demonstration **(KJ/RM)**
- 15:00 – 16:00: Continue with exercises **(AdW/ PV)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 18:00: Continue with exercises **(AdW/PV)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Wednesday 15 March: Single-dish Spectral line Observations

- 09:00 – 10:00: Single-dish Spectral Line Observations – Talk **(GM)**
- 10:00 – 11:00: interferometric Spectral Line Observations – Demonstration & Exercises **(SG)**
- 11:30 – 11:30: Tea/Coffee break
- 11:30 – 12:00: Spectrometer – Lecture & Demonstration **(GN)**
- 12:00 – 13:00: Spectral Line Observations – Practical **(GM/SG)**
- 13:00 – 14:00: Lunch
- 14:00 – 16:00: Spectral Line Observations – Practical **(GM/SG)**
- 15:00 – 16:00: Continue with exercise **(SG/GM)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 17:30: The PhD Journey without Tears – Talk **(KE/GM)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Thursday 16 March: Single-ish Pulsar Observations

- 09:00 – 10:00: Introduction to Pulsars – Lecture **(SB)**
- 10:00 – 11:00: Dispersion – Lecture & Exercises **(SB)**
- 11:30 – 11:30: Tea/Coffee break
- 11:30 – 12:00: Pulsar Observing – Demonstration **(SB)**
- 12:00– 13:00: Pulsar Sensitivity – Lecture & Exercises **(SB)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Pulsar Timing Instrumentation and Techniques – Lecture & Demonstration **(SB)**
- 15:00 – 16:00: Astrophysical Radiation Mechanisms – Invited Lecture **(MaB)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 18:00: Hike **(GM)**

- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Friday 17 March: Antenna Systems, RFI and Antenna Conversion

- 09:00 – 10:00: Antenna Systems & Maintenance – Lecture **(PS)**
- 10:00 – 11:00: RFI – Lecture **(GN)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Antenna Systems & RFI – Demonstration & Exercises **(PS/GN)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Antenna Conversion Projects– Lecture **(AL)**
- 15:00 – 16:00: The path less travelled: The adventures of building the African VLBI Network Invited Talk **(NQ)**
- 16:00 - 16:30: Tea/Coffee break
- 16:30 – 17:30: Using your Imagination – Talk **(GM)**
- 18:30 – 19:30: Star Party [labs will close at 18:00]

## Saturday 18 March: Excursion

- 10:00 – 16:00: Excursion: Planetarium (buses depart at 10:00)
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Sunday 19 March: No class, free time

- 13:00 – 14:00: Lunch
- 18:30 – 19:30: Dinner [labs will be closed]

## Monday 20 March: Radio Surveys and Data Mining

- 09:00 – 10:00: Radio Surveys – Lecture **(KE)**
- 10:00 – 11:00: Data Mining – Lecture & Demonstration **(NO)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Virtual Observatory Tools – Lecture & Demonstration **(KE)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Virtual Observatory Tools: TOPCAT & Aladin – Practical **(KE)**
- 15:00 – 16:00: Data Mining – Practical **(NO)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 17:30: Radio Telescopes of the Future – Invited Talk **(CG)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Tuesday 21 March: Introduction to Interferometry

- 09:00 – 10:00: Introduction to Interferometry – Lecture **(NS/MB)**
- 10:00 – 11:00: Two-Element Interferometer – Demonstration & Exercises **(NS/MB)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Fourier Transforms and Sampling Theorem – Lecture & Exercises **(MB)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: Advanced Interferometry – Lecture **(MB/NS)**
- 15:00 – 14:00: Imaging using CASA – Exercises **(MB/NS)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 18:00: Continue with Exercises
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Wednesday 22 March: Introduction to VLBI & Astronomy

- 09:00 – 10:00: VLBI Fundamentals – Lecture **(CG)**
- 10:00 – 11:00: Visit to HartRAO Control Room **(CG/JQ)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: VLBI Post-Correlation Analysis and Fringe-Fitting – Lecture **(MB)**
- 13:00 – 14:00: Lunch
- 14:00 – 15:00: VLBI for Astronomy – Lecture **(CG)**
- 15:00 – 16:00: VLBI for Astronomy – Lecture **(MB)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 17:30: Radio Astronomy with the NASA DSN – Invited Talk **(CG/CJ)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Thursday 23 March: Introduction to Geodetic & Astrometric VLBI

- 09:00 – 10:30: Introduction to Geodetic VLBI – Lecture **(DM/ MS)**
- 10:00 – 11:00: Introduction to VieVS – Demonstration **(DM)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 13:00: Introduction to Astrometric VLBI & Spacecraft Applications – Lecture **(CJ)**
- 13:00 – 14:00: Lunch
- 14:00 – 16:00: Exercises using VieVS – **(DM/MS)**
- 16:00 – 16:30: Tea/Coffee break
- 16:30 – 17:30: VLBI Simulations and their Applications for the AVN – Invited Talk **(DM)**
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Friday 24 March: Geophysical Modelling and Experiment Scheduling for VLBI

- 09:00 – 10:00: Geophysical Modelling and Atmospheric Propagation – Lecture **(CJ)**
- 10:00 – 11:00: Models and Mapping Functions used in VieVS – Demonstration **(DM)**
- 11:00 – 11:30: Tea/Coffee break
- 11:30 – 12:00: Planning, Scheduling and Running a VLBI Experiment – Lecture **(AdW)**
- 12:15 – 13:30: Scheduling a Geodetic VLBI Experiment – Exercises **(MS)**
- 13:30 – 14:30: Lunch
- 14:30 – 15:30: Stellar GPS: Navigating the Solar System – Invited Talk **(CJ)**
- 15:30 – 17:00: Closing Ceremony
- 18:30 – 19:30: Social Dinner [labs will close at 18:00]

## Saturday 25 March

- 10:00 – 16:00: Excursion: Maropeng (Buses depart at 10:00)
- 18:30 – 19:30: Dinner [labs will close at 20:00]

## Sunday 26 March: No class, free time

- 13:00 – 14:00: Lunch
- 15:00: Transport to Ekudeni (Networking Meeting)

## ➡ Monday 27 March – Wednesday 29 March:

- Networking Meeting

## ➡ Thursday 30 March:

- 10:30 : Transport to HartRAO
- 13:00 - 14:00: Lunch
- 18:30 - 19:30: Dinner [lab will be open from 12:00 – 18:00]

## ➡ Friday 31 March:

- 10:30 : Transport to Airport

# Content: AVN Training School

## Monday 06 March: Welcome and Introduction

- **History of Radio Astronomy**
  - Pre-history of radio astronomy
  - History of radio astronomy
  - Major discoveries
  - History of interferometry and VLBI
  - Current radio telescope facilities

## Tuesday 07 March: Introduction to Radio Astronomy

- **Radio Astronomy Introduction & Overview**
  - Electromagnetic spectrum
  - Radio waves
  - Radiometer equation
  - Signal flow
  - Astronomy, astrometry and geodesy at HartRAO
  - How everything fits together
- **Radio Antennas**
  - Types of antennas
  - Parabolic dishes: types of mounts, reflector types…
  - Antenna beam patterns
  - Apertures and diffraction pattern
  - Equipment & instrumentation introduction
- **Talk: Scientific Methods vs Serendipity**

## Wednesday 08 March: History of Radio Astronomy in South Africa

- **History of Radio Astronomy in South Africa**
  - HartRAO history since the NASA days
- **History of the AVN**
  - How the idea for an African network of VLBI telescopes was born
- **The Square Kilometre Array**
  - Big telescope
  - Big science
  - Big data
- **Tour of SANSA**
  - SANSA historical background
  - SANSA industrial applications

## Thursday 09 March: Coordinate and Timing Systems

- **Overview of Coordinates Systems**
  - The celestial sphere
  - Celestial coordinates
  - Precession, nutation and rotation
  - The International Celestial Reference Frame (ICRF)
- **Timing Systems**
  - What is time
  - Time systems
  - Clocks
  - Time scales
  - Which products to use
- **Pointing**
  - Pointing and pointing models for radio telescopes
- **Invited Talk: Travels of a Scientist**

## Friday 10 March: Microwave Receiver Systems

- **Microwave Receiver Systems**
  - Introduction to basic components used in microwave receivers
  - Performance characteristics of these components
  - Assembly of components into a complete microwave system
  - Measuring the performance of the system
  - Improving the performance with cryogenic cooling
- **Tour of the Workshop**

## Saturday 11 March: Computer Skills for Astronomy

- **Basic Introduction to Linux**
  - Getting stared with Linux
  - The Command Line Interface (CLI)
  - Basics Linux commands and file management
- **Basic Introduction to IPython Notebooks**
  - Getting started with IPython in the Jupyter Notebook
  - Importing data & basic plotting
- **Basic Introduction to Spreadsheets**
  - Importing data
  - Working with formulas

## Monday 13 March: Astronomy with a small Radio Telescope and Amateur Radio

- **Calibrating a Small Radio Telescope**
  - A simple radio telescope - a satellite dish
  - System temperature
  - Antenna temperature
  - Angular sizes
- **Measurement Errors**
  - Measuring errors
  - Combining errors
  - Calculating errors
- **Measuring the Brightness Temperature of the Sun**
  - Antenna "beam width"
  - Antenna performance (aperture & surface efficiency, pointing errors & servo performance)
  - Brightness temperature
- **Amateur Radio Astronomy**
  - How to build your own radio telescope

## Tuesday 14 March: Single-Dish Continuum Observations

- **Radio Continuum Observations**
  - Antenna beam pattern
  - Main components of the HartRAO 26m telescope microwave receiver and radiometer
  - Calibration and calibrator sources
  - Aperture efficiency and effective aperture
  - Source flux density
  - Point Source Sensitivity (PSS)
- **Drift Scan Observations and Calibration**
  - Drift scan observations
  - Monitoring of Active Galactic Nuclei
  - Measure the PSS and source flux density
- **Radiometer, Square law Detector**
  - A basic radiometer
  - Total power radiometer
  - Noise adding radiometer
  - Dicke-switched systems
  - Continuous noise injection
  - Detector diode
  - V/F and counters

## Wednesday 15 March: Single Dish Spectral Line Observations

- **Spectral Line Observations**
  - Theory of spectral line observations
  - Position and frequency switching
  - Maser monitoring observations
  - Spectral line observations of a maser source and calibrator
  - BLVI interferometry
- **Spectrometer**
  - Spectrometer to analyse the signal
- **Talk: The PhD Journey without Tears**

## Thursday 16 March: Single-dish Pulsar Observations

- **Introduction to Pulsars**
- **Dispersion**
  - Using IPython Notebook
- **Pulsar Observing**
  - Pulsar observations using the HartRAO 26m telescope
- **Pulsar Sensitivity**
  - Using IPython Notebook
- **Pulsar Timing**
  - Instrumentation and Techniques
- **Astrophysical Radiation Mechanisms [Invited Lecture]**

## Friday 17 March: Antenna Systems, RFI and Antenna Conversion

- **Radio Telescopes**
  - Astronomical drive and tracking systems...
  - Maintenance, health and safety procedures
- **Radio Frequency Interference (RFI)**
  - Use and Regulation of the radio spectrum
  - Allocation of frequency bands for Radio Astronomy
  - Measurement of RFI and mitigation procedures
- **Antenna Conversion Projects**
  - Update and overview of the AVN engineering project
  - The big picture for a conversion project
  - Engineering approach for conversions
  - Risk management
- **The Path Less Travelled: The adventures of building the African VLBI Network [Invited talk]**

## Monday 20 March: Radio Surveys and Data Mining

- **Radio Surveys**
  - Types and goals of sky surveys at different wavelengths
  - Brief history of sky surveys
  - Surveys and catalogues in the radio
  - Cross-matching catalogues
- **Data Mining**
  - Various data archives, surveys and data products
- **Virtual Observatory Tools**
  - Data discovery and visualisation, spectral analysis…
  - Aladin, TOPCAT, VO Spec, SPLAT, VOPlot…
- **Radio Telescopes of the Future [Invited Talk]**

## Tuesday 21 March: Introduction to Interferometry

- **Introduction to Interferometry**
  - Aperture synthesis
  - Resolution of an array
  - A two-element interferometer
  - Young's double slit experiment and "van Cittert-Zernike" theorem
- **Fourier Transforms and Sampling Theorem**
  - Fourier relation to sky brightness
  - How to use the FFT
  - IPython Notebook exercises
- **Advanced Interferometry**
  - Visibility sampling, Earth rotation and uv-coverage (geometry)
  - Intensity distribution
  - Using FFT, making dirty images and the CLEAN algorithm
- **Imaging Exercises using CASA**

## Wednesday 22 March: Introduction to VLBI and VLBI in Astronomy

- **VLBI Fundamentals**
  - How is VLBI different from connected-arrays
  - Short history and applications of VLBI
  - VLBI networks and equipment
  - VLBI data acquisition and correlation
- **VLBI post-Correlation Analysis and Fringe-fitting**
  - Residual delay and fringe rate errors
  - Single- and multi-band delay
  - Clock errors, RFI, data defects, phase calibration

- **VLBI for Astronomy**
  - The radio sky: galactic and extragalactic
  - Radio emission mechanisms
  - Phase referencing observations
  - Imaging of radio sources in VLBI
  - An introduction to closure phase and self-calibration
  - Continuum and spectral line observations and polarisation
- **Radio Astronomy with the NASA DSN [Invited Talk]**

## Thursday 23 March: Introduction to Geodetic and Astrometric VLBI

- **Introduction to Geodetic VLBI**
  - What is geodetic VLBI
  - Data: acquisition, correlation and analysis
  - Earth orientation and geodetic VLBI products
- **Introduction to VieVs**
  - The Vienna VLBI Software VieVS
  - Using Matlab
  - Modules of VieVS
- **Introduction to Astrometric VLBI & Spacecraft Applications**
  - History of astrometry
  - Celestial References Frames
  - Navigation
  - Networks and Surveys
- **Exercises using VieVS**
- **VLBI Simulations and their Applications for the AVN [Invited talk]**

## Friday 24 March: VLBI models and the planning and scheduling of experiments

- **Geophysical modelling and Atmospheric Propagation**
  - Recommended models
  - Latest IERS conventions
  - Models and Mapping functions used in VieVS
- **Planning, Scheduling and Running a VLBI experiment**
  - Planning your observations
    - Resolution
    - Frequency/bandwidth to use MB
    - Sensitivity needed (demo of exposure time calculators)
    - Observability (location of telescope/target, time of year ...)
    - How to submit a proposal for telescope time
  - Scheduling observations;
    - Software available for scheduling
    - Science goals and mutual visibility
    - Creating a schedule for geodetic VLBI using VieVS
- **Stellar GPS [Invited talk]**

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