

Secular and Statistical Parallax

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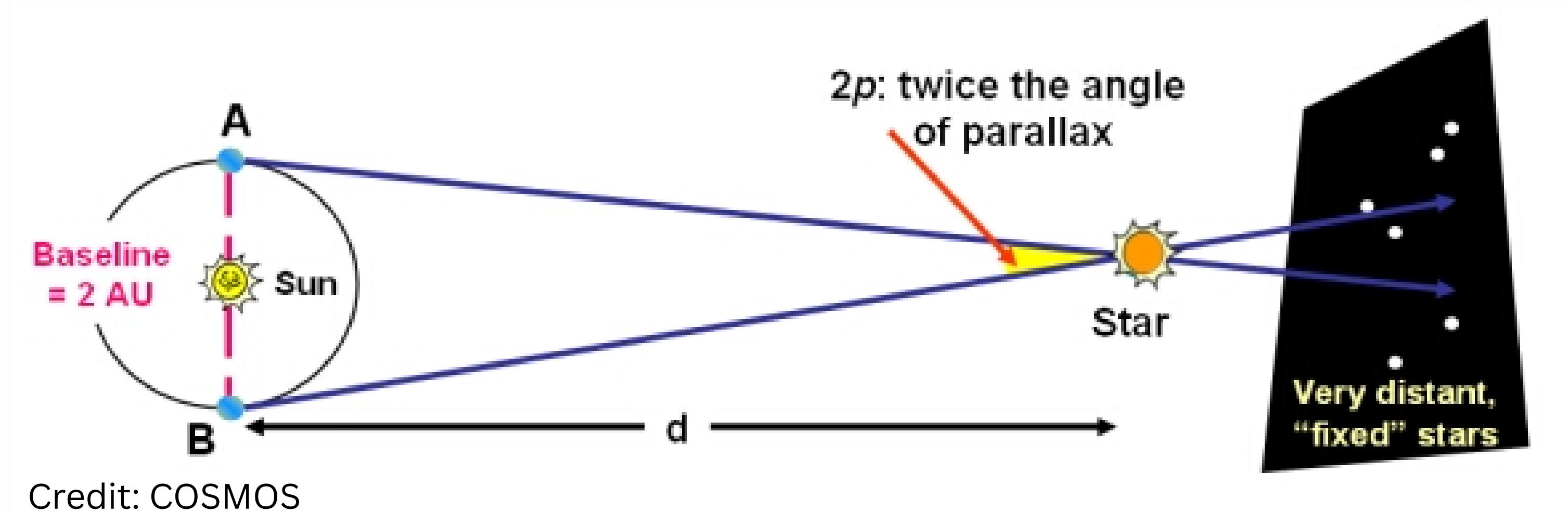
Trigonometric Parallax (b00000)

Dependent on distance between Earth and Sun

→ Half the angular displacement on the sky produced when the star is viewed from opposite sides of the Earth's orbit.

Limits

Reliable up to $d = 100$ pc from the ground



Secular Parallax (wooooo!!)

Longer baseline → larger distance range

The Sun's non-zero space velocity allows for this; the Solar System moves about 4 AU per year, double the baseline of trigonometric parallax.

Reliable up to $d = 500$ pc from the ground.

“...So observations separated by, say, twenty years give us an effective baseline **forty times larger** than that provided by the Earth's motion around the Sun.”

Binney & Merrifield

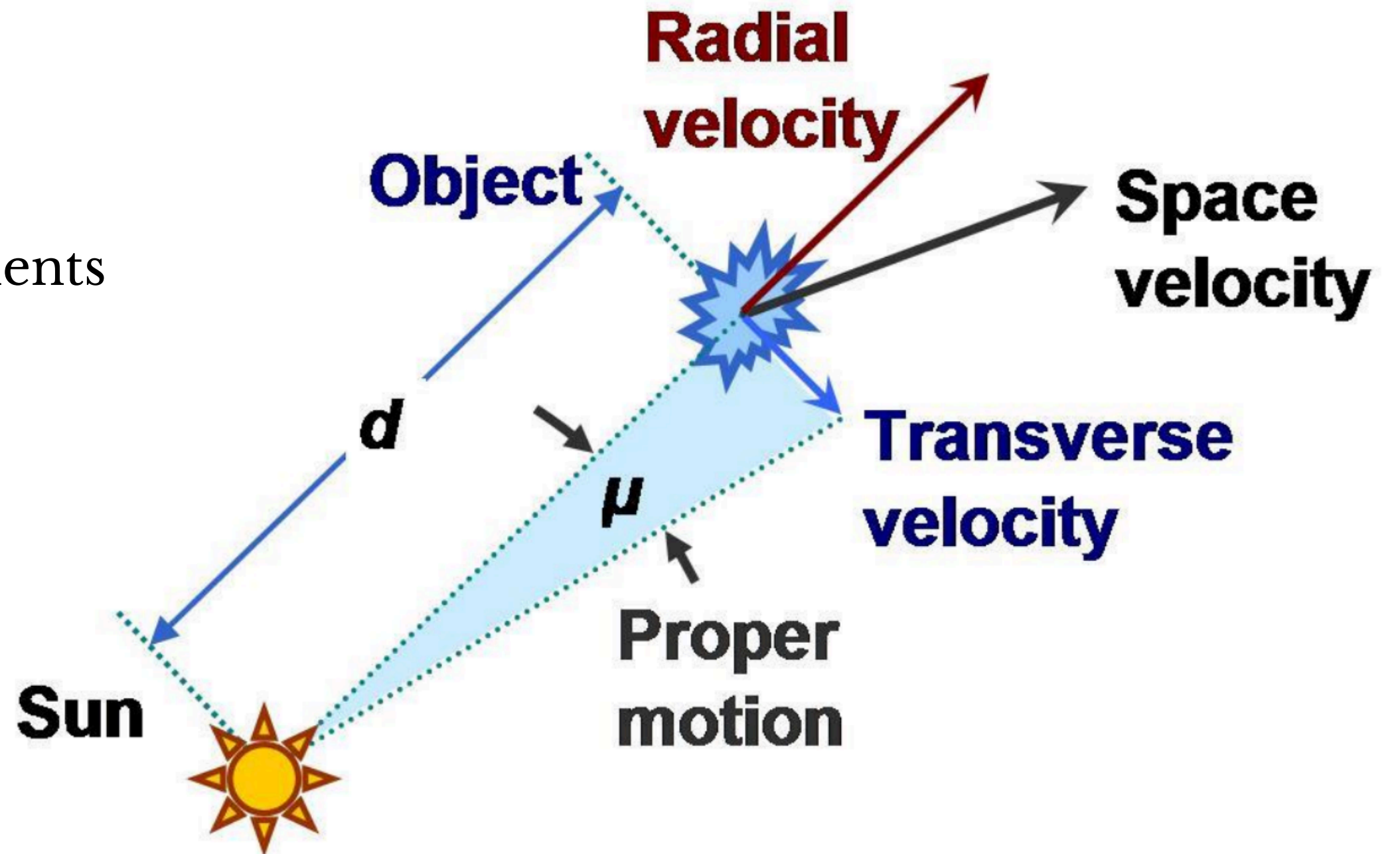
The Basics

Proper Motion

Transverse velocity;
Parallel and perpendicular components

Radial Velocities

Line of sight velocity



The Set Up

sphere of stars with similar luminosities/apparent mag

- common space velocity relative to the Sun, v
- proper motions disappear in direction of v
- measure radial velocities \rightarrow get magnitude of v
- define μ_{\perp} in directions where v_r disappears

$$x = v / \mu_{\perp}$$

Credit: Binney & Merrifield

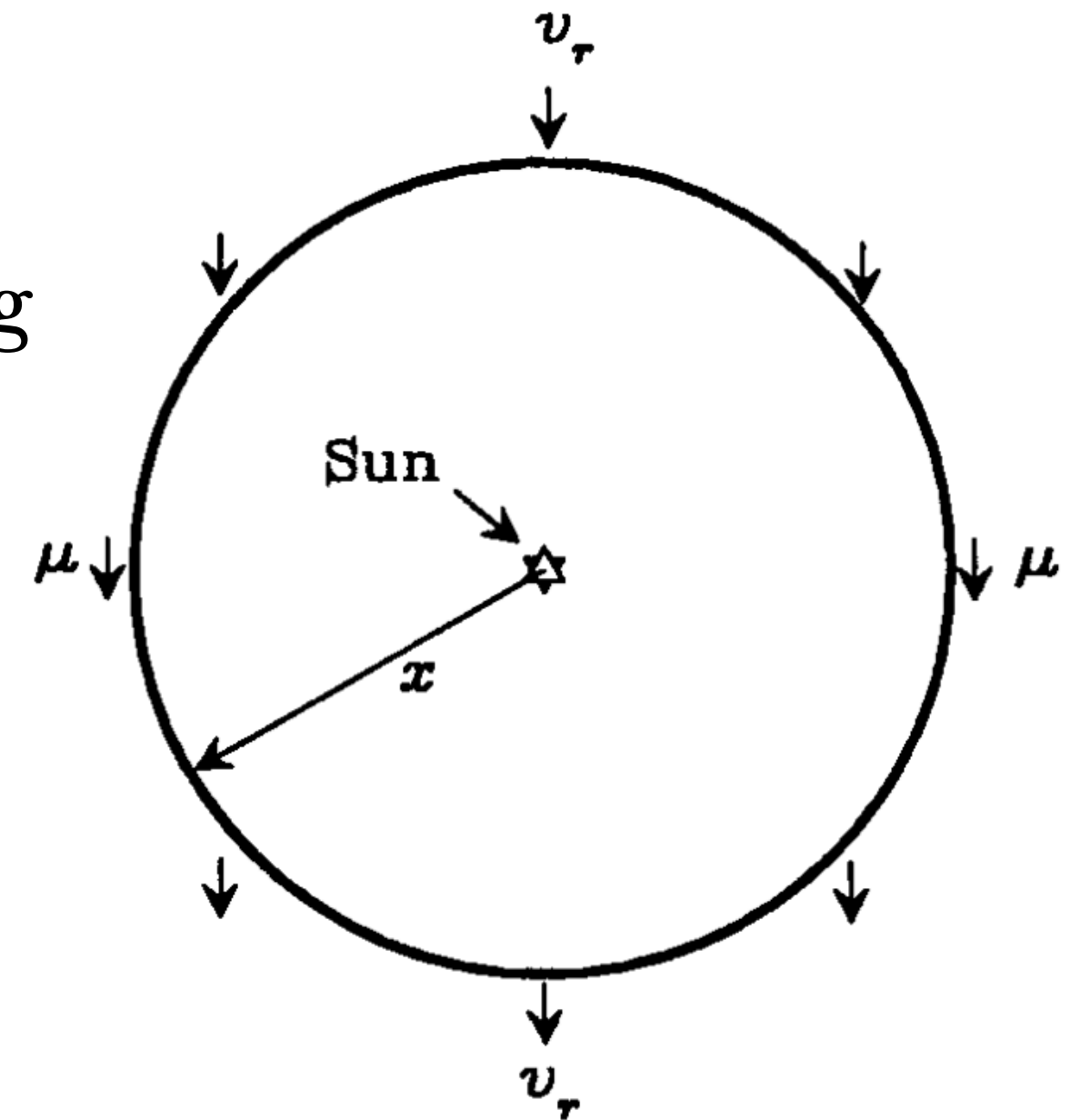


Figure 2.9 The motion relative to the Sun of stars on a sphere of radius x gives rise to both radial velocities and proper motions. In some directions the proper motion vanishes, while in others the radial velocity vanishes.

Potential Problems

Not complete

“The only proper motions it uses are those of stars that lie in directions exactly perpendicular to v .”

Different velocities

“In reality, the velocities of individual stars will scatter around some mean motion.”

→ Assume mean velocity = 0

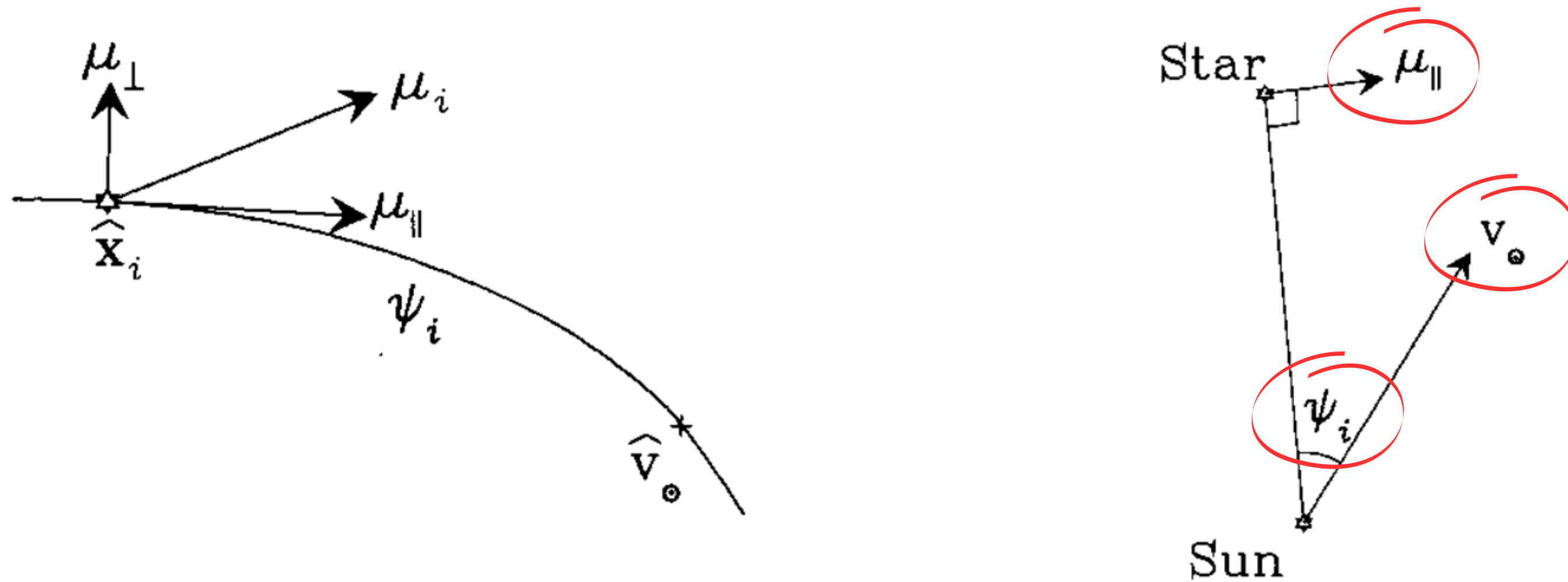
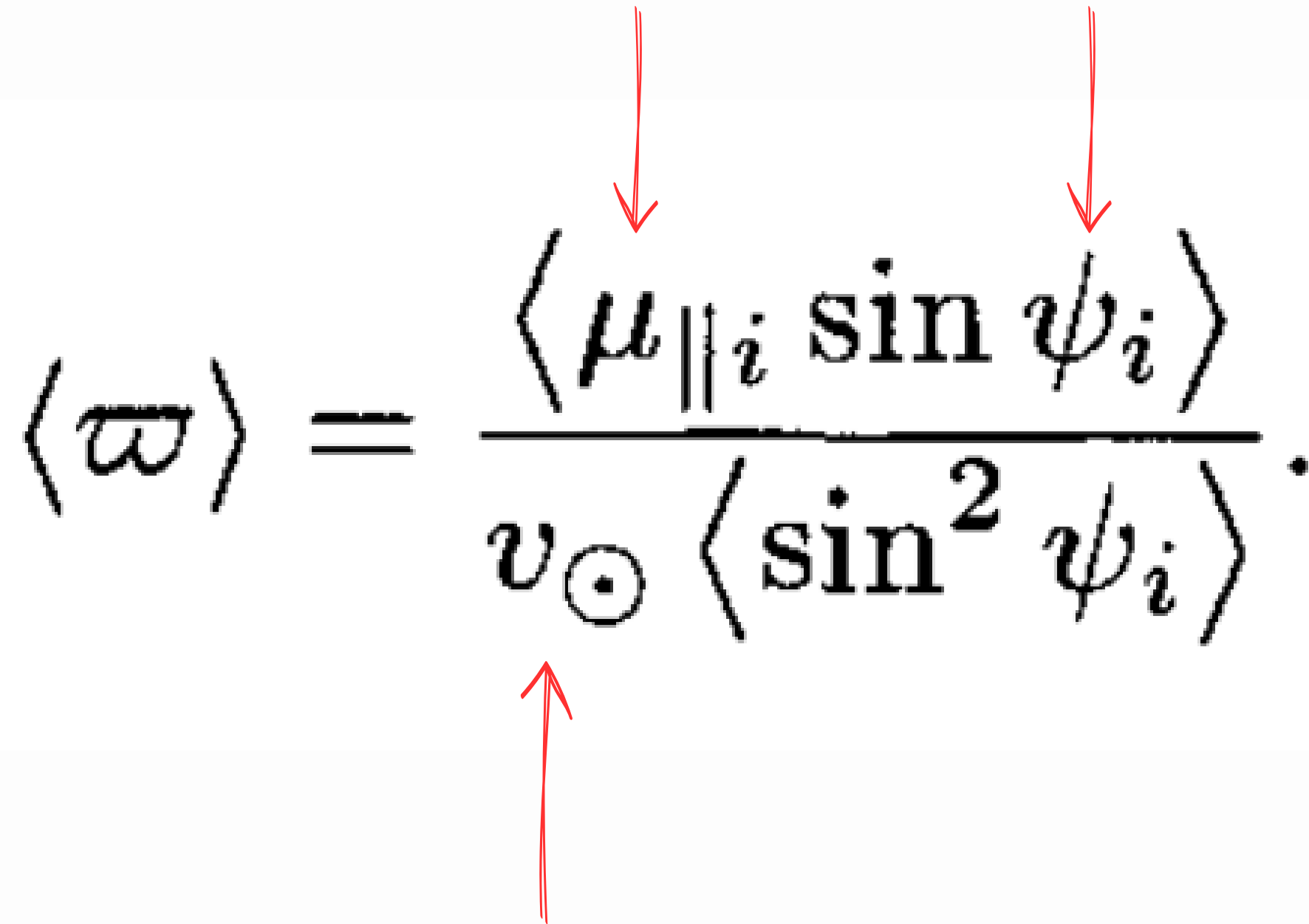


Figure 2.10 Left: on the sky, the i^{th} star is at $\hat{\mathbf{x}}_i$, while the Sun is moving in the direction $\hat{\mathbf{v}}_{\odot}$. The angle between these directions is $\psi_i = \arccos(\hat{\mathbf{x}}_i \cdot \hat{\mathbf{v}}_{\odot})$. The proper motion vector $\boldsymbol{\mu}_i$ is decomposed into components parallel and perpendicular to the great circle joining $\hat{\mathbf{x}}_i$ to $\hat{\mathbf{v}}_{\odot}$. Right: the plane containing the Sun the star and $\hat{\mathbf{v}}_{\odot}$.

Lots of math later...

Secular Parallax

Best when Sun's motion dominates the group random velocities (D. G. Turner, 2012)

$$\langle \varpi \rangle = \frac{\langle \mu_{\parallel i} \sin \psi_i \rangle}{v_{\odot} \langle \sin^2 \psi_i \rangle}.$$
The equation is displayed in a light blue box. Three red arrows point to specific parts of the equation: one points down to the Greek letter mu with a subscript i and a double vertical bar, another points down to the Greek letter psi with a subscript i, and a third points up to the symbol v with a subscript sun.

Statistical Parallax

Add assumption: velocities are isotropically distributed
→ get parallax from radial velocities

Best when group motion dominates (D. G. Turner, 2012)

$$\overline{w} = \frac{\langle |\mu_{\perp i}| \rangle}{\langle u_{r i} + v_{\odot} \cos \psi_i \rangle}$$

observed radial velocity

Limitations

Requires large number of stars with similar L

Difficult to achieve.

Errors

Dominated by uncertainties in proper motion.

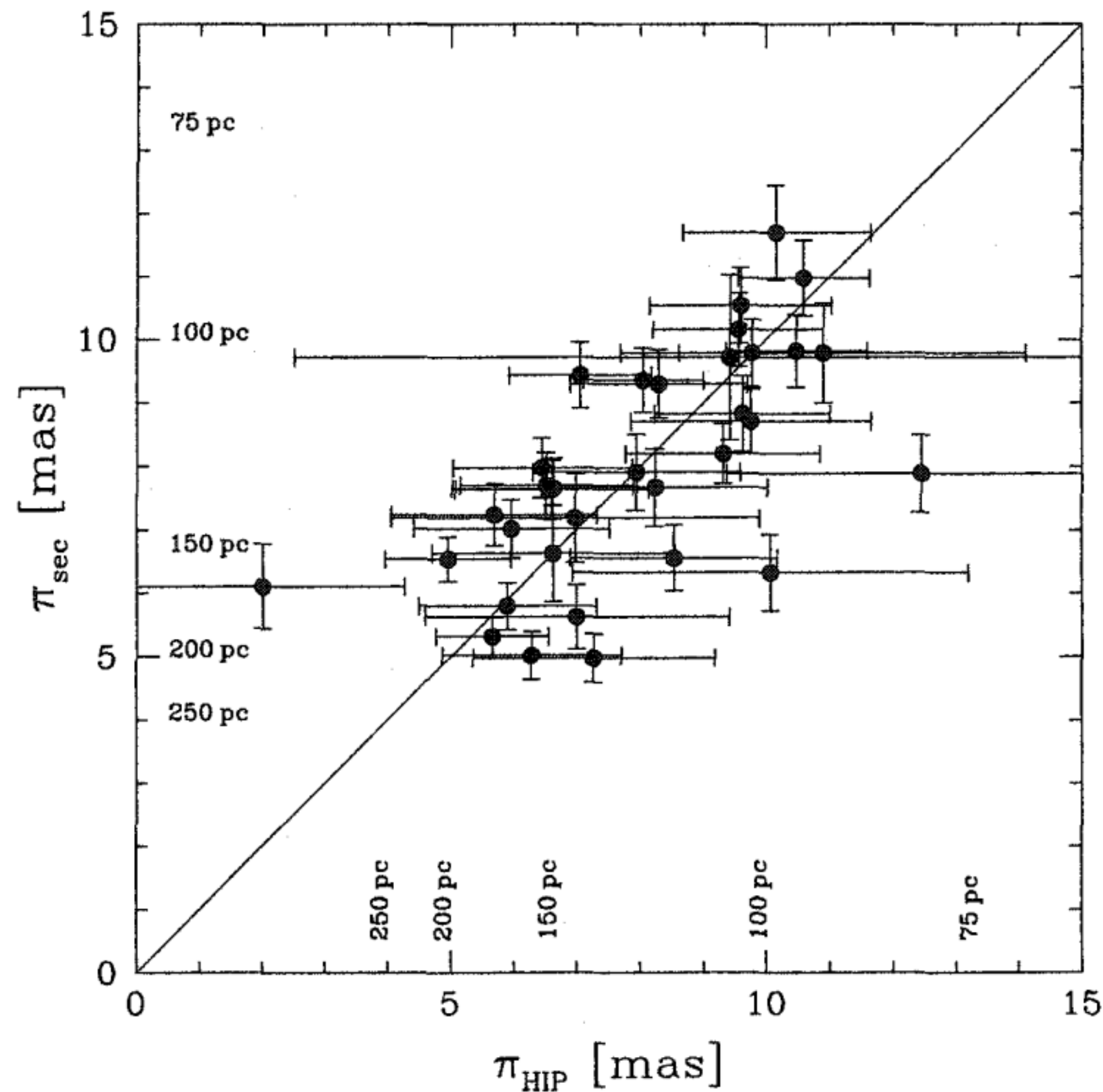
Outdated

Current parallax precisions, e.g. Gaia, are now superior.

Results

Eric Mamajek, Dissertation (2004)

- Spectroscopic survey identifying 110 Post-T Tauri star members of the nearest OB association (Sco-Cen)
- Most isolated, young field stars have poor parallax measurements or no published values
- They do have proper motions \rightarrow estimate distances with secular parallax
- Comparison to Hipparcos parallaxes shows decreased uncertainty



Now: Cosmic Secular Parallax

FREE ARTICLE

Secular Extragalactic Parallax: Measurement Methods and Predictions for *Gaia*

Jennie Paine, Jeremy Darling, Romain Graziani, and H el ene M. Courtois

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“The Earth's motion with respect to the cosmic microwave background frame means that galaxies outside the Milky Way will be subject to an ever-growing parallax shift, cosmic secular parallax.” Croft & Amsellem (2023)

Summary

- Secular parallax **extends the baseline** compared to trigonometric, therefore able to **estimate larger distances**
 - Acquired from knowledge of Sun's space motion relative to a group of stars using proper motion
- Statistical parallax adds an assumption and instead uses radial velocities
- *Secular* parallaxes work best when the **solar motion dominates** group random velocities
 - *Statistical* parallaxes work best **otherwise**

DETERMINATION OF SECULAR PARALLAXES OF REFERENCE STARS FROM RELATIVE PROPER MOTIONS OF OPEN CLUSTERS

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Thank you for listening!
Questions?