AGA5802
Coordinate Systems

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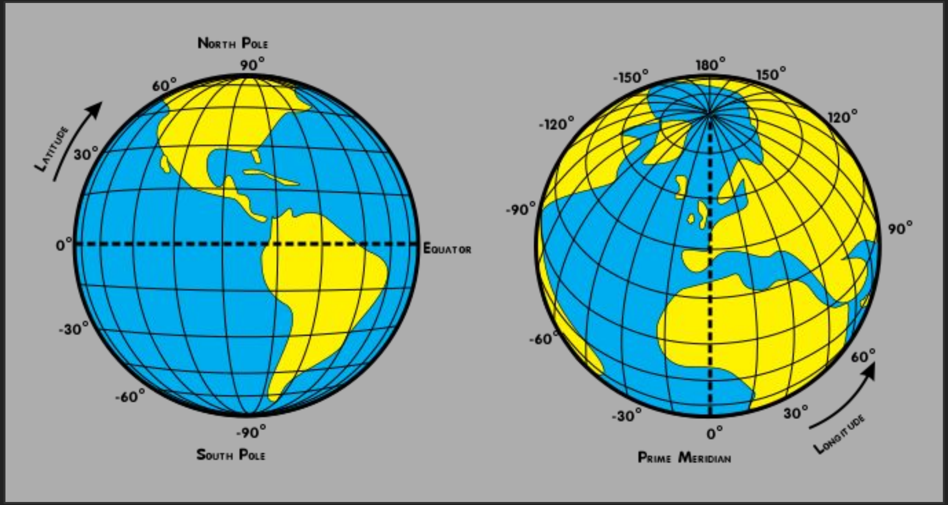
How do you know how to come to class?

- Class is
    - in Brazil
        - São Paulo
            - USP
                - Cidade Universitaria
                    - IAG
                        - Aula XXX
    - **Or**
        - Latitude
        - Longitude
        - Elevation
- At 2pm

Sky Coordinates

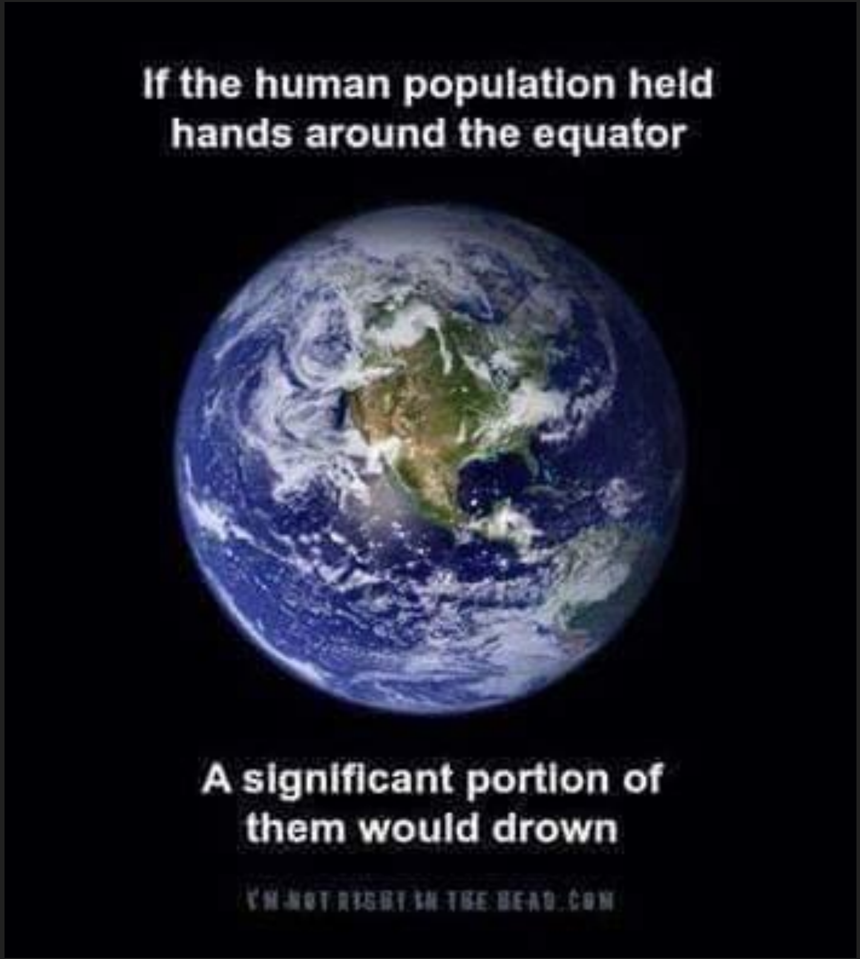
What do you need to define coordinates?

- A plane
- (which tends to have an axis)
- A way to break symmetry (N-S / E-W)
- An origin of your system



Earth Coordinates - Equator

https://www.nasa.gov/audience/forstudents/k-4/dictionary/Equator.html


If the human population held
hands around the equator
A significant portion of
them would drown

Earth Coordinates - Meridian Zero

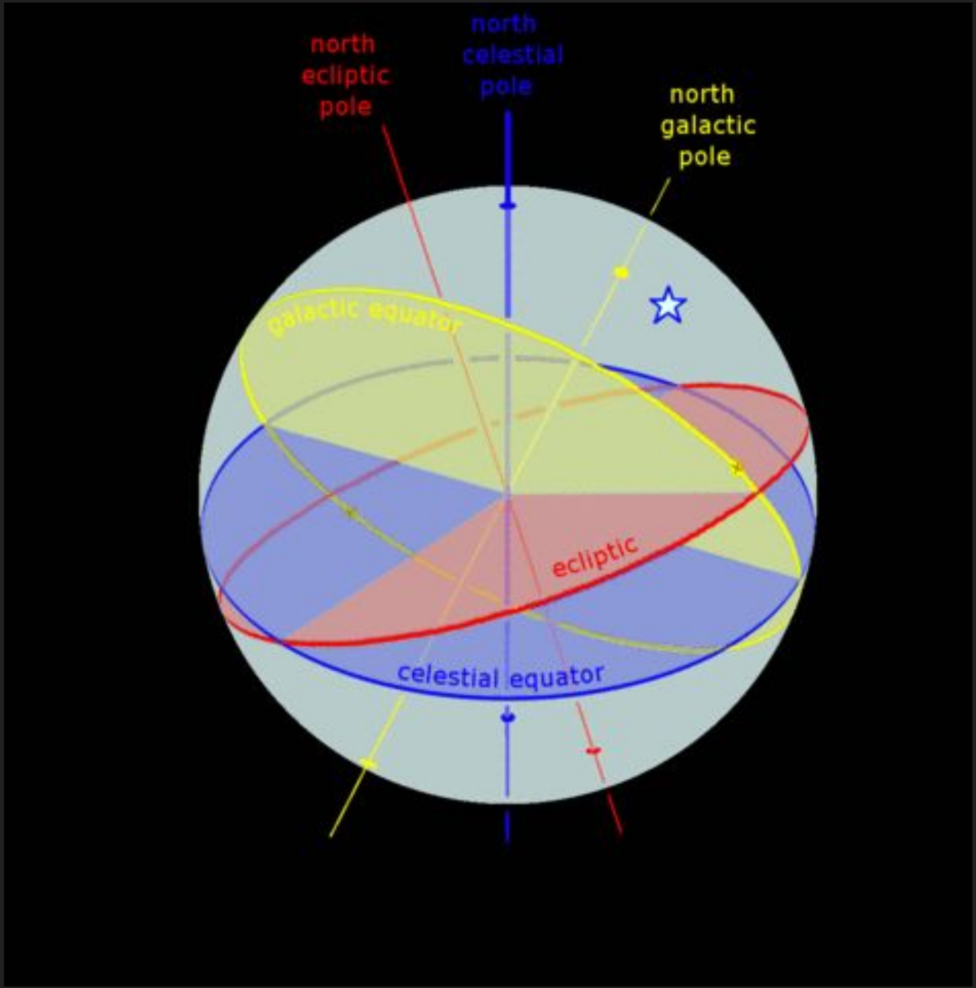
https://en.wikipedia.org/wiki/Longitude_(book)

Relevant planes

Equator

Ecliptic

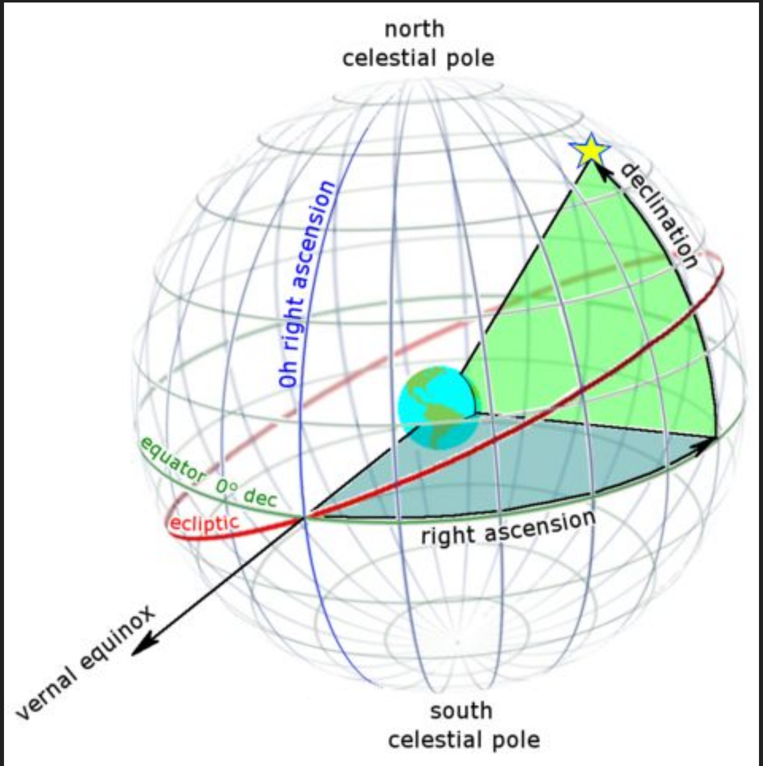
Milky Way



Declination

Angular distance from the celestial equator

Celestial poles have δ = +/- 90º

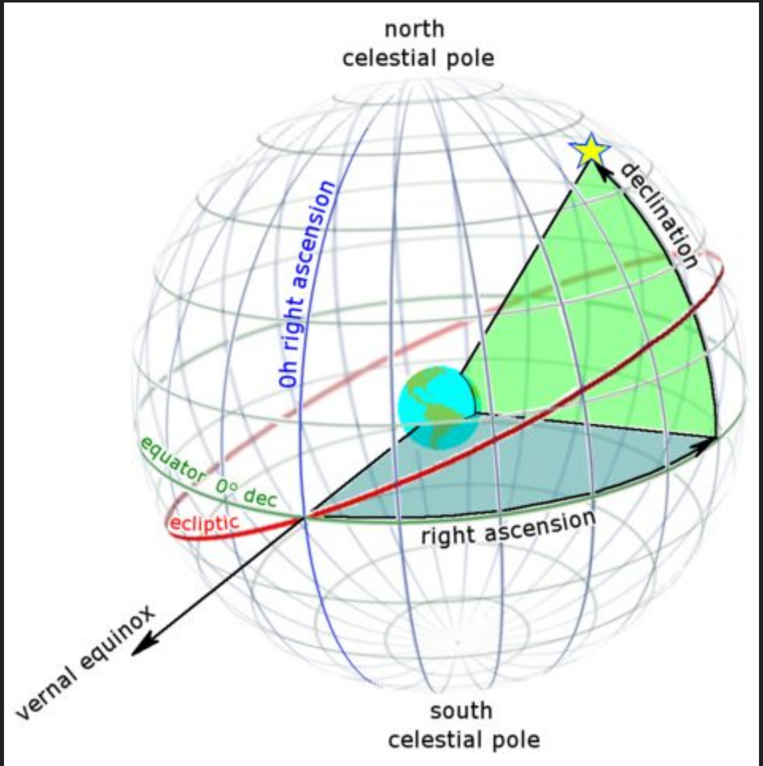


Declination of zenith

Celestial poles have δ = 90º

If the height above the horizon of the celestial pole equals the longitude of the place: can we infer the declination of zenith?

$\delta_z = l$



Circumpolar stars

Can anyone explain this picture?

-) why some tracks are longer than others?

-) can you guess the length of the exposure?

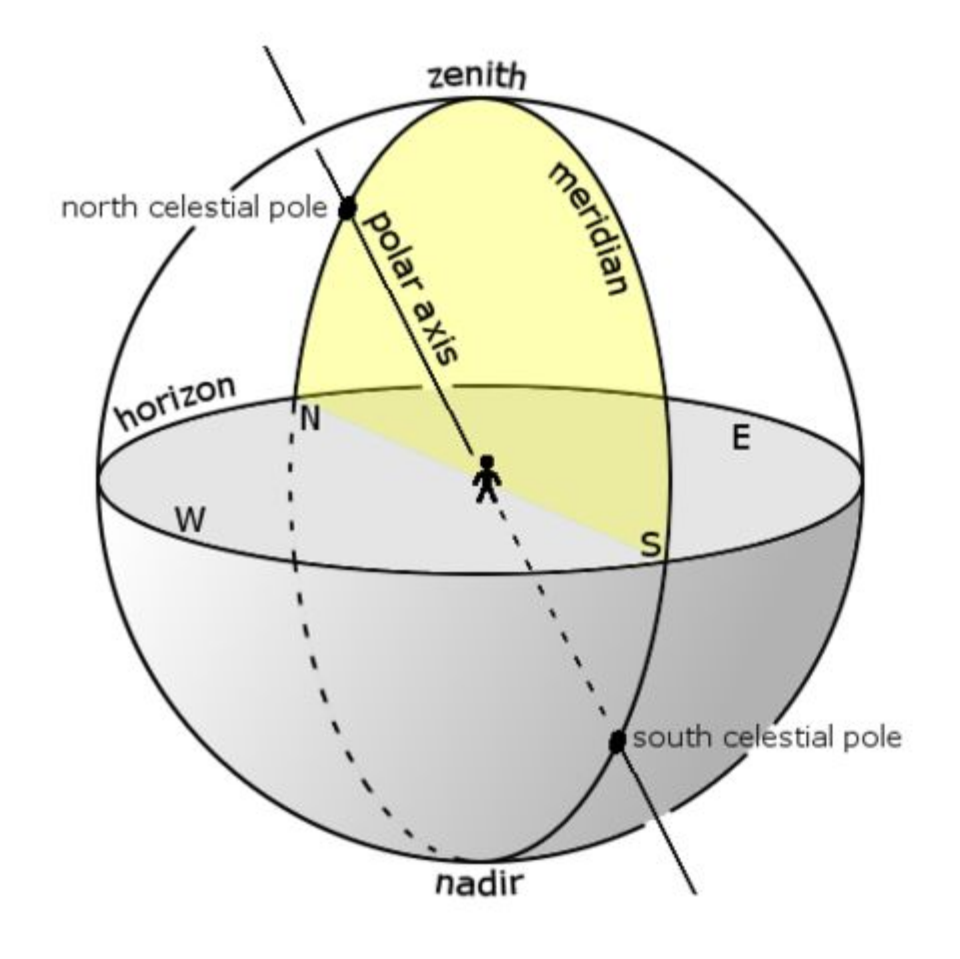
-) can you guess where the Southern Pole is?

Circumpolar Stars

The stars with declination δ > 90º - *l*

Where *l* is the local longitude never rise or set.

It's δ < -90º + l for the Southern hemisphere.



The γ point and Right Ascension (α)

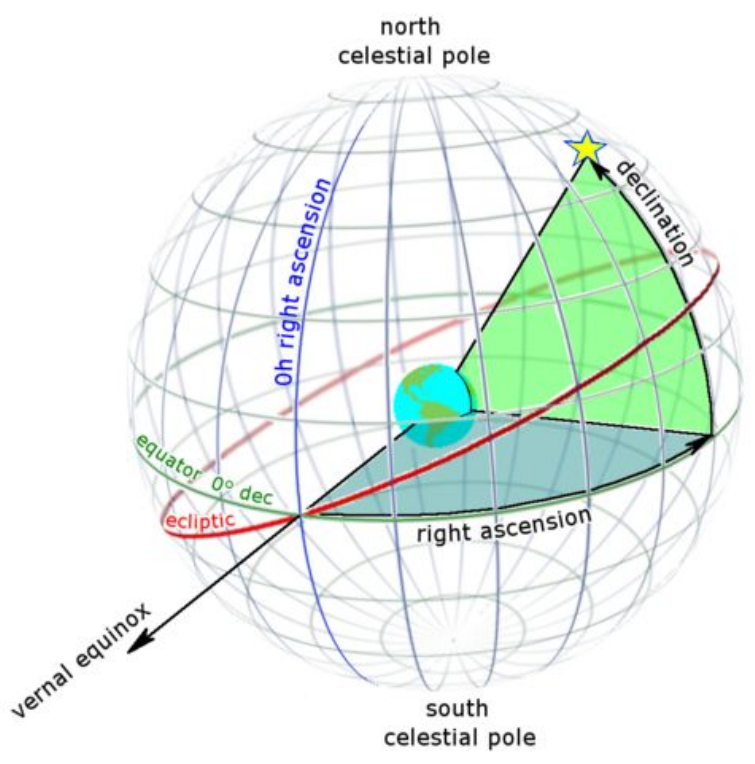
The celestial equator and the ecliptic cross in two points.

One of these points is the “vernal point”.

It is the position of the Sun on Mar21 (aprox).

ON MAR21, THE SUN HAS RA = 0h

2 π radians = 360º = 1 day = 24h

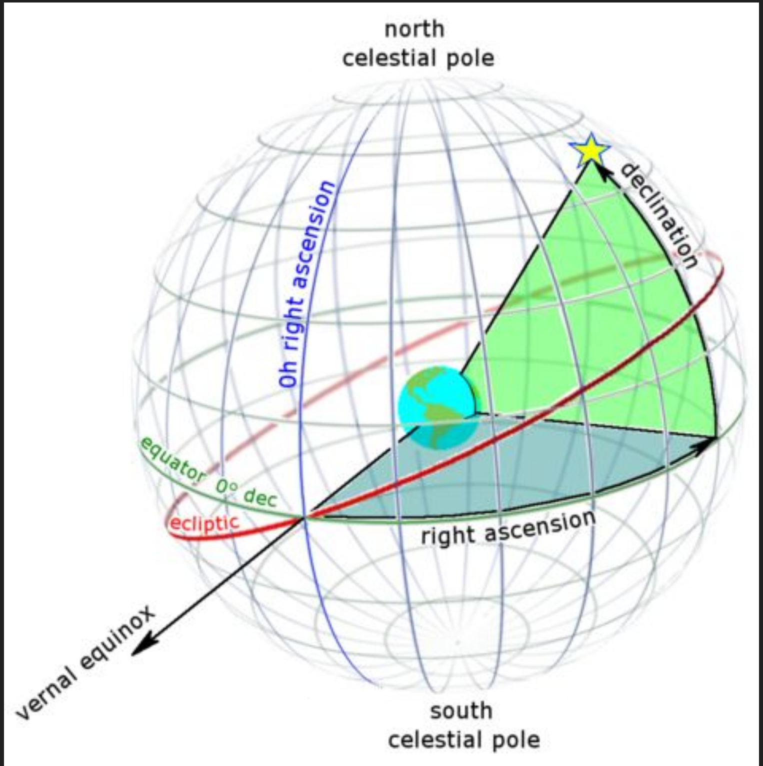


The Hour Angle

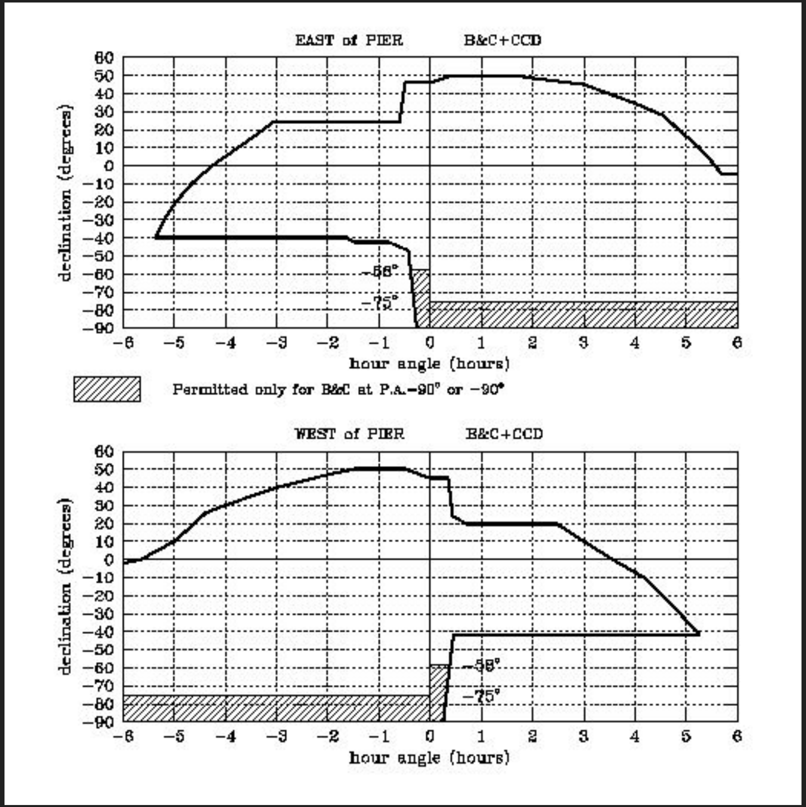
Local Sidereal Time is the (sidereal) time since the γ point has passed the local meridian.

The hour angle (HA) is:

$HA_{object} = LST - \alpha_{object}$



Pointing Limits of an Equatorial Mount



The Right Ascension of zenith

In the middle of the night (which is **NOT** midnight):

On Mar21, α_{Sun} ~ 0h

Since Sun is at nadir, at that moment, the α_{zenith} ~ 12h

Since the Sun “moves” around the Ecliptic in a year (360° = 24h = 12 months), it means that α_{zenith} changes by 2hours/month.

On Dec 21, α_{zenith} is 0h

Coordinates of zenith

What are the coordinates of zenith (in the middle of the night) on

Jun 21

Sep 21

Today

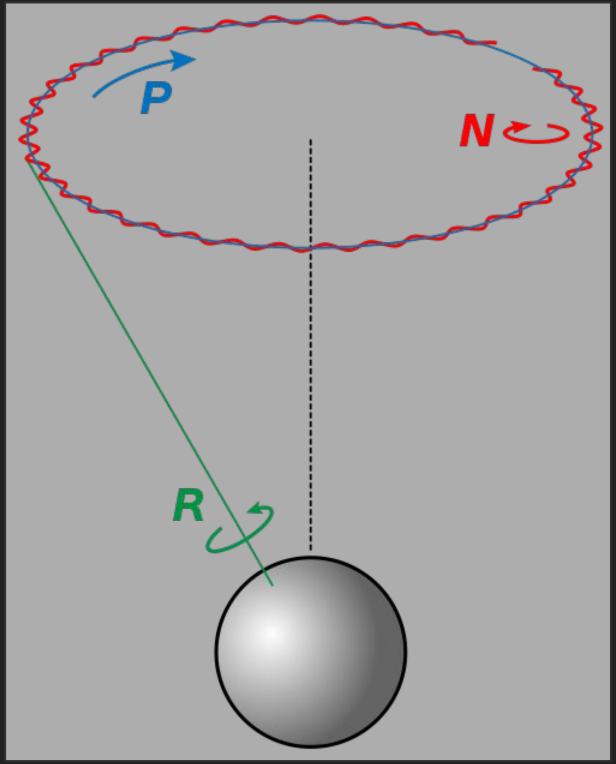
18h00

00h00

11h30

Movements of the Earth

Revolution	1 year
Rotation	1 day
Precession	25,000 years
Nutation	18.6 years



Epoch and Equinox

Define the origin of our coordinate system.

Equinox refers to the position of the vernal point.

Epoch refers to the position of a moment in time.

Reference Systems

FK4

Based on bright stars at B1950.

FK5

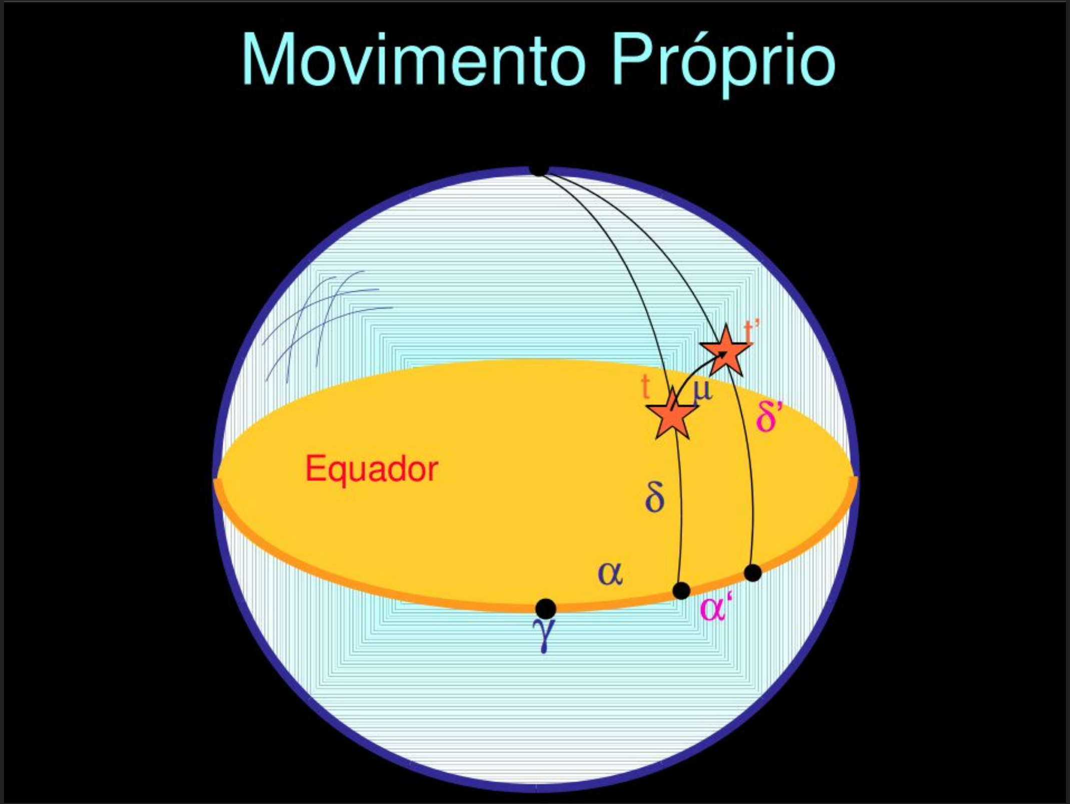
Based on bright stars at J2000.

ICRS

Based on 212 extragalactic radio sources (J2000)

Stars MOVE!

Credit: R. Teixeira
http://www.astro.iag.usp.br/~thais/aga414_files/astroposRama.pdf



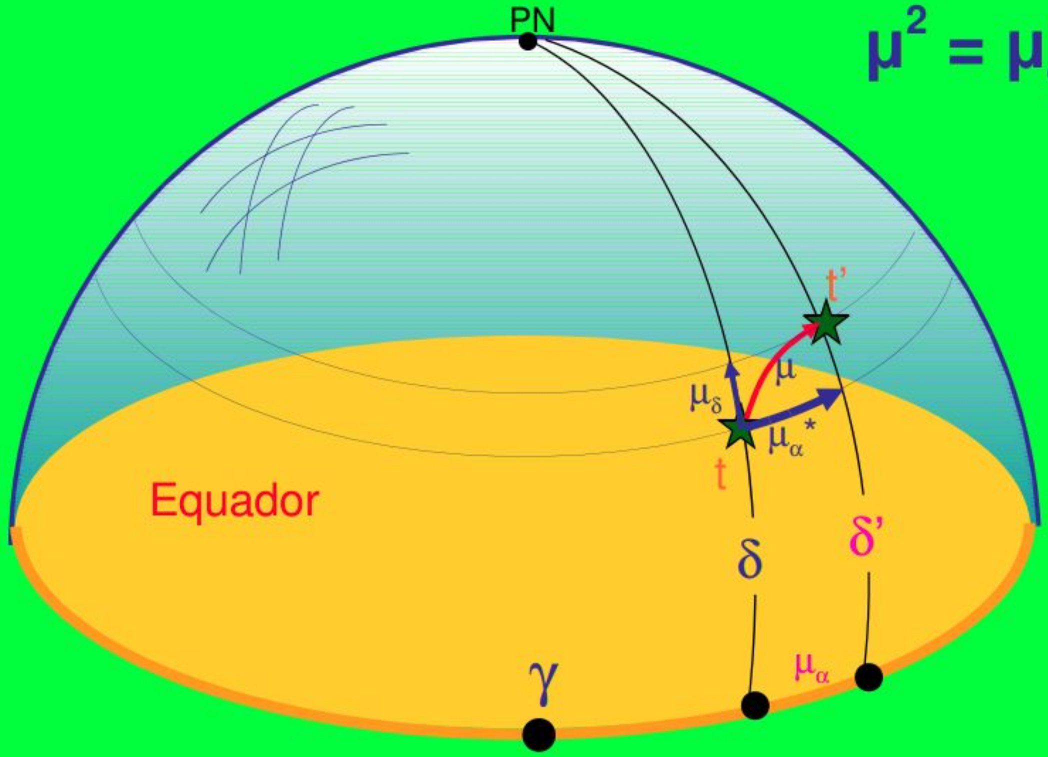
Componentes do movimento próprio

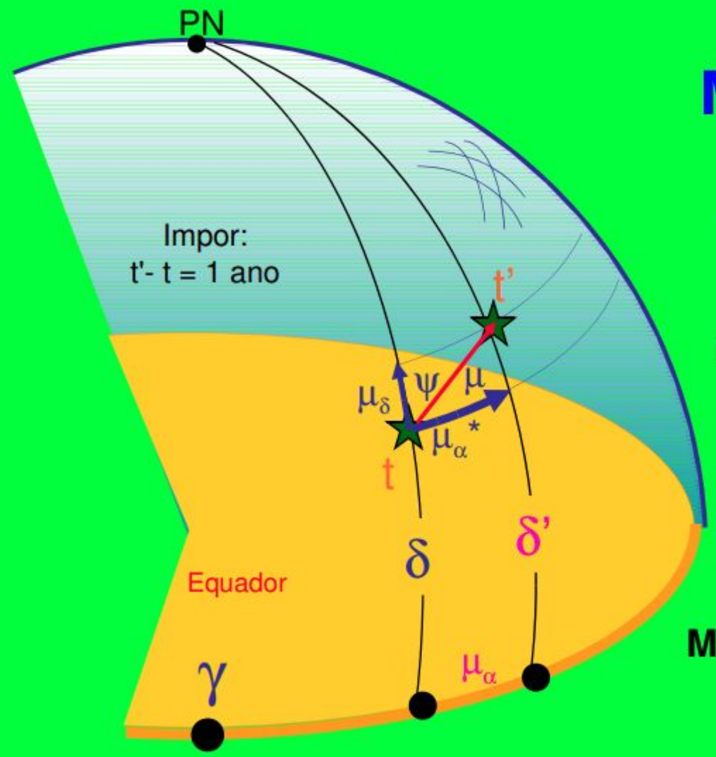
μ = movimento próprio ["/ano]

μ_α = movimento próprio em ascensão reta

μ_δ = movimento próprio em declinação

$$\mu^2 = \mu_\alpha^{*2} + \mu_\delta^2$$





Movimento próprio

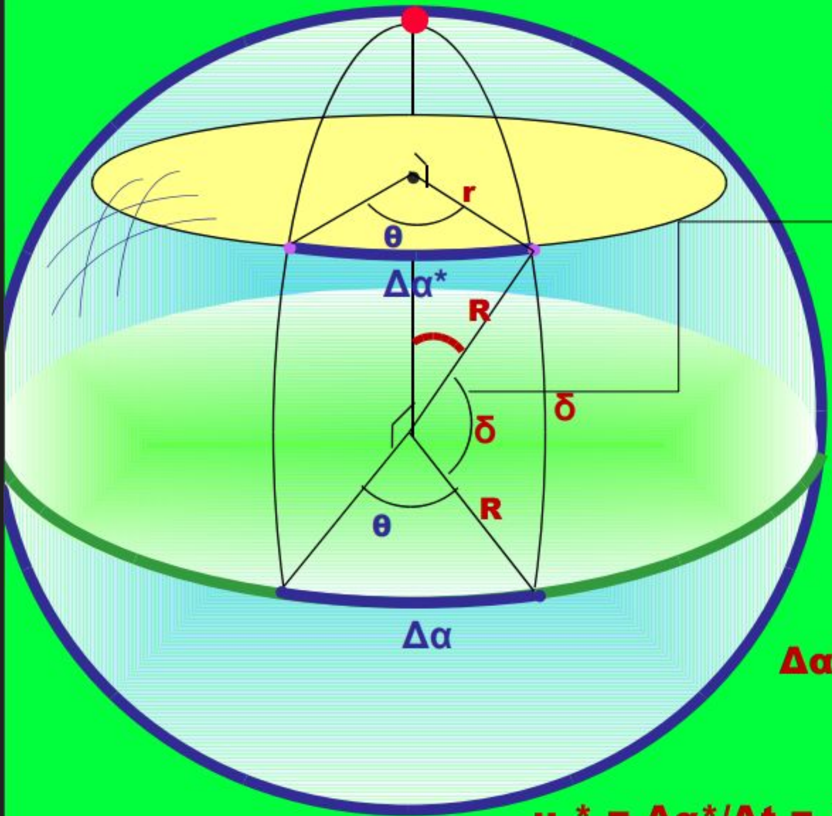
$$\mu^2 = (\mu_\alpha{}^*)^2 + (\mu_\delta)^2$$

Movimento próprio em declinação

$$\mu_\delta = \Delta\delta/\Delta t \text{ (“/ano)}$$

Movimento próprio em ascensão reta

$$\mu_\alpha = \Delta\alpha/\Delta t \text{ (s/ano)}$$



$\Delta\alpha = \theta.R \quad \Delta\alpha^* = \theta.r$

$(90° - \delta)$

$sen(90° - \delta) = r/R$

$r = R.\cos\delta$

$\Delta\alpha^* = \theta.R.\cos\delta = \Delta\alpha.\cos\delta$

PORTANTO

$\mu_\alpha^* = \Delta\alpha^*/\Delta t = \Delta\alpha.\cos\delta/\Delta t = \mu_\alpha.\cos\delta$

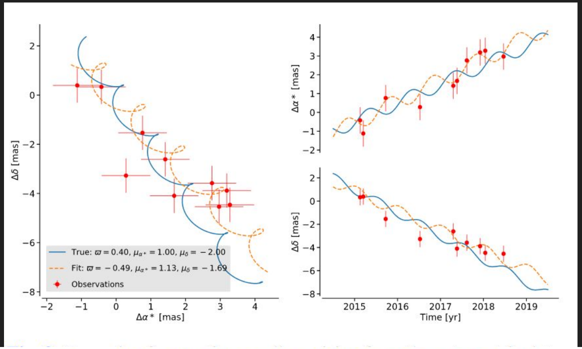
$$\mu^2 = \mu_\alpha^{*2} + \mu_\delta^2 = (\mu_\alpha \cos\delta)^2 + \mu_\delta^2$$

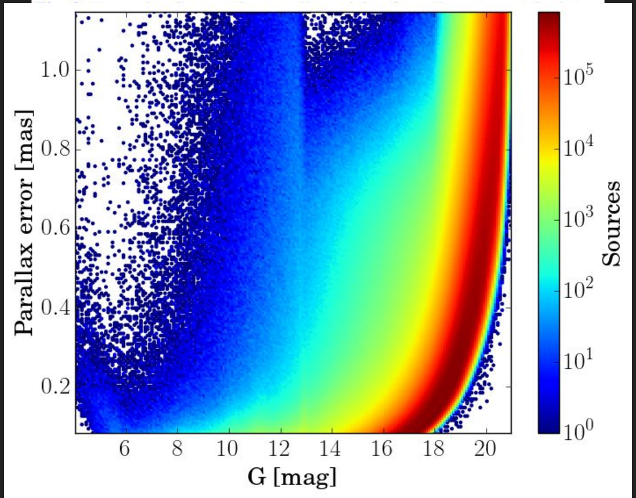
To make things more complicated: parallax

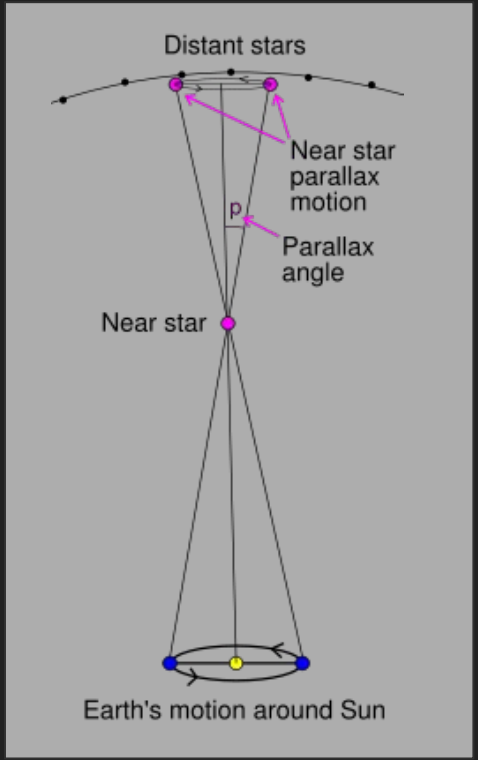
d = a tan p ~ a * p

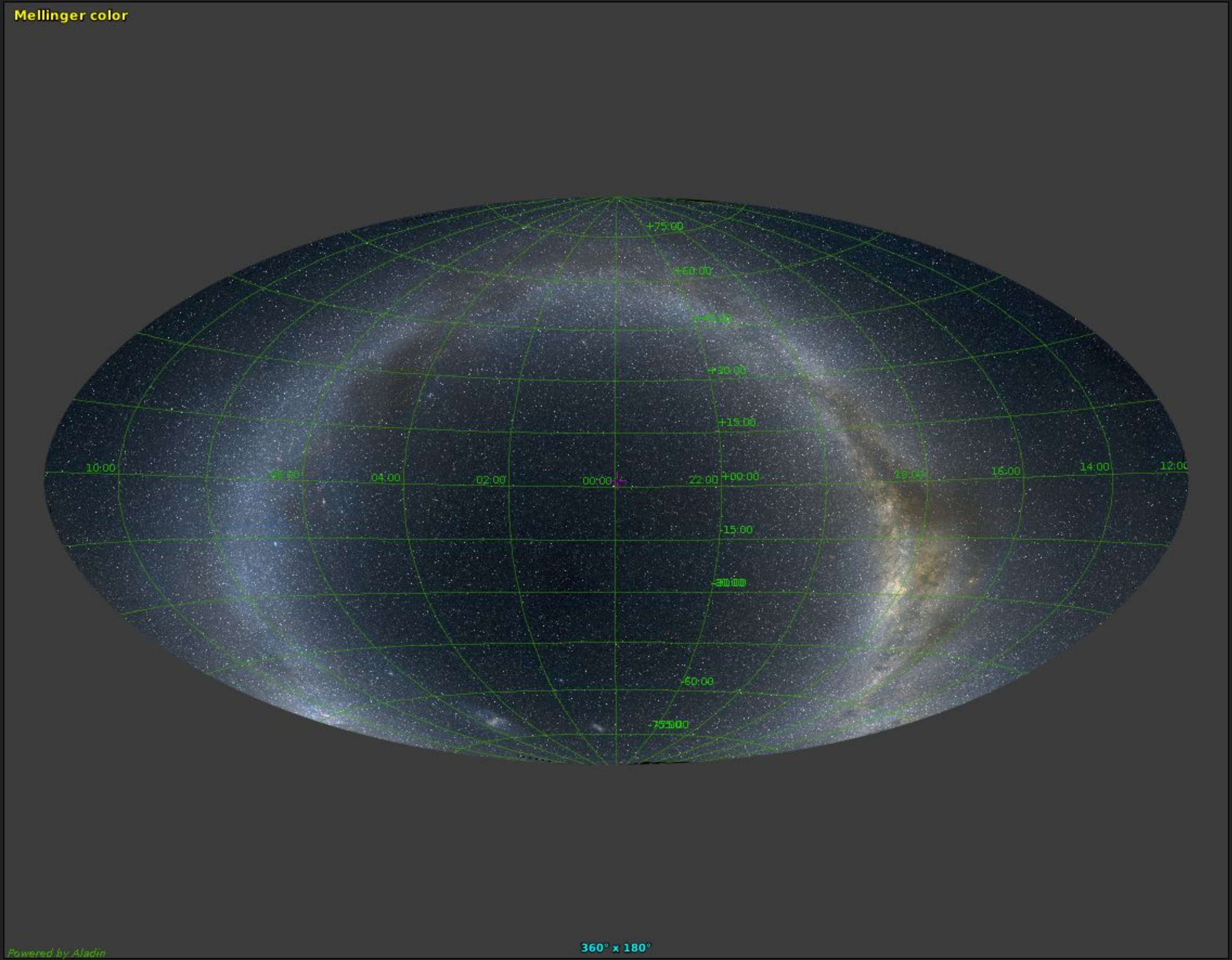
a = 1UA = 140 x 10^6 km

Gaia !








Mellinger color
+75:00
+60:00
+30:00
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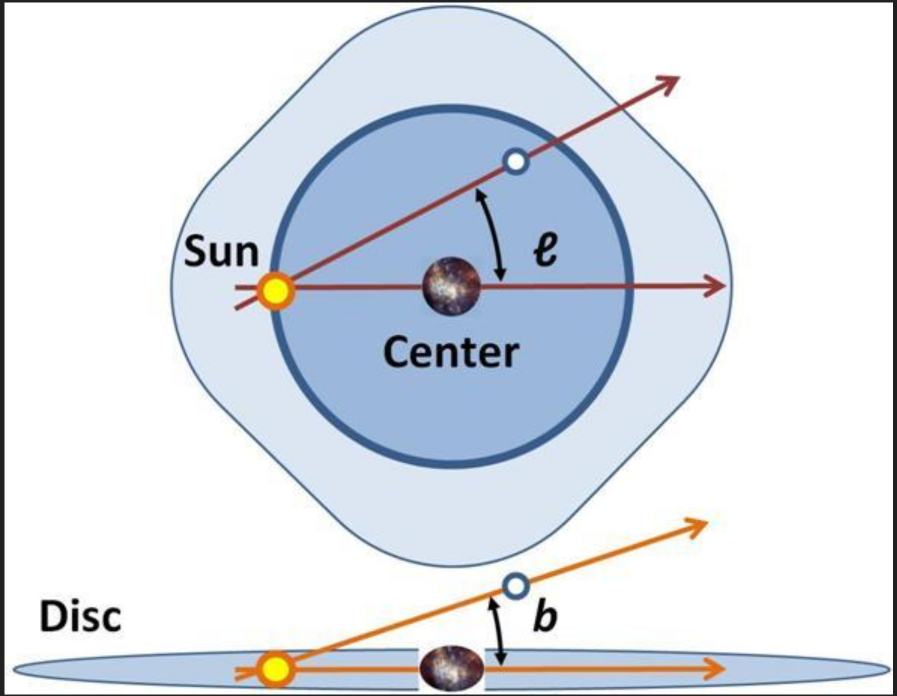
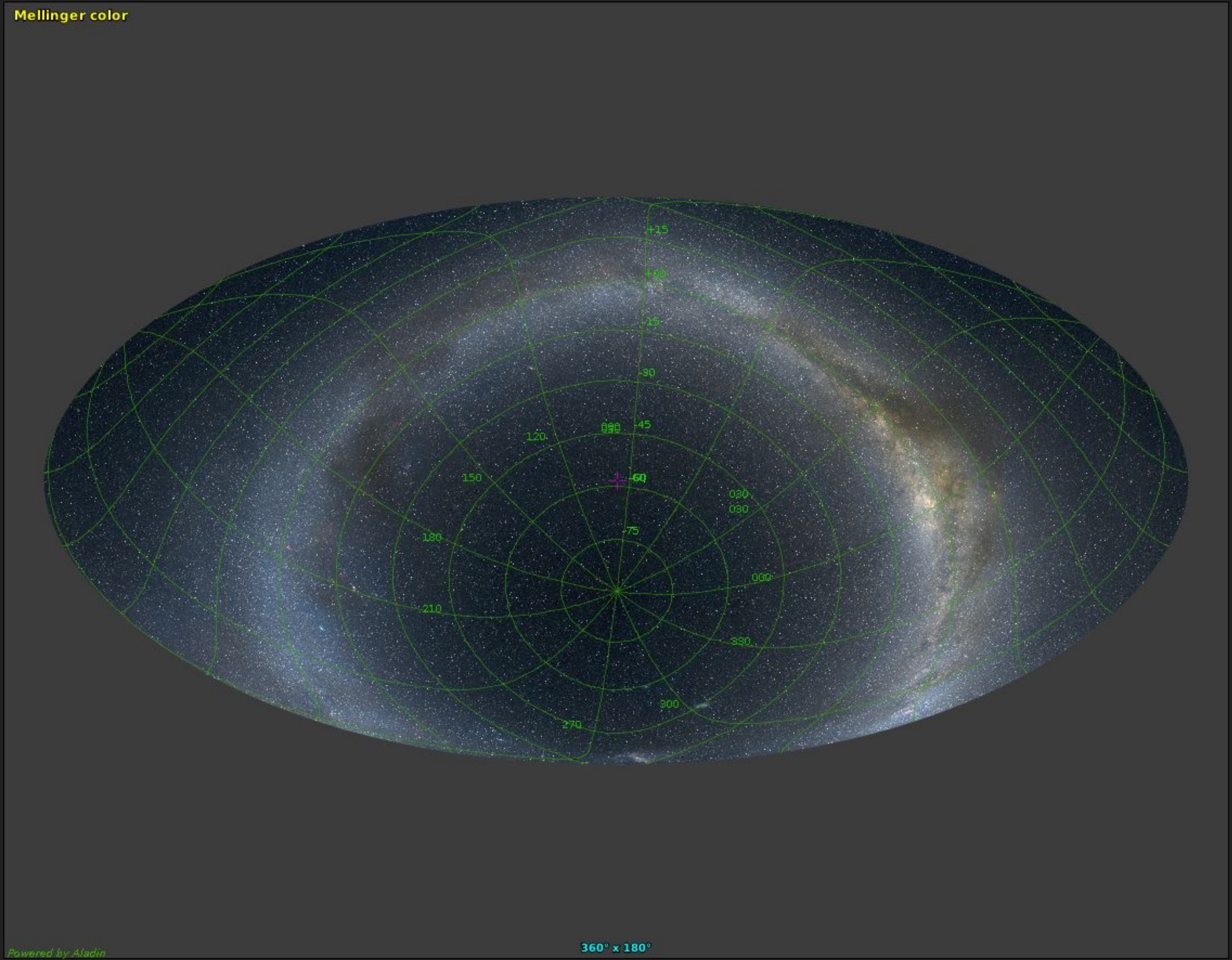
02:00
00:00
22:00
+00:00
16:00
14:00
12:00
-15:00
-60:00
Powered by Aladin
360° x 180°

Galactic Coordinates

Galactic longitude - l

Galactic latitude - b




Mellinger color
+15
+60
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-30
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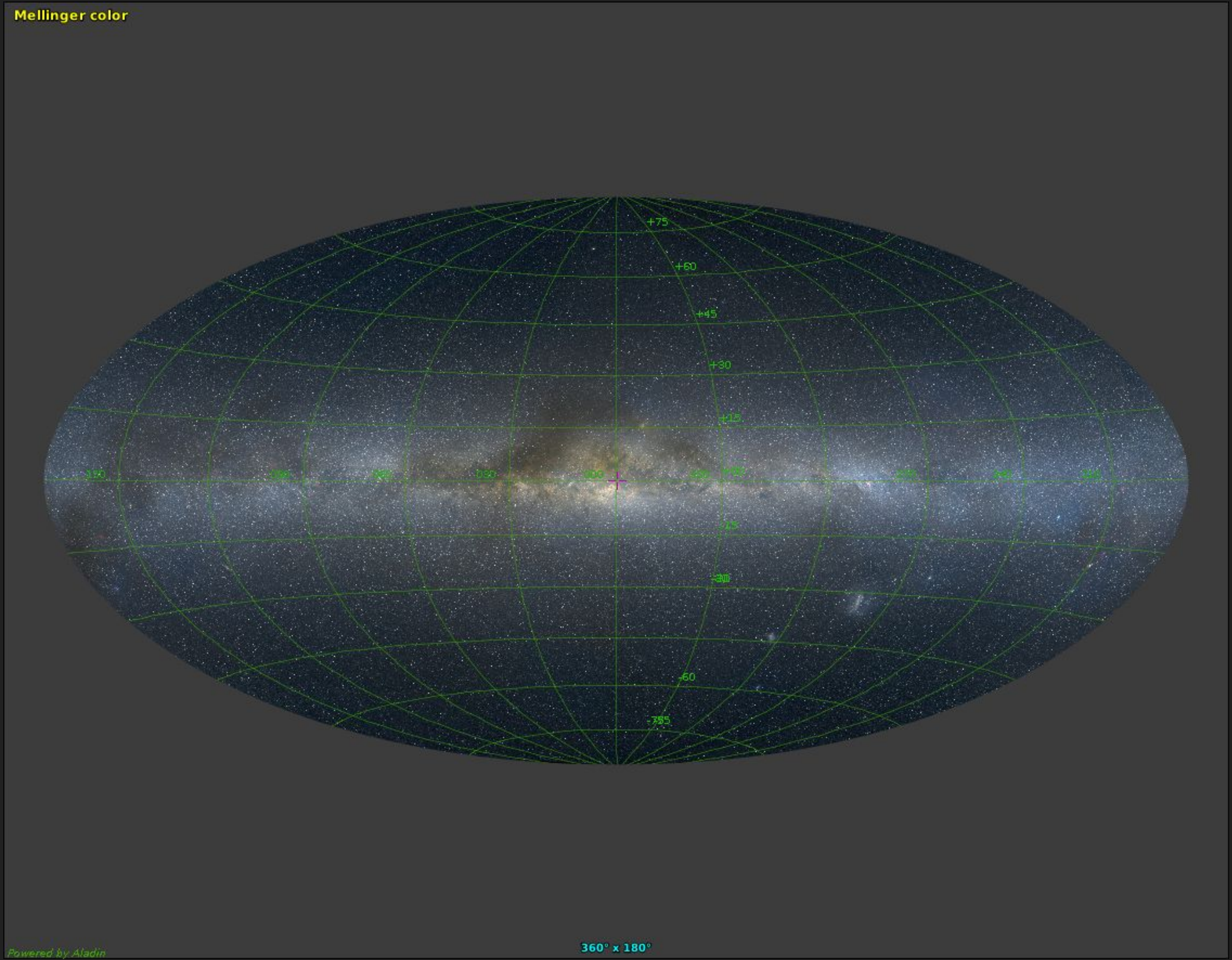
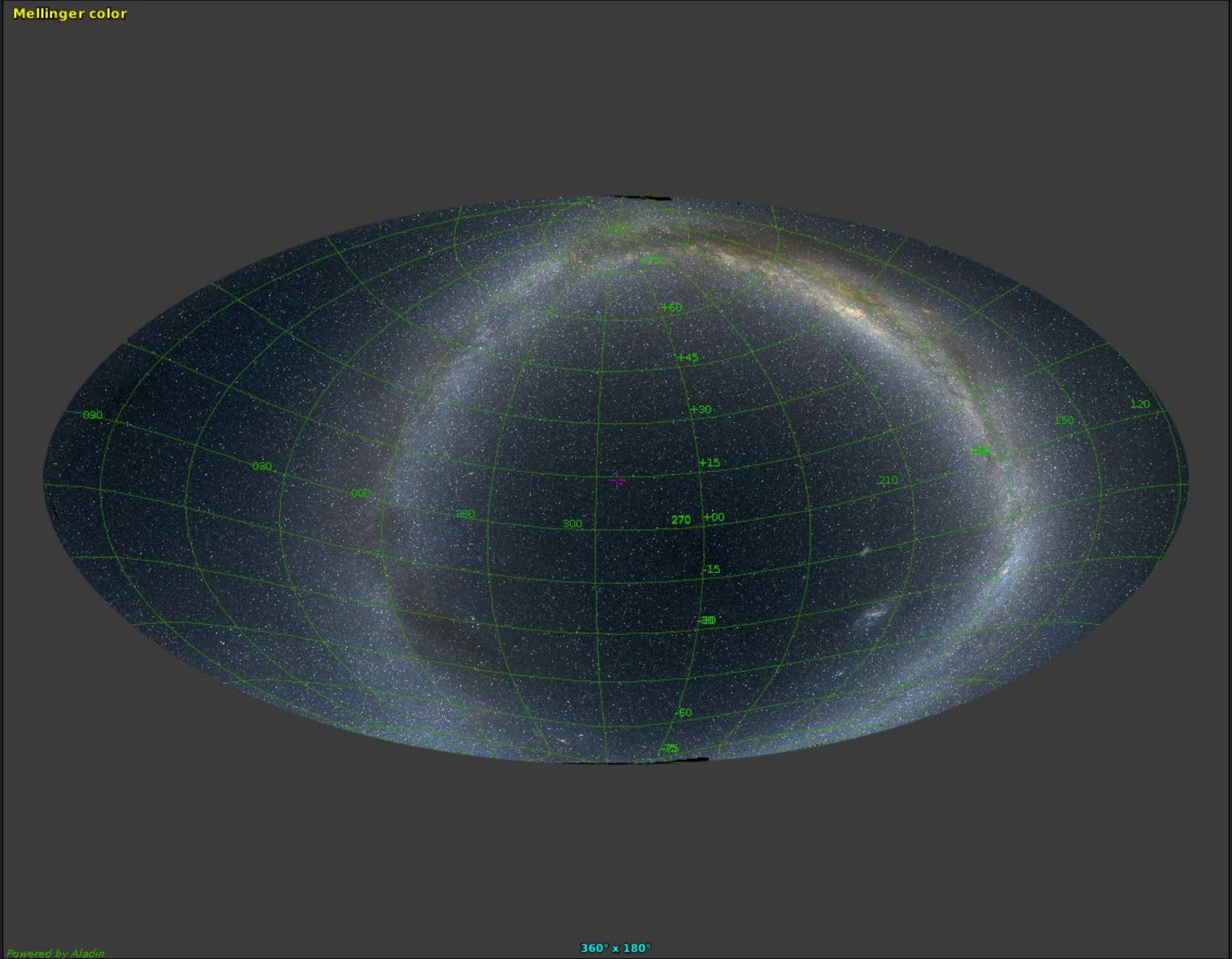
300
270
Powered by Aladin
360° x 180°


Mellinger color
+75
+60
+45
+30
+15
-15
-60
360° x 180°
Powered by Aladin

Super-Galactic Coordinates

Very little used.

Designed to have its equator aligned with the **supergalactic plane**, a major structure in the local universe formed by the preferential distribution of nearby galaxy clusters (such as the Virgo cluster, the Great Attractor and the Pisces-Perseus supercluster) towards a (two-dimensional) plane


Mellinger color
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Powered by Aladin
360° x 180°

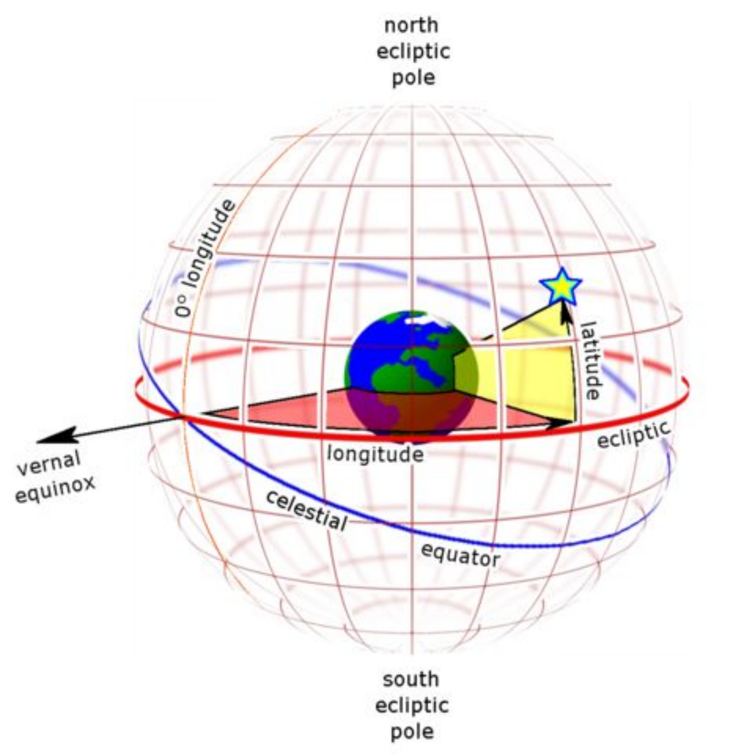
Ecliptic Coordinates

Used for objects in the Solar System

Ecliptic as main plane

Centred on Earth OR Sun

Can be either spherical or rectangular



Let’s get some objects and check their coordinates

Simbad

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

NED (NASA Extragalactic Database)

http://ned.ipac.caltech.edu/

John R. Thornstensen

https://home.dartmouth.edu/faculty-directory/john-r-thorstensen

https://www.dartmouth.edu/~physics/labs/skycalc/flyer.html

Staralt

http://catserver.ing.iac.es/staralt/index.php

Compute visibility

Compute trajectories

Programming

Most (if not all) programming languages have some library/module to deal with coordinate systems

- FORTRAN
- C
- C++
- Perl
- Python
- IDL
- R

ESO SkyCalc

https://www.eso.org/observing/etc/bin/gen/form?INS.MODE=swspectr+INS.NAME=SKYCALC

pyephem

https://rhodesmill.org/pyephem/

In case you get lost with cities:

https://github.com/brandon-rhodes/pyephem/blob/master/ephem/cities.py

Yet, pyephem is now deprecated.

One should use SkyField

https://rhodesmill.org/skyfield/

astropy

http://www.astropy.org/astropy-tutorials/rst-tutorials/coordinates.html?highlight=filtertutorials

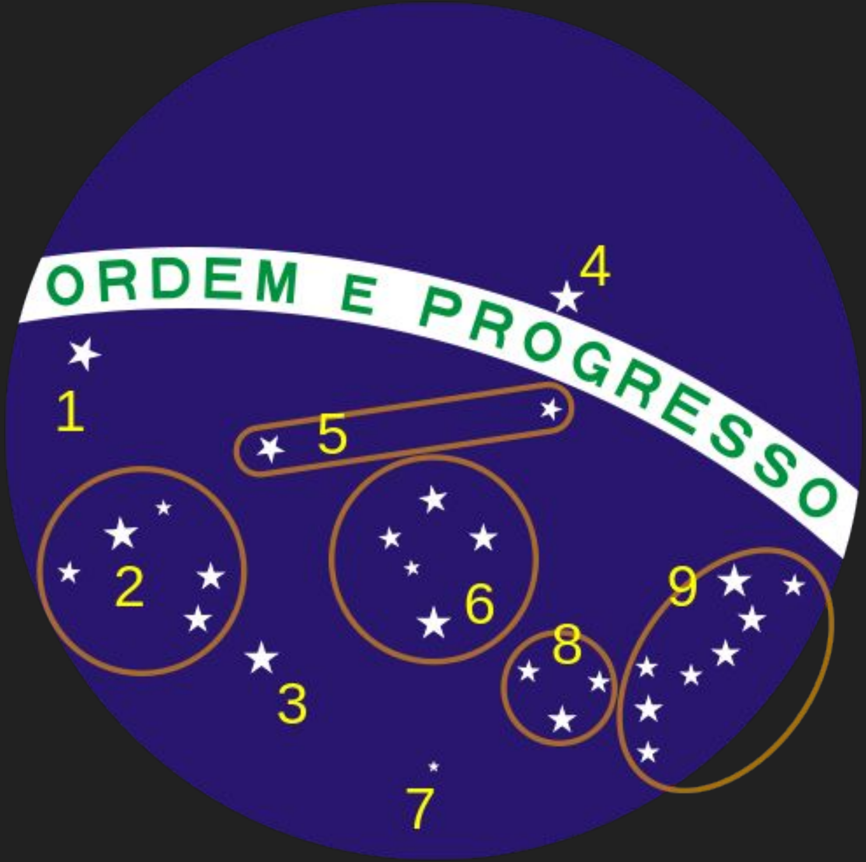
IDL

There are commands for IDL users:

https://idlastro.gsfc.nasa.gov/contents.html

The Flag of Brazil

the stars in the sky at Rio de Janeiro at 8:30 in the morning on 15 November 1889



https://en.wikipedia.org/wiki/Flag_of_Brazil#Stars

Exercises

- Draw the flag of Brazil for the same date but as if the capital was Natal instead of Rio
- Draw the flag of Brazil if the sky was Mar1, 2020 and the capital was São Paulo
- Draw the alt-az position of Sirius at noon over a year. Does it draw an analemma? Explain why
- Draw the azimuth of Sirius when it rises (i.e. when its altitude = 0 towards East) over the year. Does it vary? Explain why