Probing Supermassive Black Holes with Millimetre Light Curves from the Atacama Cosmology Telescope and the Simons Observatory

Adam D. Hincks • 26 June 2025 • mm Universe 2025, Chicago

Background map: from ACT DR6 + *Planck* (Naess et al., arXiv:2503.14451, 2025)

Millimetre Sources in ACT

Adam D. Hincks, U. Toronto
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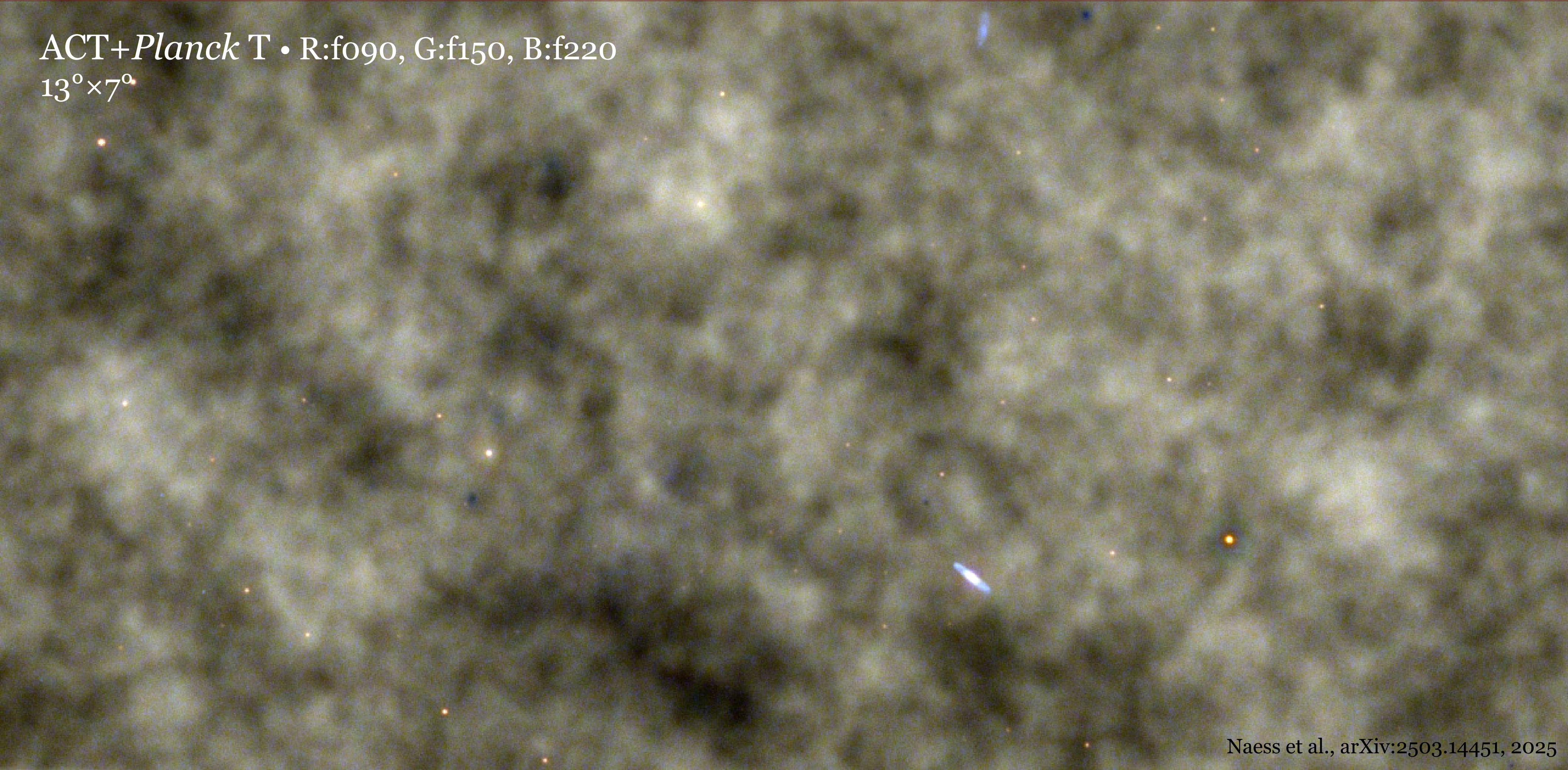

Millimetre Sources in ACT

Adam D. Hincks, U. Toronto
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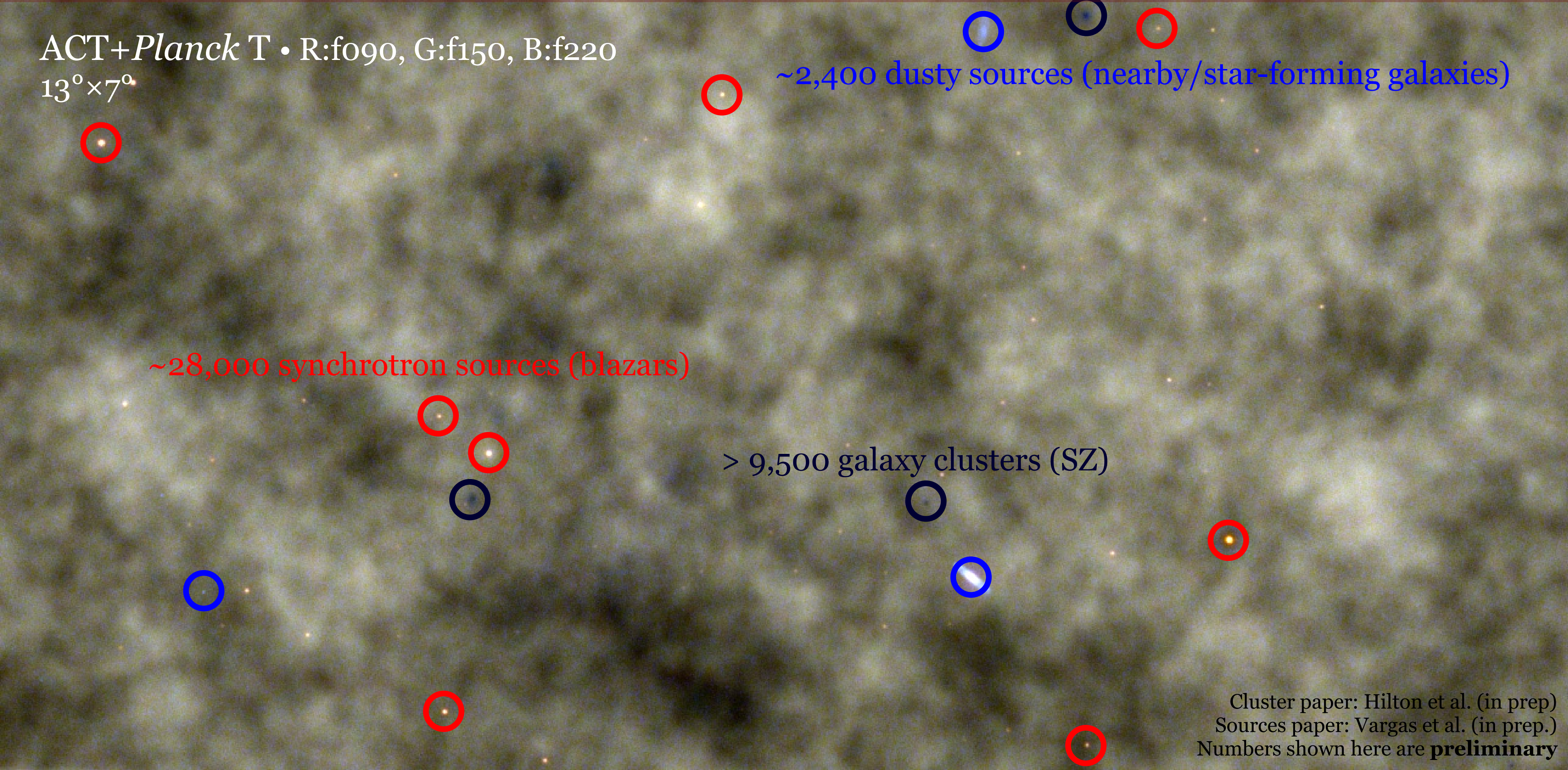

Cluster paper: Hilton et al. (in prep)
Sources paper: Vargas et al. (in prep.)
Numbers shown here are **preliminary**

First AGN Variability Dataset

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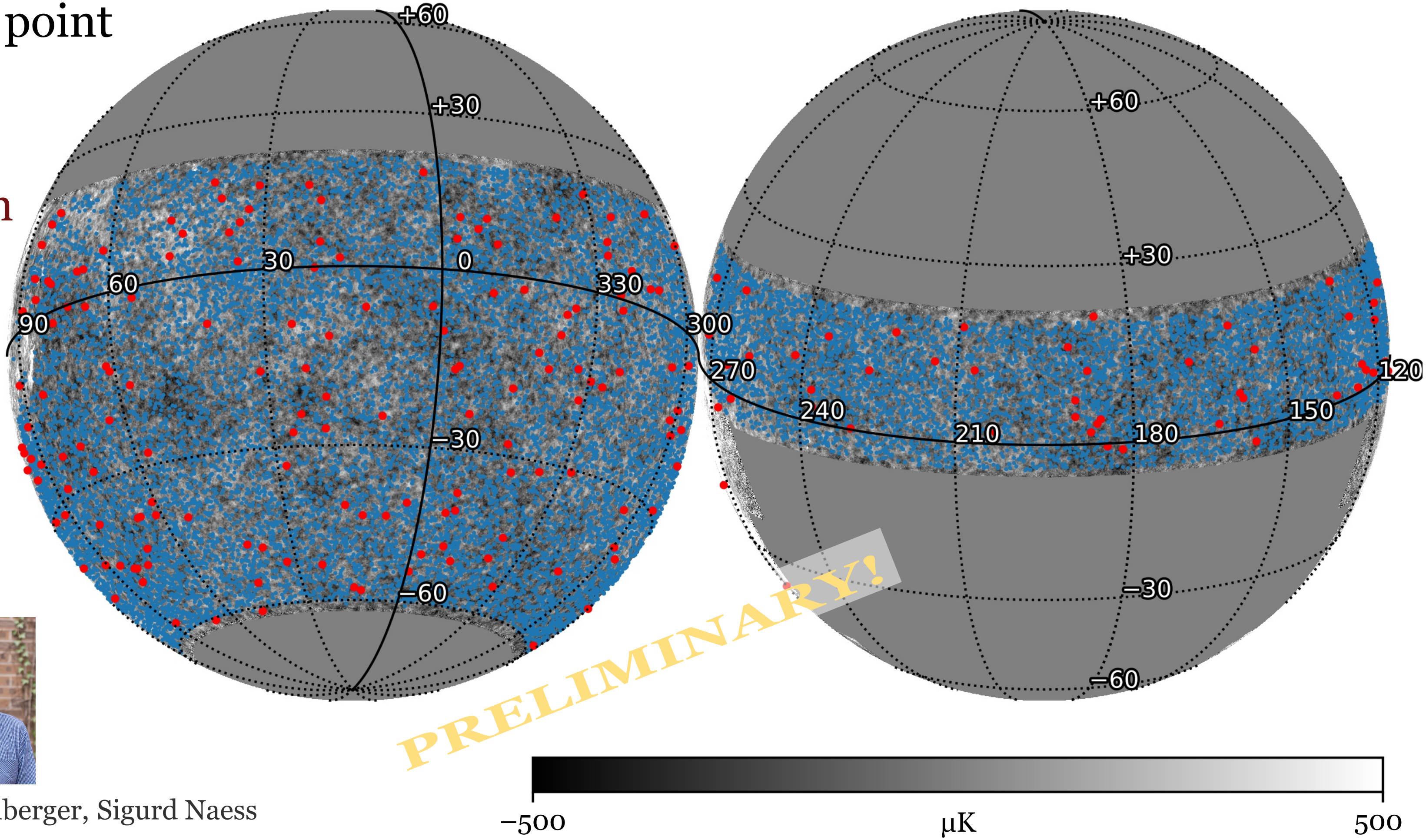
Variability of ACT point sources: low-lying fruit approach.

Sources with mean flux > 500 mJy at 95 GHz chosen for first study: 205 sources.



Cristian Vargas, Kevin Huffenberger, Sigurd Naess

First AGN Variability Dataset

Adam D. Hincks, U. Toronto
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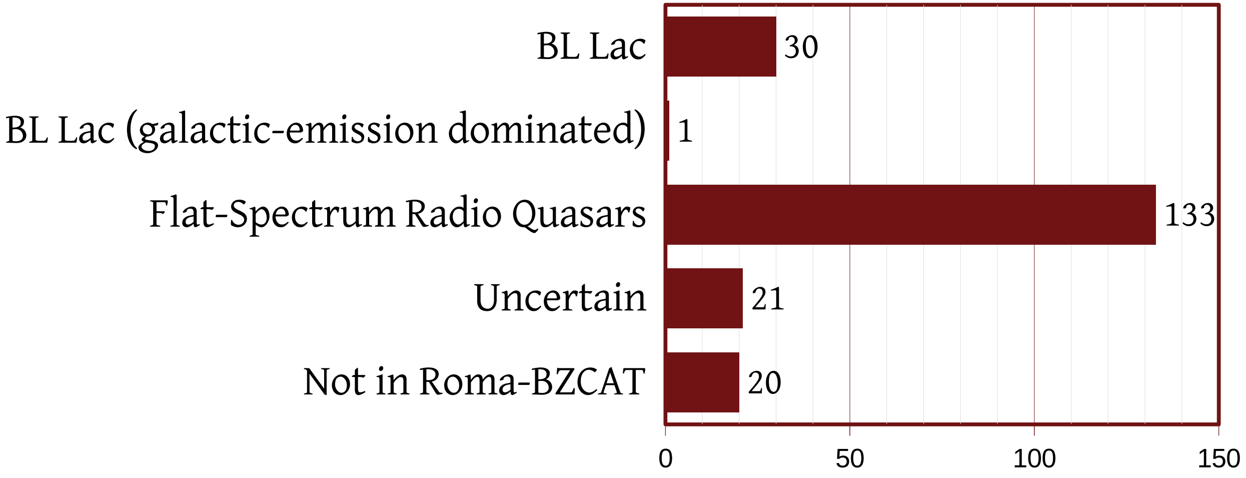
- The majority (90%) of these bright sources appear in the Roma-BZCAT Multifrequency Catalogue of Blazars [1].
- The rest are cross-matched to AT20G and/or NVSS.

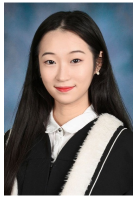


Cristian Vargas

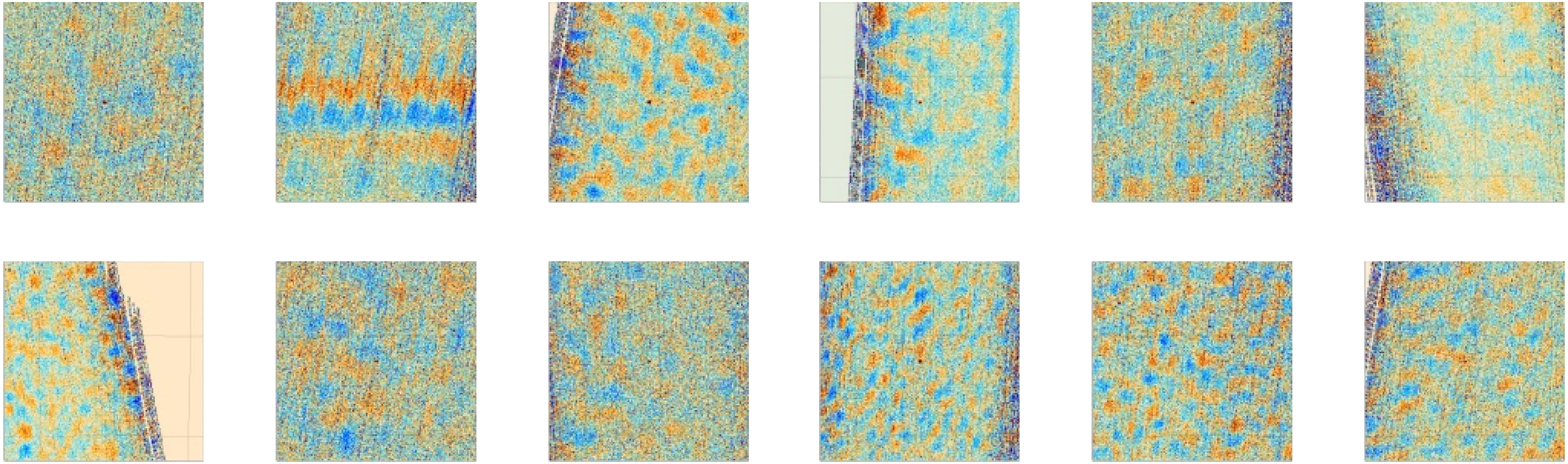
[1] Massaro et al., Ap&SS 357:75, 2015

Data Reduction

- Single-night maps made for each source in catalogue at each array–frequency combination.
- Flux extracted from matched-filtered maps. Noise model derived from real maps



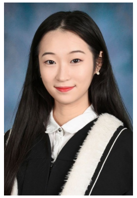
Xiaoyi Ma



Preliminary

Data Reduction

- Maps with low number of detector hits flagged.
- Maps with outlier fluxes visually examined; some flagged.
- Data points *flagged* rather than omitted → consumer decides how to use the flags.



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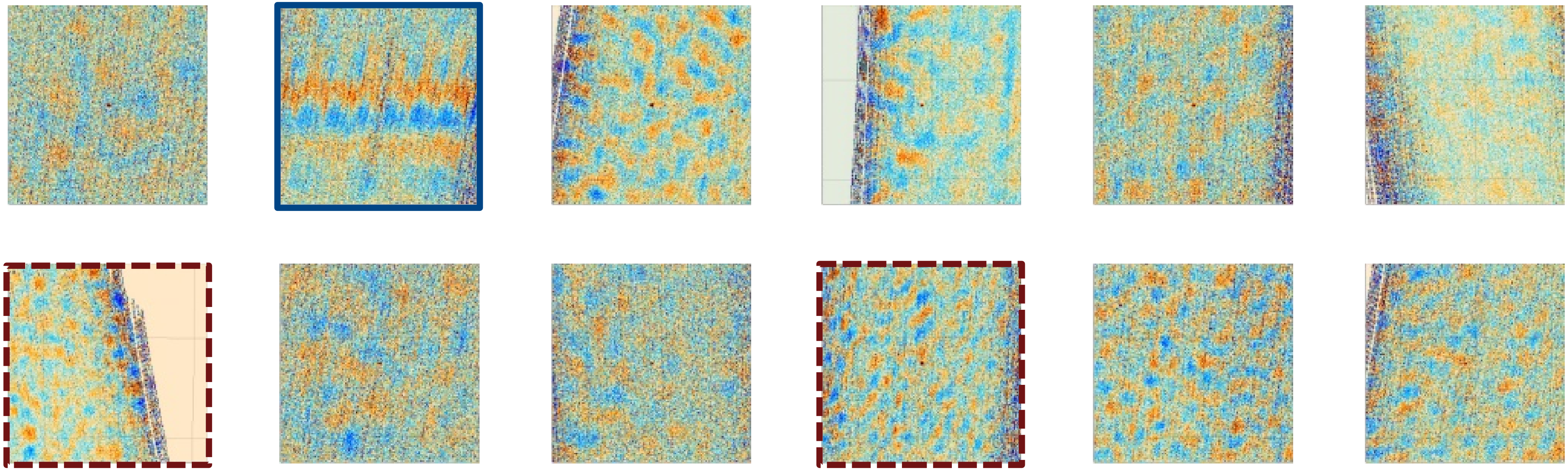

Preliminary

Example Light Curves

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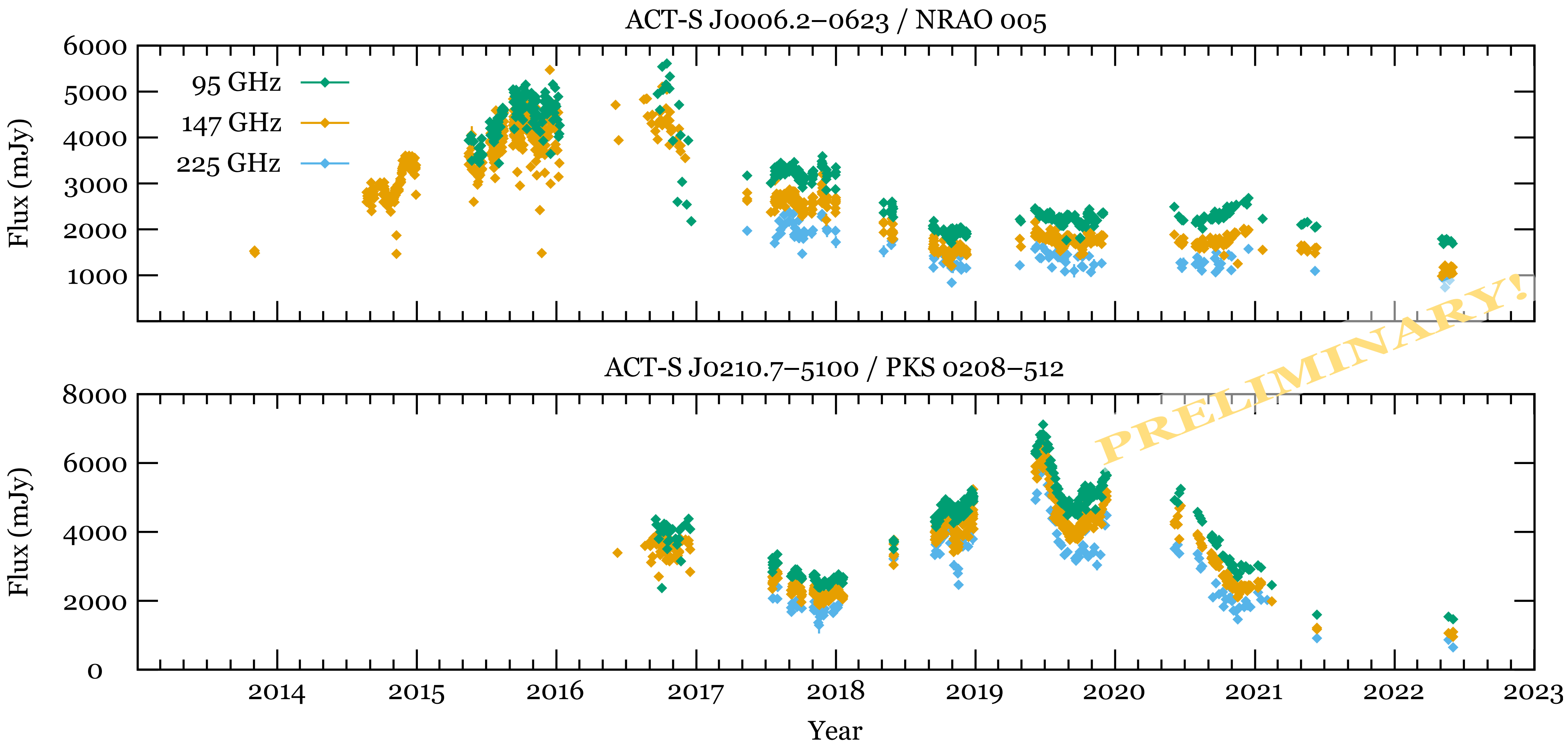

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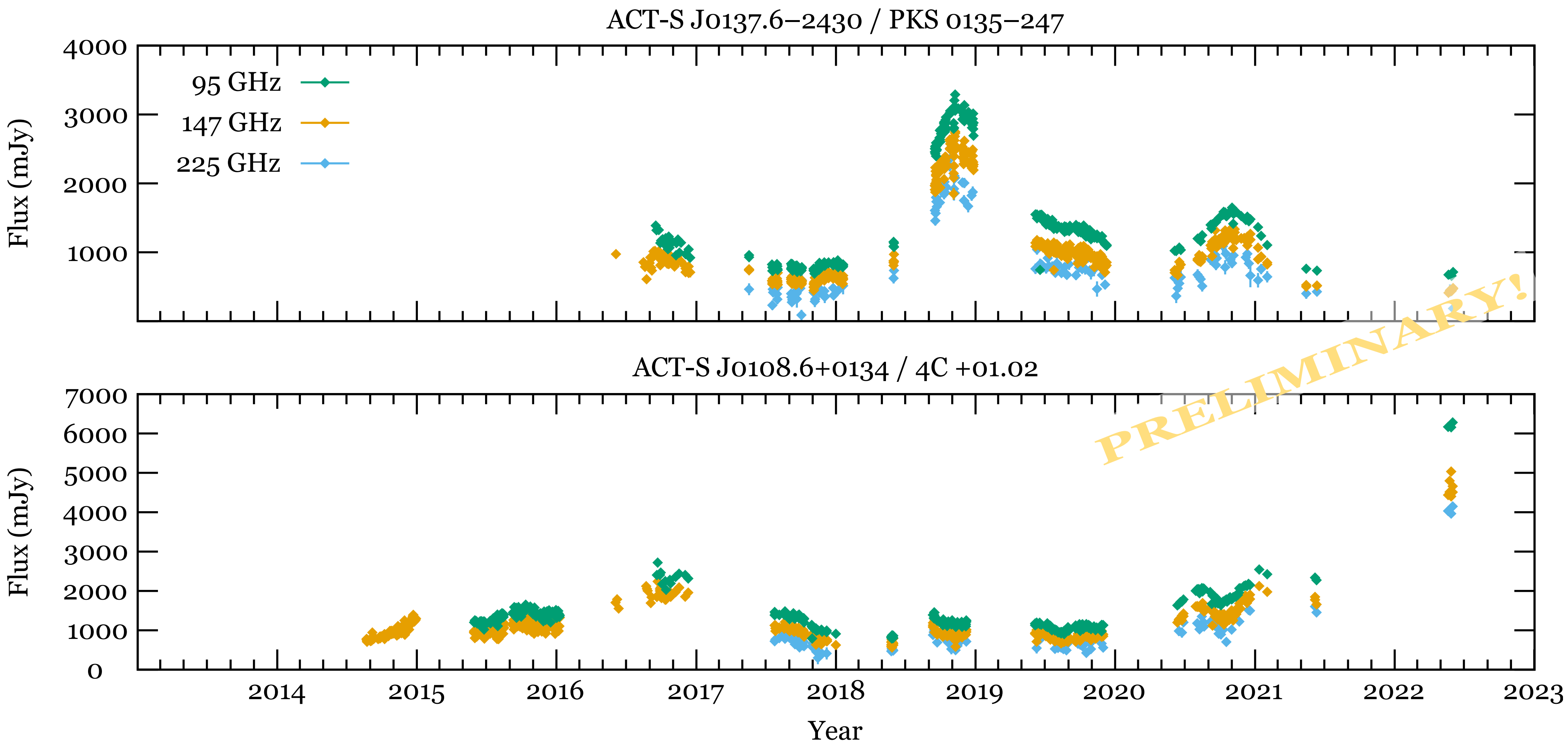

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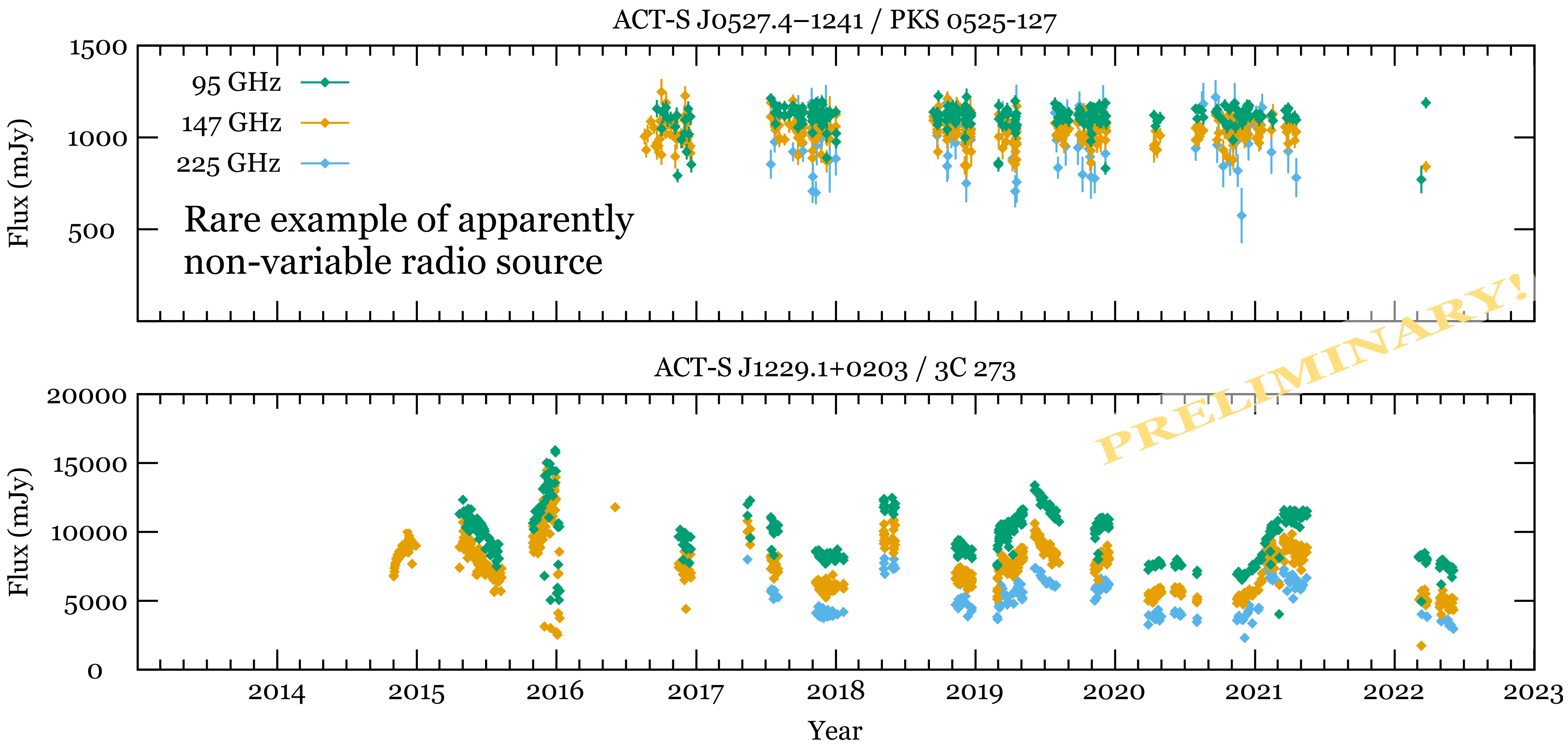

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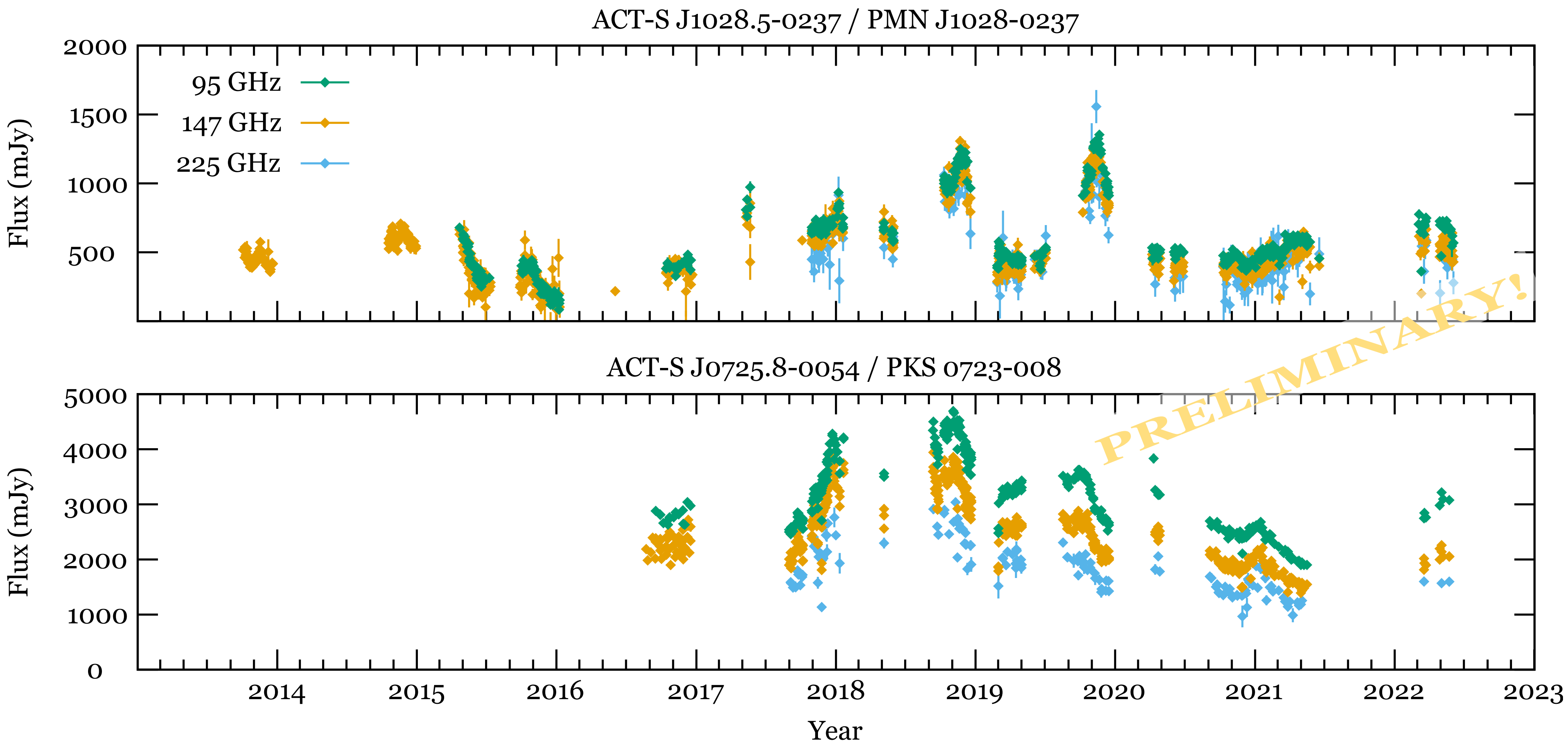

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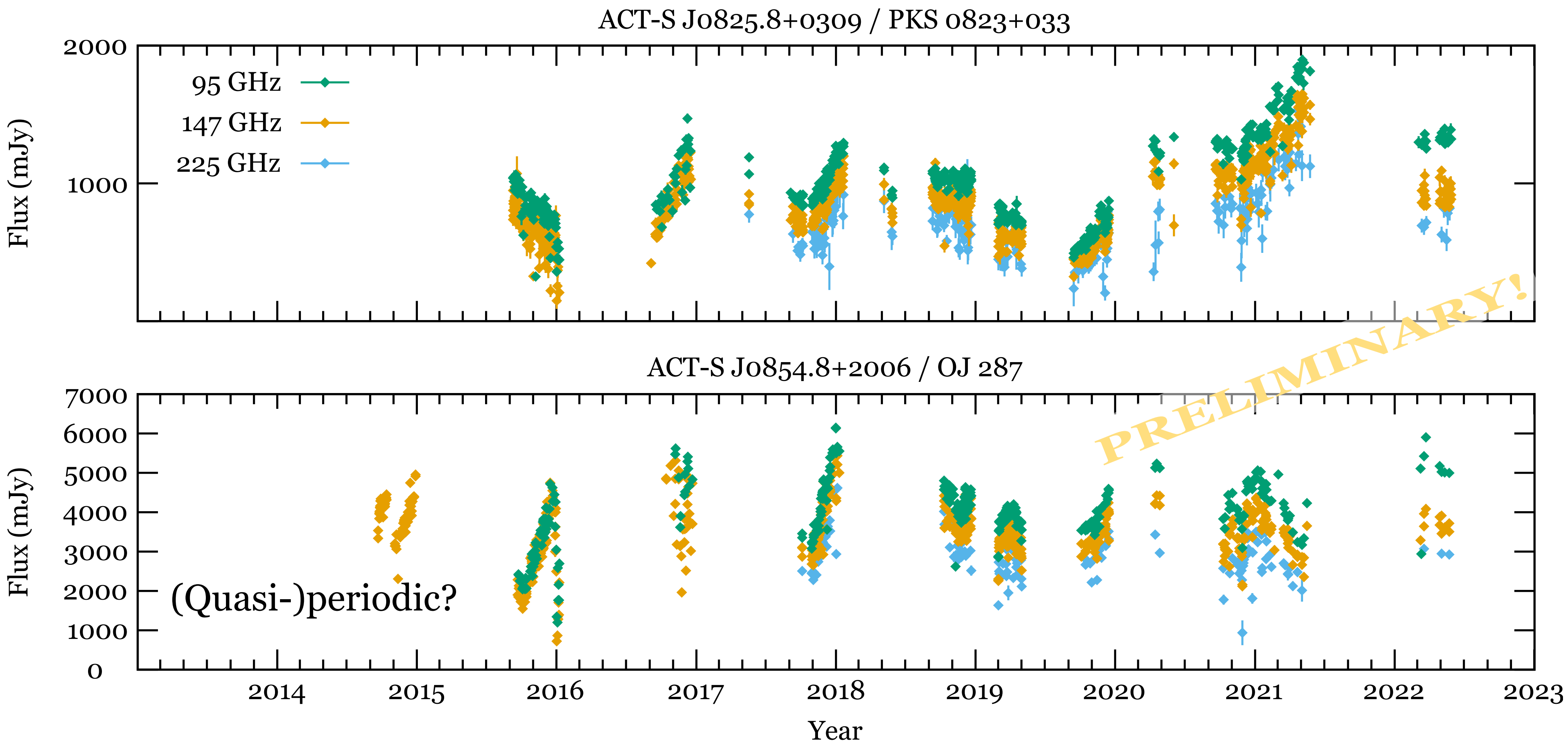
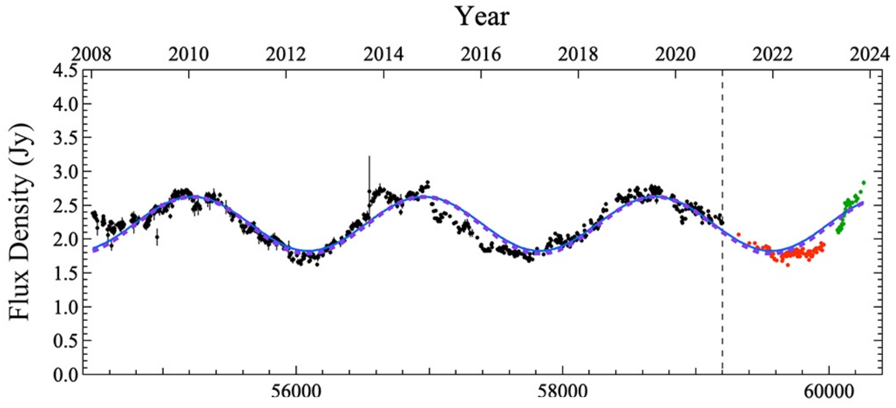
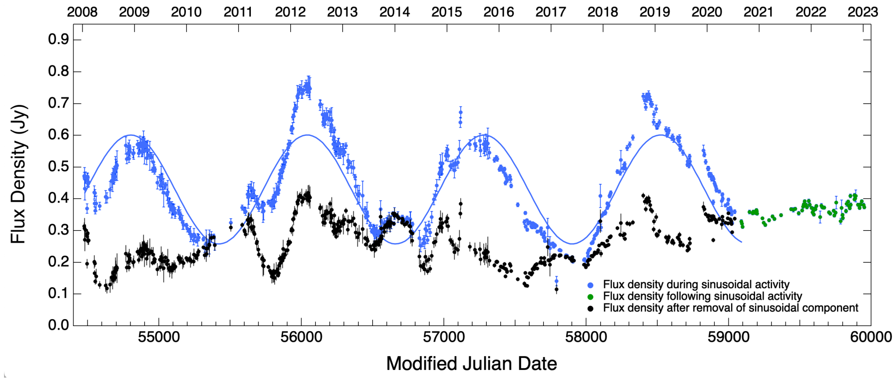


SMBH Binary Candidates





Owens Valley Radio Observatory (OVRO) monitoring programme: discovery of AGN with sinusoidal light curves at 15 GHz

Careful statistical analysis with realistic light curve simulations shows the pattern is unlikely to be random.

PKS 2131–021: 5.1σ significance [1]

PKS J0805–0111: 3.8σ significance [2]

[1] Kiehlmann et al., ApJ 985:59 (2025); see also O'Neill et al., ApJ 926:L35 (2022)
[2] de la Parra et al., arXiv:2408.02645 (2024)

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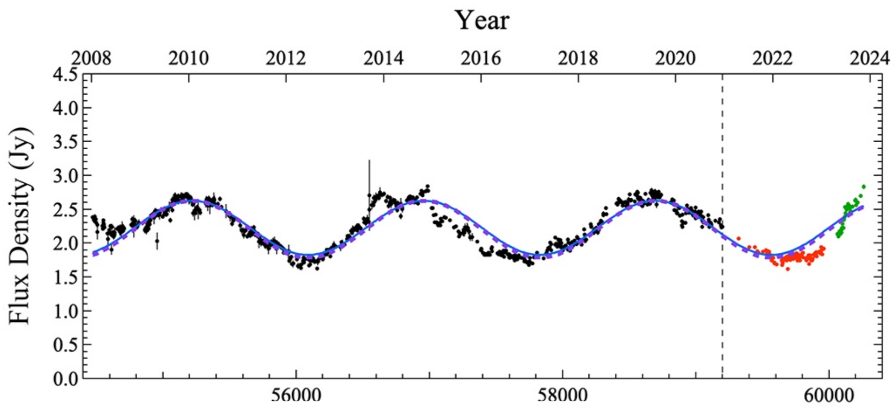

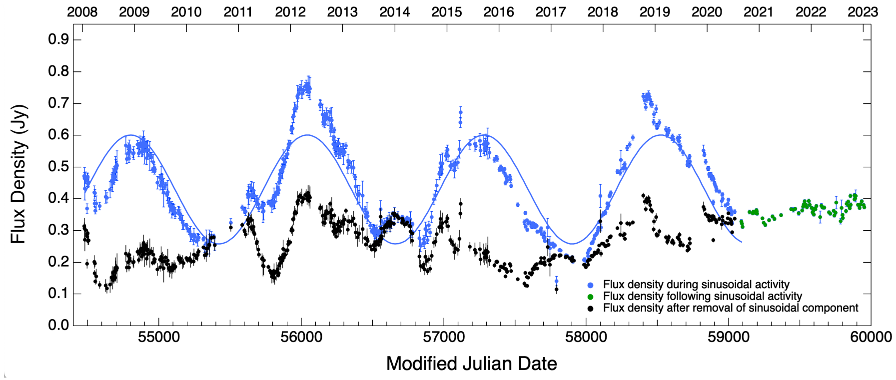

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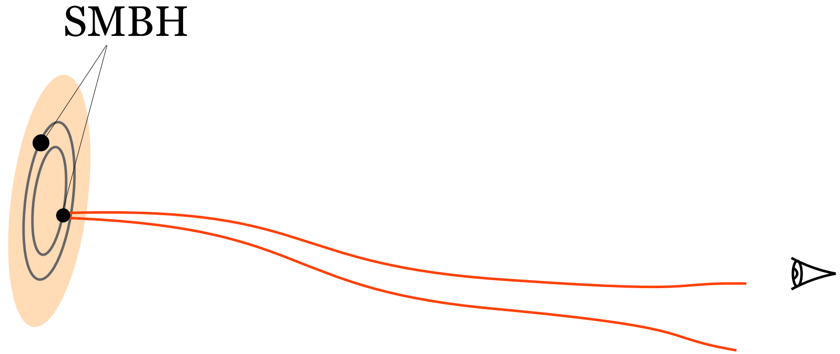

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[2] de la Parra et al., arXiv:2408.02645 (2024) • [3] Sobacchi, Sormani & Stamerra, *MNRAS* 465:161, 2017

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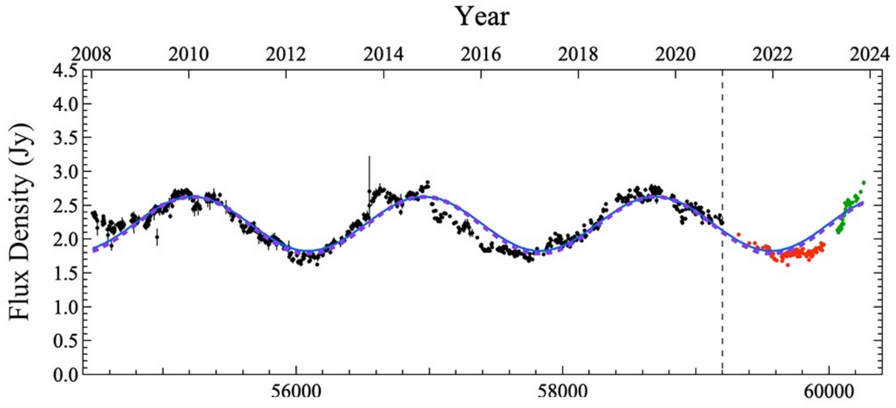

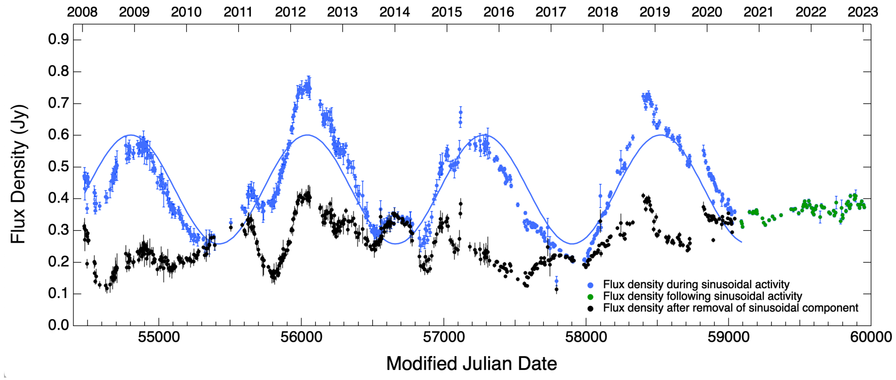

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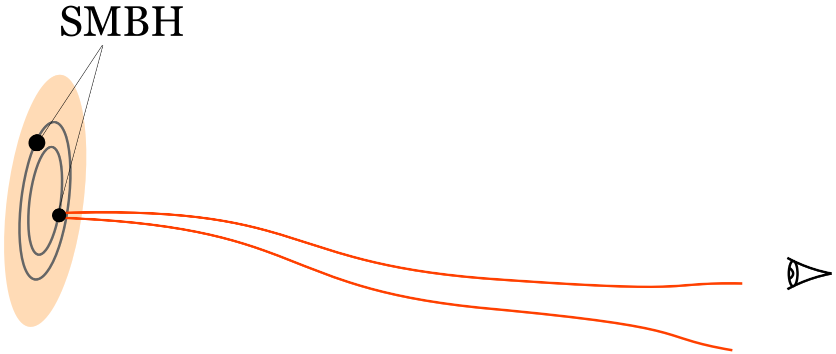

Relevant for understanding formation of SMBH as well as the nHz gravitational wave background.

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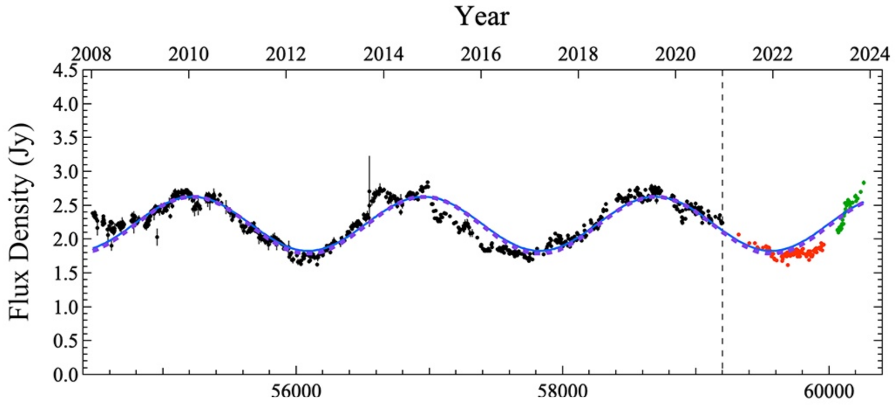

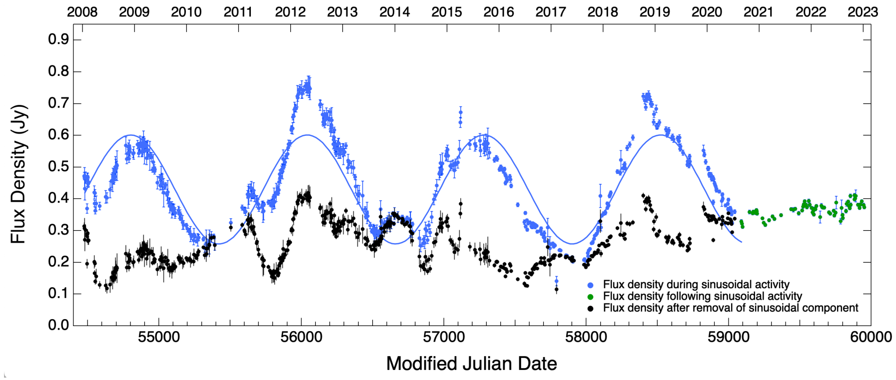

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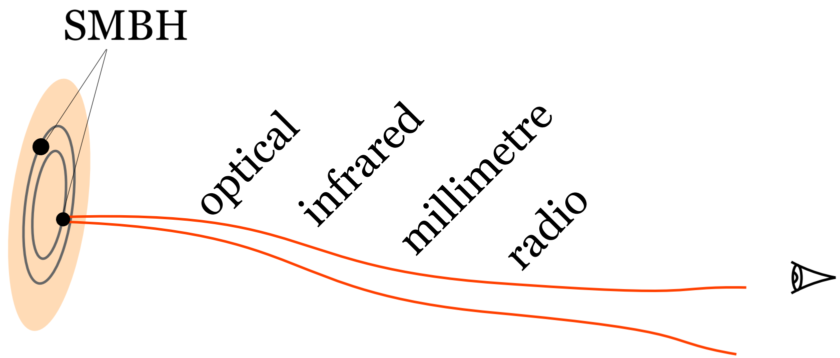

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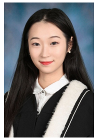

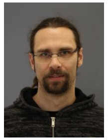

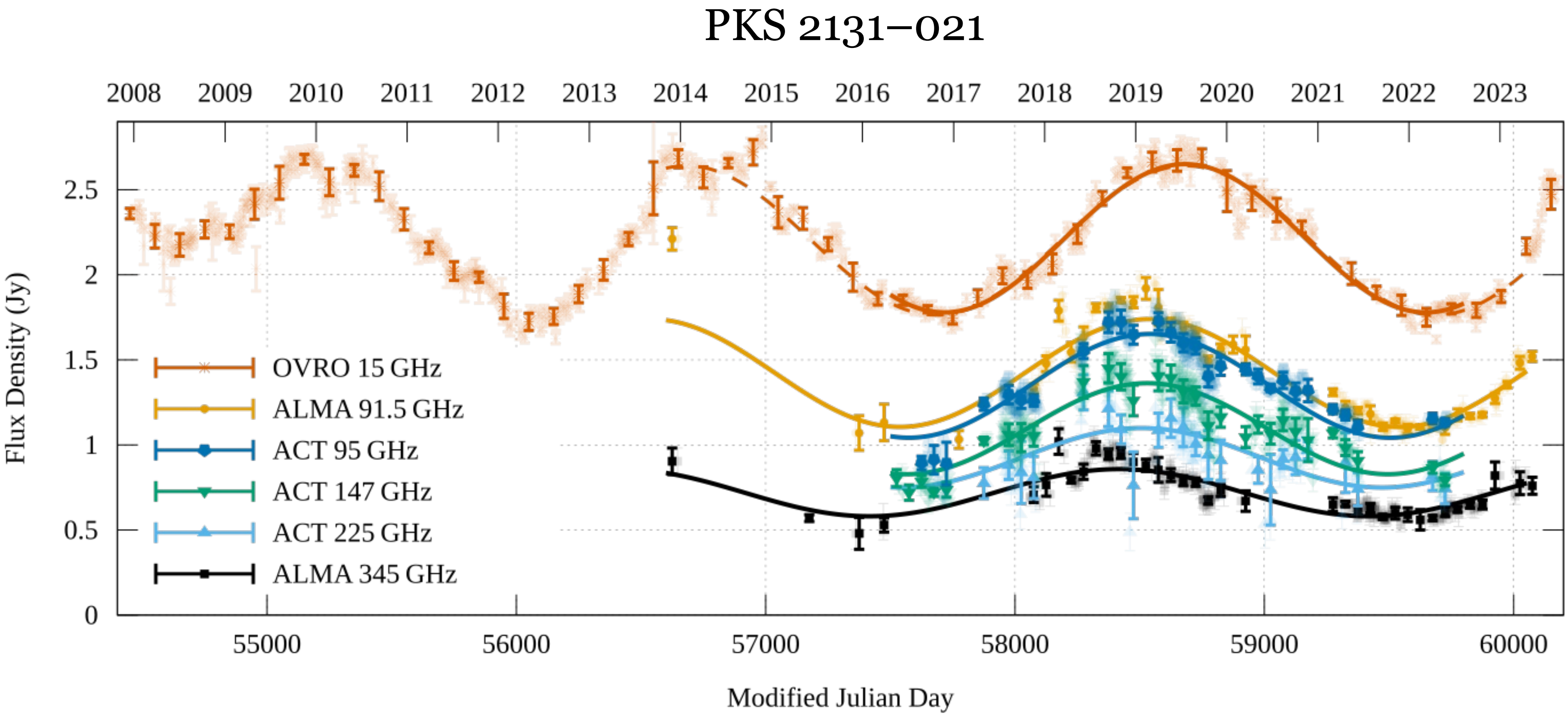

Adam Hincks, Xiaoyi Ma (Peking), Sigurd Naess (Oslo), Sebastian Kiehlmann (FORTH), Przemek Mróz (Warsaw), Tony Readhead (Caltech)
arXiv:2504.04278, 2025

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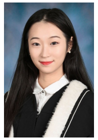

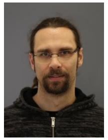

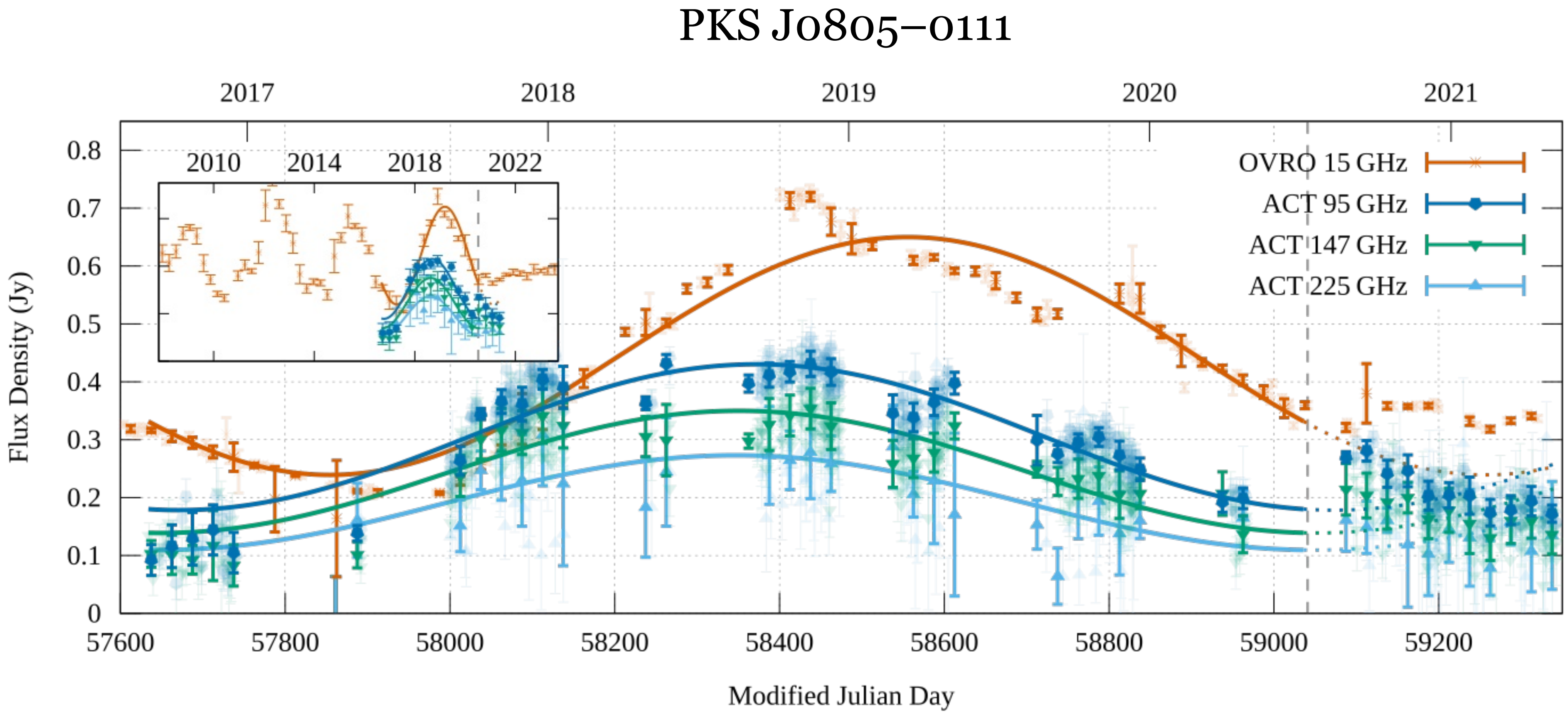

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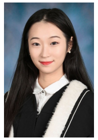
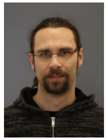
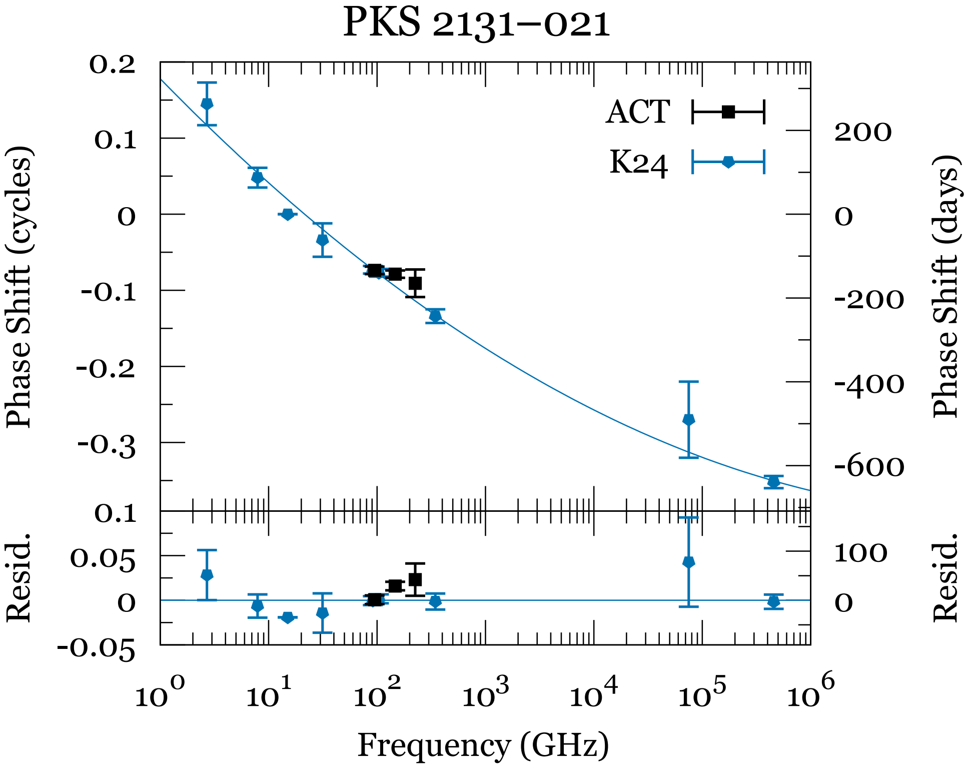
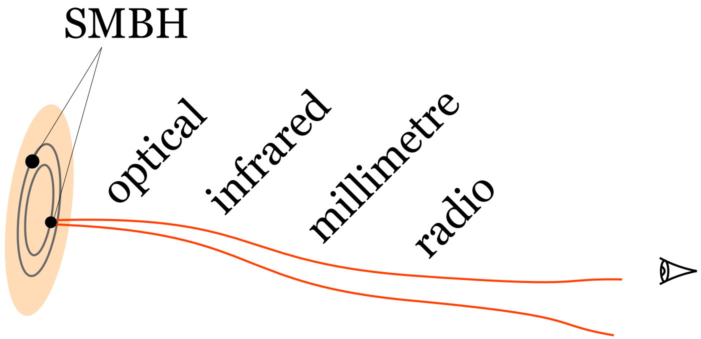






KO Model predicts monotonic phase shift as function of observing frequency, due to emission from different zones in the jet.



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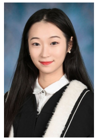

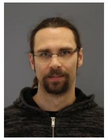

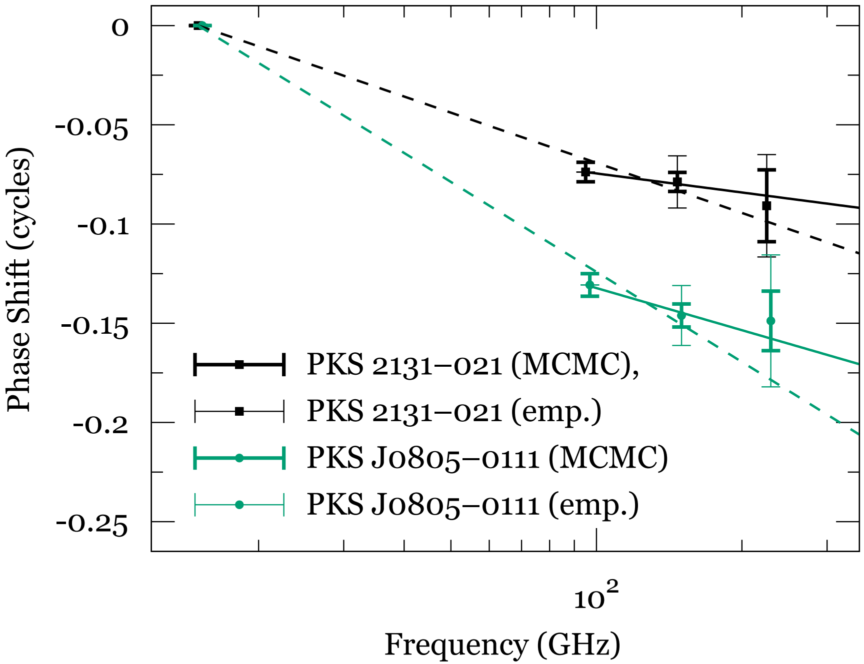

ACT data confirm in PKS J0805−0111 phenomenology previously discovered only in PKS 2131−021.

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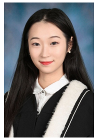

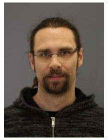

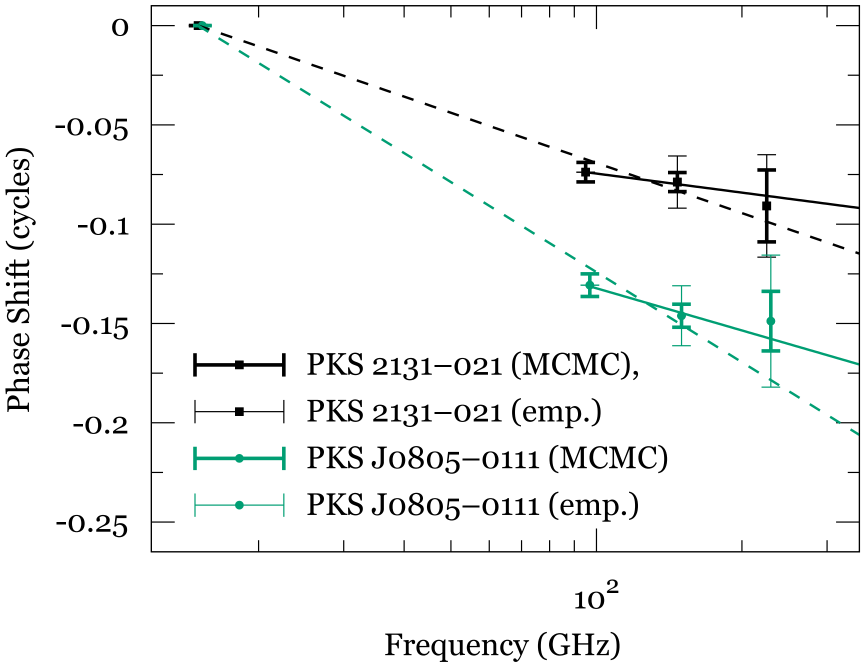

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OVRO team estimates 1% of radio blazars are SMBH binary candidates.

CMB surveys as tools for discovering SMBH binaries?

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arXiv:2504.04278, 2025

Simons Observatory

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Photo: M. Devlin/SO Collaboration

SO Large Aperture Telescope

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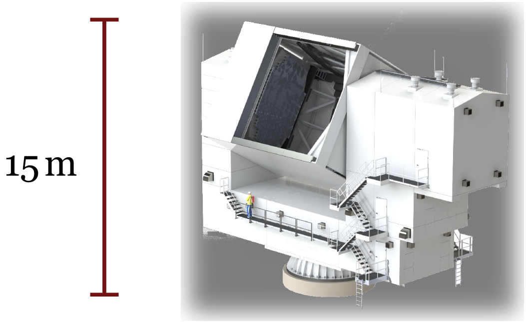
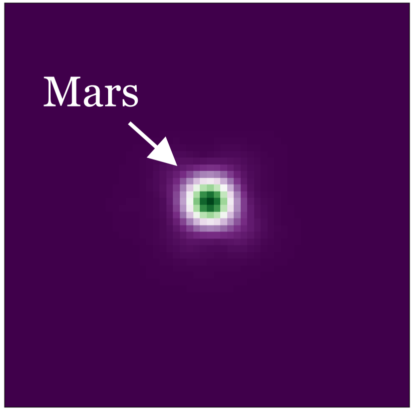
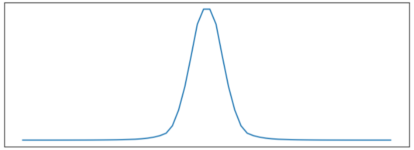
'SO nominal': currently commissioning in Chile, with some early science data collection

Large Aperture Telescope (LAT)



6 m crossed Dragone telescope





- LAT Status
- First light, Feb. 2025
- 24,000+ detectors on-sky
  (640 used for map to the left)
- Currently commissioning.
  - Early science operations to start over the coming months.

7 optics tubes
- 1 × 30/40 GHz
- 4 × 90/150 GHz
- 2 × 220/270 GHz

31,000 detectors

8× increase from ACT (≈ 3,700 detectors)

SO Large Aperture Telescope

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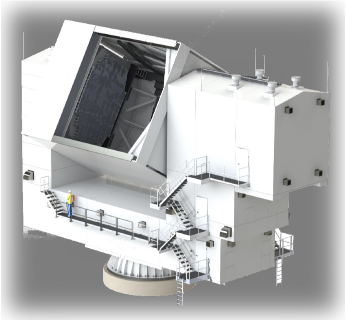
By 2028: ‘SO nominal’ + SO:UK + SO:Japan + Advanced SO (NSF)

Large Aperture Telescope (LAT)

15 m

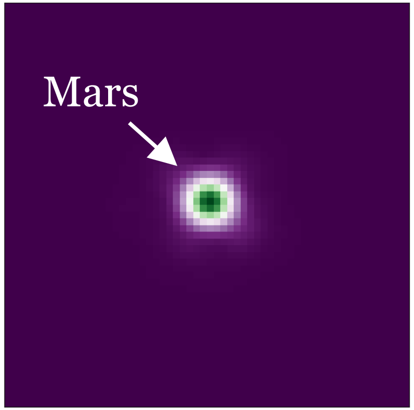


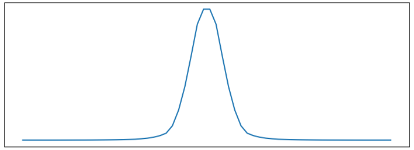
6 m crossed Dragone telescope

13 optics tubes
- 1 × 30/40 GHz
- 8 × 90/150 GHz
- 4 × 220/270 GHz

62,000 detectors

17× increase from ACT (≈ 3,700 detectors)





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SO LAT Survey

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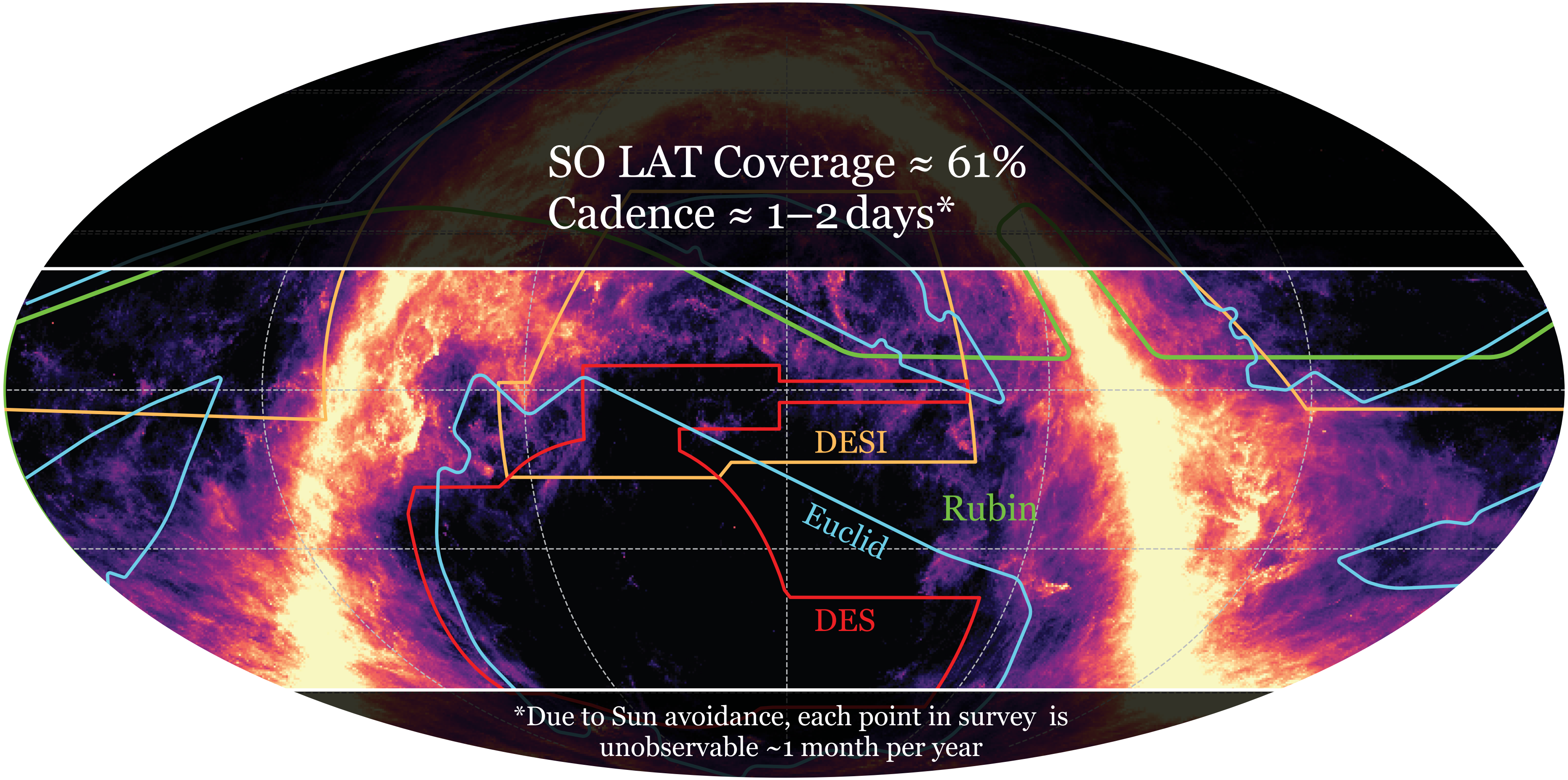

SO Collaboration, 'Science Goals and Forecasts for the Enhanced Large Aperture Telescope', arXiv:2503.00636, 2025, Fig. 3
(lightly edited; background is *Planck* 857 GHz intensity in log. scale)

AGN Monitoring Capabilities

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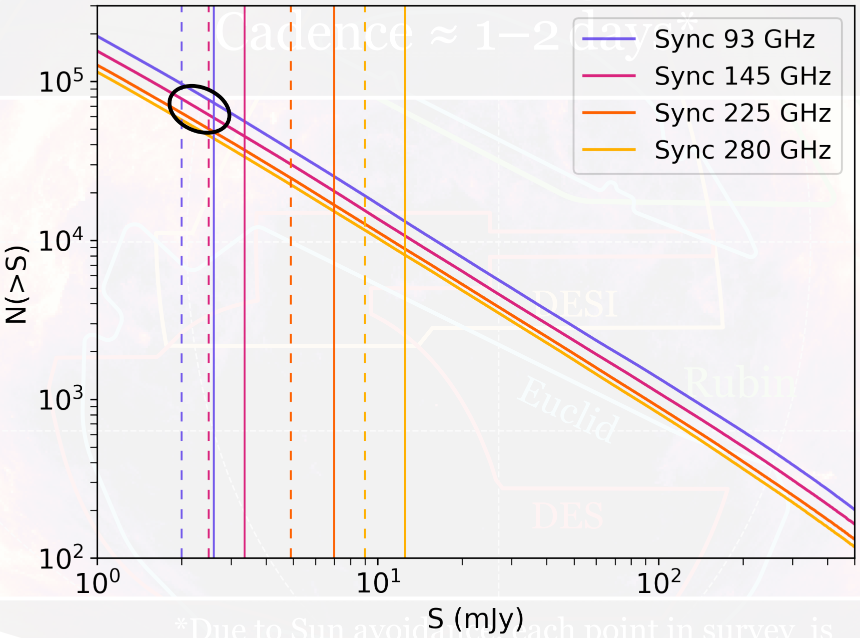
Full coadded maps (2025–34), with the goal sensitivity: **96,000 AGN**



SO Collaboration, 'Science Goals and Forecasts for the Enhanced Large Aperture Telescope', arXiv:2503.00636, 2025, Fig. 6
Number counts model: Lagache et al. (2020)

AGN Monitoring Capabilities

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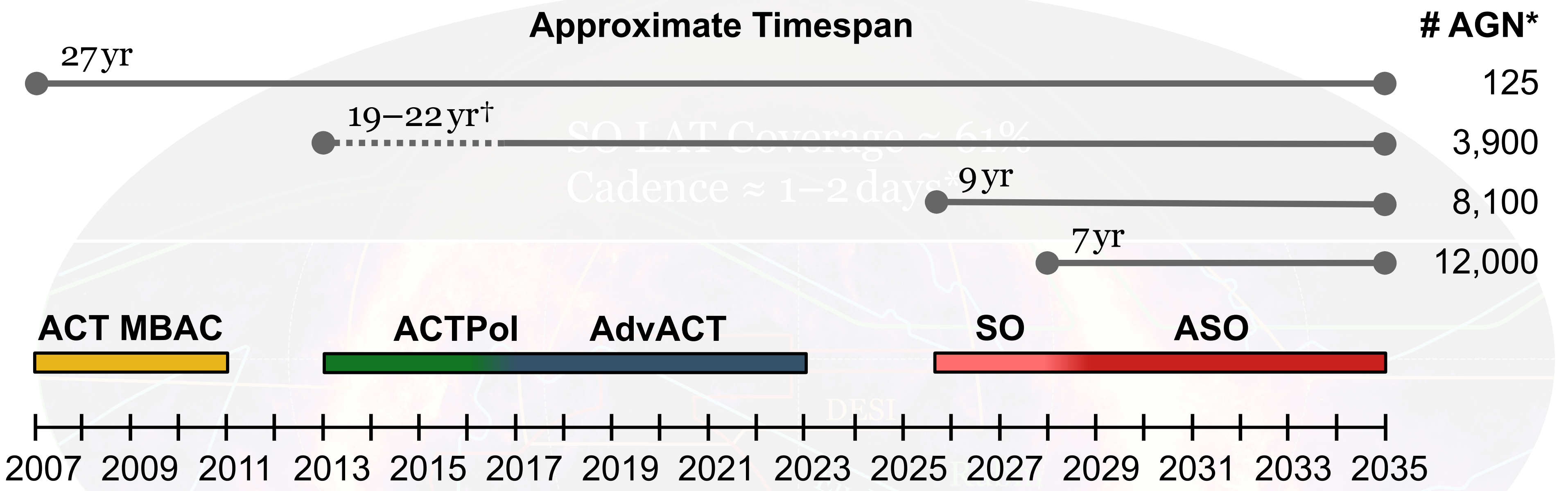

* Approximate number of AGN with **5σ measurement** of mean flux after binning six observations **(~1–2 week cadence)**, calculated from (goal) sensitivities and survey area for each experiment using the Lagache et al. (2020) 100 GHz model [1].

† ACT survey area was significantly smaller from 2013–2016 compared to 2017–2022.

C.f., SO Collaboration, 'Science Goals and Forecasts for the Enhanced Large Aperture Telescope', arXiv:2503.00636, 2025.

AGN Monitoring Capabilities

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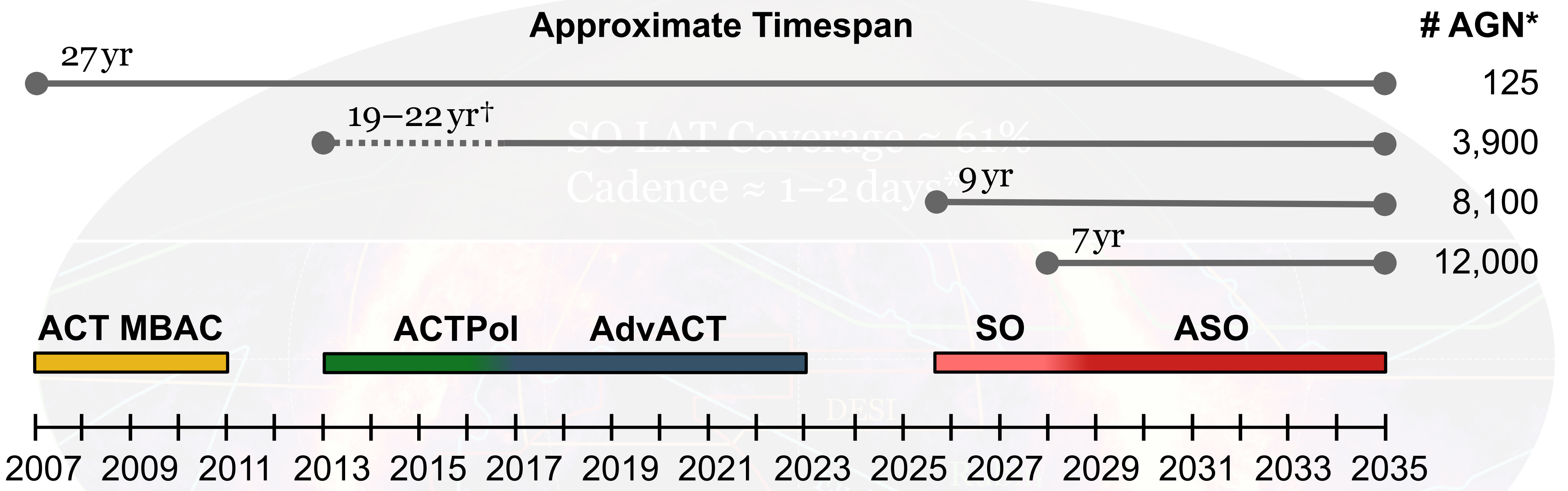

- Preliminary OVRO forecasts: ~1% of radio blazars are SMBH binaries [1,2] → SO could observe $\mathcal{O}(100)$ SMBH binary candidates.
- Opportunities for synergy with LSST and other time domain instruments (c.f., recent claim of 181 SMBHB candidates using Gaia light curves [3]).

[1] Kiehlmann et al., ApJ 985:59 (2025) • [2] de la Parra et al., arXiv:2408.02645 (2024) • [3] Huijse et al., arXiv:2505.16884 (2025)

Fin

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Thank You! Questions?

Photo: M. Devlin/SO Collaboration