ALMA observations of binary pulsar PSR B1259-63 /LS2883

Yutaka Fujita (Tokyo Metro. U.)

Akiko Kawachi (Tokai U.)
Atsuo T. Okazaki (Hokkai-Gakuen U.)
Hiroshi Nagai (NAOJ)
Norita Kawanaka (Tokyo Metro. U.))
Takuya Akahori (NAOJ)

Fujita et al. (2024) ApJL, 977, L22

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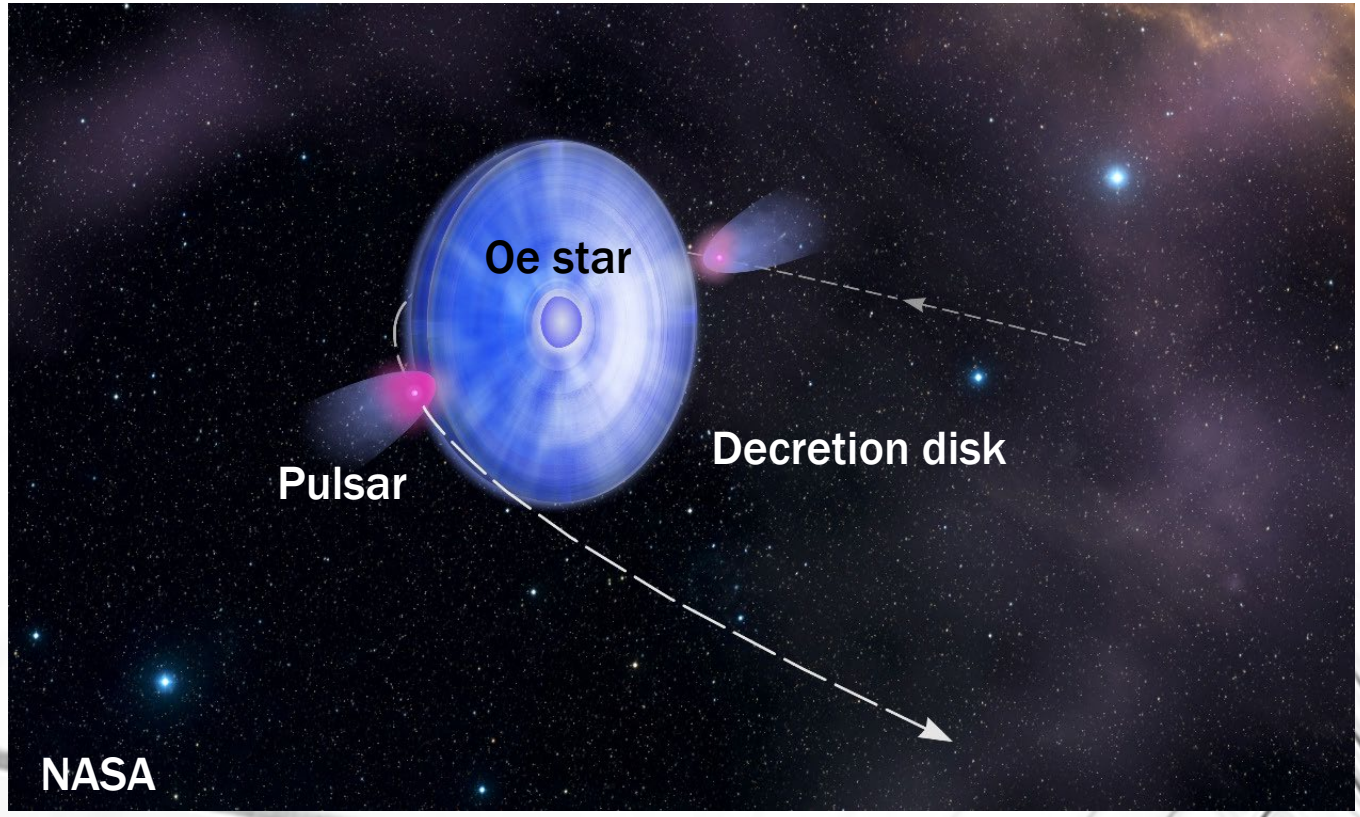
PSR B1259-63/LS 2883

Gamma-ray binaries

- Gamma-ray objects first identified in 2004
- ~9 binaries have been identified
  - Compact object (neutron star or black hole) + normal star
  - Nature of the compact object is generally unknown (neutron star or black hole?)
- PSR B1259-63/LS 2883 (B1259 hereafter) is a rare object
  - The compact star is undoubtedly a neutron star
    - Pulses have been clearly detected

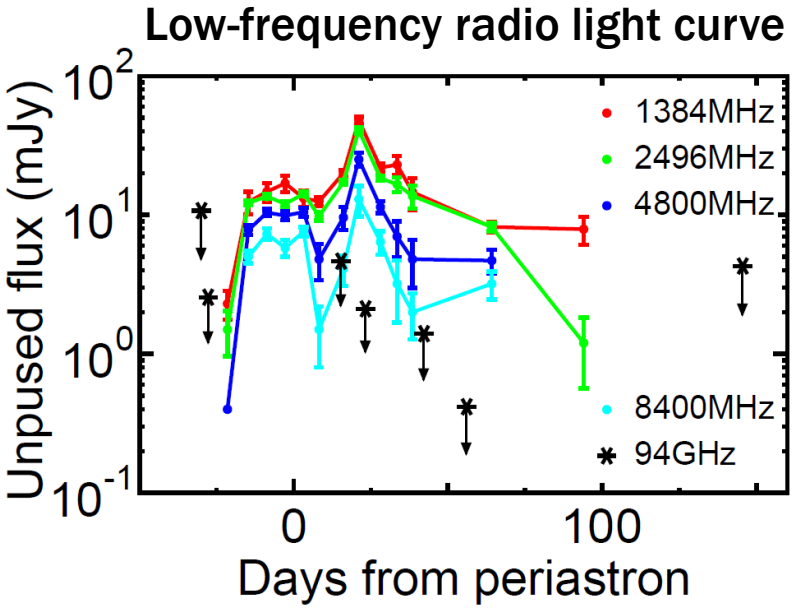
PSR B1259-63/LS 2883 (B1259)

- Pulsar + Massive Oe star ($\gtrsim 10 M_{\odot}$)
  - Orbital period ~ 3.4 yr
  - The pulsar passes the circumstellar disk twice around periastron

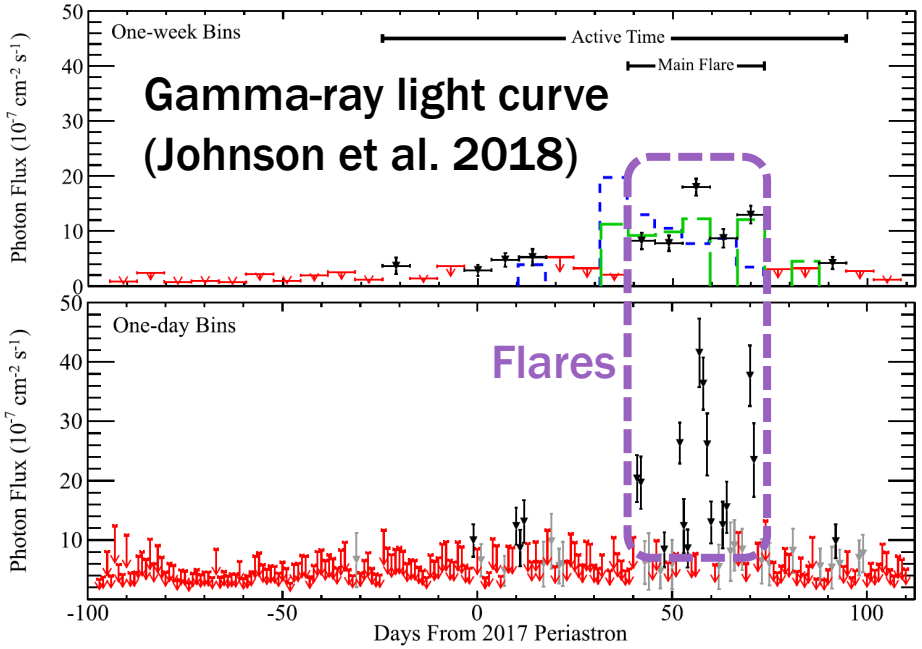


Activities of B1259

- B1259 becomes active around the periastron passage



(Fujita et al. 2019; Johnston et al. 2005)

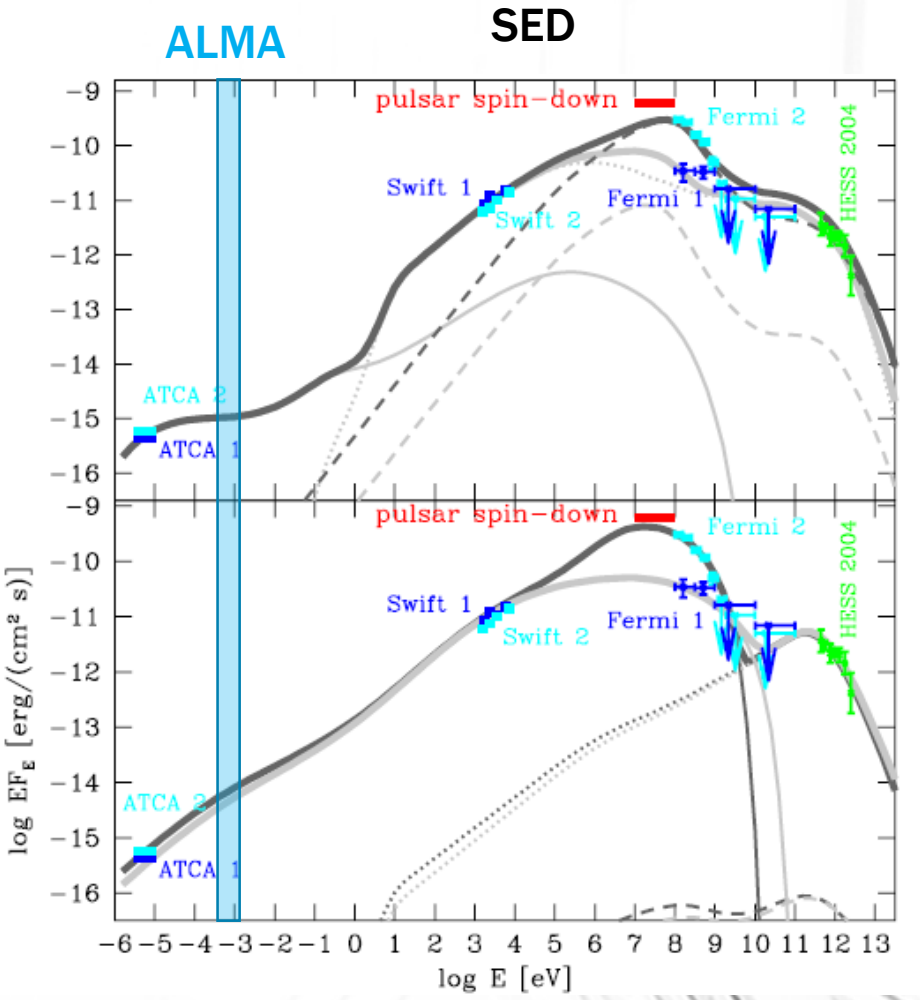


Days from periastron

- B1259 becomes quiet around apastron
  - Pulsed radio emission (pulsar) is observed

Previous observations around periastron

- Unpulsed emissions
  - Interaction between the pulsar and the circumstellar disk
  - Radio ($\lesssim$10 GHz)
    - Synchrotron
    - Obscure pulsed emission
  - X-ray
    - Synchrotron or inverse Compton?
  - Gamma-ray flares
    - Unknown origin
- Radio observations at $\gtrsim$10 GHz are limited
  - ALMA covers $\gtrsim$100 GHz!

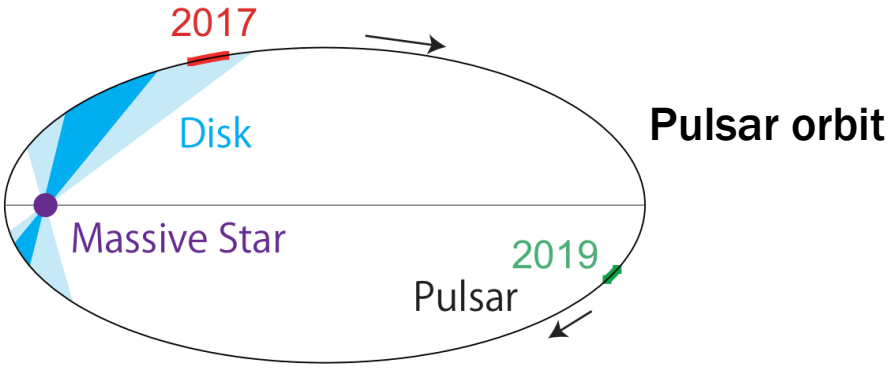


Abdo et al. (2011)

Our previous ALMA observations

Previous our ALMA observations

- We observed B1259 in 2017 and 2019



- 2017 observations (Fujita et al. 2019)
  - Just after the 2017 periastron passage
  - We detected B1259 in the submm/mm band for the first time
- 2019 observations (Fujita et al. 2020)
  - Quiet period (around apastron)
  - Compared the results with those for our 2017 observations

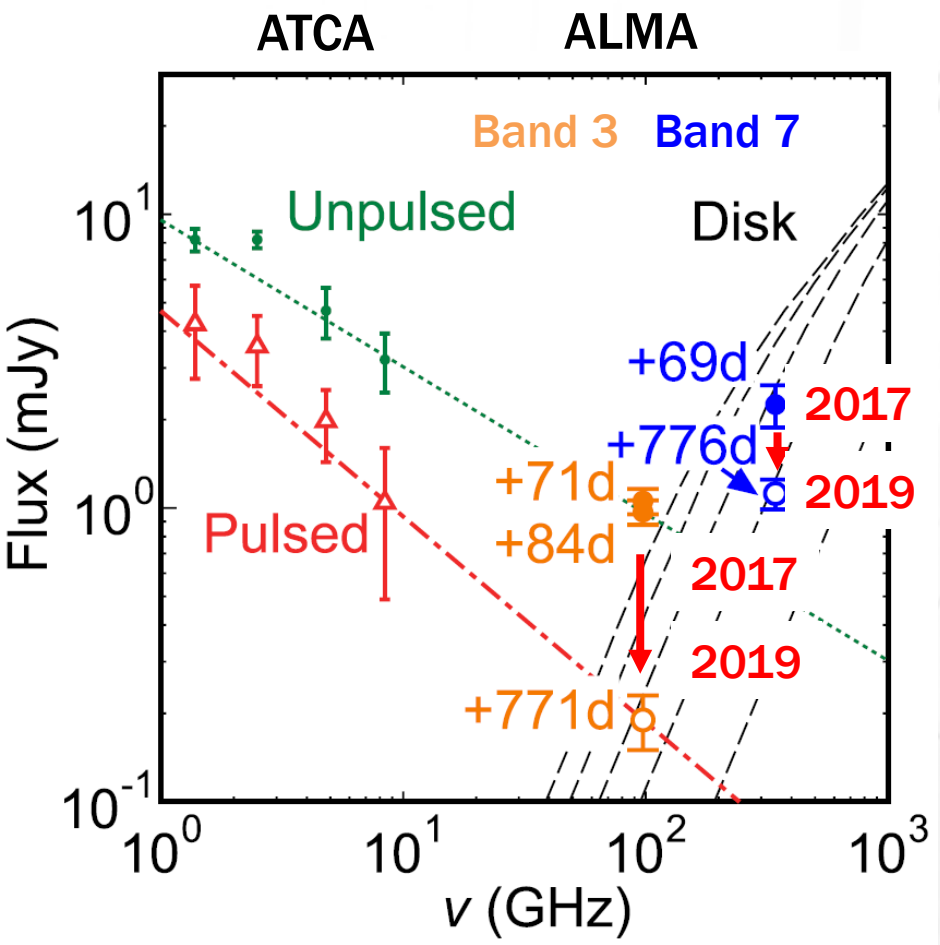
Our 2017/2019 observations

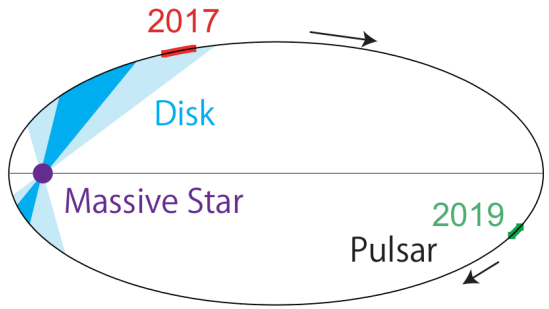
Band	Date	Day From periastron	Beam shape	Image rms (μJy beam^{-1})	Observed flux (mJy)
3 (97 GHz)	2017 December 2	+71	0.″35 × 0.″21 at 78°	41	1.1 ± 0.1
3 (97 GHz)	2017 December 15	+84	0.″42 × 0.″36 at −52°	36	0.97 ± 0.09
7 (343 GHz)	2017 November 30	+69	0.″056 × 0.″043 at −8°	87	2.3 ± 0.4
3 (97 GHz)	2019 November 2	+771	1.″98 × 1.″58 at 49°	40	0.19 ± 0.04
7 (343 GHz)	2019 November 7	+776	0.″88 × 0.″77 at 18°	90	1.12 ± 0.13
7 (343 GHz)	2019 November 27	+796	0.″91 × 0.″81 at −7°	179	>0.8

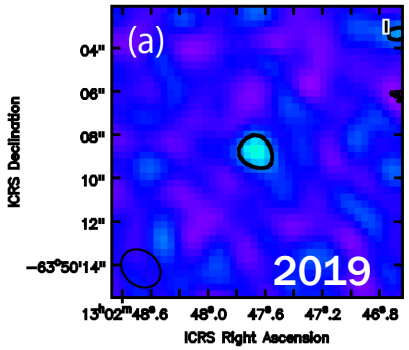
- Exposure time is ~ 5 min for each observation!

Results

- Band 3 (97 GHz)
  - 2017 observations
    - On the extrapolation of unpulsed emission
    - Synchrotron emission through pulsar-disk interaction
  - 2019 observations
    - Flux decreases
    - Consistent with pulsed emission
    - No pulsar-disk interaction



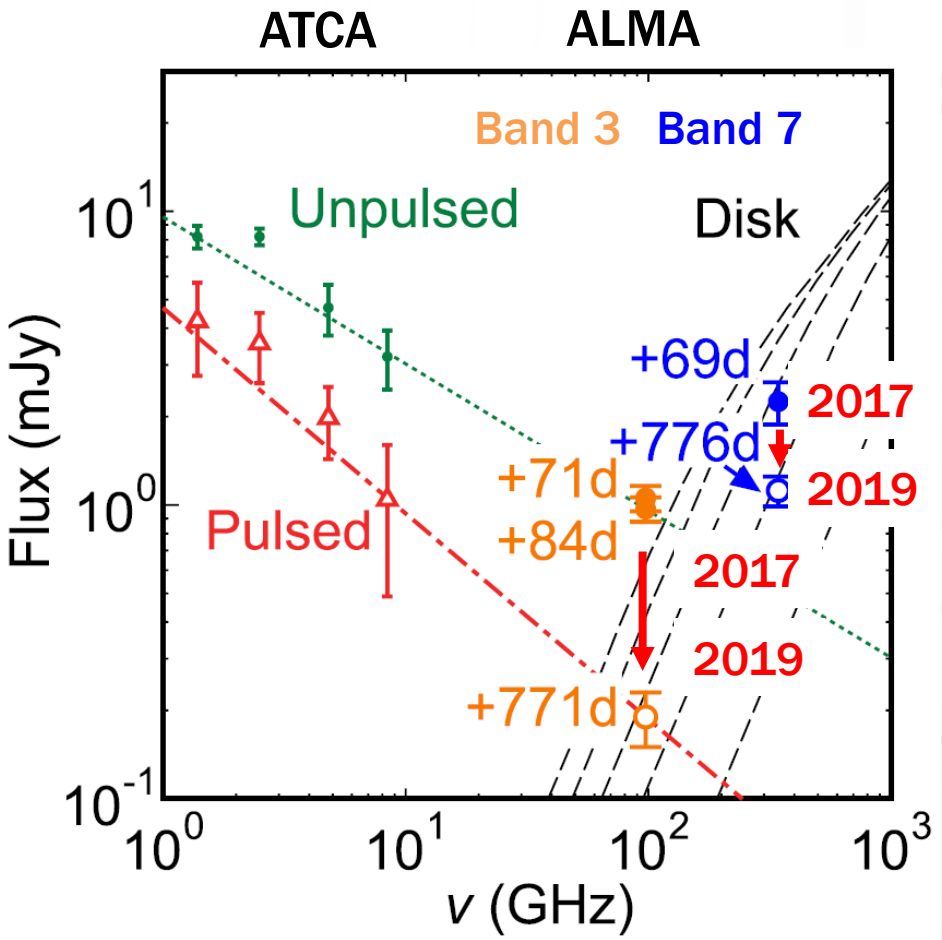


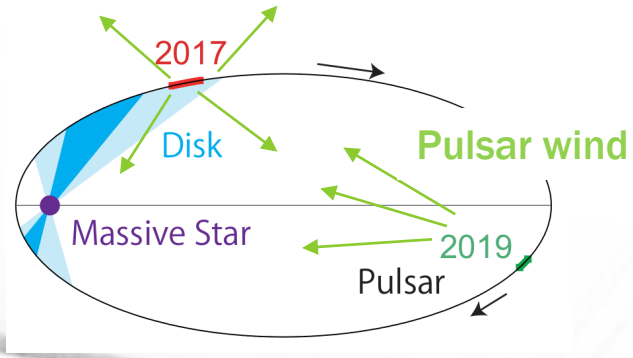


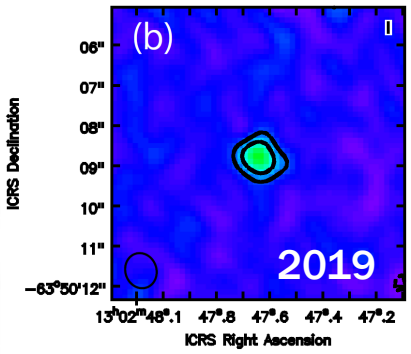
Fujita et al. (2020)

Results

- Band 7 (343 GHz)
  - 2017 observations
    - Not on the extrapolation of unpulsed emission
    - Thermal radiation from the circumstellar disk
  - 2019 observations
    - Flux decreases
      - Disk evolution?







Fujita et al. (2020)

Our new ALMA observations around periastron

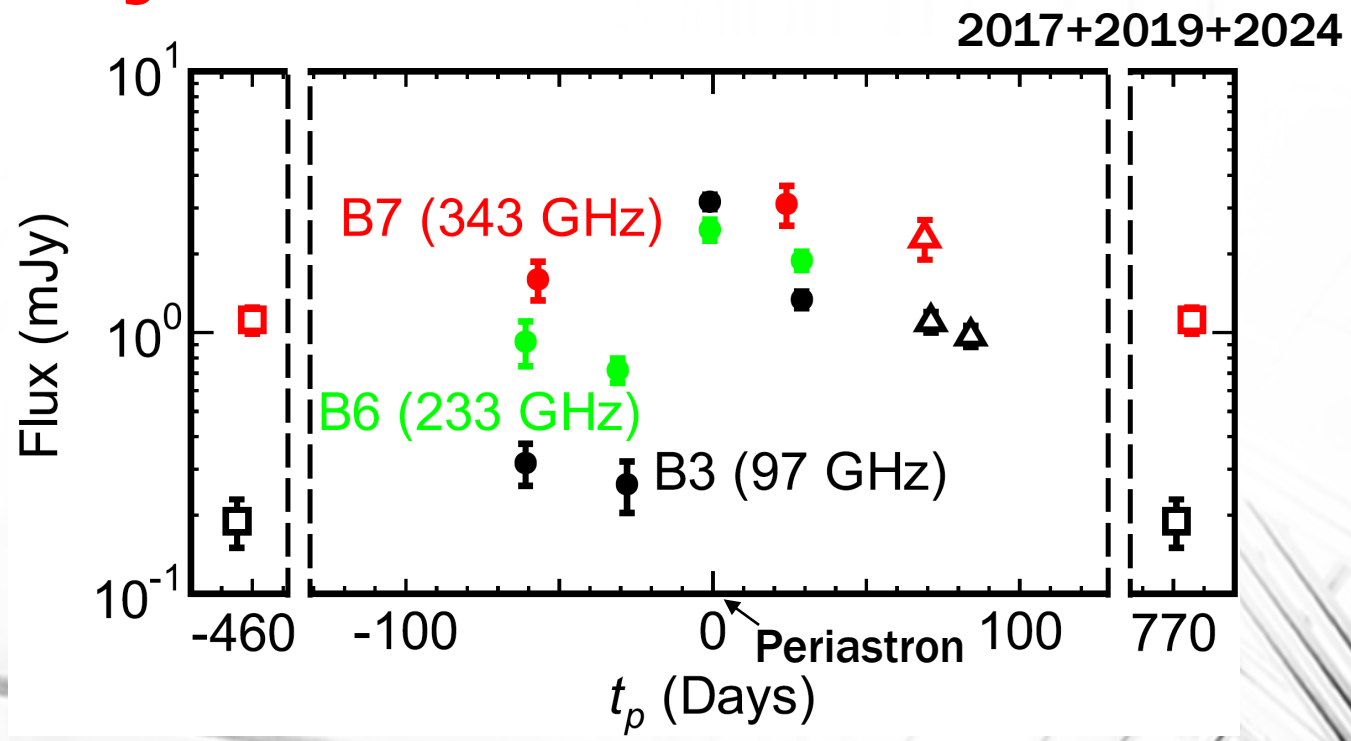
ALMA observations

- The 2021 periastron passage could not be observed due to the Covid-19 pandemic
- We observed B1259 around the 2024 periastron passage (June 30; t_p=0)
  - Bands 3, 6, and 7

Date	Day (from t_p)	Band	Freq.[a] (GHz)	N_{ant}[b]	T_{on}[c] (minutes)	Bandpass/Flux[d]	Gain[e]	Beam Shape (arcsec)	PA[f] (deg)	Image rms (μJy bm^{-1})	Observed Flux (mJy)
Apr 30	−61	3	97	44	6	J1427-4206	J1308-6707	2.0 × 1.7	61	29	0.32 ± 0.06
Apr 30	−61	6	233	44	5	J1427-4206	J1254-6111	0.86 × 0.81	42	68	0.93 ± 0.18
May 4	−57	7	343	42	5	J1617-5848	J1308-6707	0.57 × 0.50	46	122	1.60 ± 0.27
May 30	−31	6	233	45	5	J1427-4206	J1308-6707	0.41 × 0.30	−16	38	0.72 × 0.08
Jun 2	−28	3	97	41	5	J1617-5848	J1308-6707	0.92 × 0.54	43	32	0.26 ± 0.06
Jun 29	−1	3	97	45	6	J1617-5848	J1308-6707	0.48 × 0.39	−31	39	3.17 ± 0.20
Jun 29	−1	6	233	45	5	J1617-5848	J1308-6707	0.18 × 0.16	−19	48	2.48 ± 0.23
Jul 24	+24	7	343	41	5	J1617-5848	J1308-6707	0.16 × 0.11	−11	130	3.11 ± 0.54
Jul 29	+29	3	97	42	6	J1427-4206	J1308-6707	0.78 × 0.59	−23	31	1.34 ± 0.10
Jul 29	+29	6	233	42	5	J1427-4206	J1308-6707	0.35 × 0.27	−31	44	1.89 ± 0.15

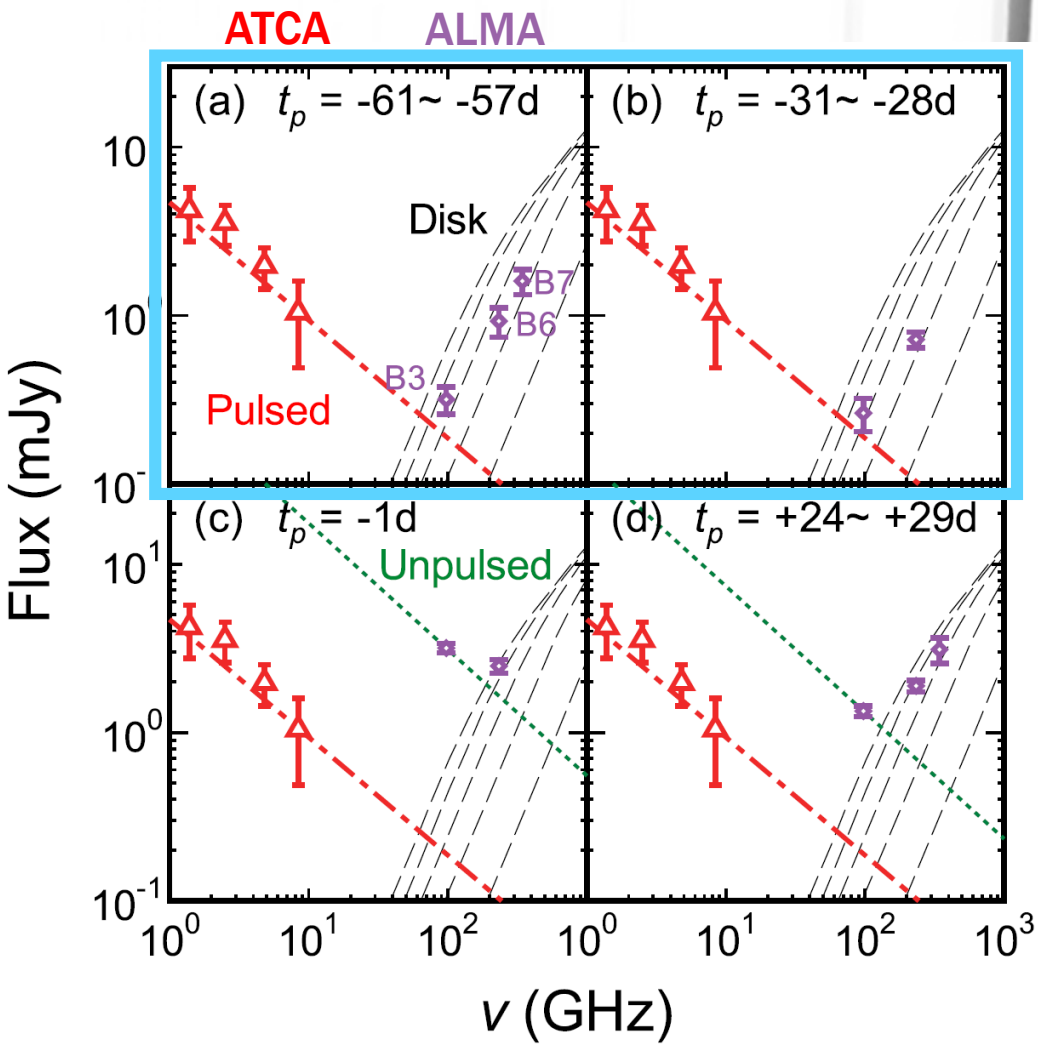
Light curves

- Flux ratio around/before the periastron
  - Band 3 > Band 6 > Band 7
- Band 7 flux did not disappear
  - Disk was not completely destroyed by pulsar passage



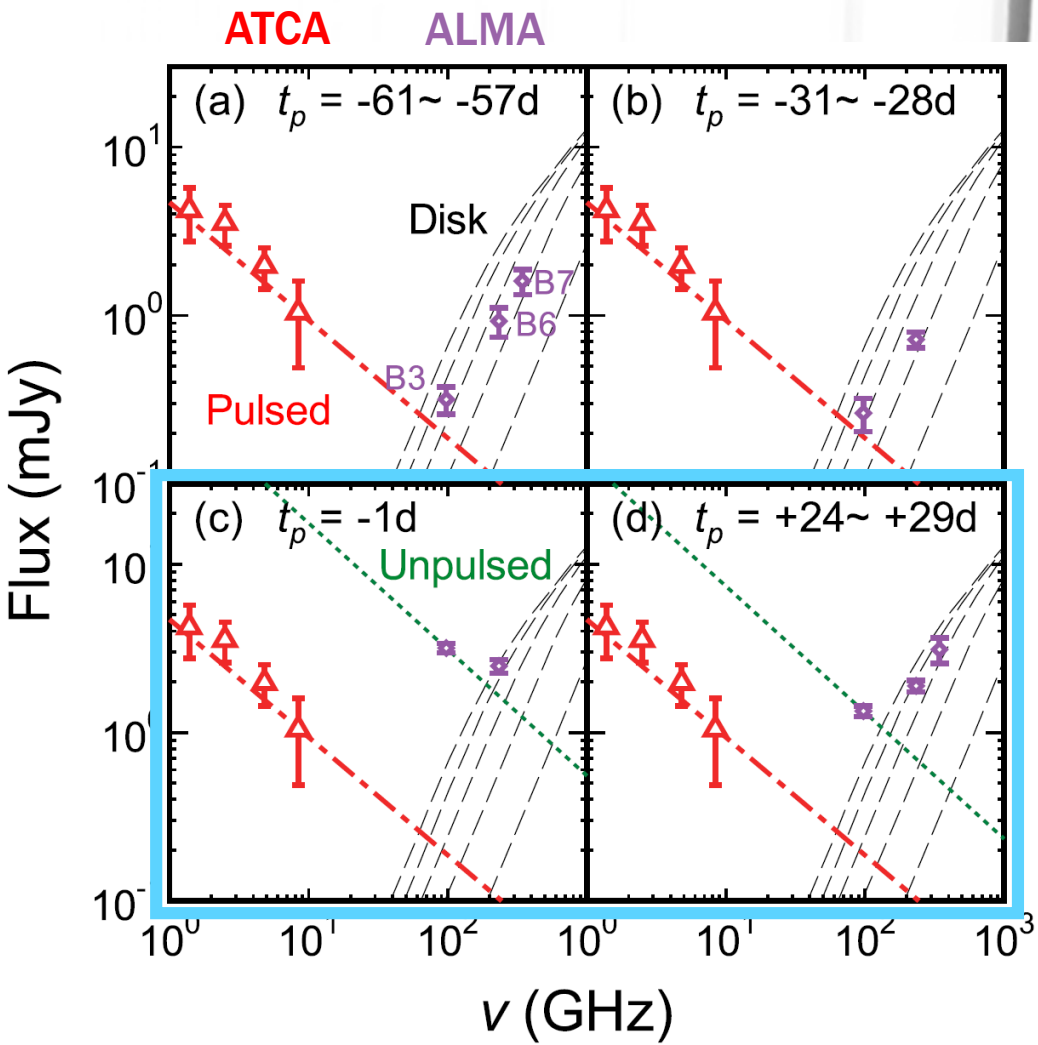
Spectral Energy Distributions

- Before periastron passage (a,b)
  - Band 3
    - Pulsed synchrotron emission
      - Pulsar
  - Band 6, 7
    - Thermal radiation from the disk
      - Unperturbed disk



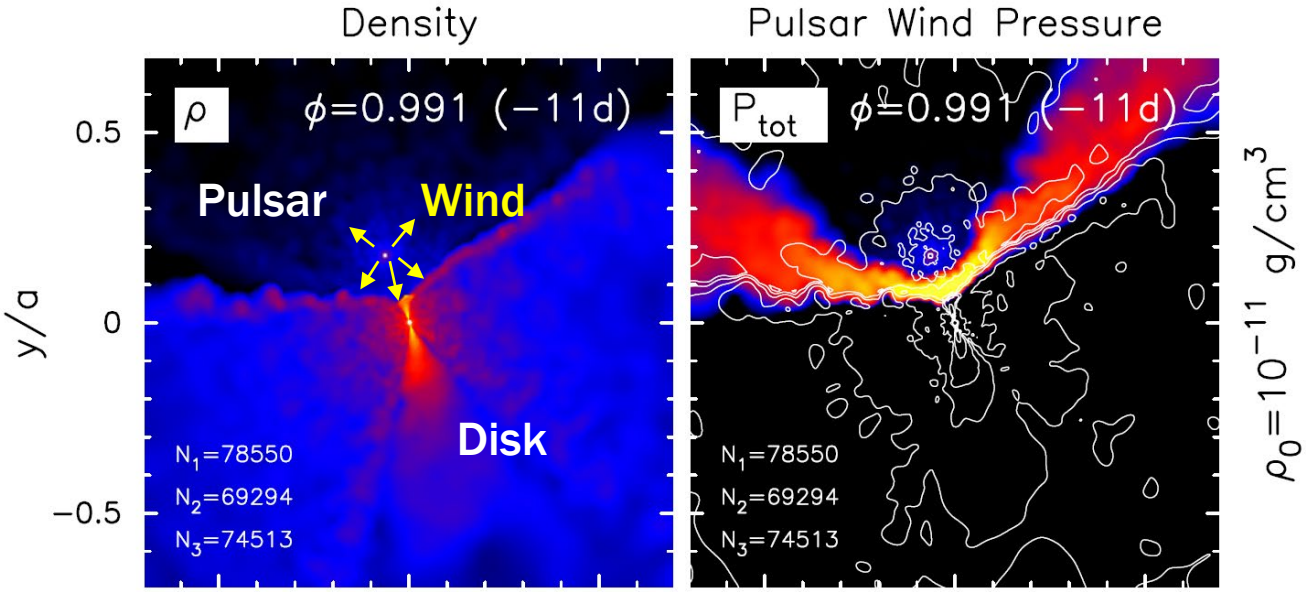
Spectral Energy Distributions

- Around and after periastron passage (c,d)
  - Band 3
    - Consistent with unpulsed synchrotron emission
      - Pulsar-disk interaction
  - Band 6, 7
    - Increased thermal radiation from the disk



Increased disk luminosity

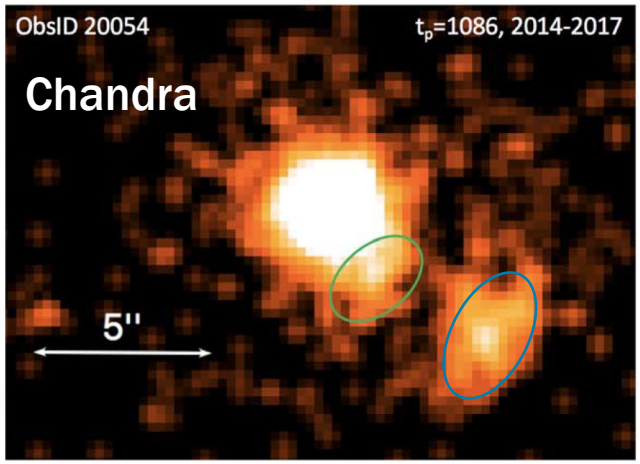
- Disk expansion through the pulsar-disk interaction around periastron?
  - Partial destruction → Gamma-ray flares?



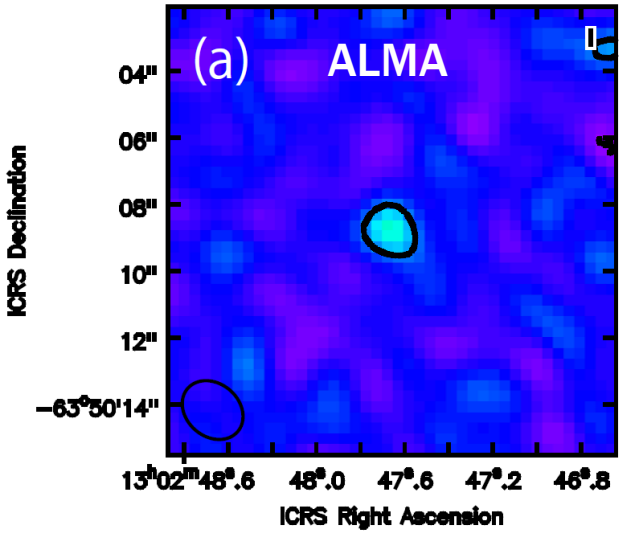
Tanaka et al. (2012)

X-ray ejecta

- Chandra discovered ejecta from the binary $\gtrsim$ 1 yr after periastron passage (Pavlov et al. 2011, 2015; Kargaltsev et al. 2014)
  - We did not find the radio counterpart
  - The radio image is consistent with a point source



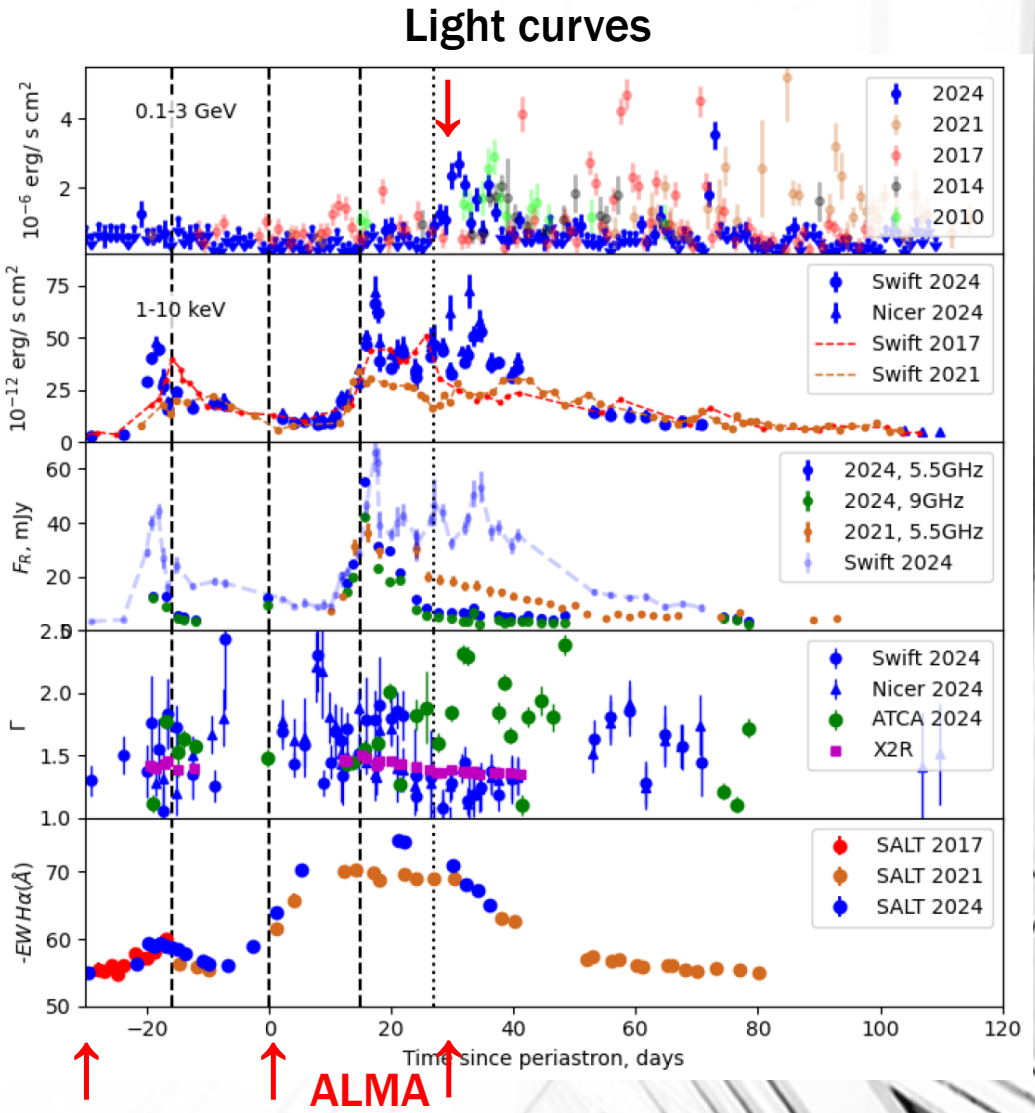
Hare et al. (2019)



Fujita et al. (2020)

Other wave lengths

- 2024 periastron passage
  - Our last ALMA observations were made at the onset of gamma-ray flares (~+30d)
  - Are the flares related to the disk expansion?



Chernyakova et al. (2024)

Summary

- We observed the gamma-ray binary B1259 around 2024 periastron
- The Band 3 flux significantly increased
  - Synchrotron
  - Pulsar-disk interaction
- The Band 6 and 7 fluxes mildly increased
  - Thermal radiation
  - Disk expansion?
    - Origin of gamma-ray flares?
- Detailed comparison with multi-band observations and numerical simulations is useful