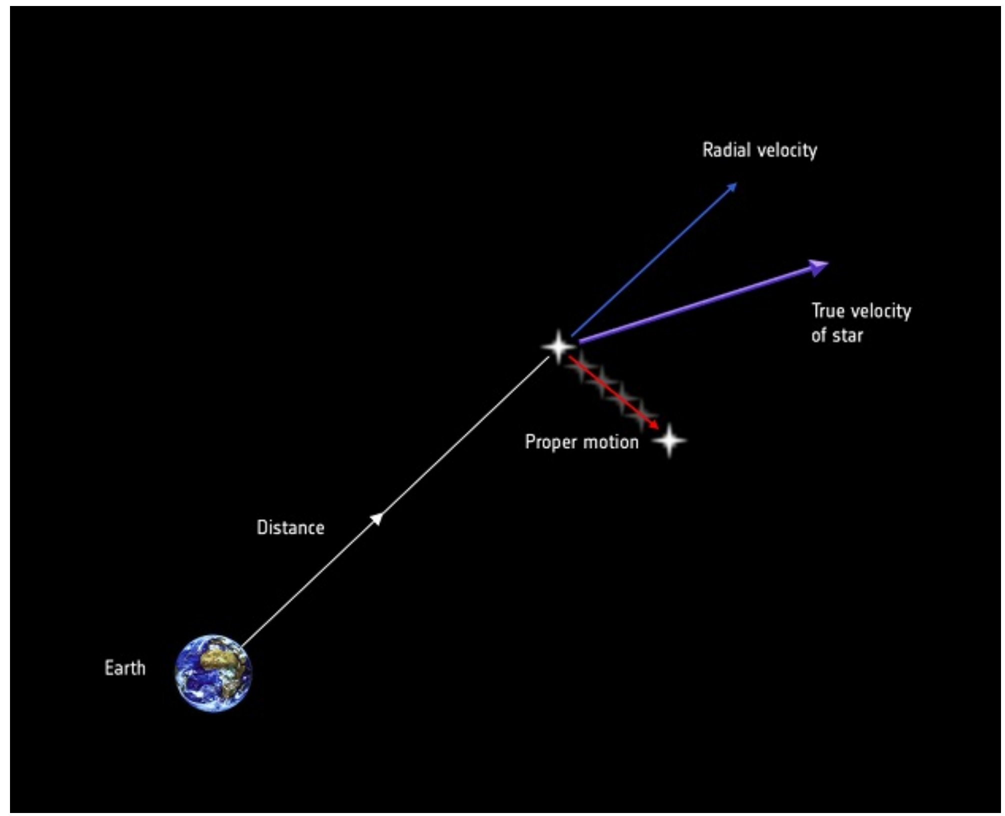
Parallax and Proper Motion

- Stellar Parallax
- The Parsec
- Proper Motion
- Radial Motion



Parallax

- Parallax is the apparent change in the position of an object due to a change in viewpoint

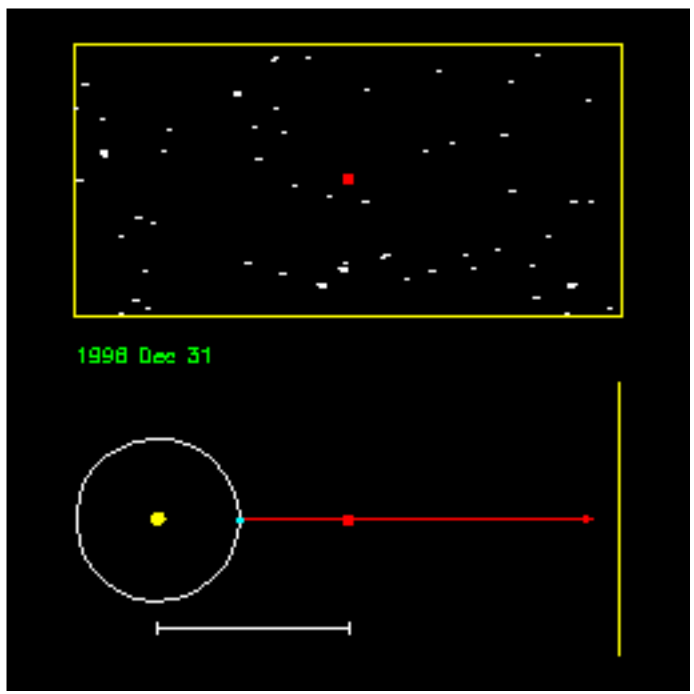
View with left eye

View with right eye

https://homeschoolsciencegeek.wordpress.com/tag/parallax/

Stellar Parallax

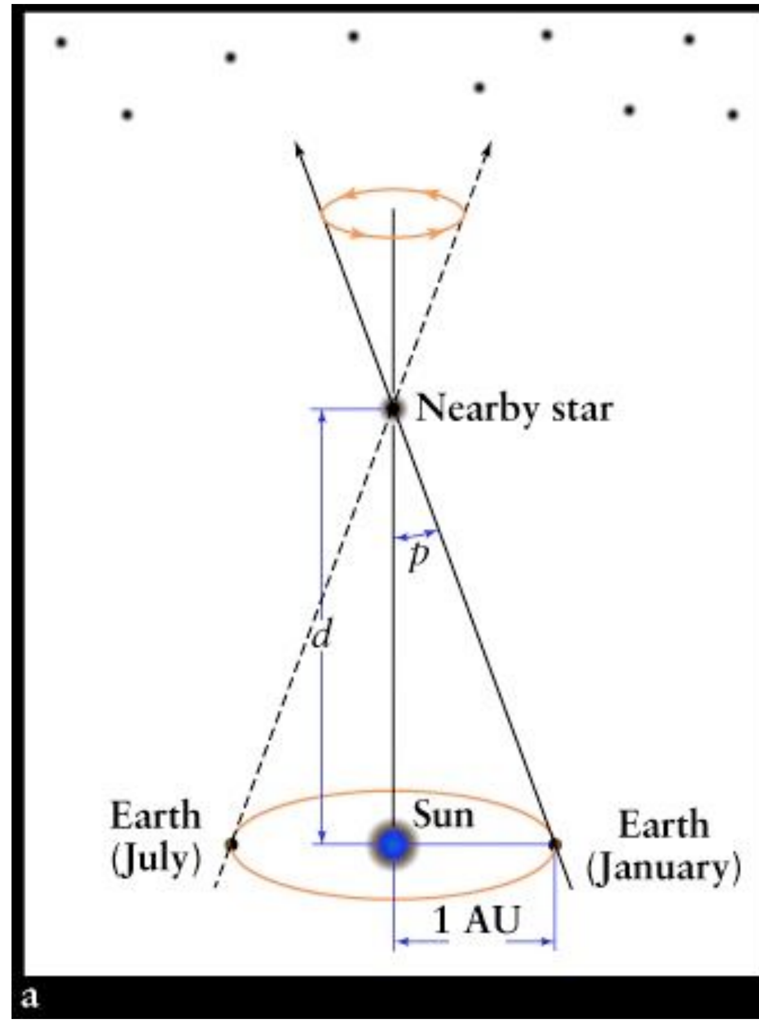
- Nearby stars also appear to move relative to more distant background stars due to the motion of the Earth around the Sun



http://www.astronomy.ohio-state.edu/~pogge/Ast162/Movies/

Trigonometric Parallax Angle

- The trigonometric parallax angle, p, of a star is half the angle through which a star appears to move relative to background stars due to the Earth's motion around the Sun in 6 months

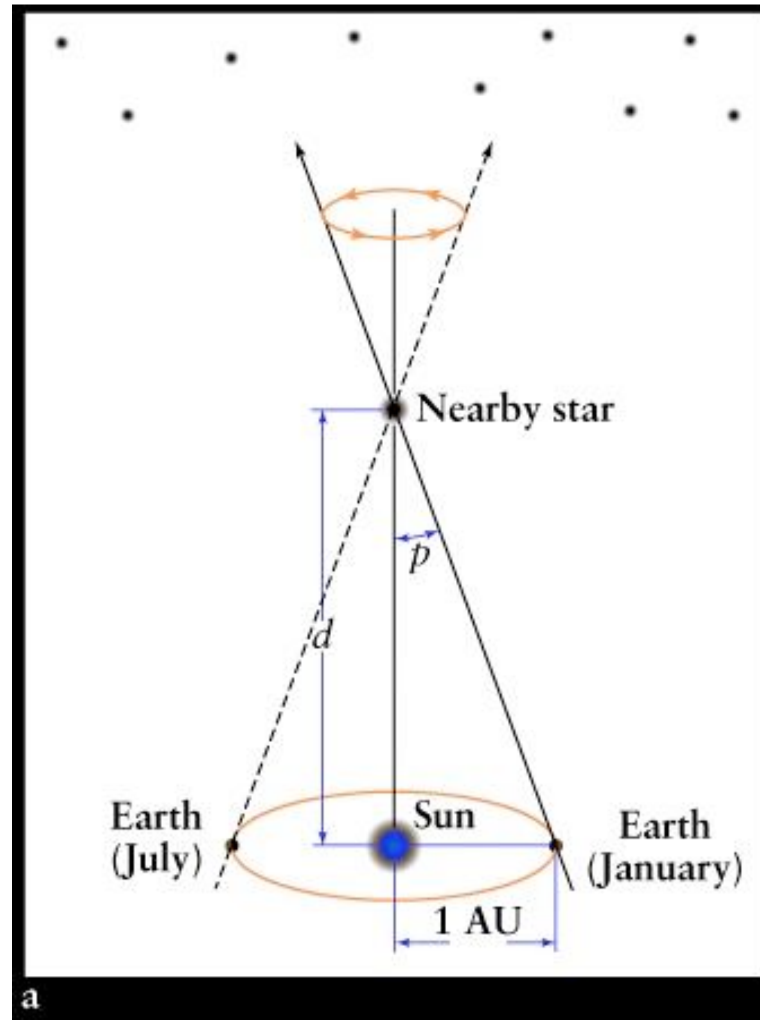


The Parsec

- The unit of distance used in astrophysics is the parsec (pc) – short for parallax arcsecond
- It is defined as the distance (d) of a star that has a trigonometric parallax angle (p) of one arcsecond

Class Exercise

- Use the right angle triangle that defines the parsec to derive how many metres are in a parsec
- Compare this to 1 light-year



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Question slide

Is the parsec in comparison to the light year?

Larger

##.##%

Smaller

##.##%

The same

##.##%

##/##

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Results slide

Is the parsec in comparison to the light year?

Larger

##.##%

Smaller

##.##%

The same

##.##%

RESULTS SLIDE

$$\frac{a}{d} = \tan p = p \qquad \text{since } p \text{ is small}$$

and where *a* is 1 AU so

$$d = \frac{a}{p} = \frac{1.5 \times 10^{11}}{1/206265} = 3.1 \times 10^{16} \text{ m} = 1 \text{ pc}$$

$$1 \text{ light-year} = ct$$

$$= 3 \times 10^{8} \times 365 \times 24 \times 60 \times 60 = 3 \times 10^{8} \times 3.1 \times 10^{7}$$

$$= 9.5 \times 10^{15} \text{ m}$$

i.e. 1 pc = 3.3 light-years

Distance

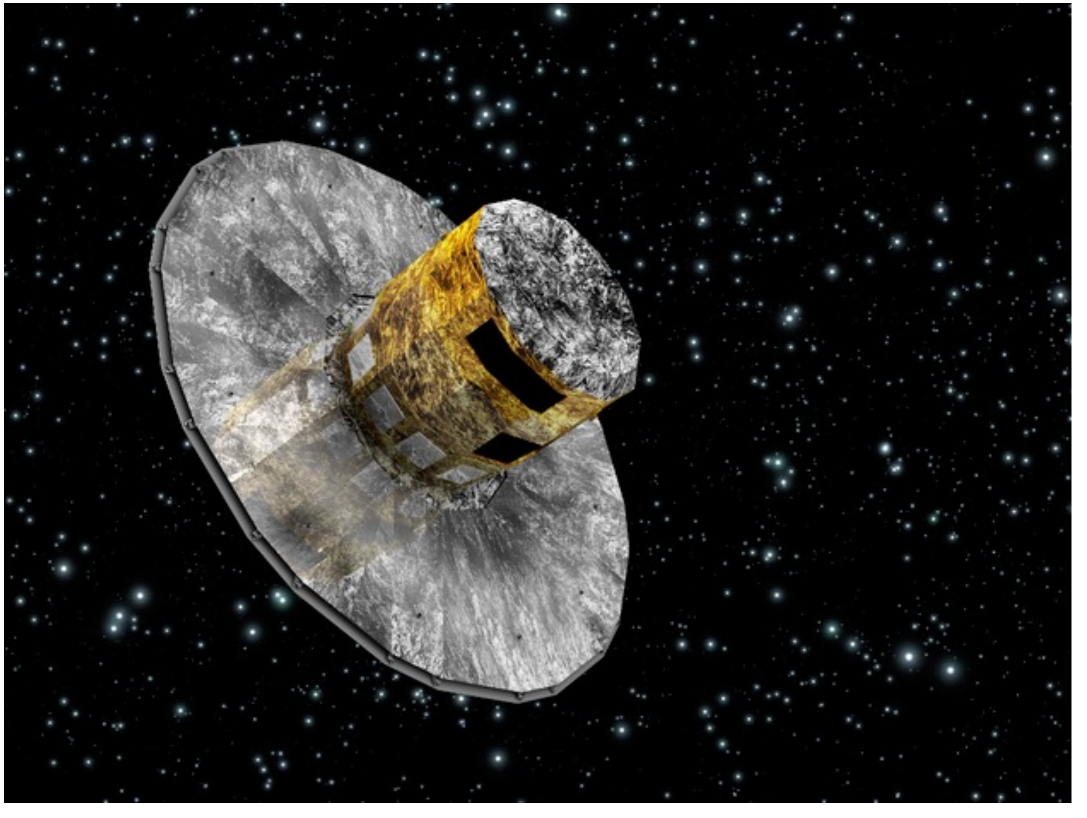
- The distance to a star is

$$d(pc) = \frac{1}{p('')}$$

- The parallax of the nearest star at 1.3 pc is therefore 0.77”
- So parallax is difficult to measure from the ground

Gaia Satellite

- Mission to measure parallaxes to an accuracy of 25 micro-arcseconds



Parallax motion on the sky exaggerated 100 000 times

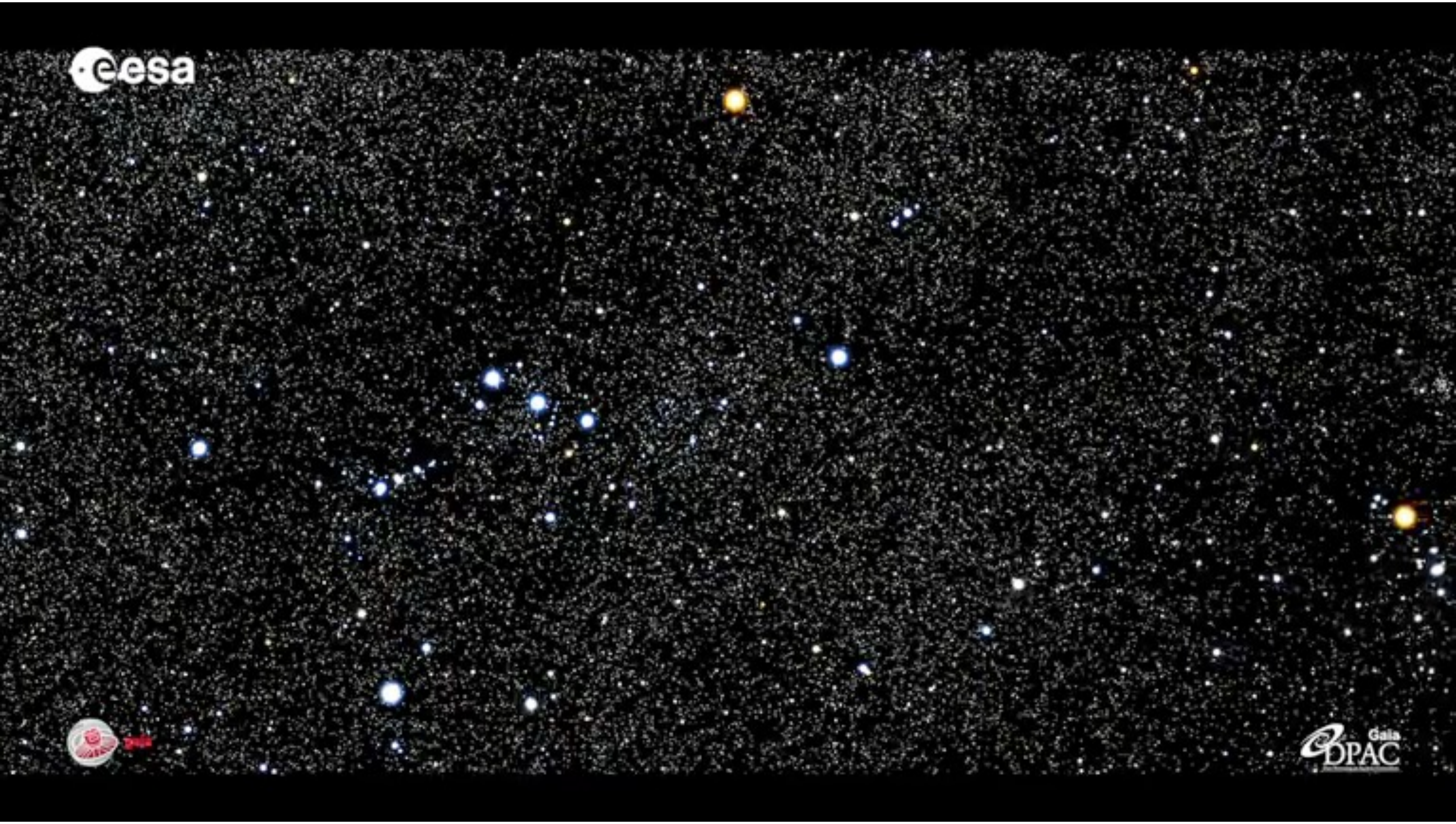
https://sci.esa.int/web/gaia/-/60233-parallax-and-proper-motion-on-the-sky

Proper Motion

- Stars also move across the sky due to their true motion – this is proper motion
- Measured in arcsecs per year

https://people.ast.cam.ac.uk/~jls/

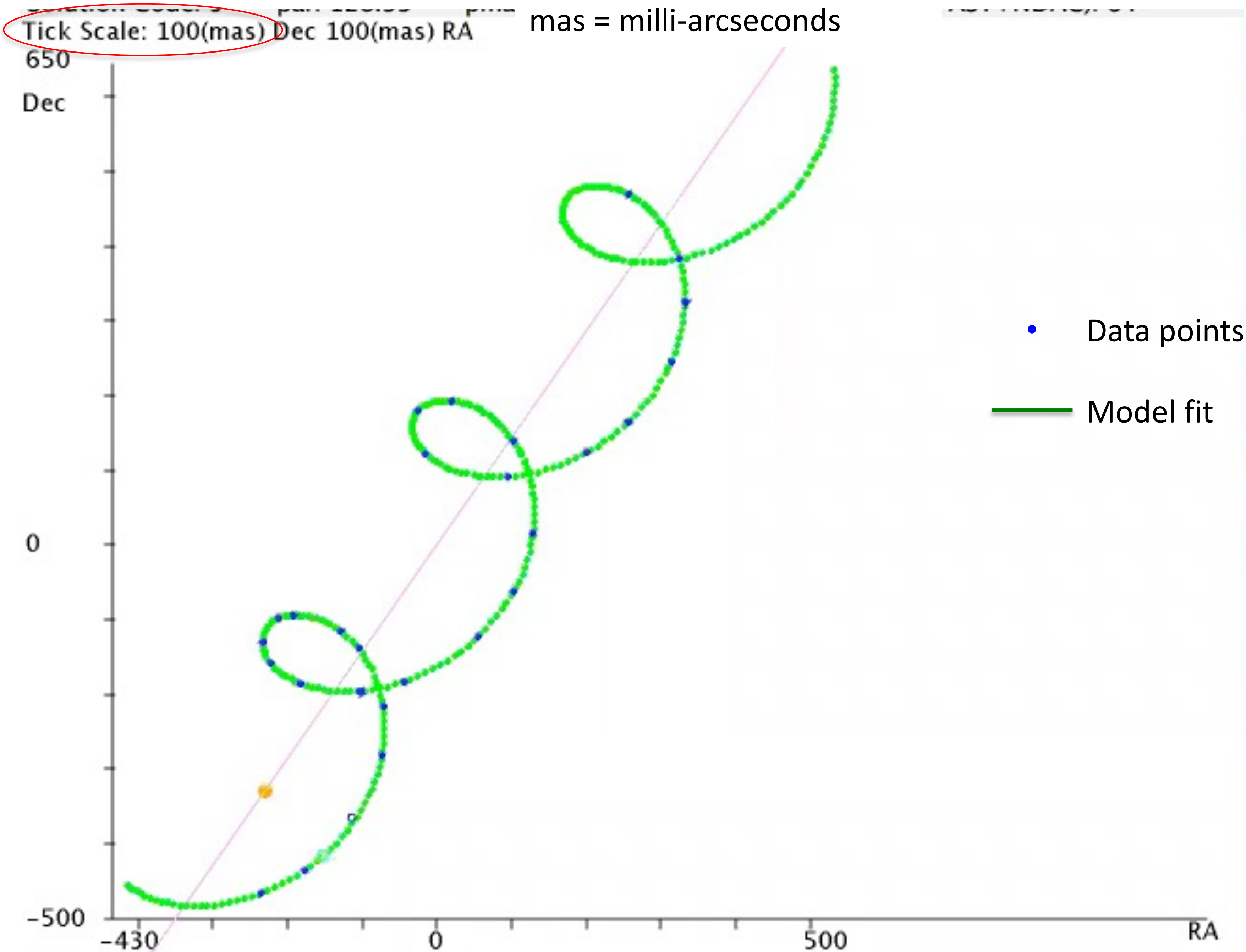
Proper motion of stars in Orion over the next half million years

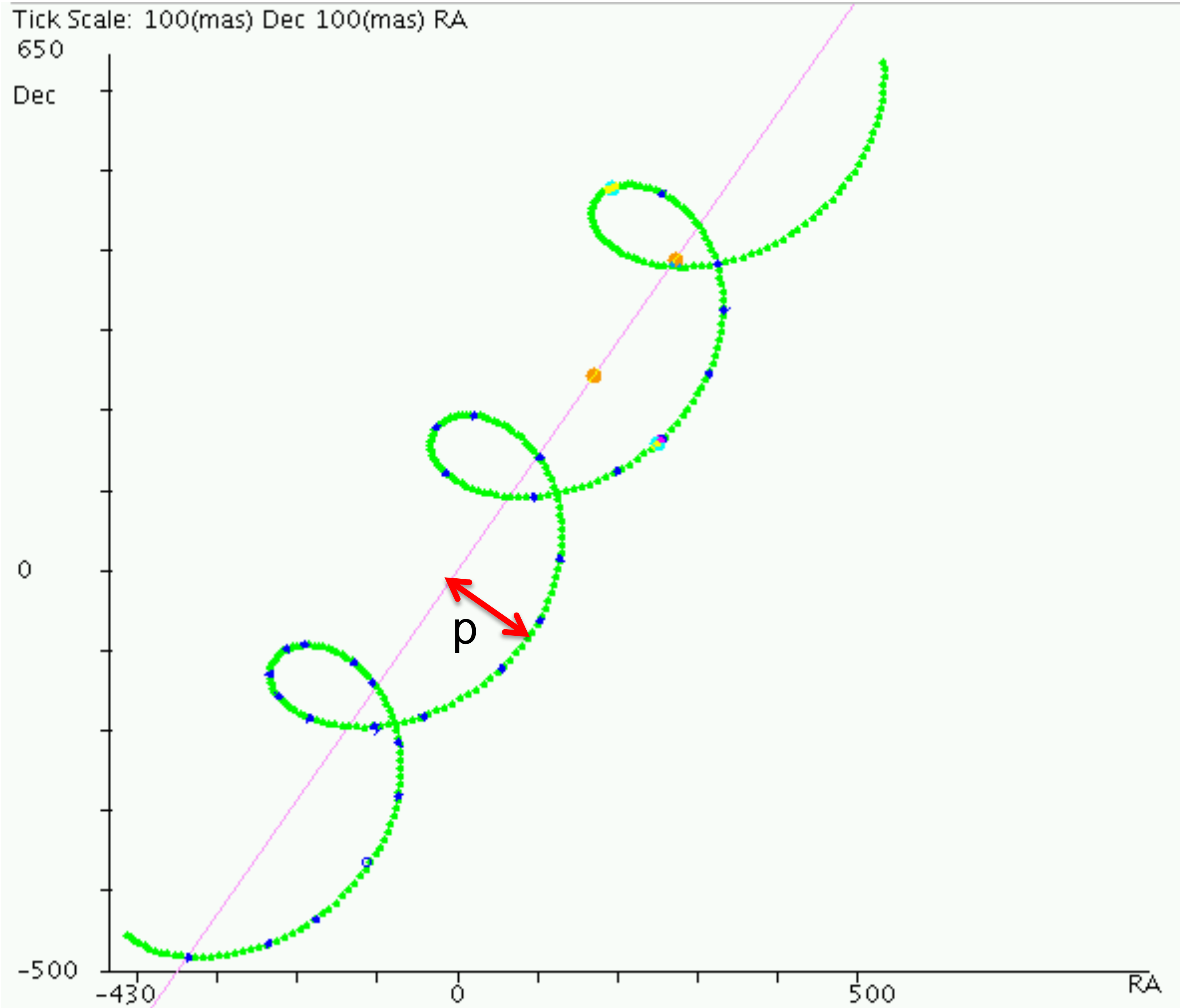


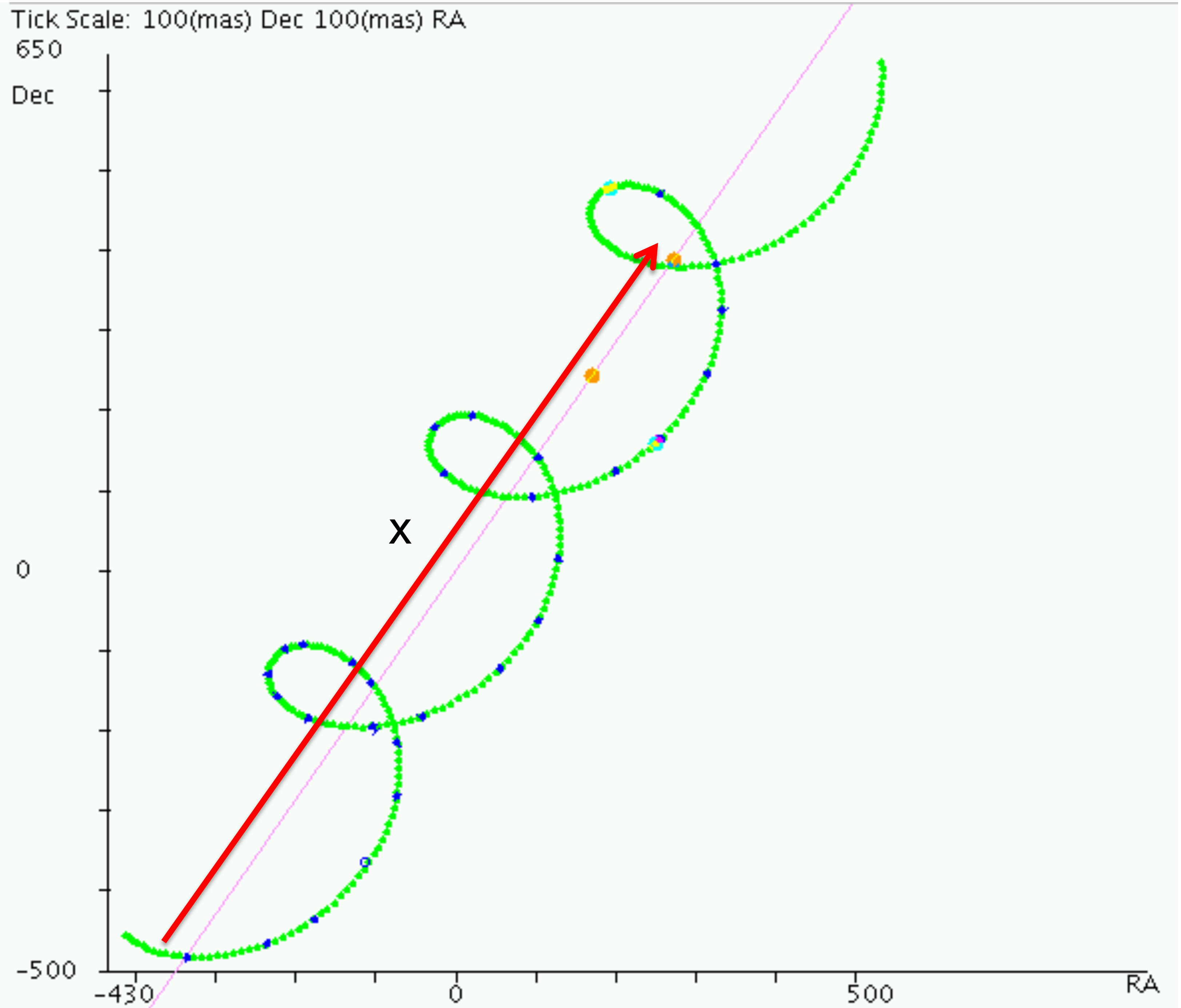
www.esa.int/Science_Exploration/Space_Science/Gaia/The_future_of_the_Orion_constellation

Class Exercise

- The graph overleaf shows data on the position of a star taken over a period of nearly 3 years
- This shows the two components of motion
- One due to parallax and one due to proper motion


mas = milli-arcseconds
Tick Scale: 100(mas) Dec 100(mas) RA
650
Dec
0
-500
-430
0
500
RA
Data points
Model fit

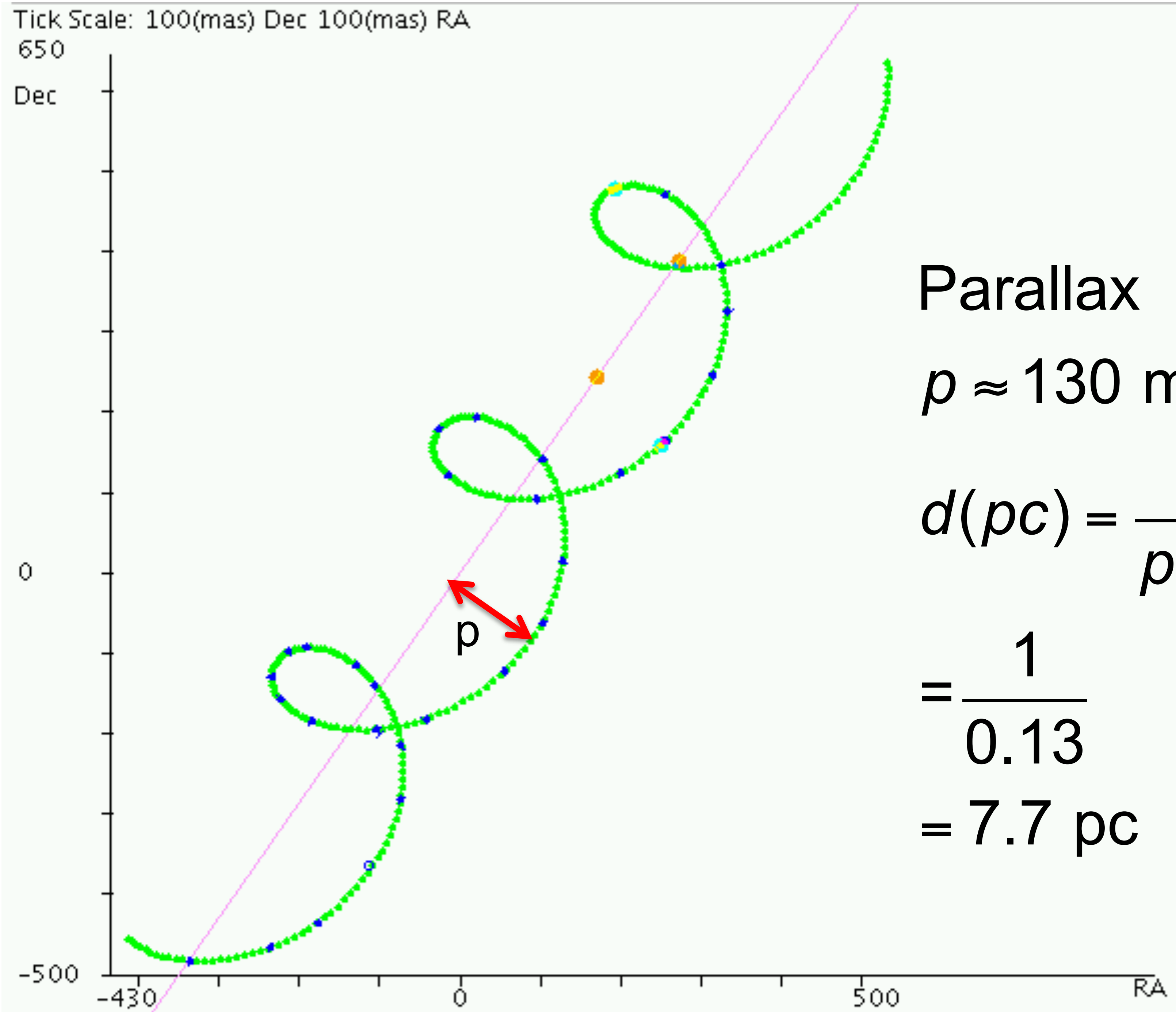

Tick Scale: 100(mas) Dec 100(mas) RA
650
Dec
0
-500
-430
0
500
RA
p



Tick Scale: 100(mas) Dec 100(mas) RA
650
Dec
0
-500
-430
0
500
RA
X

Class Exercise

- Estimate by eye the parallax angle p in arcsecs
- Find the distance to the star in pc



Parallax

$p \approx 130$ mas

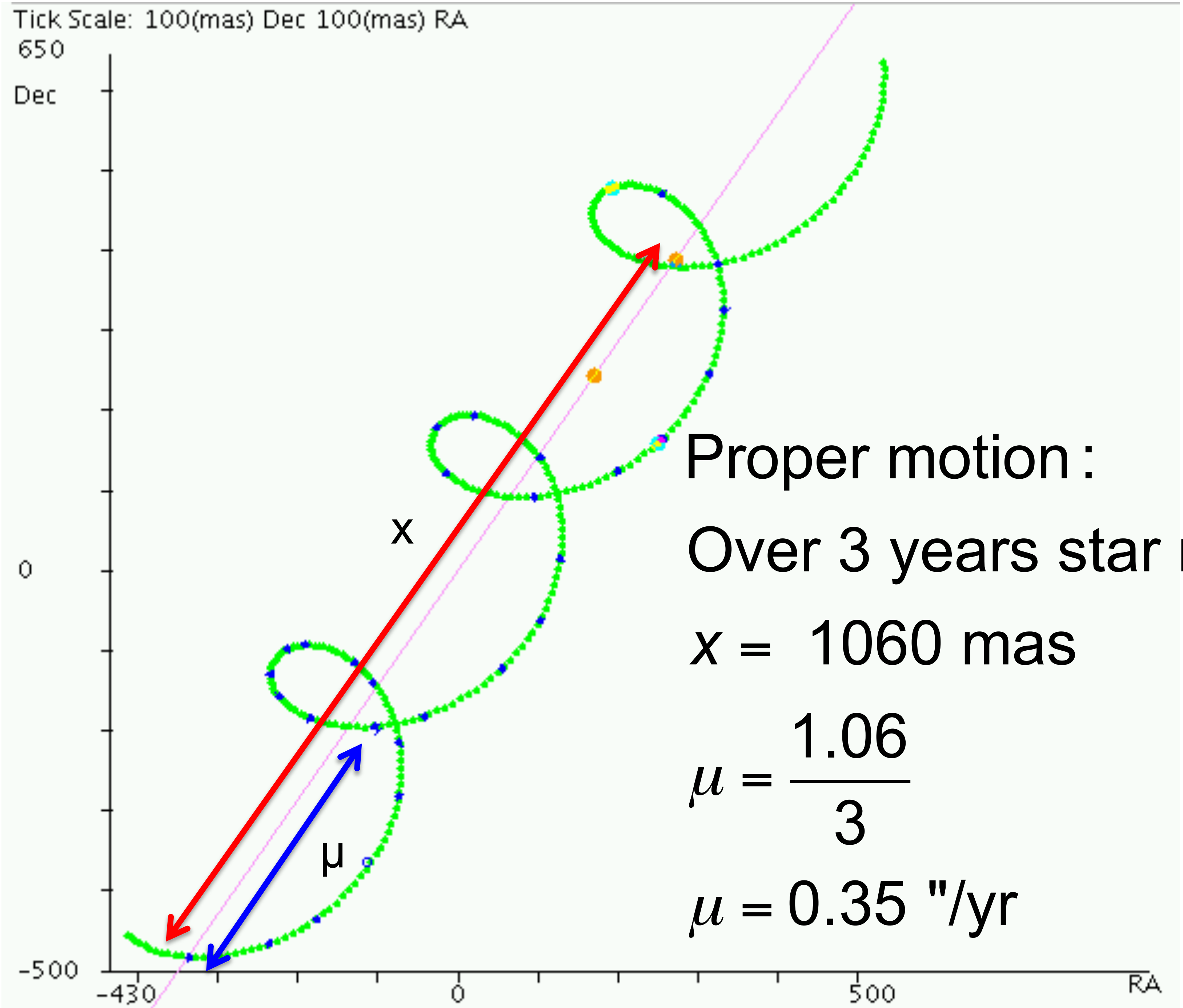
$$d(pc) = \frac{1}{p('')}$$

$$= \frac{1}{0.13}$$

$= 7.7$ pc

Class Exercise

- Estimate by eye the proper motion μ in arcsecs per year
- Find the tangential velocity (in the plane of the sky) of the star in km s^{-1}



Proper motion :

Over 3 years star moves

$x = 1060$ mas

$$\mu = \frac{1.06}{3}$$

$\mu = 0.35$ "/yr

$$v_t = \frac{l}{t}$$

Now

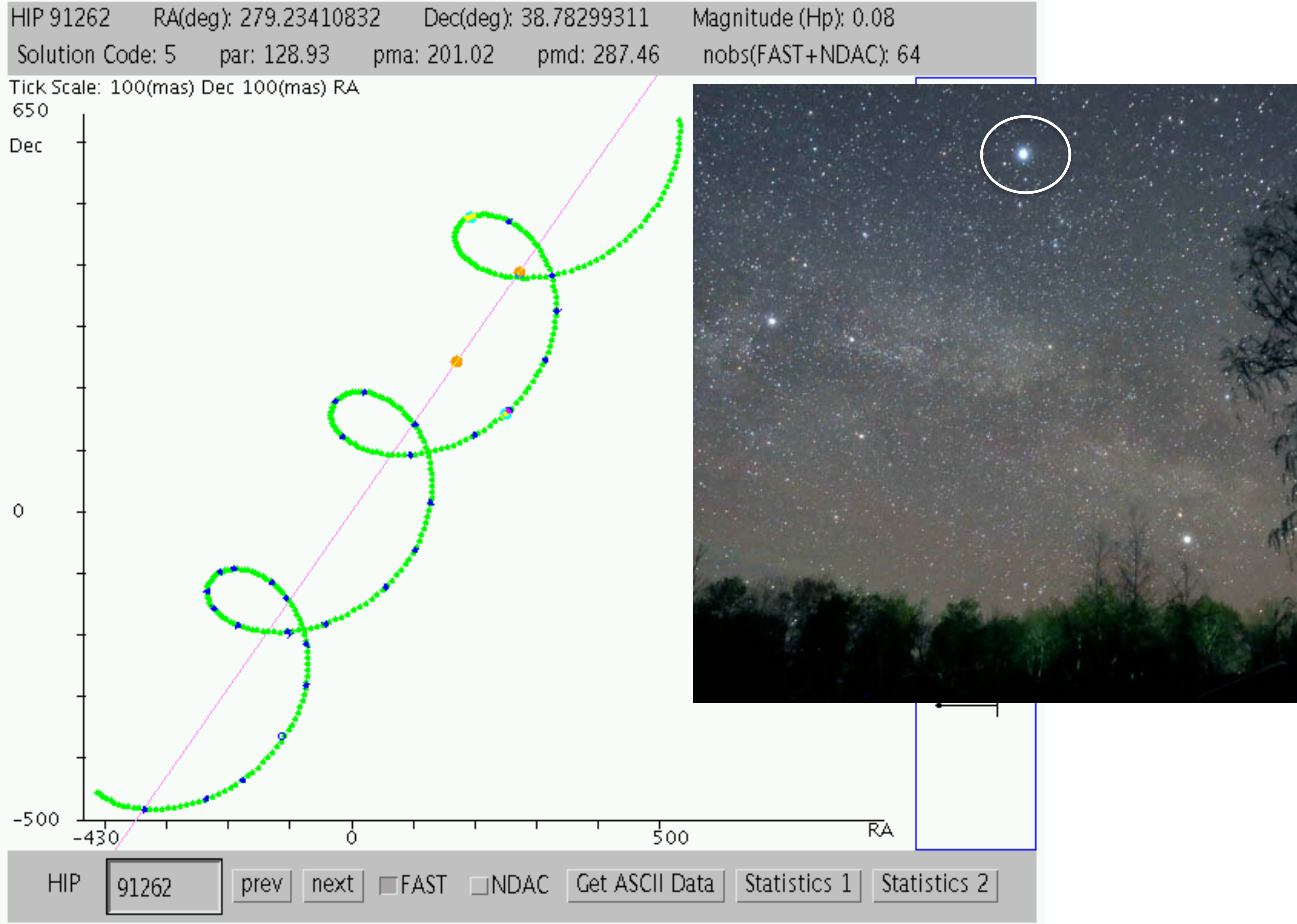
$l = \theta d$ so

$$v_t = \frac{\theta d}{t}$$

$$= \frac{\frac{0.35}{206265} \times 7.7 \times 3.1 \times 10^{16}}{3.1 \times 10^{7}}$$

$$= 1.3 \times 10^{4} \text{ ms}^{-1}$$

$$= 13 \text{ kms}^{-1}$$



https://www.cosmos.esa.int/web/hipparcos/java-tools

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What method could you use to measure the motion of a star along the line of sight?

Change in brightness

##.##%

Change in size

##.##%

Doppler effect

##.##%

Radar

##.##%

##/## Join at: **vevox.app** ID: **XXX-XXX-XXX** Results slide

What method could you use to measure the motion of a star along the line of sight?

Change in brightness ##.##%

Change in size ##.##%

Doppler effect ##.##%

Radar ##.##%

RESULTS SLIDE

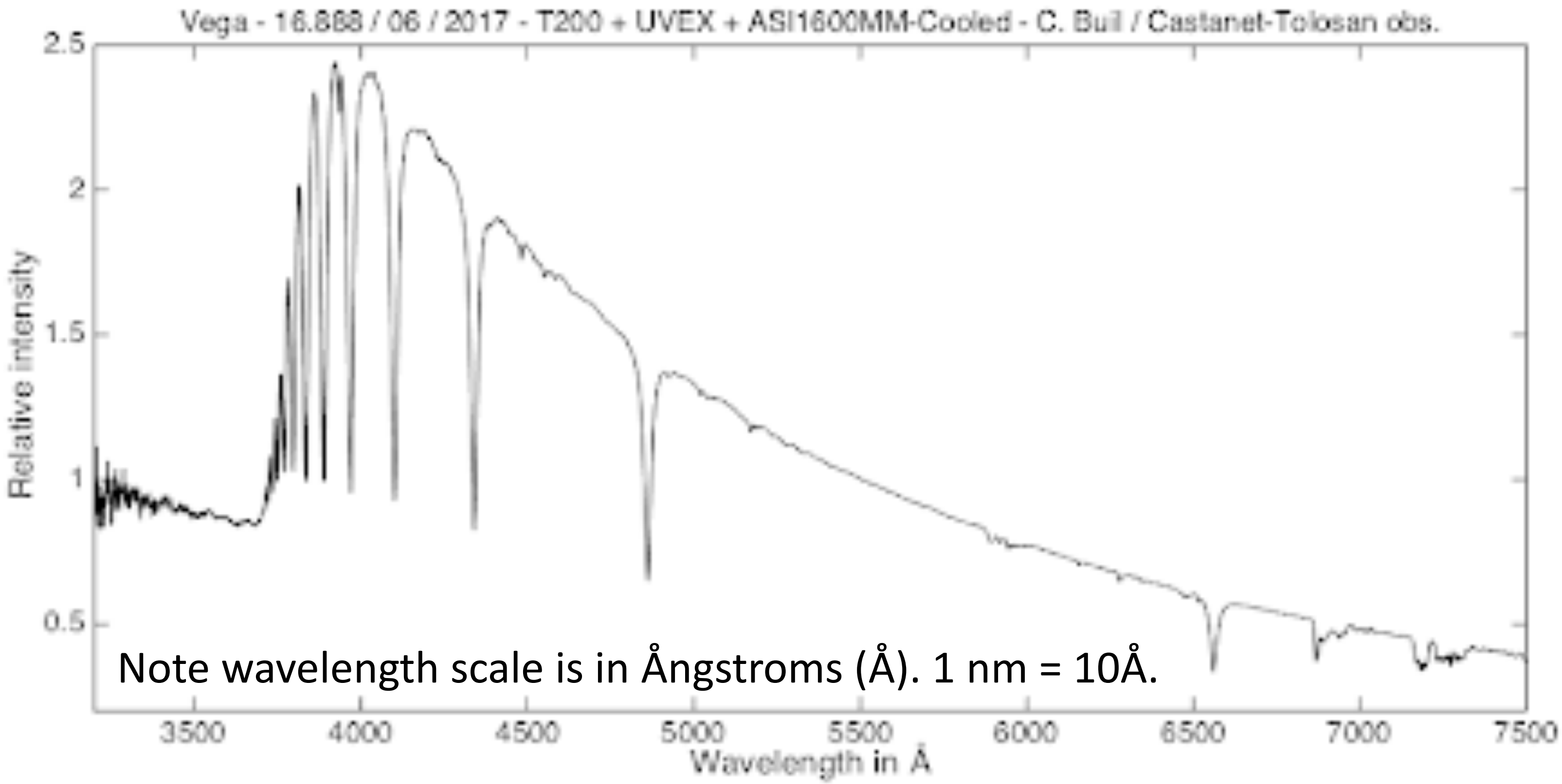
Class Exercise

- The radial component of velocity can be found from using the Doppler shift

$$v_r = \frac{\lambda_{obs} - \lambda_0}{\lambda_0} c = \frac{\Delta\lambda}{\lambda} c$$

where λ_{obs} is the observed wavelength and λ_0 is the rest wavelength

- If the observed wavelength of the Hα line is 656.236 nm and the rest wavelength is 656.280 nm what is Vega’s radial velocity in kms^{-1}?



Note wavelength scale is in Ångstroms (Å). 1 nm = 10Å.

http://www.spectro-aras.com/forum/viewtopic.php?f=8&t=1773

$$v_r = \frac{\lambda_{obs} - \lambda_{lab}}{\lambda_{lab}} c$$

$$v_r = \frac{656.236 - 656.280}{656.280} \times 3.0 \times 10^8$$

$$= -2.0 \times 10^5 \text{ ms}^{-1} = -20 \text{ kms}^{-1}$$

- Total velocity

$$v^2 = v_r^2 + v_t^2$$

$$v^2 = (-20)^2 + 13^2$$

$$v = 24\ \mathrm{kms}^{-1}$$

Summary

- Trigonometric parallax is the only direct way to measure the distance to stars
- The parsec is the standard unit of distance in astrophysics
- The Gaia satellite is measuring accurate parallaxes to a billion stars in the Galaxy
- Proper motion and radial velocity measurements give the 3D motion of stars