Giant Radio Pulses from the Crab Pulsar : Studies of Radiation Mechanisms with Simultaneous Radio and Hard X-ray Observations

Ryo Mikami

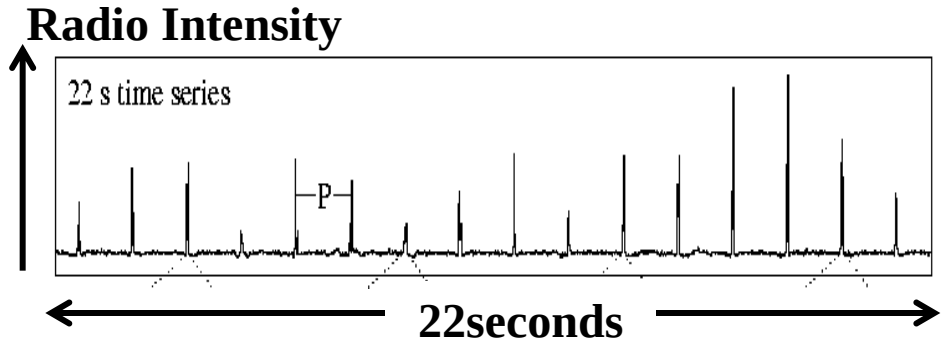
(Department of Physics, Graduate School of Science,

The University of Tokyo)

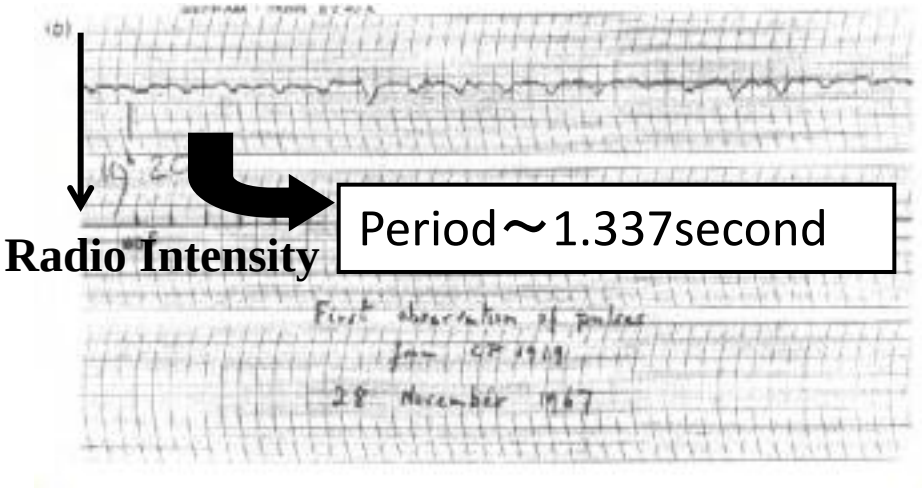
Pulsar

- The first pulsar was discovered by Hewish et al. in 1967.
- Radiation from pulsars:
  - has very regular periodicity.
  - has very wide range of frequencies.

Pulses from a pulsar(PSR B0301+19)
(in Lorimer and Kramer,"Handbook of Pulsar Astronomy",2005)

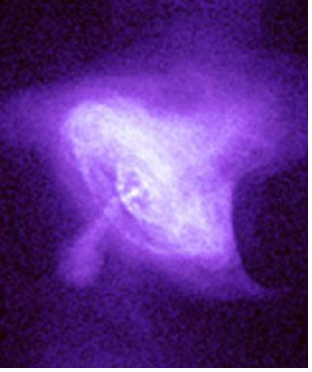


Pulses discovered by Hewish et al.
(in Lyne and Graham-Smith,"Pulsar Astronomy",2012)



- Pulsars are highly magnetized,rapid rotating neutron stars.
  (Gold(1968),Pacini(1968),etc.)
- More than 2000 pulsars have been discovered.

(according to "ATNF Pulsar Catalogue")



Crab pulsar

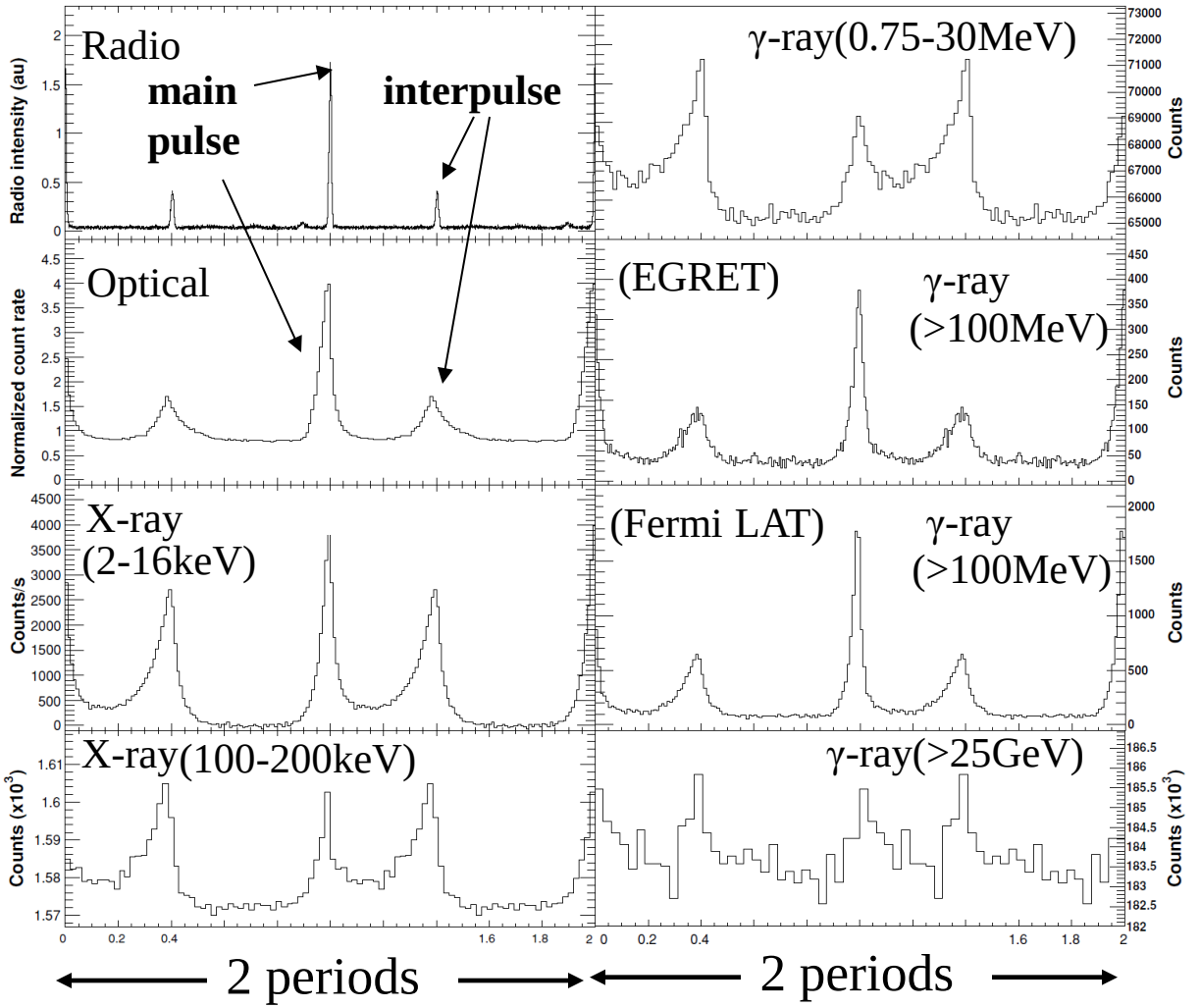
Abdo et al.,ApJ,**708**,1254(2010)

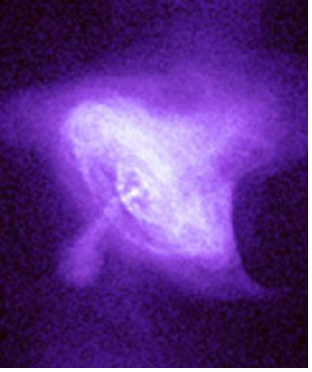
- The neutron star centered in the Crab nebula
- Its pulsed emissions have very wide frequency range.

(period～33ms)

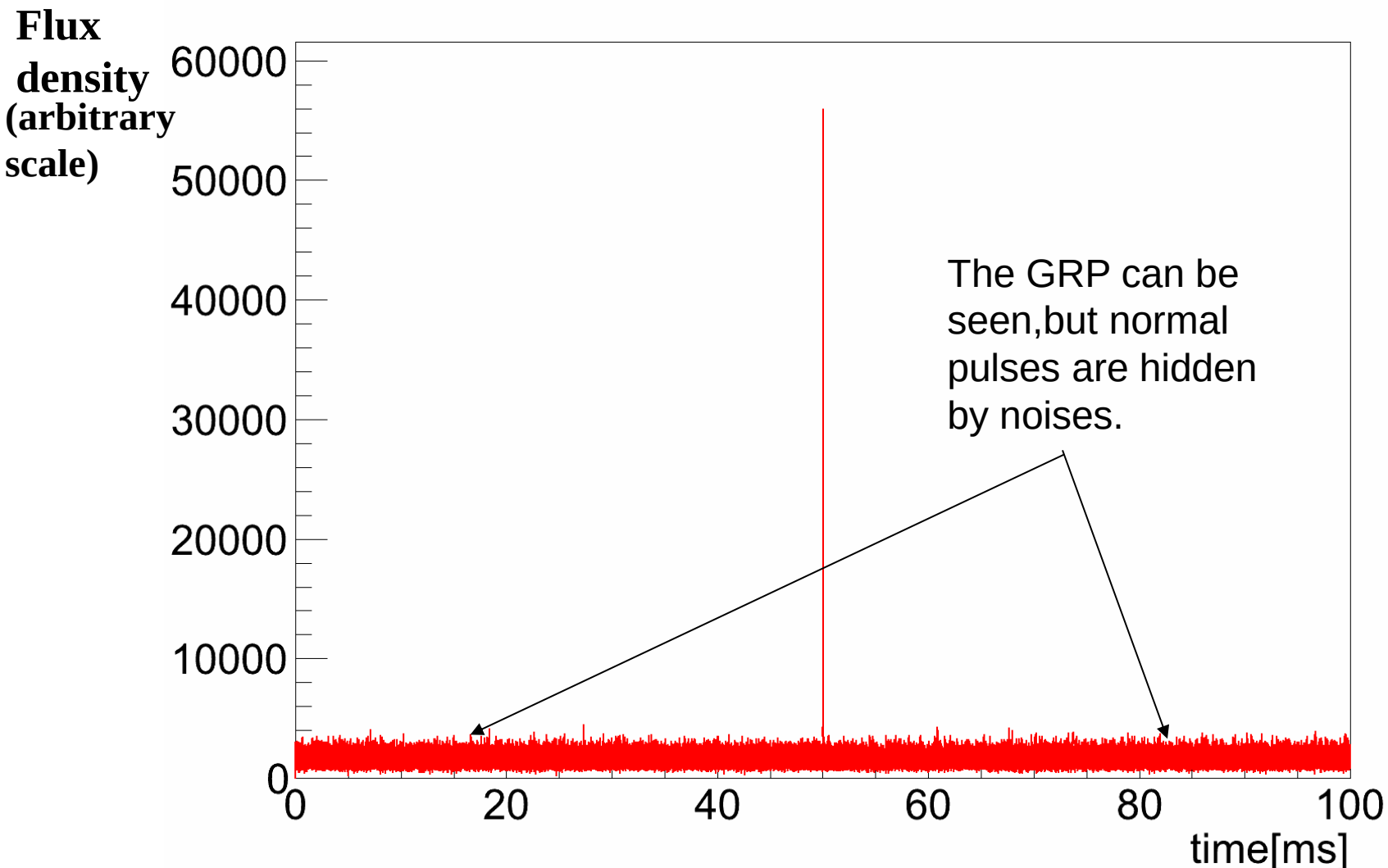
- It emits GRPs.

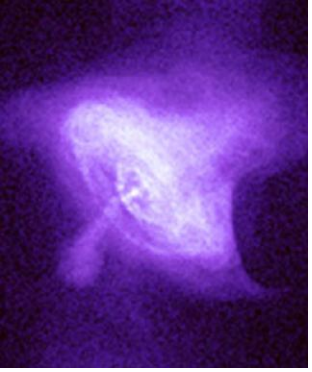
(discussed later)





A GRP from the Crab pulsar (Giant Radio Pulse)





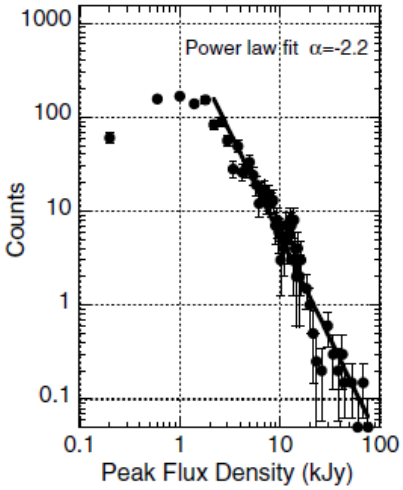
GRPs from the Crab Pulsar (Giant Radio Pulse)

- Stronger than normal pulses by more than several thousand times.
- Occur only at the phase of the main pulse or the interpulse. (Cordes et al. 2004)
- Energy distribution of GRPs follow power law. (Majid et al. 2011 etc.)

(⇔Energy distribution of normal pulses is normal distribution or exponential distribution(Hesse and Wielebinski, 1974 etc.))

- Each GRP is not correlated(,that is,independent). (Majid et al. 2011 etc.)

Peak flux denisity distribution of GRPs



Majid et al.,ApJ,**741**,53(2011)

Despite progress of observational studies of GRPs(Giant Radio Pulses), their radiation mechanisms haven't yet been revealed.

- pulsar optical/x-ray/γ-ray emissions→incoherent emissions

(If N particles emit incoherently, resulting intensity is N times as high as that of 1 particle)

- the pulsar radio emission→the coherent emission

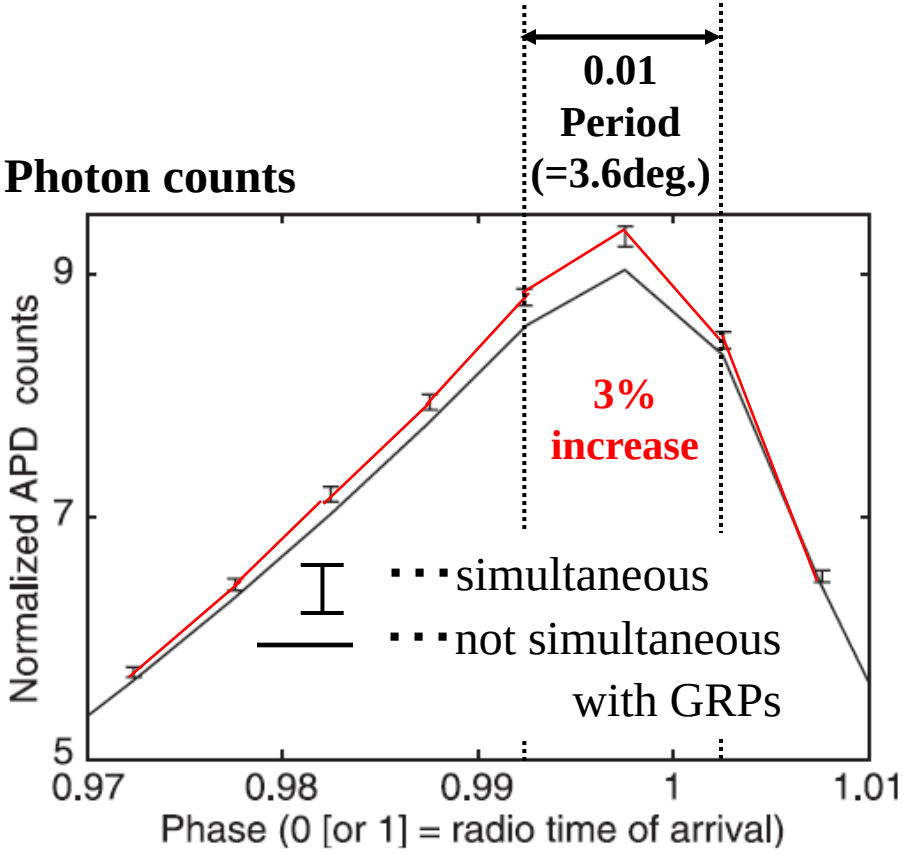
(If N particles emit coherently, resulting intensity is N^2 times as high as that of 1 particle)

→GRPs are emitted by coherent process,so it was thought that they were not correlated with other frequency pulses.

However,

Optical pulses coincident with GRPs from the Crab pulsar were on average 3% brighter than those coincident with normal pulses.

(Shearer et al.,Science, **301**, 493 (2003))



GRPs and other frequency pulses may have some correlation.

Previous correlation studies

In previous studies, **pulse flux enhancement** was investigated.
→ It was studied whether the pulse flux concurrent with GRPs is enhanced or not.

Energy band	Wave length or energy	Flux variation concurrent with GRPs	Reference
Optical	600-750nm	Enhanced by 3%	Shearer et al.(2003)
Soft x-ray	1.5-4.5keV	<200%	Bilous et al.(2012)
Hard x-ray	**15-75keV**	**This thesis.**	**This thesis.**
Soft γ-ray	50-220keV	<250%	Lundgren et al.(1995)
γ-ray	0.1-5GeV	<400%	Bilous et al.(2011)
VHEγ-ray	>150GeV	<500-1000%	Aliu et al.(2012)

Our observations of the Crab pulsar

Radio observations・・・

Made with the Kashima 34m parabola and the

Usuda 64m parabola at 1.4GHz

Hard X-ray observations・・・

Made with the Suzaku satellite

(using 15-75keV data.)

The Kashima 34m parabola antenna

The Usuda 64m parabola antenna

The Suzaku satellite

Implications from these results

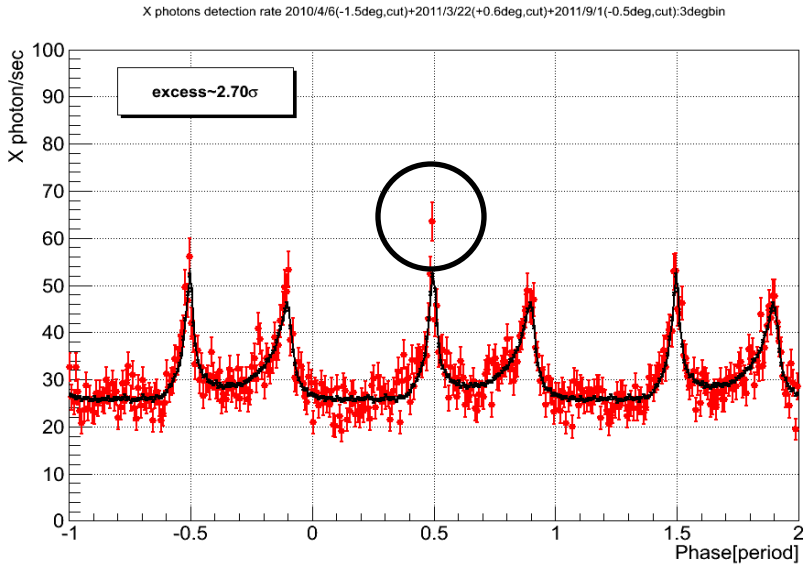
- In hard X-ray pulses incident with GRPs, flux increases only at the peak of those pulses,not at the whole of them.

→It implies that hard X-ray emission region is “partially” effected by GRPs.

→So,for example,it is thought that:

▪GRPs might be caused by a “local” increase of the number of emitting particles.

▪The region where GRPs are generated might be where particle density is locally high.



Summary

- In order to restrict the radiation(generation) mechanisms of Giant Radio Pulses(GRPs), we searched for a correlation between GRPs and hard X-ray Pulses.
- Making simultaneous radio and hard X-ray observations,we found possibilities of the increase of hard X-ray flux incident with GRPs(Apr. 6,2010: 2.50σ, Mar. 22,2011: 2.66σ,at the peak of main pulse,respectively). However,on Sep. 1,2011, no significant enhancement could be found.
- We can't determine GRP/hard X-ray correlation, but if this correlation really exists, GRP emission (generation) might be related to a local increase in the number of emitting particles.
- We are planning to make further observations to confirm these results.