30 Years of NLS1 Research and 23 Years of IWARA (Olinda 2003)

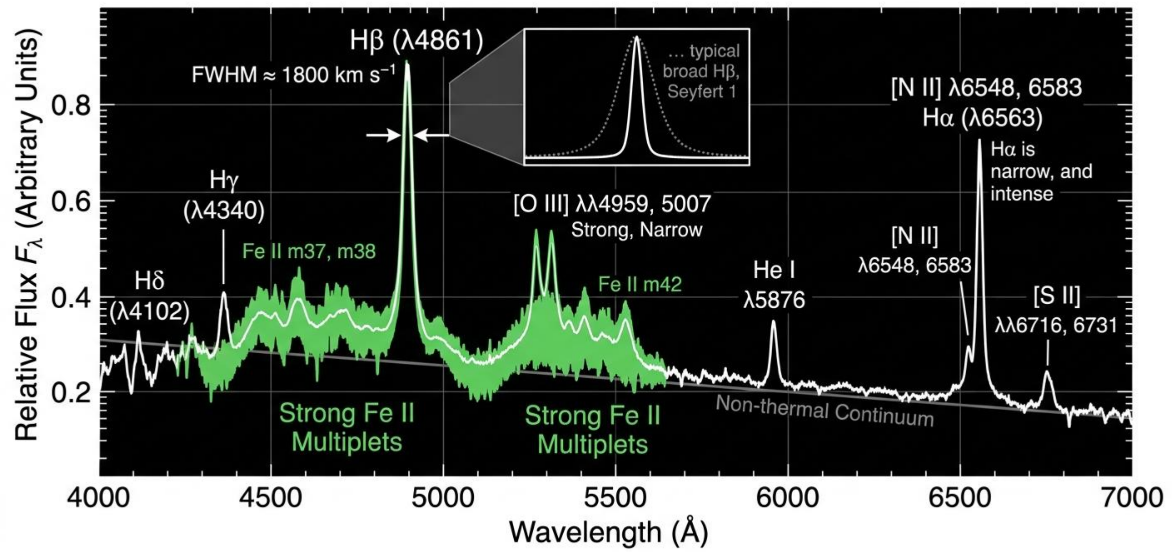
Thomas Boller
Max-Planck-Institute for Extraterrestrial Physics
Garching, Germany

From the ROSAT Revolution through XMM-Newton to eROSITA

From Ultrasoft Spectra to Cosmic Feedback

Understanding Extreme Black-Hole Accretion

Why NLS1s Matter



The Γ − FWHM H_β Correlation

The steep anti-correlation between soft X-ray photon index and optical line width demonstrates that NLS1s harbor small-mass black holes accreting at high, super-Eddington rates.

Extreme High Eddington Ratios $\lambda_{\mathrm{Edd}} = 10 \ldots 20$

NLS1s demonstrate that the small H_β widths arise from low virial velocities around the lowest supermassive black holes $M_{BH} = 10^{5 \ldots 6} M_\odot$ operating at the extreme high-accretion regime.

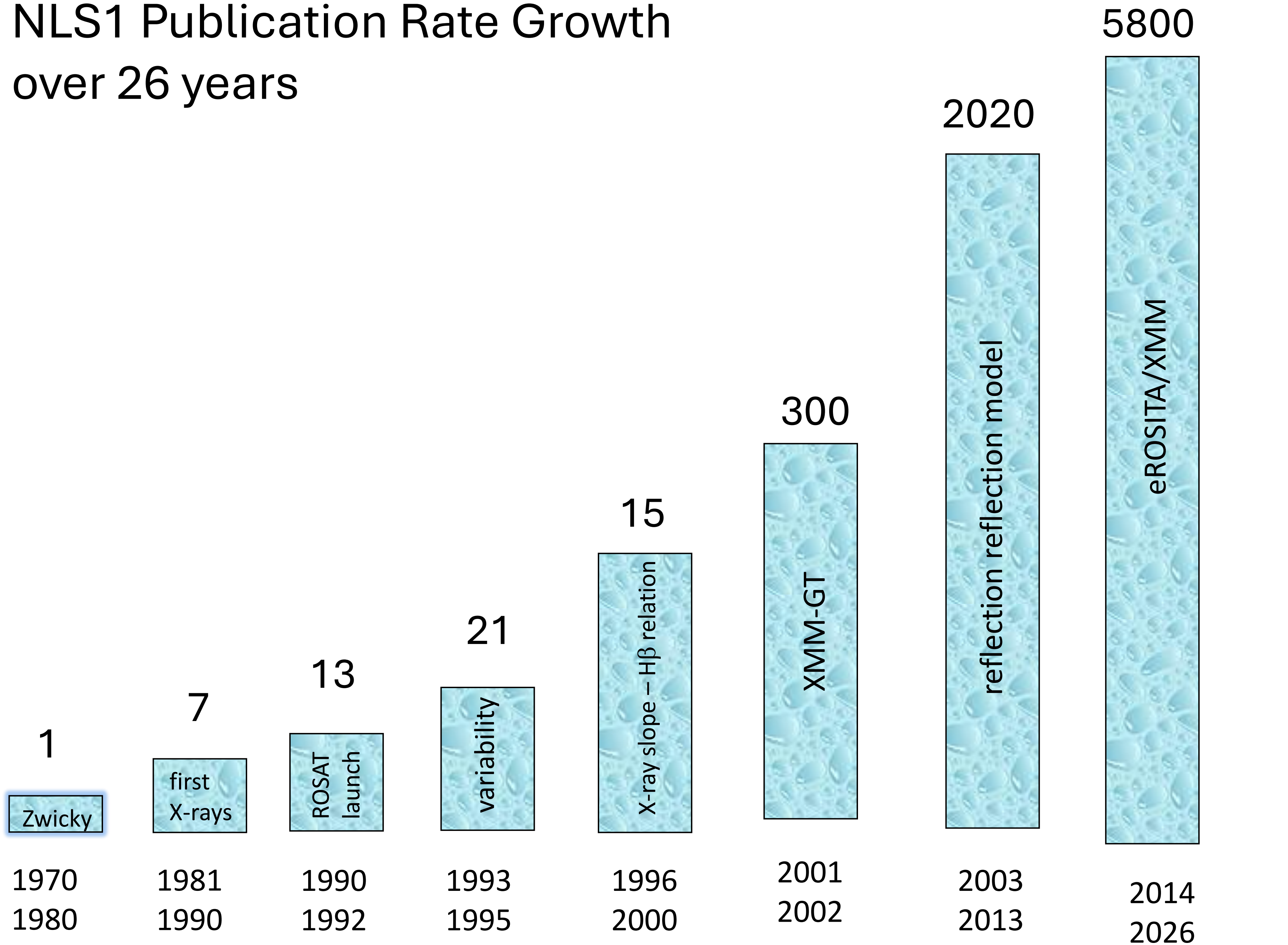
Slim Accretion Disks

Radiation-dominated, optically thick slim disks develop at super-Eddington rates to advect photon energy inward, explaining the soft X-ray excess and steep continuum of NLS1s.

Radiation-Driven Outflows

Intense radiation pressure launches powerful high-velocity winds and ultra-fast outflows, driving critical AGN feedback into the host galaxy.

NLS1 Publication Rate Growth over 26 years

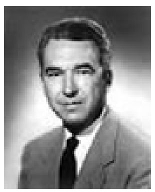


Seyfert and Zwicky: The Origins of the NLS1 Story

Broad line Seyfert 1

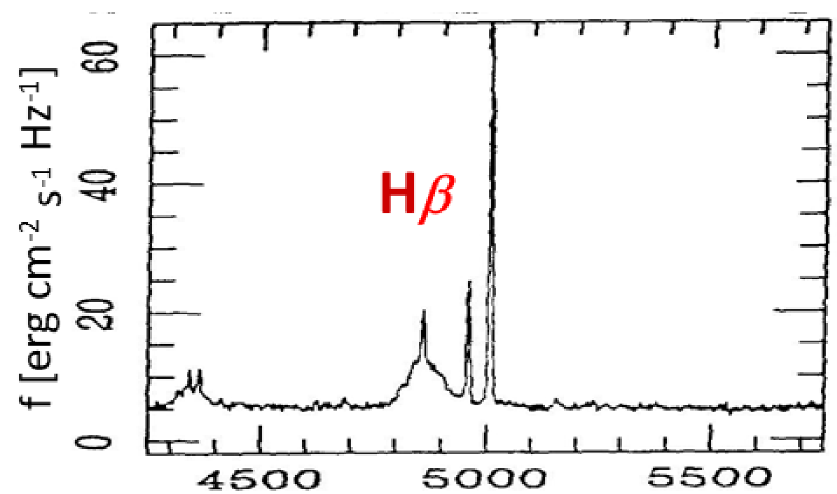
Carl Seyfert, ApJ 97, 28, 1943

FWHM Hβ~10000 km s^{-1}



*11. 2. 1911, Cleveland, Ohio
†13. 6. 1960, Nashville, Tennessee

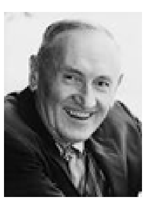
BLS1



Narrow line Seyfert 1

Fritz Zwicky, PASP 82, 93 1970

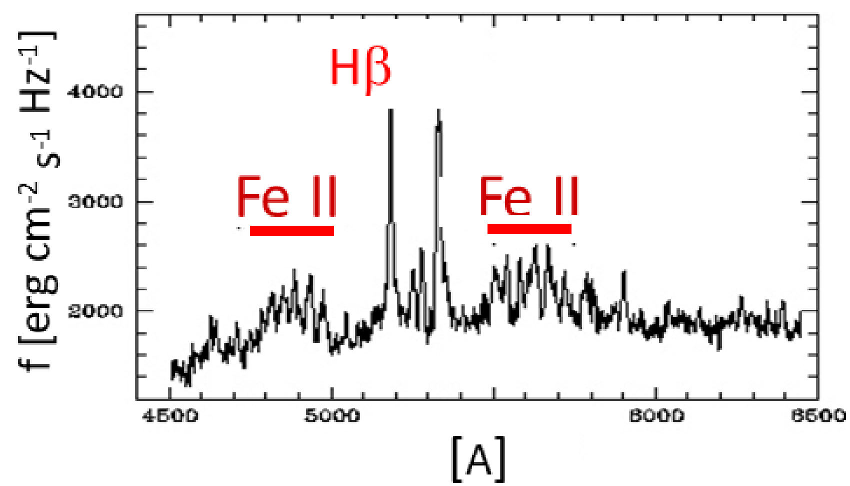
FWHM Hβ< 2000 km s^{-1}



*14. 2. 1898, Bulgaria

†8. 2. 1974, Pasadena, California

NLS1



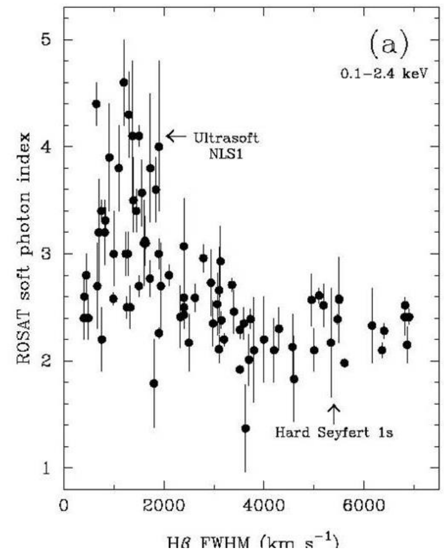
Milestones in NLS1 Research

1992 Puchnarewicz

First report on steep soft X-ray spectra

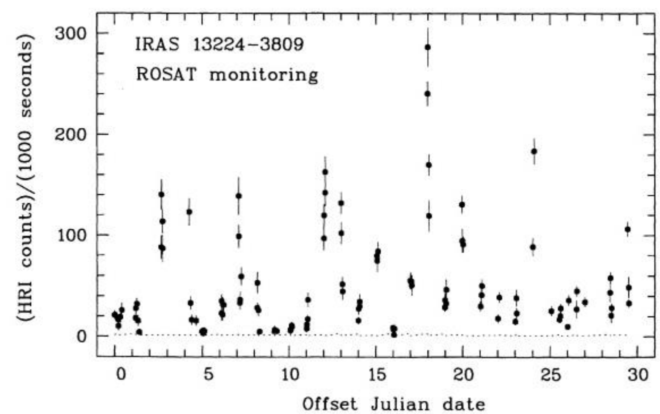
1996 Boller, Brandt & Fink

Soft X-ray continuum and optical line width relation



1997 Boller, Brandt, Fabian & Fink

Discovery of persistent and rapid variability
factor 100 in 800 seconds.



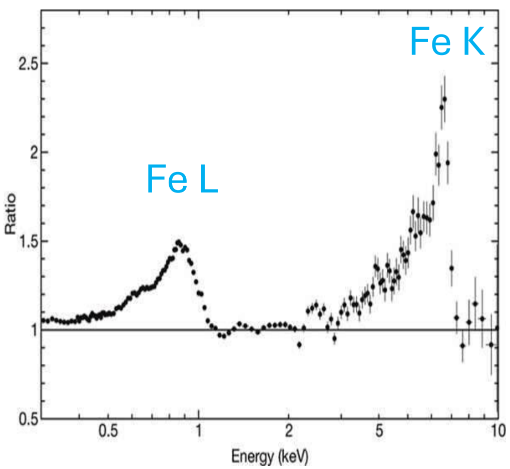
Milestones in NLS1 Research

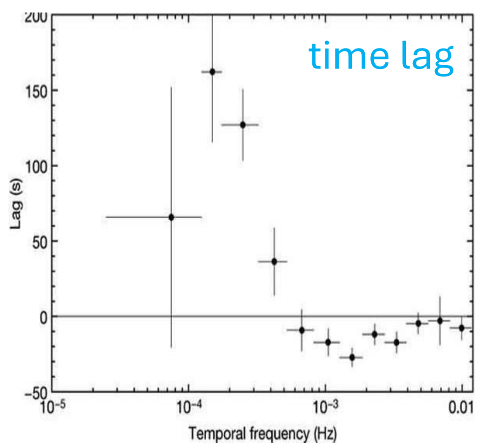
2003 Pounds

High-velocity ionized outflows

2009 Fabian

Detection of Fe K and Fe L emission and negative time lags between direct and reflected nuclear X-ray emission



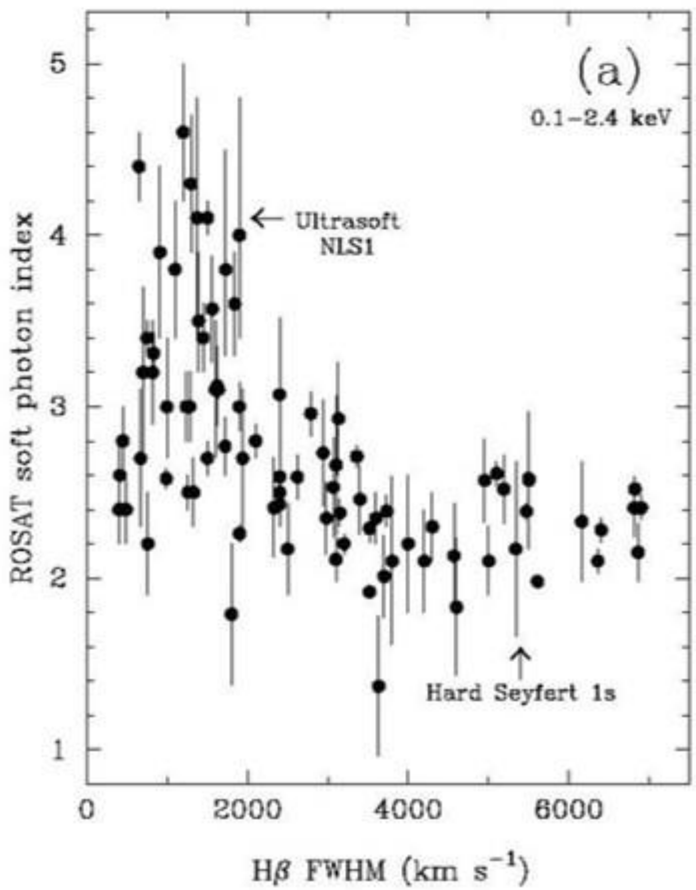


2012 Foschini, D´Ammato

Gamma-ray emission from NLS1s

ROSAT Changes Everything

The Discovery of Γ-FWHM



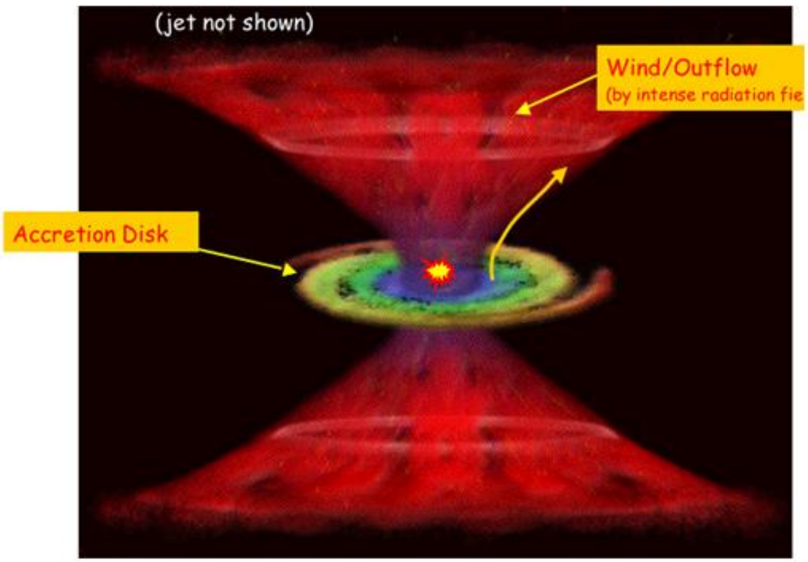
Discovery of extreme soft X-ray AGN

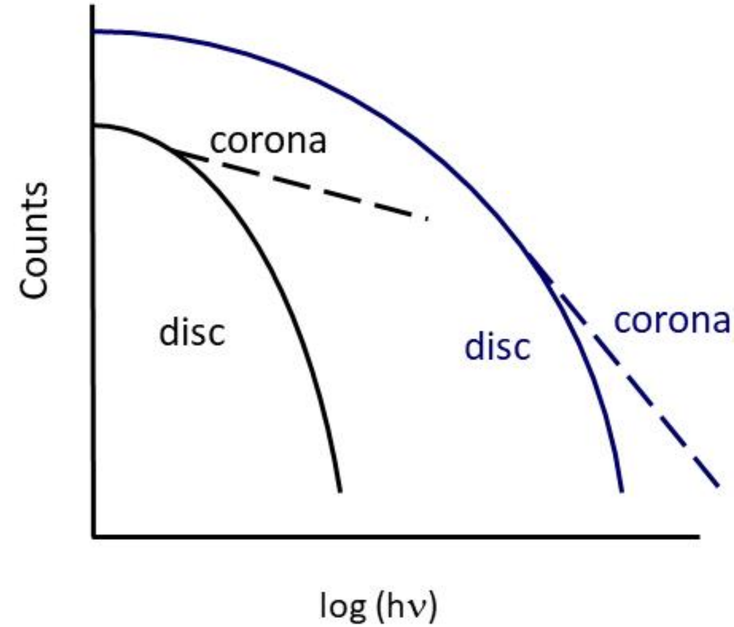
ROSAT soft X-ray photon index versus Hβ FWHM relation (Boller et al. 1996).

Why the Γ-FWHM Relation Matters

Physically Driven Seyfert Unification

AGN accretion disc photons and Comptonisation in surrounding corona





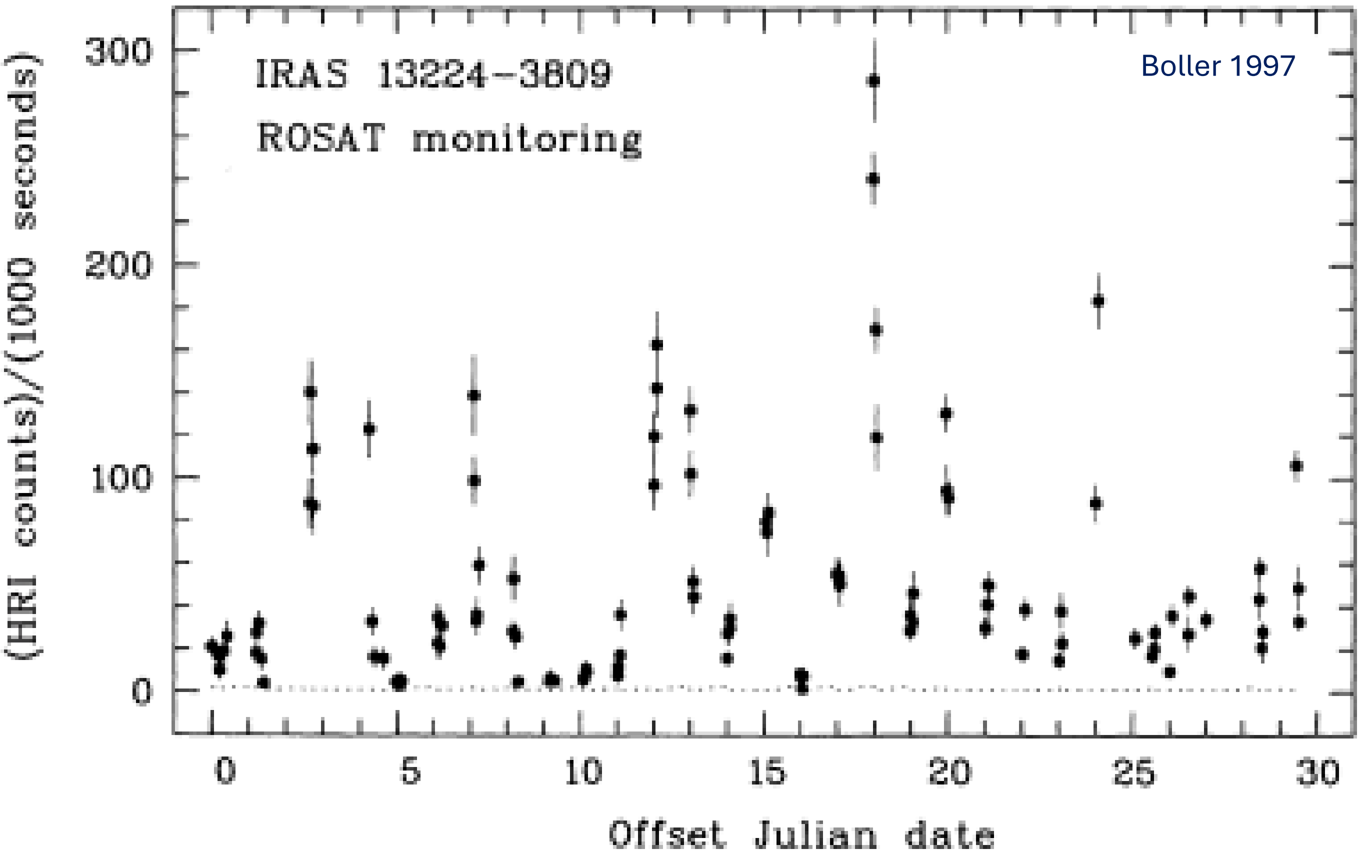
the larger the solid angle $\Omega/2\pi$ subtended by the reflector and the stronger the luminosity L_{UV} of soft photons is:

- the greater is the cooling by seed photons incident on the plasma
- the lower is the plasma electron temperature $\Theta = kT_e/mc^2$
- the steeper are the X-ray photon indices Γ
- the weaker is the X-ray luminosity L_X

$\Gamma = \ln \tau / \ln (1 + 4\Theta)$

$L_{corona} = f(\Theta, \tau)$

IRAS 13224-3809: A Prototype Extreme for NLS1 X-ray variability



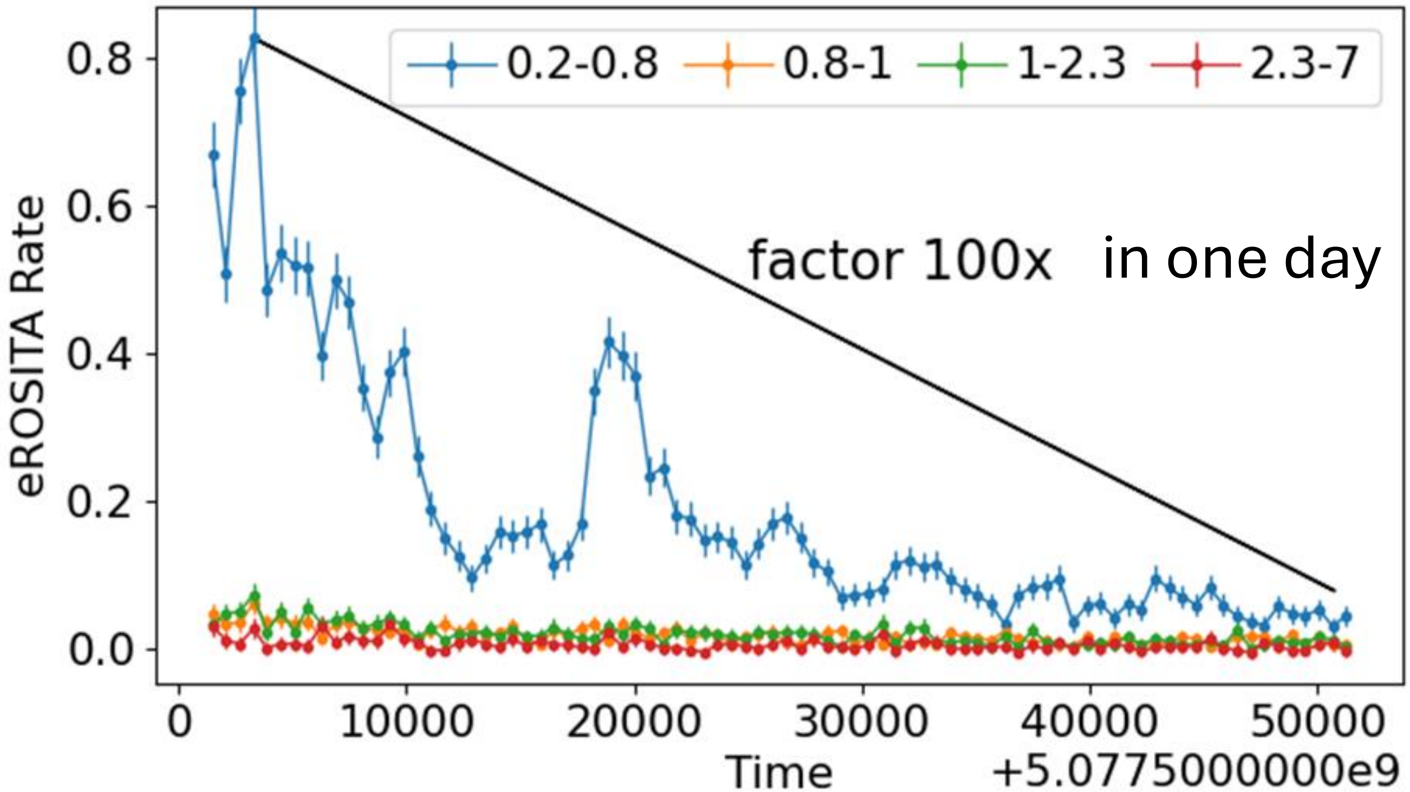
Variability factor 100 in 800 seconds

$\frac{\Delta L}{dt} = 10^{10}\ M_{\odot}$ in 800 seconds

New eROSITA Discoveries

Ultra-soft Variability

1H 0707-495, Boller 20021

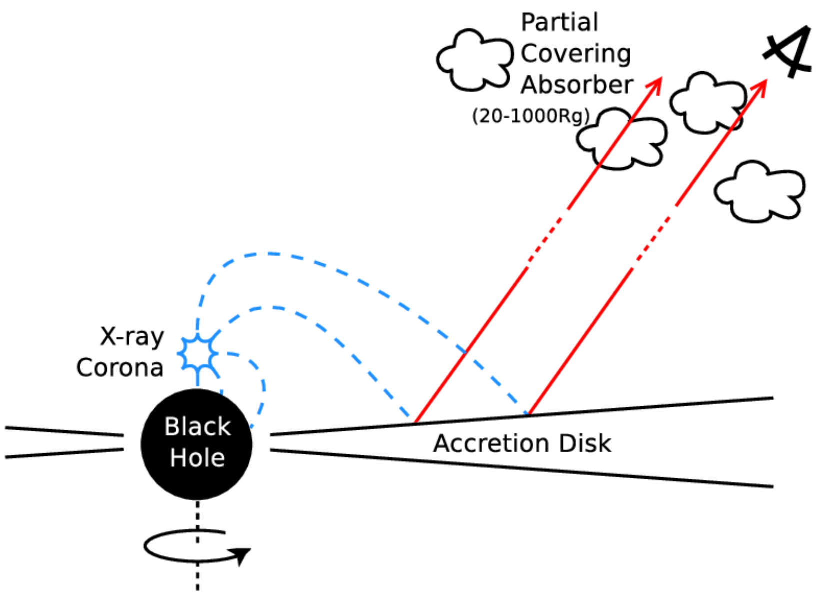


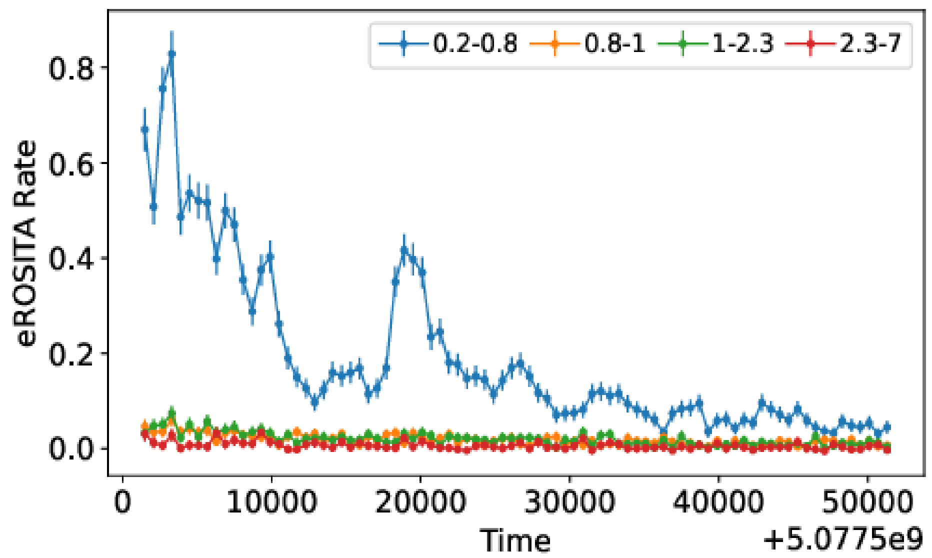
Such extreme, ultra-soft, large-amplitude flux variability in active galactic nuclei has not been detected in other X-ray observations to date.

X-ray variability is only detected in the ultra-soft 0.2-0.8 keV band.

New eROSITA Discoveries

Ultra-soft Variability – Partial Covering of Ionized Outflowing Winds



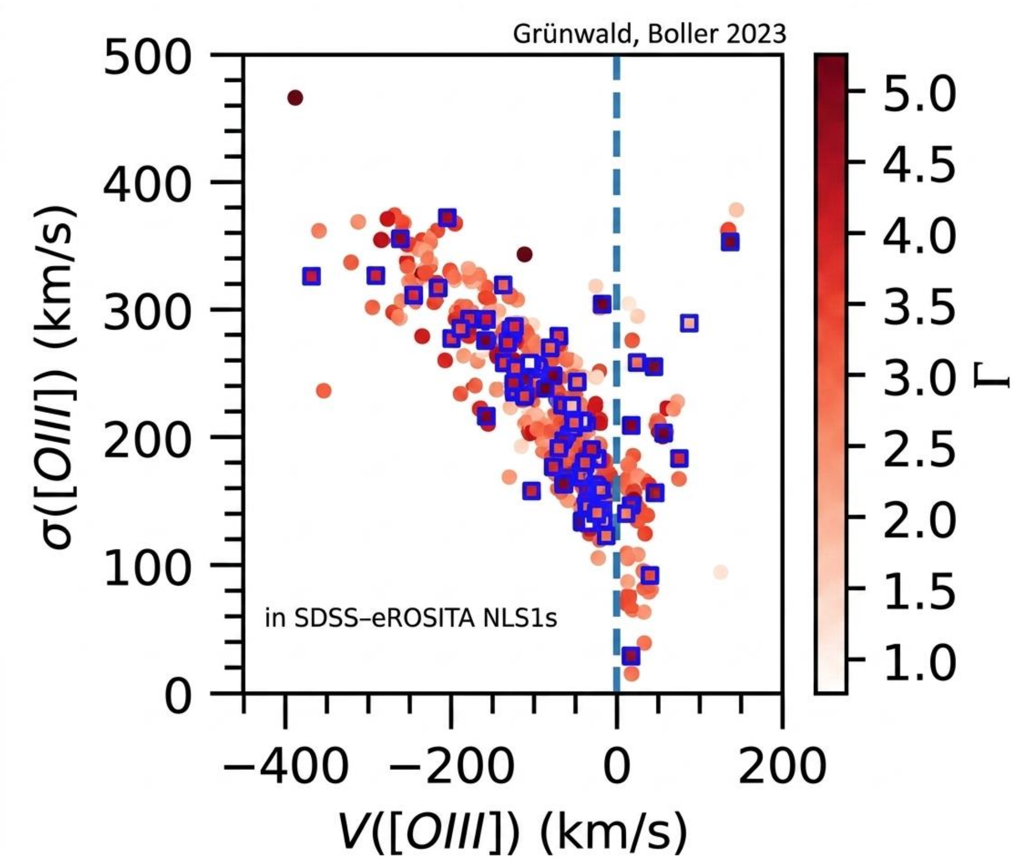


Ionized outflowing absorbers are transparent in the soft X-rays

At 1 keV, absorption features are imprinted, resulting in ultrasoft X-ray variability

New eROSITA Discoveries

Massive Feedback from Ionized Outflows from the accretion disc

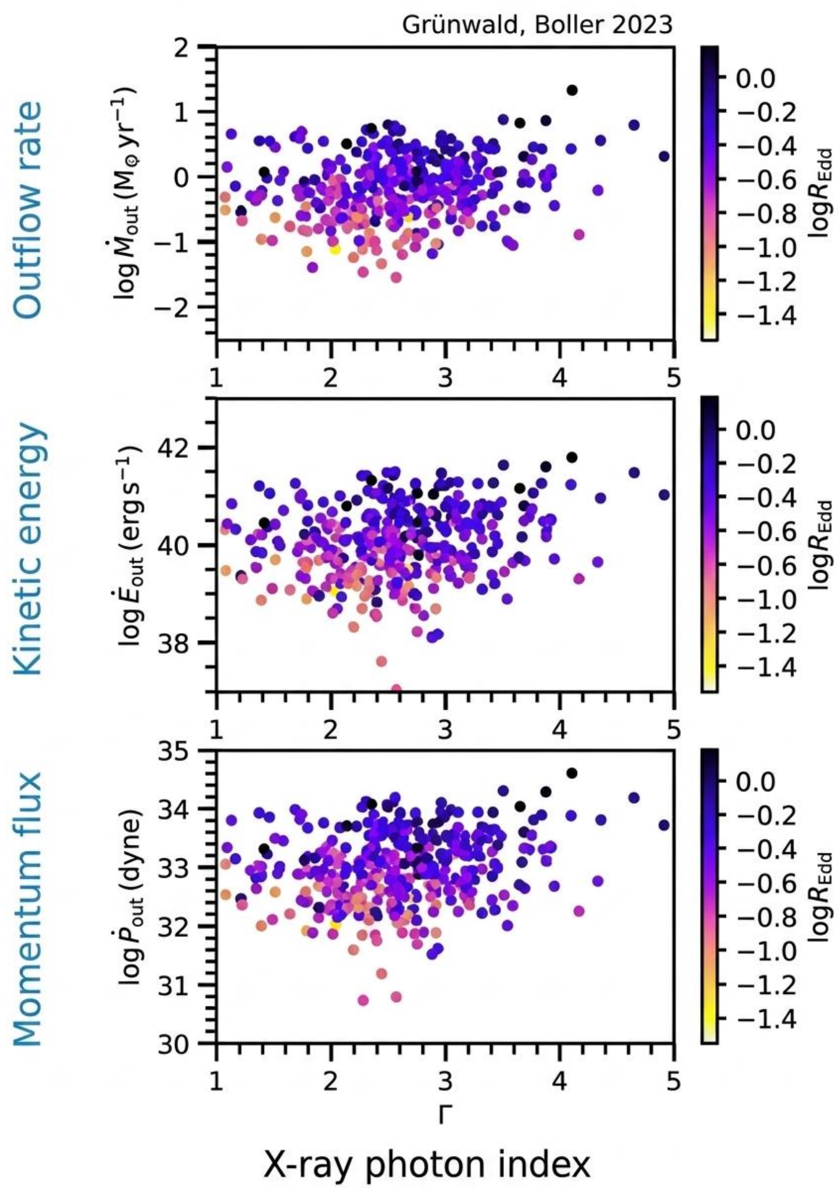


Stronger blueshifts in [O III] are systematically coupled with line dispersions, proving high-velocity outflows up to 400 $\frac{km}{s}$

Steeper X-ray spectra correlate with larger negative [O III] velocity shifts, directly connecting central accretion physics within a few R_S to galactic-scale kpc-scale NLR outflow kinematics.

New eROSITA Discoveries

Outflow energetics



Higher Eddington rates drive larger mass outflow rates.

The kinetic energy correlates with the Eddington ratio.

The momentum feedback is driven by high-accretion winds.

My Final Thoughts

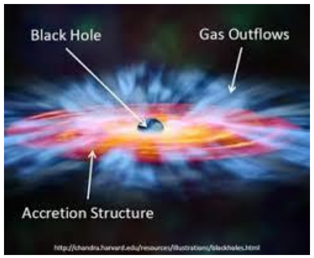
NLS1 research continues to reshape our understanding
of accretion, outflows, and feedback

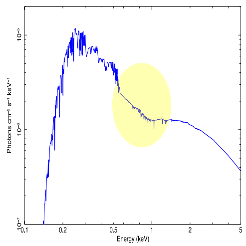
a journey perfectly aligned with the spirit of the IWARA conferences.

Backup Slide

Soft Excess Models

Ionised disc winds

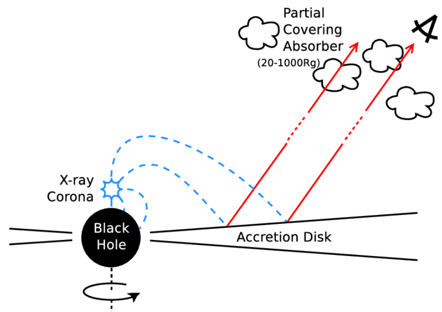




Ionised disc winds are a fundamental aspect of AGN feeding and feedback research. These winds are driven by the intense radiation and/or magnetic fields in accretion discs.

They imprint absorption features at one keV, artificially producing an soft X-ray excess.

Relativistically blurred reflection

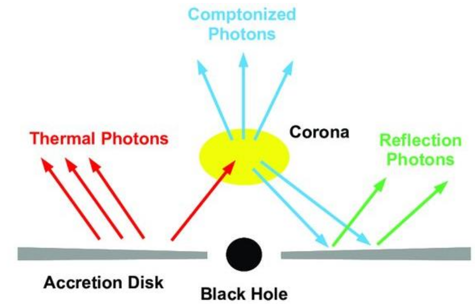


While the relativistic blurred reflection model has successfully explained many observed properties of active galactic nuclei (AGN), there remain challenges in using this model to explain the soft X-ray excess.

One of the main problems with the relativistic blurred reflection model is that it typically predicts a much larger reflection component than is observed in AGN spectra.

Another issue with the model is that it assumes that the accretion disc is a perfect, smooth surface, which may not be the case in reality. Clumps or other structures in the disc could affect the observed spectrum and, therefore impact the model's accuracy.

Warm Comptonisation



In this process, ultraviolet (UV) photons from the accretion disc surrounding the black hole are scattered by hot electrons in the surrounding warm corona layer. The scattered photons gain energy, leading to a soft X-ray excess emission observed in the X-ray spectrum of these systems.

One issue is that the model assumes a static corona geometry, whereas, in reality, the corona is likely to be more dynamic and variable. Additionally, the model does not account for the variability observed in some AGN spectra, particularly in the soft X-ray band.

The exact location and size of the layer is not known.