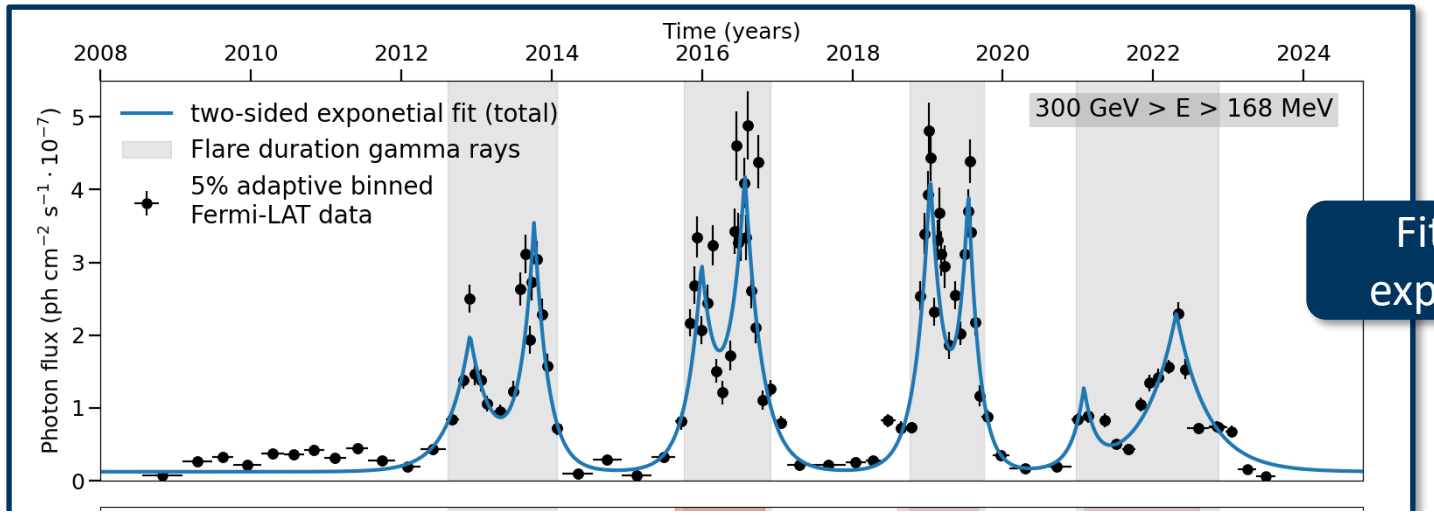
J1048+7143: A Supermassive Black Hole Binary Candidate

Ilja Jaroschewski

Collaborators: Emma Kun, Julia Becker Tjus, Silke Britzen, …

Cosmic Rays and Neutrinos in the Multi-Messenger Era

Gamma-Ray Light Curve



Fit with two-sided exponential function

J1048+7143

Kun, **IJ+** in prep.

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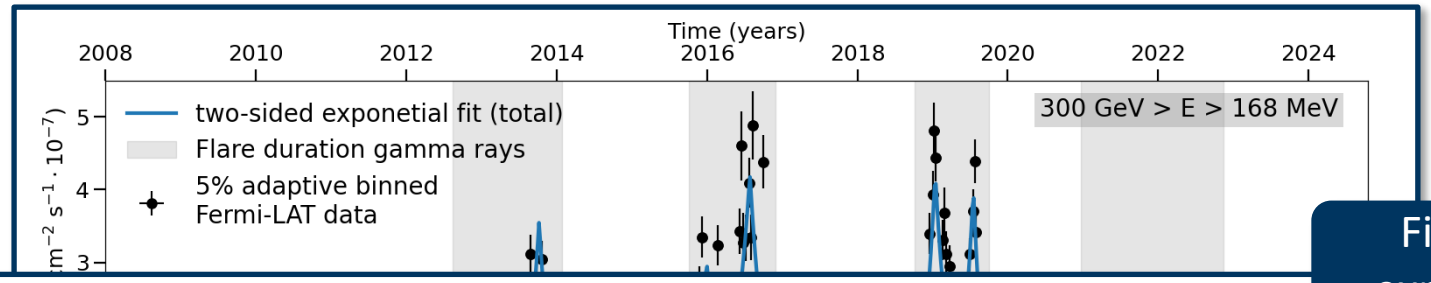

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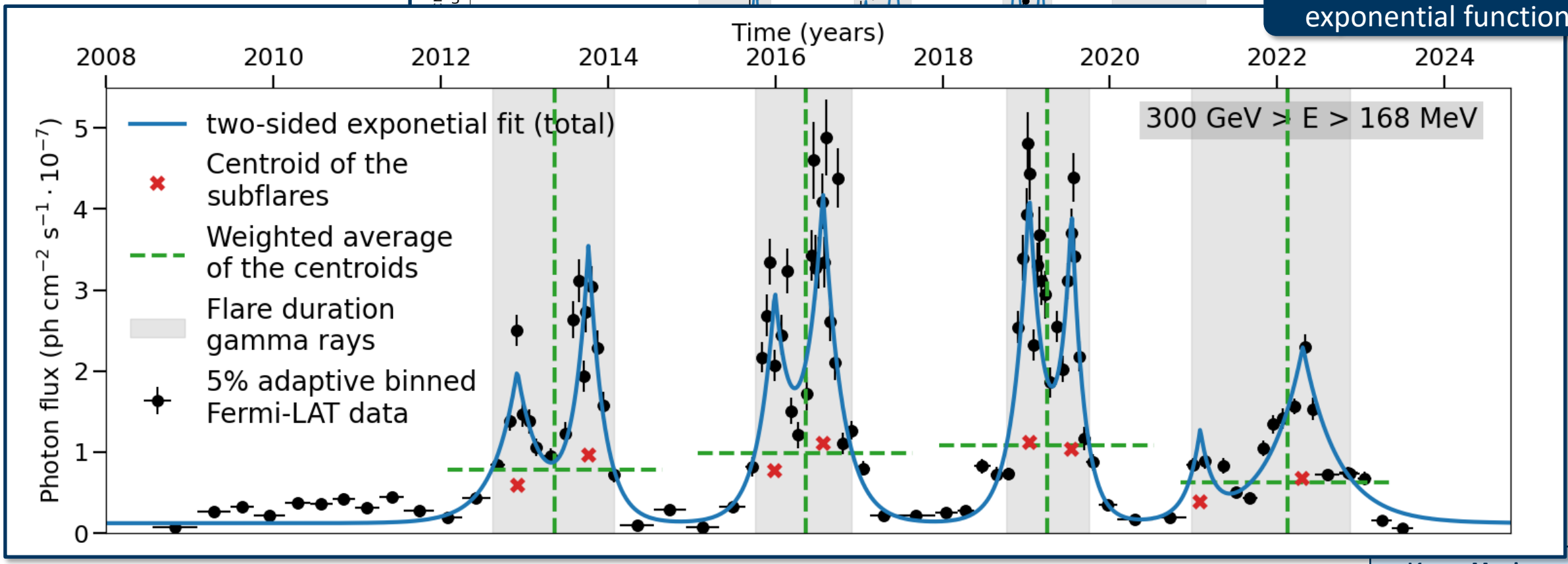

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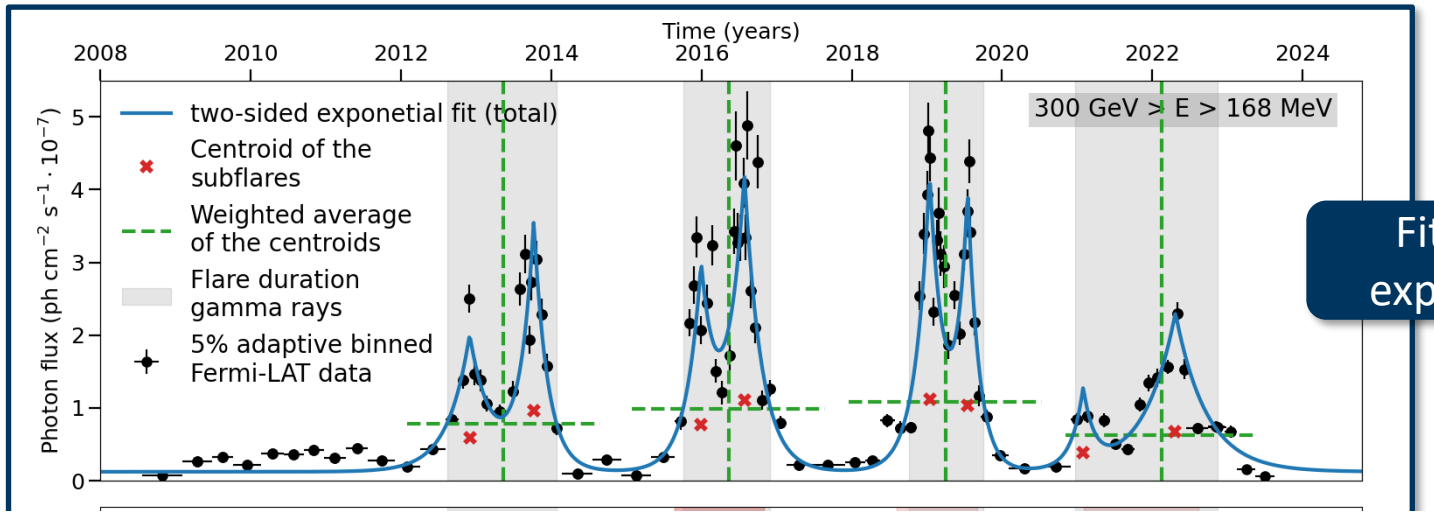
J1048+7143

Gamma-Ray Light Curve + Optical + Radio



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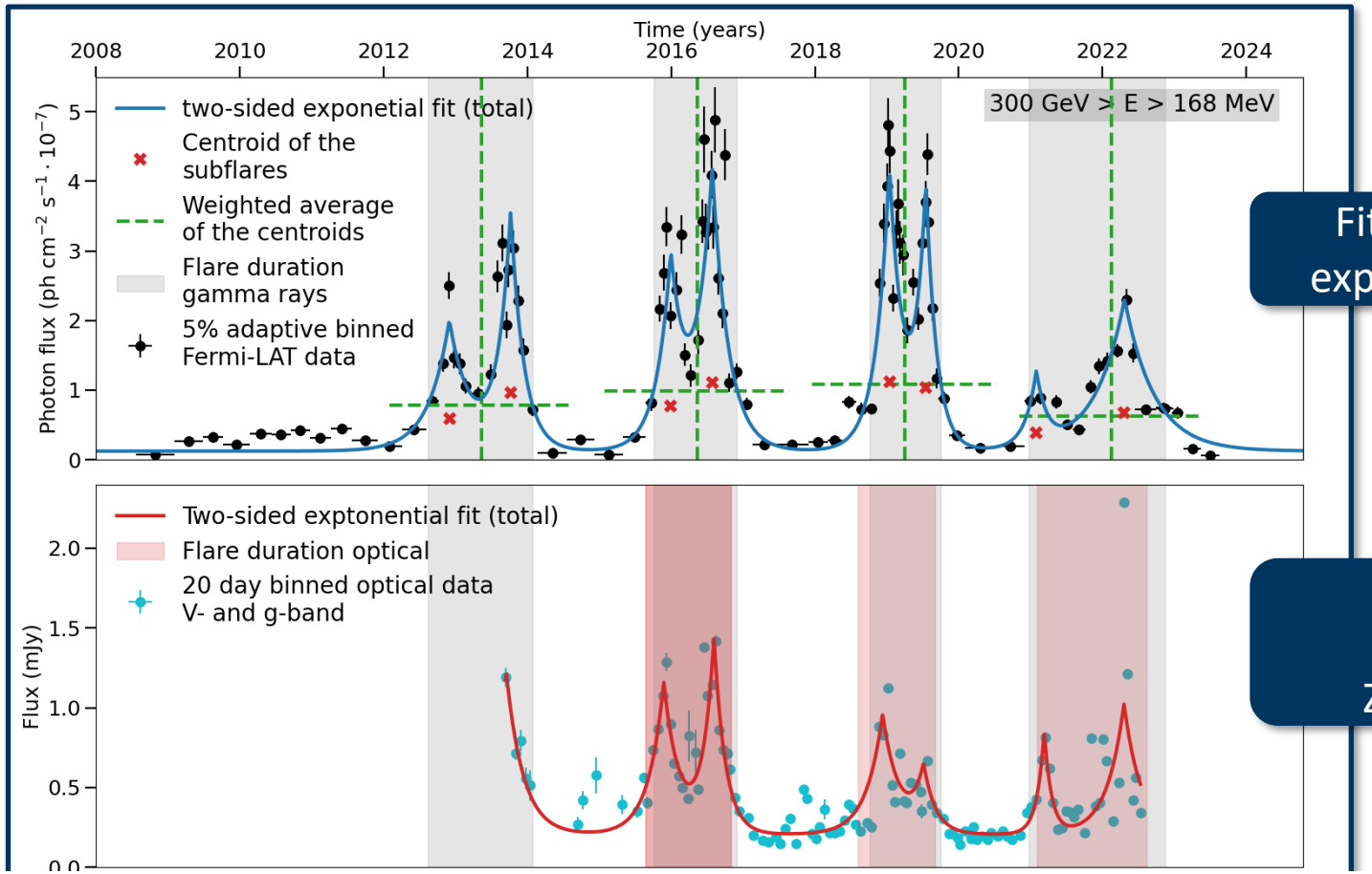

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ASAS
AAVSO
ZTF in progress

J1048+7143

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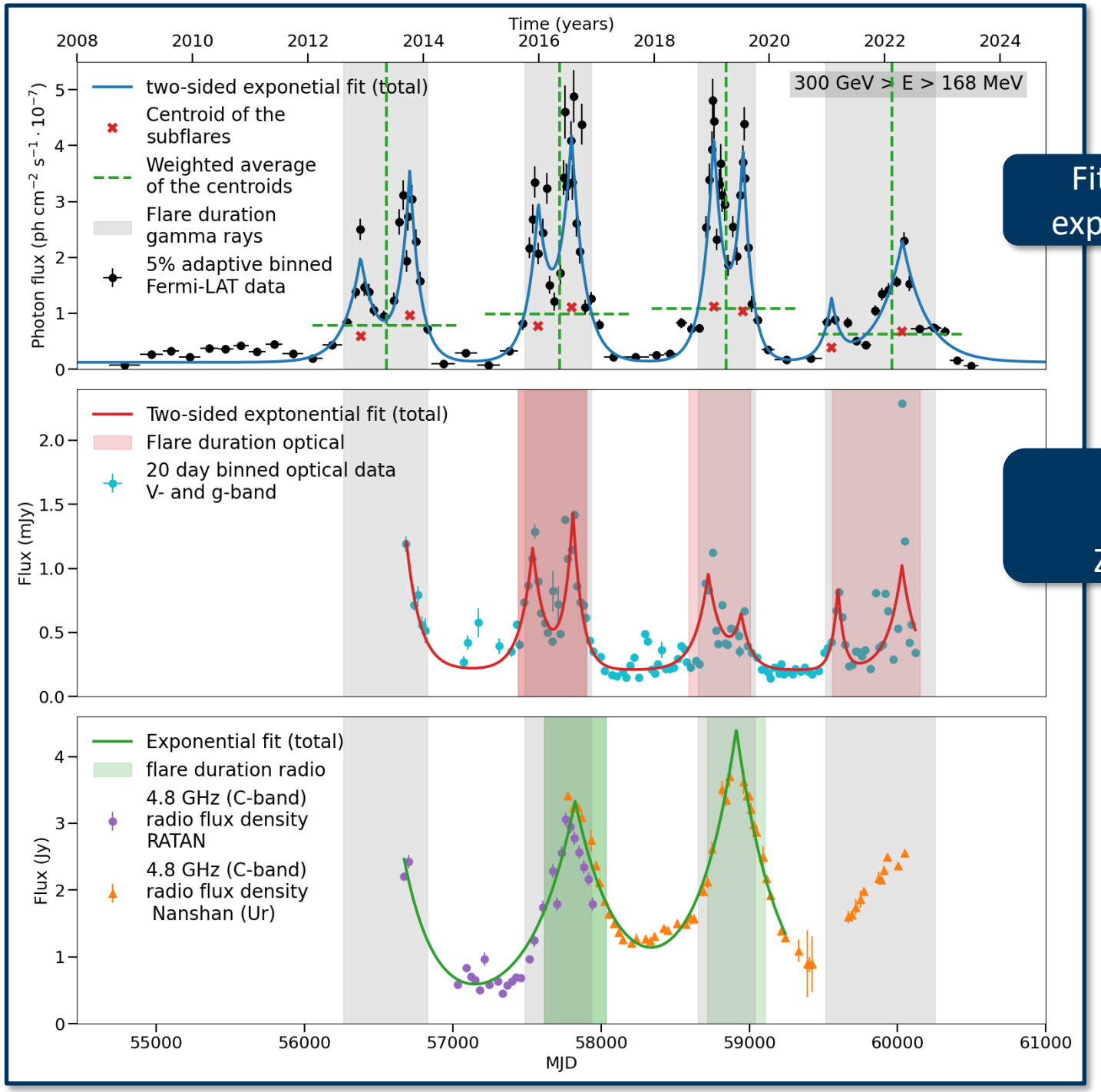

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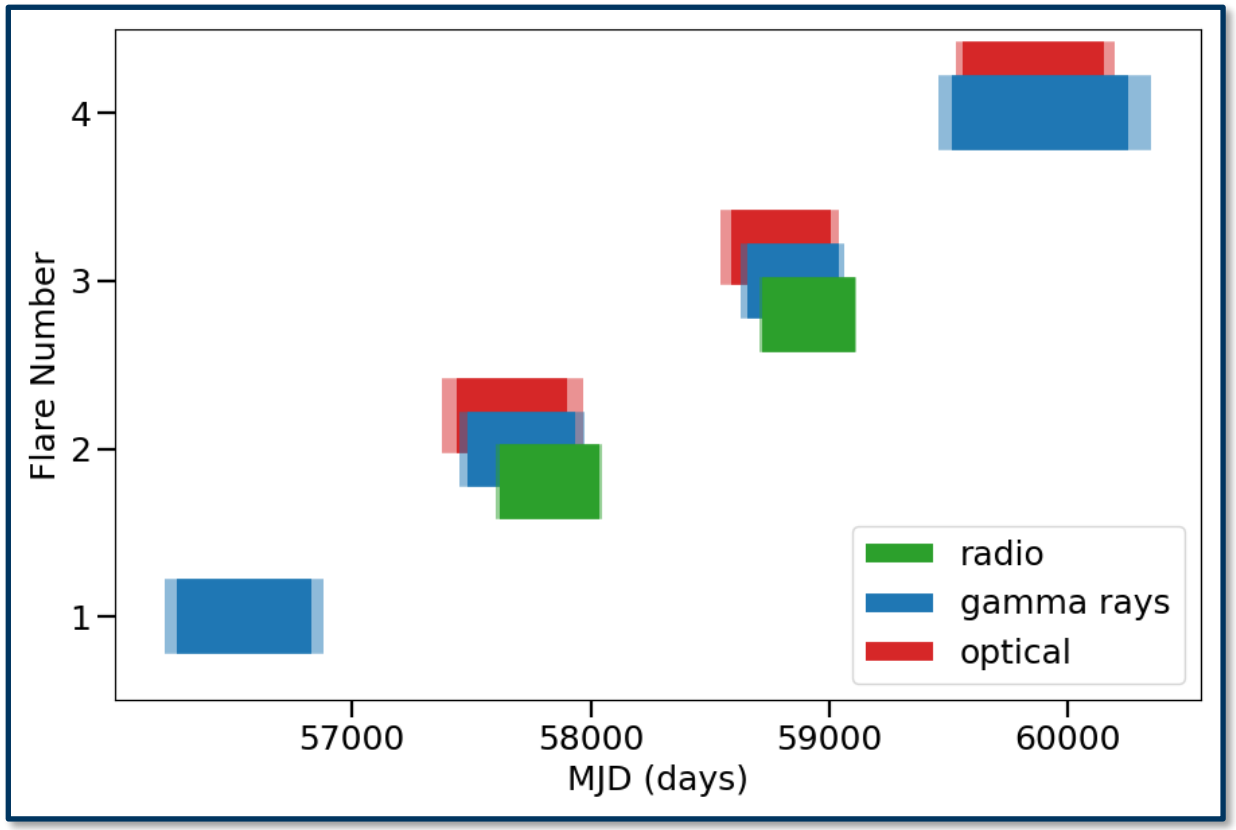
J1048+7143

Flare Durations

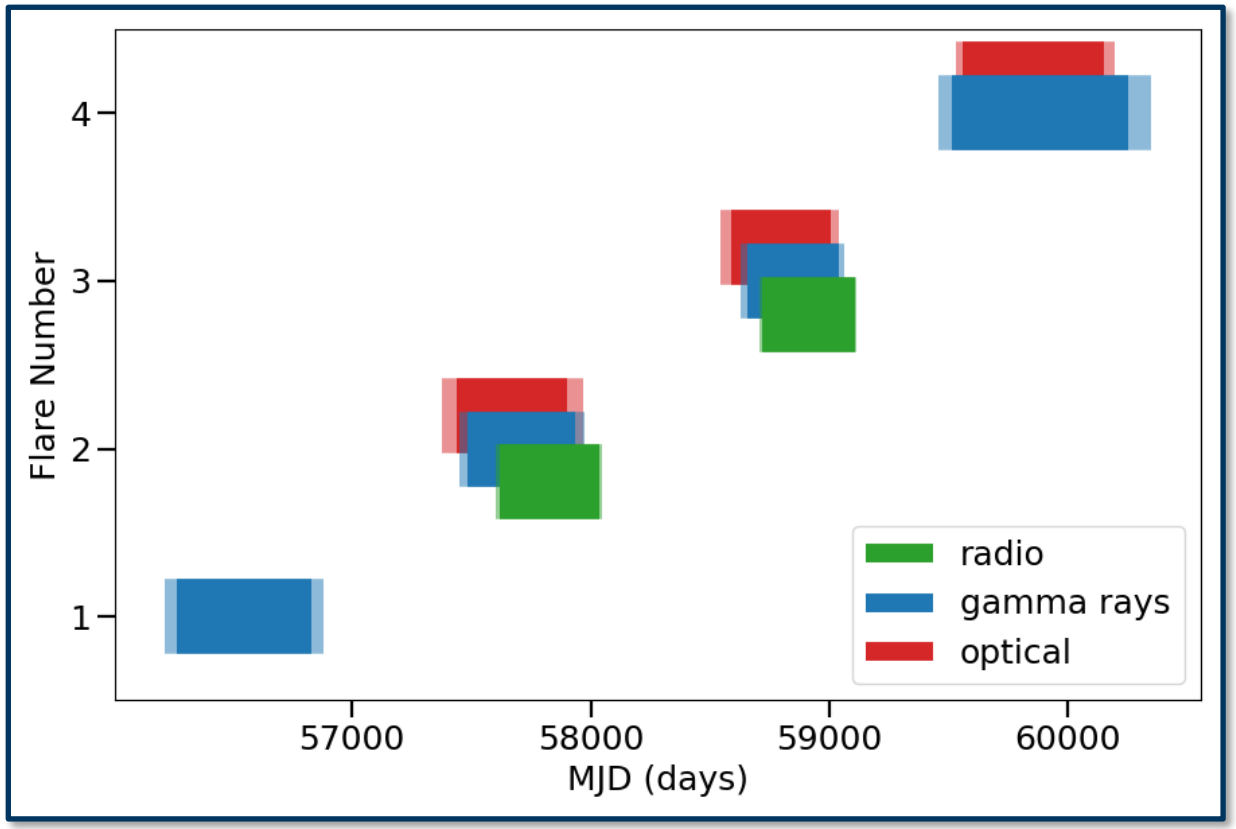
Not on Poster!

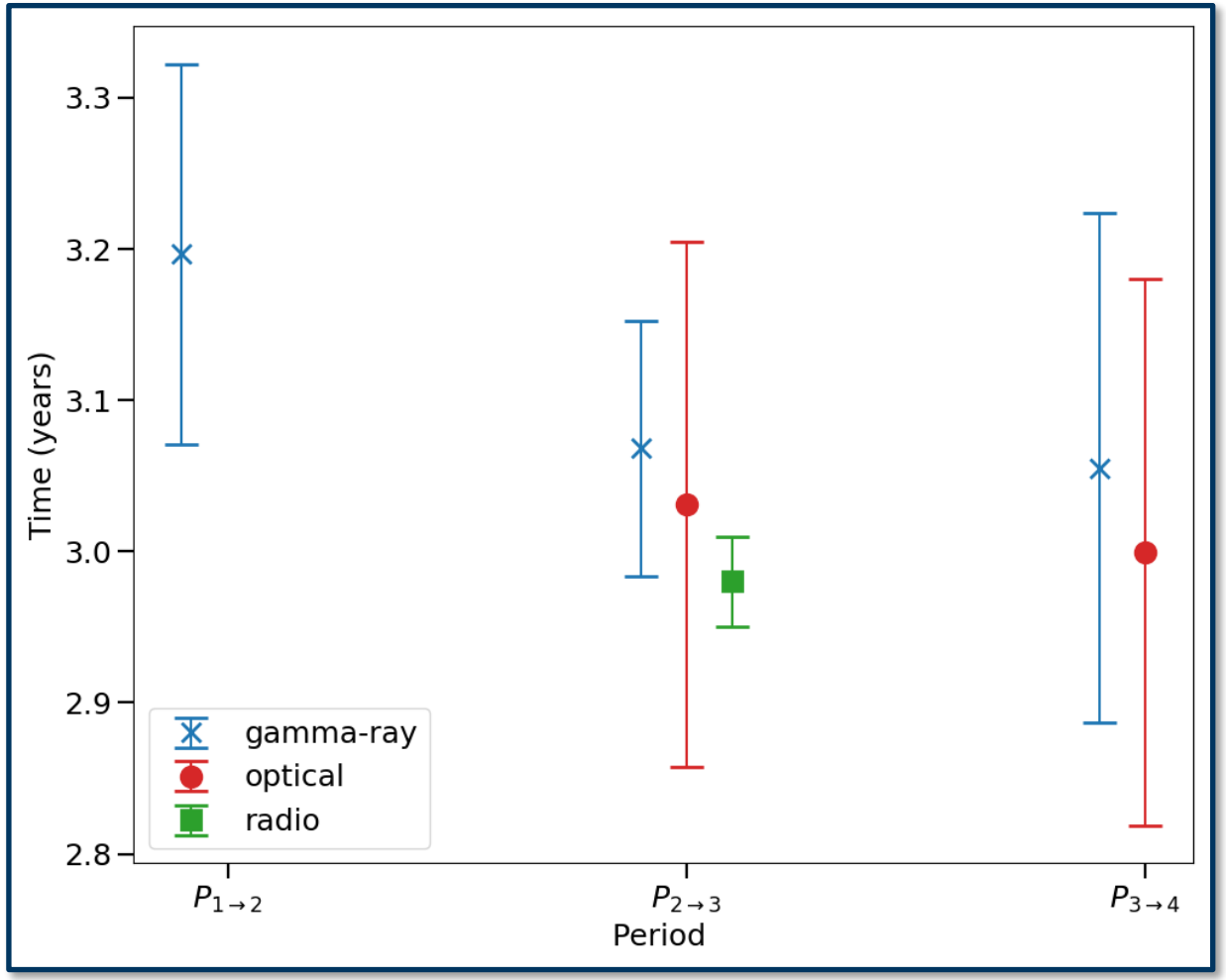


Kun, **IJ+** in prep.

Flare Durations + Periods Between

Not on Poster!





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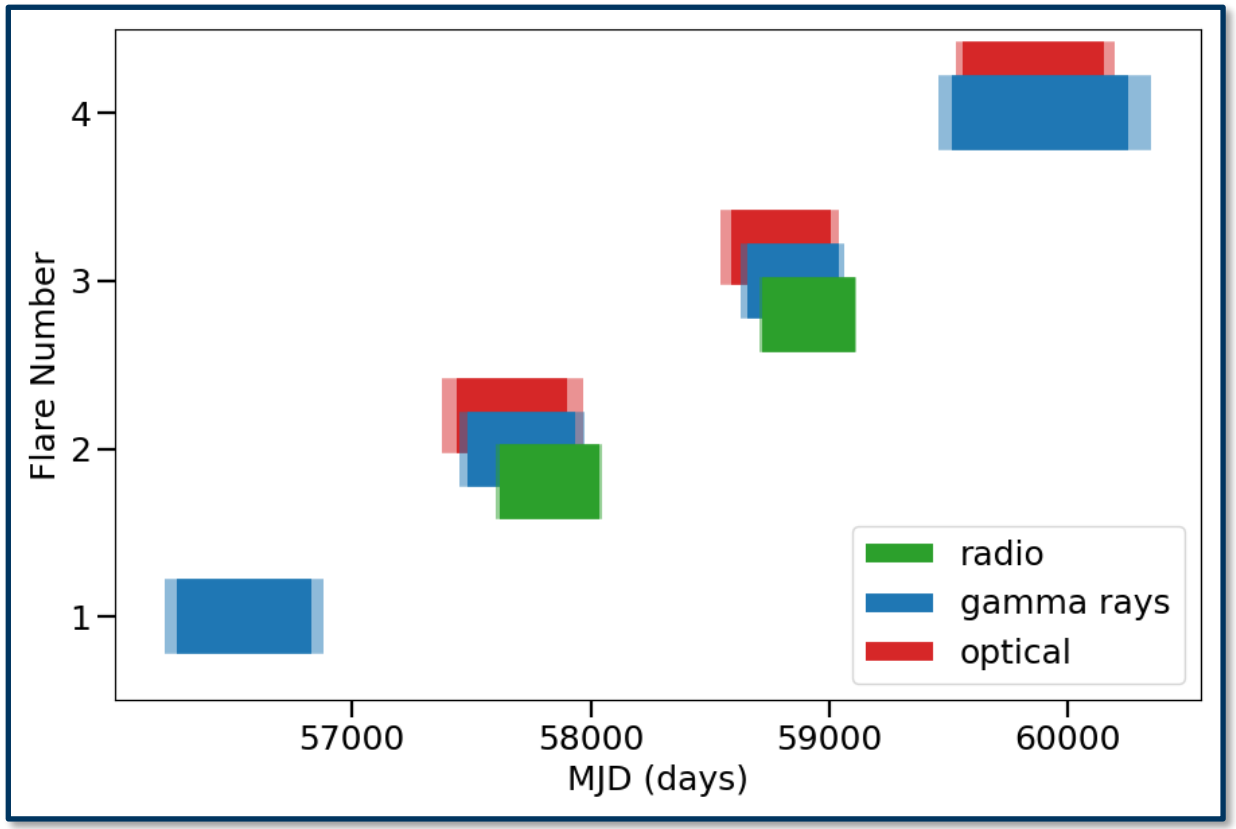

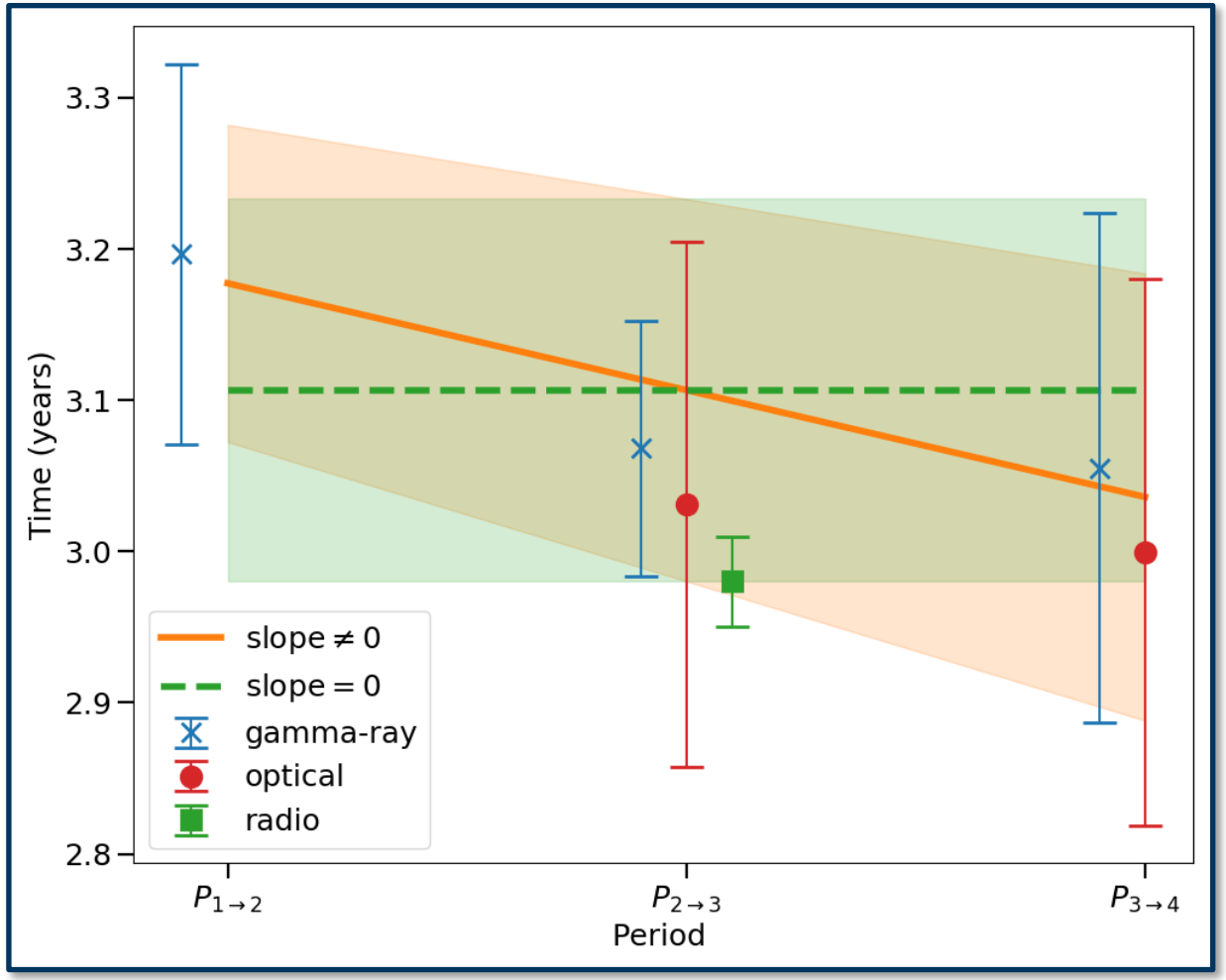

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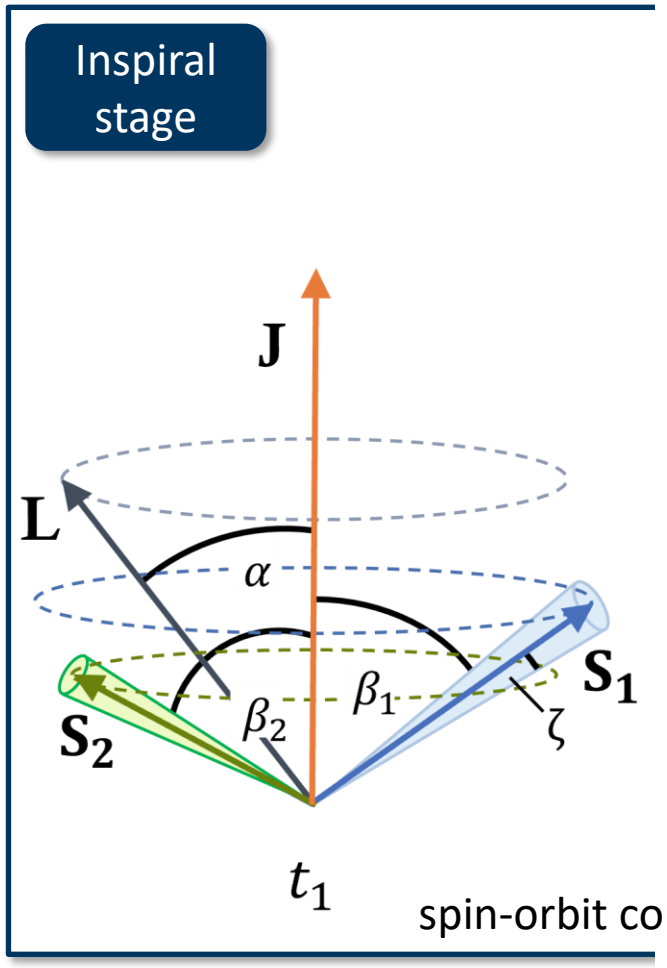
The Jet Precession Model

modified from de Bruijn et al. (2020)

The Jet Precession Model



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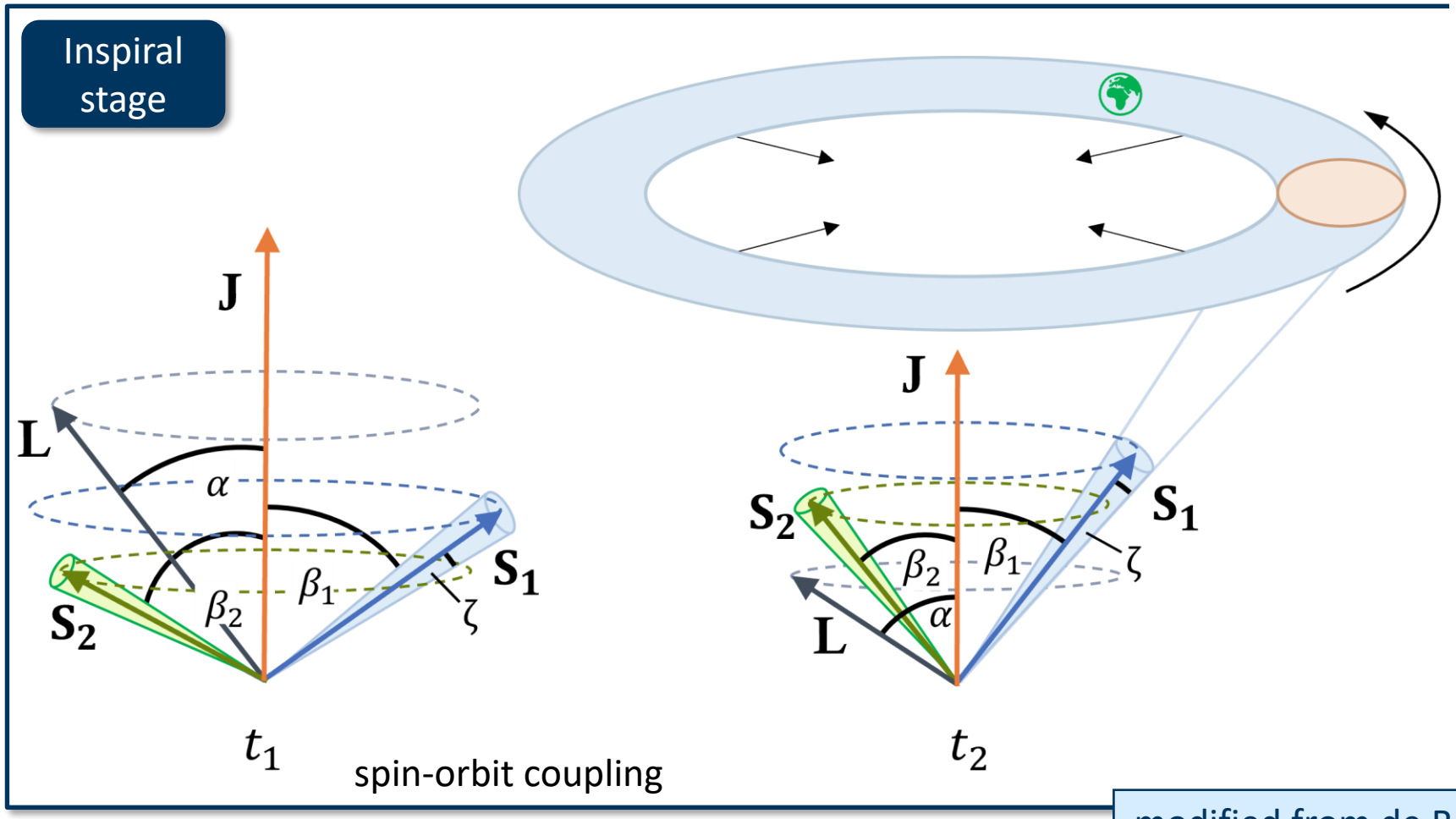

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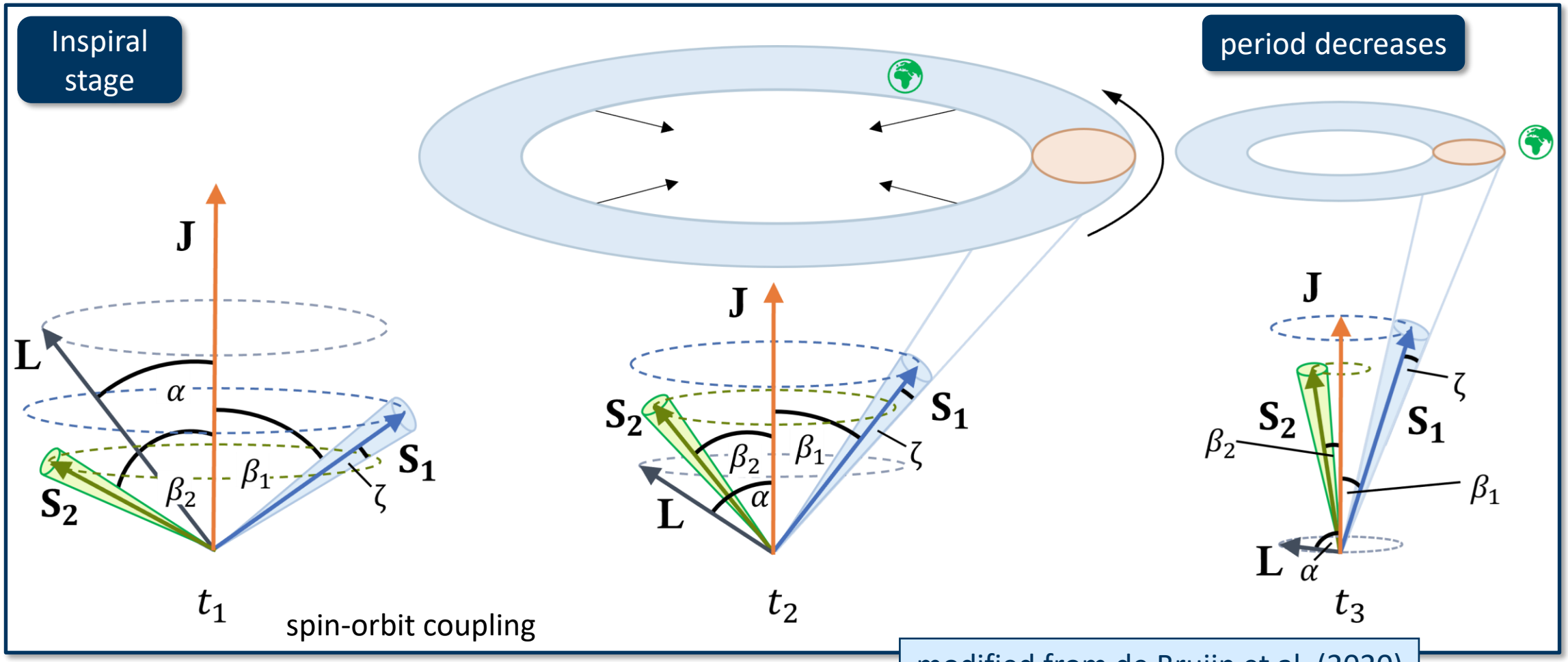

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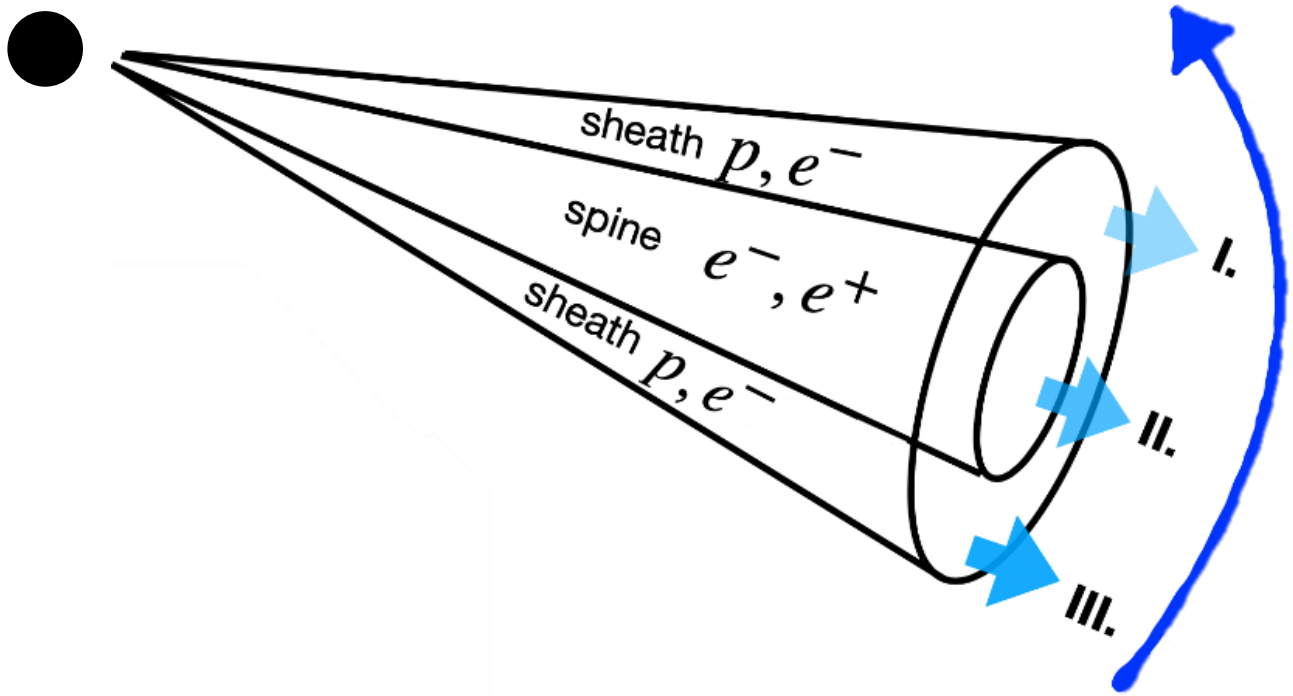
Double Peak Structure – an Explanation



Observer

Kun, **IJ** et al. (2024)

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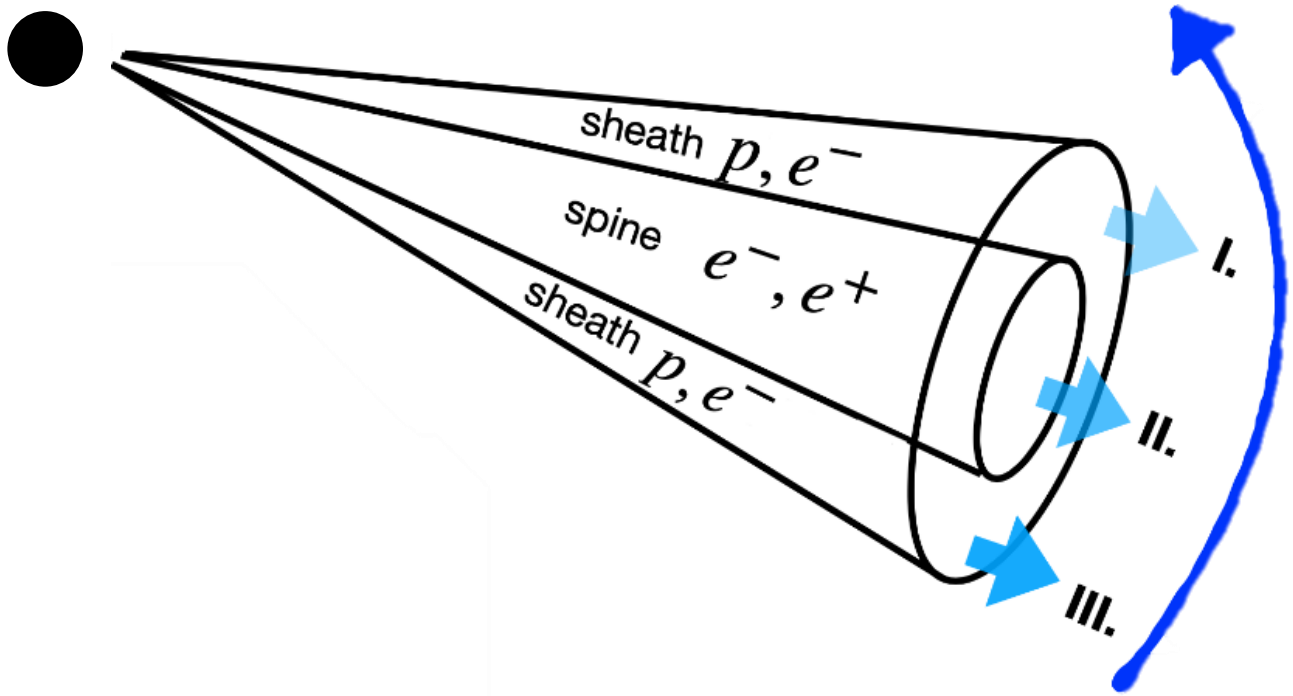

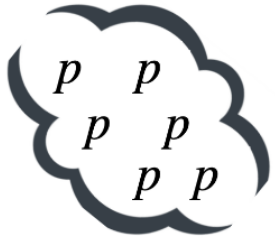

Target

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Kun, **IJ** et al. (2024)

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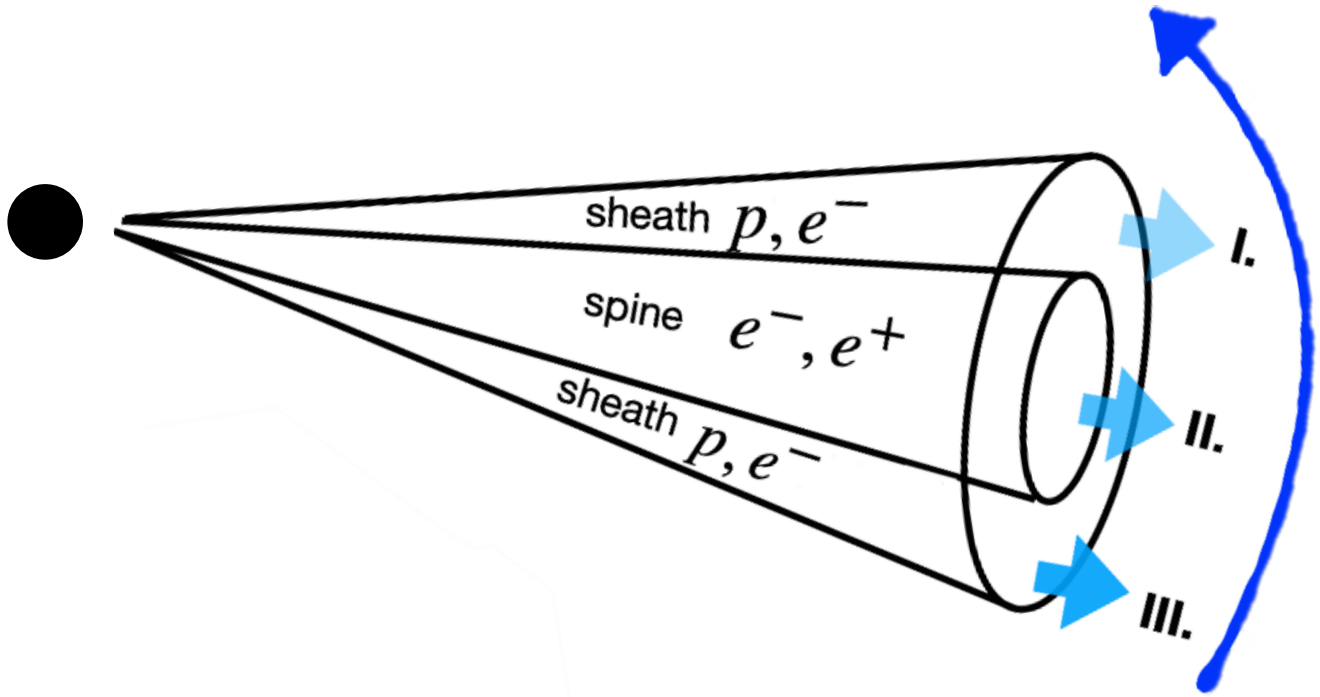

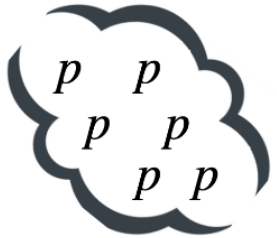

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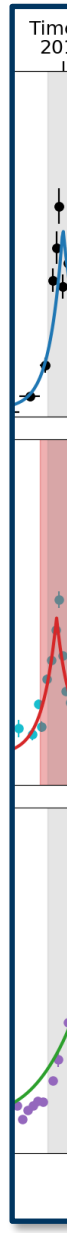

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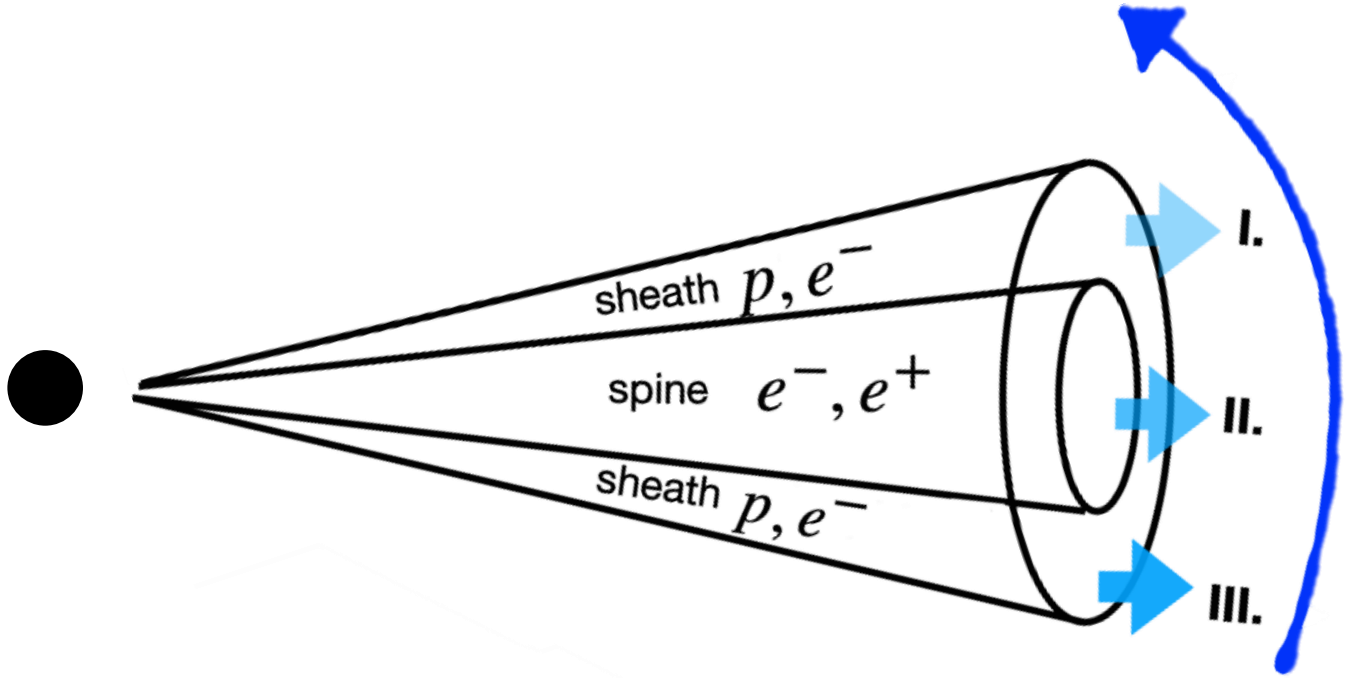

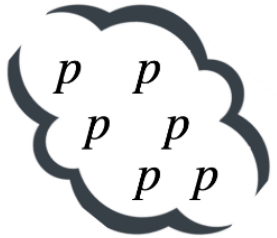

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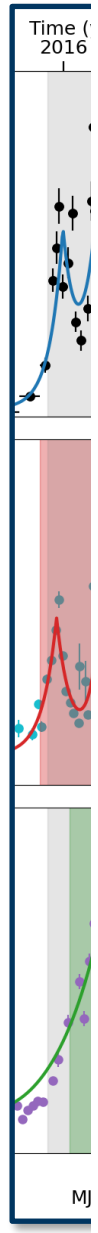

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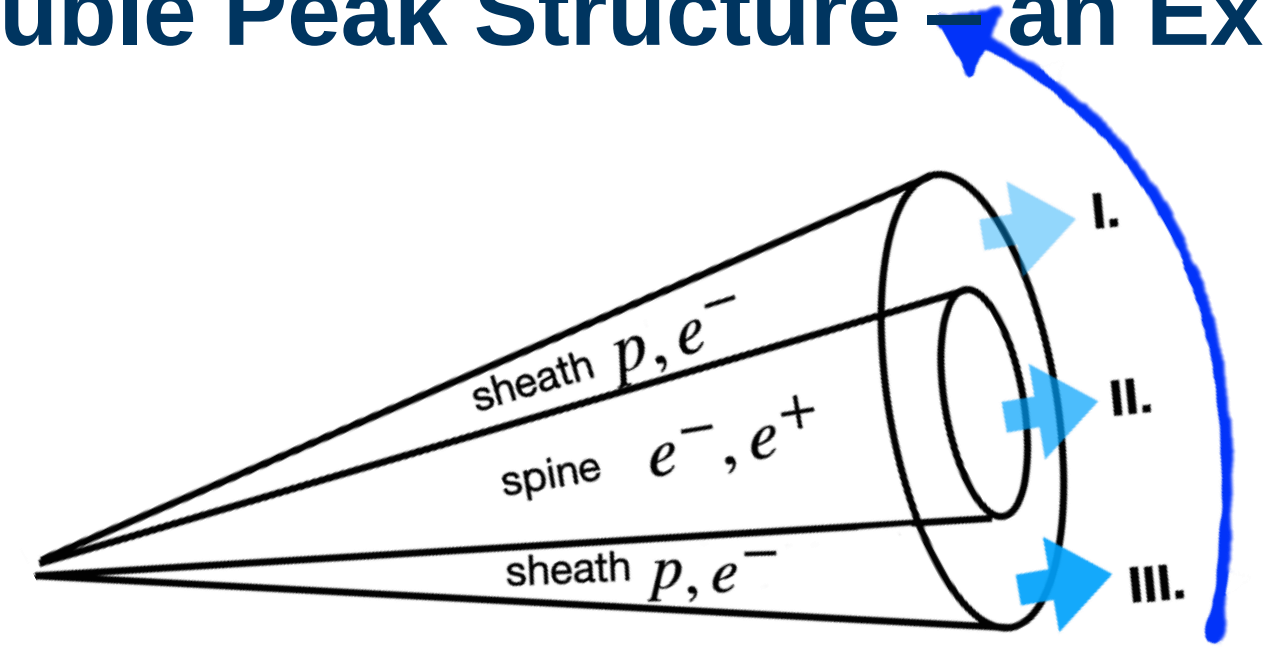

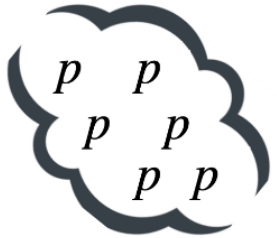

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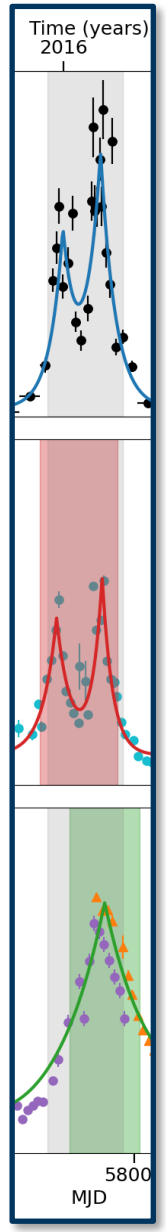


Kun, **IJ** et al. (2024)

Applying the Jet Precession Model in 2 Steps

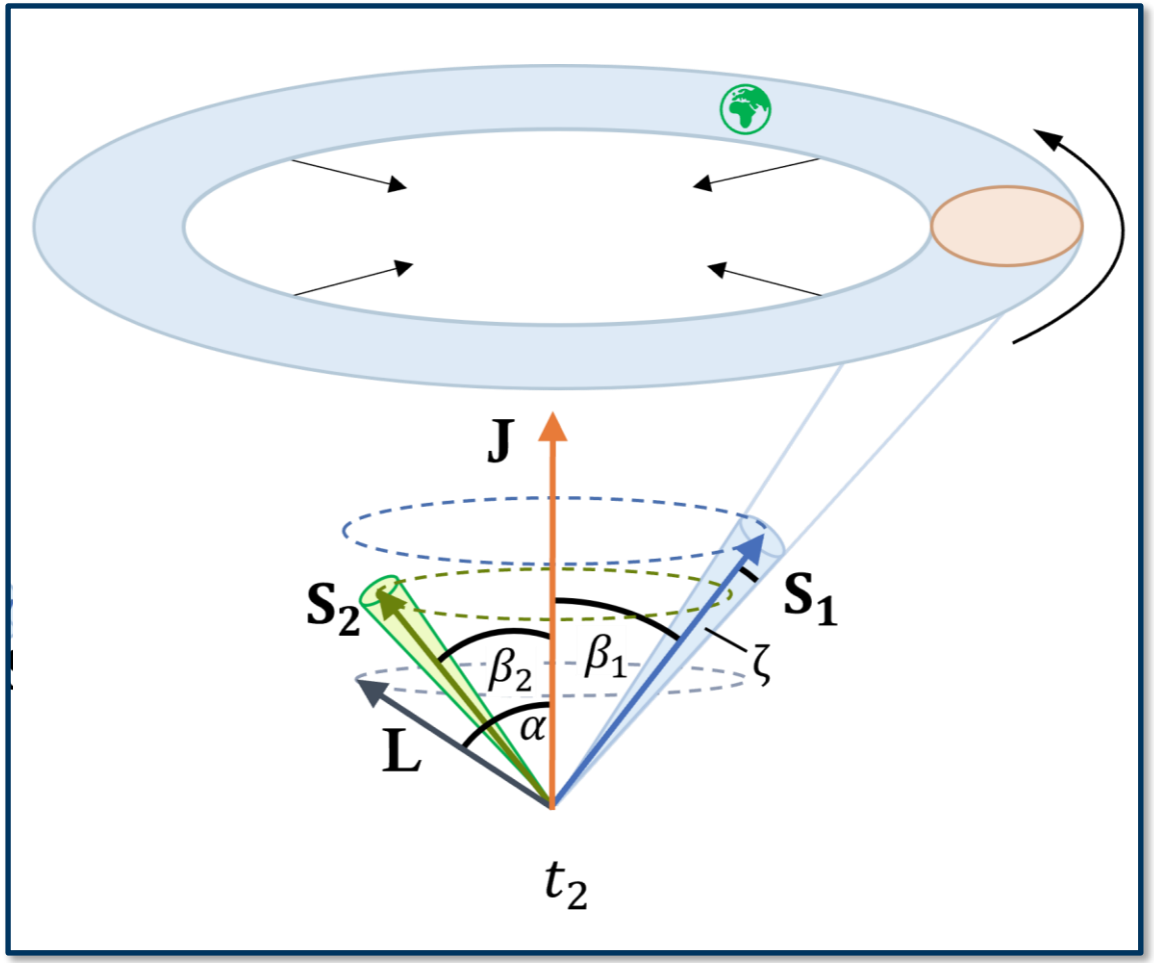
Input from Observation

1. Step

$$\phi(\Delta T_{\mathrm{GW}}, M, q) = \phi(\Delta T_{\mathrm{GW}} - P_{1\to 2}, M, q) \pm \zeta + 360°$$

2. Step

$$\phi(\Delta T_{\mathrm{GW}}, M, q) = \phi(\Delta T_{\mathrm{GW}} - P_{1\to 2} - P_{2\to 3}, M, q) \pm 2\zeta + 720$$



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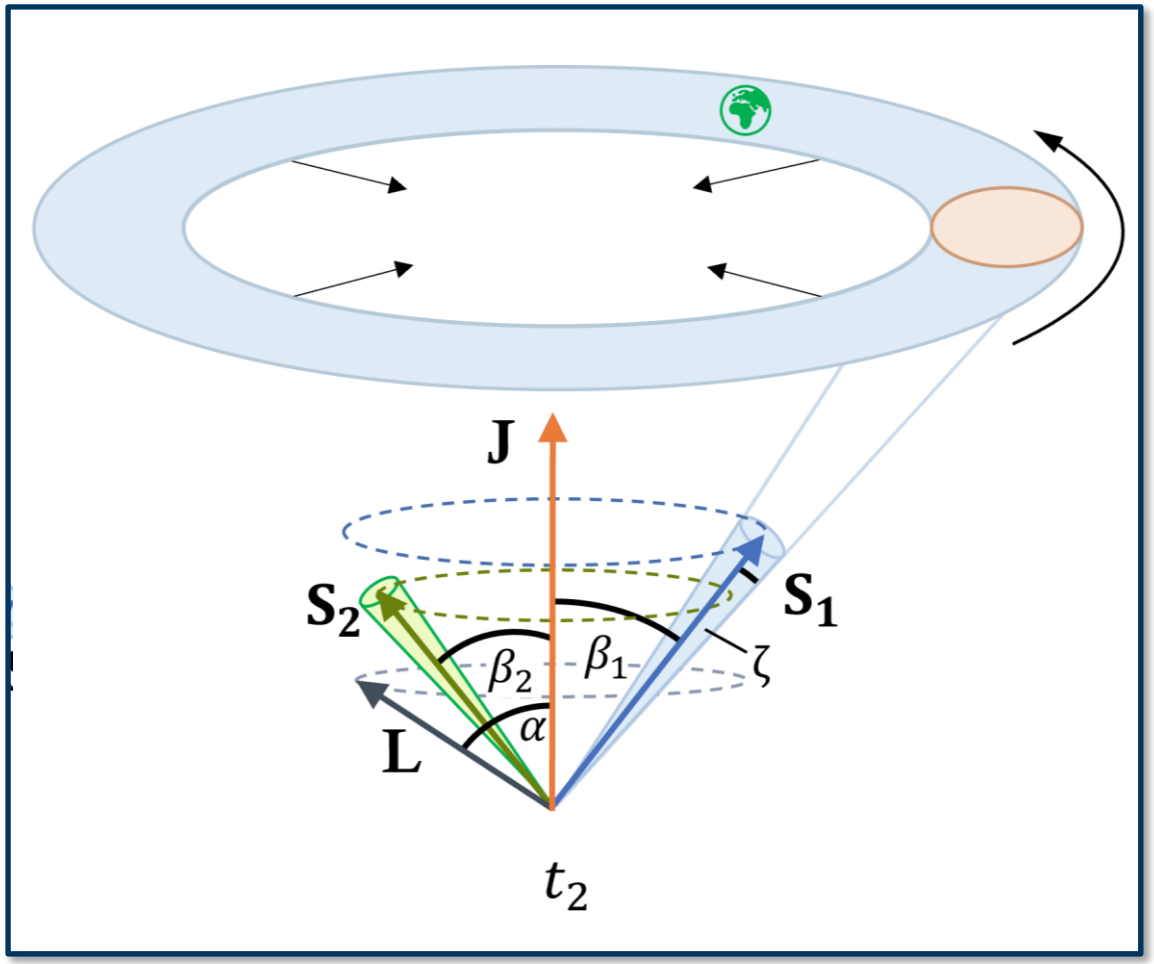

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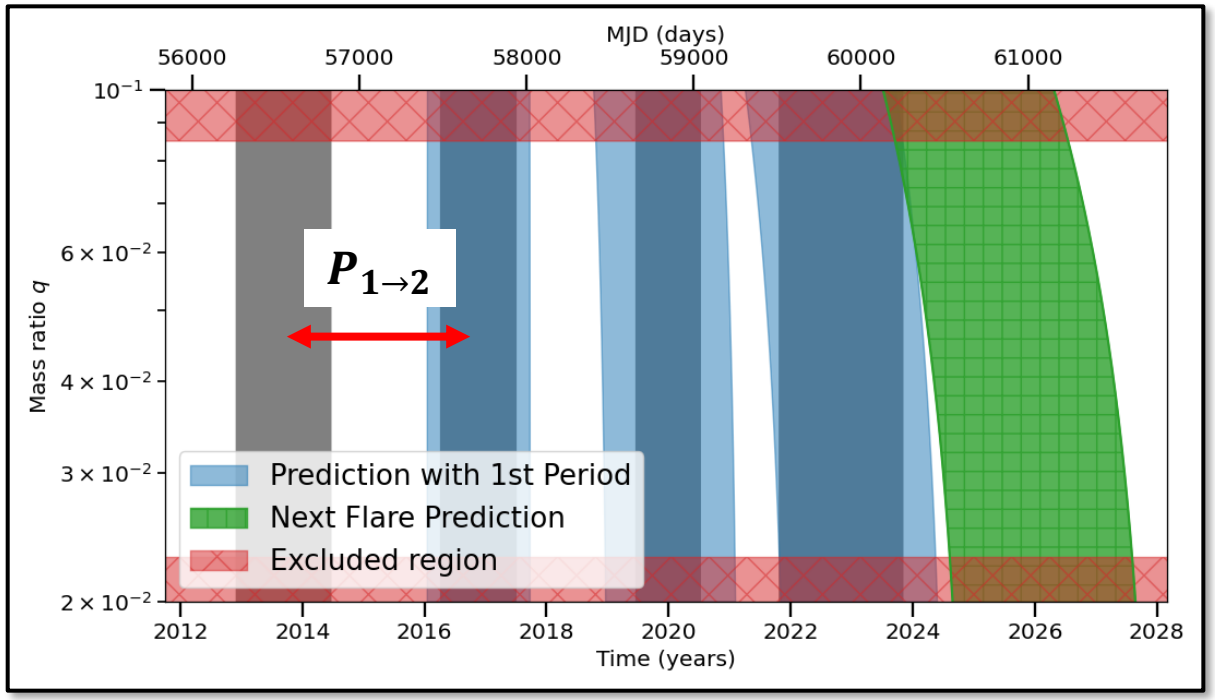
Flare Prediction in Gamma Rays – 4th Flare agrees!



half-opening angle: $\zeta \sim 5.73°$

half-opening angle: $\zeta \sim 8.34°$

Kun, **IJ** et al. (2024)

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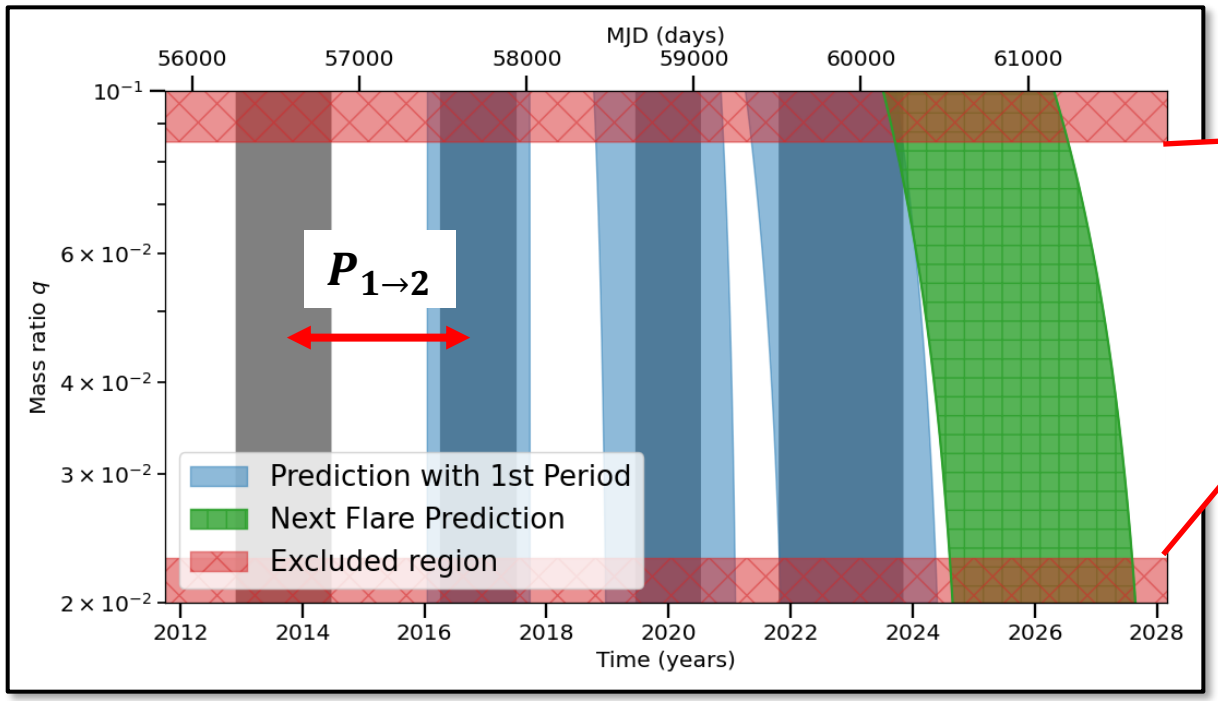

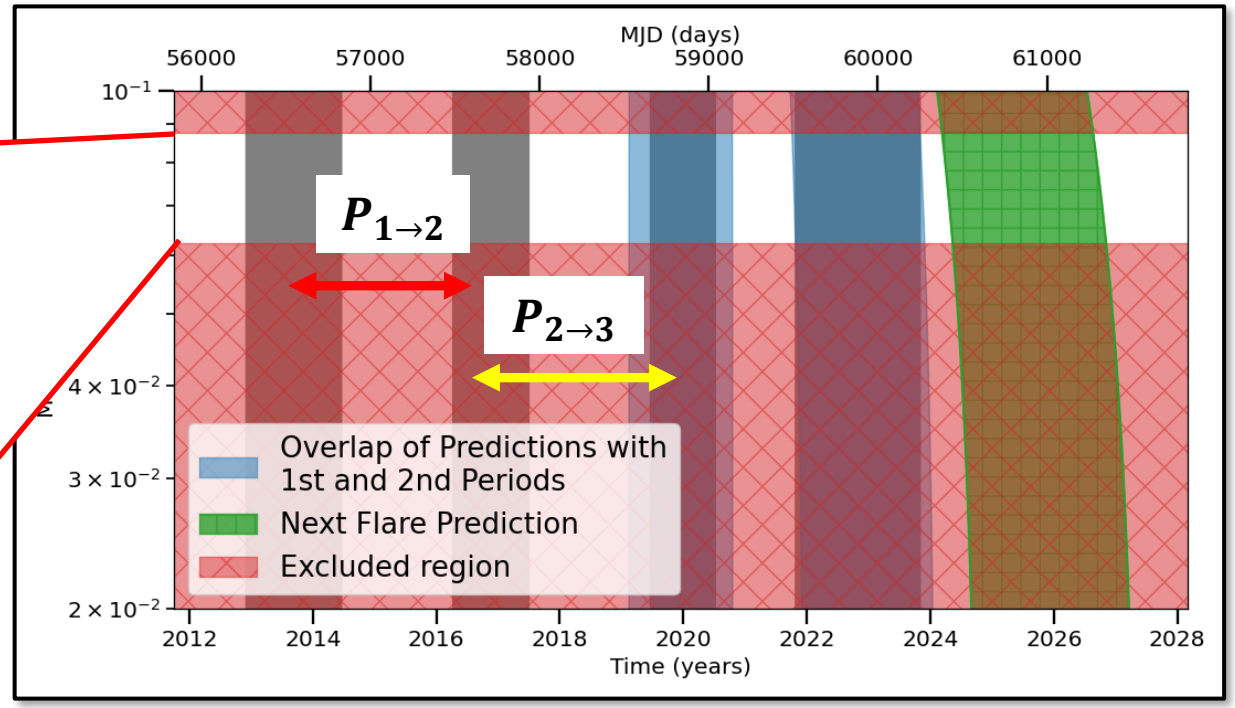

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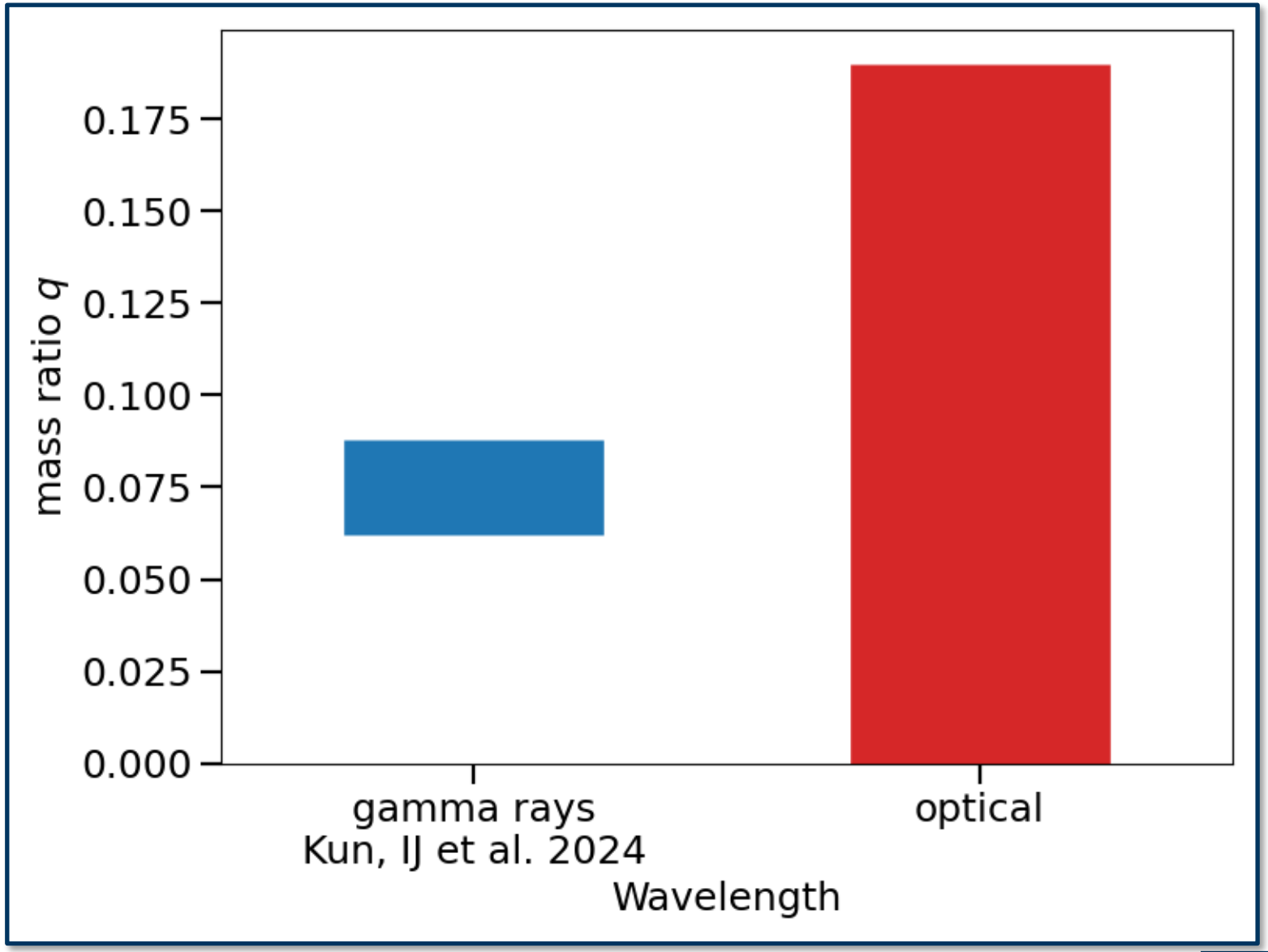
$$0.062 \leq q \leq 0.088$$

Kun, **IJ** et al. (2024)

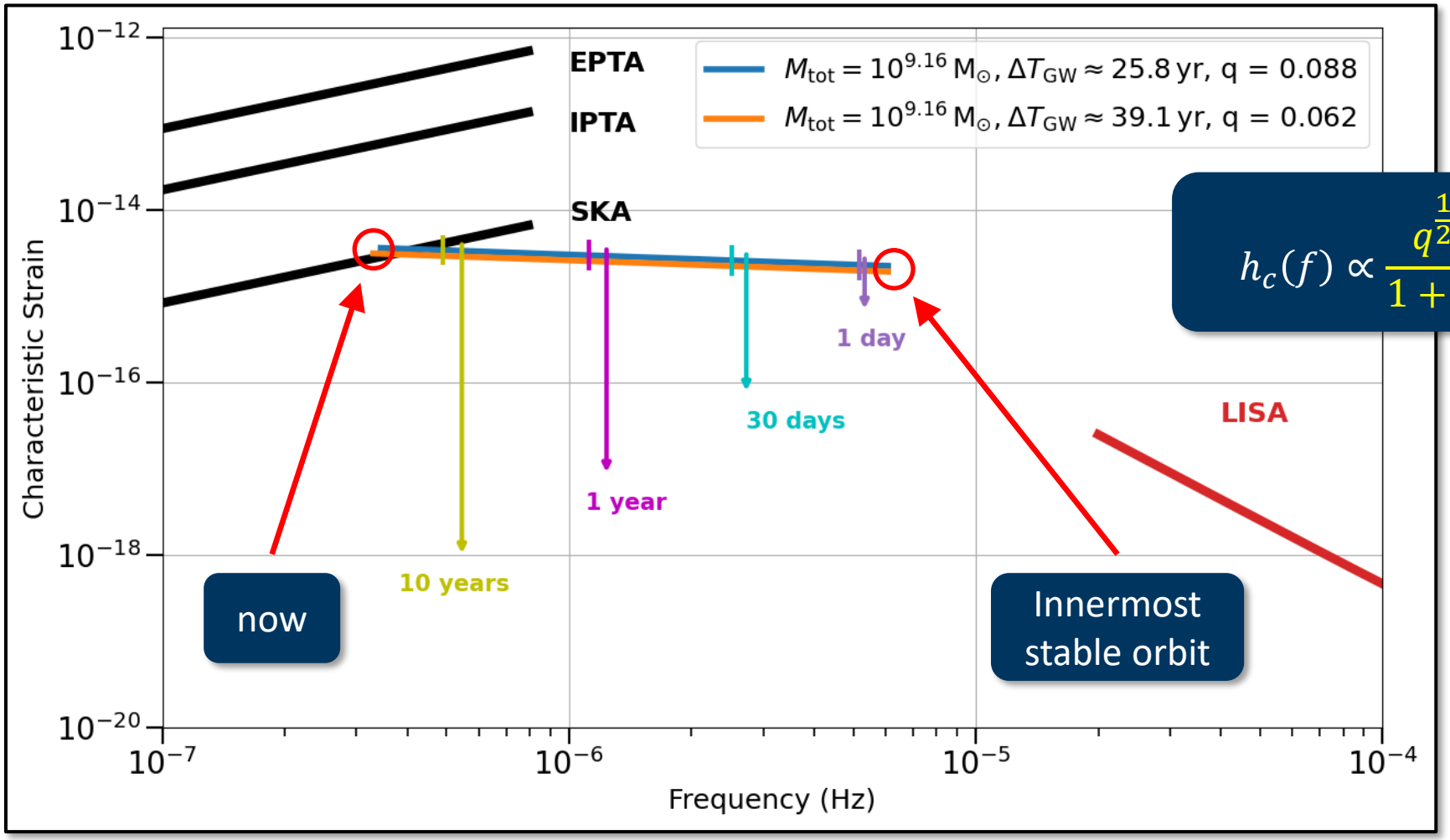
Constrained Binary Mass Ratios

Not on Poster!



IJ+ in prep.

Expected Gravitational Wave Signal



$$h_c(f) \propto \frac{q^{\frac{1}{2}}}{1+q} M^{\frac{5}{6}} \cdot \frac{1}{r(z)(1+z)^{1/2}} f^{-1/6}$$

$r(z)$: comoving distance

Kun, **IJ** et al. (2022)

Summary – Blazar J1048+7143

analytical **Jet Precession** model applied with:

1. optical

- 3 flares observed
- Mass ratio constrained from above

$$q \lesssim 0.19$$

- 4 flares observed
- 4th flare (successfully) predicted
- Mass ratio constrained from above **AND** below

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- 2 flares observed
- 3rd flare, more data necessary

Time range of next flare, if the jet will point at Earth once more: 2024 March 10 - 2026 November 6

ilja.jaroschewski@cea.fr

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Summary – Blazar J1048+7143

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in combination with **Spine-Sheath** jet model

double-peak structure in gamma rays and optical light curve explainable

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More coming:
- ZTF optical light curve → combined optical light curve
- Expected Neutrino upper limits
- Swift X-Ray light curve

Goal → Combined MM picture!

Stay Tuned!!!

Time range of next flare, if the jet will point at Earth once more: 2024 March 10 - 2026 November 6

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Appendix

Flare Prediction in Gamma Rays

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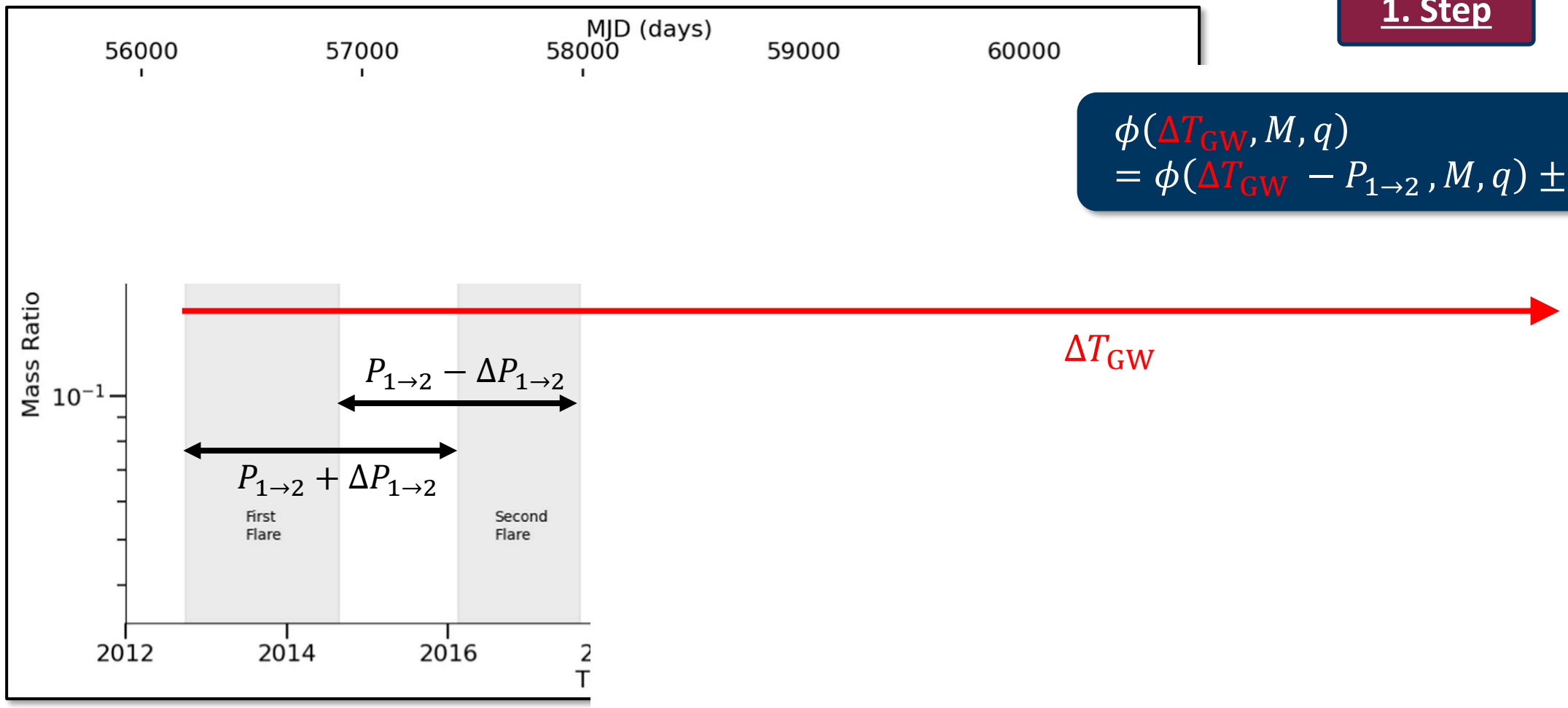

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Kun, **IJ** et al. (2022)

cea irfu

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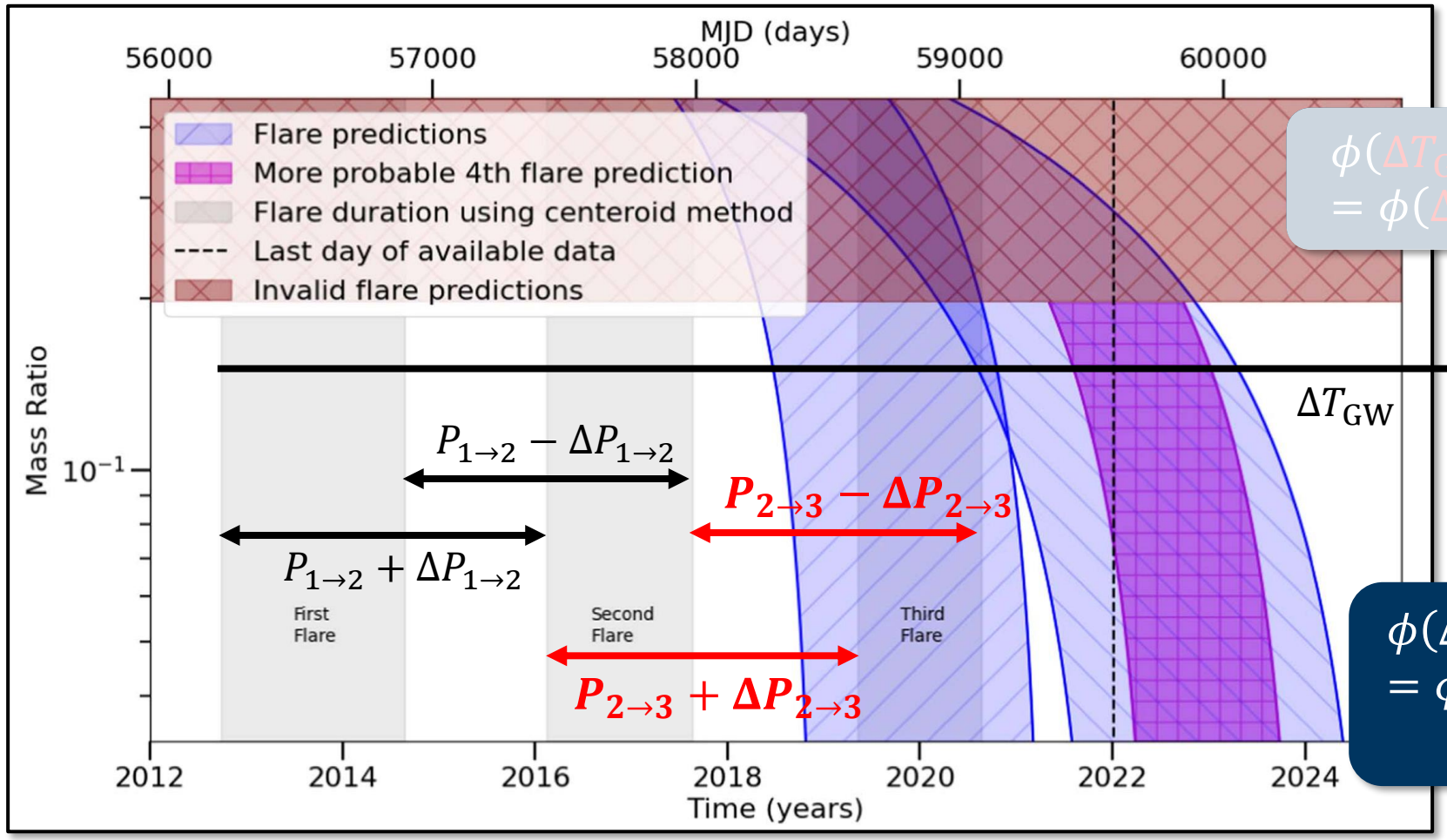

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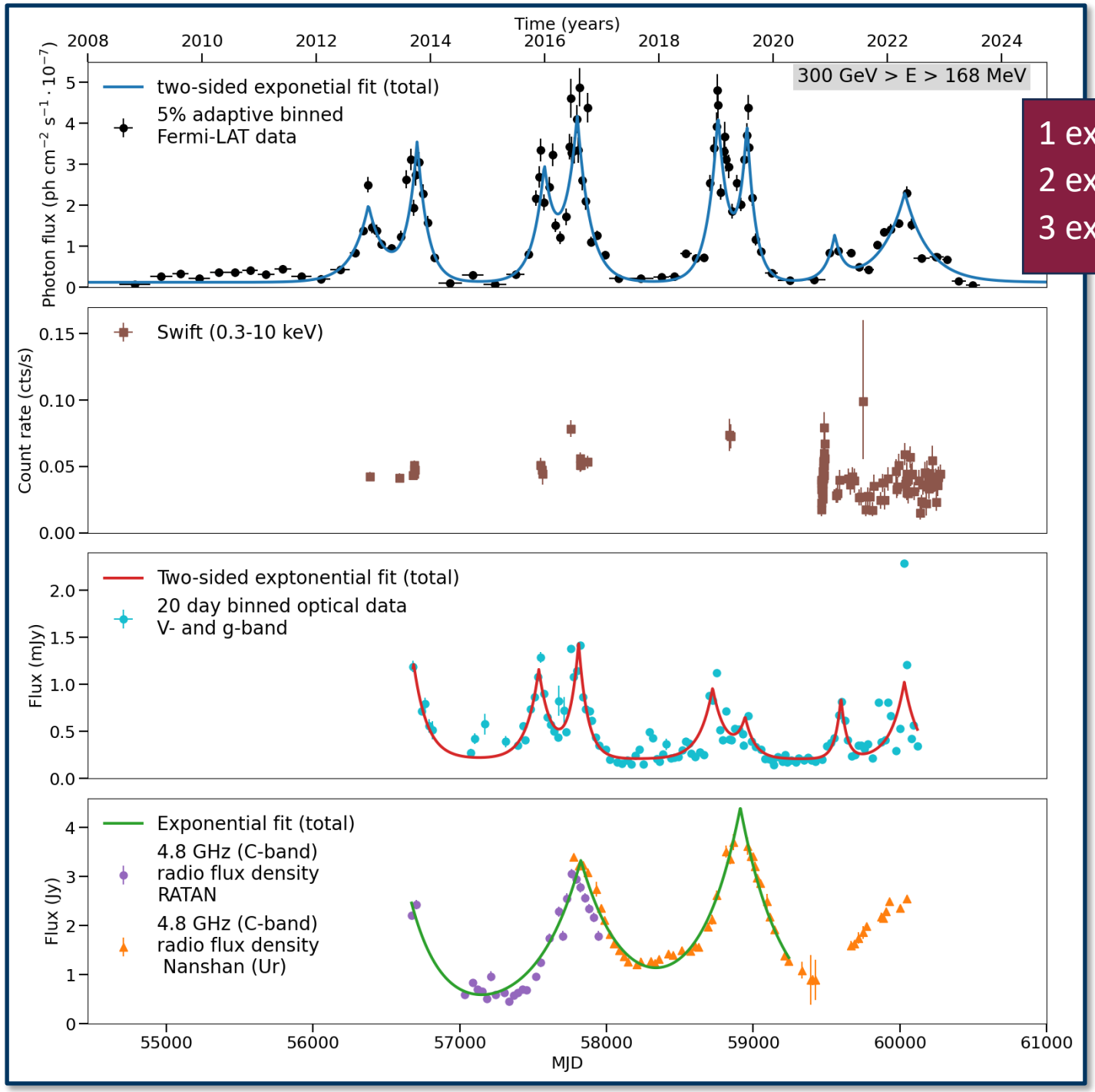
Backup:

Gamma-Ray Light Curve

+ X-Ray

+ Optical

+ Radio



1 exp func: $\chi^2_{\mathrm{red}} \approx 22.57$
2 exp func: $\chi^2_{\mathrm{red}} \approx 8.54$
3 exp func: $\chi^2_{\mathrm{red}} \approx 10.43$

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Backup: J1048+7143 – Centroid Method (Kun, IJ et al. 2022)

$$X_{i,j} = \frac{\int t \cdot F_{i,j}(t)\mathrm{d}t}{\int F_{i,j}(t)\mathrm{d}t}$$

$$Y_{i,j} = \frac{1}{2}\frac{\int F_{i,j}^2(t)\mathrm{d}t}{\int F_{i,j}(t)\mathrm{d}t}$$

$$X_i = \frac{A_i}{A_i + B_i} X_{i,1} + \frac{B_i}{A_i + B_i} X_{i,2}$$

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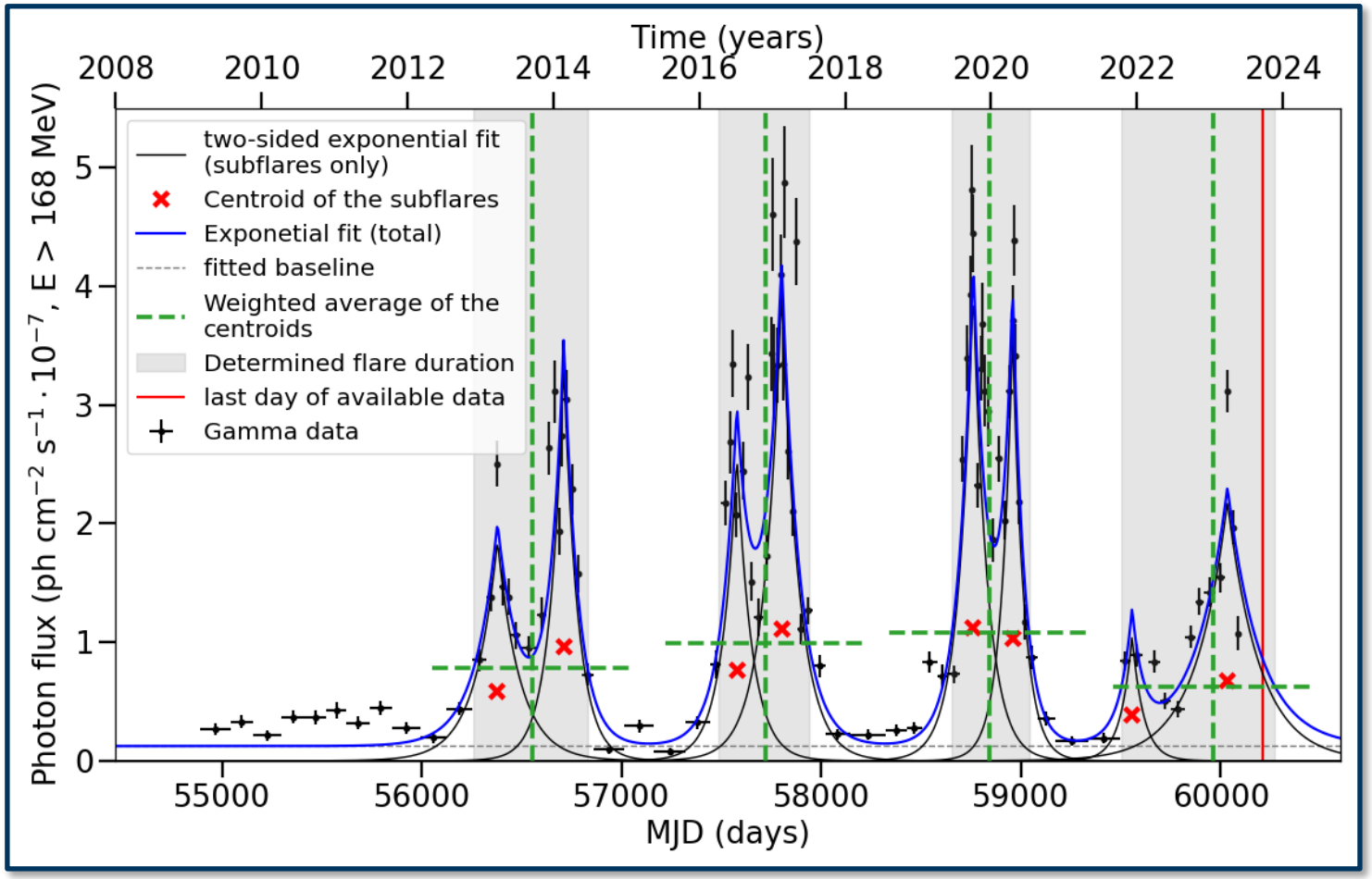

Kun, **IJ** et al. (2024)

Backup: J1048+7143 – Flare Characteristics 1/3

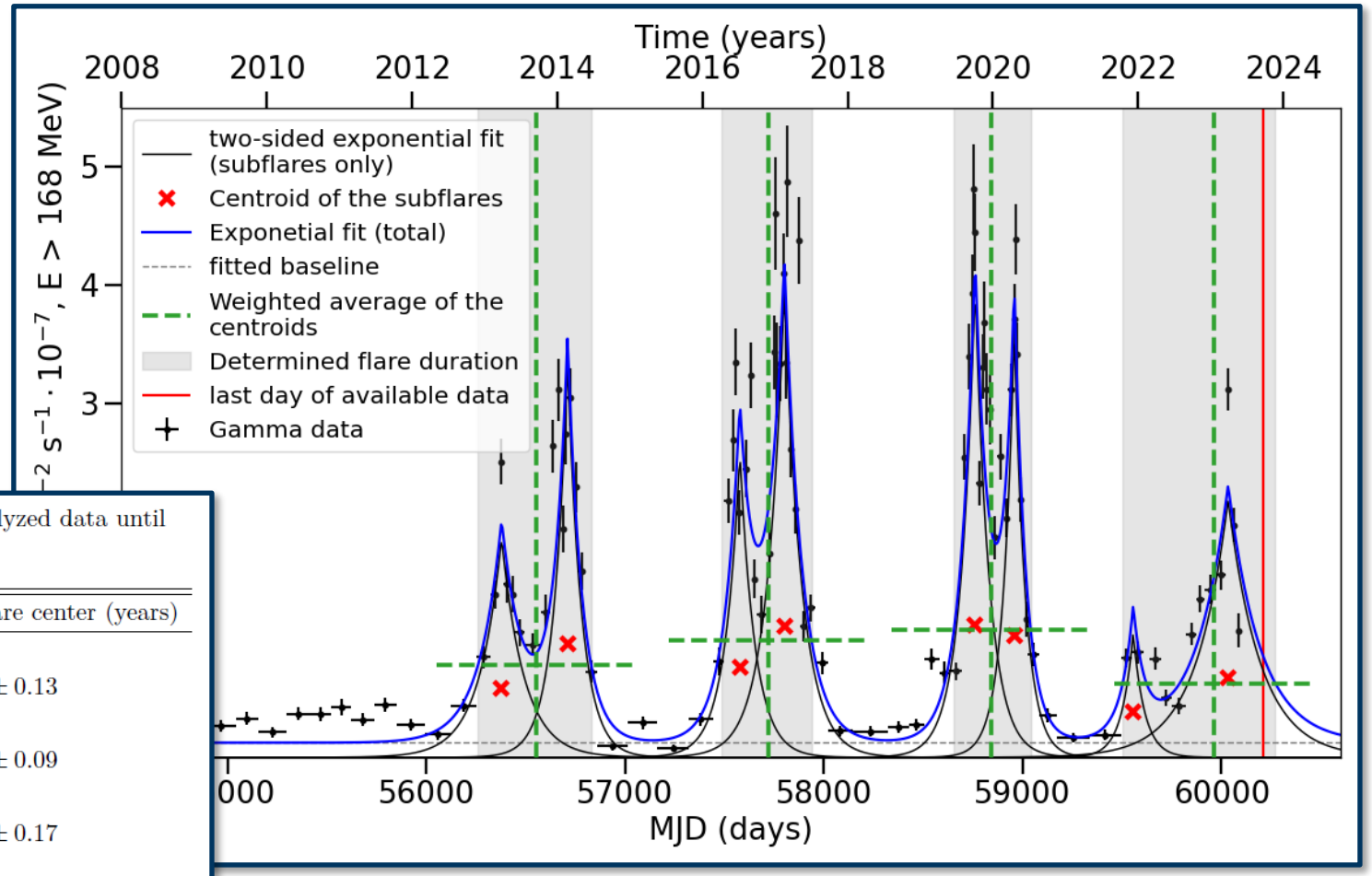

Table 5.1: Characteristics of the gamma-ray light curve of J1048+7143 (analyzed data until MJD 60099) applying the centroid method.

Parameter	Flare center (MJD)	Flare duration (days)	Time till next flare center (years)
F1	56554 ± 38	565 ± 78	
$P_{1\to2}$			3.20 ± 0.13
F2	57722 ± 25	450 ± 61	
$P_{2\to3}$			3.07 ± 0.09
F3	58842 ± 18	383 ± 38	
$P_{3\to4}$			3.06 ± 0.17
F4	59958 ± 59	756 ± 113	

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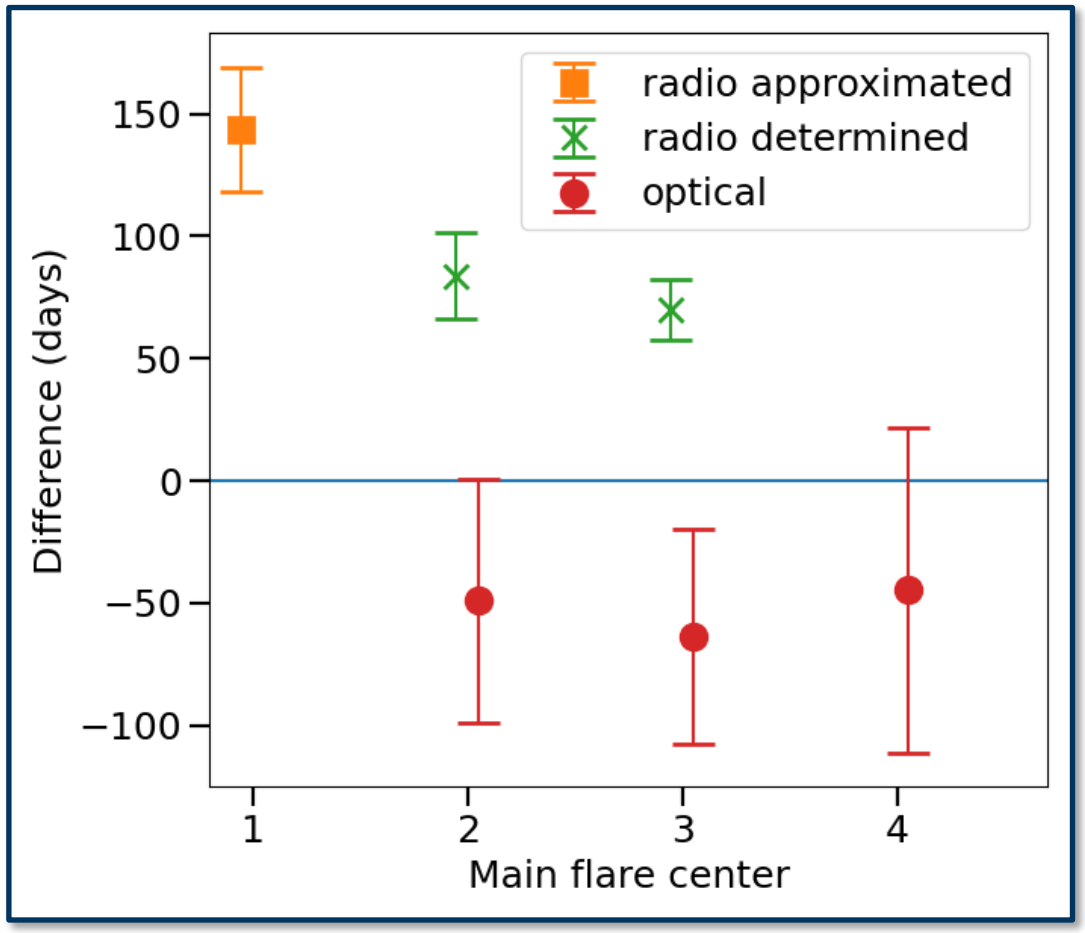
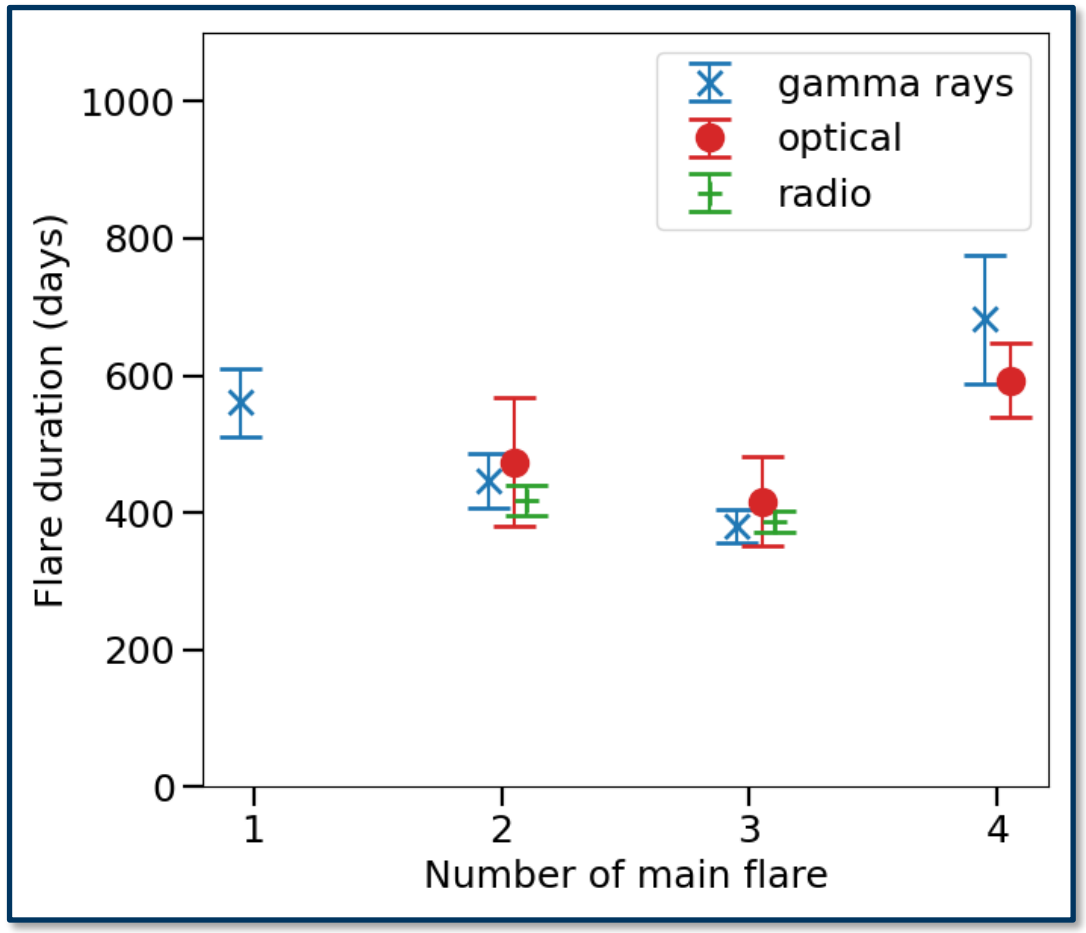
Backup: J1048+7143 – Flare Characteristics 2/3

Difference of main flare centers in the gamma-ray and radio light curve:

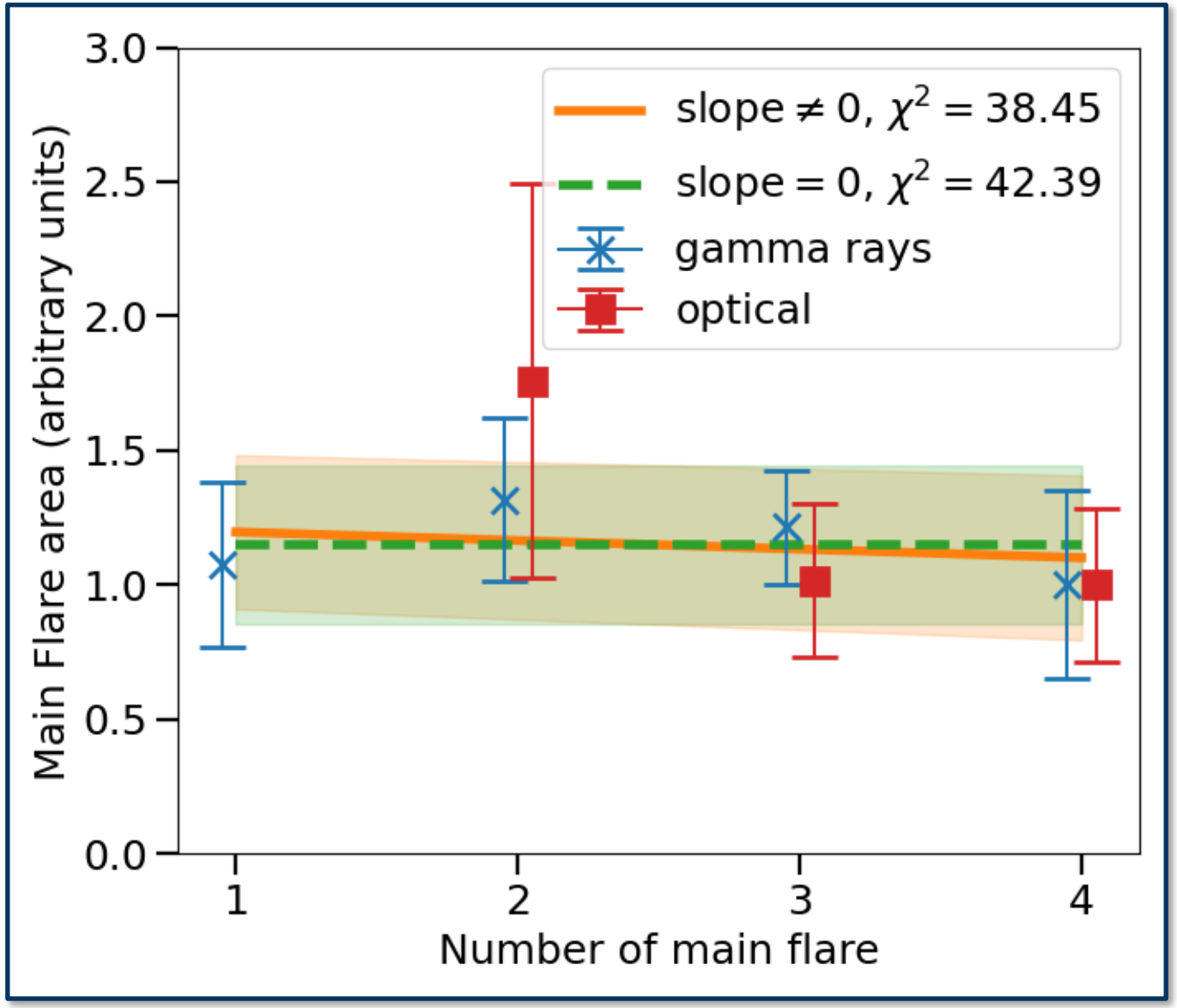


Main Flare durations:



Backup: J1048+7143 – Flare Characteristics 3/3

Flare areas normalized to last flare



Backup: J1048+7143 – Possible Nutation in Gamma Rays + Optical

Earth's path through the jet