

Coordinate Systems

Topics: observing seasons, celestial motions, coordinates, time, precession, proper motion

Sources: Chromey Ch. 3

Basic Definitions:

zenith: the point at 90° elevation

nadir: the point at -90° elevation

meridian: the great circle intersecting the south celestial pole, north celestial pole and local zenith

hour angle: the time before (-) or after (+) an object crosses the local meridian

celestial equator: projection of the Earth's equator onto the sky

celestial north pole: the point above the north pole of the Earth

ecliptic: the plane defined by the orbital plane of the Earth around the sun

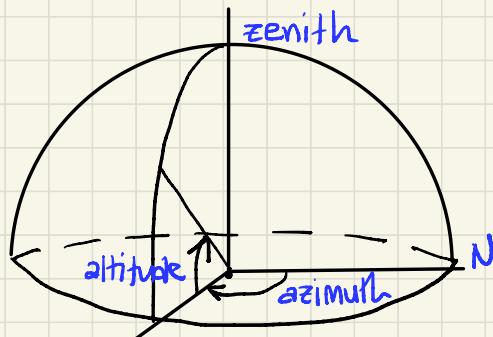
galactic plane: plane which passes through the disk of the Galaxy

Azimuthal coordinates:

azimuth: degrees east of north along the horizon
 $0^\circ - 360^\circ$

altitude or elevation: angle from the horizon, $0^\circ - 90^\circ$

zenith angle: $z = 90^\circ - \text{altitude}$



$$\text{airmass} = X = \sec z = \frac{1}{\cos z}$$

z (deg)	X
0	1.00
10	1.02
30	1.15
45	1.41
60	2.00
70	2.92
80	5.75

→ this eqn. is for a plan-parallel atmosphere (i.e. constant density), ignore curvature of Earth. It breaks down at $z \sim 75^\circ$. At greater angles $X \rightarrow \infty$, when really the maximum on the horizon is usually < 40 .

minimum airmass occurs when an object is on the meridian the minimum zenith angle is given by:

$$z_{\min} = |\text{observatory latitude} - \text{source declination}|$$

Equatorial Coordinates:

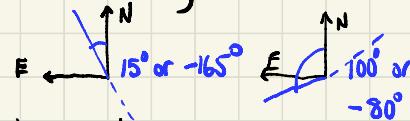
δ declination: the angle north or south of the celestial equator
 α right ascension: time, in hours, minutes, seconds (sexagesimal) from the Vernal Equinox ($\text{RA} = 0$), increases \mathbb{E}

$\text{RA} = 0, \text{dec} = 0$ in Pisces is where the Sun is located on March 21

Epoch of coordinates: B1950 (Besselian; FK4) or J2000 (Julian; FK5)

to correct for precession of Earth's axis

Position angle: the angle East of North onto the sky
 $(0^\circ$ to 480° or 0° to -180°)

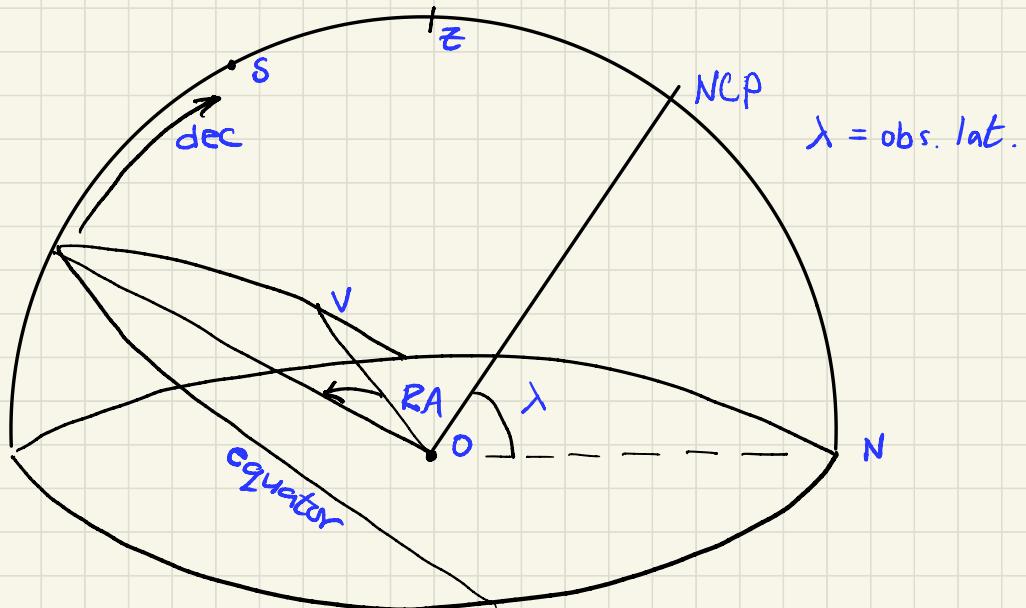
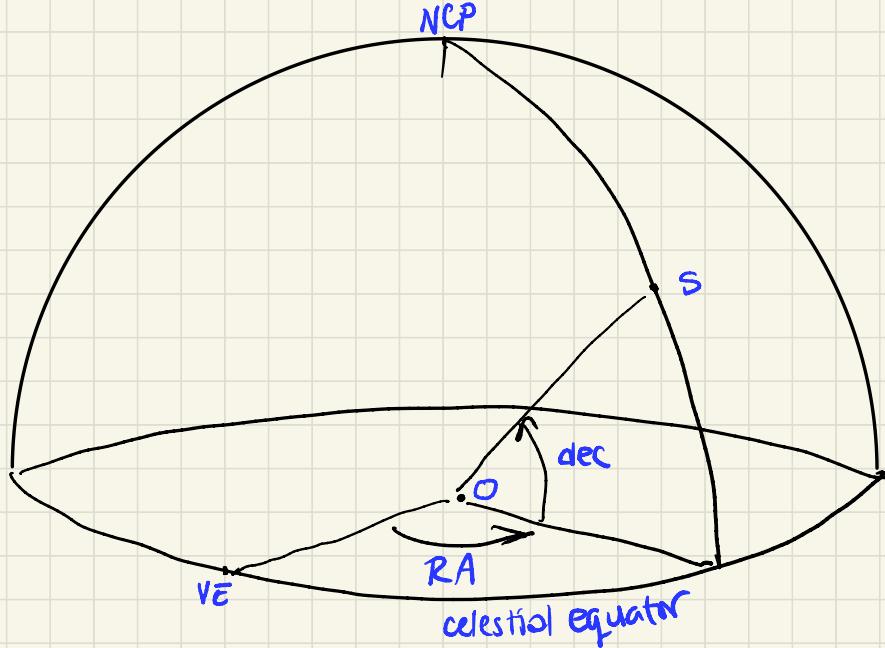


1 hour of RA = 15 degrees at the celestial equator

1 minute of RA = 15 arcminutes at the celestial equator

1 second of RA = 15 arcseconds at the celestial equator

at other dec, 1 hour of RA = $15^\circ \cos \delta$; similarly for min, sec



z.B. Convert the following equatorial coordinates in HMS format to degrees:

$$RA = 00:54:52.1$$

$$Decl. = 25:25:38.0$$

There are $\frac{360^\circ}{24h} = 15\%$ h of RA. So,

$$RA = 15\%h \cdot (0h + 54m \cdot \frac{h}{60m} + 52.1s \cdot \frac{m}{60s} \cdot \frac{h}{60m})$$

$$RA = 13.72^\circ$$

$$Decl. = 25^\circ + 25' \cdot \frac{1}{60} + 38'' \cdot \frac{1}{60} \cdot \frac{1}{60} = 25.43^\circ$$

Now go the other way:

$$RA = 220.531^\circ$$

$$Decl. = 35.4397^\circ$$

$$RA = 220.531^\circ \cdot \frac{h}{15^\circ} = 14.7021h \rightarrow 0.7021h \cdot \frac{60m}{h} = 42.1260m \rightarrow 0.126 \cdot \frac{60s}{m} = 7.56s$$

$$RA = 14:42:07.56$$

$$Decl. = 35.4397^\circ \rightarrow 0.4397^\circ \cdot \frac{60'}{60^\circ} = 26.382' \rightarrow 0.3820' \cdot \frac{60''}{60'} = 22.92''$$

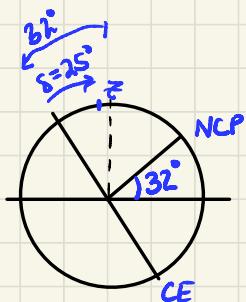
$$Decl. = 35:26:22.92$$

z.B. You are observing at Kitt Peak National Observatory (KPNO) at a latitude of $\sim 32^\circ$. What is the minimum airmass that NGC5548 will have at this site?

$$d: 14h 17m 59.534s$$

$$\delta: +25^\circ 22m 12.44s$$

$$\delta = 25 + \frac{22m}{60} \% + \frac{12.44s}{3600} \% = 25.137^\circ$$

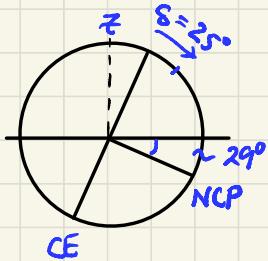


minimum zenith angle when NGC5548 crosses the meridian.

$$z_{\min} = 32^\circ - 25^\circ = 7^\circ$$

$$X_{\min} = \frac{1}{\cos z_{\min}} = \frac{1}{0.99} = 1.01$$

What about from Las Campanas, which has $\lambda = 29^\circ S$?



$$z_{\min} = 29^\circ + 25^\circ = 54^\circ$$

$$X_{\min} = \frac{1}{\cos z_{\min}} = \frac{1}{0.589} = 1.7$$

For very small separations, you can approximate the spherical surface of the sky as a plane and use the Pythagorean theorem, with a correction for declination.

$$\Theta^2 = \Delta\delta^2 + \Delta\alpha^2 \cos^2 \delta_{\text{avg}}$$

e.g.

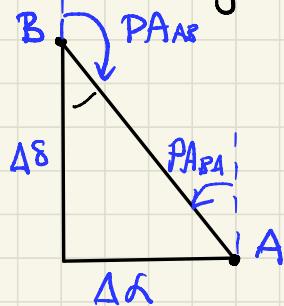
Source A has position $\alpha = 13:00:00$, $\delta = 00:00:00$ and source B has position $\alpha = 13:01:30$, $\delta = 00:00:00$. What is the angular distance between these sources?

$$\Delta\alpha = 13h 00m 00s - 13h 01m 30s = 1m 30s = 90s \text{ of RA}$$

We are at the equator so $\Delta\delta = 0$ and $\cos\delta = 1$

$$\Theta = 90s \cdot 15 \text{ arcsec/s} = 1350 \text{ arcsec}$$

Source A has position $\alpha = 13:00:00$, $\delta = 40:30:01$ and source B has position $\alpha = 13:01:02$, $\delta = 40:32:20$. What is the angular distance between these sources?



for small separations

$$\begin{aligned}\Delta\alpha &= (\alpha_B - \alpha_A) \cdot \cos \delta_{\text{avg}} \\ &= 1m 2s \cdot 15 \text{ arcsec/s} \cdot \cos(40.5196^\circ) \\ &= 706.971 \text{ arcsec} \approx 707 \text{ arcsec}\end{aligned}$$

$$\begin{aligned}\Delta\delta &= 40d 32m 20s - 40d 30m 01s \\ &= 2m 19s = 139 \text{ arcsec}\end{aligned}$$

$$\Theta = \sqrt{707 \text{ arcsec}^2 + 139 \text{ arcsec}^2}$$

$$\Theta = 720.535 \text{ arcsec}$$

$$\begin{aligned}\text{PA of B relative to A? } PA_{\text{BA}} &= \tan^{-1}(\Delta\alpha/\Delta\delta) = \tan^{-1}\left(\frac{707}{139}\right) = 79^\circ \\ \text{PA of A relative to B? } PA_{\text{AB}} &= -(180^\circ - PA_{\text{BA}}) = -101^\circ\end{aligned}$$

Galactic Coordinates (l, b):

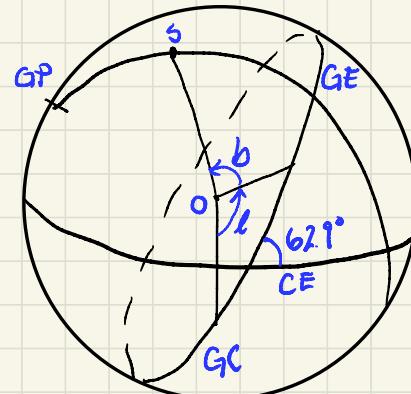
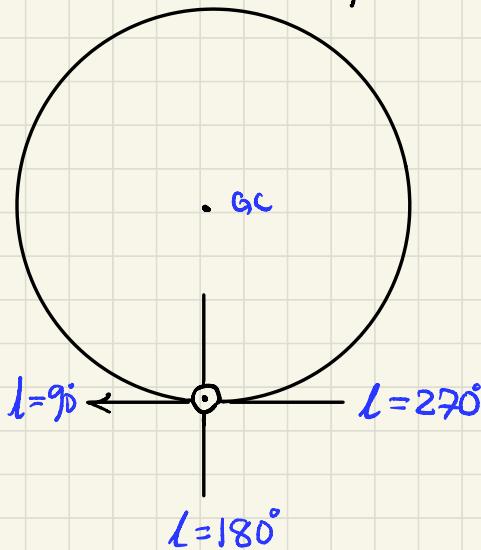
Galactic Plane ($b=0$): plane formed by the disk of the Milky Way. Inclined by 63° to the Celestial Equator.

Galactic North Pole ($b=90^\circ$): located in Coma Berenices at
 $RA = 12:51$, $dec = +27$

Galactic South Pole ($b=-90^\circ$): located in Dorado at
 $RA = 00:51$, $dec = -27$

Galactic Center ($l=0, b=0$): located in Sagittarius at
 $RA = 17:45$, $dec = -28:56$

solar circle $R \sim 8\text{kpc}$

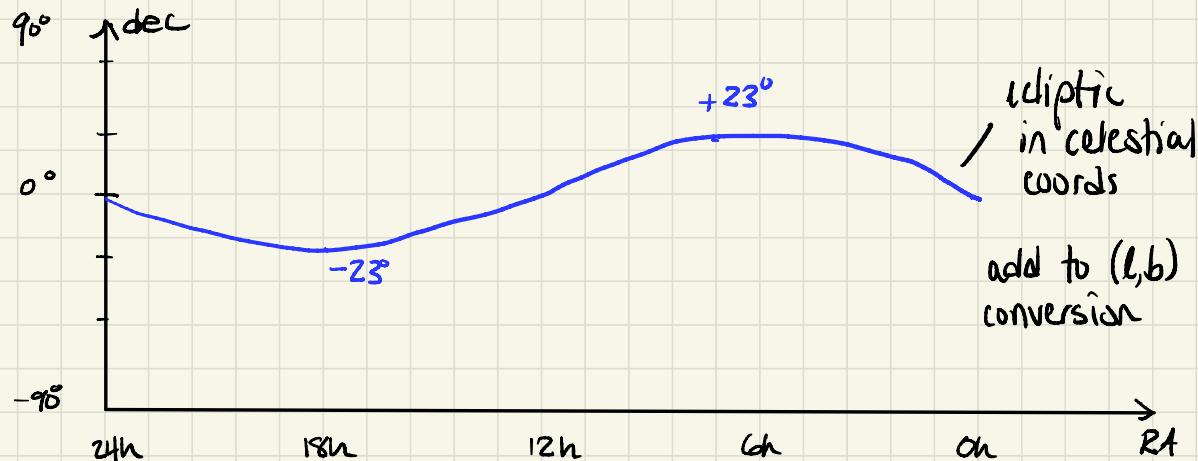


z.B.

By reading the handout chart, what is the RA and dec of a Galactic HII region at $l=30^\circ, b=0^\circ$? $RA = 16h, dec = -10^\circ$

If you are observing in the Galactic Plane, where are asteroids most likely to cause confusion?

Where the Galactic Plane crosses the Ecliptic plane.



looking at the conversion chart the ecliptic plane and galactic plane cross at RA $\sim 17.5^{\text{h}}$, dec $\sim -22^{\circ}$ and RA $\sim 5.5^{\text{h}}$ and dec $\sim 23^{\circ}$.

Ecliptic Coordinates:

- so named because eclipses occur in this plane
- the plane of the solar system, inclined 23.5° to celestial eq.

Ecliptic North : located in Draco, RA = $18^{\text{h}}00^{\text{m}}00^{\text{s}}$, dec = $+66.5^{\circ}$

Ecliptic South : located in Dorado, RA = $6^{\text{h}}00^{\text{m}}00^{\text{s}}$, dec = -66.5°

Ecliptic Lon = 0, lat = 0 located at RA = $00^{\text{h}}02^{\text{m}}33^{\text{s}}$, dec = $00^{\circ}16^{\prime}41^{\prime\prime}$

Galactic center is at Ecliptic Lon = 266° , lat = -5°