Obscured AGN in HI and X-rays:

Connecting neutral hydrogen and soft X-ray absorption in distant active galaxies with next-generation telescopes

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www.caastro.org

ASKAP-FLASH

First Large Absorption Survey in HI






Obscured AGN in HI and X-rays

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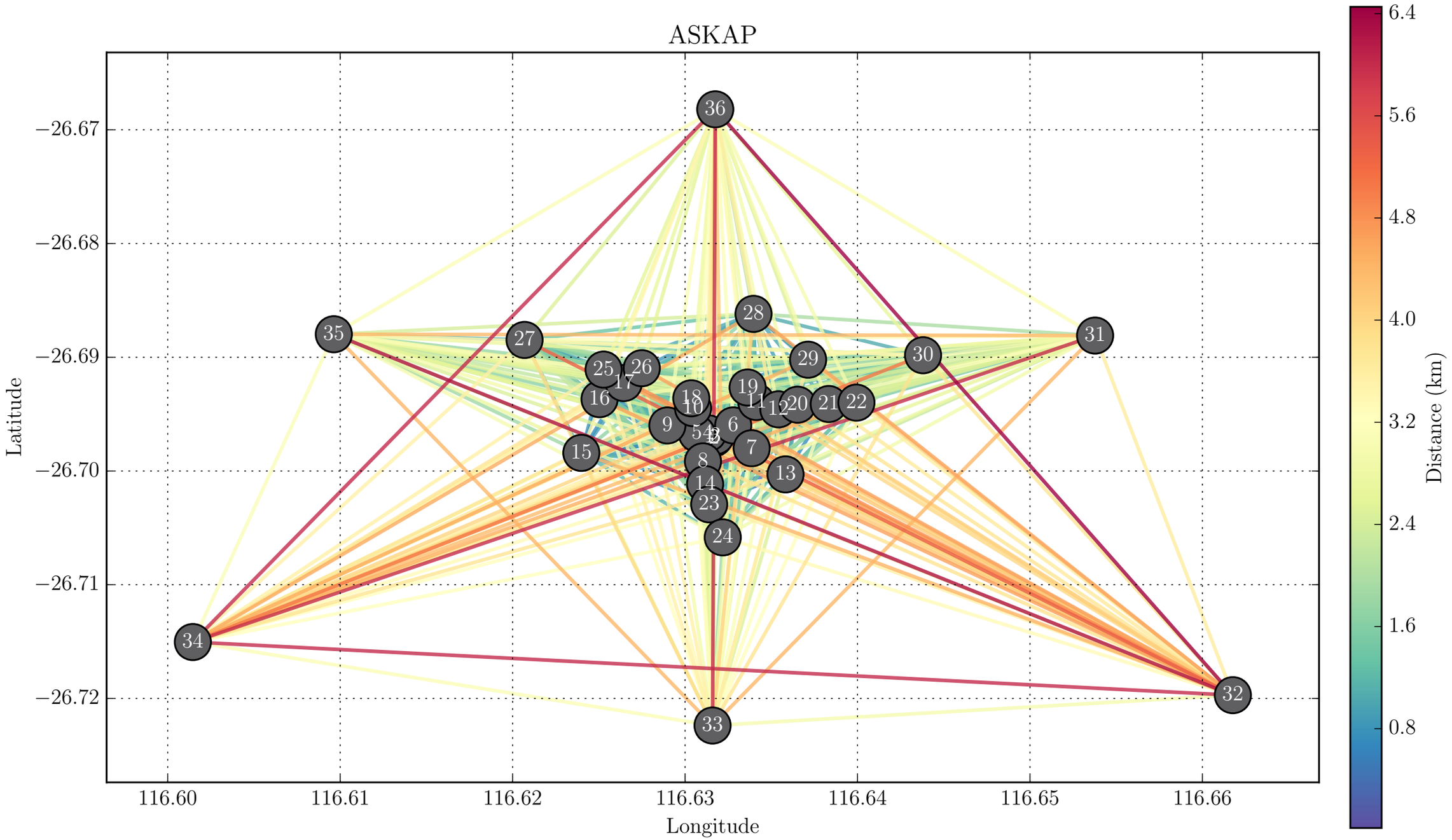
Antonis Georgakakis (MPE)

AUSTRALIAN SKA PATHFINDER

ASKAP

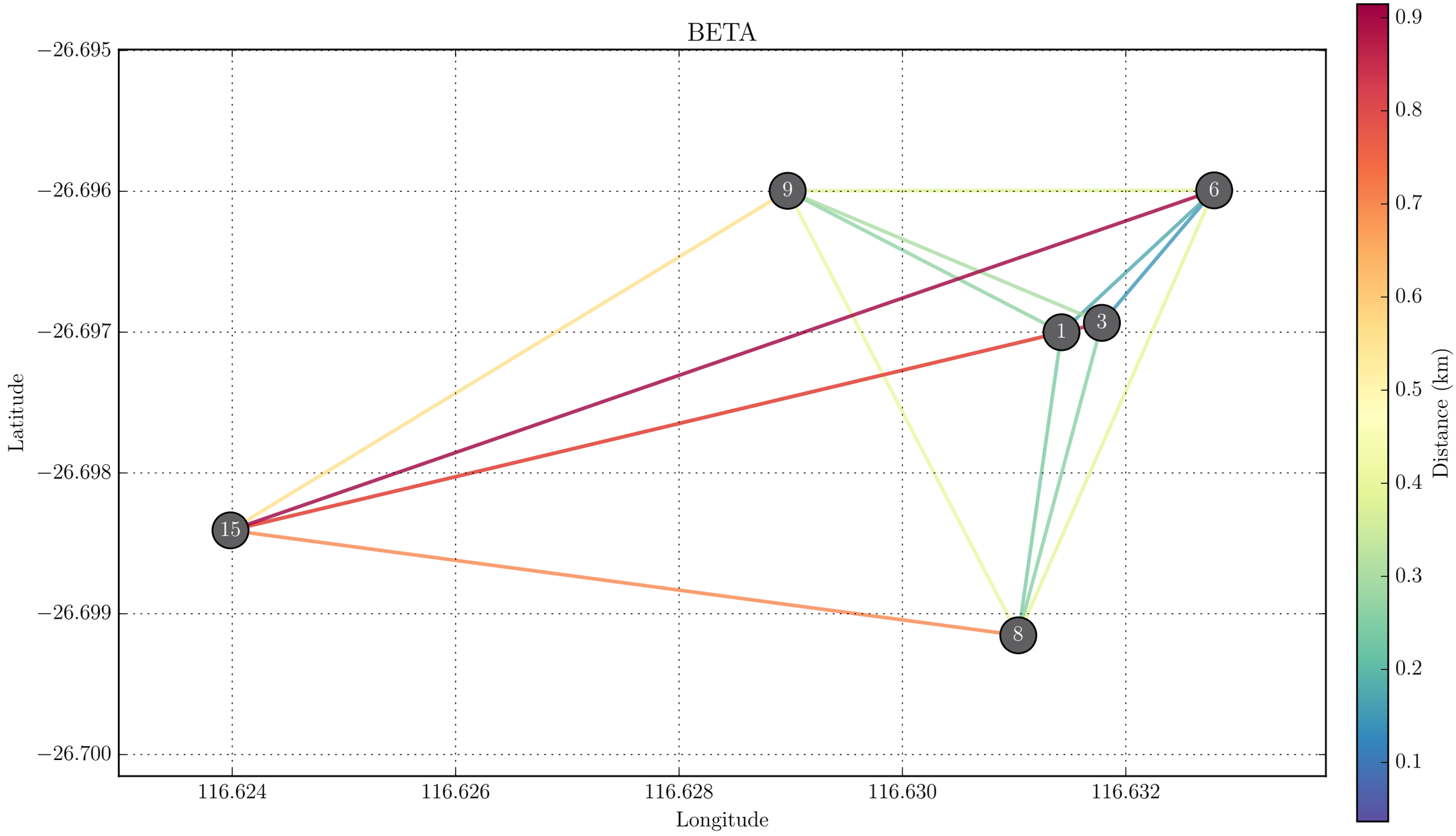
THE AUSTRALIAN SQUARE KILOMETRE ARRAY PATHFINDER

FLASH: ASKAP



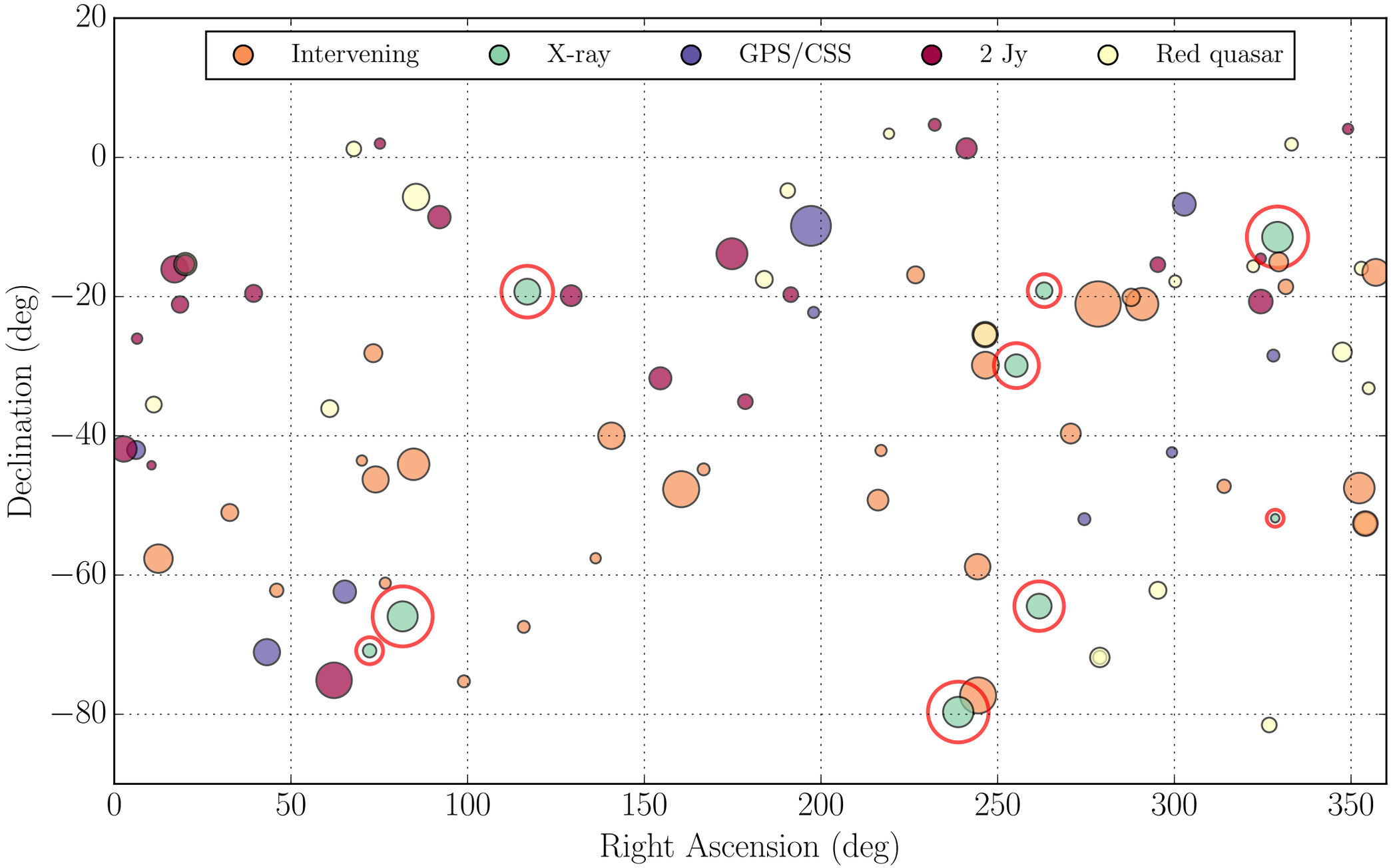
BASELINES FOR ALL 36 ASKAP ANTENNAS, COLOUR-CODED BY BASELINE LENGTH

FLASH: BETA



BASELINES FOR BETA, COLOUR-CODED BY BASELINE LENGTH

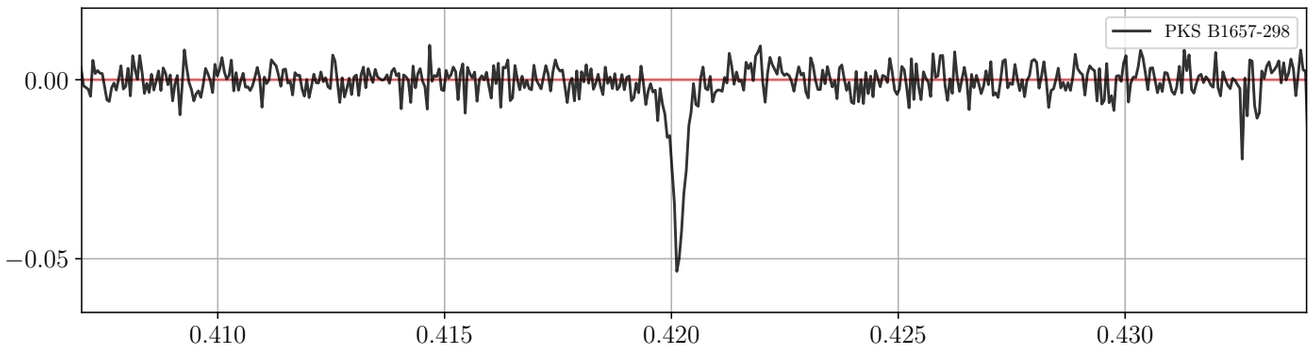
BETA observations



SAMPLES OBSERVED FOR HI ABSORPTION WITH ASKAP-BETA

Measuring N_{HI}

Linking observed optical depth to HI column density



Radio 21cm measurements are particularly sensitive to cold HI (spin temperature T_s < 200K)

$$N_{\rm HI} = 1.823 \times 10^{18} \left[\frac{T_s}{f}\right] \int \tau \, {\rm d}V$$

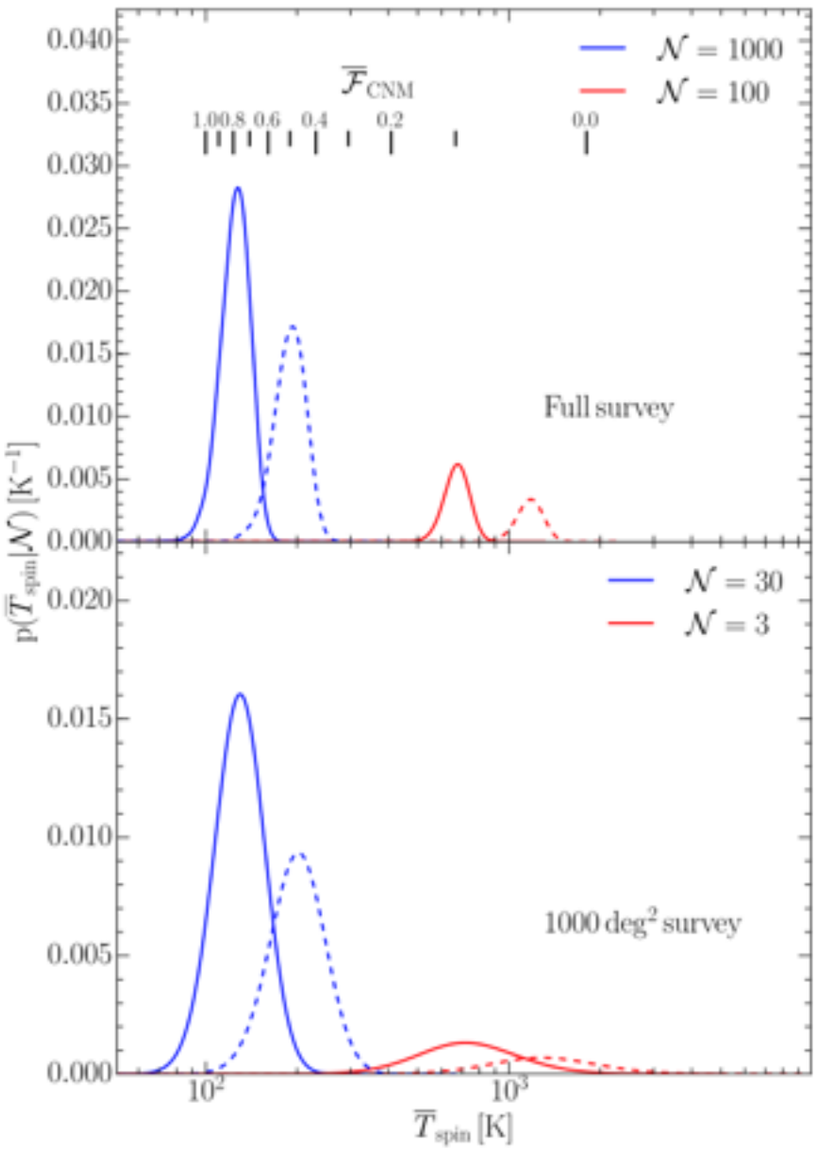
HI column density

HI spin temperature

Covering factor

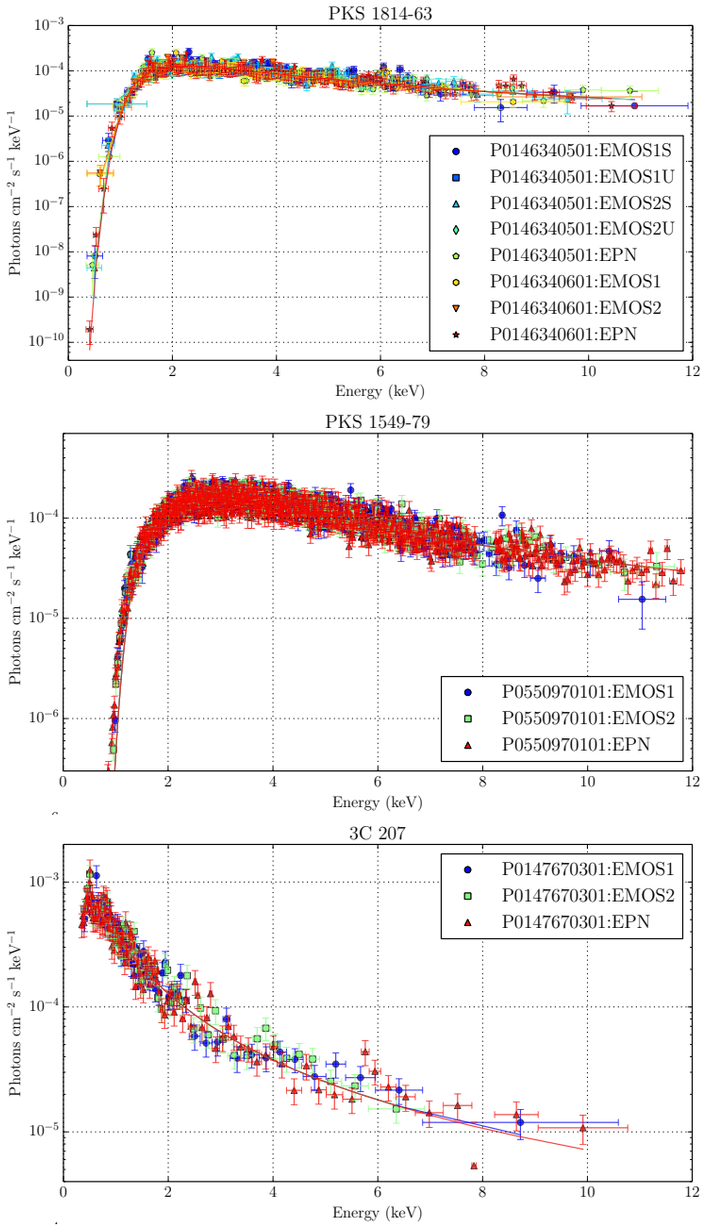
Optical depth

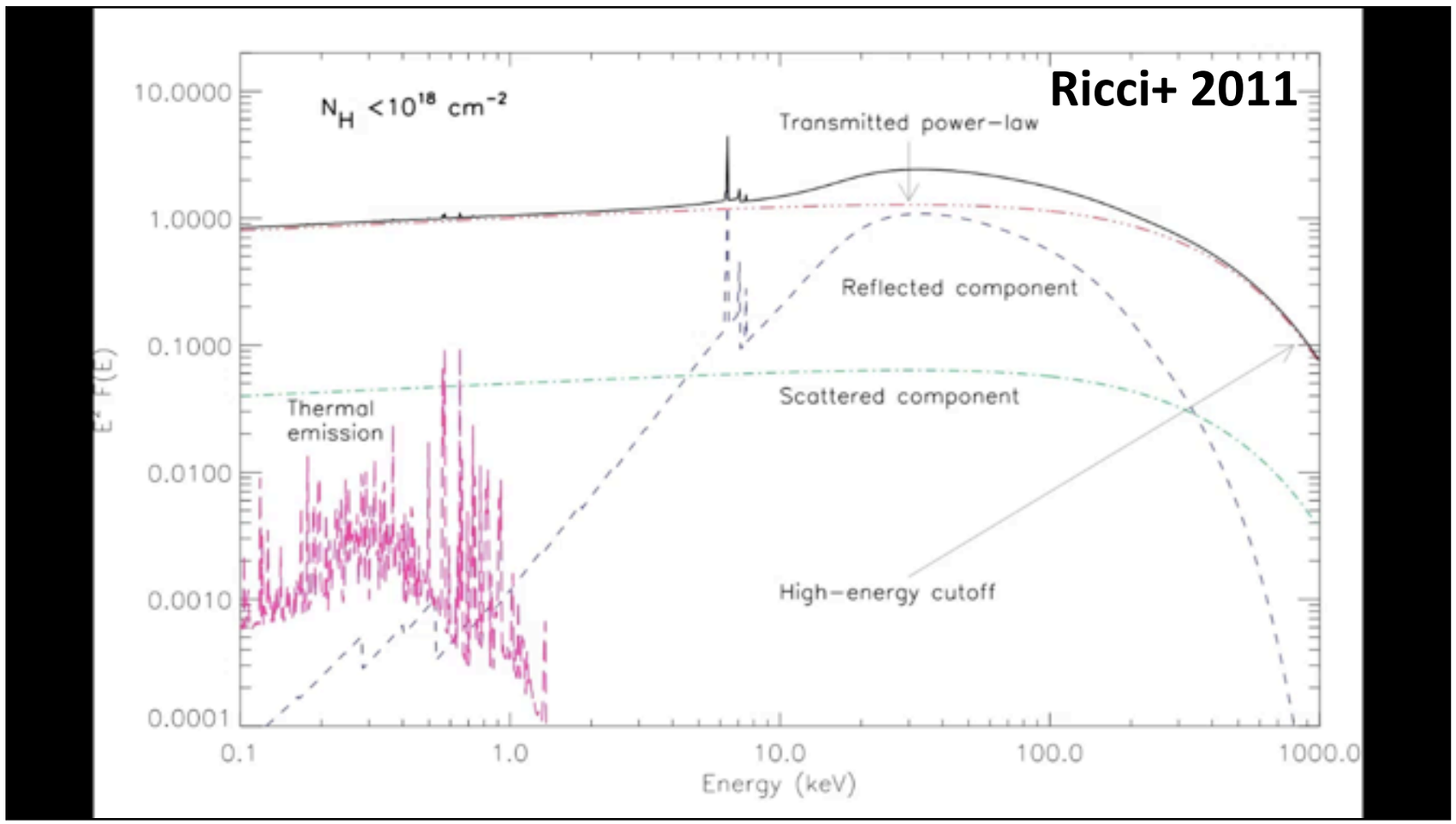
Allison+ 2016



Measuring N_H

Linking observed spectral absorption to H column

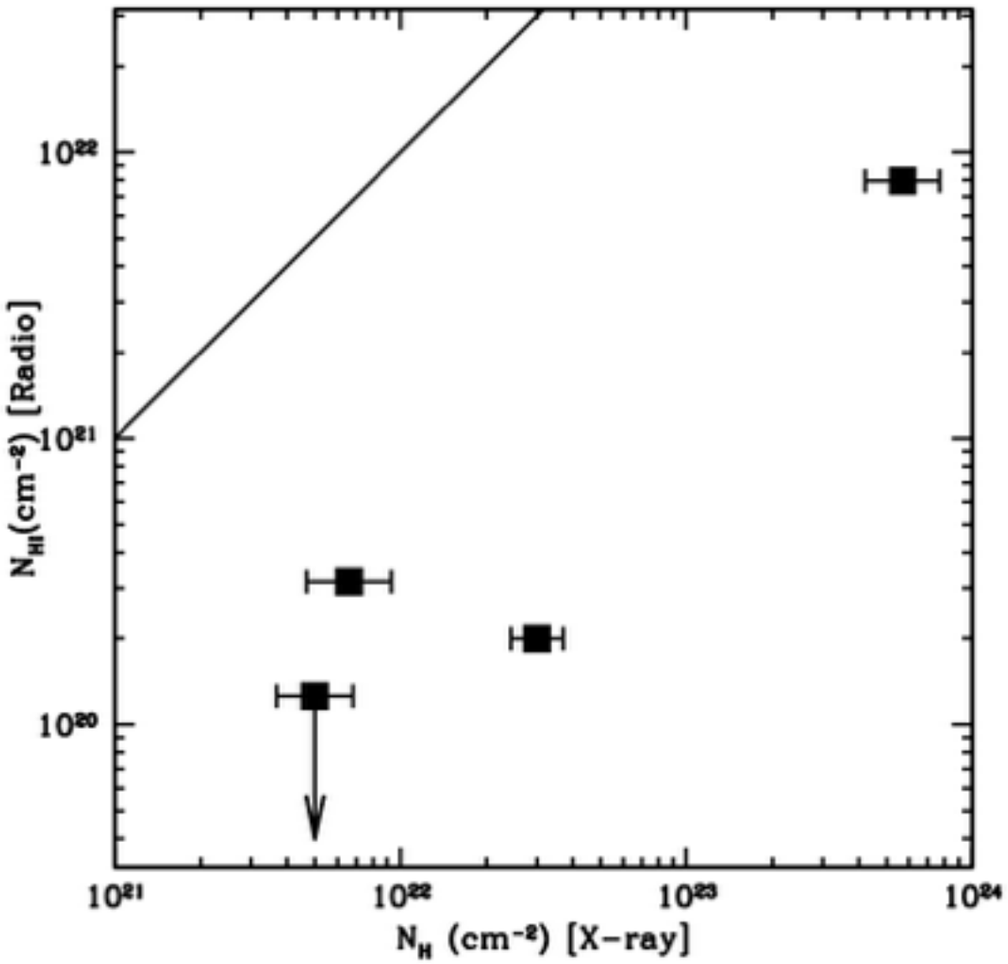




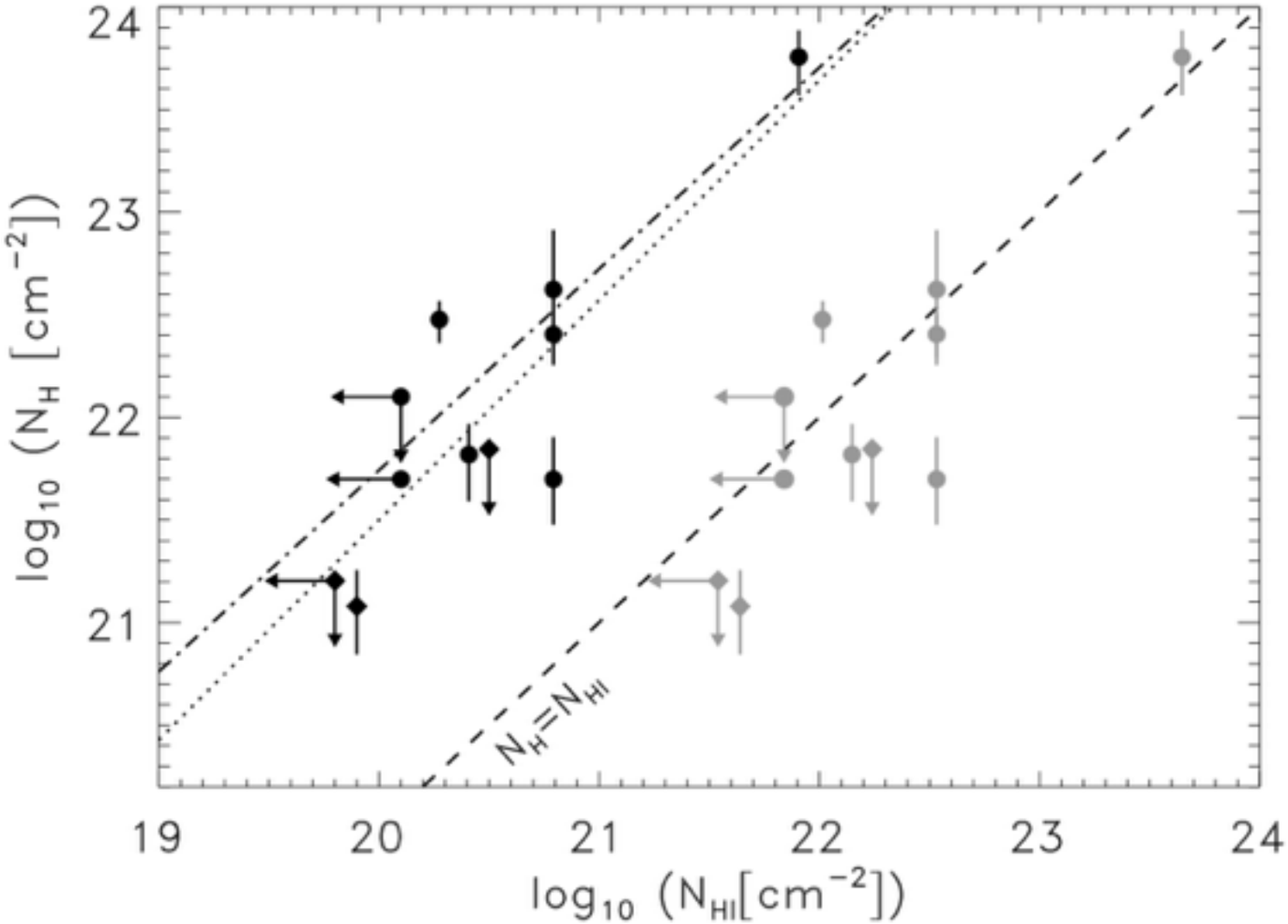
DETERMINING N_H USING SOFT X-RAY ABSORPTION

X-rays/HI in GPS sources

Vink+ 2006

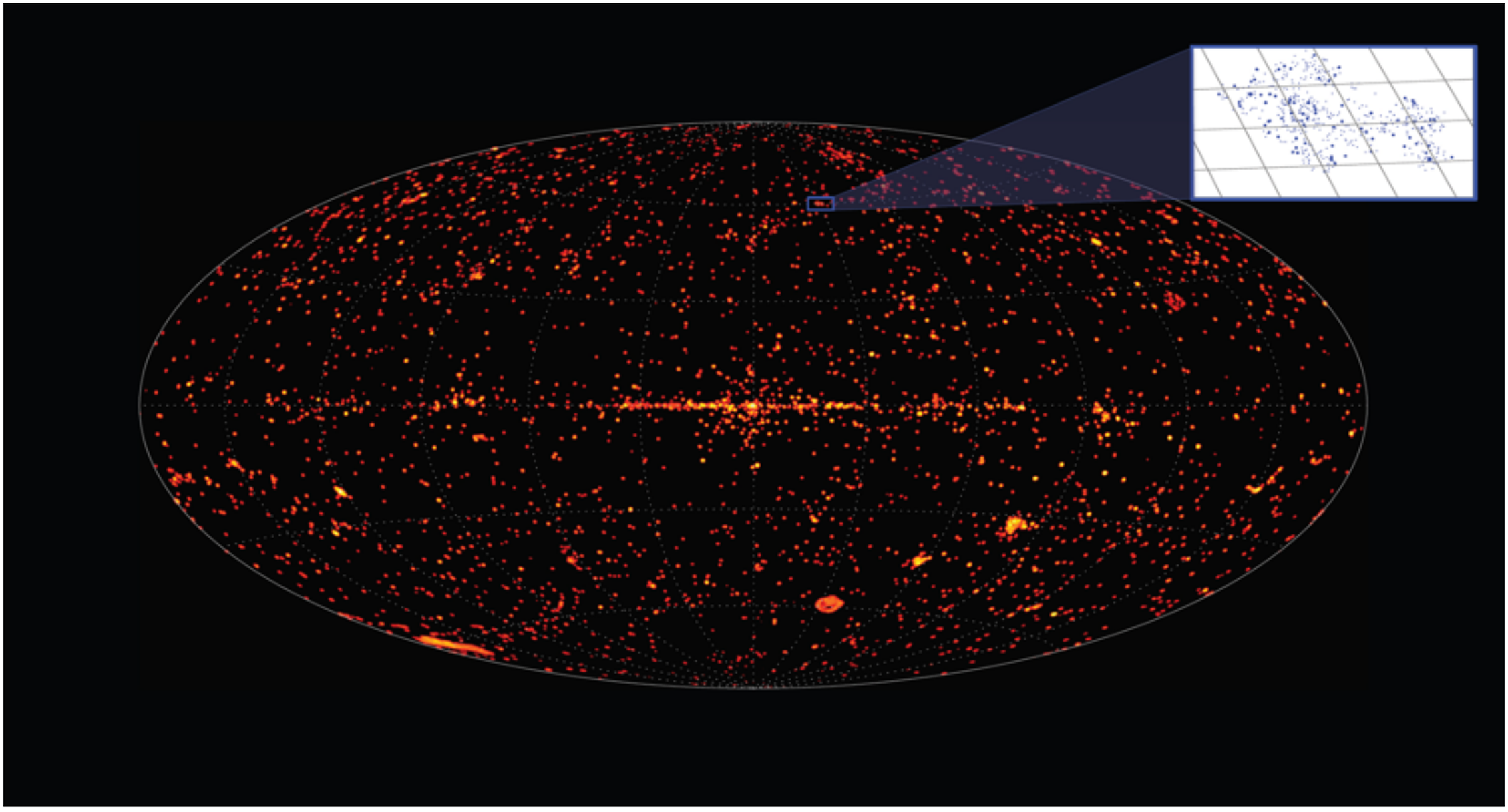


Ostorero+ 2010



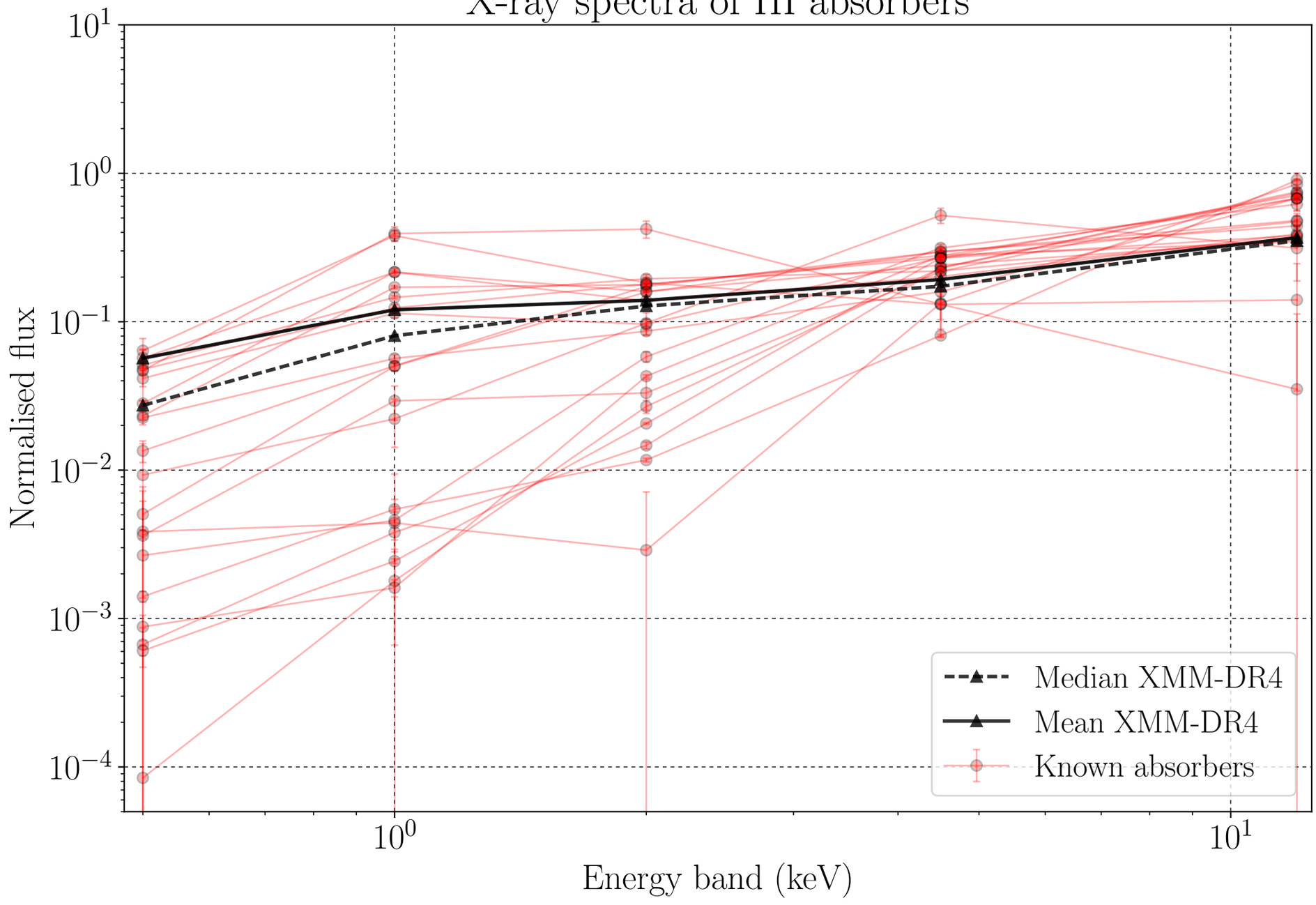
VINK+ (2006), OSTORERO+ (2010, 2015): CORRELATION BETWEEN HI ABSORPTION AND X-RAYS

3XMM DR4 catalogue



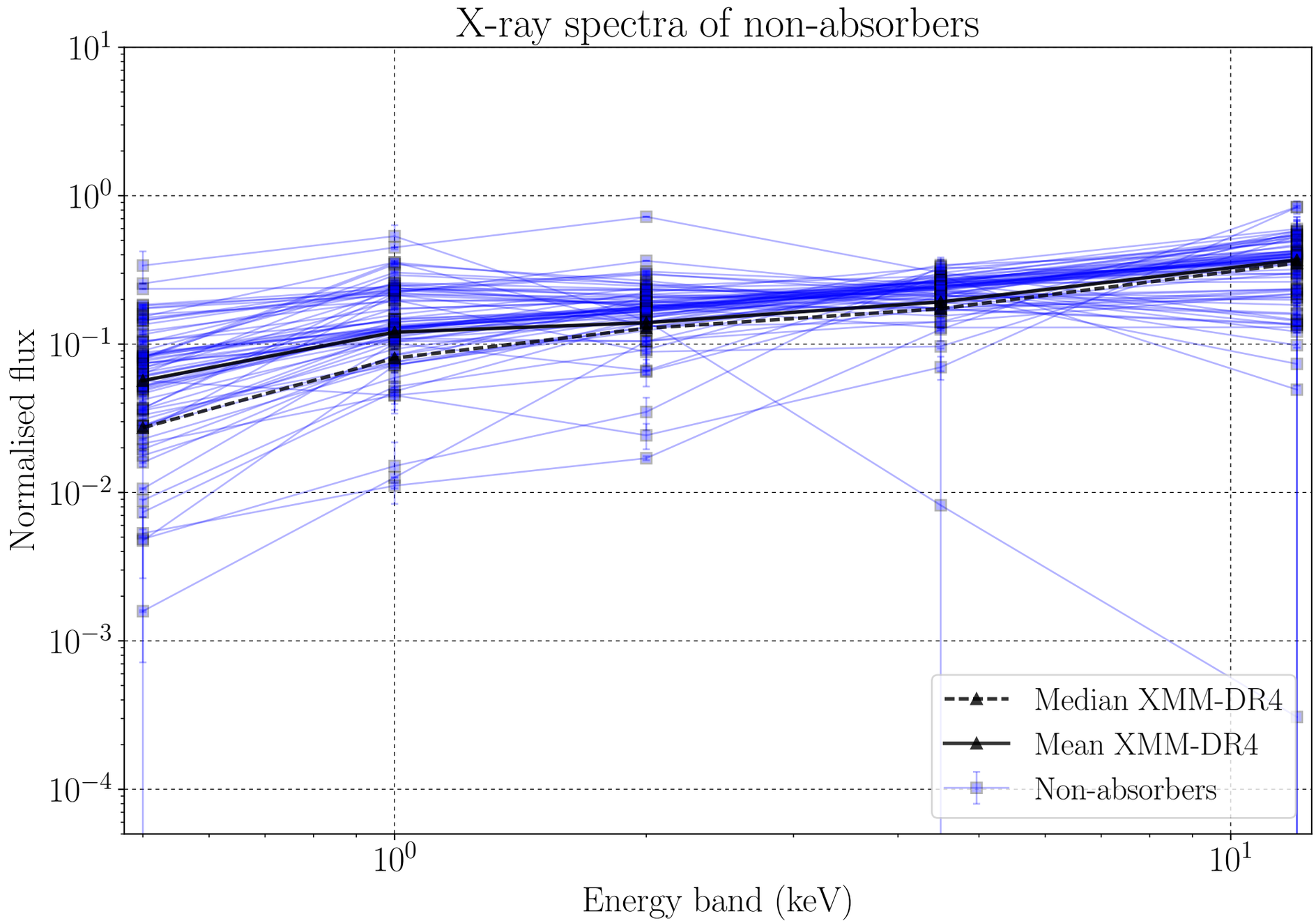
ALL-SKY 3XMM DR4: ESA/XMM-NEWTON/EPIC/M. WATSON

XMM: HI absorbers



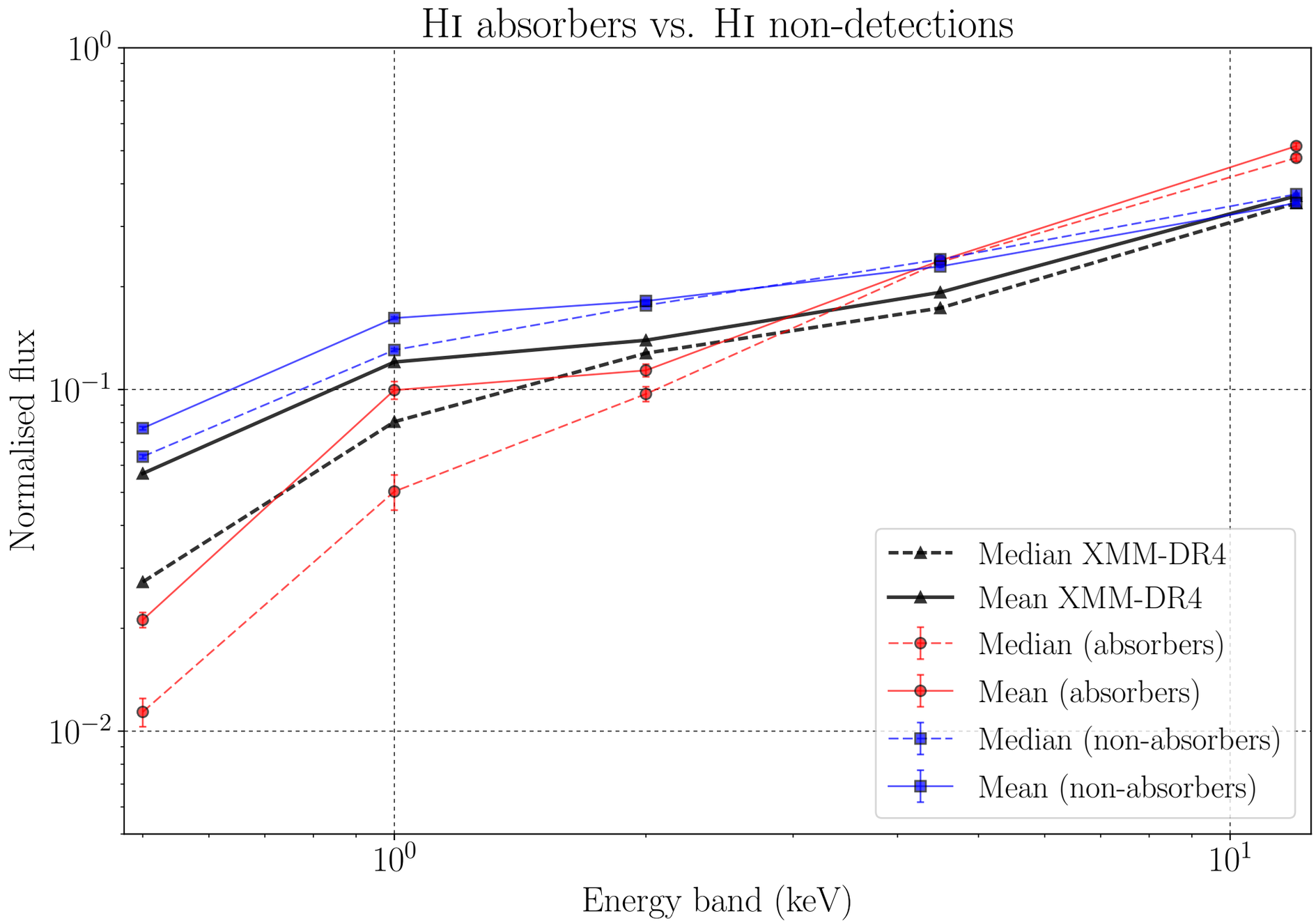
SPECTRAL PROPERTIES OF HI ABSORBERS FROM 3XMM DR4: MOSS+ (SUBMITTED)

XMM: HI non-absorbers



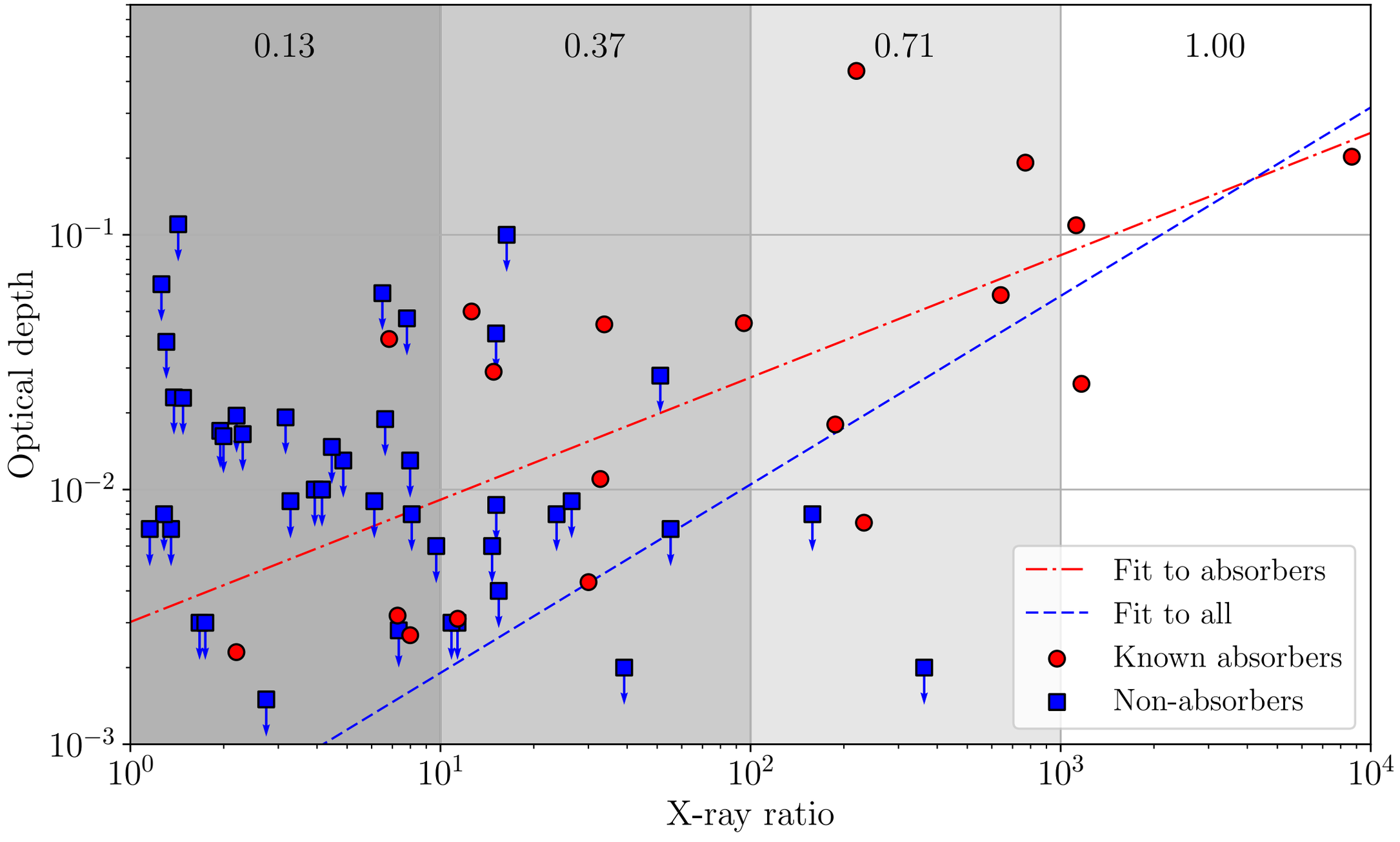
SPECTRAL PROPERTIES OF HI NON-ABSORBERS FROM 3XMM DR4: MOSS+ (SUBMITTED)

XMM: average properties



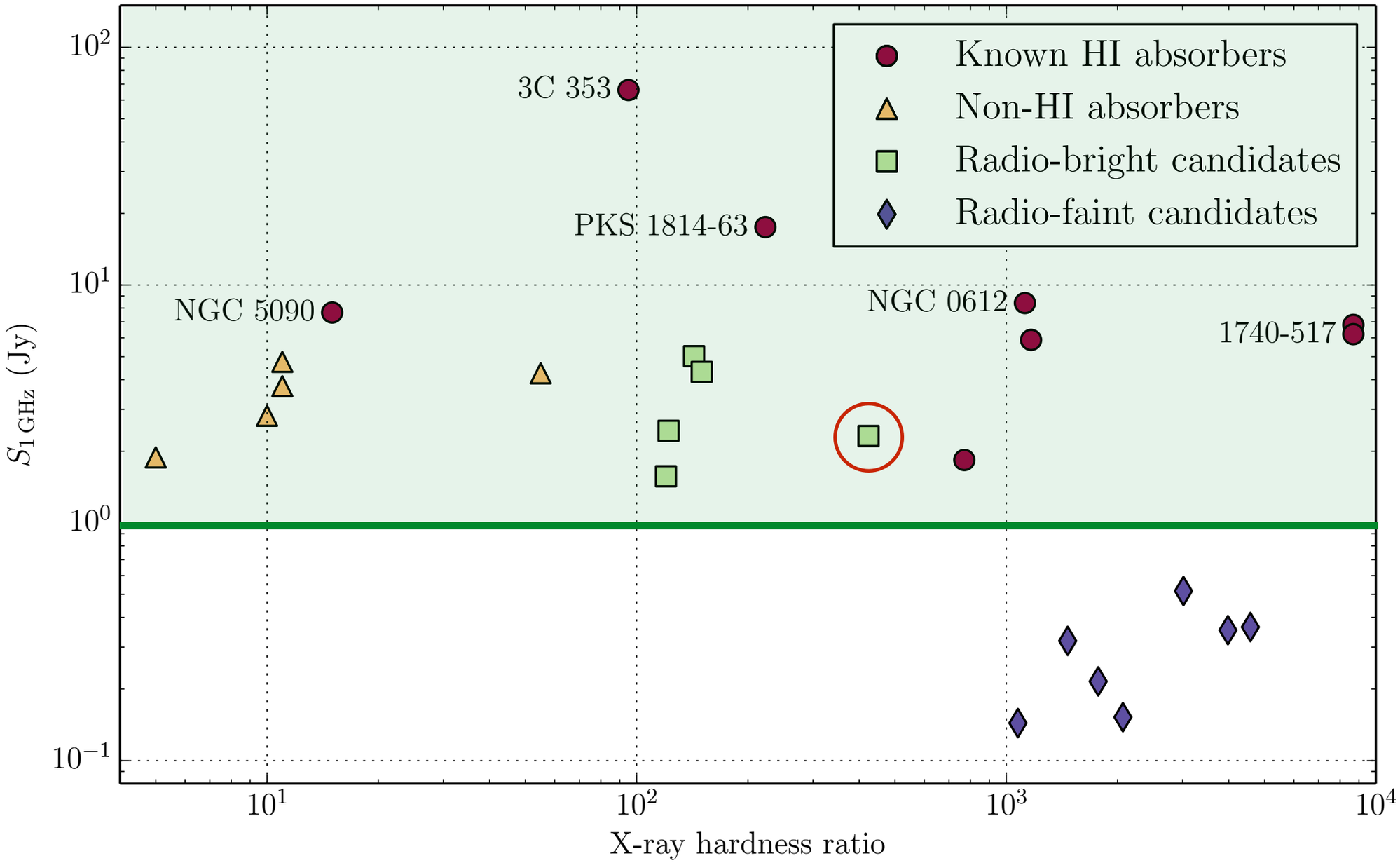
AVERAGE PROPERTIES OF ABSORBERS/NON-ABSORBERS FROM 3XMM DR4: MOSS+ (SUBMITTED)

Optical depth and X-rays



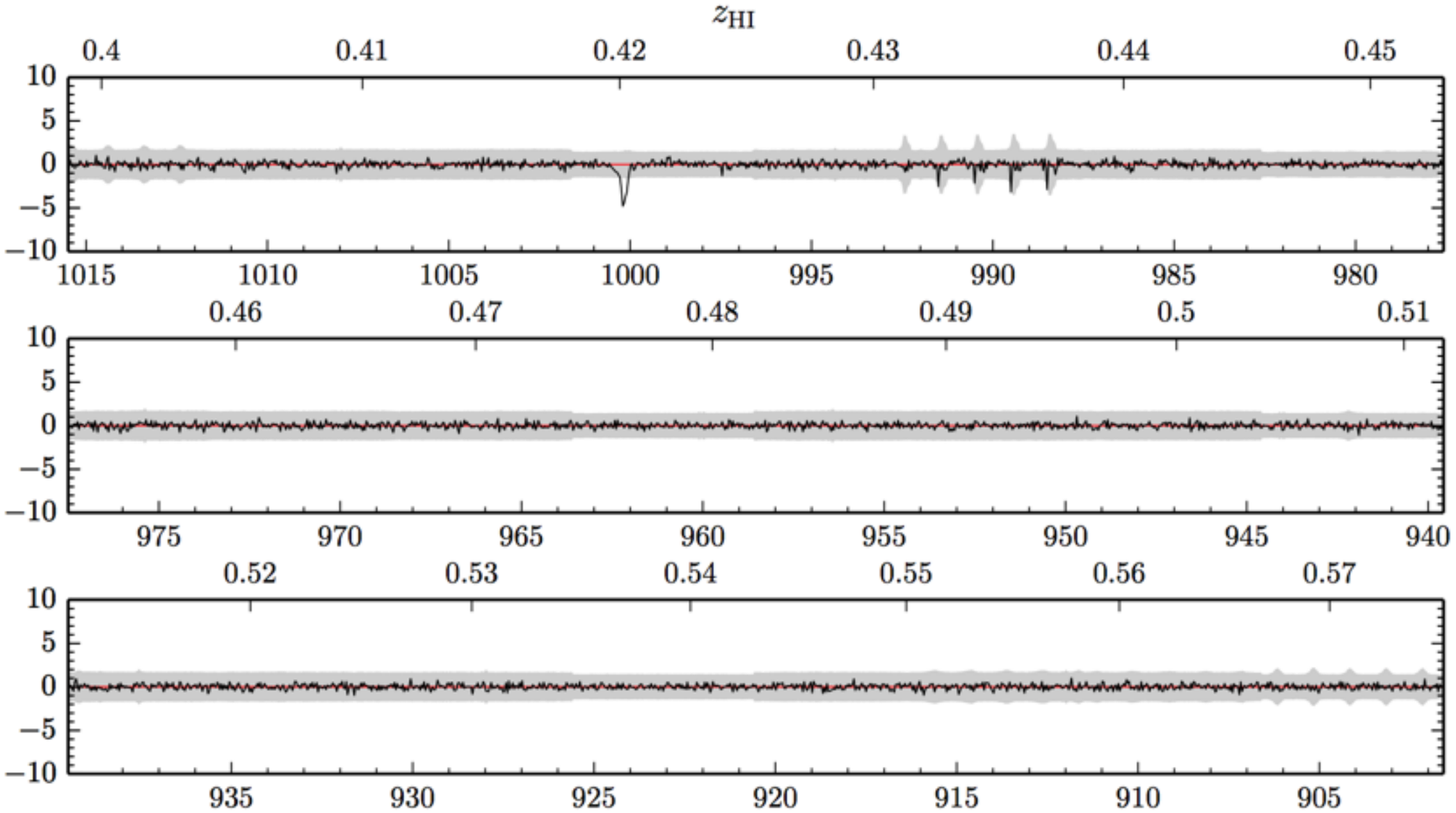
OPTICAL DEPTH VS. X-RAY RATIO FOR ABSORBERS/NON-ABSORBERS: MOSS+ (SUBMITTED)

The BETA X-ray sample



A SAMPLE OF X-RAY SELECTED RADIO-BRIGHT SOURCES TO BE OBSERVED WITH BETA

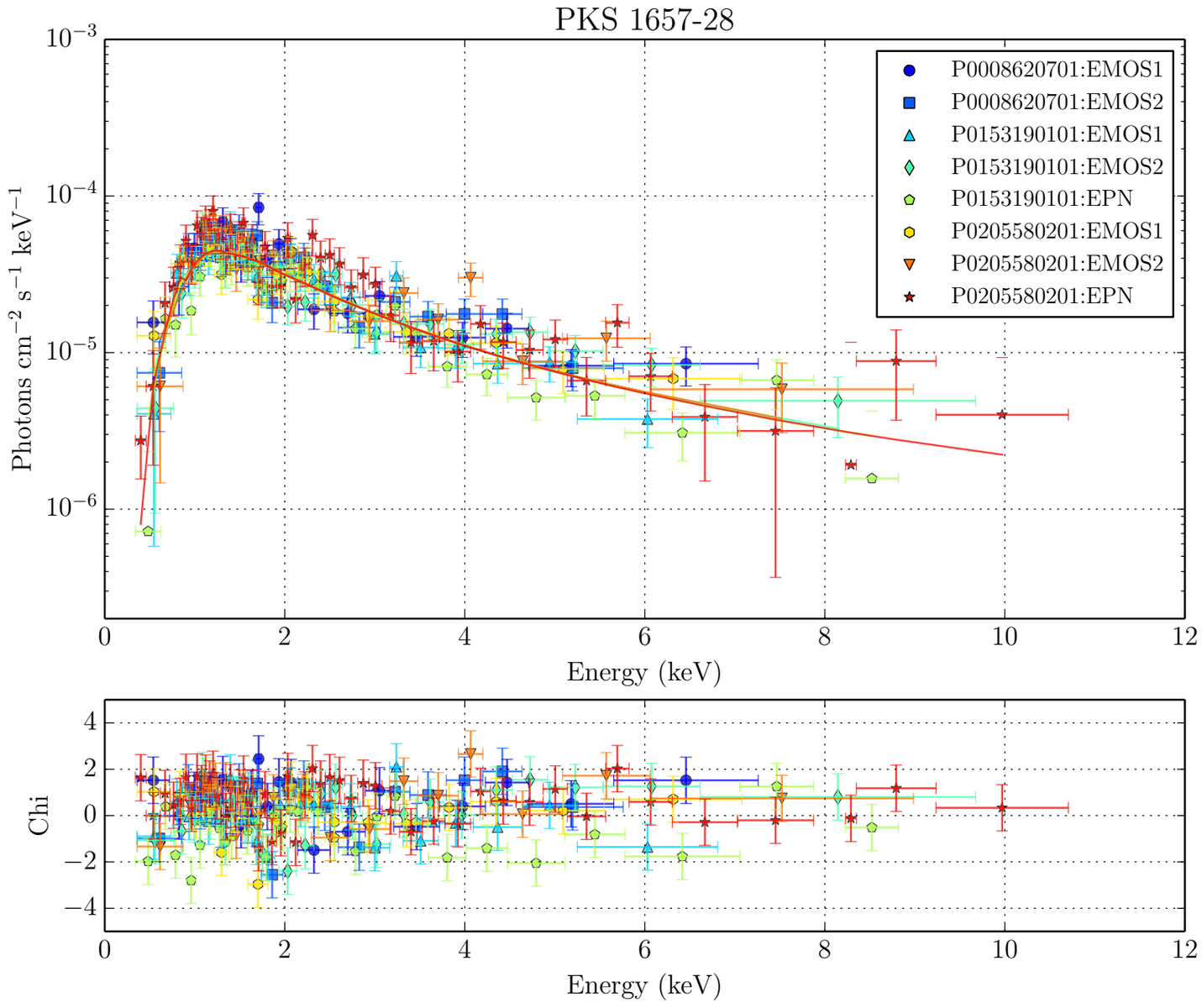
HI absorption at z = 0.42!



Line-width = 75 km s^{-1} Peak optical depth = 0.05 N_{HI} = 7.3 x 10^{20} cm^{-2}

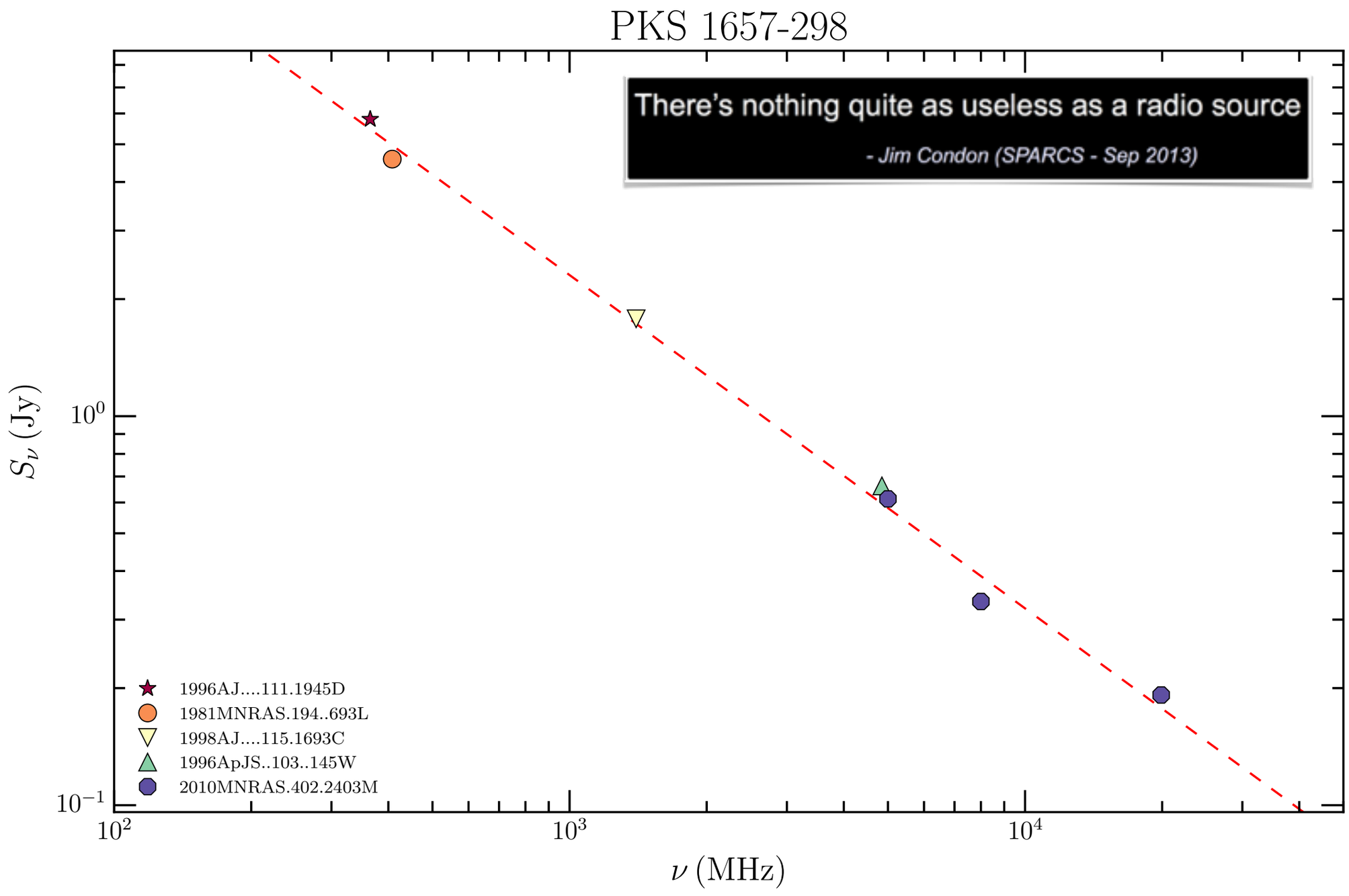
A NEW DETECTION OF HI ABSORPTION WITH BETA IN THE X-RAY SAMPLE

PKS 1657-298 in X-rays



- Observed serendipitously with XMM towards X-ray binary V* V2134 Oph
- Well-fit by an absorbed power-law model
- $N_H \sim 8 \times 10^{21}$ cm^{-2}
- Photon index $\Gamma \sim 1.9$ (consistent with ~1.6 Tengstrand+ 2009)
- $N_{HI} = 0.1\ N_H$ (T_s effect or ionised gas fraction?)

Spectrum of PKS 1657-298



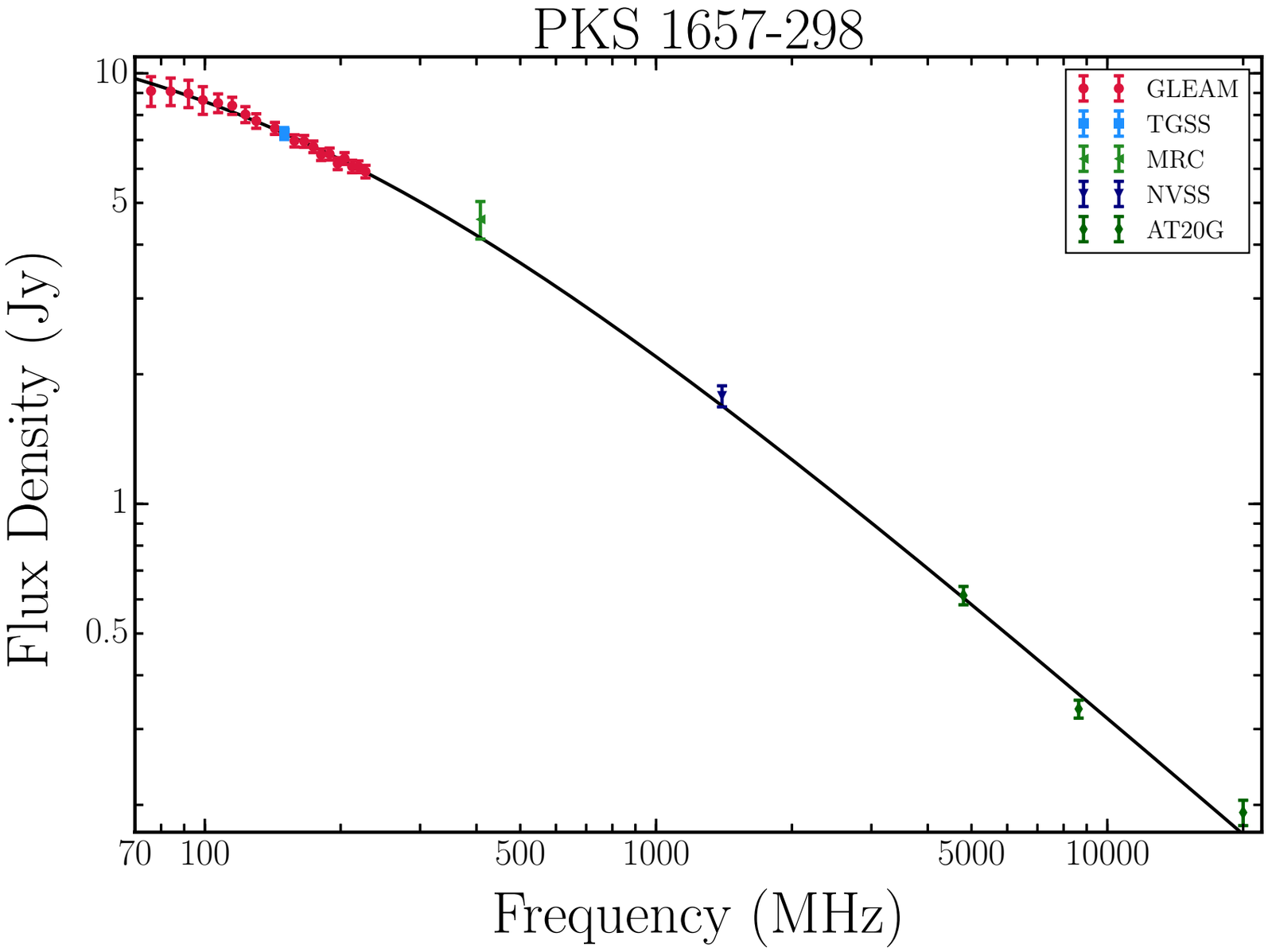
SPECTRAL ENERGY DISTRIBUTION FROM NED: A STEEP-SPECTRUM SOURCE

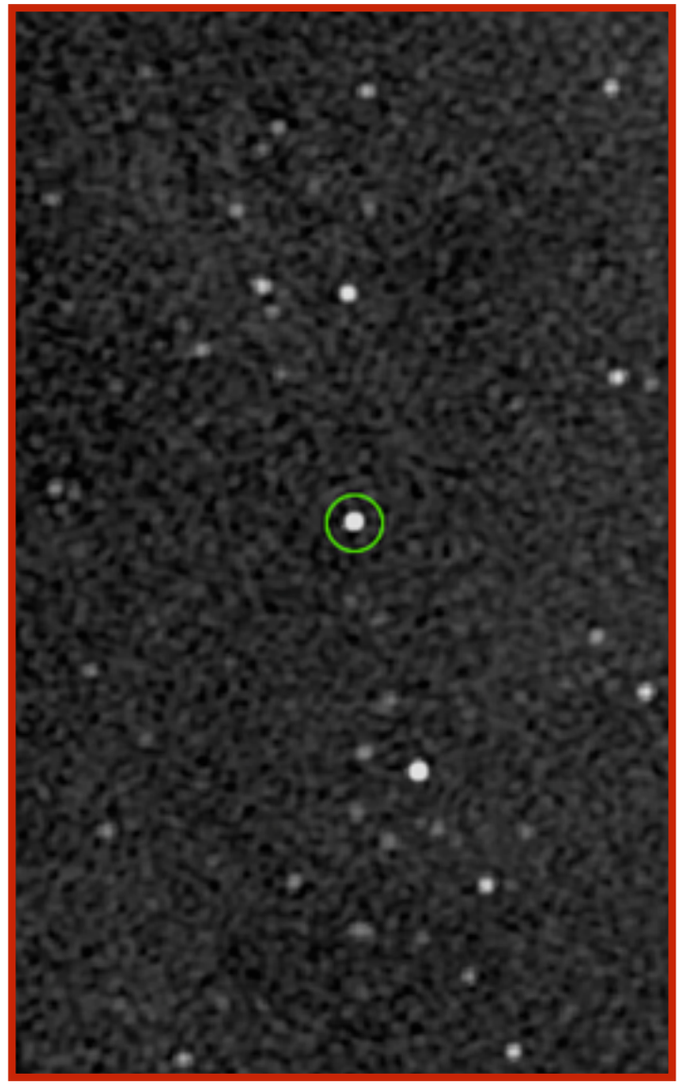
THE MURCHISON WIDEFIELD ARRAY

MWA

SPIDERS ON A TILE: E. LENC

Spectrum of PKS 1657-298

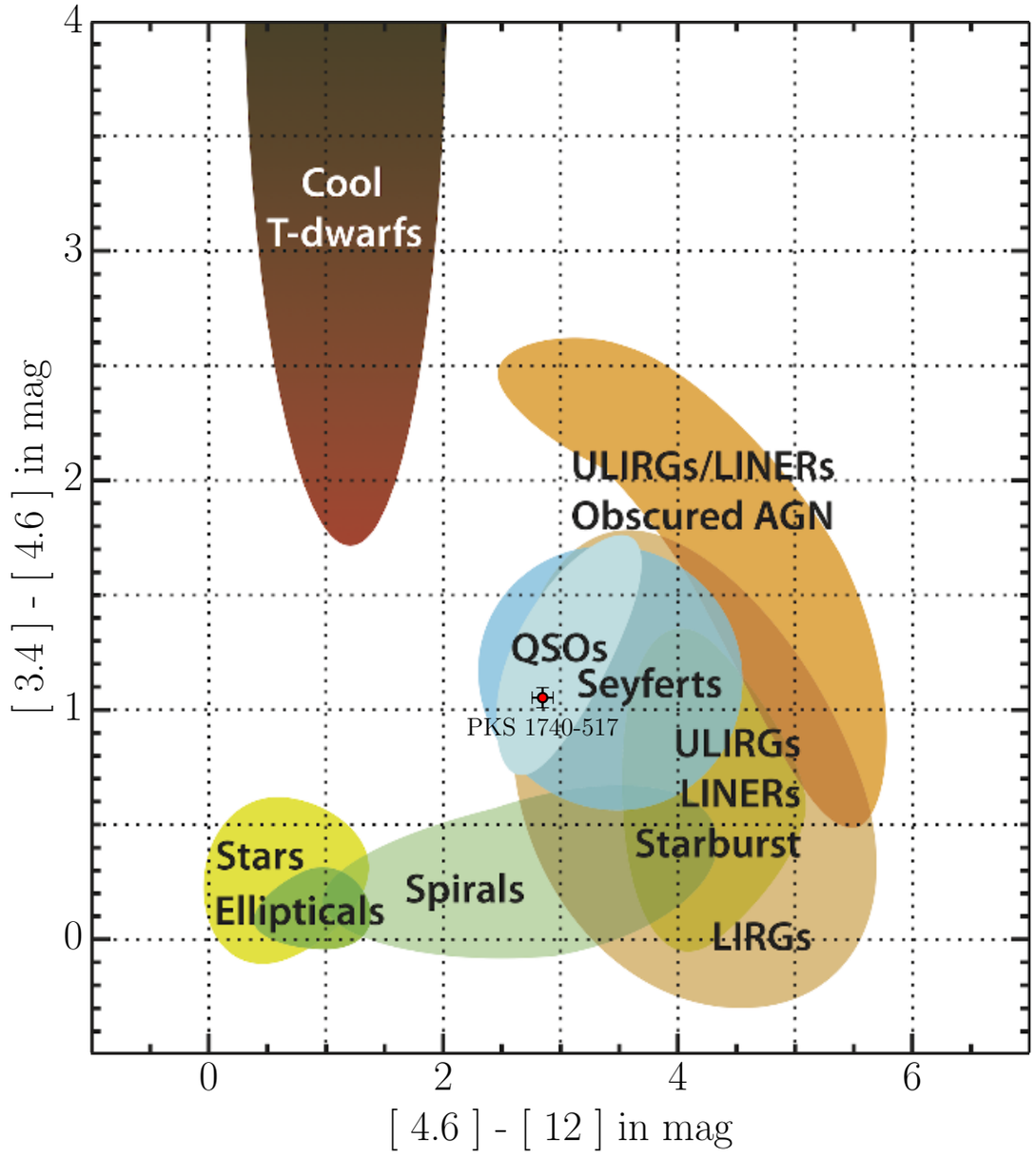




MWA DATA AND IMAGE FOR THE NEW HI DETECTION: J. CALLINGHAM/GLEAM TEAM

Characterising the host

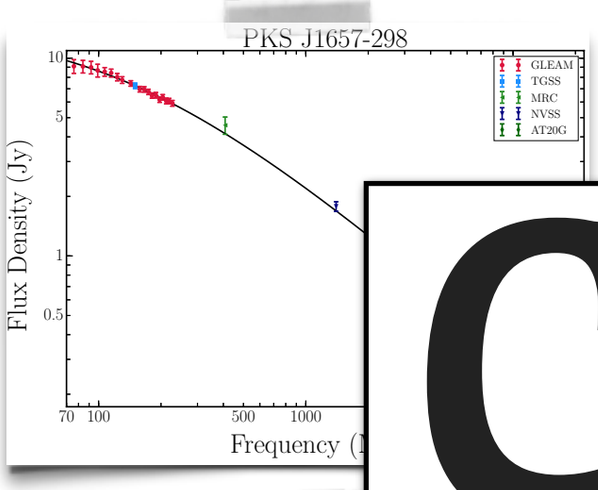
- Can use detected WISE colours to differentiate between different types of galaxies
- Background image: Wright+ (2010) showing the location of different classes of object
- PKS 1657-298 is well into the AGN region, probably a Seyfert galaxy based on ALLWISE data
- Existing large multi-wavelength datasets provide diagnostics for potentially understanding HI absorption hosts quickly

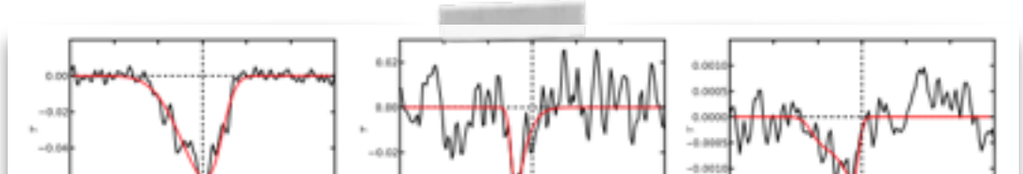


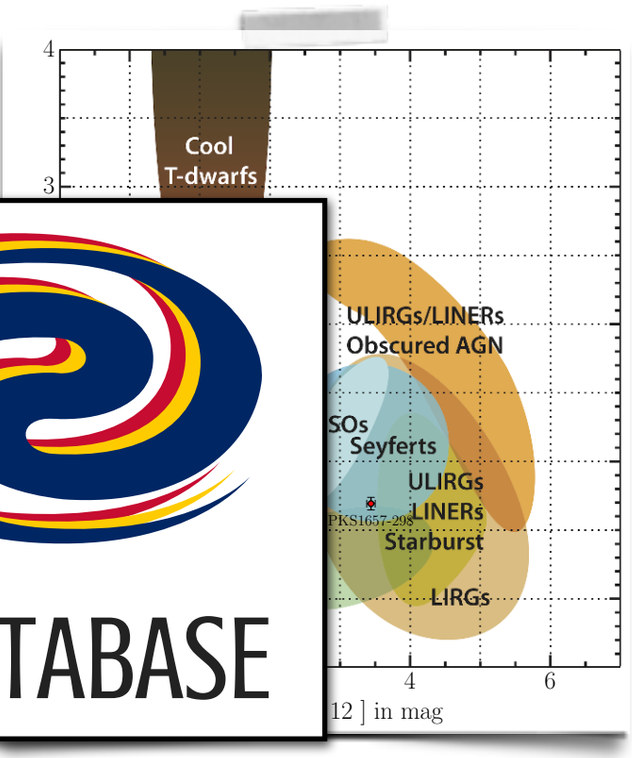
WISE COLOUR-COLOUR CLASSIFICATION OF PKS 1657-298

(C) HI Absorption Database

CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS



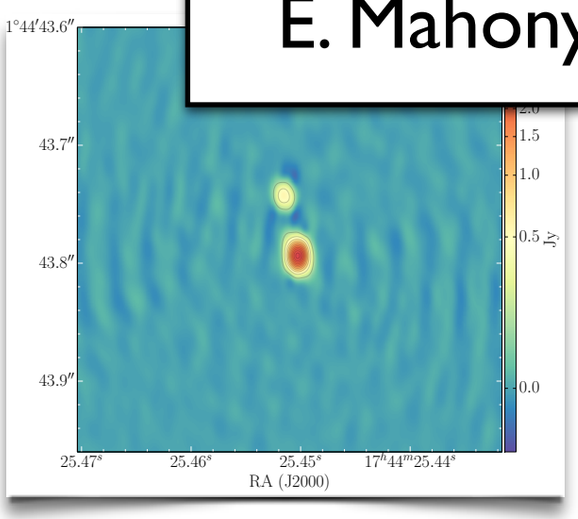


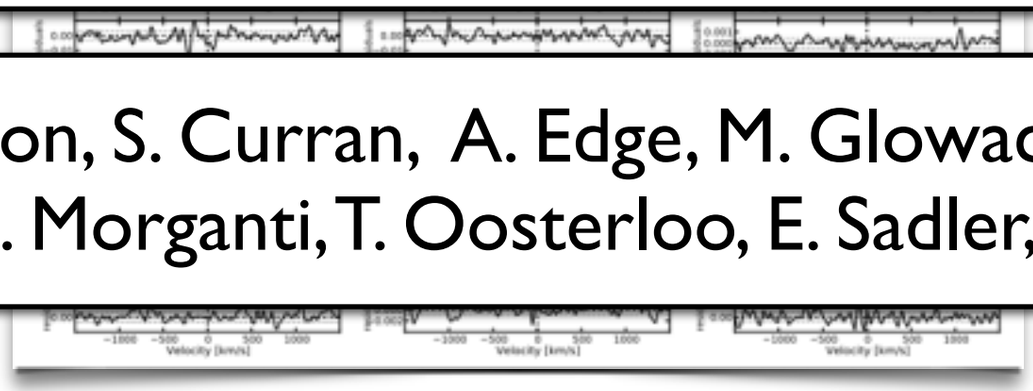


CHAD

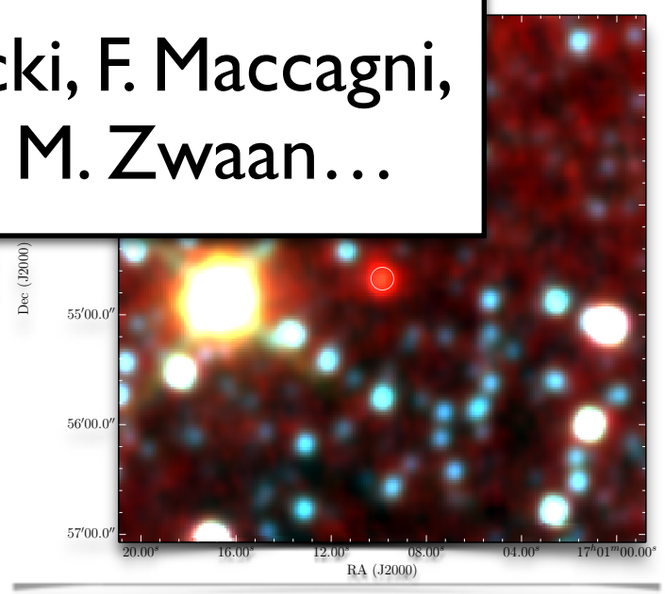
CONSOLIDATED HI ABSORPTION DATABASE

V. Moss, J. Allison, S. Curran, A. Edge, M. Glowacki, F. Maccagni, E. Mahony, R. Morganti, T. Oosterloo, E. Sadler, M. Zwaan…





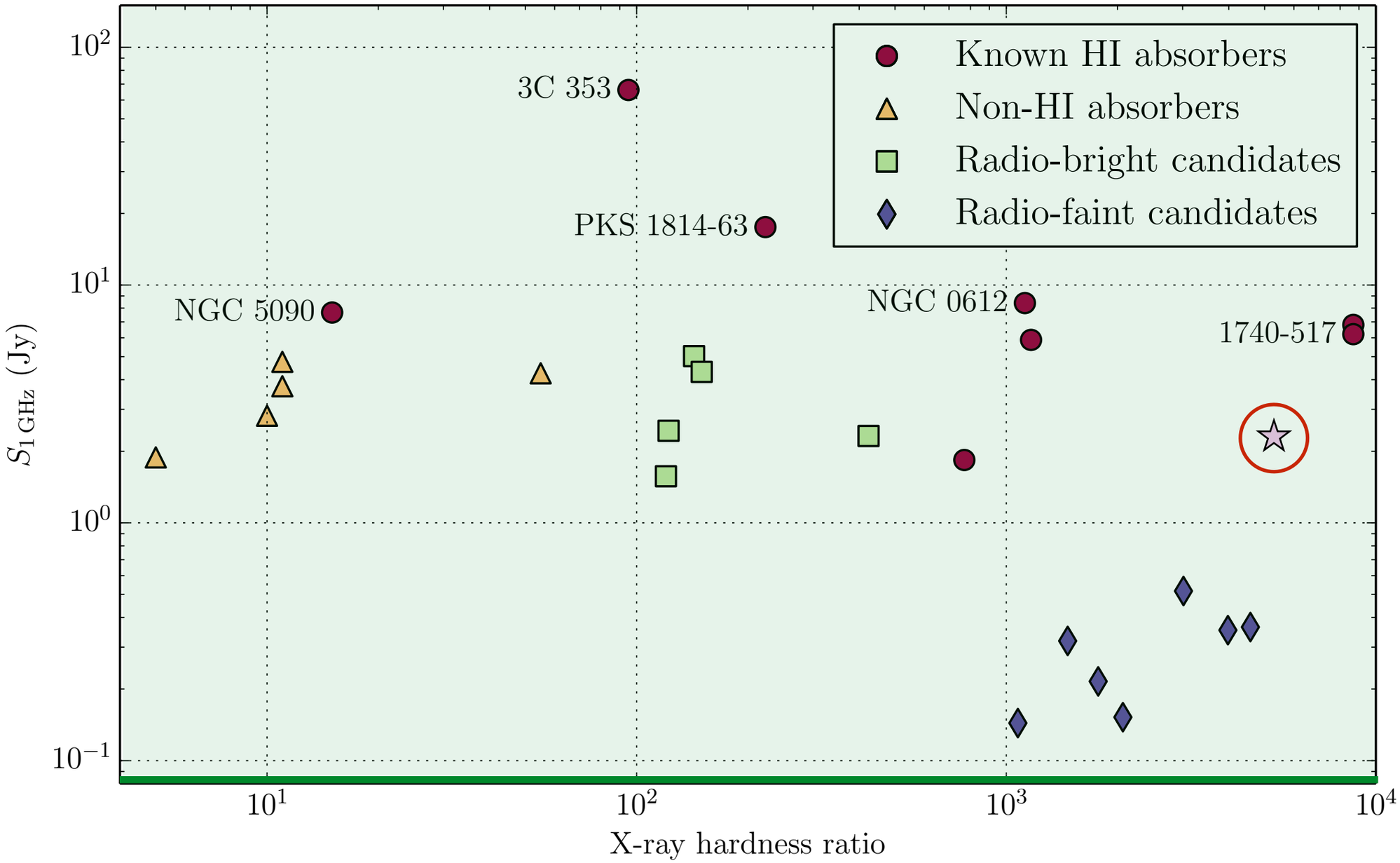
e.g. Gereb+ 2014



The 2 Jy Sample is a great example to follow!

(C) HI Absorption Database

X-ray sample for ASKAP



A checklist for near future


Spectral X-ray (all-sky) data


Mid-frequency 1-25 GHz


High-frequency 35-100 GHz

???

Redshifts over 0 < z < 1

VLBI continuum/spectral

MWA
MURCHISON
WIDEFIELD
ARRAY

Low-frequency data < 700 MHz

ASVO
ALL-SKY
VIRTUAL
OBSERVATORY

SkyView
The Internet's Virtual Telescope

Multi-wavelength all-sky data

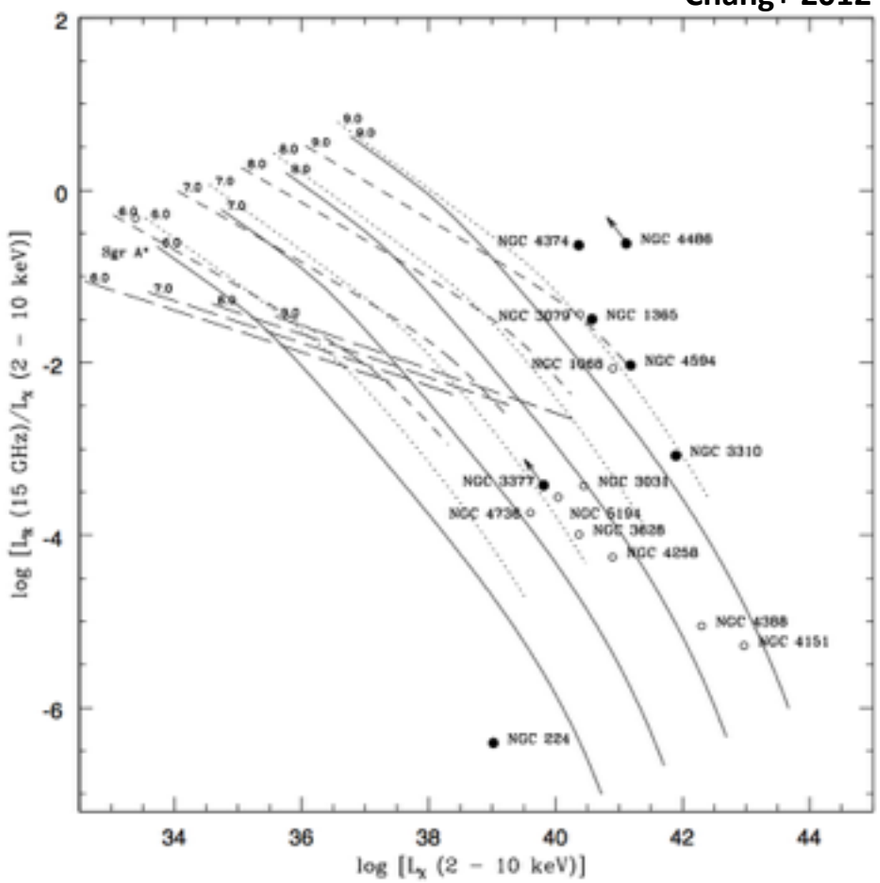
SEAFOG: eROSITA/FLASH

- MoU collaboration between CAASTRO and eROSITA_DE
- Approved as of 5th June 2017 by the Management Committee
- Current timescale planned: June 2017 - December 2019
- Will serve as useful preparation for SKA/Athena synergy beyond this time

FLASH + eRosita

- FLASH: 150,000 sources > 50 mJy (~1000 associated, ~1000 intervening)
- eRosita: all-sky mapping, 15”-30”, five bands covering 0-10 keV
- X-ray luminosity typically ~10^4 brighter than radio luminosity (see e.g. Chang+ 2012, Panessa+ 2015)
- This translates to an X-ray sensitivity requirement of ~4×10^{-12} erg cm^{-2} s^{-1} for complete coverage in eRosita
- CAASTRO/eRosita MoU: check for X-ray absorbed spectra whenever HI absorbers are detected with ASKAP

Chang+ 2012



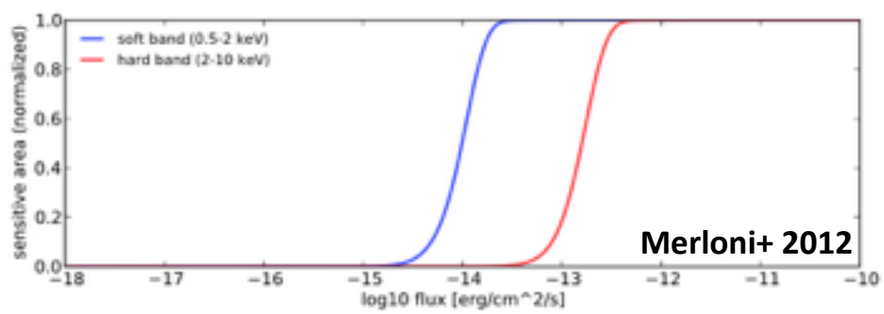
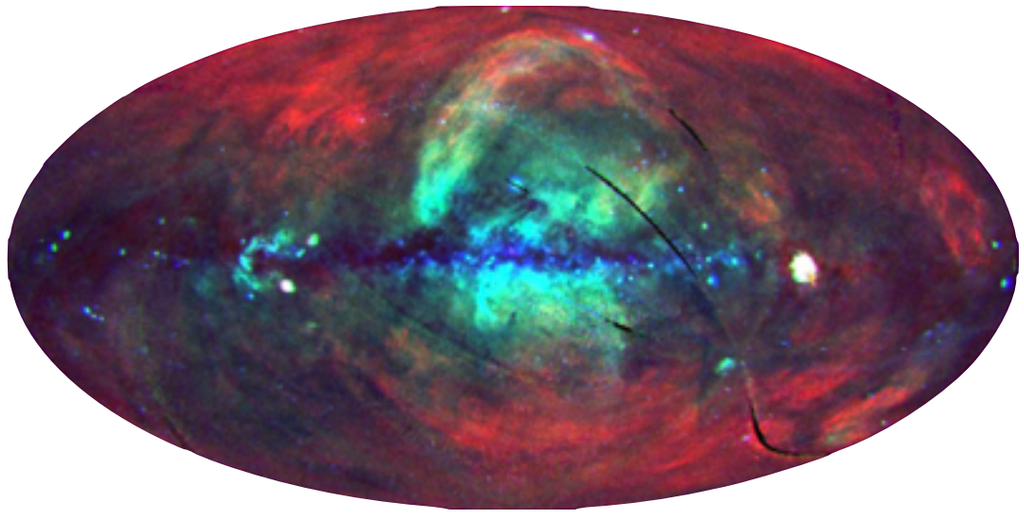


Figure 4.3.2: Sensitivity curves for the full 4-years eROSITA survey: the normalized sensitive area is plotted as a function of the limiting flux for point source detection for both soft (blue) and hard (red) band. The computations are based on the exposure map and background model of Fig. 3.1.2

FLASH + eRosita

- What do we learn from a combined FLASH/eRosita survey?
- Connection between radio AGN with/ without X-rays: emission mechanism
- What kinds of galaxies have: 1) radio AGN, 2) X-ray AGN, 3) HI absorption? Trace multi-wavelength properties
- Comparable angular resolution studies (20" FLASH, 20-30" eRosita)
- N_H vs. N_{HI} for a large sample (100s of galaxies most likely)
- Studies of variability in radio/X-rays



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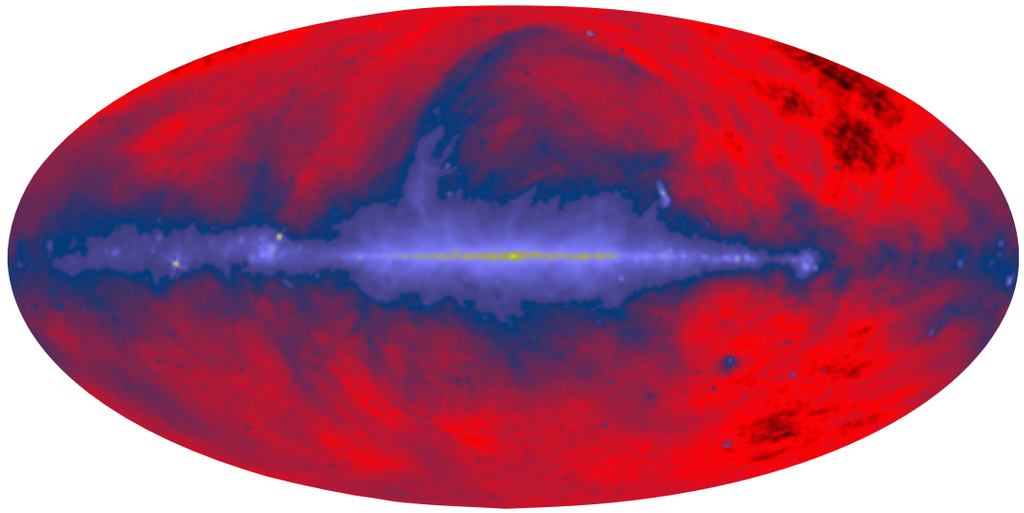

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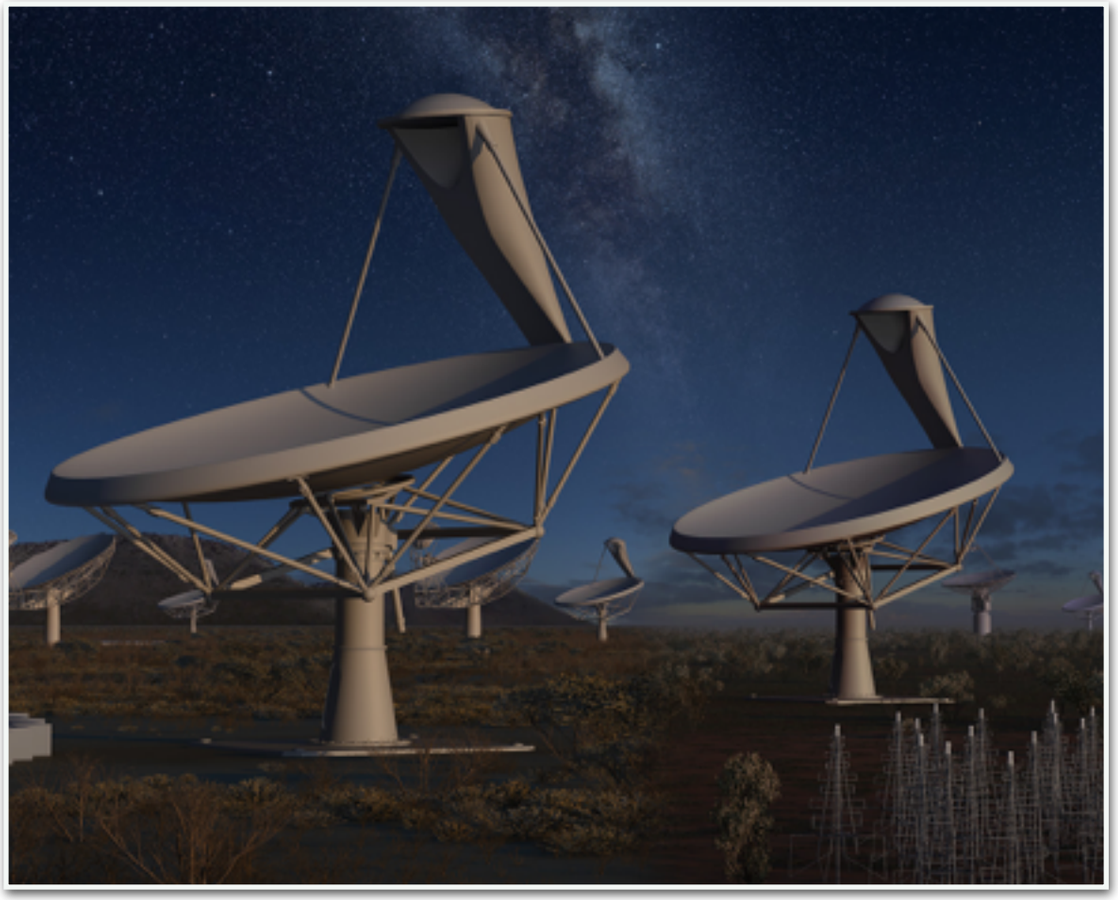
😄

FLASH + EROSITA: SYNERGIES IN SCIENCE

The future for HI+X-ray

SQUARE KILOMETRE ARRAY MID-FREQUENCY **(SKA MID)**

Redshift coverage (HI line): 0 < z < 3
Channel sensitivity (SKA1-SCI-5): 0.25 mJy at 2" (2 years)

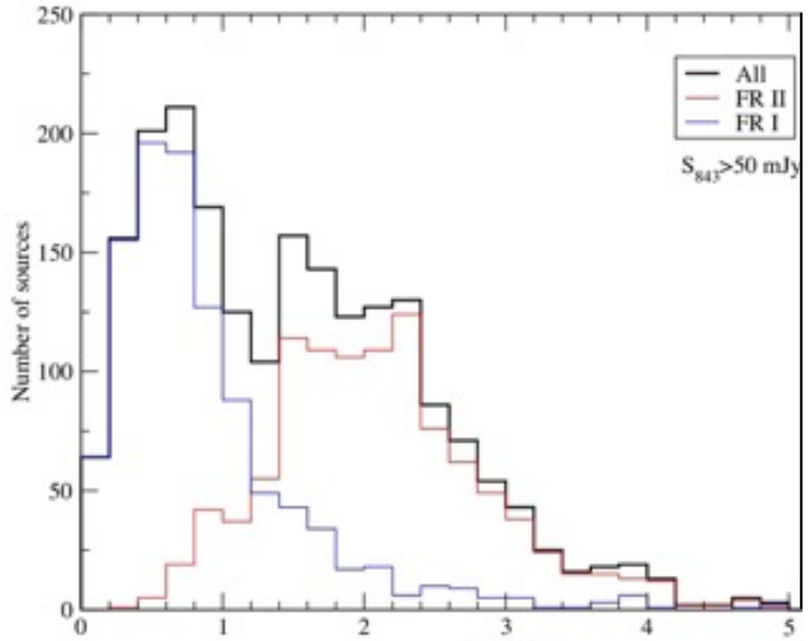


ADVANCED TELESCOPE FOR HIGH ENERGY ASTROPHYSICS **(ATHENA)**

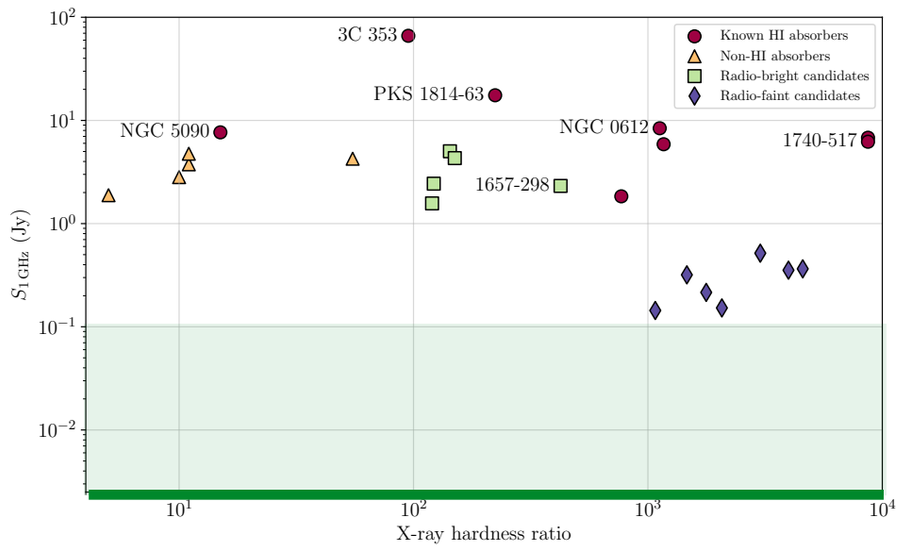
Spectral coverage (WFI): 0.2-15 keV at ~80 keV resolution
Sensitivity: 10x XMM-Newton

The SKA/Athena era

- Currently limited to the most extreme AGN in the (relatively) nearby Universe
- Sensitivity to radio sources at 0.25 mJy (millions of radio galaxies) and z < 3
- With Athena, we can identify lower luminosity, obscured AGN up to z ~ 6 and beyond (Aird+ 2013)
- SKA Low will potentially cover 50-650 MHz, extending redshift coverage
- Goal: trace both low and high column systems across 12 billion years of Universe evolution

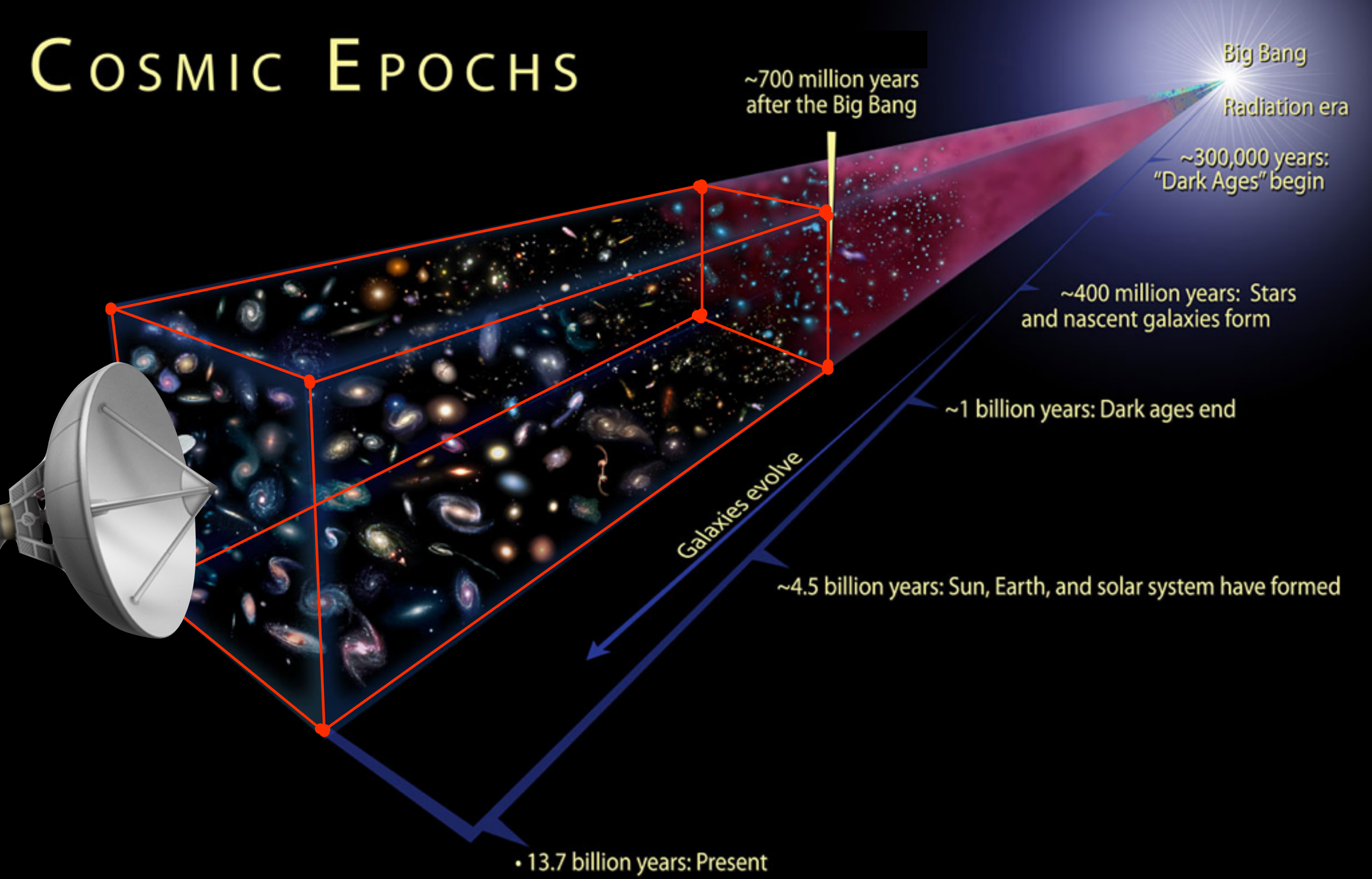


Predicted redshift distribution for continuum sources brighter than 50 mJy at 843 MHz, from the SKADS simulated sky (Wilman+ 2008)



SKA + ATHENA: SCIENCE SYNERGY FOR ABSORPTION

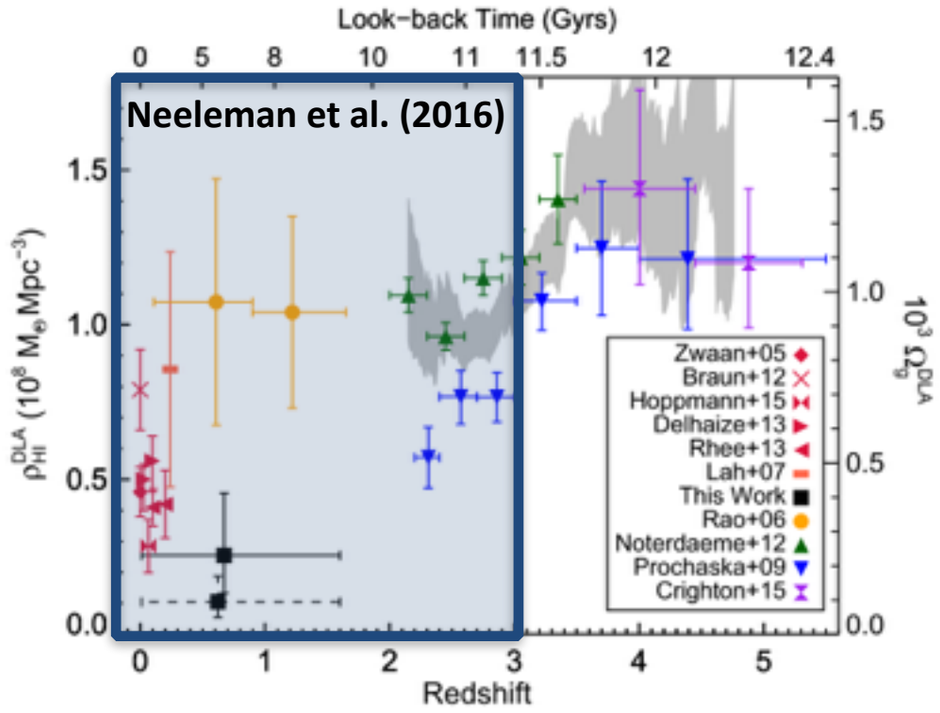
Cosmic Epochs

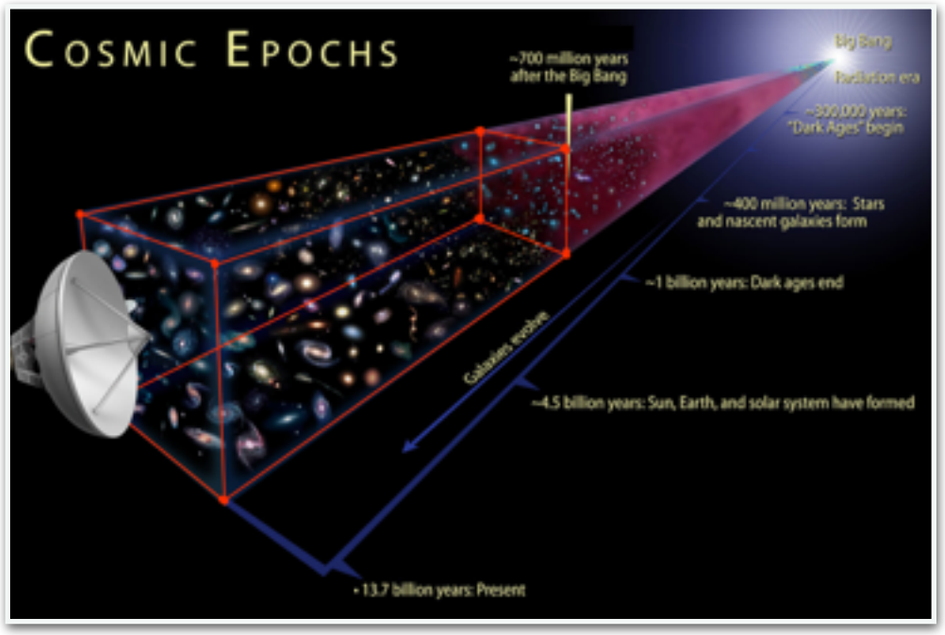


COSMIC EVOLUTION: NASA/ESA/A. FEILD (STSCI)

The SKA/Athena era

- What large-scale evolution do we see from z = 3 to the present Universe?
- How do the properties of obscuration change in low-luminosity AGN versus high-luminosity AGN?
- Detection fraction of HI absorption vs. X-ray absorption to z = 3, as well as tracing evolution in N_{HI} vs. N_H
- Multi-wavelength properties of the systems with 10^{20} cm^{-2} vs. > 10^{22} cm^{-2} (probing the DLA-type absorbers)
- Exploring unknown parameter space





THE QUESTIONS OF THE SKA/ATHENA ERA

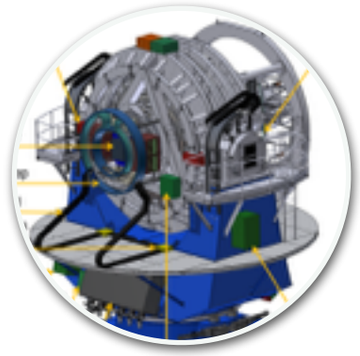
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

A checklist for future future


Spectral X-ray (all-sky) data


Mid-frequency 1-25 GHz


High-frequency 35-100 GHz




Redshifts over 0 < z < 3

VLBI continuum/spectral

Low-frequency data < 700 MHz

ASVO | ALL-SKY VIRTUAL OBSERVATORY

SkyView
The Internet's Virtual Telescope

Multi-wavelength all-sky data

CURRENT FUTURE DIRECTIONS

- **Extension of BETA X-ray sample to wider Universe:**
  1) northern + southern hemisphere
  2) lower redshifts ($0 < z < 0.4$)
  3) middle redshifts ($0.4 < z < 1$)
  4) higher redshifts ($1 < z < 3+$)
  5) effect of environment: clusters/groups
  6) high angular resolution studies in HI and X-ray
  7) lower radio/X-ray luminosities/column densities
  8) variability studies in HI and X-ray
  9) FLASH + eRosita (2018+)
  10) SKA + Athena (2028+)

Moss+ 2017 (almost!)

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Connecting X-ray absorption and 21 cm neutral hydrogen absorption in obscured radio AGN

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ABSTRACT

Many radio galaxies show the presence of dense and dusty gas near the active nucleus. This can be traced by both 21 cm HI absorption and soft X-ray absorption, offering new insight into the physical nature of the circumnuclear medium of these distant galaxies. To better understand this relationship, we investigate soft X-ray absorption as an indicator for the detection of associated HI absorption, as part of preparation for the First Large Absorption Survey in HI (FLASH) to be undertaken with the Australian Square Kilometre Array Pathfinder (ASKAP). We present the results of our pilot study using the Boolardy Engineering Test Array, a precursor to ASKAP, to search for new absorption detections in radio sources brighter than 1 Jy that also feature soft X-ray absorption. Based on this pilot survey, we detected HI absorption towards the radio source PKS 1657−298 at a redshift of $z = 0.42$. This source also features the highest X-ray absorption ratio of our pilot sample by a factor of 3, which is consistent with our general findings that X-ray absorption predicates the presence of dense neutral gas. By comparing the X-ray properties of AGN with and without detection of HI absorption at radio wavelengths, we find that X-ray hardness ratio and HI absorption optical depth are correlated at a statistical significance of 4.71σ. We conclude by considering the impact of these findings on future radio and X-ray absorption studies.

Key words: keywords

1 INTRODUCTION

The cores of active galaxies produce emission across the electromagnetic spectrum, with each wavelength opening a different window into the nature of the supermassive black holes at their centre and their surrounding medium (Heckman & Best 2014; Tadhunter 2016, and references therein). Many compact active galactic nuclei (AGN) detected at radio wavelengths are also X-ray bright, and the X-ray emission observed can be produced via a number of different mechanisms (see e.g. Haardt & Maraschi 1993; Merloni et al. 2003; Turner & Miller 2009; Worrall 2009; Fabian 2012; Reynolds 2016), such as the inner accretion flow (either an advection-dominated region, or a hot corona above the inner disk and its reflected component), directly from the jet (synchrotron emission), or from the interaction of the jet with the surrounding medium (hot thermal-plasma emission).

Previous studies investigating X-ray and radio AGN have included comparison of the column densities estimated from 21 cm neutral atomic hydrogen (HI) absorption ($N_{\rm HI}$, assuming a spin temperature) and an absorbed X-ray spectrum ($N_{\rm H}$, the combination of ionised, neutral and molecular hydrogen), find-

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Conclusions

- We are searching new parameter space for distant HI in galaxies
- We find evidence supporting the connection between hydrogen absorption and X-ray absorption
- Our BETA pilot sample revealed new HI absorption at z = 0.42
- FLASH/eRosita will allow us to conduct detailed population studies for the first time
- SKA/Athena will take us orders of magnitudes further, to the dawn of a new radio/X-ray era!