UvA MSc Radio Astronomy 2015

Important Deadlines/Dates

(All requested assignment materials should be sent to Jason at “j.w.t.hessels@uva.nl”)

- Fri April 17: Outline of mock observing proposal.
- Wed April 29: Results of simulate your own interferometer practicum.
- Fri May 1: First draft of mock observing proposal.
- Wed May 6: Field trip to ASTRON, Westerbork and LOFAR **(All Day)**.
- Fri May 15: Results of VLA interferometric imaging data analysis practicum.
- Tue May 19: Oral presentations **(15min talk + 5min questions)** of the mock observing proposals **(09:00 - 13:00; room TBD)**.
- Wed May 20: Results of LOFAR pulsar searching/timing data analysis practicum.
- Fri May 22: Final version of written mock observing proposal.
- Wed May 27: Final exam.

Summary of Practicum Sessions

(See also detailed descriptions below)

- Mon March 30: Setup computing environment.
- Wed April 1: Short lecture on how to write an observing proposal (see slides below).
- Wed April 8: Discuss observing proposal ideas in a group (outside!).
- Mon April 13: Discuss observing proposal ideas one-on-one.
- Wed April 15: Work on observing proposal yourself.
- Mon April 20: Simulate your own interferometer - session I.
- Wed April 22: Simulate your own interferometer - session II.
- Wed April 29: Calibrate and image VLA data - session I.
- Wed May 6: Field trip to ASTRON, Westerbork and LOFAR.
- Mon May 11: Calibrate and image VLA data - session II.
- Wed May 13: Search and time pulsar in LOFAR data - session I.
- Mon May 18: Search and time pulsar in LOFAR data - session II.
- Tue May 19 (shifted from Wed May 20): Mock observing proposal presentations.

Lecture Synopsis (date, title, lecturers/TAs)

Course Outline

March 30, 2015 - The History of Radio Astronomy: Past to Present - Jason

Lecture 1 (lecture slides including extra notes)

- Introduction to the course: course structure, goals, lectures, practica, etc.

- Maxwell, Hertz, Marconi
- Karl Jansky
- Grote Reber
- Technological developments during WWII
- The post-war dawn of radio astronomy
- Great discoveries in the first half century of radio astronomy
- Radio astronomy in the context of multi-wavelength astronomy
- The radio telescope as IT instrument

April 1, 2015 - The Science of Radio Astronomy: Extragalactic - Michael

Lecture 2 (lecture slides including extra notes)

- Radio Astronomy for Extragalactic Science
- Nearby Galaxies, Mapping HI, Dynamics, Magnetic Fields
- Nearby Galaxies, Astrometry, SNR, GRBs, Mapping HI, Dynamics,
- Star Formation, FIR-Radio Correlation, Lensing
- Radio Galaxies, AGN, Jets, Quasars, Gas Flows, and Radio Source Evolution
- Galaxy Groups and Clusters, Feedback, Black Hole Growth, Relics, Halos, and Shocks
- Cosmic Microwave Background, S-Z Effect, EoR, Cosmology and Large-scale Structure

April 8, 2015 - The Science of Radio Astronomy: Galactic and Solar System - Joeri

Lecture 3 (lecture slides including extra notes)

- The Milky Way
- Clouds of gas, supernovae, pulsars
- The Sun
- The Giant planets
- Radar imaging of the planets, moon, and near-Earth asteroids

April 13, 2015 - Emission Mechanisms in Radio Astronomy - Jason

Lecture 4 (lecture slides including extra notes)

- Thermal vs.non-thermal emission
- Continuum vs. line emission
- Blackbody radiation from the CMB and dust
- Free-free emission (thermal bremstrahlung)
- Radio recombination lines
- 21-cm line
- Molecular vibration and rotation lines
- MASERs
- Cyclotron radiation
- Synchrotron radiation

- Inverse Compton radiation
- Synchrotron self-Compton radiation
- Propagation effects

April 15, 2015 - The Radio Telescope - Joeri

Lecture 5 (lecture slides, all notes included on slide text)

- Antenna response: resolution and beam shapes
- Reflector types, collecting area
- The signal chain: antenna, receivers, amplifiers, and mixers
- Sensitivity: the radiometer equation

April 20, 2015 - The Techniques of Radio Interferometry I: The Basics - Jason

Lecture 6 (lecture slides including extra notes)

- Motivation for radio interferometry
- Two-element interferometer
- Basic interferometer equations
- Beam shape
- Understanding the UV-plane
- Preparing for the “Simulate your own interferometer” practicum

April 22, 2015 - The Techniques of Radio Interferometry II: Calibration - Michael

Lecture 7 (lecture slides including extra notes)

- Definition of Calibration
- Visibilities, uv Coverage, Gains, Phases
- Real Data, Data Examination, Data Editing
- Formalism, Ideal vs. Real Measurements
- Calibration Strategies and Effectiveness

April 29, 2015 - The Techniques of Radio Interferometry III: Imaging - Michael

Lecture 8 (lecture slides including extra notes)

- Imaging and Deconvolution
- Image Quality, Noise, Dynamic Range
- Wide-band imaging, Multi-frequency Synthesis
- Wide-field imaging, Facet Imaging, W-Projection
- Mosaicing

May 6, 2015 - Field Trip to LOFAR and Westerbork - All

May 11, 2015 - The Techniques of Time-Domain Radio Astronomy I: Single-dish techniques - Joeri

Lecture 9 (lecture slides including extra notes)

- Main differences between imaging and single-dish time domain astronomy
- High-time resolution recording
- Pulsar properties
- Pulsar timing

May 13, 2015 - The Techniques of Time-Domain Radio Astronomy II: High time resolution with interferometers - Jason

Lecture 10 (lecture slides including extra notes)

- Comparison with single-dish observations
- Incoherent vs. coherent summation
- Fly's Eye observations
- Fast imaging
- Advanced techniques

May 18, 2015 - The Future of Radio Astronomy - Michael

Lecture 11

- The Square Kilometre Array (SKA)
- SKA Pathfinders
- SKA Computational Challenges
- Data Intensive Astronomy
- Beyond the SKA

May 19, 2015 - Observing proposal presentations - All

May 27, 2015 - Final Exam - Jason + Daniele + Amruta

Practica (projects, dates, goals, materials)

Set up computing environment

Goal : Get you connected to the prepared computing environment.

Expected time : 1-2hrs

Sessions :

- March 30 - Simply ensure that everyone is able to login properly and create a simple python script/plot.

Materials : see printed instructions.

Mock observing proposal

Goal : Synthesize your scientific, theoretical and technical knowledge of radio astronomy by writing a mock observing proposal for a real radio telescope. Who knows: you might even want to submit it for real! The proposal is 3-4 page scientific justification (including figures), 1 page technical justification, and 1 page references maximum. Final deliverable is a PDF. You can write it as Latex, Word, or otherwise. See template below, under “Materials”.

Expected time : ~48hrs

Contribution to total grade : 35% (20% for written proposal; 15% for oral presentation)

Sessions :

- April 1 - Get some tips on how to write your proposal (see lecture notes below, under “Materials”).
- April 8 - Start discussing proposal ideas with the lecturers.
- April 13 - Disc proposal ideas one on one with Jason; Prepare a first outline to submit by Fri April 17
- April 15 - Prepare a first outline to submit by Fri April 17
- May 19 - Final presentations

Materials :

Advice on how to write your observing proposal

Proposal template .pdf

Proposal template .tex.gz (need to "gunzip")

Example observing proposal

Proposal plans and assigned “mentor”

- Timo: Probing gas in interacting galaxies - Michael
- Peter: Crab pulsar giant pulses - Joeri
- Daan: Fast radio bursts to probe the intergalactic medium - Joeri
- Sebastiaan: Intermediate Mass Black Holes as the mechanism behind Hyperluminous X-ray Sources - Jason
- Ziggy: Polarization in nearby galaxies and possible relation to star formation - Michael
- Okan: Dust formation in Supernova Remnants - Jason
- Sarah: 21-cm cosmology - Michael
- Bas: Kilonovae triggered based on LIGO gravitational wave events - Joeri

- David: X-ray/radio luminosity relation for neutron stars - Jason
- Coen: Stellar mass black holes switching off/onto the fundamental plane - Jason

Simulate your own interferometer

Goal : Deepen your understanding of how a radio interferometer works by simulating your own radio telescope from scratch using Python.

Expected time : ~16hrs

Contribution to total grade : 10%

Sessions :

- April 20 - Start writing your script to simulate the synthesized beams of various interferometer configurations.
- April 22 - Get close to finishing your script and plots. Assignment is due Wed April 29th.

Materials : Assignment and tips

Make a VLA interferometric image

Goal : Make you first radio interferometric image and understand the underlying calibration process and methods.

Expected time : ~24hrs

Contribution to total grade : 15%

Sessions :

- April 29 Data preparation and Flagging
- May 11 Calibration and Imaging
- May 13 finish off this practicum
- Submission checklist

Materials :

See above.

Field trip to Westerbork and LOFAR

Goals :

Expected time : ~9hrs

Contribution to total grade : 0% (but expect to learn a few things that may appear on the Final

Exam)

Sessions :

- May 6

Materials :

"Discover" and characterize a radio pulsar

Goals : Learn how to “discover” a radio pulsar in radio telescope and then characterize its properties.

Expected time : ~4hrs

Contribution to total grade : 10%

Sessions :

- May 18

Materials :

PSR Practicum data and assignment

Further References for Radio Astronomy

We stress that the course lecture and practica notes should serve as a self contained guide for the course (i.e. these should be sufficient background to complete the practica and write the exam, though for the mock observing proposal you will definitely need to do some independent reading of sources relevant to your chosen topic). Nonetheless, here are some of links to radio astronomy learning materials.

Links to other classes

- NRAO Essential Radio Astronomy (Condon & Ransom): http://www.cv.nrao.edu/course/astr534/ERA.shtml
- NJIT Radio Astronomy Course (Gary): http://web.njit.edu/~gary/728/
- Leiden Radio Astronomy Course (Garrett): http://www.astron.nl/~mag/dokuwiki/doku.php?id=radio_astronomy_course_description
- Leiden Radio Astronomy Course (Schilizzi): http://home.strw.leidenuniv.nl/~intema/ra2006.htm
- Glasgow Radio Astronomy Course (Woan): http://radio.astro.gla.ac.uk/ralectures/
- UvA Interferometry (Jaffe): http://home.strw.leidenuniv.nl/~jaffe/interferometry/AMS2/
- UvA Radio Astronomy (Strom): http://www.astron.nl/~leeuwen/course/RadioAstronomy_2013/Strom/
- NRAO Synthesis Imaging Summer School: http://www.aoc.nrao.edu/events/synthesis/2012/lectures.shtml
- U. Calgary radio telescope project: http://www.ras.ucalgary.ca/radiotel/

Reference books

- An introdution to Radio Astronomy
- Radio Astronomy
- High Energy Astrophysics
- Tools of Radio Astronomy
- Antennas
- Interferometry and Synthesis in Radio Astronomy