Quasi-periodic sub-pulse structure as a unifying feature for radio-emitting neutron stars

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Speaker: 金奕澄

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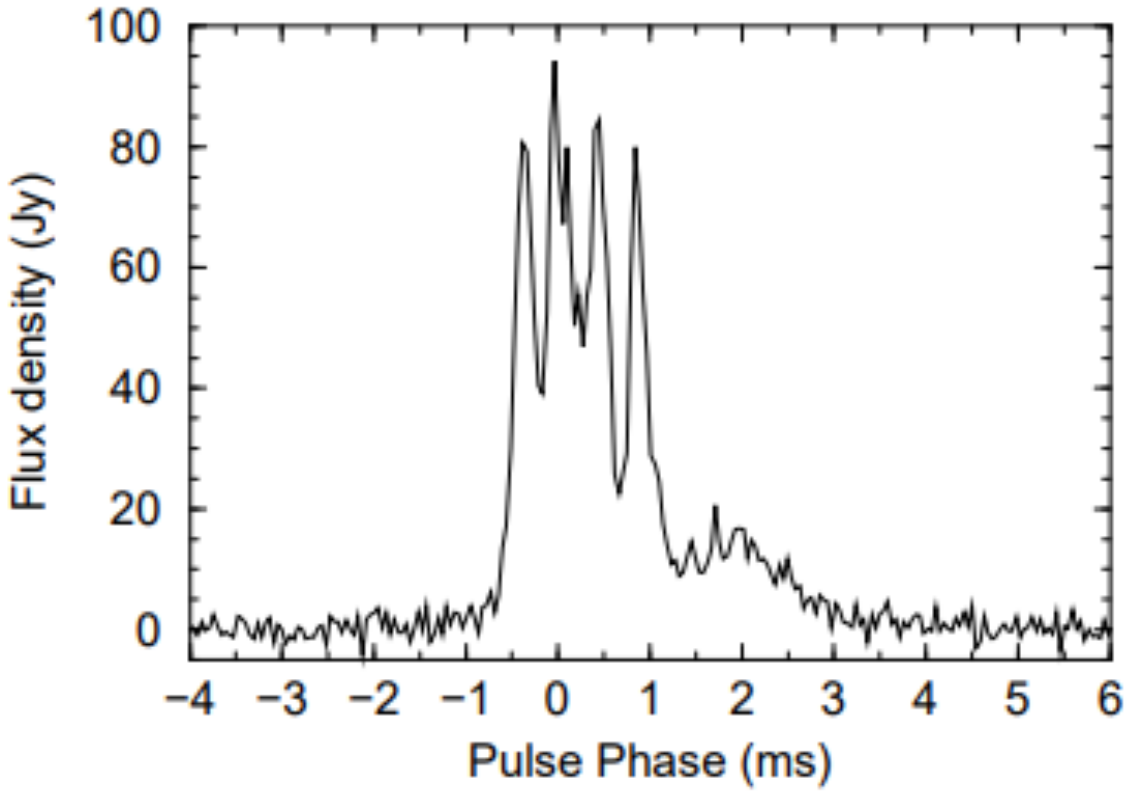
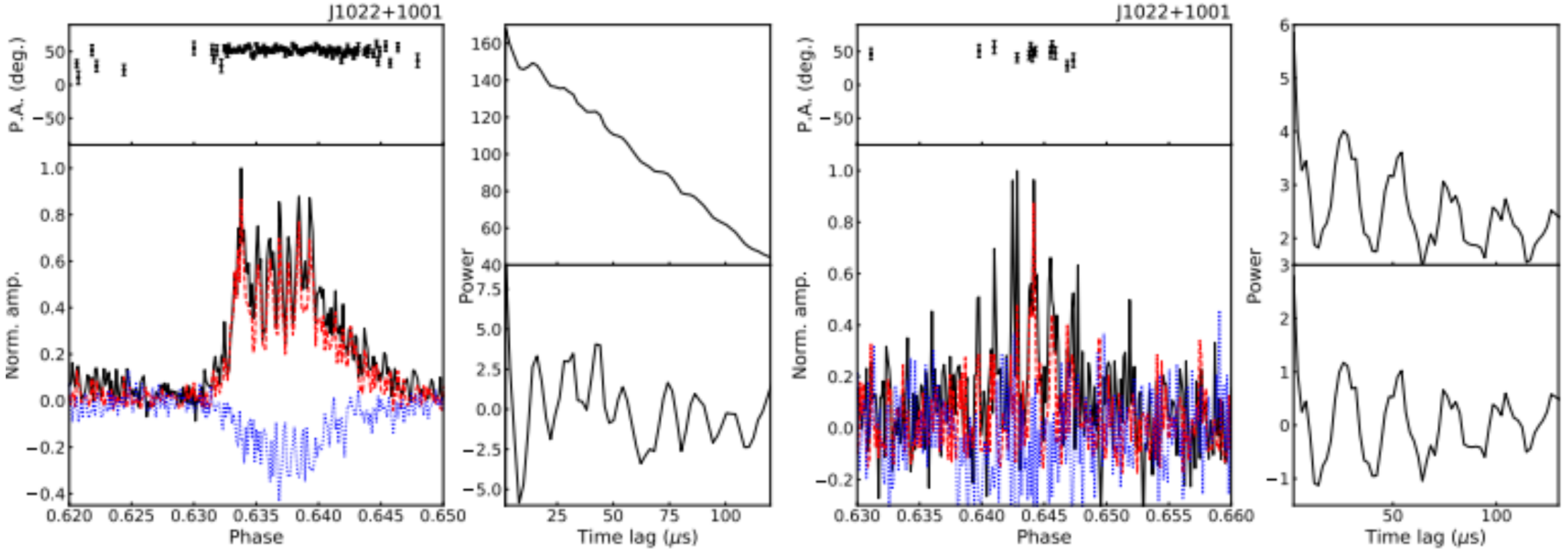
Micro-pulses observed in pulsar signals



PSR B0833−45, M. Kramer et al. 2002

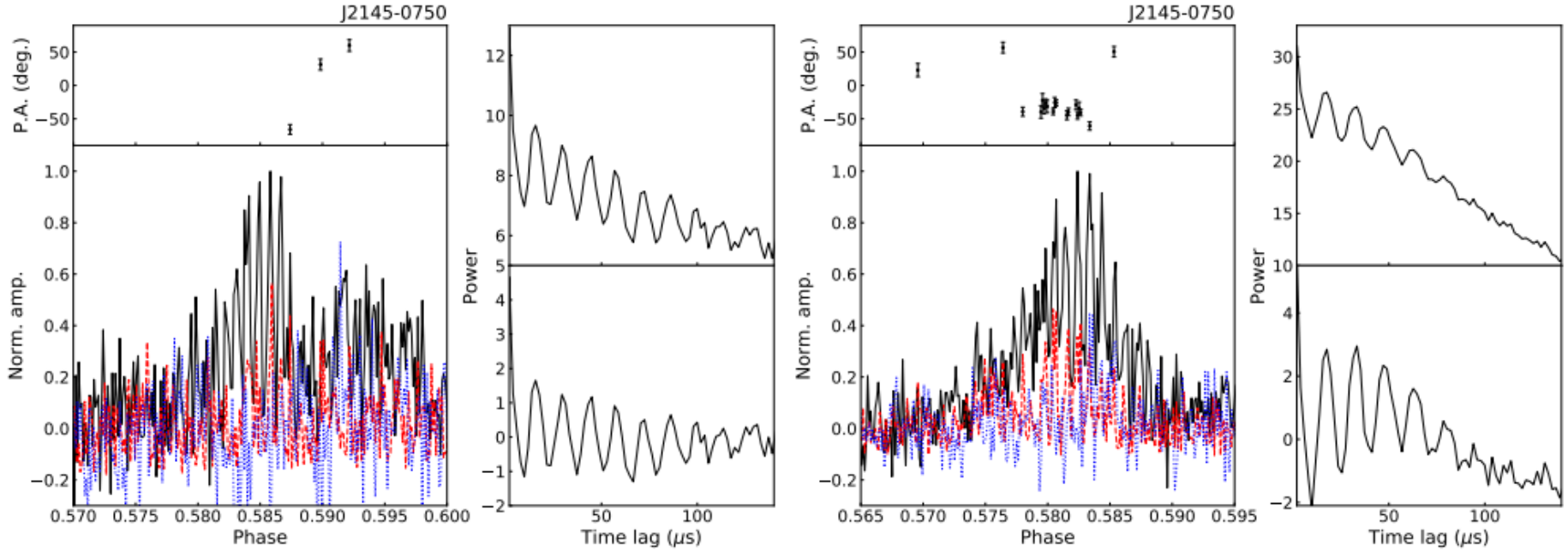
- Micro-pulses have been detected in many (80% for PSR B0833−45) pulses (independent of frequency);
- Some micro-pulses groups are quasi-periodic;
- Every quasi-periodic micro-pulses group has the same period (in the same object);
- Period depends on the rotation period.
- $P_\mu \approx 10^{-3}P, \tau_\mu \approx 0.5P_\mu$

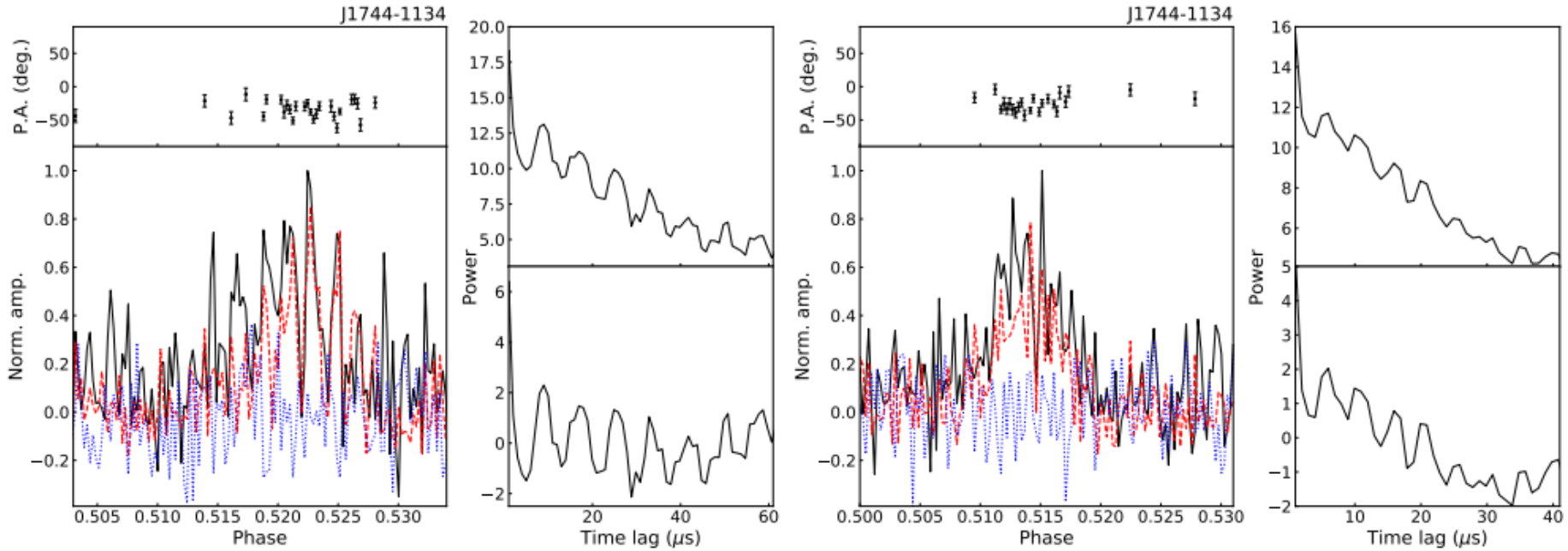
For millisecond pulsars



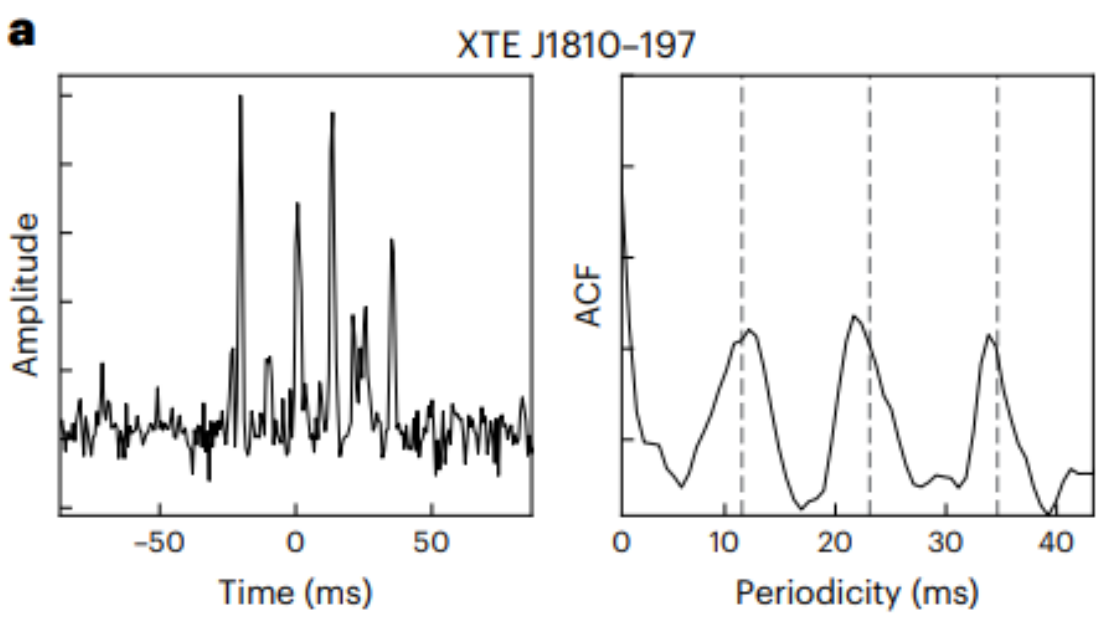
Black solid: total intensity
Red dashed: linear polarization
Blue dashed: circular polarization

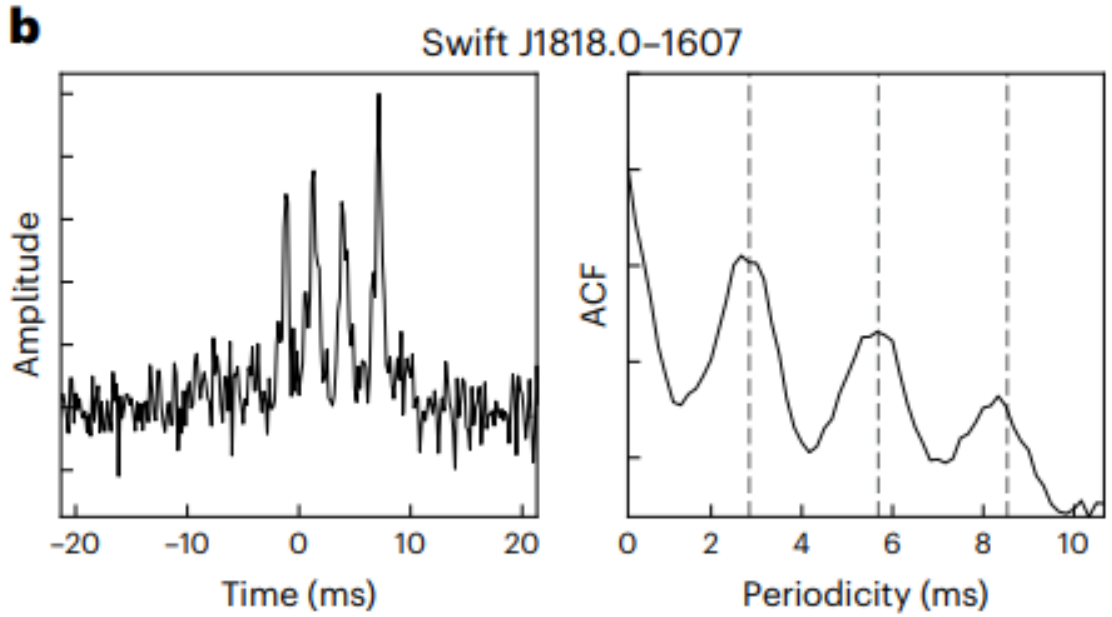
K. Liu et al. 2022


J2145-0750
P.A. (deg.)
Norm. amp.
Phase
Power
Time lag (μs)
J2145-0750
P.A. (deg.)
Norm. amp.
Phase
Power
Time lag (μs)


J1744-1134
P.A. (deg.)
Norm. amp.
Phase
Power
Time lag (μs)
J1744-1134
P.A. (deg.)
Norm. amp.
Phase
Power
Time lag (μs)

For radio-loud magnetars

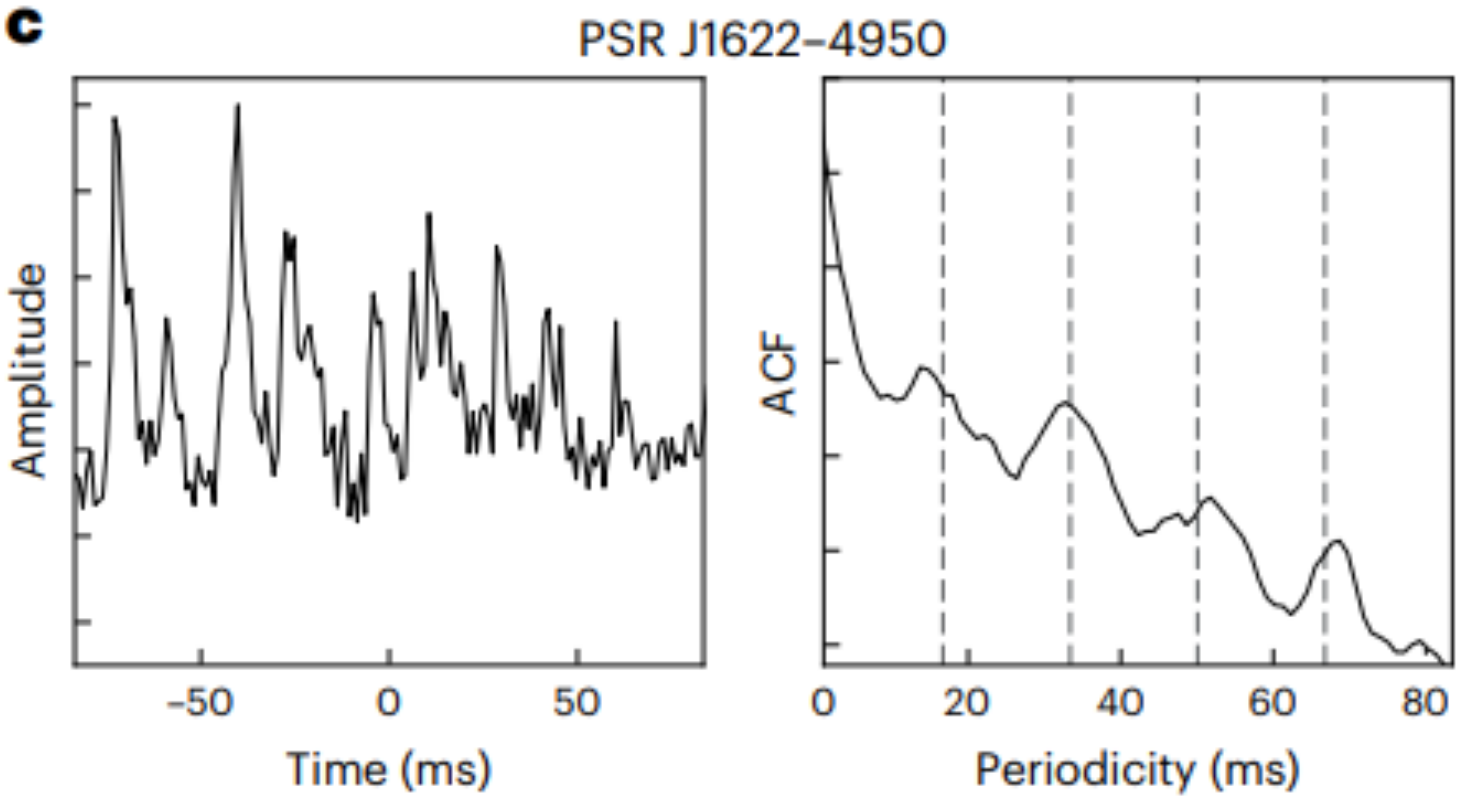




Rotation period: 5.54s
Magnetic field: 3×10^{14} G

Rotation period: 1.36s
Magnetic field: 2.5×10^{14} G

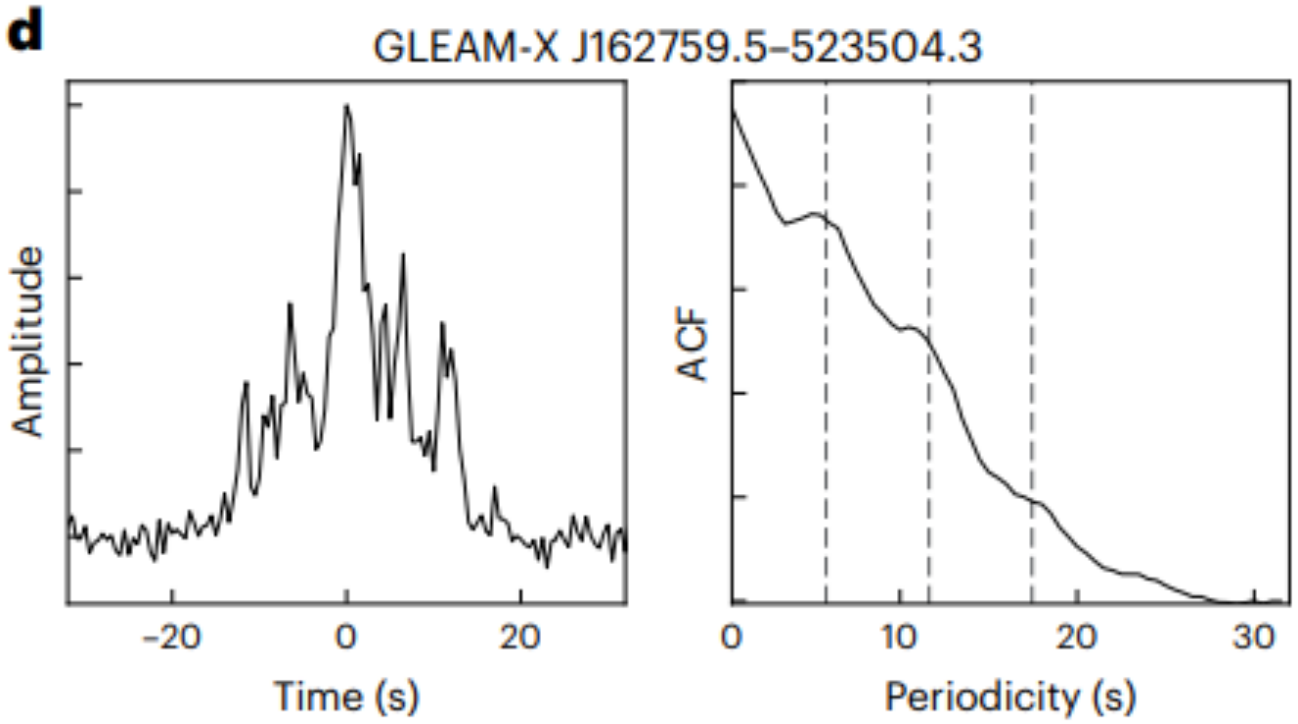
For radio-loud magnetars



Rotation period: 4.3s

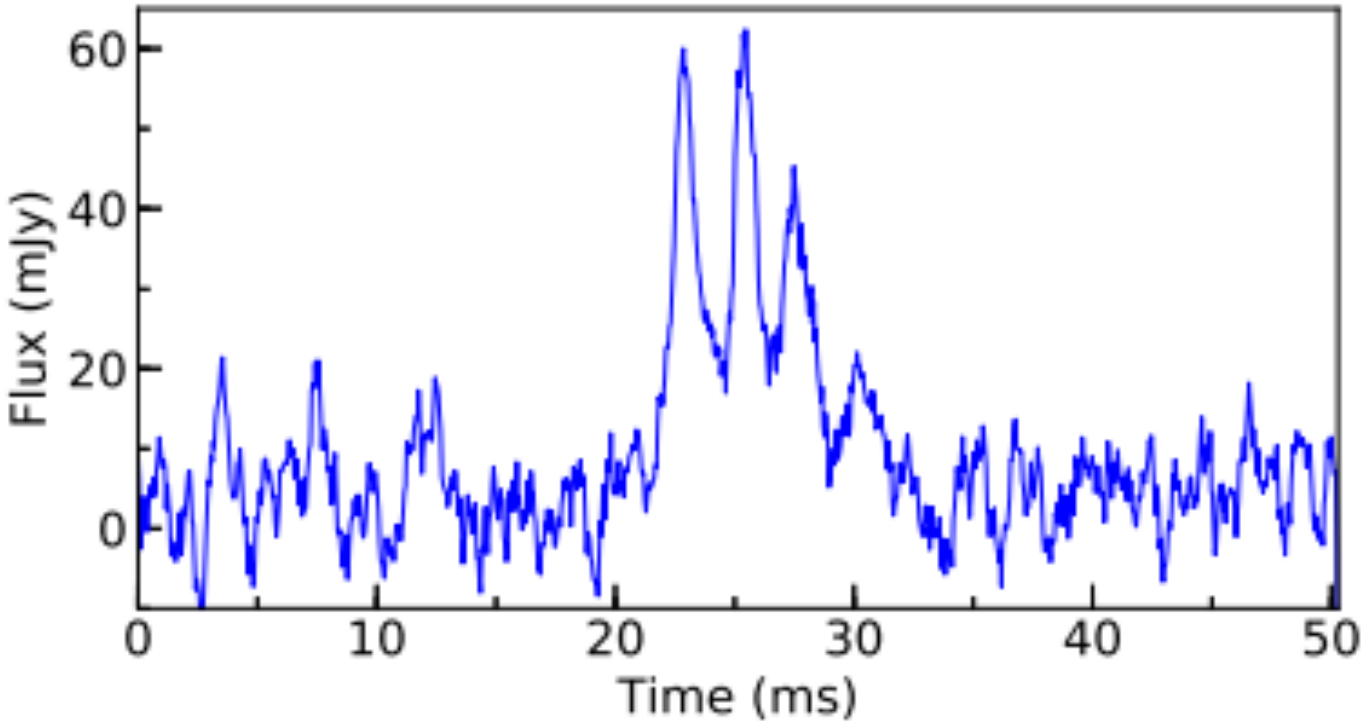
Magnetic field: 2.6×10^{14} G

For long-period pulsating radio sources (NS?)



Rotation period: 1091s
Magnetic field: ?
(more than 10^{16} G if NS)

For rotating radio transients (RRAT)



Rotation period: 2479.21 ± 0.03 ms

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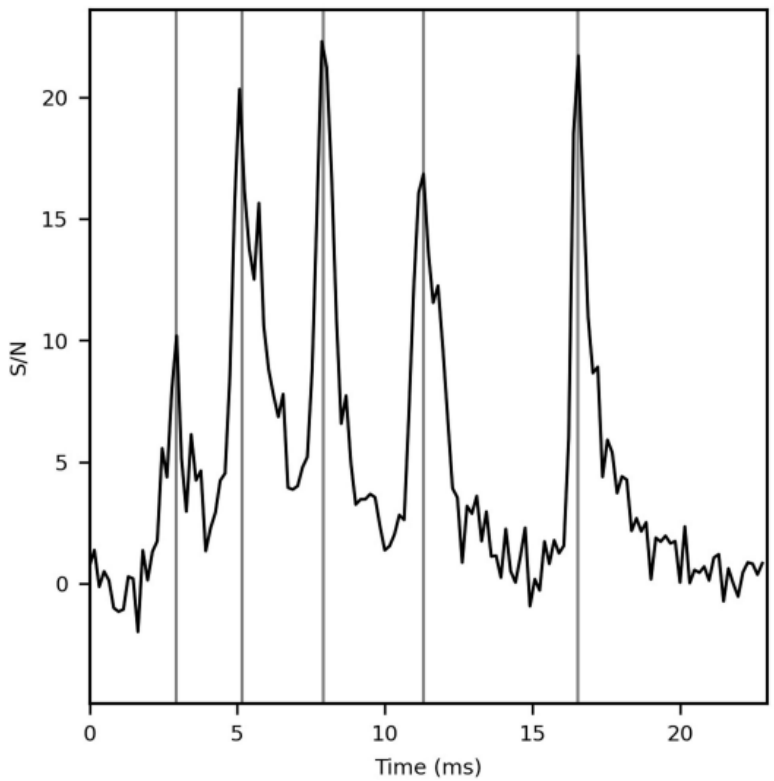
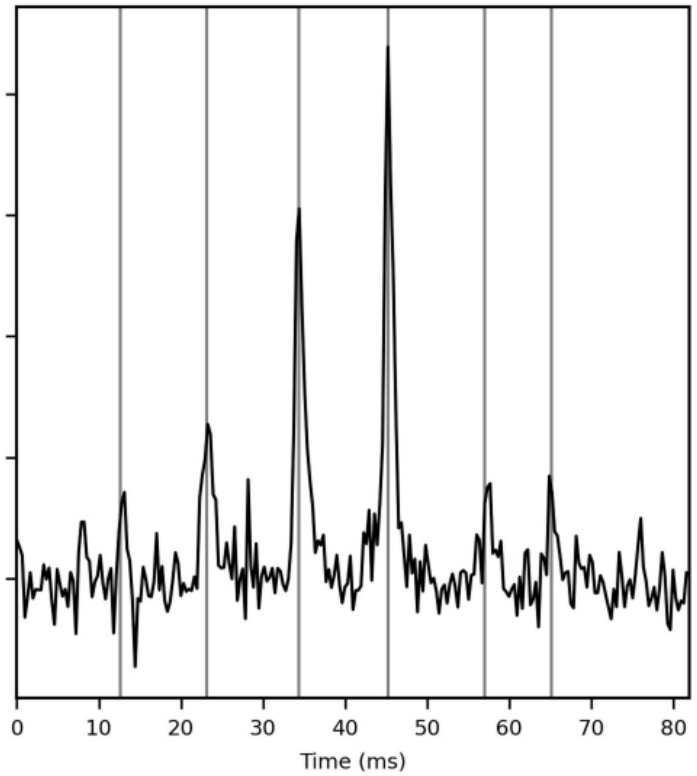
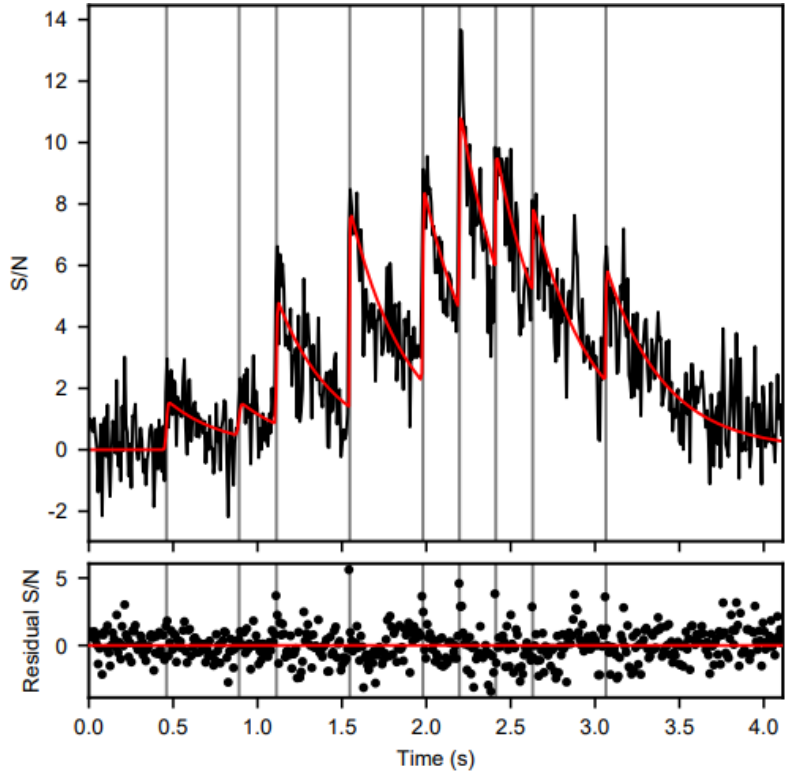
For fast radio bursts



FRB 20210206A

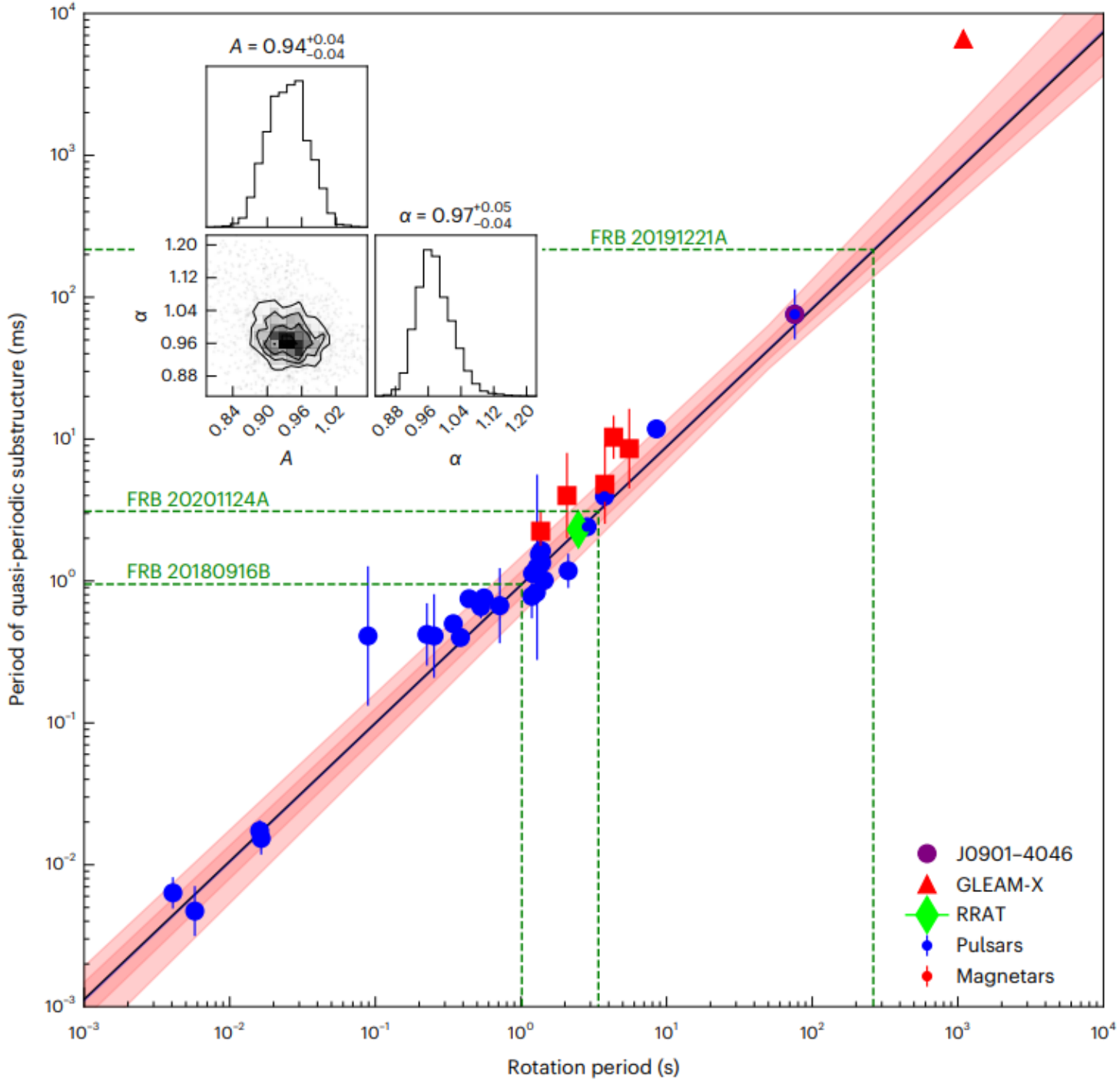


FRB 20210213A



FRB 20191221A

The CHIME/FRB Collaboration,2022



$$P_\mu = (0.94 \pm 0.04) \times P^{(0.97 \pm 0.05)} ms$$
$$\tau_\mu = (0.59 \pm 0.03) \times P^{(0.99 \pm 0.02)} ms$$

- The relation extends over about six orders of magnitude;
- The quasi-periodic sub-pulses is not always present;
- Fluctuation of period of sub-pulses are observed;

Discussion and summary

- The relation extending over about six orders of magnitude suggests that a unifying mechanism exists in all kinds of neutron stars.
- They think the quasi-periodic sub-pulse may comes from some temporary angularly periodic structure.
- Some people try to explain the structure with tearing instabilities of current sheet in magnetic reconnection process, but the work hasn't been connected to the rotation period of neutron stars. The cause of this phenomenon remains to be studied.