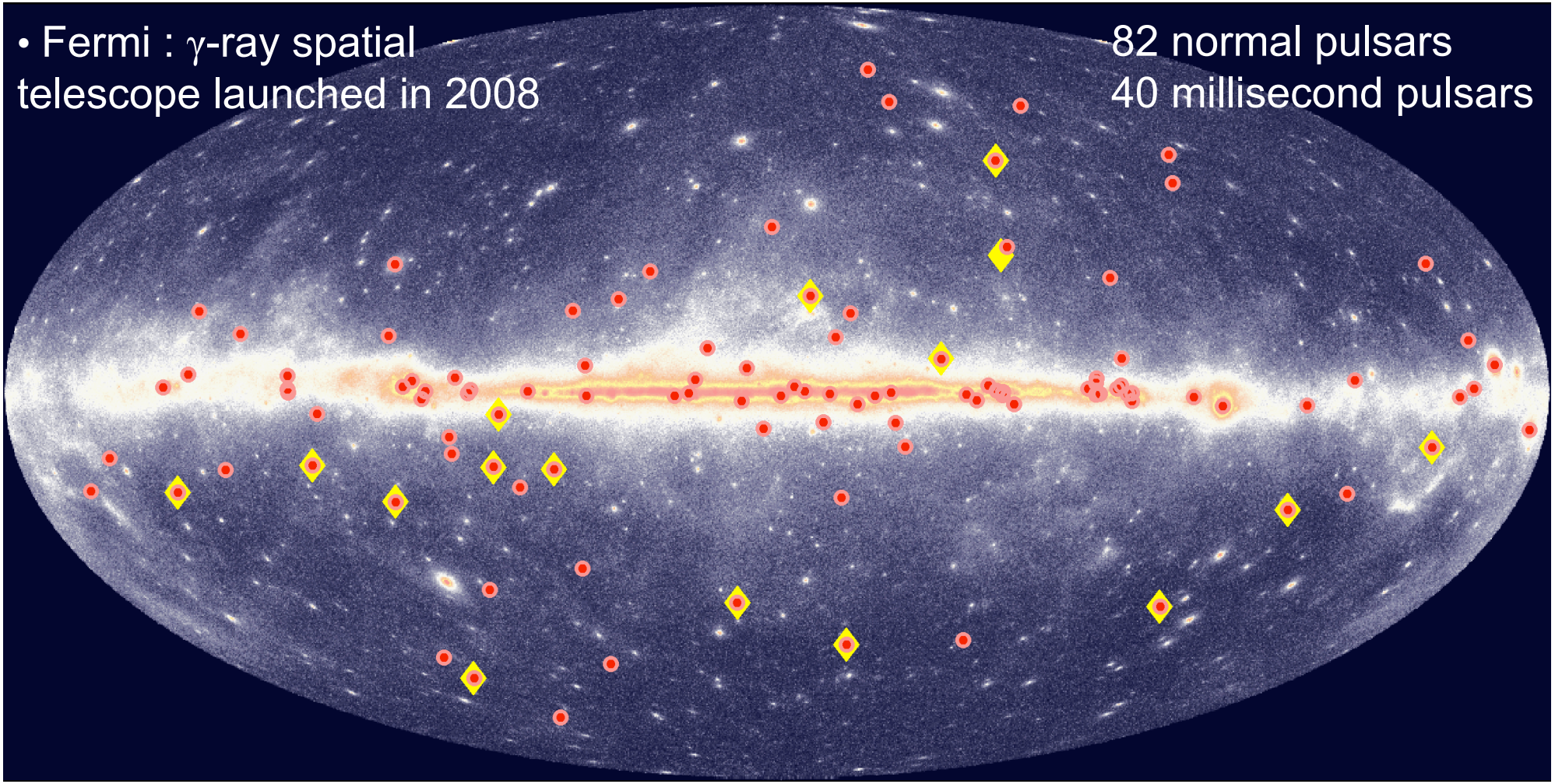
Fermi
Gamma-ray
Space Telescope

Emission Gamma des pulsars milliseconde détectés par Fermi

Nicolas Renault Tinacci
PhD Supervisor : **Isabelle Grenier**
Collaboration : **A.K. Harding**
(NASA, GSFC)

Many pulsars detected by Fermi



= studied pulsars
= detected pulsars with fermi

- **Highlighting their amazing electromagnetic activity**

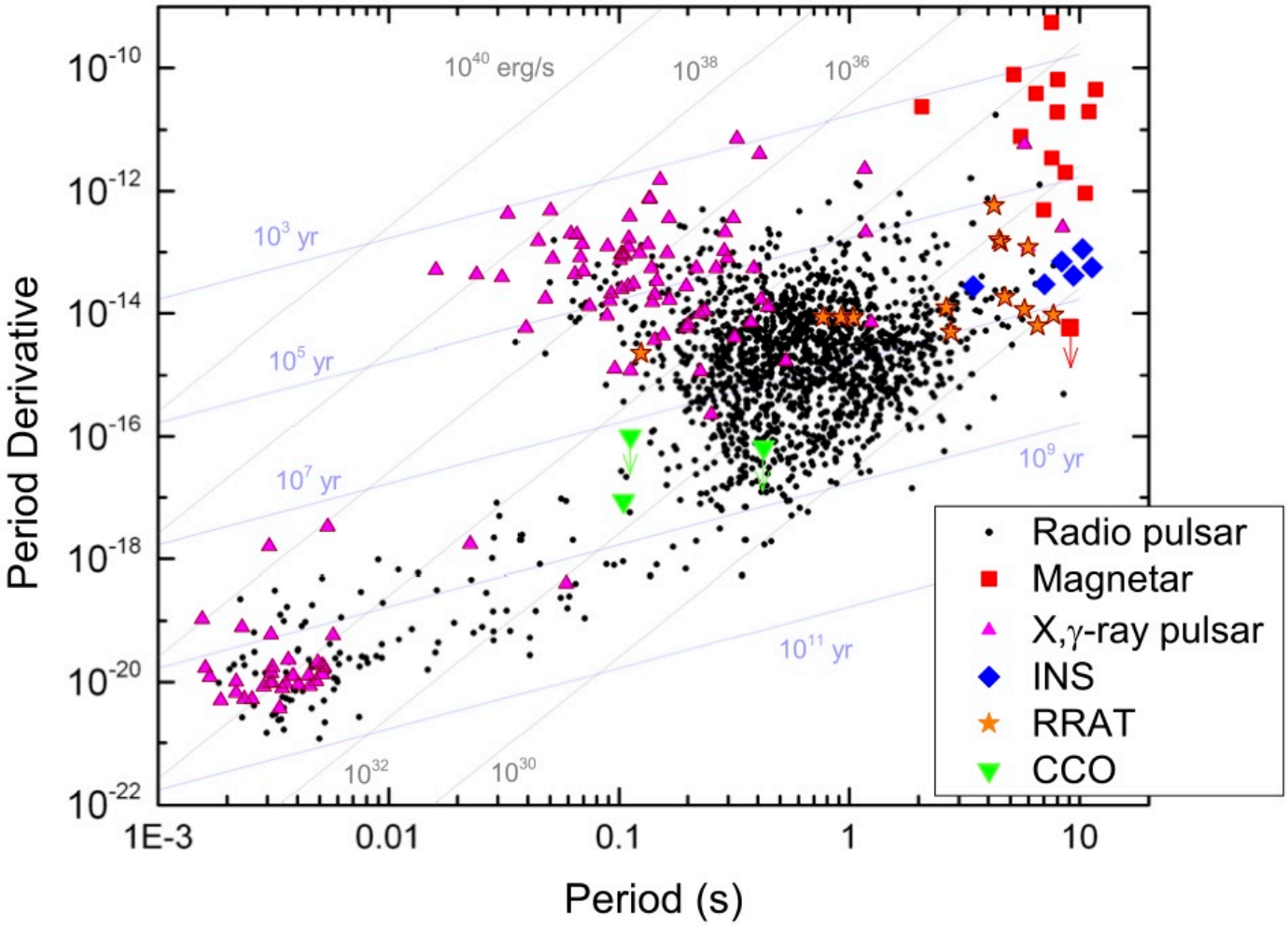
What's a neutron star?

- **Neutron star = residual (1.4 $M_\odot$,15 km) of a massive star collapsing (supernova)**
- **Highly magnetized (10^8 T = 10^{12} Gauss)**
- **Magnetospheric emission in radio, X-rays and γ-rays**
- **Characterized by :**

  Period P

  Period 1st derivative Pdot

  Rotational Power Edot …



- **Millisecond Pulsar = Recycled pulsar by its companion in a binary system**

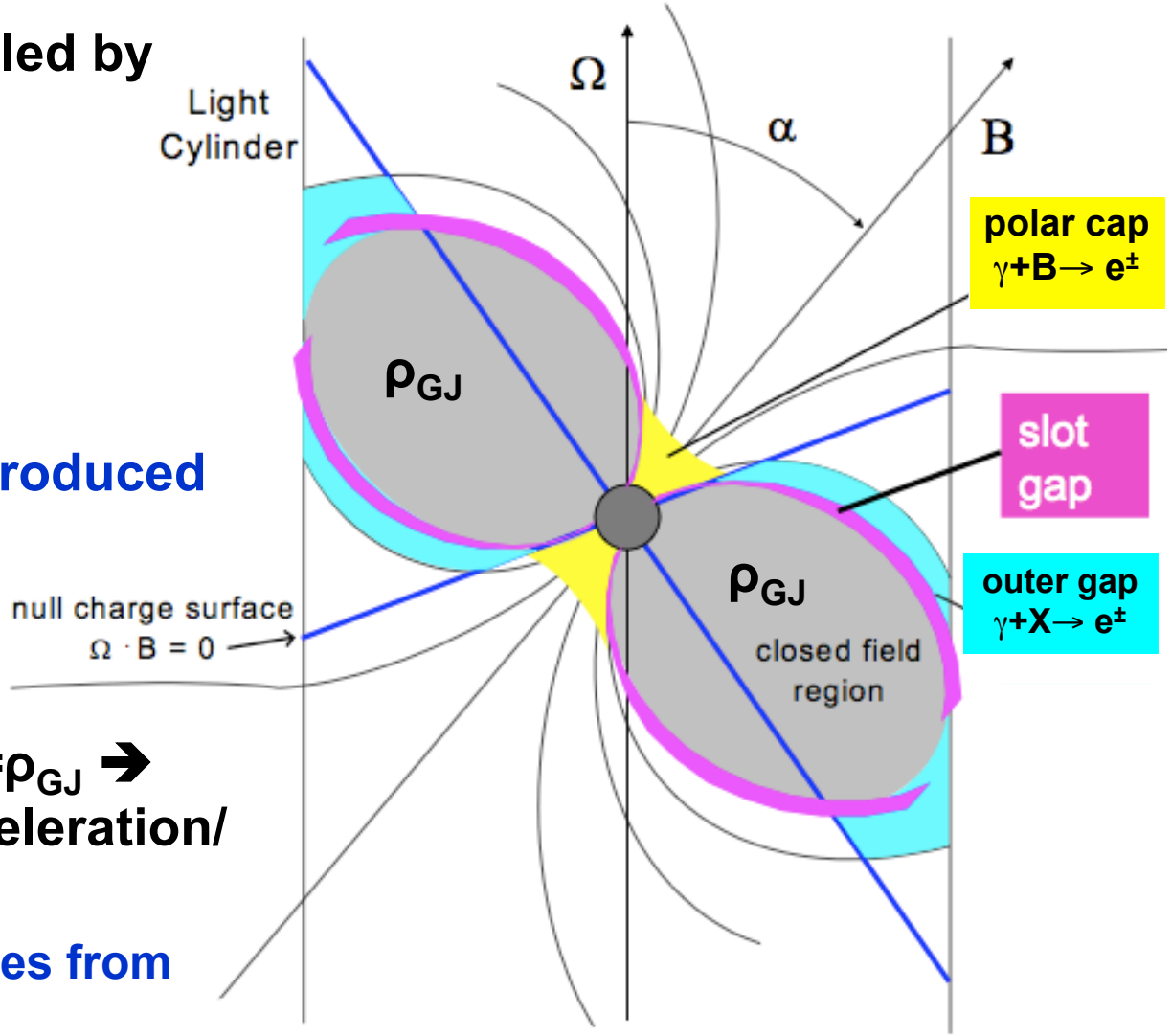
Magnetospheric Emission

- **Dipolar magnetosphere filled by free plasma in corotation**
  - **Plasma density**

    Goldreich & Julian (1969)

$$\rho_{GJ} = -2\epsilon_0 \vec{\Omega}.\vec{B}$$

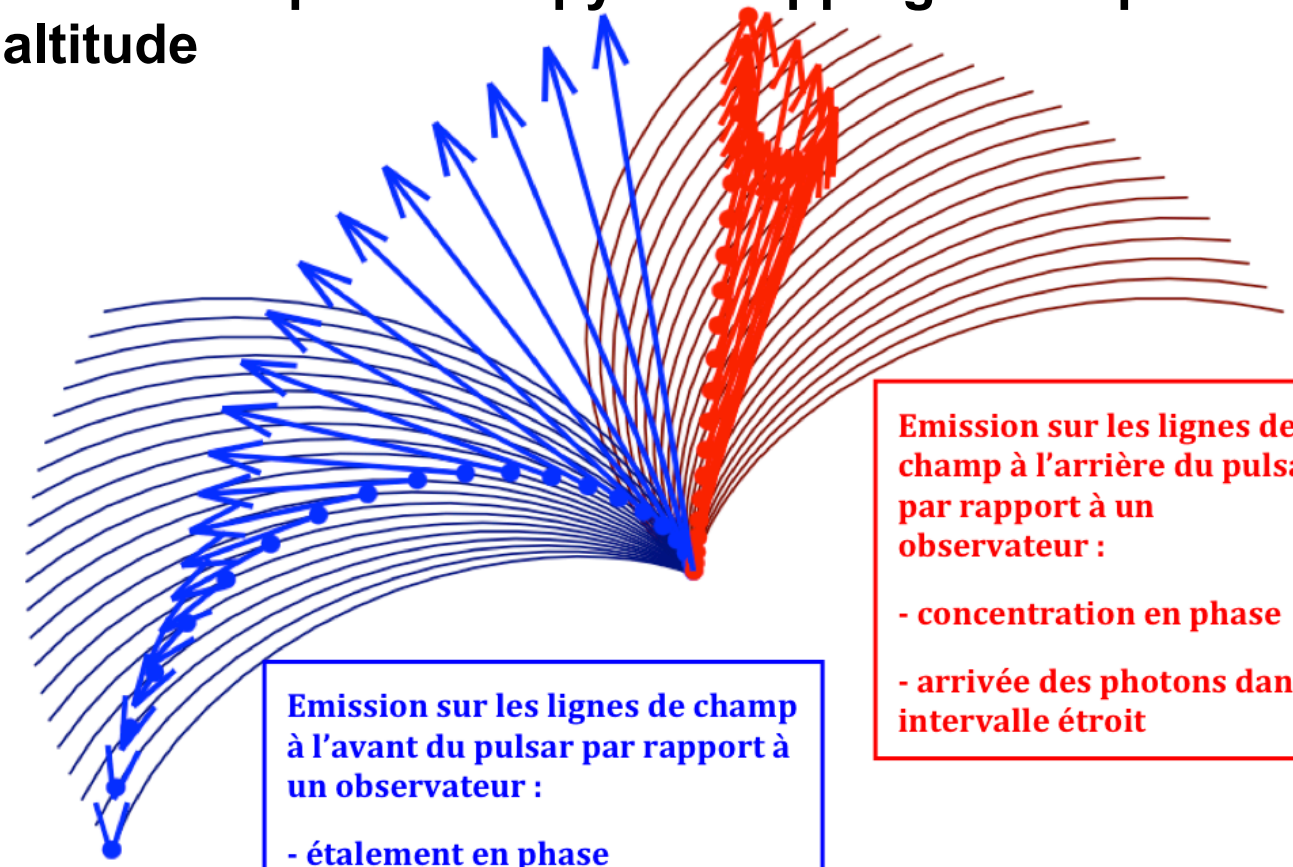
  - **$E_{//}$ screened by pairs produced in the cascades**



- **But few regions where $\rho \neq \rho_{GJ}$ ➔ ddp ➔ $E_{//}$ ➔ particles acceleration/ cascades**
  - **Slot Gap : primary particles from Polar Cap**
  - **Outer Gap : leakage beyond LC**

Caustics Peaks

- **Relativistic Phenomena (phase delay, retarded potentials, aberration) ➔ concentration in phase of photons emitted at different altitudes**
- **Phased Resolved Spectroscopy ➔ mapping of the processes with the altitude**



Emission sur les lignes de champ à l'arrière du pulsar par rapport à un observateur :

- concentration en phase

- arrivée des photons dans un intervalle étroit

Emission sur les lignes de champ à l'avant du pulsar par rapport à un observateur :

- étalement en phase

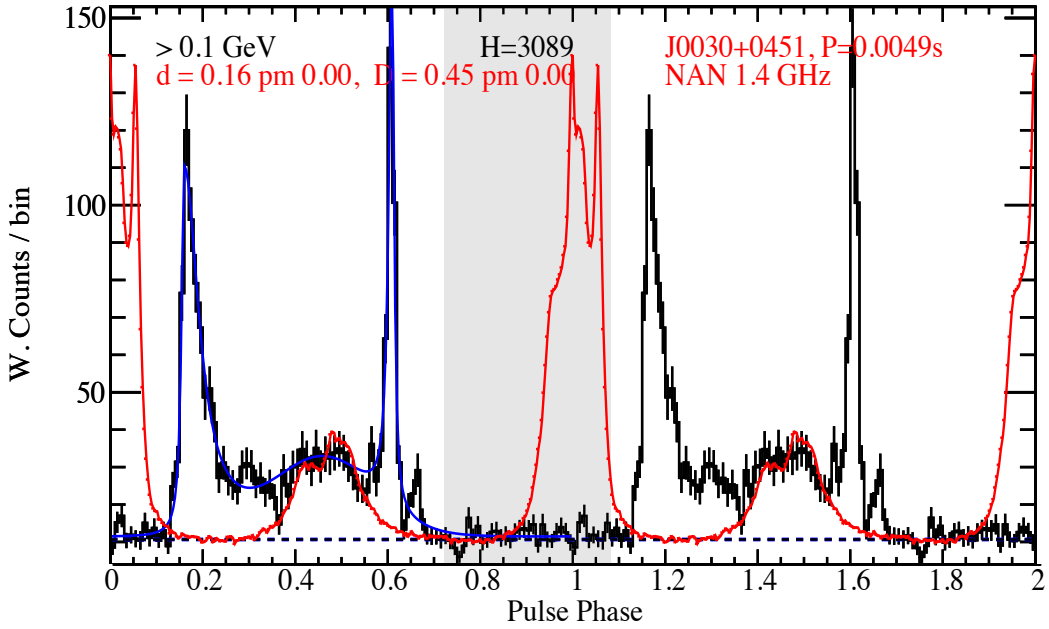
- arrivée des photons dans un intervalle de phase large

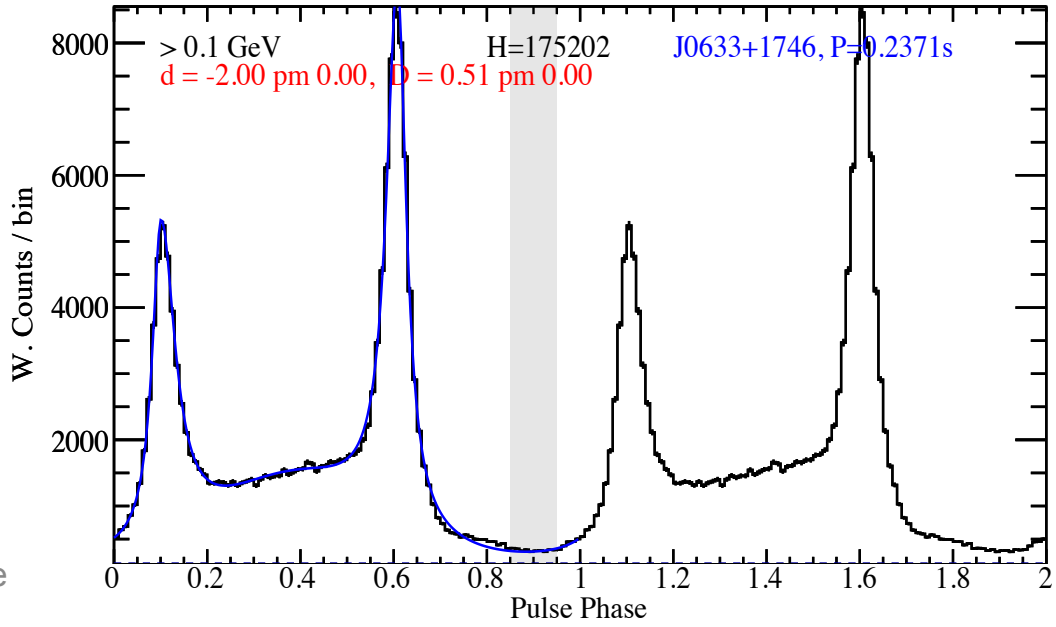
Millisecond Pulsar vs Young Pulsar

Why study MSPs ?

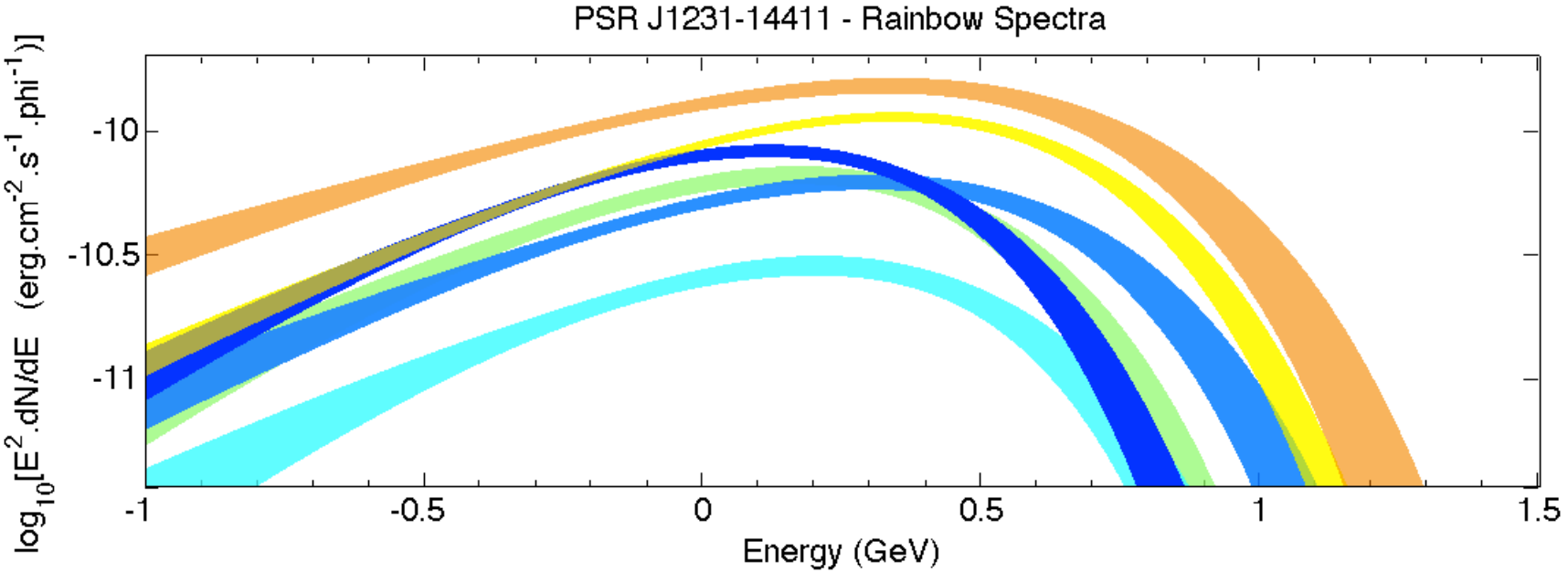
- Similar γ-ray profiles for young pulsars (10^4 years) and for MSPs (10^9 years) ➔ similar processes
- More compact magnetosphere :
  - ➔ **B** field at light cylinder of MSPs ~ that of young isolated pulsars producing similar acceleration & radiation processes to be studied
  - ➔ Caustic effects weaker
- More accurate timing

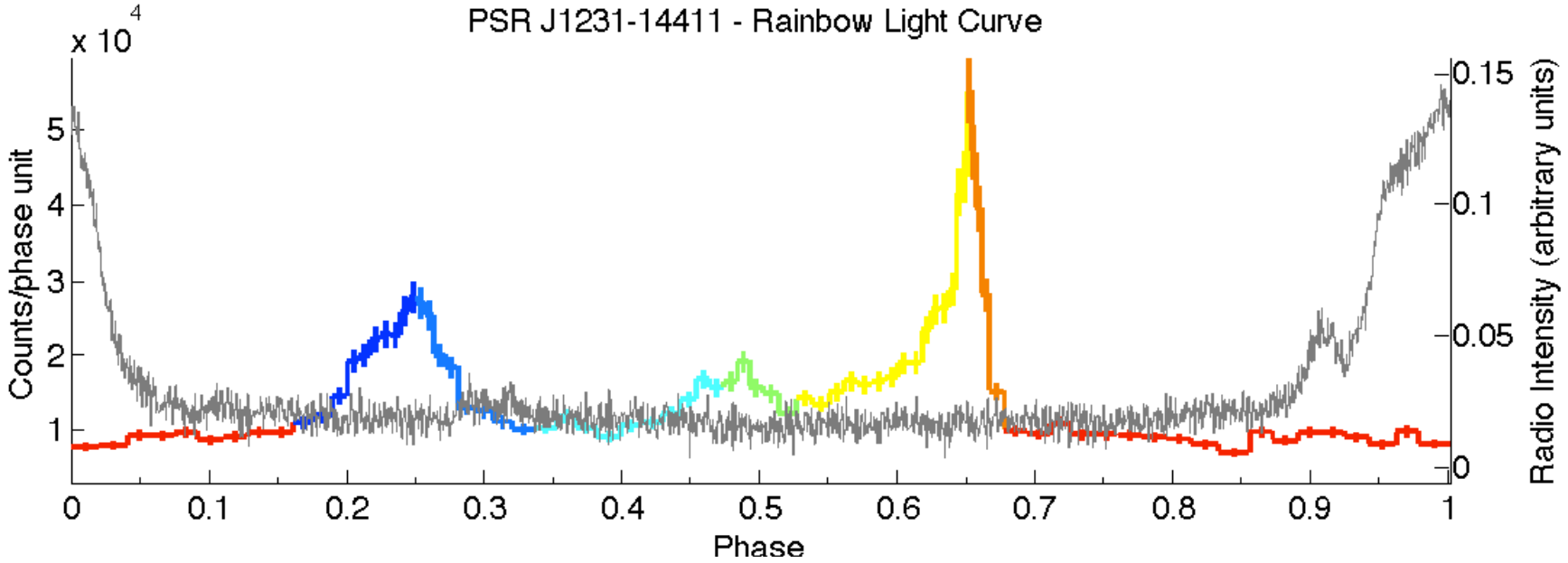
1st Phase Resolved Spectroscopy of MSPs



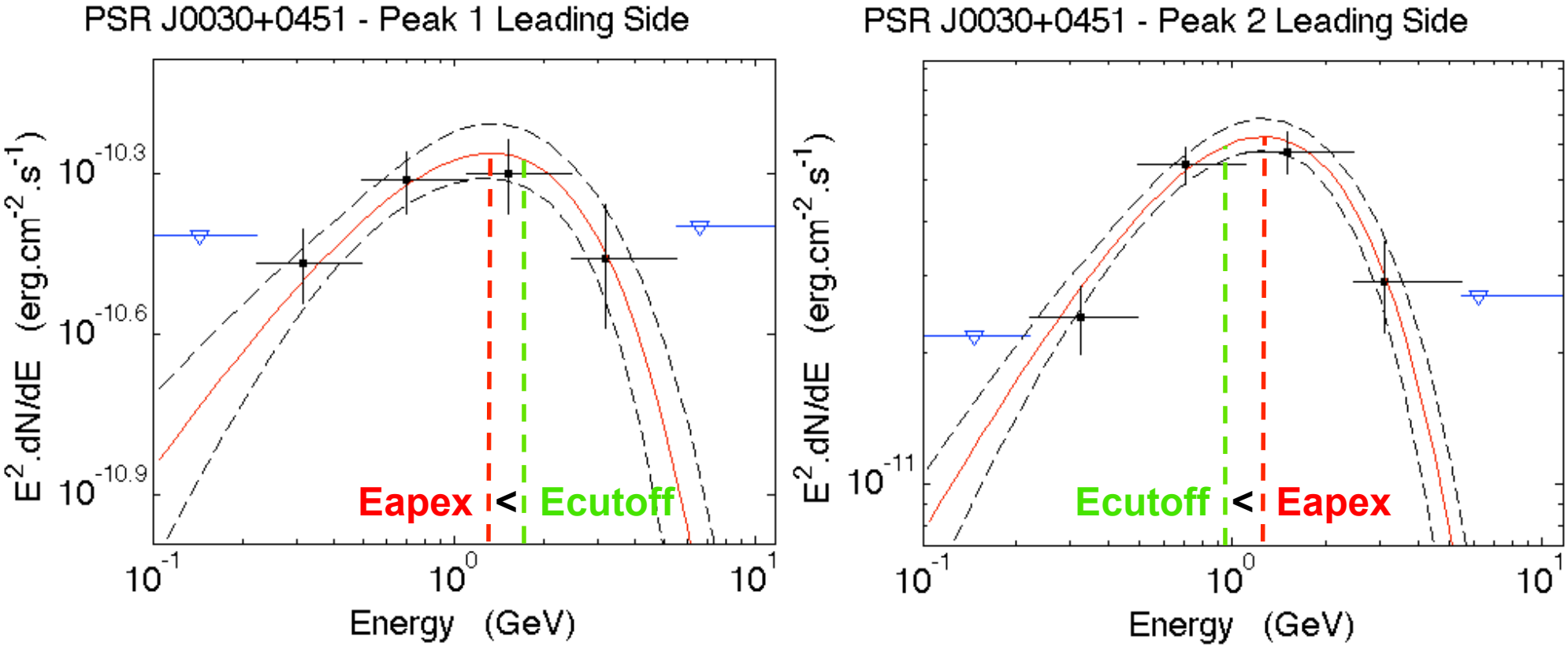


Phase Resolved Spectroscopy





Apex/CutOff Energies

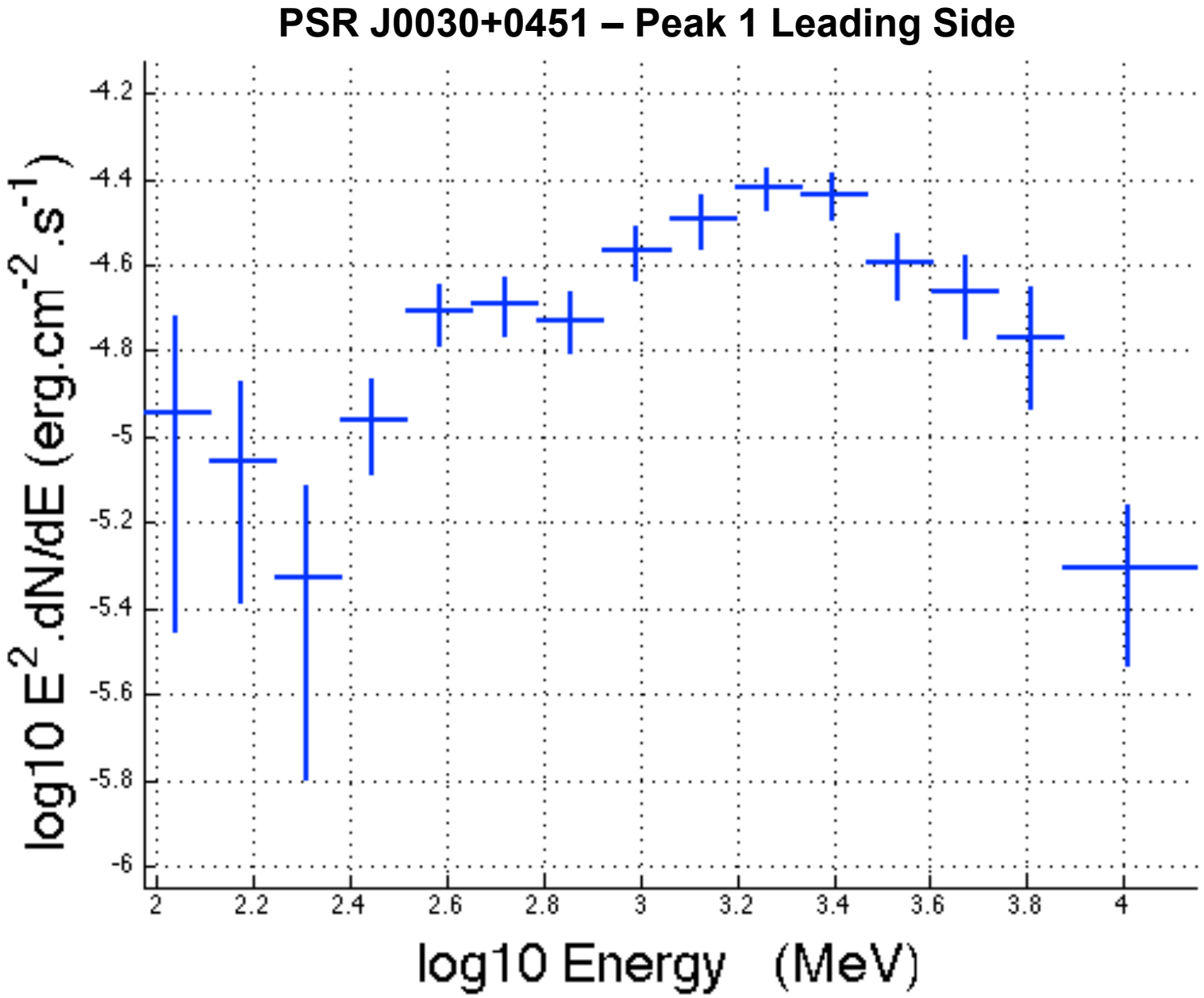


- $E_{cutoff} < E_{apex}$ for some cases
- Inability of analytical shapes to well fit the gentle spectral roll-over

➔ Analytical model not optimal

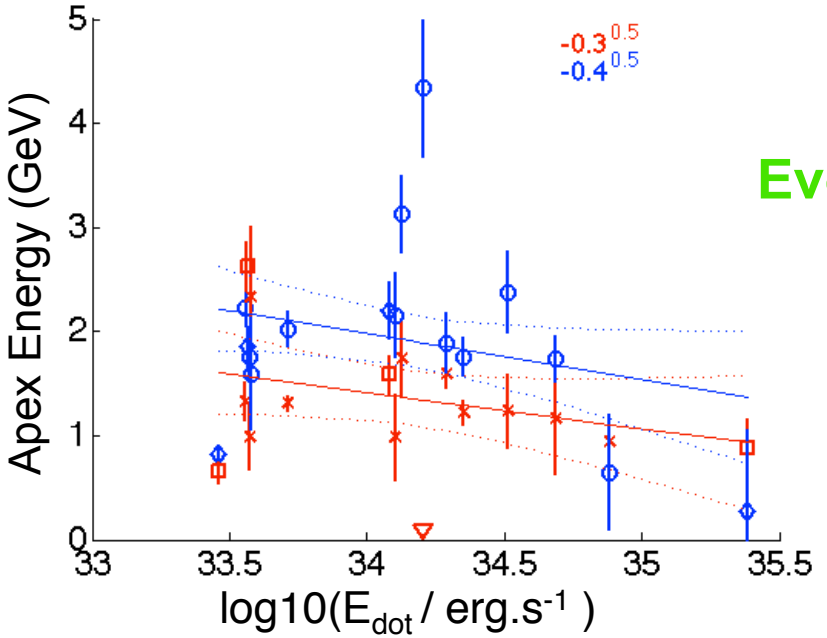
➔ Study without any assumption on spectral shapes

Without any analytical model

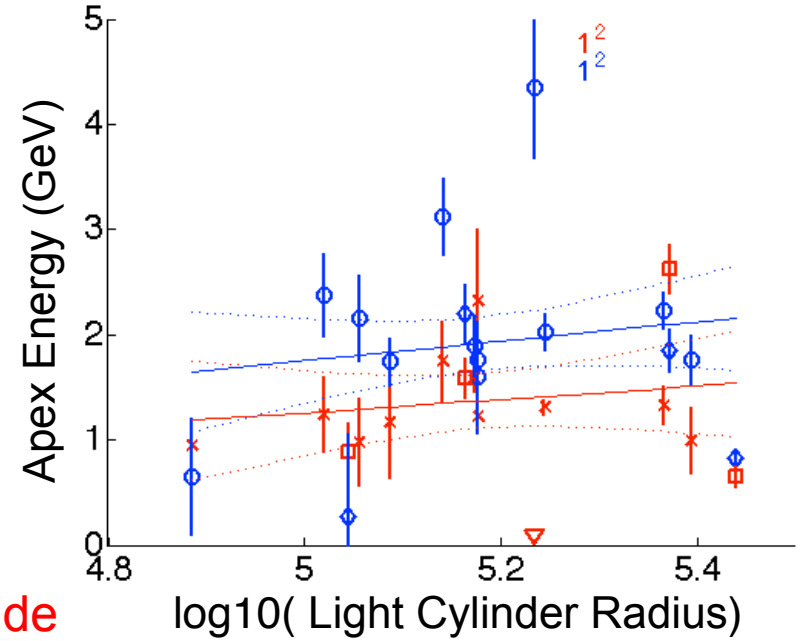


More results to come

Apex Energy



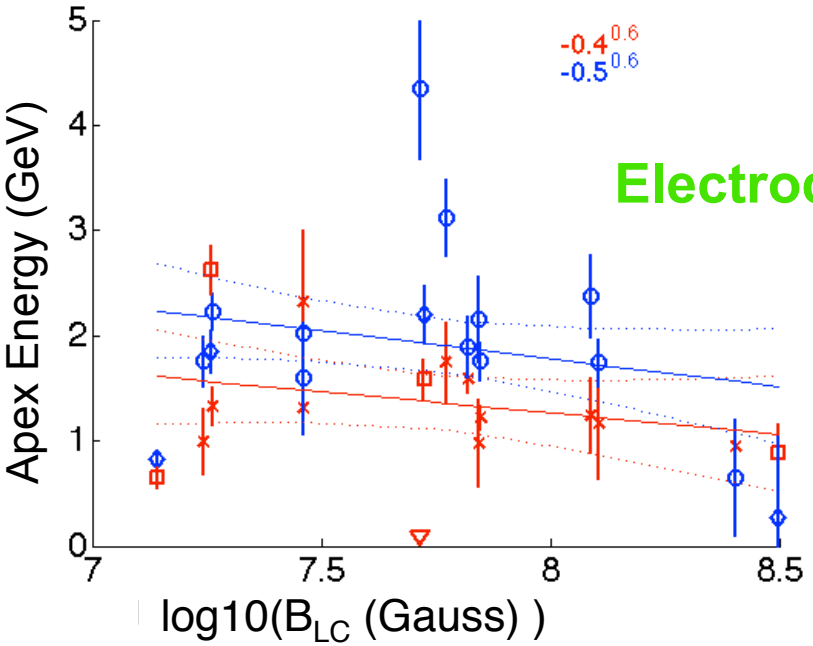
Evolution



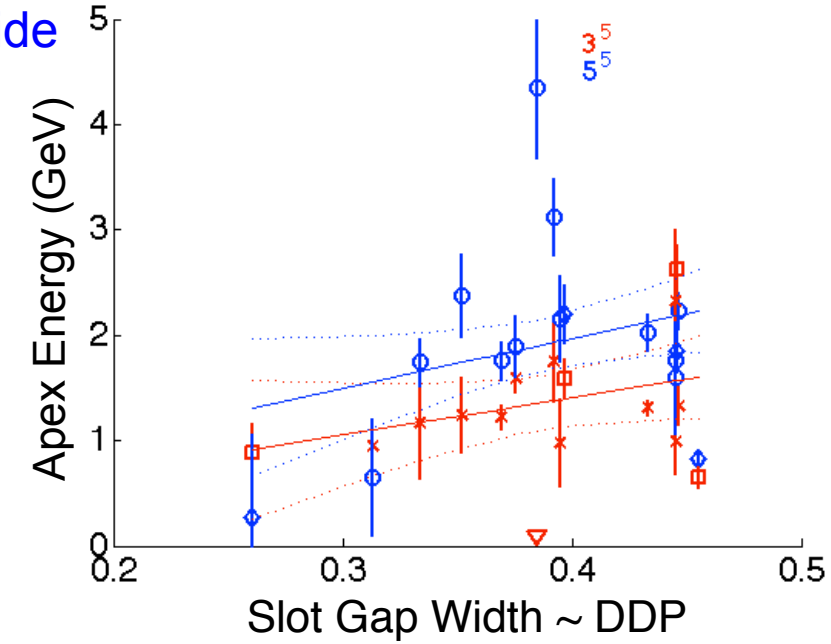
Peak 1

Leading Side

Trailing Side

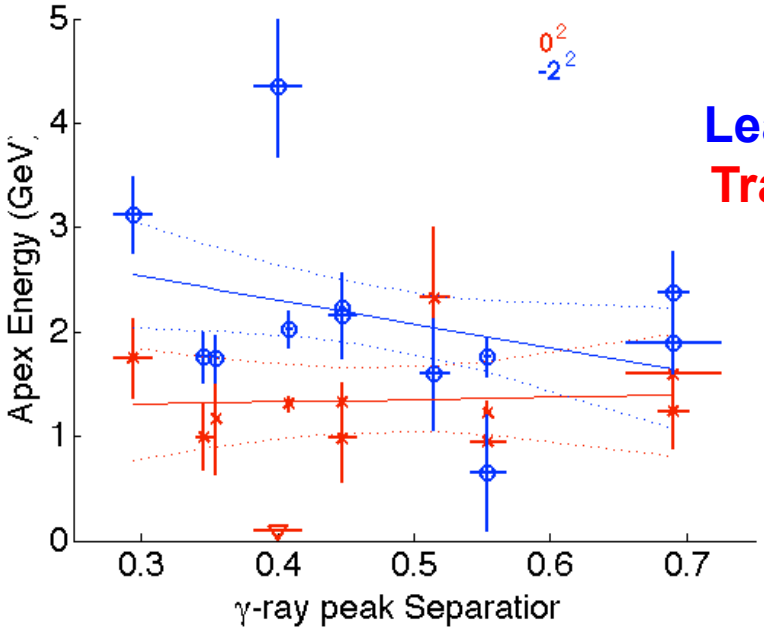


Electrodynamics

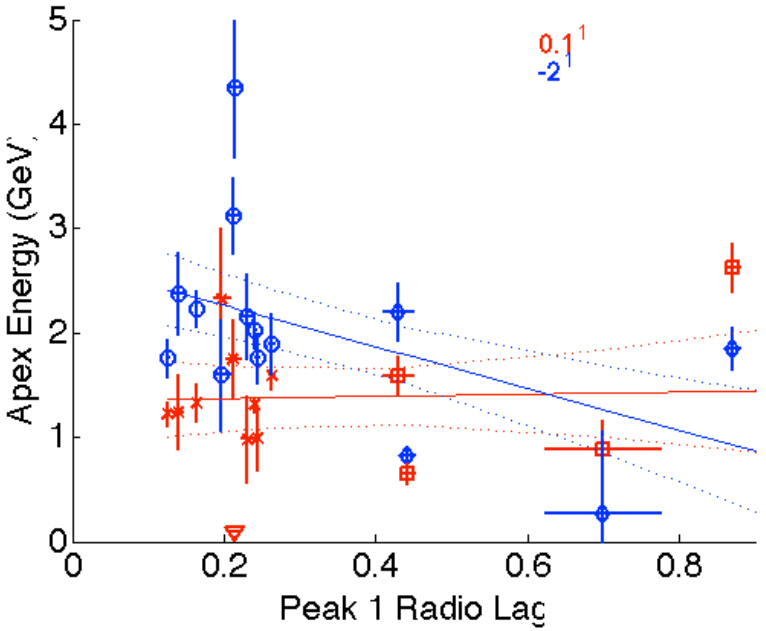


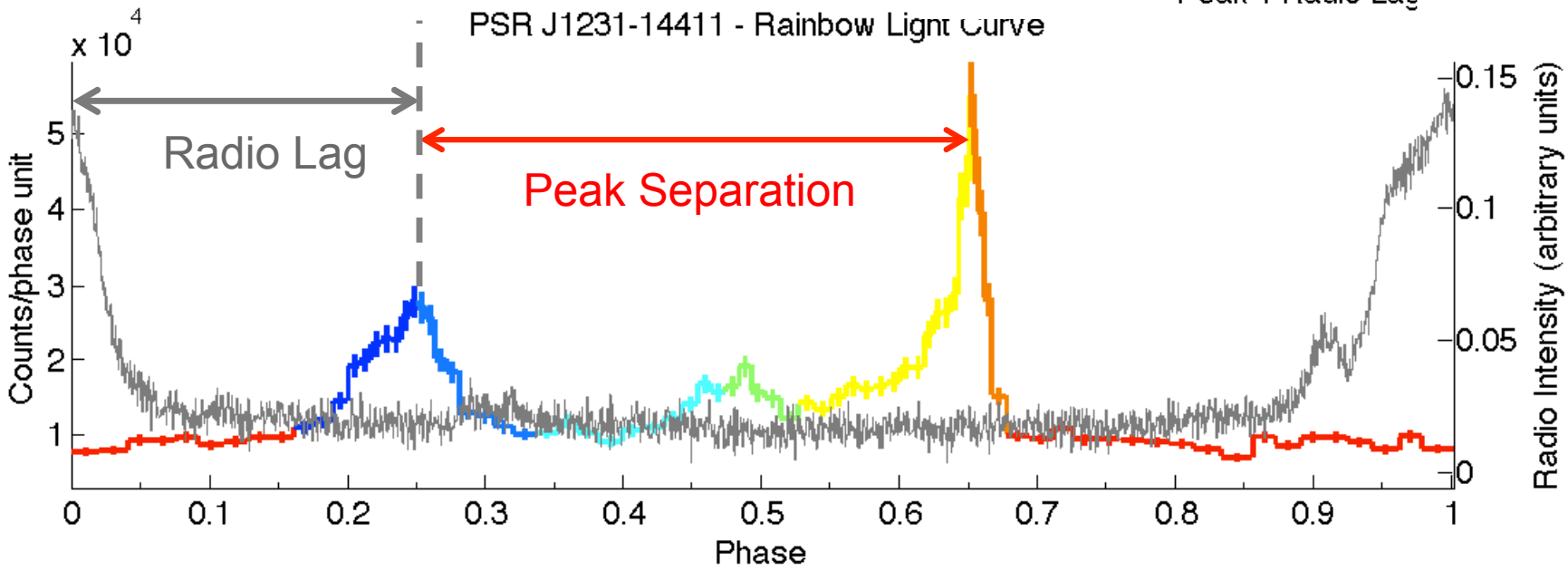
. Renault-Tina

Behaviour w/ Pulsar Geometry

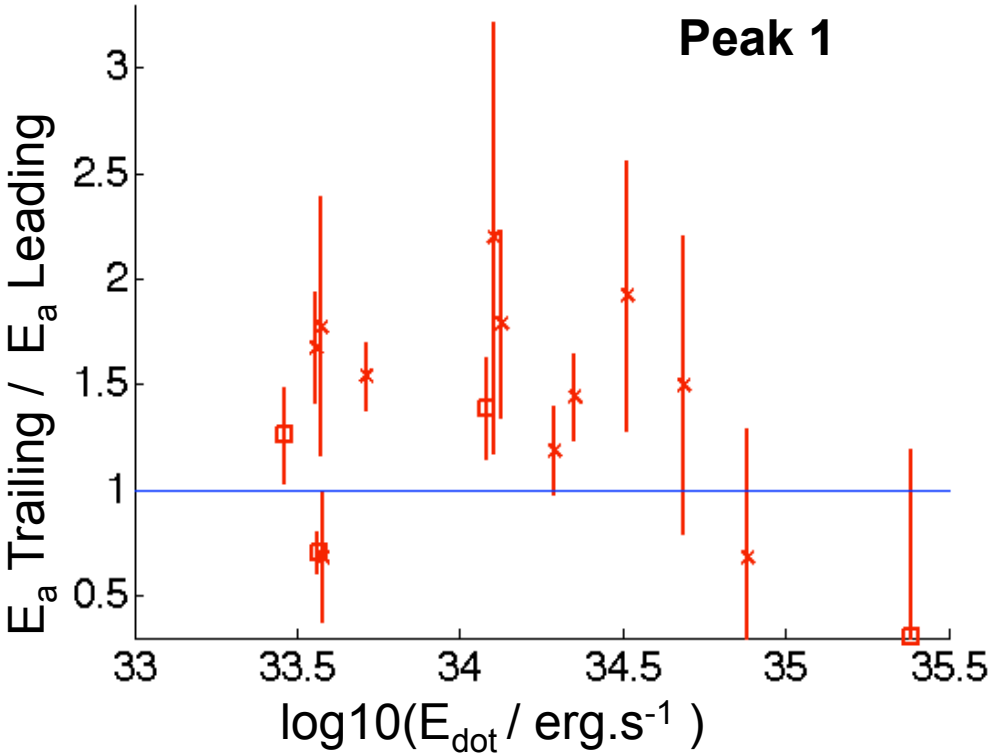


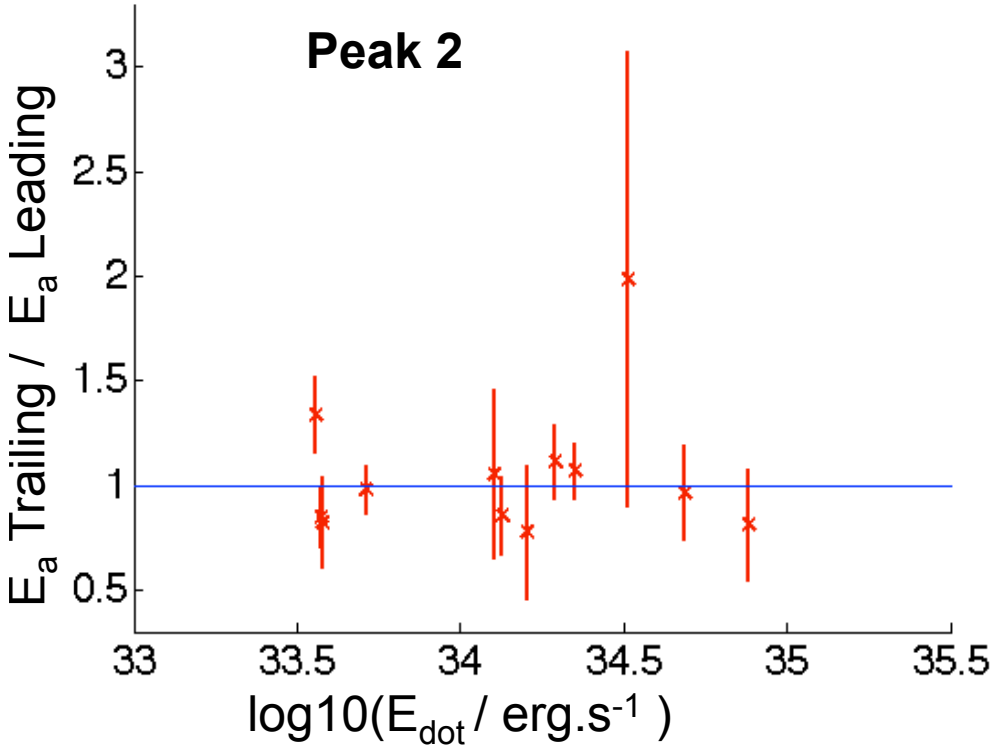
Peak 1
Leading Side
Trailing Side





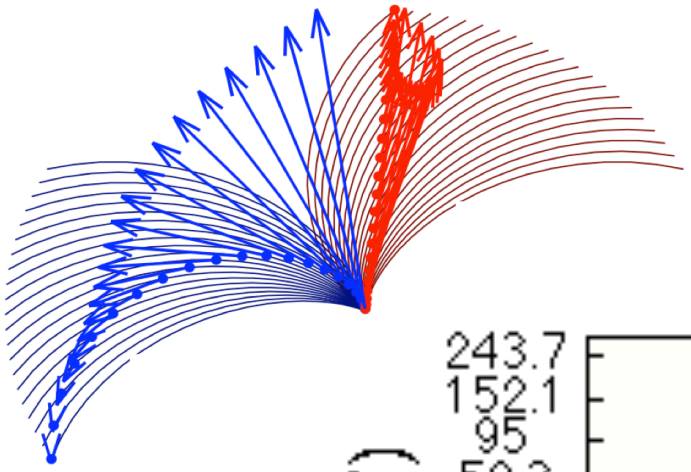
Apex Energy



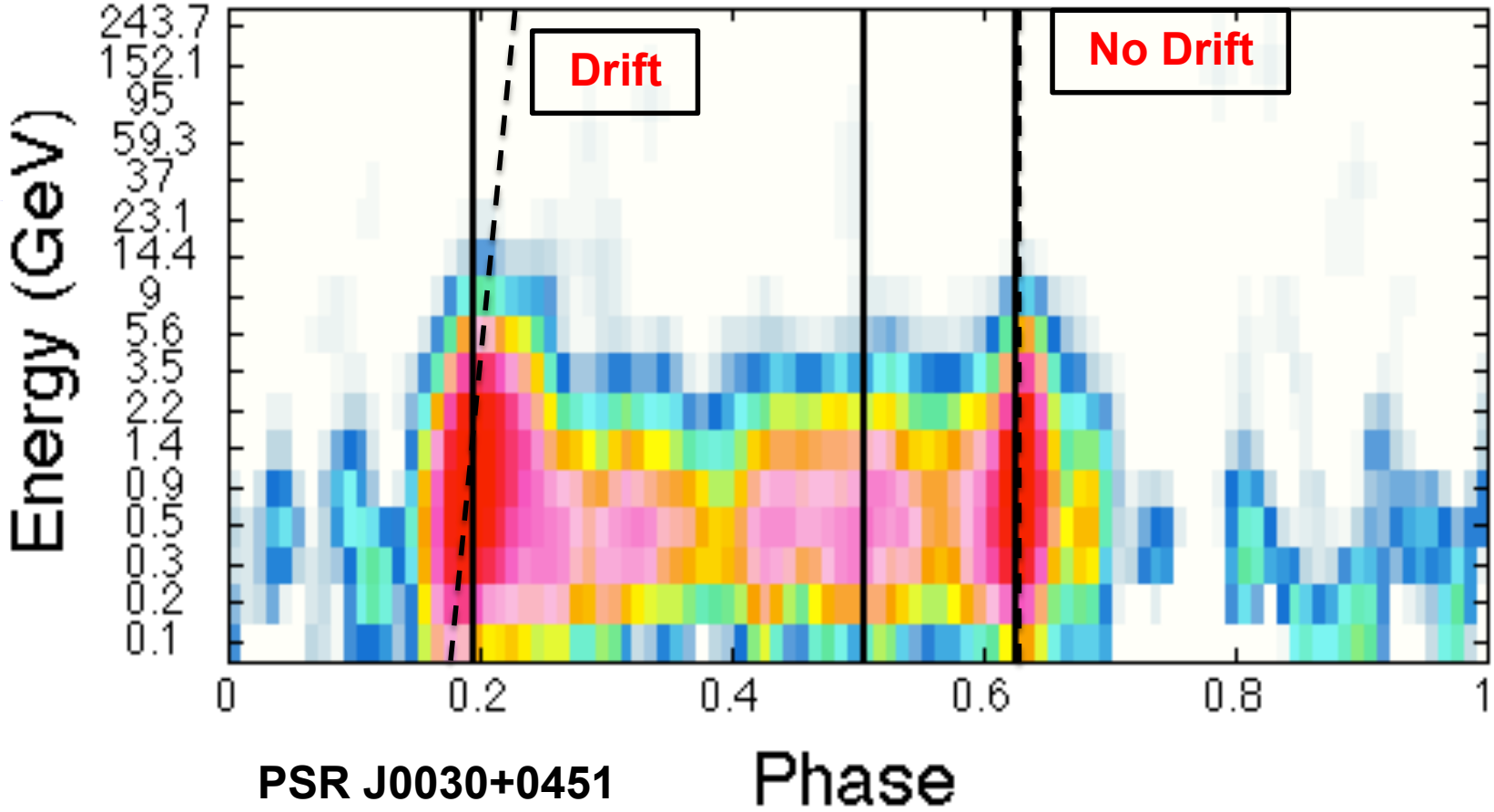


- **Peak 1 : Trailing Side harder than Leading Side**
- **Peak 2 : Trailing Side and Leading Side homogeneous**

New Visualization of Lightcurve



- Ridges detection
- Evolution of the spectral drift with pulsar characteristics
- Results to come

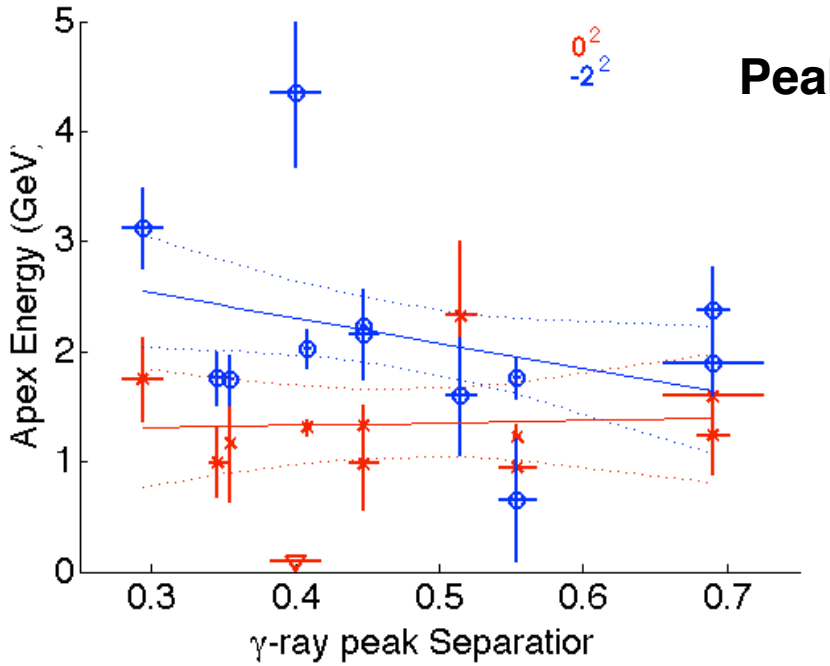


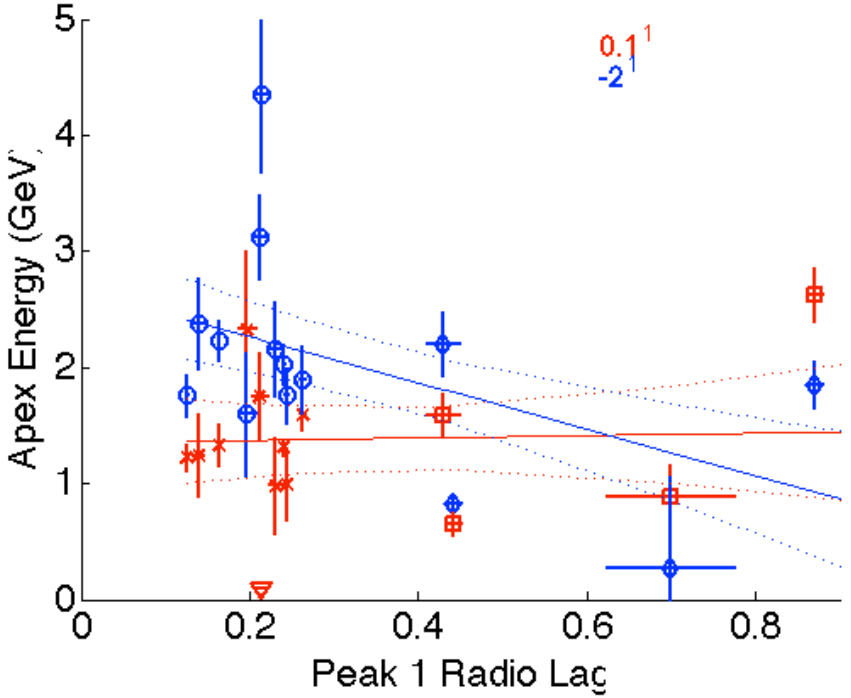
PSR J0030+0451

Thanks for your attention

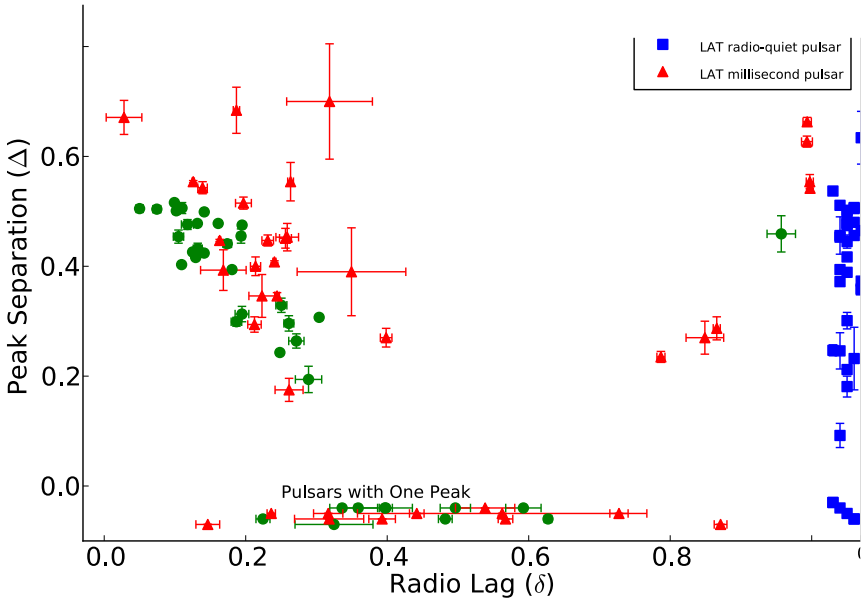
BACK UP

Behaviour w/ Pulsar Geometry





Peak 1
Leading Side
Trailing Side



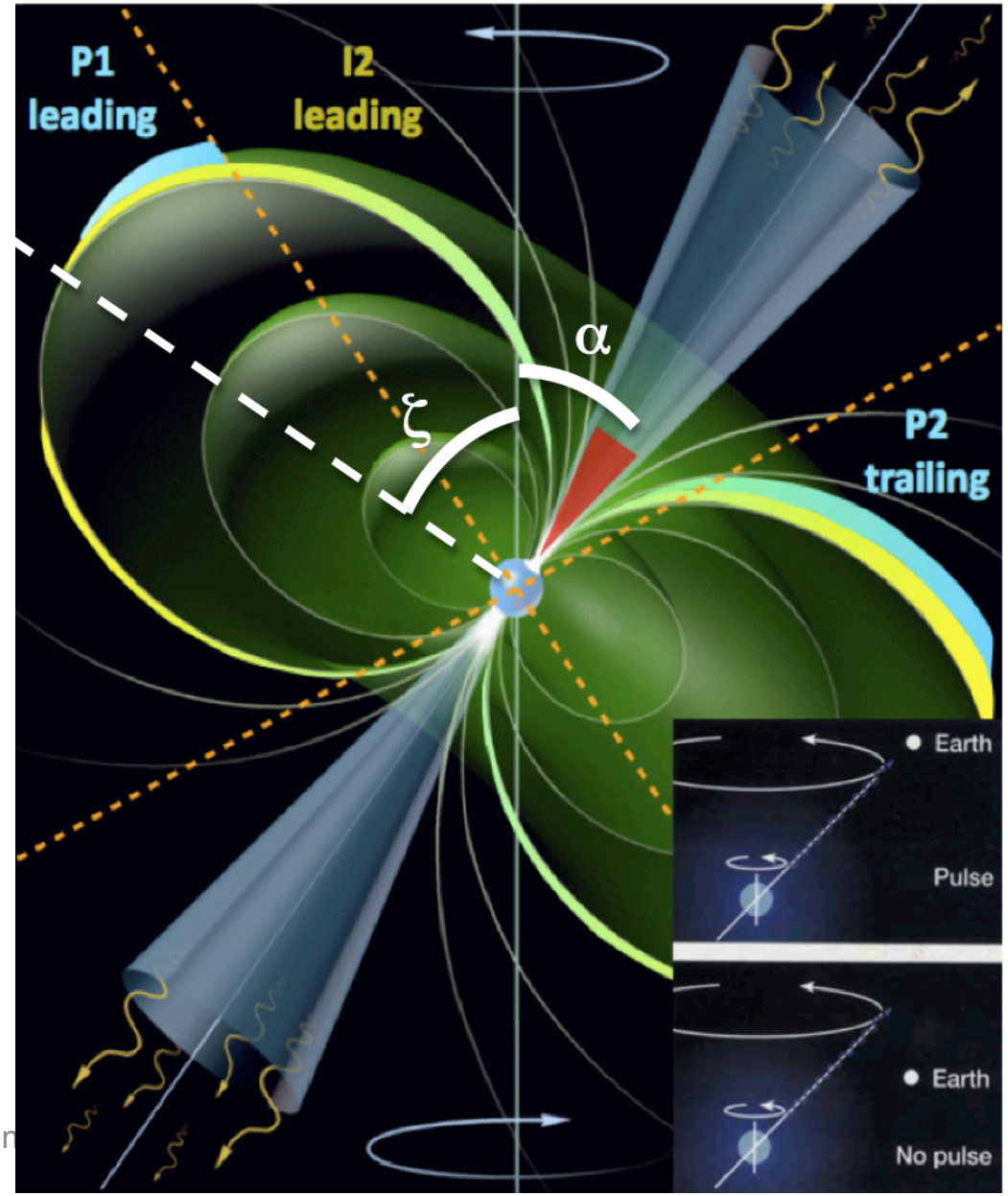
The Second Fermi Large Area Telescope Catalog of Gamma-ray Pulsars (2012)

Magnetospheric Emission

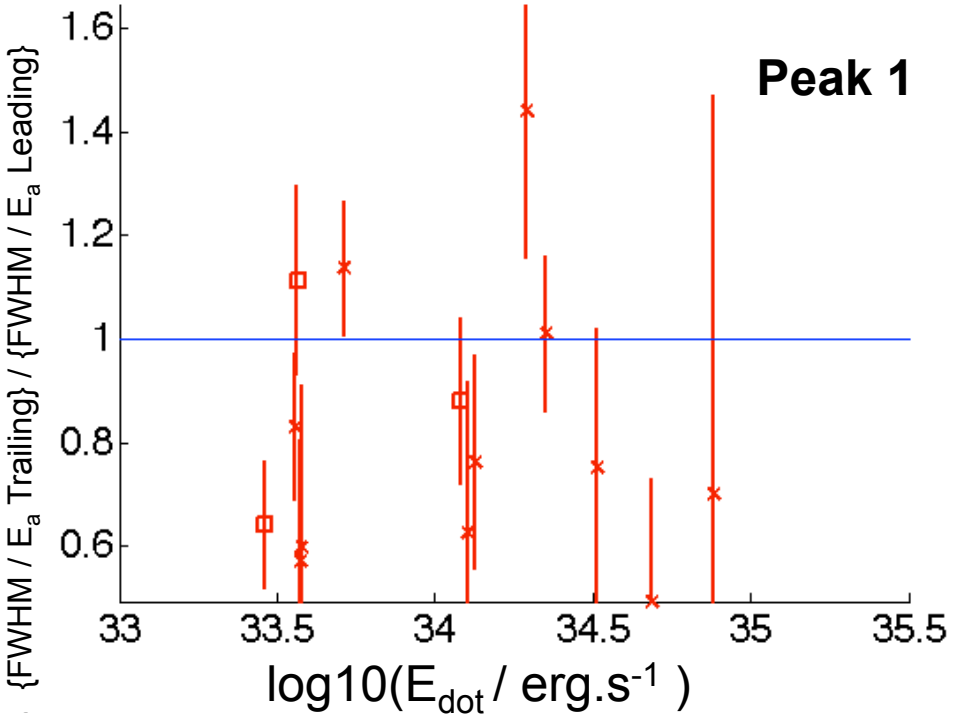
- **Radio emission, more collimated than γ-rays, lighthouse effect**

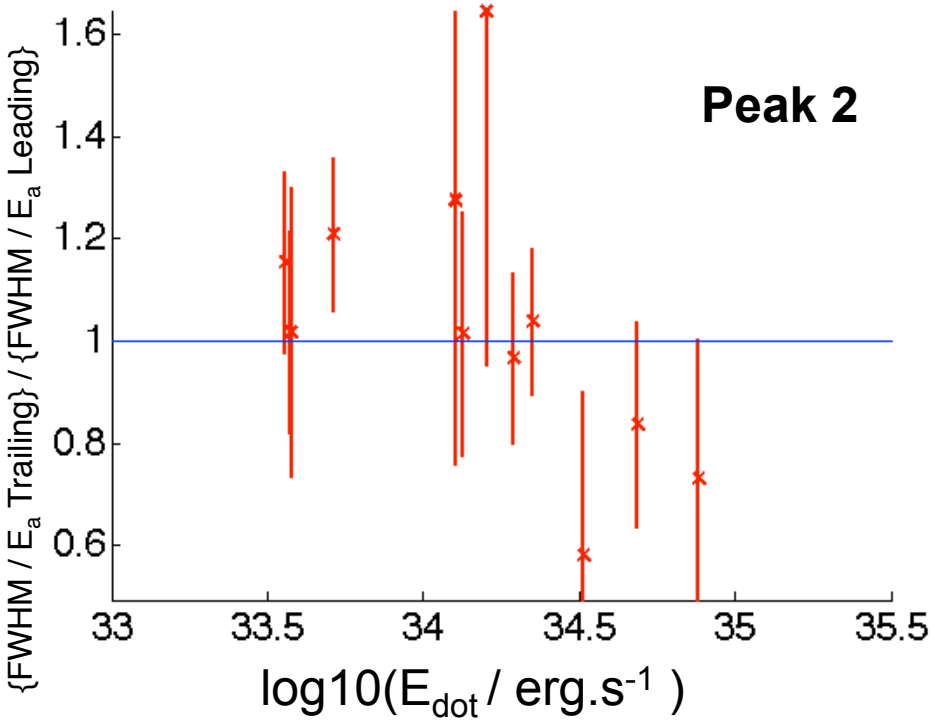
- **High energy emission**
  - **4 main models**
    - **3 different regions inside the corotating magnetosphere and 1 outside**

- **Inability of models to correctly explain the wealth of data on pulsed emission** (lightcurve profiles, phase resolved spectroscopy, luminosity evolution, beam width, coincidence or not of the radio and γ-ray beams, …)

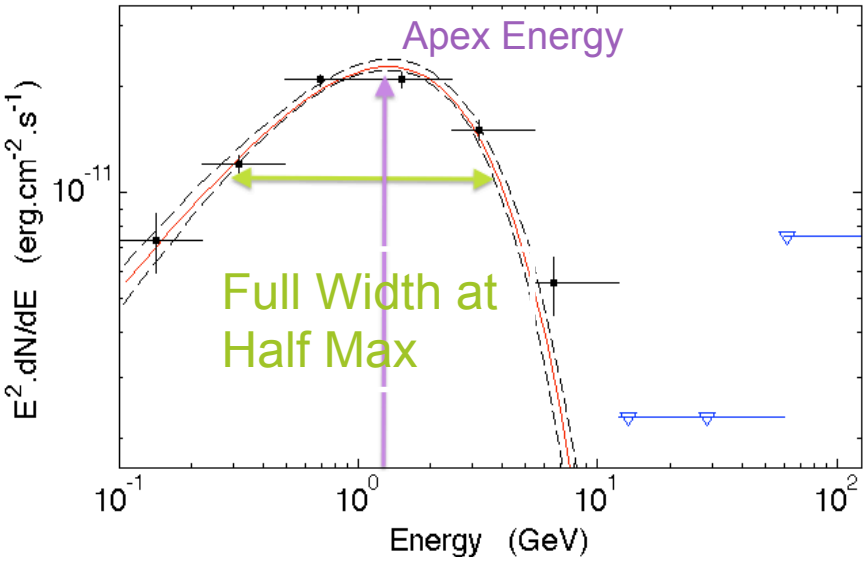


Spectrum Width at half height





- **Peak 1 : Trailing Side spectra tend to be narrower than Leading Side spectra**
- **Peak 2 : no trend for FWHM**



Results and Outlooks

- **Preliminary results of Phase Resolved Spectroscopy of MSPs :**
  - **Peak 1 trailing side harder than leading side (drift with phase to confirm)**
  - **Peak 2 leading/trailing : uniform apex energy (no drift to confirm)**
  - **No correlation between apex energy with any parameters (E_{dot}, B_s, B_{LC}, radio lag, peak separation, curvature radius of last closed magnetic field line, Gap Width, …)**

- **Outlooks :**
  - **Spectroscopy without assumed spectral shape**
    - **Apex Energy dependance with pulsar parameters ?**
    - **Spectral Evolution with Phase**
  - **2D lightcurve of MSPs**
    - **Drift detection**