Reflection and Reprocessing in Swift/BAT AGN: Evidence for a Broad Range of Covering Fractions?

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In collaboration with: Ryan Hickox, **Mislav Baloković**, Taro Shimizu, **Claudio Ricci**, Andy Goulding, David Ballantyne, **Franz Bauer**, Chien-Ting Chen, Agnese del Moro, Duncan Farrah, Michael Koss, **Stephanie LaMassa**, Alberto Masini, Luca Zappacosta

What is the Distribution of AGN Covering Fractions?

Common, typical covering fraction

Claudio Ricci's Talk

Vegan Halloween Monster Donuts

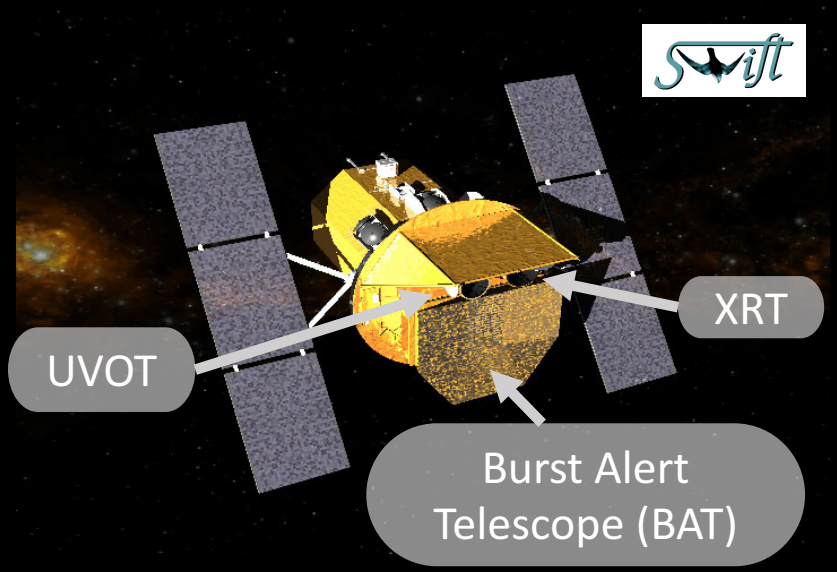
Large variety of covering fraction

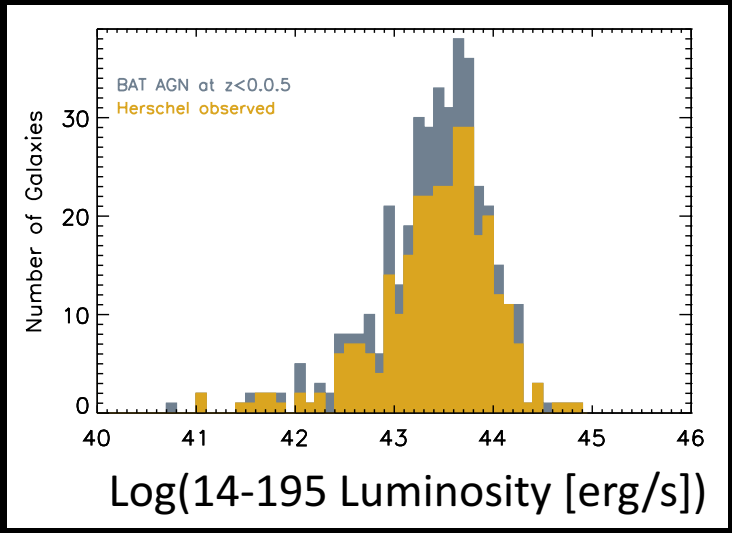
Credit: Peter Boorman

Credit: Peter Boorman

Credit: Martin Ward

Investigating Covering Fractions with Swift/BAT AGN





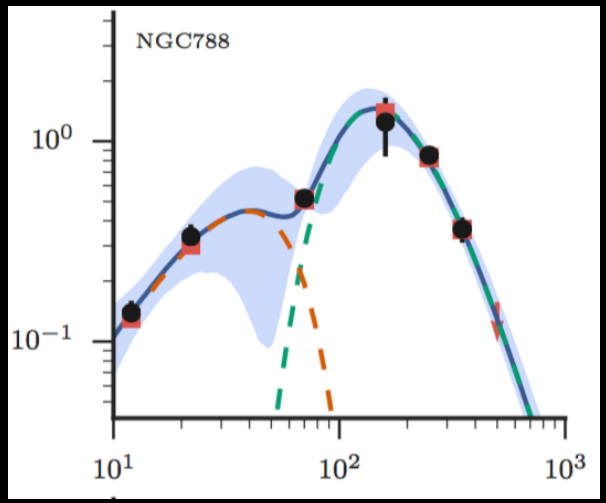
Herschel Observed Sample

313 Swift/BAT AGN at z<0.05

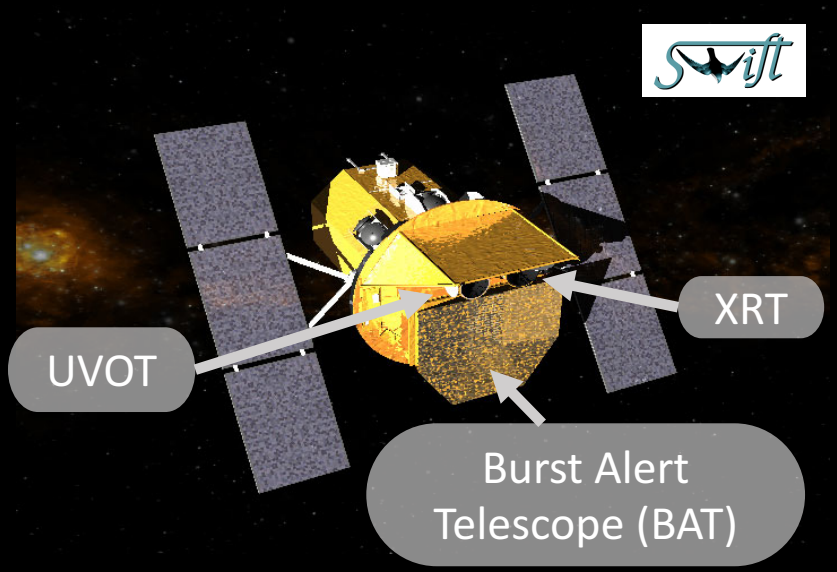
PACS (Meléndez et al. 2014)

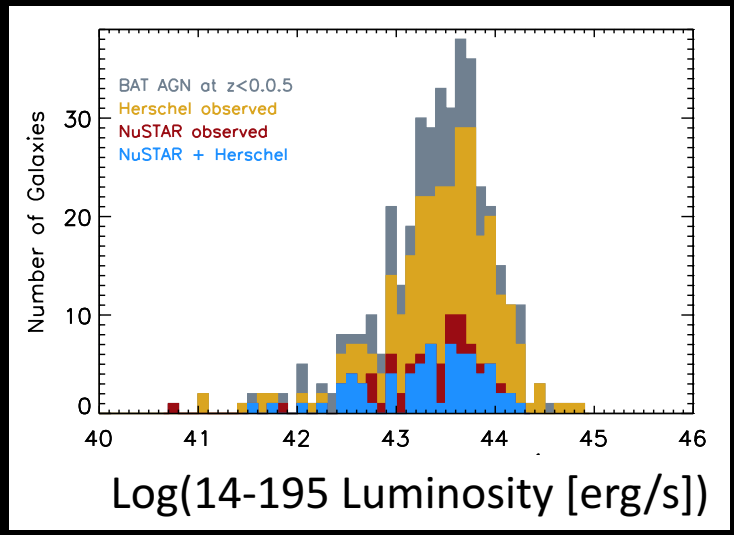
SPIRE (Shimizu et al. 2016)

Herschel + WISE SEDs (Shimizu et al. 2017)



Investigating Covering Fractions with Swift/BAT AGN





69 Obscured AGN with both

Herschel Observed Sample

313 Swift/BAT AGN at z<0.05

PACS (Meléndez et al. 2014)

SPIRE (Shimizu et al. 2016)

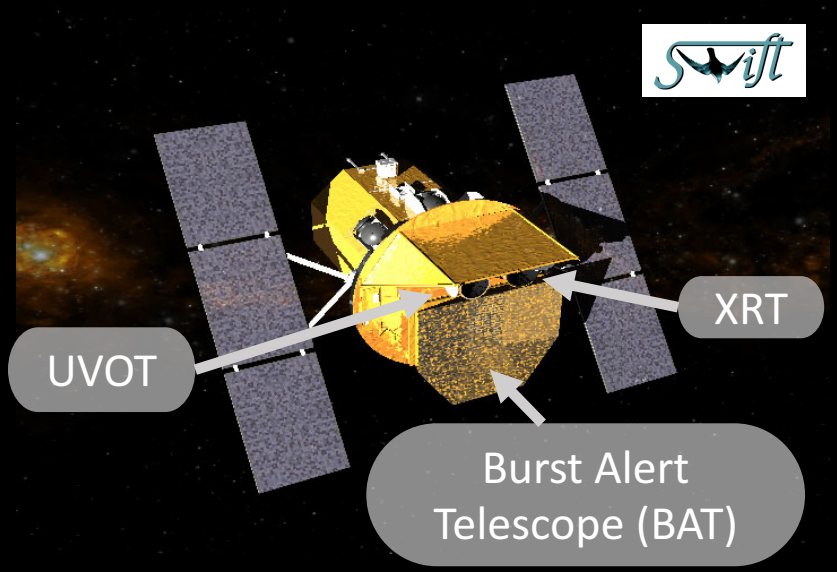
Herschel + WISE SEDs (Shimizu et al. 2017)

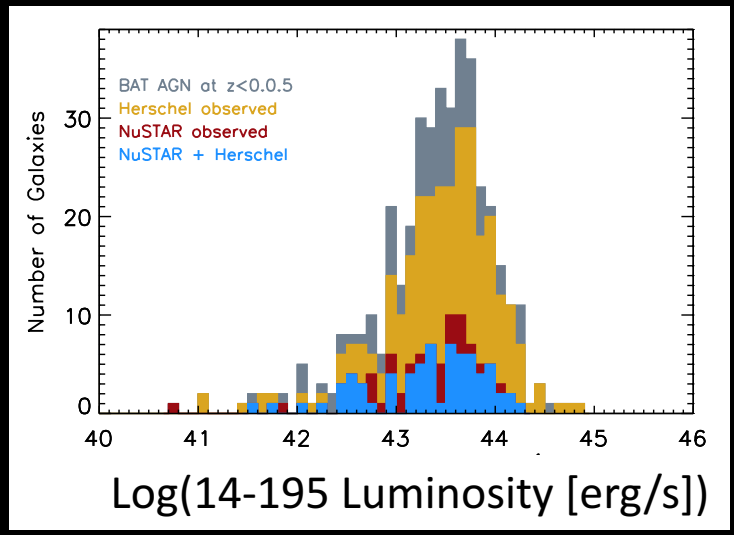
NuSTAR Observed Sample

95 Swift/BAT Sy2 at z<0.05 (Baloković et al. 2018)

Phenomenological Modeling

Investigating Covering Fractions with Swift/BAT AGN





69 Obscured AGN with both

Herschel Observed Sample

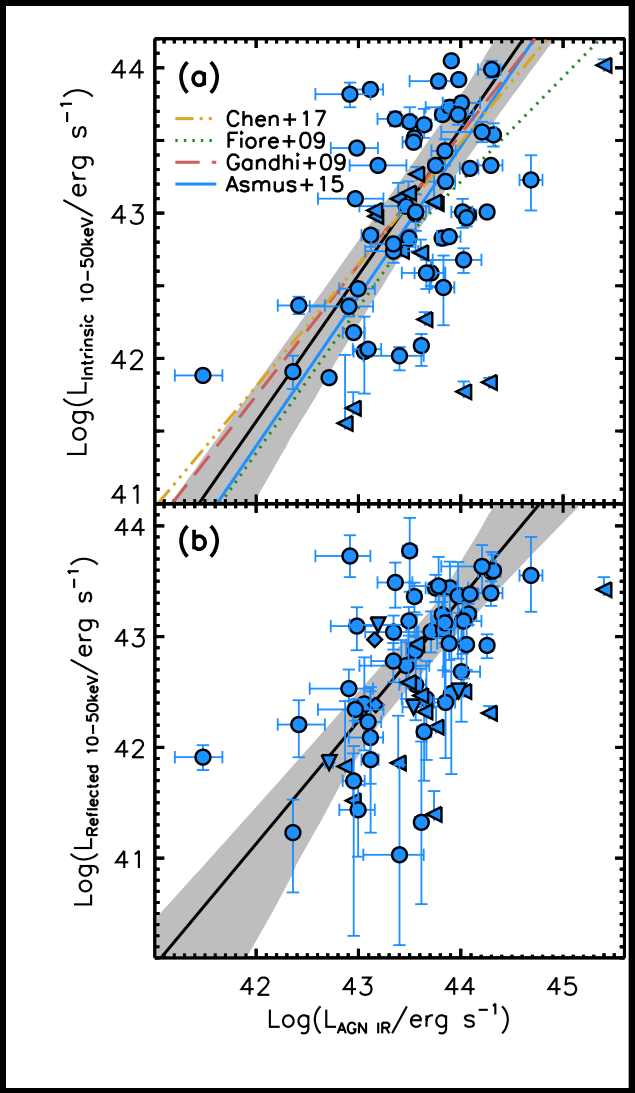
AGN IR Luminosity

NuSTAR Observed Sample

Observed, Intrinsic, and Reflected X-ray Luminosities

Reprocessing across the Wavelengths

ρ = 0.47±0.10
log(p)= -4.0±1.4



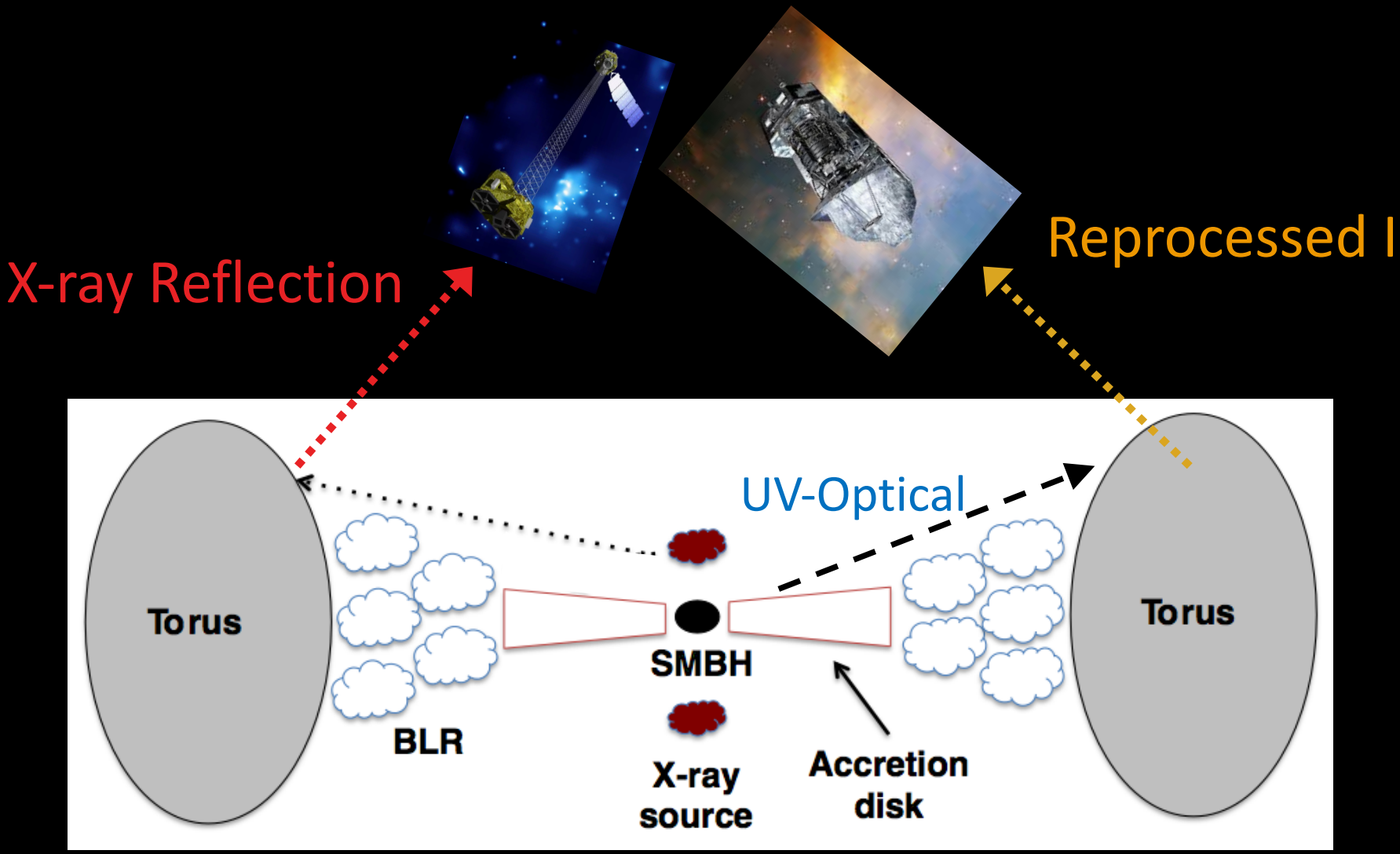
ρ = 0.61±0.08
log(p)= -6.3±1.5

Correlation analysis using ASURV survival analysis code (Lavalley et al. 1992, Isobe et al. 1986)

Bootstrapping to determine reliability of correlation.

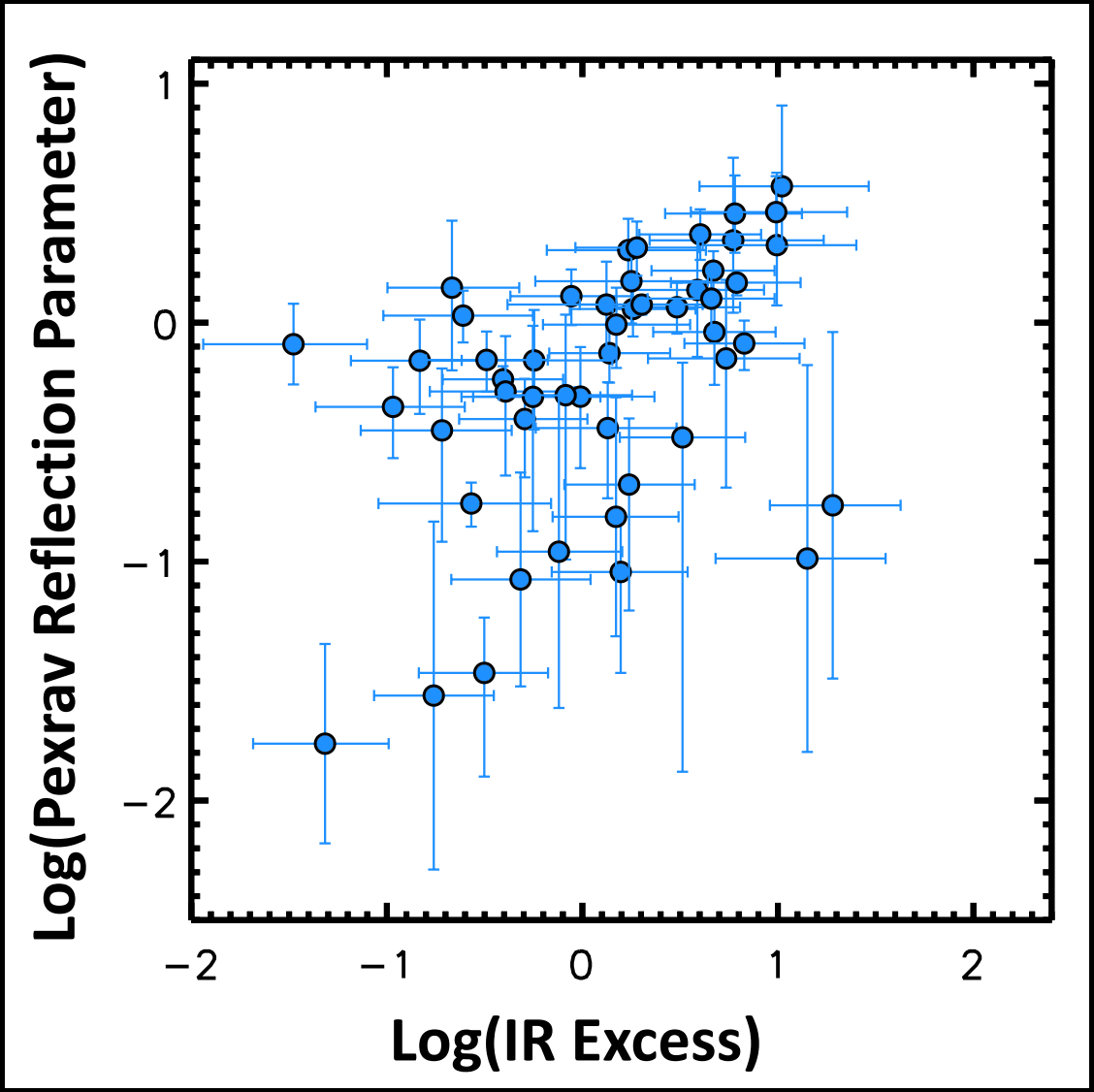
IDL ASURV bootstrapping code available at:
https://github.com/lalanz/bootstrap_asurv

Reprocessing across the Wavelengths



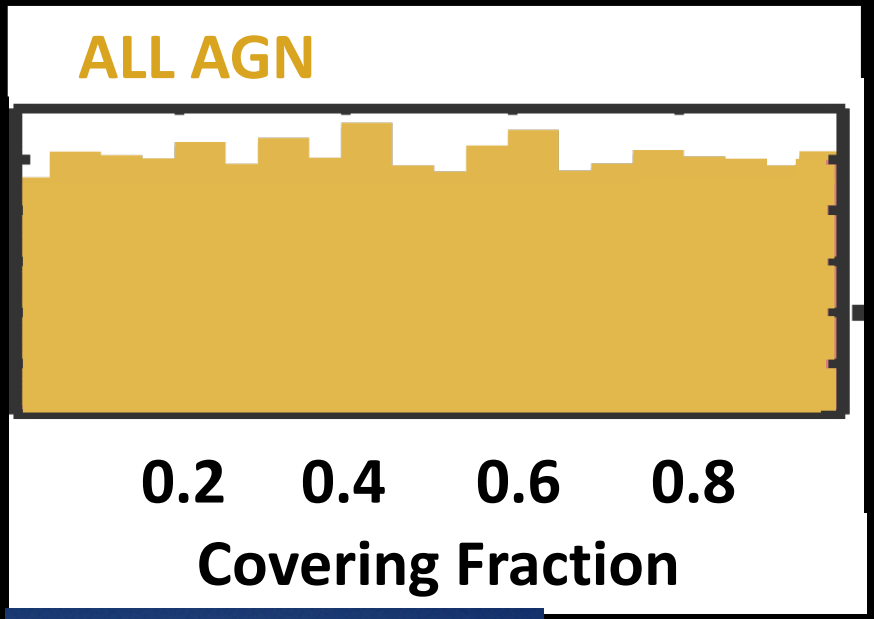
Credit: Claudio Ricci

Reprocessing across the Wavelengths

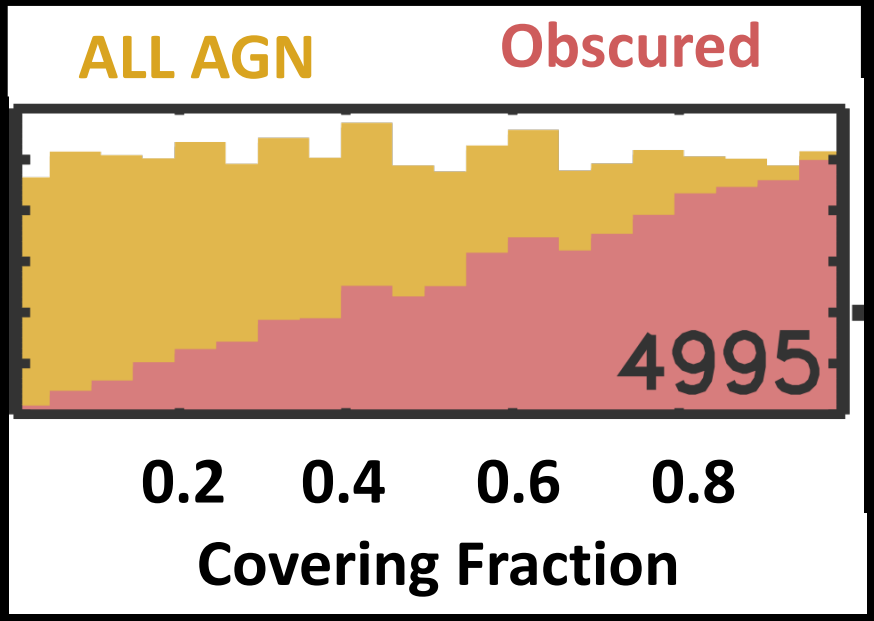


Expected IR(X) relation from Chen et al. (2017)

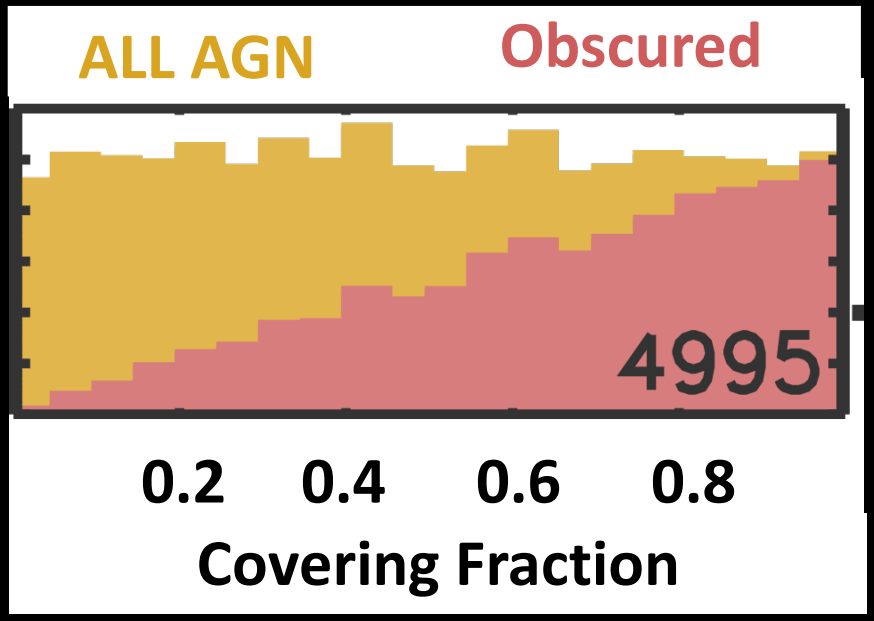
Modeling Observables for Covering Fractions

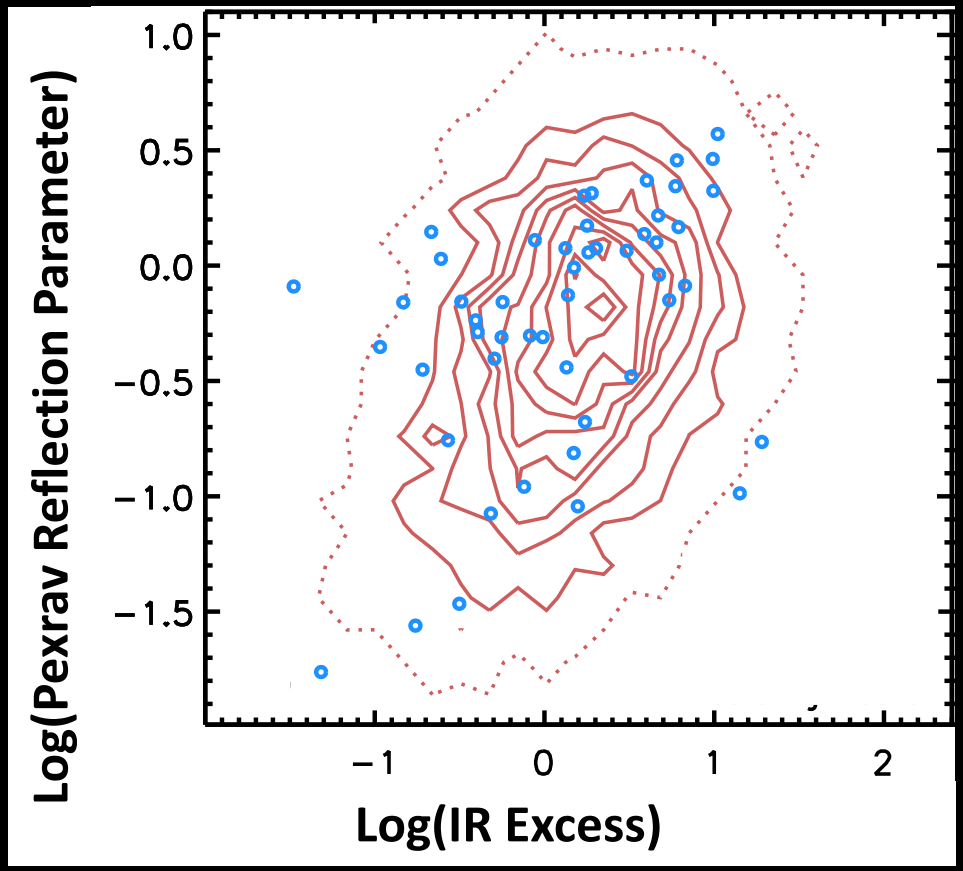


Modeling Observables for Covering Fractions



Modeling Observables for Covering Fractions

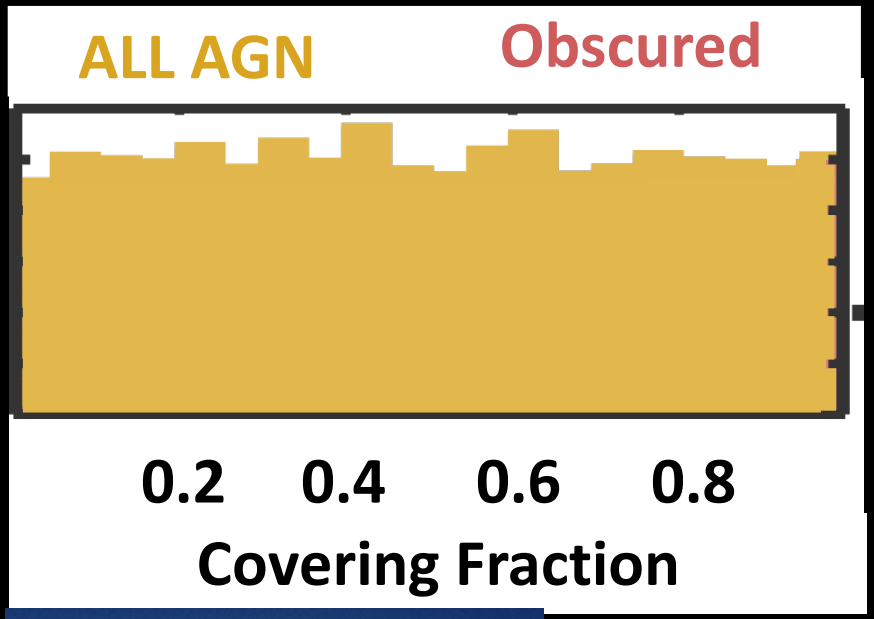




f_{cov} → R_{pex}

→ IR Excess

Modeling Observables for Covering Fractions



pex

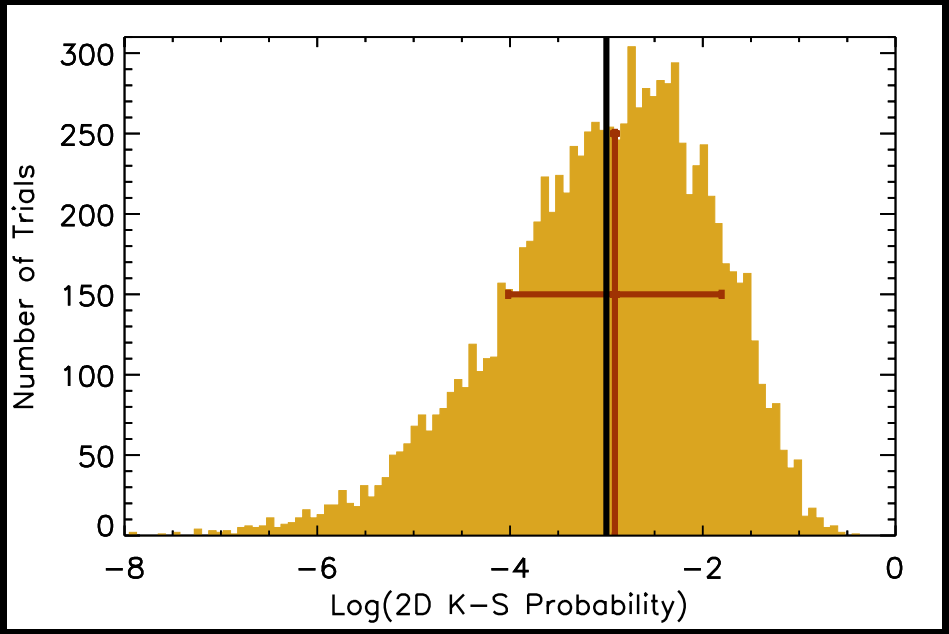
R Excess

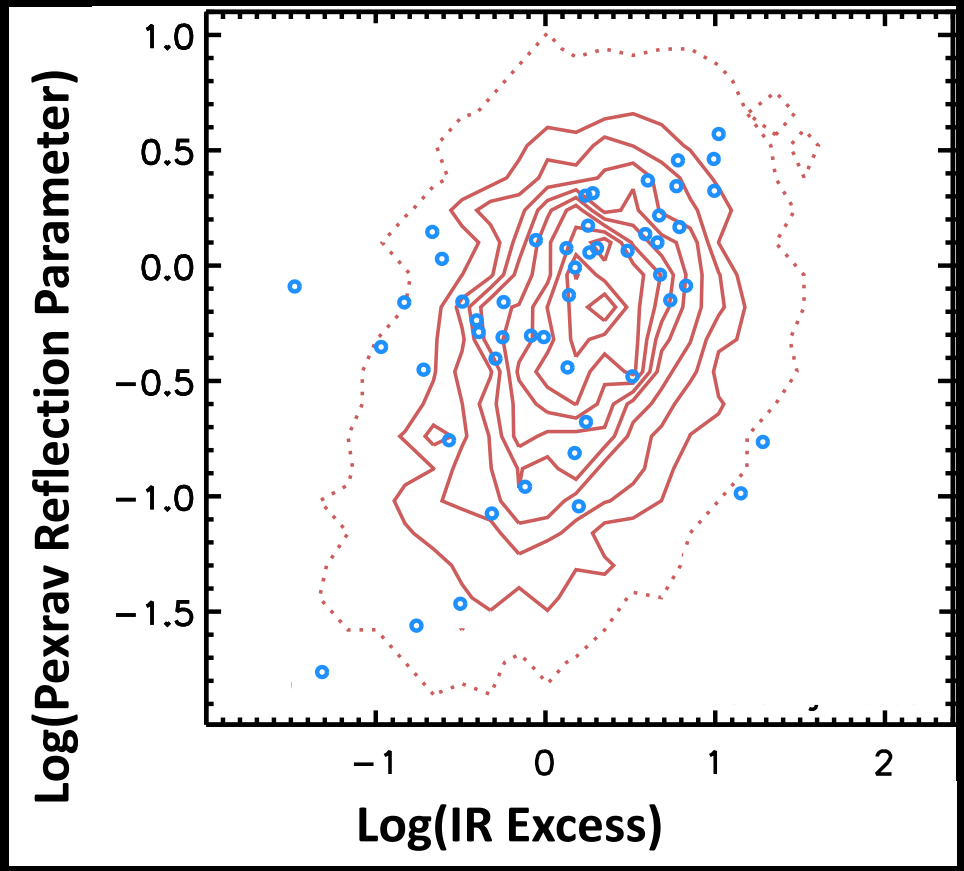
Testing Covering Fractions Distributions

Two-dimensional Kolmogorov-Smirnov (K-S) Test

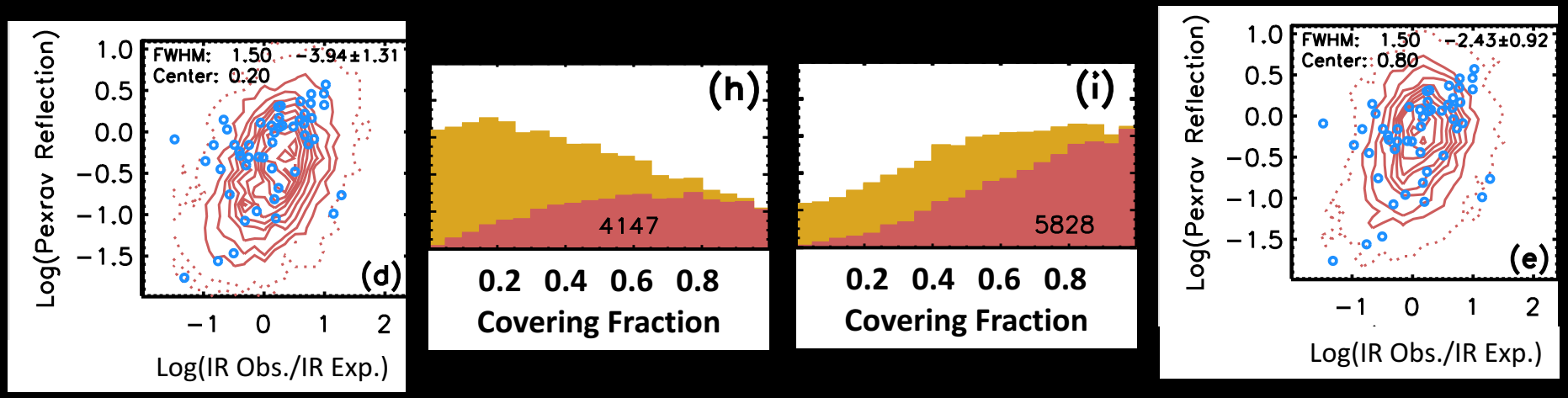
Peacock 1983; Goulding et al. 2014

Log(Probability) = -2.85±1.06

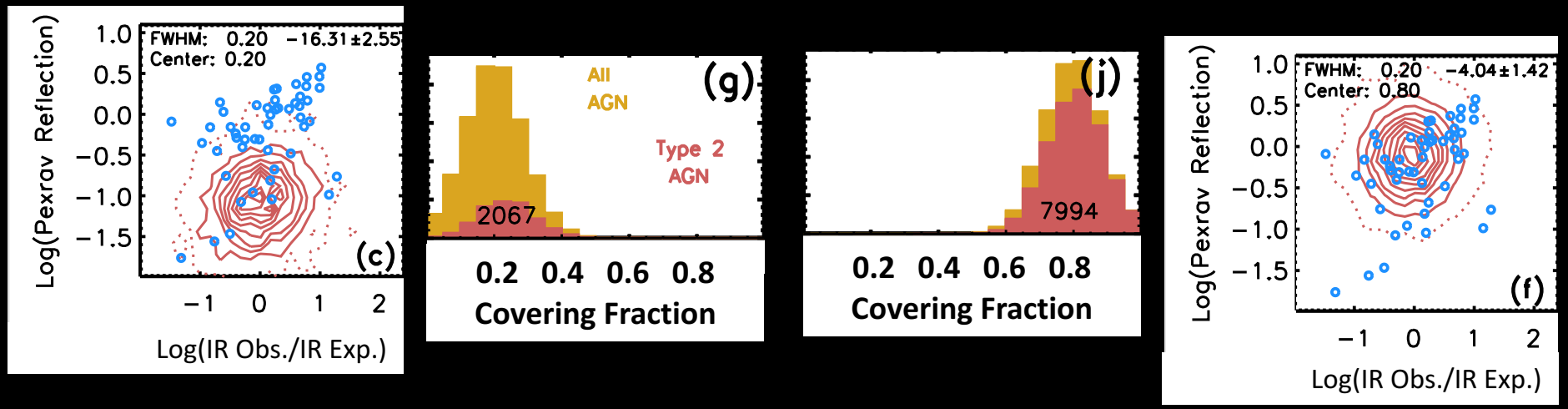




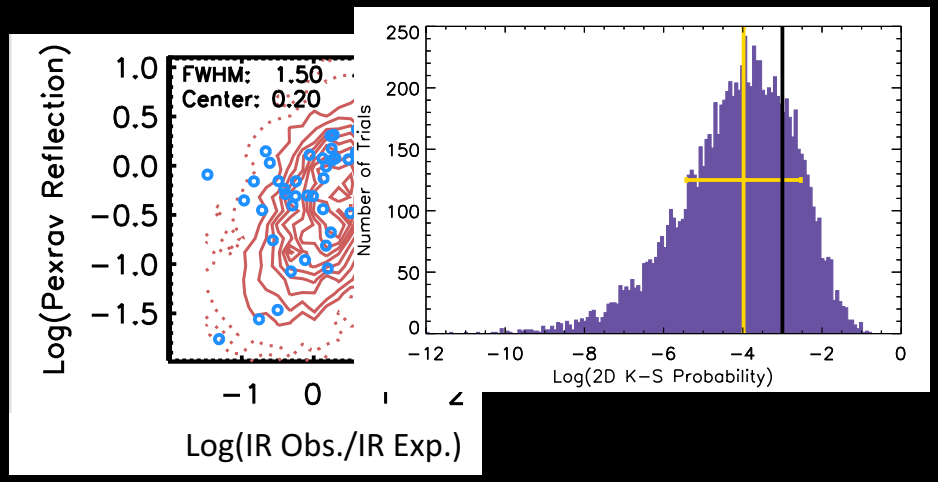
Testing Covering Fractions Distributions

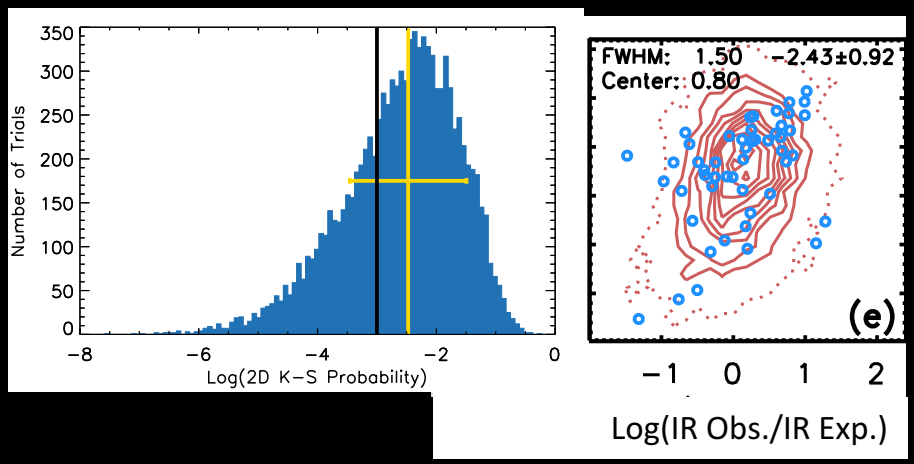


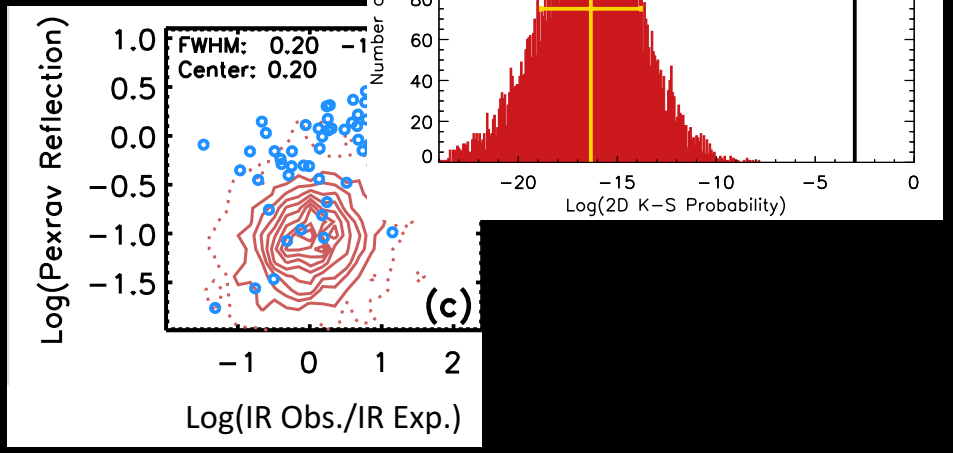
20 FWHM x 21 $\langle f_{Cov} \rangle$ + Uniform
= 421 models

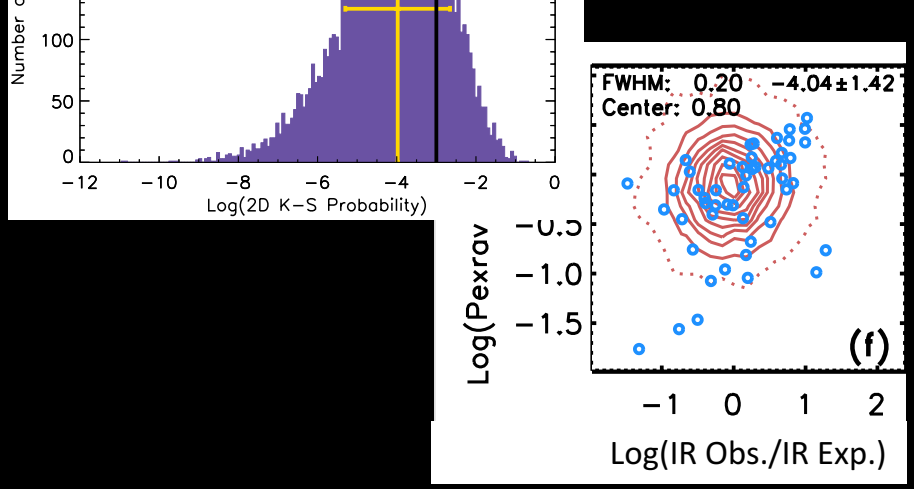


Testing Covering Fractions Distributions

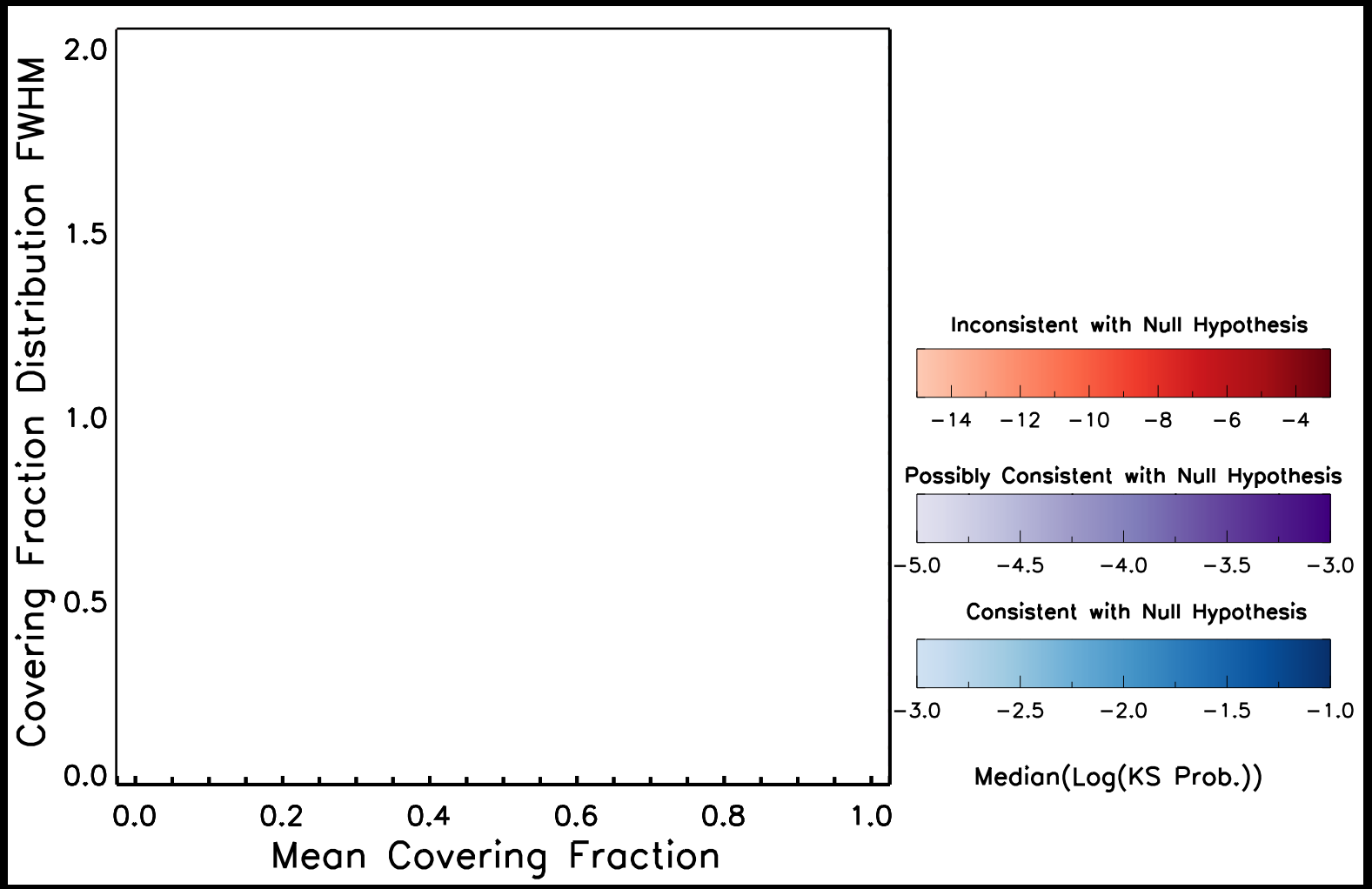








Testing Covering Fractions Distributions



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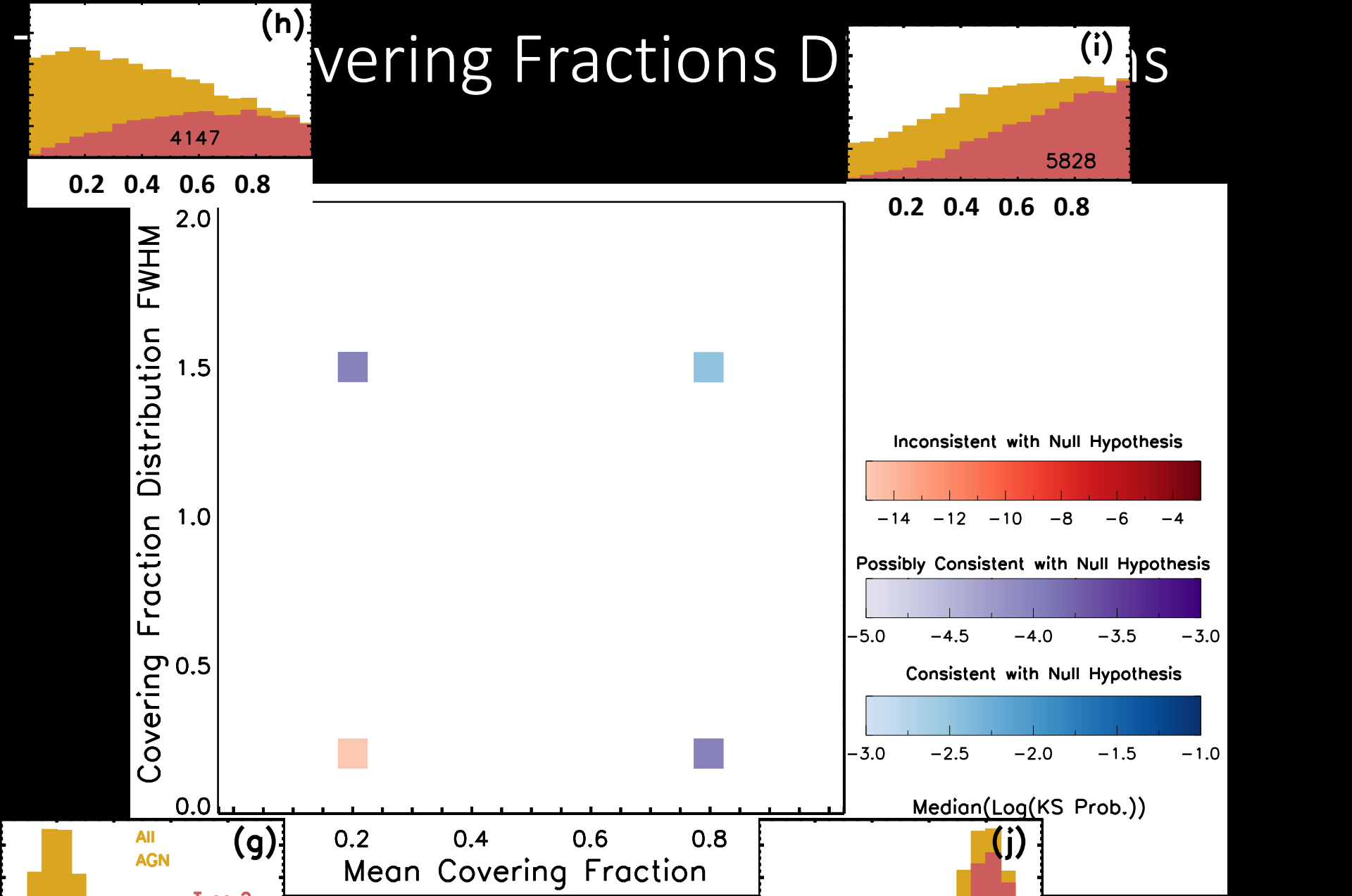

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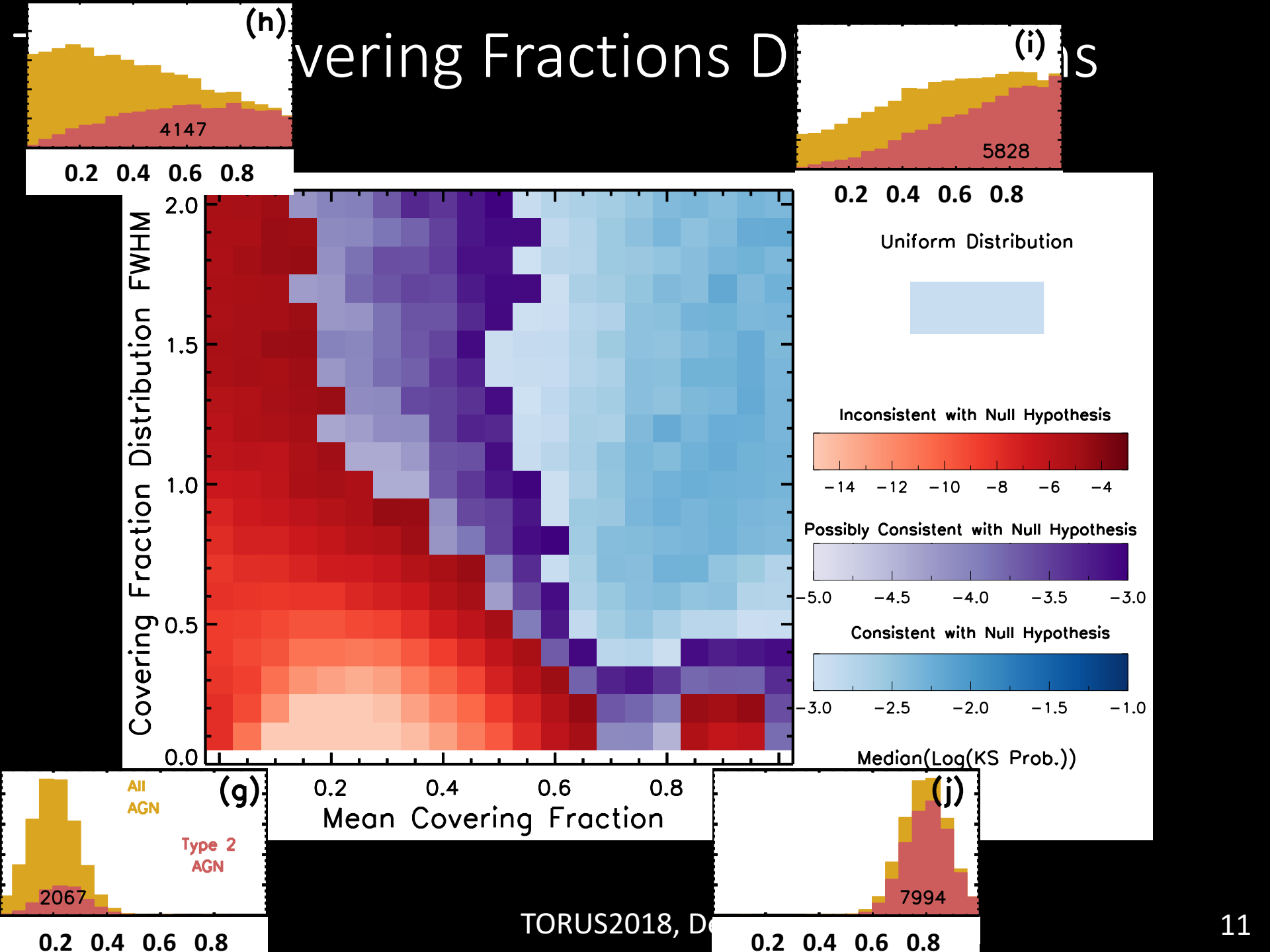

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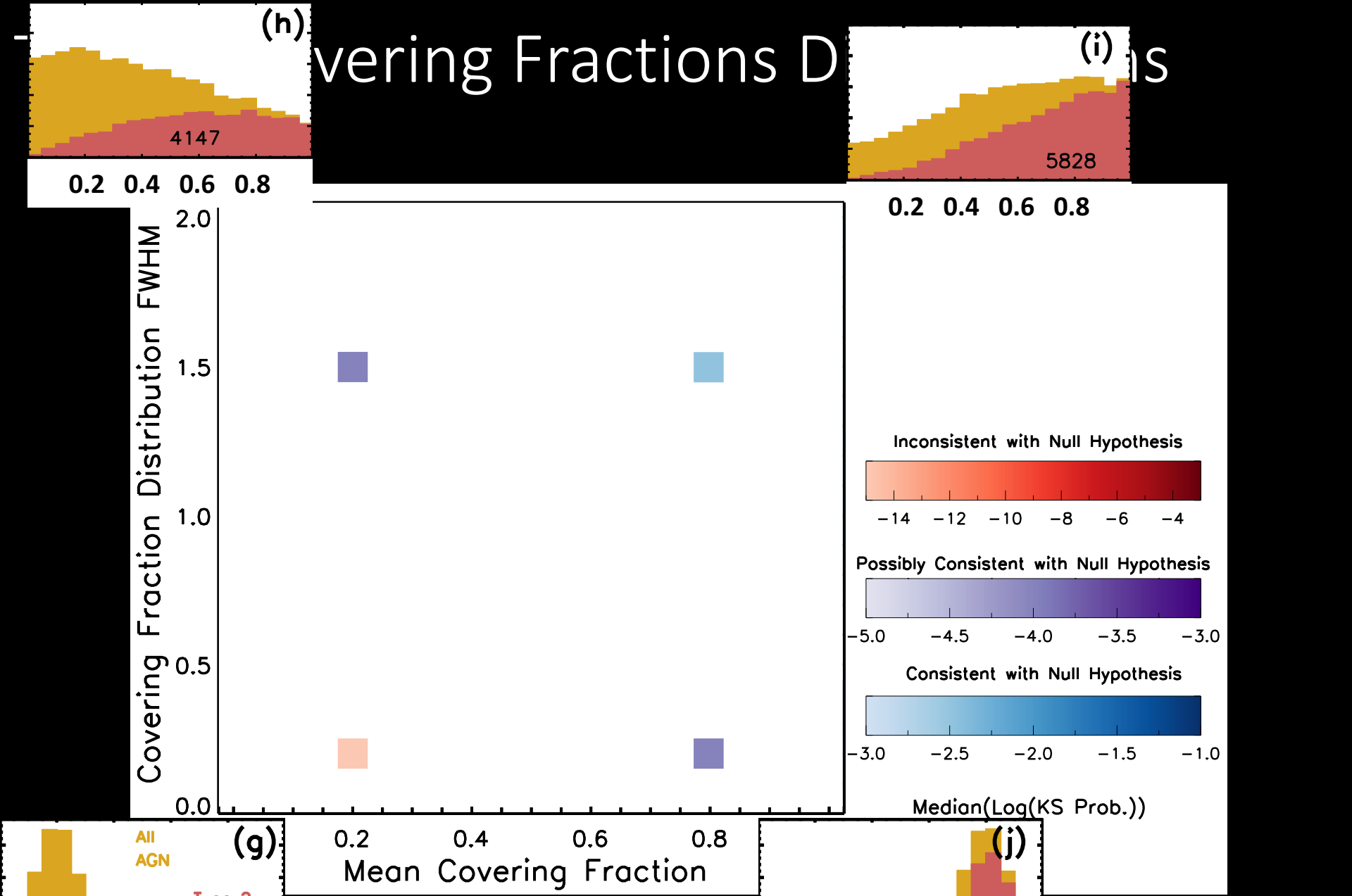
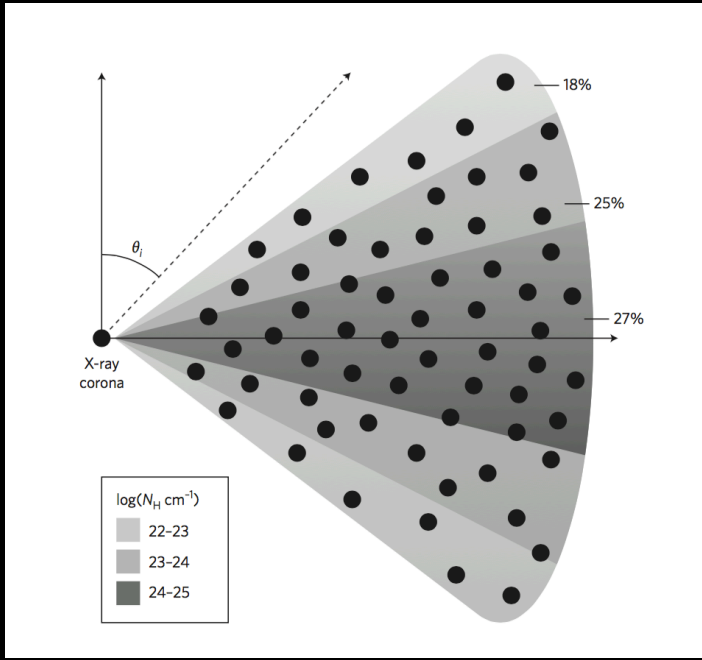


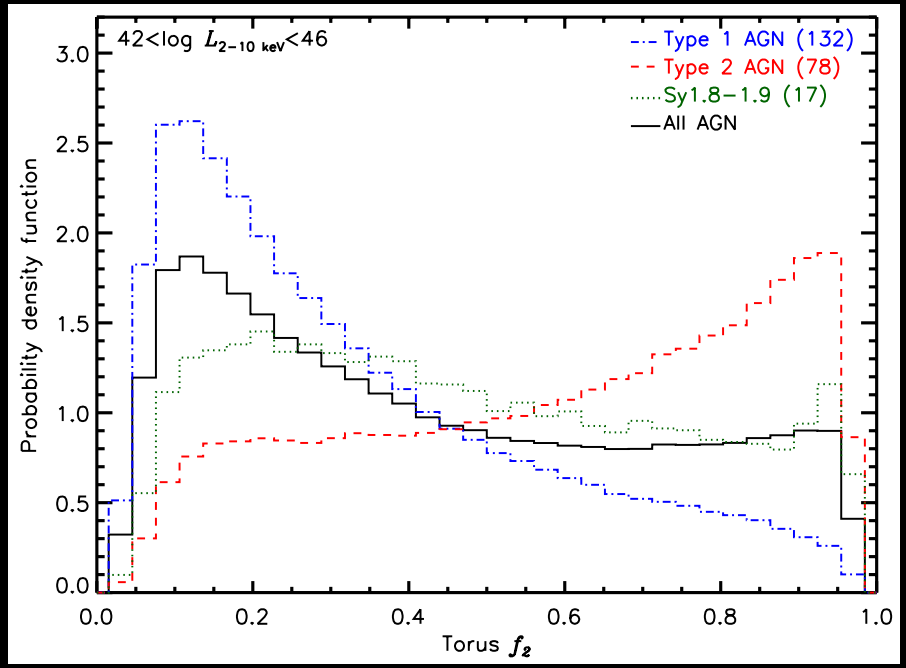
Comparing Covering Fractions Distributions

X-ray Absorption Properties of Large Samples → ~70% Obscured



e.g., Ramos Almeida & Ricci 2017
Ricci et al. 2015

IR Clumpy Torus Modeling → Broad Distributions



e.g., Mateos et al. 2016,
Ichikawa et al. 2015,
Alonso-Herrero et al. 2011
Ramos Almeida et al. 2011

Summary

- Reflected X-ray luminosity and IR AGN luminosity are correlated → a common (or related) re-processor.

- Simple empirical model to identify distributions of covering fraction that reproduce this relation

- Broad distributions best match observations

Lanz et al. ApJ accepted, arXiv:1811:02570

Stat. codes: https://github.com/lalanz/bootstrap_asurv