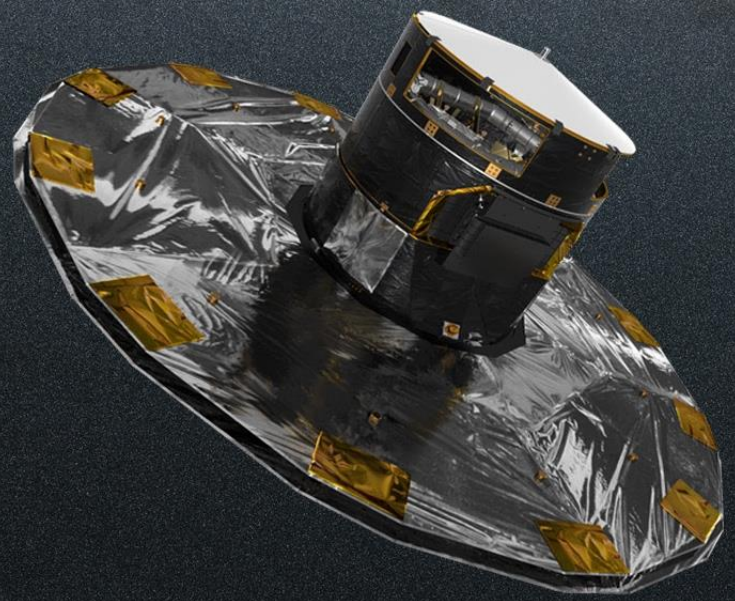
# Getting Ready for Gaia DR4



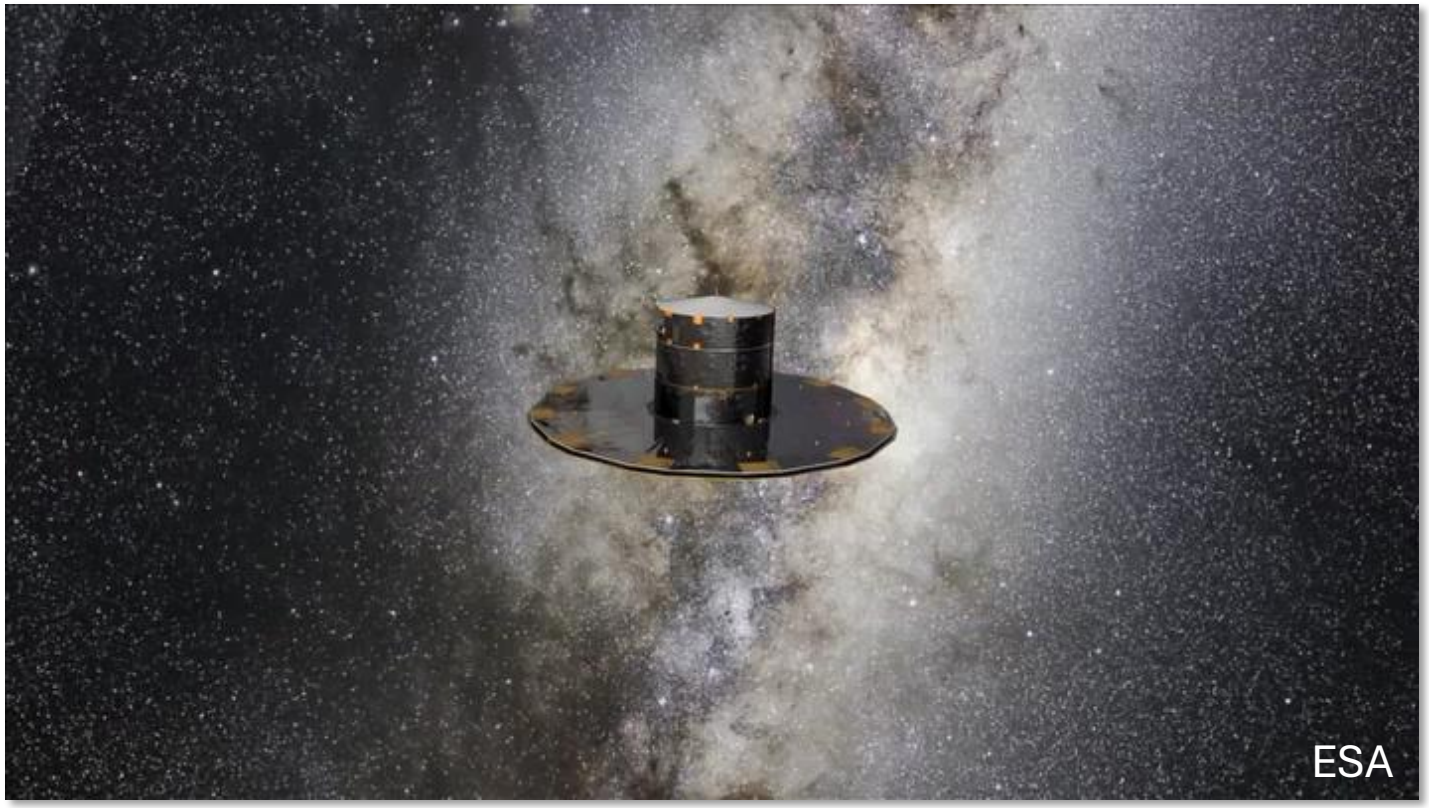
Sarah Blunt

(she/her/hers)

NSF Astronomy & Astrophysics Postdoctoral Fellow

UC Santa Cruz

# What is Gaia?



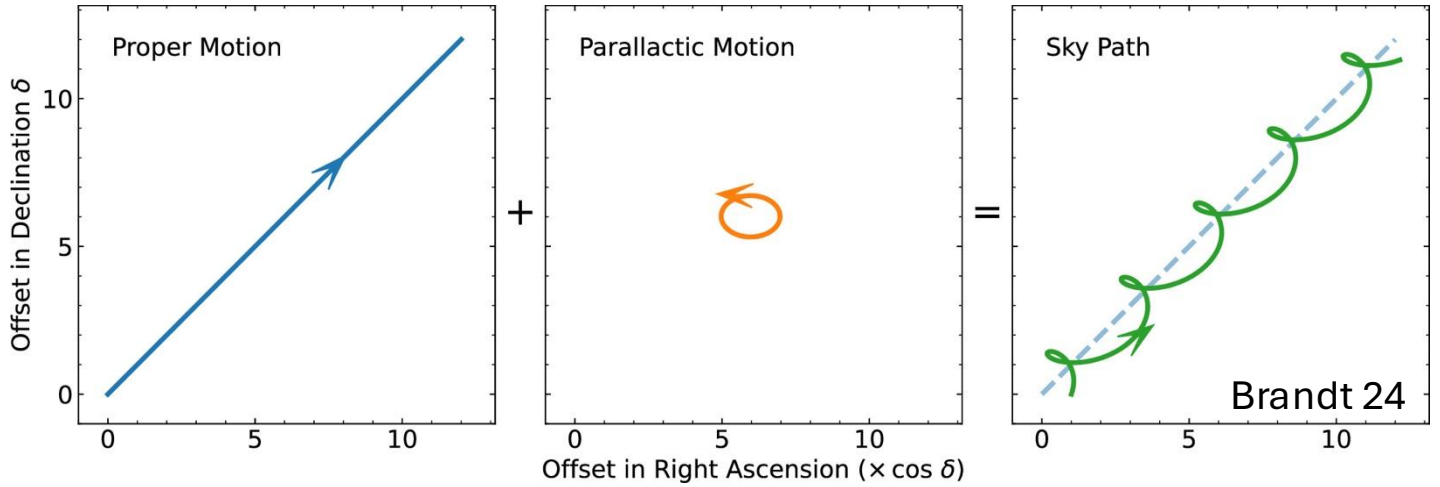

Key Features:

- Lots of pixels + timing precision = robust *local* astrometric solution
- two 1.5m FOV separated by 105° = robust *global* astrometric solution
- Satellite spin period = 6 hours, precession period = 63 days

Instruments:
**Astrometric Instrument***
Radial Velocity Spectrometer (RVS)
Photometric Instrument

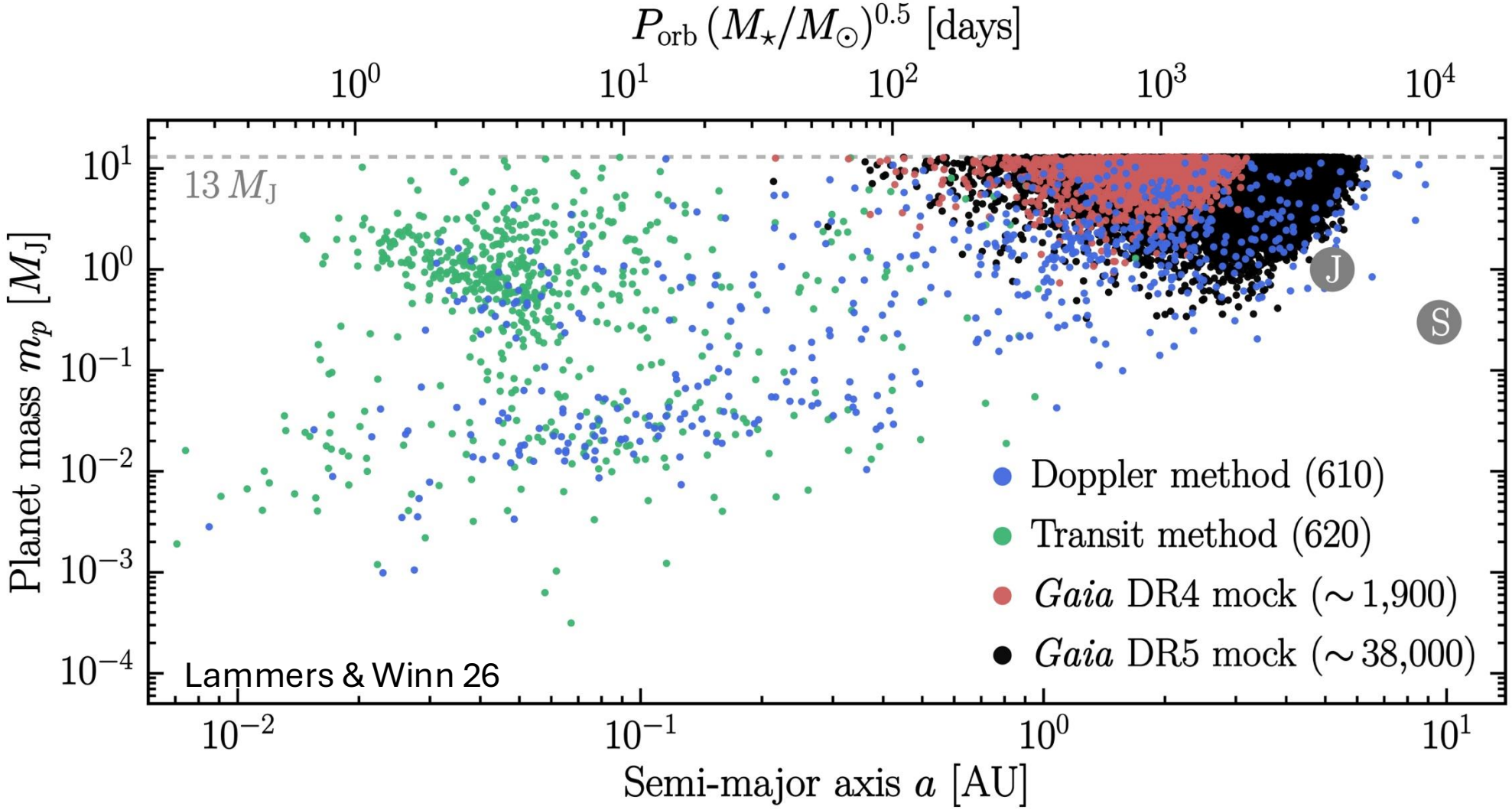
# What's new in Gaia DR4?

- Epoch astrometry (i.e. raw data) for first 5 years of mission (2014-2019)
- Exoplanet candidate list
- (other stuff)




https://www.cosmos.esa.int/web/gaia/dr4

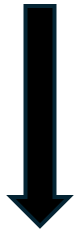
# What planets do we expect to find with DR4?



# What will we learn from Gaia astrometry alone?

$$\mathrm{R.A.}_* = \text{parallax motion} + \text{proper motion} + \frac{M_p}{M_{tot}}\Delta\mathrm{R.A.}$$

$$\mathrm{decl.}_* = \text{parallax motion} + \text{proper motion} + \frac{M_p}{M_{tot}}\Delta\mathrm{decl.}$$

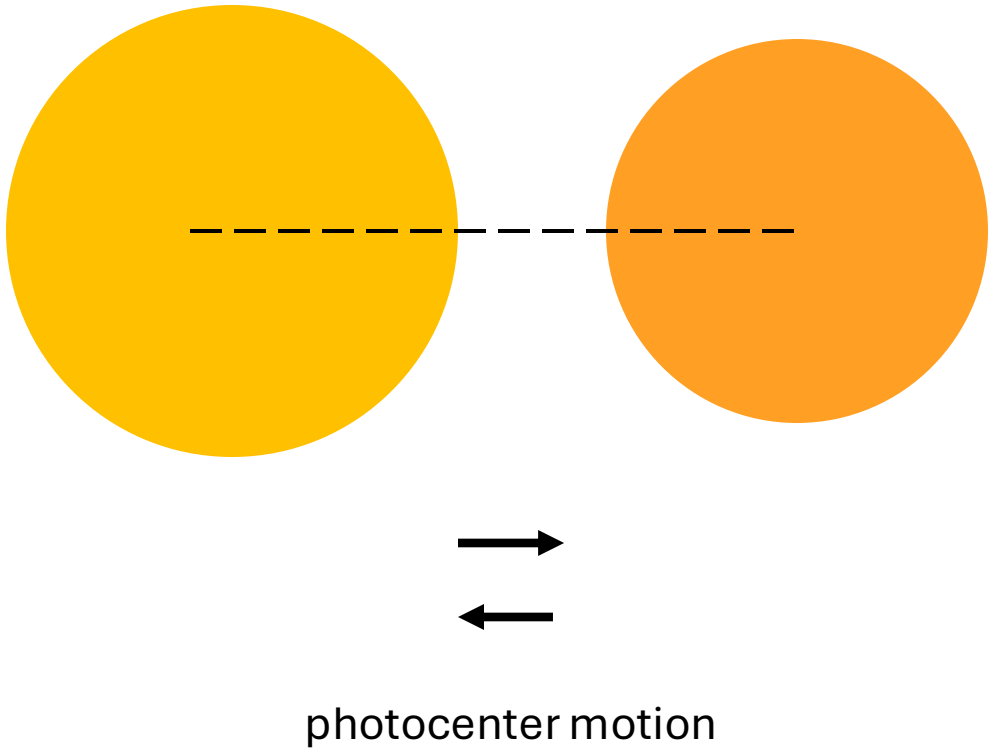


substitute Kepler's third law

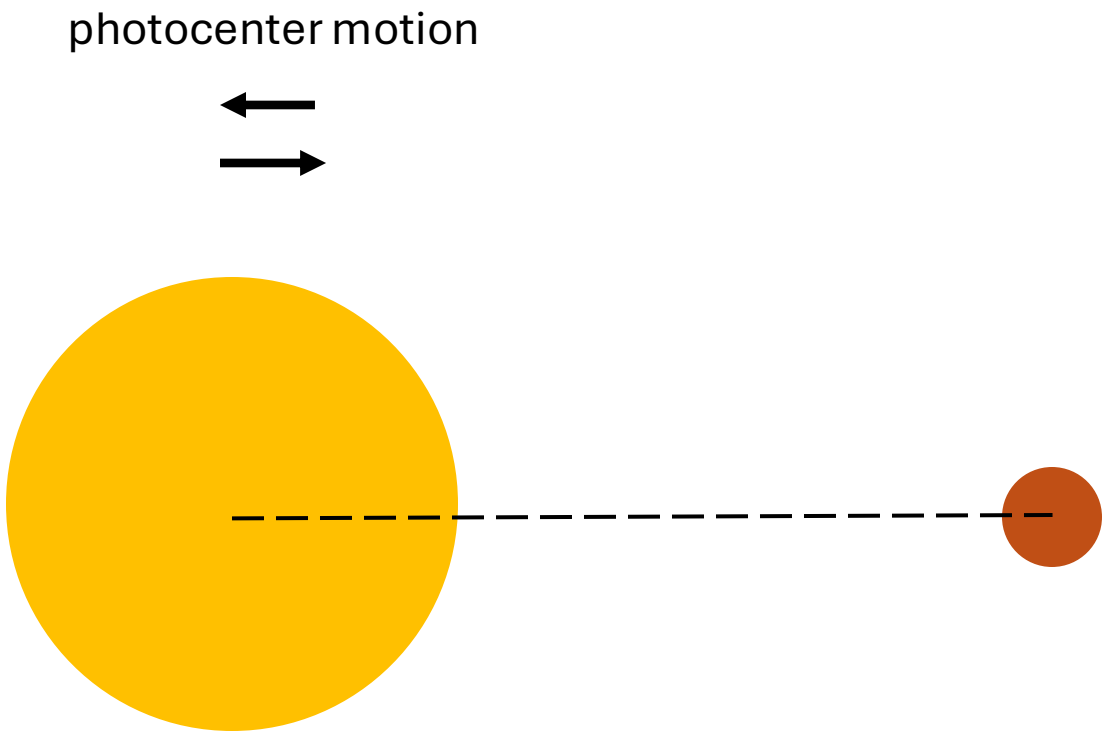
$$\text{astrometric motion} \propto \frac{M_\mathrm{p}}{M_\mathrm{tot}^{2/3}}$$

*There will be degeneracies, particularly for incomplete orbits!

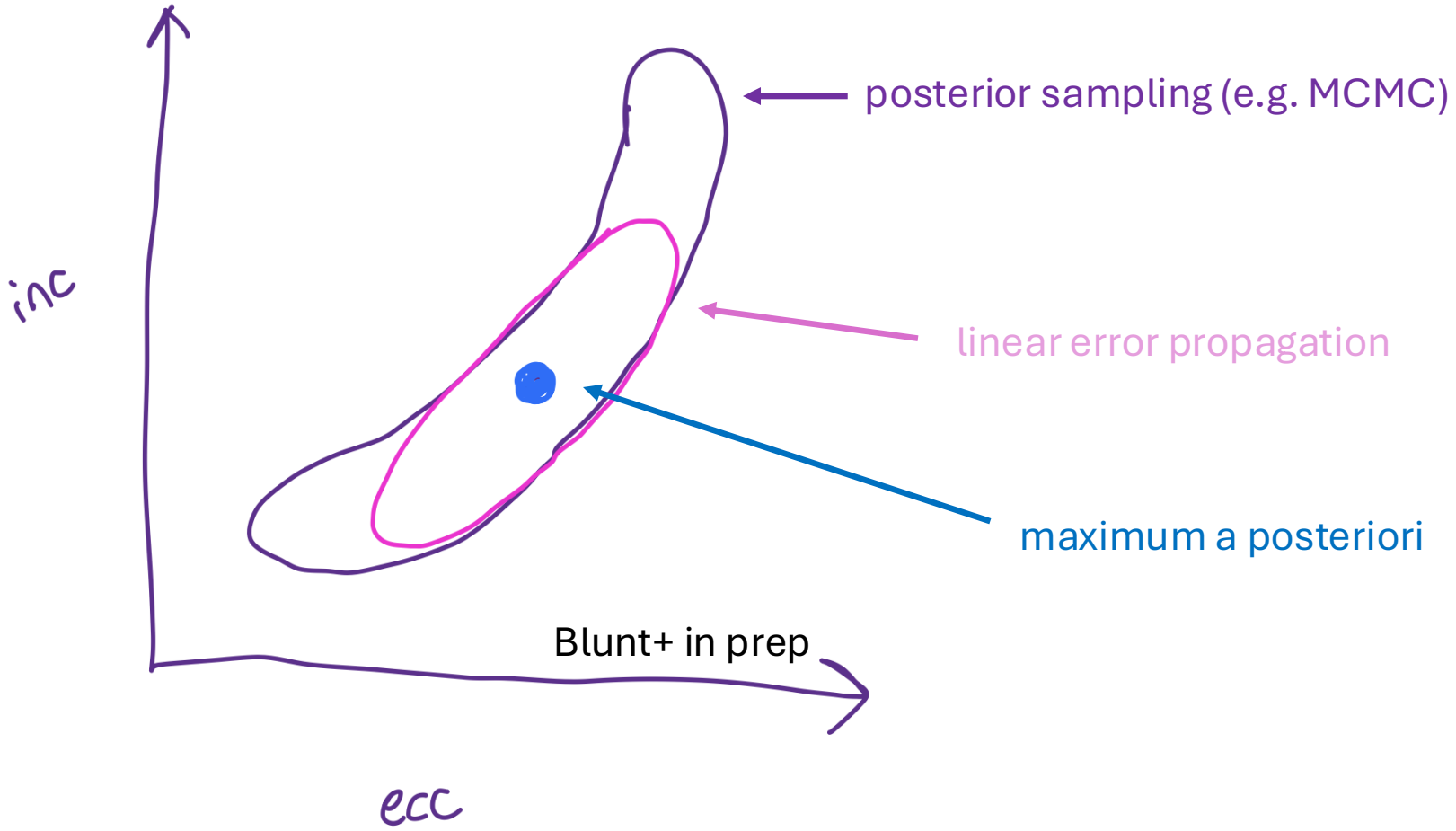
# What *astrophysical* false positives do we expect?



photocenter motion



# What *statistical* false alarms do we expect?




# What types of follow-up will be helpful?

- Spectroscopic follow-up:
  - Rule out close binary false positives*
- Photometric color-color:
  - Rule out close binary false positives*
- RV monitoring:
  - break $M_{tot}^{2/3}$ degeneracy to measure dynamical mass
  - **rule out false positives/alarms**
- Imaging follow-up:
  - same for wider-separation planets (orbital uncertainty likely greater for these)
  - atmospheric characterization

*It's still unclear (at least to me) how far we'll get from each of these, and how they compare to what we'll get for free from Gaia RVs and colors.

The Gaia Rapid Astrometry Fitting For Exoplanets (G-RAFFE) collaboration:
**fast, robust algorithms** for recovering exoplanet parameters in Gaia DR4 data.

Key team members (so far):
Clarissa Do Ó, Adrian Price-Whelan, William Thompson, Jason Wang, Daniel Yahalomi, Andy Casey, (and me :)

# ⚠ arXiv Alert! ⚠

coming soon to an arXiv near you!

**Evidence for a Peak at ~0.3 in the Eccentricity Distribution of Typical Super-Jovian Exoplanets**

Sarah Blunt [1,2] Jason Wang [2,3] Ruth Murray-Clay [1] Bruce Macintosh [1] Ryan A. Rubenzahl [4] and B.J. Fulton [5]

Hire me? :D lol jk unless…

# Getting Ready for Gaia DR4

- Gaia: μas astrometry through a) pixels + timing precision and b) dual simultaneous FOV
- Gaia DR4: epoch astrometry + exoplanet candidate list
- Gaia will be sensitive to *large* (>$M_J$) exoplanets at moderate (1-10au) separations
- Astrometry alone constrains $M_P$ / $M_{tot}^{2/3}$
- Expected astrophysical false positives: close ~equal-mass binaries
- Expected statistical false alarms: posterior uncertainty underestimation, (?)
- Follow-up avenues: photometry & spectroscopy to rule out close binary false positives; RV & imaging follow-up to confirm candidates, measure dynamical masses, and probe atmospheres.
- G-RAFFE is working on fast algorithms for orbit-fitting in the Gaia era

ps. I'm working on a PASP review of orbit-fitting for directly-imaged planets, so keep an eye on the arXiv!

# Backup Slides

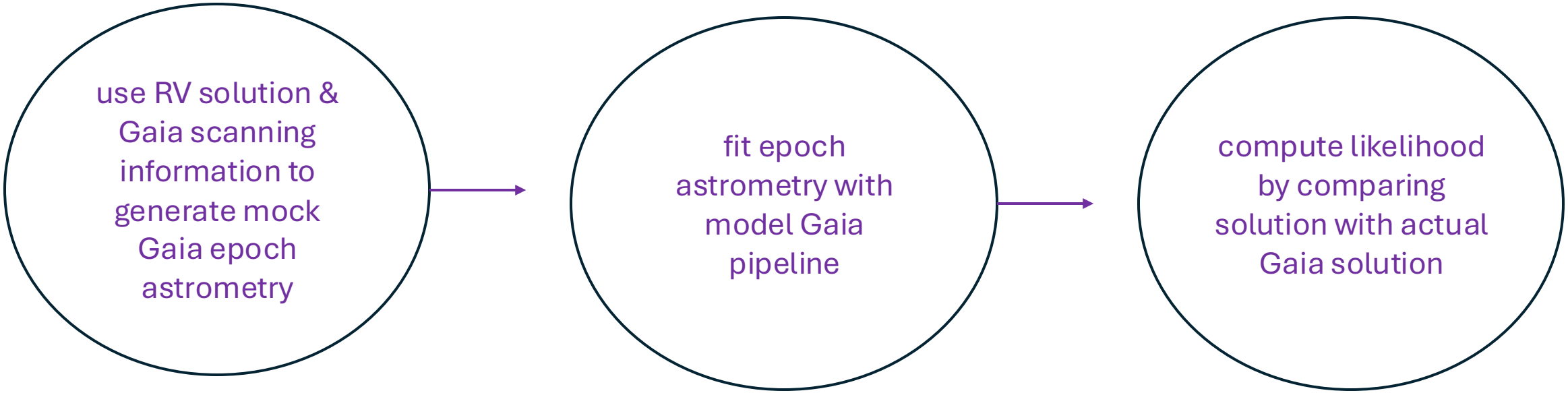
# The Gaia DR3 exoplanet pipeline:

- Nonlinear optimization to discover maximum likelihood fit
- Linear propagation of observational errors

→ → Gaussian parameter uncertainties

Based on description in Holl+ 2023

# Forward Gaia Model (FGM) addresses underestimated DR3 uncertainties by fully forward-modeling and refitting Gaia astrometry for a given target.




Blunt+ in prep

Thanks to Jason Wang & William Thompson for helpful discussions!

Lammers & Winn 26