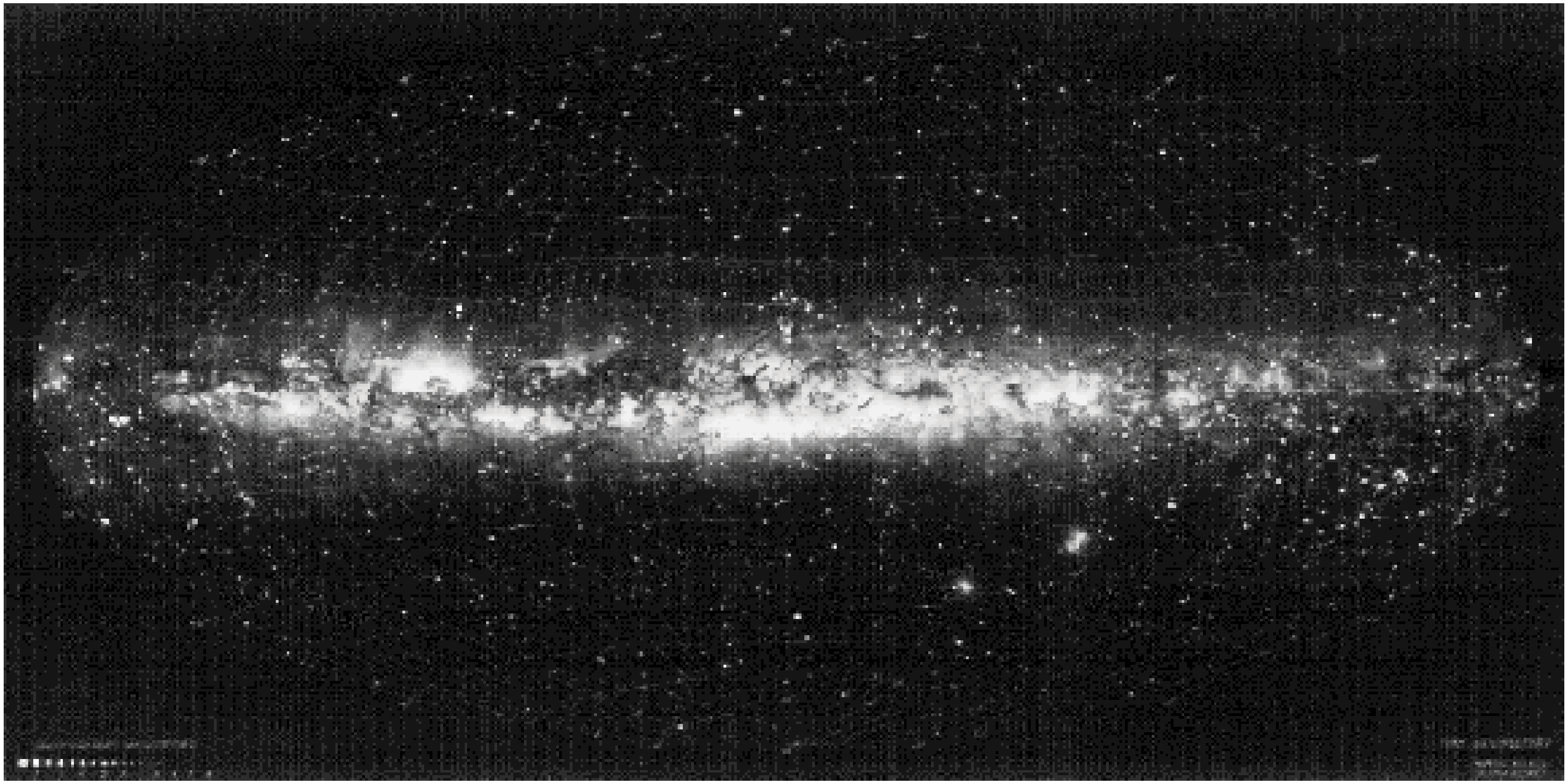
Announcements

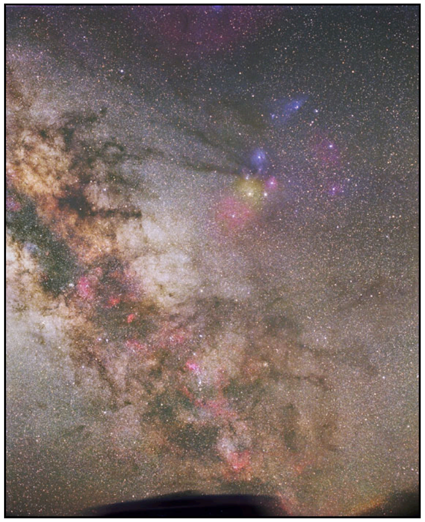
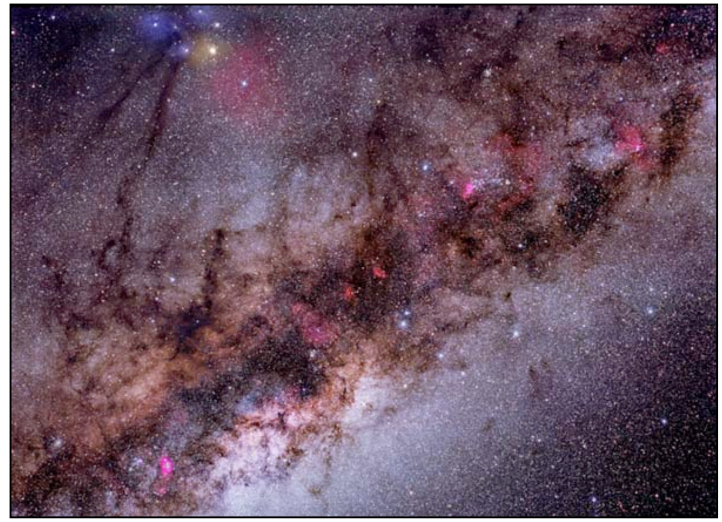
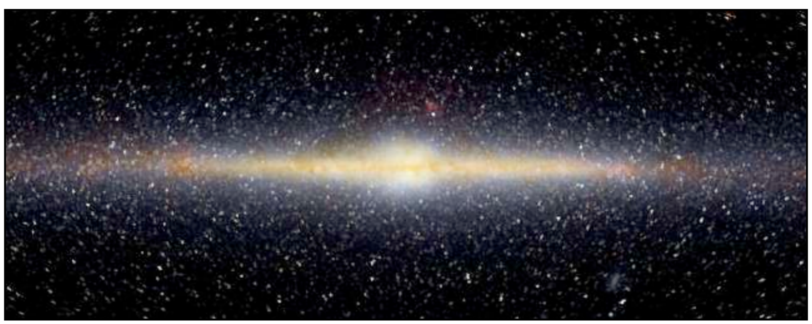
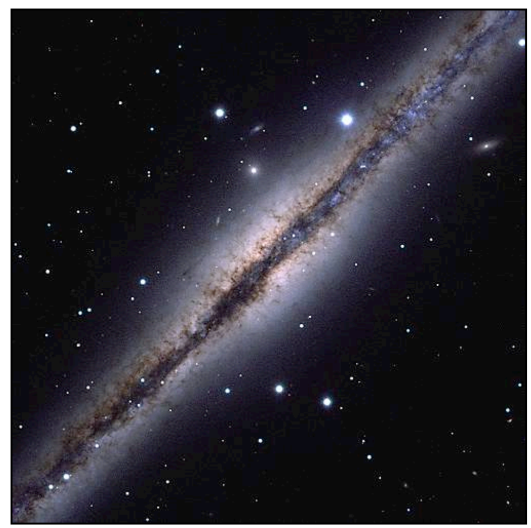
- Next section will be about the properties of stars and how we determine them.
- The spectral lab will be running this week (last chance) in the sections. Don’t miss it!

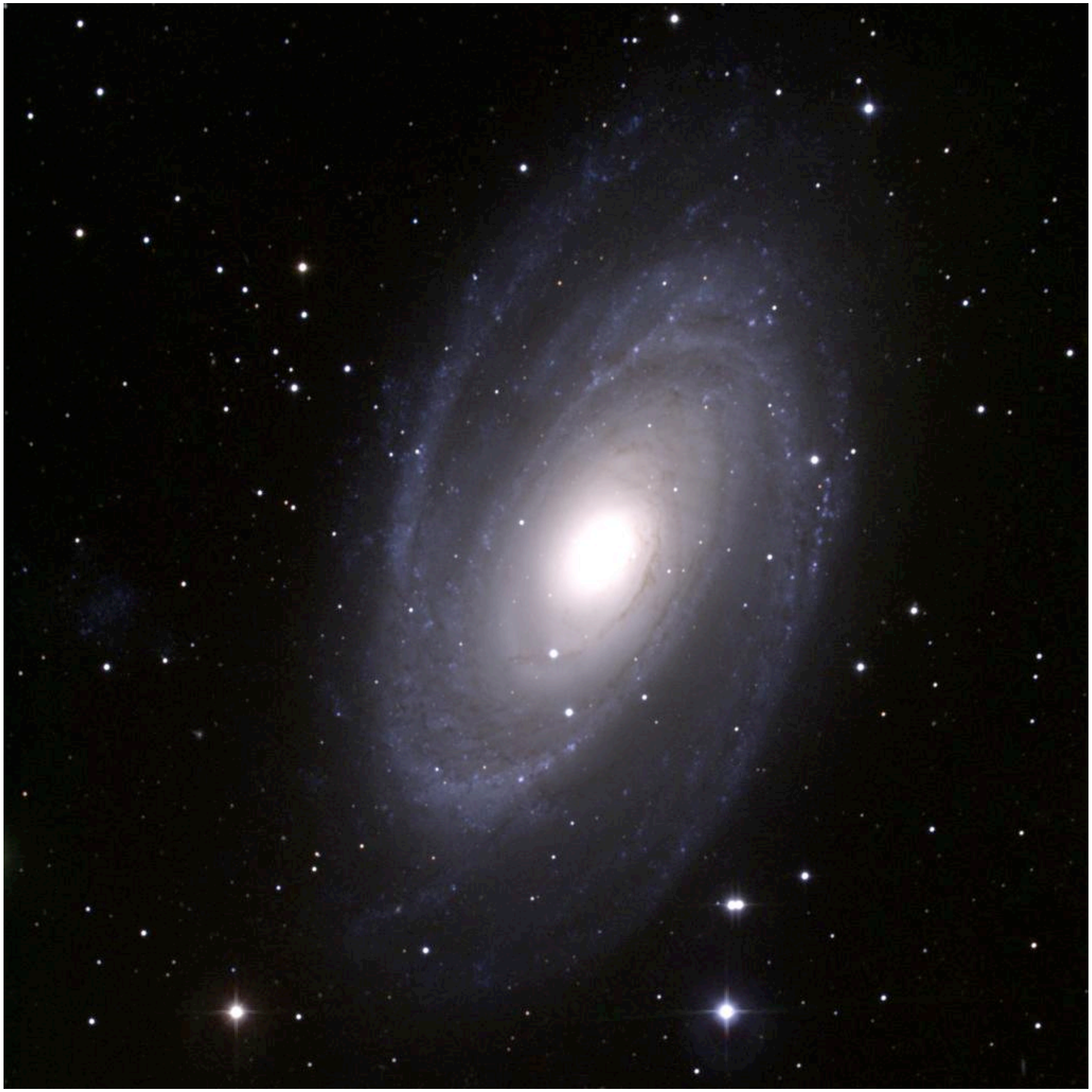
The Bigger Picture

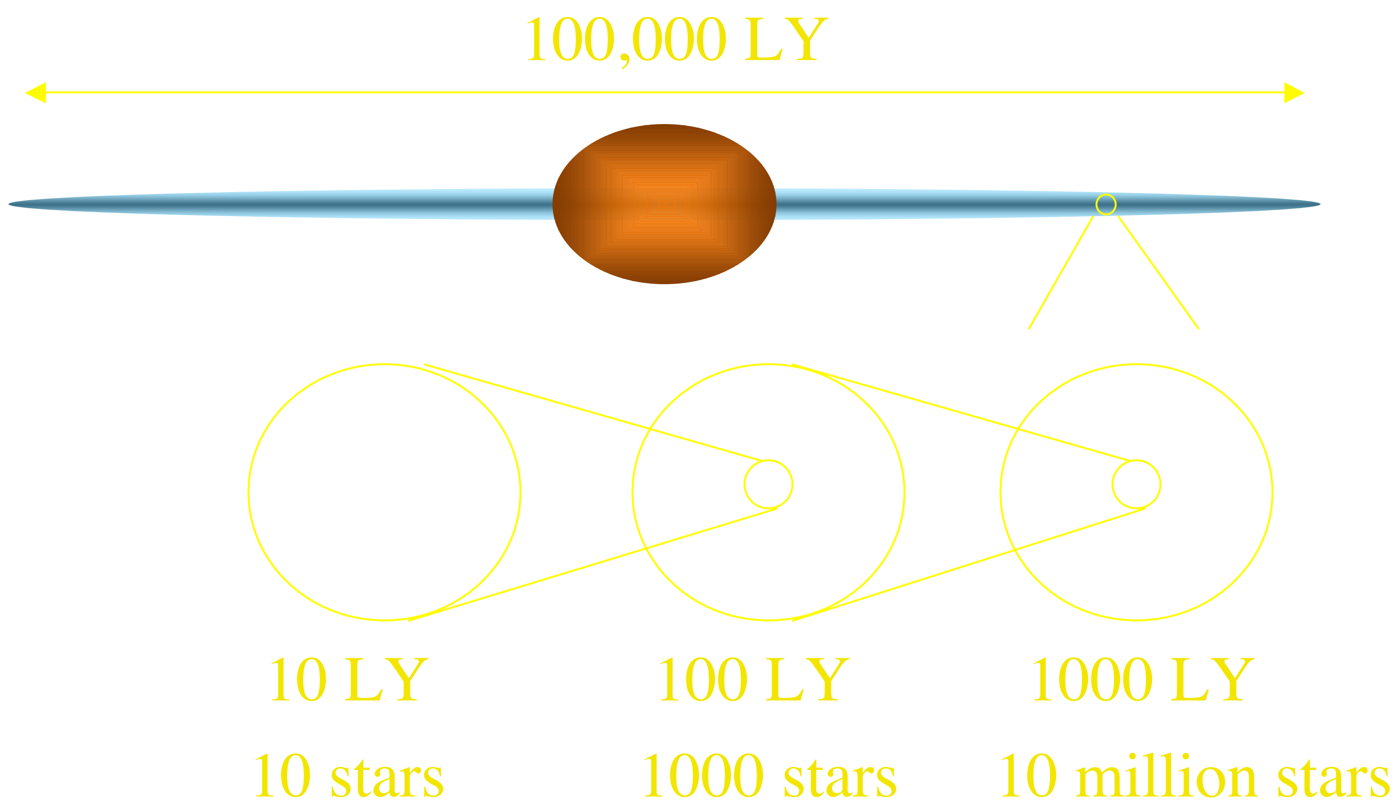
- We live on the outskirts of a pretty good-sized spiral galaxy composed of about *100 billion* stars.
- There are only about 6000 stars that you can see with the unaided eye -- not even the tip of the iceberg.
- At a dark site, you can see a diffuse glow tracing and arc across the sky. This is the *Milky Way* and our galaxy is sometimes referred to as the *Milky Way Galaxy* (or just the Galaxy)


98/Sep. 6x6 35mmF3.5 ISO1600 Shigemi Numazawa



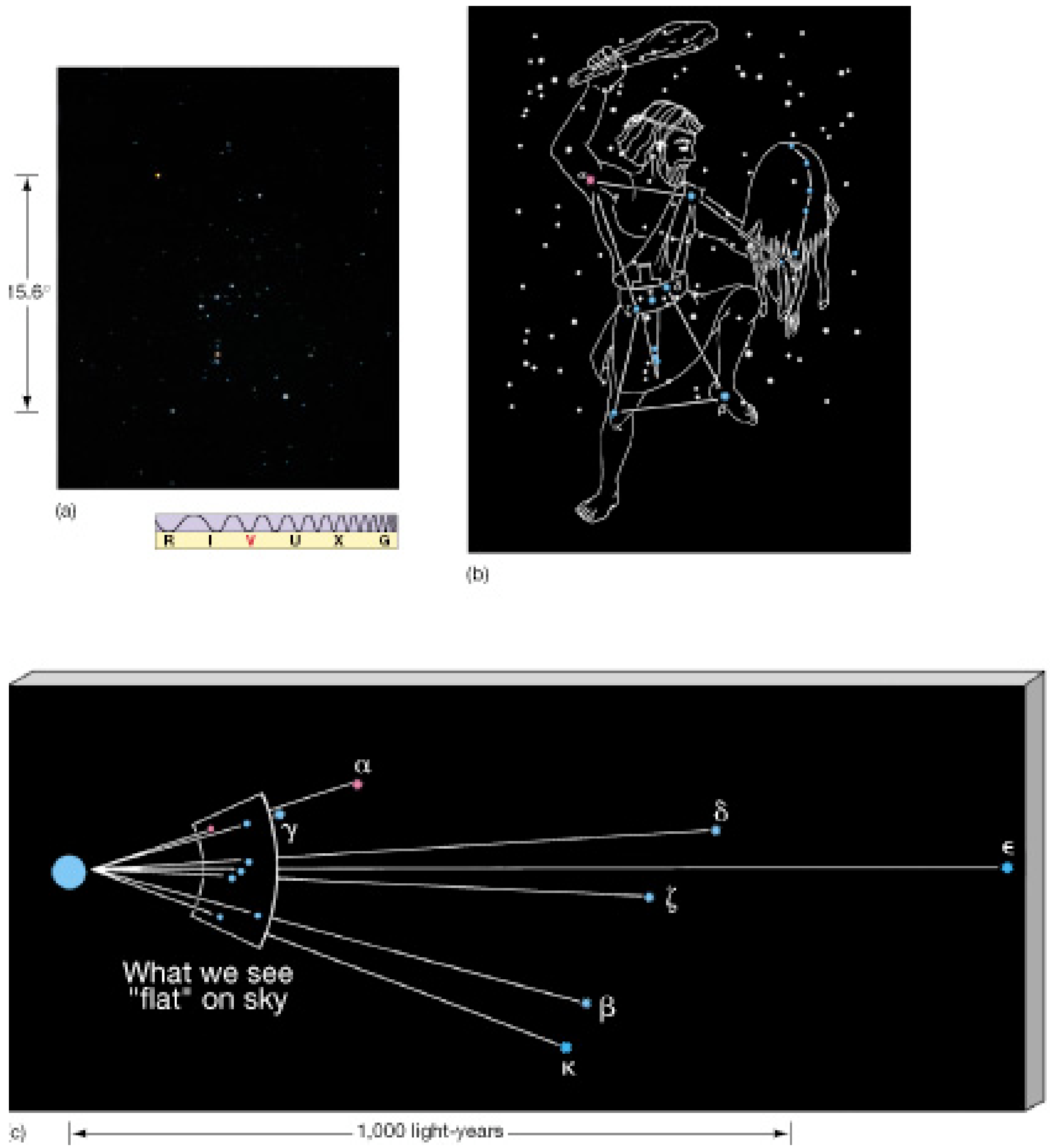








100,000 LY
10 LY
10 stars
100 LY
1000 stars
1000 LY
10 million stars

Stellar Constellations

- These are just people connecting dots.
- The stars that make up constellations are in almost all cases only close together in projection on the sky. They are not physical groupings of stars.


15.6°
(a)
R I V U X G
(b)
α
γ
δ
ε
ζ
β
κ
What we see
"flat" on sky
c)
1,000 light-years

What about Star Names?

- The brightest stars have lots of names, none official. There are some widely-used catalogues.
- A convention often used in astronomy is to use the Greek alphabet to identify the brightest stars in the constellations.

  For example: Sirius = □ Canis Majoris is the brightest star in the constellations Canis Major.

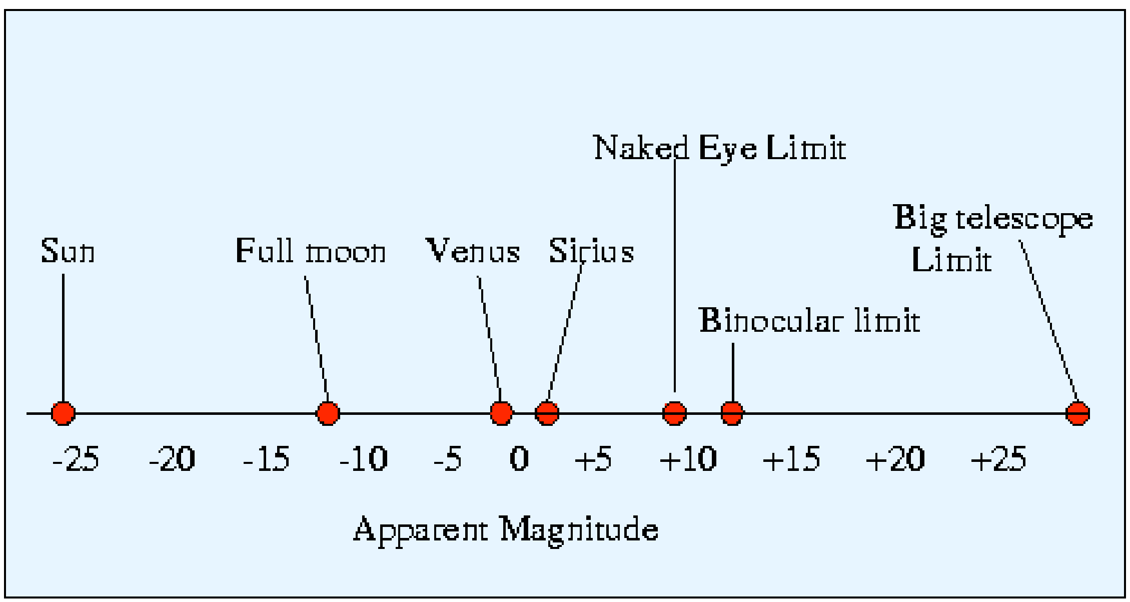
  □ Canis Majoris is the second brightest etc.

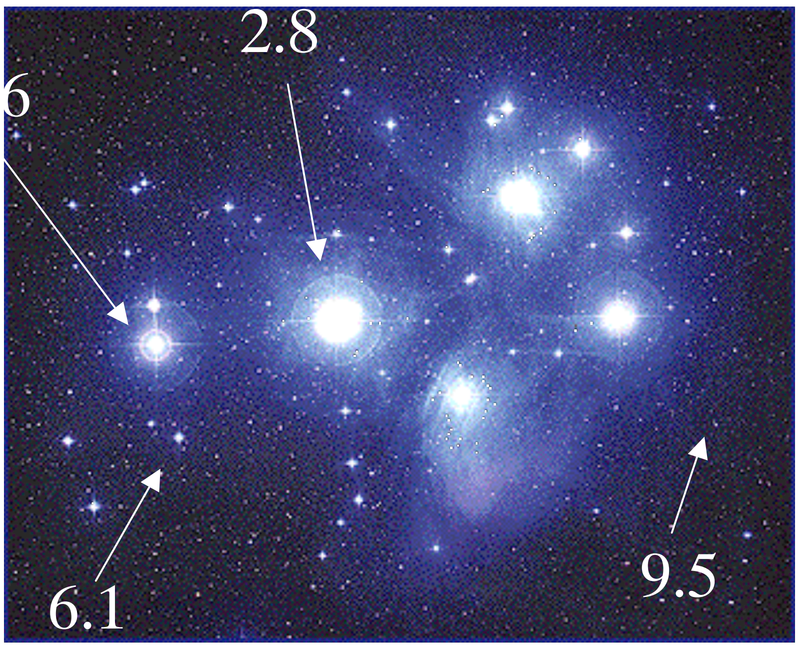
Stellar Properties

- *Brightness* - combination of distance and L
- *Distance* - this is crucial
- *Luminosity* - an important intrinsic property that is equal to the amount of energy produced in the core of a star
- *Radius*
- *Temperature*
- *Chemical Composition*

Stellar Brightness

- Will use brightness to be *apparent* brightness.
- This is not an INTRINSIC property of a star, but rather a combination of its Luminosity, distance and amount of dust along the line of sight.



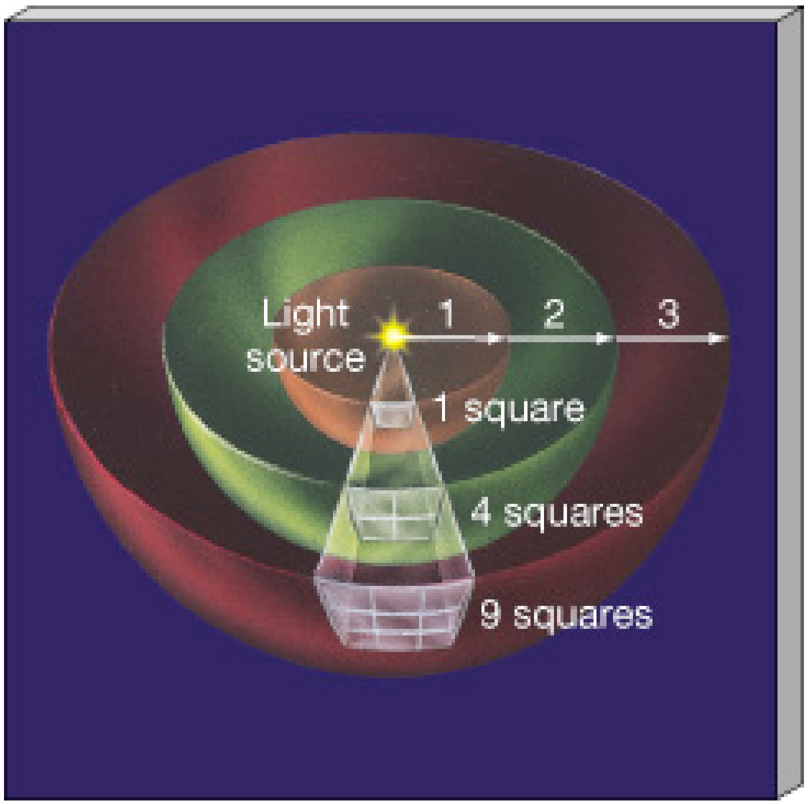


- The apparent brightness scale is logrithmic based on 2.5, and it runs backward.
- Every 5 magnitudes is a factor of 100 in intensity. So a 10th magnitude star is100x fainter than a 5th magnitude star

Stellar Distances

- It is crucial to be able to figure out the distances to stars so we can separate out the *Inverse Square Law dimming* and intrinsic brightness or Luminosity.

$$I \qquad \frac{1}{d^2}$$



- The inverse square law is due to geometric dilution of the light. At each radius you have the same total amount of light going through the surface of an imaginary sphere. Surface area of a sphere increases like R^2.
- The light/area therefore decreases like $1/R^2$

- Suppose we move the Sun to three times its current distance. How much fainter will the Sun appear?

Original distance

$$\frac{I}{I_0} = \frac{d_0^2}{d^2} = \left(\frac{d_0}{d}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$$

Original brightness

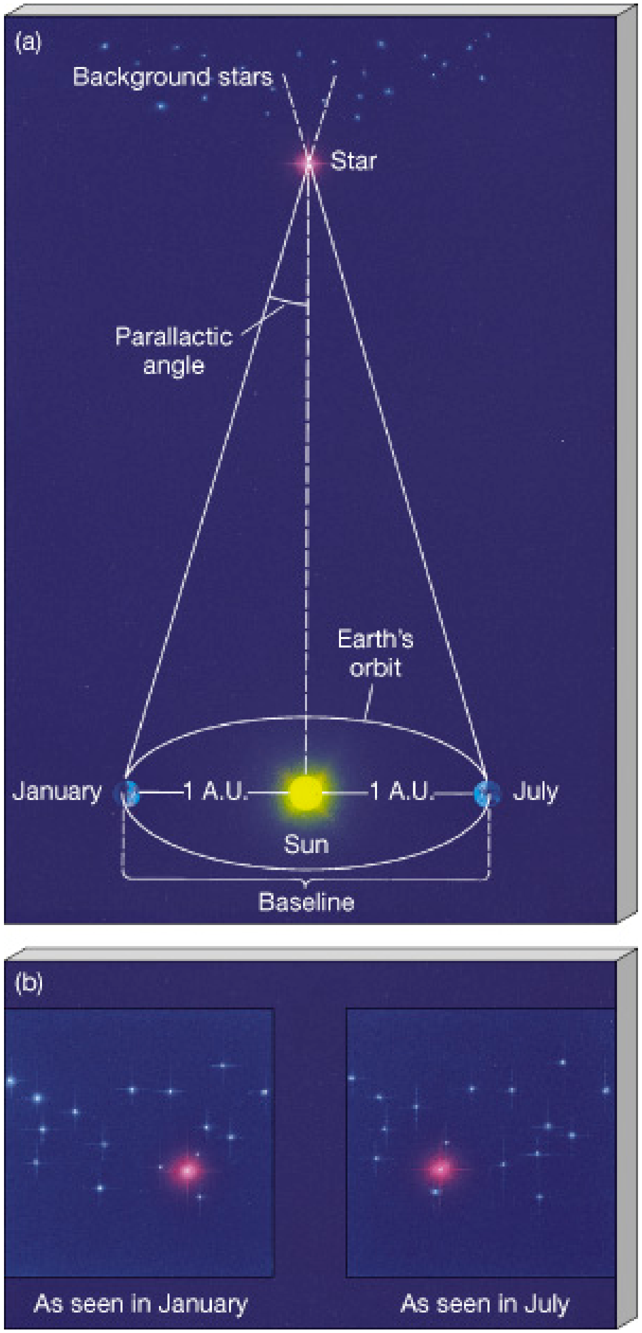
$$I = \frac{1}{9} I_0$$

Stellar Distances

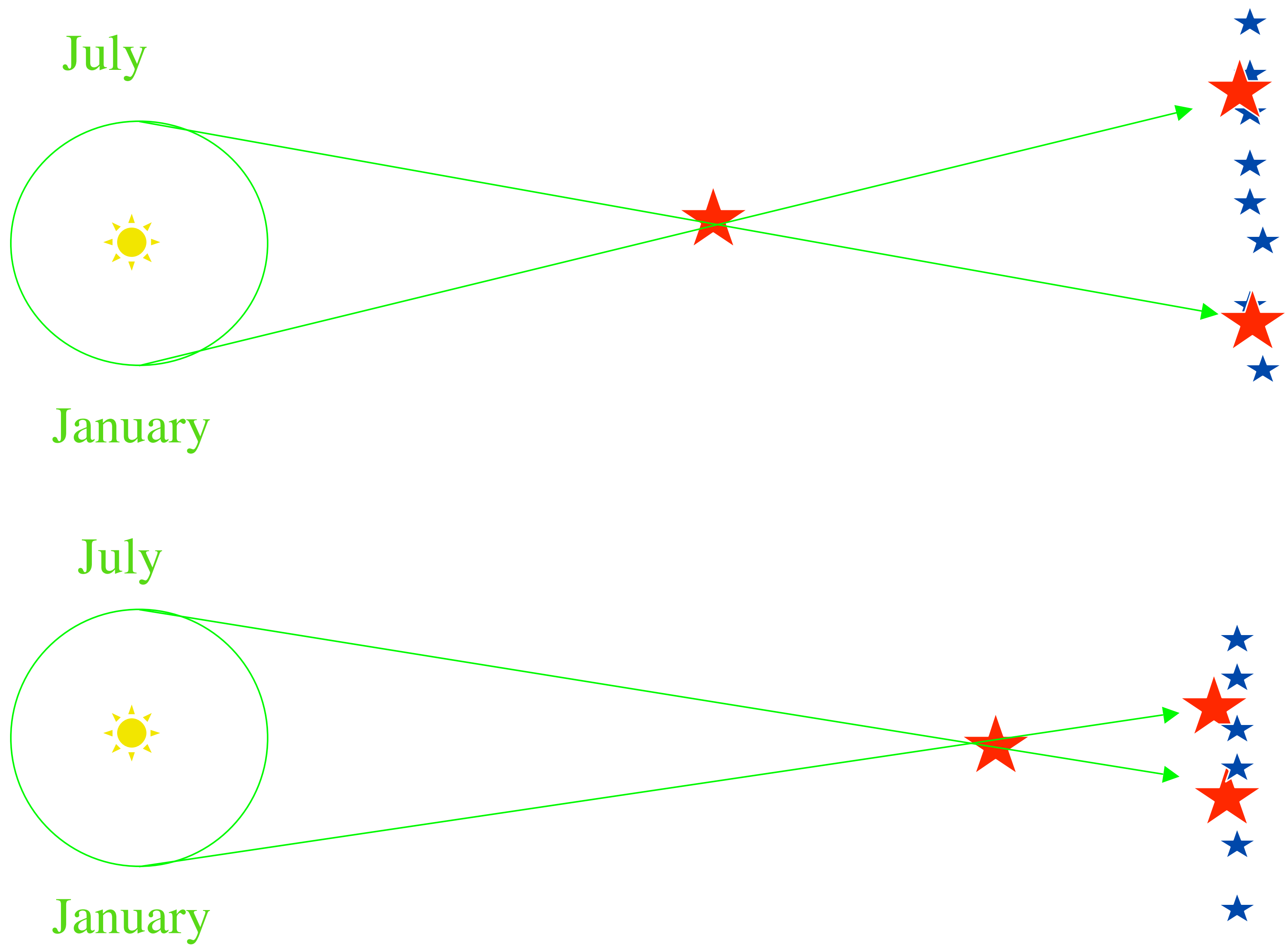
- The most reliable method for deriving distances to stars is based on the principle of Trigonometric Parallax
- The parallax effect is the *apparent* motion of a nearby object compared to distant background objects because of a change in viewing angle.
- Put a finger in front of your nose and watch it move with respect to the back of the room as you look through one eye and then the other.

Stellar Distances

- For the experiment with your finger in front of your nose, the baseline for the parallax effect is the distance between your eyes.
- For measuring the parallax distance to stars, we use a baseline which is the *diameter of the Earth's orbit*.
- There is an apparent annual motion of the nearby stars in the sky that is really just a reflection of the Earth's motion around the Sun.

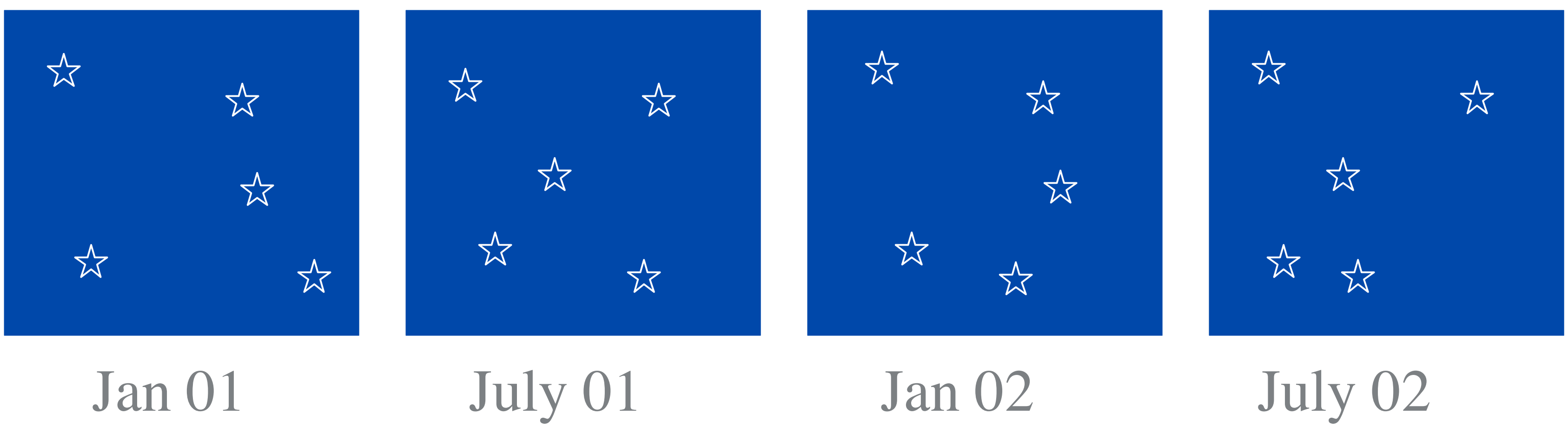


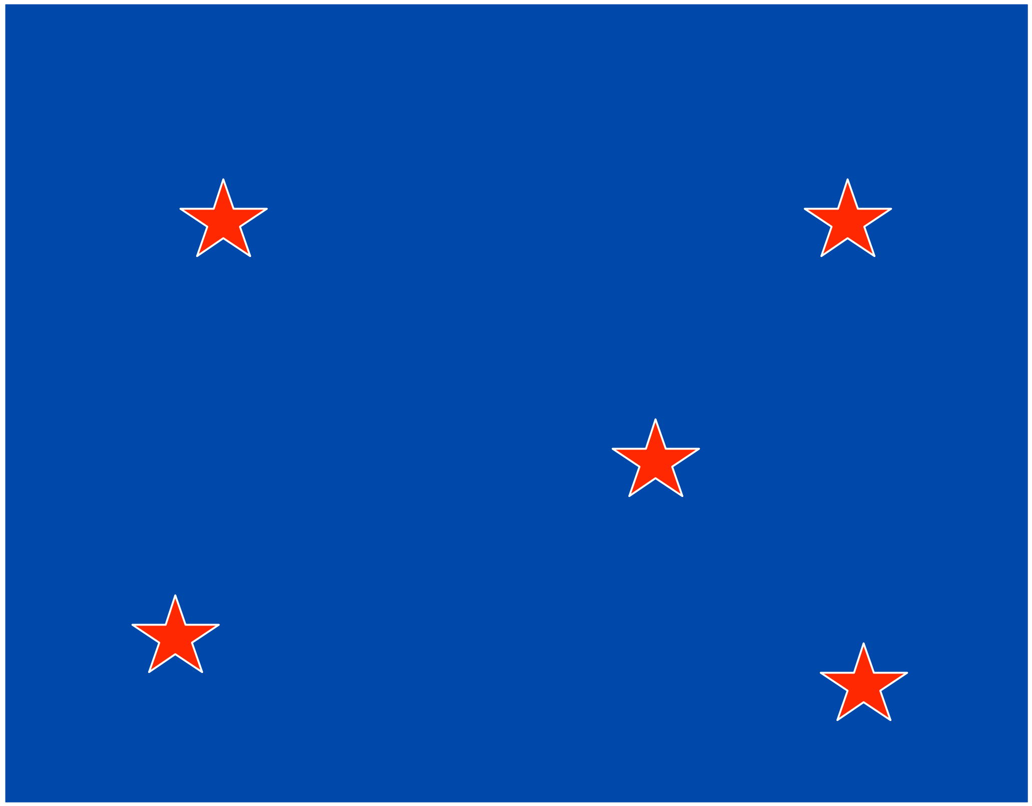
(a)
Background stars
Star
Parallactic angle
Earth's orbit
January
1 A.U.
1 A.U.
July
Sun
Baseline
(b)
As seen in January
As seen in July

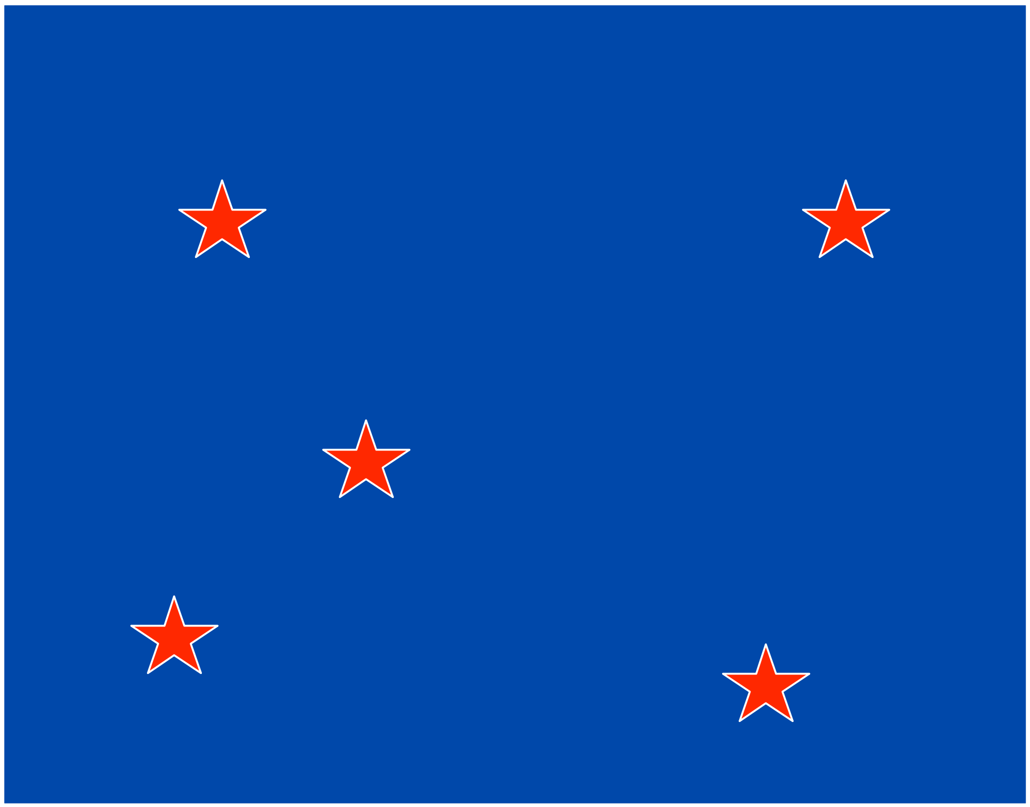

July
January
July
January

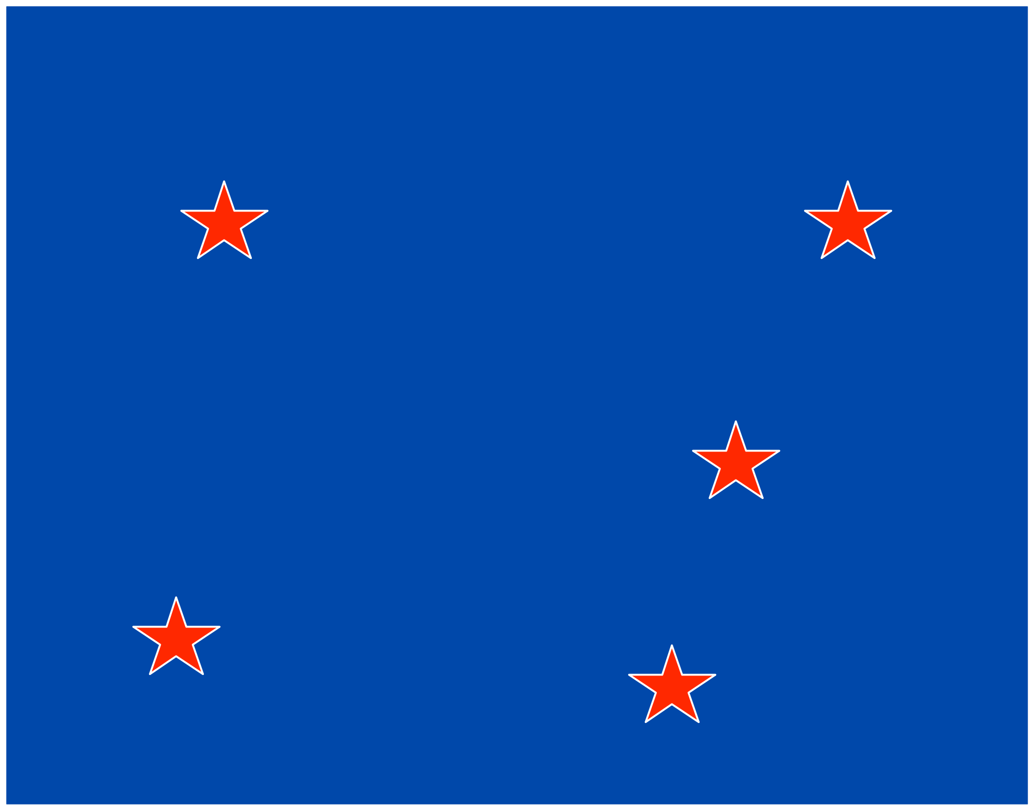
Stellar Parallax

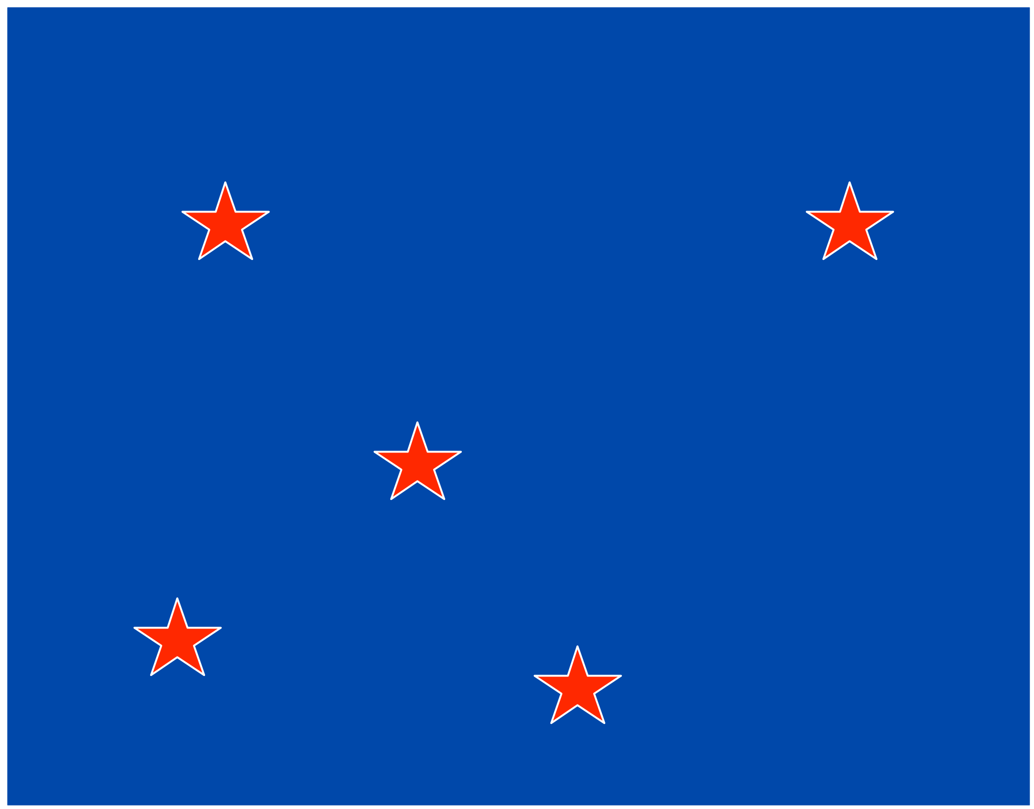
- Need to sort out parallax motion from proper motion -- in practice it requires years of observations.

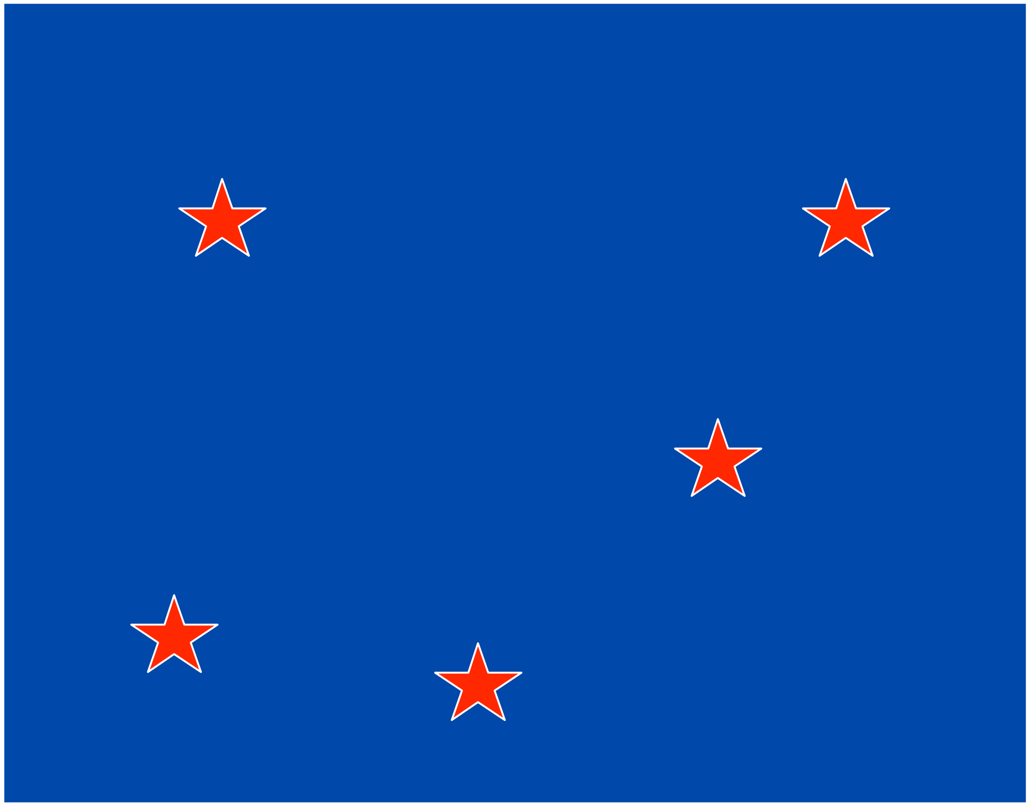


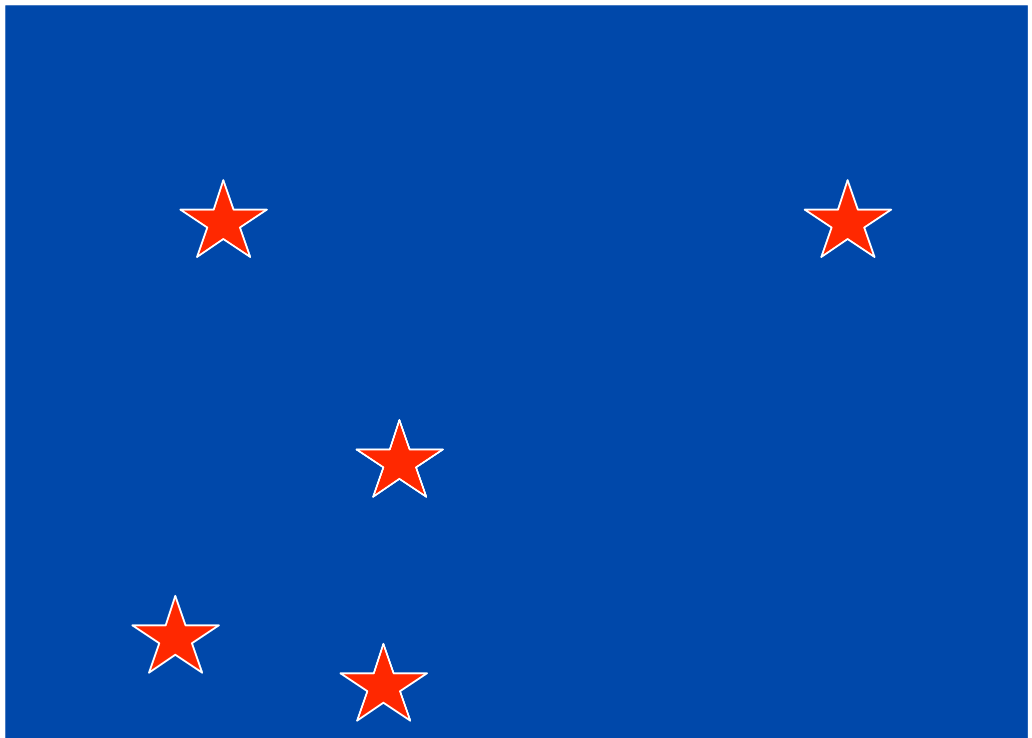


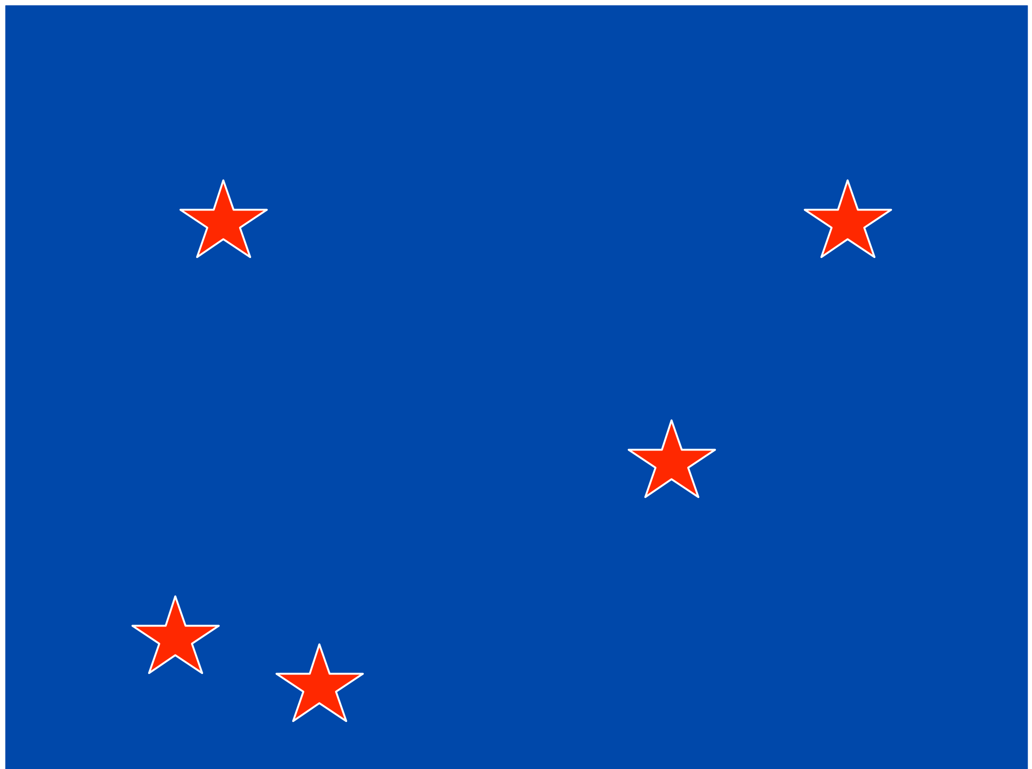


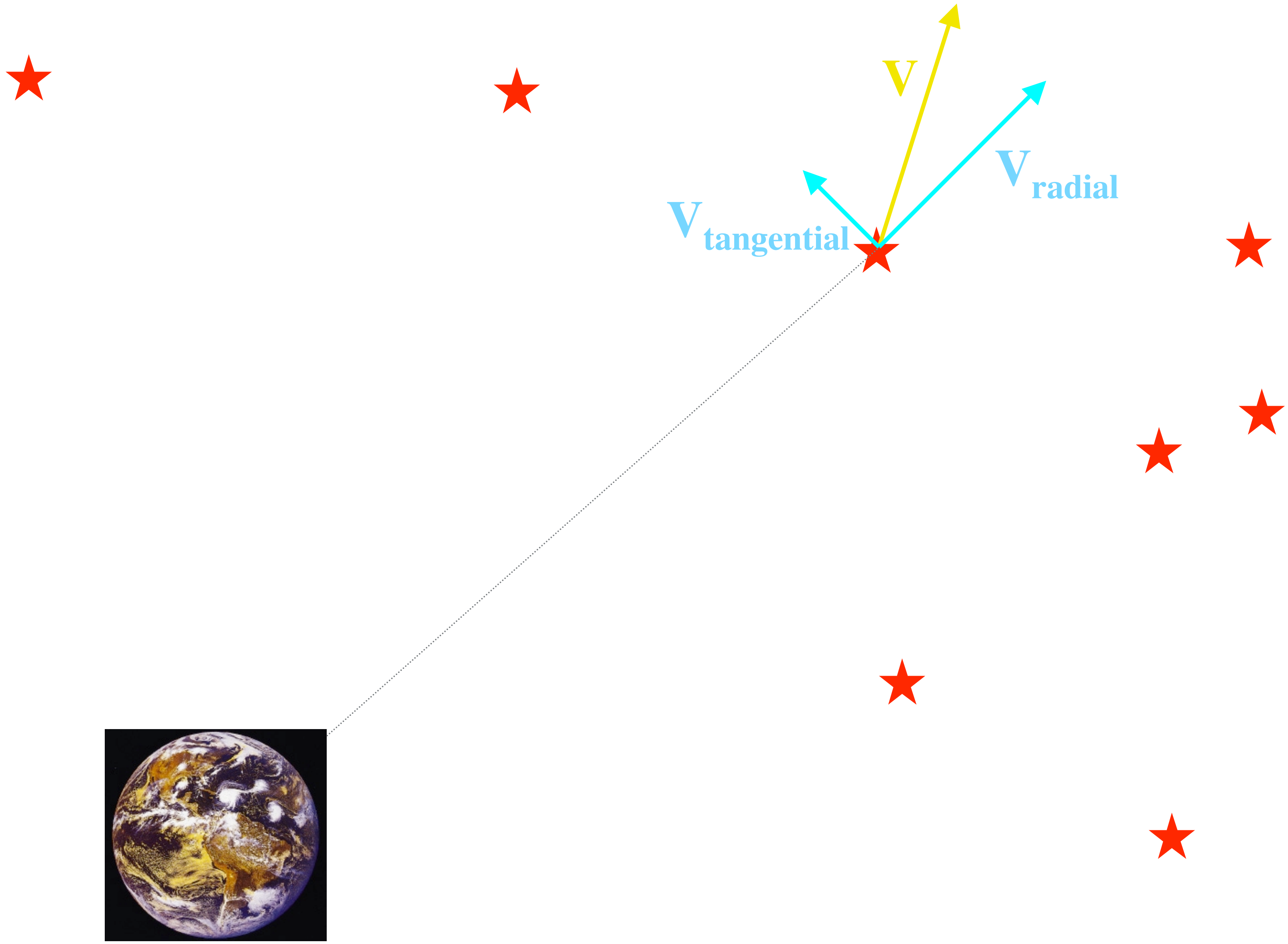








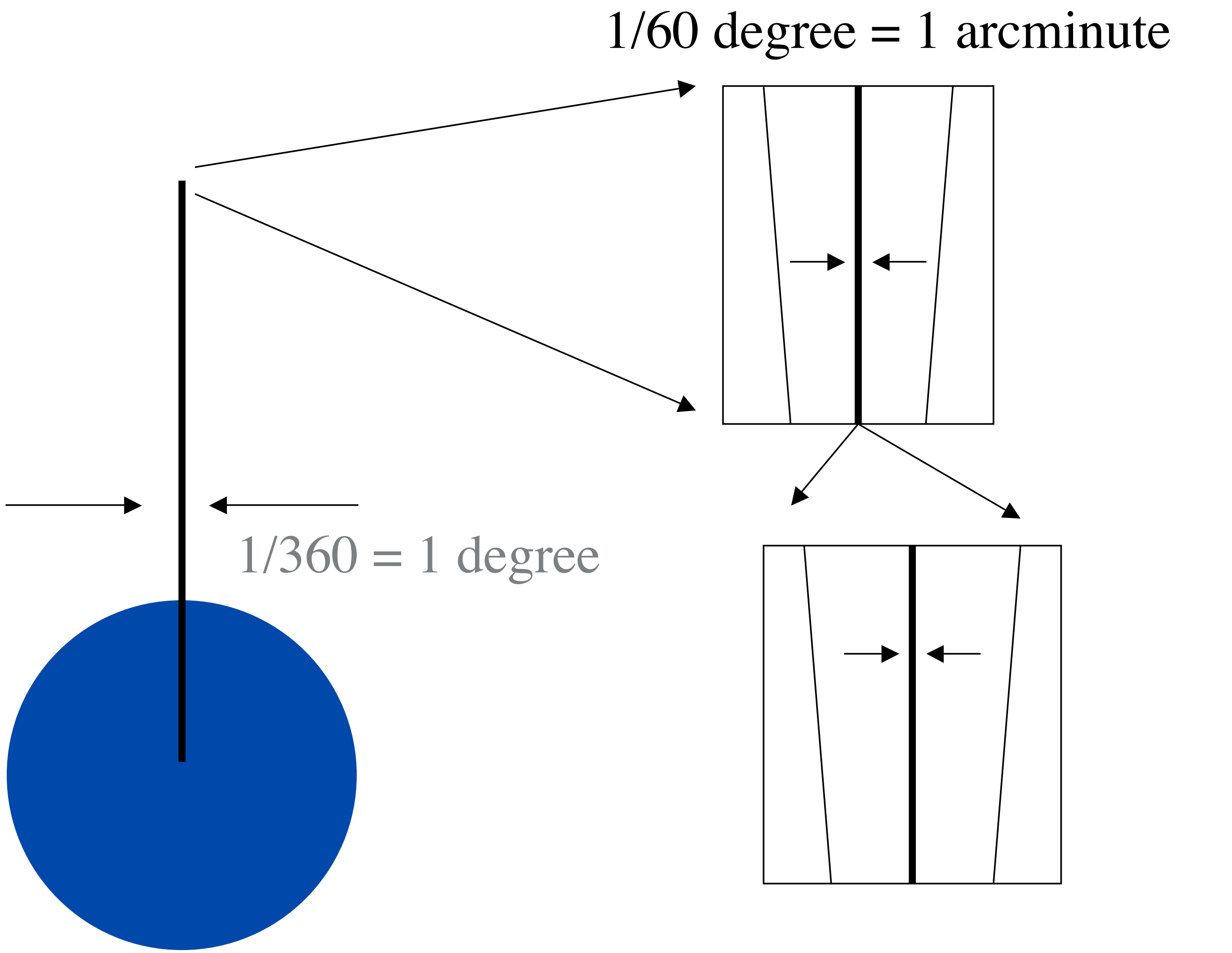




V
V radial
V tangential

Stellar Parallax

- *The Distance to a star is inversely proportional to the parallax angle*.
- There is a special unit of distance called a parsec.
- This is the distance of a star with a parallax angle of 1 arcsec.


1/60 degree = 1 arcminute
1/360 = 1 degree
1/60 arcminute = 1 arcsecond

Stellar Parallax

One arcsecond = 1’’ is therefore

$$1'' = \frac{1'}{60''} \times \frac{1^\circ}{60'} \times \frac{1\,circle}{360^\circ} = \frac{1}{1{,}296{,}000}\,\frac{circle}{''}$$

This is the angular size of a dime seen from 2 miles or a hair width from 60 feet.

Stellar Parallax

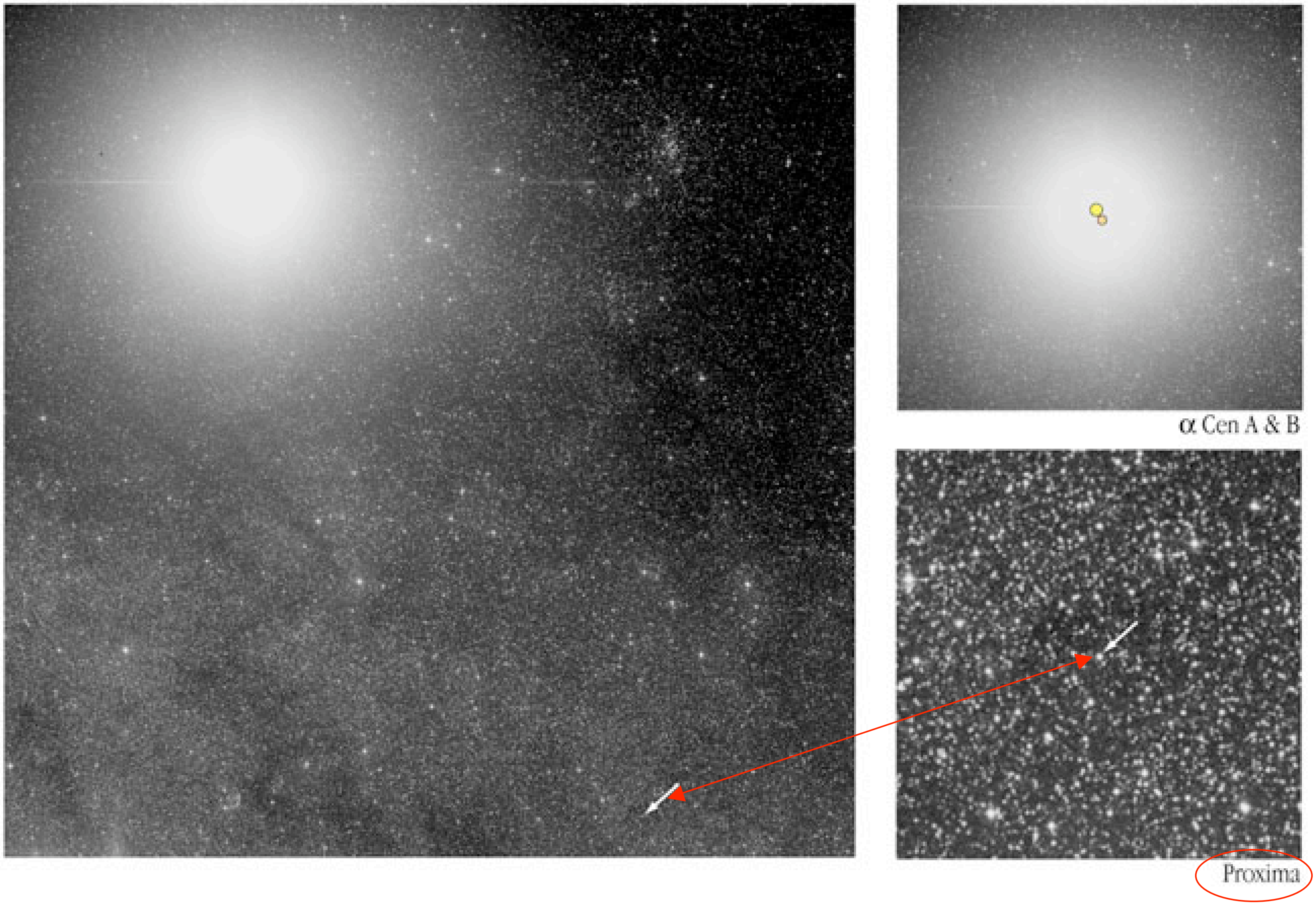
- Stellar parallax is usually called □
- The distance to a star in parsecs is:

$$d = \frac{1}{\square}$$

1 parsec = 3.26 light-years = 3.09×10^{13} km

- How far away are the nearest stars?
- The nearest star, aside from the Sun, is called Proxima Centauri with a parallax of 0.77 arcsecond. Its distance is therefore:

$$d = \frac{1}{0.77} = 1.3pc$$


α Cen A & B
Proxima

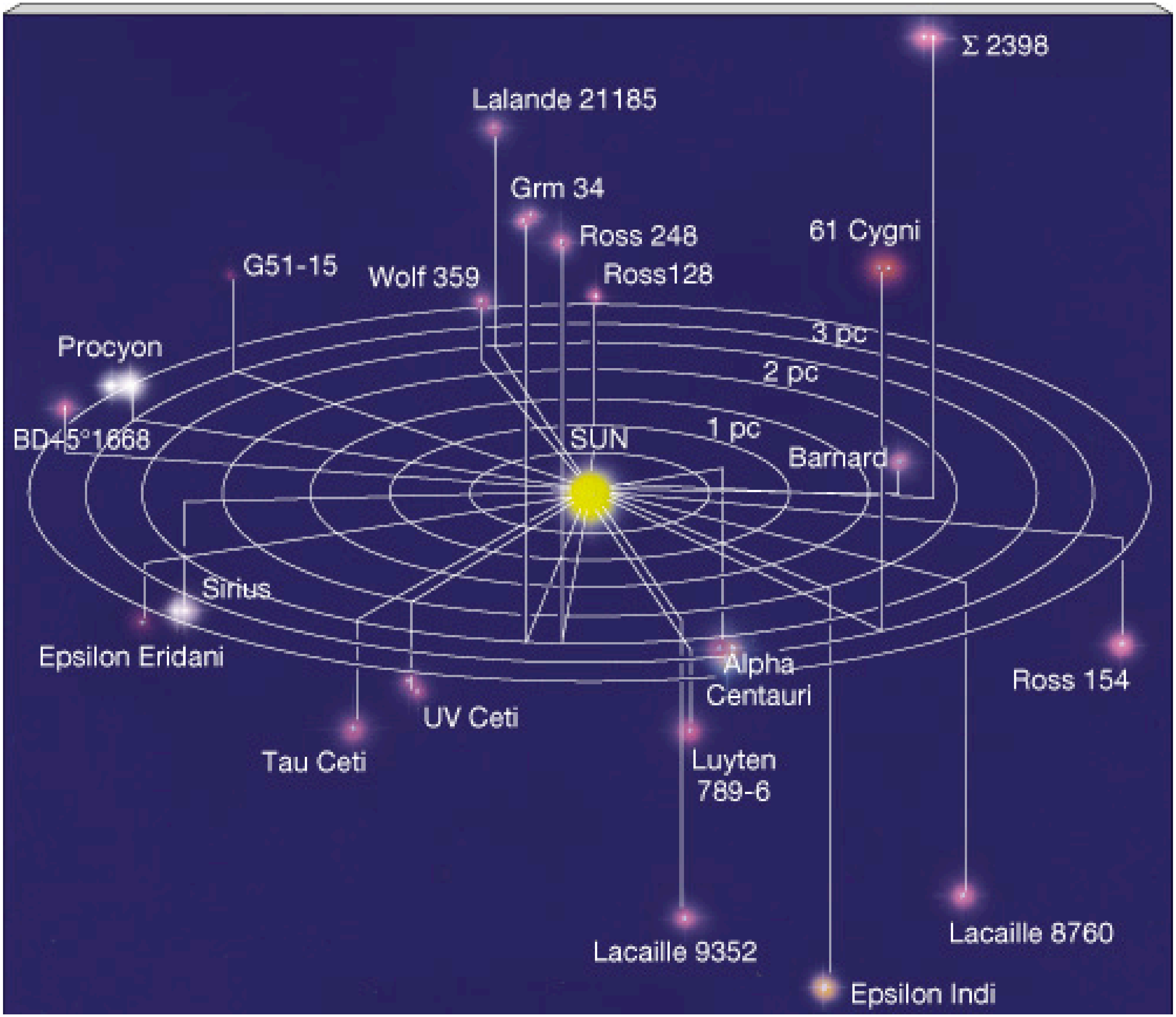
Stellar parallax

- Even the largest parallax (that for the nearest star) is small. The atmosphere blurs stellar images to about 1 arcsecond so `astrometrists' are trying to measure a tiny motion of the centroid as it moves back and forth every six months. The *lack* of parallax apparent to the unaided eye was used as a proof that the Earth did not revolve around the Sun.

- Parallax-based distances are good to about 100 parsecs --- this is a parallax angle of only 0.01 arcseconds!
- Space-based missions have taken over parallax measurements. A satellite called Hipparcos measured parallaxes for about 100,000 stars (pre-Hipparcos, this number was more like 2000 stars).

The Nearest Stars

Name	Parallax arcsec	Distance pc	Apparent magnitude	Luminosity ($L_\odot$)
Proxima Cen	0.77	1.3	11.05	0.00006
α Cen A	0.75	1.3	-0.01	1.6
α Cen B	0.75	1.3	1.33	0.45
Barnard's star	0.545	1.8	9.45	0.000045
Wolf 359	0.421	2.4	13.5	0.00002
BD +36° 2147	0.397	2.5	12.52	0.0055
Luyten 726-8A	0.387	2.6	12.52	0.00006
Luyten 726-8B	0.387	2.6	13.02	0.00004
Sirius A	0.377	2.6	-1.46	23.5
Sirius B	0.377	2.6	8.3	0.003
Ross 154	0.345	2.9	10.45	0.00048


Σ 2398
Lalande 21185
Grm 34
Ross 248
61 Cygni
G51-15
Wolf 359
Ross128
3 pc
Procyon
2 pc
1 pc
BD+5°1668
SUN
Barnard
Sirius
Epsilon Eridani
Alpha
Centauri
Ross 154
UV Ceti
Tau Ceti
Luyten
789-6
Lacaille 8760
Lacaille 9352
Epsilon Indi