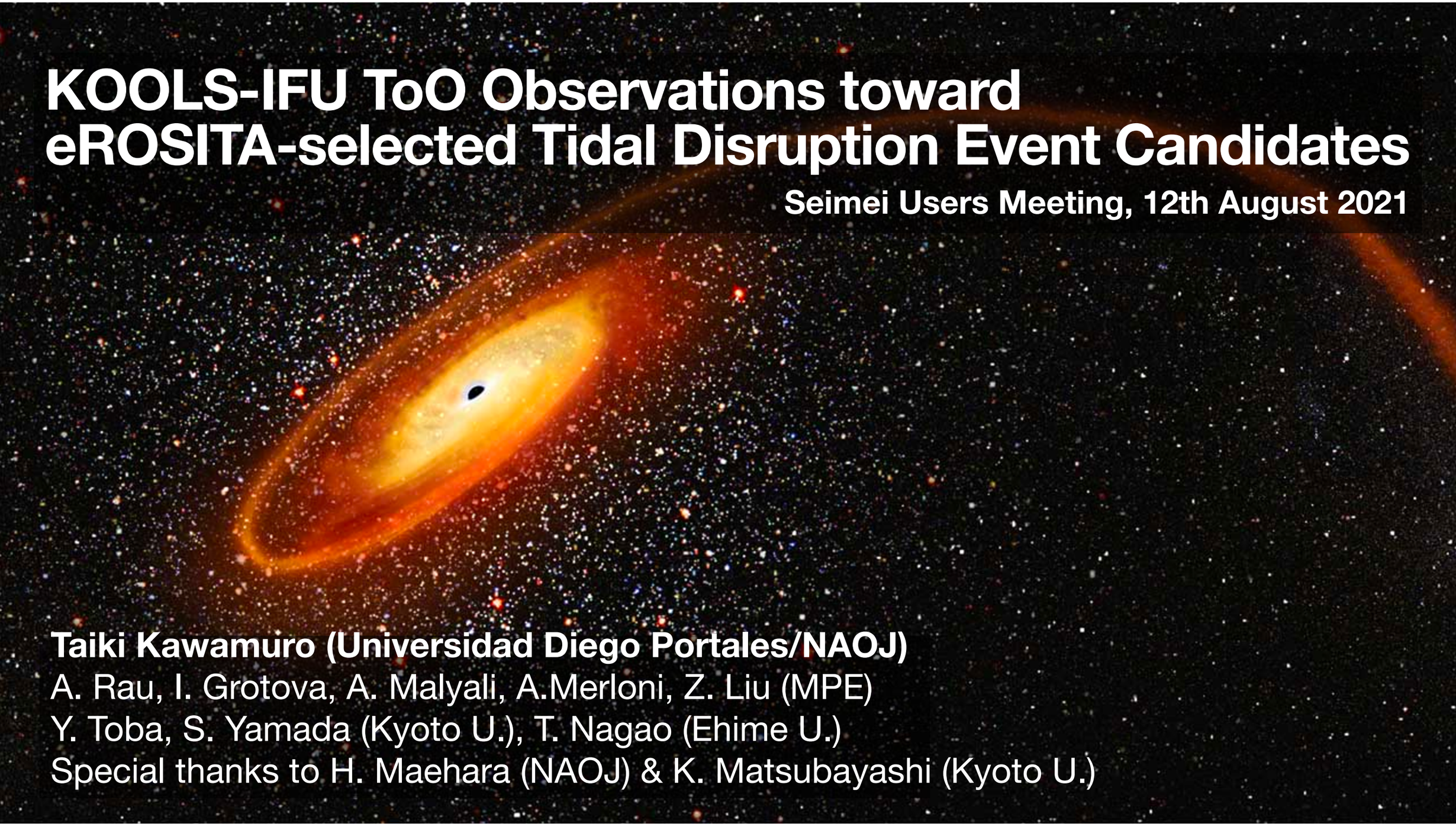
KOOLS-IFU ToO Observations toward eROSITA-selected Tidal Disruption Event Candidates

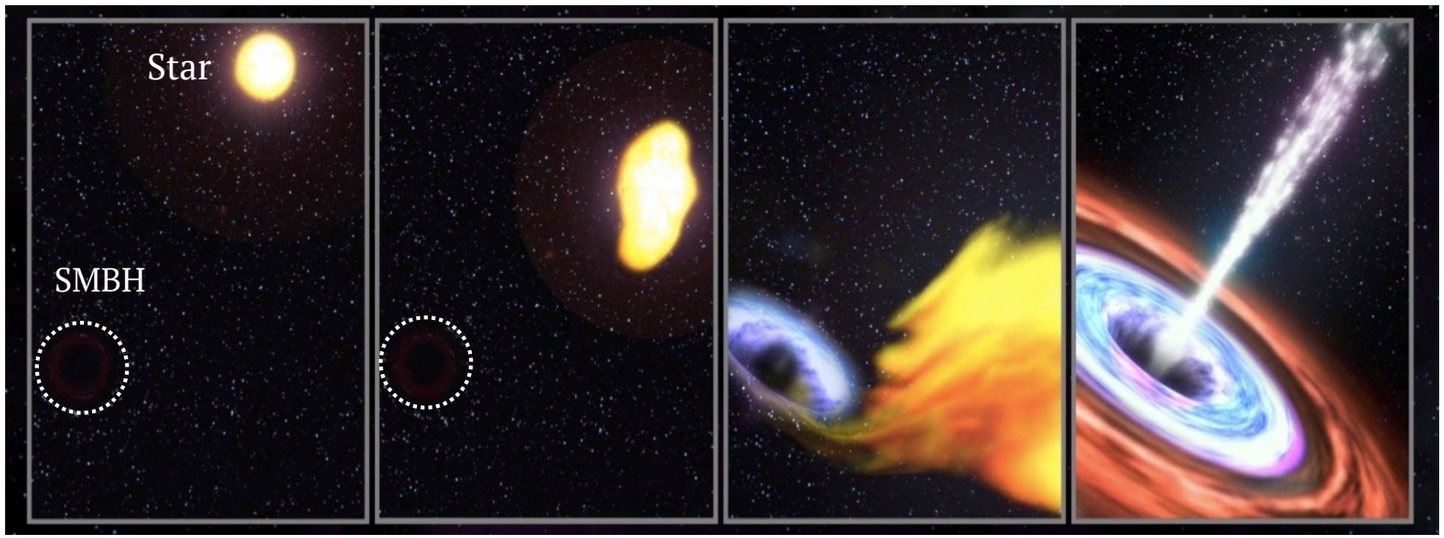
Seimei Users Meeting, 12th August 2021

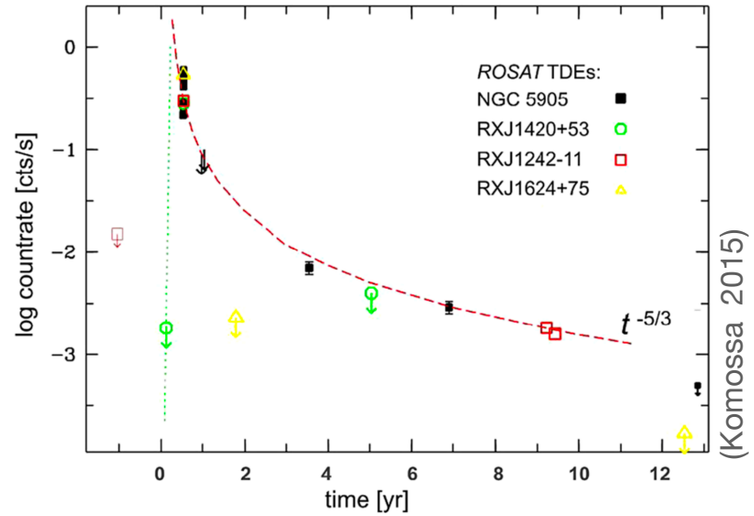


Taiki Kawamuro (Universidad Diego Portales/NAOJ)
A. Rau, I. Grotova, A. Malyali, A.Merloni, Z. Liu (MPE)
Y. Toba, S. Yamada (Kyoto U.), T. Nagao (Ehime U.)
Special thanks to H. Maehara (NAOJ) & K. Matsubayashi (Kyoto U.)

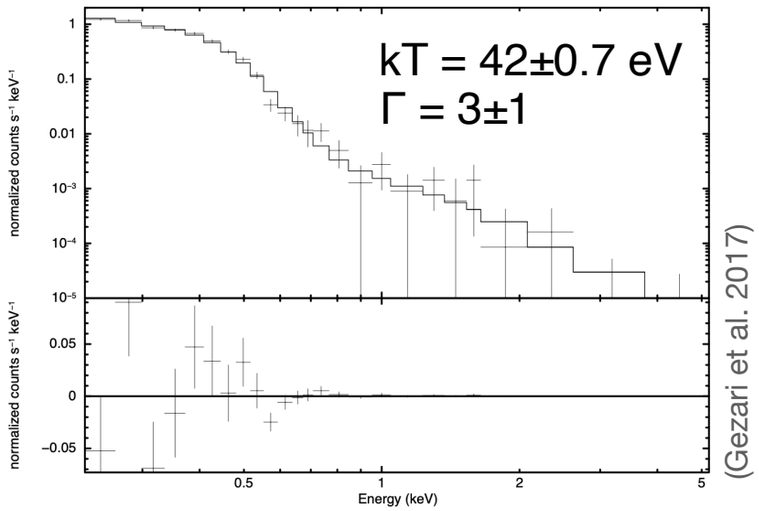
Tidal Disruption Events and X-ray Observations

(NASA)





(Komossa 2015)



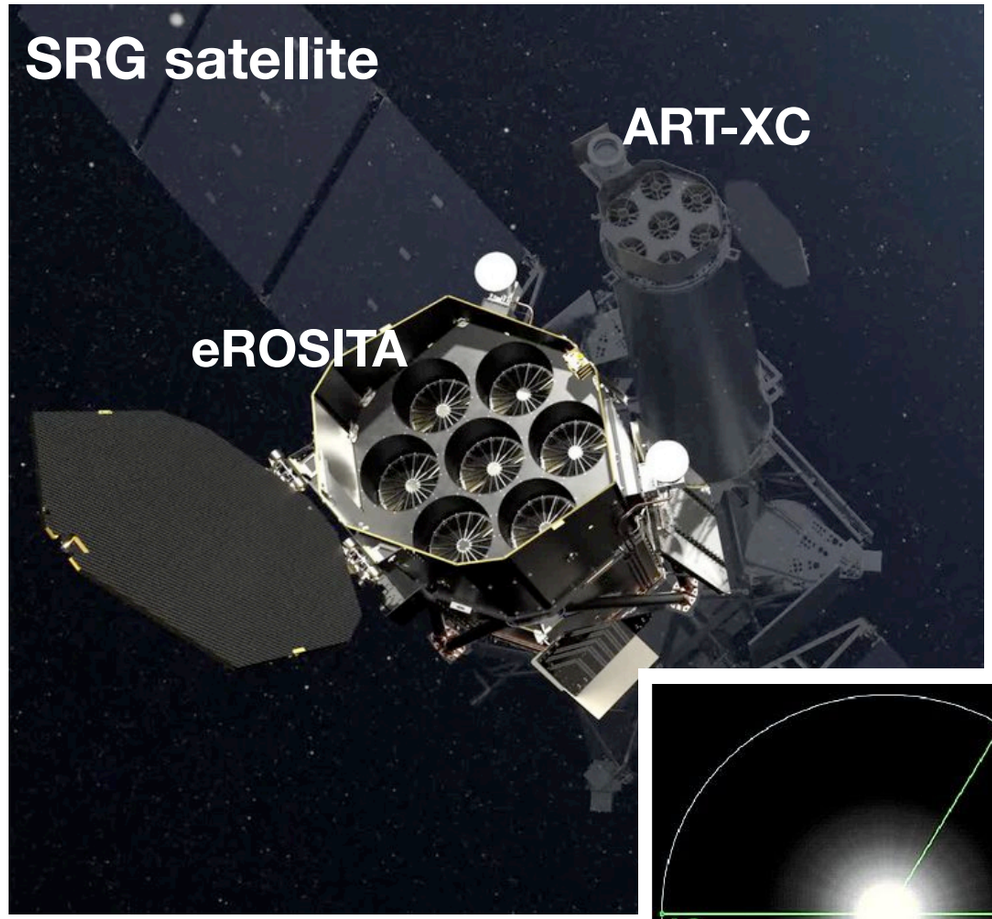
(Gezari et al. 2017)

- Signature of a star being disrupted by a SMBH in galactic nuclei
- Months-years lasting in X-ray and UV/optical as well
- Soft black-body X-ray emission, typical for ROSTA TDEs in 2000

- An invaluable class for studying the evolution of accreting matter around SMBHs

eROSITA Survey for a New and Large X-ray TDE sample

- eROSITA:
  - Launch in December 2019
  - ~ 0.5-2 keV (as main band)
  - ~ 10 times higher sensitivity than ROSAT
  - On-going all-sky scans (= eRASS)
    at a cadence of ~ 6 months
    -> 8 scans in total
- 3 scans were already completed



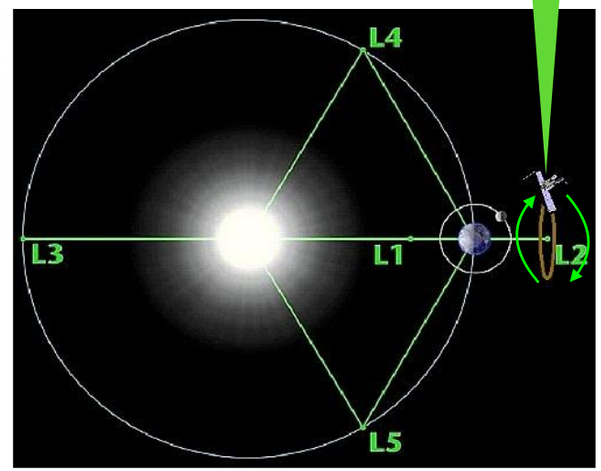
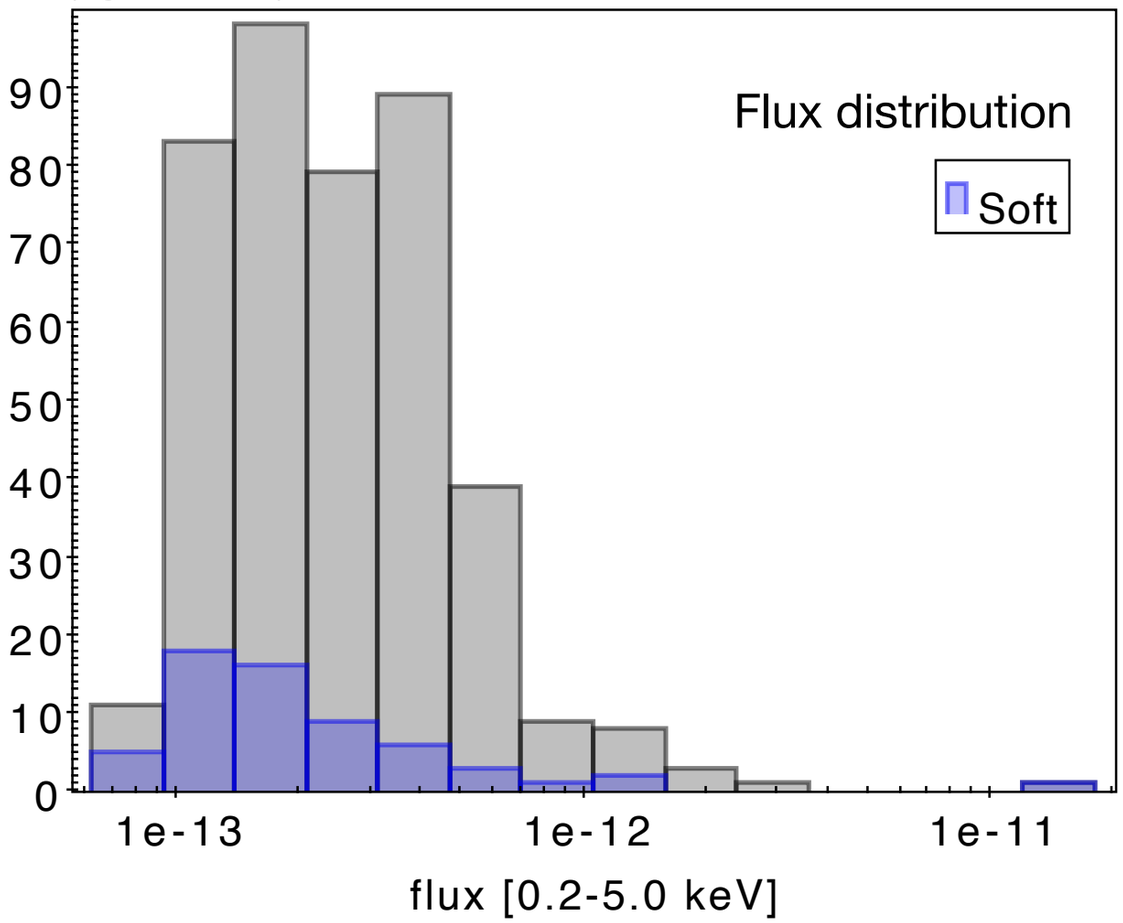


Figure 7: Illustration of the Lagrangian points in the Sun-Earth system (image credit: IKI)

Nuclear transients sample statistics
(for one year b/w June 2020-June 2021)

(Fig.: I. Grotova)



- **421** Nuclear Transients
- after additional filtering (prior follow-up)
- **61 soft** candidates/yr, ~ 30 per eRASS

Nuclear transients sample statistics

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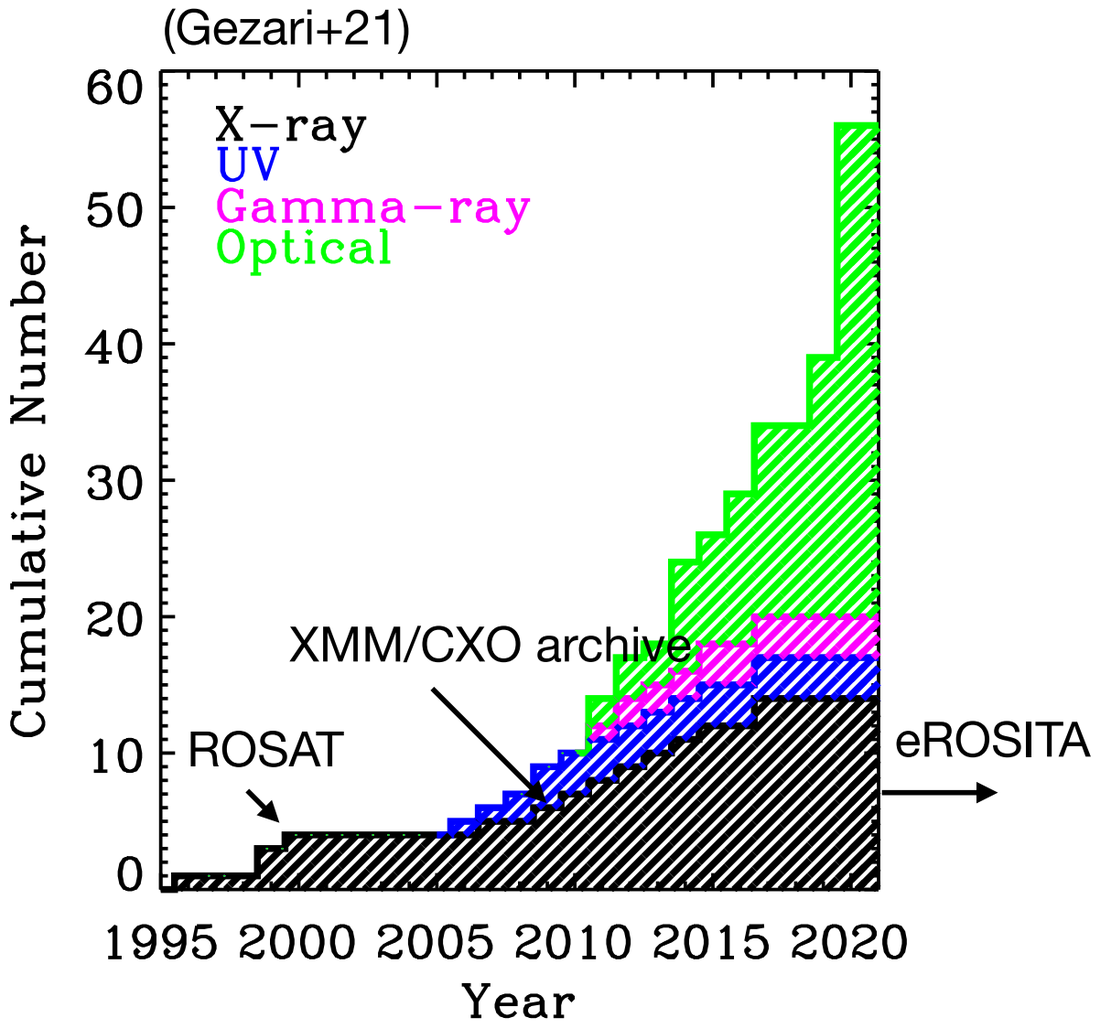
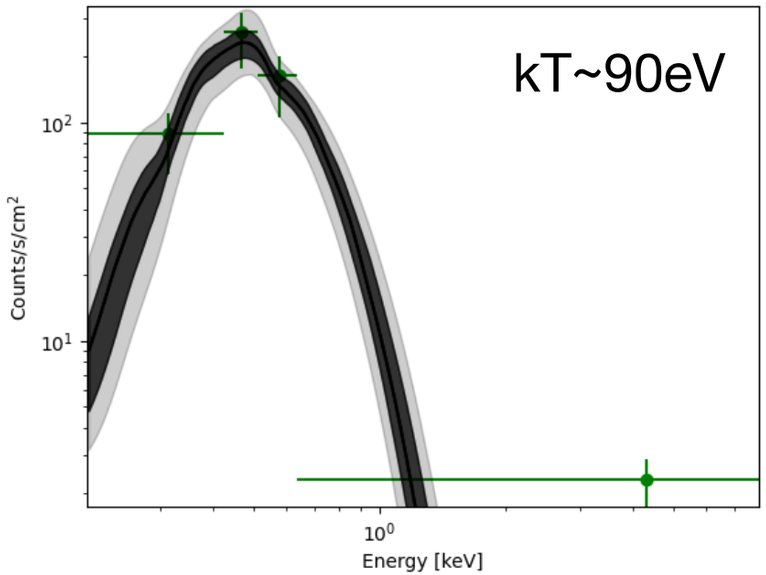


- **421** Nuclear Transients
- after additional filtering (prior follow-up)
- **61 soft** candidates/yr, ~ 30 per eRASS
- Higher identification rates than recent optical surveys !
  (i.e., ~ 40 candidates/yr)
- Now is the time for systematic follow-up obs. toward X-ray TDEs
  (Caution: this is until ~ 2024)

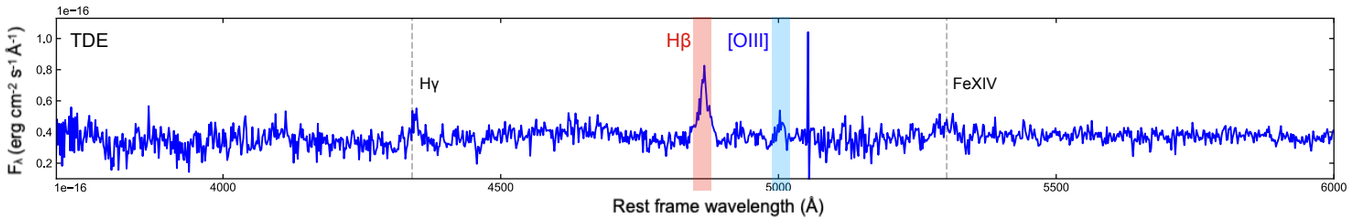
Brief Description of Search Procedure


- Weekly search for new nuclear transients from galaxies without prior signs of AGN activity

- Initial automatic selection based on
  - X-ray softness
  - Flare amplitude compared to previous eRASSs
  - Host galaxy properties or in pre-burst (e.g., W1-W2<0.5mag)
  - GAIA proper motion



X-ray/UV/**Optical**/Radio Follow-up
- Verification and removal of contaminants
- Redshift measurements
- Light curve and spectral evolution
- Energetics



Optical Spectroscopy Follow-up Efforts

Massive effort by many people combining a wide range facilities around the globe

LCO 2m + FLOYDS (MPE Time)
- Queue-schedule access (~21 observations)

ANU 2.3m + WiFeS (G. Anderson, J. Miller-Jones, A. Kafka; AAL)
- Monthly observations (9 nights so far, ~30 targets)

3.5m ESO NTT + EFOSC (PI: A. Malyali)
- Guest observer program (48 targets)

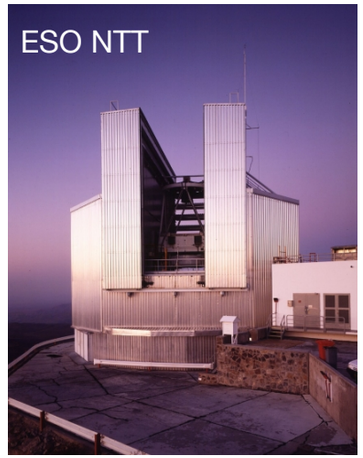
3.8m SEIMEI (PI: T. Kawamuro, Y. Toba; IECs)
- ToO Guest observer program (1 target)

※ **Only ToO access to spectroscopy**

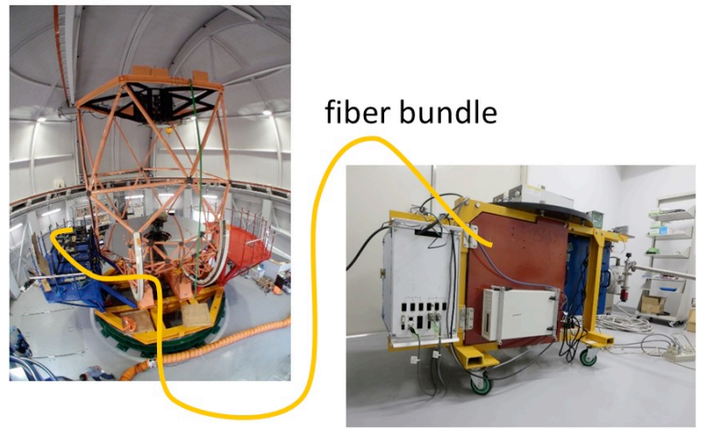
6.5m Magellan (PI: F. Di Mille, S. Ciroi; IECs)
- Opportunity observations (12 sources)

~10m SALT (PI: D. Buckley; MoU)
- SALT Transient ToO project (4 sources)

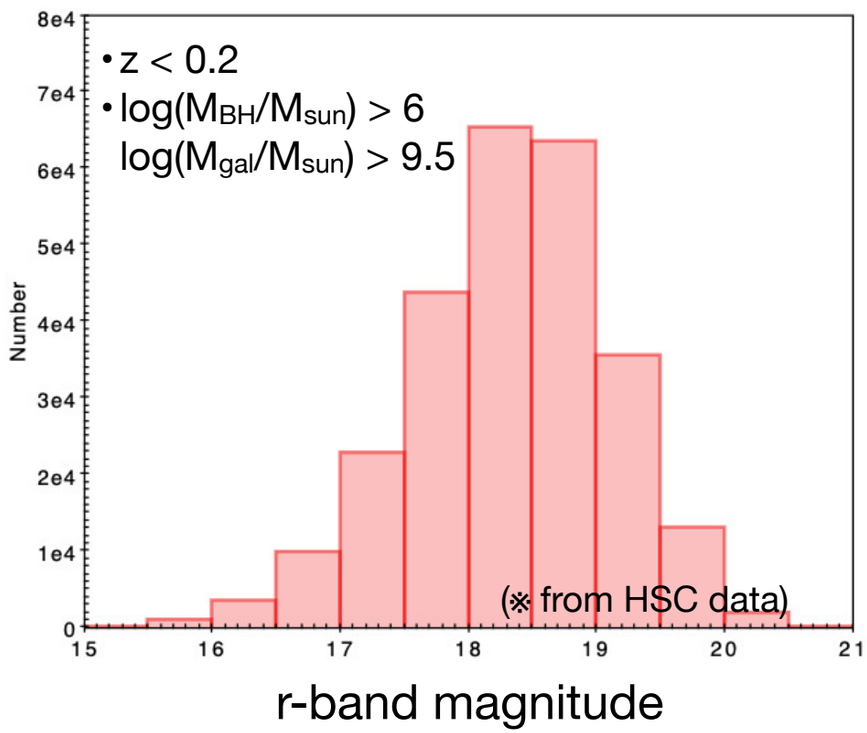
Data stored on the SciServer



Our on-going project using Seimei/KOOLS-IFU

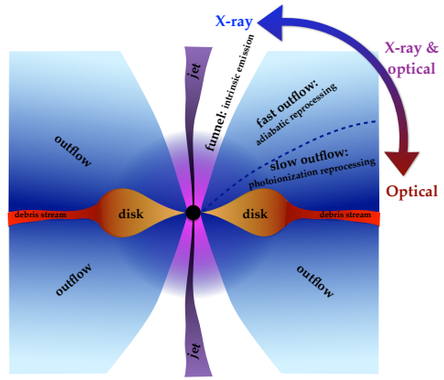


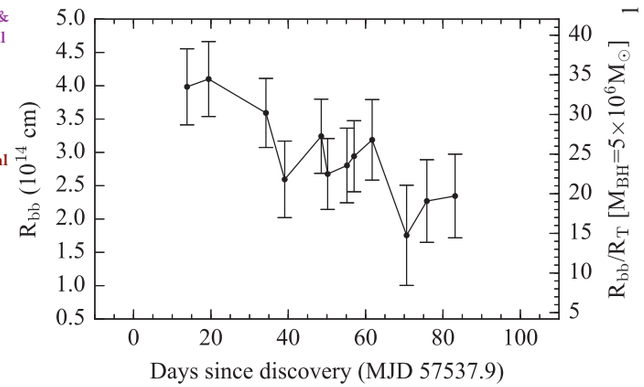
- **Why Seimei/KOOLS-IFU ?**
  - **ToO Access** :
    Only ToO access for ``spectroscopy" is invaluable
    to study time-variable TDEs
  - **Source Identification** :
    FoV of ~ 8 arcsec covers the positional uncertainty for
    eROSITA sources (i.e., *d* ~ 9 arcsec for ~ 3 sigma)
  - **High Sensitivity** :
    Sufficient spectroscopy sensitivity for most of
    eROSITA TDE candidates at z < 0.2
    → for 18.5 mag. sources, 1 hr for 15 sigma detection per 10Å
    → easier for brighter optical TDE flares

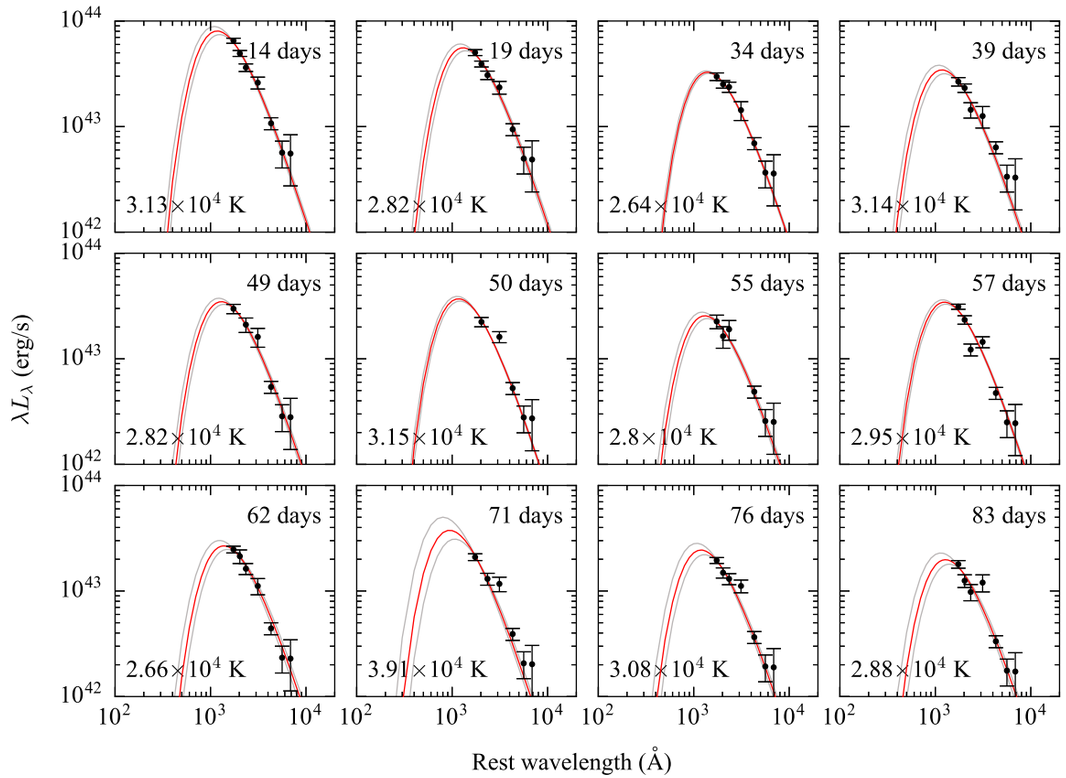


Optical studies of (optically selected) TDE candidates so far

- There are various questions to be addressed
  - What is the size of accreting material ?
    → related to a big question on how to extract angular momentum
    → $R_{\rm eff} \sim [L/4\pi\sigma T_{\rm eff}^4]^{0.5}$







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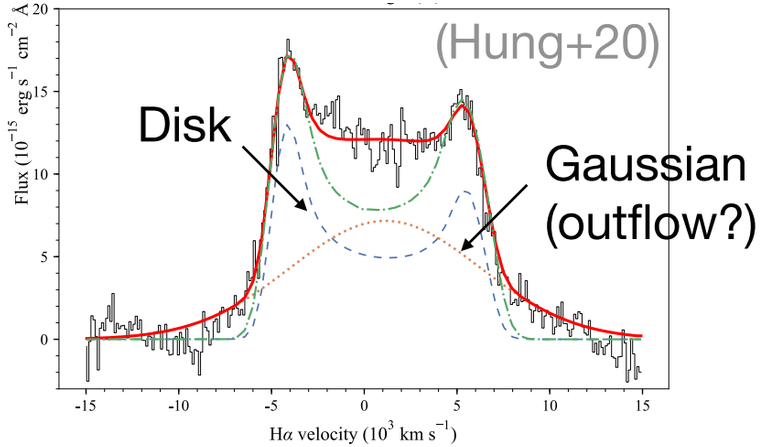
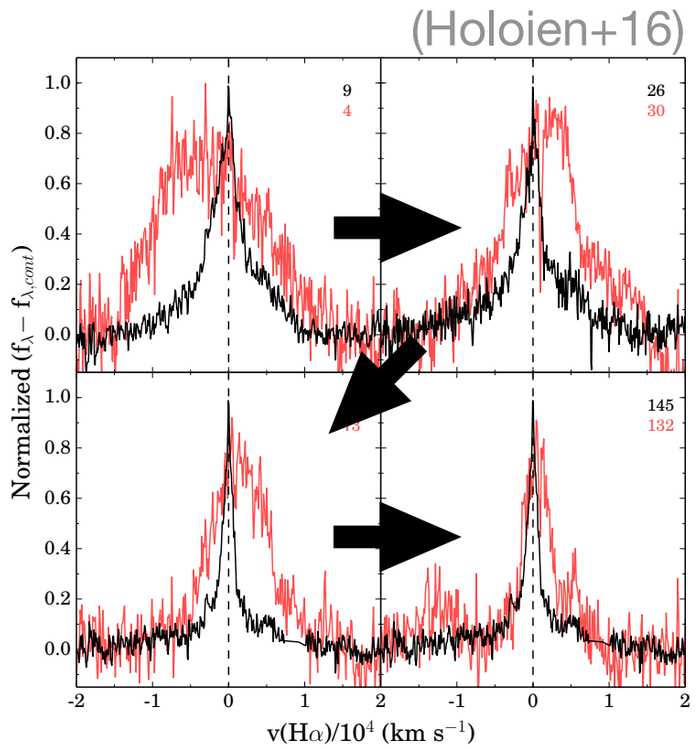
  - What is the structure of accreting matter ?
    → Disk and outflow
    → Evolution of broad lines (narrower with brighter)
    → Reverberation mapping b/w X-ray and optical





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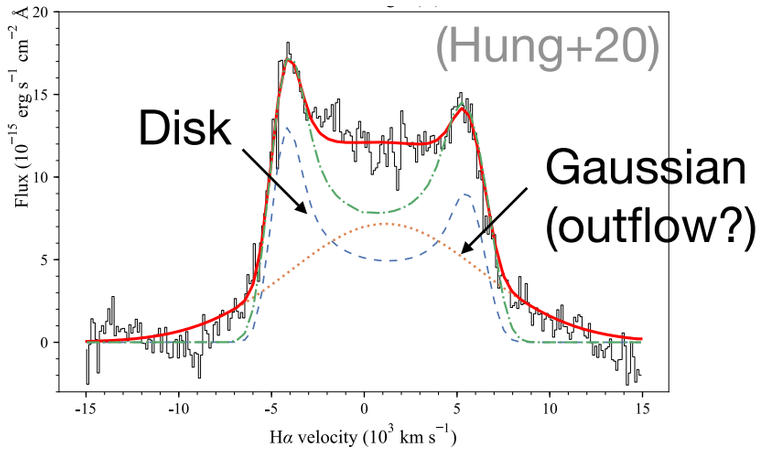
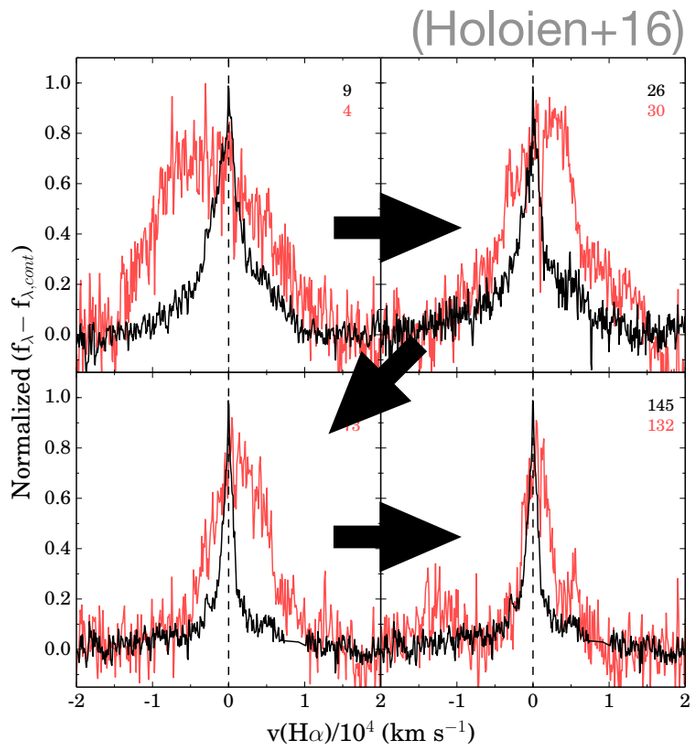
    → Disk and outflow
    → Evolution of broad lines (narrower with brighter)
    → Reverberation mapping b/w X-ray and optical
  - How are all of these aspects affected by the properties of the BH and those of the disrupted star ?
    → need a large sample

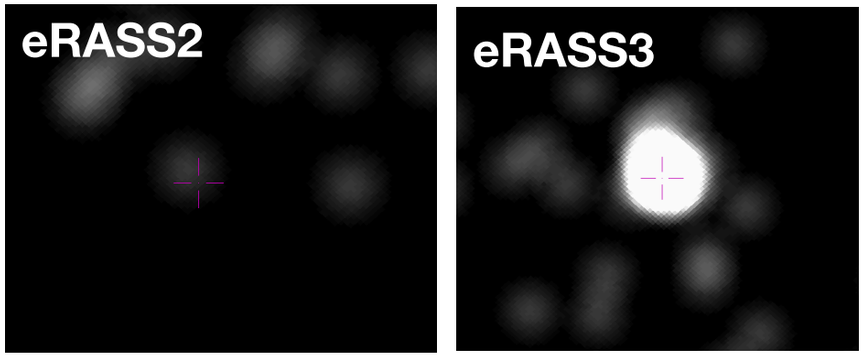


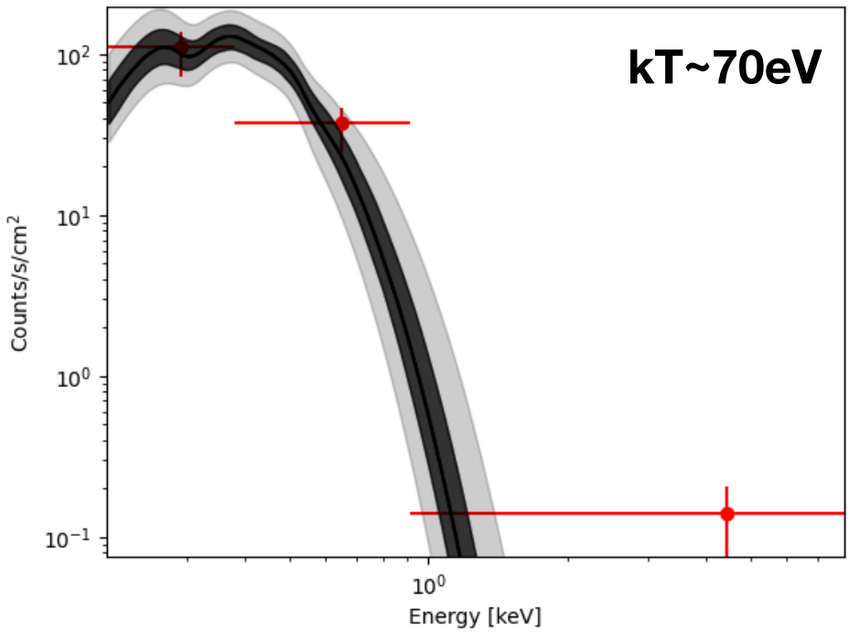


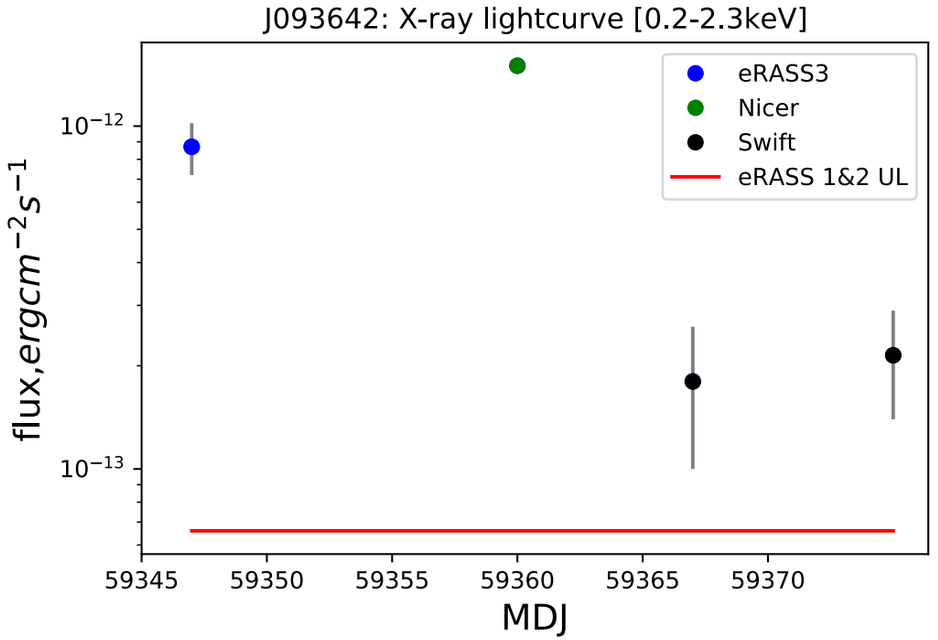
Actual optical obs. of three X-ray Events

(Only interesting objects are selected)

Source 1: eRASSt J093641.9+111347
- Ultra-soft event in a massive galaxy (Grotova et al. 2021, ATel#14668)







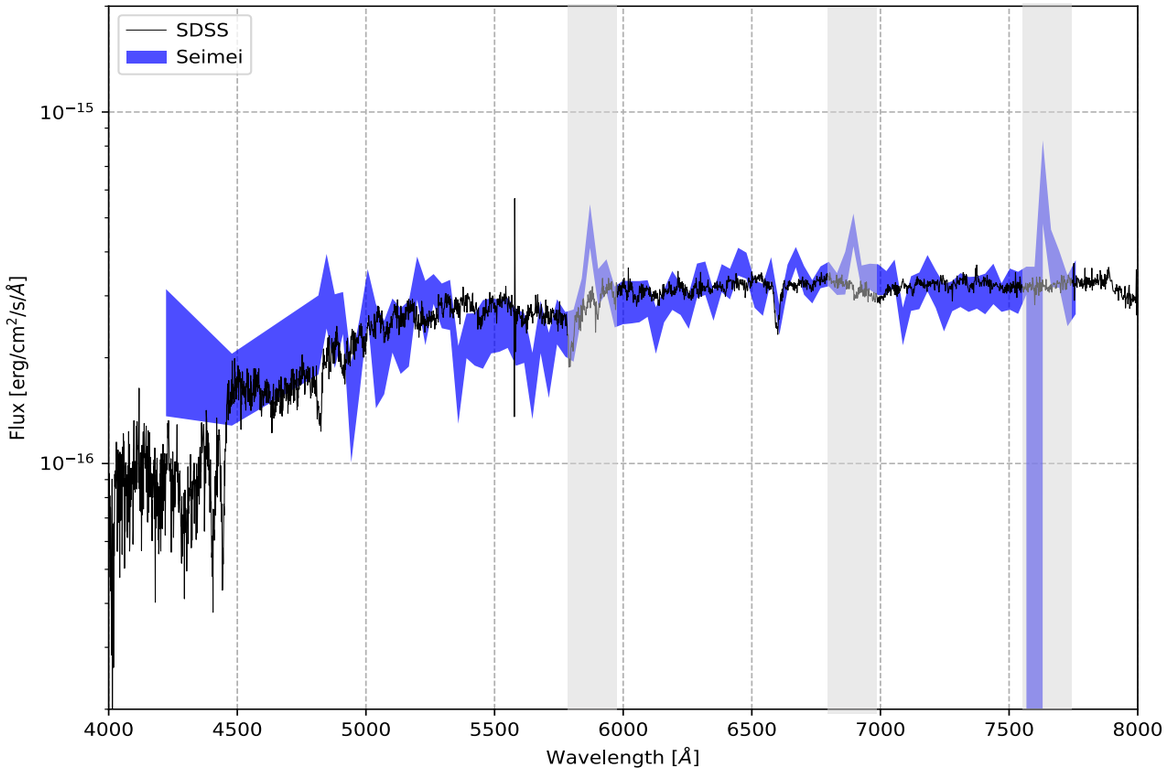
- Very soft (kT~70eV) discovery on May 13th 2021
- $f_{0.2\text{-}2.3\ keV}$~ 8.7x10^{-13} cgs, i.e. ~13x times brighter than eRASS:2 3-sigma UL
- $L_{0.2\text{-}2.3keV}$~3x10^{43} cgs
- NICER (PI: Z. Liu) & Swift follow-up (PI: I. Grotova) indicates source is fading now. Potential hardening observed
- No UV brightening detected
- WISE color W1-W2=0.15mag

Source 1: J0936 - no optical change

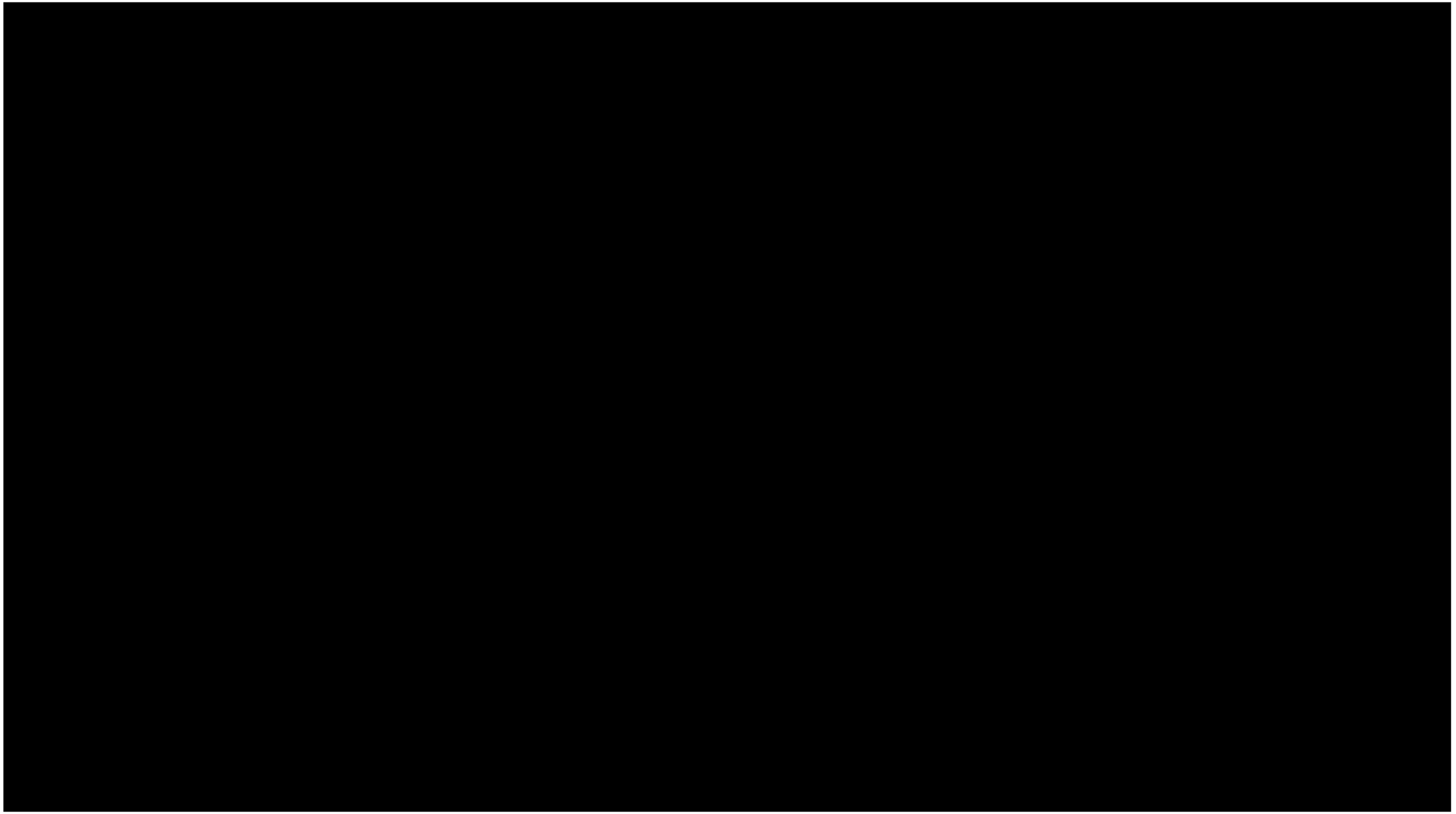
- Host is FR II radio galaxy at z=0.12
- Archival SDSS spectrum shows no emission lines
- $M_{SMBH} \sim 10^{8.8}\ M_{Sun}$ (Capetti et al. 2017)

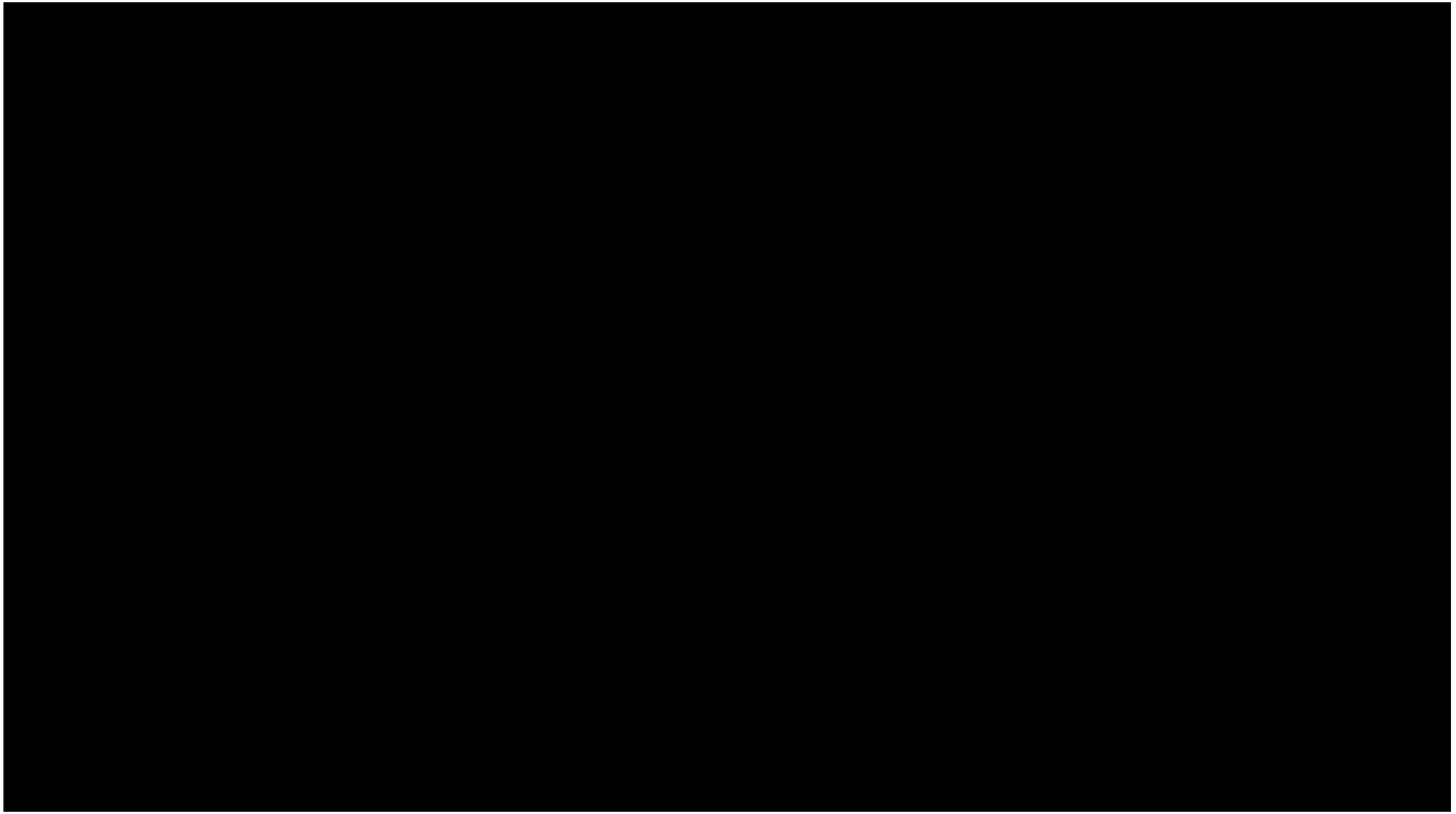
- Optical spectrum ~15d post eROSITA discovery suggests no significant change
  (Observations: S. Ciroi & F. di Mille)

Seimei: 27th May (= 2 weeks later obs.)



TDEs (cand.) are not always bright at opt. !
→ Comprehensive understanding of TDEs needs a study of X-ray TDEs

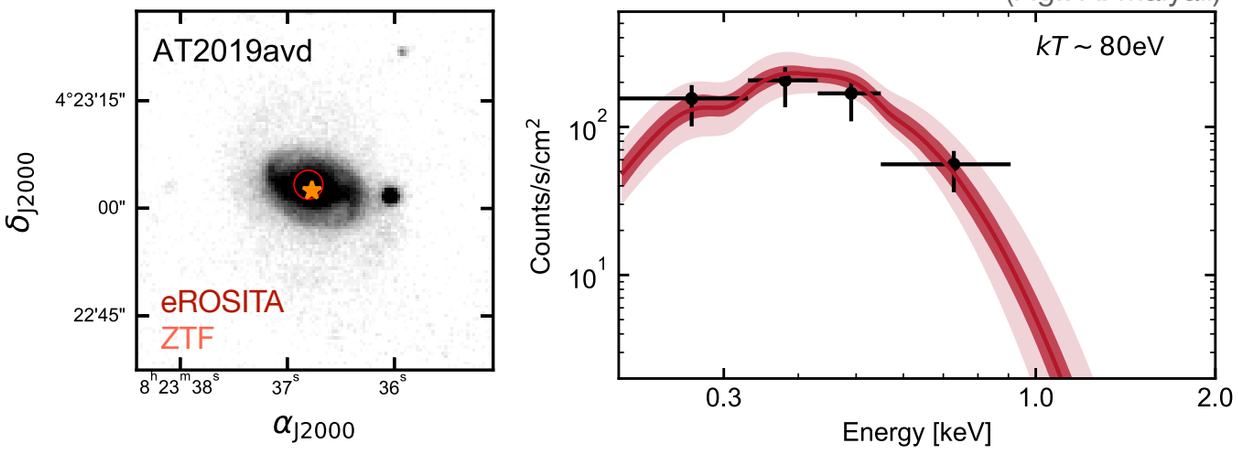




Source 3: AT 2019avd, extreme X-ray flaring and optical variability from a quiescent galaxy

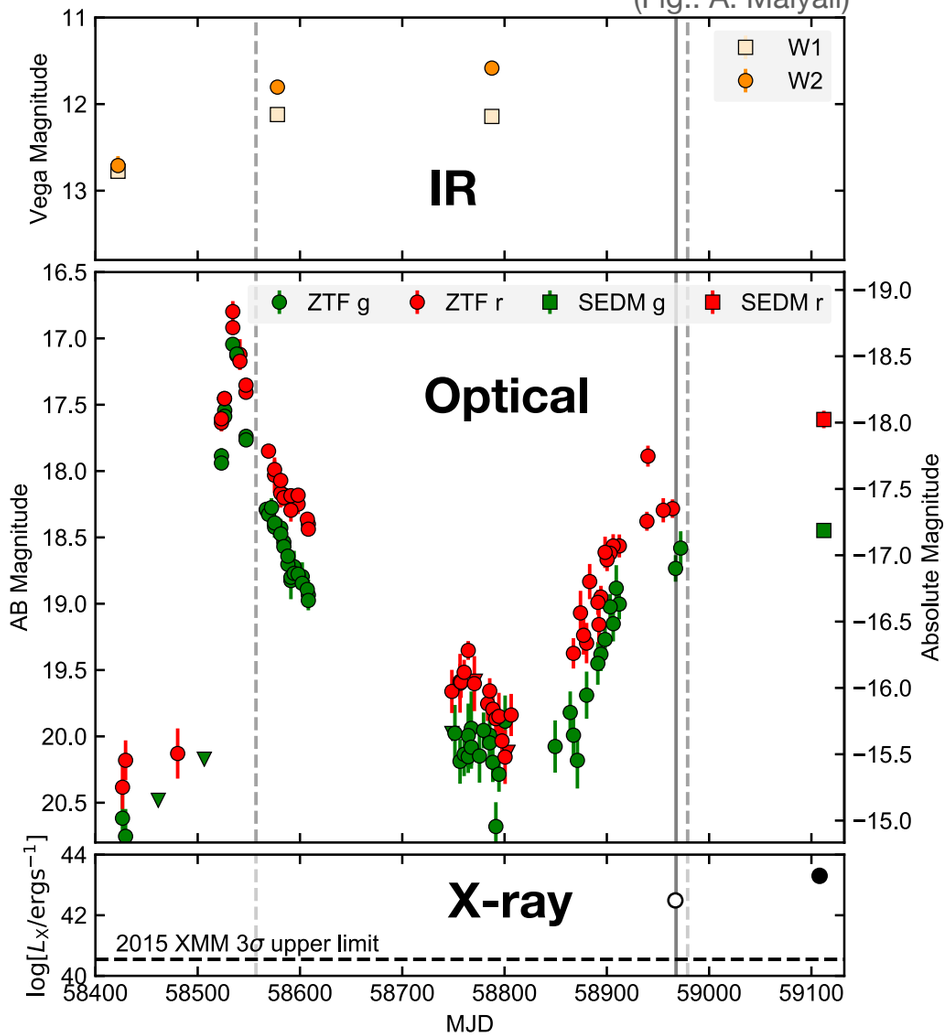
A. Malyali et al. (MPE, A&A 2021)

(Fig.: A. Malyali)



- eRASS1 discovery vs archival XMM observations
- X-ray properties (eROSITA, Swift XRT) suggest a TDE candidate
- However, optical/mid-IR light curve inconsistent with *standard* TDE interpretation
- A new class of nuclear transients?
  Stellar binary TDE? TDE involving a SMBHB?

(Fig.: A. Malyali)

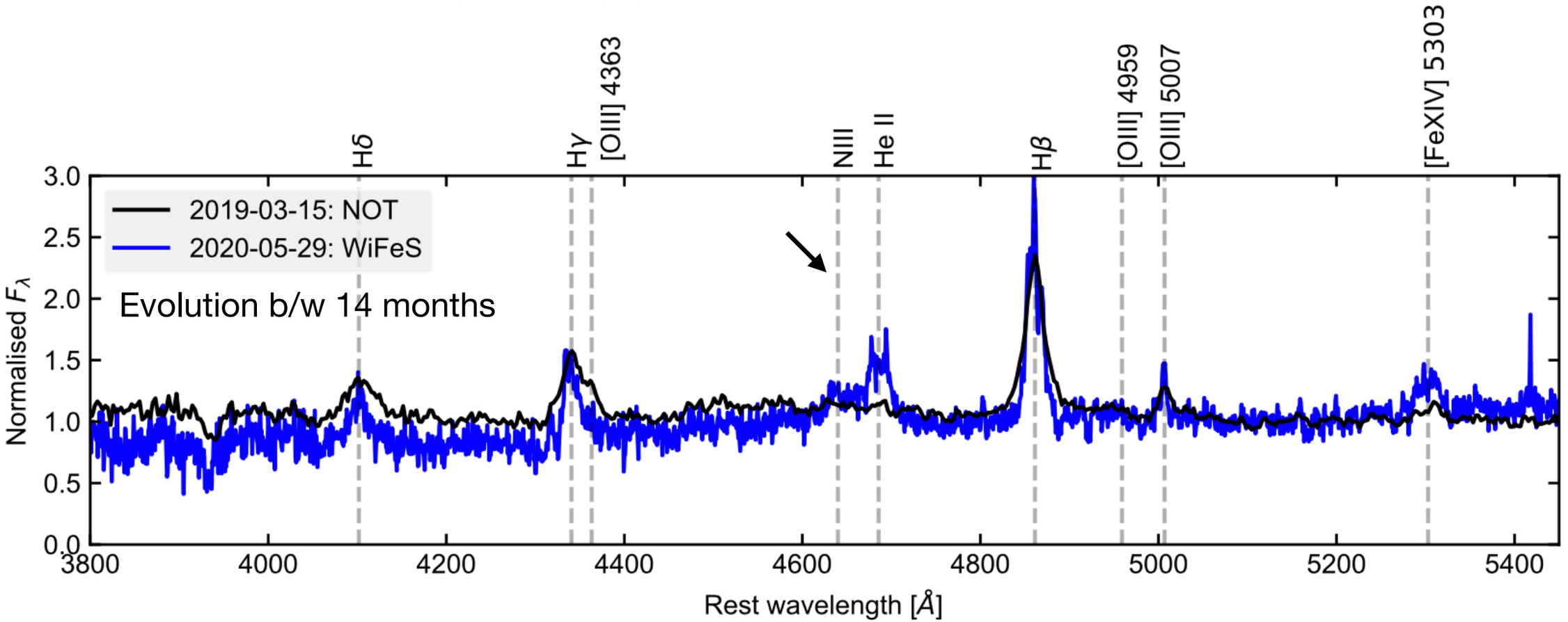


Brightens by factor of >600 in 0.2-2 keV relative to 2015 XMM upper limit

Source 3: AT 2019avd, extreme X-ray flaring and optical variability from a quiescent galaxy

A. Malyali et al. (MPE, A&A 2021)

- Detection of Bowen fluorescence lines of N_{III} 4640Å
  (i.e., Strong UV/X-ray photos → He_{II} → O_{III} → N_{III})
- The presence of UV/X-ray absorbers
- A high ratio of F(N_{III} 4640Å)/F(Hβ) suggests
  the presence of high density gas ($n_H > 10^{9.5}$ cm^{-3}), comparable to those of BLRs of AGNs



Summary

- ~30 X-ray soft nuclear transients, or TDE candidates, per eRASS (~ 6 months), which will be until ~ 2024 → *Now is the time for X-ray TDE studies*
- Optical data is very important for understanding the mass accretion in TDEs
- Optical spectroscopy have unveiled optical properties different from those found for optically selected TDE candidates
- Non-canonical behavior
  i.e., 'If you have seen one TDE candidate, you have seen one TDE candidate'