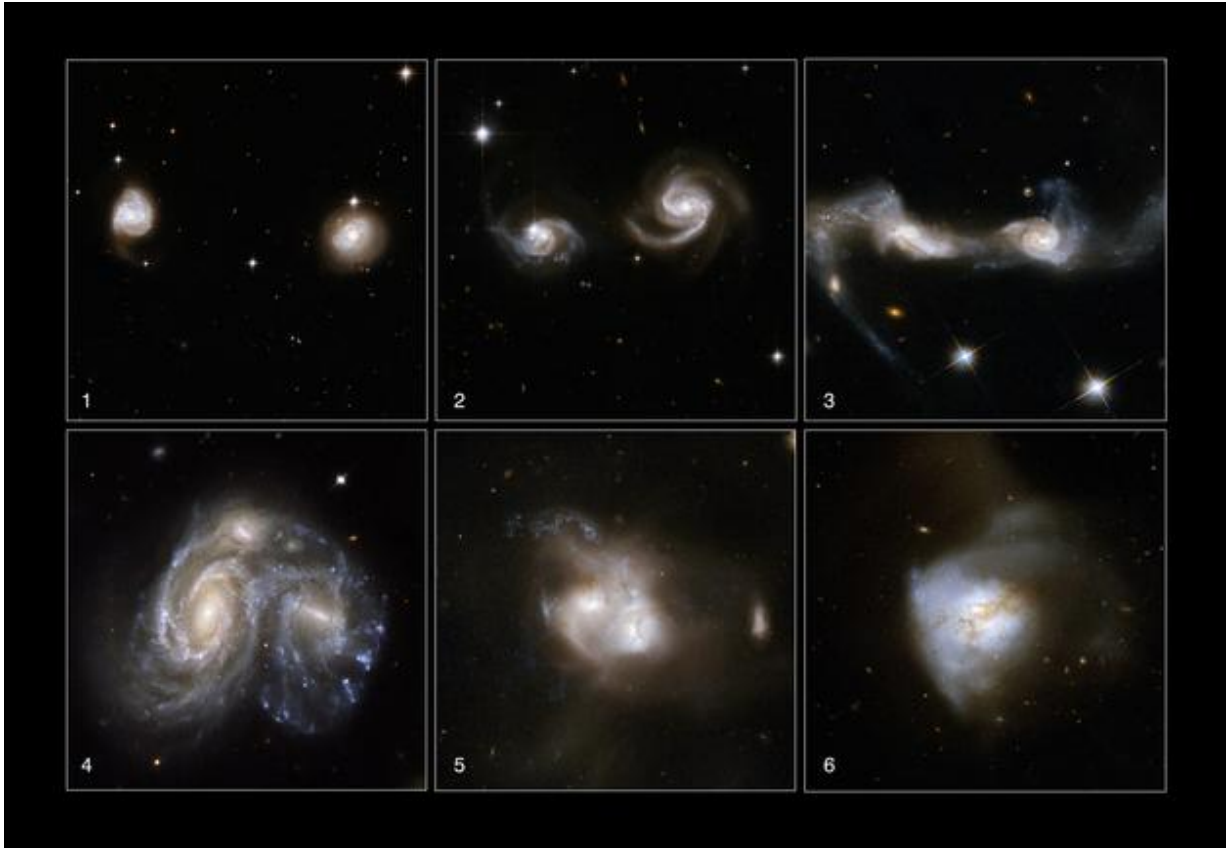
Leibniz-Institut für
Astrophysik Potsdam

Searching for supermassive black hole binaries with X-ray missions

Dusán Tubín Arenas
dtubin@aip.de

Leibniz-Institute for Astrophysics Potsdam (AIP)
Seventeenth Marcel Grossmann Meeting. Pescara, 2024

Introduction



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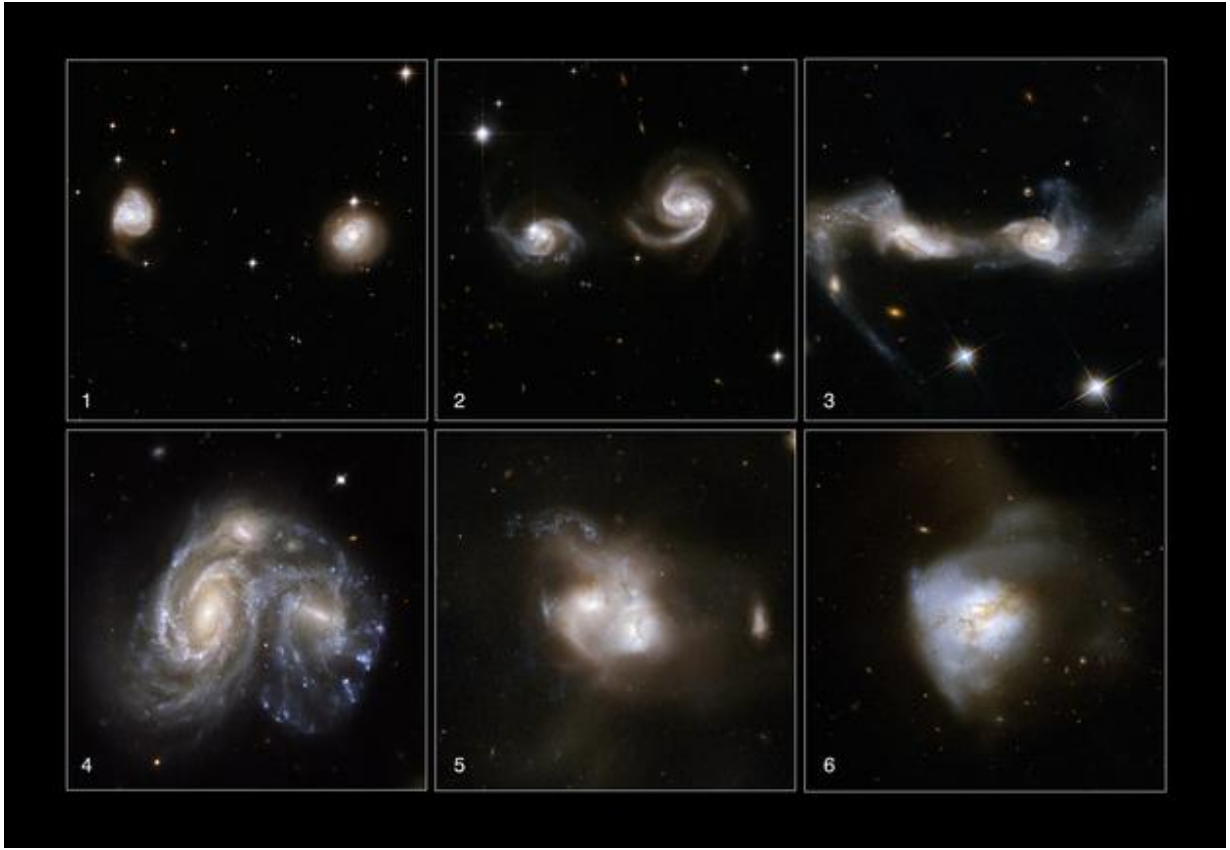
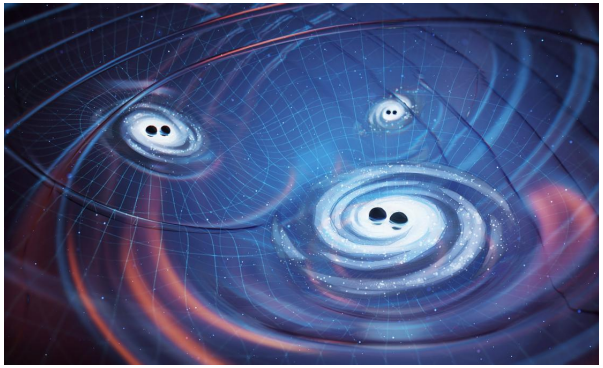
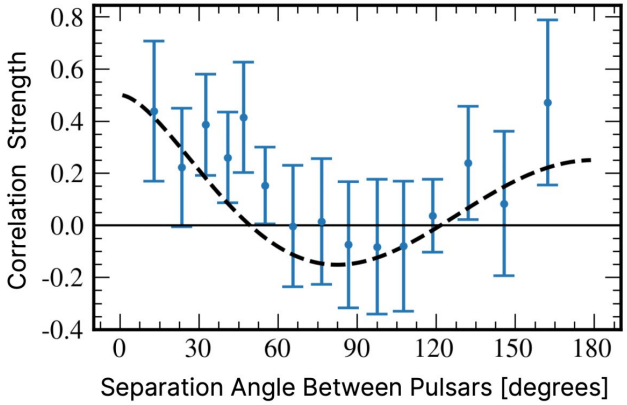


NANOGrav GW background detection





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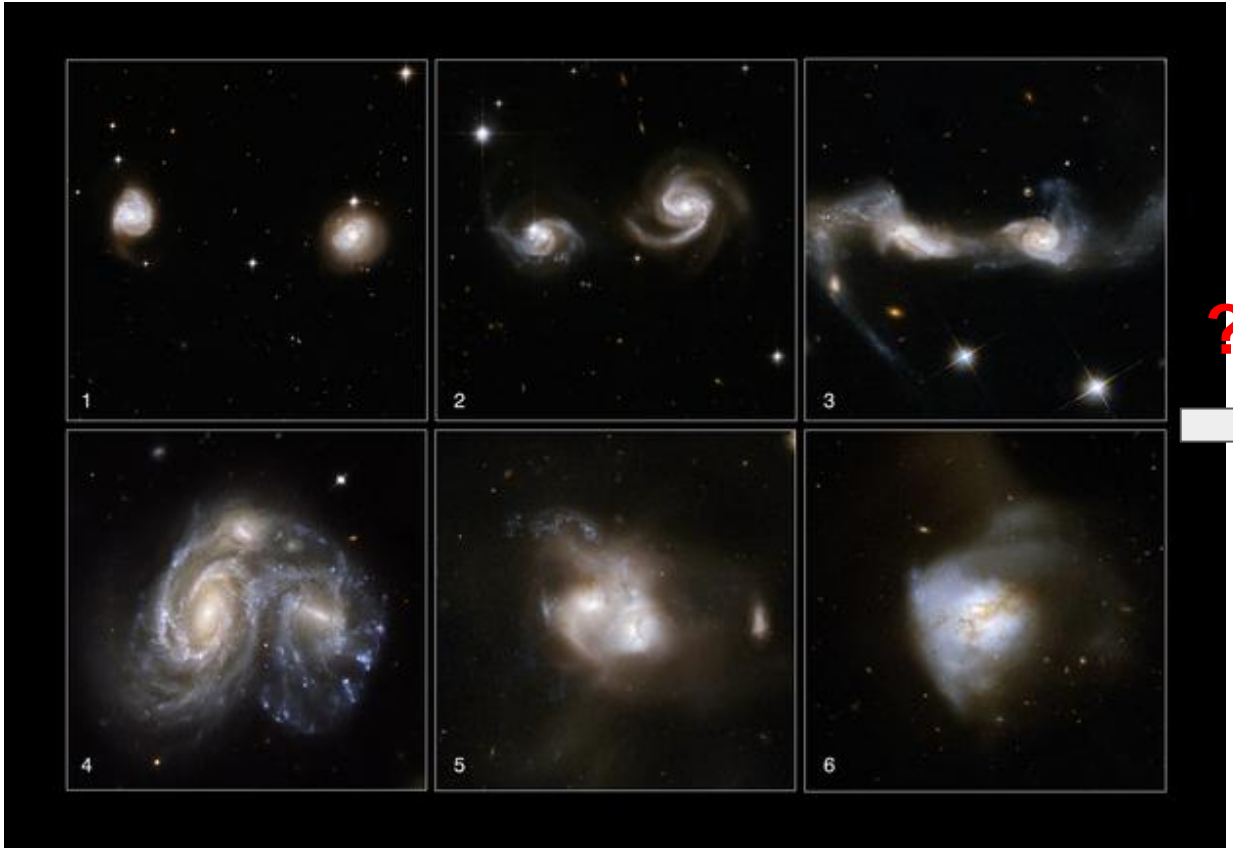

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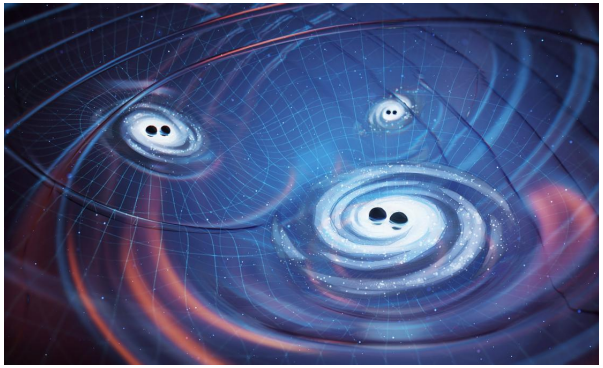

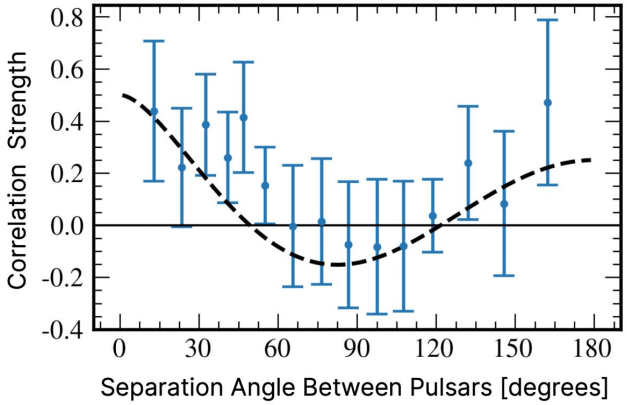

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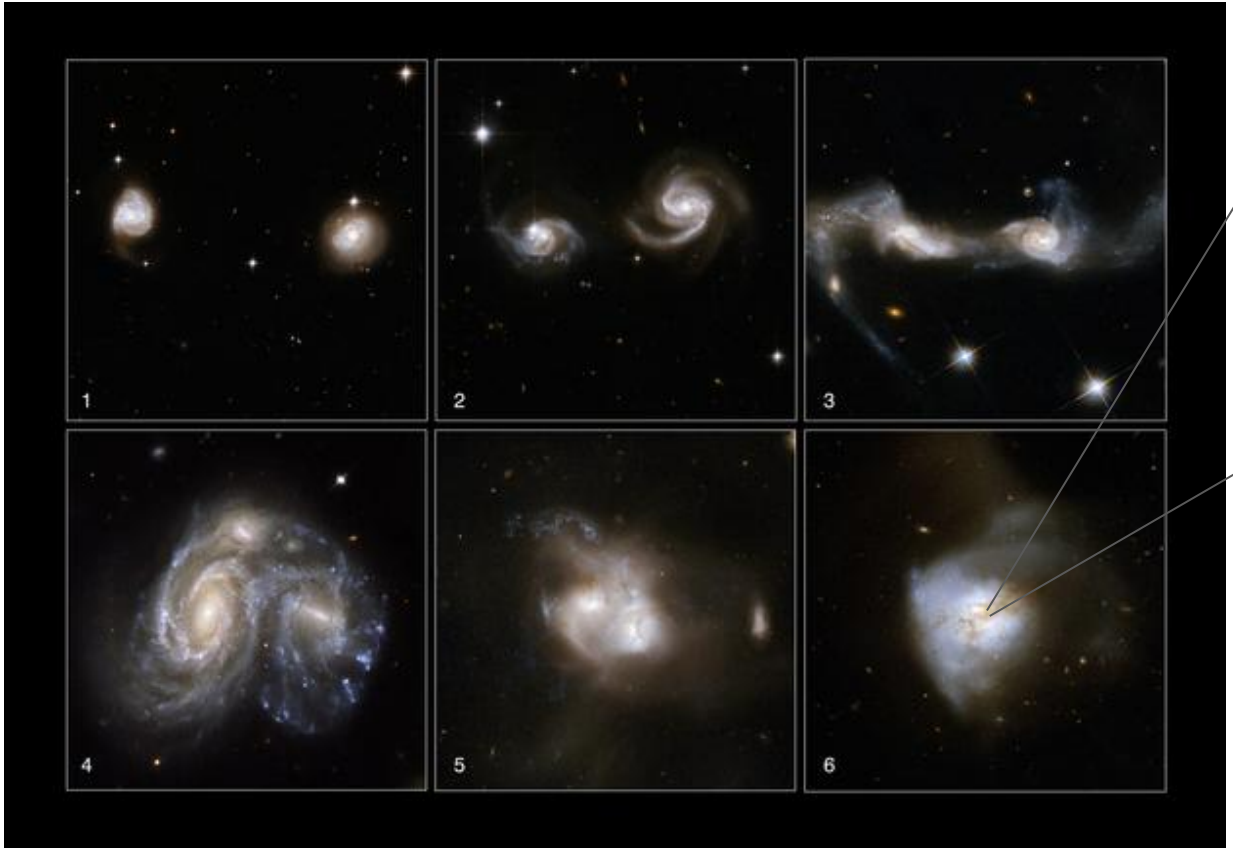

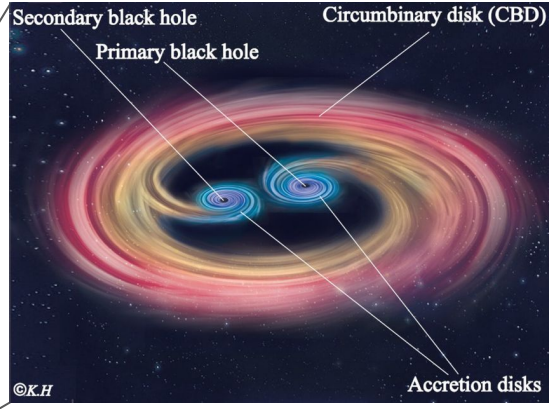

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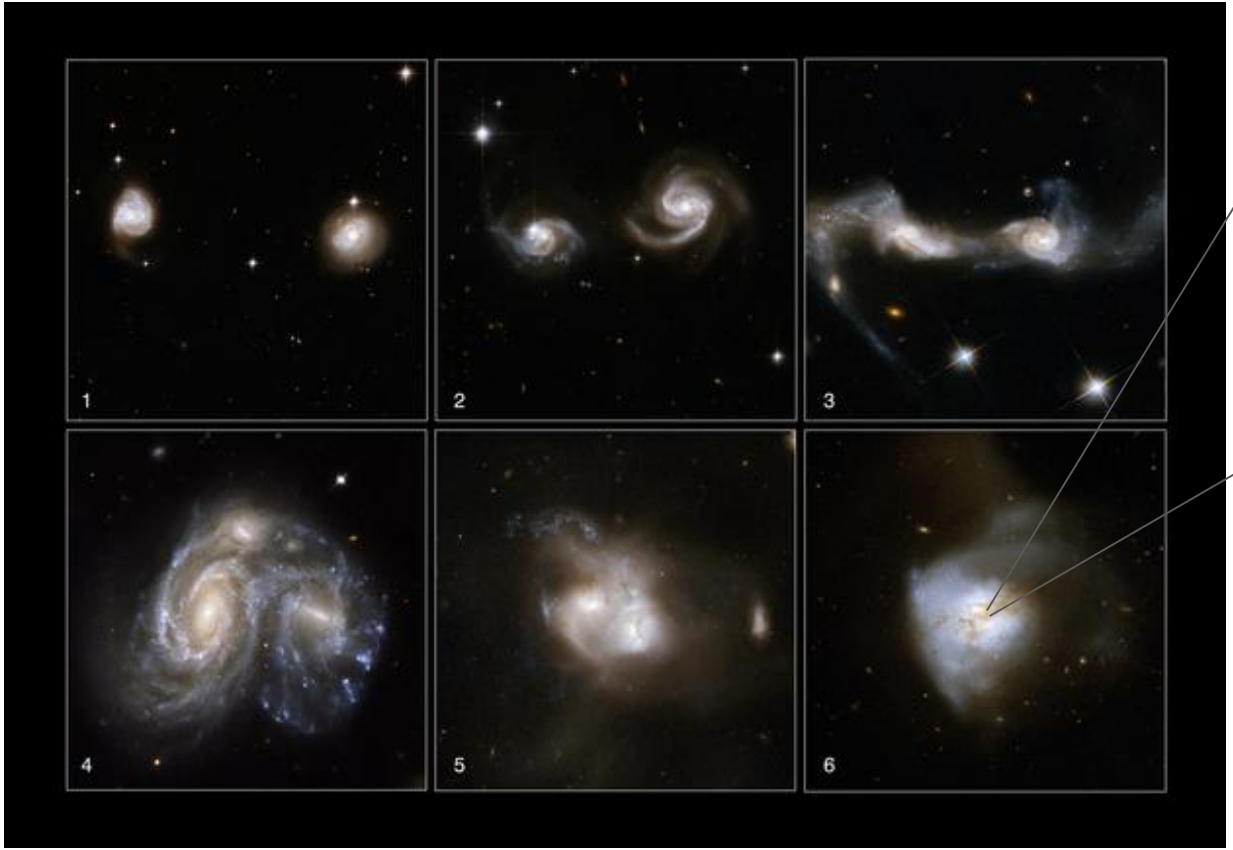
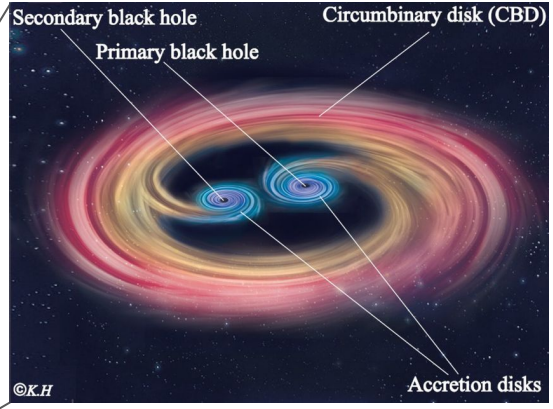




Observational evidence for SMBHB:

- X-ray variability modulated by the orbital period.
- Double-peaked Fe Kα line.

Known SMBHBs candidates

MCG+11-11-032:

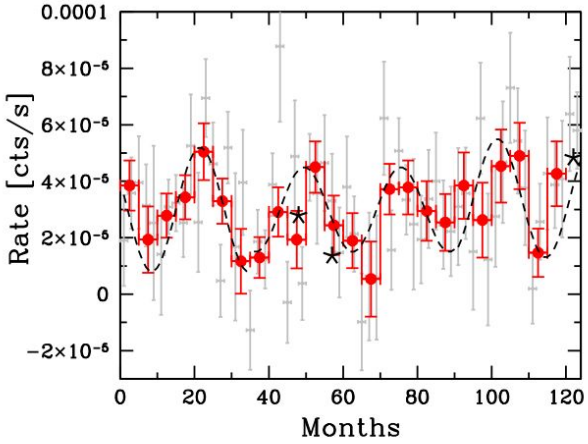


Figure 4. 15–150 keV light curve of MCG+11-11-032 taken from the *Swift*-BAT 123-month survey (2005 January to 2015 March) in time bins of two (grey data points) and five months (red filled circles). Error bars mark 1σ uncertainties. The black skeletal symbols represent the binned XRT count rates overlapping in time with the BAT monitoring and rescaled to BAT count rates (see Section 3.2). For visual purposes only, we overplotted a modular function obtained by summing four sinusoidal components with equal period but different amplitudes (dashed black curve).

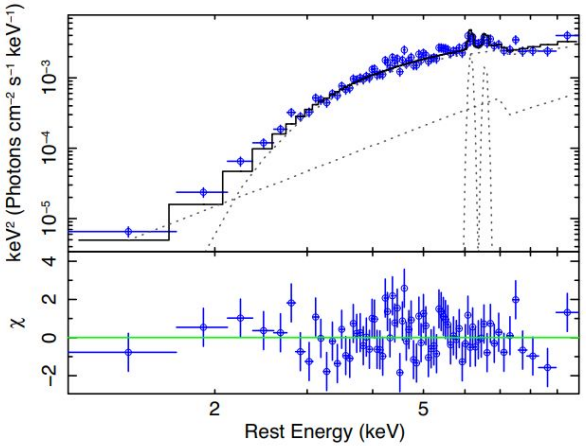


Figure 9. Upper panel: the model, which includes an intrinsically absorbed power-law plus a continuum reflection component and two narrow emission lines [*tbabs*∗(*ztbabs*∗*zpowerlw*+*pexrav*+*zgauss*+*zgauss*), model 4 in Table 3], is plotted over the spectrum of MCG+11-11-032. Note that this plot was obtained by creating fluxed spectrum against a simple $\Gamma = 2$ power-law and then overlaying the best-fitting model. Lower panel: relevant residuals, plotted in terms of sigmas.

P. Severgnini et al. (2018)

Mrk 915:

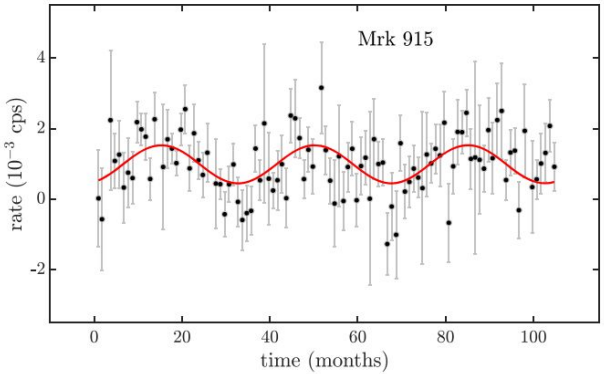
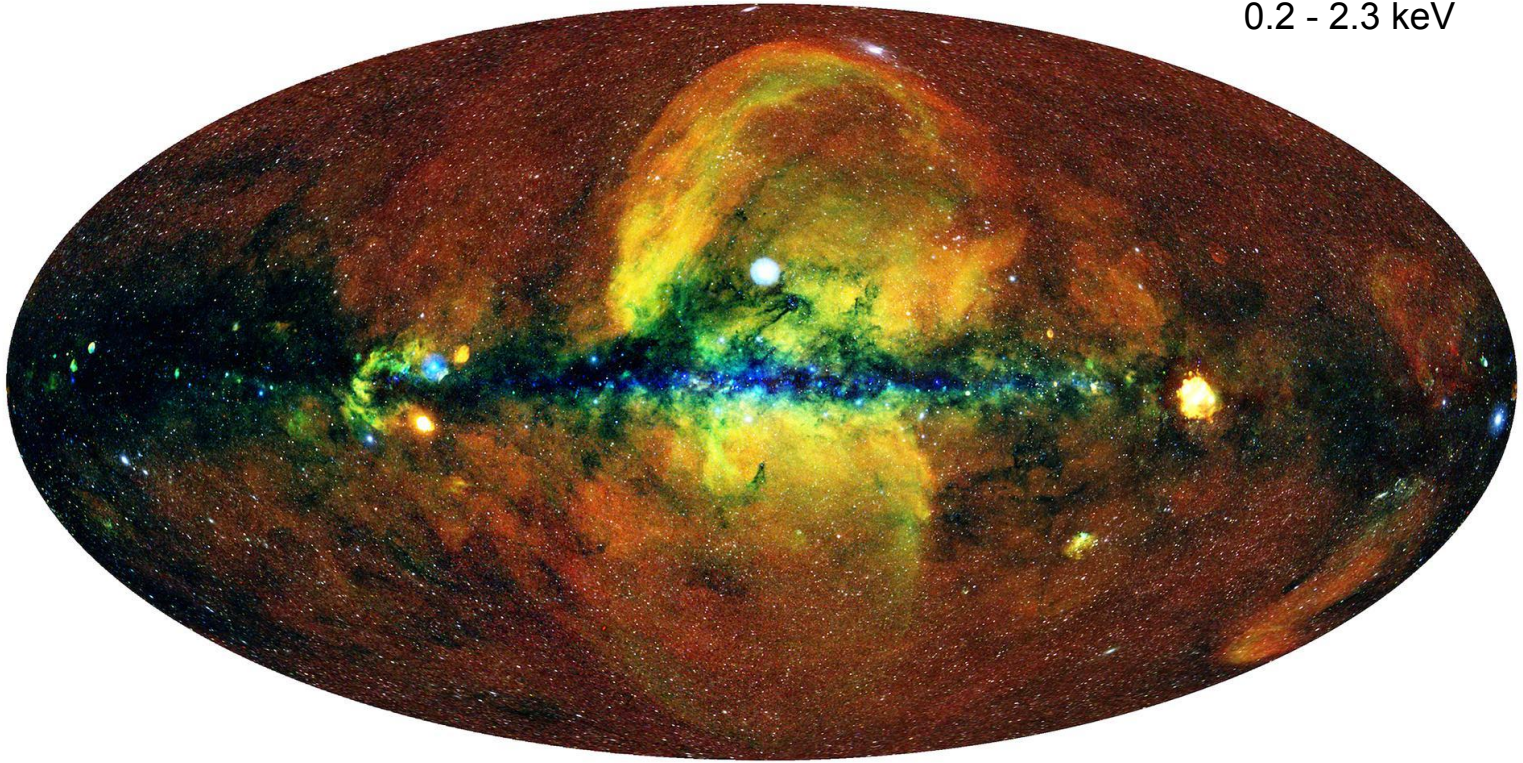


Figure 7. Hard X-ray light curve of Mrk 915. The red line represents the best-fit sinusoidal curve.

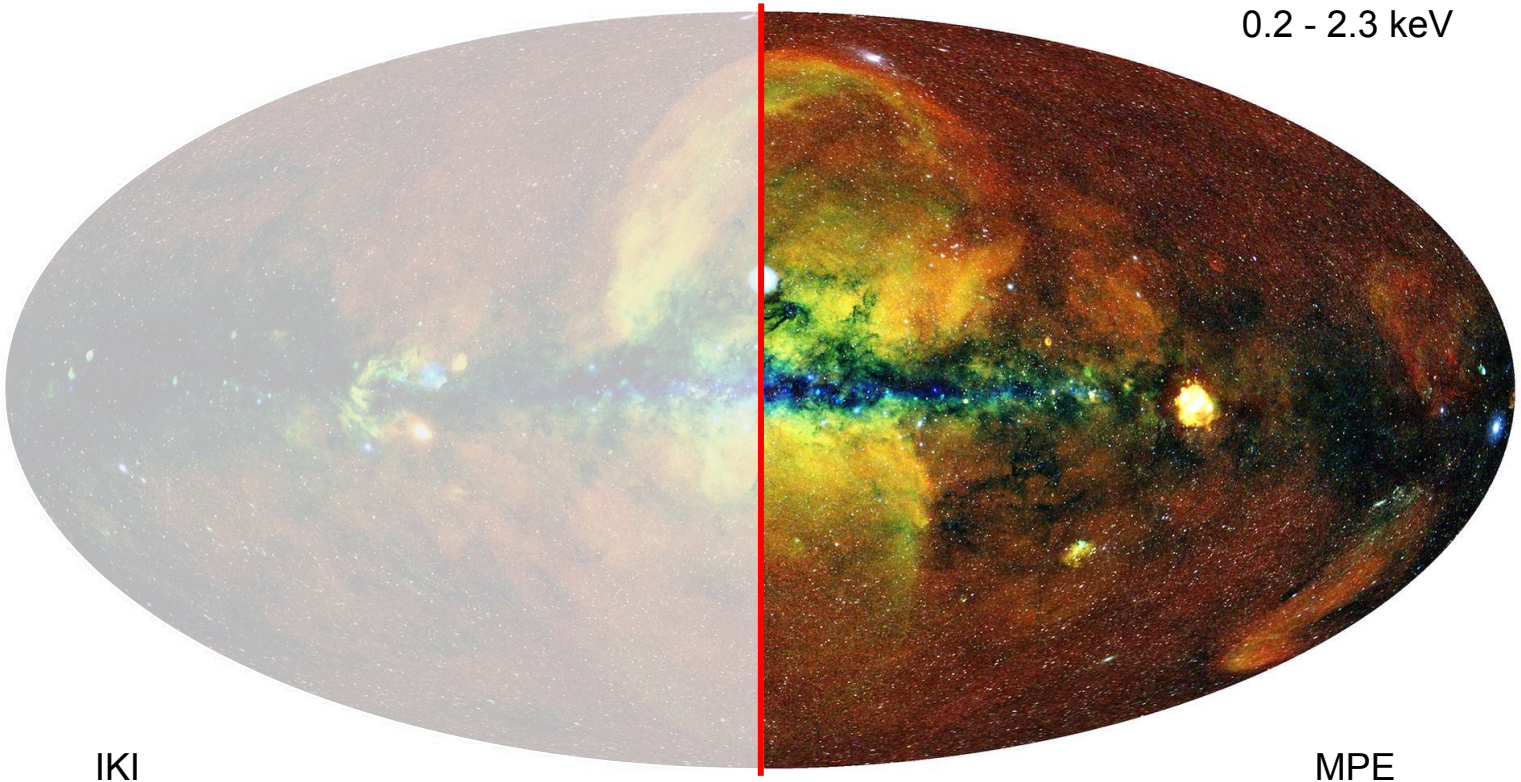
R. Serafinelli et al. (2020)

SRG/eROSITA



Predehl et al. (2021)

SRG/eROSITA



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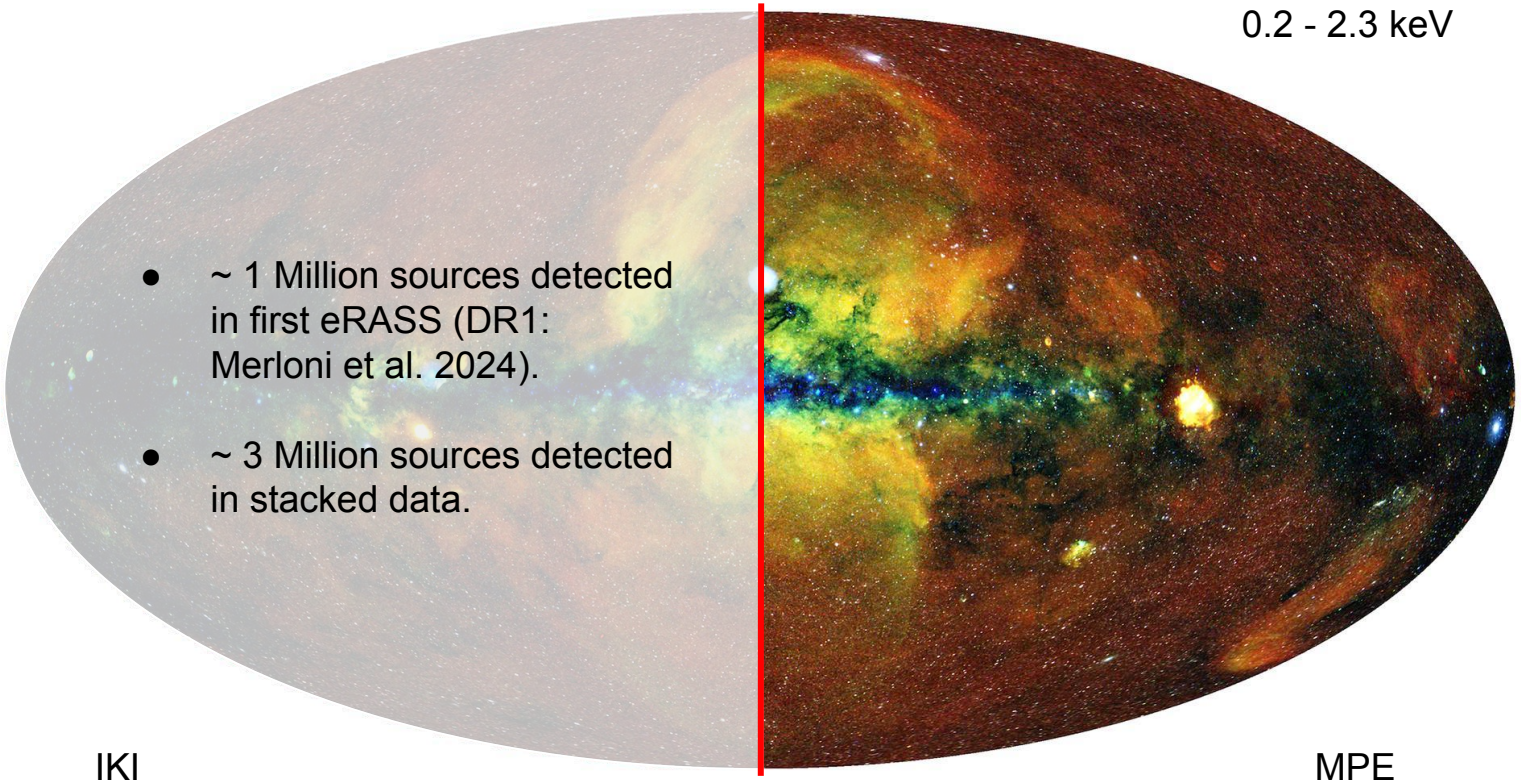
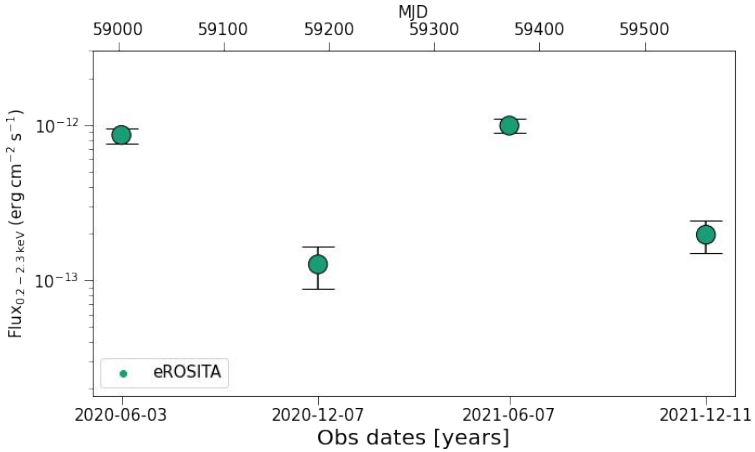


- ~ 1 Million sources detected in first eRASS (DR1: Merloni et al. 2024).
- ~ 3 Million sources detected in stacked data.

Selecting candidates

- Search for “up-down-up-down” or “down-up-down-up” light curves in extragalactic sources.



Legacy Survey DR10 image.

Tubín-Arenas et al. (in prep.)

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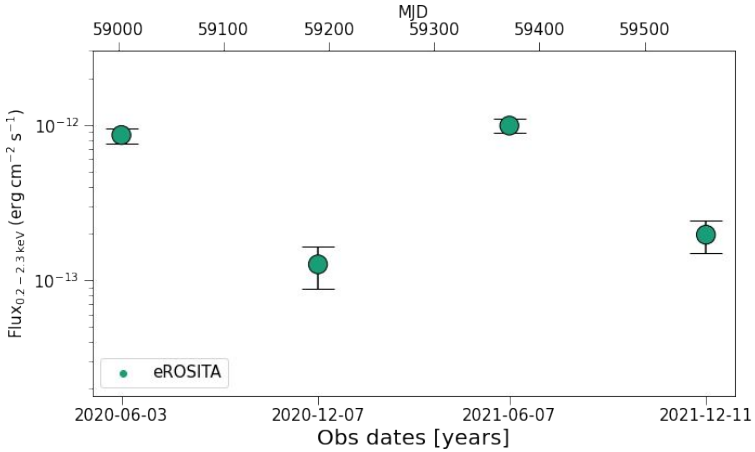

Legacy Survey DR10 image.

Periods of ~ 4 and ~12 months → milli-pc separations!

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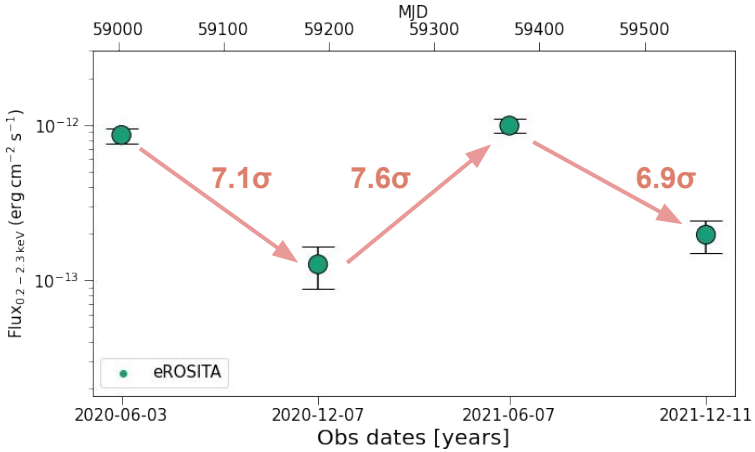
- Request a significance > 3σ between eRASS scans.



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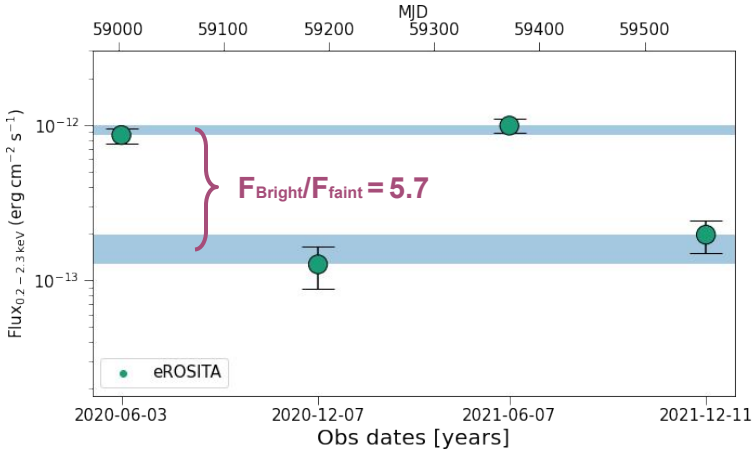

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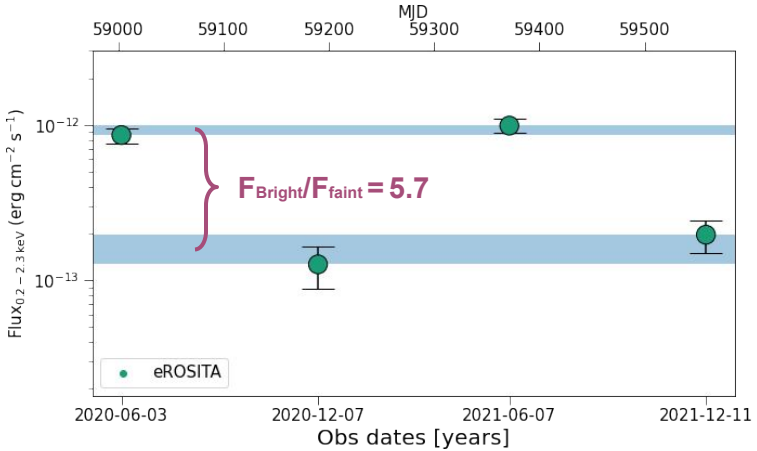

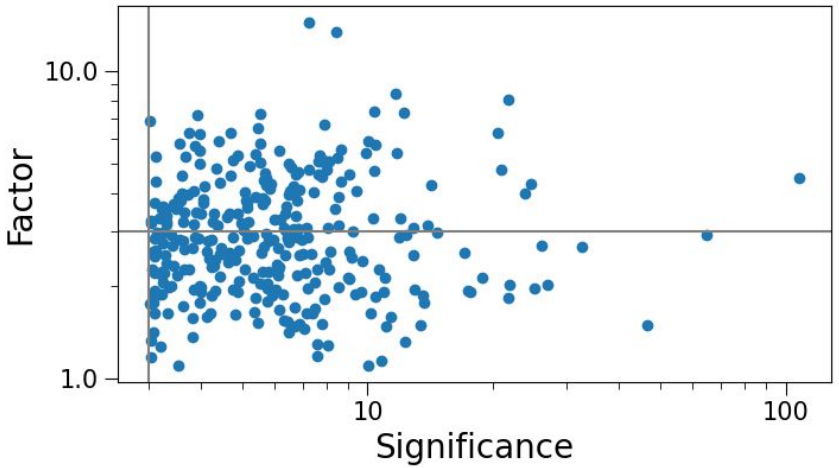

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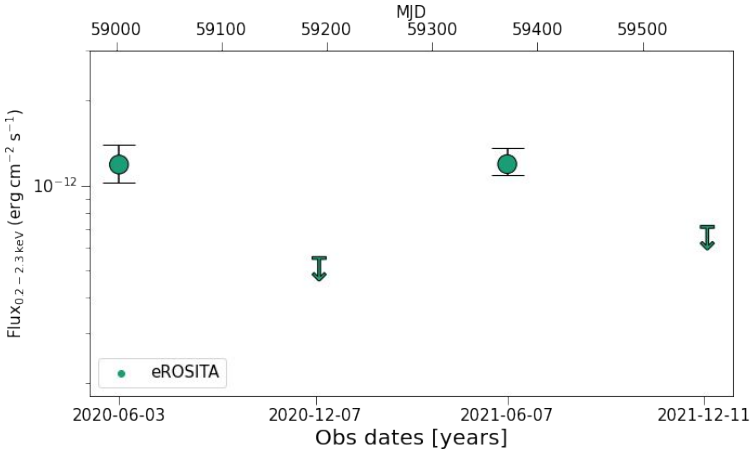
- Sort by ratio between “bright” and “faint” flux states.
- 34 SMBHB candidates have $F_{Bright}/F_{Faint} > 5$.
- Non detections in certain eROSITA scans are also considered.



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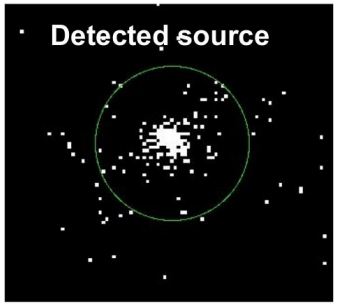
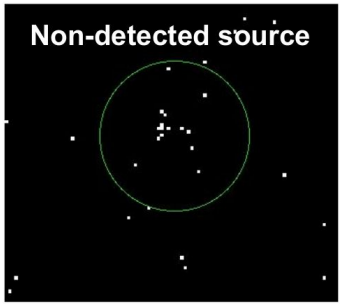
Tubín-Arenas et al. (in prep.)

Advertisement: The eROSITA Upper Limits (Tubín-Arenas et al. 2024)



$\mathrm{Flux}_{0.2-2.3\ \mathrm{keV}} = 5.3 \times 10^{-12}\ \mathrm{erg\ s^{-1}\ cm^{-2}}$



$\mathrm{Flux}_{0.2-2.3\ \mathrm{keV}} = ??$

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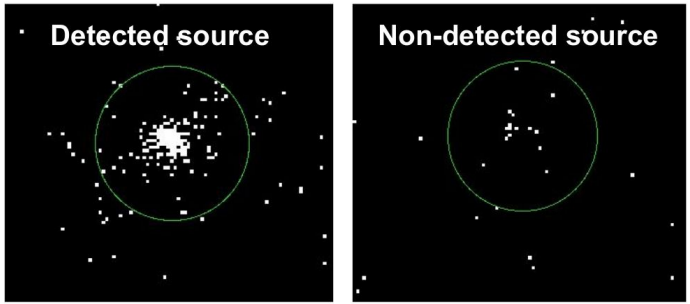

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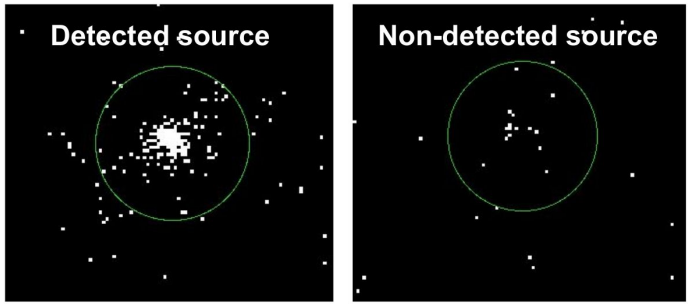
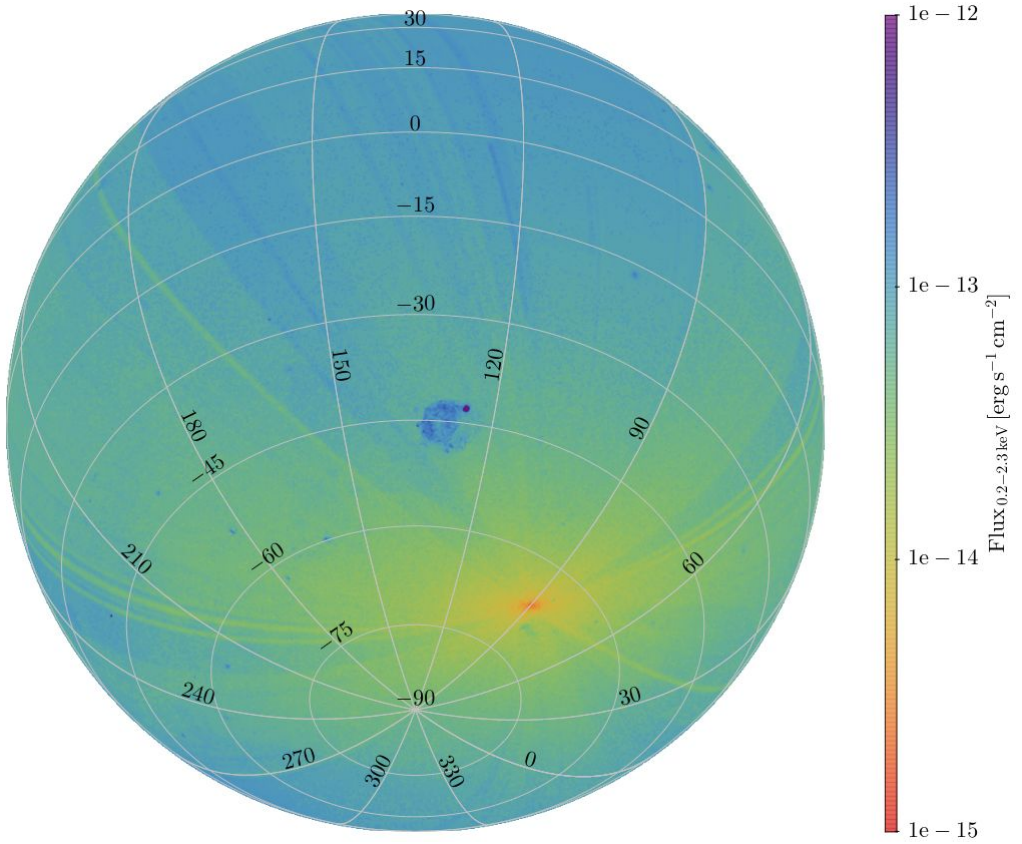


$\mathrm{Flux}_{0.2-2.3\,\mathrm{keV}} = 5.3 \times 10^{-12}$ erg s^{-1} cm^{-2}

$\mathrm{Flux}_{0.2-2.3\,\mathrm{keV}} < 5.9 \times 10^{-13}$ erg s^{-1} cm^{-2}



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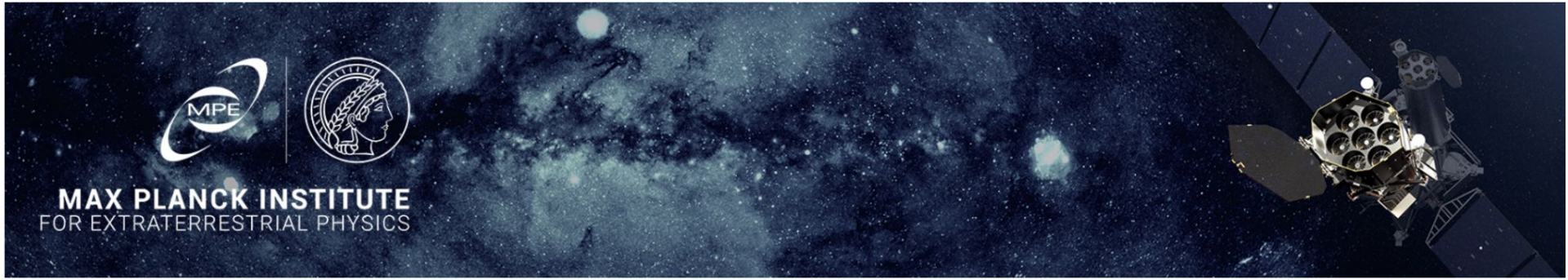

eRODat: eROSITA-DE Data Release 1 archive

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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)

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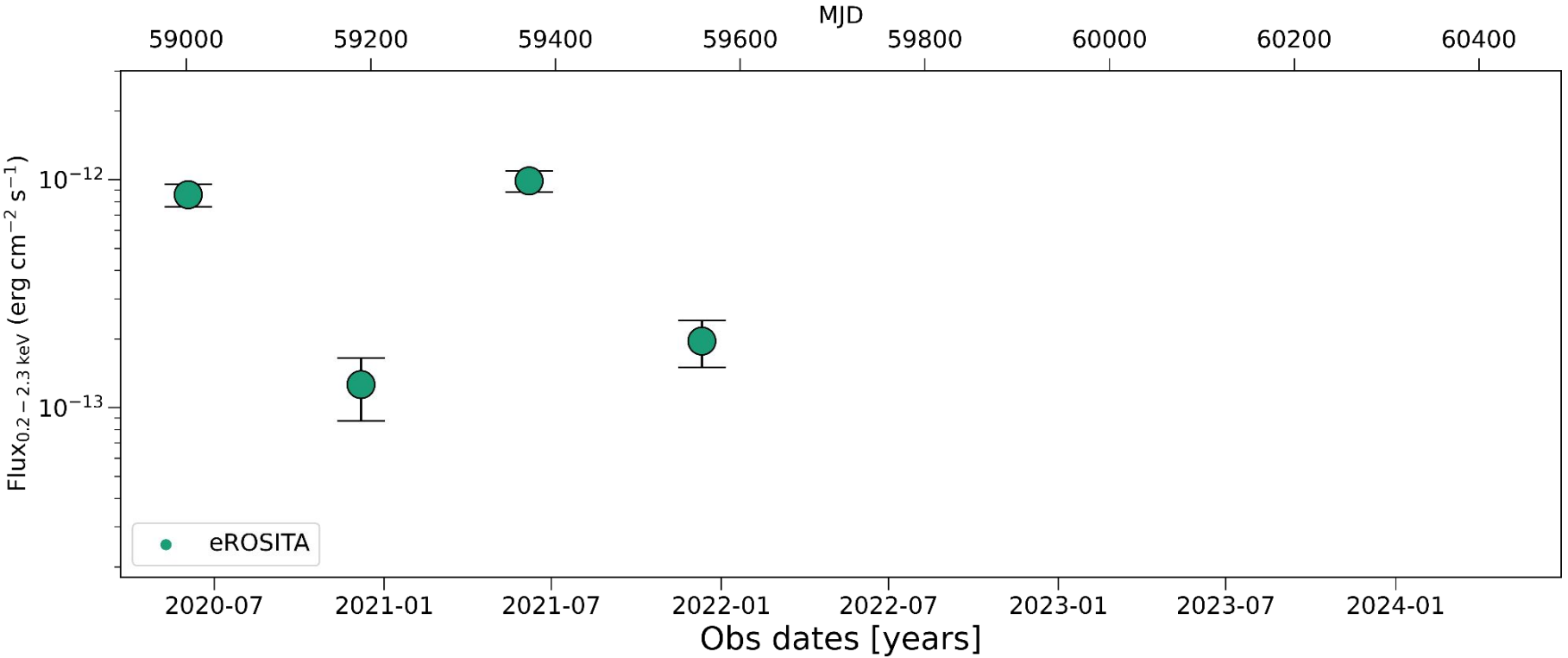
Follow up of the best SMBHB candidates



Tubín-Arenas et al. (in prep.)

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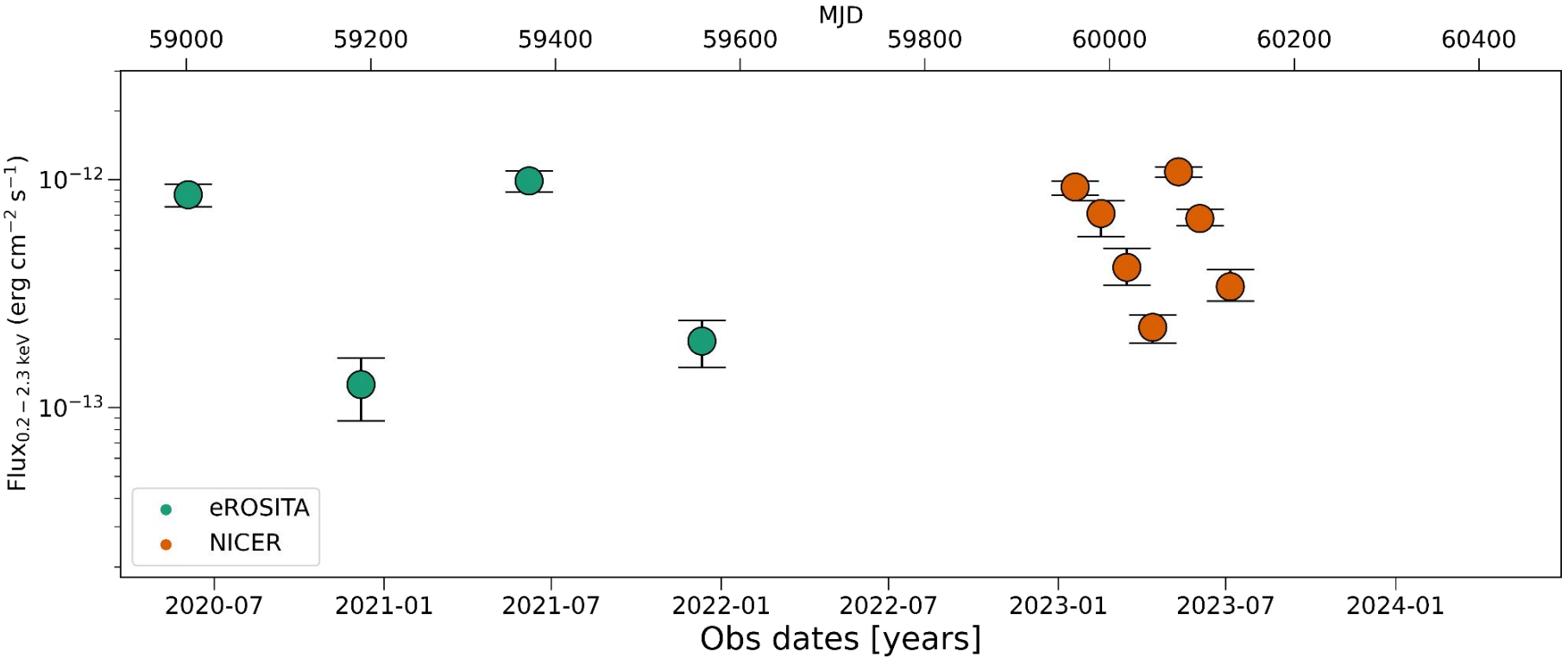

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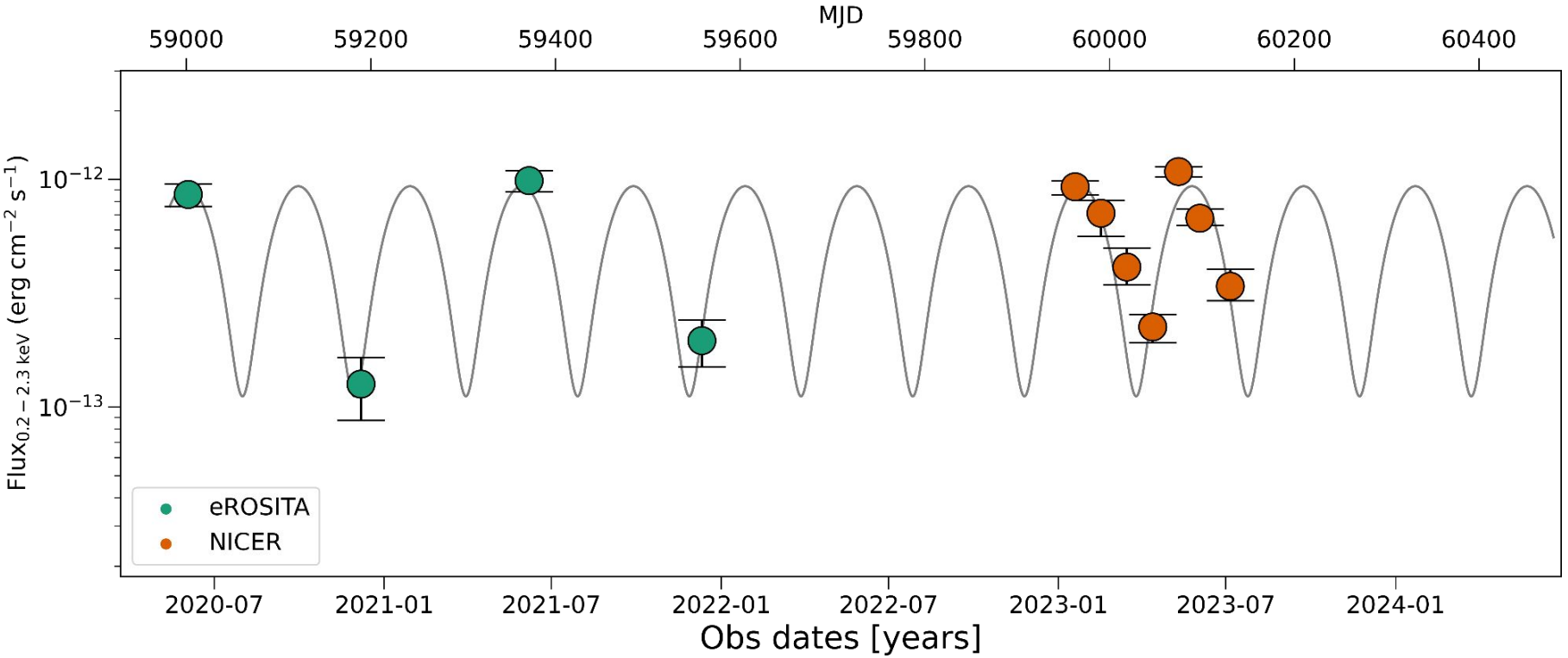

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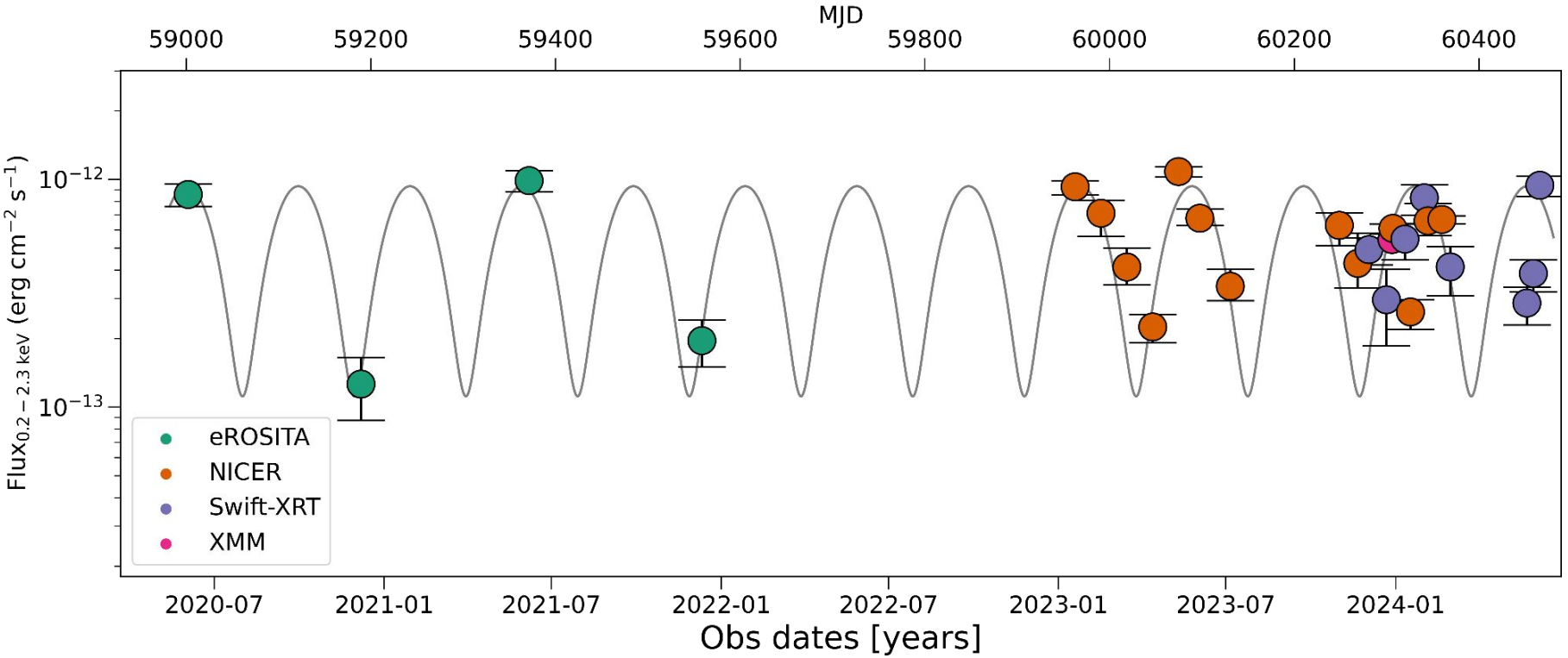

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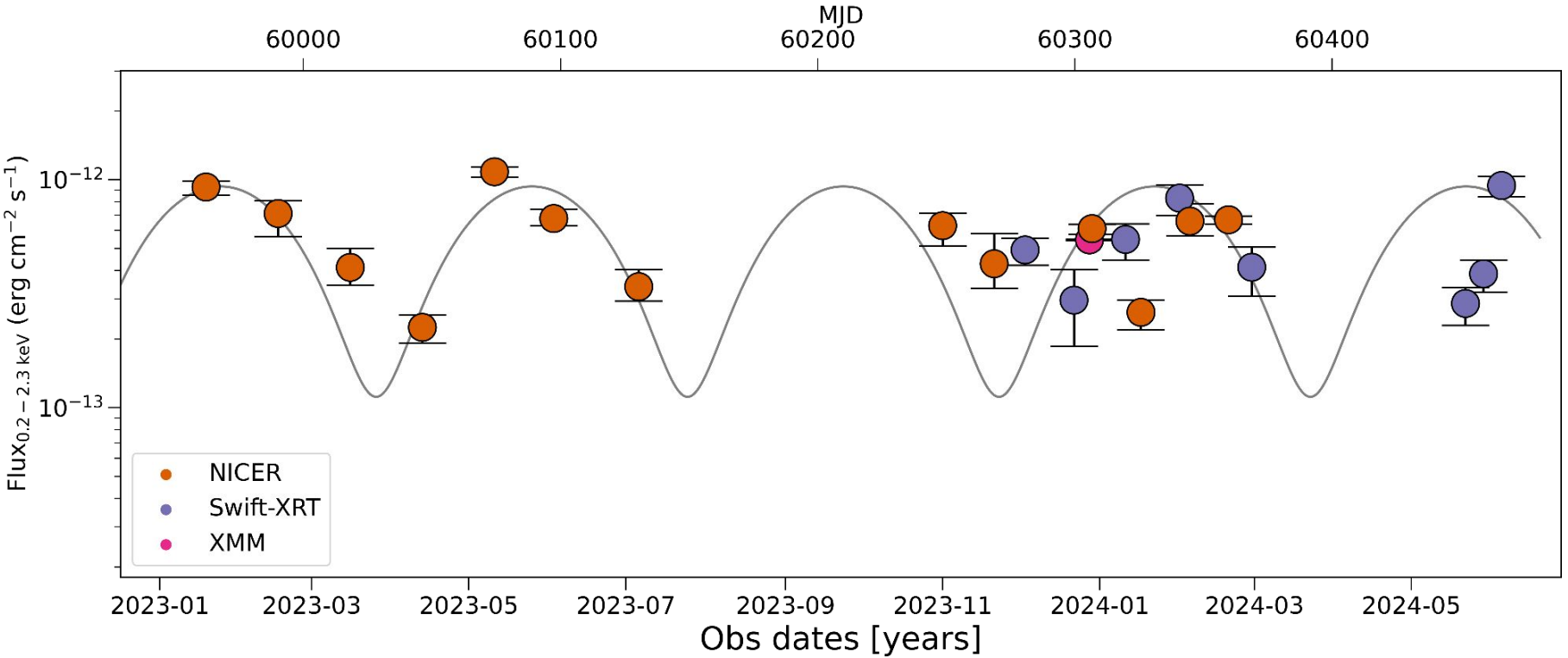
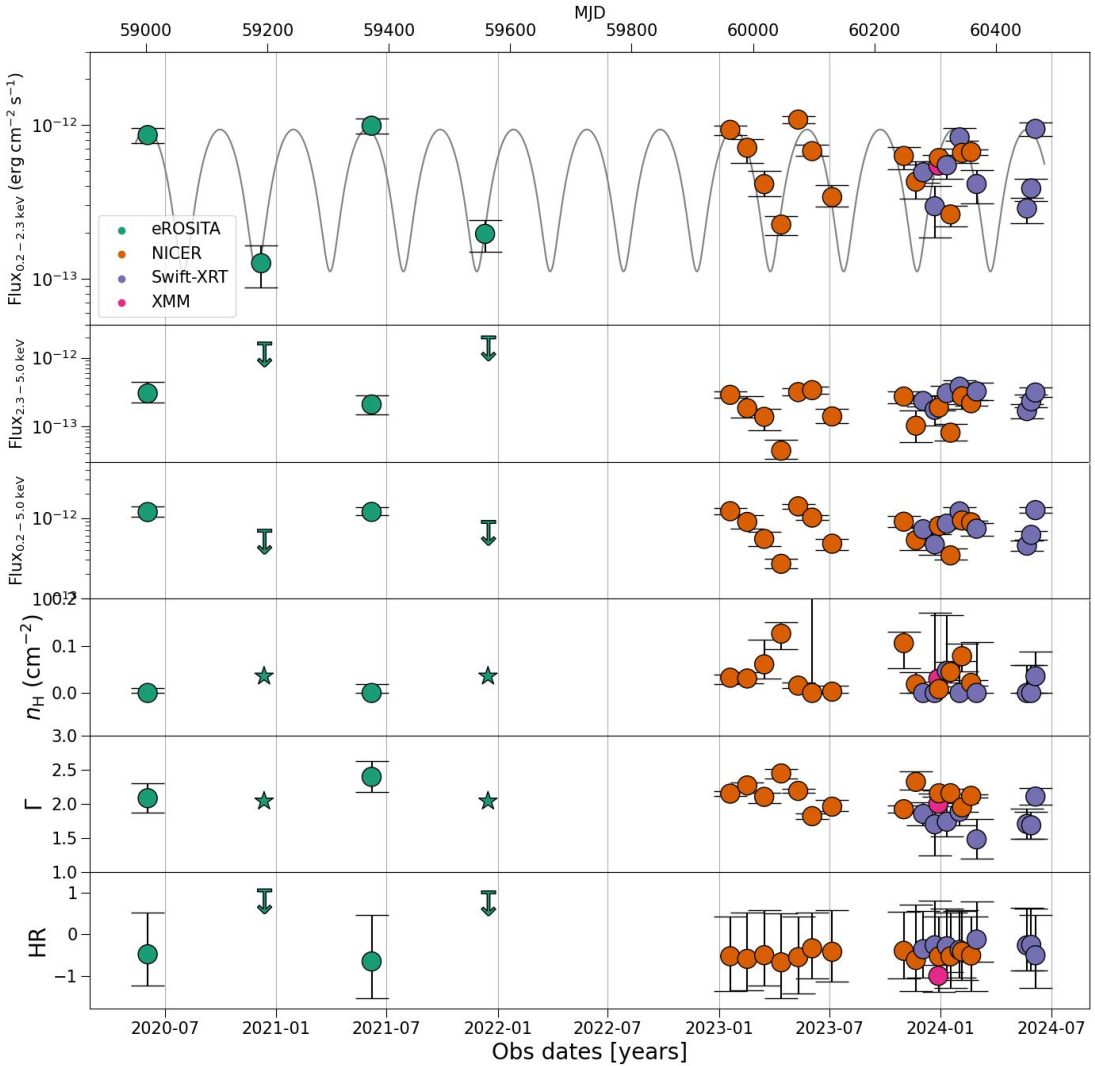


Tubín-Arenas et al. (in prep.)

Spectral properties of the SMBHB candidate



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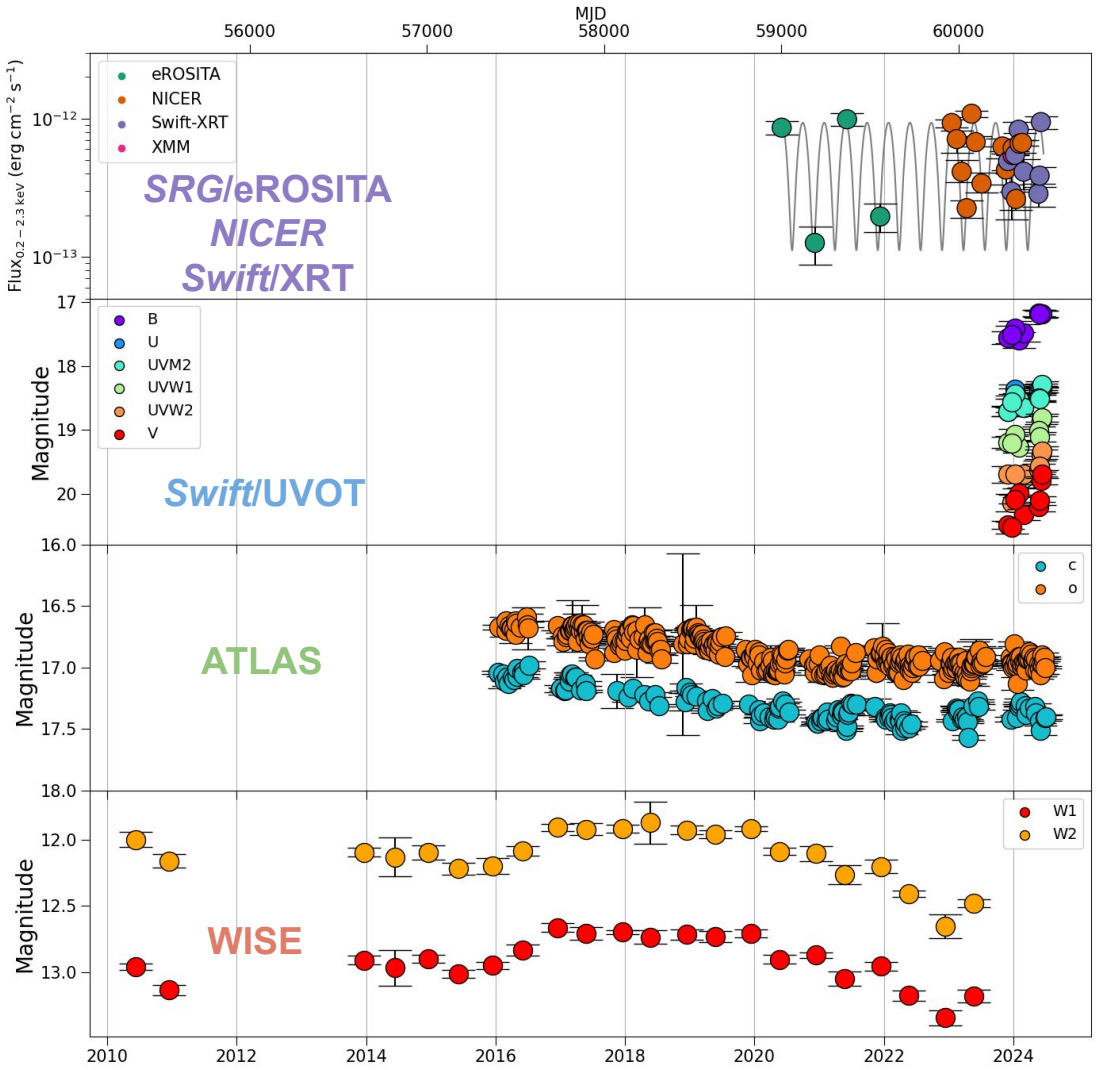
Multi-wavelength view of the SMBHB candidate



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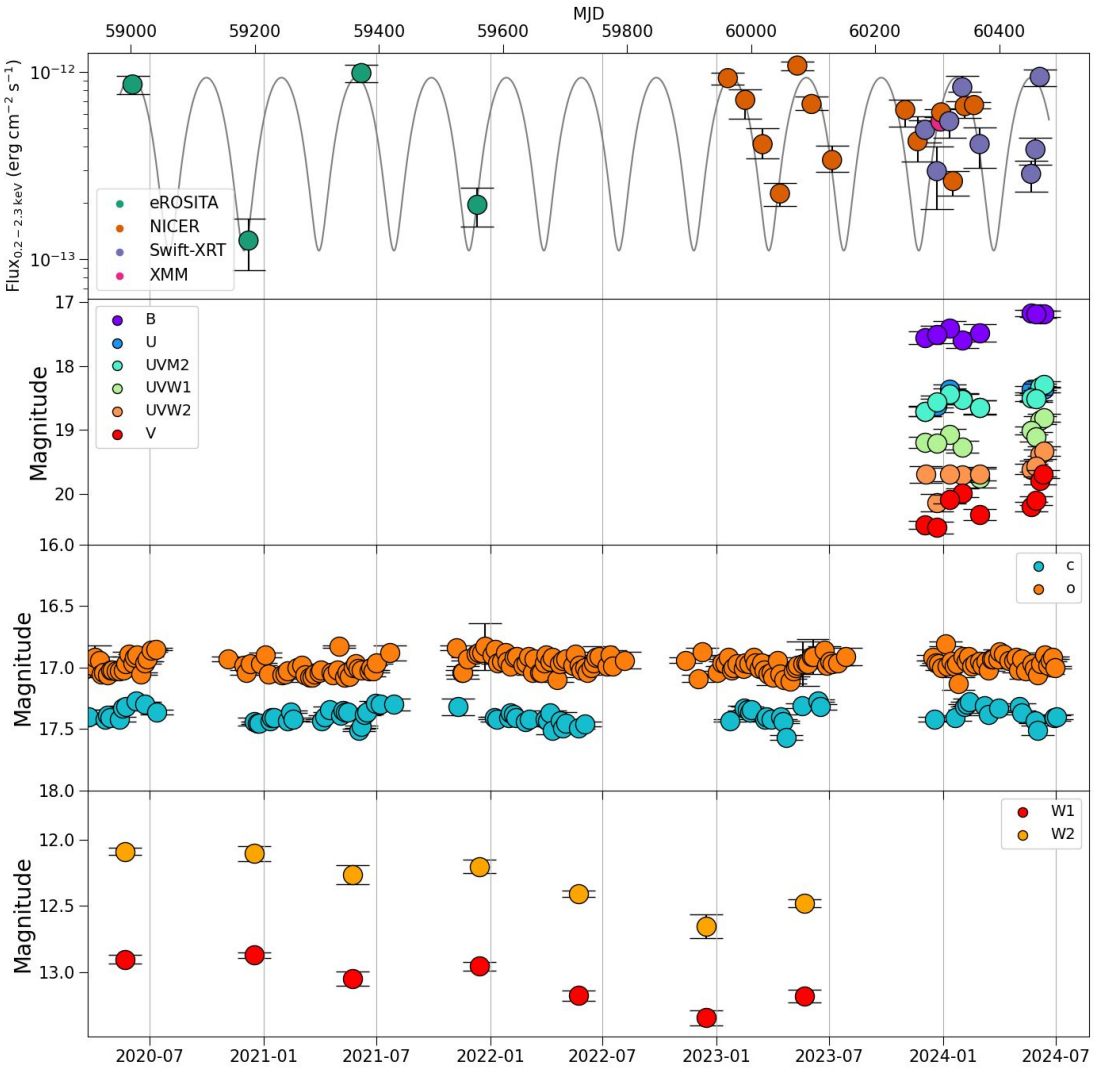

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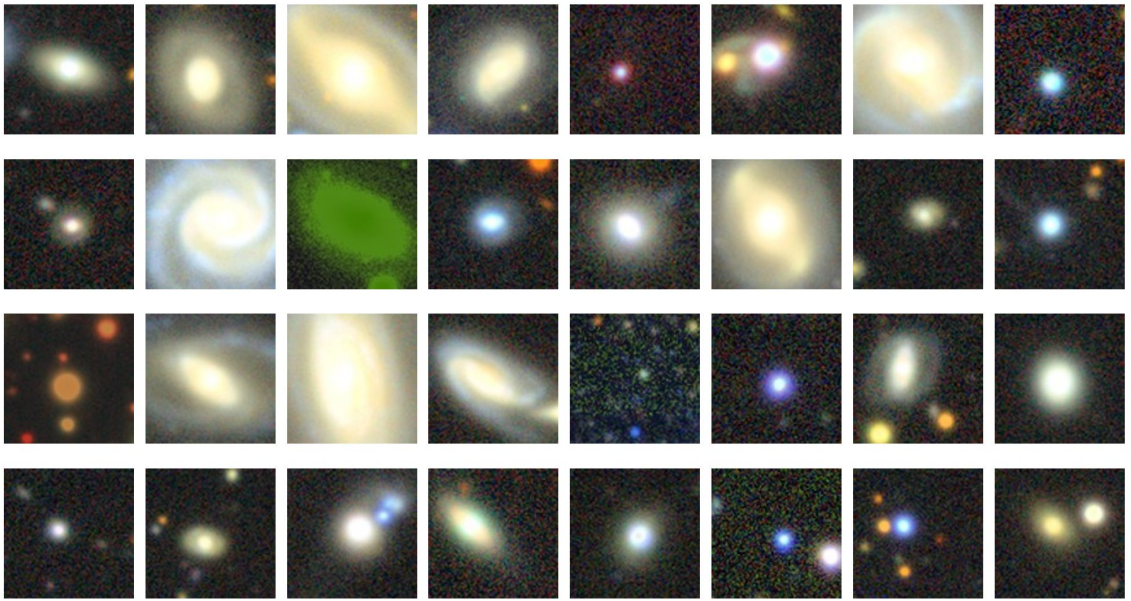
So far…

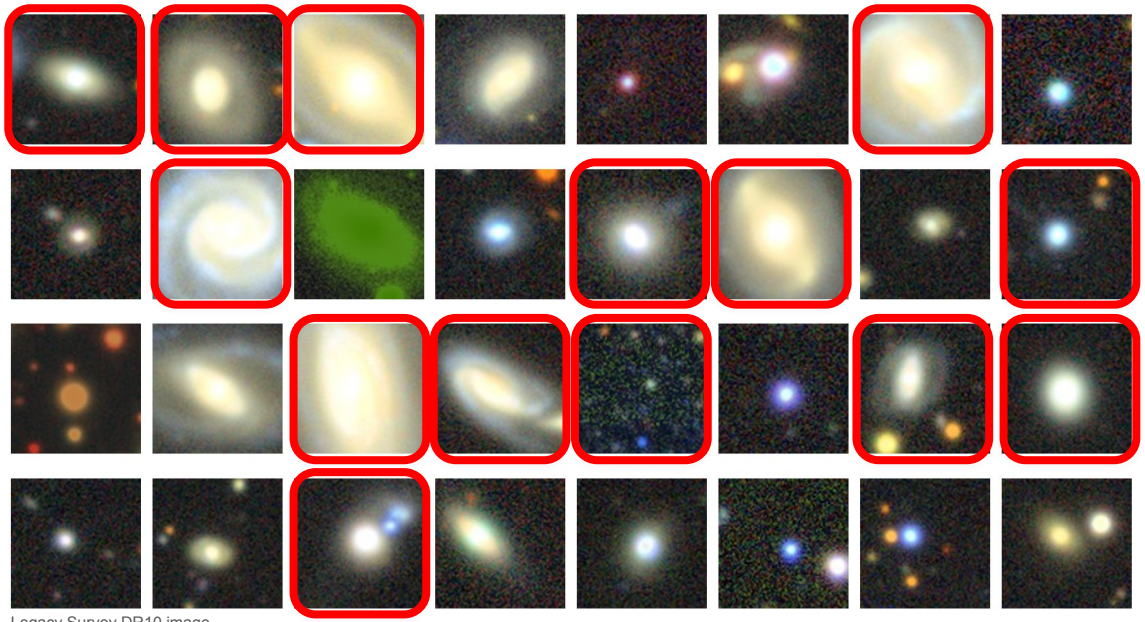
- 34 eROSITA-selected SMBHB candidates with $F_{Bright}/F_{Faint} > 5$.



Legacy Survey DR10 image.

So far…

- 34 eROSITA-selected SMBHB candidates with $F_{Bright}/F_{Faint} > 5$.
- 16 of which we can follow up with NICER and Swift.



Legacy Survey DR10 image.

So far…

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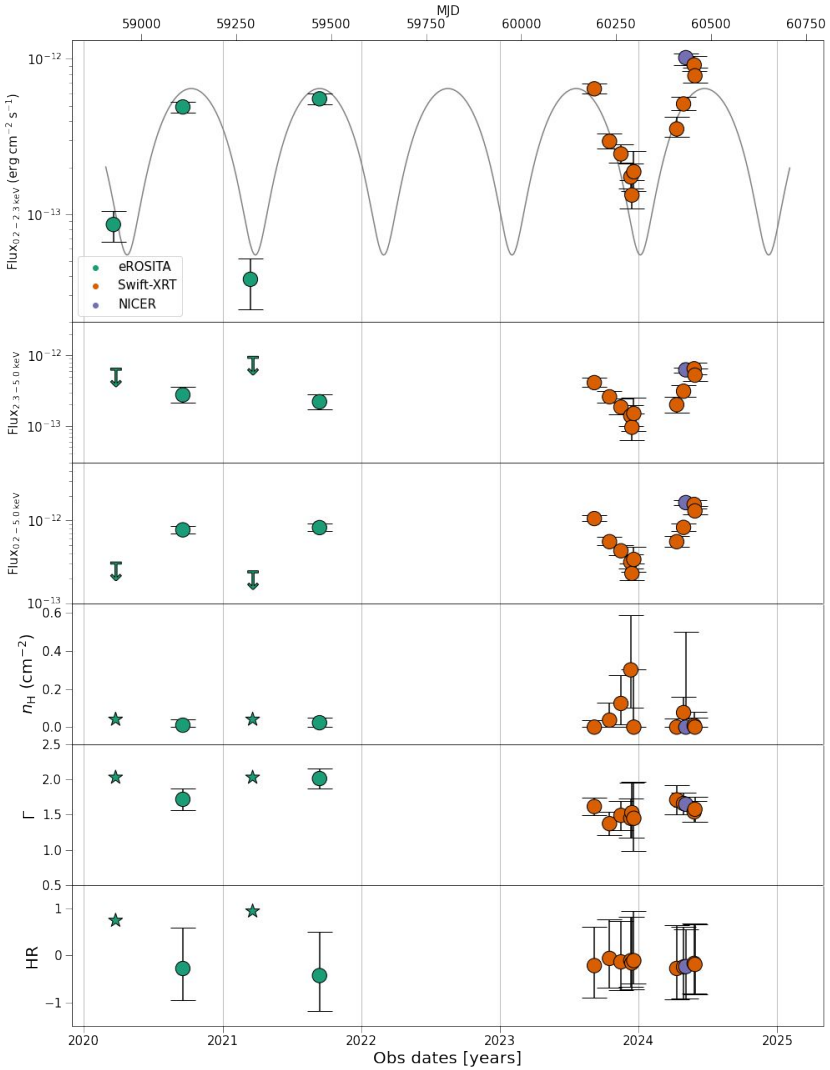
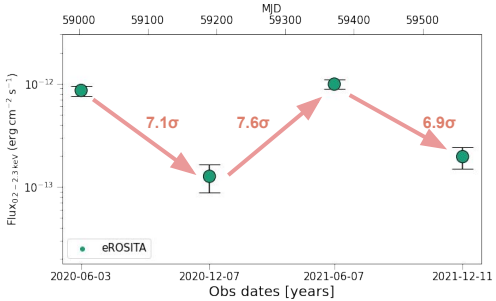
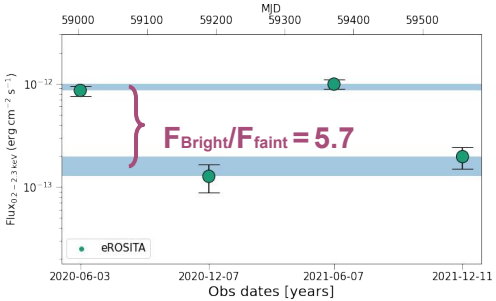
- Another “promising” candidate.
- 6 NICER monitoring campaigns ongoing.

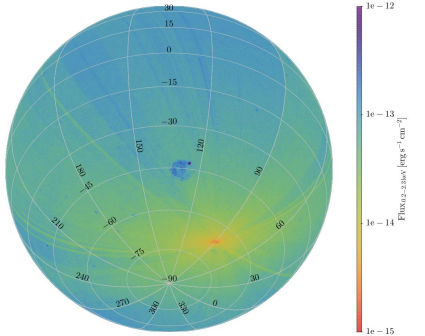


Conclusions

- 34 eROSITA-selected SMBHB candidates with $F_{Bright}/F_{Faint} > 5$.
- 16 of which we can follow up with NICER and Swift.
- Another “promising” candidate.
- 6 NICER monitoring campaigns ongoing.
- If successful, we could discover the SMBHB with the smallest separation!







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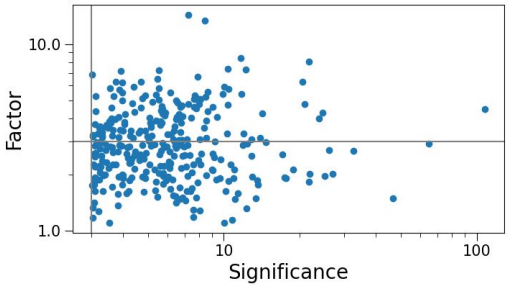

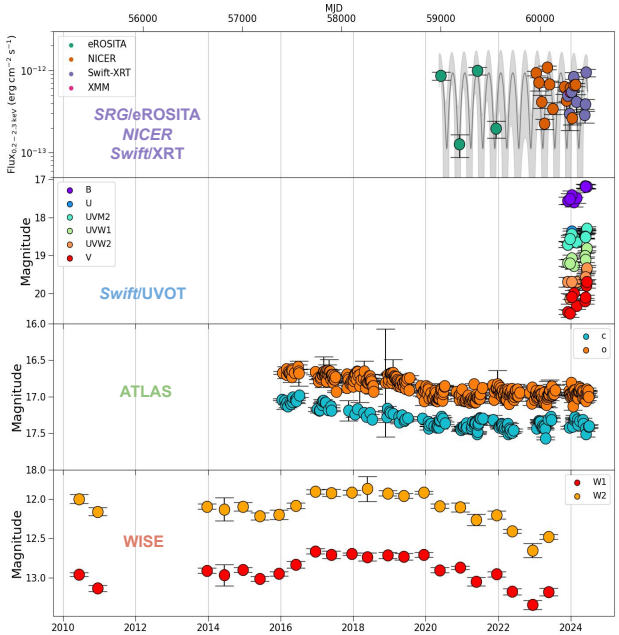

Tubín-Arenas et al. (in prep.)

Leibniz-Institut für
Astrophysik Potsdam

Searching for supermassive black hole binaries with X-ray missions

Dusán Tubín Arenas
dtubin@aip.de

Leibniz-Institute for Astrophysics Potsdam (AIP)
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