X-ray observations and the search for Fermi-LAT gamma-ray pulsars

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for the Fermi-LAT Collaboration

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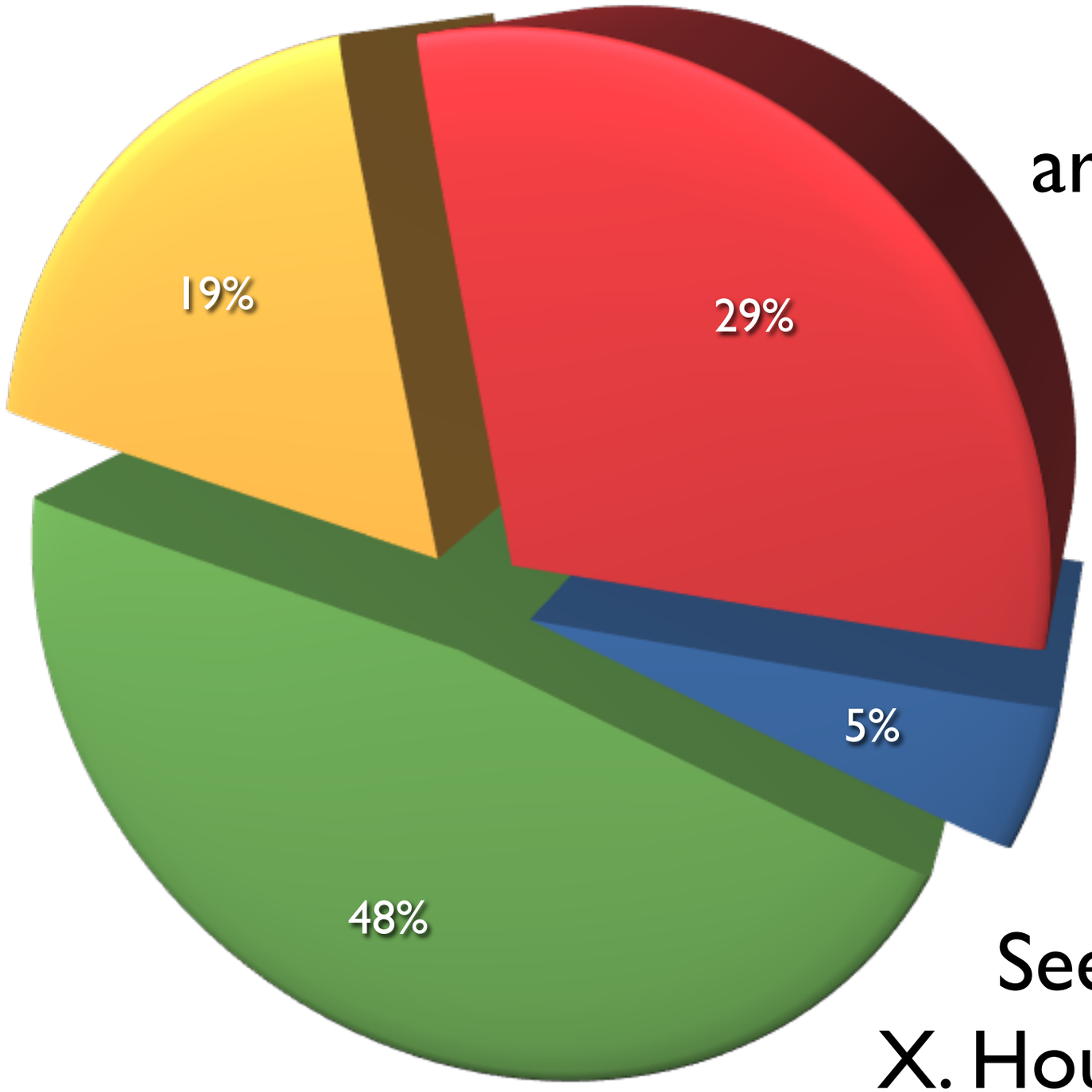
- LAT Collaboration
- Pulsar Timing and Search Consortia ... in particular all our radio colleagues!
- The conference organizers

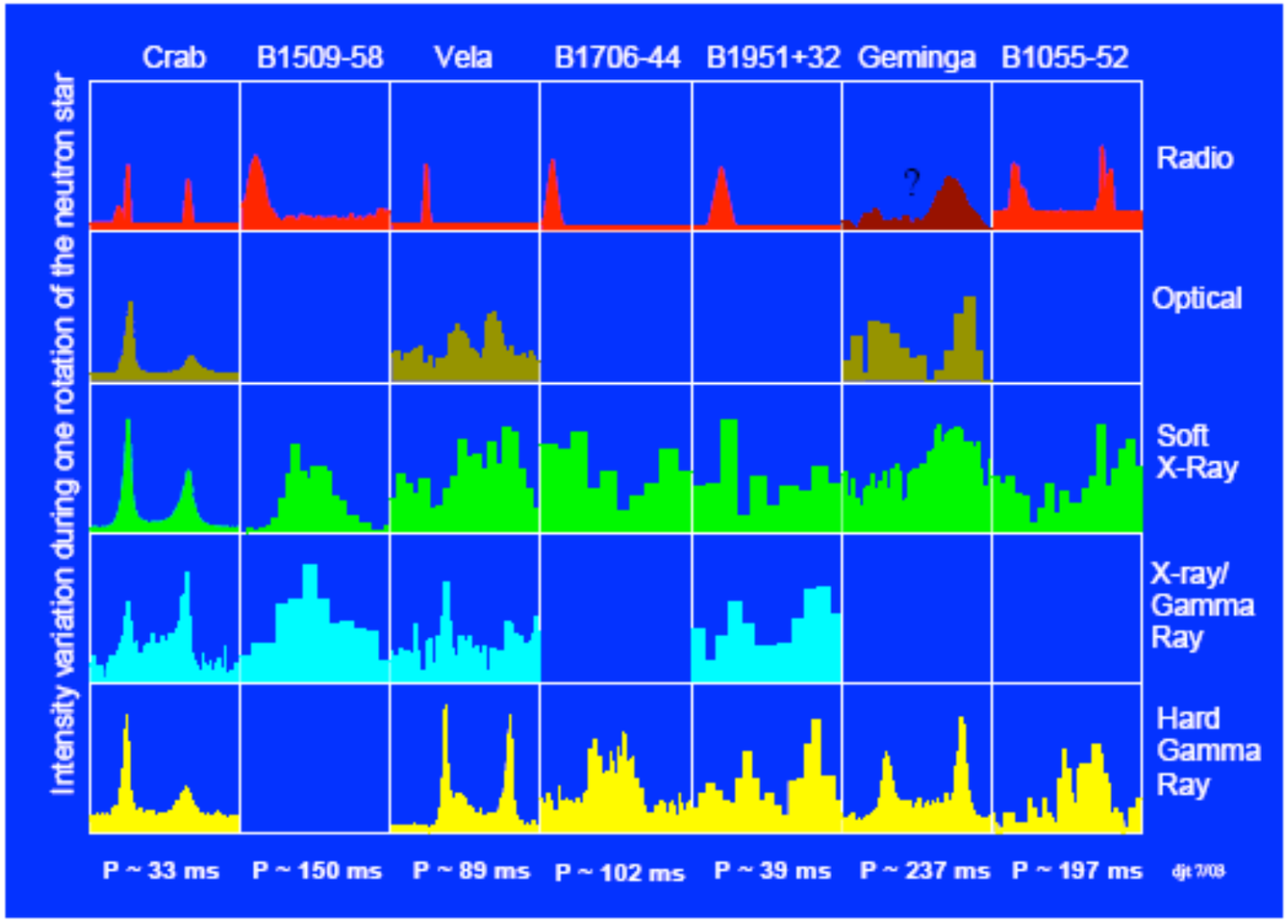
The gamma-ray pulsar pie



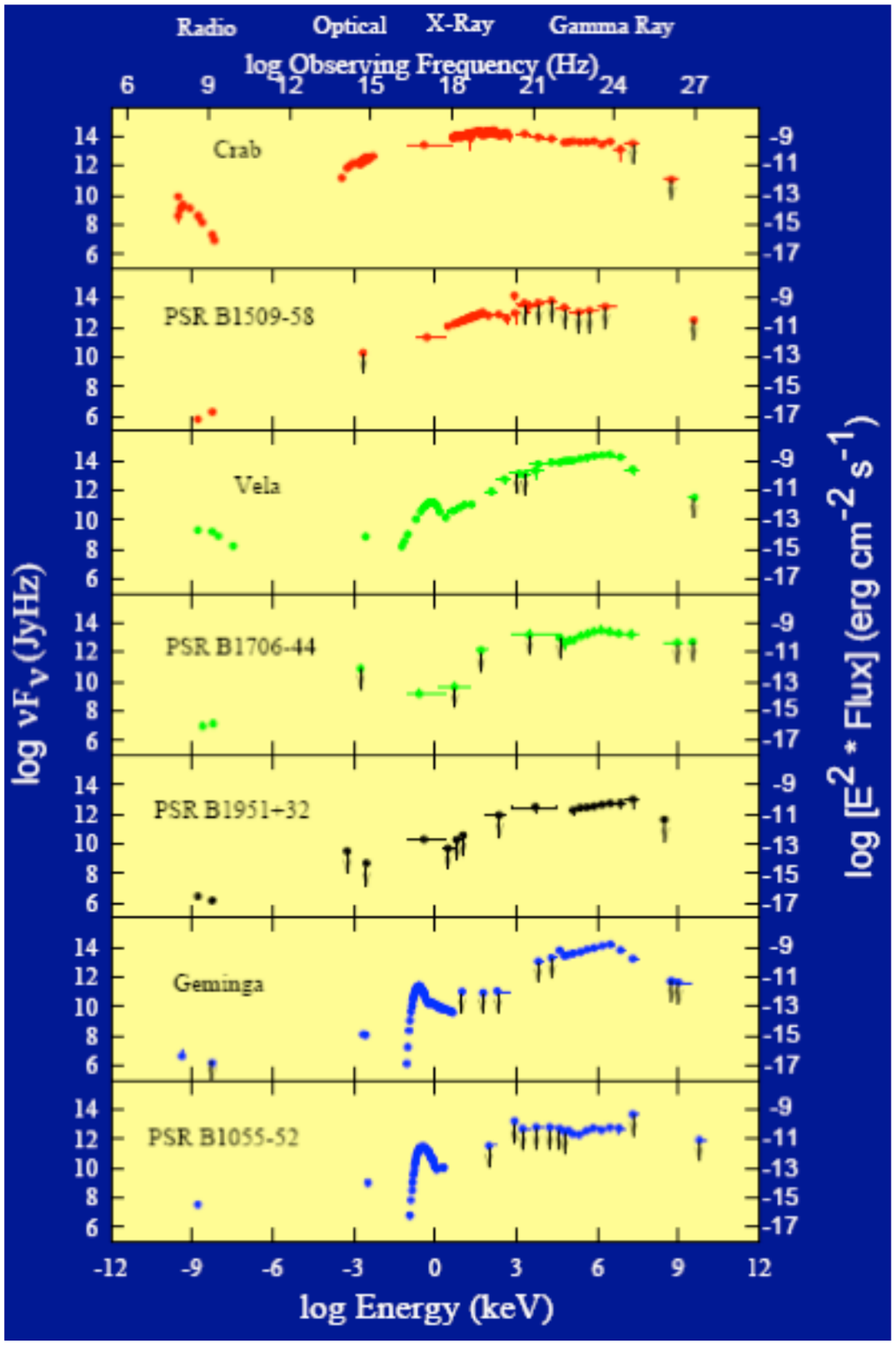
See 2PC:
arXiv:1305.4385

See poster by
X. Hou & D. A. Smith
on the latest PSUE
discoveries

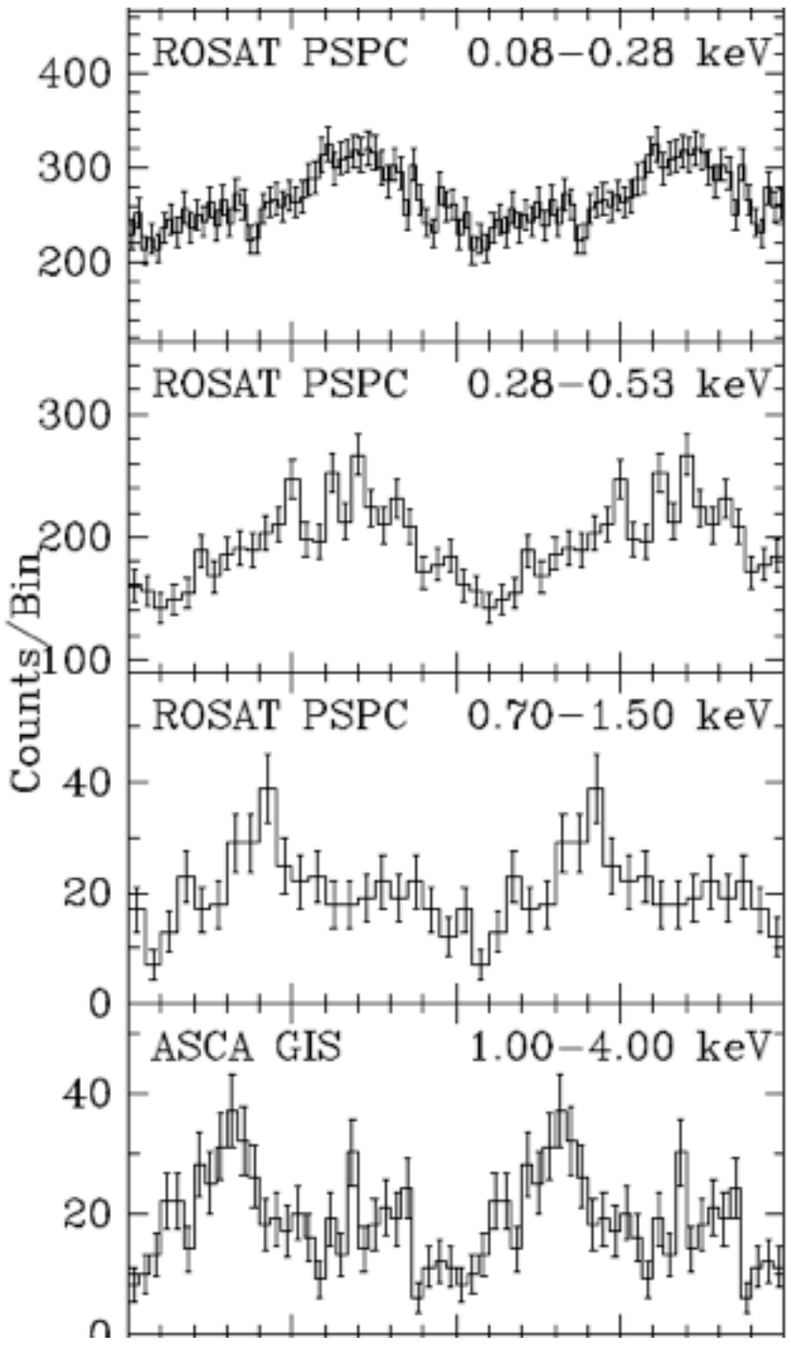
The multi-wavelength nature of pulsars



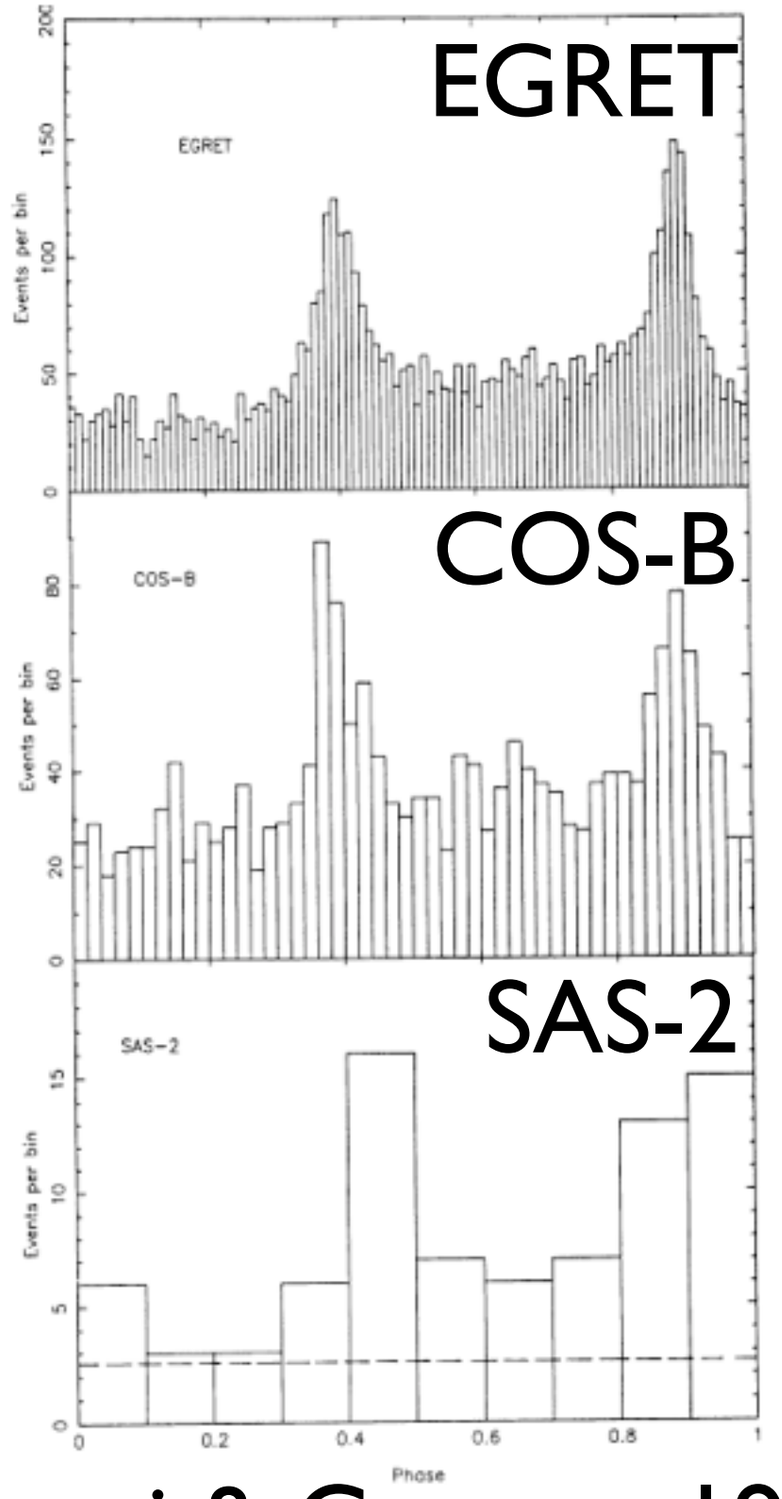
Credit: Thompson 2004



G-ray⟶X-ray ⟶ G-ray: Geminga

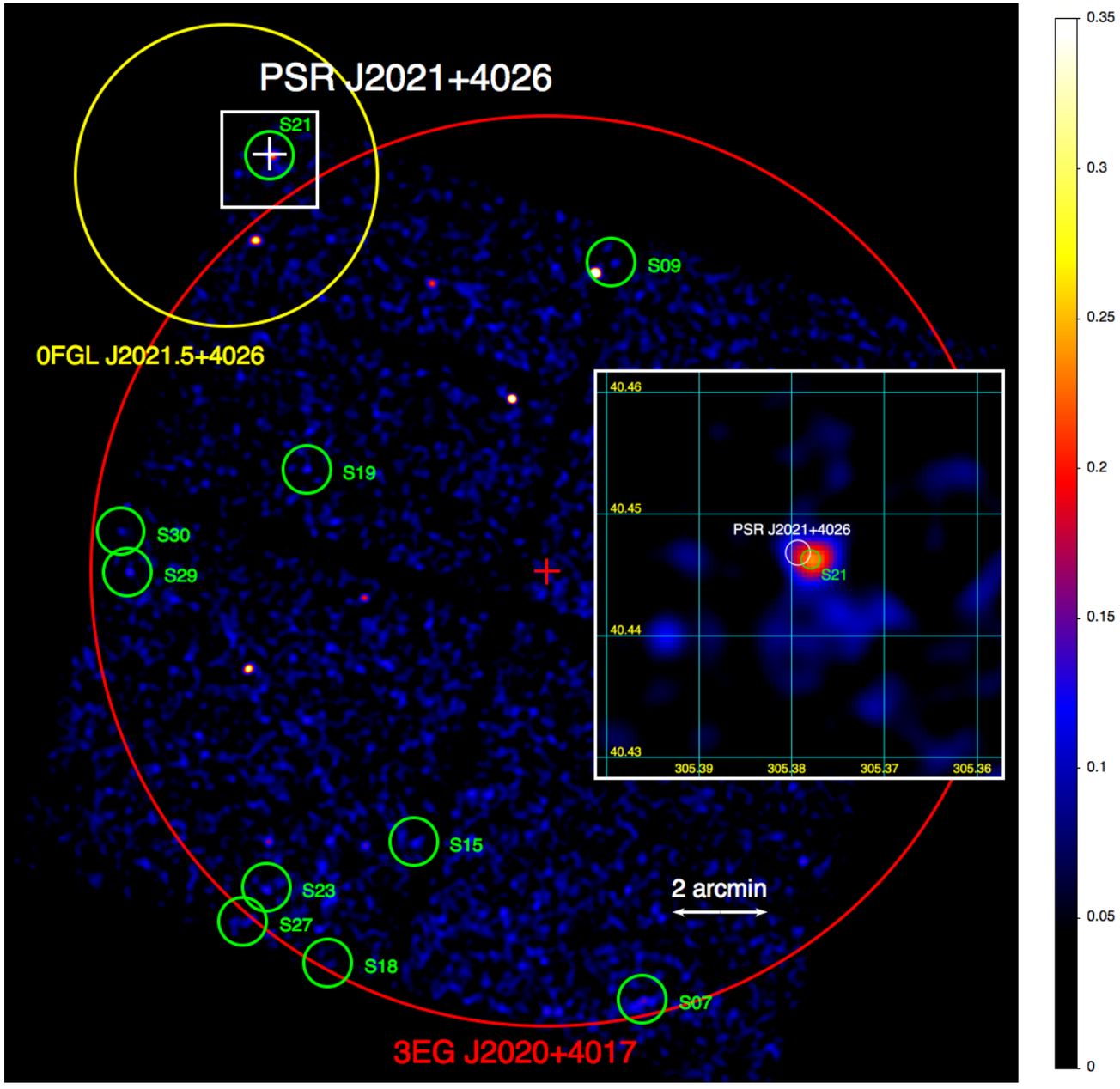


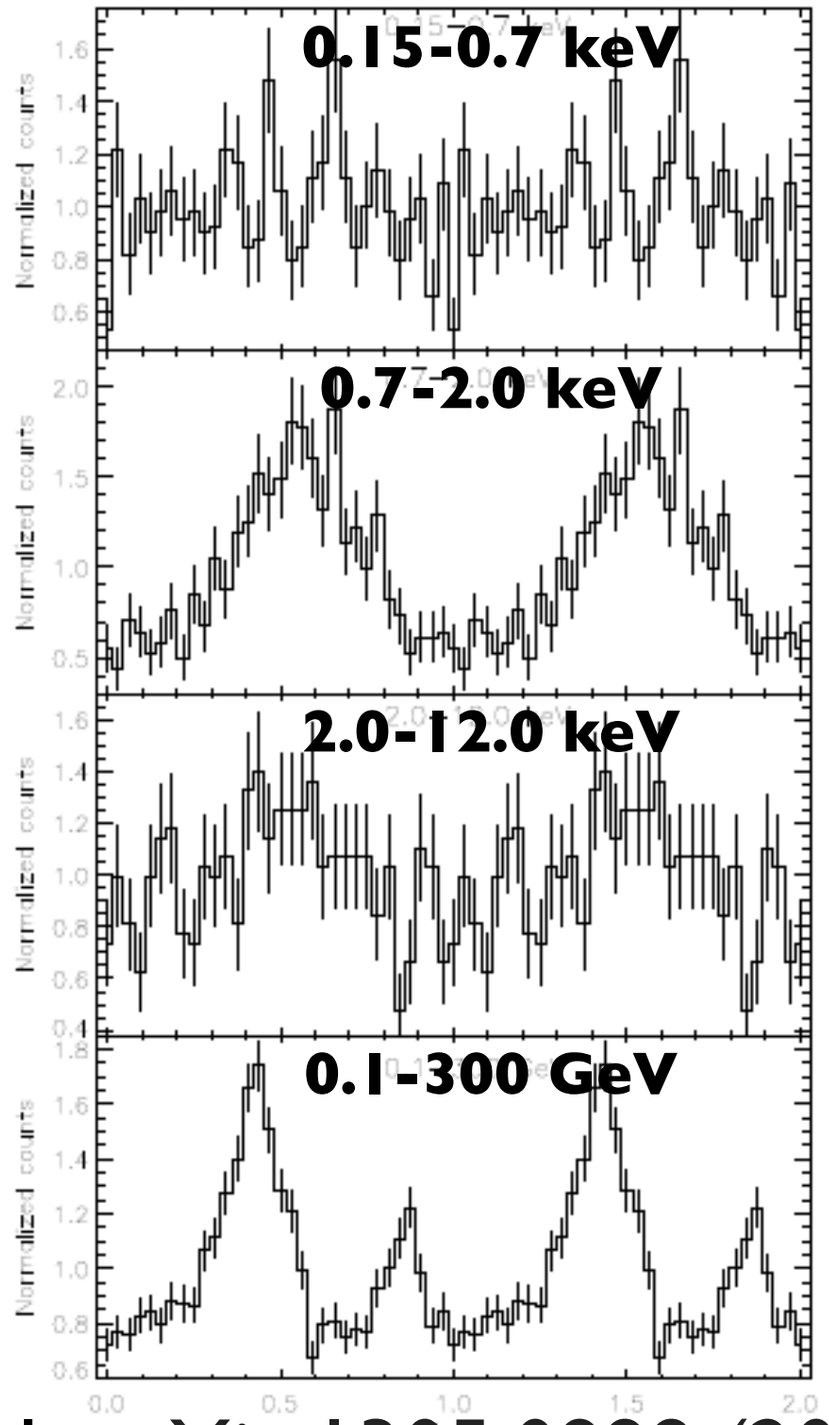
Halpern & Holt 1992
Halpern et al. 1997



Bignami & Caraveo 1992
Mattox et al. 1992

X-ray→ Gamma-ray →X-ray: The Gamma Cygni pulsar



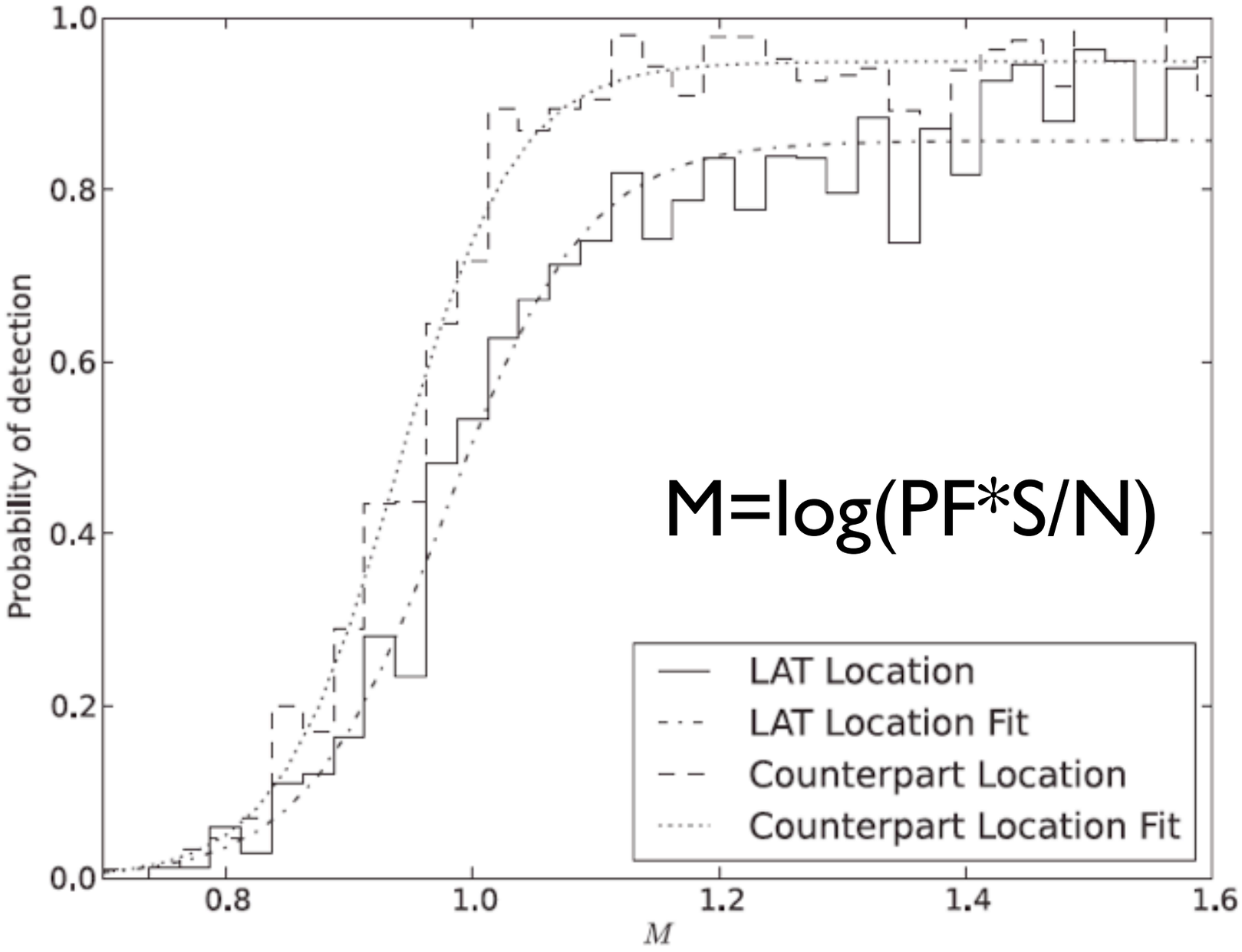


Abdo et al. *Science* **325**, 840 (2009)

Weisskopf et al. (2011)

Lin et al., arXiv:1305.0998 (2013)

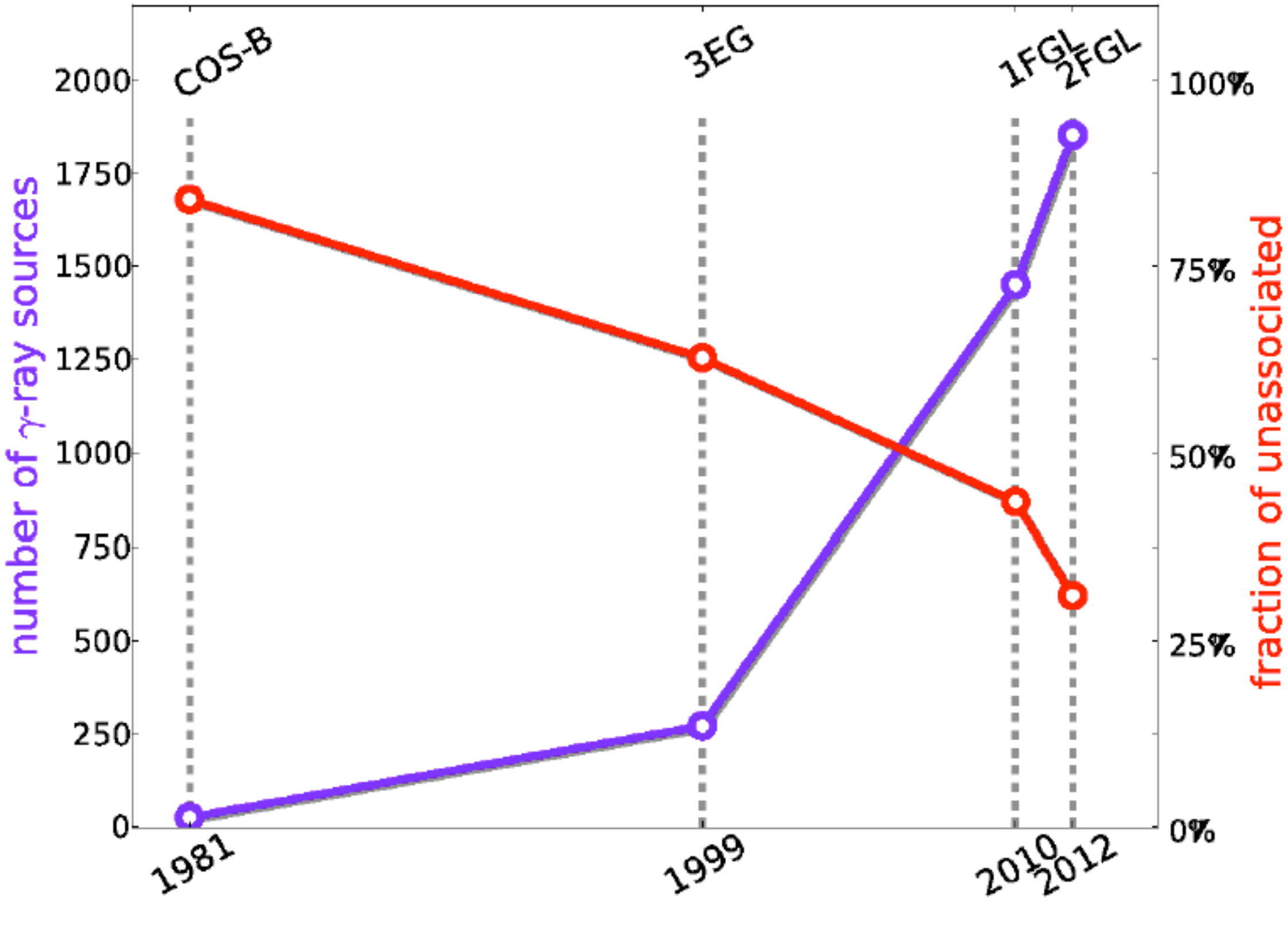
Improvement in sensitivity using X-ray counterparts



M=log(PF*S/N)

Dormody et al. 2011

Potential gamma-ray pulsars



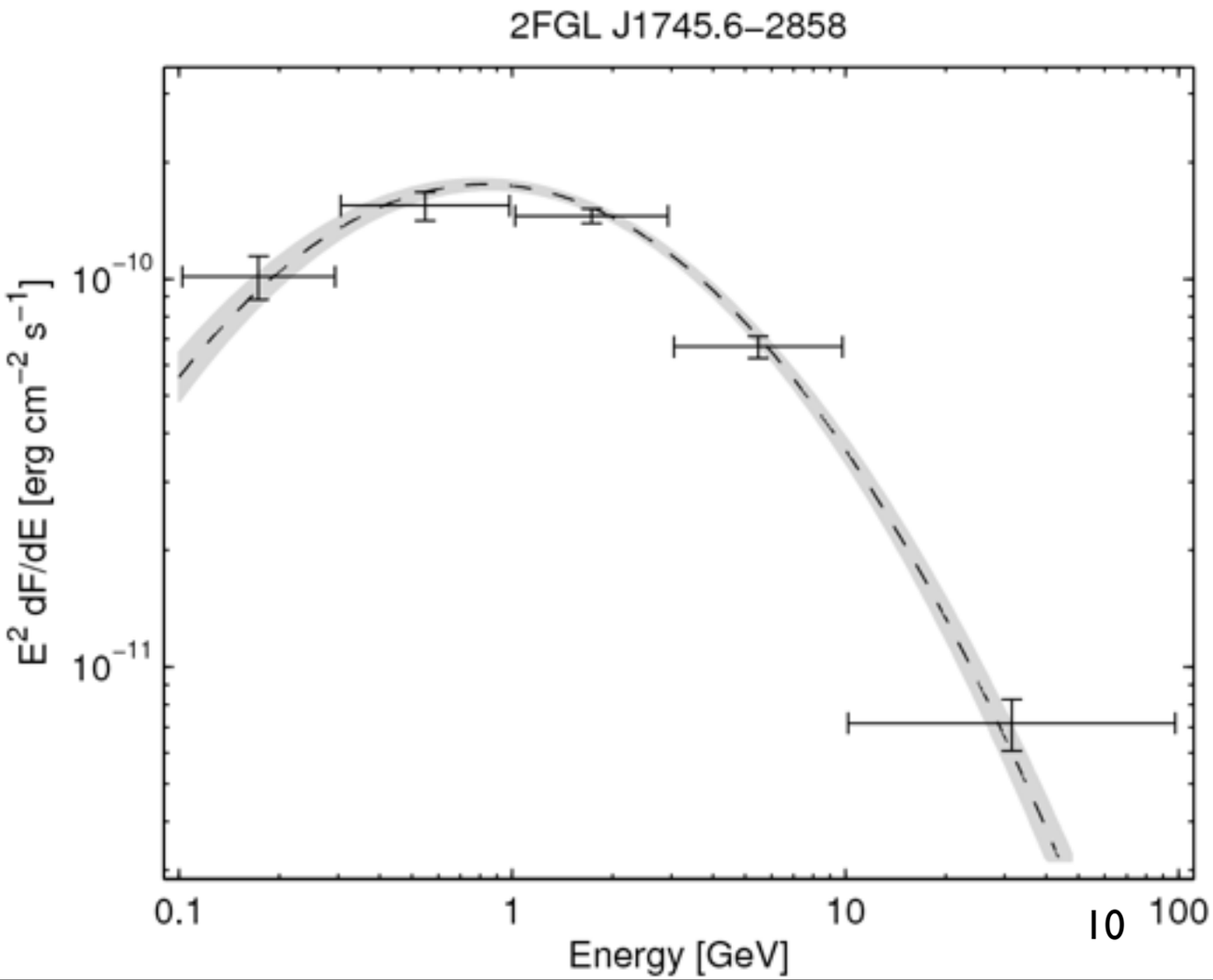
What about 0FGL?
(aka The Bright Source List)

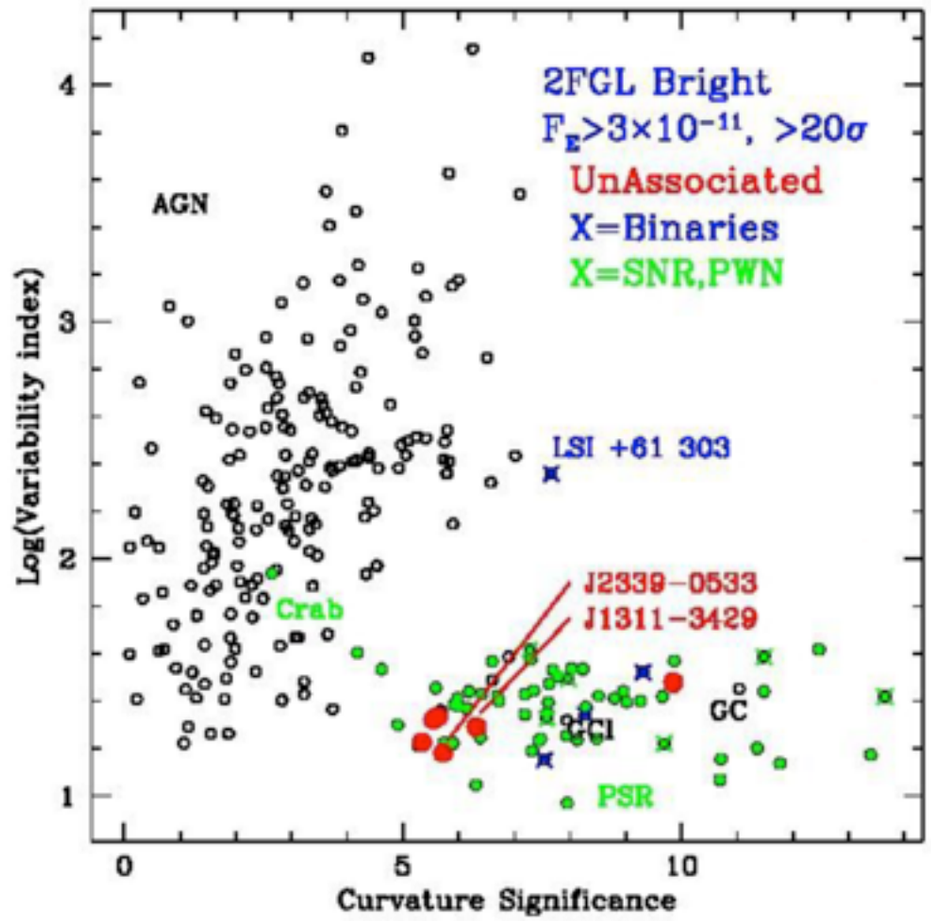
- 205 sources at > 10 sigma (in 3 months)
- Only ~5% unassociated sources left
- 53 (25%) 0FGL sources associated with pulsars
  - 75% young pulsars ... of which:
    - 60% radio-quiet and 40% radio-loud
  - 25% MSPs (all radio-loud)

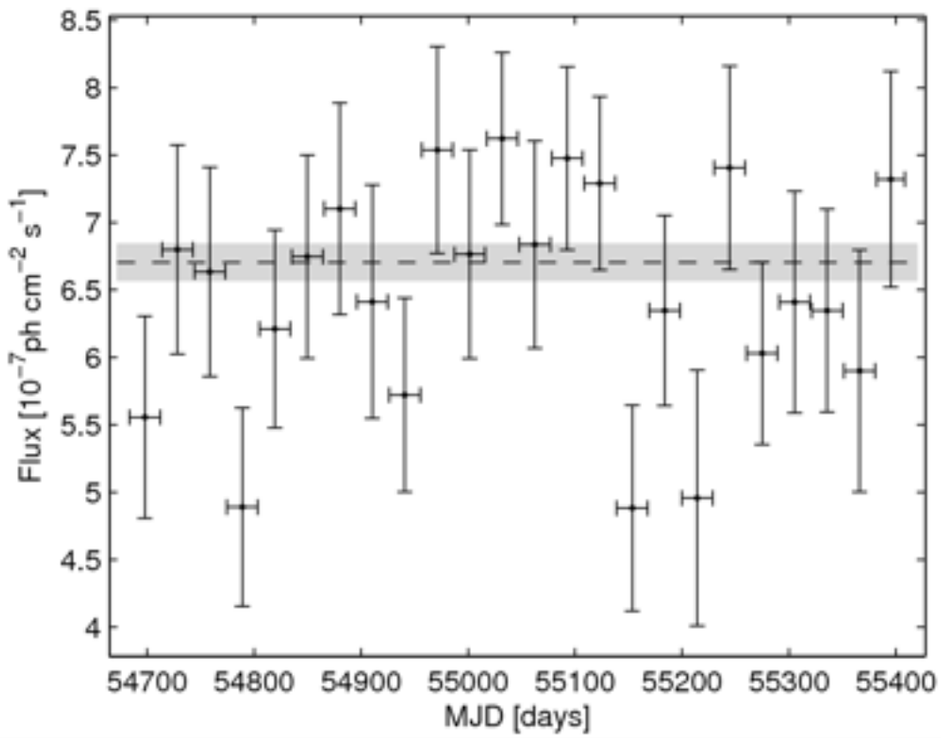
Conclusion: Not many (if any) radio-quiet MSPs out there!

Best gamma-ray PSR candidates

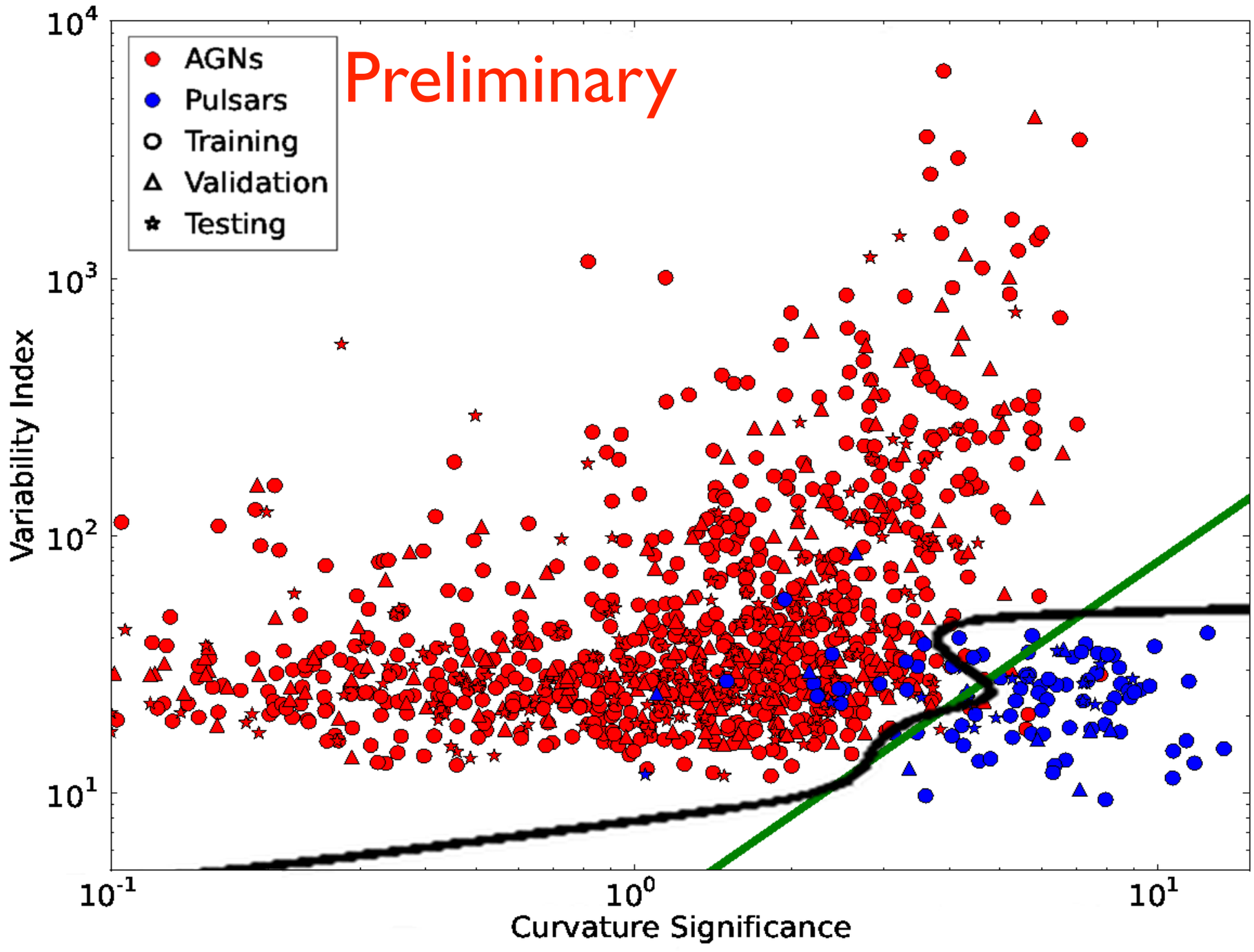
- Bright/Significant
- Curved Spectrum
- Non-variable
- Promising X-ray counterparts







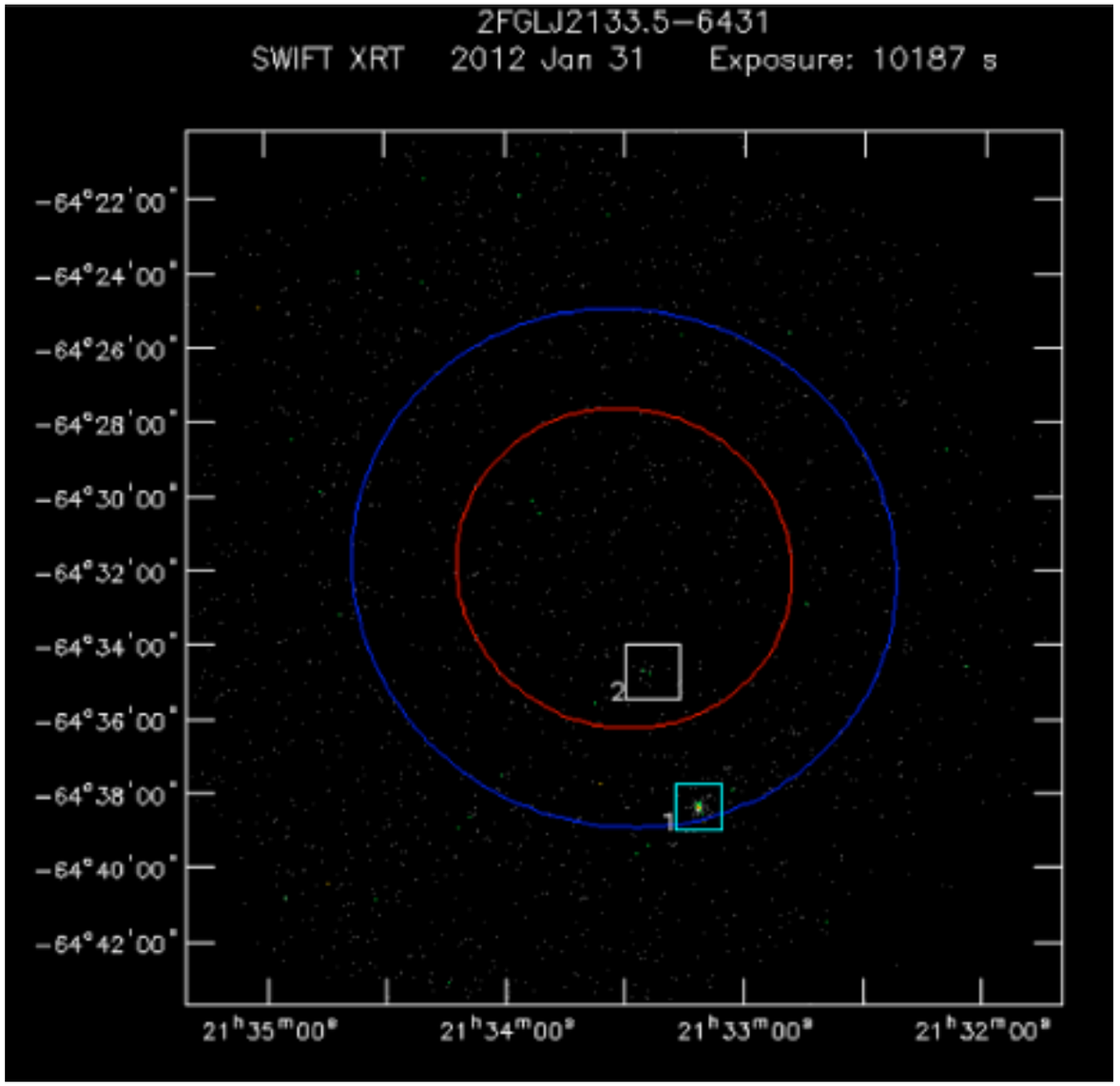
Improving candidate selection via artificial neural networks



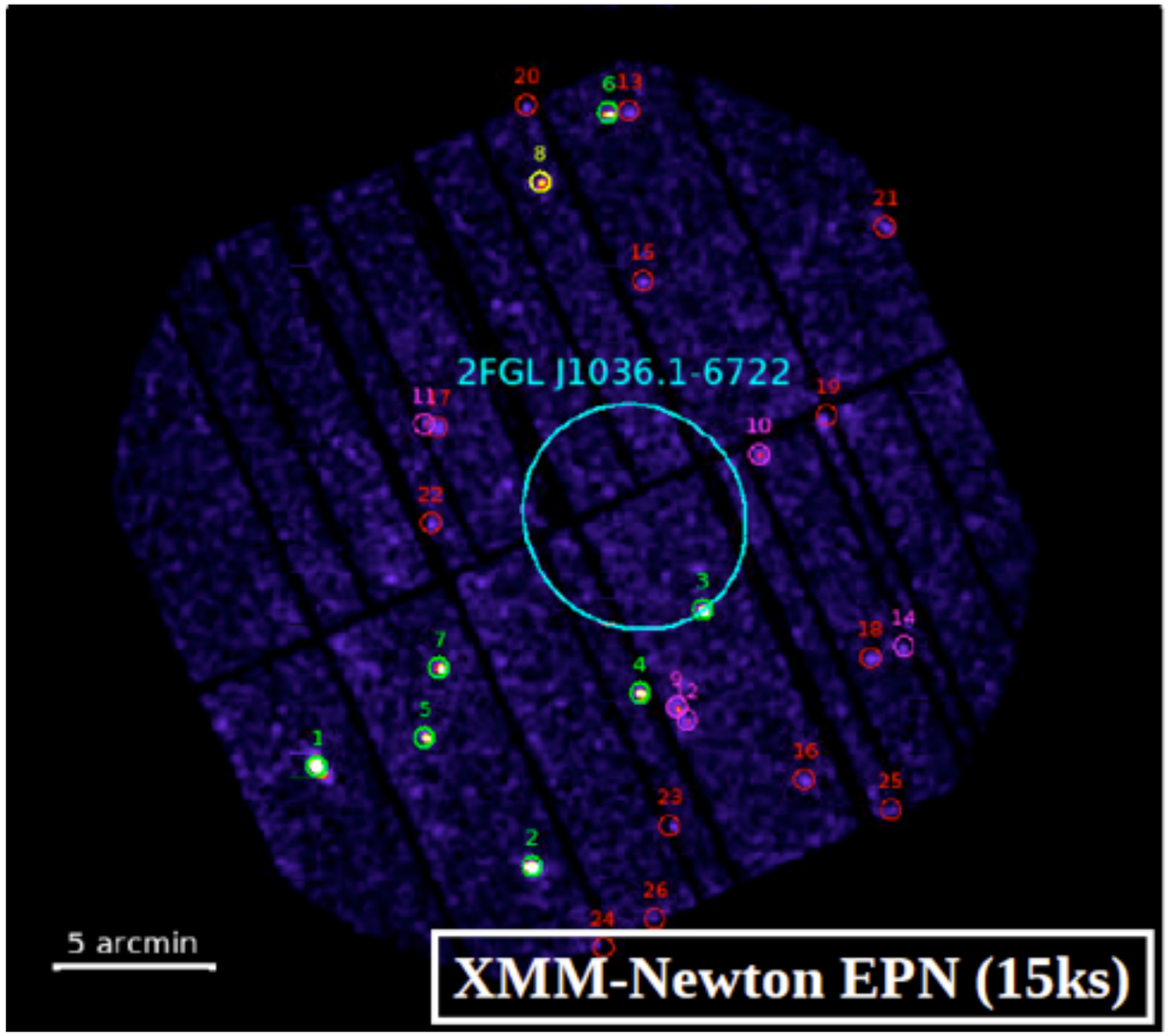
Credit: Salvetti et al. (HEAD 2013)

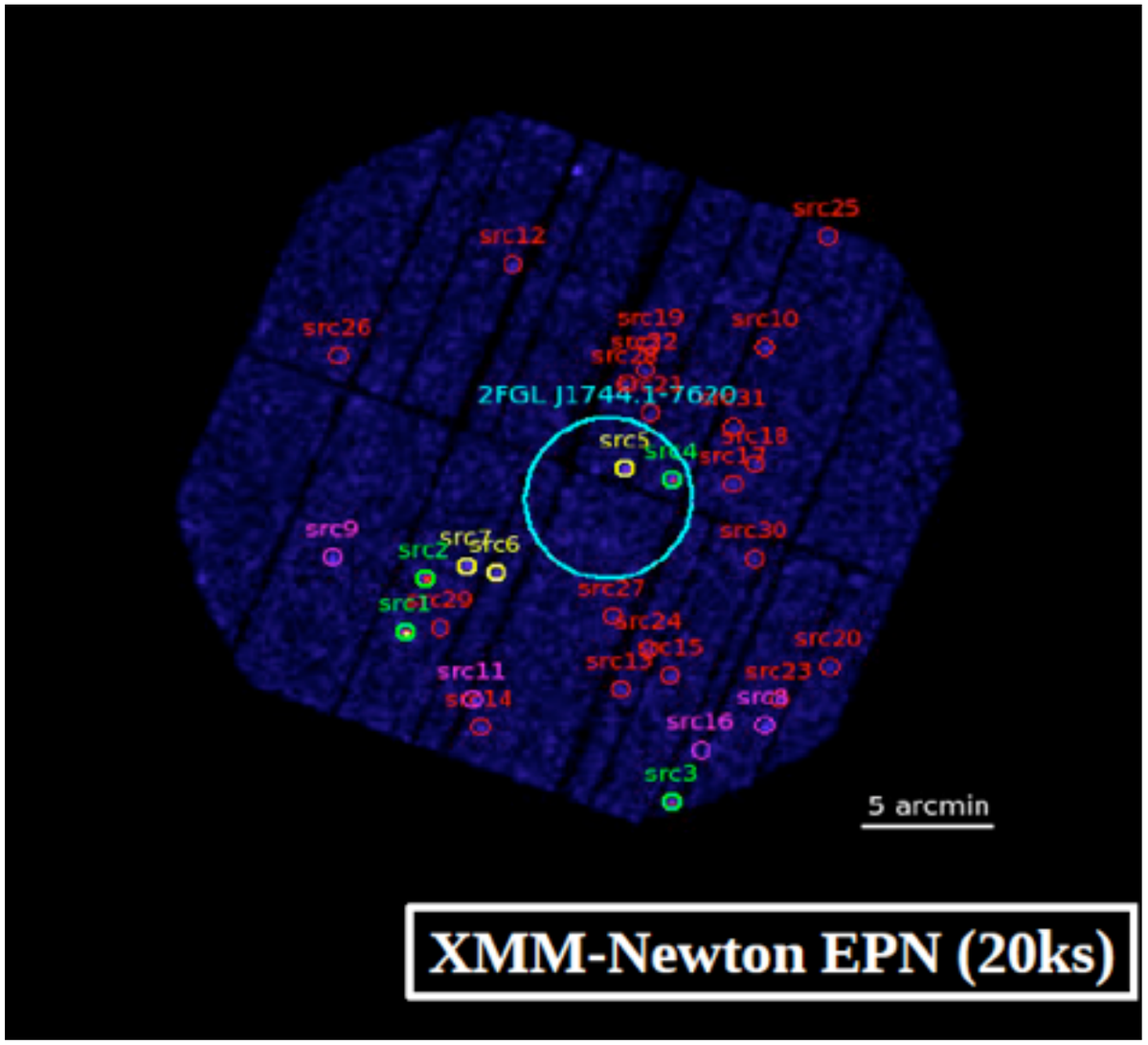
The *Swift* follow-up program (PI: Falcone)

- http://www.swift.psu.edu/unassociated/
- Pulsar candidates ~10 ks
- Other unassociated ~4-5 ks
- 1FGL sources ~ 250 obs.
- 2FGL sources ~ 180 obs.
- Total: ~2000 X-ray sources



XMM Observations of pulsar-like unassociated sources





2FGL J1036.1-6722

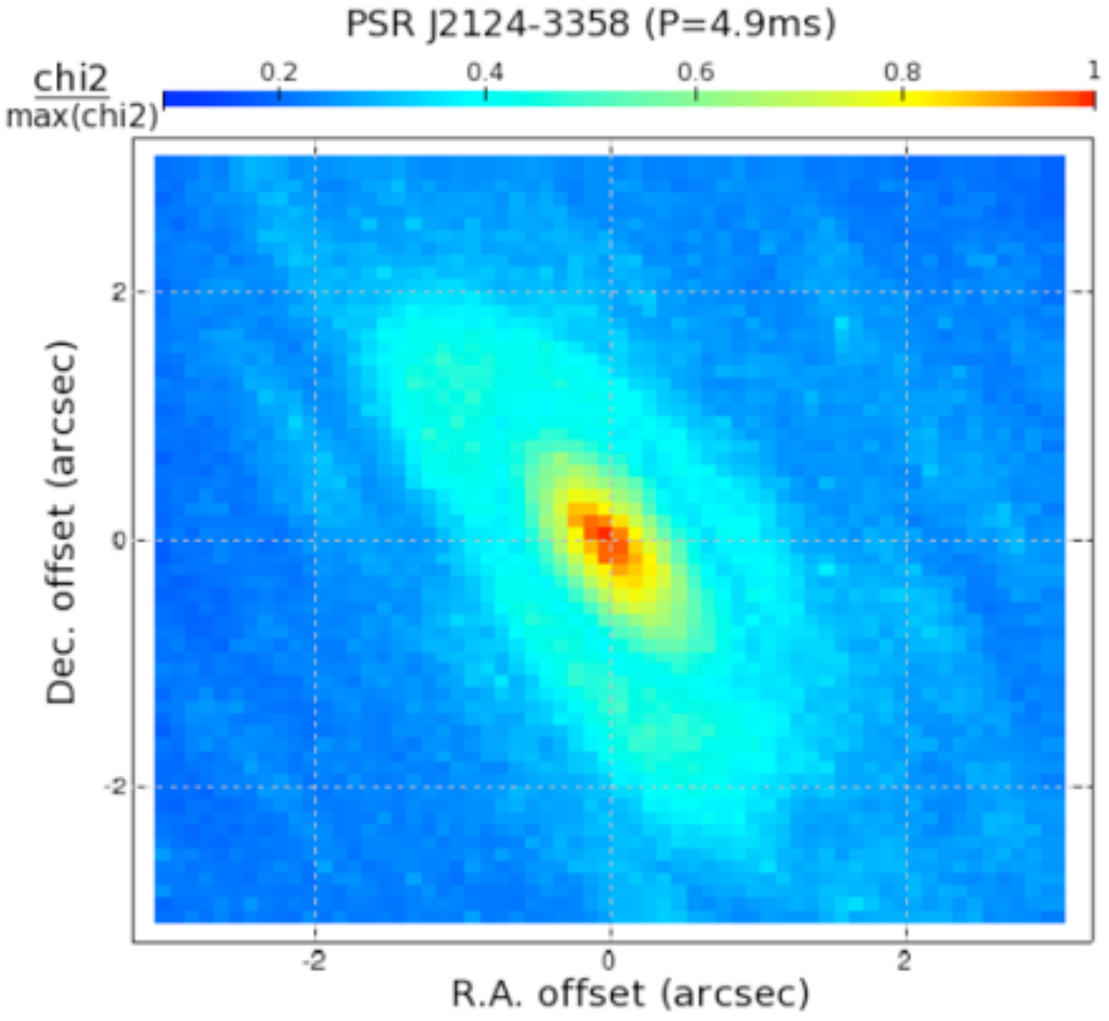
Fγ/Fx > 2200

2FGL J1744.1-7620

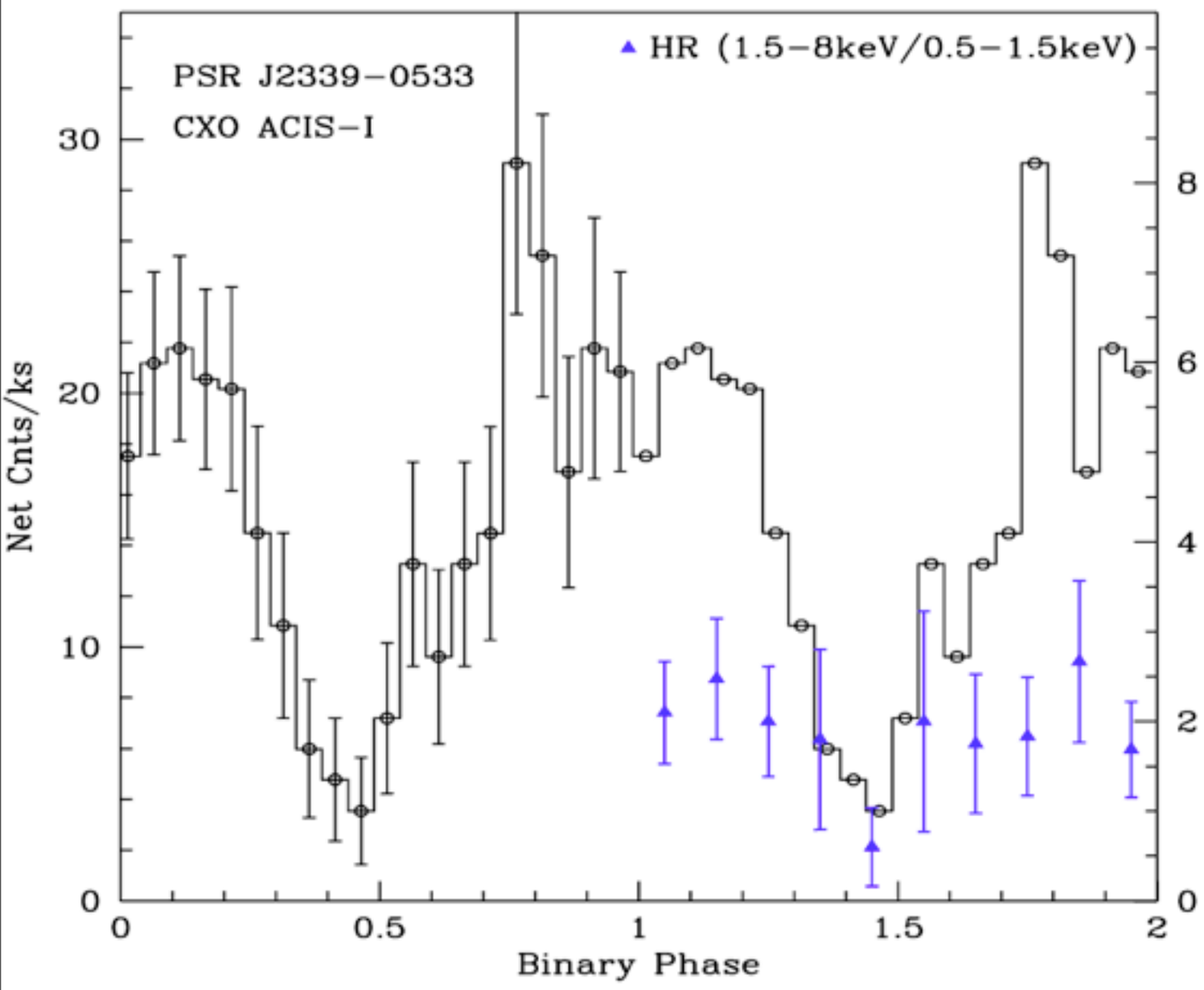
Fγ/Fx > 5500

LAT Searches for MSPs

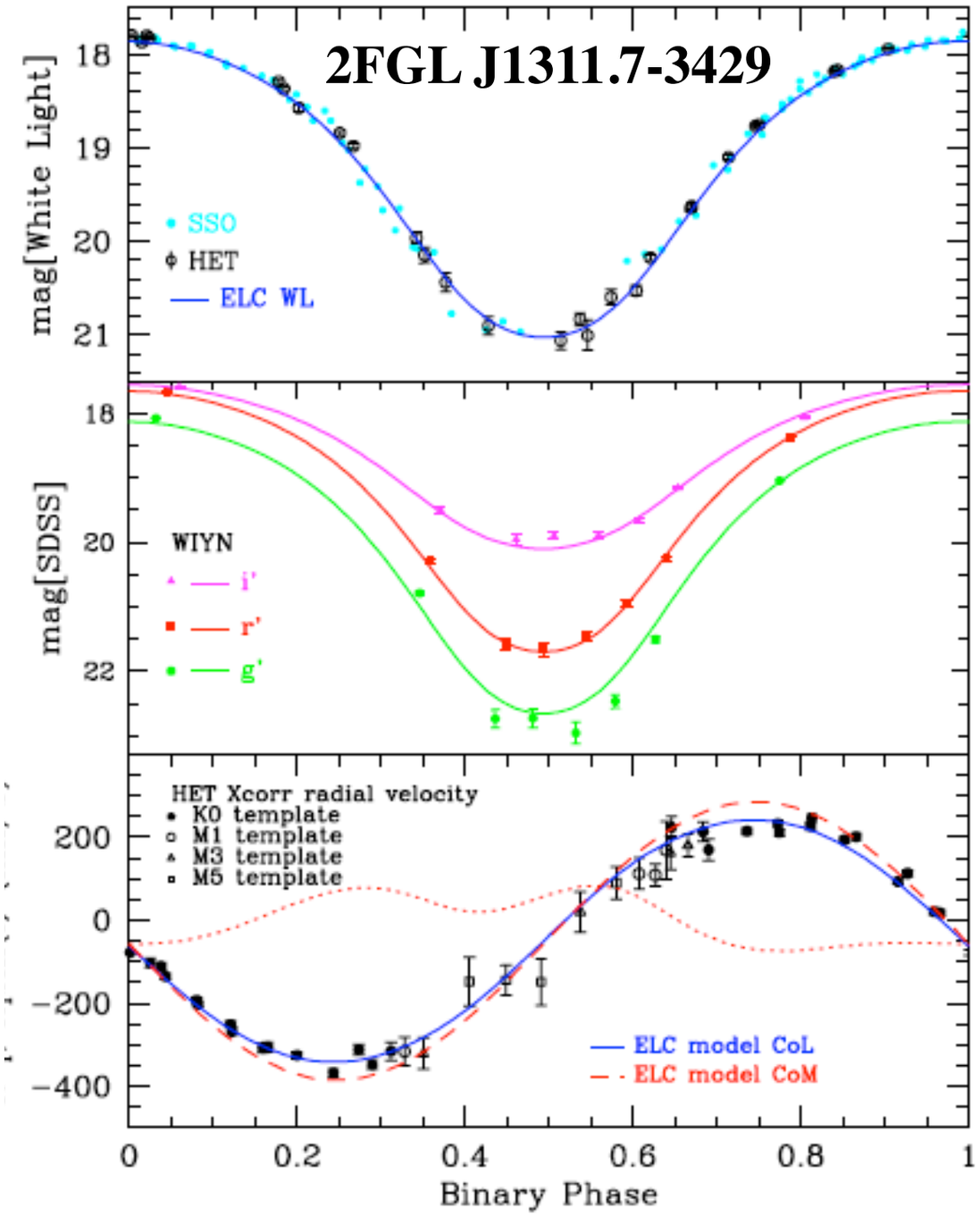
- More CPU/memory intensive
- More sensitive to position
- Most (>80%) are in binaries
- Full blind search of binary pulsars is currently unfeasible
- MWL obs. are desirable for isolated MSP searches and essential for binary ones
- Fortunately ... MSPs are extremely stable! (no F1 scan)



Searches for Black Widows



Romani & Shaw, ApJL 743, 26 (2011)



Romani, ApJL 754, 25 (2012)

Summary

- A large fraction of gamma-ray pulsars are radio-quiet, making X-rays the next best alternative for their study
- X-ray observations of gamma-ray pulsar candidates improve the sensitivity of LAT blind searches by:
  - pinpointing plausible X-ray counterparts
  - identifying binary systems
  - constraining the (unknown) pulsar parameters
- X-ray follow-up observations with *Swift*, *Chandra*, and XMM have produced many potential counterparts
- Blind searches in gamma rays are ongoing ... stay tuned!

Thank You!