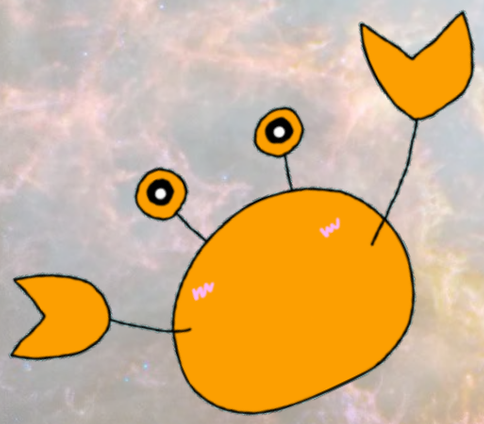
Results of simultaneous radio and optical observations of the Crab pulsar with IMONY on the Seimei telescope

(高速撮像システム IMONY を用いた カニパルサーの電波・可視光同時観測成果)



Mizusawa VLBI Observatory, NAOJ

Kazuaki Hashiyama

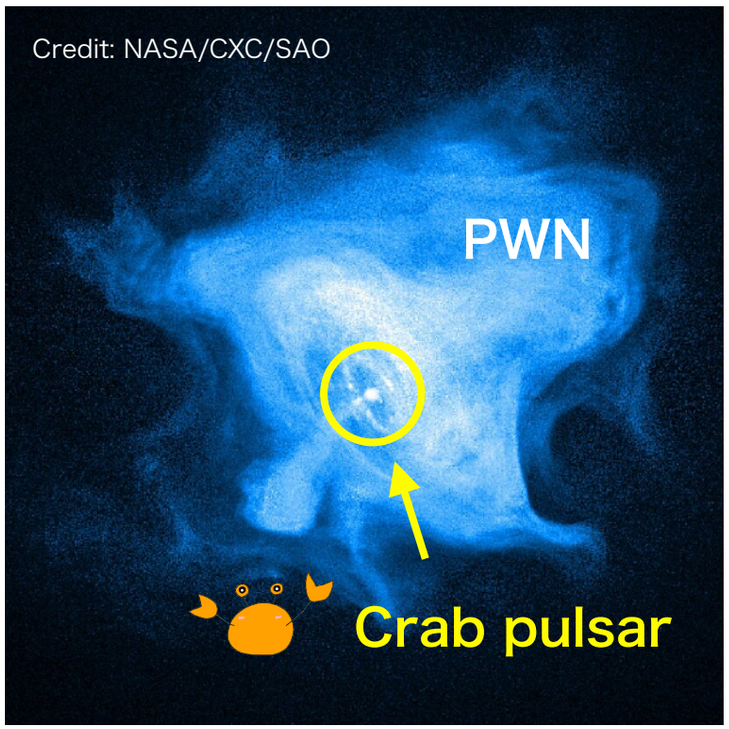
2025/9/4 10:15-10:30

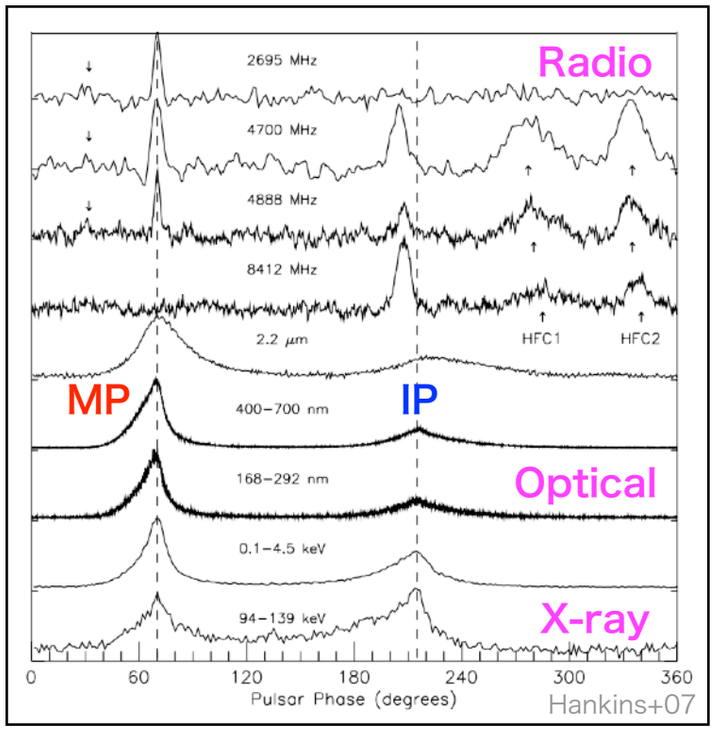
Seimei Users Meeting @Institute of Science Tokyo (Online)

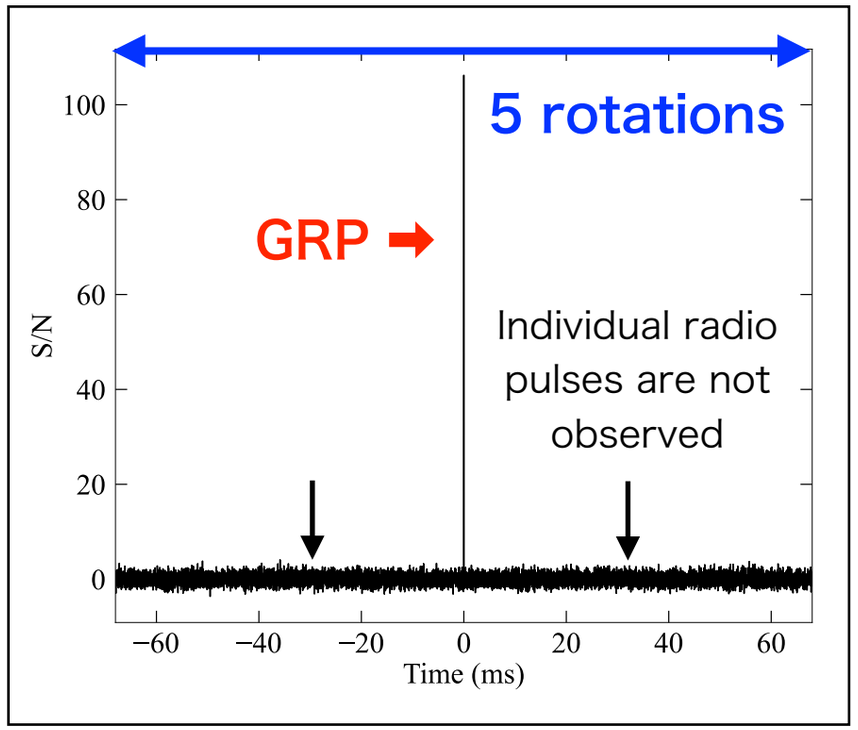
Motivations

What is an origin of transient radio bursts?

- **Fast Radio Bursts (FRBs) from unknown sources**
- **Giant Radio Pulse (GRP) from some pulsars (e.g., PSR B0531+21)**
  - The Crab pulsar is located at the center of the Pulsar Wind Nebula (PWN), emitting pulses every 34 ms in multiple wavelength
  - The pulse profile has two peaks, Main Pulse (MP) and Inter-Pulse (IP)
  - The luminosity of GRPs is >10 times brighter than the time-averaged intensity



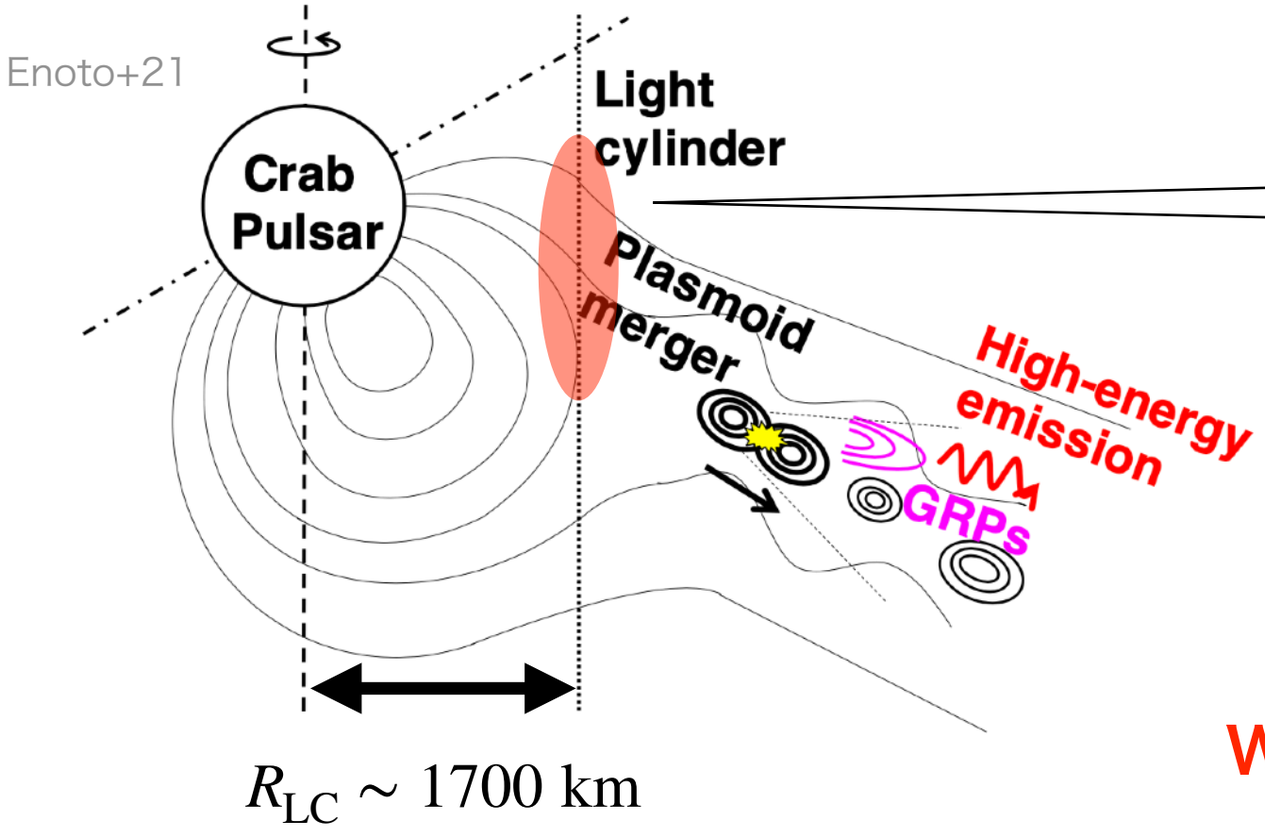


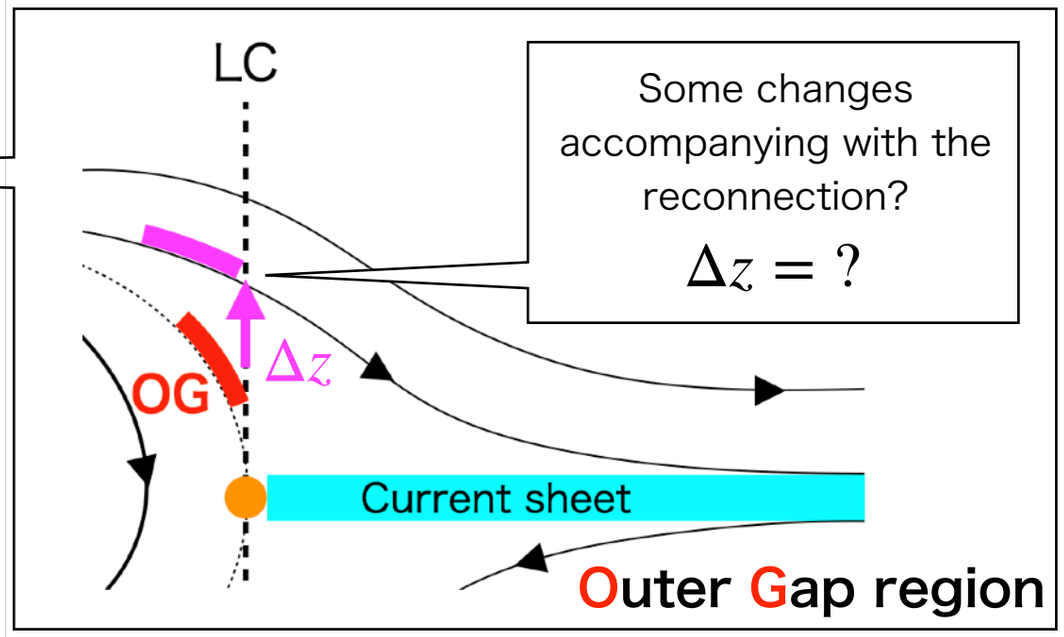


Giant Radio Pulses (GRPs)

Emission mechanism has yet to be unveiled

- **GRPs are detected in 0.1% of observed pulsars**
  - GRPs from the Crab pulsar are emitted only in MP and IP phases
  - The emission rate of the Crab pulsar depends on frequencies $\sim f_{\rm obs}^{-3.4}$ (E. Sujin, ph.D thesis)
- **Magnetic reconnection is one of the plausible models**



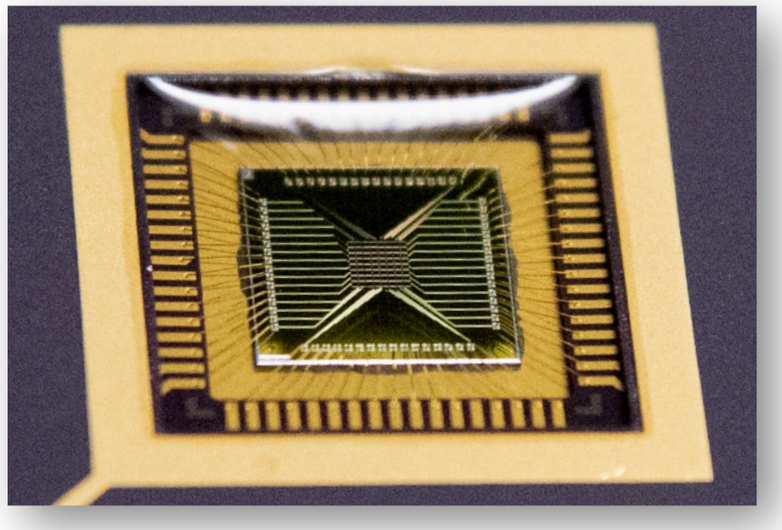


What happens before/after GRPs?

Imager of MPPC-based Optical photoN counter from Yamagata (IMONY)

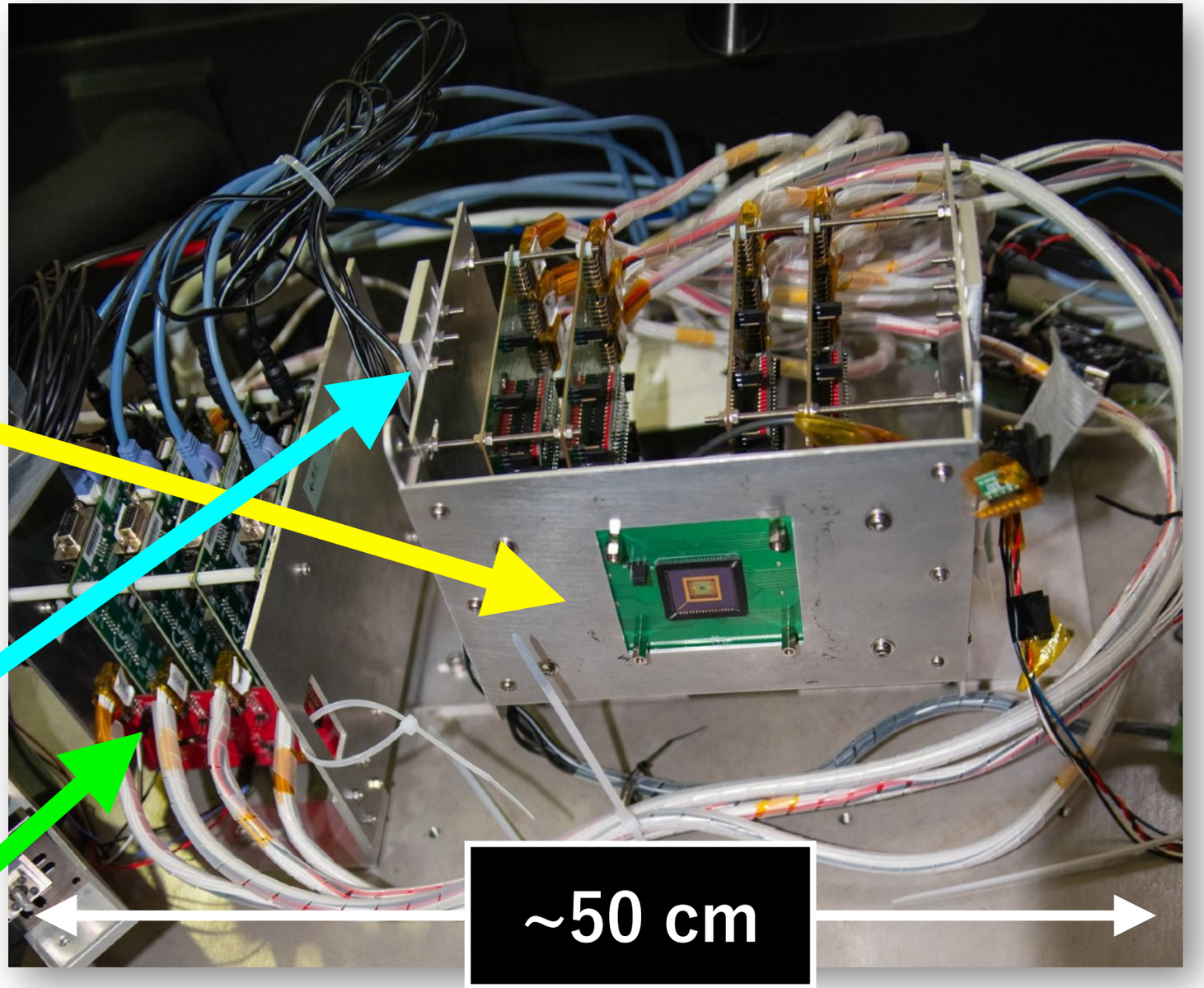
(Nakamori+21, Hashiyama+24, Sato+24, Hasebe+24, and **Nakamori & Hashiyama+25, PASJ** ←New!)

① Geiger-APD array

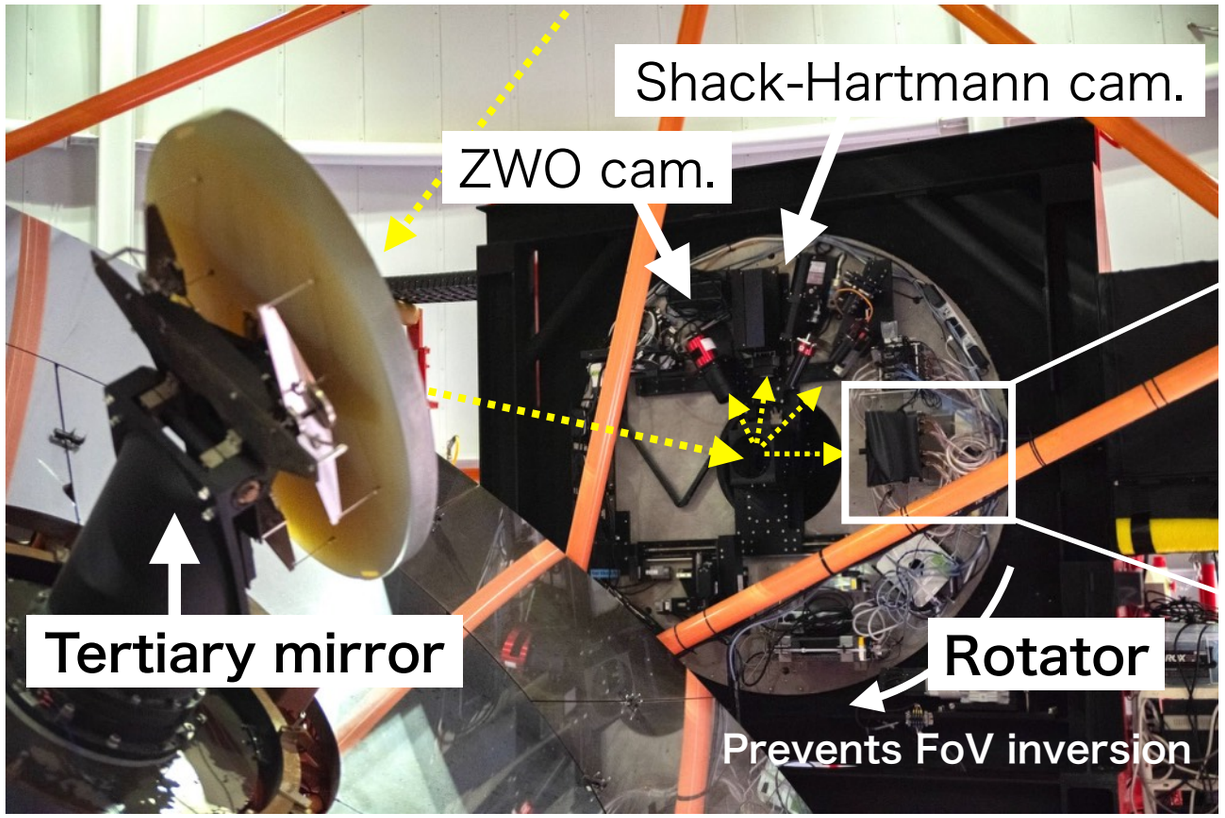


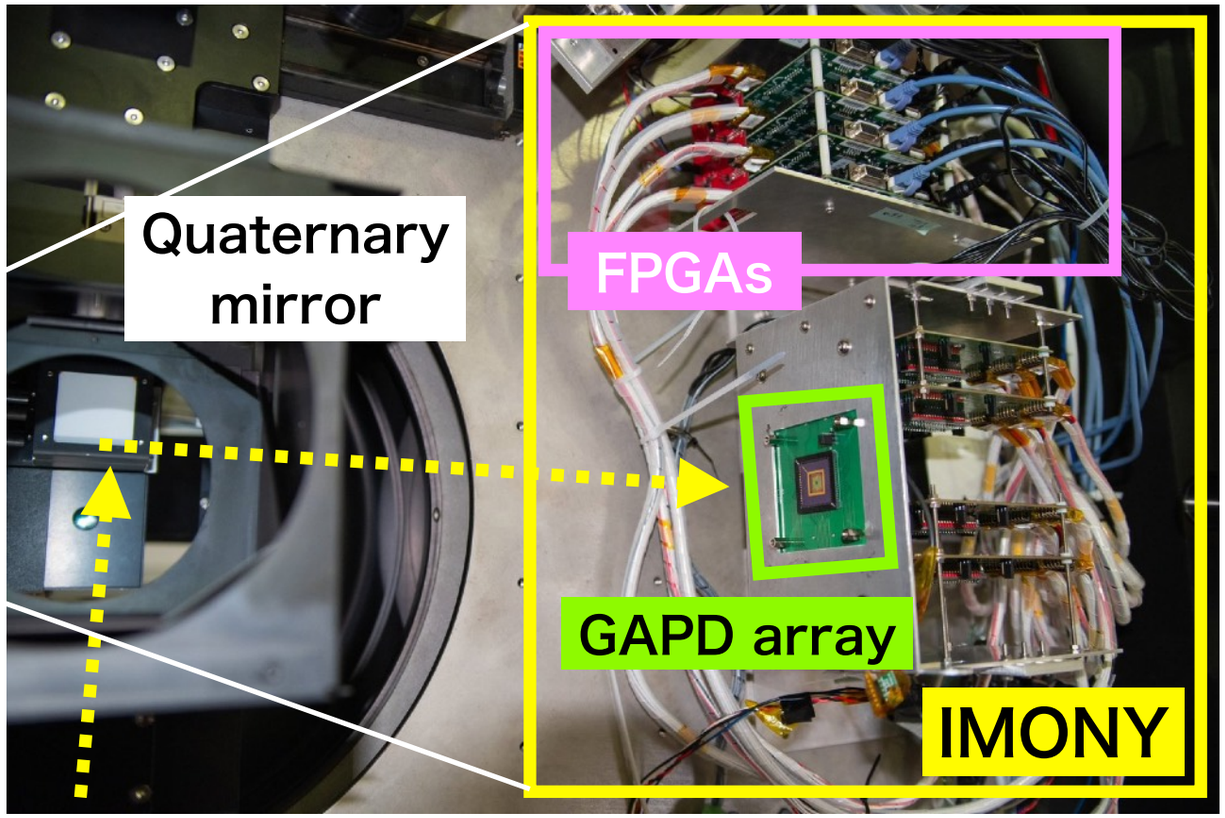
② Front-end Boards

③ Time-stamping system



Installation of IMONY





Mounted on the rotator of the Seimei telescope

- **IMONY does not equipped any color filters and cooling systems**
- **Data processing procedures:**
  - Once a photon is detected, a photo-electron is produced and increased
  - The electric signal is amplified on the front-end board
  - A timestamp is attached on the commercial FPGA board and sent to the PC

Observation

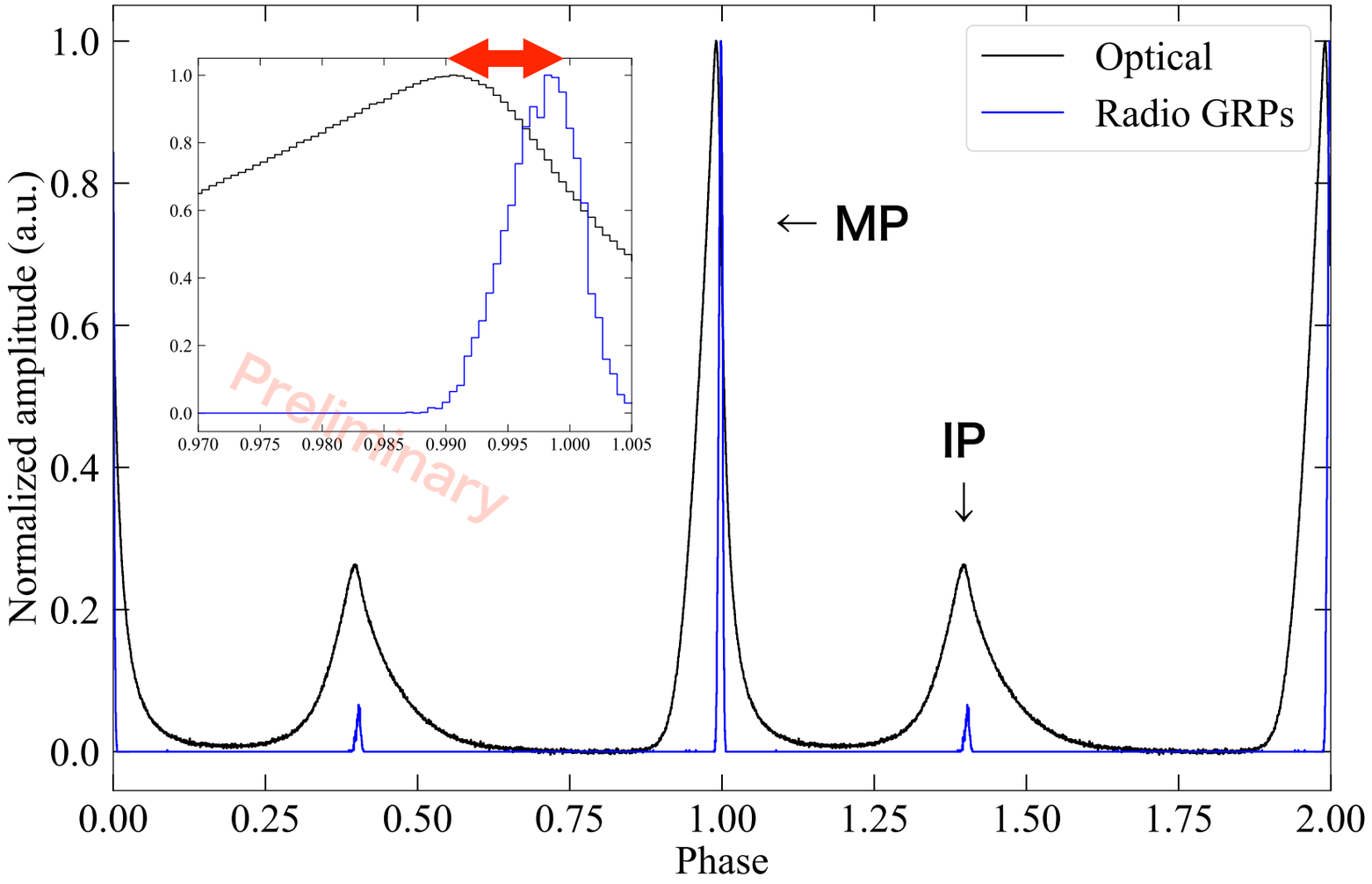
Epoch	Weather	Bands	Eff. Obs. Time (Opt)	Eff. Obs. Time (Rad)
2024/2/5	☀️	Optical	1.2 h	—
2024/2/6	🌤️	Optical	0.37 h	—
2024/2/7	🌤️	Optical/Radio	0.33 h	11.4 h
2024/2/8	🌤️	Optical/Radio	0.53 h	11.4 h
2024/2/9	☀️	Optical	1.9 h	—
2024/2/10	☀️	Optical	2.2 h	—
2024/2/11	🌤️	Optical	1.3 h	—
		Total	**7.8 h**	**22.8 h**

Observation was performed in 5–11 Feb. 2024

- **No observation days were lost due to bad weather**
- **We performed Rad./Opt. simultaneous observations in 2/7 & 8**

  However, only about 1 hour of simultaneous observation was possible due to cloud cover

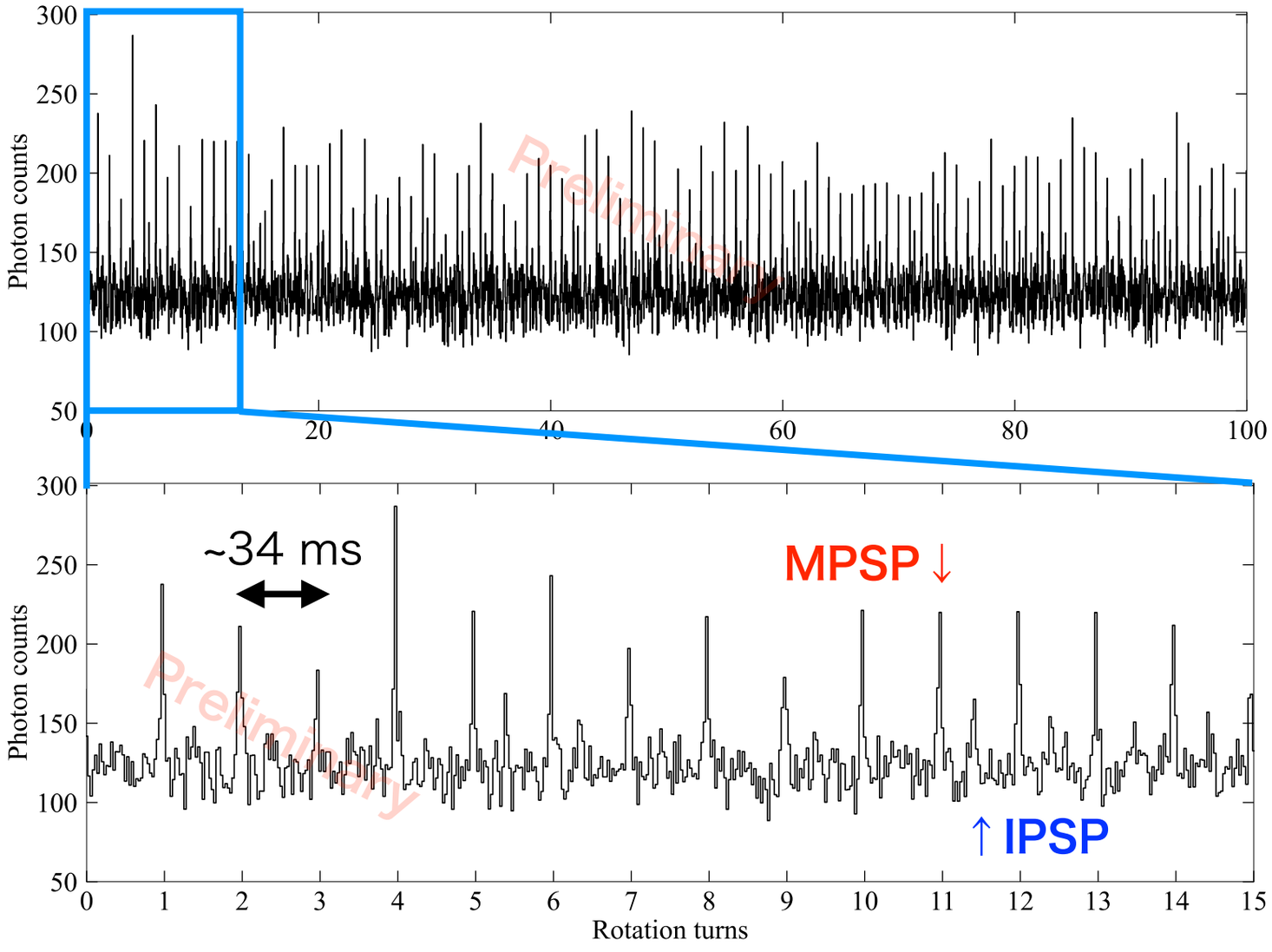
Optical phaseogram

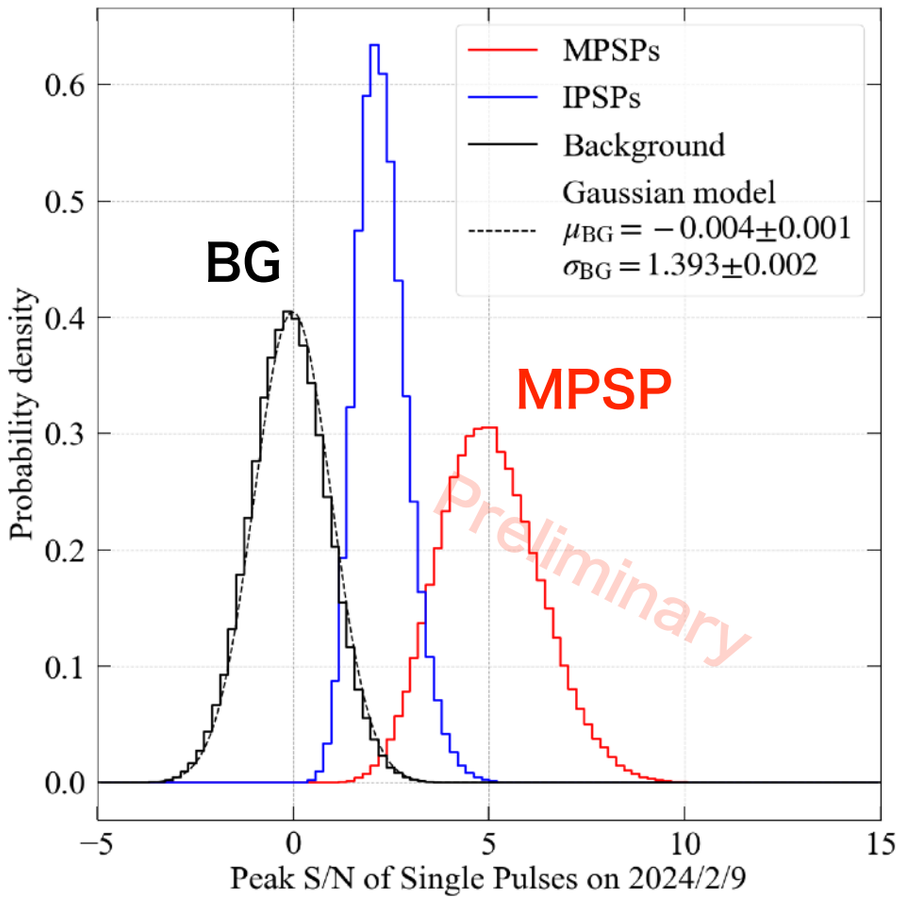


Optical pulsation was successfully detected

- **Optical timings were calculated based on the timing of radio MP**
- **Peak timing of optical emission leads radio peak by 258±10 us**
  - ✓ Consistent with previous observations such as Oosterbroek+08 (255±21 us)

Optical single pulses





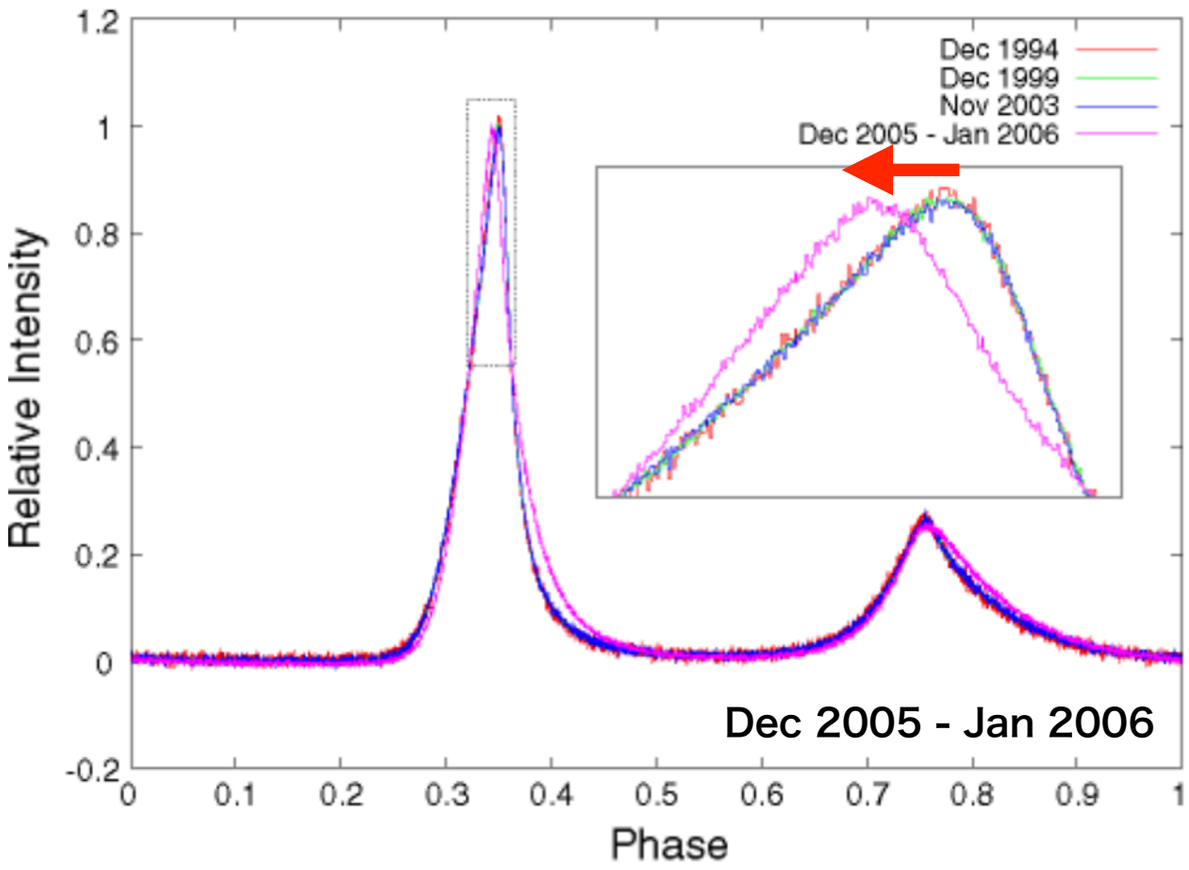
↑
The distribution of peak S/N
of MPSP and IPSP on 9 Fev. 2024

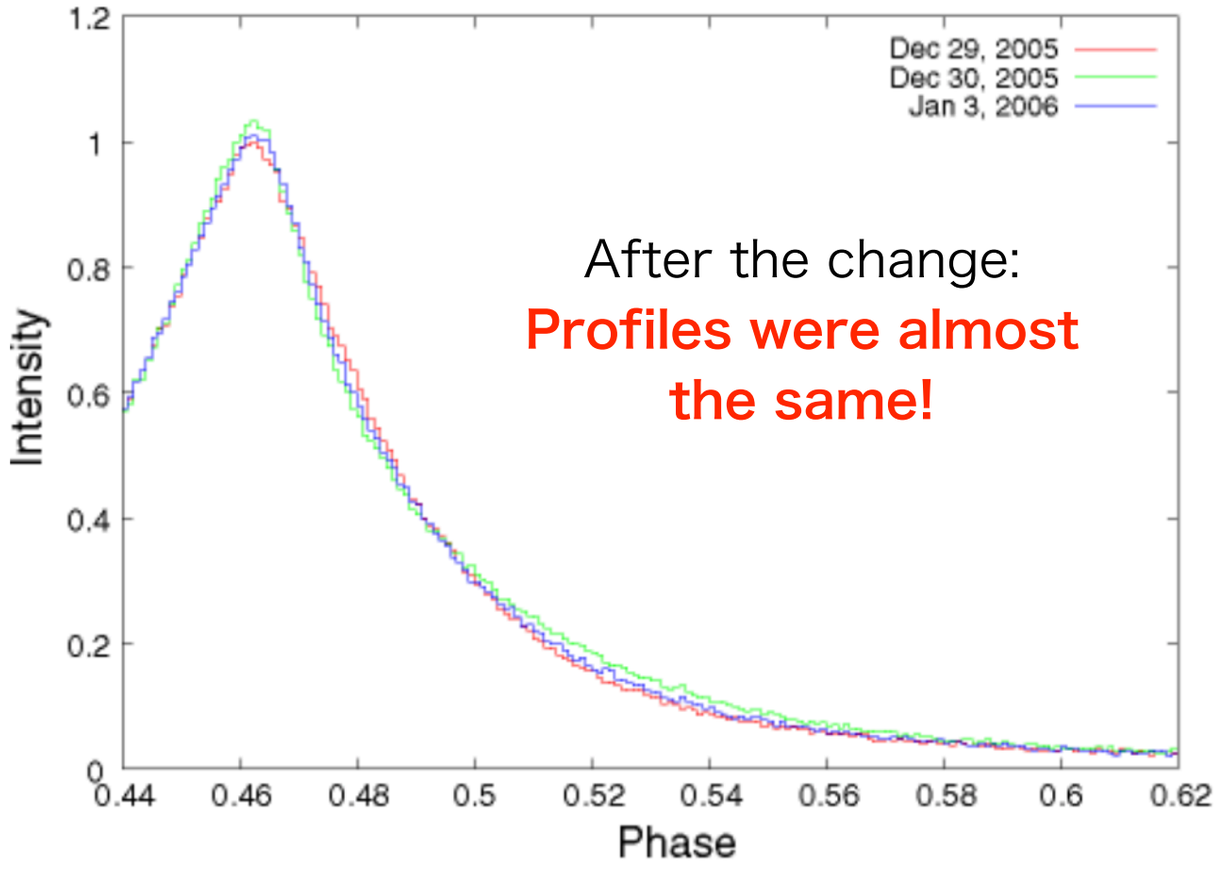
Successfully detected optical pulse per rotation

- ~5σ for MPSP and ~3σ for IPSP on average
- Considering the photon statistics, we analyzed MPSPs in detail

Is there a timing modulation?

Emission stability





After the change:
Profiles were almost the same!

Is the optical pulsation always the same?

- **Optical emission always comes from the same region?**

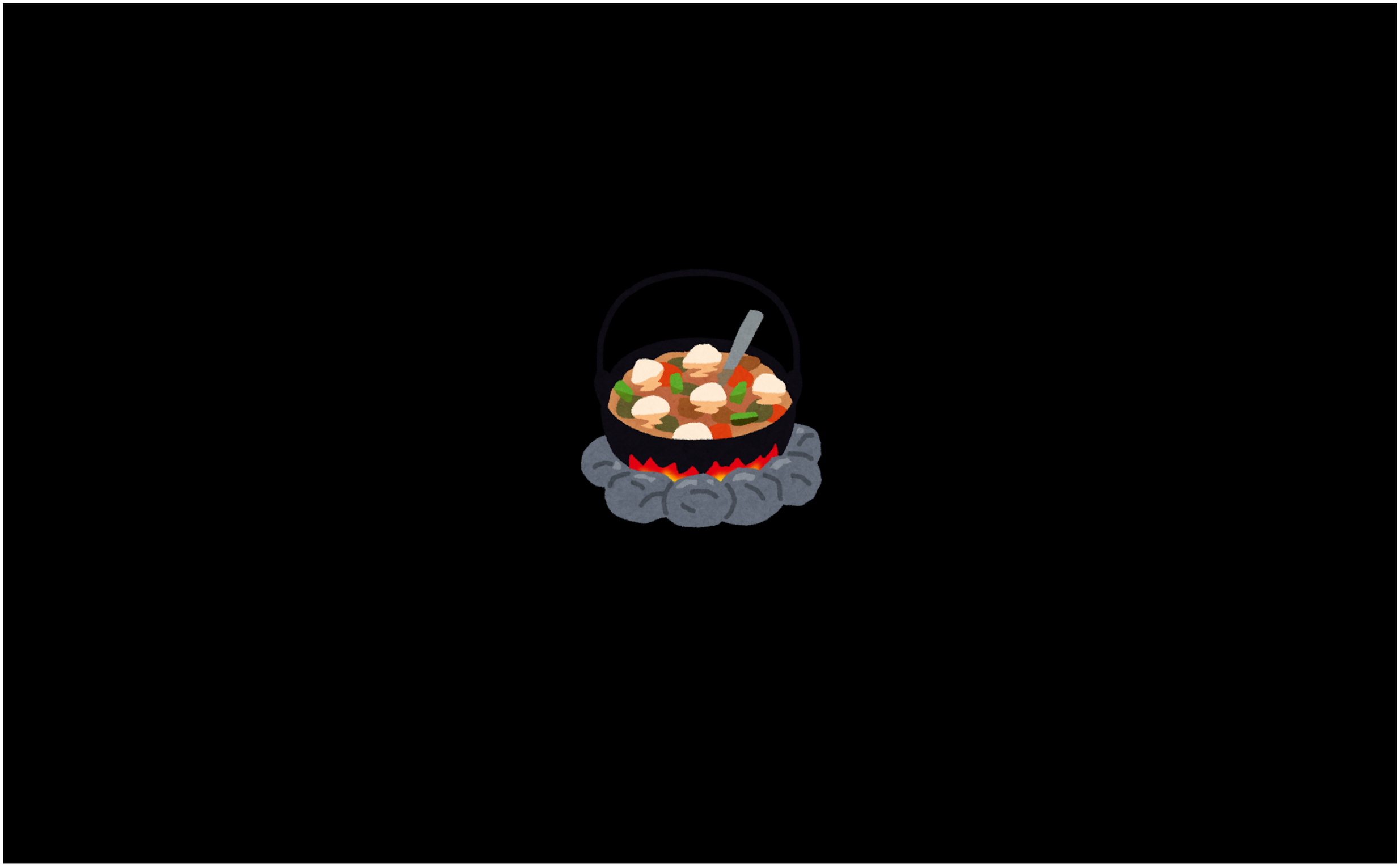
  Optical to gamma-ray emission is considered to be produced from the **OG region**

- **Karpov+07 found a mode change of optical pulse profiles**

  ➡ **Quasi-periodic change of the pulse beam orientation?**

How about our data?

Was there a glitch?



Summary

Motivations

Our purpose is **to understand the origin and emission mechanism of bright radio bursts** such as FRB and GRP