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Mode change of the gamma-ray pulsar, PSR J2021+4026

(Zhao et al. 2017, ApJ)

Collaborators:
J. Takata, *Y. Chai (HUST) ,C.W. Ng, C.-P. Hui, K.S. Cheng (HKU), L.C.C. Lin (IAA, Taiwan), D.C.C. Yen (FJCY, Taiwan), P.H.T. Tam (SYSU), C.Y. Hui (CNU, Korea), A.K.H. Kong (NTHU, Taiwan)*

Contents

1 INTRODUCTION

Pulsar's Glitch

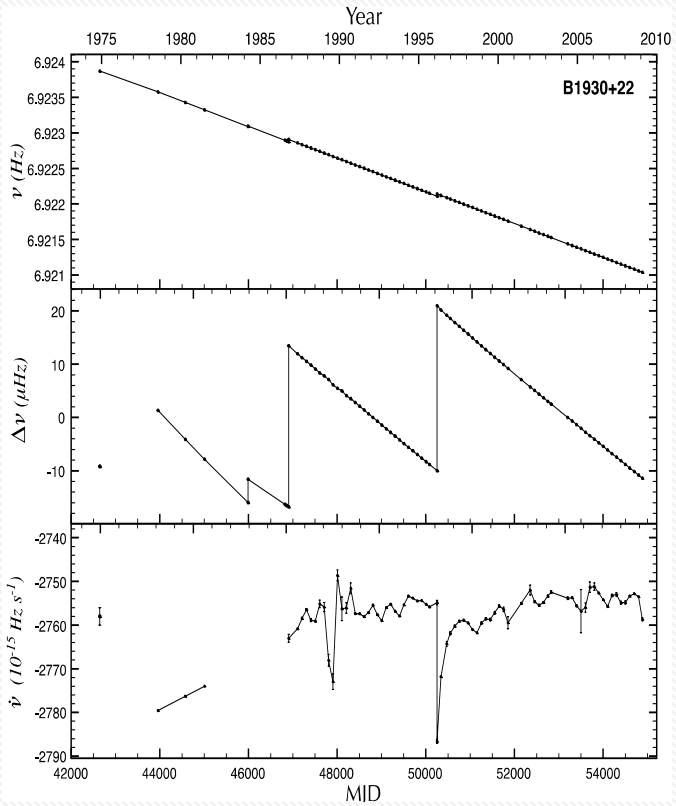
- Sudden changes in the spin frequency (f) and spin down rate ($\dot{f}$).

- ~165 glitching pulsars, discovered by
  - Radio observations
  - Gamma-ray observations

(*c.f. pulsar glitch catalog, http://www.jb.man.ac.uk/pulsar/glitches.html*)

-- The glitch of PSR J2021+4026 is very unique.
→ Change in the gamma-ray emission properties at the glitch.

Spin evolution of PSR B1930+22



f

Df

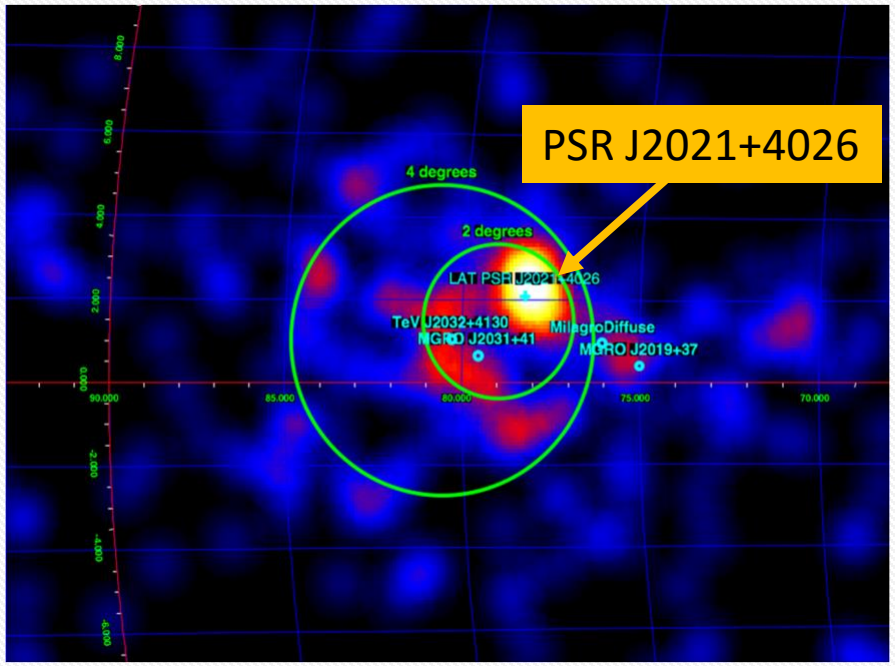
$\dot{f}$

(Espinoza et al. 2011)

2 PSR J2021+4026 Previous works

PSR J2021+4026 is a typical middle gamma-ray pulsar.

Gamma-ray sources at Cygnus region



TS map around Cygnus region

1st variable gamma-ray pulsar

(*radio-quiet*, *isolate*)

- $f \backsim 3.8$ Hz (P ~ 265 ms)
- $\dot{E}_{SD} \sim 10^{35}$ erg/s
- $B \sim 4 \times 10^{12}$ G
- $\tau_c \sim 77$ kyr

2 PSR J2021+4026 Previous works

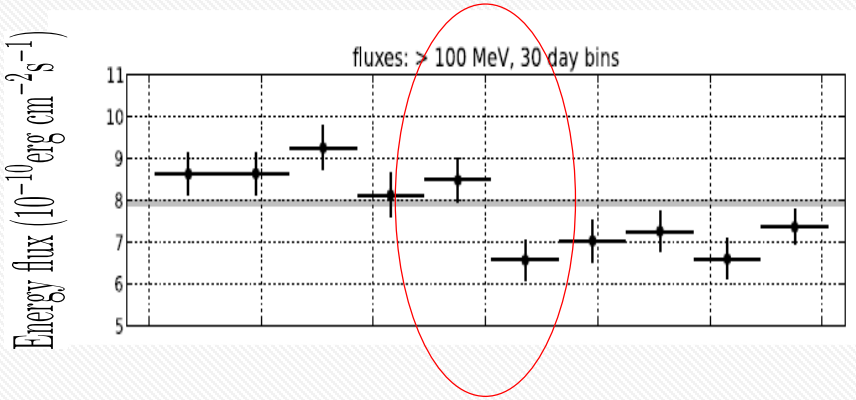
Glitch at 2011, Nov. (Allafort et al 2013)

1. Gamma-ray flux suddenly decreases ~20%.

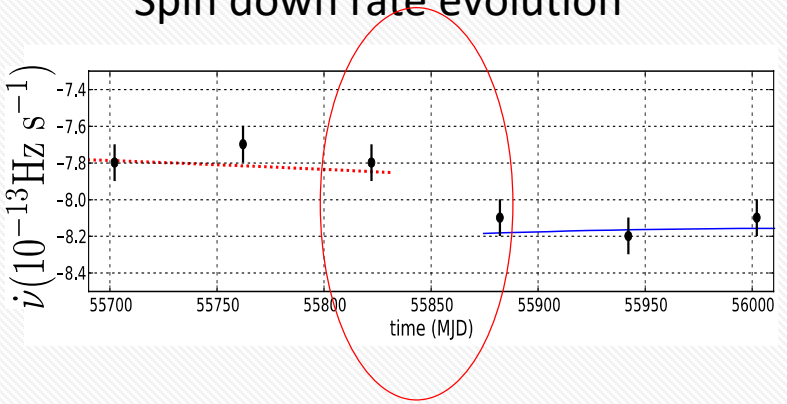
2. Spin down rate ($\dot{f}$) increases ~4%.

3. Small third peak in the pulse profile disappeared after the glitch.

>100MeV Flux evolution

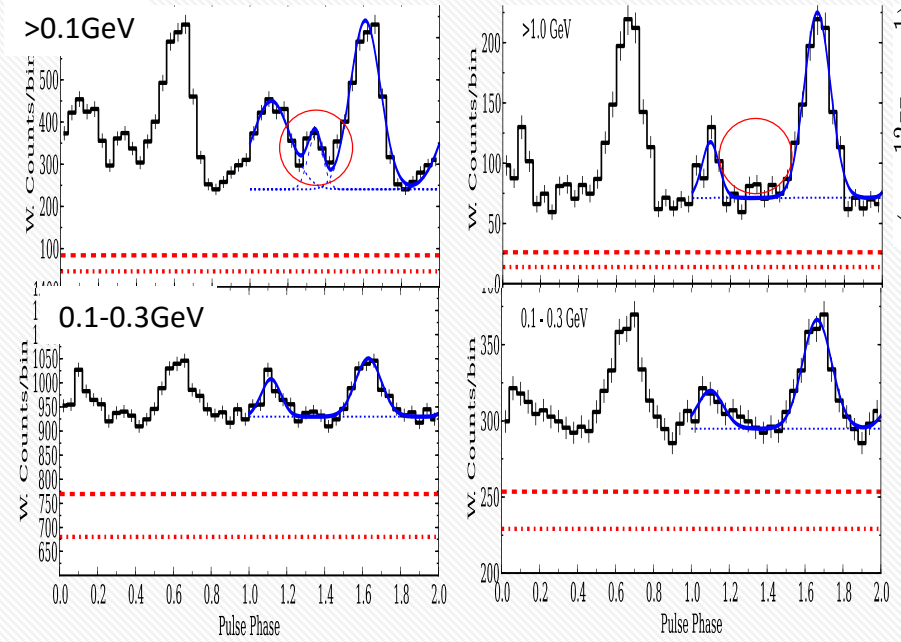


Spin down rate evolution



Pre glitch

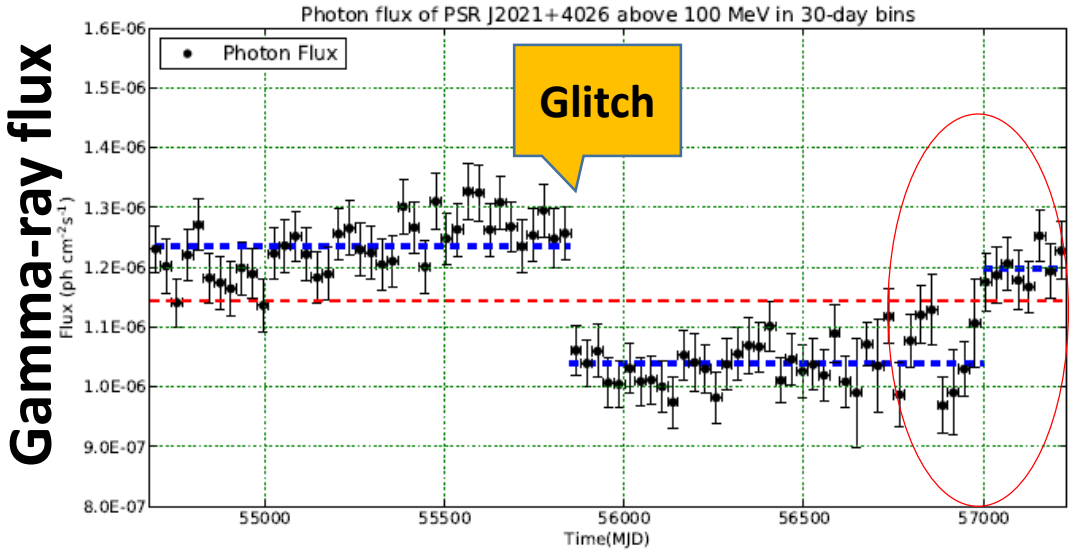
Post glitch



Two rotation phase

2 PSR J2021+4026 Previous works

- Indication of second jump in the gamma-ray flux at around 2014 Dec. (Ng, et al 2016)
  - Another glitch?
  - No timing analysis.



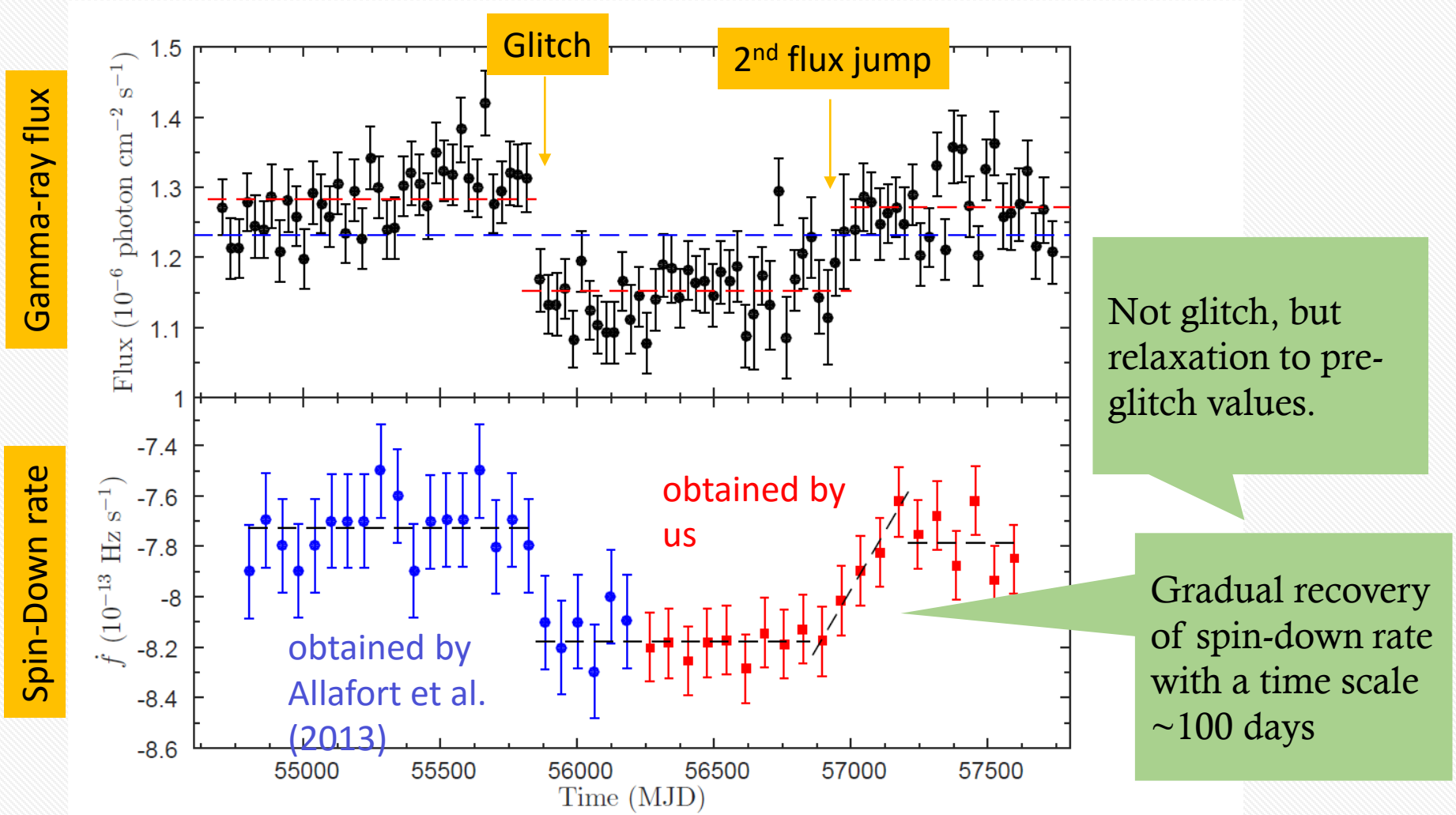
- Purpose of this work

- ~8 years Fermi-LAT data (**more than one year of Ng et al.**)
  (2008 August – 2016 December)

- Detail **spectral and timing analyses** after the glitches.

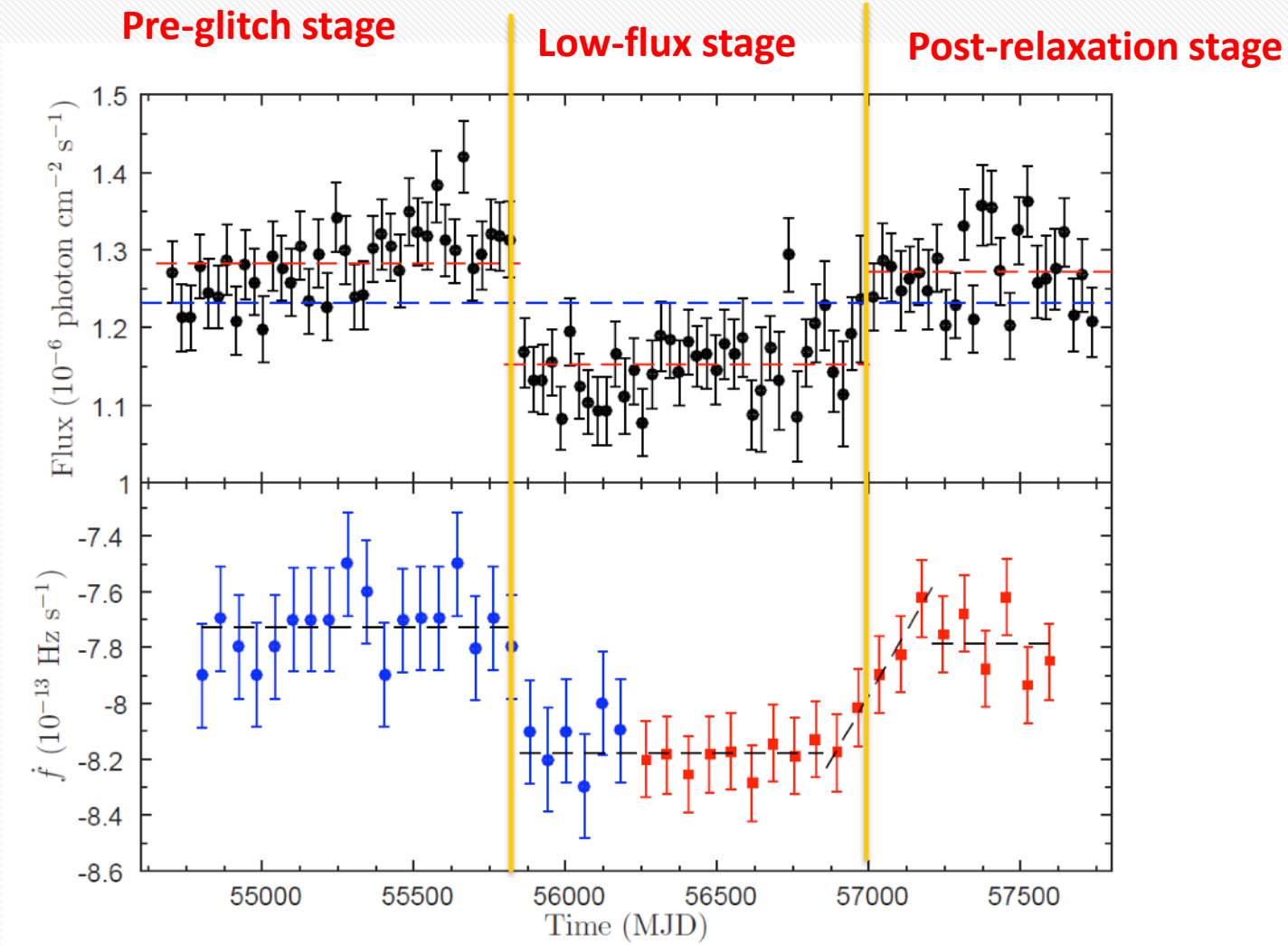
3 Result

- Gradual recoveries of both gamma-ray flux and spin down rate at ~2014, Dec.



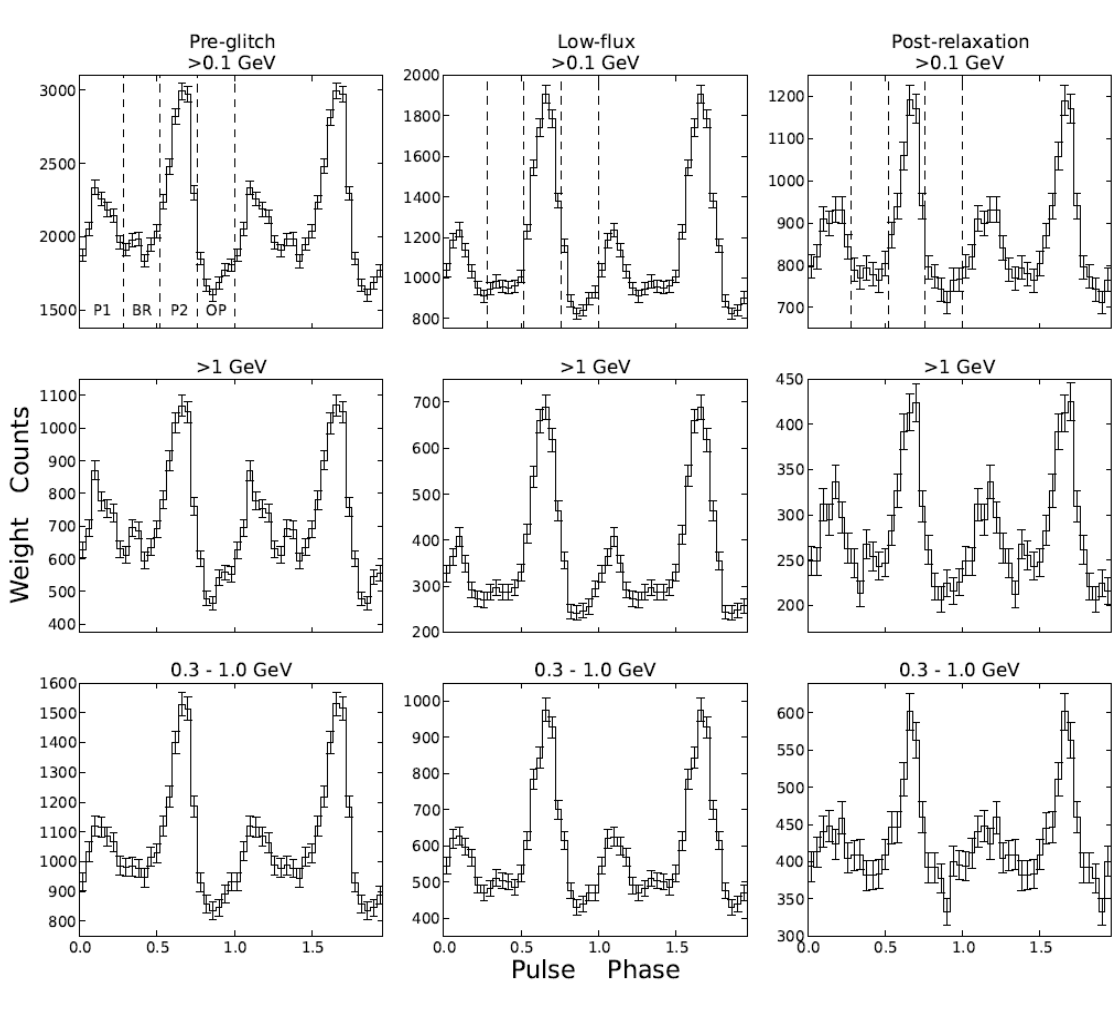
3 Result

- Three stages



3 Result

Pulse profiles of three stages.

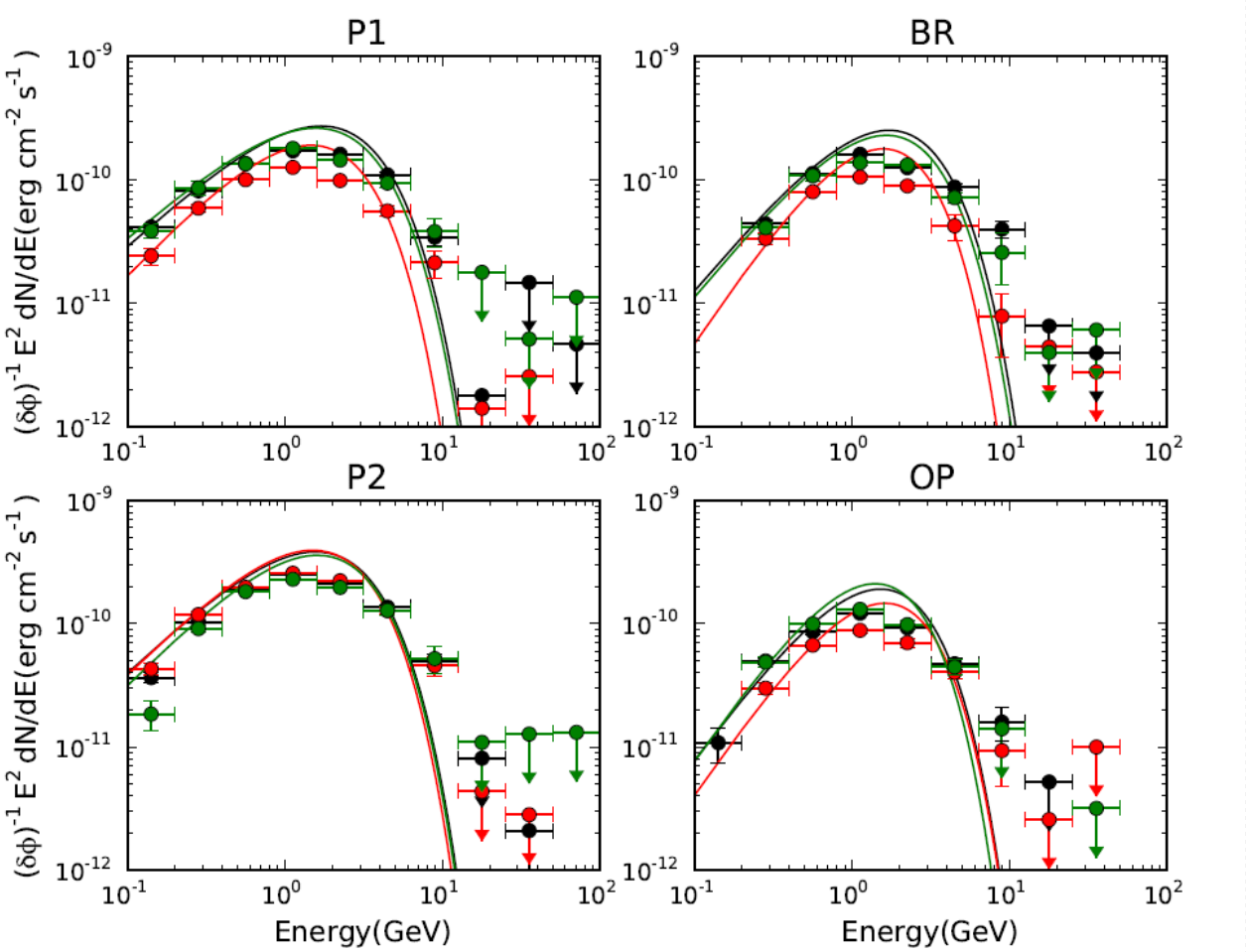


- The third peak disappeared at low flux state (Allafort et al. 2013)
- With current data quality, we cannot conclude the recovery of third peak.

Peak1/Peak2 height ratio and the pulse widths after relaxation are more consistent with those of pre-glitch stage.

3 Result

Phase-resolved spectra of three stages.



Pre-glitch

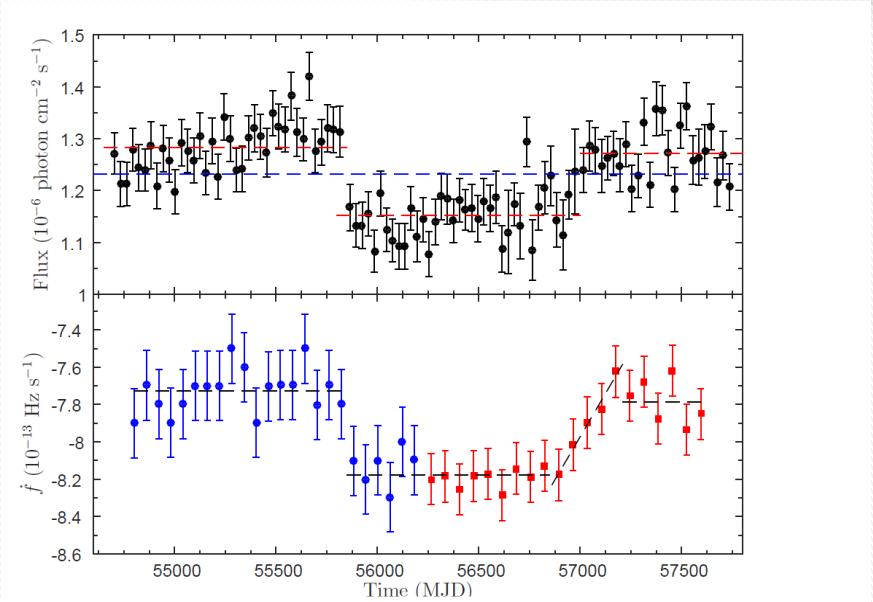
Low-flux

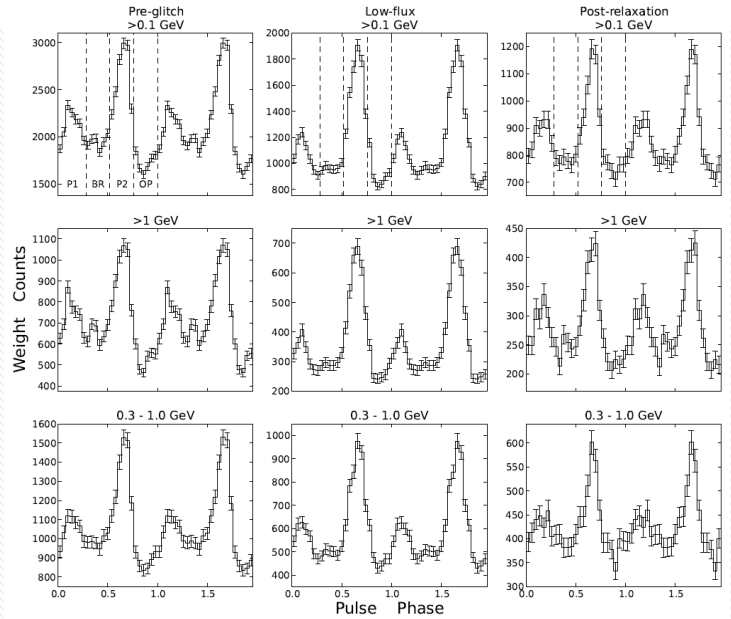
Post-relaxation

Lines:

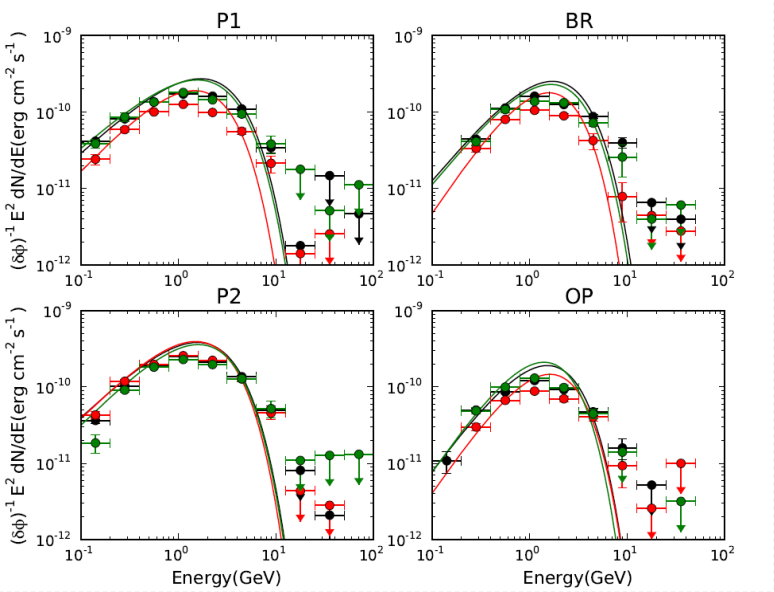
$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\Gamma} \exp\left[-\left(\frac{E}{E_C}\right)^{b}\right],$$

3 Result





- All emission properties at the post-relaxation are consistent with those of pre-glitch stage.

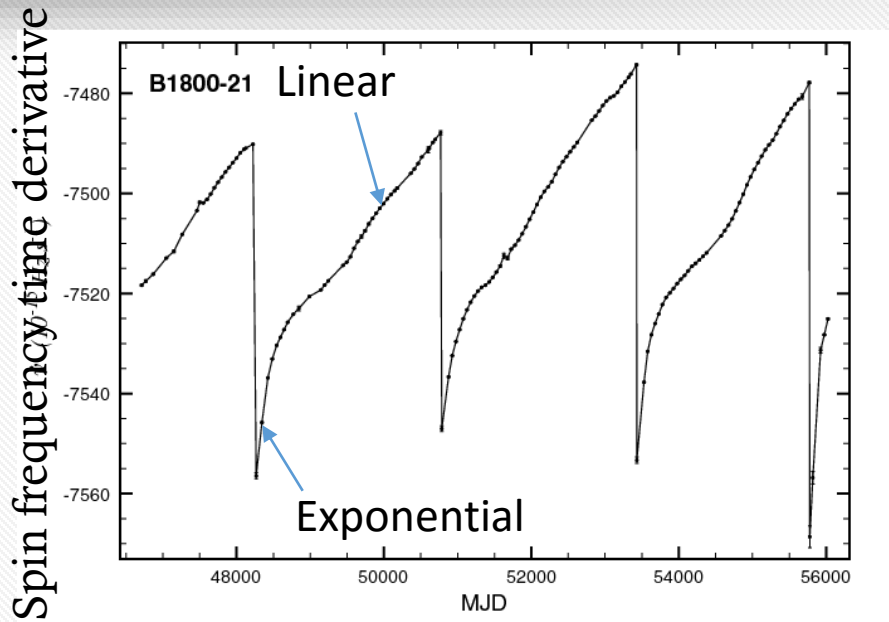


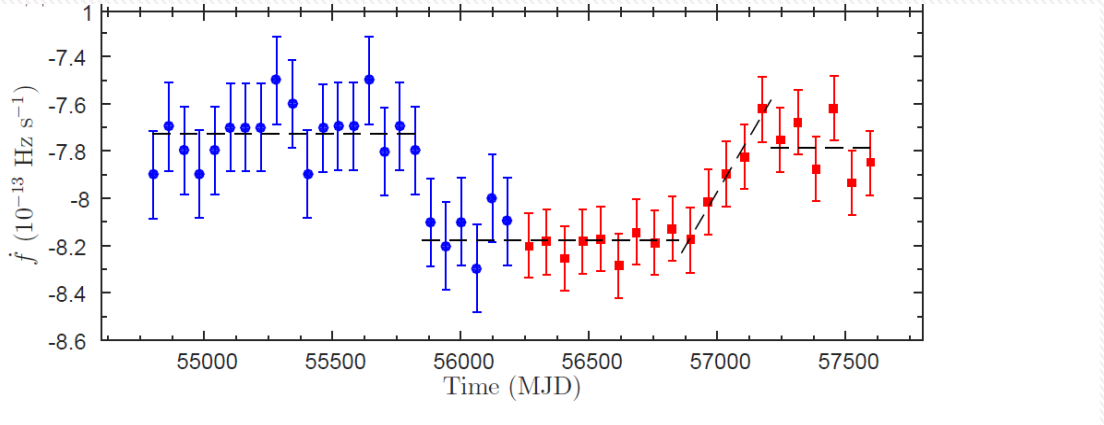
4 Interpretation

PSR J2021+4026 shows unique evolution of the spin down rate after the glitch.

- No linear recovery of usual glitch.

- Permanent-like change of spin down rate (and gamma-ray flux) for ~three year.
- > Glitch triggered a **change in the global magnetosphere**





4 Interpretation

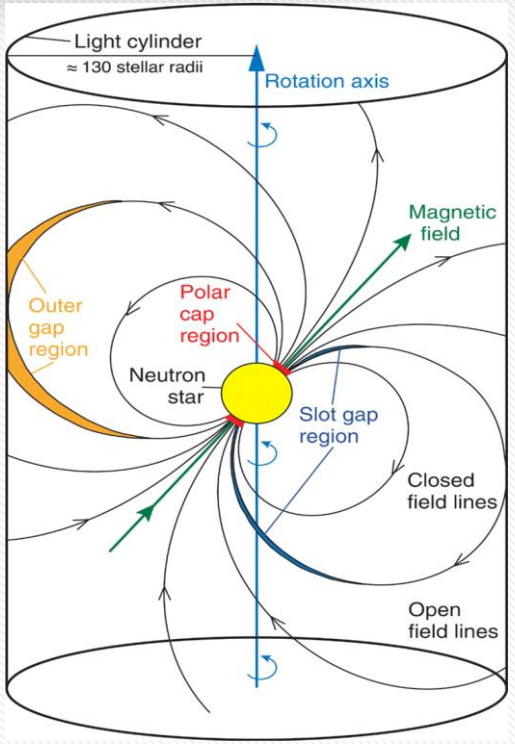
- Two Possibilities

(1) Change of the magnetic inclination-→ Spin down luminosity depends on the inclination angle (Spitkovsky 2006)

$$L_{sd} \sim \frac{\mu^2 \Omega^4}{c^3}(1+\sin^2\alpha)$$

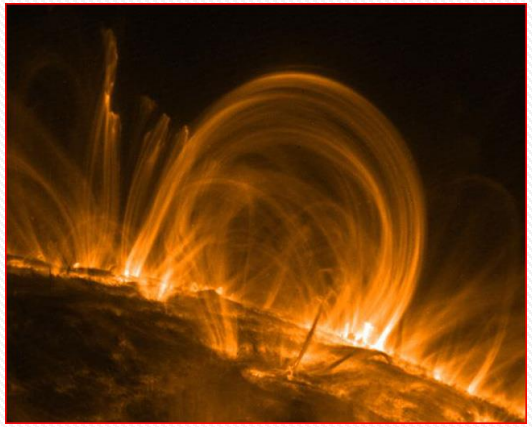
- ~4% of the change of the spin down rate

→if $\alpha=60^o$, $\Delta\alpha\sim5^o$ (Ng, Takata, Cheng, 2016)



(2) Change in the local magnetic field around polar cap

→ Magnetic pair-creation process changes the global electric current, yielding the change of the spin down rate.



- We are now analyzing the X-ray data taken in post-relaxation.

Summary

1. This pulsar had a glitch at MJD 55850.
2. The pulsar started to change the state from ~MJD 57000.
3. The flux, phase-resolved spectrum and pulse profile returned to the previous state.
4. The evolution of timing parameter suggests the state changed at MJD 57000 is not second glitch.
5. PSR J2021+4026 may serve as an another example to show a mode change of the radiation due to the state change of the global magnetosphere

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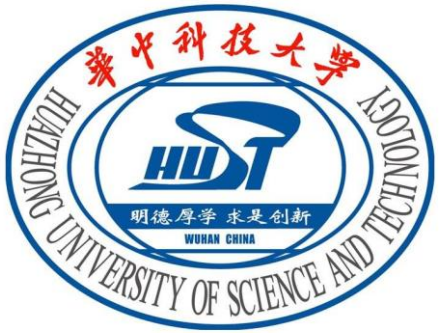

Thank you for listening

Supervisor： Jumpei Takata　Reporter：赵静