High speed mode of Tomo-e Gozen: Application for Optical Pulsars

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Tomo-e Gozen Camera

Tomo-e Gozen Camera

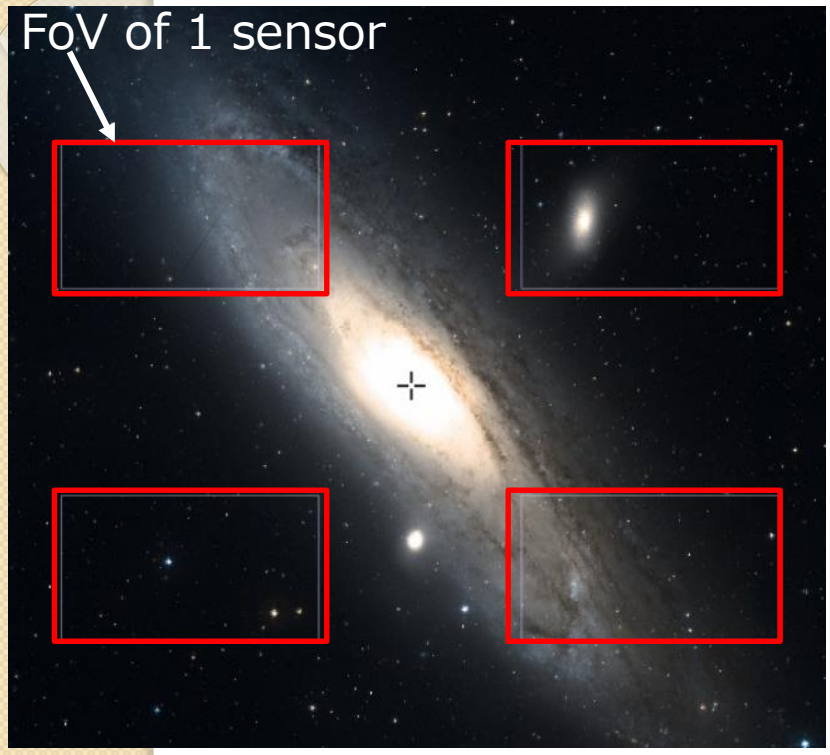
Extremely wide field CMOS camera

Telescope	Kiso Schmidt (aperture105cm, seeing~4")
Filed of view	22 deg^2 in ϕ 9 deg
Sensor	CMOS (1k x 2k) x 84
Frame rate	2 frame / sec (0.5sec/frame)
Read out time	<0.5sec
Wavelength	optical

Full frame mode of Tomo-e can see
≳seconds time scale events

Partial mode (high speed mode) of Tomo-e

Full frame mode



2000 * 1200 pix^2 each
-> 0.5 sec cadence

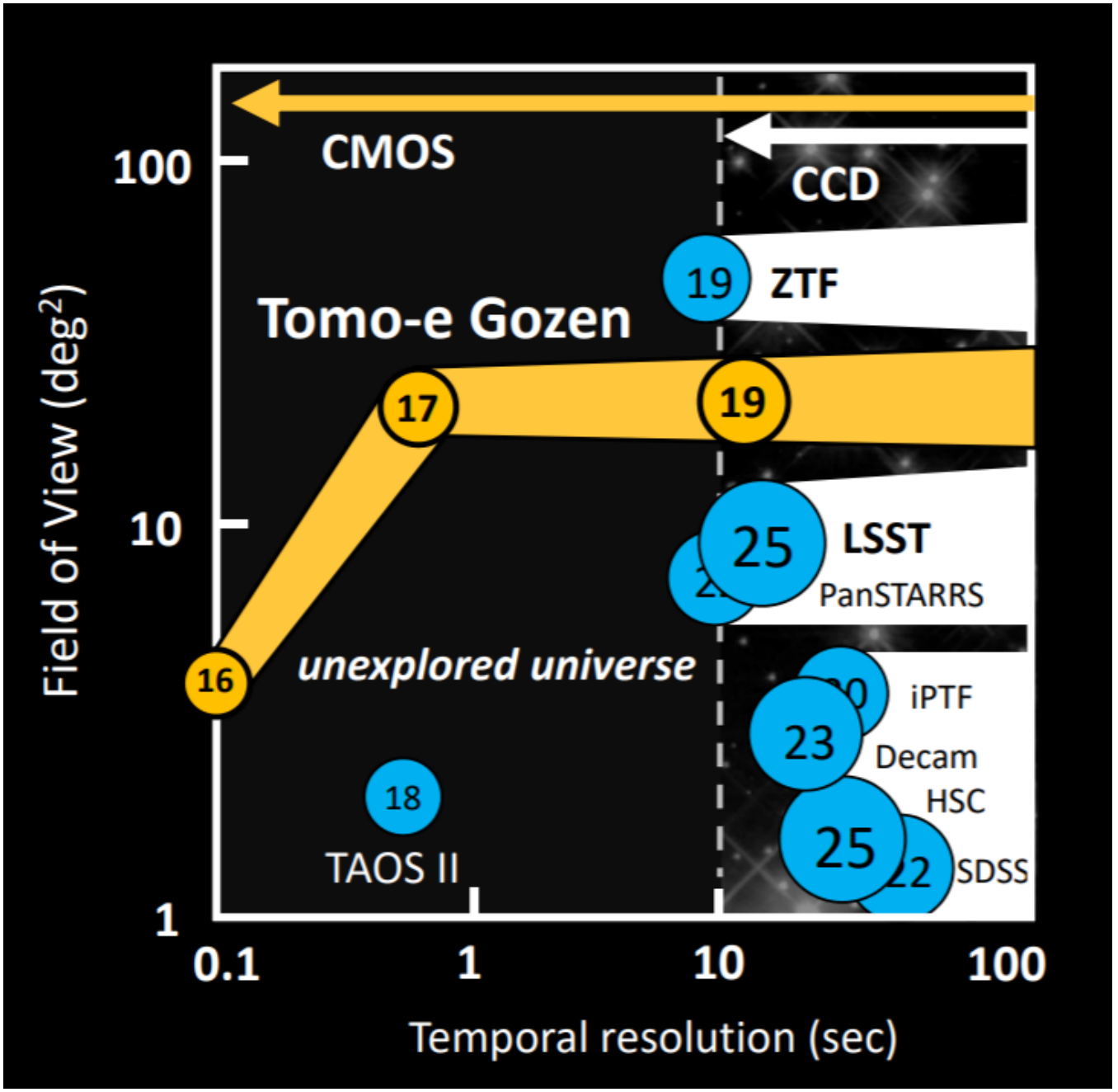
Partial frame mode

1000 * 500 pix^2 each
-> 0.12 sec cadence

Partial mode of Tomo-e can see
sub-seconds time scale events

Survey power for transients

Limiting magnitudes are showed in the circles

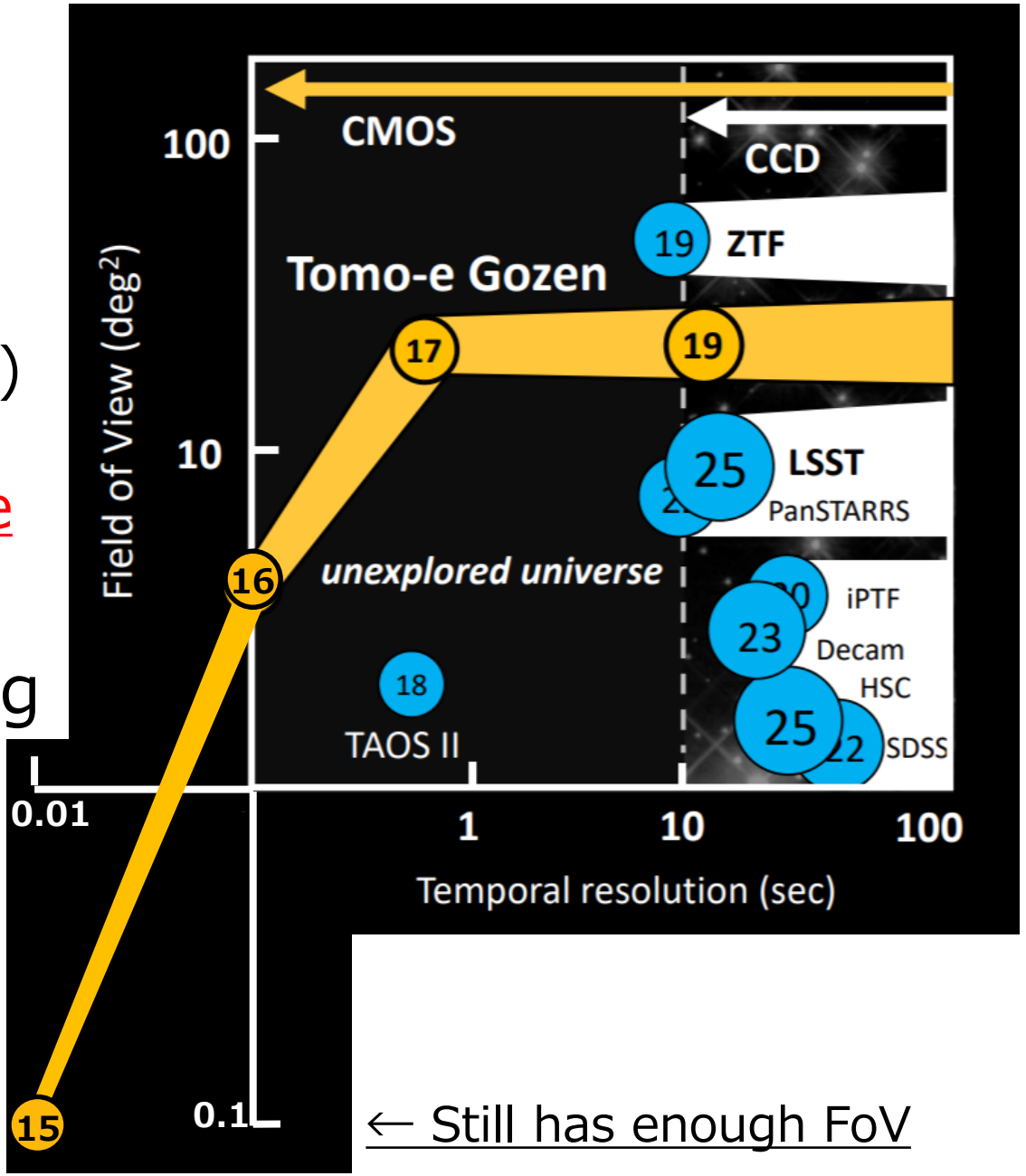


slide:
Shigeyuki Sako

Survey power for transients

280 * 24 pix^2
(FoV = 0.05 deg^2)
->
5.2 msec cadence

Transient or Pulsating Objects that have ~10msec time scale can be searched by Tomo-e

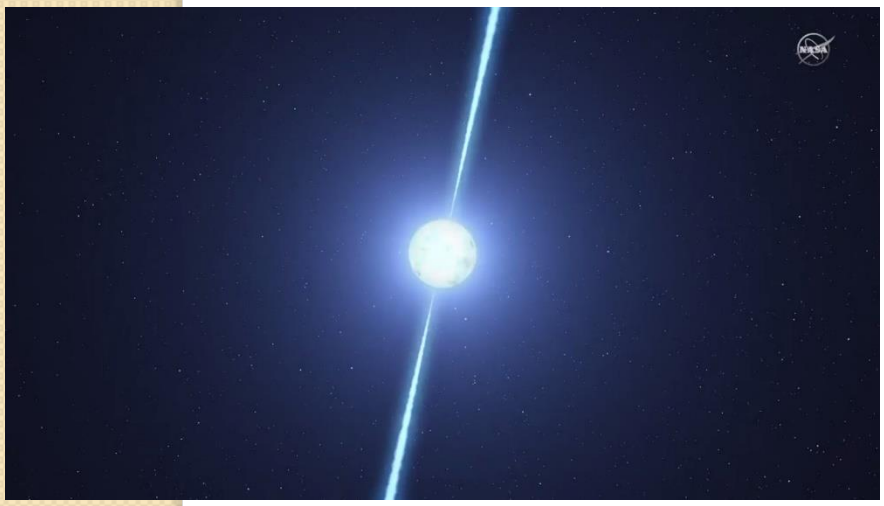


← Still has enough FoV

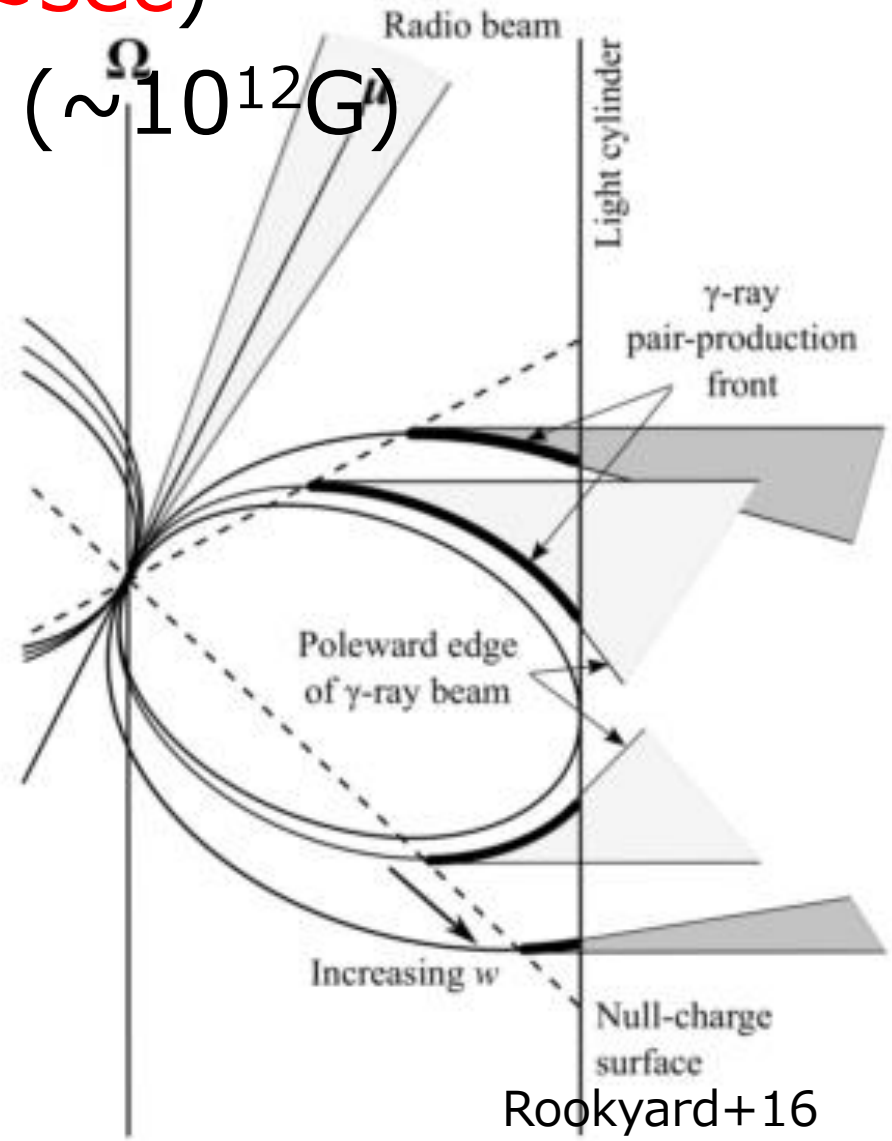
About Pulsars

What is pulsar?

- Pulsed emission (due to beaming effect)
- Fast Rotation (Period≲sec)
- Strong magnetic field (~10^{12}G)
- Neutron Star

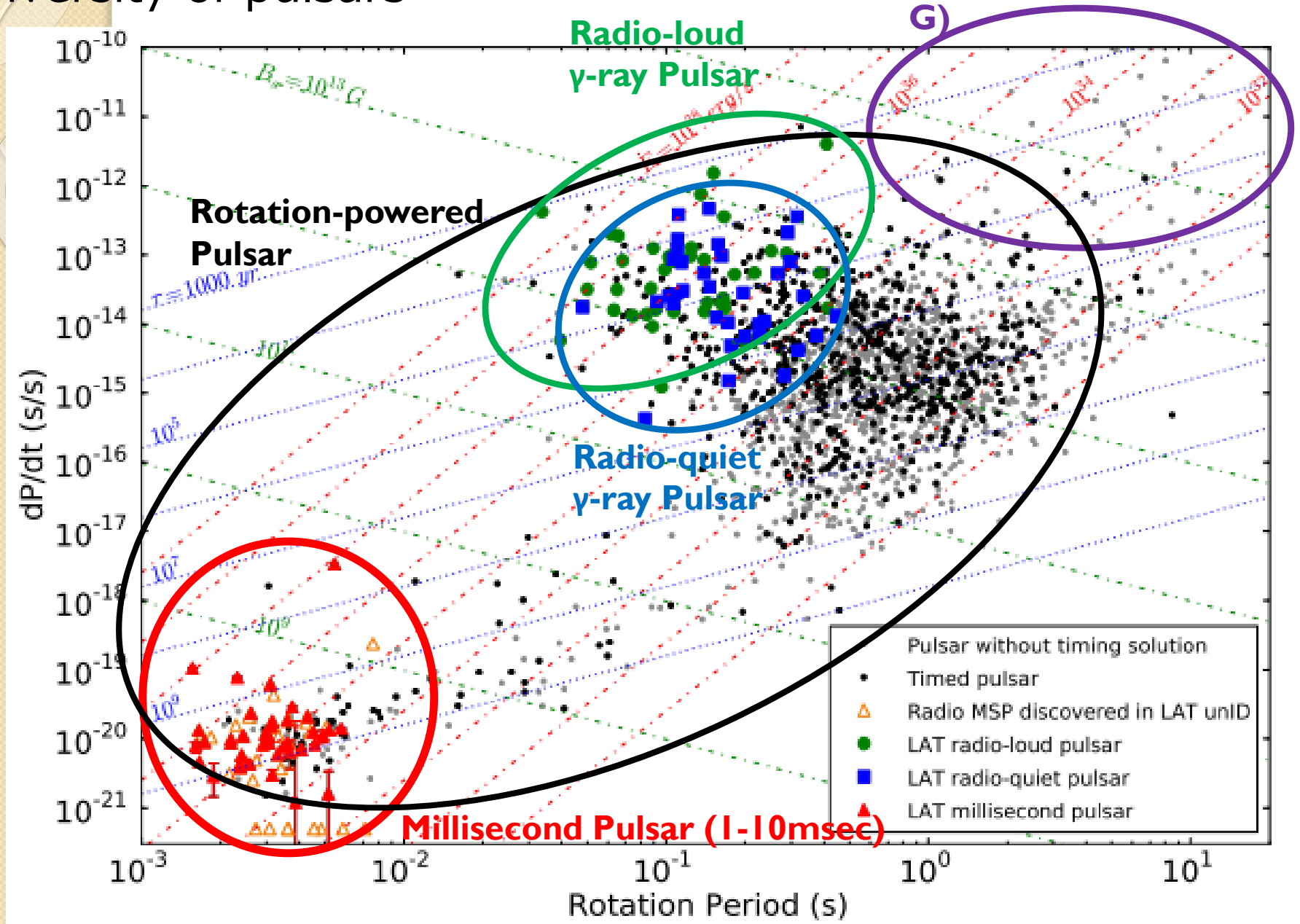


Neutron star…
Radius ~ 10km
Mass ≳ 1.4 solar mass
Only visible Nuclear matter



Rookyard+16

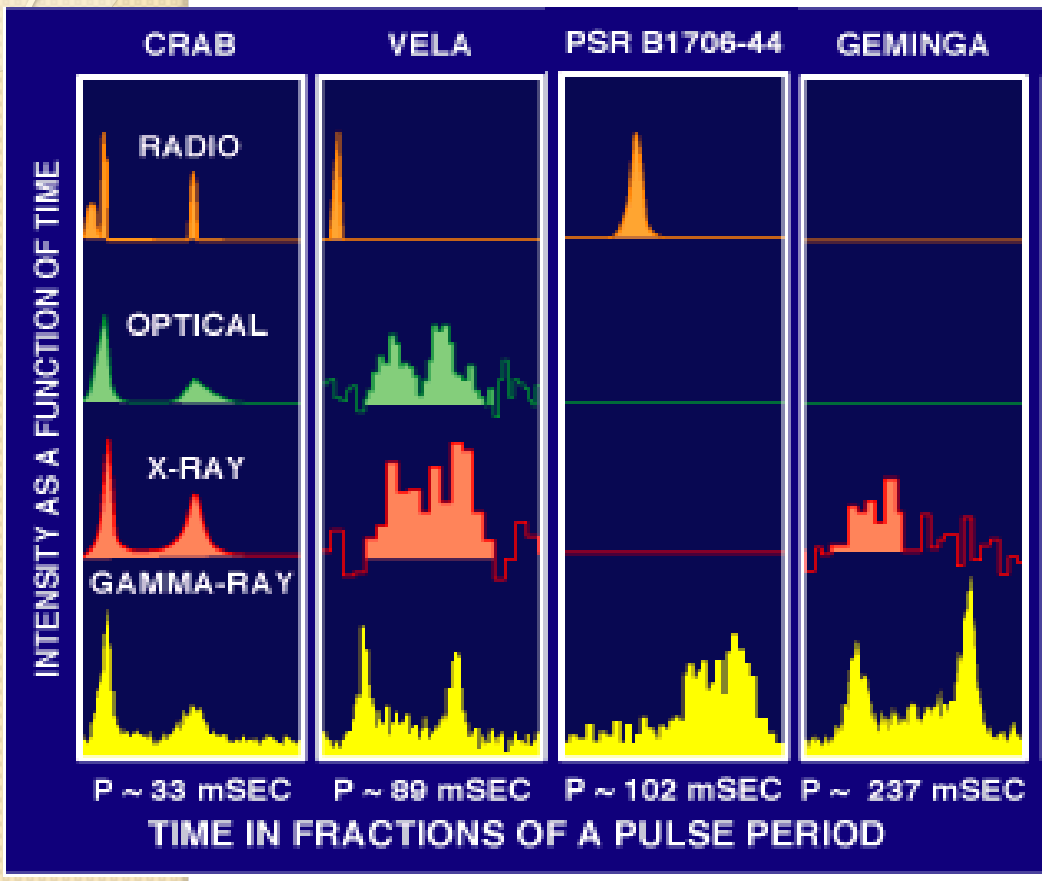
Diversity of pulsars



Abdo+13

Current status of optical observations for Pulsars

Diversity of light curve in a period



Thompson 04

in Radio,
~2000 pulsars
are detected.

In X-ray
~400 pulsars

In γ-ray
~200 pulsars

In optical bands,
only 5 phase-resolved pulsars are detected.

All optical pulsars have been detected
only by follow-up observation for Radio/X･γ-ray survey.

Pulsar observation by Tomo-e

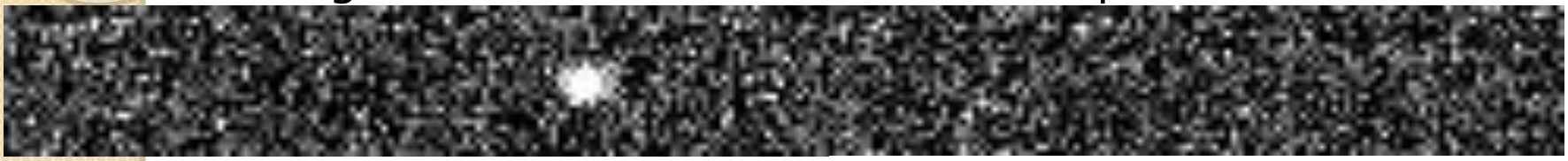
Test Observation for Crab Pulsar

Test observation for Crab pulsar

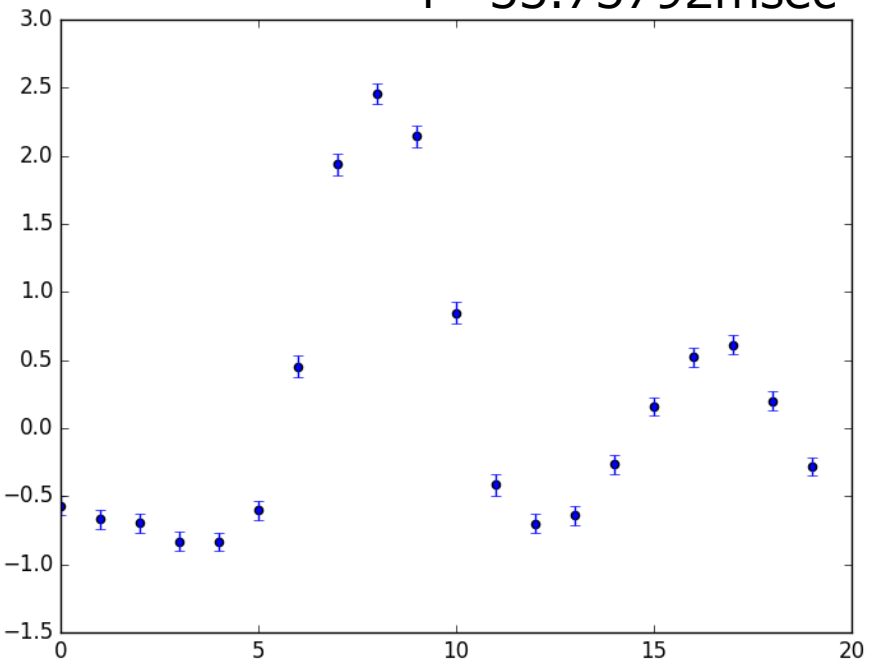
↓Mean image for 50000 frames (322 sec)

Oct. 2017 by Tomo-e Q0

↓ “Mean image of Peak 10000 frames” – “Off-peak 40000 frames”



P=33.73792msec



frames	Pulses	SD	S/N
100	∼20	0.73	8
300	∼70	0.46	13
1000	∼200	0.27	22
3000	∼700	0.19	30
10000	∼2000	0.13	50

Relation between
number of frames and S/N

Sufficient S/N for pulsar survey

Optical pulsar survey plan by Tomo-e Gozen

Survey Parameters

Conditions

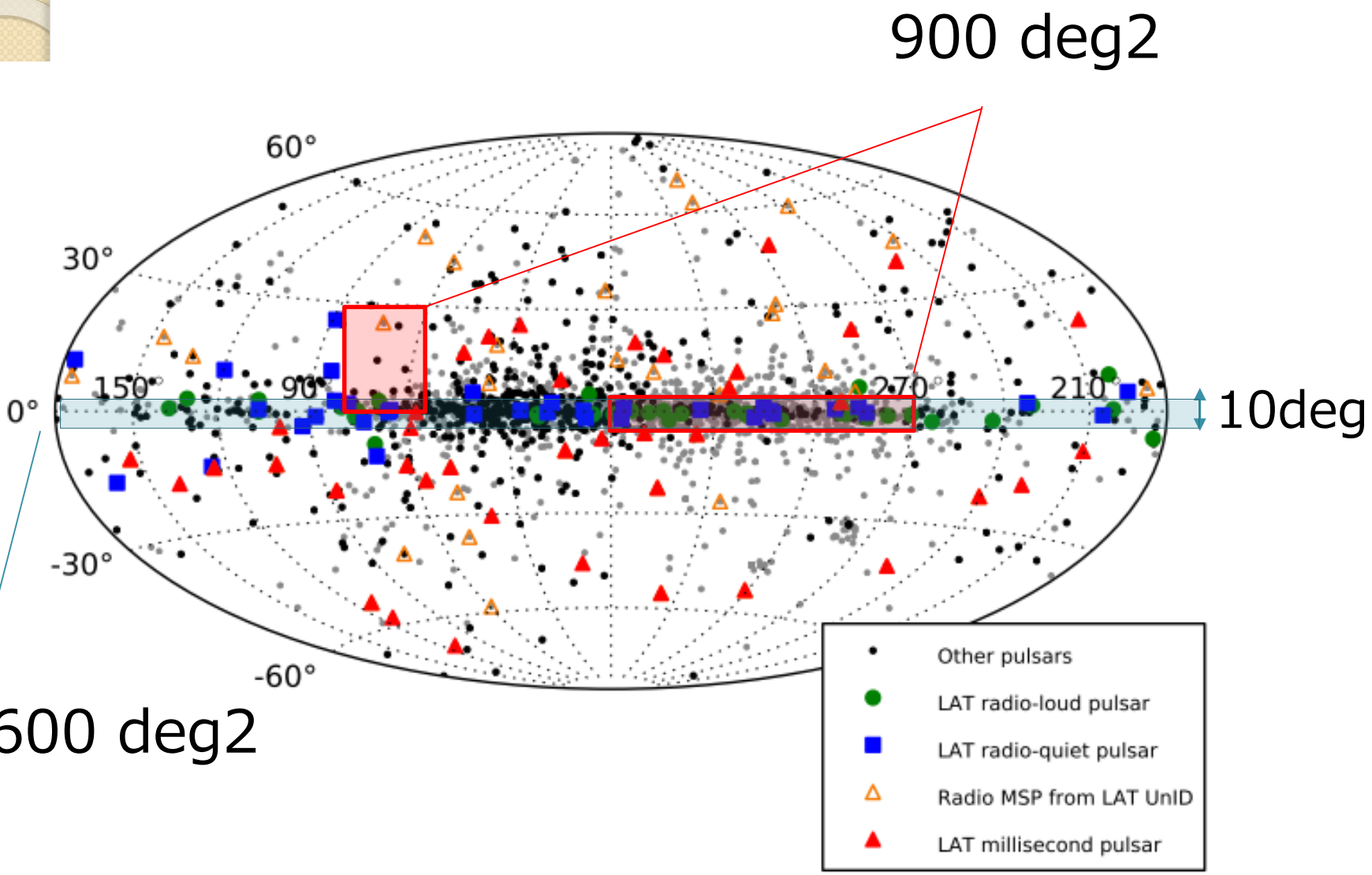
- FoV of Tomo-e Gozen (180Hz): 0.04 deg^2
- Time for Telescope moving: 6 sec

Parameters

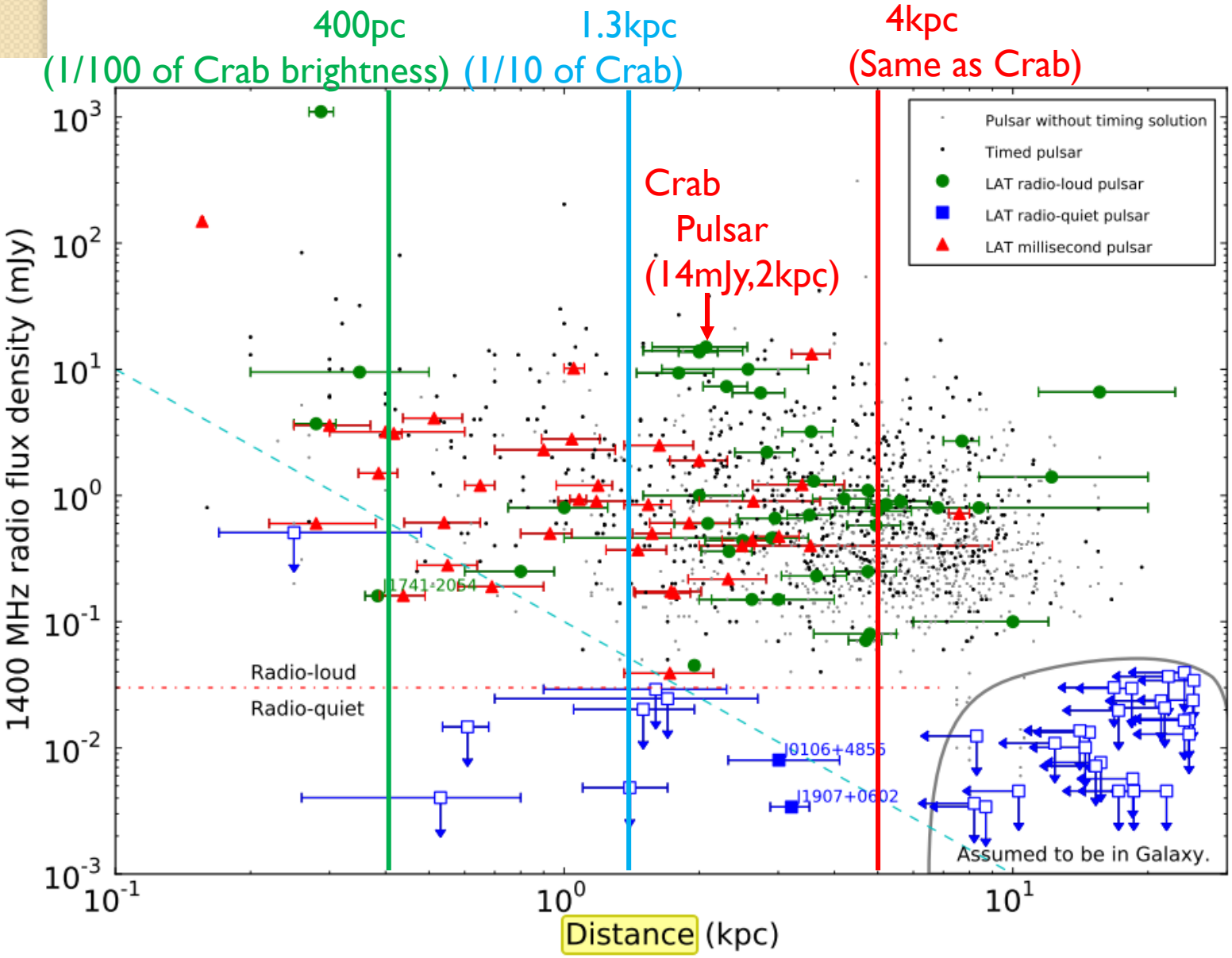
- Total Exposure time
- Total Observation time

e.g. Observation of 6 sec/FoV for 10 nights
gives 950 deg^2
(x 4 season = 3800 deg^2)

Survey Area

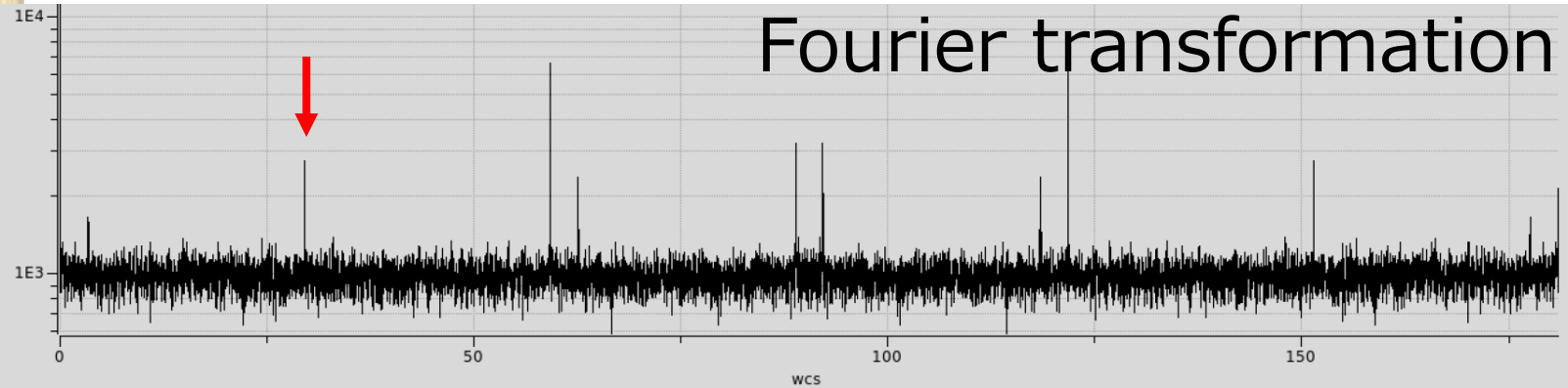

900 deg2
60°
30°
0°
-30°
-60°
150°
90°
270°
210°
10deg
3600 deg2
Other pulsars
LAT radio-loud pulsar
LAT radio-quiet pulsar
Radio MSP from LAT UnID
LAT millisecond pulsar

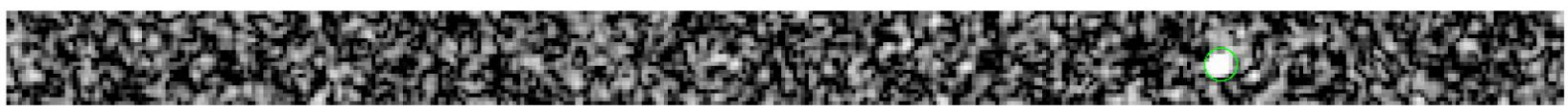
Survey depth (for 6 sec /FoV)



- Detecting pulsars that have unknown periods can be done with Fourier Transformation.

(Father studies)





Simultaneous observations with Radio and X-ray

- In Crab Pulsar, it is reported that its optical pulses are ~3% enhanced when Giant Radio Pulses occur.

Simultaneous observations have been done by Tomo-e with Radio (Kashima NICT) and X-ray (NICER)

2018/03/13-14

2018/04/07

2018/12/26-30

Now under analysis

One of the good points of Tomo-e for this obs. is that its wide field allows us to use reference stars for comparing different obs. periods.

Thank you!