PHY 517 / AST 443:
Observational Techniques in Astronomy

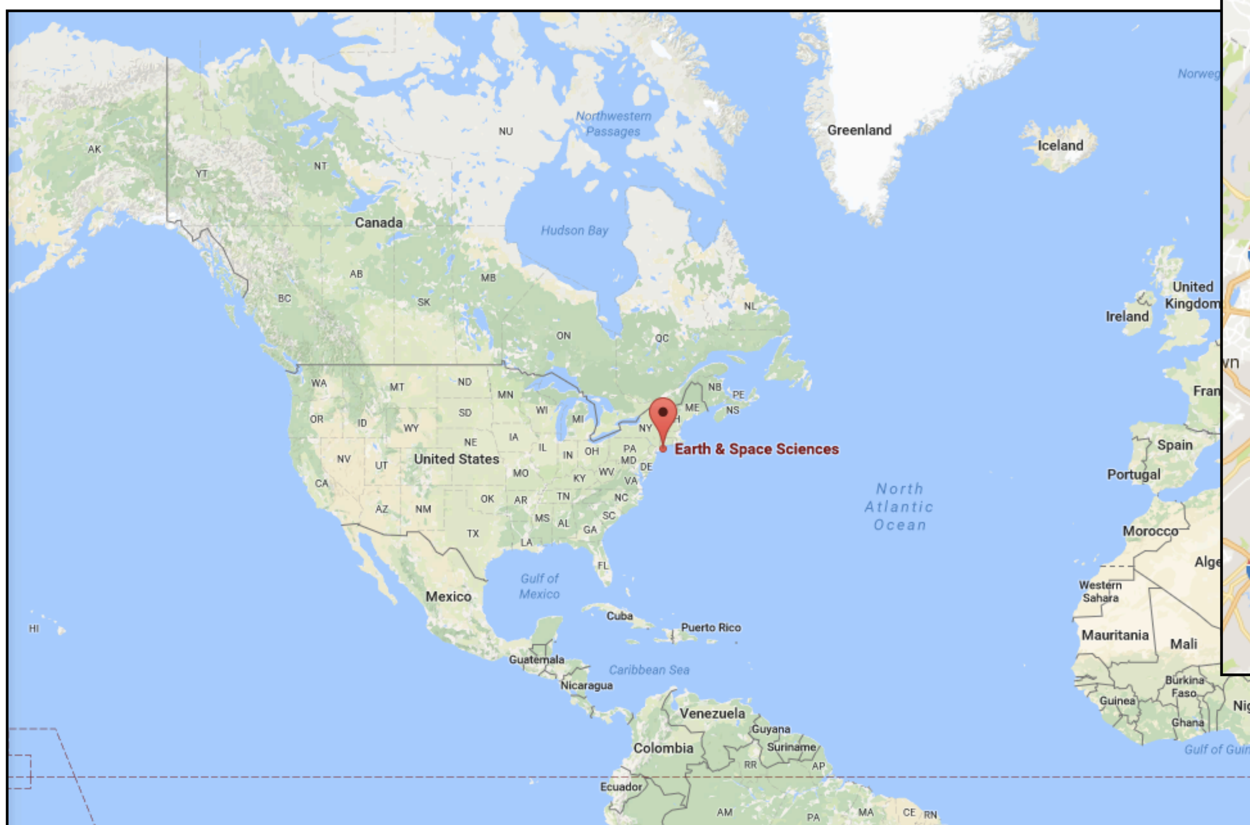
Lecture 1:
How to find things in the Sky /
Astronomical Coordinate Systems

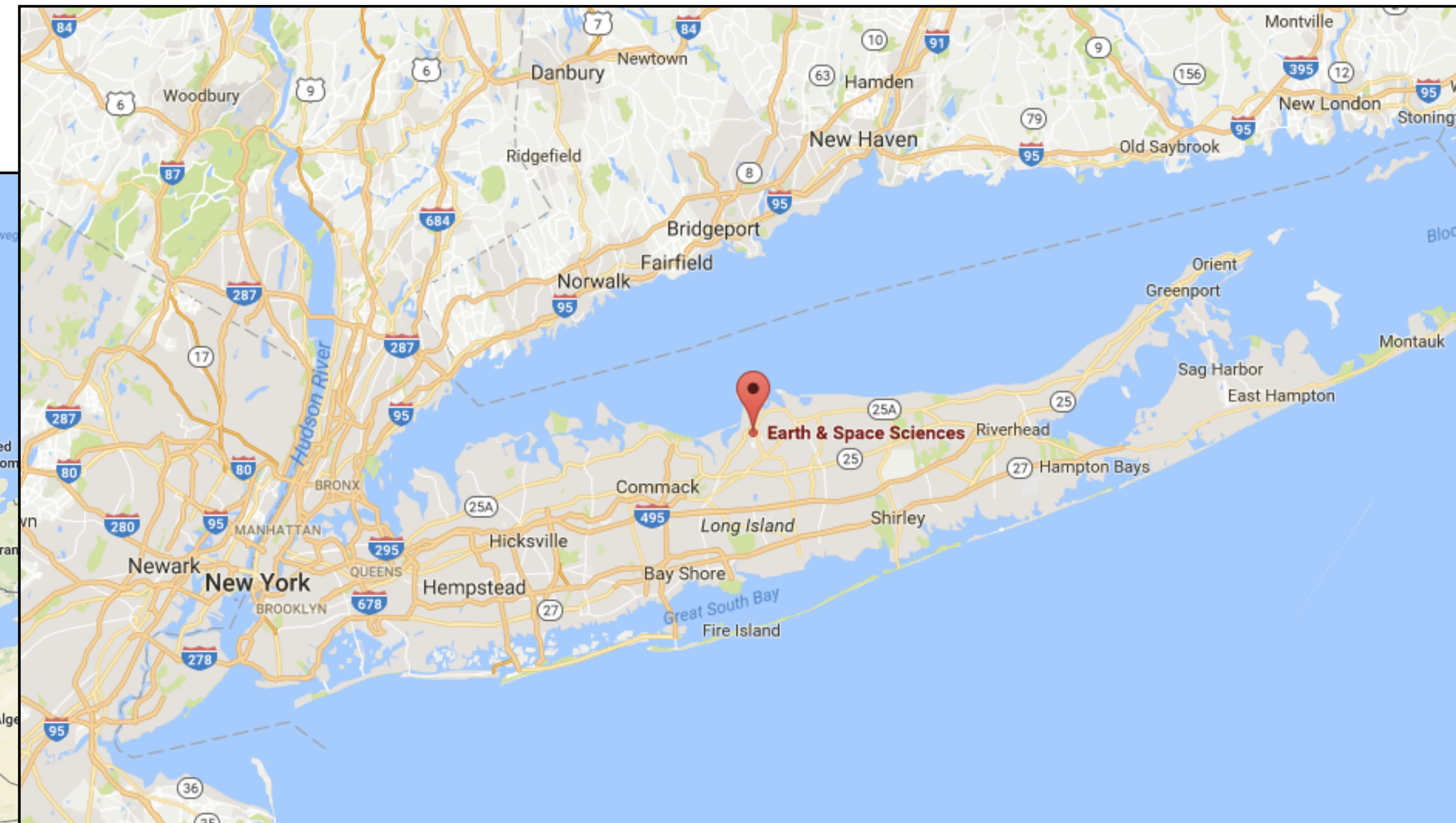
How do you find things in the Sky?

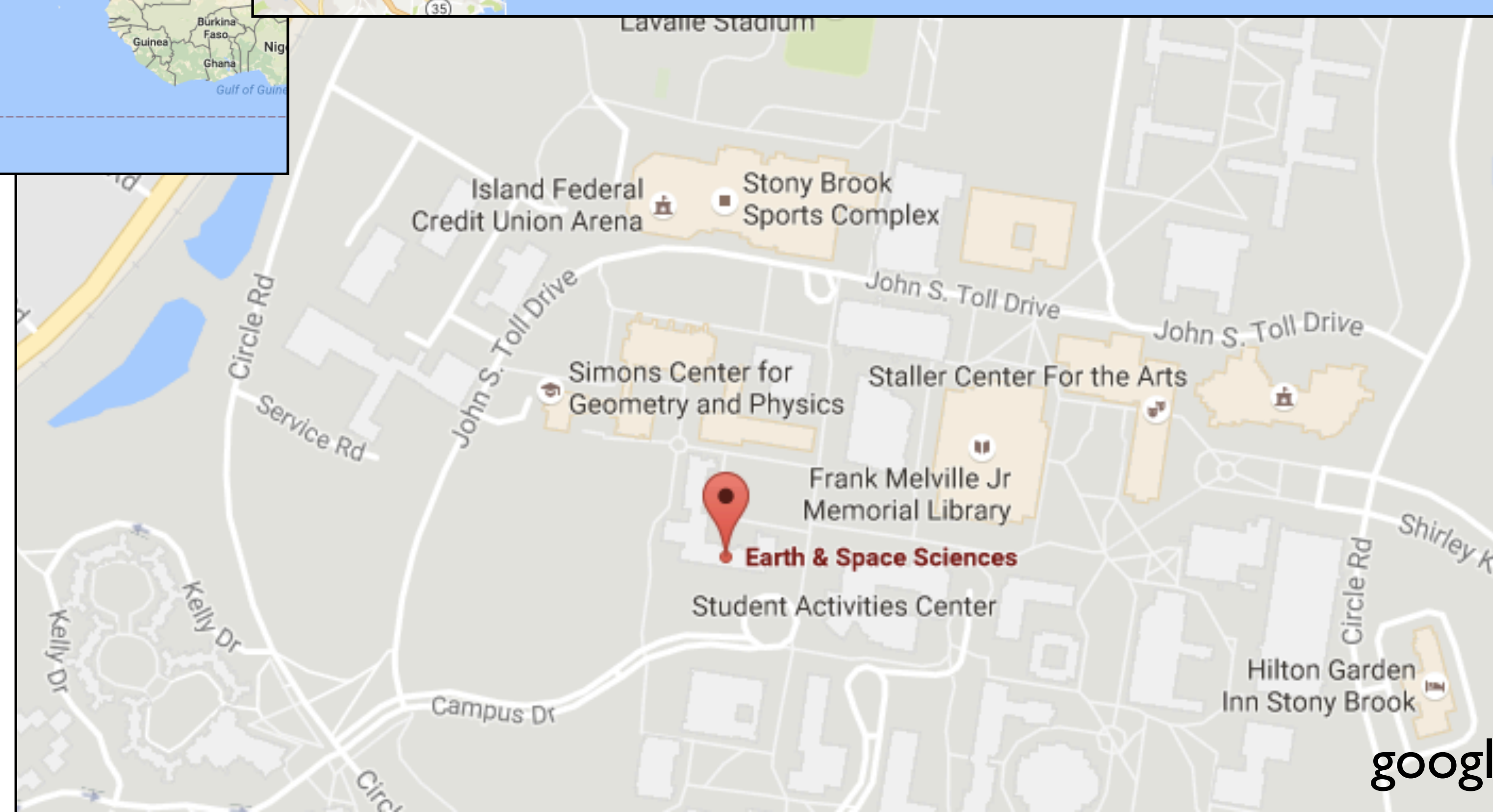
How do you find things on Earth?

How do you find things on Earth?

1. maps





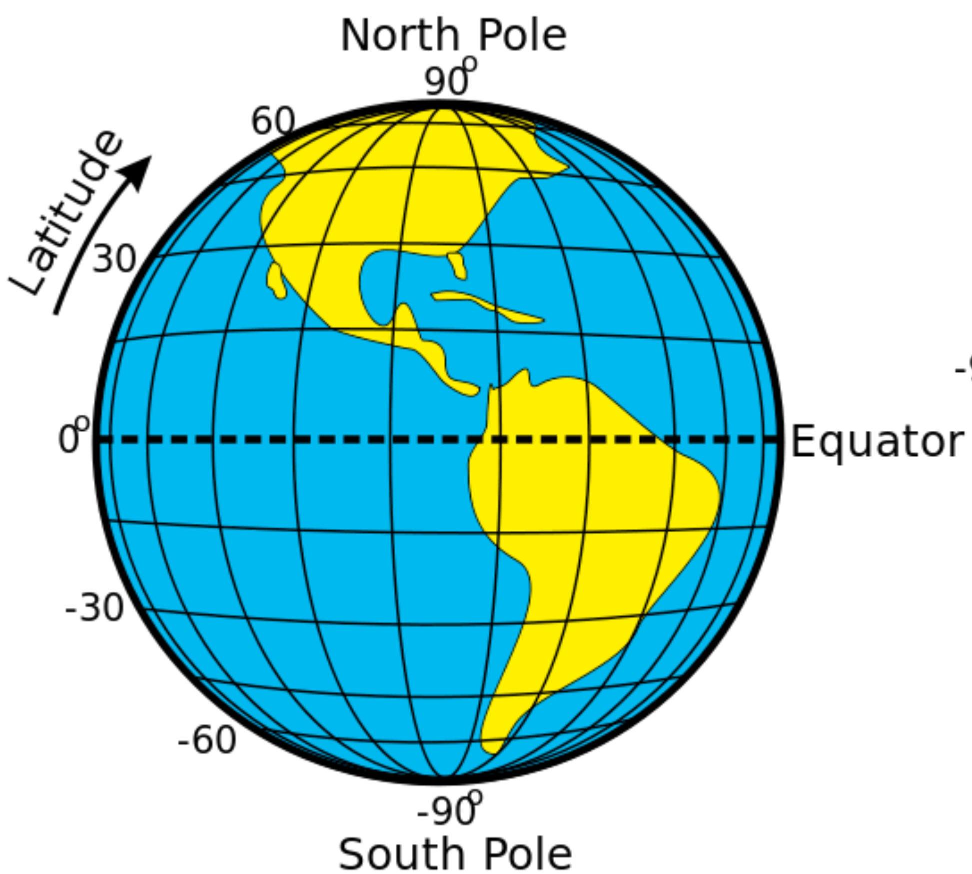


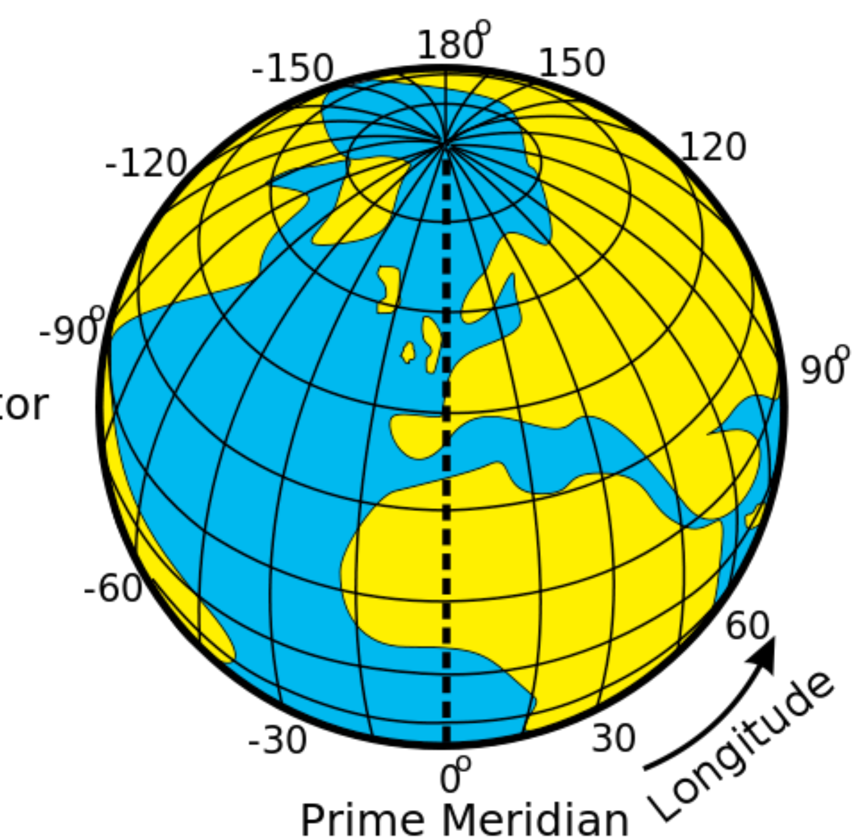
"pattern matching"

google.com

How do you find things on Earth?

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





Coordinates: 40.914224°N 73.11623°W

Stony Brook University

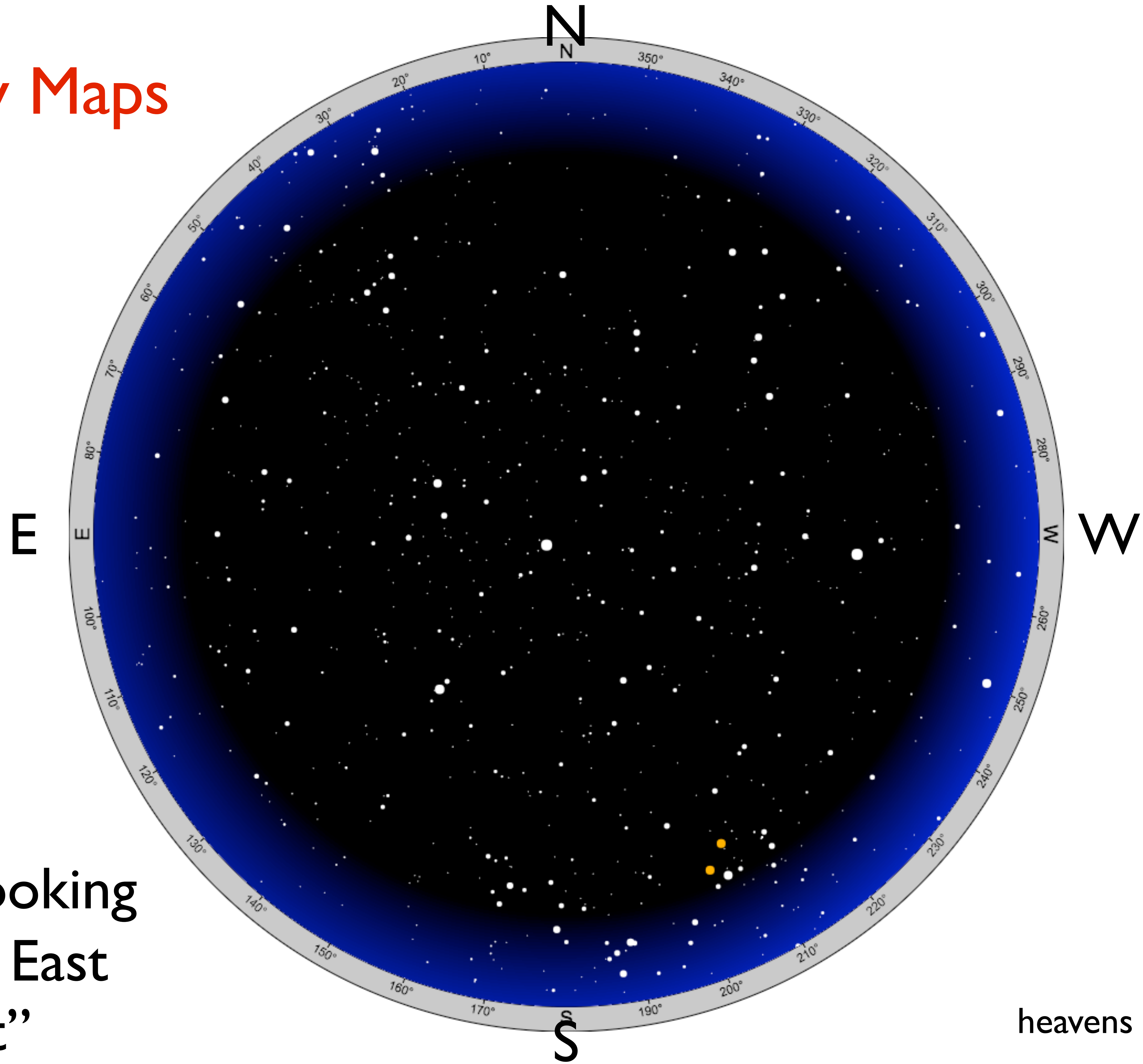
Former names	State University College on Long Island (1957–1962)
Type	• Public • Research university • Sea-grant • Space-grant
Established	1957
Endowment	$247.4 million (2015)[1]
President	Samuel L. Stanley
Provost	Dennis Assanis
Academic staff	2,471 (fall 2013)
Students	21,115 (West Campus)[2] 3,847 East Campus[2] 310 Southampton[2] 25,272 **Total**
Undergraduates	16,831 (2015 Fall)[2]
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

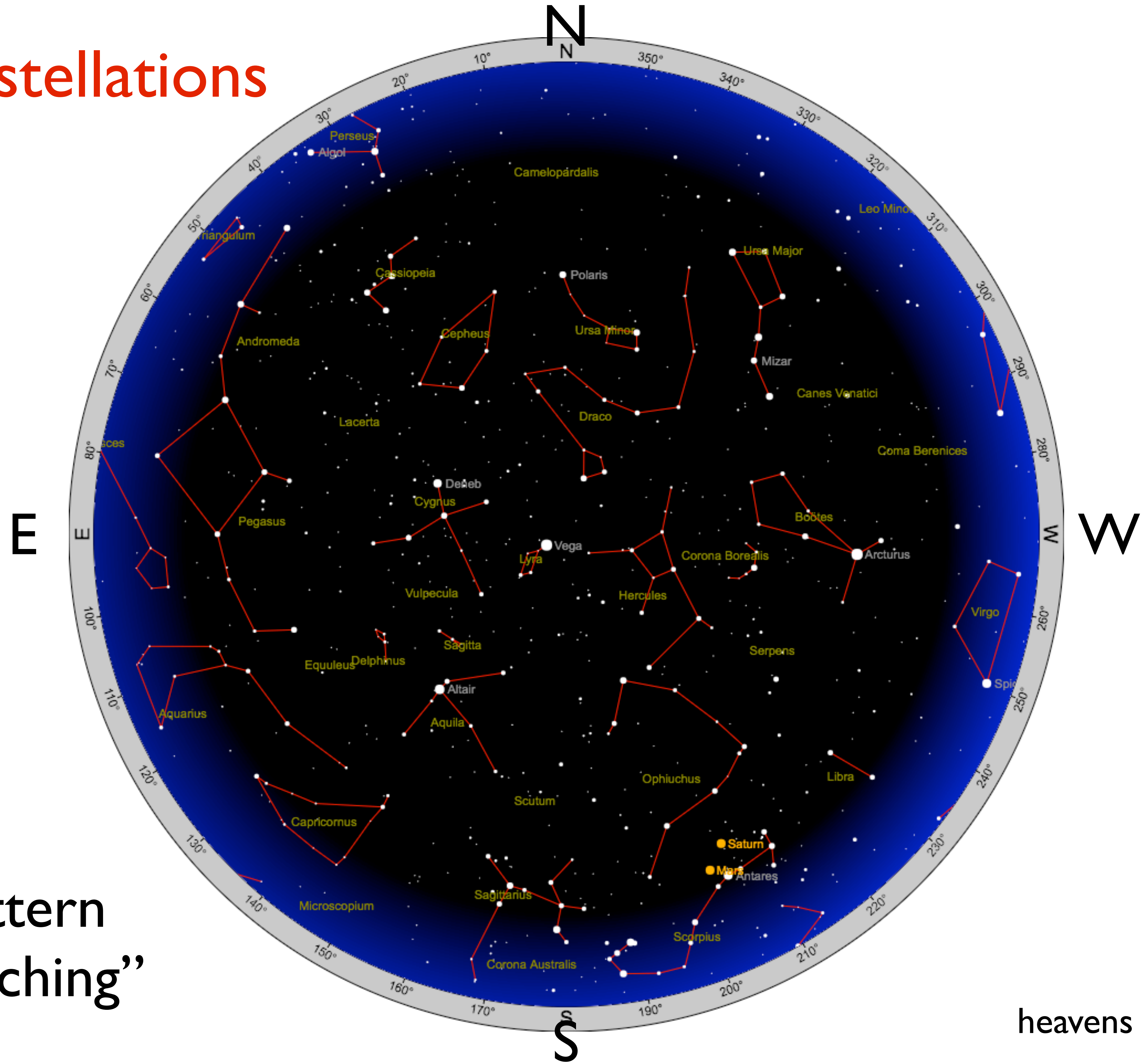
Sky Maps



NB: looking up → East is "left"

heavens above

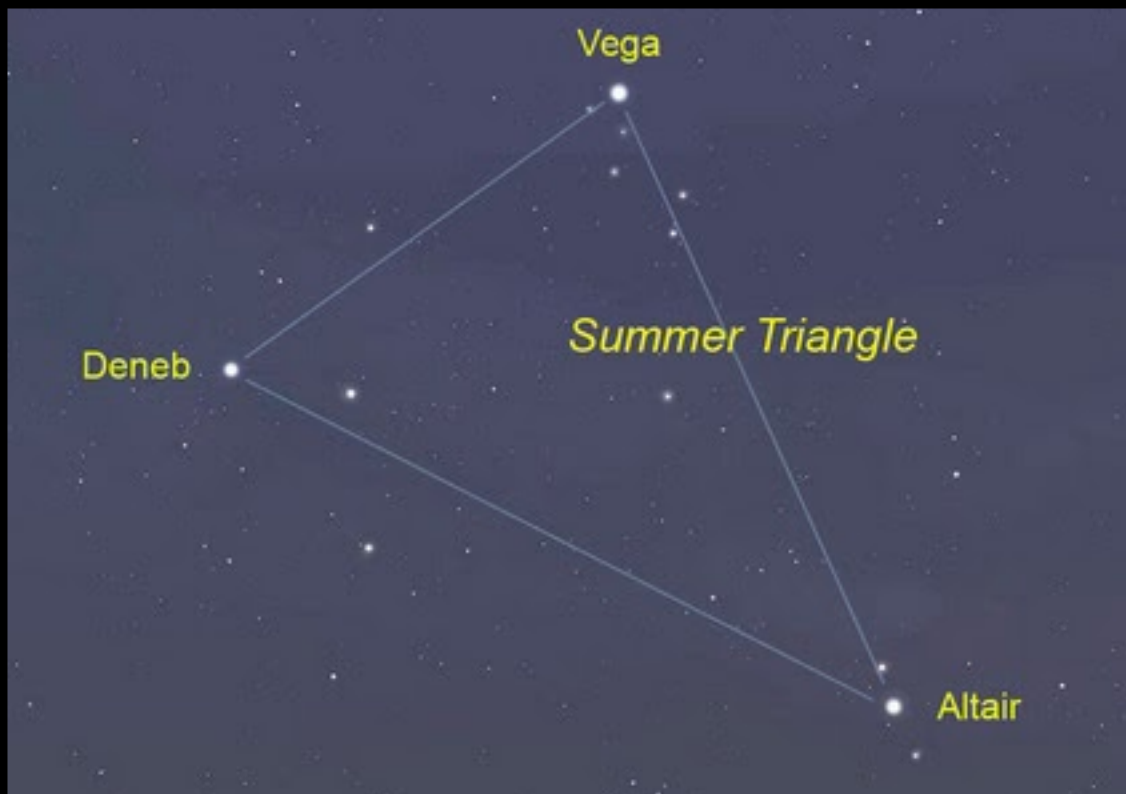
Constellations



“pattern matching”

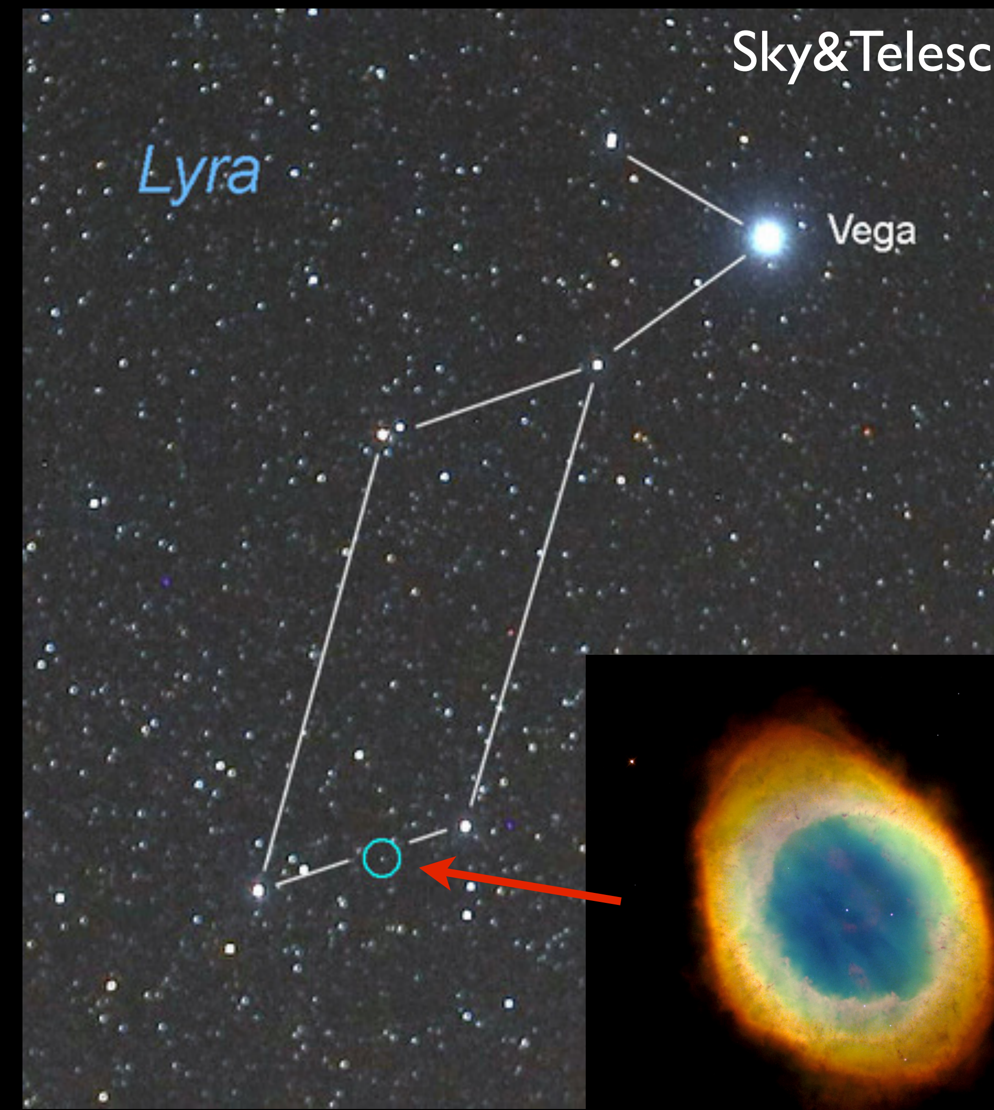
heavens above

How to find the Ring Nebula (M57)



AstroBob / Stellarium

Sky&Telescope



NASA

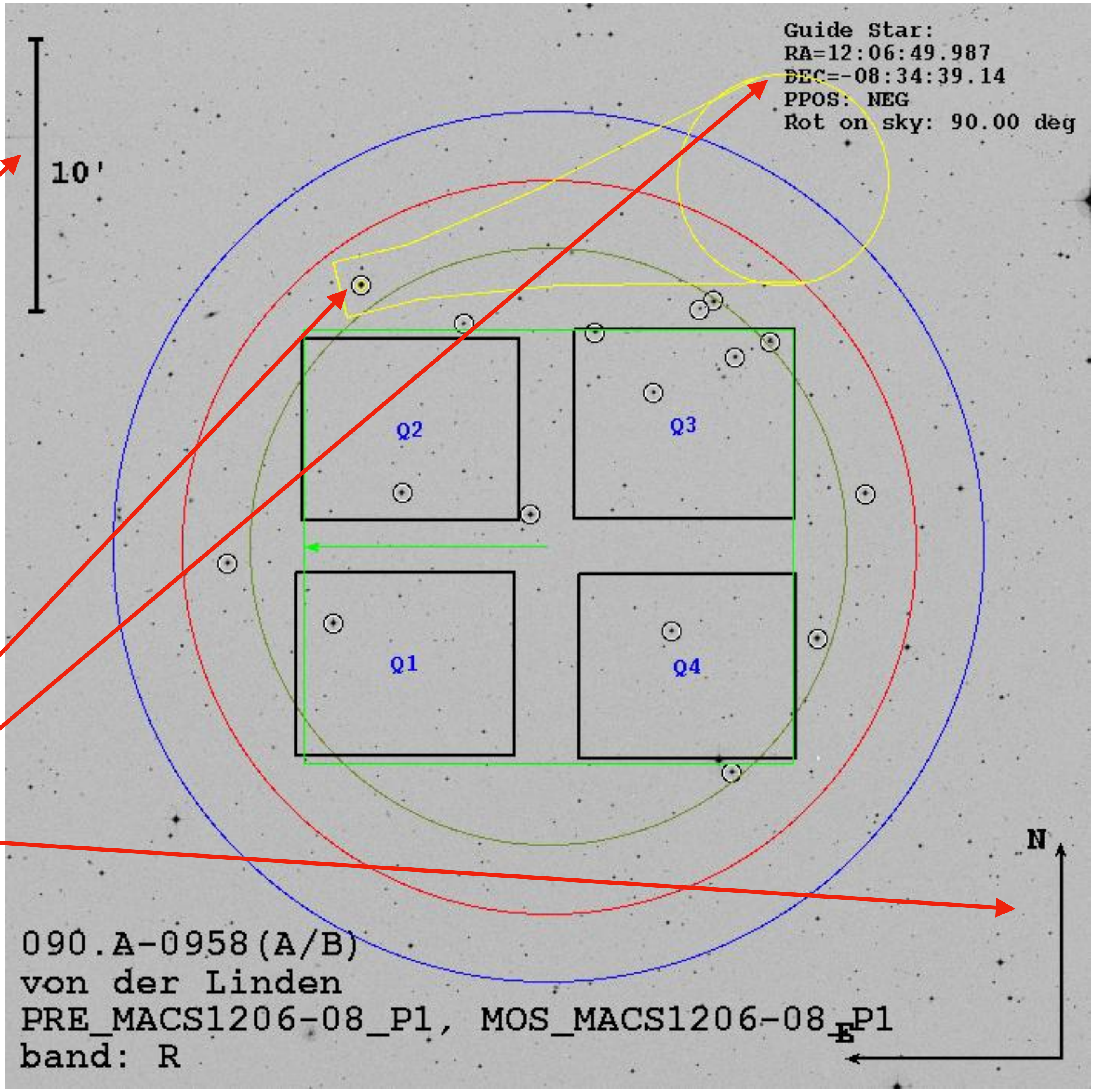
asterisms: easy-to-recognize star groupings

constellations: officially defined sky regions, based on historical asterims

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

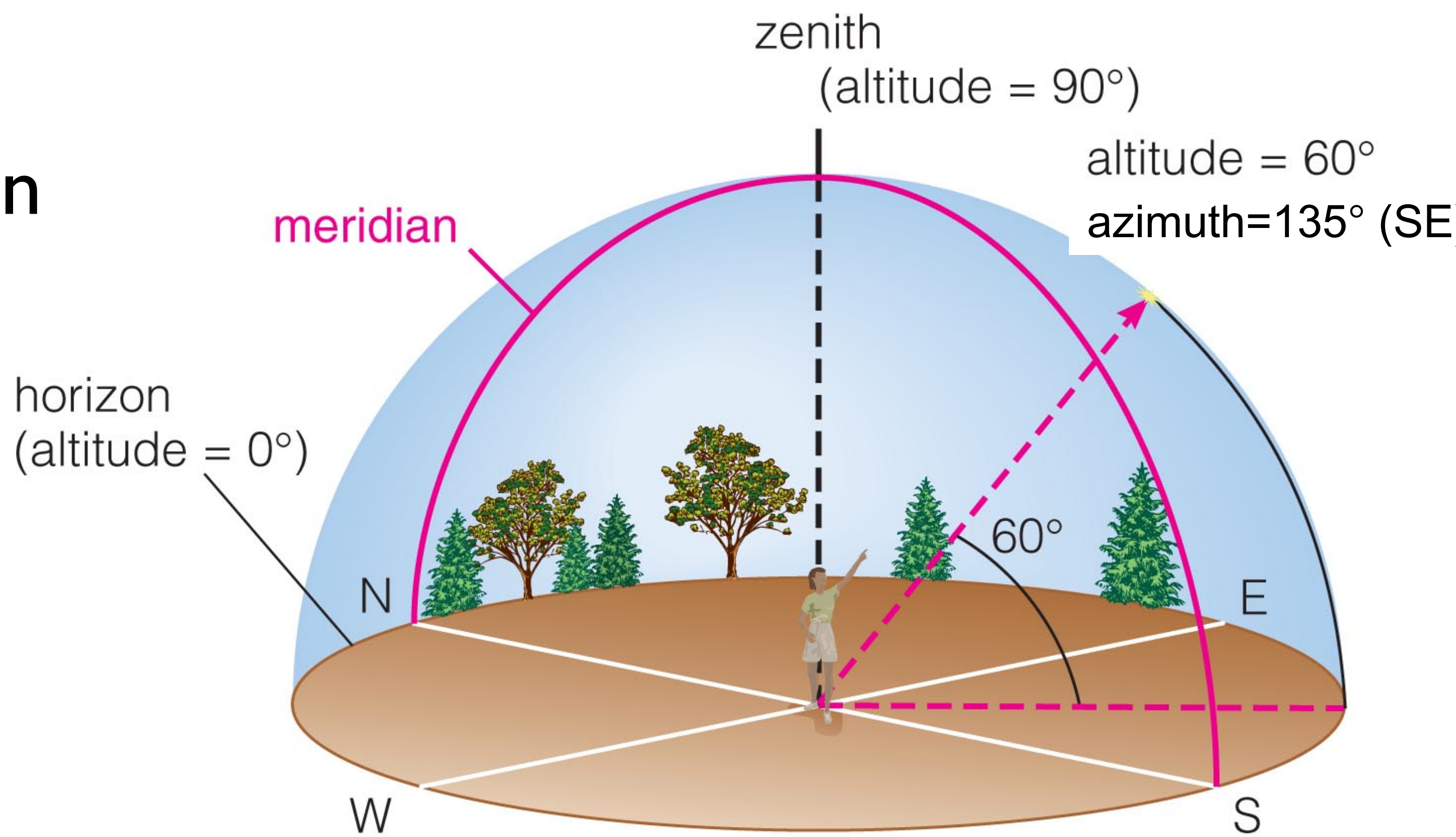
the sky above *a specific location*, *at a specific time*, is half a sphere - can be described with 2 (positive) angular coordinates

altitude: angular distance to the horizon

azimuth: angular distance from north

zenith: point overhead

meridian: north-south line

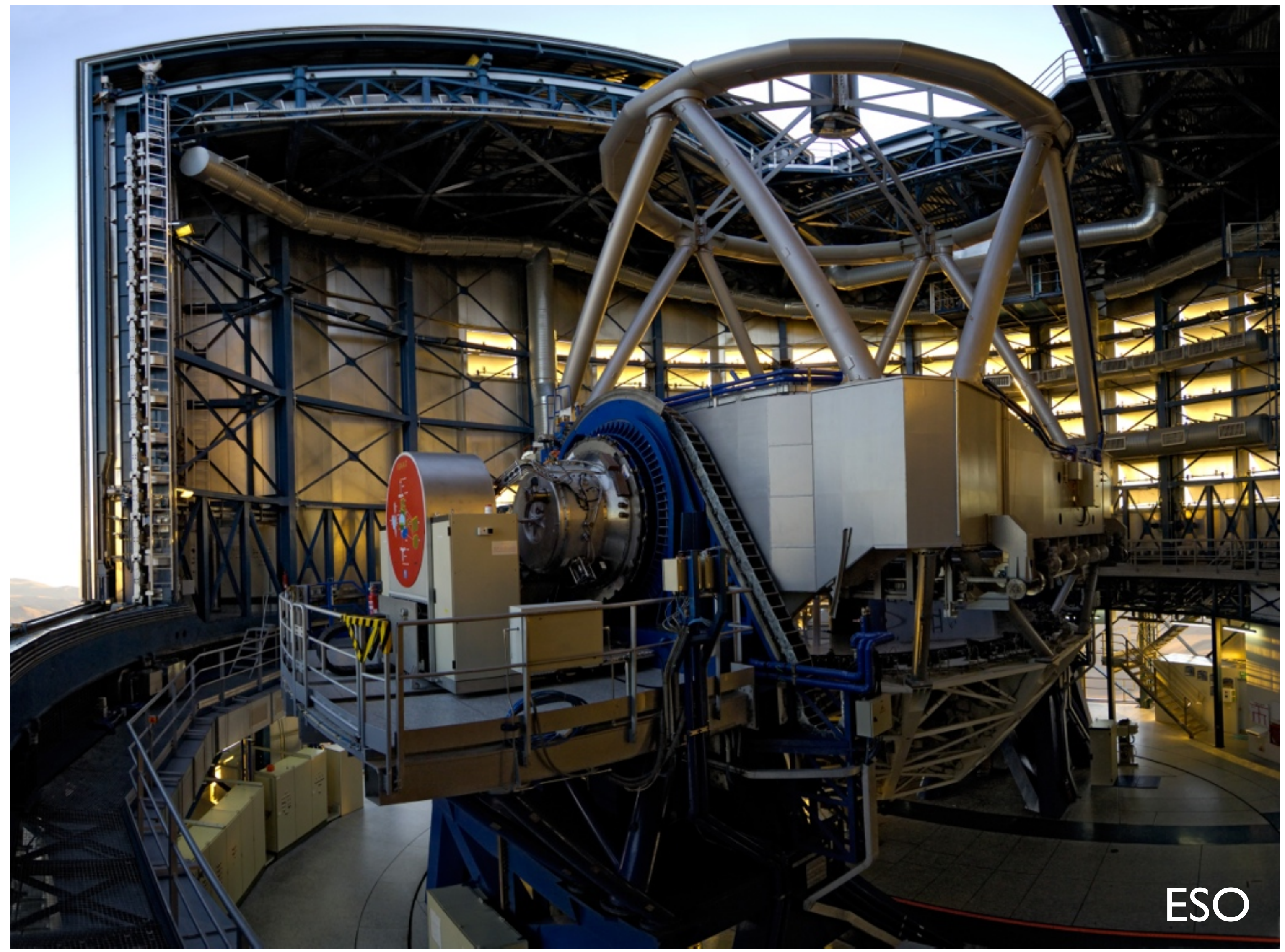


Pearson Education

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

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

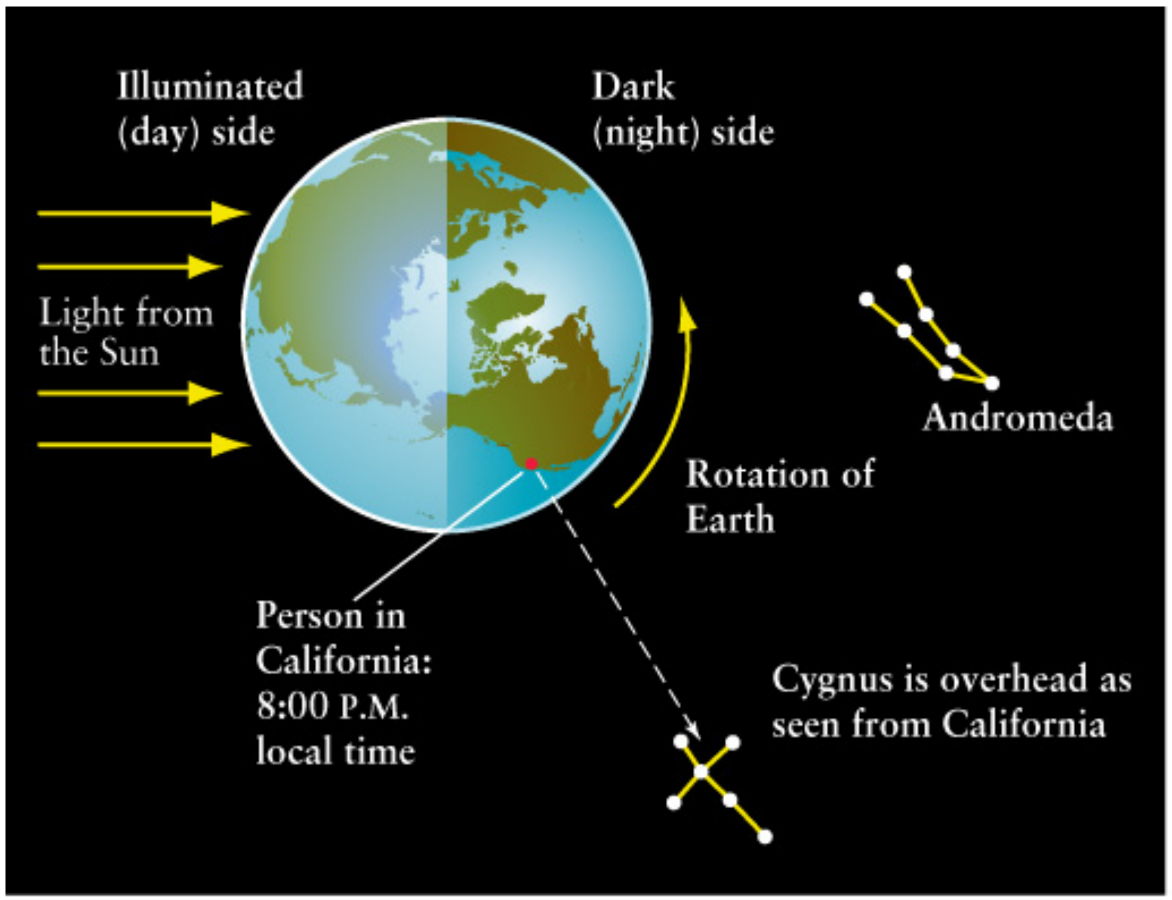
is my target “up” ? (altitude > 0°)

is my target “observable” ? (altitude > 30° / 40° / 50°)

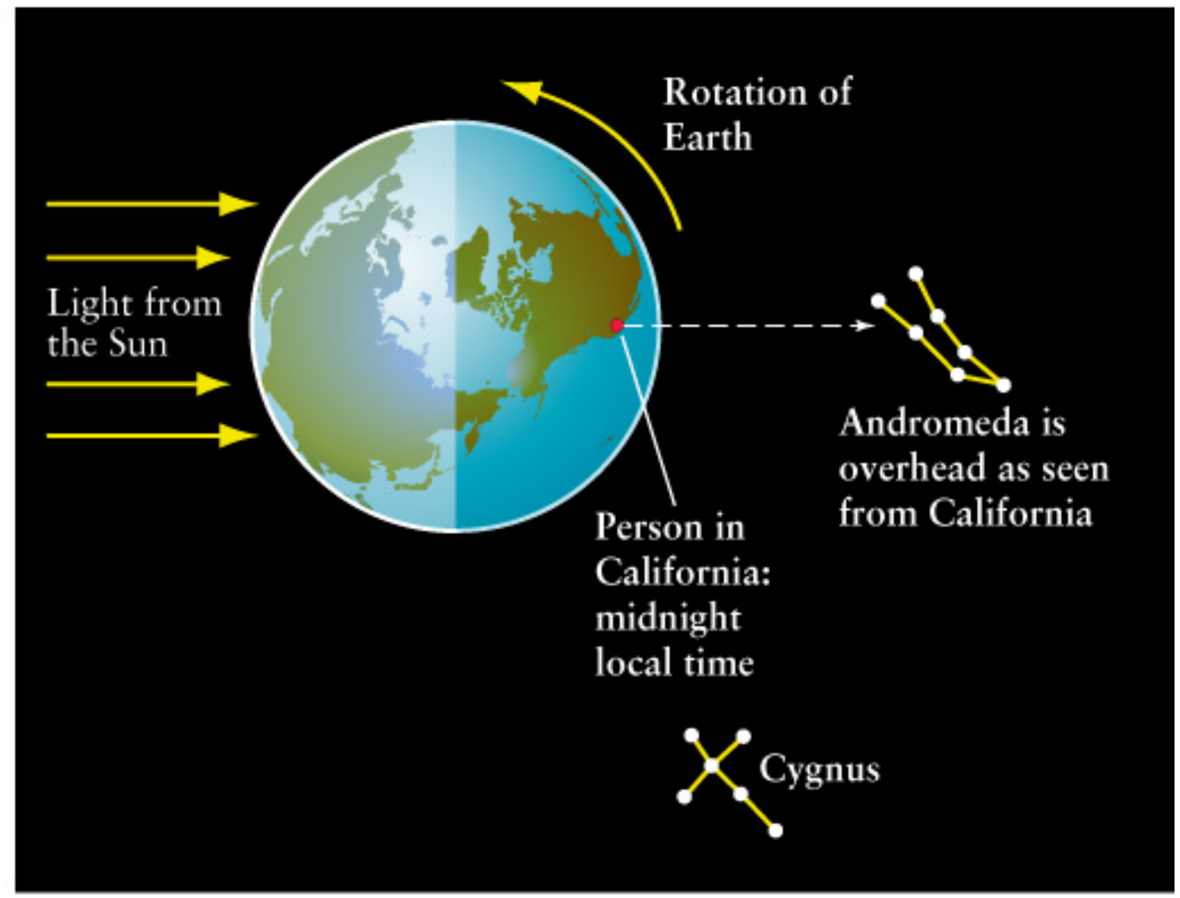
Rotation of the Earth

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

Bailey, Slater & Slater



(a) Earth as seen from above the north pole



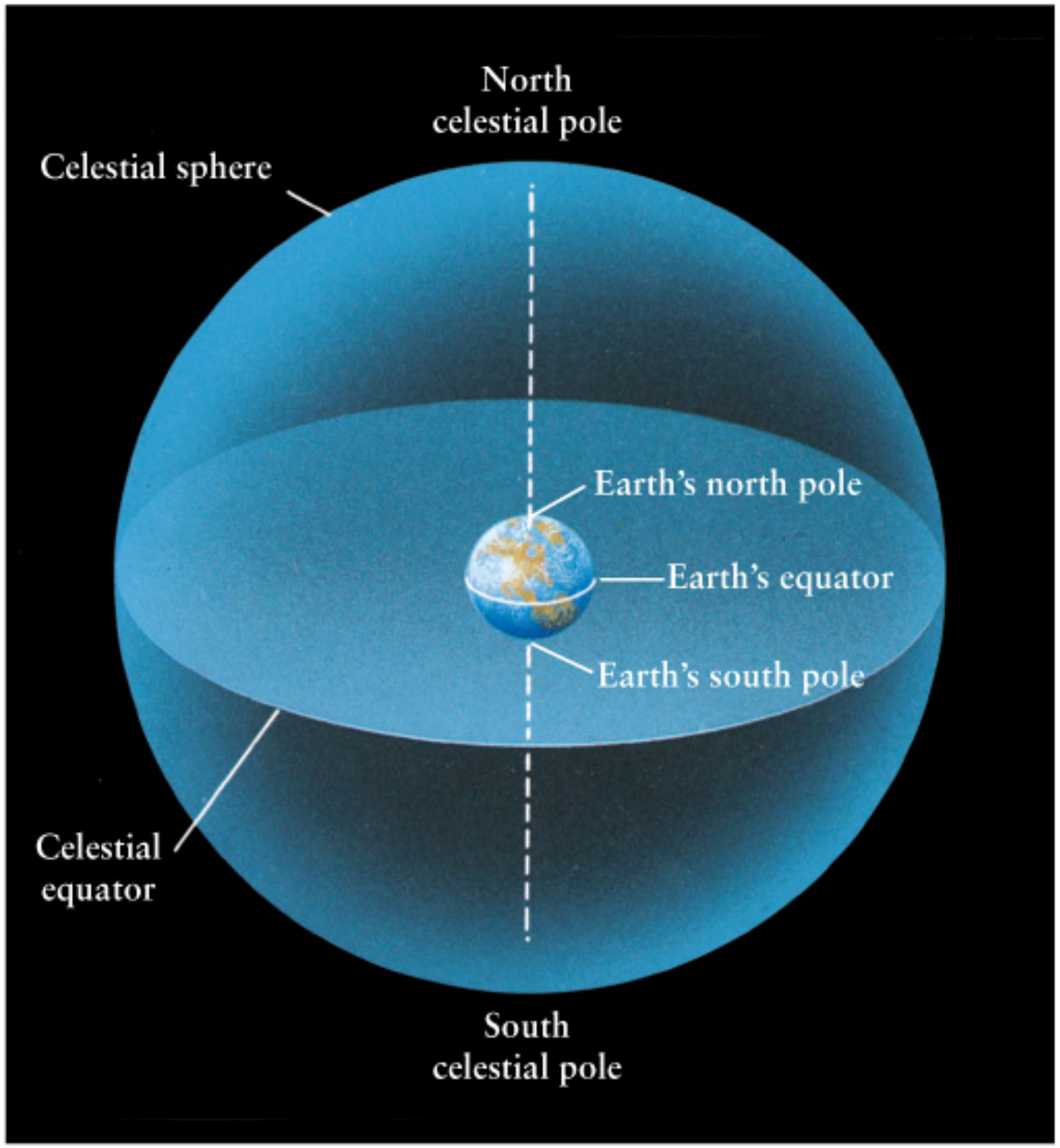
(b) 4 hours (one-sixth of a complete rotation) later

Andromeda is to the East; Cygnus is overhead

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

the Sky appears to rotate East to West

Celestial Sphere



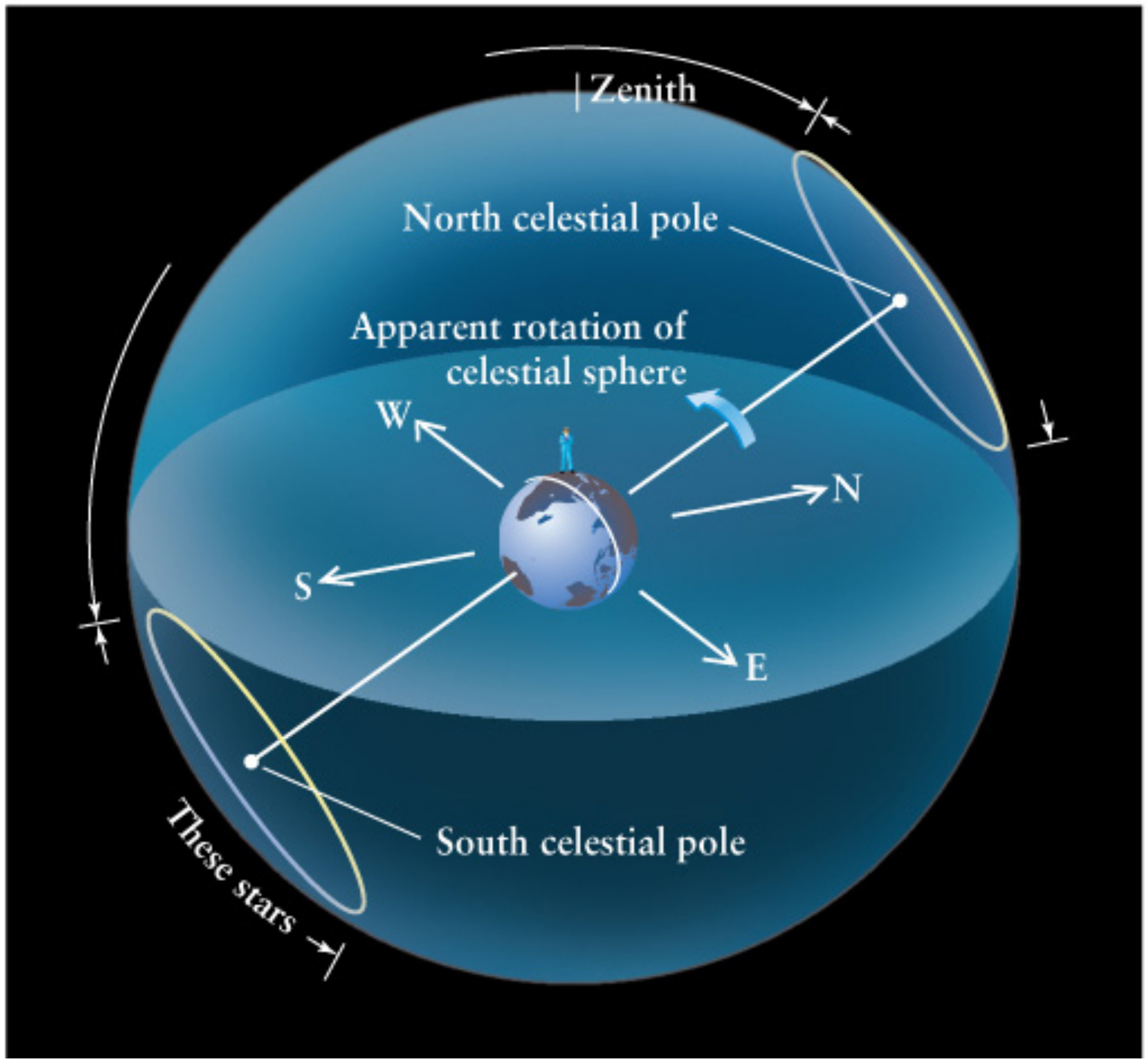
Bailey, Slater & Slater

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



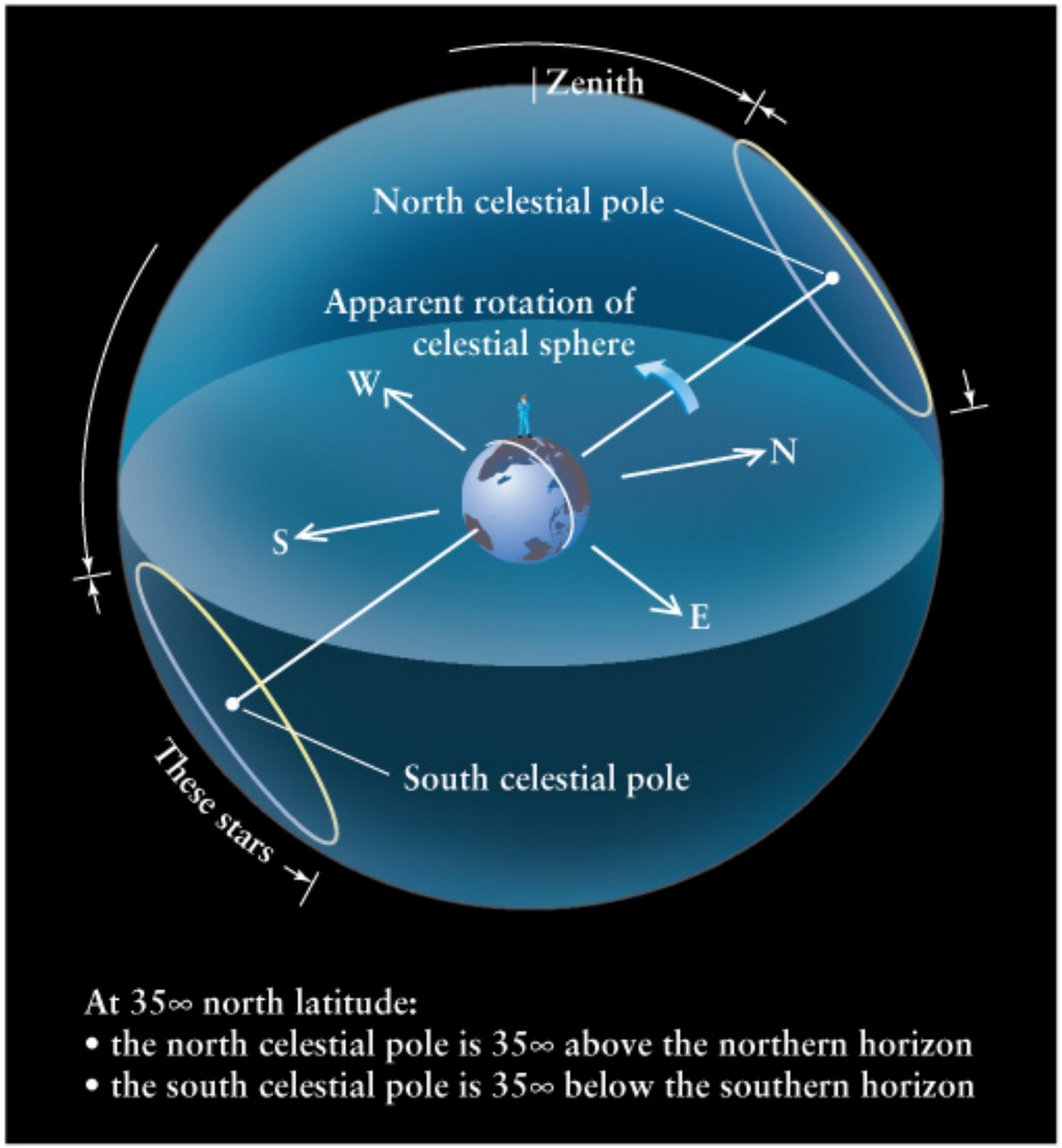
Bailey, Slater & Slater

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



Bailey, Slater & Slater

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"

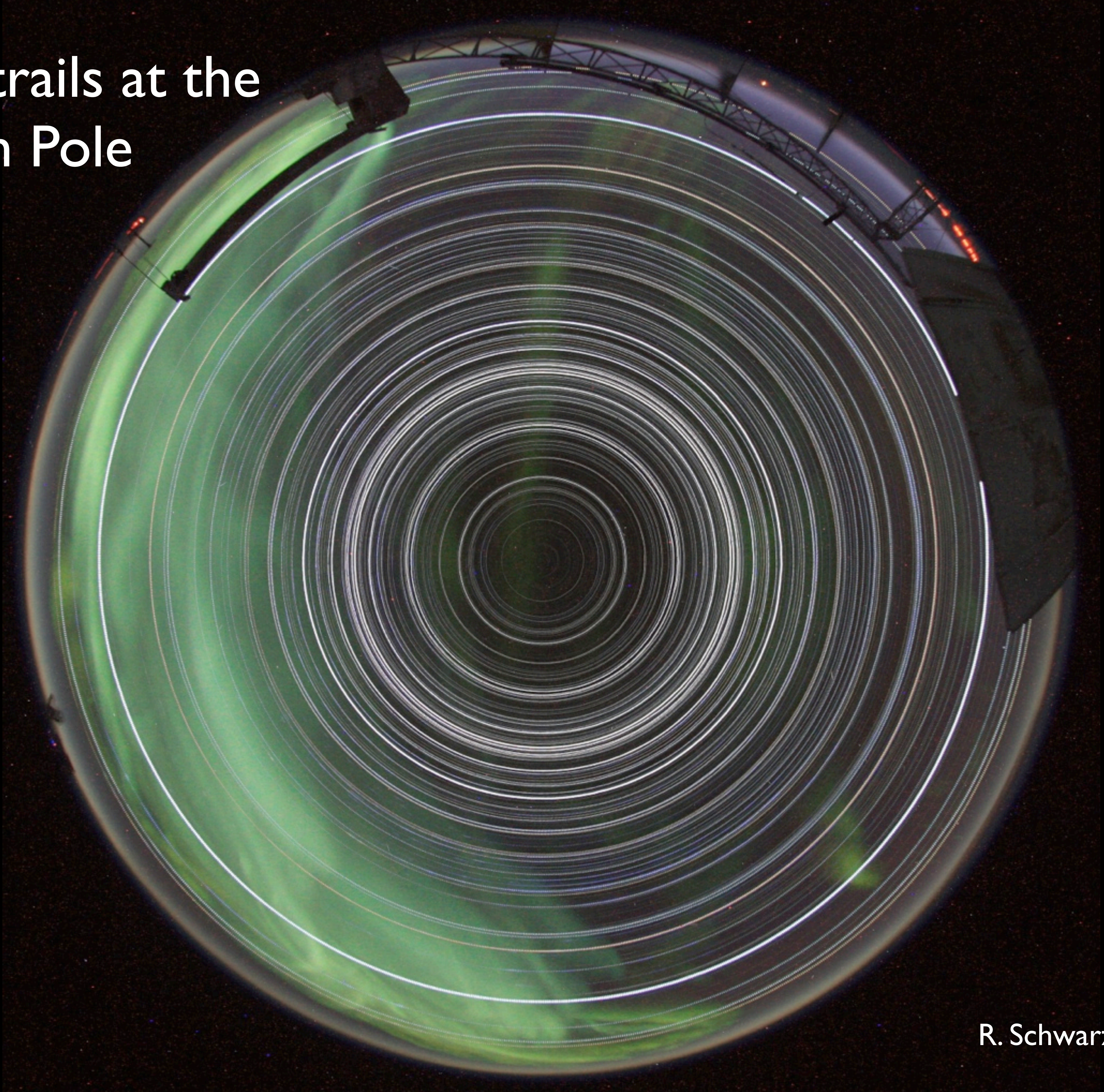
can never see objects within 41° of South Pole

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

Star trails over CTIO, (c) Jose Delgado

Star trails at the equator

Star trails at the South Pole



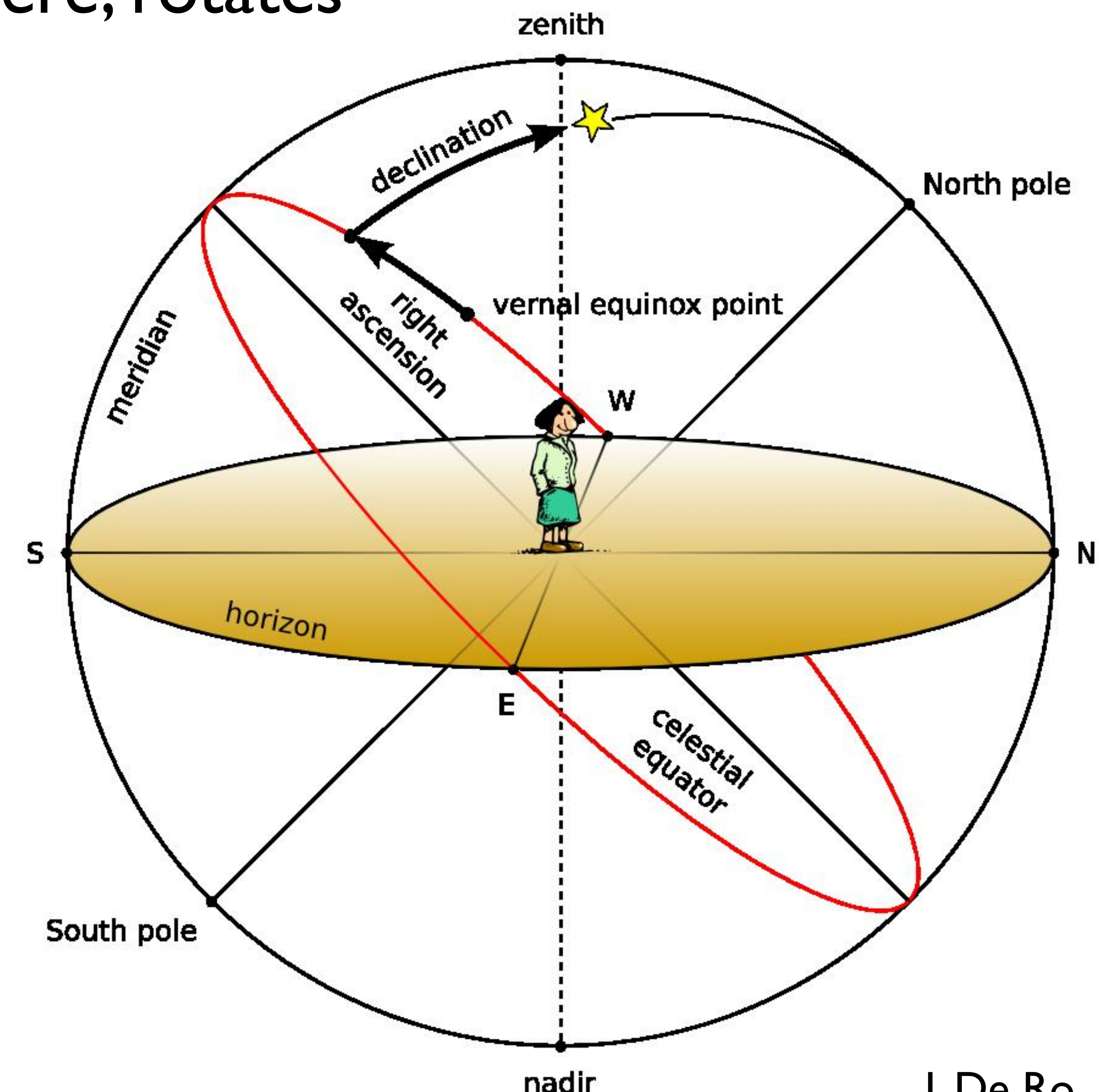
R. Schwarz

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)

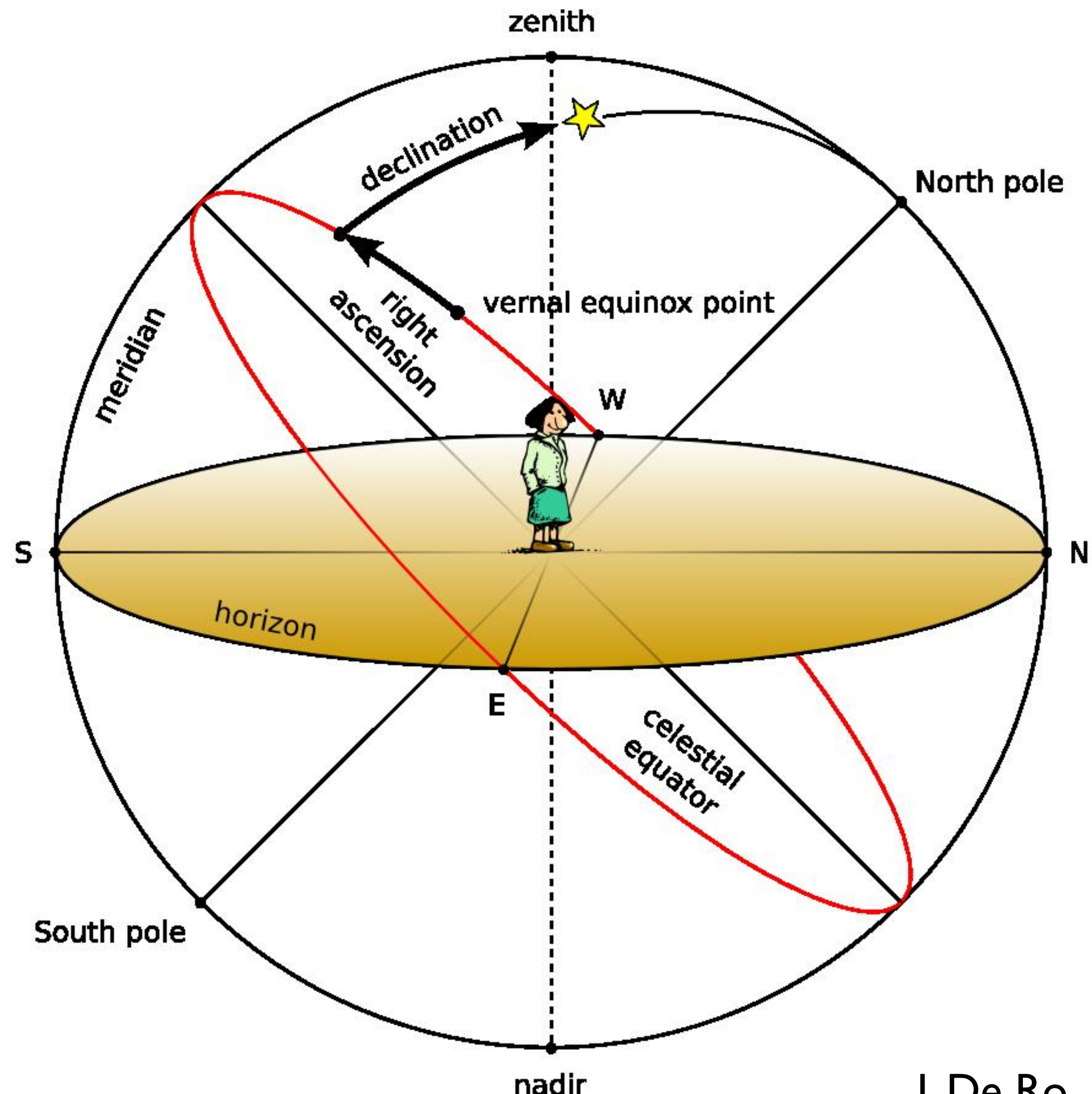


J. De Ro

Equatorial (RA/Dec) Coordinate System

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

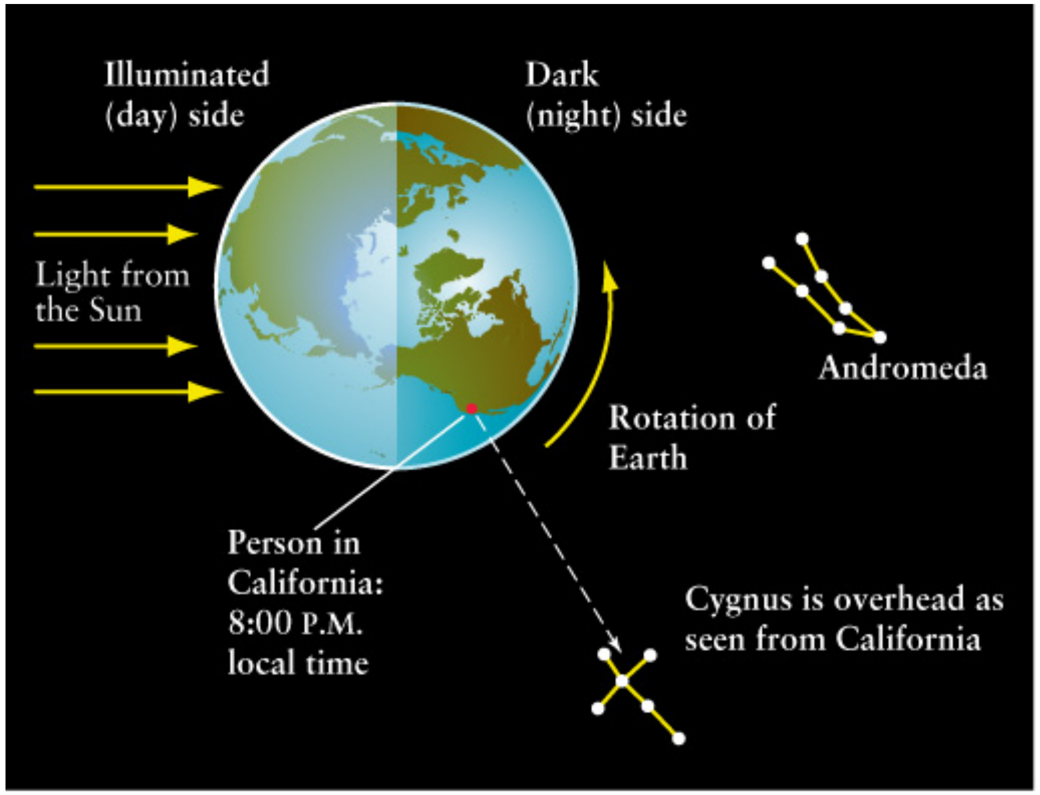
right ascension α: can also be measured in degrees ($0^\circ \leq \alpha < 360^\circ$), however:



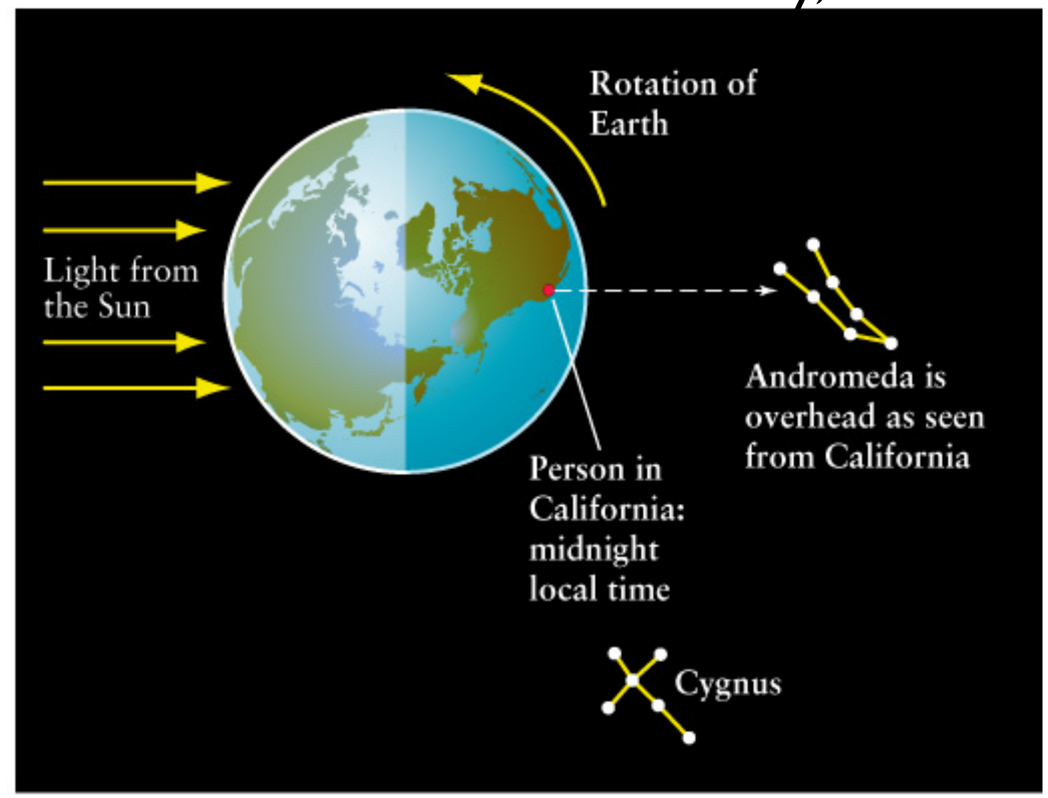
J. De Ro

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 passes the meridian

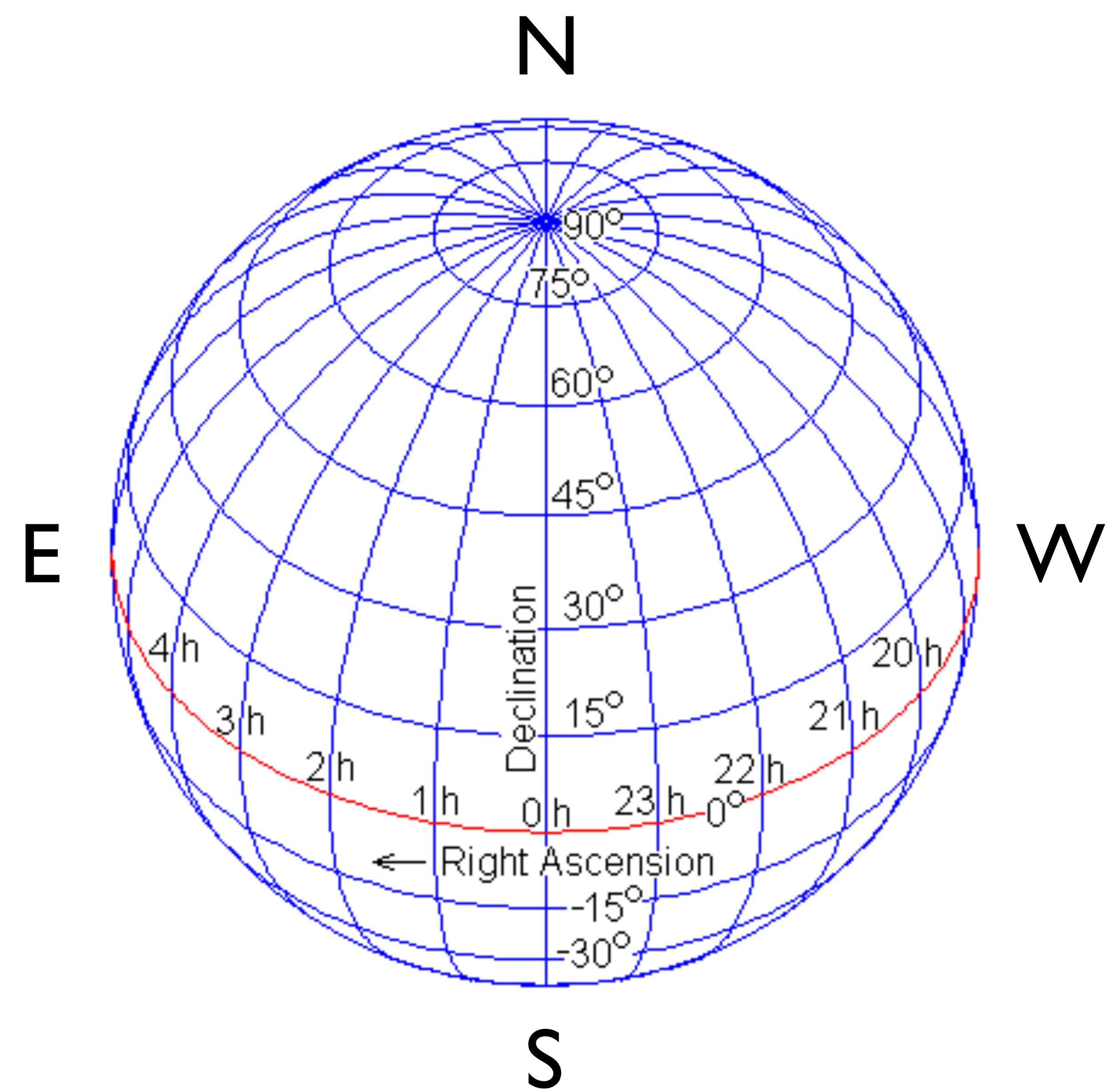
e.g.: reference point (0h) culminates (passes meridian) at a certain time; all points that culminate 4 hours later have α = 4h

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)



S. Dutch

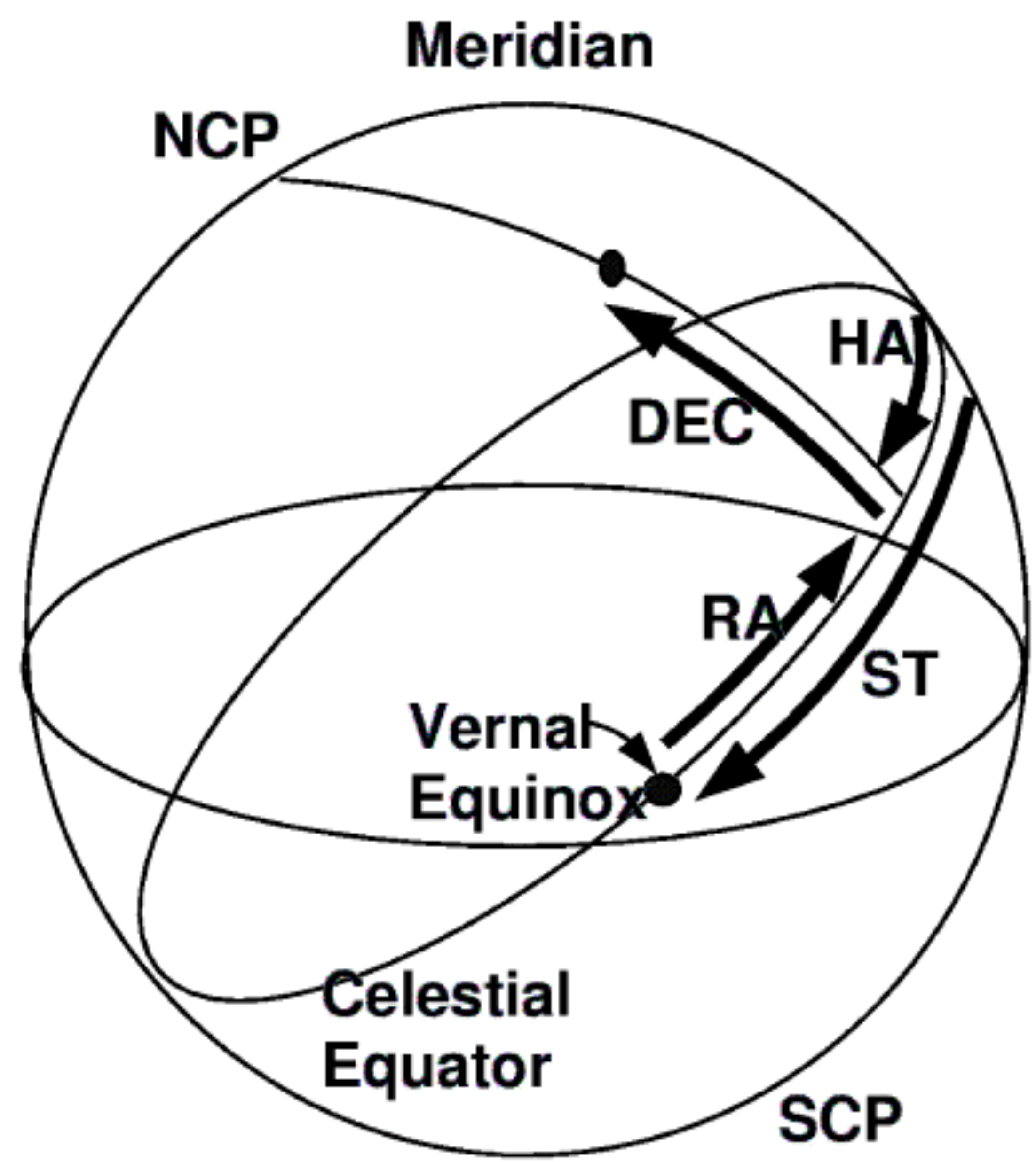
RA, LST, and Hour Angle

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

HA = LST - α_{object}

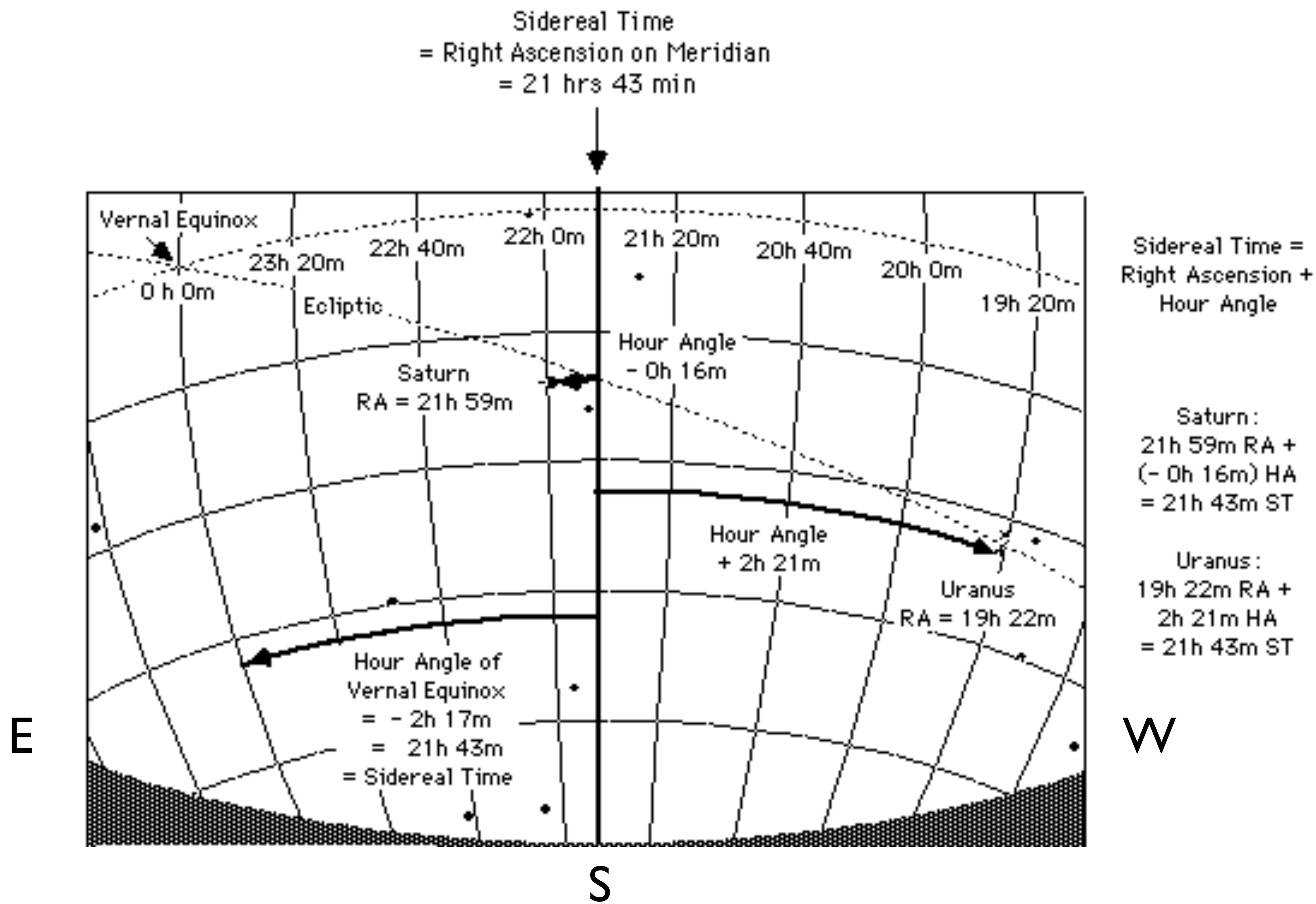
HA > 0h: object has already culminated, it is "setting" and in the western half of the sky

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



R. O'Connell

Example


Sidereal Time
= Right Ascension on Meridian
= 21 hrs 43 min
Vernal Equinox
0 h 0m
23h 20m
22h 40m
22h 0m
21h 20m
20h 40m
20h 0m
19h 20m
Ecliptic
Hour Angle
- 0h 16m
Saturn
RA = 21h 59m
Hour Angle
+ 2h 21m
Uranus
RA = 19h 22m
Hour Angle of
Vernal Equinox
= - 2h 17m
= 21h 43m
= Sidereal Time
Sidereal Time =
Right Ascension +
Hour Angle
Saturn:
21h 59m RA +
(- 0h 16m) HA
= 21h 43m ST
Uranus:
19h 22m RA +
2h 21m HA
= 21h 43m ST
E
W
S

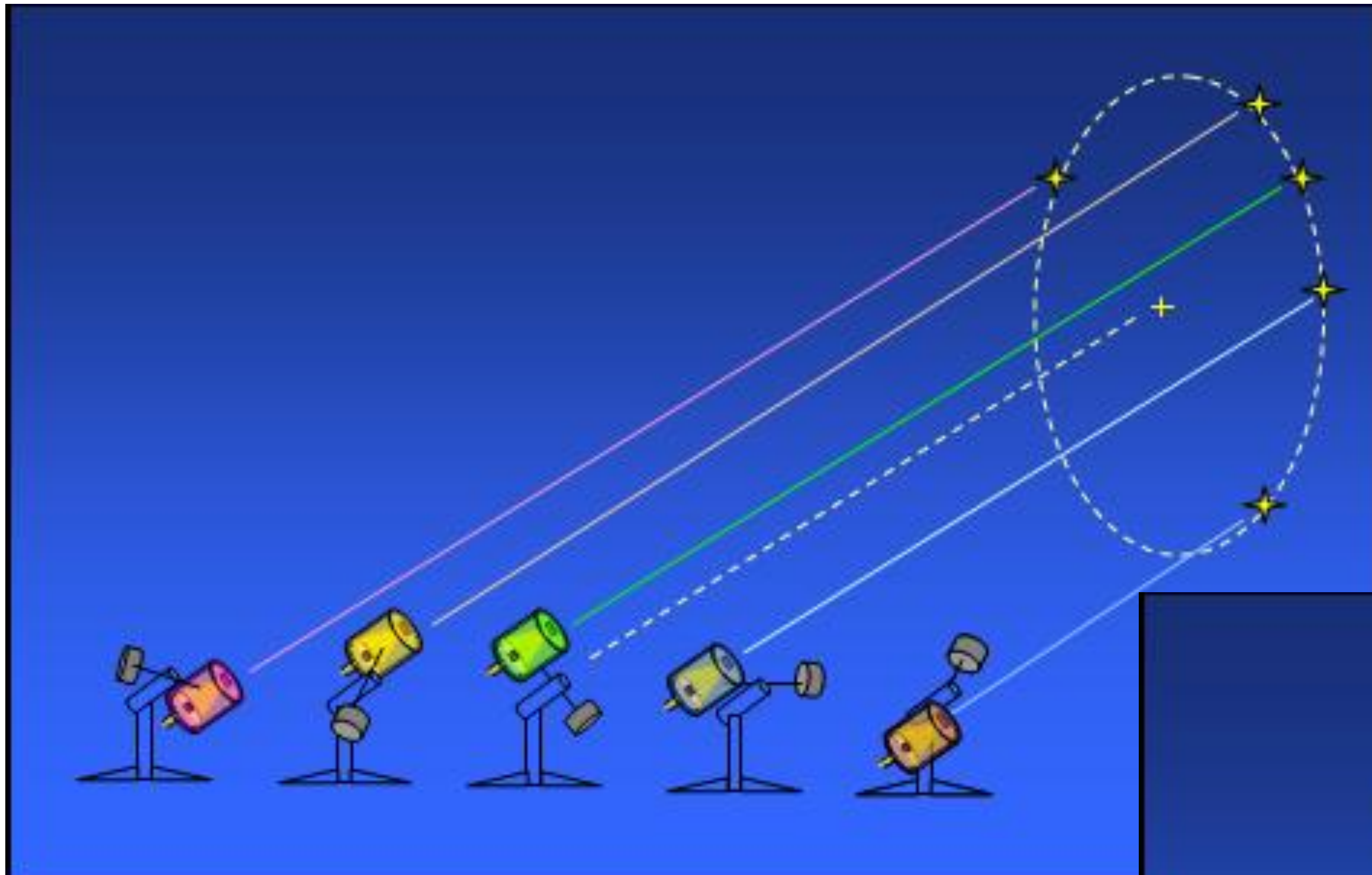
Equatorial telescope mounts

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

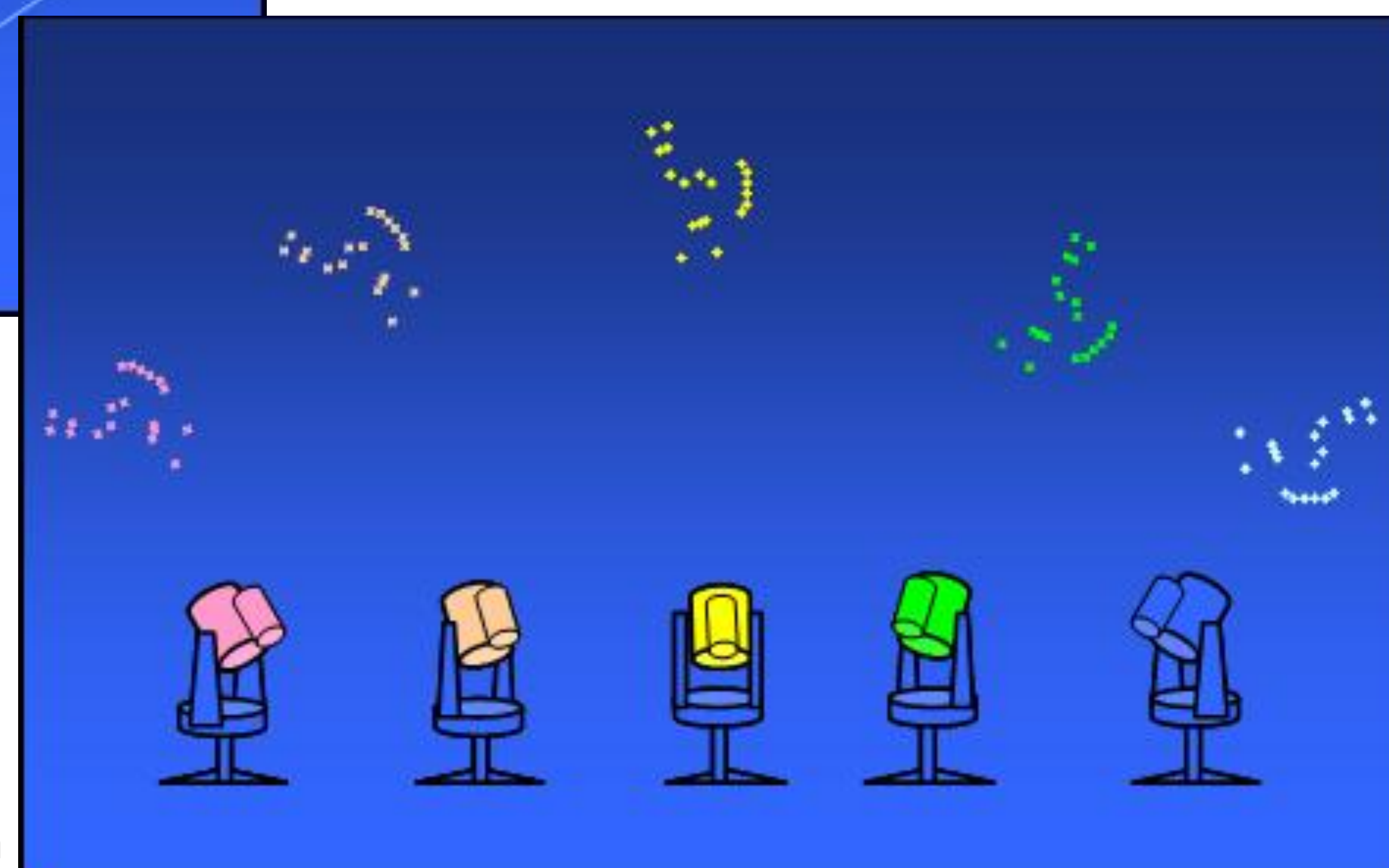
equatorial mount: one axis is parallel to Earth's rotation axis → need to track only in this axis, with constant speed

Equatorial telescope mounts

removes the need for a field de-rotator



alt/az mount



equ. mount

Astronomy Asylum

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

A. von der Linden

R.A. and Dec - format

both can be expressed as degrees:

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

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

often expressed in sexagesimal system:

$$00^{\mathrm{h}}42^{\mathrm{m}}44.33^{\mathrm{s}}, +41^\circ 16'\, 07.5''$$
$$00\!:\!42\!:\!44.33, +41\!:\!16\!:\!07.5$$

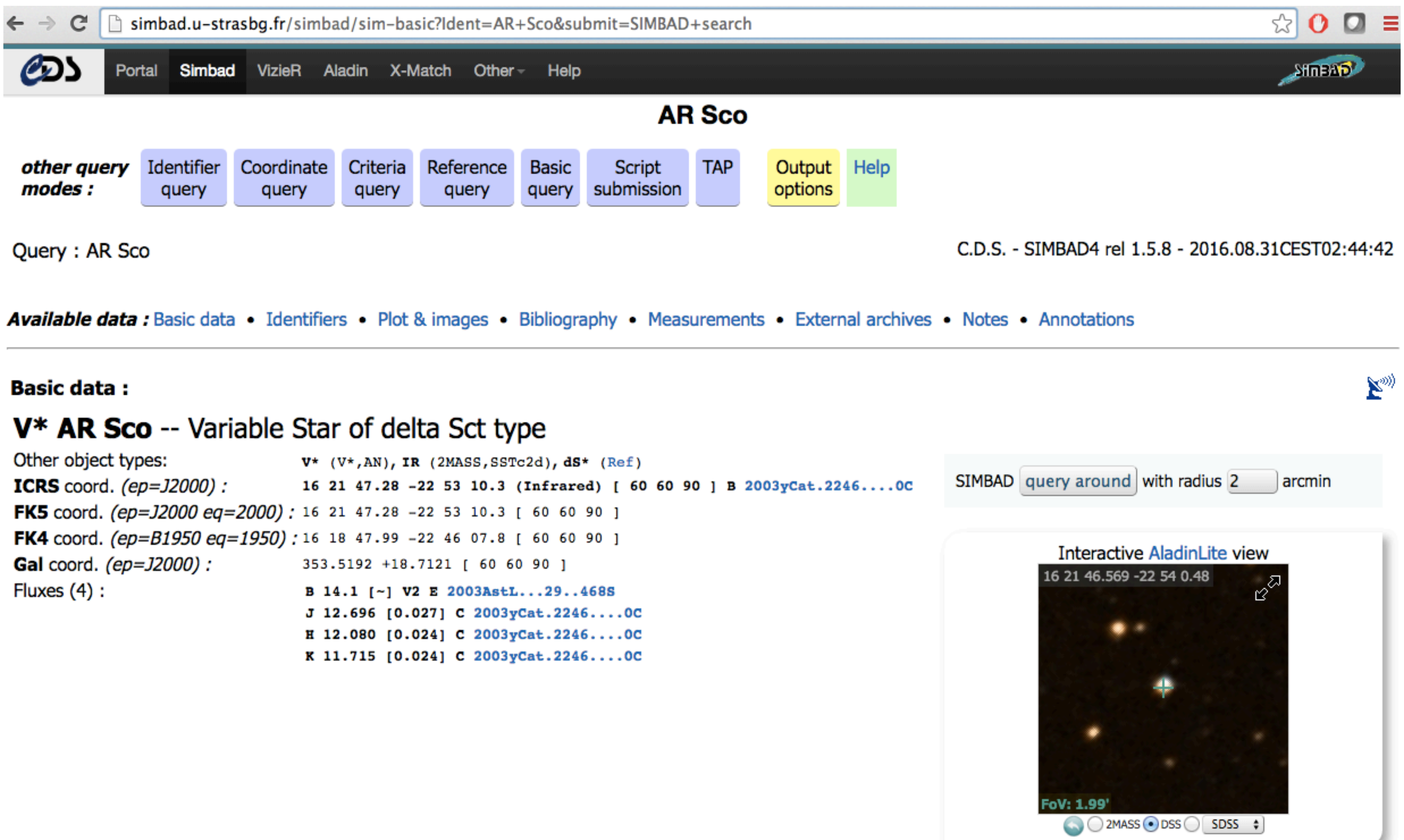
note:

$$24^{\mathrm{h}} = 360^\circ$$
$$1^{\mathrm{h}} = 15^\circ$$
$$1^{\mathrm{m}} = 15^\circ/60 = 0.25^\circ = 15'$$
$$1^{\mathrm{s}} = 15^\circ/3600 = 0.25' = 15''$$

Looking up coordinates / information

SIMBAD astronomical database:

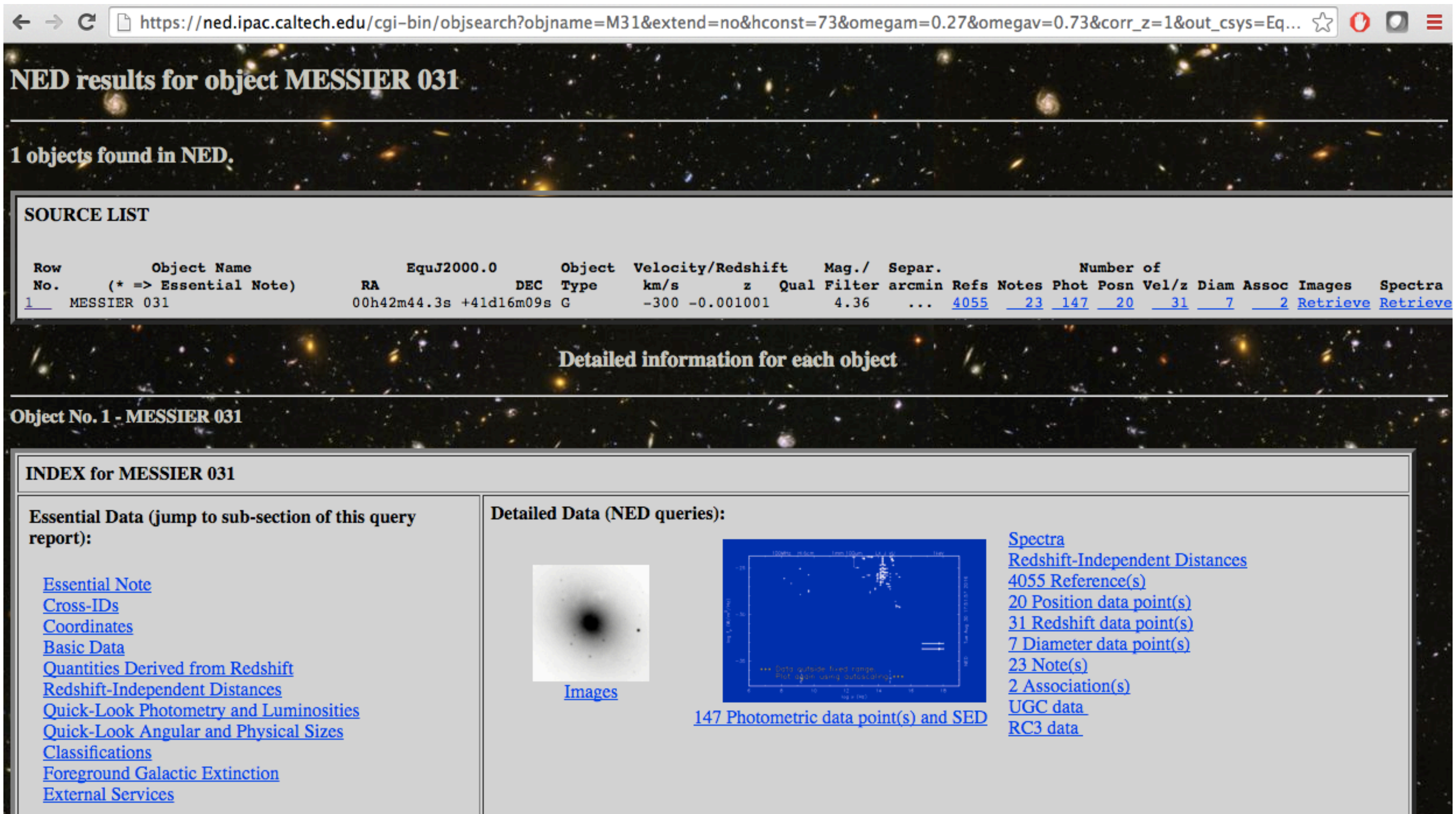
http://simbad.u-strasbg.fr/simbad/



Looking up coordinates / information

NASA/IPAC Extragalactic Database (NED)

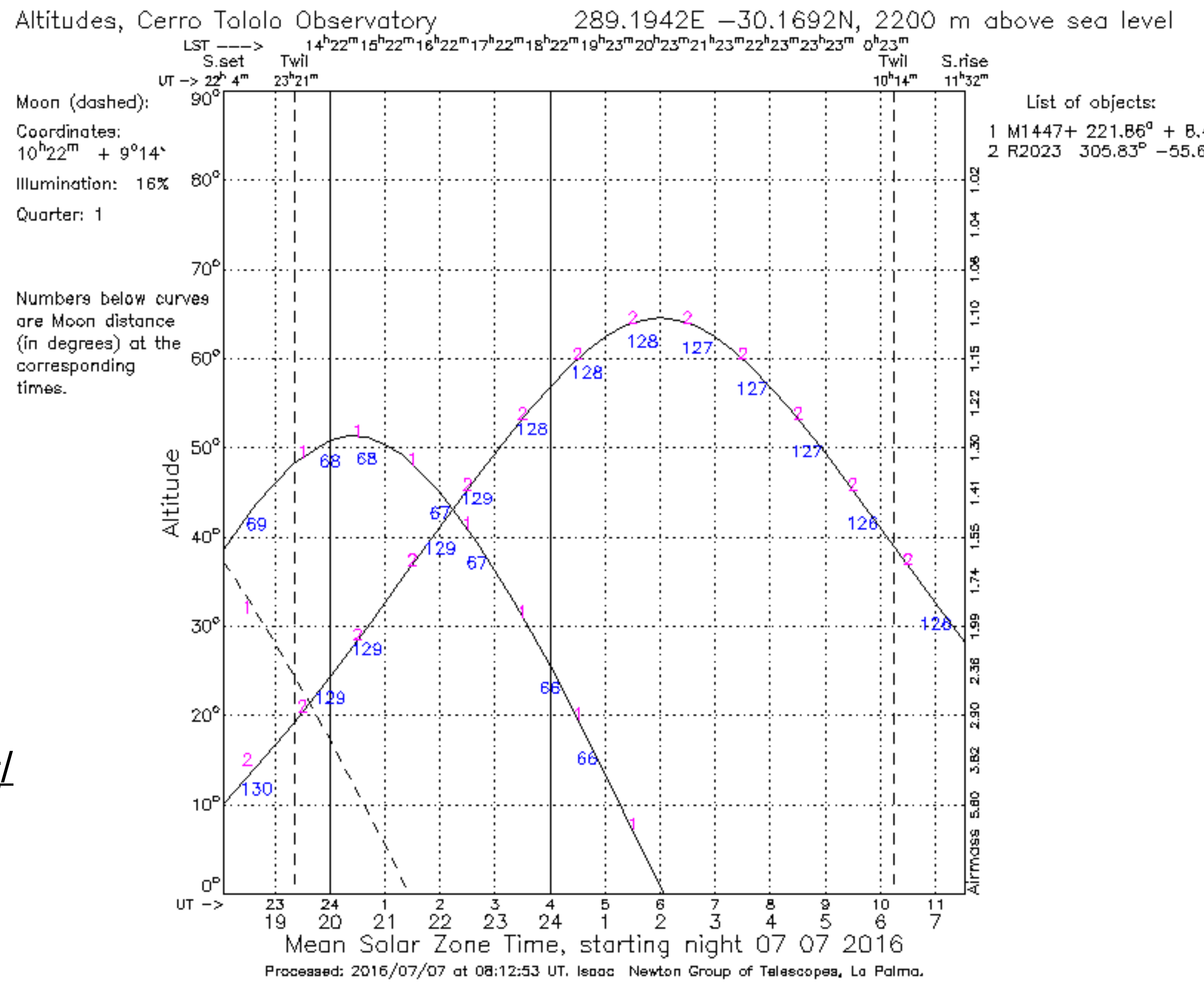
https://ned.ipac.caltech.edu/



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)



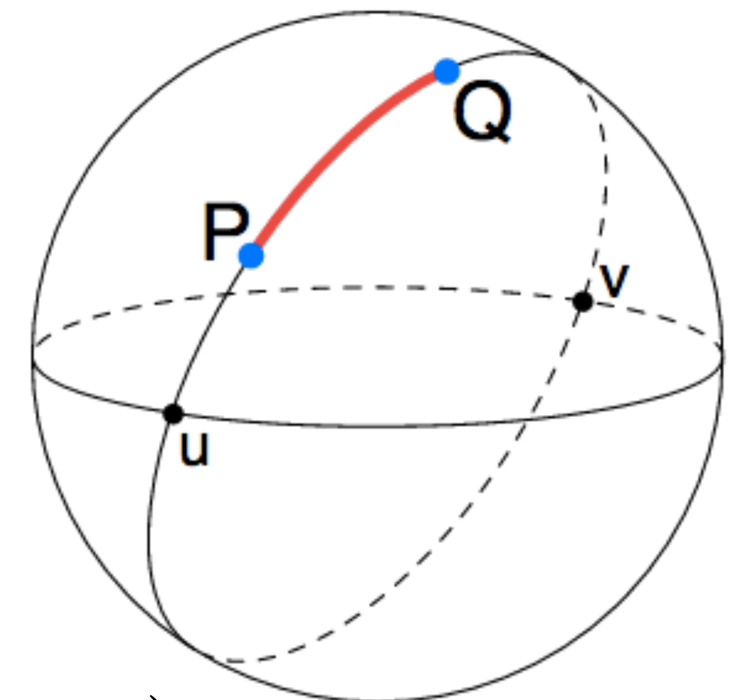
also see

http://www.briancasey.org/artifacts/astro/airmass.cgi

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



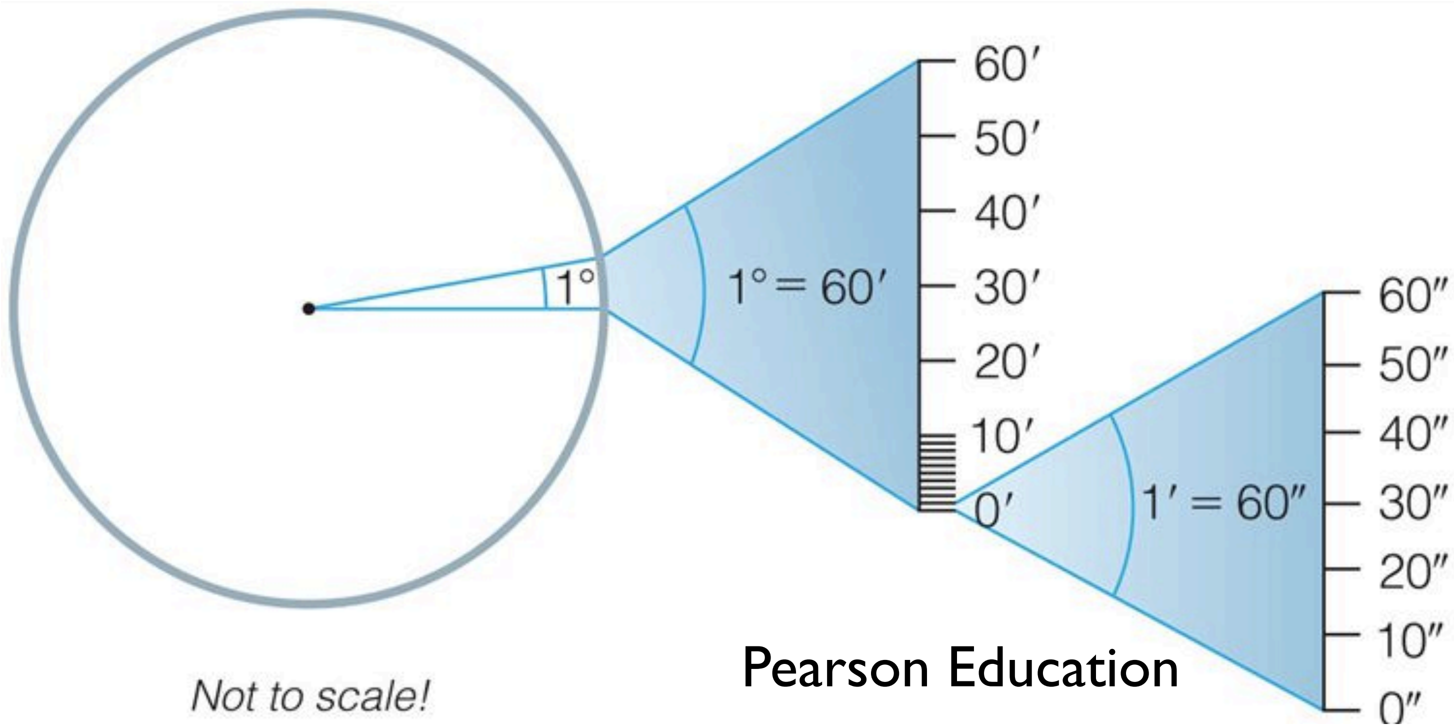
$$\cos(\gamma) = \cos(90^\circ - \delta_1)\cos(90^\circ - \delta_2) + \sin(90^\circ - \delta_1)\sin(90^\circ - \delta_2)\cos(\alpha_1 - \alpha_2)$$

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

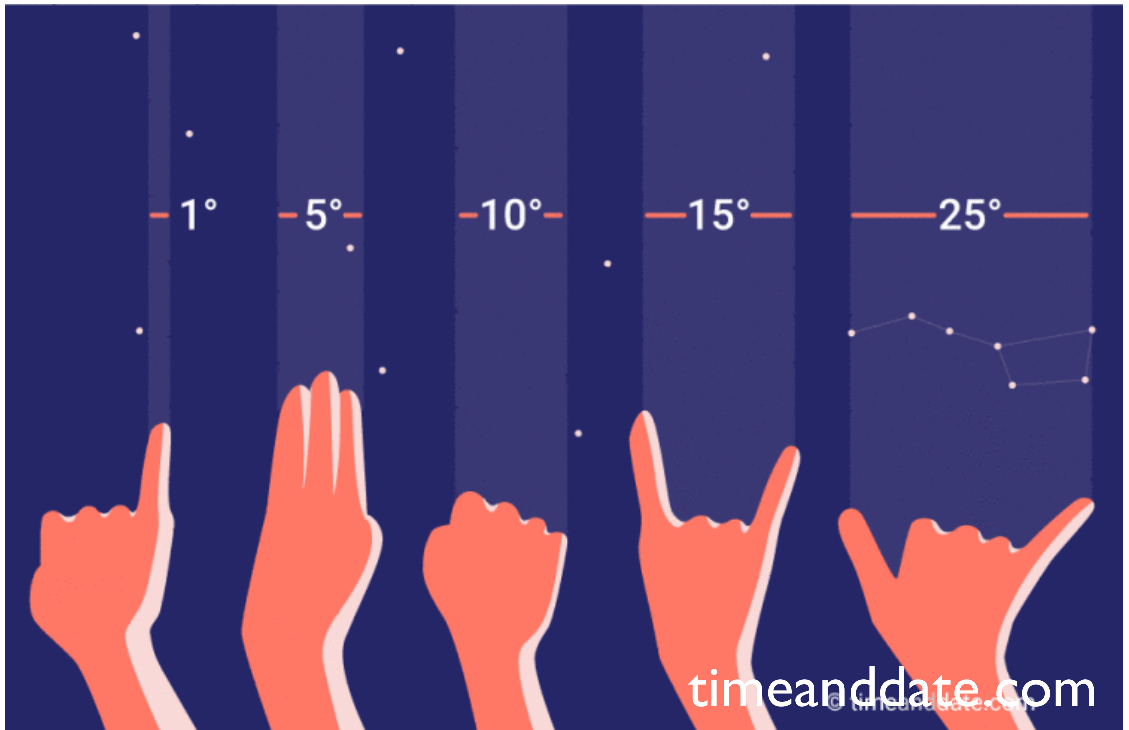
$$\gamma \simeq \sqrt{((\alpha_1 - \alpha_2)\cos(\delta_1))^2 + (\delta_1 - \delta_2)^2}$$

Lengths and distances on the Sky

usually given in degrees (˚), arcminutes (‘), arcseconds (“)

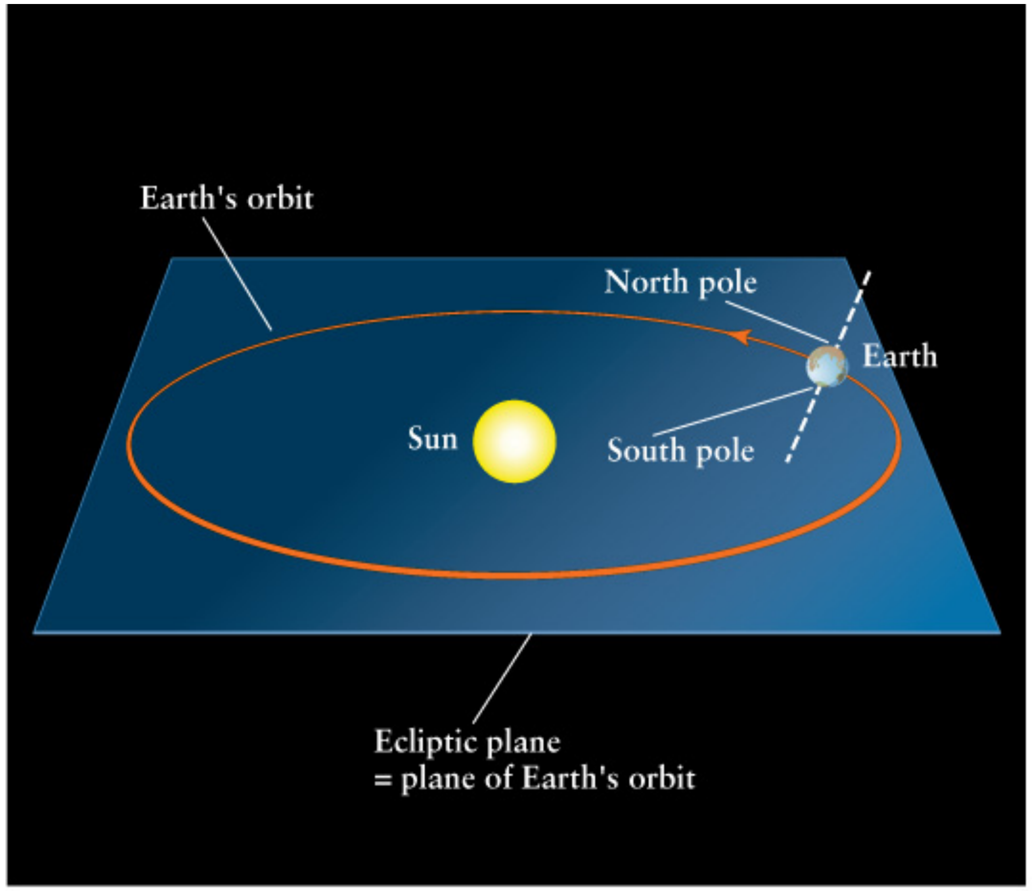


Moon: diameter is ~ 0.5˚ = 30’

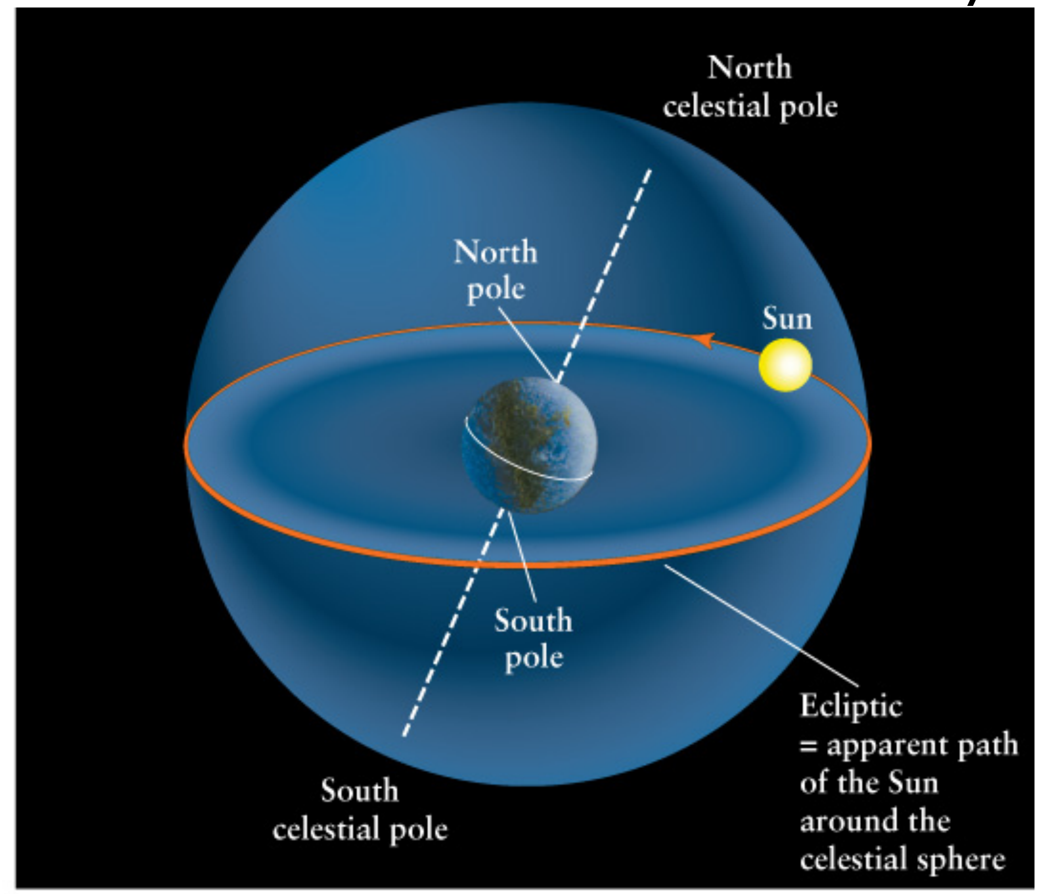


Motion of the Sun in the Sky

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

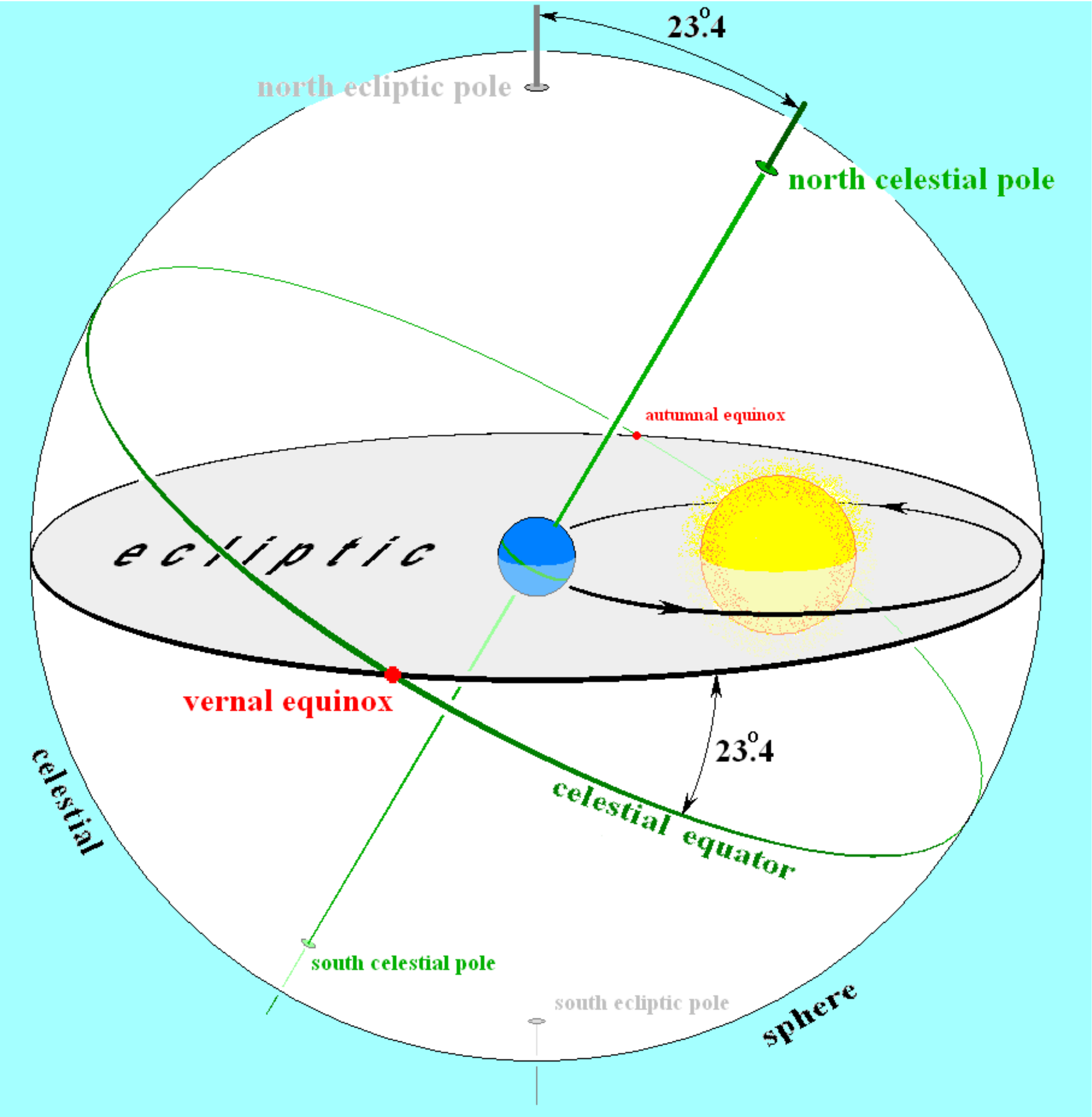
Motion of the Sun in the Sky

Sun travels along the ecliptic

equator and ecliptic intersect in two points: the equinoxes

why are they called equinoxes?

the vernal (spring) equinox marks RA=0h

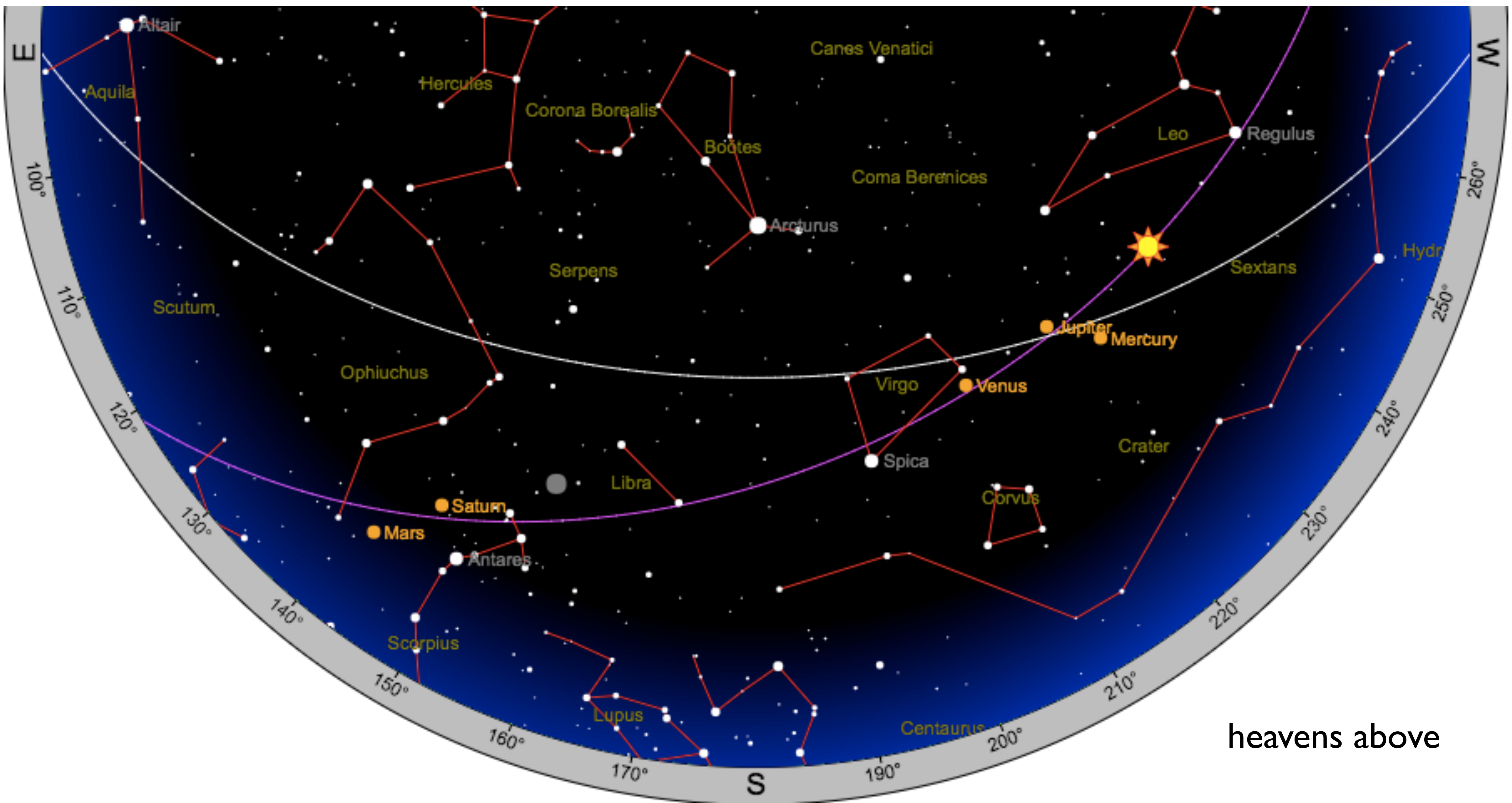


wikipedia

Other Solar System objects

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

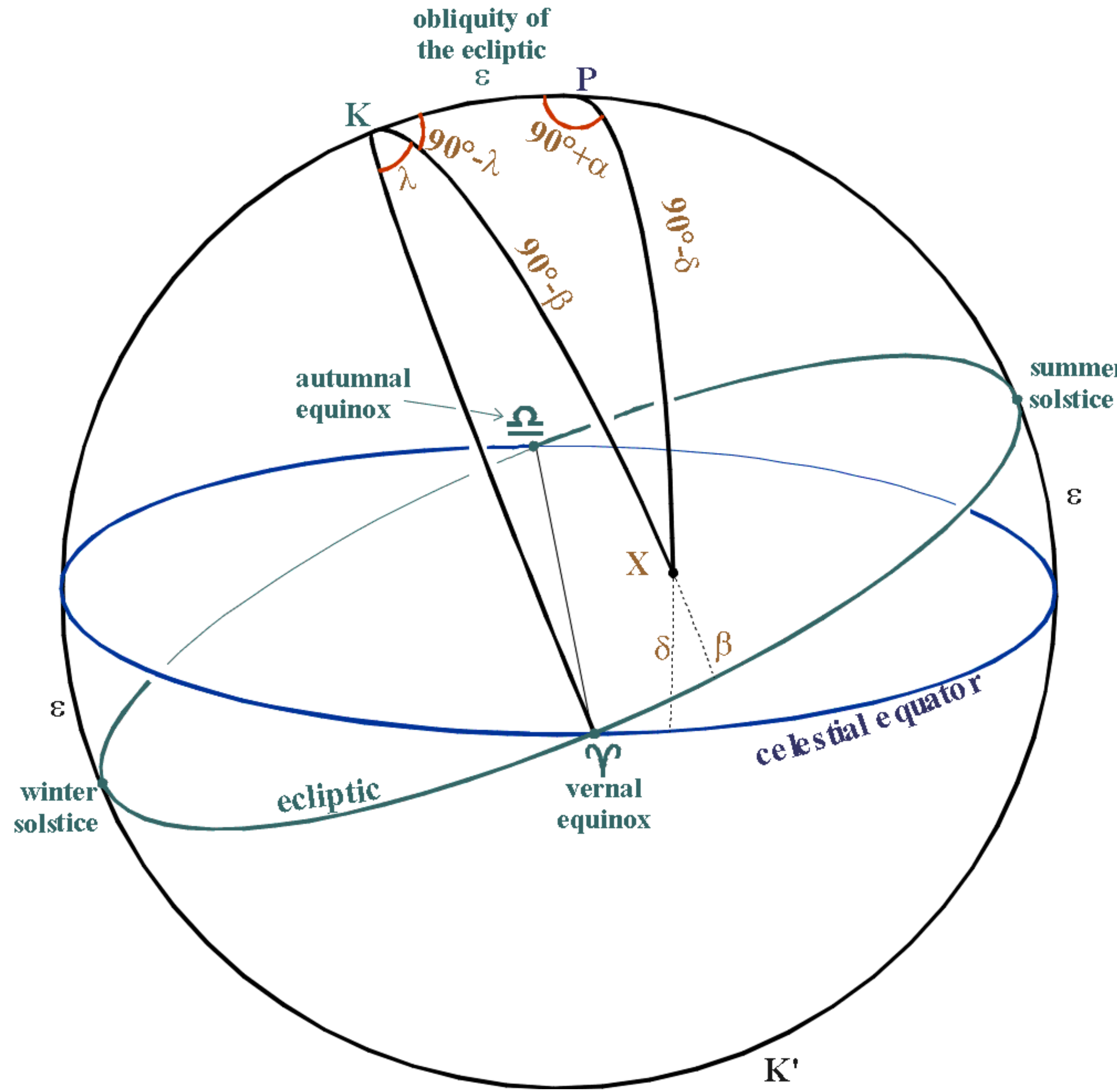
→ Moon and planets also approximately follow the ecliptic



heavens above

Ecliptic coordinates

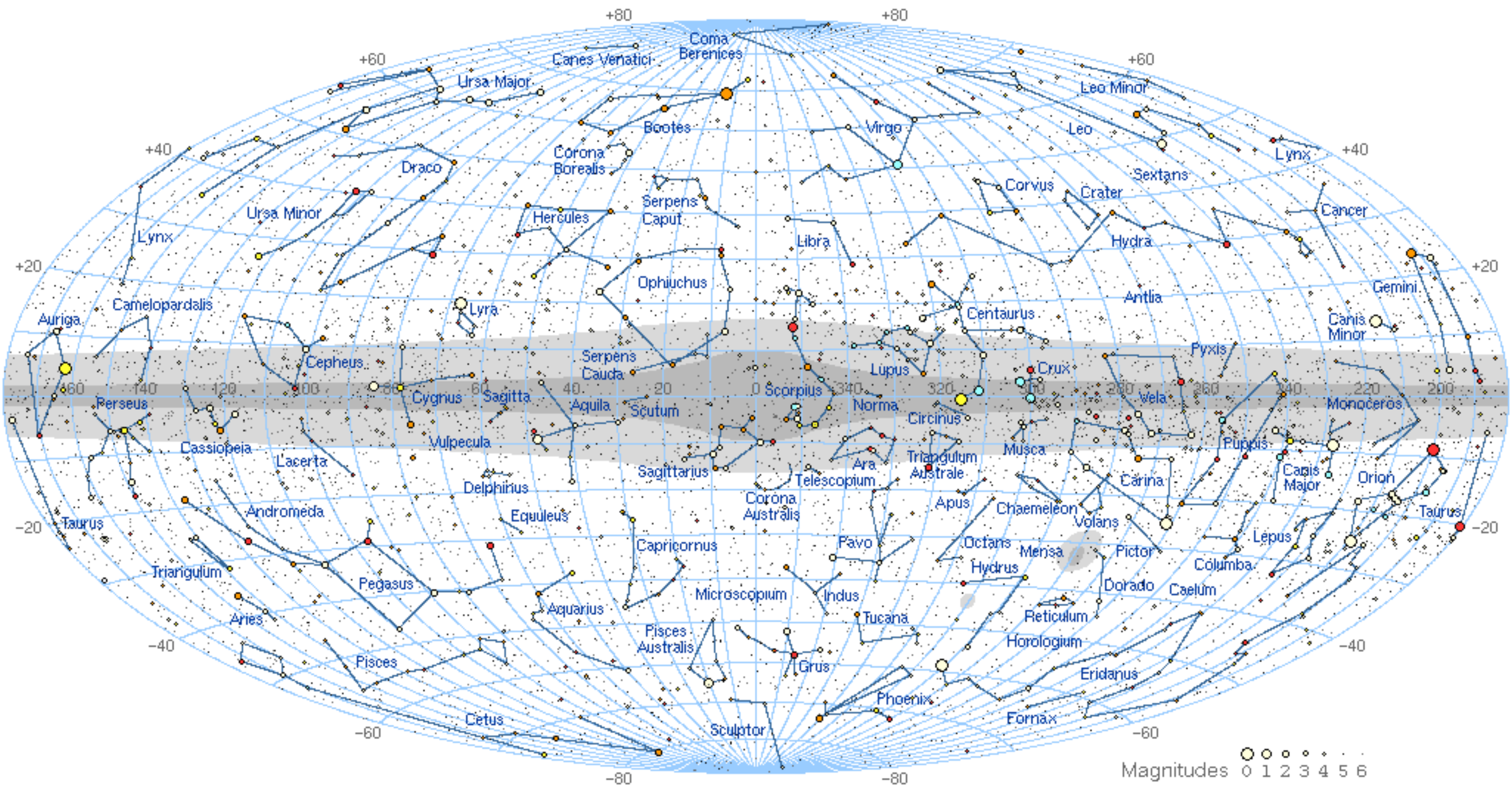
use ecliptic as "equator"



F. Vincent

Galactic coordinates

use the plane of the Galaxy as “equator”



Atlas of the Universe