

# 山口32m電波望遠鏡によるFRB観測現状と Tomo-e Gozenを用いた光・電波連携

青木 貴弘 (山口大学)



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山口トモエ  
FRB同時観測

Tomoki Morokuma (UT/IoA)

2019/05/08(Wed) 10:00-

# 山口 32 m 電波望遠鏡

## ▶ Frequency

- › 6 GHz (0.5 GHz BW)
- › 8 GHz (0.5 GHz BW)

## ▶ Polarization

- › Left Circular
- › Right Circular

## ▶ $7\sigma$ Sensitivity

- › For FRBs: 3 Jy = 7.7 AB mag @ 1 ms integration
- › For Pulsars: 70 Jy = 4.3 AB mag @ 2  $\mu$ s integration

## ▶ Field of View

- › 5' x 5' @ 6 GHz, 4' x 4' @ 8 GHz

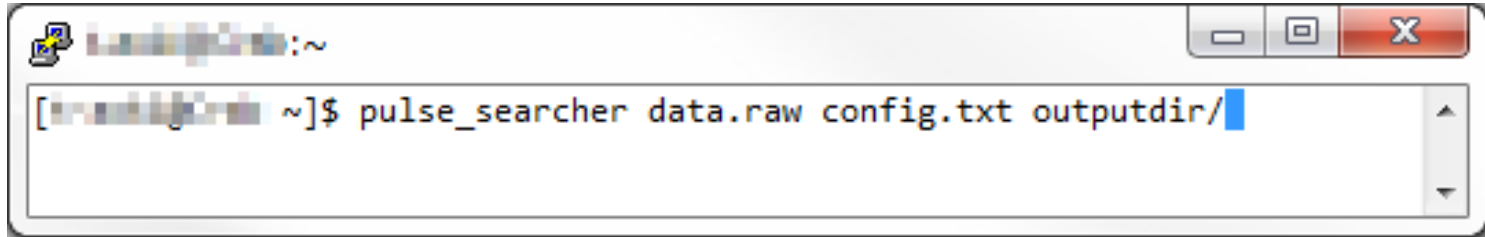


# 山口 32 m 電波望遠鏡

- ▶ 2019年から本格的に電波パルス観測
- ▶ 観測対象
  - › Giant radio pulse (GRP) from pulsars
  - › Fast radio burst (FRB)



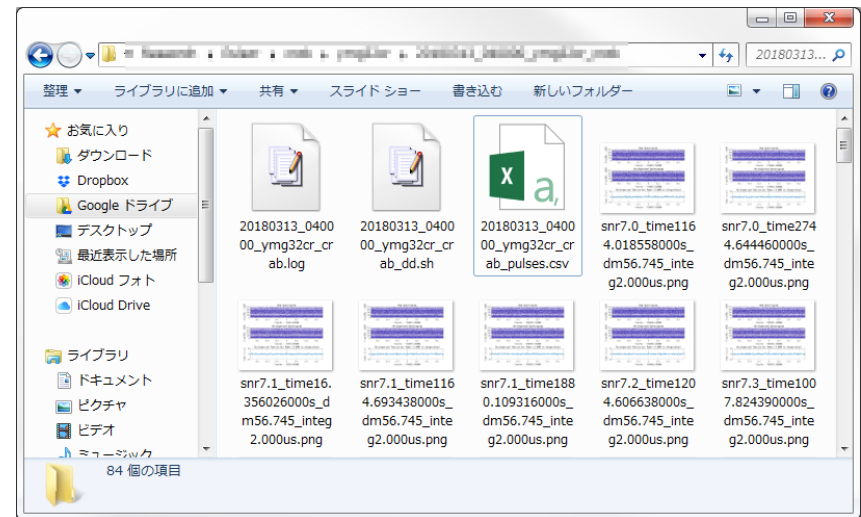
# パルス探査ソフトの開発



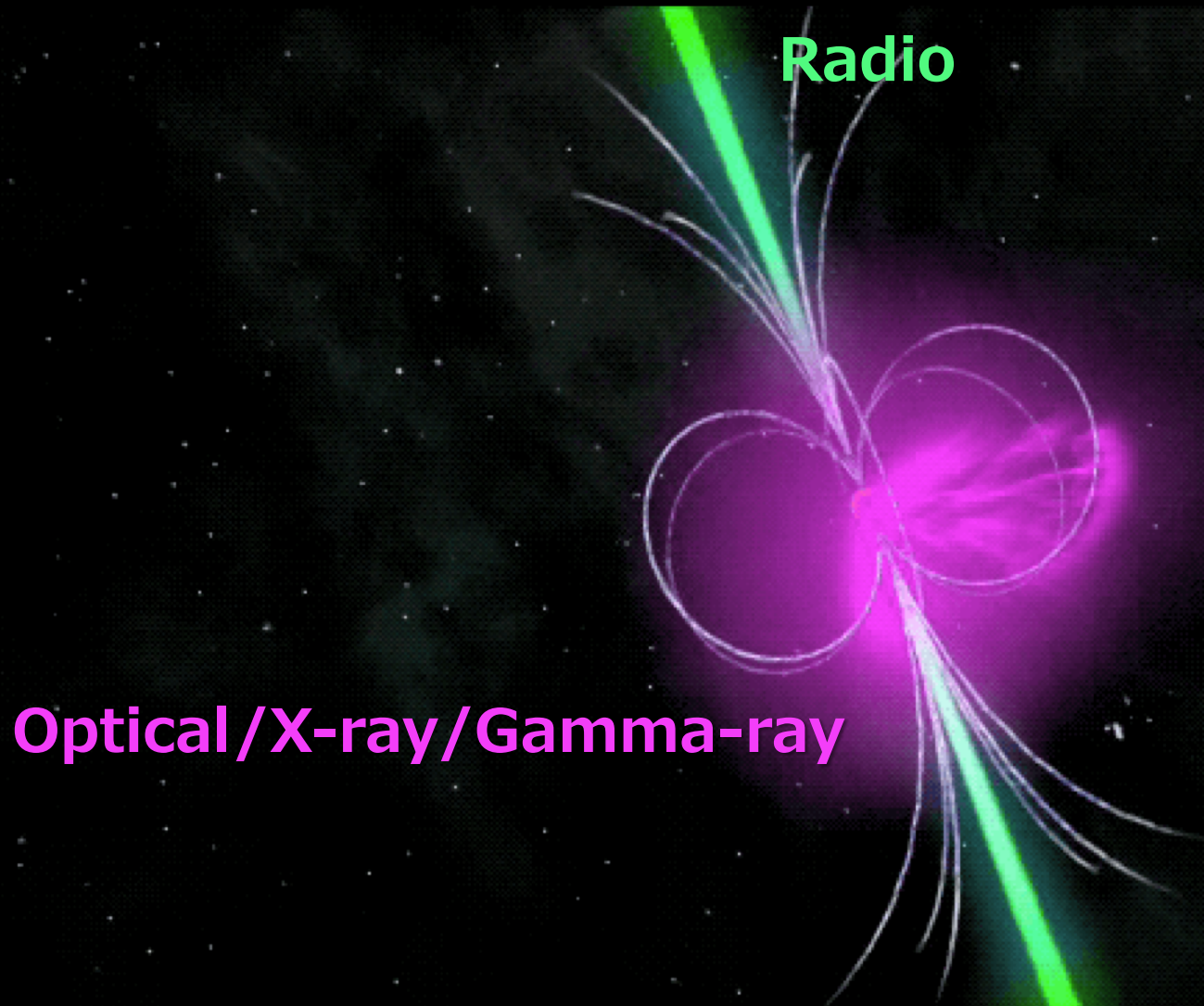
```
[~]$ pulse_searcher data.raw config.txt outputdir/
```

## ▶ 出力ファイル

- › 解析経過ログ (\*.log)
- › パルスのリスト (\*.csv)
- › パルスの画像 (\*.png)
- › data.raw からパルスデータを抽出するbashスクリプト (\*.sh)



# Pulsar Observations



# 観測対象: Giant Radio Pulse (GRP)

- ▶ パルサーからのパルス
  - › Ordinary pulse (average pulse, integrated pulse, etc.)
    - » 世界中で常に観測・解析されている
  - › Giant pulse
    - » 放射機構、放射領域がわかっていない

## 典型的な観測設定

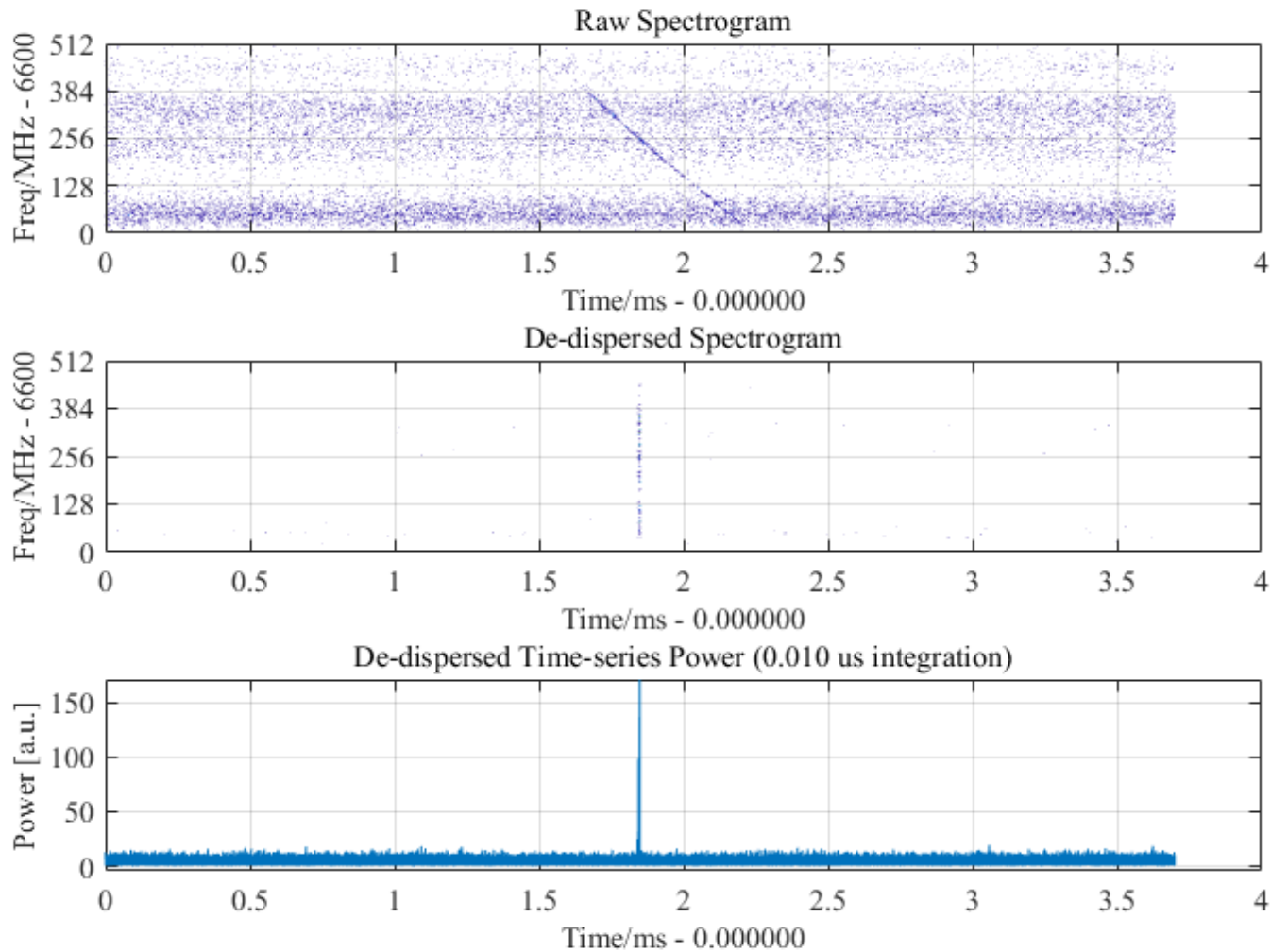
観測対象	GRPを放つパルサー
周波数	6GHz & 8GHz 同時観測 <ul style="list-style-type: none"><li>• 6600 – 7112 MHz (512 MHz BW)</li><li>• 8192 – 8704 MHz (512 MHz BW)</li></ul>
偏波	右回り円偏波
7 $\sigma$ 感度	70 Jy @ 2 $\mu$ s 積分



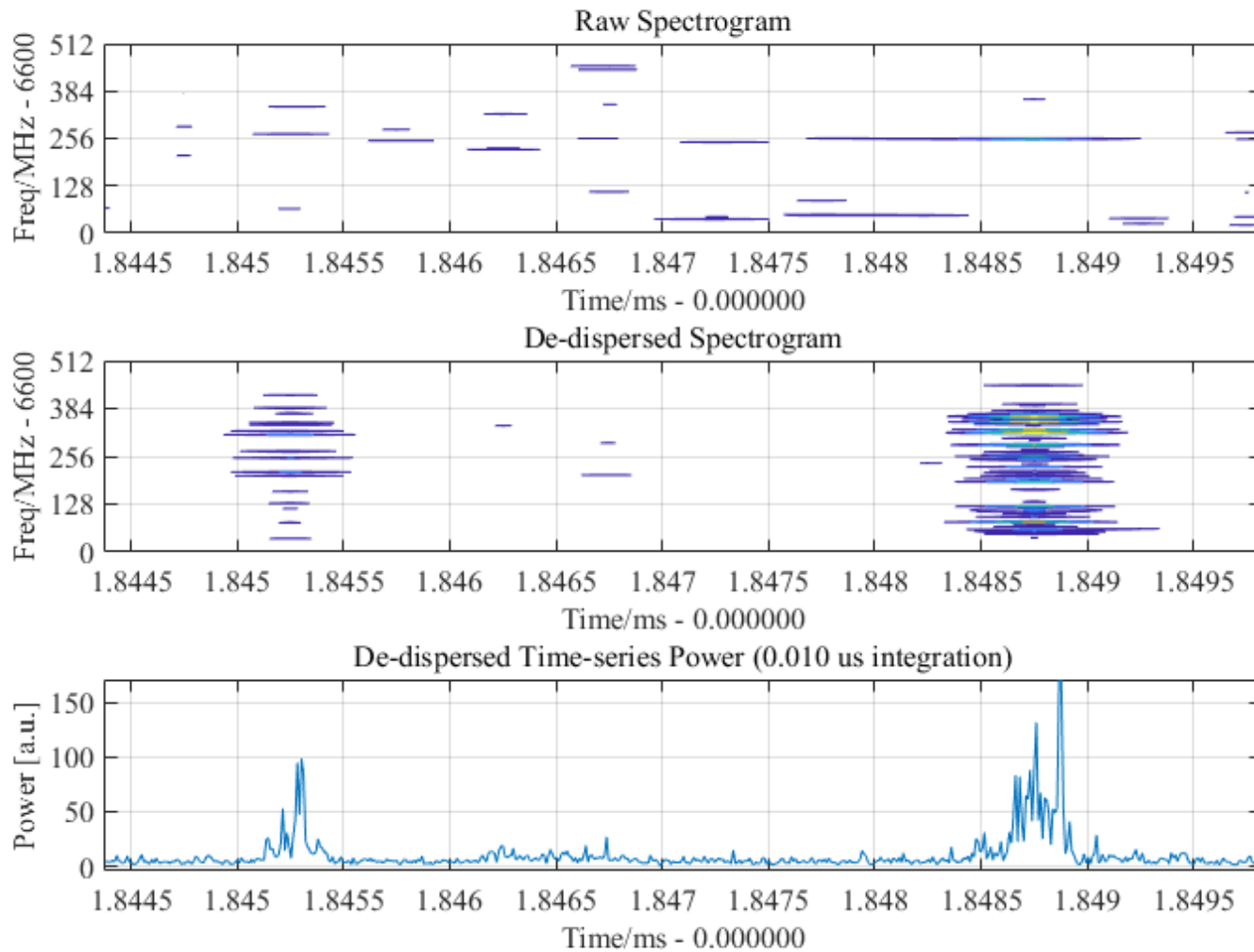
# 観測対象と観測結果

GRP Pulsar	P [ms]	DM [pc/cm <sup>3</sup> ]	Obs. duration	# of GRPs
B0031-07	943	10.922	1 hr	0
J0218+4232	2.3	61.252	1 hr	0
B0656+14	385	13.977	2 hr	0
<b>B0531+21 (Crab)</b>	<b>33</b>	<b>56.745</b>	<b>~50 hr</b>	<b>~10 pulses/hr</b>
B1112+50	1656	9.186	2 hr	0
J1752+2359	409	36.196	1 hr	0
B1821-24	3.0	119.857	not yet	
J1823-3021A	5.4	86.880	5.5 hr	0
B1937+21	1.6	71.024	not yet	
B1957+20	1.6	29.117	4 hr	0

# Giant Pulse from Crab Pulsar

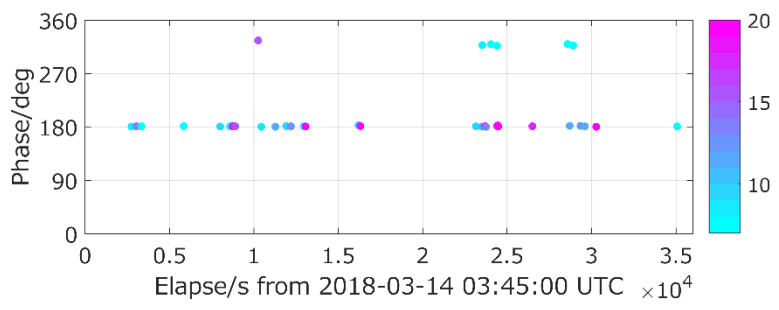
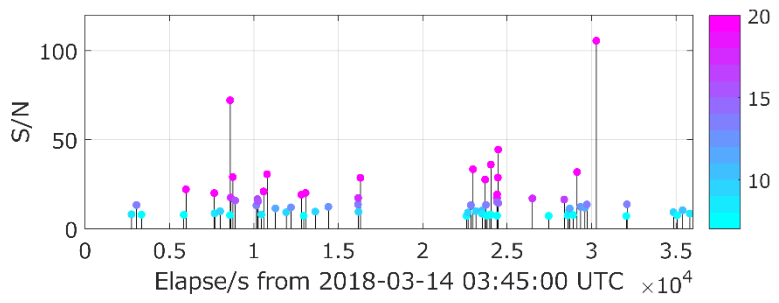


# Giant Pulse from Crab Pulsar

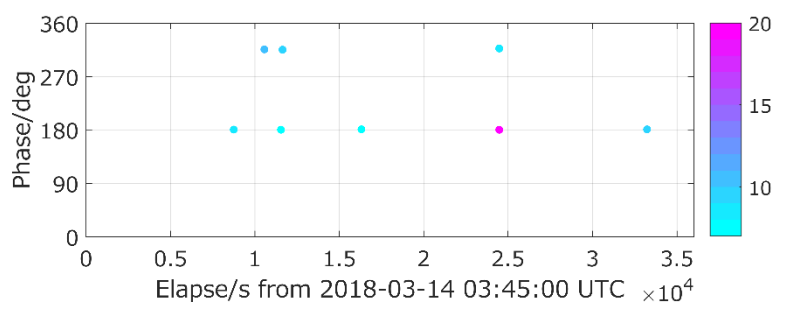
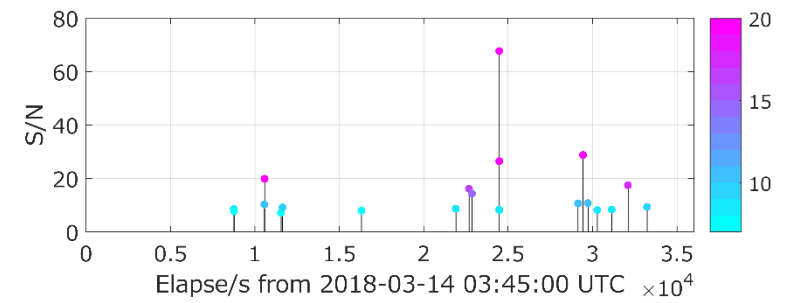


# Giant Pulse from Crab Pulsar

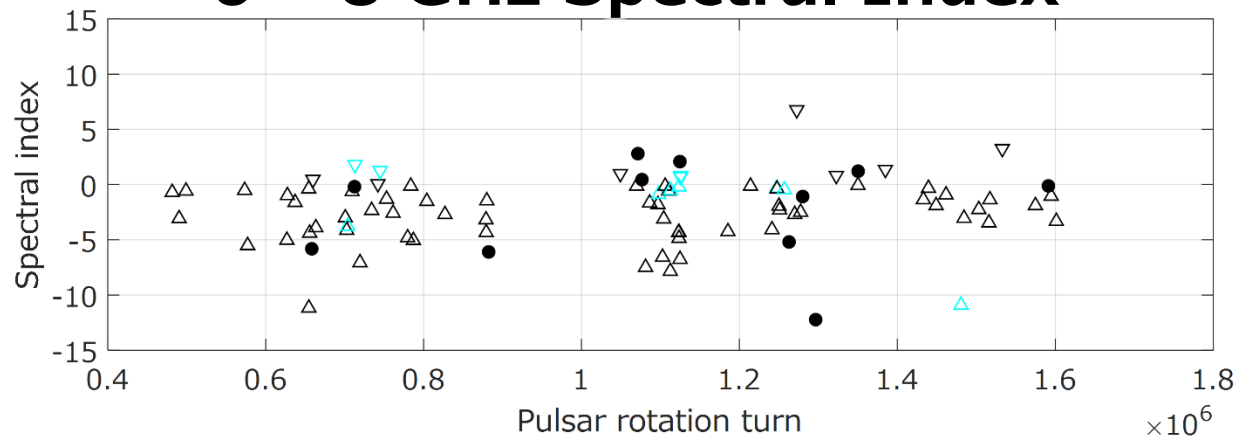
## 6 GHz GRPs



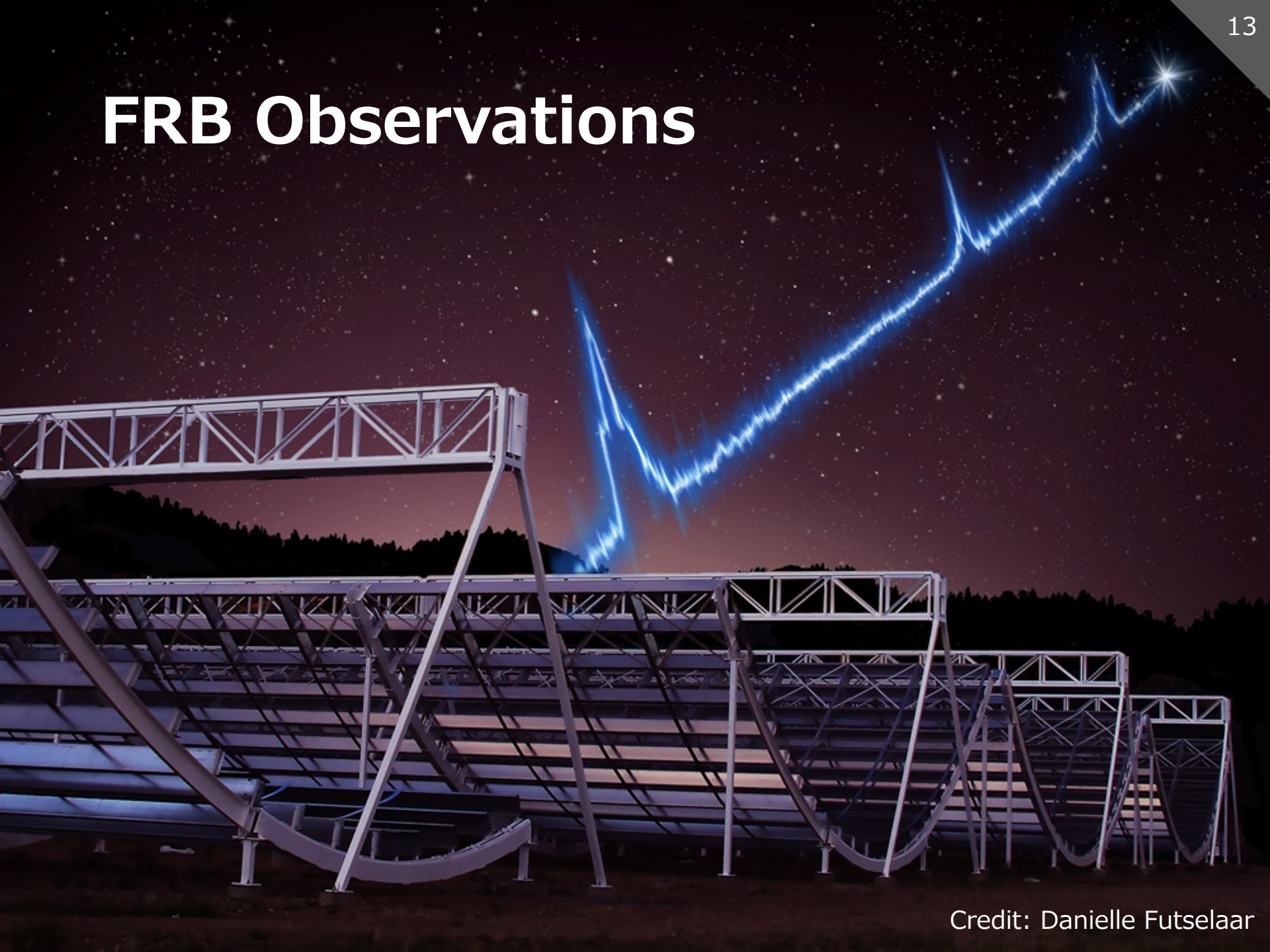
## 8 GHz GRPs



## 6 – 8 GHz Spectral Index

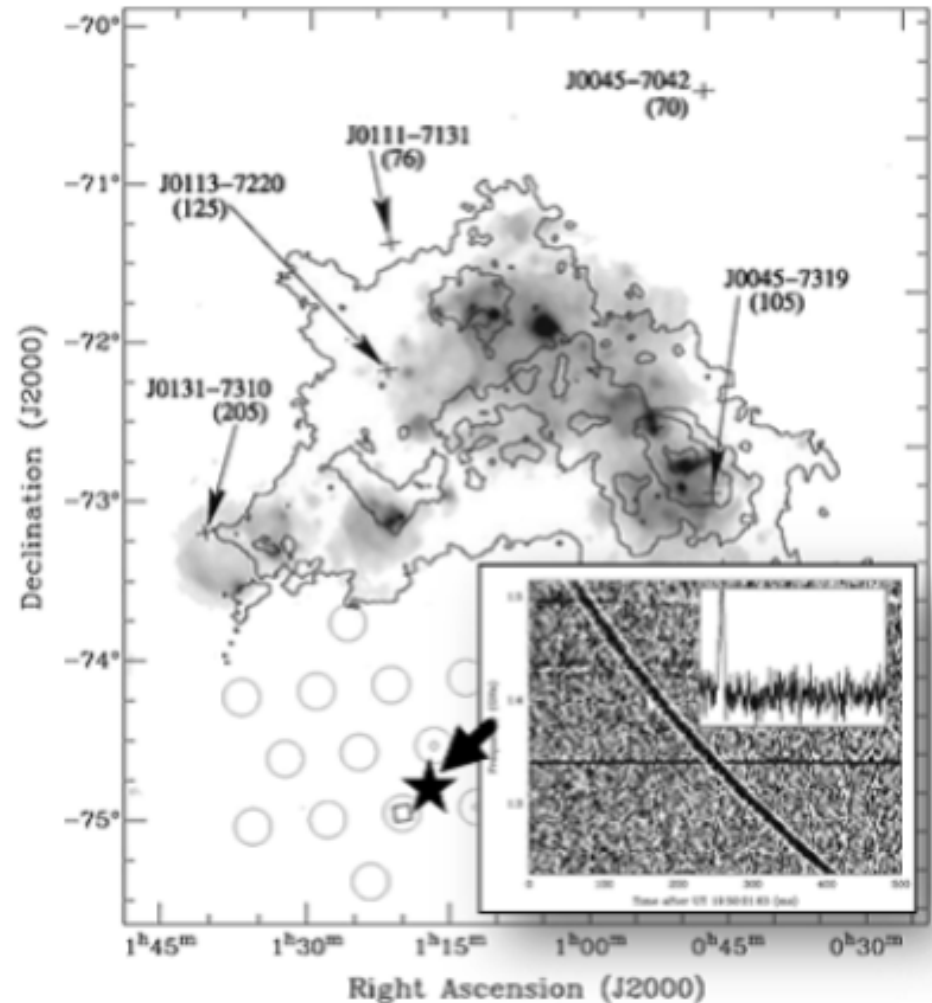


# FRB Observations



# Fast Radio Burst (FRB)

- ▶  $DM > \sim 300 \text{ pc cm}^{-3}$ 
  - › Extra-galactic origin?
- ▶ Flux  $\sim 1 \text{ Jy}$
- ▶ Duration  $\sim 1 \text{ ms}$
- ▶ Population
  - › Single FRB
  - › Repeating FRB



山口トモエ  
FRB同時観測

Tomoki Morokuma (UT/IoA)

2019/05/08(Wed) 10:00-

# 山口トモエのターゲット

## LETTER

<https://doi.org/10.1038/s41586-018-0864-x>

### A second source of repeating fast radio bursts

The CHIME/FRB Collaboration\*

The discovery of a repeating fast radio burst (FRB) source<sup>1,2</sup>, FRB 121102, eliminated models involving cataclysmic events for this source. No other repeating FRB has hitherto been detected despite many recent discoveries and follow-ups<sup>3–5</sup>, suggesting that repeaters may be rare in the FRB population. Here we report the detection of six repeat bursts from FRB 180814.J0422+73, one of the 13 FRBs detected<sup>6</sup> by the Canadian Hydrogen Intensity Mapping Experiment (CHIME) FRB project<sup>7</sup> during its pre-commissioning phase in July and August 2018. These repeat bursts are consistent with its origin from a single position on the sky, with the same dispersion measure, about 189 parsecs per cubic centimetre. This line of sight traces approximately twice the expected Milky Way column density of free electrons, which implies an upper limit on the source redshift of 0.1, showing it to be closer to Earth by a factor of at least 2 than FRB 121102<sup>8</sup>. In some of the repeat bursts, we observe subpulse frequency structure, drifting and spectral variation reminiscent of that seen in FRB 121102<sup>9,10</sup>, suggesting similar emission mechanisms or propagation effects. This second repeater, found among the first few CHIME/FRB discoveries, suggests that there exists—and that CHIME/FRB and other wide-field, sensitive radio telescopes will find—a substantial population of repeating FRBs.

FRB 180814.J0422+73 was discovered by the CHIME/FRB project<sup>6,7</sup>

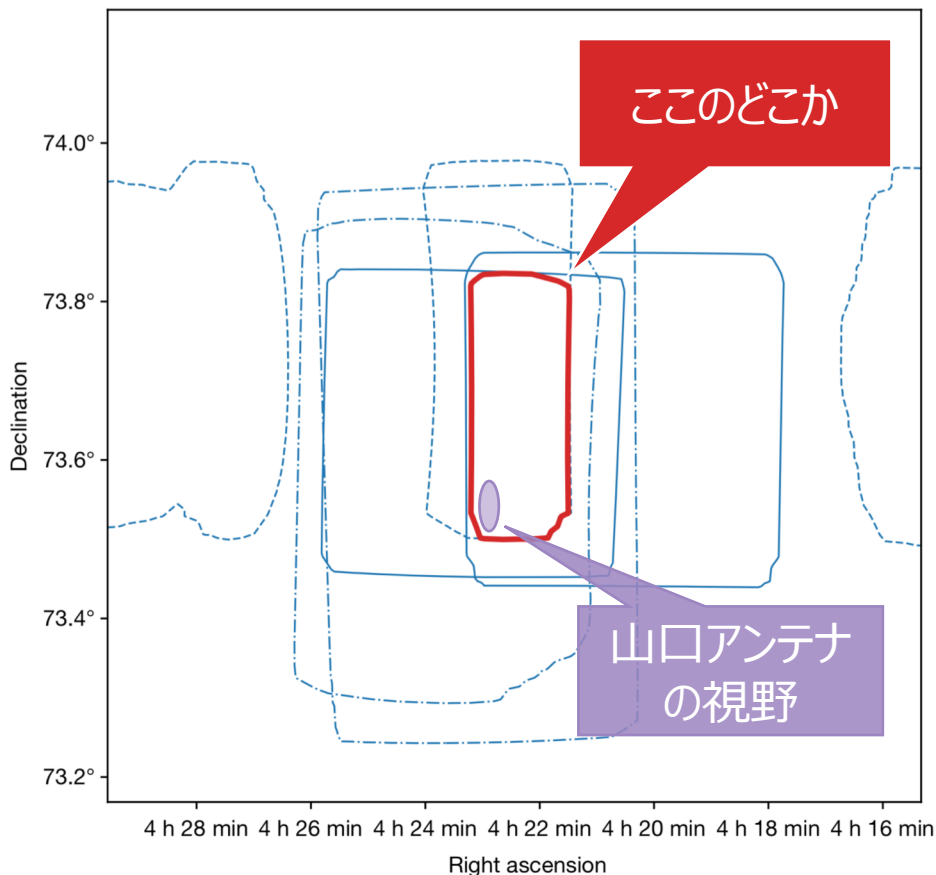
beam and was initially assigned an incorrect RA and not classified as extragalactic. As the CHIME/Pulsar data has higher time resolution, we show that in Fig. 2.

We have searched for repeat bursts from the other 12 sources discovered during the pre-commissioning phase<sup>6</sup> by looking for events of similar DM when their best-estimated position was in the main lobes of the formed beams. We found no events exceeding our signal-to-noise (SNR) threshold of 10. Each of the 12 was subject to a different exposure and sensitivity; two have higher declinations, hence more exposure, than for FRB 180814.J0422+73, so are likely to have substantially lower observed repeat rates, if they are repeaters. A detailed discussion of this will be presented elsewhere.

The automated pipeline<sup>7</sup> recorded raw intensity data to disk for all CHIME/FRB repeat events from FRB 180814.J0422+73 except for the burst on 6 September, for which the system failed to record to disk. The events with intensity data allow us to examine their dynamic spectra (see Fig. 2) and measure refined burst parameters (see Table 1). The 6 September event has only metadata determined by the automated pipeline and therefore we have only coarse estimates of its properties; however, these are sufficient to verify that it was from the same source. Polarimetry of FRB 121102 revealed one of the highest rotation measures ever seen<sup>9</sup>, an important clue about the source environment. No polarization information was available for the events reported here, but



# Repeating FRB 180814 (FRB R2)



## ▶ Localization

- › RA 04h22m22s
- › Dec +73d40'
- › Error  $\sim 0.3 \text{ deg} \times 0.3 \text{ deg}$

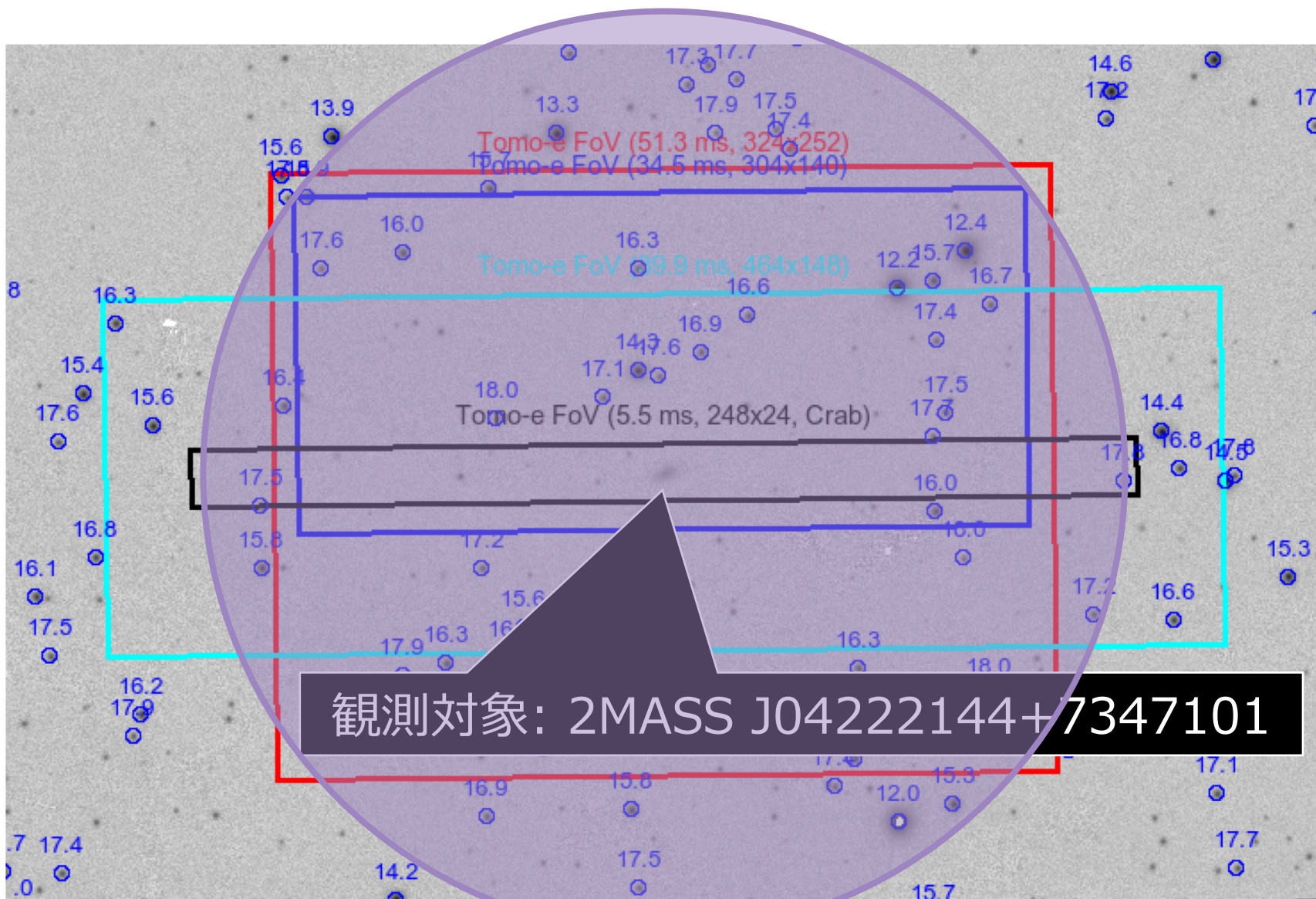
## ▶ エラー範囲すべてを掃くには、山口32m鏡だと数十ポインティング必要...

- › 観測銀河を絞る必要性

## ▶ GLADEカタログ対応銀河を山口トモエで同時観測

- › 2MASS  
J04222144+7347101
  - › Redshift: 0.078
  - › Distance: 354 Mpc

# FRB R2 の光・電波同時観測



# FRB R2 の光・電波同時観測

観測日時: 2019-05-23 20:05 – 21:03 JST (1 hour)

## 山口32m電波望遠鏡

- ▶ Frequency
  - › (6600 – 7112 MHz)
  - › 8192 – 8704 MHz
- ▶ Polarization
  - › Right circular
- ▶ Integration Time
  - › 1 ms
- ▶  $7\sigma$  sensitivity
  - ›  $3 \text{ Jy} = 7.7 \text{ AB mag}$
- ▶ FoV
  - ›  $4' \times 4'$



## 木曾105cmシュミット光学望遠鏡

- ▶ Instrument
  - › Tomo-e Gozen
- ▶ Filter
  - › None
- ▶ Exposure Time
  - › 41 ms / frame (24.4 Hz)
- ▶ Image Size
  - › 400 x 240 pixel (7.8 x 4.7 arcmin<sup>2</sup>)
- ▶ # of Frames
  - ›  $\{[41 \text{ ms} \times 1000] \times 5\} \times 15$
- ▶ Note
  - › [0.5 s x 6] full-frame images between the 5 continuous exposures



# FRB R2 の光・電波同時観測

## ▶ FRB 非検出

- › 単に確率の問題
- › 感度が足りない
- › ターゲットが悪い

## ▶ 山口ではこの観測の他にも何度が実施

- › FRB R1: 2019-011 6 hours
- › R2: 2019-049 4 hours
- › R2: 2019-058 1 hour
- › R2: 2019-105 2 hours
- › R2: 2019-134 1 hour
- › R2: 2019-143 1 hour (今回の)

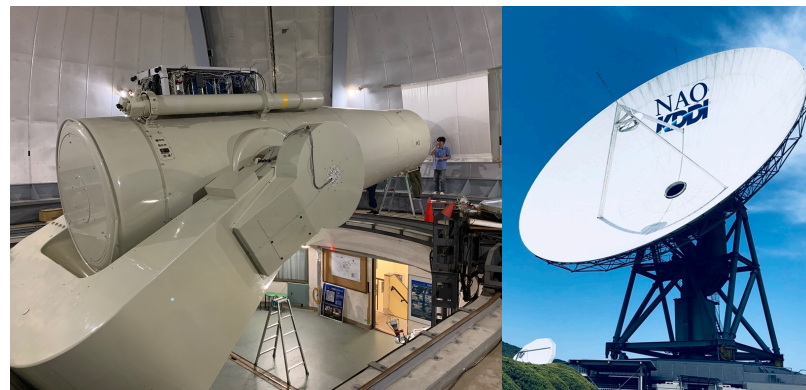
## ▶ 木曽は未解析

- › 電波で受からないと、FRBらしきフラッシュがあってもデブリと見分けられない



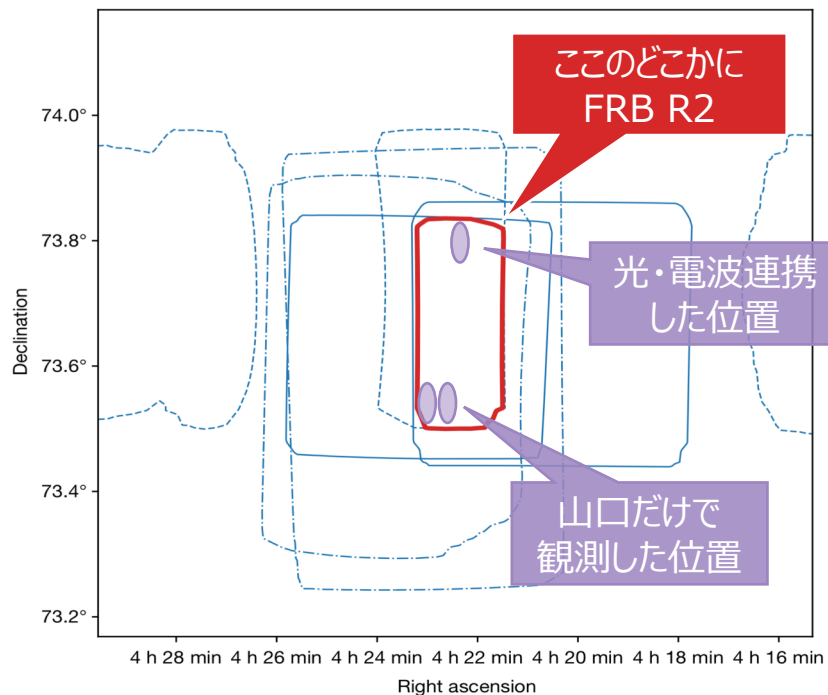
# FRB R2 の光・電波同時観測

- ▶ R2領域を計9時間観測して非検出
  - › Rate < 0.3 event/hour (95% confidence upper limit)
  - › 意味のある数値ではない

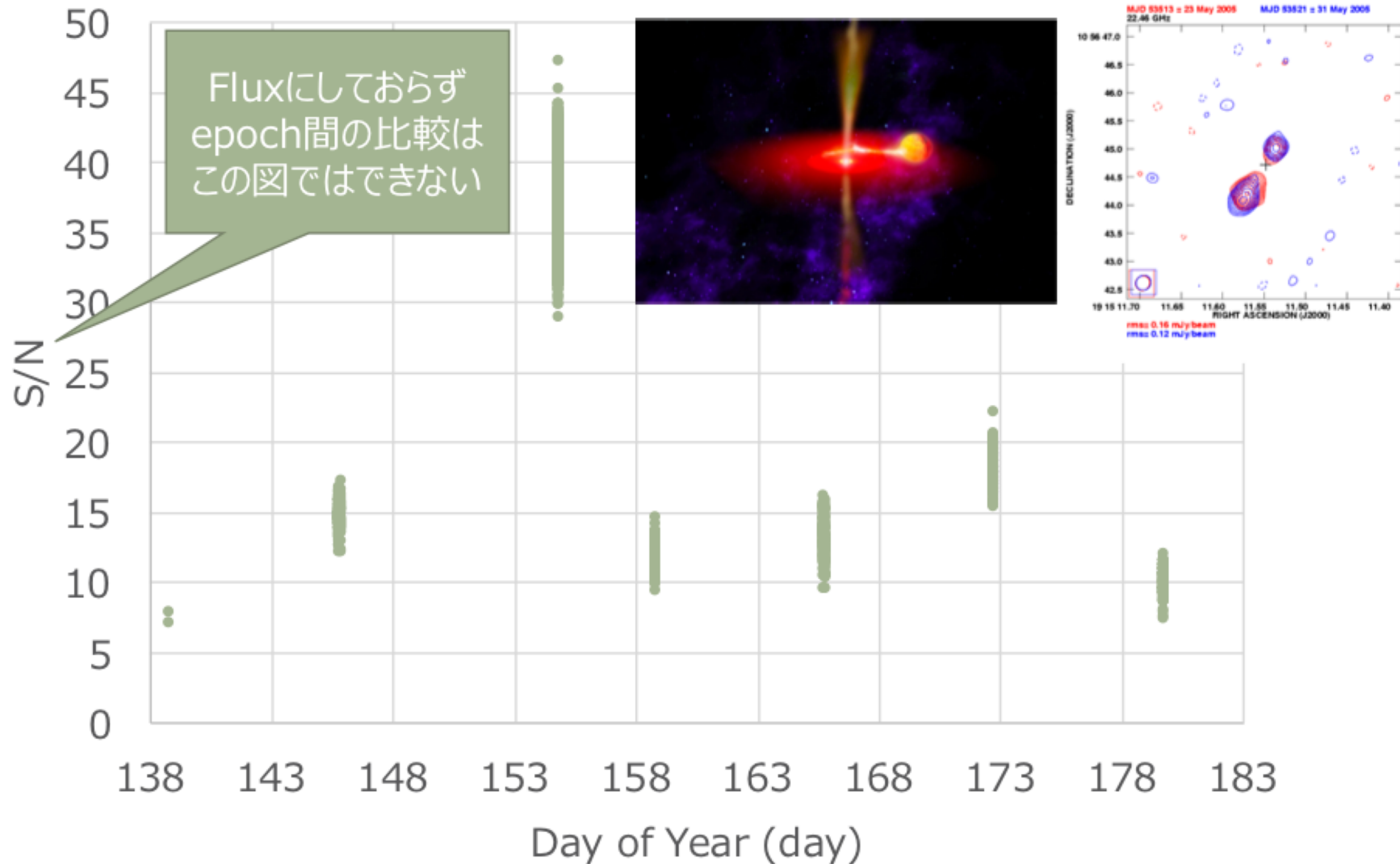


- ▶ J04222144+7347101を光・電波同時に1時間観測して非検出
  - › Rate < 3 event/hour
  - › これは意味のある数値

▶ FRB受かればいいなあ！



# X線連星 GRS 1915+105 電波追観測



# X線連星 GRS 1915+105 電波追観測

