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X-ray/IR selection of AGN

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Talk outline

- Introduction
  - Why do we want to find high redshift AGN?
  - How do we find them?
- Our analysis
  - 12μm galaxy sample
  - Optical line ratio diagnostics
  - X-ray analysis
  - AGN definition
  - Local tests of high-z AGN selection methods
- Summary and Conclusion

Introduction

- Complete and reliable samples of AGN are needed for:
  - Evolution of galaxies - linked to growth/activity of central supermassive black holes? Both were growing rapidly at z~1-3
  - The history of accretion power in the universe
  - Origin of the cosmic X-ray background (CXB)
- Mid-IR commonly used to select high-z AGN using Spitzer
- Techniques successful for dominant AGN (quasars). Less sensitive to AGN with significant starburst emission
- AGN samples selected in one waveband suffer from incompleteness and unreliability, ➔ multi-wavelength approach needed.
- Local well-studied galaxy samples provide valuable insight into their higher-z analogues
- Characterising local Compton thick (CT) AGN is also useful as a large population of as-yet unfound CT AGN is predicted at high-z from modelling of the CXB.

12 Micron Galaxy Sample

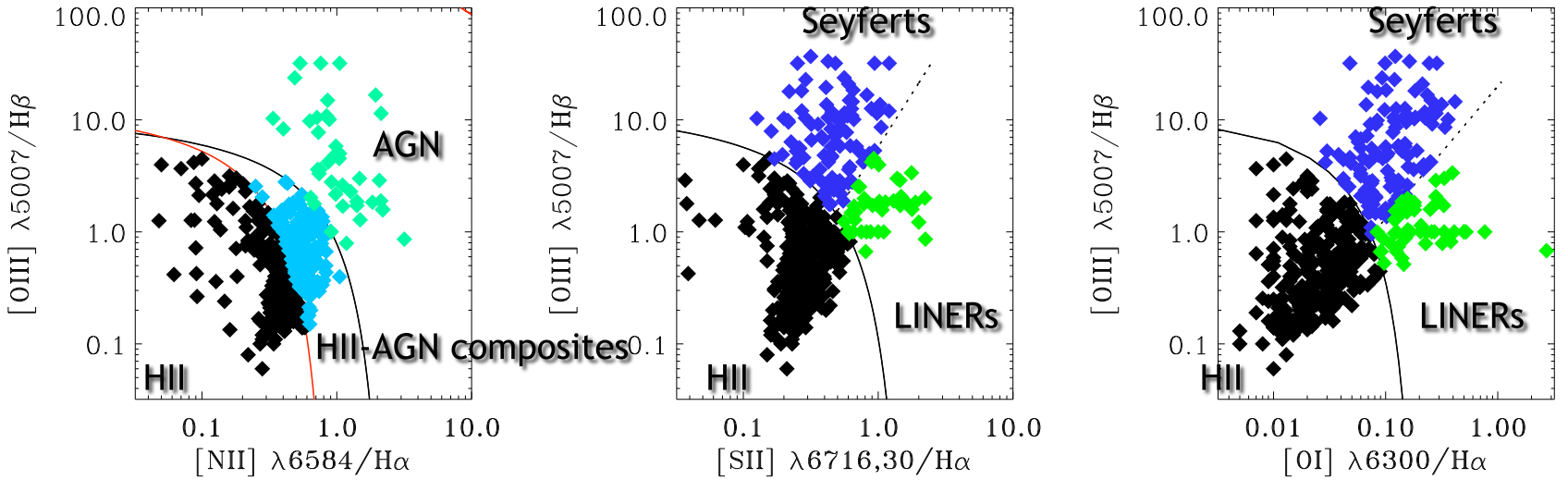
- We use the (extended) 12 micron galaxy sample (12MGS) of 893 local ($z<0.3$) galaxies selected at 12μm using IRAS (Rush, Spinoglio & Malkan 1993).
- The 12MGS has been widely studied, at many wavelengths and has much supporting data.
- Particularly useful as an IR selected sample for comparing to other IR works, especially as 12μm corresponds exactly to 24μm at $z=1$, where Spitzer MIPS observes
- We collect H, K (near-IR) and IRAS photometry for the sample (Malkan and Spinoglio 89, Spinoglio+ 95)

Optical Spectroscopy

✧ We compile optical line flux data from the literature (~550 galaxies, namely H-α, H-β, [OIII]λ5007, [NII]λ6584, [SII]λλ6716,30 and [OI]λ6300) for line ratio diagnostics

(Armus+89, Baan+98, Corbett+03, De Grijp+92, Goncalves+99, Ho+97, Kewley+01, Kim+95, Kong +02, Kopylov+04, Kuraszkiewicz+04, Maia+87, Osterbrock+93, Sekiguchi+93, Spinelli+06, Vaceli +97, Veron-Cetty+86, Malkan+ in prep, SDSS)

✧ We use line ratio diagnostics of Kewley+ 06 to separate Seyfert 2s, starbursts and LINERs.



X-ray analysis

✧ 129 XMM-Newton observations of 12MGS were reduced + spectra extracted (all galaxy types).

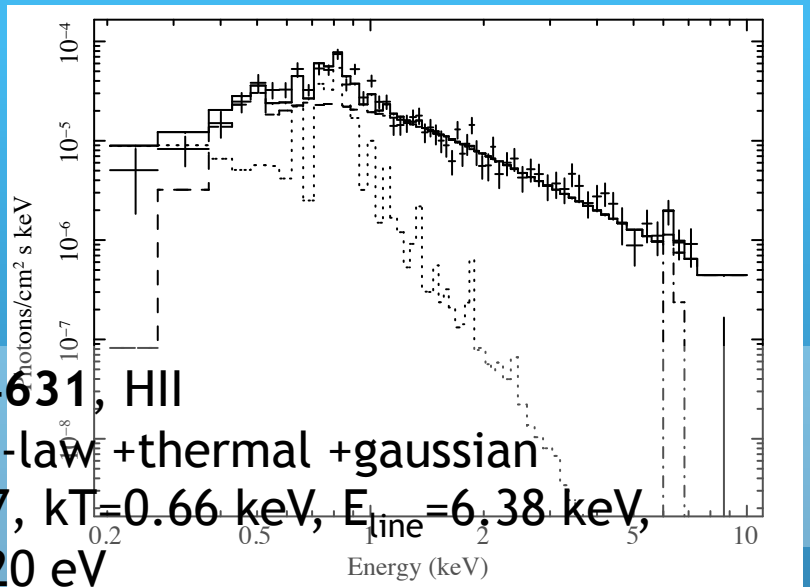
✧ Spectra fitted with baseline power-law model with galactic absorption.

✧ Extra model components added as statistically required (Δx^2 constraints). Including

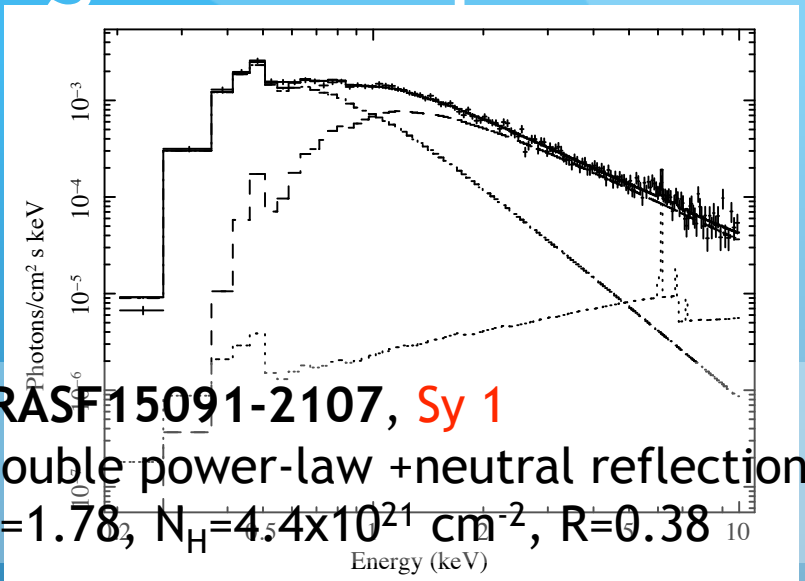
- thermal emission from a plasma (raymond-smith model)
- black-body curve (for soft excess)
- warm absorption (cwa18 model)
- Compton reflection from neutral matter (pexmon, Nandra et al 2007)
- heavy absorption by neutral matter (Brightman & Nandra, in prep)
- gaussians for line emission and absorption

✧ Through spectral fitting we determined the X-ray luminosity and the neutral absorption present of the galaxies

X-ray spectral fitting – examples…

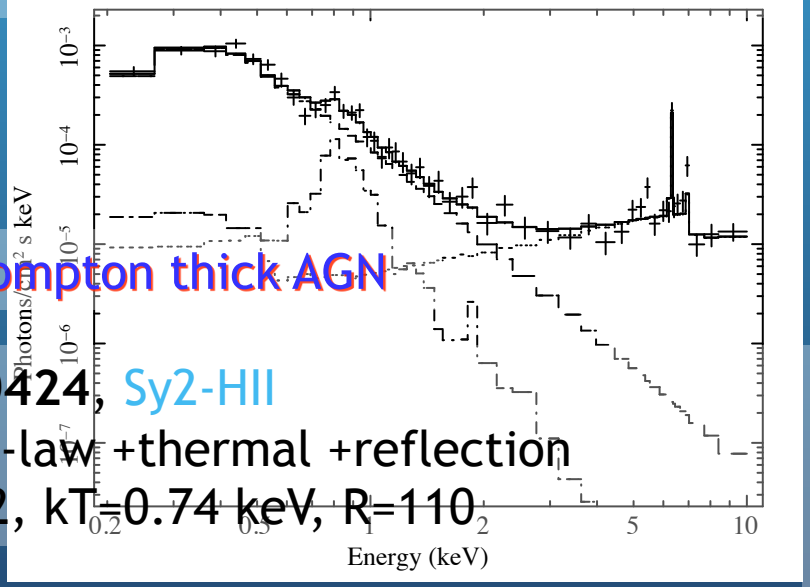


NGC 4631, HII
power-law +thermal +gaussian
Γ=1.87, kT=0.66 keV, E_{line}=6.38 keV, EW=520 eV

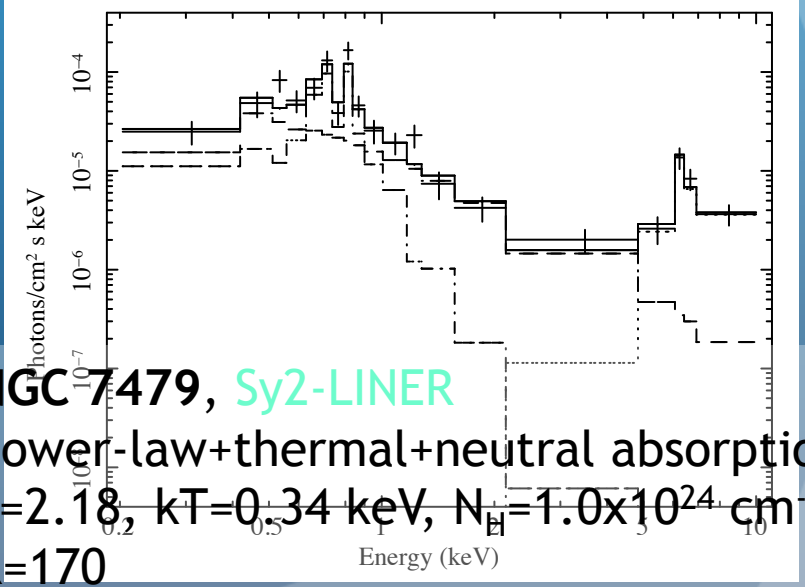


IRASF15091-2107, Sy 1
double power-law +neutral reflection
Γ=1.78, N_H=4.4x10^{21} cm^{-2}, R=0.38

- Compton thick AGN



NGC 0424, Sy2-HII
power-law +thermal +reflection
Γ=1.72, kT=0.74 keV, R=110

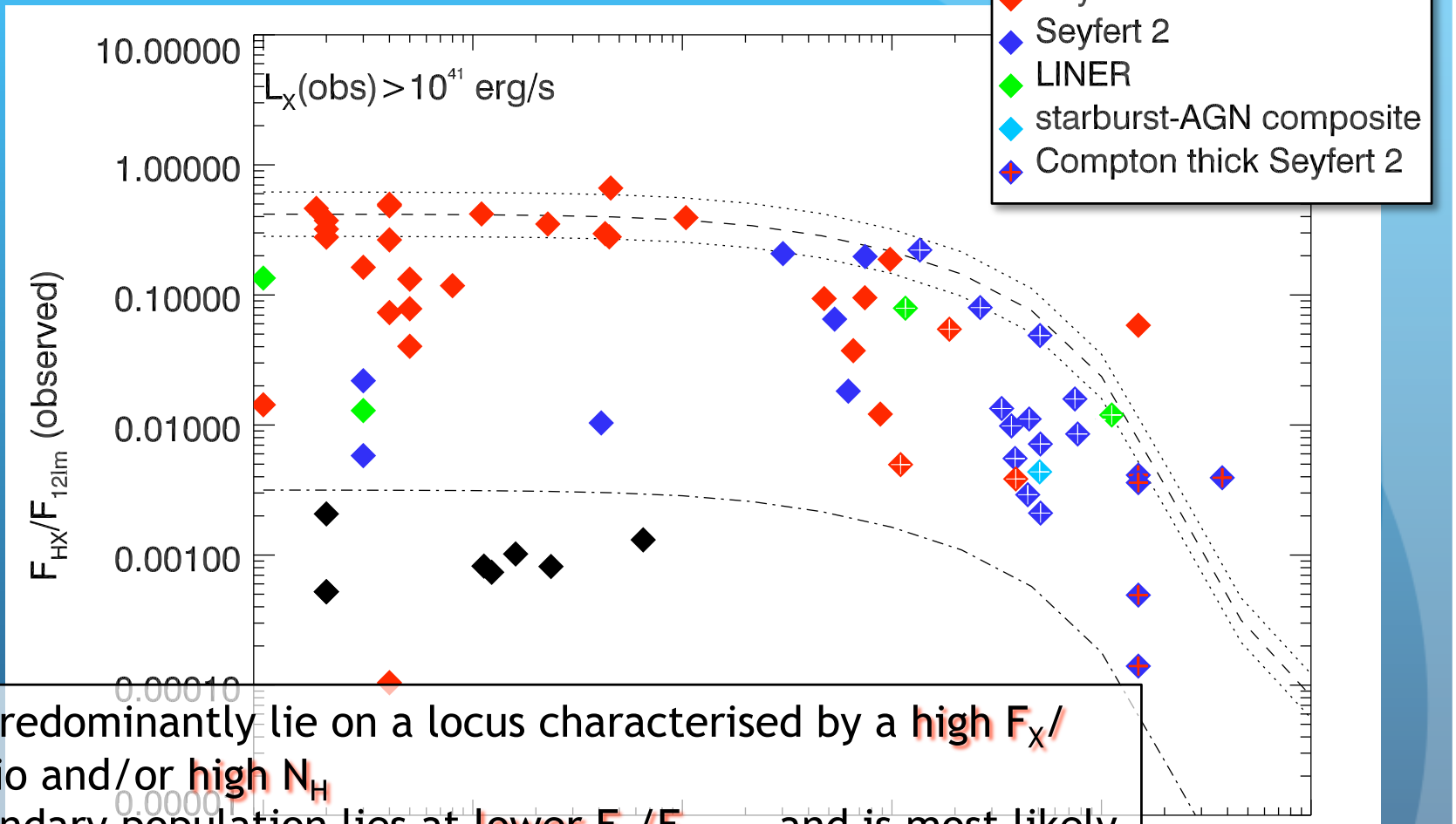


NGC 7479, Sy2-LINER
power-law+thermal+neutral absorption
Γ=2.18, kT=0.34 keV, N_H=1.0x10^{24} cm^{-2}, R=170

AGN sample definition

- In order to extrapolate to high-z we need to construct a solid well defined sample of AGN.
- We chose the following selection criteria:
  - ✓ All Seyfert types and LINERS with $L_X > 10^{41}$ ergs^{-1}
  - ✓ $N_H > 10^{23}$ cm^{-2} and $L_X > 10^{41}$ ergs^{-1}
  - ✓ Sy2 or LINER with $L_{OIII} > 10^{41}$ ergs^{-1} ($\approx 10^{44}$ ergs^{-1} bolometric)
  - ✓ Any galaxy type with $L_X > 10^{42}$ ergs^{-1}

X-ray – IR relationship



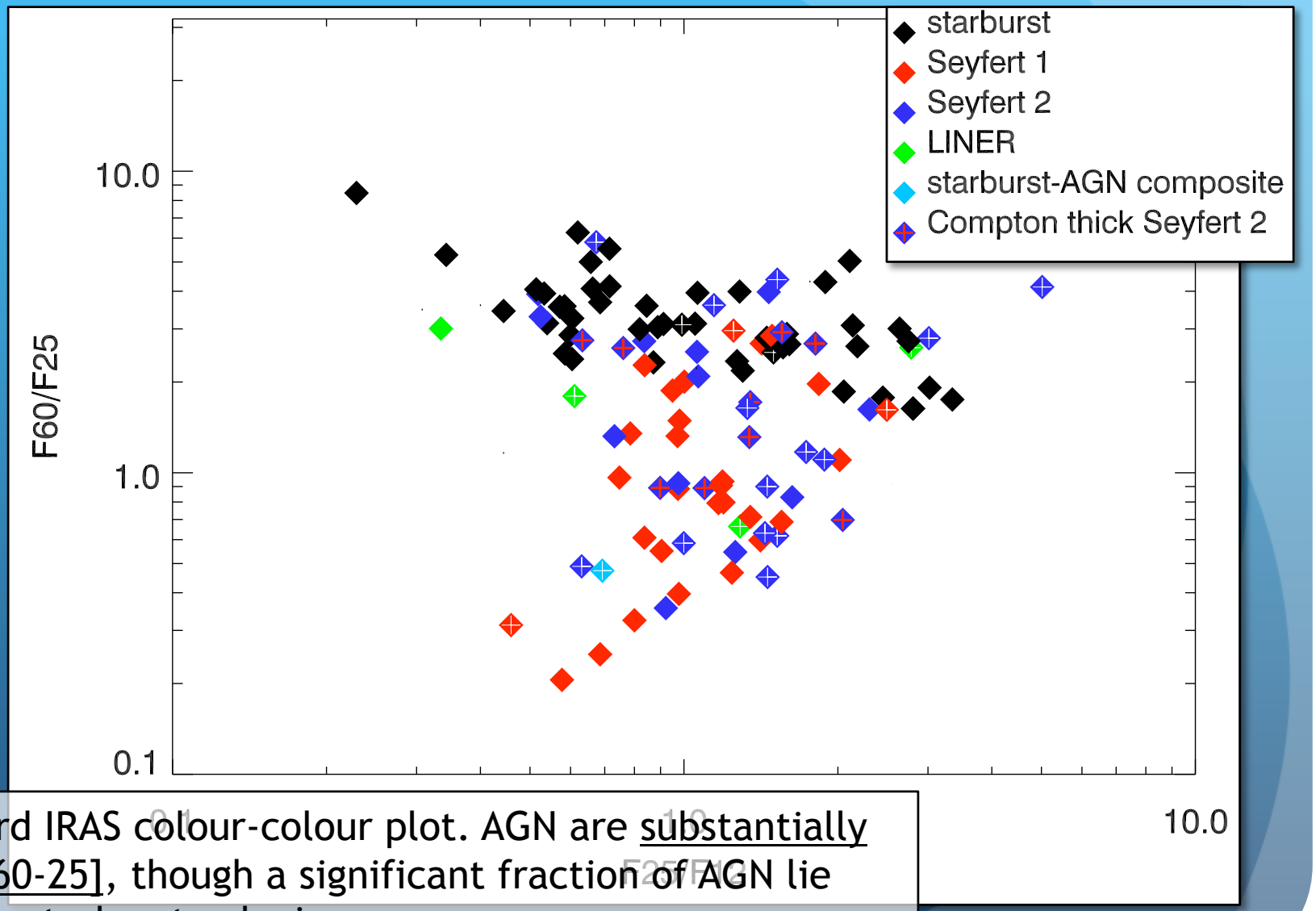
✧ AGN predominantly lie on a locus characterised by a high $F_X/F_{12\mu m}$ ratio and/or high N_H

✧ A secondary population lies at lower $F_X/F_{12\mu m}$, and is most likely contaminated by star-forming galaxies

✧ For L_{HX}(observed) > 10^{41} ergs^{-1} this plot shows that AGN can be selected with $F_{HX}/F_{12\mu m} > 10^{-2.5}$ and $N_H > 10^{23}$ cm^{-2}

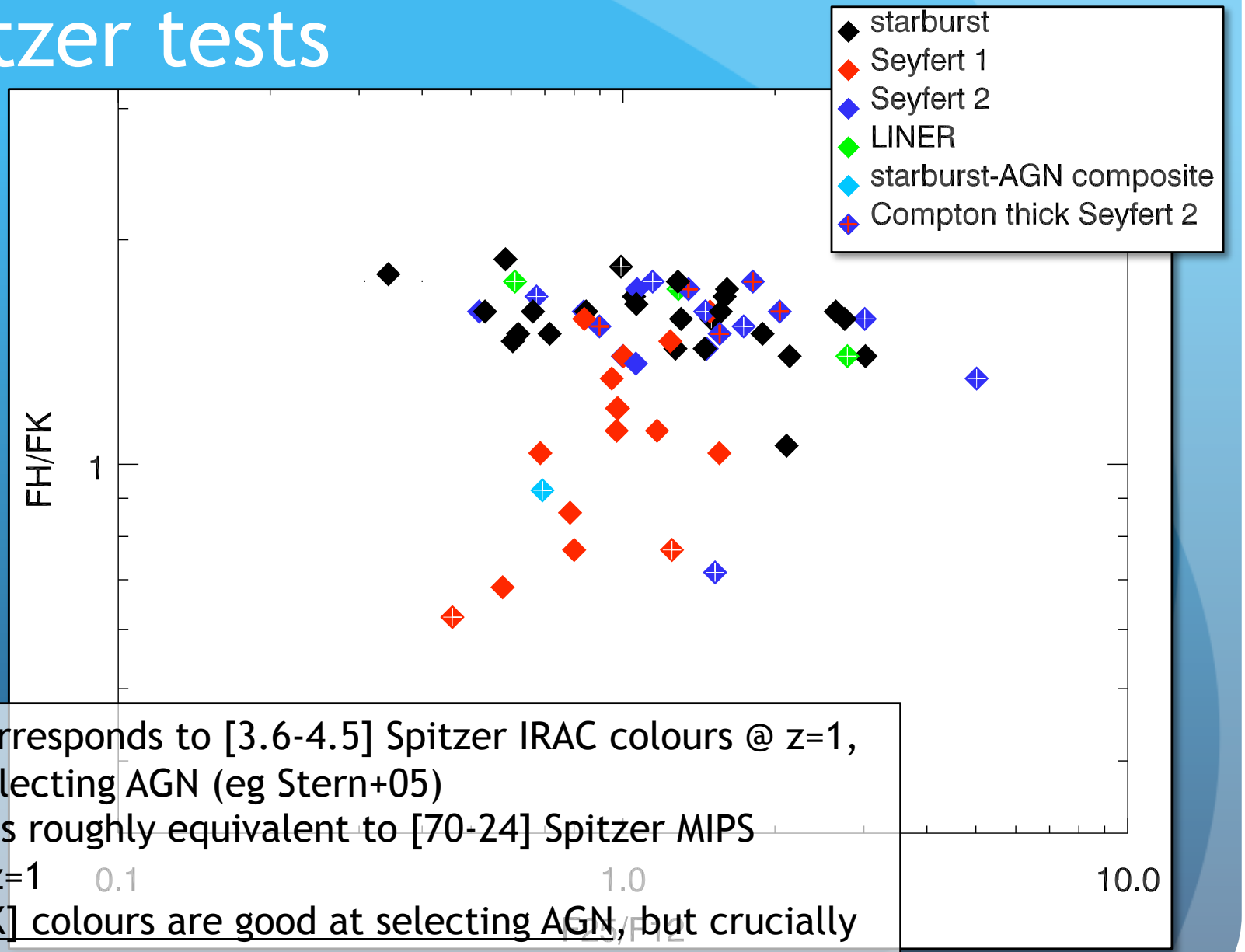
✧ However, N_H difficult to measure in high-z observations

IRAS colour-colour characteristics



✧ Standard IRAS colour-colour plot. AGN are substantially bluer in [60-25], though a significant fraction of AGN lie among the starburst galaxies.

Spitzer tests

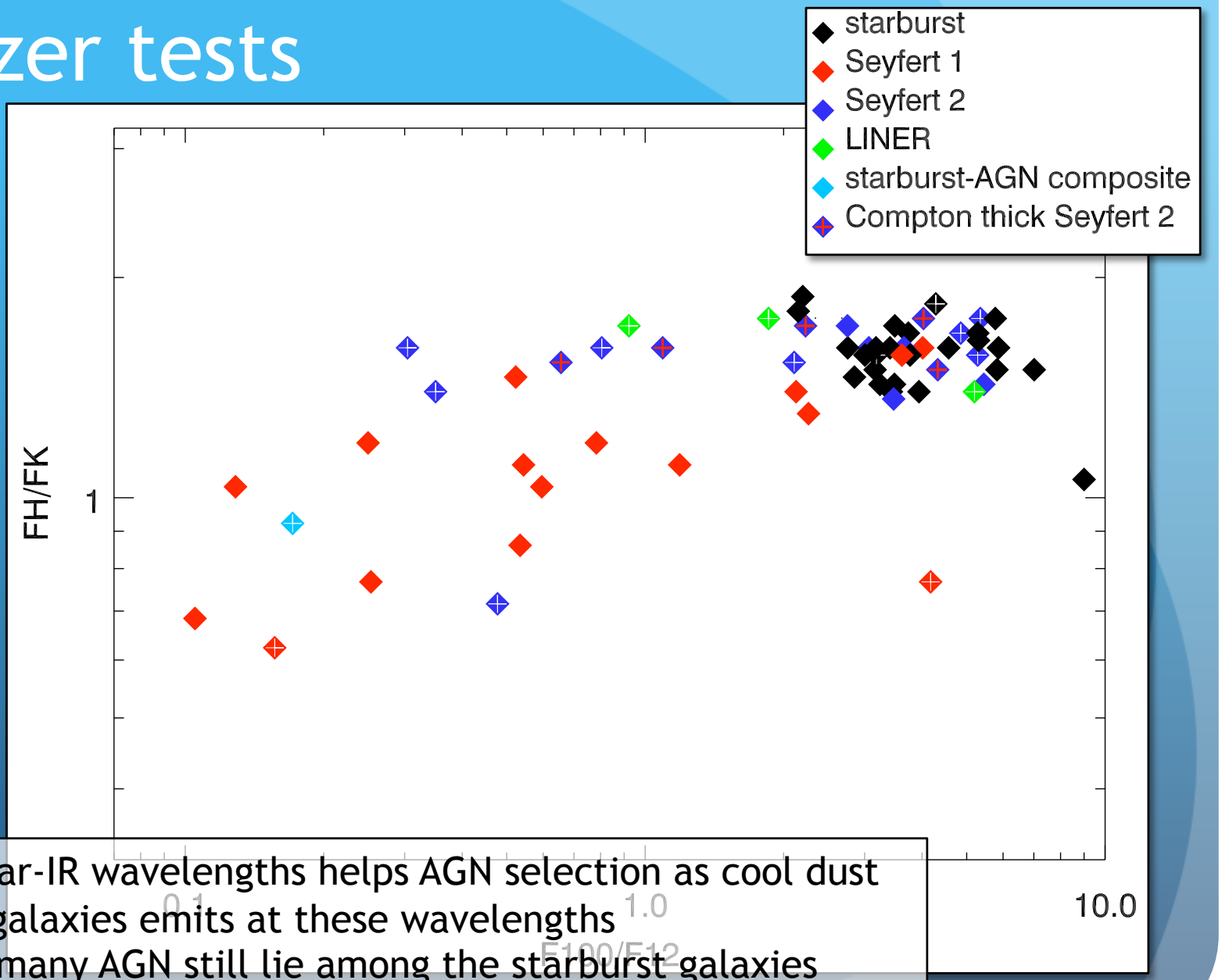


✧ [H-K] corresponds to [3.6-4.5] Spitzer IRAC colours @ z=1, used for selecting AGN (eg Stern+05)

✧ [25-12] is roughly equivalent to [70-24] Spitzer MIPS colours @ z=1

✧ Red [H-K] colours are good at selecting AGN, but crucially miss all Compton thick AGN.

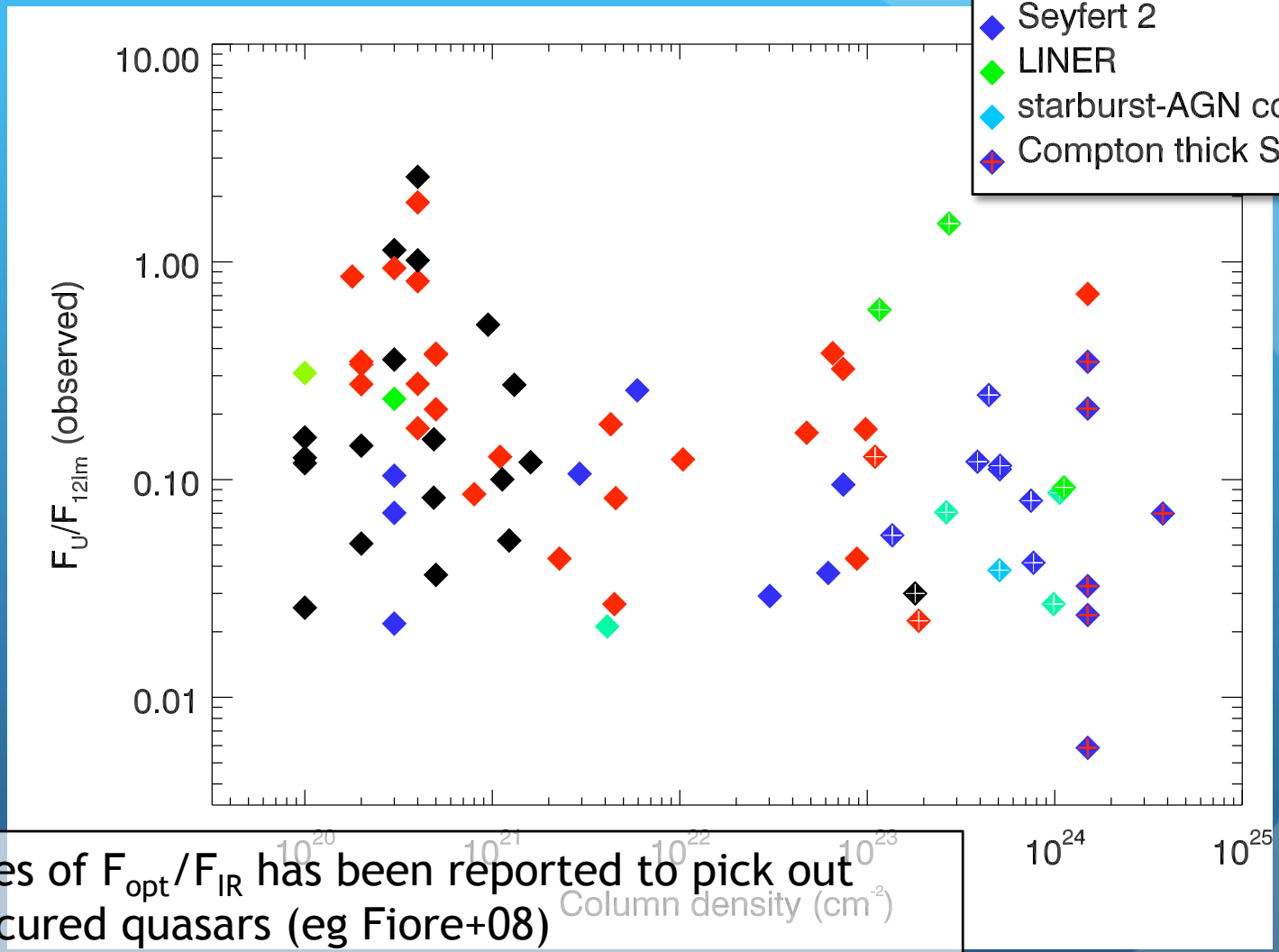
Spitzer tests



✧ Going to far-IR wavelengths helps AGN selection as cool dust in starburst galaxies emits at these wavelengths

✧ However, many AGN still lie among the starburst galaxies

Heavy obscuration tests



✧ low values of F_{opt}/F_{IR} has been reported to pick out heavily obscured quasars (eg Fiore+08)

✧ Here, [U-12] is equivalent to [R-24] @ z=1. However, it does not show a significant correlation with N_H

Summary & Conclusions

- We constructed a well defined local AGN sample selected at 12μm
- We note a connection between the hard X-ray - 12 μm ratio and activity type which may be useful for high-z AGN selection
- We confirm that selecting AGN in one wavelength regime will not produce complete samples
- In order to select a complete unbiased high-z AGN sample, mid-IR, far-IR and X-ray observations must be used in conjunction
- X-ray observations only can determine whether an AGN is Compton thick.