Radiatively-driven clumpy absorbers in the NLSy1 IRAS 13224-3809

Takuya Midooka (U. Tokyo, ISAS/JAXA)

Misaki Mizumoto (Kyoto Univ.), Ken Ebisawa (U. Tokyo, ISAS)

東京大学
THE UNIVERSITY OF TOKYO

JAXA

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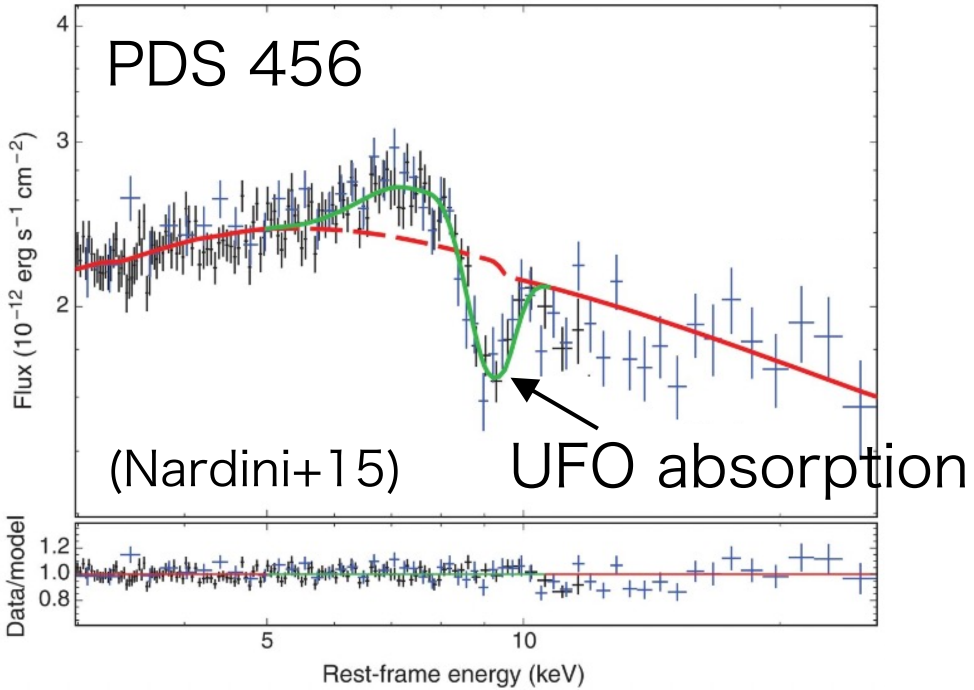
Talk plan

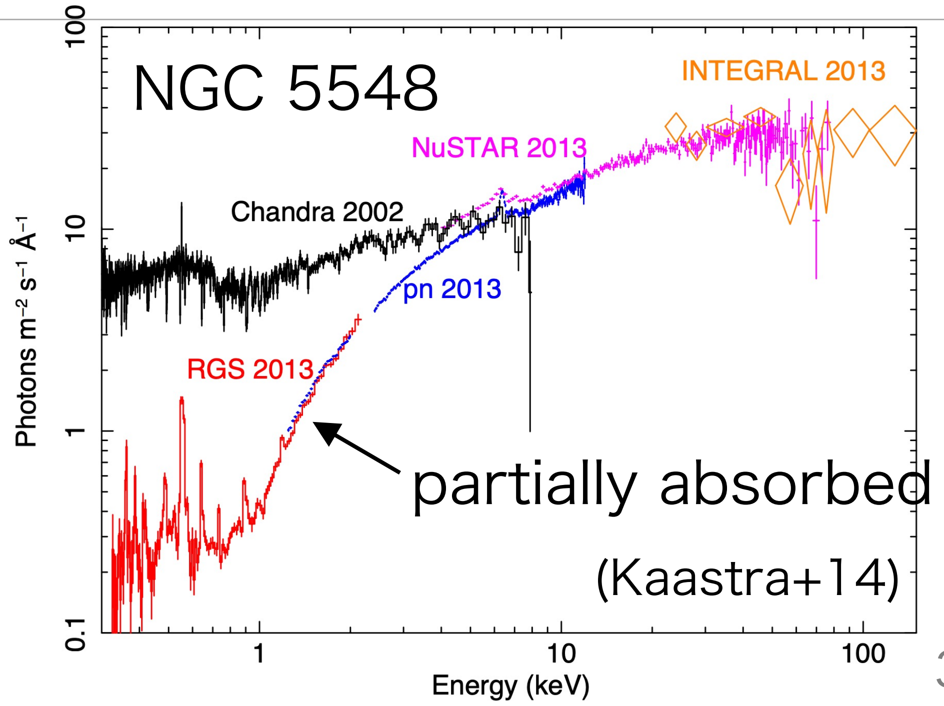
1. Introduction
2. Target: IRAS 13224-3809
3. Method: spectral-ratio model fitting
4. Results
5. Summary

Constrained the outflow velocity of clumpy absorbers by "spectral-ratio model fitting"

1. Intro: Most AGNs host various absorbers

	observation	outflow velocity	origin
warm absorbers (WAs)	~65% of AGN (notably, radio-quiet Sy1)	< 2000 km/s	wind from NLR? torus? disk?
ultrafast outflow (UFO)	~40% of Sy1,2	0.1-0.3 c	disk winds?
clumpy absorbers (clumps/obscurers)	parts of Sy1	zero? (**unknown**)	**BLR clouds? torus? disk winds?**



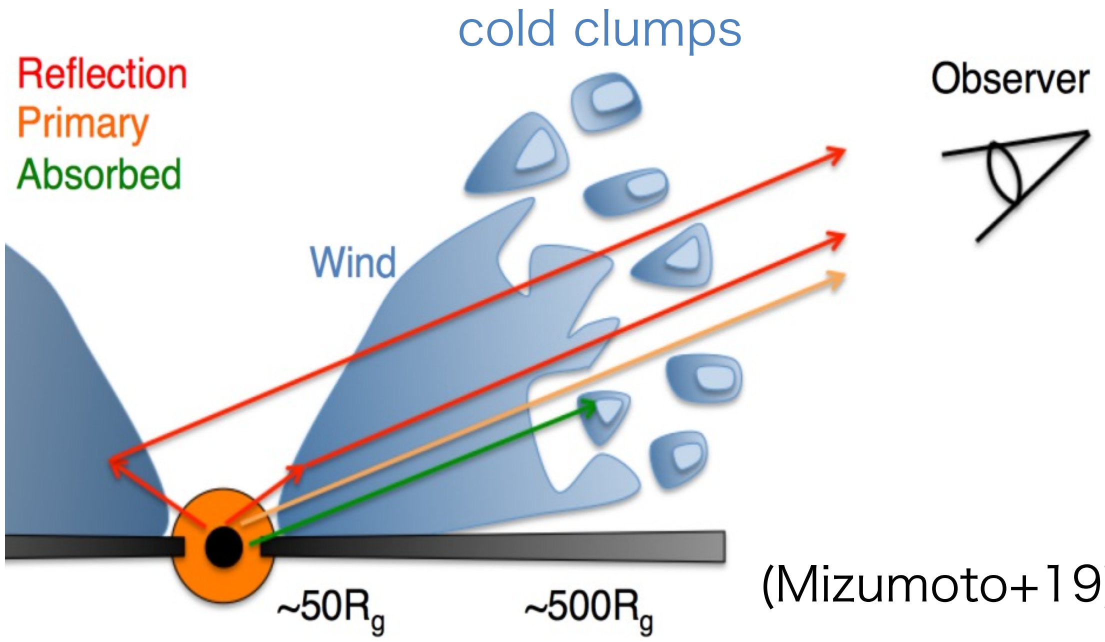


1. Intro: Are clumps originated from wind?

To explain the observed X-ray spectra, both the clumps and the disk winds (the origin of UFO) are required.

We want to explain the both in a unified picture

The "Hot-inner Clumpy-outer wind" (Mizumoto+19) model suggests that the clumps are wind origin.



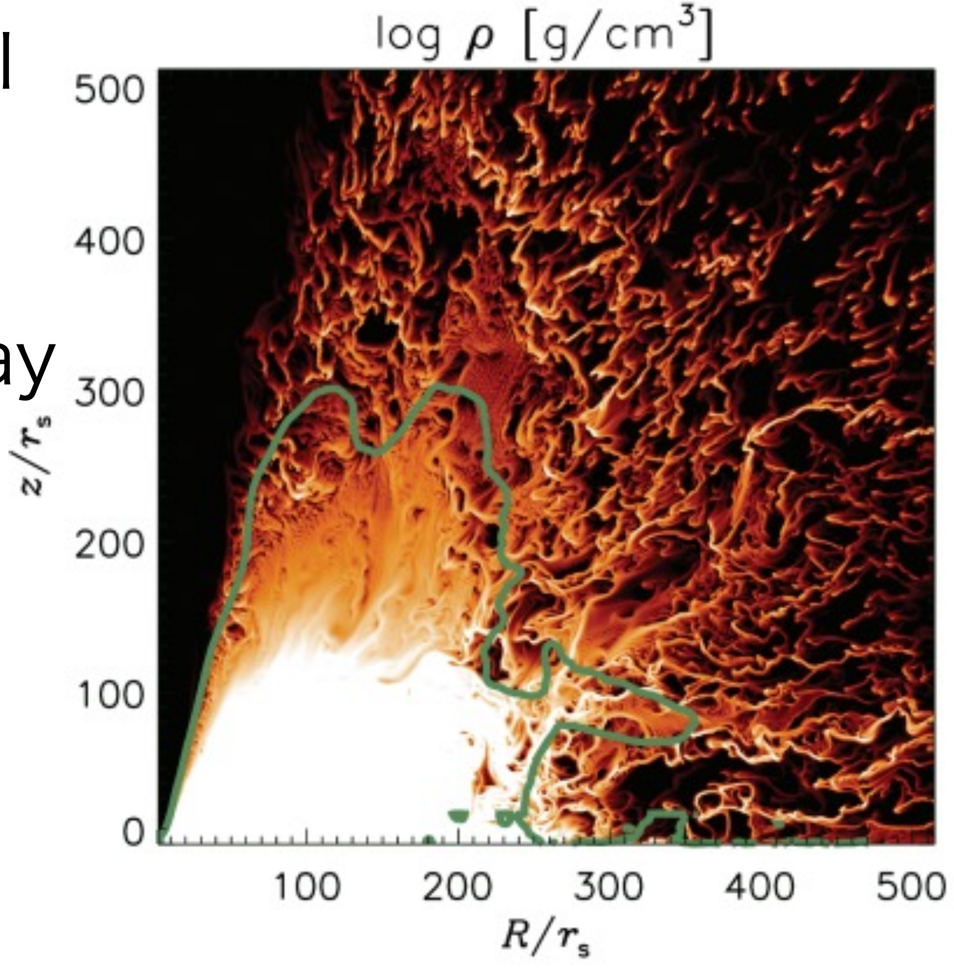
(Mizumoto+19)

However, observational evidence does not exist that clumpy absorbers are outflowing

1. Intro: Outflow Simulation

- Radiation-MHD simulation of supercritical accretion flow
- Disk wind is driven by the radiation
- Wind turns into many clumps further away (Rayleigh-Taylor + RHD instabilities)

→ Hot-inner Clumpy-outer wind model is supported by theoretical studies



(Takeuchi+13, Kobayashi+18)

1. Intro: Challenges in observational studies

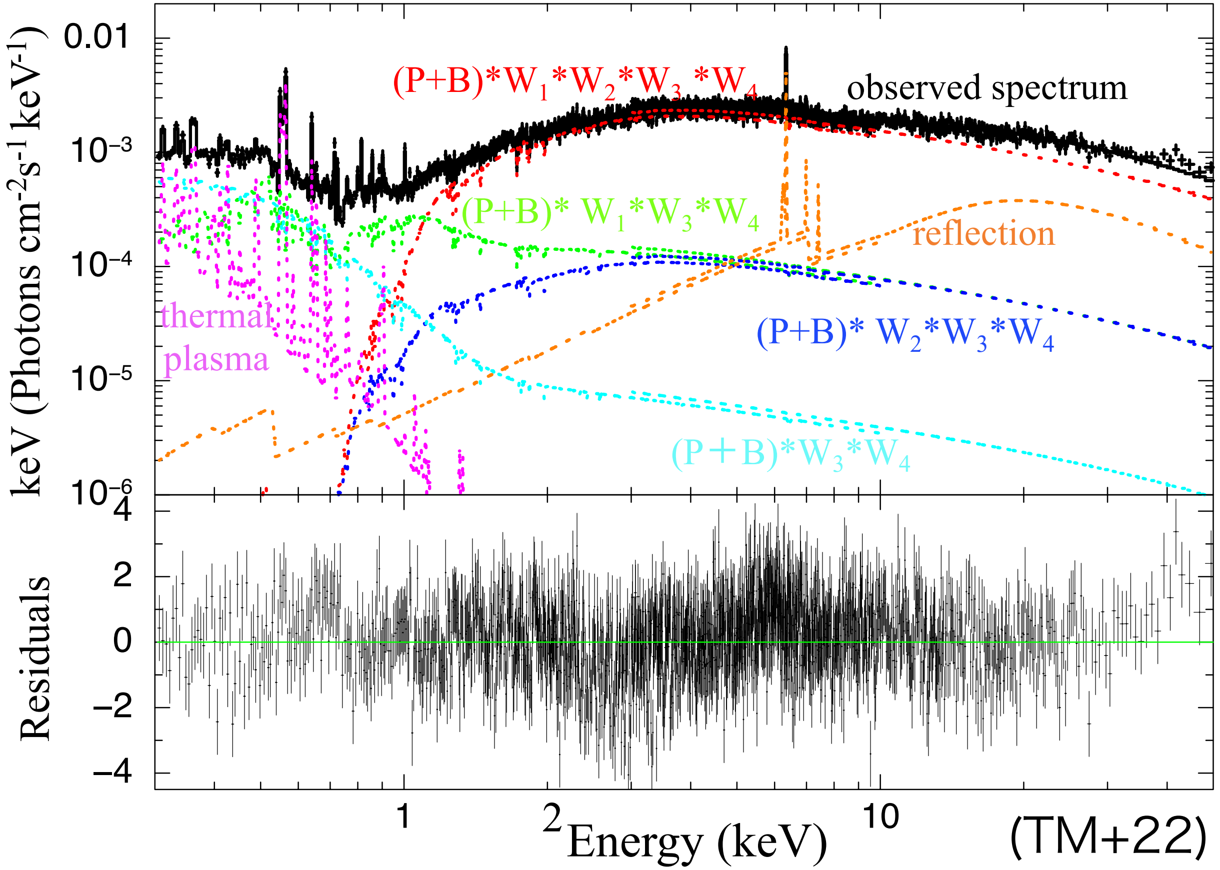
In the 0.3-2 keV band, there are various components

- thermal plasma
- soft-excess
- WAs
- clumpy absorbers (CF, $\xi, N_{\mathrm{H}}, v_{\mathrm{out}}$)

Spectral parameters are degenerate
→ v_{out} of clumps cannot be constrained

P: Powerlaw (PL)
B: soft-excess
W_1, W_2: clumps
W_3, W_4: WAs

NGC 5548



(TM+22)

1. Intro: Goal of the analysis

We implemented a novel method "Spectral-ratio model fitting"

The purpose of this study is

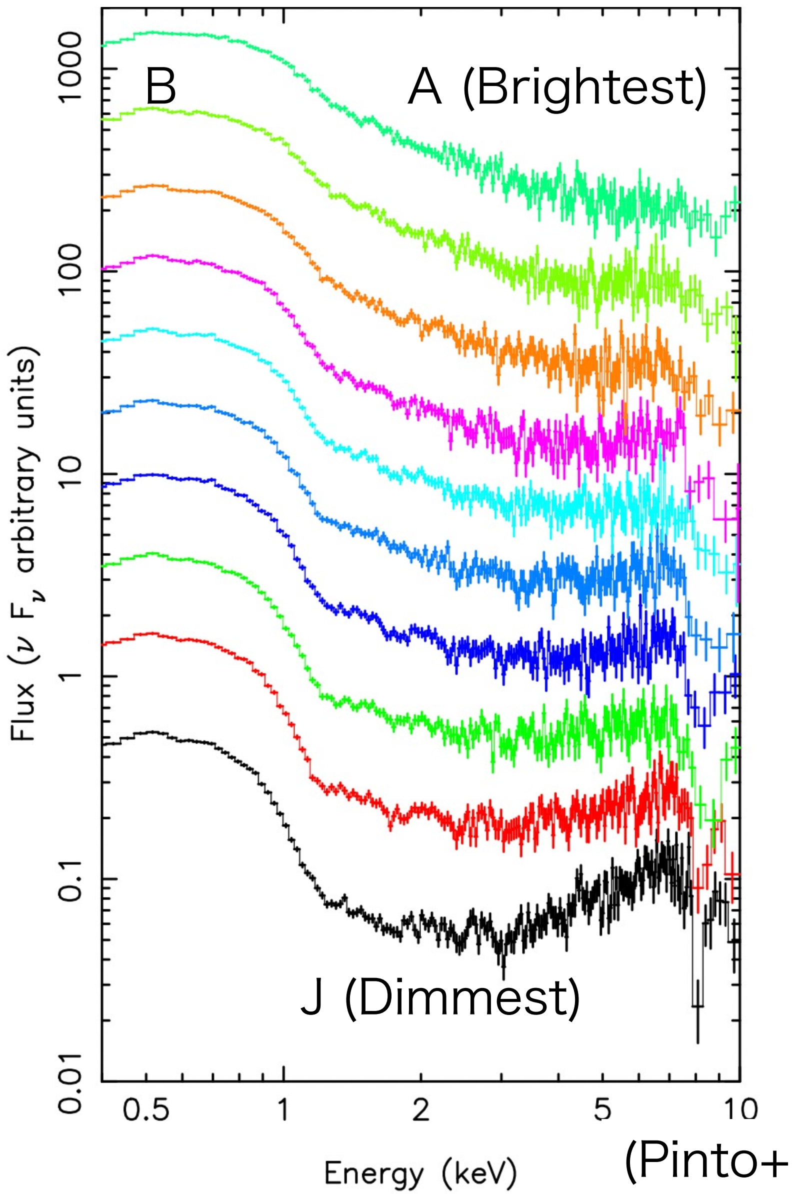
- to constrain v_{out} of the clumps
- to confirm whether the clumps are outflowing

2. Target: NLSy1 IRAS 13224-3809

- $0.5\text{–}2 \times 10^6\ M_\odot$ (Alston+19)
- 1.5Ms observed by XMM-Newton in 2016
- 0.2-0.3c UFO absorption lines detected
- The dimmer the X-rays,
  - the deeper the UFO absorption (Parker+17)
  - the slower the UFO velocity (Chartas+18)
- Spectral variation can be modeled with partial absorption by clumps(Yamasaki+16)

→ Ideal target to examine the relation between the UFO and the clumps

Intensity-sliced spectra



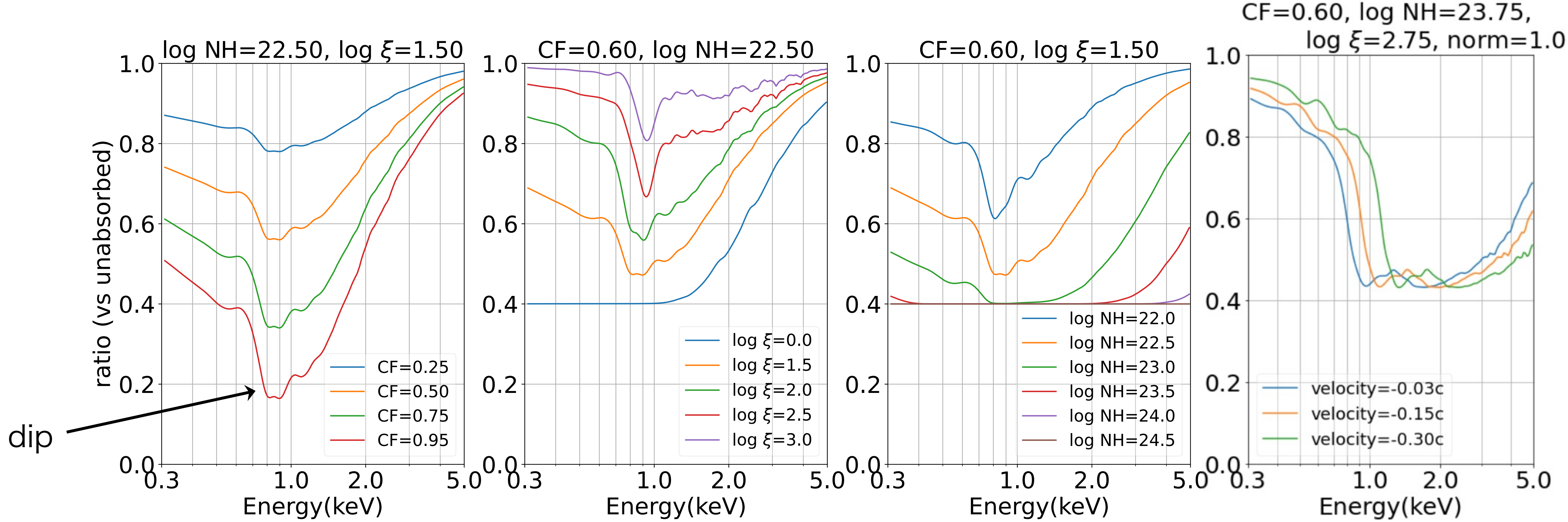
(Pinto+18)

3. Method: Spectral-ratio models

Model: PL partially absorbed by ionized clumps (pow*zxipcf)

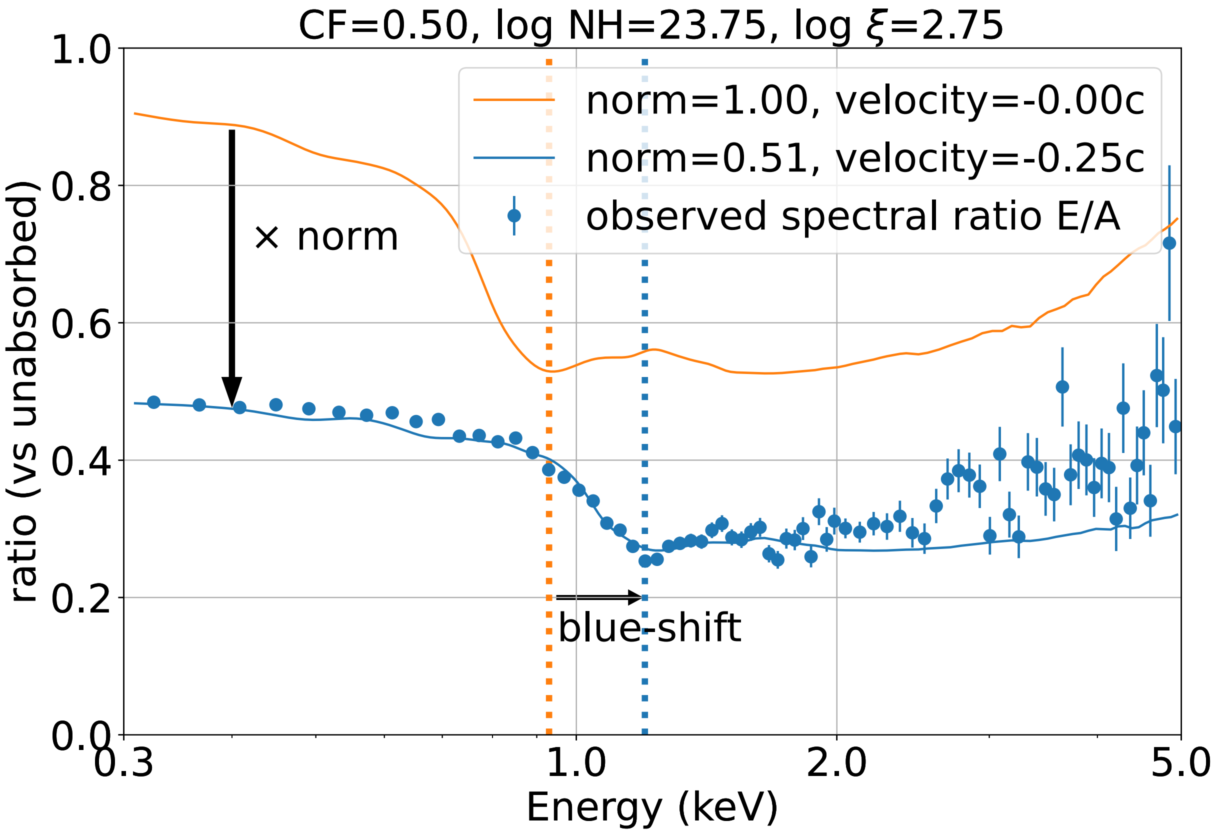
Assumption: covering fraction (CF) of the brightest spectrum is 0

Modeled spectral ratios by taking the ratio to the brightest one



3. Method: model vs observation

Shape of the spectral ratio is determined by the clump parameters (CF, $\xi, N_{\rm H}$)

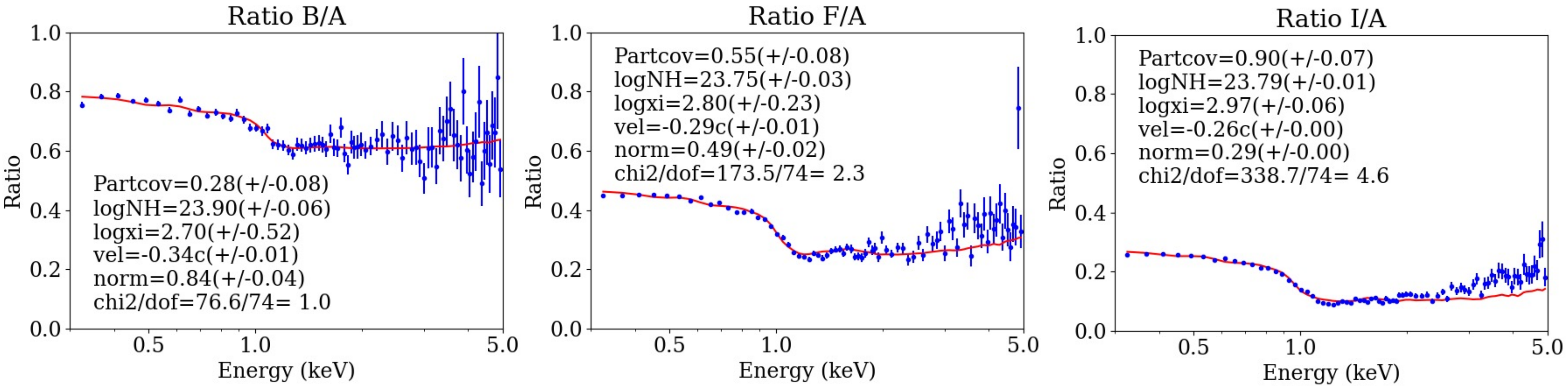


Dip energy needs to be blue-shifted

In addition to the above parameters, we need variations of continuum norm and outflow velocity $v_{\rm out}$ of clumps

4. Results: Spectral-ratio model fitting

brighter ←- → dimmer



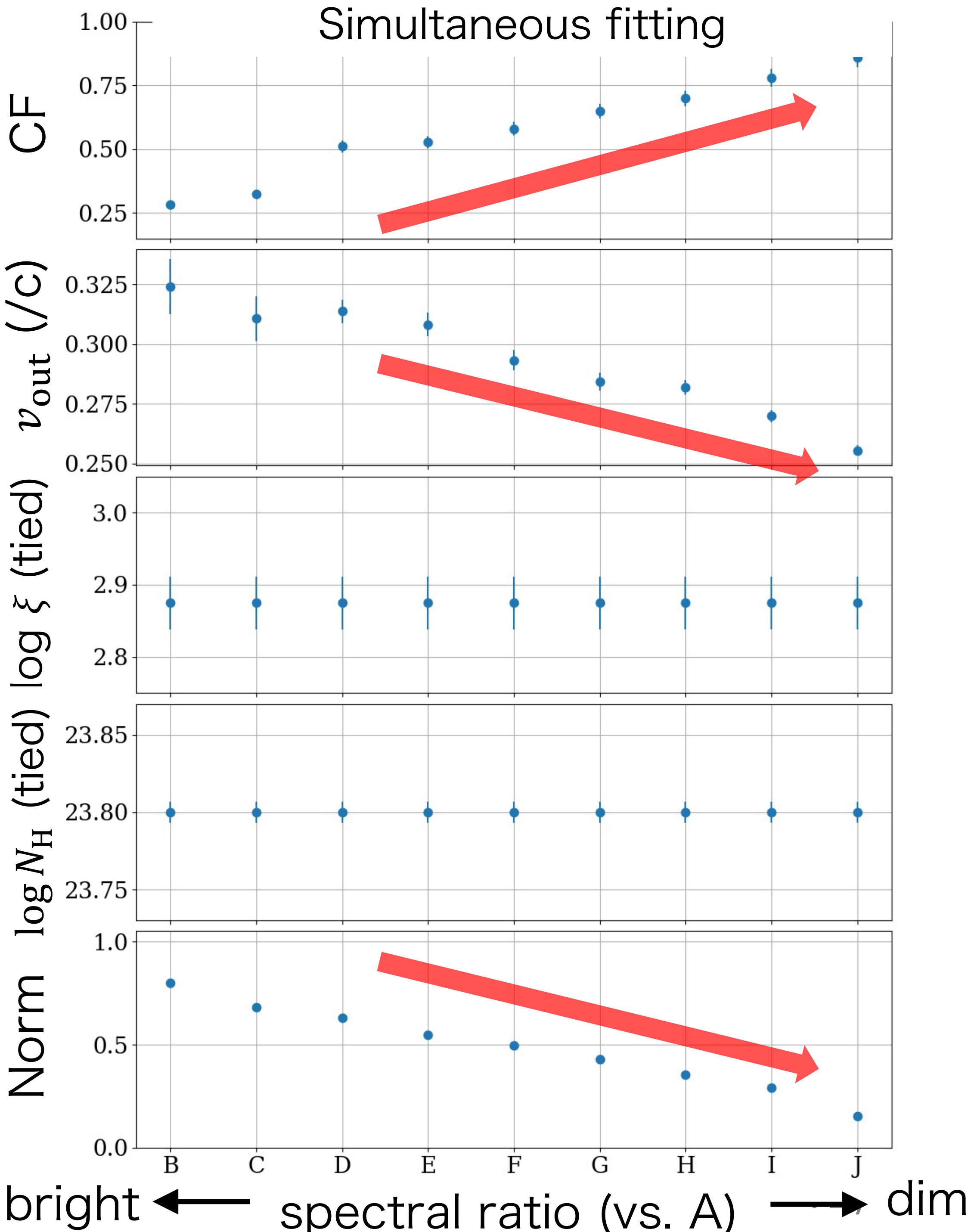
All the 9 (B/A … J/A) observed spectral ratios
are successfully fitted

* Residuals above 3 keV may be due
to changes in PL index

4. Results: best-fit params

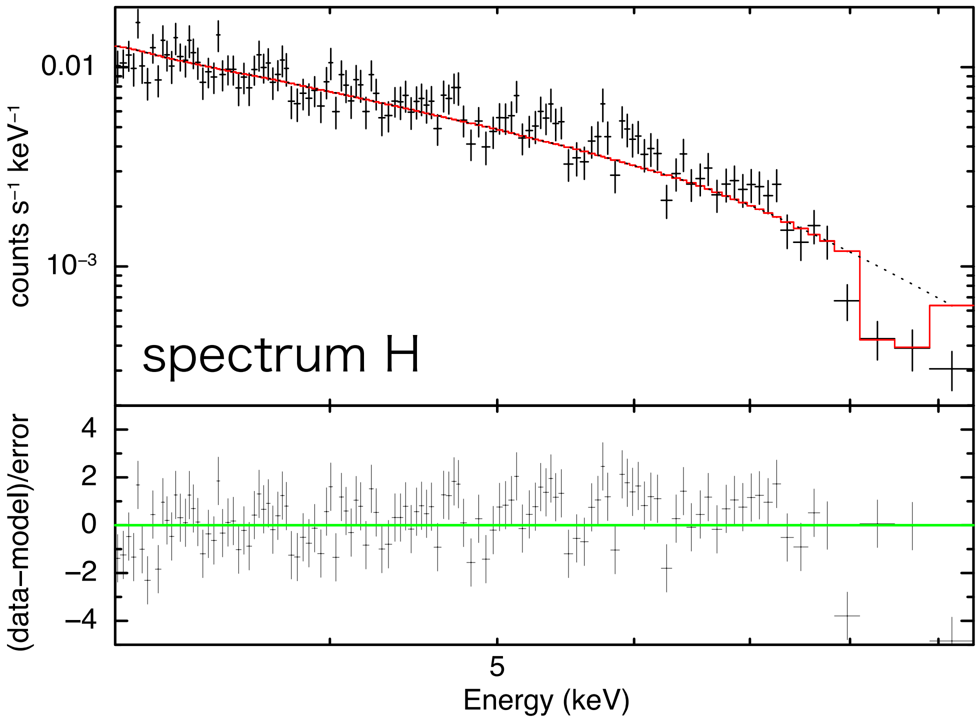
- v_{out} is strongly constrained and comparable to that of the UFO (~0.2-0.3c)
- As the X-ray flux gets dimmer
  - CF gets higher
  - v_{out} gets lower
  - PL norm gets lower
- constant ξ, N_{H} regardless of flux

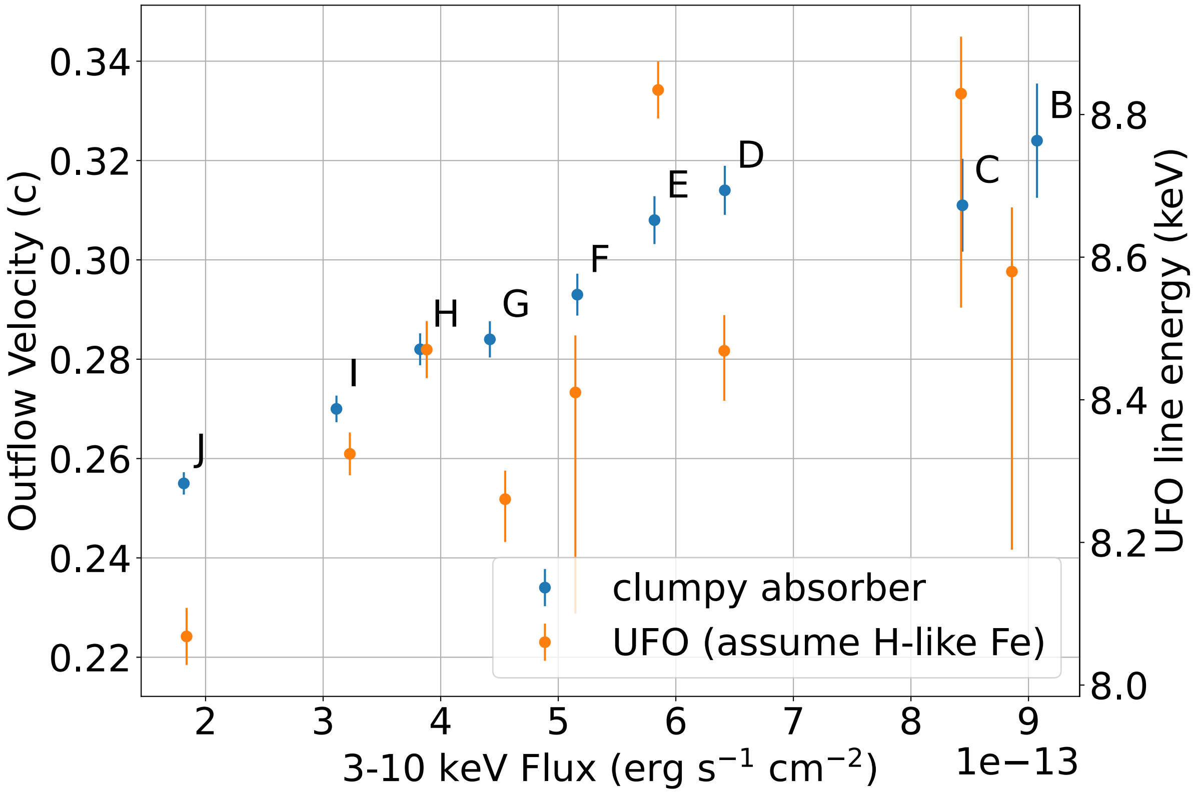
➡ First observational indication that the clumpy absorber is driven by the radiation pressure



4. Results: Velocity of the clumps and UFO

We fitted each intensity-sliced spectrum assuming a simple model (PL + gauss).
UFO velocities are estimated from the best-fit UFO line energy.





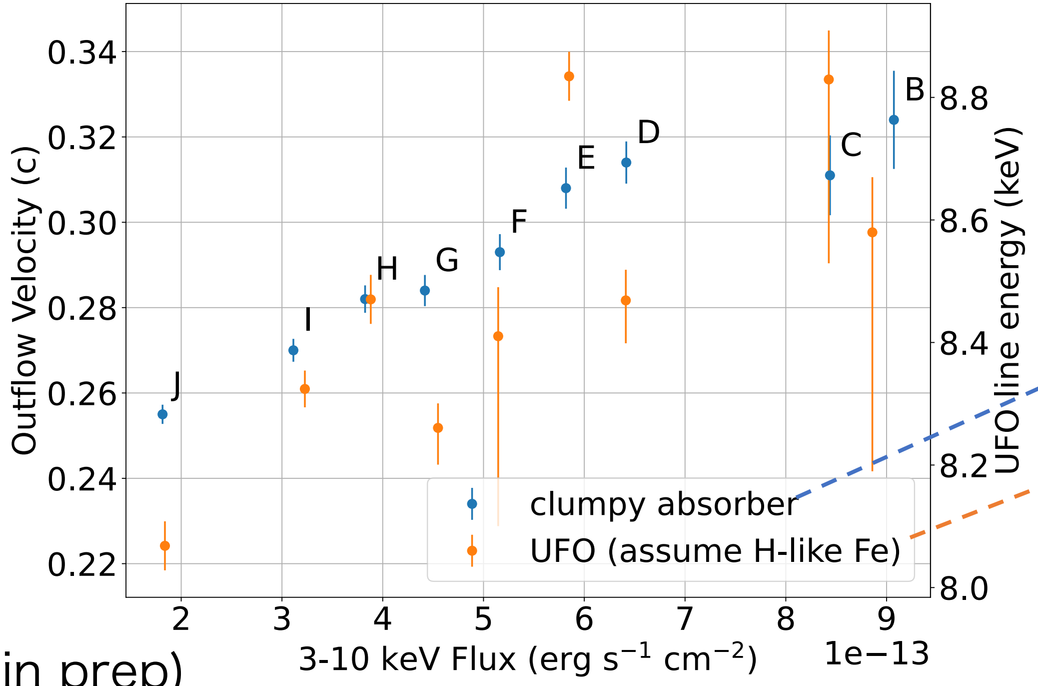
- Velocity of the clumps are comparable to that of the UFO
- Similar variations with the X-ray flux

→ consistent with the "Hot-inner Clumpy-outer wind" model

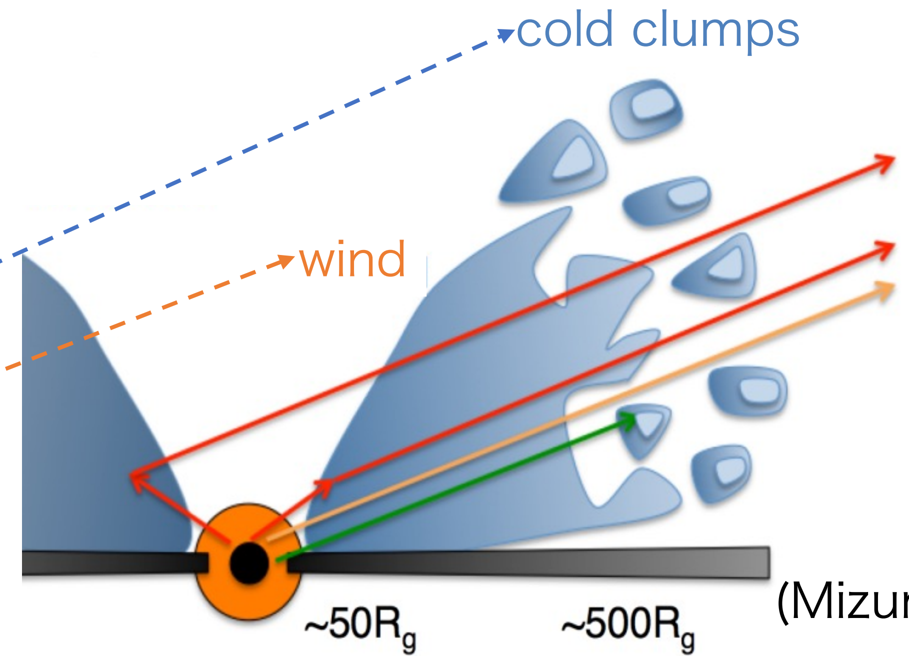
5. Summary

- XMM observed IRAS 13224 for 1.5Ms.
- We invented a "spectral-ratio model fitting" in 0.3-5keV.
- We found that v_{out} of clumps and UFO are comparable and have similar flux dependence.

Our finding supports the "Hot-inner Clumpy-outer wind" scenario.



(TM+, in prep)



(Mizumoto+19)