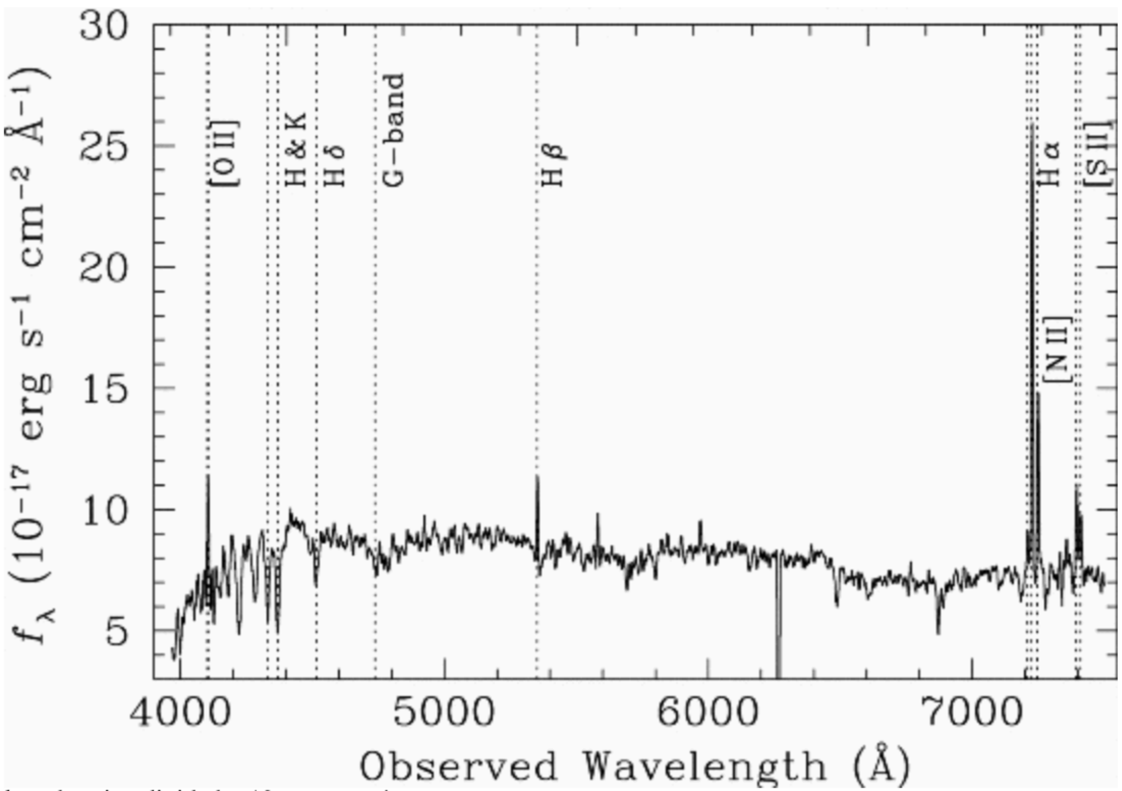
Lecture 2:

Practical Aspects of Observing

Rutgers Physics 346: Observational Astrophysics   January 26, 2021

Quiz #1: Graded with a solution available on Canvas.

Comments: Be sure to label both your axes (including units) and key features in a spectrum. The question asked for a single spectrum (of a single source) that exhibits continuum emission, absorption lines, and emission lines. Example:



Question: What type of galaxy is that?

From http://spiff.rit.edu/classes/phys301/lectures/doppler/doppler.html

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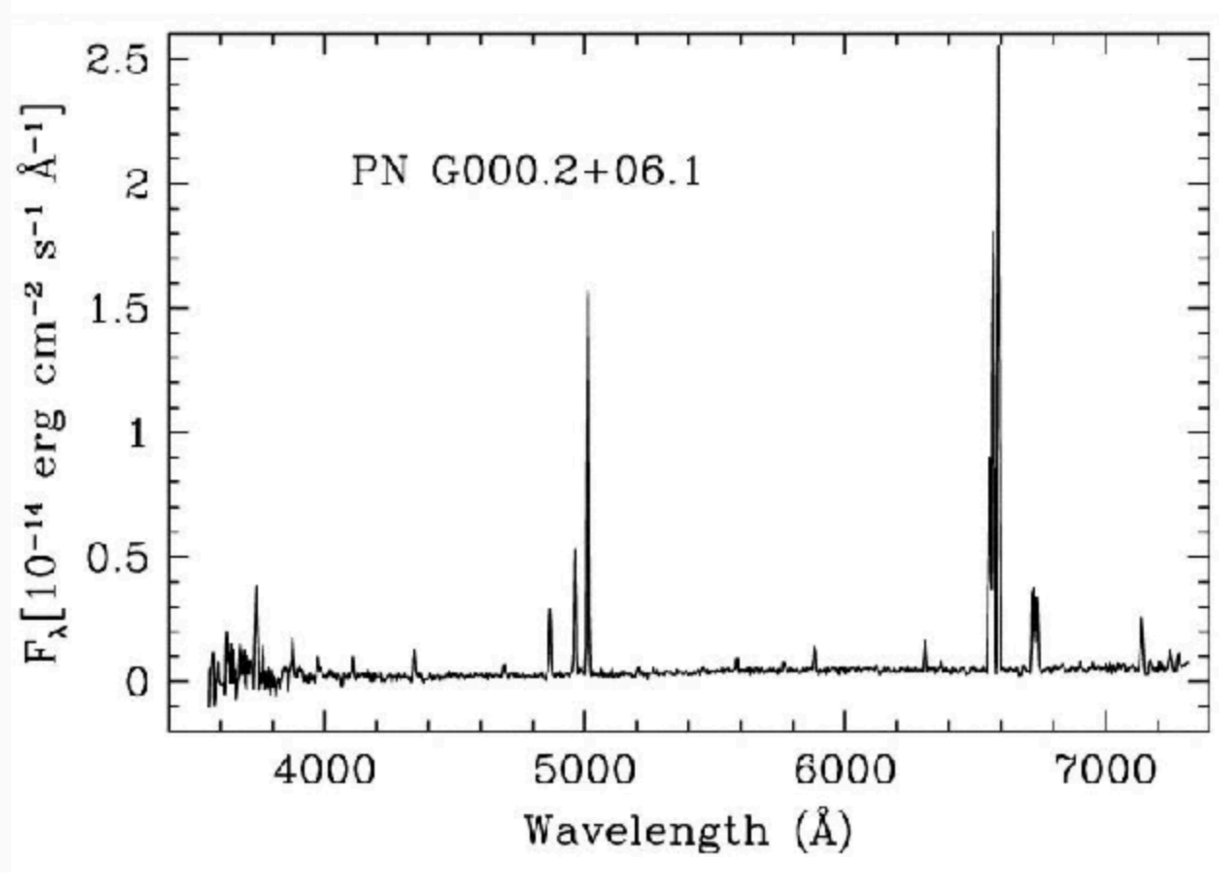

Question: What type of object is that?

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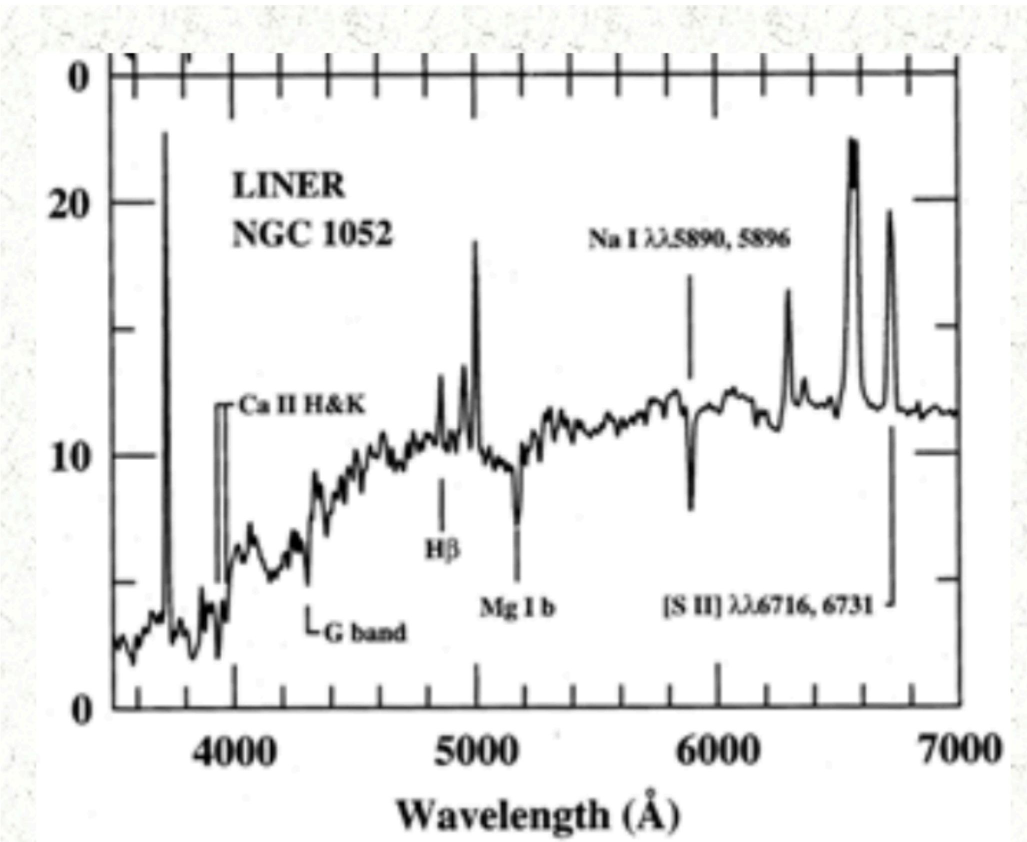


Question: What type of object is that?

From https://ned.ipac.caltech.edu/level5/Glossary/Essay_liner.html

Spectra: Single Star vs Galaxy Light

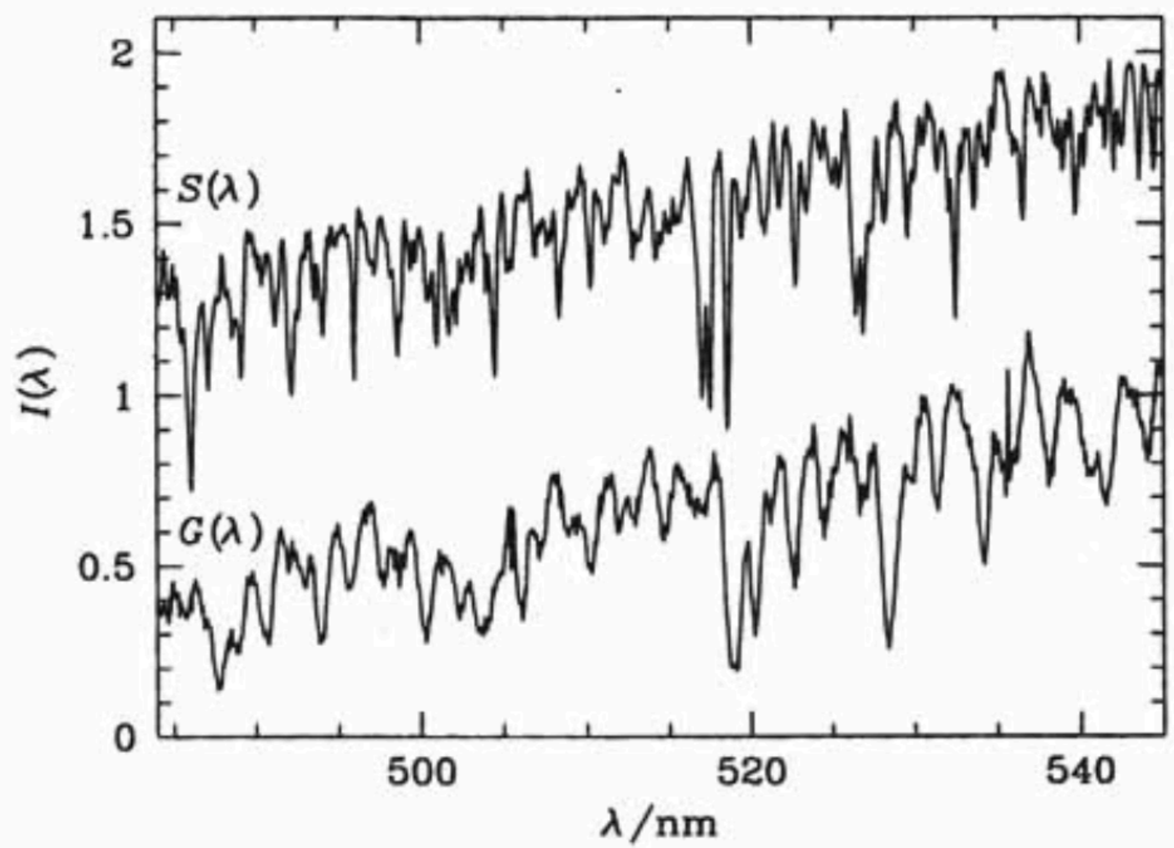


Figure 11.1 Spectra of a K0 giant star (S) and the center of the lenticular galaxy NGC 2549 (G). These data cover a small part of the optical spectrum around the strong Mg b absorption feature at 518 nm.

From http://people.virginia.edu/~dmw8f/astr5630/Topic07/t7_spec_K0_gals.html

Practical aspects of observing

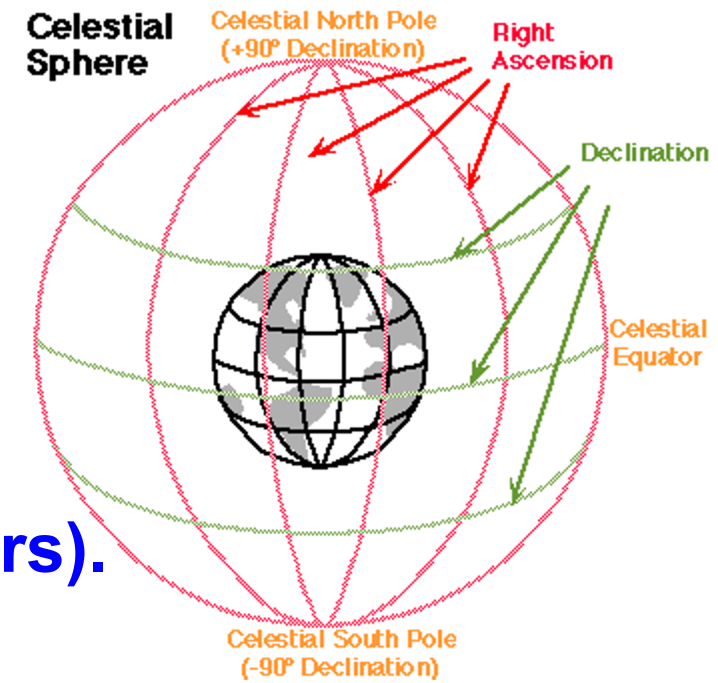
+ where sources are on the sky (i.e., coordinate systems)

+ how far away from us sources are (i.e., distances and redshifts)

+ what effects the atmosphere has, and why we build telescopes where we do

Celestial coordinates: units of R.A.

Right ascension (“R.A.”, α) & declination (“Dec.”, δ) = celestial longitude and latitude that describe a source's position on the sky.



R.A. runs from 0º to 360º, or from 0 hours to 24 hours; Dec. runs from – 90º to +90º.

Question:

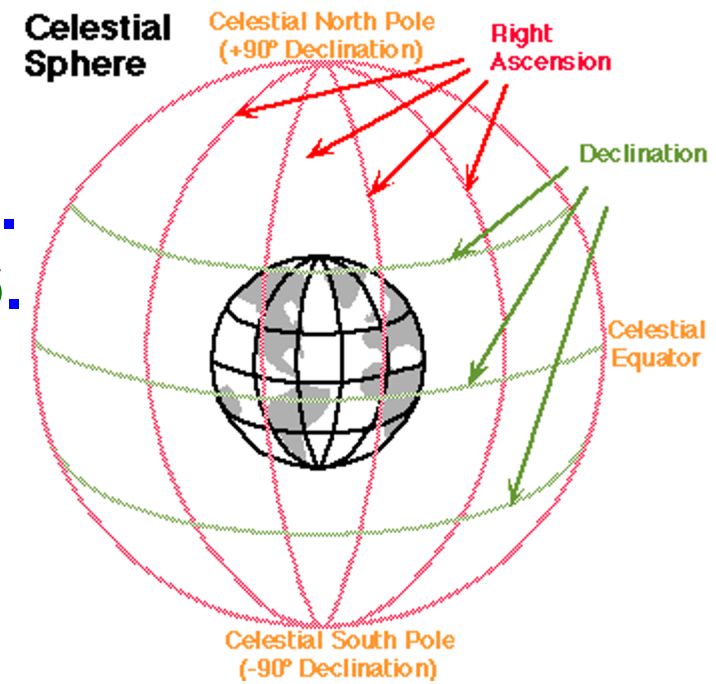
A source has R.A. 14:11:45.2 (hours). What is this in units of degrees?

Answer:

$15 \times (14 + 11/60 + 45.2/3600) = 212.938333^{\circ}$.

(Note that R.A. 23:59:59 corresponds to 359.995833º.)

Celestial coordinates: separations



Question:
Source A lies at 02:33:24.5 +15:32:29.
Source B lies at 02:33:32.9 +15:24:06.
How far apart are they on the sky?

Answer:

$\Delta\delta$ is easy: $(24 \times 60 + 6) - (32 \times 60 + 29) = -503'' = -8.383'$

$\Delta\alpha$ is harder: $15 \times (32.9 - 24.5) \times \cos(15.4715) = 121'' = 2.024'$

For small angles, can use the Pythagorean theorem:

$$\text{separation} \simeq [(\Delta\delta)^2 + (\Delta\alpha)^2]^{1/2} = 8.6'$$

Question: What's a fully accurate, easy-to-code way to calculate angular separation?

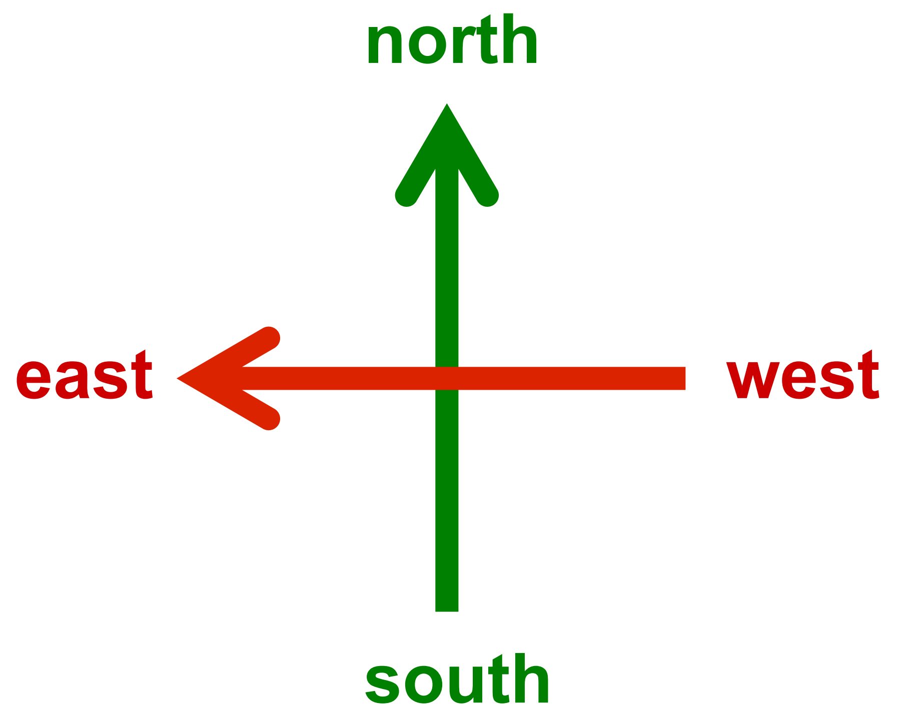
Celestial coordinates: directions

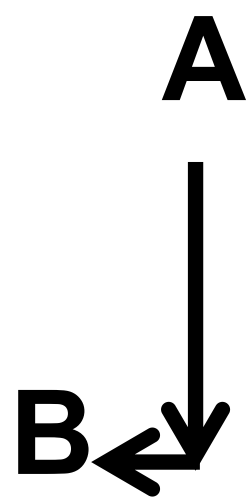
Consider again: source A lies at 02:33:24.5 +15:32:29,
source B lies at 02:33:32.9 +15:24:06.

How do they *look* on the sky?

$\Delta\delta = -8.383'$

$\Delta\alpha = 2.024'$





Celestial coordinates: precession

In what circumstances can a source's right ascension and declination change?

(1) It's a solar system object (Sun, planet, asteroid, etc.)

(2) It's a nearby star with a high “proper motion” across the sky (e.g., α Cen).

(3) We wait long enough that the earth's rotation axis wobbles a little (i.e., it **precesses**).

To deal with (3), every right ascension and declination must be specified with an **epoch** (“B1950” and “J2000” are common).

Celestial timekeeping

Astronomers use two principal time conventions:

(1) UT = Universal Time

This is a solar time that corresponds (apart from daylight savings) to the local time in Greenwich, England.

At a given moment, UT is the same everywhere.

(2) LST = Local Sidereal Time

This is the R.A. that is directly overhead right now.

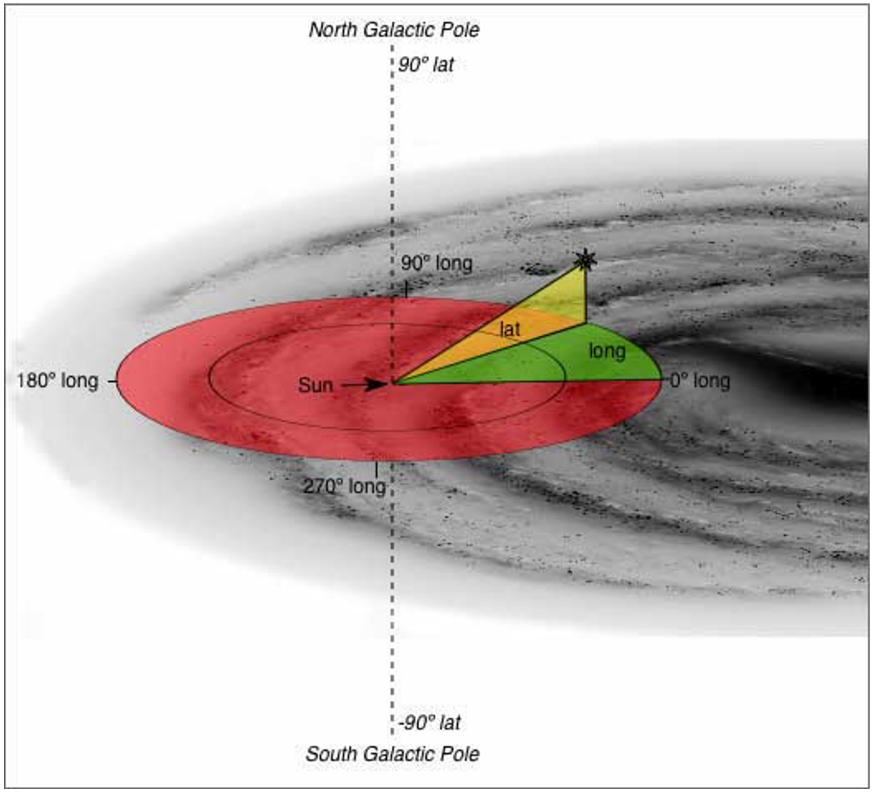
At a given moment, LST is different at different longitudes.

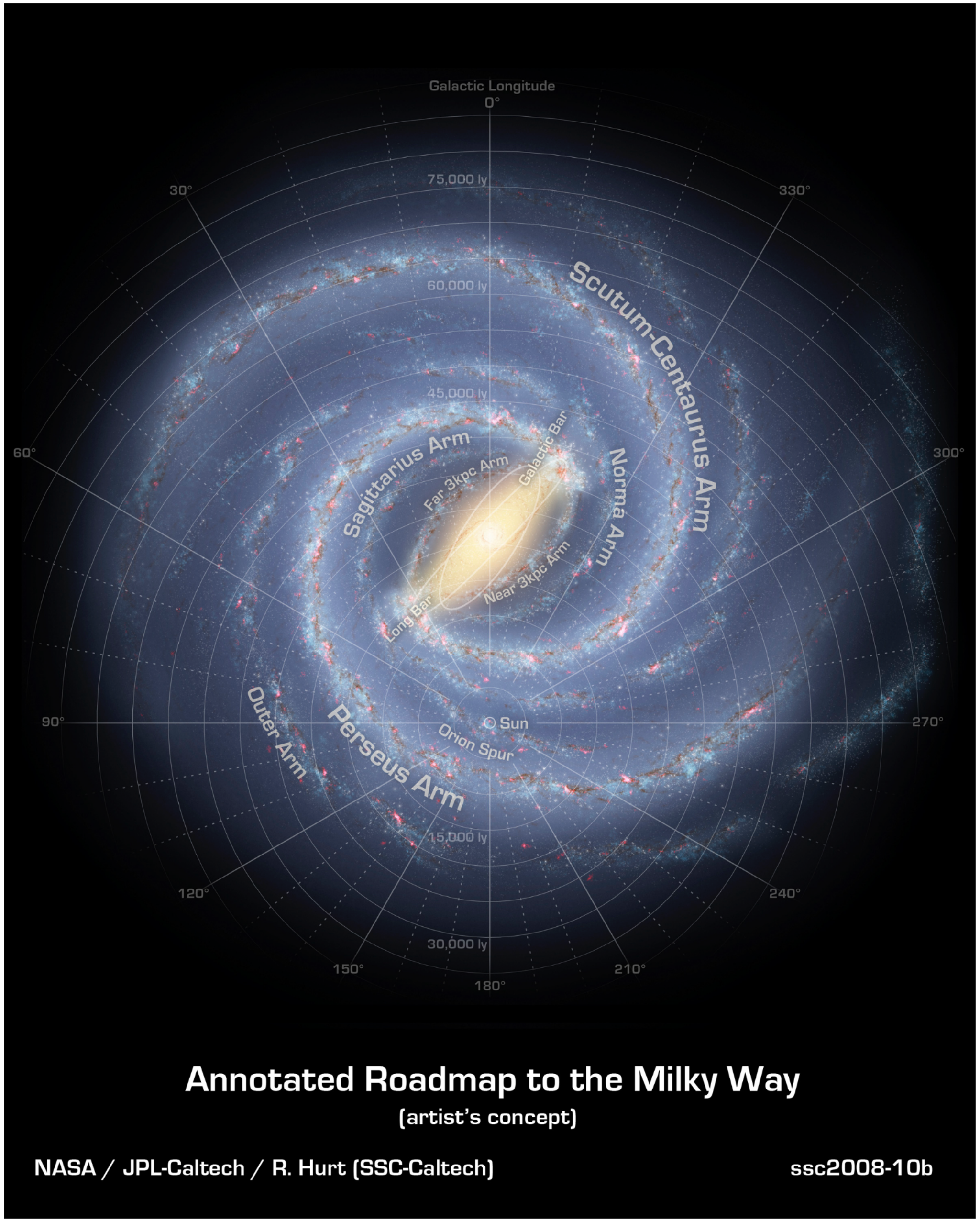
(It is slightly different for different students in this class!)

“Galaxy” with a capital “G” = the Milky Way

Galactic coordinates

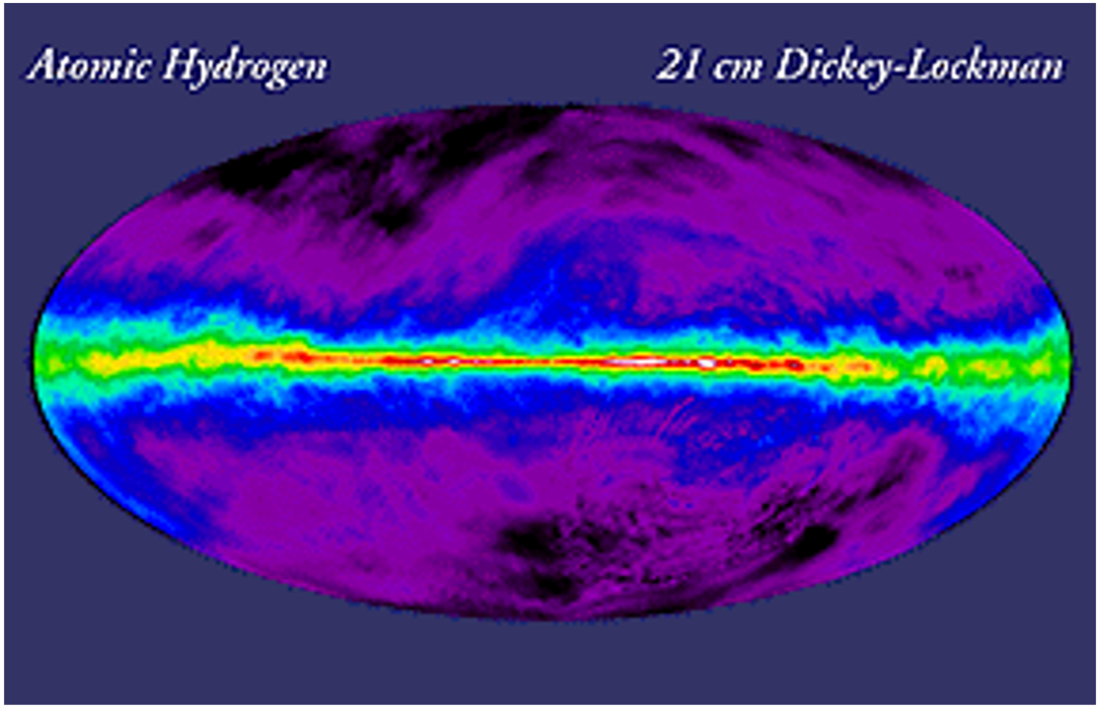
The Sun is located in the disk.
b = Galactic latitude
(above/below plane)
l = Galactic longitude
(0 towards Galactic Center;
90 towards Sun's motion
= clockwise from “above”)





The sky plotted in Galactic coordinates

Nearly all the HI (neutral H) in the Milky Way is located in the disk, which we observe edge-on.



(Mollweide/Aitoff projection plotted in Galactic coordinates)

Horizontal coordinates

These are "telescope-centered" (not absolute) coordinates:

altitude = 0–90 degrees above horizon

azimuth = 0–360 degrees east of north

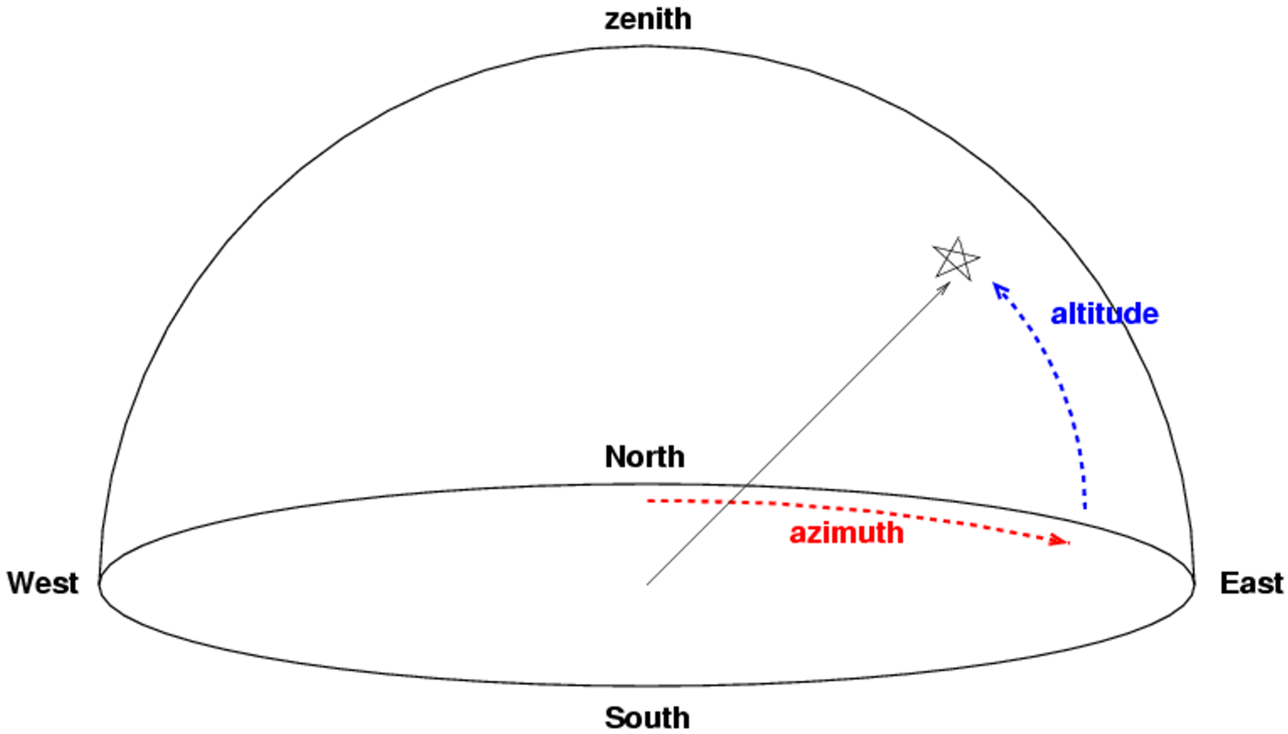
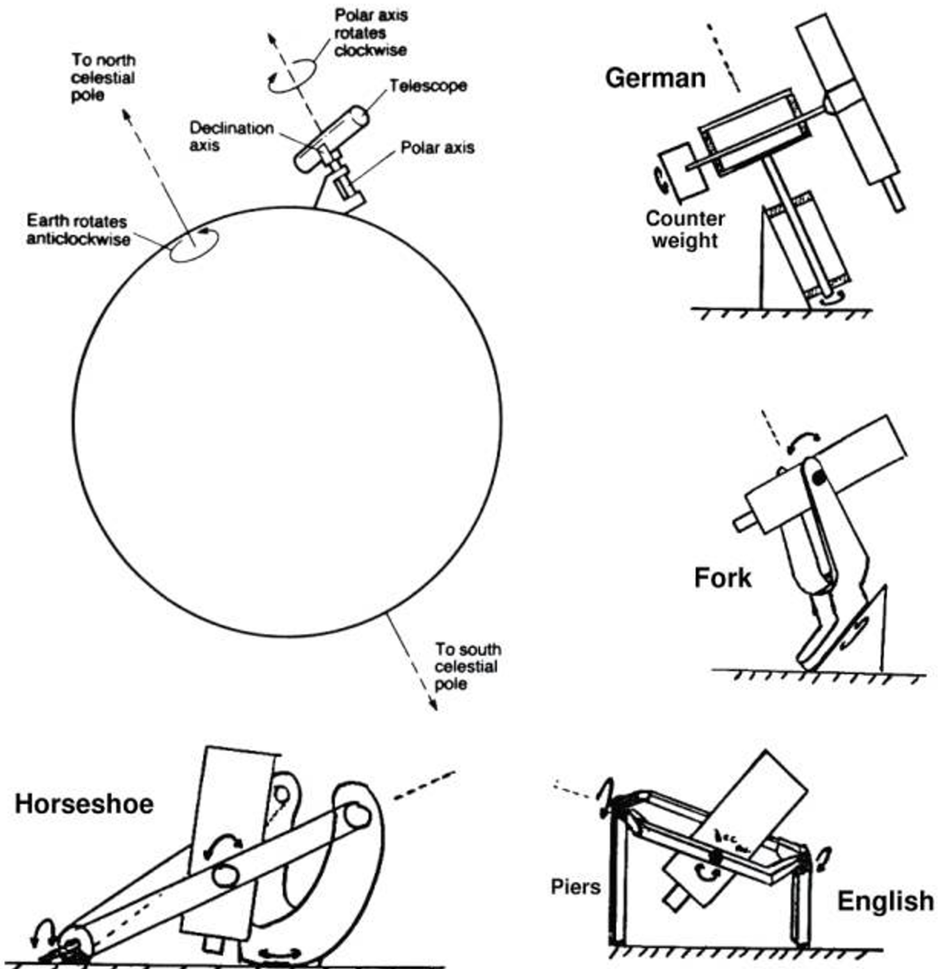


image credit: RIT

Not all telescopes move in alt and az



Equatorial mount: only move one axis to track a source

Alt-az mount:
move both axes
to track a source

<u>Most *modern* telescopes are alt-az</u>

140 ft diameter telescope at the Green Bank Observatory:

(1) world's largest telescope with an equatorial mount

(2) contains world's largest ball bearing!

With the advent of computers, tracking sources with alt-az telescopes became much more reliable.

Light vs. the atmosphere

Earth's atmosphere is opaque to incoming radiation at gamma ray, X-ray, ultraviolet, and far-infrared wavelengths.

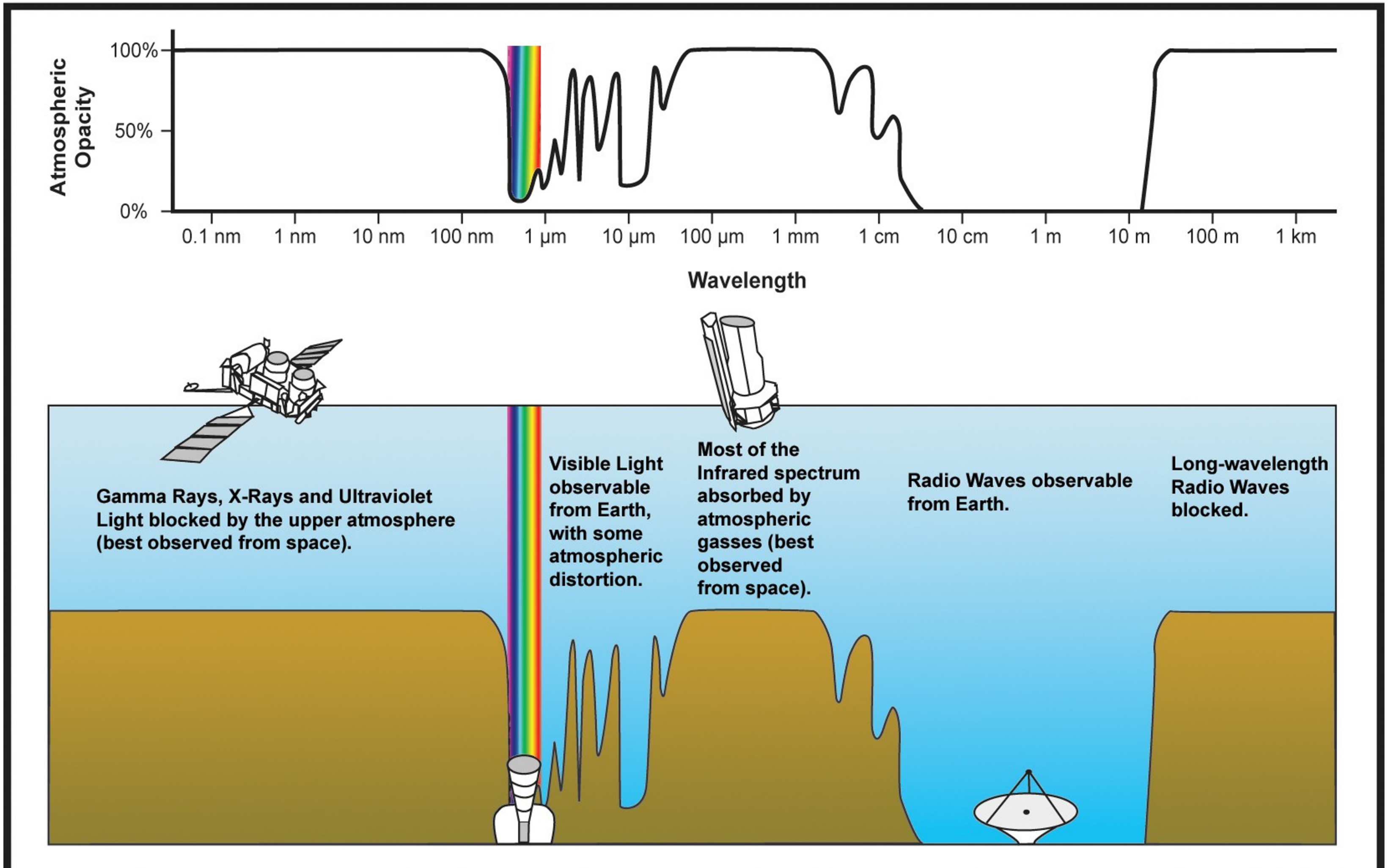


image credit: NASA

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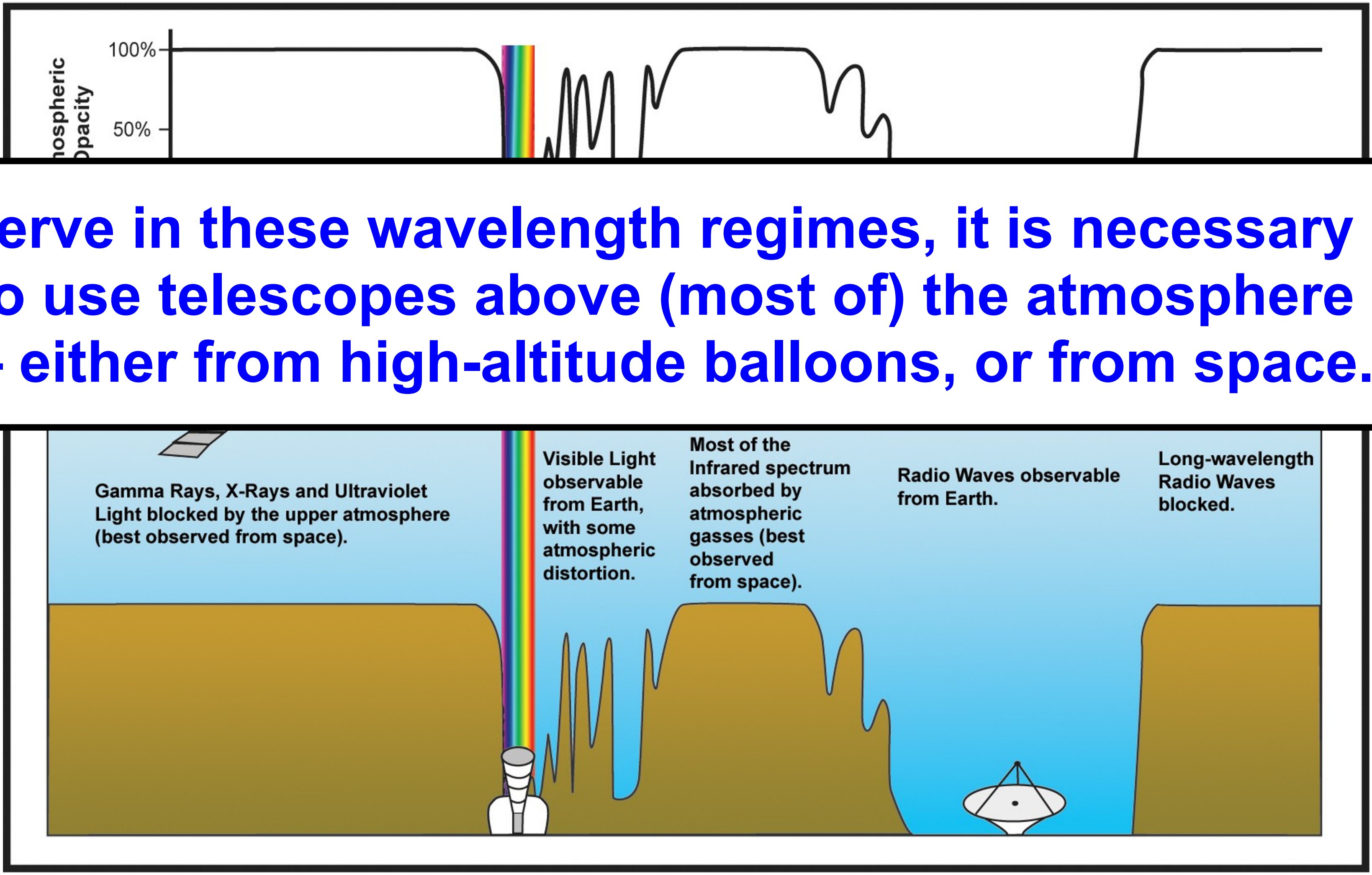

To observe in these wavelength regimes, it is necessary to use telescopes above (most of) the atmosphere – either from high-altitude balloons, or from space.

image credit: NASA

“Good” opacity is still non-zero

At optical, near-infrared ($\lambda \sim 1$–$2\ \mu$m), and millimeter ($\lambda \sim 1$–3 mm) wavelengths, atmosphere is still partially opaque:

+ optical: liquid water drops (i.e., clouds) are the main problem
+ millimeter: water vapor is the main problem
+ near-infrared: water, carbon dioxide, and methane molecules are the main problem

The more clouds/water vapor, the worse the data.

At radio ($\lambda \sim 1$–20 cm) wavelengths, the atmosphere is not a big problem, but radio frequency interference (RFI, like light pollution) from human sources is.

Another complication: Sun and Moon

At optical and near-IR wavelengths, we cannot observe during the day (no big surprise!).

At night, scattered light from the Moon is a problem for optical (but not near-IR) observations.

Millimeter and radio observations can be conducted in the daytime! However, it is not possible to observe sources that are very close to the Sun (especially at longer radio wavelengths, where the Sun has a larger size and affects more of the sky).

Millimeter and radio observations are not affected by the Moon at all.

A final complication: turbulence

Random motions in the atmosphere mean that ordered wavefronts from astronomical sources become distorted by the time they reach the Earth's surface.

At optical/near-IR wavelengths, this turbulence means that there is a minimum angular size ("seeing") that a star will appear to have, no matter how large the telescope is that observes it.

In principle, the angular size of a star should be ~ λ/D (diffraction limit, getting smaller for larger telescopes). Atmospheric turbulence prevents this from happening.

Seeing depends on the location and the current weather, but is better (sharper) in near-IR than in optical.

A final complication: turbulence

Random motions in the atmosphere mean that ordered wavefronts from astronomical sources become distorted by the time they reach the Earth's surface.

At millimeter wavelengths, atmospheric turbulence makes it harder to obtain high-quality images with arrays of telescopes. (This will be discussed more in future lectures.)

At long radio wavelengths, atmospheric turbulence has no effect on observations, but there can be odd effects due to the ionosphere.

How should we schedule observations?

Very often, different types of observations on the same telescope require different conditions. This situation often leads to different levels of dynamical scheduling, in which observations are scheduled on short notice in as close to optimal conditions as possible.

Examples:

- **observe in near-IR during full/gibbous Moon phases ("bright time") and in optical during new/crescent phases ("dark time")**
- **observe in near-IR when the seeing is worse and in optical when the seeing is better (can change on a timescale of half an hour!)**
- **observe at 3mm when the water vapor is worse and at 1mm when it is better (can change on a timescale of half an hour!)**

Homework for Thursday, Jan. 28

Do: Quiz #2 will appear on Canvas Assignments at 4:40pm, due at 9pm tonight.

Do: Worksheet #1 will appear on Canvas Assignments soon. You should work on all 3 problems before our project meeting on Thursday, since there will be a chance to ask question then. It will be due via Canvas at 9pm on Thursday.