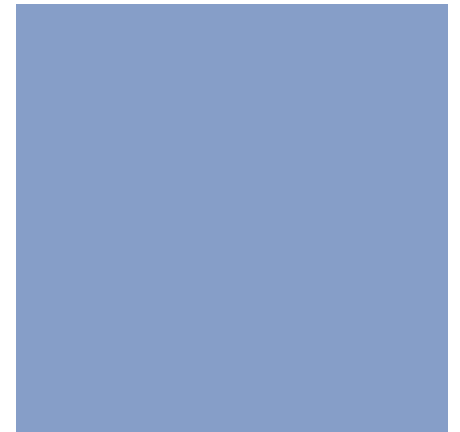
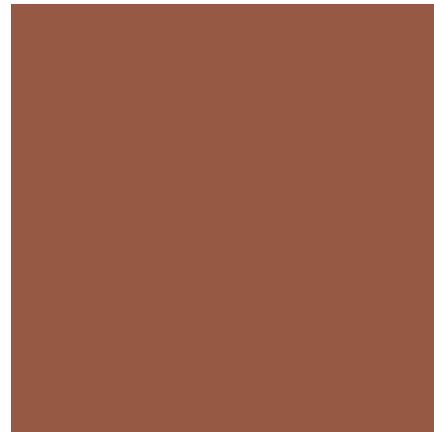




ALMA, ATCA  
Observations of the  
gamma-ray binary  
PSRB 1259-63/  
LS2883



Akiko KAWACHI (Tokai University)  
... Y. Fujita, T. Akahori, H. Nagai  
& M. Yamaguchi



## Outline

- PSR B1259-63/ LS2883 binary .. Parameters and non-thermal emissions
- ATCA 3mm observations  
ALMA 3mm and sub-mm observations and results
- Discussions

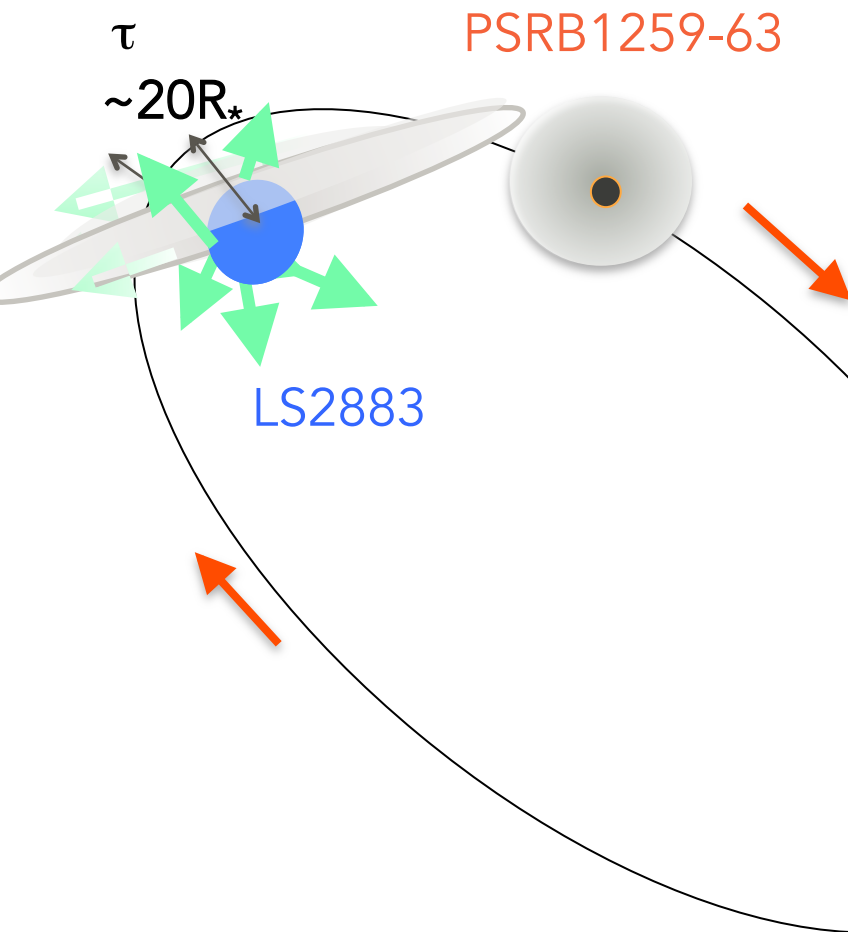
*“First detection of PSR B1259-63/  
LS 2883 in*

*the millimeter and sub-millimeter  
wavelengths with ALMA”,*

*Fujita+, PASJ in printing*

*arXiv: 1904.08429*

+ PSR B1259-63/ LS2883  
a binary of pulsar + Be star

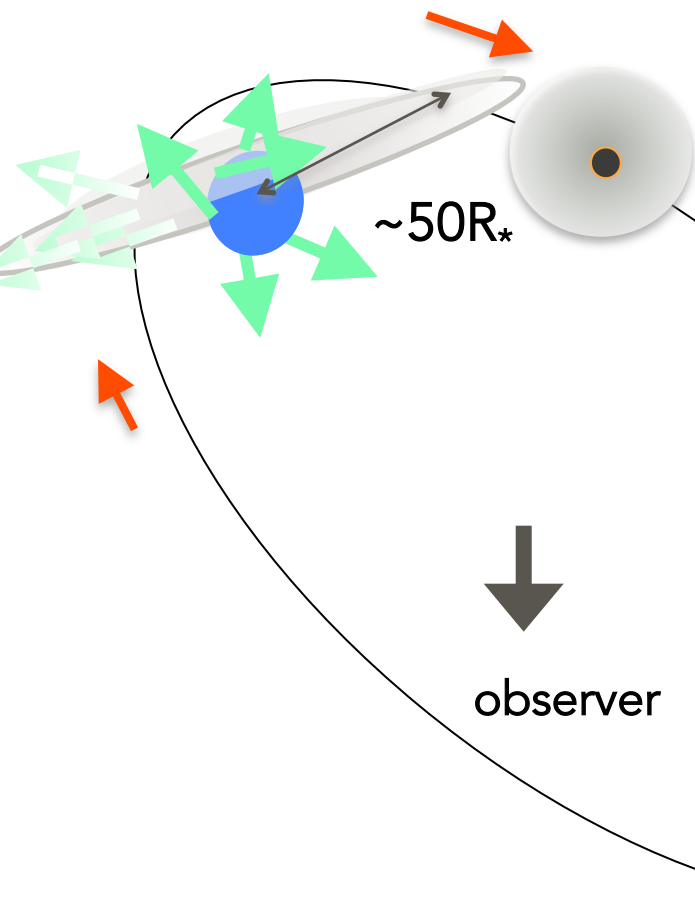


$P = 47.76 \text{ msec}$   
 $\dot{E} = 8.3 \times 10^{35} \text{ erg/s}$

Type = O9.5Ve  
 $M_* \sim 31 M_\odot$     $R_* \sim 9.2 R_\odot$   
 $d = 2.6 \text{ kpc}$

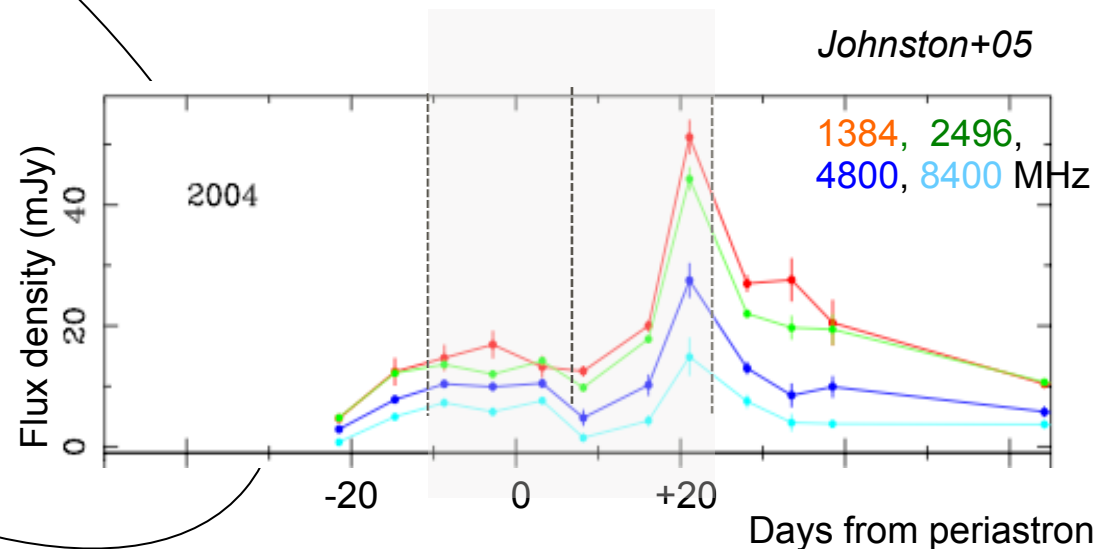
Highly eccentric ( $e=0.87$ ) orbit  
Orbital period = 3.4 yrs

# + Pulse eclipse at periastron passage & unpulsed Emissions



**No pulse** :  $\tau - 20\text{d} - \sim\tau + 20\text{d}$   
Twice disk "crossing" of pulsar  
→

Unpulsed, power-law radio  
Emissions appeared.

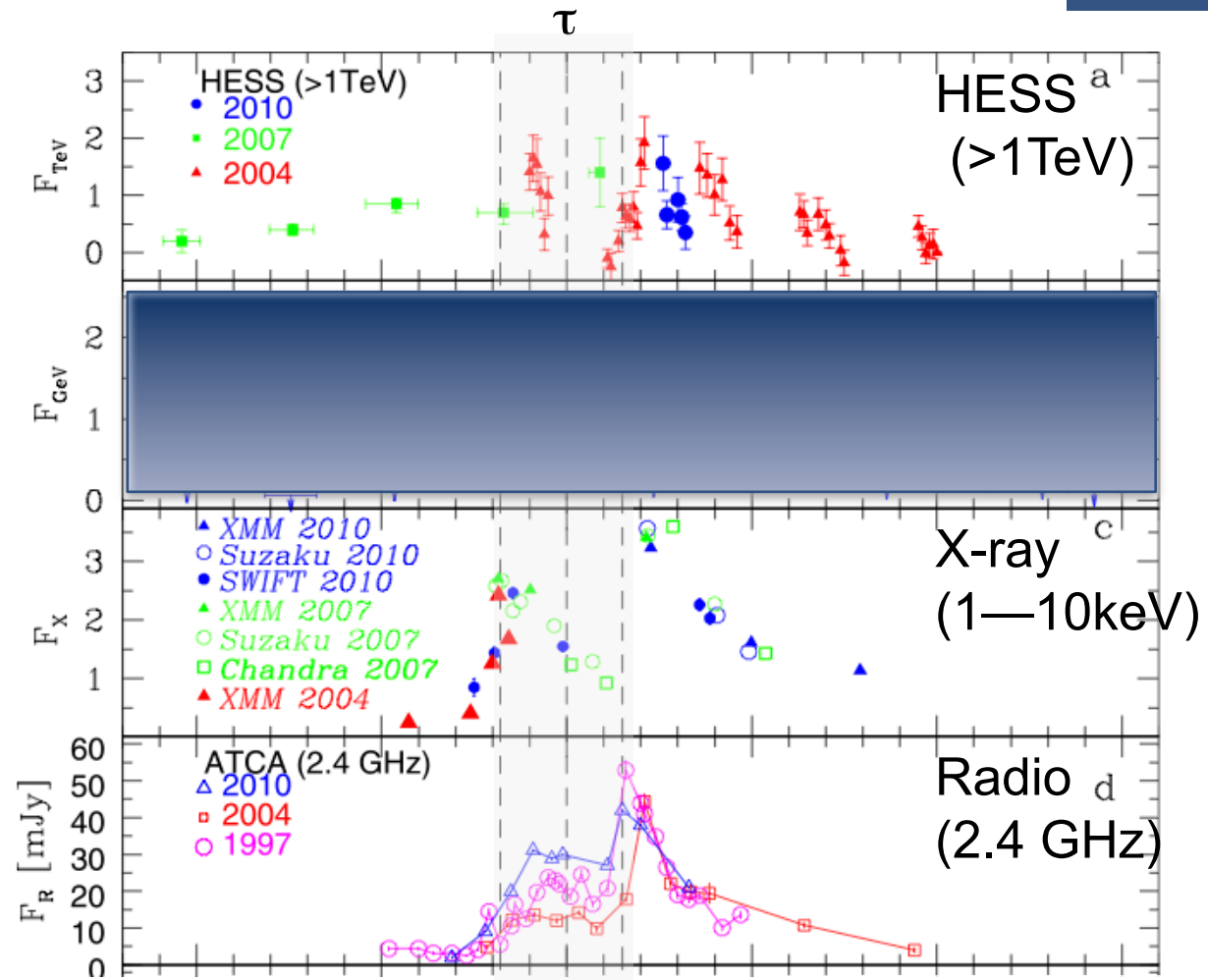


# + Non-thermal multi-wavelength emissions around periastron

■ ~two-peak flare similar feature among the bands.

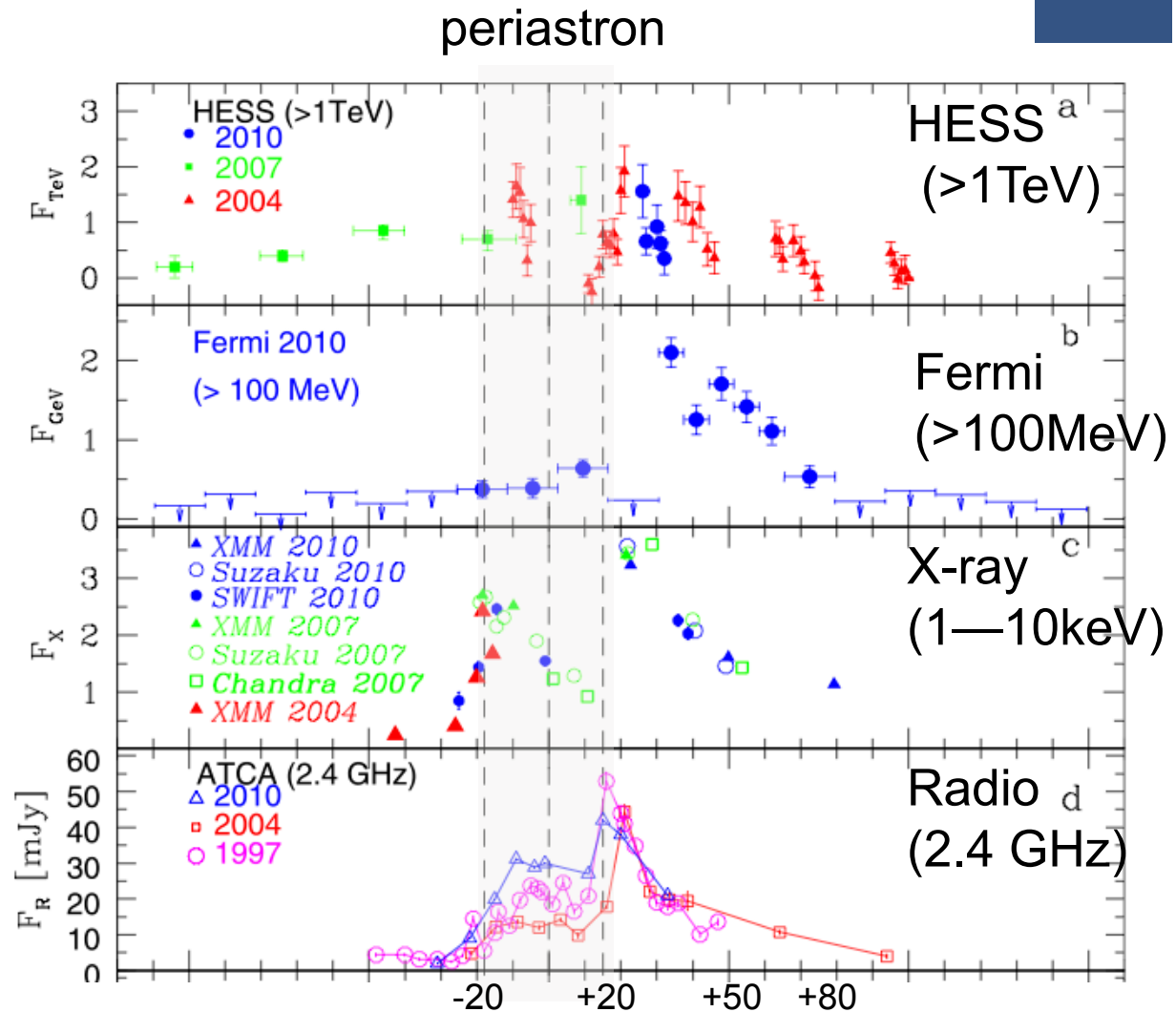
■ Pulsar wind + Stellar wind / circumstellar disk

→ accelerated electron injected ..



# + GeV flare discovered at different orbital phase

No association  
w/ the other  
Energy bands ??

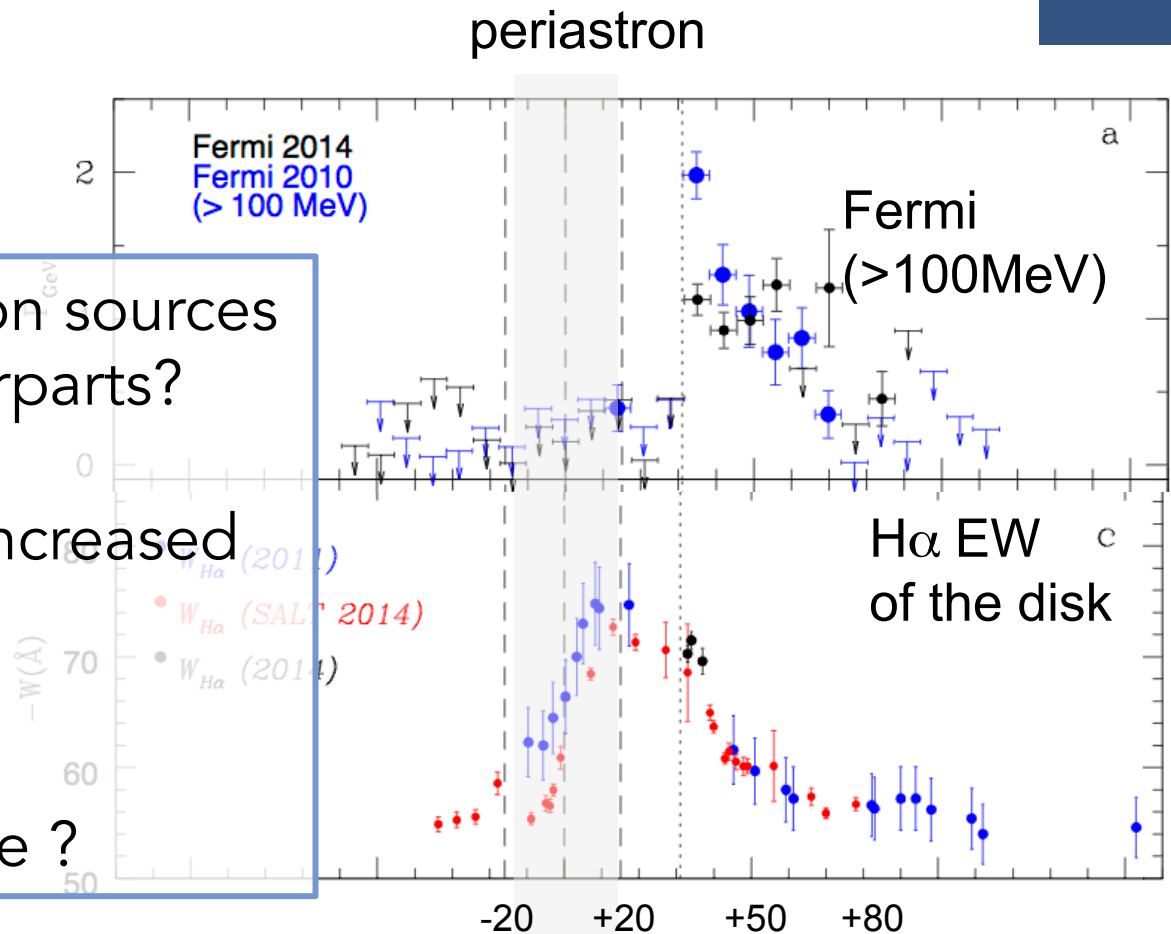


# + What's the Trigger of GeV flare

? Two injected electron sources  
X-ray/Radio counterparts?

? Brems. w/ sudden increased  
matters ?

↔ disk disrupted  
and triggered the flare ?





# Motivation for mm/sub-mm radio observations

## *Yet unexplored band*

- Link from low- $\nu$  radio to X-ray
- association with the GeV flare ?
- Sub-millimeter band may get the **circumstellar disk**

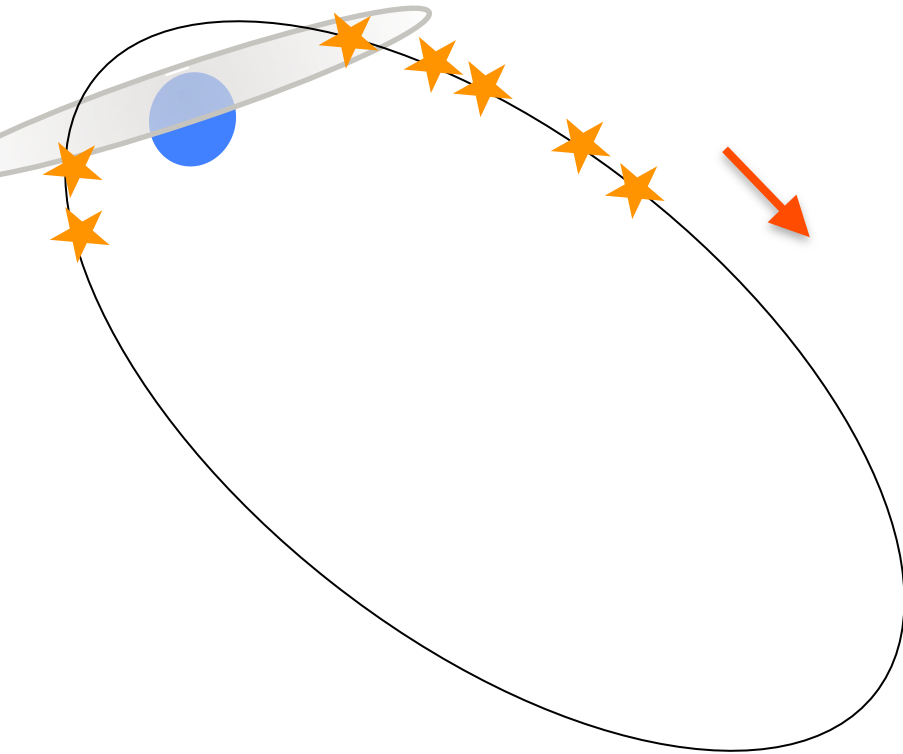
← *Contamination of Pulse ?*

Estimated to be negligible

← *Good weather preferable*



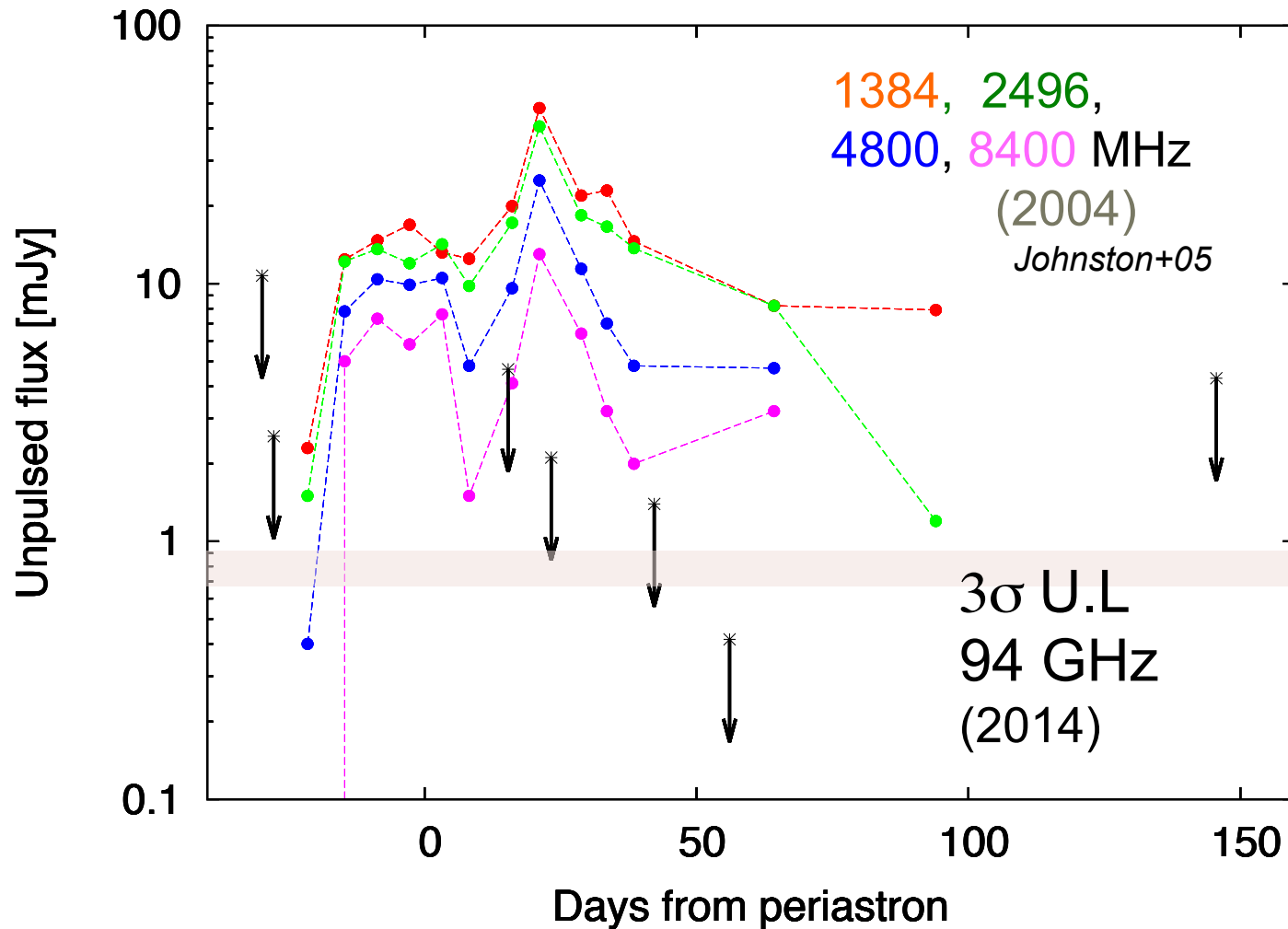
# + Australian Telescope Compact Array Observations (2014 cycle)



- 22-m antennas (5 of 6 w/ 3-mm receiver)
- Dual IF .. Mean freq. 94.0 GHz
- Several 10-min--~hour effective obs. time.
- Moderate weather conditions.
- Pulsar binning mode not applied.

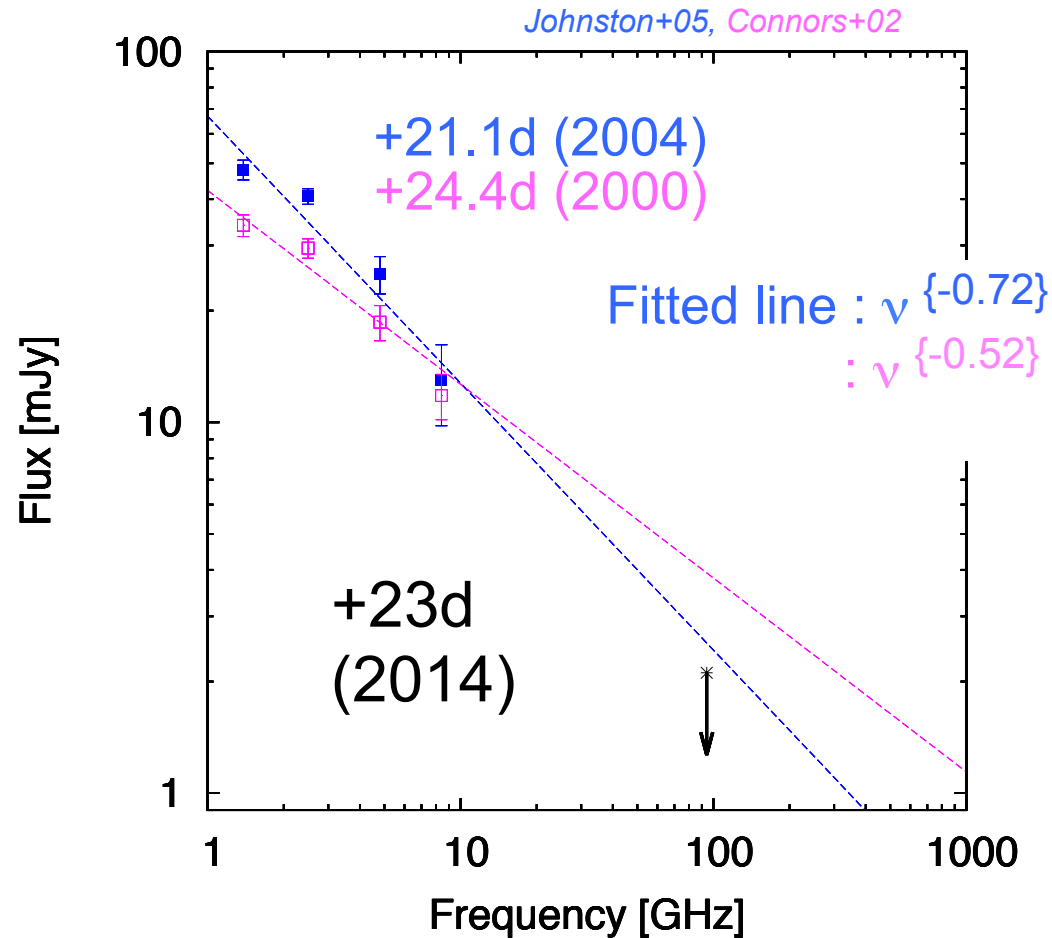


# ATCA (2014) Results .. U.L. ~a few mJy



~Expected  
Sensitivity  
if in good  
observing  
condition

- + ATCA U.L. suggests Slightly soft spectrum around 2<sup>nd</sup> peak



# + Atacama Large Millimeter/submillimeter Array Observations (2017 cycle)

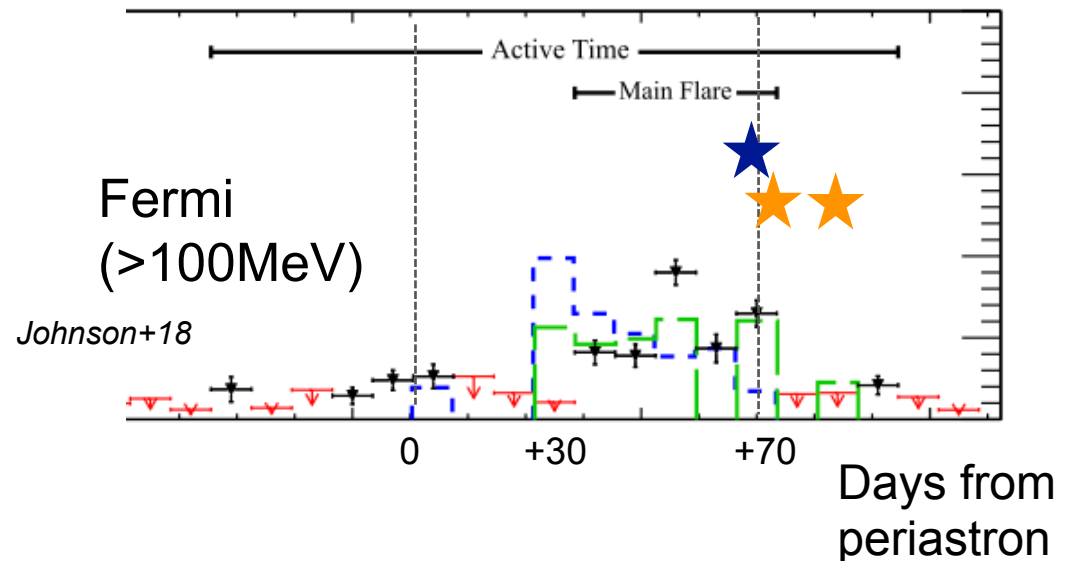
- [Band3] .. 97 GHz
- [Band7] .. 343 GHz
- 12-m antenna x 42—47
- ~5 min. effective obs. Time



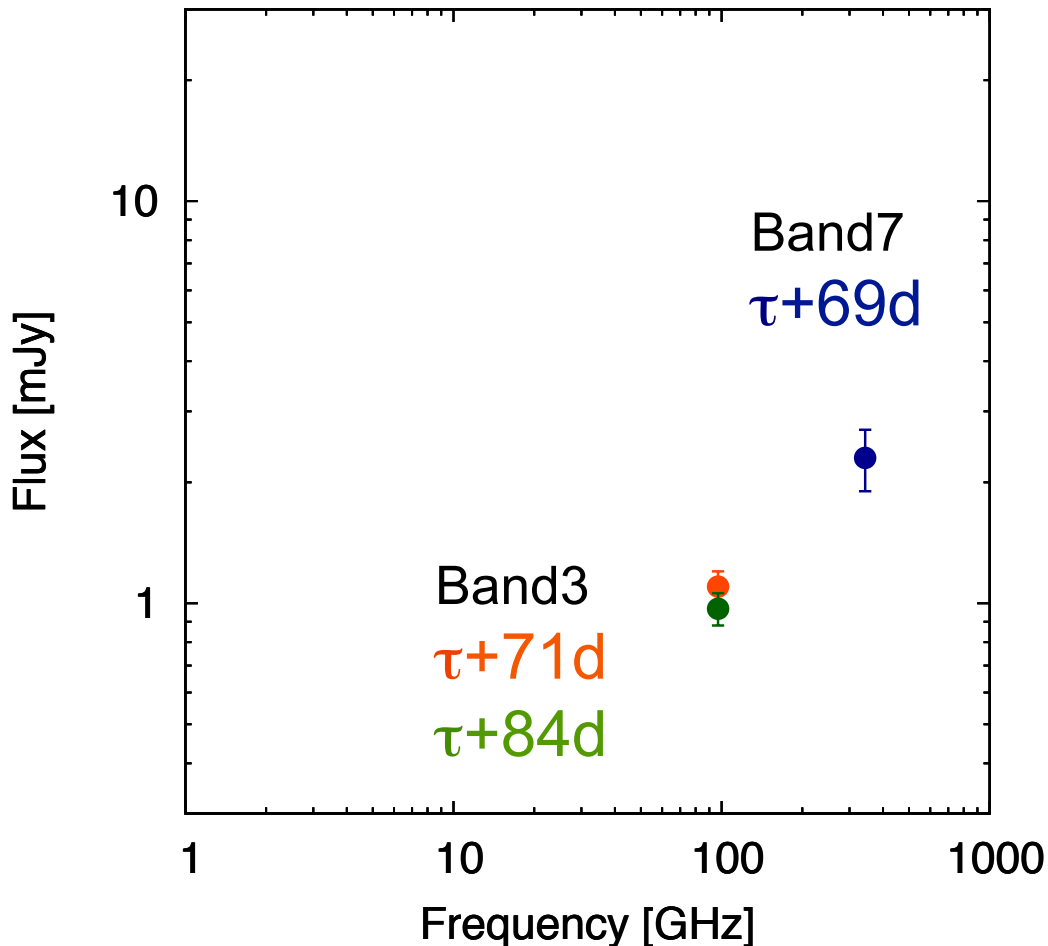
- Beam shape

~0".4 sq. for Band3

~0".05 sq. for Band7



+ ALMA (2017) Results .. a compact single source **detected**.



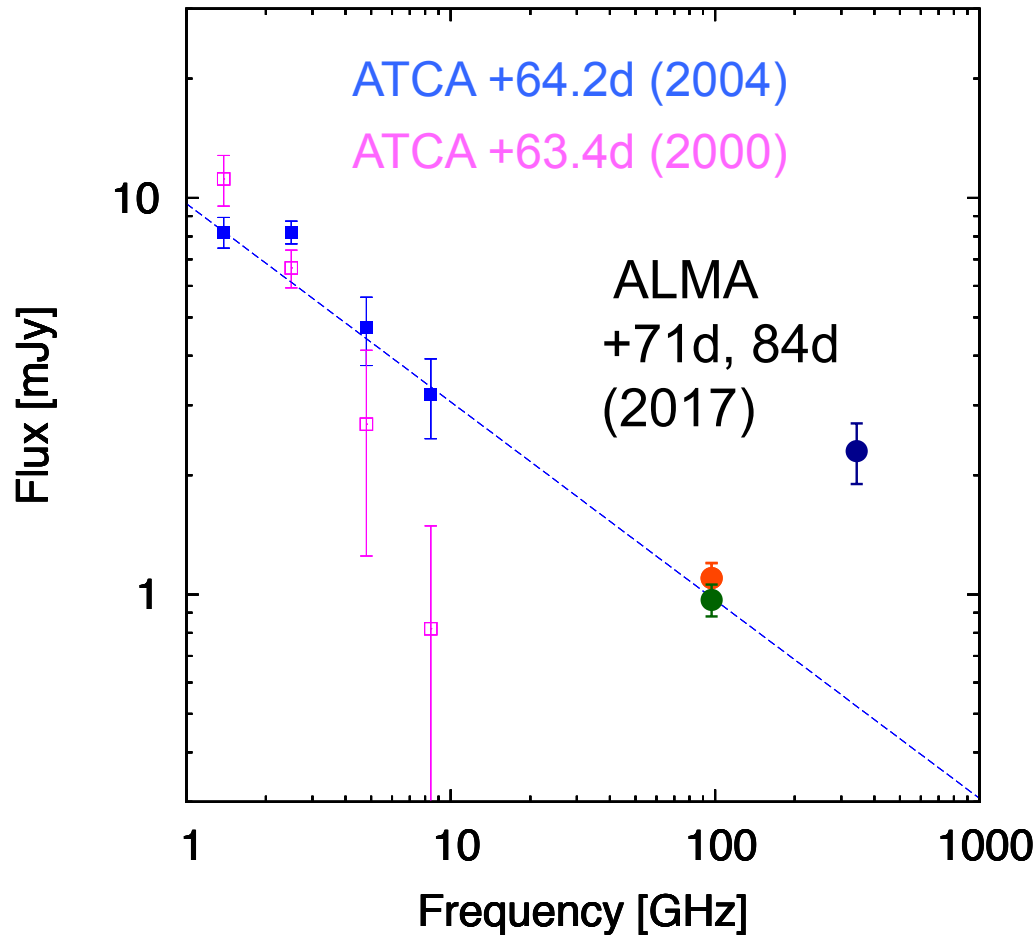
■ No variation between  $\tau+71d$  and  $84d$

→ No association with the GeV flare.

■ Different emission origins

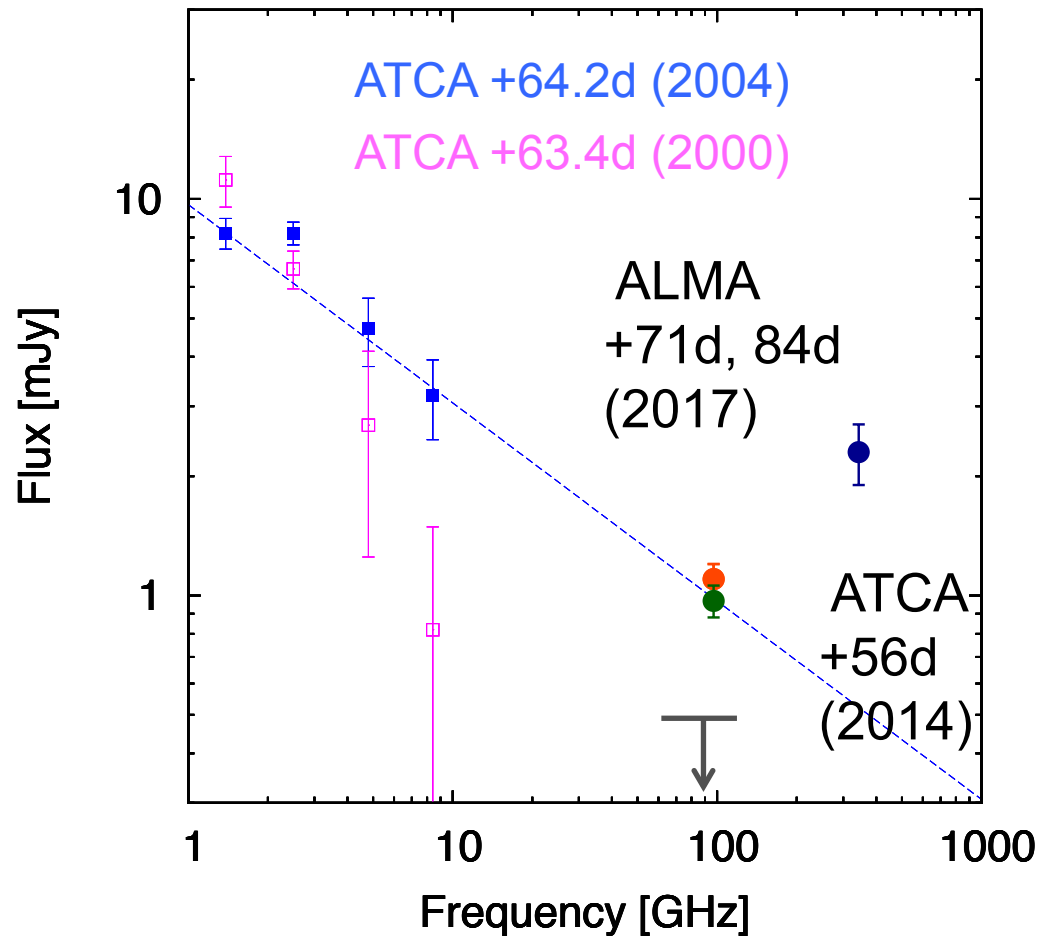
for Band 3 and Band 7 are proposed.

+ Band3 Results .. ~Smooth power-law extrapolation from low- $\nu$



- Smooth Extrapolation  $\nu^{-0.5}$  from ATCA low- $\nu$
- ➔ Radio emission ~ *Synchrotron emission*

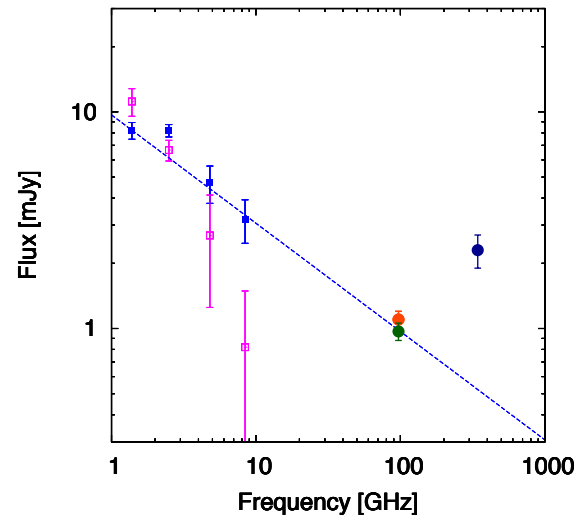
+ Band3 Results .. ~Smooth power-law extrapolation from low- $\nu$



■ Variation among orbital cycles  
& daily changes

# + Synchrotron Emission by injected electrons

Considering



*Synchrotron loss* after electron injection (assumed as  $\tau+20d$ ,  $\sim 2^{\text{nd}}$  pulsar crossing of the disk) till  $\tau+84d$  detection,

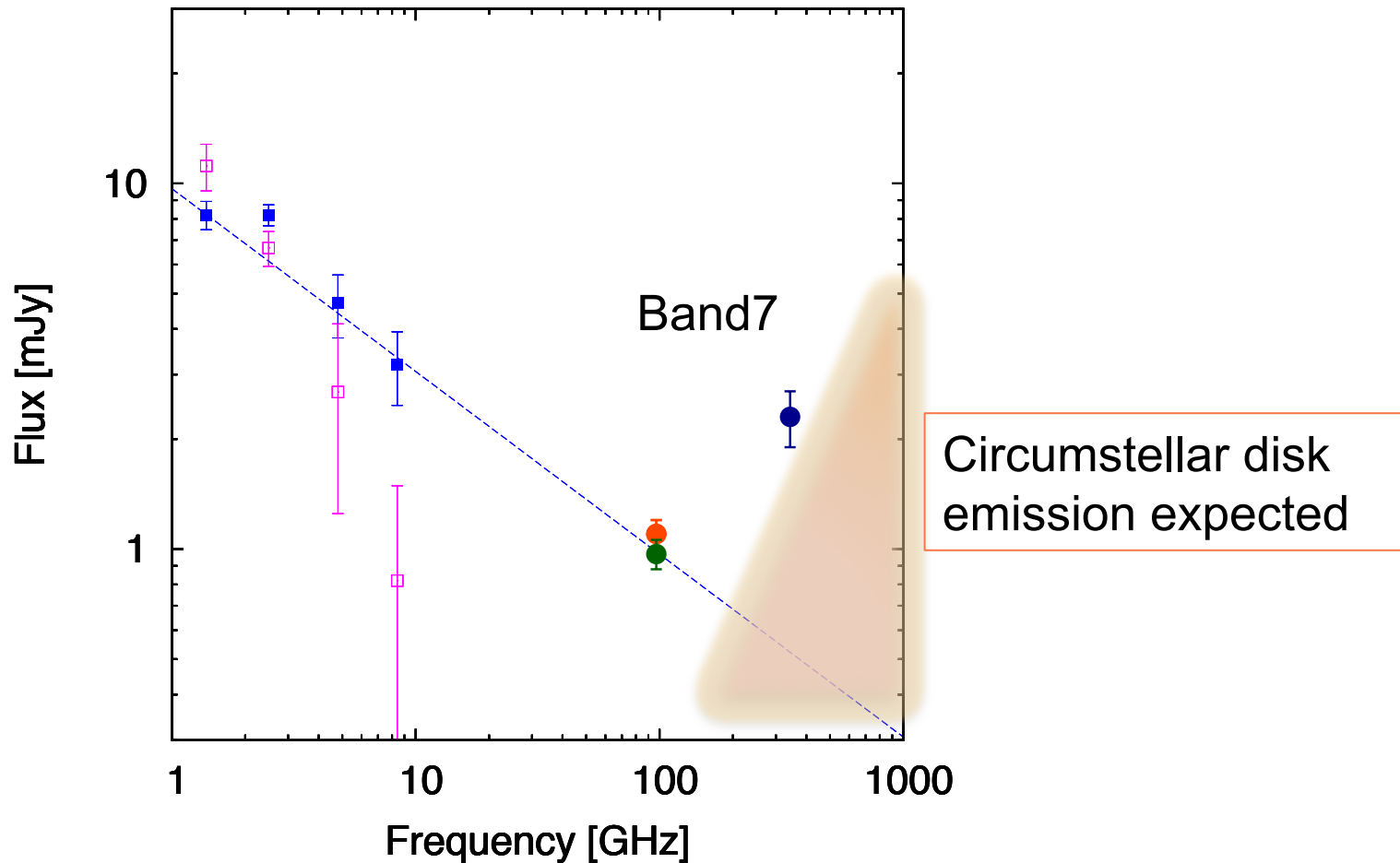
we constrain the synchrotron parameters for emission at 97 GHz as

magnetic field  $B \leq \sim 0.6 \text{ G}$  &  $\gamma > \sim 360$

→ Emission is likely to extend  $\sim$  X-ray

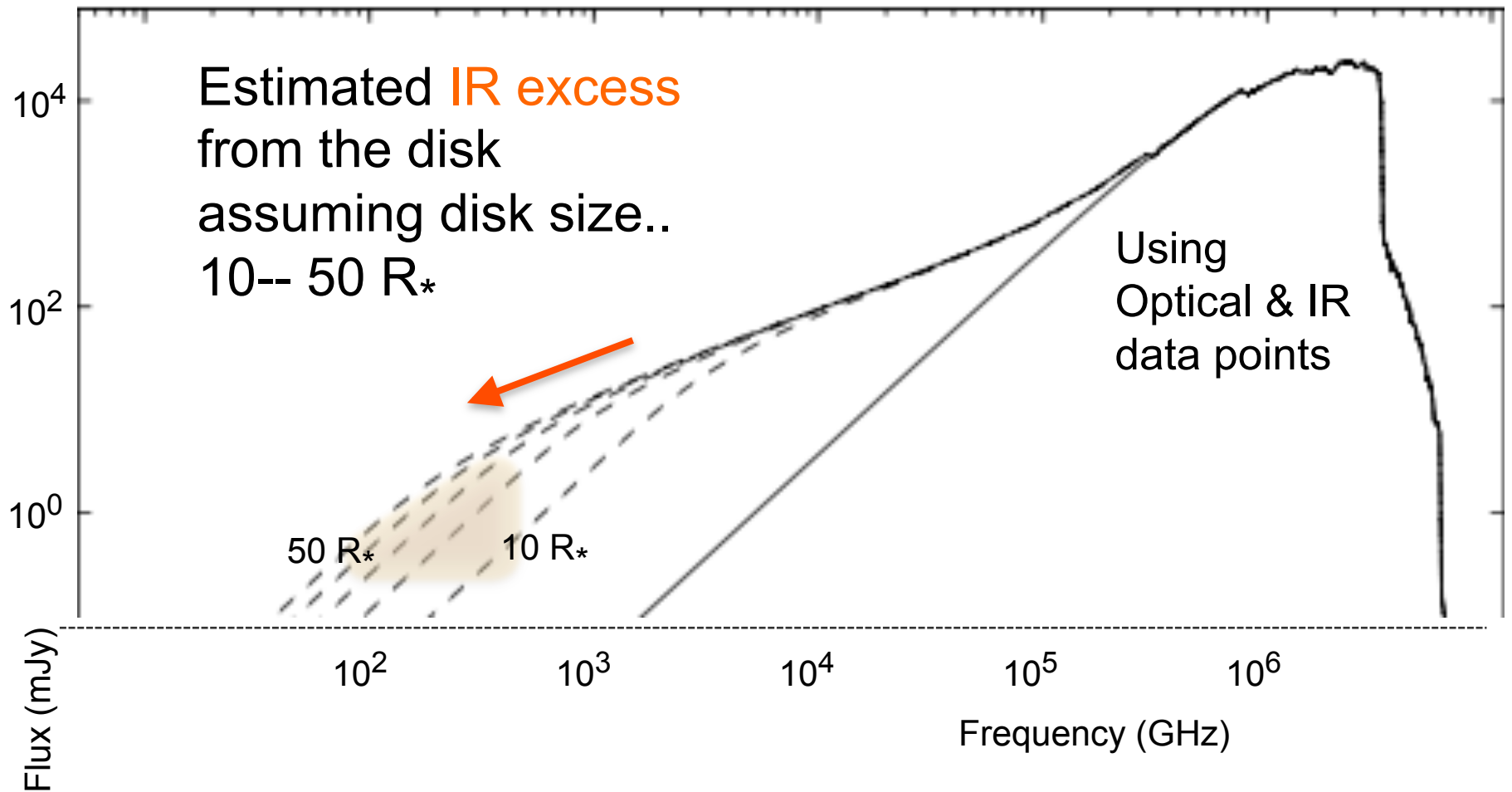


- + Band 7 result .. circumstellar disk radiation in the radio band ?

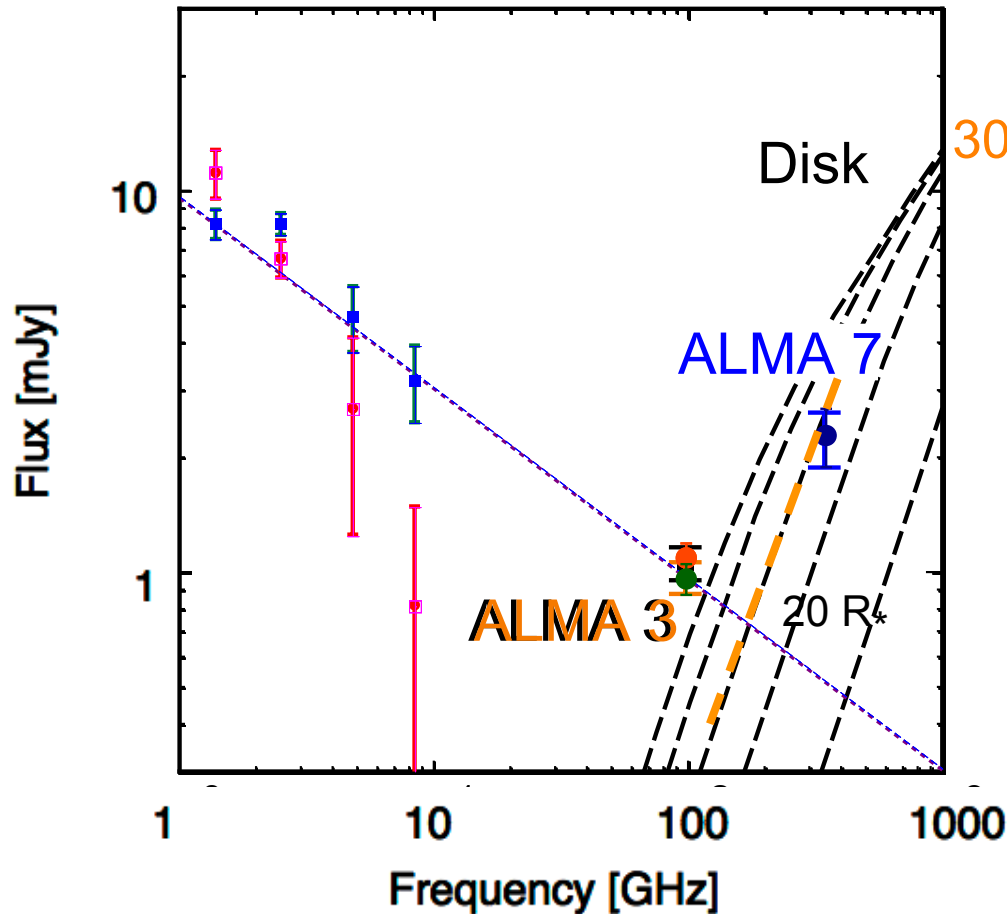


# + Broadband emission model of LS 2883

Be disk : van Soelen & Meintjes (2011)



# + Band 7 Result .. detection of circumstellar disk at sub-millimeter



■ Hint of gas disk size  
obtained as  $\sim 30R_*$

Smaller ? Normal ?

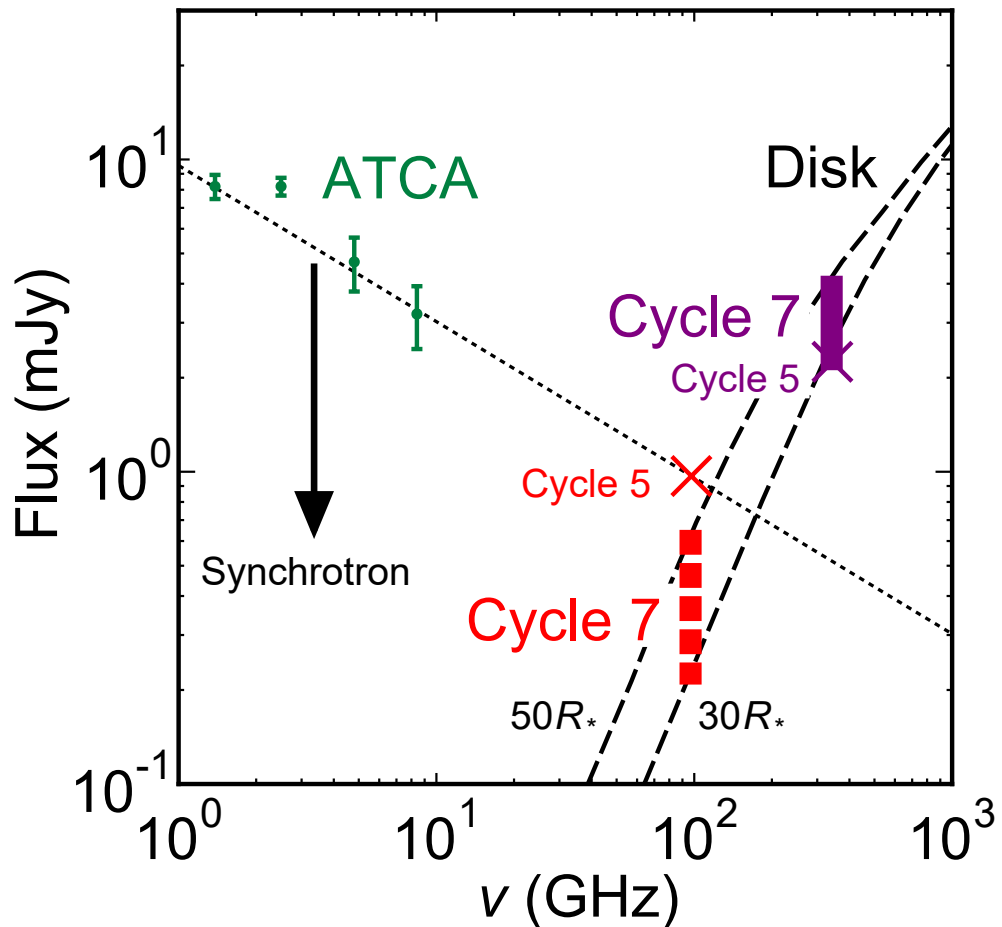
→ Quiescent phase  
ALMA observations will  
make it clear.

# + ALMA Cycle 7 Proposal (approved)

■ ~Quiescent phase

■ Disk component..  
~ Increase

■ Synchrotron ..  
~decrease



## + Radio Structure detectable in these bands ?

- Moldon+11 shows  $\sim 50$ mas (120 au) extended and variable radio structure, located off-center (25—45 mas) @2.3GHz
- Our results
  - ★ Band3: 97GHz : cannot be resolved by ALMA
  - ★ Band7: **343GHz : U.L. on the extended source**
- Future prospects
  - <-> Band6:  $\sim 200$ GHz promising



Let's add  
mm/sub-mm  
bands in the  
campaign !

## Summary

- We have performed mm, sub-mm observations of this gamma-ray binary **for the first time**.
- ALMA **detected** a compact source at **97GHz** and **343 GHz** in post-periastron phase in 2017 orbital cycle. The GeV flare coincided with the former observation.
- **Different origins** for these emissions of two frequencies are proposed and discussed. The Be circumstellar **disk contributes to the sub-mm signal**.
- Temporal change of the disk size may be related with the GeV flare. Quiescent phase observations using ALMA are in schedule.



Backup

# + ATCA observation summary

**Table 2.** The calibrators and observed fluxes for the ATCA observations in 2014

Date	Day (from $t_p$ )	Observing Time (min)	Calibrators			Residual RMS ( $1\sigma$ ) (mJy)
			Bandpass	Flux	Gain/Phase	
Apr 4	-29.9	20	PKS 1253-055	Mars	PKS 1305-668	3.58
Apr 6	-27.8	286	PKS 0537-441	Jupiter	PKS 1305-668	0.853
May 19	+15.4	82	PKS 1921-293	Uranus	PKS 1305-668	1.550
May 27	+23.3	68	PKS 1253-055	Uranus	PMN J1326-5256	0.704
Jun 15	+42.2	74	PKS 1921-293	Saturn	PMN J1326-5256	0.466
Jun 29	+56.1	71	PKS 1253-055	Mars	PMN J1326-5256	0.139
Sep 26	+145.6	58	PKS 0537-441	Jupiter	PMN J1326-5256	1.43



# + ALMA Observation Summary

**Table 1.** Angular resolution, image rms, and observed fluxes for the ALMA observations in 2017

Band	Date	Day (from $t_p$ )	Beam Shape	Image RMS ( $\mu\text{Jy beam}^{-1}$ )	Observed Flux (mJy)
3 (97 GHz)	Dec 2	+71	$0.35'' \times 0.21''$ at $78^\circ$	41	$1.1 \pm 0.1$
3 (97 GHz)	Dec 15	+84	$0.42'' \times 0.36''$ at $-52^\circ$	36	$0.97 \pm 0.09$
7 (343 GHz)	Nov 30	+69	$0.056'' \times 0.043''$ at $-8^\circ$	87	$2.3 \pm 0.4$