# The Effect of Unresolved Contaminant Stars on the Cross-Matching of Photometric Catalogues

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Tim Naylor, also University of Exeter
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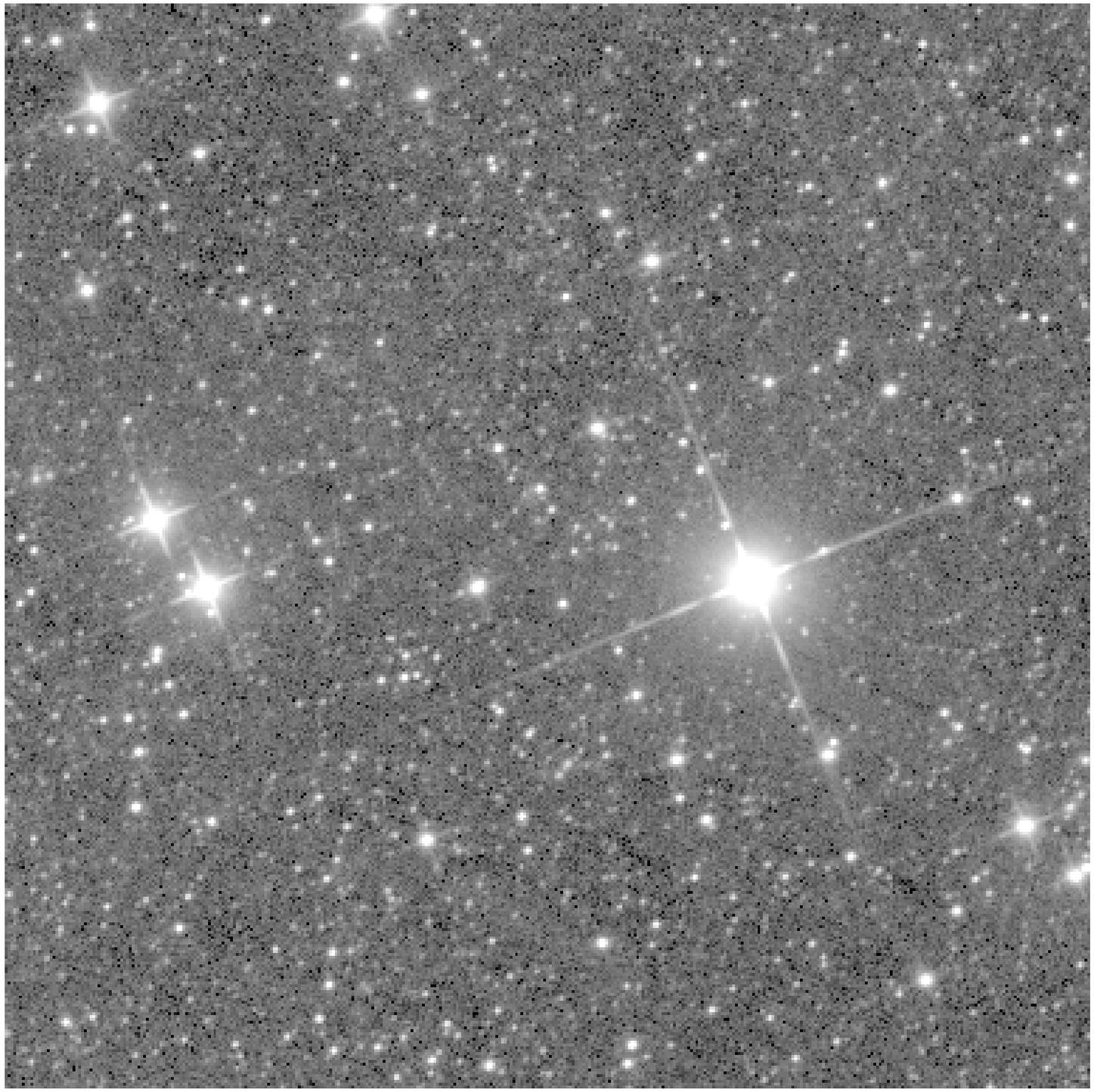
LSST:UK Consortium

University of Exeter from my flat, 21/7/20

# Photometric Observations



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

*WISE* W1
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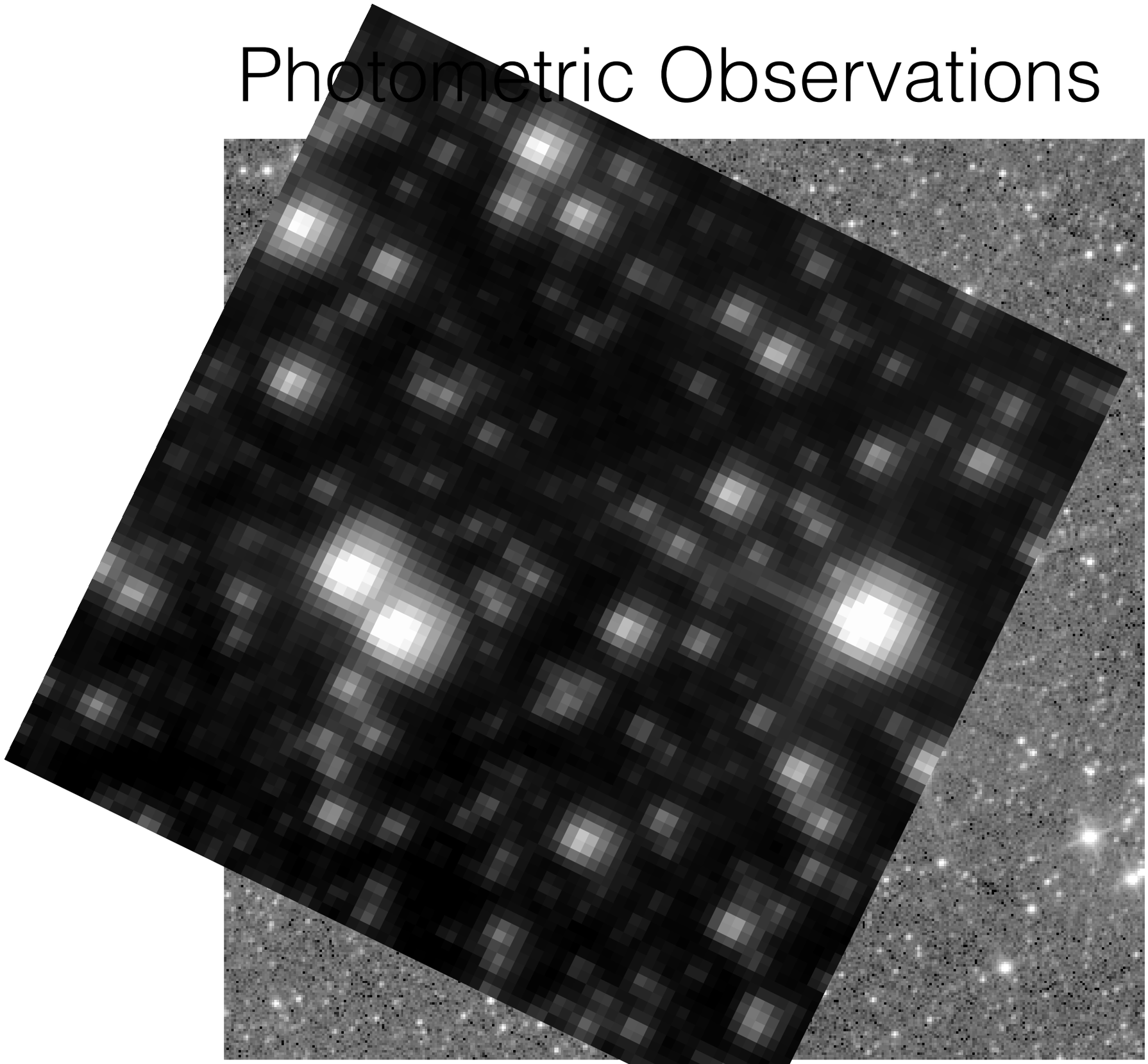
# Photometric Observations



*WISE* - Wright et al., 2010, AJ, 140, 1868
*TESS* - Ricker et al., 2015, JATIS, 1, 14003

*TESS* T
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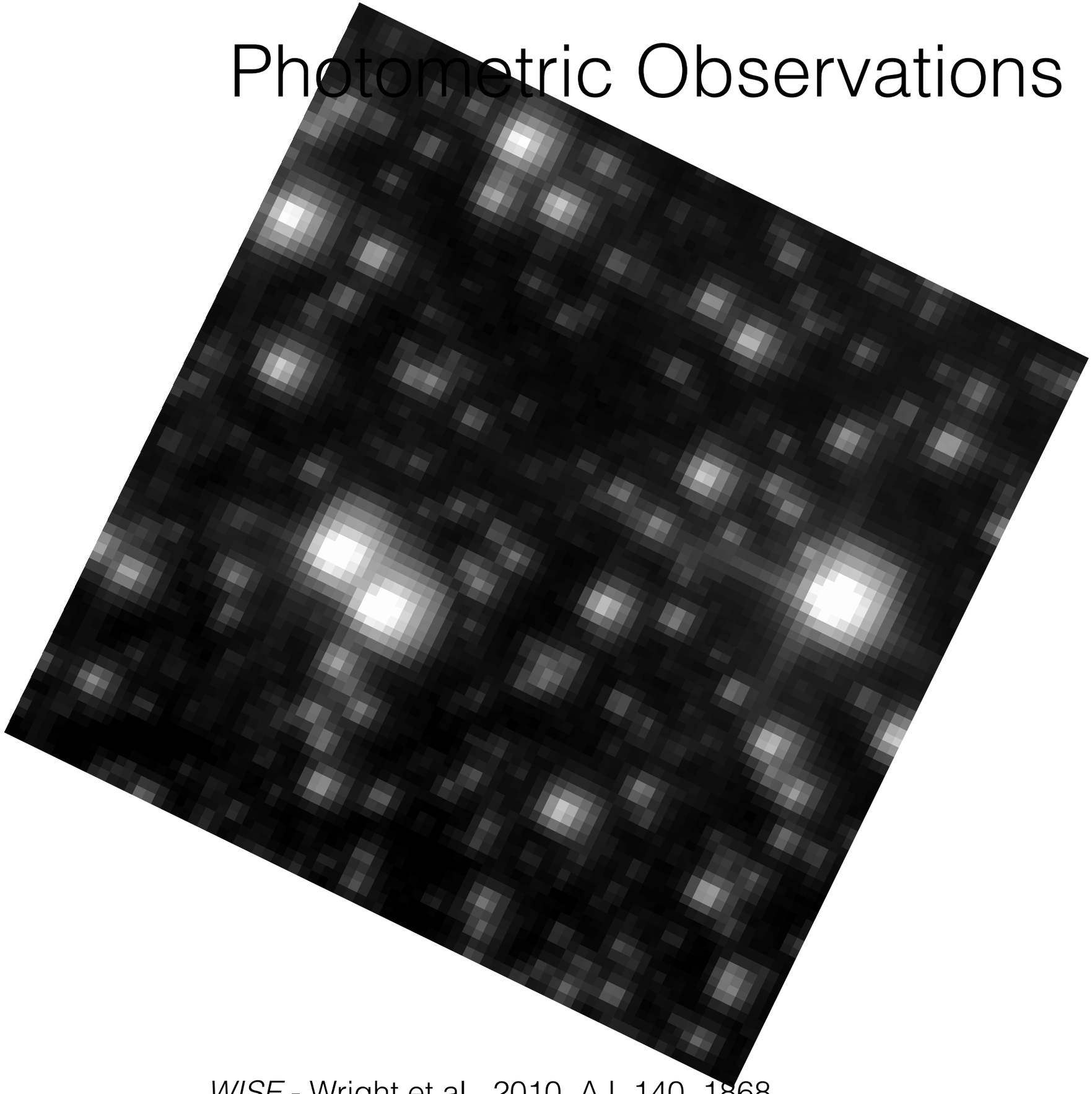
# Photometric Observations



*WISE* - Wright et al., 2010, AJ, 140, 1868
*TESS* - Ricker et al., 2015, JATIS, 1, 14003

*TESS* T
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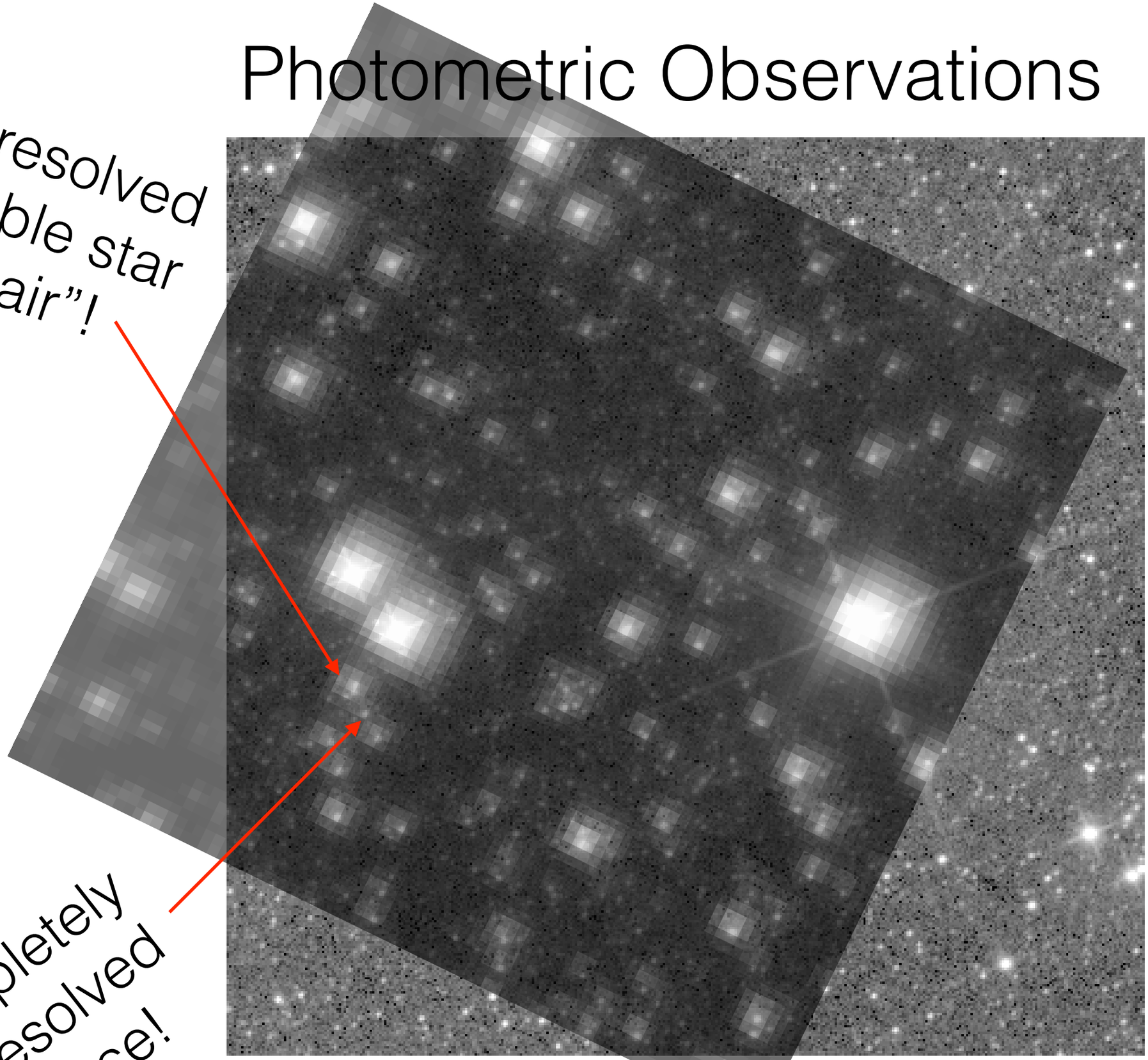
# Photometric Observations




*WISE* - Wright et al., 2010, AJ, 140, 1868
*TESS* - Ricker et al., 2015, JATIS, 1, 14003

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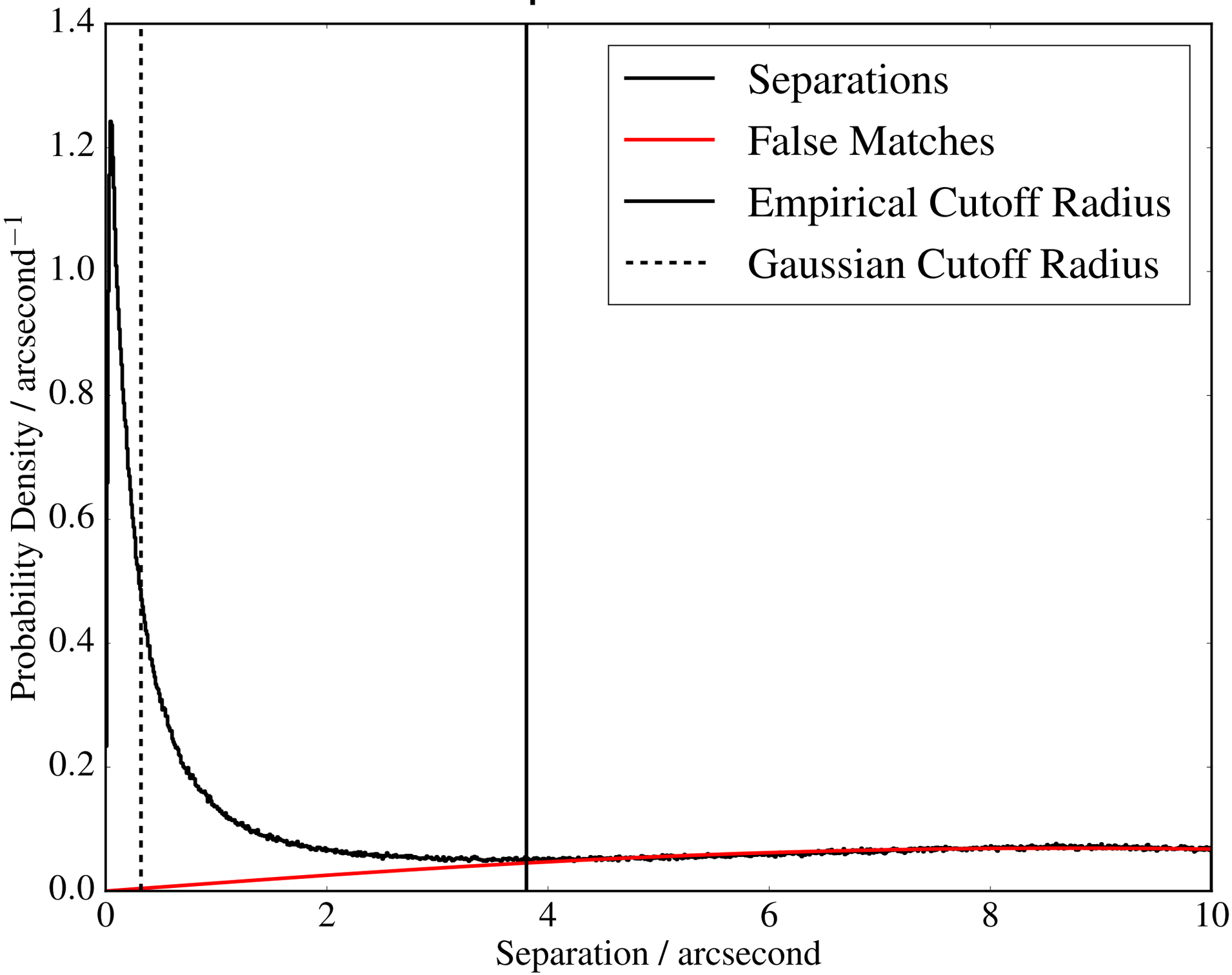
# Cross-match Separation Distributions




*Gaia* DR2 - Gaia Collaboration, Brown A. G. A., et al. 2018, A&A, 616, 1
*WISE* - Wright et al., 2010, AJ, 140, 1868

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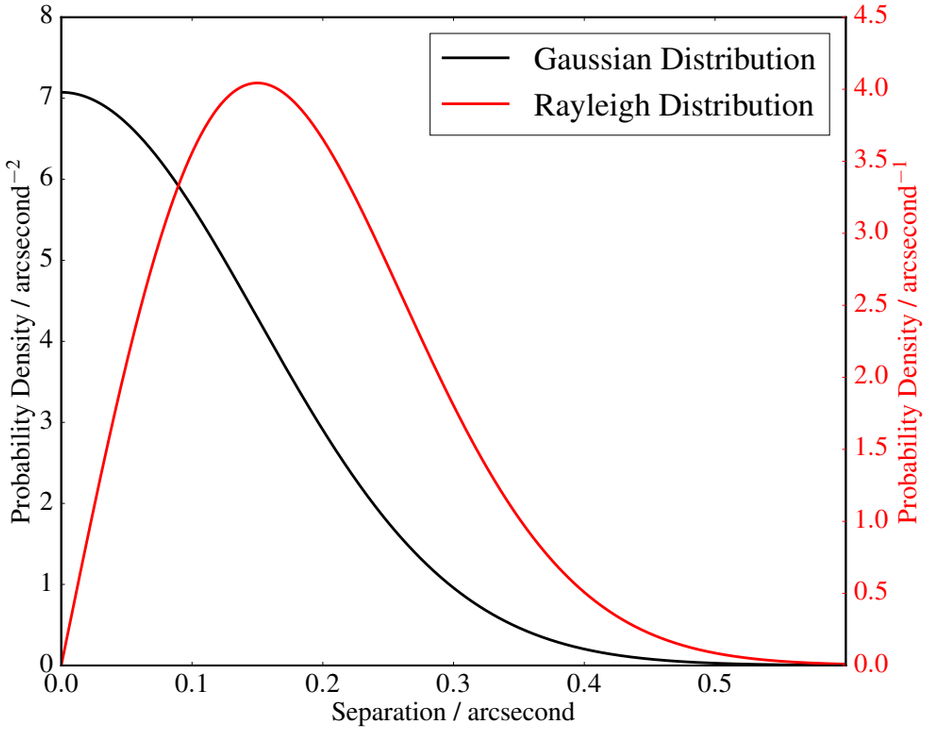
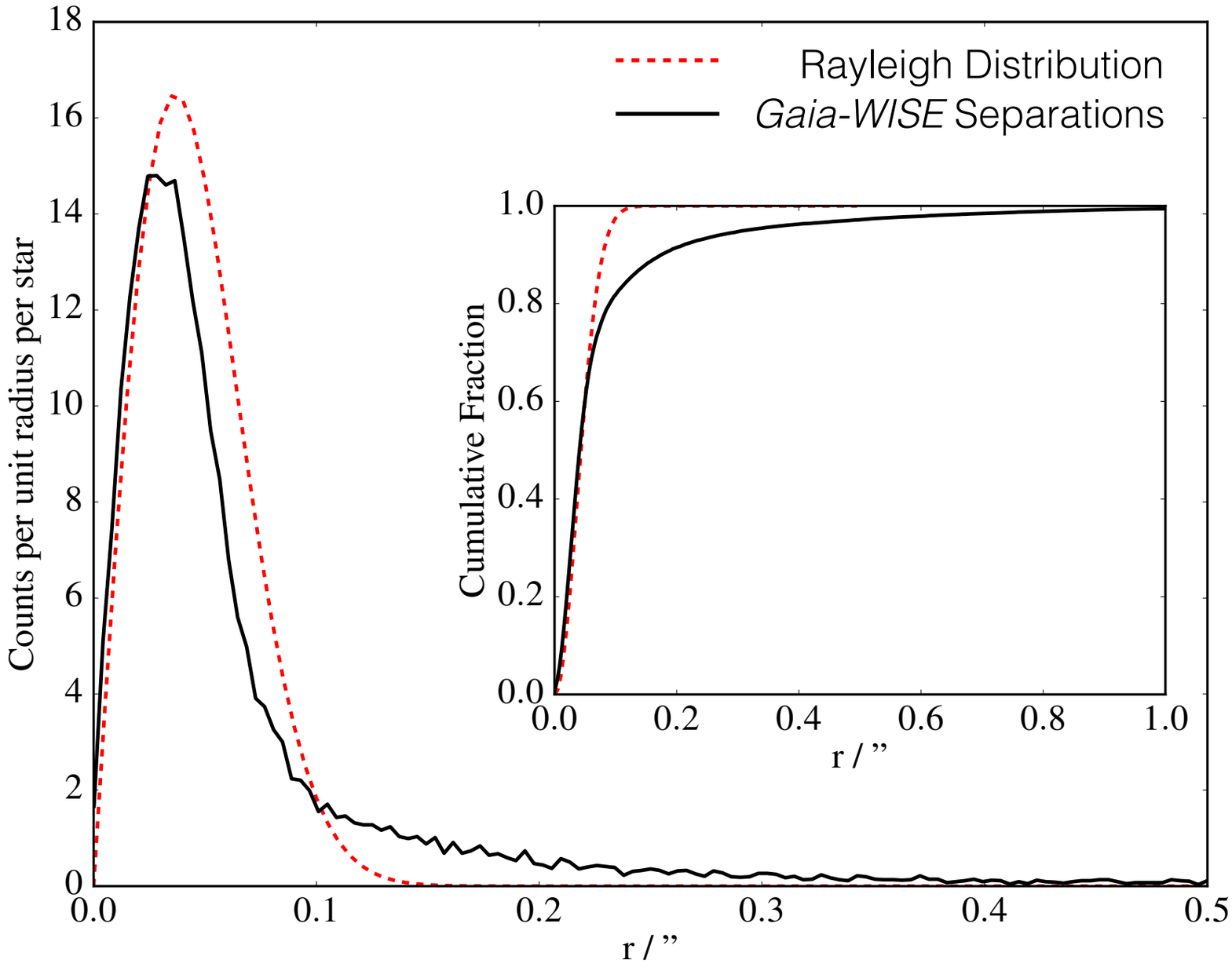
# The Astrometric Uncertainty Function

$$g(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

$$\downarrow$$

$$g(r, \sigma) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}$$




*Gaia* DR2 - Gaia Collaboration, Brown A. G. A., et al. 2018, A&A, 616, 1
*WISE* - Wright et al., 2010, AJ, 140, 1868
Wilson & Naylor, 2017, MNRAS, 468, 2517

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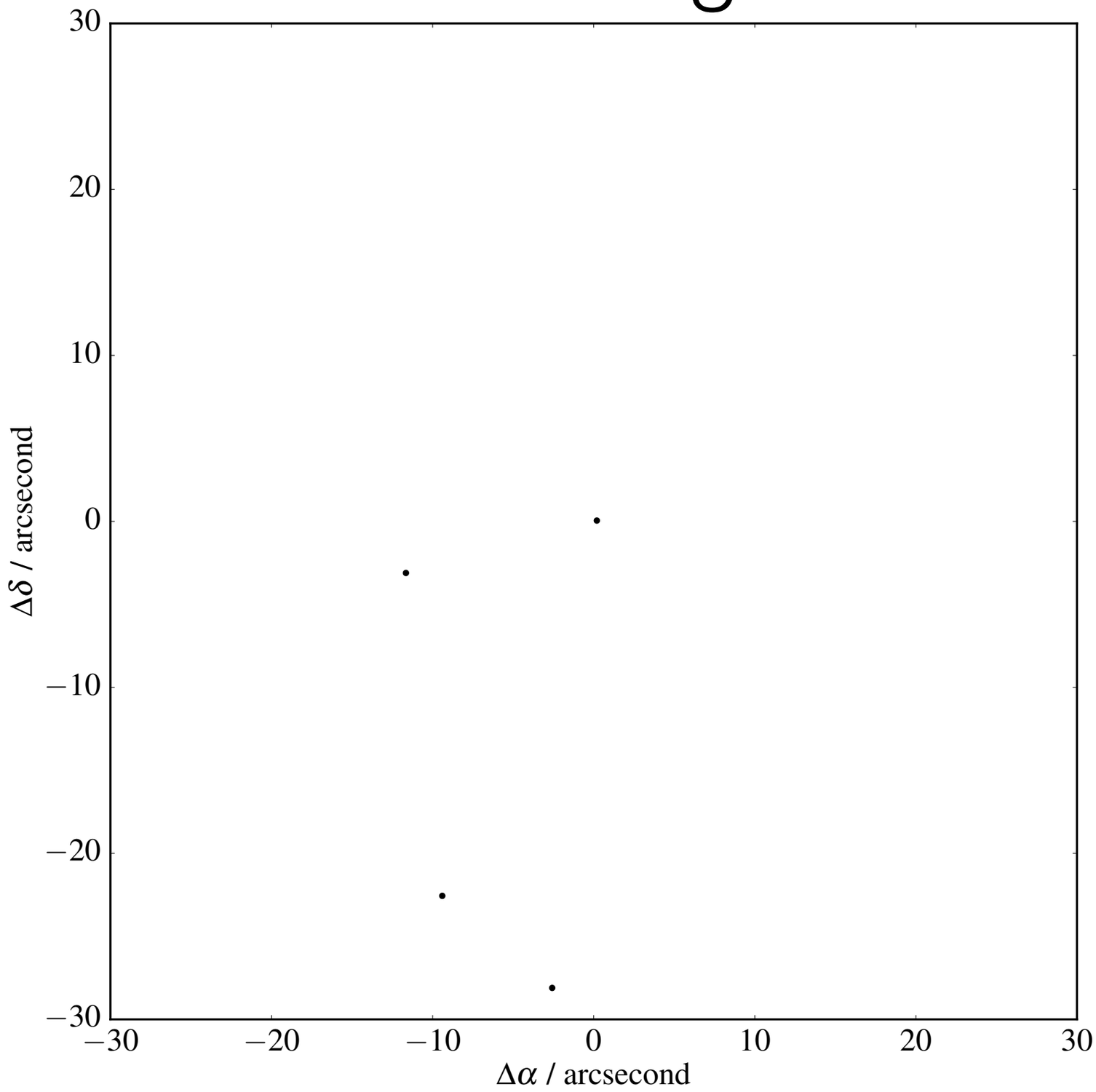
# The Astrometric Uncertainty Function: Crowding




Wilson & Naylor, 2017, MNRAS, 468, 2517

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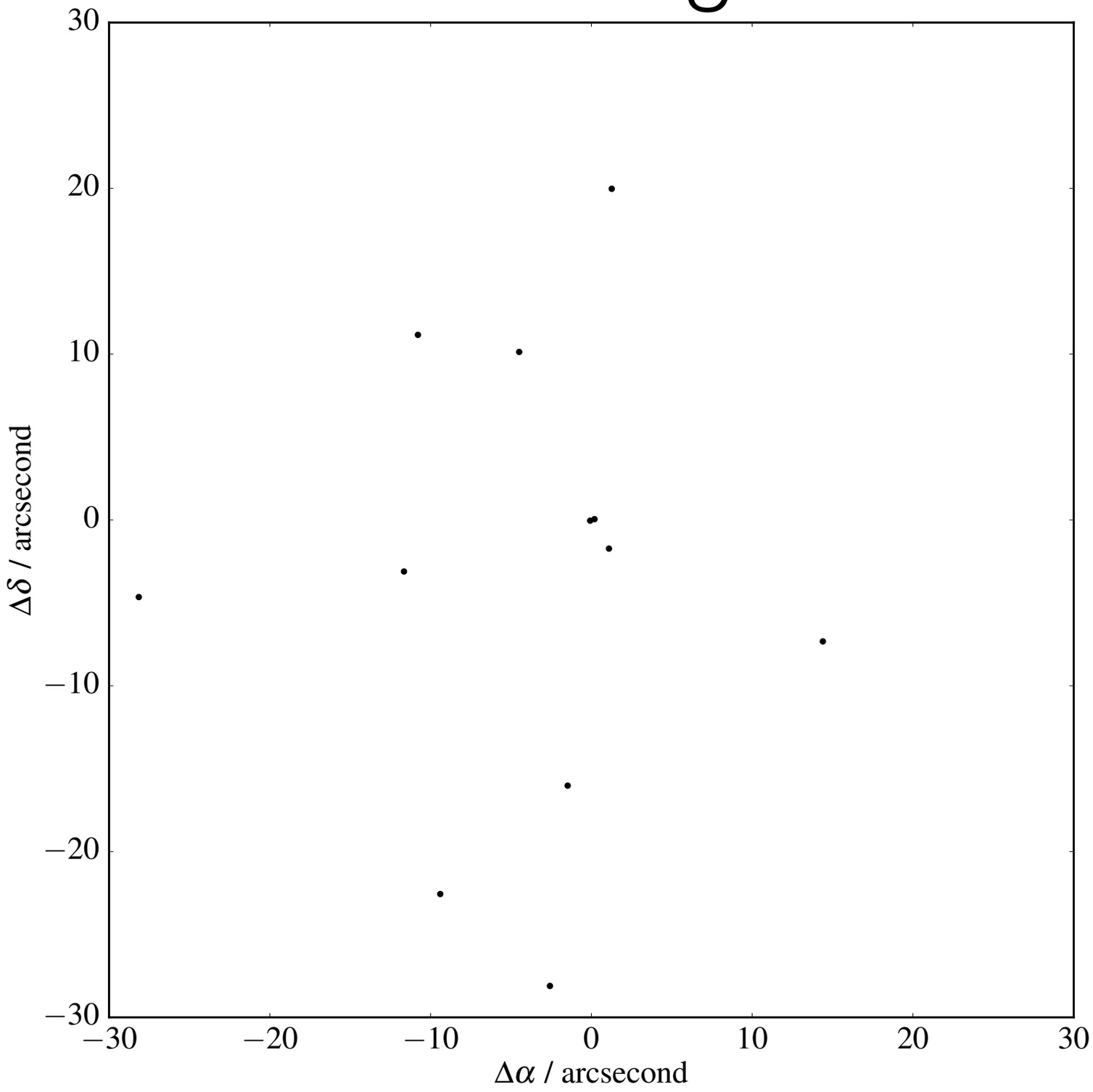
# The Astrometric Uncertainty Function: Crowding




Wilson & Naylor, 2017, MNRAS, 468, 2517

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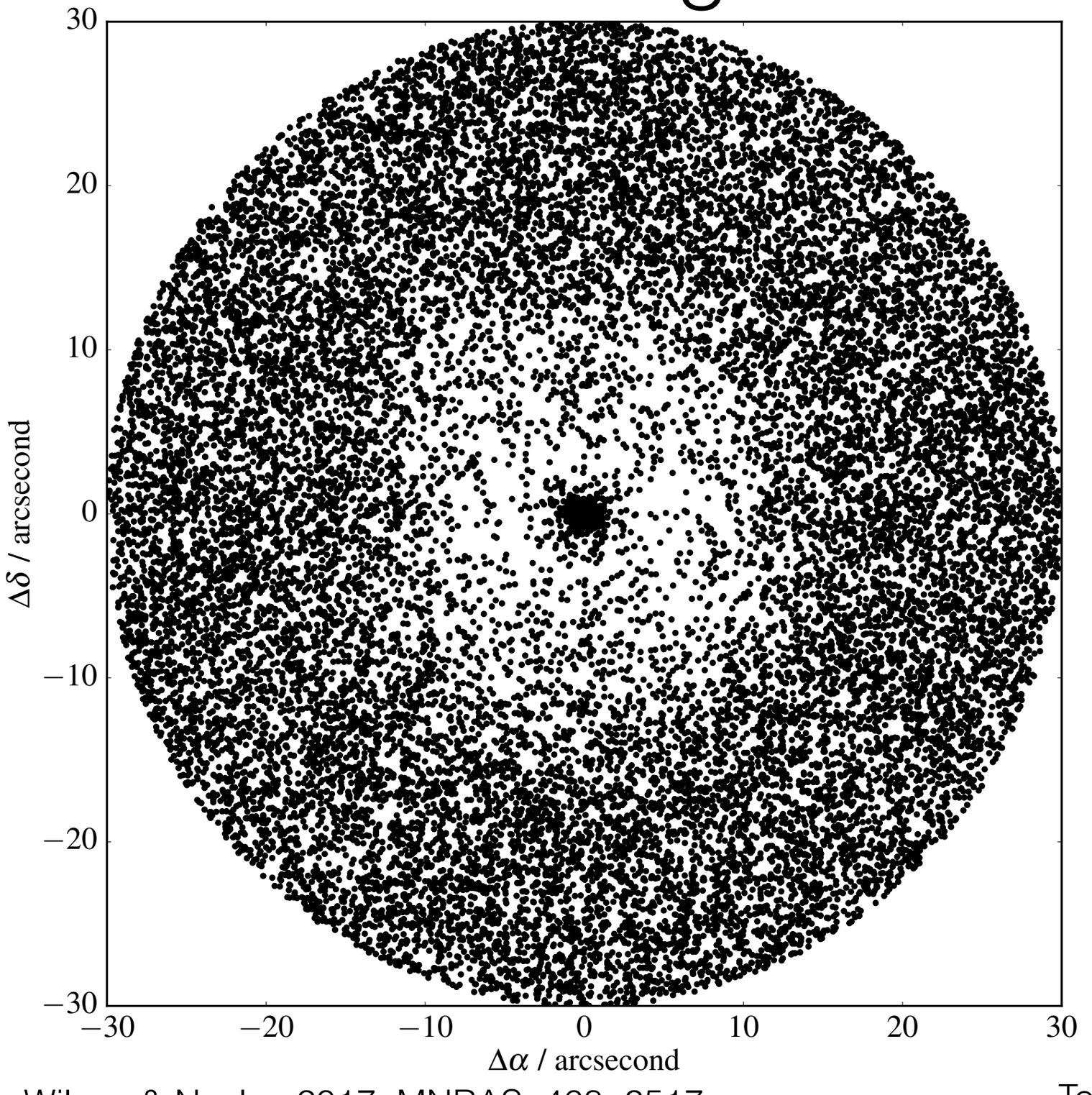


Wilson & Naylor, 2017, MNRAS, 468, 2517

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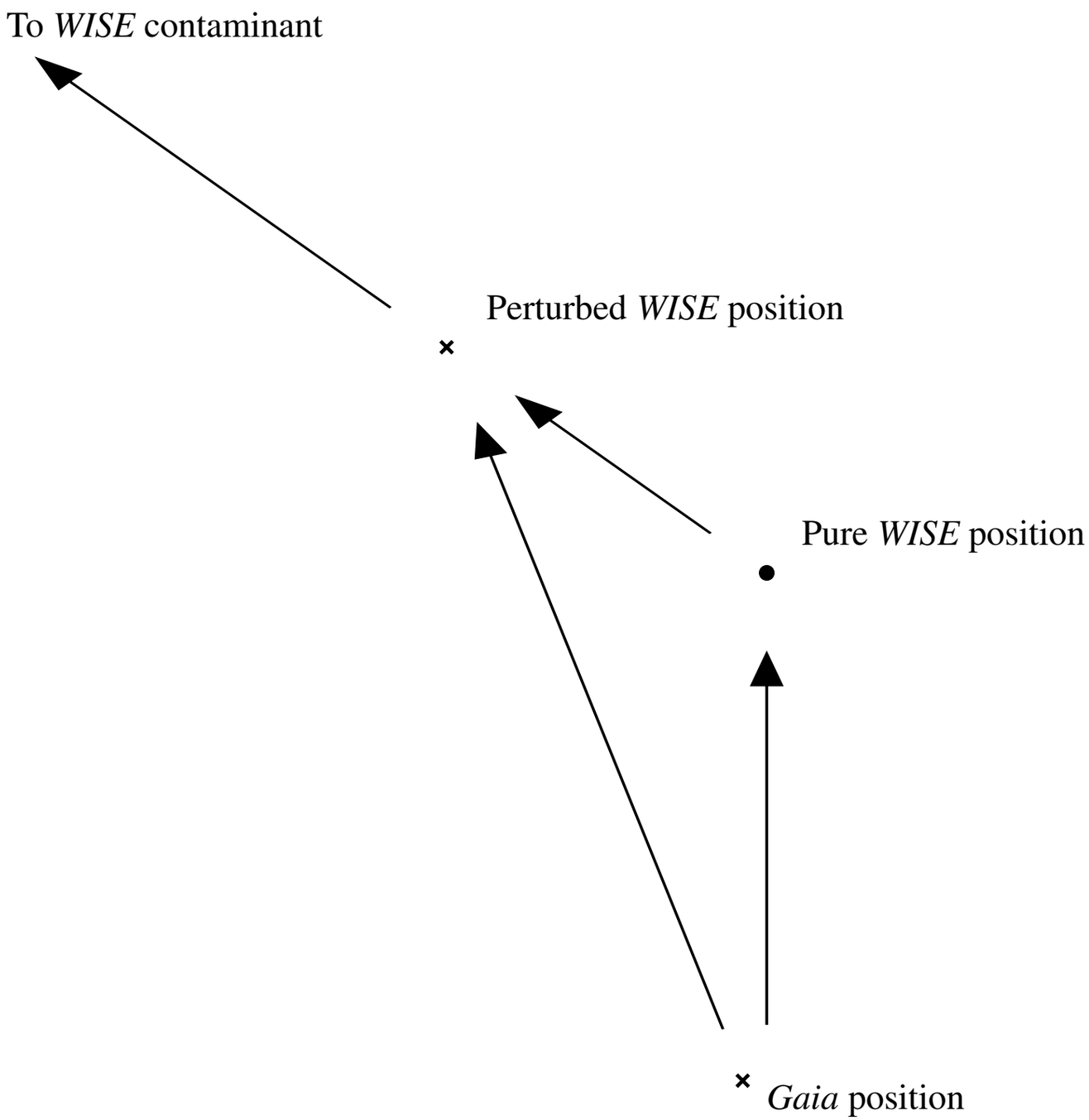
# The Astrometric Uncertainty Function: Perturbation




Wilson & Naylor, 2017, MNRAS, 468, 2517

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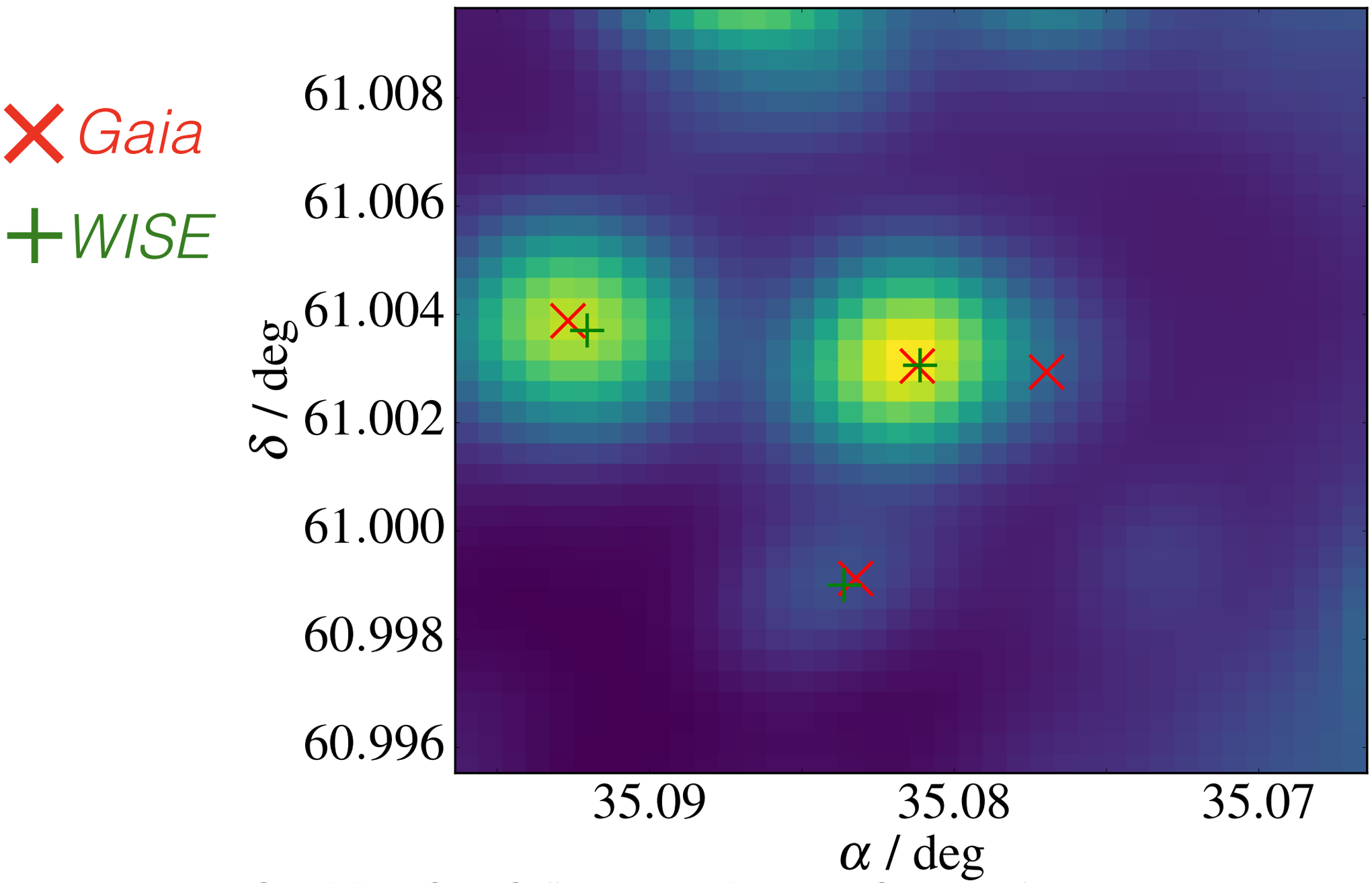
# The Astrometric Uncertainty Function: *Gaia-WISE* Resolved Blend




*Gaia* DR2 - Gaia Collaboration, Brown A. G. A., et al. 2018, A&A, 616, 1
*WISE* - Wright et al., 2010, AJ, 140, 1868
Wilson & Naylor, MNRAS, 2018b, 481, 2148

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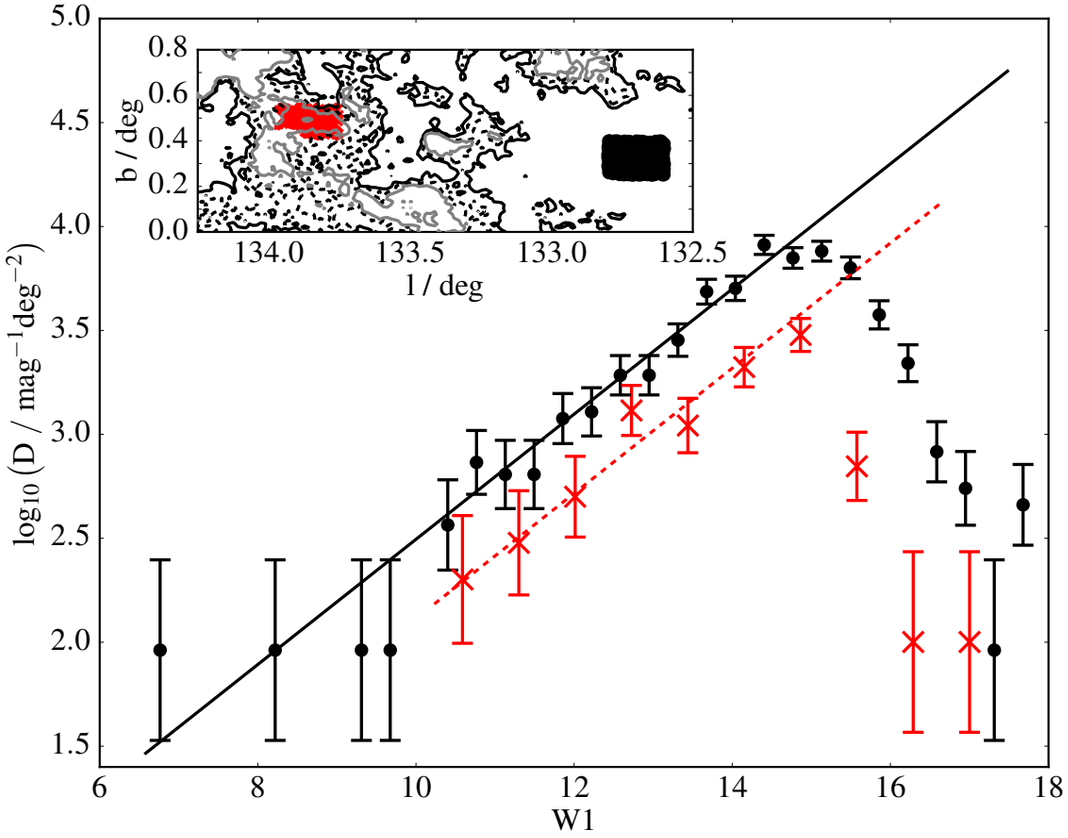
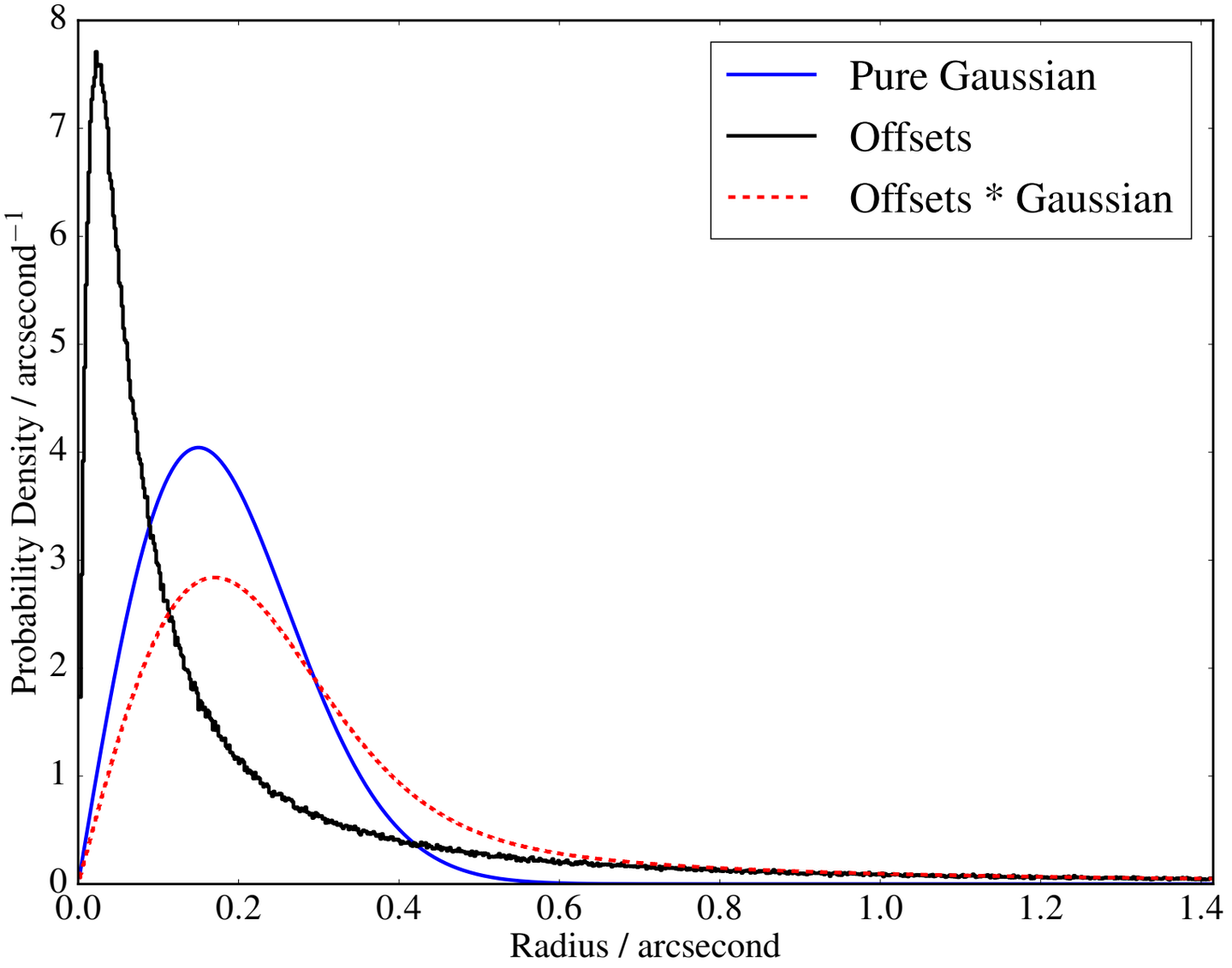
# The Astrometric Uncertainty Function: Building Empirical AUFs




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

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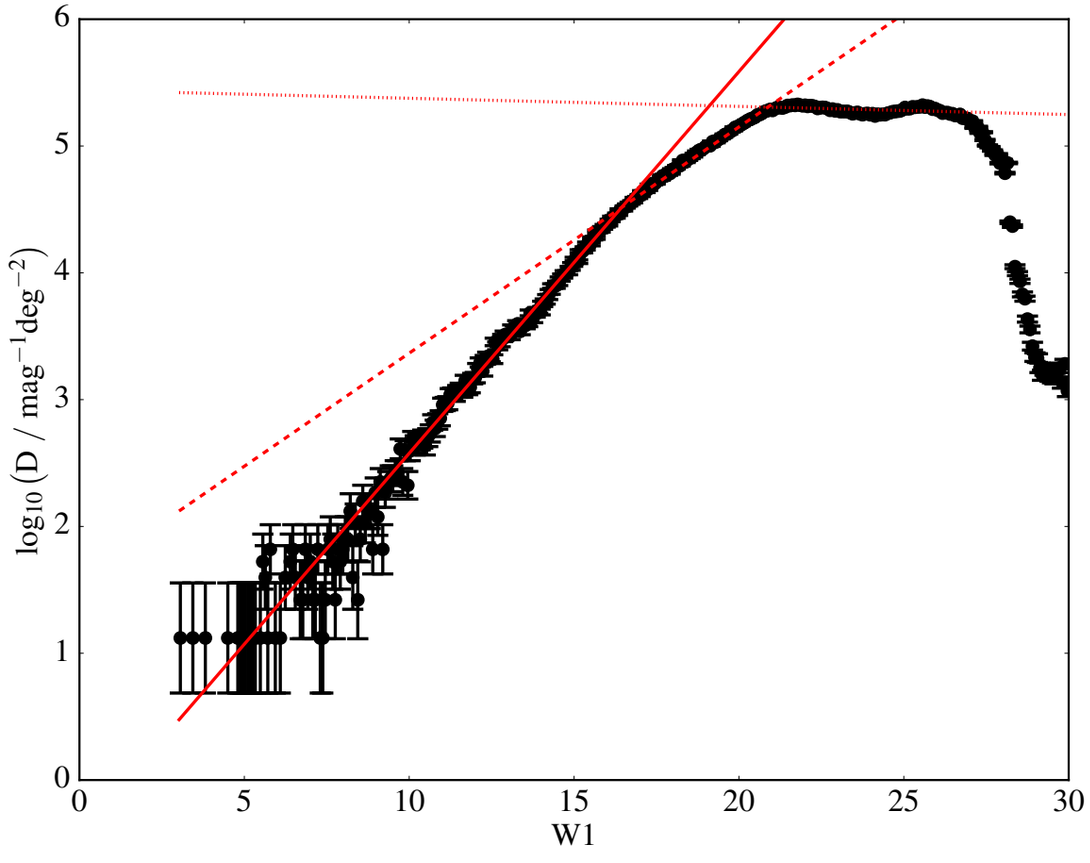
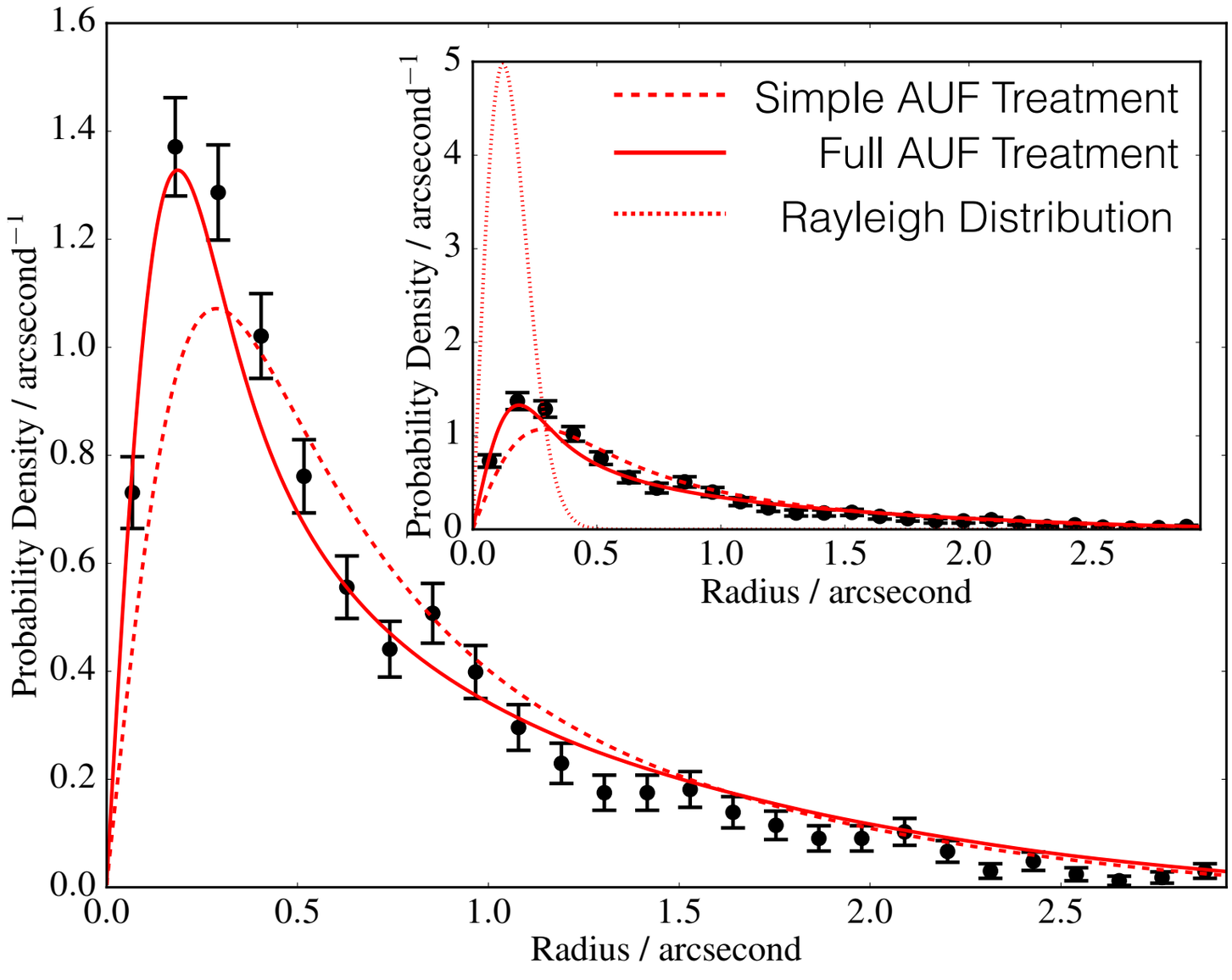
# Contamination Effects: Effects Below Sensitivity Limit




TRILEGAL - Giradi et al., 2005, A&A, 436, 895
Wilson & Naylor, 2018b, MNRAS, 481, 2148

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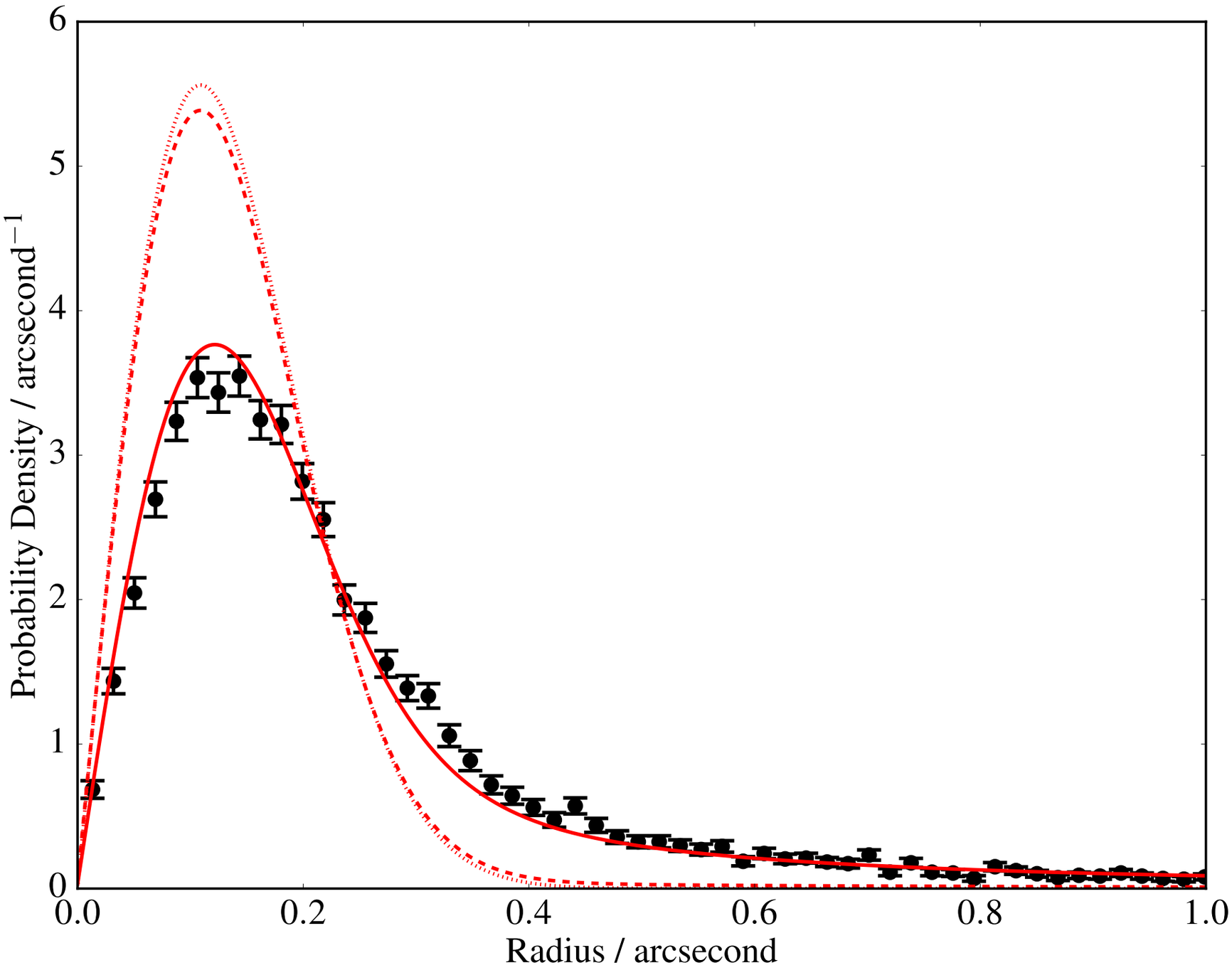
# Contamination Effects: Galaxy Contamination




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

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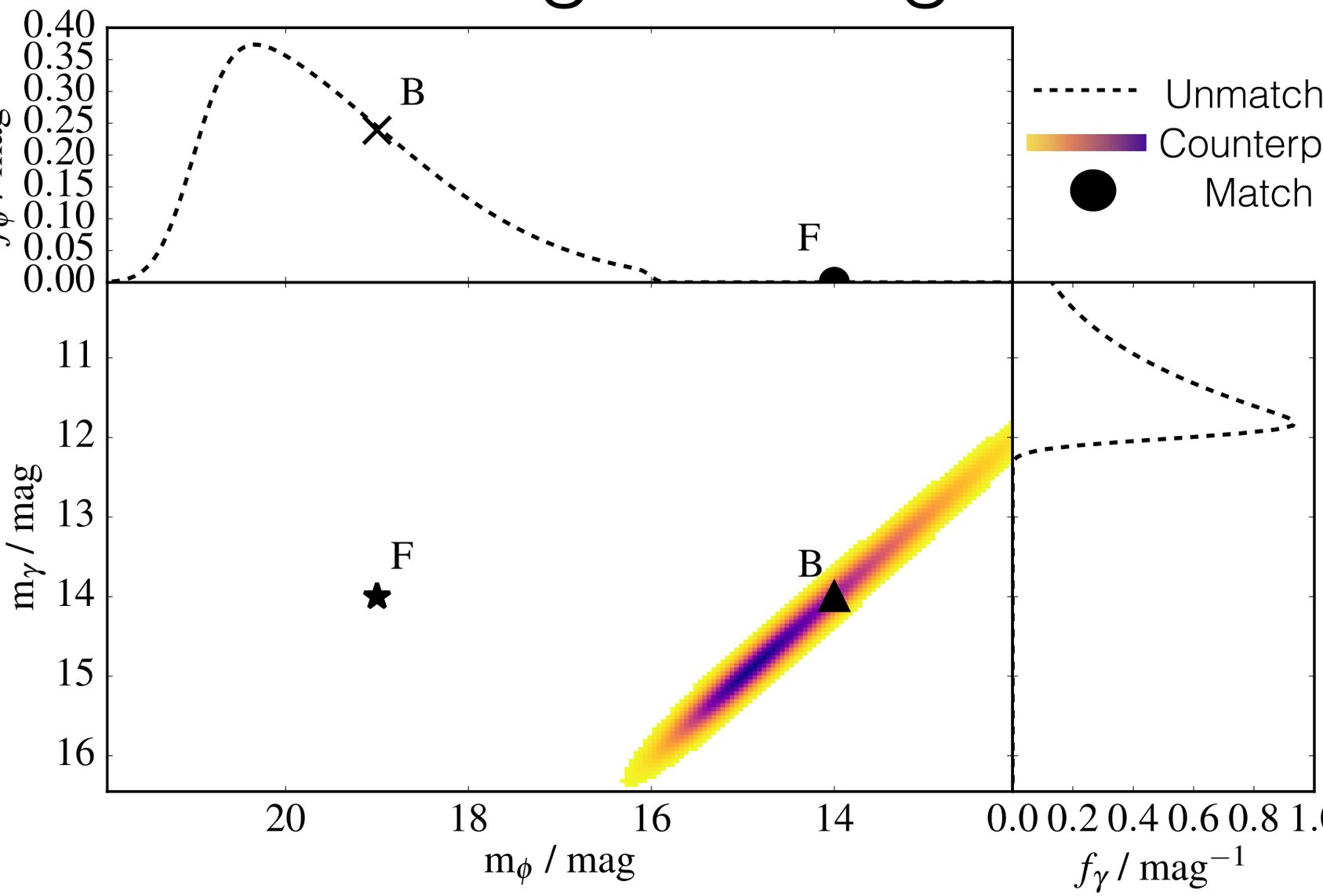
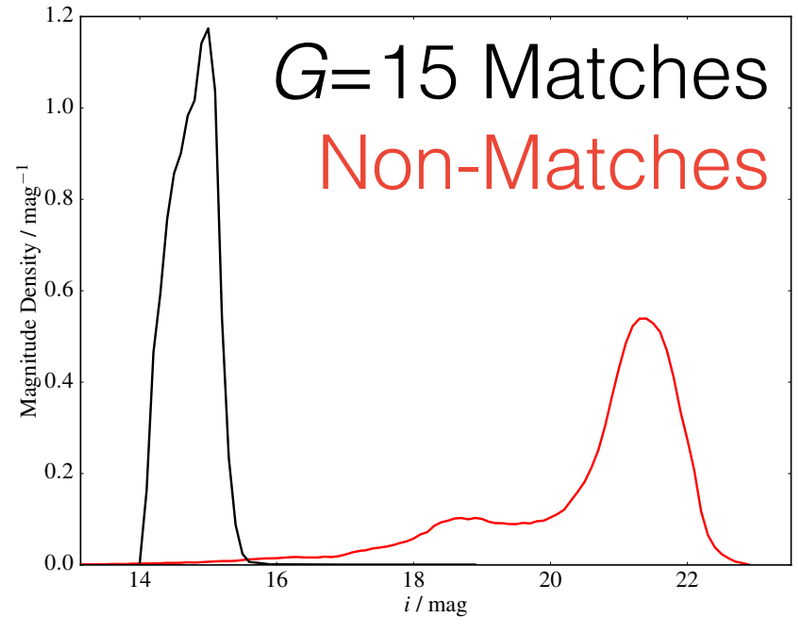
# Probability-based Catalogue Matching: Including the Magnitude Information




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

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

Barentsen et al., 2014, MNRAS, 444, 3230
Wilson & Naylor, 2018a, MNRAS, 473, 5570

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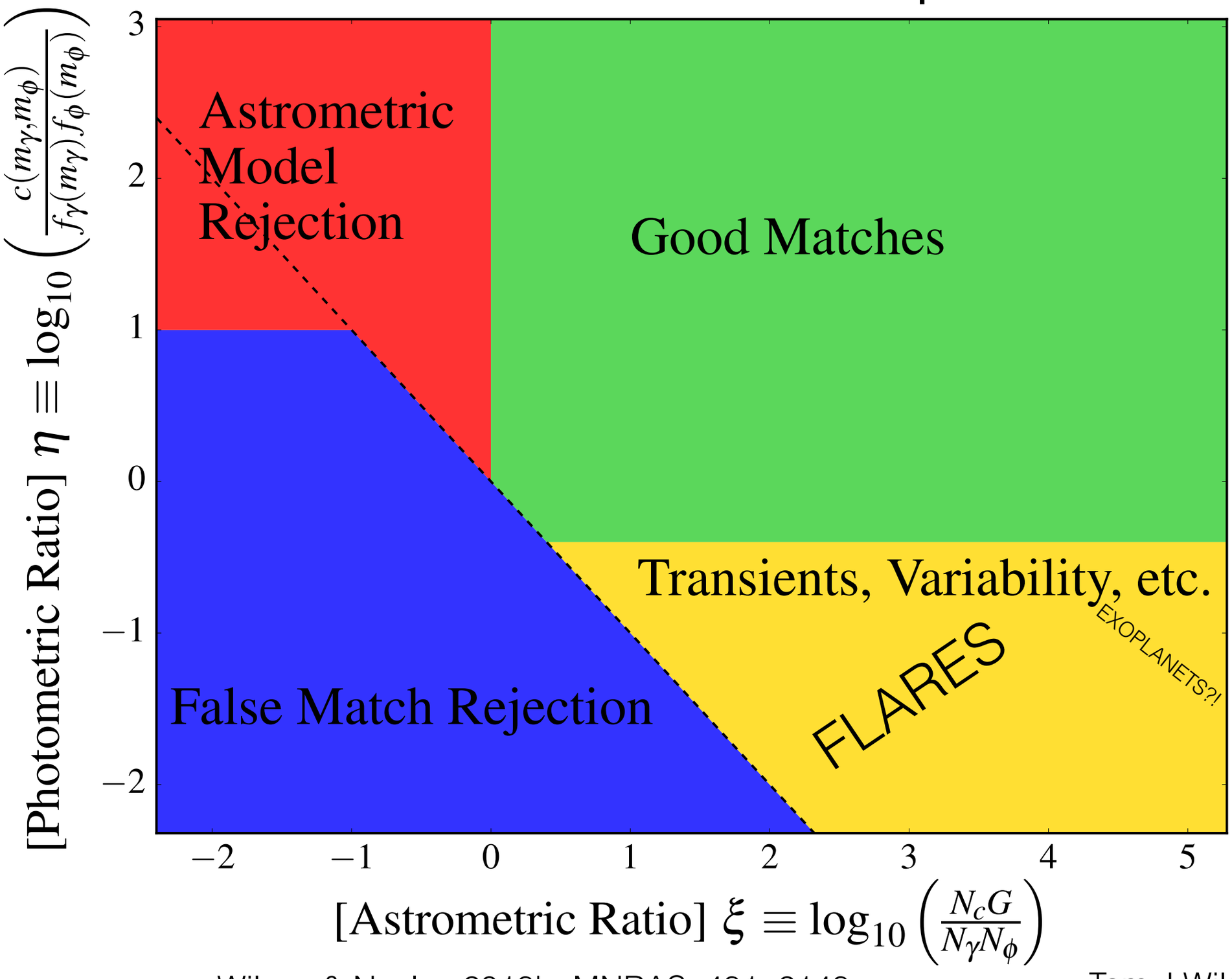
# Probability-based Catalogue Matching: The Likelihood Ratio Space




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

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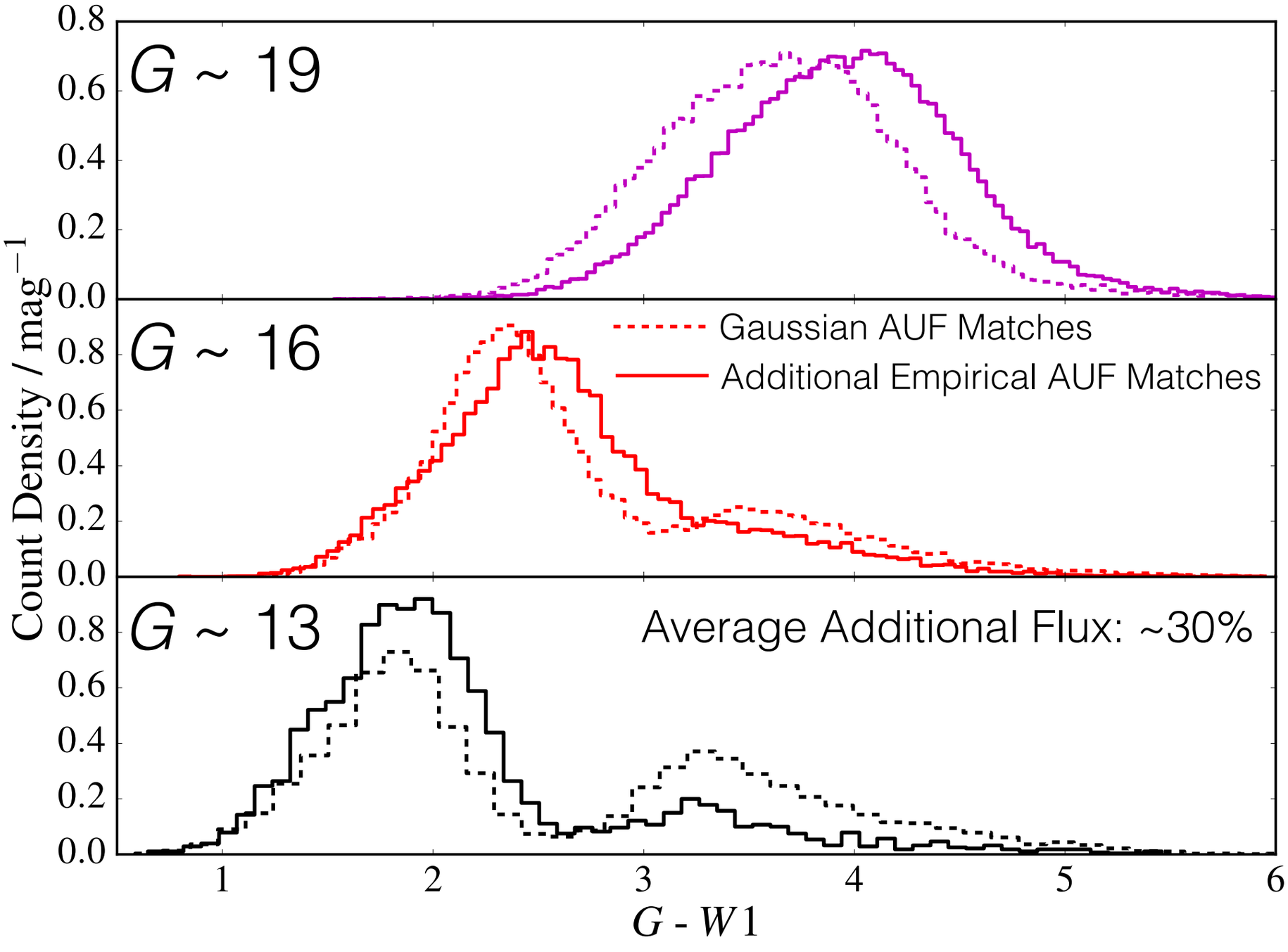
# Contamination Effects: Perturbation-Colour Correlation




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

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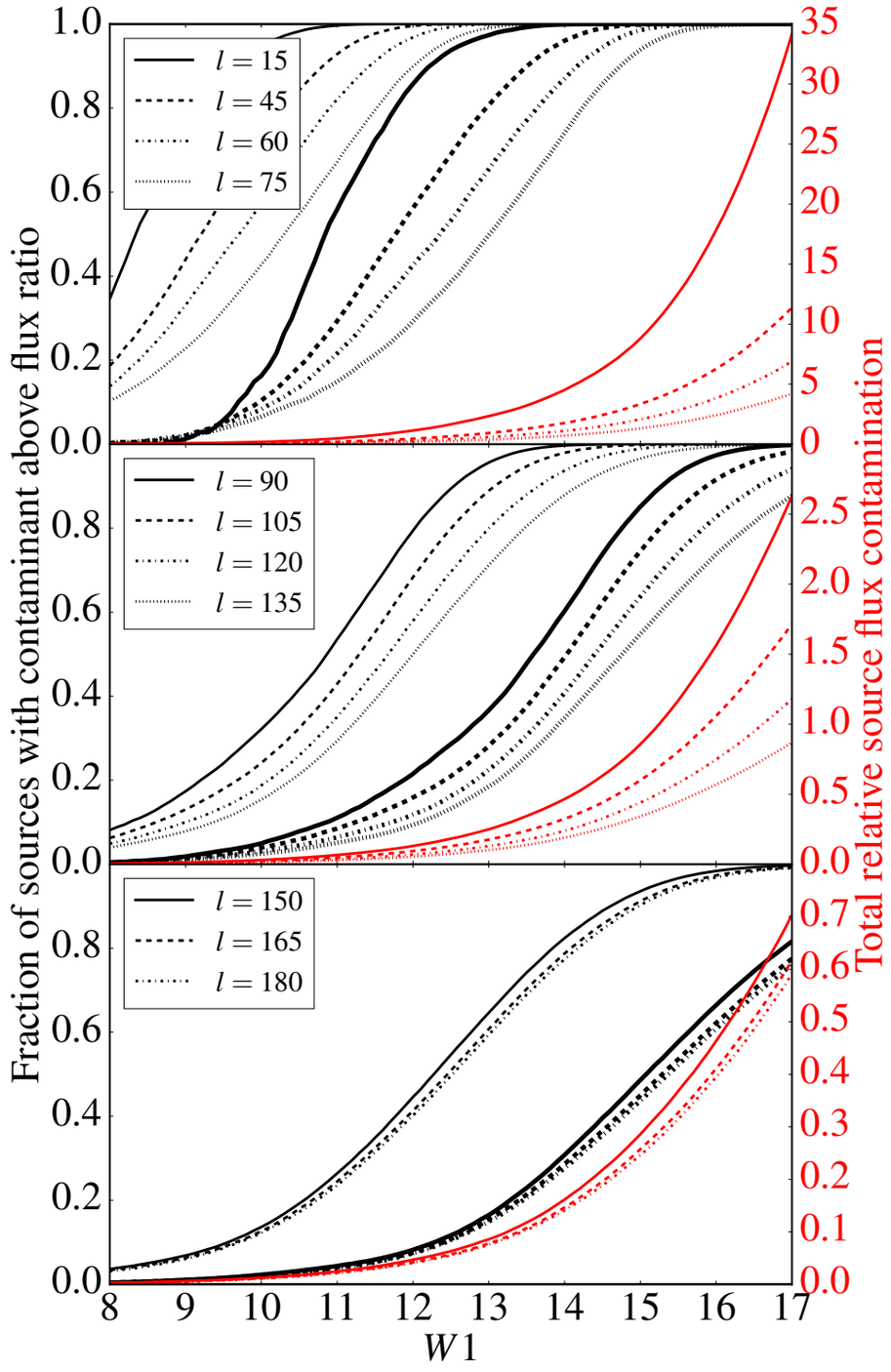
# Contamination Effects: Contamination Rates & Amounts




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

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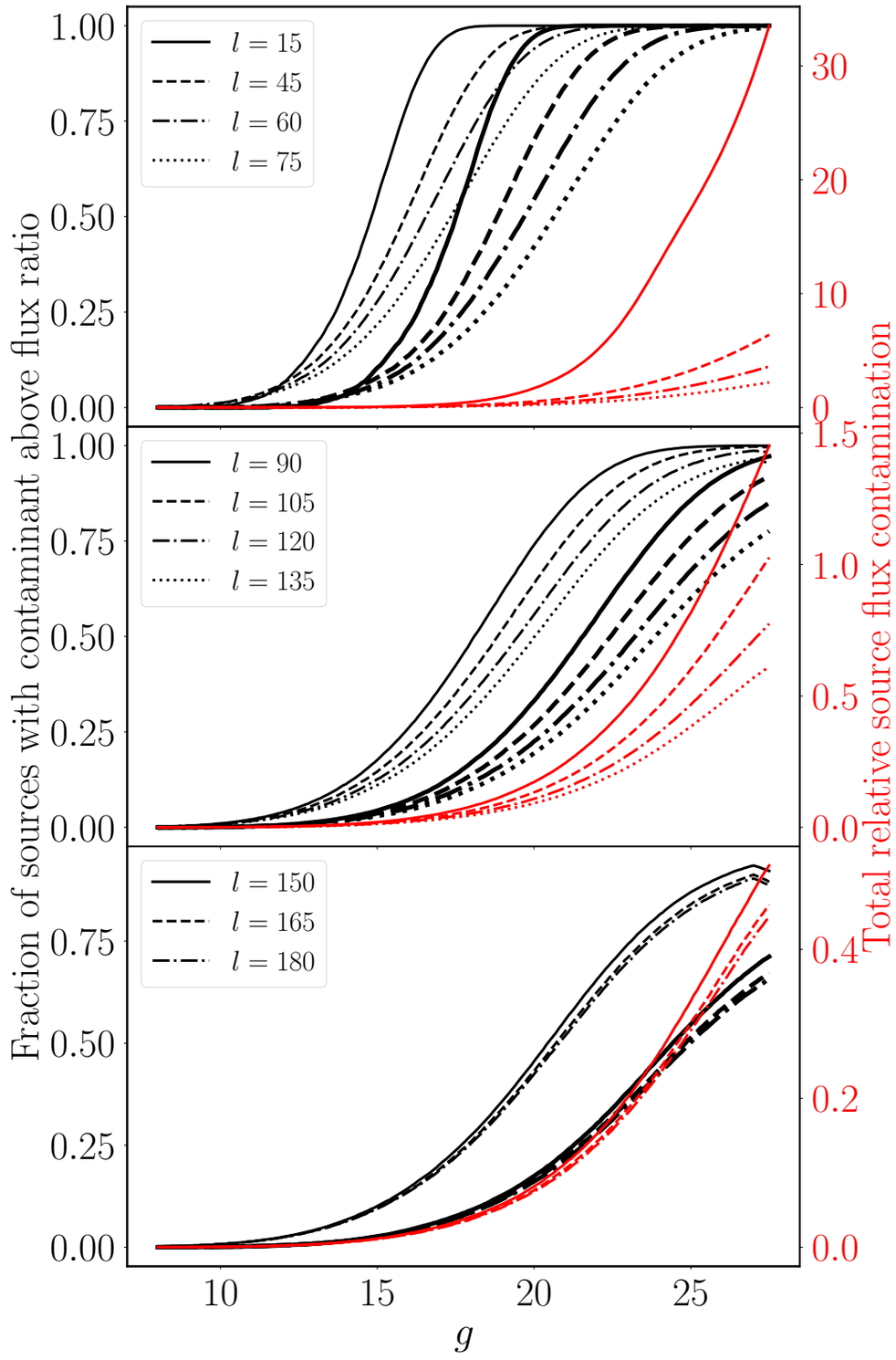
# The Astrometric Uncertainty Function: Considering Vera C. Rubin Observatory's LSST

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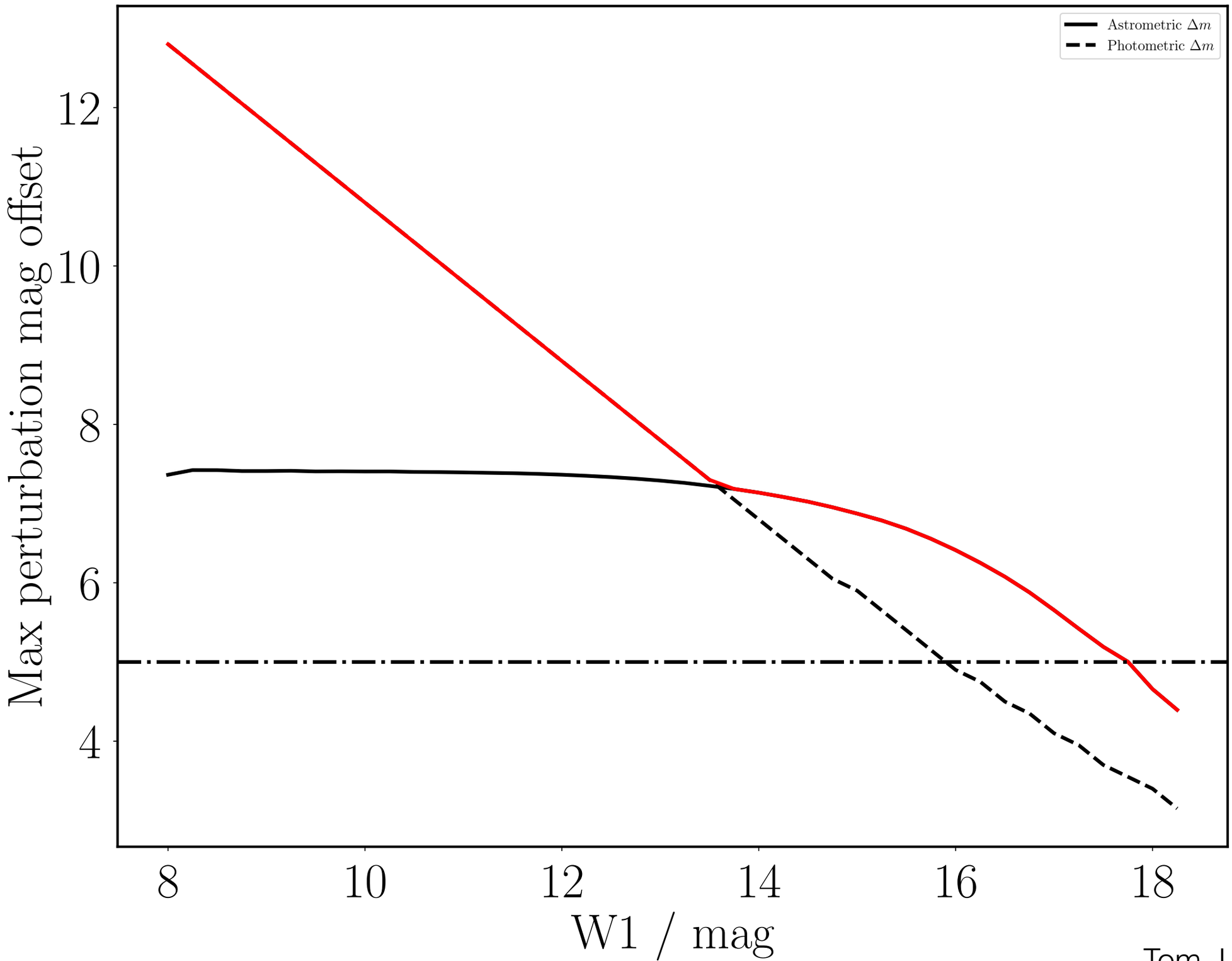
# The Astrometric Uncertainty Function and LSST: A Crisis of Completeness Limit

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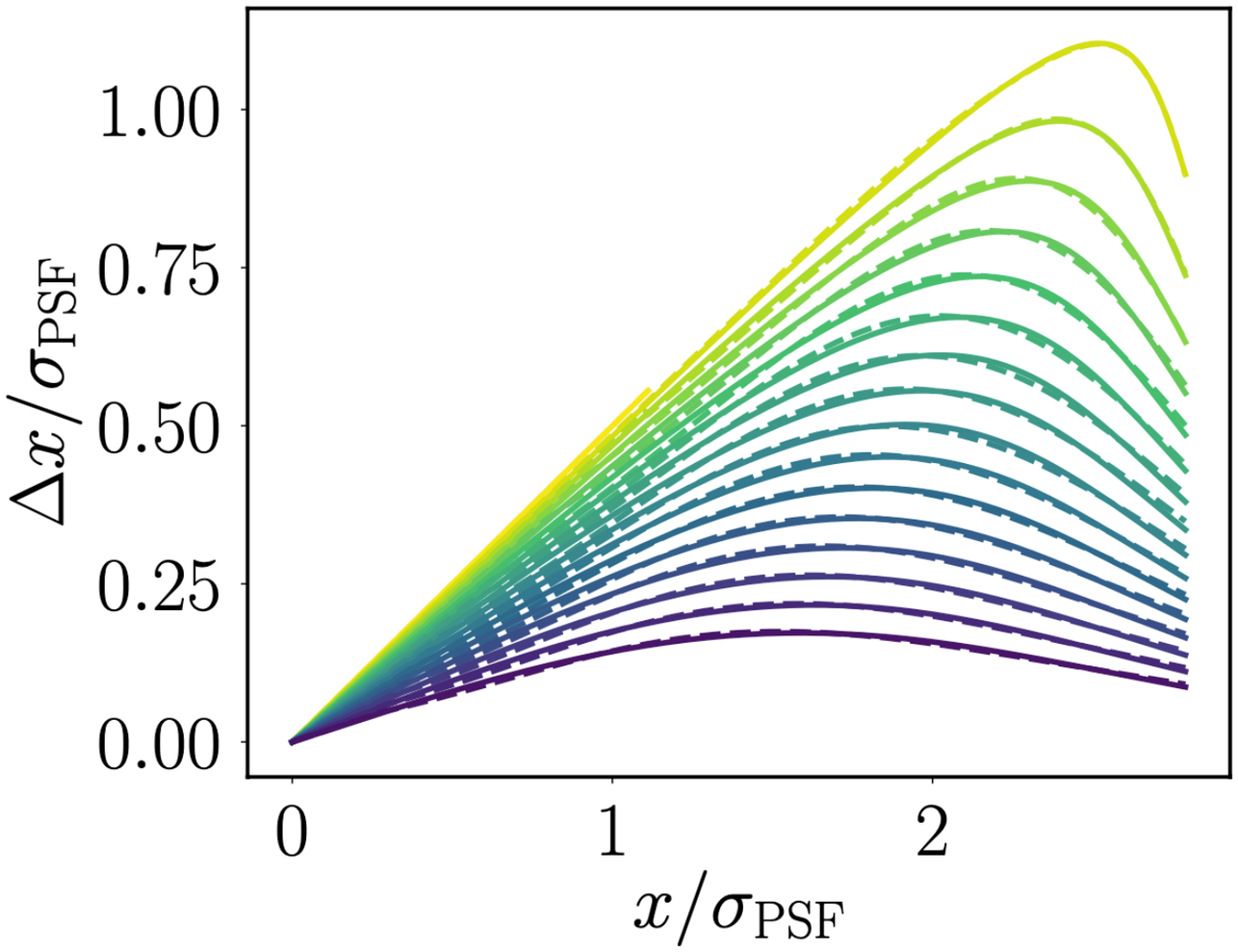
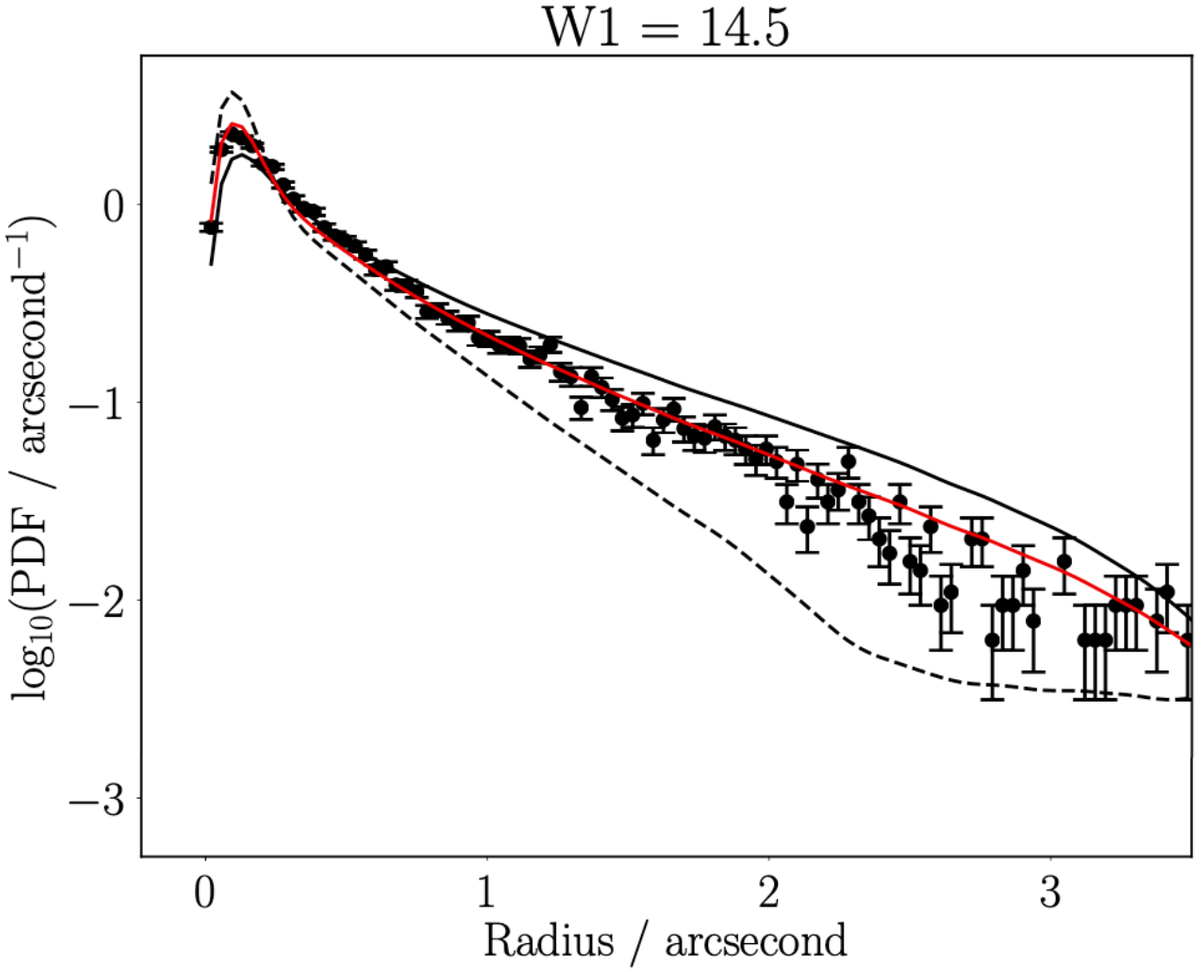
# The Astrometric Uncertainty Function and LSST: Probing the Faintest Sources

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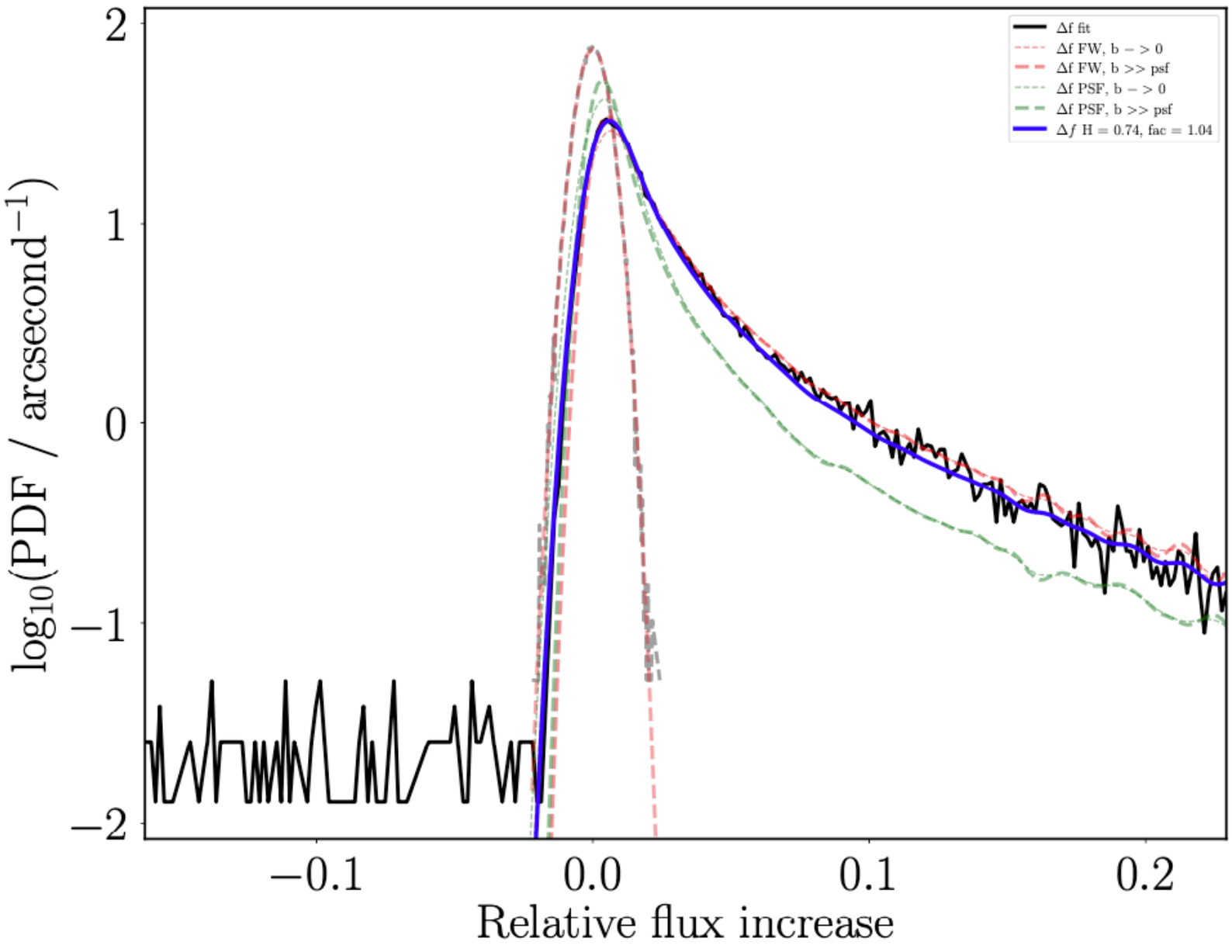
# The Astrometric Uncertainty Function and LSST: Improving the “Photometric Contamination Function”

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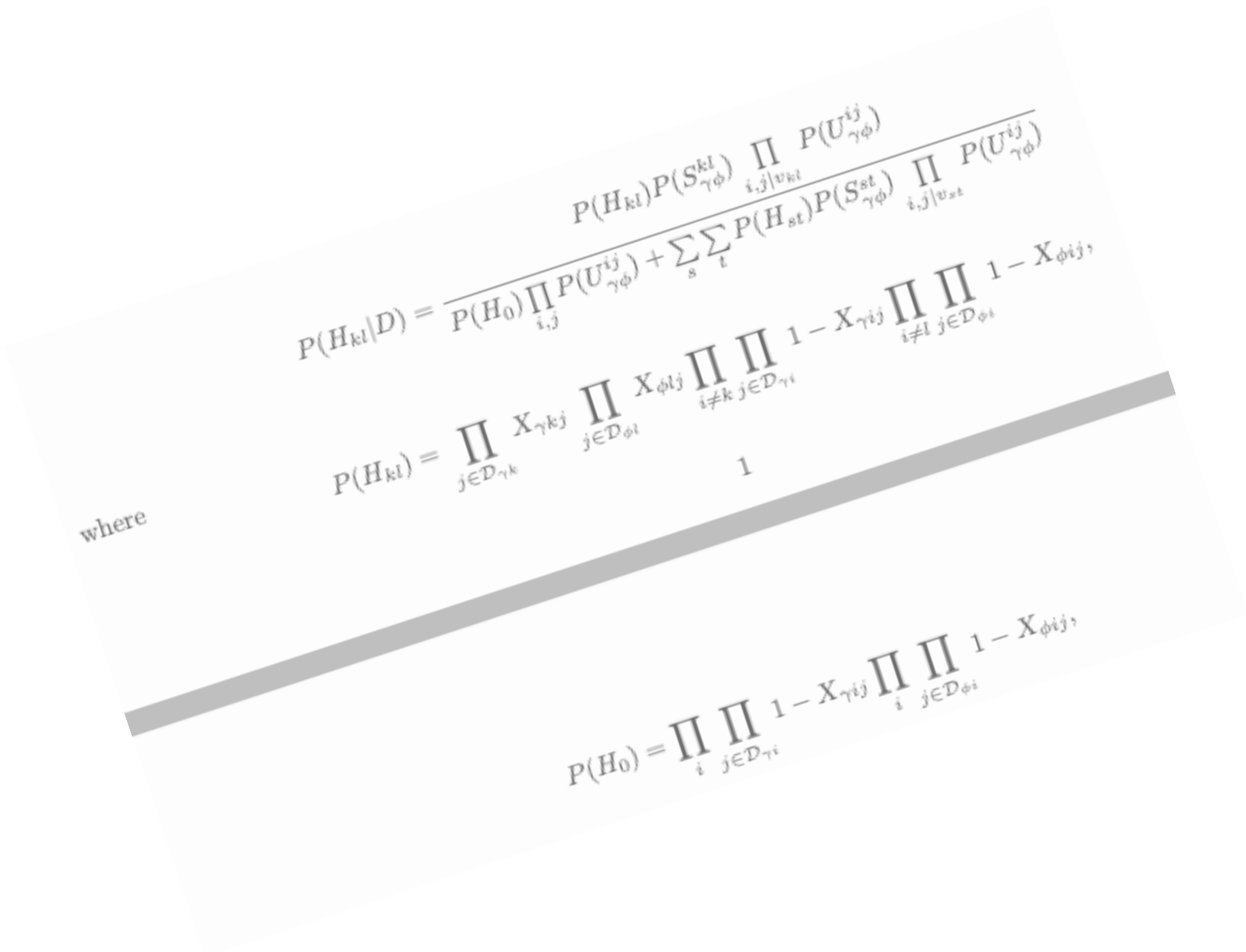
# The Astrometric Uncertainty Function and LSST: Extensions to Cross-Match Algorithm



$$P(H_{kl}|D) = \frac{P(H_{kl})P(S^{kl}_{\gamma\phi}) \prod_{i,j|v_{kl}} P(U^{ij}_{\gamma\phi})}{P(H_0)\prod_{i,j} P(U^{ij}_{\gamma\phi}) + \sum_s \sum_t P(H_{st})P(S^{st}_{\gamma\phi}) \prod_{i,j|v_{st}} P(U^{ij}_{\gamma\phi})}$$

$$P(H_{kl}) = \prod_{j\in\mathcal{D}_{\gamma k}} X_{\gamma kj} \prod_{j\in\mathcal{D}_{\phi l}} X_{\phi lj} \prod_{i\neq k} \prod_{j\in\mathcal{D}_{\gamma i}} 1 - X_{\gamma ij} \prod_{i\neq l} \prod_{j\in\mathcal{D}_{\phi i}} 1 - X_{\phi ij},$$

where

$$P(H_0) = \prod_i \prod_{j\in\mathcal{D}_{\gamma i}} 1 - X_{\gamma ij} \prod_i \prod_{j\in\mathcal{D}_{\phi i}} 1 - X_{\phi ij},$$

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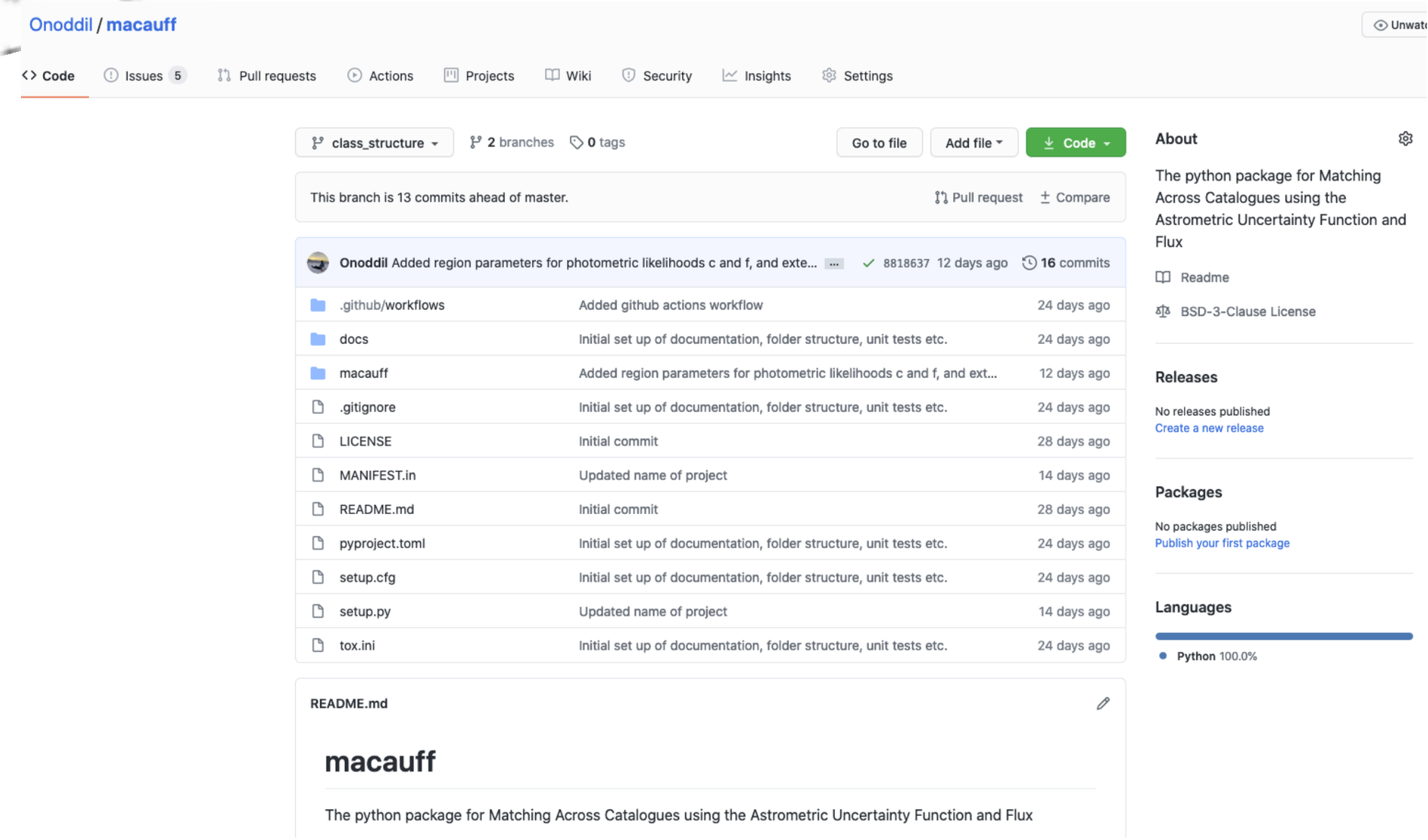
# The Astrometric Uncertainty Function and LSST: Open Source Code Development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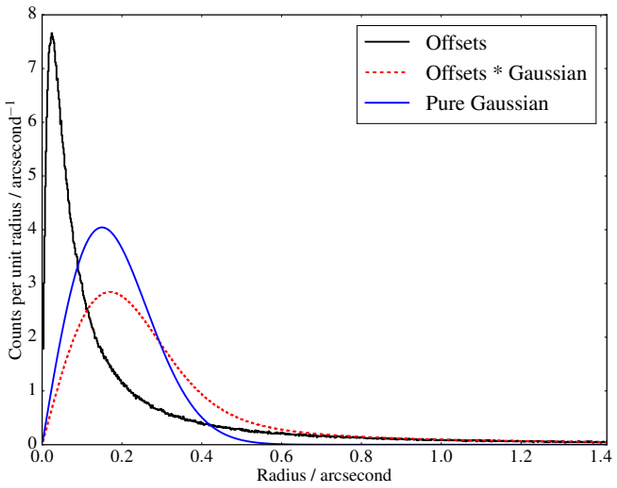
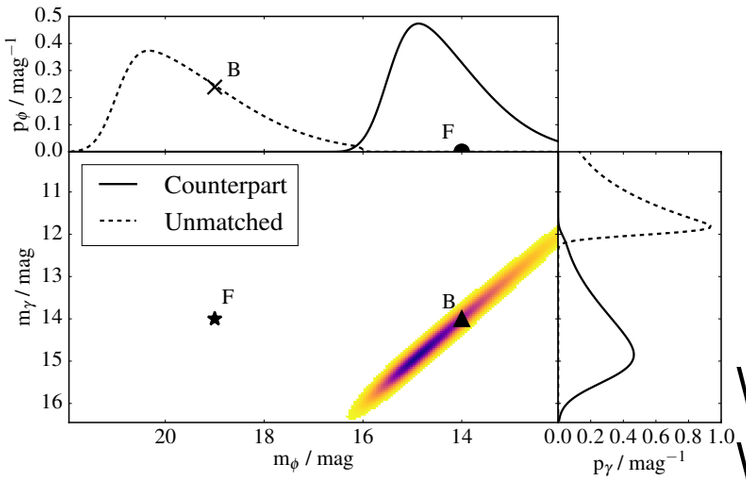
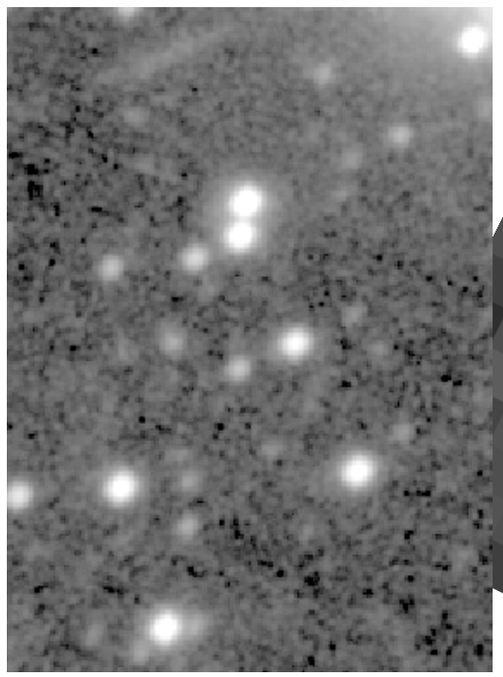
# The Effects of Unresolved Contaminant Stars on the Cross-Matching of Photometric Catalogues: Conclusions

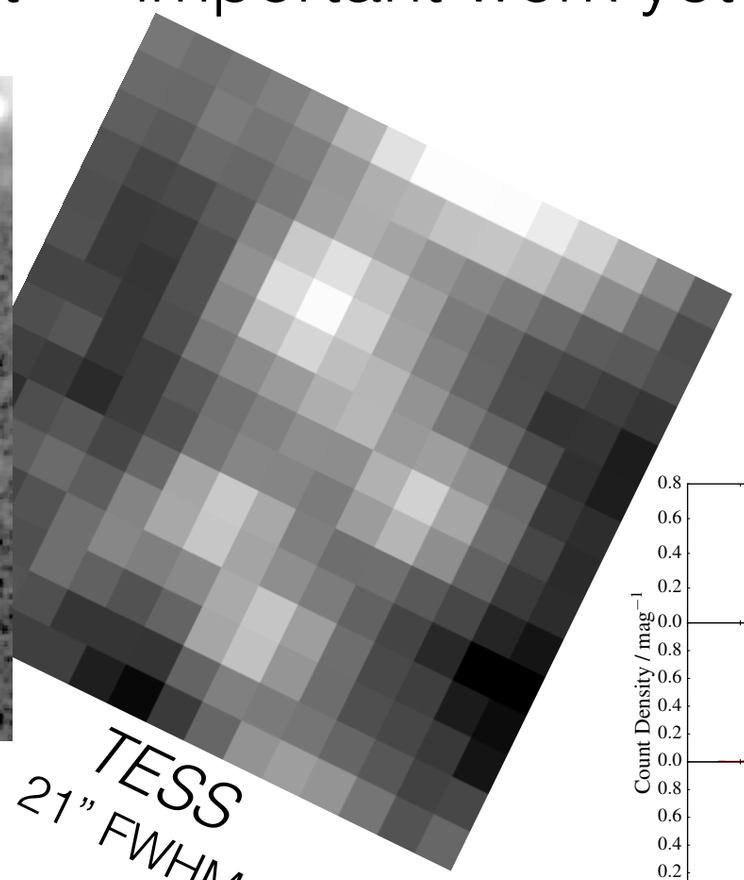
- Blended star contamination causes positional shifts
- *WISE* objects are up to 30% flux contaminated, with *WFIRST* and *LSST* suffering similar blending in the future
- Disentangle this information with proper treatment in the cross-match to a higher angular resolution dataset — important work yet to be done!



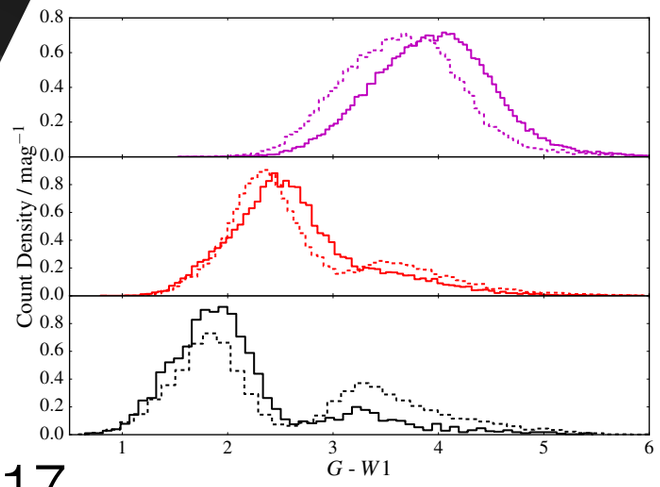



*WISE*
6” FWHM



*TESS*
21” FWHM




Wilson & Naylor, 2017, MNRAS, 468, 2517
Wilson & Naylor, 2018a, MNRAS, 473, 5570
Wilson & Naylor, 2018b, MNRAS, 481, 2148

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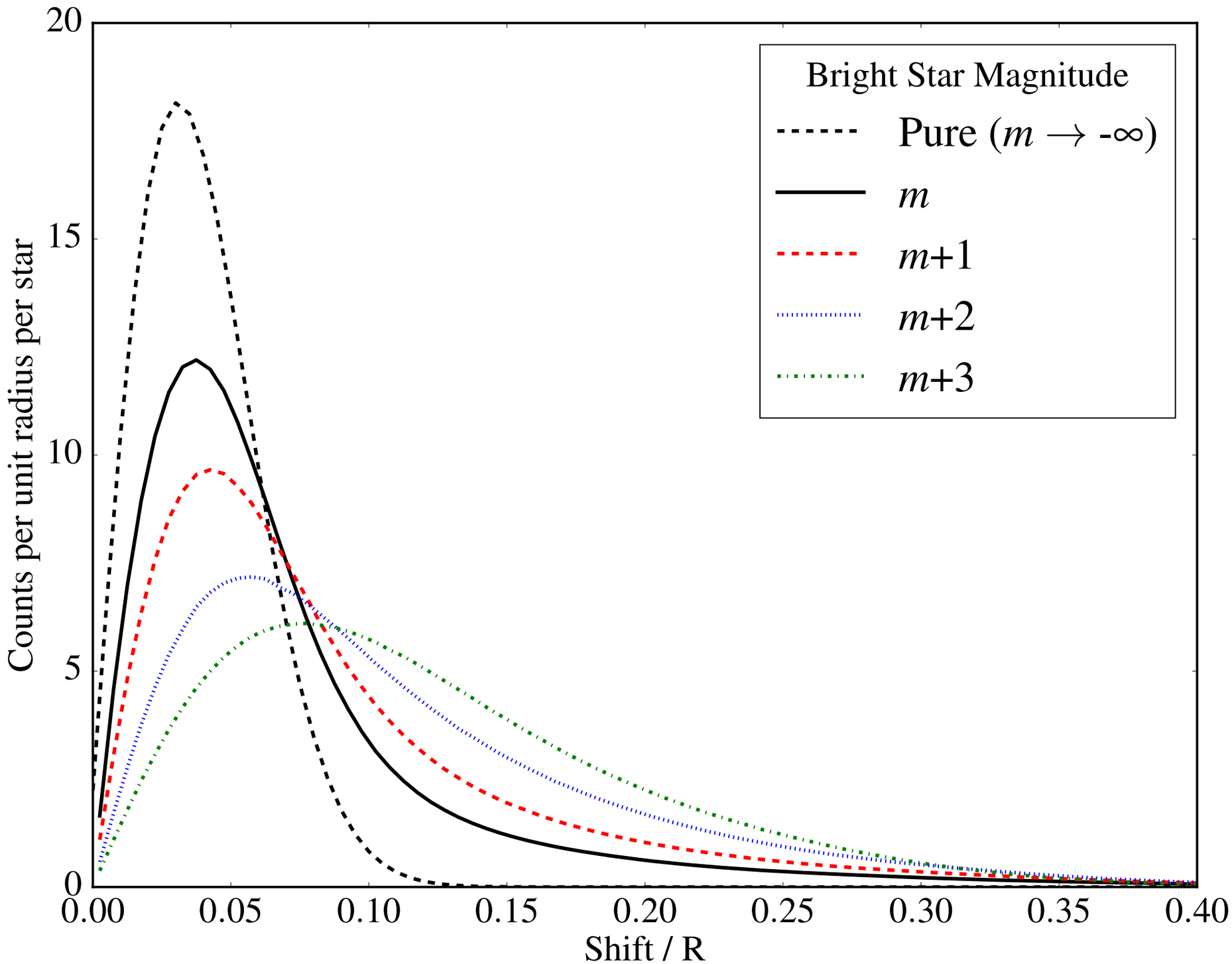
# The Astrometric Uncertainty Function: Synthetic Non-Gaussian Tails




Wilson & Naylor, 2017, MNRAS, 468, 2517

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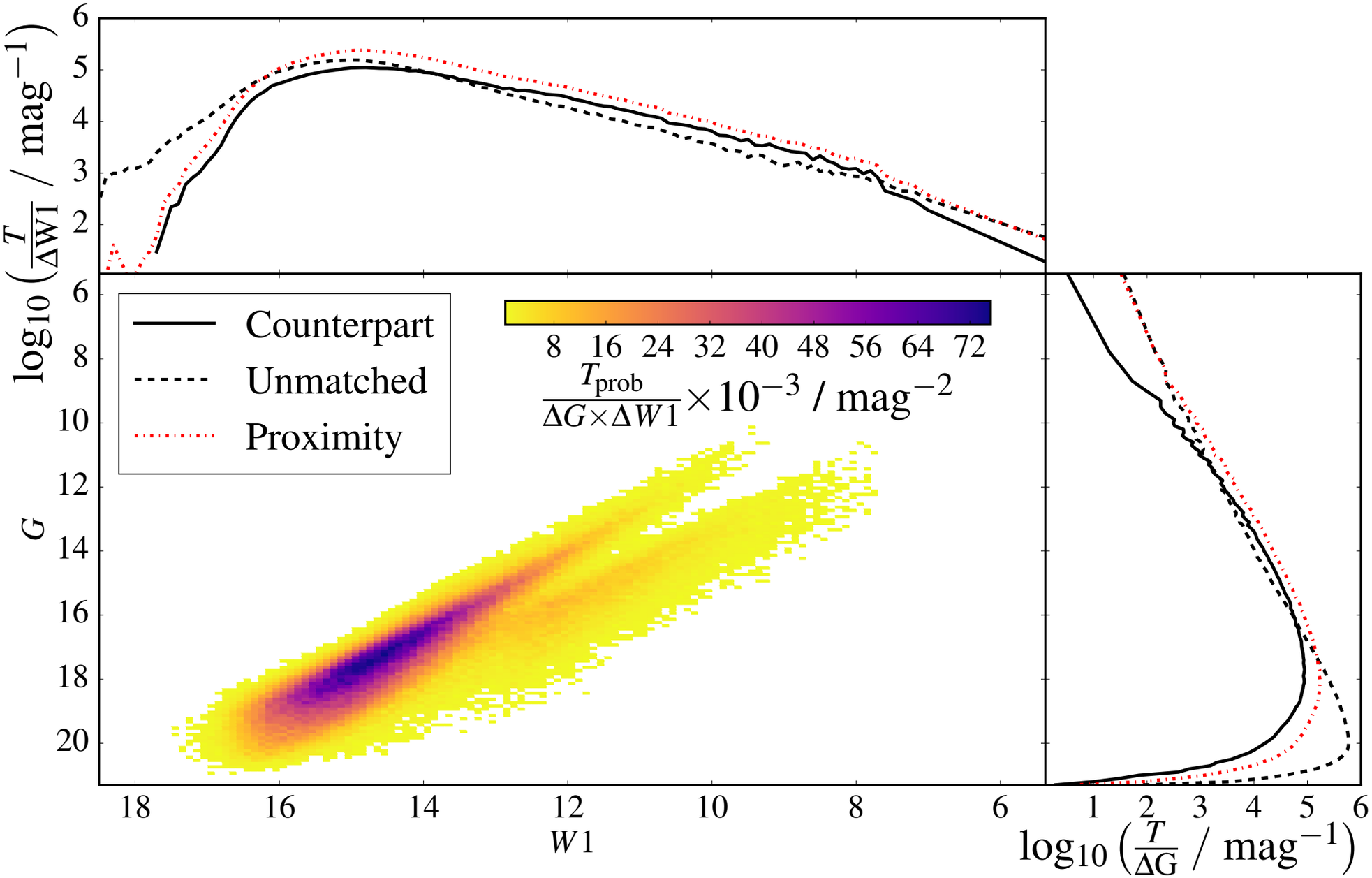
# Contamination Effects: *Gaia-WISE* Gaussian Matches




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

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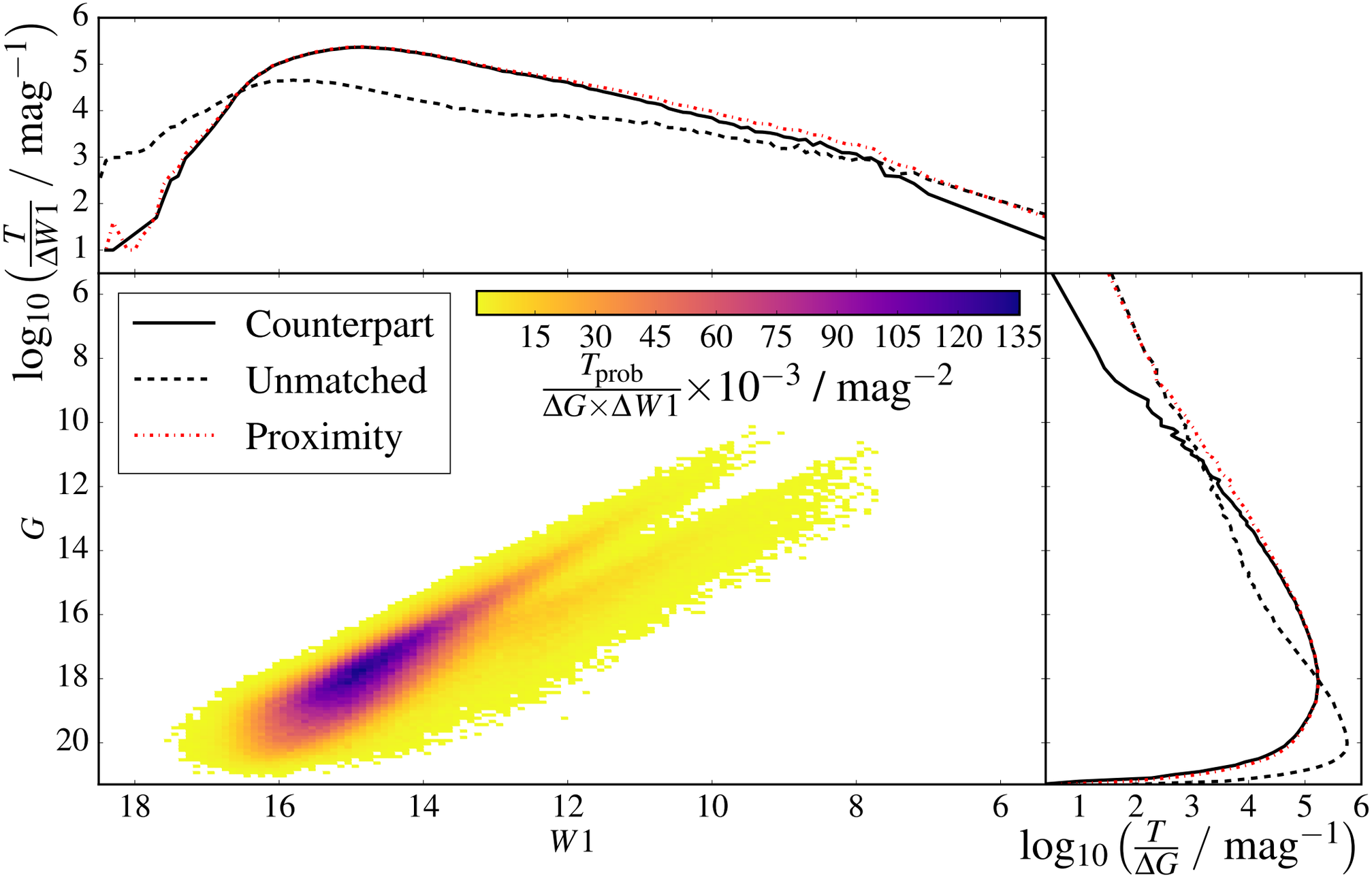
# Contamination Effects: *Gaia-WISE* Empirical Matches




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

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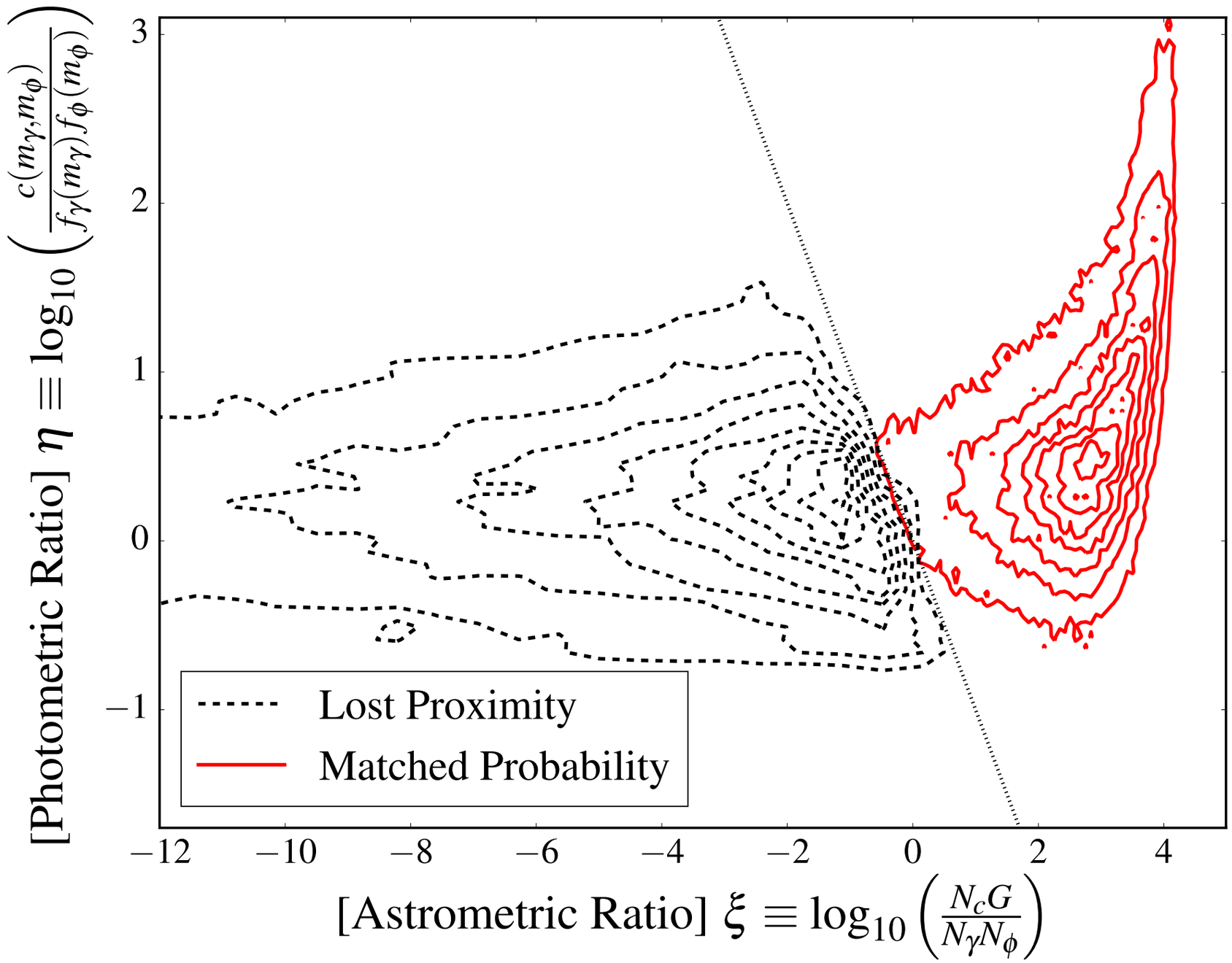
# Contamination Effects: Lost Proximity Matches




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

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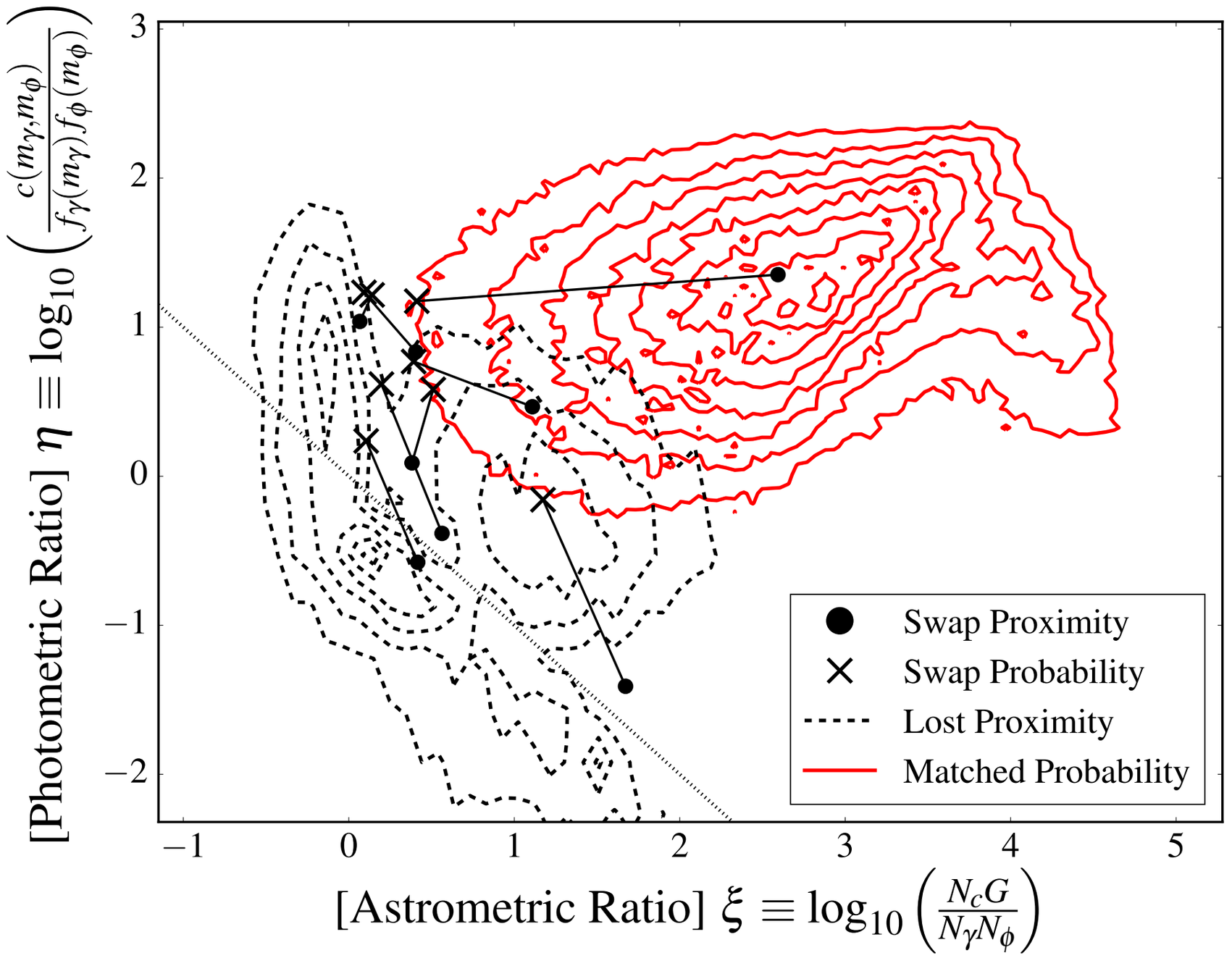
# Contamination Effects: Lost Proximity Matches




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

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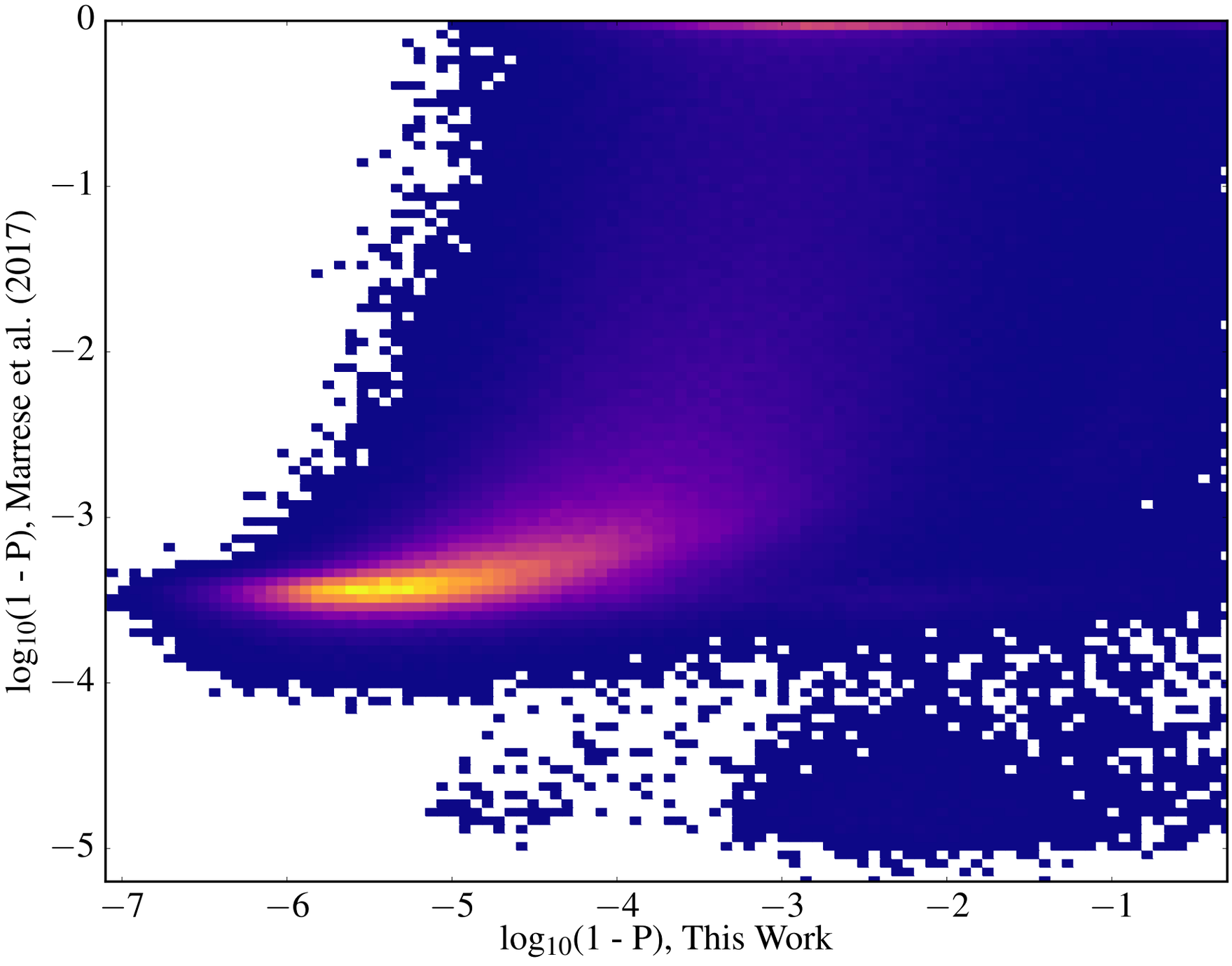
# Contamination Effects: *Gaia* Lost Matches




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

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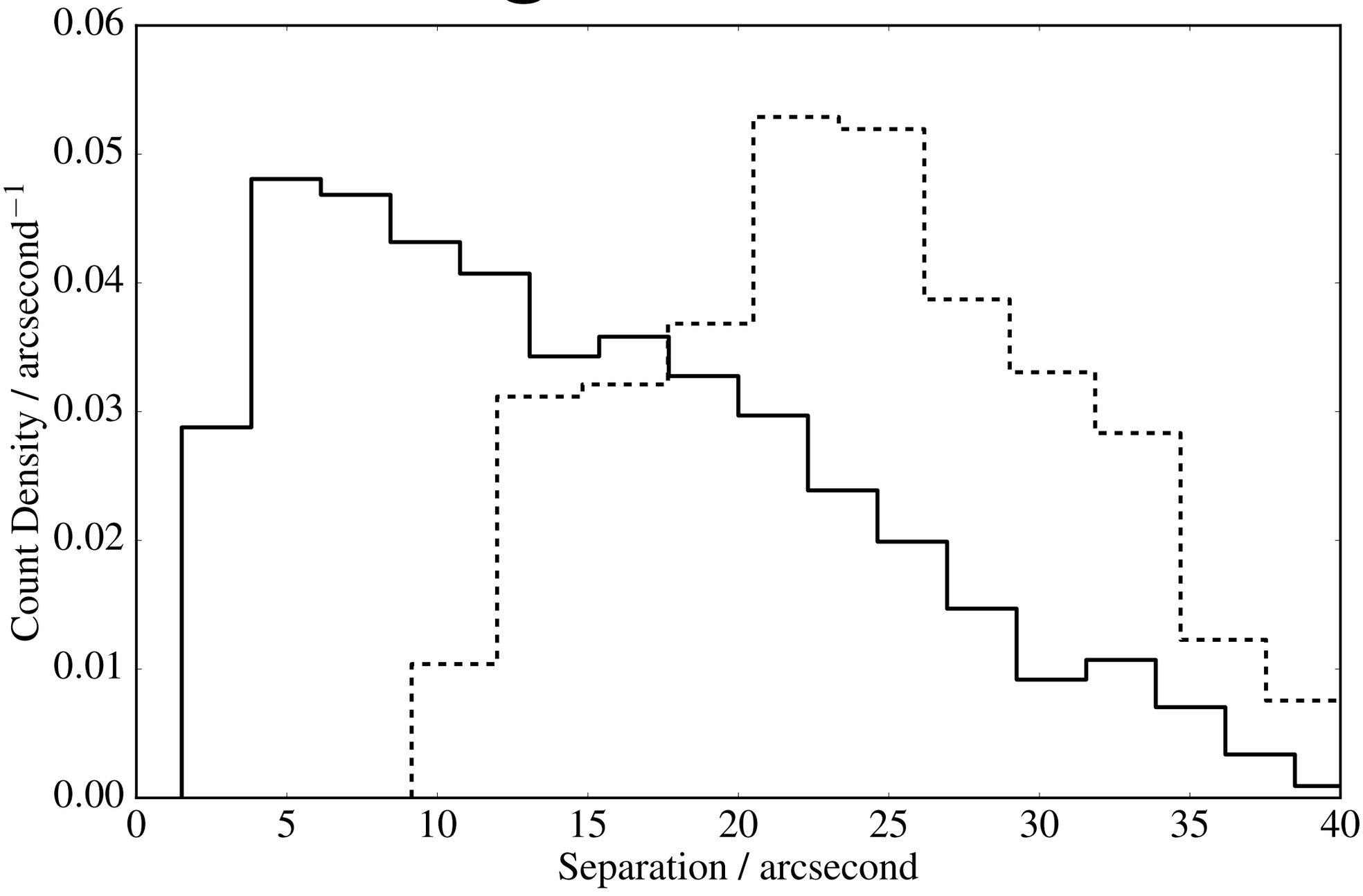
# Contamination Effects: Resolving Contaminants




Spitzer - Werner et al., 2004 ,ApJS, 154, 1
IRAC - Fazio et al., 2004, ApJS, 154, 10
Wilson & Naylor, MNRAS, 2018b, 481, 2148

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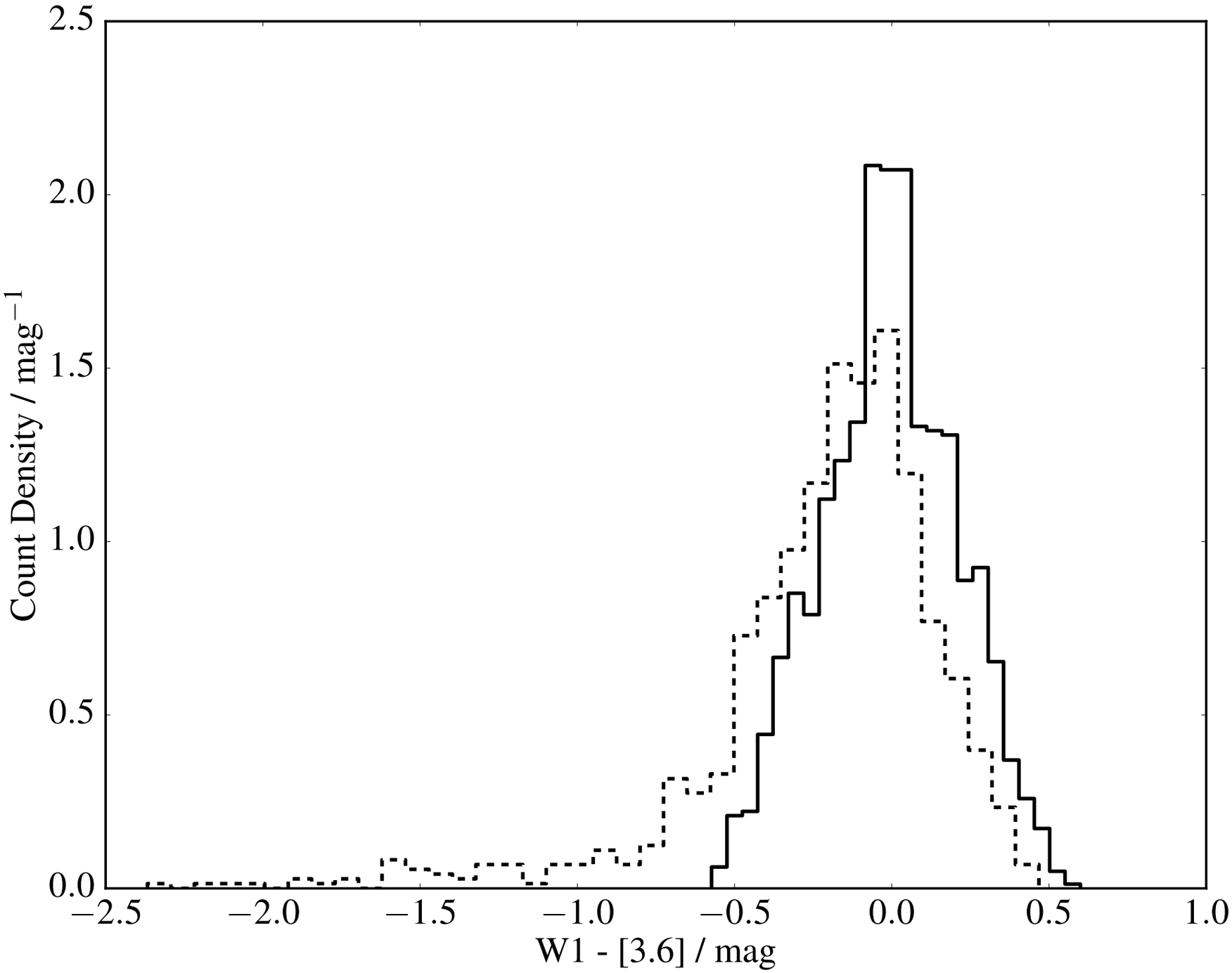
# Contamination Effects: Resolving Contaminant Flux




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

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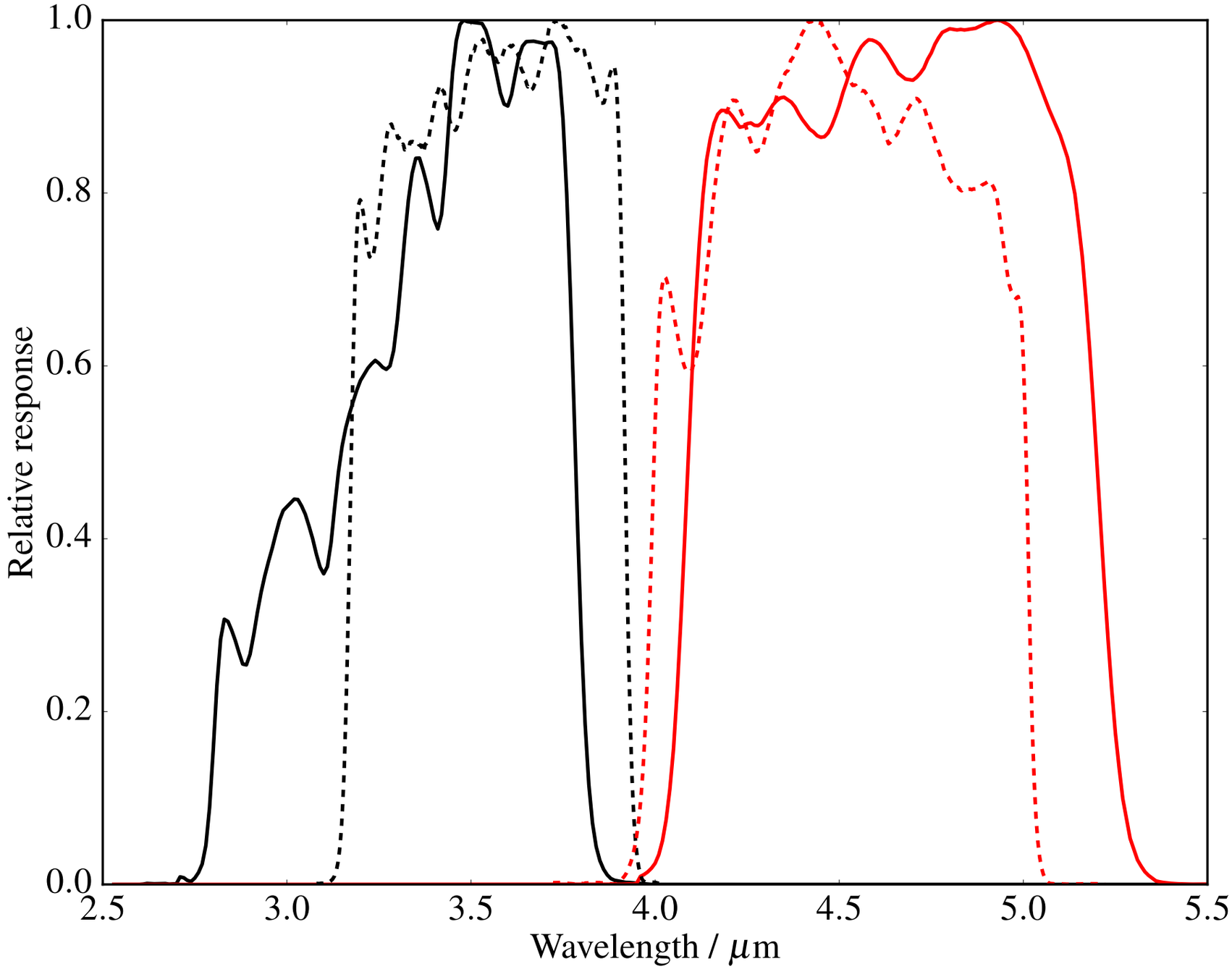
# Contamination Effects: Wavelength Coverage

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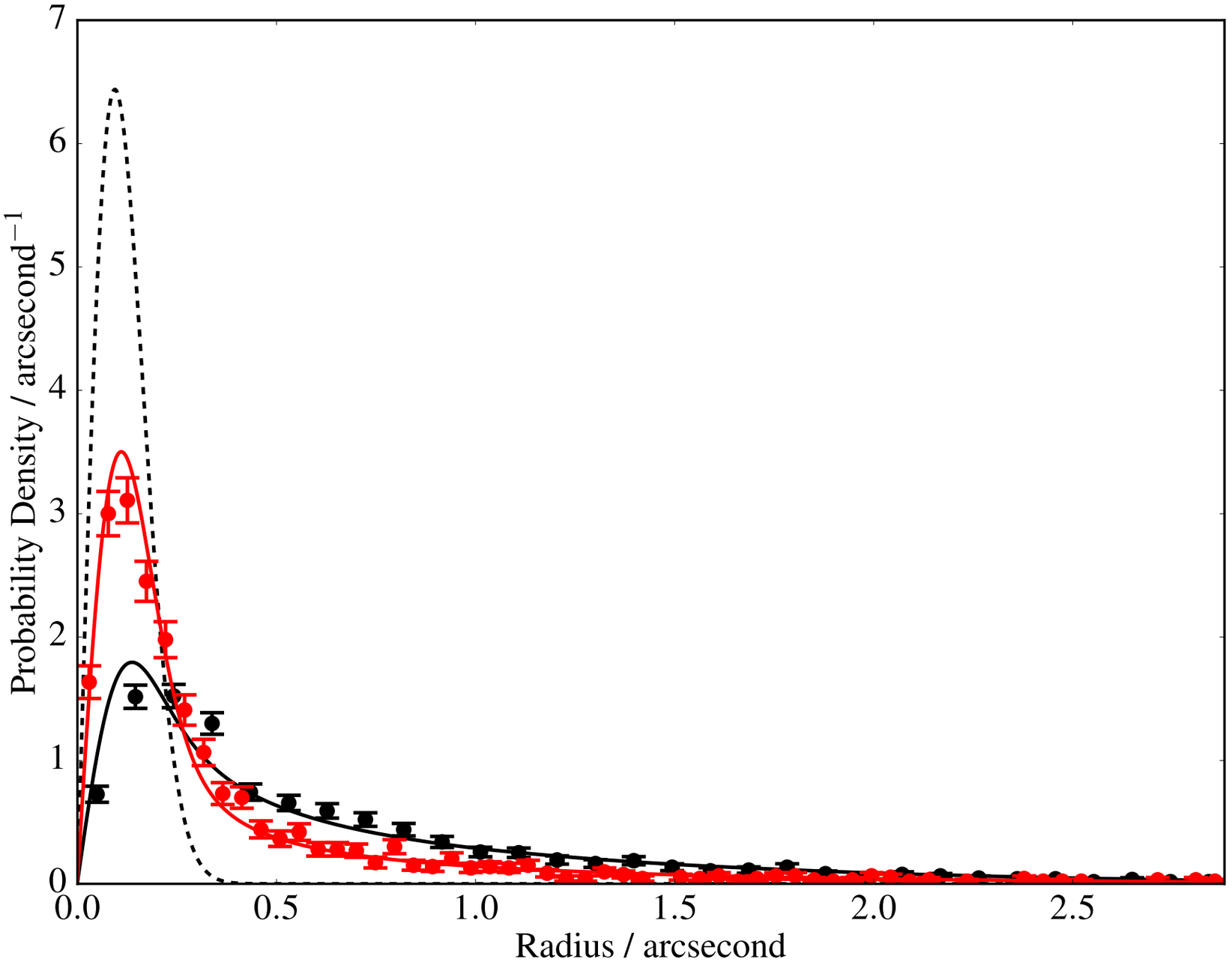
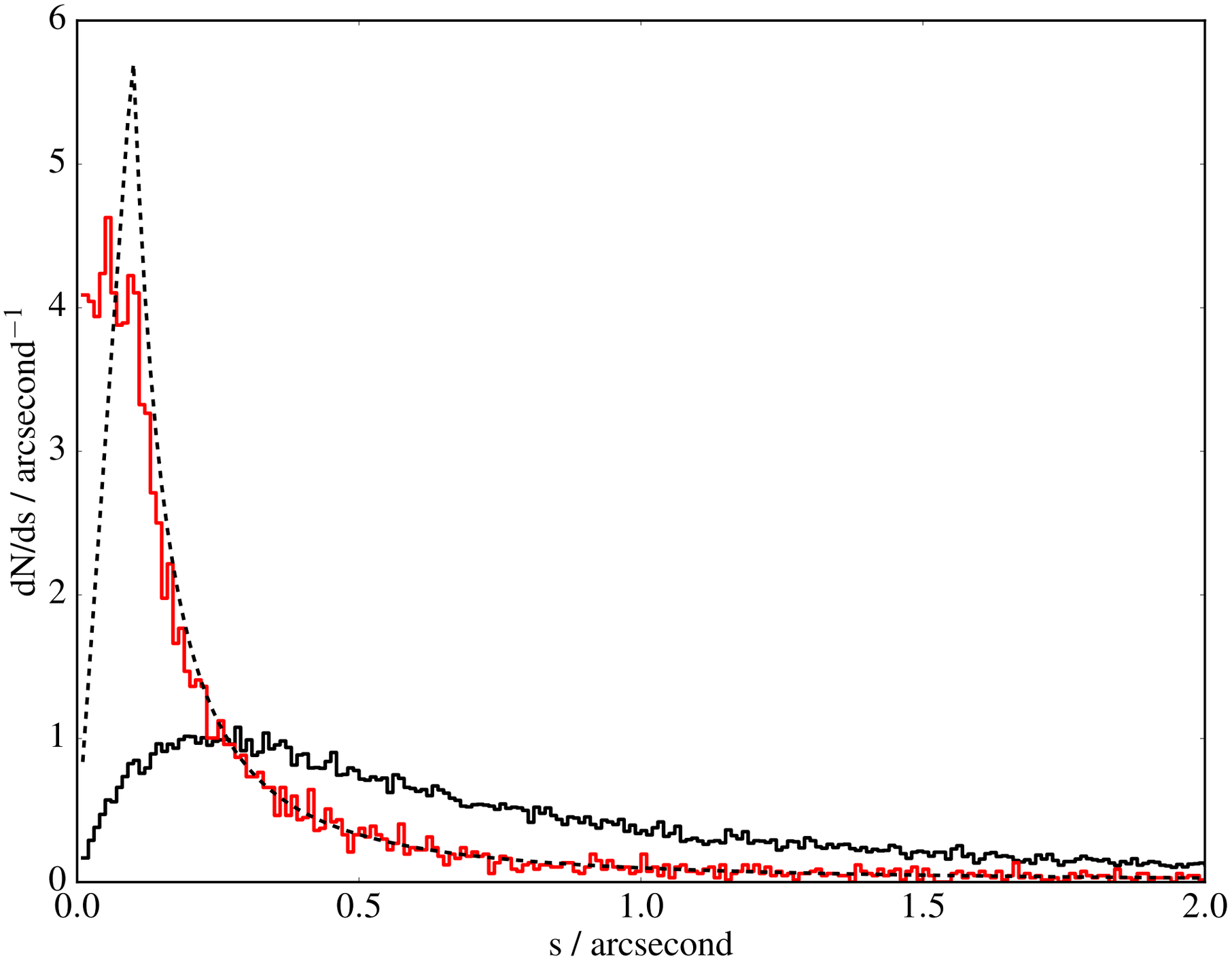
# Contamination Effects: Crowding Normalisation



# The Astrometric Uncertainty Function: Analytical perturbations




Wilson & Naylor, 2017, MNRAS, 468, 2517

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