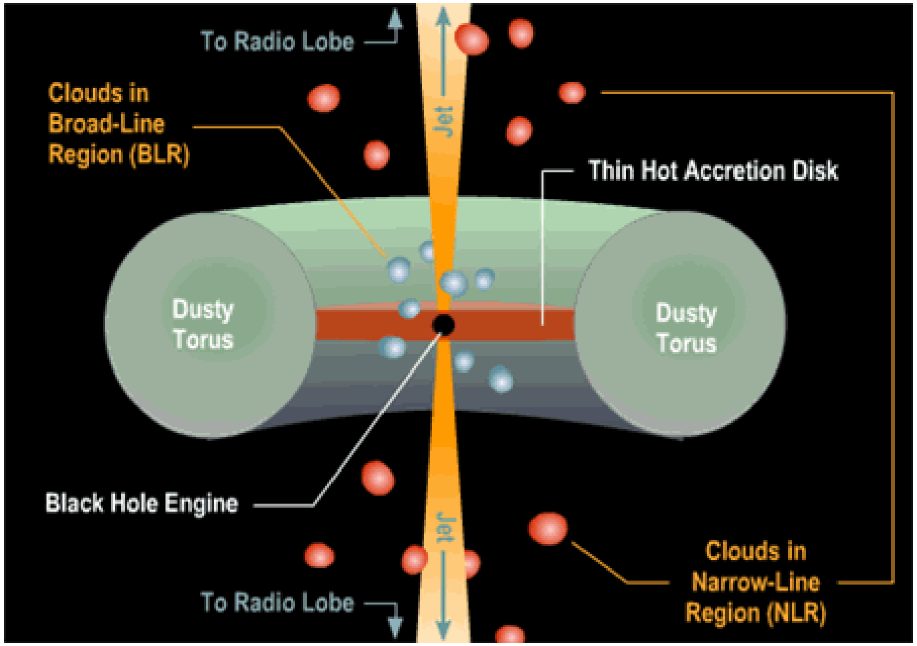
Using Infrared Colors to Identify Obscured AGN

By Ryan Allured and Hannah Marlowe based on:

MID-INFRARED SELECTION OF ACTIVE GALACTIC NUCLEI WITH THE WIDE-FIELD INFRARED SURVEY EXPLORER. I. CHARACTERIZING WISE-SELECTED ACTIVE GALACTIC NUCLEI IN COSMOS
Stern et al. 2012
http://adsabs.harvard.edu/abs/2012ApJ...753...30S

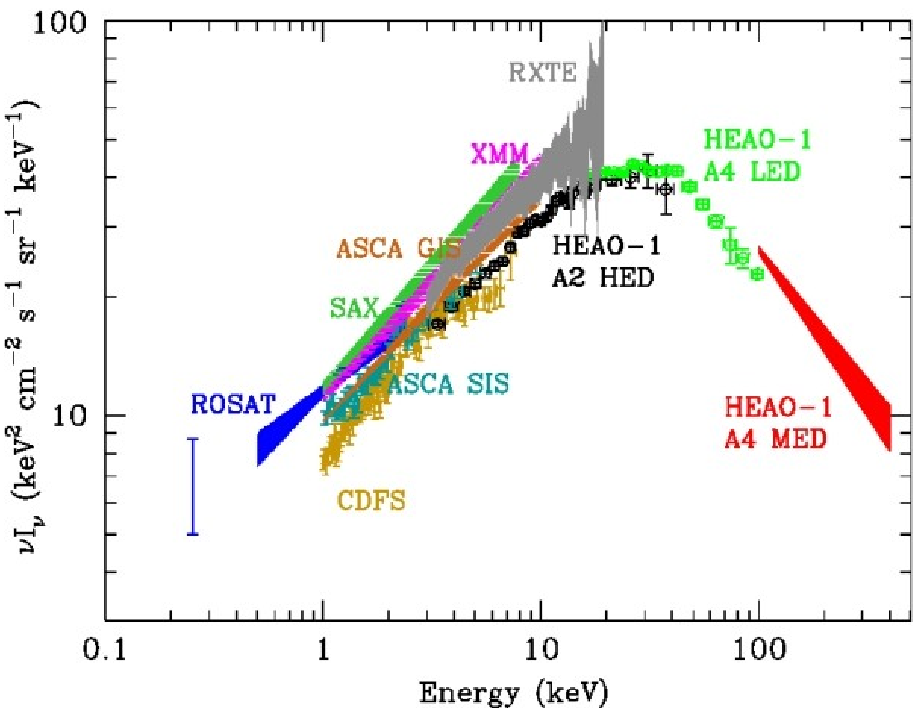
Active Galactic Nuclei

- What are they?
  - Accreting SMBH in galactic centers
  - High luminosity allows probe of early universe
- Emit across EM spectrum
  - Thermal radiation
    - Big Blue Bump
    - Heated dust
  - Power law
    - Radio synchrotron
    - High energy (Comptonization)



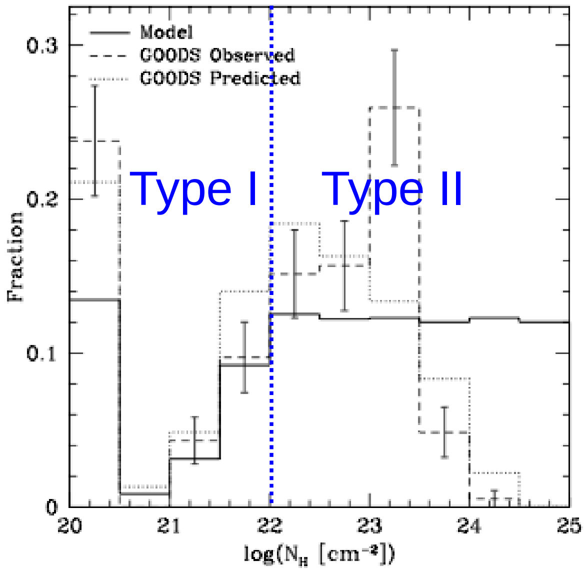
Why Do We Care?

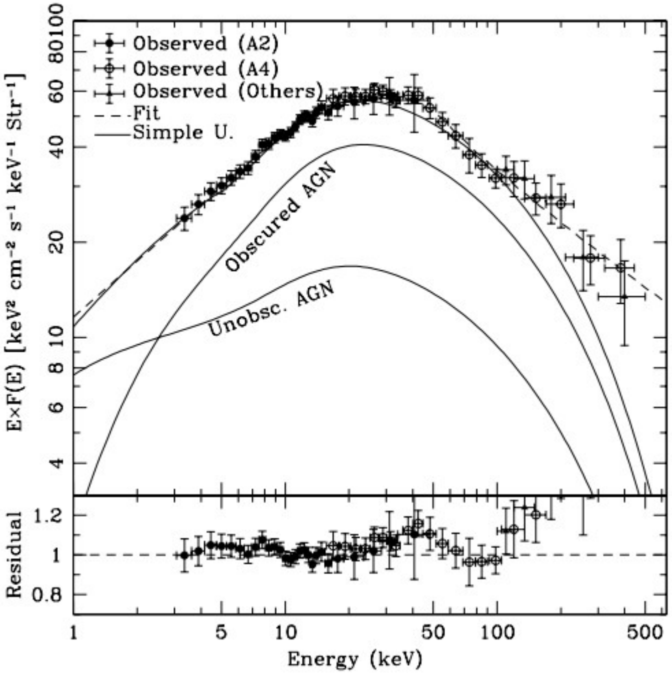
- There is an apparently diffuse X-ray background (XRB)
- In the 2-8 keV band, Chandra and XMM-Newton surveys of deep fields have resolved > 80% of the XRB
- Roughly 83% and 95% of these sources are classified as AGN in the 0.5-2 keV and 2-8 keV bands, respectively
- X-Ray background could be explained by the superposition of unobscured (type I) and obscured (type II) AGN



Type I (Unobscured) vs. Type II (Obscured) AGN

- Obscured AGN lack broad line emission and have a harder X-ray spectrum due to absorption of soft X-rays in the dusty torus
- Cutoff between Type I and Type II defined by Hydrogen column density
- To account for the XRB, need ~3:1 ratio of obscured to unobscured AGN
- Observations biased toward unobscured



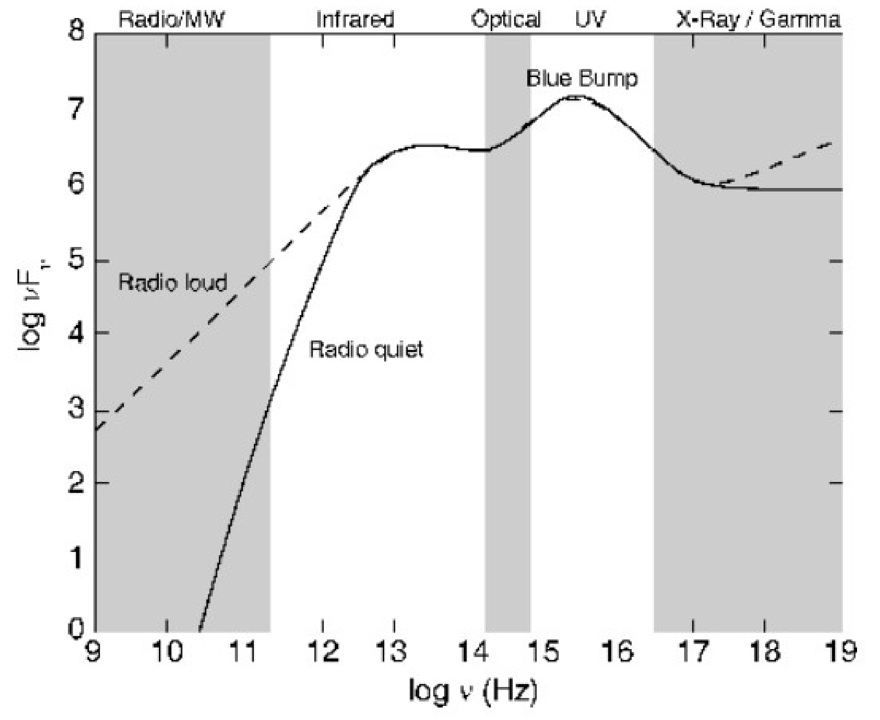


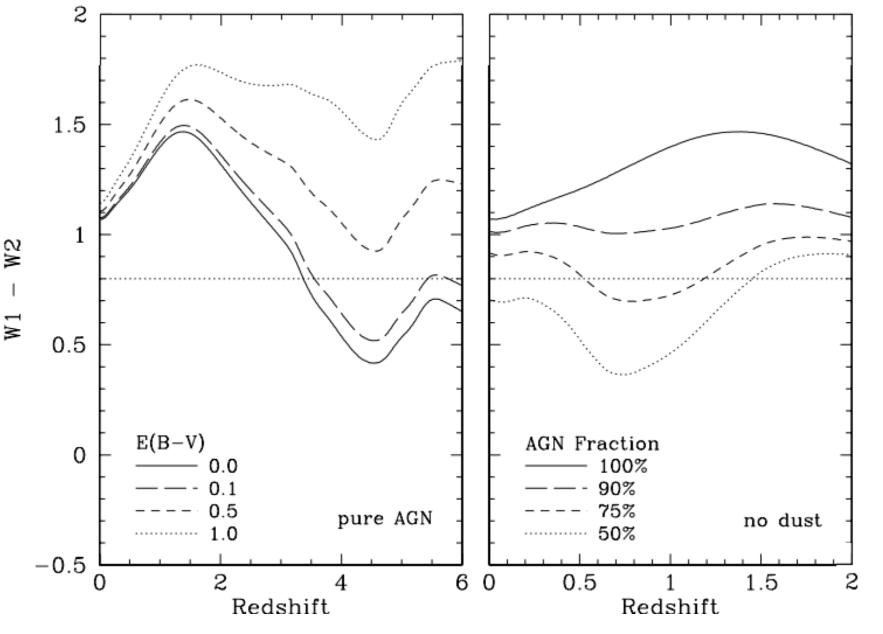
How Do We Observe Obscured AGN?

- It is not possible to observe obscured AGN in all wavelengths due to absorption and scattering in the torus. We have a few choices:
  - Radio
    - Only ~10% expected to be radio loud
  - X-ray
    - Not sensitive enough, or small field of view (non-survey)
  - MIR!
    - Can differentiate MIR AGN spectrum from stellar black bodies in a normal galaxy
    - Use WISE (Wide-Field Infrared Survey Explorer)
- COSMOS Field
  - Well studied 2 square degree field at high galactic latitude (l=237.6 b=42.5)
  - Shallow coverage for WISE will actually be better for AGN selection

WISE Selection Criteria

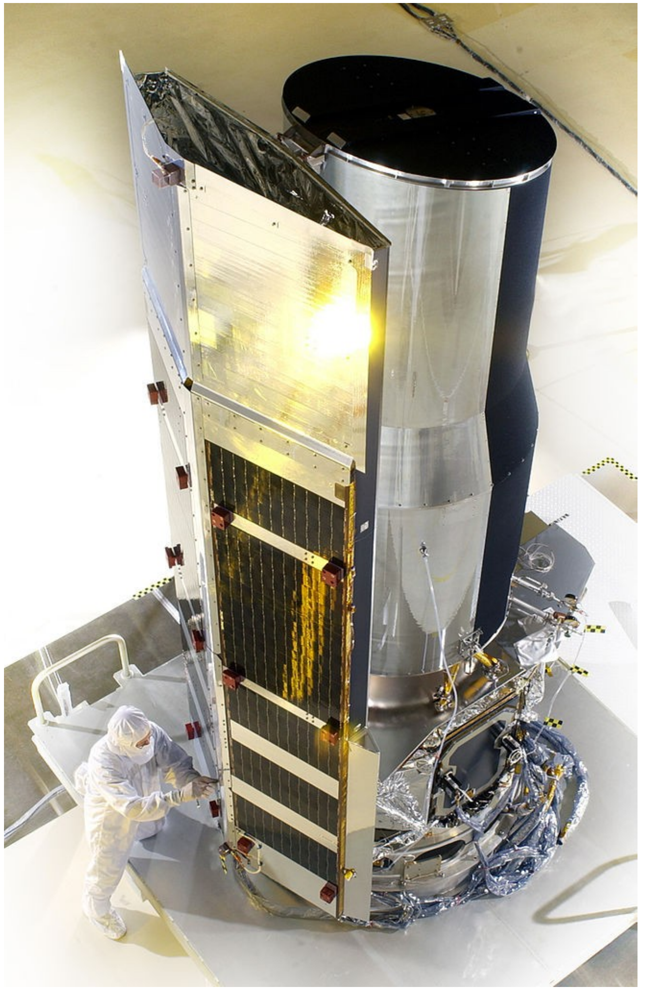
- Use a color-color criterion to pick out the typical AGN MIR spectum
- Trade off between completeness and reliability
- From models, choose a cutoff:
  - [3.4]-[4.6]≥0.8, Vega
- Expect criterion to work well in the COSMOS field
  - Low galactic contamination
  - Red color selections cuts out normal galaxies which are bluer up to z~1.2
  - High redshift galaxies not detected at WISE COSMOS depth





IRAC 'Truth Sample'

- IRAC (Infrared Array Camera) onboard Spitzer
- Previous studies use IRAC color criteria to select AGN
- Use previously determined IRAC criterion as a gauge of the WISE selection (Stern et al. 2005)
- Of AGES (AGN and Galaxy Evolution Survey) sources in Bootes field, IRAC criteria selects 91% of Type I and 40% of Type II spectroscopically identified AGN
- 17% of IRAC selected AGN not spectroscopically classified as AGN by Hectospec Redshift Survey



Analysis

- Select AGN from WISE data in COSMOS field
- Catalogs obtained through the Infrared Science Archive (IRSA)
- Compare WISE-selected AGN with IRAC selected AGN (truth sample)
- Determine what fraction of WISE-selected AGNs are detected in other bands
  - VLA; XMM-Newton; Chandra
  - Compare expected fractions in radio and X-ray
- Estimate Type I/Type II using optical comparison to SDSS

WISE + IRAC Matching

- Determine WISE sources with IRAC counterparts:
- S-COSMOS (IRAC)
  - Require no error flags
  - Remove sources with negative flux measures
  - Require [3.6] $\geq$ 11 for saturation
- WISE Requirements:
  - Require no error flags
  - S/N in W2 $\geq$ 10

- Find 7684 WISE sources with IRAC counterparts

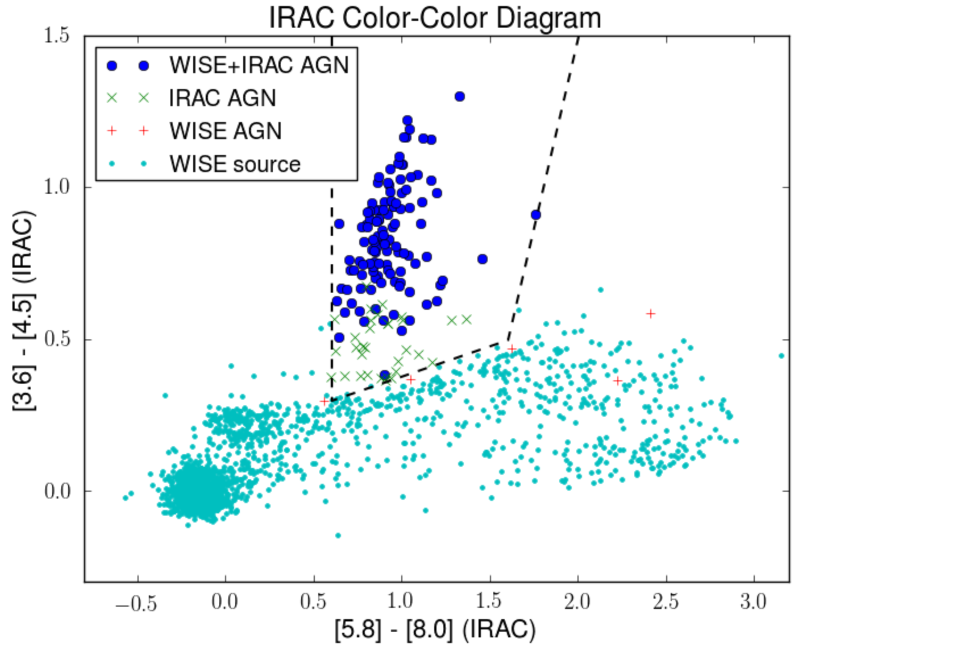
AGN Selection

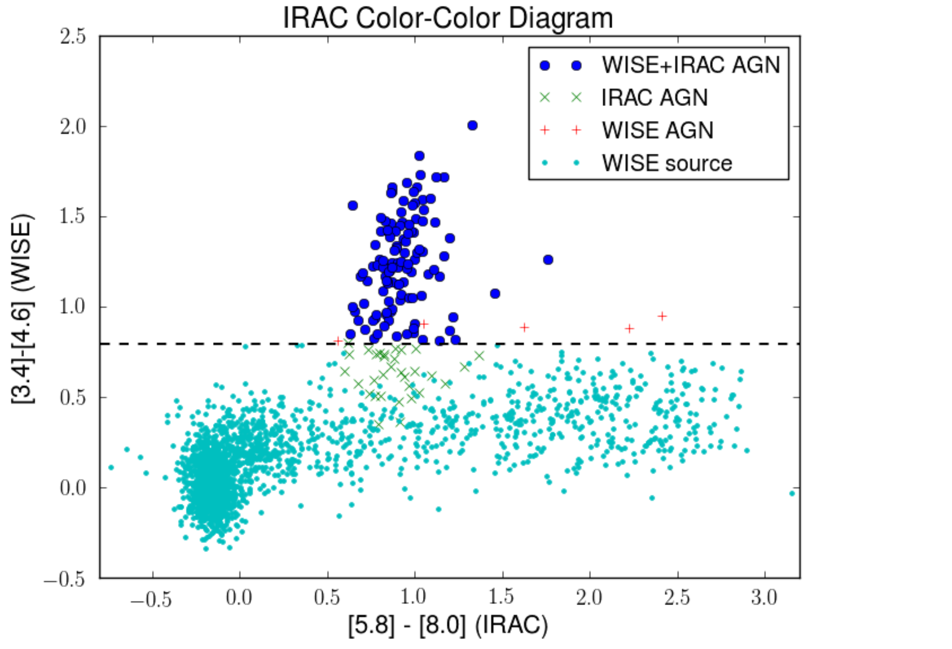
- AGN color selection criteria applied to 7684 sources detected in both IRAC and WISE
- 143 sources match IRAC selection criteria for AGN ("Truth Sample")

$$([5.8]-[8.0]) > 0.6 \wedge$$
$$([3.6]-[4.5]) > 0.2 * ([5.8]-[8.0]) + 0.18 \wedge$$
$$([3.6]-[4.5]) > 2.5 * ([5.8]-[8.0]) - 3.5$$

- 123 match WISE color criteria

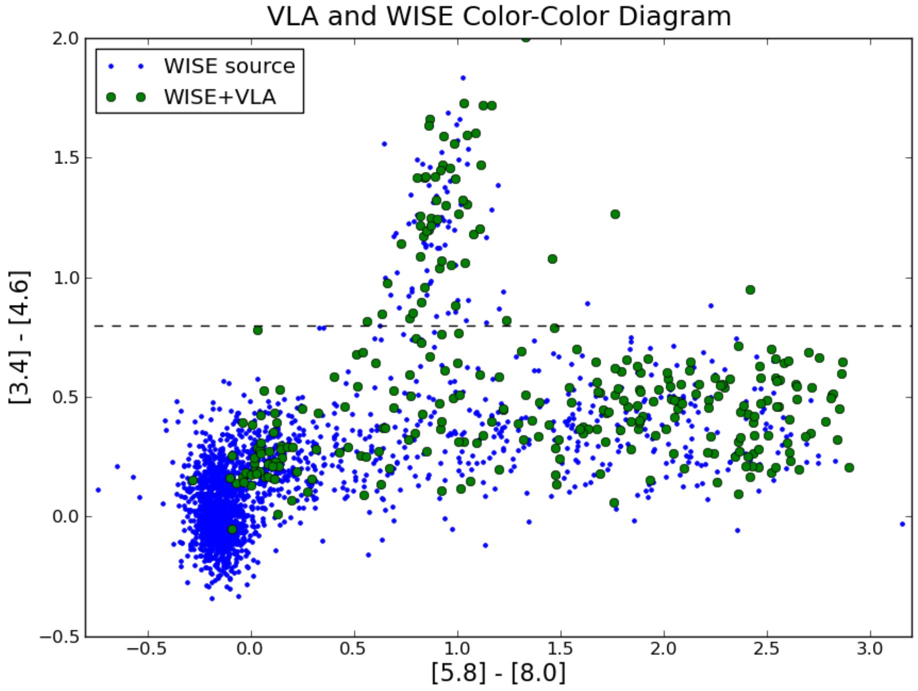
  ([3.4]-[4.6]) > 0.8
- 116 match both IRAC and WISE color criteria
- **Completeness: 116.0/148 = 0.784**
- **Reliability: 116.0/123 = 0.943**



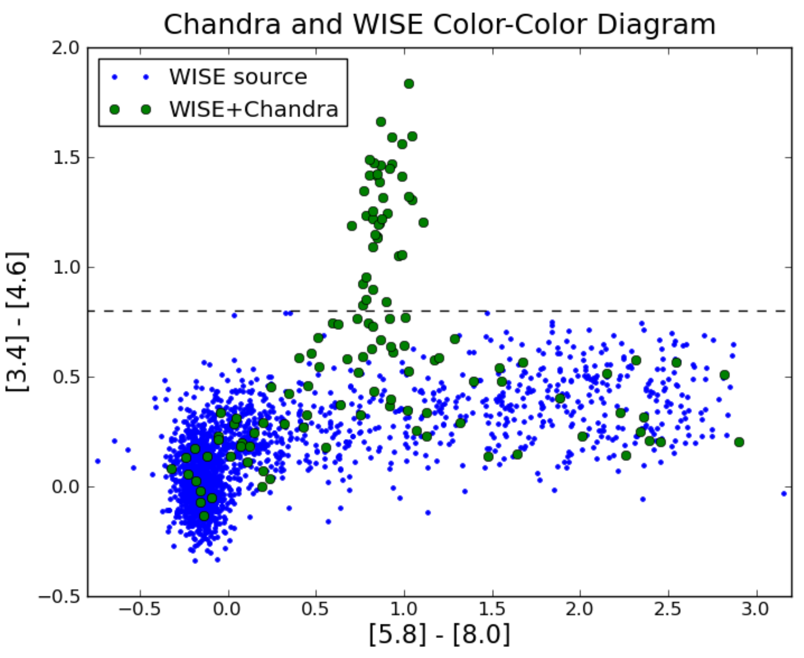


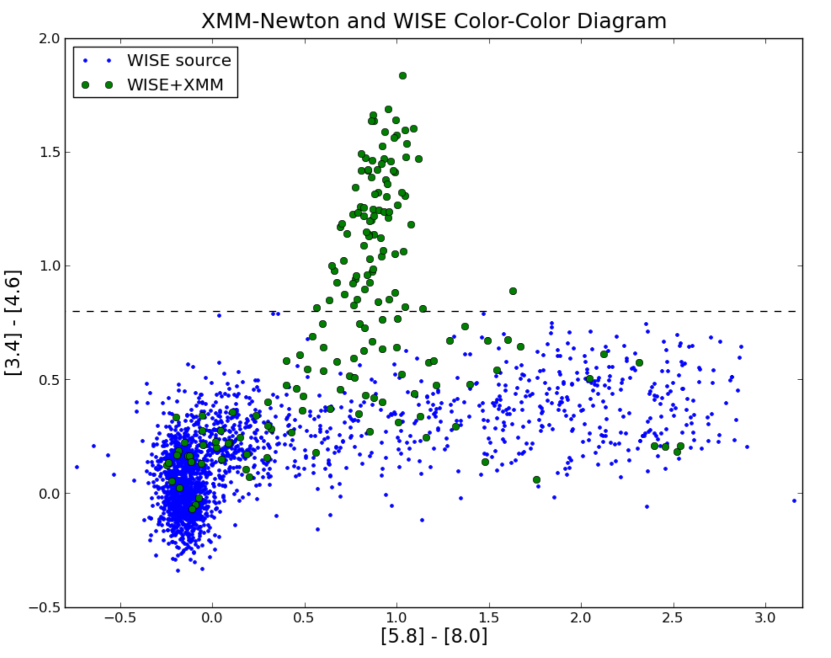
Radio Comparison with VLA

- VLA deep coverage of COSMOS at
  - 20 cm
  - 350 hrs primarily in A-array
  - 1''.5 resolution
  - ~11μJy sensitivity
- Out of 2864 VLA sources in COSMOS, using 1''.5 radius:
  - 2864 sources in field
  - 293 matches with WISE
  - 50 matches to WISE+IRAC AGN (43%)
- Detected but not necessarily radio 'loud'
  - Could expand and look at a cutoff value of radio luminosity to check radio loud percentage



Multiwavelength Properties: XMM-Newton and Chandra

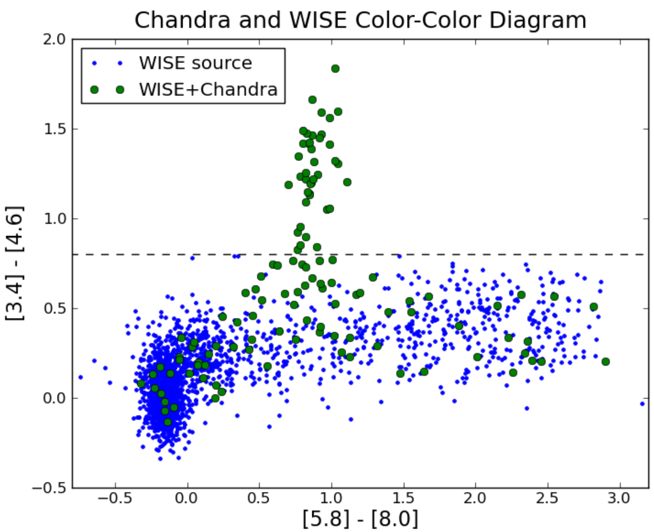


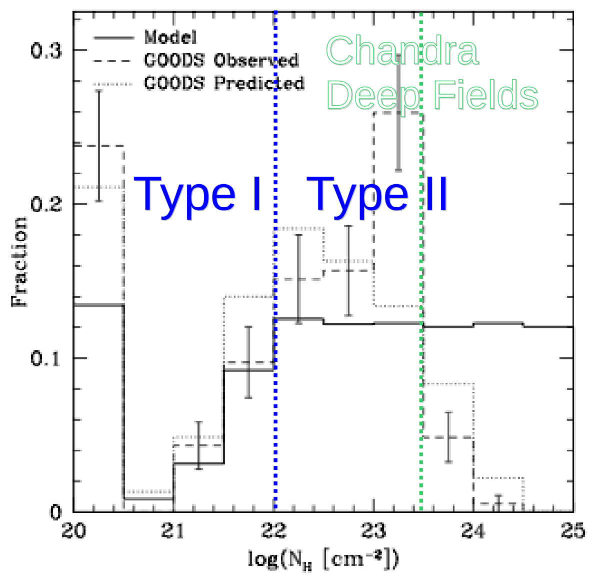


- 0.9 deg^2 field in COSMOS to an overall flux limit of 5.7x10^16 ergs/(cm^2 s)
- 1760 total sources in field
- 180 matches to WISE (2".5 radius)
- 40 matches to WISE+IRAC:
- 44.4 deg^-2 compared to 58 deg^-2 (77%)

- Entire field to depth of 7x10^16 ergs/(cm^2 s)
- 1887 sources in field
- 180 matches to WISE (3".5 radius)
- 86 matches to WISE+IRAC (74%)

Model Comparison of Chandra Sources





- Chandra is able to observe some Type II AGN up to H column densities of ~10^23.5
- Expect Chandra to detect ~64% of sources which roughly agrees with our results (77%)
- Those sources not detected by Chandra expected to be *heavily* obscured AGN

Comparison to SDSS

- Number of obscured AGN estimated by assuming they would not be detected by SDSS since the optical flux of Type II AGN is below the limit of SDSS
  - Type II = WISE AGN not detected by SDSS
  - Type I = WISE AGN also detected by SDSS
- Cross referencing our sources with SDSS (data release 7) catalog using a 2'' radius finds 38 galaxy matches
- Obscured/unobscured = (116-38)/ 38 = 2.05:1
- Efficiency of IRAC normilization leads 4.5:1
  - (not done in Stern et al.)

Conclusions

•Find completeness and reliability compared to IRAC of 78% and 94% respectively

•Obscured/unobscured ratio ~4.5 (reasonable)

•Comparing the density of AGN on other parts of the sky on the equator with high galactic latitude, we find similar results

- (10,0): 222/4 = 55.5 AGN/deg^2
- (60,0): 248/4 = 61.5 AGN/deg^2
- (165, 0): 219/4 = 54.75 AGN/deg^2
- (195,0): 309/4 = 77.25 AGN/deg^2
- (345,0): 215/4 = 53.75 AGN/deg^2

- Best fit constant = 59.87 with a reduced chi2 of 1.11
- P-value for rejecting that it is constant is 0.353 — much too high to reject.

Positional Errors