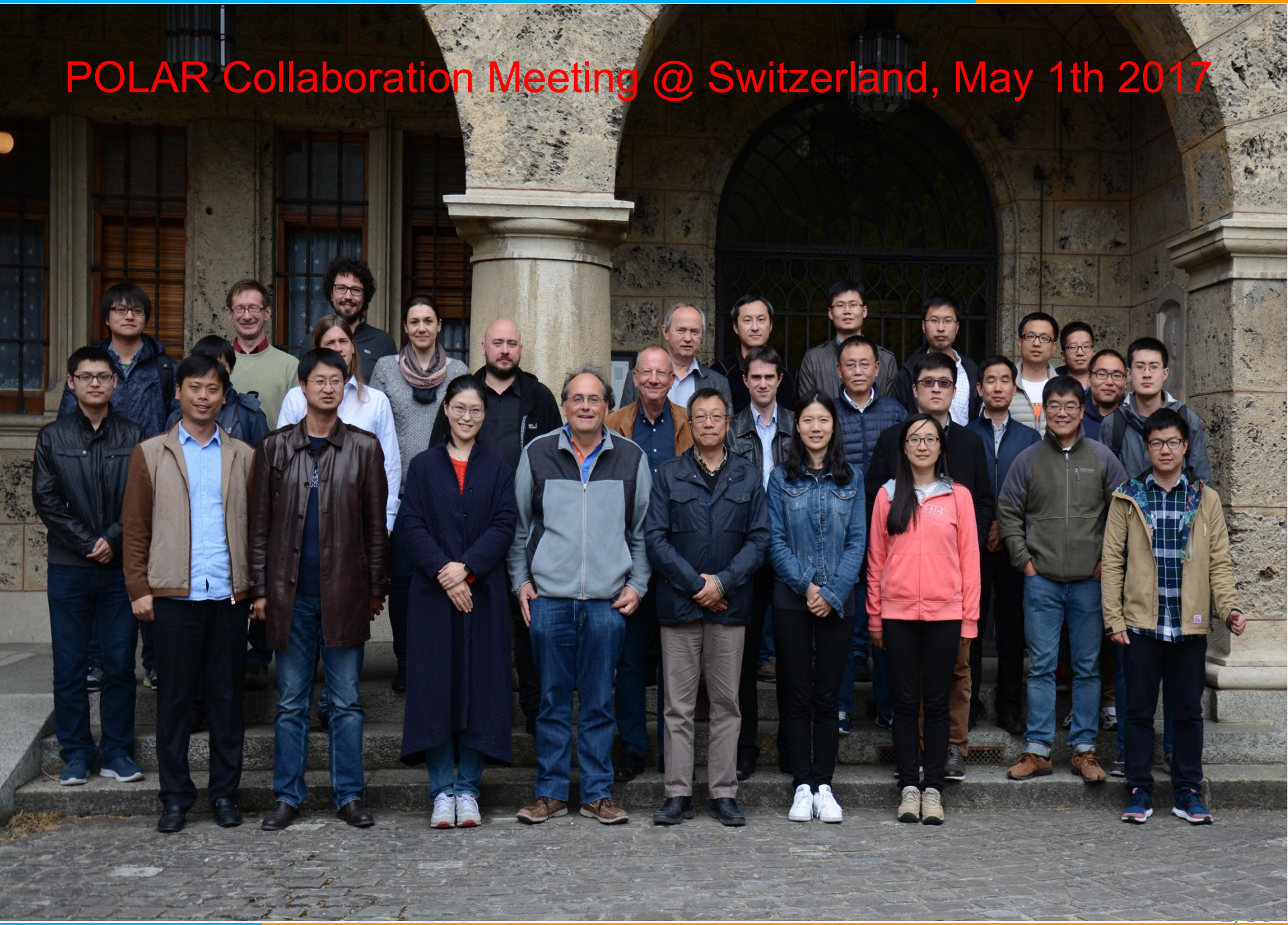
The Profile, Timing and Potential Polarimetry of the Crab Pulsar

POLAR Collaboration

2017-06-28 Wuhan

POLAR Collaboration Meeting @ Switzerland, May 1th 2017



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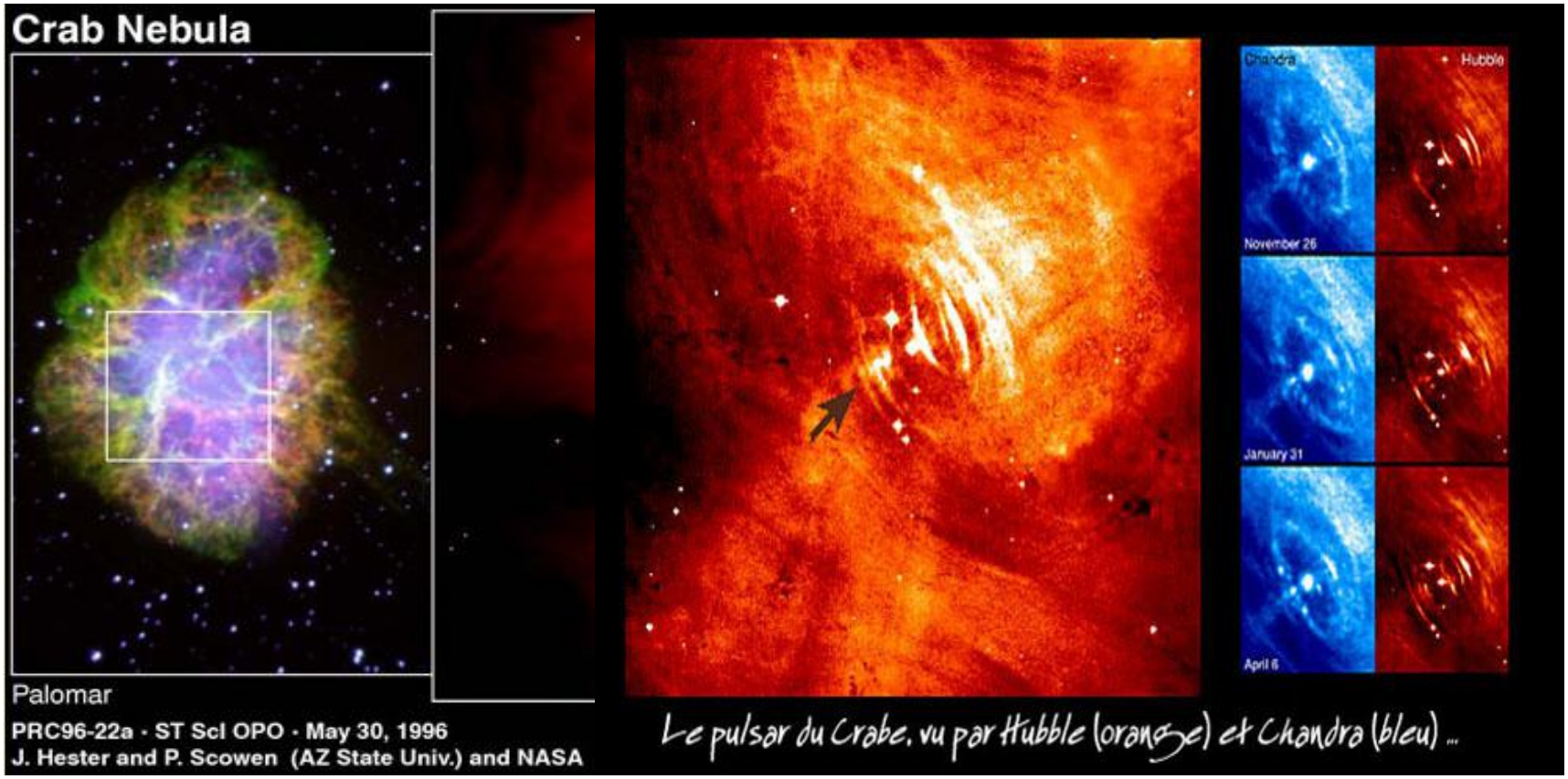
- **Summary**

Brief Introduction

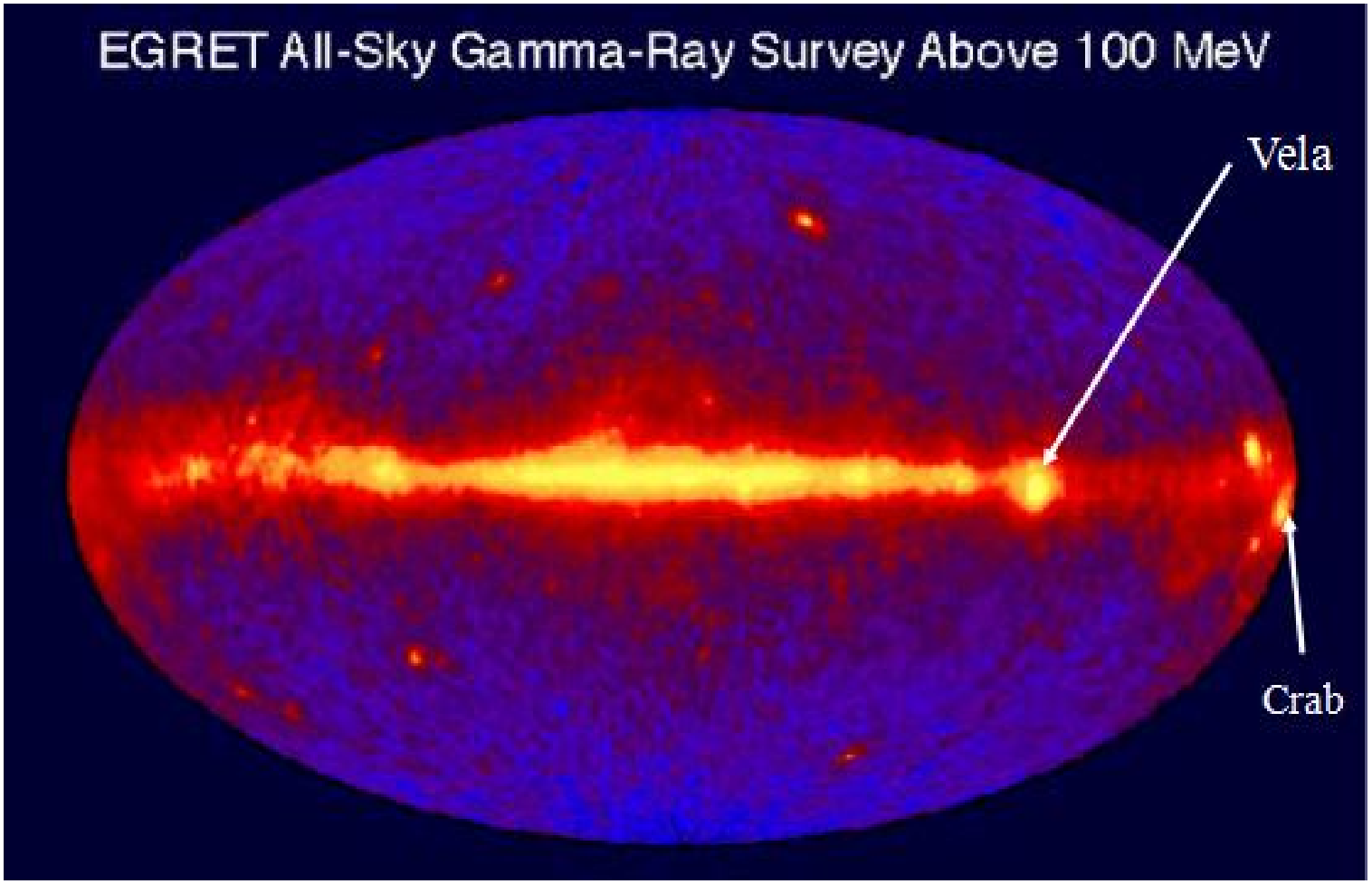
- **Crab Pulsar**
  - **-- In1054, Chinese spotted a supernova in the sky. SN 1054**
  - **-- In 1968, found Crab Pulsar at the heart of the Crab Nebula.**



NASA & http://www.astropolis.fr/articles/les-objets-du-ciel/les-pulsars/images/crabe.jpg

Brief Introduction

- **Crab Pulsar**
  - **-- Very bright in the sky**

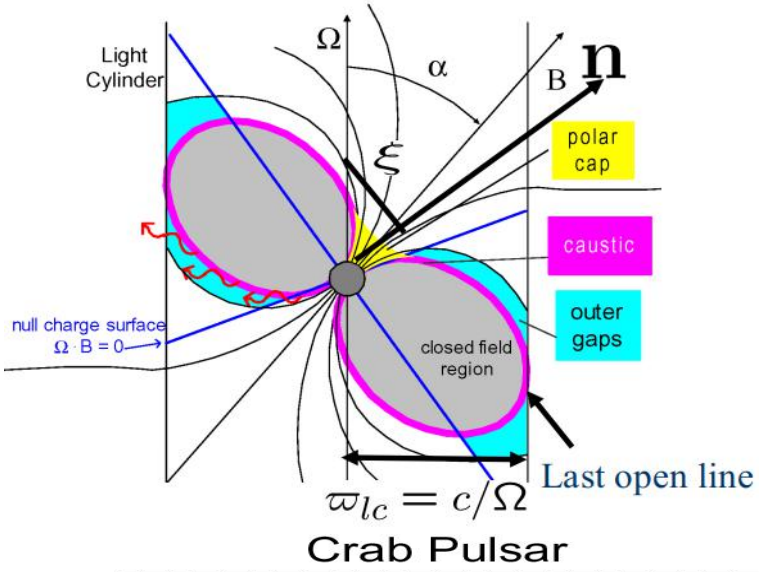


Brief Introduction

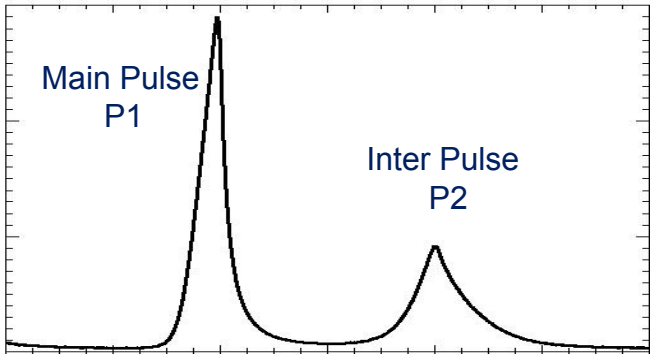
- **Crab Pulsar**

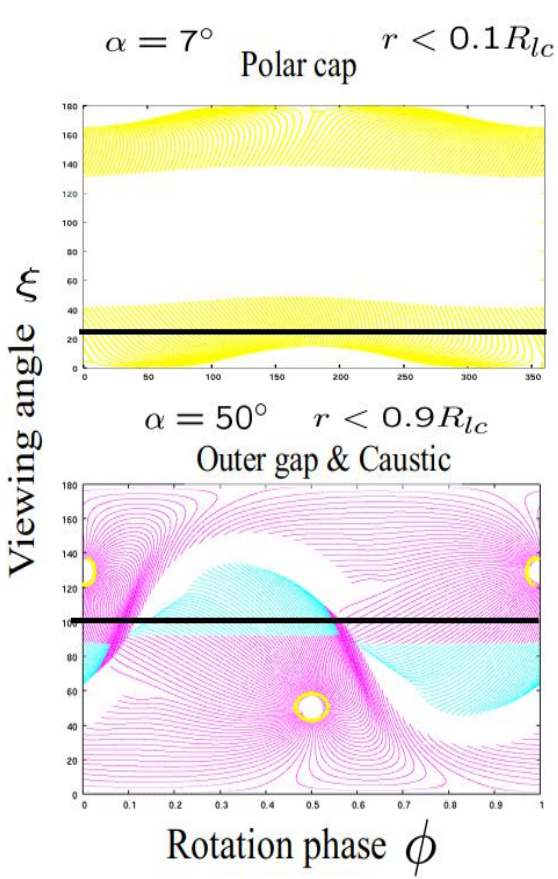
  --Theoretical emission model: polar gap, caustic, outer gap, etc.

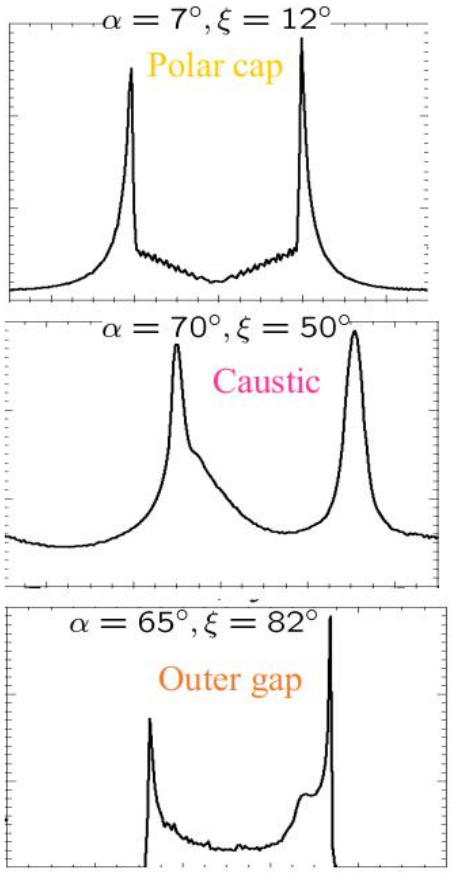
  --Observation effect: double-pulse in light curve



Crab Pulsar





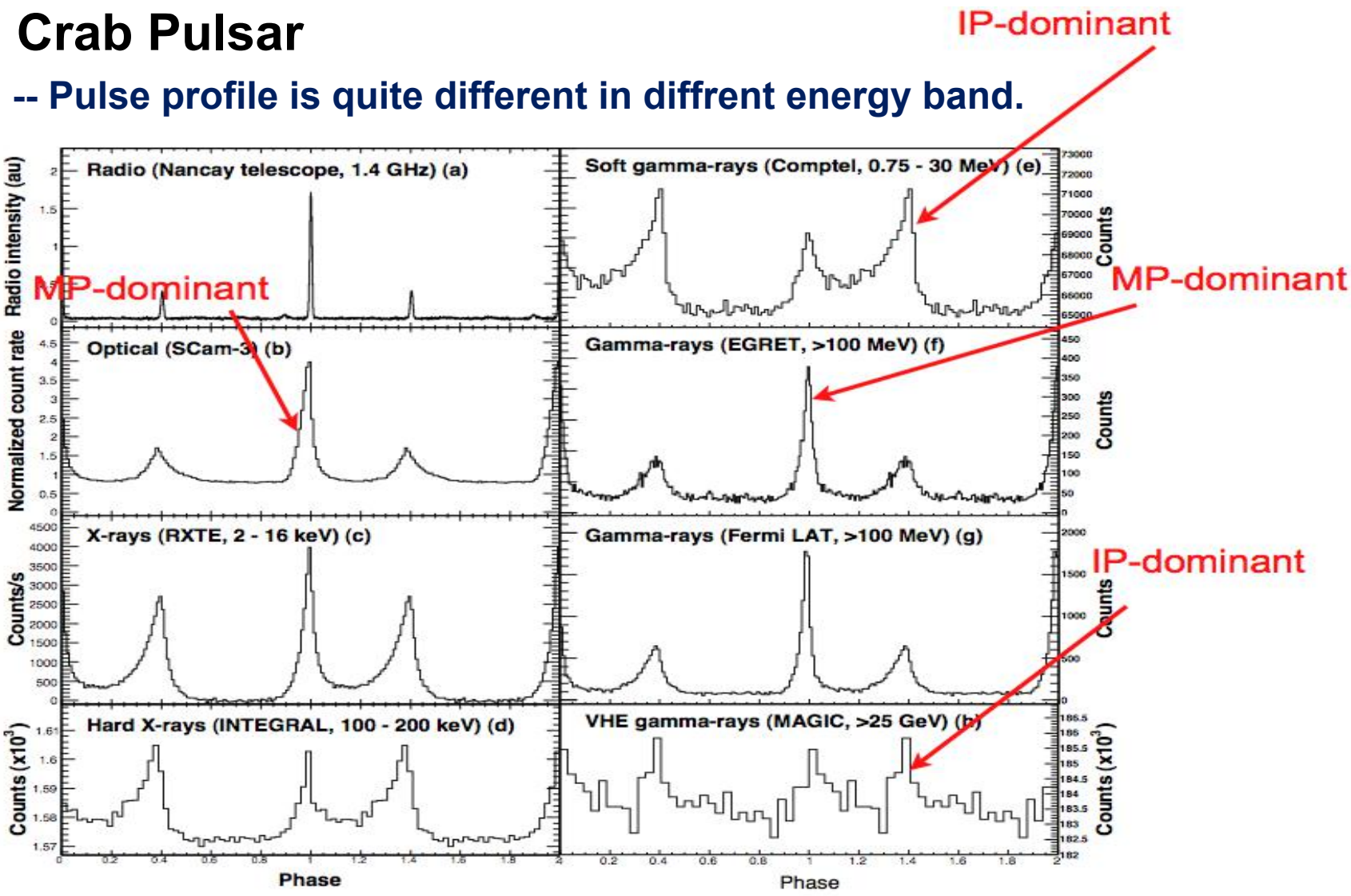


Cite form J. Takata's meeting report

Brief Introduction

- **Crab Pulsar**

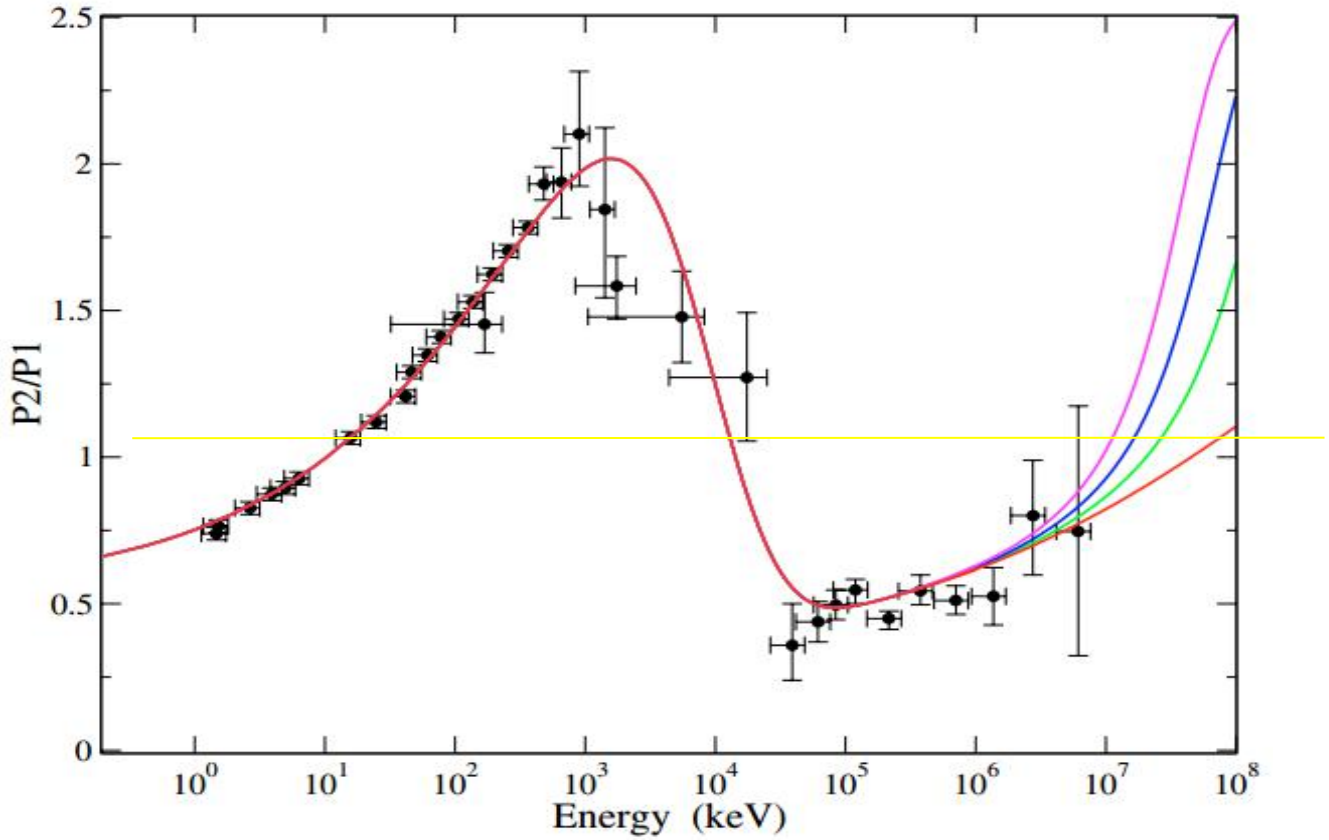
  -- Pulse profile is quite different in diffrent energy band.



https://inspirehep.net/record/1185073/files/Crab-profile.png

Brief Introduction

- **Crab Pulsar**
  - **-- Different SED in P1 and P2.**



Kuiper et al. 2001

Brief Introduction

- **Crab Pulsar**

Reported polarization:

-- Different SED in P1 and P2.

-- Novick et al. (1972), Aerobee 350, 5-20keV, P=15%±5%, φ=156° ±10° ;

-- Weisskopf et al. (1976), OSO-8, 2.6keV, P=19.2%±1%, φ=156.4° ±1.4° ;

-- Forot et al. (2008), IBIS, 15-10000keV, P=47+19−13%, φ=100° ±11° ;

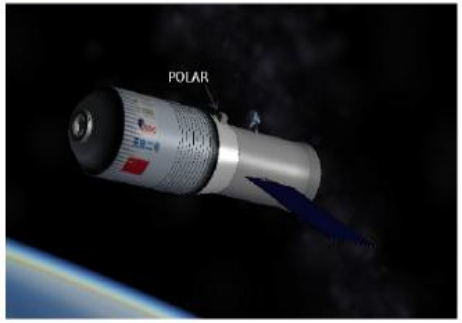
-- Dean et al. (2008), SPI, 100-1000keV, P=46%±10%, φ=123° ±11° (0.5–0.8);

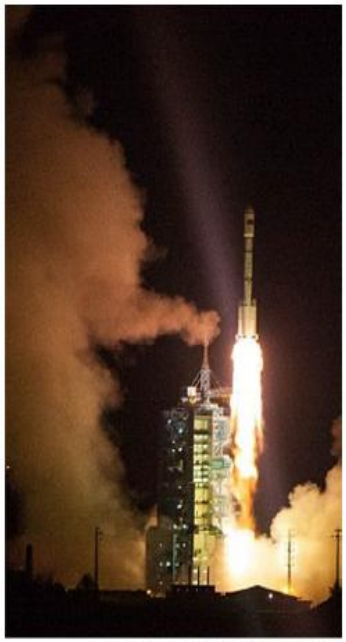
-- Chauvin et al. (2013), SPI, 130-440keV, P=28%±6%, φ=117° ±9° ;

-- Chauvin et al. (2016), PoGOLite, 25-240 keV, P~18.4+9.8−10.6%, φ=149° ±16°

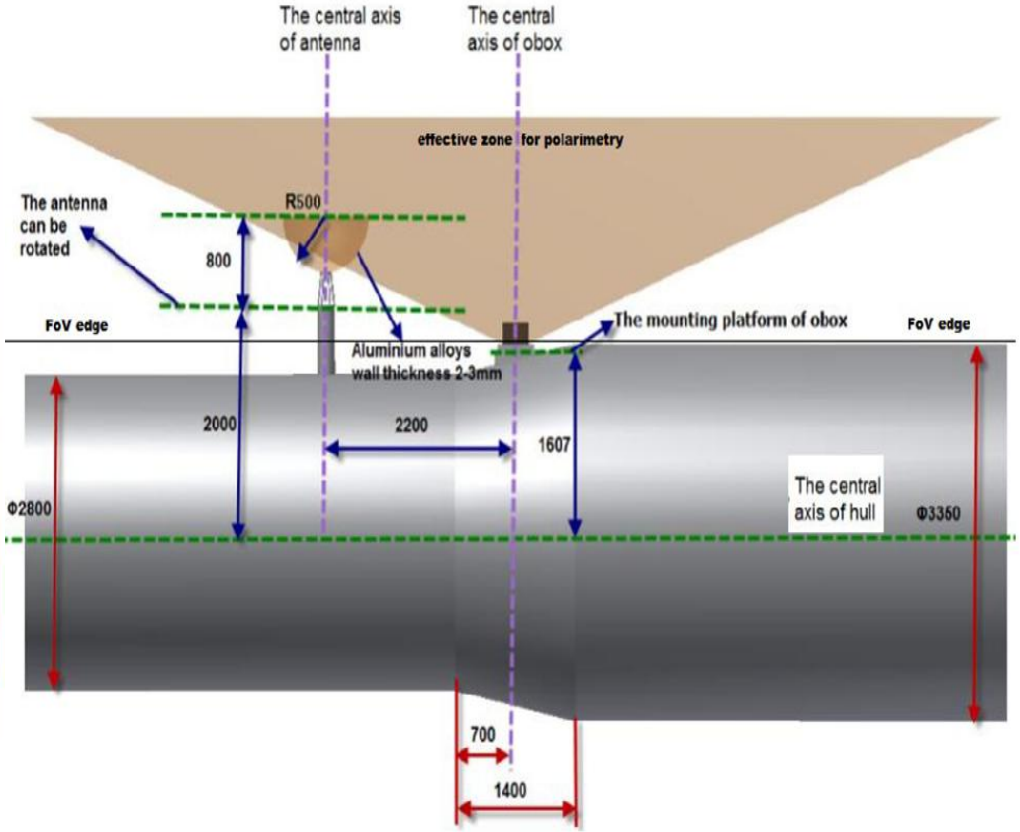
Brief Introduction

- **POLAR Instrument**
  - **-- POLAR is on board of the Chinese space laboratory TG-2 which was launched in Sep. 15th 2016**





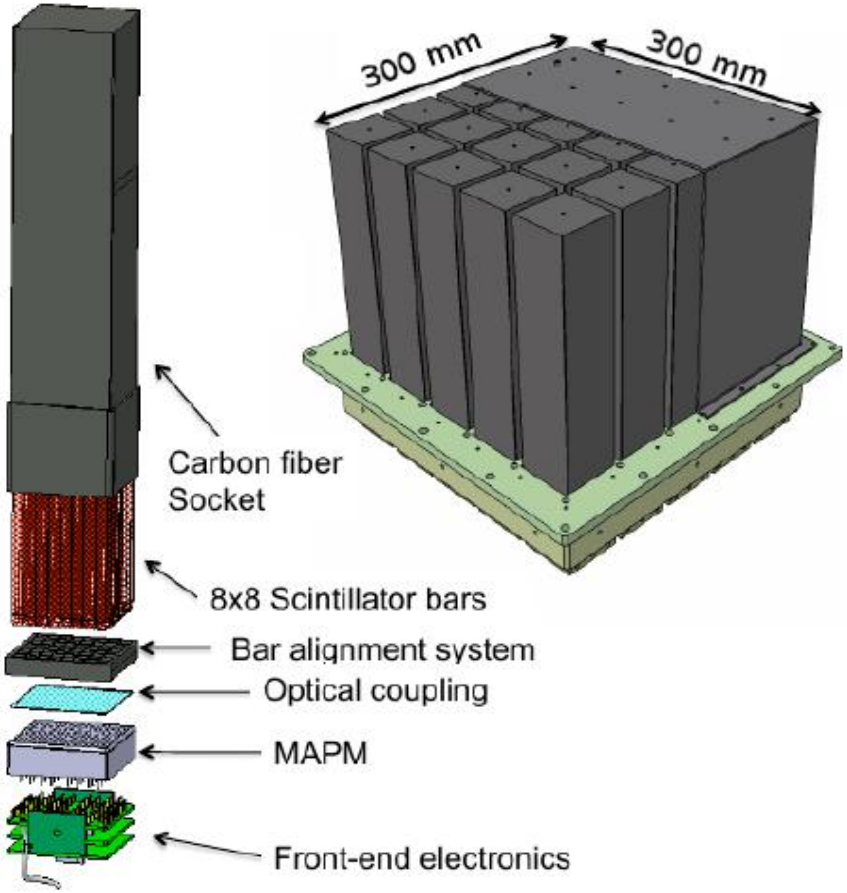
Credit: South China Morning Post



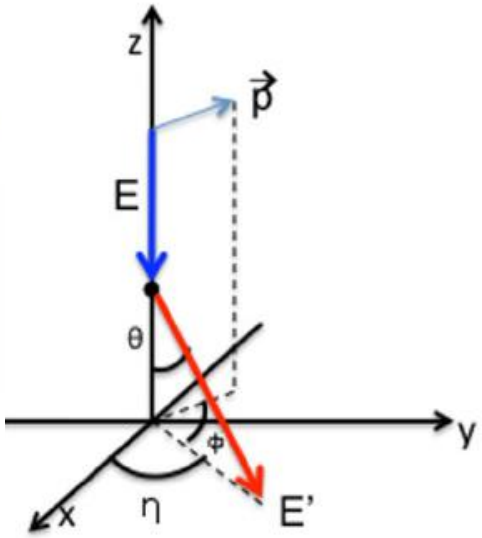
M. Kole NSS talk

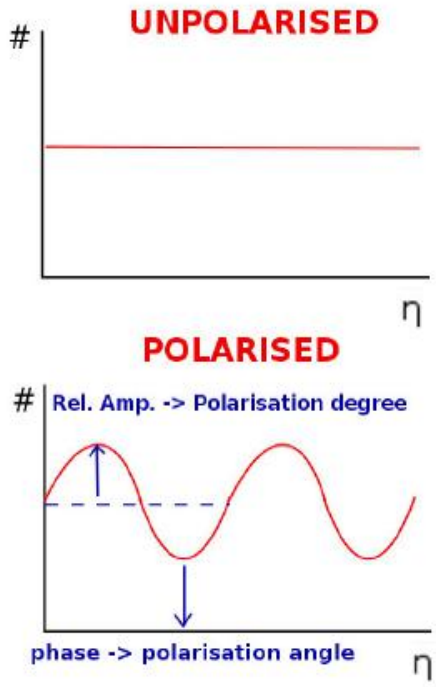
Brief Introduction

- **POLAR Instrument**
  - **-- Structure and detecting principles. (Sensitive at 50~500KeV band)**



$$\frac{d\sigma}{d\Omega} = \frac{r_o^2}{2}\frac{E'^2}{E^2}\left(\frac{E'}{E} + \frac{E}{E'} - 2\sin^2\theta\cos^2\phi\right).$$

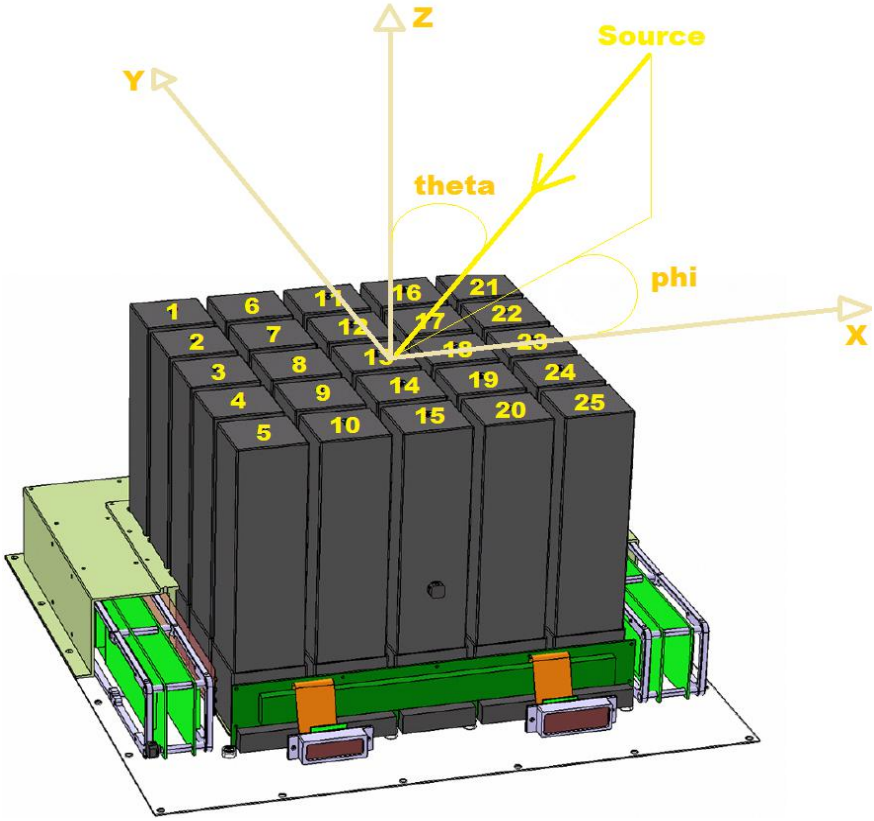


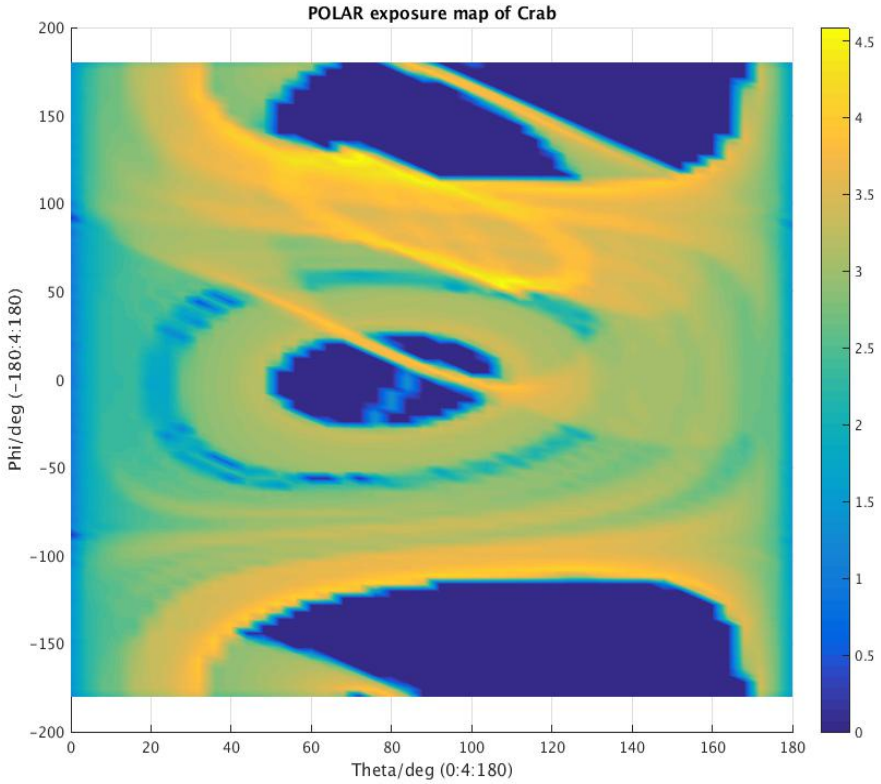


M. Kole et al 2016

Brief Introduction

- **POLAR Instrument**
  - **-- The defination of incident angle**
  - **-- The Crab exposure map of POLAR**

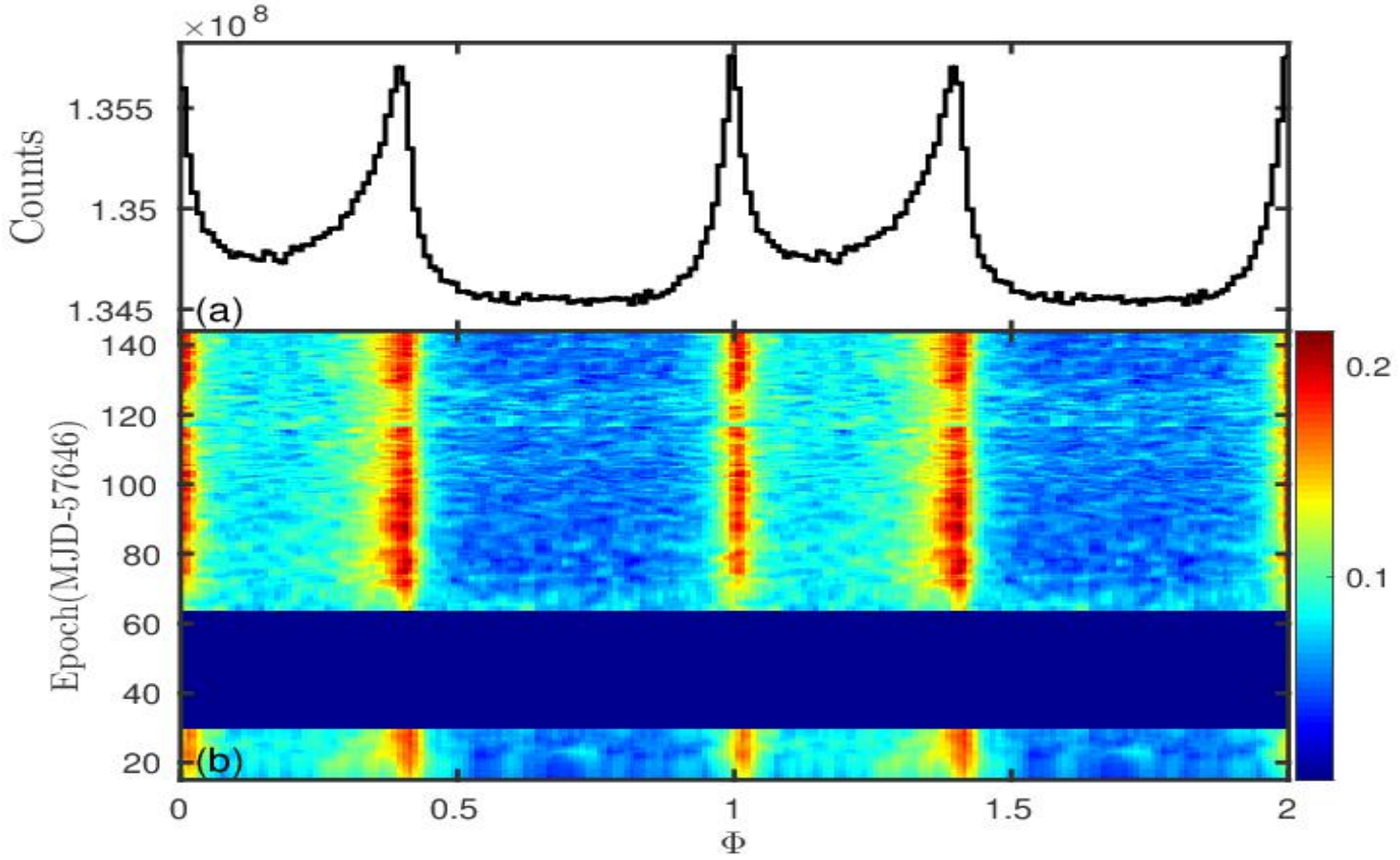




Li, H. C., Ge, M. Y., et al, ICRC Conf. Proc. 2017

Crab Pulse Profile

- **Total Profile**



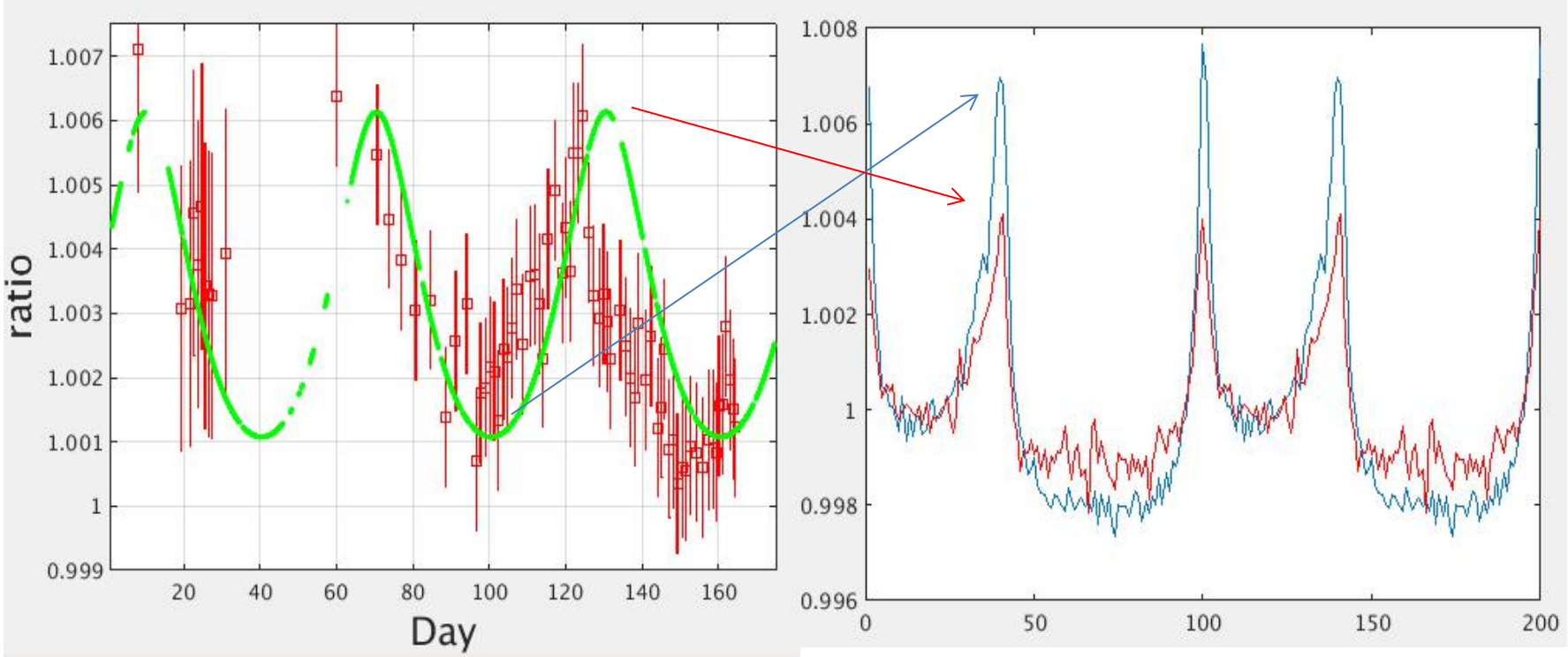
Panel (a) shows the total pulse profile accumulated from all observations. Panel (b) exhibits the normalized profiles with background subtraction observed in every day.

Zheng, S. J., Ge, M. Y., et al, Physica, Mechanica & Astronomica, 2017

Crab Pulse Profile

- **Evolution of pulse profile**

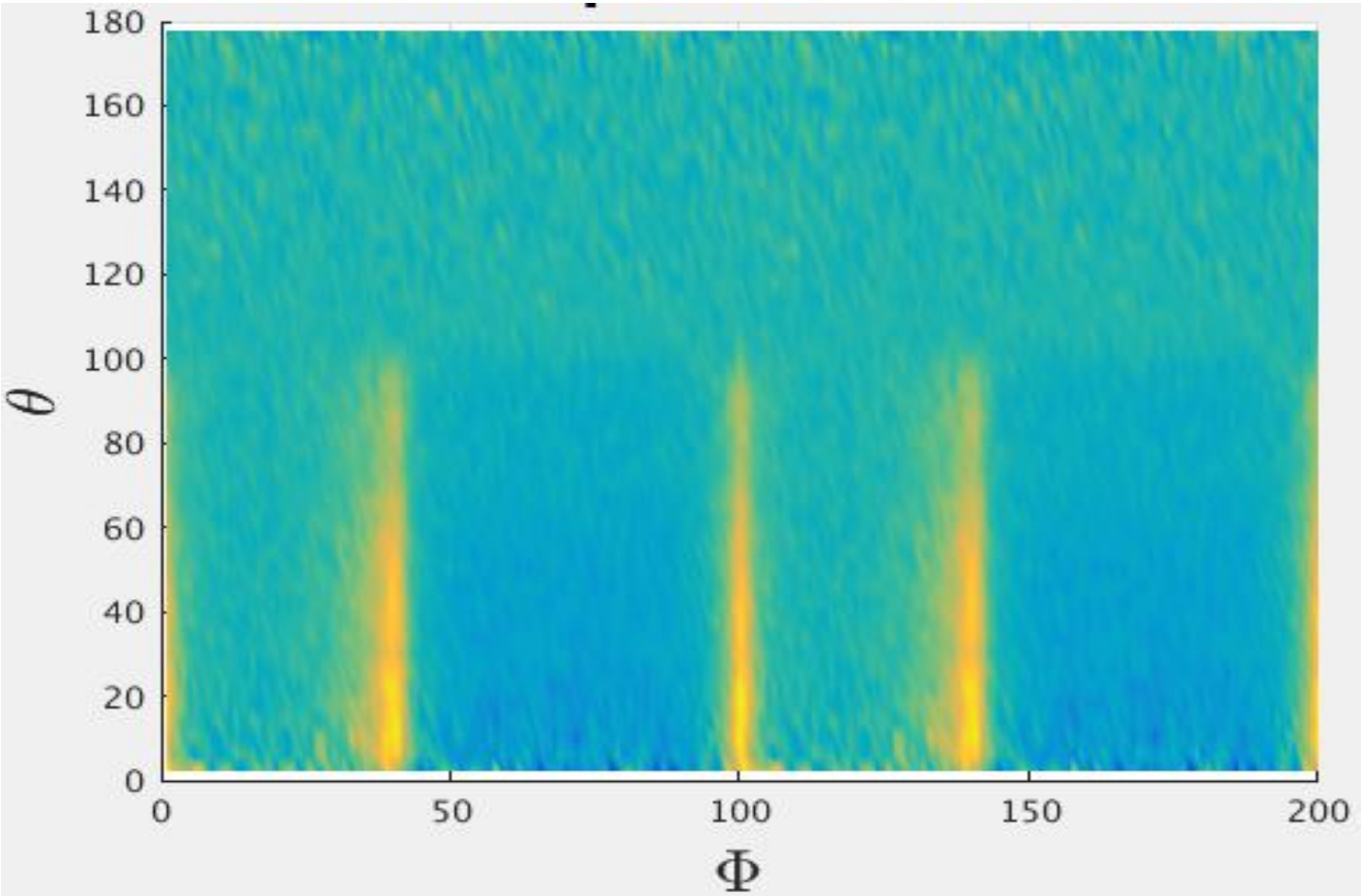
  The profile varies with time.



Left: cnts' ratio of two peaks.(Green line: theta vs. time). Right: diagram of phase histogram.

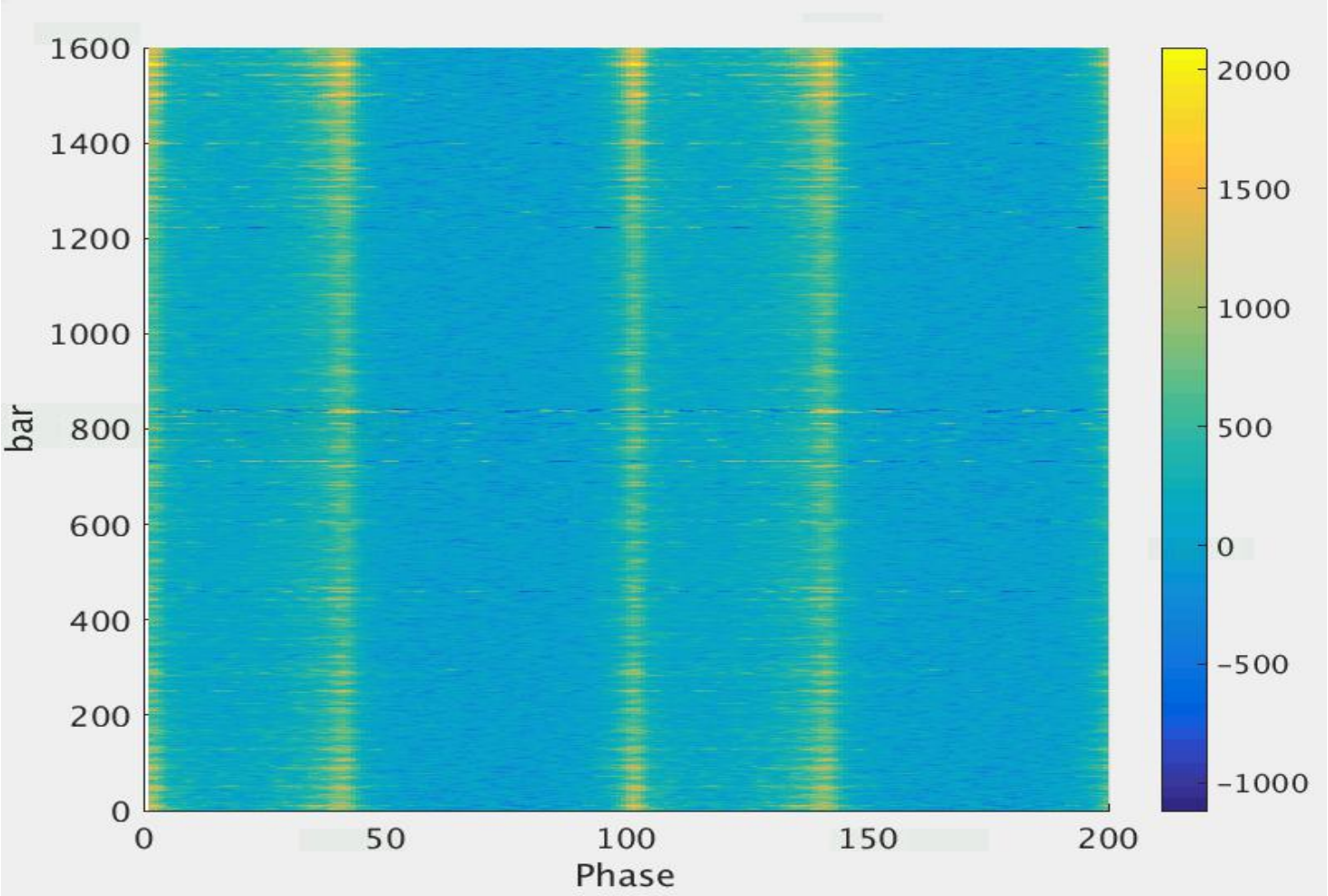
Crab Pulse Profile

- **Profile vs. theta**
  - **-- It indicate that POLAR's FoV in its energy range is larger than 100°;**
  - **-- The instrument box response varies with theta insident angle.**



Crab Pulse Profile

- **Profile vs. 1600 channels**
  - **-- The pulsed photons of Crab are captured by every channel.**

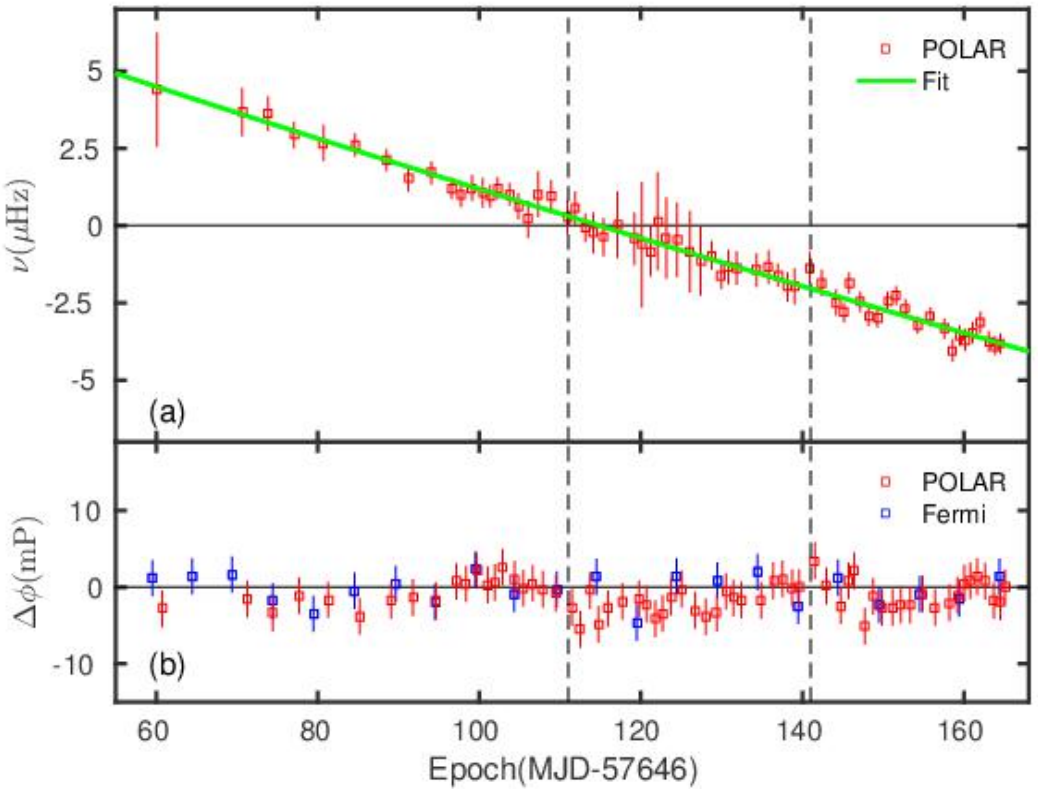


Timing analysis

- **Time systerm is reliable with accuracy ~85us (RMS):**
  - **-- We combined the observation data to search the spin parameters of the pulsar;**
  - **-- TOAs were calculated with the spin parameters and fitted utilizing TEMPO2**
  - **-- Same process with Fermi.**

Table 1: The timing parameters of the Crab pulsar

Parameters	Value
PEPOCH(MJD)	57697.040344079745
F0(Hz)	29.6484272934(4)
F1(10^{-10} Hz s^{-1})	-3.689865(1)
F2(10^{-20} Hz s^{-2})	1.16(1)
F3(10^{-28} Hz s^{-3})	3.4(3)



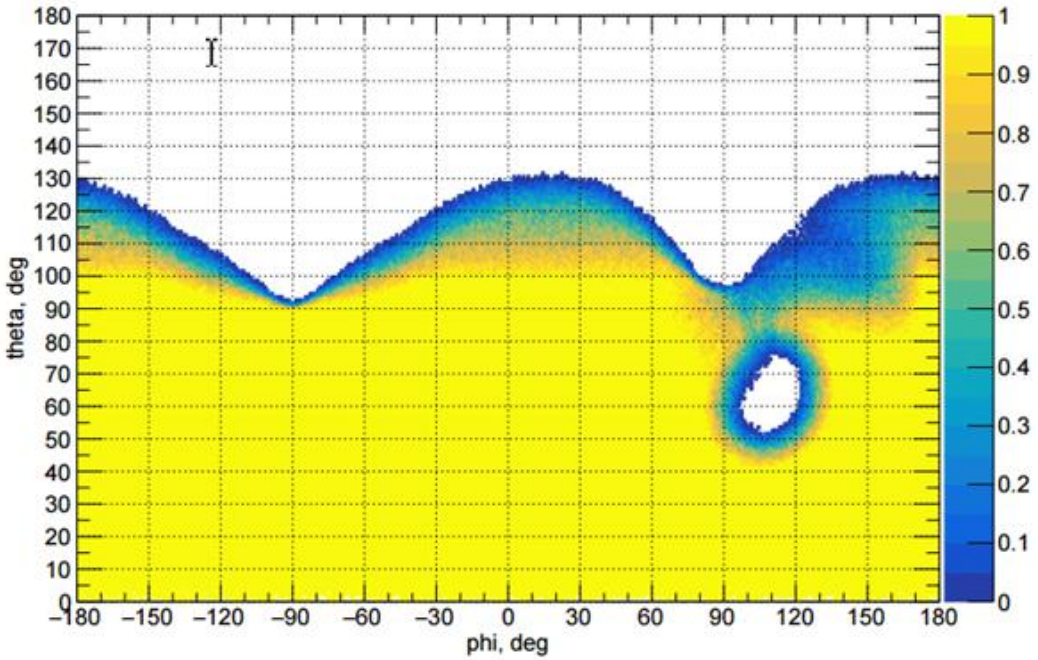
(a): evolution of spin frequency. Red dot is obtained from POLAR, The green line represents the fitted result. Liner term has been substracted. (b): timing residual.

Influence Factors

- **Including but not limited to：**
  - Detection efficiency
  - Projected area
  - Visible efficiency
  - Cnts rate

$$\mathrm{r} = \eta(\theta,\varphi)\mathrm{A}(\theta,\varphi)\mathrm{V}(\theta,\varphi)\int_{E1}^{E2} f(E)dE$$

Visible efficiency from simulation

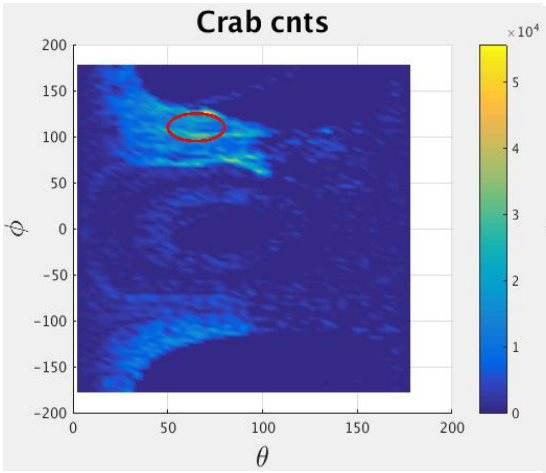


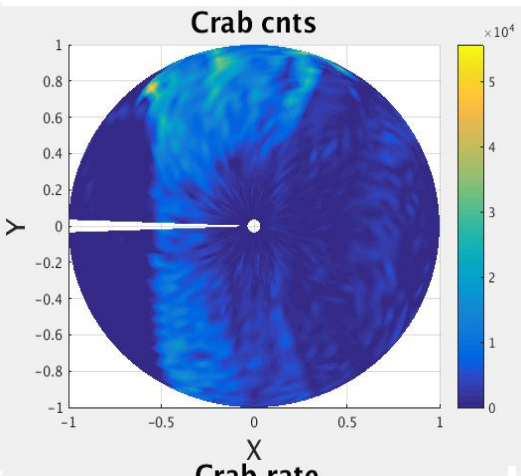
Simulated by Juan Zhang

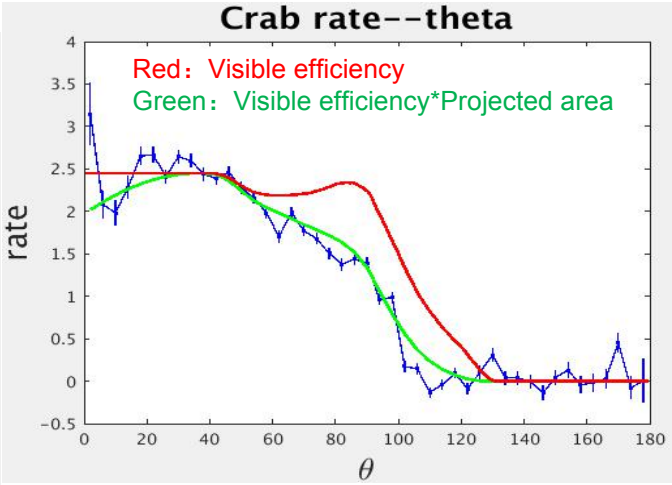
Influence Factors

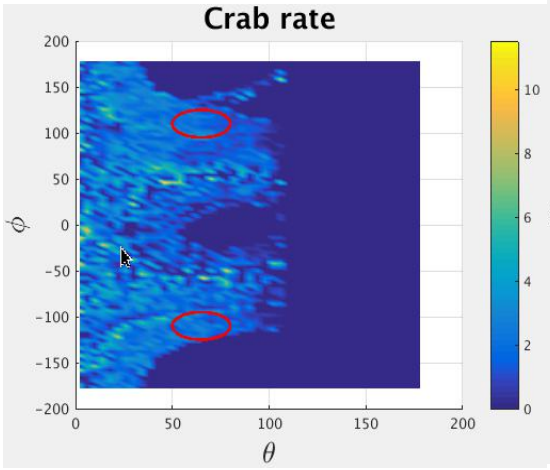
- **Nhits=2~5**

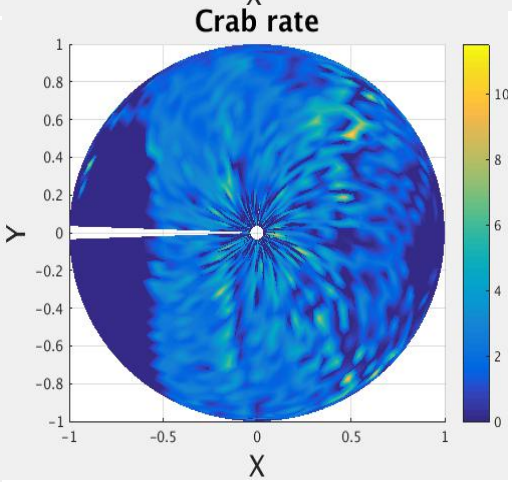
Try to fiting the rate distribution

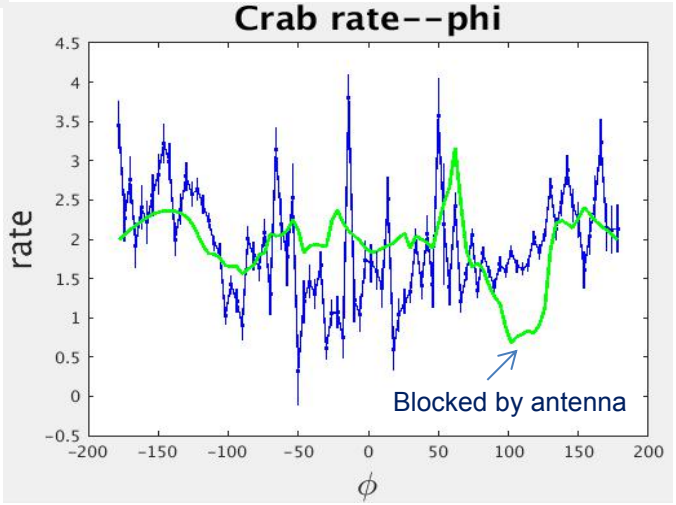








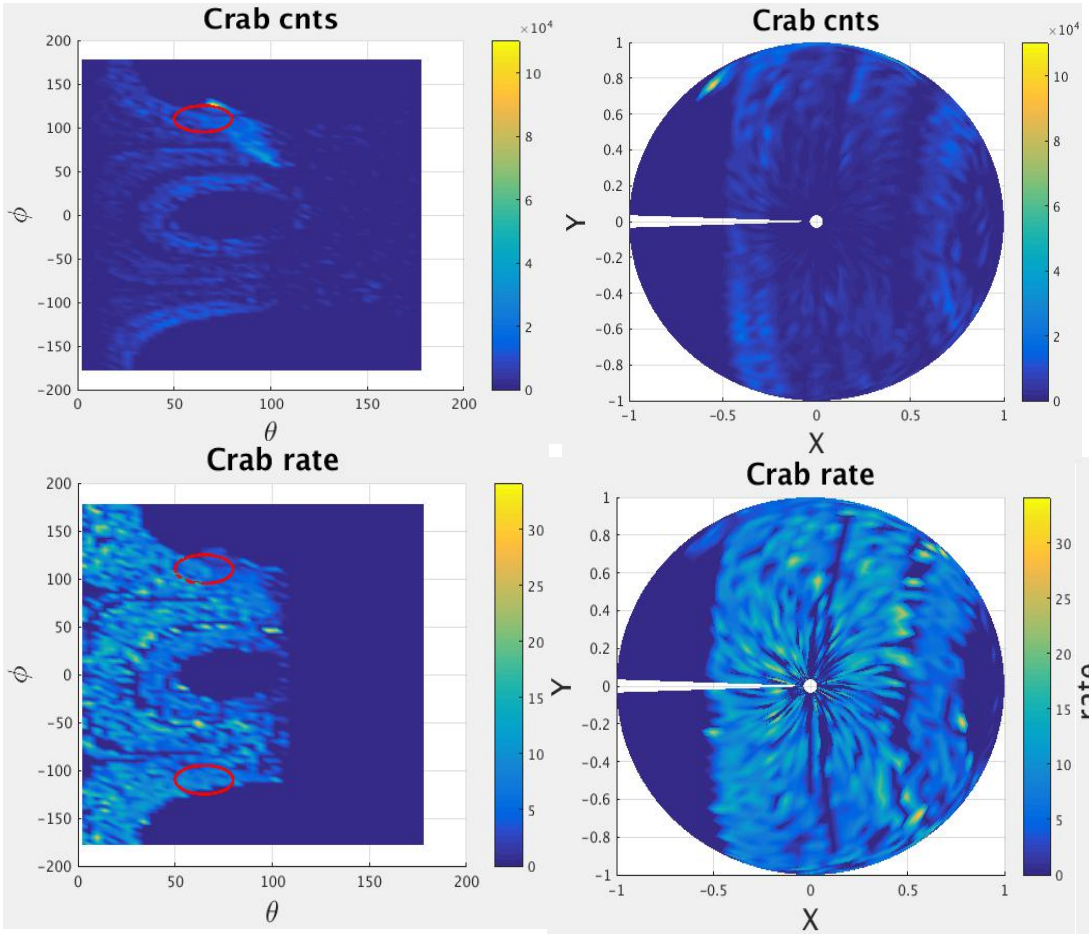


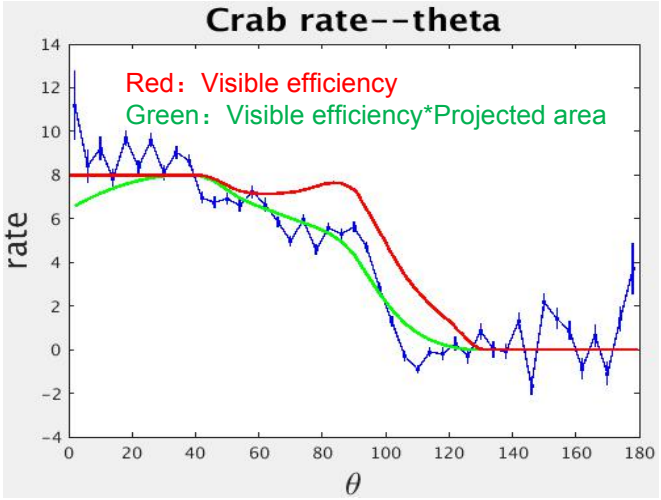


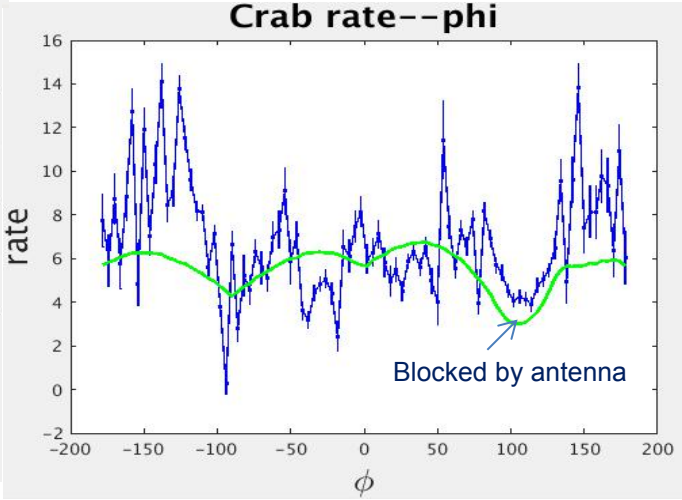
Influence Factors

- **Nhits=1**

  Try to fiting the rate distribution







Potential Polarimetry

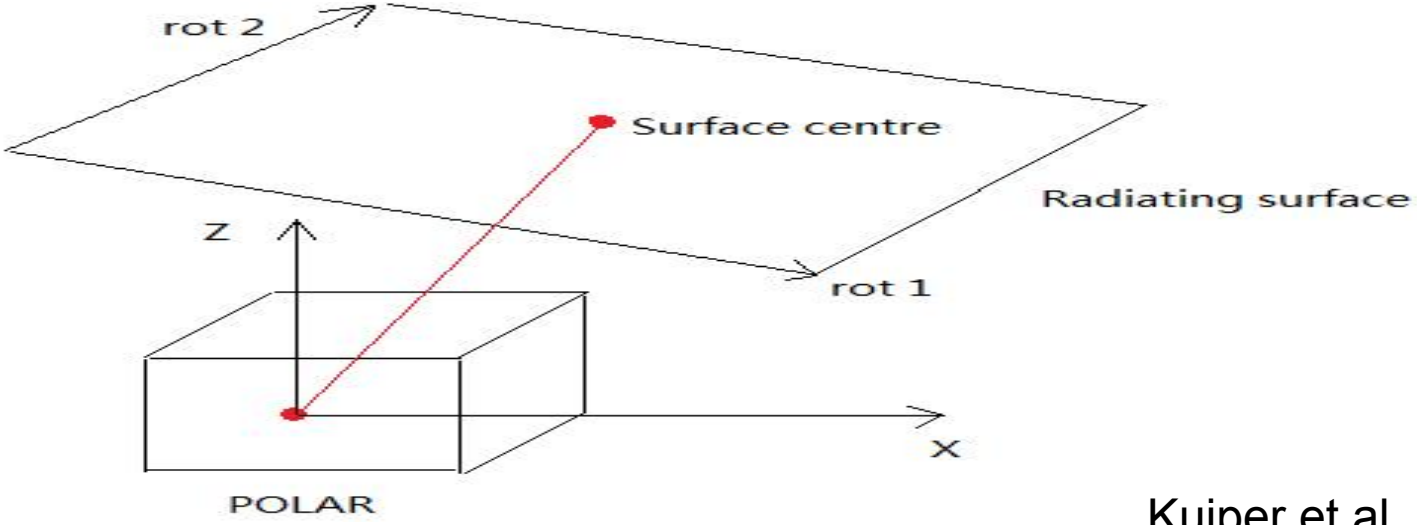
- **The basic methods same as GRB**
- **Difficulties：** **the incident angle between the Crab and POLAR varies with time**

  -- So we have to obtain modulation curve as a function of incident angle;

  -- Or every event should map to the vertical plane of Crab's radiation direction.
- **Precondition：**

  -- Using Monte Carlo simulation to reappear the Crab observation on POLAR.

  -- Simulate different polarization Crab source in parallel, and compare these simulation results with observation results.



Kuiper et al. 2001

$$F_p = 726E^{-1.276}e^{-0.074\ln E} + 1464E^{-1.665}e^{-0.159(\ln E)^2} + 2021E^{-2.022}$$ (ph s^{-1} m^{-2} keV^{-1})

Summary

- POLAR detected a significant Crab pulse signal;
- Spin frequency searching shows that time systerm accuracy ~85us.
- The response of Crab detection varies with many factors;
- Simulation are processing and we expecting to reappear the Crab observation on POLAR
- Crab polarization of POLAR is on the way.
- Seaching of other pulsars will processing next.

- Li, H. C., Ge, M. Y., et al, ICRC Conf. Proc. 2017

THANKS