An X-ray view to pulsars

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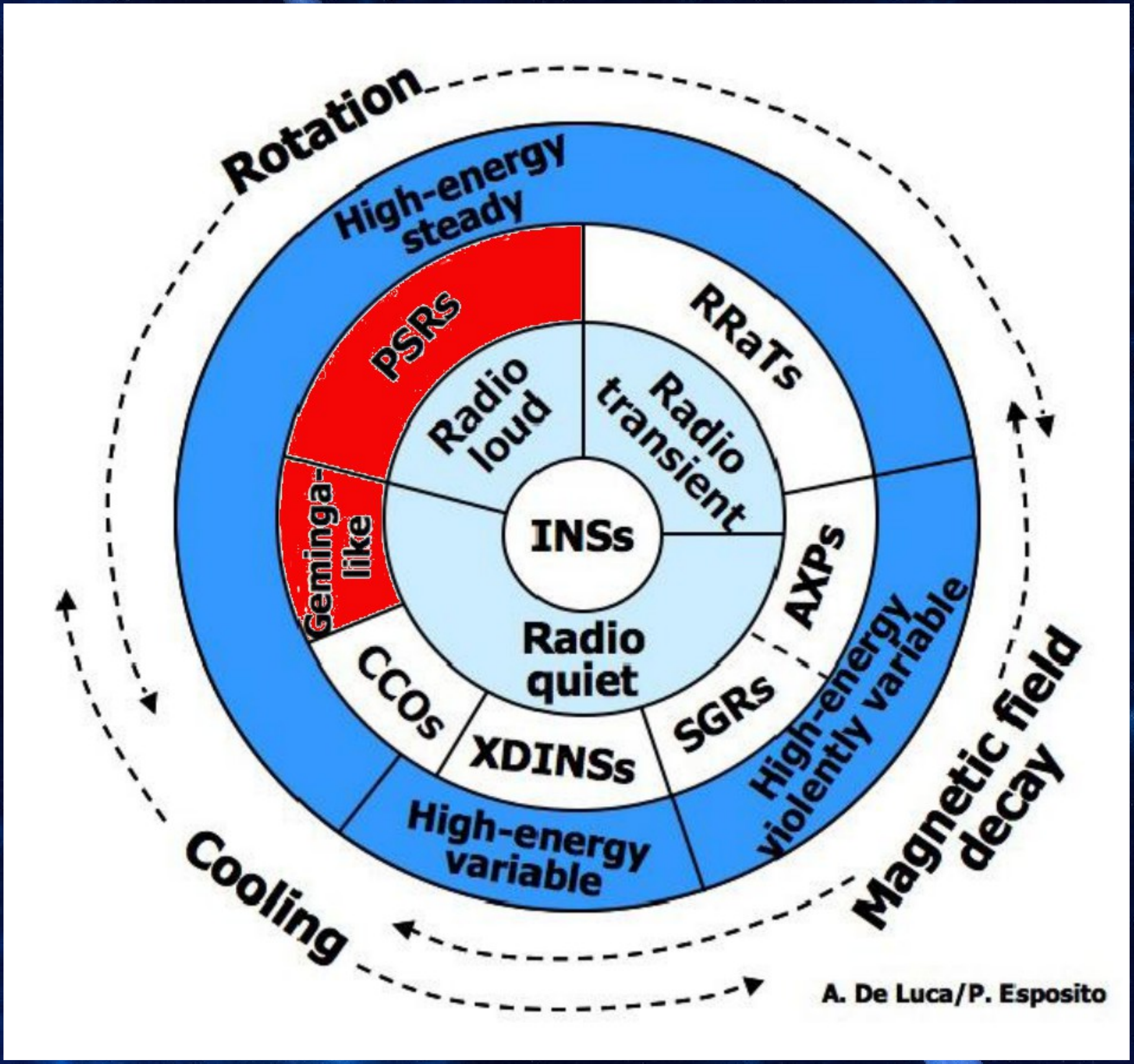
Overview

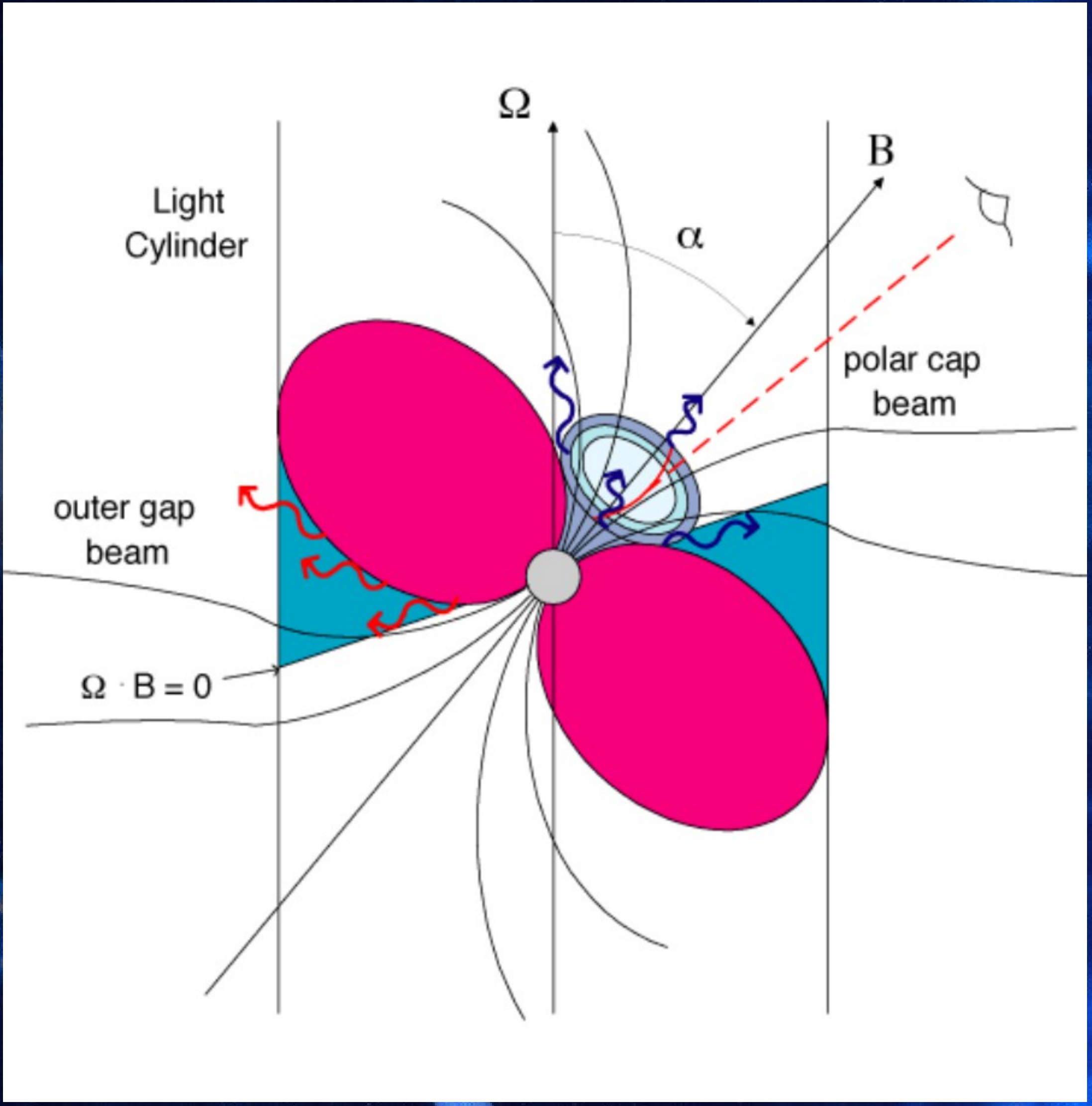
- Emission from rotation-powered pulsars
- X-ray pulsar emission: J1741 & J1813
- Future prospects & a new XMM-Newton tool

Rotation-powered, “classical” pulsars



Rotation-powered emission

- PSRs as rotating, magnetized NSs radiating at expense of rotational energy
- $E_{rot} \sim 10^{28}$-10^{38} erg/s
- Efficiency $\eta_i = L_i/E_{rot}$
- $\eta_{radio} \sim 10^{-6}$
- $\eta_x \sim 10^{-3}$
- $\eta_\gamma \sim 10^{-1}$
- Pulsar engine not yet understood



Radio and γ-ray bands

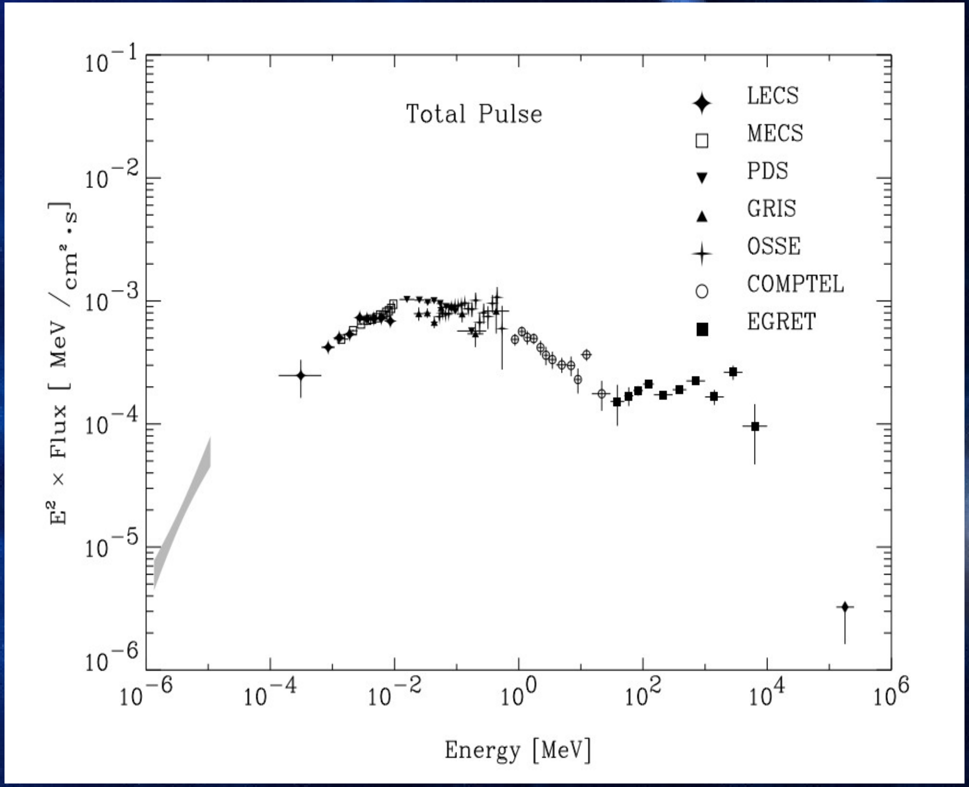
Radio pulsars:

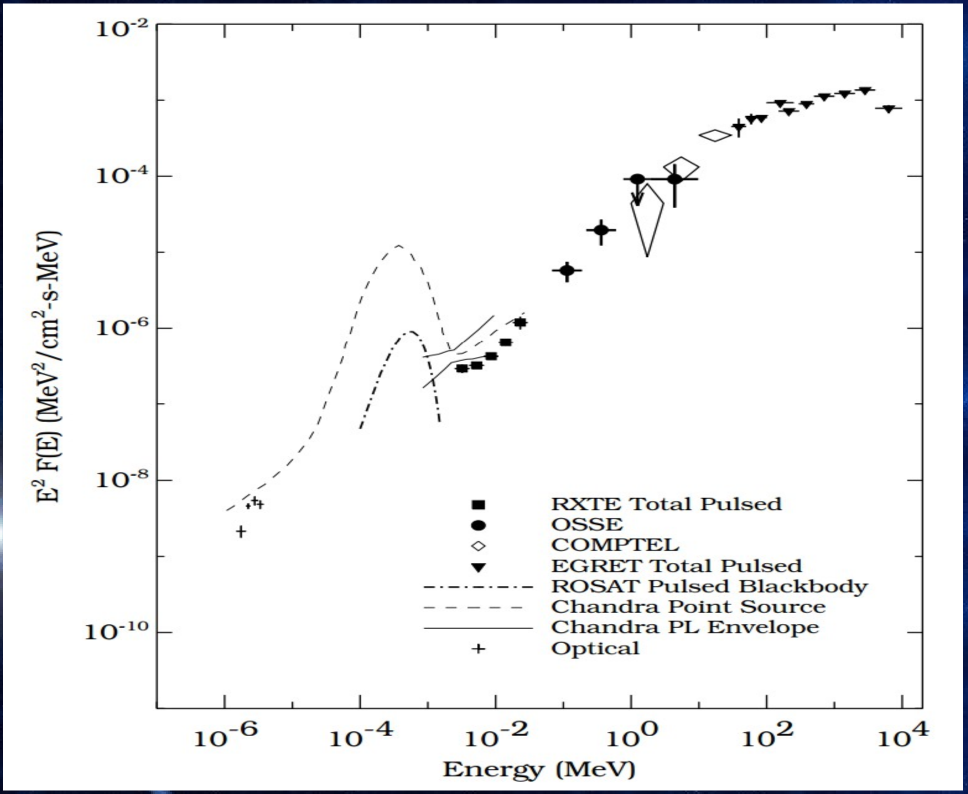
- >2100 since Hewish+68, listed in ATNF PSRs database
- Thousands of articles spanning 50 years
- Synchrotron radiation from the inner magnetosphere (polar cap?)

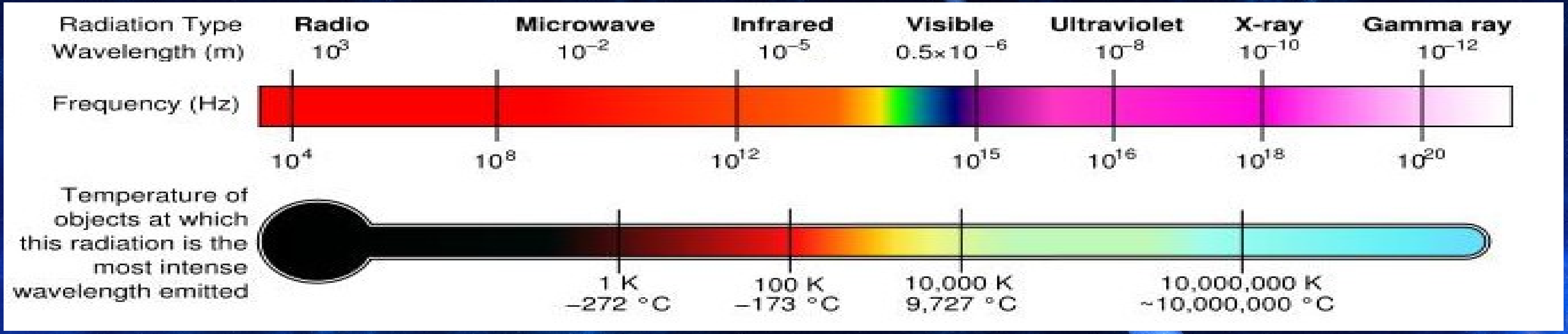
γ pulsars:

- >160 since Campbell+73, listed in 2PC
- Only seven psrs before Fermi(2008); tens of articles since then
- Curvature radiation from the outer magnetosphere (outer gap, slot gap, ...)

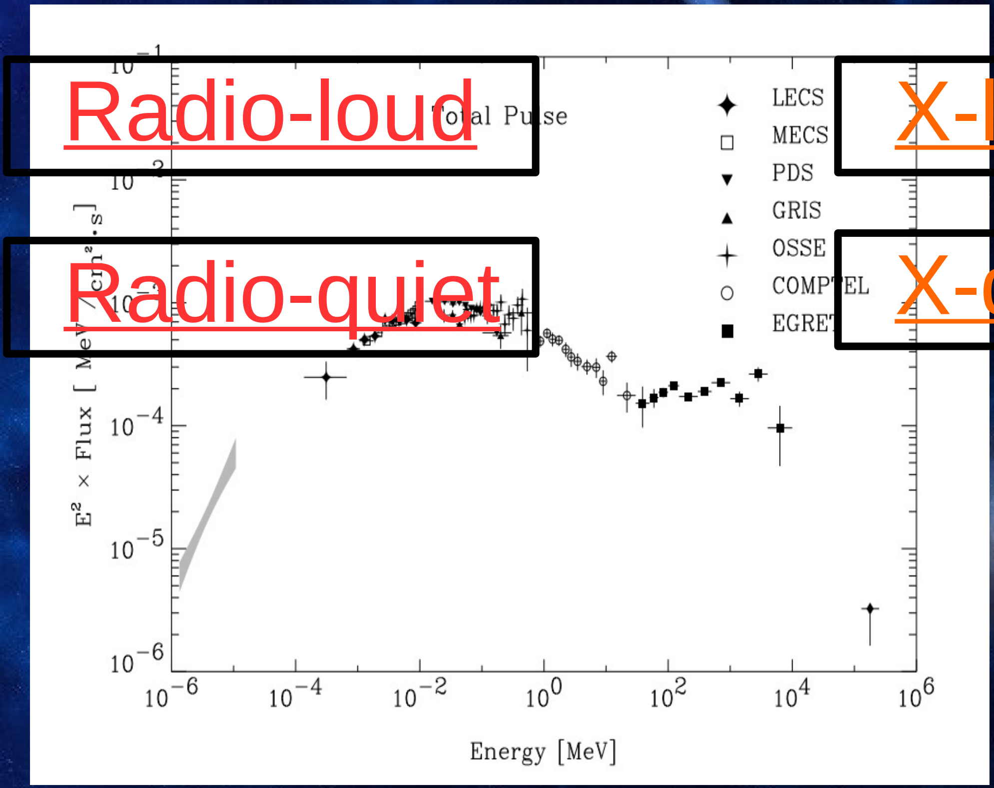
Spectral Energy Distribution

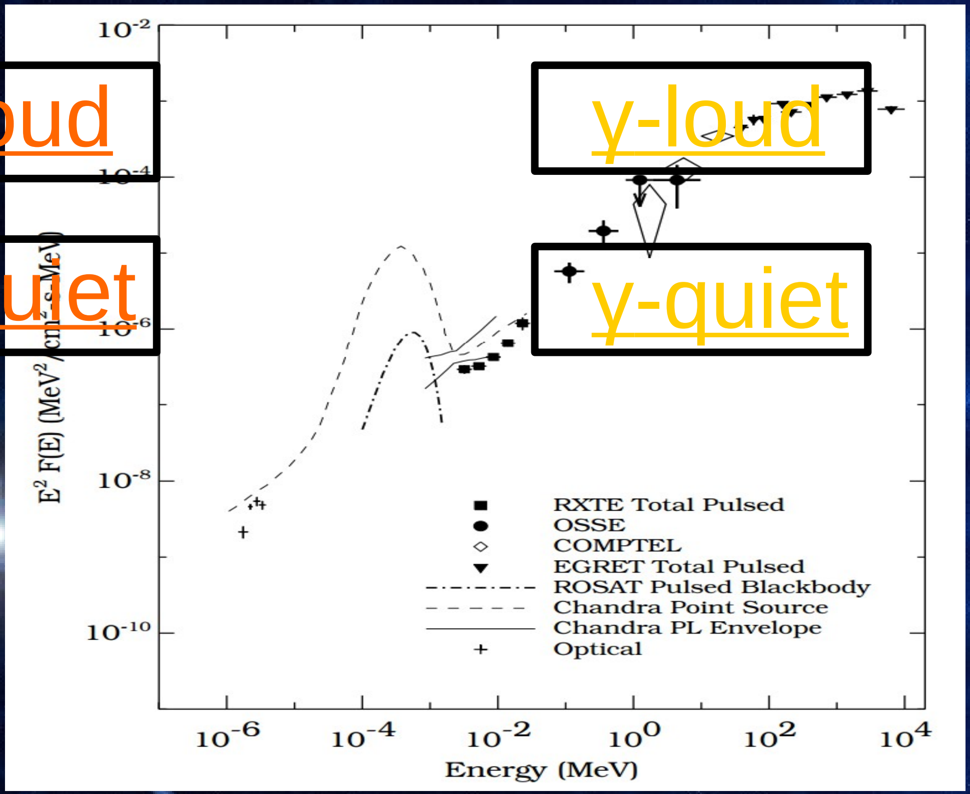


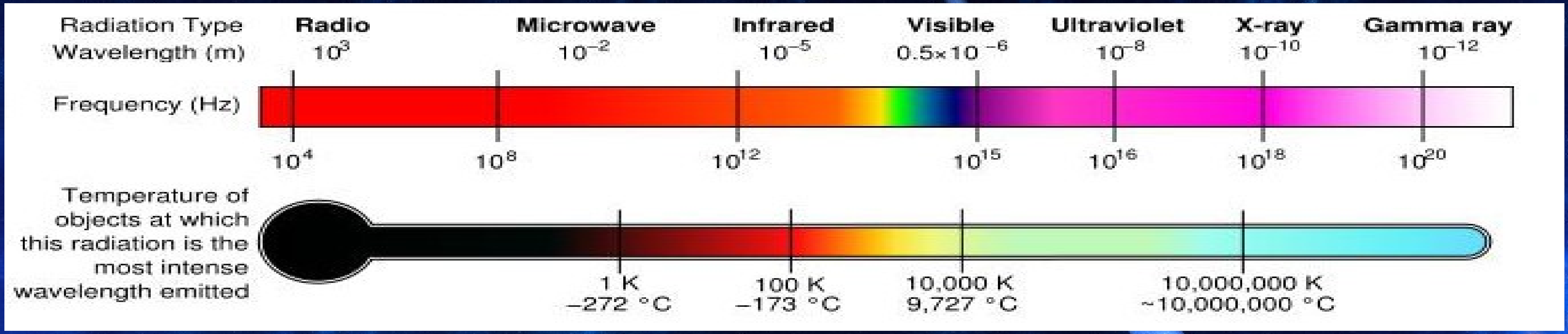




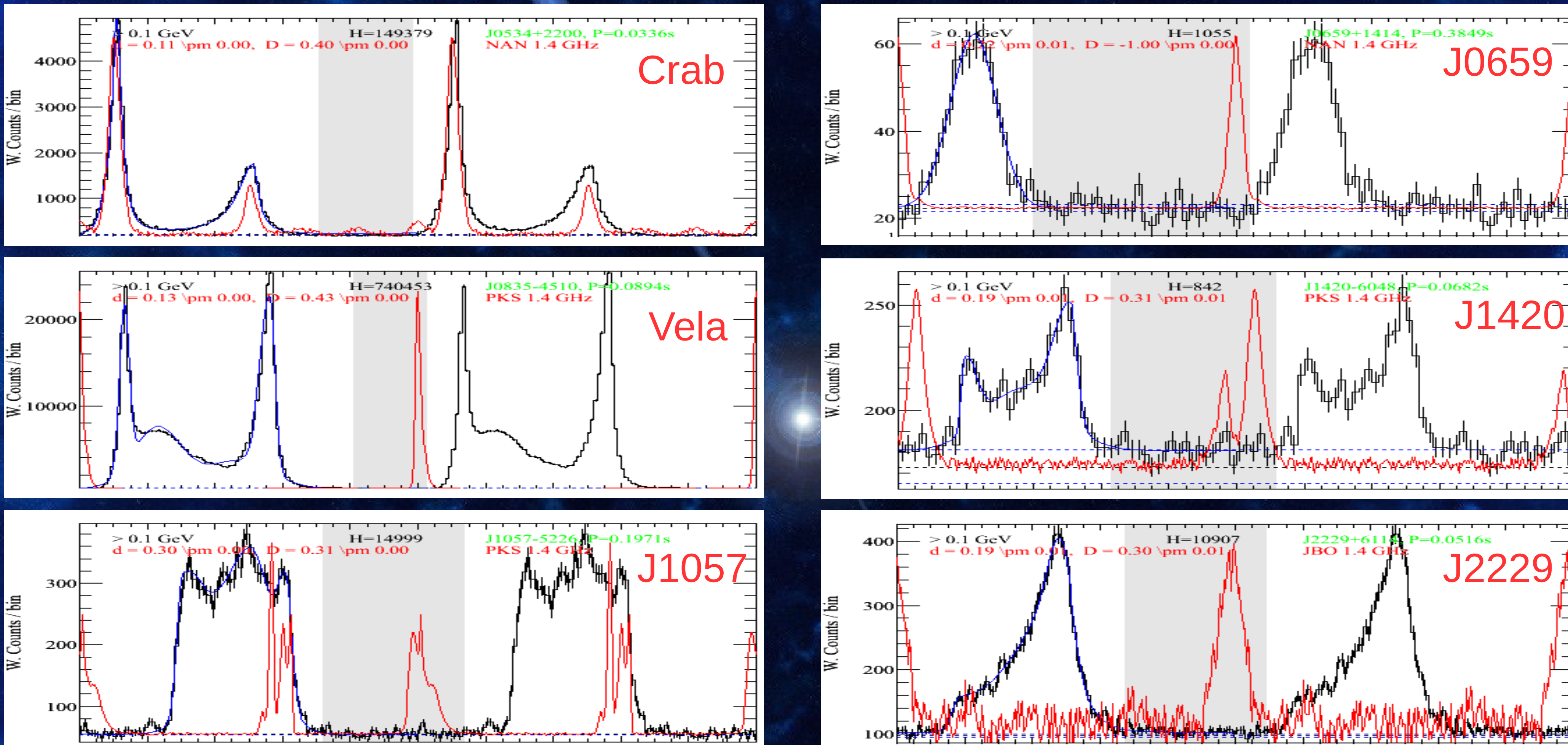
Spectral Energy Distribution



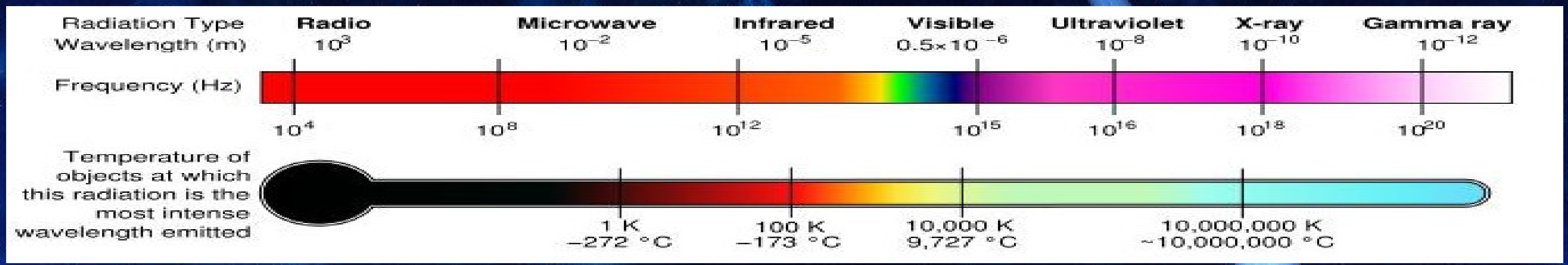




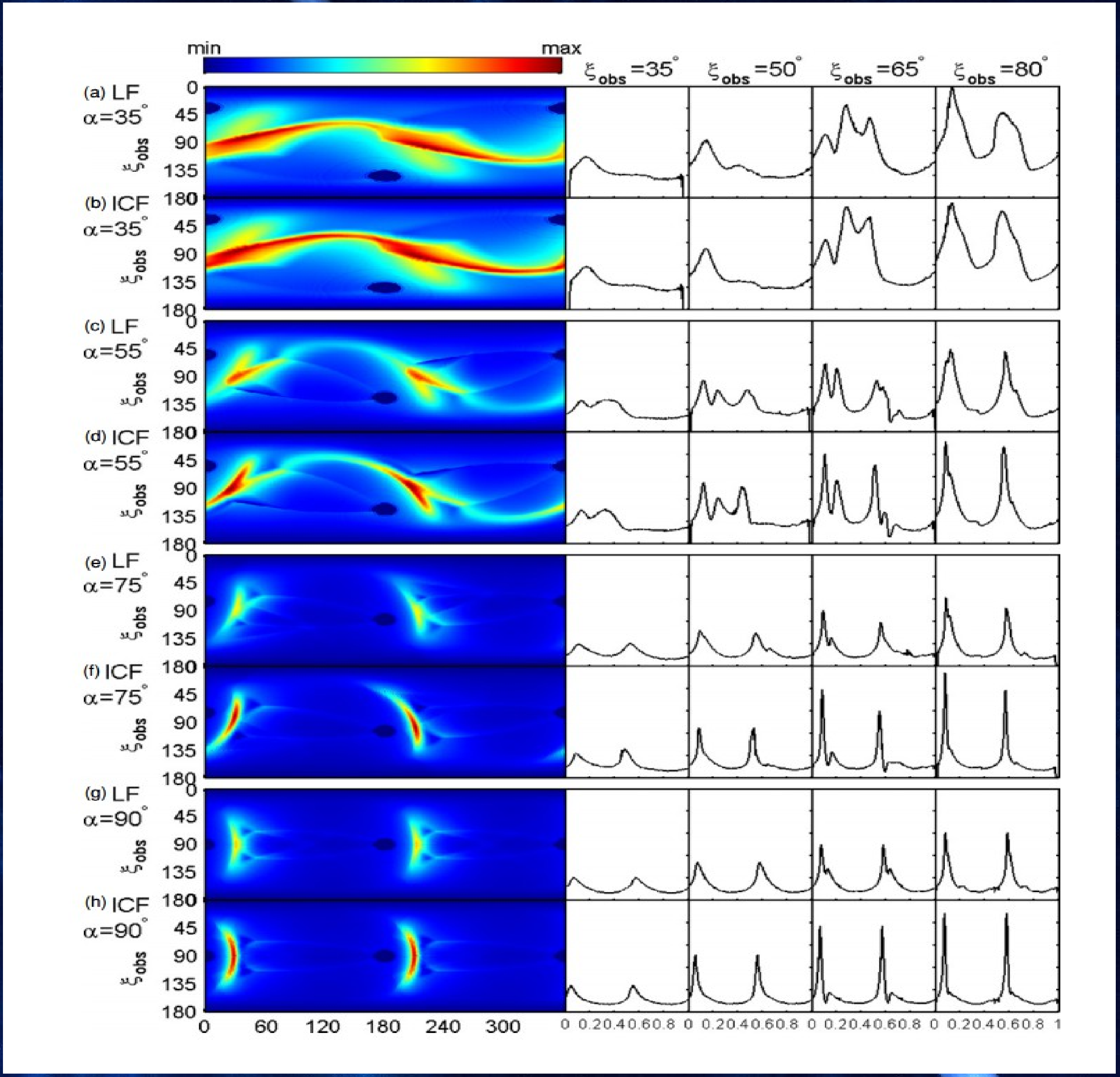
Multiwavelength emission



Abdo+13

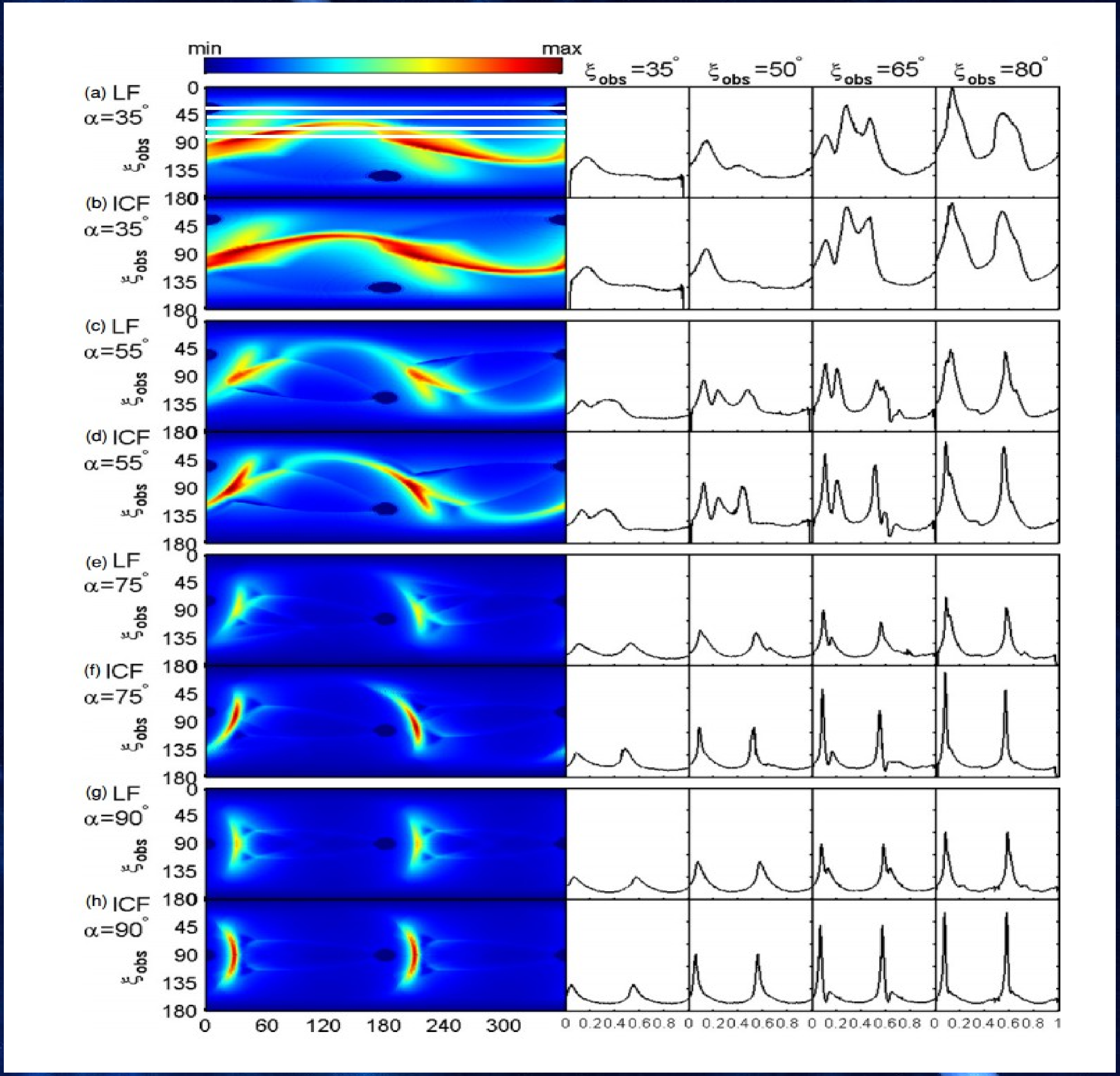


Radio and γ-ray simulations



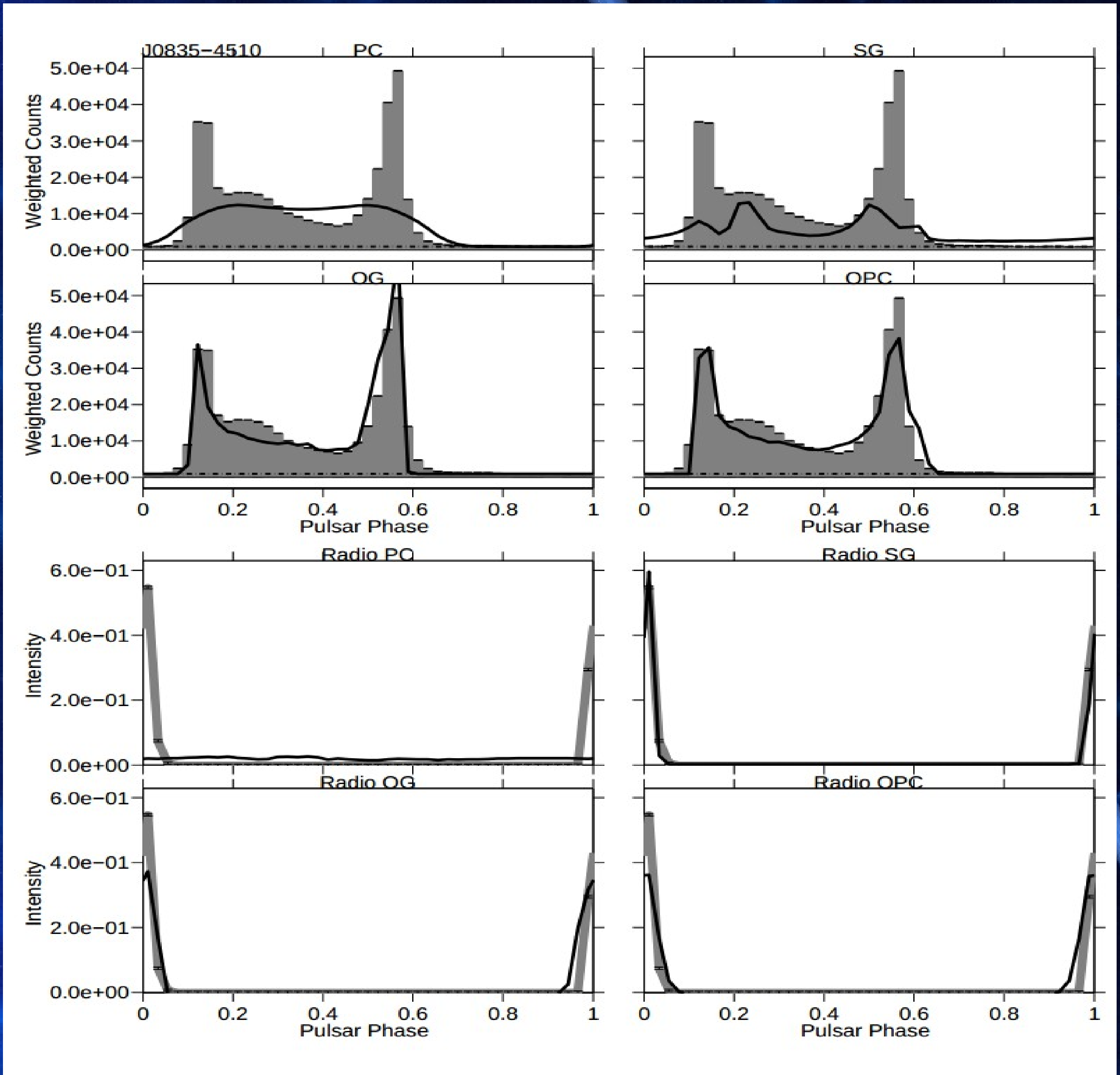
Bai&Spitkovski 10

Radio and γ-ray simulations



Bai&Spitkovski

Radio and γ-ray simulations



- In particular, the best results came from simultaneous radio-γ-ray simulations.
- Pierbattista+14 tested different emission models and “found” the geometry of ~120 Fermi pulsars

Pierbattista+14

X-ray band - 1

- Lack of X-ray surveys, few telescopes with adequate time/spectral resolution result in dishomogeneous observations (0s to 1Ms)
- Few, incomplete catalogs in literature: Becker09 (45 psrs), Marelli+11&2PC (49 psrs)
- Many observational papers but few theoretical paper focussed on X-ray emission
- (Thermal, non-thermal, nebular emissions mixed)
- Synchrotron radiation from particles in outer magnetosphere is thought to produce a broad spectrum of emission from infrared to up to 10 MeV... but it works only for the Crab (no phase lag!)

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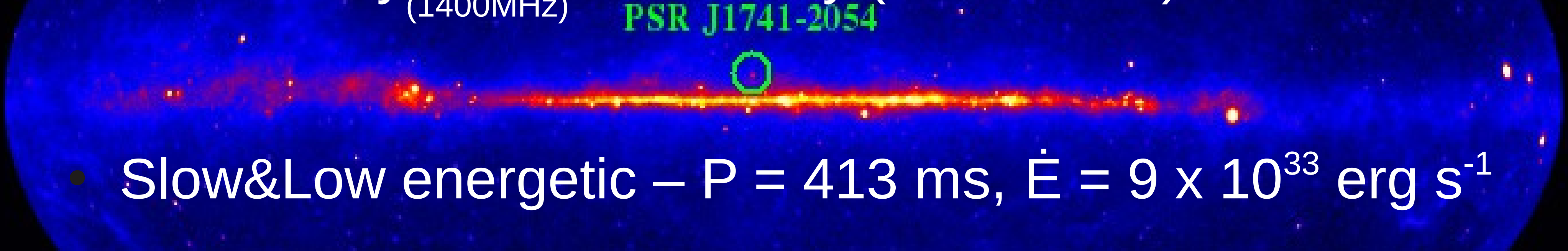
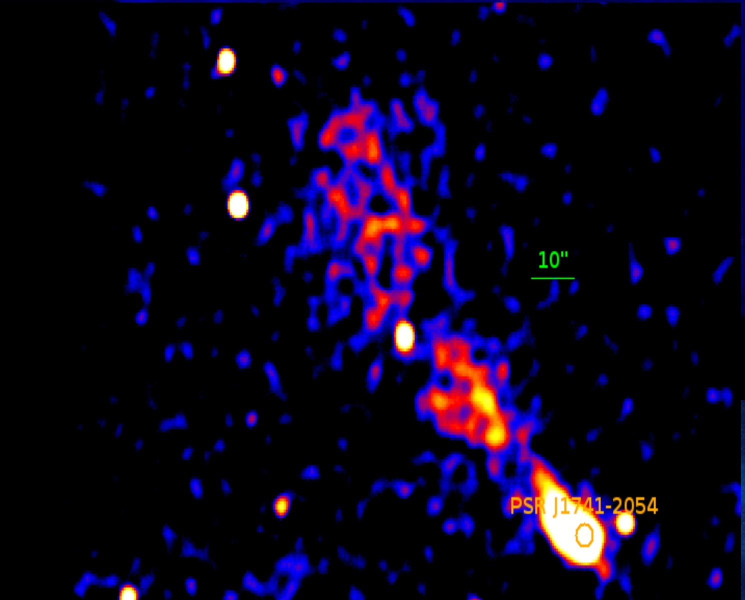
J1741-2054

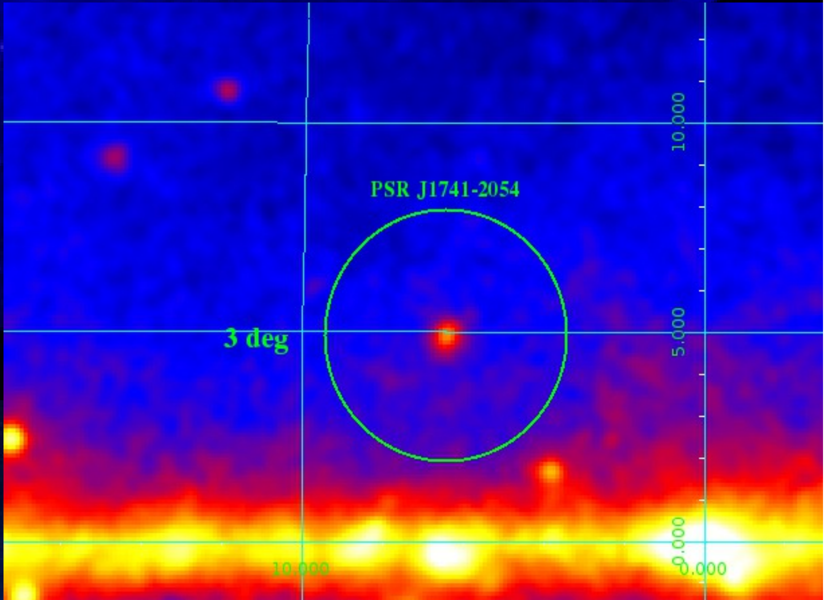
- Bright γ-ray source located 5° from the plane, at a distance of about 400 pc (DM)
- Parkes detected it as a radio-faint pulsar – flux density$_{(1400MHz)}$ = 0.16 mJy (Camilo+09)



- Slow&Low energetic – P = 413 ms, $\dot{E}$ = 9 x 10^{33} erg s^{-1}



Marelli+14

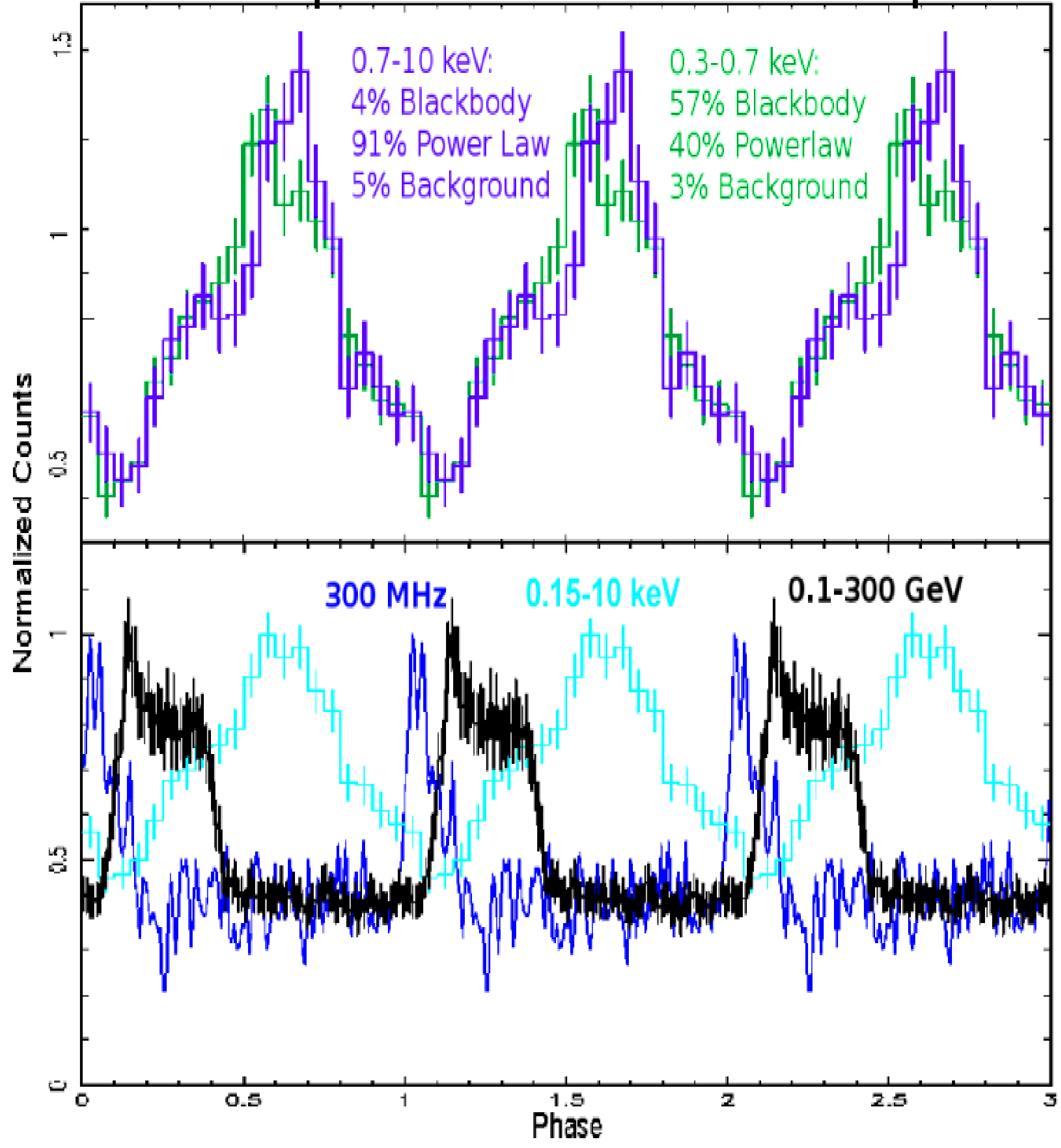


J1741 – X-ray light curve

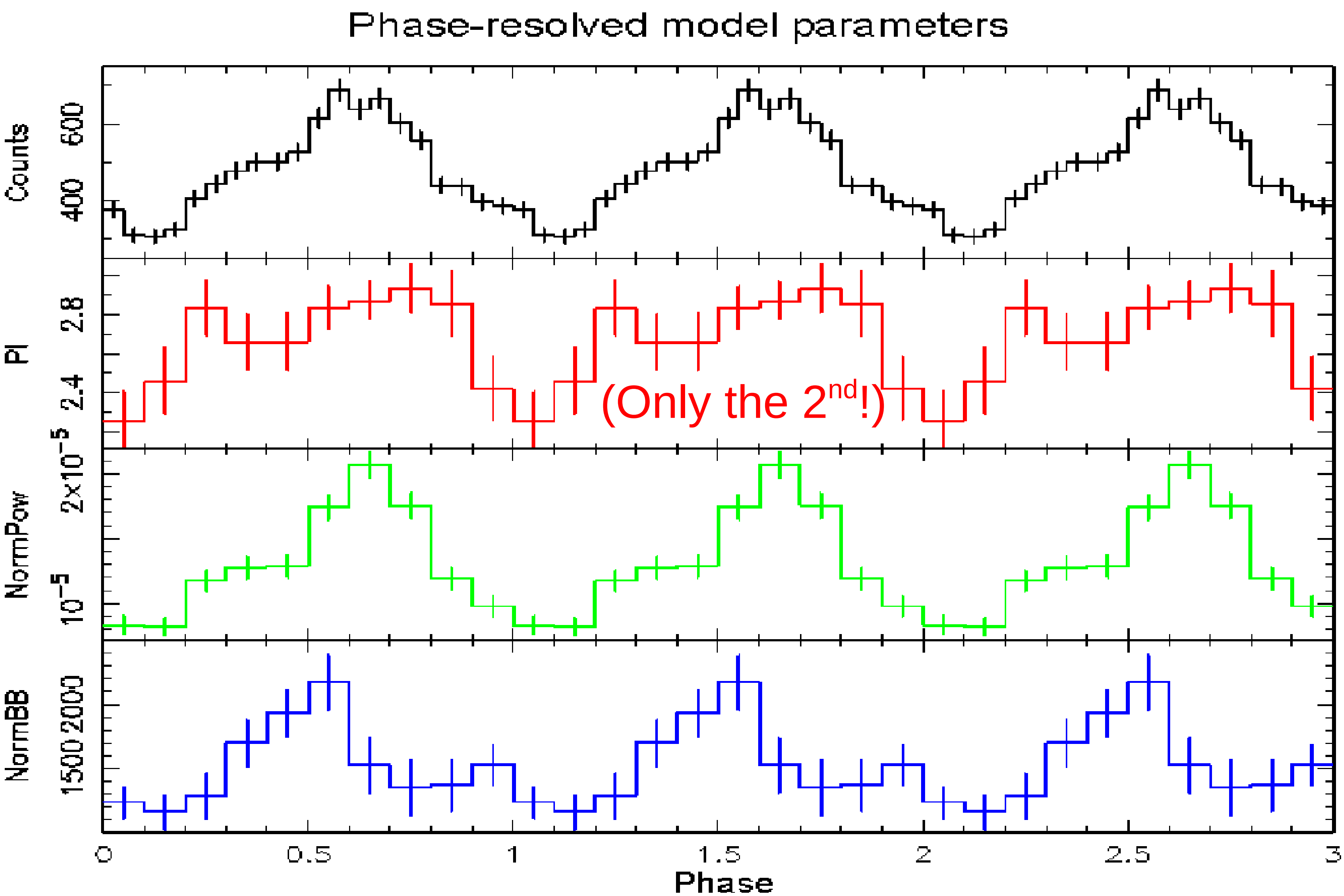
- BB and PL ~40% pulsed
- Thermal and non-thermal peaks in phase

- X, radio, γ-ray peaks out of phase
- No γ-ray spectral variation with phase
- X-ray spectral variation with phase

Non-th 38% pulsed Th 36% pulsed

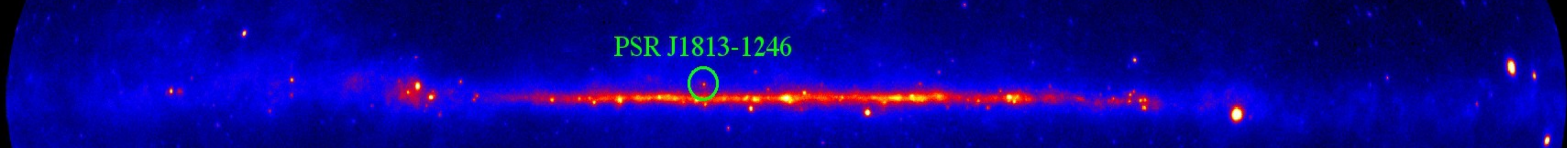


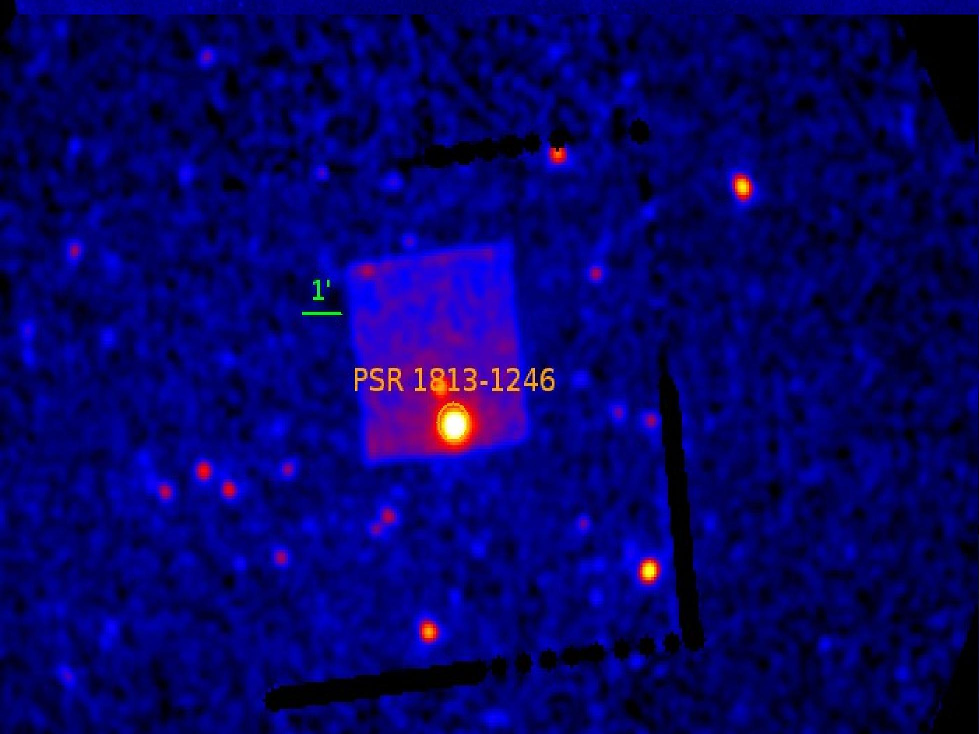
J1741 – X-ray phase-resolved

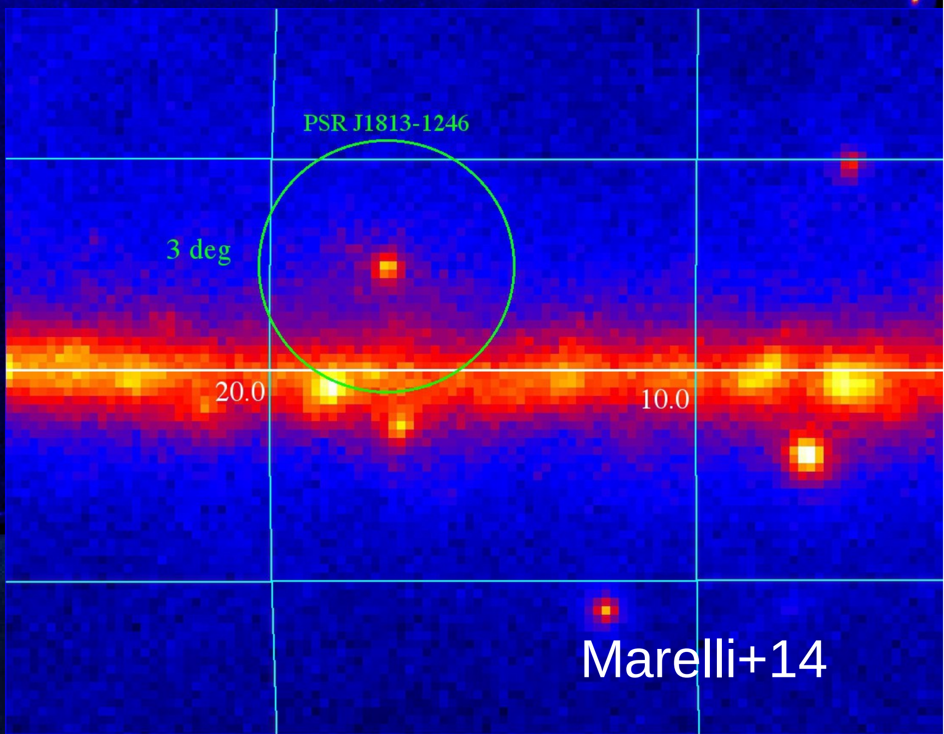


J1813-1246

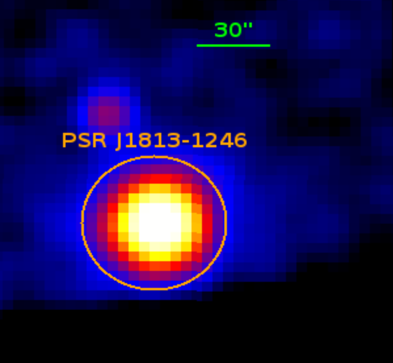
- Located 2.5° from the plane, > 2.5 kpc
  Bright in γ-rays & radio quiet
- 2nd most energetic radio-quiet pulsar ($\dot{E}$ = 6.3 x 10^{36} erg s^{-1}) and the fastest one (P = 48.1ms)



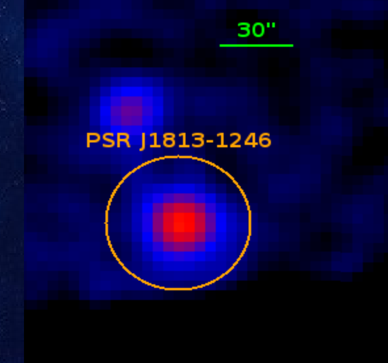




Marelli+14



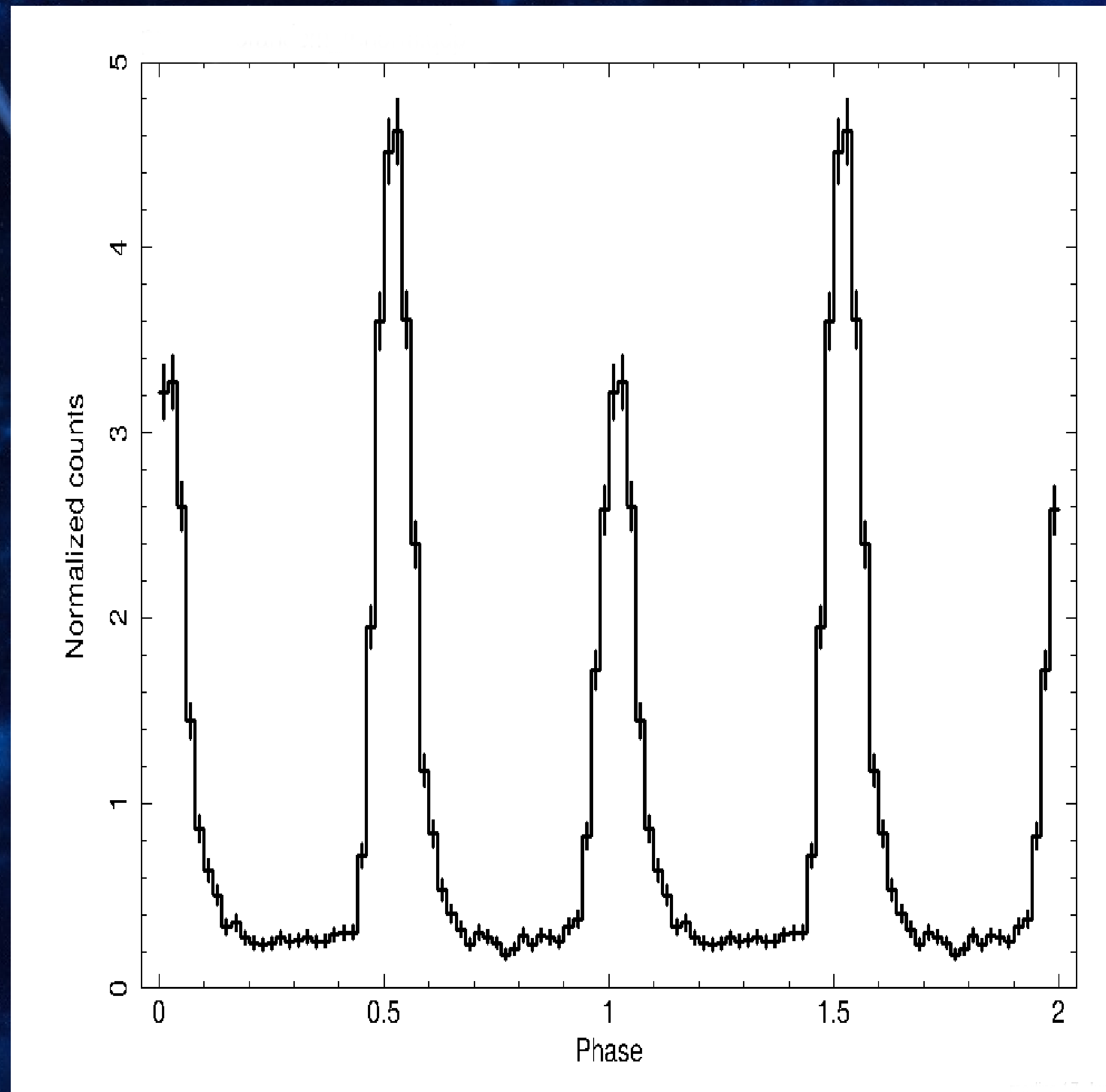
J1813 – X-ray light curve

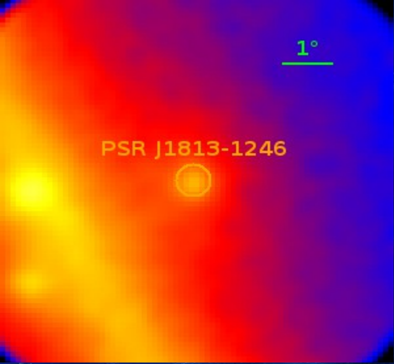


- VERY pulsed
  PF = (96 ± 3) %

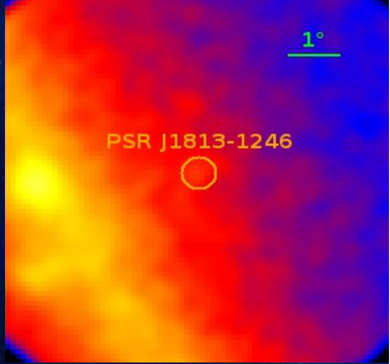
- Two asymmetric peaks
  phase lag 0.496±0.001
- Off-pulse emission
  (17σ)

- No spectral variation
  with phase down to
  0.08 in Γ (3σ)

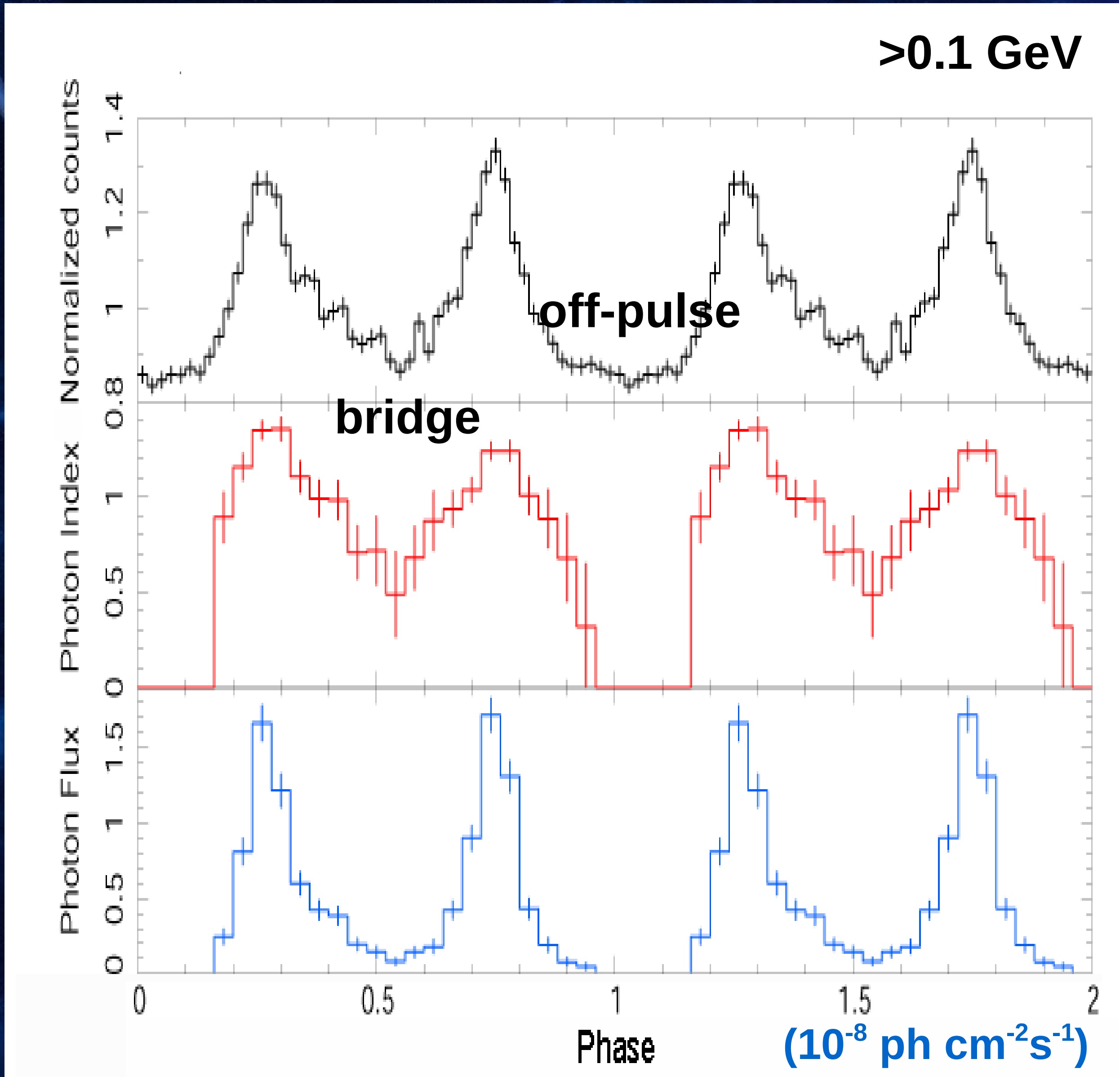




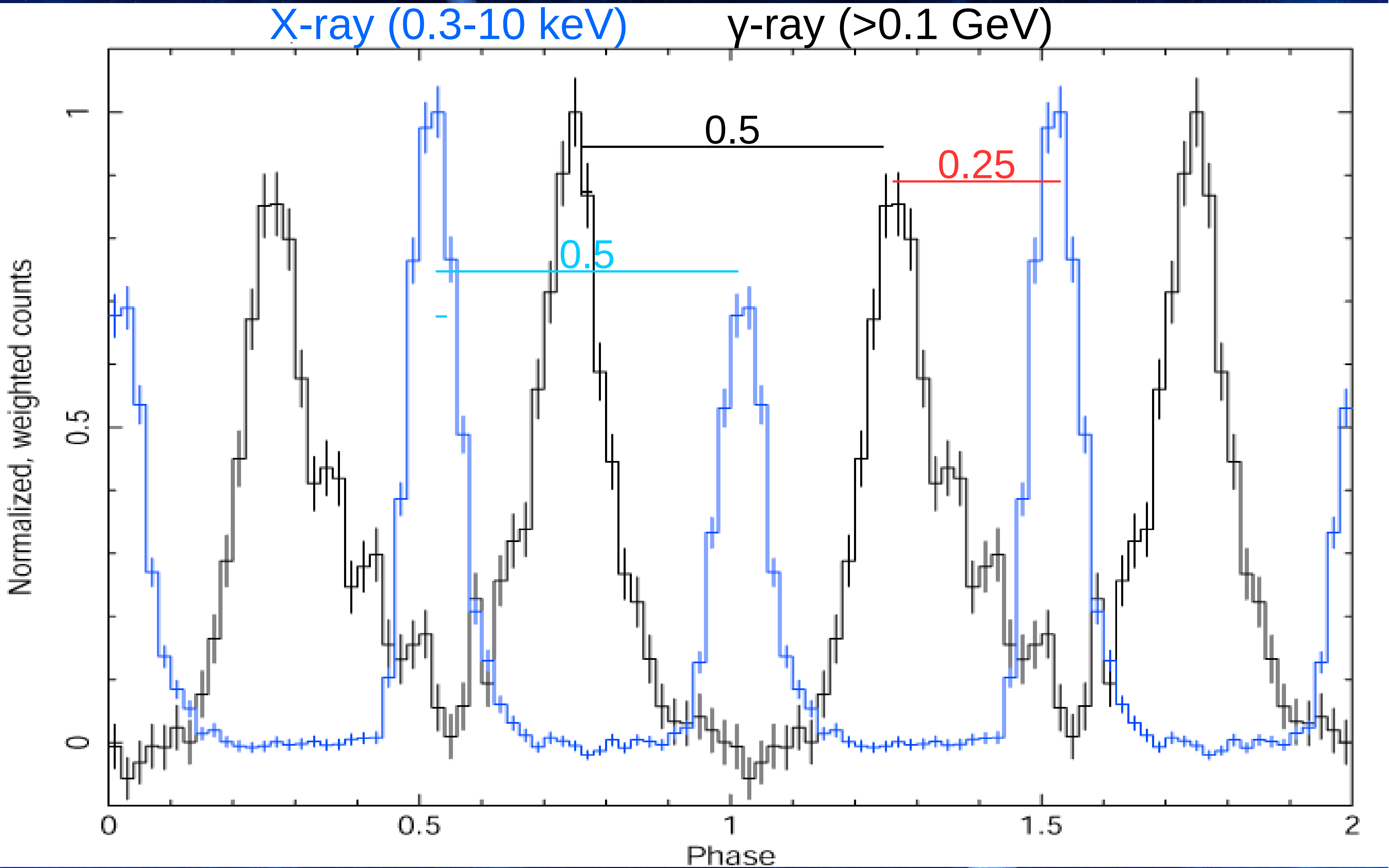
J1813 – γ-ray light curve



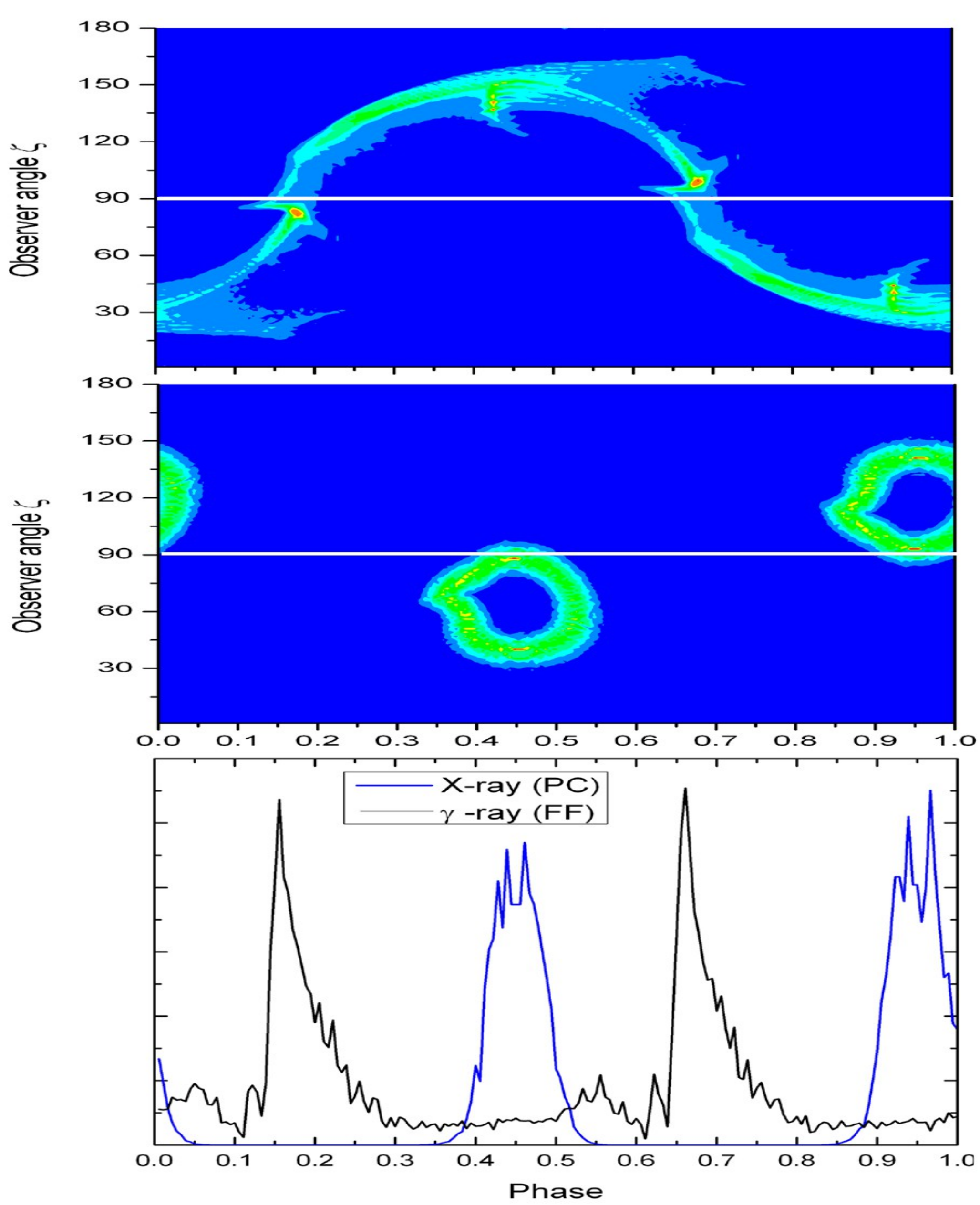
- Two asymmetric peaks phase lag 0.485±0.003
- No off-pulse emission
- Very significant (>>10σ) spectral variation with phase, mainly due to Γ, with softening during peaks



J1813 – MWL light curve



J1813 – new geometrical model



- magnetic inclination angle of 60°
- a) simulated γ-ray emission for a separatrix layer model from outer magnetosphere
- b) simulated cone beam X-ray emission from the polar caps for an emission altitude 0.2 R_{LC}
- c) Model γ-ray and X-ray light curves for a viewing angle of 90°

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X-ray band - 2

87 X-ray psrs

43 puls.

45 not puls.

22 pow | 17 pow+bb | 2 bb | 2 ?

33 pow | 7 pow+bb | 3 bb | 2 ?

14 X-ray psrs with “good” non-thermal light curve and spectrum

A comprehensive, multiwavelength study of the spectra and light-curves of these pulsars is necessary to build a model!

– MY FUTURE WORK –

A new tool for X-ray band

In γ-rays, photon weighting based on position and spectrum resulted to be a winning method to minimize source contamination, coming from high positional uncertainties.

This increases the sensitivity to pulsars by more than 50% under a wide range of conditions (Kerr+11)

In X-rays, positional uncertainties are ~10 lower, but...

We have much more point-like and extended sources and we have a possibly high background, so that...

We should test a similar method

XMM-Newton photon weighting

I am developing a python program that evaluates for each photon the probability of coming from one of the sources in an input list

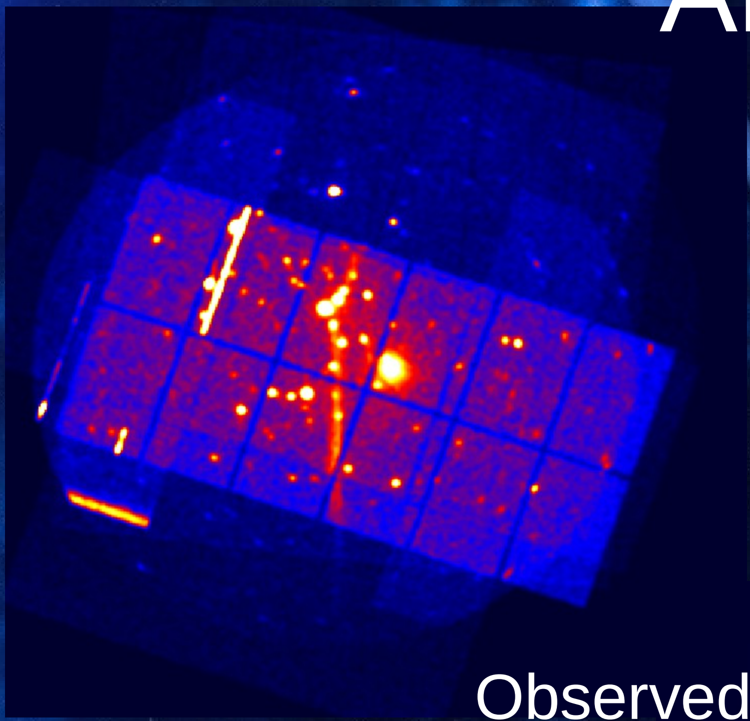
Input: event file, sources positions, sources spectra, sources spatial extension and shape

Output: probability columns in event file, different band simulated & subtracted images

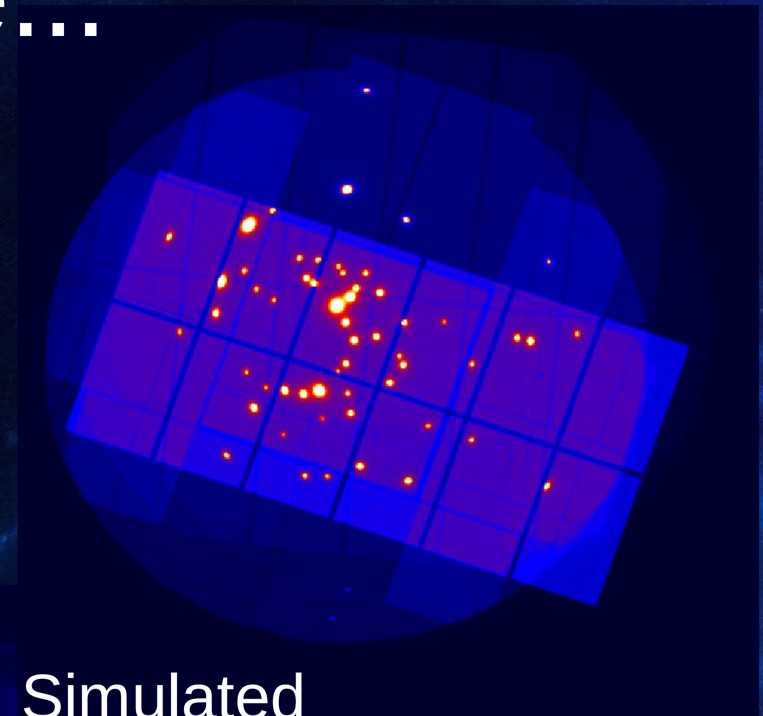
Tests on the first versions revealed an improvement ranging from 1.1 to 2 of the H-value in a pulsation search of six known X-ray pulsars

PRELIMINARY!

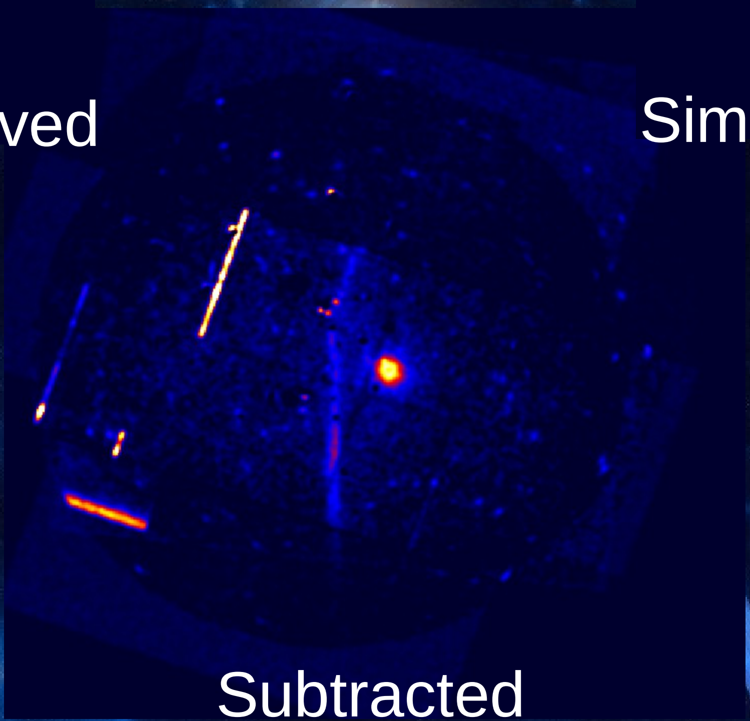
An example...



Observed

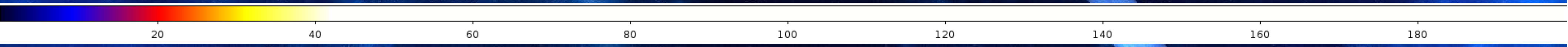


Simulated



Subtracted

Marelli+ in prep



(Thank you for the attention!)