

(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/>

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

Personnel

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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 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 Jha) 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 or programs that you write (you will get an account on the common-use computer running Linux).

Course meetings

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

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

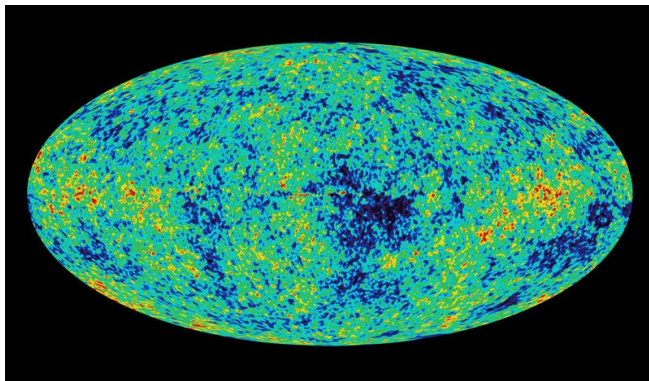
In general: one week will be “observation” week, one week will be “analysis” week. During analysis weeks, one of us will be “on call” at each of the regular lab times.

Lectures

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

**+ techniques: single-dish telescopes,
interferometry**

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



Last lecture: student choice

May 2nd = last day of class:

I will lecture on a topic 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”

This year: the New Jersey roots of radio astronomy? why garage door openers are evil? your idea here...

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 telescope'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

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 4/22: drive to Green Bank

Sat 4/23: tours of telescopes, labs;

hands-on observing of

stellar nurseries and/or

hydrogen in the Milky Way

Sun 4/24: return to Rutgers



Rutgers at Green Bank: 2008



Rutgers at Green Bank: 2009



Rutgers at Green Bank: 2010



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)**

Do not include:

- (1) full scripts used to obtain data**
- (2) the raw data themselves**

Write in active voice (“We did...”), and be faithful to the data!

Absences and late work

Absences:

- (a) mine: you will have two guest lectures (2/28 and 4/18)
- (b) yours: unless you have a medical emergency, tell me **in advance** 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. This means that a lab report handed in ten or more days late will automatically receive a zero.”

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), please let me know.

What's different about radio astronomy?

Wavelengths are longer ($\lambda = 0.35\text{mm} - 6\text{m}$, vs. $\sim 0.0005\text{mm}$ 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, **H₂** = 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 February 1**
(<http://science.nrao.edu/opportunities/summerstudents.shtml>)
- + **Arecibo Observatory, Puerto Rico: deadline February 2nd**
(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)**



Giant Metrewave Radio

Telescope (GMRT)



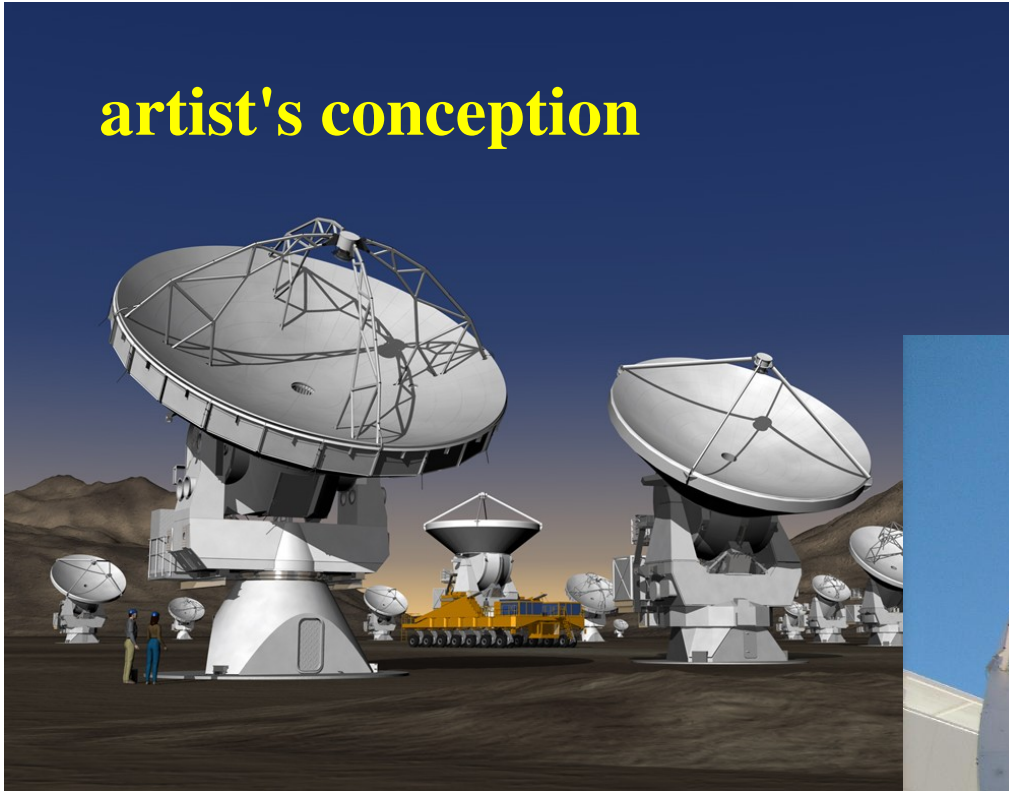
**Institute for Radioastronomy
in the Millimeter (IRAM)**

What radio telescopes *will* researchers use?

ALMA = Atacama Large Millimeter/submillimeter Array

in northern Chile

artist's conception



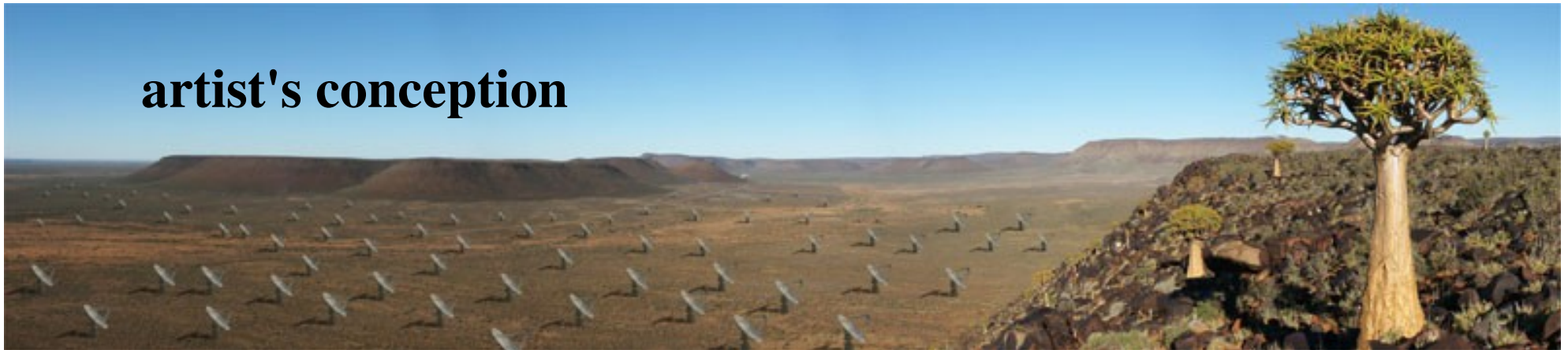
reality (September 2009)



What radio telescopes *will* researchers use?

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

artist's conception



This will be a precursor for the Square Kilometer Array (SKA – name refers to collecting area), which there are plans to build in western Australia or southern Africa.

A common thread: go to high/remote sites

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

(1) at shorter wavelengths ($\lambda < 1\text{cm}$), **atmospheric water vapor**

⇒ go to a **high** site

(2) at longer wavelengths, ($\lambda > 1\text{cm}$), **radio frequency**

interference (RFI) from man-made sources

⇒ go to a **remote** site

Note: Serin is neither high nor (more key for $\lambda = 21\text{cm}$) 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 $< \lambda/10$).**

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



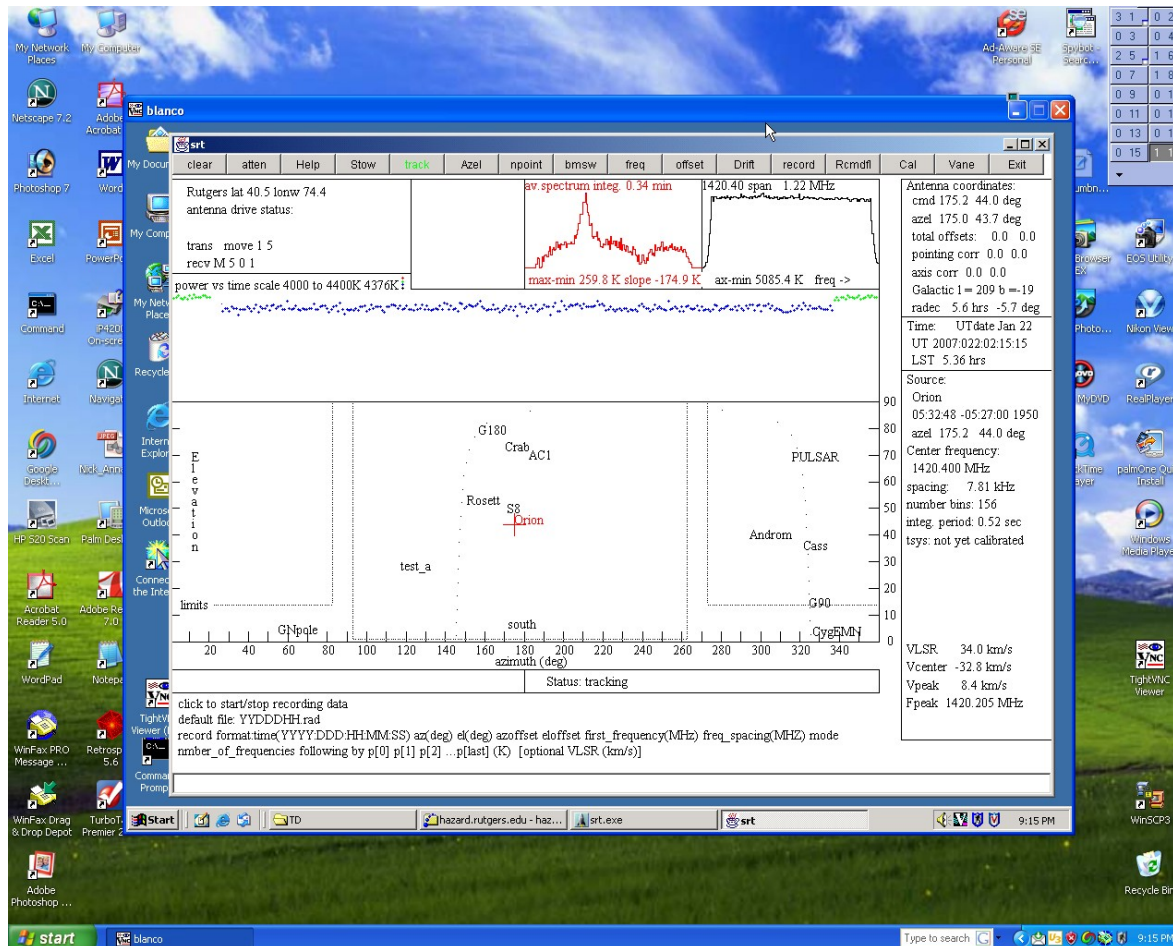
More details about the SRT...

Receiver is sensitive to light with $\lambda = 21\text{cm}$, 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 90° (north celestial pole)

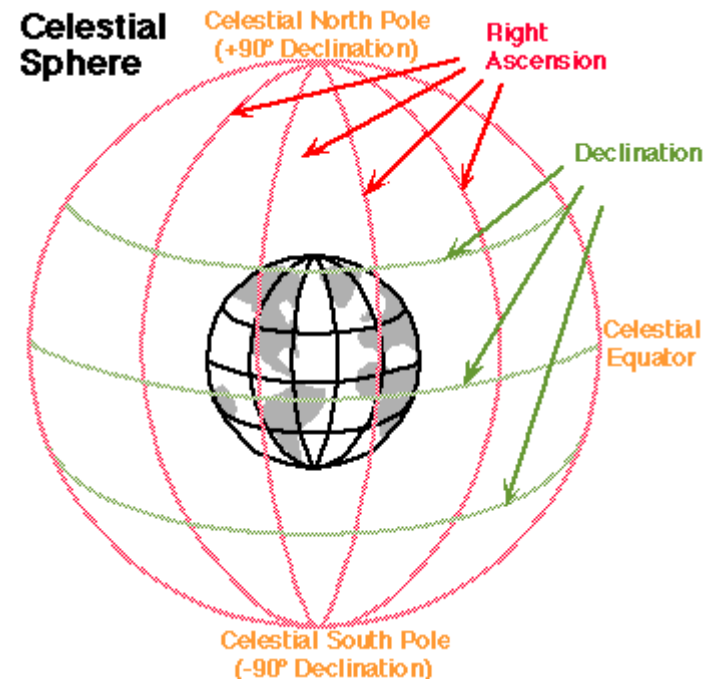
to -90° (south celestial pole) – like latitude

+ **right ascension** ranges from 0° (for stars, galaxies, etc.

that transit at midnight on 9/21) to 90° (farther east)...

to 360° – like longitude

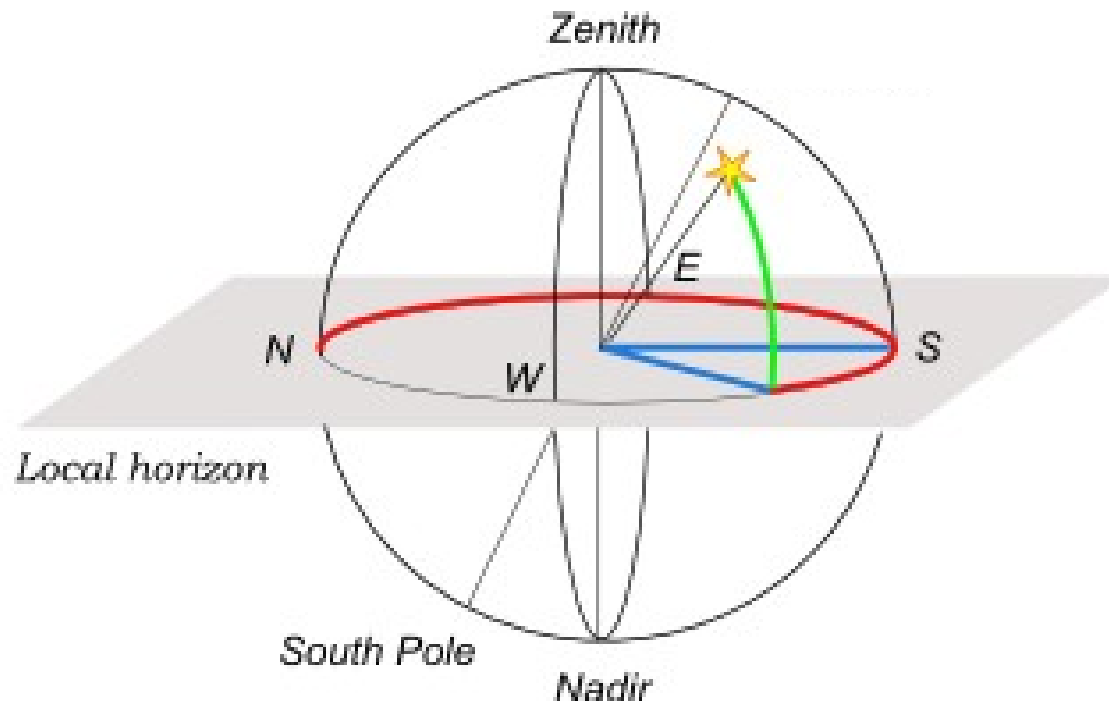
Celestial coordinates of
solar system objects
change (relatively)
rapidly.



Coordinate systems: telescope's point of view

Horizontal coordinates:

- + **elevation** ranges from 90° (zenith) to 0° (horizon)
- + **azimuth** ranges from 0° (north) to 90° (east) to 180° (south) to 270° (west) to 360° (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) sets the frequency to 1415 MHz**
- (2) slews to the Sun and does an “npoint” scan**
- (3) moves 30 degrees in azimuth away from the Sun**
- (4) pauses for 30 seconds before moving back to the Sun**