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The current state of disk wind observations in galactic Black Hole LMXBs through X-ray absorption lines

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Finding Extreme Relativistic Objects 10th Edition

March 31 2022

The current context

- Accretion in Black Hole X-ray Binaries

❑ Low-Mass X-ray Binaries

- Accretion through Roche-Lobe overflow → Accretion disk

The current context

- Accretion in Black Hole X-ray Binaries

❑Low-Mass X-ray Binaries

- Accretion through Roche-Lobe overflow → Accretion disk

Switch between two standard states

- Hard State → Hard SED, jet in radio
  signature of (possibly) truncated accretion disk

- Soft State → Soft SED, no jets, accretion disk extends close to the EH

The current context

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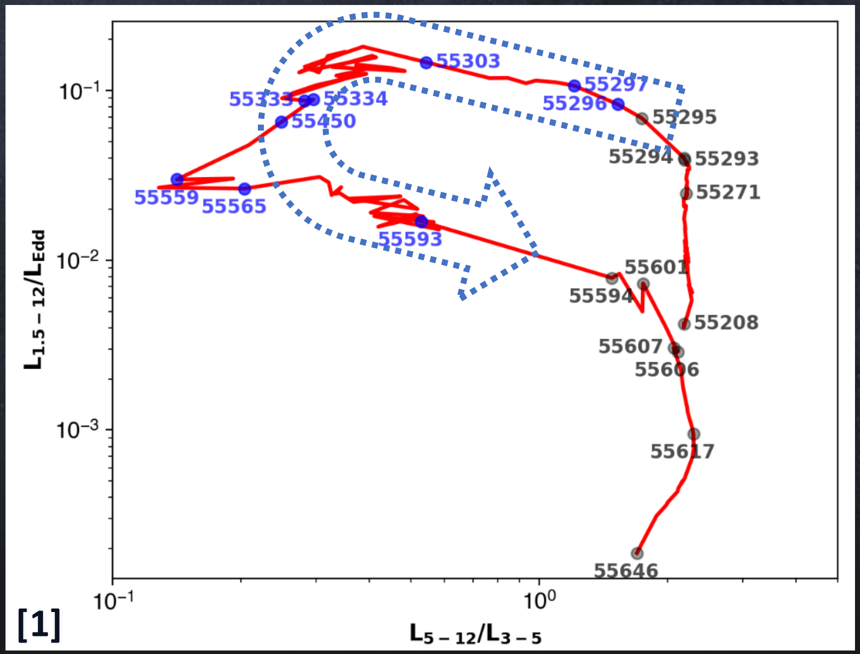
Switch between two standard states

Soft State



Hard State

[1] Petrucci et al. 2019

The current context

- Winds detections in Black Hole X-ray Binaries

❑ First detections of blueshifted narrow absorption lines before 2000[2][3]

- material + low speed = not jet

❑ Many detections in the 2000s with the new generation of XRTs

[2] Ueda et al. 1998

[3] Kotani et al. 2000

The current context

- Winds detections in Black Hole X-ray Binaries

❑First detections of blueshifted narrow absorption lines before 2000[2][3]

- material + low speed = not jet

❑First global analysis by Ponti et al. In 2012

[2] Ueda et al. 1998

[3] Kotani et al. 2000

The current context

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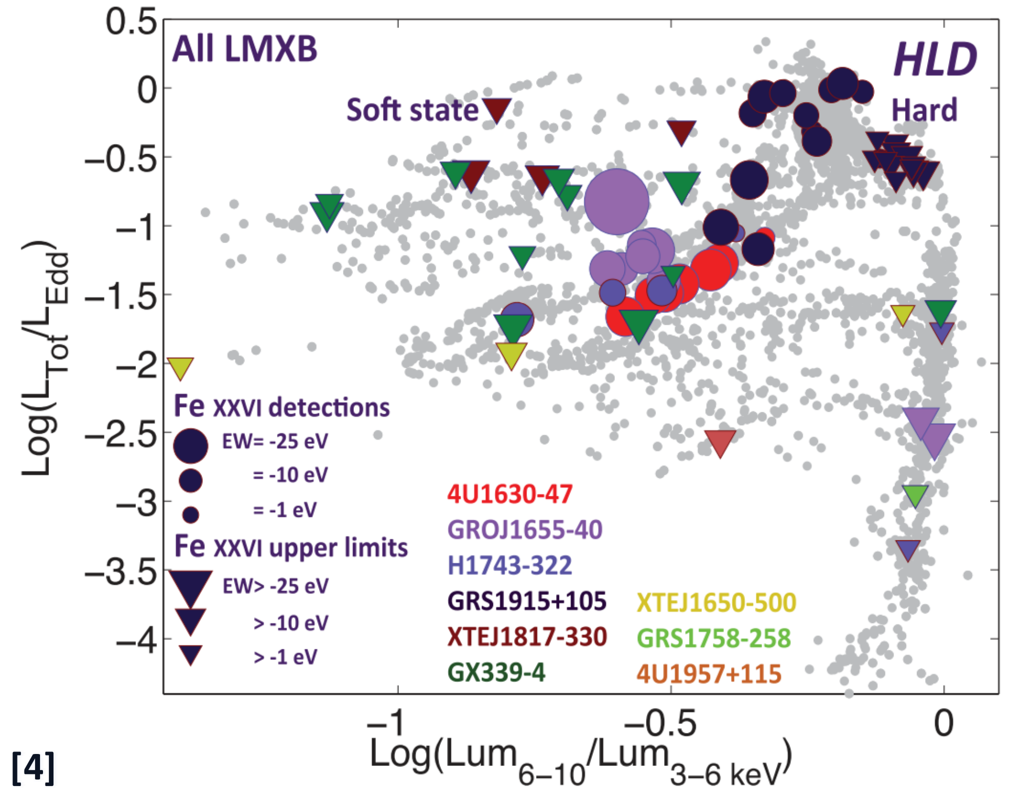


[4]

[2] Ueda et al. 1998

[3] Kotani et al. 2000

[4] Ponti et al. 2012

The current context

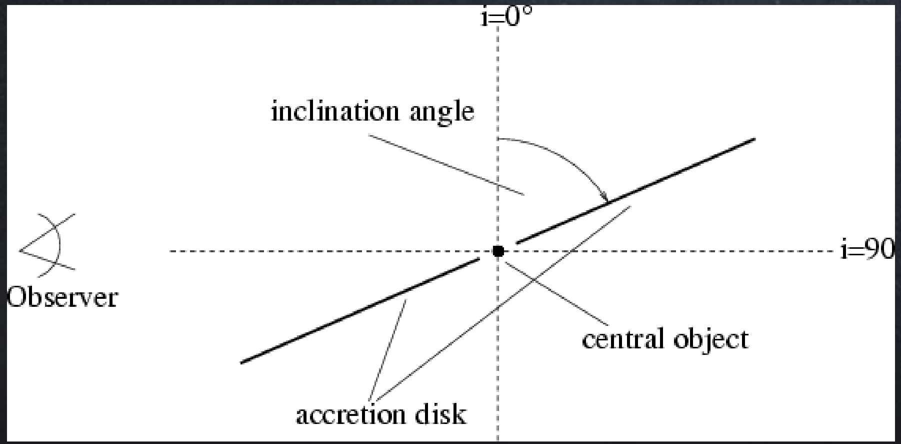
- Winds detections in Black Hole X-ray Binaries

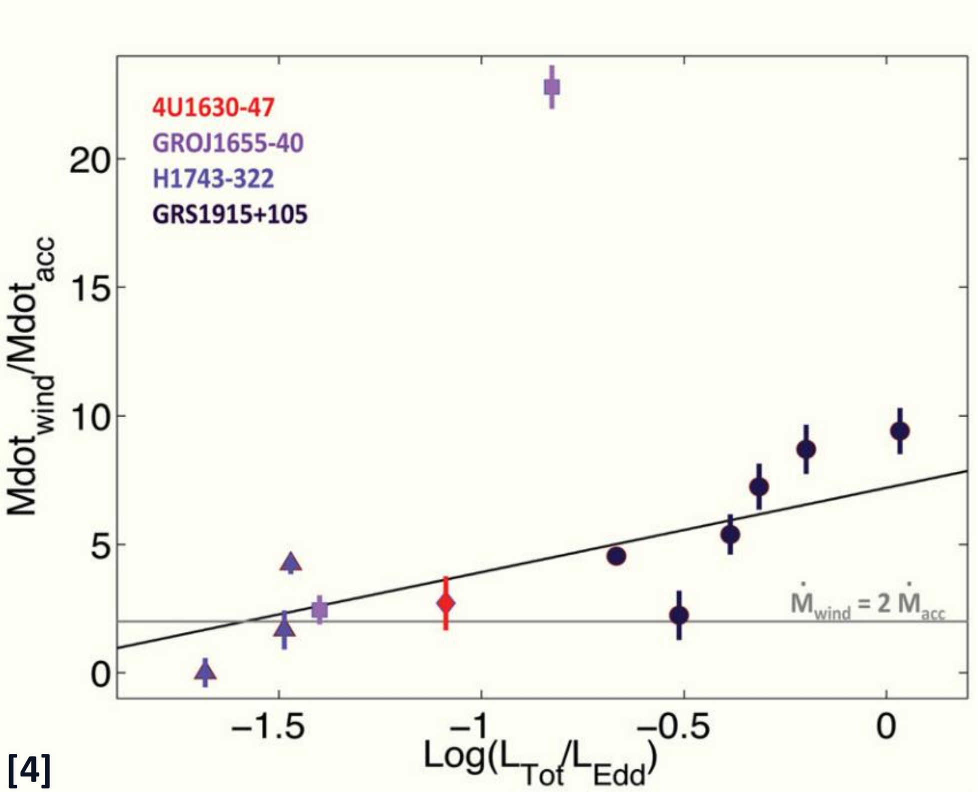
❑First detections of blueshifted narrow absorption lines before 2000[2][3]

- material + low speed = not jet

❑Winds → soft state

→ high inclination





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The current context

- Winds detections in Black Hole X-ray Binaries

❑Low-Mass X-ray Binaries

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QUICK FIELD: Author First Author Abstract Year Fulltext All Search Terms

"black hole" + "low mass X-ray Binary" year:2012-2022

Your search returned **533** results

❑Due time for a new analysis

Methodology

- Main elements

Methodology

- Main elements

To do a global analysis, we need:

❑ A sample of sources

- All the BHLMXB candidates from BlackCAT[5] + WATCHDOG[6]

  68 sources + 13 more

❑ Data from these objects

- Let's start with all XMM EPIC pn exposures → 140 exploitable spectra from 33 sources

❑ A Methodology

[5] Corral-Santana et al. 2016

[6] Tetarenko et al. 2016

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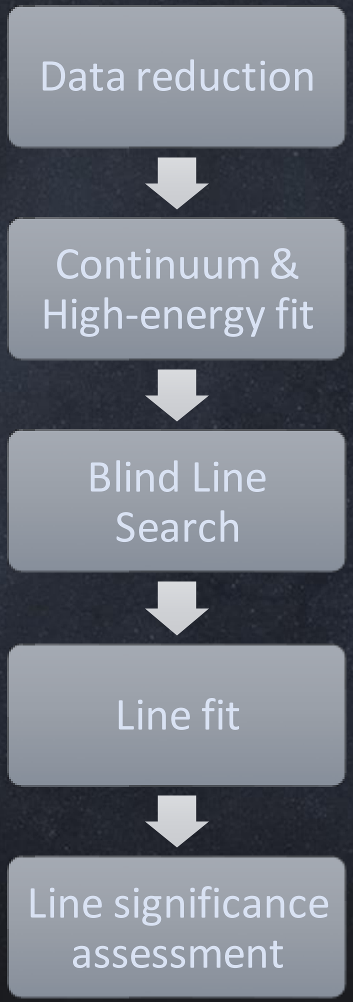
Methodology

- Line detection

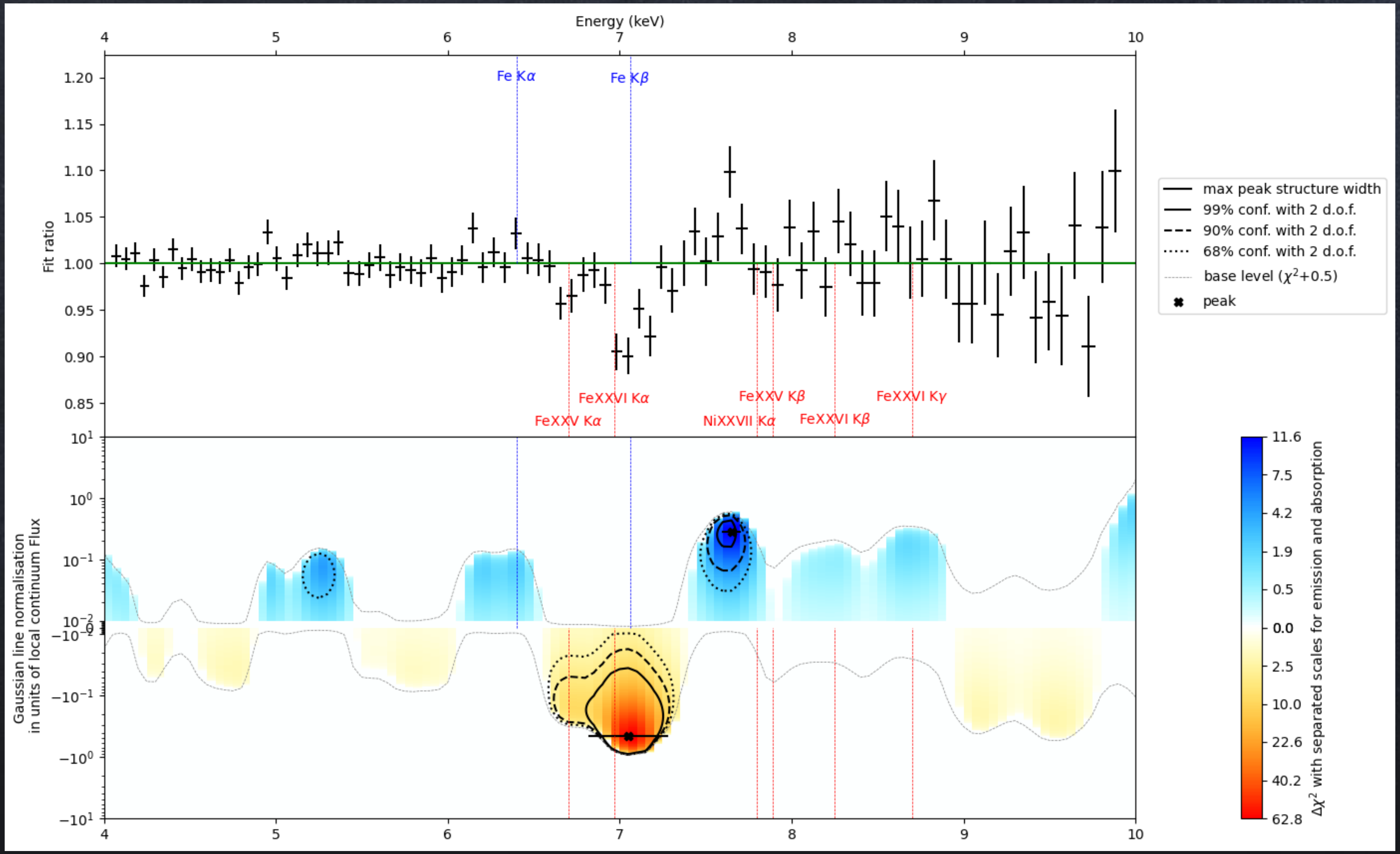
❑ Methodology



Methodology

- Line detection

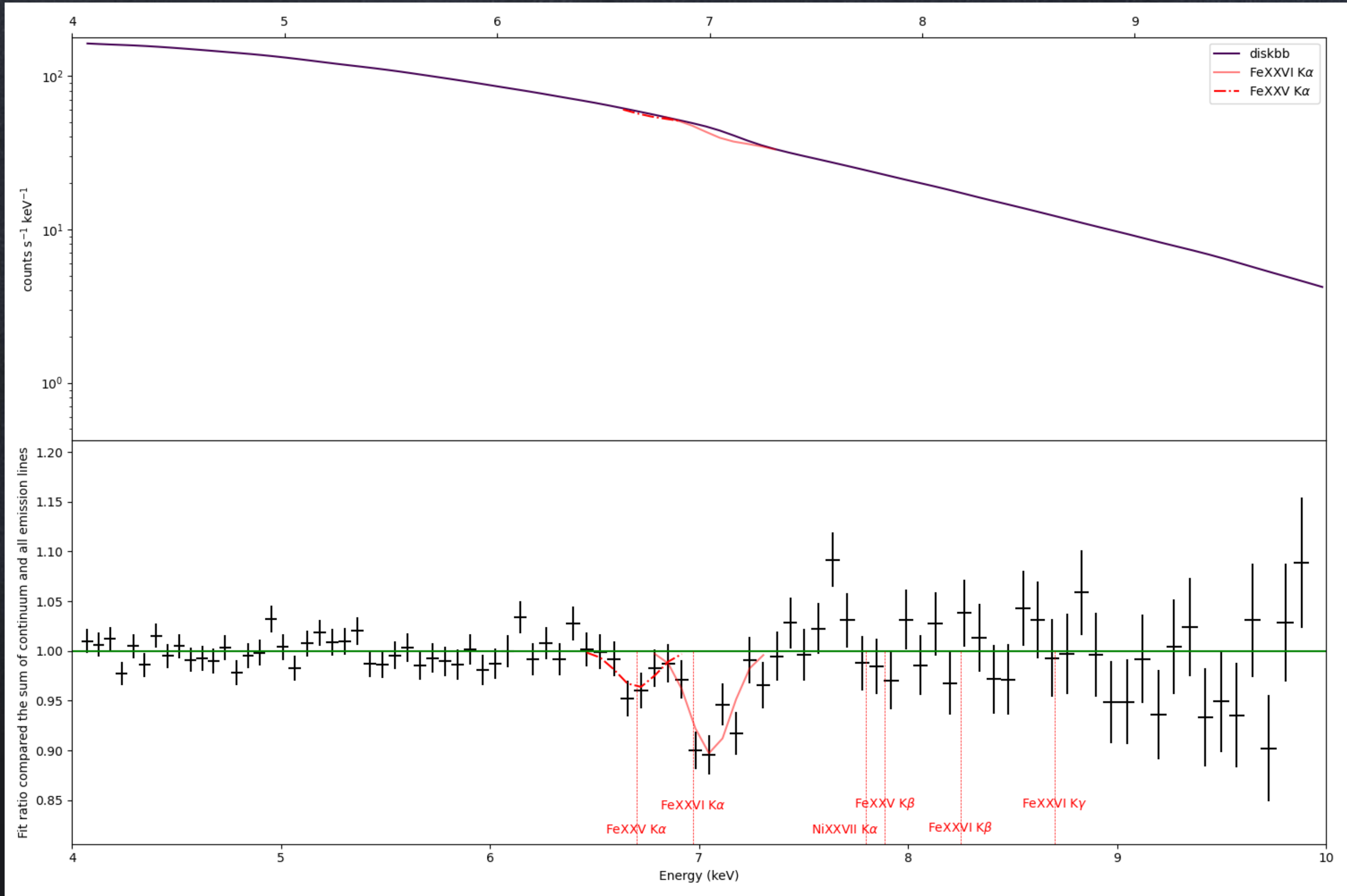
❑ Example of output after step 2 (blind search) in 4U1630-47



Methodology

- Line detection

❑ Follow-up of the previous exposure after step 3 (line fit)



Methodology

- Line detection

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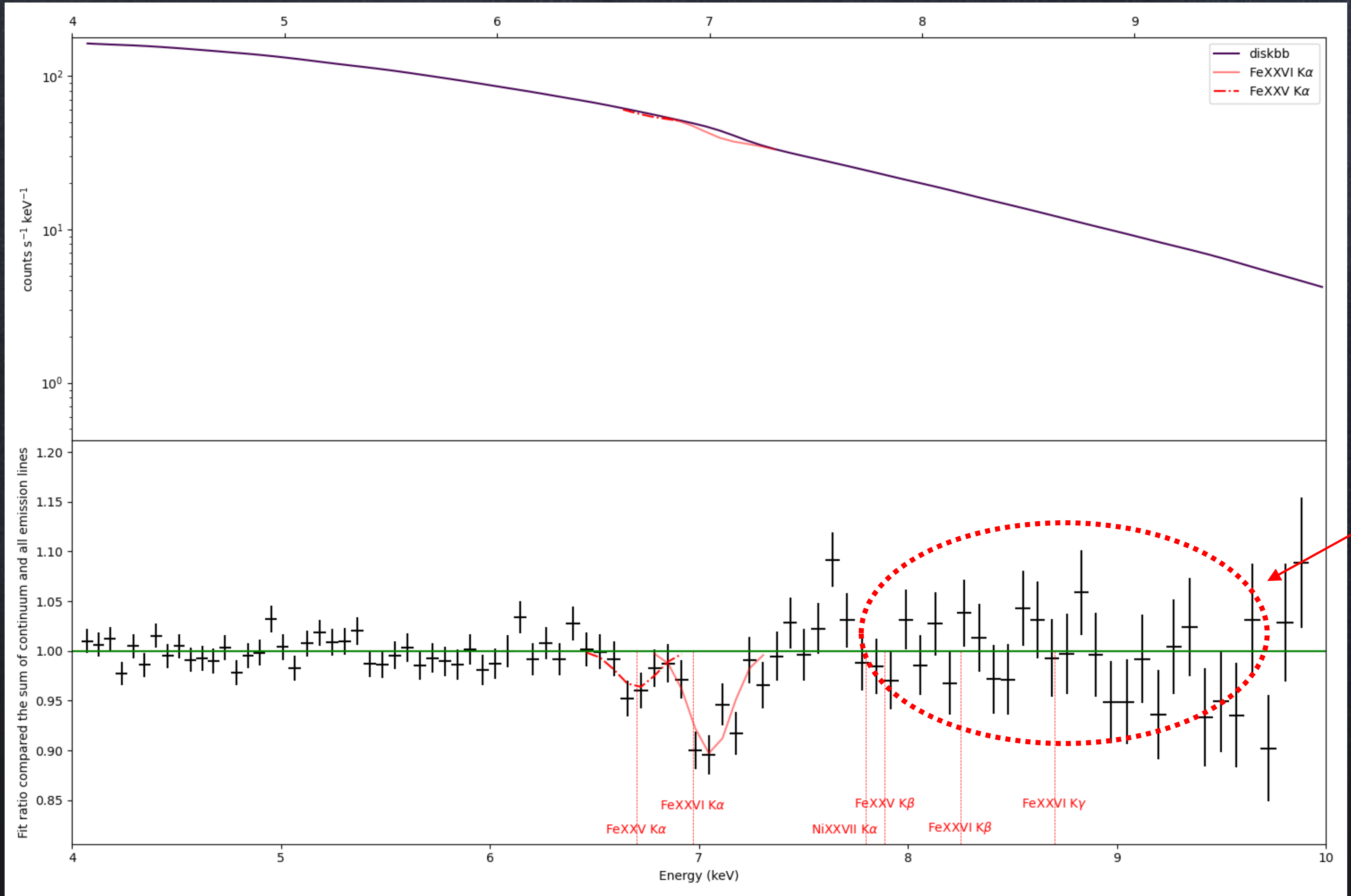


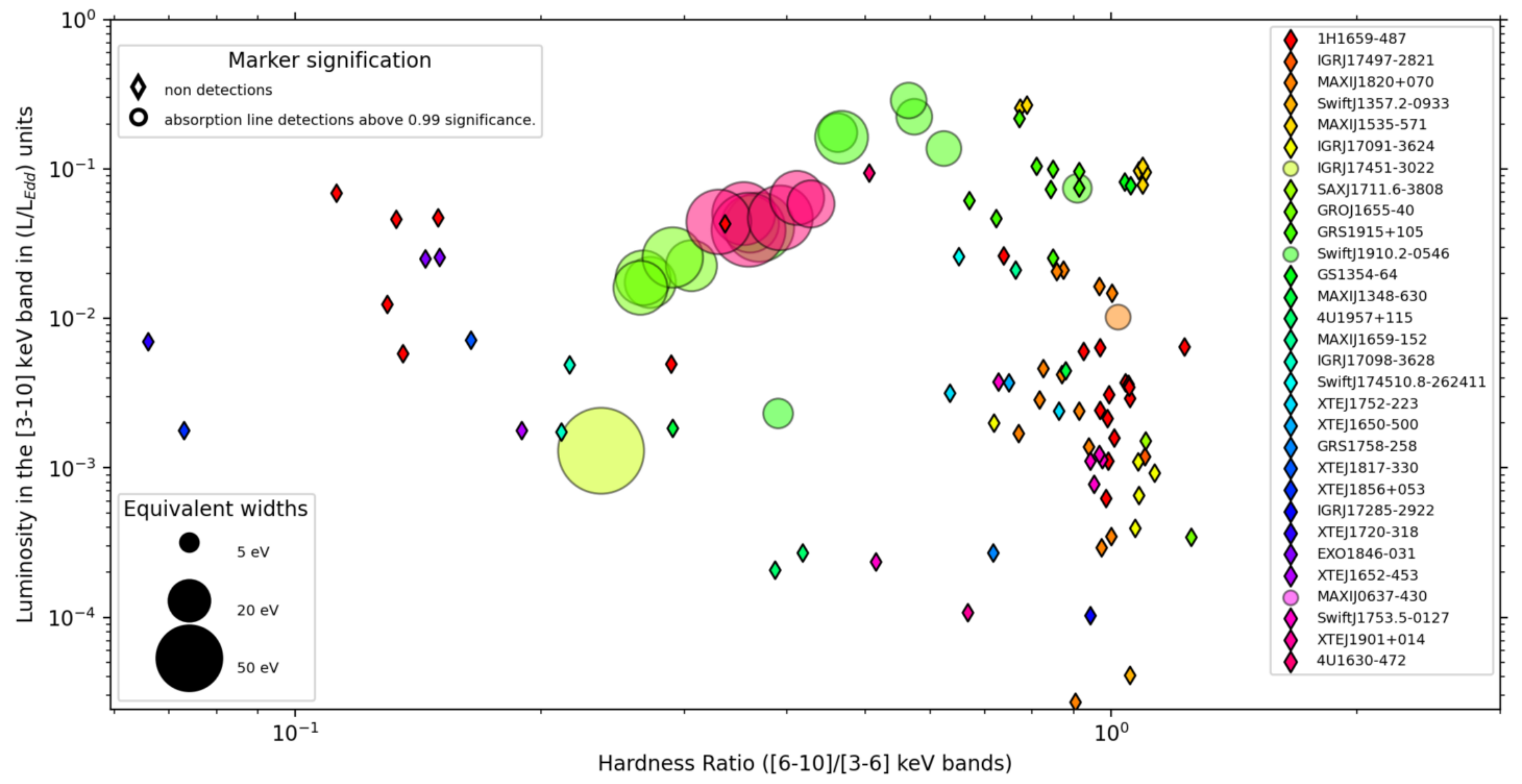
Tested in a second blind search

Results

- Global HID behavior

❑ Main HID for the sample with sources as color

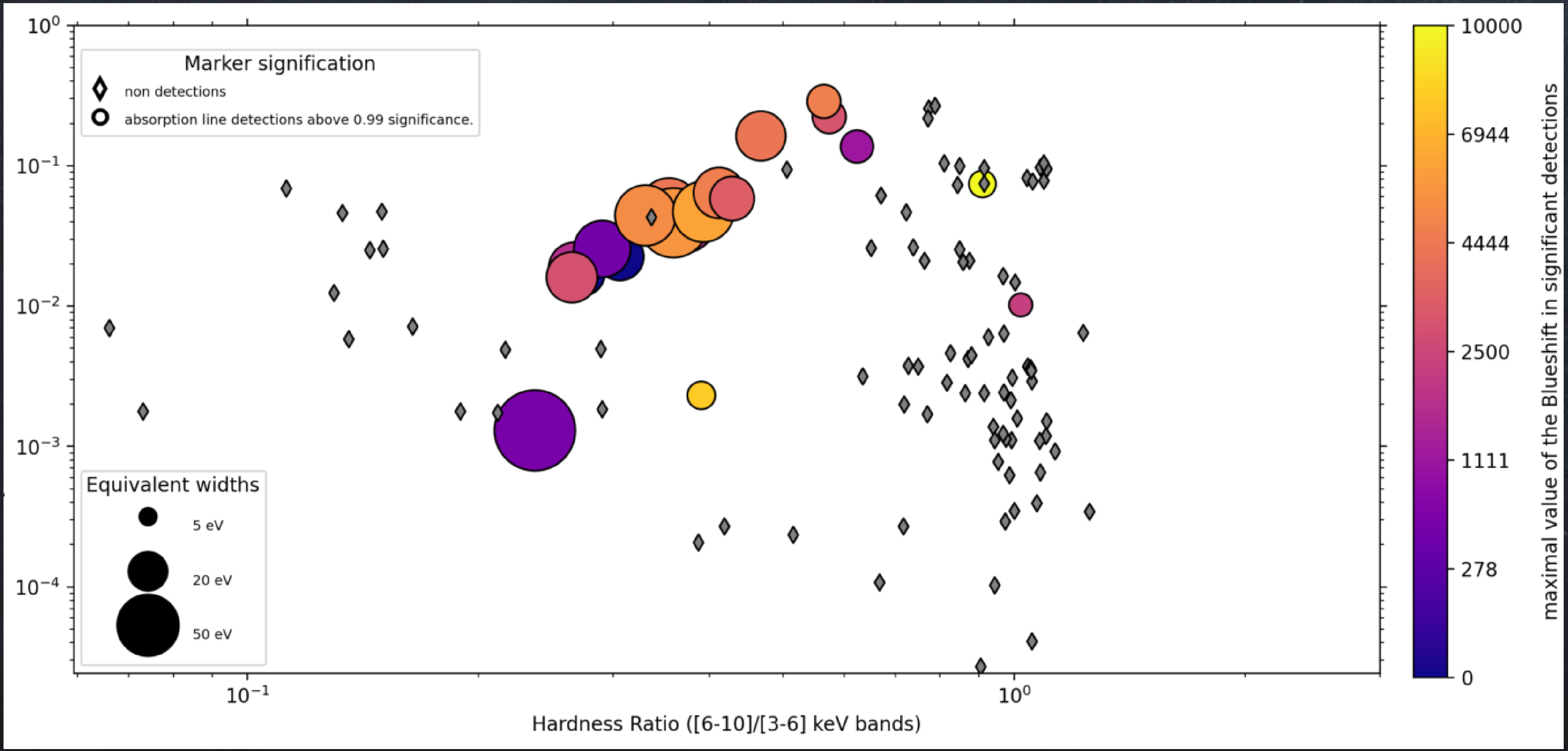
- Almost all detections are in soft or in transitioning states



Results

- Global HID behavior

❑Main HID for the sample with blueshift in km/s



Results

- Distributions

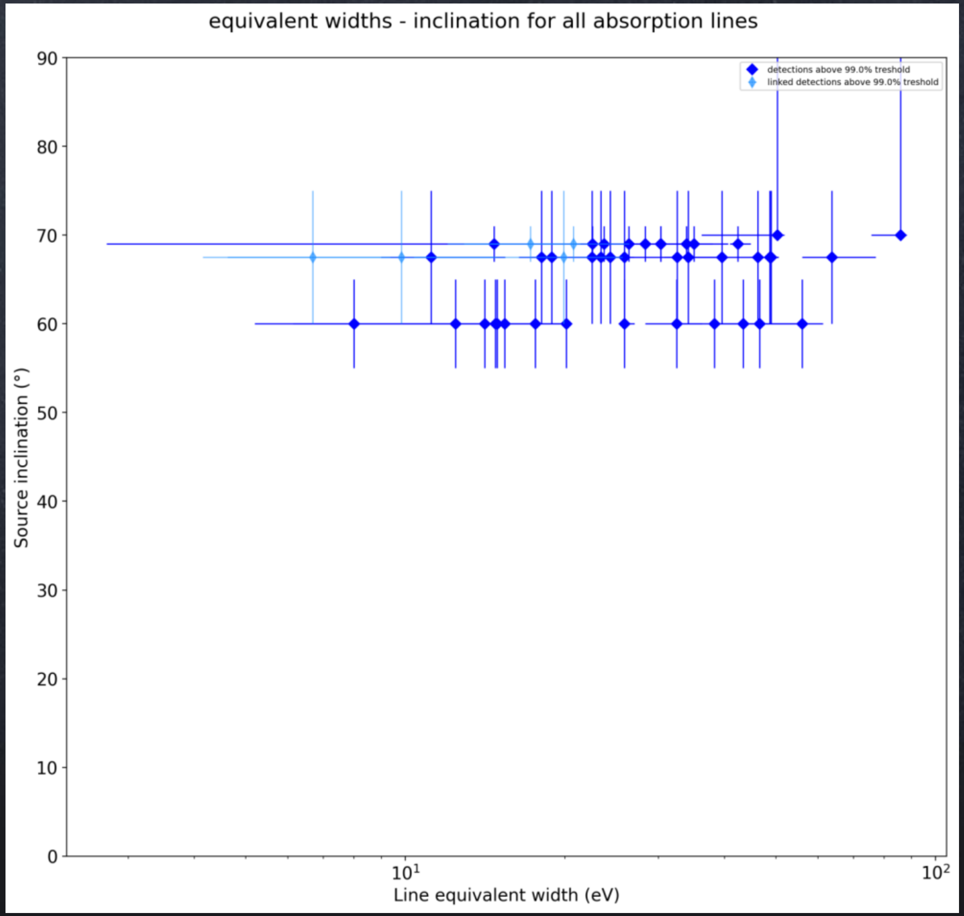
- There are 33 sources with XMM exposures, 15 of which have constraints on their inclination.
- Detections are considered significant above 0.99 confidence

	Number of sources with at least 1 detection	Number of individual significant detections
All Lines	10	46
FeXXV Kα	4	14
FeXXVI Kα	7	20
NiXXVII Kα	3	4
FeXXV Kβ	2	4
FeXXVI Kβ	2	4
FeXXVI Kγ	2	0

Results

- Distributions

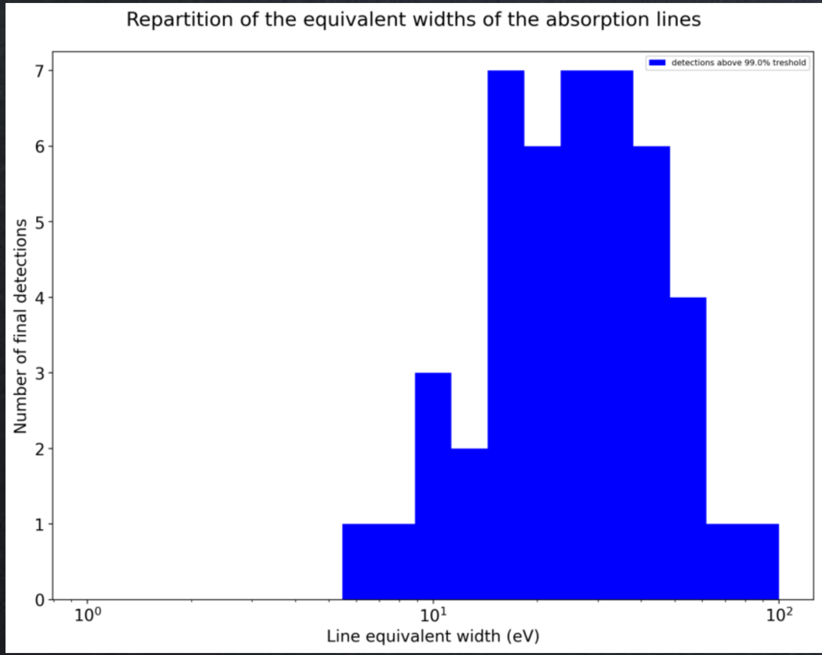
❑All significant line detections are for high-inclined objects

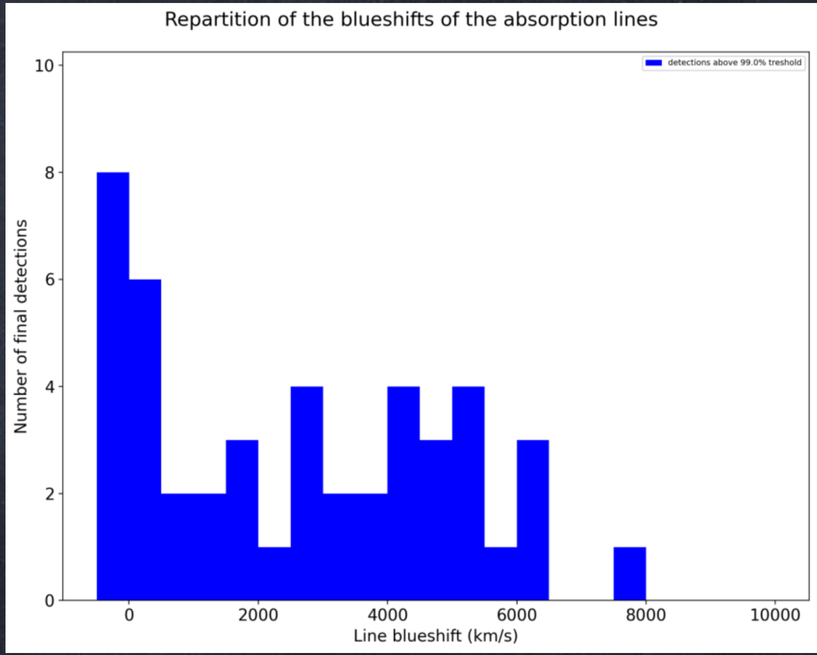


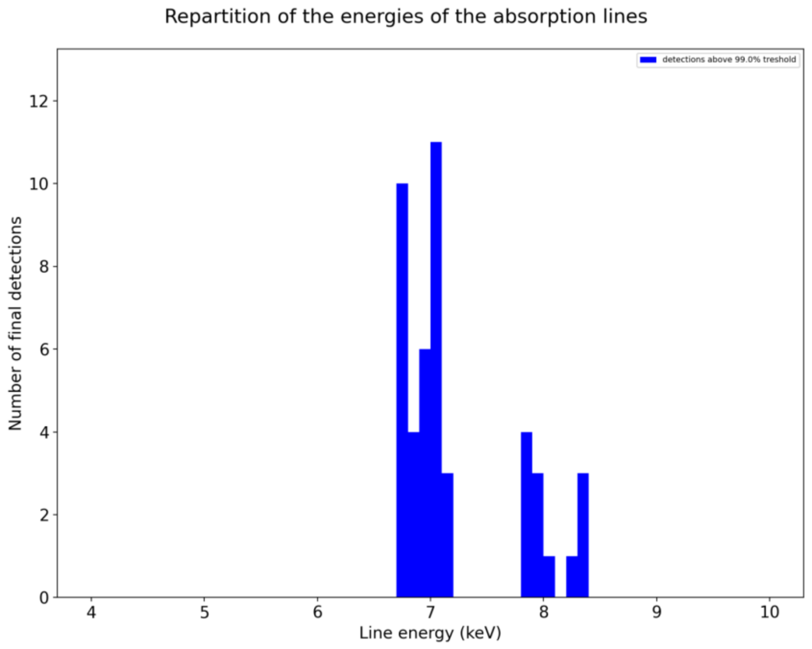
Results

- Distributions

❑Repartition of the intrinsic line parameters







Results

- Correlations

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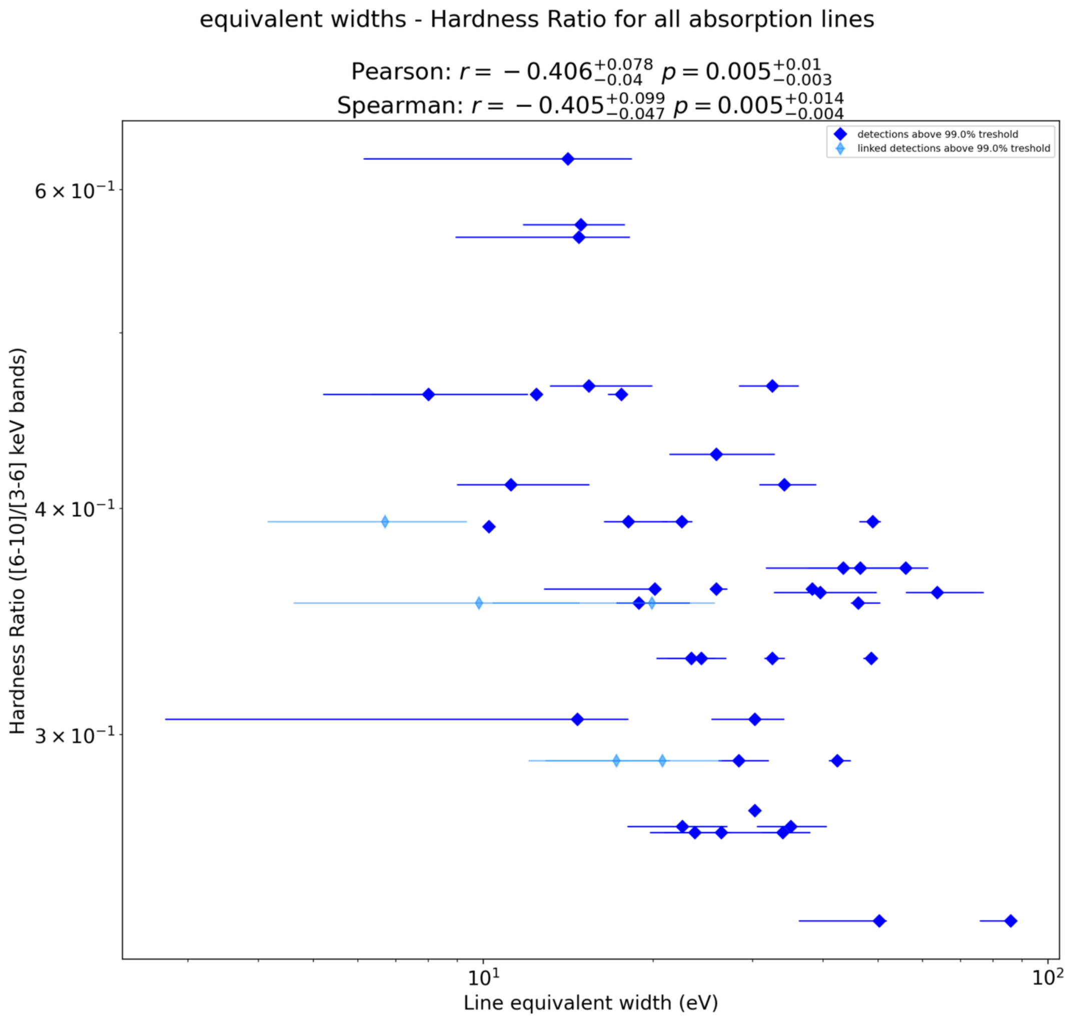
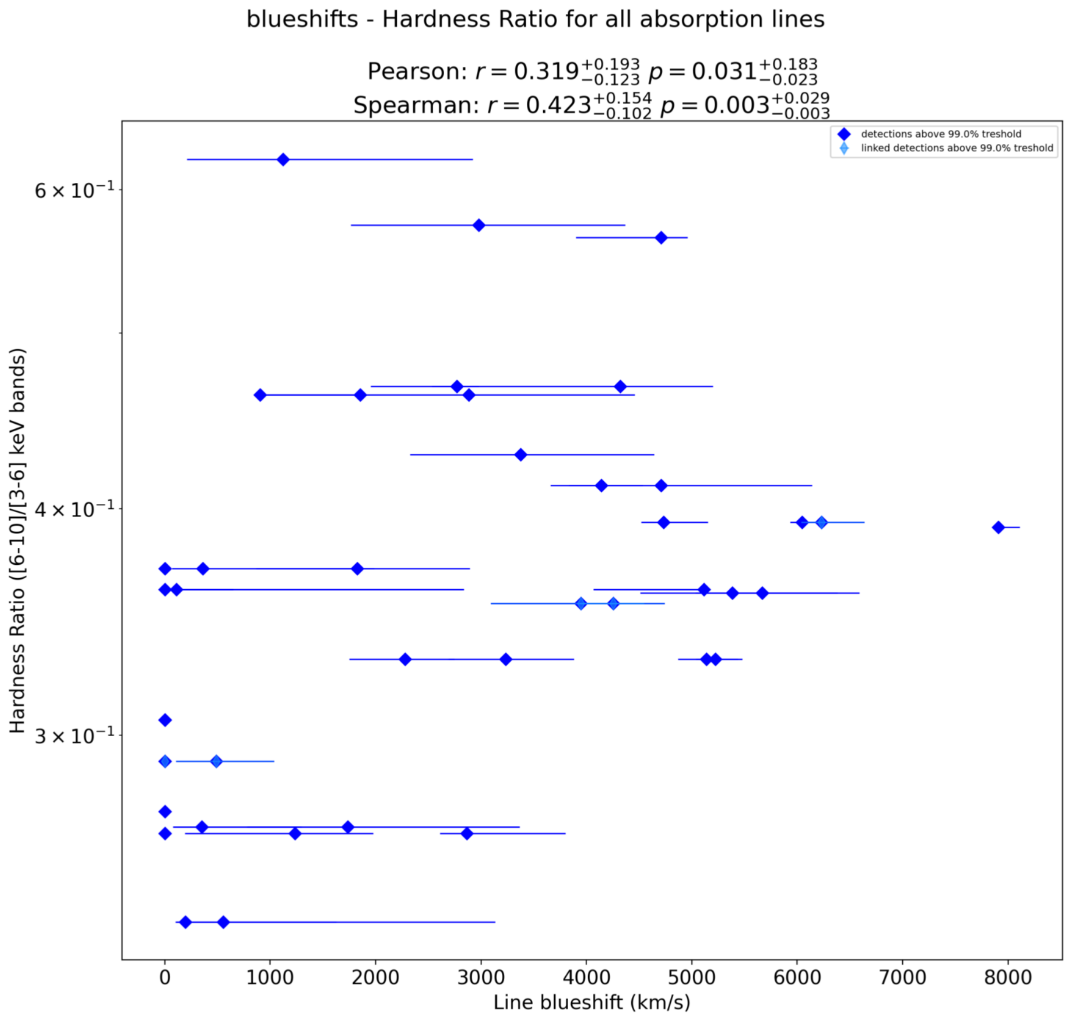
❑ Equivalent width – HR for all lines: "significant" correlation

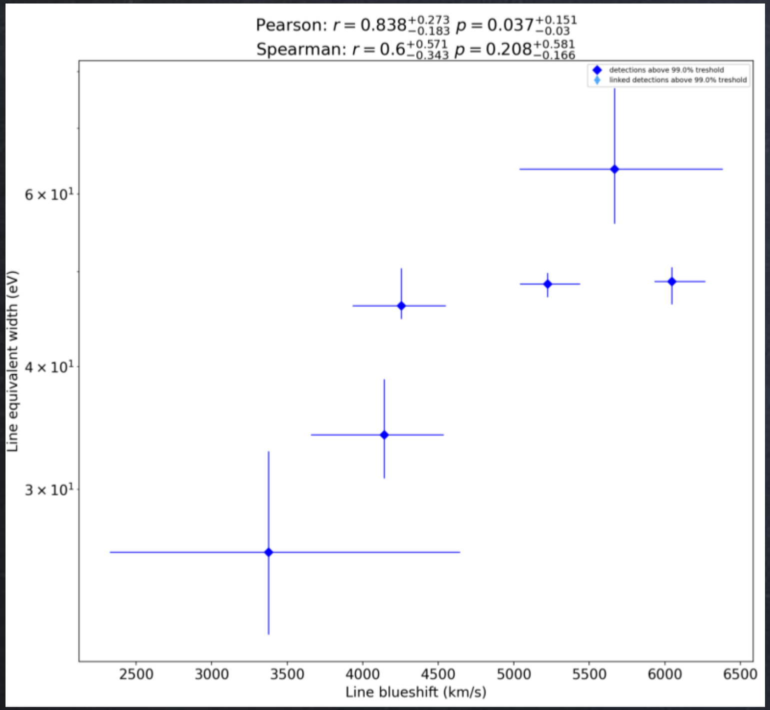


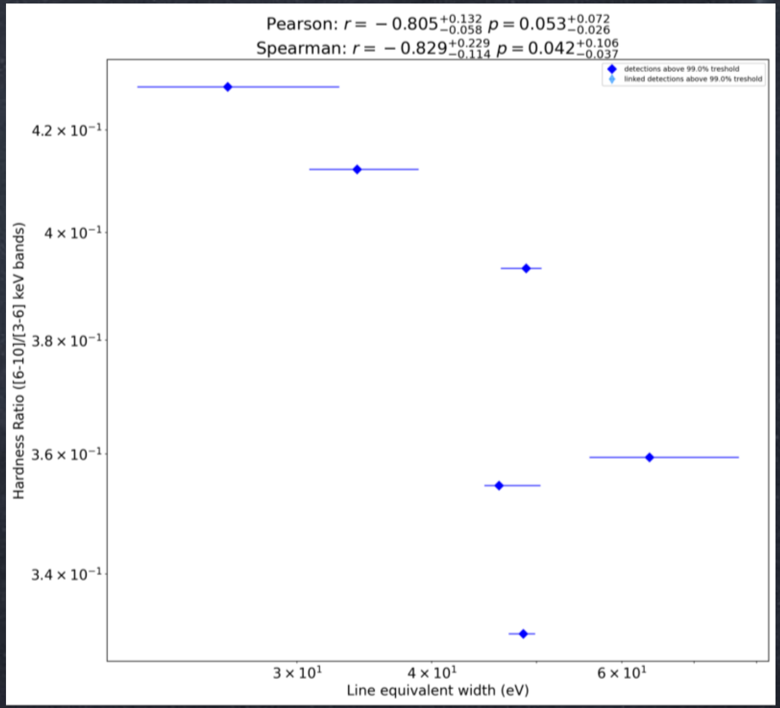


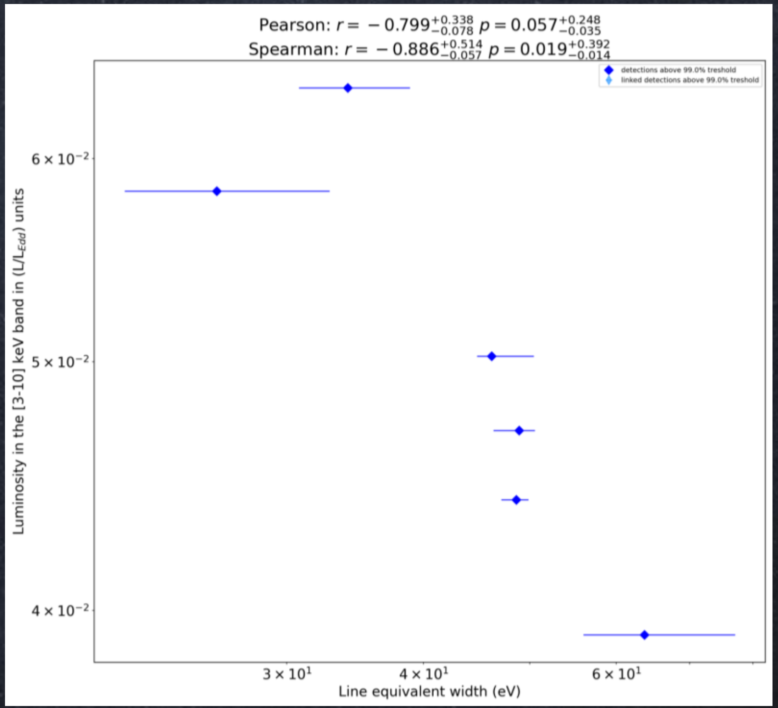
Results

- Correlations

❑ Hints at multiple correlations in 4U for FeXXVI Kα







Results

- Correlations

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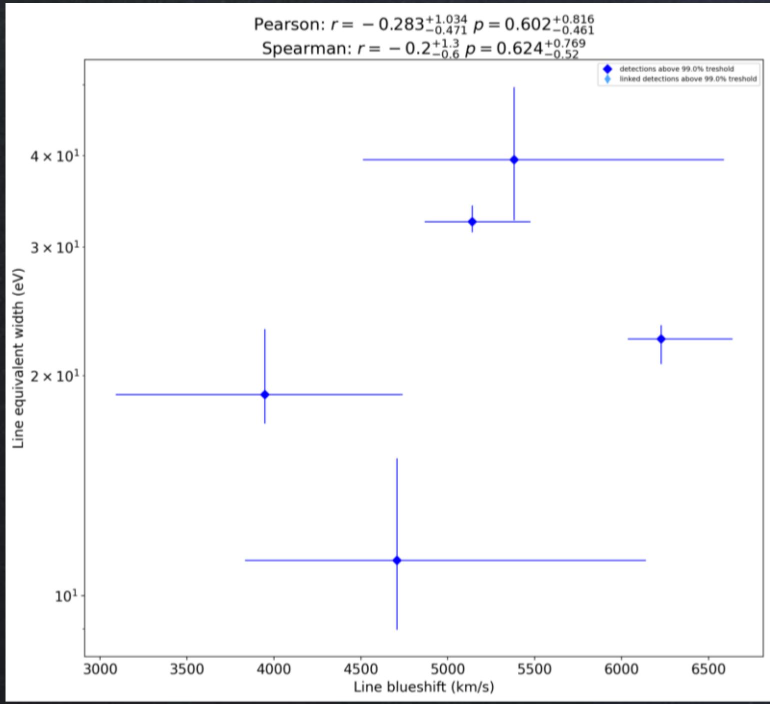
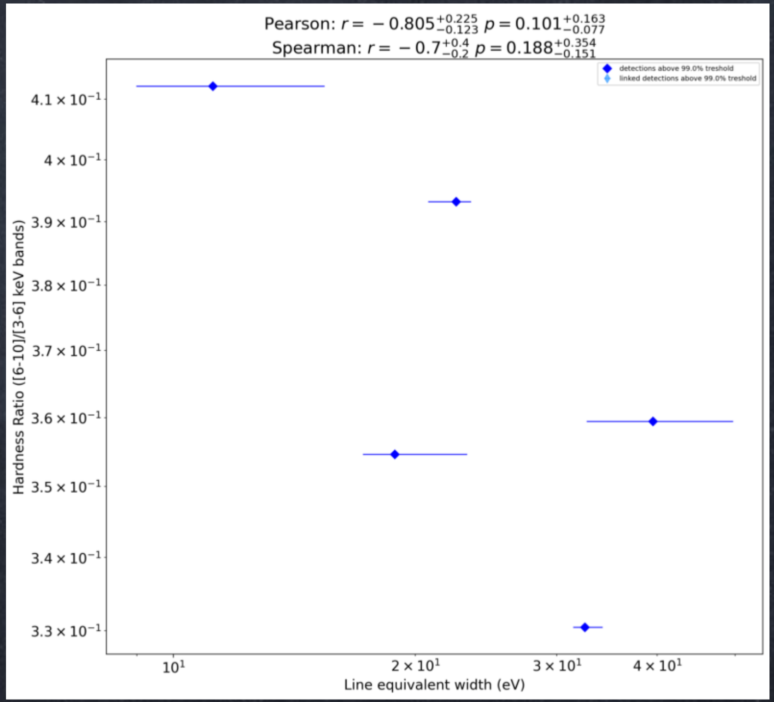
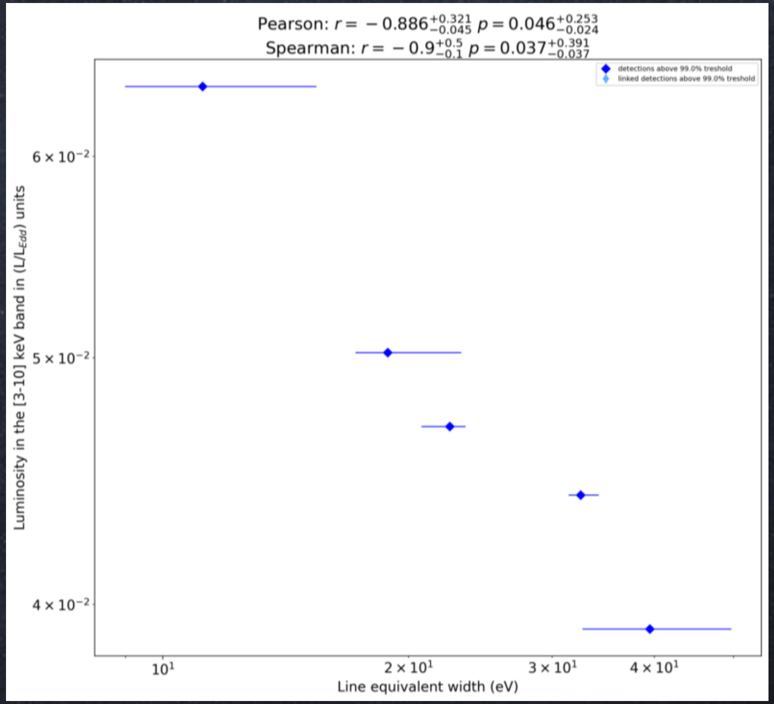


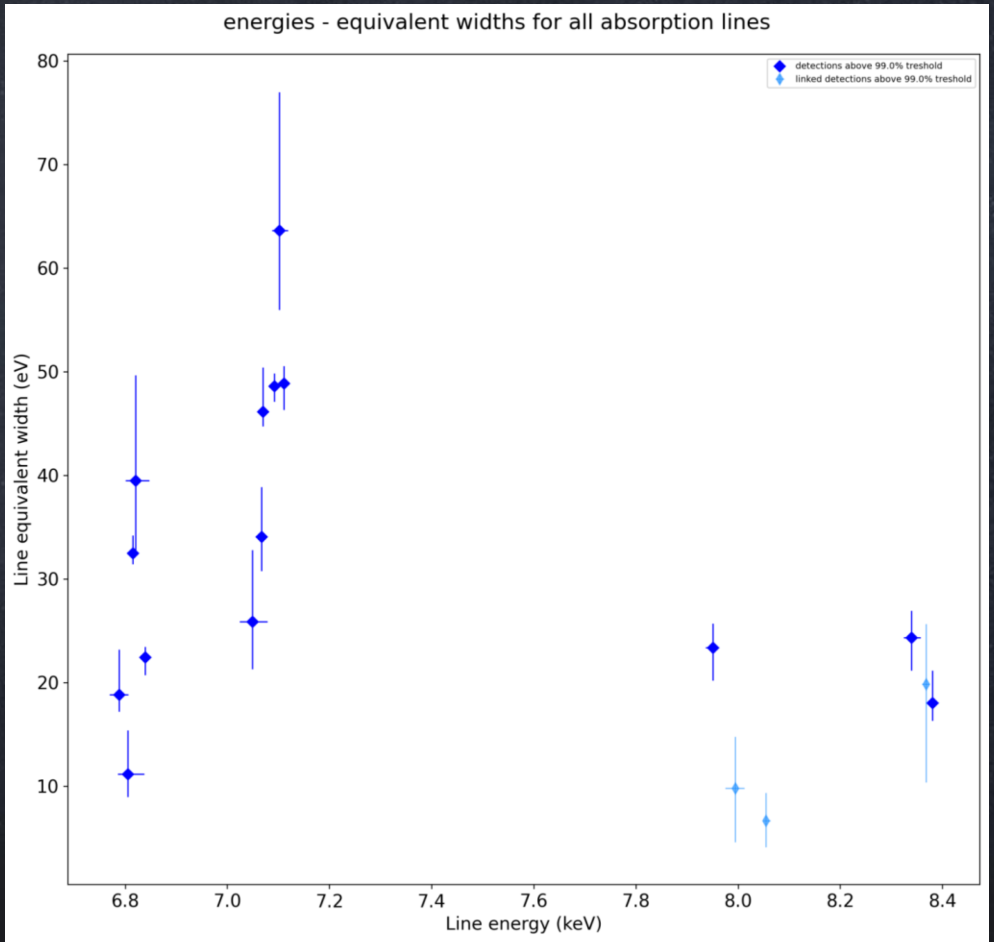




Results

- Correlations

❑Opposing trends between Kα and Kβ lines



Prospects

- We can test other correlations from the analysis
  - Presence/absence of emission lines
  - Ratios between parameters of lines of the same complex
  - Differences between linked/unlinked line parameters

- Caveats/improvements of the analysis itself
  - Use more physical models for tabulated objects
  - Probe at more exotic lines/parameter spaces
    (redshifted lines/search in strong emission features/…)

- Add MOS exposures when available, and Chandra/Suzaku data

- Compute stability curves and check the compatibility with physical models

Thanks for your attention !

Methodology

- Line detection

❑Methodology

- Data reduction
  - data download, reduction and products (spectra) computation
- Continuum + High-Energy fits
  - simplistic models (absorbed pl +/diskbb) in [0.3-10]keV and [4-10]keV
- Blind search
  - 2d $\Delta\chi^2$ map from the addition of a narrow line with varying E and F
- Second fitting procedure to get the line parameters
  - Progressive addition of significant emission/absorption components
- Significance assessment of the lines with MC simulations
  - Fakeit ‘till you make it

Methodology

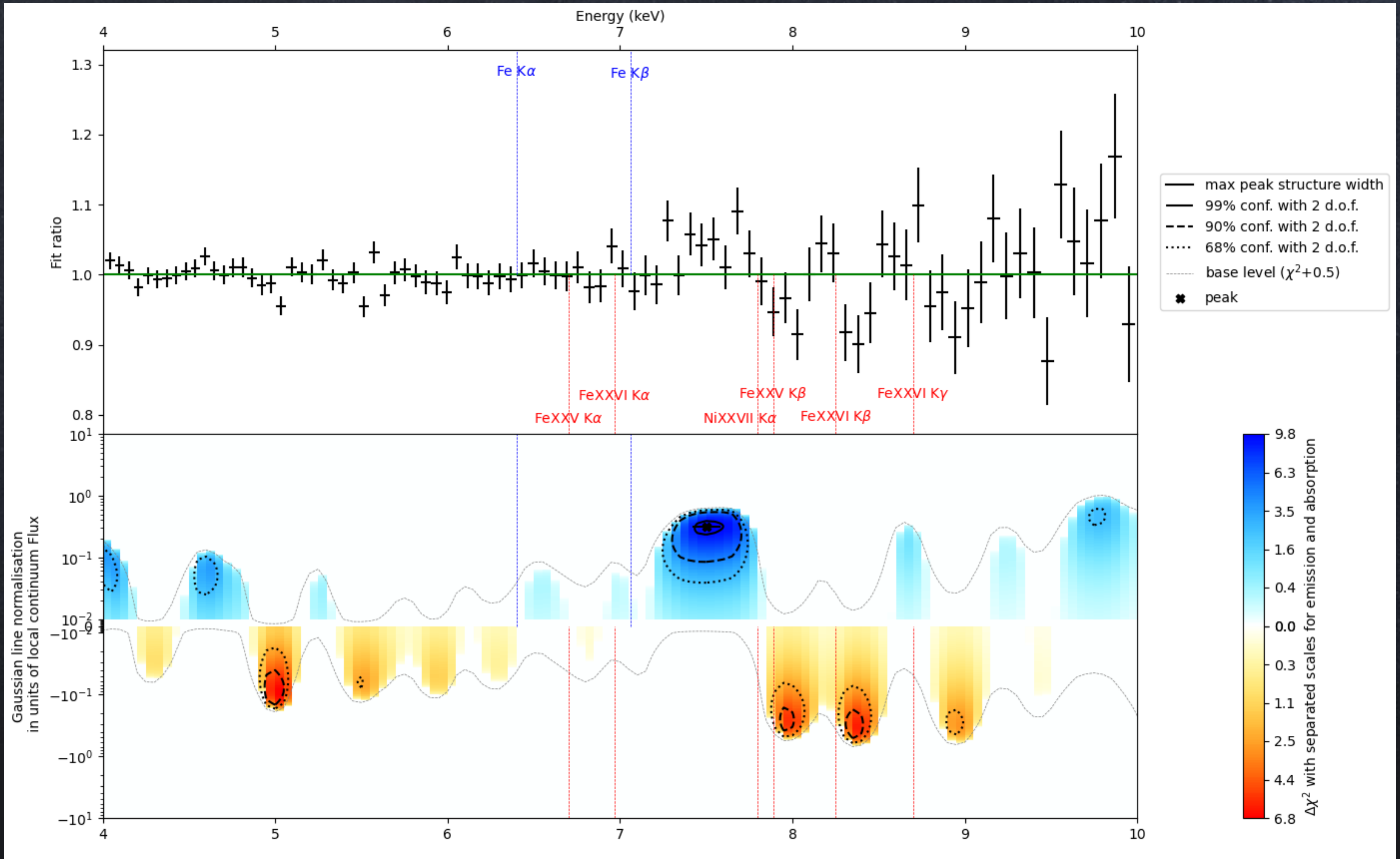
- Line detection

❑ Beside each final fit parameter/uncertainty and the flux in diverse bands computed from the continuum model, for all lines we store:
  - The equivalent width/associated errors
  - The blueshift/associated errors
  - The line significance computed from the fakeit simulations
    (each line is considered significant above 99%)
  - The ‘linked’ status of each line’s energy

Methodology

- Line detection

❑Second blind search from the results of the incremental fit



The current context

- Modeling and stability of absorption lines

The picture is much more complex now

❑What about intermediate states ?

- Many observations but unclear global behavior

↓

❑Thermal and/or MHD driving[5][6] to launch the material ?

- $T_{wind} \ll T_{acc}$

↓

❑The spectral shape affects the thermal stability and ξ

- Wind always here[7] but only detectable in the right conditions ?

[5] Díaz-Trigo & Boirin 2016 [6] Tetarenok et al. 2018 [7] Sánchez-Sierras & Muñoz-Darias 2020

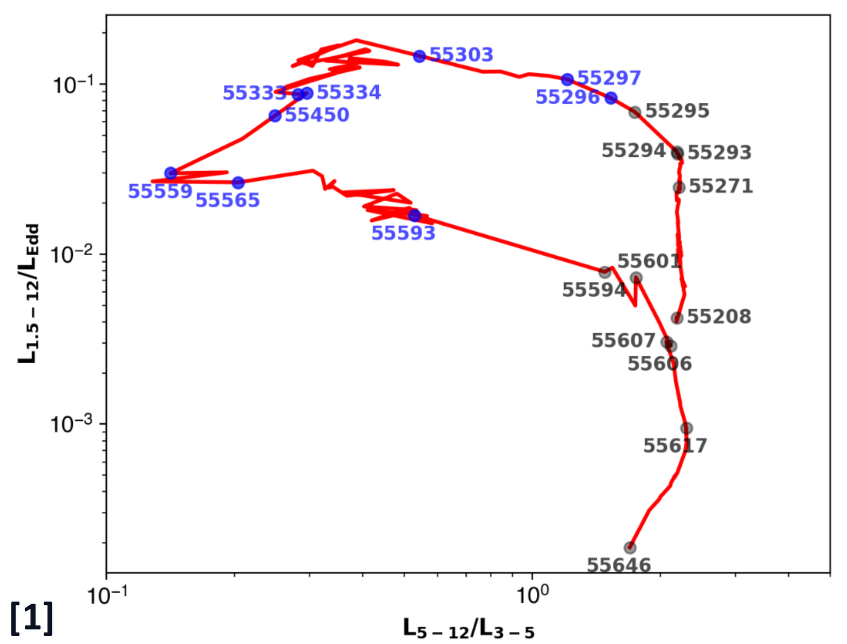
The current context

- Modeling and stability of absorption lines

❑ The wind thermal stability curves can be computed

- Very sensitive to the SED → requires broad band data that doesn't exis

❑ With a bit of physically motivated[8] extrapolation…[9]



[1]

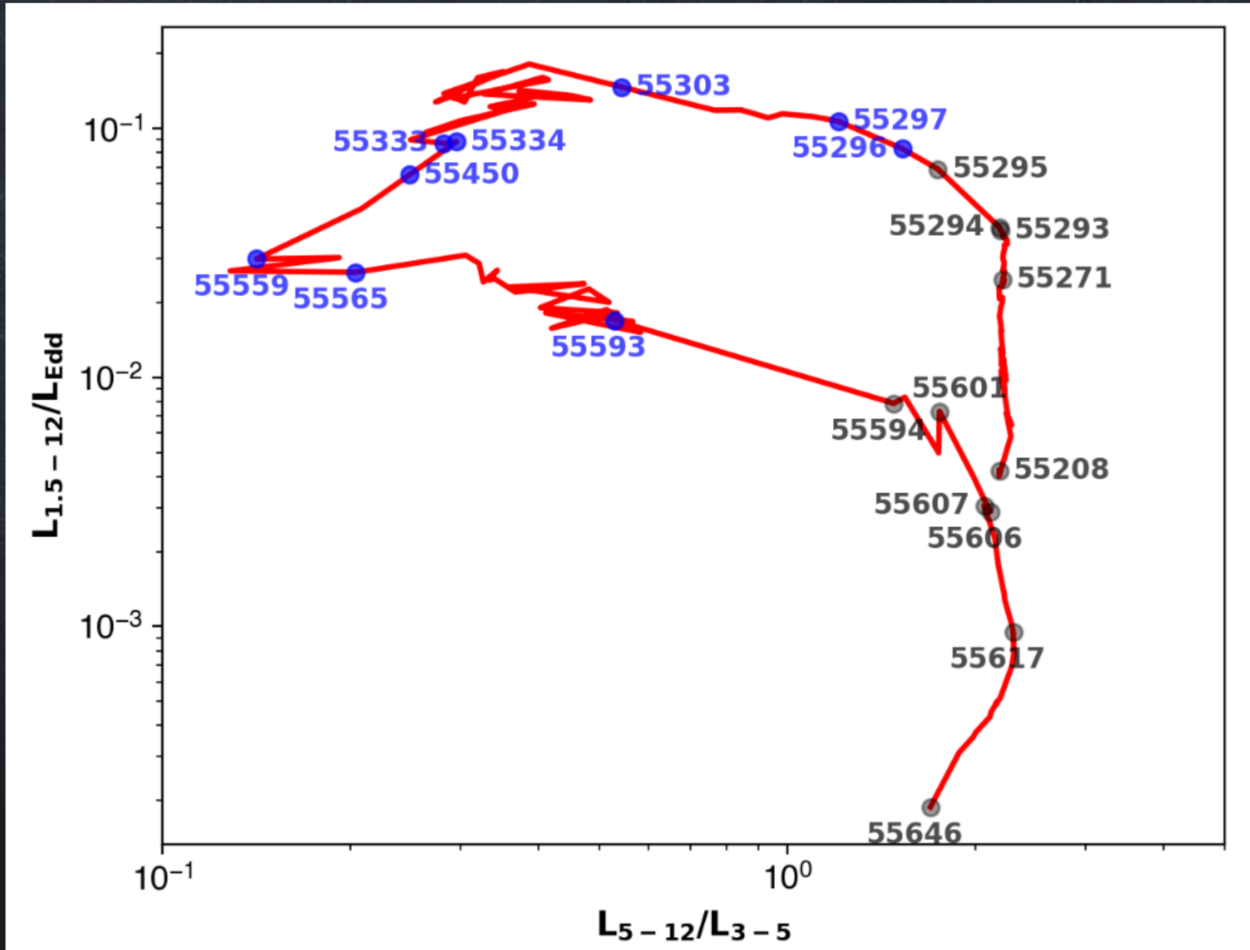
[8] Marcel et al. 2018

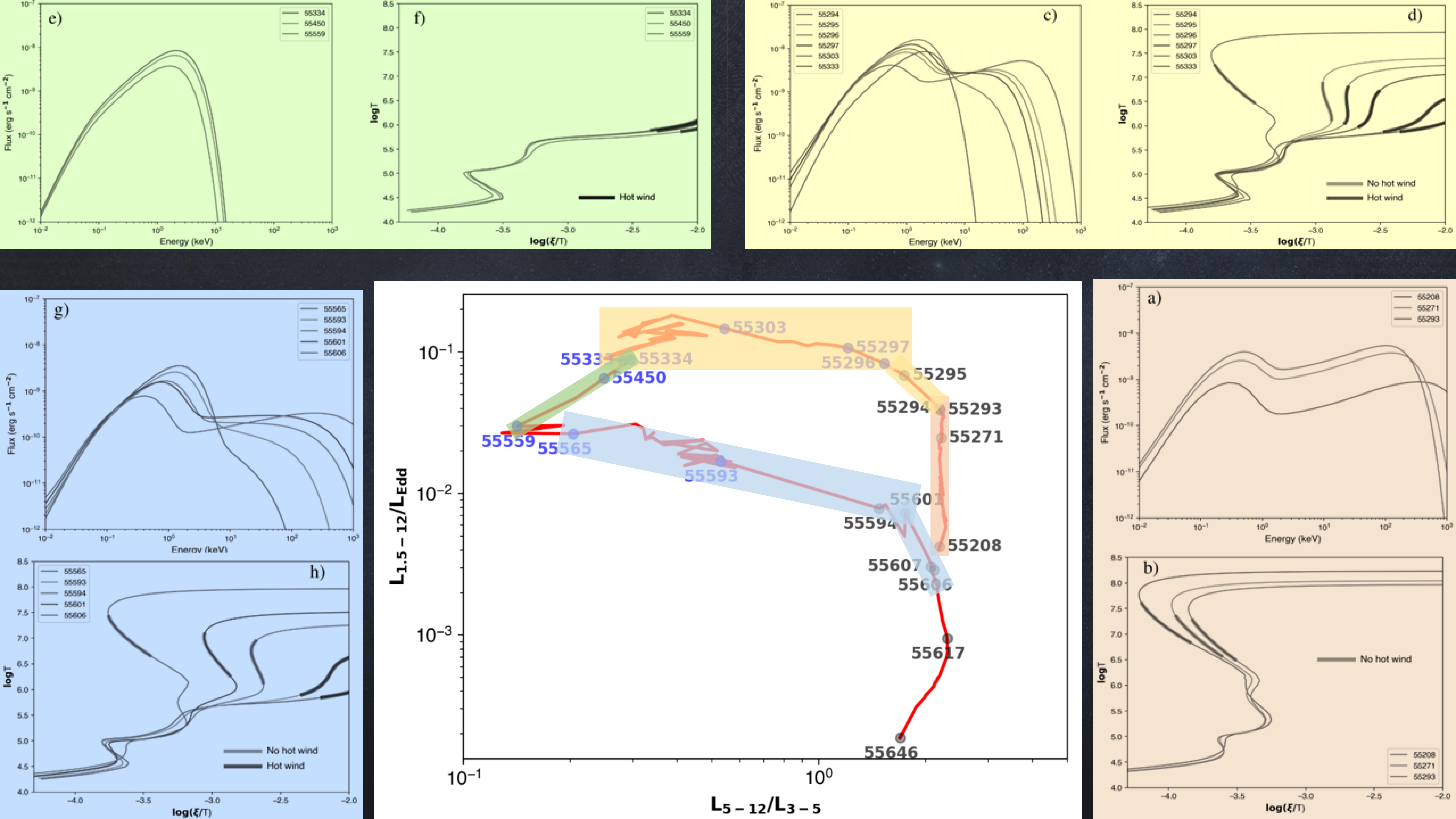
[9] Marcel et al. 2019

[1] Petrucci et al. 2021

The current context

- Modeling and stability of absorption lines





e)
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55450
55559
Flux (erg s^{-1} cm^{-2})
Energy (keV)
f)
Hot wind
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log(ξ/T)
c)
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No hot wind
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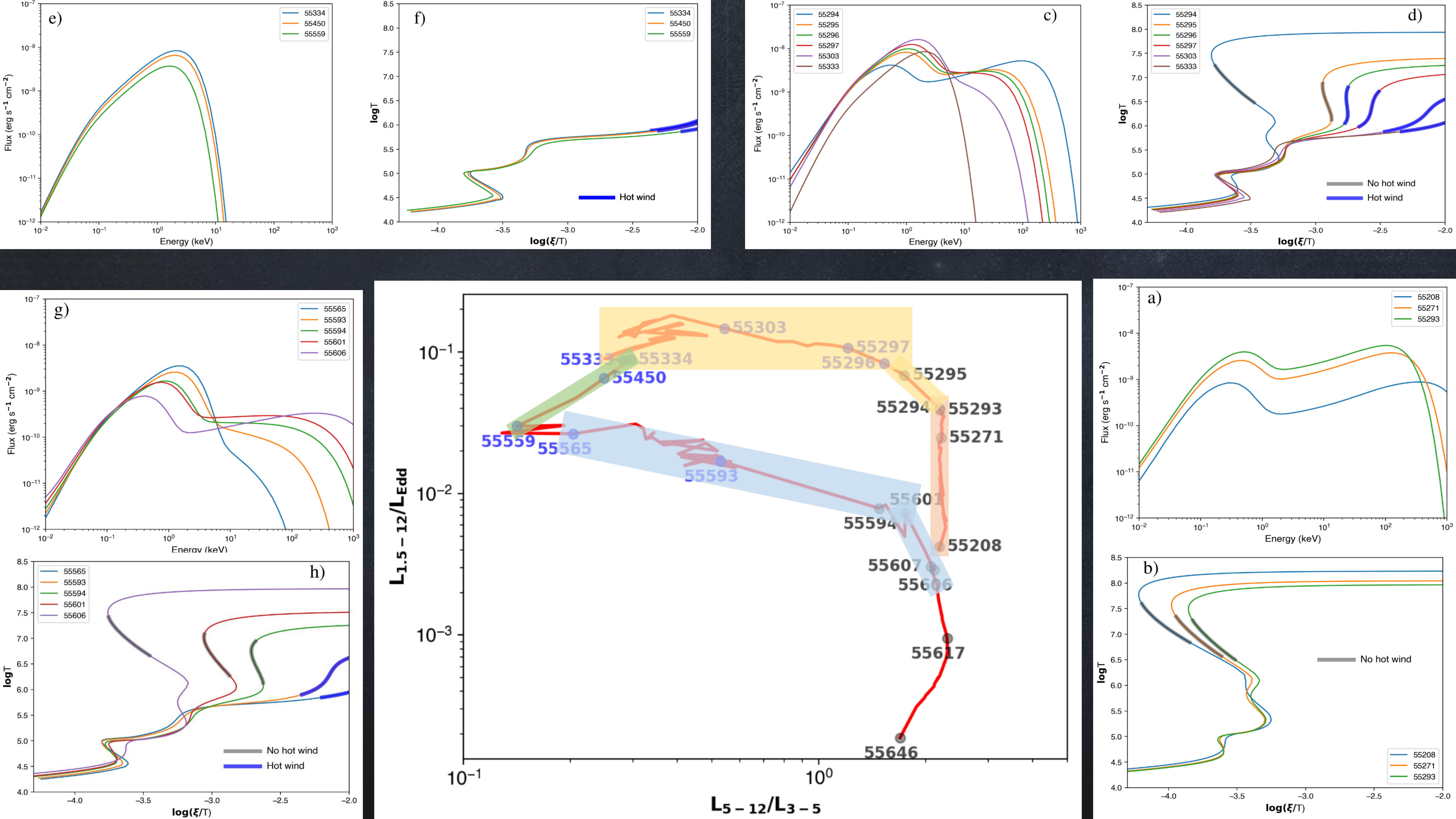
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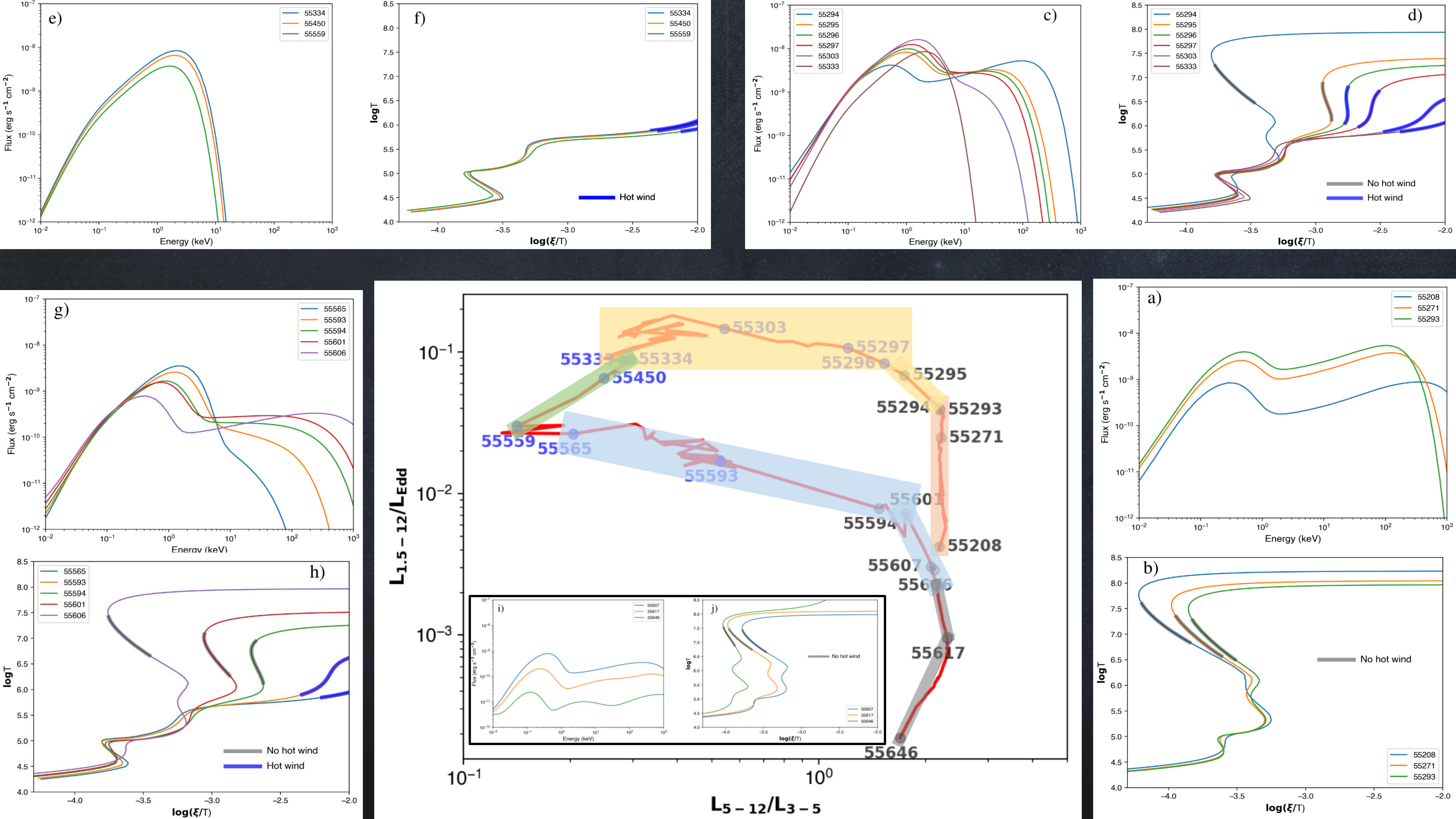

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The current context

- Modeling and stability of absorption lines

❑Now to be compared with observations for objects with detections