18.03.2026

X-ray spectral study of the NLS1 galaxy ARK 564

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Young Astronomers Meeting 2026
Nicolaus Copernicus Astronomical Center
Polish Academy of Sciences

Contents

Active Galactic Nuclei

- AGN - central region of Active Galaxies
- Powered by accretion of matter onto SMBH located at the center
- Strong X-ray emission

- Classification of AGN:-

➢ Seyferts
➢ Radio galaxies
➢ Quasars
➢ Blazars

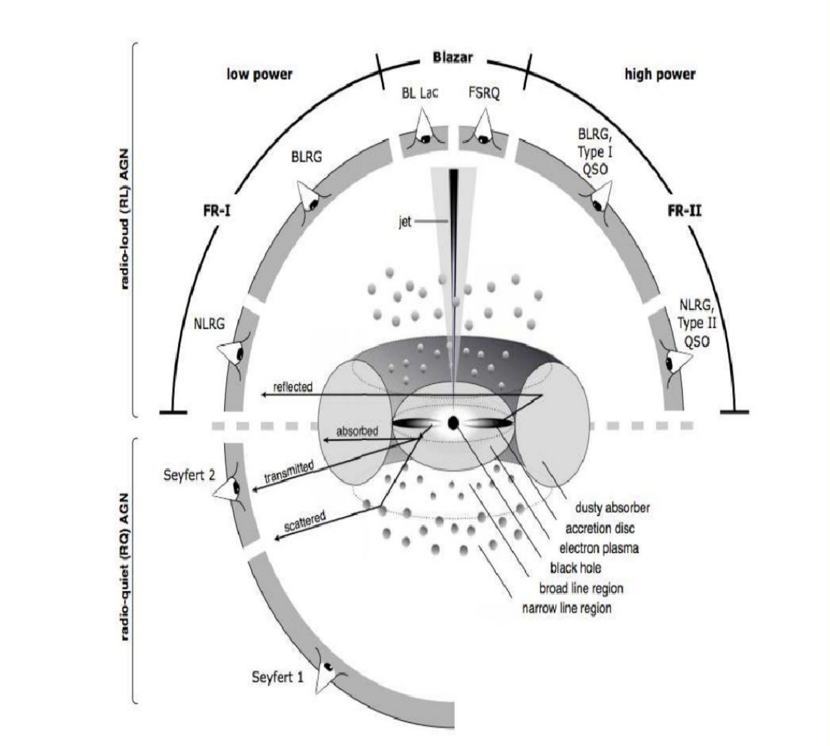


Image credit: Volker Beckmann and Chris Shrader

NLS1 galaxy

- Narrow-Line Seyfert 1 Galaxies (NLS1s) are a subclass of Seyfert galaxies with :
  - Narrow optical Balmer lines
  - Relatively low black hole masses
  - High Eddington accretion rates
- Variability observed on timescales from hours to years
- X-ray variability probes the innermost regions of AGN
- Narrow-Line Seyfert 1 galaxies (NLS1s) often show strong X-ray variability

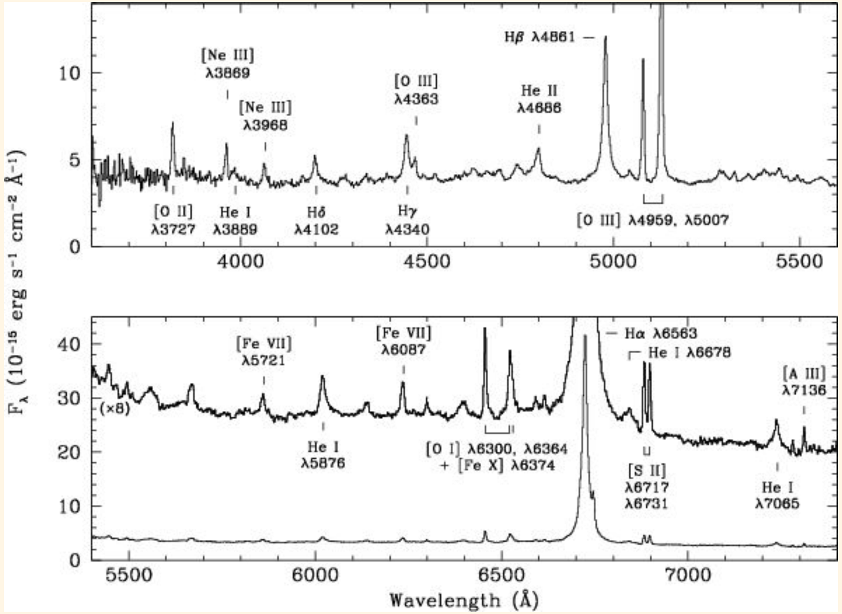


Image credits: A&A 365, 400-408 (2001);DOI: 10.1051/0004-6361:20000152

Source selection

- Source : Ark 564
- Type: Narrow-Line Seyfert 1 galaxy
- Redshift: $z \approx 0.0246$
- Known properties:
  - ➢ Prominent Soft excess
  - ➢ Significant X-ray variability

- Aim :
  - ➢ Long term variability study to understand the disk-corona system
  - ➢ Study the flux variability and luminosity evolution

Observations

- Telescope : Swift-XRT
- Energy Range : 0.3-10 keV
- Multi-epoch observations spanning several years
- Data reduction :
  - ➢ Standard Swift-XRT pipeline
  - ➢ Spectra extracted in XSELECT
  - ➢ Pile-up correction performed
  - ➢ Standard RMF file used
  - ➢ ARF file generated using source spectrum
  - ➢ Spectra grouped for Chi-squared statistics

- Around 70 observations spanning ~16 years

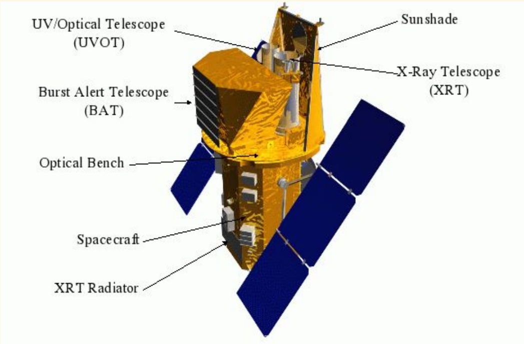


Image credits : UKSSDC Swift

Spectral Analysis

- Galactic absorption: Tbabs ; nH fixed at 4.98 E+20

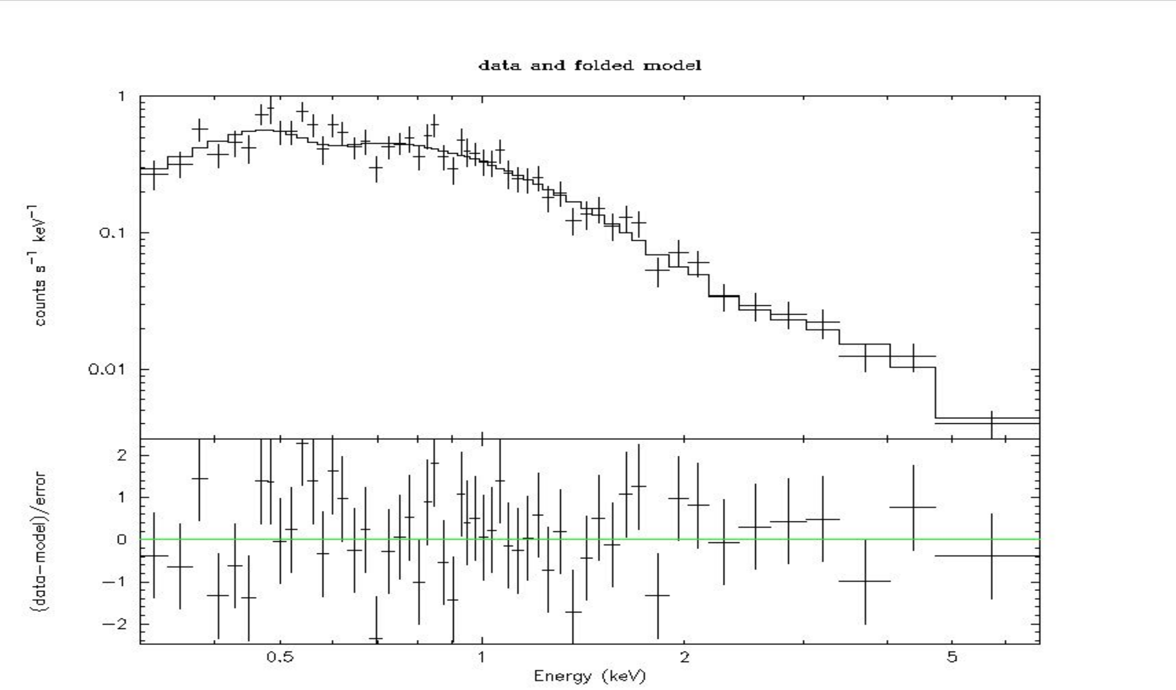
Phenomenological model

- Model: Tbabs*(Power law+Black body)
- Free parameters:
  - ➢ Photon index (Γ)
  - ➢ Power-law normalization

Comptonization model

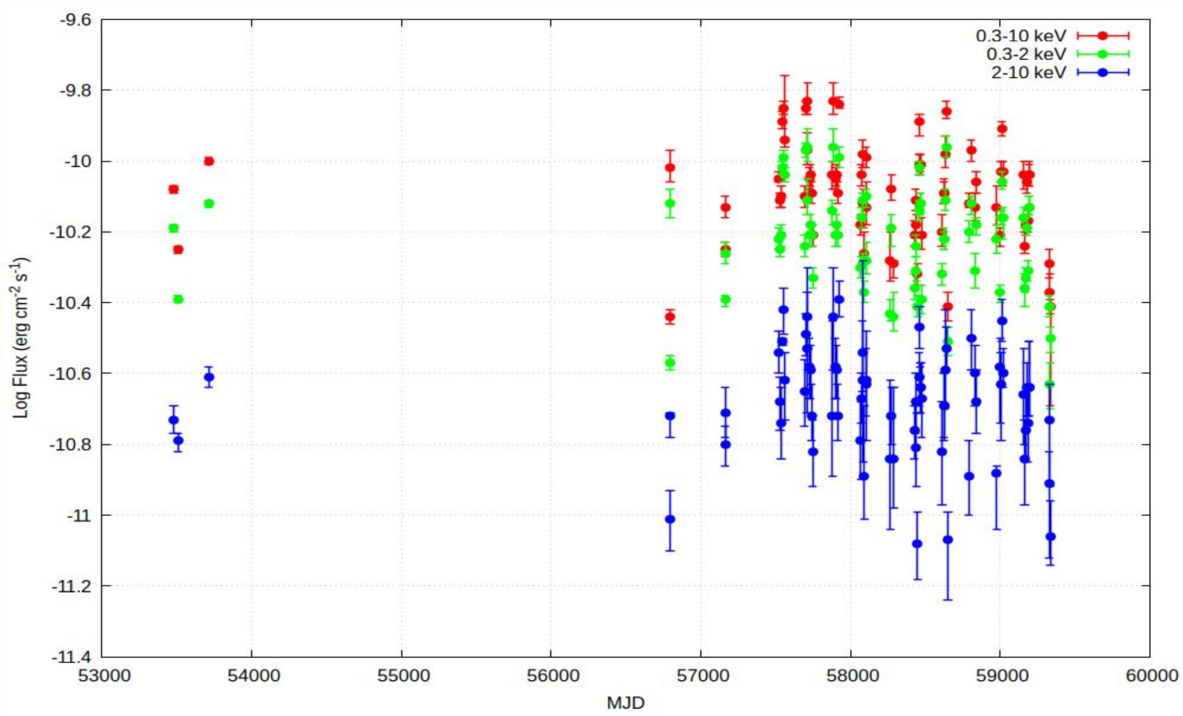
- Model: Tbabs*Simpl*NthComp
- Free parameters:
  - ➢ Simpl Γ
  - ➢ NthComp Γ
  - ➢ Fractional Scattering
  - ➢ Normalization

Spectral Fit Results



Spectral fits in the 0.3-10 keV band for the observation 00081687001 of Ark 564.
Top panel shows the unfolded spectrum and bottom panel shows the data-to-model.

Long-Term Flux Variability



Variation of logarithmic flux values across MJD

Luminosity evolution

- Luminosity calculated from the measured flux values using the equation :

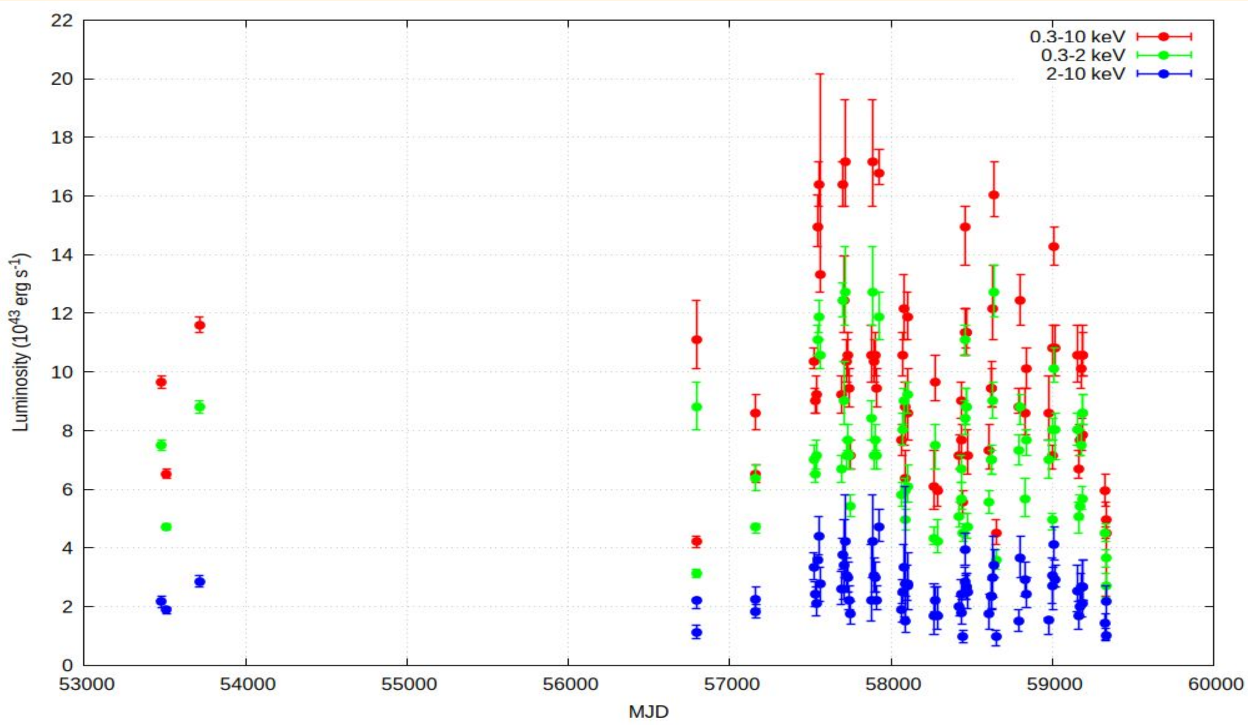
$$L = 4\pi d^2 F$$

- Eddington ratio:

$$L/L_{Edd}$$

$$L_{Edd} \approx 1.26\times10^{38}\ (M/M_{\odot})\ \mathrm{erg\ s^{-1}}$$

Luminosity evolution



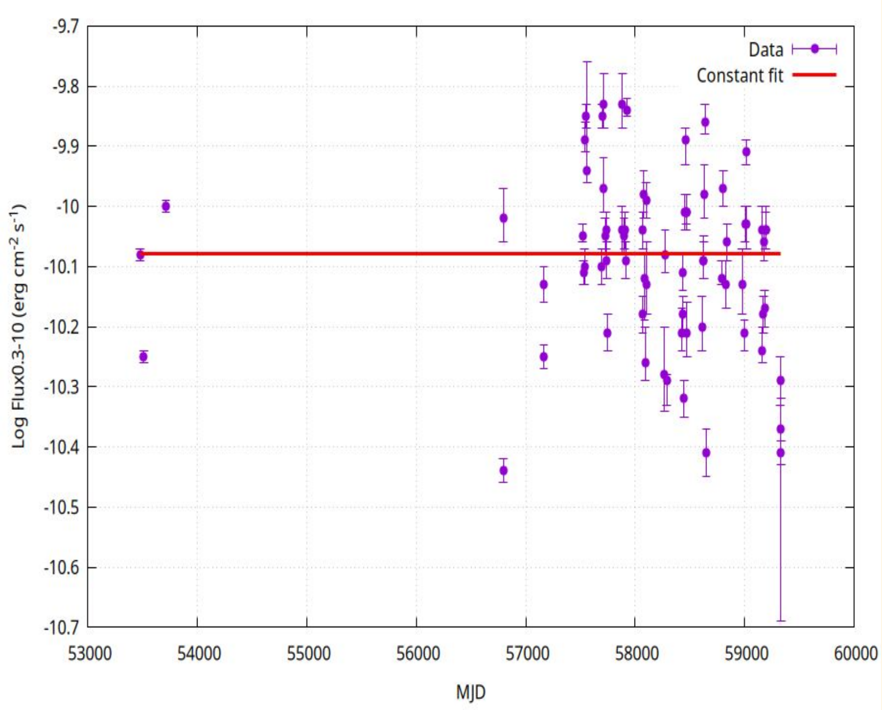
Temporal evolution of Luminosity as a function of MJD

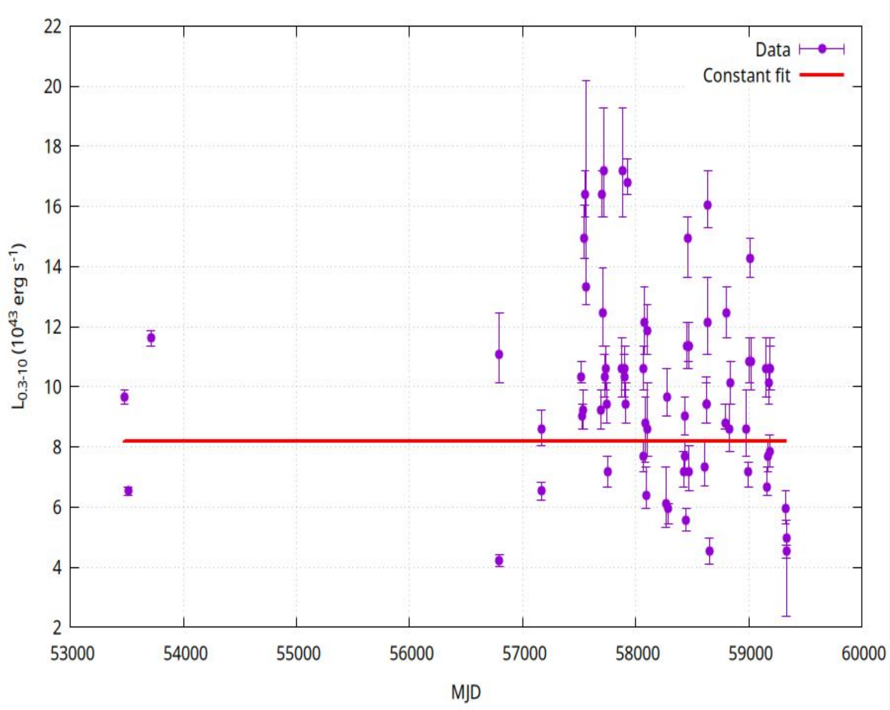
Variability Analysis

- Constant model fitted to parameters
- Variability quantified using reduced χ2

- The variability analysis shows that both flux and luminosity vary significantly over time, with the strongest variability observed in the soft X-ray band.
- The fractional scattering parameter is also highly variable, indicating changes in the disk–corona interaction.
- Photon index remains nearly constant, indicating stable coronal spectral shape across epochs

Parameter	χ^2_v
Γ_{Simpl}	0.64
$logF_{0.3-10}$	28.68
$logF_{0.3-2}$	33.49
$logF_{2-10}$	5.64
Fr_{sc}	13.31
$\log F^{\rm nthcomp}_{0.3-10}$	2.81
$L_{0.3-10}$	30.47
$L_{0.3-2.0}$	33.70
L_{2-10}	7.29
L/L_{edd}	29.91
$L^{nthcomp}_{0.3-10}$	2.45
$L_{nthcomp}/L_{edd}$	2.44



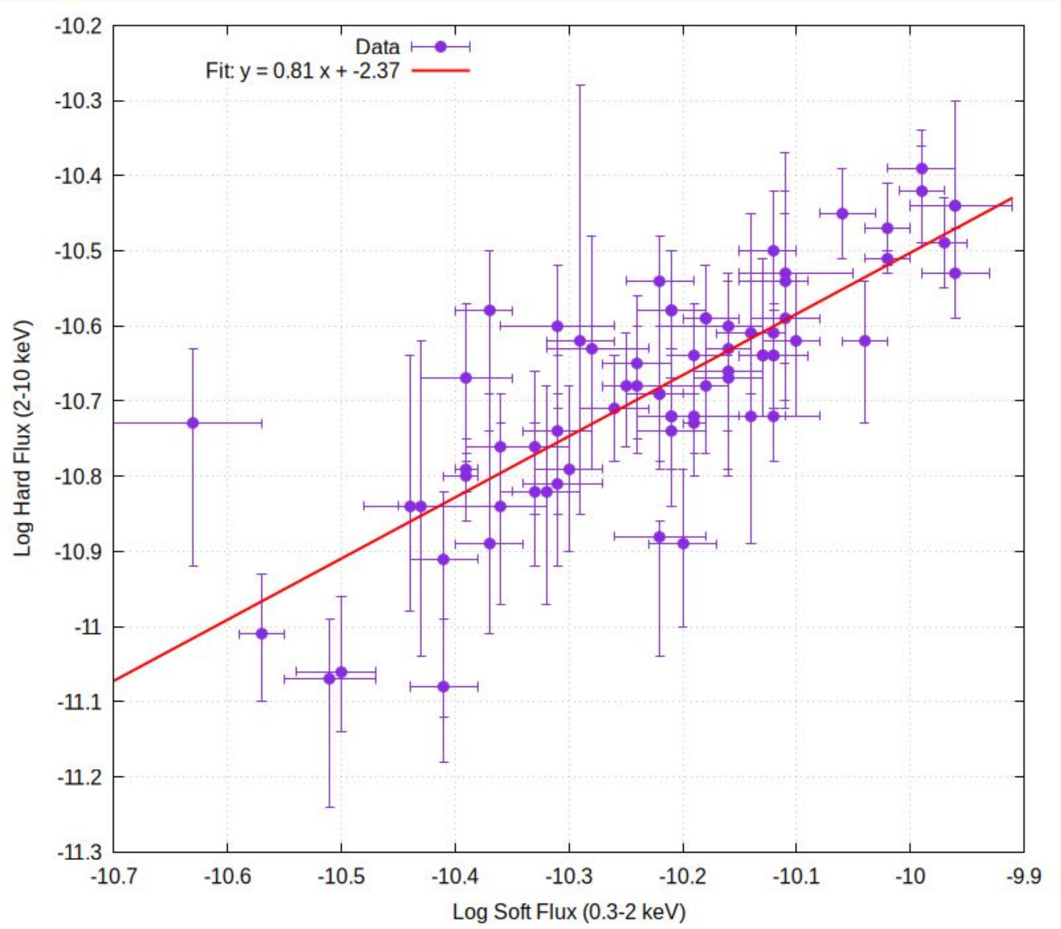


χ2 analysis of flux and luminosity of the model Tbabs*Simpl*NthComp

Correlation Analysis

- Pearson and Spearman correlation tests performed
- Correlation strength quantified using *r* and significance via p-values

- Strong positive correlations between fluxes in different energy bands, indicating that the variability is largely coherent across the X-ray spectrum.
- In contrast, the spectral parameters, such as the photon index and fractional scattering, show little to no significant correlation with flux. This suggests that while the overall emission varies significantly, the spectral shape remains relatively stable.



Correlation analysis of log flux in hard (2-10 keV) and soft (0.3-2 keV) bands

Results and Discussion

- Strong long-term variability in flux and luminosity
- Highest variability in soft X-ray band
- Fractional scattering (Fsc) is variable
- Photon index Γ remains constant
- Strong flux–flux correlations across energy bands
- No significant correlation between spectral parameters and flux

Conclusion

- Ark 564 exhibits strong long-term X-ray variability, particularly in the soft energy band
- Both flux and luminosity show significant variations over time, indicating a highly dynamic emission process
- The photon index remains nearly constant, suggesting that the overall spectral shape does not change substantially
- Strong correlations between fluxes in different energy bands indicate that the variability is coherent across the X-ray spectrum
- The variability is primarily driven by changes in emission strength, while the coronal properties remain relatively stable

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Thank you!

Table 3: Pearson Correlation between different parameters. Column 3 indicates pearson's correlation coefficient and column 4 indicates p-value. Fluxes are given in units of erg cm^{-2} s^{-1}

Model	Parameter 1	Parameter 2	r	p
tbabs*(pow+bbody)	Γ_{Pl}	$logF_{0.3-10}$	-0.15	0.17
	Γ_{Pl}	$logF_{0.3-2}$	-0.03	0.73
	Γ_{Pl}	$logF_{2-10}$	-0.48	0.00
	$logF_{0.3-10}$	$logF_{2-10}$	0.85	0.00
tbabs*Simpl*Nthcomp	Fr_{sc}	$logF_{0.3-10}$	-0.06	6.63×10^{-1}
	Fr_{sc}	$logF_{0.3-2}$	-0.04	7.50×10^{-1}
	Fr_{sc}	$logF_{2-10}$	0.003	9.82×10^{-1}
	$logF_{0.3-2}$	$logF_{2-10}$	0.75	1.84×10^{-11}
	$\log F_{0.3-2}^{\rm nthcomp}$	Fr_{sc}	0.17	0.21

Table 4: Spearman's correlation between different parameters. Column 3 indicates Spearman's rank order correlation coefficient and column 4 indicates p-value. Fluxes are given in units of erg cm^{-2} s^{-1}

Model	Parameter 1	Parameter 2	r	p
tbabs*(pow+bbody)	Γ_{Pl}	$logF_{0.3-10}$	-0.10	0.33
	Γ_{Pl}	$logF_{0.3-2}$	-0.006	0.95
	Γ_{Pl}	$logF_{2-10}$	-0.42	6.28×10^{-5}
	$logF_{0.3-10}$	$logF_{2-10}$	0.84	2.03×10^{-23}
tbabs*Simpl*Nthcomp	Fr_{sc}	$logF_{0.3-10}$	-0.09	5.34×10^{-1}
	Fr_{sc}	$logF_{0.3-2}$	0.05	7.16×10^{-1}
	Fr_{sc}	$logF_{2-10}$	-0.04	7.86×10^{-1}
	$logF_{0.3-2}$	$logF_{2-10}$	0.74	2.13×10^{-11}
	$\log F_{0.3-2}^{\rm nthcomp}$	Fr_{sc}	0.02	0.84