

PHY 517 / AST 443: **Observational Techniques in Astronomy**

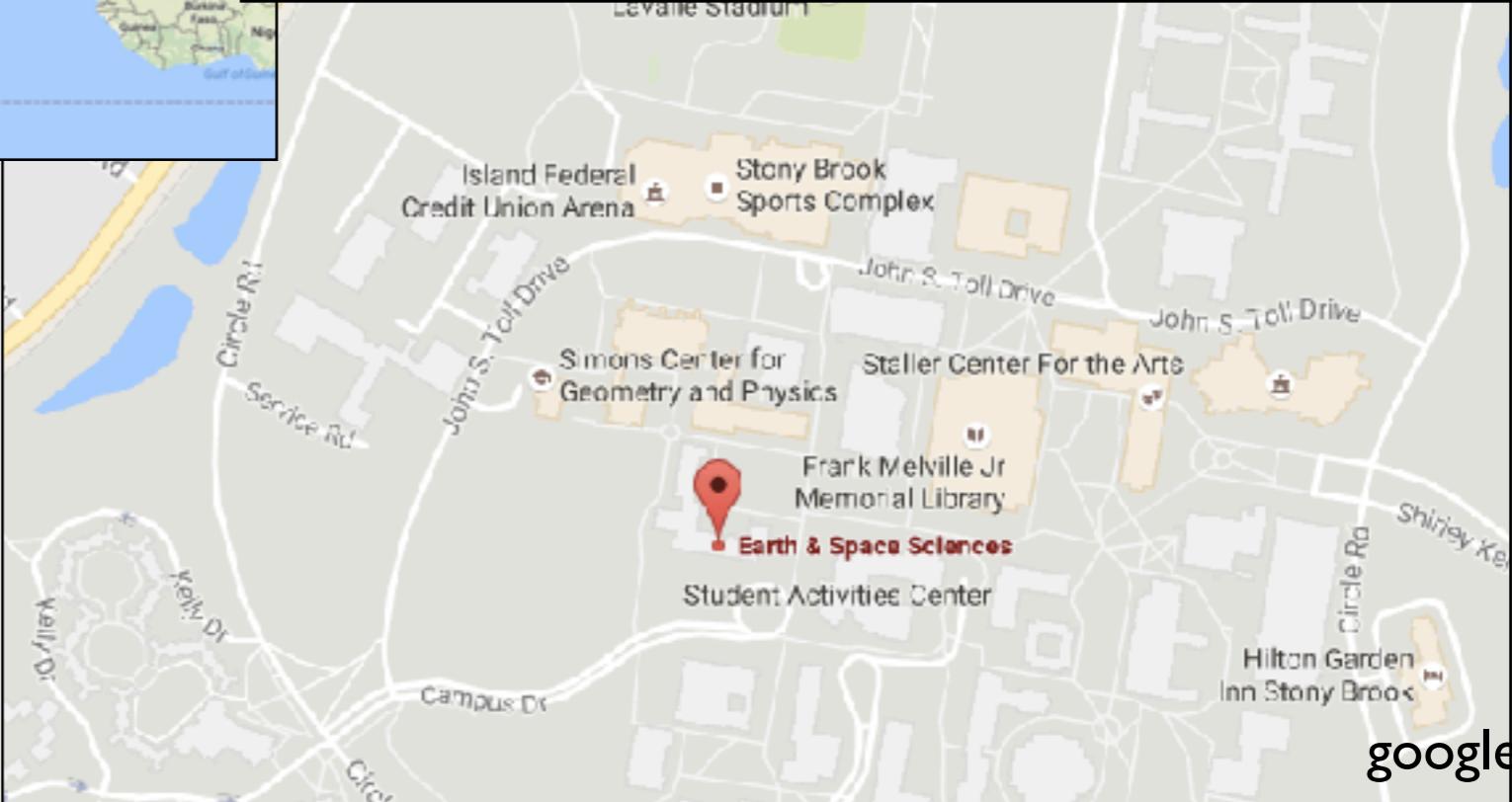
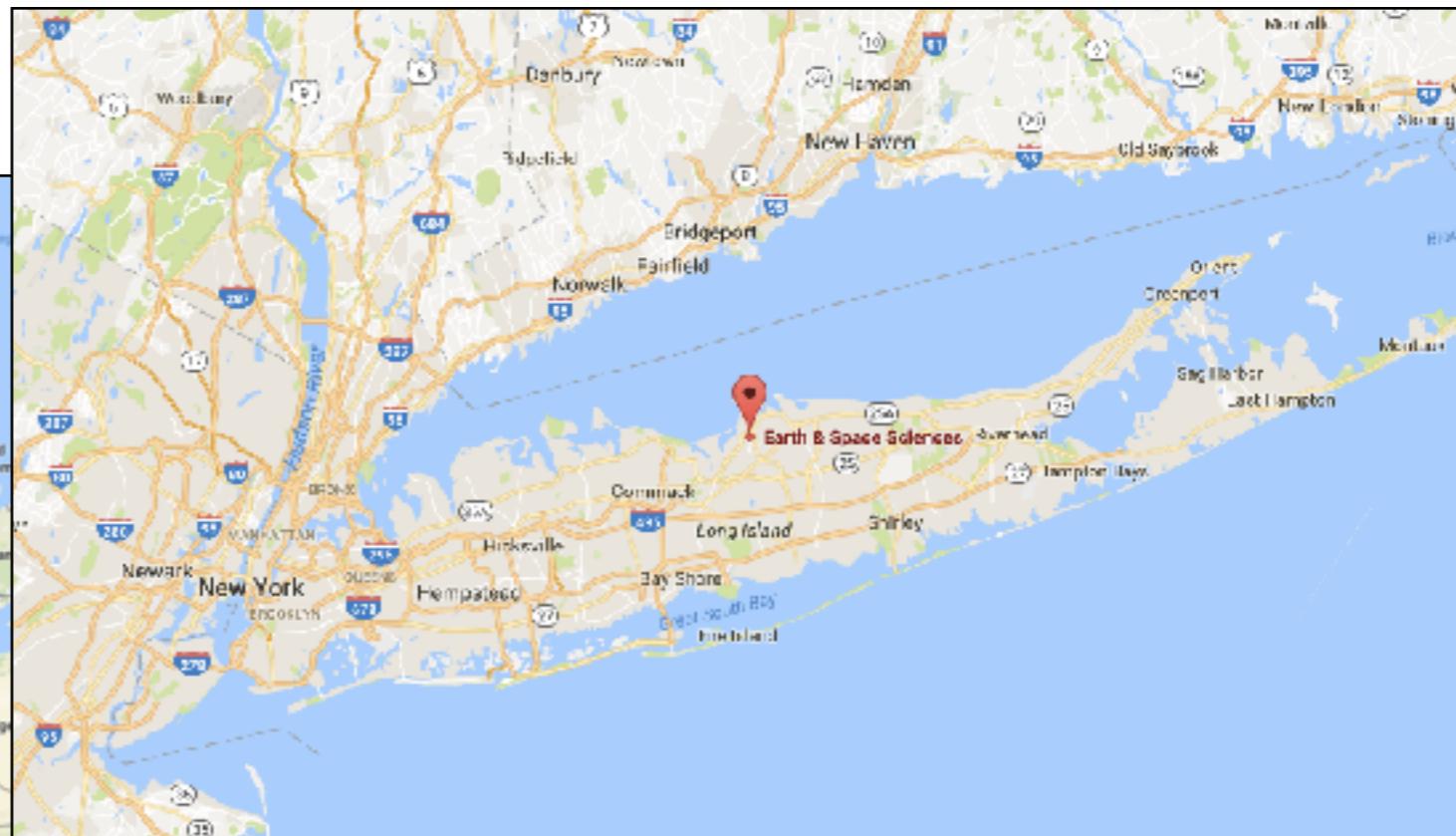
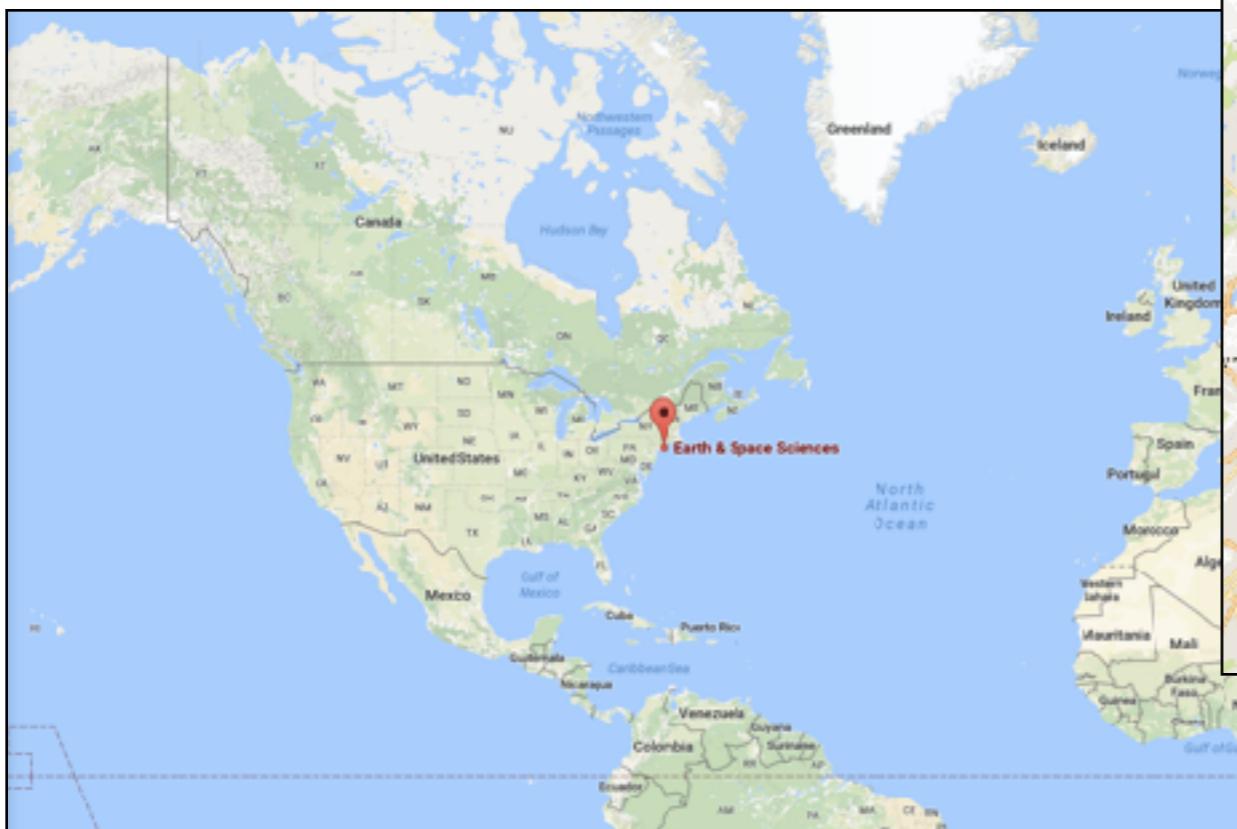
Lecture I:
How to find things on the Sky /
Astronomical Coordinate Systems

How do you find things on the Sky?

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

How do you find things on Earth?

I. maps



“pattern matching”

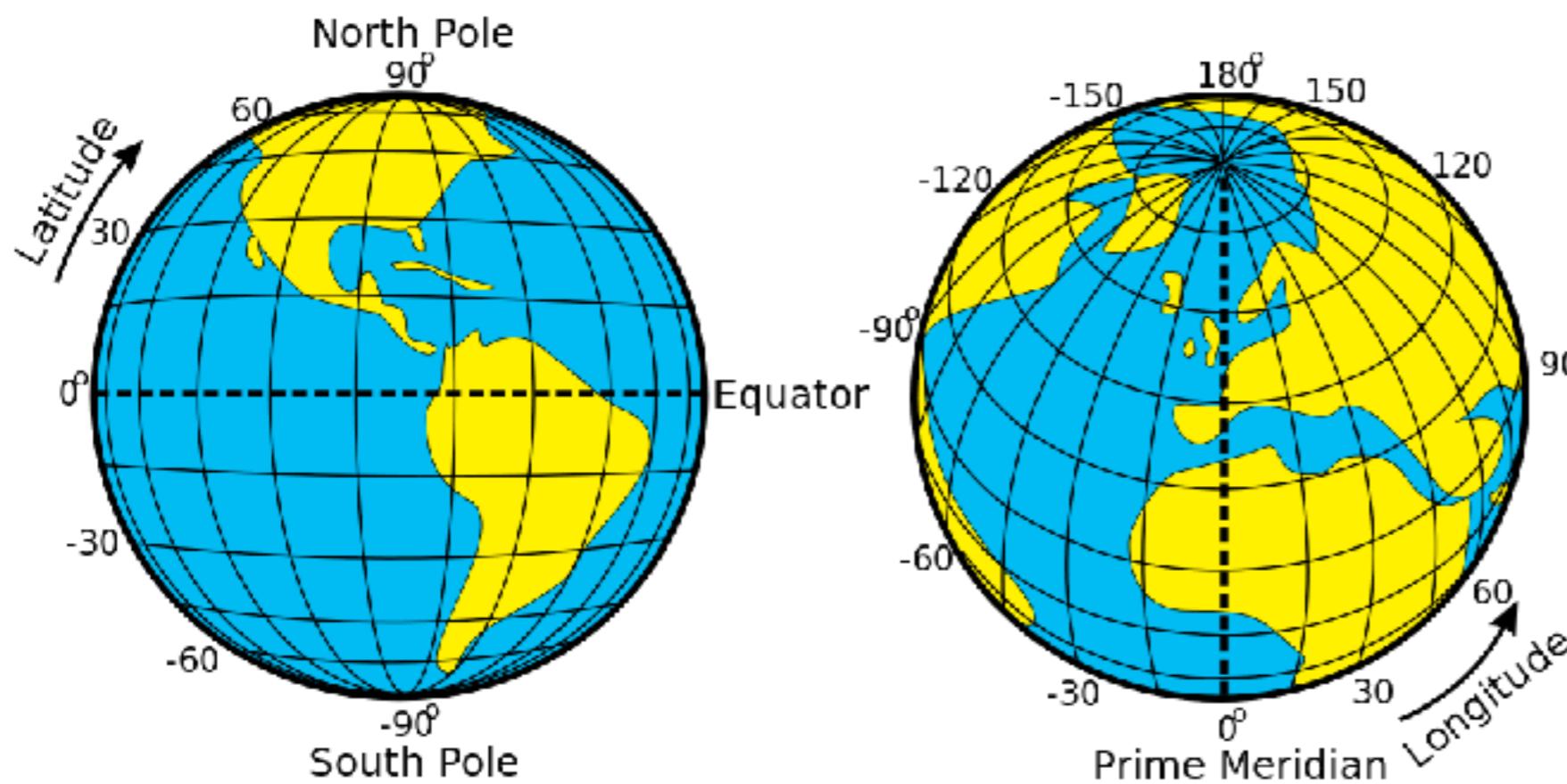
How do you find things on Earth?

Stony Brook University

State University of New York at Stony Brook



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



Former names	State University College on Long Island (1957–1962)
Type	Public research university center
Established	September 16, 1957; 66 years ago ^[1]
Parent institution	State University of New York
Accreditation	MSCHE
Academic affiliations	AAU · URA · USU · Seagrant · Space-grant
Endowment	\$390.5 million (2023) ^[2]
Chancellor	John B. King Jr.
Provost	Carl W. Lejuez
Academic staff	3,027 (Fall 2023) ^[3]
Students	25,710 (Fall 2022) ^[4]
Undergraduates	17,509 (Fall 2022) ^[4]
Postgraduates	8,201 (Fall 2022) ^[4]
Location	Stony Brook, New York, United States
wikipedia	40.917°N 73.124°W ^[5]

How do you find things on the Sky?

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

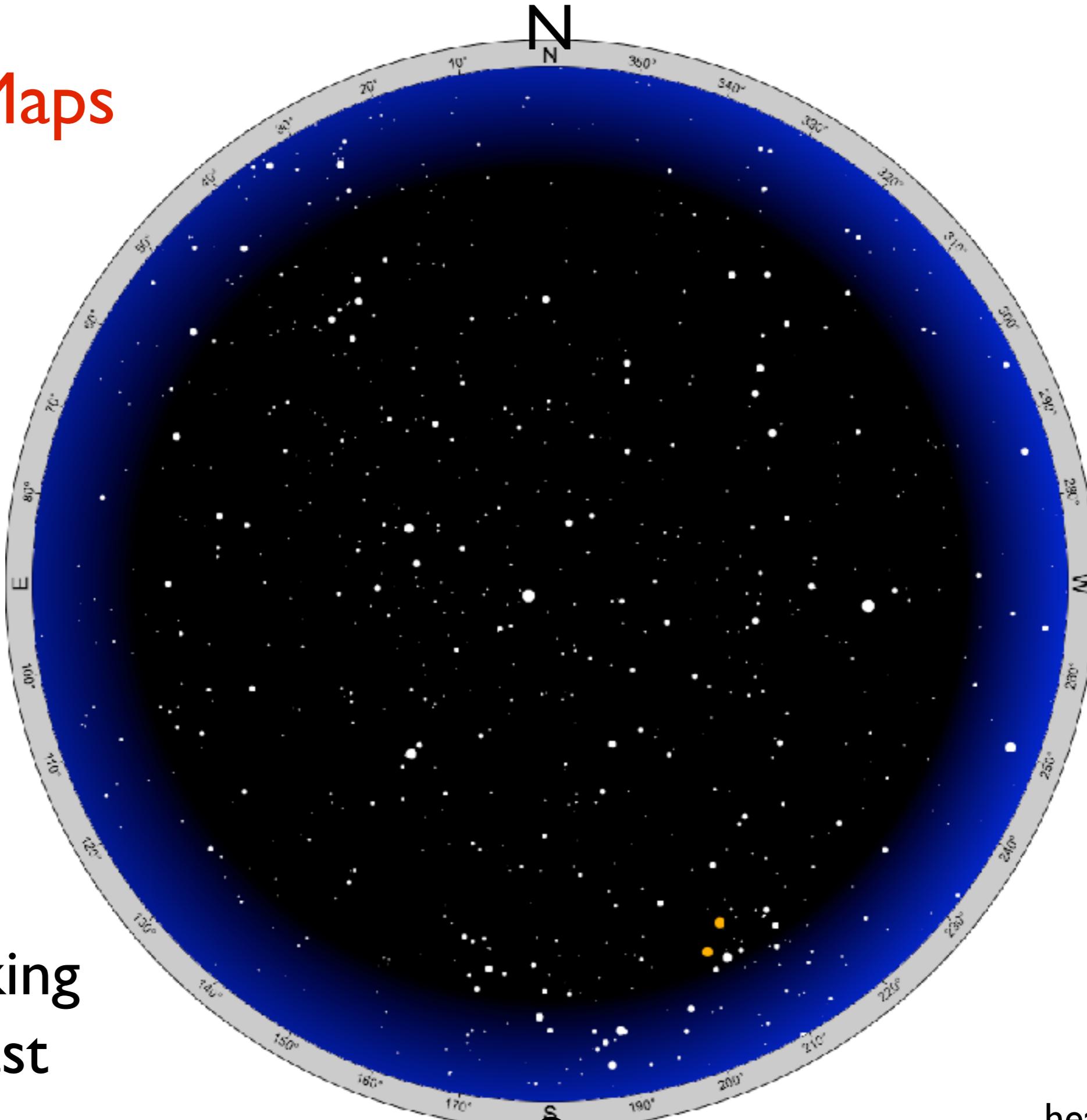
Sky Maps

E

W

N

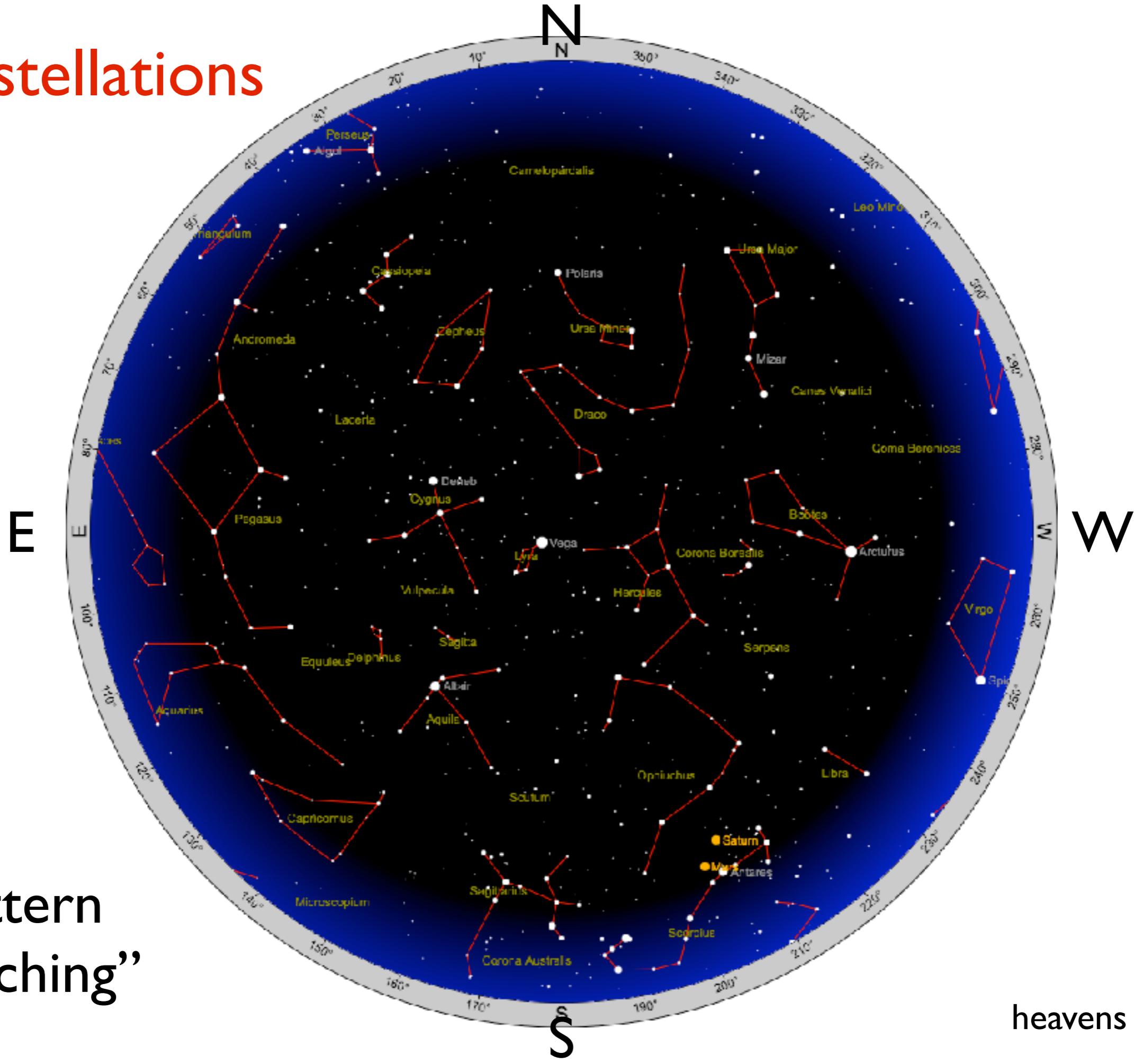
S



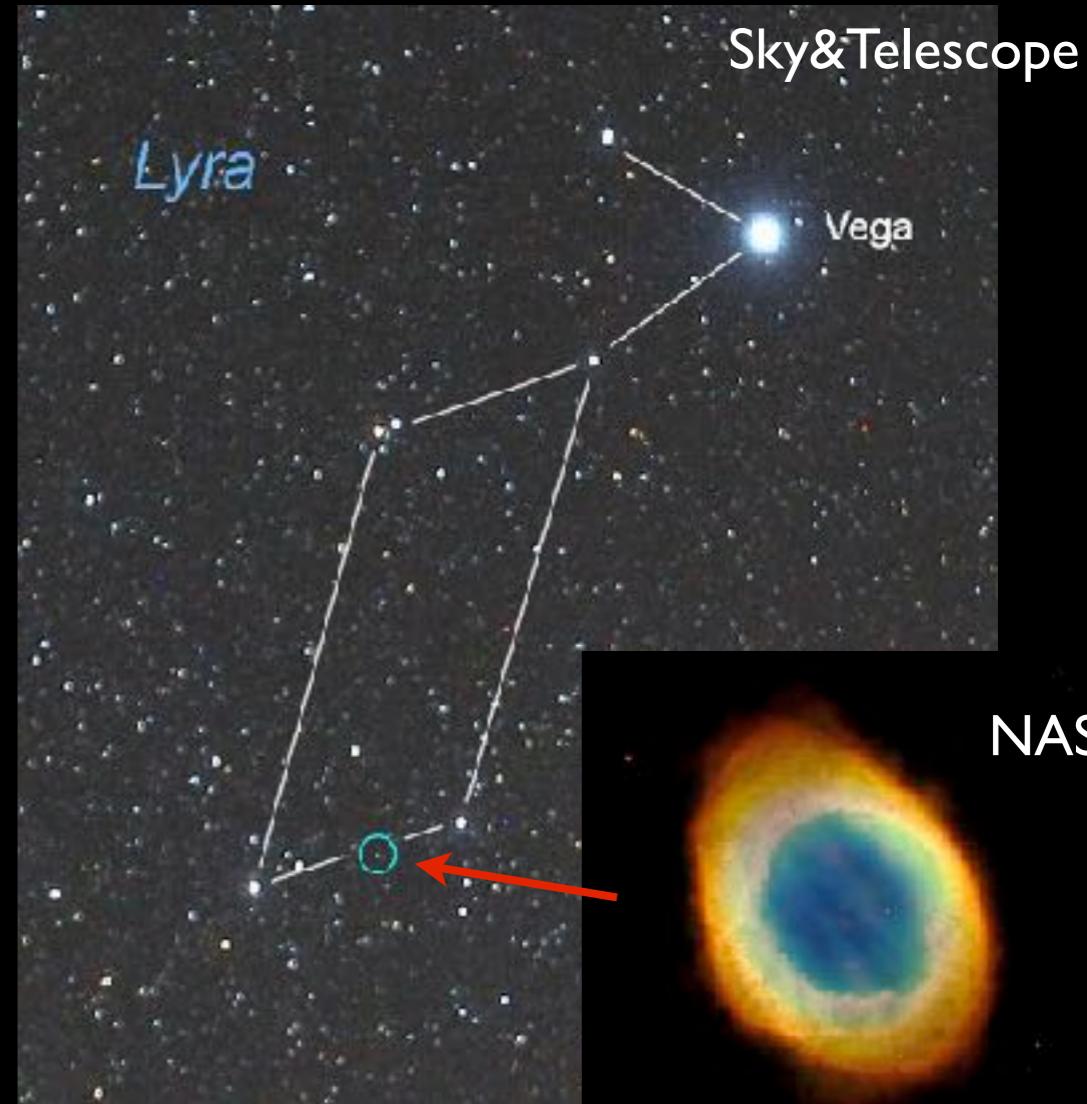
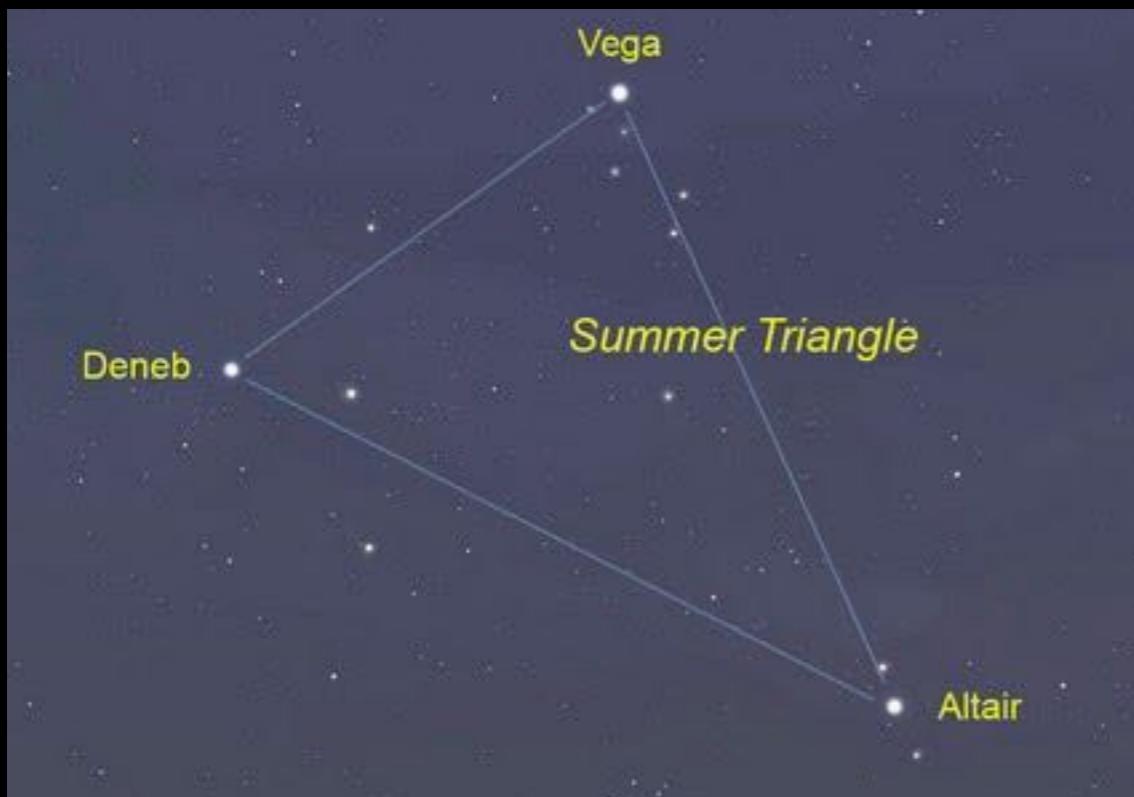
NB: looking
up → East
is “left”

heavens above

Constellations



How to find the Ring Nebula (M57)



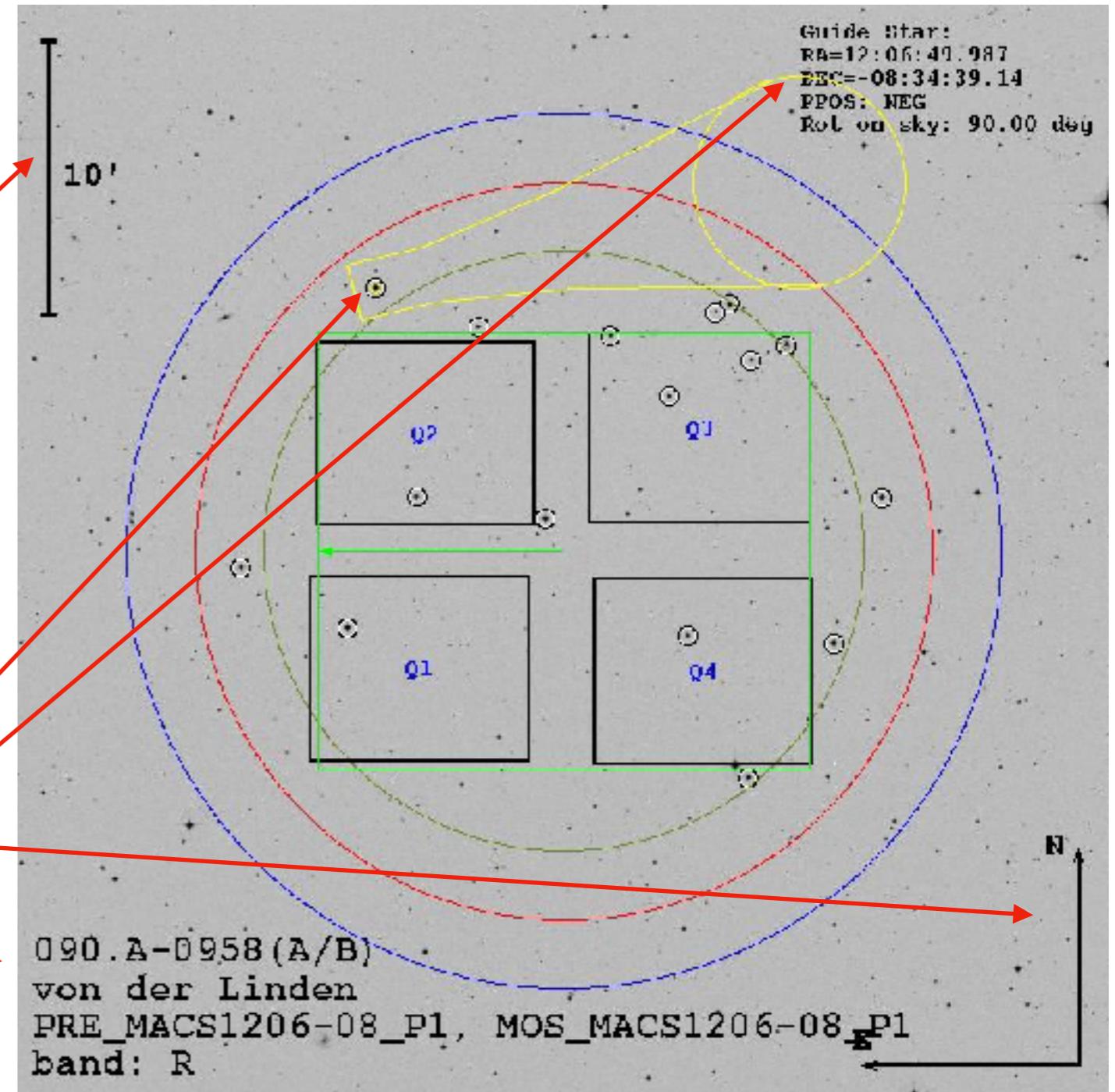
asterisms: easy-to-recognize star groupings
constellations: officially defined sky regions, based on historical asterisms

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 / orientation
- identifiers / target



Astronomical coordinate systems

Horizontal (or “Alt/Az”) Coordinate System

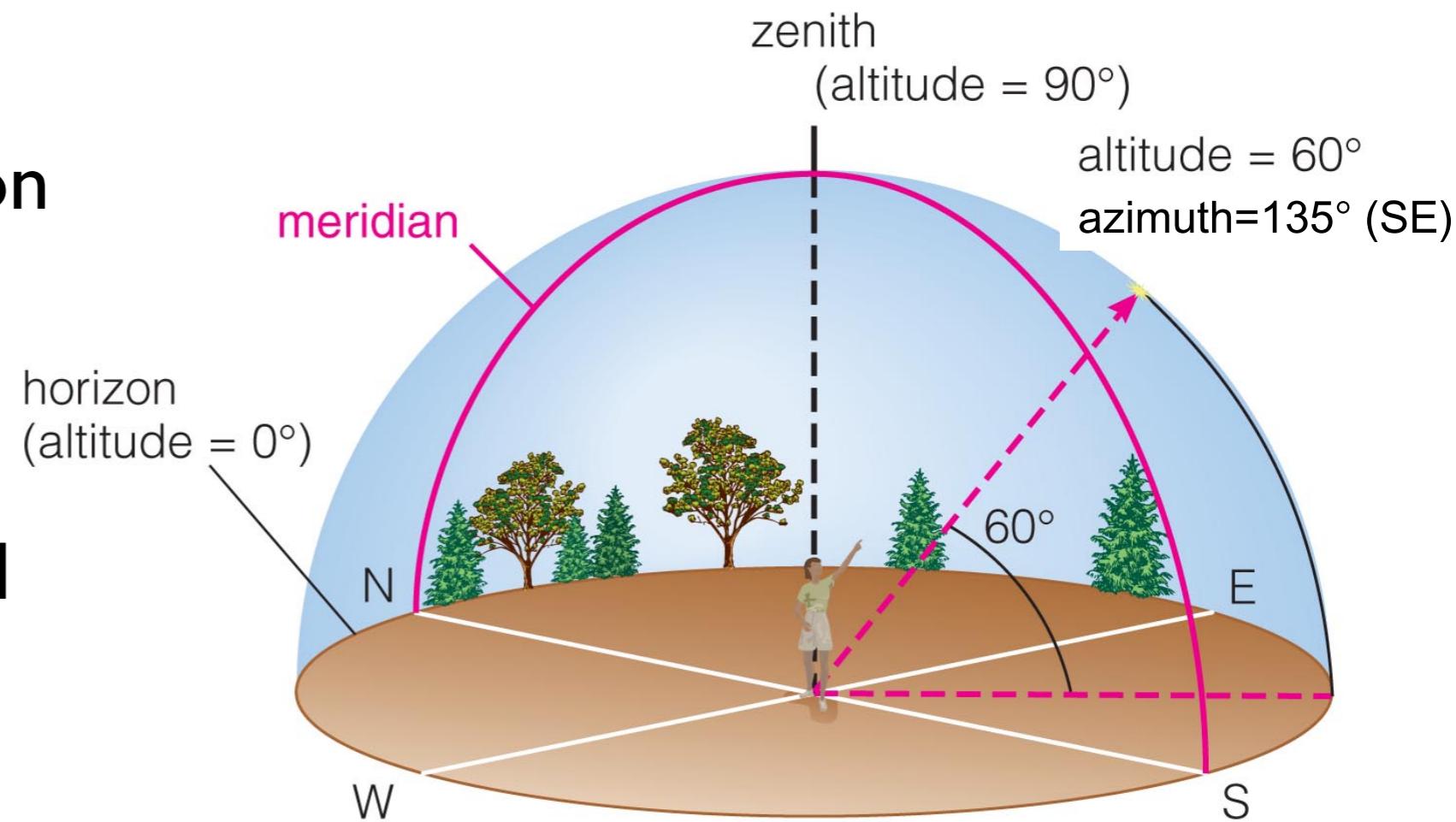
the sky above a specific location, at a specific time, is half a sphere - can be described with 2 (positive) angular coordinates

altitude: angular distance to the horizon

azimuth: angular distance from north

zenith: point overhead

meridian: north-south line



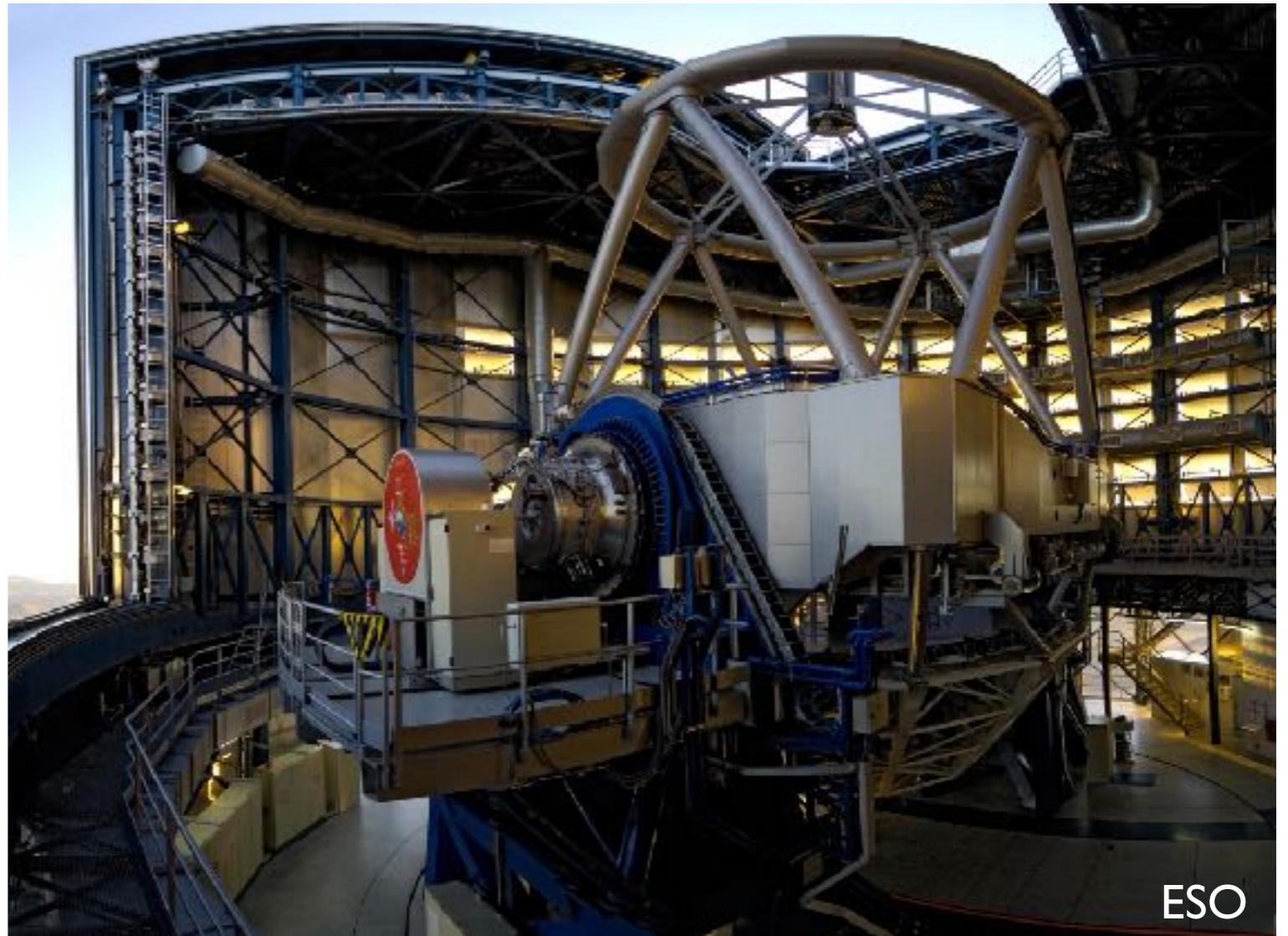
Horizontal (or “Alt/Az”) Coordinate System

alt-az telescope mounts: simple, very stable



M. Rahman

Dobsonian-style
telescope (~8 inch)



ESO

Very Large Telescope (8 meters)

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

still, 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

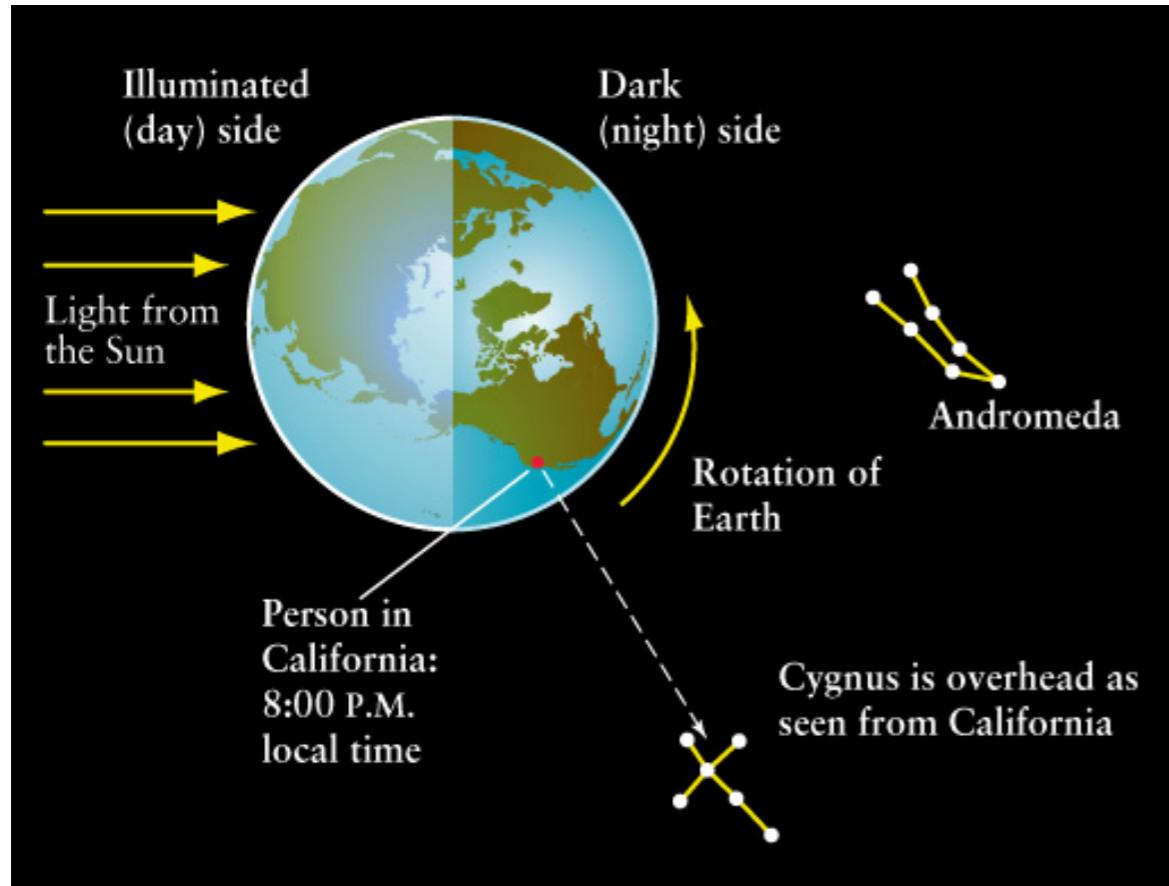
is my target “up” ? ($\text{altitude} > 0^\circ$)

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

Rotation of the Earth

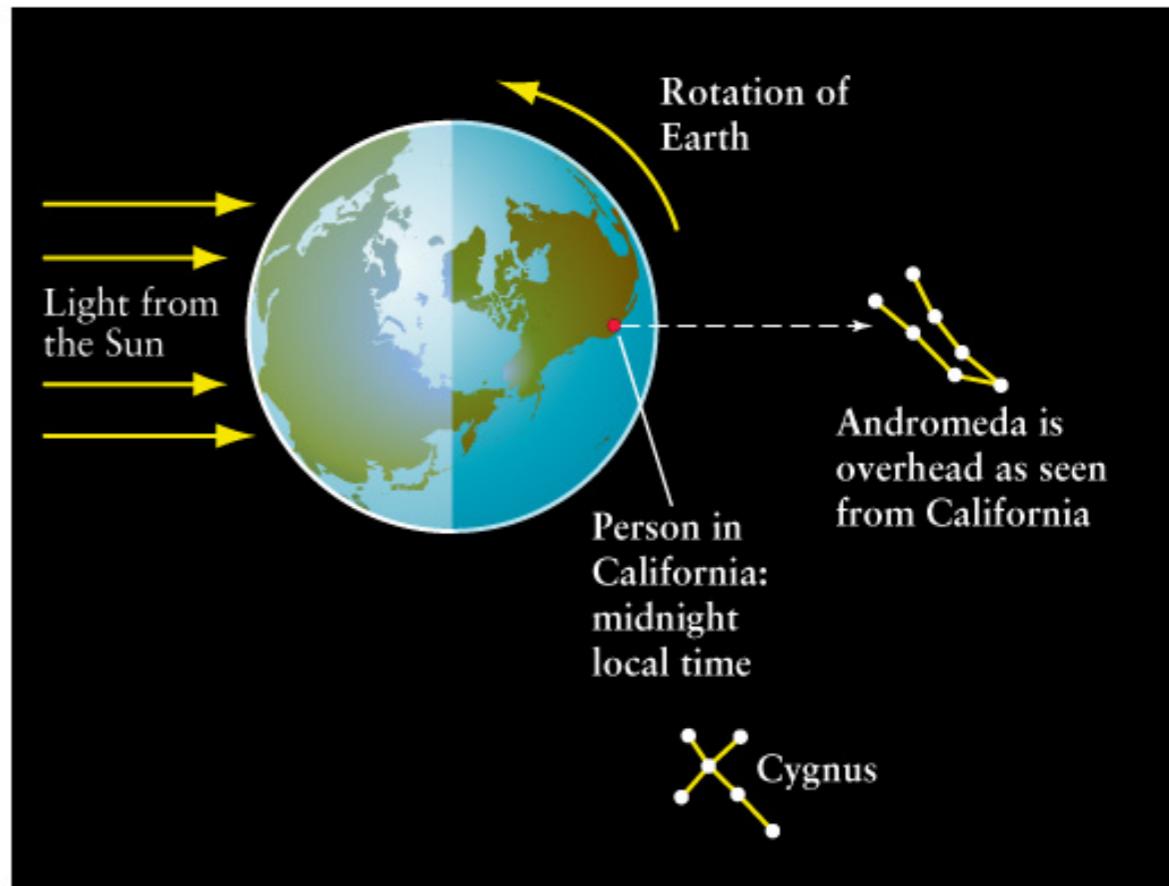
looking down on the north pole, Earth rotates counter-clockwise

Bailey, Slater & Slater



(a) Earth as seen from above the north pole

Andromeda is to the East; Cygnus is overhead

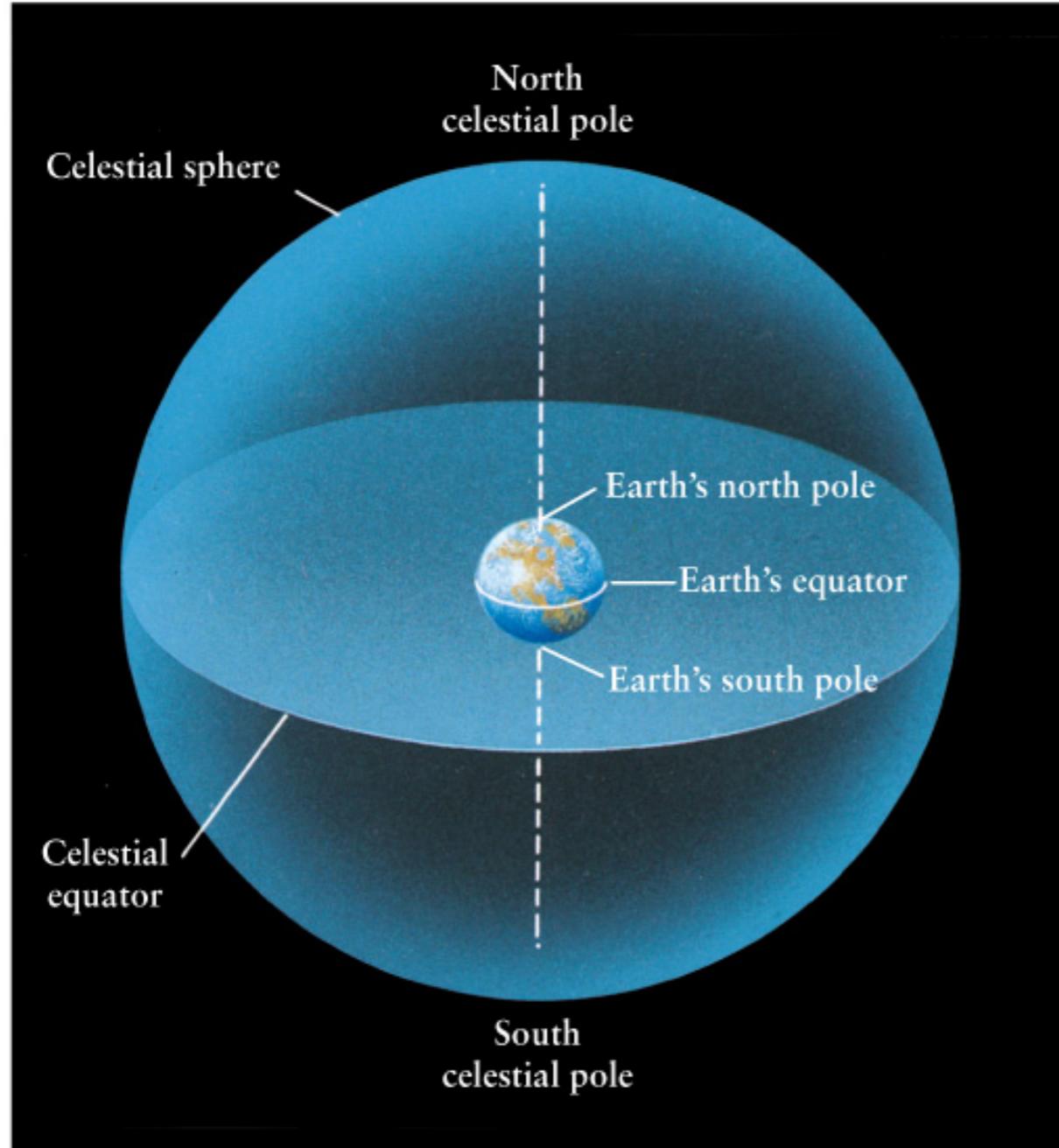


(b) 4 hours (one-sixth of a complete rotation) later

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

- the Sky appears to rotate East to West
- objects rise in the East; culminate in the South (when they cross the meridian); and set in the West

Celestial Sphere

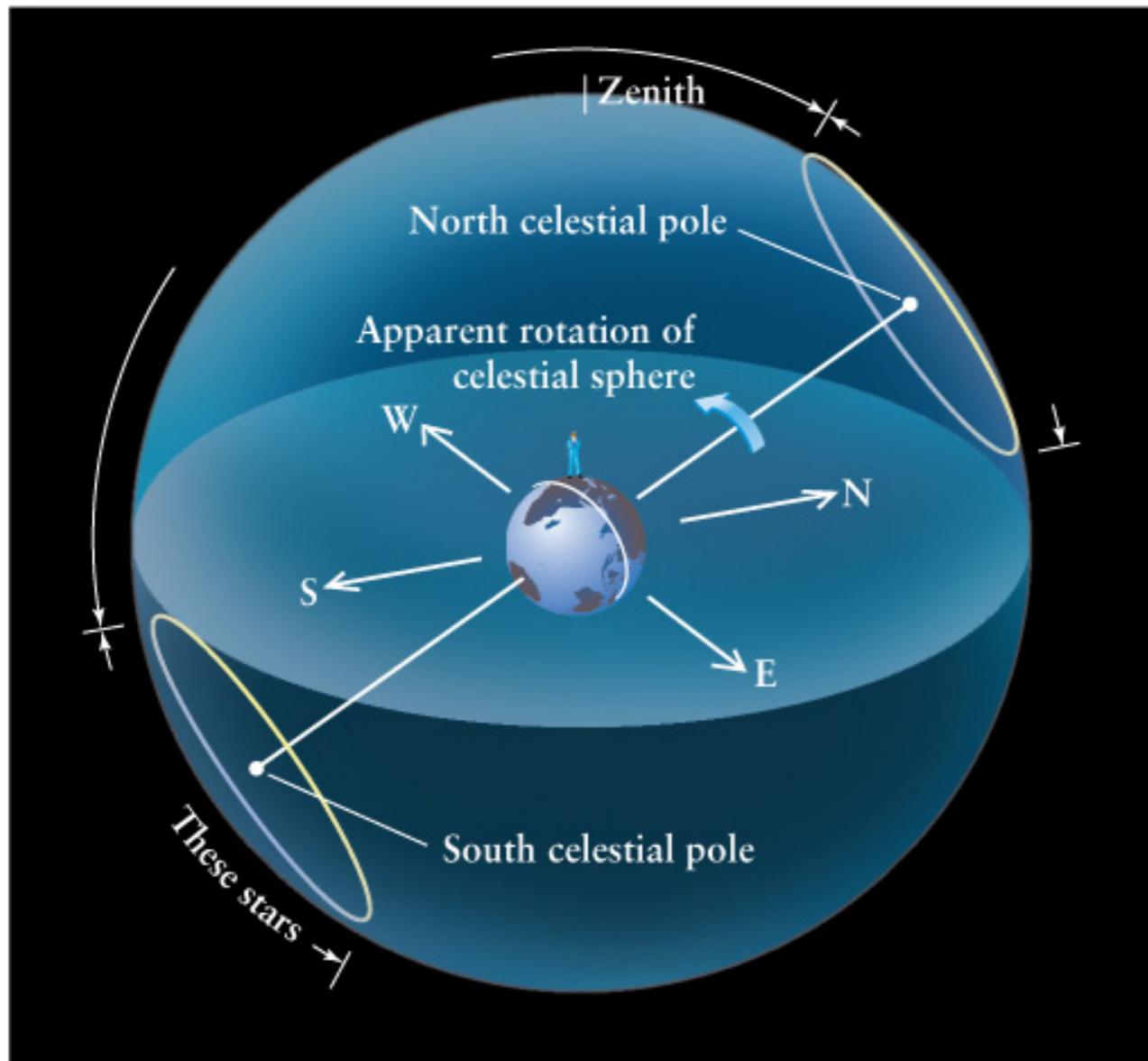


celestial sphere: describe objects by their position on a sphere centered on rotating Earth

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

celestial equator: projection of Earth's equator

Apparent motion in the Sky

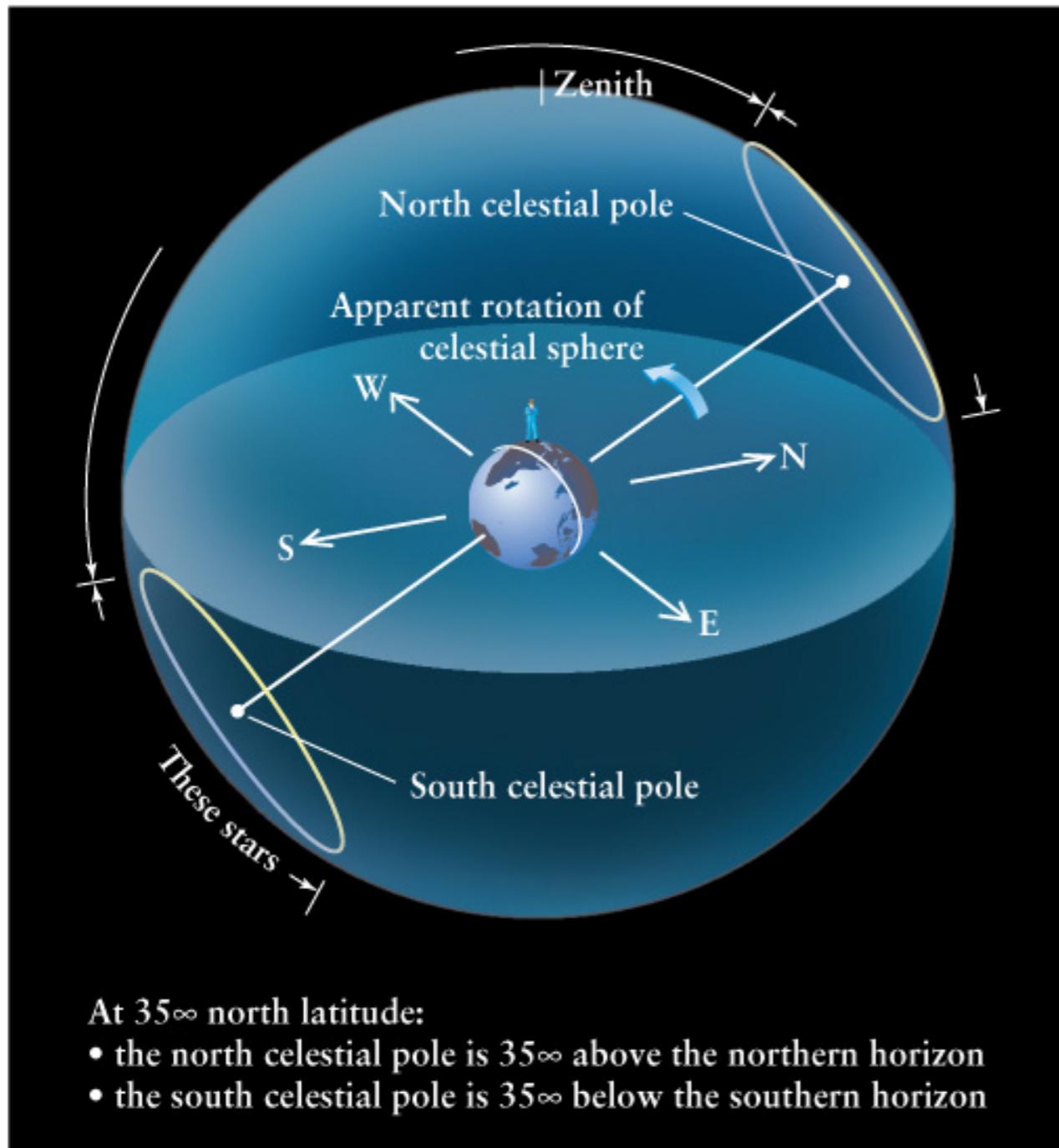


apparent sky motion depends on latitude of observer

e.g. SB is 41° 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



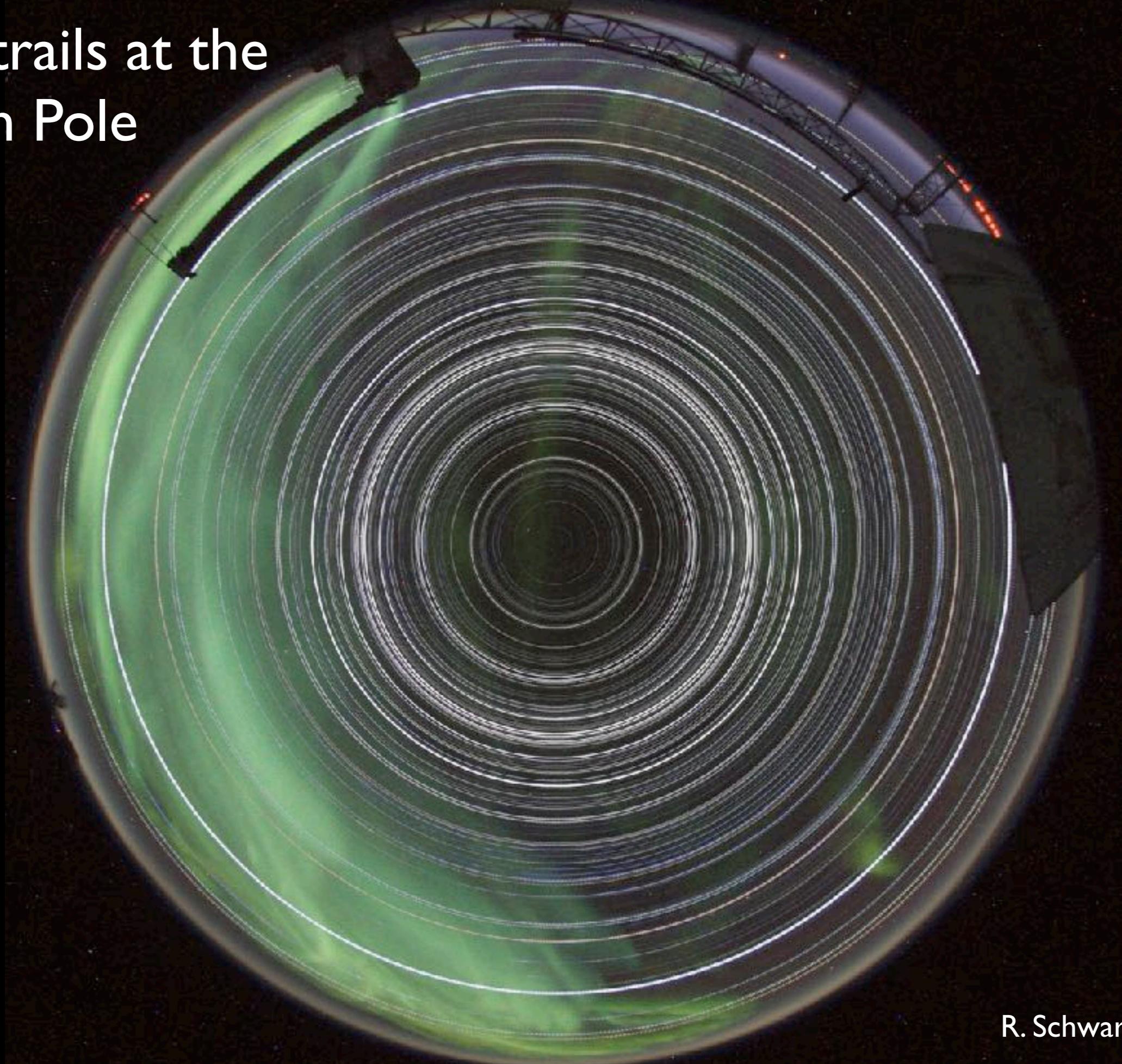
Star trails over CTIO, (c) Jose Delgado

Star trails at the equator



© Stéphane Guisard

Star trails at the South Pole



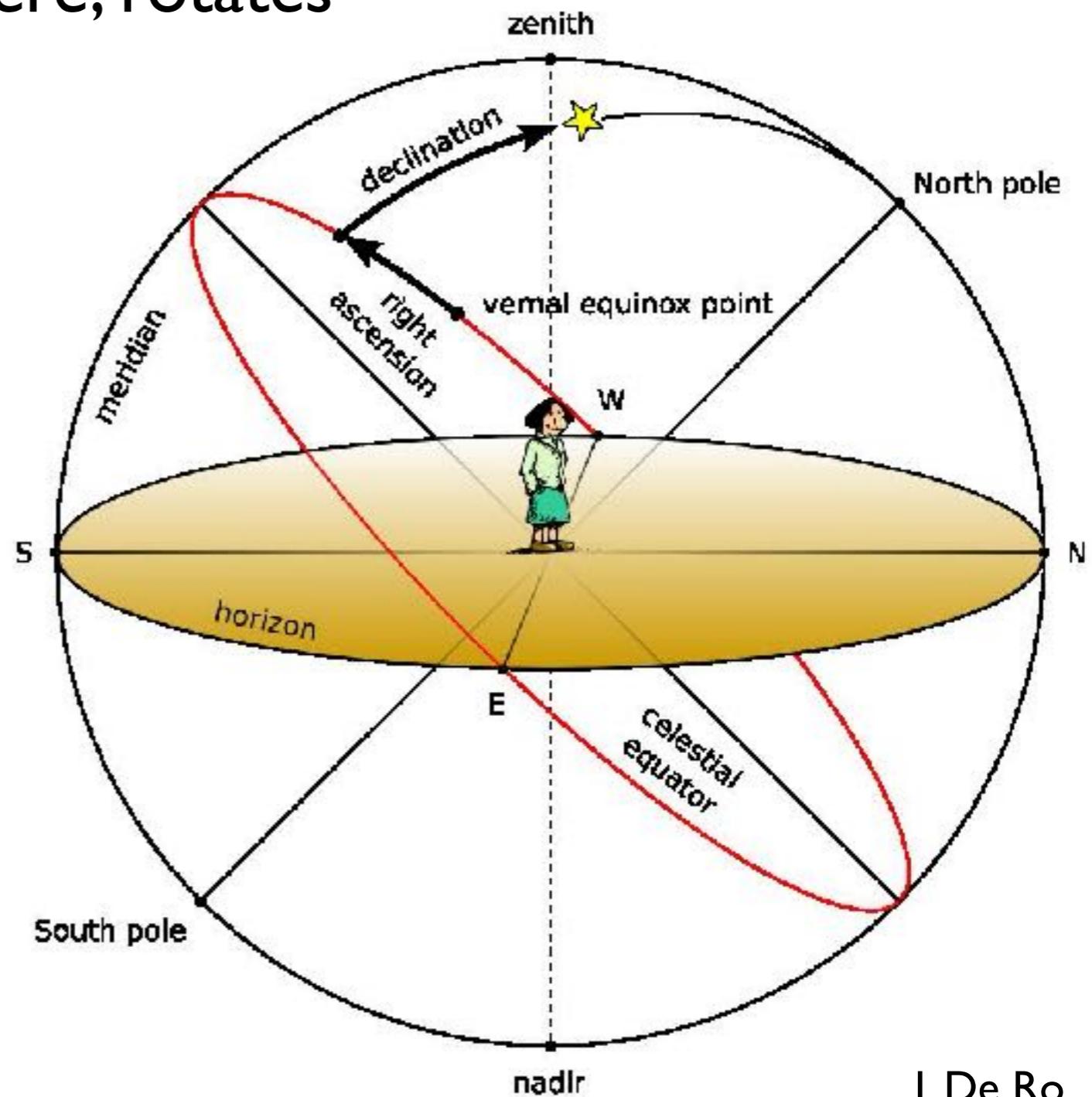
R. Schwarz

Equatorial (RA/Dec) Coordinate System

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

declination δ : angular distance from the celestial equator

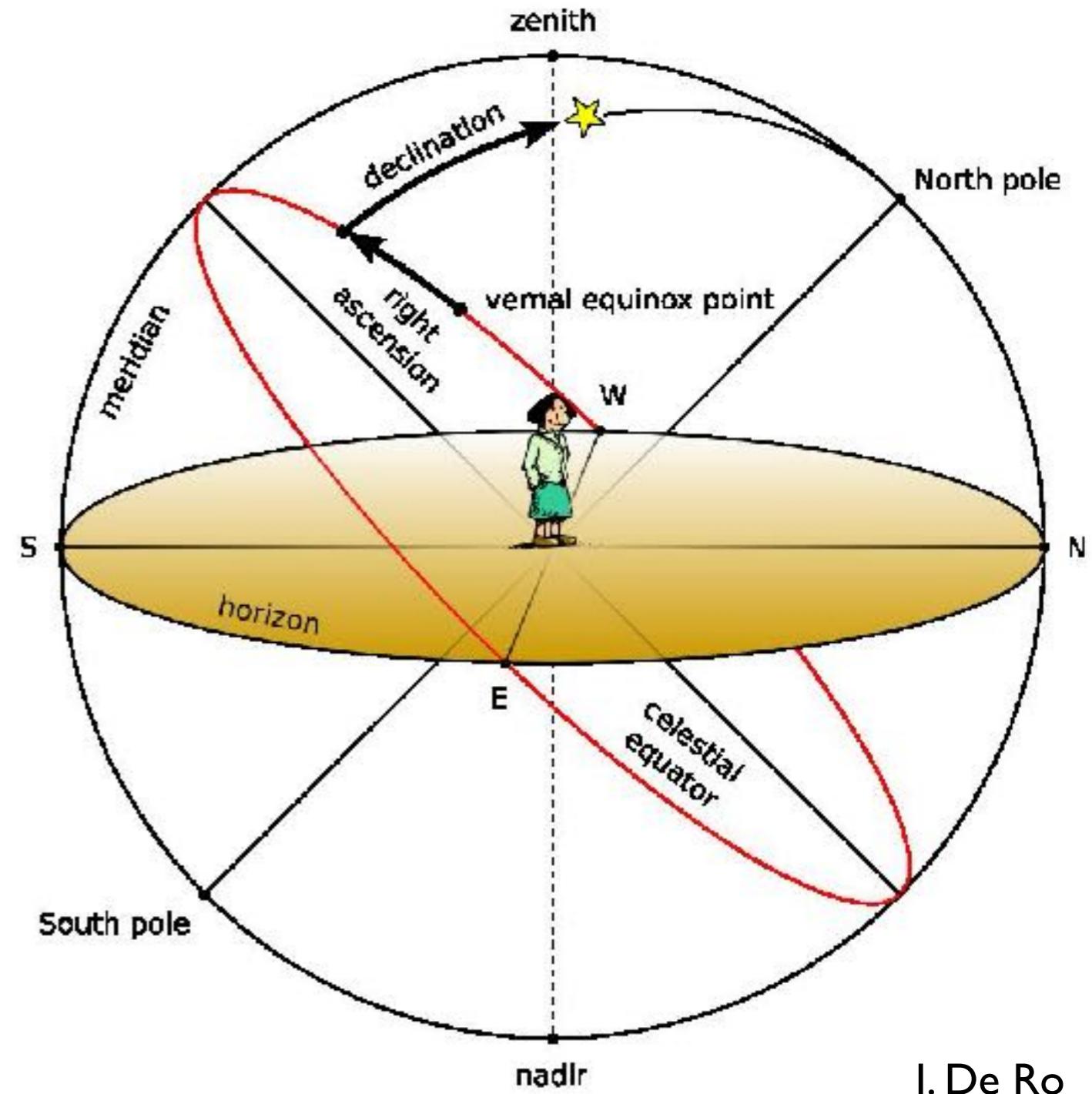
right ascension α : angular distance from vernal equinox (later; special point on equator)



Equatorial (RA/Dec) Coordinate System

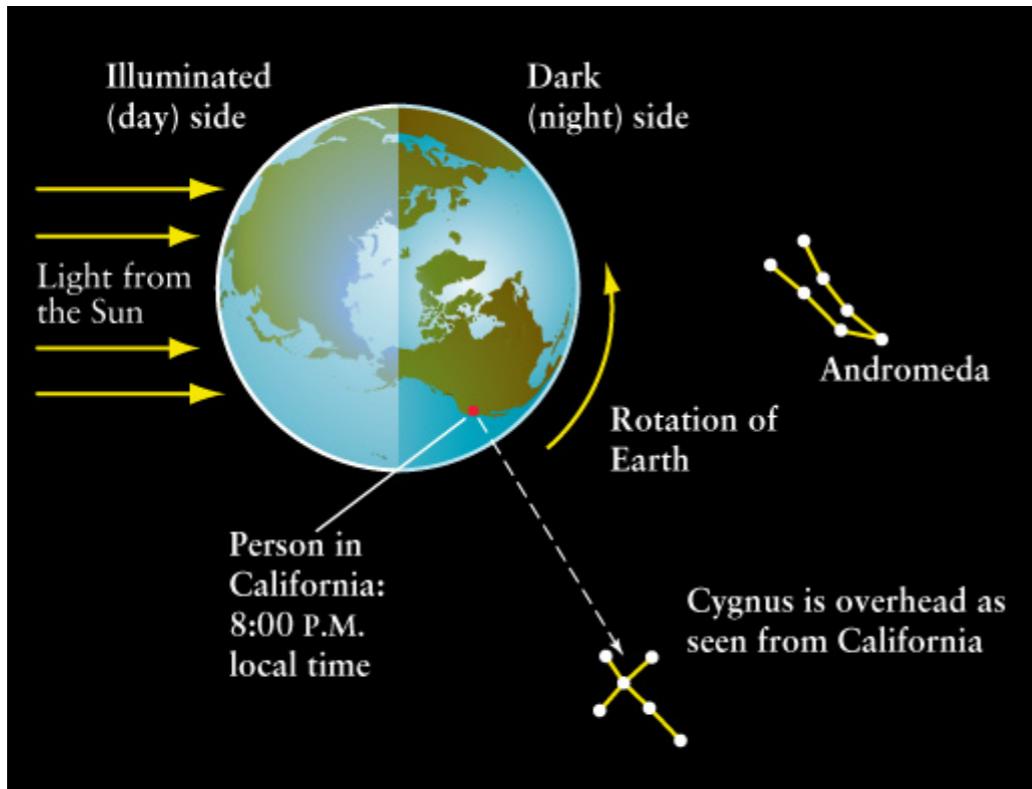
declination δ : measured in degrees, $-90^\circ \leq \delta \leq 90^\circ$ (like latitude)

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

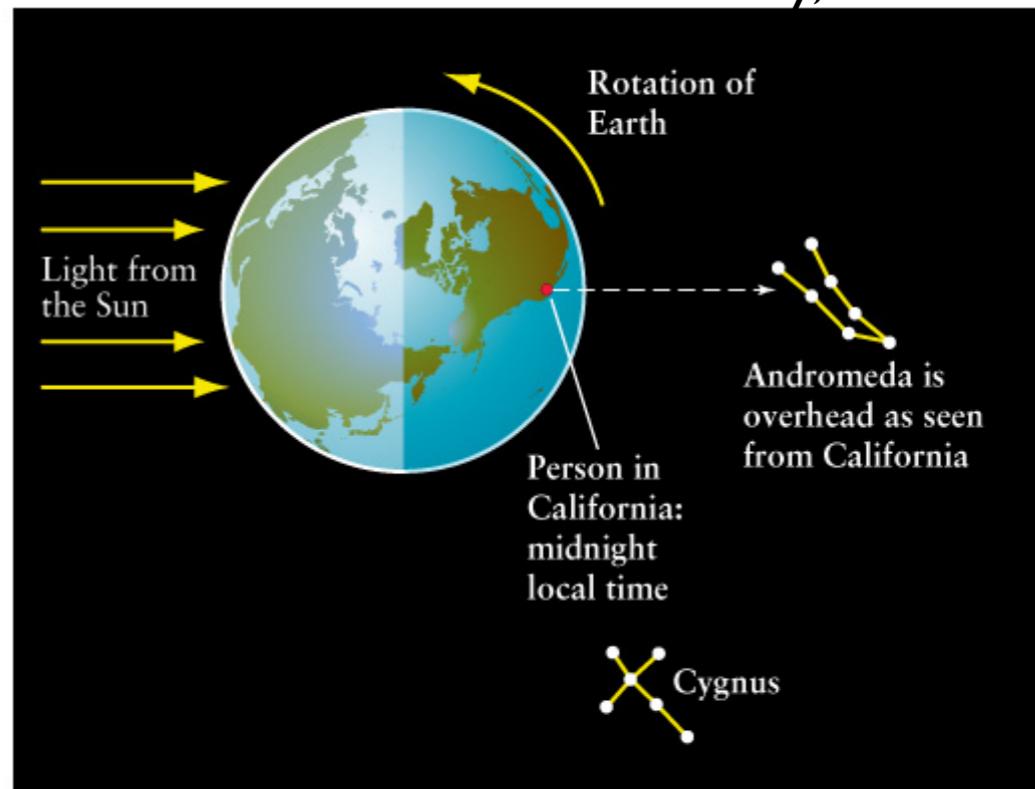


Right ascension (RA)

Bailey, Slater & Slater



(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 passing the meridian

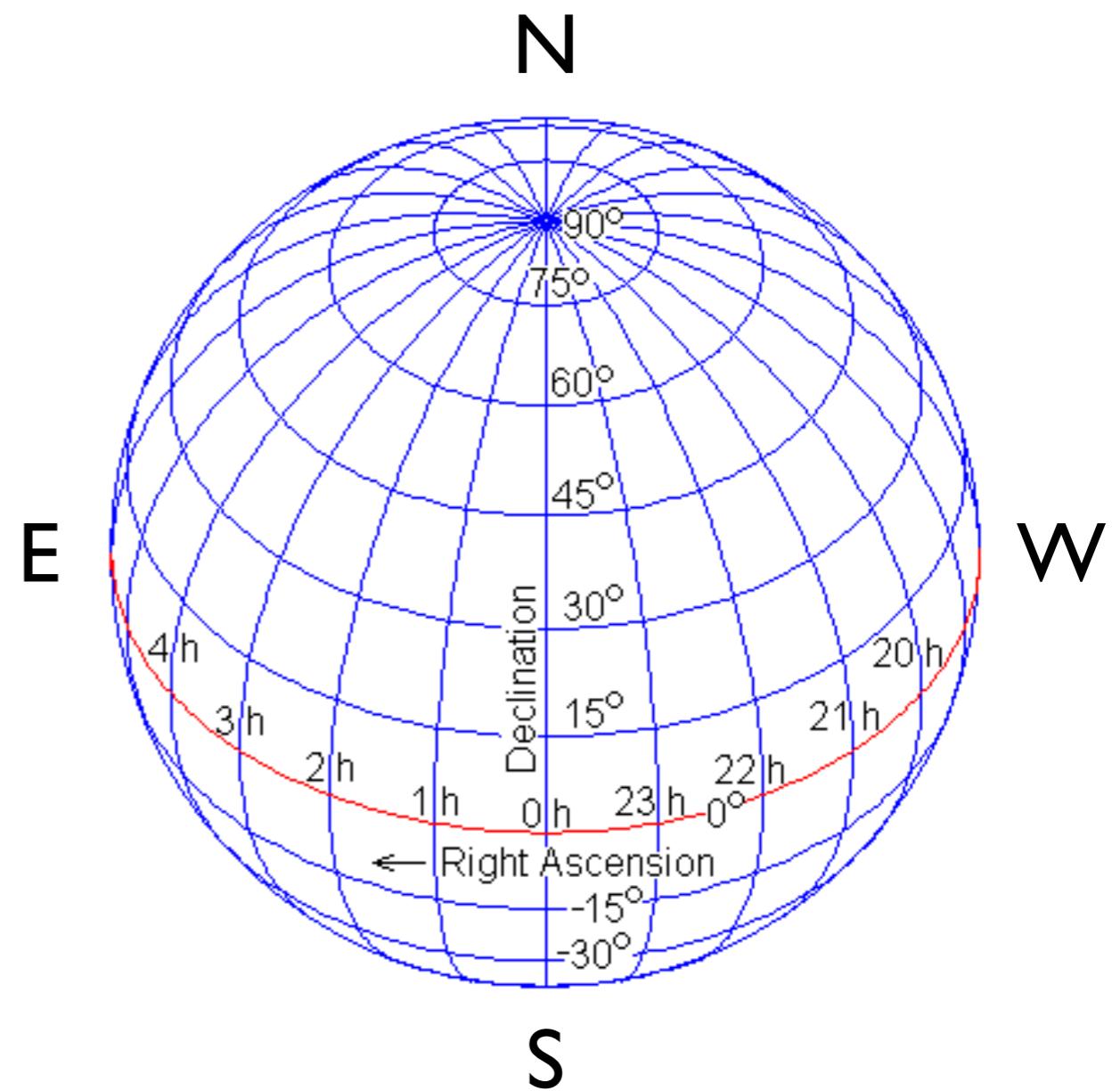
e.g.: reference point (0h) culminates (passes meridian) at a certain time; all points that culminate 4 hours later have $\alpha = 4h$

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)



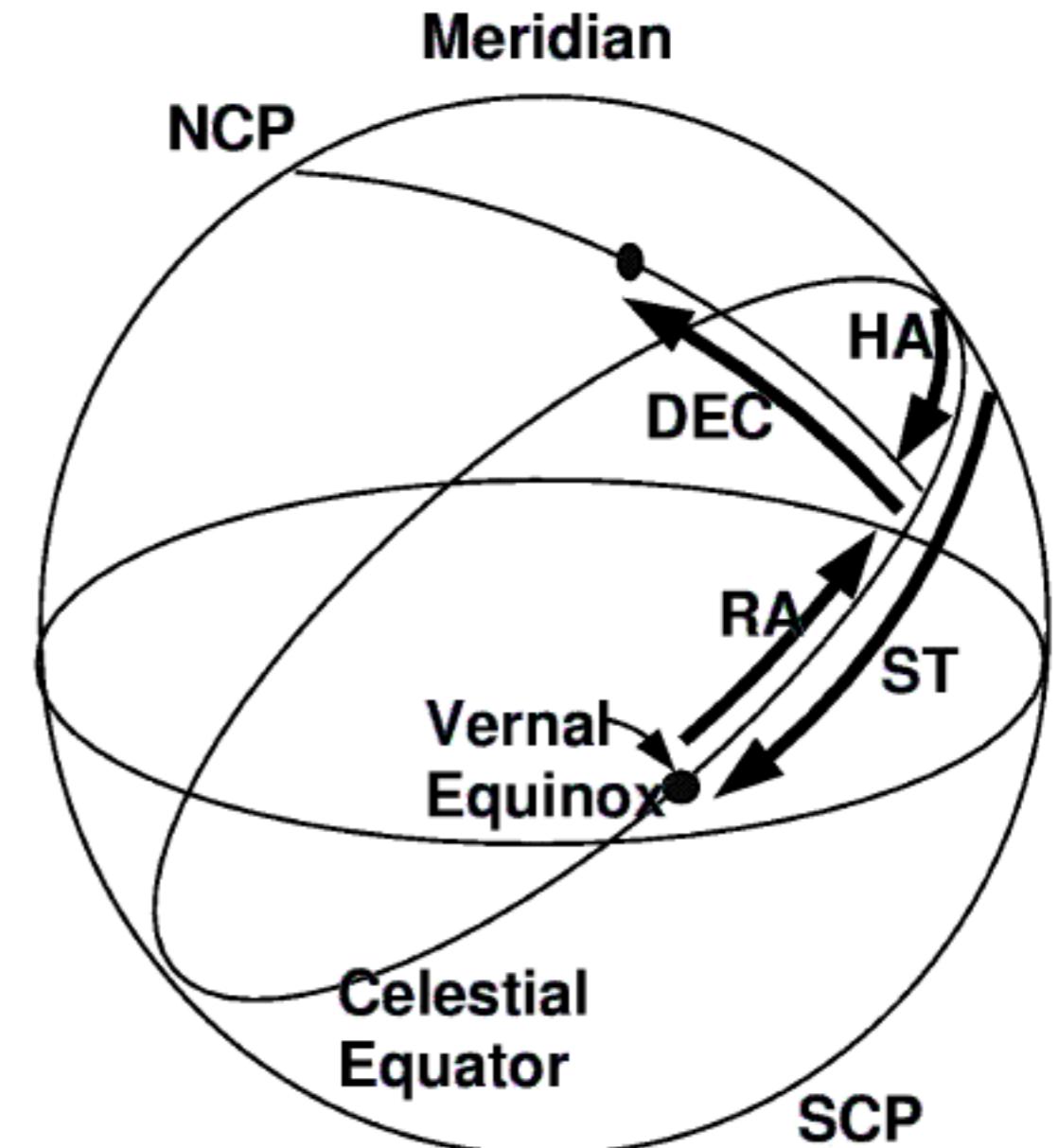
RA, LST, and Hour Angle

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

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

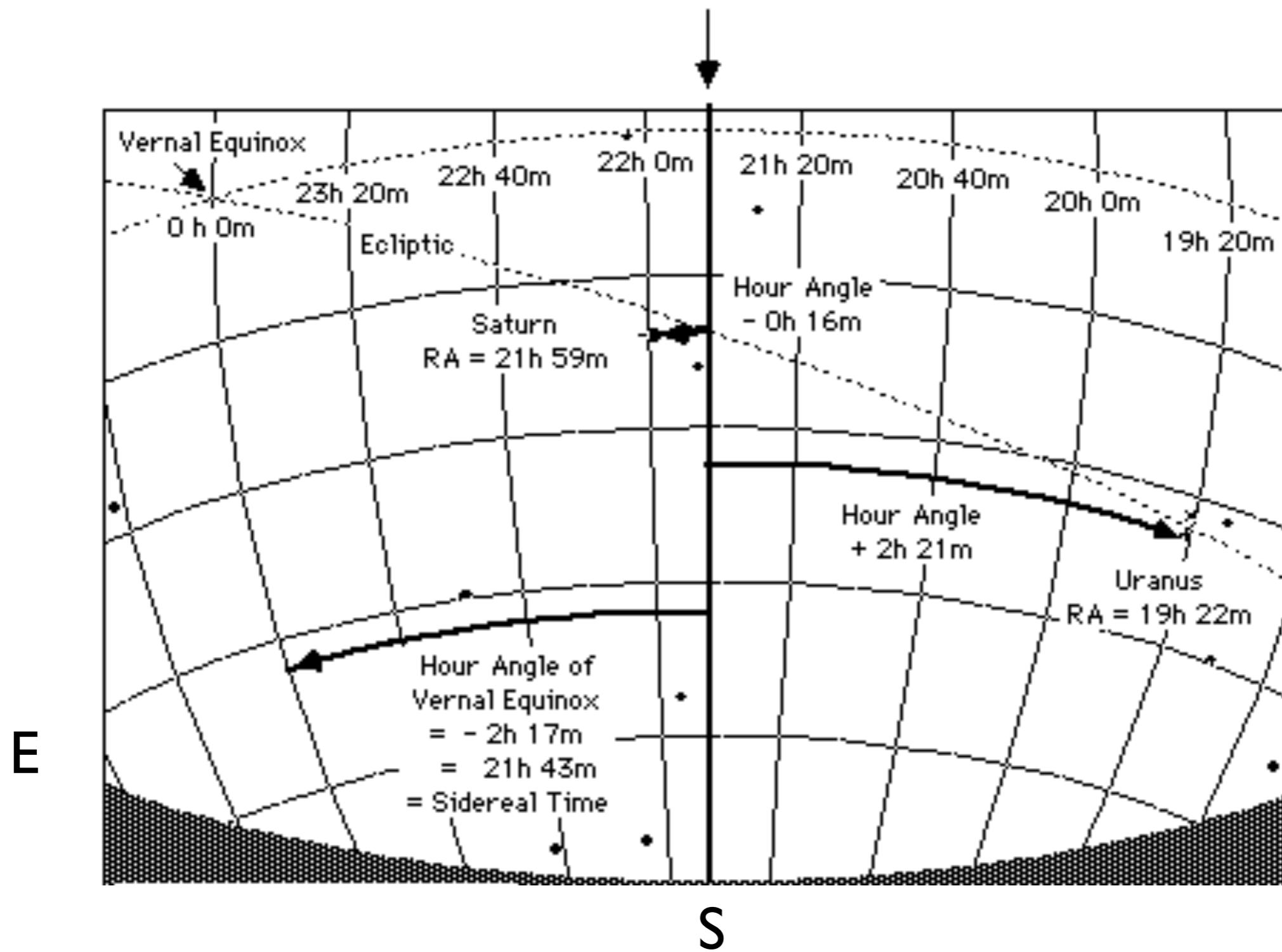
$HA > 0h$: object has already culminated, it is “setting” and in the western half of the sky

$HA < 0h$: 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



$$\text{Sidereal Time} = \text{Right Ascension} + \text{Hour Angle}$$

$$\text{Saturn: } 21\text{h } 59\text{m RA} + (-0\text{h } 16\text{m}) \text{ HA} = 21\text{h } 43\text{m ST}$$

$$\text{Uranus: } 19\text{h } 22\text{m RA} + 2\text{h } 21\text{m HA} = 21\text{h } 43\text{m ST}$$

Equatorial telescope mounts

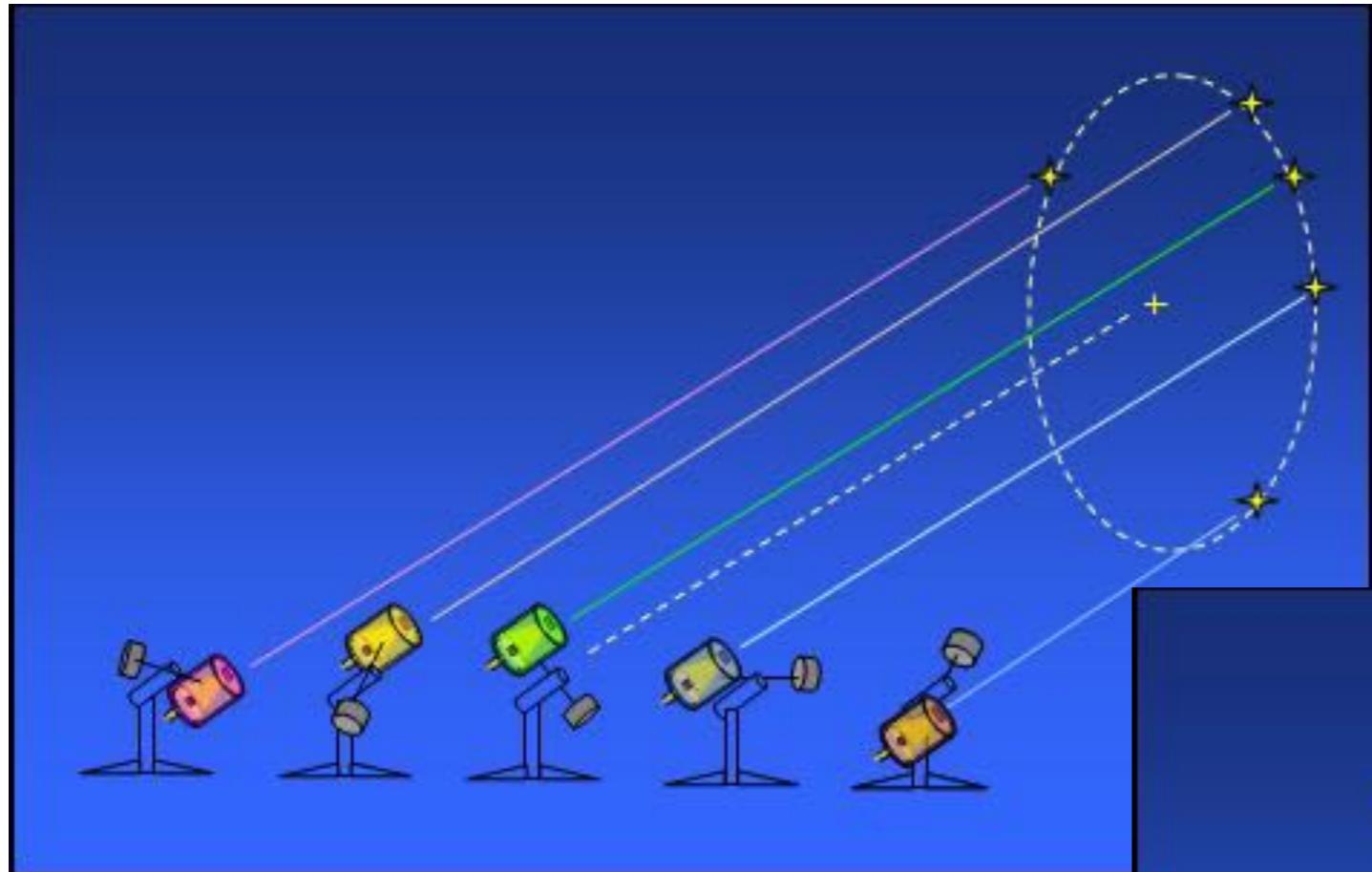
Alt/az mounts: need to track object in two axis, with variable speed

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



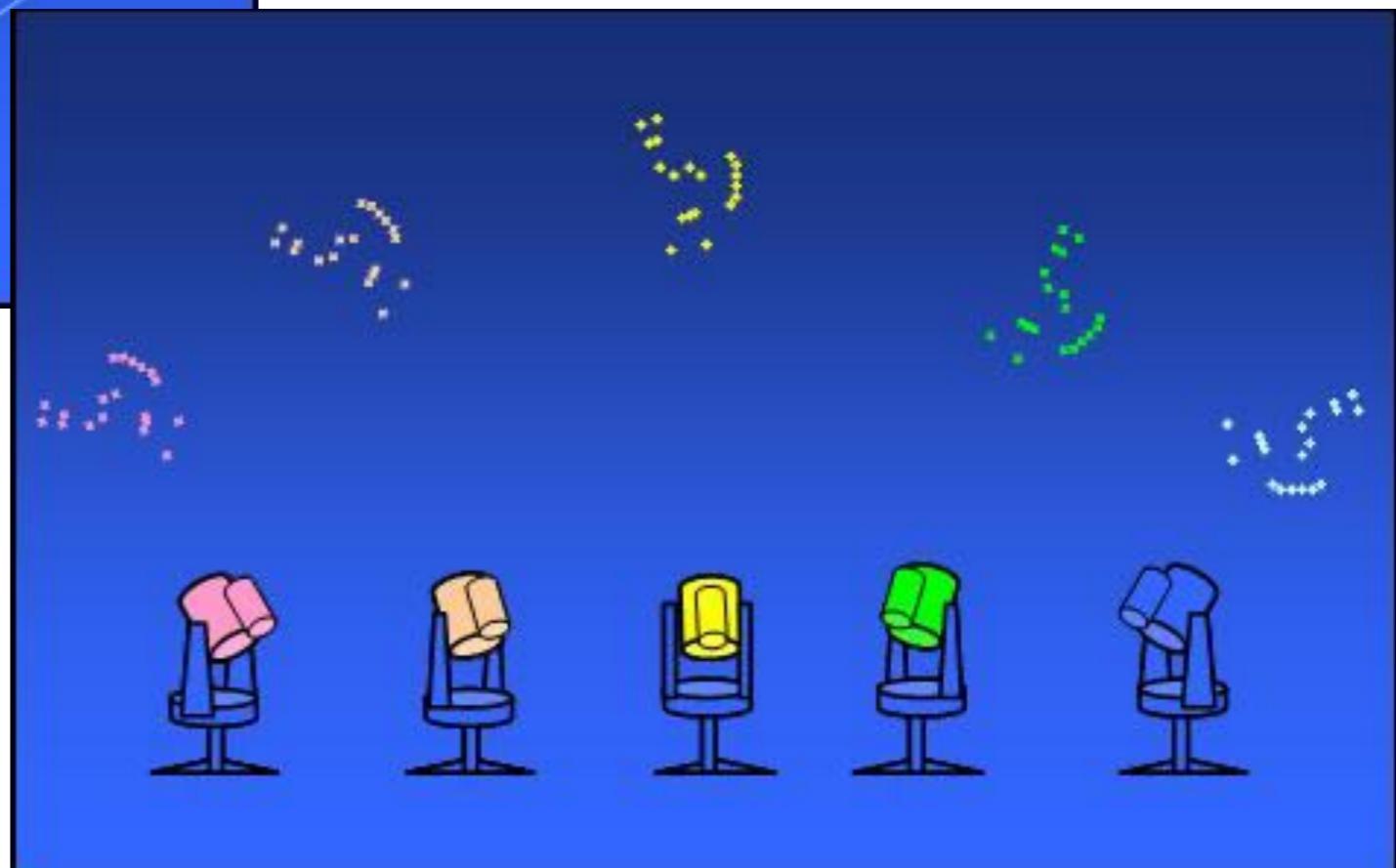
Equatorial telescope mounts

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



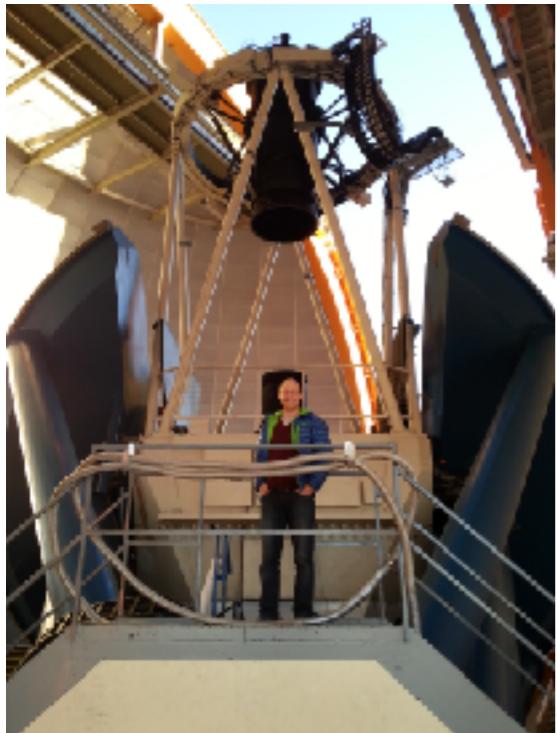
alt/az mount

equ. mount

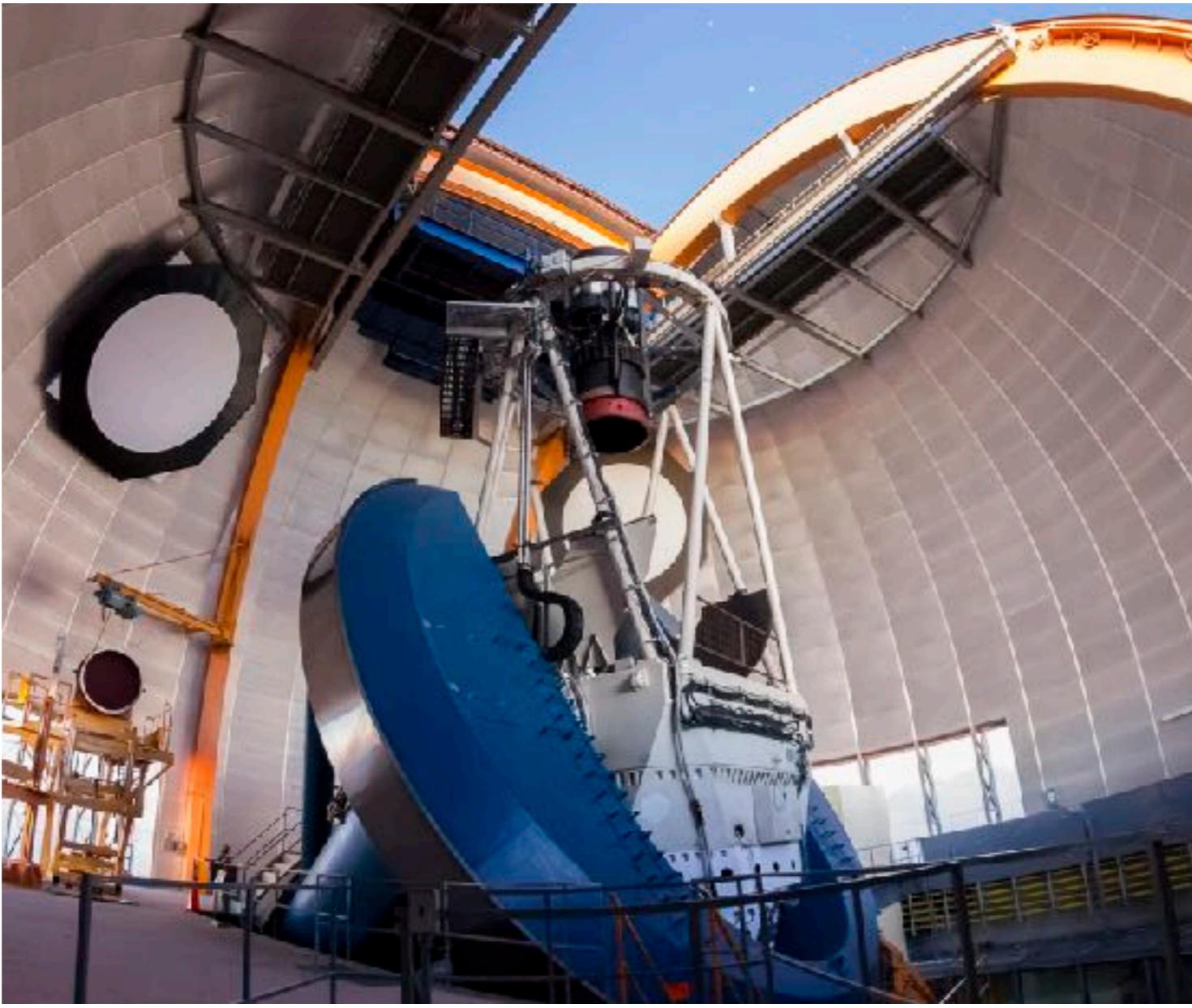


Equatorial telescope mounts

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



K. Bechtold



A. von der Linden

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

EDS Portal Simbad VizieR Aladin X-Match Other Help SIMBAD

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,SS2c2d), 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]

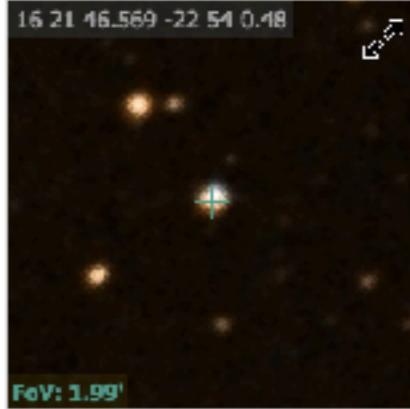
FK4 coord. (ep=B1950 eq=1950) : 16 18 47.99 -22 46 07.8 [60 60 90]

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

Fluxes (4) : B 14.1 [-] V2 B 2003yCatL...29..4688
J 12.696 [0.027] C 2003yCat.2246....oc
H 12.080 [0.024] C 2003yCat.2246....oc
K 11.715 [0.024] C 2003yCat.2246....oc

SIMBAD query around with radius 2 arcmin

Interactive AladinLite view
16 21 46.569 -22 54 0.48



FeV: 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. arcmin	Number of Qual Filter Refs Notes Phot Posn Vel/z Diam Assoc Images Spectra
1	MESSIER 031	00h42m44.3s	-41d16m09s	6	-300 -0.001001	4.36 ...	4055 23 147 20 31 7 2 Retrieve Retrieve

Detailed information for each object

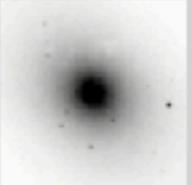
Object No. 1 - MESSIER 031

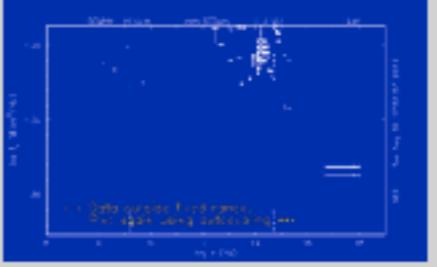
INDEX for MESSIER 031

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](#)

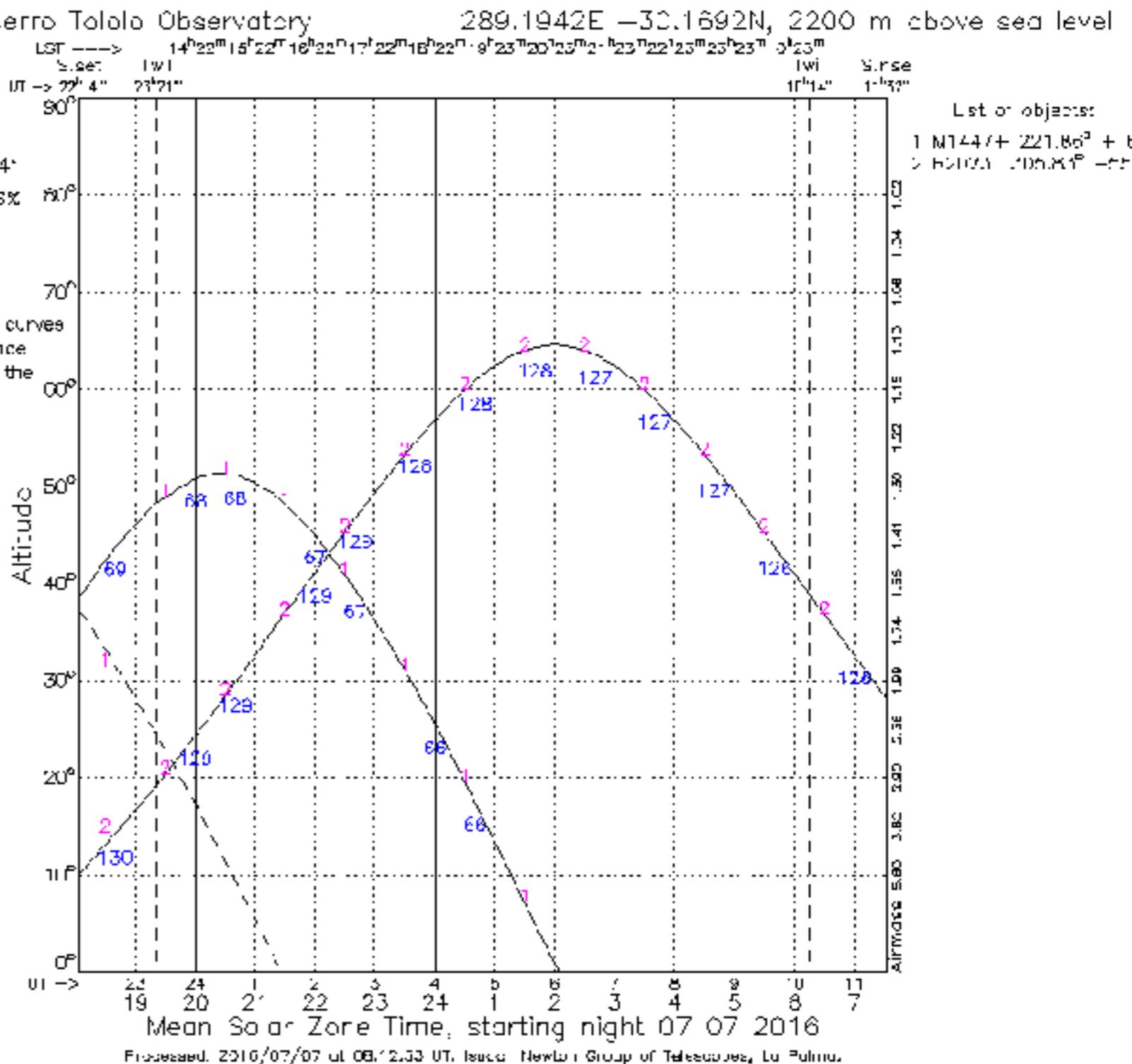
 [147 Photometric data point\(s\) and SED](#)

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)



also see

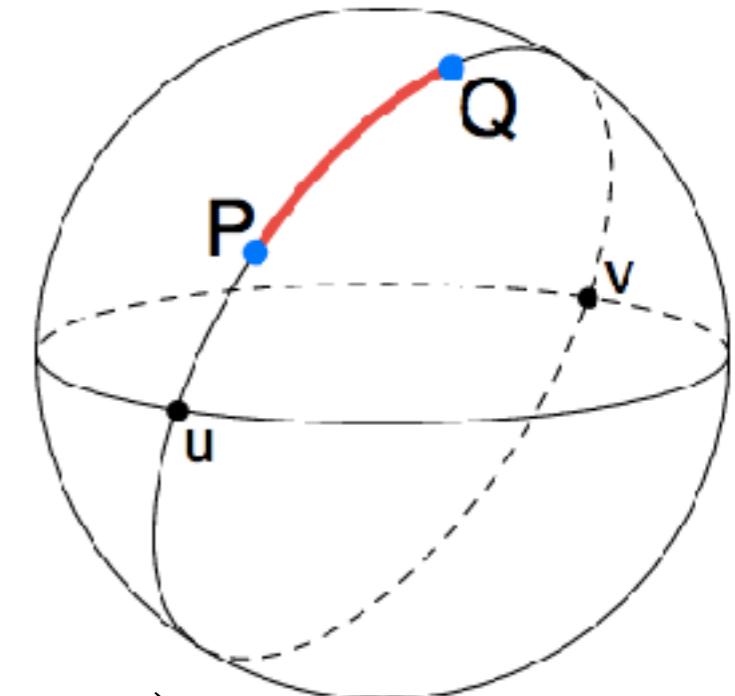
[http://www.briancasey.org/
artifacts/astro/airmass.cgi](http://www.briancasey.org/artifacts/astro/airmass.cgi)

Distance between two objects

two objects at (α_1, δ_1) and (α_2, δ_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

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

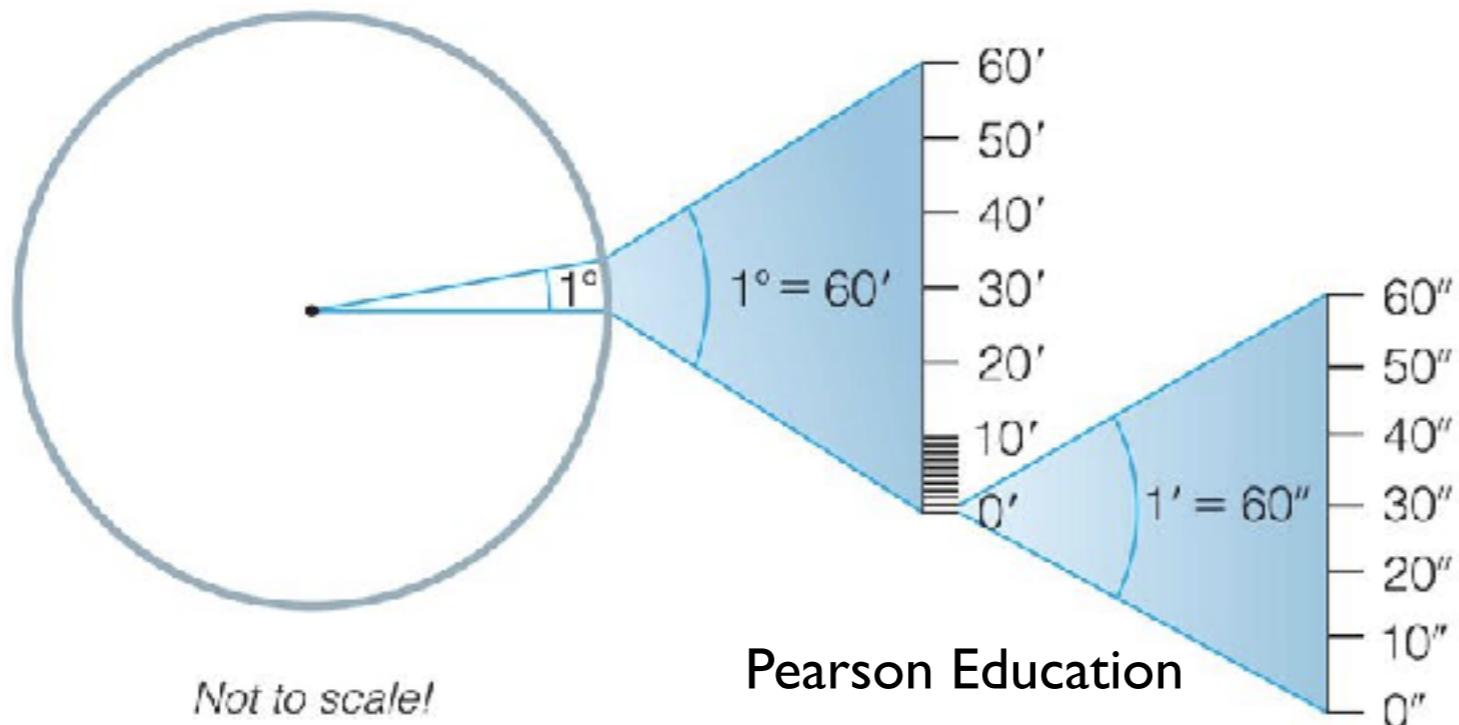


for small distances, can use Euclidian approximation;
HOWEVER, need to include $\cos(\delta)$

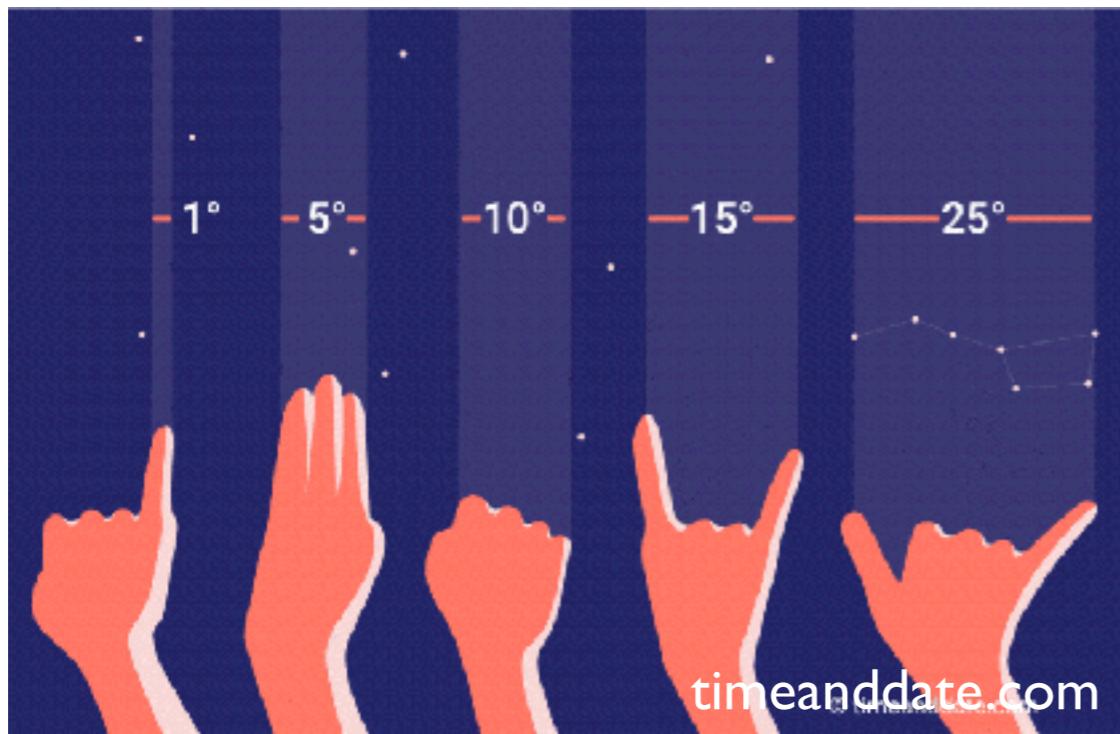
$$\gamma \simeq \sqrt{((\alpha_1 - \alpha_2) \cos(\delta_1))^2 + (\delta_1 - \delta_2)^2}$$

Lengths and distances on the Sky

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

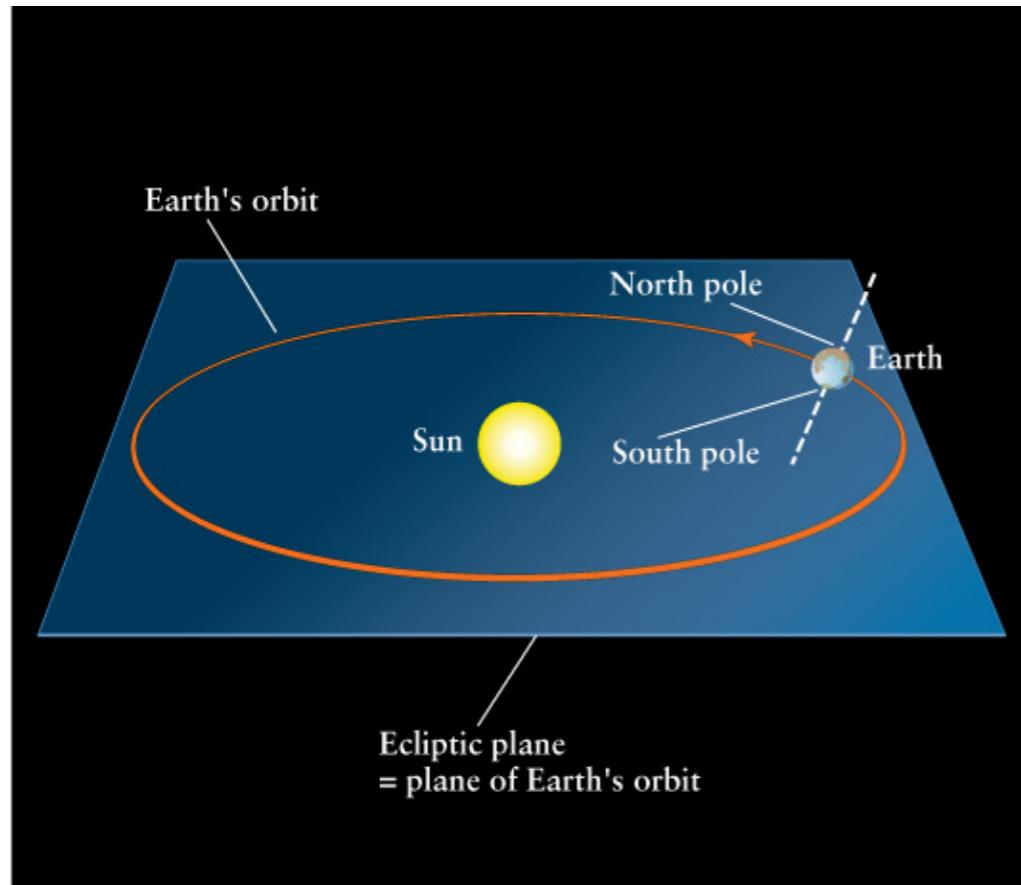


Moon: diameter is
 $\sim 0.5^{\circ} = 30'$

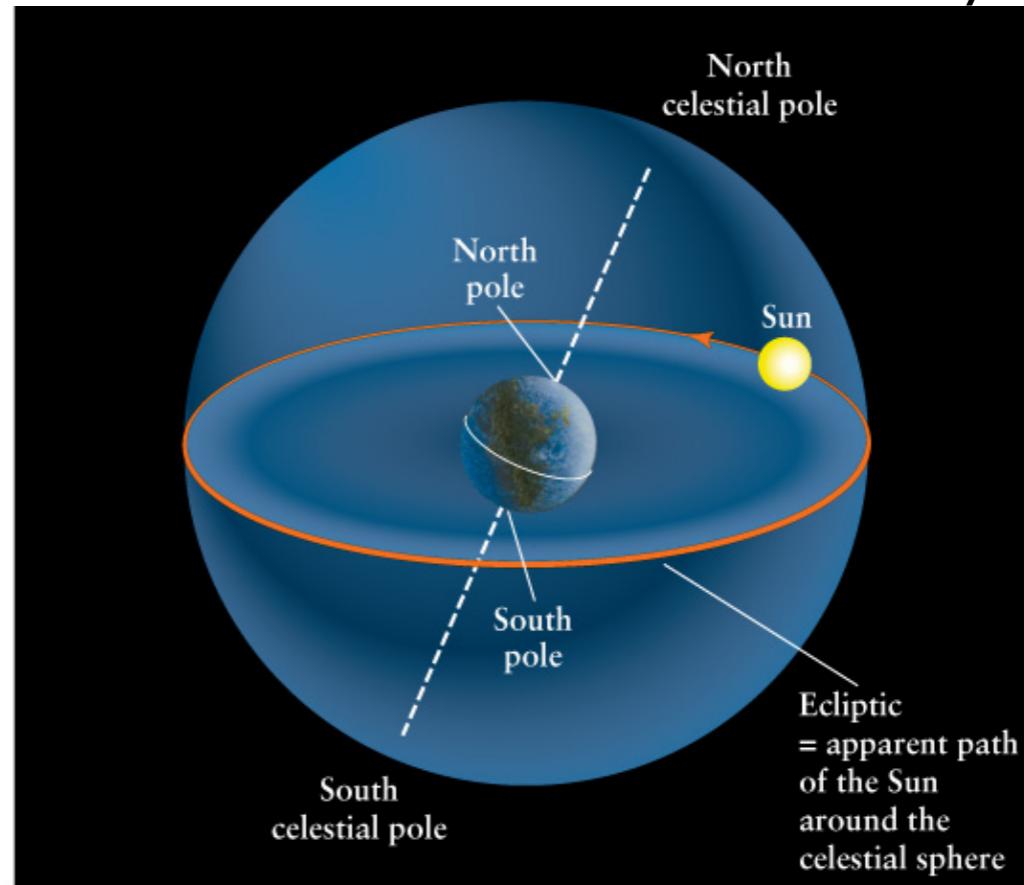


Motion of the Sun in the Sky

Bailey, Slater & Slater



(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

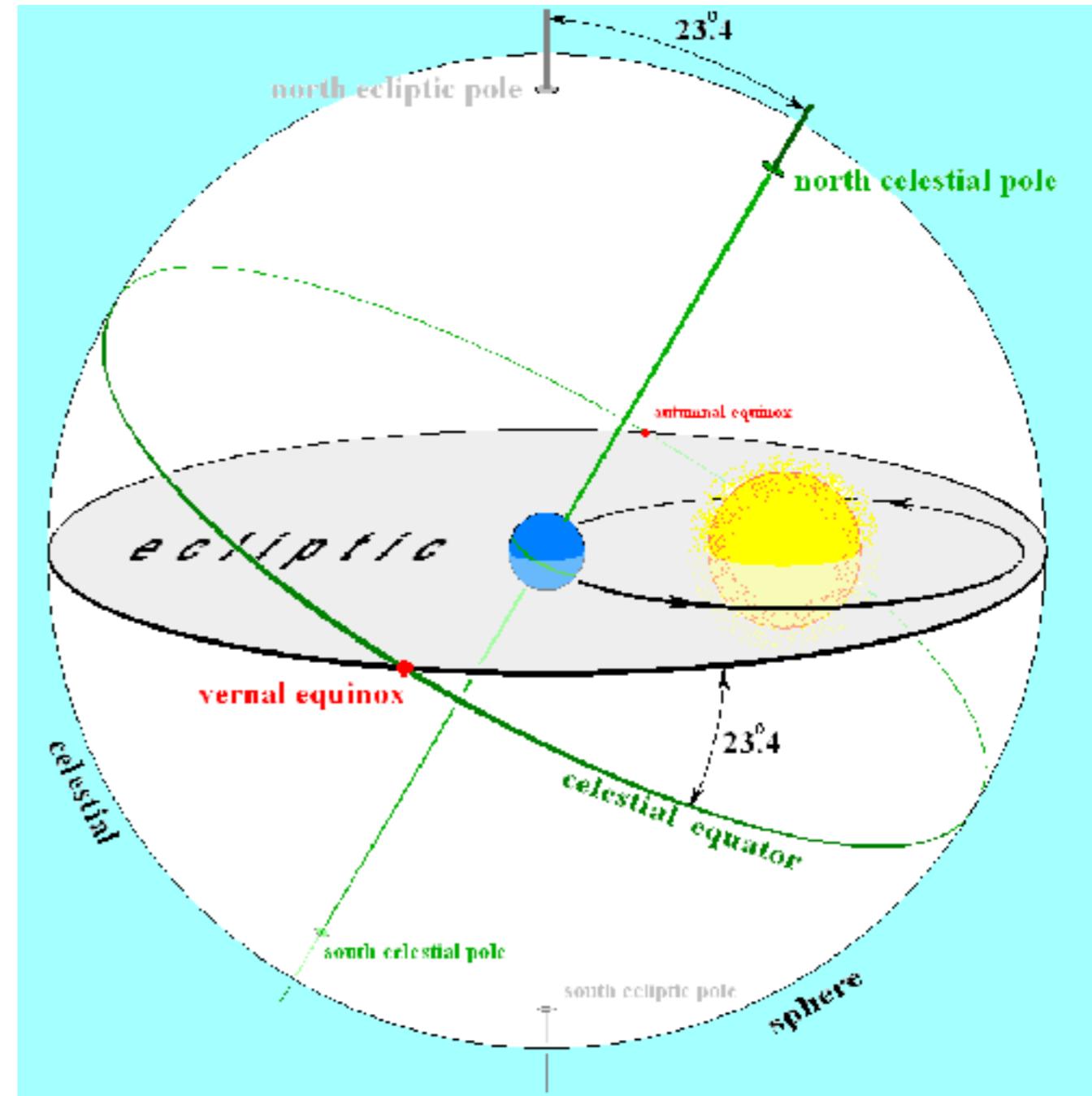
Motion of the Sun in the Sky

Sun travels along the ecliptic

equator and ecliptic intersect in two points:
the equinoxes

why are they called equinoxes?

the vernal (northern spring) equinox marks RA=0h

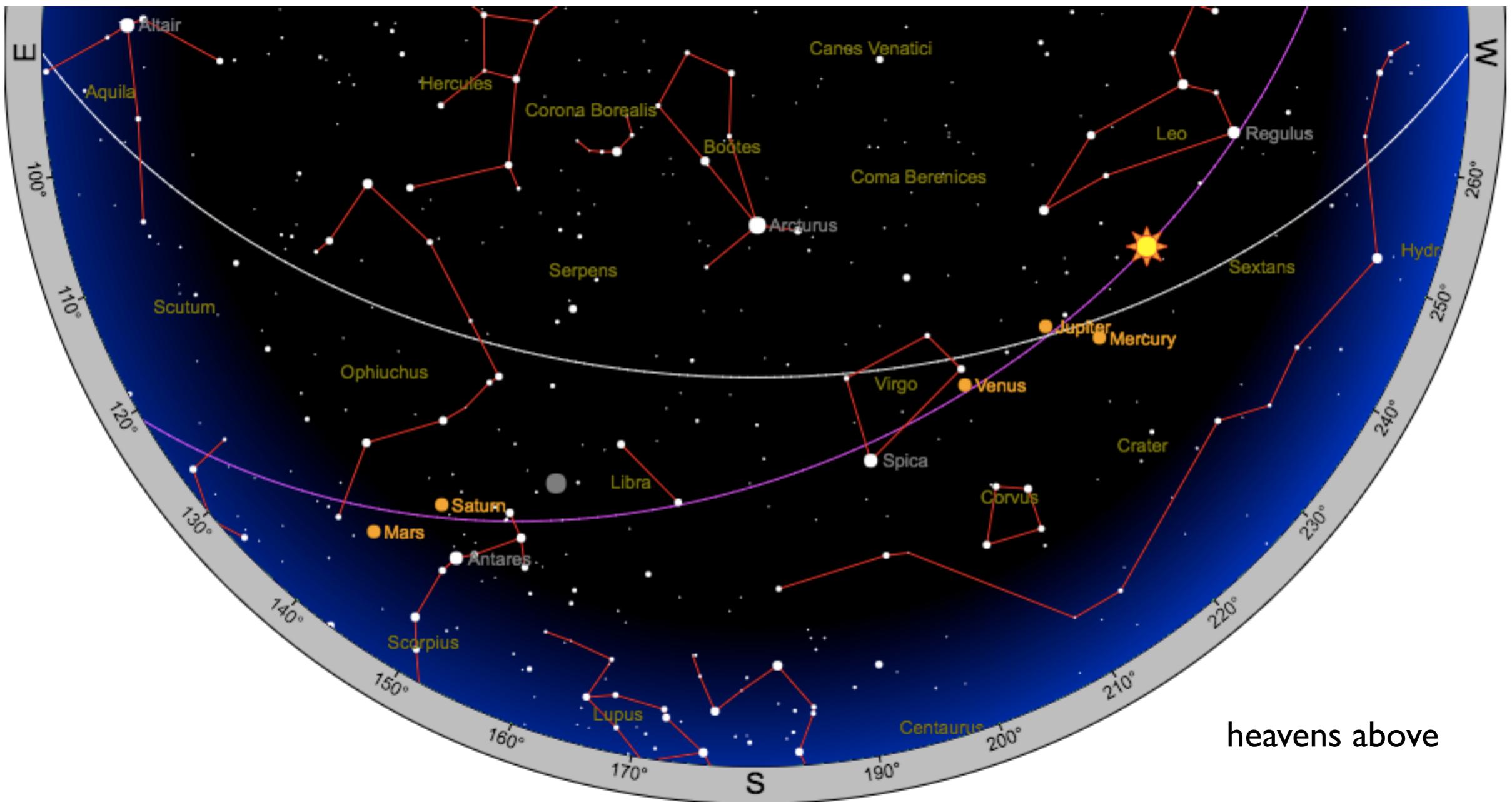


wikipedia

Other Solar System objects

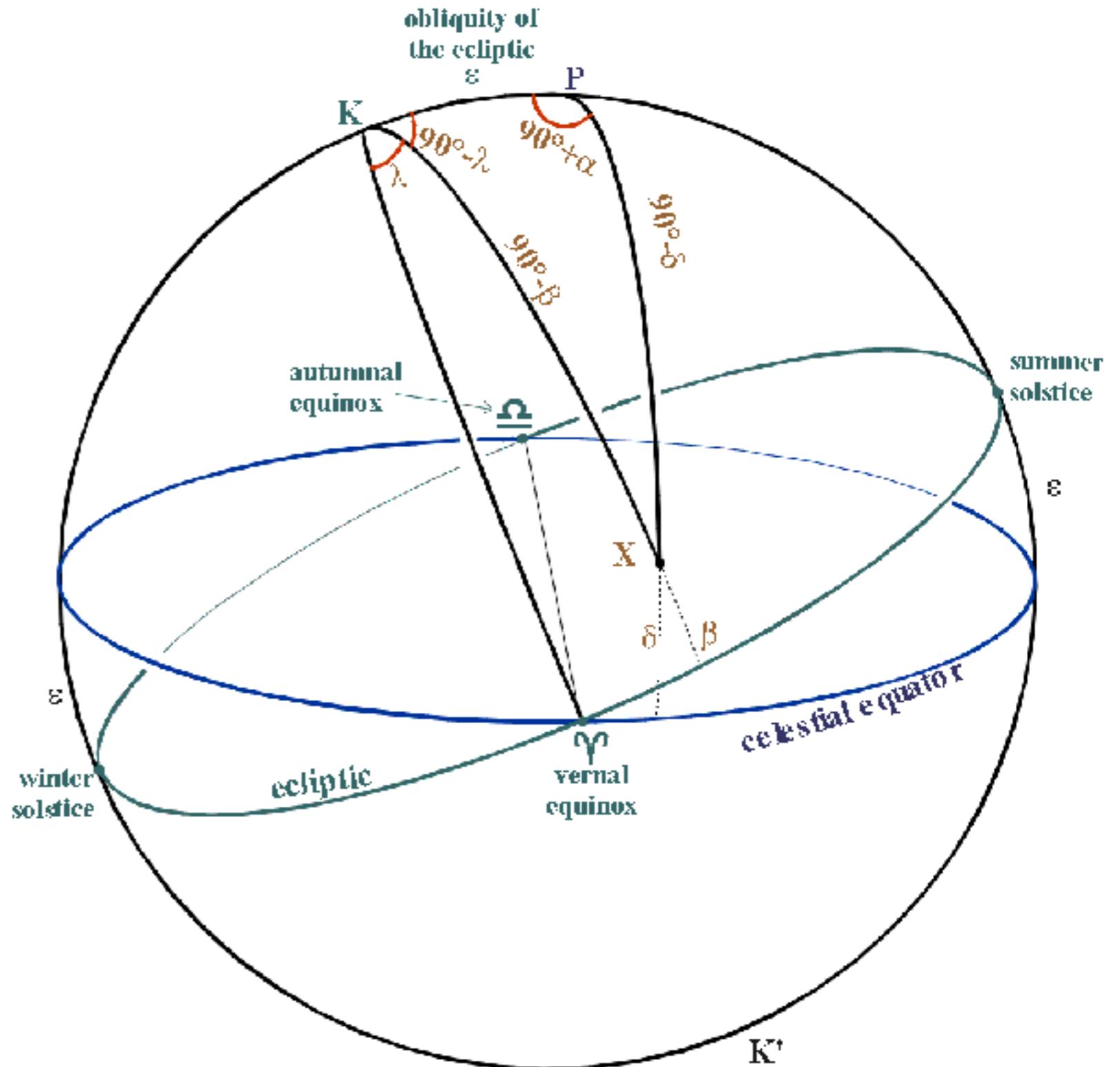
the orbital planes of most planets (and moons) are similar to Earth's orbital plane

→ Moon and planets also approximately follow the ecliptic



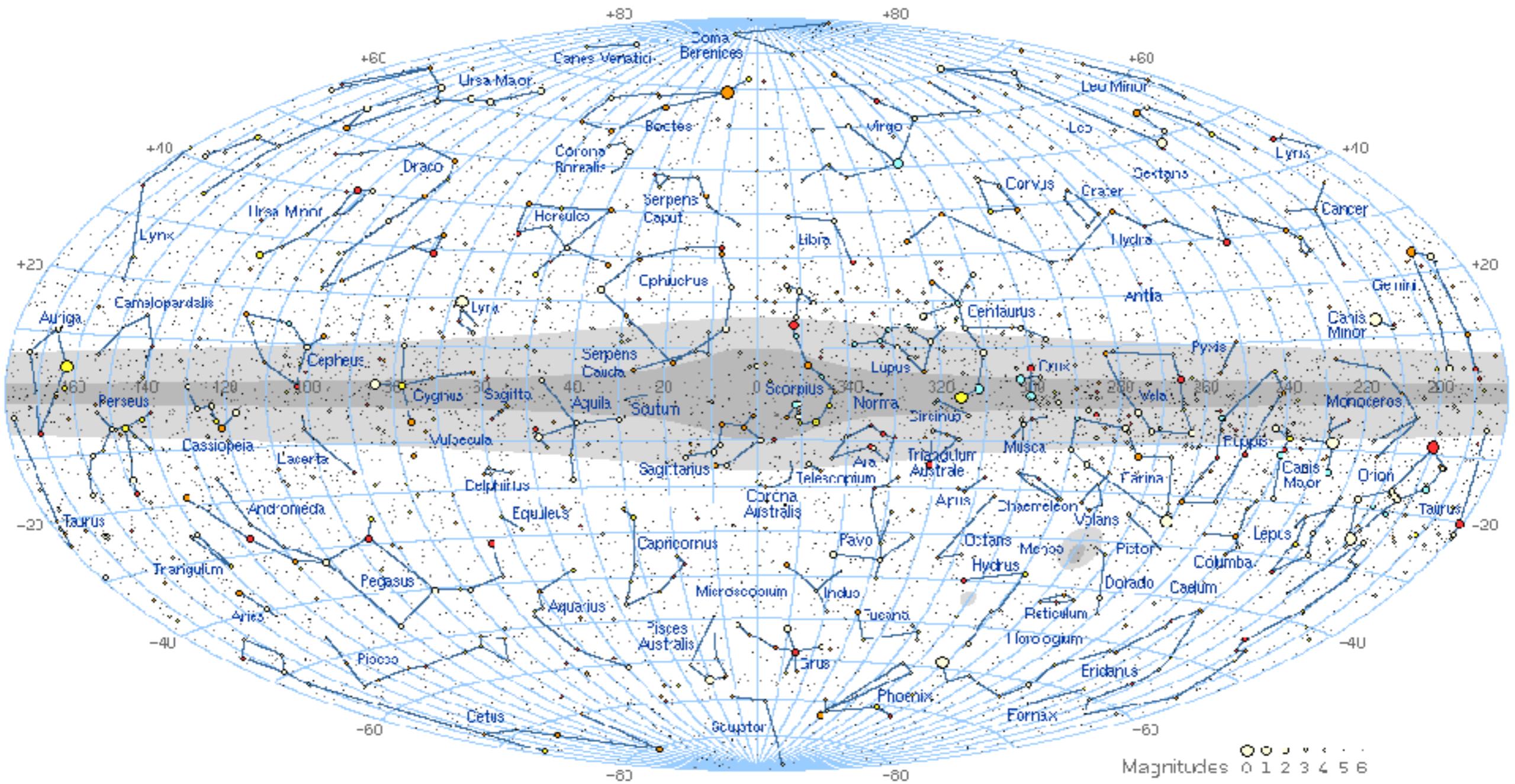
Ecliptic coordinates

use ecliptic as
“equator”



Galactic coordinates

use the plane of the Galaxy as “equator”



Homework 1

- due this Friday!
- please fill out the pre-class questionnaire by tonight
- the HW includes some reading assignments, some questions to answer, assignments to familiarize yourself with Simbad and StarAlt
- also: an assignment to schedule Lab 1 as soon as I tell you your lab groups
- for Wednesday: please bring your laptop!