

# Science

14 August 2009 | \$10

Fermi  
Detecting Gamma-Ray Pulsars

AAAS

## What Is A Radio/Gamma **Aligned** Millisecond Pulsar?

## And What Isn't?

### Matthew Kerr

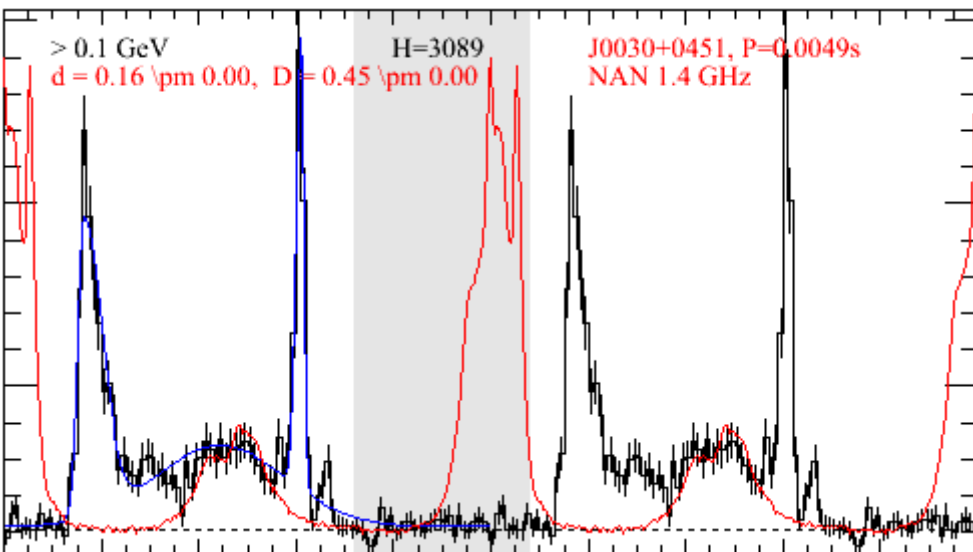
kerrm@stanford.edu

Thanks to 2PC team!

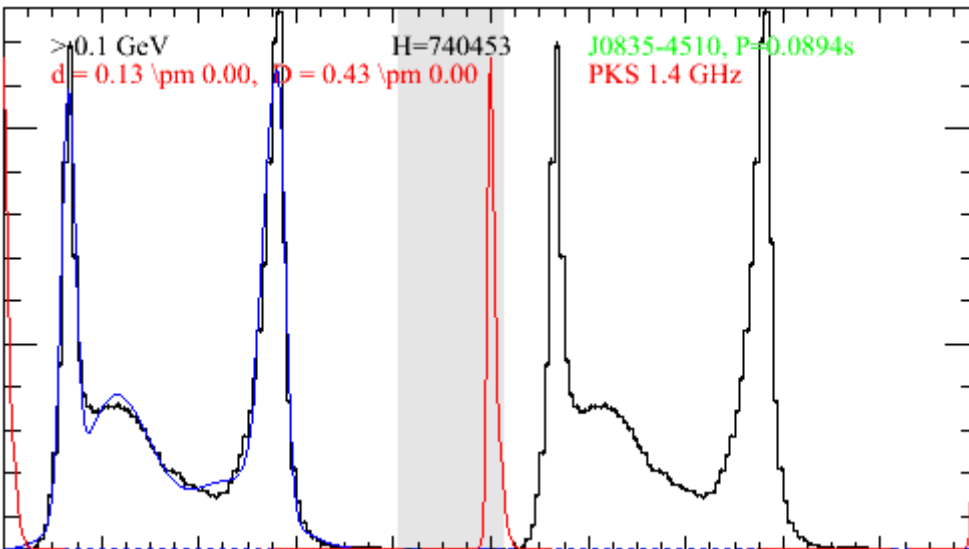
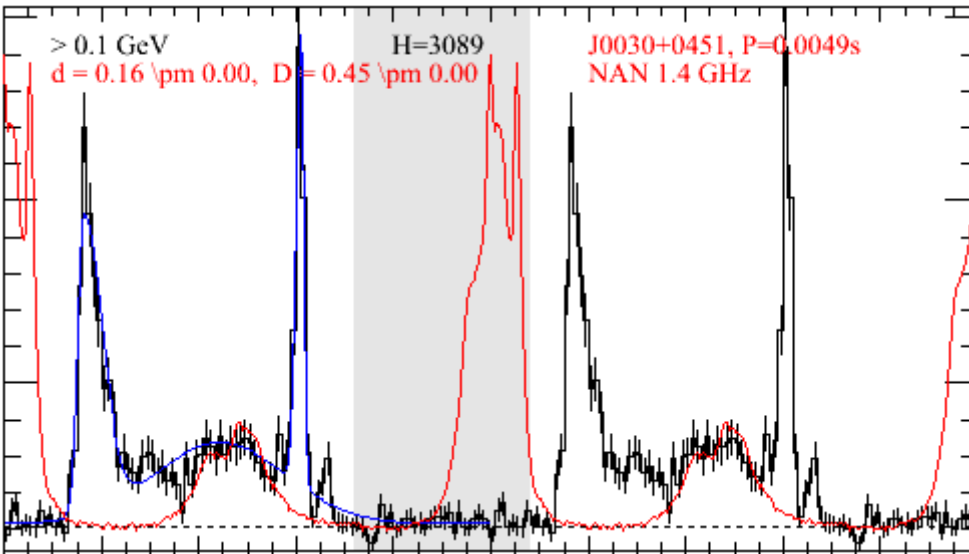
(NB: 2PC plots are preliminary.)

Stanford University / KIPAC

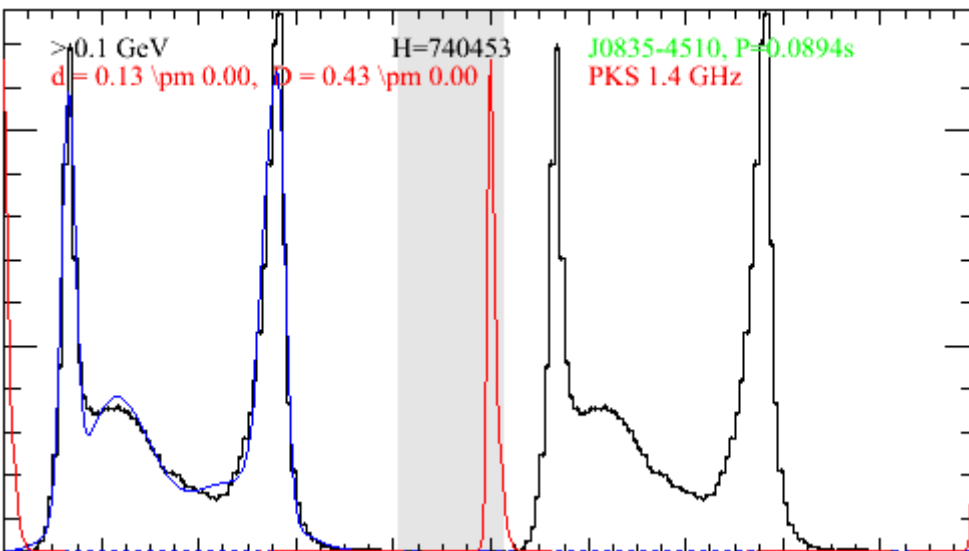
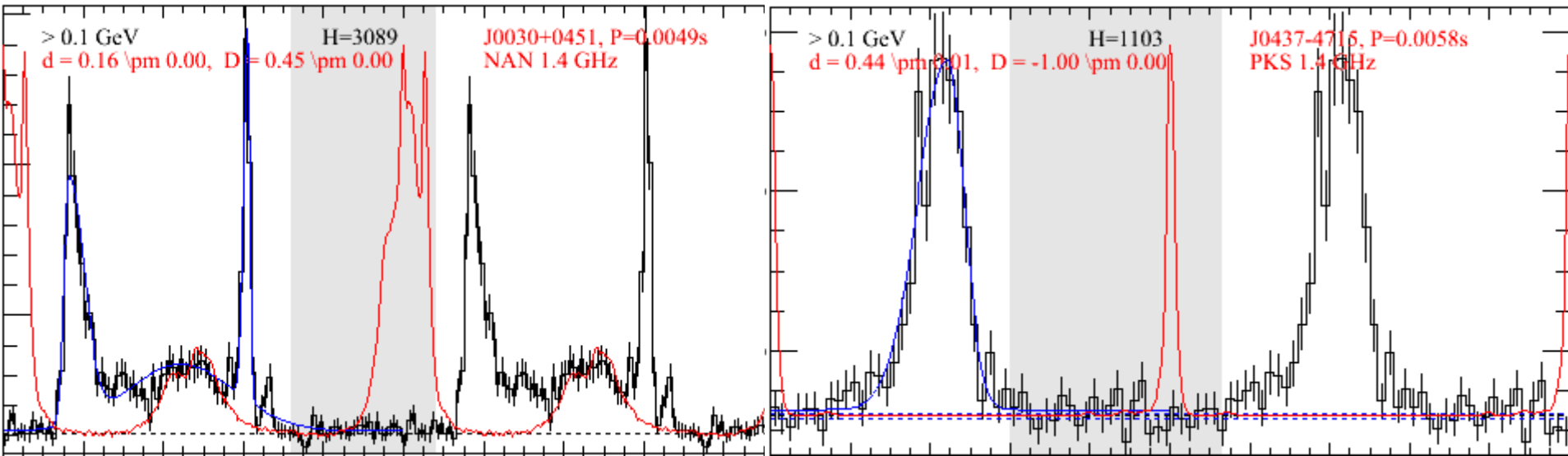
# Morphology of Fermi MSPs



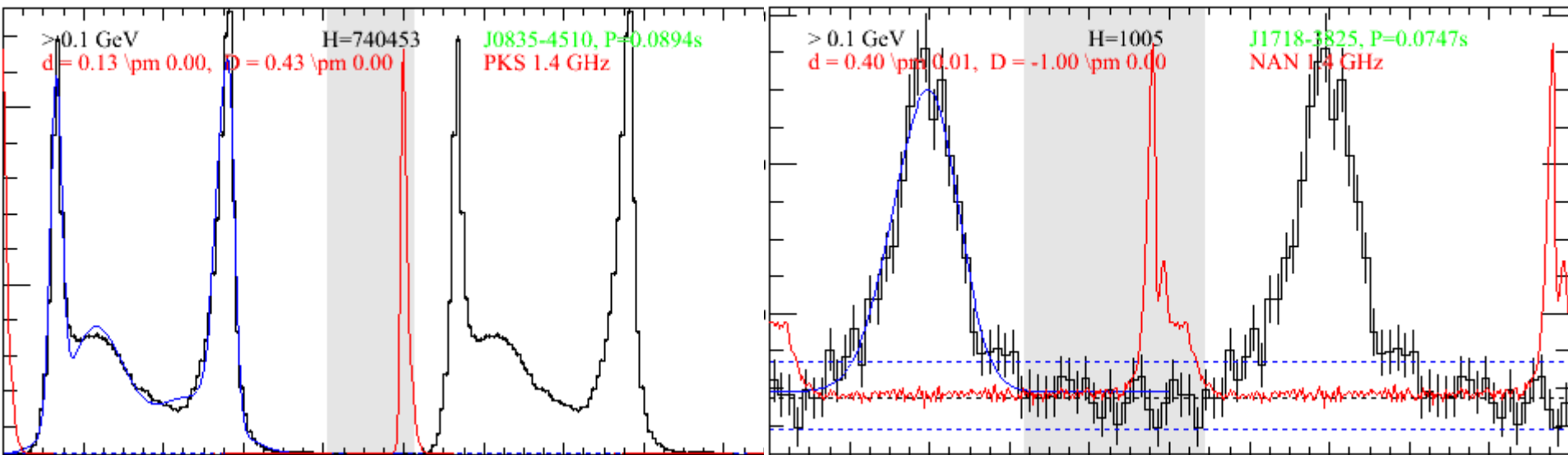
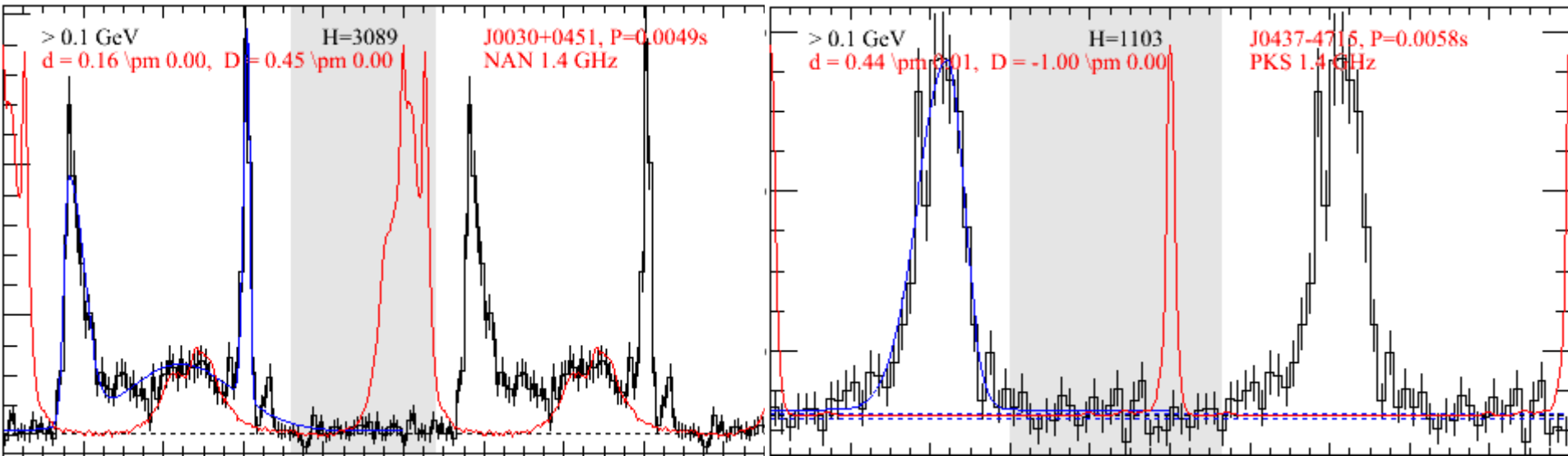
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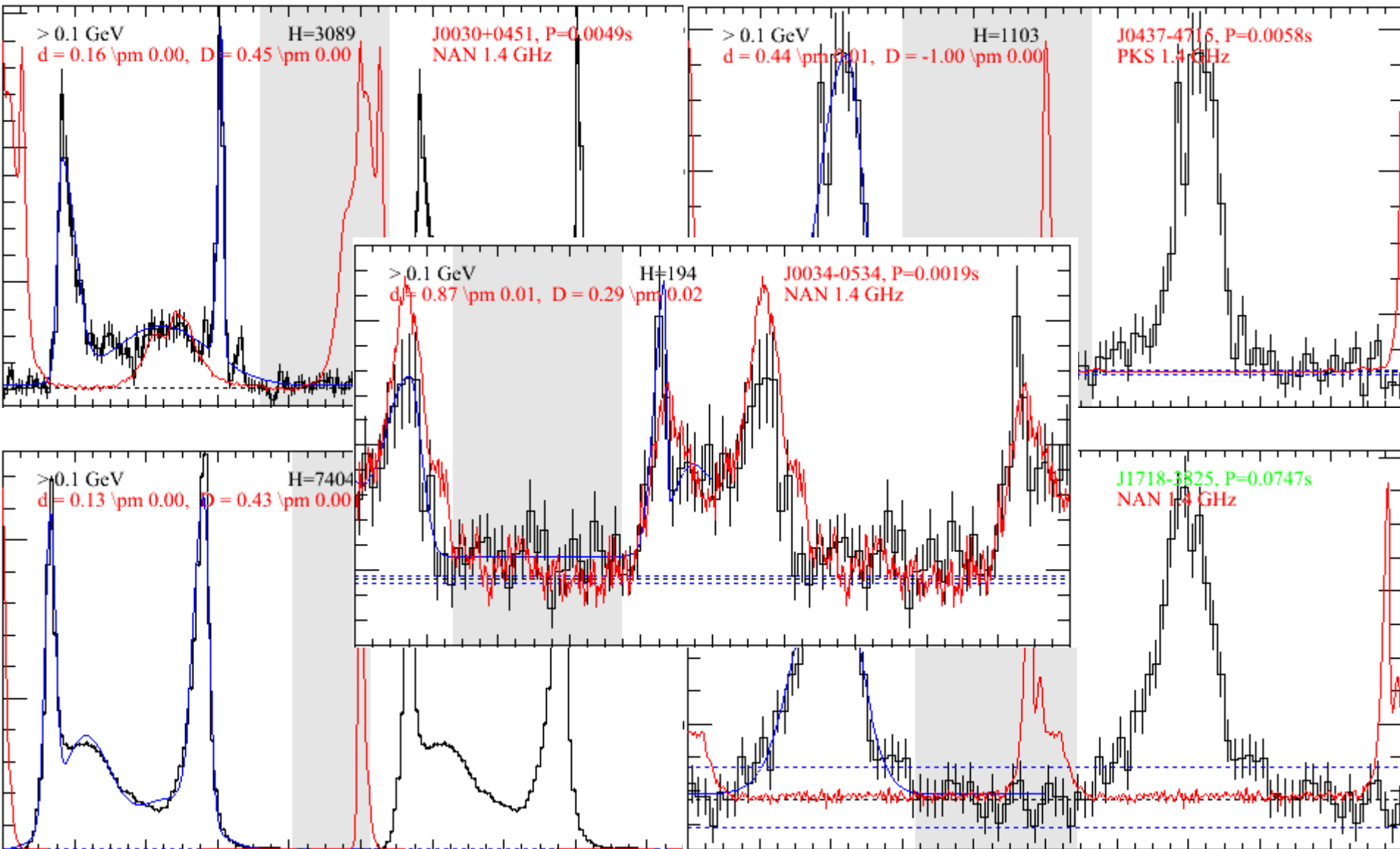
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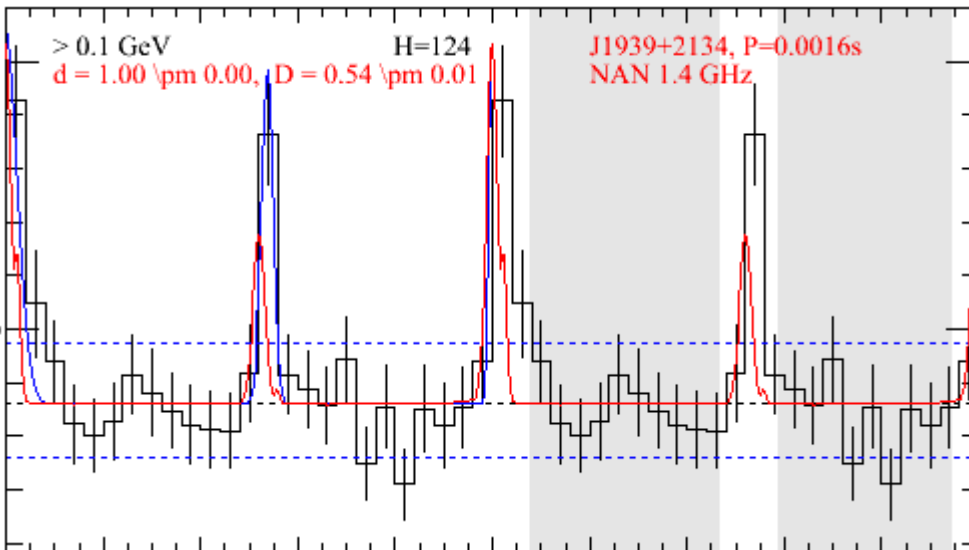


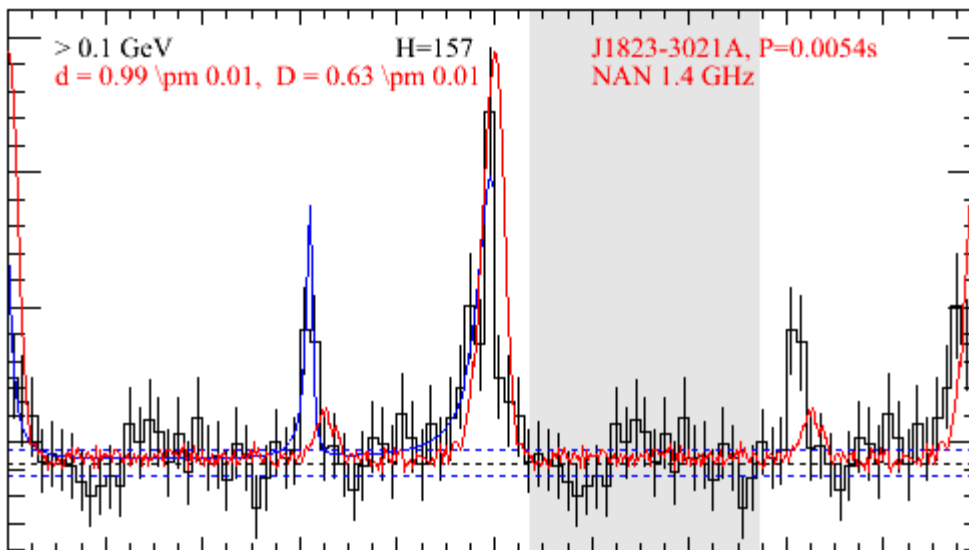
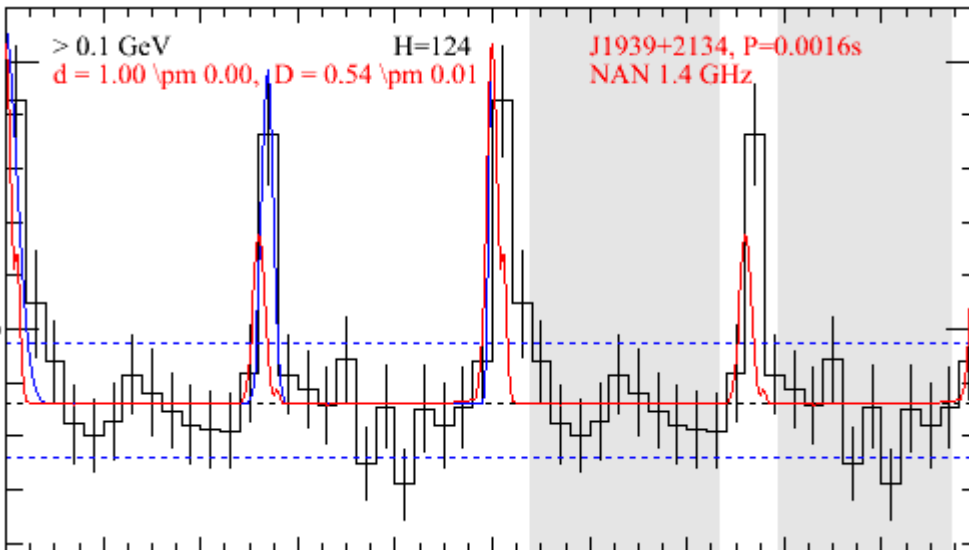
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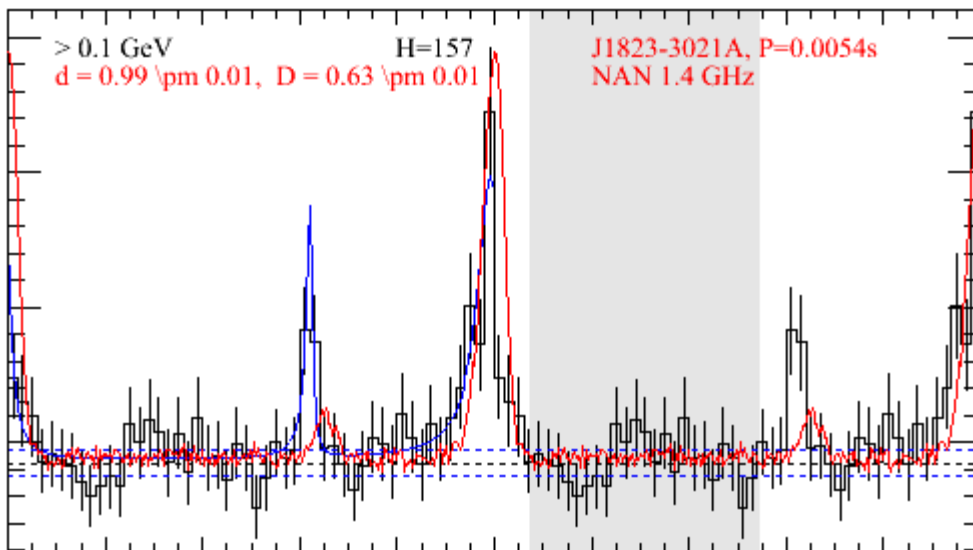
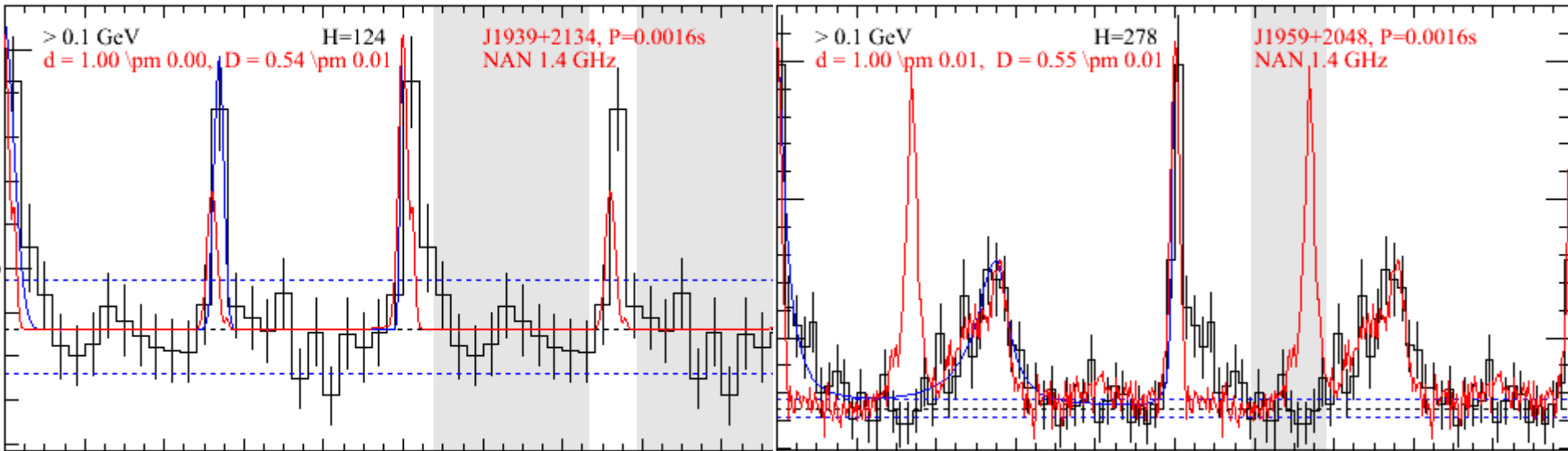
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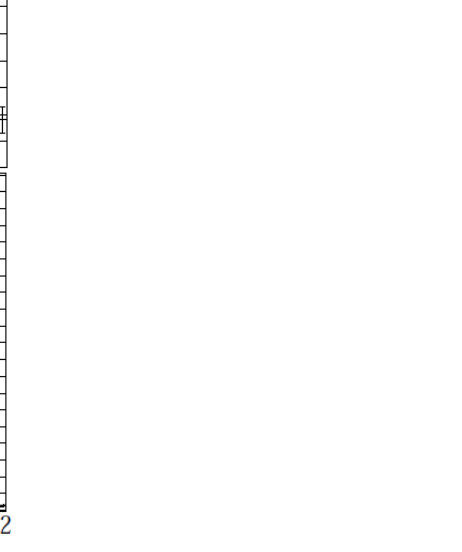
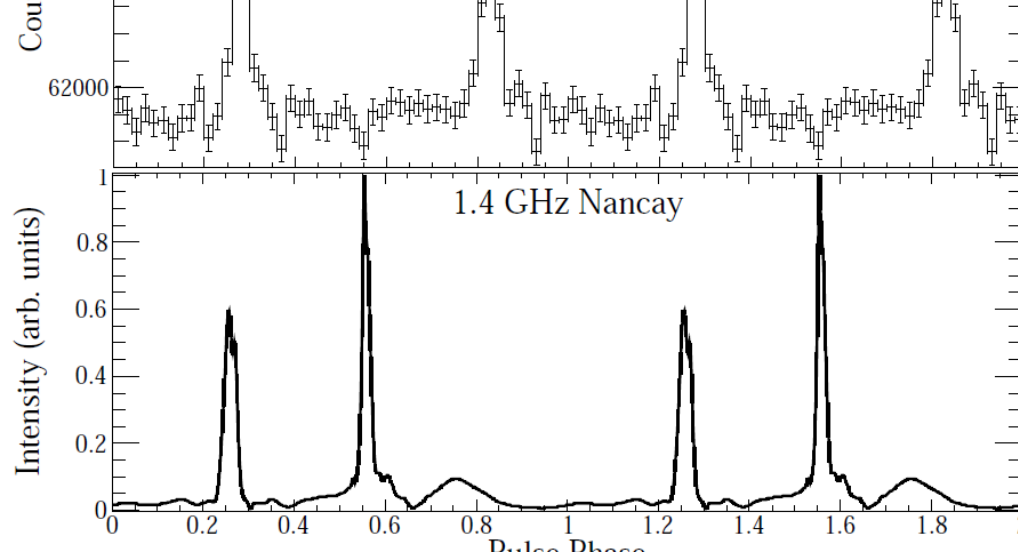
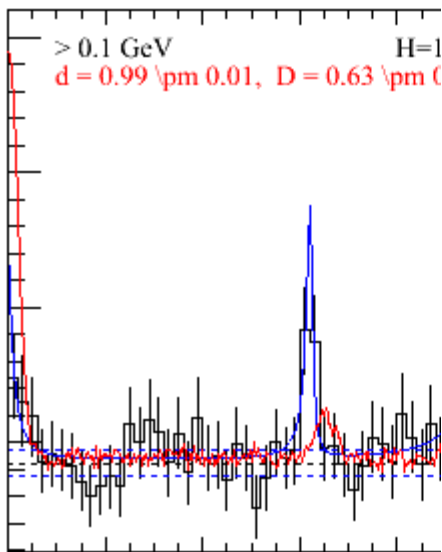
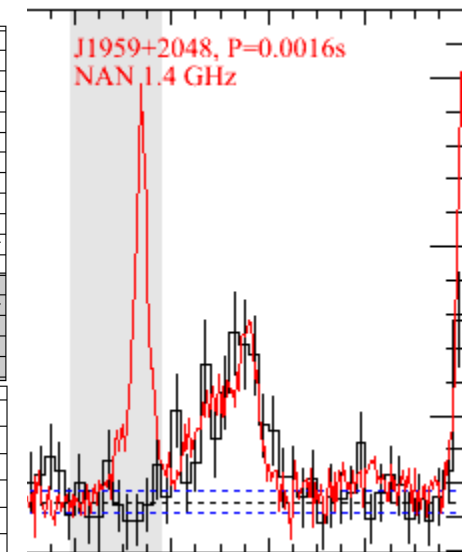
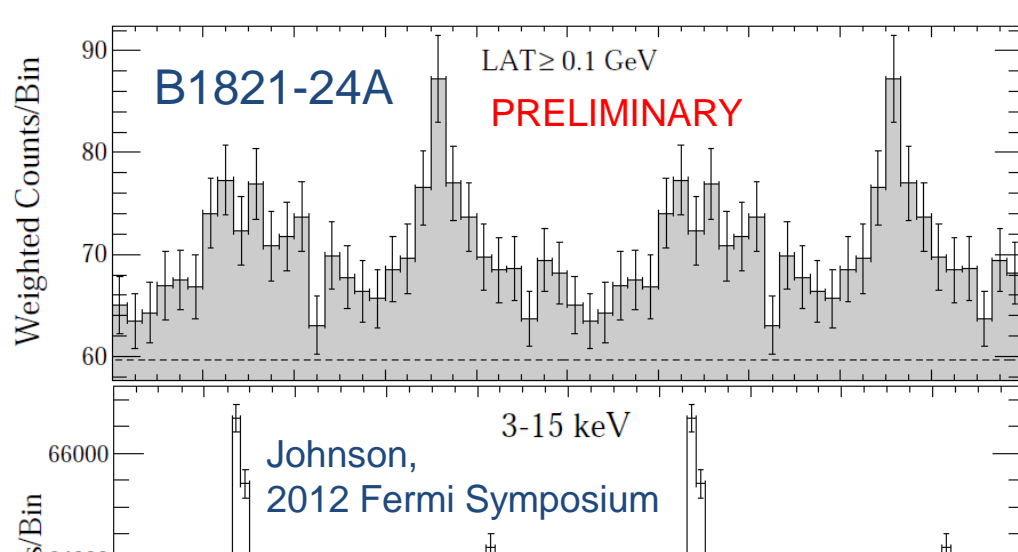
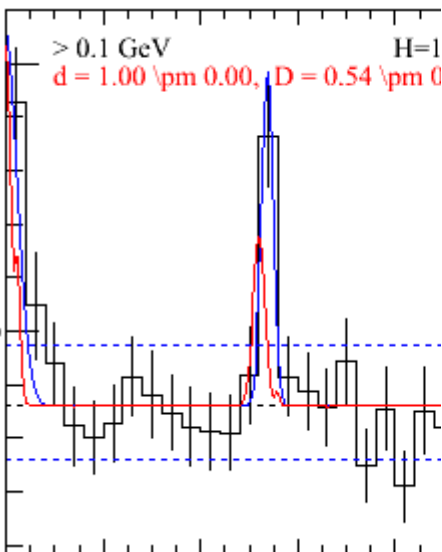




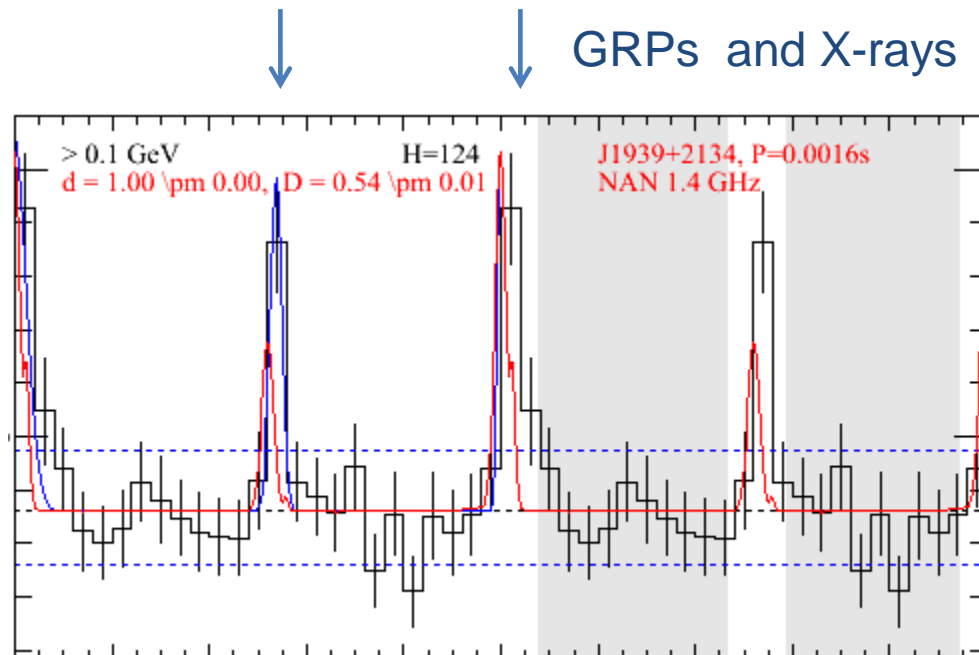




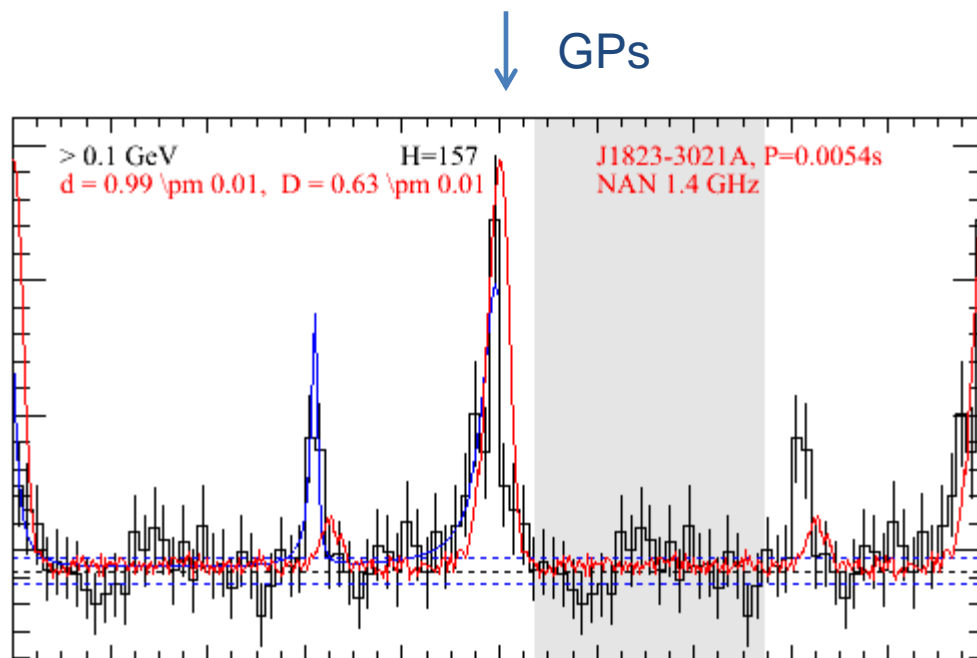




- One of the highest  $\dot{E}$  MSPs.
- Extremely high  $B_{LC} \sim 10^6 G$ .
  - GRPs most strongly associated with large  $B_{LC}$  in both young & recycled.
- X-ray (Cusumano+ 2003) and gamma-rays fully-aligned (phase and morphology) with GRPs (Cognard+ 1996).
  - Just like Crab (without bridge emission.)

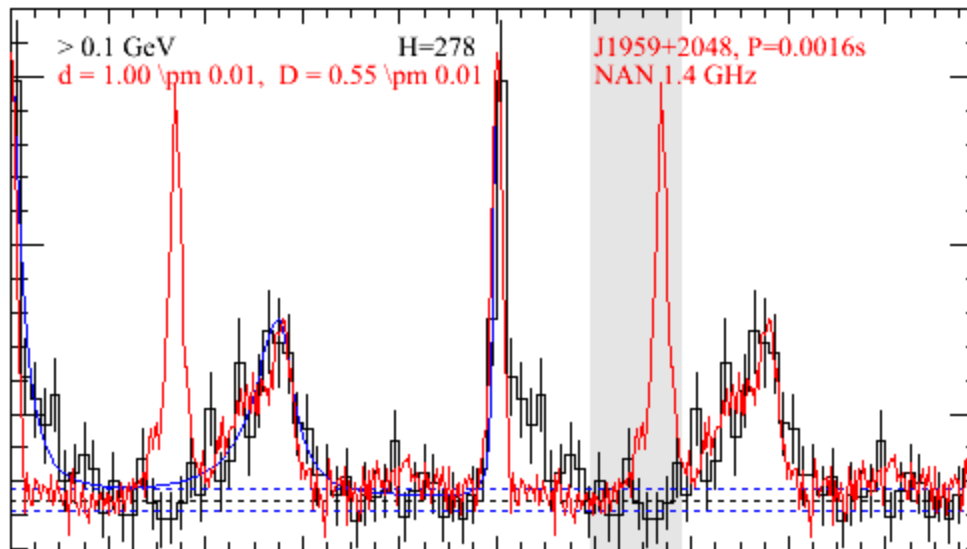


- Highest  $\dot{E}$  MSP.
  - Gamma-ray efficiency implies measured  $\dot{E}$  close to intrinsic value (Freire+ 2011).
- Giant pulses in phase with latter half of primary radio peak (Knight+ 2005).
- No X-ray detection despite Chandra/XMM observations.
- Soft radio emission.

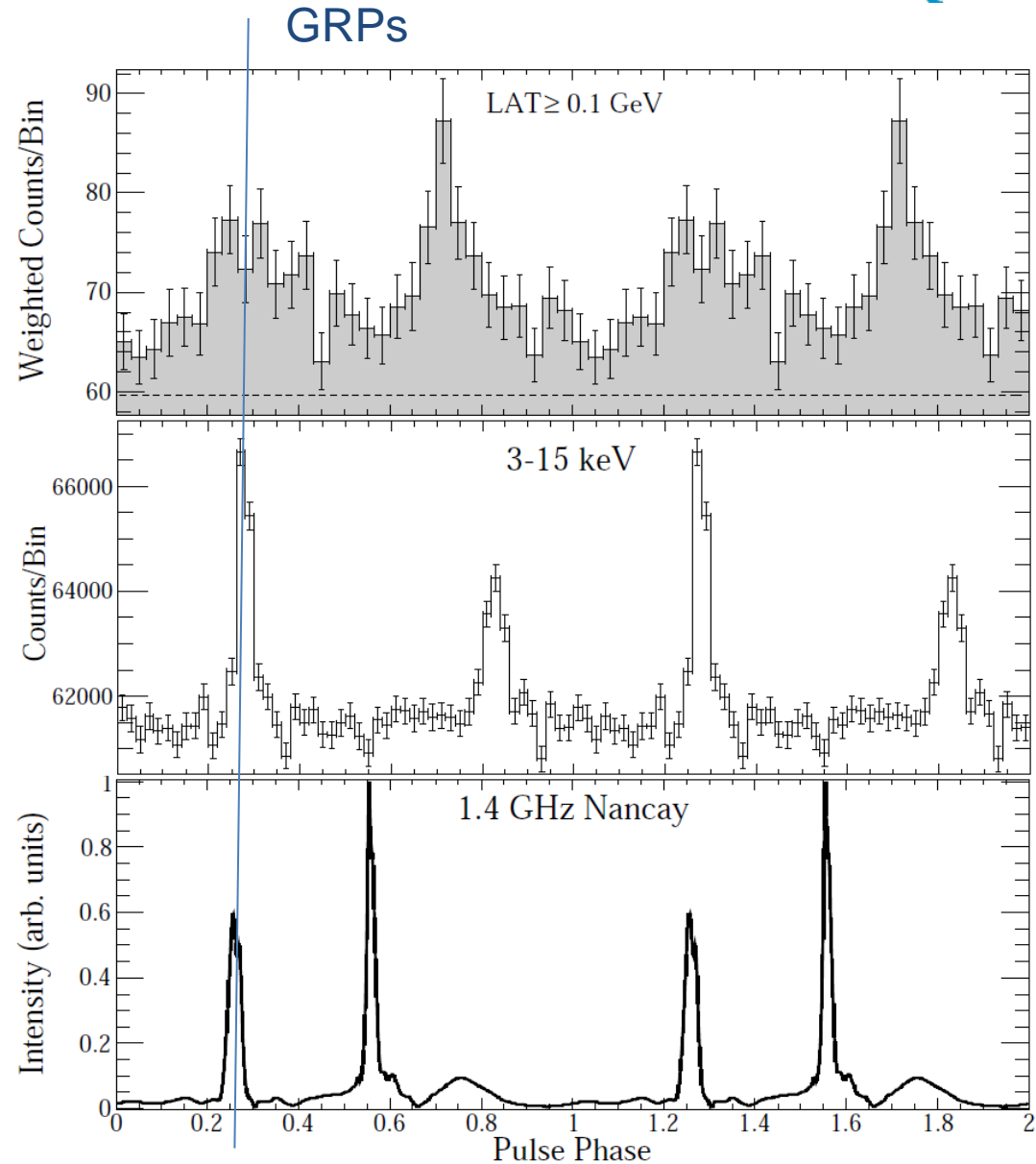


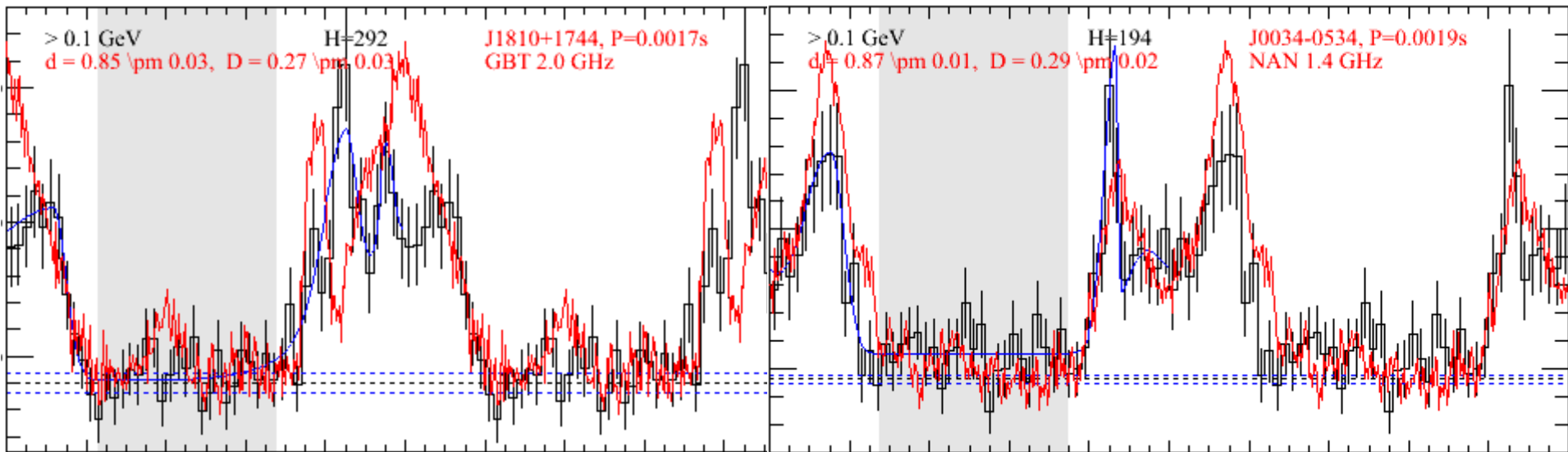
- The eponymous Black Widow pulsar.
- Modest  $\dot{E}$ , but very high  $B_{LC}$ . Giant pulse candidate?
  - No strong X-rays (Guillemot+2012), missing indicator.
    - X-rays don't appear to be aligned with \*anything\*; more timing observations needed.
  - But, potential detection by Knight+ 2006.
- Gamma-ray alignment suggestive of reality of GRPs.

↓ GPs?



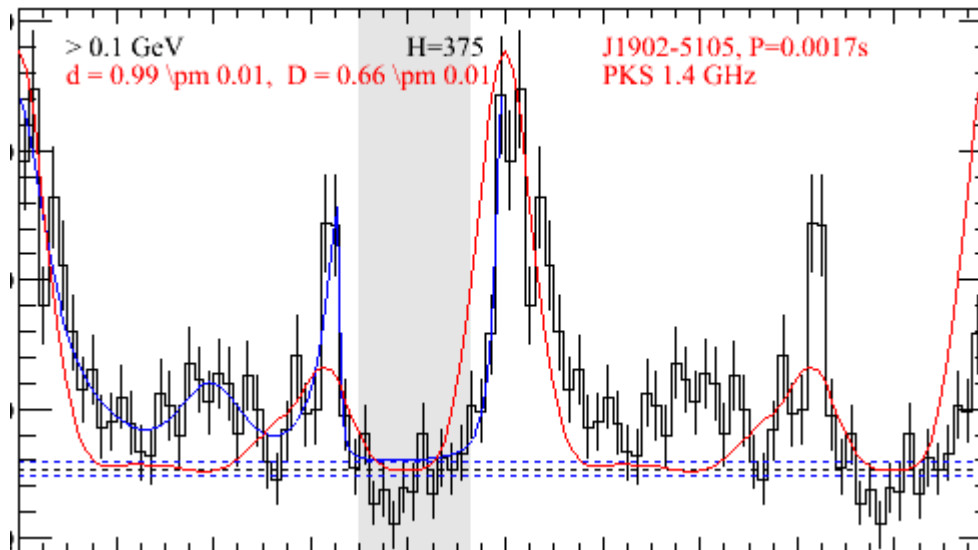
- Recent Fermi detection (T. Johnson @ Fermi Symposium).
- Emits GRPs (Romani & Johnston 2001).
- X-ray and GRPs in alignment (phase and morphology).
- Gamma-rays appear to be aligned, but differ in morphology, and primary peak aligns with nothing.
  - If we take GRP/gamma alignment seriously, what mechanism broadens highest energy emission?





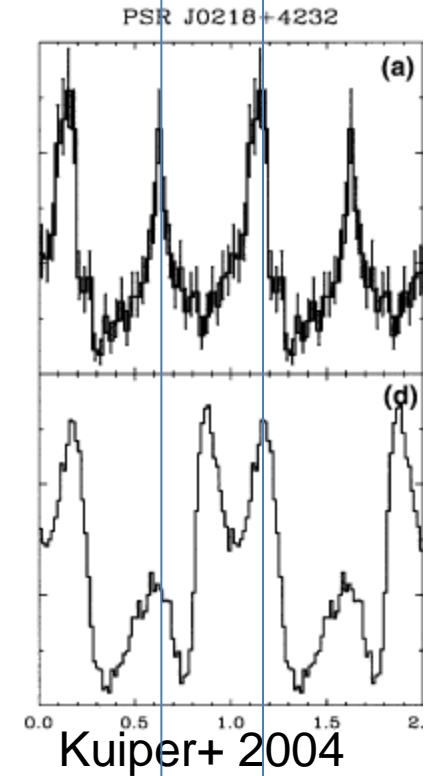
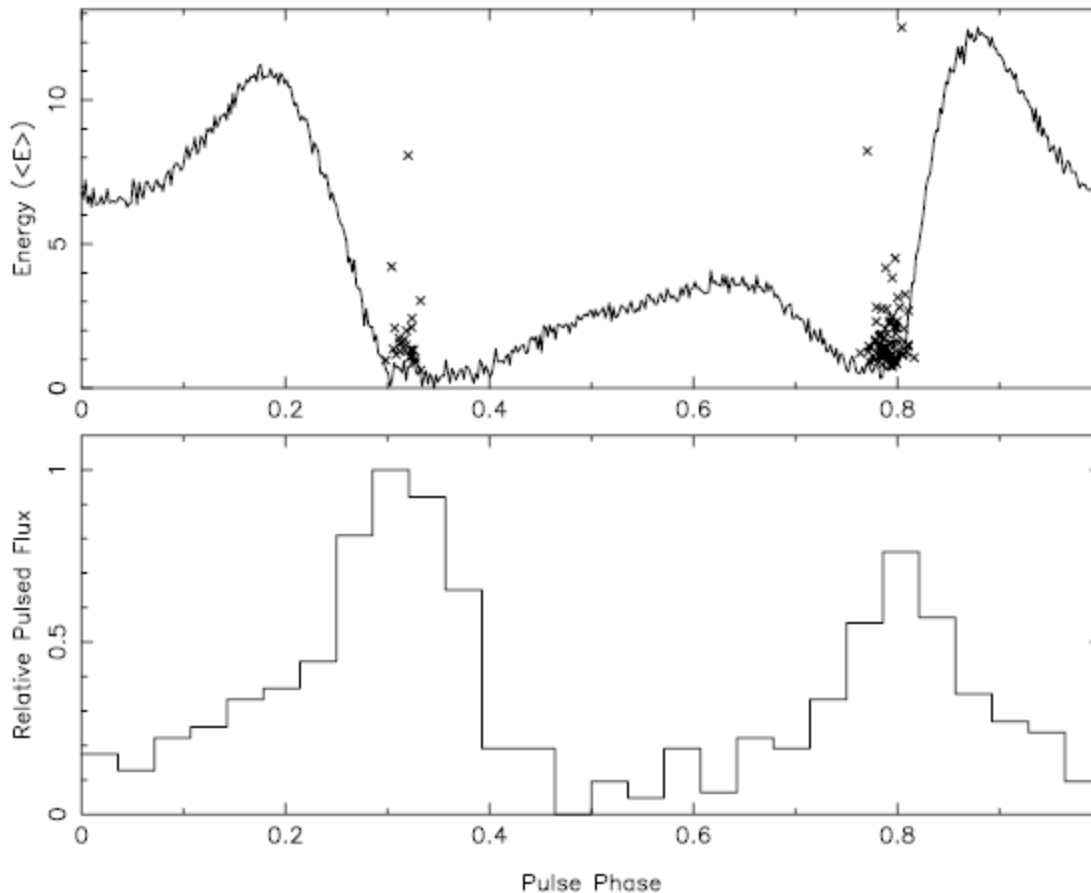
- Aligned radio/gamma MSPs with strikingly different morphology.
- Lower  $\dot{E}$ 's, but  $B_{LC}$ 's still relatively high.
- Unconstraining UL on J0034-0534 GRPs (Knight+ 2005); J1810+1744 too new for such things.
- J0034-0534 is X-ray quiet; J1810+1744 X-ray detected.
- Are these more (magnetically) aligned than the energetic examples? Or is an important physical component (e.g. copious pair production) absent?

- Discovered relatively recently (PSC).
- $\dot{E}$  is modest (like B1957, J0034, J1810...), but  $B_{LC}$  is right up with the rest of the aligned/GRP emitters.
- Light curve is reminiscent of Crab, but only an upper limit on X-ray flux.
- Need more MW observations.

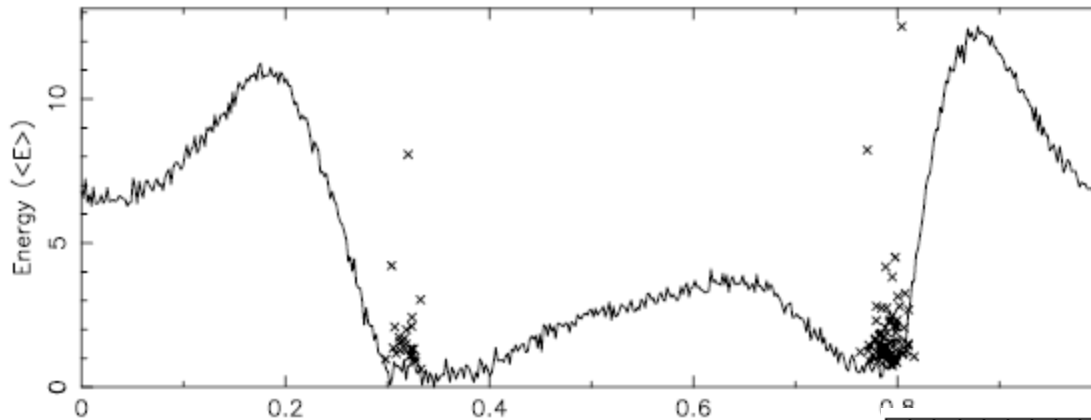




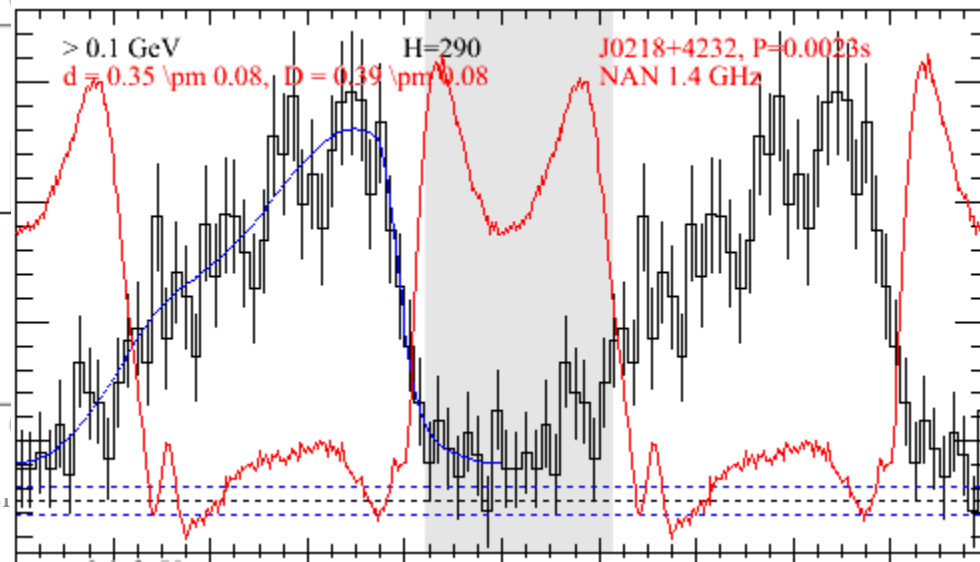
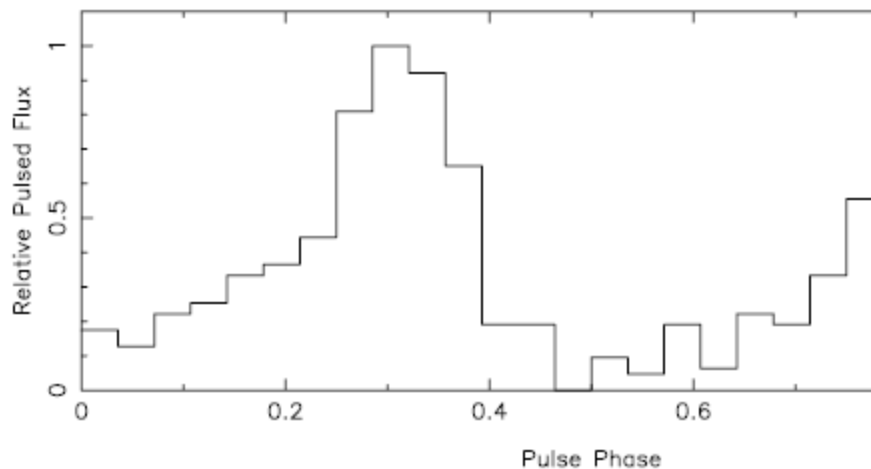
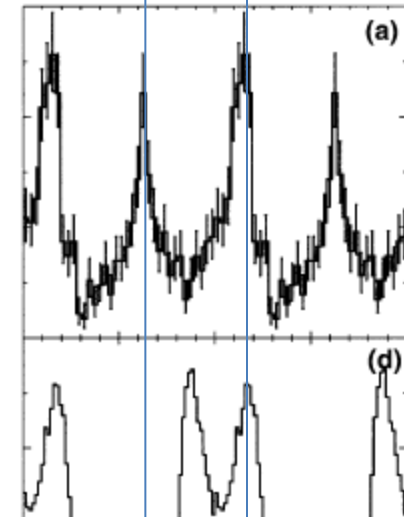
- Large  $\dot{E}$  and  $B_{LC}$ . “Unpulsed” radio emission (Navarro+ 1995).
- Emits GRPs (Knight+ 2008) at radio minima.
  - Are they phase-aligned with X-rays?
  - Surface emission + high altitude GRPs?



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PSR J0218+4232



# “Aligned” MSP Cheatsheet

Name	P ms	$\dot{E}$ $10^{34}$ erg/s	$B_{LC}$ $10^4$ G	GPs	X-rays	-s	Binary	Aligned
J0034-0534	1.88	3.0	13.6	? (UL)	N (UL)	3	N	Y
J0218+4232	2.32	24.4	31.4	Y	Y (al?)	2.8	N	N
J1810+1744	1.66	4.0	17.8	?	Y (al?)	?	Y / BW	Y
B1820-30A	5,44	82.9	24,8	Y	N (UL)	2.7	N / GC	Y
B1821-24A	3.05	220.0	71.8	Y	Y (A)	2.8	N / GC	Y?
J1902-5105	1.74	6.9	22.1	?	N (UL)	?	N	Y
B1937+21	1.56	110.0	99.5	Y	Y (A)	2.3	N	Y
B1957+20	1.61	16.0	25.2	Y	Y (al?)	3.6	Y / BW	Y

Credit to Espinoza et al., in press, for many of these quantities.

- These pulsars share many physical links:
  - Radio/gamma phase alignment and morphology.
  - Radio/X-ray/GRP phase-aligned emission.
  - GRP emission / high  $B_{LC}$ .
  - Soft radio spectra.
- Do missing features point to physical differences, or merely a need for more observations?
  - Are aligned rgMSPs good predictors for giant pulses?
  - What role do viewing angle ( $\zeta$ ) and magnetic inclination ( $\alpha$ ) play in the presence or appearance of these features?
  - What role does  $\dot{E}$  play?
  - Modern baseband searches for GRPs J0034-0534, J1810+1744, J1902-5105 would be useful for establishing a connection to lower  $\dot{E}$  MSPs.
    - Radio spectral indices for J1810, J1902.
    - Additional observations of B1957+20.
  - Deeper X-ray observations to detect components in phase with gamma/GRPs?