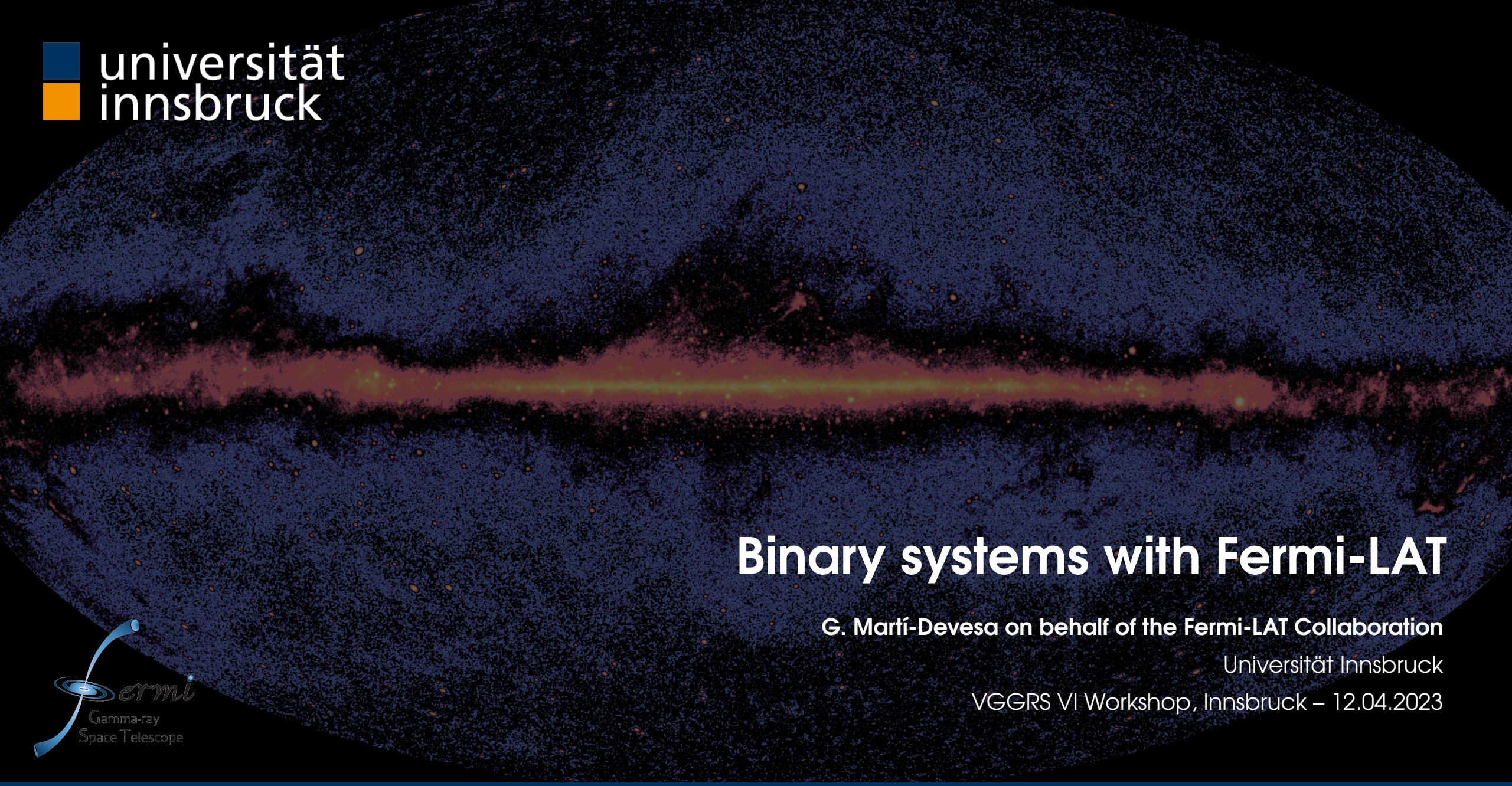
universität innsbruck



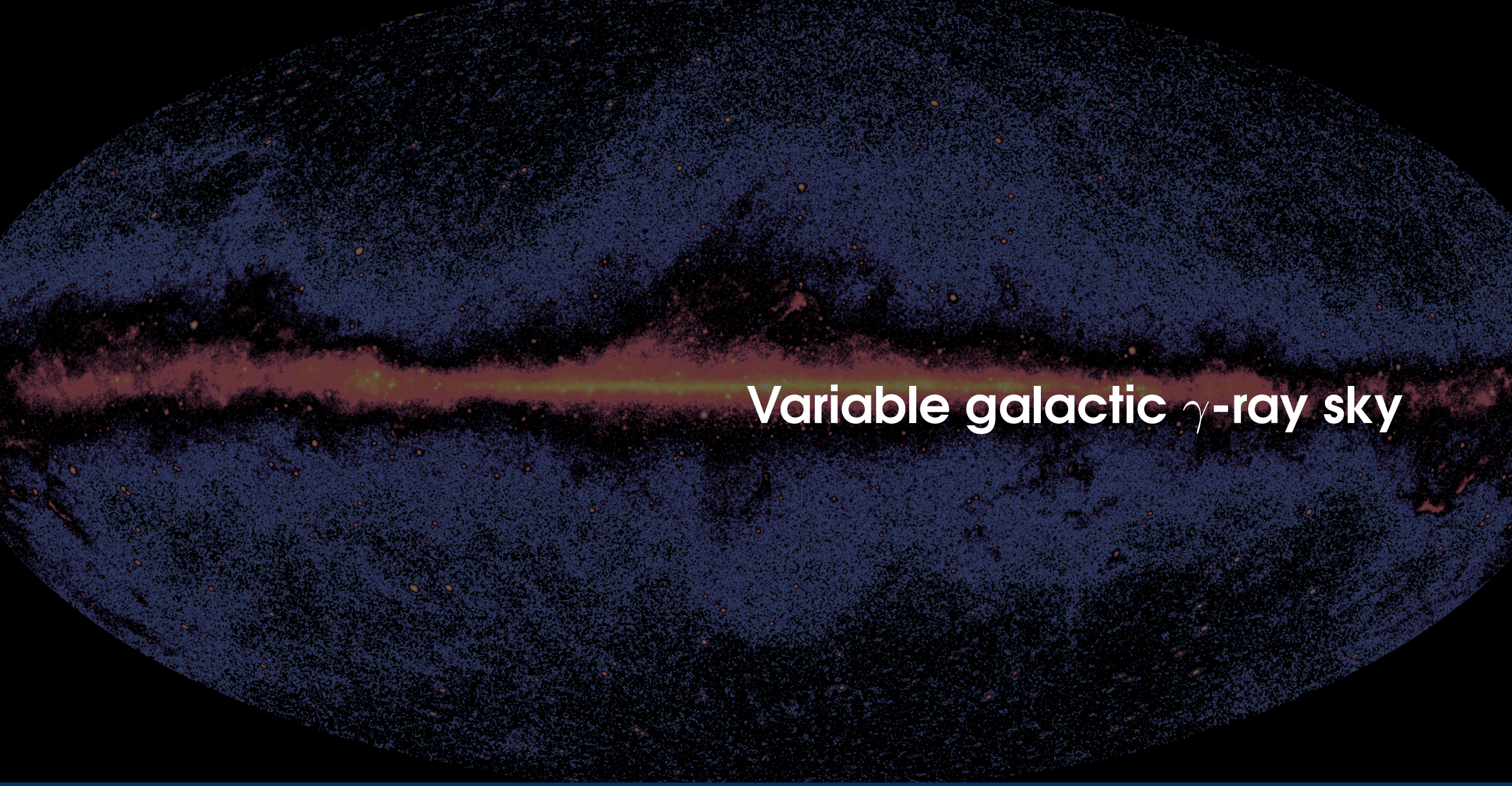
Binary systems with Fermi-LAT

G. Martí-Devesa on behalf of the Fermi-LAT Collaboration

Universität Innsbruck

VGGRS VI Workshop, Innsbruck – 12.04.2023

Fermi Gamma-ray Space Telescope

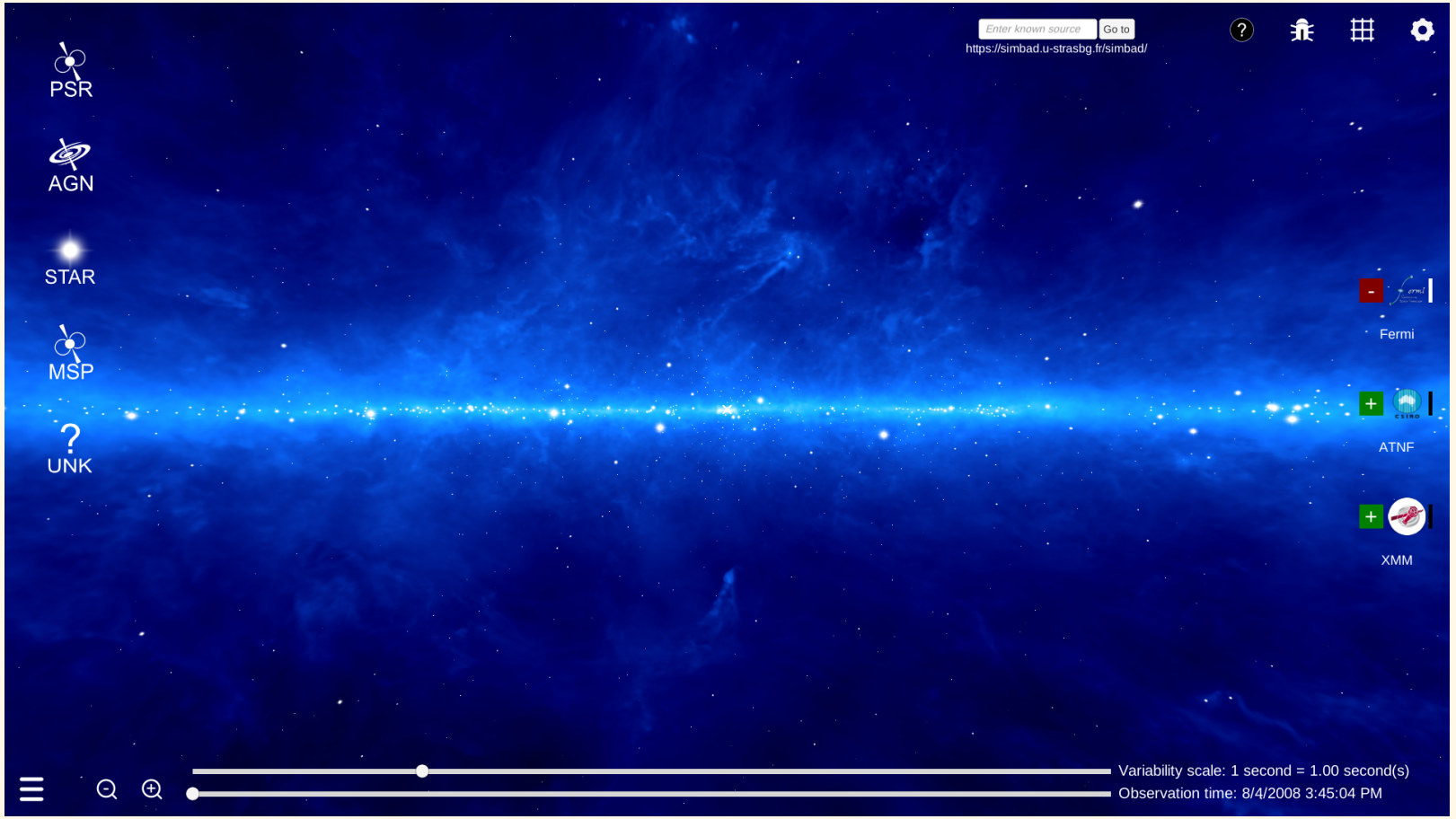

Variable galactic γ-ray sky

The GeV sky as seen by *Fermi*-LAT

Interactive

Credit: P. Martin & R. Combelles / Fermi-LAT Collaboration

The variable sky as seen by *Fermi*-LAT



Interactive!

Credit: P. Martin & R. Combelles / Fermi-LAT Collaboration

The variable sky as seen by *Fermi*-LAT

Shortest time scales

Pulsars (isolated and in binaries) are the largest Galactic population

Gamma-ray pulsars in this catalog[d]	**294**	
Spectral fits (with free b parameter)[f]		255 (116)
Profile fits in $\geq$ 1, 2, 6 energy bands		237, 129, 29
Young gamma-ray pulsars	150	
Radio-quiet[e]		70
Gamma-ray MSPs	144	
Isolated, Binary		32, 112
Discovered in LAT blind searches		10
Radio-quiet		6
Black Widows, Redbacks:		32, 13
Radio MSPs discovered in LAT sources	119	
with gamma-ray pulsations		78
waiting for ephemeris phase-connection[d]		33

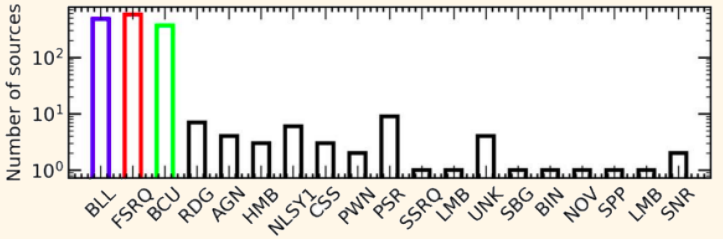
Third Pulsar Catalog
Smith et al. 2023, submitted

Intermediate time scales
~ 1 day/week

Least populated time-scale: physics or methods?

Long time scales

Flares / transient sources detected, but mostly extragalactic



Light Curve Repository
Fermi-LAT Collaboration 2023, ApJS

1 What we know about binaries at GeV energies

1

What we know about binaries at GeV energies

2

Some things we need to understand about the GeV emission from binaries

1

What we know about binaries at GeV energies

2

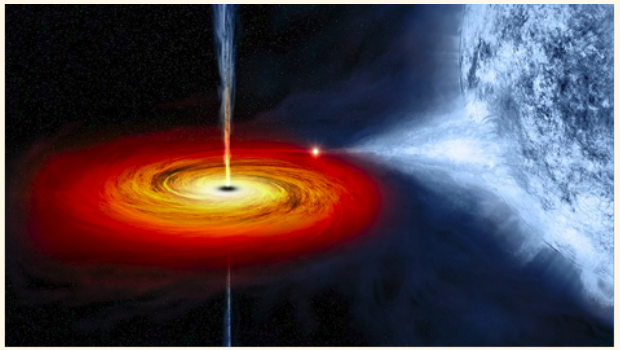
Some things we need to understand about the GeV emission from binaries

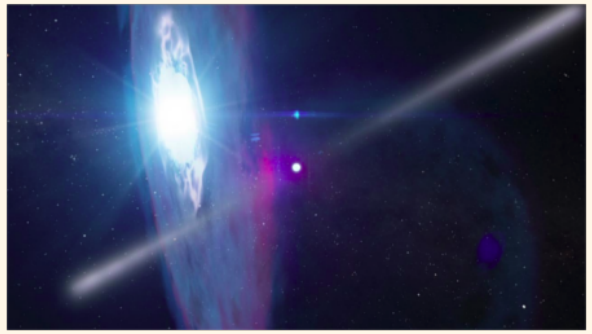
3

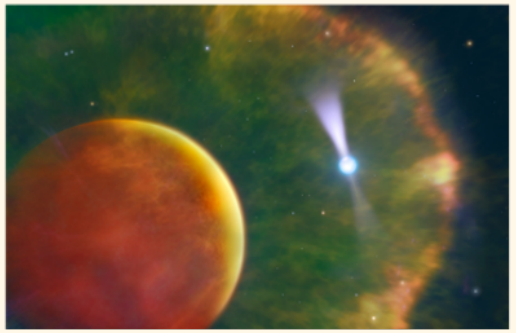
What we could do with *Fermi*-LAT


What we know

Binaries at high energies





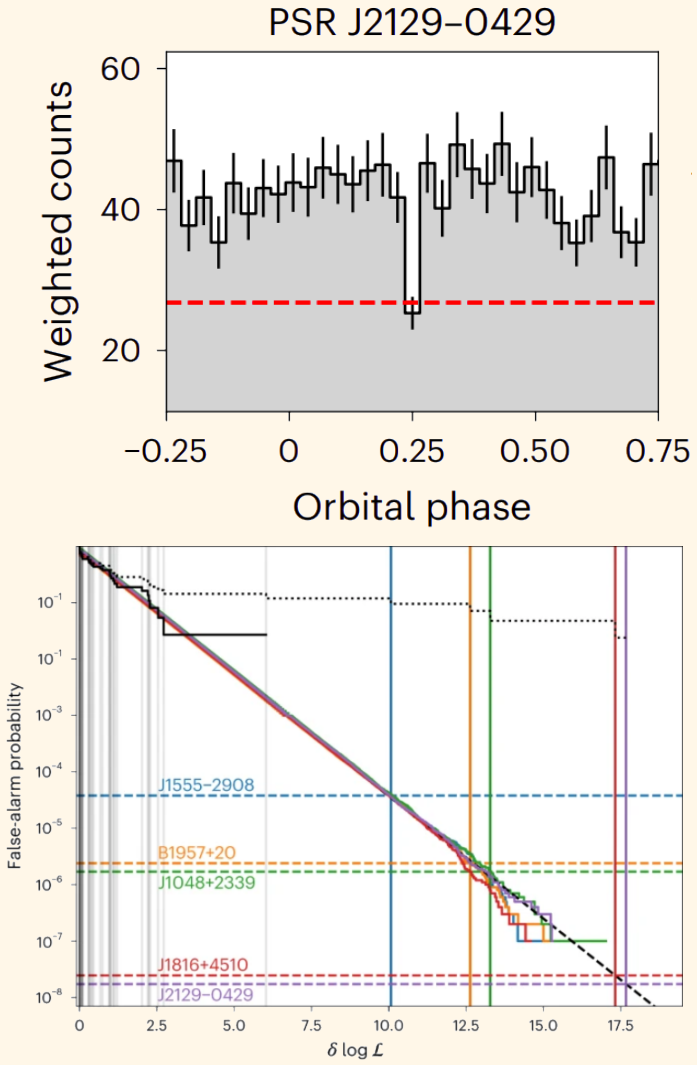


Update on spider binaries

Low mass companions. Two subtypes: red-backs and black-widows

45 systems detected at GeV, but none at TeV (yet). Inconclusive evidence for γ-ray intra-binary shock emission (GeV brightening?)

Timing precise enough for the detection of eclipses!



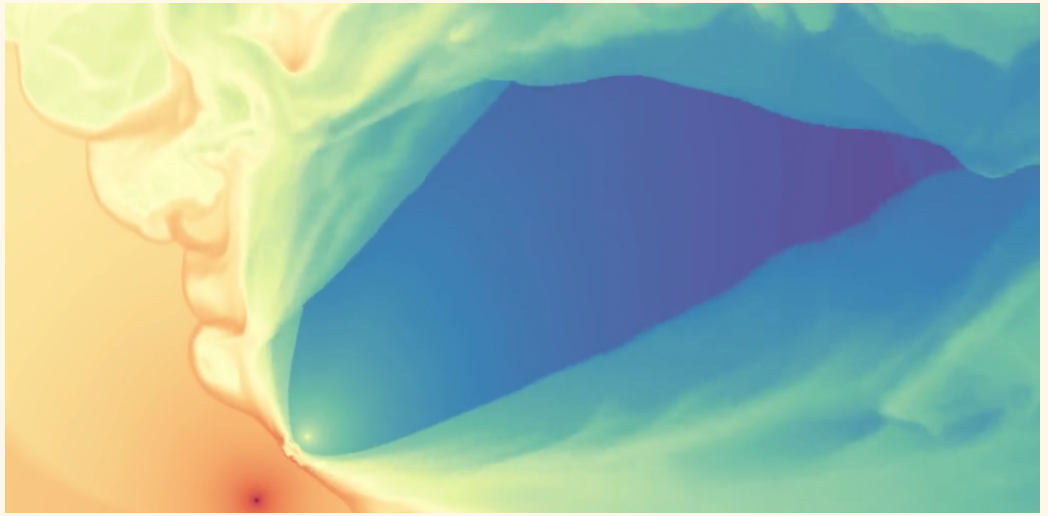
Credit: Clark et al. 2023, Nature Astronomy

Update on high-mass binaries

MWL view: γ-ray binaries seem to differ phenomenologically from microquasars (outbursts, energy-dependent correlations, radio ...)

Emission above 1 MeV, but the term γ-ray binaries is not used uniformly in the literature

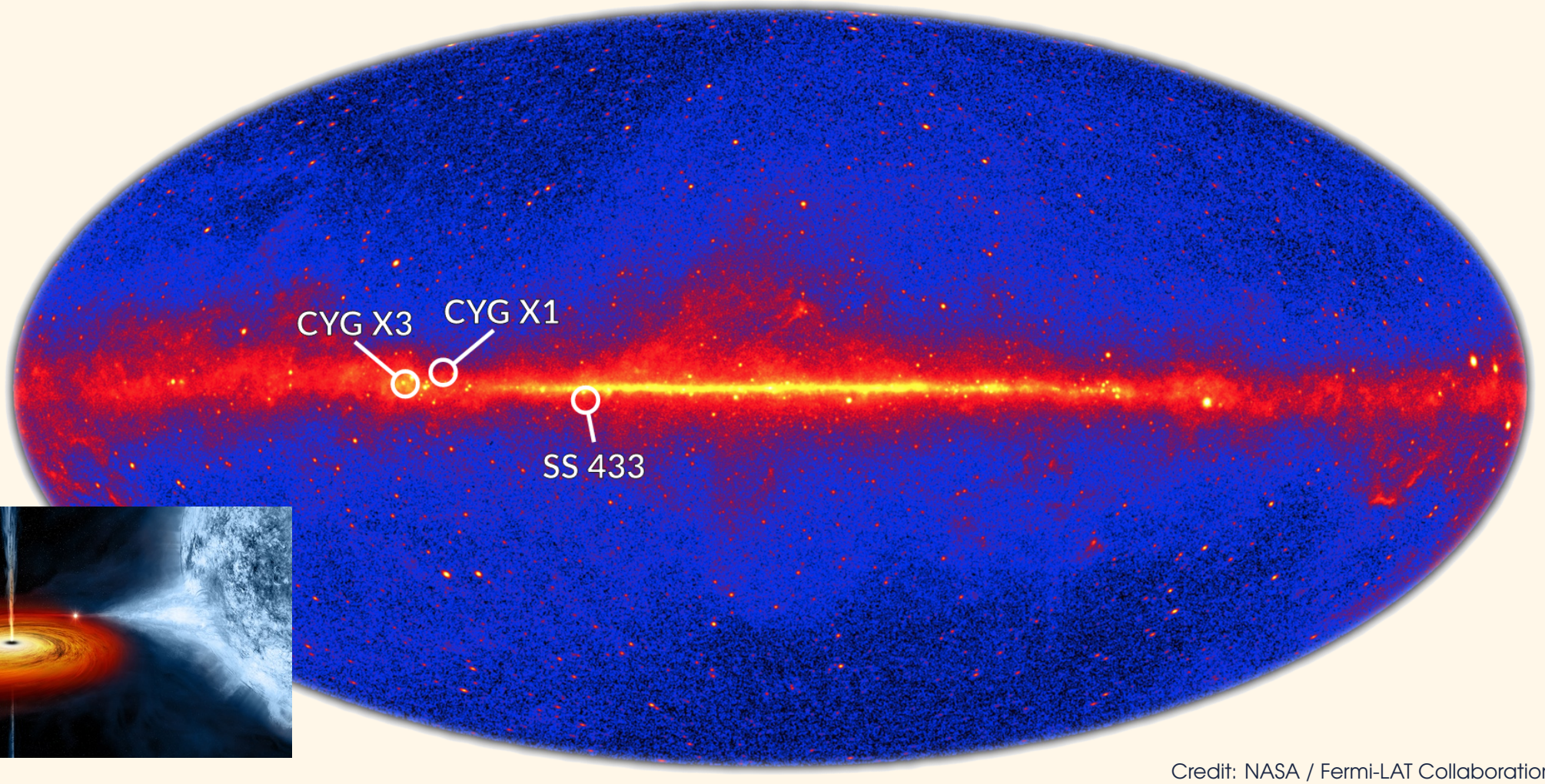
There appear to be some systems substantially less luminous in the GeV regime: HESS J0632+057 and HESS J1832-093



Credit: David Huber

Binaries in the Galactic Plane

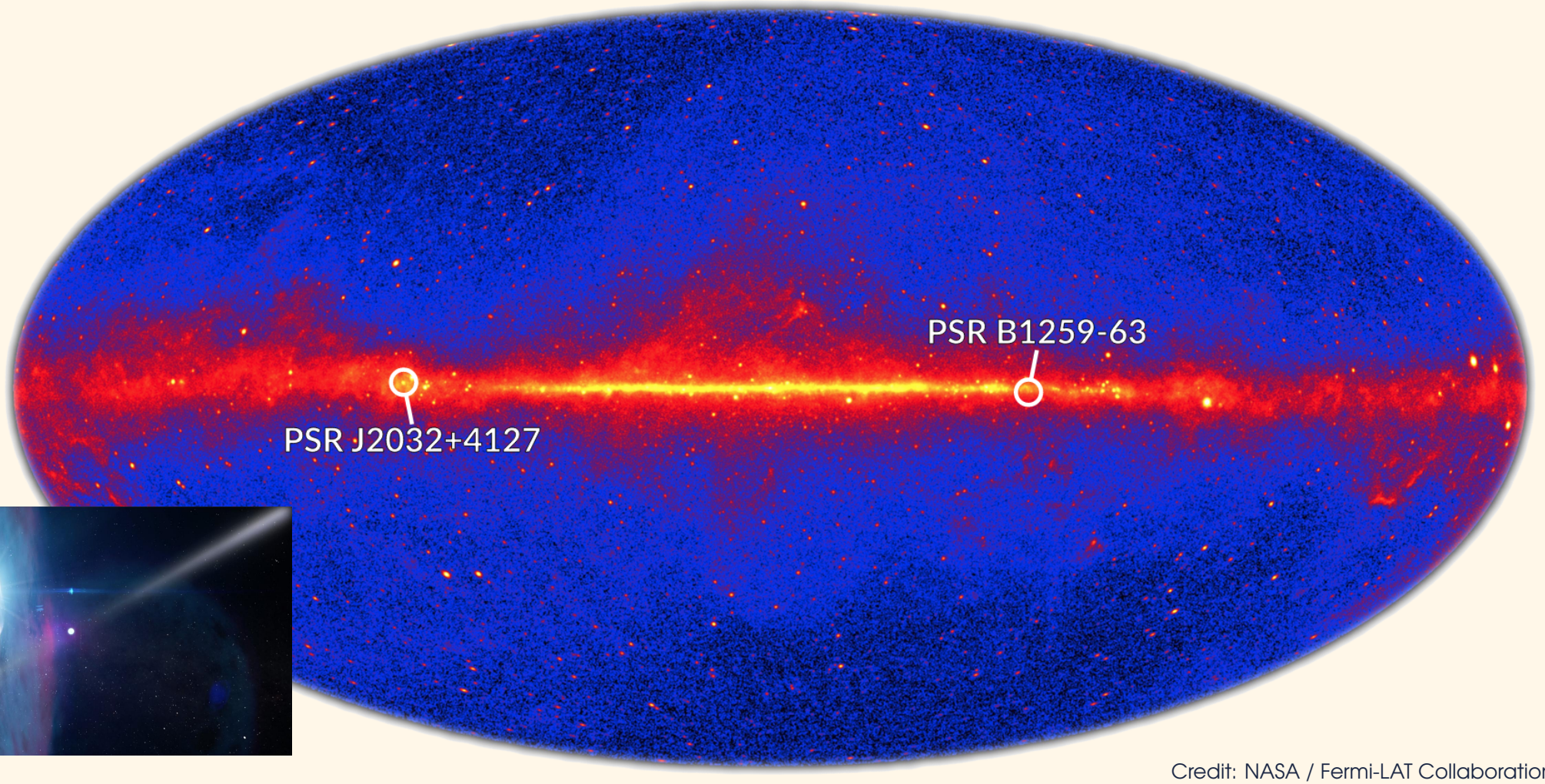
Microquasars



Credit: NASA / Fermi-LAT Collaboration / D. Huber

Binaries in the Galactic Plane

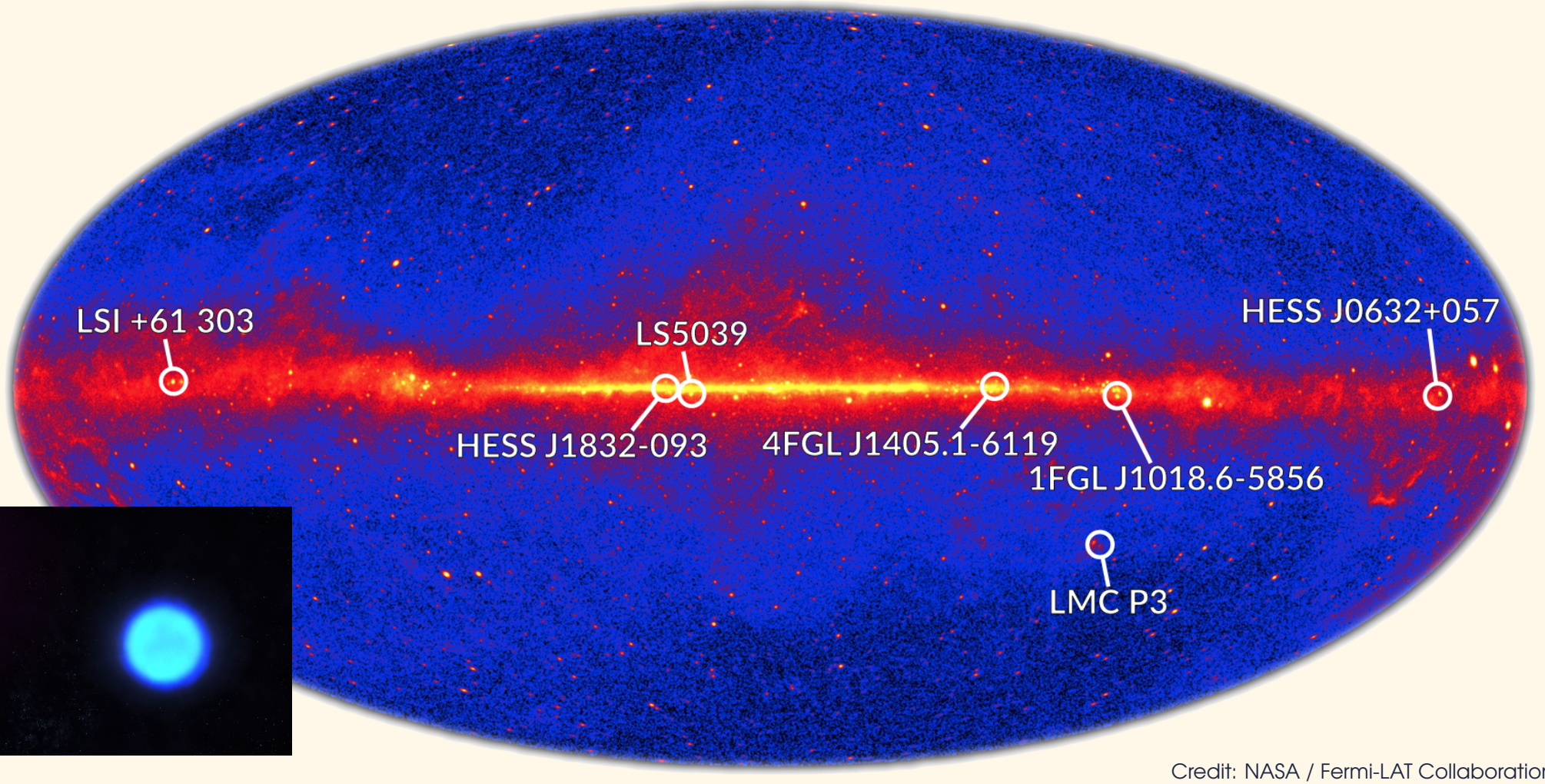
Long period binaries



Credit: NASA / Fermi-LAT Collaboration / D. Huber

Binaries in the Galactic Plane

Binaries with compact objects



Credit: NASA / Fermi-LAT Collaboration / D. Huber

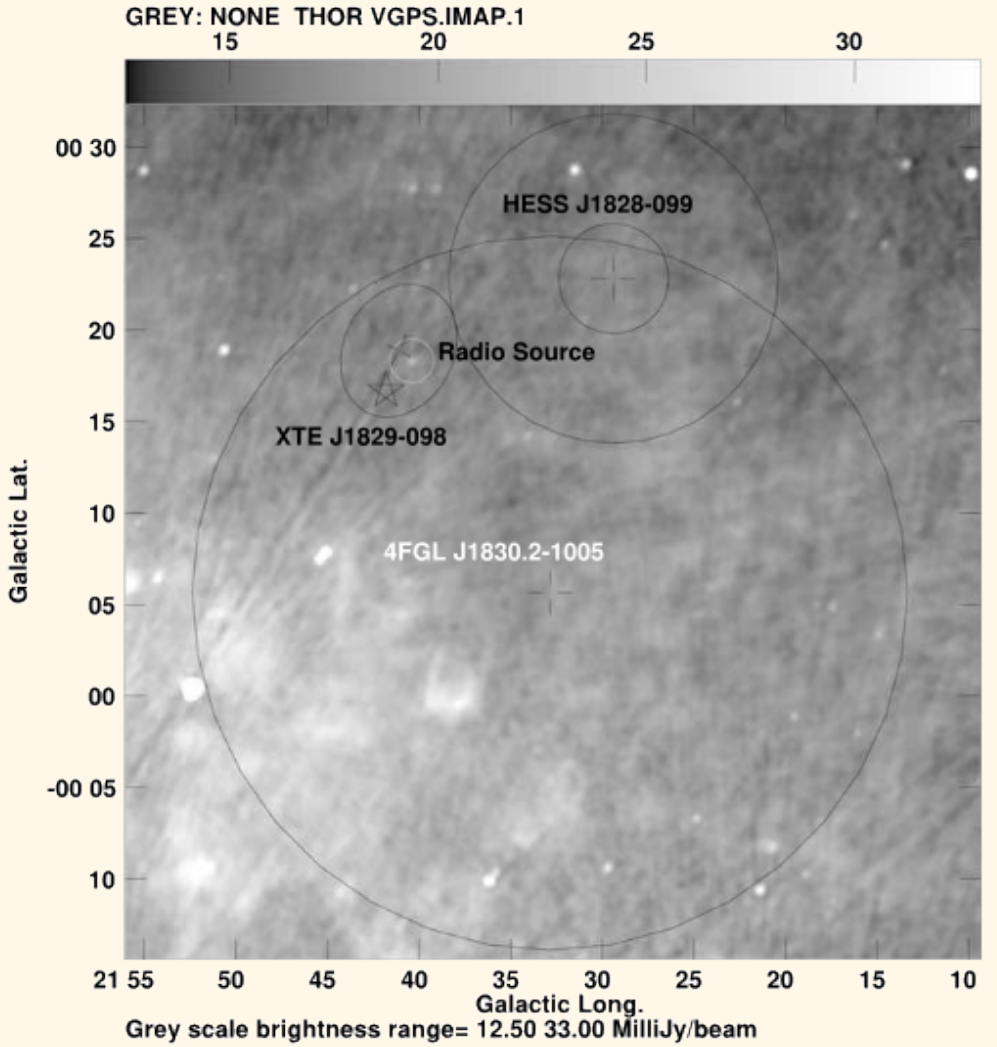
Is HESS J1828-099 a binary?

HMXB (7.8s pulsar + Be) marginally compatible with the point-like TeV source

Radio counterpart consistent with the X-ray source, but not TeV

Four outbursts in 11 years (with a suggested period of $\sim$ 246 d)

Proposed GeV extended (?) counterpart, likely too soft for a binary, no variability



De Sarkar et al. 2022


What we do not know

a) What are the different components in the GeV band?

b) Are HESS J0632+57-like systems common?

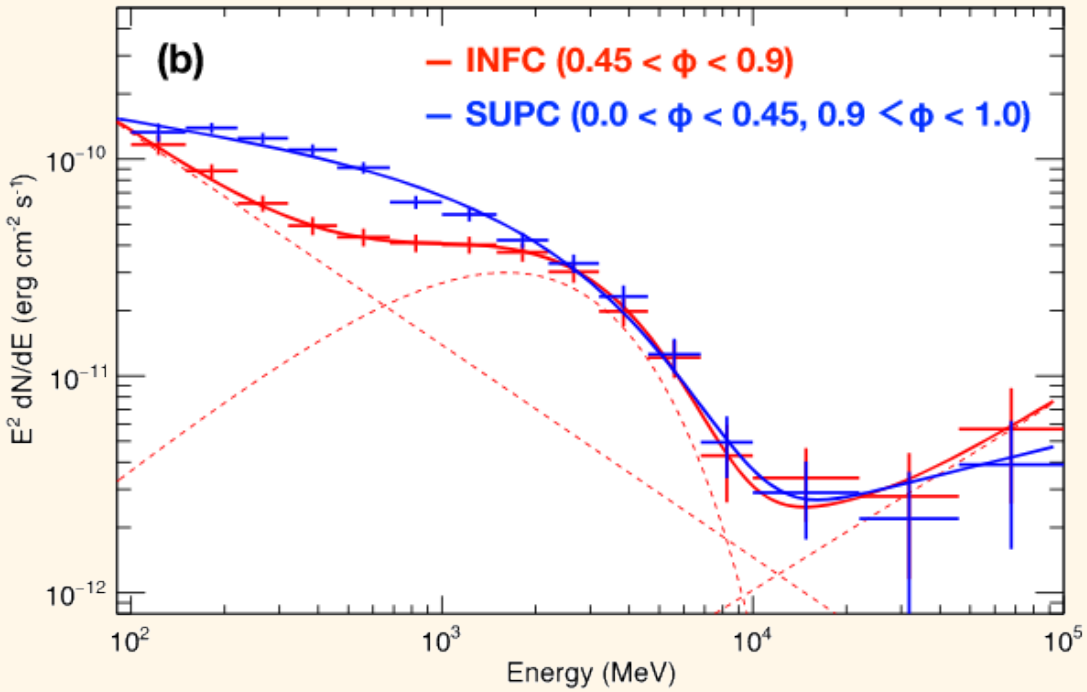
c) How many binaries remain unidentified in the GeV sky?

a) What are we detecting?

Are there two or three components?

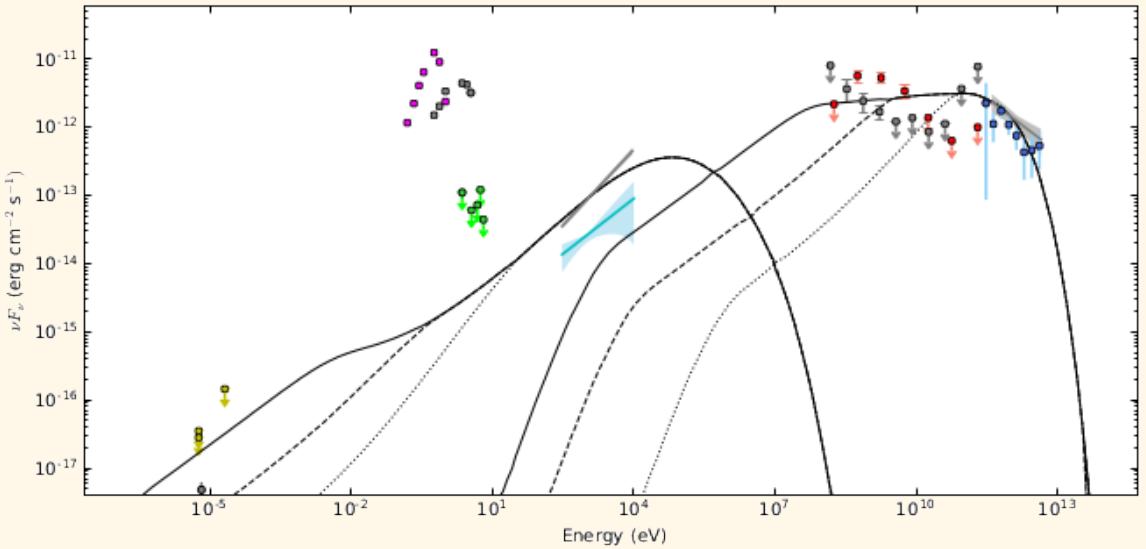
Evidence of non-orbital components in sections of the spectrum (e.g. Chen et al. 2016, Yoneda et al. 2021)

Need for additional, constant component at those energies? Magnetosphere? (e.g. Dubus et al. 2015, An & Romani 2017, Huber et al. 2021)



Yoneda et al. 2021

b) Do we have more GeV-faint binaries?



Martí-Devesa & Reimer 2020

A second GeV-faint binary identified:
HESS J1832-093 (Martí-Devesa & Reimer 2020)

HESS J0632+057-like systems will never be detected with current systematic searches

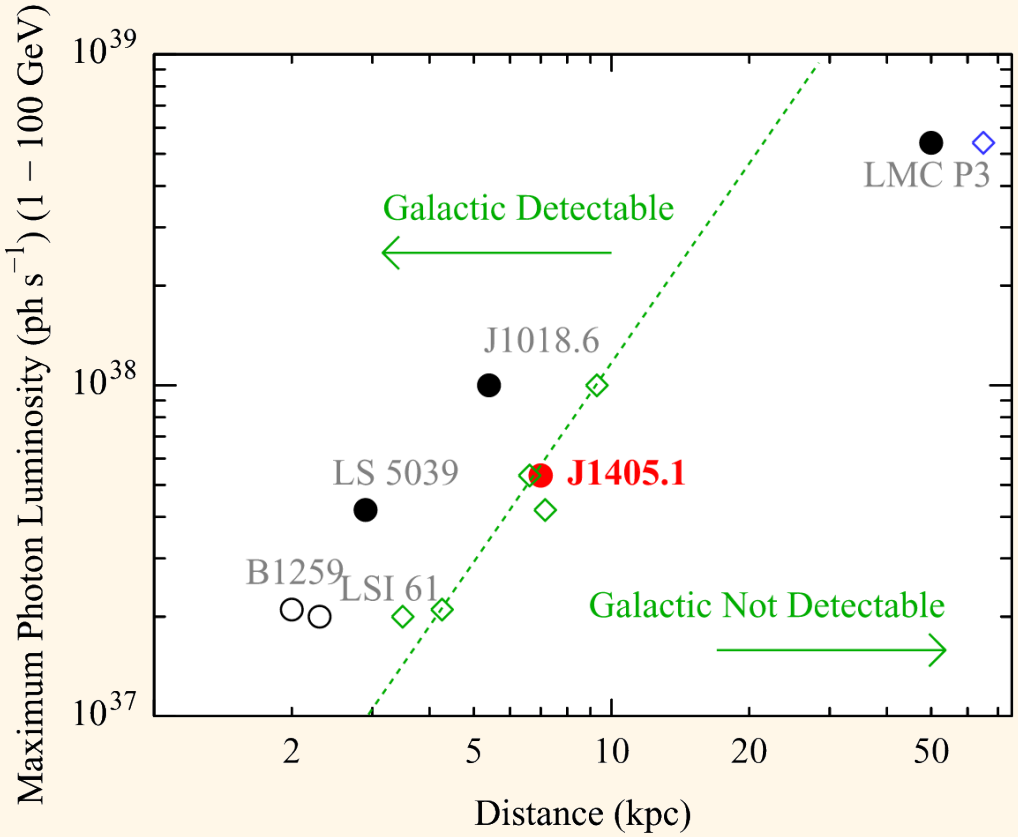
These systems represent the largest uncertainty in population studies (see Dubus et al. 2017)

c) How large is the population?

After the discovery of LMC P3, Corbet et al. 2016 suggested we got already all binaries

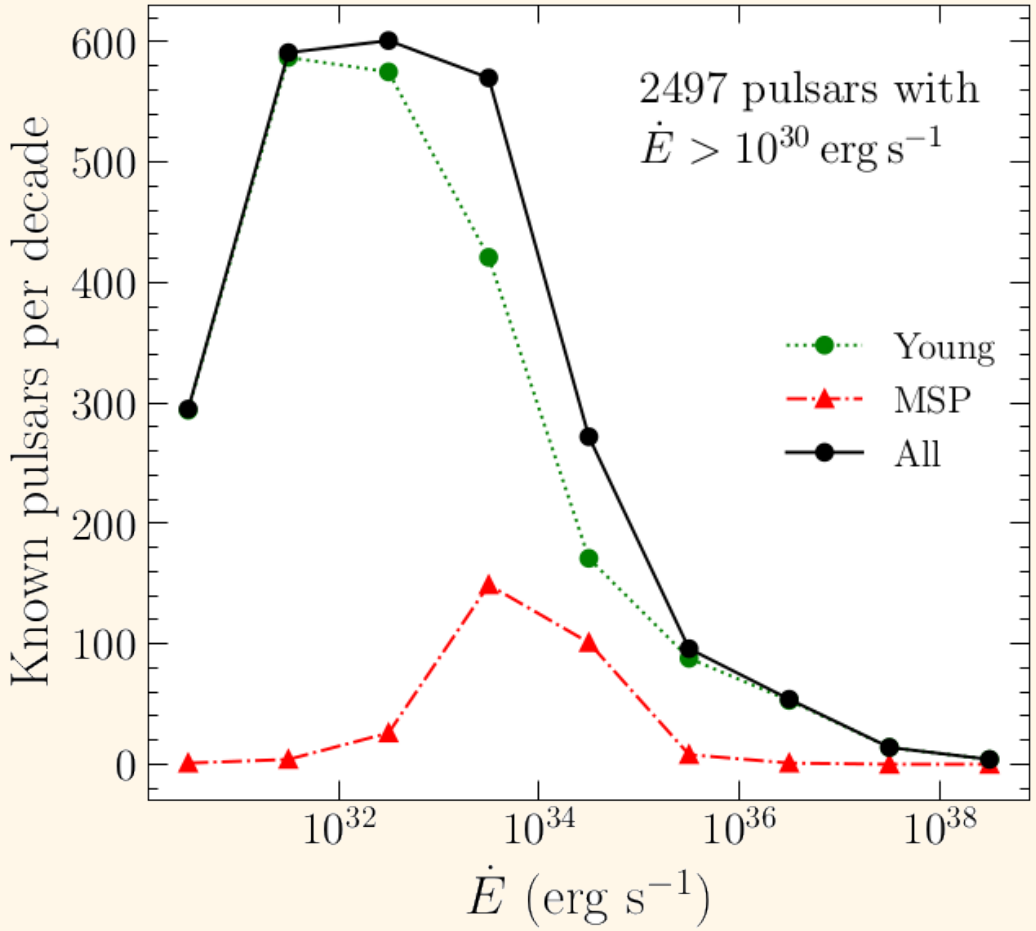
But they later detected 4FGL J1405.1-6110 (Corbet et al. 2019)

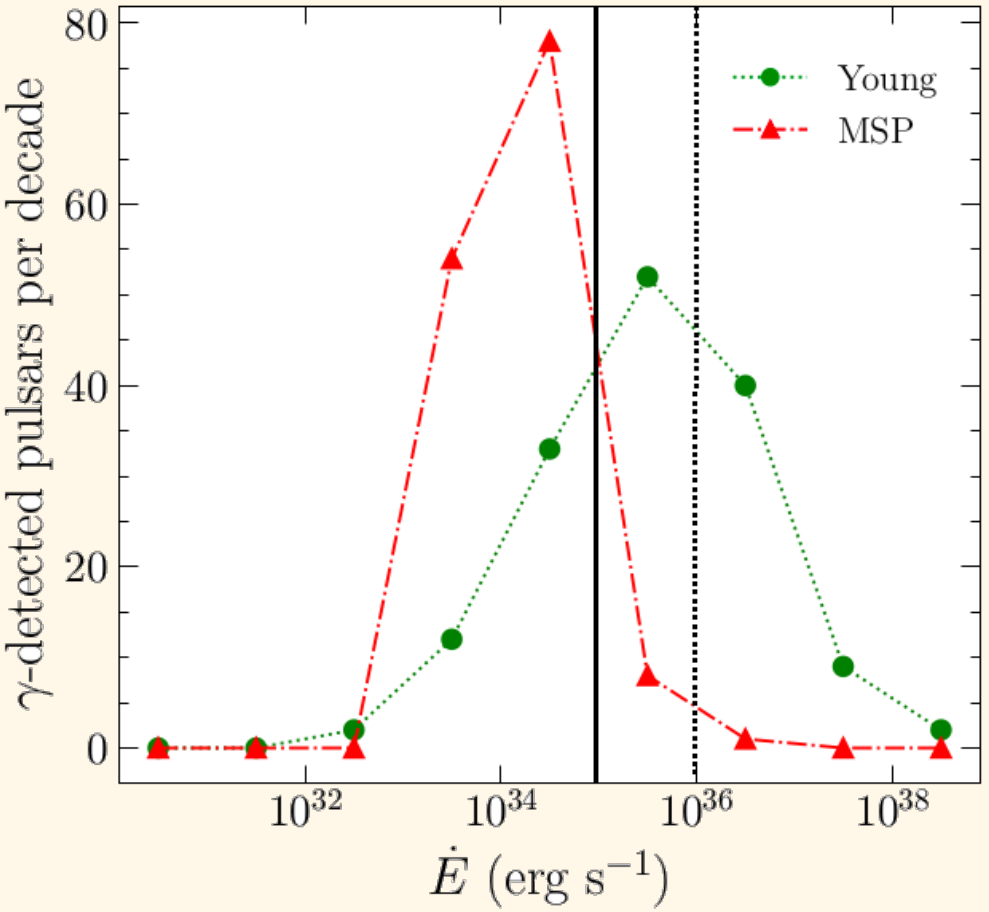
Alternative methods? Or how do we push down this limit? Do we expect more?



Corbet et al. 2019

On the parent young pulsar population





Adapted from Smith et al. 2023, submitted (3PC)

What we could try

Introducing variability in the likelihood calculation (Kerr 2019)

$$\log L = \sum_i \left[\log \sum_j \lambda_j(\Omega_i, E_i) - \sum_j \lambda_j(\Omega_i, E_i) \right] = \sum_i \left[\log \sum_j \lambda_{j,i} \right] - \sum_j \Lambda_j$$

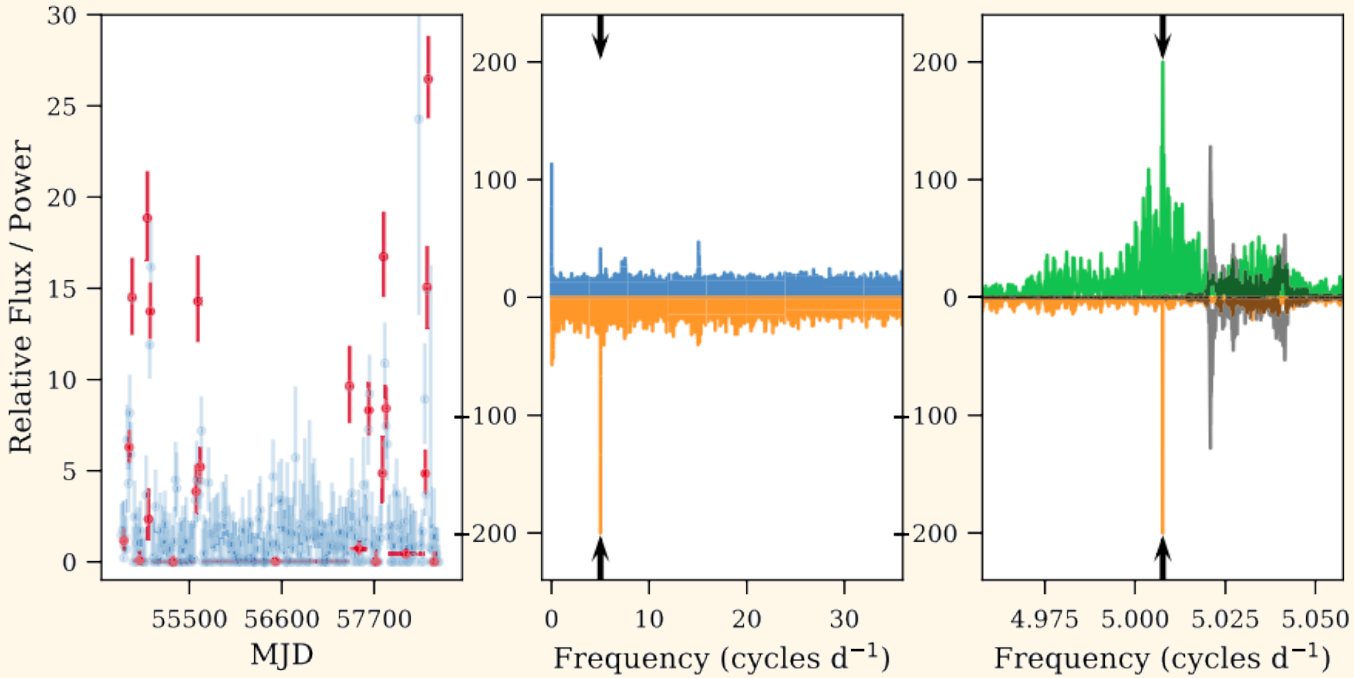
Typically, the weights $w_{j,i} = \lambda_{i,j} / \sum_j \lambda_{i,j}$ can be used to boost sensitivity in periodicity searches (Corbet & Kerr 2010)

Now consider that for some data segment P_k with fractional exposure f_k, the variability of a source is introduced as $\lambda_{j,k} = (1 + \alpha_{j,k})\lambda_j$

$$\log L_k = \sum_{i \in P_k} [\log(1 + \alpha_k w_i + \beta_k(1 - w_i))] - \alpha_k f_k \sum_i w_i - \beta_k f_k \sum_i (1 - w_i)$$

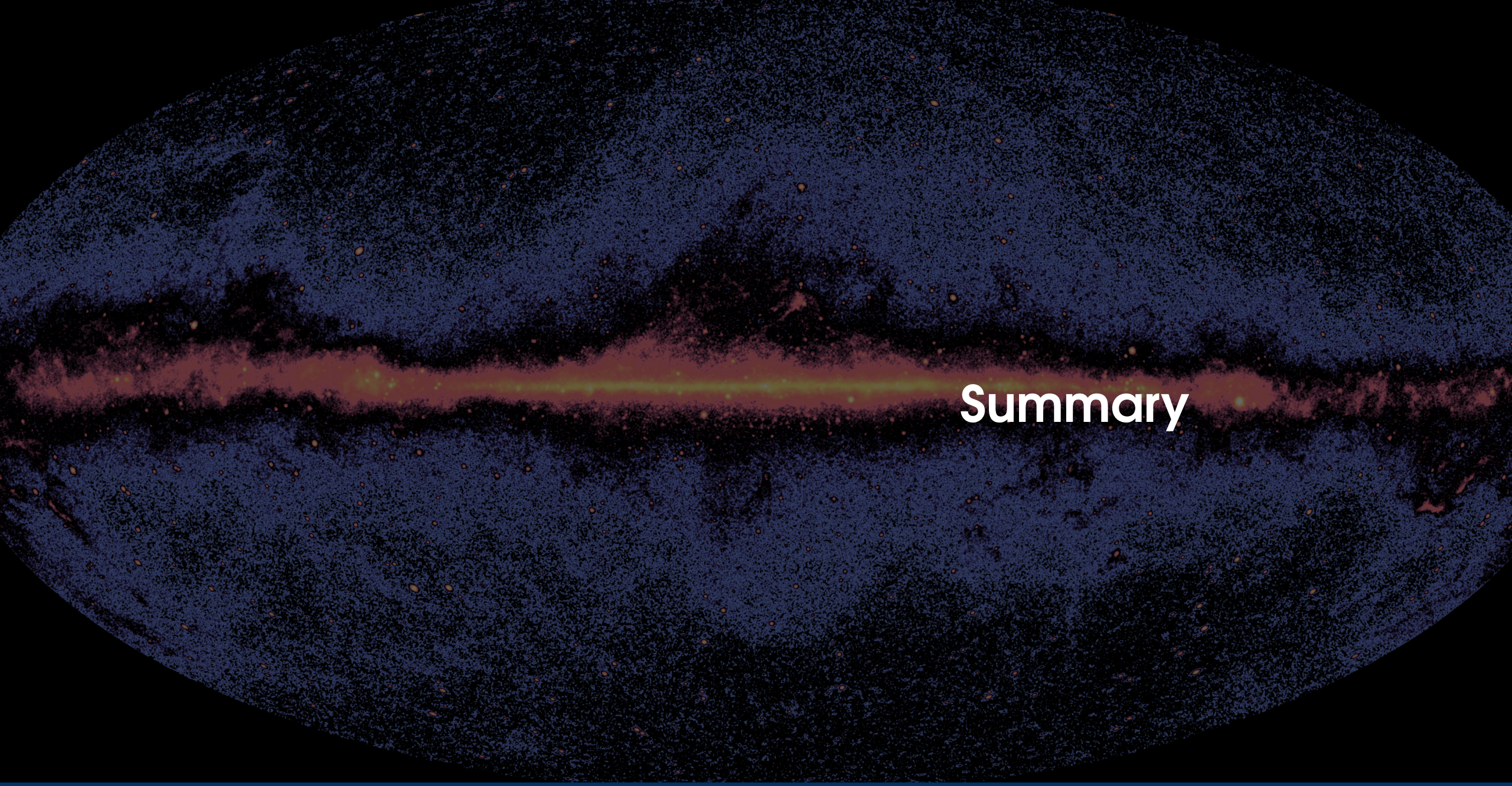
Advantages of this formulation

Flexibility on the assumption of $\alpha(t)$, can account for background fluctuations $\beta(t)$, computationally faster



Kerr 2019, ApJ

Ongoing work!



Summary