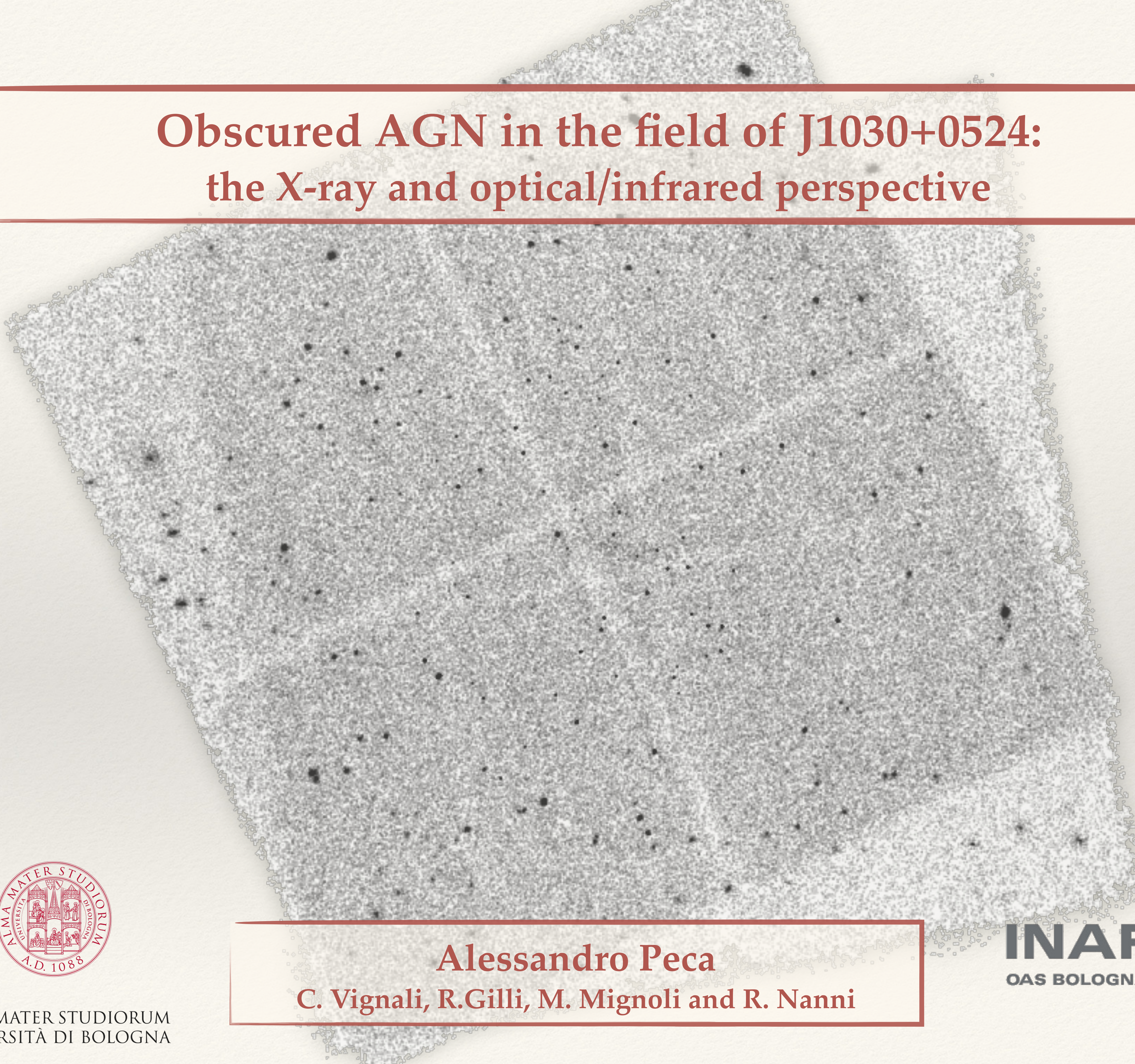

Obscured AGN in the field of J1030+0524:
the X-ray and optical/infrared perspective

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Outline

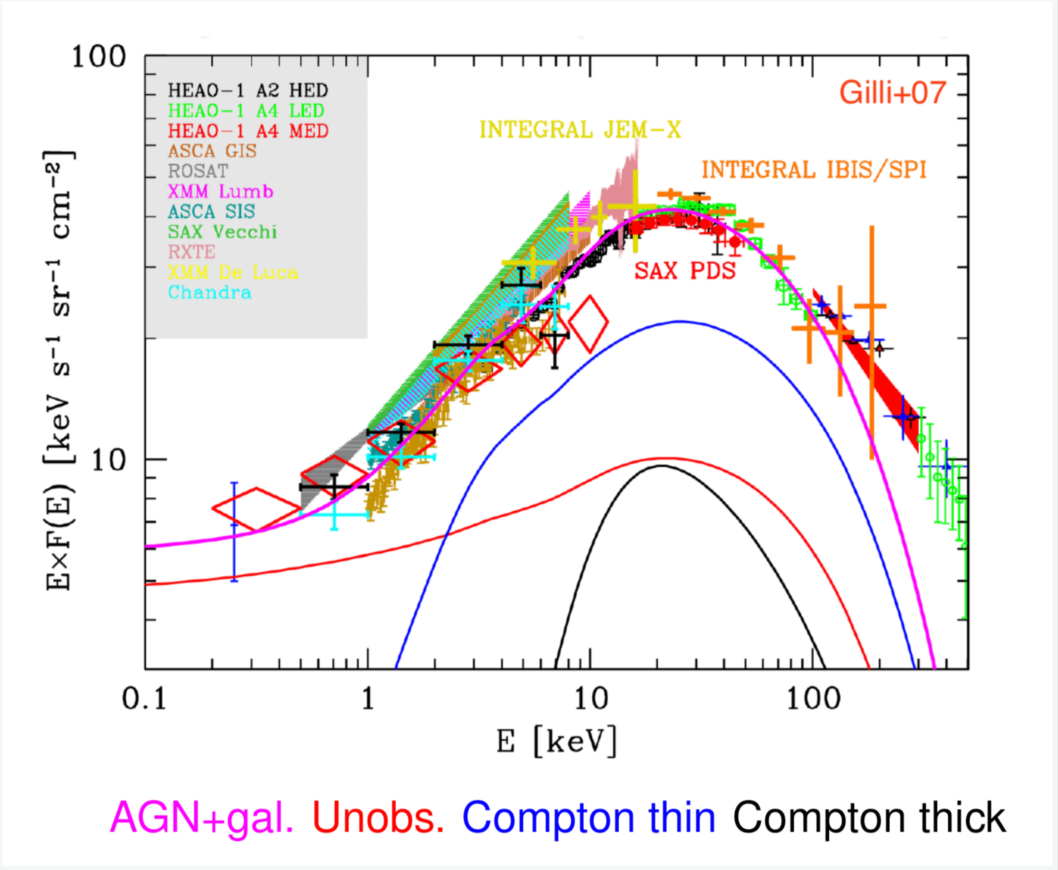
Aim: disclose and characterise obscured AGN in the J1030 field

Method: redshift from X-ray spectra + SED fitting

- Introduction
- The field around the $z = 6.31$ SDSS QSO J1030+0524
- Obscured AGN sample selection
- Redshifts from X-ray analysis and spectral simulations
- Photometric redshifts from SED fitting (optical/IR bands)
- Obscured AGN properties and results
- Conclusions and future prospects

Introduction: why obscured AGN?

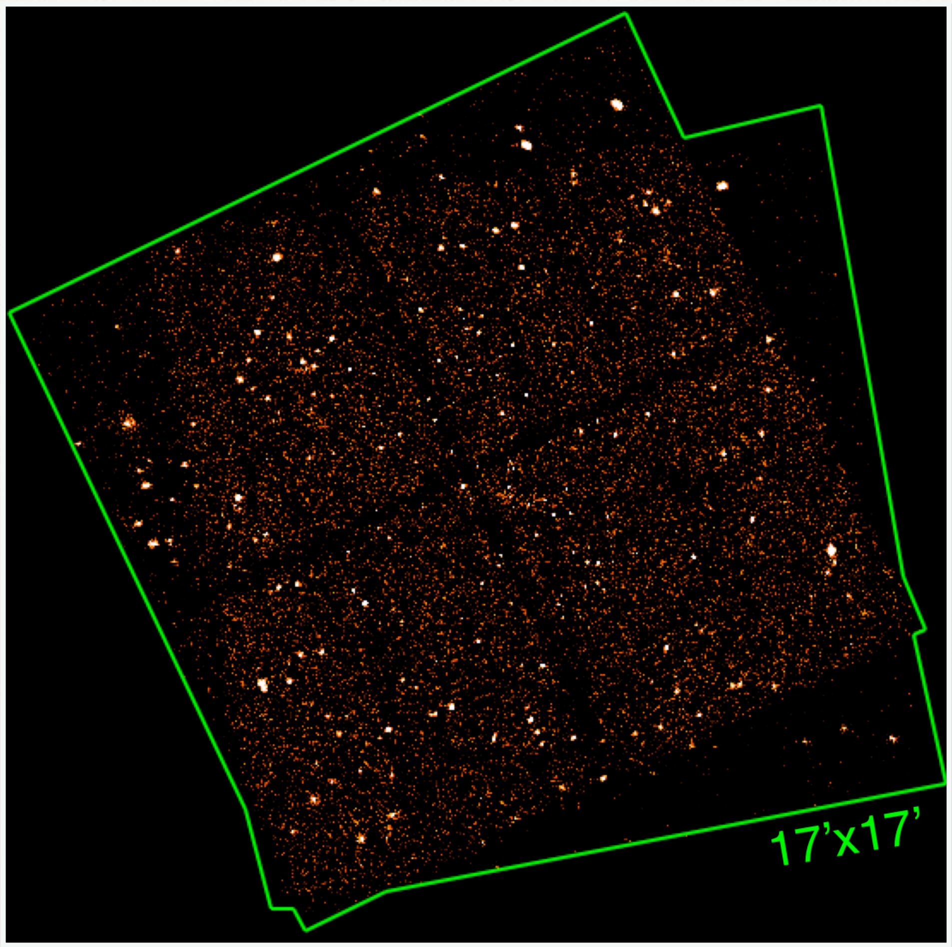
- X-ray background synthesis models predict a large number of heavily obscured AGN (e.g.; Gilli+07; Treister+09; Akylas+12)
- Deep X-ray surveys show that ~80-90% of the growth of black holes occurs during the obscured phases
- The number of obscured AGN seems to increase at high redshift (e.g.; Vito+18)



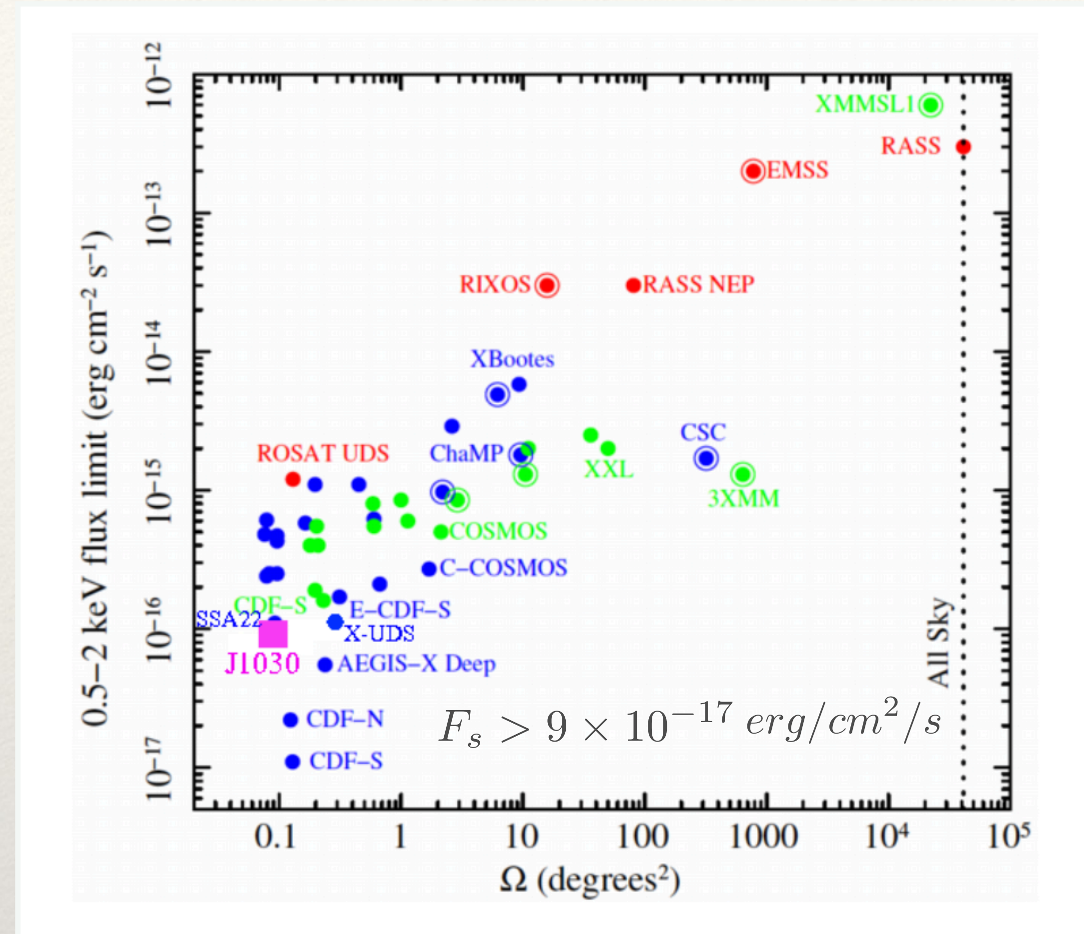
➡ Deep X-ray fields are needed

➡ Redshifts are fundamental to derive intrinsic AGN properties and study their evolution

The J1030 field: deep Chandra observation



See Nanni+18 for further details

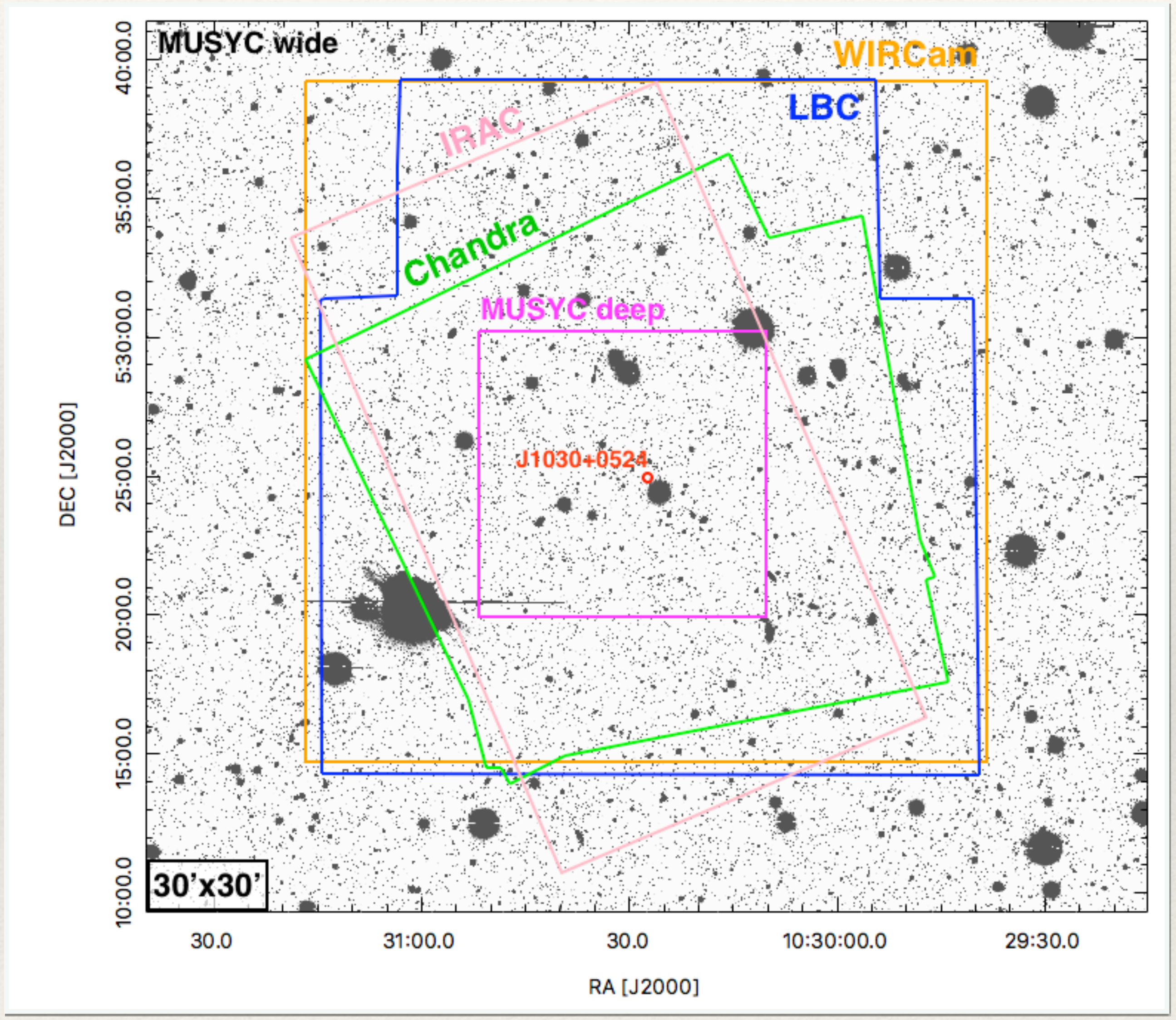


The field was observed with Chandra/ACIS-I for a total of ~500ks and a FoV ~335 arcmin^2:

- J1030 is the 4th deepest X-ray survey ever observed
- > 250 sources identified (Nanni et al. in prep.)

The J1030 field: optical/NIR/MIR imaging

J1030 offers a great multi-wavelength coverage
(see http://www.oabo.inaf.it/~LBTz6/1030/ for a complete review)

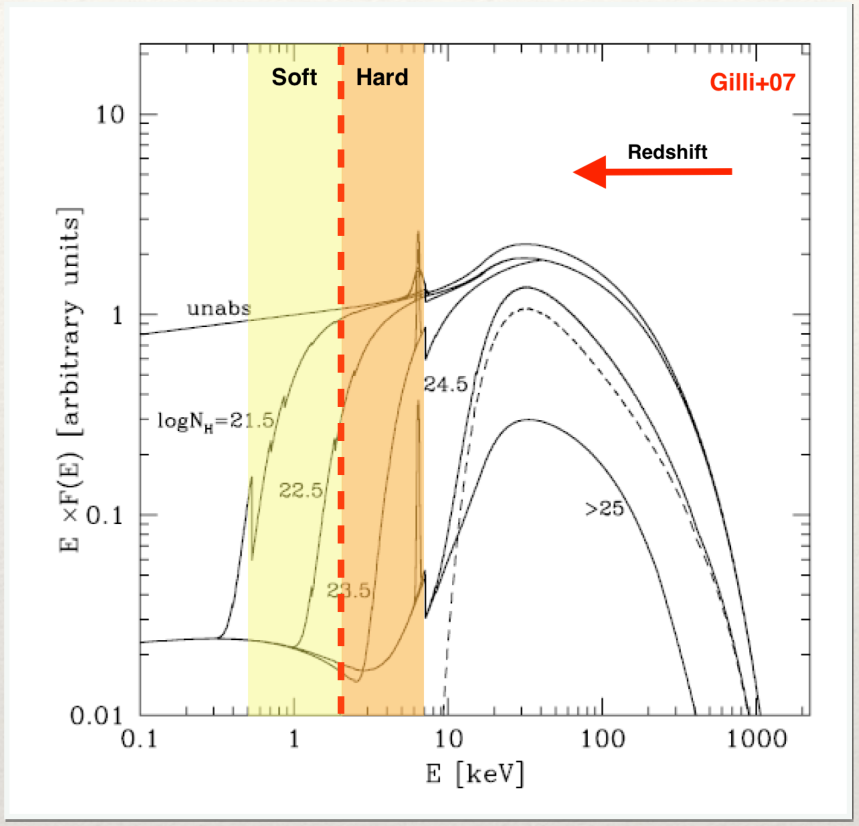


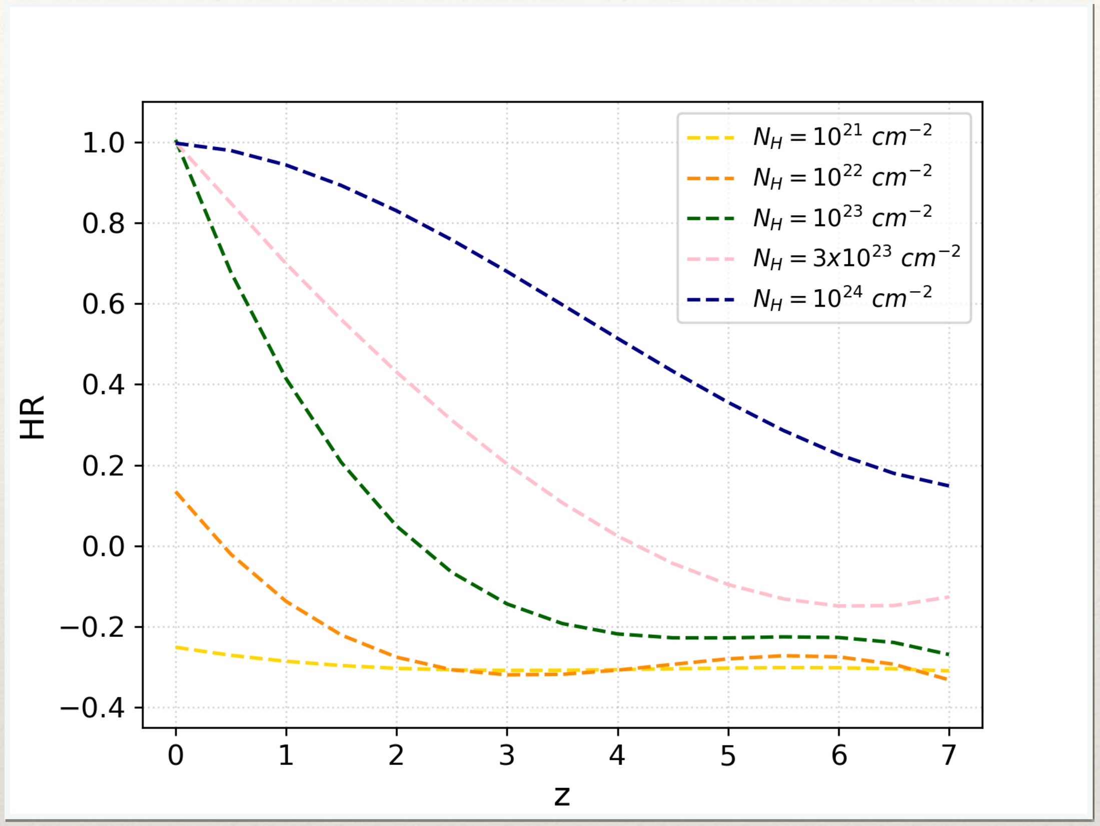
Instrument	Bands	Depth [5σ]
LBT/LBC (Morselli+14)	*r, i, z*	27.5, 26, 25
CFHT/WIRCam (Balmaverde+17)	*Y, J*	24.5, 25
MUSYC BVR	*U, B, V, R, I, z*	25-26
MUSYC K wide	*U, B, V, R, I, z, K*	21
MUSYC K deep	*U, B, V, R, I, z, J, H, K*	23
Spitzer/IRAC	*ch1, ch2*	22-23

+ VLT, Keck and LBT spectroscopic observations in optical bands

Obscured AGN sample selection: HR

How to select obscured AGN?



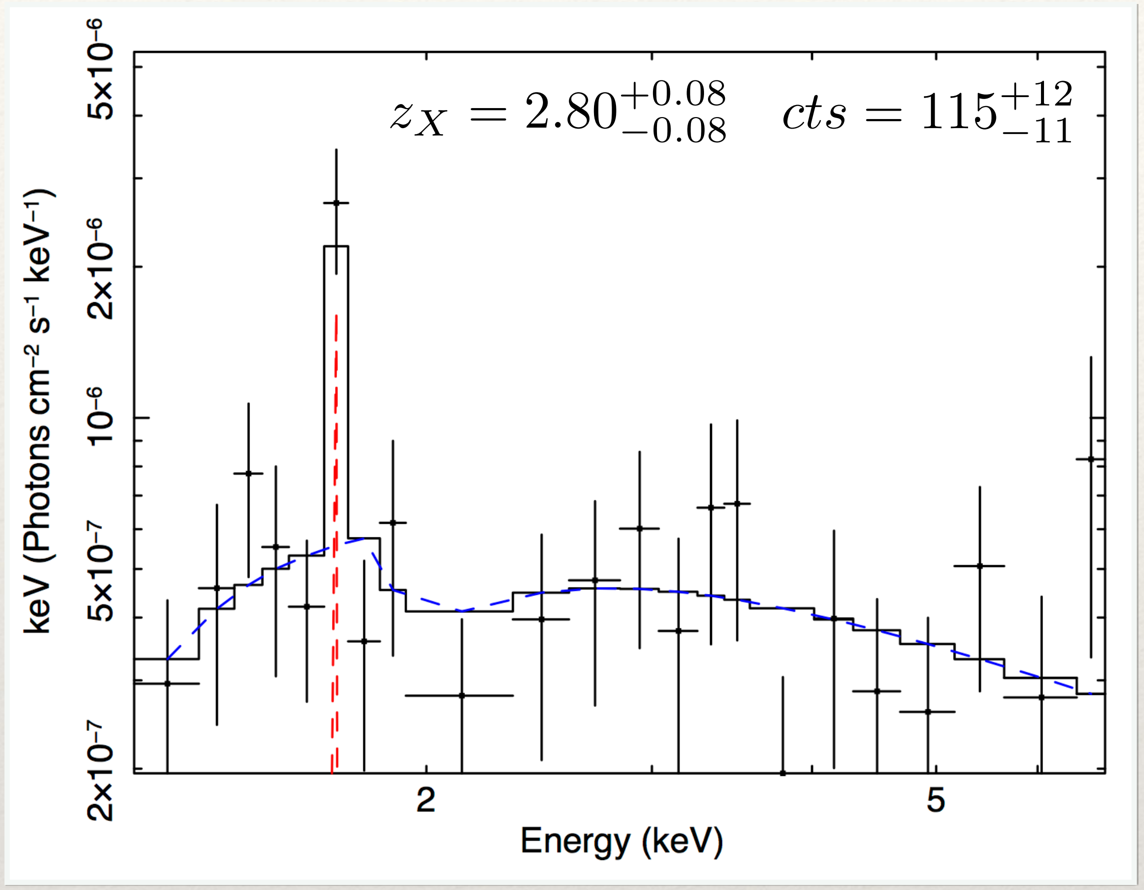


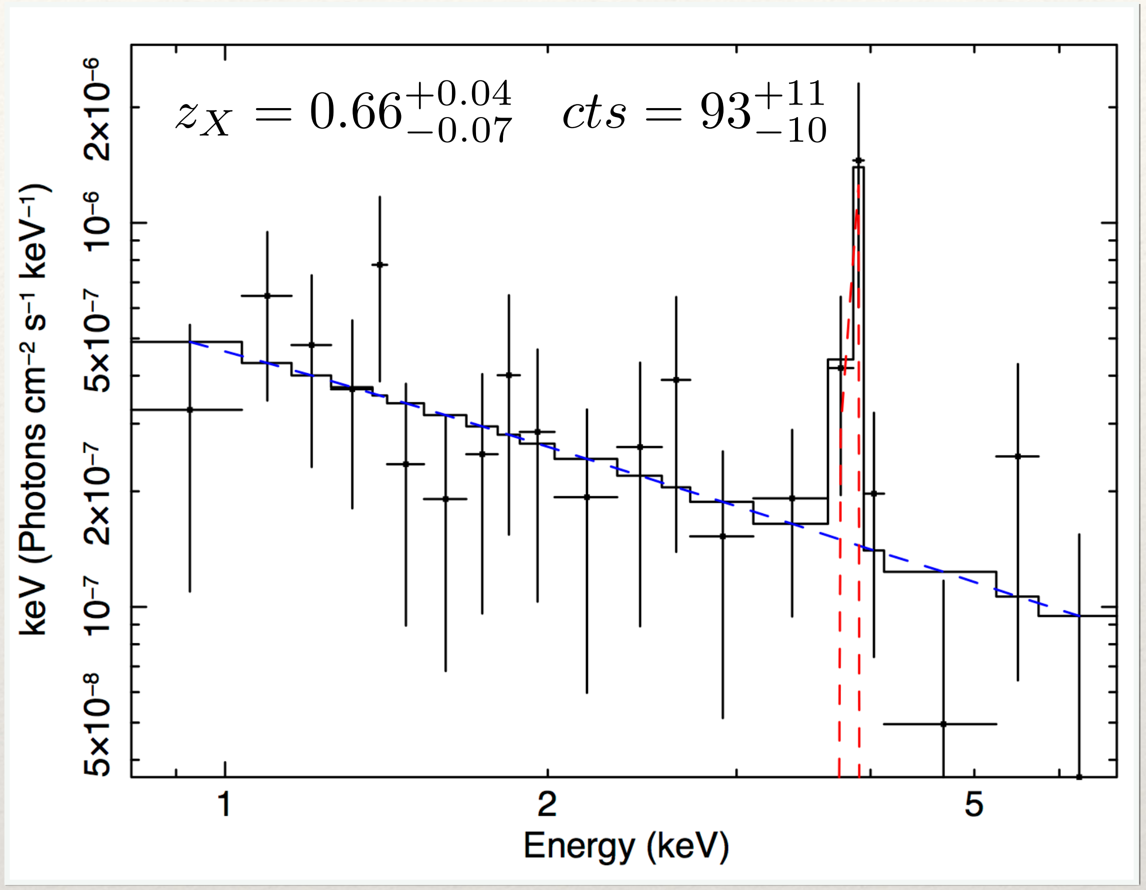
I. $\mathbf{HR} = \frac{\mathbf{H-S}}{\mathbf{H+S}} \geq \mathbf{-0.1}$ is a (redshift dependent) absorption indicator

II. **Net counts > 50** : in order to identify the 6.4 keV Fe emission line, 7.1 keV Fe absorption edge and/or the photoelectric cut-off

→ 76 candidates (net counts ~ 80)

X-ray analysis and spectral simulations

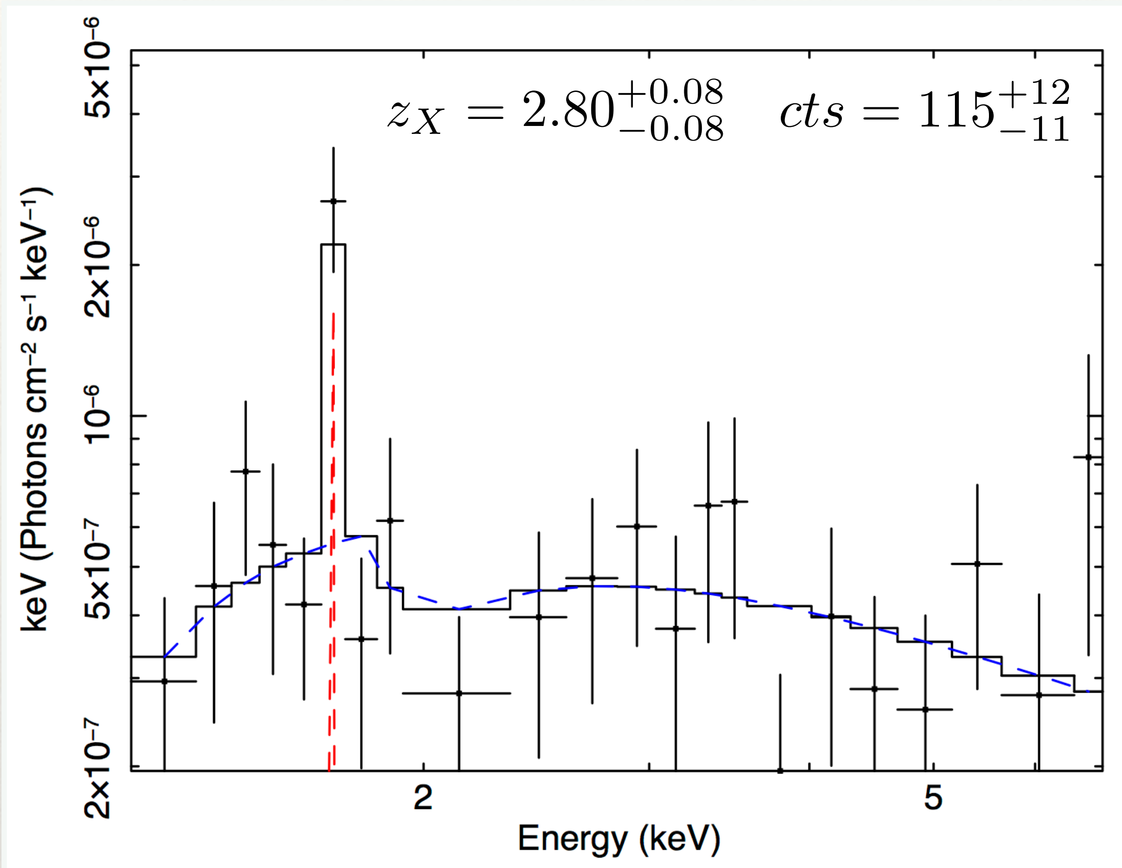


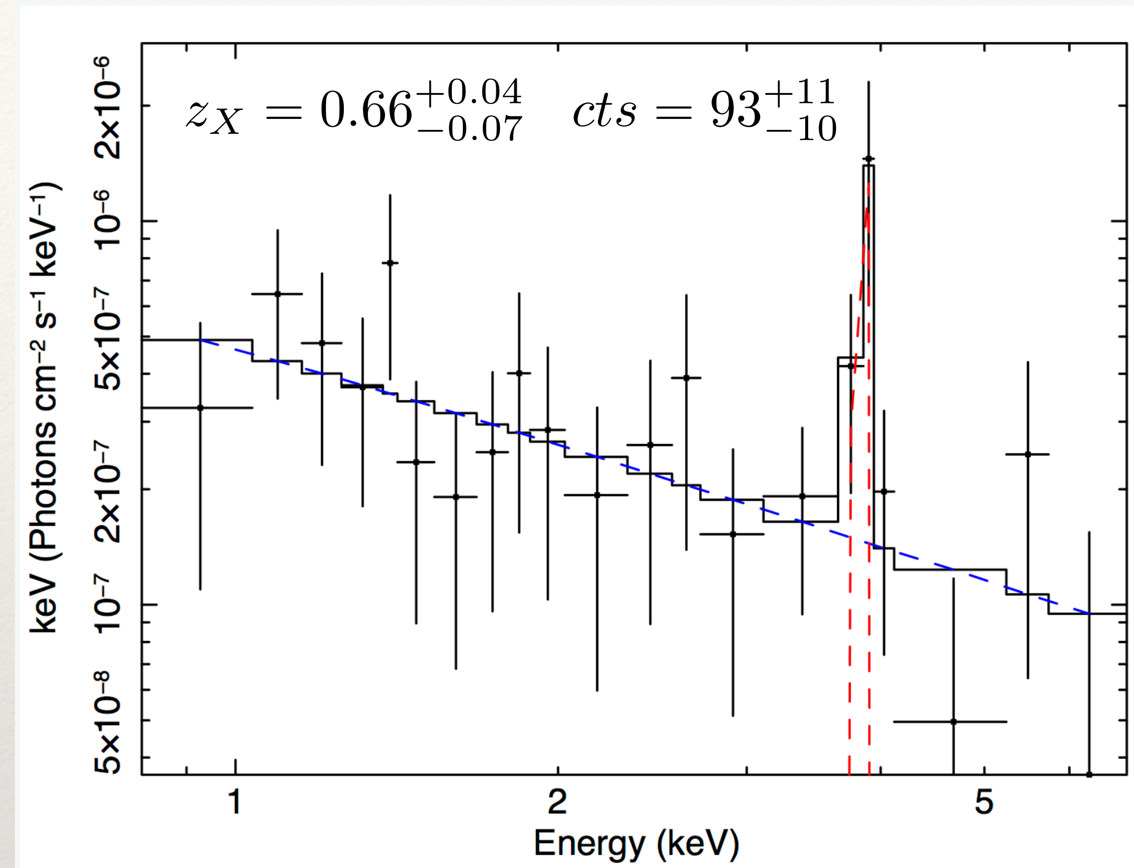


X-ray redshifts from low-count statistics spectra are not trivial to derive

The significance of spectral features needs to be further evaluated

X-ray analysis and spectral simulations





X-ray redshifts from low-count statistics spectra are not trivial to derive

The significance of spectral features needs to be further evaluated

→ X-ray spectral simulations

X-ray analysis and spectral simulations

Spectral simulations

Starting from the **real** extracted **spectra**:

- same instrument response (arf, rmf)
- same statistics
- same background

Determining the probability that an observed line is a statistical fluctuation or not.

X-ray analysis and spectral simulations

Spectral simulations

Starting from the **real** extracted **spectra**:

- same instrument response (arf, rmf)
- same statistics
- same background

Determining the probability that an observed line is a statistical fluctuation or not

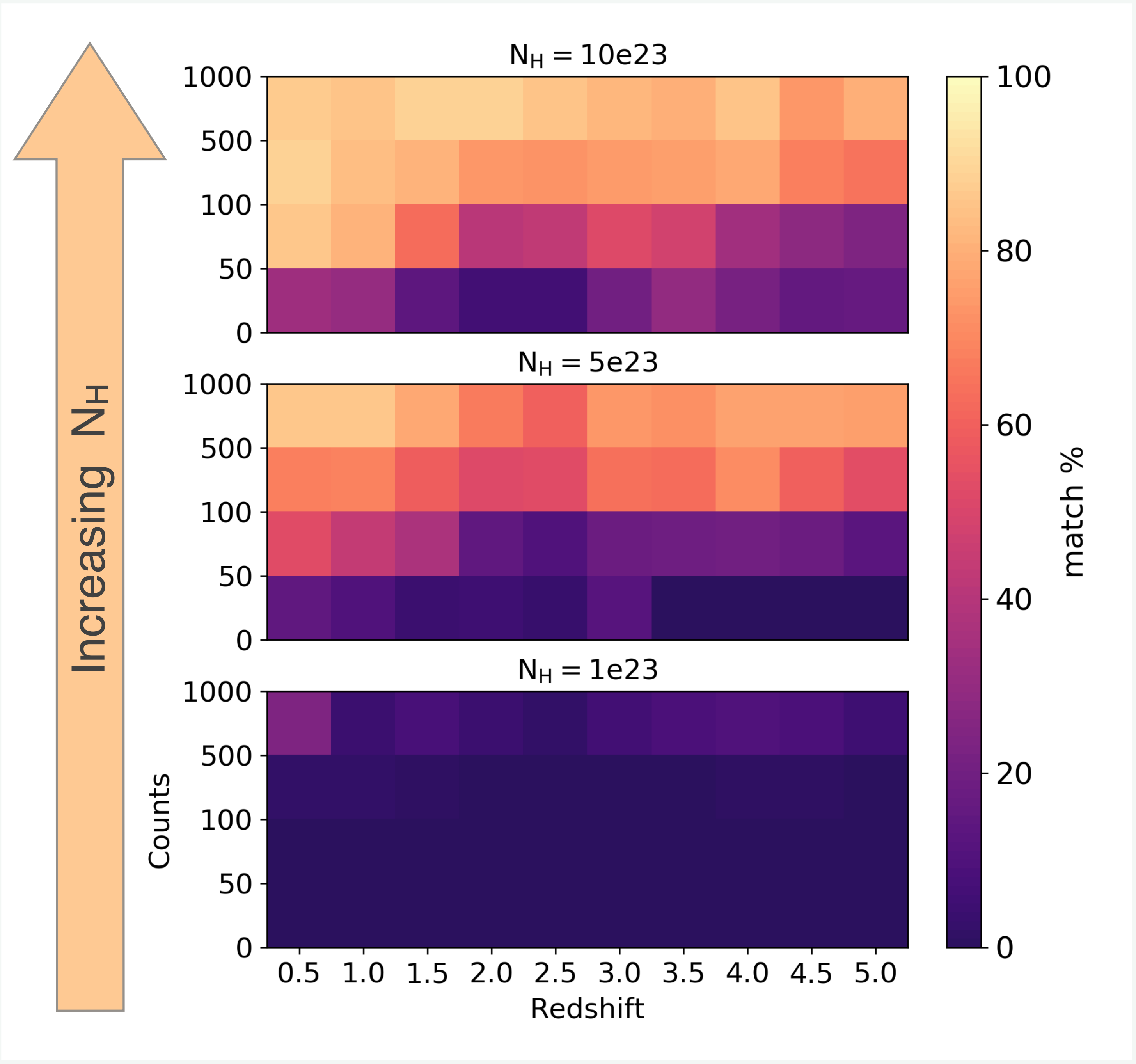
Starting from a **theoretical model** (absorption * (powerlaw + gauss)):

- real responses and background
- same total exposure time (~500 ks)
- typical obscured AGN physical parameters (N_H, z, flux, lumin.)

Verify for which parameters and statistics redshifts can be derived

X-ray analysis and spectral simulations

Model: absorption * powerlaw

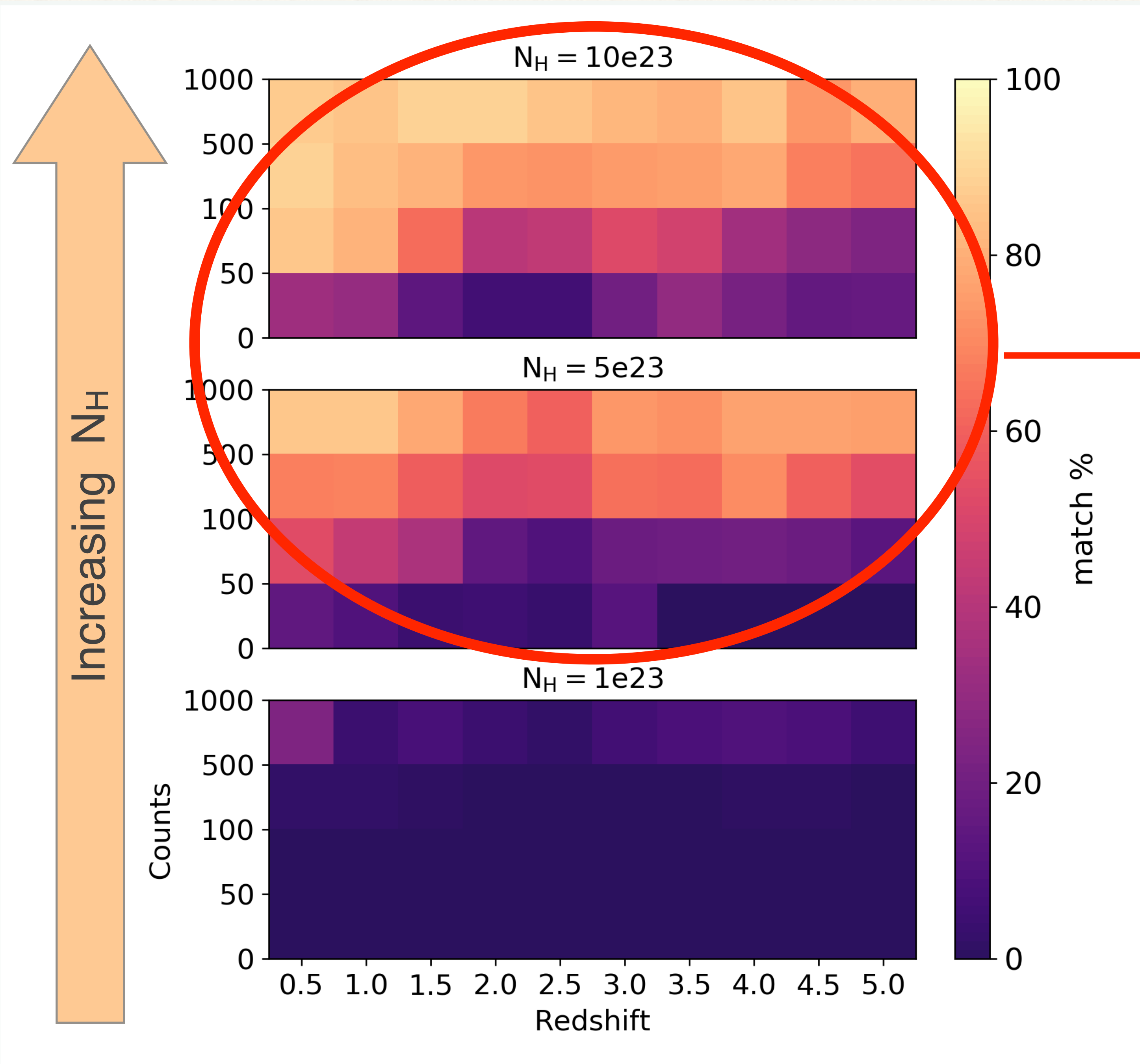


$$\text{match\%}\ (z, N_H, \text{cts}) = \frac{\text{num}\ (z_{X,\text{fit}} \pm \Delta z)}{\text{num}\ (z_{\text{sim}})}$$

See Peca et al. in prep. for details

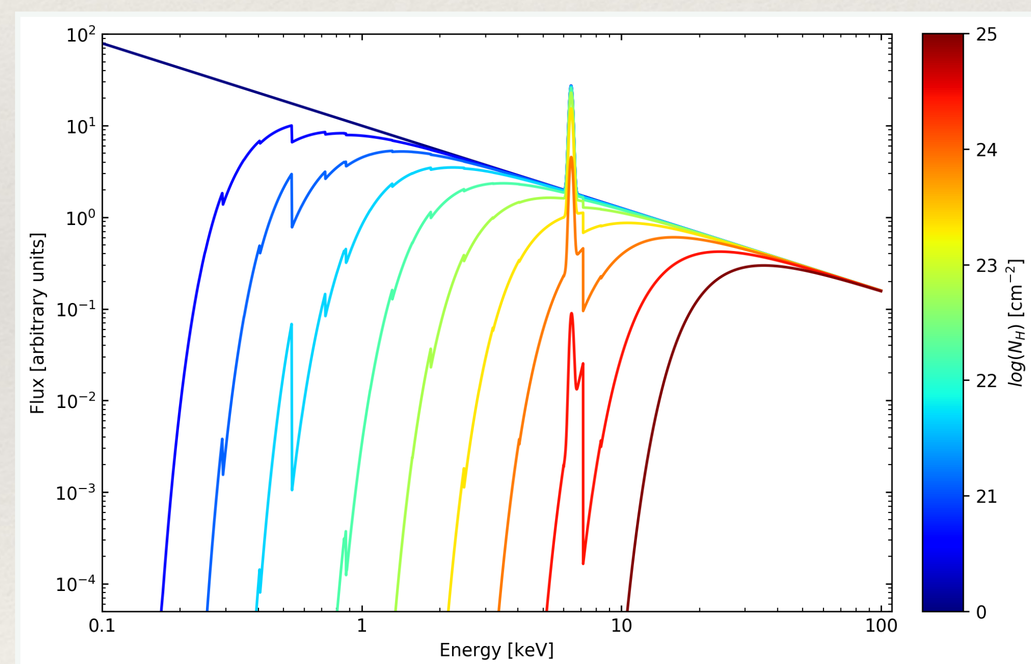
X-ray analysis and spectral simulations

Model: absorption * powerlaw



$$\text{match\%}\ (z, N_H, cts) = \frac{\text{num}\ (z_{X,\text{fit}} \pm \Delta z)}{\text{num}\ (z_{\text{sim}})}$$

We need high N_H column densities to identify X-ray redshifts!



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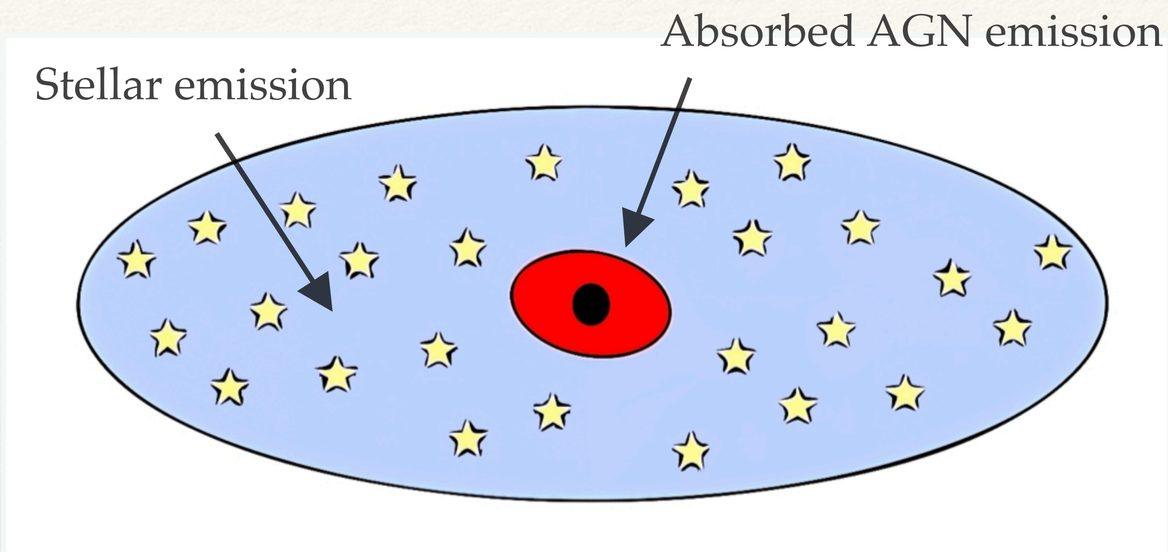
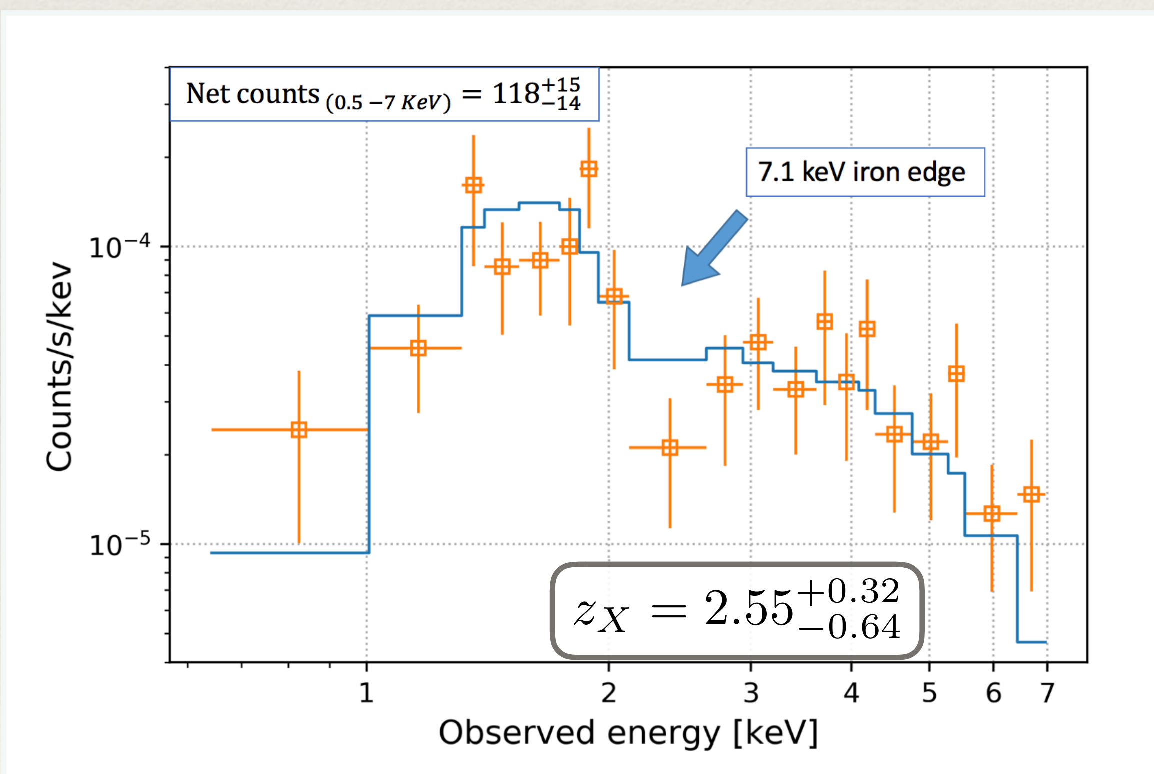
SED fitting: optical / infrared bands

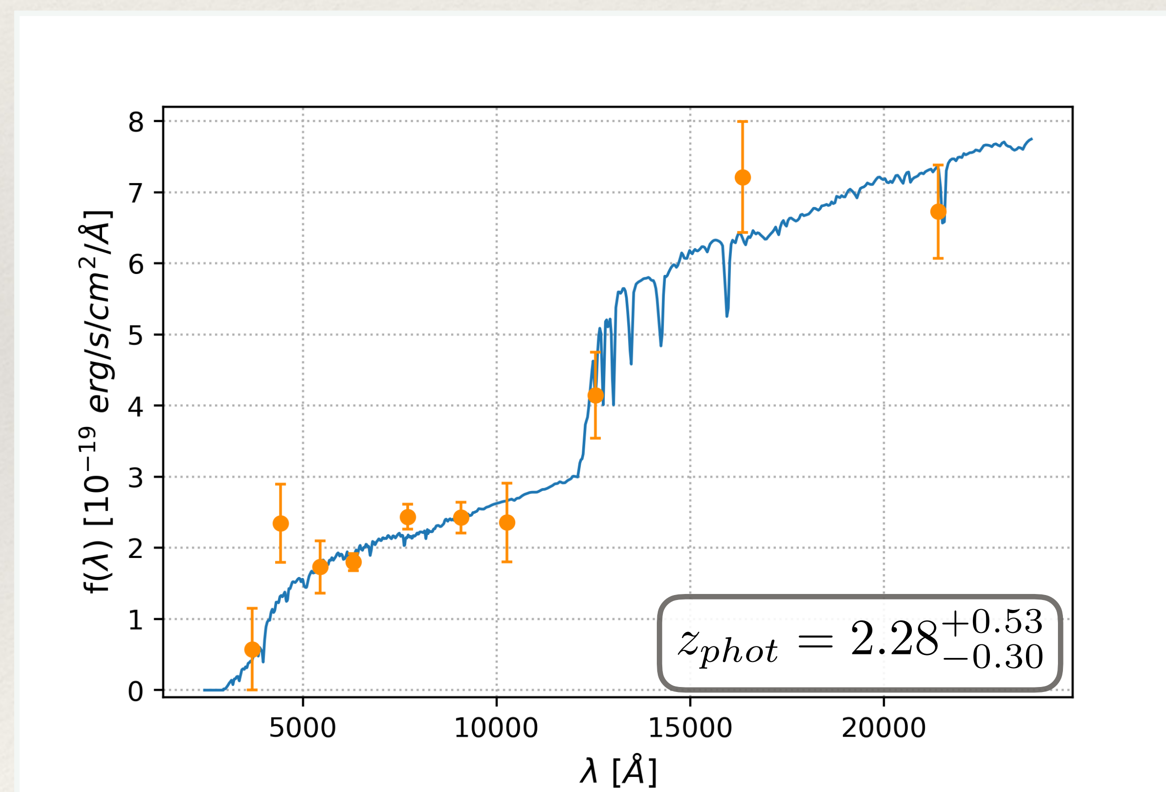


Due to the obscuring material, the host galaxy dominates the AGN optical emission (see Hickox+18 for a review)

↓ ↓ ↓

We performed photometric redshifts through a SED fitting procedure (*hyperz*, Bolzonella+00).





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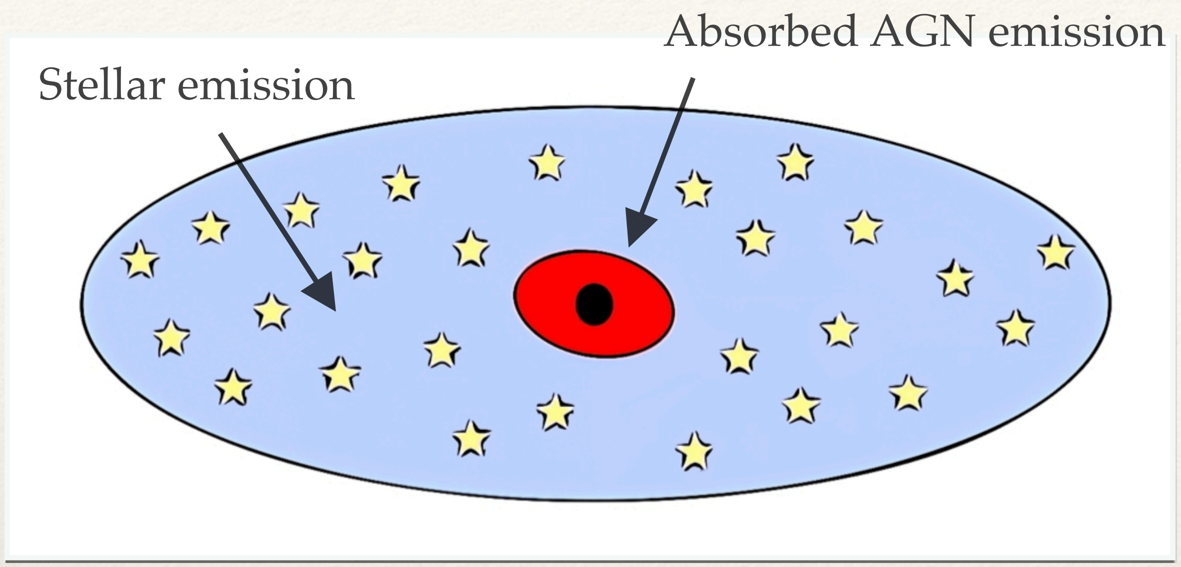

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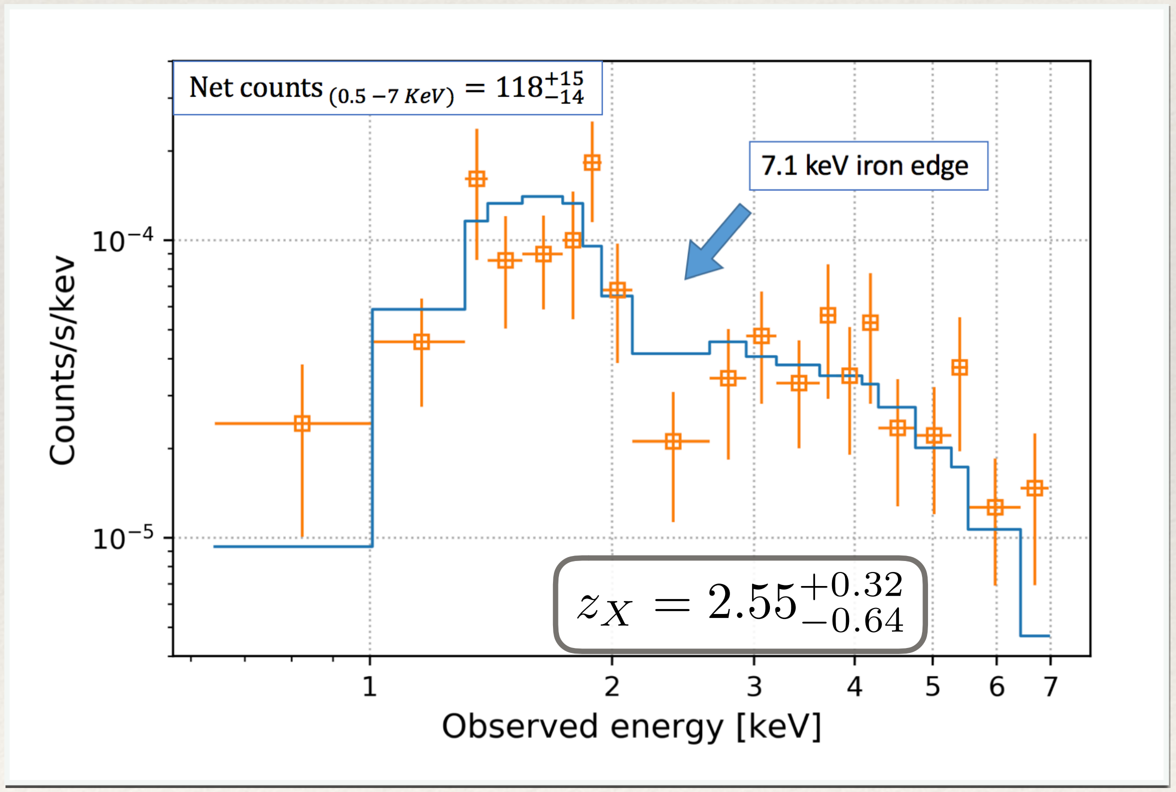
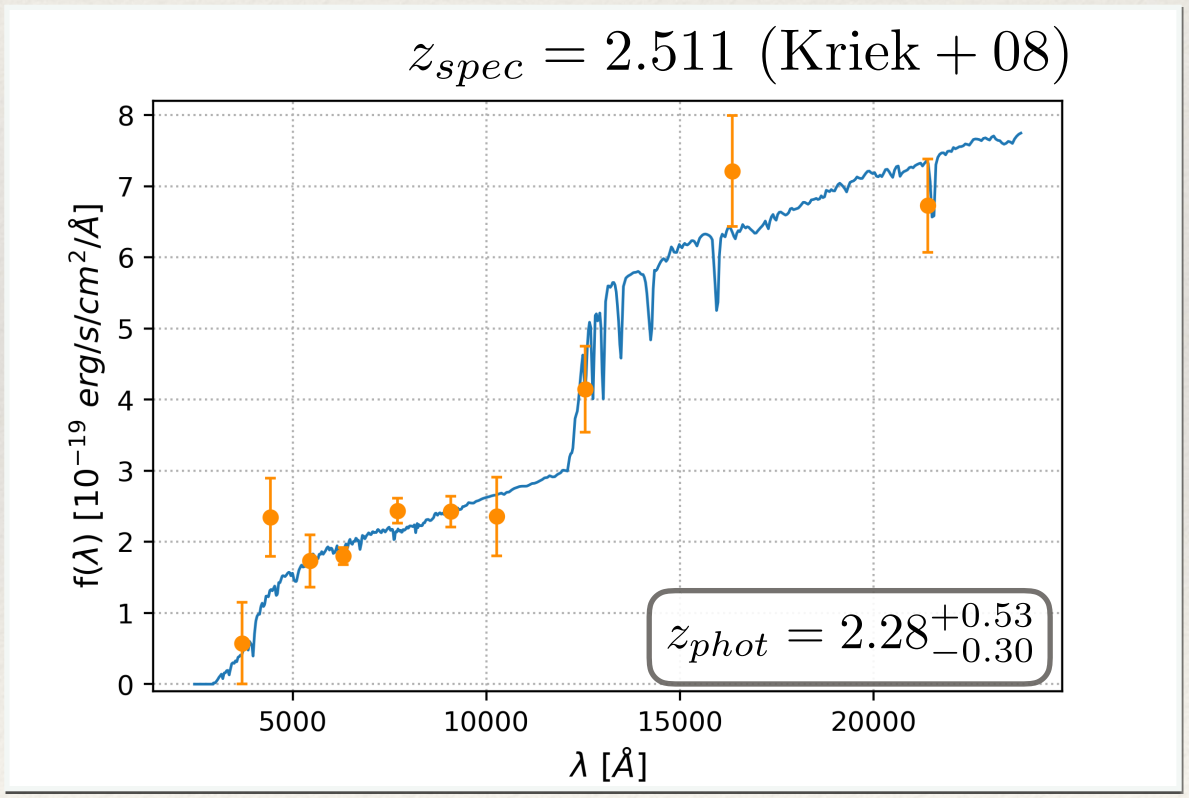
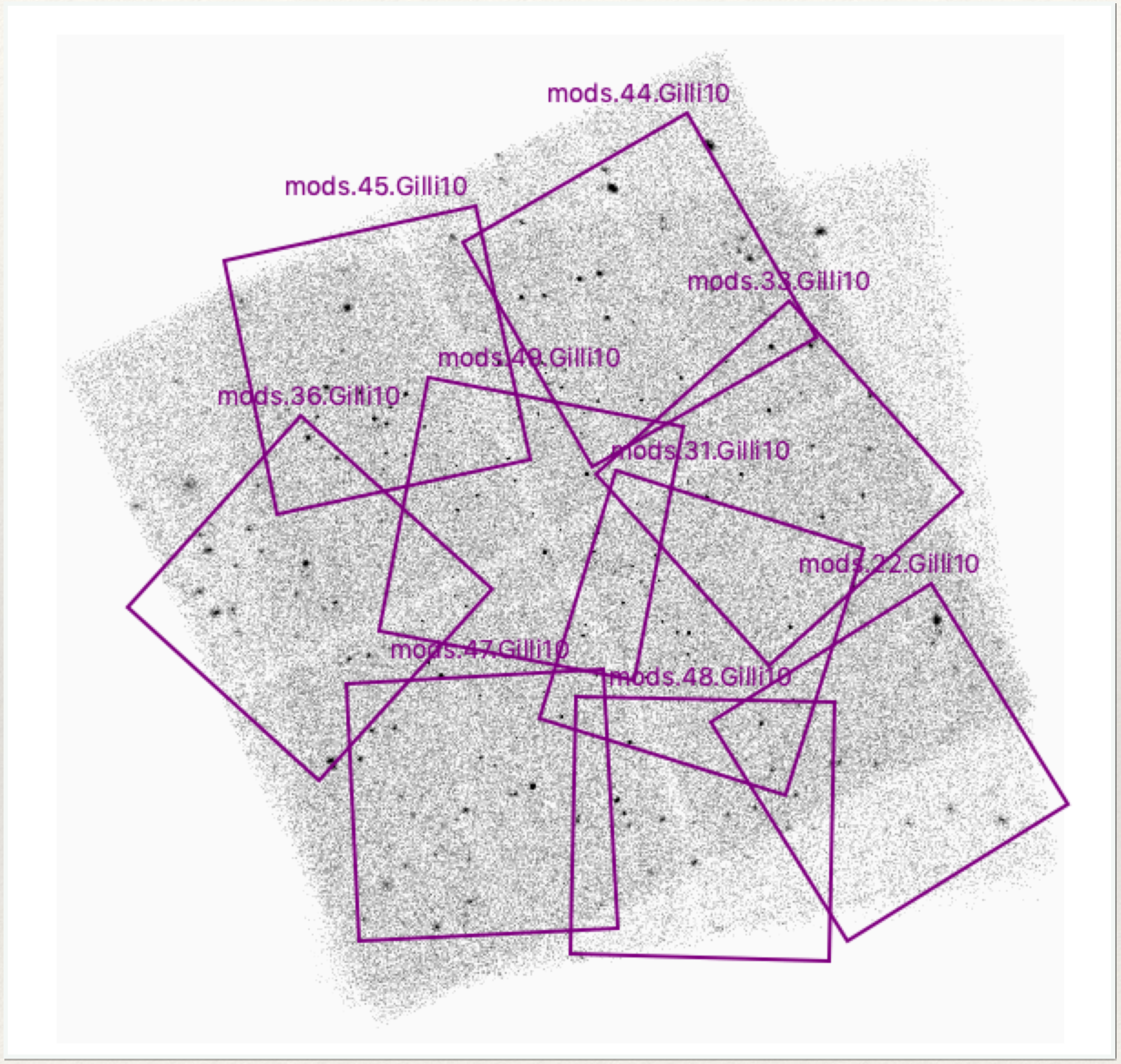




➡ A new LBT spectroscopic campaign has just been completed

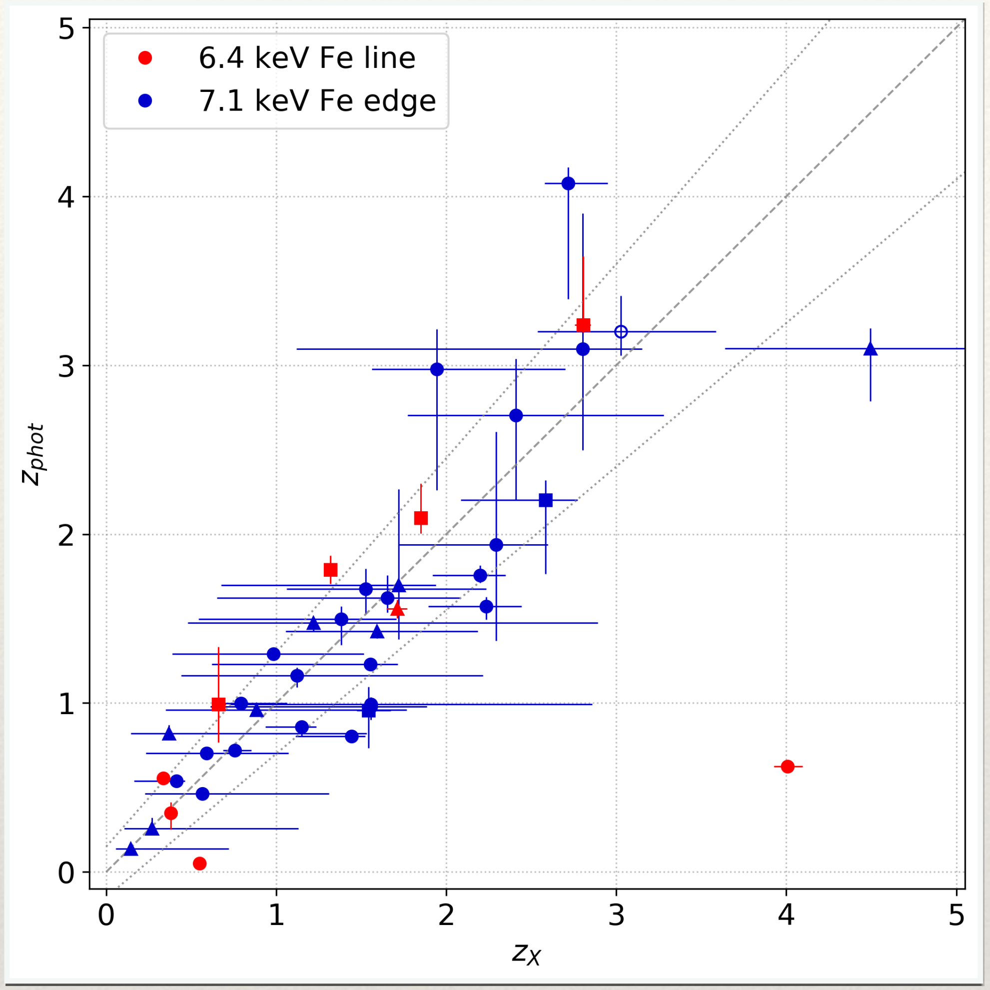
LBT strategic program: optical/NIR spectroscopy



9 LBT/MODS masks (4h/mask, PI R. Gilli)
Targets: ~200 X-ray sources
Completed in May 2019

We could confirm the redshift solutions for the detected sources: it is challenging to derive z_{spec} for faint sources (low S/N)!

Obscured AGN in the J1030 field: redshift results



Preliminary results

Photometric redshifts suggest that it is possible to get an X-ray solution even for low-count statistics in presence of (heavily) obscured AGN.

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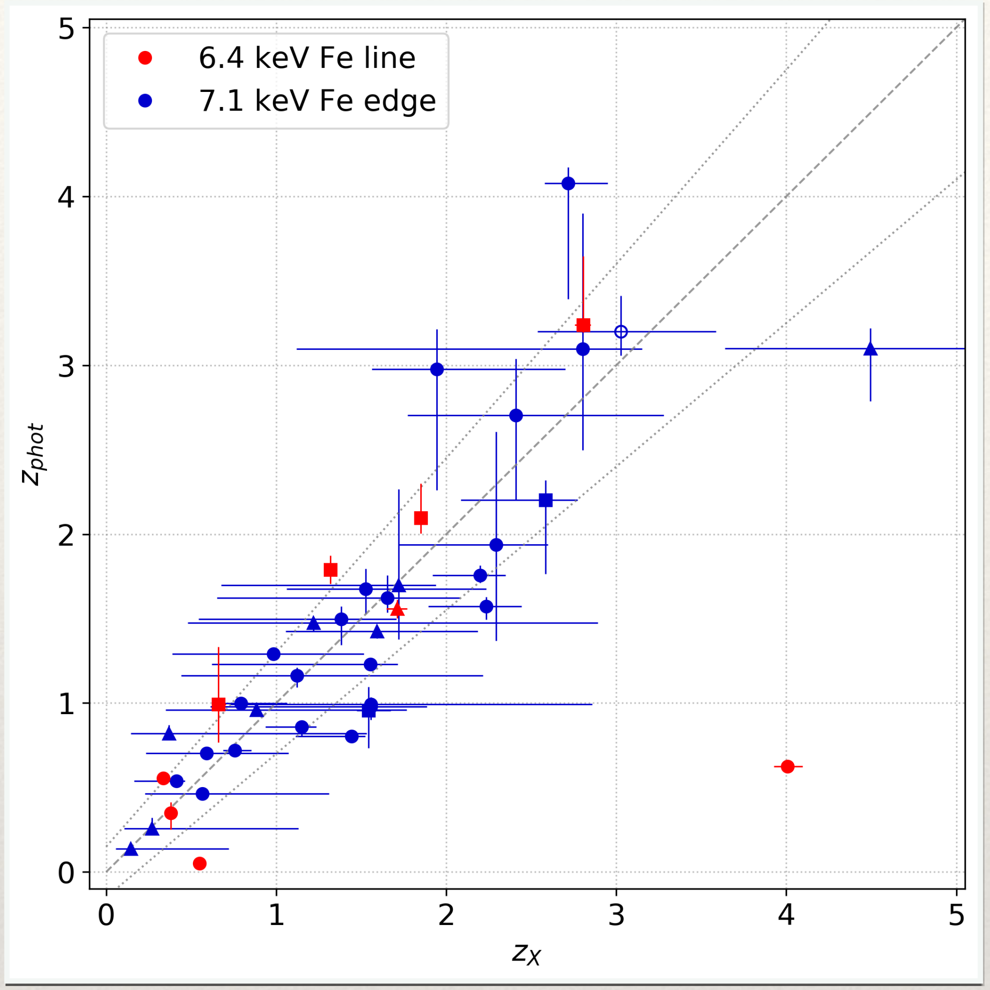

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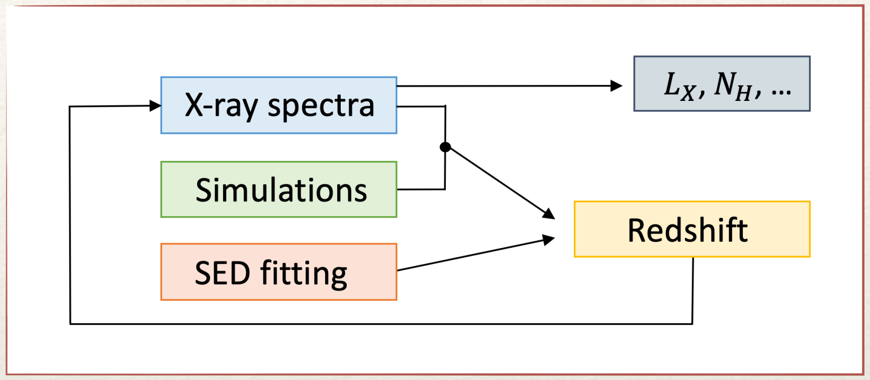

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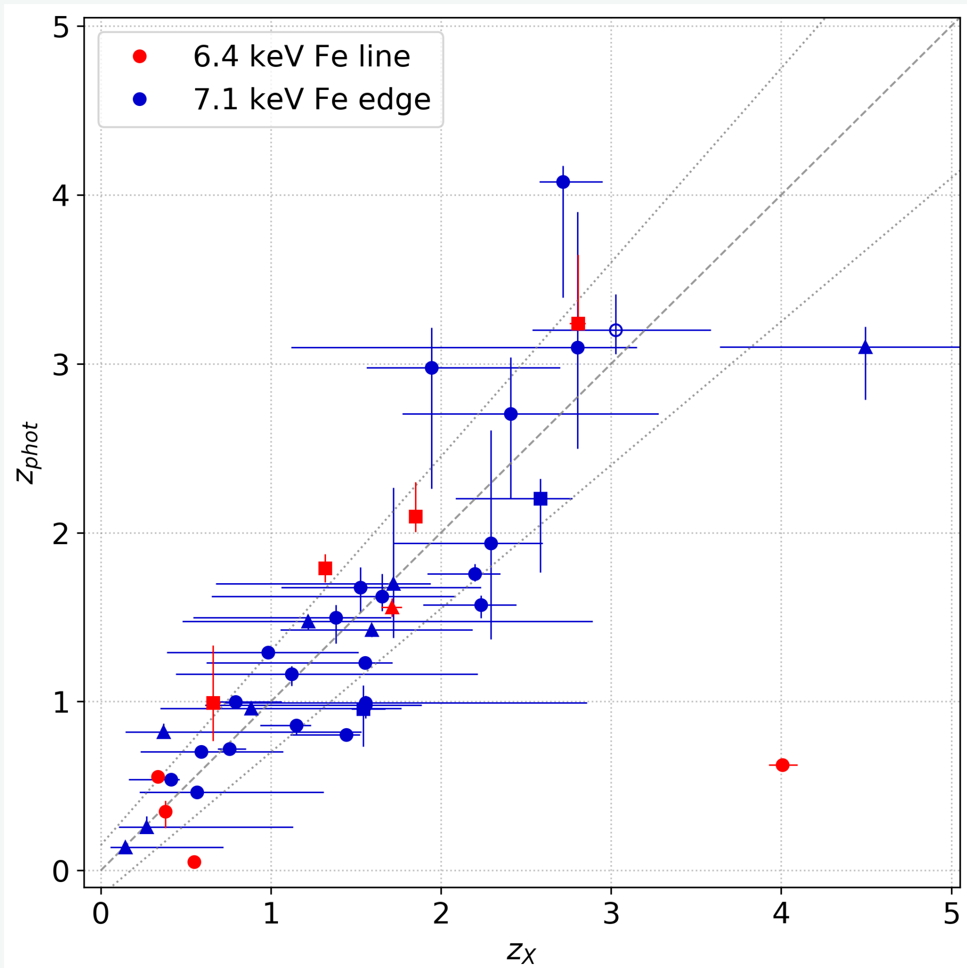

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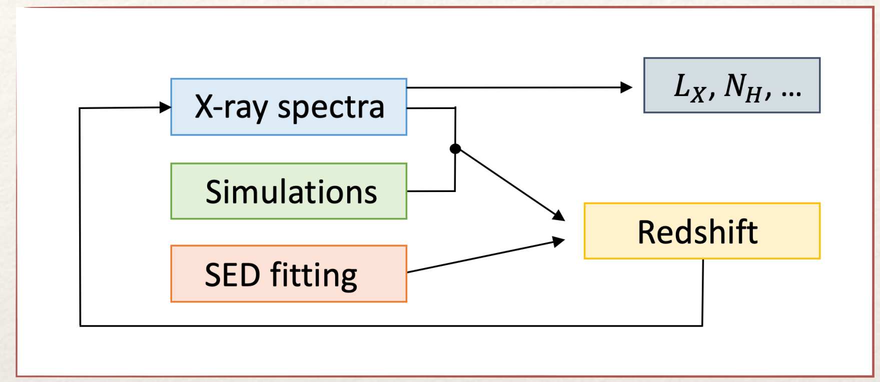
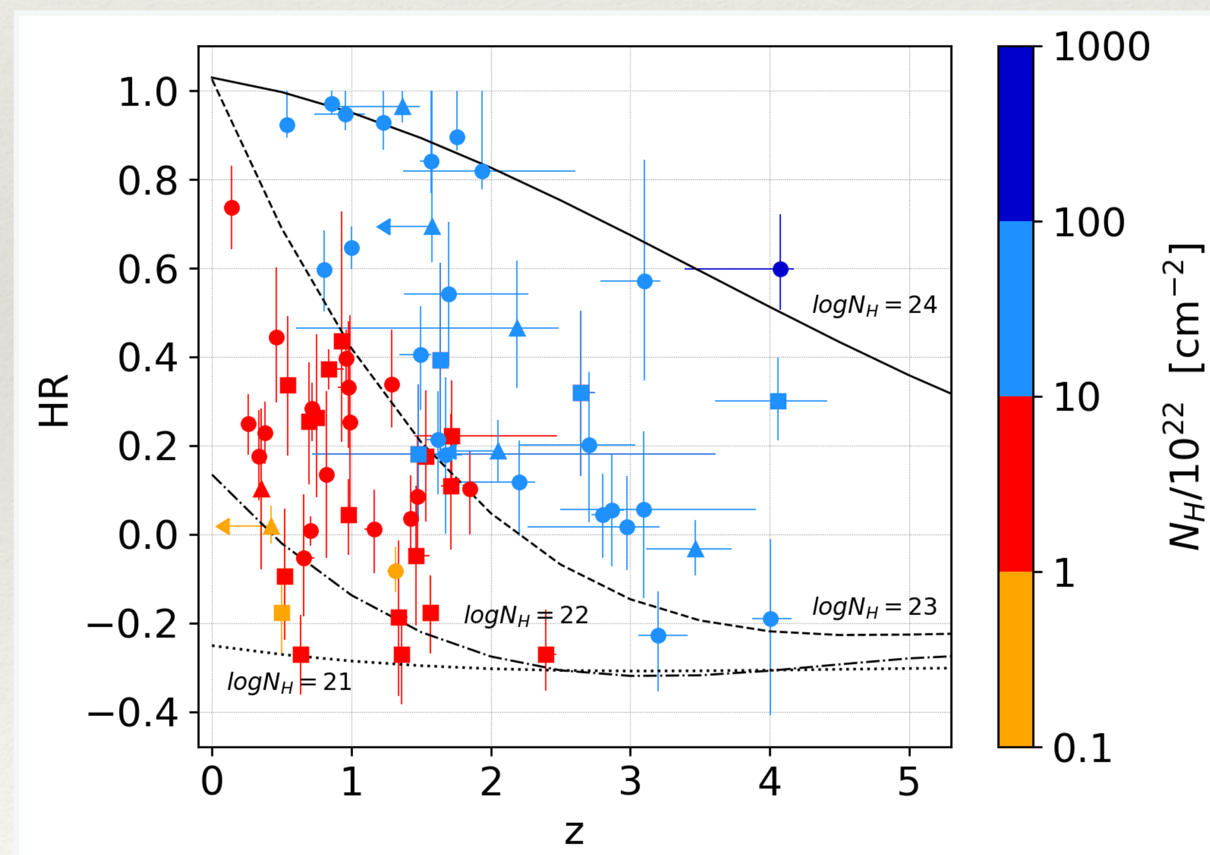


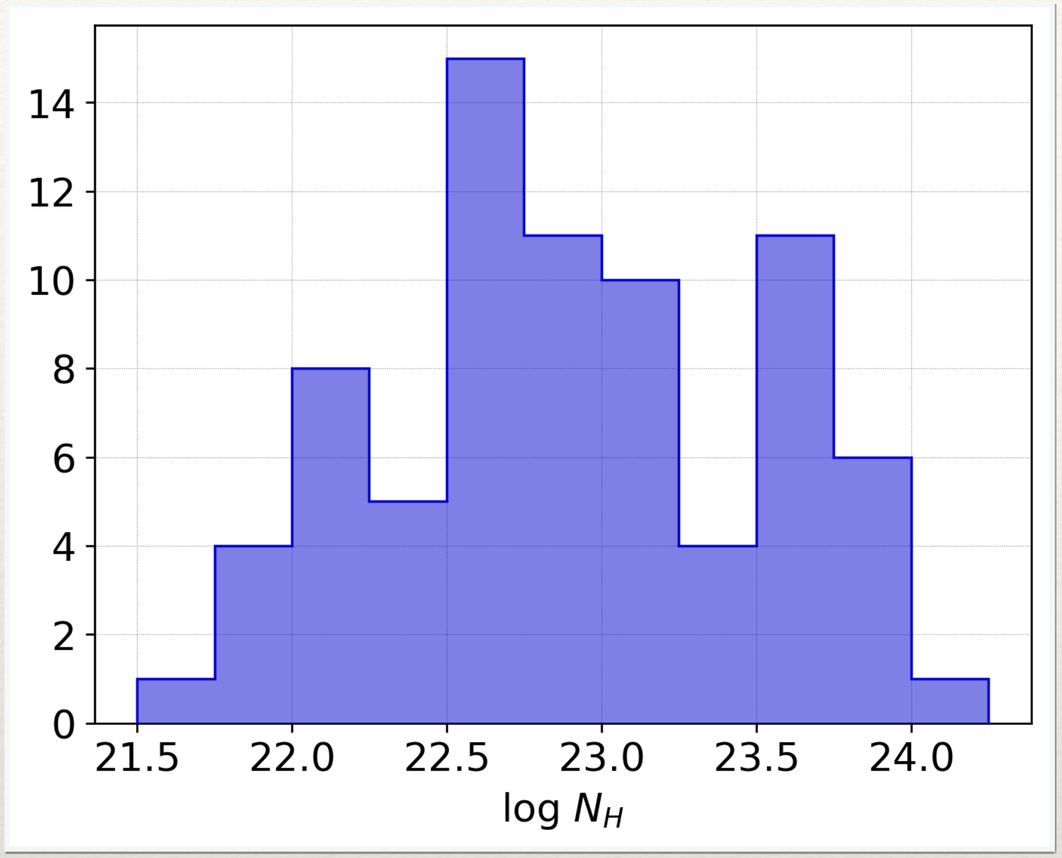
Preliminary results

Redshift solutions: X-ray z if Fe Kα line is detected, photometric z elsewhere.

Consistency test using the obtained solutions: good agreement with the expected HR trends



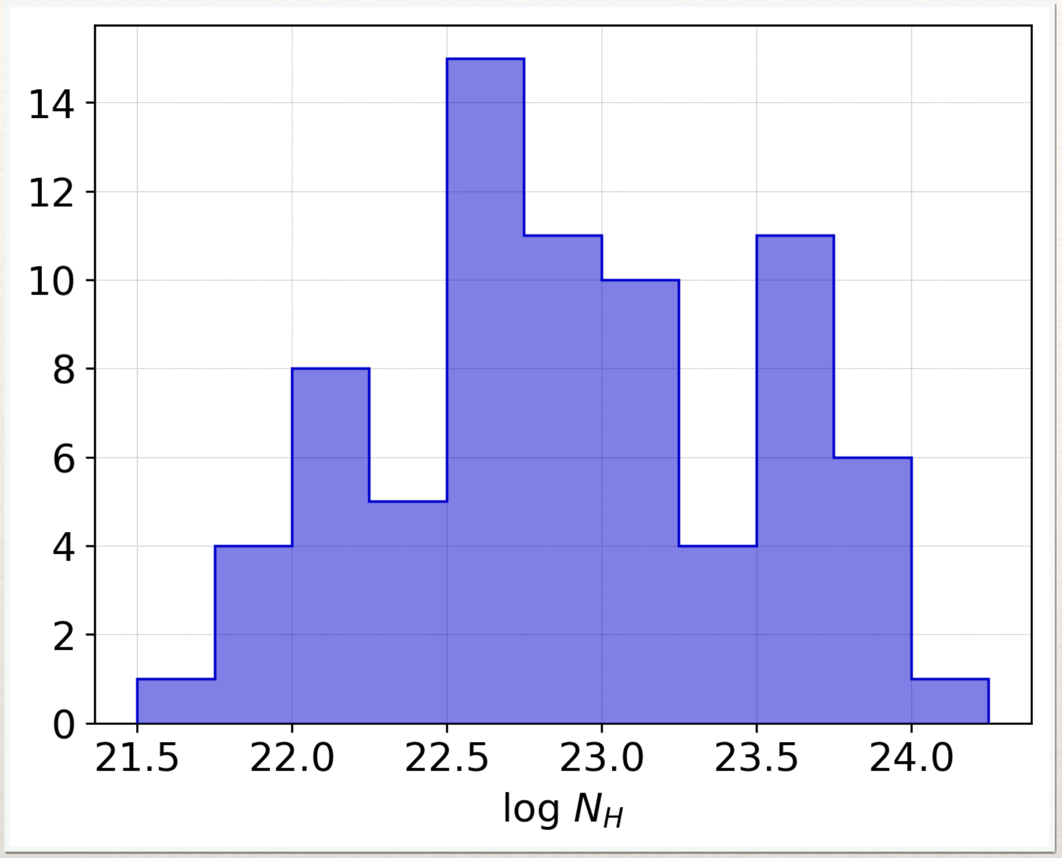
Obscured AGN in the J1030 field: properties



- Column densities mostly in the Compton-thin regime, with a median value of $N_H \approx 2 \times 10^{23} cm^{-2}$

Preliminary results

Obscured AGN in the J1030 field: properties



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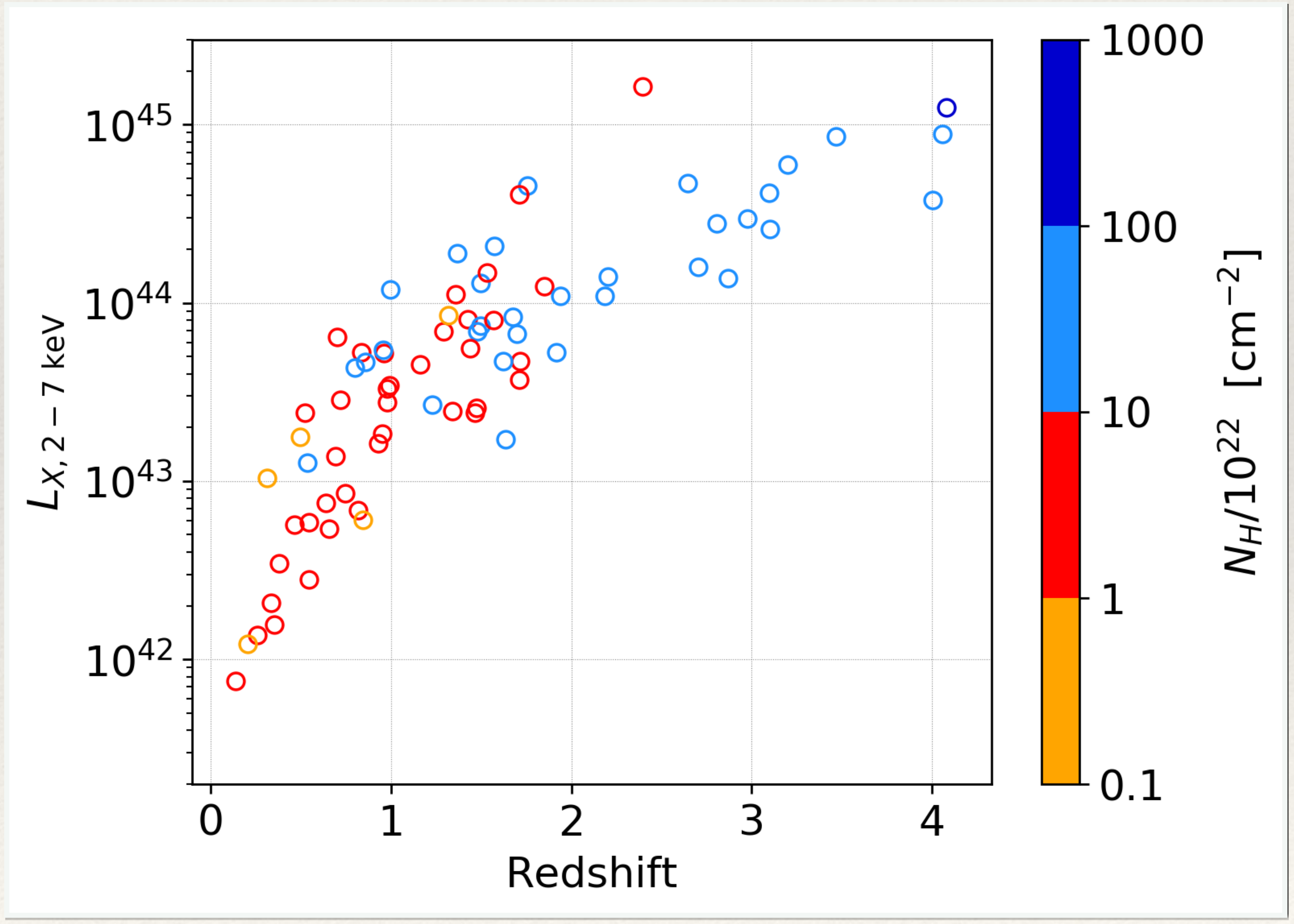

Preliminary results

Conclusions: why should we use this method?

- The X-ray emission can reveal obscured AGN, even if the optical and NIR emission is completely extincted
- X-ray redshifts are a powerful tool once we have limited information/photometry and play an important role in the study of these objects

Where we should use this method:

- X-ray deep fields: e.g., in CDFS there is ~5% of X-ray detections without optical counterparts
- Spectroscopic campaigns are often difficult to obtain and deriving z_{spec} is challenging (very long exposure time and low S/N for faint objects)
- For highly obscured AGN, optical spectra are not always able to uniquely identify the AGN emission
- X-ray spectral simulations can be used for predictions about obscured AGN detection in future X-ray missions (e.g., eRosita, Athena)

Thank you for your attention!

ευχαριστώ!