

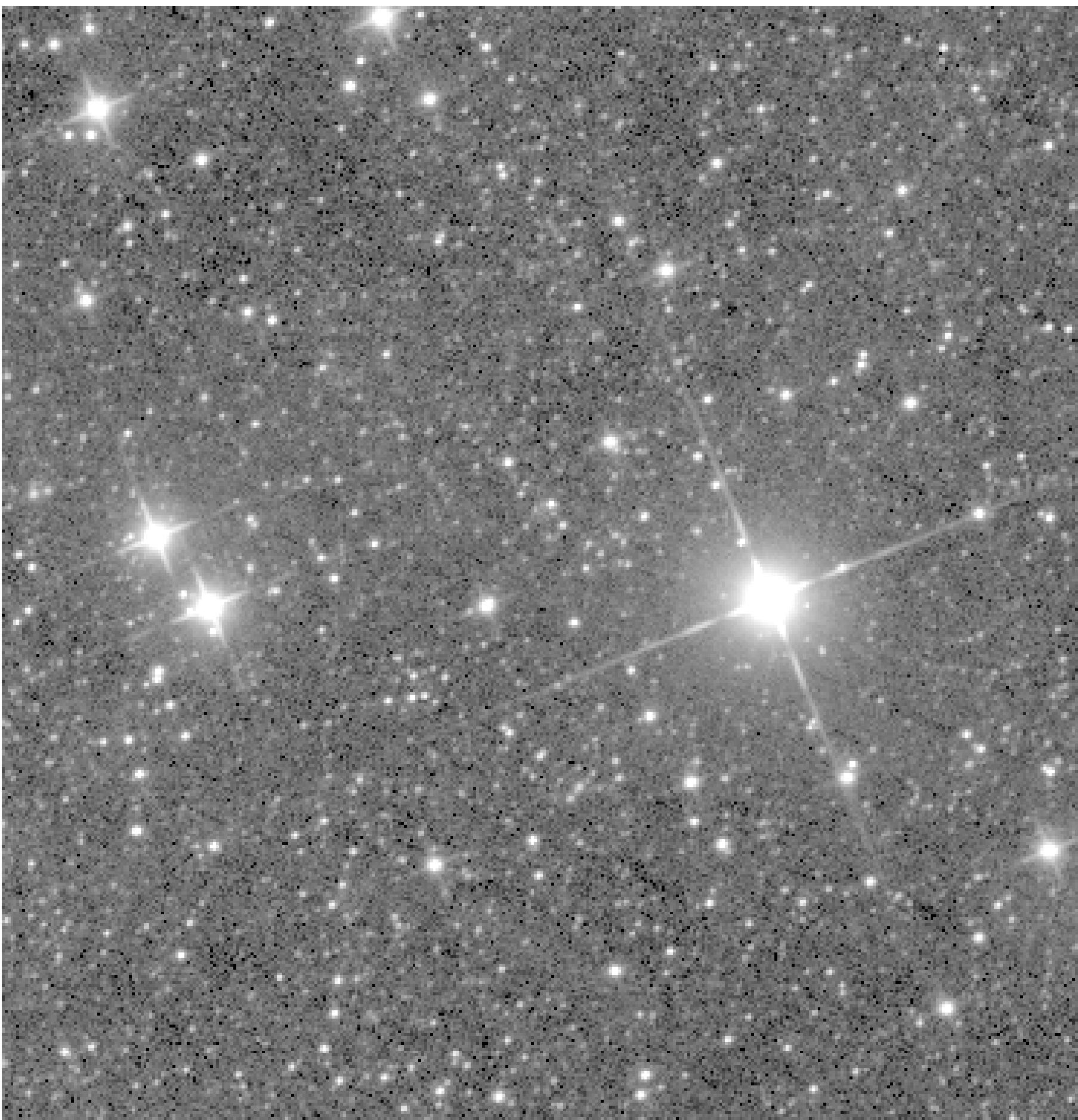
Better identification of variable and transient sources using improved catalogue cross-matching techniques

Tom J Wilson (he/him) and Tim Naylor

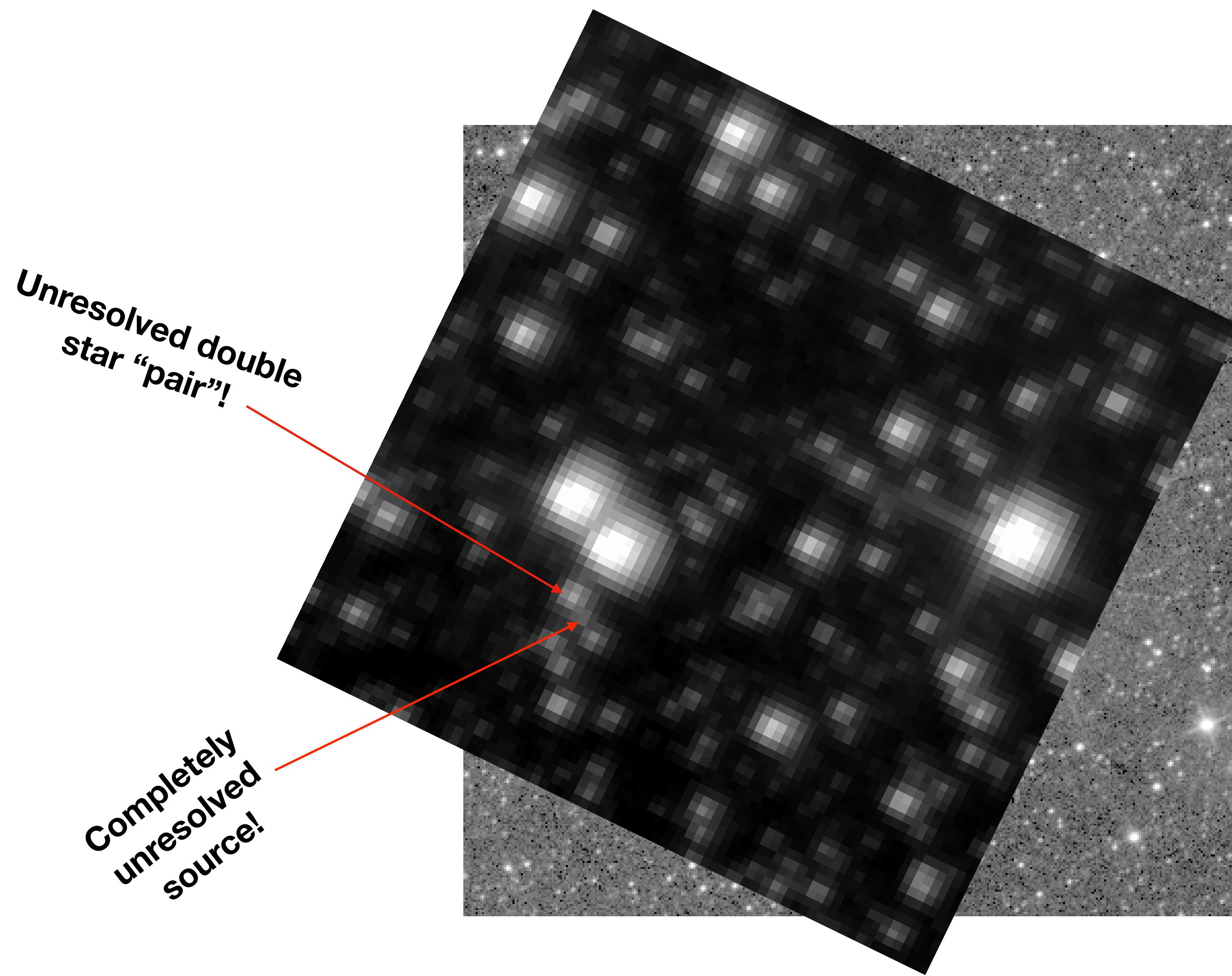
University of Exeter

t.j.wilson@exeter.ac.uk

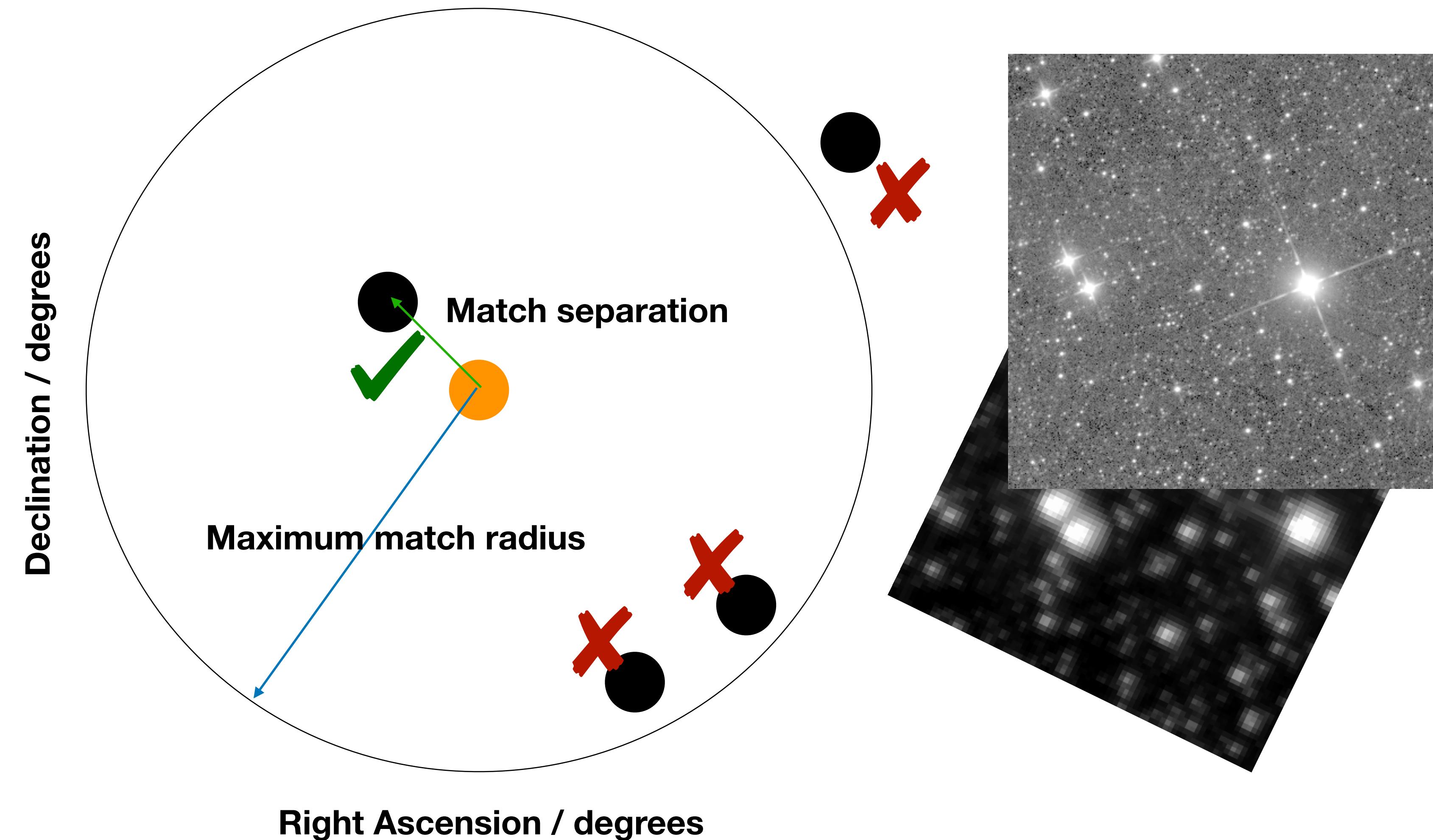
Photometric Observations



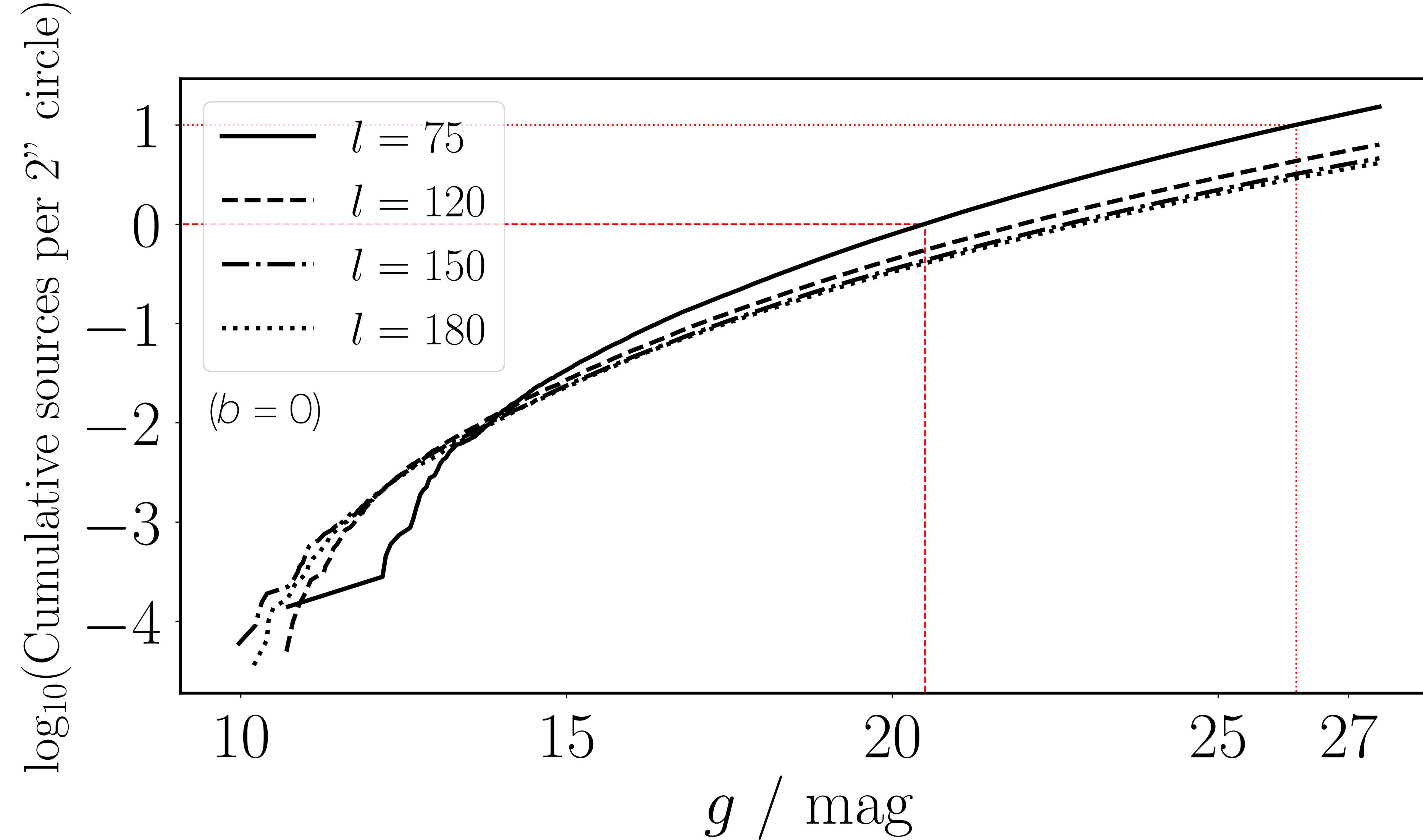
Photometric Observations



Catalogue Cross-Matching

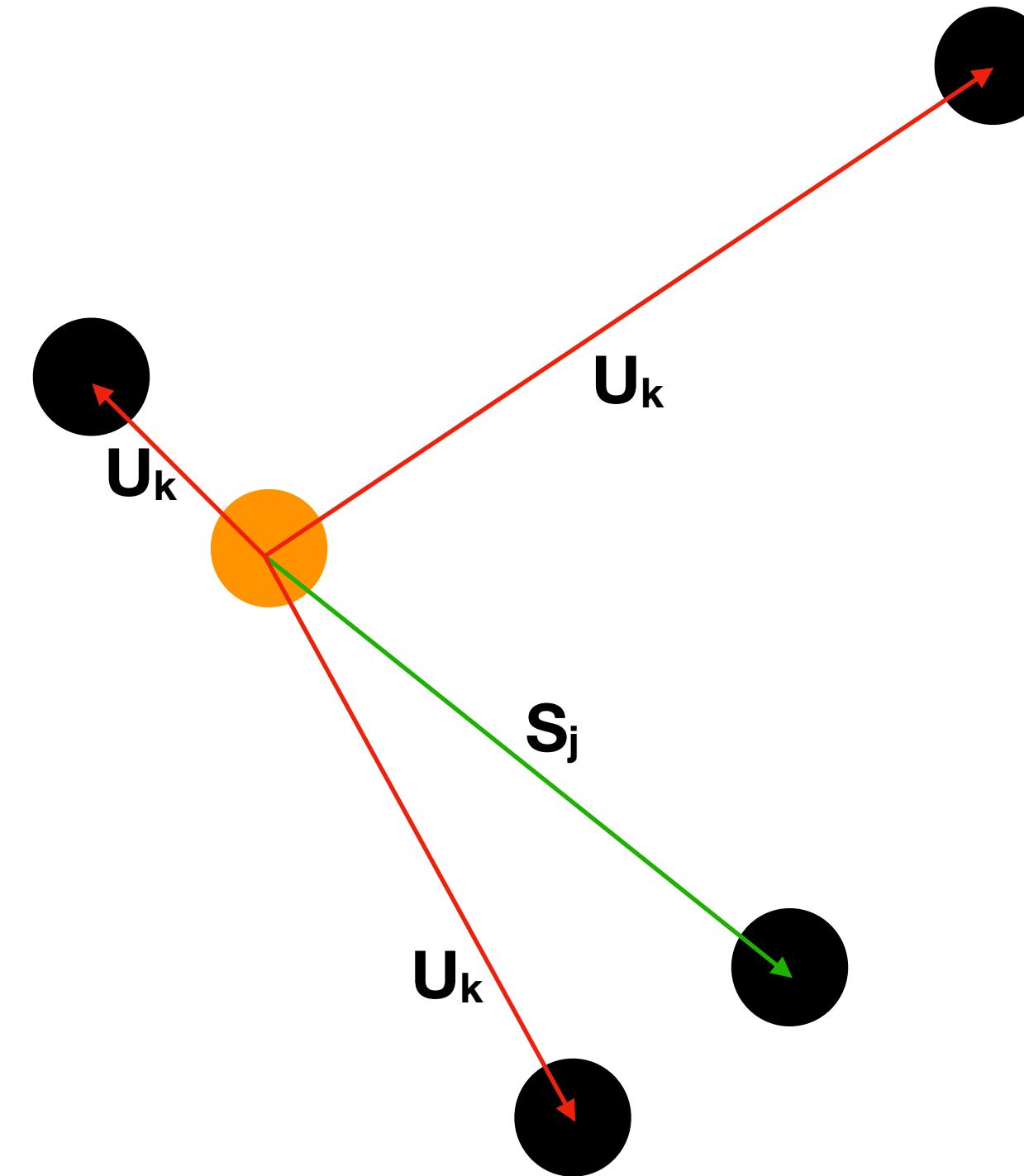


Vera C. Rubin Observatory's LSST's Completeness Depth



Catalogue Cross-Matching

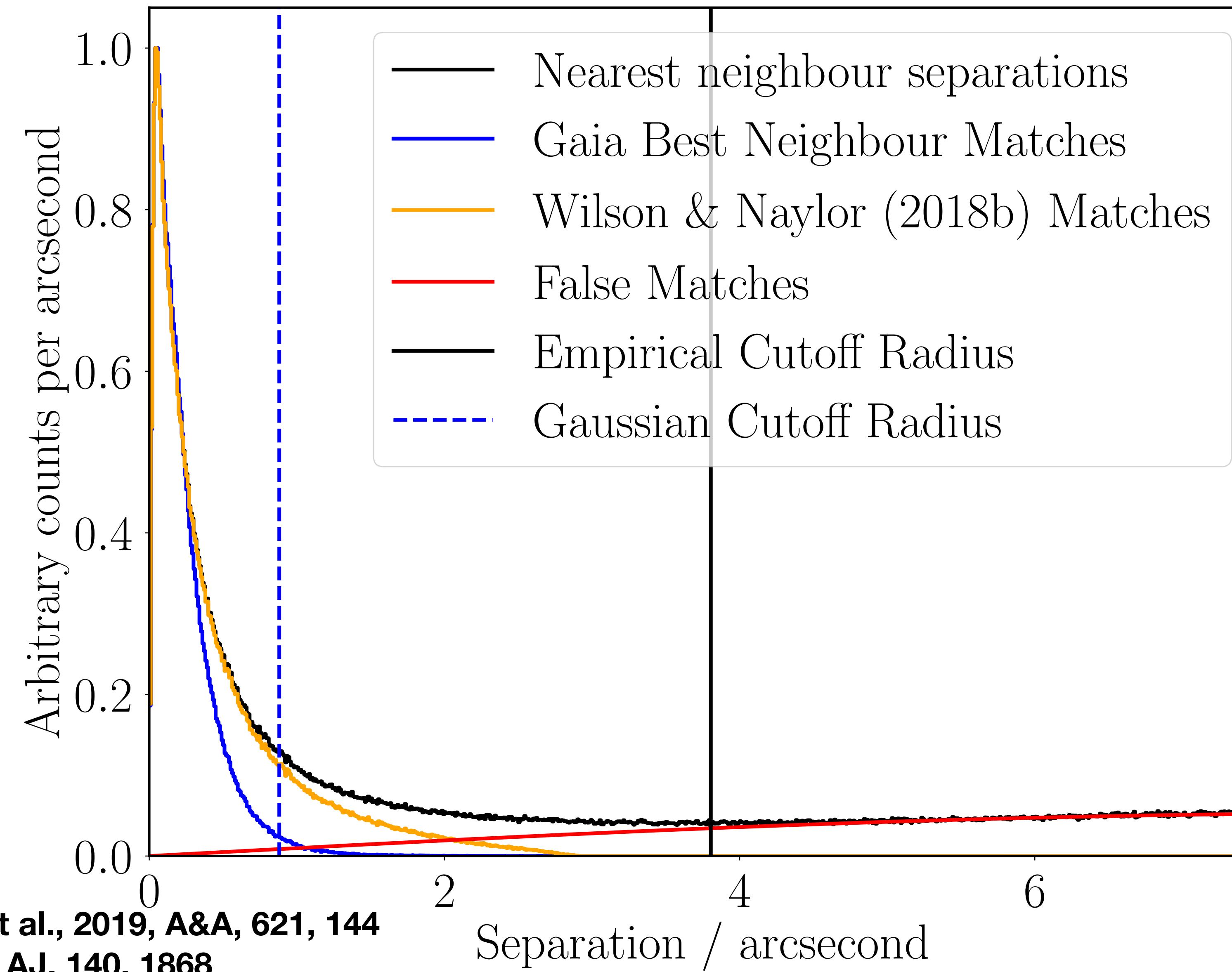
Declination / degrees



Right Ascension / degrees

$$L = \frac{q(m, c) f(x, y)}{n(m, c)}$$
$$R_j = \frac{\Pr \left[S_j \cap \left(\bigcap_{k \neq j} U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right]}{\sum_i \Pr \left[S_i \cap \left(\bigcap_{k \neq i} U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right] + \Pr \left[(m_s > m_{\text{lim}}) \cap \left(\bigcap_k U_k \right) \cap \left(\bigcap_{k'} E_{k'} \right) \right]}.$$

Cross-match Separation Distributions



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

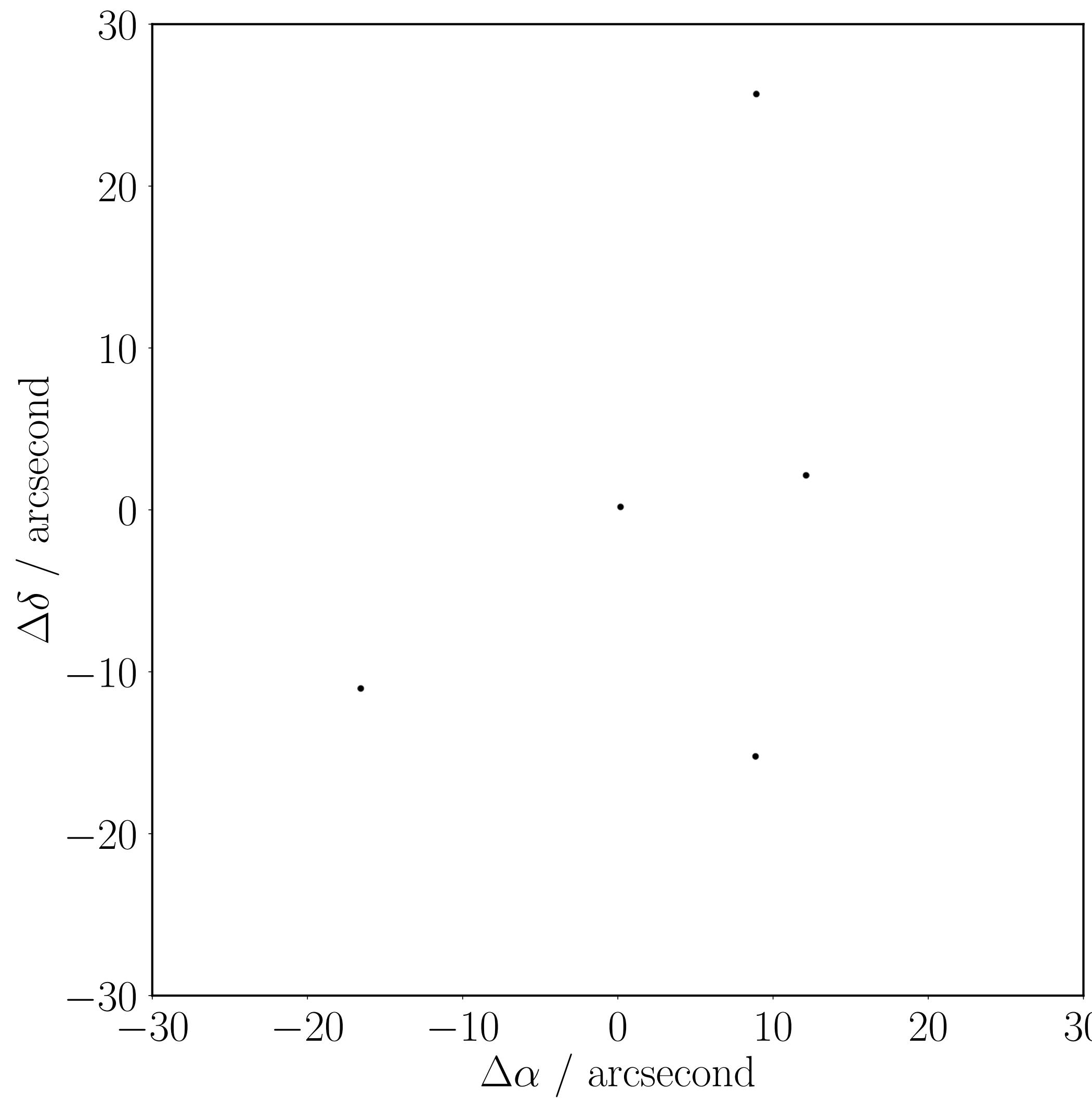
WISE - Wright et al., 2010, AJ, 140, 1868

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

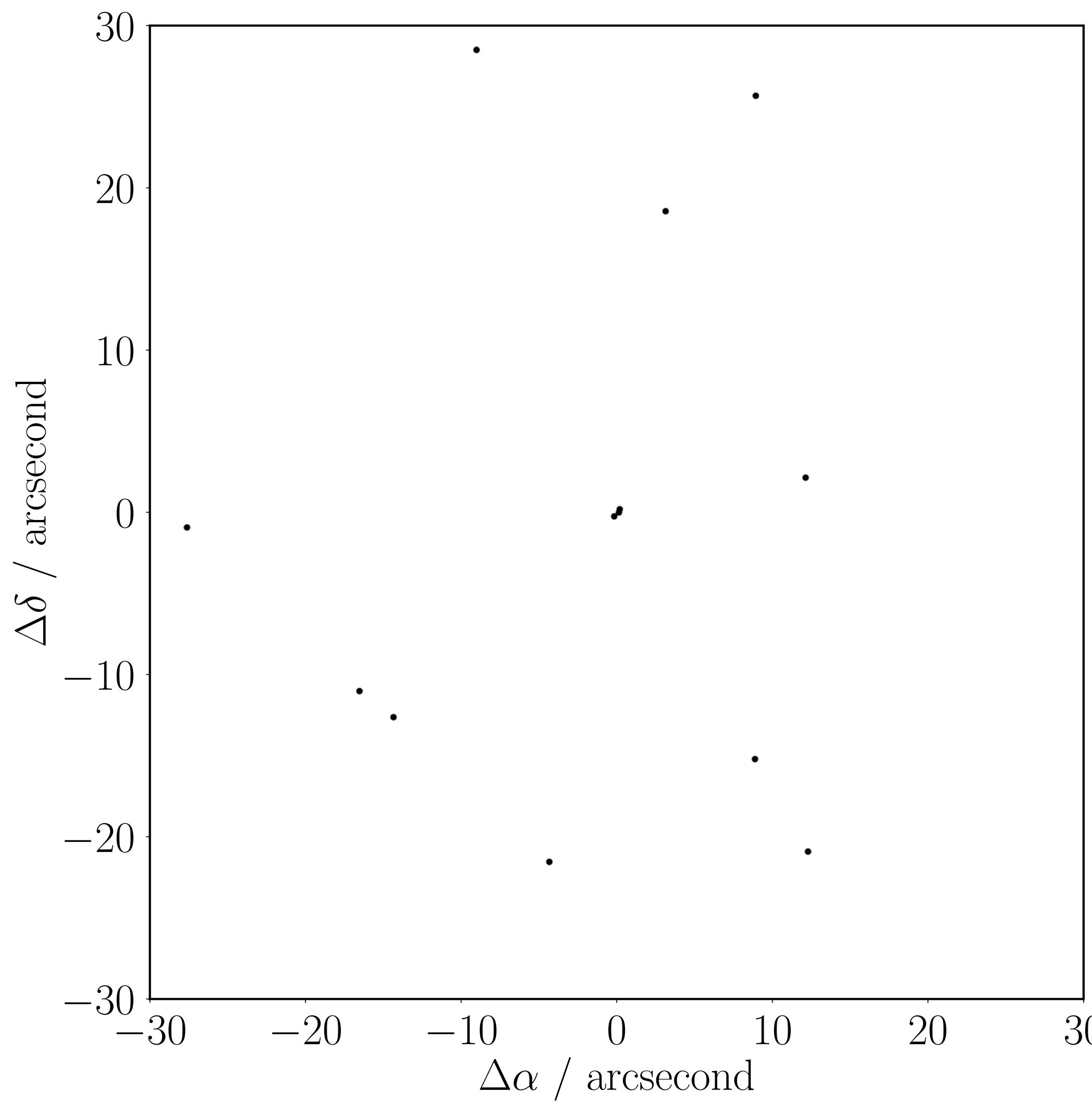
Gaia DR2 - Gaia Collaboration, Brown A. G. A., et al. 2018, A&A, 616, 1

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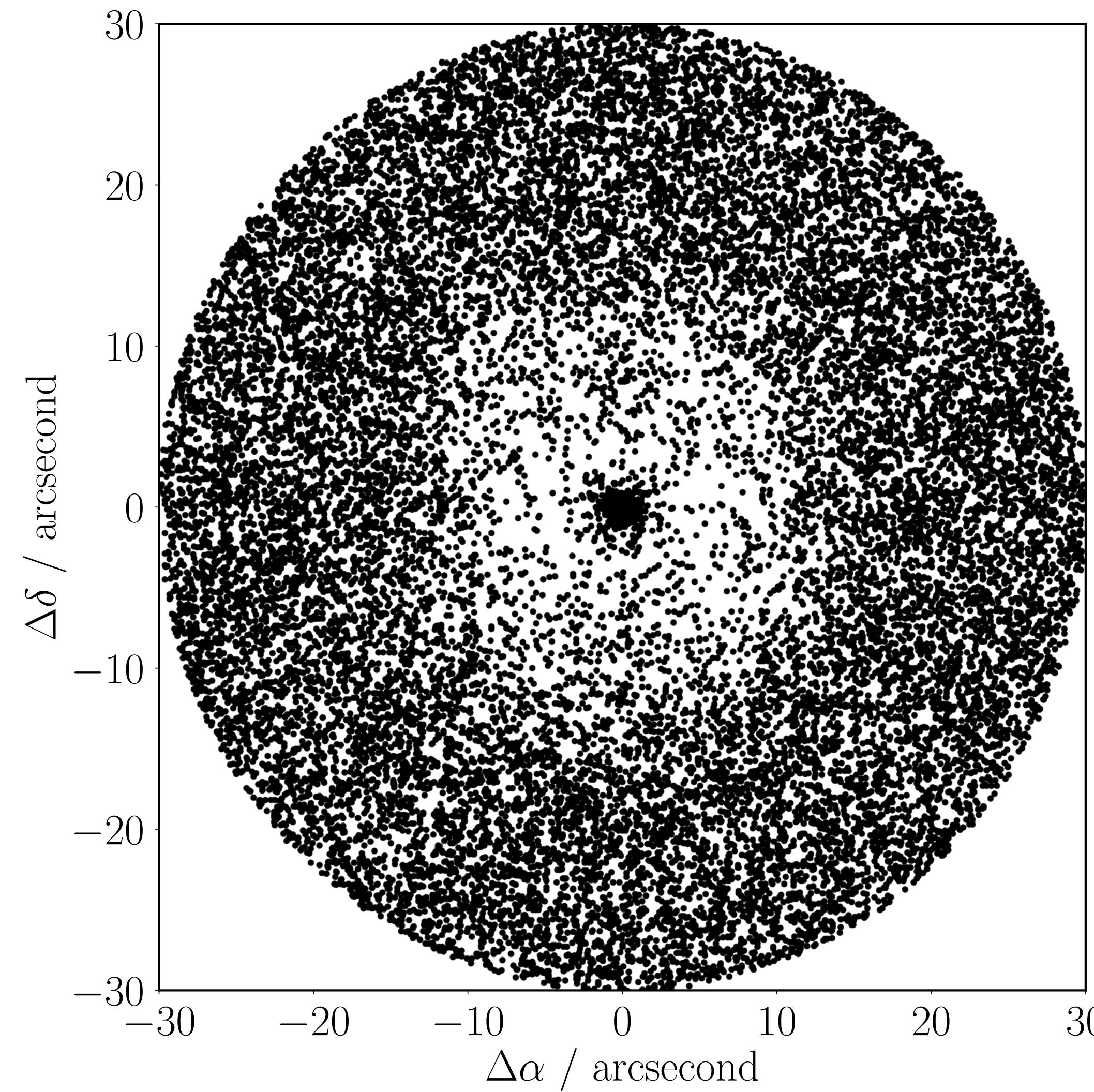
The Astrometric Uncertainty Function: Crowding



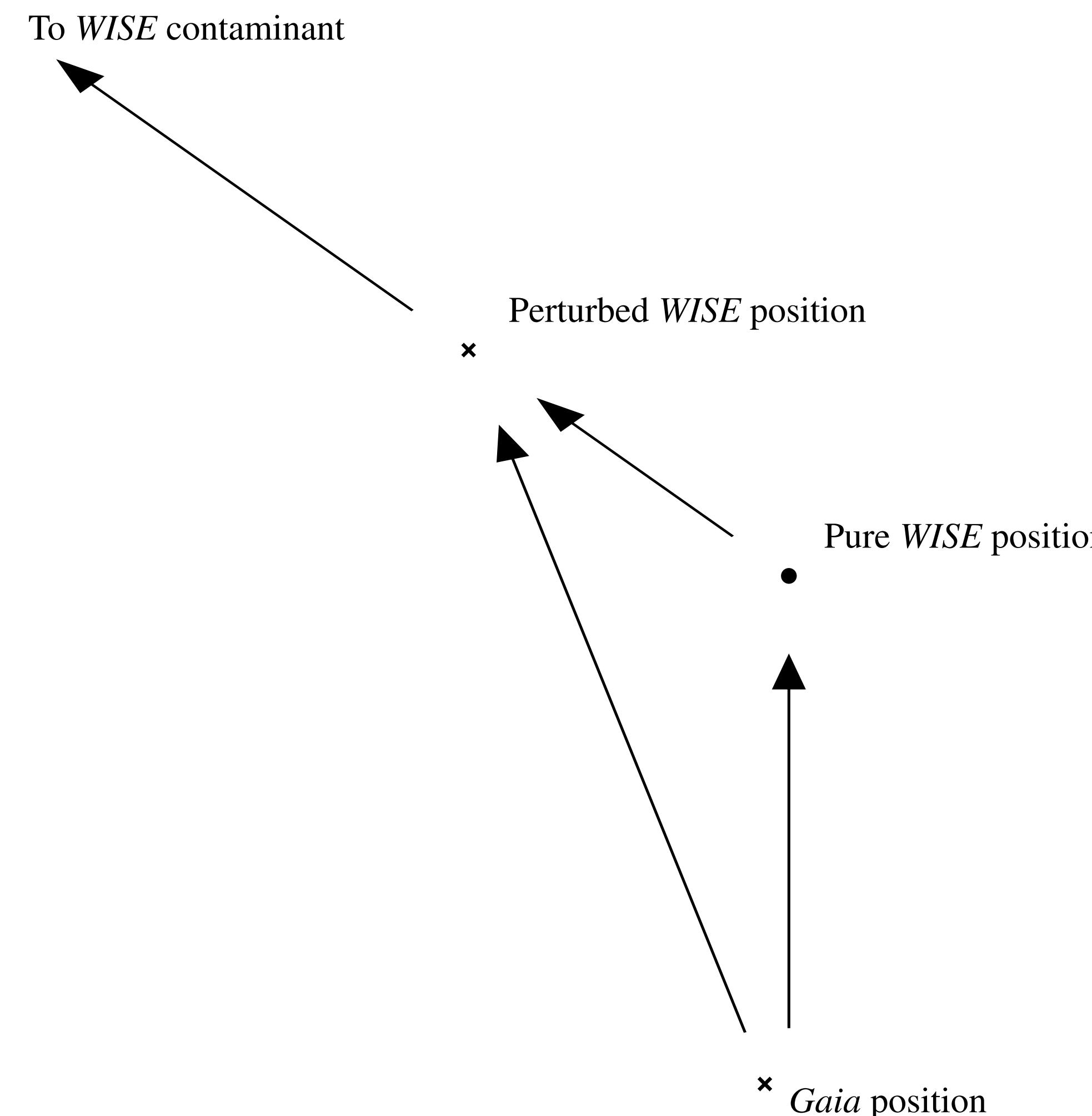
The Astrometric Uncertainty Function: Crowding



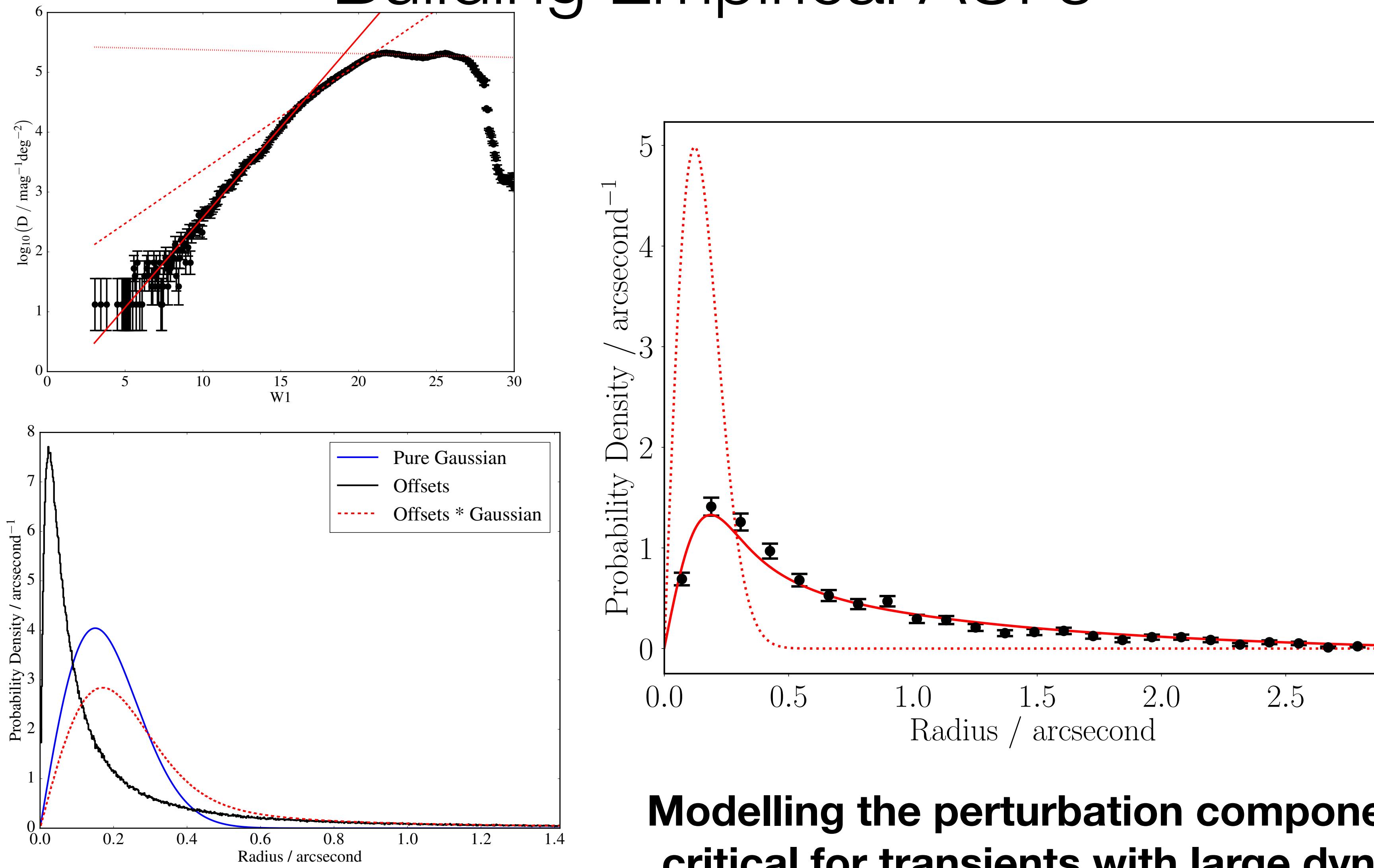
The Astrometric Uncertainty Function: Crowding



The Astrometric Uncertainty Function: Perturbation

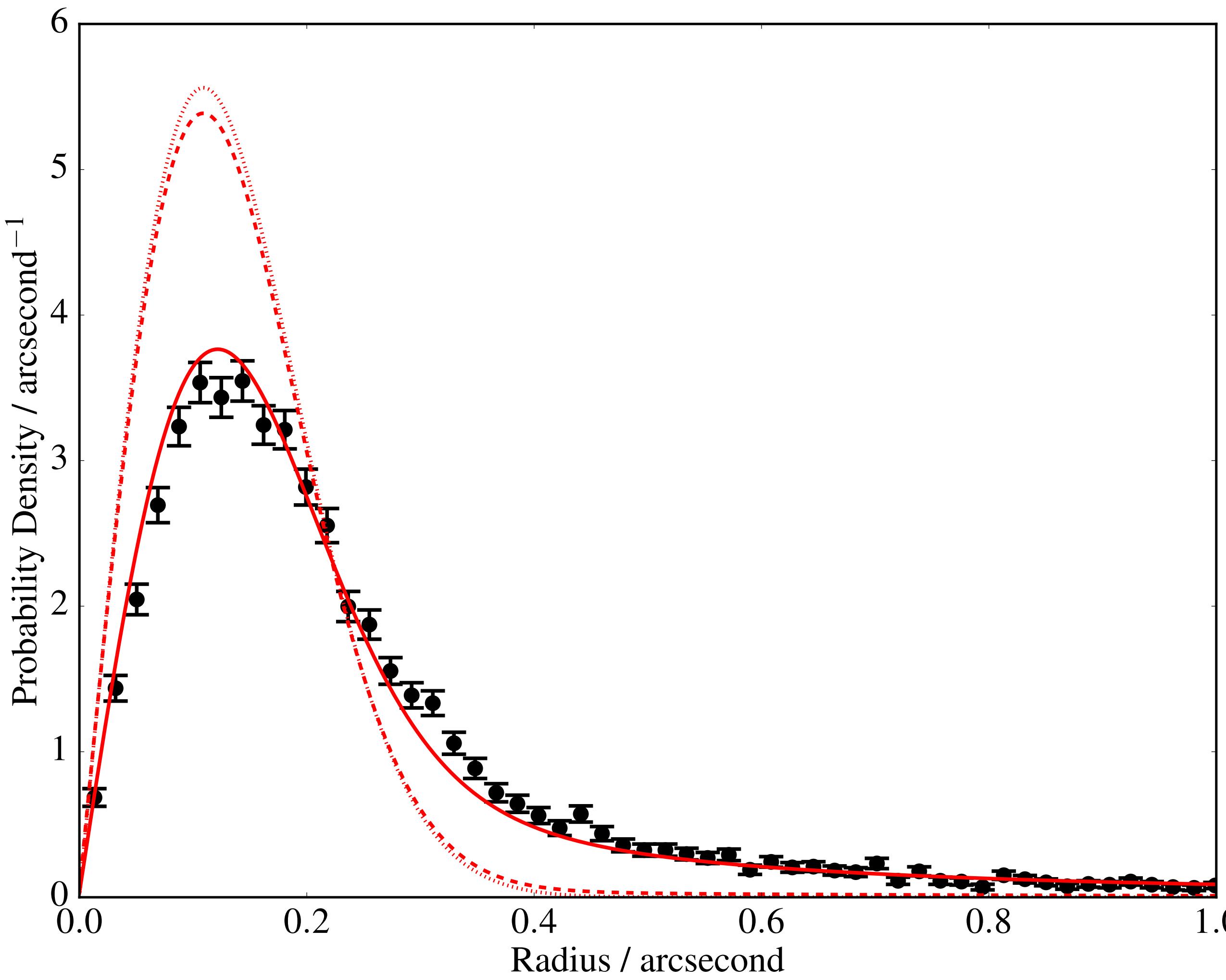


The Astrometric Uncertainty Function: Building Empirical AUFs

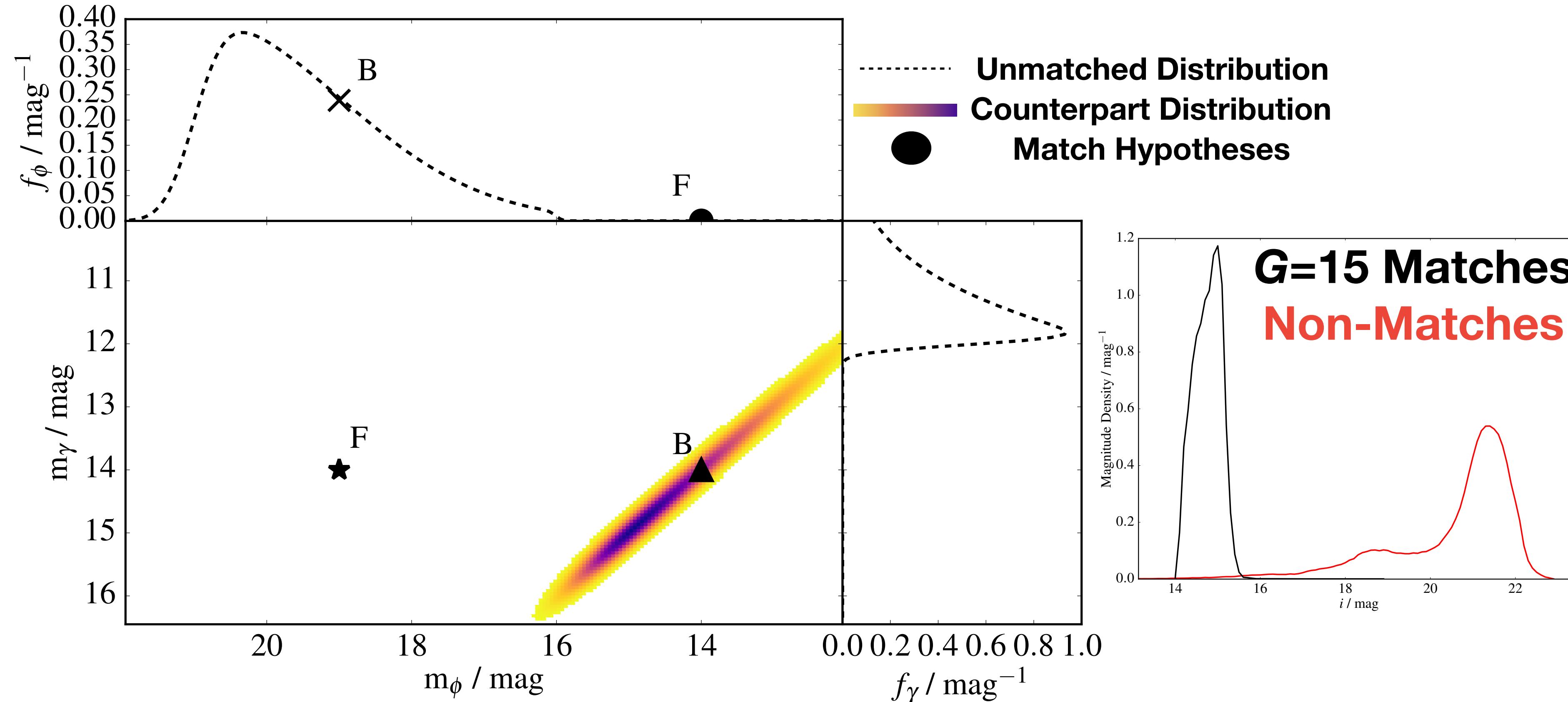


**Modelling the perturbation component of the AUF
critical for transients with large dynamic ranges!**

Contamination Effects: Galaxy Contamination



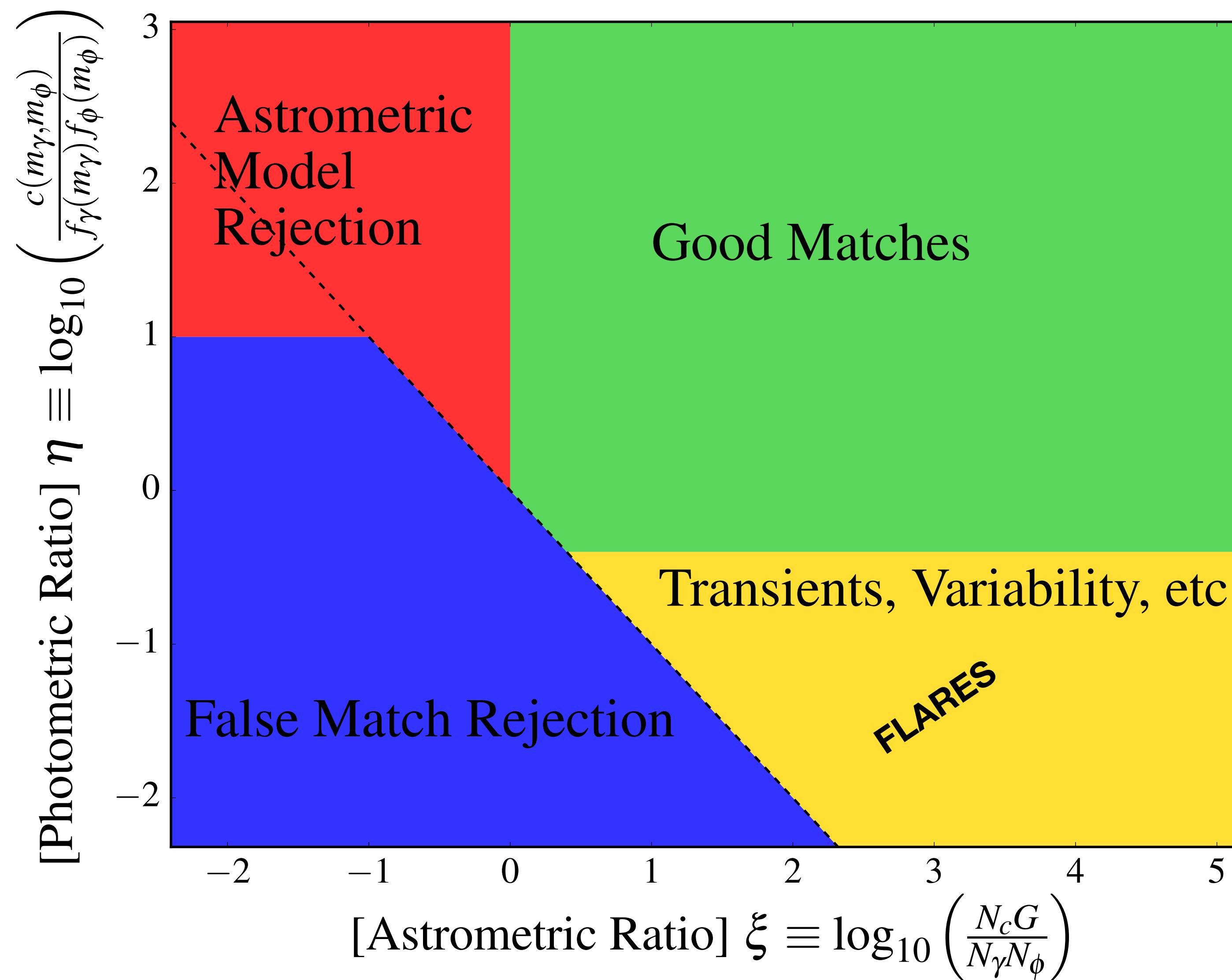
Probability-based Catalogue Matching: Including the Magnitude Information



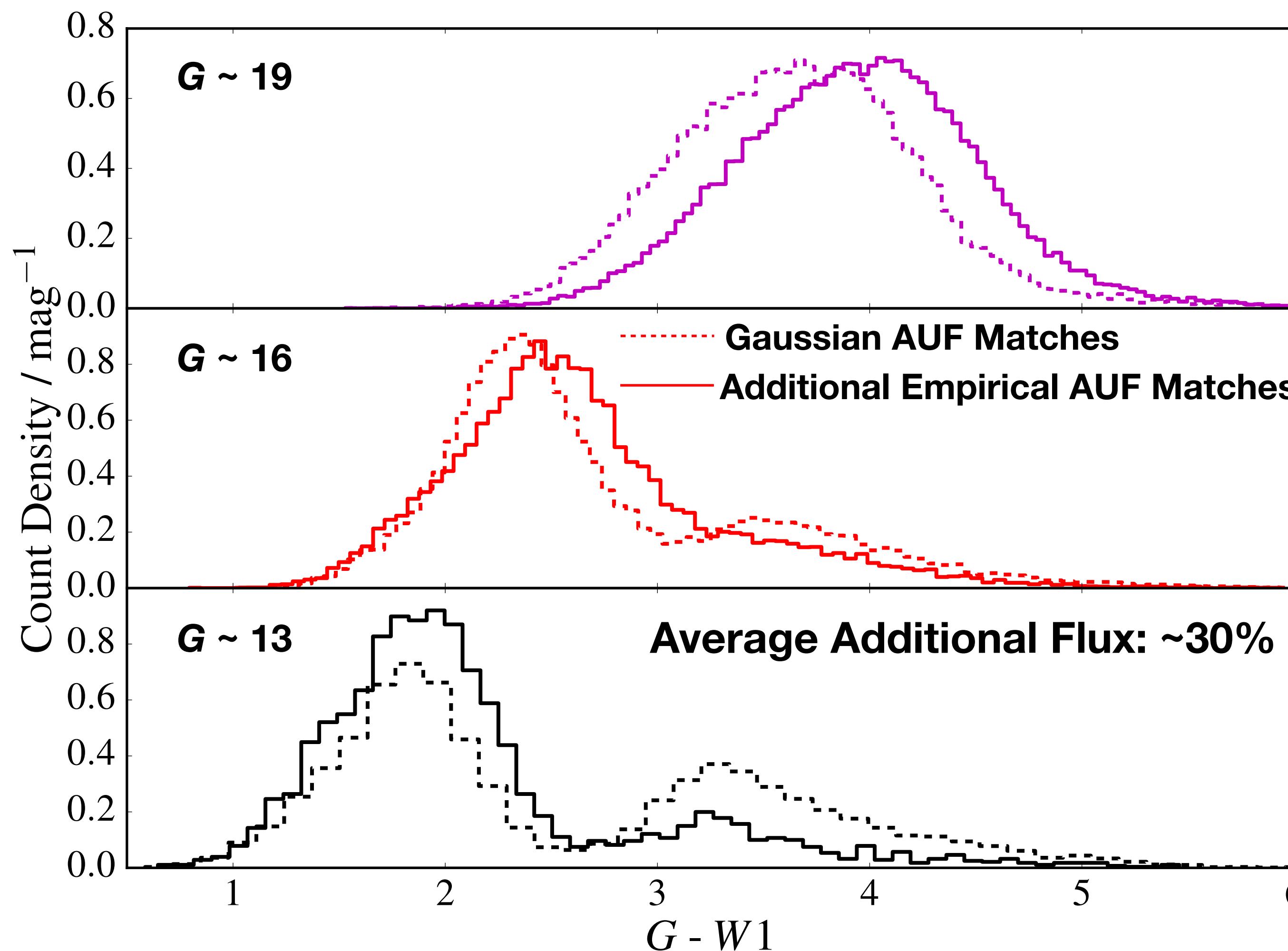
$$g(x_k, y_k, x_l, y_l) = N_c \iint_{-\infty}^{+\infty} h_\gamma(\Delta x_{kl} - x, \Delta y_{kl} - y) h_\phi(x, y) dx dy$$

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

Probability-based Catalogue Matching: The Likelihood Ratio Space



Contamination Effects: Perturbation-Colour Correlation



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

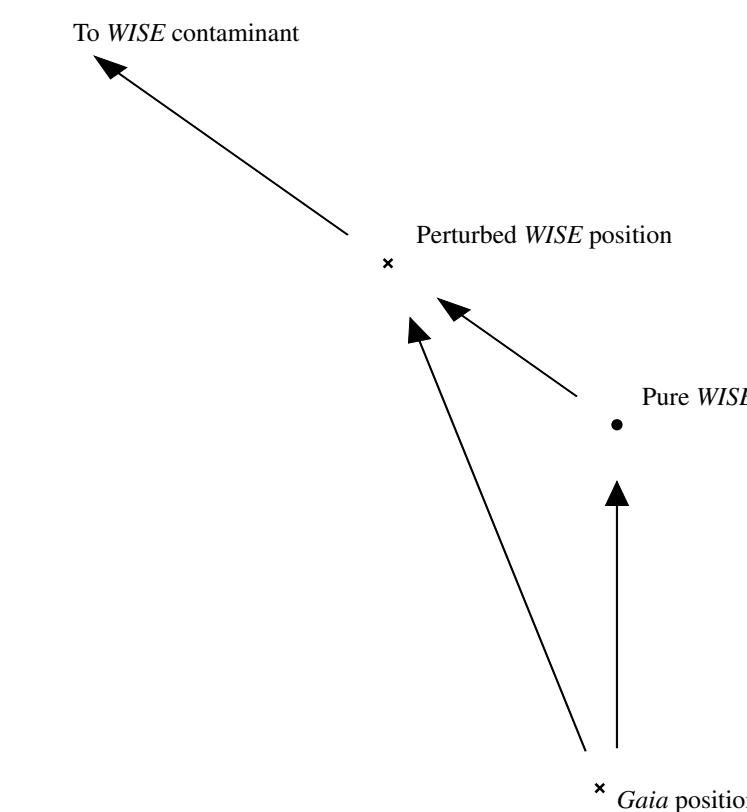
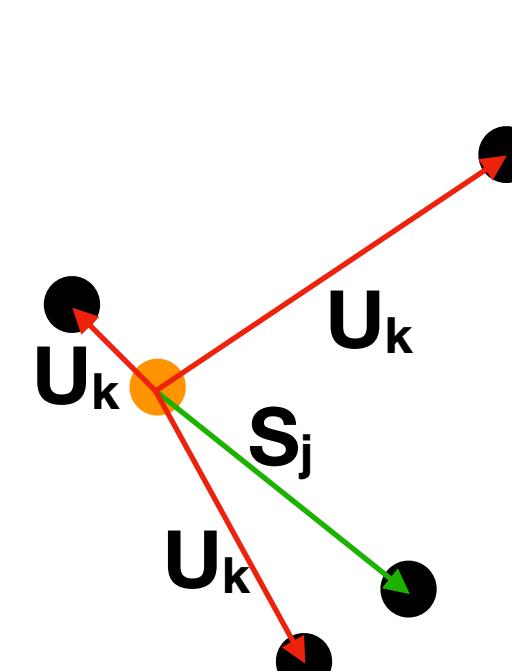
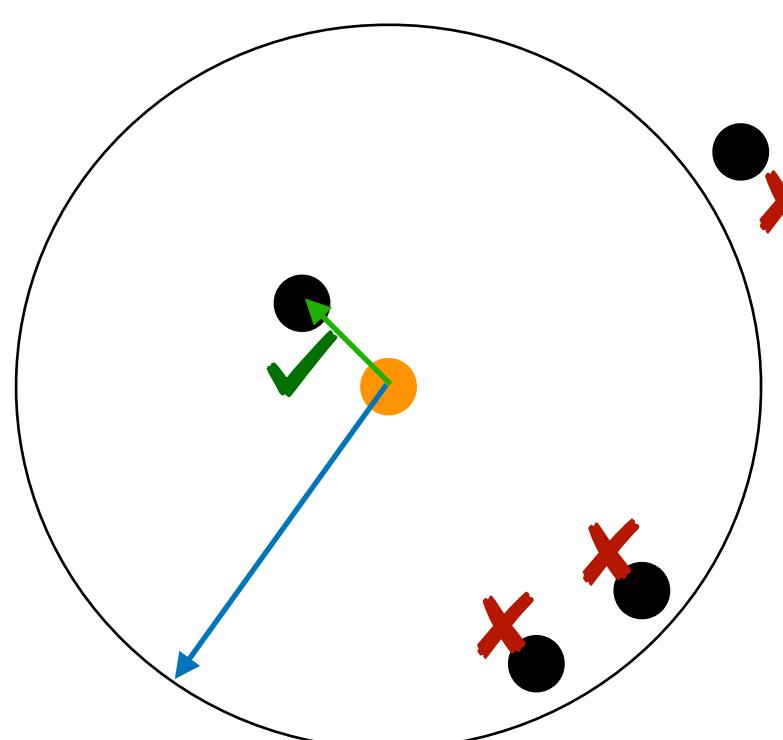
What does this mean for TVS?

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

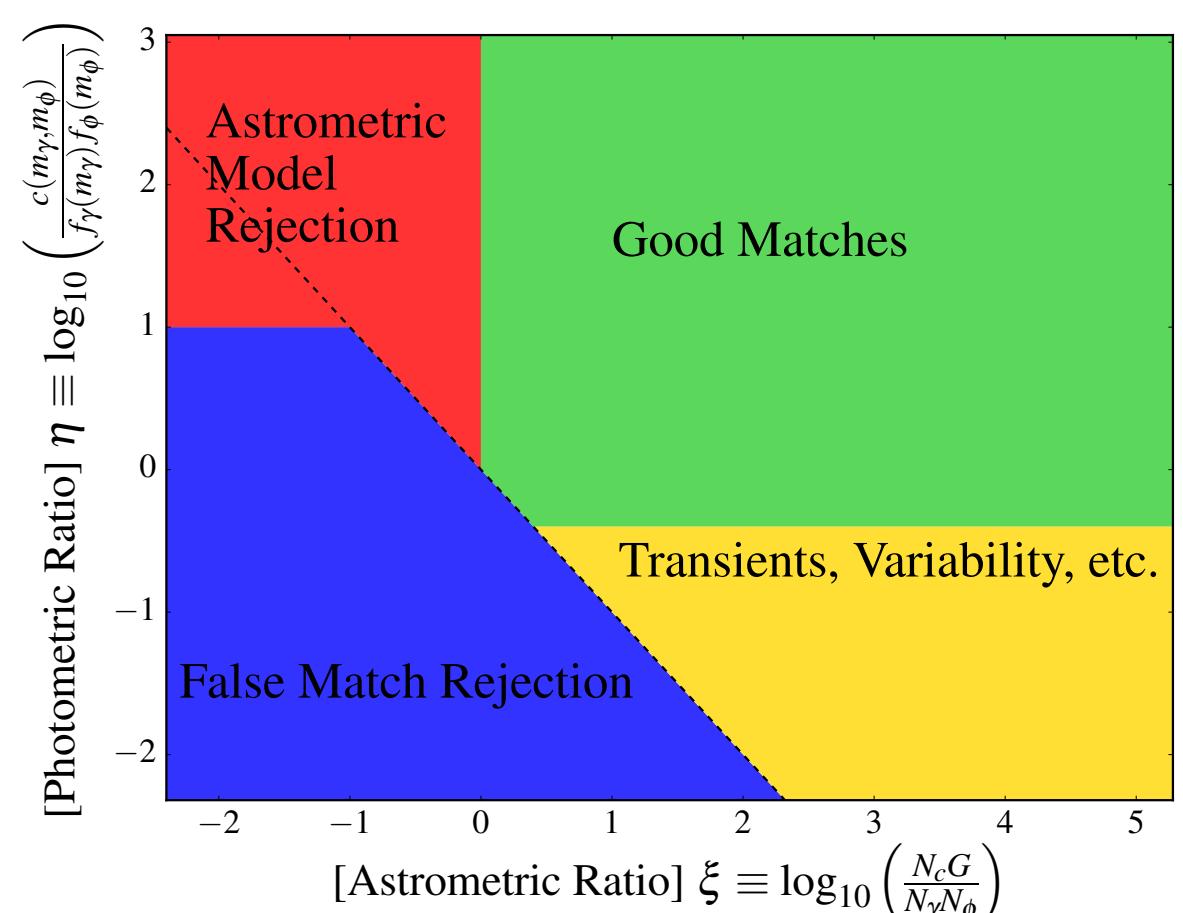
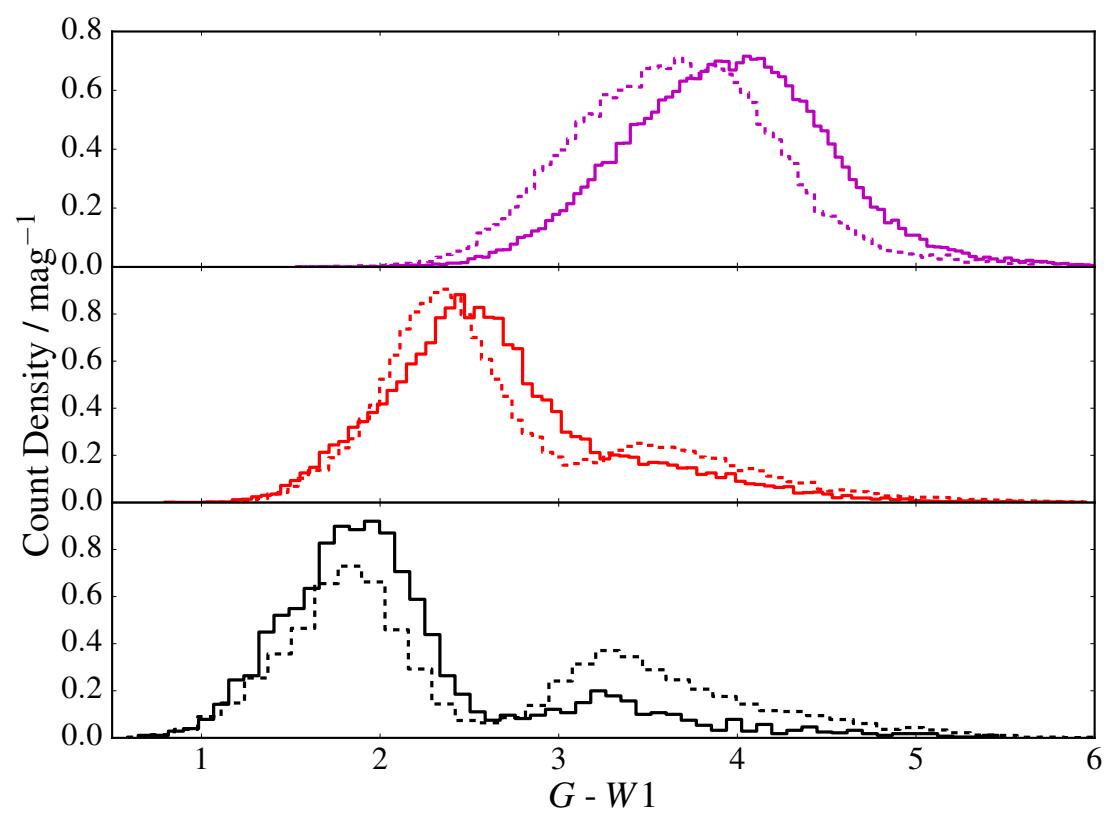
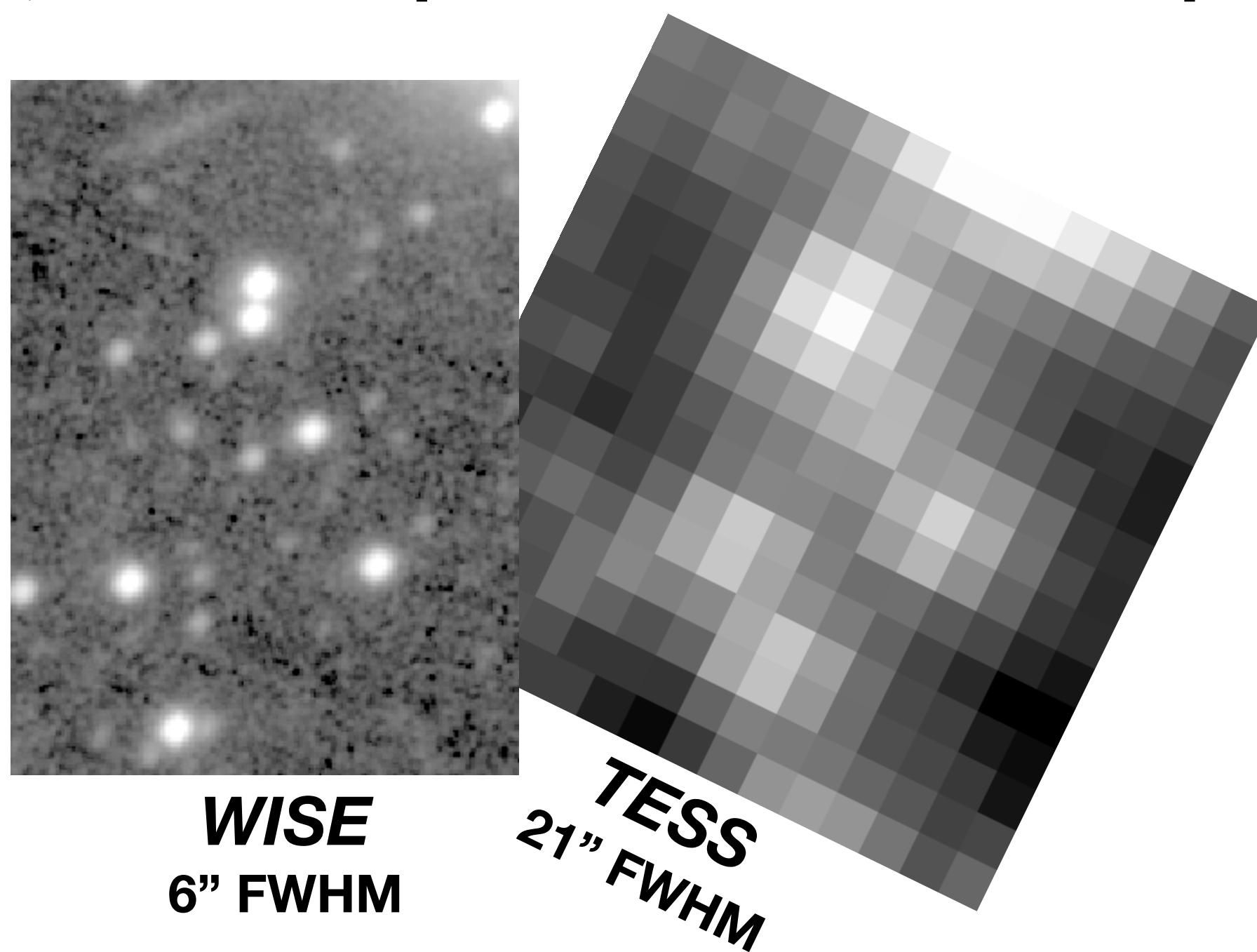
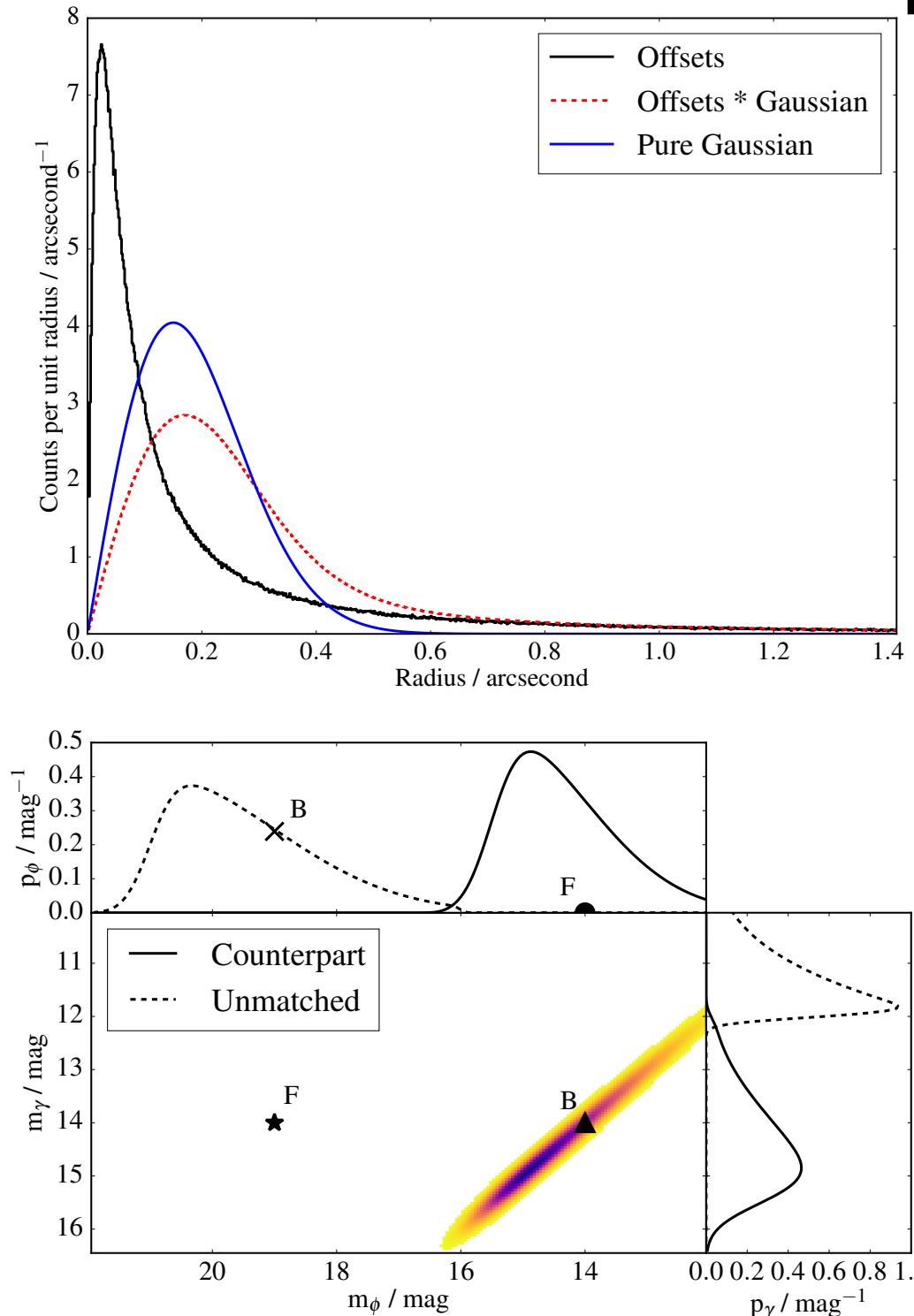
The “smart” astronomer: uses our cross-matches to get the correct number of matches
and information on how much flux contamination is brightening their progenitor!



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



Wilson & Naylor, 2017, MNRAS, 468, 2517

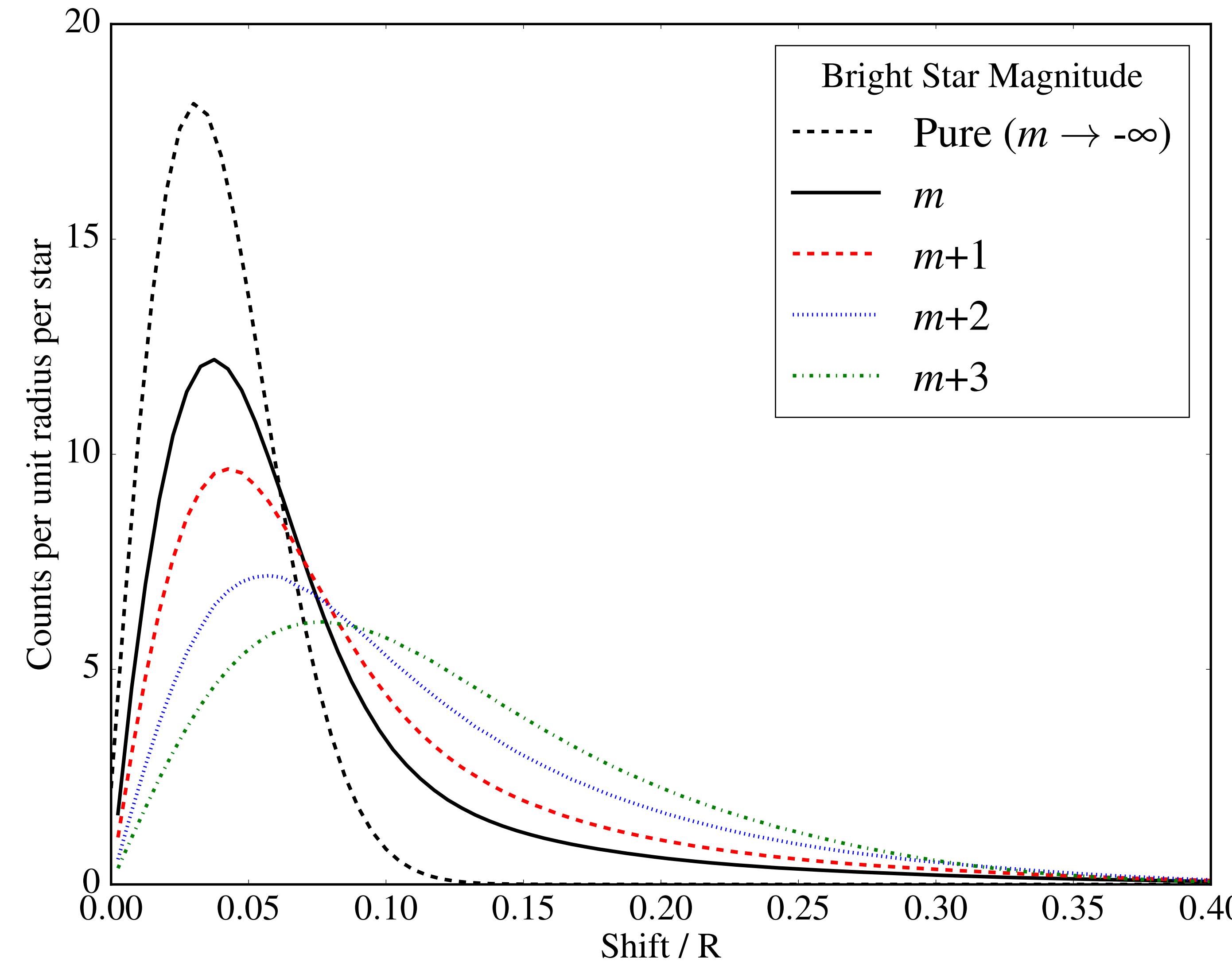
Wilson & Naylor, 2018a, MNRAS, 473, 5570

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

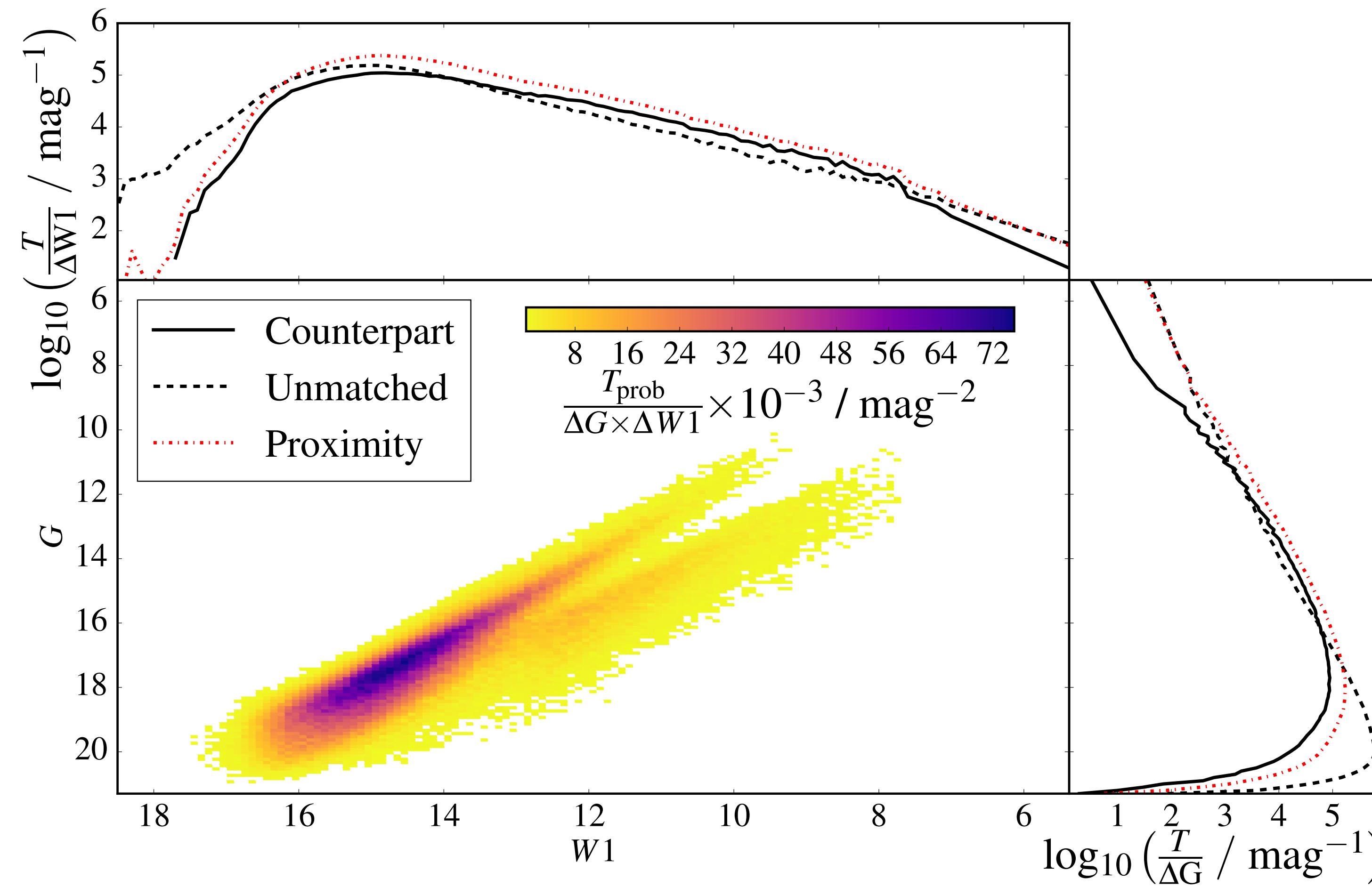
<https://github.com/Onoddil/macauff>

Tom J Wilson @onoddil

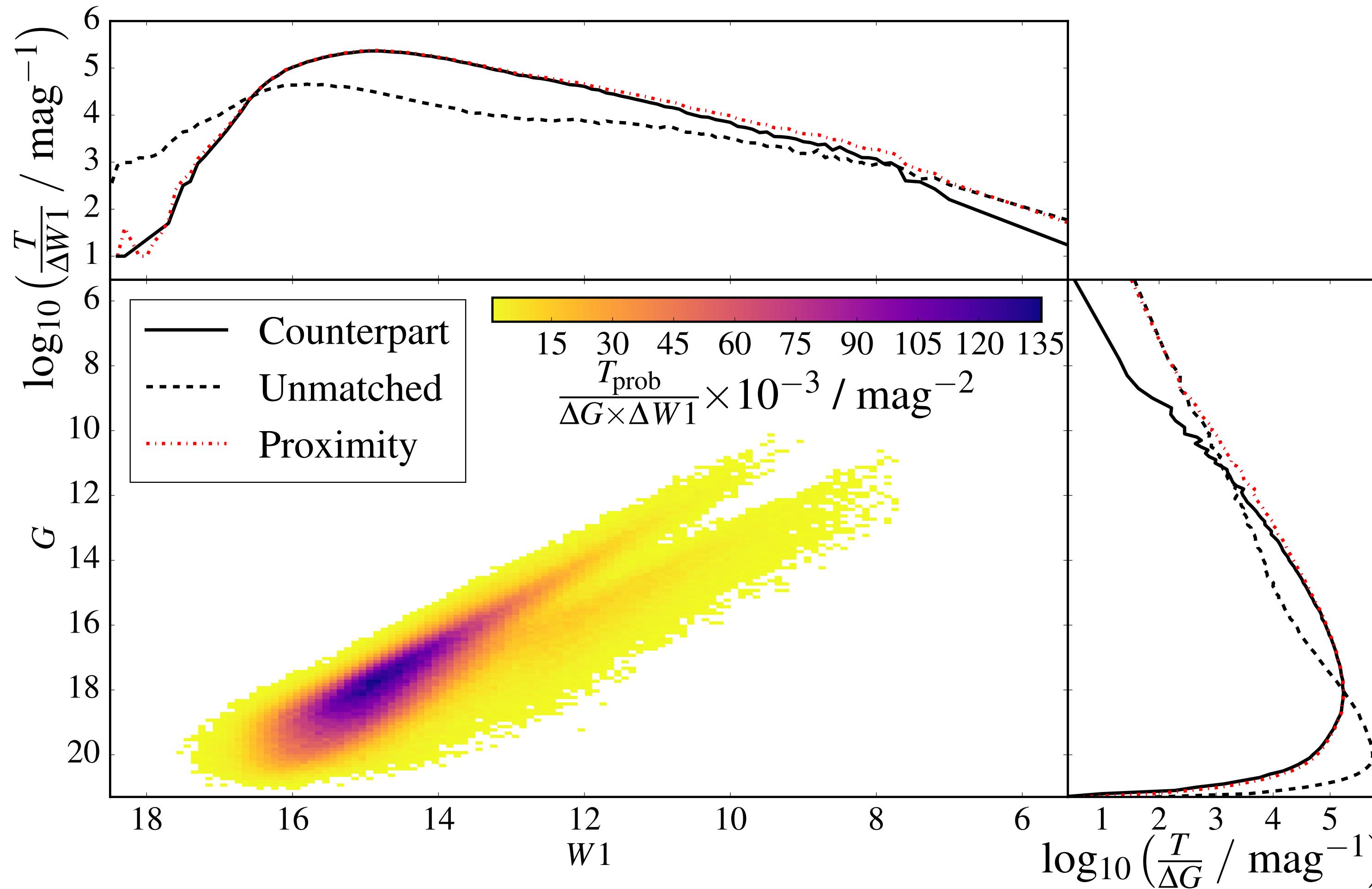
The Astrometric Uncertainty Function: Synthetic Non-Gaussian Tails



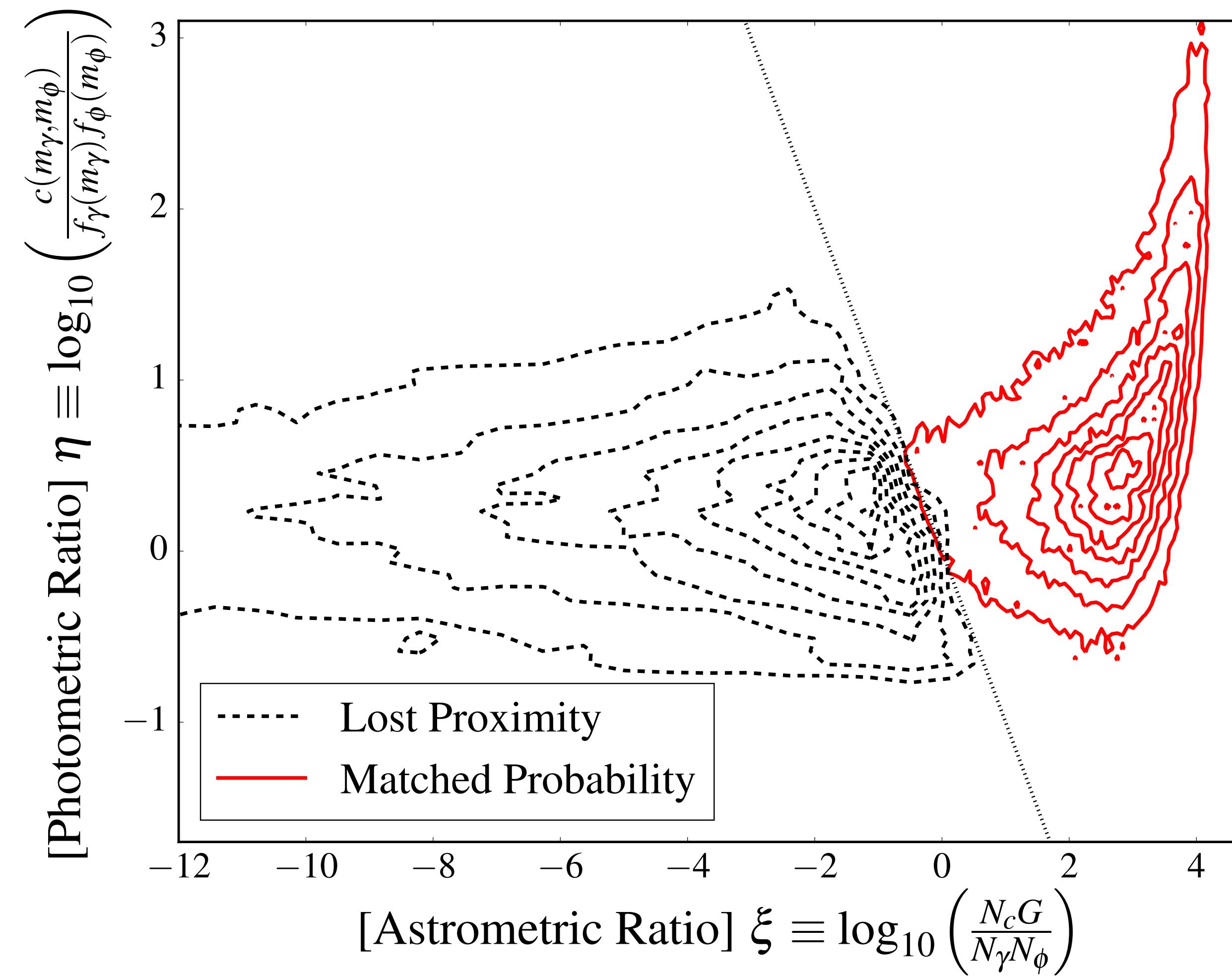
Contamination Effects: Gaia-WISE Gaussian Matches



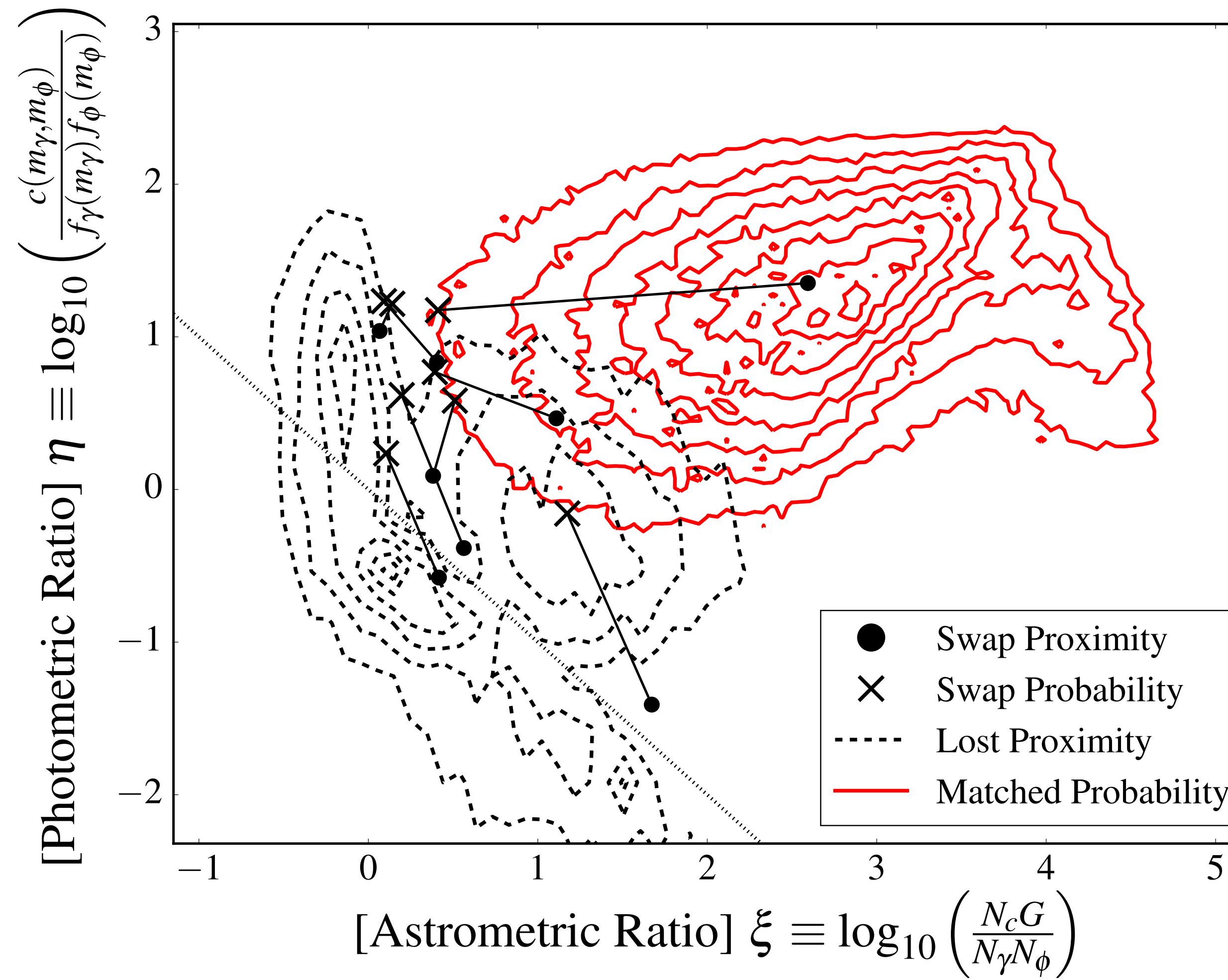
Contamination Effects: Gaia-WISE Empirical Matches



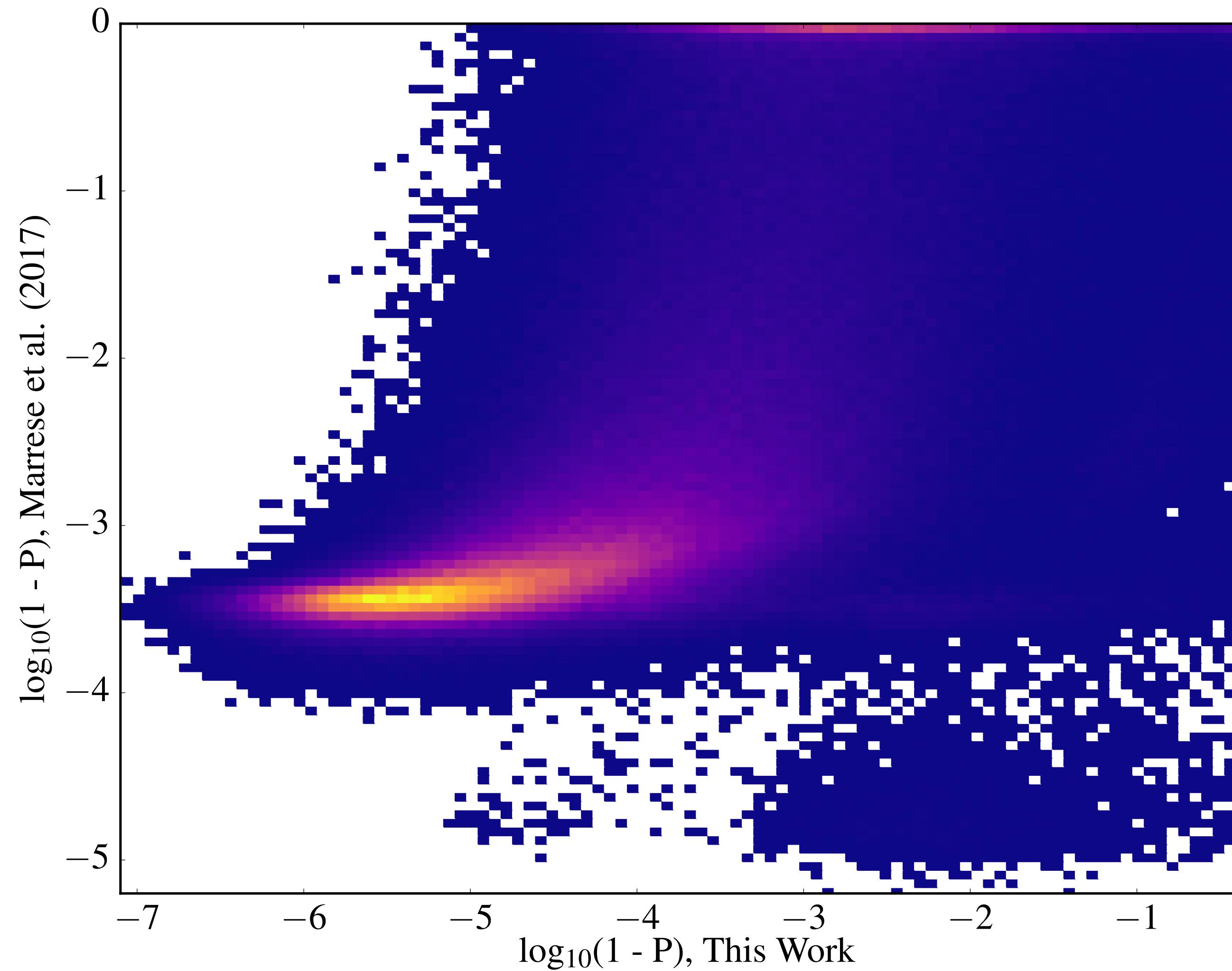
Contamination Effects: Lost Proximity Matches



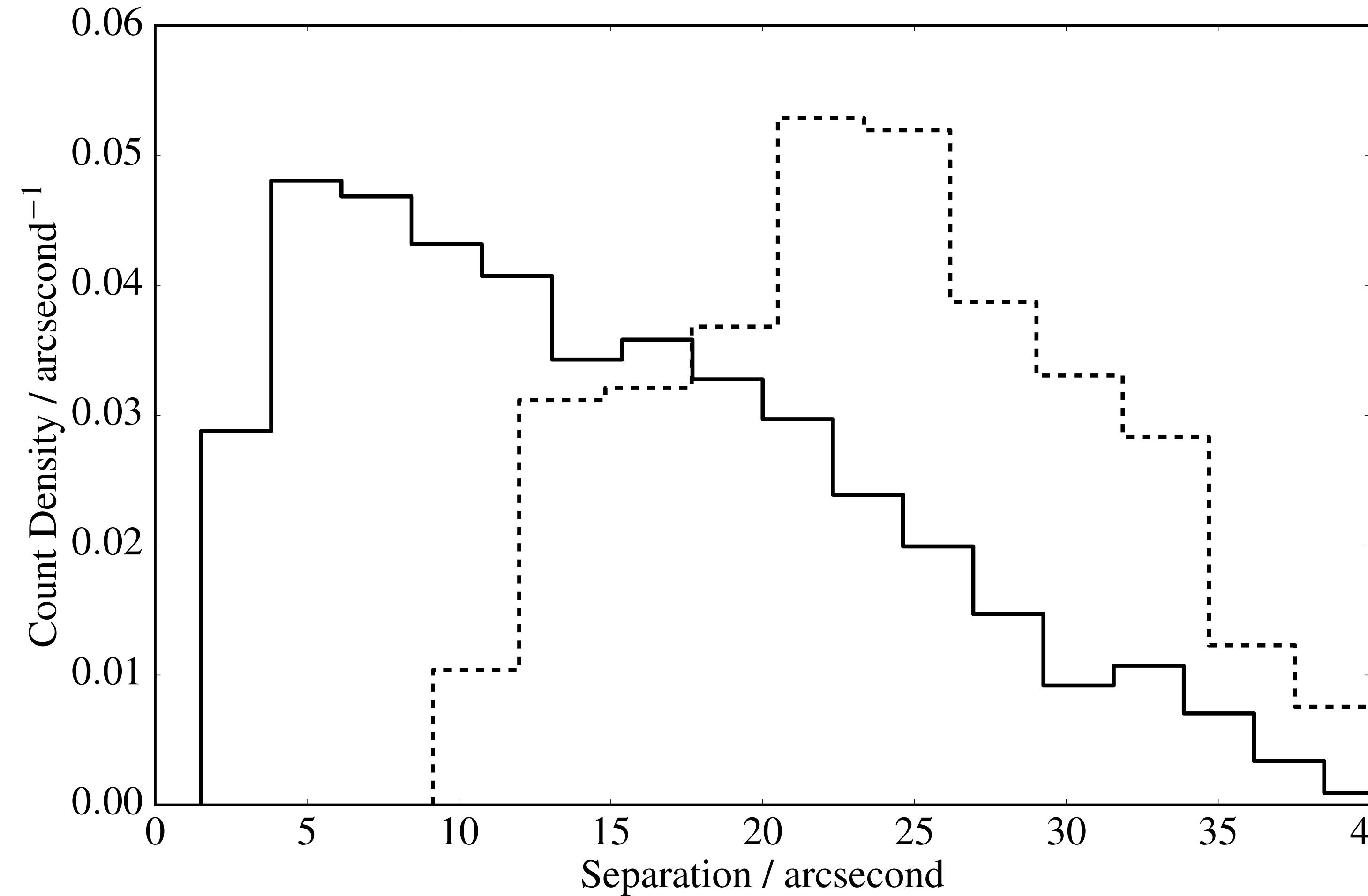
Contamination Effects: Lost Proximity Matches



Contamination Effects: Gaia Lost Matches



Contamination Effects: Resolving Contaminants



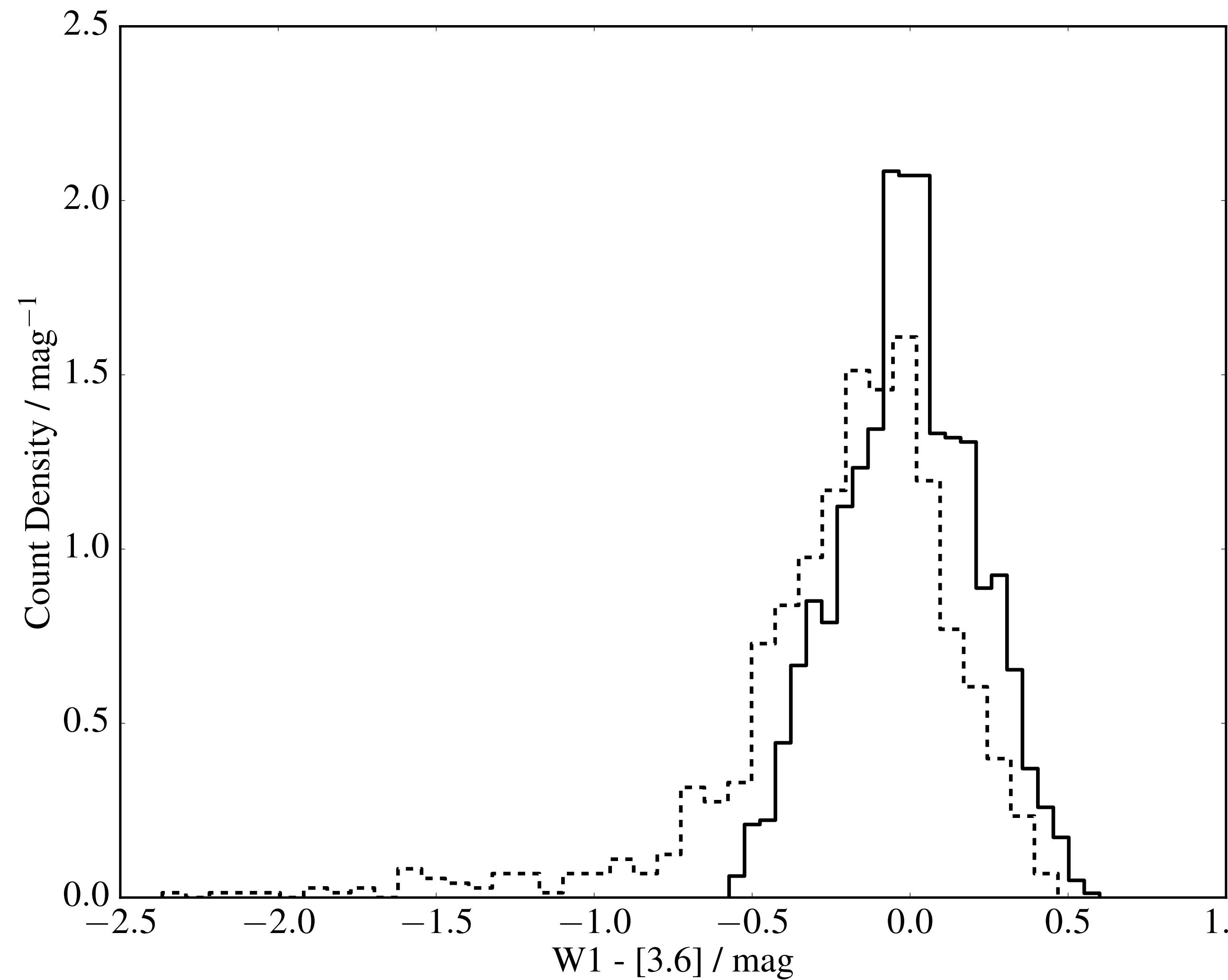
Spitzer - Werner et al., 2004 ,ApJS, 154, 1

IRAC - Fazio et al., 2004, ApJS, 154, 10

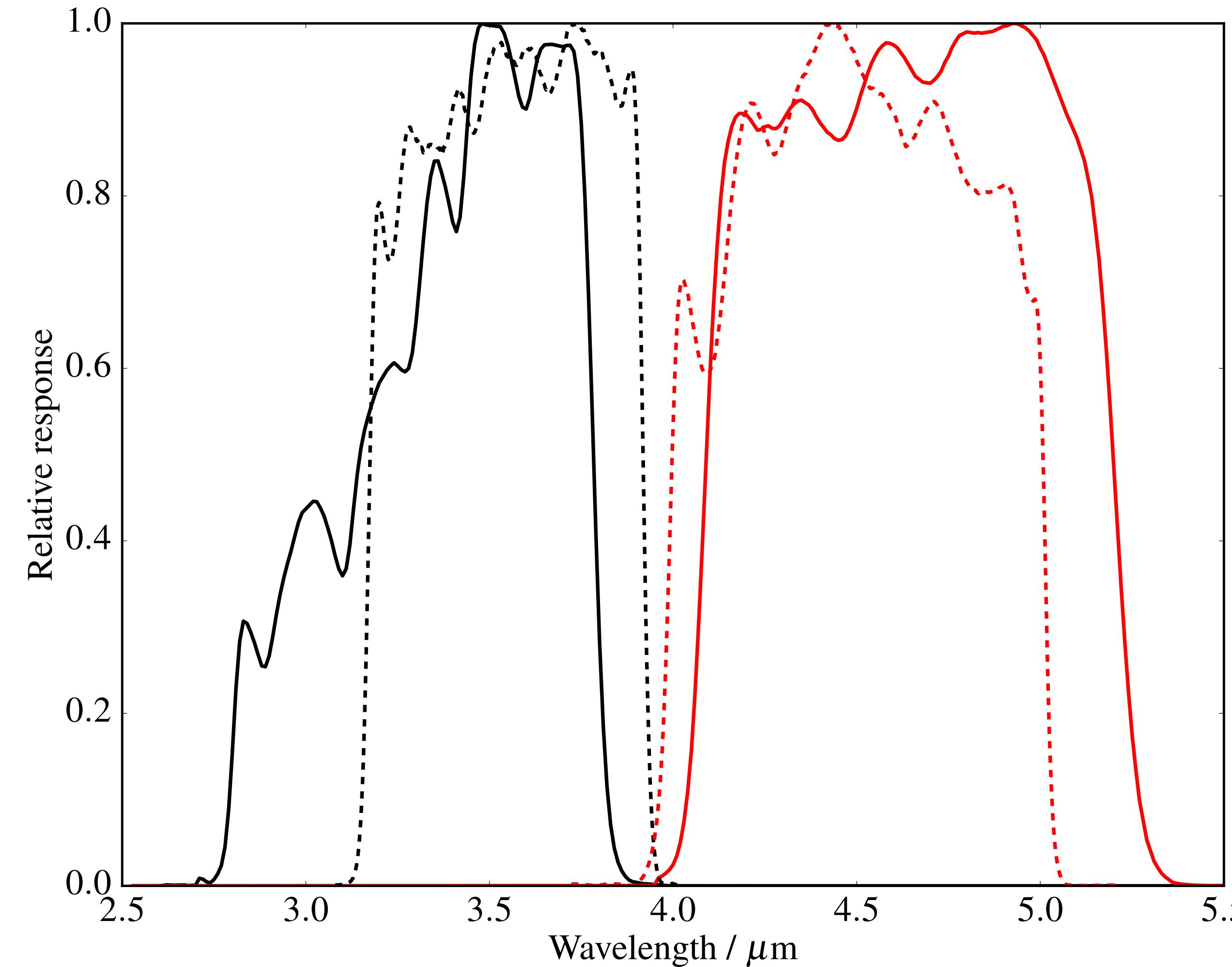
Wilson & Naylor, MNRAS, 2018b, 481, 2148

Tom J Wilson @onoddil

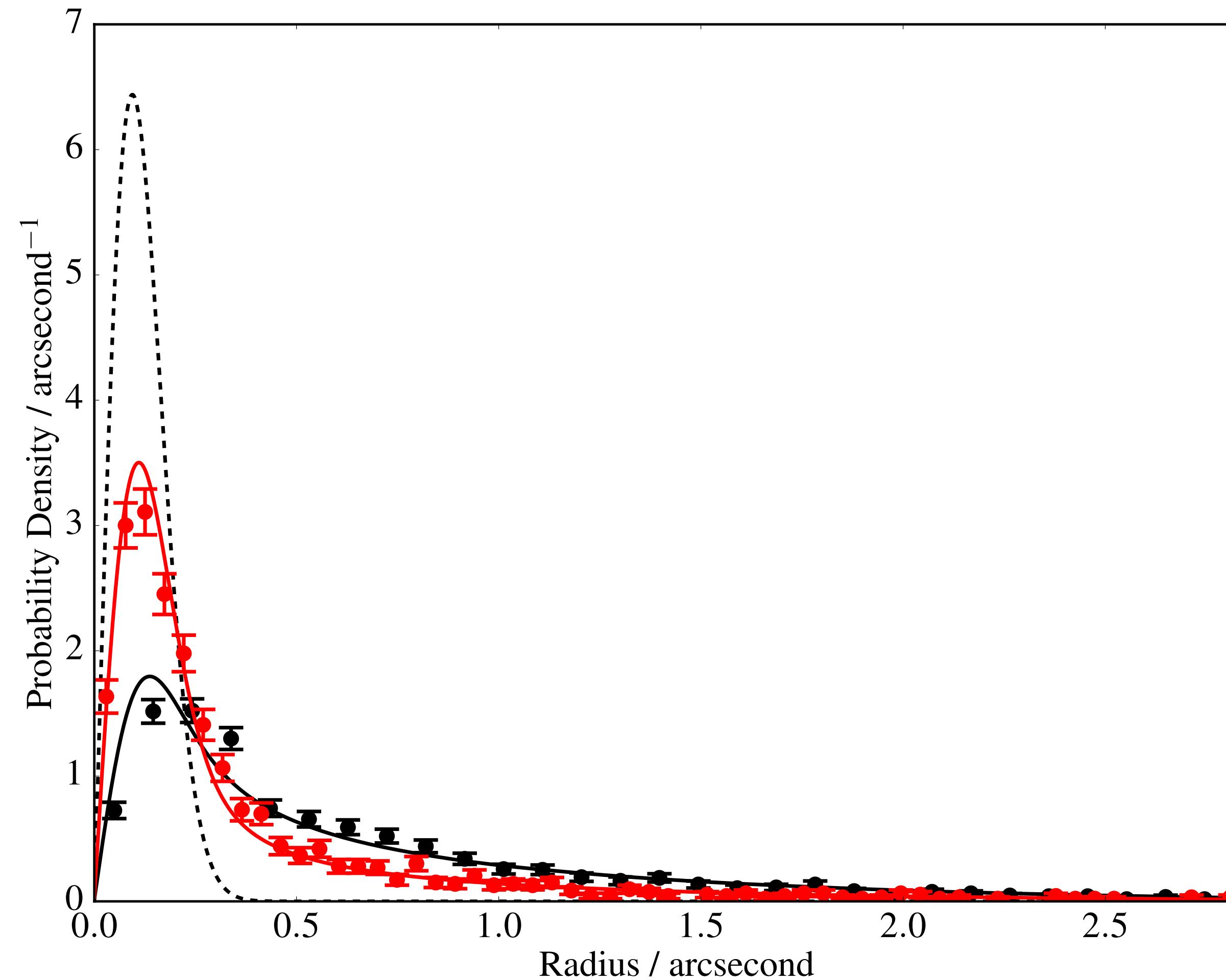
Contamination Effects: Resolving Contaminant Flux



Contamination Effects: Wavelength Coverage



Contamination Effects: Crowding Normalisation



The Astrometric Uncertainty Function: Analytical perturbations

