Discovery of the Pulsar J2016+3711 in Supernova Remnant CTB87 with FAST

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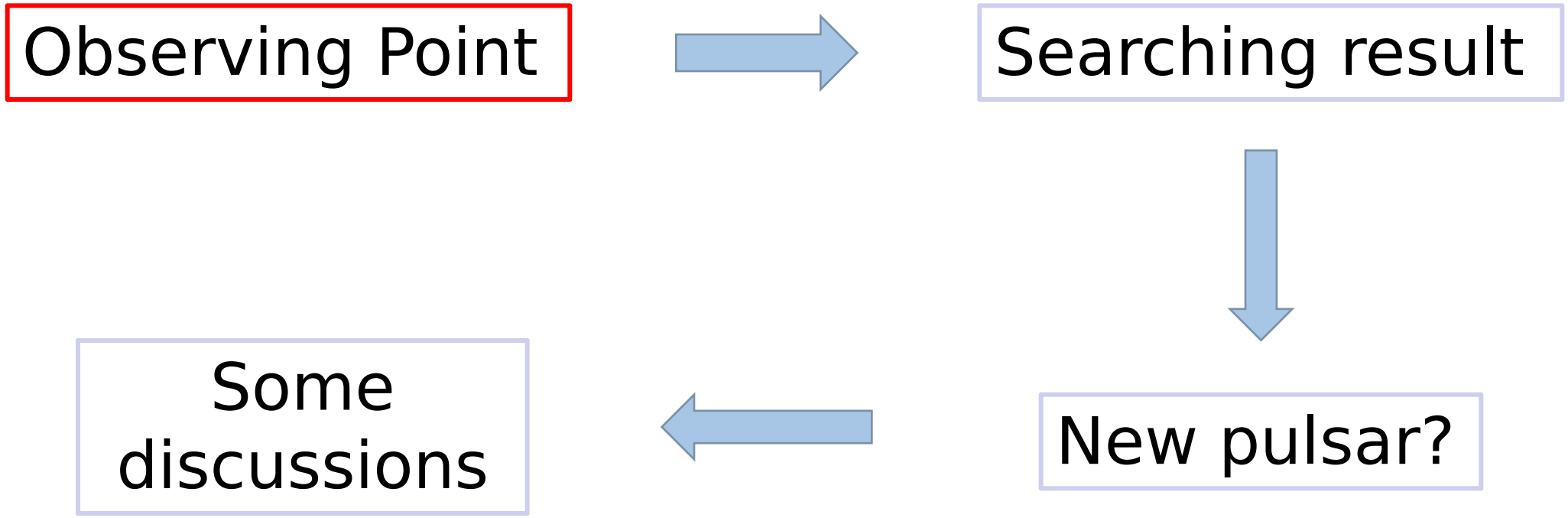
Introduction

- Pulsar Wind Nebula (PWN):
  - An important component of supernova remnant (SNR)
  - Produced by relativistic winds of rotation powered neutron star
  - Containing pulsar
- Searching pulsar in PWN can:
  - Study the pulsar formation and the SN explosion mechanism
  - Bridge the gap between the theoratic and observation

Our work: Searching the radio pulse toward the PWN



Observation

- In the 2019 'risk-sharing' observation
- Using FAST, central beam
- 1.05 - 1.45GHz receiver
- 4096 frequency chanels
- Time resolution: 49.152us
- Toward 5 targets
- HPBW ~ 3.5' at 1.1GHz

Observation

- Using FAST, central beam
- In the 2019 'share
  observation
- 1.05 - 1.45GHz rec
- 4096 frequency ch
- Time resolution: 4
- Toward 5 targets
- HPBW ~ 3.5' at 1.1

Name	RA	Dec	LST Rise	LST Set	Integration time (s)	Repeats
CTB 87	20:16:09.2	37:11:10.5	18:30	22:10	3600	1
HESS J1832-093 (G22.7-00.2)*	18:32:45.04	-09:21:53.9	17:20	19:50	3600	1
3C 396	19:04:04.7	05:27:11.8	17:50	19:20	3600	1
DA 495	19:52:12	29:25	18:00	21:50	3600	1
DA 530*	20:52:20	55:17	18:30	22:30	3600	1

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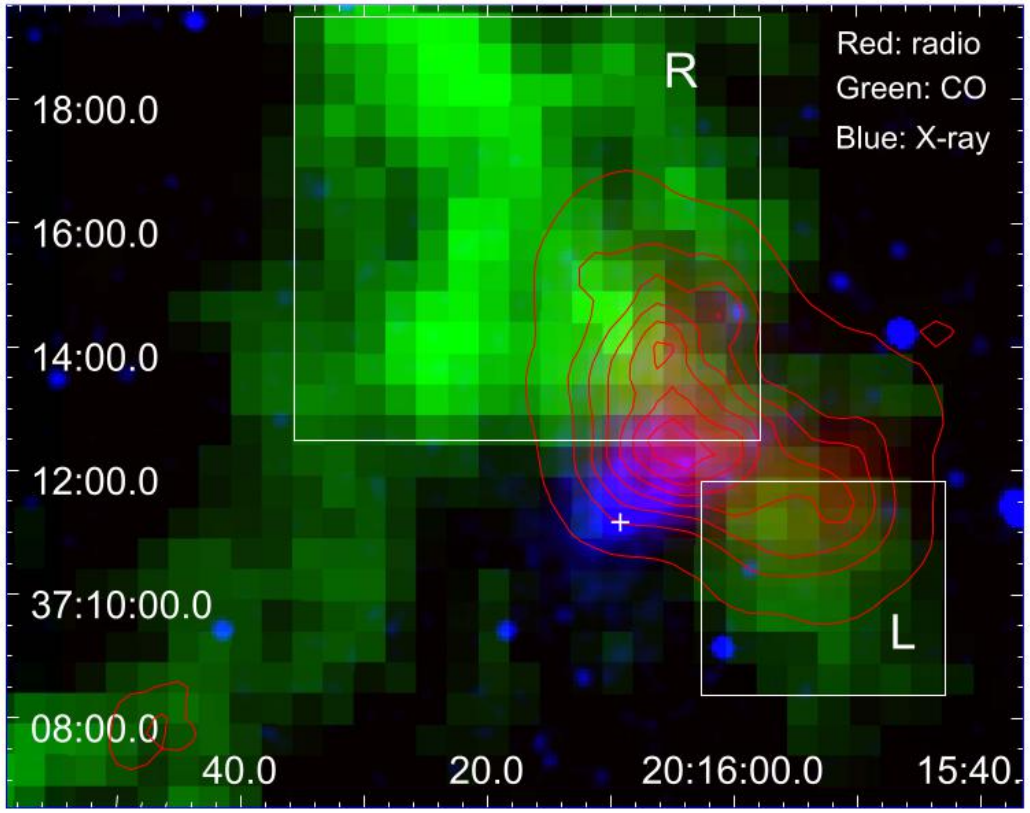
DA 530*	20:52:20	55:17	18:30	22:30	3600	1

Unfortunately, only two target's data are usable

SNR CTB87

- A filled-center-type SNR
- l=74.9 b=+1.2
- Distance: ~6.1kpc
- X-ray: PWN + point source
- Associated with MC at ~-58km/s
- Located in a superbubble



Multiwave map of CTB87
---- Liu et al. 2018

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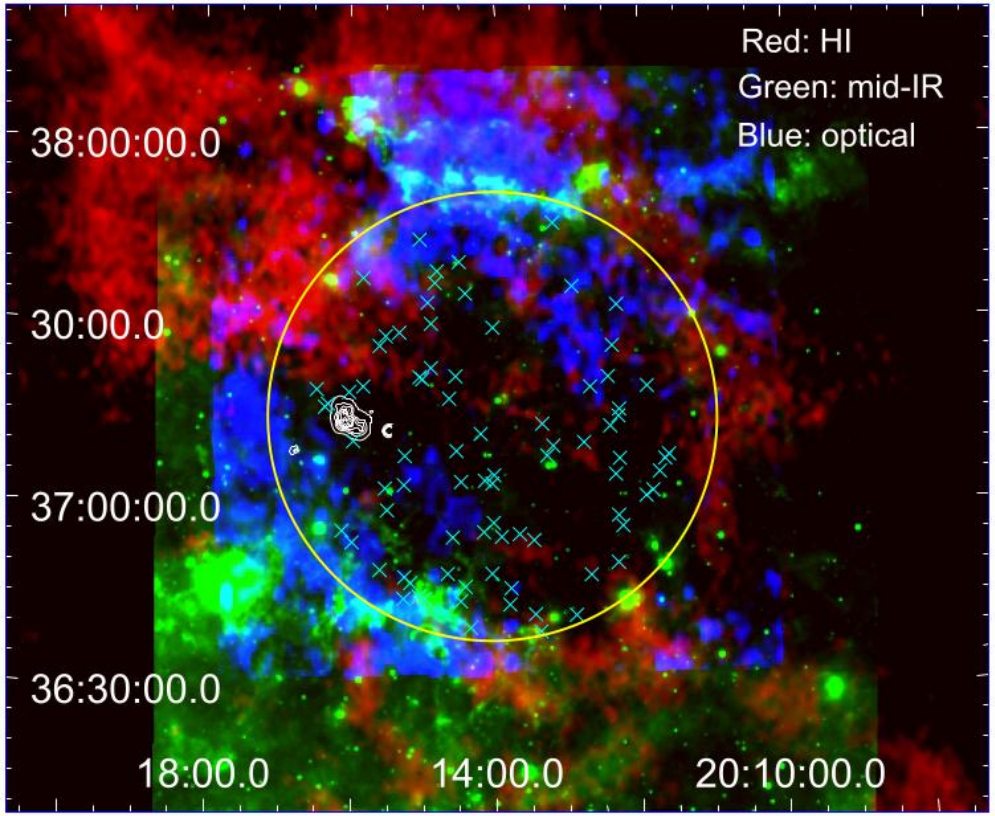

Multiwave morphology of the superbubble toward CTB87
---- Liu et al. 2018

Observation

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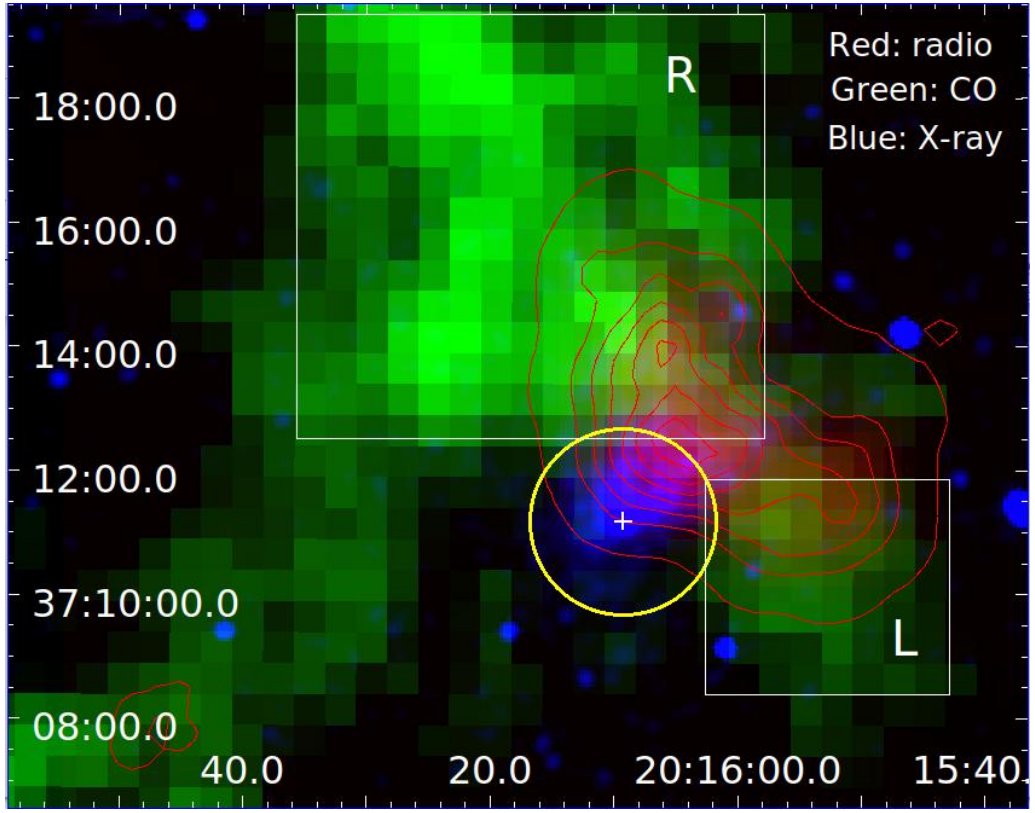
- Toward 2/5 targets
- HPBW ~ 3.5' at 1.1GHz



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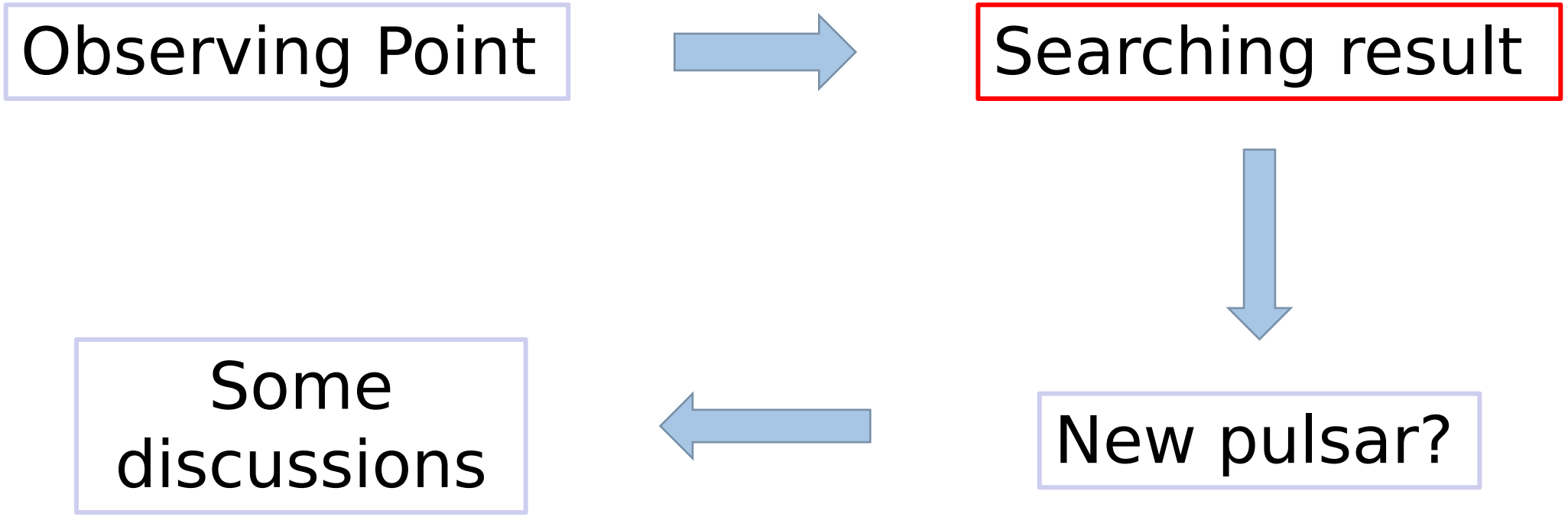
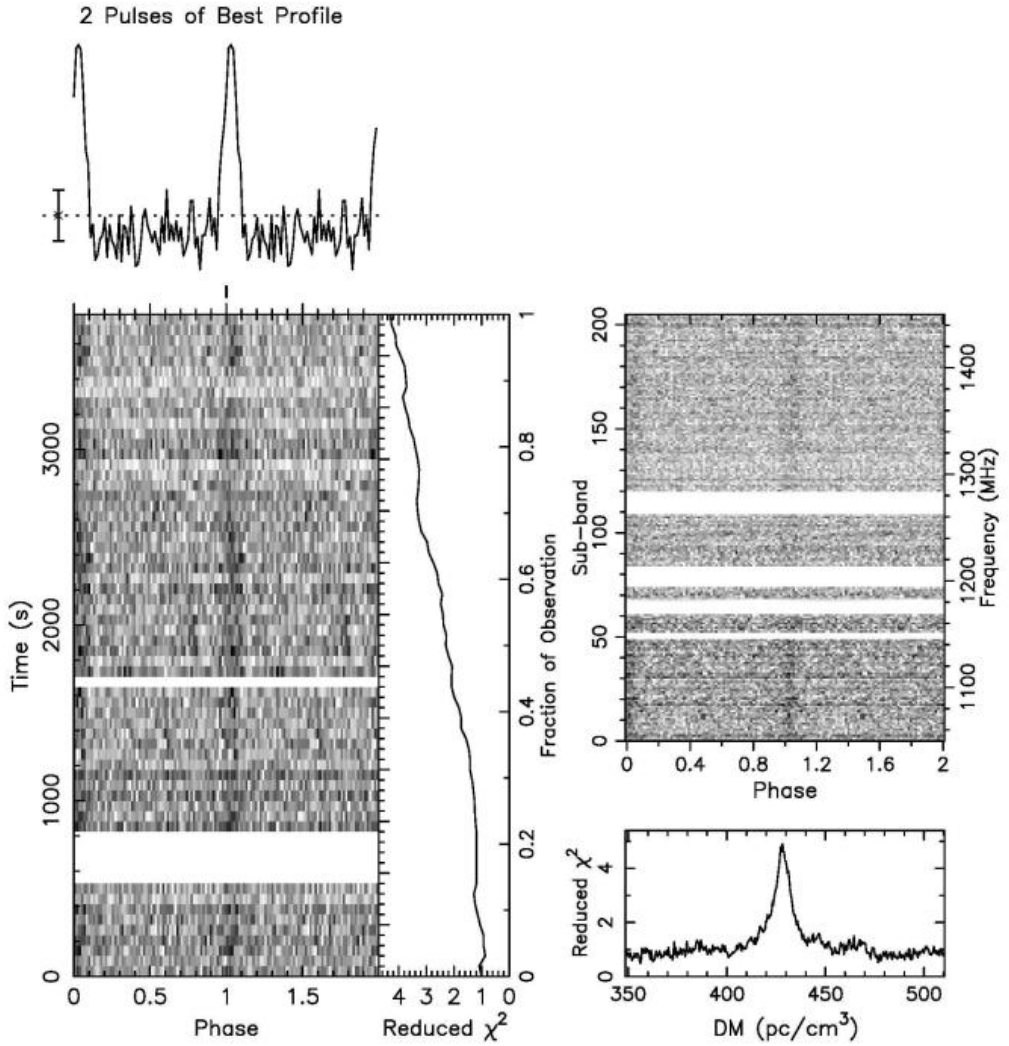


Detected radio pulses toward SNR CTB87

1. Significance: 10.8
2. P ~ 50.8 ms,

   DM ~ 430 pc cm^{-3}
3. d_{DM} = 13.3kpc vs.

   d ~ 6.1kpc
4. Yet no significant γ-ray pulsation have been found



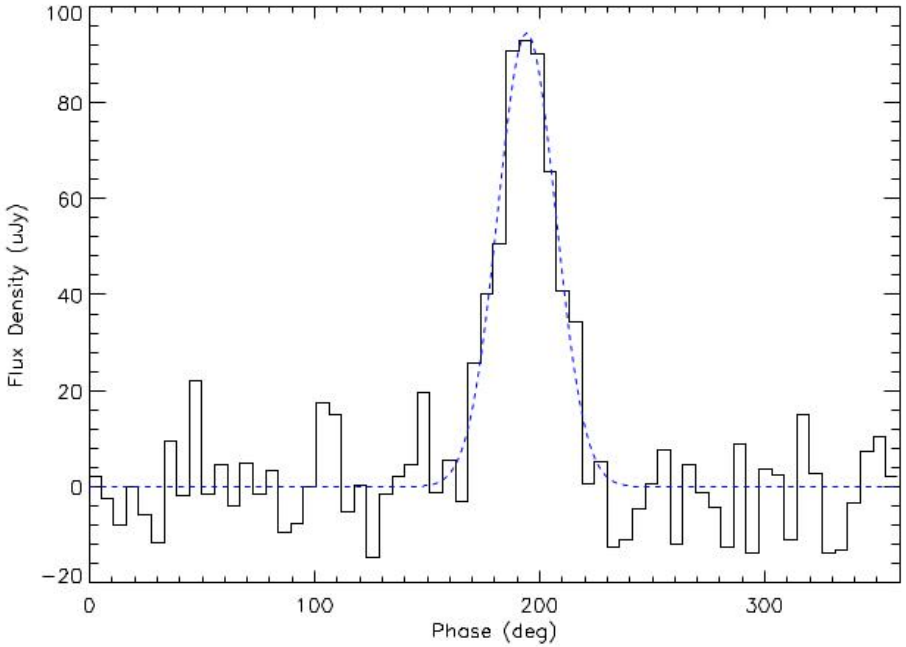
The integrated pulse profile

Can be well described by a single Gaussian component

The width of the profile:

W50 ≈ 28.1°

Weff ≈ 32.2°



Integrated pulse profile

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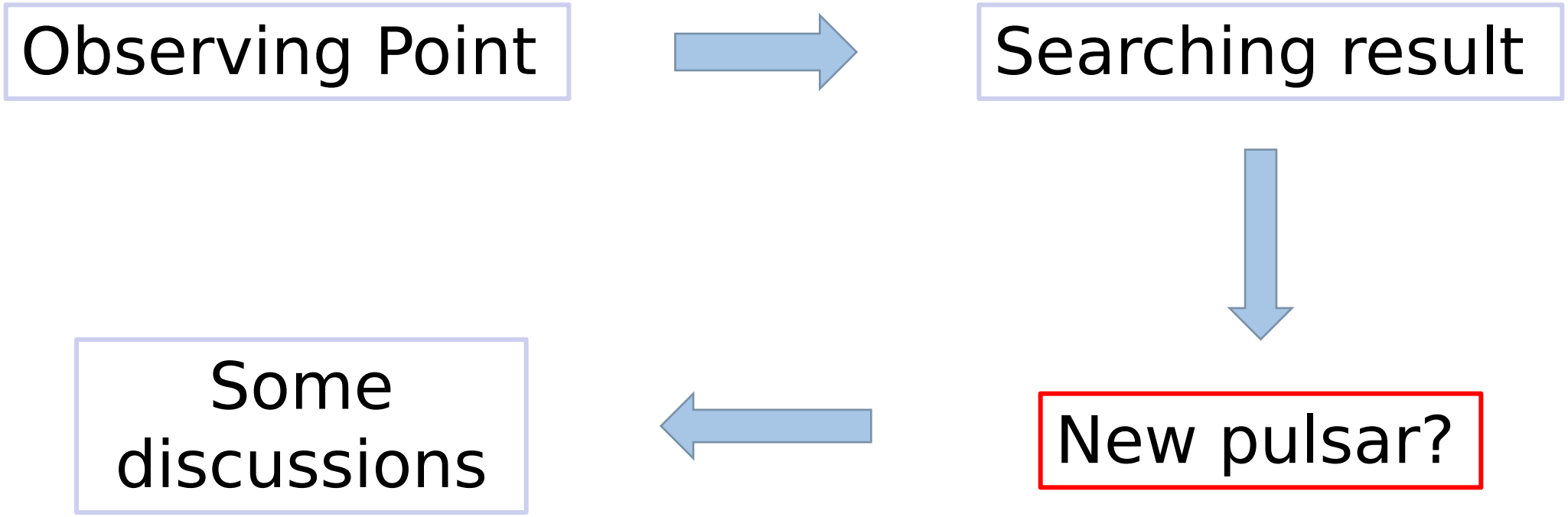

Is the radio pulse from a new discovered pulsar?

Pulsar	RA	Dec	Offset (degree)	DM (pc cm^{-3})	Period (ms)
J2004+3429	20:04:46.9	+34:29:17.7	3.55	351.0	240.95
J2005+3411g	20:05:45	+34:11	3.77	489.0	651.05
J2005+3547	20:05:17.4	+35:47:25.4	2.59	401.6	615.03
J2005+3552	20:05:47.5	+35:52:24.3	2.46	455.0	307.94
J2010+3230	20:10:26.5	+32:30:07.3	4.83	371.8	1442.45
J2021+3651	20:21:05.4	+36:51:04.8	1.04	367.5	103.74
J2022+3842	20:22:21.6	+38:42:14.8	1.95	429.1	48.58
J2022+3845g	20:22:11	+38:45	1.76	487.5	1008.90
J2030+3929g	20:30:47	+39:29	3.41	491.9	1718.42

Known pulsars near our target in 5^{o} region with DM in 330 - 530

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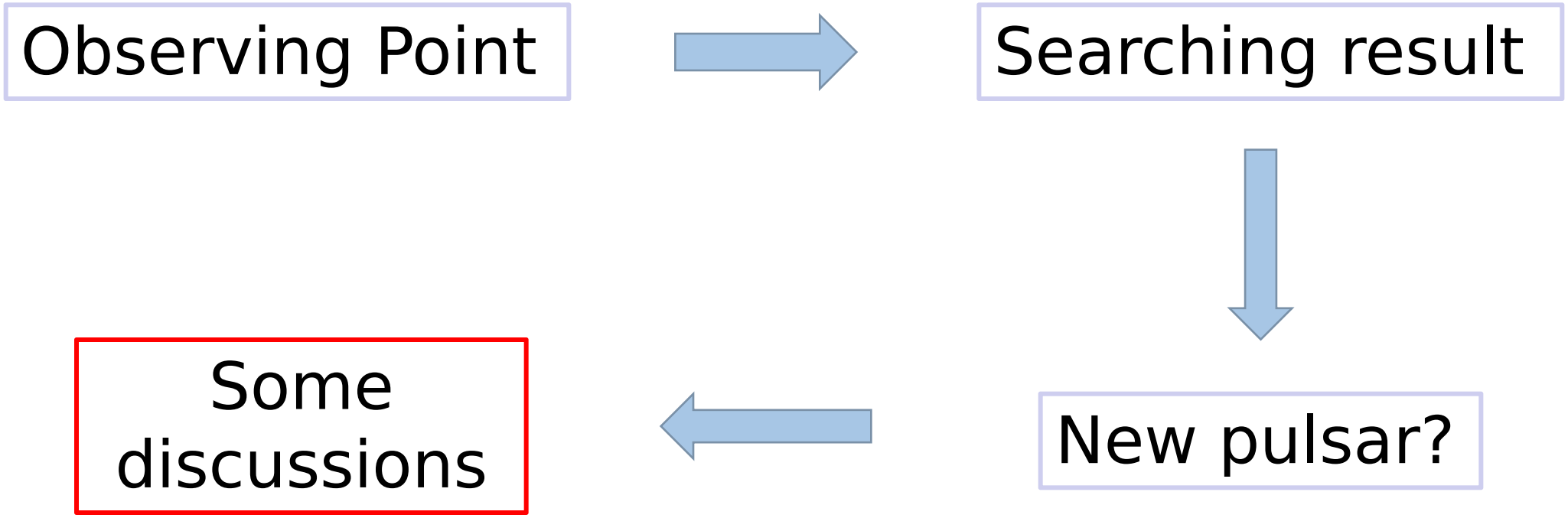


Flux density of the pulsar

- Mean flux density ~ 15.5 uJy

$$F_{1.25\mathrm{GHz}} = \frac{S_{\mathrm{S/N}}\beta}{(N_p \Delta\nu\, t_{\mathrm{int}})^{1/2}} \left(\frac{W_{\mathrm{eff}}}{P - W_{\mathrm{eff}}} \right)^{1/2} \frac{T_{\mathrm{sys}} + T_{\mathrm{sky}}}{G},$$

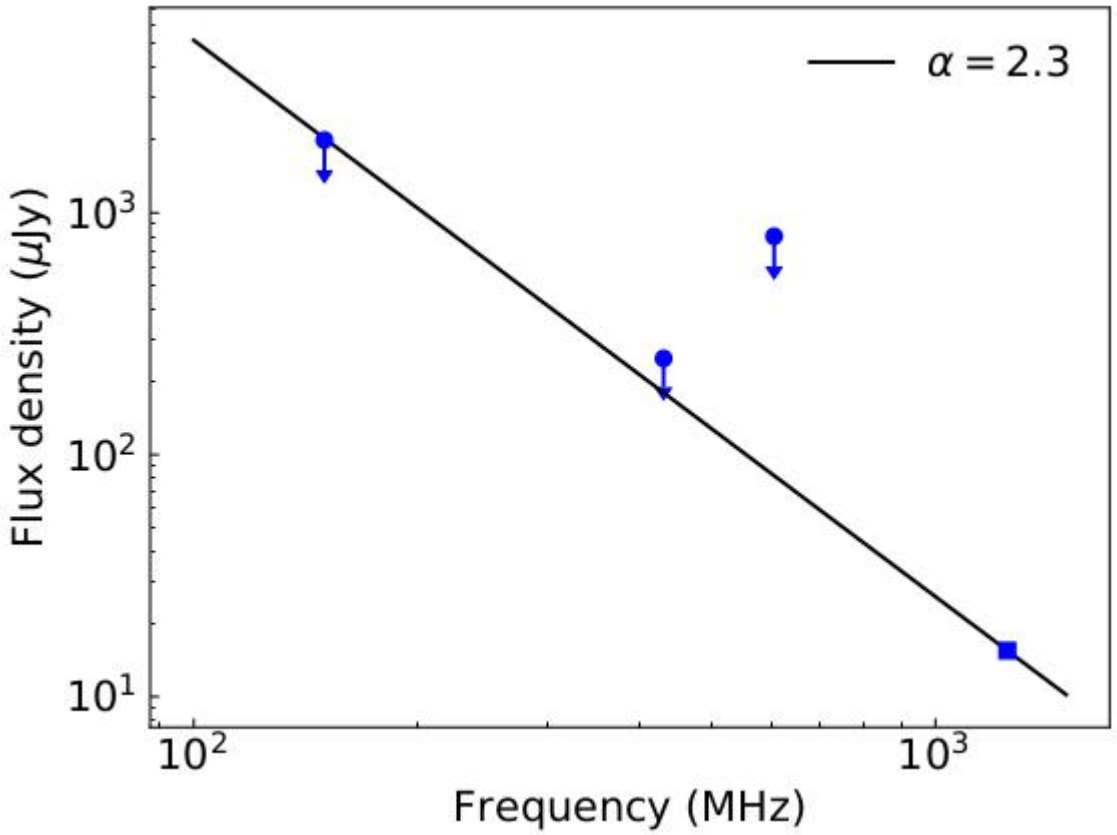
- 5σ upper limit: 2mJy at 150 MHz (straal+19), 0.25 mJy at 430 MHz (Gorham+96), 0.8 mJy at 606 MHz (Lorimer+98)

Spectral index

1. Pulsars have steep spectra
   in flux density $F_v \propto v^{-\alpha}$
2. $F_v = 15.5(v/1250)^{-\alpha}$ uJy

   -> α should < 2.3, not to contradict the typical value

Notably, some young pulsars have broken power law spectra



Other properties of the pulsar

- An estimate of the characteristic age $\tau \sim 10^4$yr was given (Matheson+ 13)
- $P_{dot} = P/[(n-1)\tau] \sim 8.5\times10^{-14}$ s s^{-1}
- Surface dipole magnetic field $B \sim 2.1\times10^{12}$ G

- P_{dot} , τ, and B are crudely estimated -> need ToA observation to precisely measure/estimate them

Thanks!