Course Outline: https://outline.uwaterloo.ca/view/n4vmhp

SCI238 W23

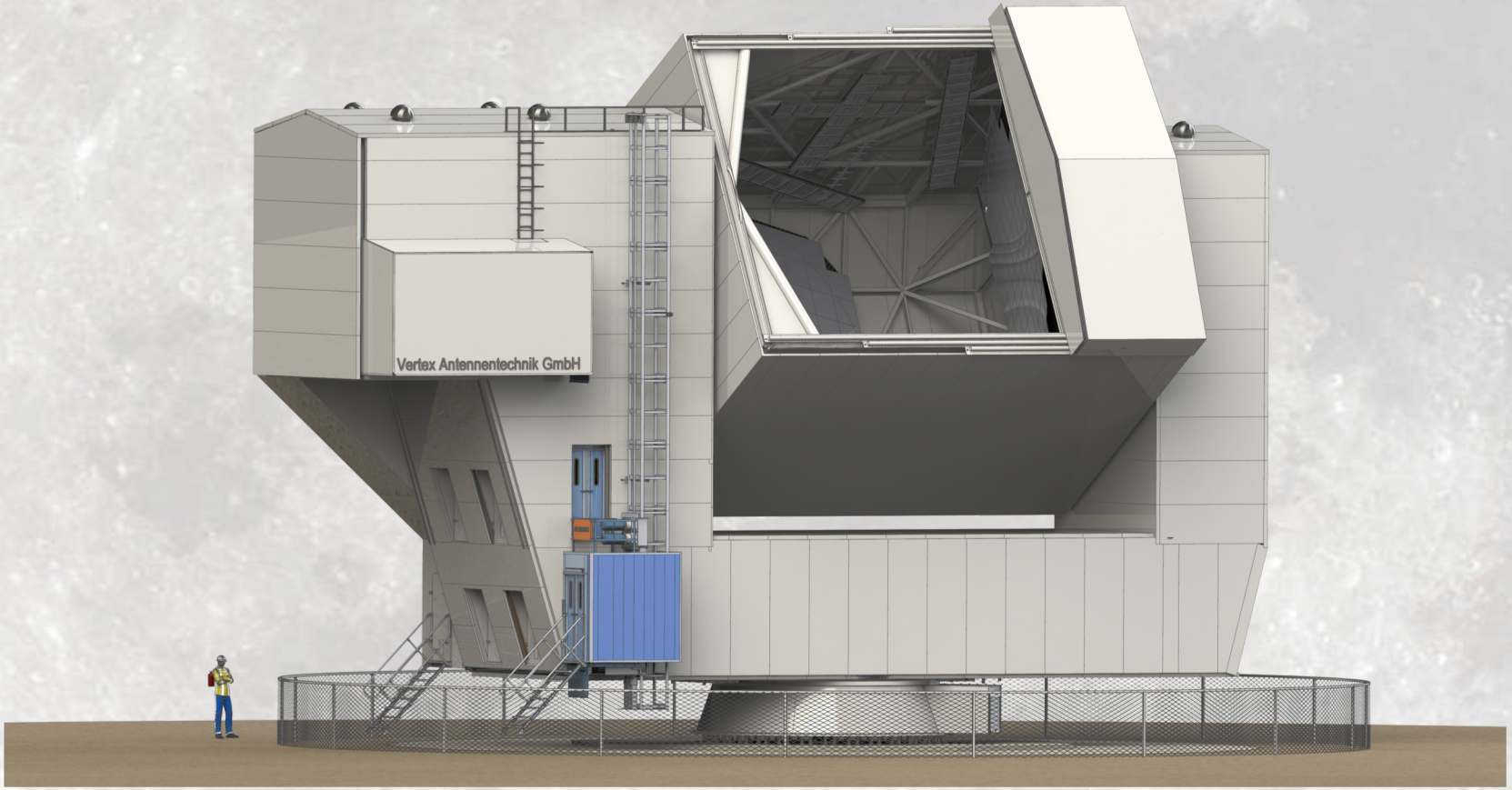
Lecture 1: The Sky

The Sky from Waterloo tonight (Jan 9) at 6pm

Instructor: Professor Mike Fich

- Started as hobby in high school astronomy club
  - Learned to make telescopes, and to find objects in the sky (planets, constellations, comets and other fuzzy things)
- B.Sc. (UWaterloo) and Ph.D. (University of California, Berkeley)
- Research in the structure of galaxies (e.g. dark matter) and in the birth of stars
- My research work requires the building of instruments (e.g. cameras) to be installed on telescopes. I am now building a telescope in Chile - These projects take hundreds of people, tens of millions of dollars, and tens of years

Artist's picture of the Fred Young Submillimeter Telescope to be installed at the CCAT Observatory in Chile in late 2023.



TOP 10 CELESTIAL EVENTS IN 2023

January 4
Quadrantids' peak

February 1
Bright comet C/2022 E3 (ZTF)

April 20
Hybrid solar eclipse

May 17
Lunar occultation of Jupiter

August 13
Perseids' peak

August 27
Saturn at opposition

August 31
The biggest Full Moon of 2023

October 14
Annular solar eclipse

November 3
Jupiter at opposition

December 14
Geminids' peak

9 January, 2023

This week's events:

the Sun: (9 Jan) sunrise 7:52, sunset 17:03 (5:03pm)

the Moon: (rise: 18:31, set: 9:55) Full Moon was on Jan 6

Mercury: (rise: 7:22, set:16:52) too close to Sun to see

Venus: (9:03, 18:29) very low in south-west at sunset

Mars: (13:41, 05:12) high in south-east at sunset

Jupiter: (11:12, 23:16) in south at sunset

Saturn: (9:44, 19:52) low in south-west at sunset

https://in-the-sky.org/whatsup_times.php?year=2023&month=01&day=09&town=6176823

Today's Lecture

- Overview of Course
  - course outline, special dates, assessments (assignments, exams), textbook, Learn, math requirements
- naked eye astronomy – where things are in the sky and how they appear to move: stars and constellations, rotation of the Earth, measuring angles in the sky (positions/"sky coordinates")
- Motions appear complex because

  (1) motions are not (all) circular

  (2) motions are not in the same plane

  (3) we are on the Earth, spinning and also moving around the Sun…

Science 238 Lecture Plan

Topics (22 lectures):

- The Sky
- Early Astronomy
- Tools: gravity and radiation(light)
- Planets (6 lectures!)
- Stars
- Galaxies
- Cosmology
- Extraterrestrial Life

Special Dates

Office Hours in room PHYS 255 Tuesdays 2 – 4 pm

No classes
Feb 20 – Feb 24 (Study Week)

Midterm Exam
Monday February 27 (in class)

Last Lecture
March 29
(no class on April 3 unless "snow day" during Term)

Grading Schemes

Two grading schemes – you will receive the best grade from the two schemes:

- Homework 30%, Midterm Exam 30%, Final Exam 40%
- Homework 15%, Midterm Exam 15%, Final Exam 70%

A Formula Page will be provided with each exam

Note: assignments and exams are very different in emphasis (calculations [assignments] vs factual material [exams]).

Textbook

- The textbook is excellent, free (available on-line at openstax.org)
  - Astronomy 2e (i.e. second edition – don't get the earlier outdated version!) by Fraknoi, Morrison, and Wolff
  - The textbook has much more detail than an instructor can cover in a set of lectures!!!
- The course structure is nearly identical to the order of the text
  - It will be obvious which parts of the text go with the lectures (so there isn't a real need for a separate list of reading).
  - The largest difference: the Formation of the Solar System and the discovery of Extrasolar Planets are with "Planets" in this course (but appear later in the textbook)

Homework Assignments

Four Homework Assignments – they will be posted on Learn at least nine days before the Due Date. Tentative Due Dates (subject to change):

February 1, February 15, (Midterm exam) March 15, March 29

- Primarily mathematical content, problem solving
- Hand-in through Learn!
- Late assignments accepted, no penalty in grade, **BUT no assignments accepted after solutions posted on-line** (solutions will be posted a few days to a week after the due date).
- You may discuss assignments with other students but you are not permitted to copy ANYTHING from another person's work.
  - The Teaching Assistants will be looking for cheating on assignments.

How to do well in this course

- Do the Assignments!!! **Yourself!!!!** If you need help see Professor in Office Hours
- Take notes: the Lecture Slides will be available on Learn, usually a day in advance, BUT THESE DO NOT REPLACE YOUR OWN NOTES. The Lecture Slides are just a visual placeholder… usually many words are used in the Lecture to describe each slide and these words are not on the slide!
- Avoid sitting near people using laptops for non-class purposes. It has been found that people with distracting laptops in classes cause a drop in grades for everyone who can see their laptop screen.
  http://news.yorku.ca/2013/03/13/multitasking-on-laptop-impedes-classroom-learning-york-u-study-shows

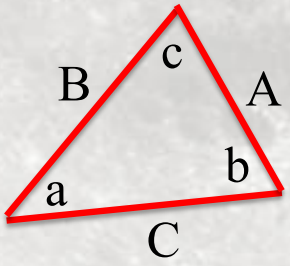
If you will use a laptop for tasks other than making notes about this class please sit in back of classroom !!!

Math Requirements

- No calculus required
- some simple algebra, geometry, trigonometry used
  - For example: triangles often appear in astronomy
    - Right angle relationships, Interior angles add to 180 degrees, …
    - radians are often used instead of degrees

$$1\,radian = \frac{180}{\pi}\,degrees = 57.2957795\ldots degrees$$

    - sin law and cosine law are frequently used (angles a,b,c below. Edge lengths A,B,C)



$$\frac{\sin a}{A} = \frac{\sin b}{B} = \frac{\sin c}{C}$$

$$A^2 = B^2 + C^2 - 2BC\cos a$$

Math: powers and logs

- powers (exponential notation for powers of ten)
  - $1 = 10^0$, $10 = 10^1$, $1{,}000{,}000 = 10^6$
  - $7{,}531{,}000 = 7.531 \times 10^6$ (Important in discussion of significant figures!!!)
  - $10^9/10^4 = 10^{9-4} = 10^5$ (not $10^{9/4}$!!!)
  - $1/t^{2.2} = t^{-2.2}$ $7^{1/2} = 7^{0.5} = \sqrt{7} = 2.645751311$ ...
- simple logarithms
  - In this class log x always means $\log_{10} x$, **not** $\log_e x$ or $\log_2 x$
  - log 10 = 1 $100 = 10^2$ → log 100 = log 10^2 = 2 log 10 = 2
  - log $x^{3.4}$ = 3.4 log x
  - log (ab) = log(a) + log (b) log $(1.3x^{3.4})$=log1.3 + 3.4log x
  - log $(x^a)^b$ = log (x^{a+b})

S.I. units and multipliers

second, meter, kilogram, Kelvin: 1000x multipliers

e.g. 500 nanometers (500 nm) = 0.5 micrometers (0.5 μm or microns) = 5×10^{-7} meters (this is the wavelength of green light – where your eye is the most sensitive)

Name	Symbol	value		Name	Symbol	value
tera (trillion, billion)	T	10^{12}		milli	m	10^{-3}
giga (billion, milliard)	G	10^{9}		micro	μ	10^{-6}
mega	M	10^{6}		nano	n	10^{-9}
kilo	k	10^{3}		pico	p	10^{-12}

Math tools

Strongly recommend you watch narrated powerpoint show SCI238 Background info.pptx available on Learn course page

- Some hints/suggestions on plotting (especially linear vs log) formats and apps
- Map or image projections
- Significant figures - relate to precision of the measurement
  - Too many ”sig. figs.” is equivalent to “misleading the reader”

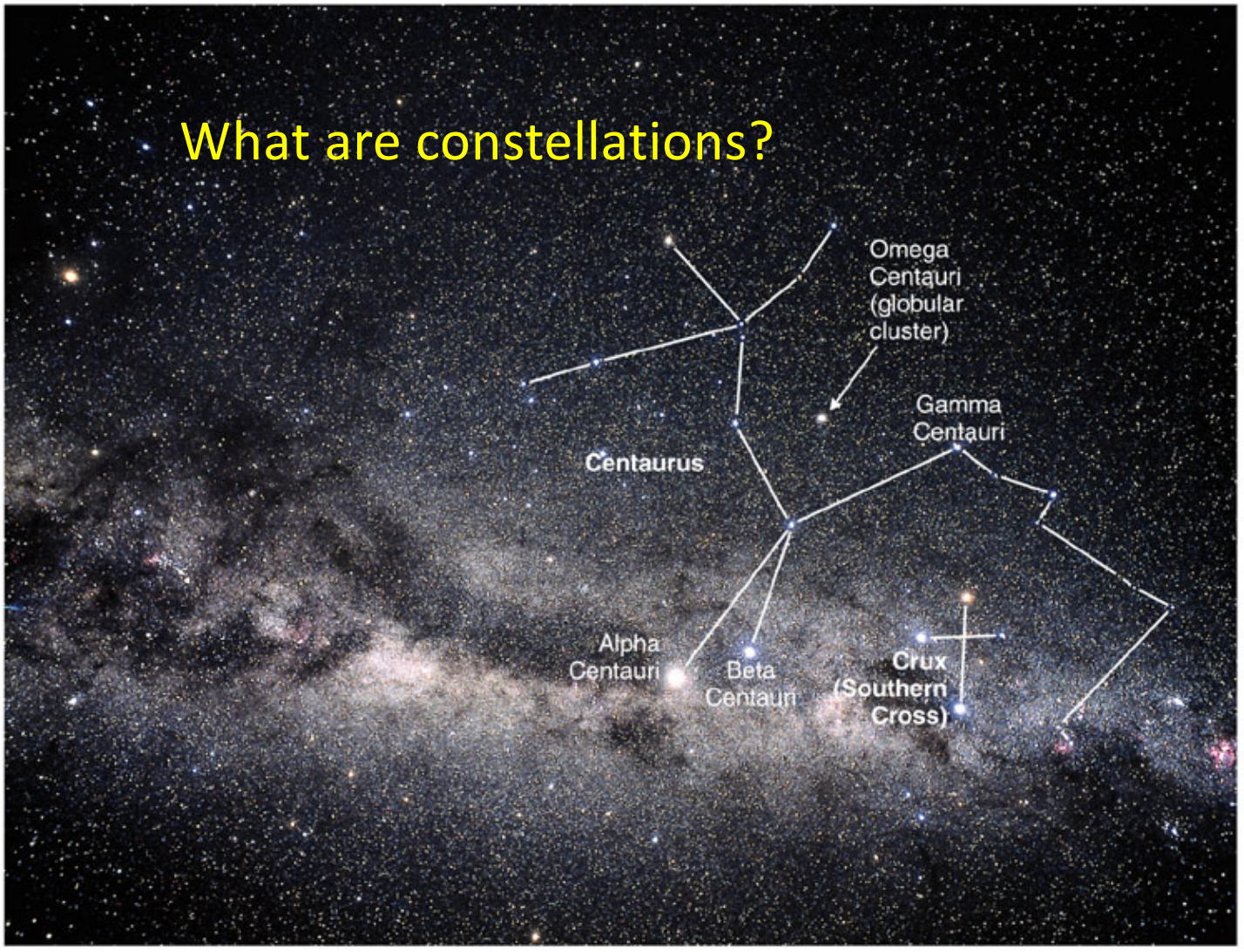
What do you know about the night sky? …not know? Why?

The night sky is so bright, where the people are,.. Most people can't see much in the sky

Naked Eye Astronomy

- what can you determine about the Universe around us – with your eyes alone? …no telescope, no photographs …perhaps with a time-keeping device and a protractor?
- much was known about the Universe – especially about our Solar System – before the telescope was invented…
- most of what we can learn comes from making notes of what we see… especially: where things are in the sky and how they move. Where in the sky is the moon? When is it full? How is this related to the tides? Where is Mars? When is Mars bright?
- observe for yourself

What are constellations?



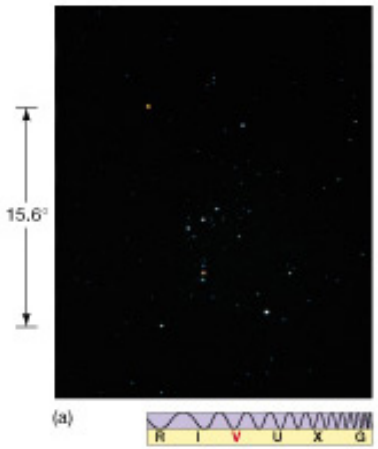
Constellation “Orion”:

- striking pattern
- bright stars
- different colours
- gaseous nebula
- star clusters

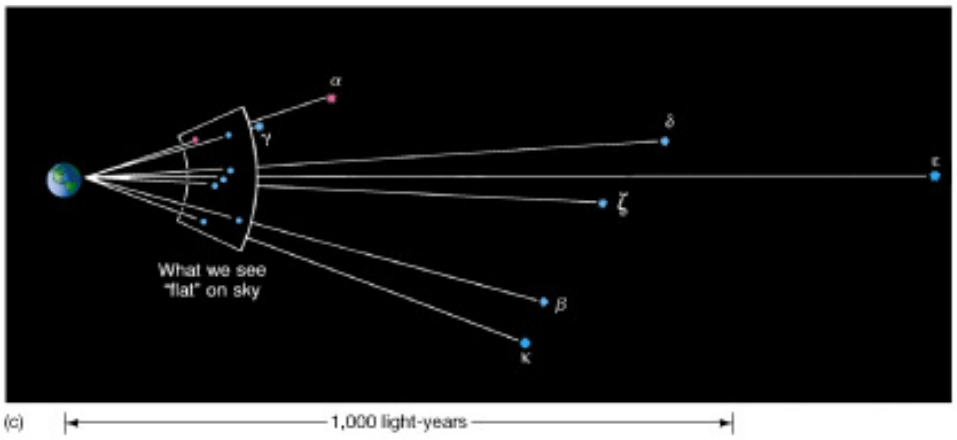
- ”winter” constellation in northern hemisphere

Orion

the star pattern

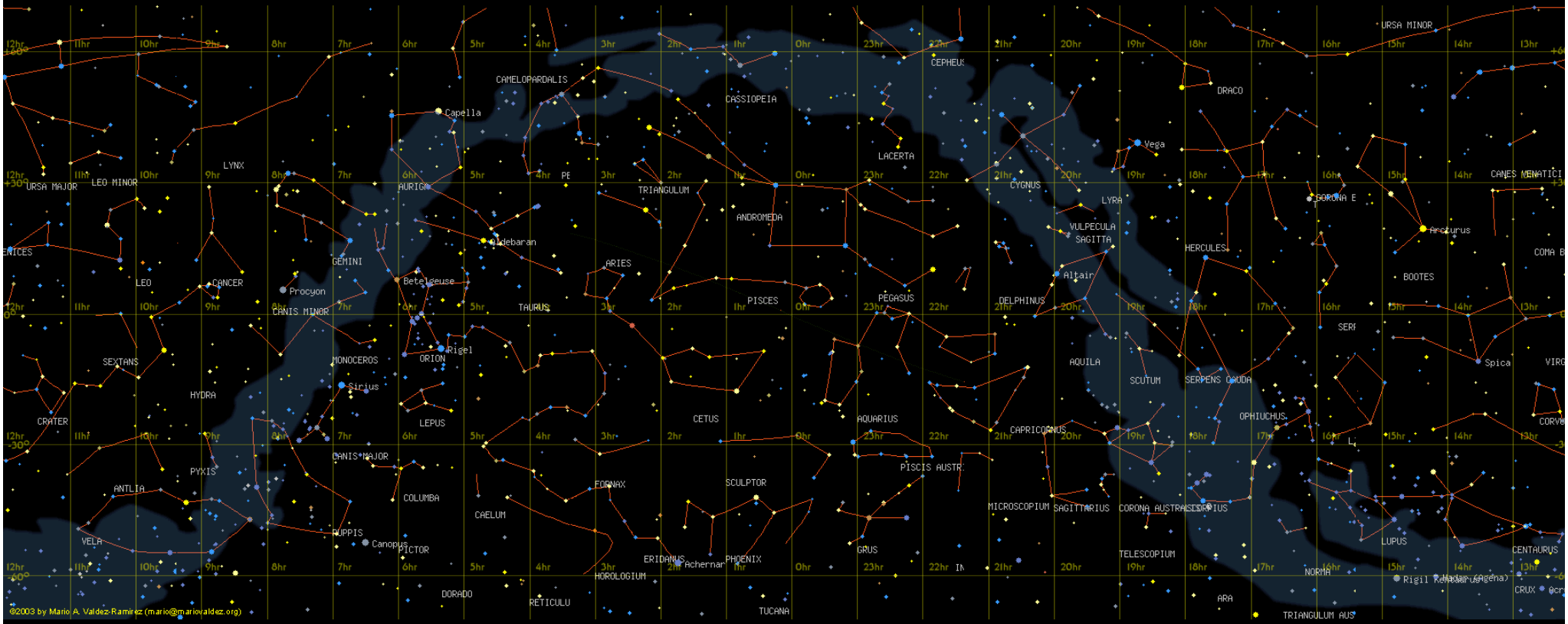


constellation "drawing"



the "real" picture

(most of) The Sky and Constellations

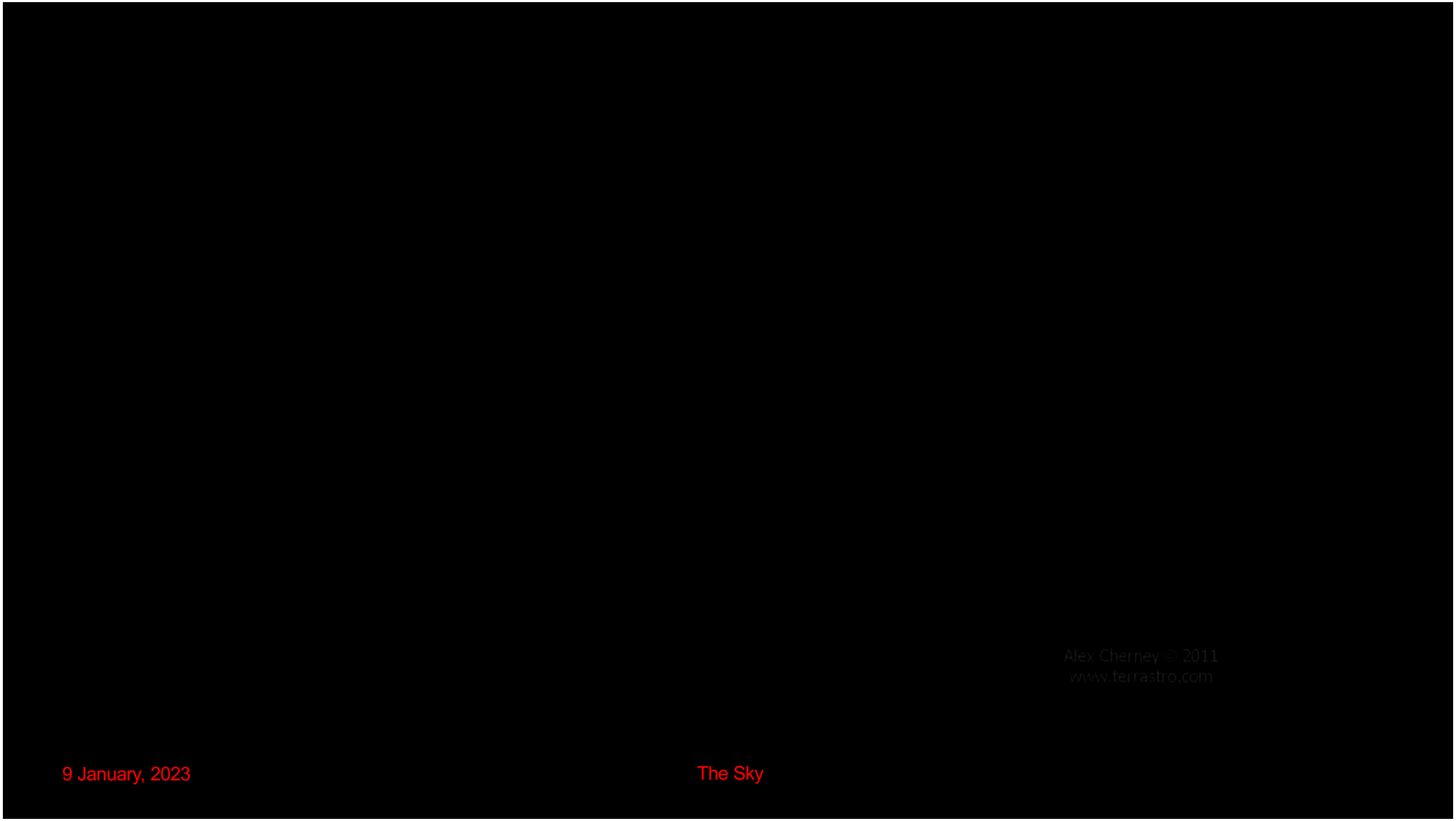


Motions in the Sky

- Where in sky? daily rotation of sky (of Earth, really!) This lecture

Next lecture

- motion of Moon from one day to next, and change in "phases"
- motion of Sun from one day to the next
  - hard to notice, because when the Sun is up you can't see the stars; but the Sun is in a (slightly) different part of the sky (with respect to the stars) every night… how can you tell that this is true?
- motion of planets

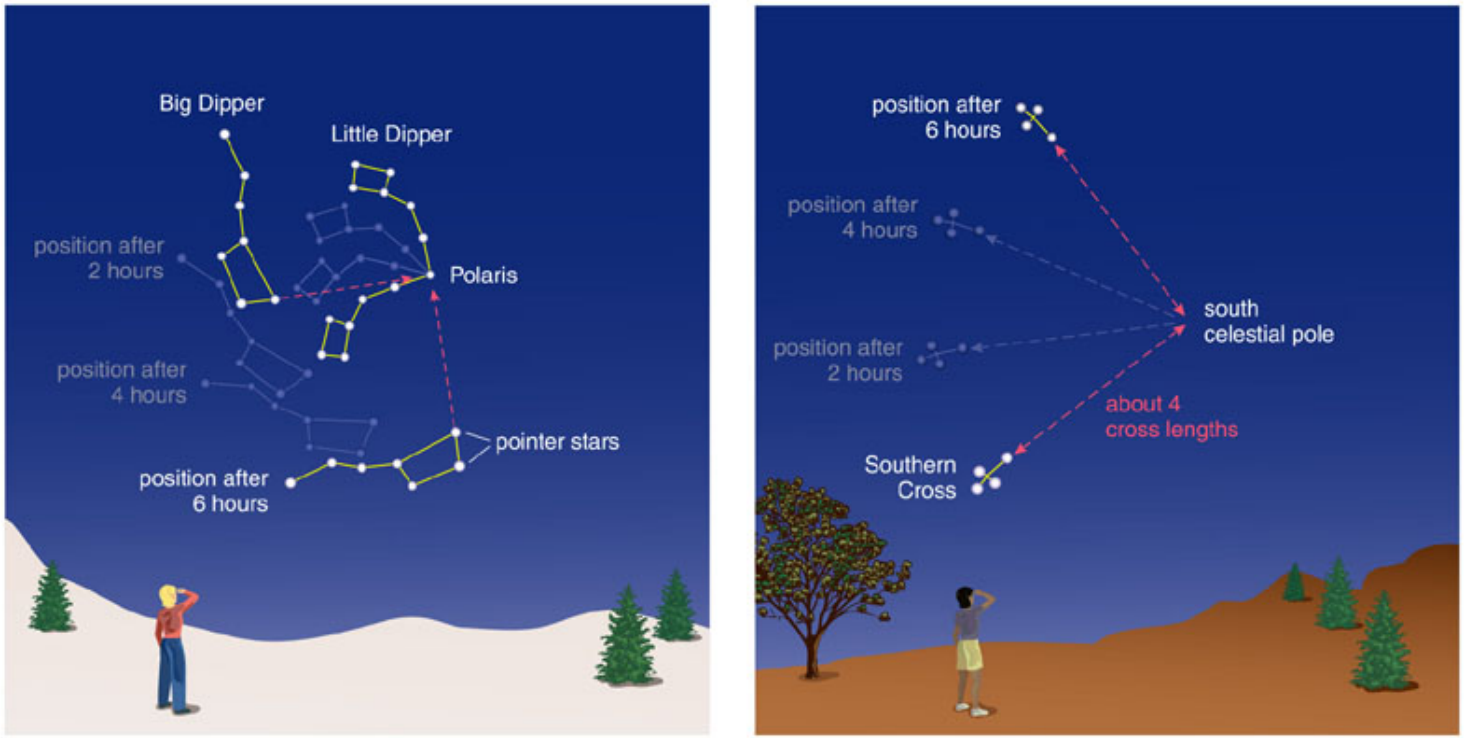


9 January, 2023

The Sky

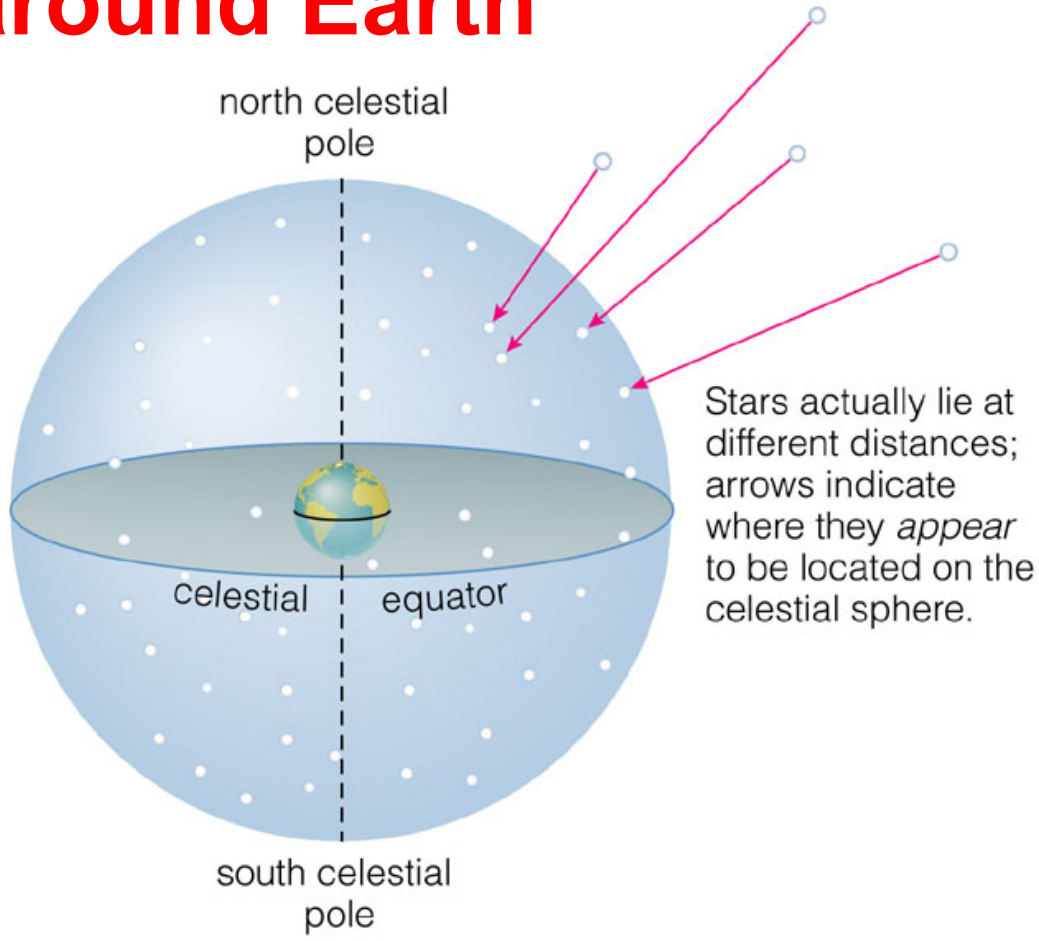
Stars move “around the sky”

Rotation of Earth

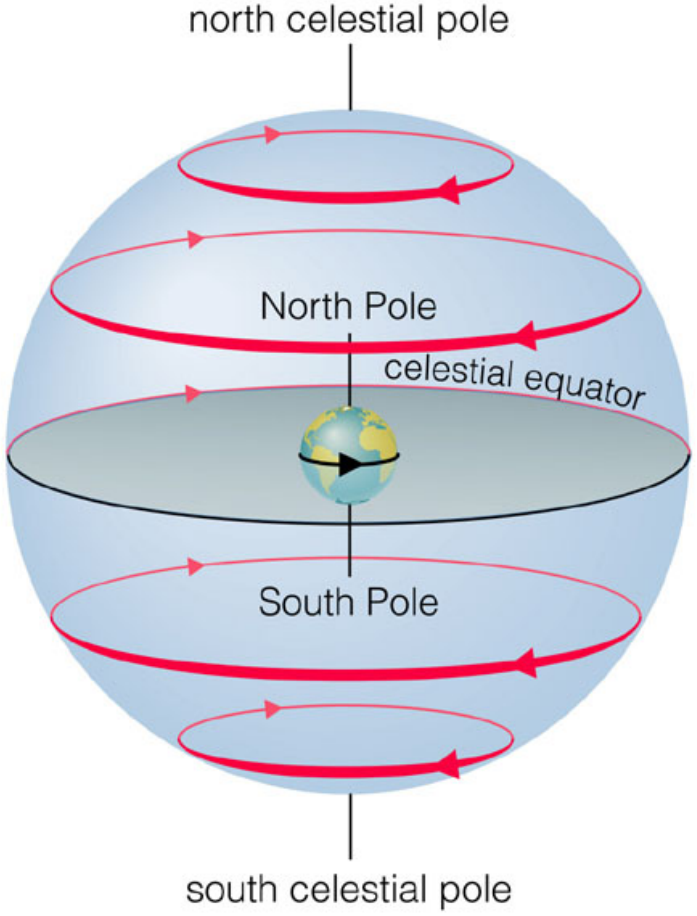


apparent rotation of the sky

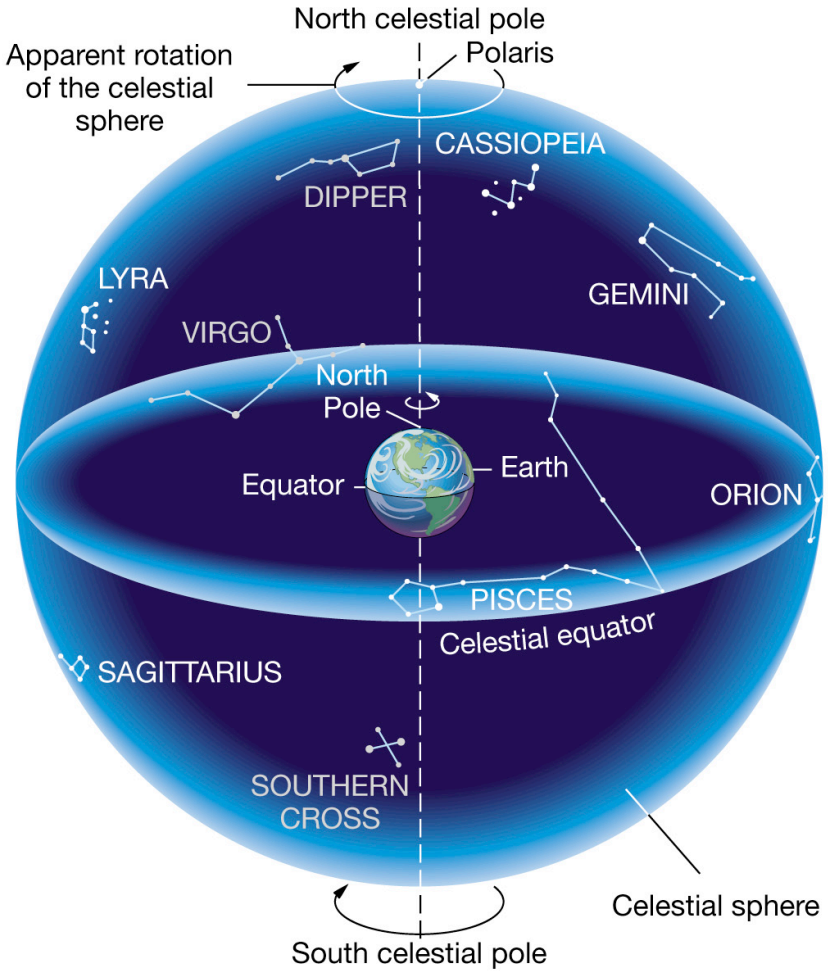
Stars appear to lie on a great "celestial sphere" around Earth



Earth's rotation makes the celestial sphere appear to rotate about us (from East to West)



Earth's rotation makes the stars appear to move

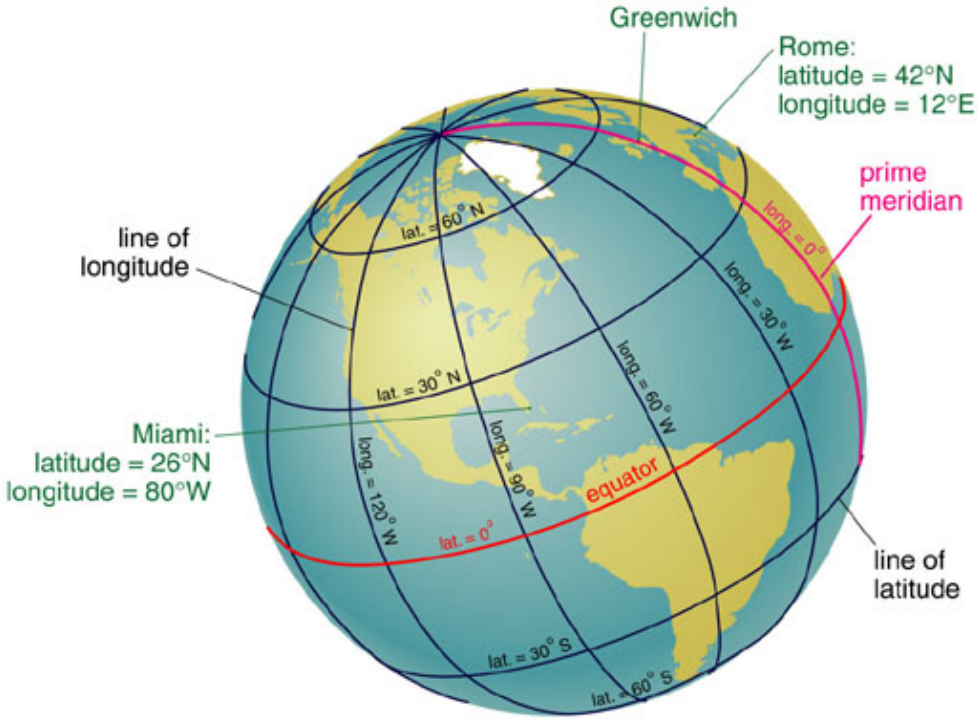


Location in the sky

- how do we identify the location of things in the sky, on the Celestial Sphere?

…need a (spherical) coordinate system of some kind.

- on Earth: use longitude and latitude…(angles with respect to the centre of the Earth, with 0° longitude at Greenwich, England and 0° latitude at the Equator.
- also, how do we measure angles in the sky?



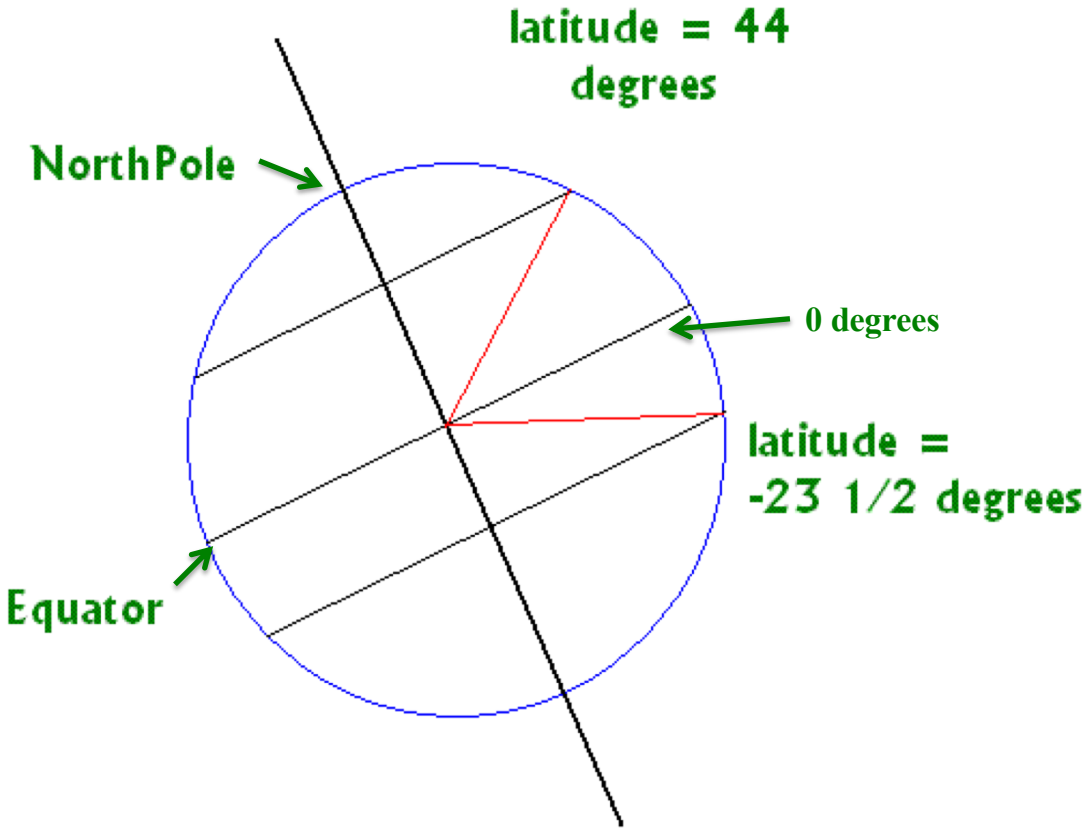
latitude = N/S angular distance

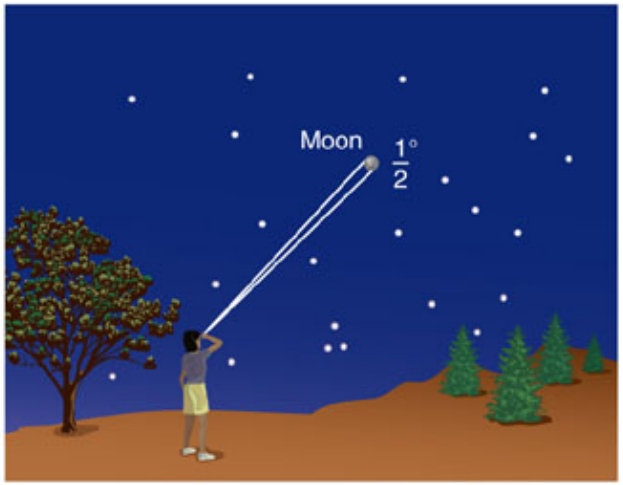
longitude = E/W angular distance

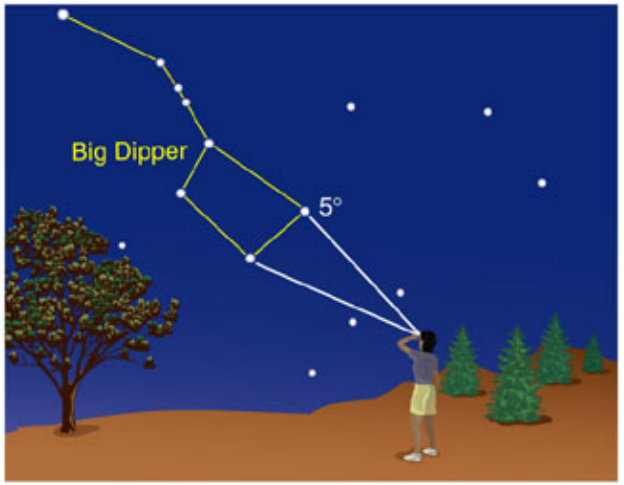
Greenwich

9 January, 202

Latitude (side-view, cross-section of Earth)



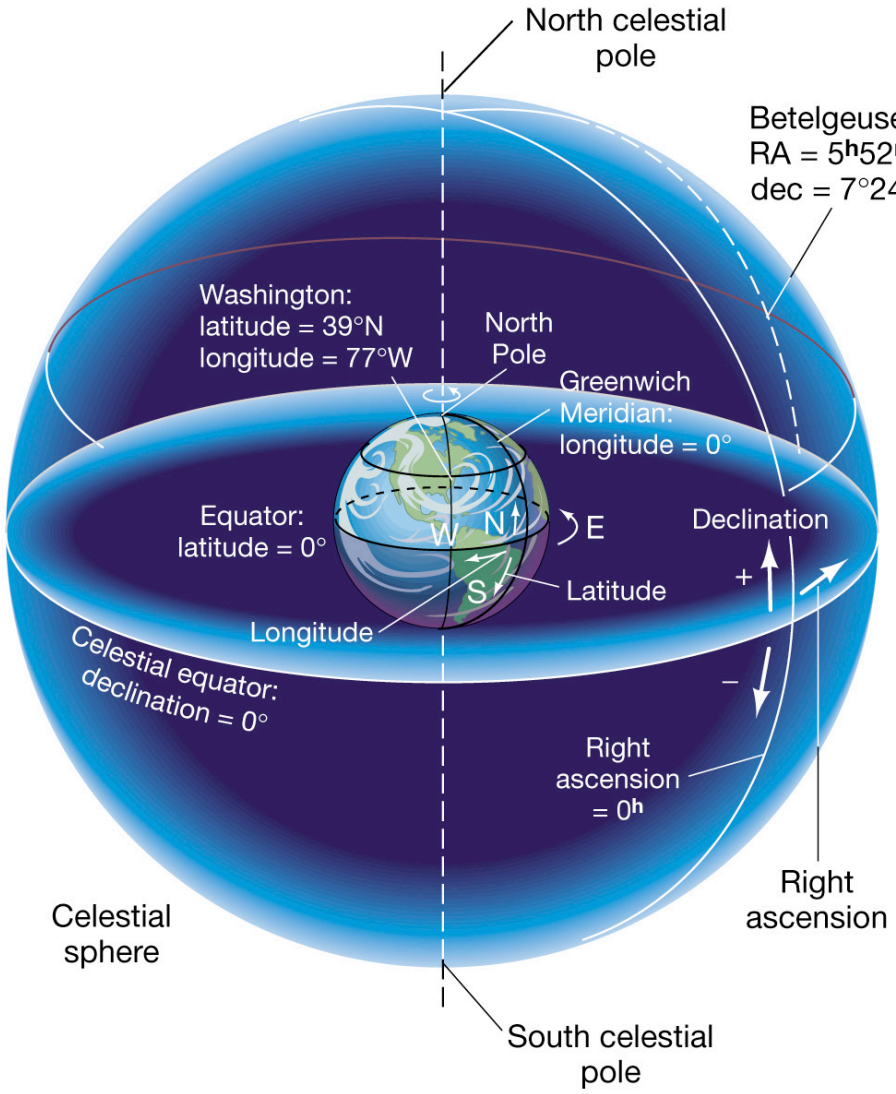




9 January, 202

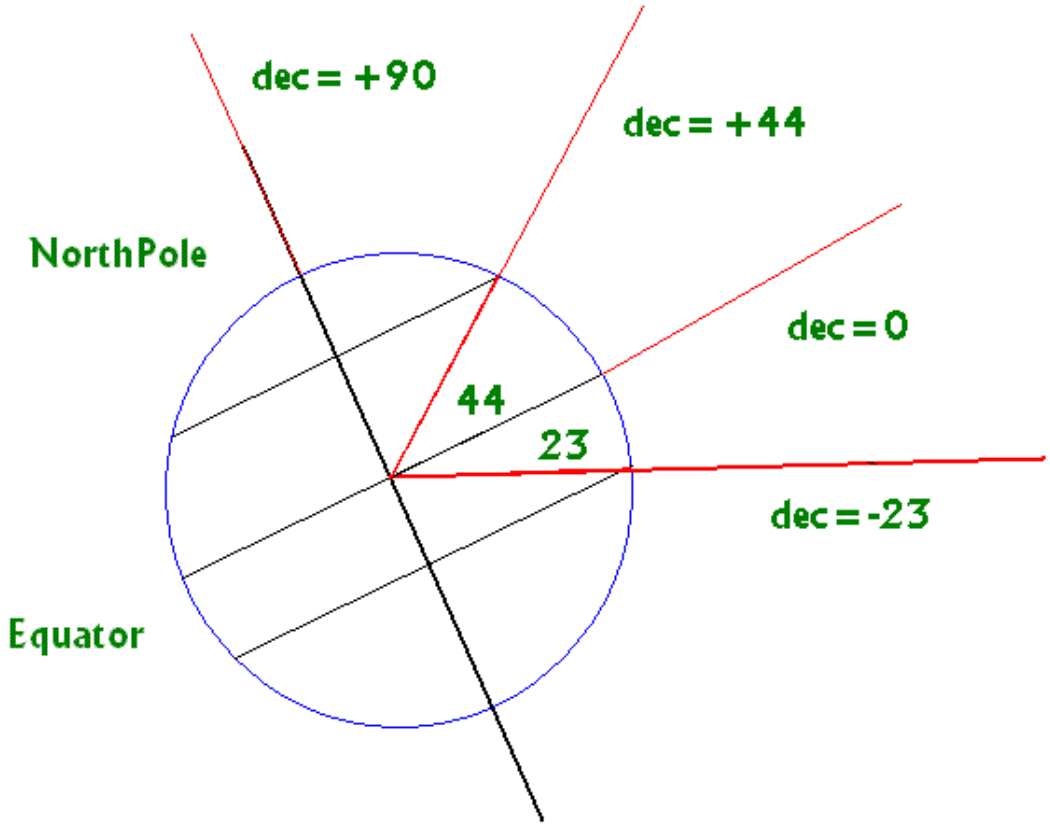
Measuring Positions in the Sky

- angular position… measured in degrees, (arc)minutes, (arc)seconds
  - 1 degree = 60 **arcmin** = 3600 **arcsec** …or… $1^\circ = 60' = 3600''$
- coordinate system for sky => longitude and latitude on Earth, extended out into space
  - latitude → **declination** (or Dec or δ)
  - longitude → **Right Ascension** (or R.A. or α)… ?? but sky "moves (once every 24 hours); stars constantly change longitude…. need to fix the sky coordinate.
  - Right Ascension: measured in hrs, min, sec; arbitrary fixed zero point in the sky (originally = position of the Sun at the instant Spring starts)



9 January, 2023

Declination

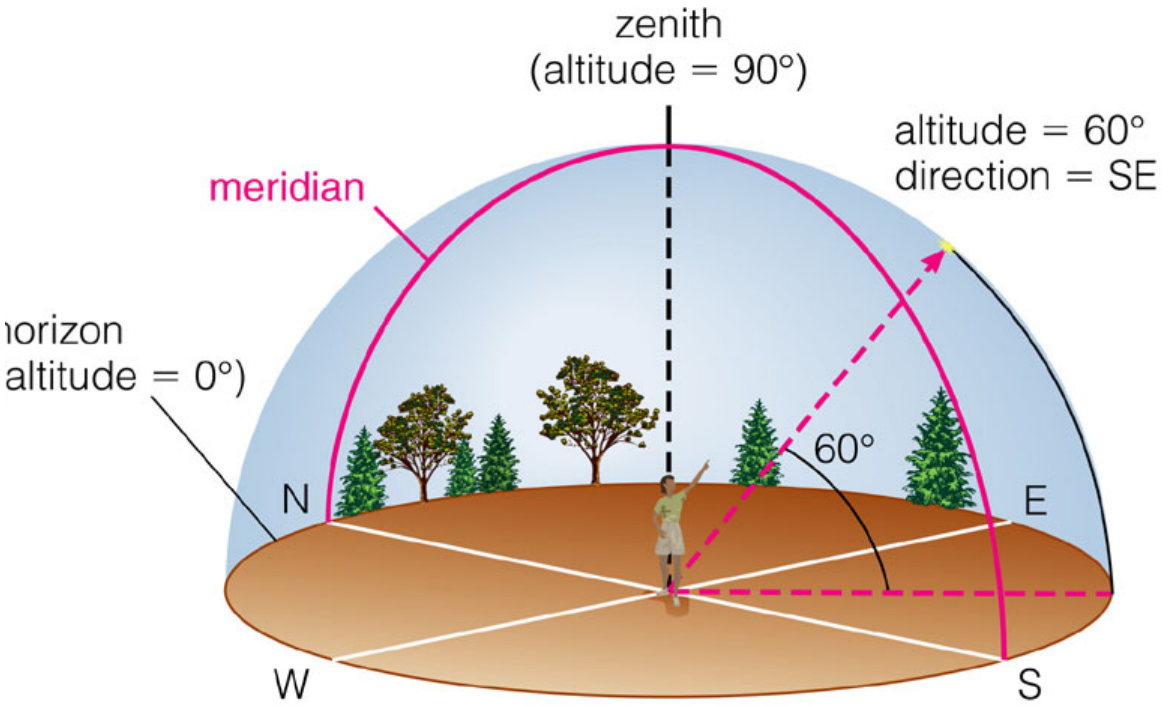


The sky seen from a fixed position on the Earth

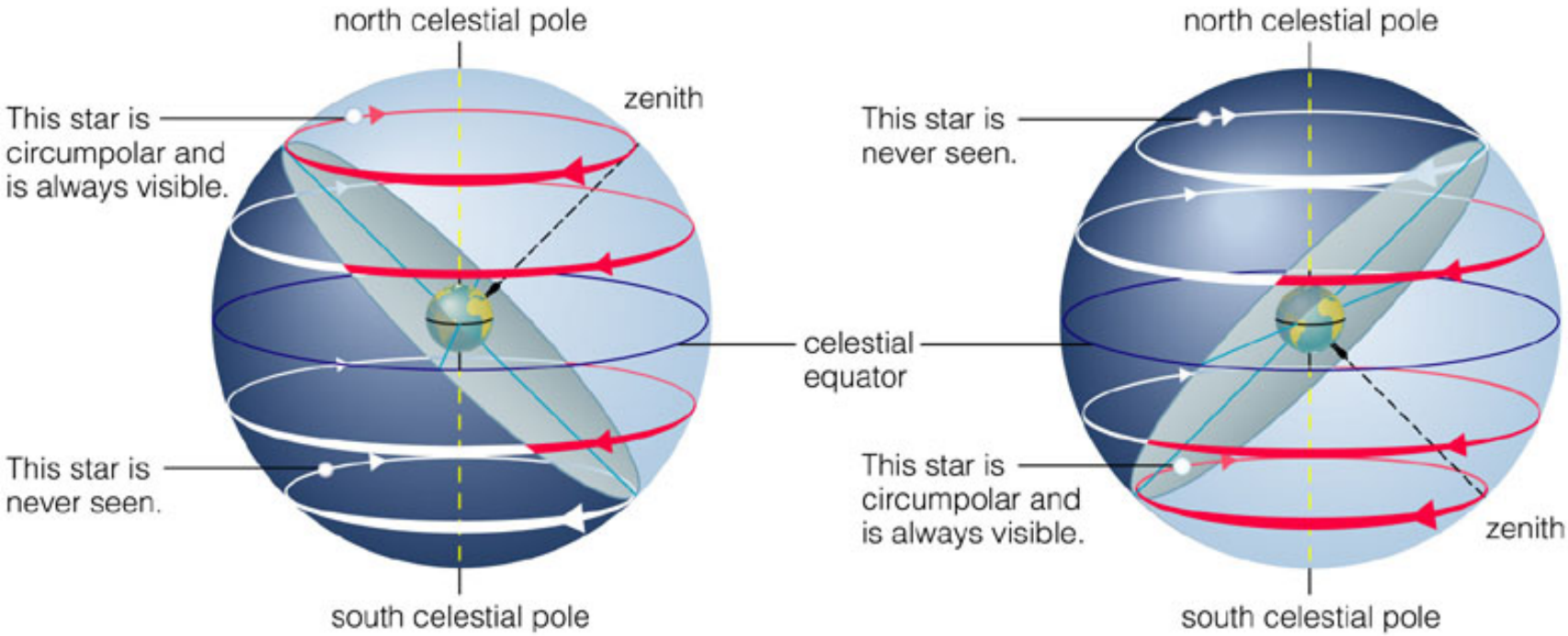
Our local coordinates (where we see things in the sky) depends on where we are on the Earth, the time of day, where the Earth is in its orbit around the Sun.

Our usual coordinates are “altitude” or “elevation” (zero is horizon, 90 is overhead) and “azimuth” (zero is due North, 90 is due East)

In these coordinates the positions and motions can be complex!



- the sky we see on Earth varies with latitude
- NCP altitude = observer's latitude



Star/sky rotation depends on latitude

latitude determines altitude of “centre”

Sky rotation at the Equator

Sept. 14 2007, Montlaux, France. Stars near the celestial equator make almost straight lines.

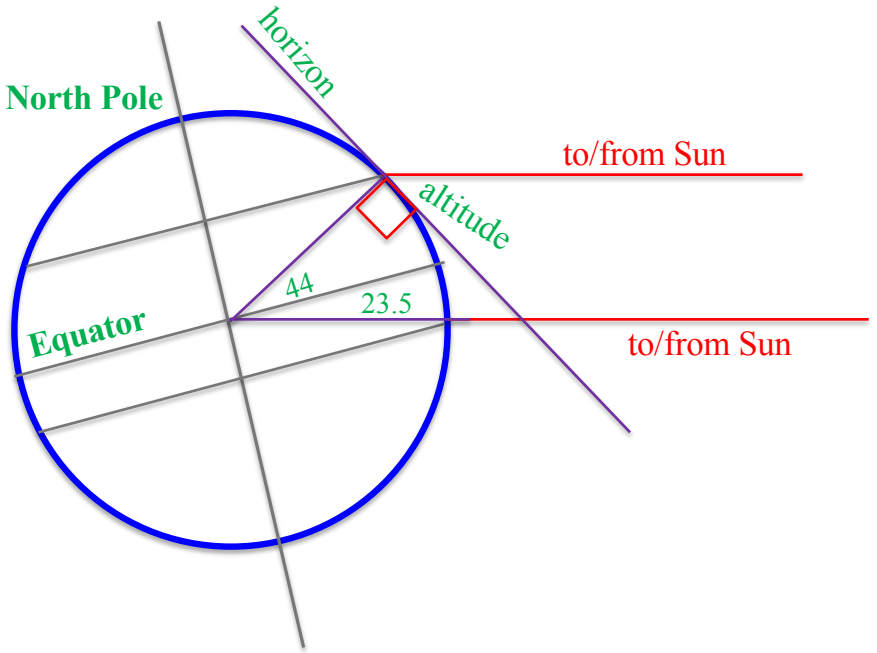
Note Venus rising on the left, a satellite leaving the frame at the top left.

477 consecutive 30 second exposures over 4.3 hours

Positions of objects in “your” sky

How high in “your” sky will an object be? For example, Sun at noon on 21 December (Solstice)?

- we are at a latitude of 44°.
- On 21 Dec the Sun is at a declination of -23.5° (would be seen directly overhead at noon at latitude of -23.5°).
- how high in the sky (altitude) is the Sun at noon?
- altitude = 180 – 44 – 23.5 – 90
  = 22.5°



Next Lecture

- Motion of the Sun (and Moon) through the sky
  - ✓ the ecliptic: path of the Sun + planets in the sky
  - ✓ Seasons
  - ✓ Time and the calendar
- Precession of the poles, eclipses etc.
- early astronomy – knowledge of Solar System, motions, scale