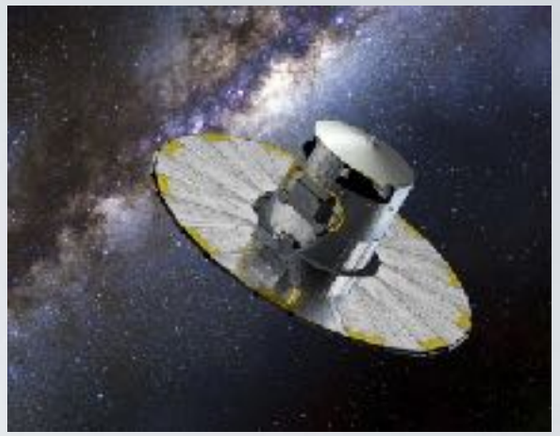
Extragalactic proper motions

Alex Hall

Based on arXiv:1811.05454

Gaia

The billion star surveyor



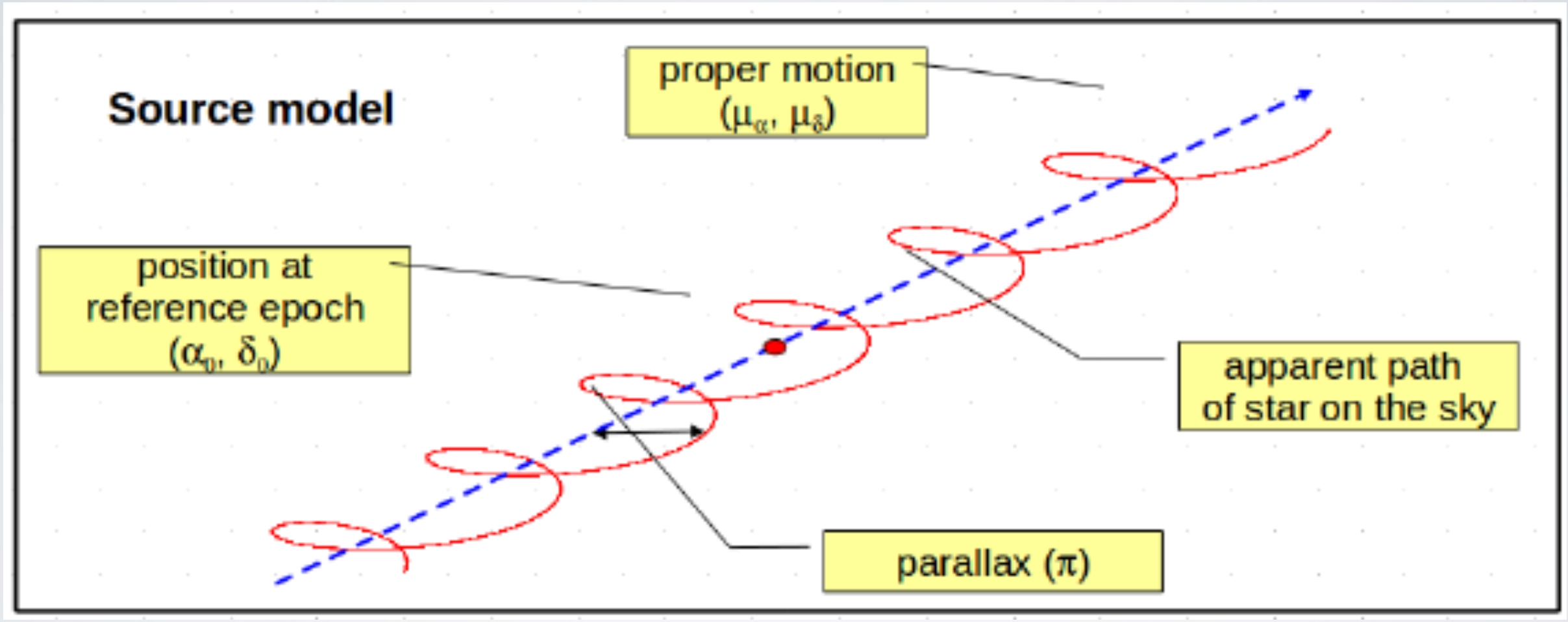


Figure credit: L. Lindegren

Galaxies in Gaia?

Parallaxes and proper motions of:

Galaxies in Gaia?

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~10^9 stars

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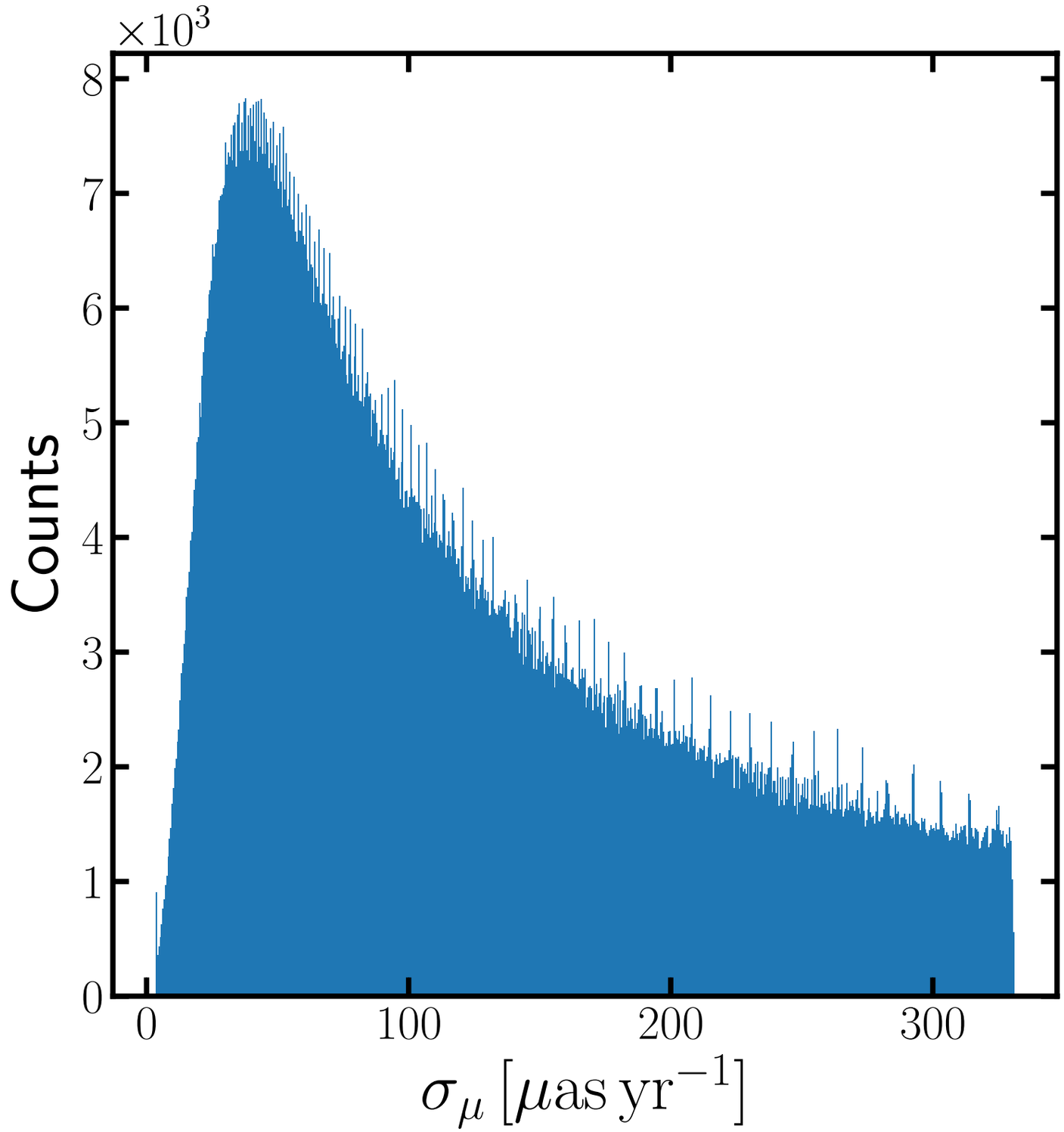
Galaxies in Gaia?

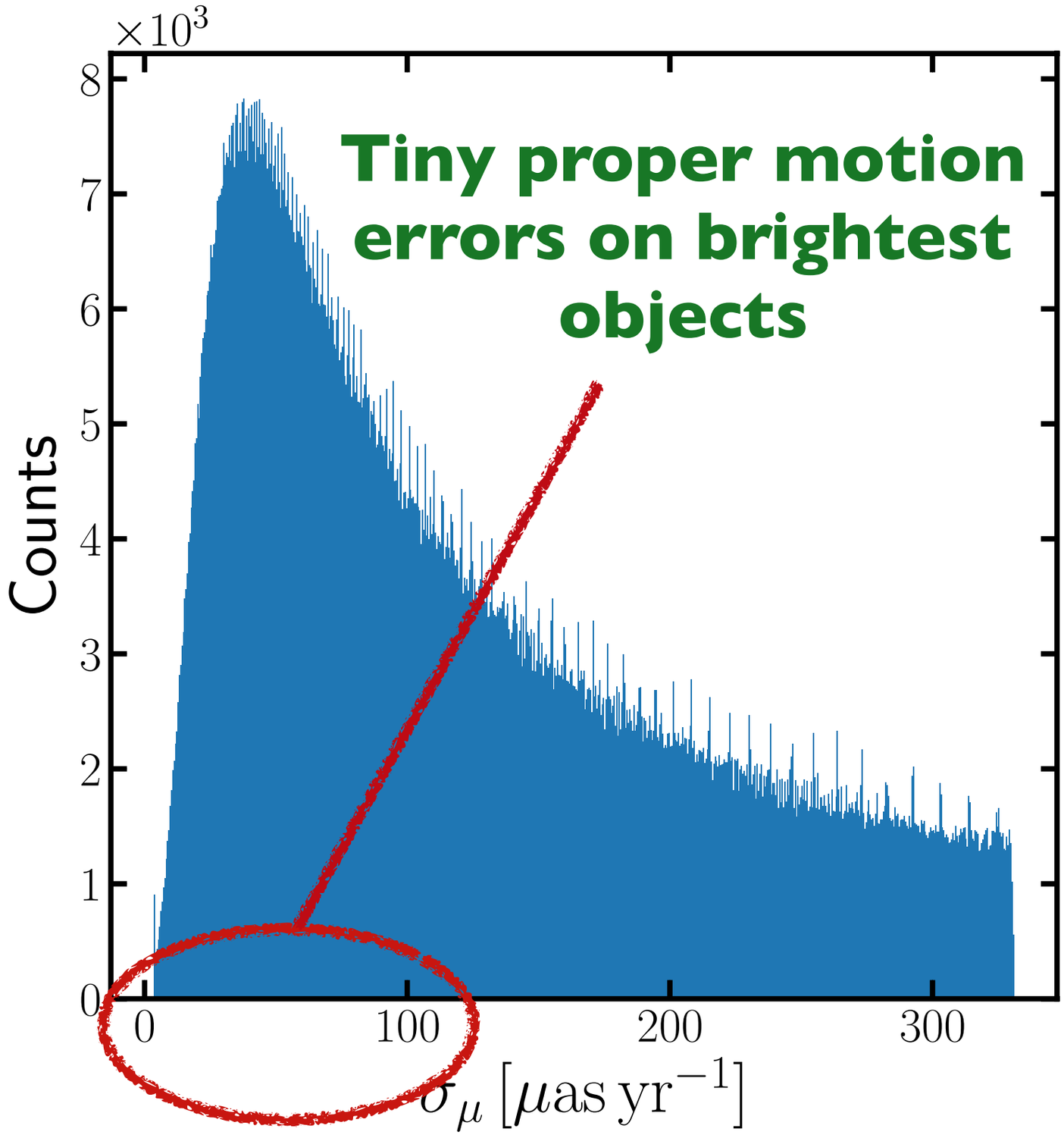
Parallaxes and proper motions of:

- **~10^9 stars**
- **~$10^{5\text{-}6}$ quasars**
- **~10^6 galaxies**

Gaia proper motion errors



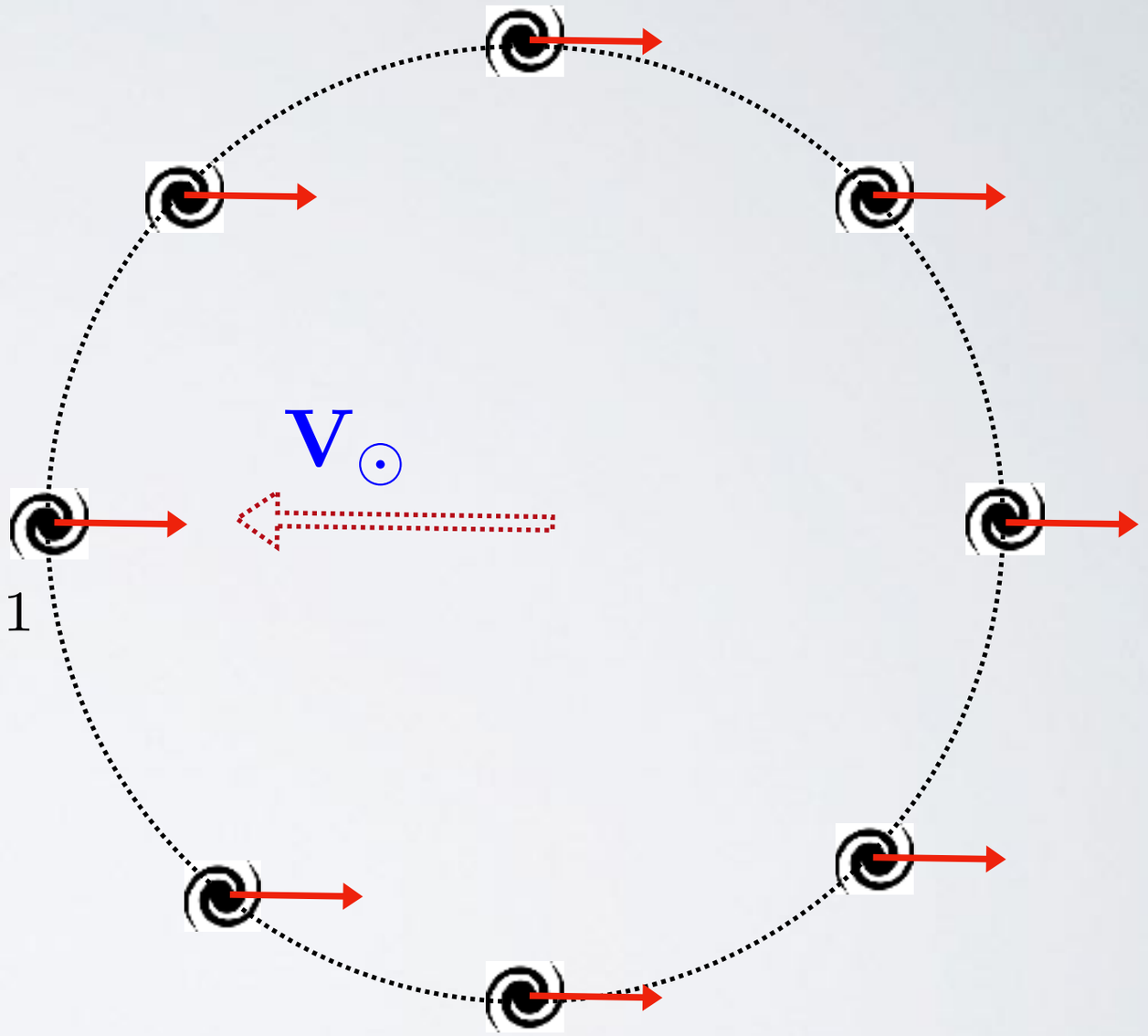
Gaia proper motion errors



Sources of extragalactic proper motion

1) Solar System moves relative to galaxies ('secular parallax')

$$\mu(r) \sim 80 \left(\frac{r}{1\,\mathrm{Mpc}} \right)^{-1} \mu\mathrm{as\,yr}^{-1}$$

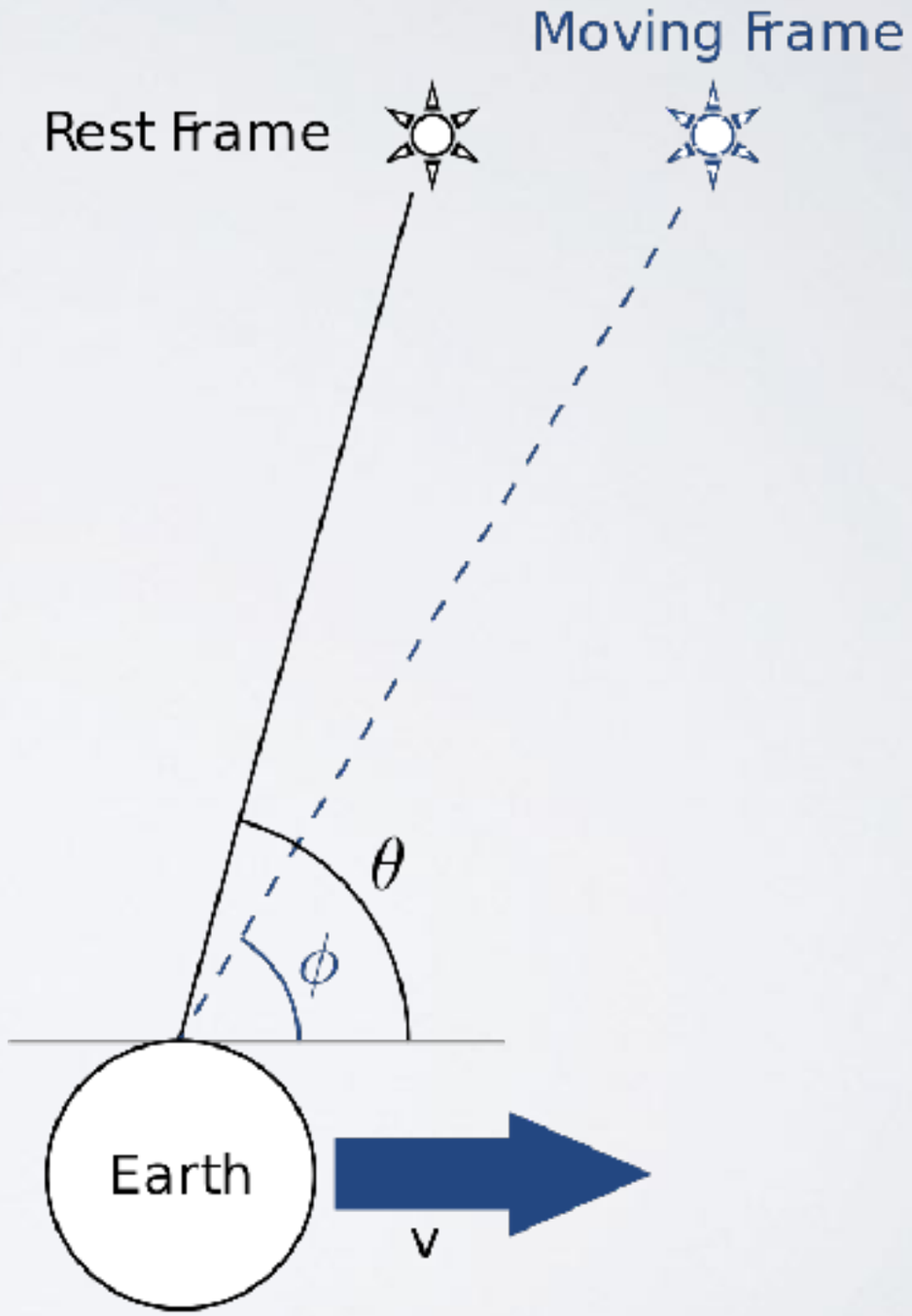


Dipolar angular structure

Sources of extragalactic proper motion

2) Solar System accelerates towards galactic centre ('secular aberration drift')

$$\mu(r) \sim 4\,\mu\mathrm{as\,yr}^{-1}$$



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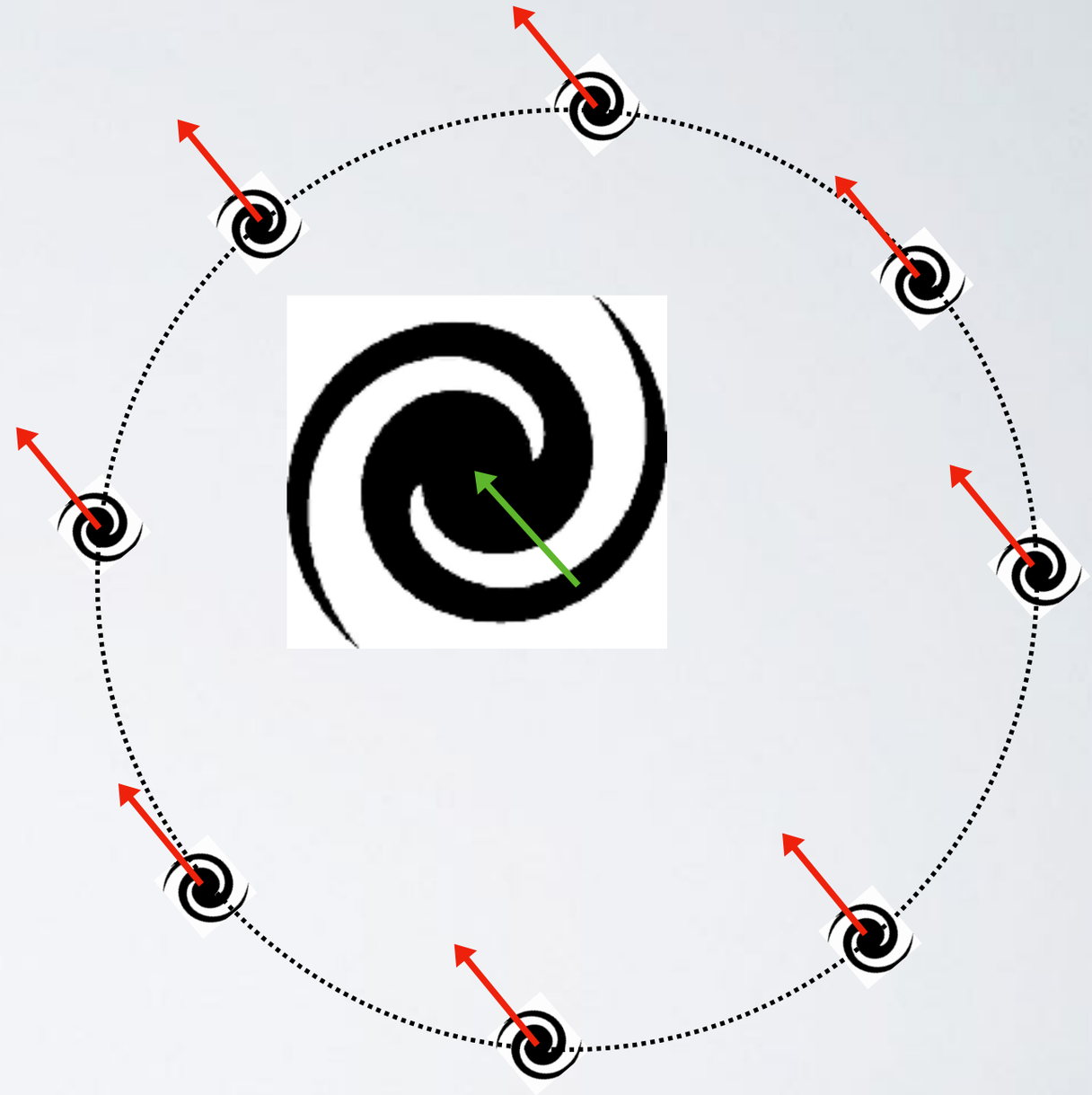
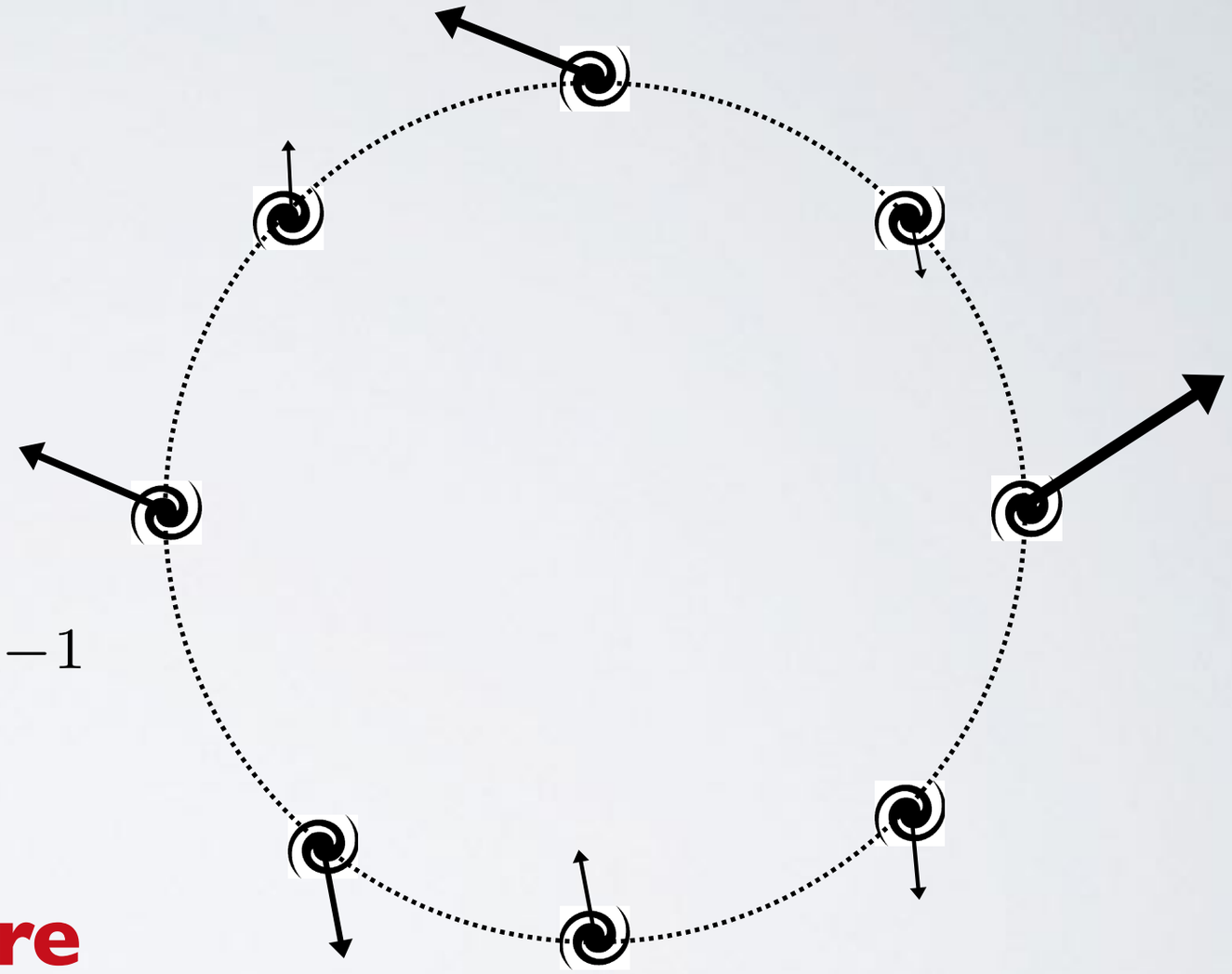


Dipolar angular structure

Sources of extragalactic proper motion

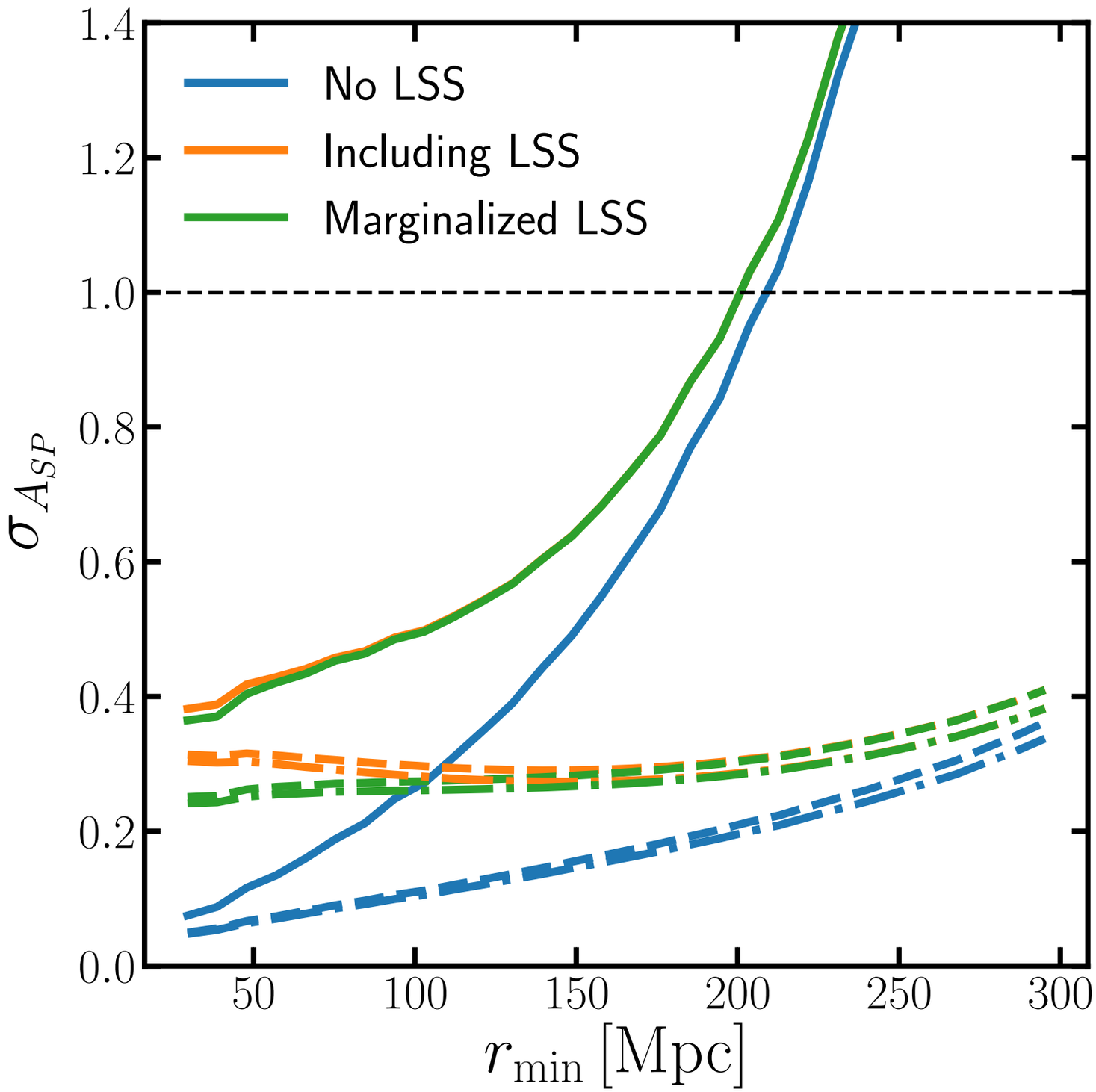
3) Galaxies move due to gravitational structure formation



$$\mu(r) \sim 90 \left(\frac{r}{1\,\mathrm{Mpc}} \right)^{-1} \quad \mu\mathrm{as\,yr}^{-1}$$

Complex angular structure

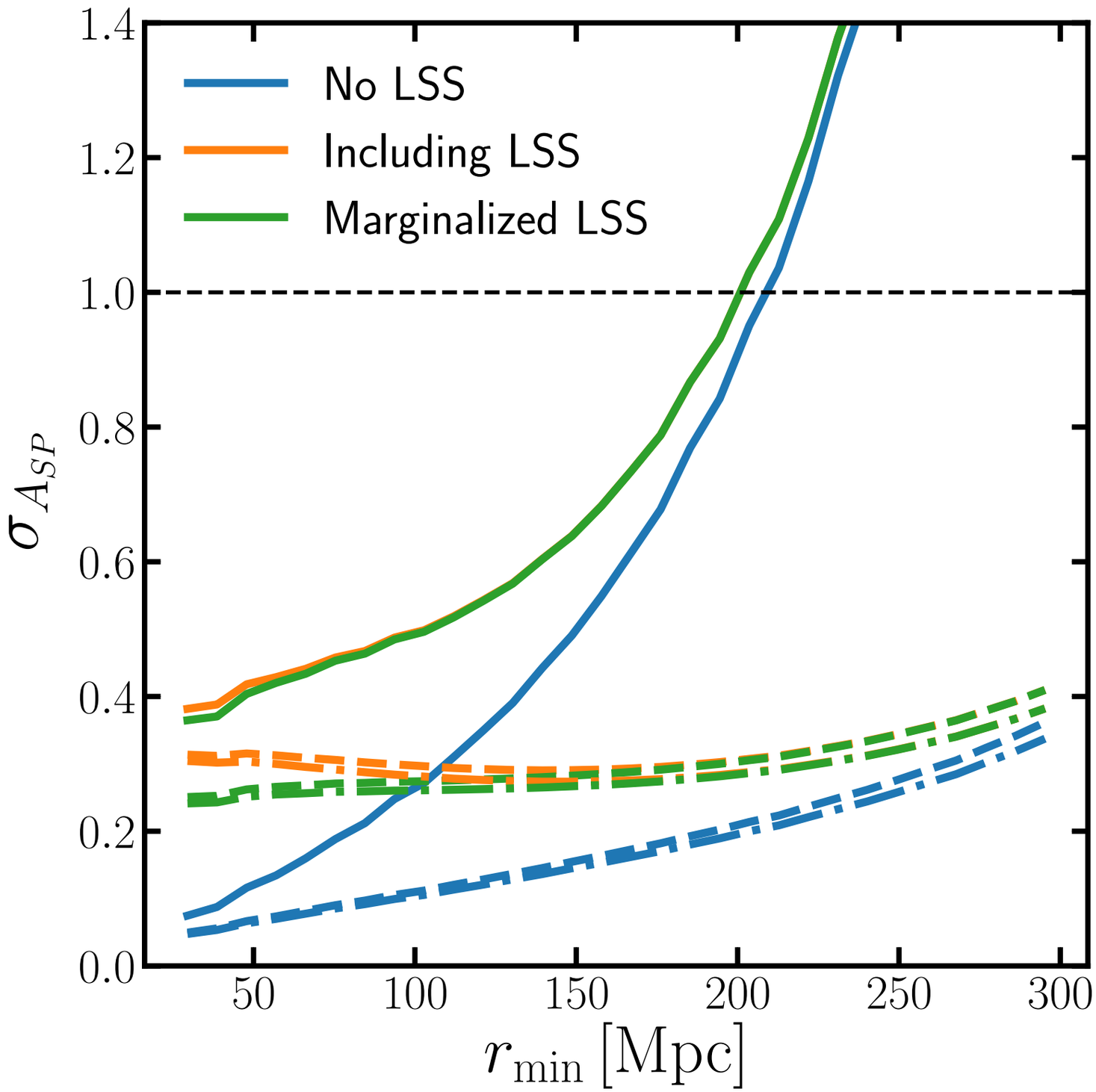
Forecast error on secular parallax



Dashed lines: fixed SAD

Solid lines: varying SAD

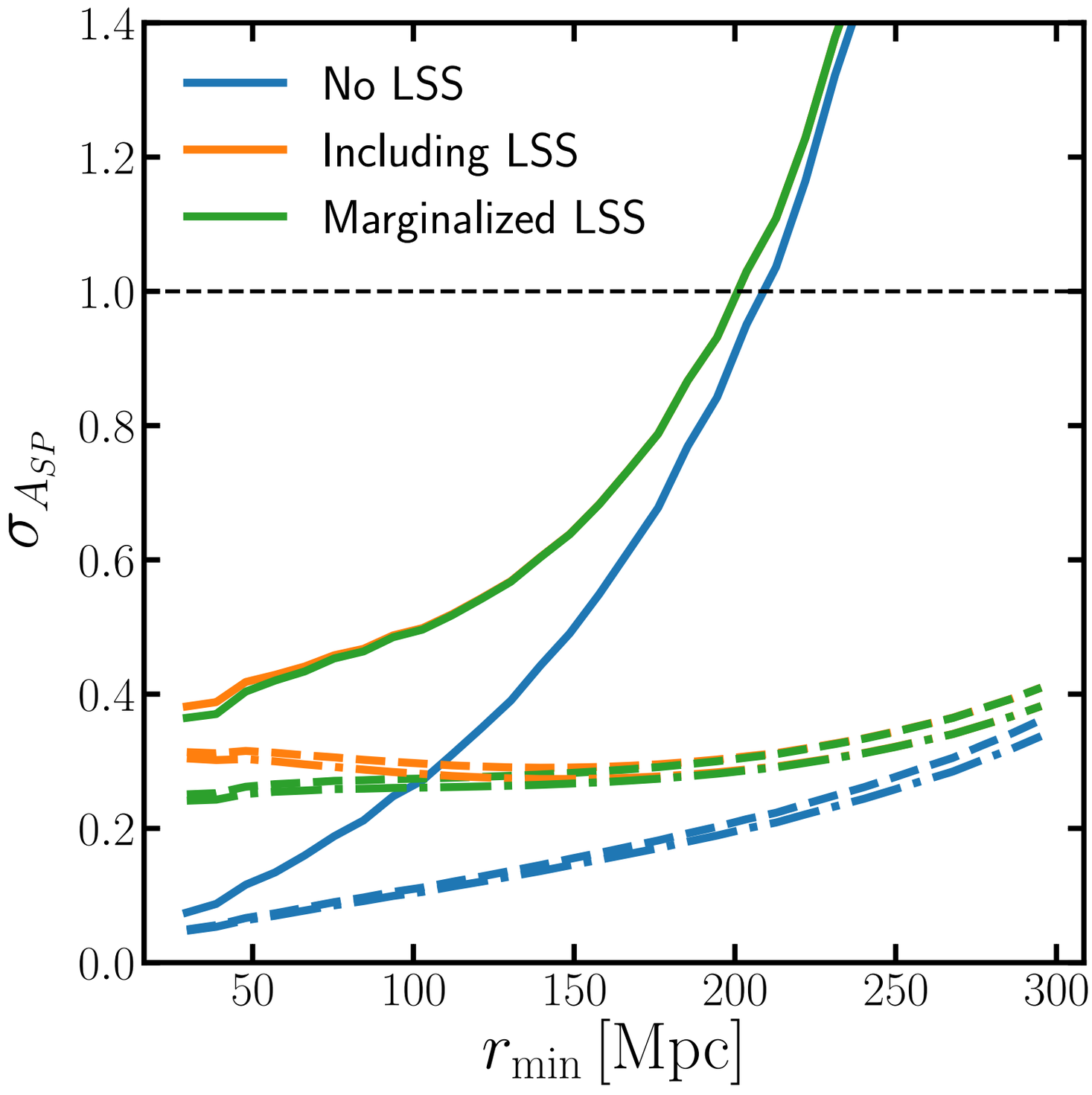
Forecast error on secular parallax



$\mu \sim v_\odot / r$

$z \sim H_0 r$

Forecast error on secular parallax

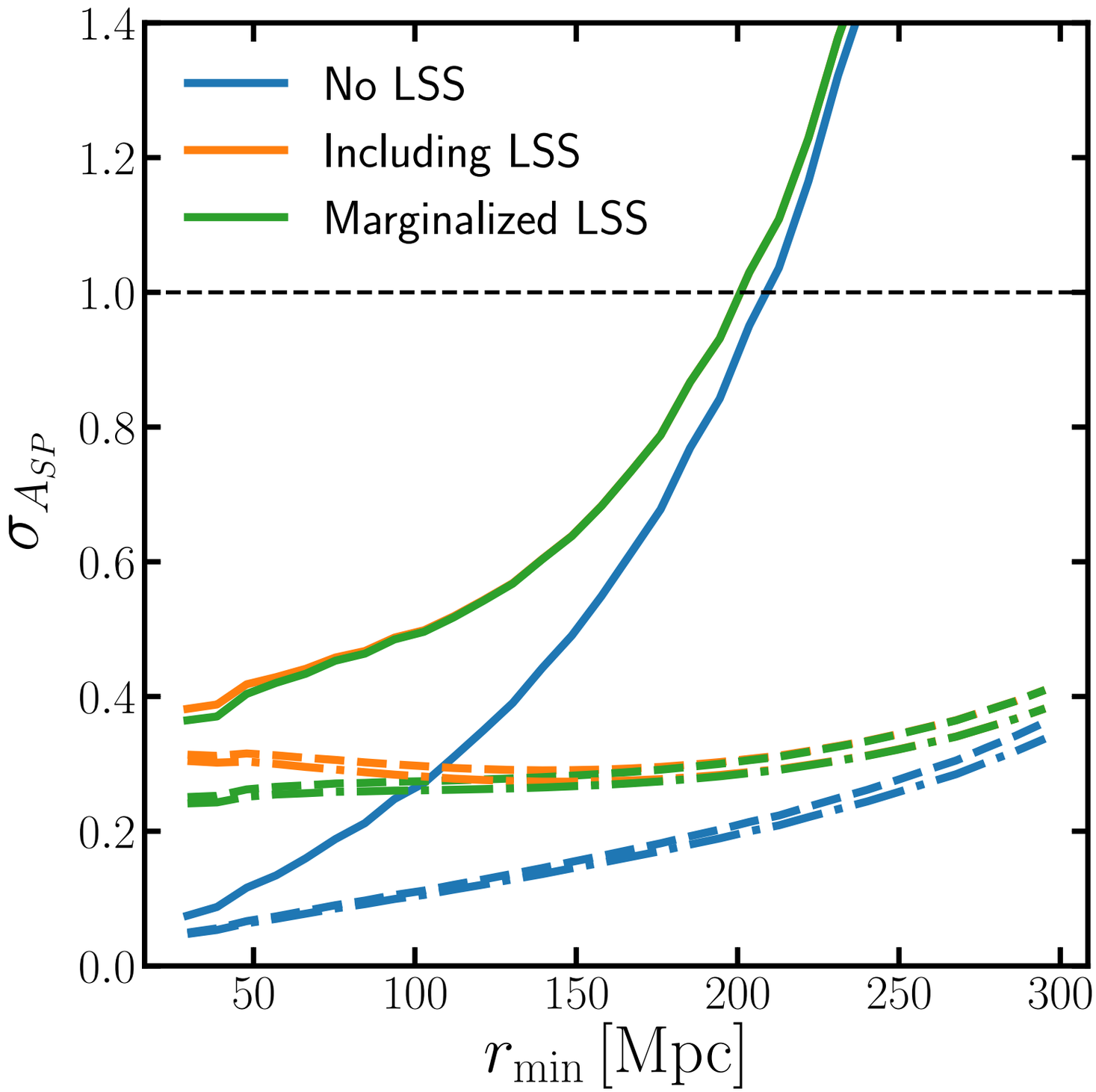


$\mu \sim v_\odot / r$

$z \sim H_0 r$

Get from CMB dipole

Forecast error on secular parallax



$\mu \sim v_\odot / r$

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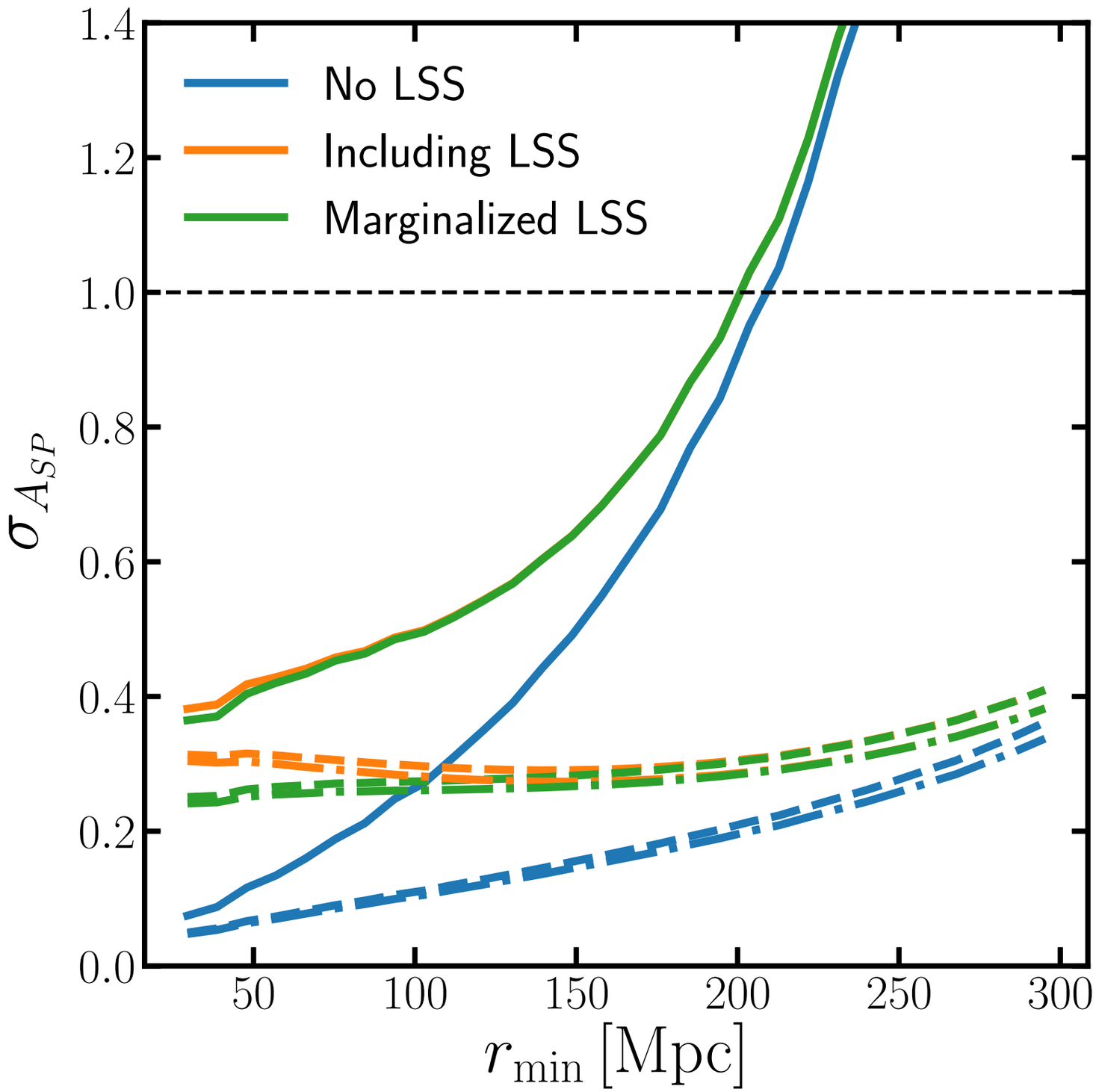
Get from spectrum

Forecast error on secular parallax

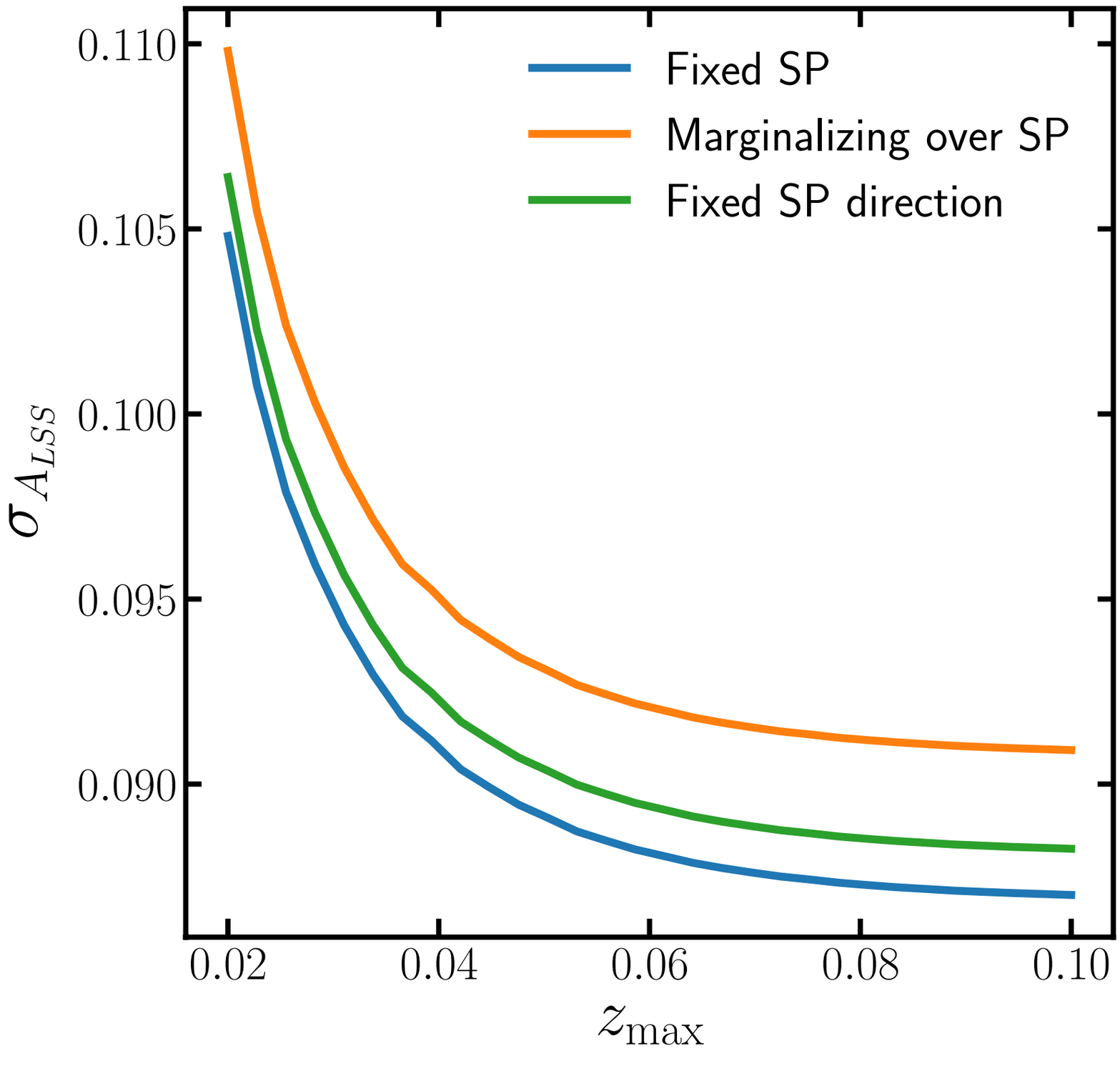


$\mu \sim v_\odot / r$

$z \sim H_0 r$

Amplitude measures H_0

Forecast error on transverse velocity power spectrum



Amplitude measures $f\sigma_8 H_0$

Conclusions

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arXiv:1811.05454

- **Gaia will measure proper motions for a million galaxies**
- **A probe of the Solar System's local motion with respect to the CMB and the Hubble constant**
- **A probe of transverse velocities due to gravitational collapse - a probe of dark energy**
- **Gaia: 2-sigma detection of local motion, 10-sigma detection of LSS transverse velocities**
- **Complicated by relativistic aberration, centroid errors, cosmic variance, bulk flow…**