Reading: Ch. 2. Sect. 2.1, Chapter 4, Sect. 4.1-4.3
Recitations: start a week from Friday (9/6)
Homework #1 - available now, due in Lecture next Tuesday (9/3)

Last time: **Scales of the Universe**

- The size of our solar system, galaxy, and Universe
- contents of our solar system
- Universe is mostly empty space (density = 10^{-23} g/cm^3)
- **we are mostly "star stuff" produced in stars and supernovae**
  - space, H, He -> planets, people ... how?
- Strange and wonderful worlds on the way
- Time scales of the Universe (age ~ 13.6 billion years)

Today: **Finding your way in the sky (and on Earth)**

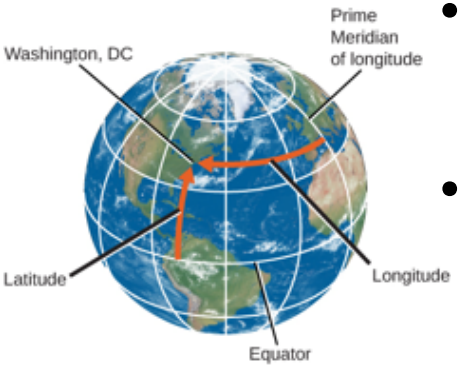
- The Celestial Sphere, link with terrestrial coordinates
- Horizon (local) System
  - altitude (horizon to zenith) and azimuth (East from due North)
- Celestial (Equatorial) coordinate system fixed to the stars
- Finding the celestial pole and equator from anywhere

discovering our solar system:

- to all appearances, the Earth is the center of *everything*
- the sky is ever-changing, but in a predictable way (mostly)
- patterns in ***space*** were "easy" (ex. constellations)
- how did we identify patterns in ***time*** to enable ***predictions***?
  - sunrise/sunset
  - seasons
  - moon phases
  - planetary orbits (around Earth)
  - the Sun-centered solar system, and birth of modern science
- careful observations of celestial bodies were (and are) essential

Ways to measure the sky

Earth First: Positions on the globe



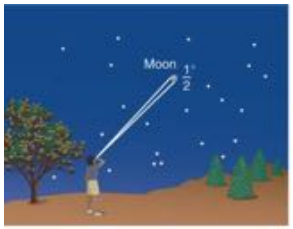
- latitude
  - angle from equator (=0^o) to pole (=90^o)
- longitude
  - angle West from Prime Meridian (agreed zero point)

Example: Ames, IA

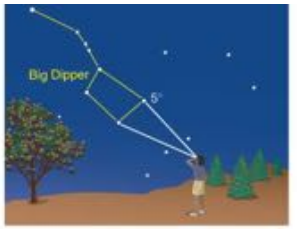
latitude: 42^o 1'(minute) North

longitude: 93^o 37' West

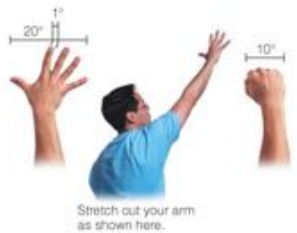
Measuring across the sky: angular measure



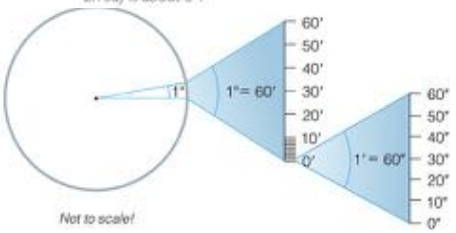
a The angular size of the Moon is about 1/2° (which is also the angular size of the Sun).



b The angular distance between the two "pointer stars" of the Big Dipper (which point to the North Star, Polaris; see Figure 2.13a) is about 5°.

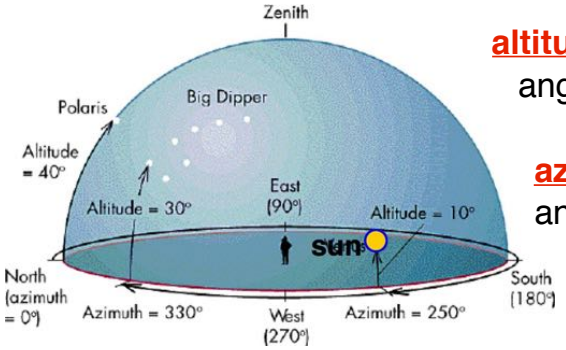


c You can estimate angular sizes or distances with your outstretched hand.



The Bowl of the Sky

The Horizon (Local) System



altitude :
angle from • horizon (0^o)
to • zenith (90^o)

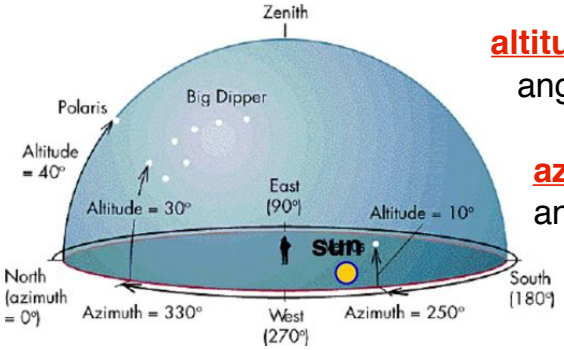
azimuth :
angle East from
• due North (0^o)
(agreed zero point)

Example 1: the North Star (Polaris)
altitude: 42^o (in Ames)
azimuth: 0^o

Example 2: the Sun
altitude: 10^o
azimuth: 250^o

The Bowl of the Sky

The Horizon (Local) System



altitude :
angle from • horizon (0^o)
to • zenith (90^o)

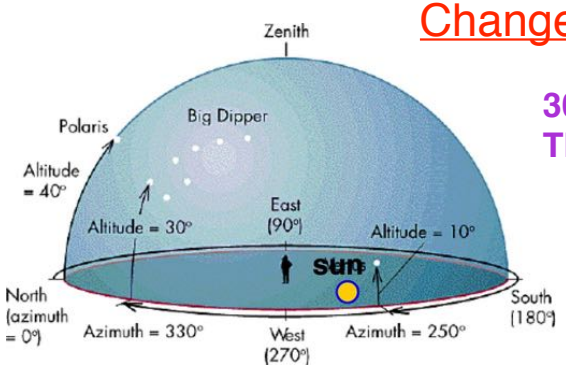
azimuth :
angle East from
• due North (0^o)
(agreed zero point)

Example 1: the North Star (Polaris)
altitude: 42^o (in Ames)
azimuth: 0^o

Example 2: the Sun
altitude: 3^o
azimuth: 258^o
But 30 minutes later....

The Horizon Coordinates

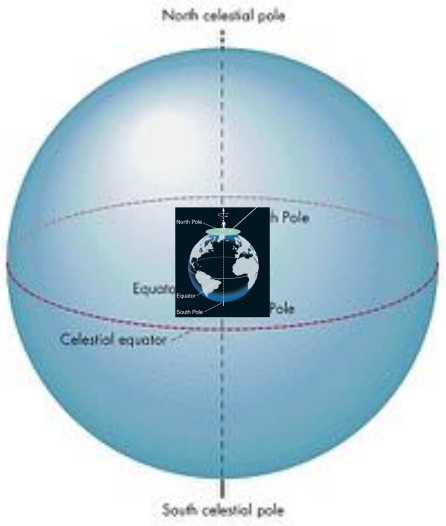
Change with time!

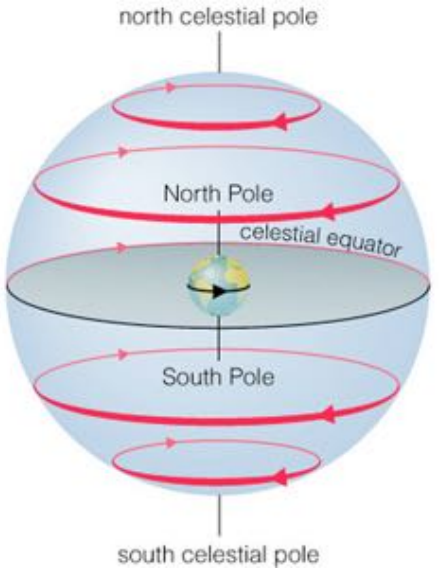


30 minutes later....
The sun goes down
altitude: 3^o
azimuth: 258^o

Horizon system of locating things fails:
at different times (Earth's rotation = diurnal motion)
at different places (extremes: North pole, equator)

Celestial Globe





The Celestial Coordinate System

The equatorial coordinate system
analog to longitude and latitude on Earth,
affixed to the stars

- Declination (celestial latitude):

angle from

- **celestial equator** (0^o)
  (extension of the Earth's equator to the sky)

to

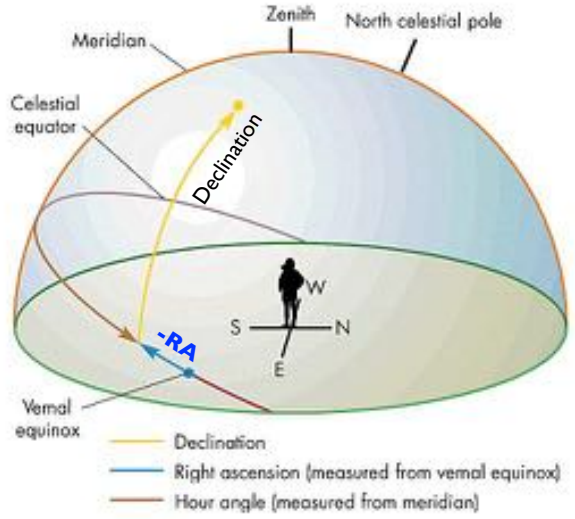
- North or South **celestial pole** ($\pm 90^o$)
  (extension of the Earth's axis to the sky)

- Right Ascension (celestial longitude):
  - angle East from **vernal equinox**
    (agreed zero point = place of the Sun on 21 March)
  - measured in hours, minutes (1 hour =15 degrees)
  - from 0 hours to 24 hours around the sky to the East

Celestial Coordinates

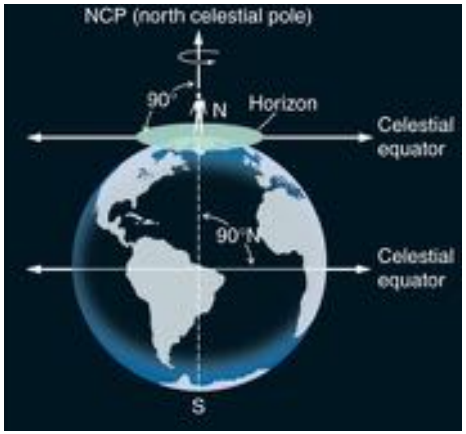
declination (dec) : just like latitude

right ascension (R.A.) : measured East from vernal equinox



Finding the Celestial Pole and Equator in your sky

At the **Earth's North Pole:**

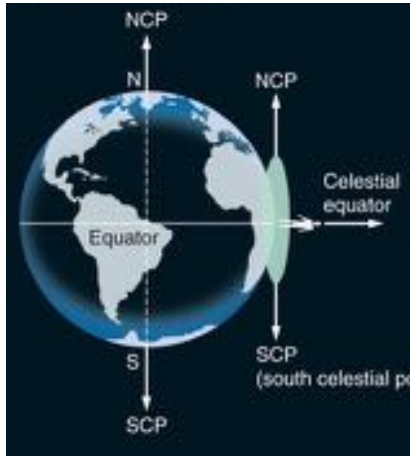


- Celestial equator:
  - always on the horizon
- Celestial poles:
  - North CP always at the Zenith
  - South CP always directly below your feet

No stars rise or set; move parallel to horizon

Finding the Celestial Pole and Equator in your sky

On the **Earth's equator:**

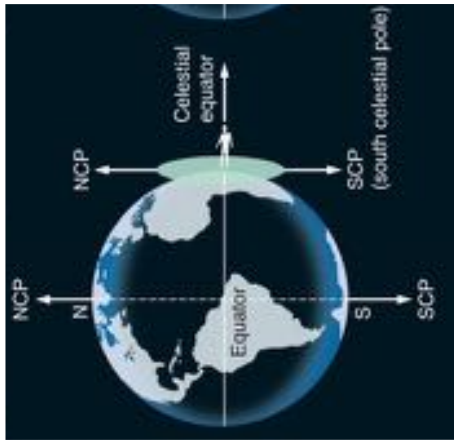


- Celestial equator:
  - always overhead
  - West through Zenith to East
- Celestial poles:
  - always on horizon
  - due North and due South

All stars rise and set as the Earth turns

Finding the Celestial Pole and Equator in your sky

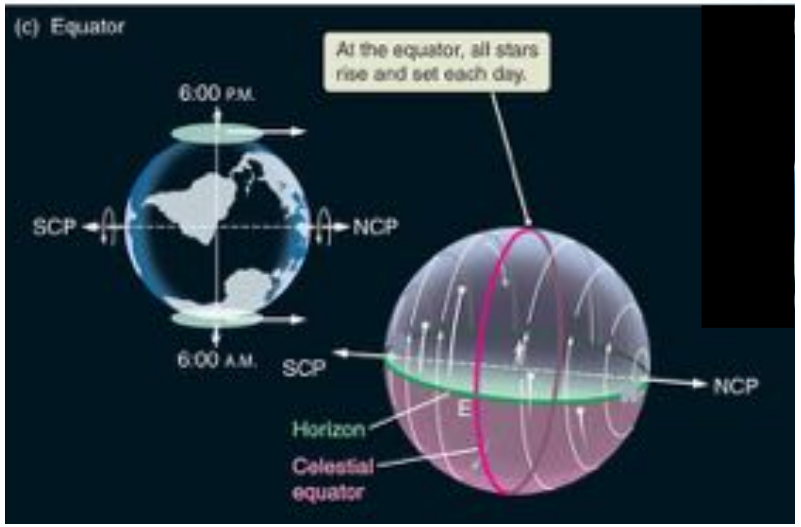
On the **Earth's equator:**



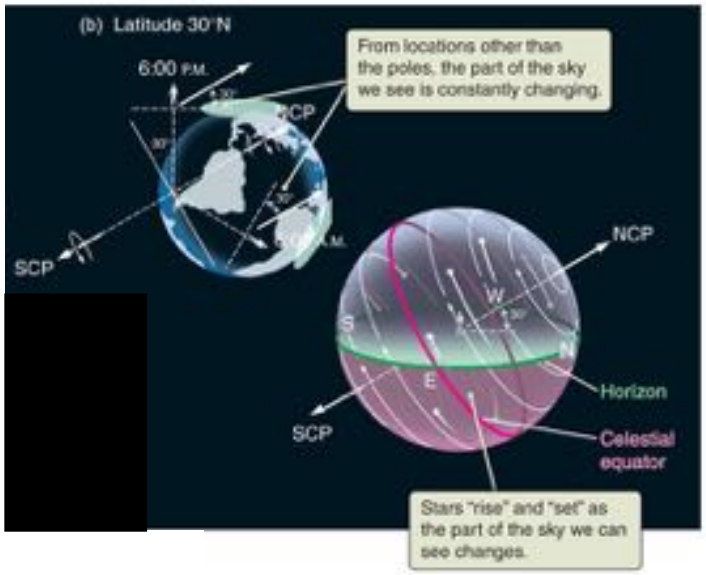
- Celestial equator:
  - always overhead
  - West through Zenith to East
- Celestial poles:
  - always on horizon
  - due North and due South

All stars rise and set as the Earth turns

Equatorial View

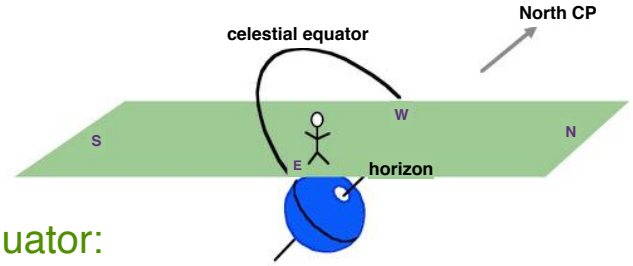


Mid-latitude view



Finding the Celestial Pole and Equator in your sky

At other (middle) latitude:



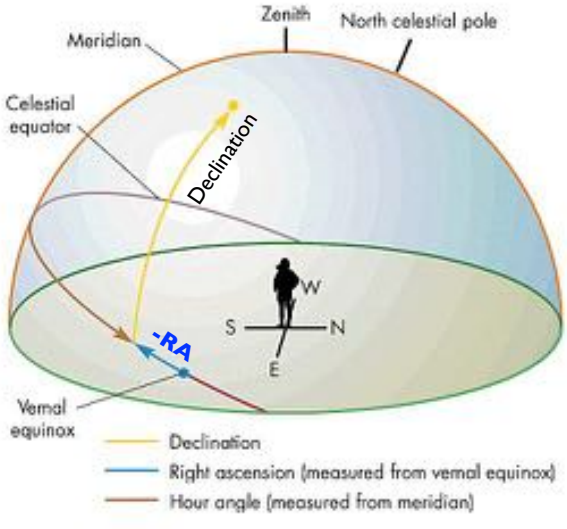
- Celestial equator:
  - tilted down from zenith by an angle equal to latitude
  - West through meridian to East
- Celestial poles:
  - due North (azimuth=0)
  - altitude equal to the latiude of the observer

Some stars rise and set,
others circle the pole (circumpolar)
and others are never seen

Celestial Coordinates

declination (dec) : just like latitude

right ascension (R.A.) : measured East from vernal equinox



Celestial Coordinates

declination (dec) : just like latitude

right ascension (R.A.) : measured East from vernal equinox

R.A. of vernal equinox = 0h 0m; dec = 0^o

Example 1: Vega

dec = $+38^o$ 44' (+=N)
R.A. = 18h 32m 30s

Example 2: The NCP

dec = 90^o
R.A. = ??

Example 3: Sun (on March 21)

dec = 0^o 0'
R.A. = 0h 0m

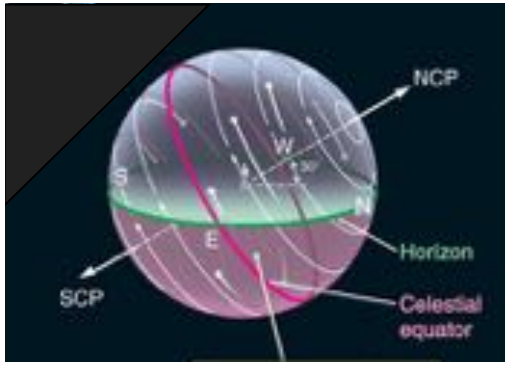
Example 4: Sun (on Dec 21)

dec = -23^o 37' (- = S)
R.A. = 18h 0m

Diurnal (Daily) Motions of the Sky

stars move in circles around the celestial poles

- one circle per sidereal day
- biggest circle on celestial equator (dec. = 0^o)
- smaller circles nearer poles (higher declination)



Circumpolar regions

diurnal circle lies entirely above the horizon

declination > 90^o – latitude