The extragalactic sky seen by eROSITA

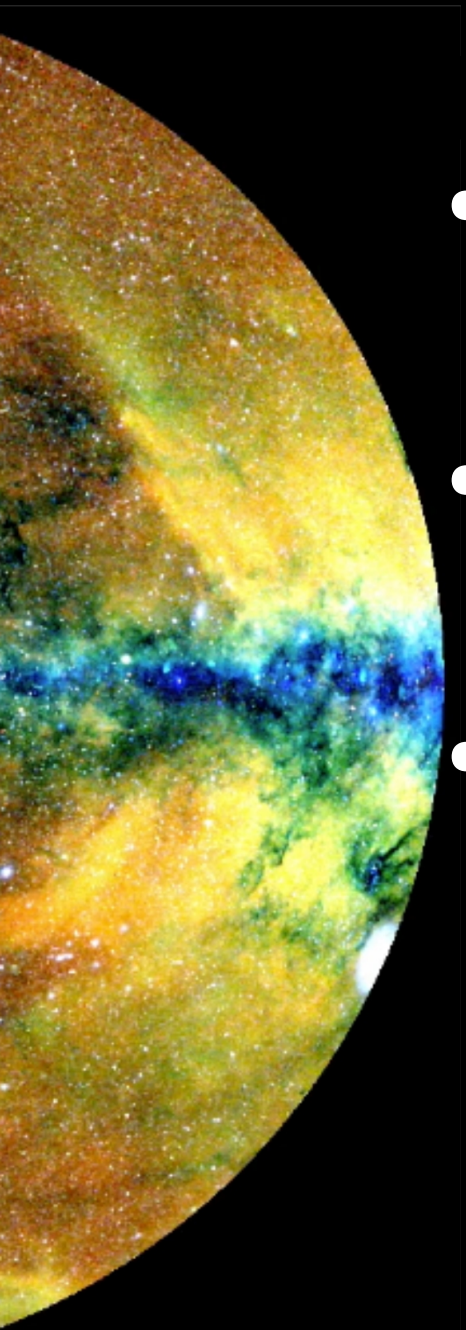
Johannes Buchner

on behalf of the German eROSITA collaboration

Chair of the eROSITA AGN working group

RICAP, Sep 2024

Takeaways



- All-sky survey
  in 2020 -- 0.2-5 keV
- Data Release 1:
  erosita.mpe.mpg.de/dr1/
- AGN science highlights

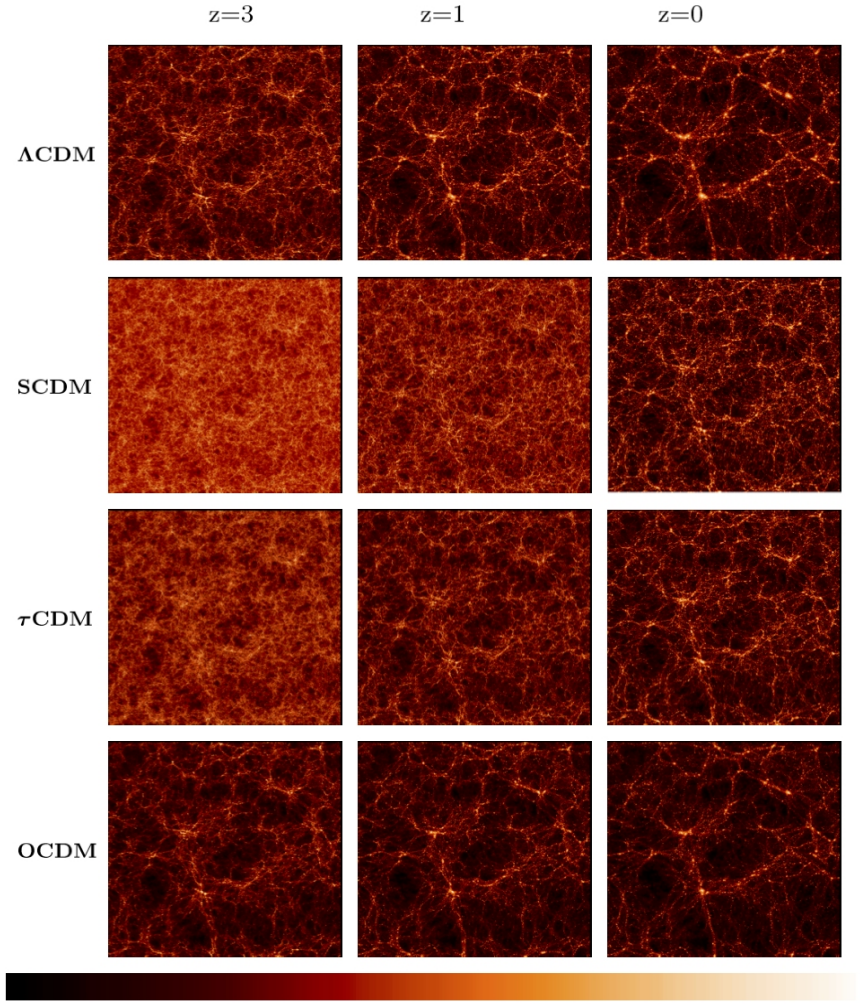
Future:

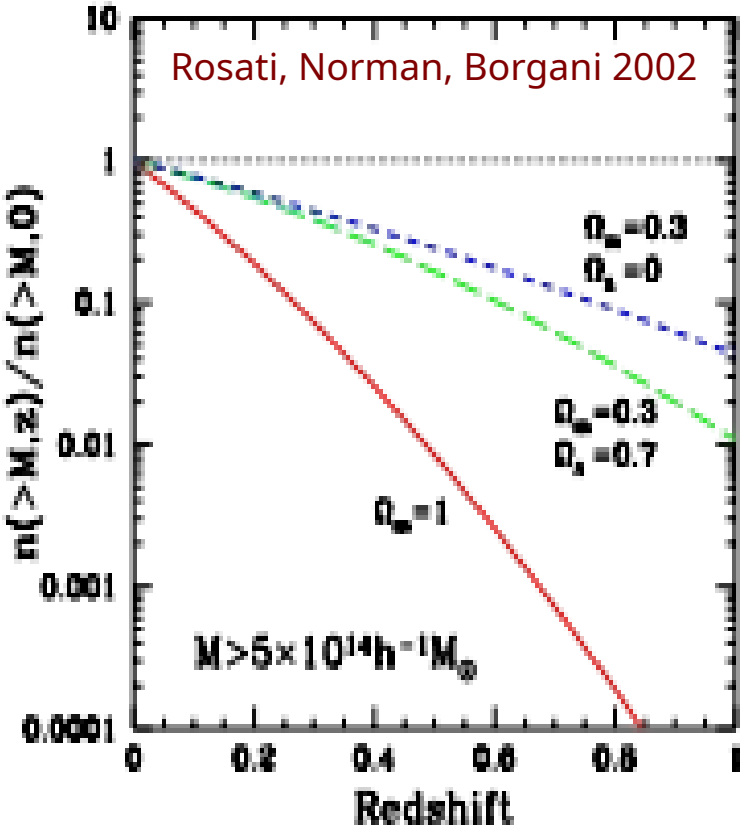
- 3.5 more surveys
  - + Multiwavelength counterparts, redshifts, data expertise
  - + Collaborate with the German eROSITA collaboration
- Tech flying on Einstein Probe/FXT

Why eROSITA? Clusters Cosmology

- Clusters are *exponentially sensitive* tracers of **growth of structures**
- Signature of clusters:
  hot (~10^7 K) extended X-ray ICM
- eROSITA (PSF, sensitivity) designed to detect >10^5 clusters (Pillepich+ 2018)

The Virgo Collaboration; Jenkins et al. 1998

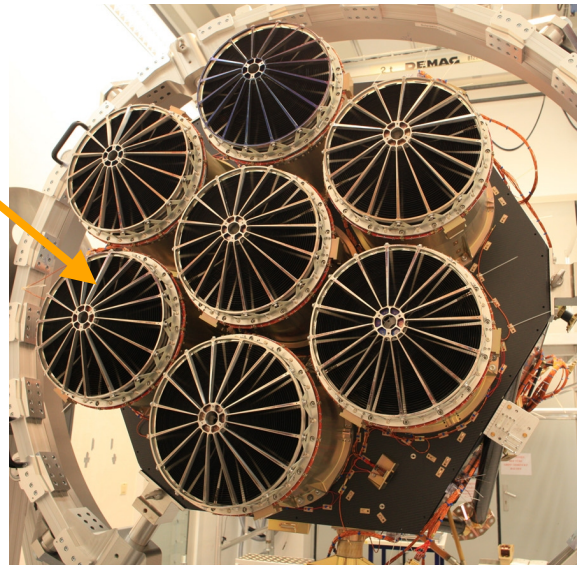




eROSITA: hardware

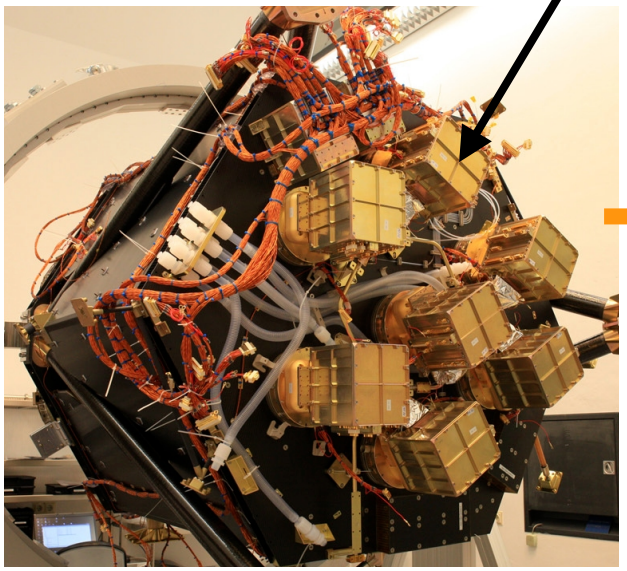
Front

X-rays

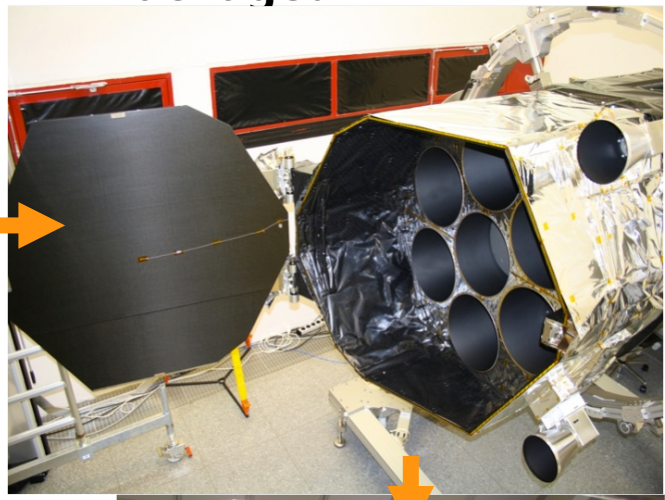


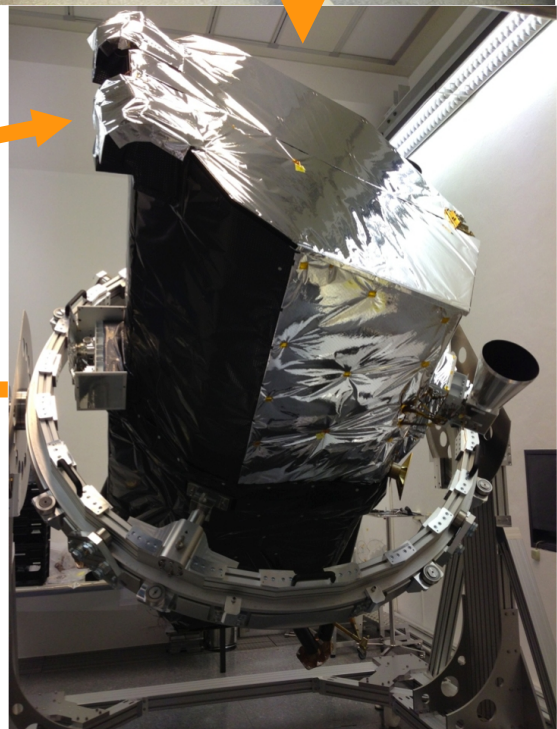
Back

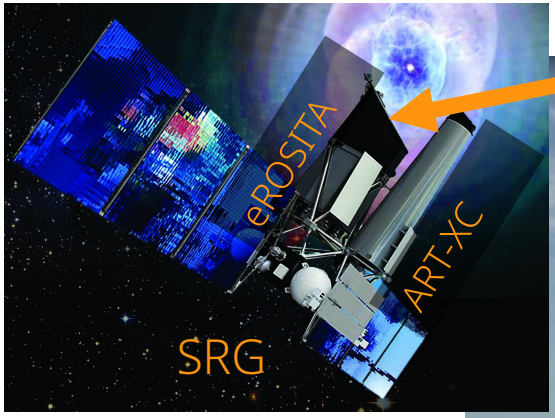
CCD

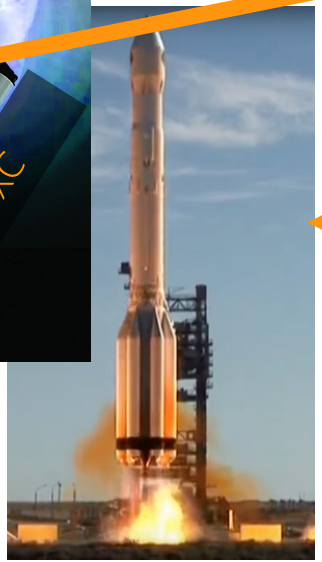


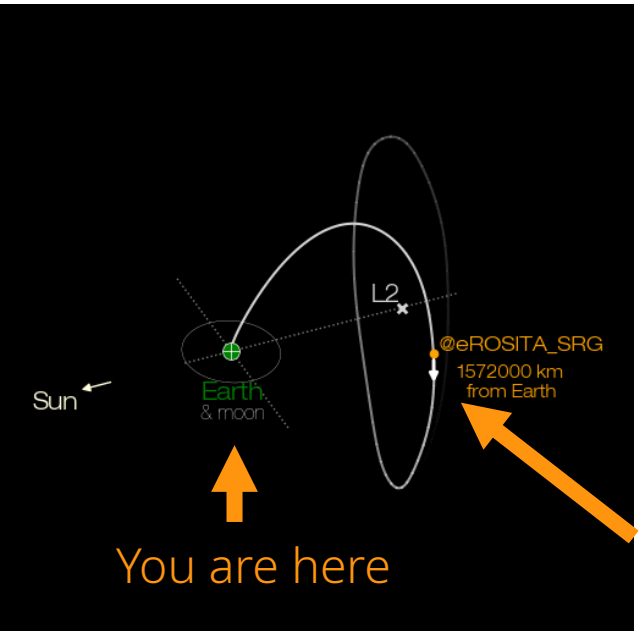
Packaged







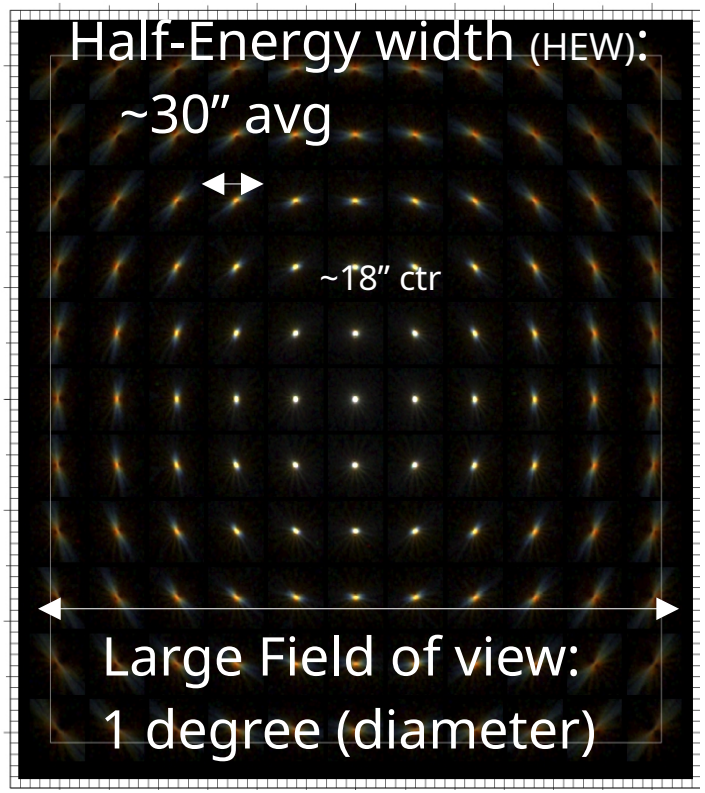


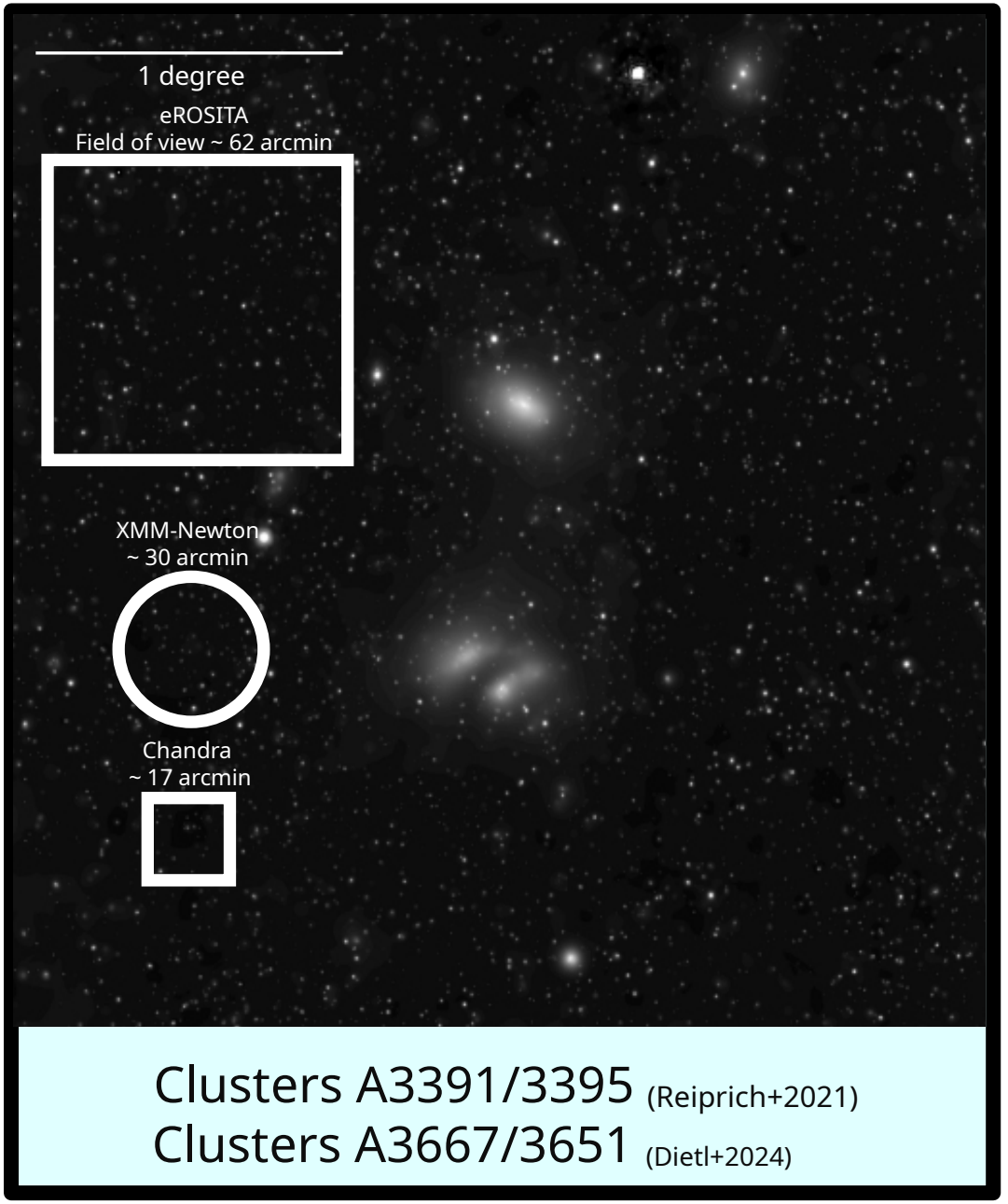


Launch to
L2 (Earth-Sun)

eROSITA on SRG Predehl et al. 2021

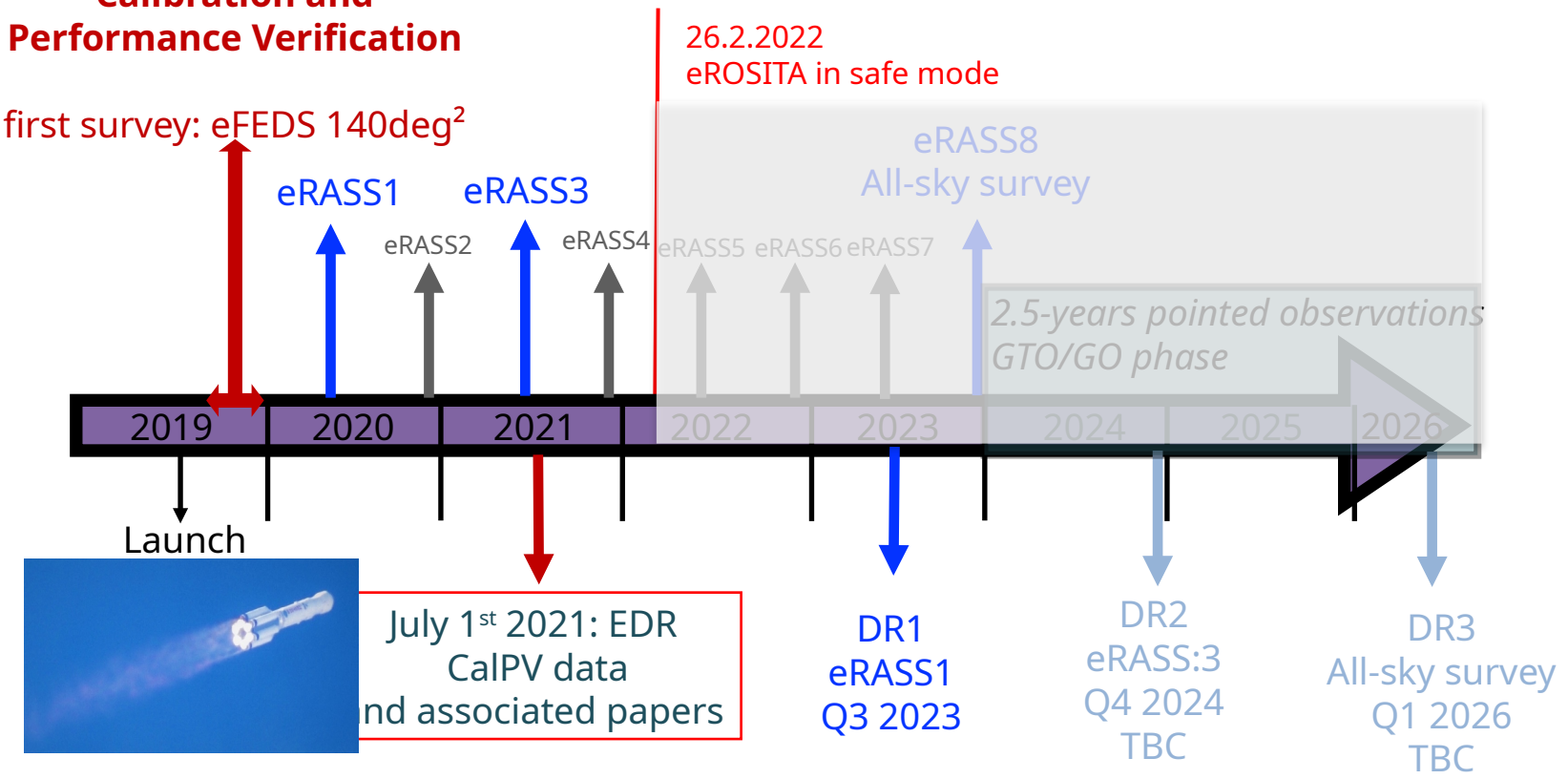
- Large Effective area
  ~1300 cm² @1keV, ~XMM-Newton
- Large field of view
- pnCCD 384x384x7=million pixels (9.4”)
  - **High spectral resolution**
    ~80eV @1.5keV
  - no chip gaps, no ‘out of time’ events (framestore)





SRG Programmatics

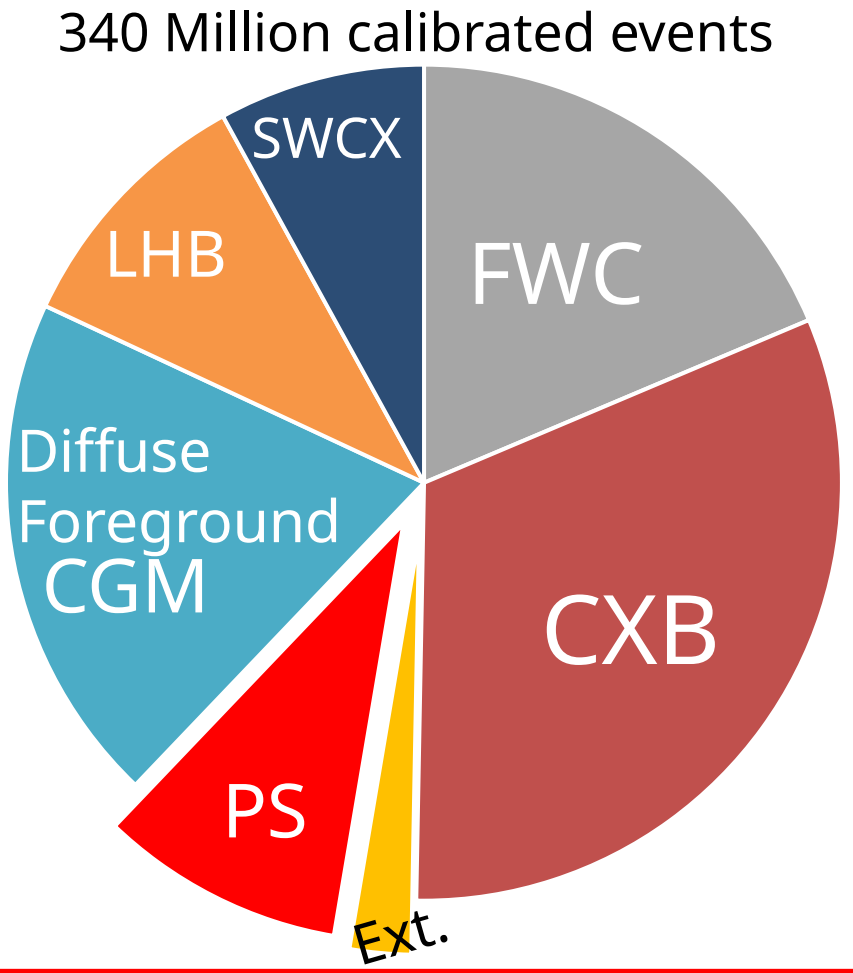
eRASS = eROSITA All-Sky Survey



- Early Data Release (EDR) in 2021: several fields, including eFEDS mini-survey
- DR1 on 31.1.2024
- DR2 (eRASS:4.x) TBD (about two years from now)

The eRASS1 (soft) Photon Pie

- 107 Million CXB photons
- 67 Million MW Hot CGM photons (58M halo + 9M 'Corona'; Ponti+'23)
- 63 Million Instrumental BKG photons (FWC)
- 34 Million Local Hot Bubble photons
- 27 Million Solar Wind Charge Exchange photons
- 8 Million Extended Sources' photons
- 32 Million Point Sources' photons
  - 24 Milllion AGN photons; 8 Million Stars photons



0.9 million point sources

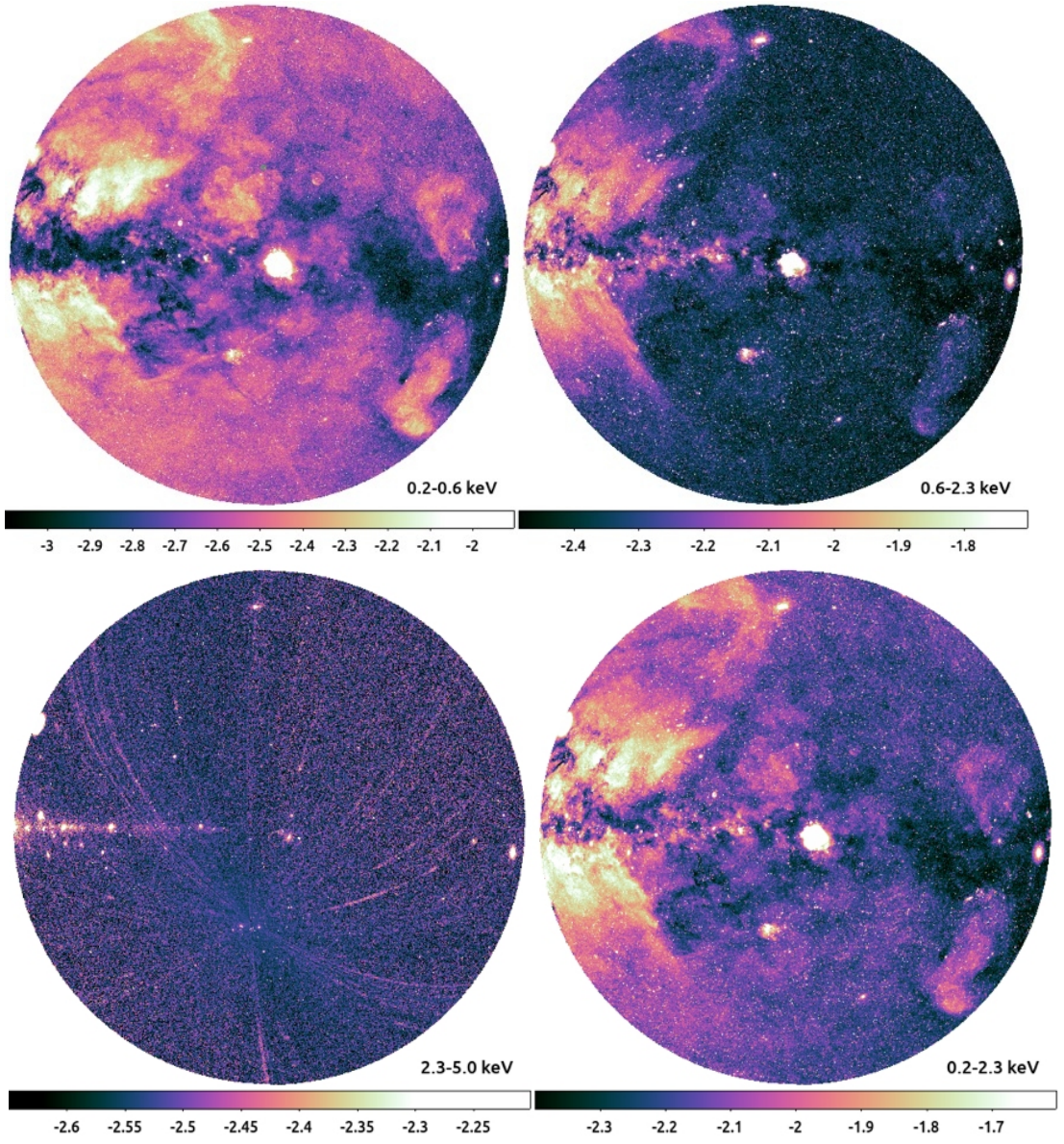
doubles the number of known X-ray sources!

Sensitivity:

- ~5x10^{-14} erg/s/cm^2 [0.2-2.3 keV]; **4-5x deeper than RASS**
- ~7x10^{-13} erg/s/cm^2 [2.3-5 keV]

Merloni et al. (2024)

eROSITA-DE Data Release 1 products



Merloni et al. (2024)

erosita.mpe.mpg.de/dr1/

- Software
- Calibration DB
- Attitude files
- Exposure maps
- Events
- Count rate maps
- Source catalogues
- X-ray Spectra
- Light-curves

Upper limit for a single position

Find an upper limit on the sky for a single sky position. Please either enter a position directly (in decimal degrees or sexagesimal), or give an object name and click resolve, to find the position using the Sesame name resolver.

Please see this page and Tubín-Arenas et al. (2024) for further details. Both Tubín-Arenas et al. (2024) and Merloni et al. (2024) should be referenced if these upper limits are used.

Object name: Resolve
Longitude: 180 Latitude: -45 Coordinate System: ICRS
Band: 024 (0.2-2.3 keV)

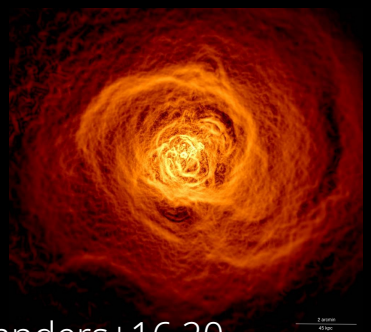
Submit query Defaults

Query catalog by position &
Upper limit server in 0.2/0.6/2.3/5.0 keV

Tubín-Arenas et al. (2024)

Navigating the eROSITA X-ray sky

Coma Cluster
Sco X-1
Virgo Cluster
Shapley Supercluster
Centaurus Cluster
Crab Pulsar
Cygnus Superbubble
Cyg X-1
Cas A
North Polar Spur
G156.2+05.7 SNR
Perseus Cluster
Cyg X-2
Cygnus Loop
Large Magellanic Cloud
Fornax Cluster
Vela SNR
Orion Nebula



Sanders+16,20

SRG/eROSITA 0.3-2.3 keV - RGB Map

eROSITA-DE

|gal_long|>180

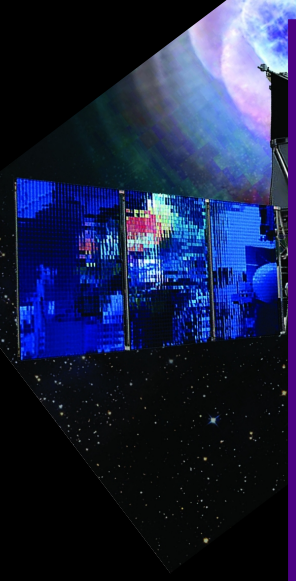
MPE

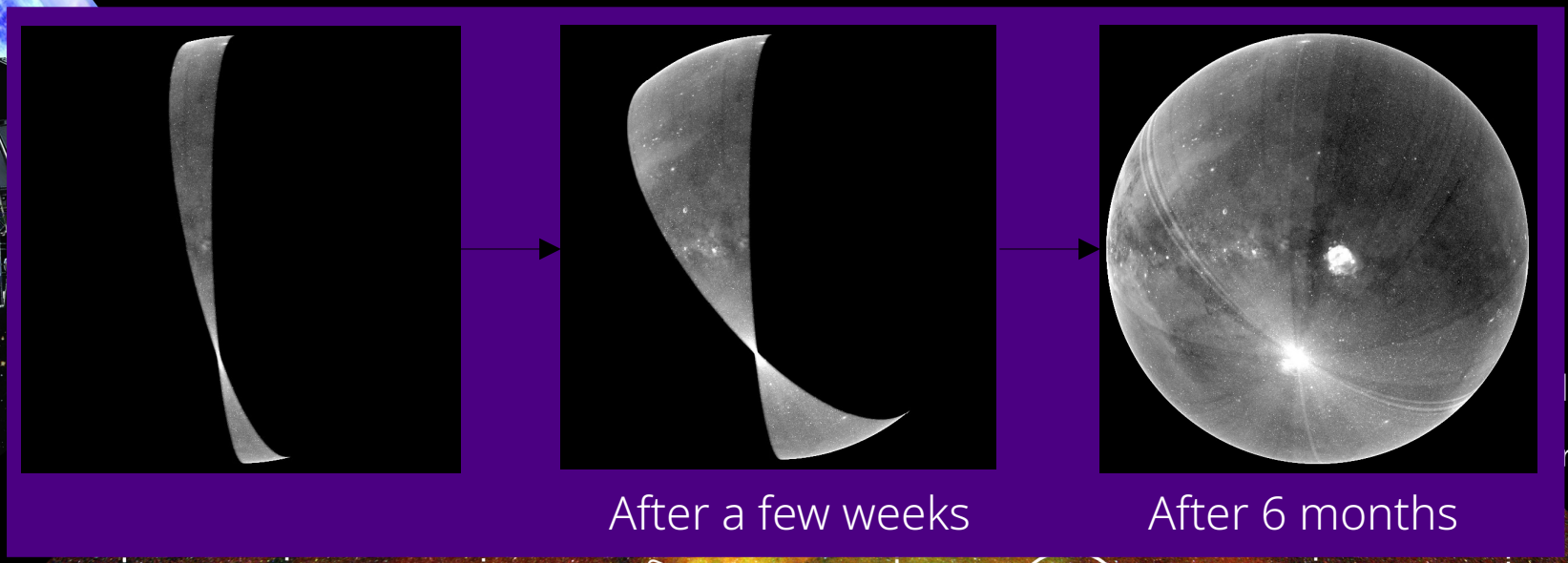
<Video>

See it here:

- https://phys.org/news/2024-01-erosita-sky-survey-largest-high.html

- https://www.mpe.mpg.de/7461950/erass1-presskit



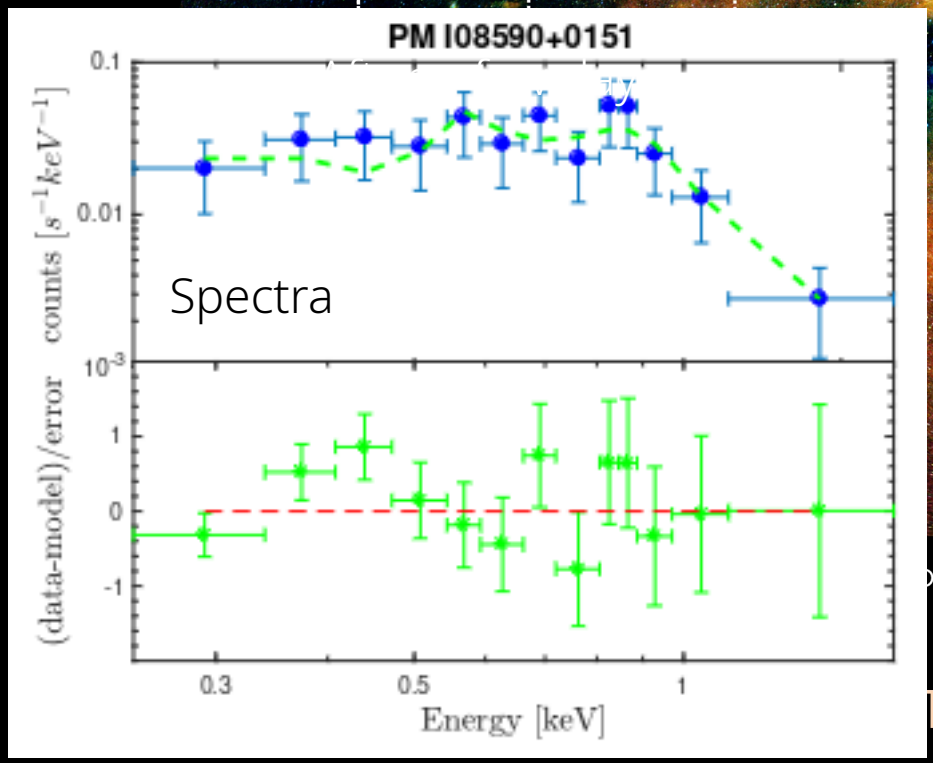


eROSITA

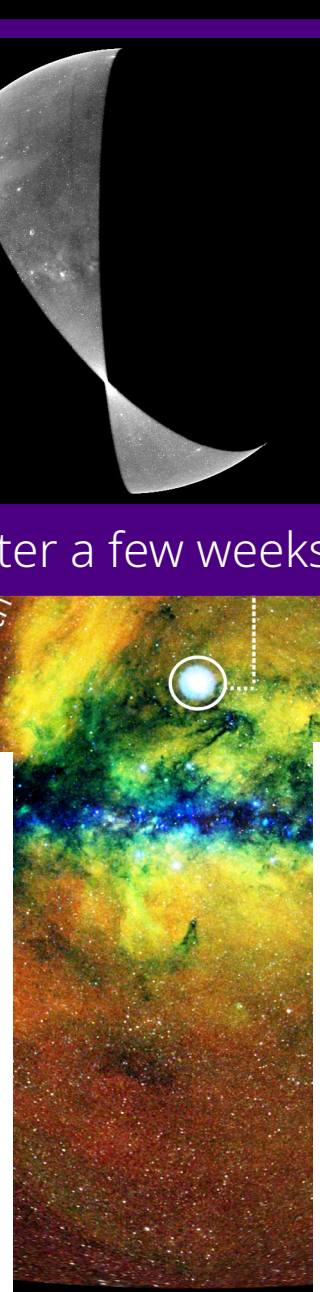
luster

rab Pulsar

North

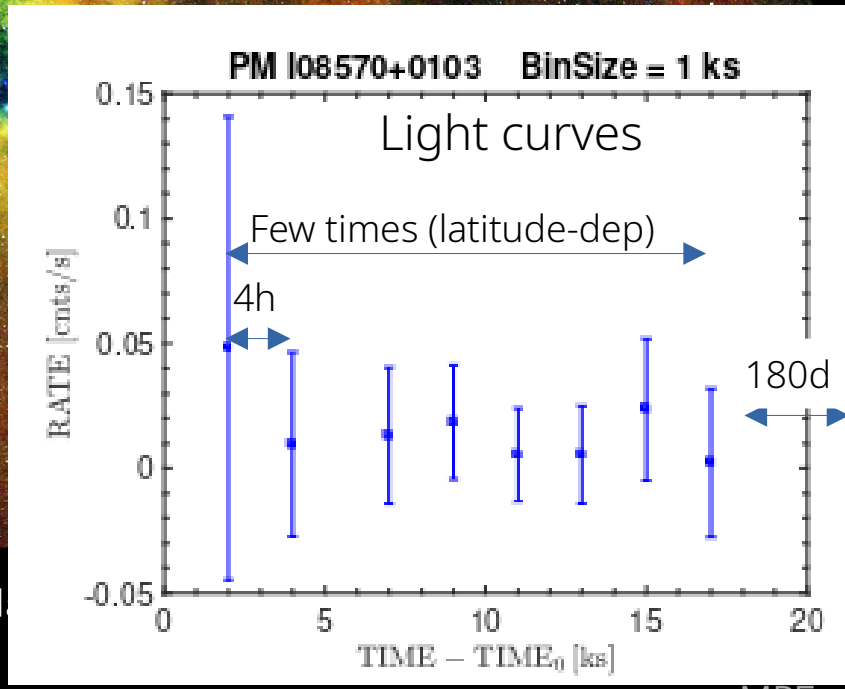


Magaudda+22



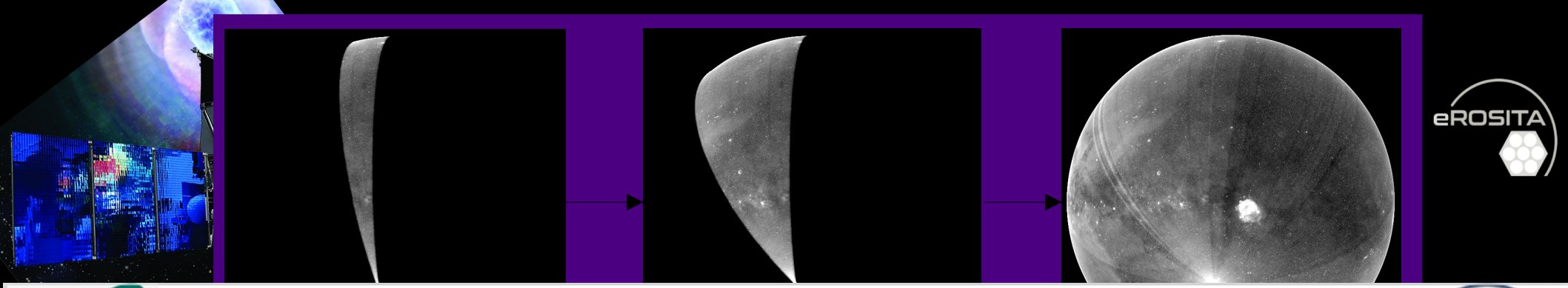
oop

Large Magell



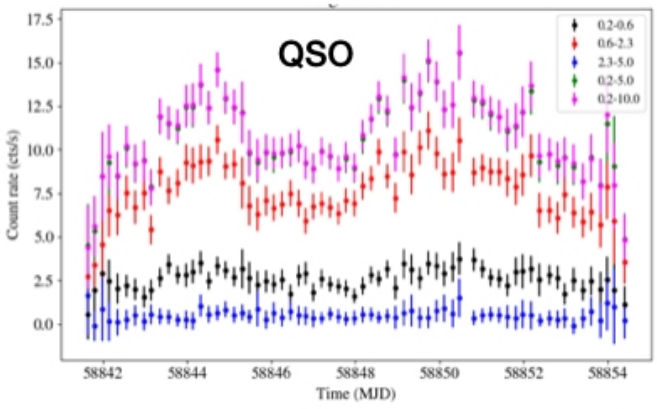
TA 0.3-2.3 keV - RGB Map

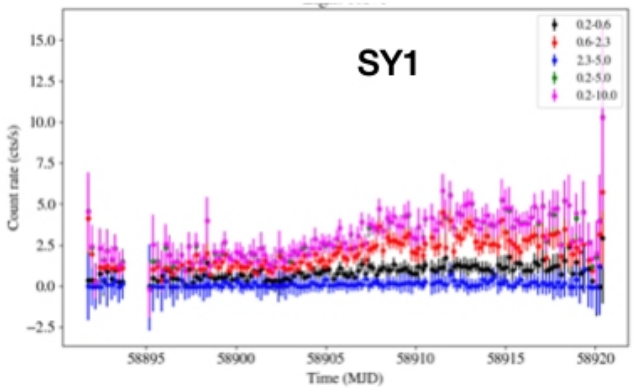
MPE

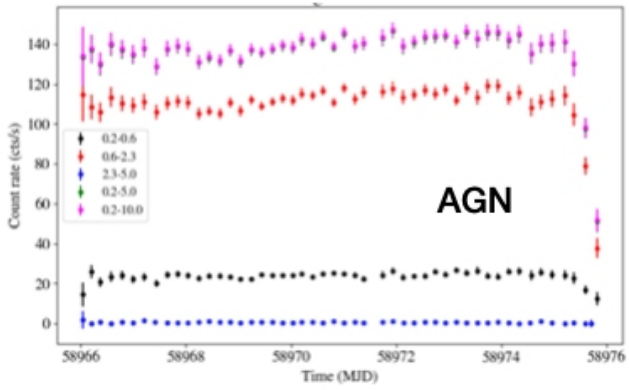


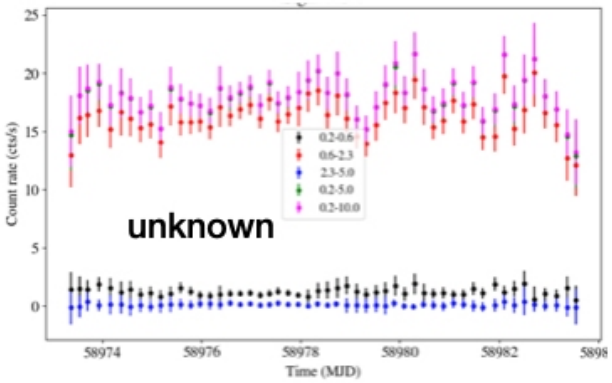
Varying AGN (and not only) in the SEP
(Bogensberger+2022a, 2022b tbs)

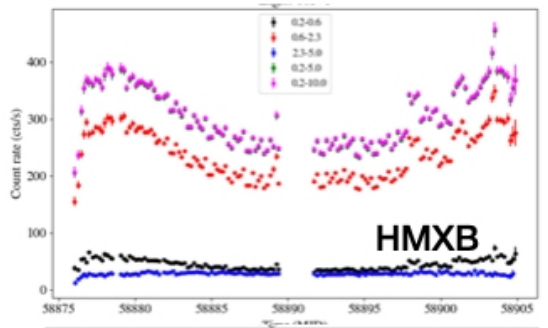
David Bogensberger

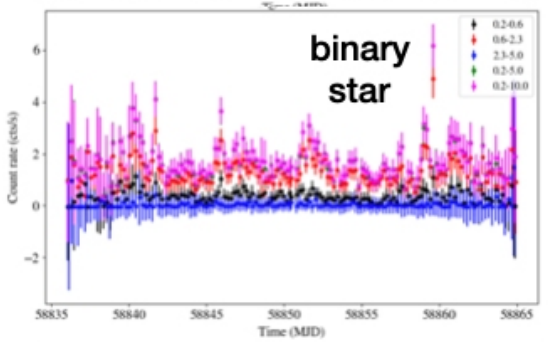


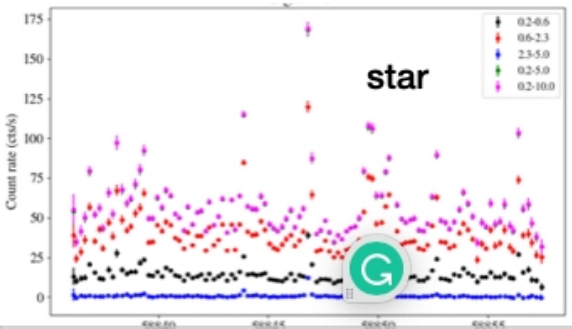






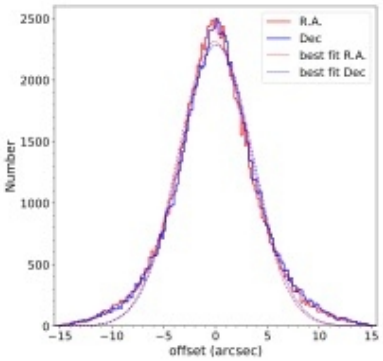


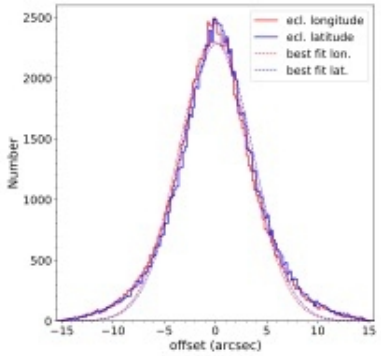




M. Salvato, CCE, November 2022

Astrometry: Median positional error = 4.3”



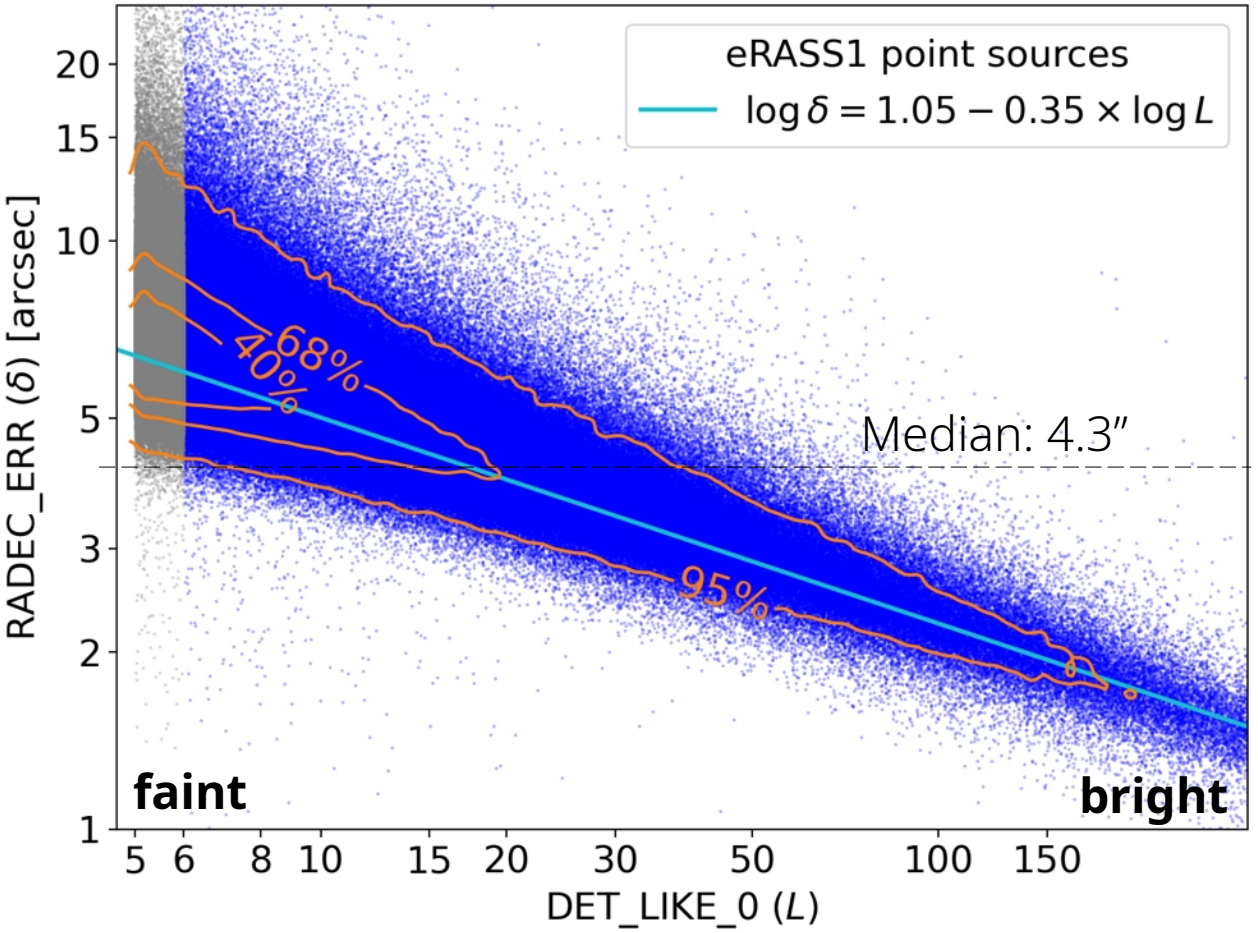


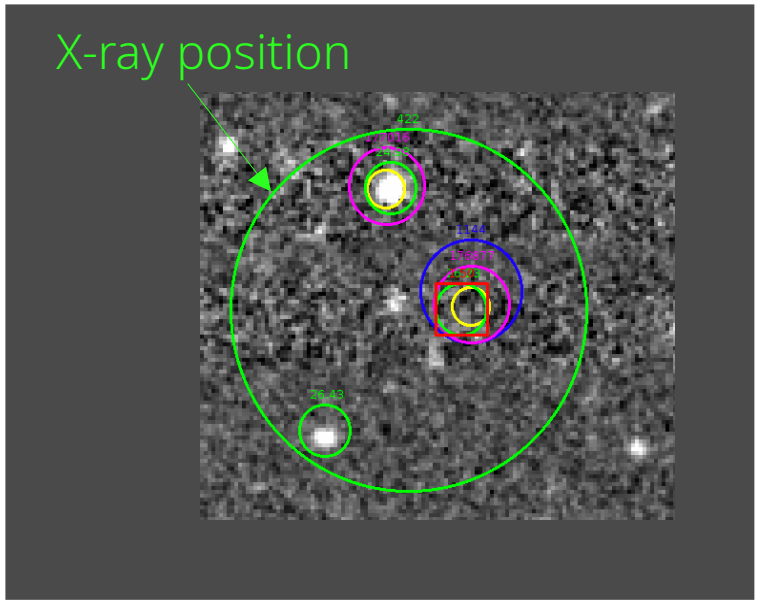
ΔRA ΔDEC

Δelat Δelong

Merloni et al. (2024)

Point sources astrometric accuracy



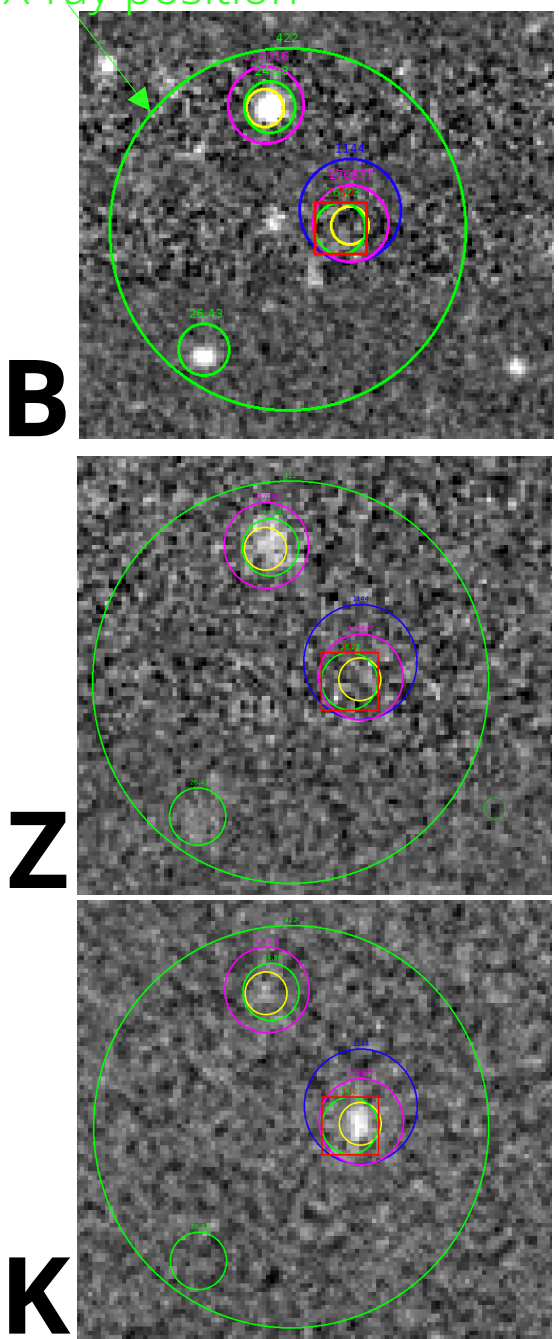


NWAY: probabilistic cross-matching to optical-MIR surveys

Salvato et al 2021: >95%+ purity and completeness

Catalog in prep.

NWAY – Bayesian association



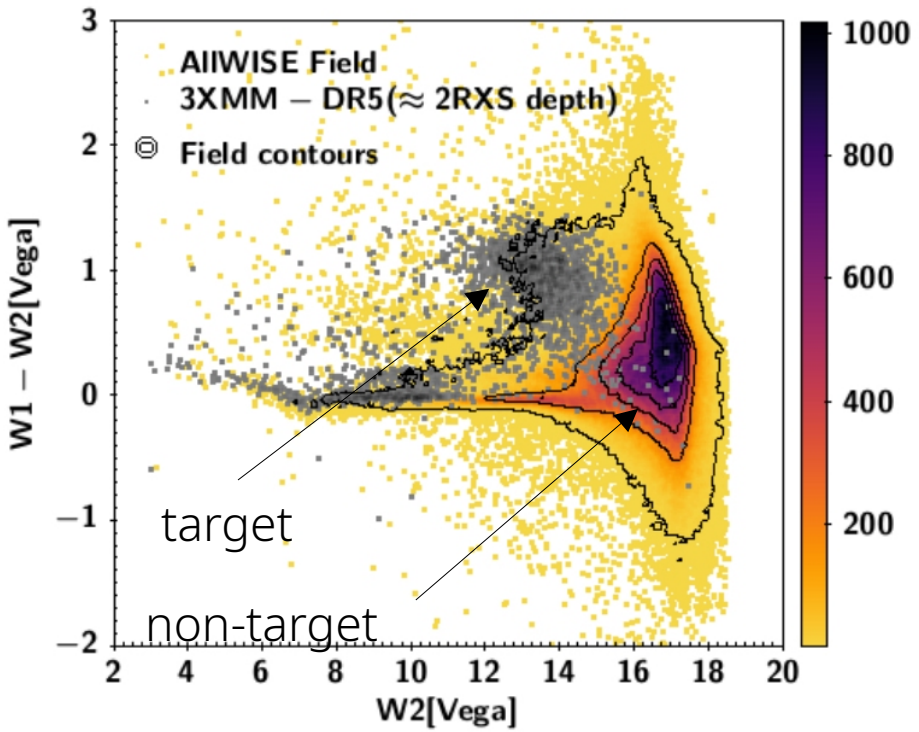
- Automated association of N catalogs simultaneously

Salvato, Buchner+18

https://github.com/JohannesBuchner/nway

- Use color information to weigh alternatives in a consistent Bayesian framework

→ higher completeness and purity
→ becoming popular across fields (135 citations)



Automatically learn separations

Transfer learning from previous surveys

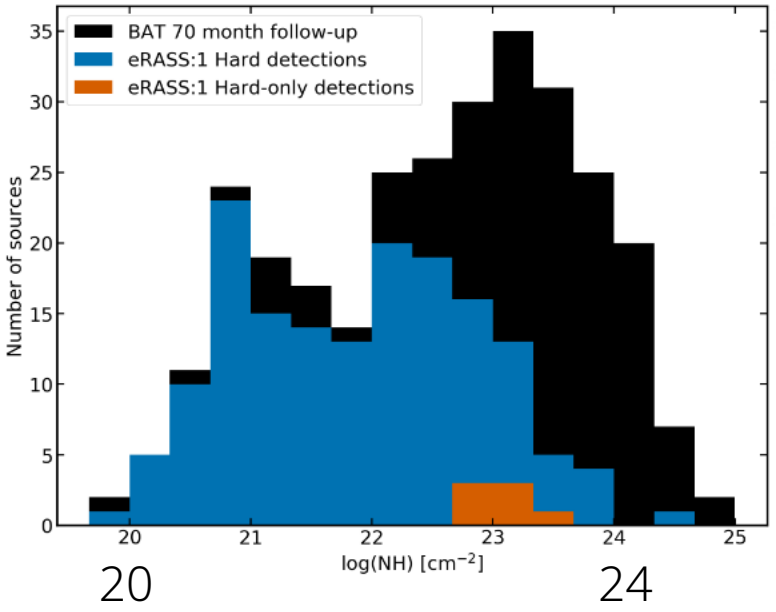
ML priors: Random forests learn photometry of X-ray sources → judge probability of NWAY options (Julien Wolf)

Salvato, Wolf+21

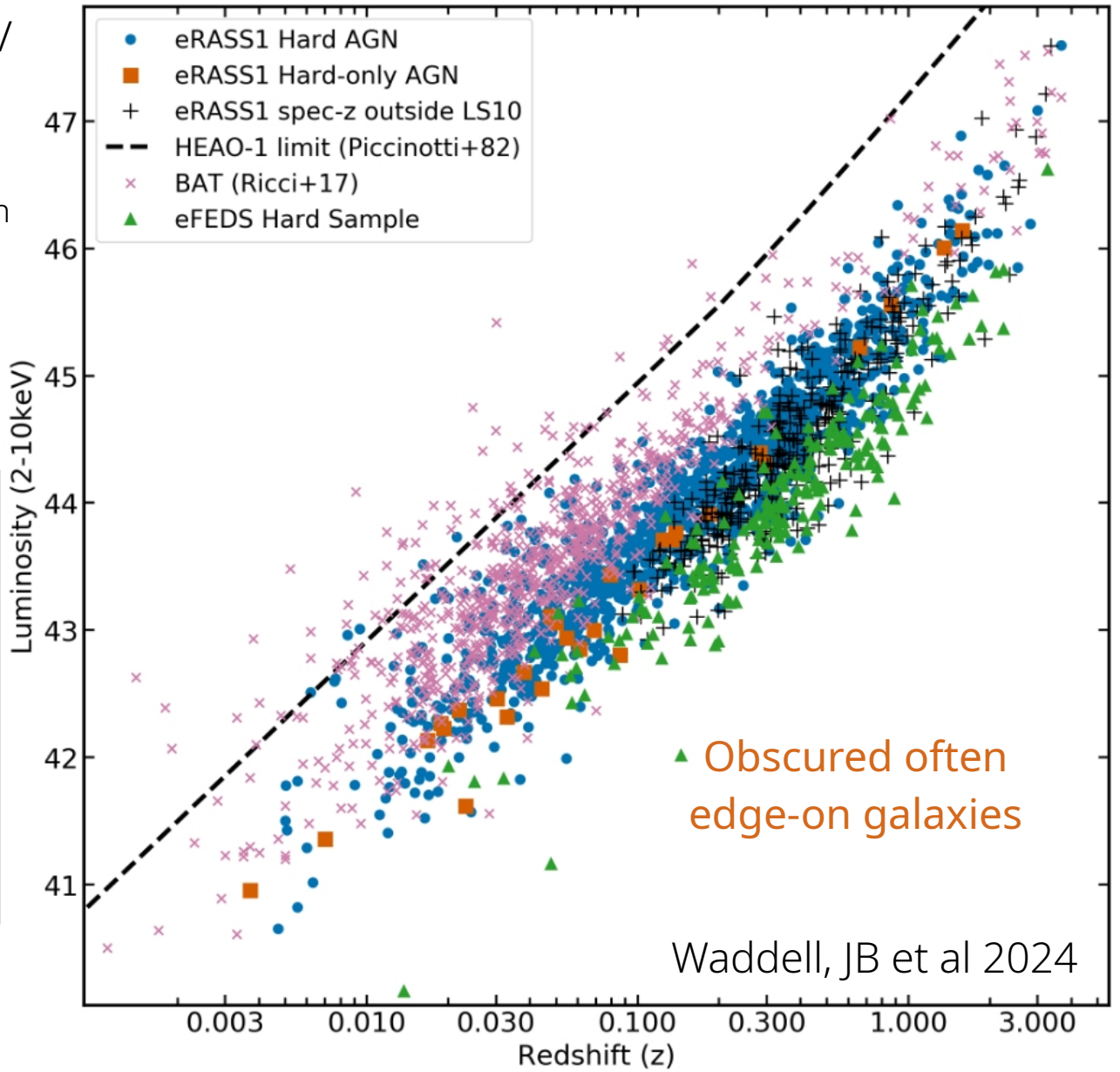
The hard X-ray sample

Deepest imaging survey 2.3 - 5 keV

4895 clean point sources
319 beamed AGN → Steven Hämmerich
325 stars
1328 non-beamed AGN with redshifts



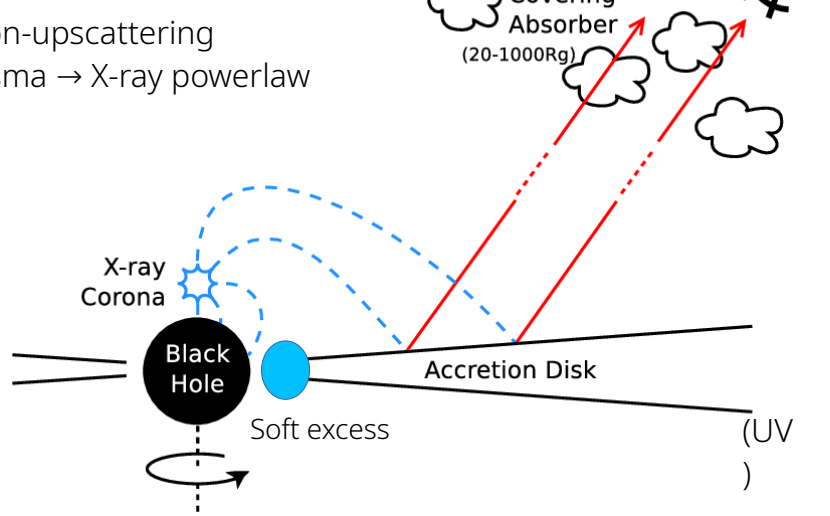
Obscuring column density

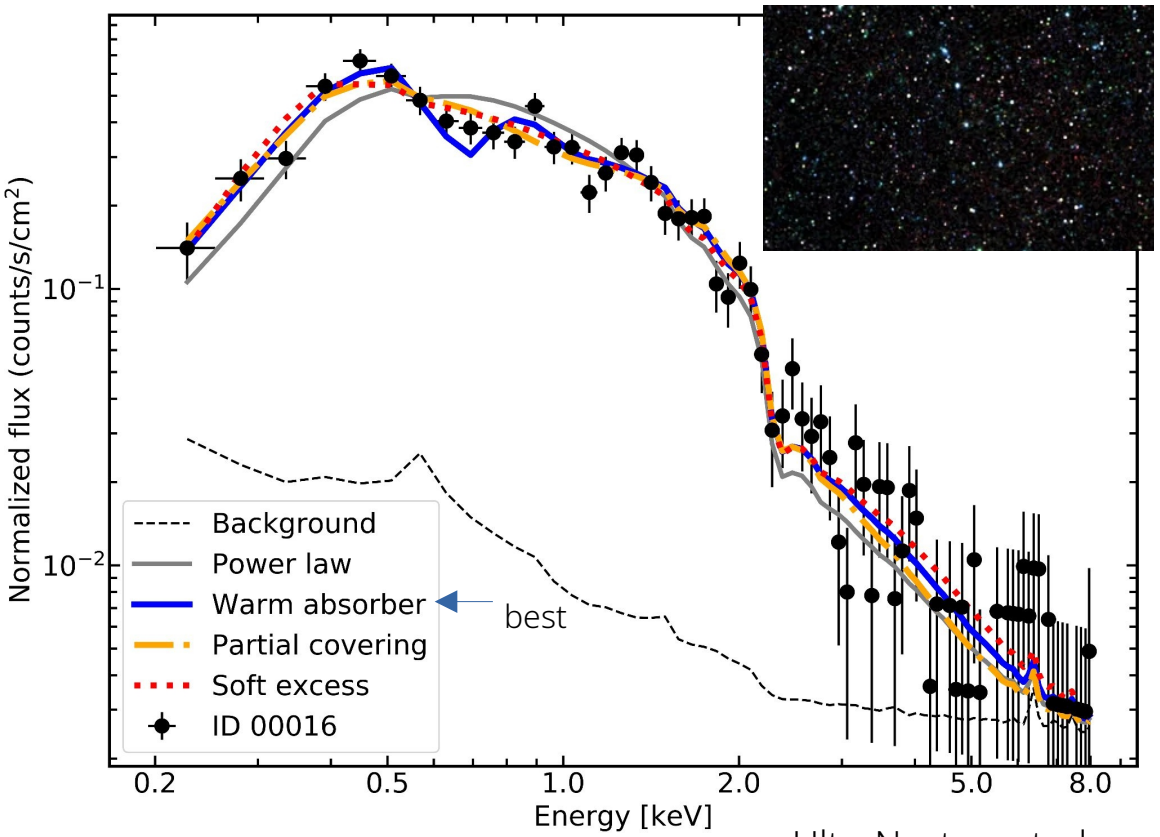


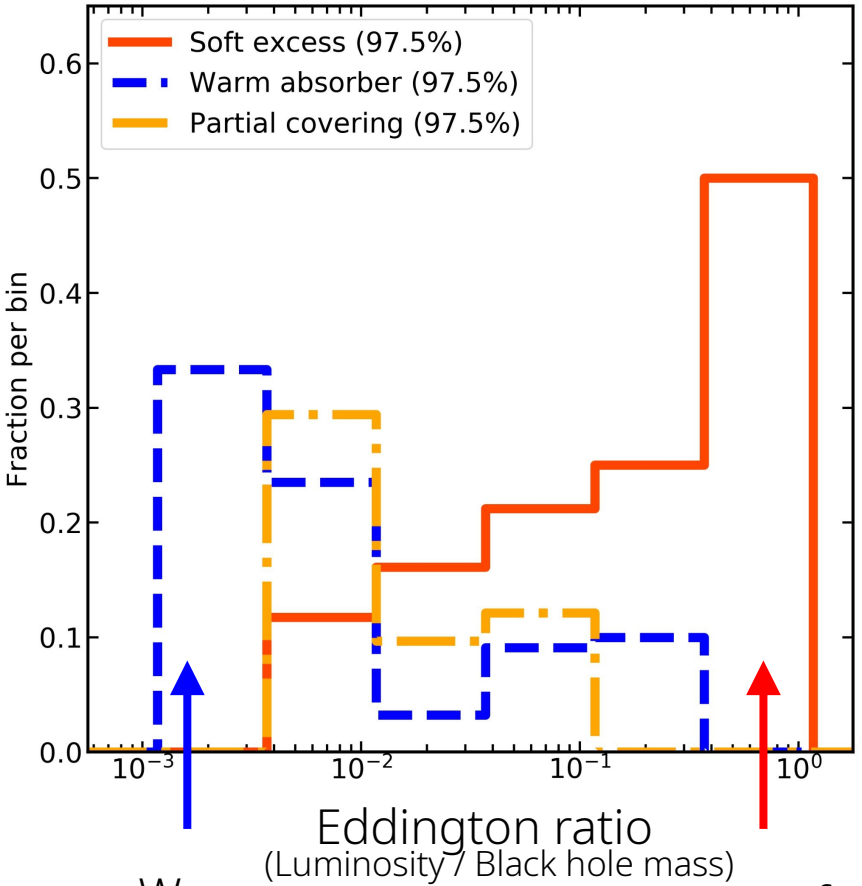
AGN processes

soft excess, ionised or partial absorbers?

(Sophia Waddell, K Nandra, JB)







X-ray spectroscopy with modern statistical tools can reliably distinguish between physical scenarios

UltraNest, nested sampling research

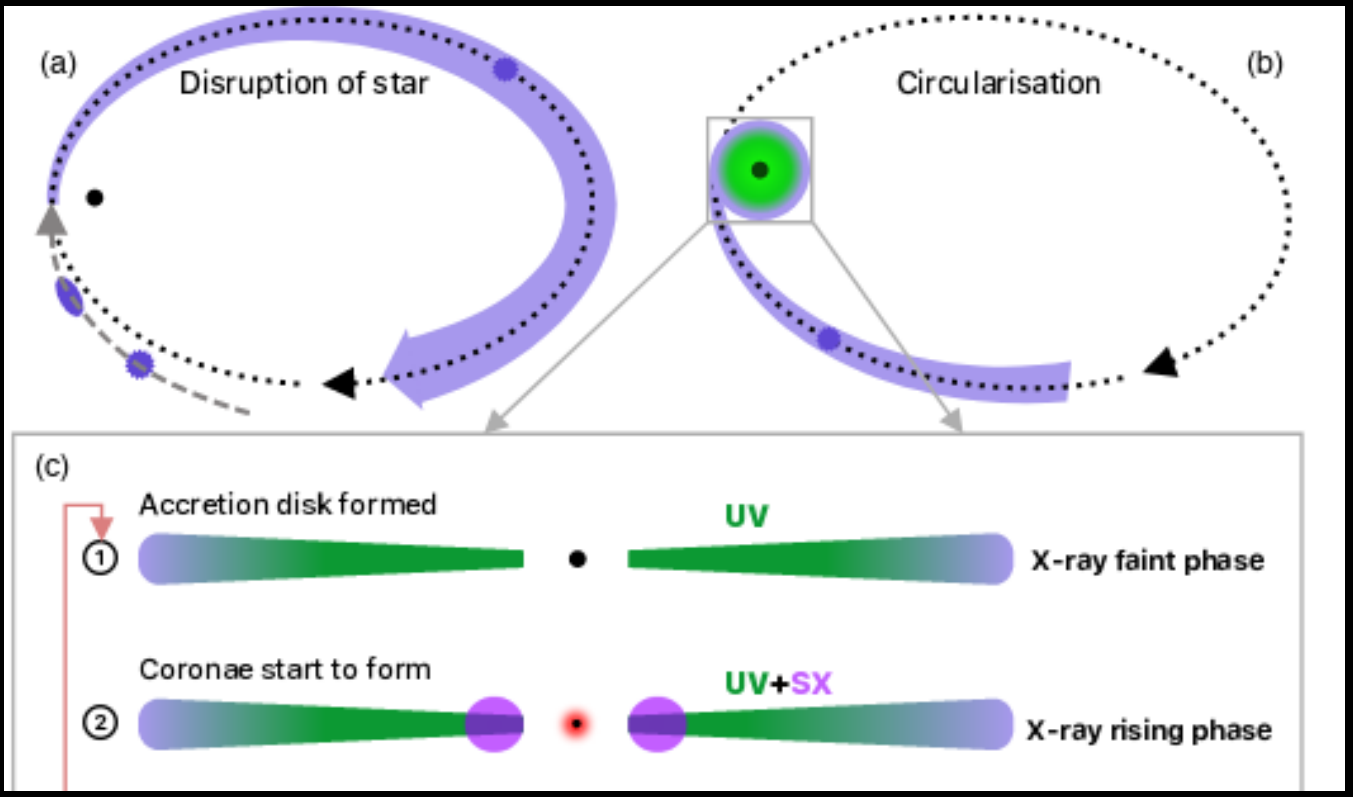
Sophia Waddell et al., accepted

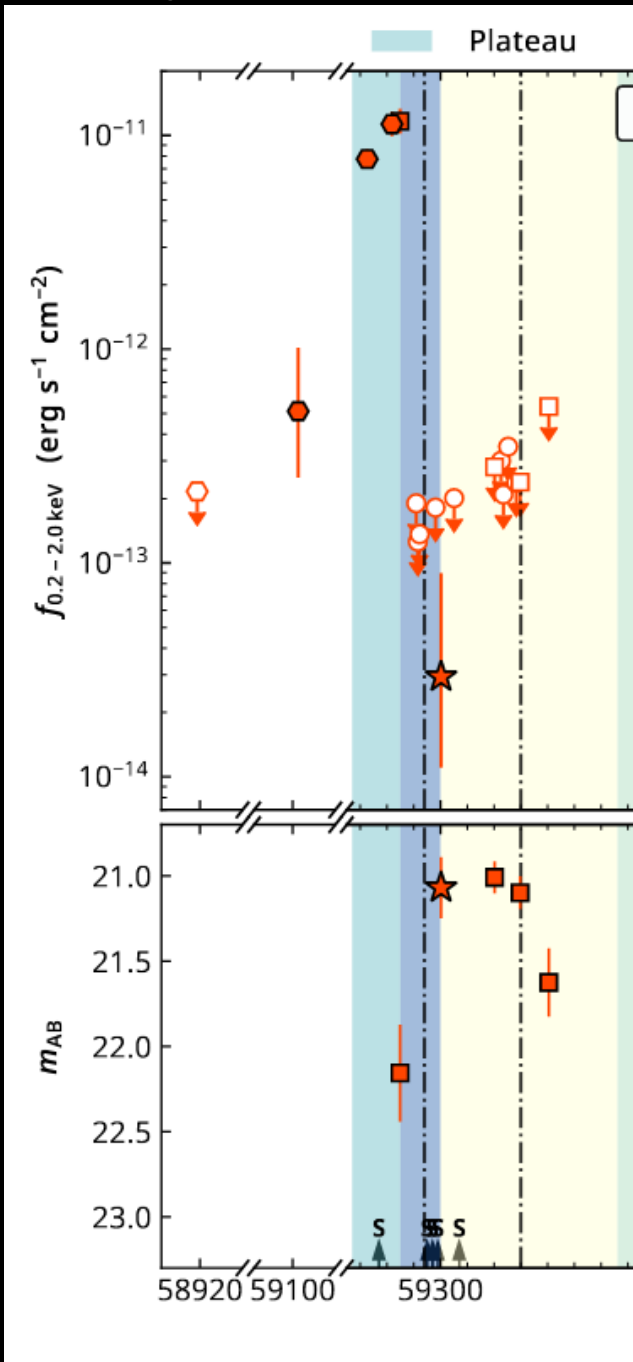
Warm absorbers common

Soft excess common

Tidal Disruption Events

Arne Rau, Zhu Liu, Adam Malyali, Iuliia Grotova, ...

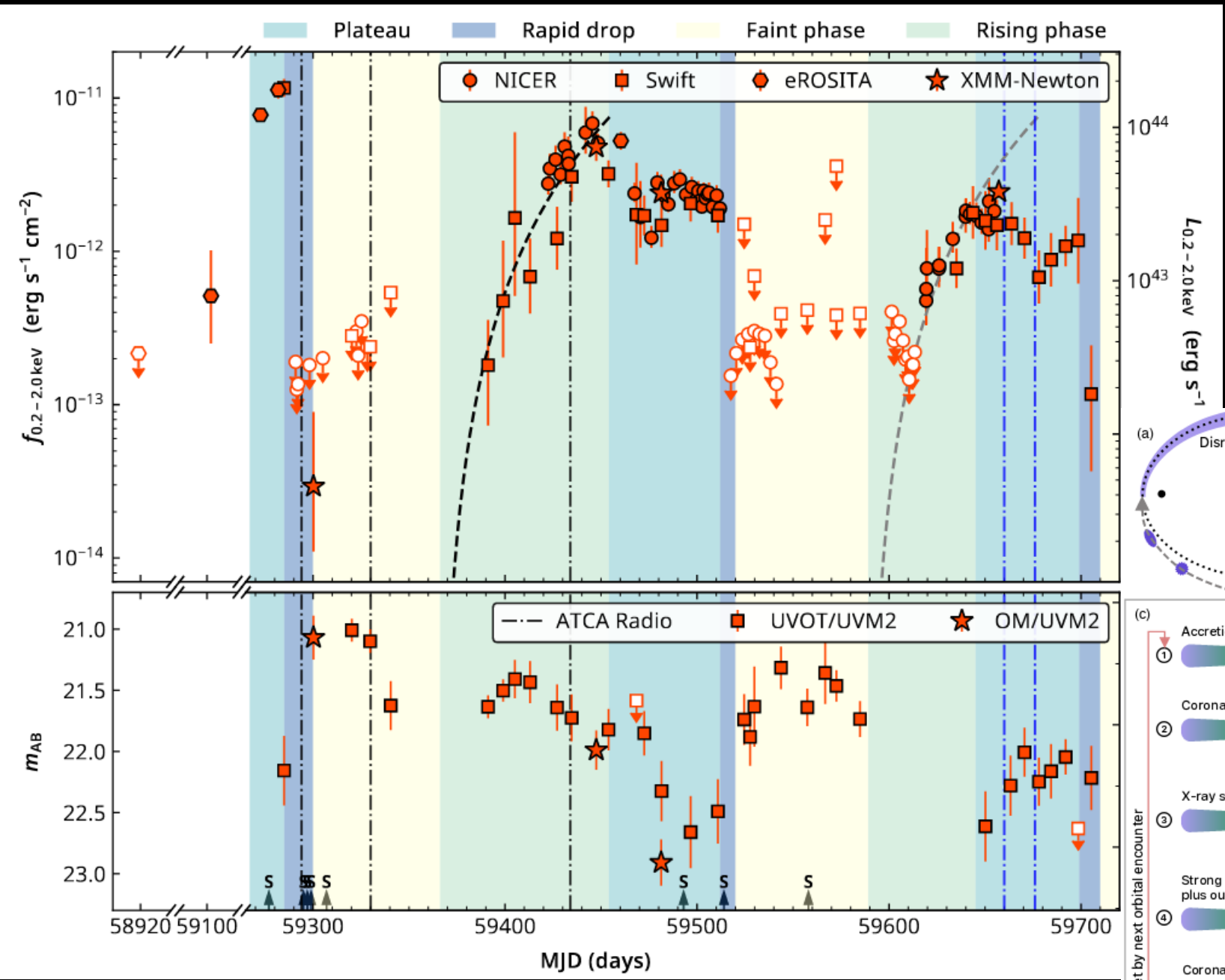




arxiv: 2208.12452

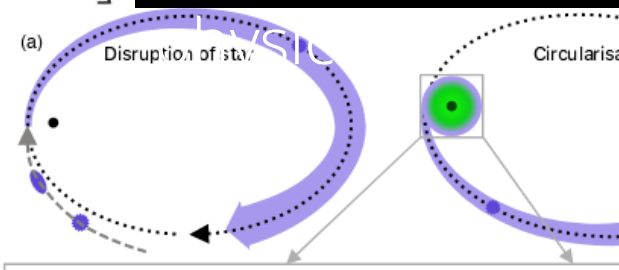
Tidal Disruption Events

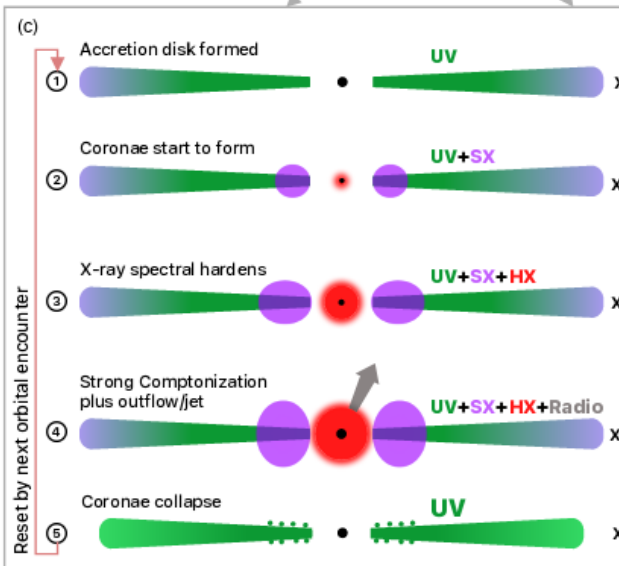
Arne Rau, Zhu Liu, Adam Malyali, Iuliia Grotova, ...



First repeating TDE in X-rays

Laboratory for accretion disk





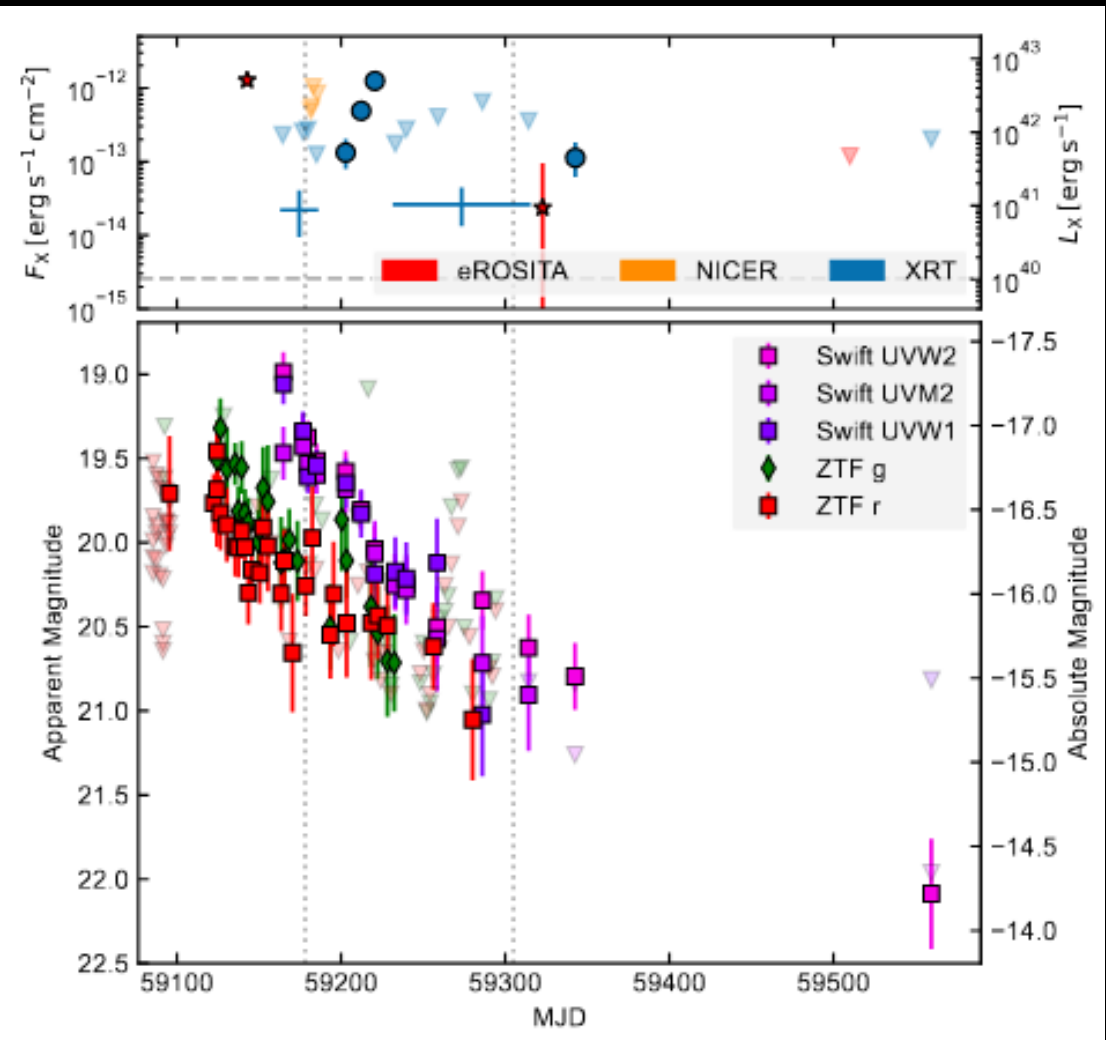
arxiv: 2208.12452

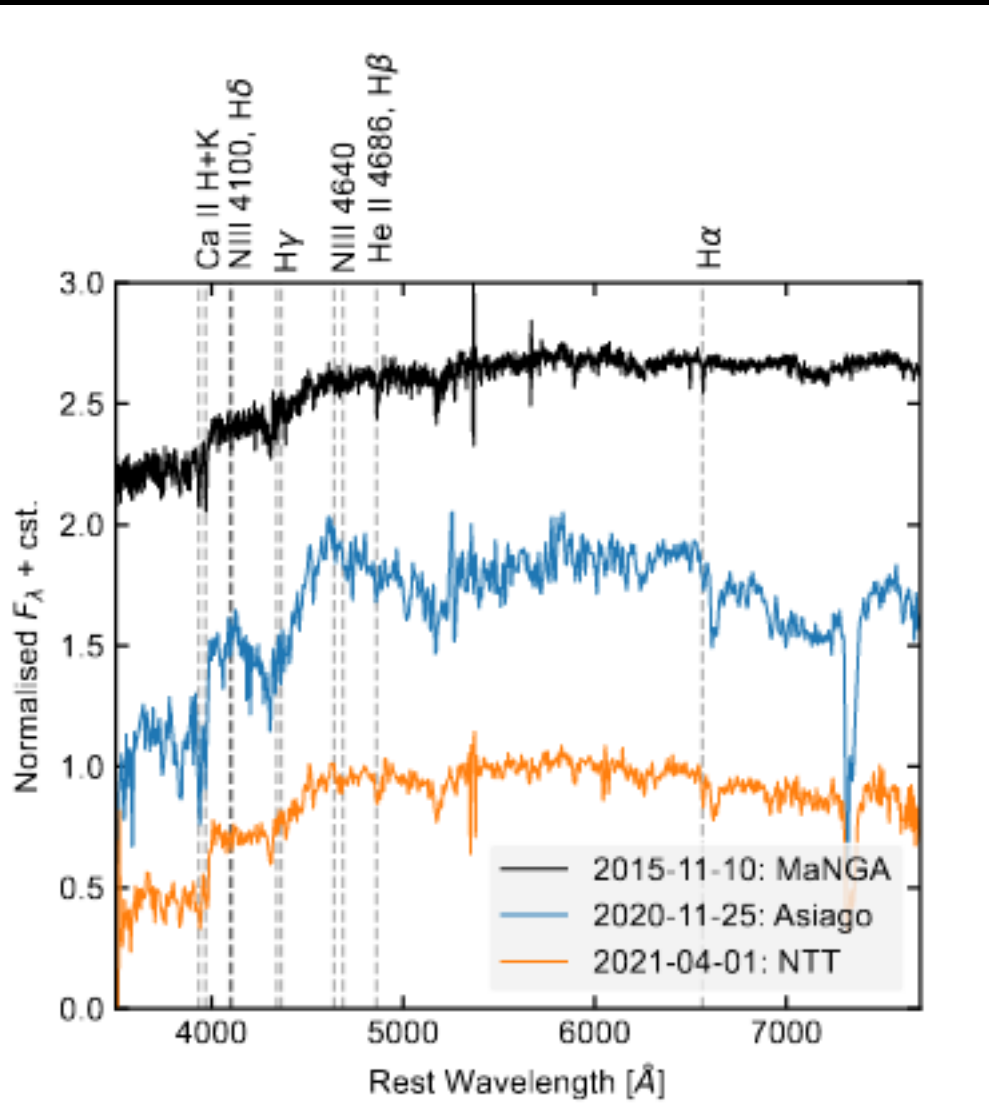
(+QPE sources, TDE+QPE sources, ...
AGN variability breaking accretion disk theory)

Tidal Disruption Events II

Arne Rau, Zhu Liu, Adam Malyali, Iuliia Grotova,
David Homan, Mirko Krumpe...

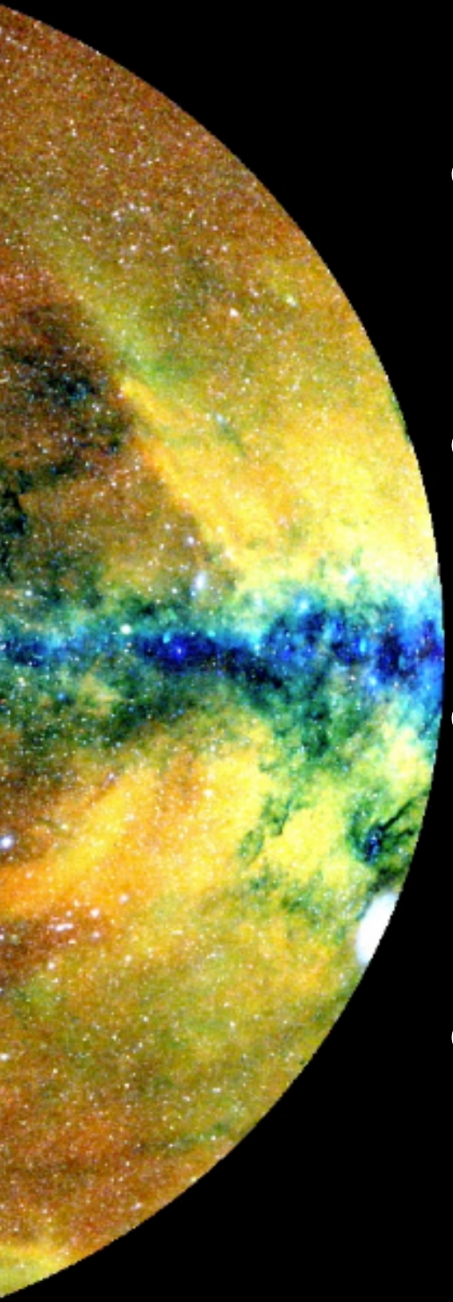
"lets find things that look like a TDE"
→ "What does a TDE look like?"





GRAHSP: Genuine Retrieval of the AGN host stellar population (Buchner+24, in press)

Takeaway: eROSITA DR1



- All-sky survey
  in 2020 -- 0.2-5 keV
- Data Release 1:
  erosita.mpe.mpg.de/dr1/
- Large AGN samples
- Transients

Future:

- 3.5 more surveys
  - + Multiwavelength counterparts, redshifts, data expertise
  - + Collaborate with the German eROSITA collaboration
- Tech flying on Einstein Probe