AGN feeding at Super-Eddington rates and AGN ionised wind feedback from the gravitational - up to the kpc-scale: Recent results from eROSITA

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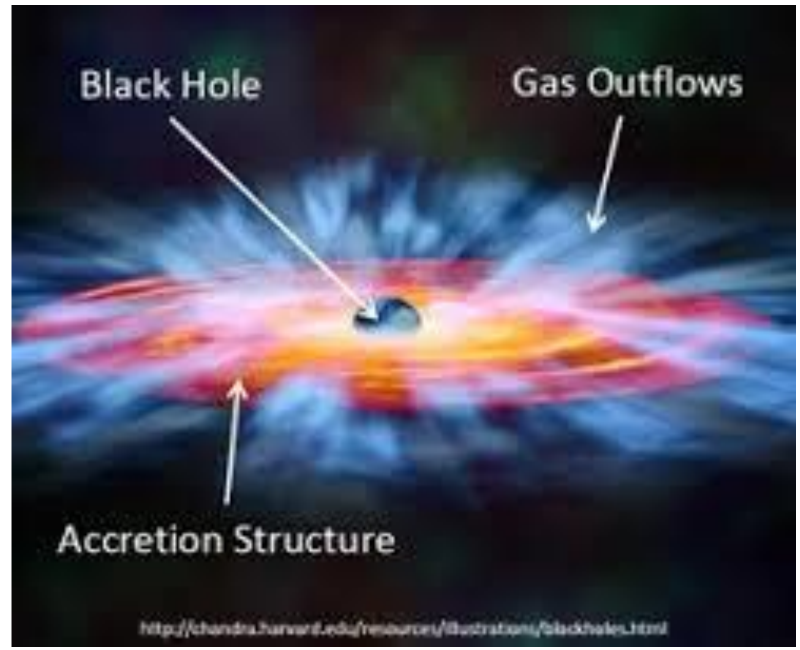


I . Ionised outflows from X-ray absorption lines

II. Ionised outflows and ultra-soft X-ray variability

III. Ionised outflows from NLS1 studies with eROSITA in SDSS DR12

I. AGN ionised outflows from X-ray absorption lines

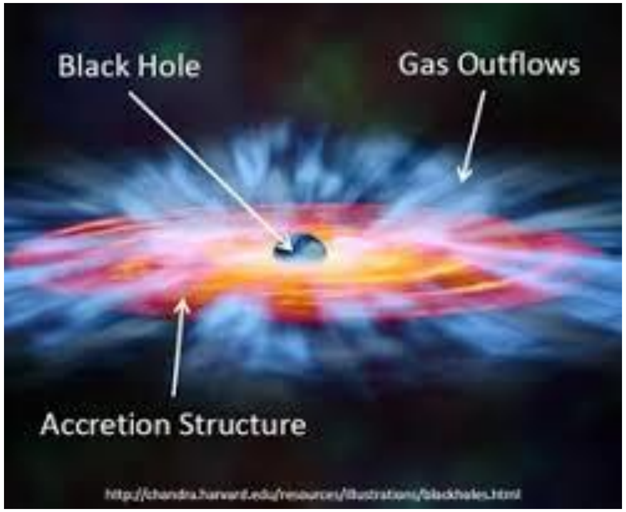


Image credit: S.M. McGraw
http://www.phy.ohio.edu/~mcgraw/Research.html

Outflowing winds, launched from the accretion disk, provide the most promising mechanism for driving AGN feedback.

These winds deposit enormous amounts of energy out of the galaxy.

The energy is larger then the binding energy of the galaxy, capable for driving feedback (Fabian 2012).

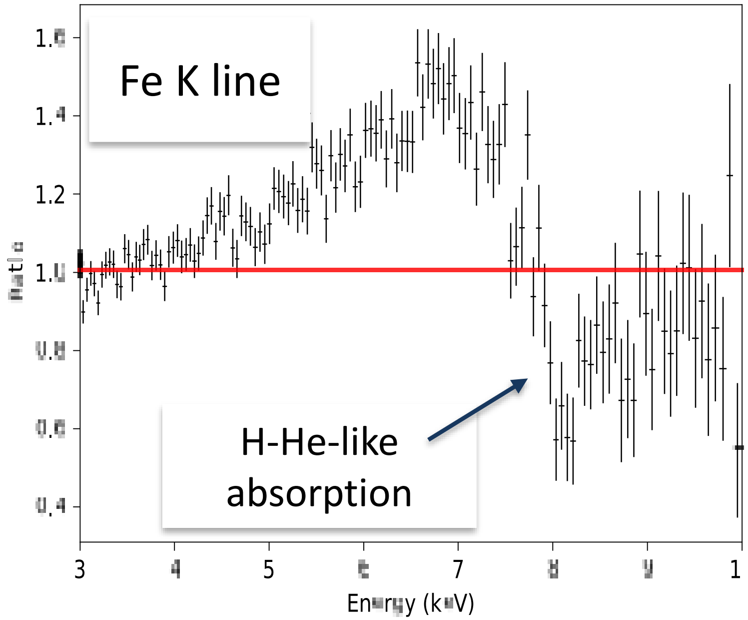
Winds are accelerated by radiation pressure and magnetic fields reaching 0.2-0.3 c (e.g. Pounds et al. 2003, King 2003).

There are two modes of feedback, radiative (winds) and kinetic (jets).

This shuts off star formation and cuts off fuel for further AGN accretion.

AGN Outflows

Winds - Feedback – UFOs – **absorption lines** – partial covering



X-rays are being absorbed by outflowing winds that crosses our line of sight to the central X-ray source.

This leads to atomic absorption lines in AGN spectra as signatures of outflowing winds.

Absorption lines at energies between 8-9 keV are explained **by blueshifted H-like (6.7 keV) and He-like (6.97 keV) lines** (Chartas 2002, Pounds 2003, Reeves 2003, discovery papers).

This requires outflowing wind velocities of 0.2-0.3 c.

AGN Outflows

Winds - Feedback **– UFOs –** absorption lines – partial covering

Some UFO detections that are beyond question,

- because of the detection of multiple absorption lines from several different elements with the same velocity, e.g. PG 1211+143 Pounds (2003)

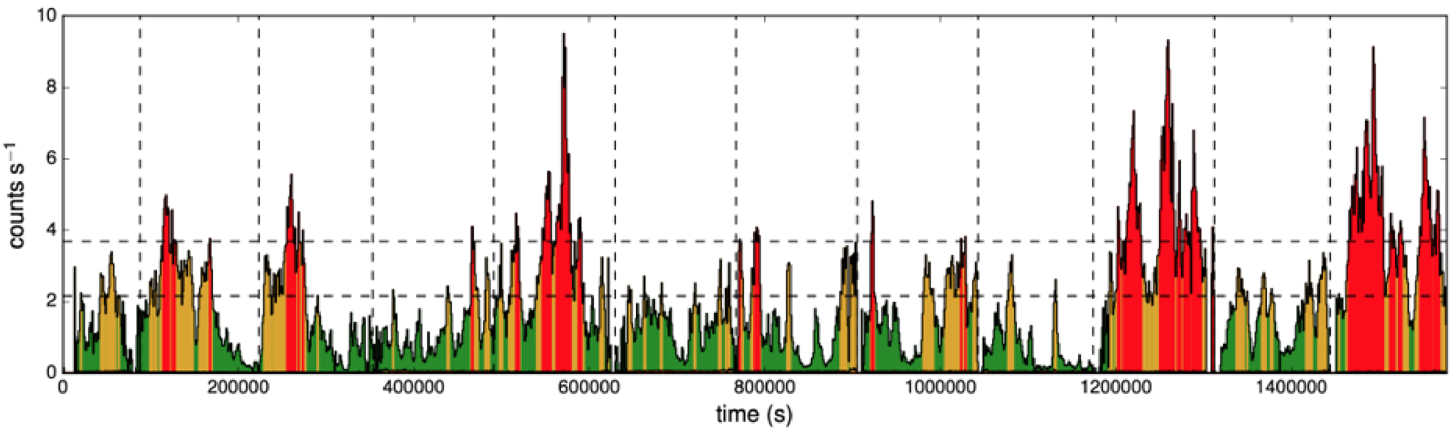
- because the same absorption feature is found from multiple instruments, e.g. PDS 456: Reeves (2018)

- because break-through observations of IRAS 13224-3809 have been performed with the longest uninterrupted X-ray observing campaign for a single AGN ever taken (Parker 2017)

AGN Outflows

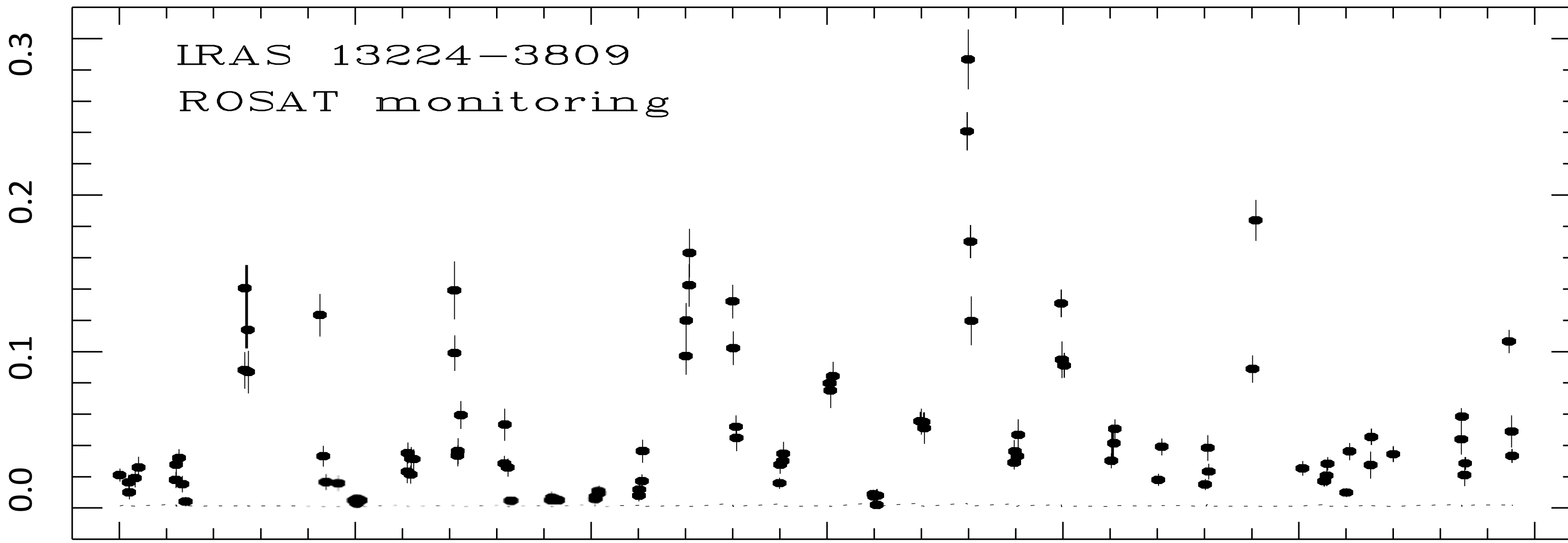
Winds - Feedback – UFOs – absorption lines – partial covering

IRAS 13224-3809



Parker 2017

1.5 Msec



time (s)

Boller 1997

2.6 Msec

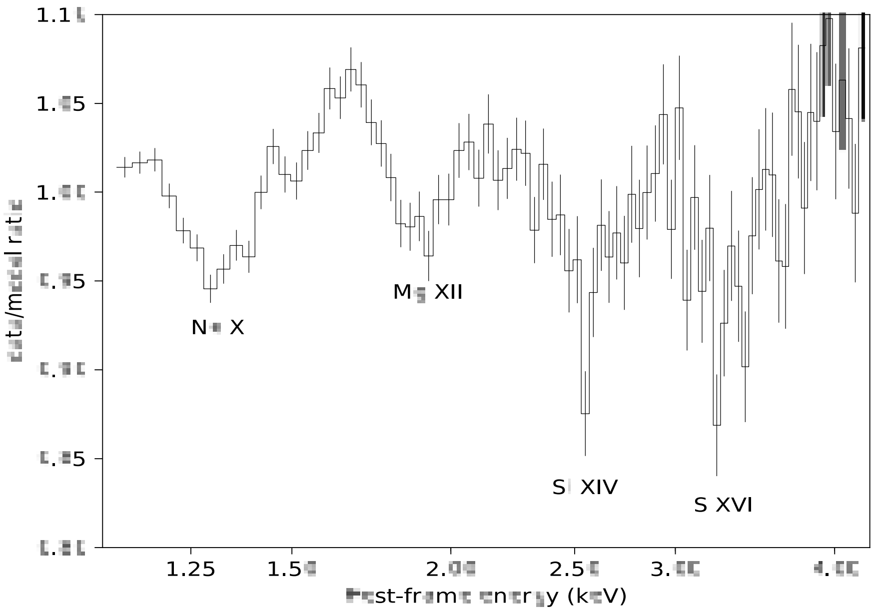
AGN Outflows

Winds - Feedback **– UFOs – absorption lines** – partial covering

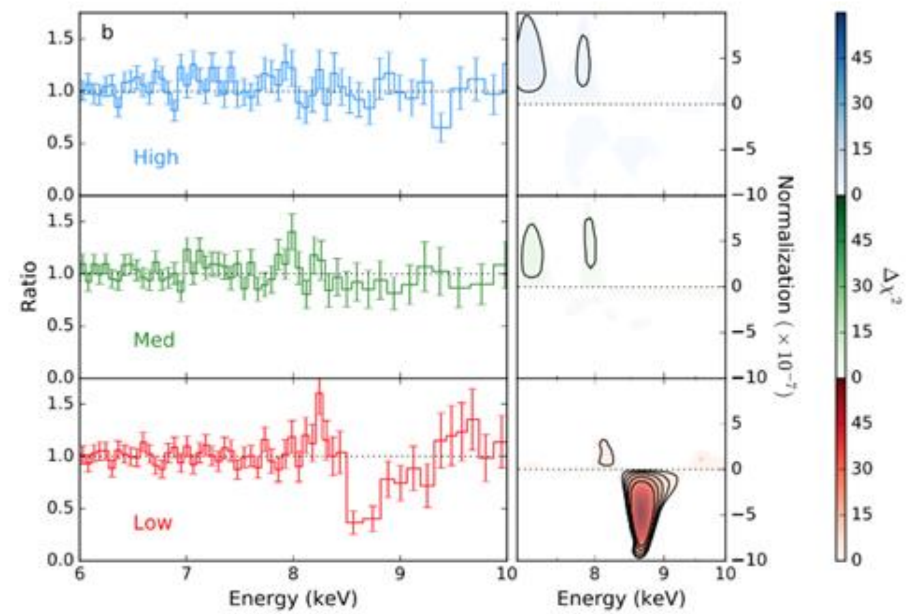
multiple absorption lines from different elements, all blue-shifted by a velocity of 0.23c

v = 0.23 c

IRAS 13224-3809



over-ionisation in high flux state

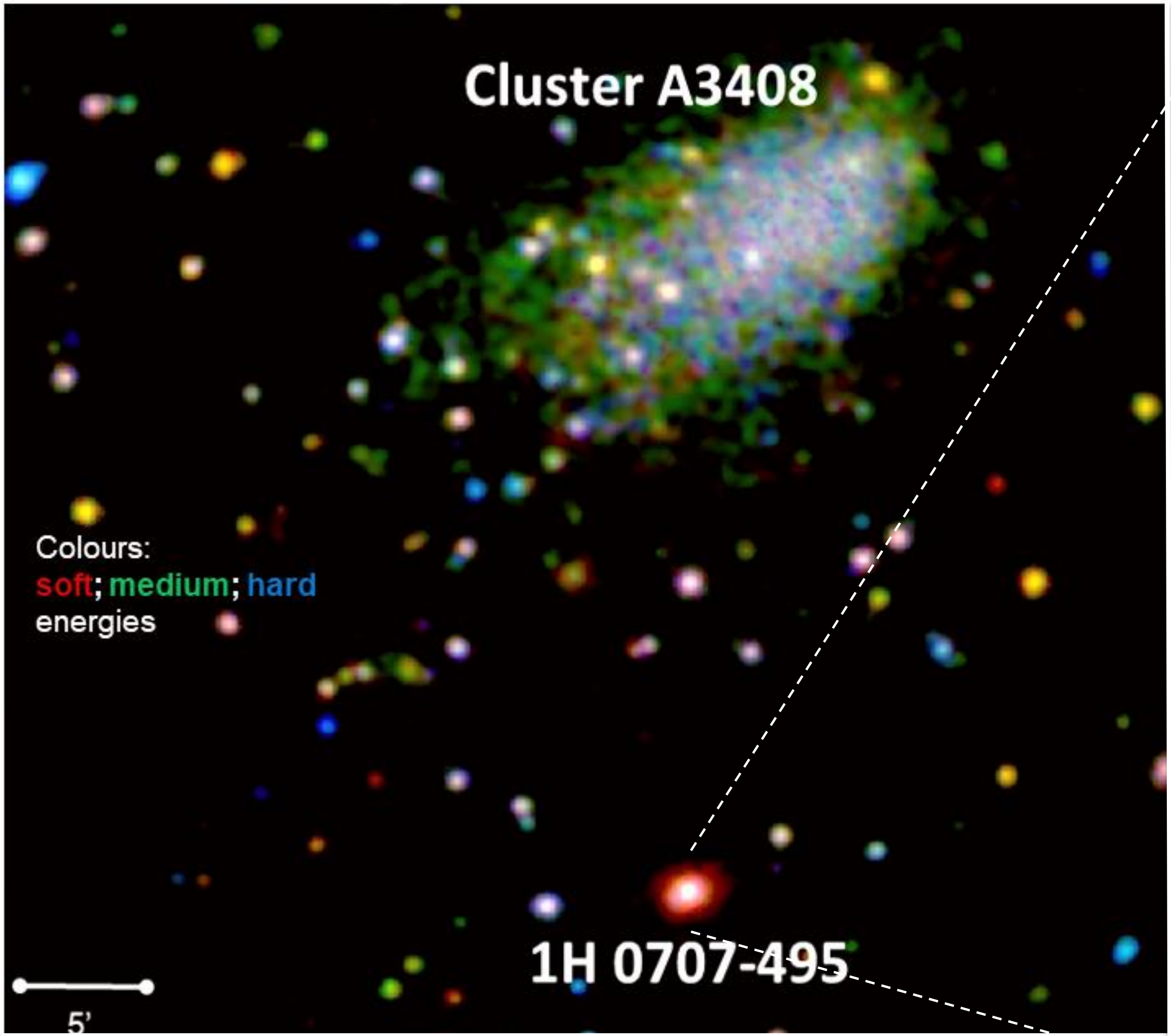


low-ionisation degree in low flux state
wind detectable

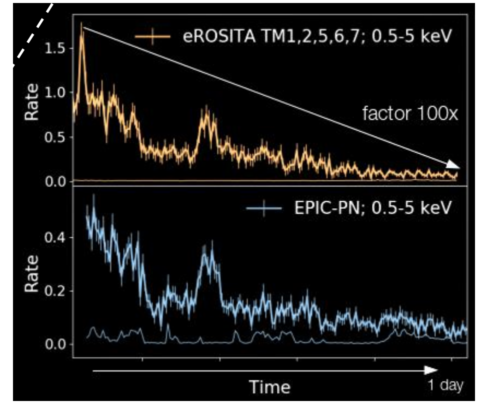
II. Ionised outflows and ultra-soft X-ray variability

Discovery of ultra-soft X-ray variability in an eROSITA observation of 1H 0707−495

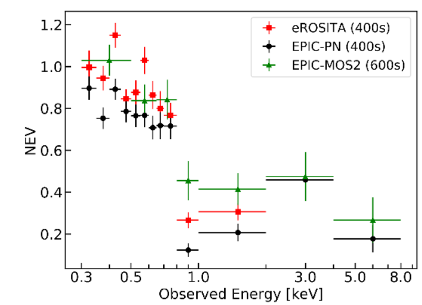
Th. Boller, T. Liu, P. Weber, R. Arcodia, T. Dauser, J. Wilms, K. Nandra, J. Buchner, A. Merloni, M.J. Freyberg, M. Krumpe, S. G. H. Waddell
Astronomy and Astrophysics, 2021



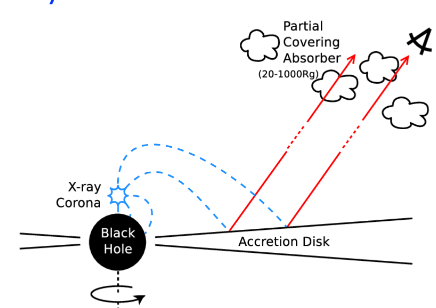
Extreme amplitude variability



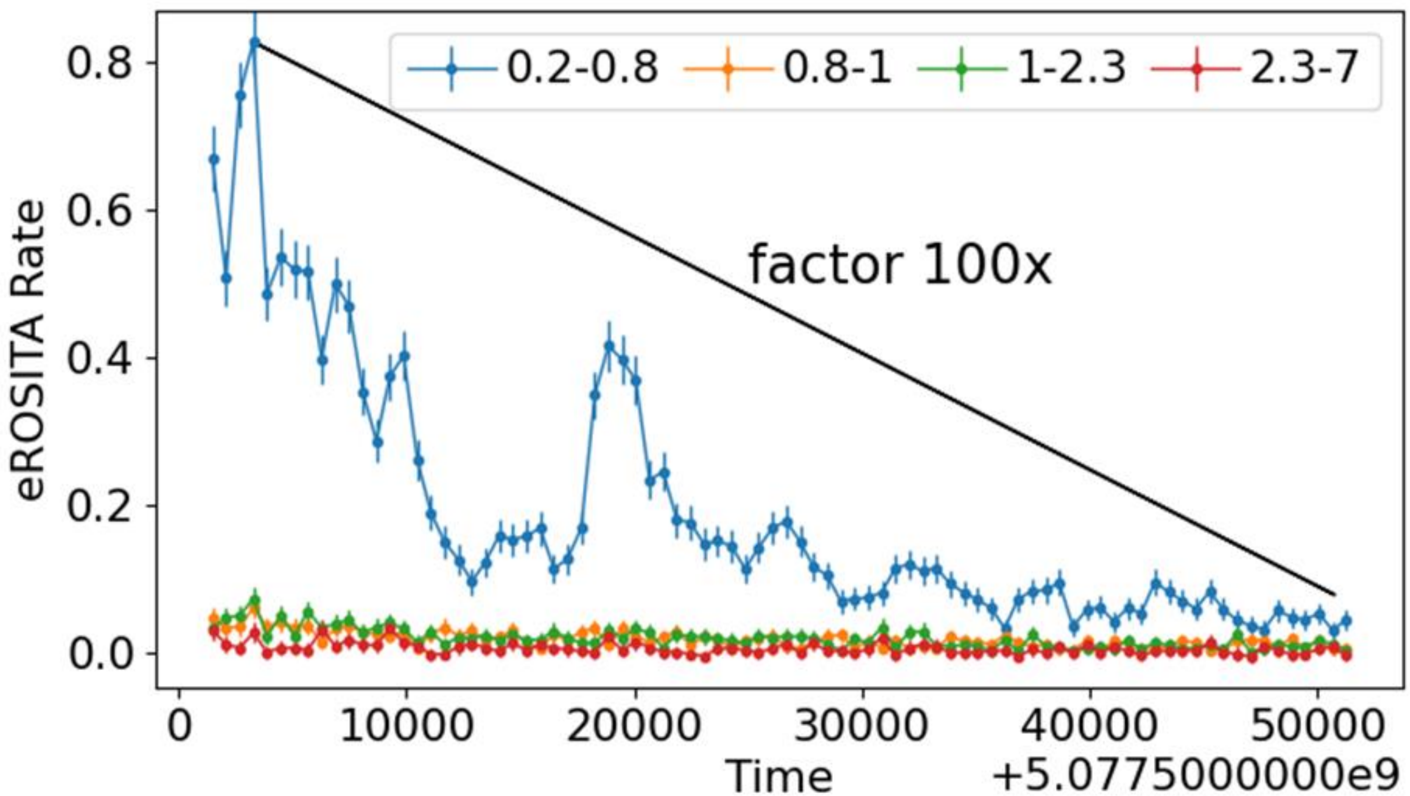
Extreme ultra-soft variability



Physical model



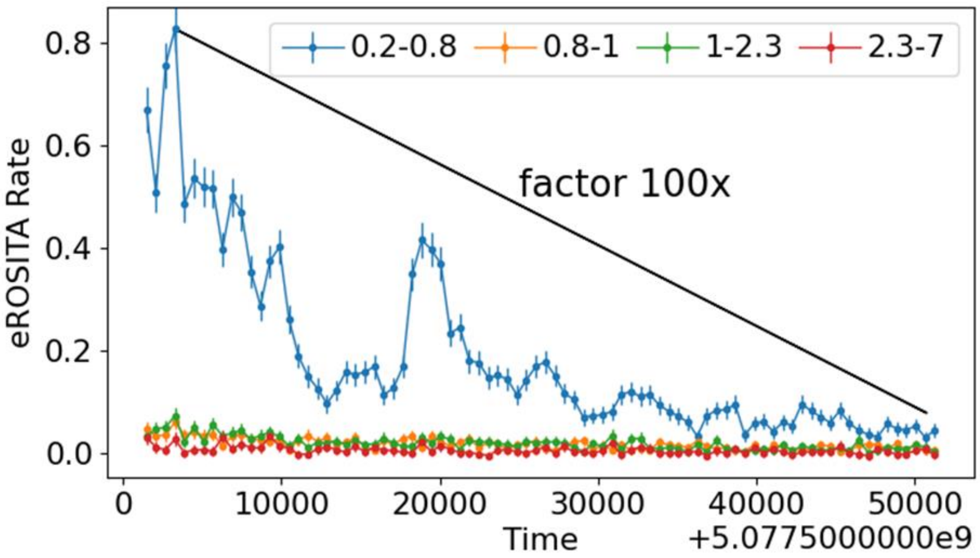
Extreme amplitude variability with a factor of 100 in just one day

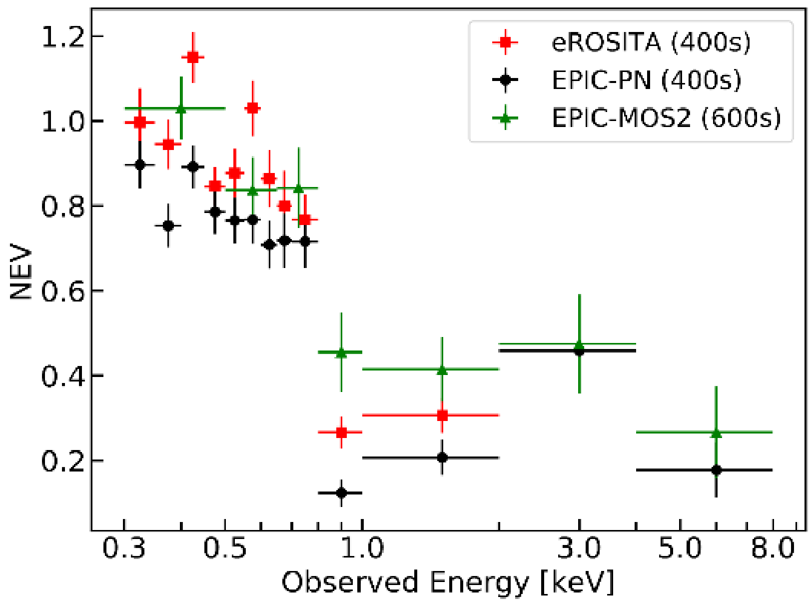


1H 0707-495 showed a dramatic flux drop in about one day.

Such extreme ultra-soft and large-amplitude flux variability in active galactic nuclei has not been detected with other X-ray observations so far.

Exteme ultra-soft variability





eROSITA light curve in four energy bands.

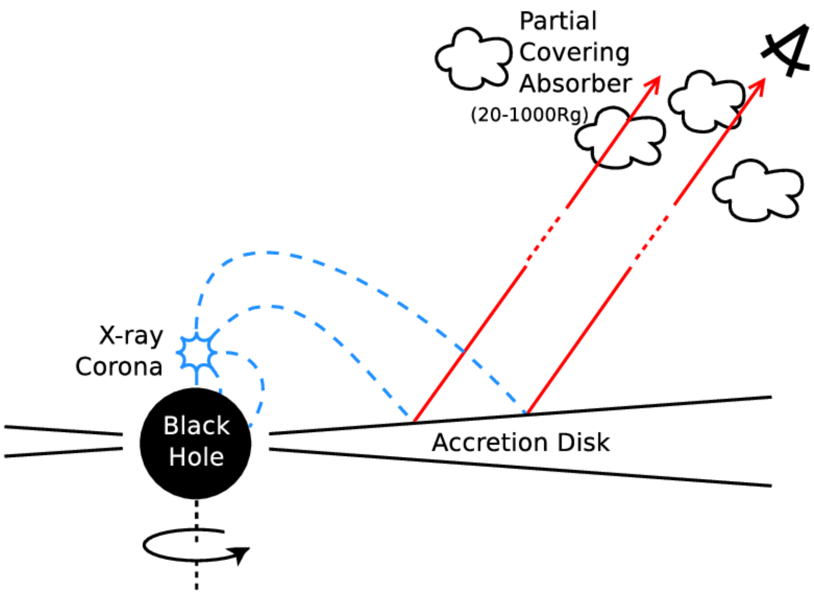
The energy band up to only 0.8 keV is dominating the amplitude variability.

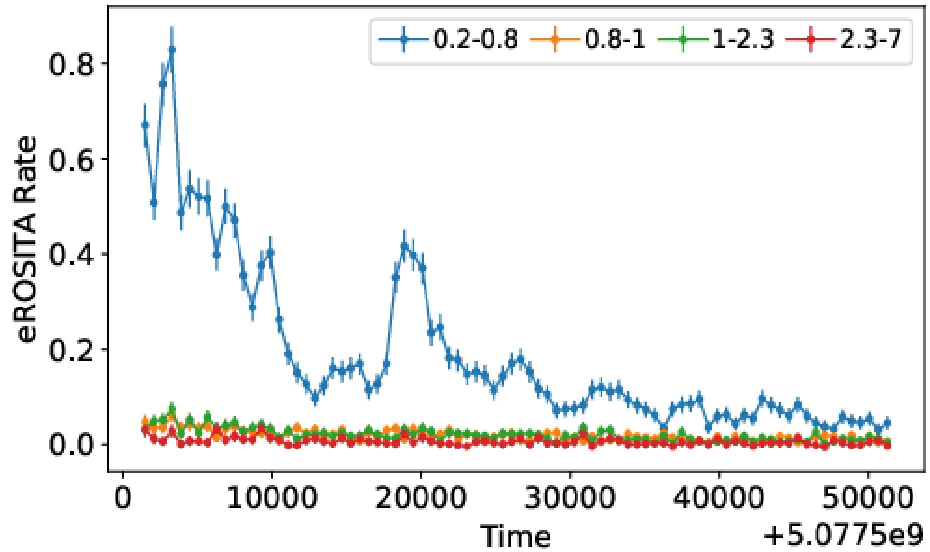
Absence of such variations in above 0.8 keV.

The Normalized Excess Variance (NEV) spectra confirm the ultra-soft variability below 0.8 keV.

Physical Model

Ionized outflowing clumpy winds



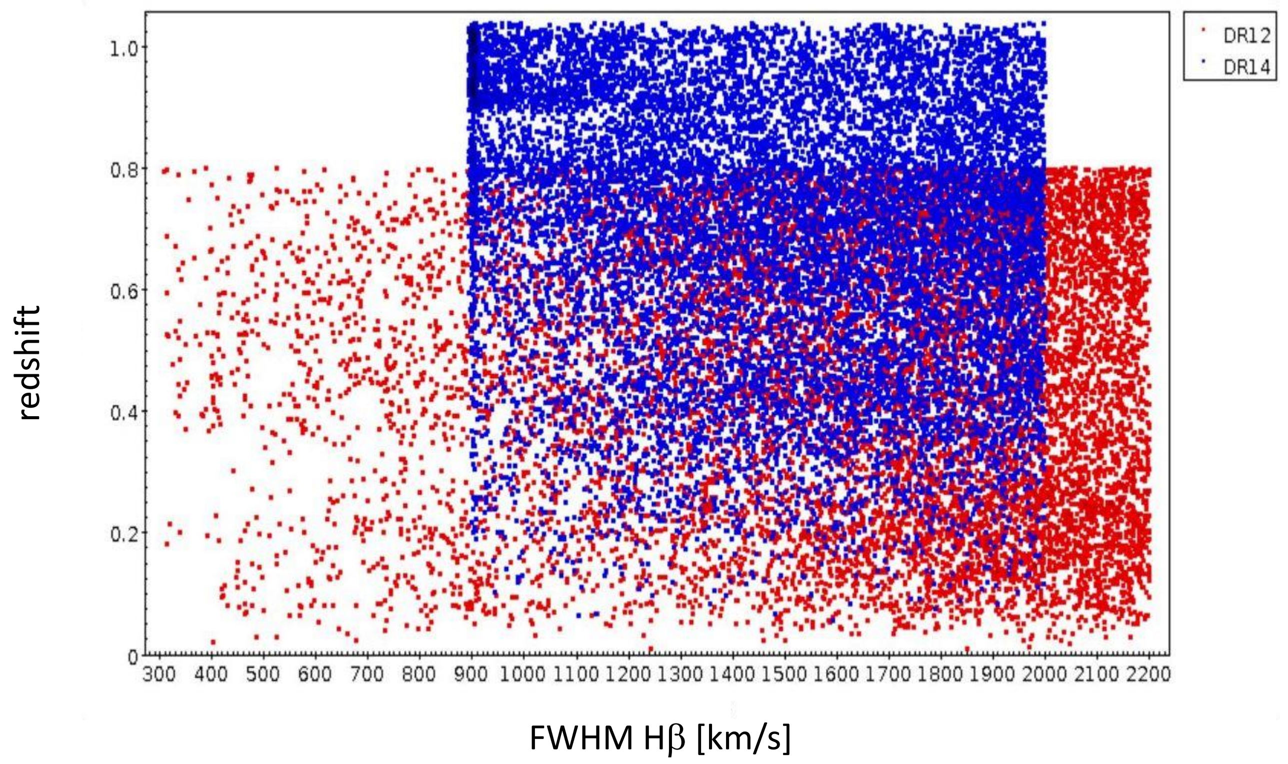


Ionized outflowing absorbers are **more transparent in the soft X-rays** than neutral absorbers and thus **show leakage effects in the soft X-rays**, explaining the ultra-soft light curve

III. Ionised outflows from NLS1 studies with eROSITA in SDSS DR12

The first look at narrow-line Seyfert 1 galaxies with eROSITA

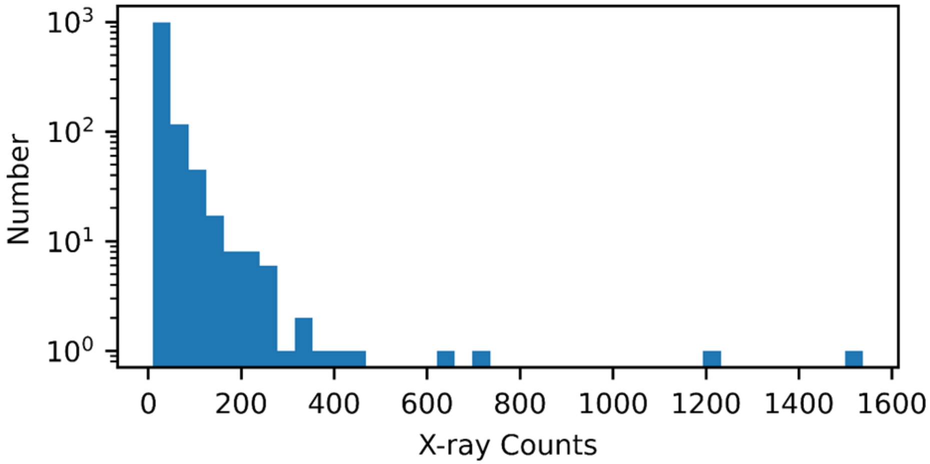
Th. Boller, G. Grünwald S. Rakshit et al.

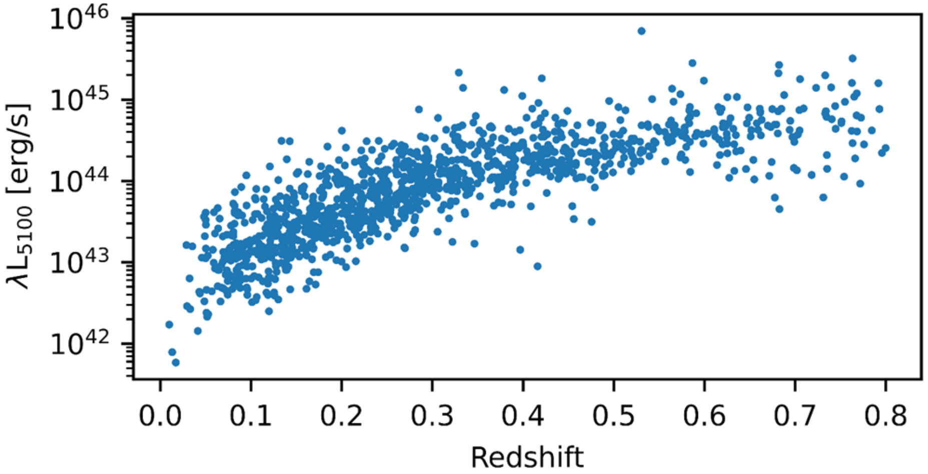


21.000 NLS1 identifications from SDSS DR12, DR14 QSO catalogues (Rakshit 2017, 20, 21)

The largest sample of spectroscopically confirmed NLS1s to date.

DR12 NLS1s cross-match with eRASS1





2142 NLS1s from: DR12 NLS1 catalogue

861 NLS1s from: DR14 QSO catalogue

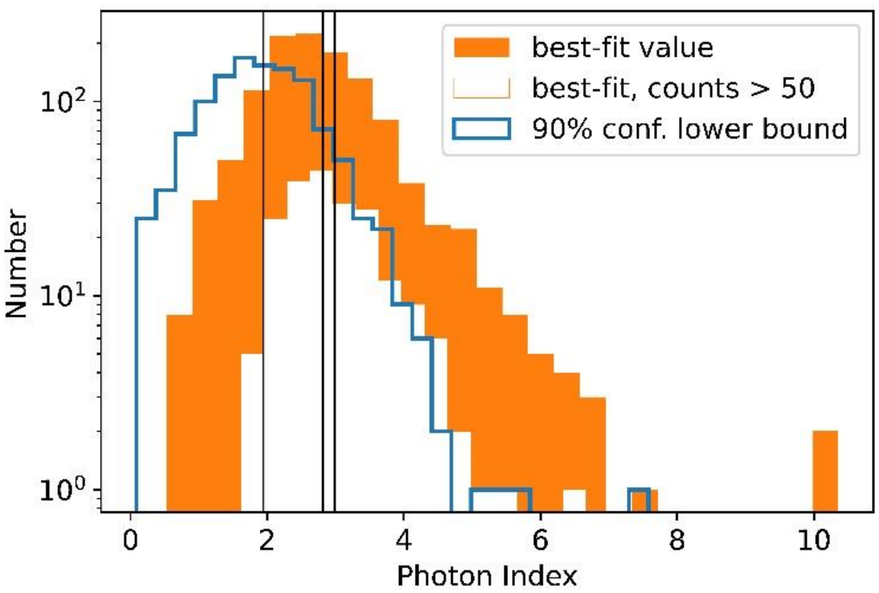
82 NLS1s from: high-redshift catalogue

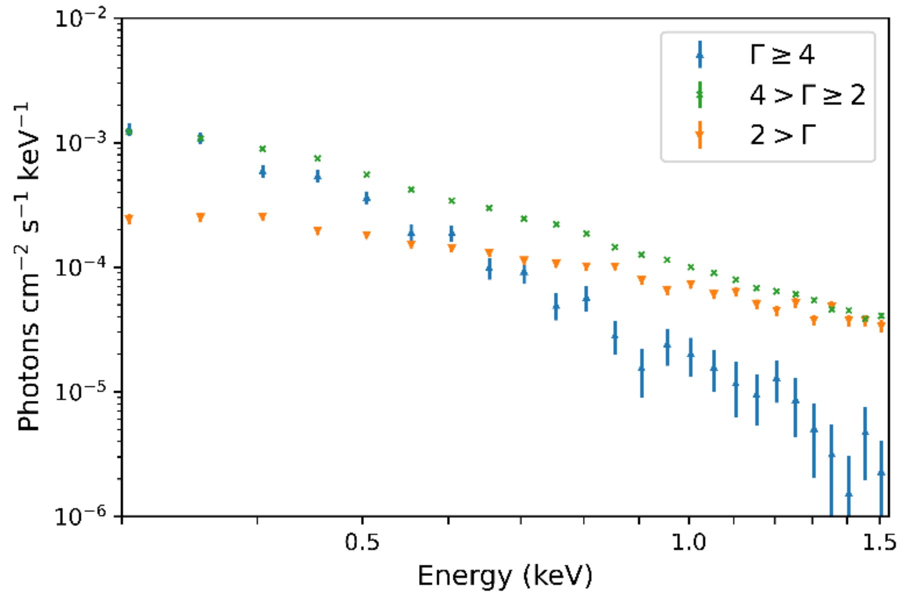
2530 NLS1s to study NLS1 physics

SDSS DR12 eRASS1 Spectral Analysis

steep photon index distribution as expected

1. Detection of an ultra-soft X-ray photon index tail with values between 4 and 10



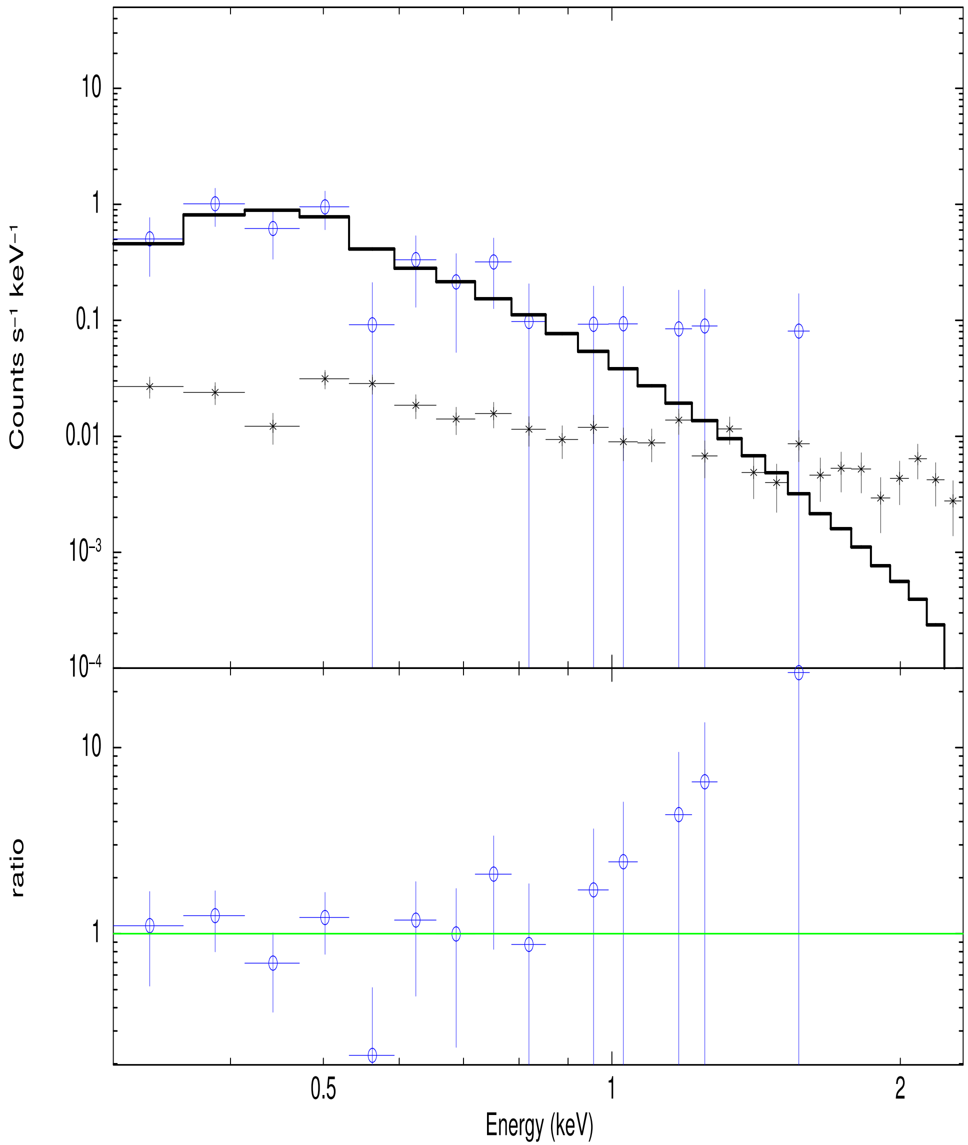


10 per cent of the sample in the super soft tail

DETUID	PhoIndex	PhoIndex_lower	PhoIndex_upper	nH	nH_lower	nH_upper	cts	z
em01_140084_020_ML00023_001_c946	10.385502	7.198757	10.688715	0.611793	0.356340	0.832680	24.337200	0.3417
em01_209084_020_ML00124_002_c946	8.782125	4.525496	10.299629	0.501824	0.121941	0.738113	14.280355	0.7337
em01_129054_020_ML00018_002_c946	8.533560	4.786647	10.640280	0.309060	0.089364	0.548738	23.739782	0.2662
em01_189072_020_ML00051_001_c946	8.378783	4.952550	10.223104	0.599076	0.221664	1.079725	18.795660	0.2137
em01_183069_020_ML00035_001_c946	8.065990	4.772657	10.755741	0.524685	0.265365	0.942294	15.409771	0.2246
em01_152090_020_ML00006_002_c946	7.388509	5.817737	10.579296	0.698390	0.505968	1.175435	48.462673	0.2885
em01_174066_020_ML00054_003_c946	7.154804	3.877715	10.879382	0.399609	0.230112	1.302544	14.215561	0.3727
em01_154078_020_ML00020_002_c946	7.066828	4.523824	10.898712	0.875940	0.395542	2.005721	20.455444	0.1630
eb01_192063_020_ML00197_002_c946	6.971652	3.355024	10.548374	0.324658	0.086484	0.657355	12.496328	0.6718
em01_170066_020_ML00019_001_c946	6.920359	4.407906	10.368034	0.202407	0.064773	0.448717	27.740050	0.2942
em01_161069_020_ML00051_001_c946	6.879091	4.573071	10.744977	0.261516	0.074513	0.681341	13.863149	0.5796
em01_053090_020_ML00134_002_c946	6.877900	4.483353	10.710673	0.425715	0.217371	1.131812	11.560096	0.3773
em01_135060_020_ML00043_003_c946	6.785499	4.656496	10.845284	0.476882	0.297247	1.344705	15.260881	0.2729
em01_144081_020_ML00104_002_c946	6.610566	3.385393	10.402319	0.344511	0.087934	0.860576	10.946913	0.2131
em01_151069_020_ML00050_002_c946	6.564499	3.165260	9.985895	0.295944	0.018897	0.807131	19.151955	0.0818
em01_164090_020_ML00027_002_c946	6.558144	3.171082	10.625506	0.257539	0.076205	0.795410	11.303929	0.4427
em01_182063_020_ML00029_001_c946	6.425486	4.074032	10.614256	0.274848	0.083628	0.730711	27.981413	0.4355
em01_137084_020_ML00067_003_c946	6.401820	3.848216	9.501036	0.408056	0.145125	0.813739	10.133834	0.5322
em01_044099_020_ML00016_002_c946	6.395150	4.333710	9.113086	0.177761	0.039210	0.403304	38.504784	0.6251
eb01_153051_020_ML00027_002_c946	6.227789	3.392369	9.819319	0.279753	0.074719	0.721286	18.686604	0.2339
em01_044099_020_ML00055_002_c946	6.206514	3.469697	10.746221	0.460354	0.196842	1.215652	27.025970	0.3022
em01_142063_020_ML00030_002_c946	6.143856	3.523136	10.122254	0.554583	0.222242	1.168170	18.395613	0.2445
em01_206084_020_ML00021_001_c946	6.071952	4.148352	9.923722	0.379389	0.150394	0.946865	31.779692	0.3222

150 Objects with Γ between 10 and 4

Objects with unphysically high photon indices but even more ultrasoft 30 yrs ago in ROSAT



Photon Index = $6.5_{4.5}^{9.1}$

Powerlaw Norm = (7 +- 3) e-05

NH_FIT = (0.16 +- 0.09) e+22

NH_GAL = 0.024 e+22

Source over bkg 1.3 keV

CTS_0 = 61.1

2MASSI J0904232+400704 (Sy1)

2RXS

HR1 (ROSAT) = -0.638 +-0.095

Object with unphysically high photon index but even more ultrasoft 30 yrs ago in ROSAT

2RXS-MPE-MJF-TN-005 : 2nd ROSAT PSPC All-Sky Survey X-ray Source Catalog (2RXS): V 55912

Ultra-soft ROSAT band
0.1-0.4 keV

Soft ROSAT band
0.5-0.9 keV

Medium ROSAT band
0.9-2.0 keV

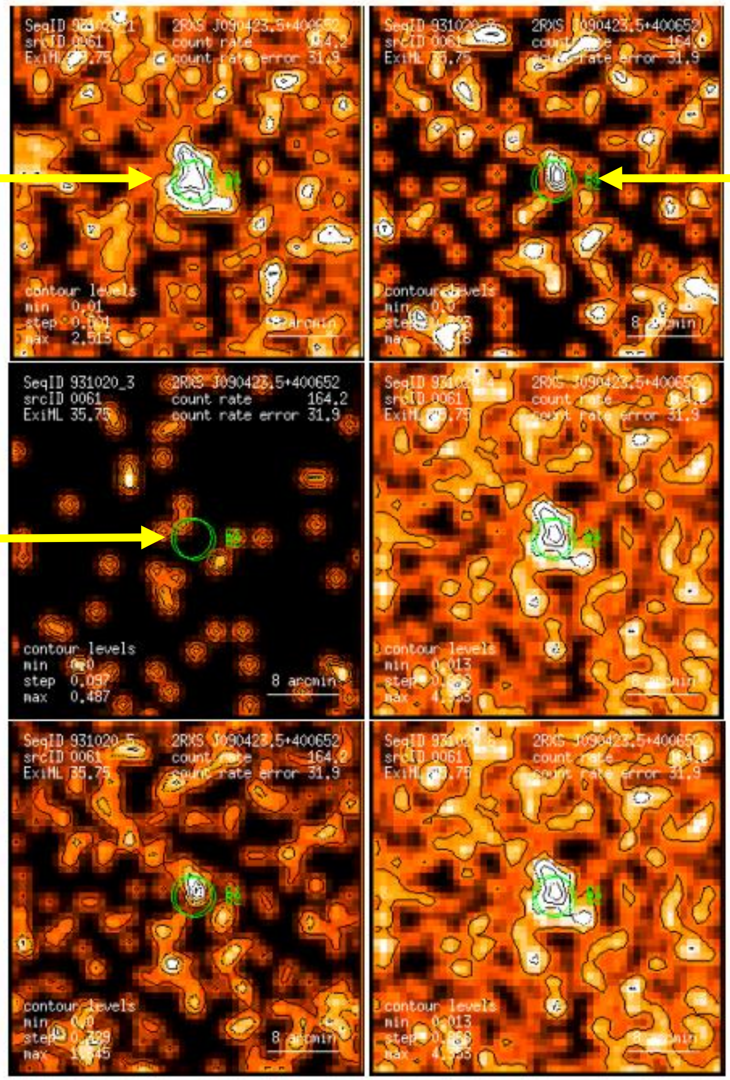
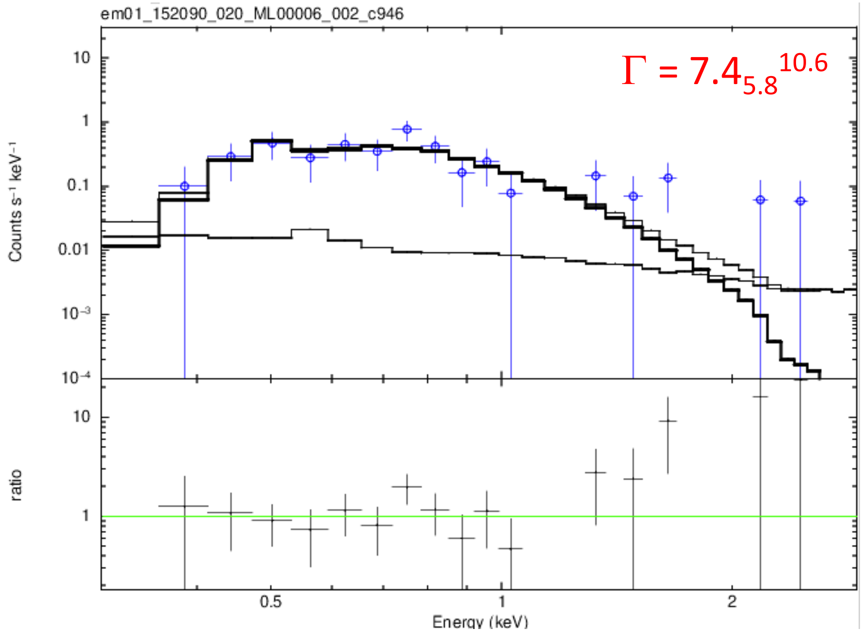
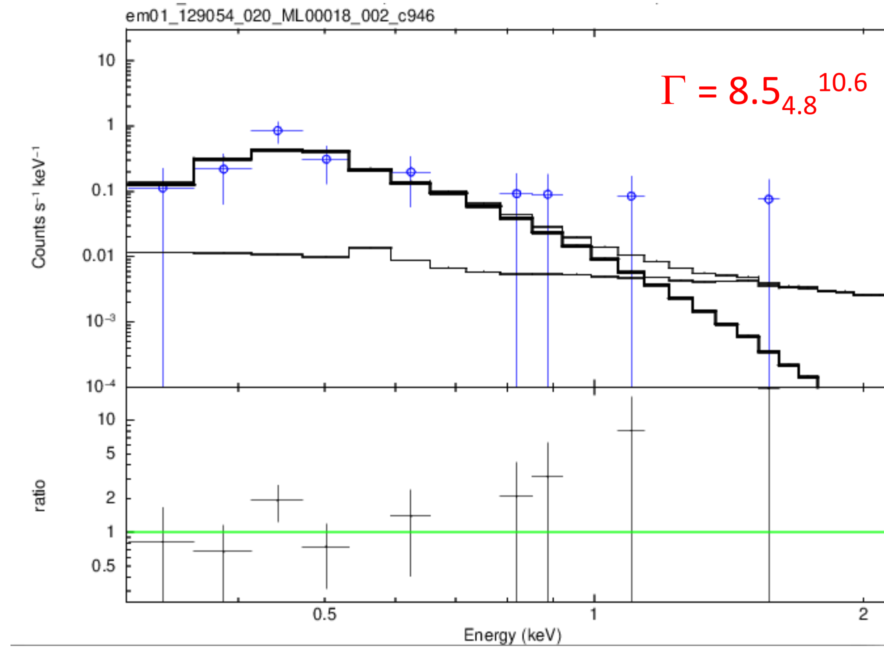


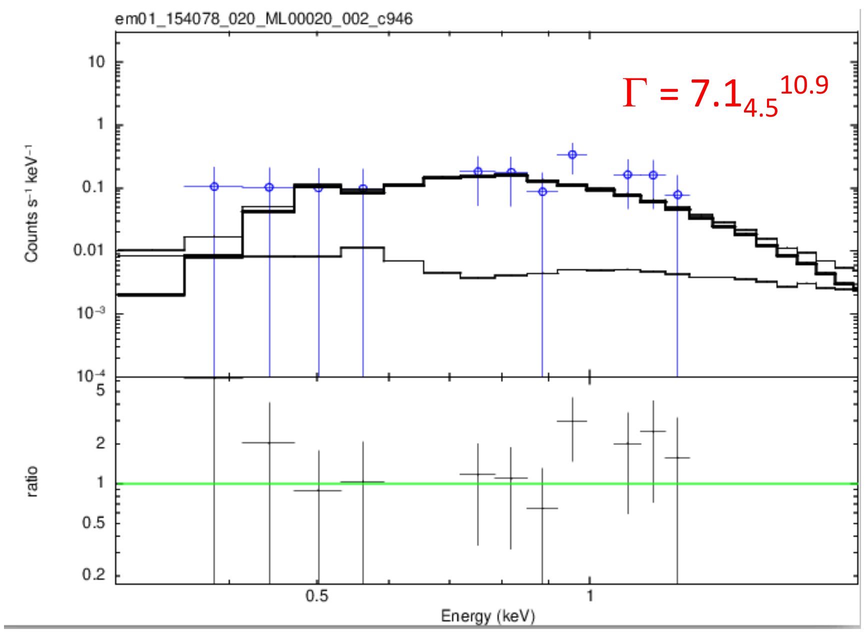
Figure 61: RASS 931020: detection 0061: band rate images, Gaussian filter: (1) PSPC channels 11 – 41, (2) 52 – 90, (3) 91 – 201, (4) 11 – 235, (5) 52 – 201, (6) 11 – 201. Broad band rates in counts/ks. Band rate contour levels in counts/ks/arcmin^2.

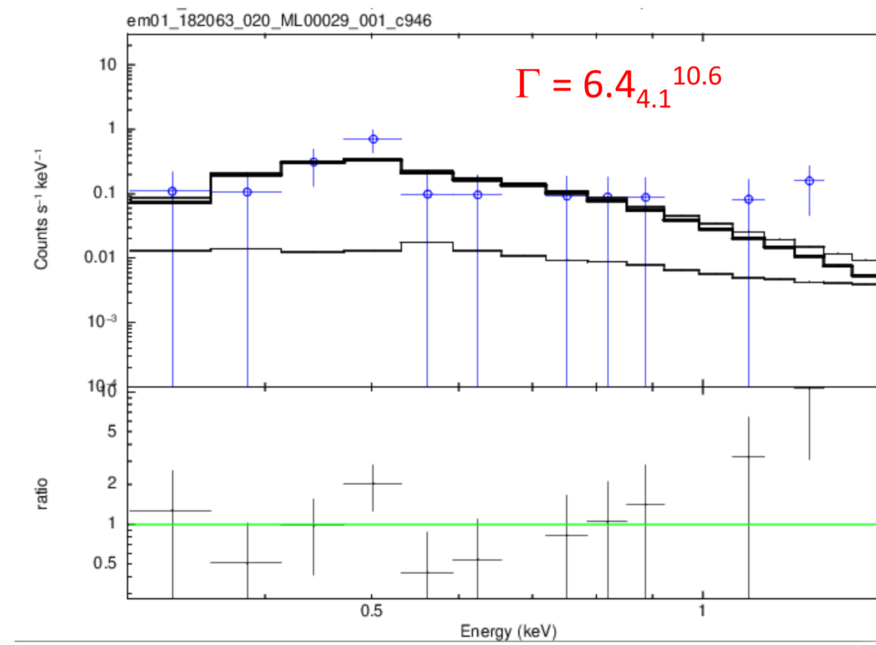
Freyberg 2RXS-MPE-MJF-TN005
2RXS Boller, Freyberg et al.

Objects with unphysically high photon indices

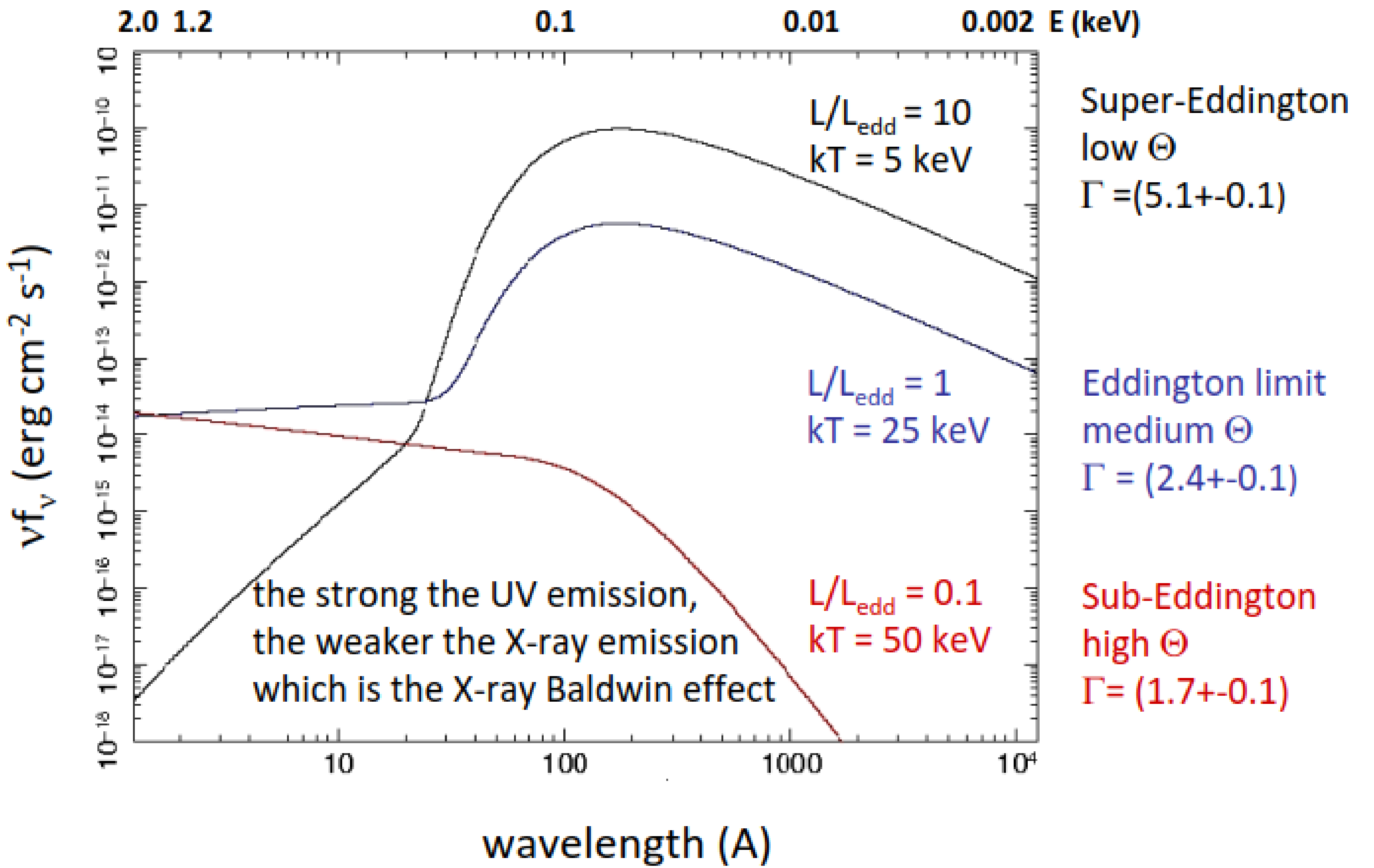








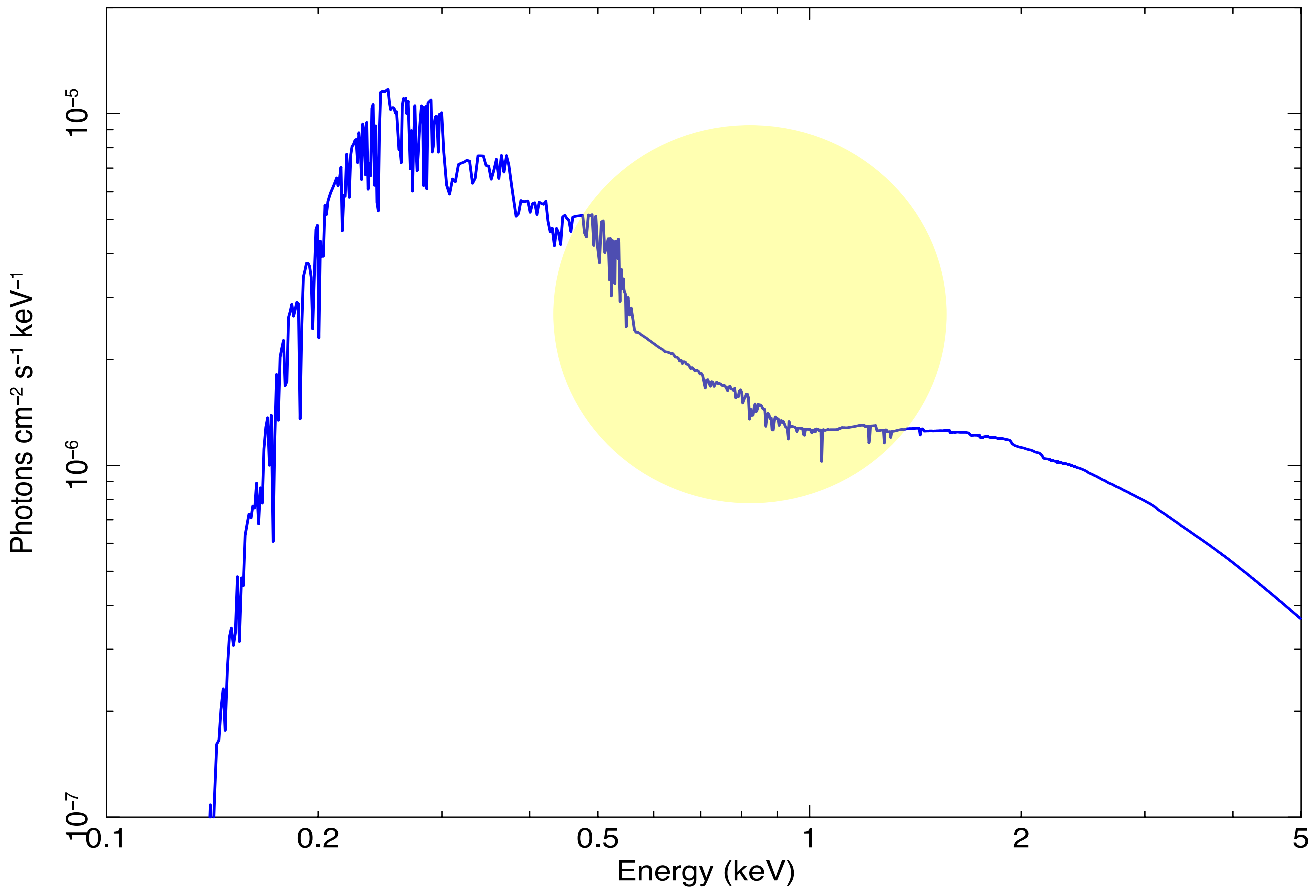
XMM-Newton simulations of AGN accretion states and Comptonized plasma parameters



Photoionized wind outflow, partial covering, absorption, and powerlaw

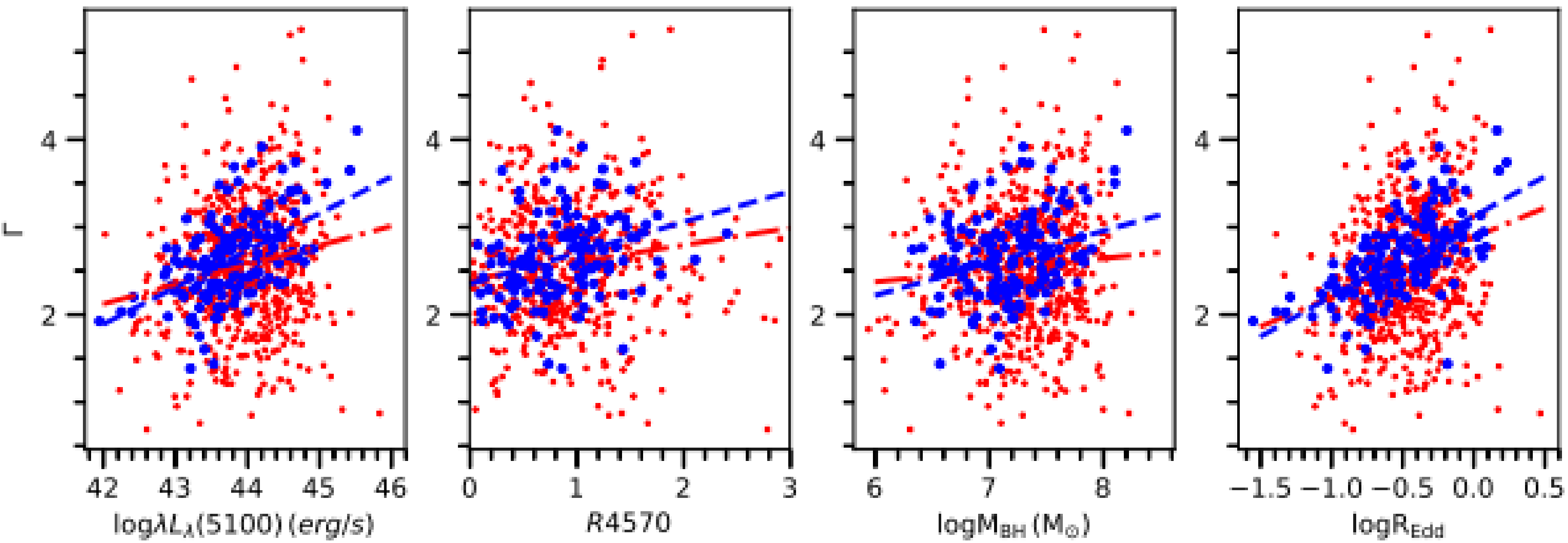
Supersoft tail cannot be explained by standard comptionization models

Outflowing winds imprint additional absorption features at 1 keV, resulting into photon indices between 4 and 10



Combining X-ray spectral analysis with large scale optical outflow indicators [O III] and Hβ

Correlations photon index and accretion rate parameters probing outflows at the gravitational radius scale

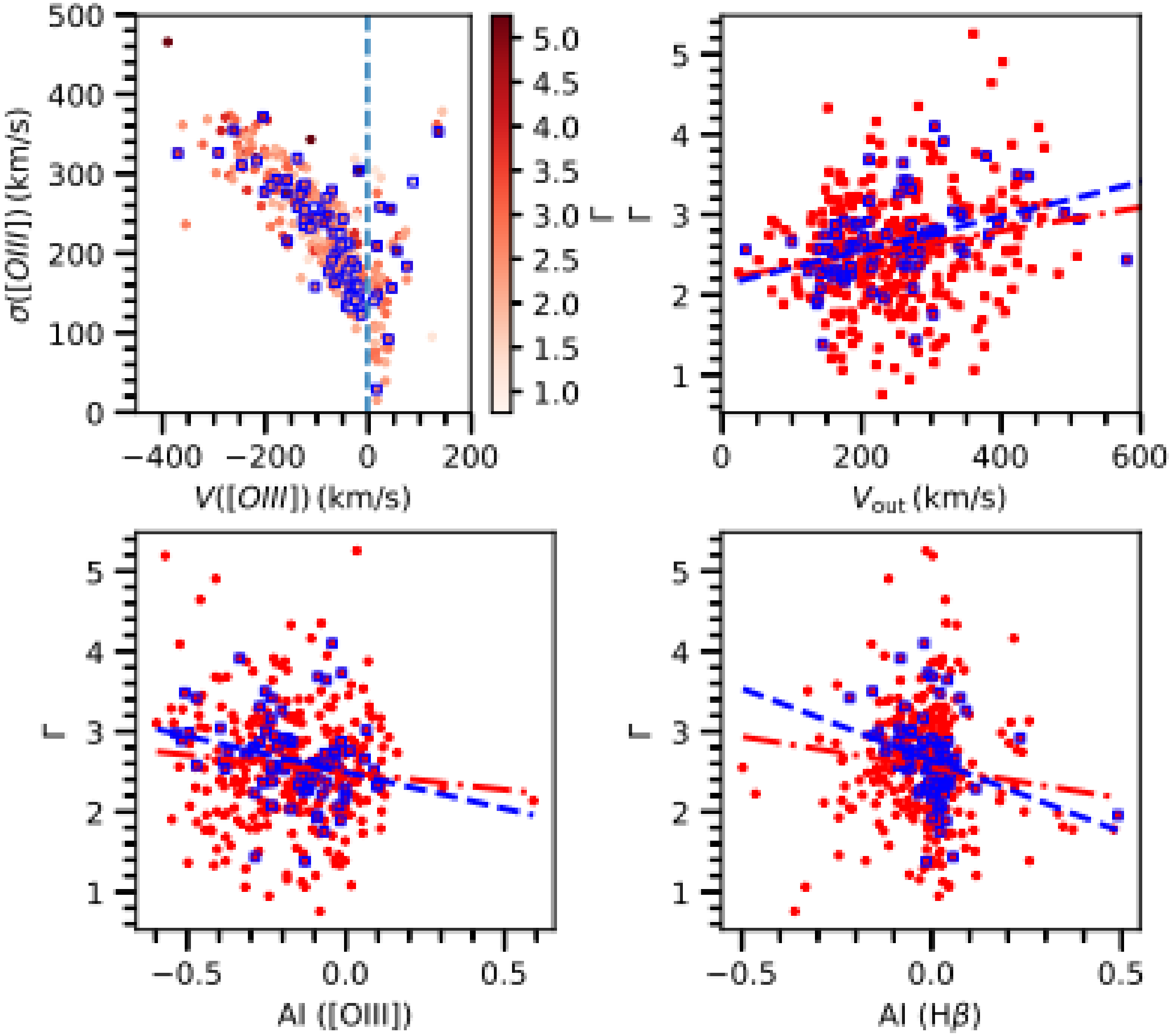


strong correlations between

- the **soft X-ray photon** index with
- the Eddington rate,
- the Fe II strength,

probing outflow at the gravitational radius scale

We demonstrate that the soft-X-ray photon index correlates with the large-scale [O III] and Hβ outflow



Strong correlations between

- outflow velocity and v- dispersion

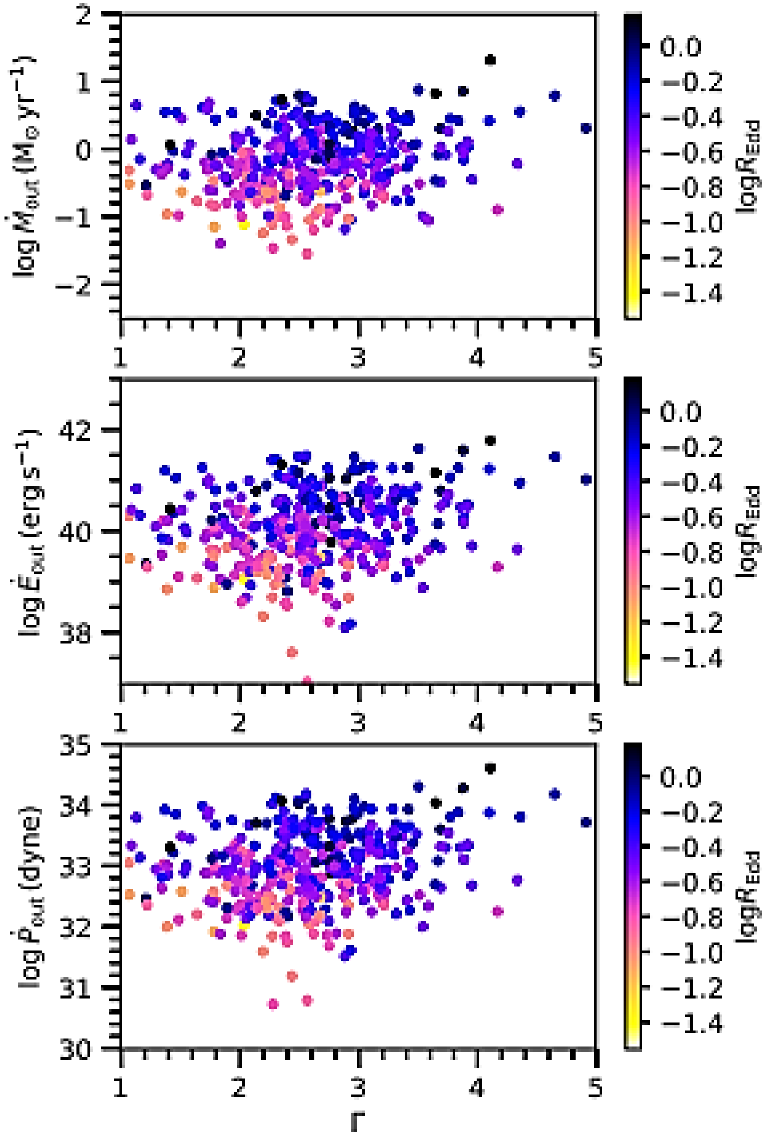
– Γ outflow velocity

– Γ and line assymetry AI

Ionized winds launched from the accretion disc provides the best physical driver for outflows from the gravitational radius up to the kpc-scale

outflow

Outflow energetics



Mass outflow up to 100 M_{sun} per year

Energy injection rate up to 10^{42} erg/s

Momentum flux up to 10^{35} dyne

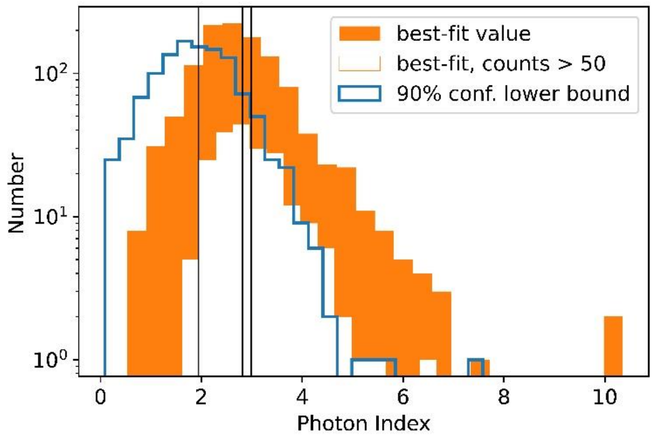
AGN **feeding** and AGN **feedback** work together
to self-regulate the black hole growth and galaxy evolution

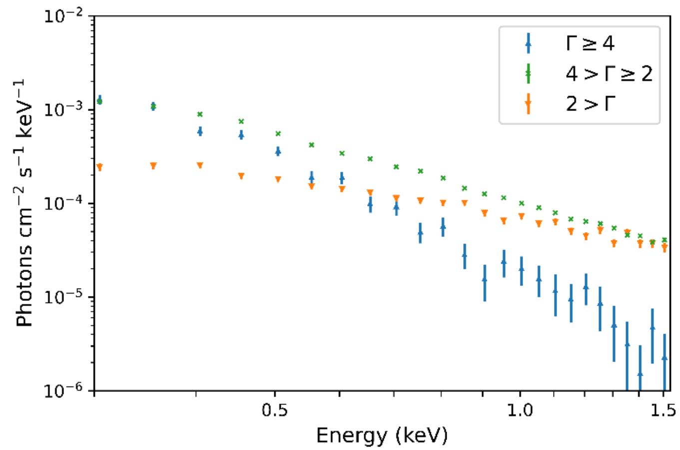
The first look at narrow-line Seyfert 1 galaxies with eROSITA - Summary

G. Grünwald, Th. Boller, S. Rakshit, J. Buchner, T. Dauser, M. Freyberg, T. Liu, M. Salvato, A. Schichtel

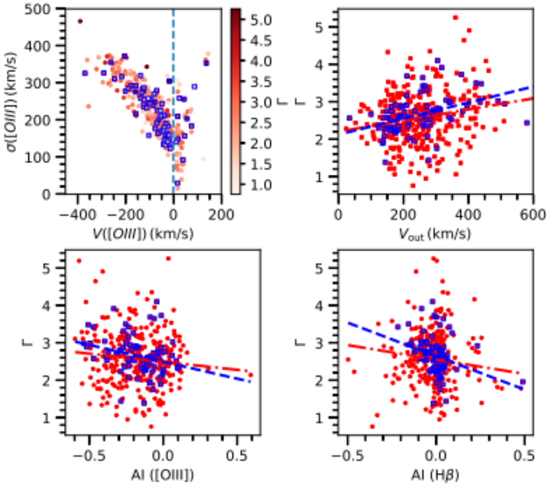
accepted for publication in the 4. Extragalactic astronomy section of A&A on Nov 9, 2022

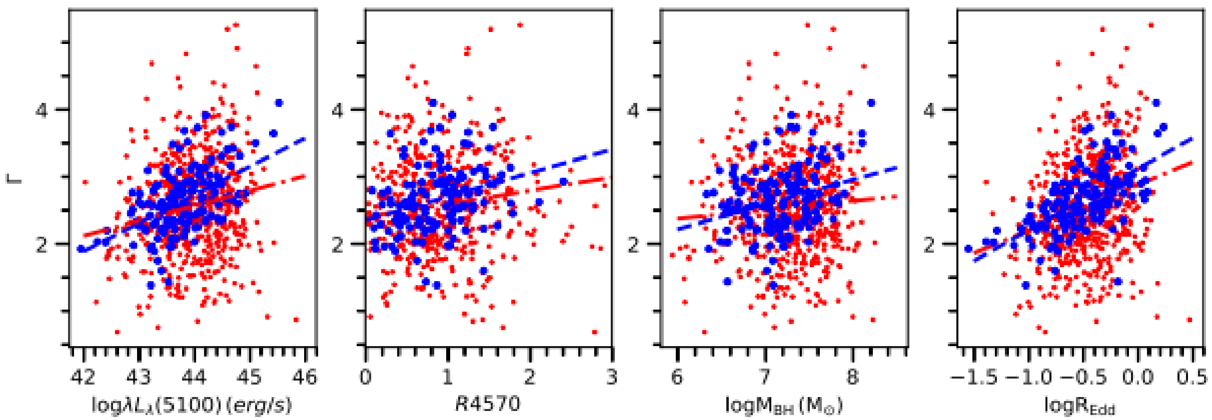
1. Detection of an ultra-soft X-ray photon index tail with values between 4 and 10





2. We demonstrate that the soft-X-ray photon index correlates with the large-scale [O III] and Hβ outflow





Ionised outflows from the gravitational radius up to the kpc-scale provide the best physical explanation