Needles in a Galactic haystack:
Tracking millisecond pulsars responsible for the Fermi GeV excess

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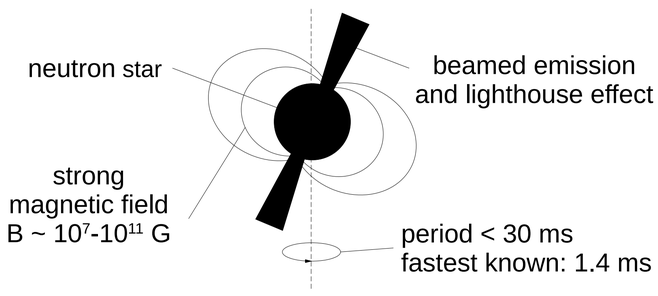
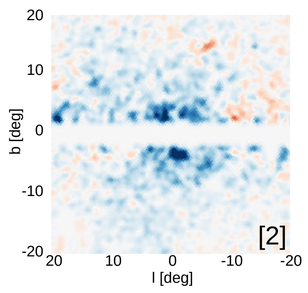
I. The Fermi GeV excess and the millisecond pulsar hypothesis

Millisecond pulsars (MSPs):



The Fermi GeV excess [1]:



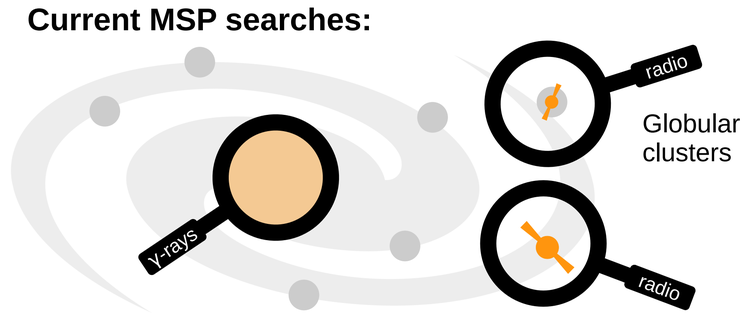
Fermi data - astrophysical background

↓

γ-ray excess in the Galactic bulge

Caused by MSPs?

Current MSP searches:

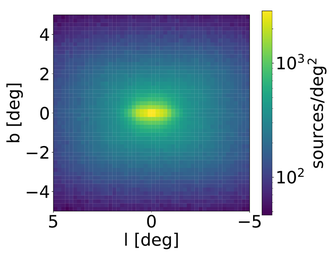


Bulge millisecond pulsars are hiding but some evidence encourages us to look for them.

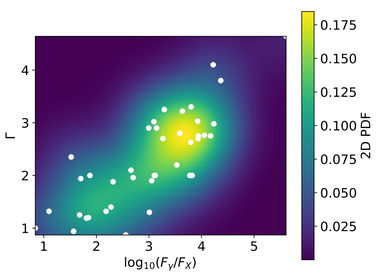
II. Simulation and X-ray detectability

Bulge MSP population Monte Carlo simulations [3]

1. Accounting for the excess:
- same morphology
- same γ-ray luminosity



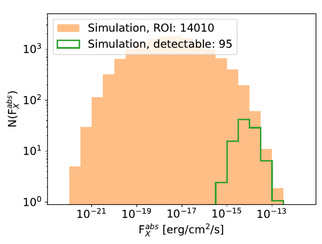
About 30,000 bulge MSPS



2. Empirical γ-to-X flux ratio:
- from known MSPs
- correlated with the spectral index

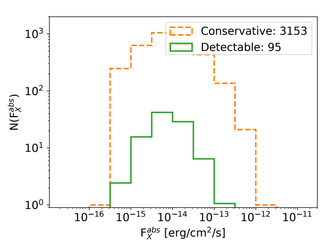
Could Chandra have detected this population?

Yes!



About a hundred in 6°×6° around the Galactic center

Is this compatible with the latest Chandra source catalog?



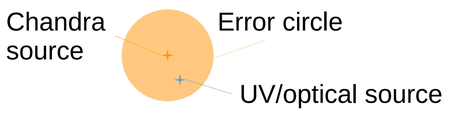
Conservative selection of MSP-compatible sources:
- non extended
- non variable
- power-law spectrum

The MSP hypothesis is not excluded by X-ray data.

III. Promising candidate selection

MSP-compatible Chandra sources with [4]...

1. ...neither UV nor optical counterpart

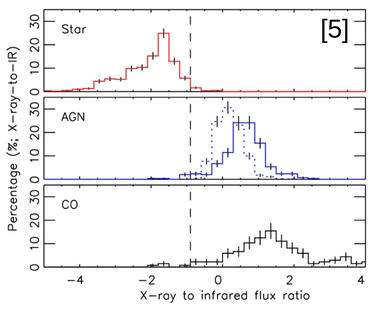


Excluded **Excluded** **Excluded** **Kept**

2. ...no IR counterpart or a faint one

Compact objects [5]:
$\log_{10}(F_X/F_{IR}) > 0.5$

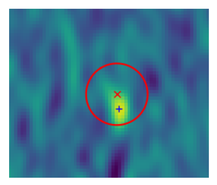
About 40 compact objects found



3. ...or a radio counterpart

- Unpublished VLA images
- PyBDSF algorithm
- 1400 MHz flux

10 sources only detected in radio and X-rays



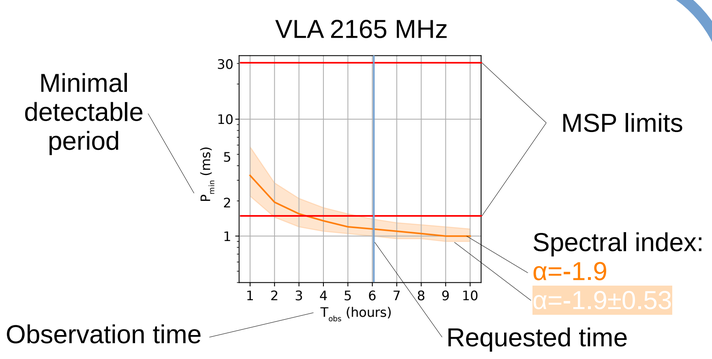
More than 50 MSP candidates are promising enough for follow-up studies.

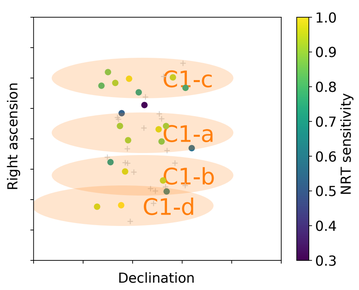
IV. Radio follow-up

1. VLA-Chandra candidates

Predicting the optimal observation time to undoubtely confirm the MSP nature with:
- Parkes (Australia)
- GBT (USA)

ABOUT 55 HOURS OF OBSERVATION GRANTED!





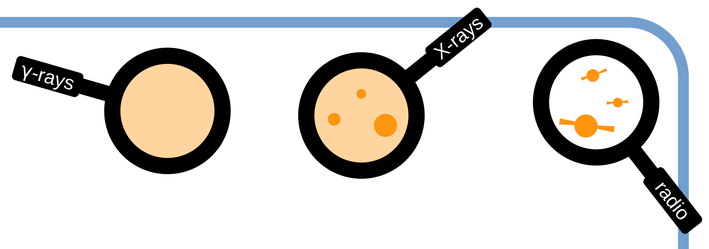
2. Clustered candidates from deep Chandra pointings

Optimizing the observation strategy with the NRT (France):
- Cover the maximum number of candidates
- In a minimum amount of time
- With a maximal sensitivity

ABOUT 18 HOURS GRANTED!

Work in progress. Preliminary results are encouraging!

Conclusion and perspectives



- We found many bulge MSP candidates using multiwavelength data.
- Radio observations will conclusively adjudicate on their pulsar nature.
- If not pulsars, then what are they?

- Multimessenger astronomy (Einstein Telescope [6], CTA [7]) will also help solving the GeV excess mystery in the future.

References

[1] Simona Murgia, Annu. Rev. Nucl. Part. Sci. 2020.70:455-483
[2] Francesca Calore *et al,* JCAP03(2015)038
[3] **Joanna Berteaud** *et al,* Phys. Rev. D 104, 043007
[4] **Joanna Berteaud** *et al,* PoS(ICRC2021)681
[5] Dacheng Lin *et al*, ApJ 756 27
[6] Francesca Calore *et al,* Phys. Rev. Lett. 122, 081103
[7] Oscar Macias *et al,* MNRAS 506, 1741–1760

Acknowledgements

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