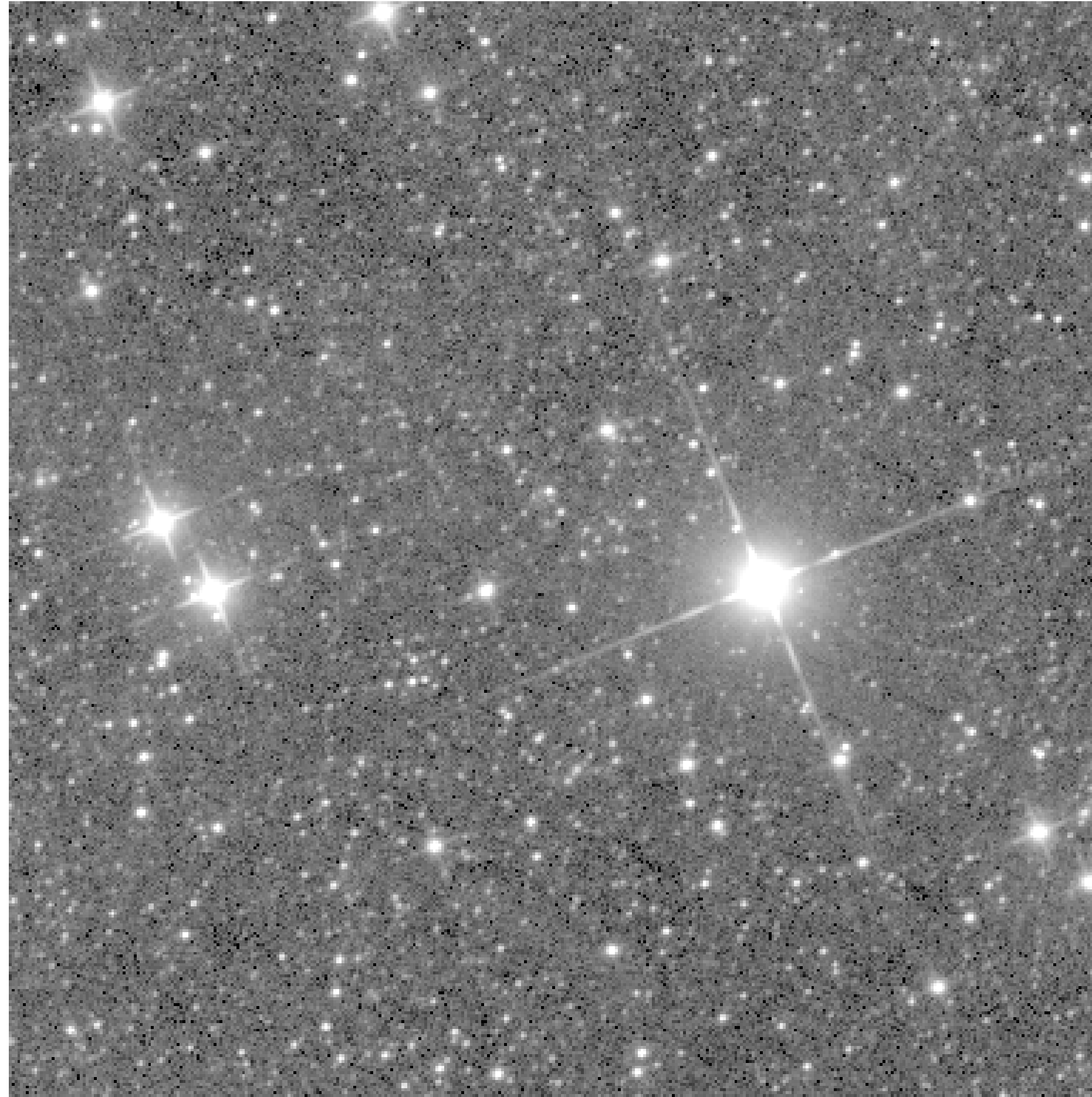


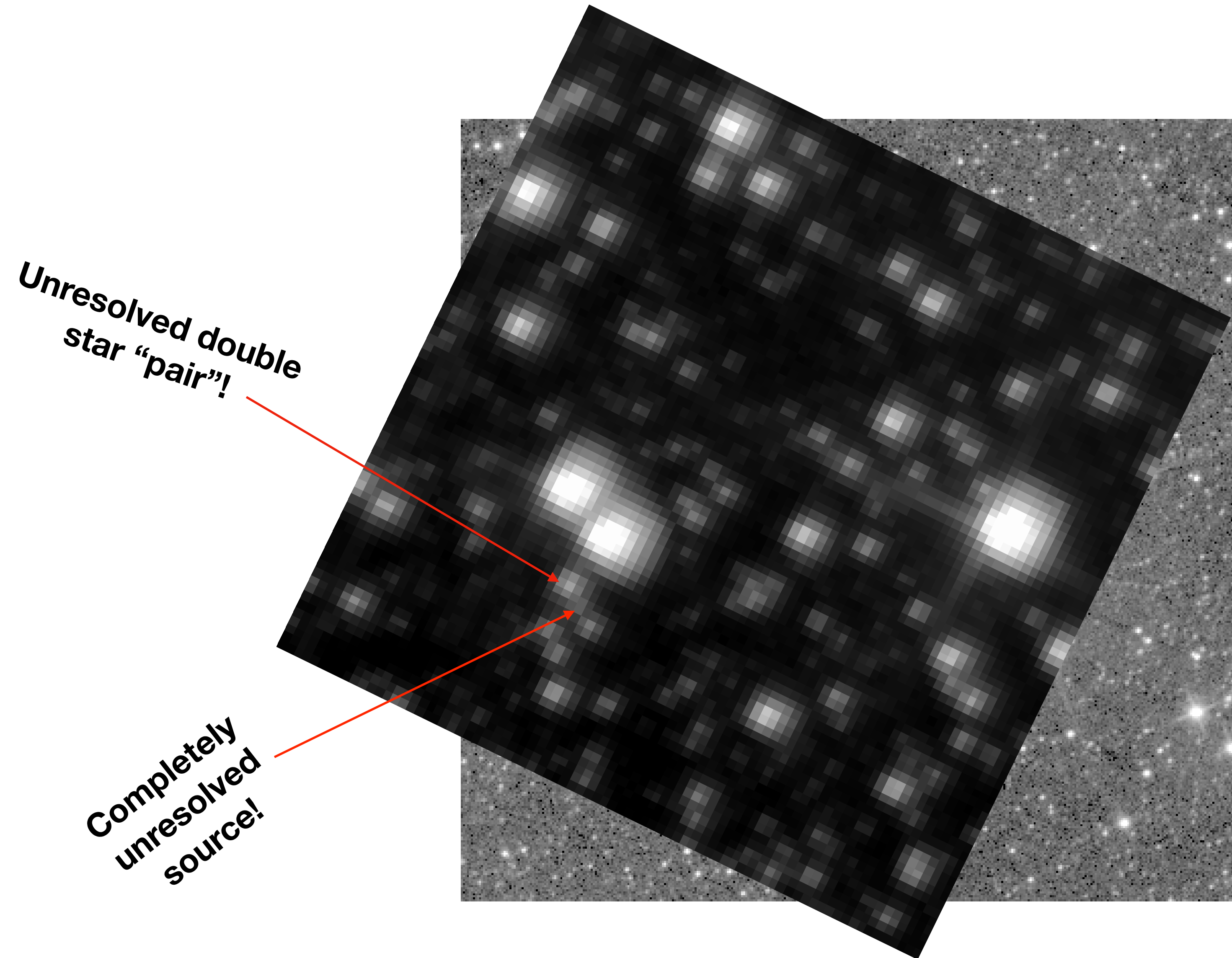
Better identification of variable and transient sources using improved catalogue cross-matching techniques

Tom J Wilson (he/him) and Tim Naylor
University of Exeter
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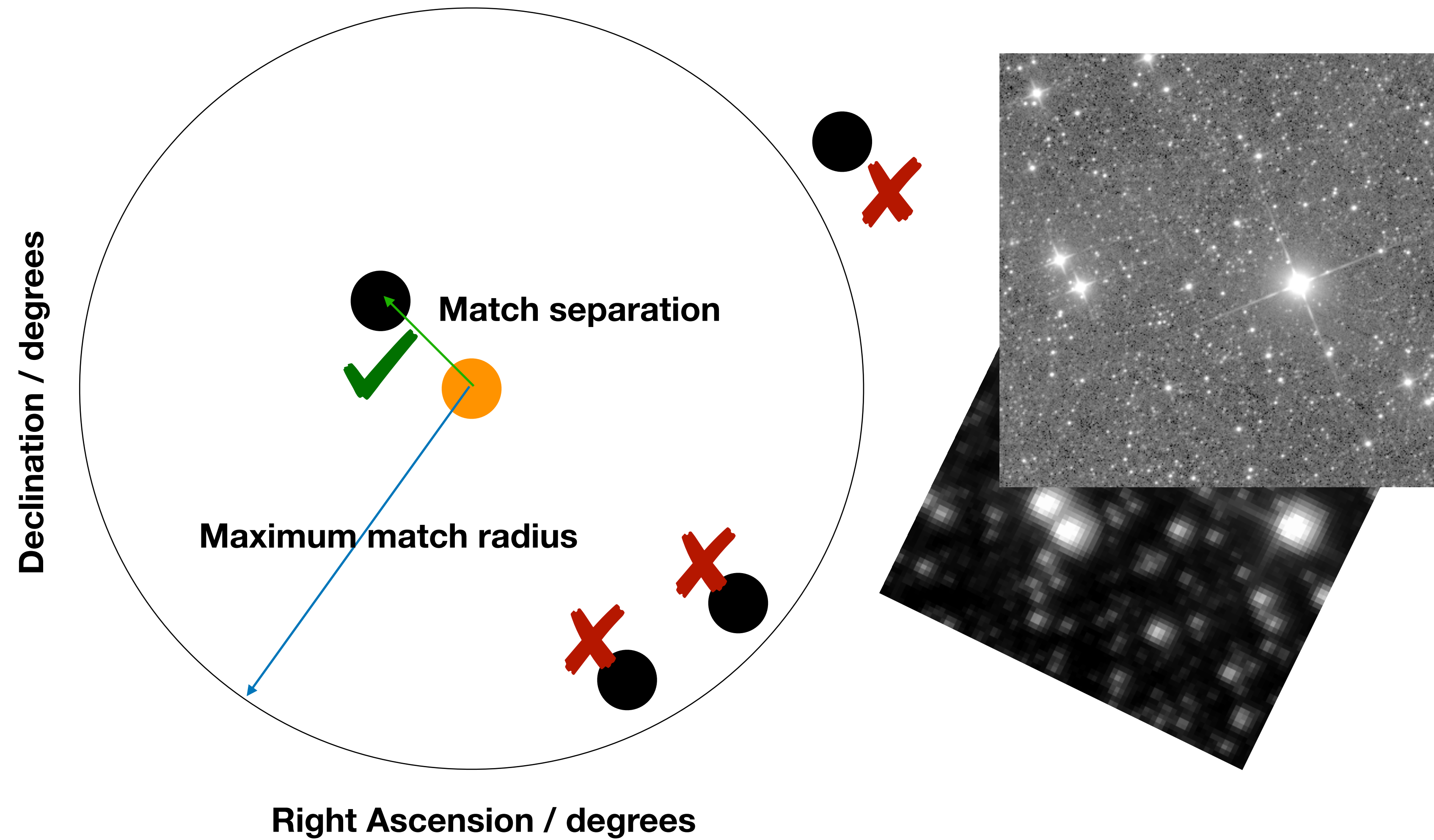
Photometric Observations



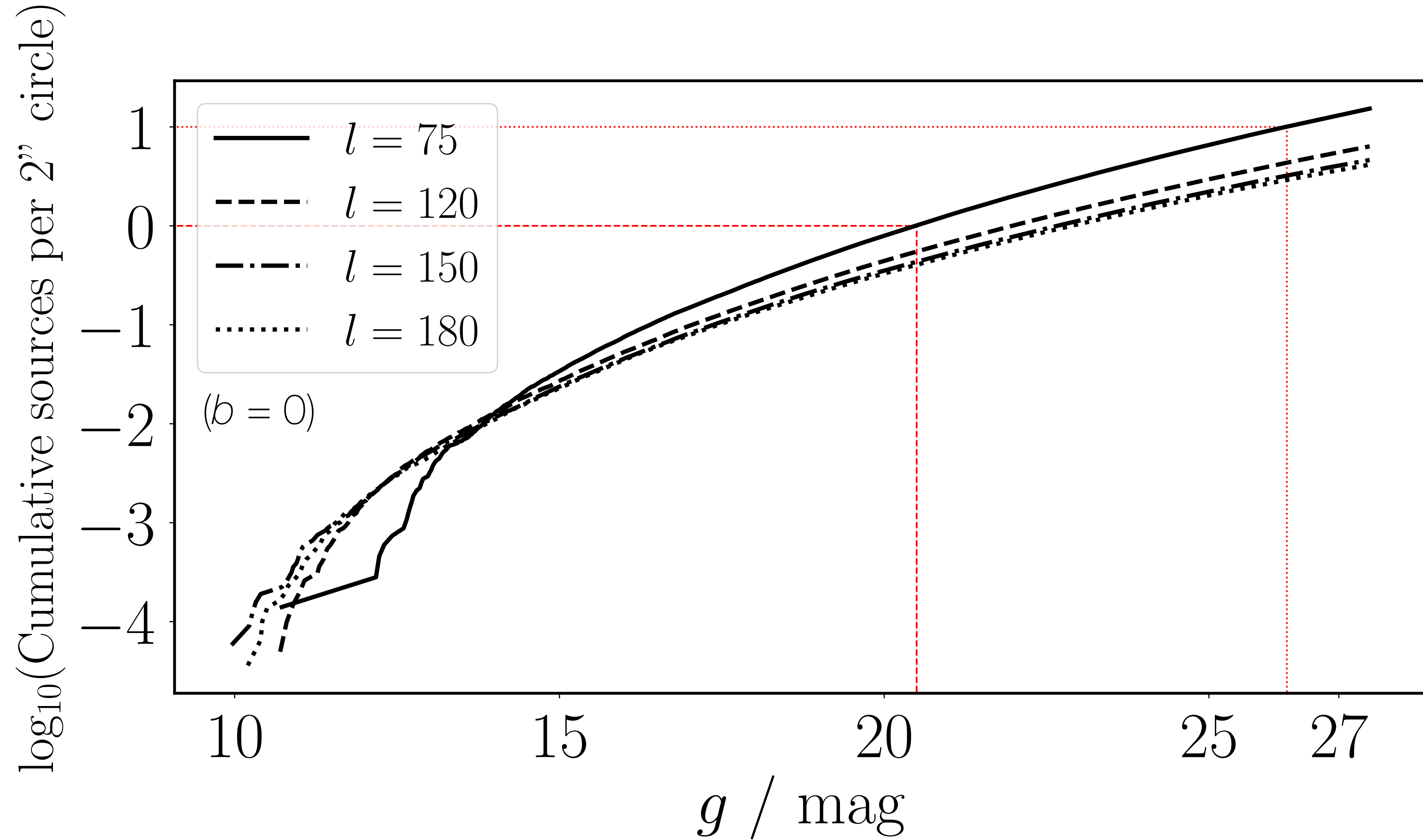
Photometric Observations



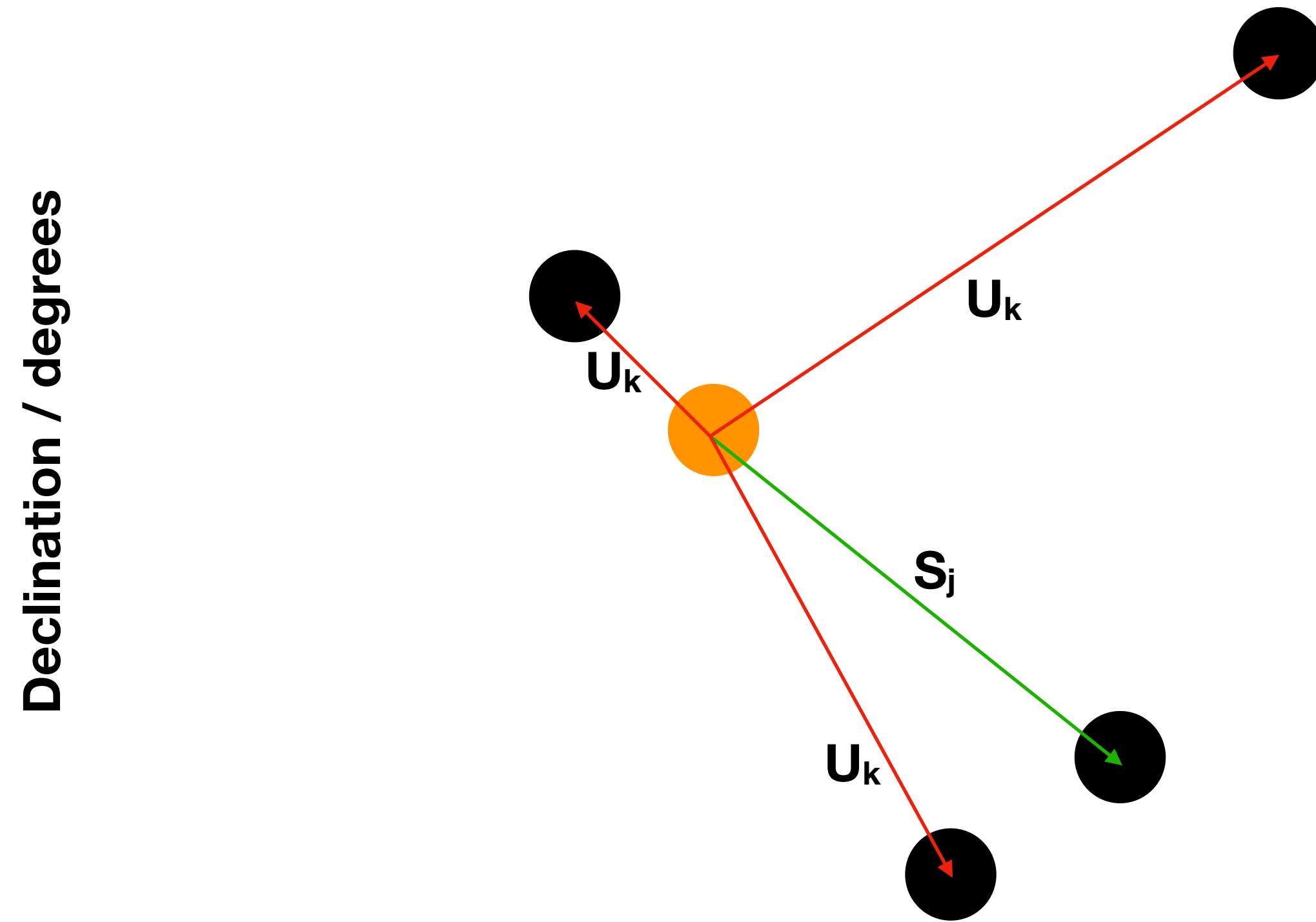
Catalogue Cross-Matching



Vera C. Rubin Observatory's LSST's Completeness Depth



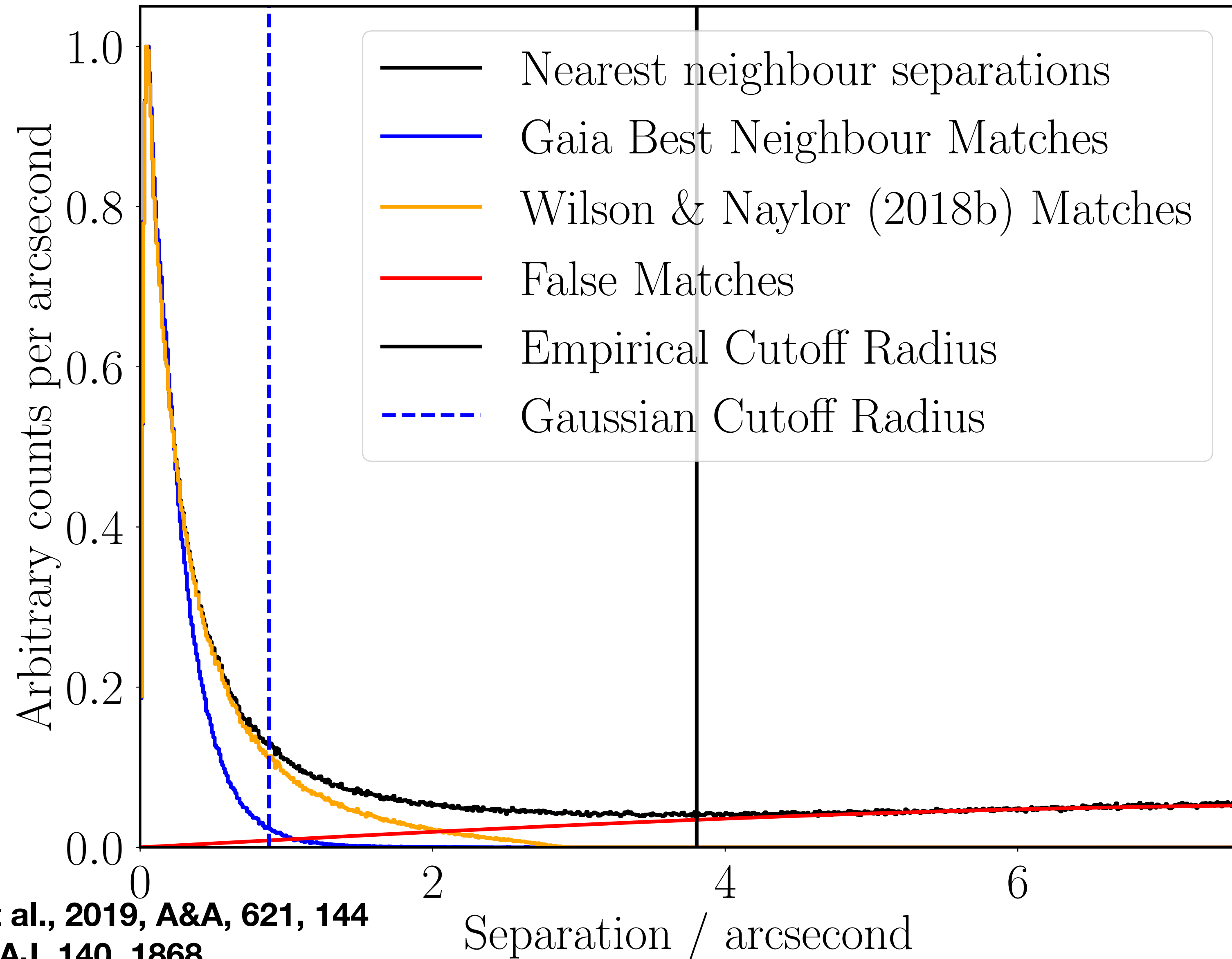
Catalogue Cross-Matching



$$L = \frac{q(m, c) f(x, y)}{n(m, c)}$$

$$R_j = \frac{\Pr \left[S_j \cap \left(\bigcap_{k \neq j} U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right]}{\sum_i \Pr \left[S_i \cap \left(\bigcap_{k \neq i} U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right] + \Pr \left[(m_S > m_{\text{lim}}) \cap \left(\bigcap_k U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right]}$$

Cross-match Separation Distributions



Gaia matches - Marrese et al., 2019, A&A, 621, 144

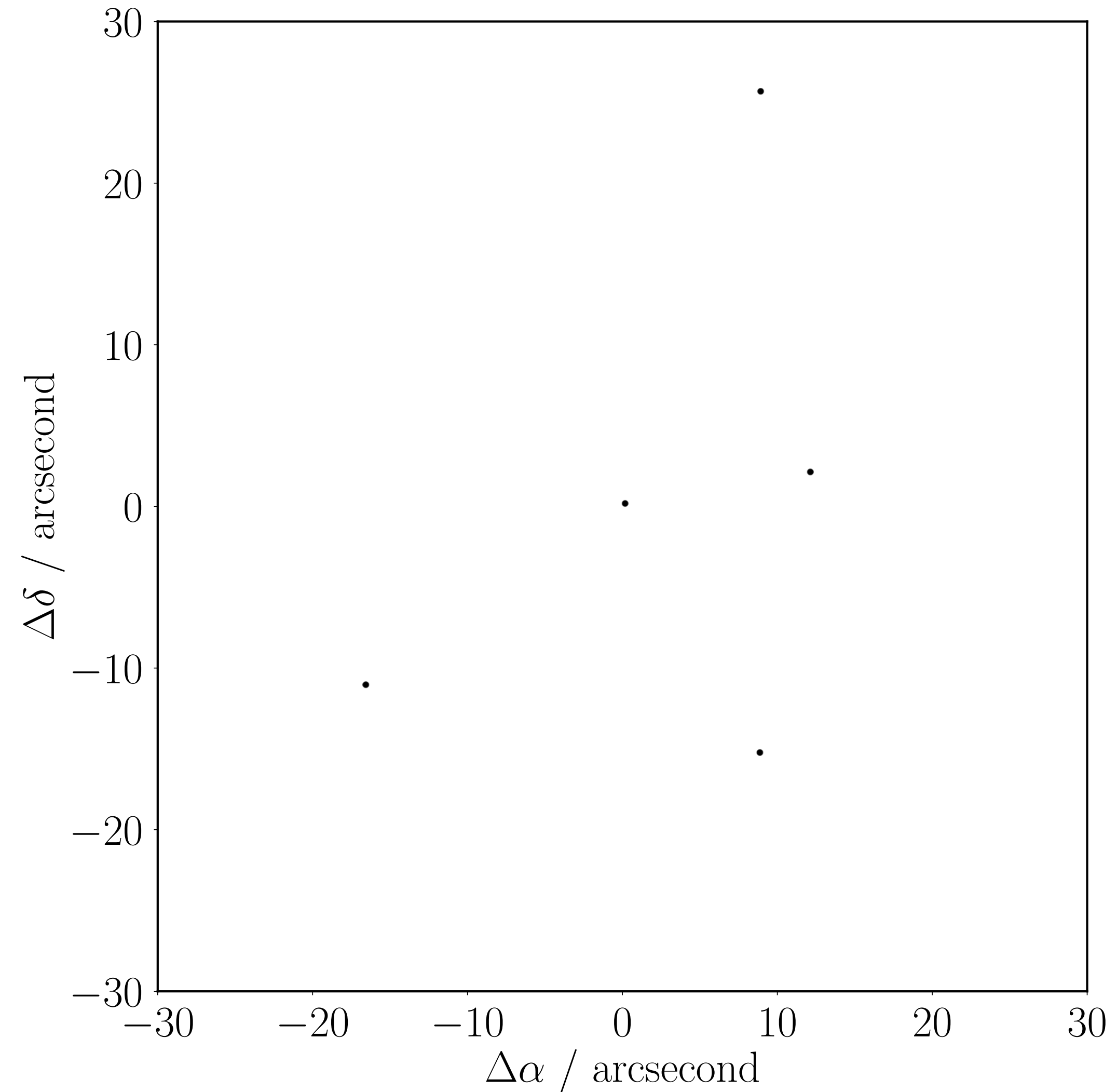
WISE - Wright et al., 2010, AJ, 140, 1868

Wilson & Naylor, 2018b, MNRAS, 481, 2148

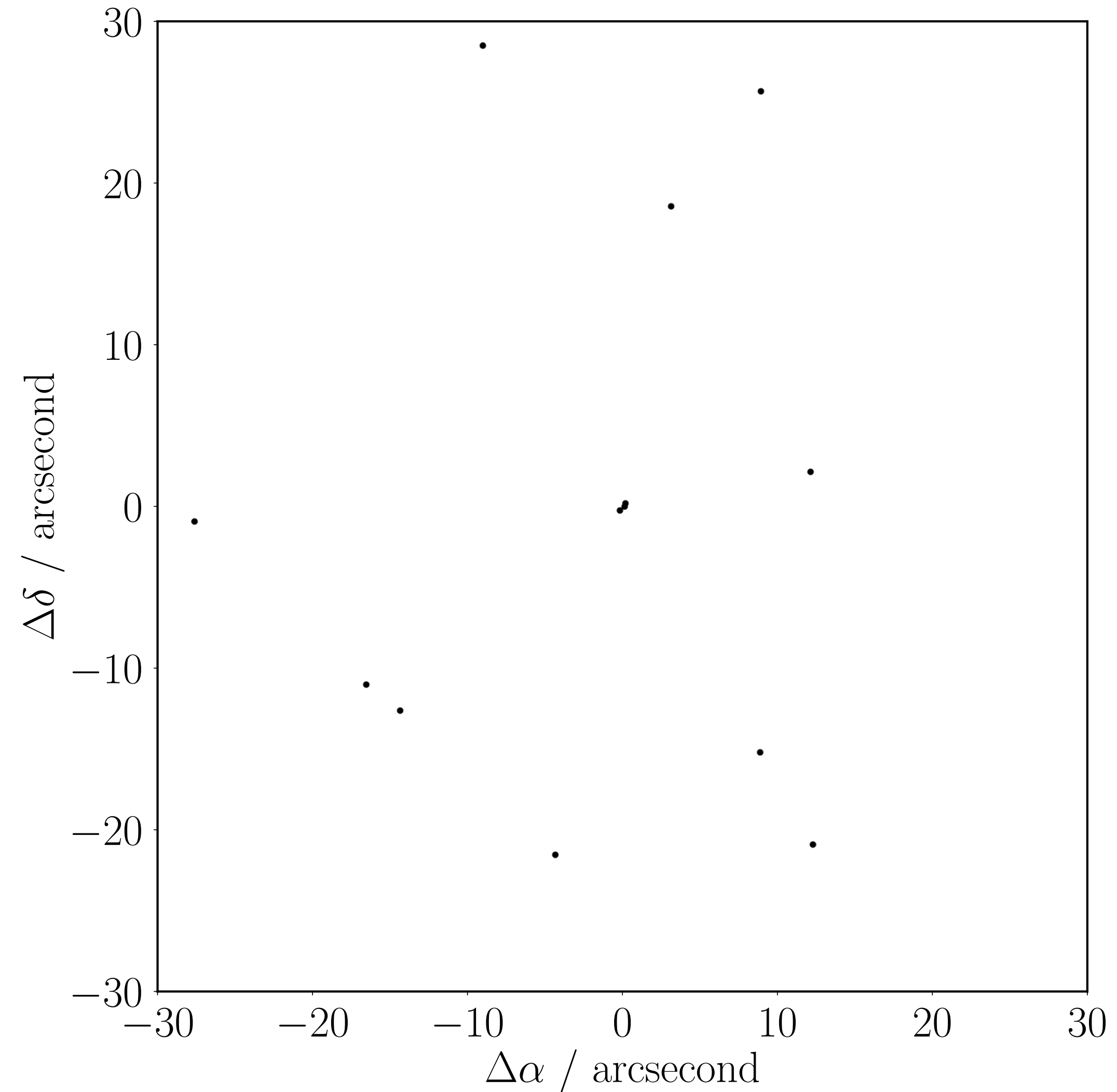
Gaia DR2 - Gaia Collaboration, Brown A. G. A., et al. 2018, A&A, 616, 1

Tom J Wilson @onoddil

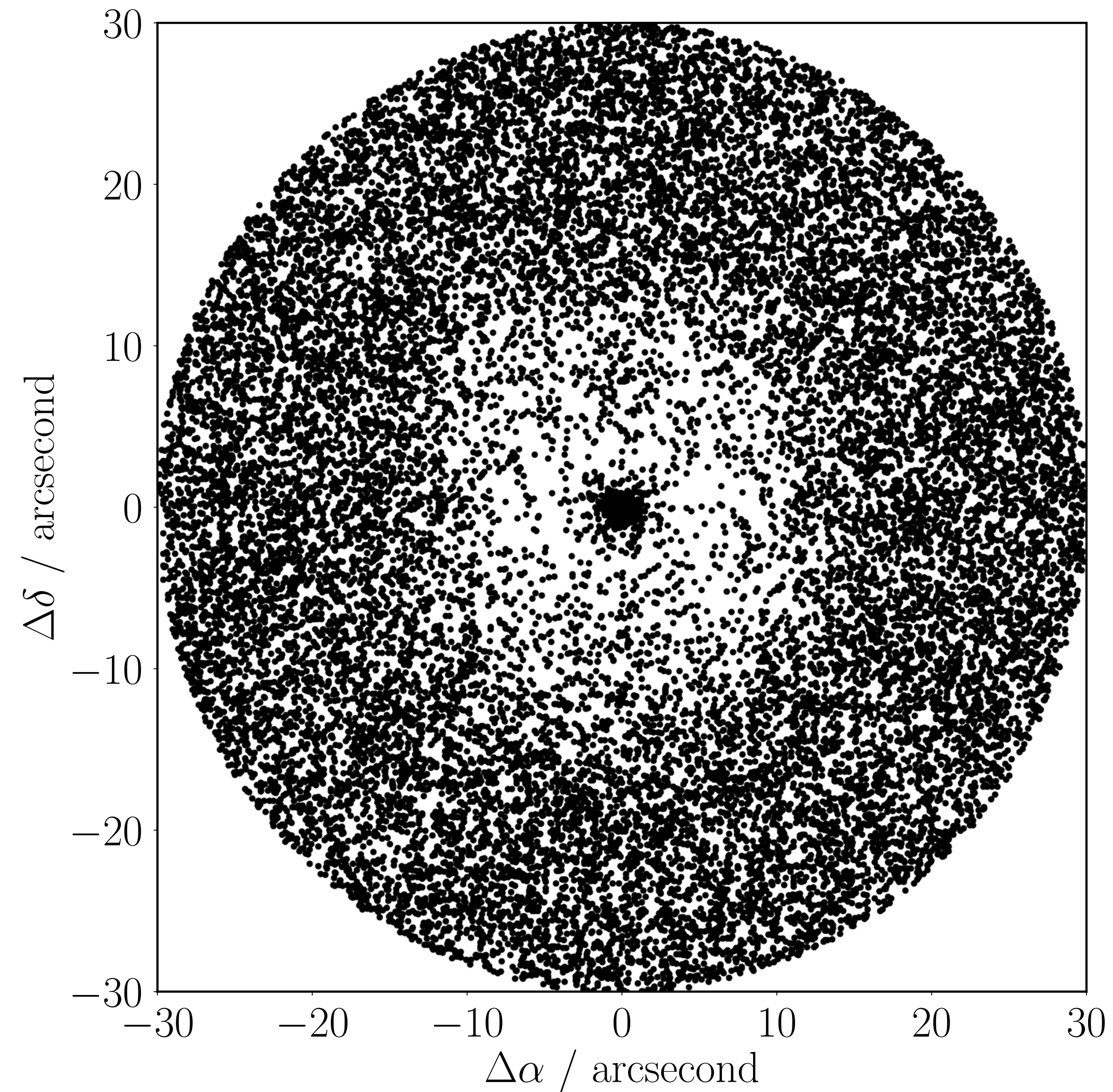
The Astrometric Uncertainty Function: Crowding



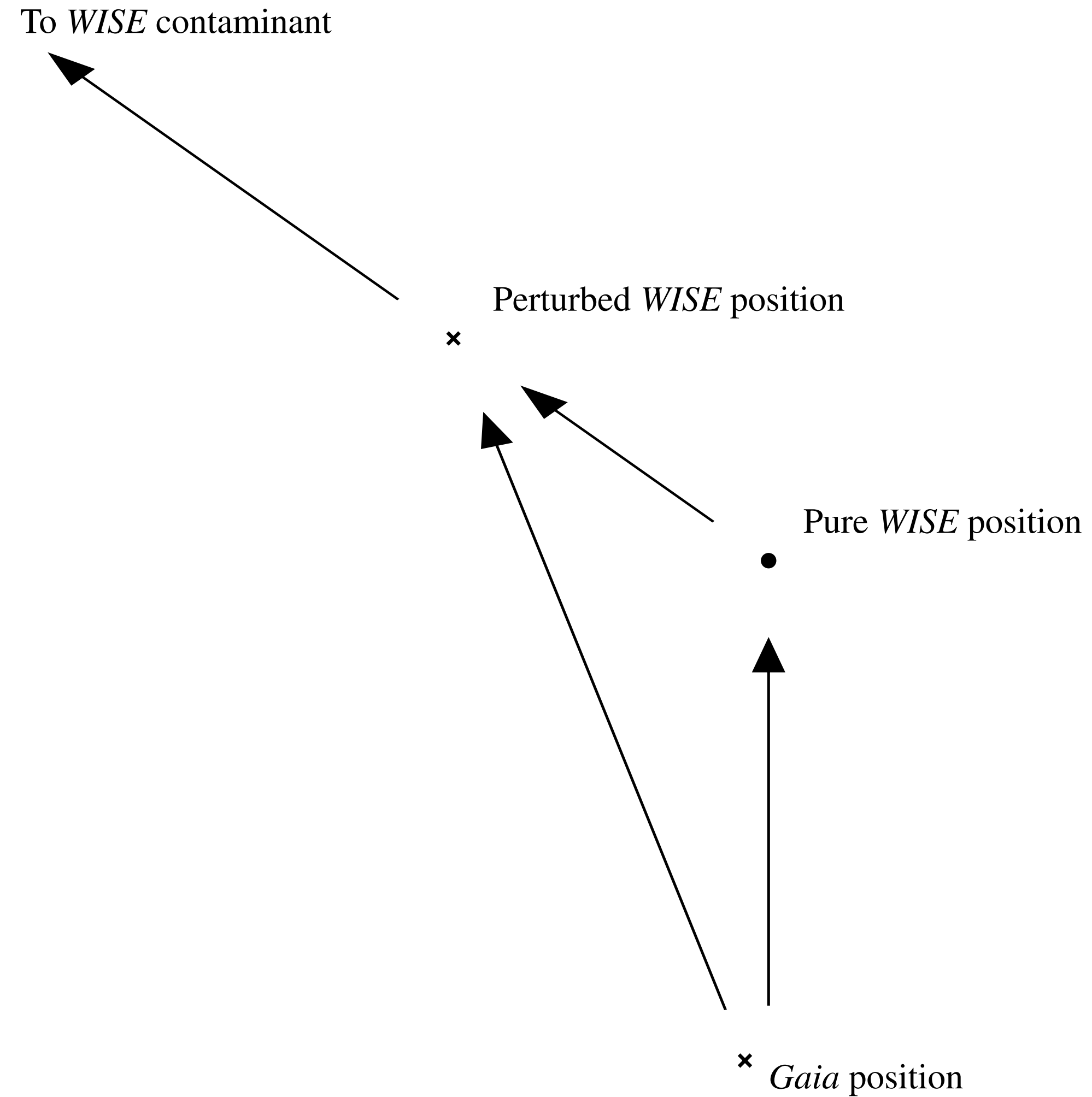
The Astrometric Uncertainty Function: Crowding



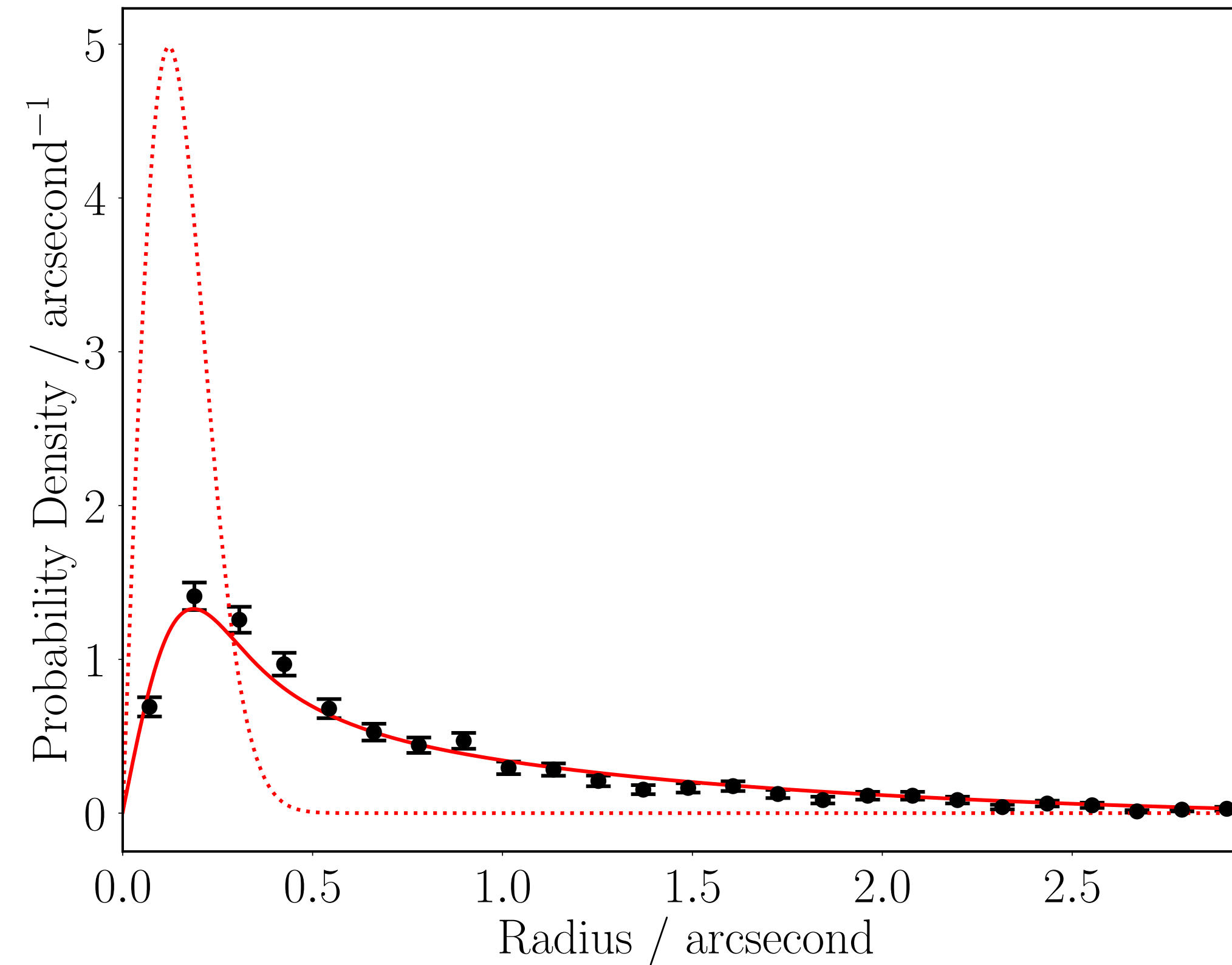
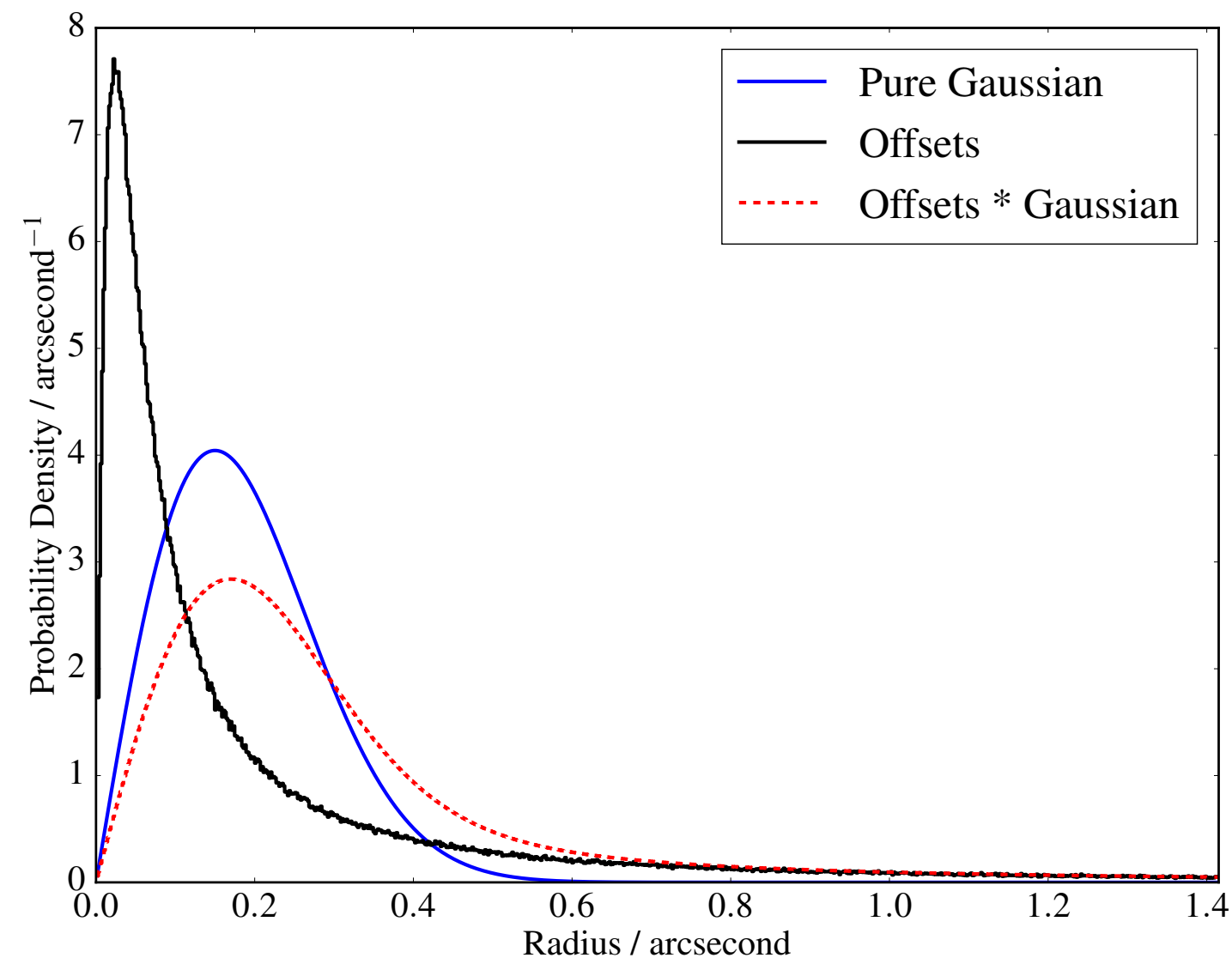
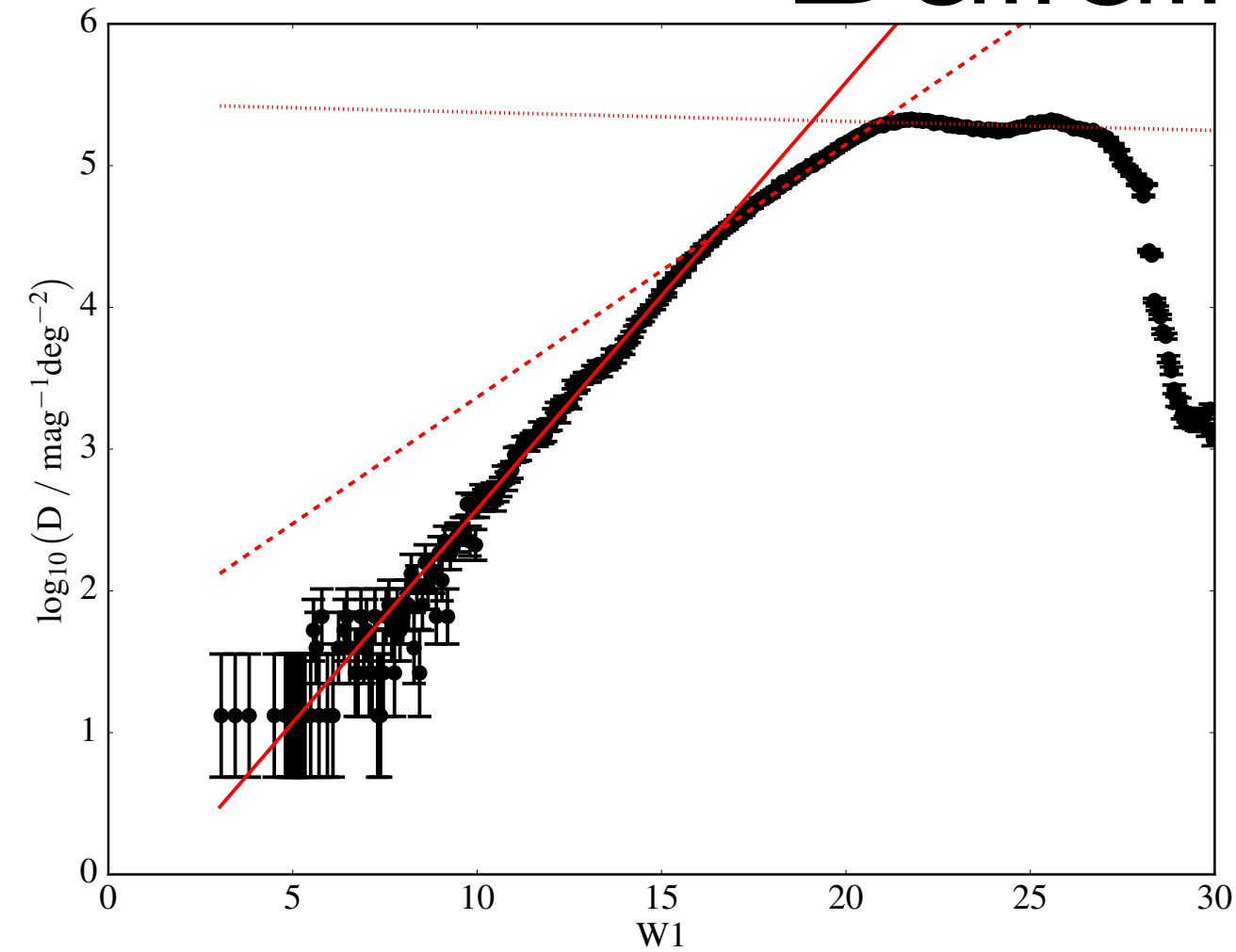
The Astrometric Uncertainty Function: Crowding



The Astrometric Uncertainty Function: Perturbation

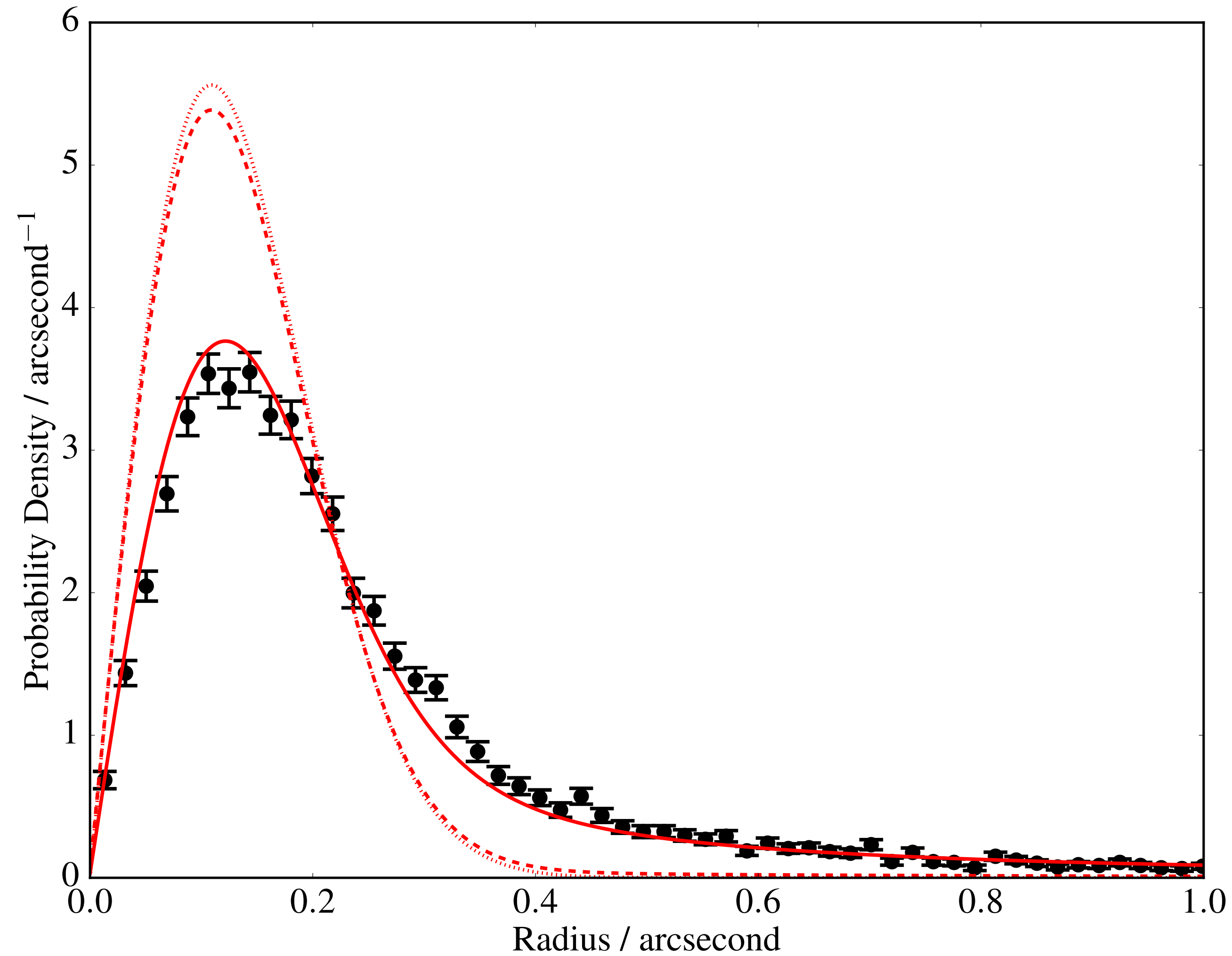


The Astrometric Uncertainty Function: Building Empirical AUFs

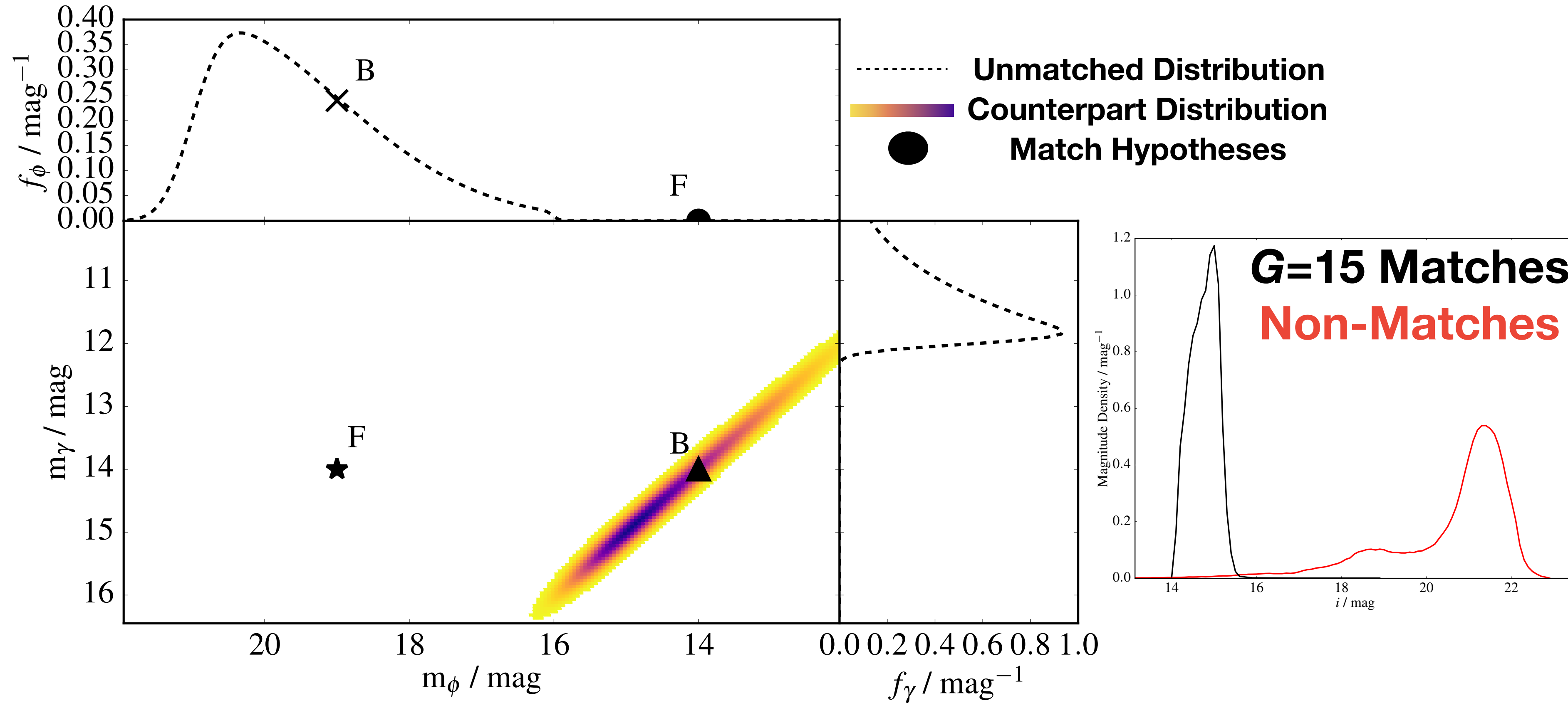


**Modelling the perturbation component of the AUF
critical for transients with large dynamic ranges!**

Contamination Effects: Galaxy Contamination



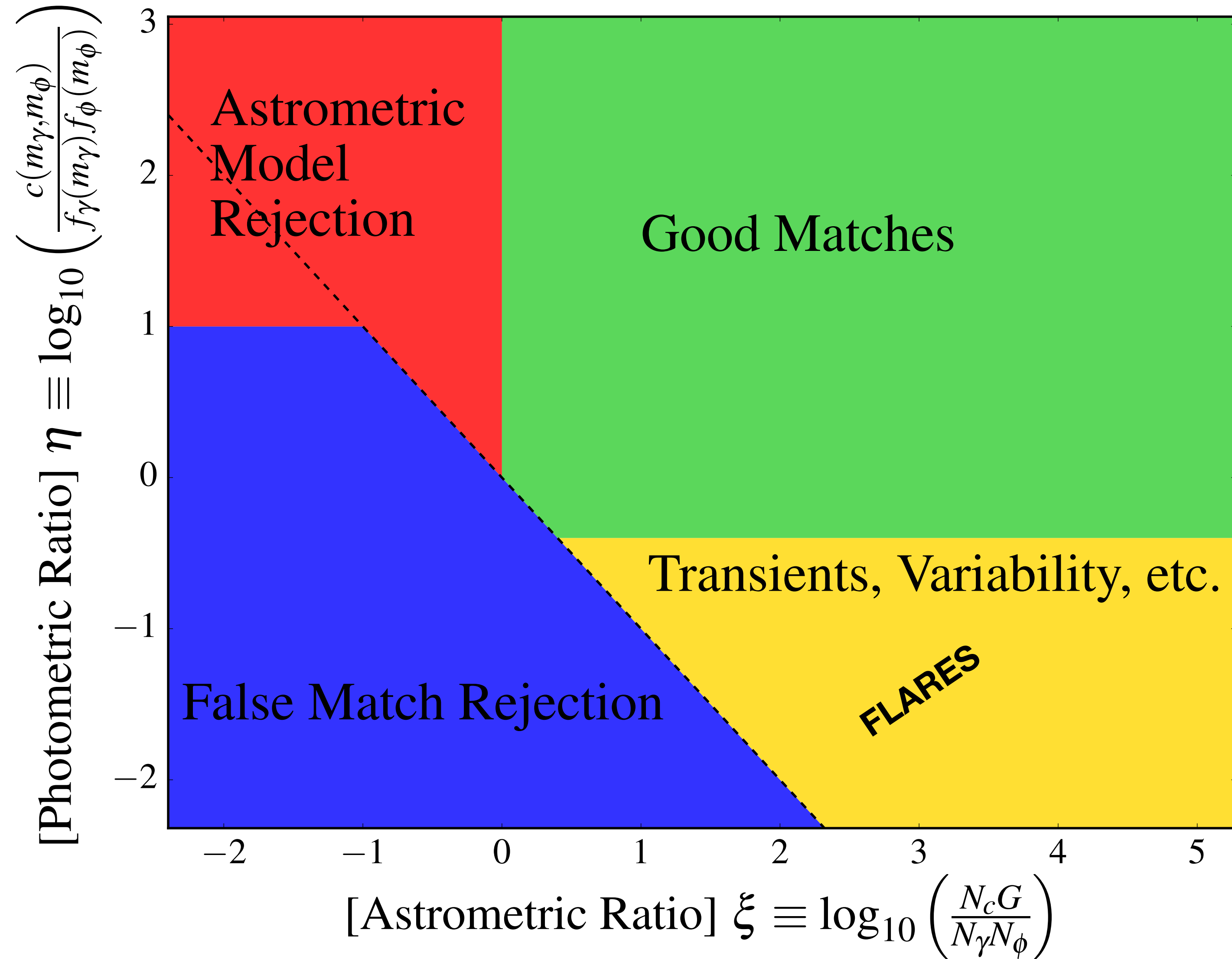
Probability-based Catalogue Matching: Including the Magnitude Information



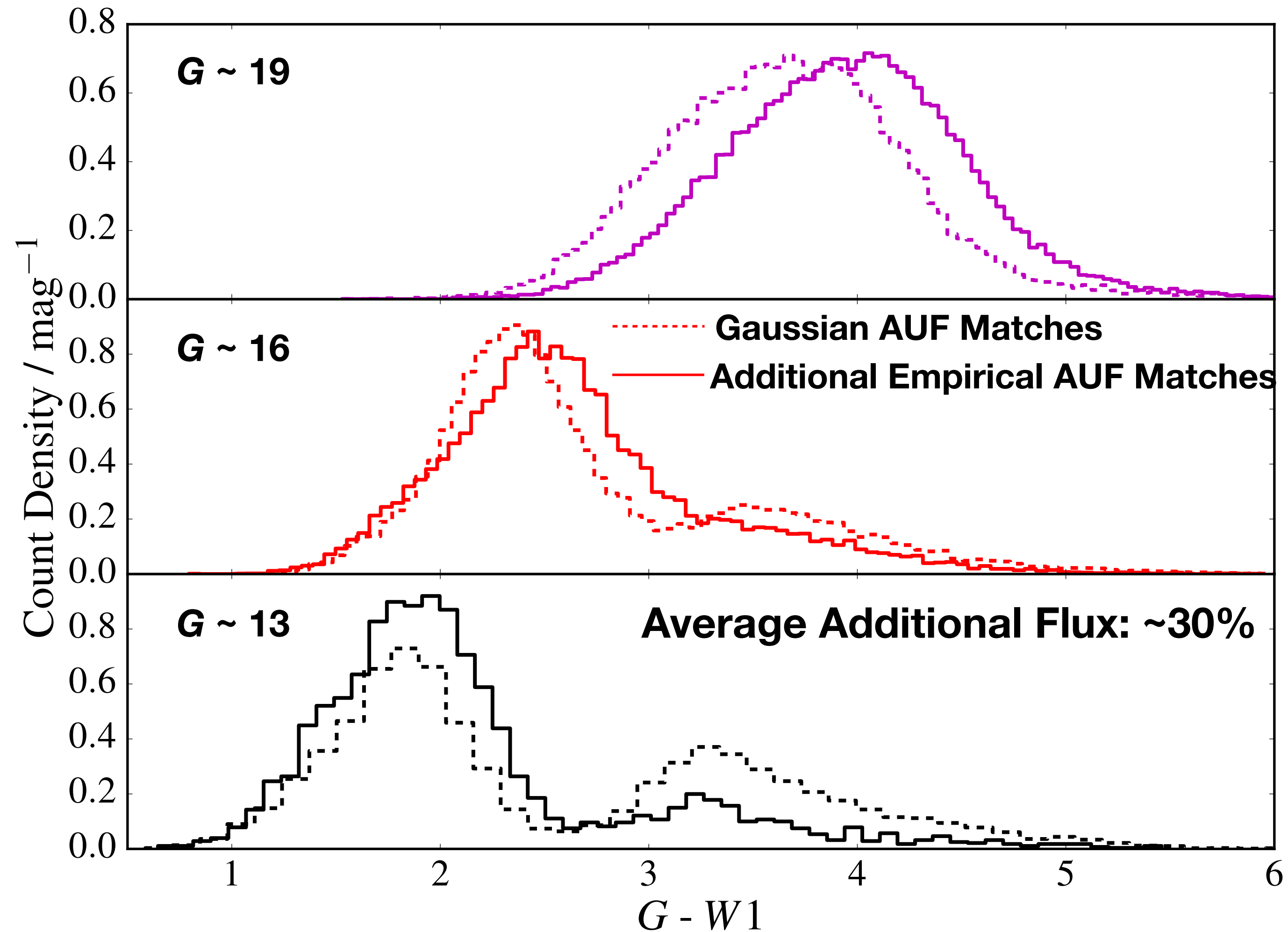
$$g(x_k, y_k, x_l, y_l) = N_c \iint_{-\infty}^{+\infty} h_\gamma(\Delta x_{kl} - x, \Delta y_{kl} - y) h_\phi(x, y) dx dy$$

$$= N_c \times (h_\gamma * h_\phi)(\Delta x_{kl}, \Delta y_{kl}).$$

Probability-based Catalogue Matching: The Likelihood Ratio Space



Contamination Effects: Perturbation-Colour Correlation



**“Extra flux” has an impact
on derived proper motions
and parallaxes!**

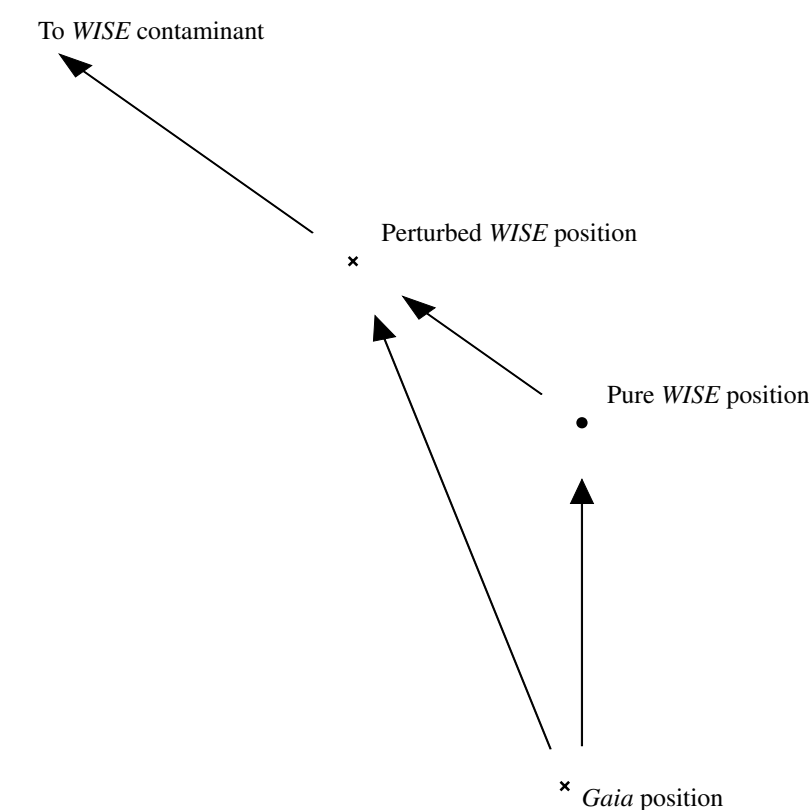
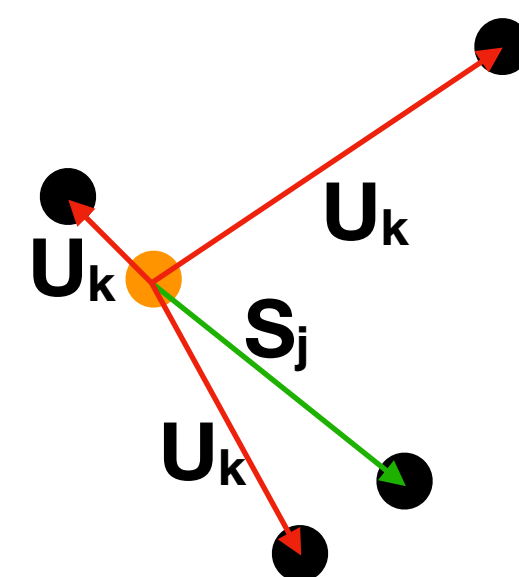
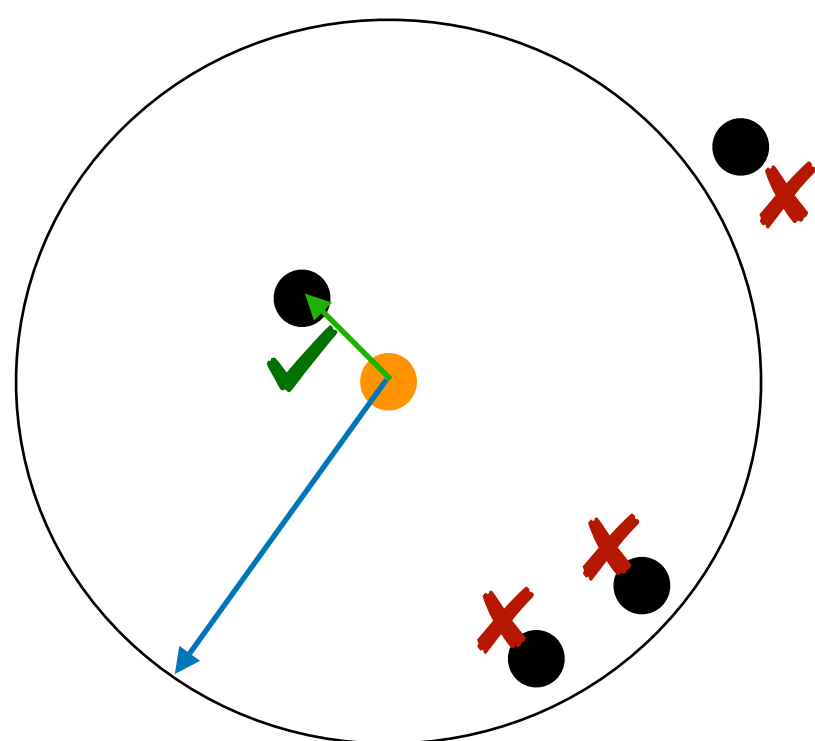
What does this mean for TVS?

The “busy” astronomer: uses a quick and simple 2” match for bright transients -> Too many matches

The “Bayesian” astronomer: uses astrometric centroid uncertainty to reduce match radius -> Too few matches

The “careful” astronomer: includes perturbation from blended objects in the AUF -> Correct number of matches

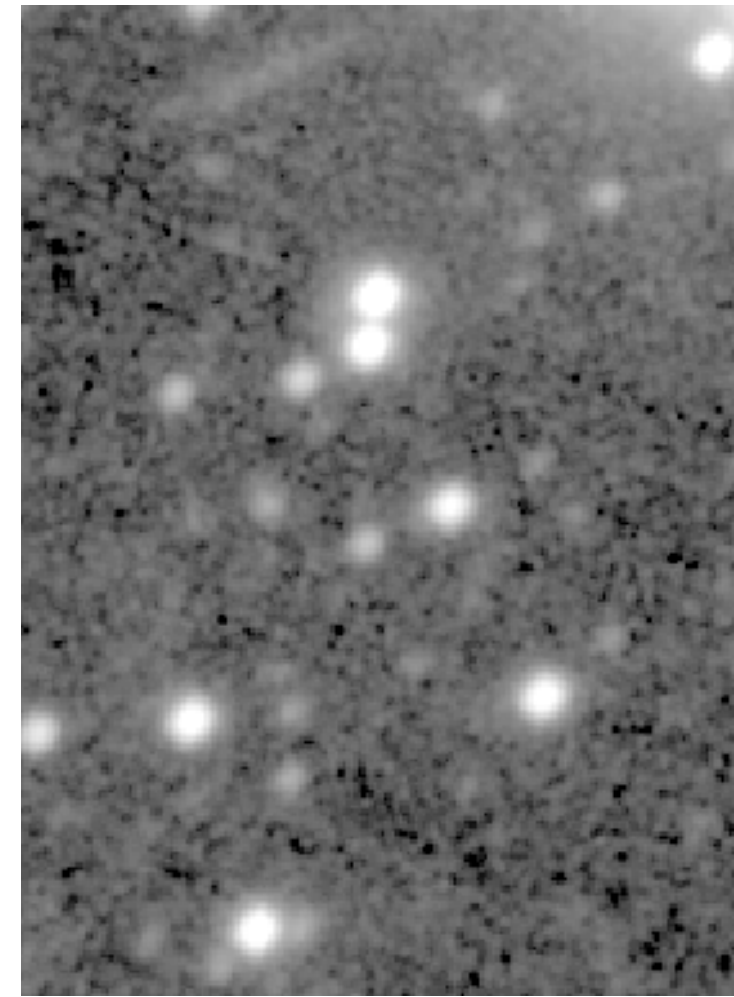
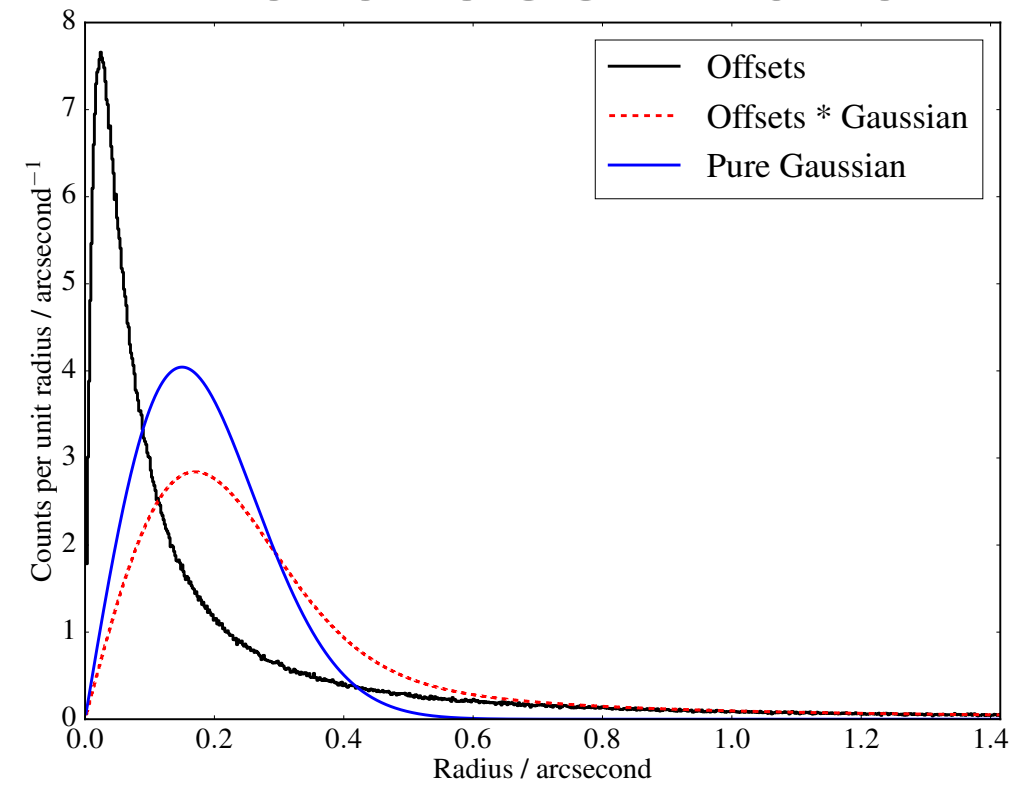
The “smart” astronomer: uses our cross-matches to get the correct number of matches *and* information on how much flux contamination is brightening their progenitor!



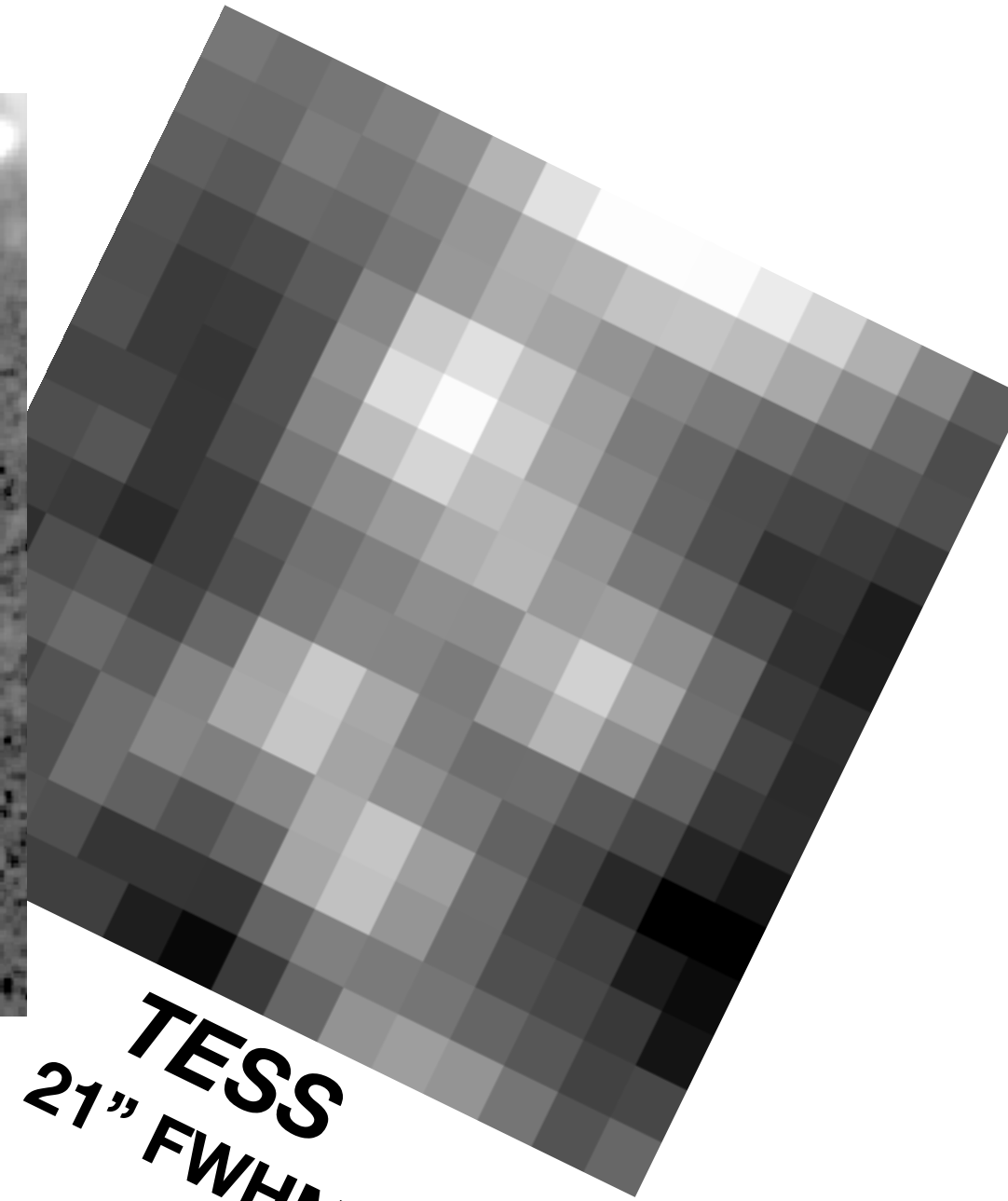
you downloading your favourite cross-matches, probably

Conclusions

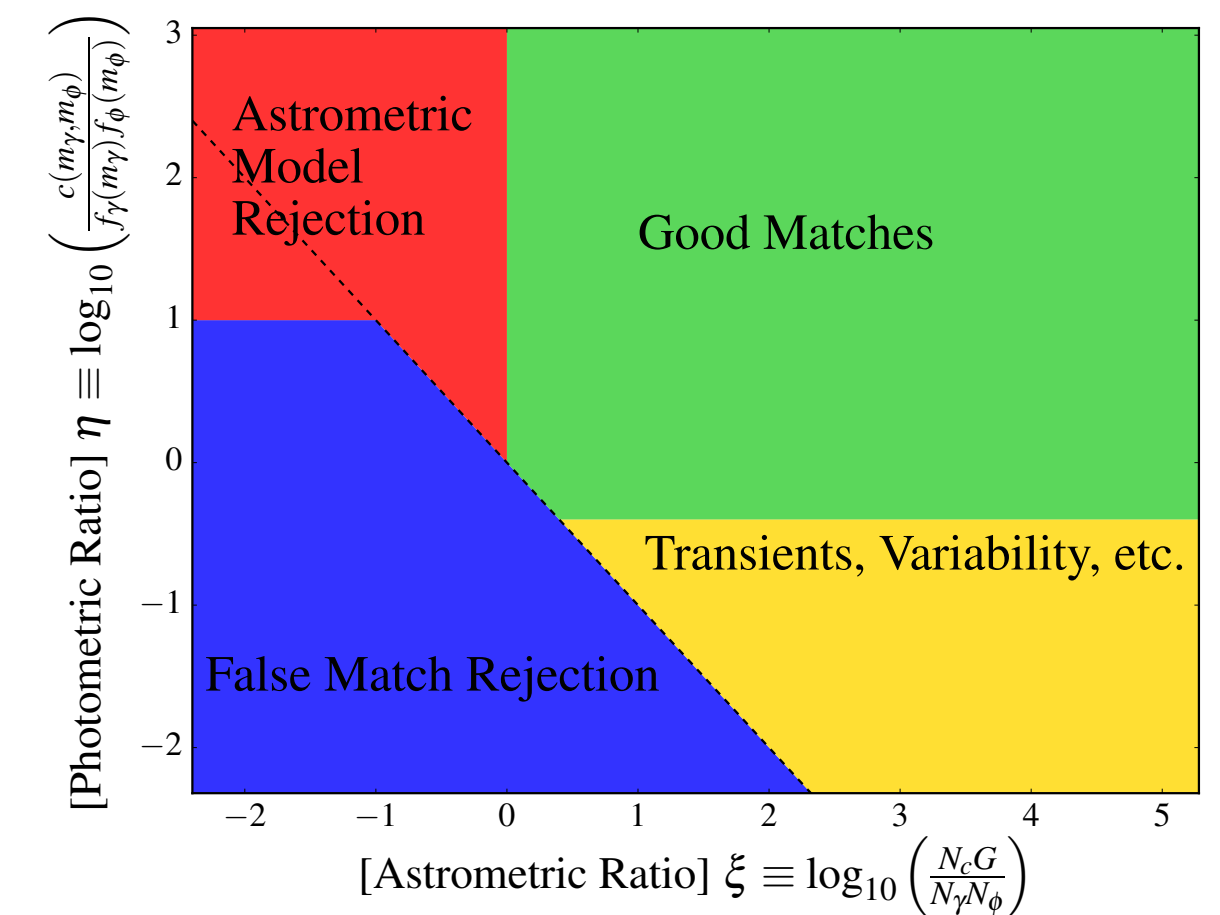
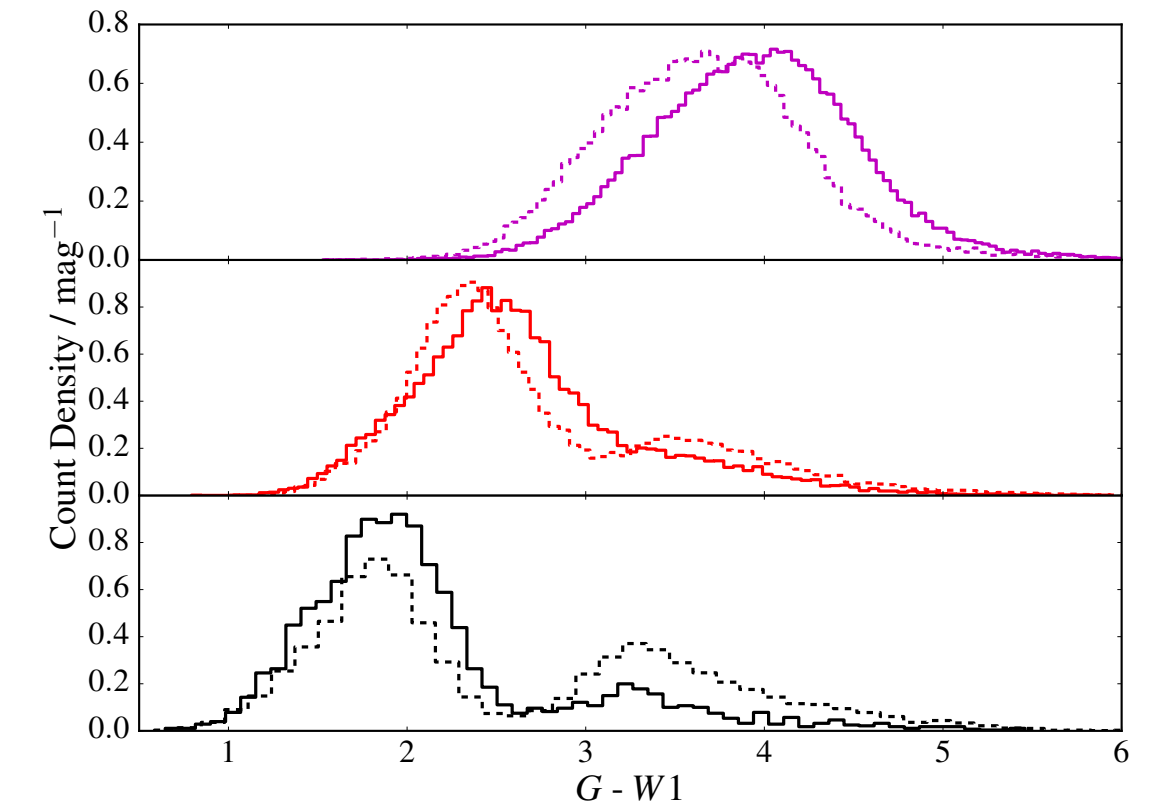
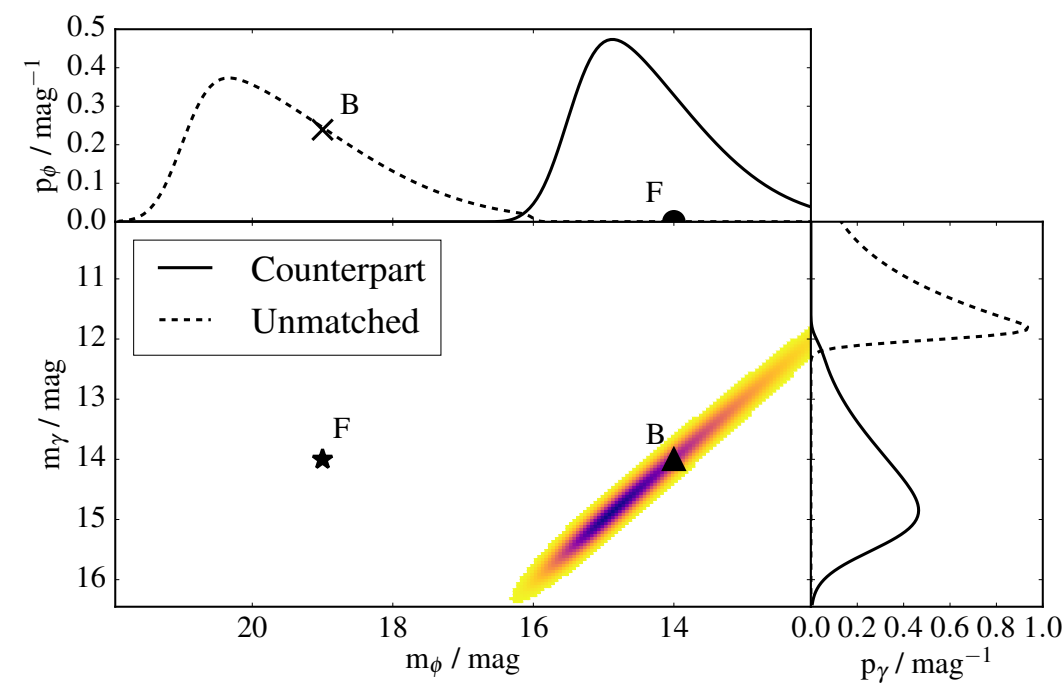
- **Blended star contamination causes positional shifts, important to model for transients with high dynamic ranges**
- ***WISE* objects are up to 30% flux contaminated, with *WFIRST* and *LSST* suffering similar blending in the future – can mimic IR disc excess!**
- **Can recover transients and variable stars better with proper treatment in the cross-match process, vital at unprecedented *LSST* depths**



WISE
6'' FWHM



TESS
21'' FWHM



Wilson & Naylor, 2017, MNRAS, 468, 2517

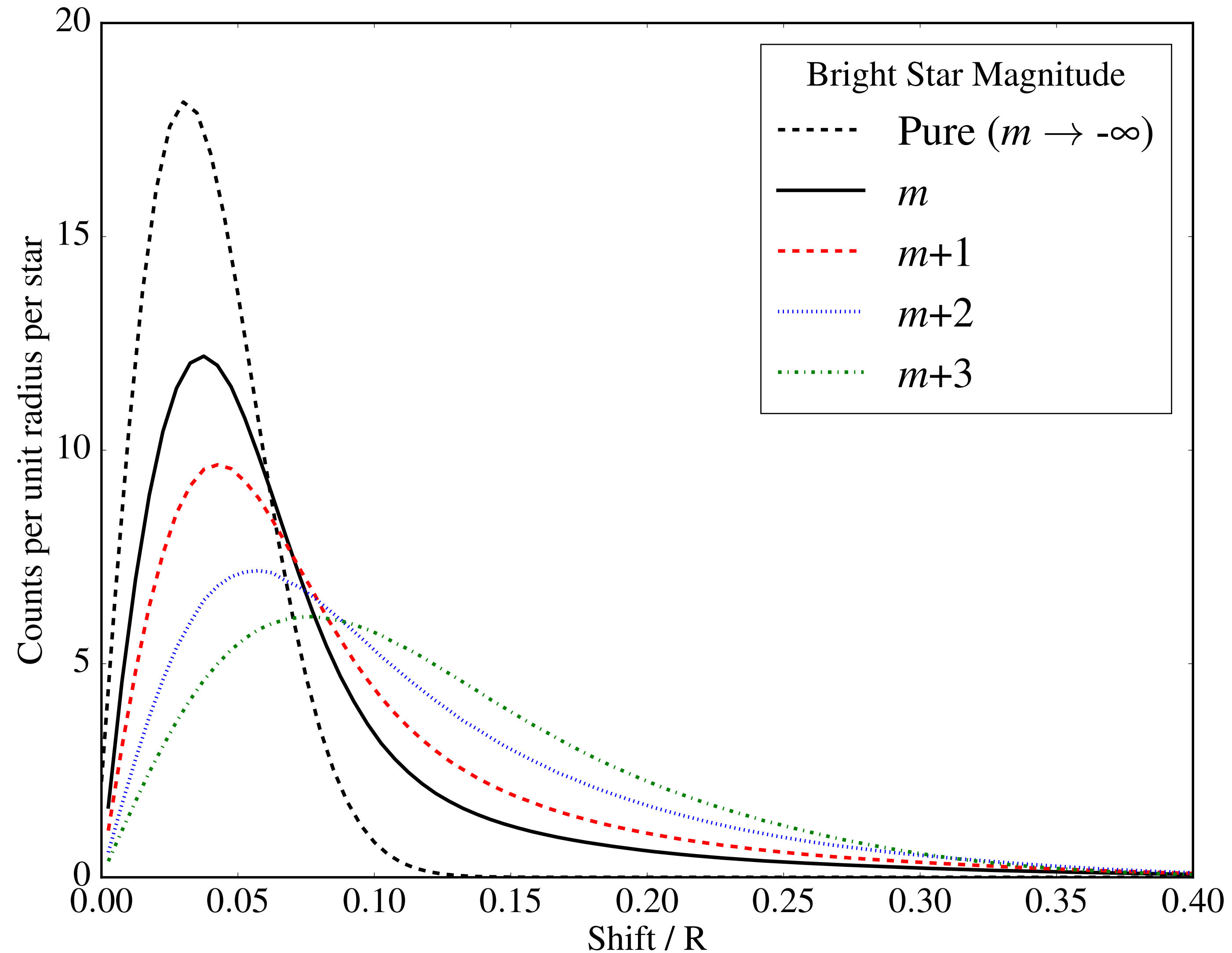
Wilson & Naylor, 2018a, MNRAS, 473, 5570

Wilson & Naylor, 2018b, MNRAS, 481, 2148

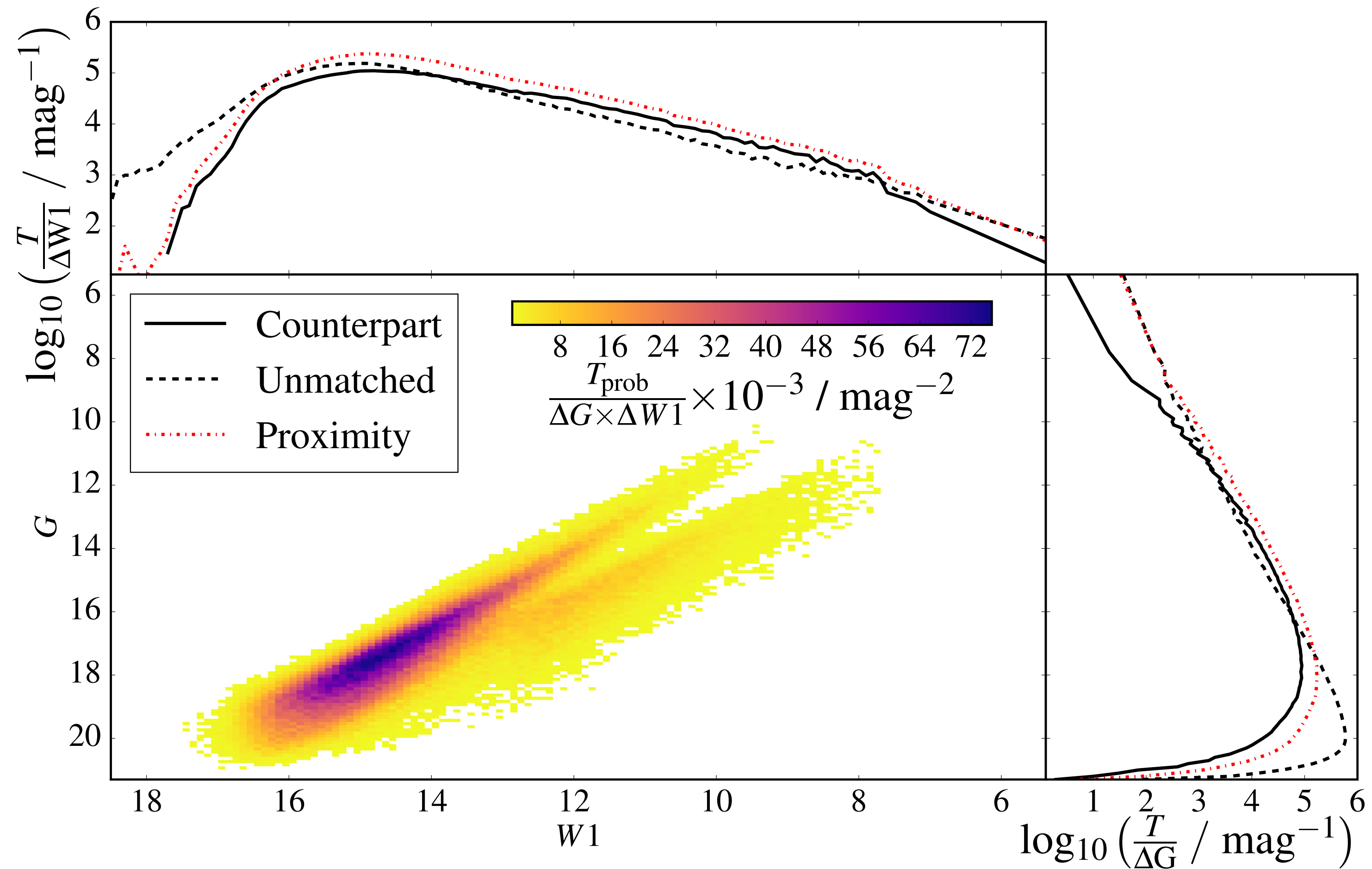
<https://github.com/Onoddil/macauff>

Tom J Wilson @onoddil

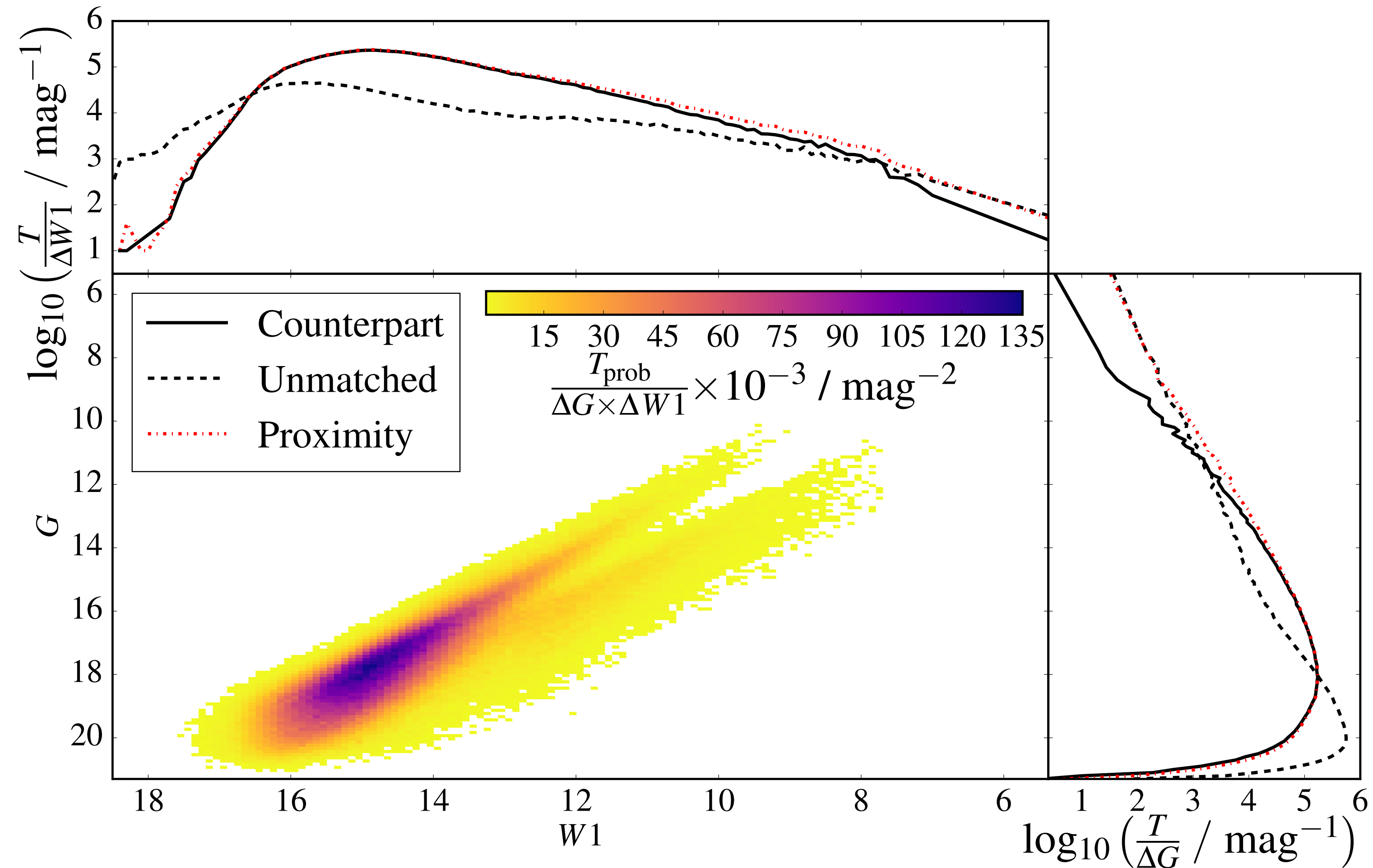
The Astrometric Uncertainty Function: Synthetic Non-Gaussian Tails



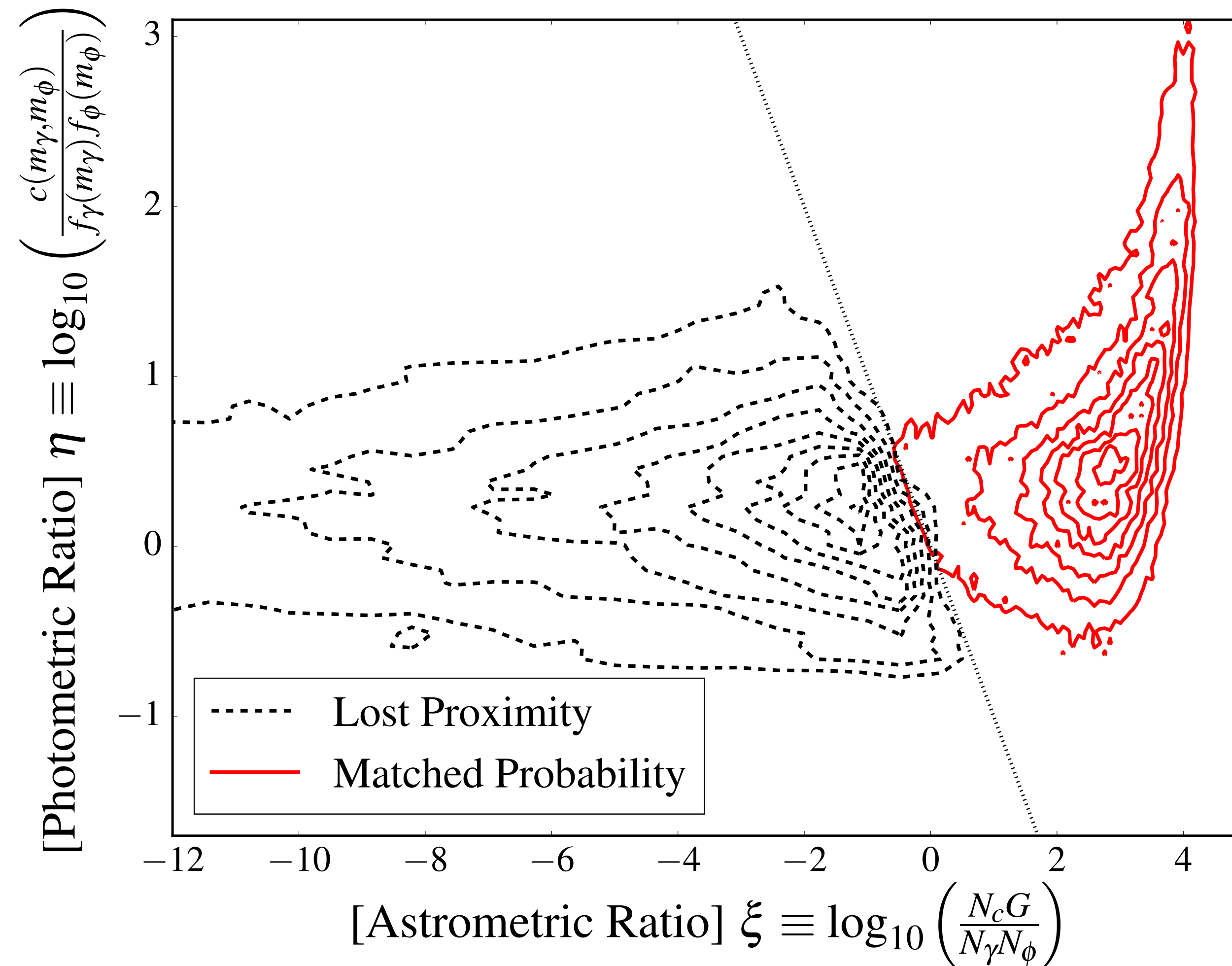
Contamination Effects: Gaia-WISE Gaussian Matches



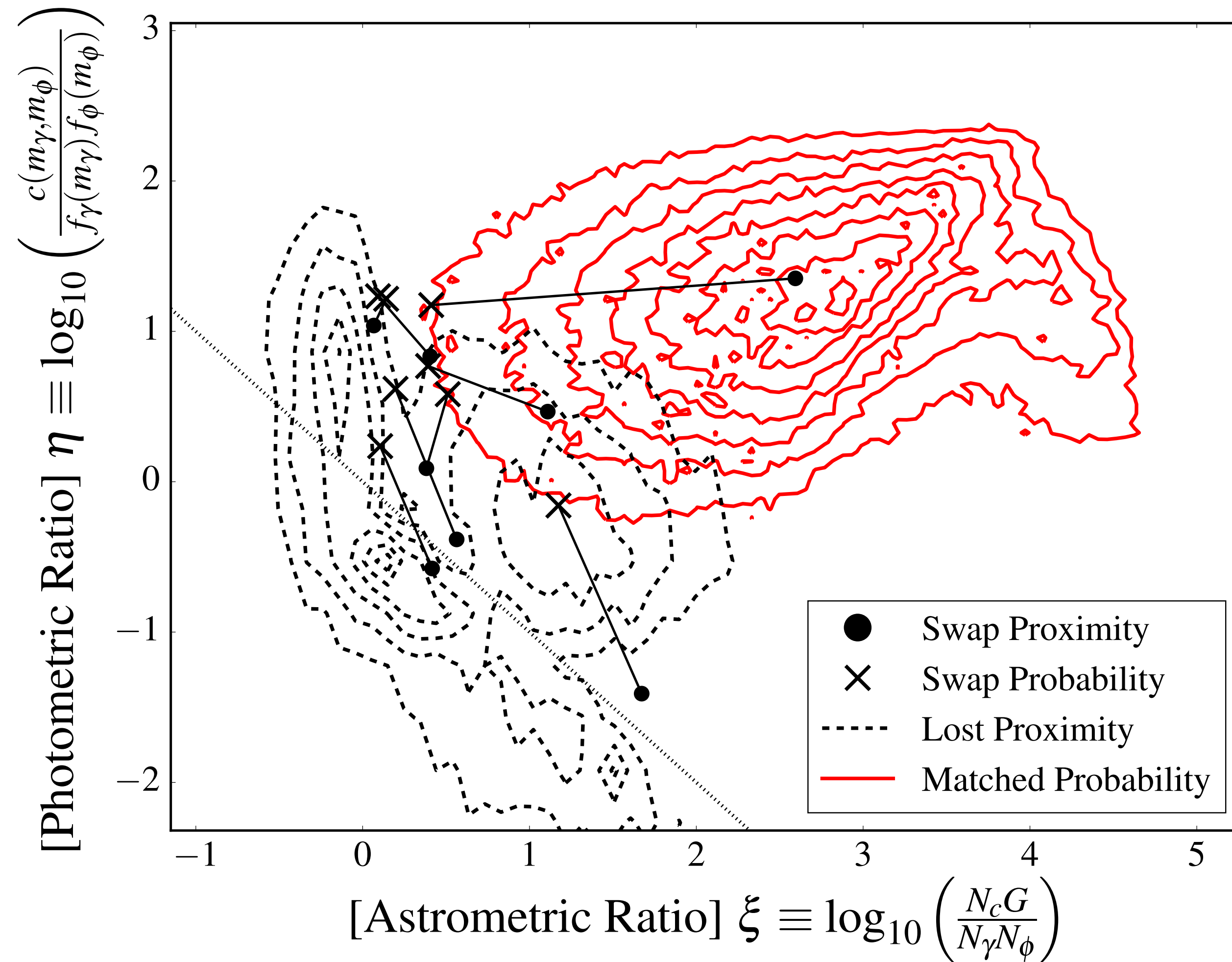
Contamination Effects: Gaia-WISE Empirical Matches



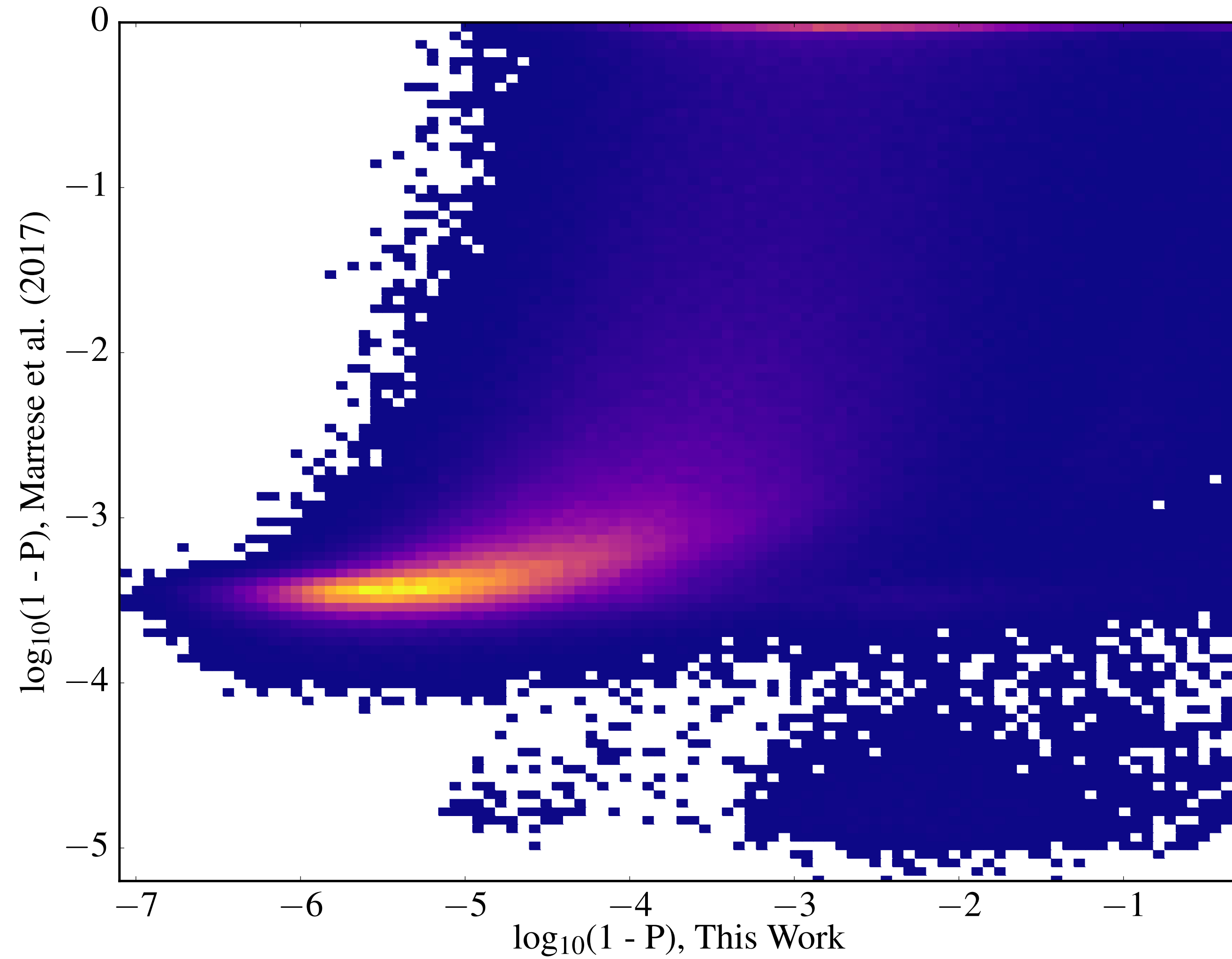
Contamination Effects: Lost Proximity Matches



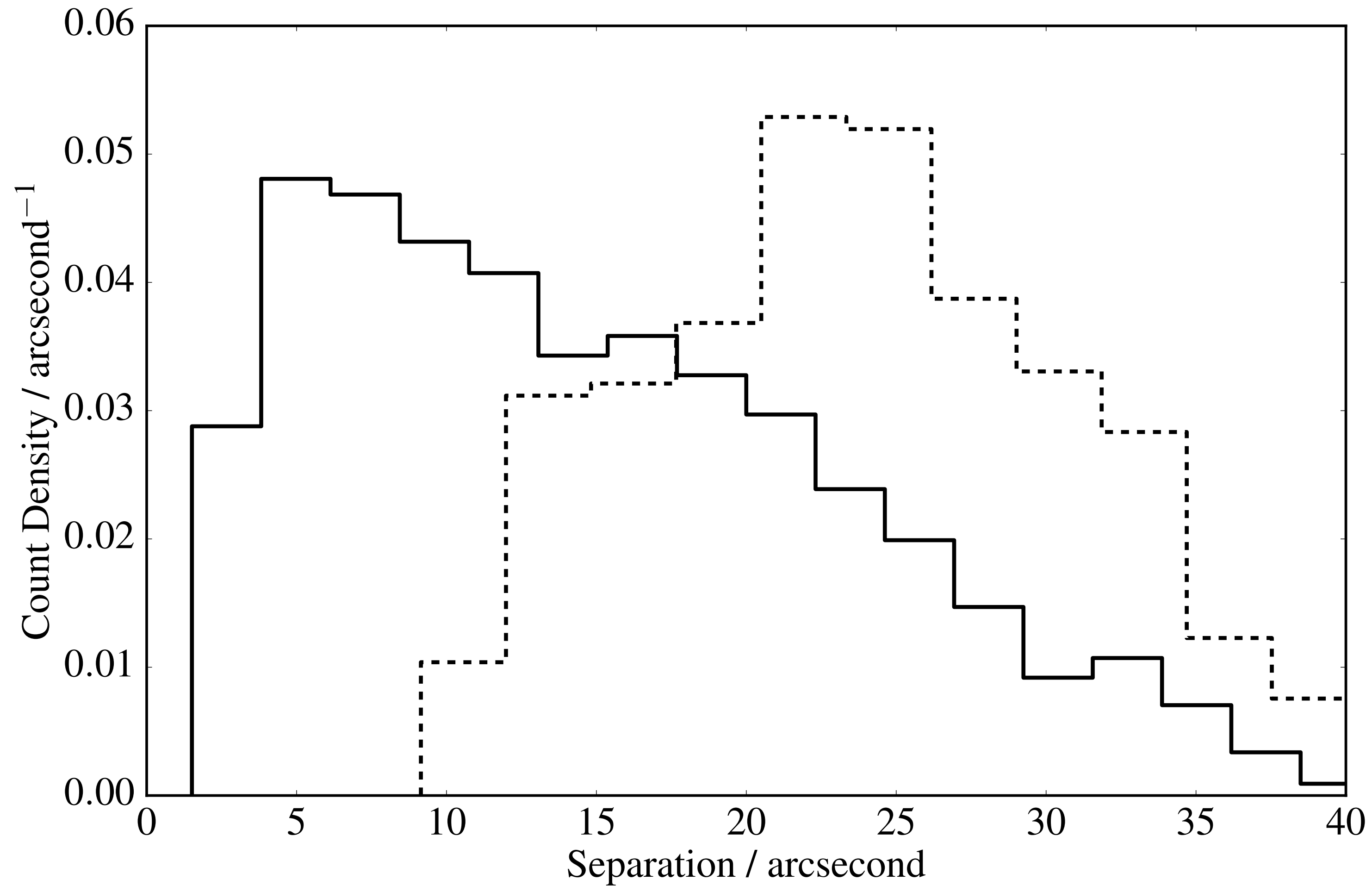
Contamination Effects: Lost Proximity Matches



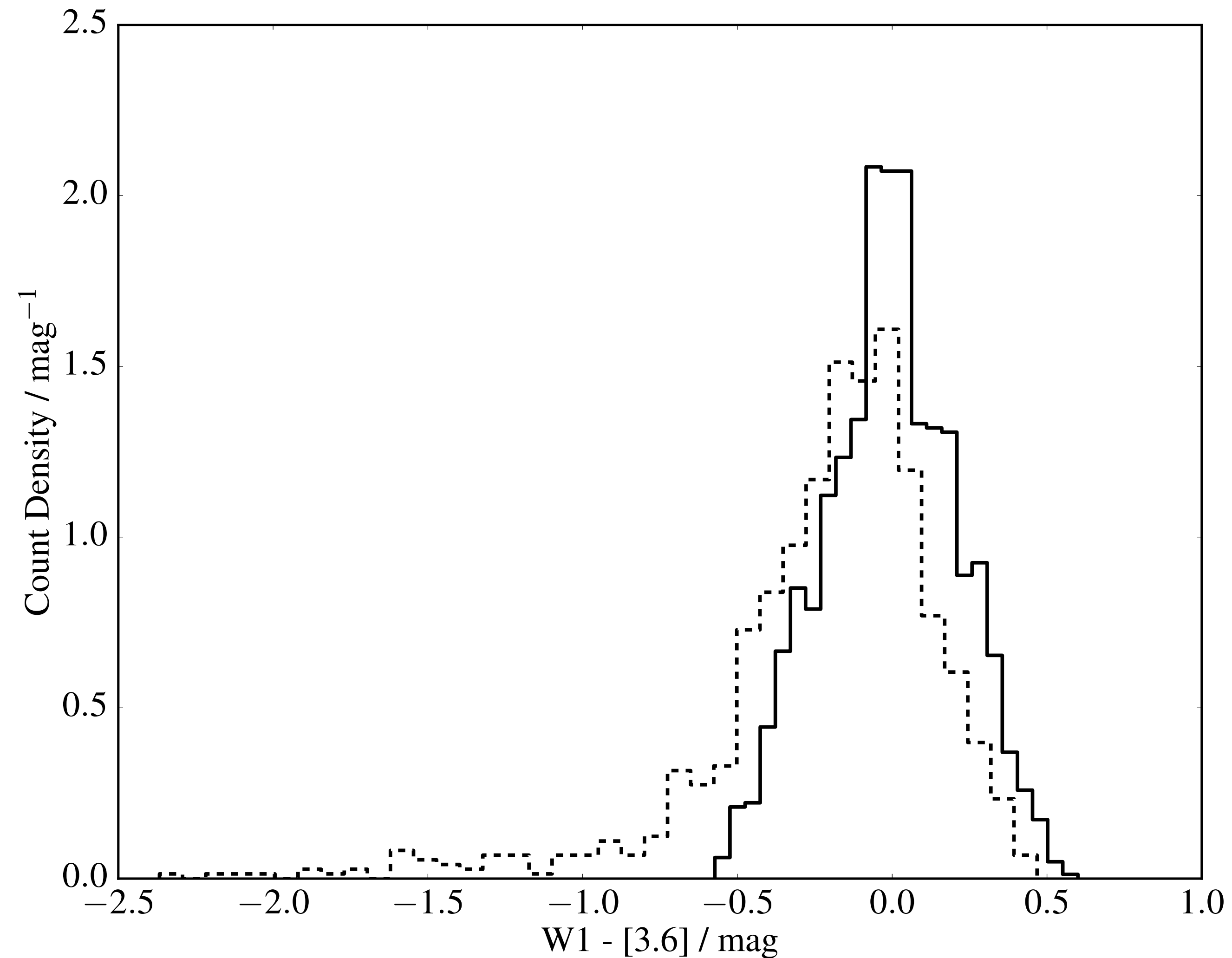
Contamination Effects: Gaia Lost Matches



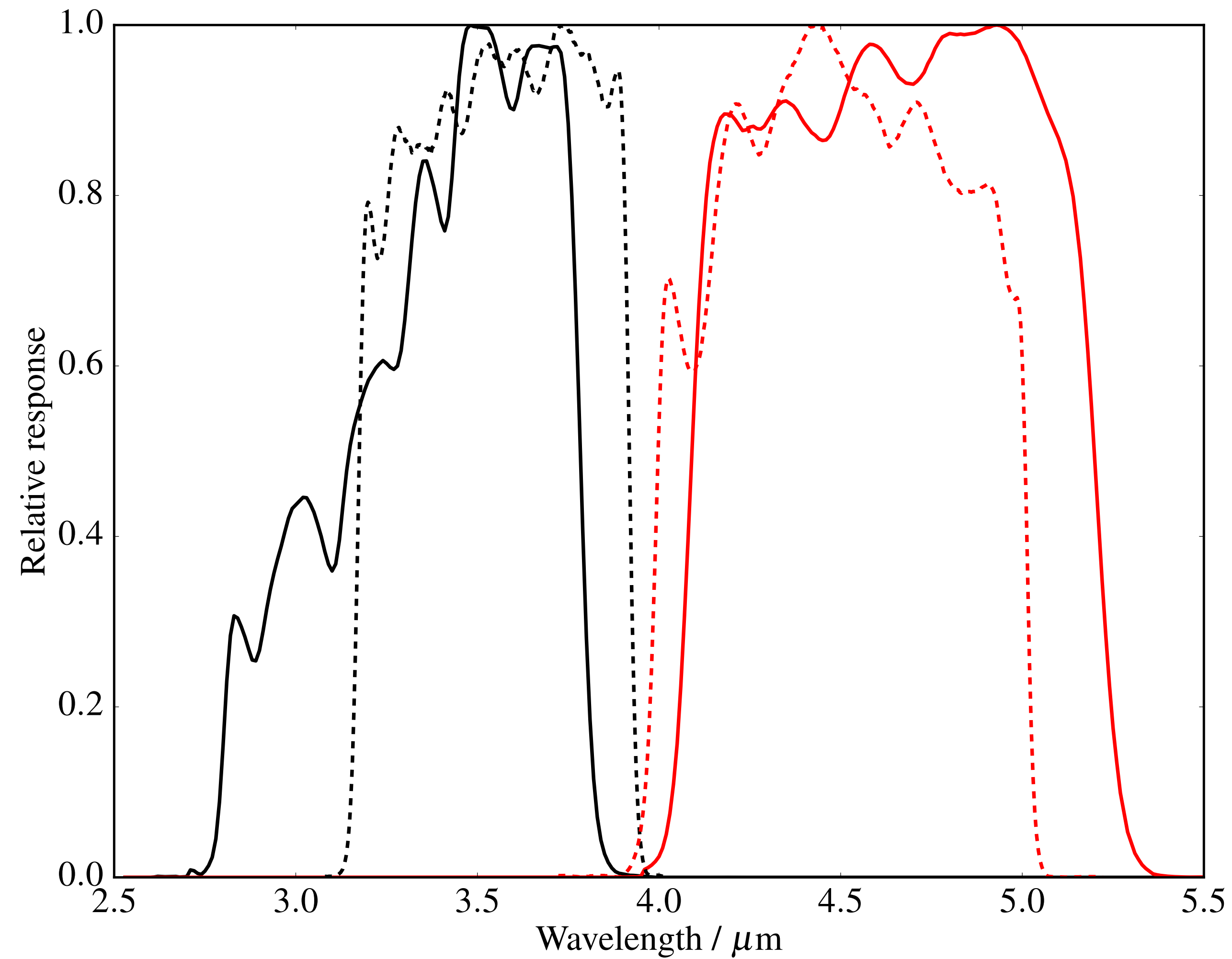
Contamination Effects: Resolving Contaminants



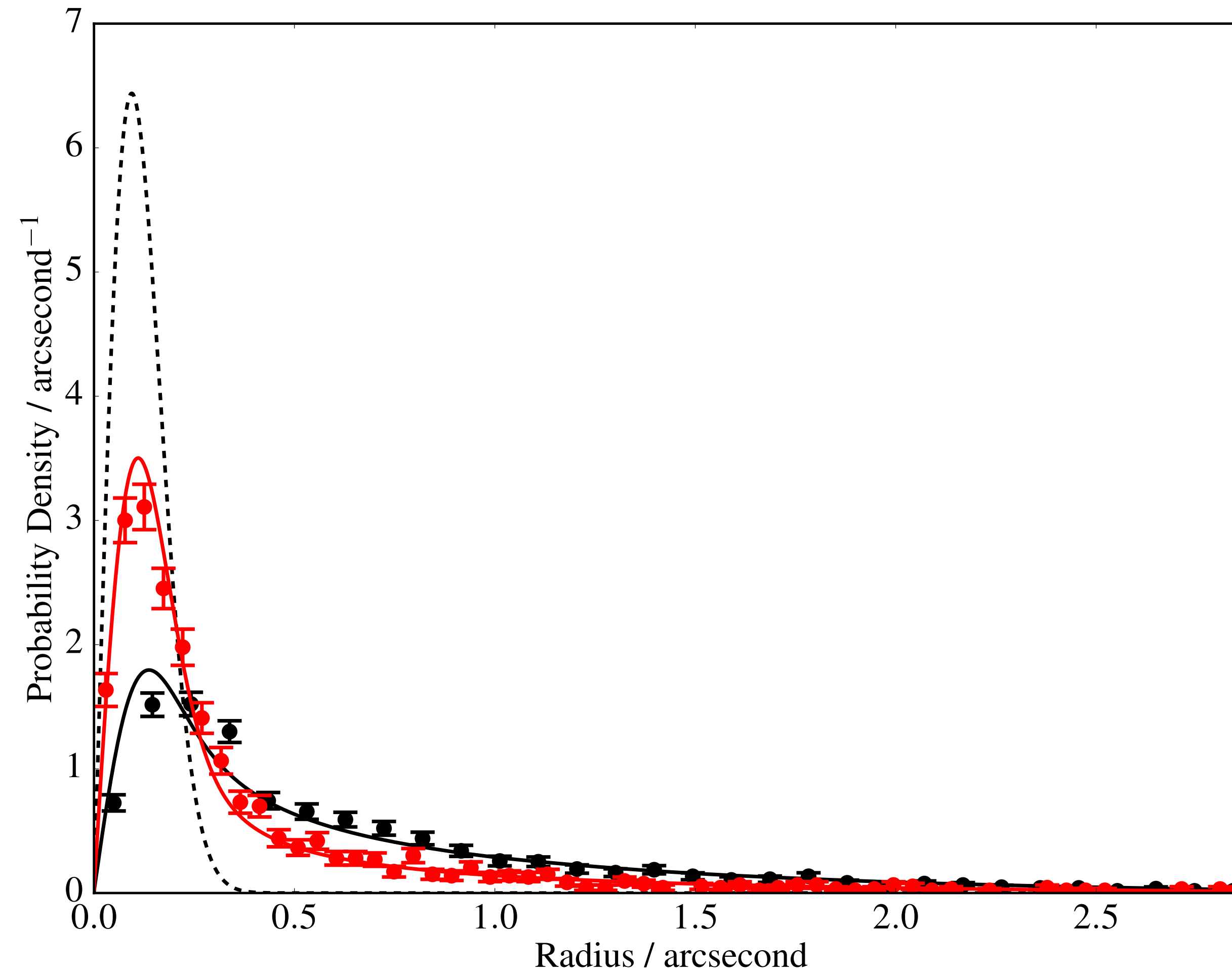
Contamination Effects: Resolving Contaminant Flux



Contamination Effects: Wavelength Coverage



Contamination Effects: Crowding Normalisation



The Astrometric Uncertainty Function: Analytical perturbations

