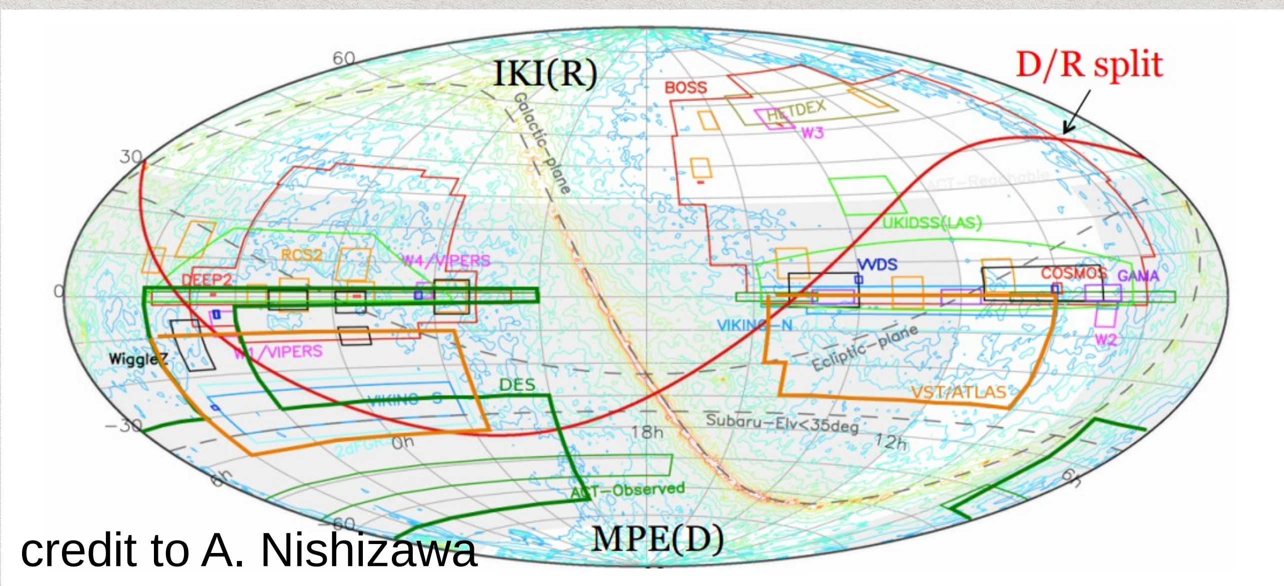
Exploring Strongly Variable AGN: Multi-Wavelength Insights into X-Ray-Selected AGN Transient Events with Small and Large Telescopes

OISTER workshop 10.12.2024

Malte Schramm
University of Potsdam

X-ray selected transient events from eROSITA

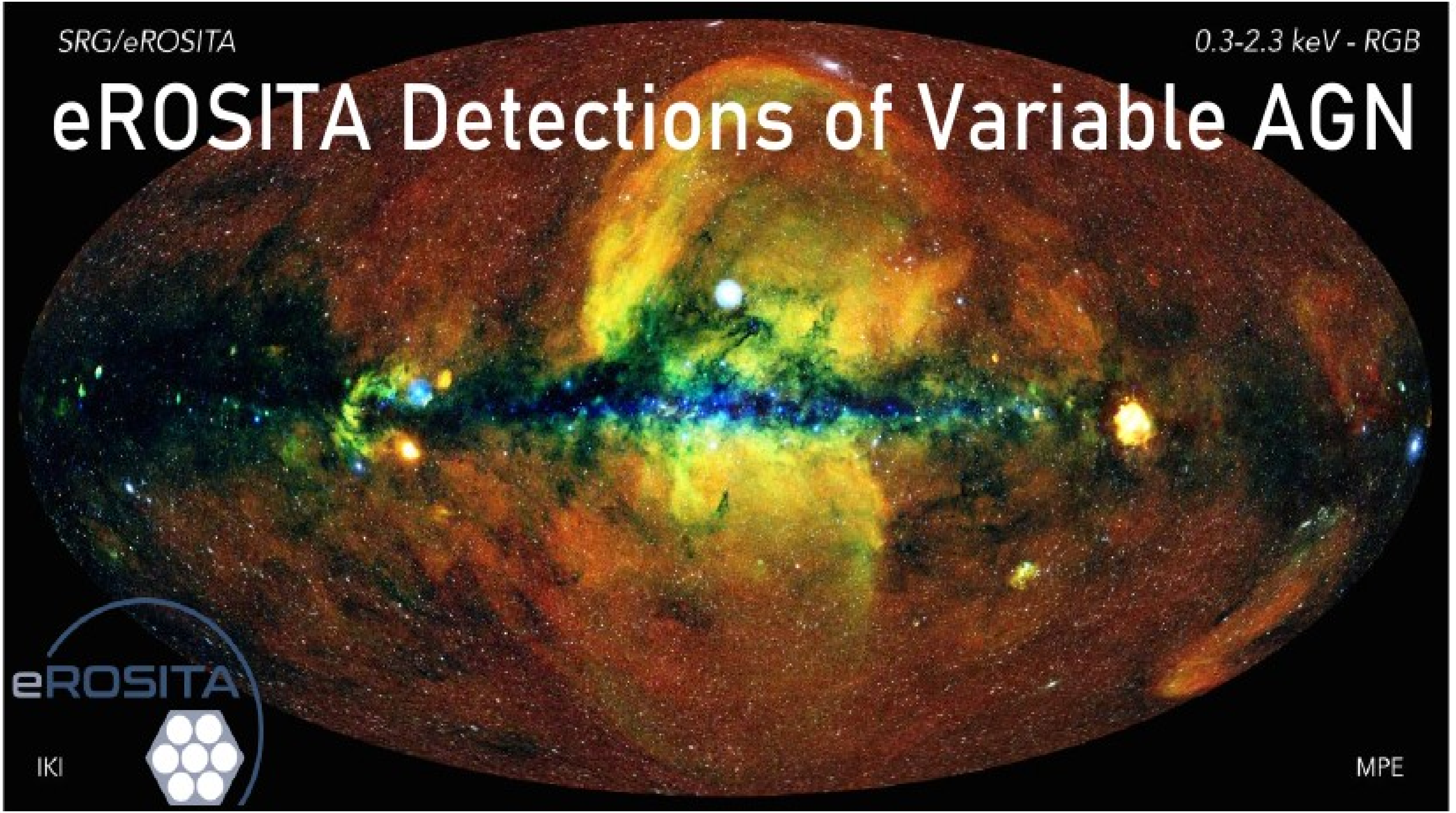
Sky split between RU and DE consortium

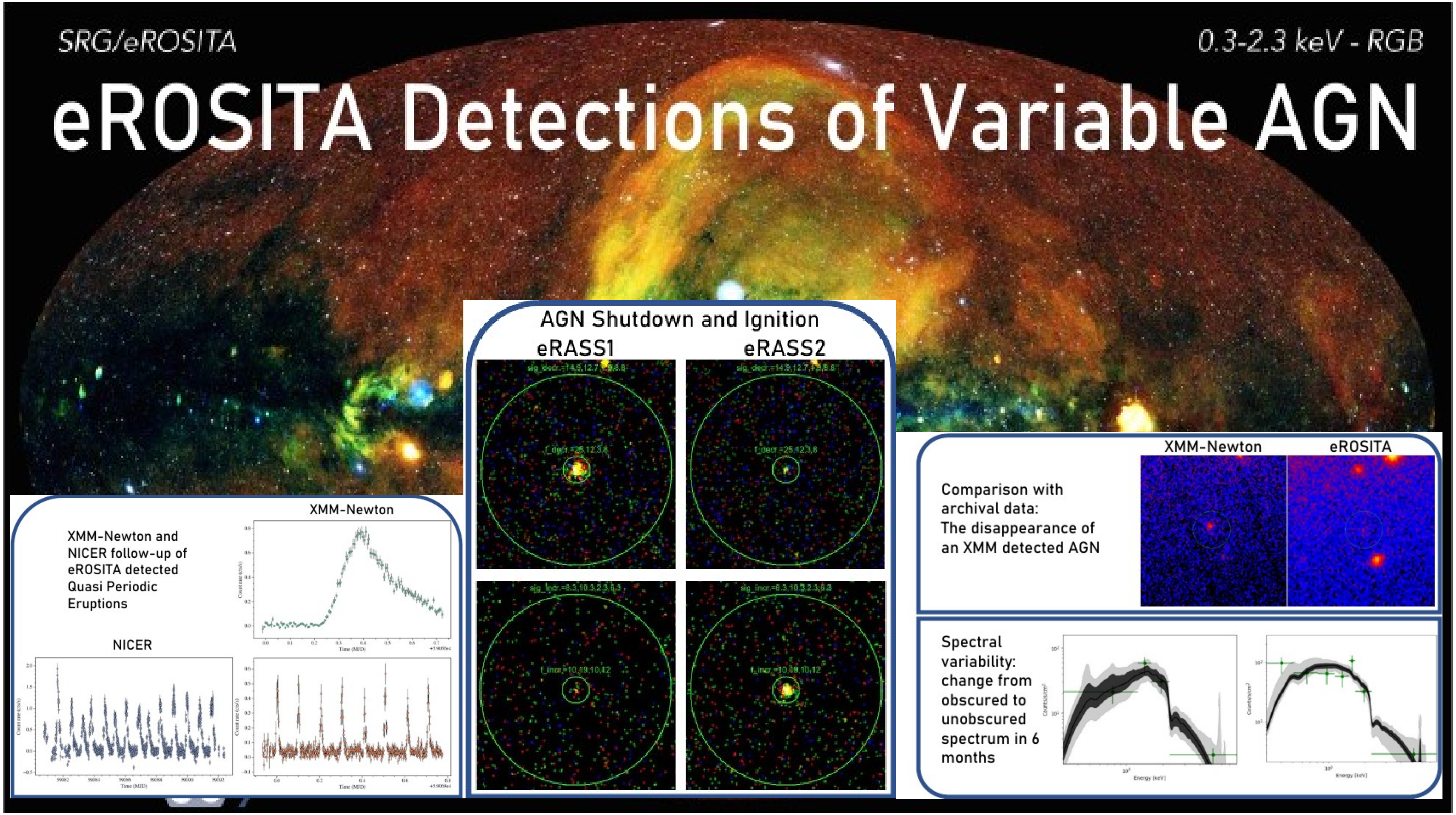


credit to A. Nishizawa

Launch Dec 2019
Every 6 months
All sky scan eRASS
0.2-10 keV

Monitoring of 1,000,000 AGN every 6 months


SRG/eROSITA
0.3-2.3 keV - RGB
eROSITA Detections of Variable AGN
eROSITA
IKI
MPE

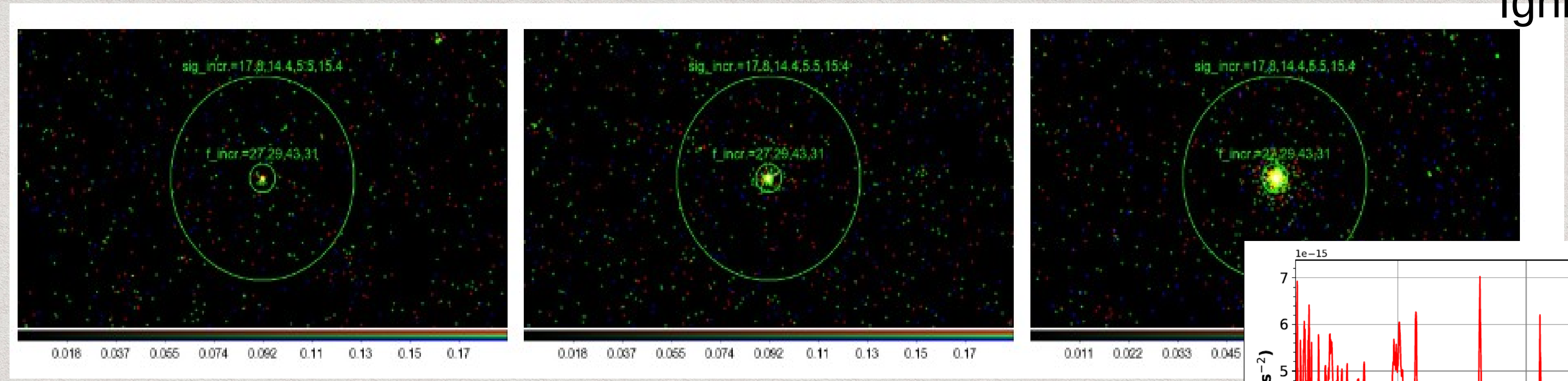

SRG/eROSITA
0.3-2.3 keV - RGB
eROSITA Detections of Variable AGN
AGN Shutdown and Ignition
eRASS1
eRASS2
XMM-Newton and NICER follow-up of eROSITA detected Quasi Periodic Eruptions
XMM-Newton
NICER
Time (MJD)
XMM-Newton
eROSITA
Comparison with archival data: The disappearance of an XMM detected AGN
Spectral variability: change from obscured to unobscured spectrum in 6 months
Energy (keV)

X-ray transient events - CLAGN

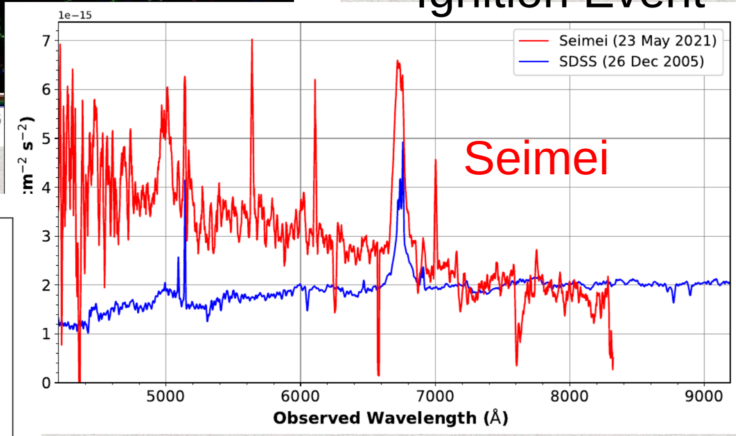
Some follow-up using OISTER

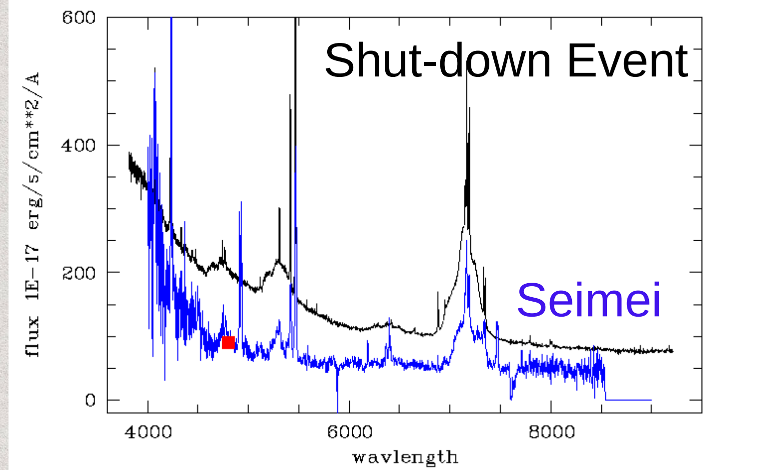
eRASS 1 eRASS2 eRASS3

Ignition Event

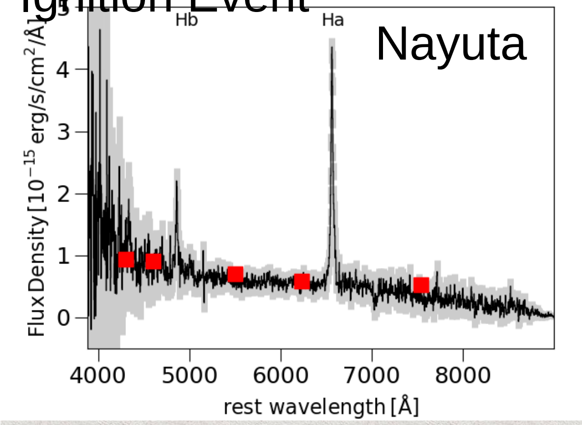


Ignition Event





Ignition Event



Seimei/Kools+Nayuta/Malls
→ 32 requests / 14 observed / 10 successful

4 Multi-Wavelength case studies of X-Ray & optically selected AGN

- Mostly follow-up of eROSITA selected transients
- Southern Sky: SALT,VLT,NTT,Gemini-S,SOAR + many small <1m telescopes for photometry
- Northern Sky: LBT,Gemini-N,Asiago,NOT,Seimei,Nayuta



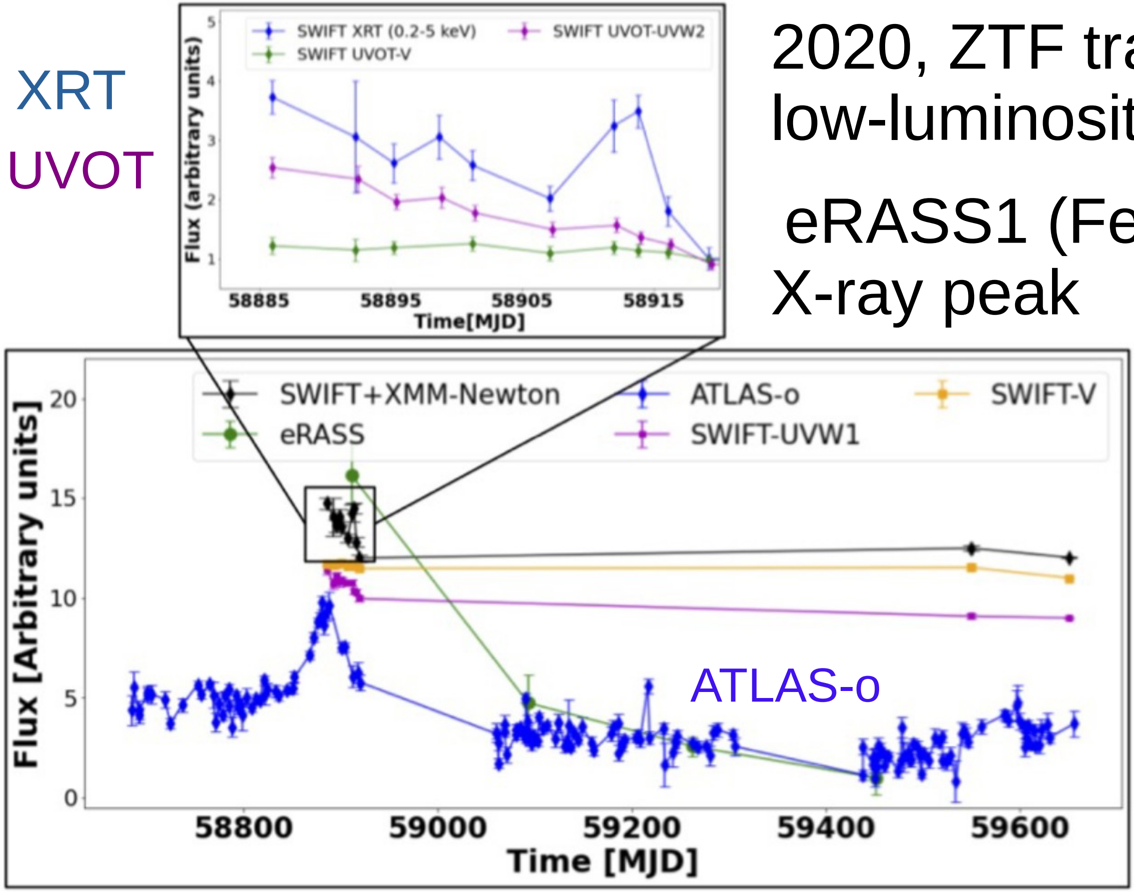





Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

SWIFT XRT

SWIFT UVOT



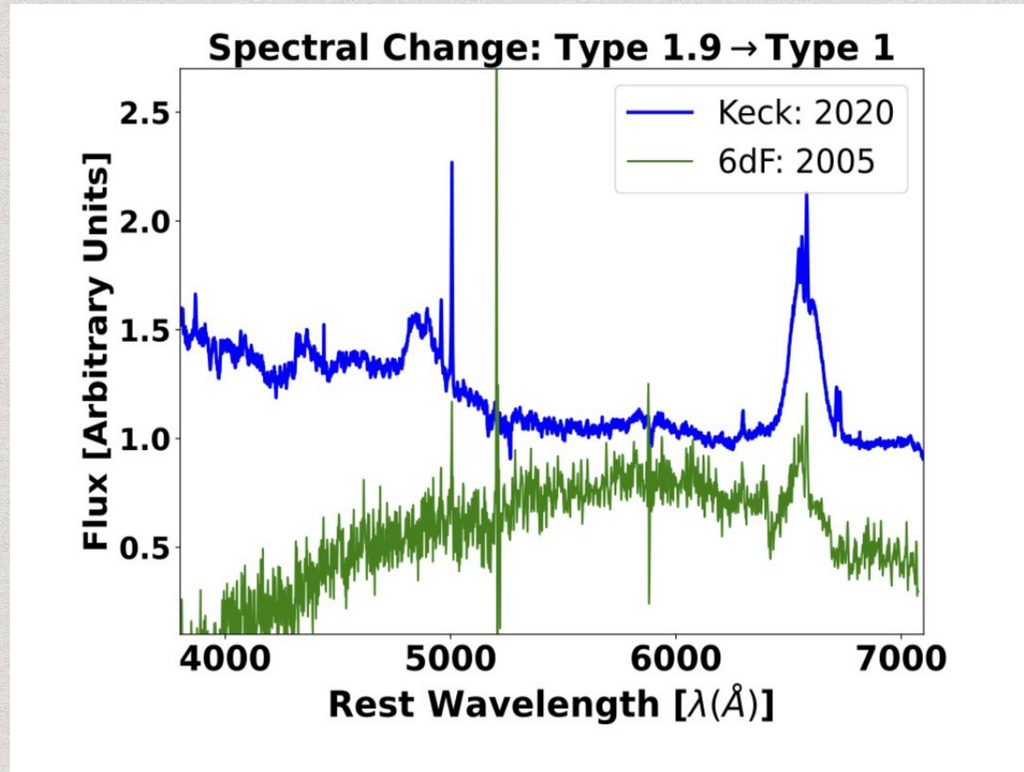
2020, ZTF tracked a 40-day flare in a low-luminosity Seyfert at z=0.07

eRASS1 (Feb. ’21) caught the X-ray peak

triggered observations with Swift, XMM-Newton, SALT, VLT, Keck, SAAO and others til Mar. 23

no soft excess - X-rays & UV tracked well, consistent with thermal Comptonization in a hot corona only

Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

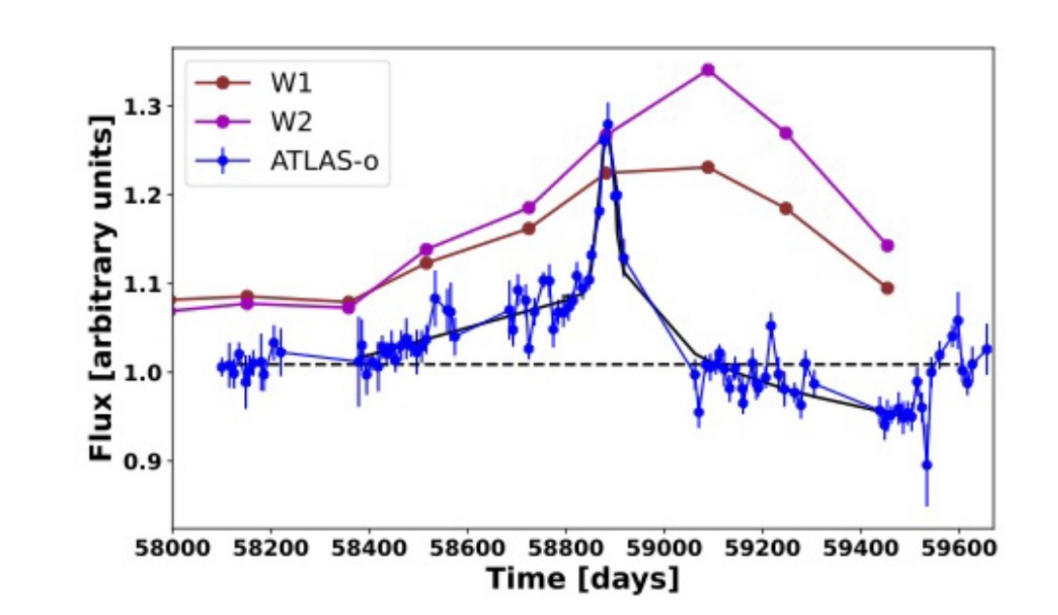


- **Optical spectra:** Broad Hβ and a blue continuum appear during 2020-2021, indicating a transition from type 1.9 in archival spectra to type 1.

  However, by 2022, both the continuum and broad Hβ line had faded, and the source had reverted to a type 1.9.

Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

We modeled the dust echo in the IR using WISE → radii 0.2—1.0 pc



- Broad Balmer lines were double-peaked, indicating a disk-like BLR

αOX holds steady at 1.2, indicating likely no majorchange to accretion flow throughout the event

Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

SUMMARY:

Disk instability in a low-luminosity AGN's

Previously-existing disk-like accretion flow: Optical/UV continuum (25-50 Rg) flared/decreased by ~20

⟶ Drove appearance of broad Hβ

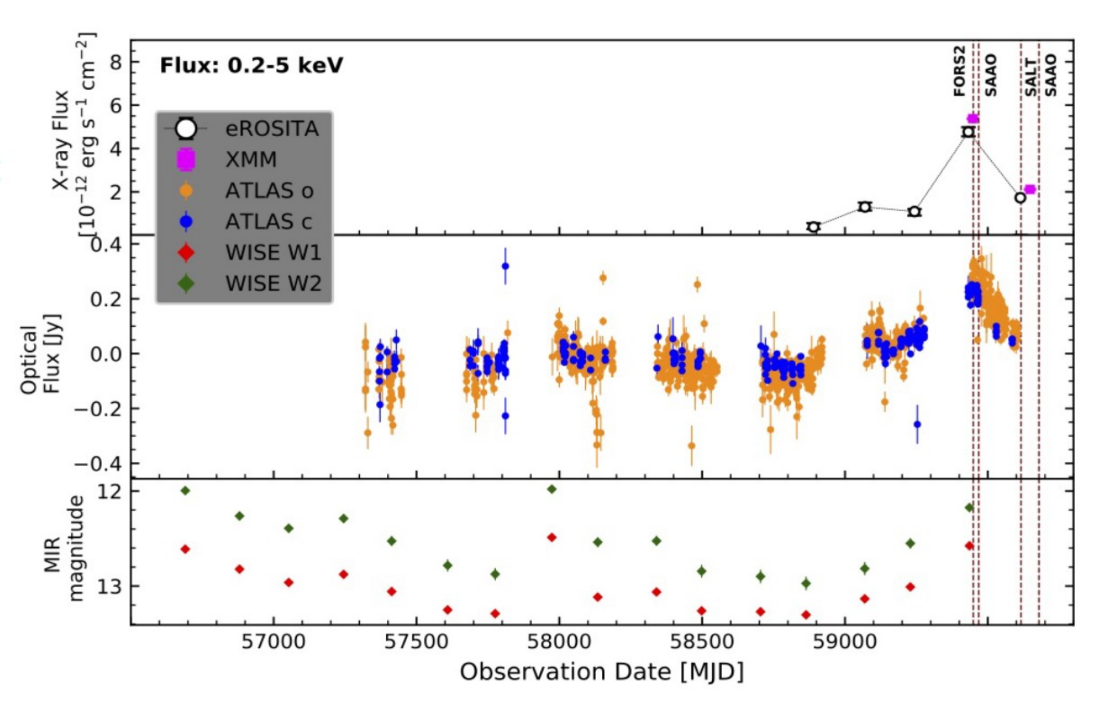
⟶ X-ray flared by ~6 via Thermal Comptonization.

⟶ IR dust echo from pc-scale dust

Saha et al. A&A submitted

Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

eRASS 3→4: F(0.2-5 keV) increased by 6
eRASS 4→5: F(0.2-5 keV) decreased by 3;
UVM2 drops by factor 4



Extreme variation in soft X-ray photon index: from 2.8 to 2.2 in 6 months as the flare subsided.

We triggered followups with XMM-Newton, NICER, SAAO, SALT, VLT

Ground-based photometry, Aug. 2021 -- Sep. 2022

Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

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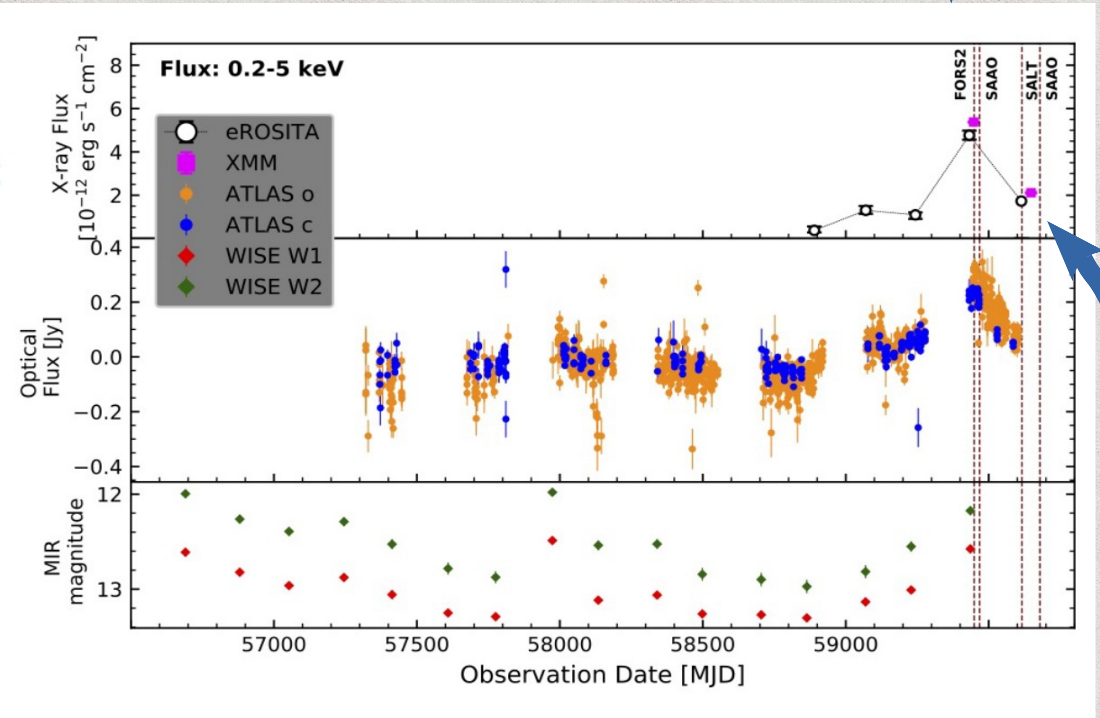
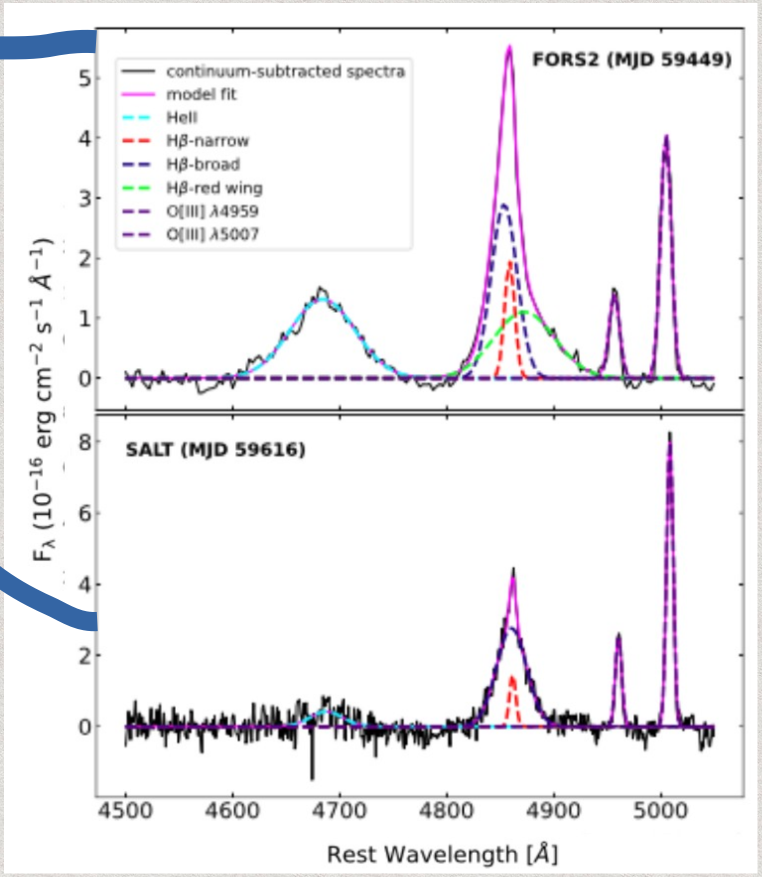
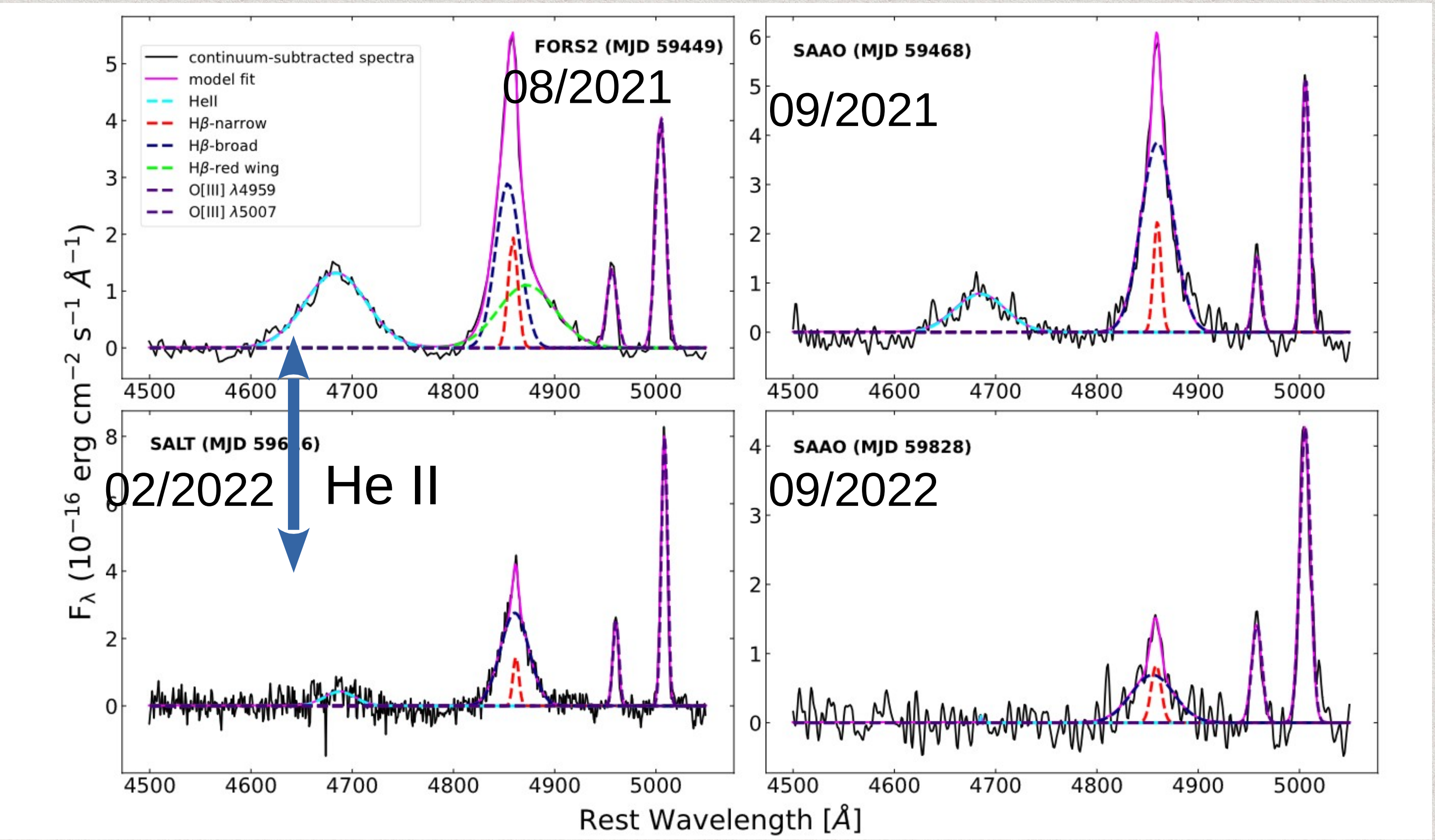




Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

The broad He II λ4686 line disappeared within five months as the optical/UV/X-ray continuum faded; broad Hβ flux dropped only by a factor of a few.

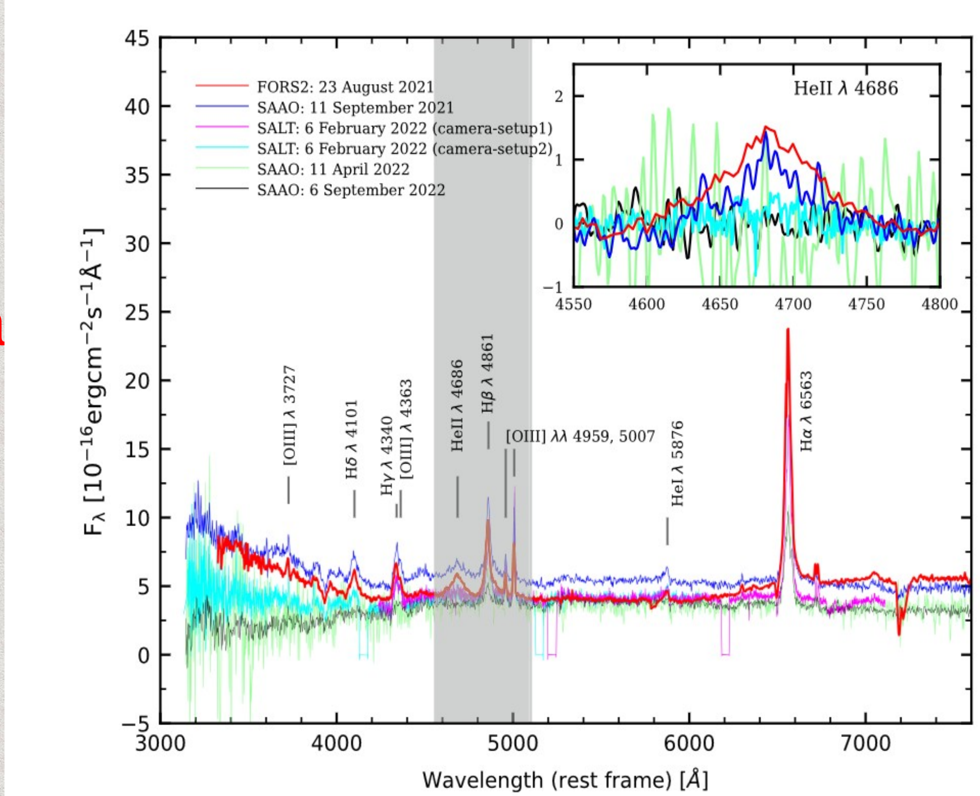
Strong He II variability implied extreme luminosity flaring in the EUV-emitting region of the inner disk.



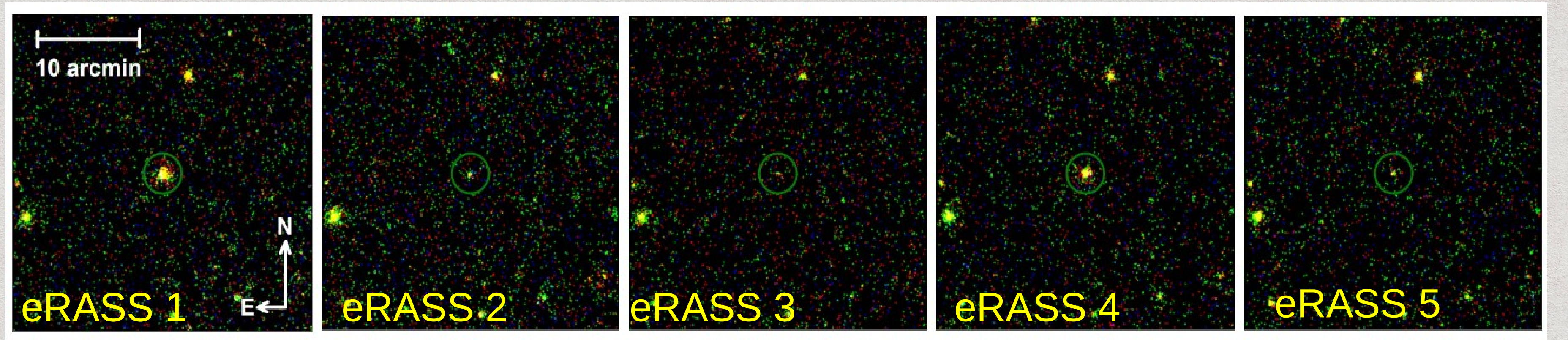
Multi-wavelength flaring/CLAGN event in a low-luminosity Seyfert

SUMMARY:
Event caused by temporary burst of accretion in the inner disk, likely a disk instability event.
⟶ Drove X-ray flaring and decay via thermal Comptonization
⟶ Drove changing-look behavior in He II λ4686 emission from the inner BLR

Published in Krishnan et al.2024

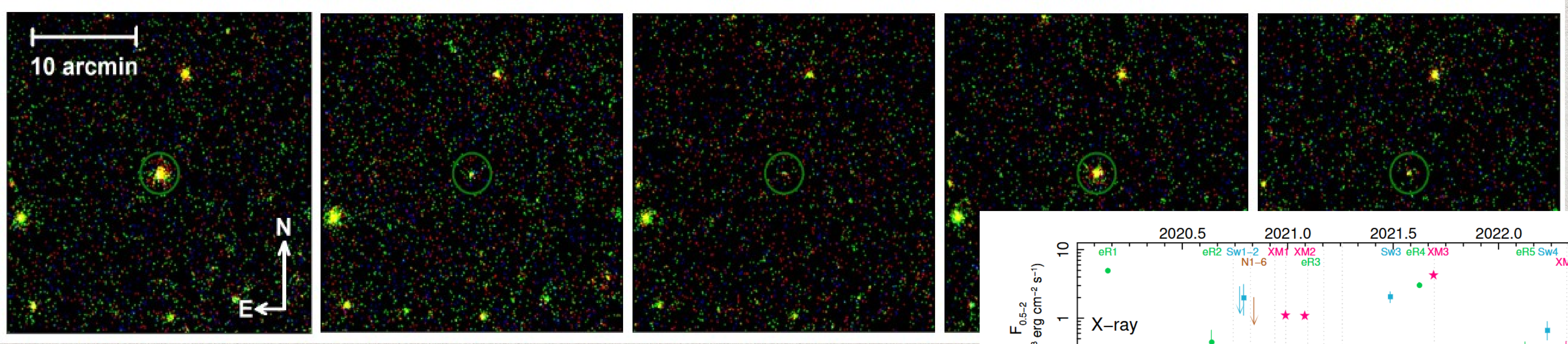


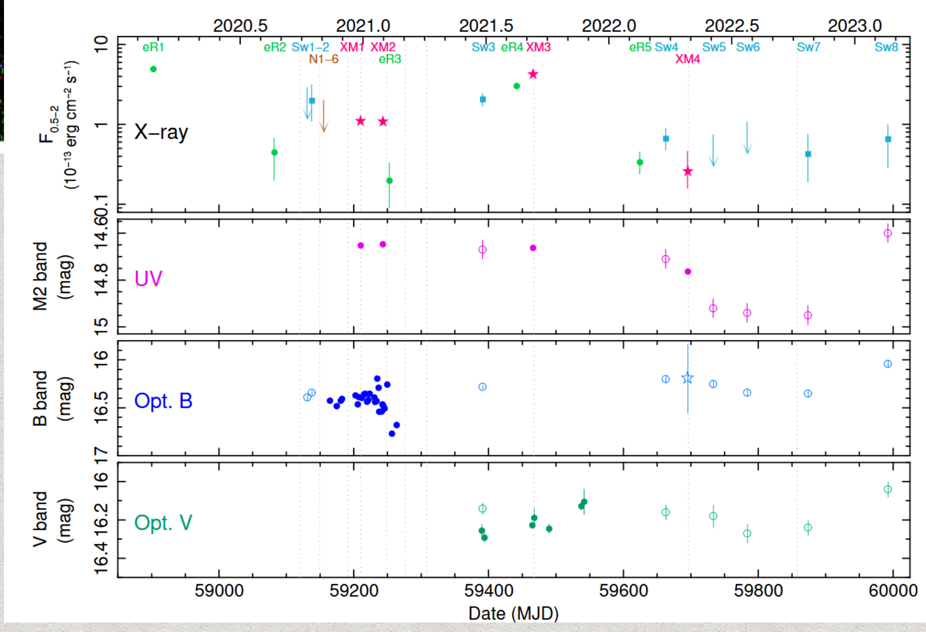
The first AGN cloud occultation events discovered with eROSITA



- eROSITA detected major soft X-ray variations in a Sy 1 at z=0.28;

The first AGN cloud occultation events discovered with eROSITA

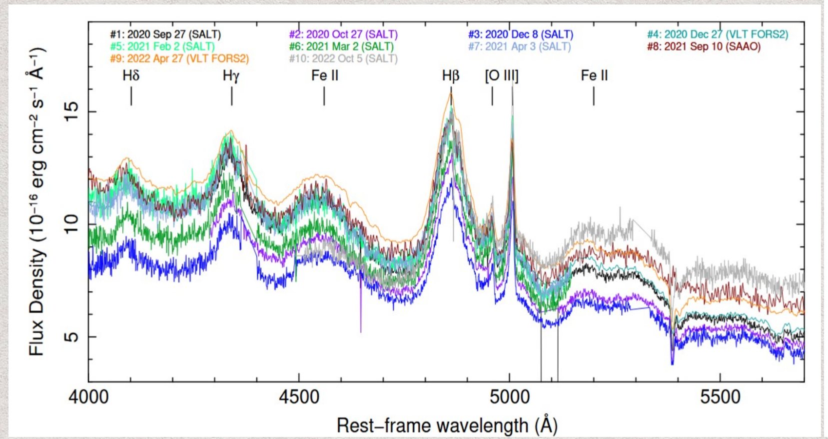


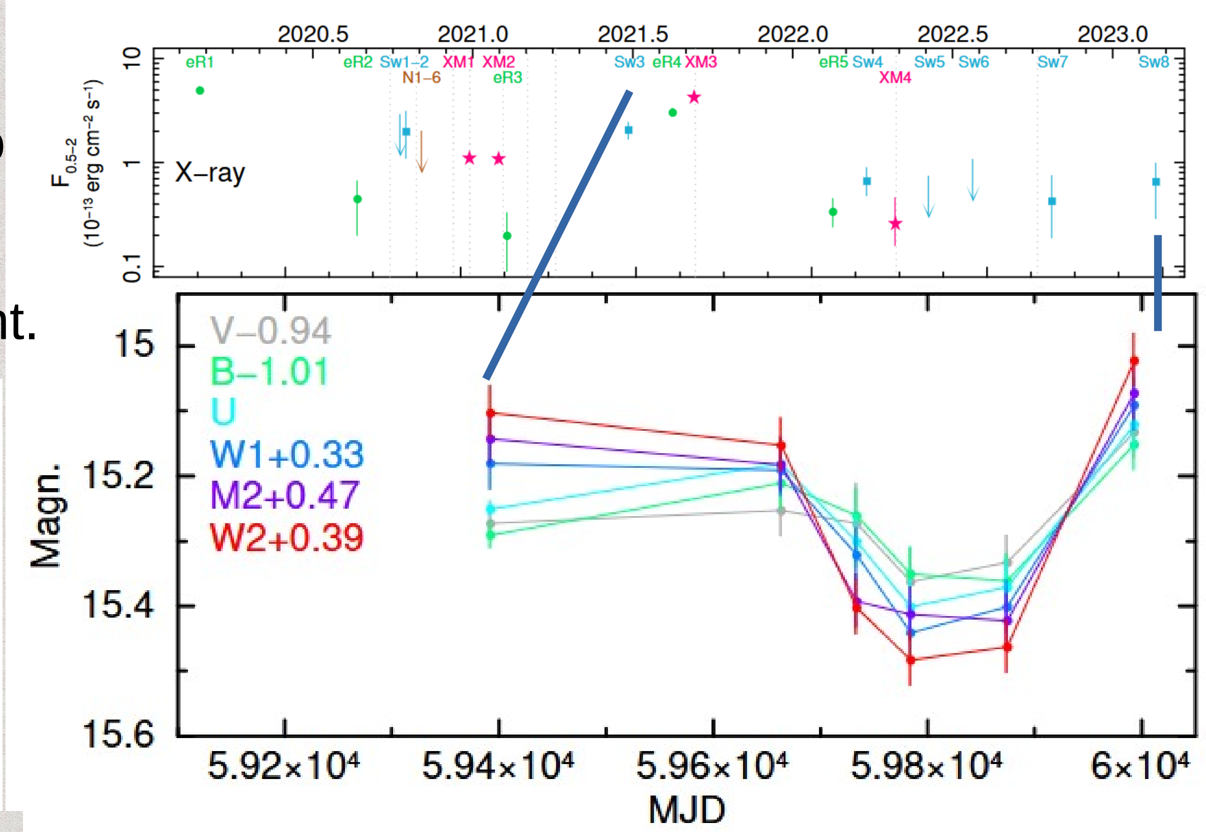


- eROSITA detected major soft X-ray variations in a Sy 1 at z=0.28;
- after each major decrease – increase - decrease, we triggered XMM-Newton, NICER, Swift, ground photometry, VLT, and SALT, SAAO for multi-wavelength campaign spanning Feb. 2020 — Feb. 2023, tracing two major low soft X-ray states.

The first AGN cloud occultation events discovered with eROSITA

- The UV/optical continuum varied only minimally (<40%)
- The optical/UV SED showed no reddening due to dust;
- optical spectra showed no variation in the Balmer decrement.





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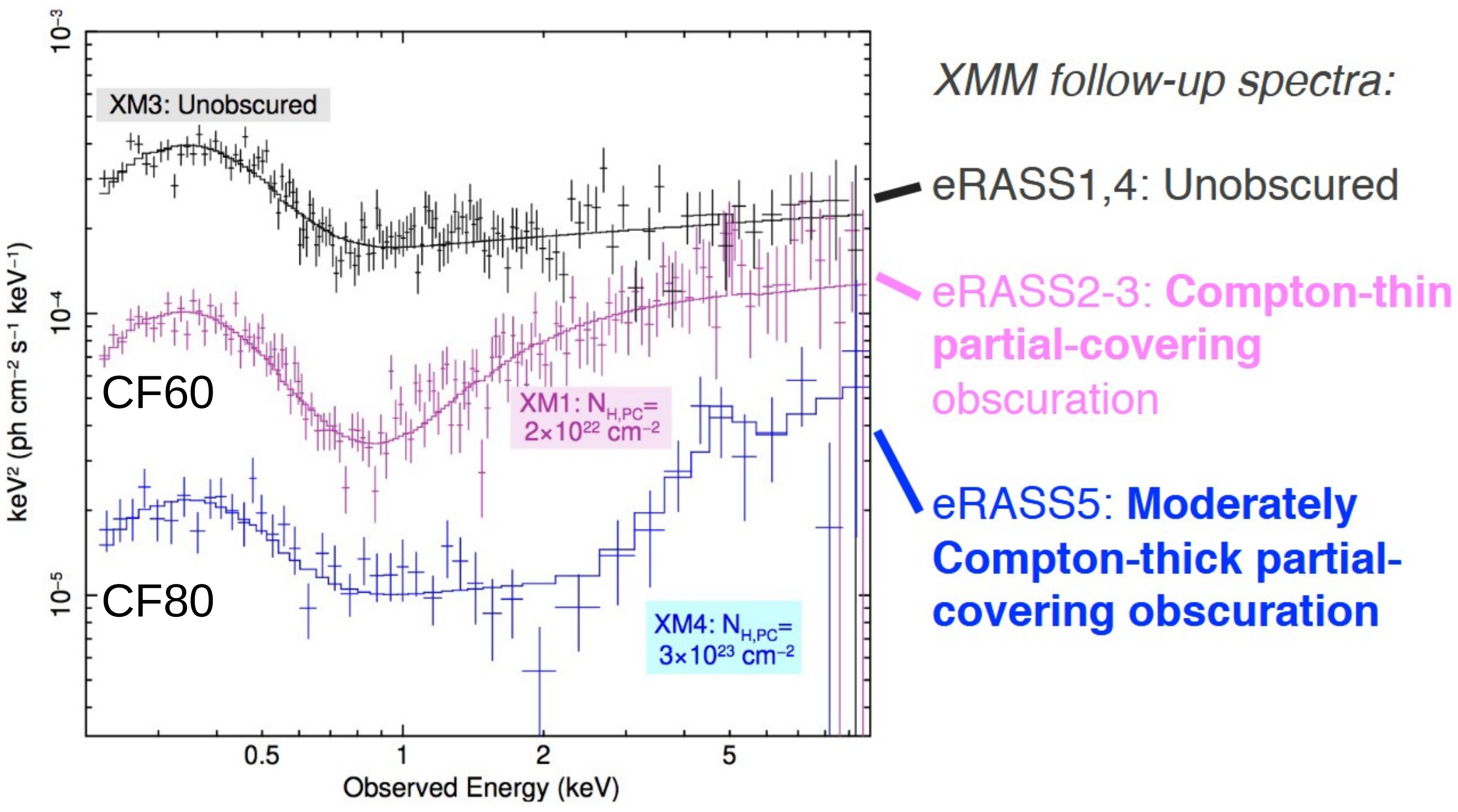


XMM-Newton follow-up spectra confirmed that each low flux state was due to line-of-sight partial-covering obscuration by gas with NH ~ 10^{22-23} cm^{-2}.

The first AGN cloud occultation events discovered with eROSITA

SUMMARY:
The obscuration events are consistent with compact clouds commensurate with the outer BLR , or a sustained dust-free wind with numerous compact dense X-ray obscuring clumps, launched from the inner disk.

Published in Markowitz et al. 2024

Photometric RM of extremely variable AGN

- Goal: study the Broad-Line Region (BLR) in active galactic nuclei (AGNs) by measuring time delays (lags) between continuum and line flux variations.
- A cost-effective alternative to Spectroscopic Reverberation Mapping (Spectroscopic RM).

  Why Monitor Extremely Variable AGNs?
- Large-amplitude variability provides stronger signals, making them ideal candidates for RM.
- Time-domain photometry is sufficient to detect continuum reprocessing in the BLR

Photometric RM of extremely variable AGN

Requires intensive long-term monitoring with high-resolution spectrographs.
Dependent on large, expensive, and oversubscribed telescopes (e.g., Keck, VLT).

Advantage: Smaller facilities are more accessible, cost-effective, and easier to schedule.
Bulk Observations: Use smaller telescopes to perform regular, high-cadence photometric monitoring – use SALT for spectroscopy

Currently four AGN are being monitored. Selection based on redshift and optical/Xray variability

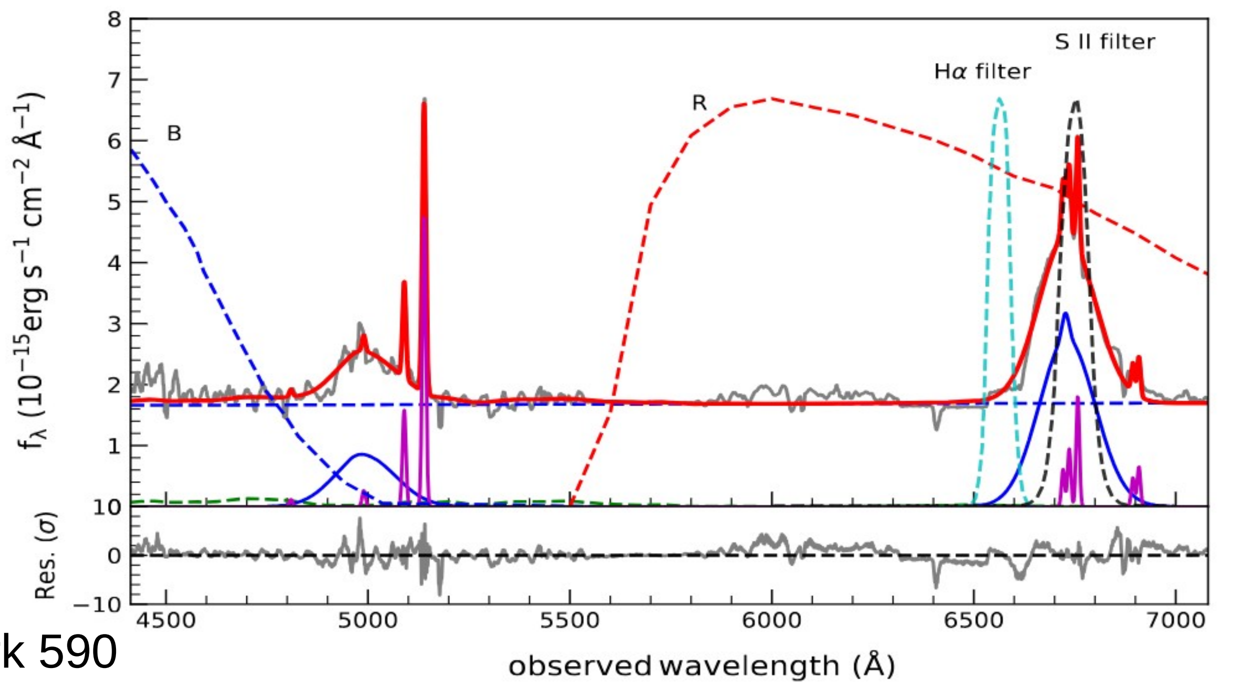
Photometric RM of extremely variable AGN

What we need is good consistent coverage of the sky – currently Skynet

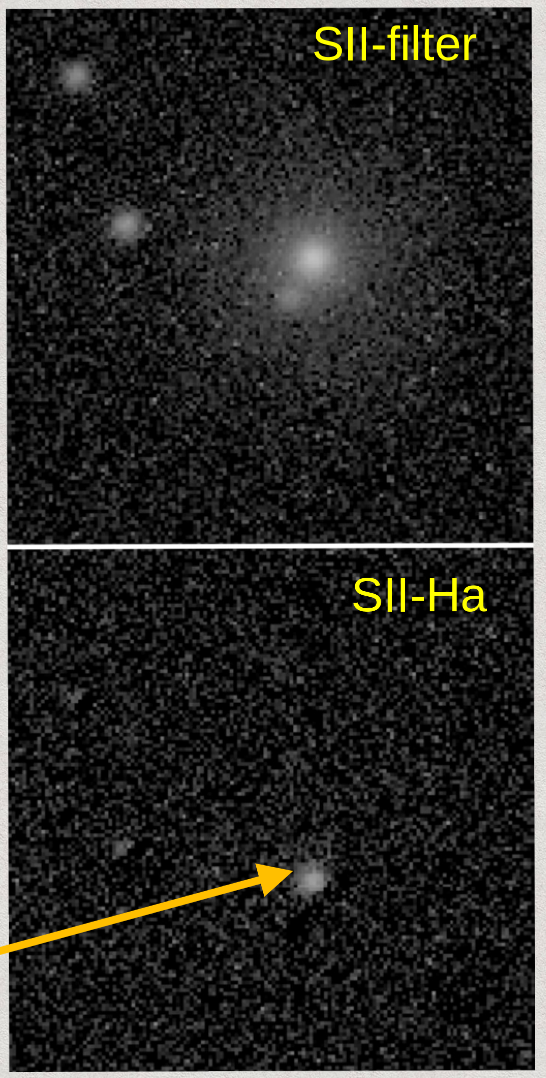
TRT Network: Idea:
4 clone telescopes 16 filters

Photometric RM of extremely variable AGN

We make use of two adjacent NB filters SII + Ha
to trace the changes in the broad emission line



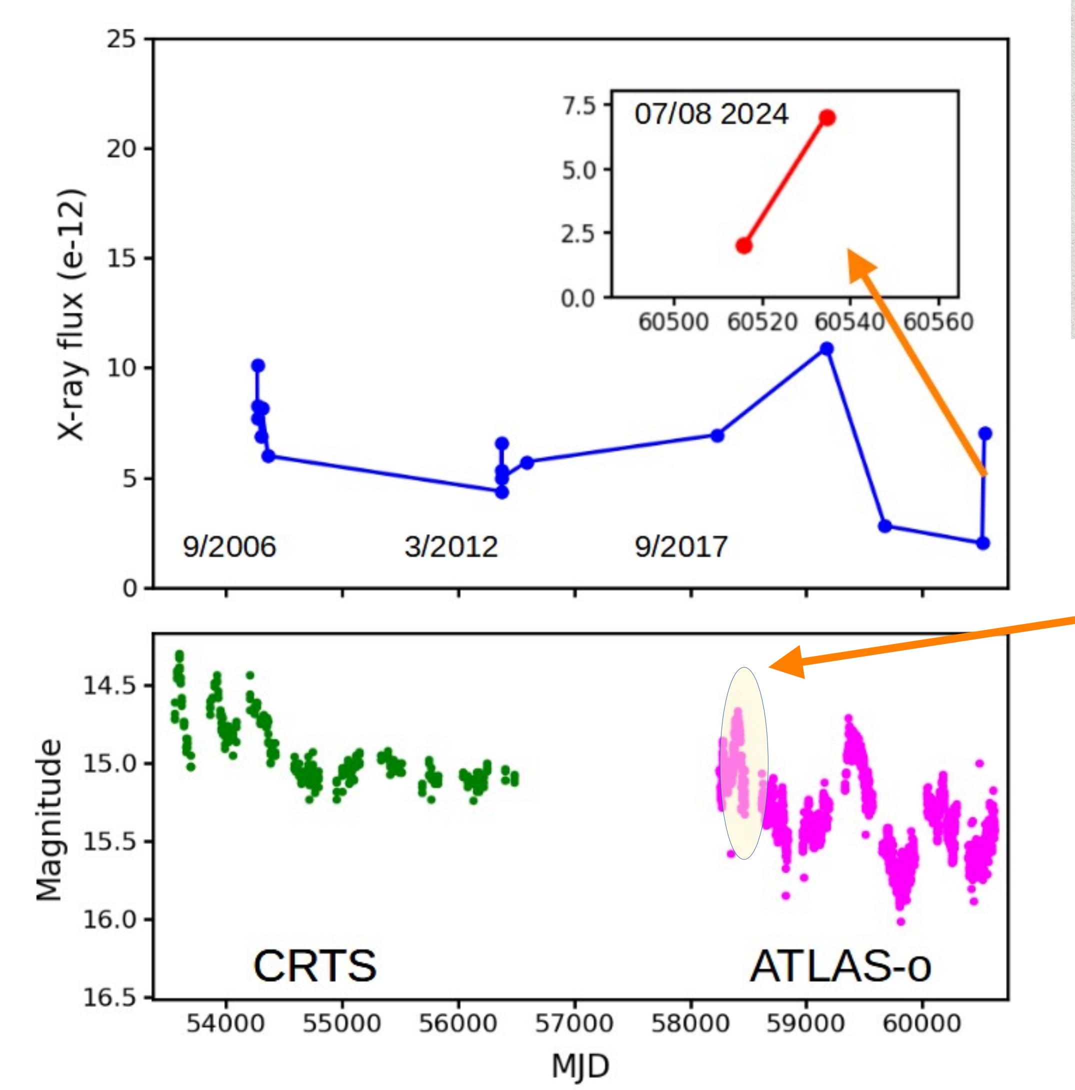
Mrk 590



Only Ha-emission remains after
subtracting the Ha-filter from SII
good quality from 60cm telescope

Mandal et al. 2021

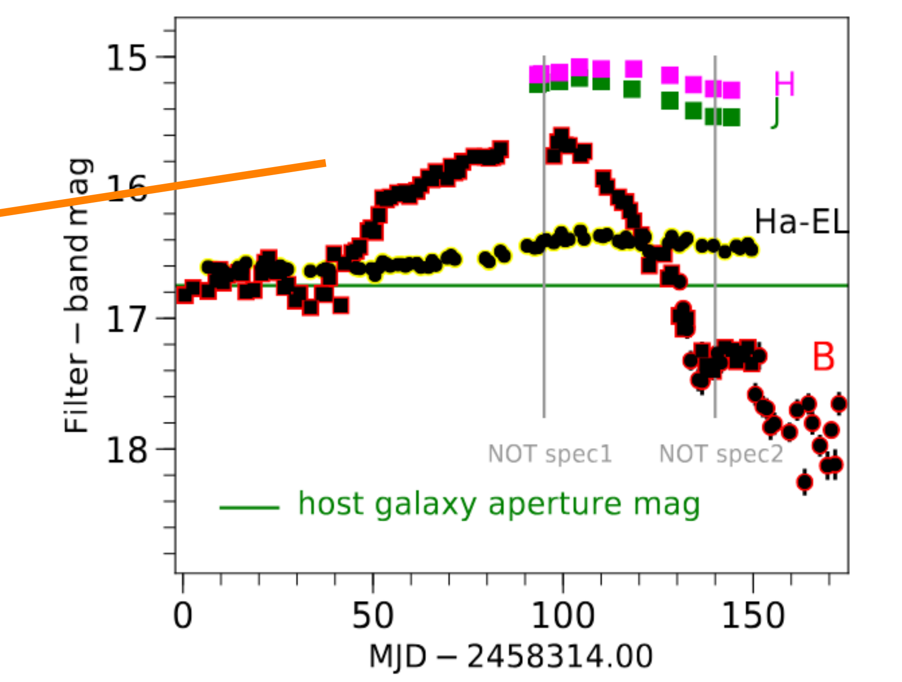
Photometric RM of extremely variable AGN



Current campaign

Extremely variable Seyfert 1 at z=0.03

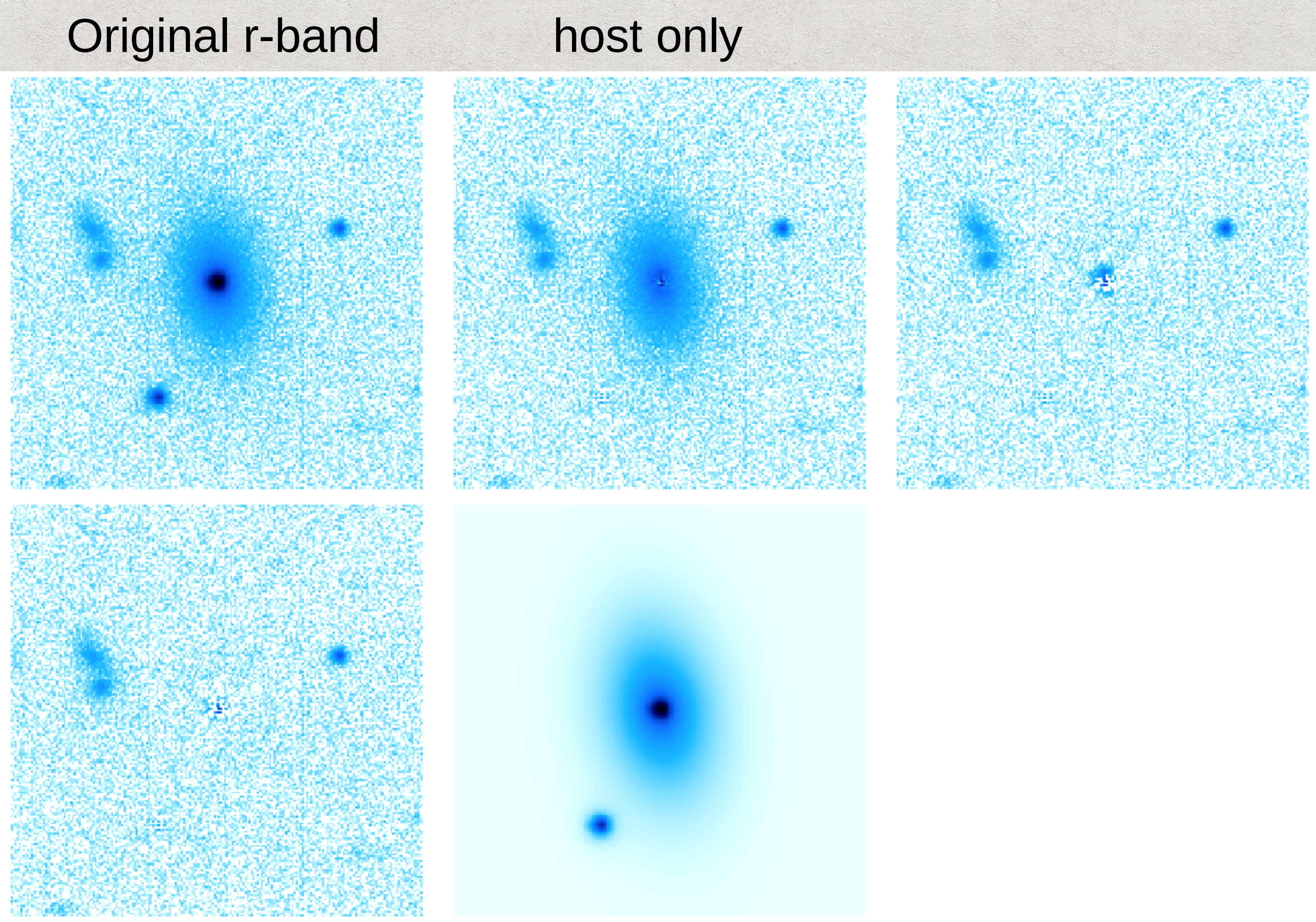
2018-campaign



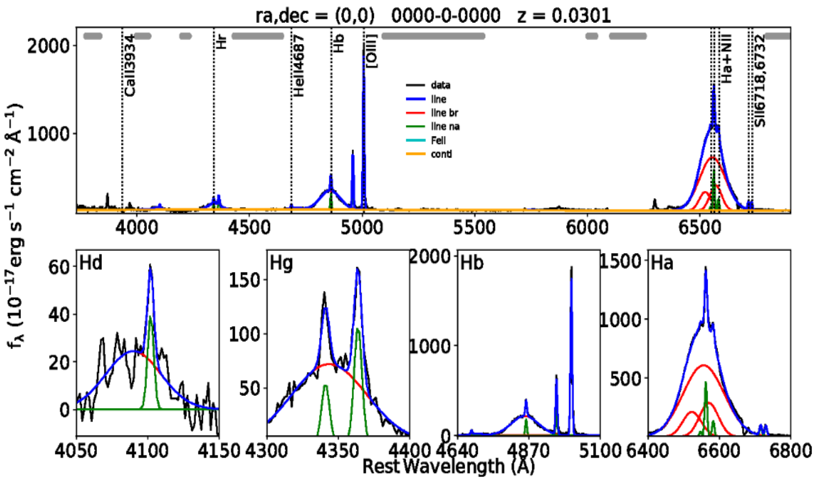
Photometric RM of extremely variable AGN

Strong contamination of the host galaxy
Need to properly account for the host flux

Use good seeing GMOS data during weak phase to model the host galaxy.
Create aperture corrections by modeling deep stacks of our monitoring data

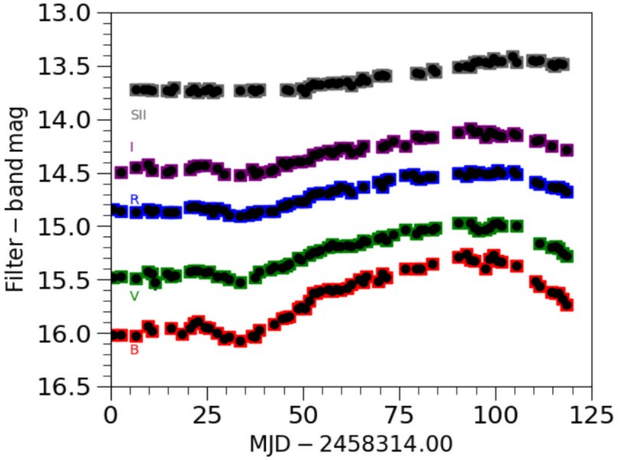


Photometric RM of extremely variable AGN

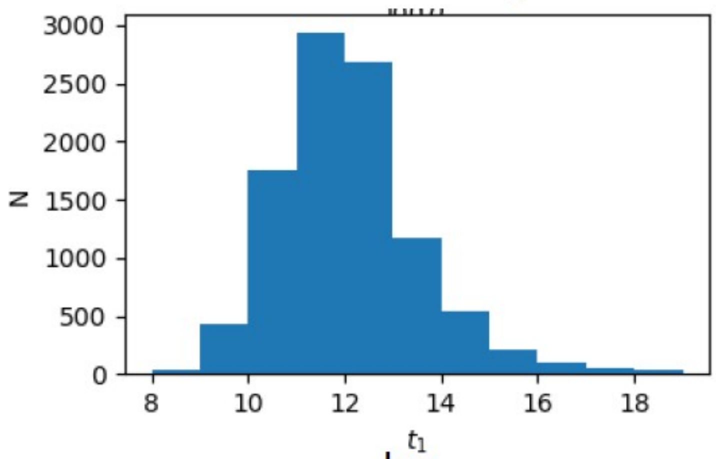


In 2018: Very high cadenc
with mainly 1 optical
telescope
We take spectra only once
few weeks or months.

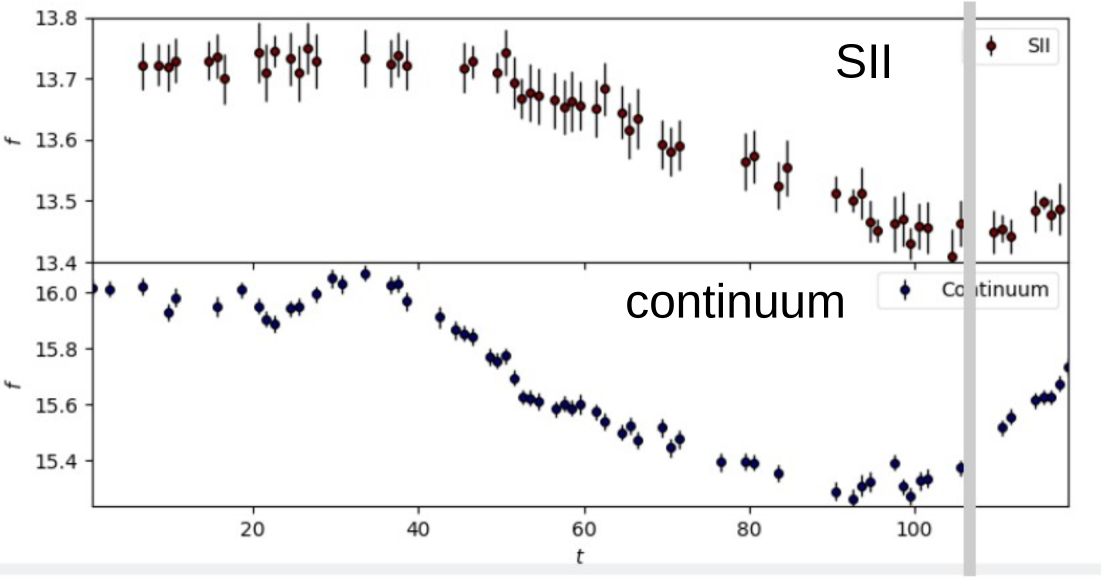
Ha-lag detected



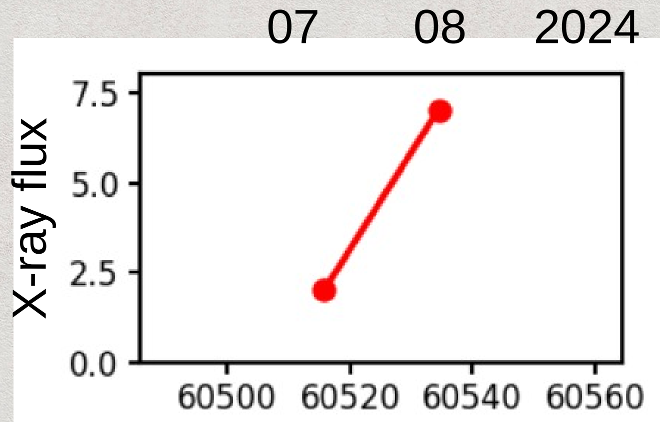
low:10.7 Med:11.9 high: 13.4



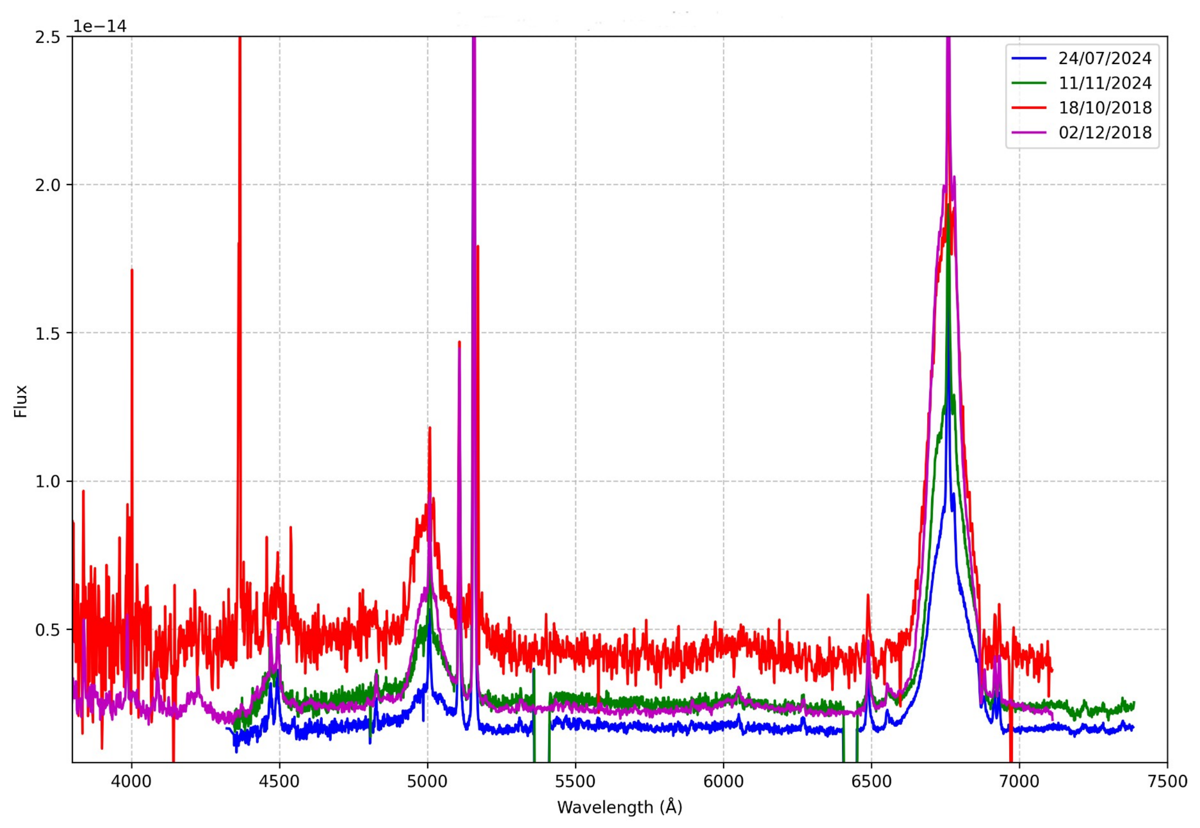
lag



Photometric RM of extremely variable AGN



Current campaign started 2024 at the lowest X-ray flux ever observed for this source – we observe rapid increase In the X-ray flux over 19d – UV/optical also increasing



July 24 2024 the Ha/Hb ratio is 7.1 meaning Av = 0.9 mag
Nov 11 2024 Ha/Hb=5.1
Never see full CLAGN

For comparison:
During 2018 outburst Ha/Hb=4

Photometric RM of extremely variable AGN

SUMMARY:
Need to test several scenarios:
Need XMM to test for partial-covering obscuration since Gamma_HX is usually rather flat (~1.5) BUT current HR errors are large

More likely accretion driven variability Optical/UV continuum and emission-line monitoring shows significant variability following X-rays

Dust-Related Absorption: SED modeling and optical/UV photometry shows some reddening

Conclusion

- Several case studies that make use of small optical telescopes to trace X-ray selected transient events
- Small robotic telescopes can monitor events with high cadence in many filters
- Photometric RM can compete with spec. RM – cheap, high cadence, allow specific triggers for spectroscopy
- large facilities mostly for spectroscopy