Detection of Crab nebula and Pulsar with HAGAR telescopes

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Gamma Ray astronomy group

DHEP

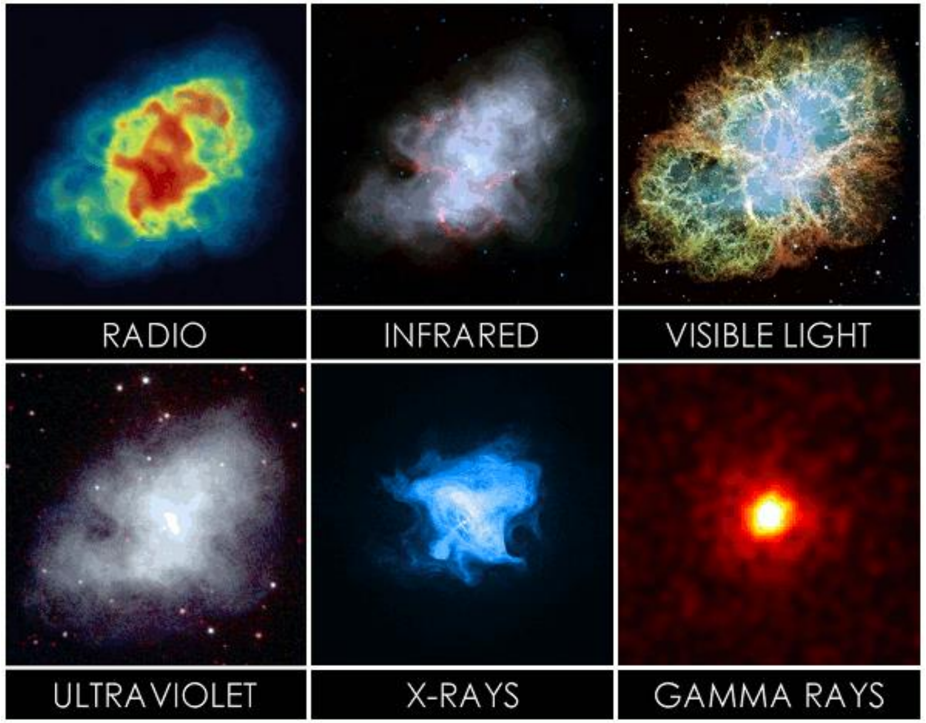
Outline:

- Crab Nebula and Pulsar
- HAGAR telescopes
- Observations and analysis
- Results

Crab system: Nebula + Pulsar

- The remains of the Supernova explosion in AD 1054.
- The remnant consists of two different, bright, sources: Pulsar and Nebula
- Emission predominantly by non-thermal processes, covering a huge energy range (radio to TeV)
- Both objects have played a key role in the development of high energy astrophysics.
- Very strong and stable at TeV

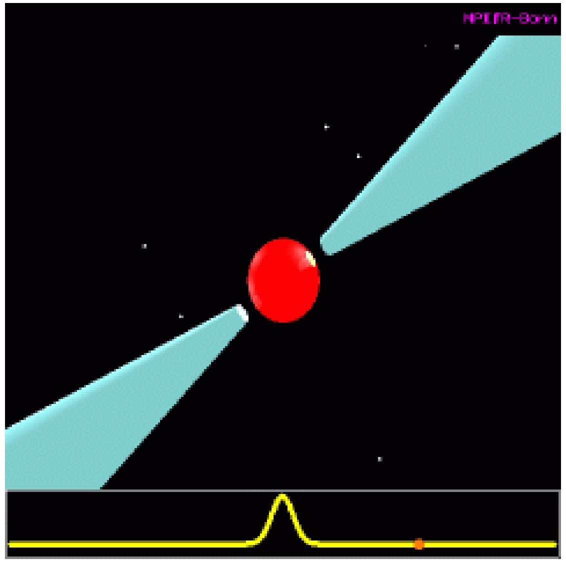
Standard candle for VHE gamma ray telescopes.



Credits: NRAO/AUI and M. Bietenholz; NRAO/AUI and J.M. Uson, T.J. Cornwell (radio); NASA/JPL-Caltech/R. Gehrz / University of Minnesota (infrared); NASA, ESA, J. Hester and A. Loll / Arizona State University (visible); NASA/Swift/E. Hoversten, PSU (ultraviolet); NASA/CXC/SAO/F.Seward et al.(X-rays); NASA/DOE/Fermi LAT/R. Buehler (gamma rays).

Pulsar

- Pulsars are rapidly rotating neutron stars that emit periodic pulses of electromagnetic radiation range from milliseconds to seconds.
- It is Pulsating because it's rotating and magnetic axis is misaligned with rotational axis.



Rotation Powered :

$$\frac{dE}{dt} = 4\pi^2 I P^{-3} \dot{P}$$

$$\dot{E} = 3.95 * 10^{31} \left(\frac{\dot{P}}{10^{-15}} \right) \left(\frac{P}{\text{sec}} \right)^{-3}$$

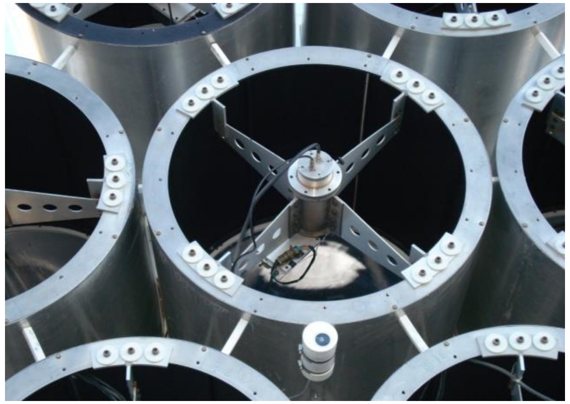
Accretion powered : Compact star pull matter from the surface of it companion. This matter then travels fast and falls into the compact member and circles around it, spiraling inward. The spiraling matter heats up by friction and radiates X-ray (thermal).

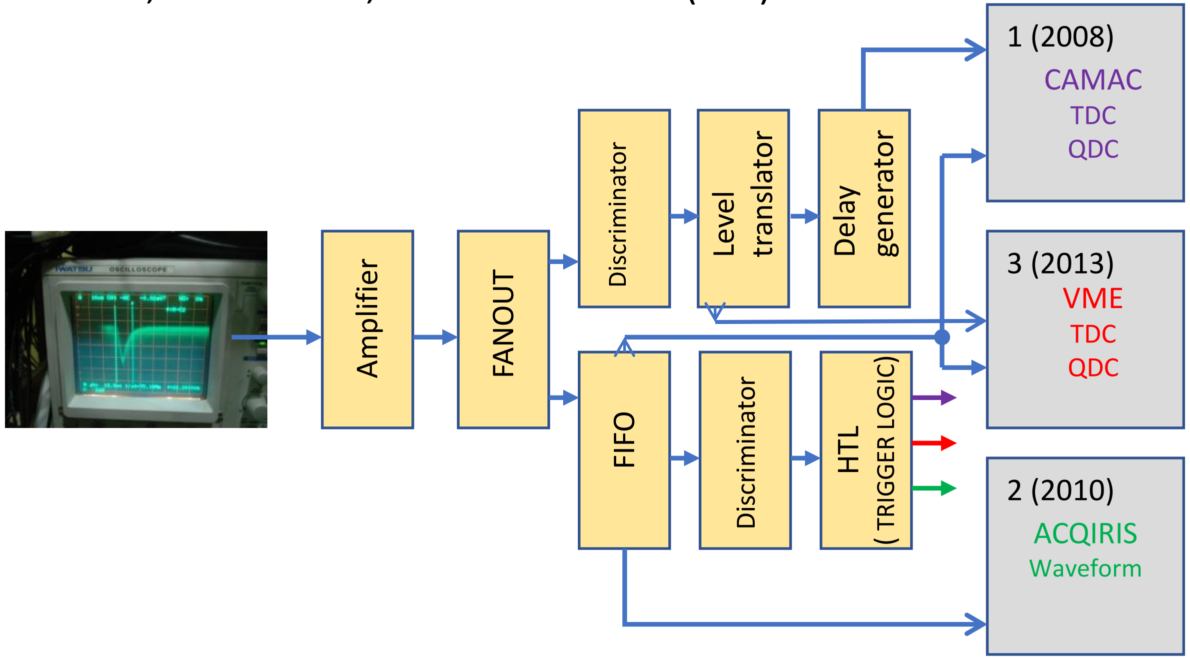
Magnetic field powered : Magnetars

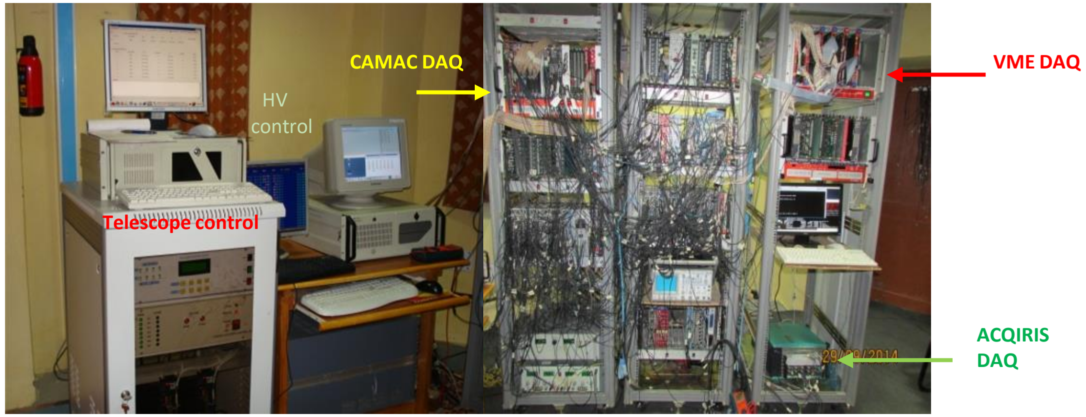
HAGAR : High Altitude Gamma Ray Observatory

(Array of 7 Atmospheric Cherenkov Telescopes)

Site: $32^{d}46^{m}46^{s}$N, $78^{d}57^{m}51^{s}$E, 4273m asl Hanle (Leh)





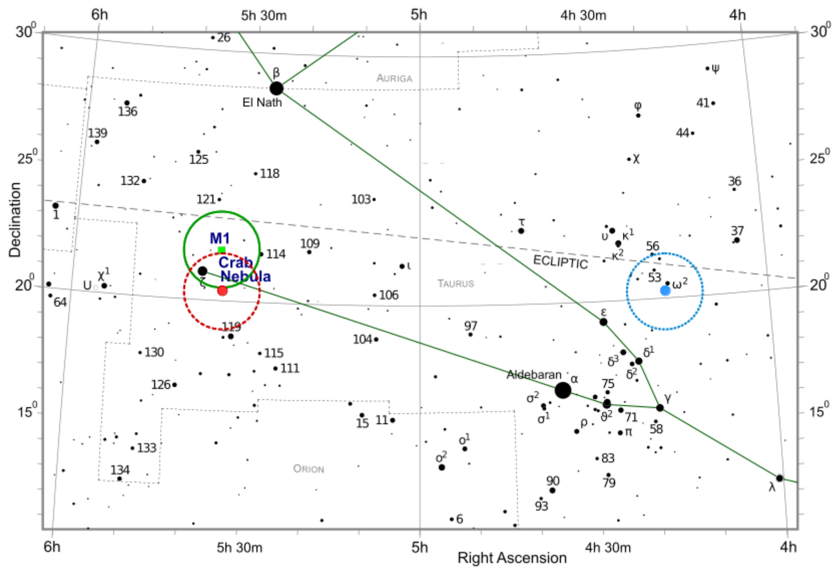


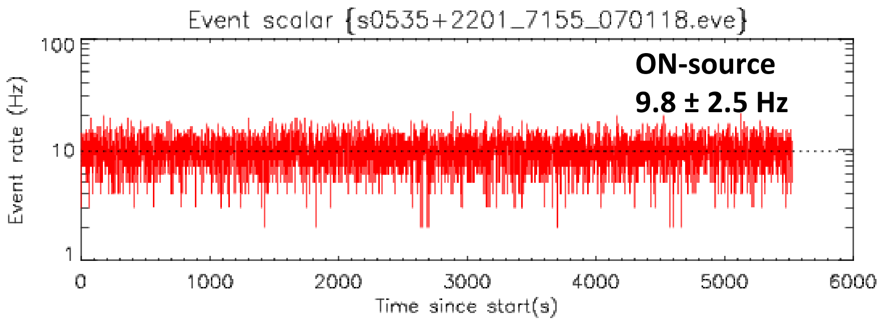
HAGAR : Crab observations

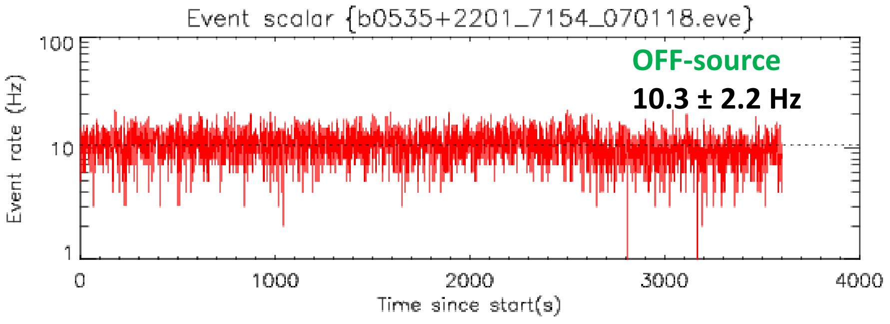
Observations : ON-OFF mode (source followed by its background or vice versa)

Signal : Comparison of cosmic-ray events from a gamma ray source region with similar cosmic-ray background region.

Sky map: Crab observations

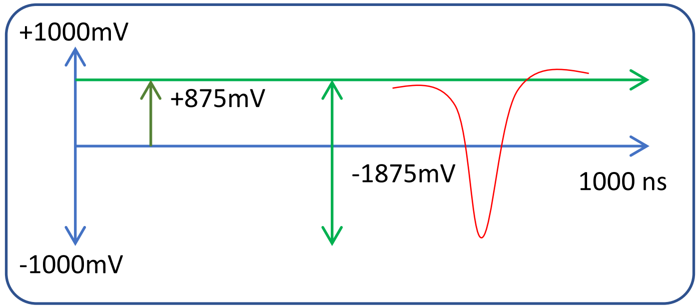


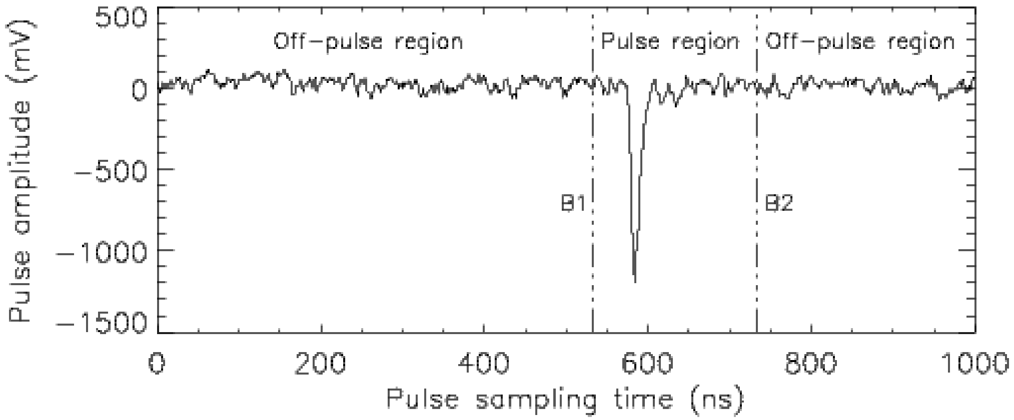


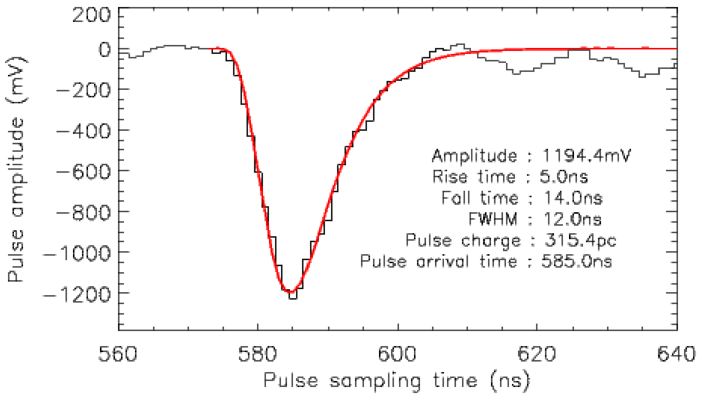


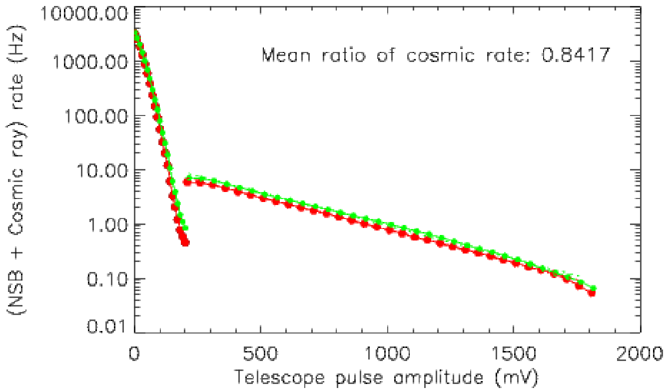
HAGAR : Data reduction

Acqiris : 8bit waveform digitizer	
Parameter	Configuration
Full scale (8bit)	2000 mV
Voffset	+875 mV
Pre-trigger delay	800 ns
Sampling period	1ns
Samples	1000



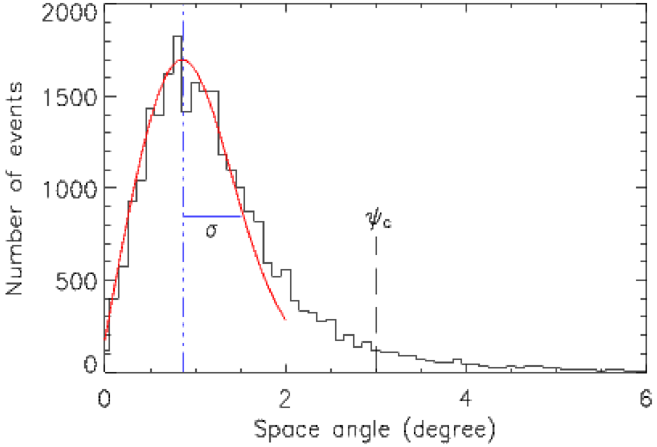


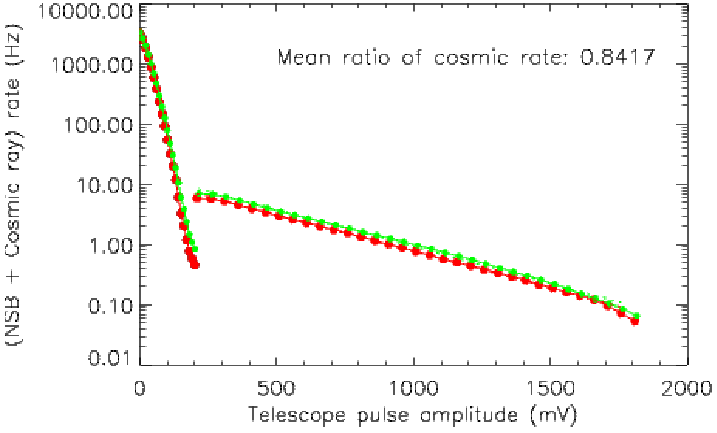


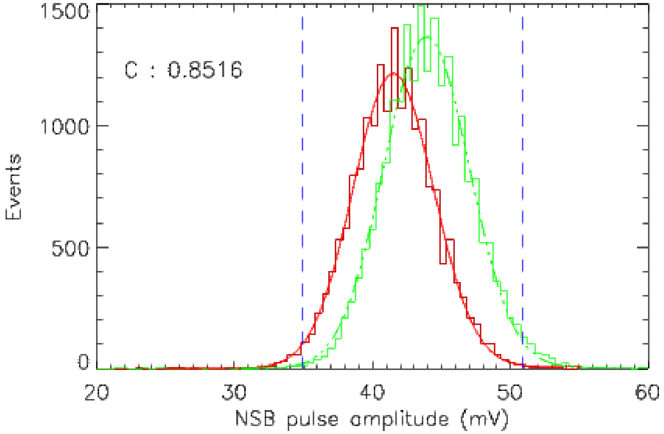


HAGAR : Crab Nebula

Normalization of ON-OFF pair :







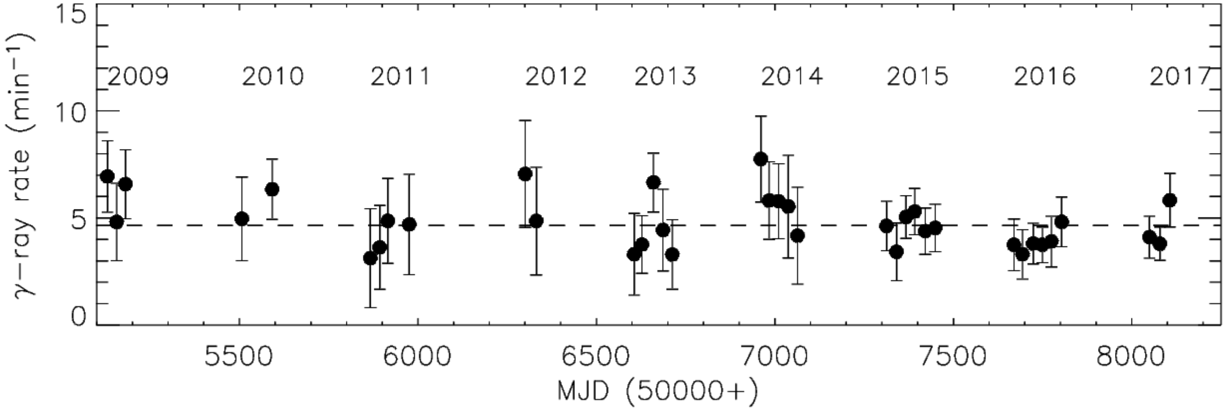
$$Signal = (N_{ON} - R * N_{OFF})$$

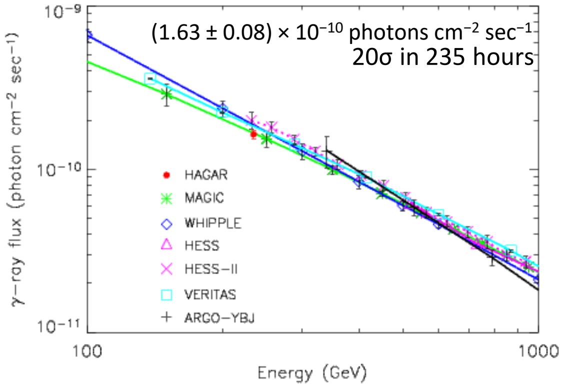
$$Signal\ error = \sqrt{(N_{ON} + R^2 * N_{OFF})}$$

$$Significance = \frac{(N_{ON} - R * N_{OFF})}{\sqrt{(N_{ON} + R^2 * N_{OFF})}}$$

Result-1: Crab nebula (*Standard candle in gamma ray sky*)

Duration:
235 hours





B.B.Singh et.al, Experimental Astronomy, DOI 10.1007/s10686-01909623-1,2019

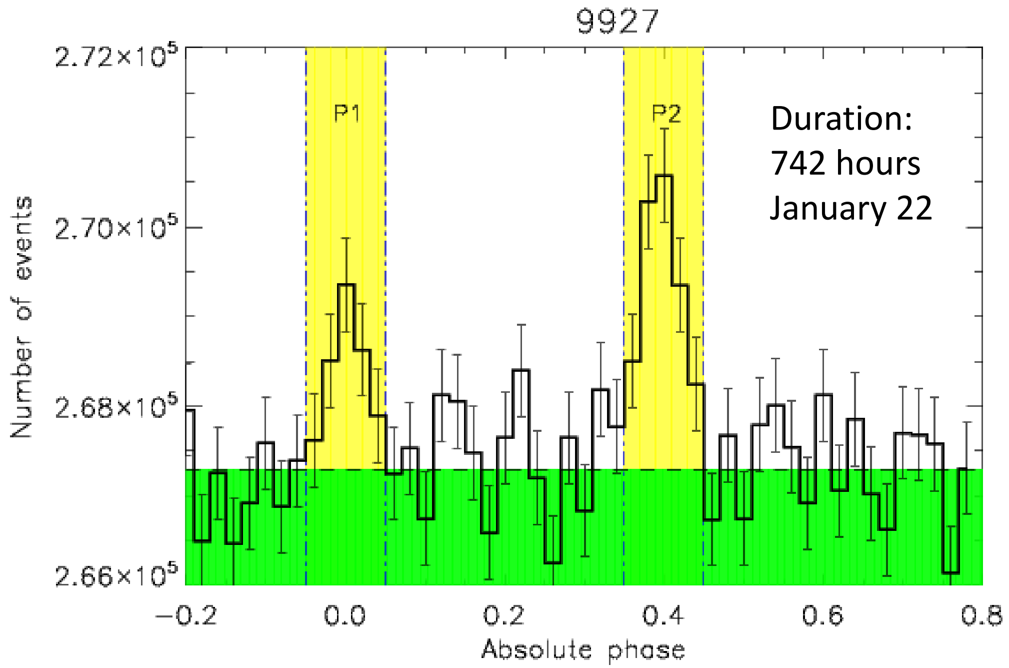
Search of Periodic Signal : Pulsar Timing

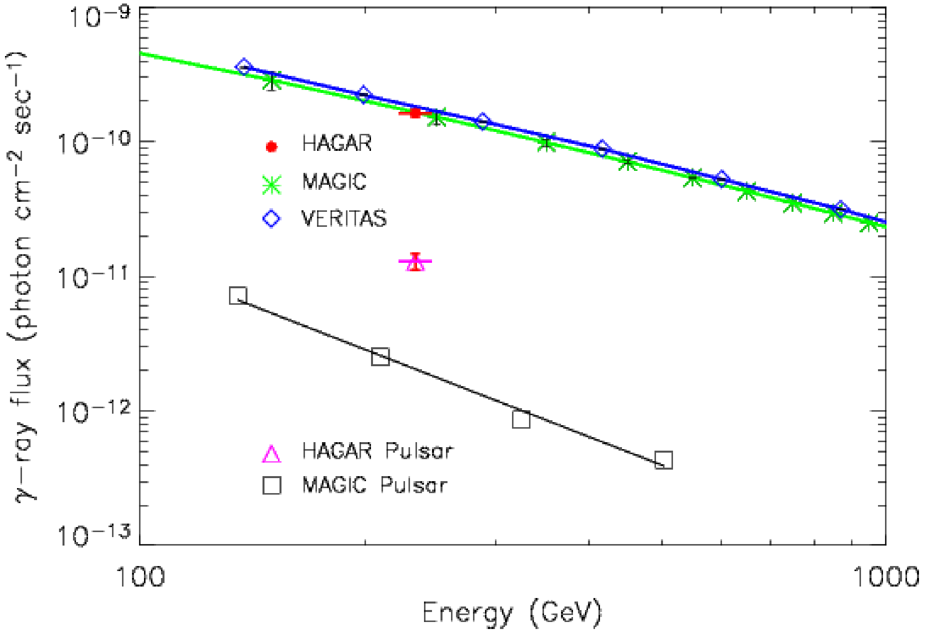
A pulsar emits pulses and these pulses travel to our telescopes, where we measure their times of arrival (TOAs).
Many other phenomenon influence measured TOAs.
Clock (Leap second), Geometric delay, Dispersion delay and Relativistic

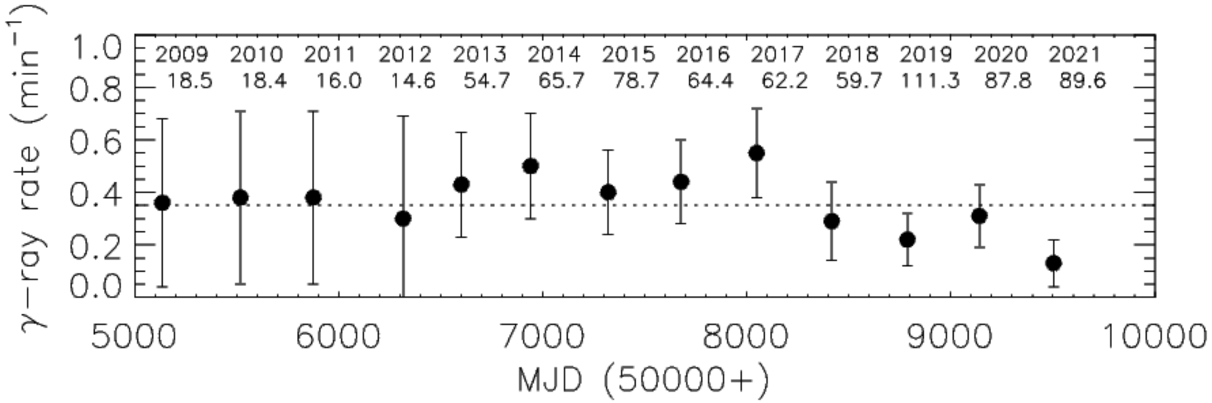
$$\phi(t) = \phi(t_o) + f_o.(t - t_o) + \frac{1}{2}\dot{f}(t - t_o) + \frac{1}{6}\dot{f}(t - t_o)^3 + ...$$

TEMPO codes in prediction mode can be used for barycentric corrections. In prediction mode or ‘tz’ mode, TEMPO calculates pulsar ephemeris over short period of time (typically hours) in the form of simple polynomial expansion. Reference phases Φ_o at epoch T_o are calculated over period of 3 hours centered with the transit time of pulsars at observatory site in the steps of 10 minute interval for each run data.

Result-2: Crab Pulsar







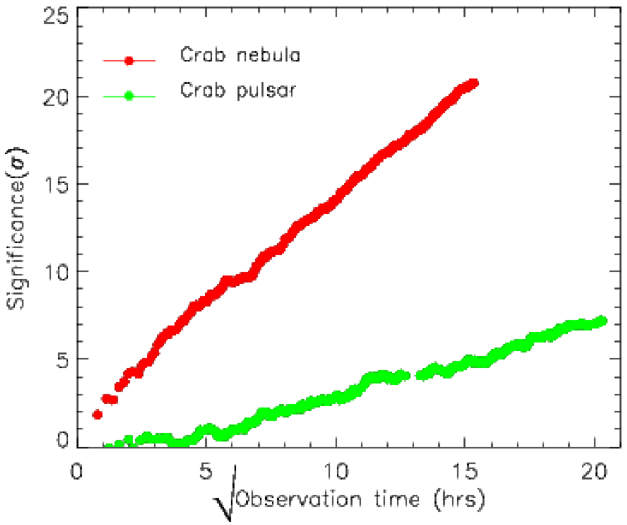


Photo source : Dorje Angchuk (IIA, Leh)