

# Revisiting G21.5-0.9's X-Ray Spectral Break in NuSTAR Data



Soichiro Hattori<sup>1</sup>, Samayra Straal<sup>1</sup>, Joseph D. Gelfand<sup>1</sup>,  
Patrick O. Slane<sup>2</sup>, Tea Temim<sup>3</sup>, Emily Zhang<sup>4</sup>

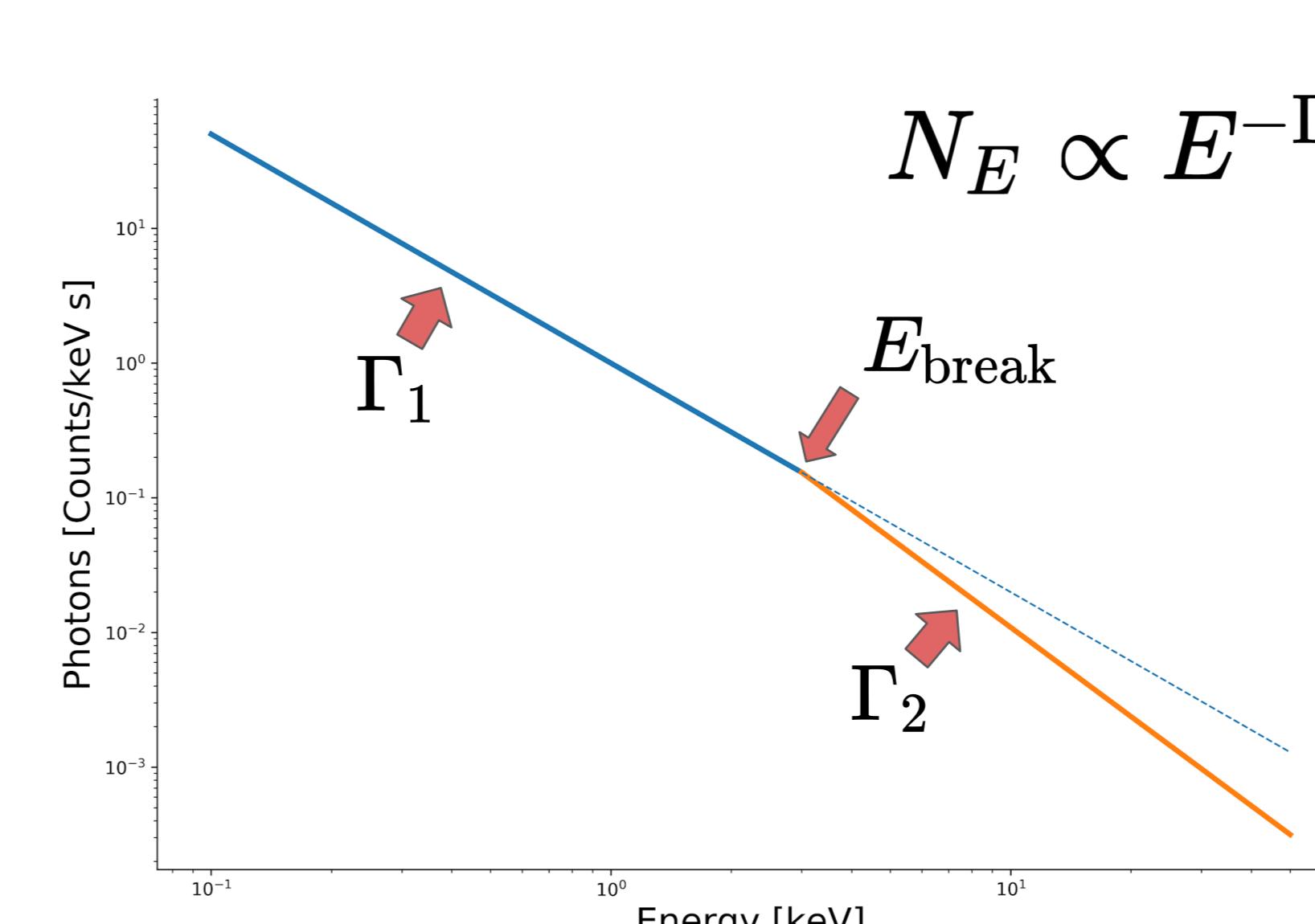
## The significance of G21.5-0.9 & its spectral break

Pulsar Wind Nebulae (PWNe) are produced by the interaction between the central pulsar and their surrounding material



Credit: NASA/CXC/U.Manitoba/H.Matheson & S. Safi-Harb

- **G21.5-0.9** is a well studied source across the electromagnetic spectrum with lots of data
- Its young age ( $\sim 1000$  yrs) and spherical shape make it an excellent candidate to model using **one-zone models**



### Spectral Break

The break energy could help us understand the **acceleration mechanism of particles** at the PWNe's termination shock (currently unresolved problem)

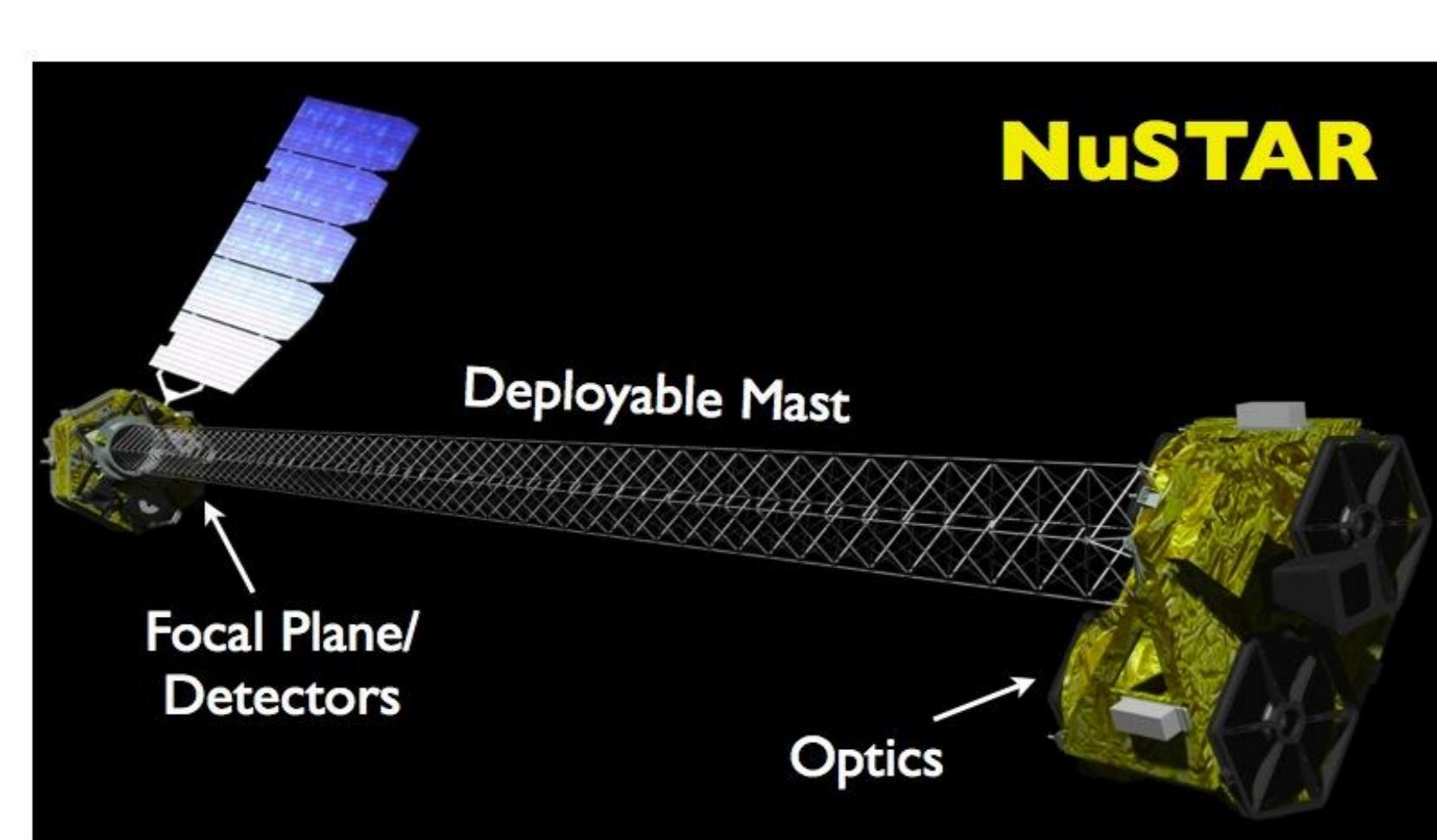
Recent analyses of G21.5-0.9 X-ray spectra report:

- *NuSTAR* shows break of  $\Delta\Gamma \approx 0.1$  at  $E \approx 9$  keV (Nynka 2014)
- *Hitomi* shows break of  $\Delta\Gamma \approx 0.4$  at  $E \approx 7$  keV (Hitomi 2018)

## Analyzing NuSTAR data of G21.5-0.9

### NuSTAR

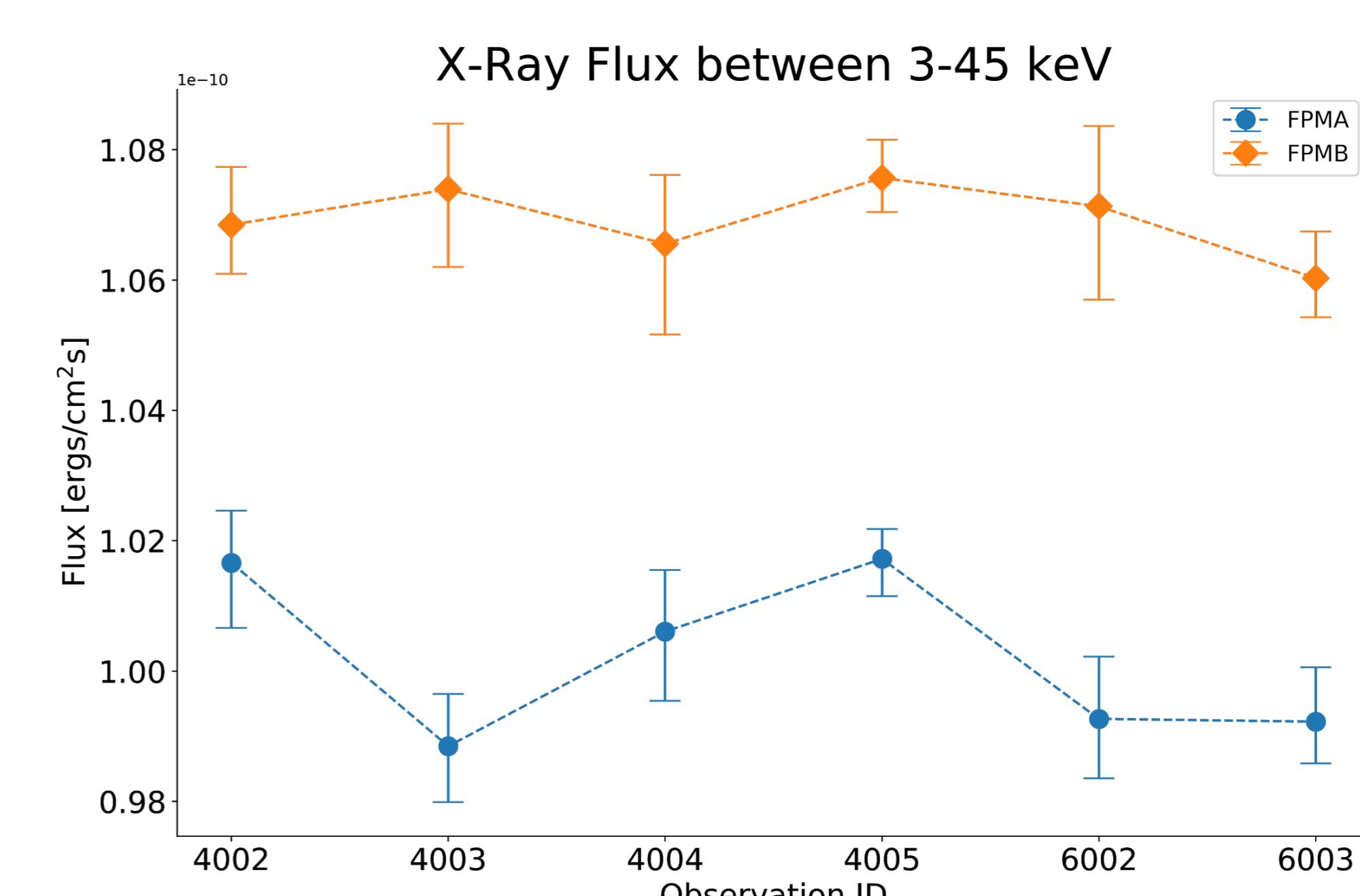
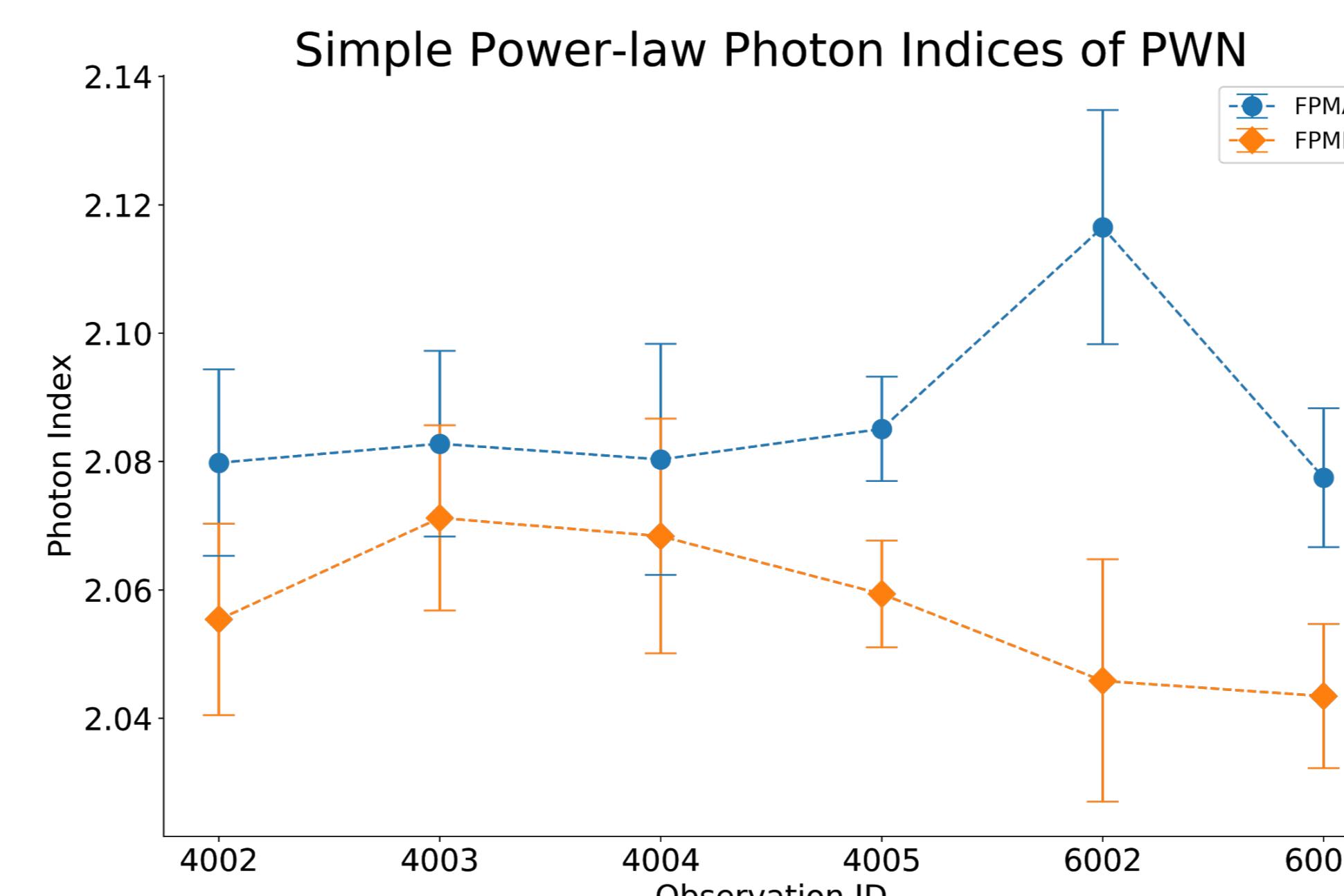
- Energy Range: **3-79 keV**
- Energy Resolution: **0.4 keV at 10 keV**
- Has two co-aligned detector units referred to as **FPMA** and **FPMB**
- **G21.5-0.9** was observed on **nine** separate occasions totaling **413.2 ks**



Courtesy NASA/JPL-Caltech

### Why reanalyze G21.5-0.9's NuSTAR data?

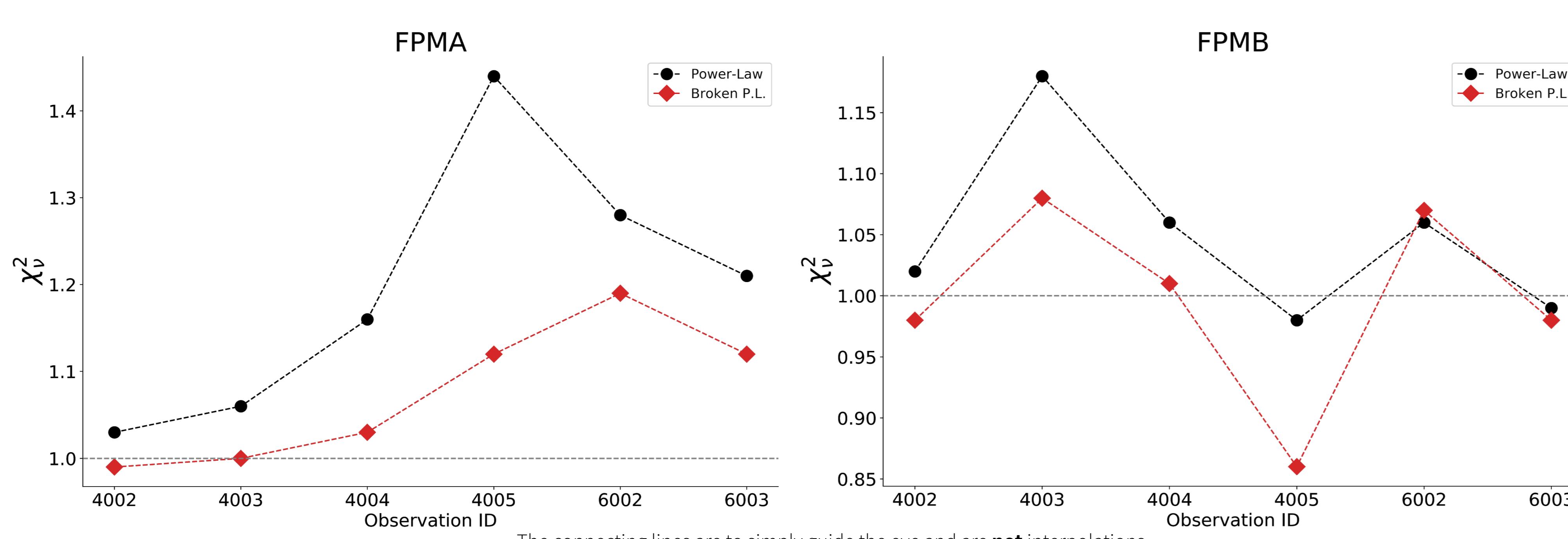
- Analyzed **~190 ks** of previously unused data
- Fit with **composite model** that separates emission of PWN from emission of other components (Guest, Safi-Harb, Tang 2018)
- Fit **FPMA & FPMB data separately** for each observation instead of simultaneous fit



FPMB flux is consistently higher than FPMA flux by ~5%

Photon Index is different between FPMA and FPMB

## Results between FPMA and FPMB are different!



- **FPMA:** Across all observations, **broken p.l.** had a reduced chi-squared closer to unity than power-law
- **FPMB:** For **4 out of 6 observations** (4002, 4005, 6002, 6003) the **power-law** model had a reduced chi-squared closer or equally close (4002) to unity compared to the broken p.l.
- **4005** and **6003** are the two longest obs. and account for **>50%** of total time

### Take-Home Message

The results from FPMA & FPMB are different enough to warrant a closer analysis into the NuSTAR data of G21.5-0.9 to confirm a spectral break!

### Upcoming Work

- More **statistics!** (likelihood ratio between the two models, errors on parameters, c-stat goodness of fit)
- Look for **systematic issues** by checking NuSTAR data from other sources
- Explore possible **disagreement with Hitomi**
- Use **one-zone models** to infer parameters of entire system

### Affiliations

<sup>1</sup>NYU Abu Dhabi, PO Box 129188, Abu Dhabi, United Arab Emirates

<sup>2</sup>Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

<sup>3</sup>Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

<sup>4</sup>Columbia College, Columbia University, 116th St & Broadway, New York, NY 10027, USA

Email: soichiro@nyu.edu

### References

1. Gaensler, B. M., & Slane, P. O. (2006), ARAA, 44, 17.
2. Nynka, M. et al. (2014), ApJ, 789, 72.
3. Madsen, K. K. et al. (2015), ApJs, 220, 8.
4. Guest, B. T., Safi-Harb, S., & Tang, X. (2019), MNRAS, 482, 1031.
5. Hitomi Collaboration (2018), PSAJ, 70, 38.
6. Tsujimoto, M. et al. (2011), A&A, 525, A25.
7. Slane, P. (2017), Handbook of Supernovae, 2159.
8. Tanaka, S. J., & Takahara, F. (2011), ApJ, 741, 40.
9. Seward, F. D., & Charles, P. A. (2010), Exploring the X-ray Universe, Cambridge University Press.
10. Torres, D. F. (2017), Modelling Pulsar Wind Nebulae, 446.