Physics 343

Observational Radio Astronomy

course number = 01:750:343

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

(also linked from http://www.physics.rutgers.edu/~ajbaker/)

Personnel

Professor

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(godfather = Emeritus 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 will be on reserve in SERC, and an online "Essential Radio Astronomy" course taught at the University of Virginia is linked from our main web page.

Pre/corequisite: Physics 341/342 ("Principles of Astrophysics," now with Professor Gawiser) should be taken already or concurrently, unless you have special permission.

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

Course meetings

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

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

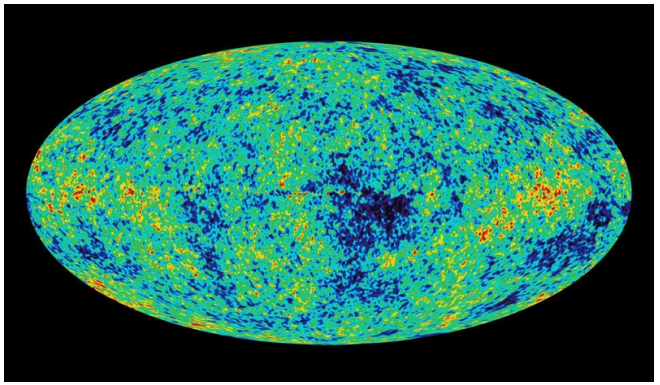
In general: one week will be "observation" week, one week will be "analysis" week. During analysis weeks, one of us will be "on call" in our office at each of the regular lab times.

Lectures

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

+ techniques: single-dish telescopes, interferometry

+ science: planets, interstellar medium, compact objects, cosmic microwave background



Last lecture: student choice

May 5th = last day of class:

I will lecture on 1–2 topics that you choose shortly after spring break. Any topic related to radio astronomy is fair game.

Previous years:

"Current and Future Radio Astronomy Projects"

"The Search for Extraterrestrial Intelligence"

"Gravitational Waves & Organic Material in Space"

"SETI & Galaxy Collisions"

"Exoplanets & Quasars"

Labs

Six labs planned, of which at least three 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 studying "radio frequency interference"

Visit to Green Bank

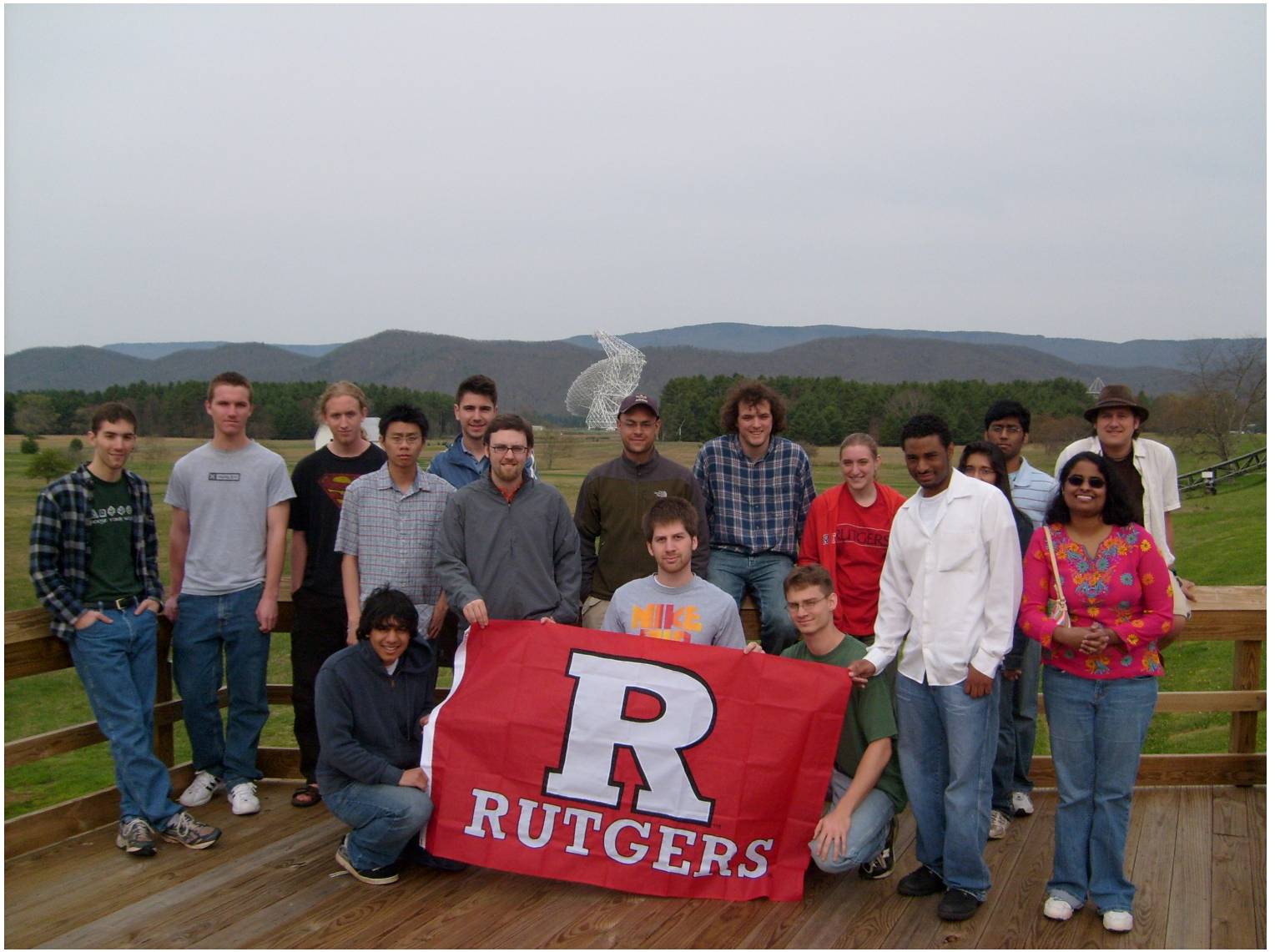
The National Radio Astronomy Observatory (NRAO) has a site in Green Bank, WV in the middle of the National Radio Quiet Zone. This is the location of the world's largest fully steerable radio telescope (100m diameter).

Fri 4/25: drive to Green Bank

Sat 4/26: tours of telescopes, labs; hands-on observing of a stellar nursery in the Milky Way

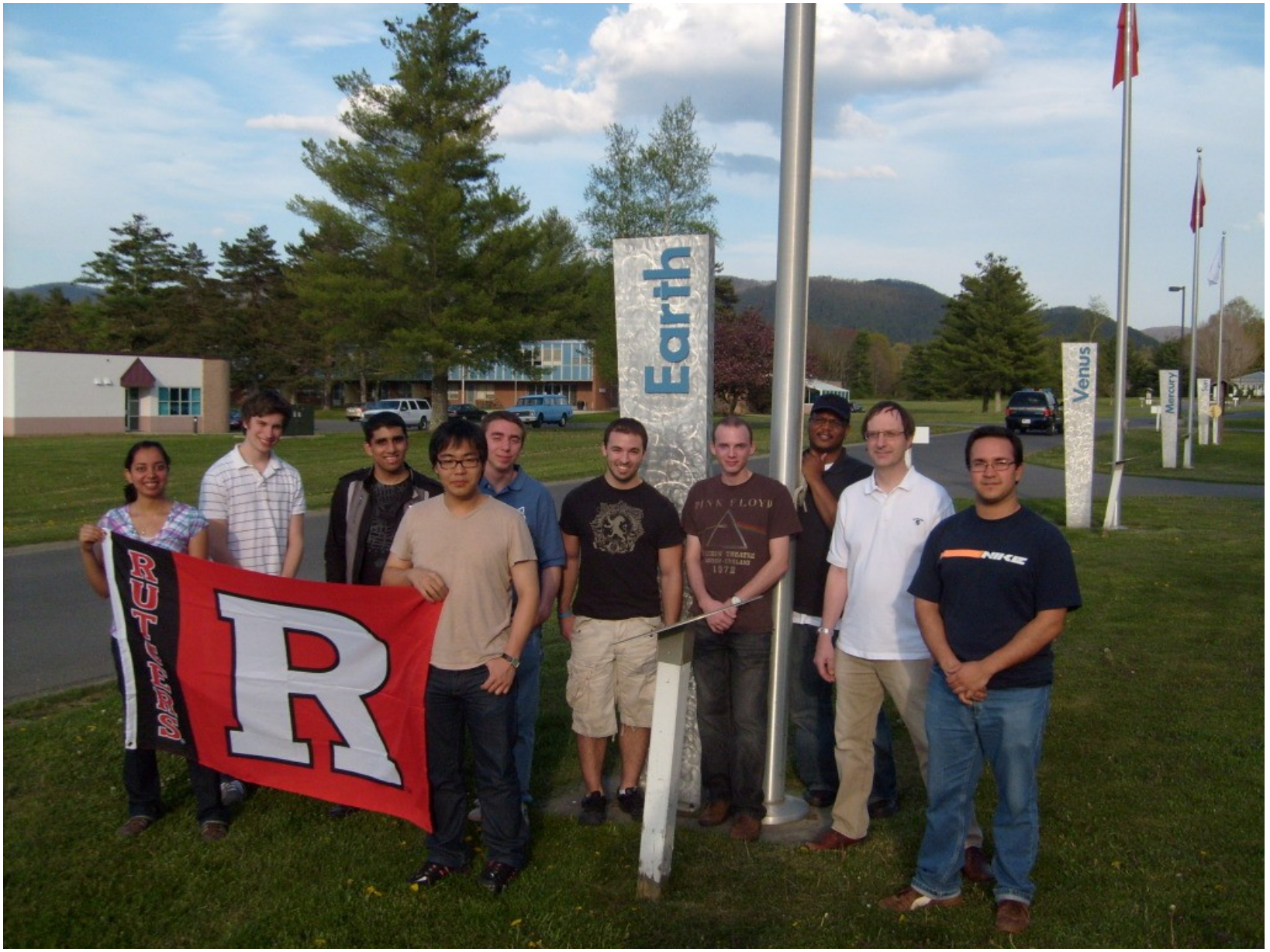
Sun 4/27: return to Rutgers

Rutgers at Green Bank: 2008



Rutgers at Green Bank: 2009

Rutgers at Green Bank: 2010



Rutgers at Green Bank: 2012

Rutgers at Green Bank: 2013

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).

Regarding lab reports...

Do include:

(1) a brief description of the purpose of the observations

(2) a brief description of the observations (e.g., how many data points per position? was a script modified in any way?)

(3) a description of your analysis (number-crunching)

(4) a discussion of your results (plots and sketches help; consider your sources of uncertainty)

(5) a summary of your most important conclusions

Do not include:

(1) full scripts used to obtain data

(2) the raw data themselves

Email submission of a PDF file before 11:59pm is acceptable.

Absences and late work

Absences:

Unless you have a medical emergency, you should tell Prof. Baker in advance via https://sims.rutgers.edu/ssra/ or get zero quiz/participation points

Late penalty, quoting from website:

"I am willing to be somewhat flexible, but unless I tell you otherwise, I will deduct 10% *off the top* for each day a lab report is handed in late (the first deduction hits at 11:59pm on the nominal due date). This means that a lab report handed in three days late will receive at best a grade of 70%..."

Good advice for this class (and beyond)

Ask questions (even if they seem "stupid"), and speak in lab!

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.

Two items in the "optional" category

There may be several afternoons or evenings during the semester when I am observing with the GBT from my office. I will alert you to these sessions as they are scheduled; you are welcome to come watch. (No extra credit, but can be educational/entertaining.)

Except in extreme cases, I will not be grading your lab reports for quality of writing. If you would like me to comment on the writing in your lab reports (there will be no impact on your grade, and degree of scrutiny will depend on how pressed I am for time), please email me.

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)

Jansky Very Large Array (JVLA, 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 (2015?) research opportunities

Research Opportunities for Undergraduates (REU) programs...

+ National Radio Astronomy Observatory (Socorro, NM; Charlottesville, VA; Green Bank, WV): deadline February 1 (https://science.nrao.edu/opportunities/student-programs/summerstudents)

+ Arecibo Observatory, Puerto Rico: deadline January 27 (http://www.naic.edu/reu_program.html)

What radio telescopes do researchers use?

Small university and large international facilities...

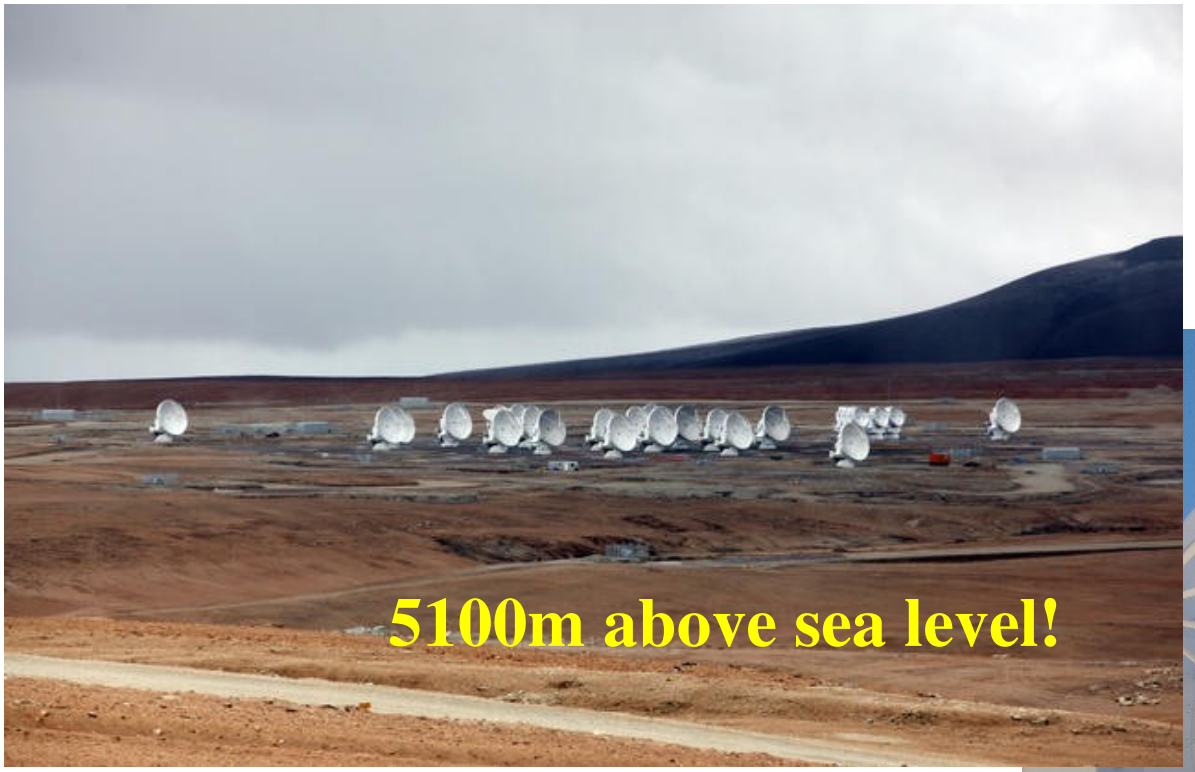
Institute for Radioastronomy in the Millimeter (IRAM)

Giant Metrewave Radio Telescope (GMRT)

What radio telescope do researchers use?

ALMA = Atacama Large Millimeter/submillimeter Array

in northern Chile



operations support facility

What radio telescopes *will* researchers use?

MeerKAT = "more" Karoo Array Telescope" in northwest South Africa; engineering office is in Cape Town

This will be a precursor for the Square Kilometer Array (SKA – name refers to collecting area), which will be built in western Australia and southern Africa.

A common thread: go to high/remote sites

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

(1) at shorter wavelengths (λ < 1cm), atmospheric water vapor

⇒ go to a high site

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

⇒ go to a remote site

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

Quiz

More details about the SRT...

Antenna diameter = 2.3m (standard satellite dish).

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

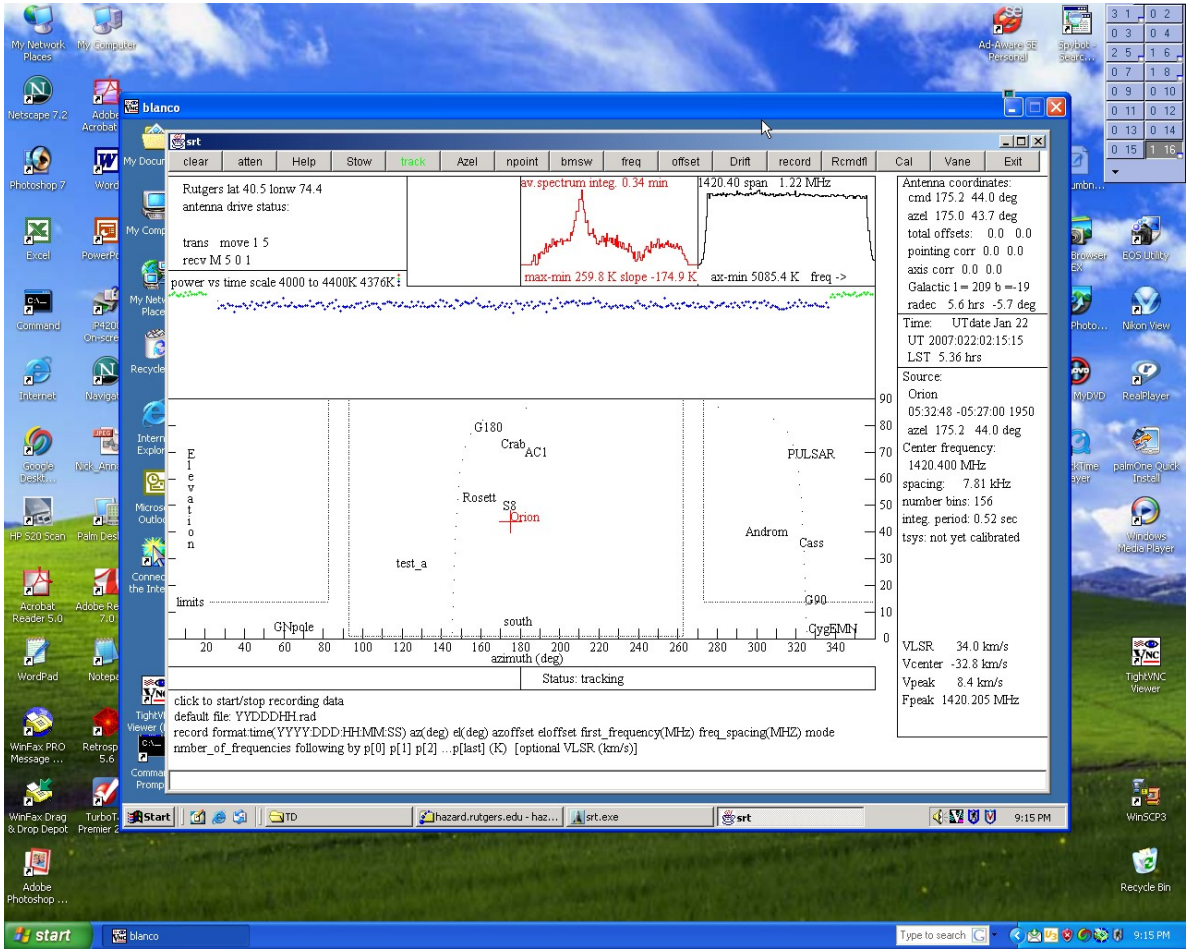
Mount = azumith/elevation design (with some limits).

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.

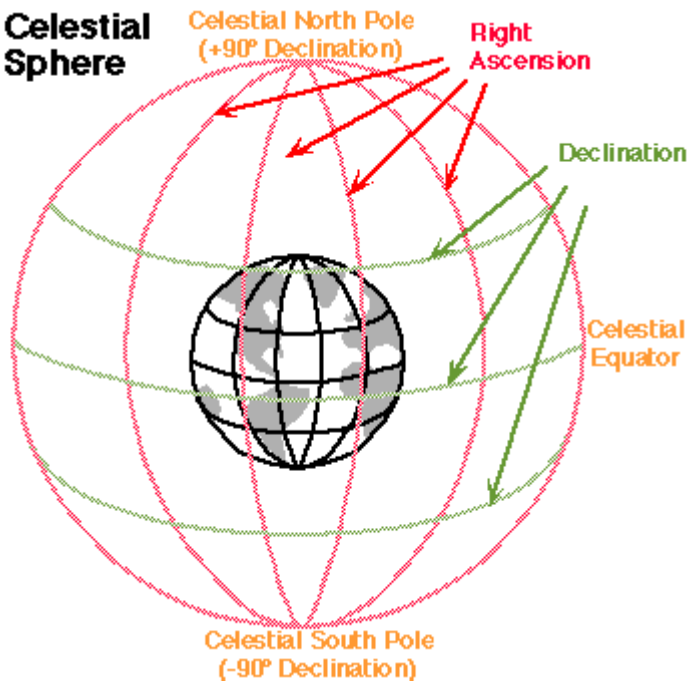
Coordinate systems: earth's point of view

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.

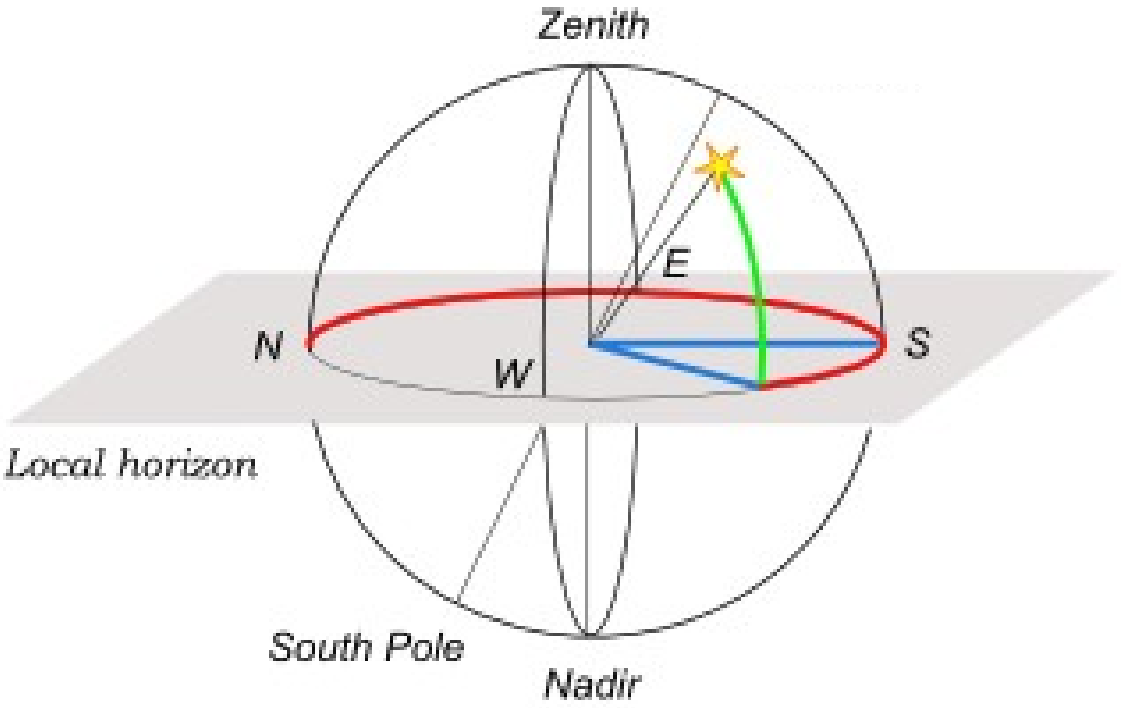


Coordinate systems: telescope's point of view

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 Monday:

Read through the documentation on the SRT.

As a practice exercise (not to be turned in), write a script that does the following:

(1) sets the frequency to 1415 MHz

(2) slews to the Sun and does a raster scan

(3) pauses for 30 seconds to observe the Sun

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

(5) pauses for 30 seconds before moving back to the Sun