(Astro)Physics 343
Observational Radio Astronomy

astrophysics course number = 01:105:343

physics course number = 01:750:343

web page = http://www.physics.rutgers.edu/ugrad/343/

Personnel

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(godfather = Prof. Tom Devlin)

Please check your email regularly!

This is how we will distribute information on schedules, labs, etc.

It is also the best way for you to reach us when we are busy and/or travelling.

Requirements

Textbook: none. Three useful books are on reserve in the physics library, and an online "Essential Radio Astronomy" course taught at the University of Virginia is linked from our main web page.

Prerequisite: (Astro)Physics 341/342 ("Principles of Astrophysics" with Professor Keeton) should be taken already or concurrently.

Other: a scientific calculator; access to a computer that can do number-crunching with Excel or programs that you write.

Course meetings

Lectures: Serin 401, once a week, M 10:20-11:40

Labs: Serin 403b, times TBD (you will have assigned slots)

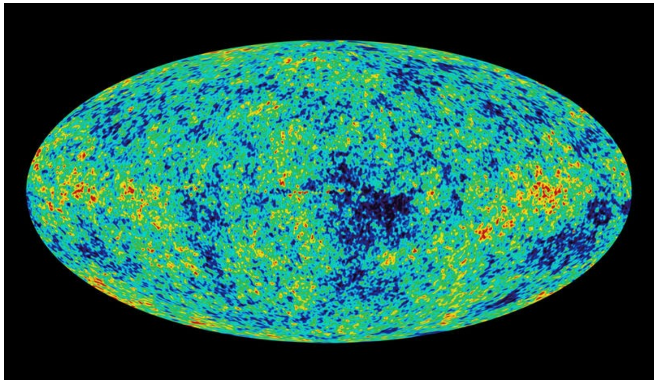
In general: one week will be "observation" week, one week will be "analysis" week. When/where we meet in "analysis" week will depend on your schedules.

Lectures

We'll talk about material relevant to the labs, but also about radio astronomy in general:

+ techniques: single-dish telescopes, inteferometry

+ science: stars, planets, interstellar medium, active galactic nuclei, cosmic microwave background



Labs

Six labs planned, of which at least four will use the Small Radio Telescope (SRT, diameter = 2.3m) on the roof:

#1: measuring a telecope's beam

#2: calibrating a telescope's response; measuring solar variability

#3: measuring the thickness of the Milky Way's disk

#4: measuring the Milky Way's rotation curve

#5: millimeter interferometry of an external galaxy

#6: class visit to Green Bank, West Virginia, or a final project with the SRT (very faint object? troubleshooting?)

Visit to Green Bank (still tentative)

The National Radio Astronomy Observatory (NRAO) has a site in Green Bank, WV in the middle of the National Radio Quiet Zone. This is the location of the world's largest fully steerable radio telescope (100m diameter).

Fri 4/25: drive to Green Bank

Sat 4/26: tours of telescopes, labs; hands-on nighttime observing of hydrogen in the Milky Way and/or a "mystery object"

Sun 4/27: return to Rutgers

Grades

Course grades will be based on a combination of:

- **+ quizzes during lecture (10%) - can happen at any time!**
- **+ participation during lecture (10%)**
- **+ preparation for and active participation during labs (30%)**
- **+ lab reports (50%)**

Lab reports should be written up individually even if observations were done in teams.

The Green Bank trip will count as the sixth lab (with no report).

Good advice for this class (and beyond)

Ask questions (even if they seem "stupid").

Record everything you do in lab in a single, chronologically organized lab notebook. (This will help you remember what you did even days or weeks later, and will make it easier for us to help troubleshoot if there are problems.)

Remember that every measurement comes with a unit and an uncertainty.

What's different about radio astronomy?

Wavelengths are longer (λ = 0.35mm – 6m, vs. ~0.0005mm for visible light). This has several consequences:

Telescopes have larger diameters and lower surface accuracies.

Observations can often be done during day or night, and are less limited by the atmosphere (clouds, turbulence, etc.).

Detectors are often sensitive to the phase of incident radiation, not just its amplitude (in the sense of a complex number).

What do we study with radio telescopes?

Typically, we study interstellar matter:

- **dust grains that glow because they're warm**
- **ionized plasmas that glow because they're warm, or because charged particles are accelerated in magnetic fields**
- **clouds of atomic and molecular gas producing line emission**

(Astronomy jargon that we'll see again: HI = neutral atomic hydrogen, HII = ionized hydrogen, H_2 = molecular hydrogen.)

What radio telescopes do researchers use?

National Radio Astronomy Observatory (NRAO):

Green Bank Telescope (GBT, in West Virginia)

Very Large Array (VLA, in New Mexico)

Very Long Baseline Array (VLBA, all over)

What radio telescopes do researchers use?

National Astronomy and Ionosphere Center (NAIC):

Arecibo Observatory (in Puerto Rico; 305m diameter!)

Summer research opportunities

Research Opportunities for Undergraduates (REU) programs...

+ National Radio Astronomy Observatory (Socorro, NM; Charlottesville, VA; Green Bank, WV): deadline TODAY (see http://www.nrao.edu/students/summer-students.shtml)

+ Arecibo Observatory, Puerto Rico: deadline February 6th (see http://www.naic.edu/science/summer_set.htm)

What radio telescopes do researchers use?

Small university and large international facilities...

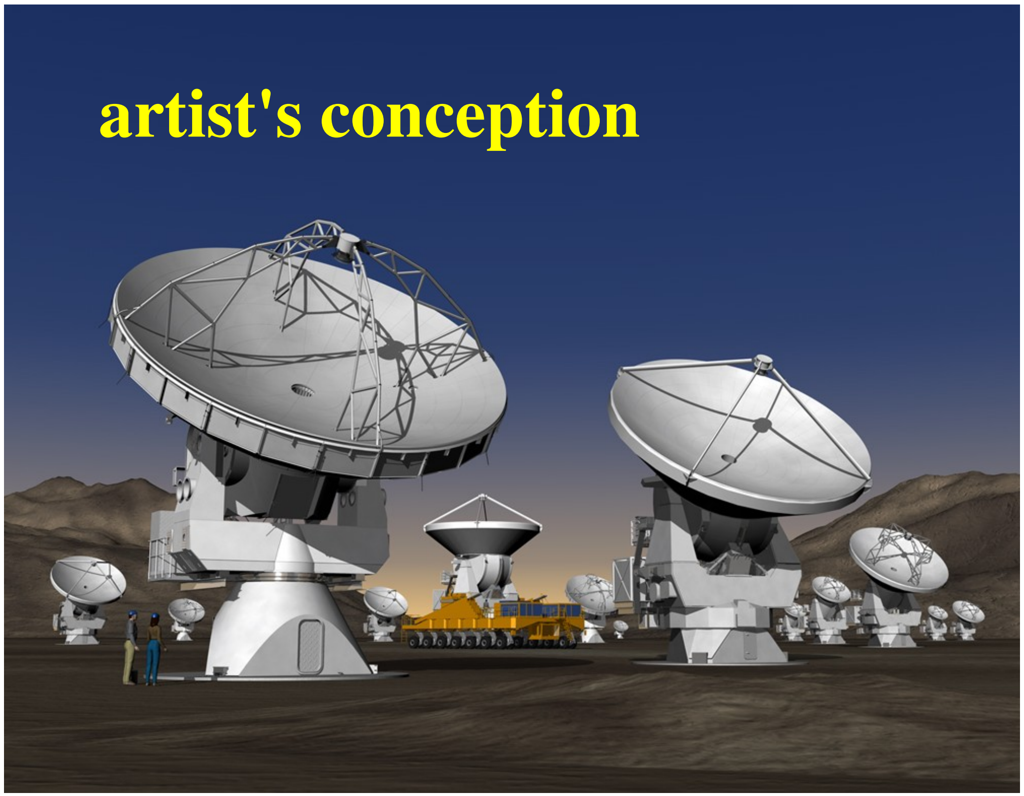
Combined Array for Research in Millimeter Astronomy (CARMA)

Institute for Radioastronomy in the Millimeter (IRAM)

Giant Metrewave Radio Telescope (GMRT)

What radio telescopes *will* researchers use?

Atacama Large Millimeter Array (ALMA, northern Chile)



Square Kilometer Array (SKA, western Australia or southern Africa) – name refers to collecting area

A common thread: go to high/remote sites

For cutting-edge research, the two big obstacles are:

(1) at shorter wavelengths ($\lambda < 1$cm), atmospheric water vapor

⇒ go to a high site

(2) at longer wavelengths, ($\lambda > 1$cm), radio frequency interference (RFI) from man-made sources

⇒ go to a remote site

Note: Serin is neither high nor (more key for $\lambda = 21$cm) remote...

Quiz

More details about the SRT...

Antenna diameter = 3m (standard satellite dish).

Aluminum frame + mesh surface (will reflect all light if holes are < $\lambda/10$).

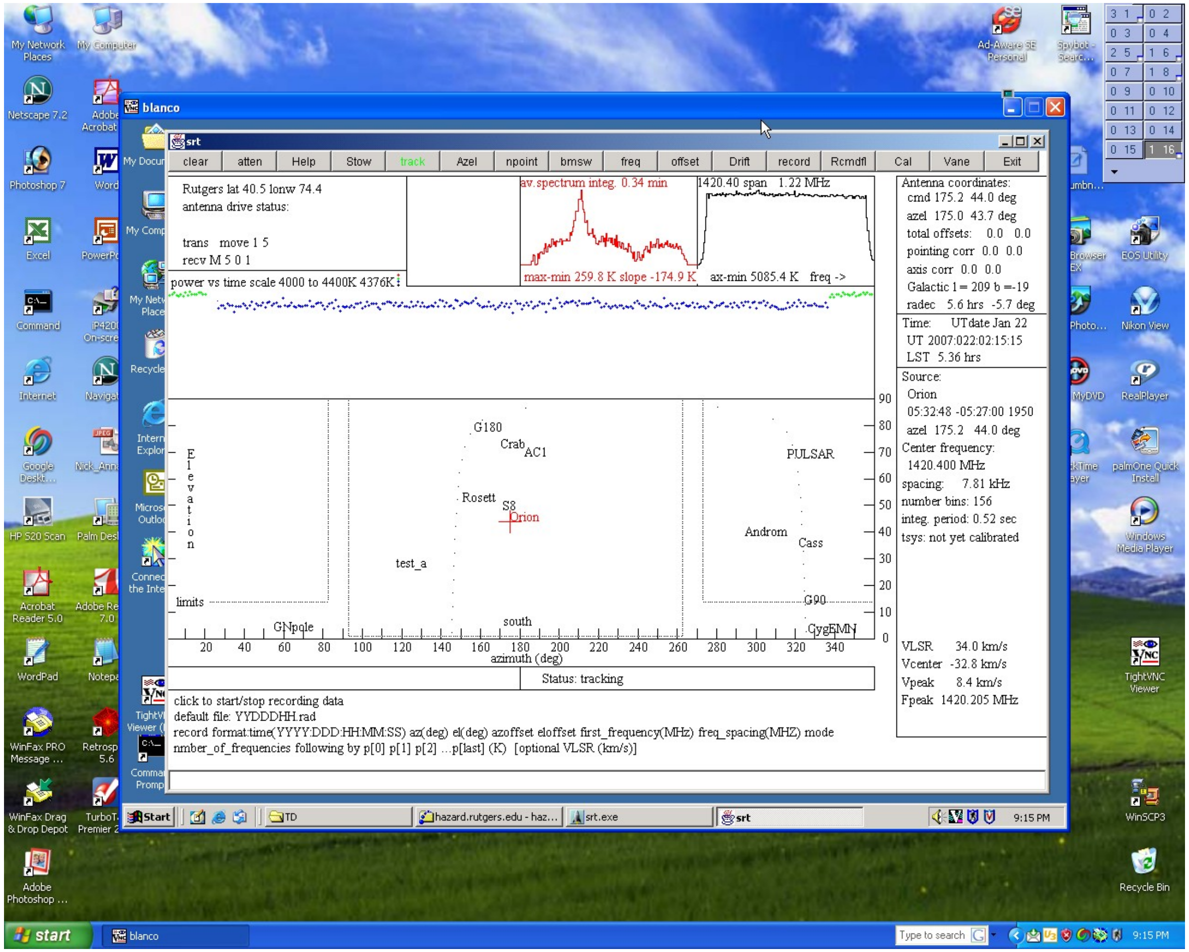
Mount = azimuth/elevation design (with some limits).

More details about the SRT...

Receiver is sensitive to light with λ = 21cm, which is where the main transition of atomic hydrogen (HI) lies.

Both continuum and line observations are possible.

More details about the SRT…



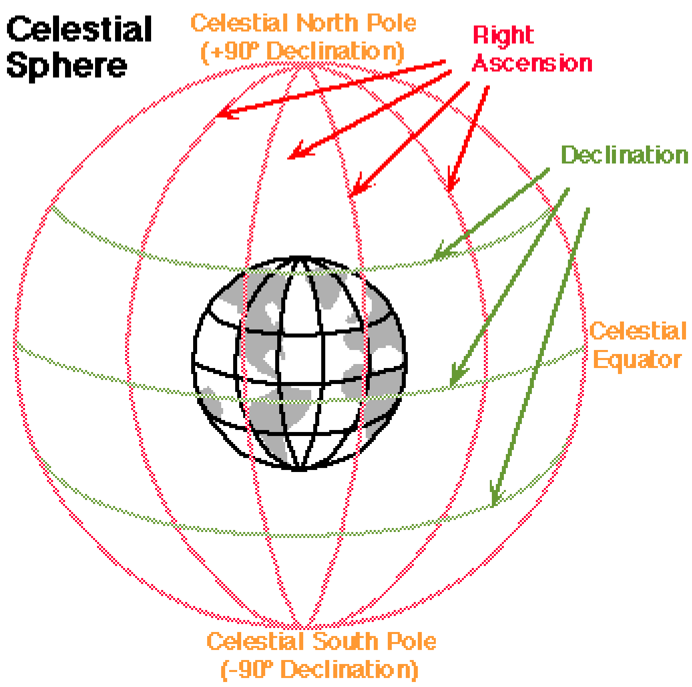
Control software is written in Java for a Windows platform.

Command sequences are prepared using a scripting language.

Coordinate systems: earth's point of view

Celestial coordinates:

- **+ declination ranges from 90º (north celestial pole) to -90º (south celestial pole) – like latitude**
- **+ right ascension ranges from 0º (for stars, galaxies, etc. that transit at midnight on 9/21) to 90º (farther east)... to 360º – like longitude**



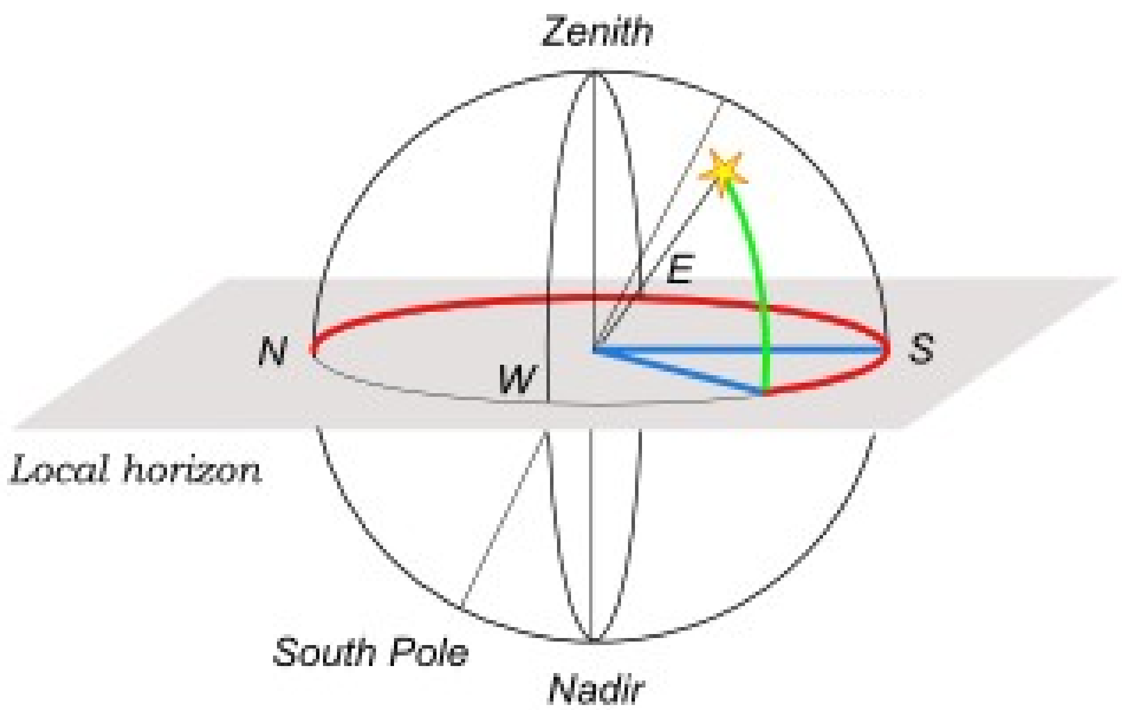
Celestial coordinates of solar system objects change (relatively) rapidly.

Coordinate systems: telescope's point of view

Horizontal coordinates:

+ **elevation** ranges from 90º (zenith) to 0º (horizon)

+ **azimuth** ranges from 0º (north) to 90º (east) to 180º (south) to 270º (west) to 360º (north) around the horizon



Preparation for lab #1

Homework for next time:

Read the documentation on the SRT.

Write a script that does the following:

(1) points at the Sun

(2) sets the frequency to 1415 MHz

(3) moves 30 degrees in azimuth away from the Sun

(4) does a calibration

(5) points back at the sun and does an "npoint" scan