

# PHY 517 / AST 443: Observational Techniques in Astronomy

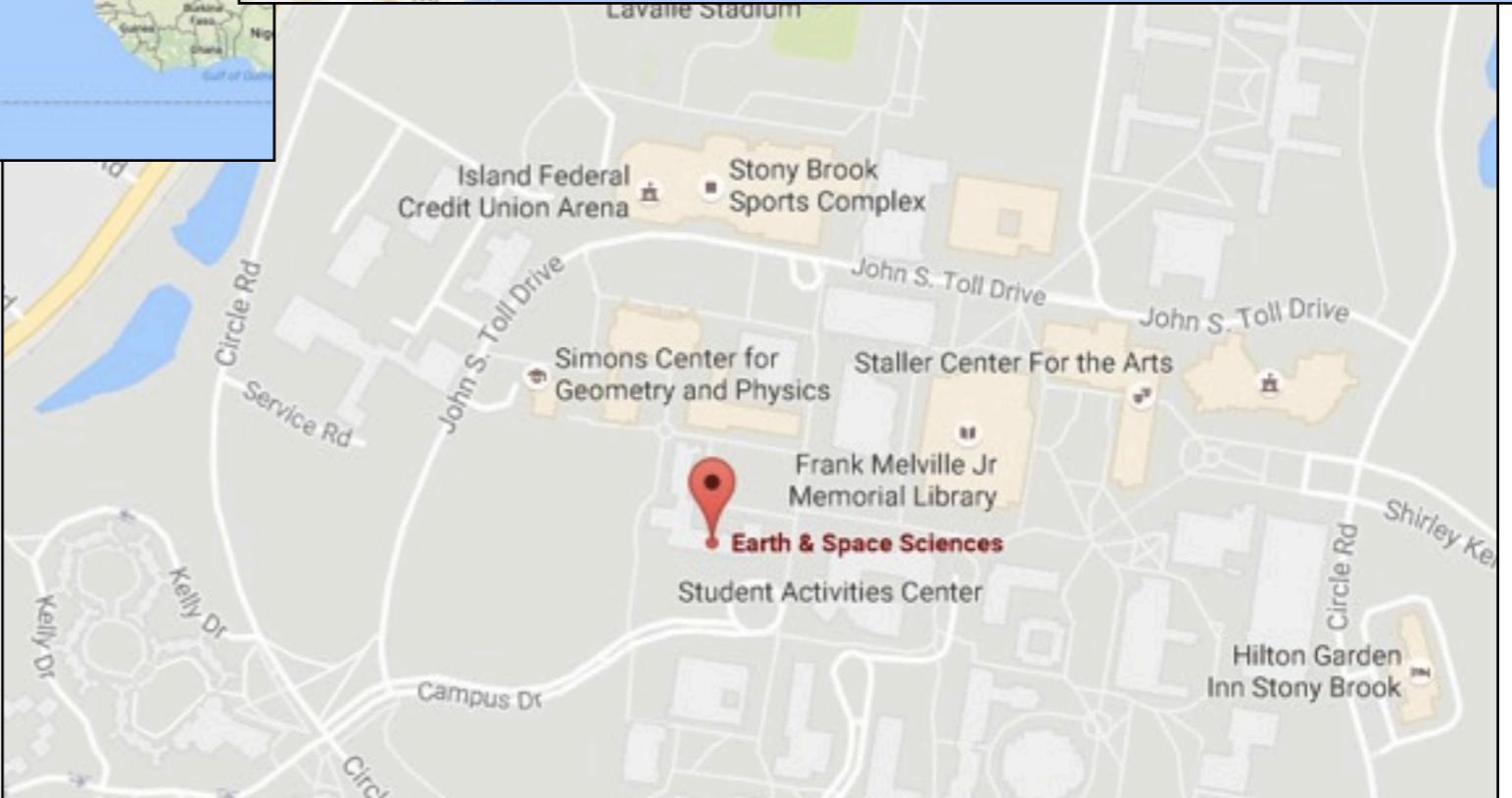
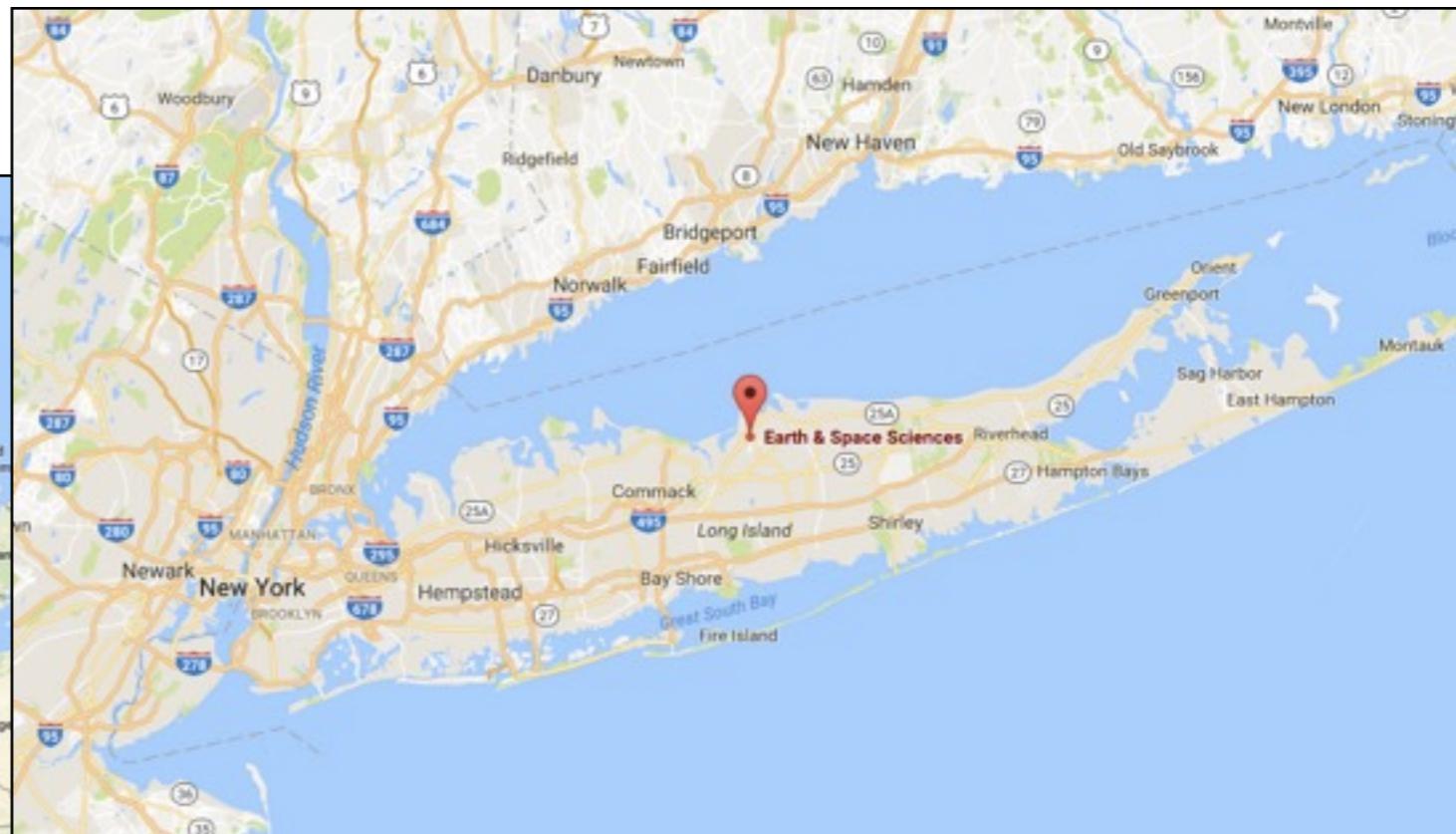
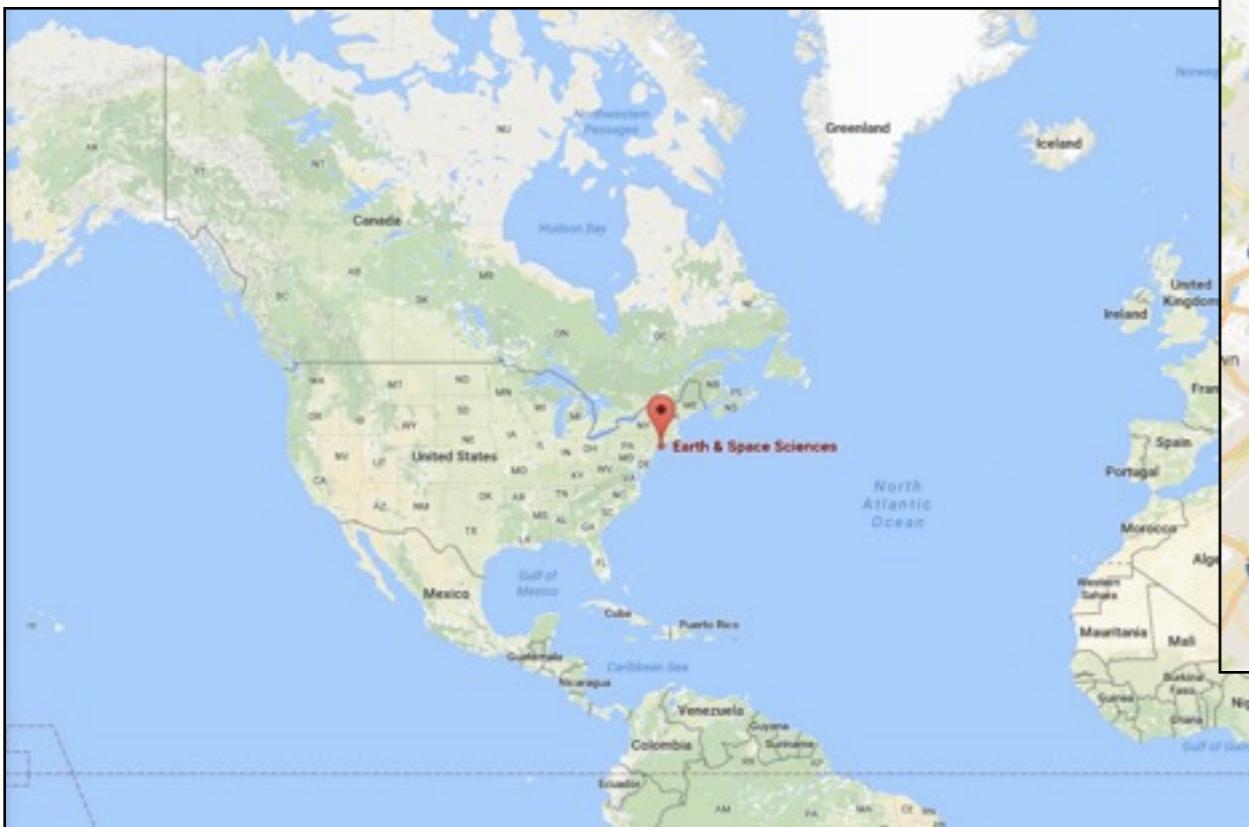
Lecture I:  
How to find things in the Sky /  
Astronomical Coordinate Systems

**How do you find things in the Sky?**

How do you find things **on Earth?**

# How do you find things on Earth?

## I. maps

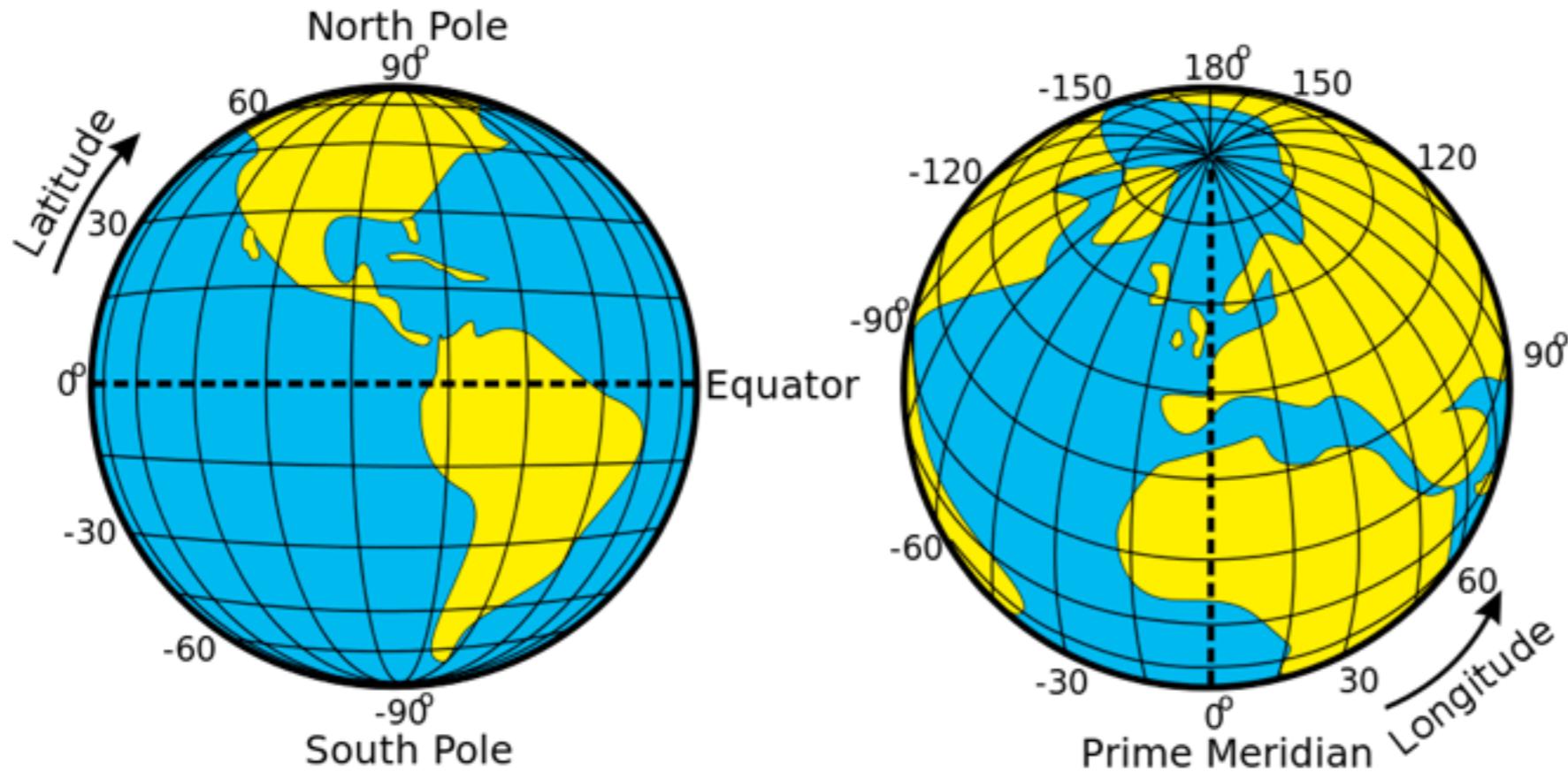


“pattern matching”

# How do you find things on Earth?

Coordinates:  40.914224°N 73.11623°W

2. latitude and longitude: 2 angular coordinates, related to Earth's rotation



**Stony Brook University**



**Former names** State University College on Long Island (1957–1962)

**Type**

- Public
- Research university
- Sea-grant
- Space-grant

**Established** 1957

**Endowment** \$247.4 million (2015)<sup>[1]</sup>

**President** Samuel L. Stanley

**Provost** Dennis Assanis

**Academic staff** 2,471 (fall 2013)

**Students** 21,115 (West Campus)<sup>[2]</sup>

3,847 East Campus<sup>[2]</sup>

310 Southampton<sup>[2]</sup>

25,272 Total

**Undergraduates** 16,831 (2015 Fall)<sup>[2]</sup>

**Postgraduates** 8,441 (2015 Fall)

**Location** Stony Brook, New York, U.S.

40.914224°N

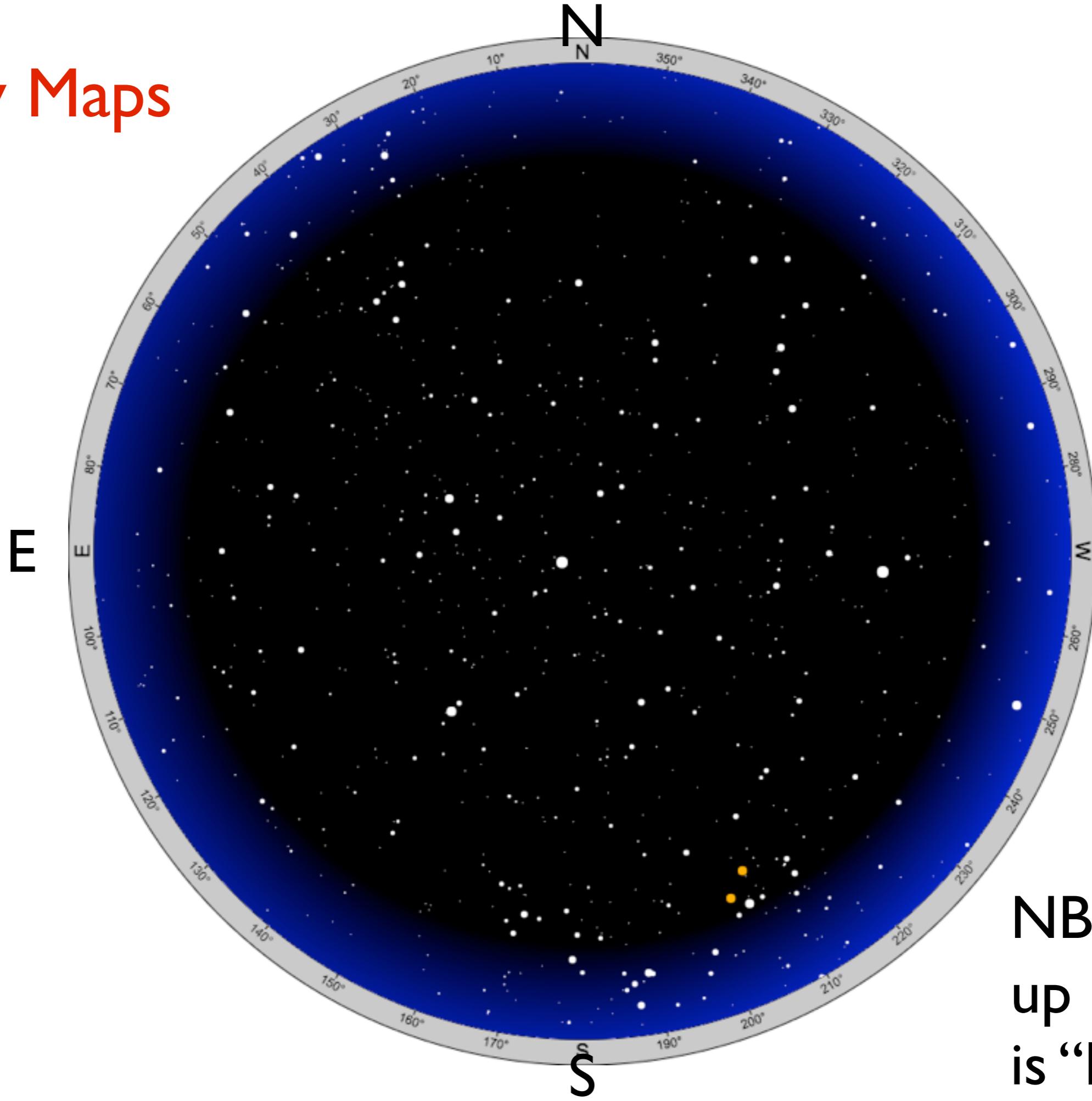
73.11623°W

wikipedia

# How do you find things on the Sky?

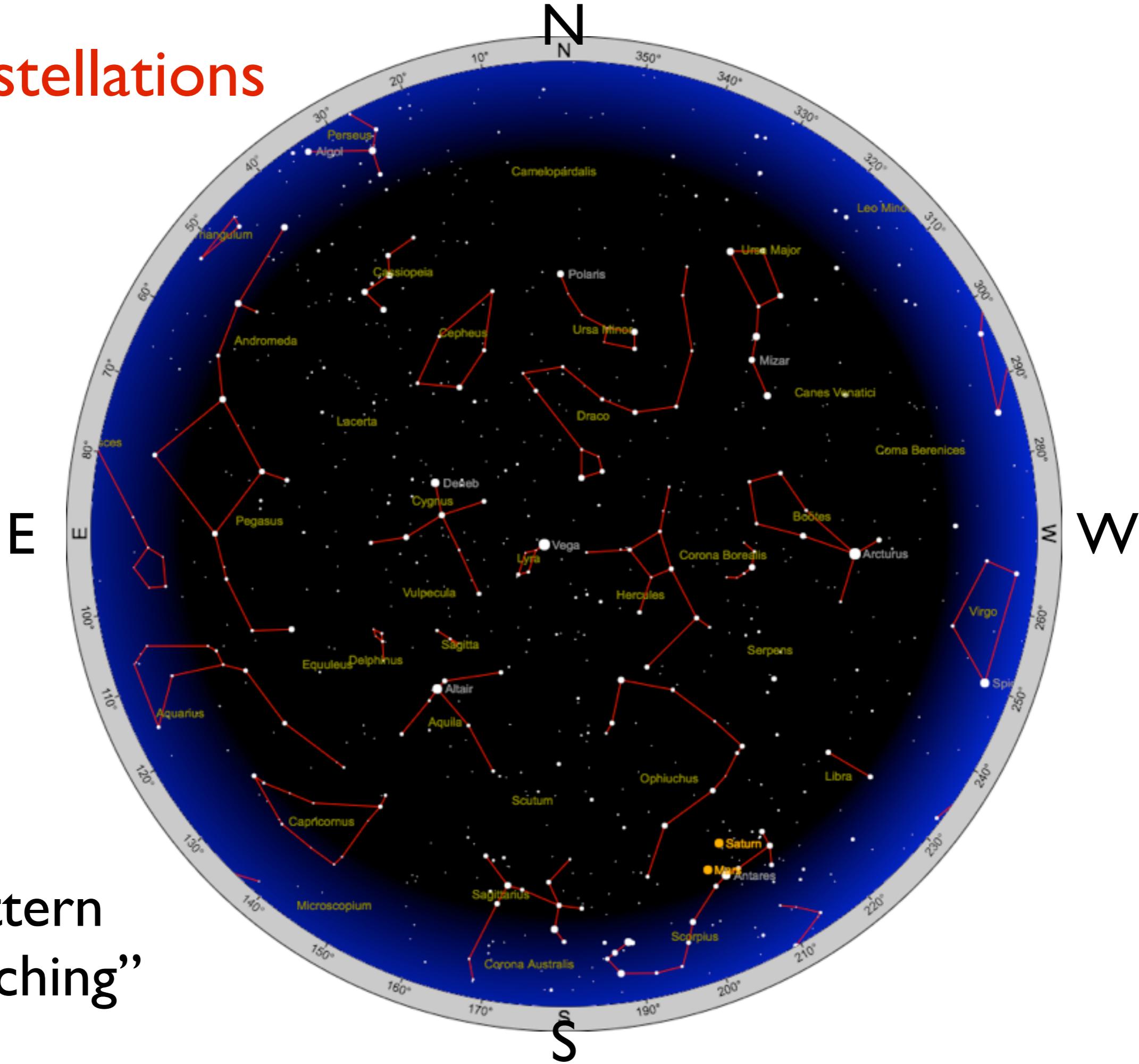
- similar to Earth:
  1. maps, “finding charts”, pattern matching
  2. angular coordinate systems

# Sky Maps



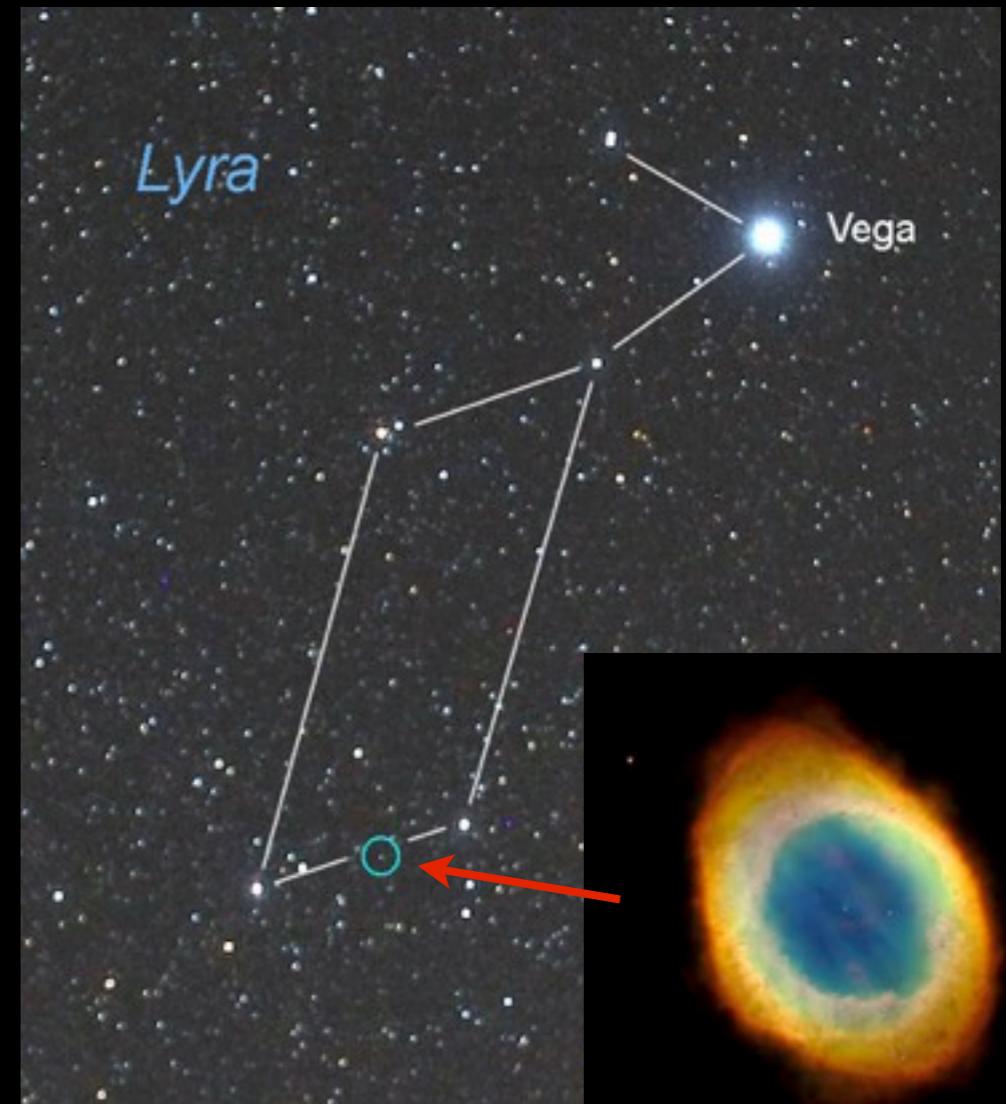
NB: looking  
up → East  
is “left”

# Constellations



“pattern  
matching”

# How to find the Ring Nebula (M57)



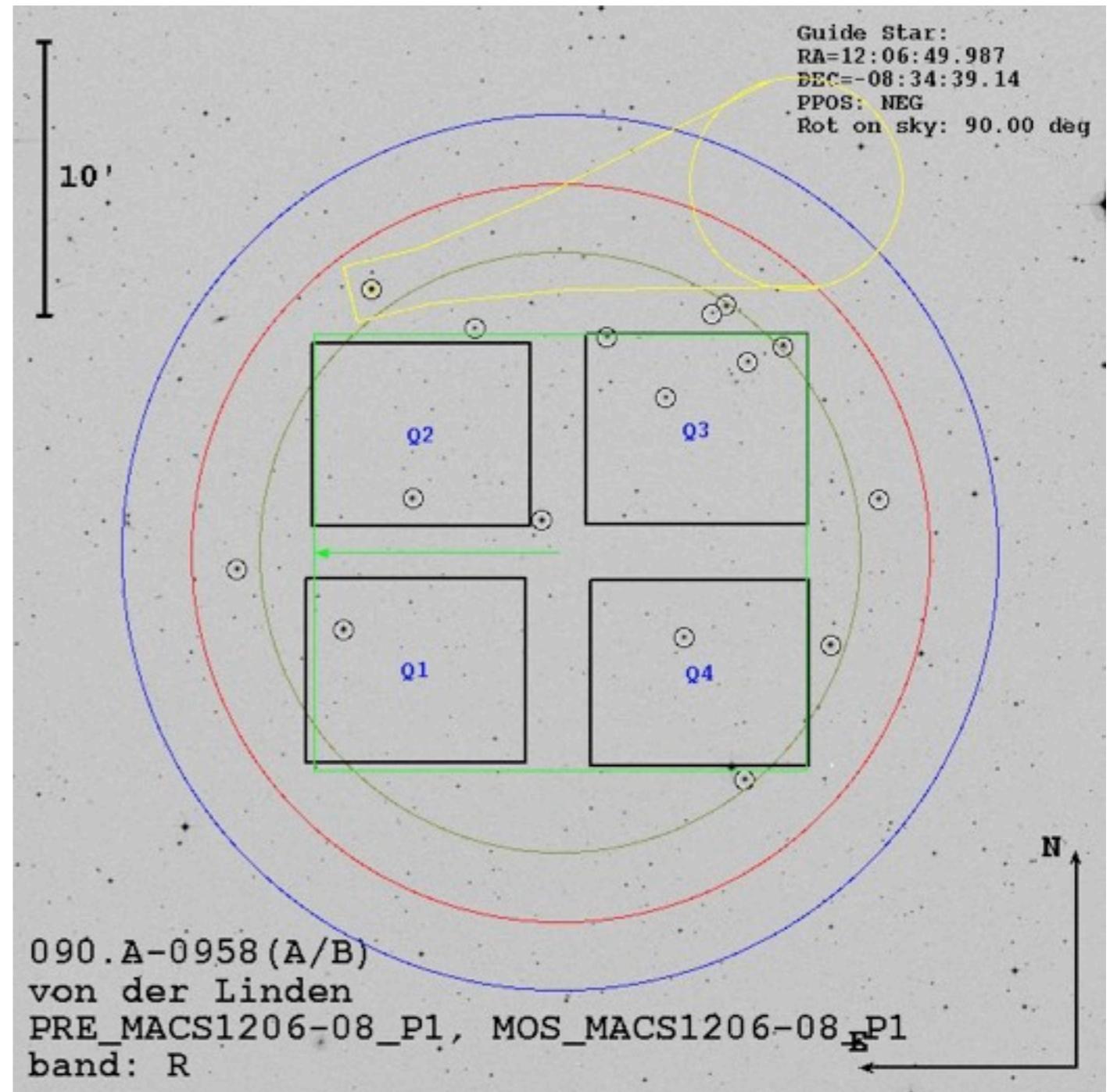
**asterisms:** easy-to-recognize star groupings  
**constellations:** officially defined sky regions, based on historical asterisms

# Sky maps in professional astronomy

**finding charts:** big telescopes usually look at small sky regions; need to make sure you're looking at the right object!

include:

- scale
- direction
- identifiers / target
- instrument-specific features: field of view, guide star



# Astronomical coordinate systems

# Horizontal (or “Alt/Az”) Coordinate System

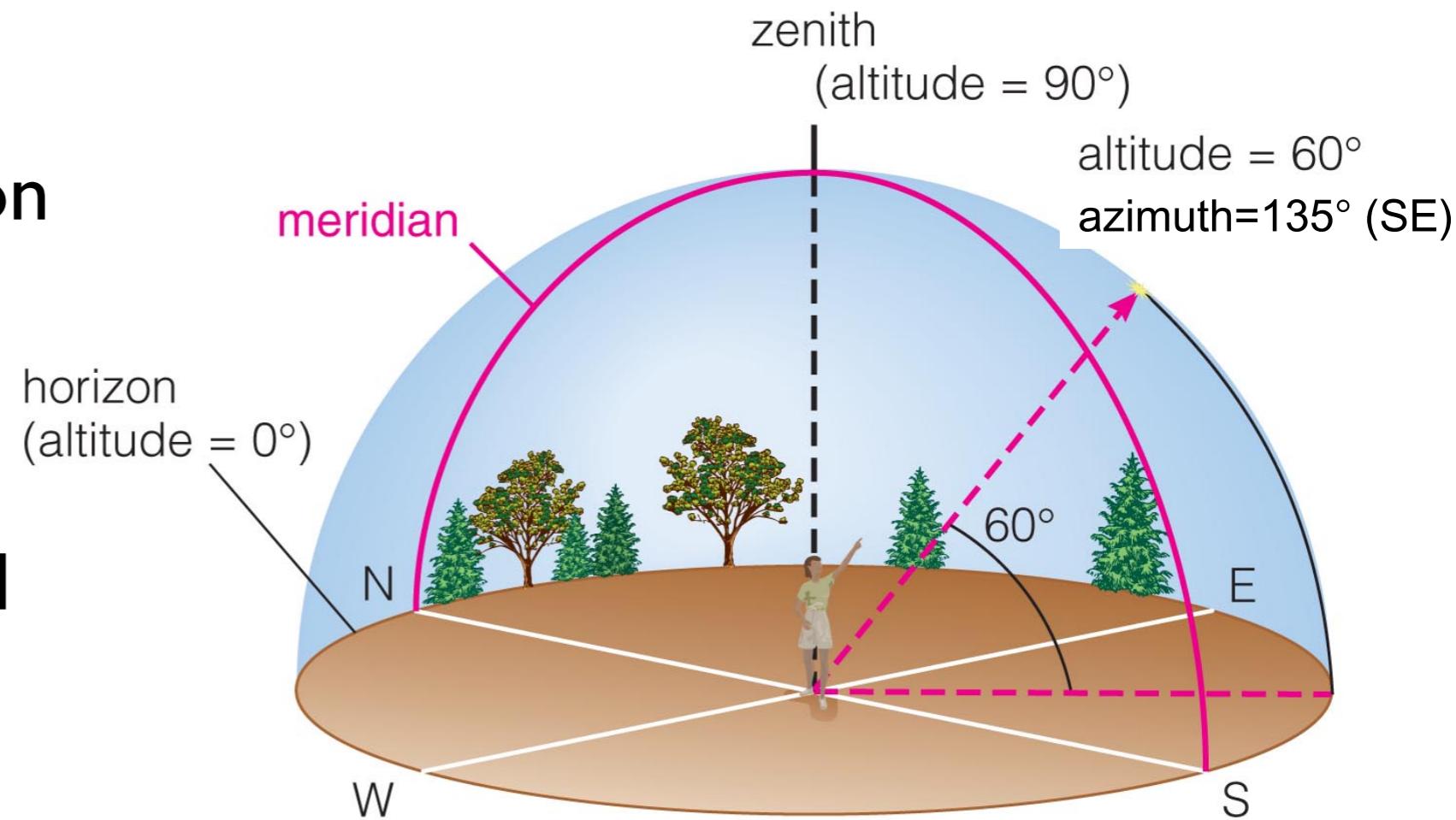
the sky above a specific location, at a specific time, is half a sphere - can be described with 2 (positive) angular coordinates

**altitude:** angular distance to the horizon

**azimuth:** angular distance from north

**zenith:** point overhead

**meridian:** north-south line

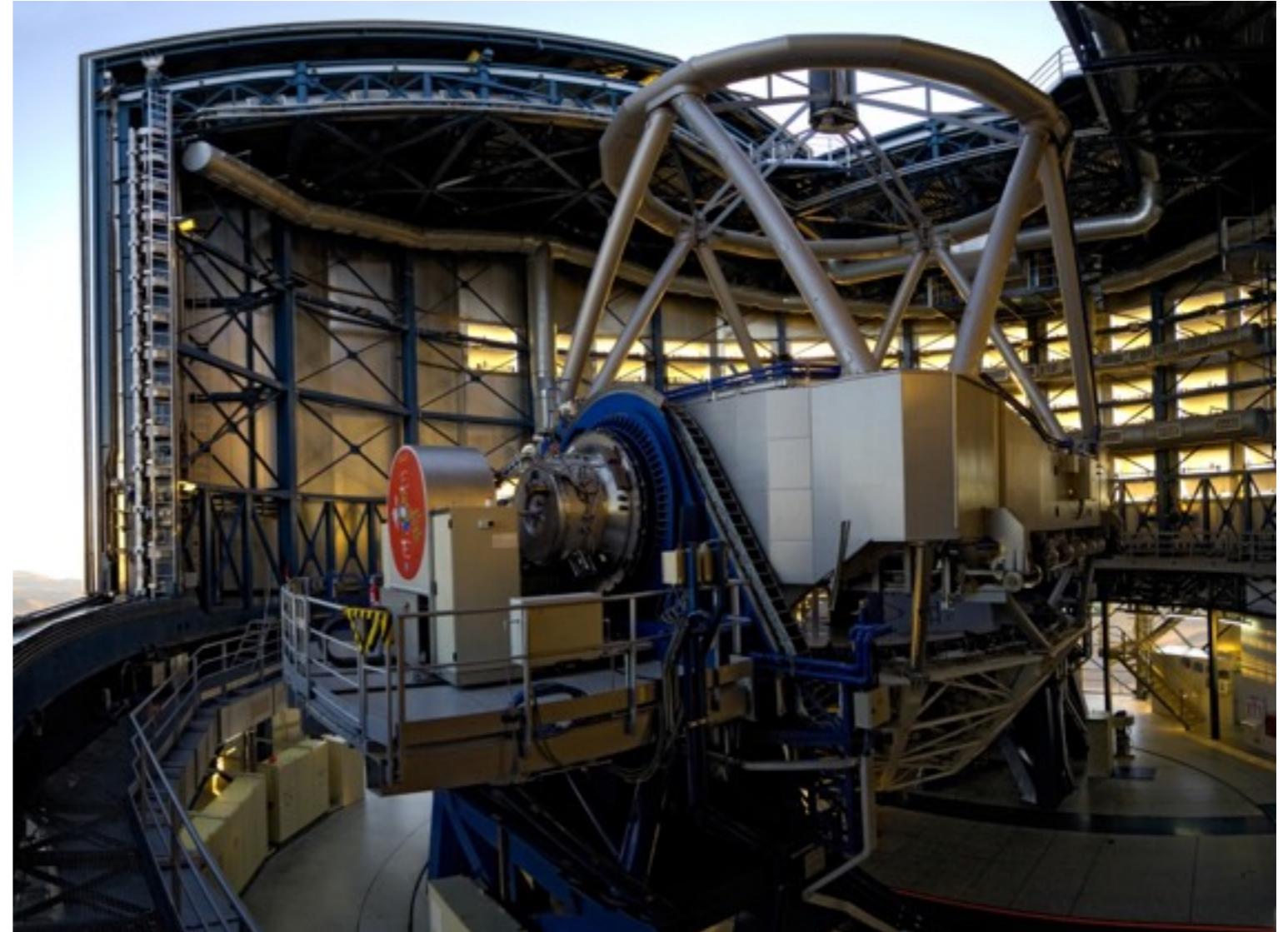


# Horizontal (or “Alt/Az”) Coordinate System

alt-az telescope mounts: simple, very stable



Dobsonian-style  
telescope (~8 inch)



Very Large Telescope (8 meters)

An Alt-Az telescope mount in action:

<http://sguisard.astrosurf.com/Anim-astro/P21-P22/P21-P22.html>

# Horizontal (or “Alt/Az”) Coordinate System

because of the rotation of the Earth: altitude and azimuth of a given object vary with time

in practice, we use “sky” coordinates to locate objects

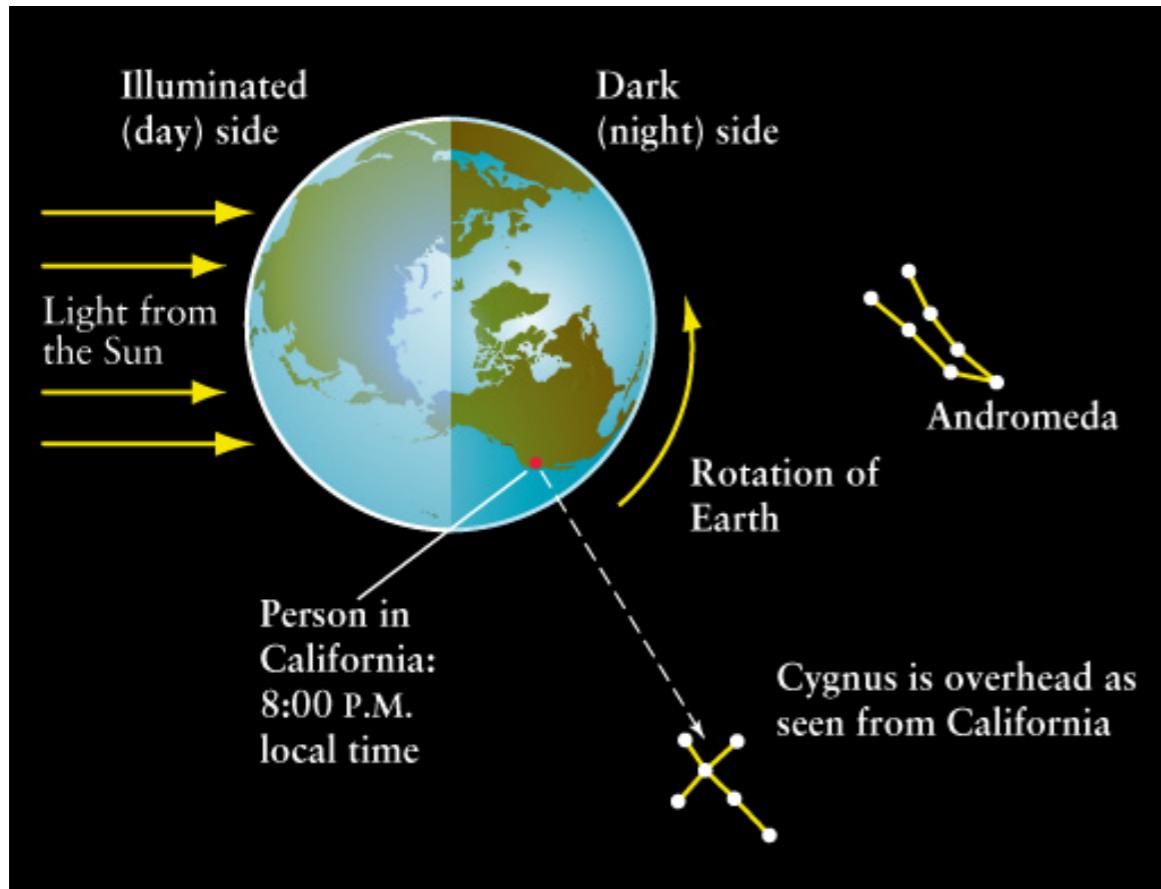
you need to (approximately) know the altitude and azimuth of your target independent of the telescope mount and how you plan to find the target

is my target “up” ? ( $\text{altitude} > 0^\circ$ )

is my target “observable” ? ( $\text{altitude} > 30^\circ / 40^\circ / 50^\circ$ )

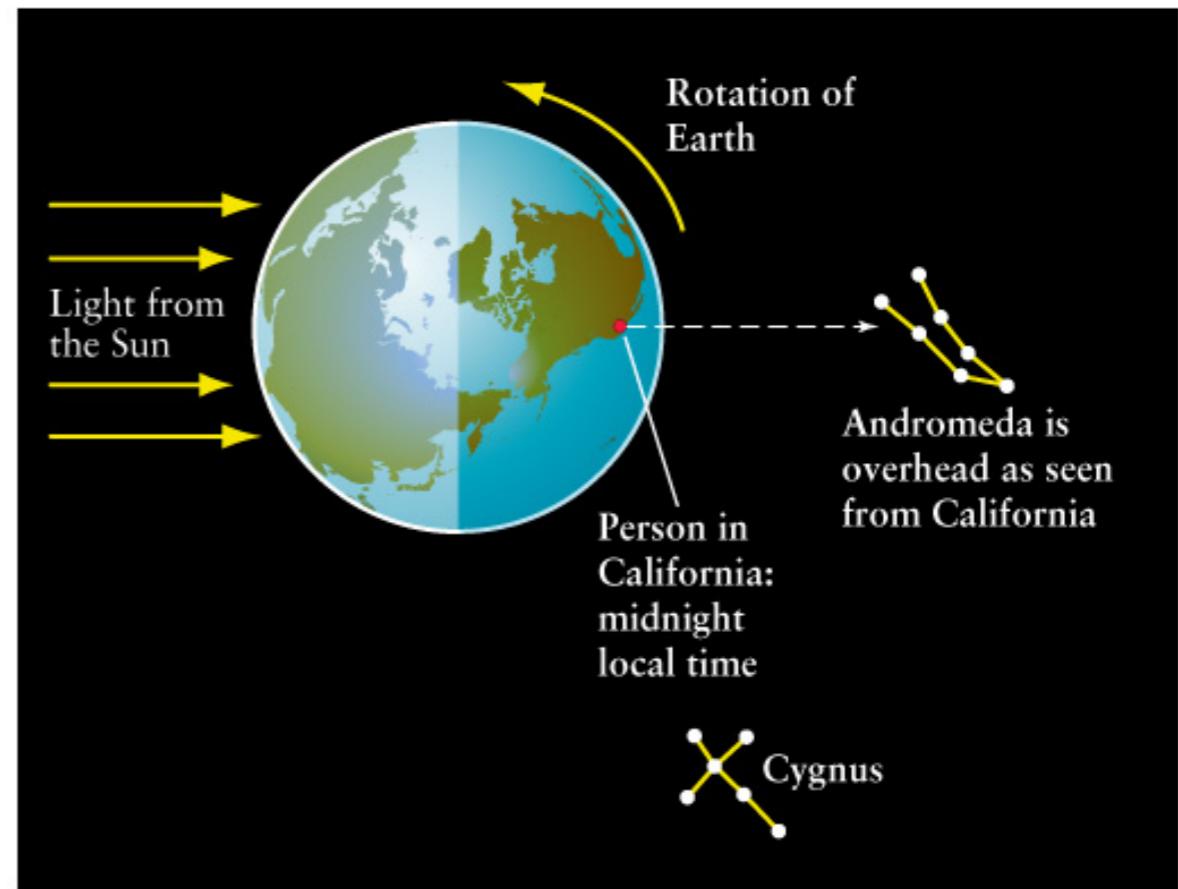
# Rotation of the Earth

looking down on the north pole, Earth rotates counter-clockwise



(a) Earth as seen from above the north pole

Andromeda is to the East;  
Cygnus is overhead

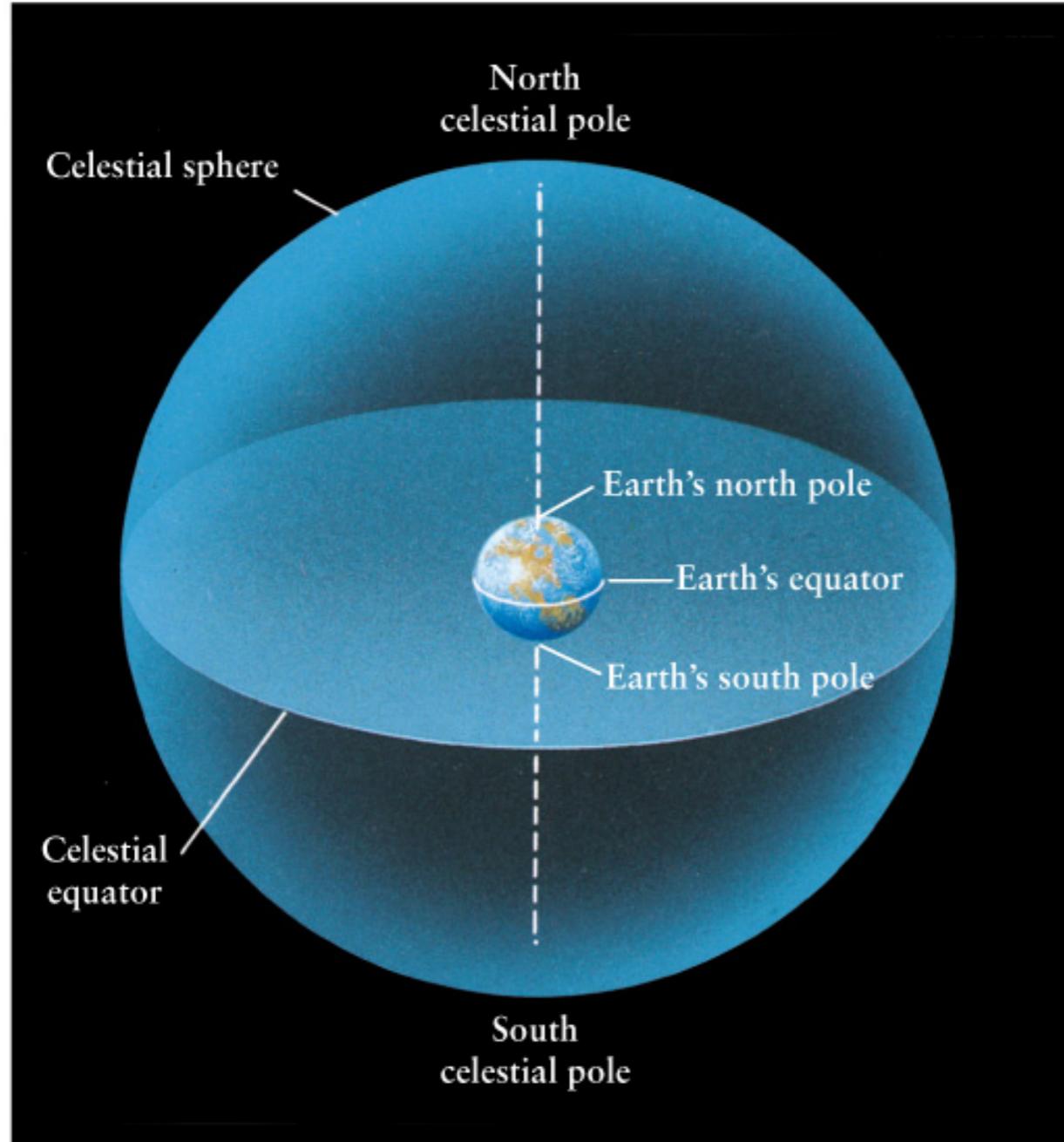


(b) 4 hours (one-sixth of a complete rotation) later

4 hrs later: Andromeda is  
overhead; Cygnus is to the West

the Sky appears to rotate East to West

# Celestial Sphere

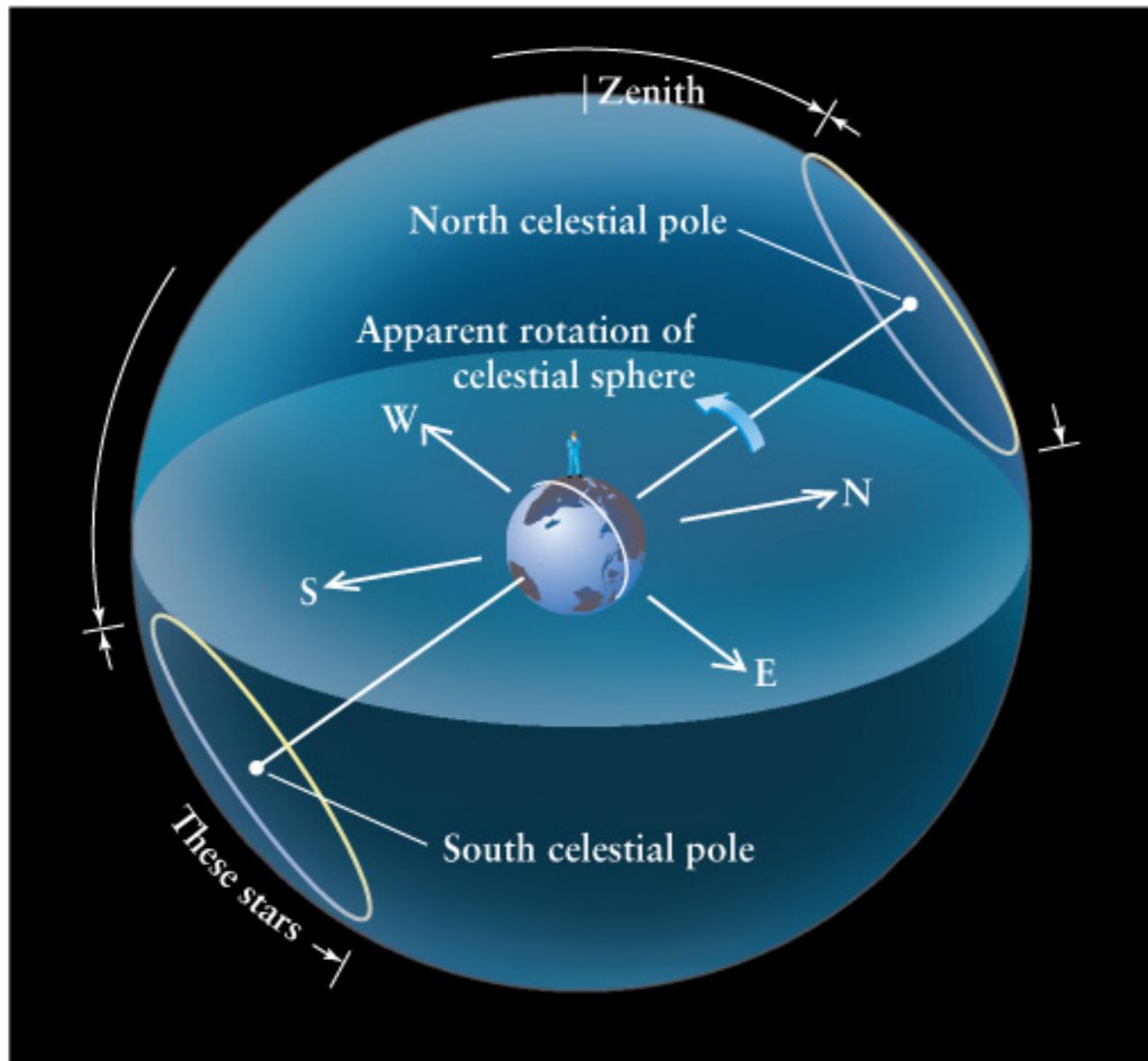


celestial sphere: describe objects by their position on a sphere centered on us

**celestial north / south pole:** projection of Earth's north / south pole

**celestial equator:** projection of Earth's equator

# Apparent motion in the Sky

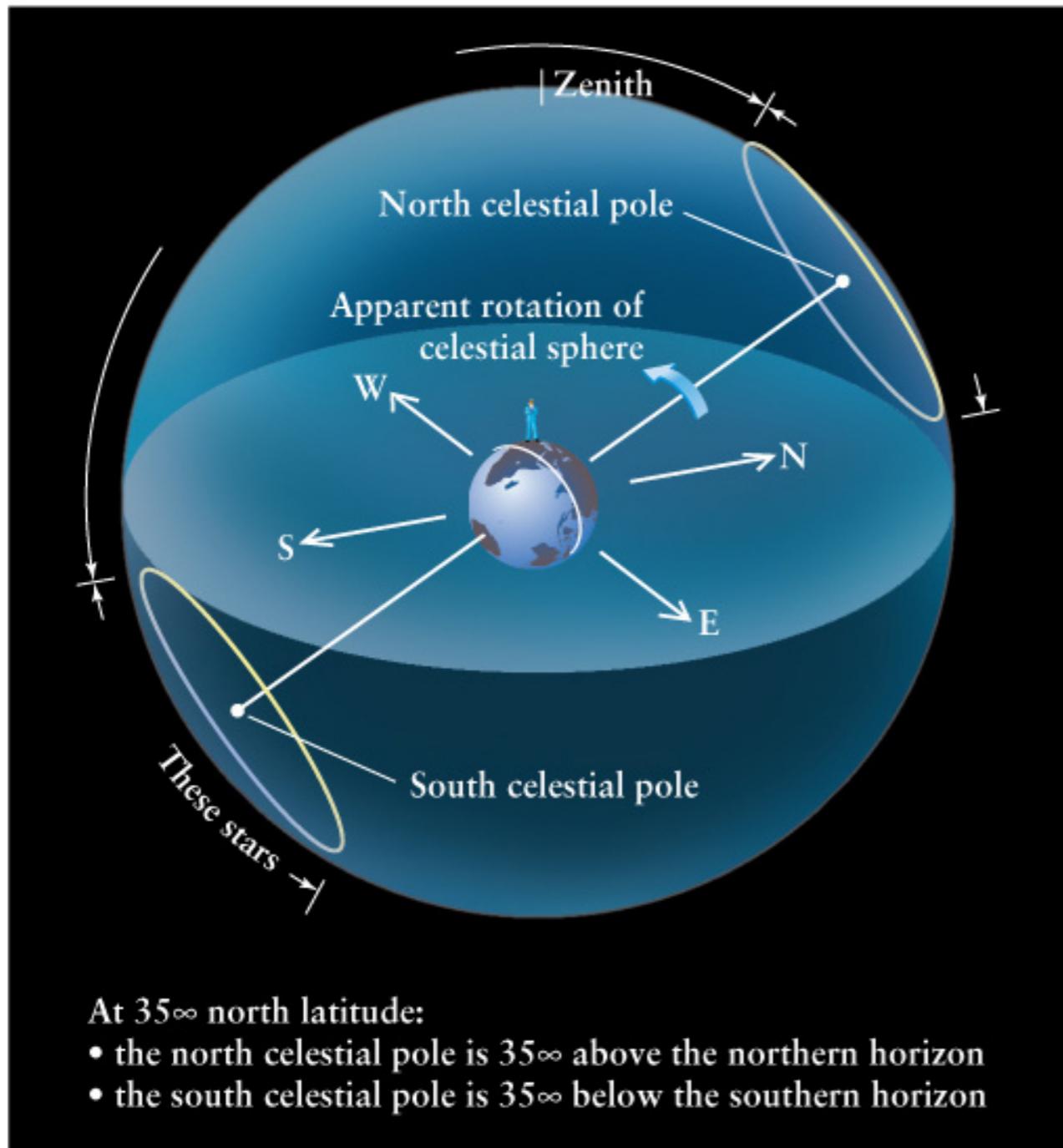


apparent sky motion depends on latitude of observer

e.g. SB is  $41^\circ$  north:

North Pole is at what altitude?

# Apparent motion in the Sky



apparent sky motion depends  
on latitude of observer

e.g. SB is 41° north:

North Pole is at 41° altitude

objects within 41° of NP are  
always “up” - “circumpolar”

can never see objects within  
41° of South Pole

all other objects rise in the  
East, set in the West



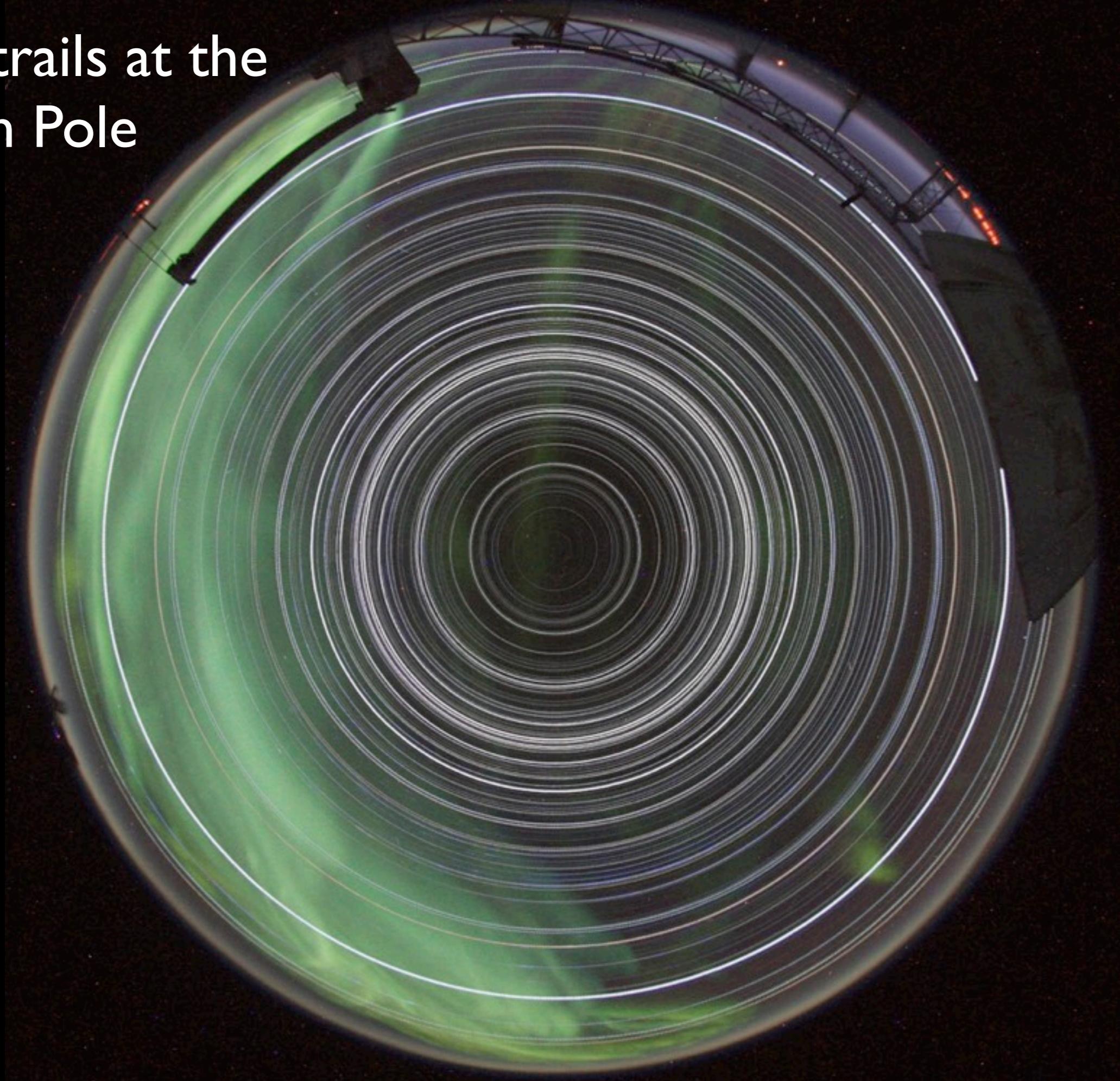
Star trails over CTIO, (c) Jose Delgado

# Star trails at the equator



© Stéphane Guisard

# Star trails at the South Pole

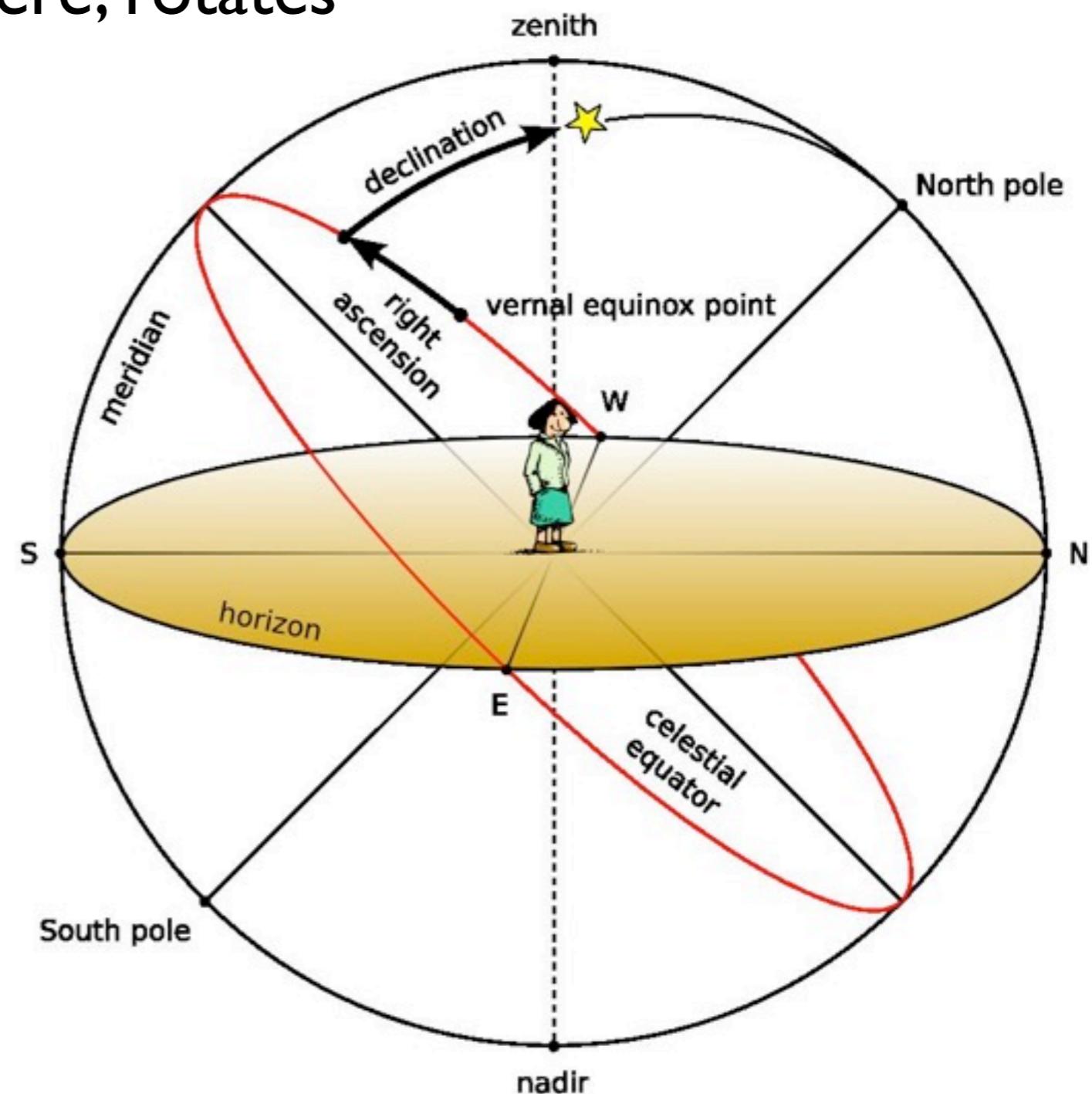


# Equatorial (RA/Dec) Coordinate System

“fixed” to the celestial sphere, rotates with the sky

**declination  $\delta$ :** angular distance from the celestial equator

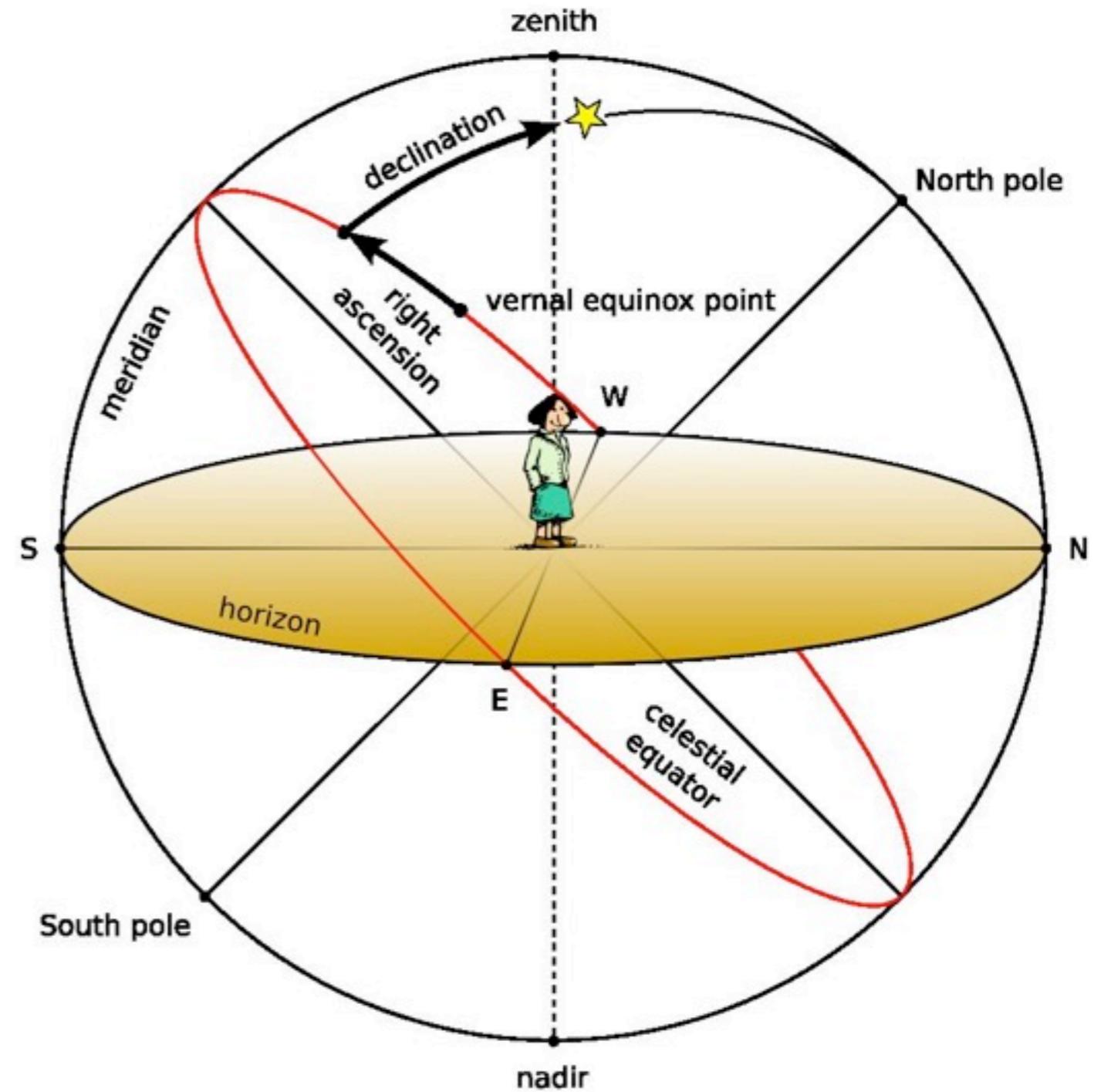
**right ascension  $\alpha$ :** angular distance from vernal equinox (later; special point on equator)



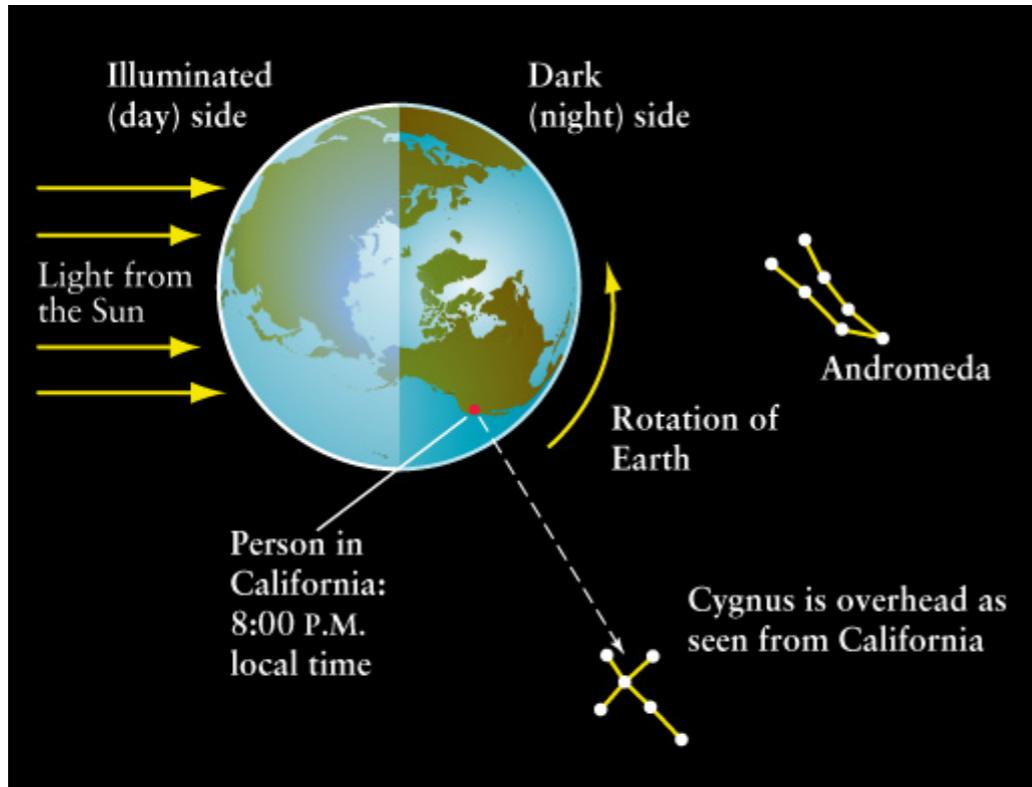
# Equatorial (RA/Dec) Coordinate System

**declination  $\delta$ :** measured in degrees,  $-90^\circ \leq \delta \leq 90^\circ$  (like latitude)

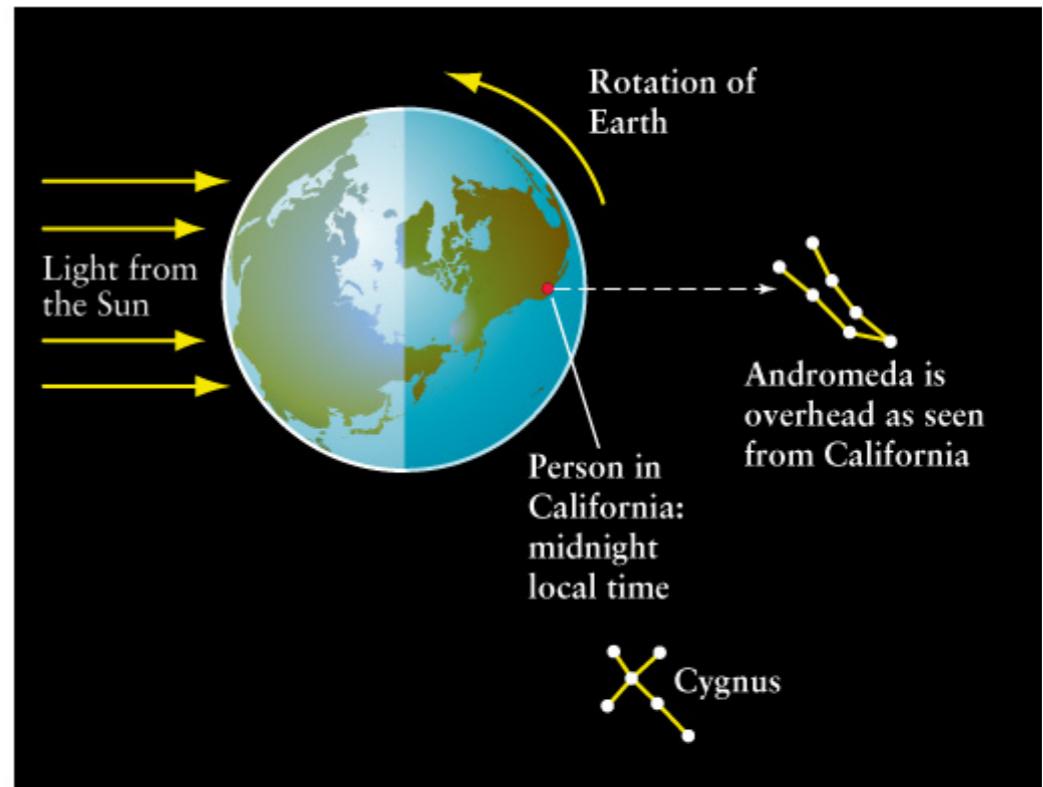
**right ascension  $\alpha$ :** can also be measured in degrees ( $0^\circ \leq \alpha < 360^\circ$ ), however:



# Right ascension (RA)



(a) Earth as seen from above the north pole



(b) 4 hours (one-sixth of a complete rotation) later

a “natural” way to define right ascension is in units of time:

“distance” between two points is given by the time interval between each of them passes the meridian

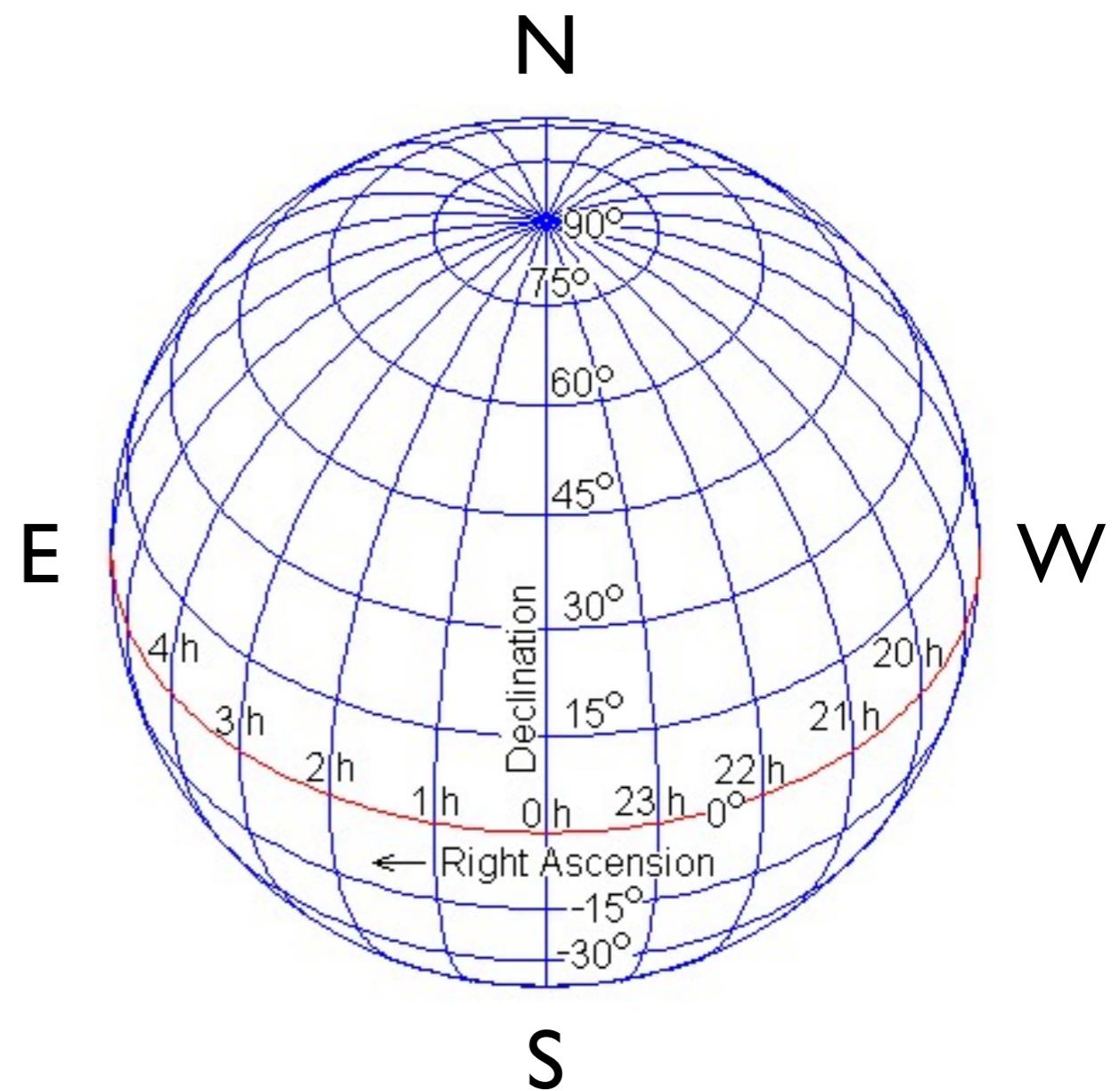
e.g.: reference point (0h) culminates (passes meridian) at midnight; all points that culminate 4 (star)-hours later have  $\alpha = 4\text{h}$

# Right ascension (RA) + Local Sidereal Time (LST)

sky rotates East to West;  
East is “left”

R.A. runs from right to left  
in astronomical maps!

**local sidereal time (LST):** RA  
of the objects currently  
culminating (on meridian)



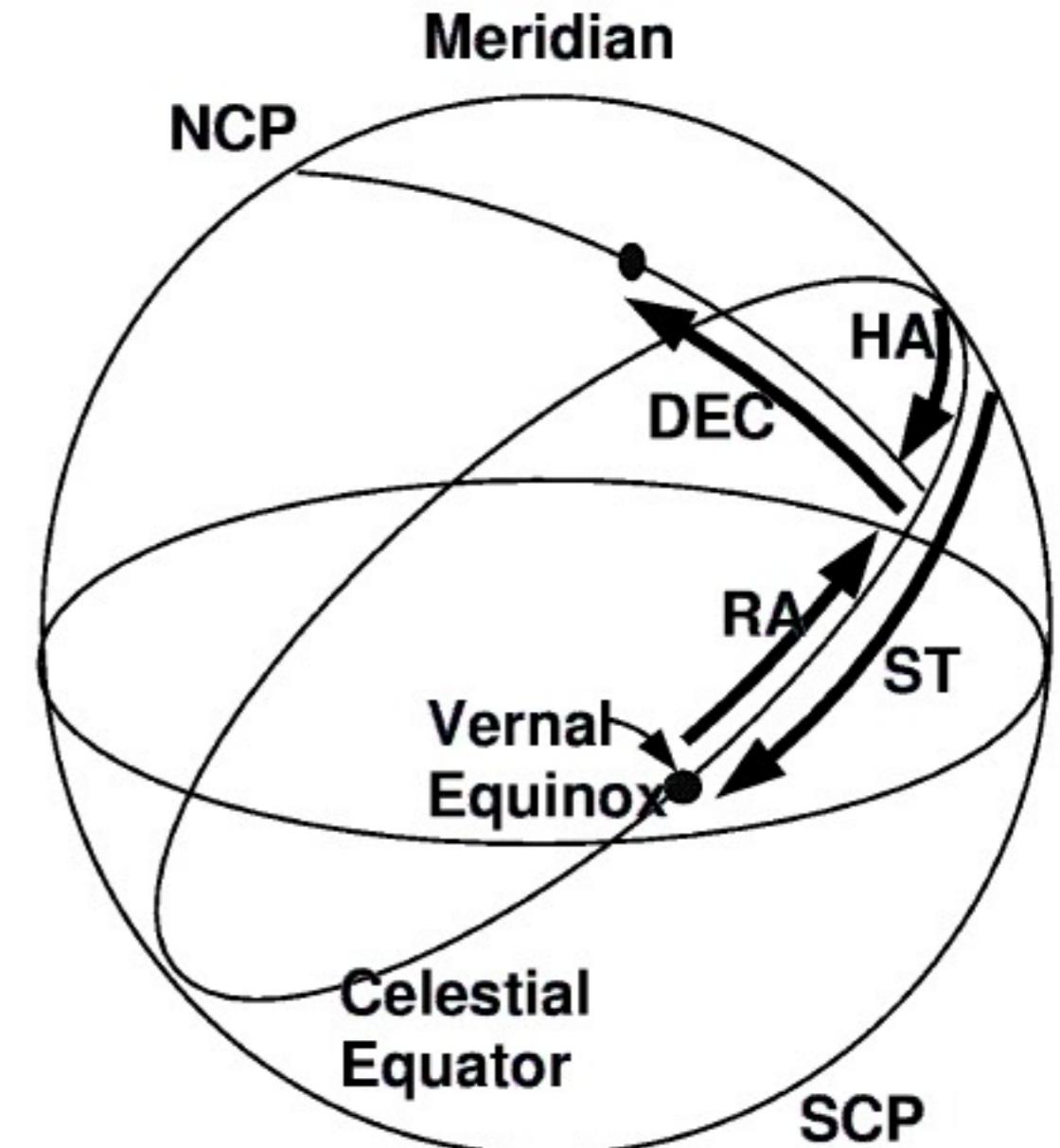
# RA, LST, and Hour Angle

hour angle (HA): time that has passed since object culminated

$$HA = LST - \alpha_{\text{object}}$$

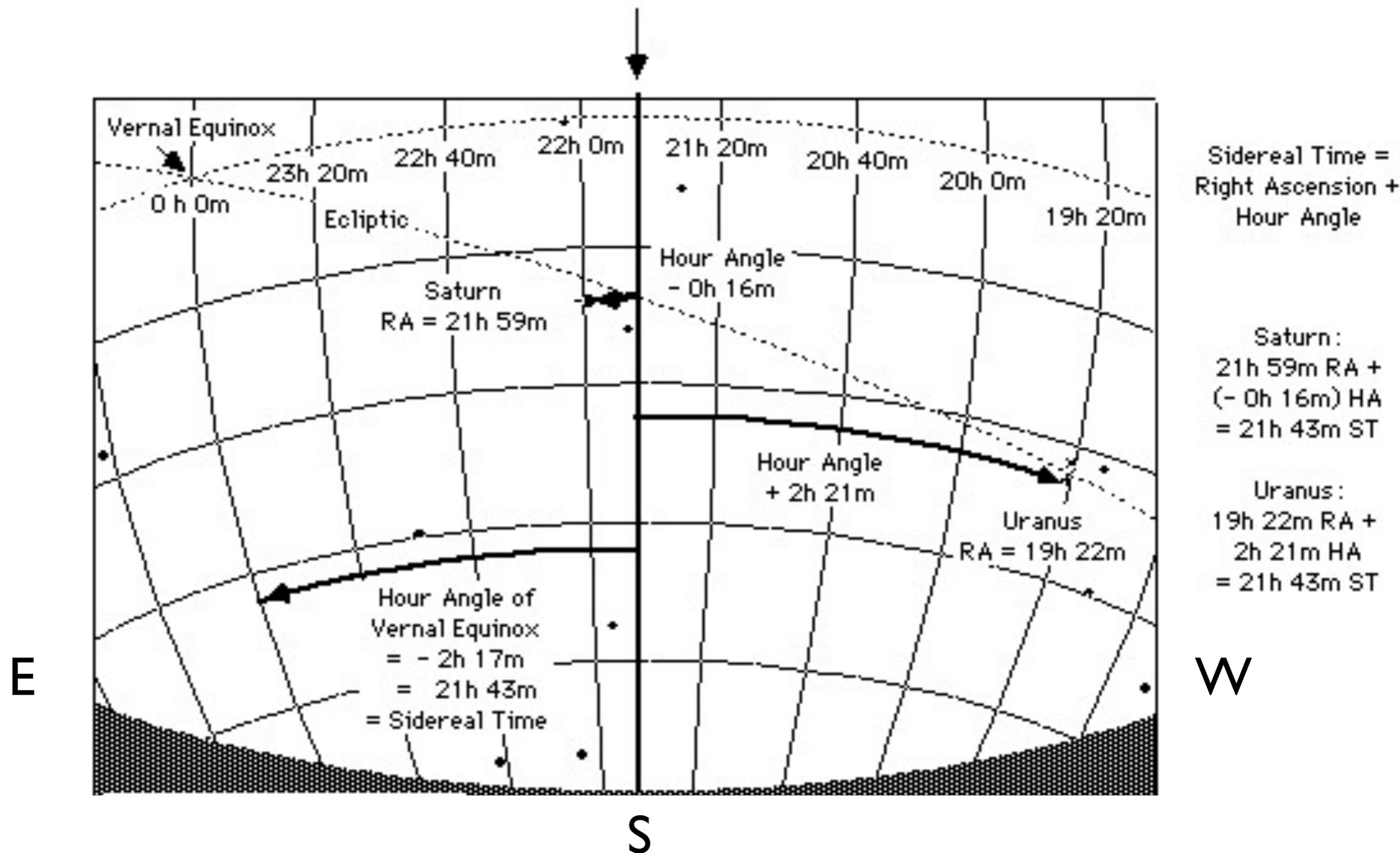
HA > 0h: object has already culminated, it is “setting” and in the western half of the sky

HA < 0h: object is rising, is in the eastern half of the sky, will culminate in  $|HA|$  hours



# Example

Sidereal Time  
= Right Ascension on Meridian  
= 21 hrs 43 min



# Equatorial telescope mounts

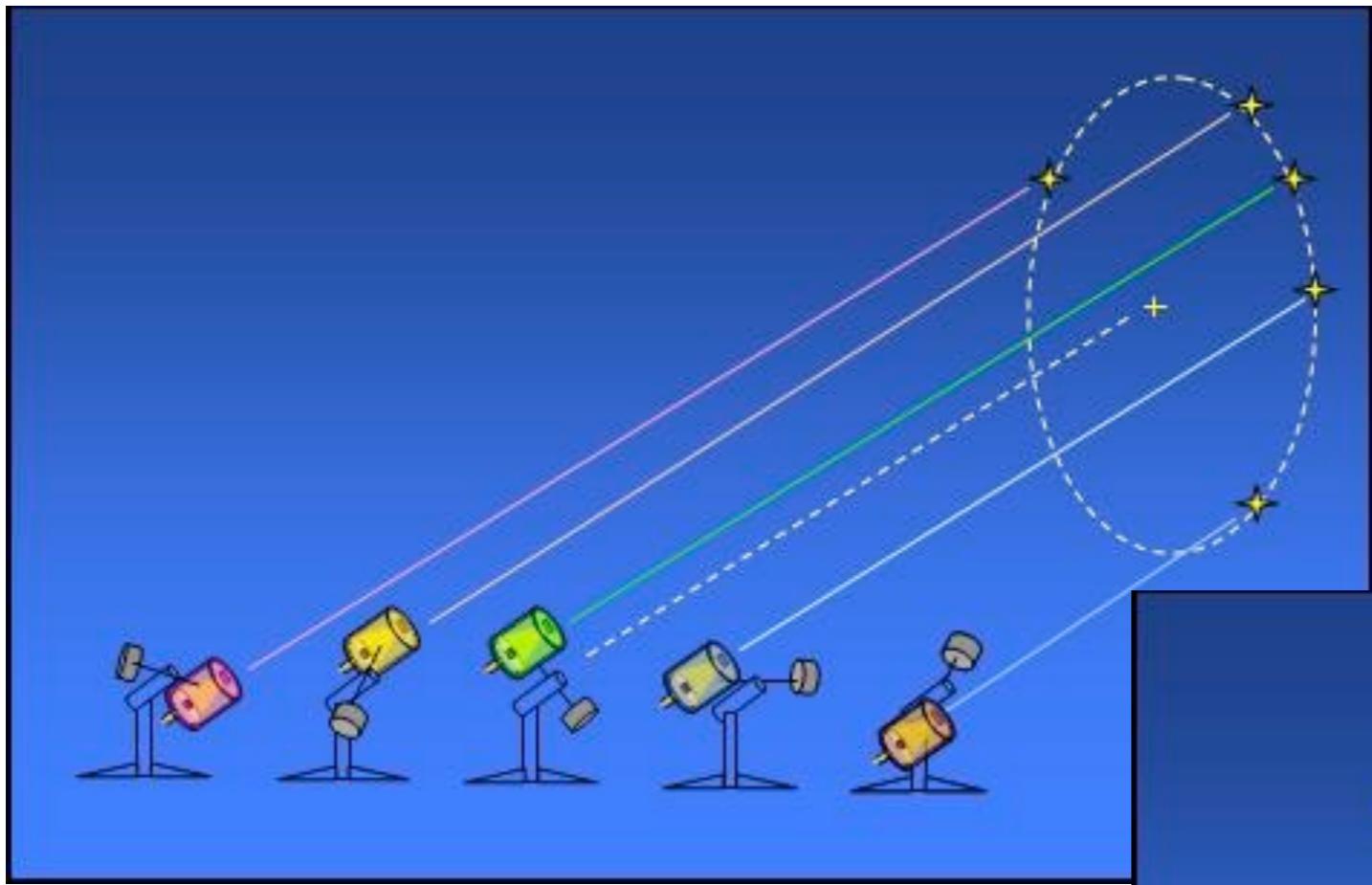
Alt/az mounts: need to track object in two axis, with variable speed

equatorial mount: one axis is parallel to Earth's rotation axis → need to track only in this axis, with constant speed

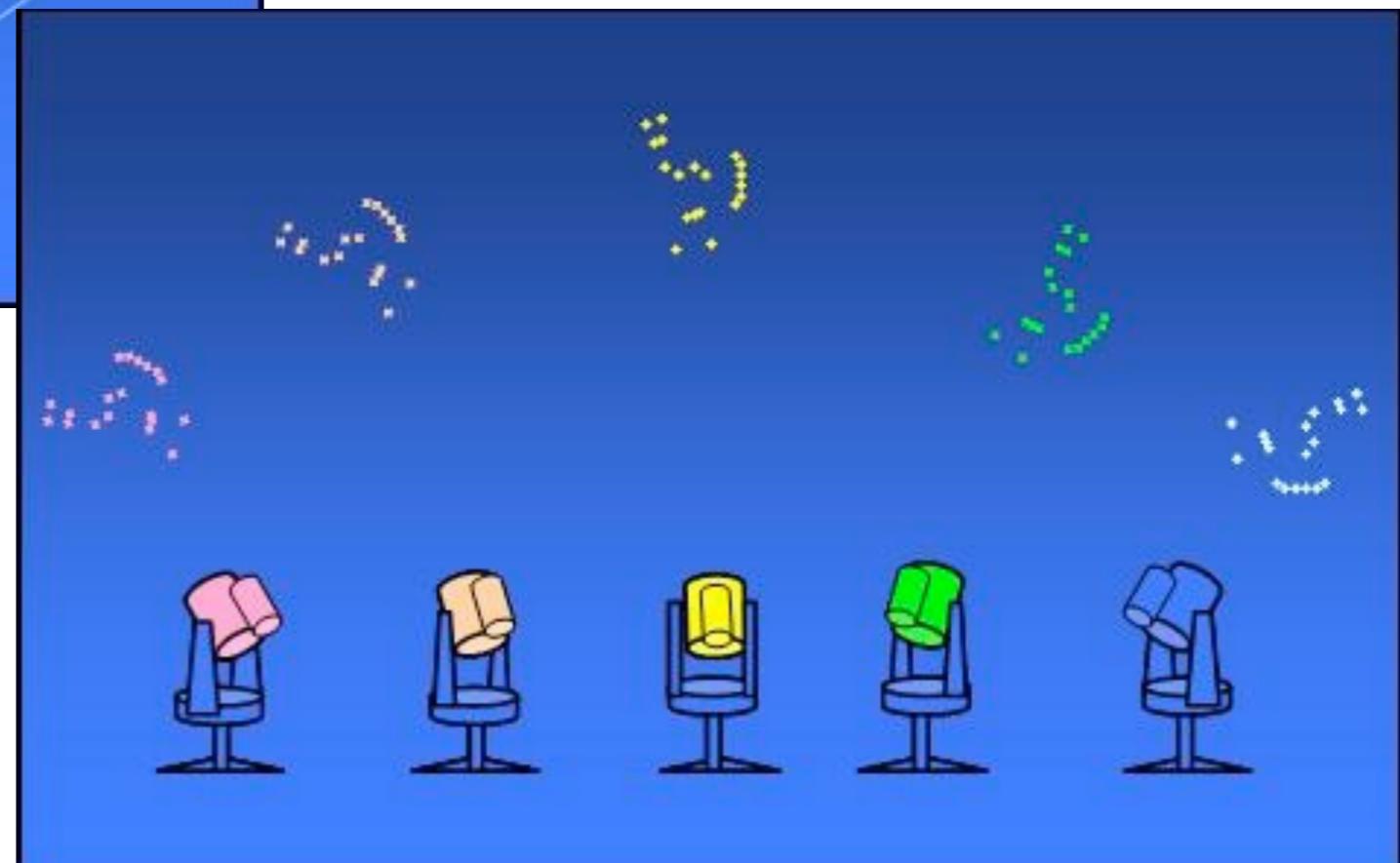


# Equatorial telescope mounts

removes the need for a **field de-rotator**



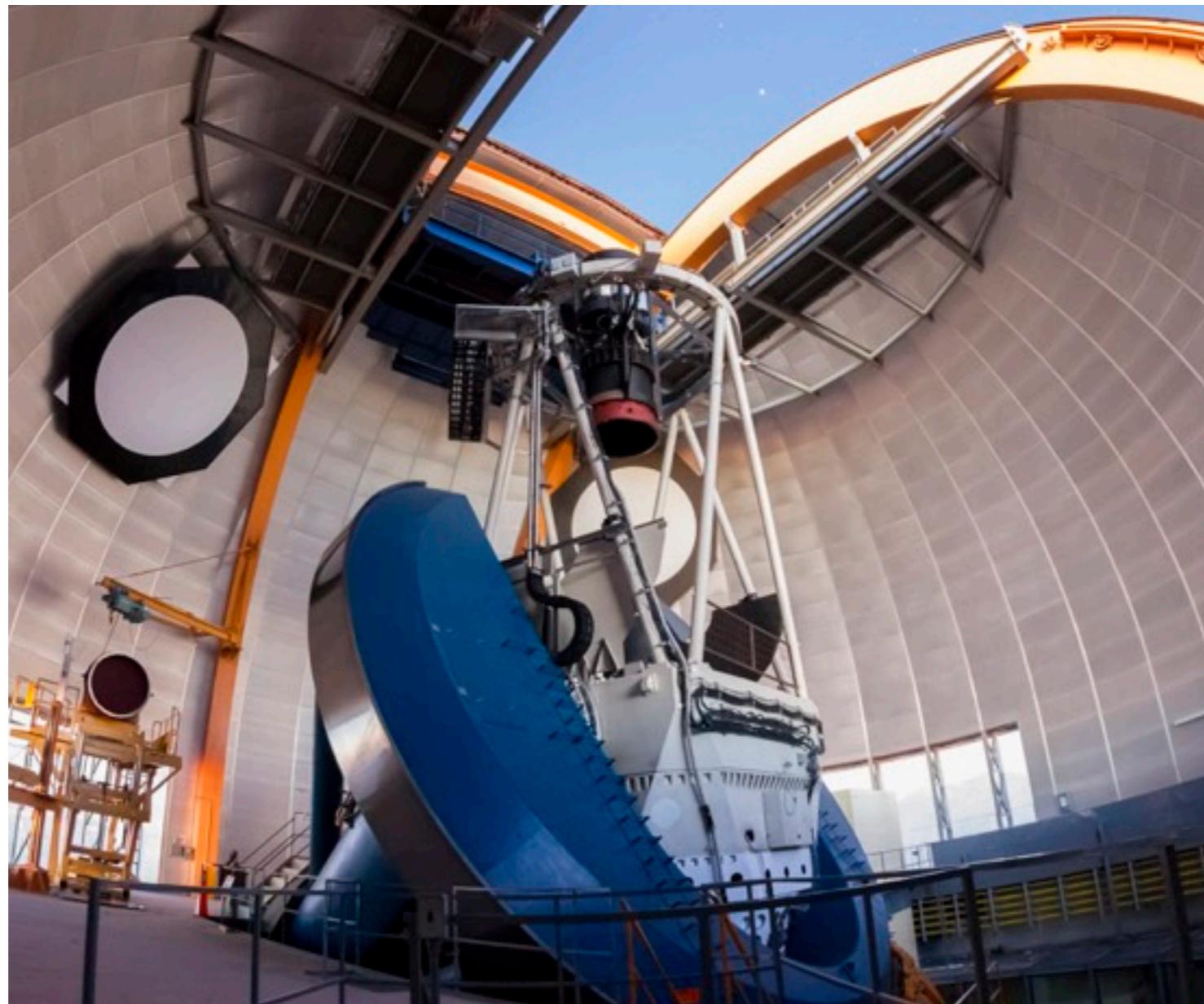
equ. mount



alt/az mount

# Equatorial telescope mounts

not feasible for the largest telescopes  
found on some intermediate-class telescopes, e.g. 4m  
telescope on Kitt Peak and Cerro Tololo





# R.A. and Dec - format

both can be expressed as degrees:

$$0^\circ \leq \alpha < 360^\circ$$
$$-90^\circ \leq \delta \leq +90^\circ$$

e.g. M31:  $10.6847^\circ, +41.26875^\circ$

often expressed in sexagesimal system:

$00^{\text{h}}42^{\text{m}}44.33^{\text{s}}, +41^\circ16'07.5''$

$00:42:44.33, +41:16:07.5$

note:  $24^{\text{h}} = 360^\circ$

$1^{\text{h}} = 15^\circ$

$1^{\text{m}} = 15^\circ/60 = 0.25^\circ = 15'$

$1^{\text{s}} = 15^\circ/3600 = 0.25' = 15''$

# Looking up coordinates / information

SIMBAD astronomical database:

<http://simbad.u-strasbg.fr/simbad/>

simbad.u-strasbg.fr/simbad/sim-basic?Ident=AR+Sco&submit=SIMBAD+search

CDSSIMBAD

AR Sco

**other query modes :** Identifier query Coordinate query Criteria query Reference query Basic query Script submission TAP Output options Help

Query : AR Sco C.D.S. - SIMBAD4 rel 1.5.8 - 2016.08.31CEST02:44:42

**Available data :** Basic data • Identifiers • Plot & images • Bibliography • Measurements • External archives • Notes • Annotations

**Basic data :**

**V\* AR Sco -- Variable Star of delta Sct type**

Other object types: V\* (V\*,AN), IR (2MASS,SSTc2d), dS\* ([Ref](#))

**ICRS coord. (ep=J2000) :** 16 21 47.28 -22 53 10.3 (Infrared) [ 60 60 90 ] B [2003yCat.2246....OC](#)

**FK5 coord. (ep=J2000 eq=2000) :** 16 21 47.28 -22 53 10.3 [ 60 60 90 ]

**FK4 coord. (ep=B1950 eq=1950) :** 16 18 47.99 -22 46 07.8 [ 60 60 90 ]

**Gal coord. (ep=J2000) :** 353.5192 +18.7121 [ 60 60 90 ]

**Fluxes (4) :**

B	14.1	[~]	V2	E	<a href="#">2003AstL...29..468B</a>
J	12.696	[0.027]	C	<a href="#">2003yCat.2246....OC</a>	
H	12.080	[0.024]	C	<a href="#">2003yCat.2246....OC</a>	
K	11.715	[0.024]	C	<a href="#">2003yCat.2246....OC</a>	

SIMBAD [query around](#) with radius 2 arcmin

Interactive AladinLite view  
16 21 46.569 -22 54 0.48  
FoV: 1.99'  
2MASS DSS SDSS

# Looking up coordinates / information

## NASA/IPAC Extragalactic Database (NED)

<https://ned.ipac.caltech.edu/>

NED results for object MESSIER 031

1 objects found in NED.

SOURCE LIST

Row No.	Object Name (* => Essential Note)	EquJ2000.0 RA	Object DEC	Velocity/Redshift km/s	Mag./z	Separ. Qual Filter arcmin	Number of Refs Notes Phot Posn Vel/z Diam Assoc Images Spectra
1	MESSIER 031	00h42m44.3s	+41d16m09s	G -300 -0.001001	4.36	...	<a href="#">4055</a> <a href="#">23</a> <a href="#">147</a> <a href="#">20</a> <a href="#">31</a> <a href="#">7</a> <a href="#">2</a> <a href="#">Retrieve</a> <a href="#">Retrieve</a>

Detailed information for each object

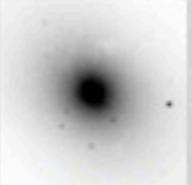
Object No. 1 - MESSIER 031

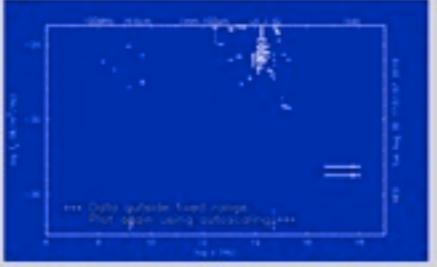
INDEX for MESSIER 031

Essential Data (jump to sub-section of this query report):

- [Essential Note](#)
- [Cross-IDs](#)
- [Coordinates](#)
- [Basic Data](#)
- [Quantities Derived from Redshift](#)
- [Redshift-Independent Distances](#)
- [Quick-Look Photometry and Luminosities](#)
- [Quick-Look Angular and Physical Sizes](#)
- [Classifications](#)
- [Foreground Galactic Extinction](#)
- [External Services](#)

Detailed Data (NED queries):

 [Images](#)

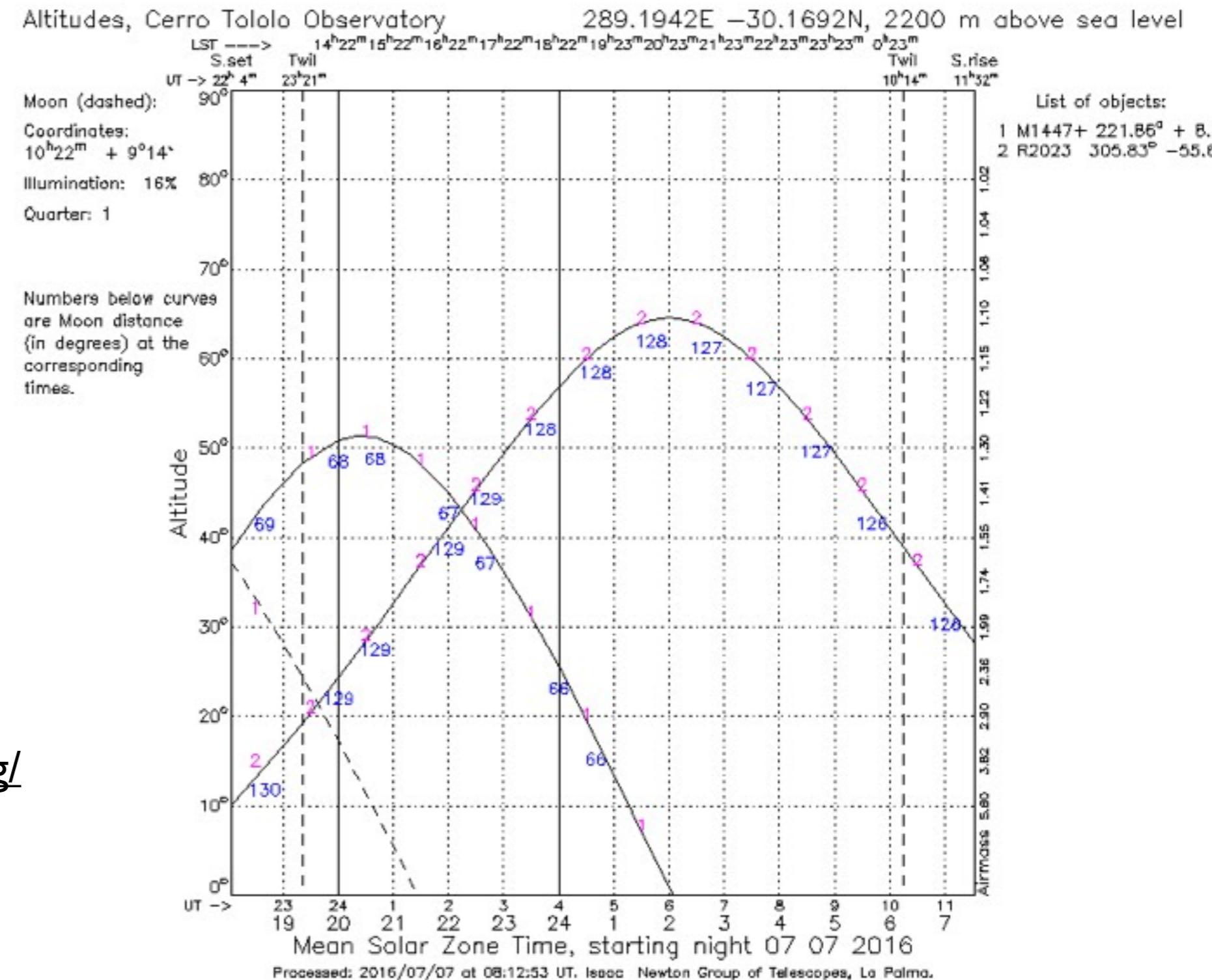
 [147 Photometric data point\(s\) and SED](#)

Spectra  
[Redshift-Independent Distances](#)  
[4055 Reference\(s\)](#)  
[20 Position data point\(s\)](#)  
[31 Redshift data point\(s\)](#)  
[7 Diameter data point\(s\)](#)  
[23 Note\(s\)](#)  
[2 Association\(s\)](#)  
[UGC data](#)  
[RC3 data](#)

# Object visibility tool

“StarAlt”: <http://catserver.ing.iac.es/staralt/>

given input catalog of object positions, plots their altitude vs. time (+ a few other features)

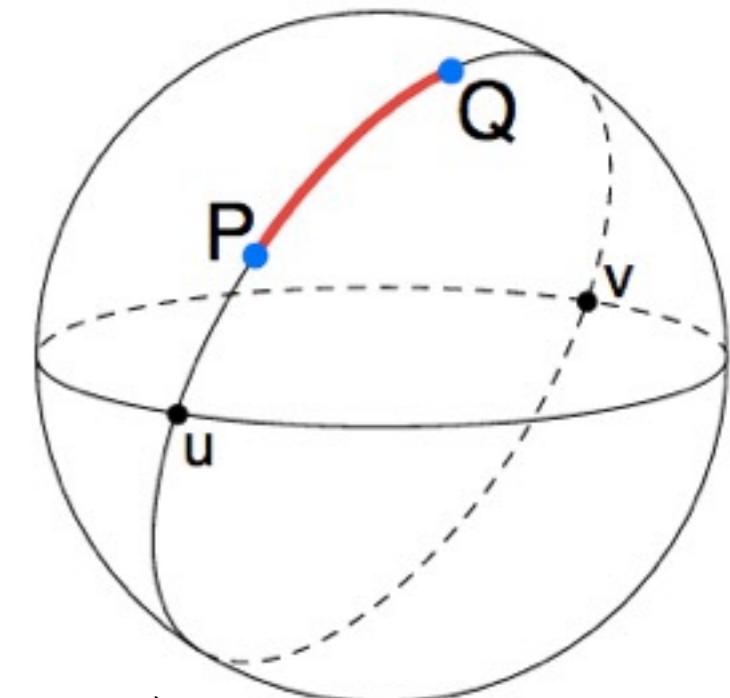


# Distance between two objects

two objects at  $(\alpha_1, \delta_1)$  and  $(\alpha_2, \delta_2)$  - how far apart are they?

- surface of a sphere is non-Euclidian
- e.g. sum of angles in a triangle is  $> 180^\circ$
- need to use spherical geometry

$$\cos(\gamma) = \cos(90^\circ - \delta_1) \cos(90^\circ - \delta_2) + \\ \sin(90^\circ - \delta_1) \sin(90^\circ - \delta_2) \cos(\alpha_1 - \alpha_2)$$

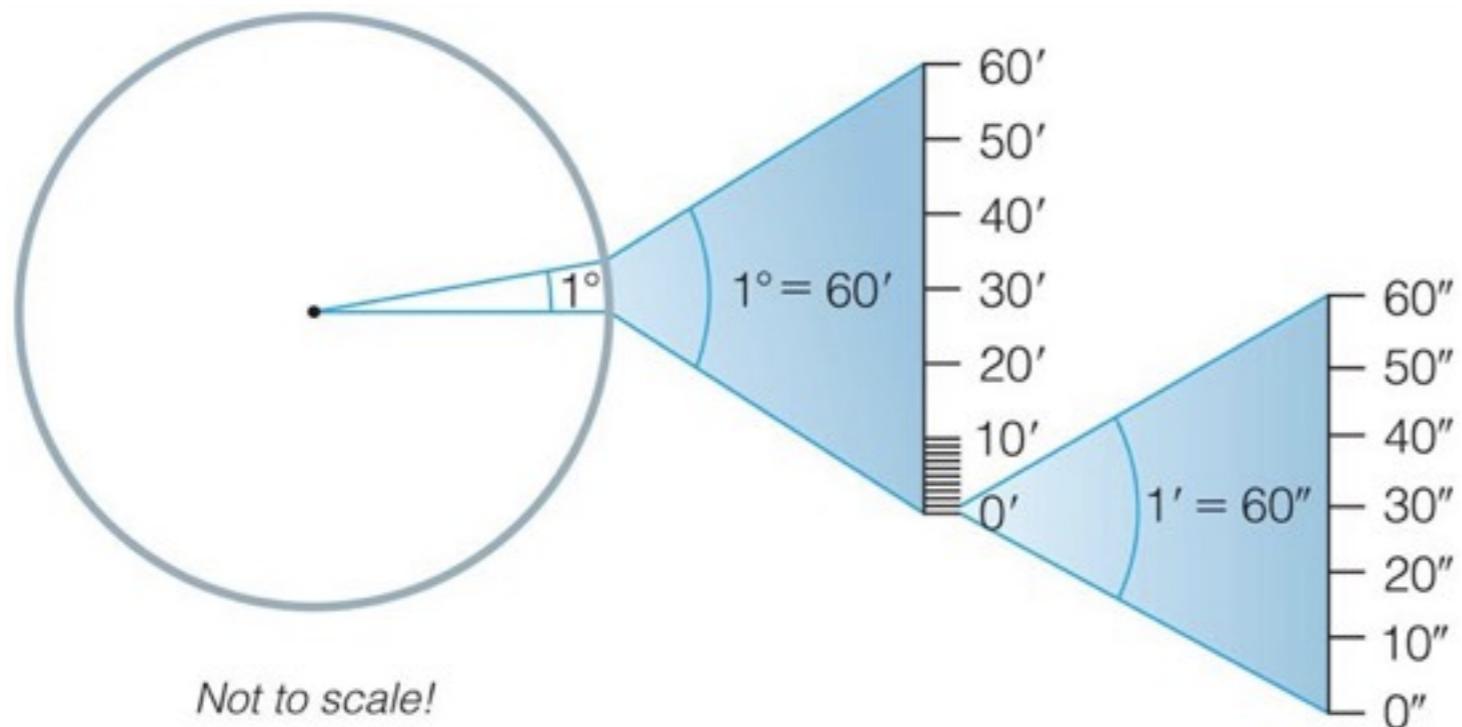


for small distances, can use Euclidian approximation;  
HOWEVER, need to include  $\cos(\delta)$

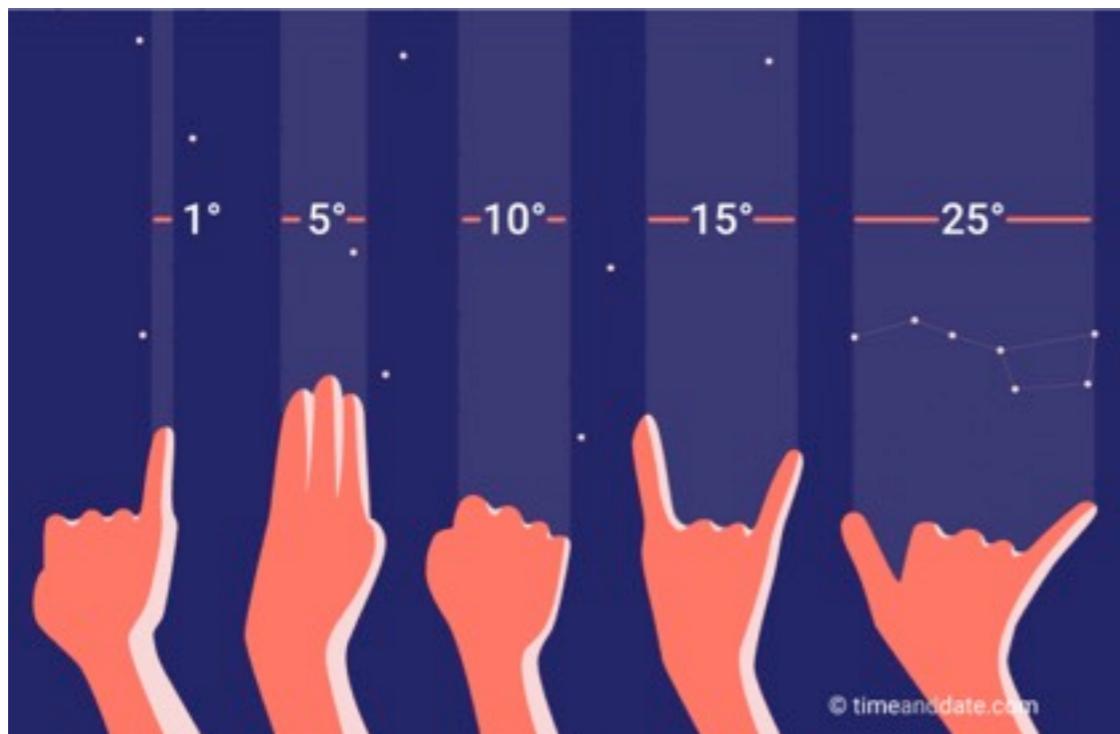
$$\gamma \simeq \sqrt{((\alpha_1 - \alpha_2) \cos(\delta_1))^2 + (\delta_1 - \delta_2)^2}$$

# Lengths and distances on the Sky

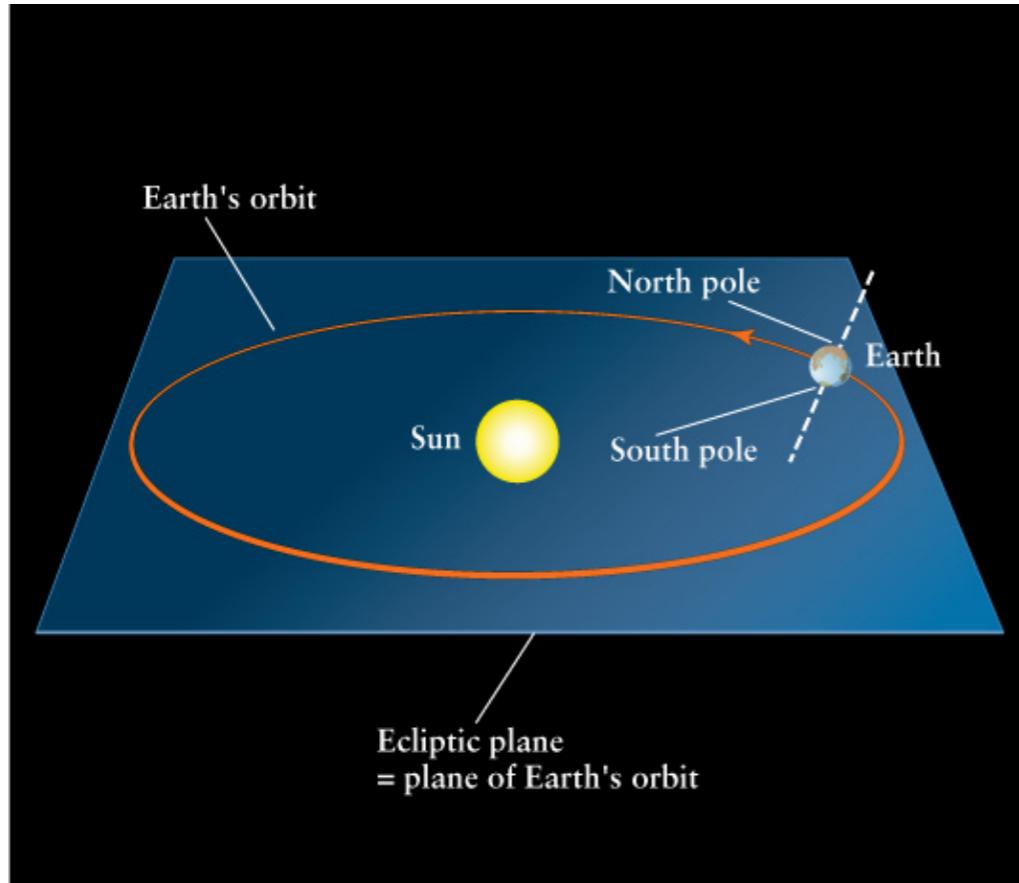
usually given in degrees ( $^{\circ}$ ), arcminutes ( $'$ ), arcseconds ( $''$ )



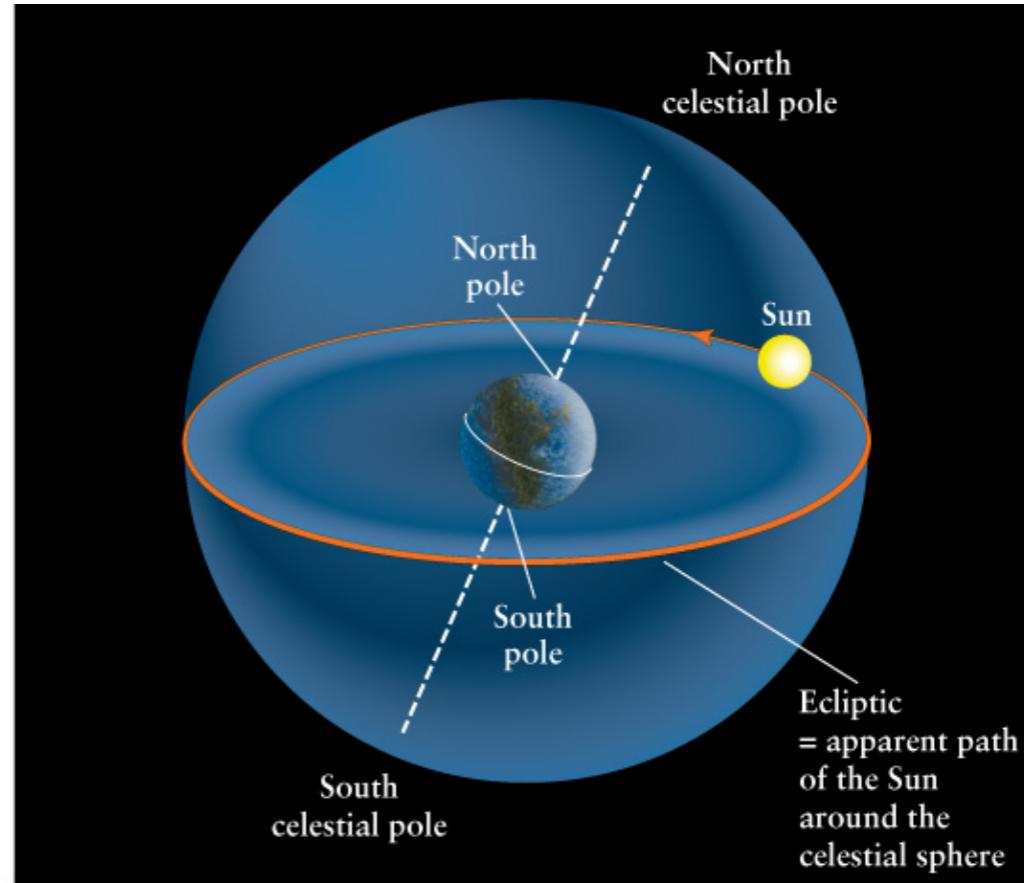
Moon: diameter is  
 $\sim 0.5^{\circ} = 30'$



# Motion of the Sun in the Sky



(a) In reality Earth orbits the Sun once a year



(b) It appears from Earth that the Sun travels around the celestial sphere once a year

Earth's motion around the Sun defines the **ecliptic plane**

its projection onto the Celestial Sphere is the **ecliptic**

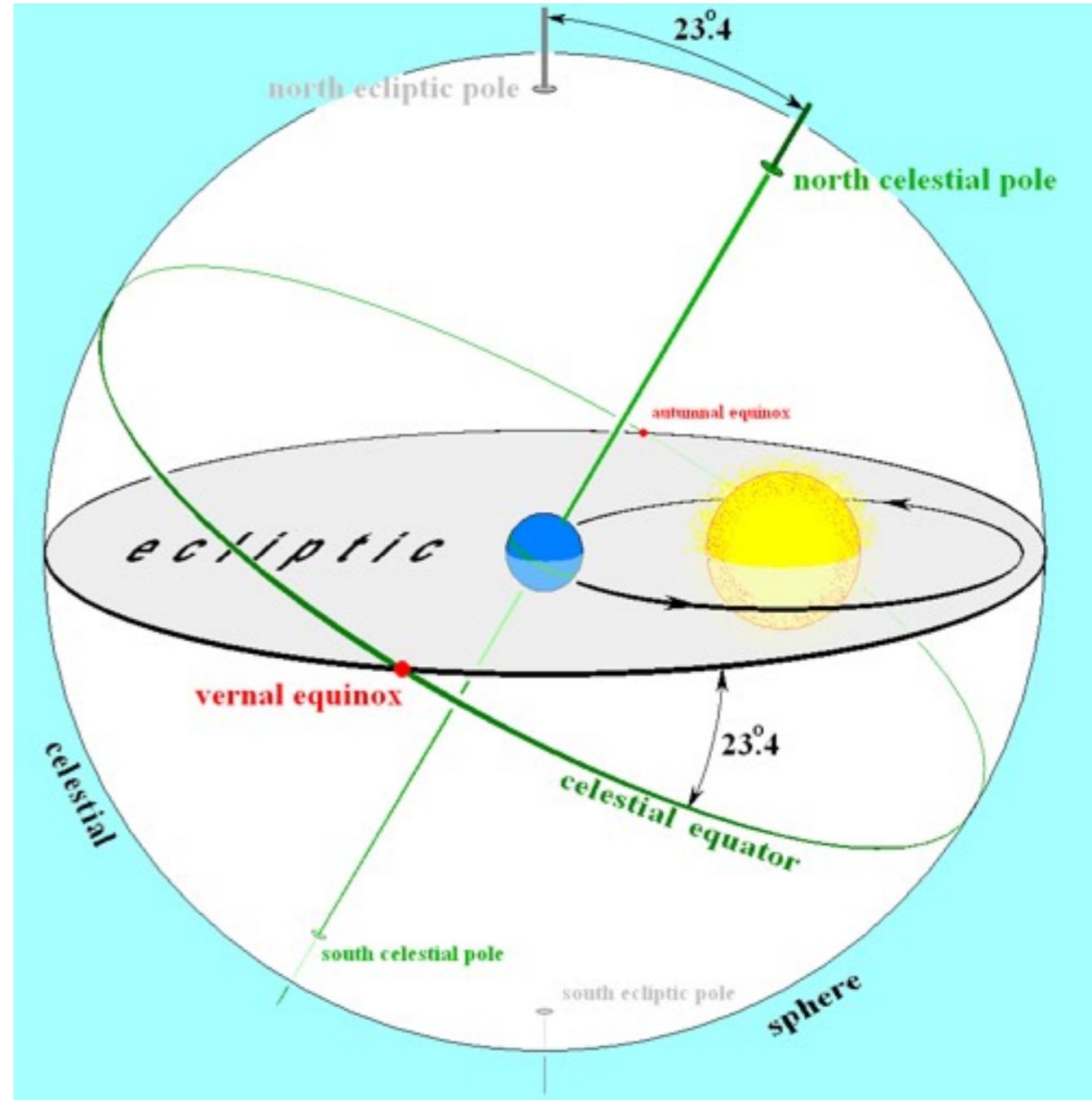
Earth's axis is tilted with respect to its orbit → the ecliptic is **NOT** the same as the celestial equator

# Motion of the Sun in the Sky

equator and ecliptic intersect in two points:  
the equinoxes

*why are they called  
equinoxes?*

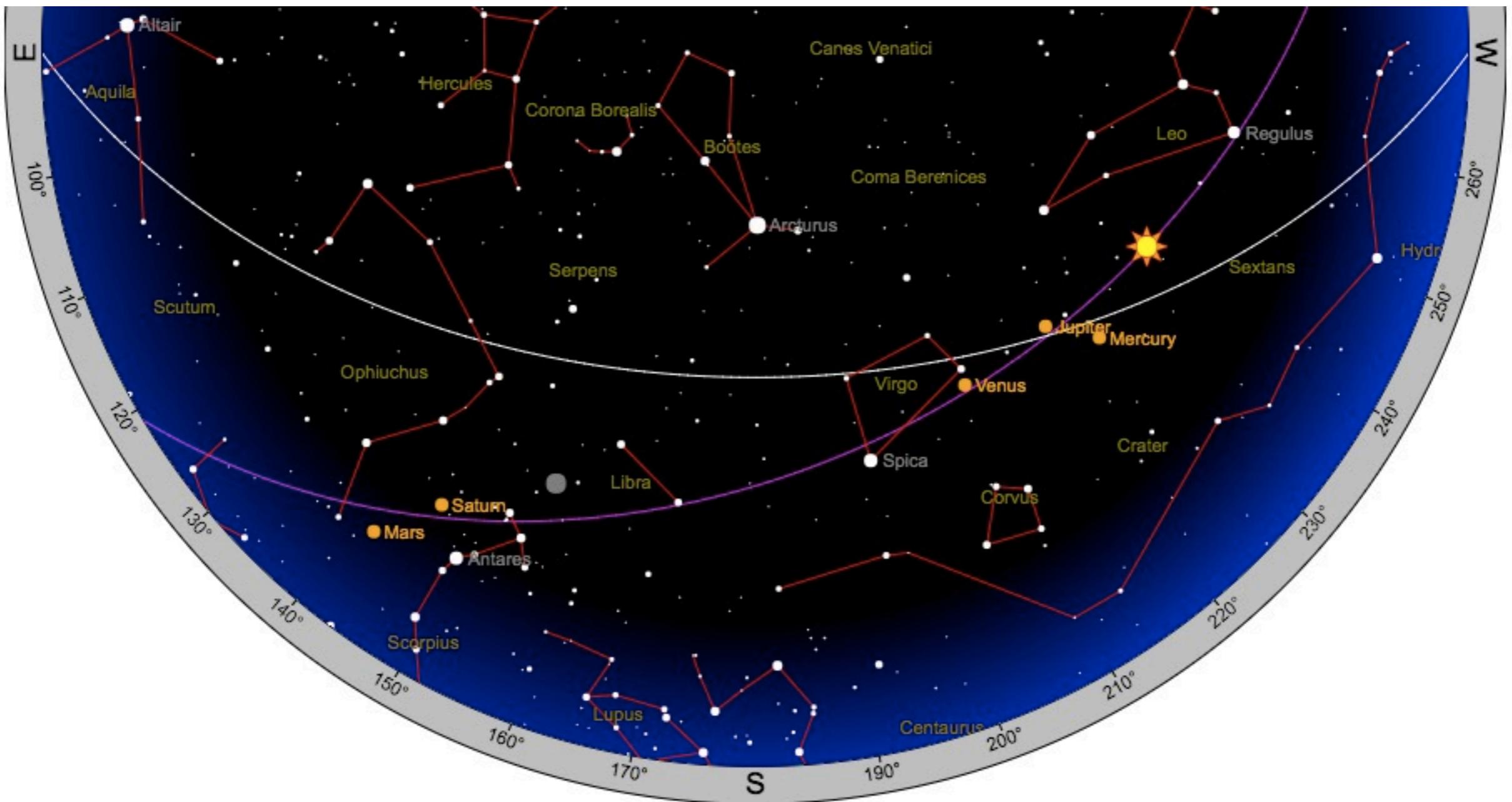
the vernal (spring)  
equinox marks RA=0h



# Other Solar System objects

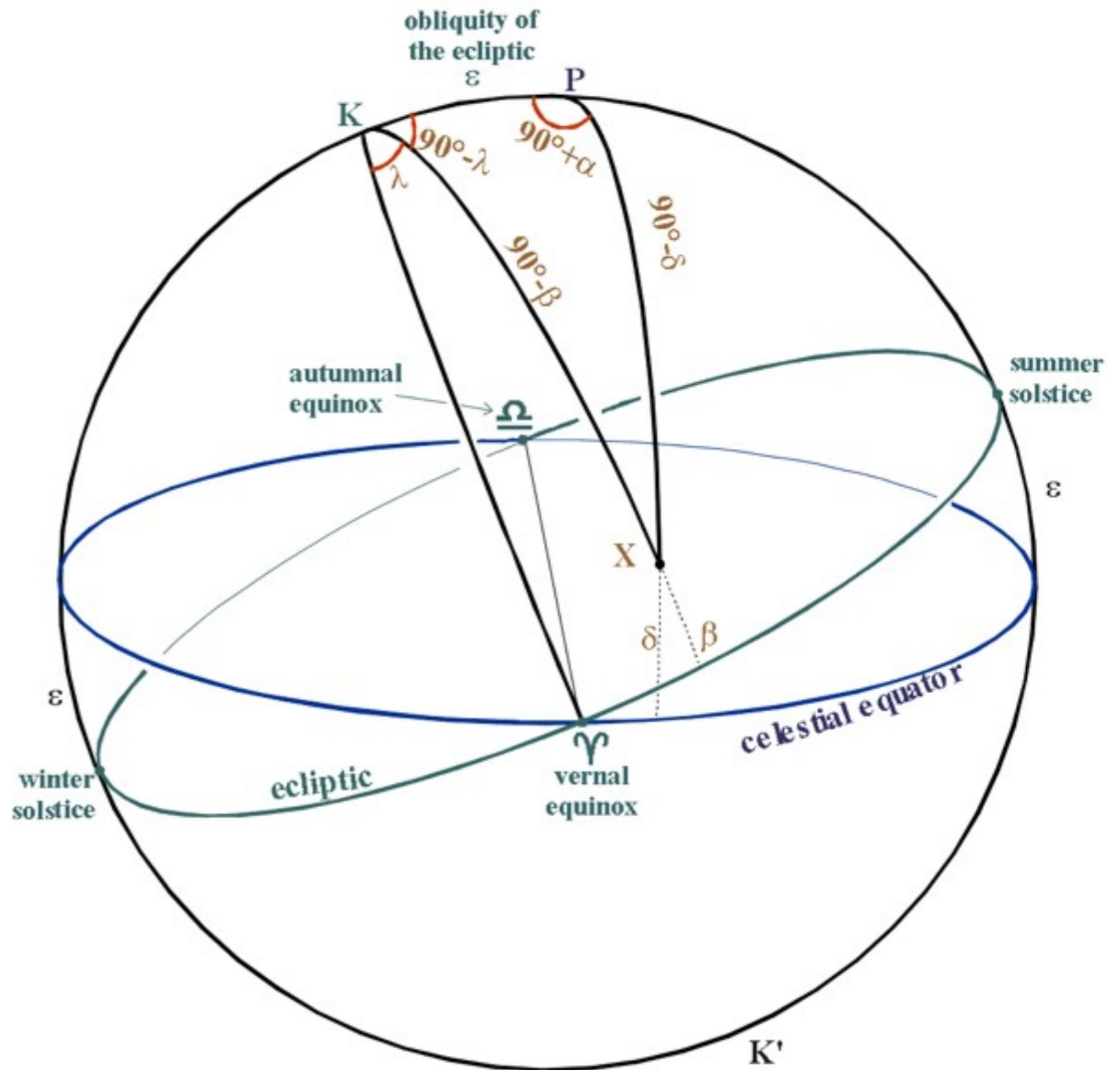
the orbital planes of most planets (and moons) are similar to Earth's orbital plane

→ Moon and planets also approximately follow the ecliptic



# Ecliptic coordinates

use ecliptic as  
“equator”



# Galactic coordinates

use the plane of the Galaxy as “equator”

