UvA MSc Radio Astronomy 2017

Important Deadlines/Dates

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

- Week of Apr 17 (just after Easter): discuss Mock proposal idea with your advisor. Schedule a date/time with them for this.
- Wed Apr 21: Outline of mock observing proposal.
- Mon May 1: First draft of mock observing proposal.
- Wed May 10: Results of simulate your own interferometer practicum.
- Wed May 10: Second draft of mock observing proposal.
- Wed May 17 (just before RA Field Trip): Results of VLA interferometric imaging data analysis practicum.
- Thu May 18: Field trip to ASTRON, Westerbork and LOFAR (All Day).
- Tue May 23: Results of LOFAR pulsar searching/timing data analysis practicum.
- Wed May 24 (**May change; conflict with NAC**): Oral presentations (15min talk + 5min questions) of the mock observing proposals (09:00 - 13:00; room TBD).
- Mon May 29: Final version of written mock observing proposal.
- Fri Jun 2: Final exam.

Summary of Practicum Sessions

(See also detailed descriptions below)

- Practicum 1 - Apr 3 - Joeri + Daniele - Short lecture on how to write an observing proposal (see slides below).
- Practicum 2 - Apr 7 - Jason + Joeri + Michael + Daniele - Discuss observing proposal ideas in a group (outside if possible!).
- Practicum 3 - Apr 17 - Arrange appt. w your advisor - Discuss observing proposal ideas one-on-one.
- Practicum 4 - Apr 21 - Jason - Work on observing proposal yourself.
- Practicum 5 - Apr 24 - Jason + Daniele - Setup computing environment.
- Practicum 6 - May 1 - Jason - Simulate your own interferometer - session I.
- Practicum 7 - May 8 - Michael - Simulate your own interferometer - session II.
- Practicum 8 - May 12 - Michael - Calibrate and image VLA data - session I.
- Practicum 9 - May 15 - Joeri - Calibrate and image VLA data - session II.
- RA Field Trip - May 18 - All day
- Practicum 10 - May 19 - Jason - Search and time pulsar in LOFAR data - session I.
- Practicum 11 - May 22 - Michael - (**NAC - Maybe move**) - Search and time pulsar in LOFAR data - session II.
- Final Presentations - May 24 - All - (**NAC - Maybe move**)
- Final Exam - Jun 2 - All

Lecture Synopsis (date, title, lecturers/TAs)

Course Outline

April 3, 2017 - The History of Radio Astronomy: Past to Present - Joeri

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 7, 2017 - 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 10, 2017 - 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 21, 2017 - 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 24, 2017 - 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

May 1, 2017 - 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

May 8, 2017 - 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

May 12, 2017 - 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 15, 2017 - 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 18, 2017 - Field Trip to LOFAR and Westerbork - All

May 19, 2017 - 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 22, 2017 (** May change; conflict with NAC **) - The Future of Radio Astronomy - Michael

Lecture 11 (lecture slides including extra notes)

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

May 24, 2017 (** May change; conflict with NAC **) - Observing proposal presentations - All

June 2, 2017 - Final Exam - Jason + Daniele

Practica (projects, dates, goals, materials)

Set up computing environment

Goal : Get you connected to the prepared computing environment.

Expected time : 1-2hrs

Sessions :

- Apr 24 - 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 :

- Apr 3 - Get some tips on how to write your proposal (see lecture notes below, under “Materials”).
- Apr 7 - Start discussing proposal ideas with the lecturers.
- Apr 10 - Disc proposal ideas one on one with advisor; Prepare a first outline to submit by Wed Apr 19
- Apr 21 - Prepare a first draft to submit by Wed Apr 26
- May 24 - Final presentations (**NAC - may change**)

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 “advisor”

- Frank Backs (advisor: Jason) - Massive young stellar objects in M17 with ALMA - 1st draft
- Valentina Peirano Bastías (advisor: Michael) - AGN feedback
- Jorrit Bootsma (advisor: Joeri) - Proto-planetary disks (planetary masses, dust trapping) - 1st draft + feedback, 2nd draft
- Eric Gisolf (advisor: Jason) - Proto-planetary disks (water distribution) - 1st draft
- Diogo Gomes (advisor: Joeri) - Space Weather, specifically Solar Flares - no outline, no draft yet (2017-05-03)
- Kelly Gourdji (advisor: Jason) - Pulse morphology FRB121102 - 1st draft
- Filipe Andrade de Matos (advisor: Joeri) - Exoplanet radio emission from intelligent life - 1st draft + feedback
- Vincent van der Meij (advisor: Joeri) - Differences between repeating/non-repeating FRBs - 1st draft + feedback
- Kriek van der Meulen (advisor: Michael) - Wasp-43b (a hot jupiter of mass around 2Mj)
- Yashar Robert (advisor: Michael) - Protoplanetary disks and the pebble accretion paradigm of planet formation with ALMA
- Emma van der Wateren (advisor: Jason) - Search for transitional millisecond radio pulsars - 1st draft
- Stephan de Wit (advisor: Jason) - Cataclysmic variables - 1st draft pending

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 :

- May 1 - Start writing your script to simulate the synthesized beams of various interferometer configurations.
- May 8 - Get close to finishing your script and plots. Assignment is due Wed May 10.

Materials : Assignment and tips Some code snippets for guidance

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 :

- May 12 Data preparation and Flagging
- May 15 Calibration and Imaging
- May 19 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 18

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 19
- May 22

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