Observational Astronomy

Santiago González-Gaitán
santiago.gonzalez@tecnico.ulisboa.pt

Observational Astronomy

Syllabus

Duration: 22^{nd} September to $20th^{t}$ October

Classes: Mondays 5-7pm and Tuesdays 2-5pm.

Material:

1) Basics of astronomical targets: planets, moons, stars, nebulae, galaxies
2) Astronomical observations: coordinate systems, time systems, magnitudes, photometry, colors
2) Planning observations: ephemerides, planetariums, observing proposals
3) Telescopes and cameras, photometry, spectrography, exposure times
4) CCD noise, image analysis and data reduction: bias, darks, flats, hot pixels, cosmic rays
5) Data analysis, statistics and visualization
6) Scientific writing, literature

Observational Astronomy

Syllabus

Hands-on sessions: scientific observing projects

In this course we will develop a scientific project to be elaborated in small groups in which we will go through the different scientific steps of an observational astronomer: writing an observing proposal, planning observations with a telescope, reducing and analyzing the data, writing a research report or paper.

Observational Astronomy

Syllabus

Hands-on sessions: scientific observing projects

In this course we will develop a scientific project to be elaborated in small groups in which we will go through the different scientific steps of an observational astronomer: writing an observing proposal, planning observations with a telescope, reducing and analyzing the data, writing a research report or paper.

Evaluation

Observing Proposal: 25%
Data products (images, figures, codes): 15%
Final short paper: 40%
Final presentation: 20%

Observational Astronomy

Projects

The course is based on the elaboration of a scientific project that should be carried out in groups of maximum three students. Below a list of possible projects and a simple description are presented. It is expected that the students will research on the chosen topic and prepare a) an observing proposal, b) reduce and analyze the data, and c) write a scientific report in paper format of the full project.

Observational Astronomy

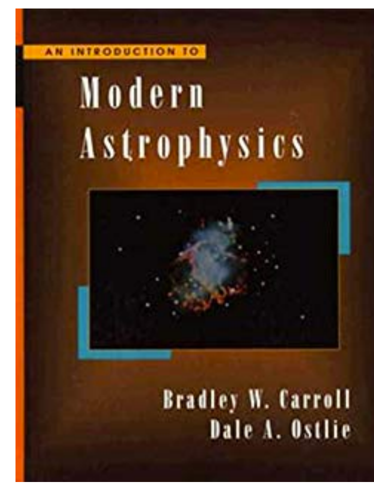
Projects

The course is based on the elaboration of a scientific project that should be carried out in groups of maximum three students. Below a list of possible projects and a simple description are presented. It is expected that the students will research on the chosen topic and prepare a) an observing proposal, b) reduce and analyze the data, and c) write a scientific report in paper format of the full project.

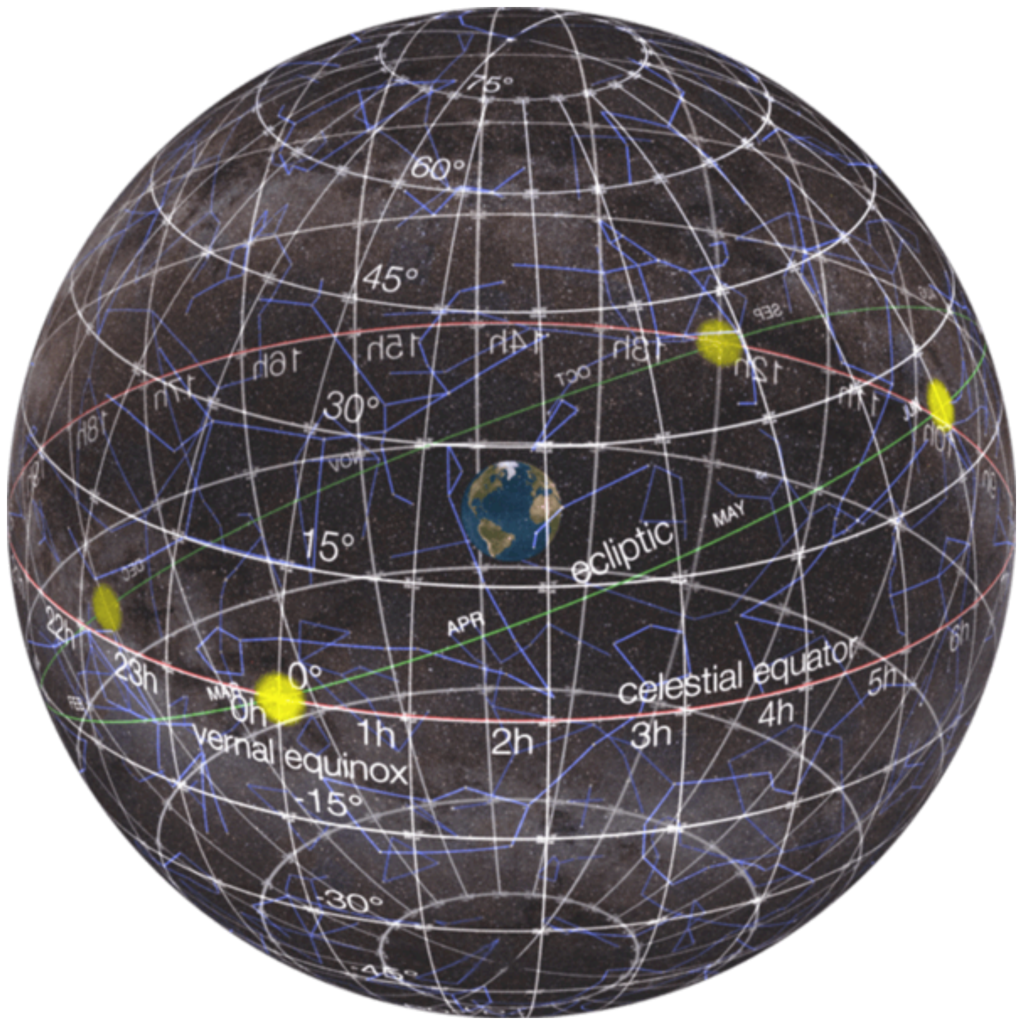
1) **Stellar cluster**
2) **Galaxy**

Bibliography

- Bennett, Donahue, Schneider & Voit: The Cosmic Perspective, (8th Edition, 2016)
- Carroll & Ostlie: An Introduction to Modern Astrophysics (2nd Edition, 2013)
- Wikipedia
- http://burro.case.edu/Academics/Astr306/
- http://spiff.rit.edu/classes/phys445
- http://www.astronomynotes.com
- https://web.njit.edu/~gary/202
- https://faculty.virginia.edu/ASTR5110
- https://pulsar.sternwarte.uni-erlangen.de
- https://ww.astro.caltech.edu/~george/ay1/lec_pdf/



1. Coordinate systems

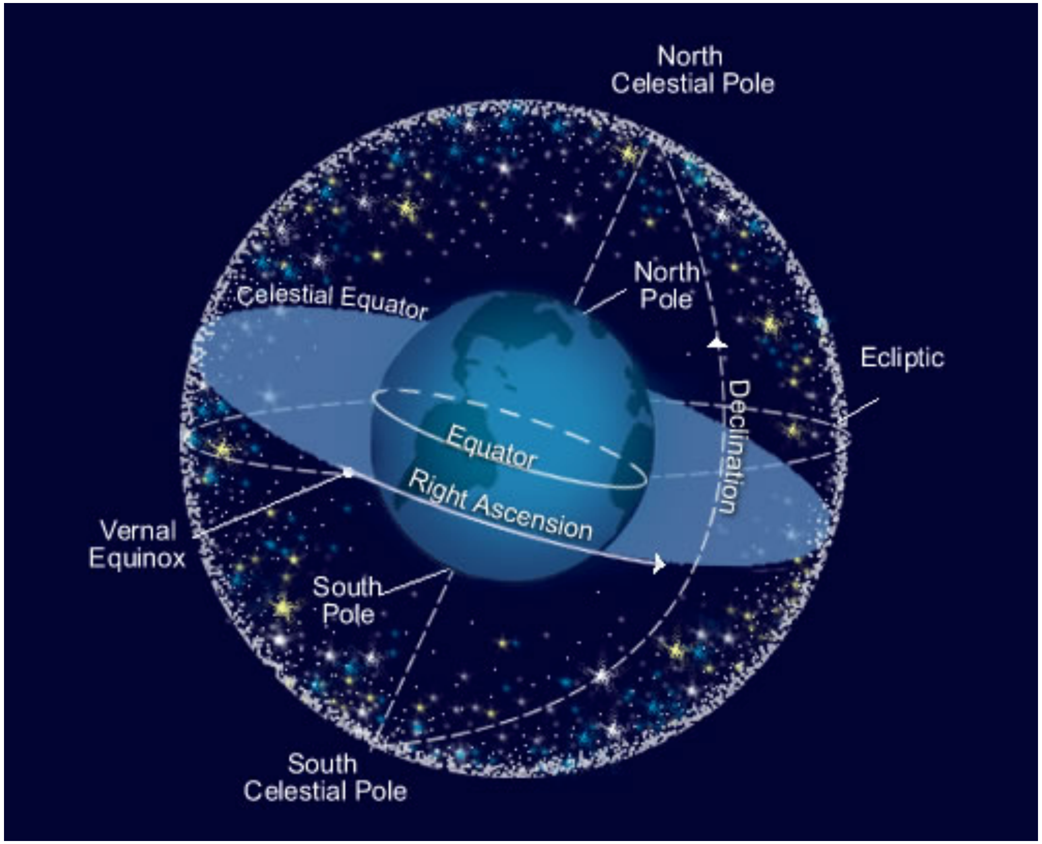


1. Coordinate systems

A. Observer coordinate system: Alt and Az
B. Equatorial coordinate system: RA and DEC
C. Galactic coordinate system: ℓ and b

1. Coordinate systems

- **Celestial sphere**: abstract sphere with Earth in the center
- **Celestial equator**: projection of Earth's equator
- **Celestial poles**: projection of Earth's poles

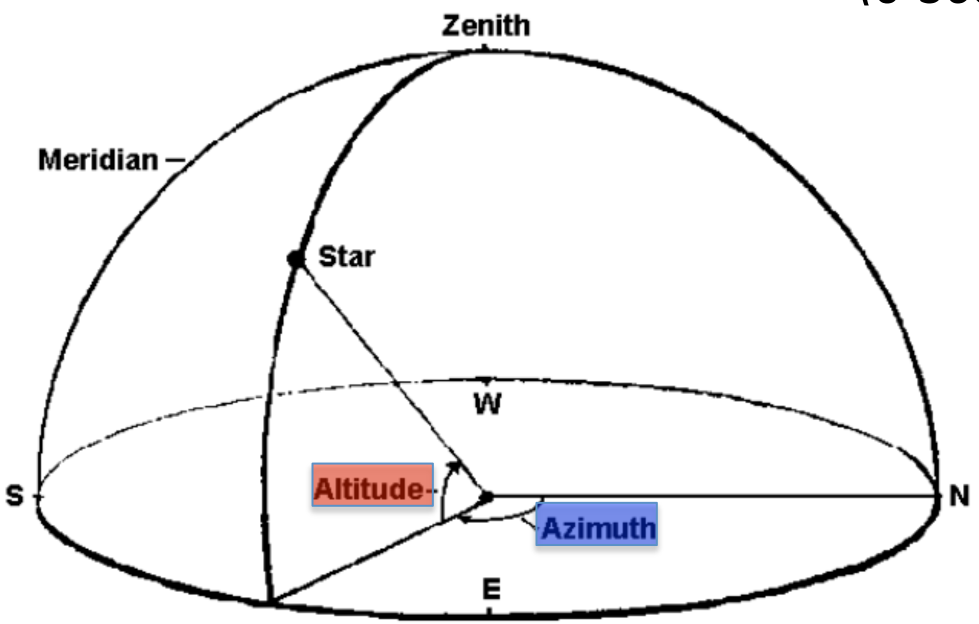


1. Coordinate systems

A. Observer coordinates: Altitude and Azimuth

- **Observer**: located at center
- **Zenith**: straight up, highest
- **Horizon**: lowest circle visible from observer
- **Meridian**: North-South line through the zenith

- **Altitude**: angular height above the horizon (horizon=0°, zenith=90°)
- **Azimuth**: angle on horizon between North and star (0-360°)

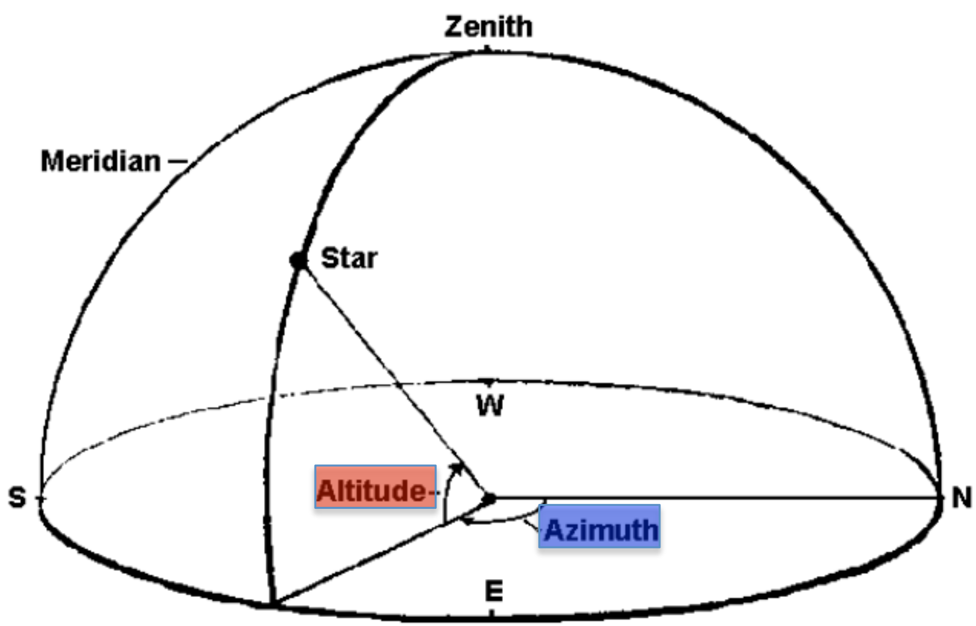


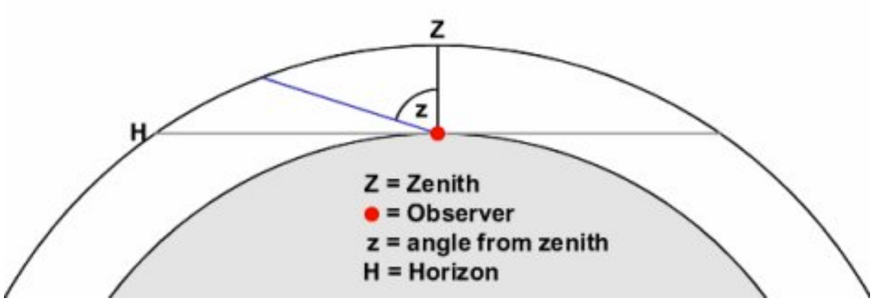
1. Coordinate systems

A. Observer coordinates: Altitude and Azimuth

Airmass (X):

- similar to altitude, it measures amount of air light passes through to reach observer
- Light is attenuated when passing through atmosphere (scattering and absorption)
- X ≈ 1/cosz with z, the zenith angle = 90°-altitude (X=1 at zenith)





1. Coordinate systems

B. Equatorial coordinates: RA and DEC

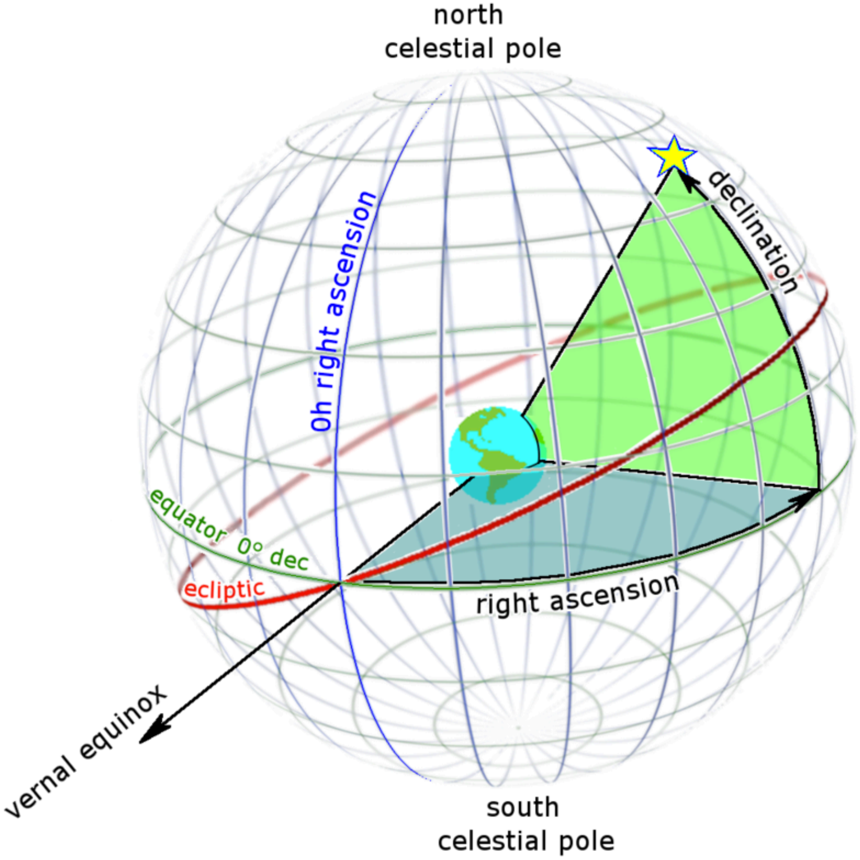
Declination (δ): angular distance from the celestial equator

- + = north, - = south
- -90° to 90°

Right ascension (α): angular distance along circles perpendicular to celestial equator

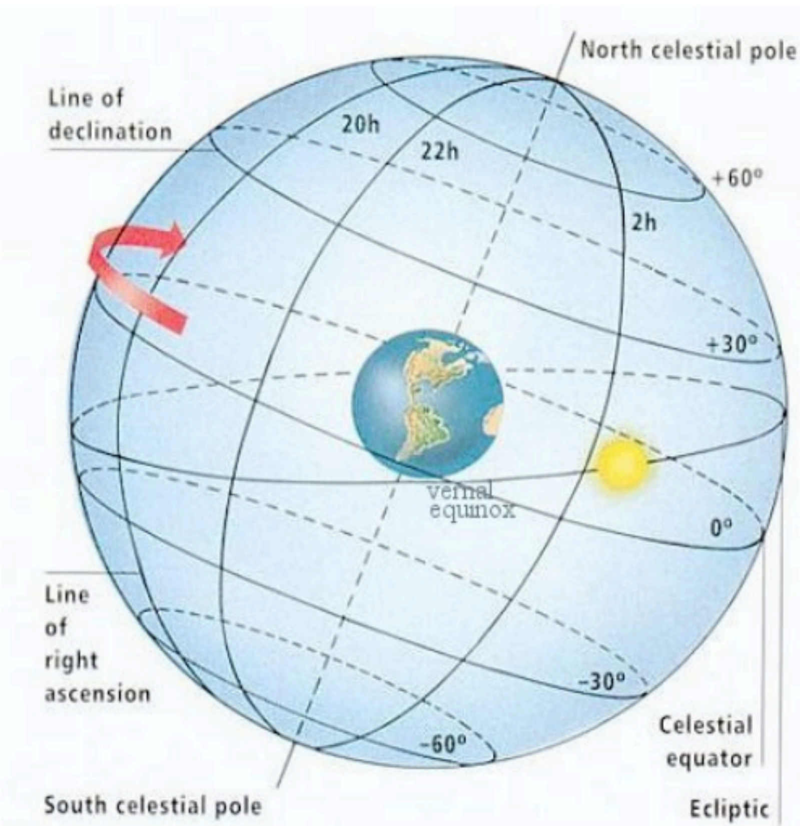
- 0 to 360°
- Measured eastwards from the sun at March equinox

Ecliptic: Sun's path projection



1. Coordinate systems

B. Equatorial coordinates: RA and DEC



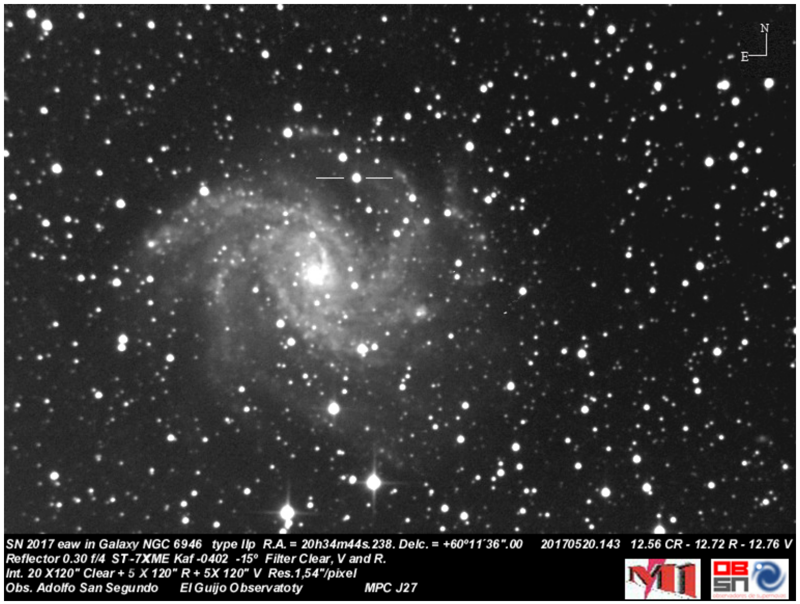
- **Declination (δ)**: measured in degrees, min/sec of arc
- **Right ascension (α)**: measured in sexagesimal time (hr,min,sec) or degrees

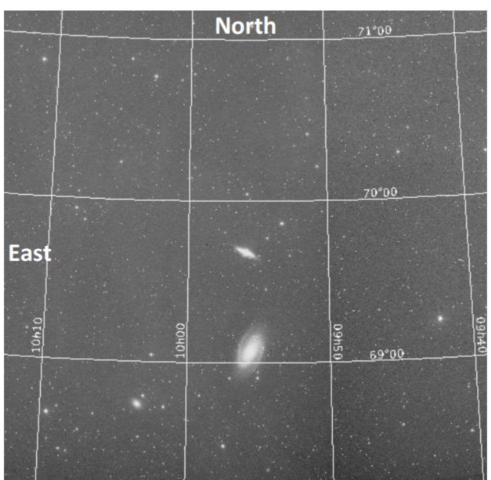
Sexagesimal time:
Hrs, Min, Sec: sphere has 24h
(1h=60min, 1min=60s)
Angles:
Arcminute: 1/60 degree
Arcsecond: 1/60 arcmin

Example: Andromeda galaxy
RA 0h 42m 44s | Dec +41° 16′ 9″
RA 10.6833 | Dec 41.2692

1. Coordinate systems

Projection effects





An apparently flat image is actually a curved surface!

Distance between two objects:

$\Delta\delta = \delta_1 - \delta_2$

$\Delta\alpha = (\alpha_1 - \alpha_2) * \cos(\delta)$

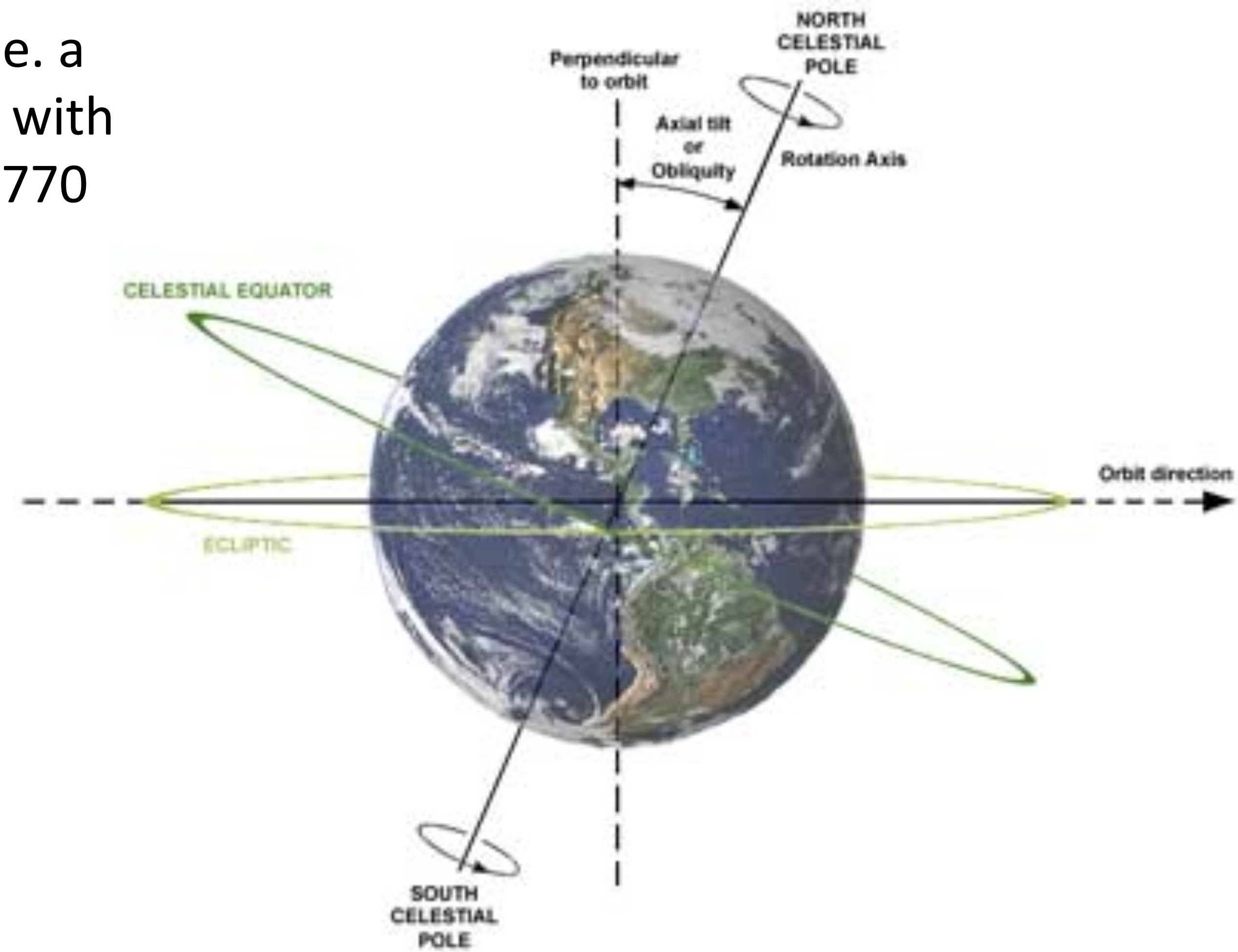
1. Coordinate systems

Earth rotation

Earth rotates along its N/S axis to the E
Stars rise from E to W
The center of the circles marks the celestial pole

1. Coordinate systems
Earth precession

Earth has a precession, i.e. a change of rotational axis with time, with a period of 25770 years.

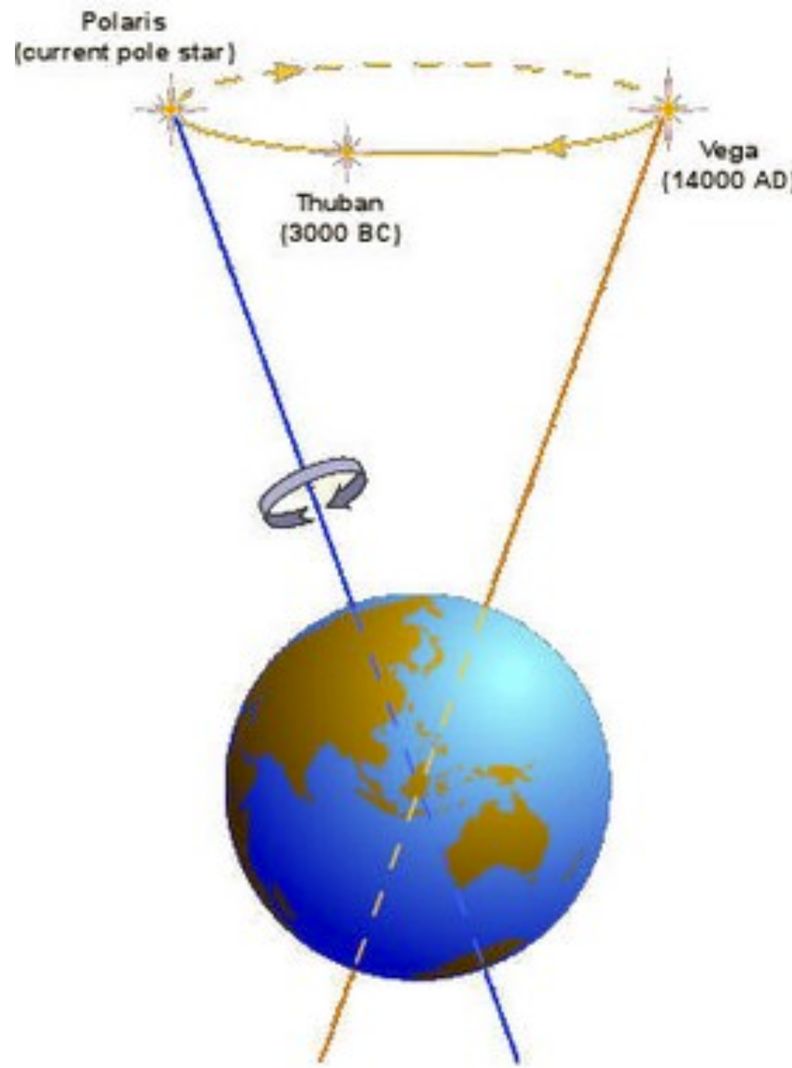


1. Coordinate systems
Earth precession

Earth has a precession, i.e. a change of rotational axis with time, with a period of 25770 years.

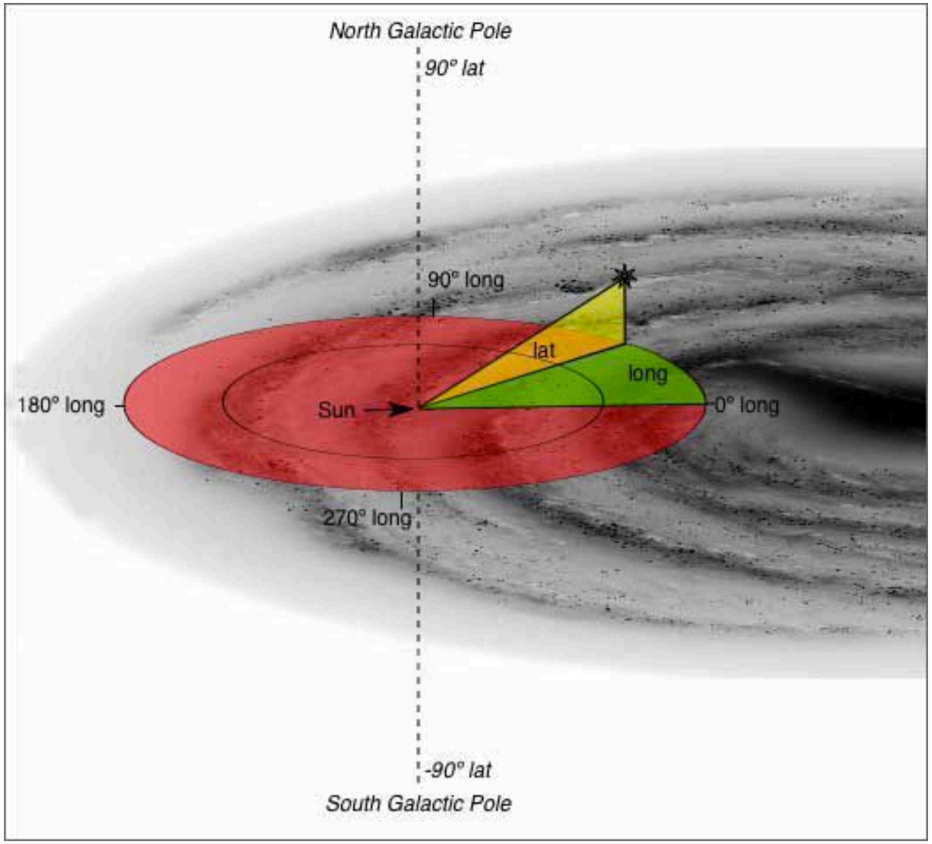
The equatorial coordinate system depends on the Earth's rotational axis, so coordinates change with time!

Coordinates have an **epoch**, e.g. "J2000" refer to coordinates in 2000 AD.

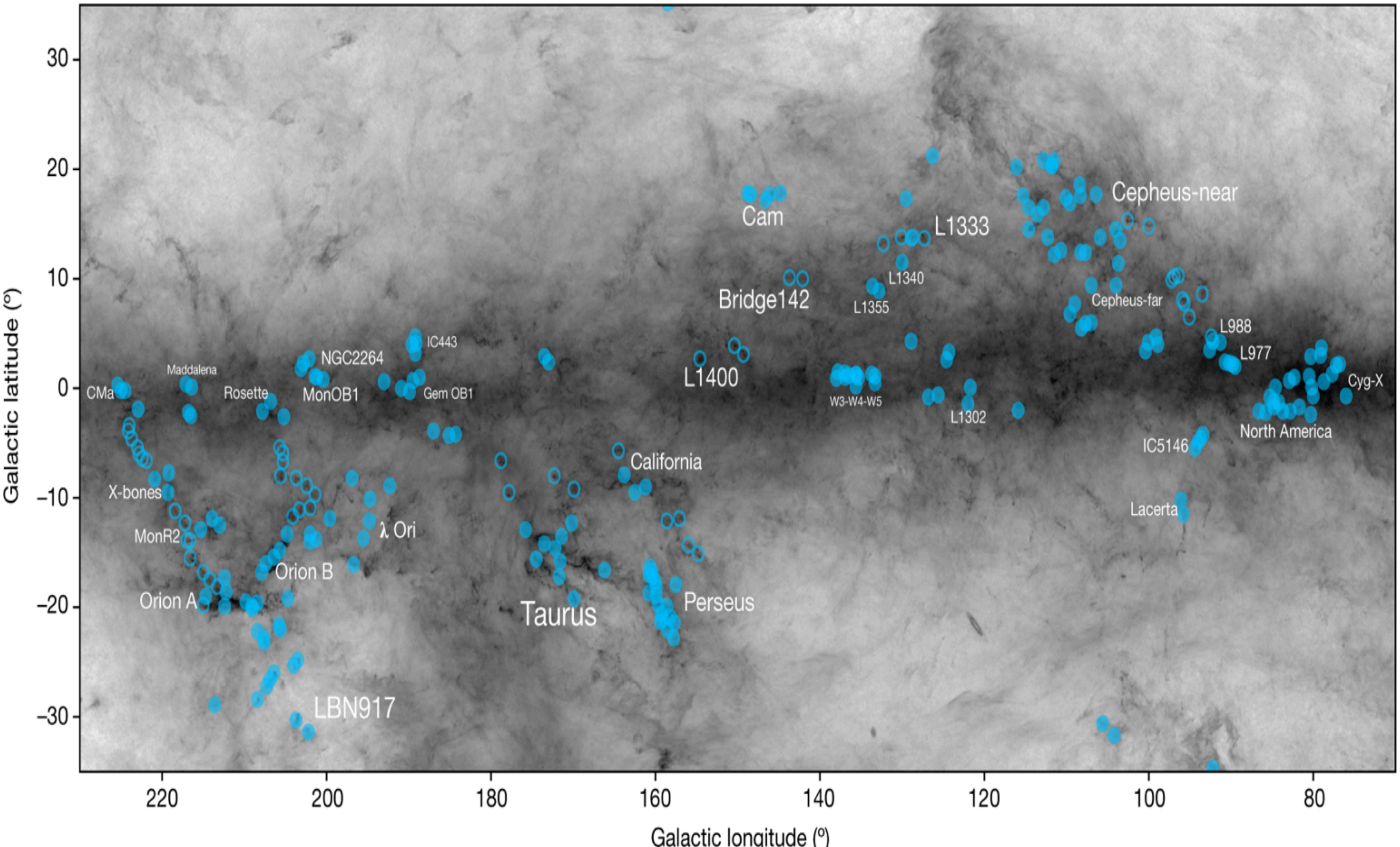


1. Coordinate systems

C. Galactic coordinates: ℓ and b

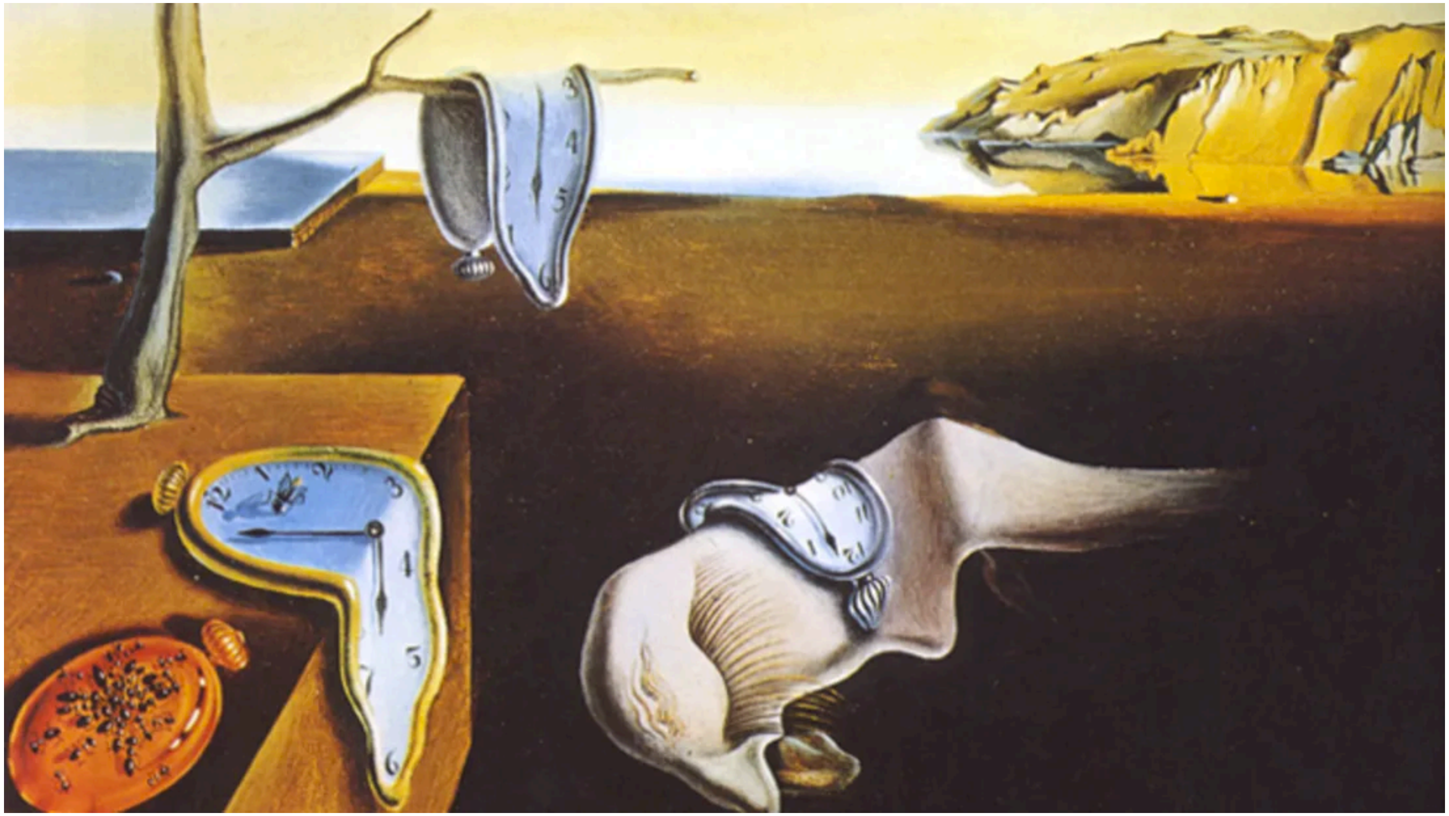


- Sun in the center
- Measurement from line connecting Sun and center of MW
- **Longitude (ℓ)**: measured in degrees, min/sec of arc
- **Latitude (b)**: measured in sexagesimal time (hr,min,sec) or degrees (-90° to 90°)
- **Galactic center:** ℓ =0, b=0
- **Direction of motion:** ℓ =90°, b=0
- Earth axis is tilted 80° from galactic plane



Alves et al. (2020)

2. Time systems



2. Time systems

A. Civil time
B. Universal time (UT)
C. Julian date (JD)
D. Local sidereal time (LST)

2. Time systems

A. Civil time

Civil time is the standard daily time of our clocks based on the Sun, varying from one place of the Earth to the other

2. Time systems

A. Civil time

Civil time is the standard daily time of our clocks based on the Sun, varying from one place of the Earth to the other.

B. Universal time UT

Universal time (UT) is global and does not change. In its simple way, it is defined according to one place on Earth (Greenwich).

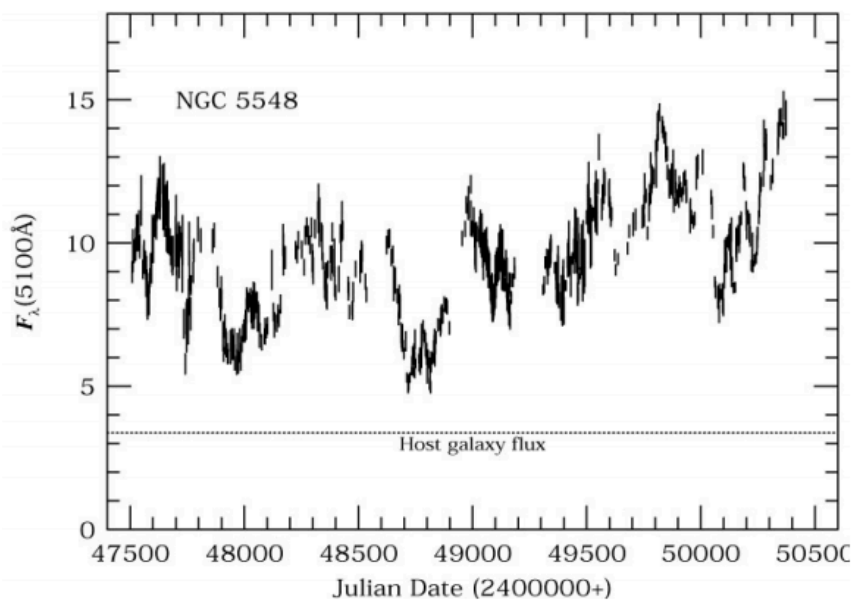
Lisbon time = UT + 1 (summer) or UT (winter)

2. Time systems

C. Julian date

- **Julian date (JD)** system allows to have continuous day counting (no months, years…)
  Number of days since noon, UT on 1st of January 4173 BE
- **Modified Julian Date (MJD)**: Number of days since 17th of November 1858.

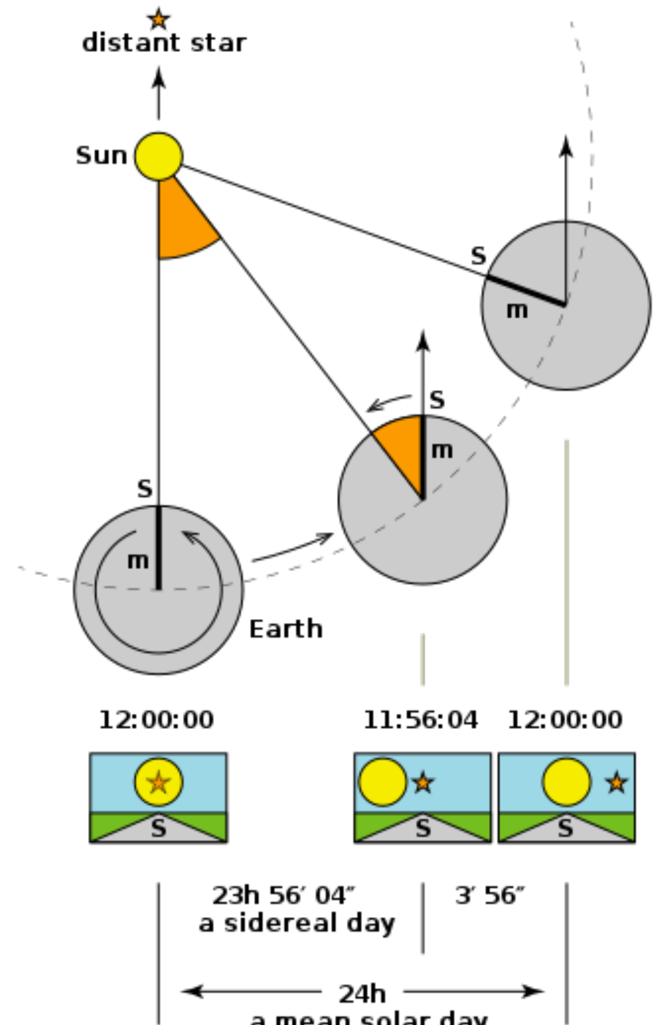
$$MJD = JD - 240000.5$$



2. Time systems

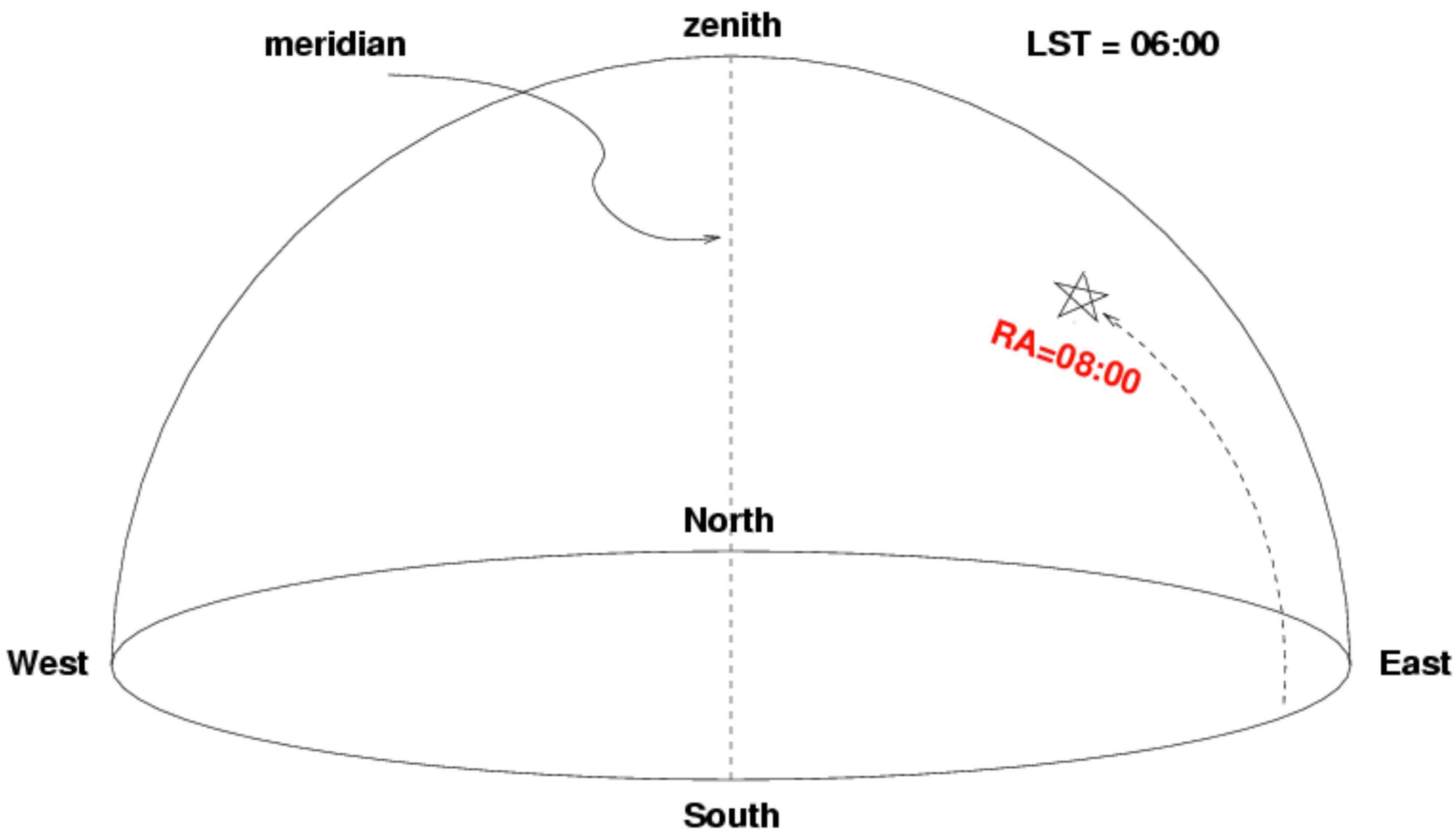
D. Sidereal time

- **Sidereal time** is a system based on distant (fixed) stars, not on the Sun
- Earth spins on its axis AND rotates around the Sun
  - **Solar day** (noon to noon): 24h
  - **Sidereal day** (one Earth rotation): 23h56m
- Viewed from the same location, a star will be seen on same location another night at same sidereal time
- Every star rises 4 mins earlier each night



2. Time systems

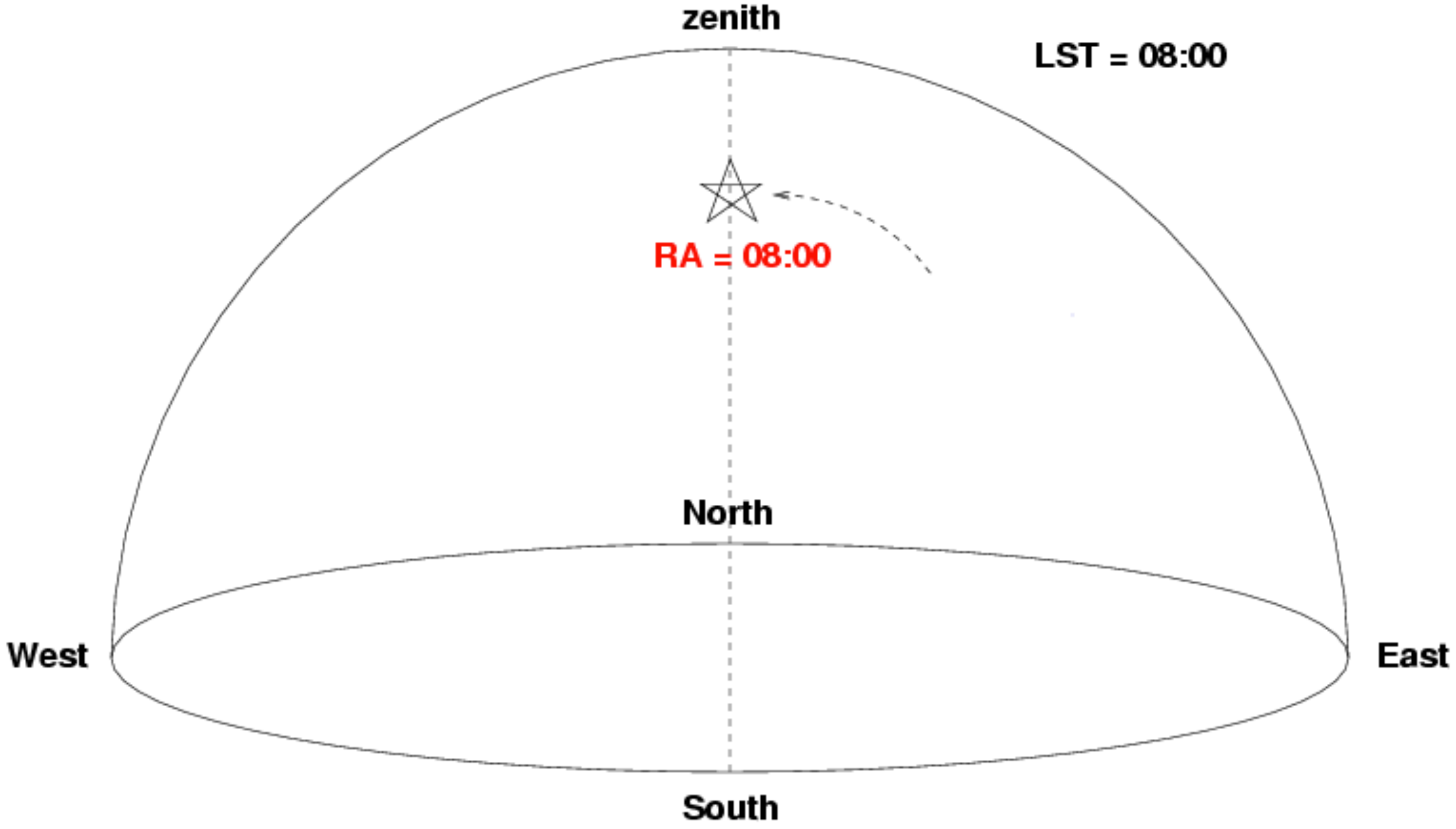
D. Sidereal time



- **Local Sidereal time (LST)** is the RA currently transiting, i.e crossing the meridian.
- **Hour Angle (HA)** = LST-RA

2. Time systems

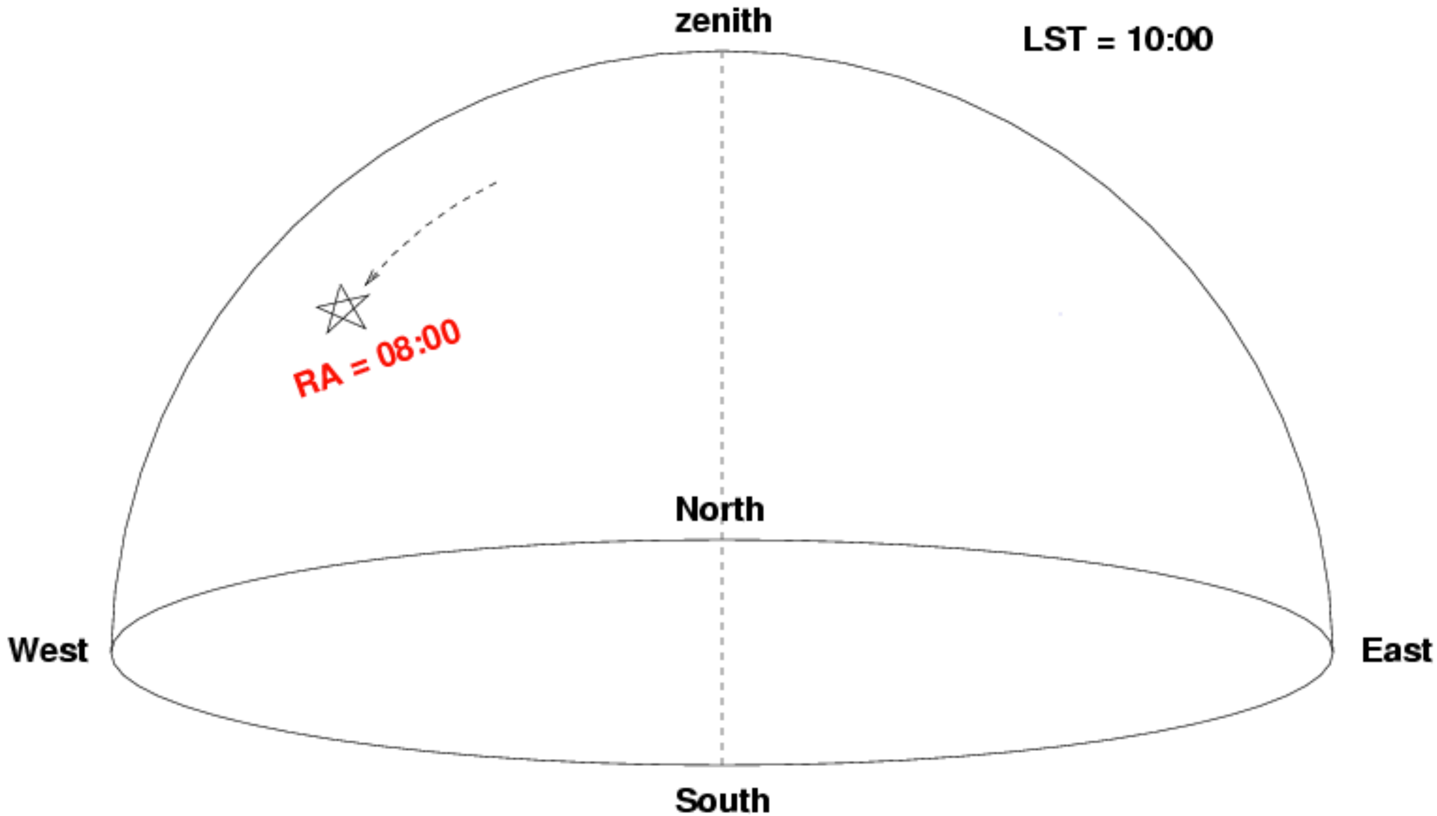
D. Sidereal time



- **Local Sidereal time (LST)** is the RA currently transiting, i.e crossing the meridian.
- **Hour Angle (HA)** = LST-RA

2. Time systems

D. Sidereal time



- **Local Sidereal time (LST)** is the RA currently transiting, i.e crossing the meridian.
- **Hour Angle (HA)** = LST-RA

Hands-on!

Planning an observation

- **Ephemeris:** provides trajectories of astronomical objects
- **Visibility**: observability of an object from a certain place during a certain time. Shows altitude over time.

Tools

- **Stellarium:** home planetarium (Mac, Win, Linux)
- **SkyMap**: mobile sky tool
- **Visibility tools**:
  - https://observability.date/
  - http://catserver.ing.iac.es/staralt/

Hands-on!

Planning an observation

Let's plan observations from a telescope in Lisbon/Chile. Organize following objects to observe from sunset to sunrise Lisbon time and from Paranal, Chile. Each object should be observed for 0.5h and count with 10min to move the telescope to the new position.

Lisbon: -9.1393, 38.7223, 10m

Paranal: 24°37'38''S, 70°24'15''W, 2635m

Objects

- Moon
- Saturn
- Jupiter
- Albireo
- Mizar & Alcor
- Orion Nebula (M42)
- Andromeda (M31)
- Hercules Cluster (M13)
- Double Cluster (NGC869 & NGC884)
- Ring Nebula (M57)
- Dumbbell Nebula (M27)