# (Astro)Physics 344
# Observational Optical Astronomy

**physics course number = 01:750:344**

**web page = http://www.physics.rutgers.edu/ugrad/344/**

**Sakai page = OBSERV OPTICAL ASTRO F18**

# Personnel

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**(godfather = Prof. Ted Williams)**

**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.**

# Professor Tad Pryor

## B.S. and Ph.D. in Astronomy
## Arrived at Rutgers in January 1988
## Optical Observational Astronomy

In the background, the dome of the 4-meter diameter Mayall telescope at the Kitt Peak National Observatory, outside Tucson, Arizona.

Professor Pryor at the 6.5 m diameter MMT (Monolithic Mirror Telescope).

Research interests:

* globular clusters
* dwarf satellite galaxies of our own Milky Way galaxy

Much of my current research is carried out with the Hubble Space Telescope, a 2.4 m diameter telescope in low Earth orbit (about 570 km above the surface).

# Requirements

**Optional Textbook: Observational Astronomy, 3rd edition by Birney, Gonzalez, & Oesper**

**Prerequisite: (Astro)Physics 341/342 ("Principles of Astrophysics" with Professors Buckley and Brooks) should be taken previously or, in special cases, concurrently.**

**Other: a scientific calculator; access to a computer that can connect to the internet.  For analysis of images taken with the computer, i.e., "image processing" you will connect to a the astrolab server running Linux using VNC.  Can do this with your own computer or the one in Ph&A Bld room 401.**

# Course meetings

**Lectures: SEC-216, once a week, Th 6:40-8:00 PM**

**Labs: Physics & Astronomy Bldg room 401, you will be assigned either 7-9 or 9-11 PM on one of Su, M, Tu, W, or F nights**

**Usually, one week will be an “observation” week and the following will be an “analysis” week.**

# Lectures

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

**+ techniques: optical telescopes, imaging, spectroscopy**

**+ science: stars, star clusters, nebulae, galaxies, etc.**

# Labs

**Seven labs planned, most of which will use the 0.5 m diameter telescope of the Schommer Observatory. The tentative list is:**

**#1: Getting to Know The Sky & IDL**
**#2: Visual Observing with the 0.5 m Telescope**
**#3: Introduction to CCD imaging: Measuring Brightness and Position**
**#4: Observing with a CCD: Photometry of M31 and M32**
**#5: Measuring the Transit of an Exoplanet**
**#6: Color-magnitude diagram of a star cluster**
**#7: Nebular Spectroscopy**

# Grades

**Course grades will be based on a combination of:**

- **+ participation during lecture (5%)**
- **+ preparation for and active participation during labs (5%)**
- **+ lab reports (90%)**

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

# 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 images/spectra taken? What day and time? Were any problems encountered?)**

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

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

**Do not include:**

**(1) unimportant or repetitive steps in observing**

**(2) detailed description of "routine" analysis steps**

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

# Absences and late work

**Absences:**

**(a) mine: none currently scheduled**

**(b) yours: unless you have a medical emergency, tell me in advance or get zero participation points**

**Late penalty, quoting from the syllabus:**

**Unless you have my prior approval, late lab reports will receive a maximum of 90% credit. No report will be accepted after the solution is handed out.**

# Good advice for this class (and beyond)

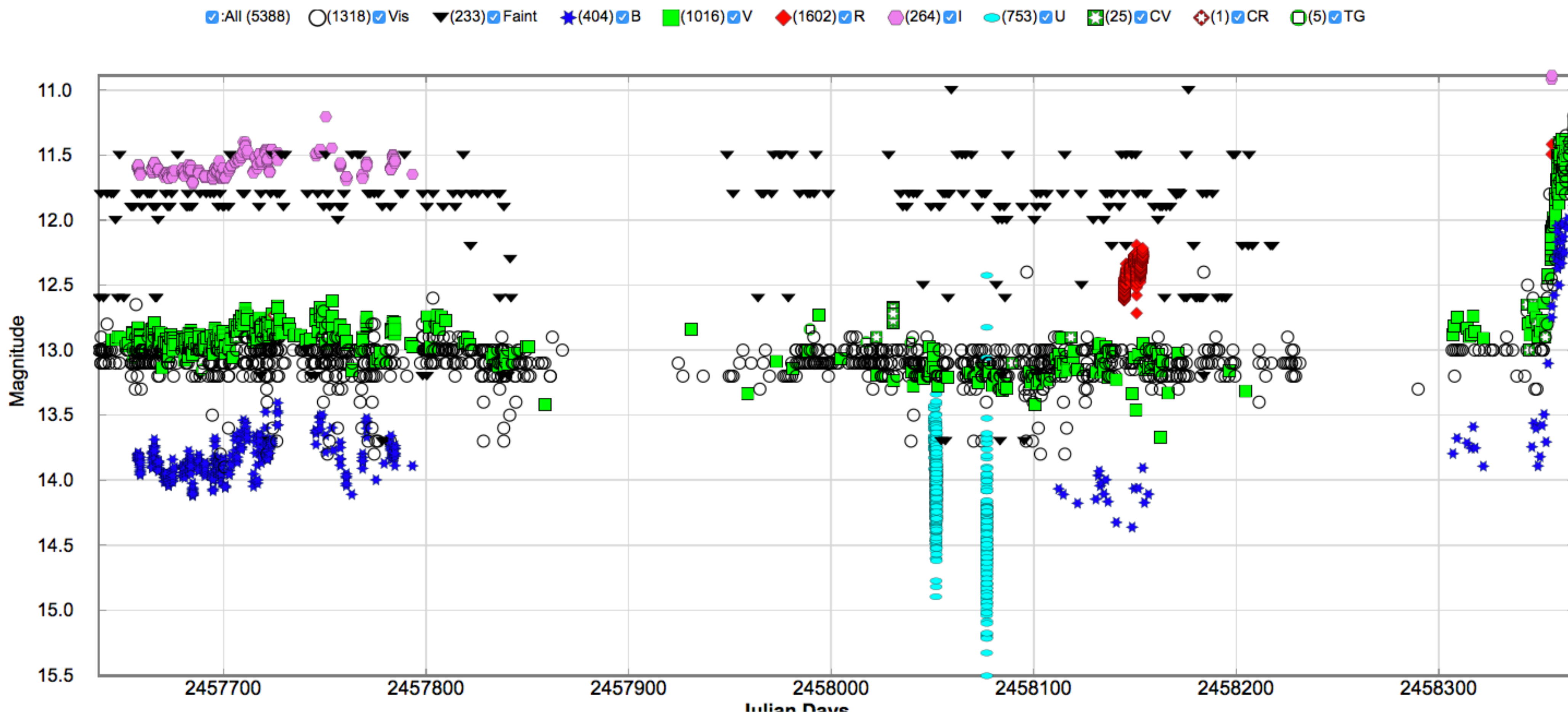
**Ask questions (even if they seem "stupid"), and speak in lab!**

**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.**

# Planning an Observation

- Imagine that we want to observe the variable star GK Persei (a white dwarf accreting matter from a companion in a binary system). It started rapidly brightening on August 24th (AAVSO data).



# Planning an Observation

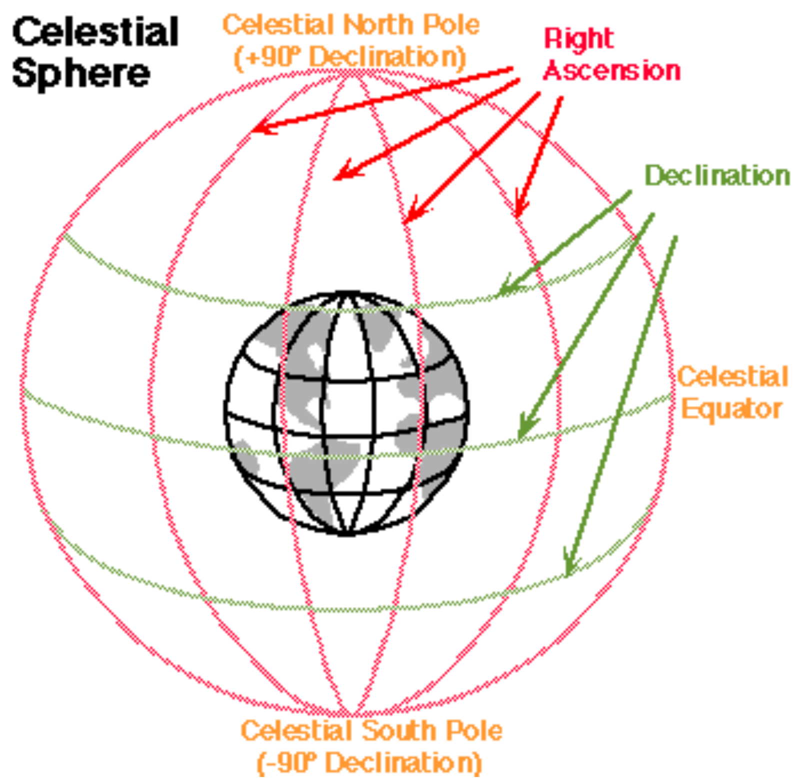
- Imagine that we want to observe the variable star GK Persei. What information is needed about the target?
  - Where is the object on the sky (w.r.t other stars, say)?
  - Where is that point on the sky w.r.t. our horizon (above, below)?
    - Depends on our location on Earth and the date and time there.
  - For observations at visible wavelengths, also want to know if the Sun is above the horizon (i.e., is it day or night).
    - Depends on the (local) civil time and time of year (season).

# Coordinate systems: Earth's point of view

Celestial coordinates on the fictitious "celestial sphere":

+ 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



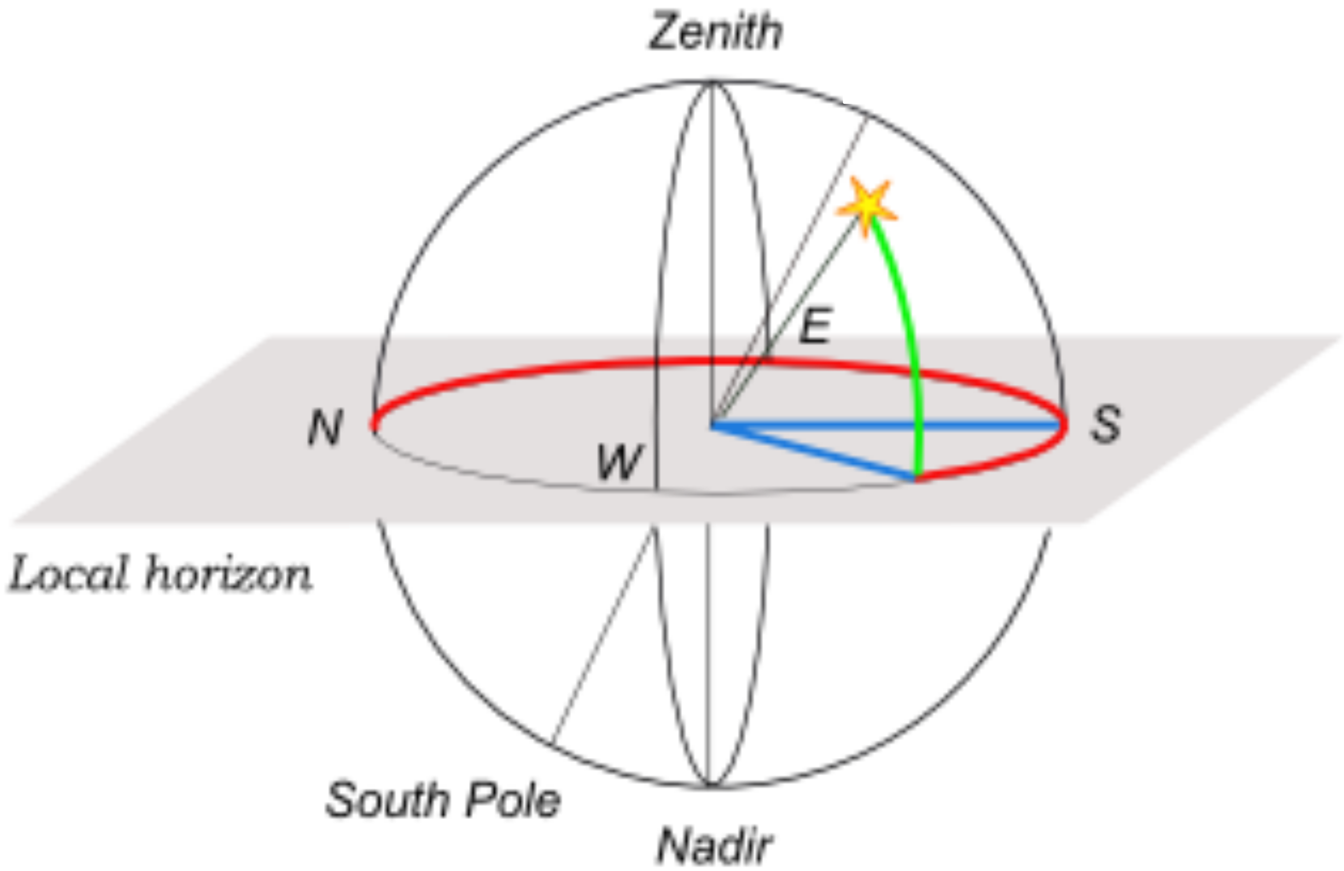

Celestial coordinates of solar system objects change (relatively) rapidly. Coordinates of stars change slowly (usually a small fraction of an arcsecond/yr.

# <u>Coordinate systems: telescope's point of view</u>

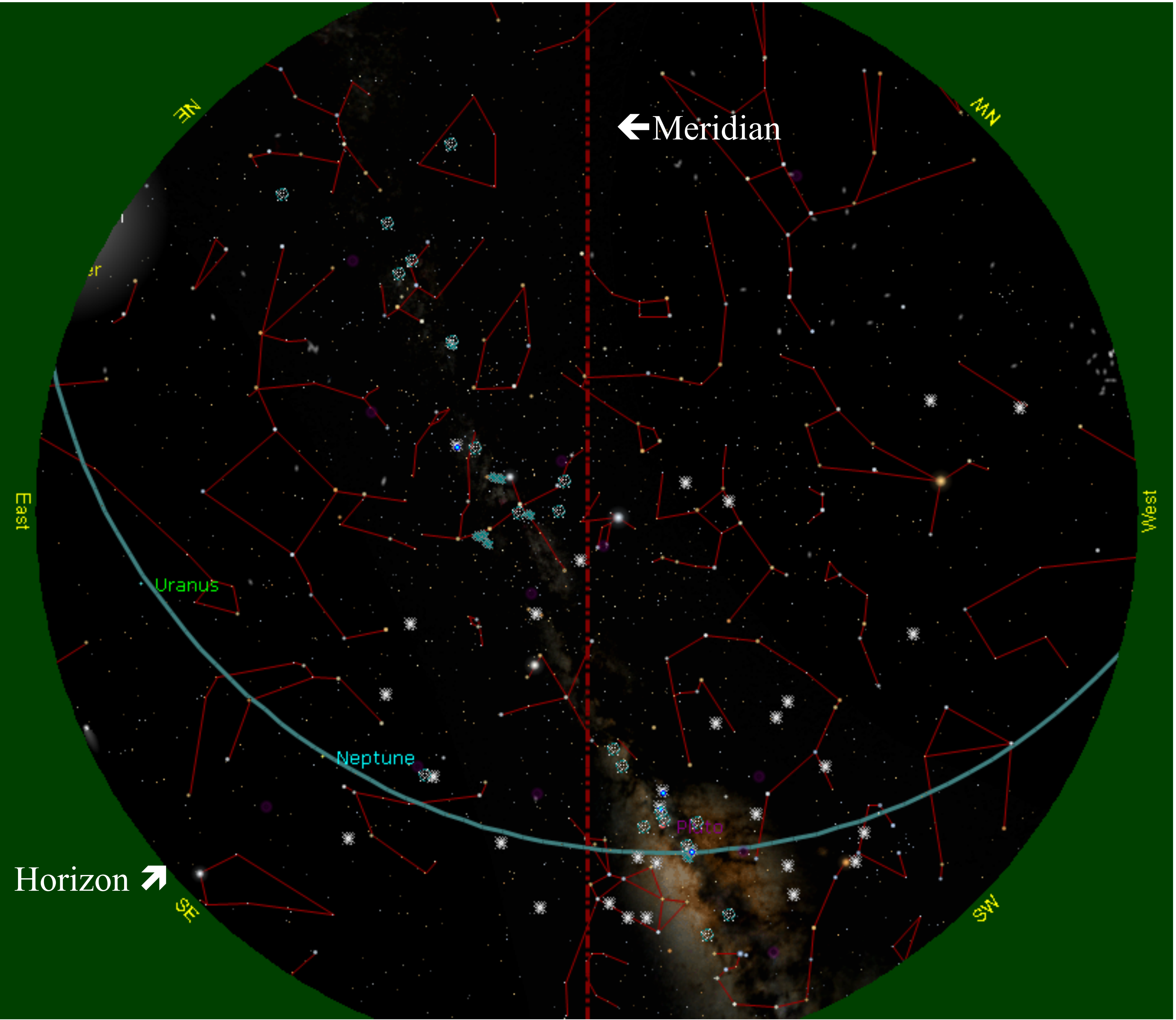
**<u>Horizon</u> coordinates:**

+ **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



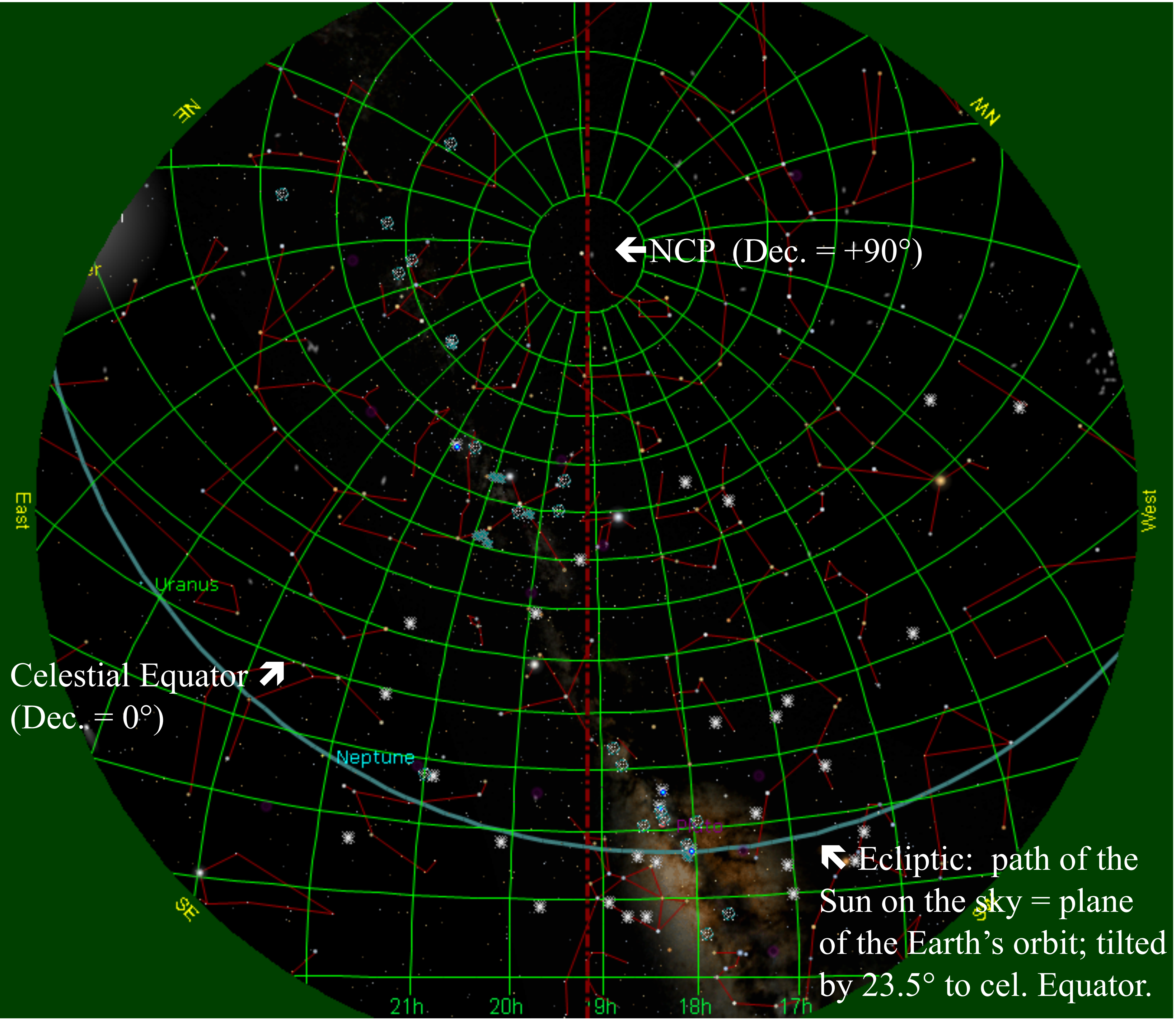
# Coordinate Systems: Rutgers View




*The Sky*: Squash the bowl of the visible sky flat to a disk for display – note that this causes distortion.

The edge of the disk is the horizon. The center of the disk is the zenith.

# R.A. and Dec. – green grid

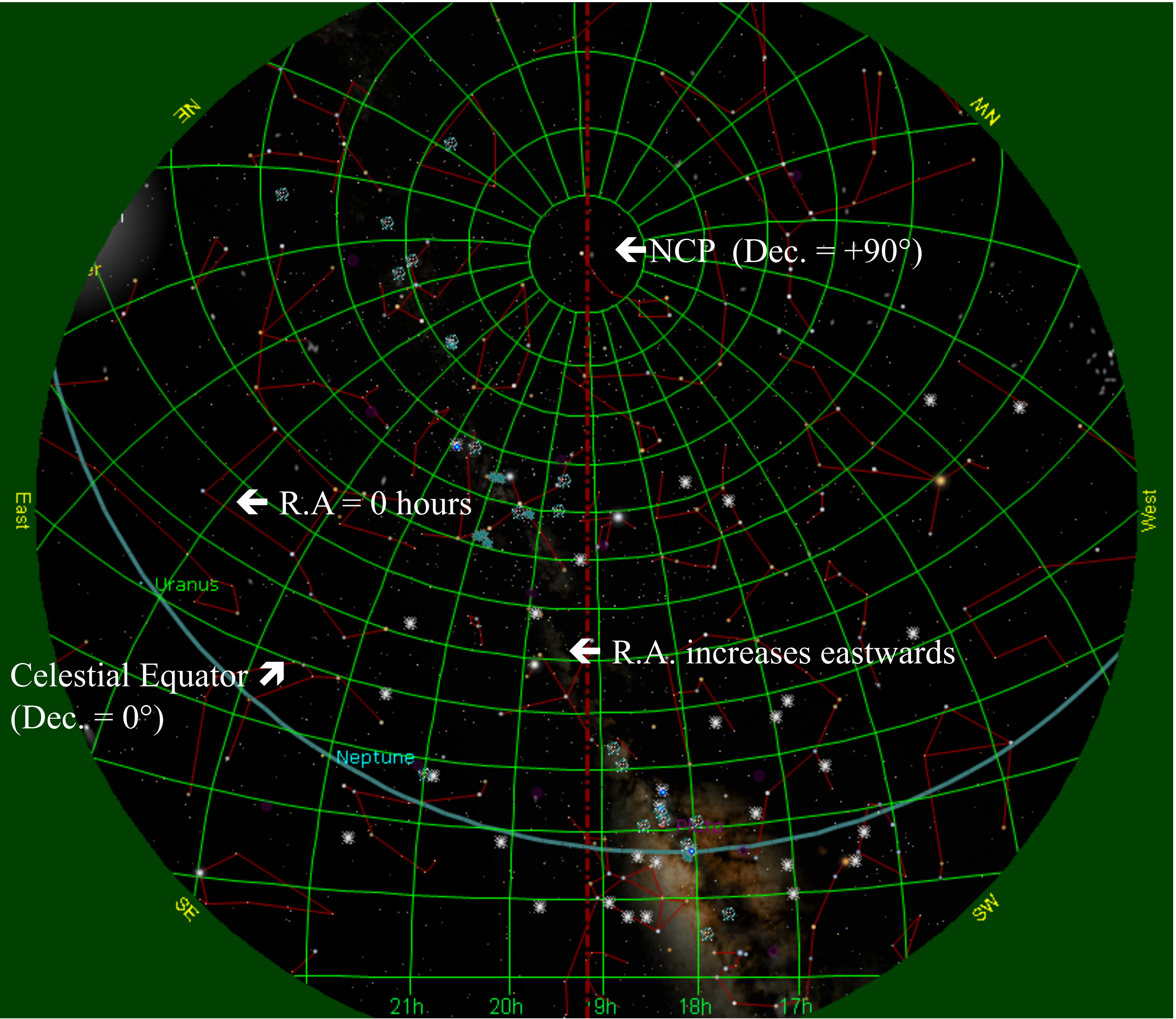



North Celestial Pole (NCP) – where the Earth's rotation axis intersects the celestial sphere.

NCP altitude is $90° - \text{latitude}$
$= 90° - 40.52°$
$= 49.48°$

Zenith at Dec. of 40.52°

# R.A. and Dec. – green grid




0 hours R.A. is where the Sun crosses the celestial equator going north (on March 21st).

R.A. increases towards the East. Thus, objects with larger R.A.'s cross the meridian later.

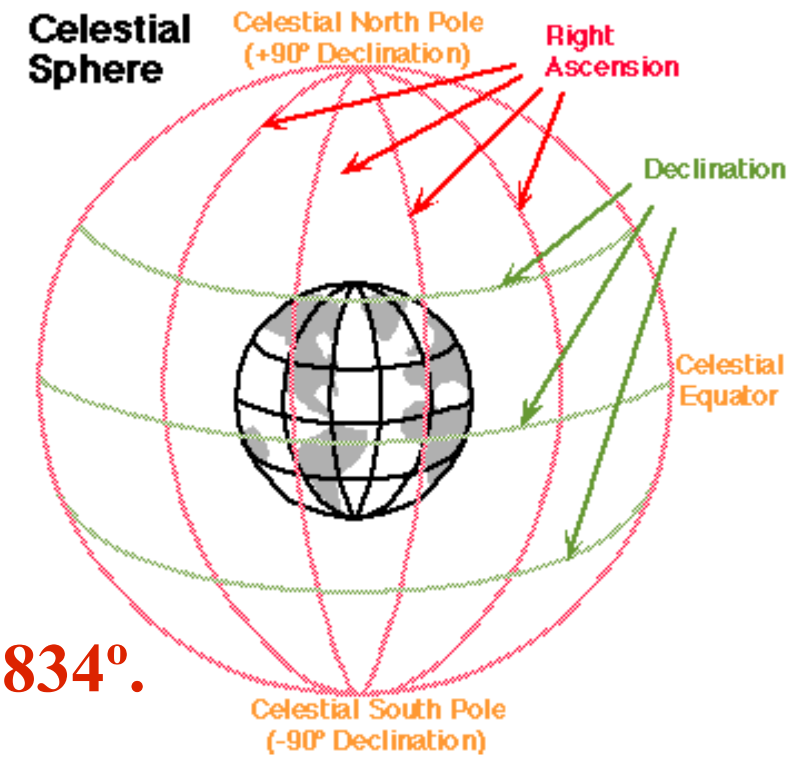
# Celestial coordinates: units

**Right ascension ("R.A.", α) & declination ("Dec.", δ) = celestial latitude and longitude that describe a source's position.**

**R.A. units: hours, minutes, & seconds of time**

**24 hours = 360 degrees ➔ 1 hour = 15 degrees**

**Dec. units: degrees, minutes, & seconds of arc (60 minutes = 1 degree)**




**Example # 1:**

**GK Per has R.A. 03:31:12.01.**

**What is this in units of degrees?**

**Answer:**

**$15 \times (3 + 31/60 + 12.01/3600) = 52.750834^{o}$.**

**(Note that R.A. 23:59:59 corresponds to $359.995833^{o}$.)**

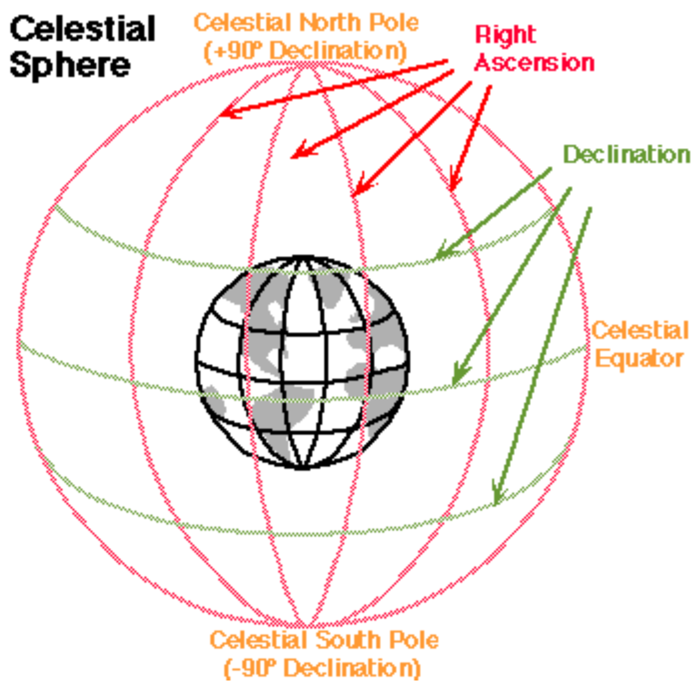
# Celestial coordinates: source separations

**Example # 2:**

**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?**




**For spherical coordinates, must use spherical geometry.**

**Answer:**

**Δδ is easy: (24 * 60 + 6) – (32 * 60 + 29) = –503" = –8.383'**

**Δα is harder: 15 * (32.9 – 24.5) * cos(15.4715) = 121" = 2.024'**

**For small differences, separation ≃ $[(\Delta\delta)^2 + (\Delta\alpha)^2]^{1/2}$ = 8.6'**

# Celestial coordinates: directions

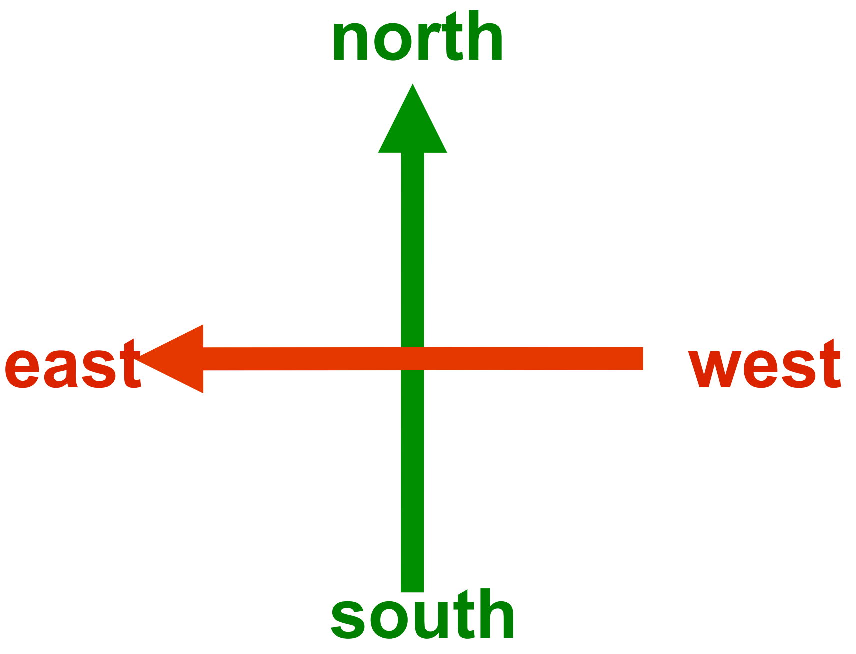
**Consider again: source A lies at 02:33:24.5 +15:32:29,**

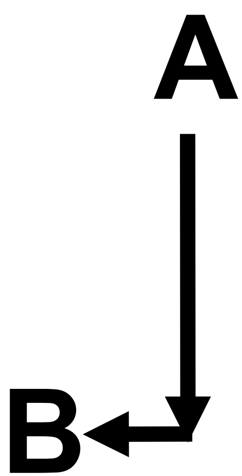
**source B lies at 02:33:32.9 +15:24:06.**

**How do they *look* on the sky?**

**$\Delta\delta = -8.383'$**

**$\Delta\alpha = 2.024'$**




Note that east/west are reversed compared to terrestrial maps because are looking up rather than down.

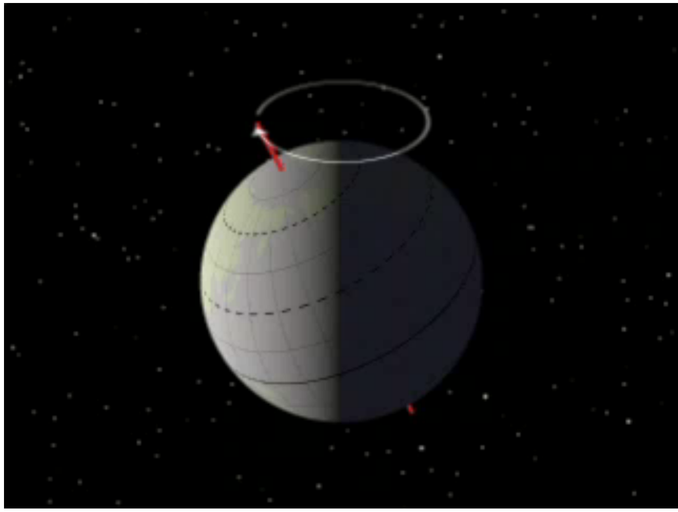
# Celestial coordinates: precession

When can a source's right ascension and declination change?

(1) It's a solar system object (Sun, moon, planet, asteroid, etc.). The Sun moves ~1°/day.

(2) It's a nearby star with a high "proper motion" (e.g., α Cen). 4470 stars known with p.m. > 0.5 arcsec/yr.

(3) We wait long enough that the earth's rotation axis wobbles a little (i.e., it precesses). Coordinates can change by tens of arcseconds/yr.



To deal with (3), every R.A. and Dec. must be specified with an epoch ("B1950" and "J2000" are common).

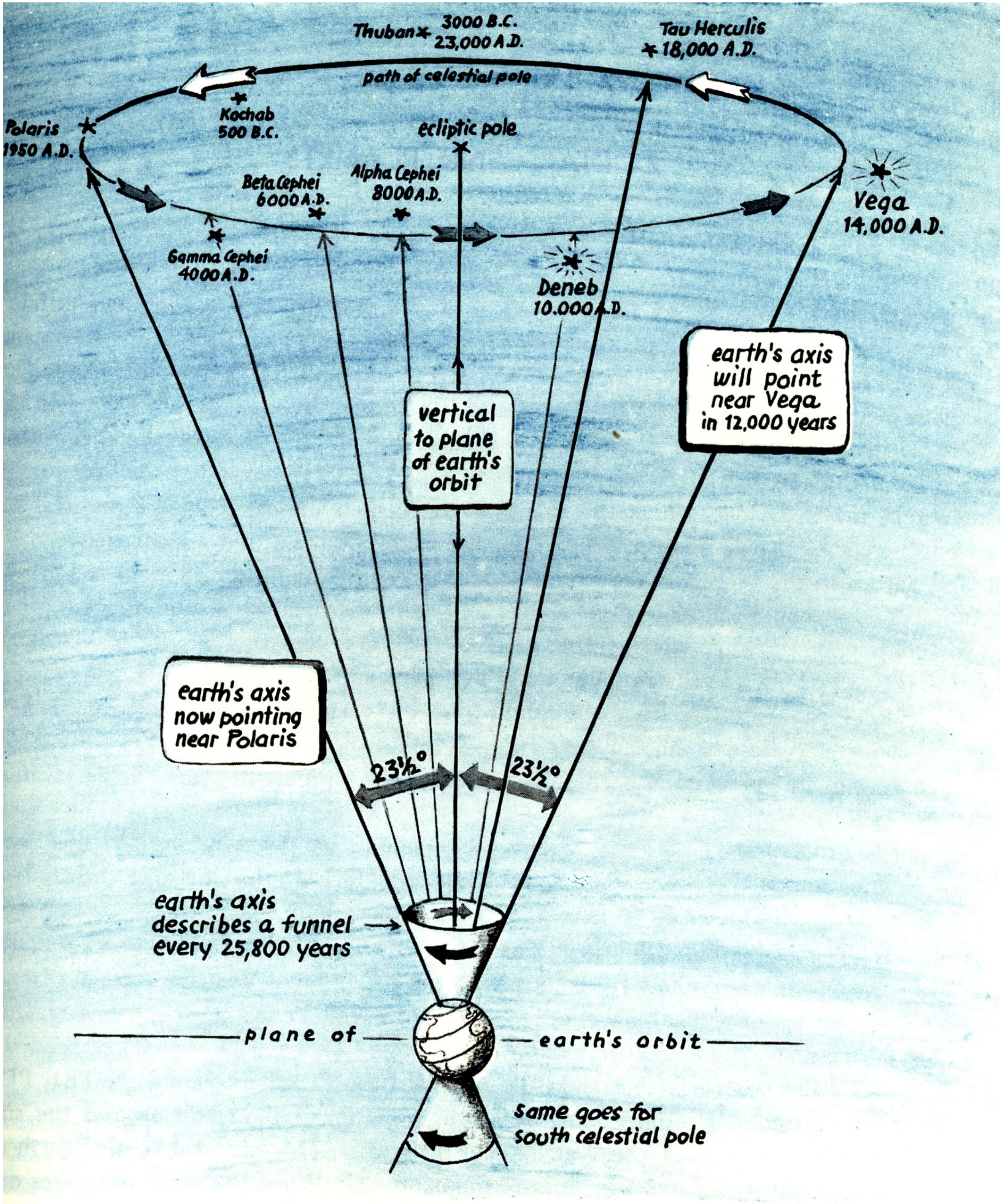



Figure 24: The Wobble of the Earth's Axis

Changing "pole star" over the period of the precession of the equinoxes from *The Stars: A New Way to See Them* by H. A. Rey.

# Celestial timekeeping (Ch. 2)

Astronomers use two principal time conventions:

(1) UT = Universal Time

This is a (mean) 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. of objects on the meridian right now. At a given moment, LST is different at different terrestrial longitudes.