

# Trigonometric Parallax

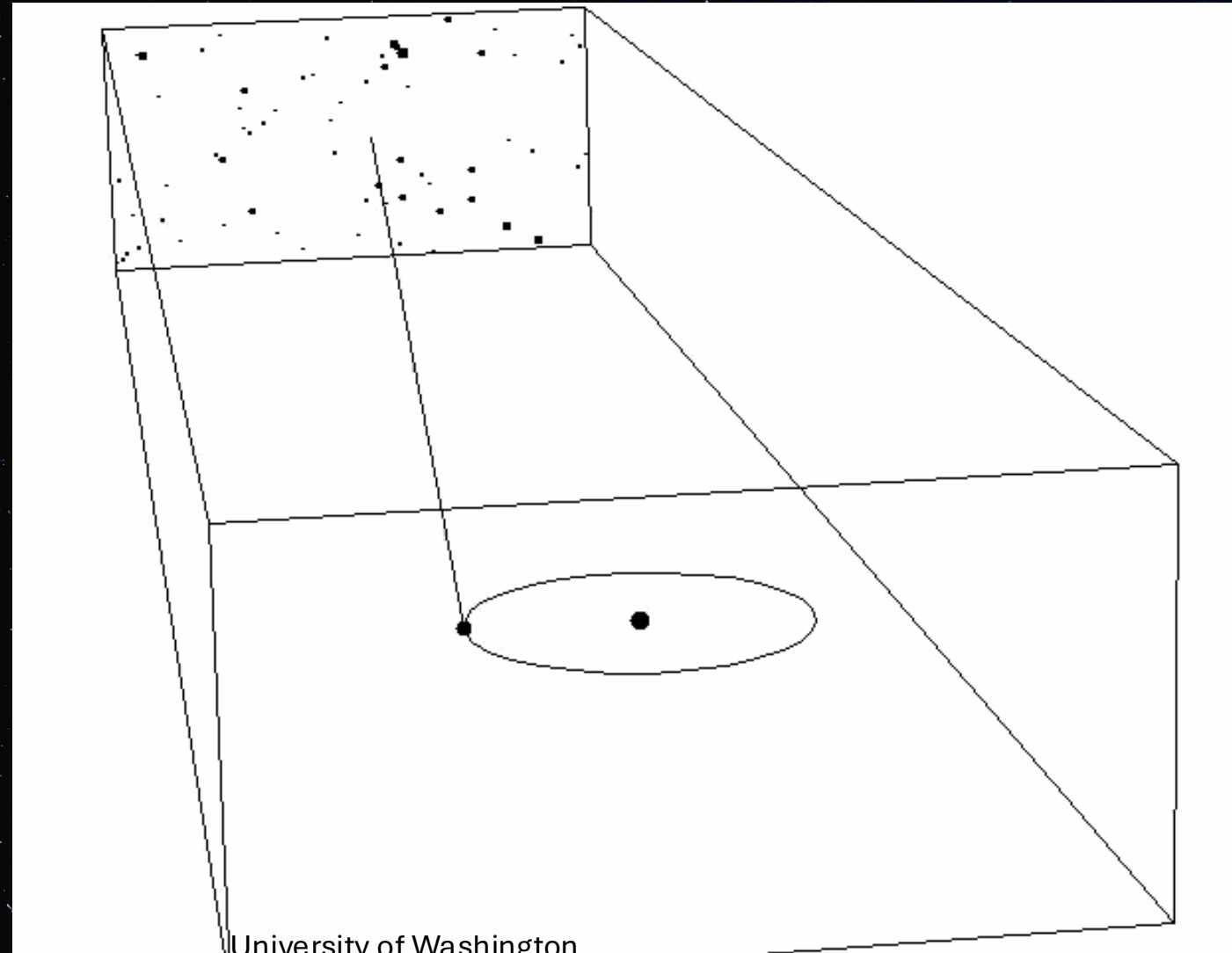
1st Rung of the Distance Ladder

ASTR 8400

Lexi Azoulay

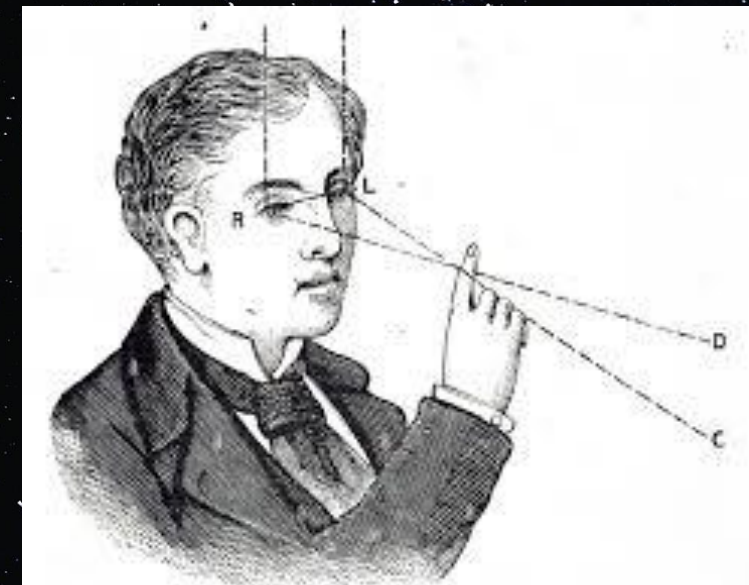
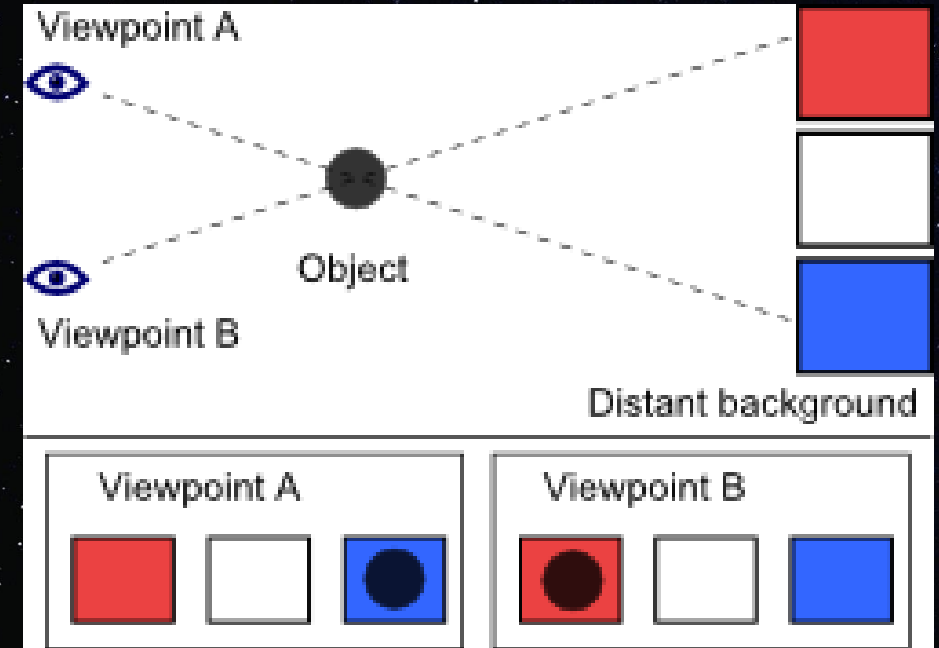
# What is parallax???

- Apparent shift of an object's position relative to more distant background caused by a change in the observer's position
- Perspective effect based on geometry of Earth's orbit around the Sun



# Eye demonstration

- Our eyes provide a small parallax effect
  - Stereo vision
- Creates depth perception
- Only works for close objects (hint hint)
  - When object is far away, shift in position of the foreground objects to background is too small for eyes & brain to register



# So, what does this tell us about the distance to objects in the sky?

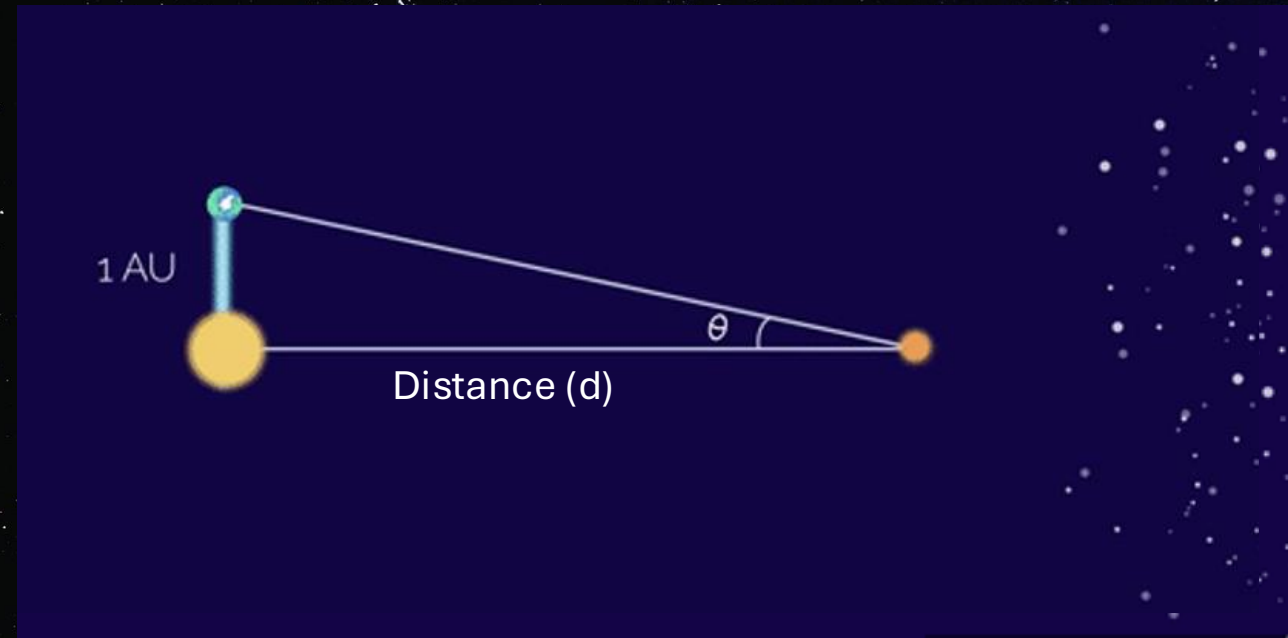
- Trigonometry!
- Creating a right triangle



# So, what does this tell us about the distance to objects in the sky?

- Trigonometry!
- Creating a right triangle
- Distance from star to Earth is the hypotenuse

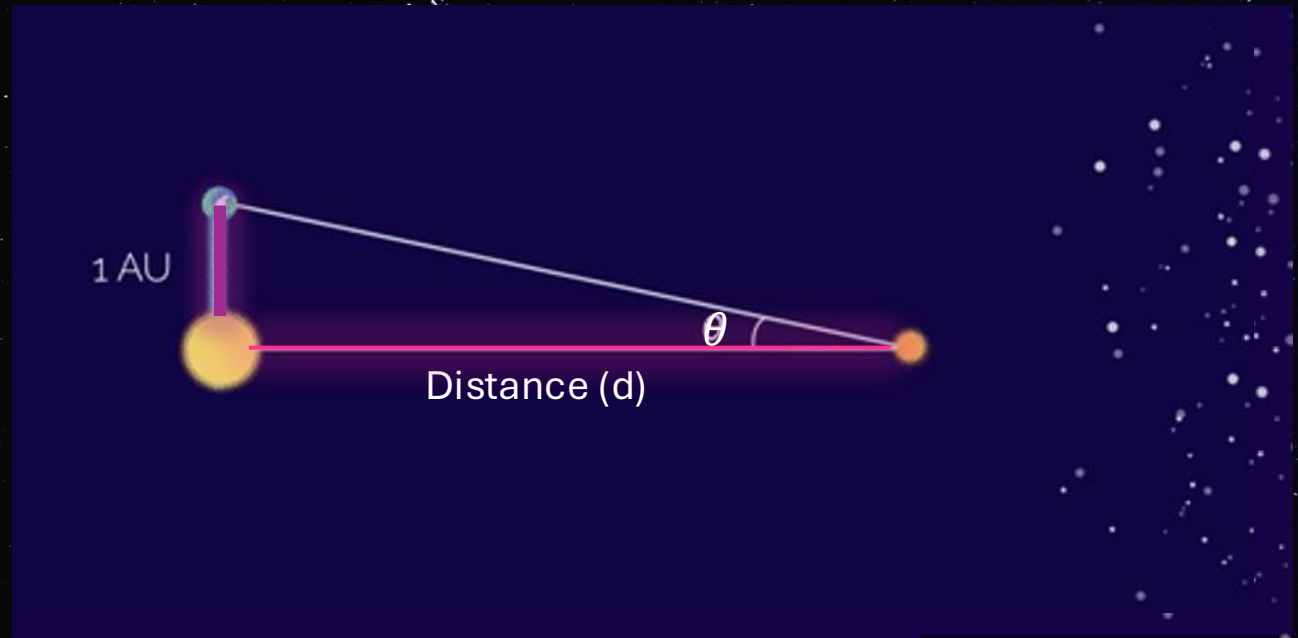
SohCahToa



So, what does this tell us about the distance to objects in the sky?

**T**o a  
a n g e n t  
o p p o s i t  
a d j a c e n t

$$\tan \theta = \frac{1 \text{ AU}}{d}$$



# So, what does this tell us about the distance to objects in the sky?

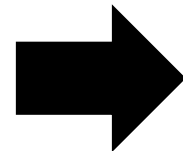
To a  
a o a  
n p d  
g p j  
e o a  
n s c  
t i e  
t n  
e t

$$\tan \theta = \frac{1 \text{ AU}}{d}$$

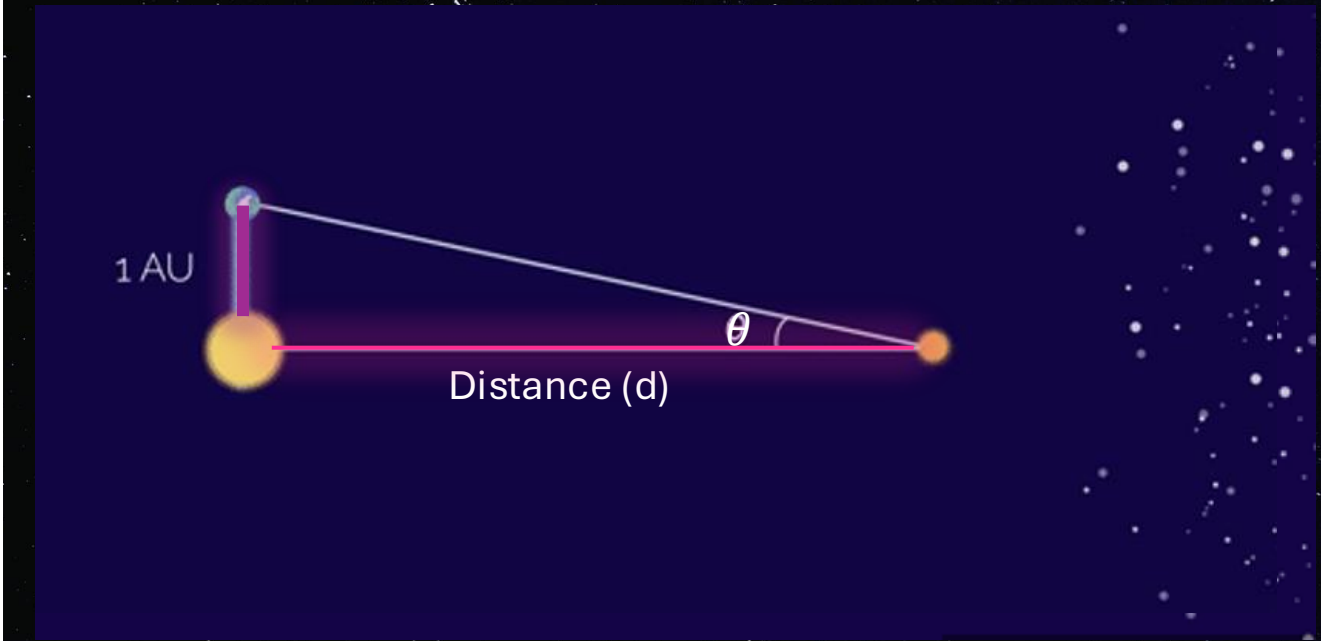
Want distance (d):

$$d = \frac{1 \text{ AU}}{\tan \theta}$$

Apply small angle approximation:  $\tan \theta \approx \theta$



$$d = \frac{1 \text{ AU}}{\theta}$$

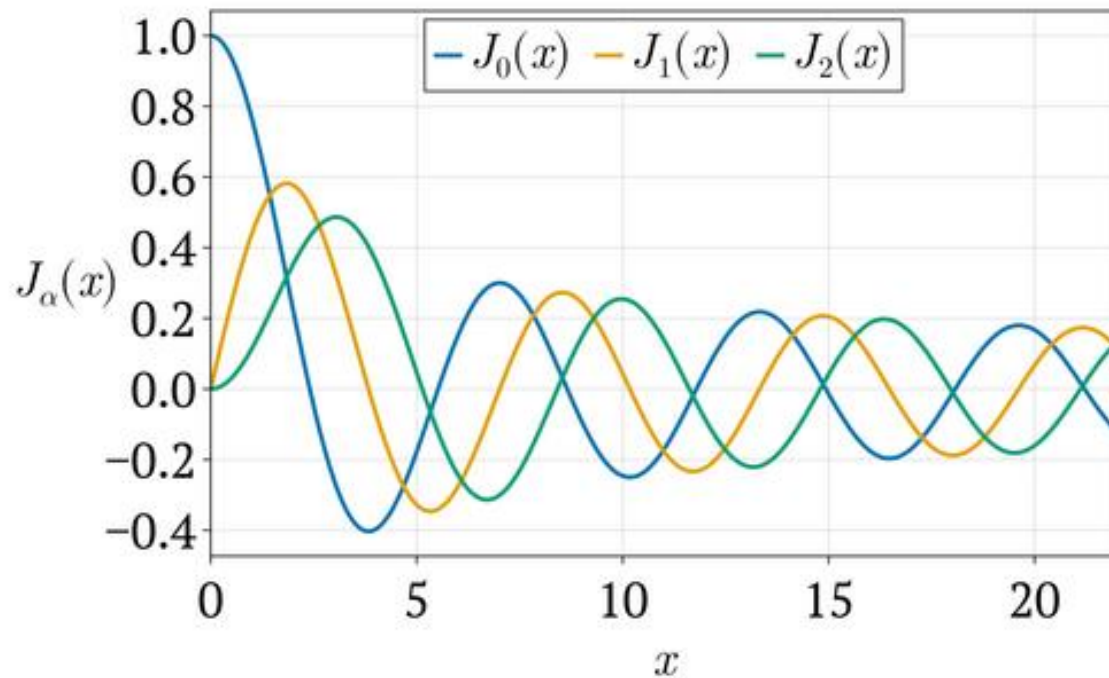


# Who figured this out?

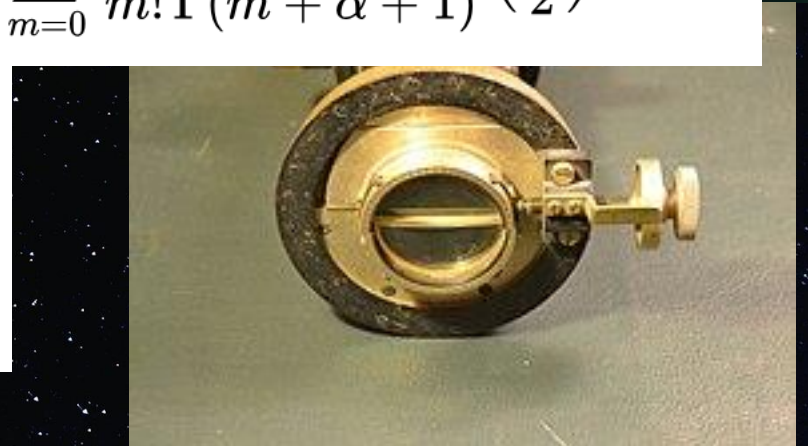
- Theorized in 17<sup>th</sup> century as evidence for a heliocentric solar system
- Didn't have good/accurate enough telescopes to measure at the time (they still tried)
- Ancient Greeks used the concept to try to get distance to moon (thought stars were too far away to measure)
- Robert Hooke tried in 1674 (unreliable measurements)
- James Bradely tried again in 1729 (instead observed aberration of light)

# Who figured this out?

- Fredrich Bessel made the 1<sup>st</sup> successful stellar parallax measurement in 1838



$$J_\alpha(x) = \sum_{m=0}^{\infty} \frac{(-1)^m}{m! \Gamma(m + \alpha + 1)} \left(\frac{x}{2}\right)^{2m + \alpha},$$



# Who figured this out?

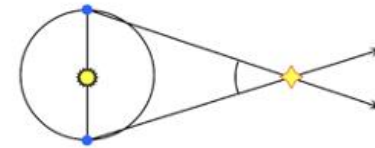
- Fredrich Bessel made the 1<sup>st</sup> successful stellar parallax measurement in 1838
- Using a heliometer (refracting telescope with a split objective lens) for 6 months
- 61 Cygni to have a parallax of 0.315 ''
- Getting a distance of 10.4 light years
- Close to actual parallax: 0.286'' (11.4 ly)



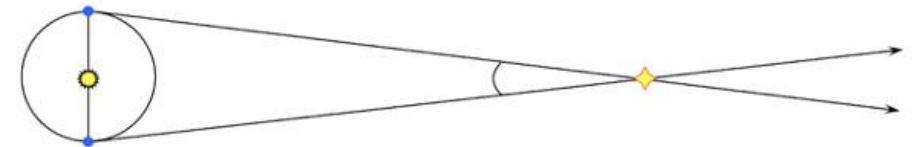
# Limitations to Parallax

- Farther away stars are harder to measure
- Atmospheric turbulence limits ground-based observations to 1''

*Closer stars have larger parallaxes:*



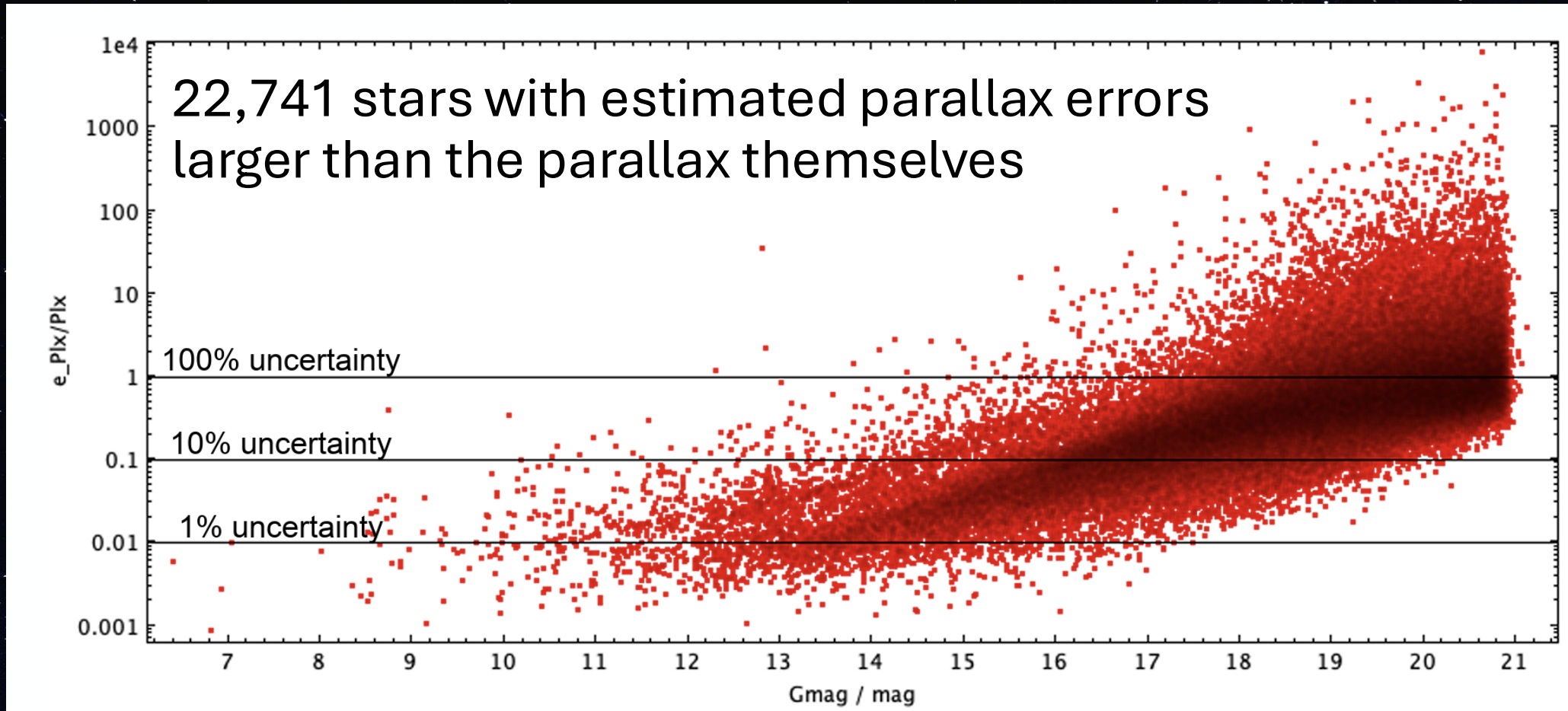
*Distant stars have smaller parallaxes:*



# Distance range expanded by Hipparcos & Gaia

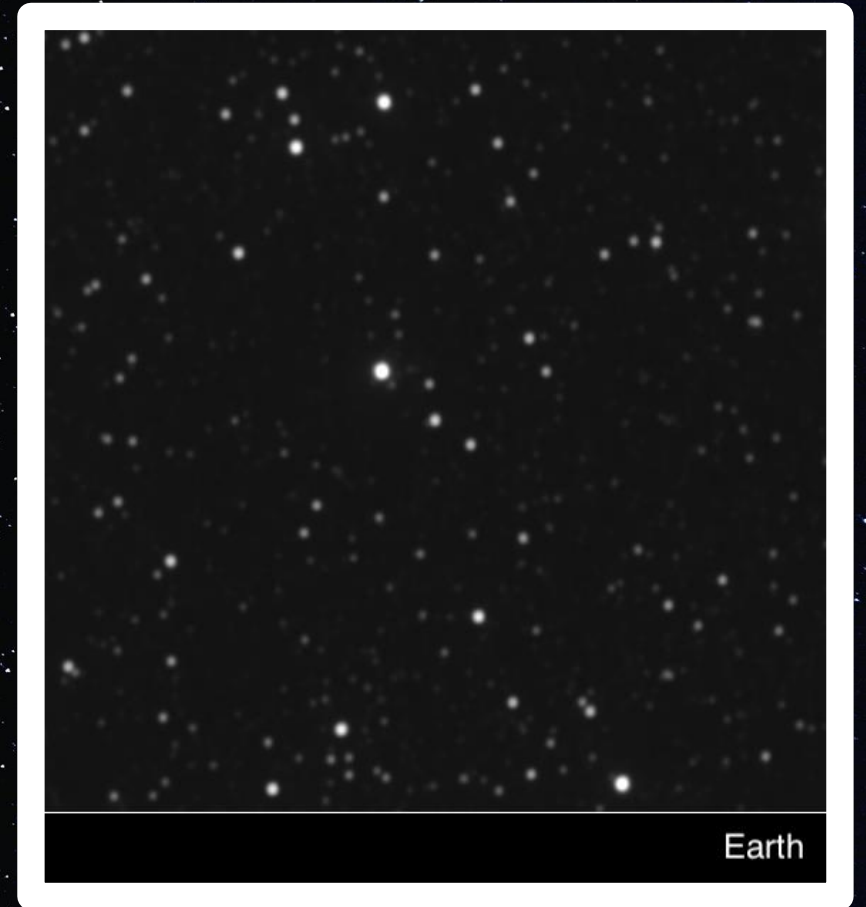
- Space-based => gets rid of atmosphere limitation
- Hipparcos (1989 – 1993) expanded range to 200-500pc
  - catalogue of 120,000 stars, all accurate in position and parallaxes to about one thousandth of a second of arc
- Gaia (2014-2025) expanded to get accurate parallax to 300pc
- But errors are still high
- 1000 parsecs gives ~10% error with Gaia

# Gaia Uncertainty Ratios v G Magnitudes



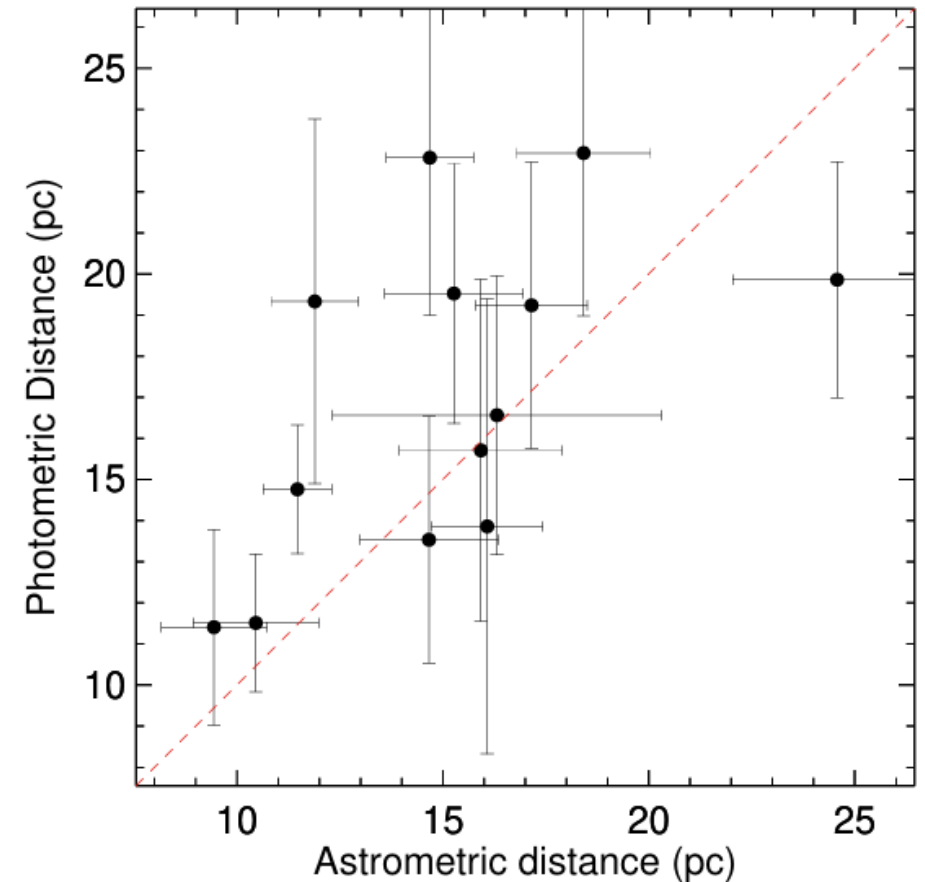
# New Horizons Demonstration

- In 2020 New Horizons (~47 AU) observed Proxima Centauri & Wolf 359
- Measured large parallaxes: 32.4" (Proxima Cen), 15.7" (Wolf 359)
- Large Earth–spacecraft baseline makes the parallax shift directly visible in images
- Used primarily to demonstrate parallax and test spacecraft navigation using stars



# Parallax of Cold Brown Dwarfs with Spitzer & HST (Marocco et al., 2026)

- Measured distances to 13 cold brown dwarfs using Spitzer + HST astrometry
- Fit proper motion and parallax to isolate the parallax motion
- Parallax gives more accurate, geometric distances than photometric
  - Due to large brightness scatter



**Questions?**