High Energy Gamma ray A

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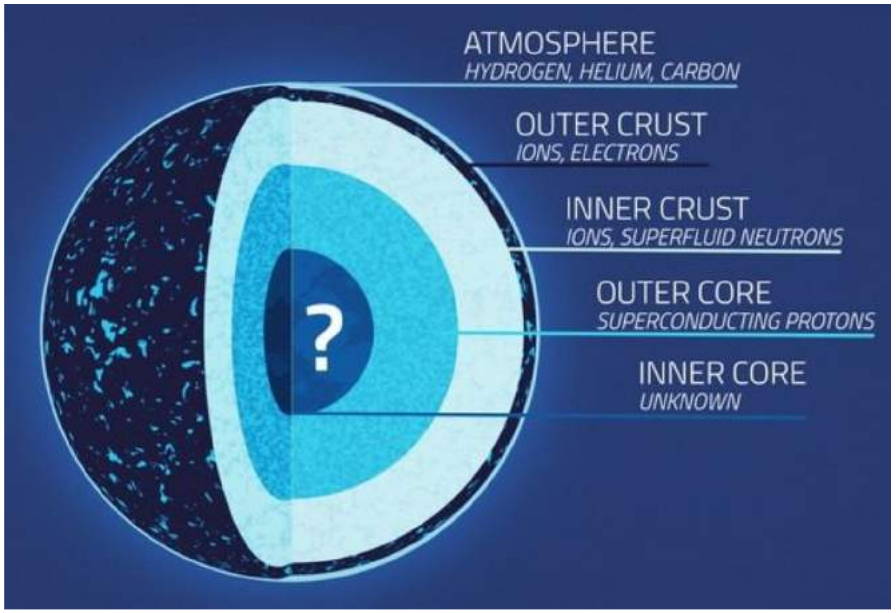
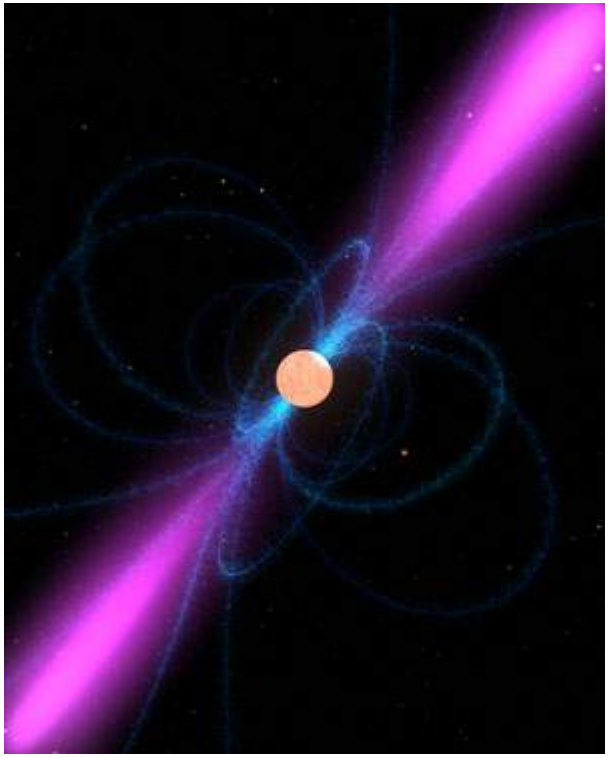
1.Introduction

Neutron stars

- Typical radius: 10 km
- Typical mass: 1 solar mass
- Density:10^{17}kg/m^3
- Magnetic field: 10^4 – 10^{11} T



Credit: NASA's Goddard Space Flight Center

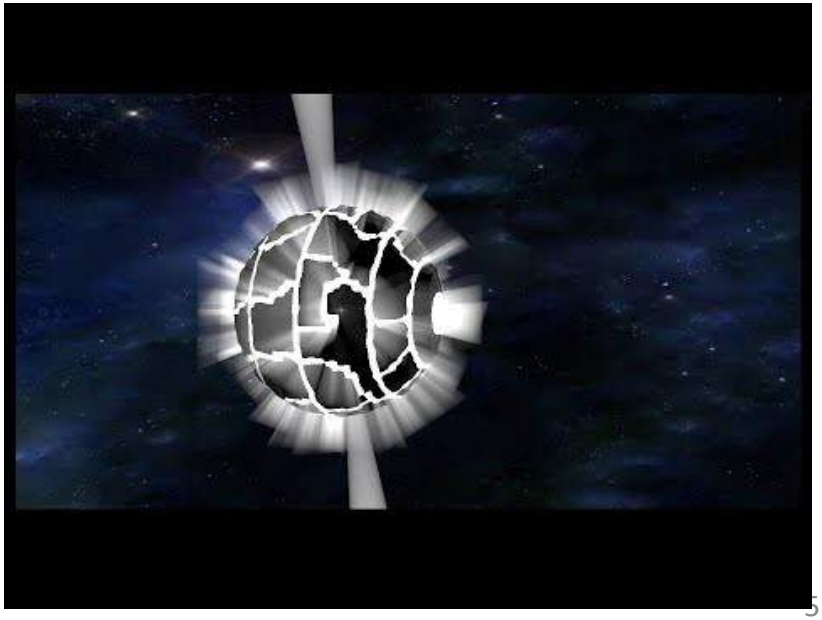


Credit: NASA

Neutron stars are really extreme objects!

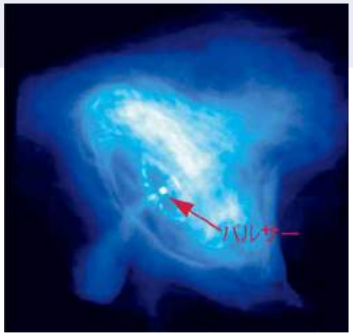
Pulsar

- Very fast rotating neutron stars
- Extraction and acceleration of particles by the powerful magnetic field
- Production of pulsed electromagnetic emission
- Loss of energy due to radiation emission: rotational spindown

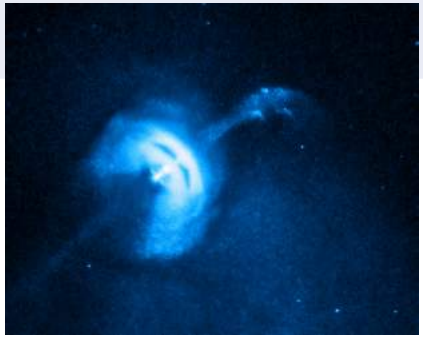


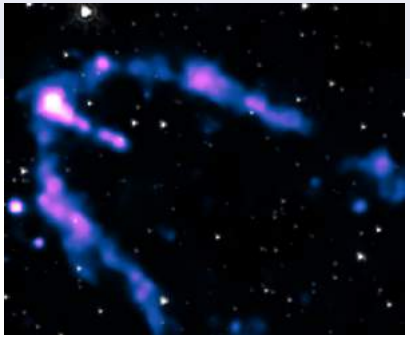
We analyze

	THE CRAB	VELA	GEMINGA
Age [years]	964 (Supernova in 1054 A.D.)	~10.000	~300.000
Distance [ly]	~7180	~960	~800
Rotational period [ms]	~33	89	237



Credit: JAXA


Credit: NASA


Credit: NASA

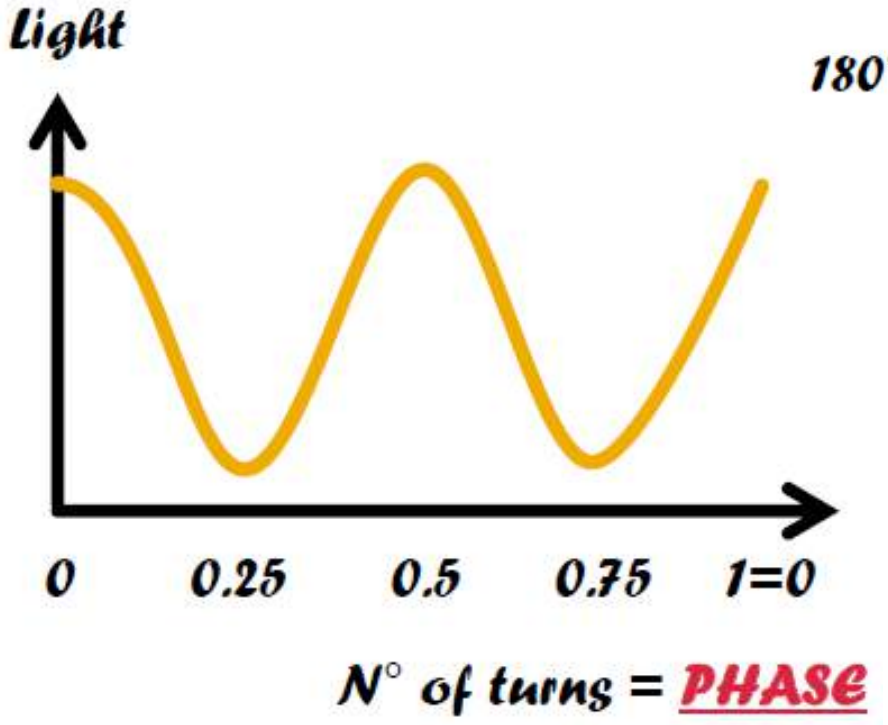
The Fermi Gamma-ray Space Telescope

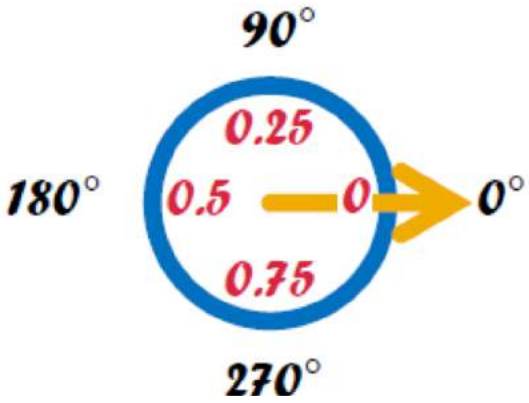
- Mission type:
  Gamma-ray observatory
- Launch date:
  11 June 2008, 16:05 UTC
- Atitude: 525.9 - 543.6 km
- Period: 95.33 min

It is the most sensitive gamma-ray observatory in orbit!

What's phaseogram?

- Phaseogram:
  Sum up events that happen at the same phase
- Phase:





Physical information on the pulsar!

Our mission

1. Learn about pulsar, Fermi, the way to analyze and etc…
2. Produce a phaseogram
3. Decide frequencies and frequencies derivatives
4. Analyze something strange

2.How to analyze

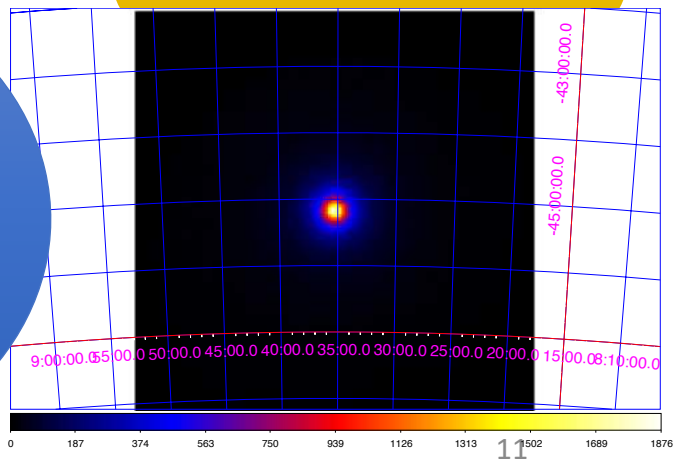
How to analyze

Download Each Data

The selection of exact photons

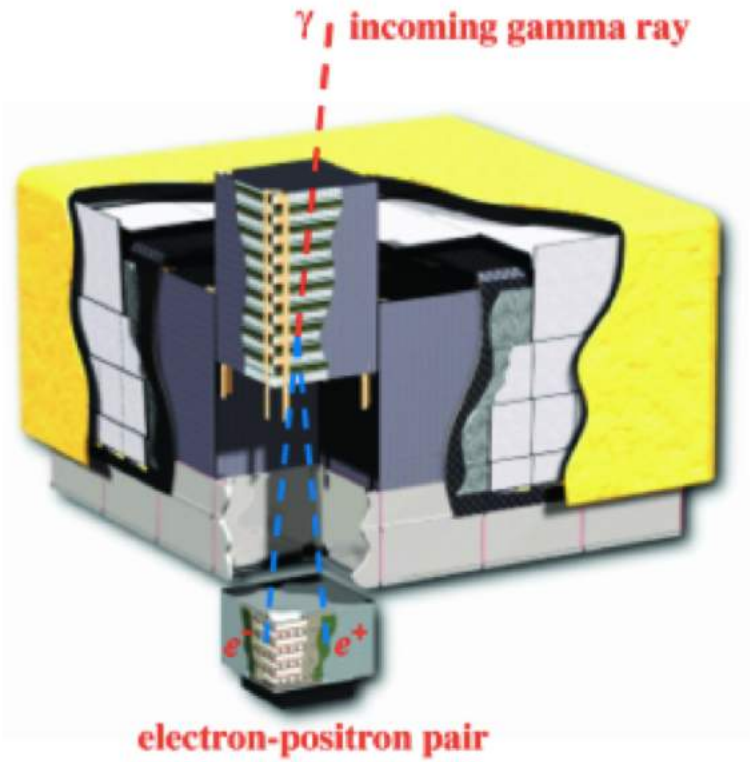
Make Count Map of The Crab, VELA and Geminga

Energy range 300～30000MeV

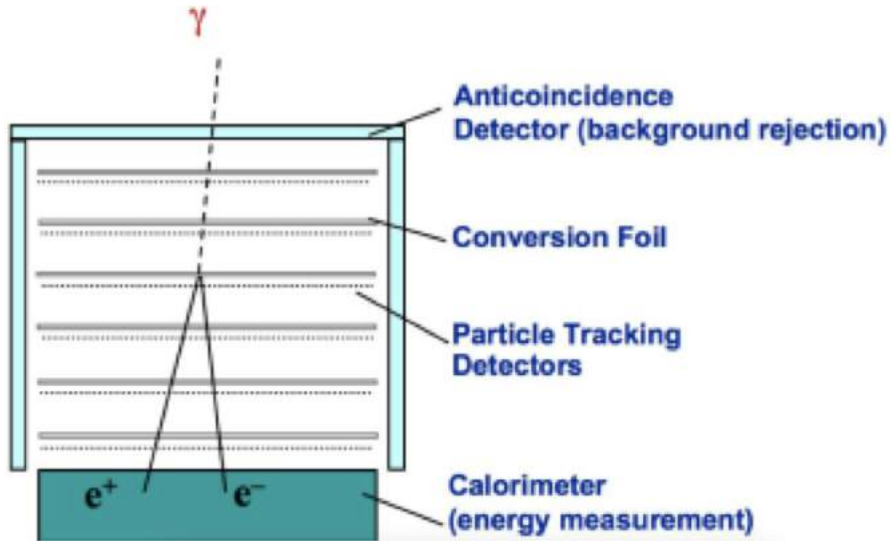


How to get data

Fermi



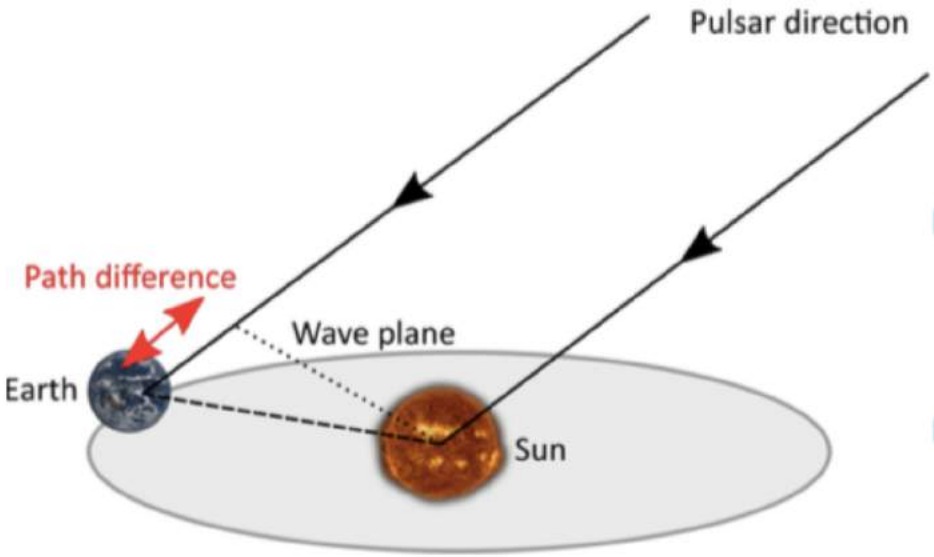
LAT



What can we get?

- The direction from which photons come.
- To measure amount of energy of one photon.

How to define the time



- What should we think about to define the correct time:

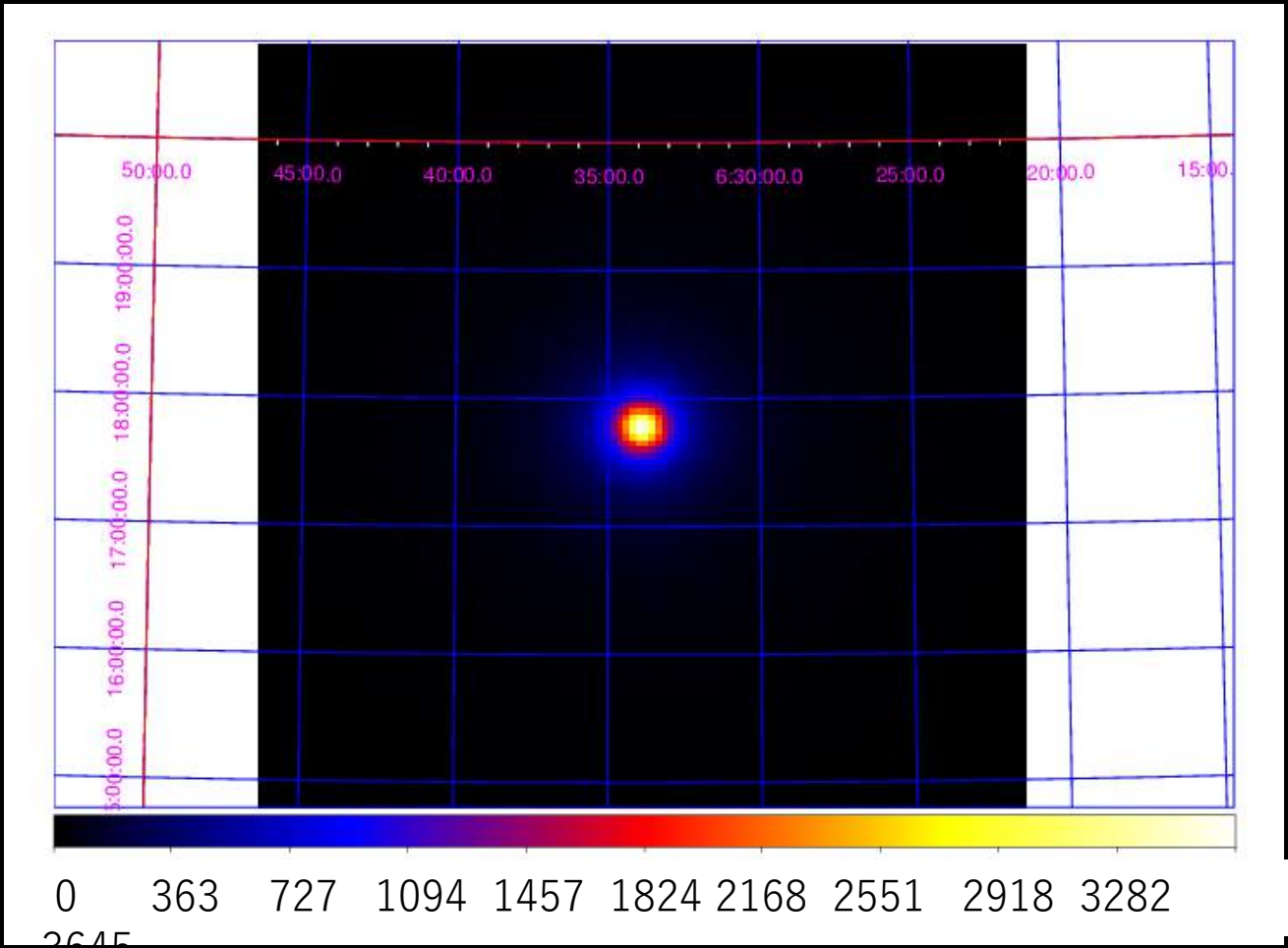
→ Barycentric Collection

- **Geometrical** correction (Rømer delay)
- **Special relativity** correction (Einstein delay)
- **General relativity** correction (Einstein, Shapiro delay)

3.Result

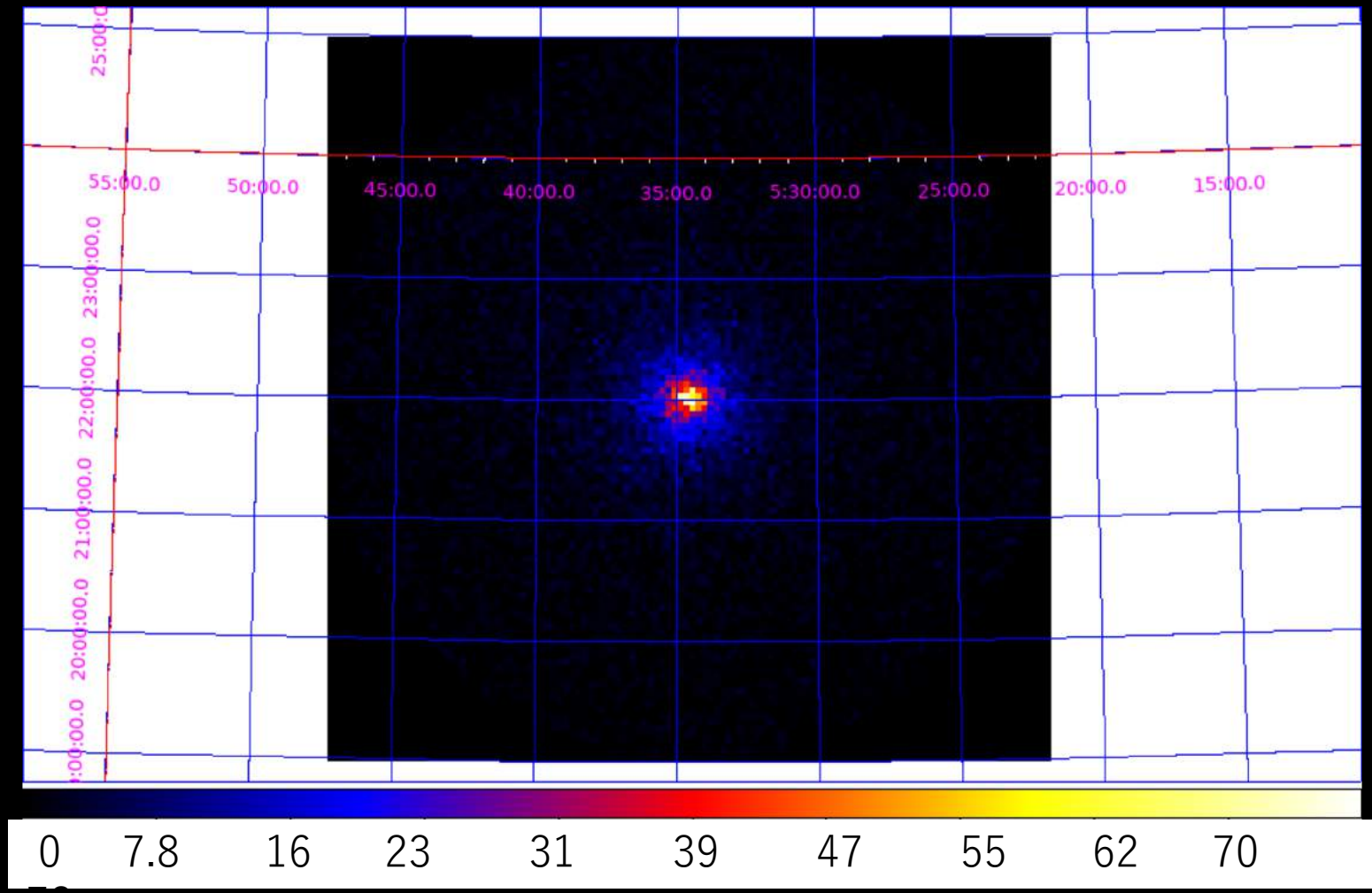
Counts Map　① Geminga

2008-08-04 ~ 2018-03-06



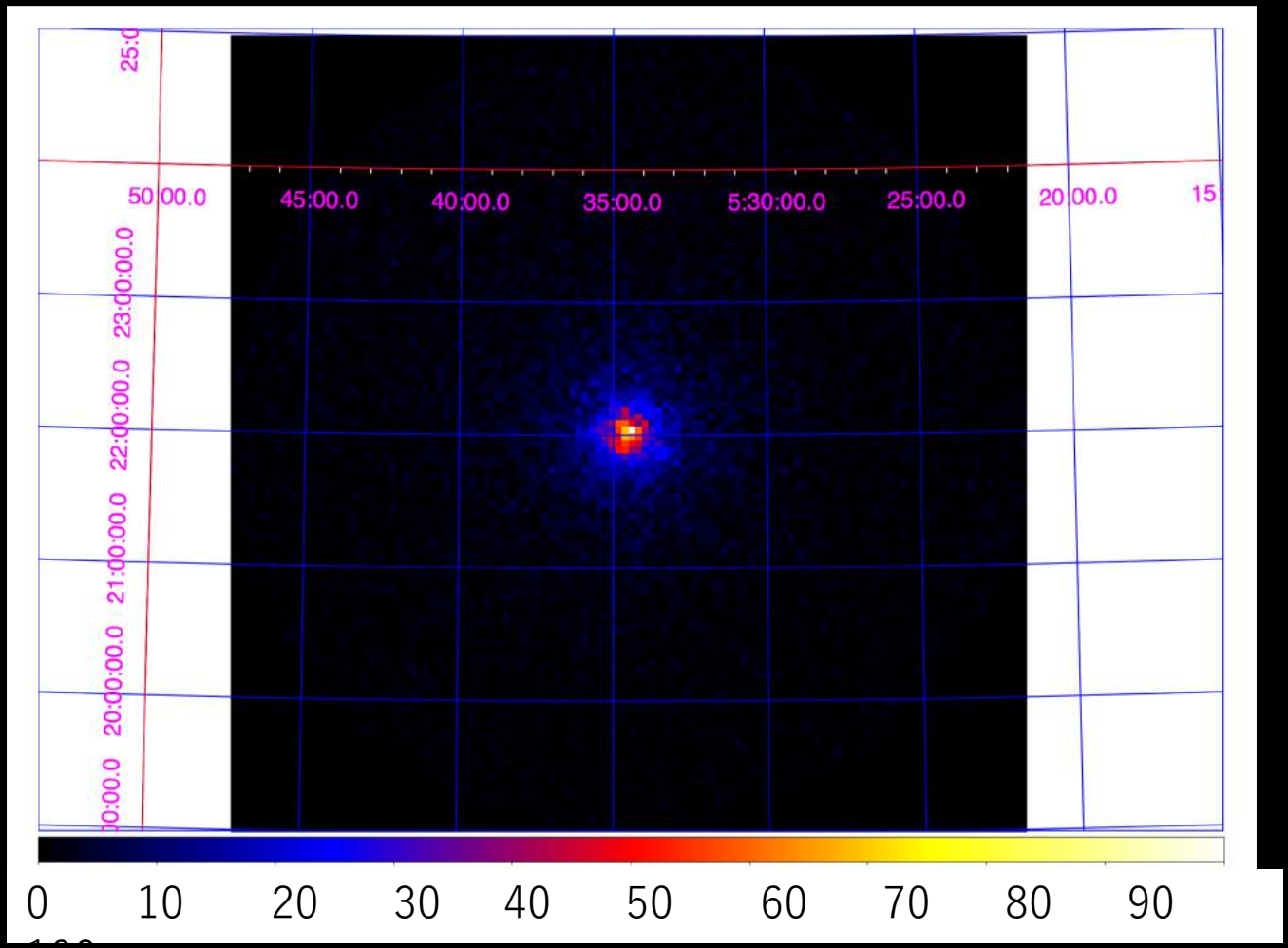
Counts Map　② Crab (A)

2017-01-01 ~ 2018-07-31



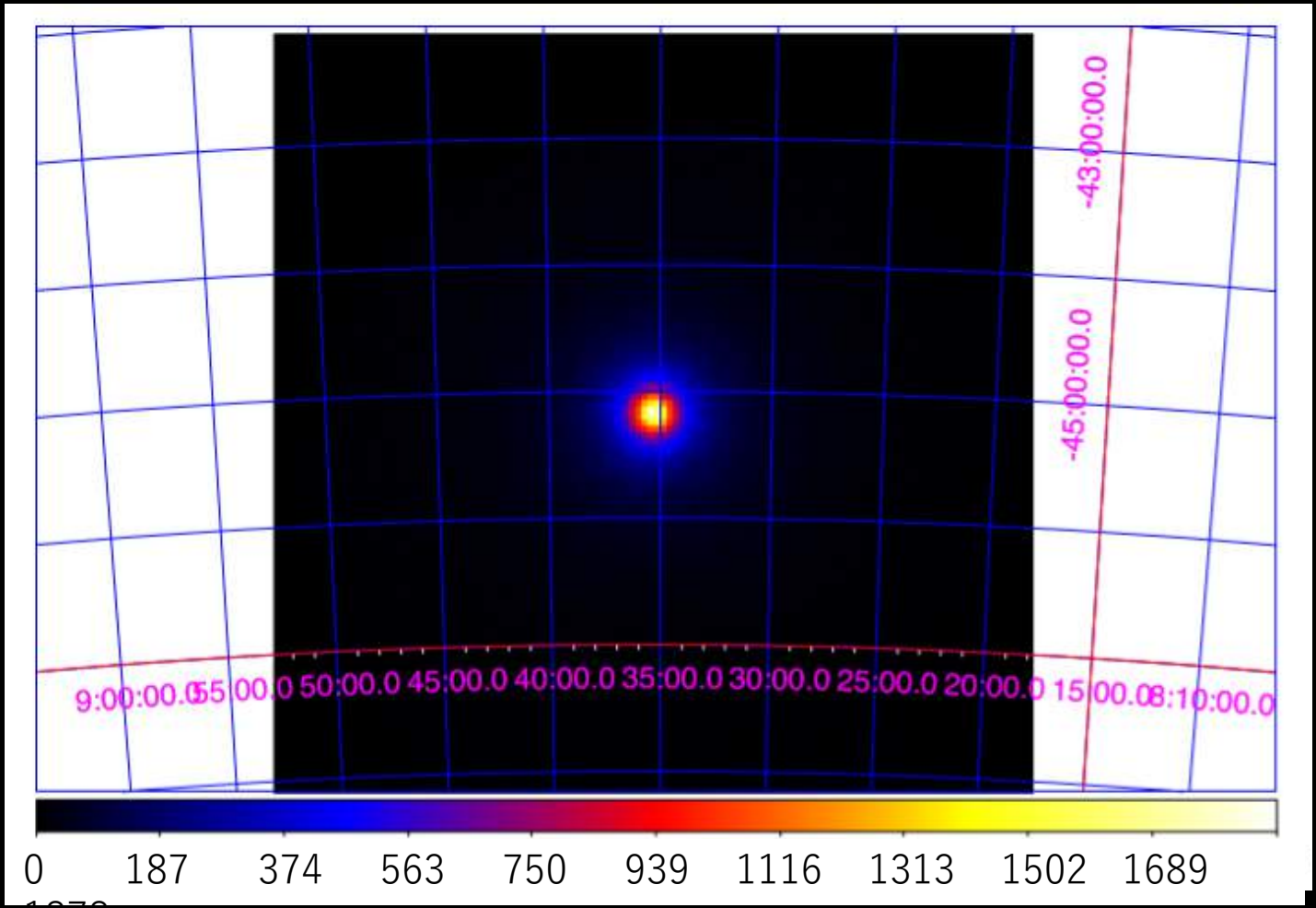
Counts Map ③ Crab (B)

2017-08-01 ~ 2018-03-06

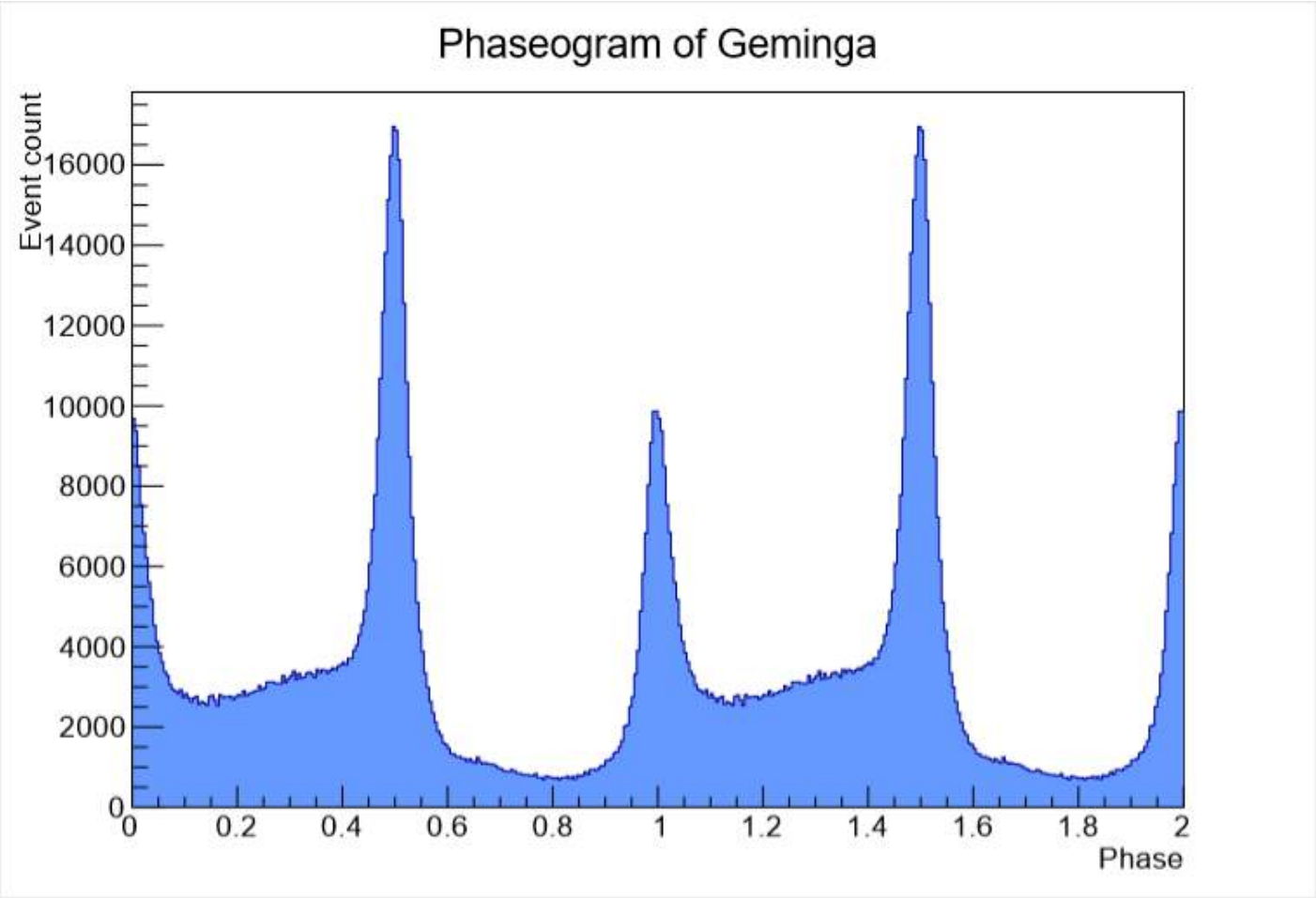


Counts Map ④ Vela

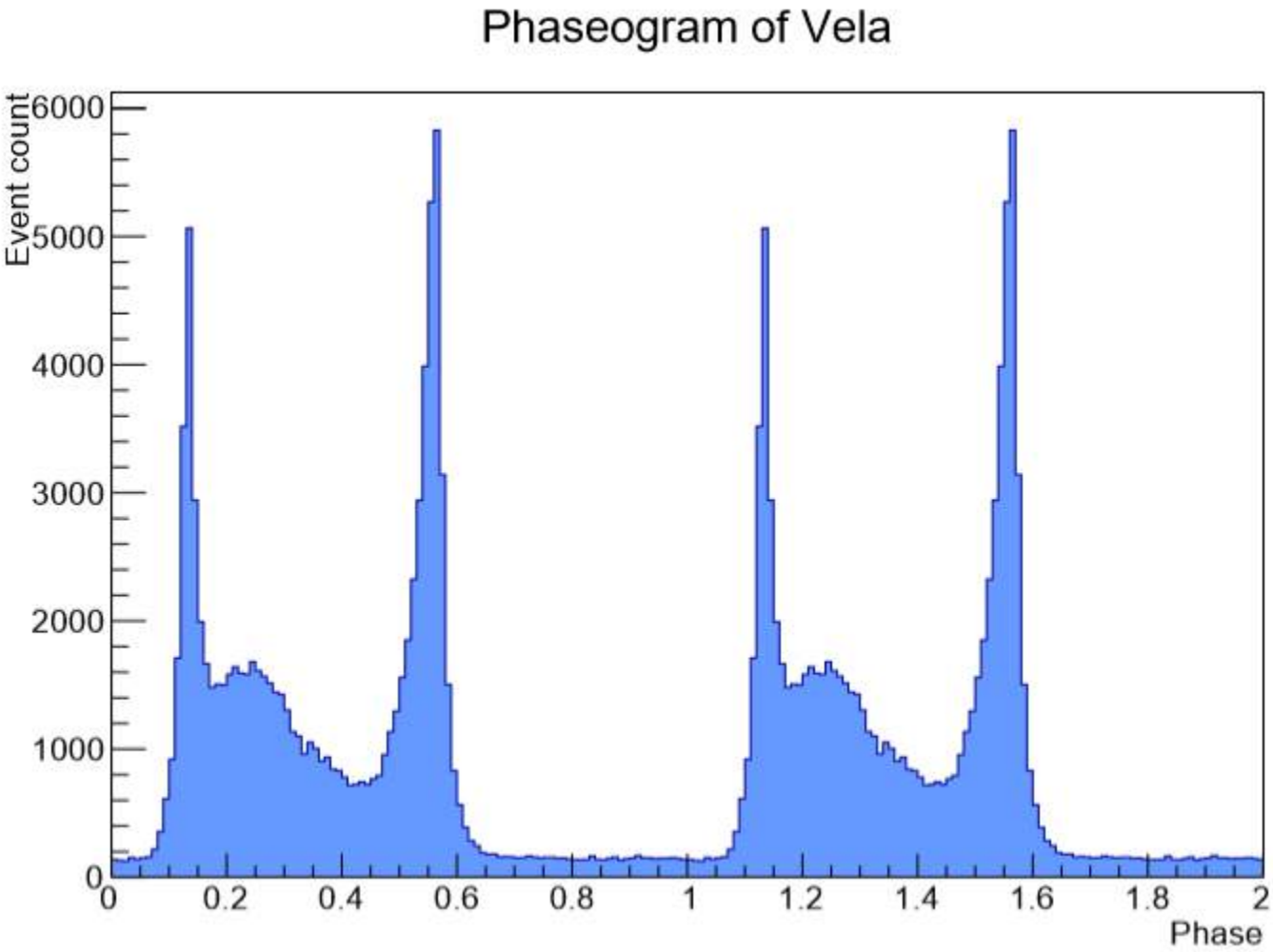
2008-11-30 ~ 2011-02-08



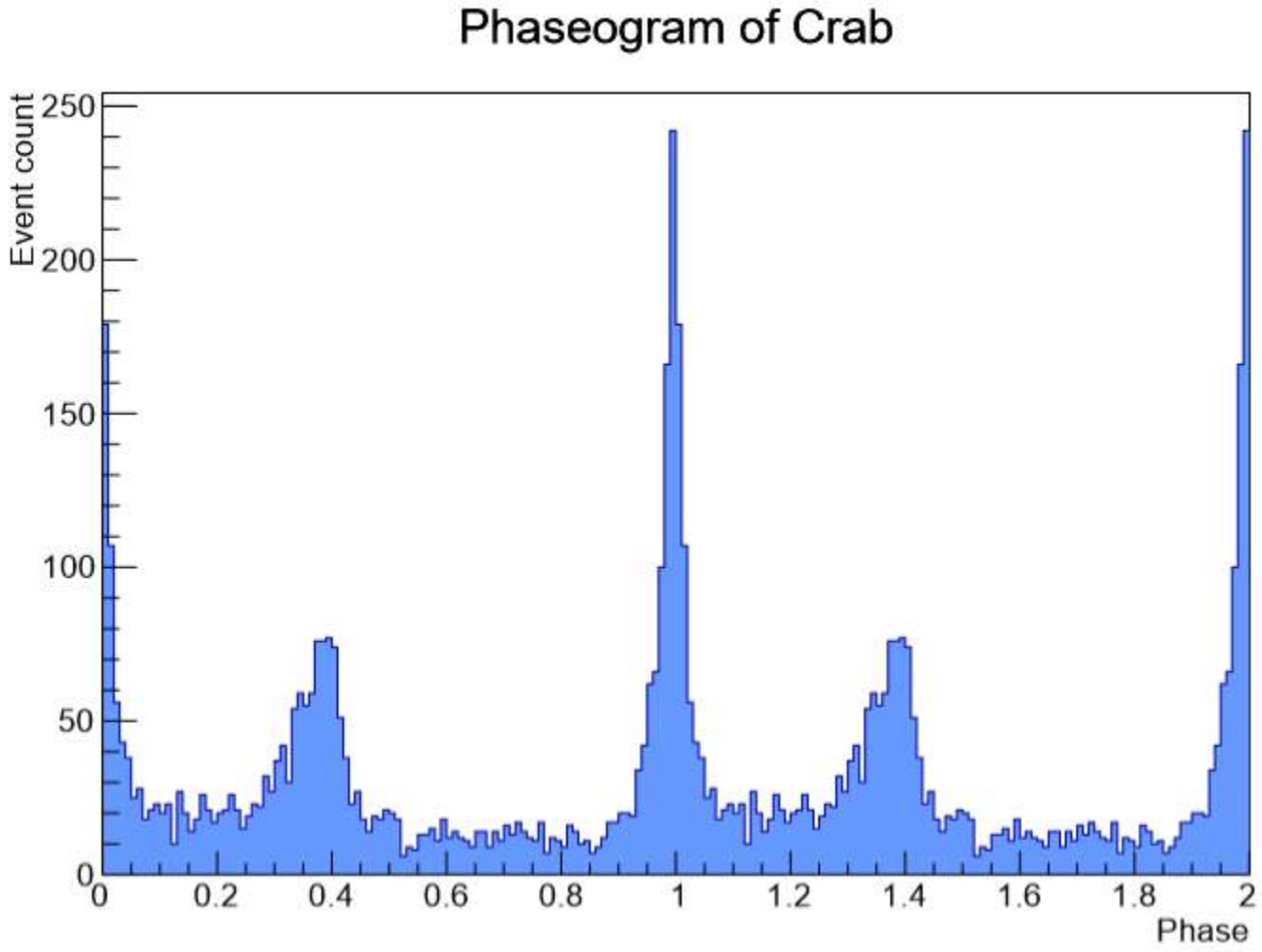
Shape of Pulse (Geminga)



Shape of Pulse (Vela)



Shape of Pulse (Crab)

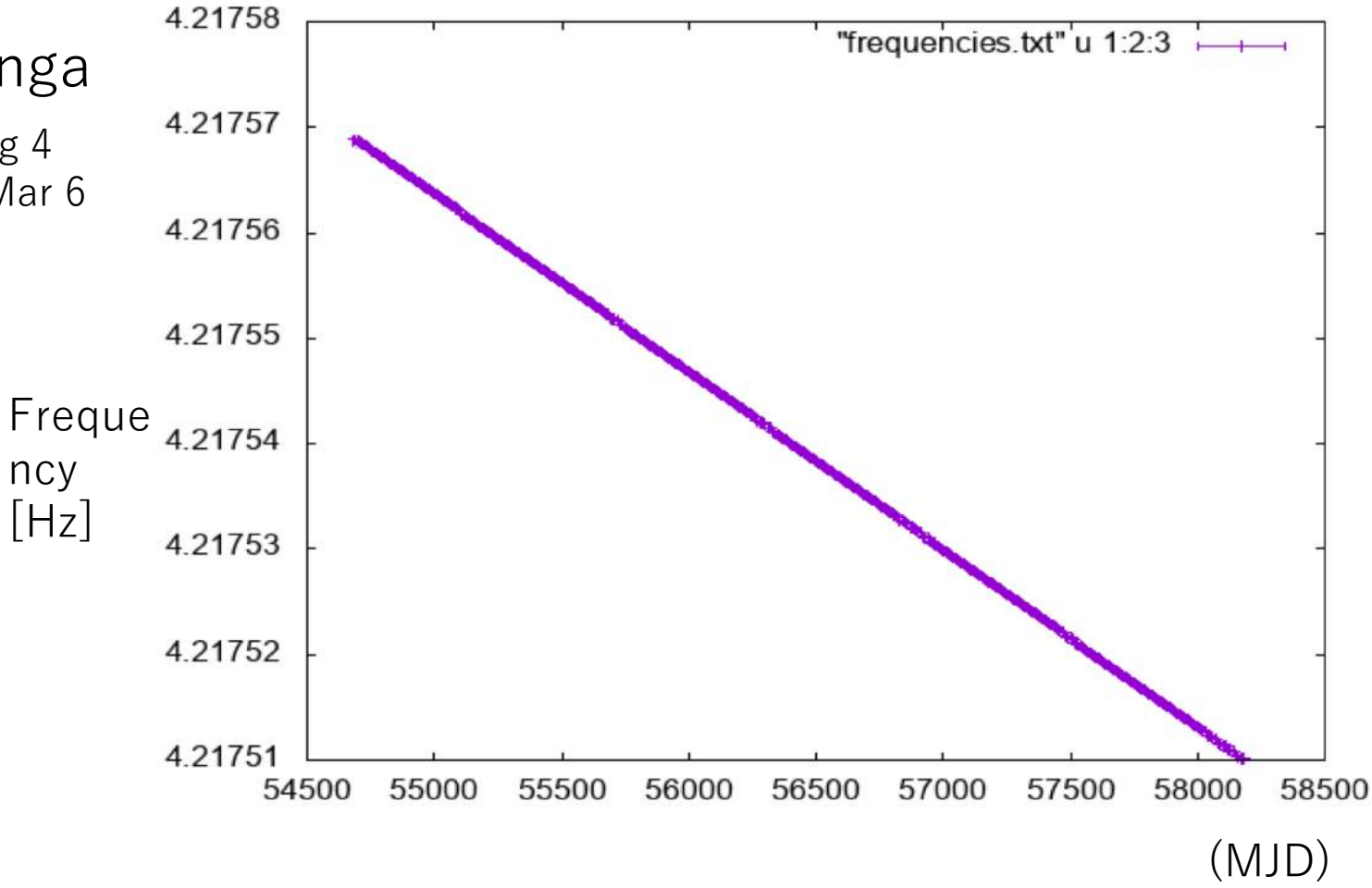


Frequency is decreasing….

Observation Time is for about 10 Year !!

Geminga

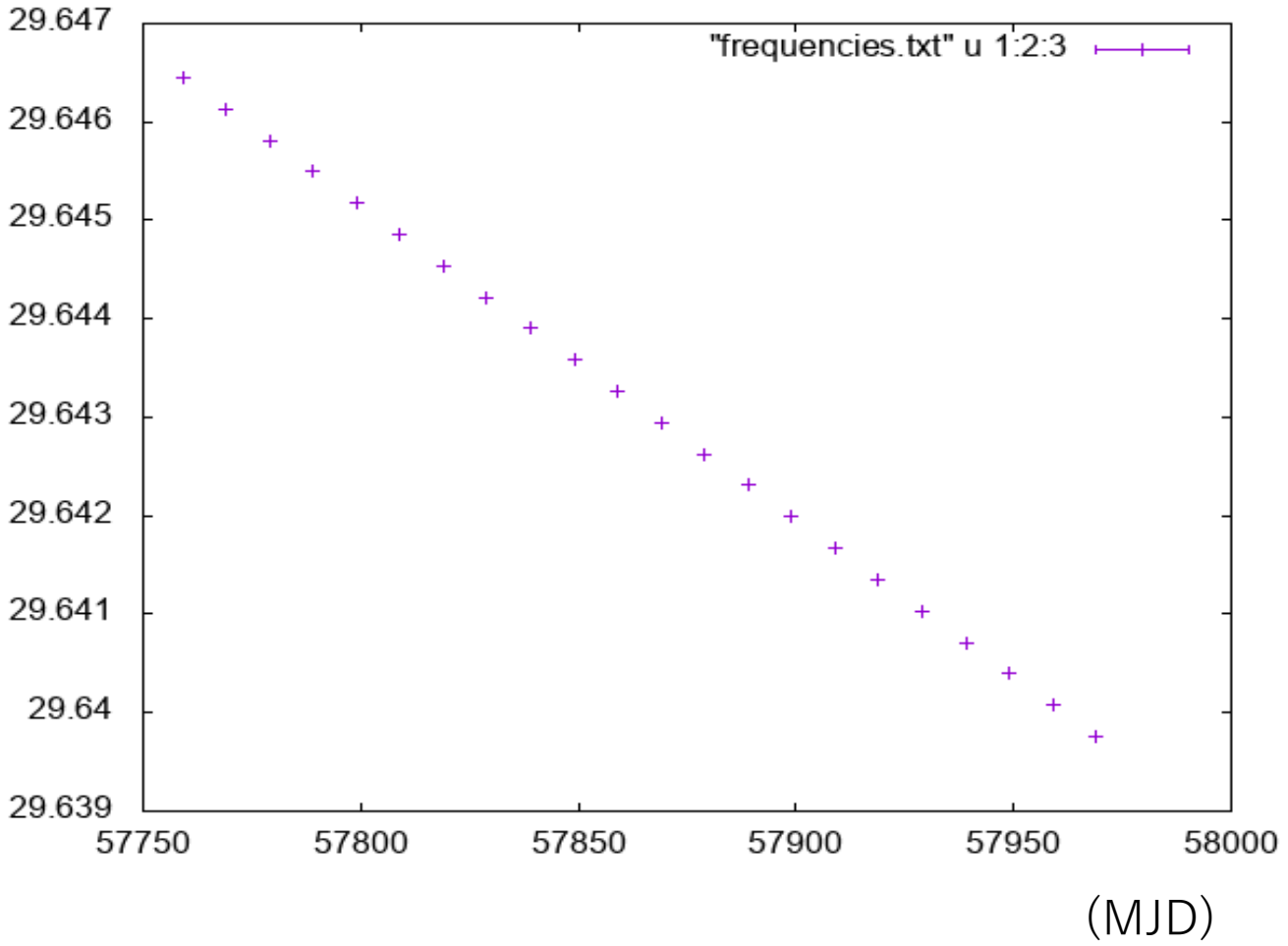
2008 Aug 4
– 2018 Mar 6



Frequency is decreasing….

Crab

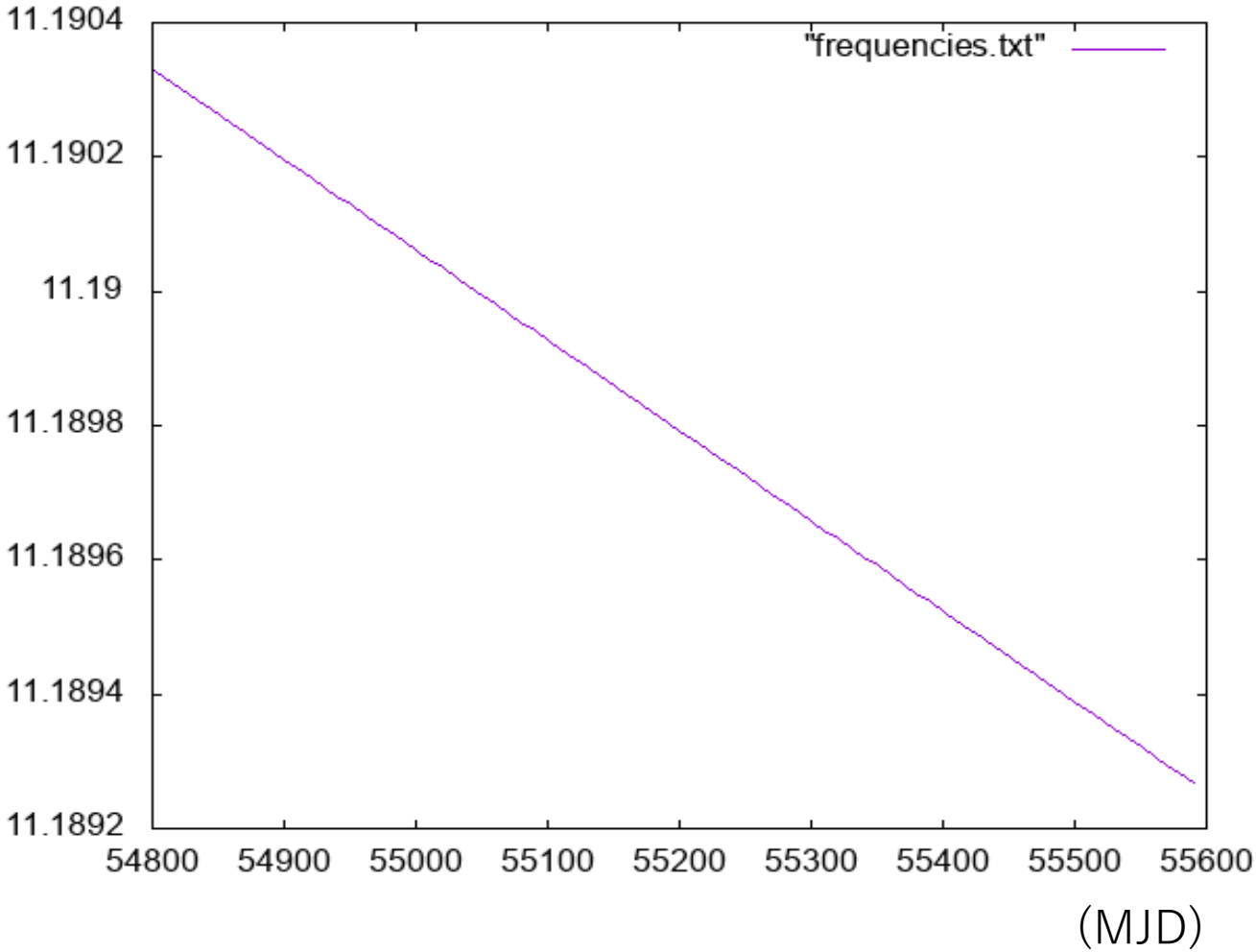
2017 Jan 1
- 2017 July 31



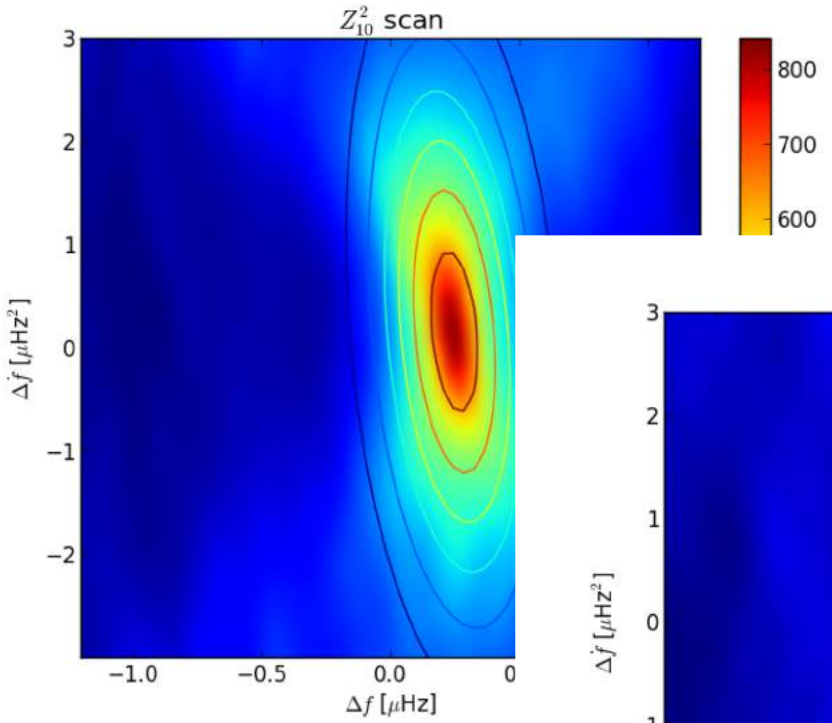
Frequency is decreasing….

Vela

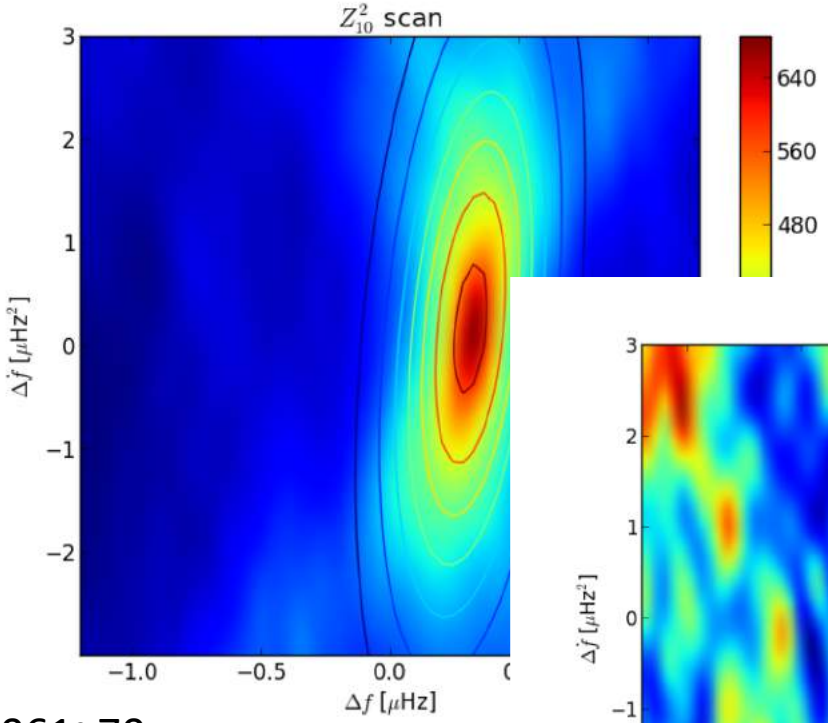
2008 Nov 30
- 2011 Feb 8



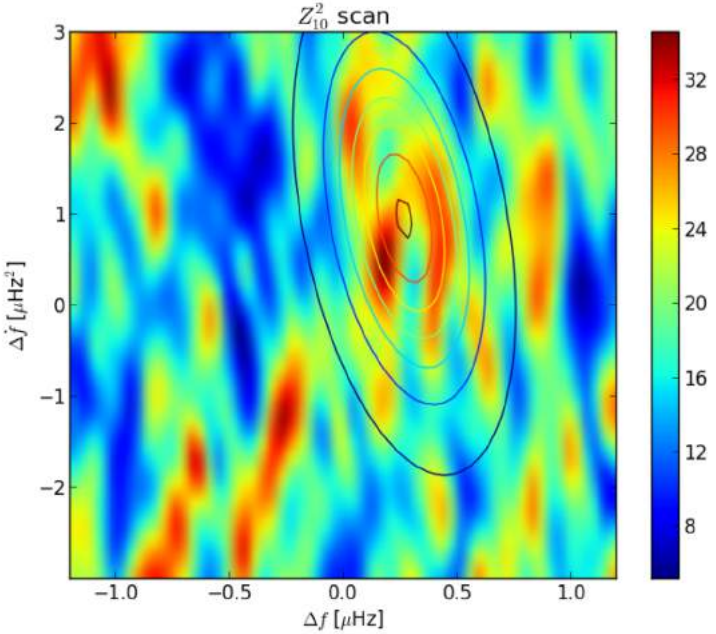
Frequency ….changed ?



MJD 58051~60



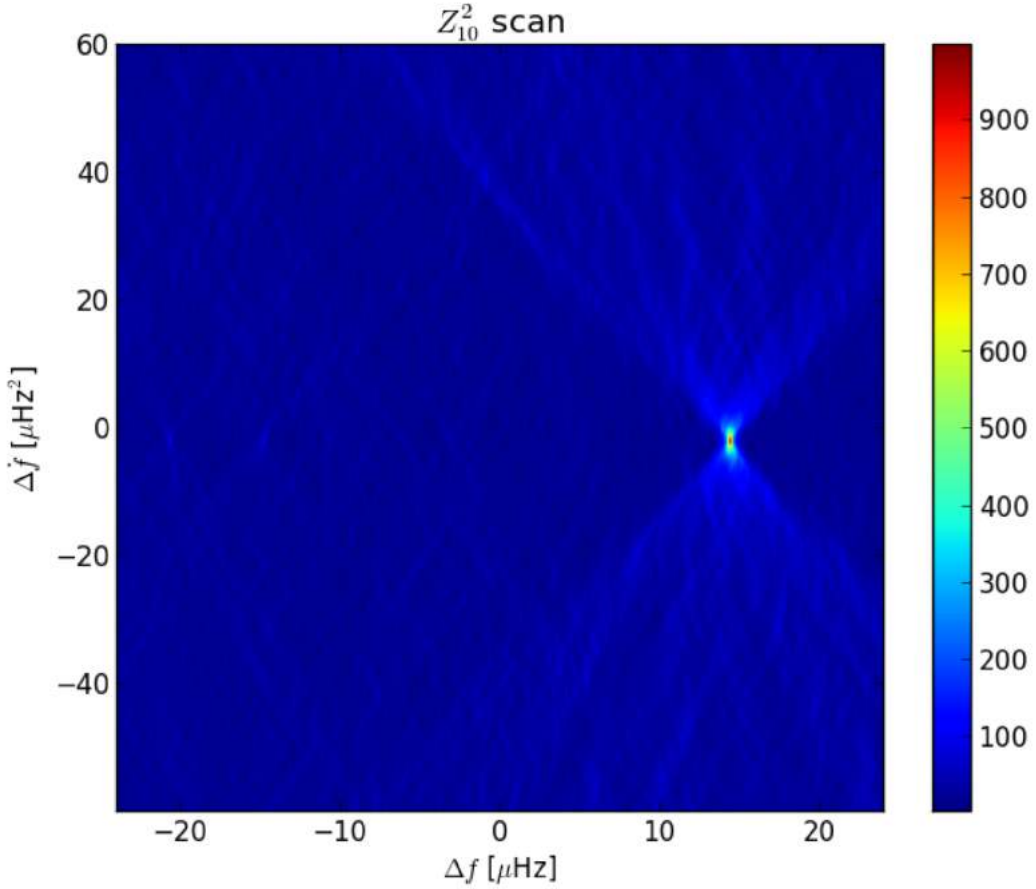
MJD 58061~70



MJD 58071~ 80

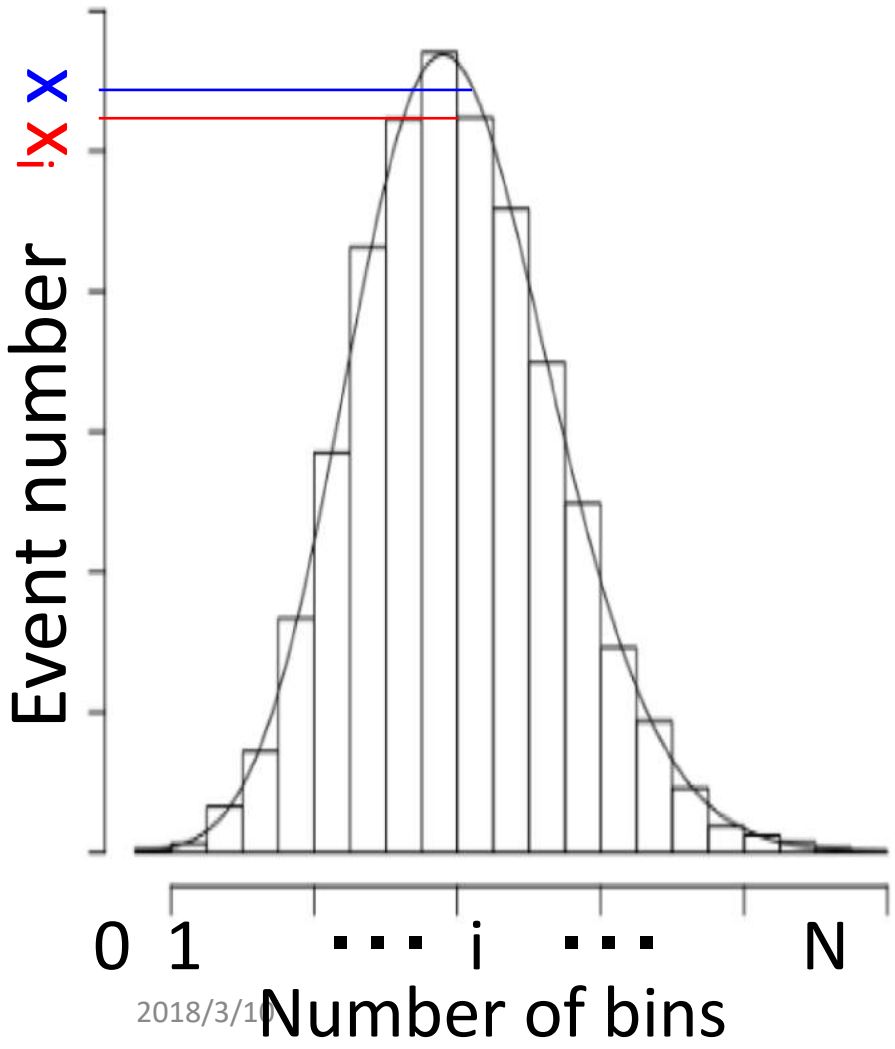
Frequency ….changed ?

MJD 58071~ 80



4.Discussion

Chi-Square test



Evaluation of deviation between experimental data and model

$$\chi^2 = \sum \frac{1}{N\text{-}1} \frac{(x_i - X)^2}{(\sqrt{N})^2}$$

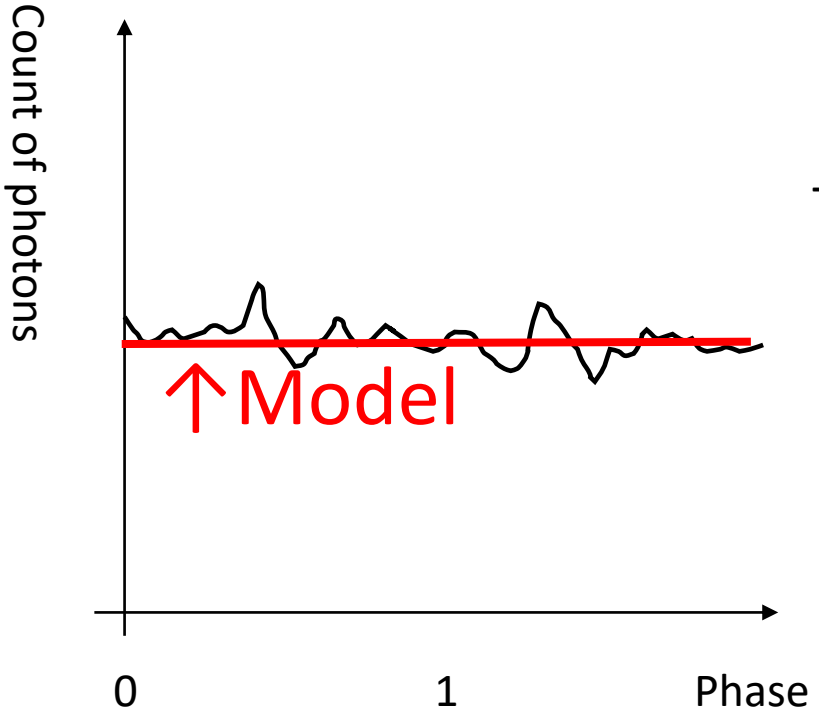
N: Number of bins

x_i: Counts of photons (experimental data)

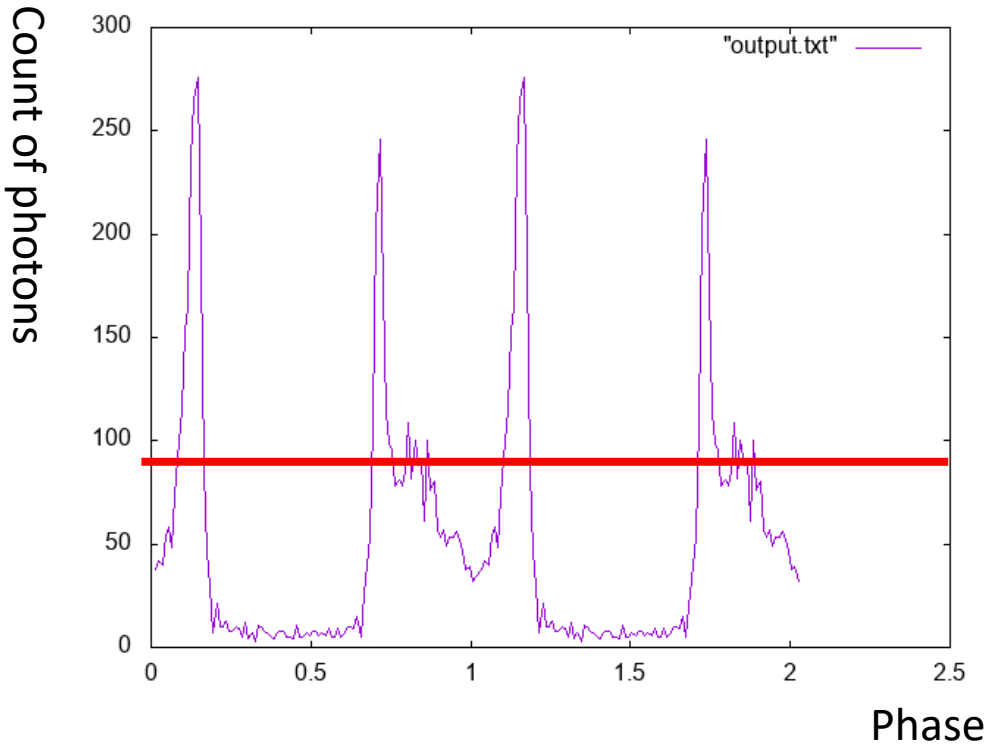
X: Counts of photons (model data)

Statistical test of pulsation

$\chi^2 \sim 1$



$\chi^2 \gg 1$

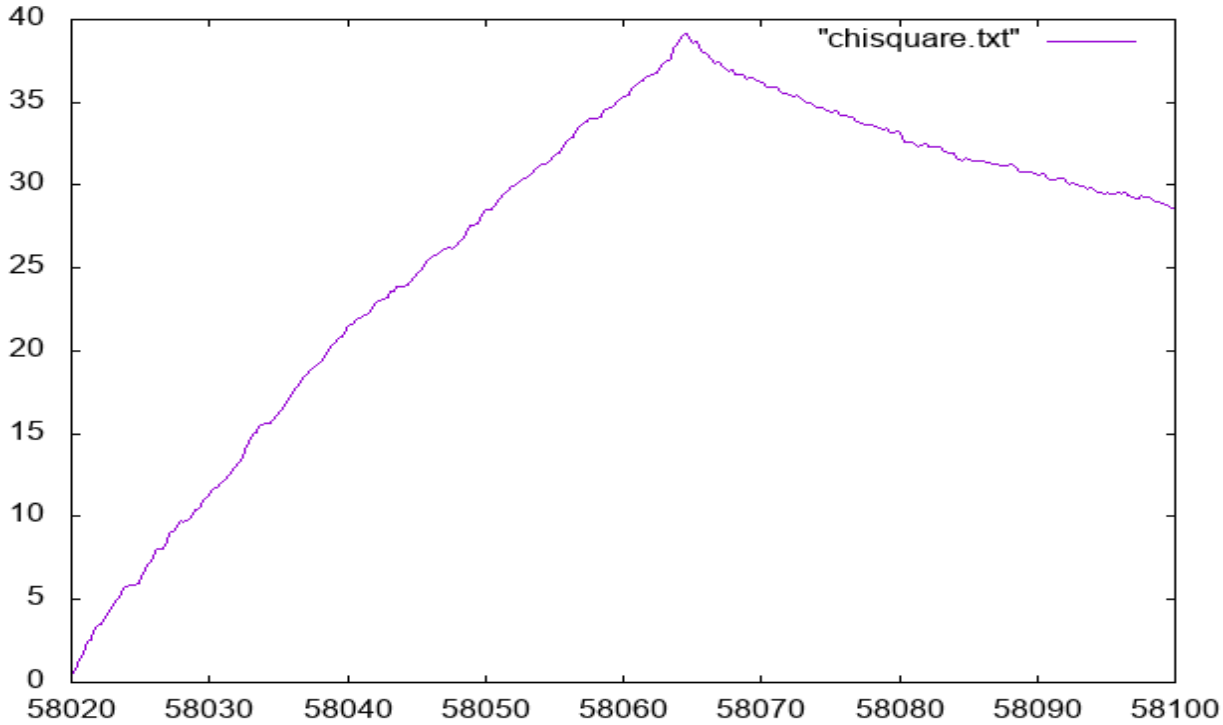


How to fit

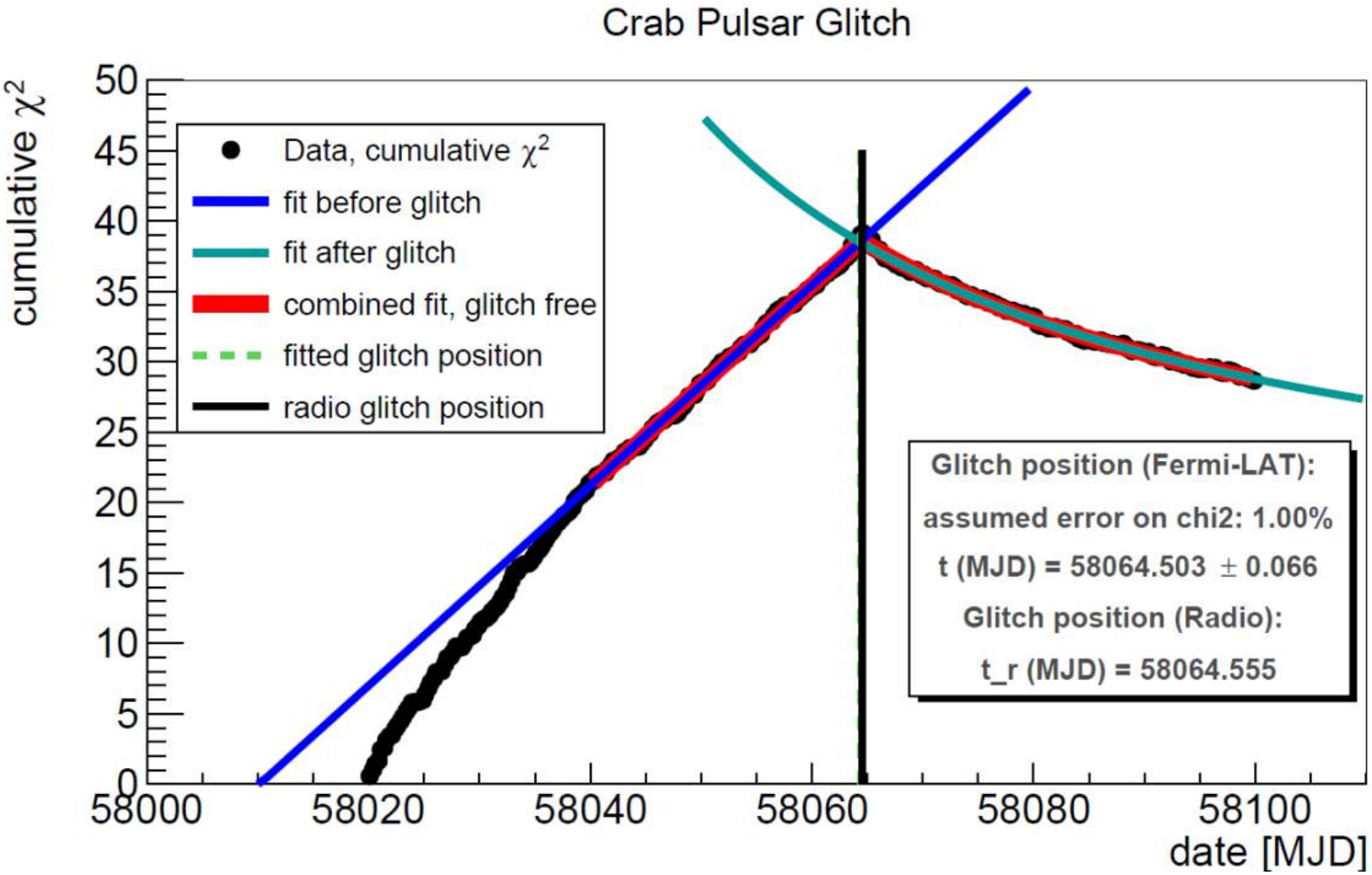
We tried to know when the event happened with chi square statistics.

We discovered the edge in graph.

→It is possible that at this time, the event occurred.



Decide when the event happened



We investigated the edge's time by changing two line.

→The event happened at "58064.503 ± 0.066".

Compare with other wave area

We checked

“The Jodrell Bank Observatory with the 42-ft Lovell Telescope(1400 MHz)” .

Reference:
Shaw+2017(Atel#10939)

→The event happened at

58064.555(3)(MJD)

(58064.503(66))

⇒The two data are consistent within a statistical error.

https://en.wikipedia.org/wiki/Lovell_Telescope#/media/File:Lovell_Telescope_5.jpg

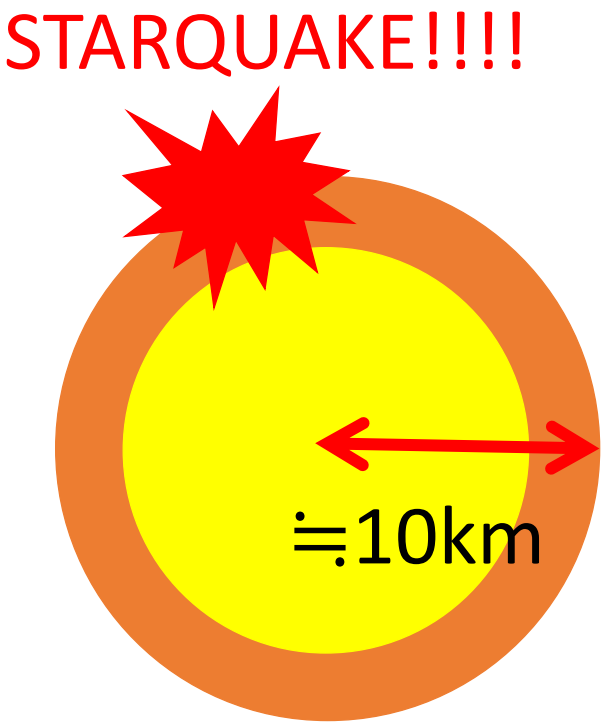
What was the event?

We discovered the two things.

1. The gamma ray from the Crab pulsar changed and the time is consistent in two wave areas.
2. The pulsar's frequency increased after the event.

⇒We expected that the event was "GLITCH".

What is happened on the CRAB?



- We think …

Starquake

on the CRAB.

- If we assume that the preservation of angular moment is valid…

$$\frac{\Delta R}{R} \sim \frac{\Delta \nu}{\nu}$$

ΔR=5～10mm Sedimentation

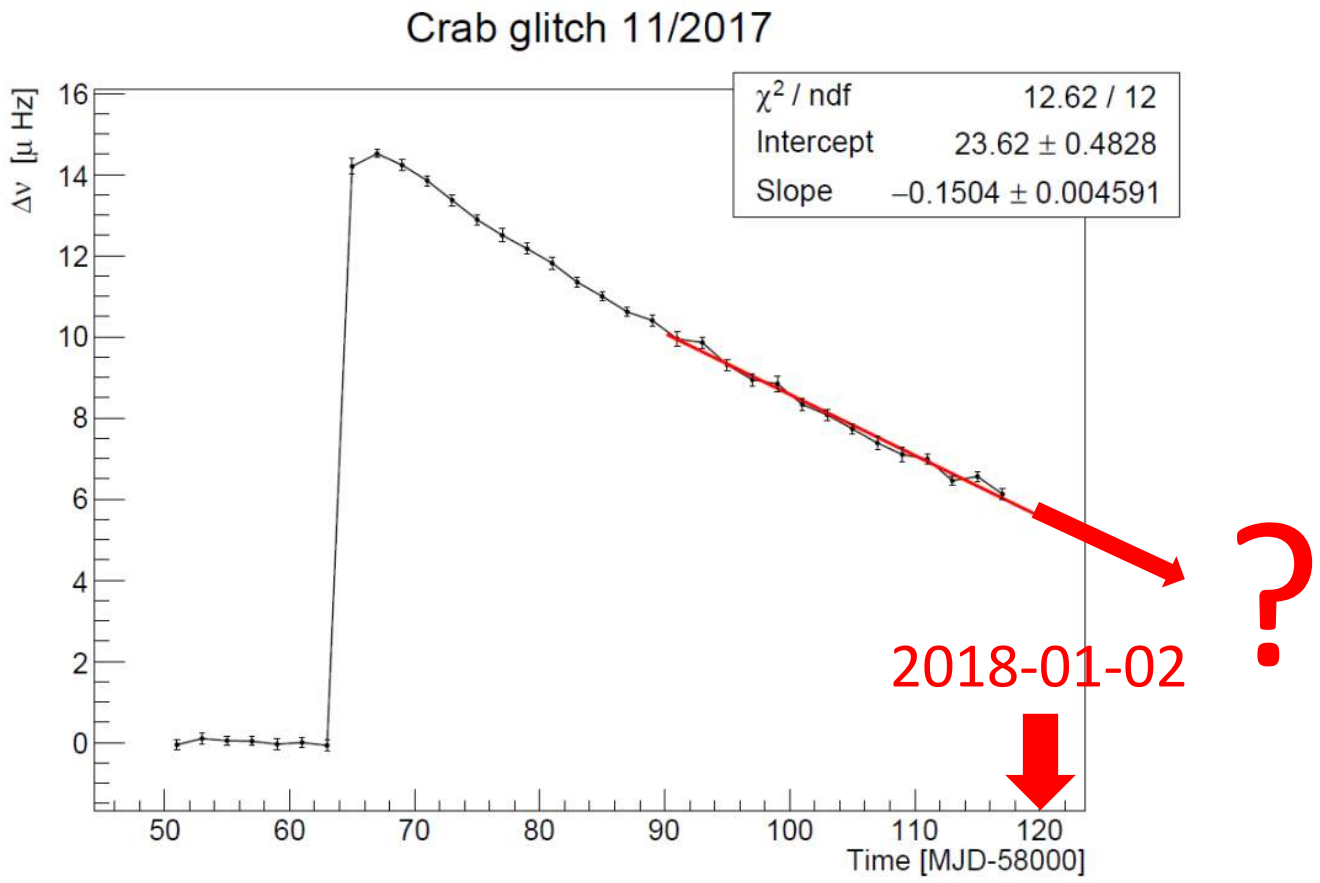
5.Summary

How much did the frequency change?

We investigated how much the frequency changed.

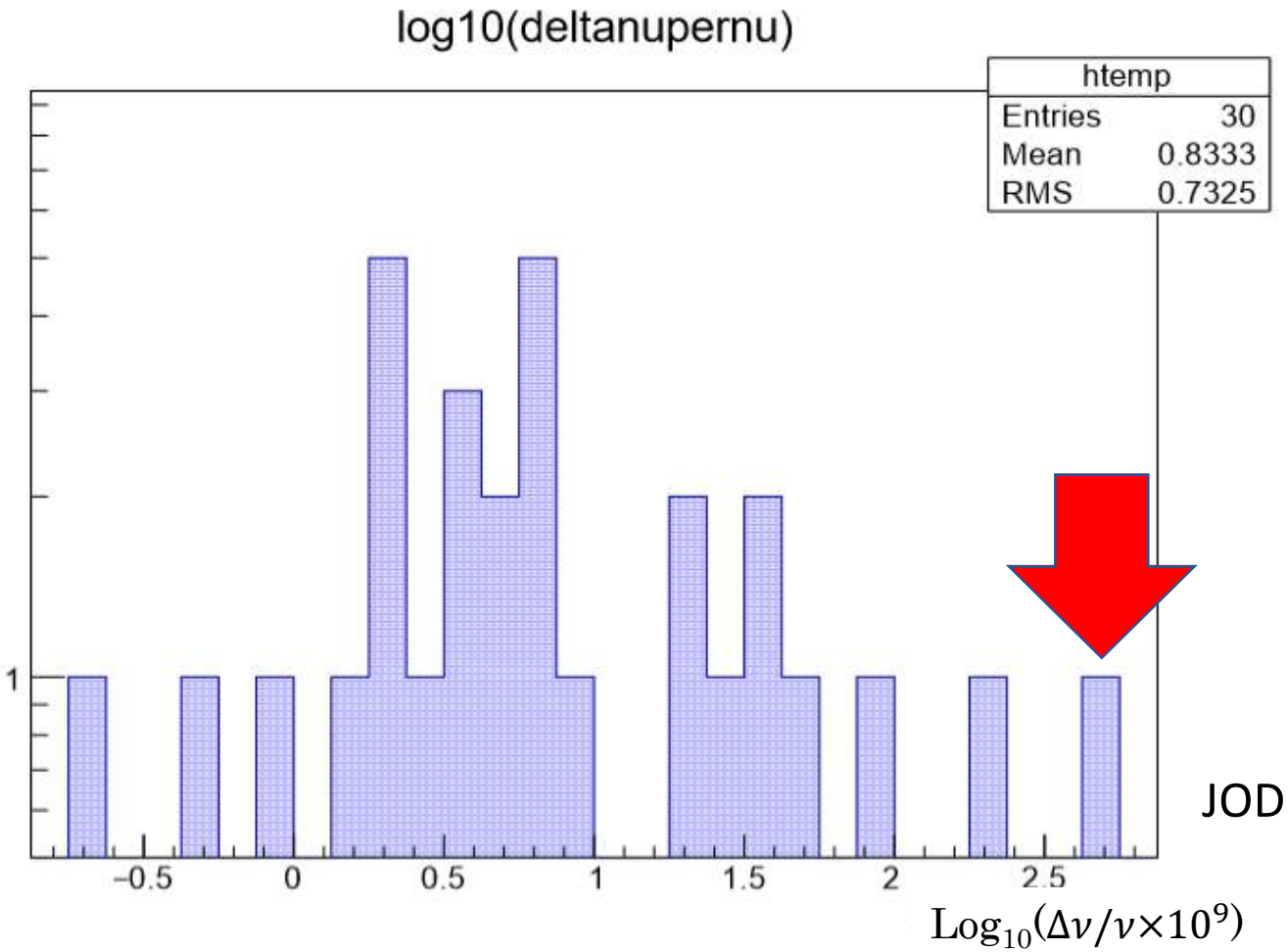
→The frequency increased by 14μHz.

Question? : We need more study !!

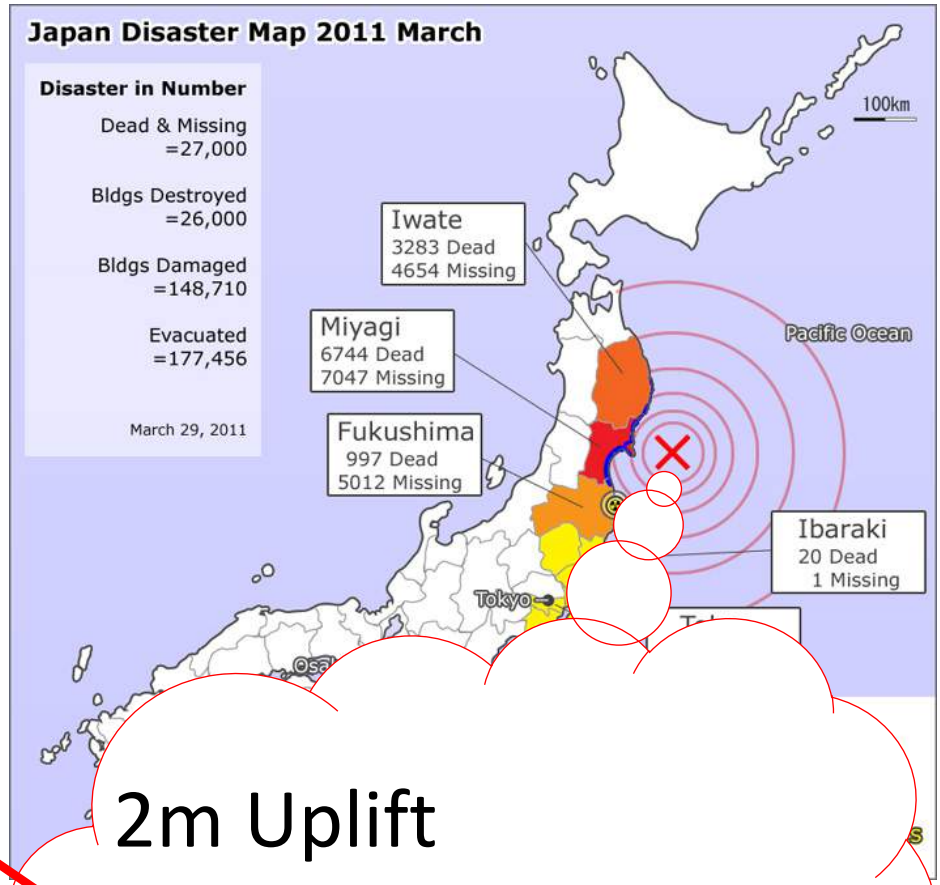


We made a histogram of Δν/ν.

It shows that the Glitch we discovered is the biggest one.



JODRELL BANK



0.01m Sedimentation
Radius of neutron star
≒ 10^4m
Magnitude = 23.5Mw

2m Uplift
Earth radius ≒ 10^6m
Magnitude = 9.0Mw

Thank you for your attention

Back up

Glitch

delta_nu
v.s. MJD

When the Glitch happen?

Cumlative chi2 v.s. MJD

Relaxation…???

Glitch recovery (exponential decay in nu-MJD plot)