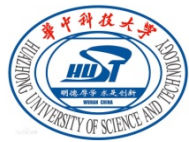

Searching for Compact Pulsar Binaries

Biping Gong

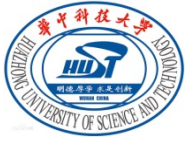
Huazhong University of Science & Technology

FPS7, Guangzhou, July 5, 2018



Hunting for ultra-compact binaries

- $P_b = 109$ min (2000)
 $P_b = 95$ min (2012)
 $P_b = 14$ min
 $P_b < 10$ min



Alternative ways of searching them?

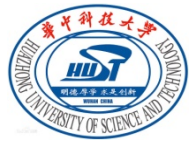
- Over **50%** of stars are in binary systems
- Searching method:
- **Acceleration search**



Our search of ultra-compact pulsar binaries

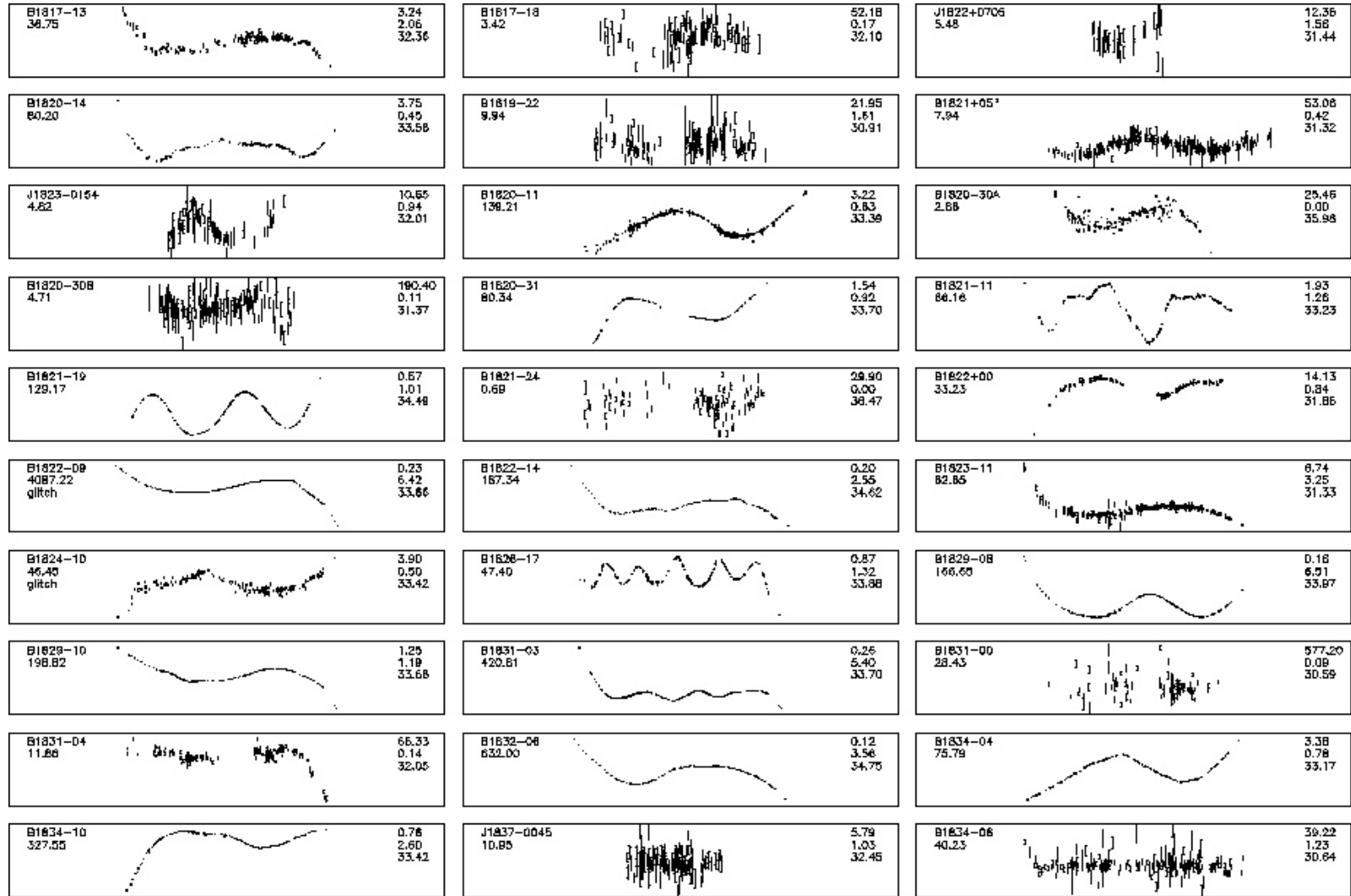
- We started from

Long-term timing noise



Pulsar timing noise

O-C



Hobbs et al. 2010

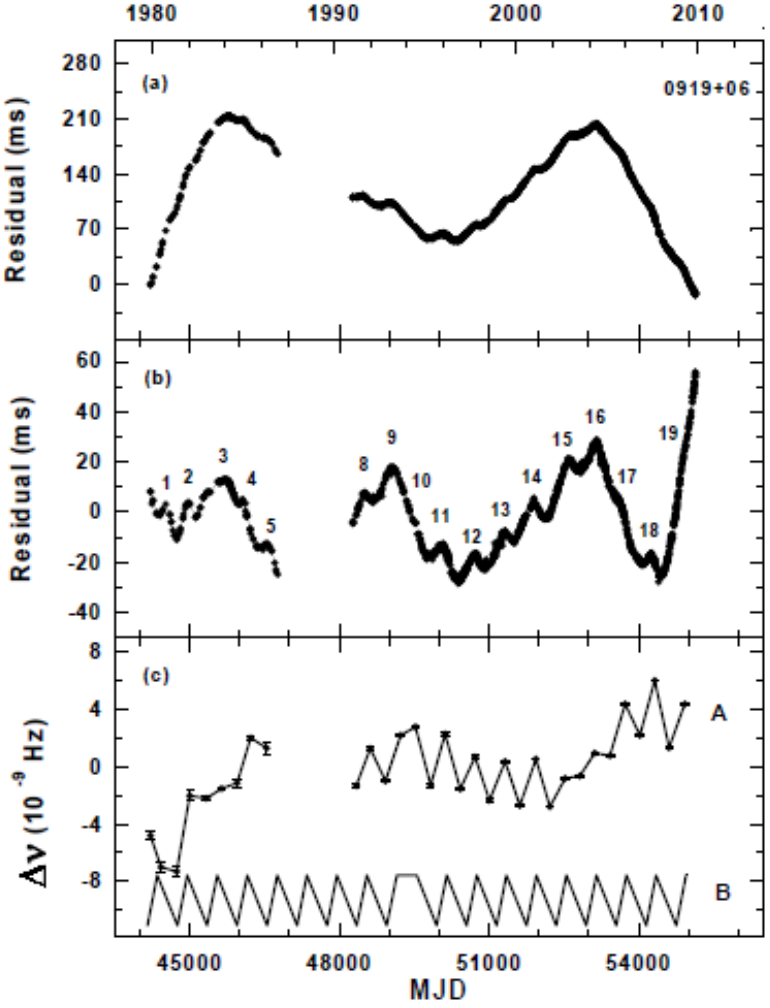
粒子与天体物理研究所

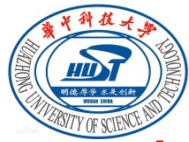
quasi-periodic

)



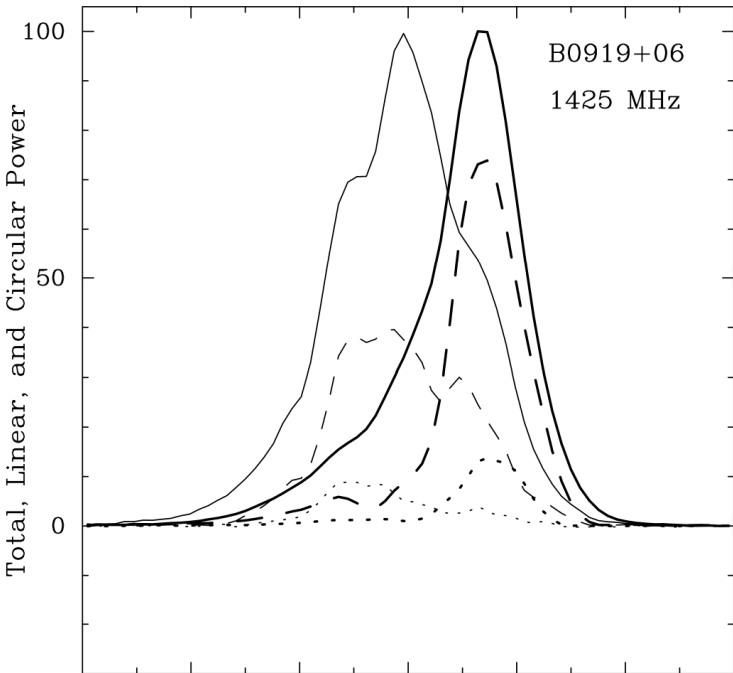
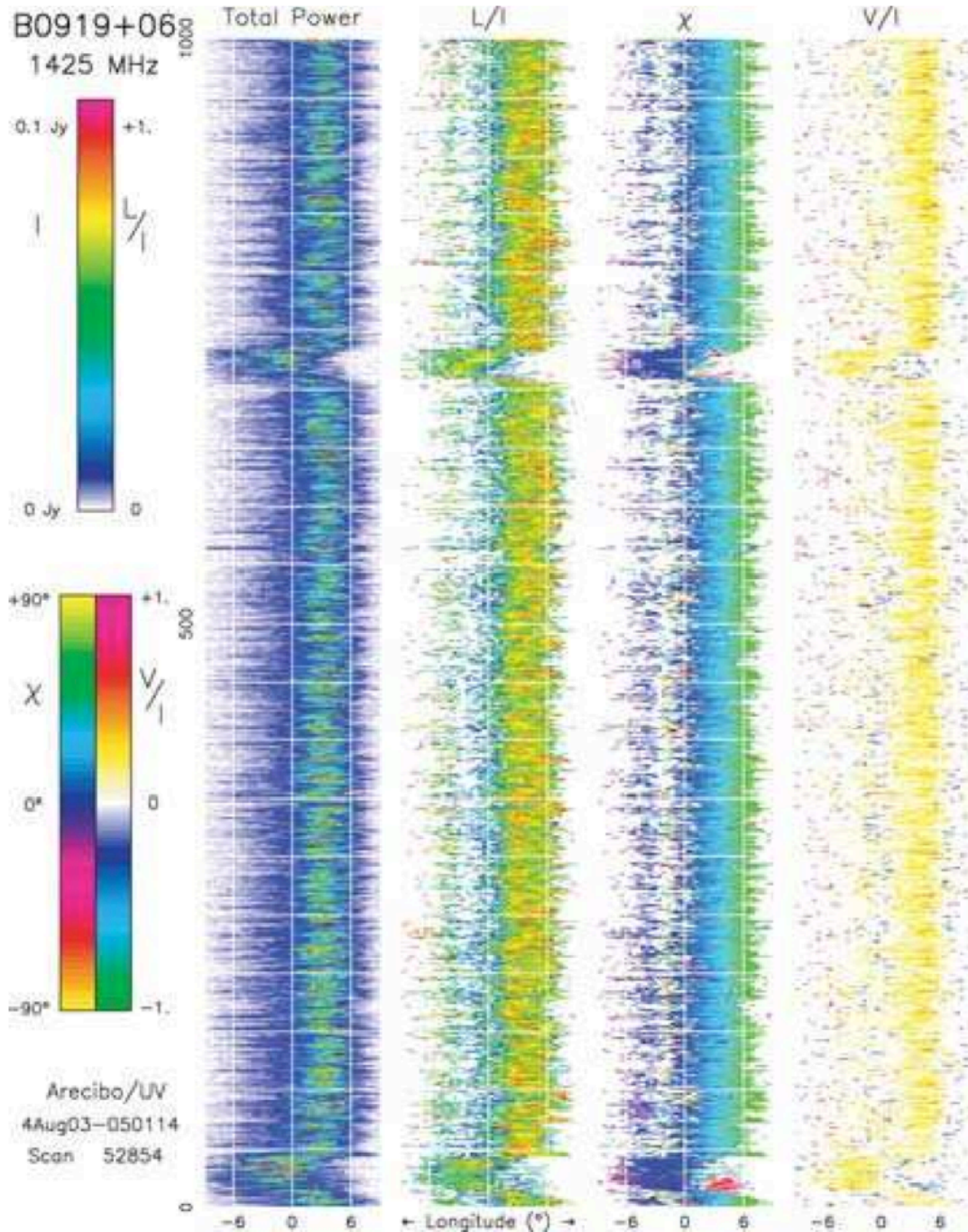
Long-term timing noise of **SINGULAR** pulsar PSR B0919+06

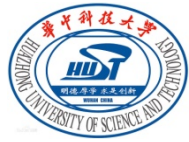




Short-term timing of PSR B0919+06

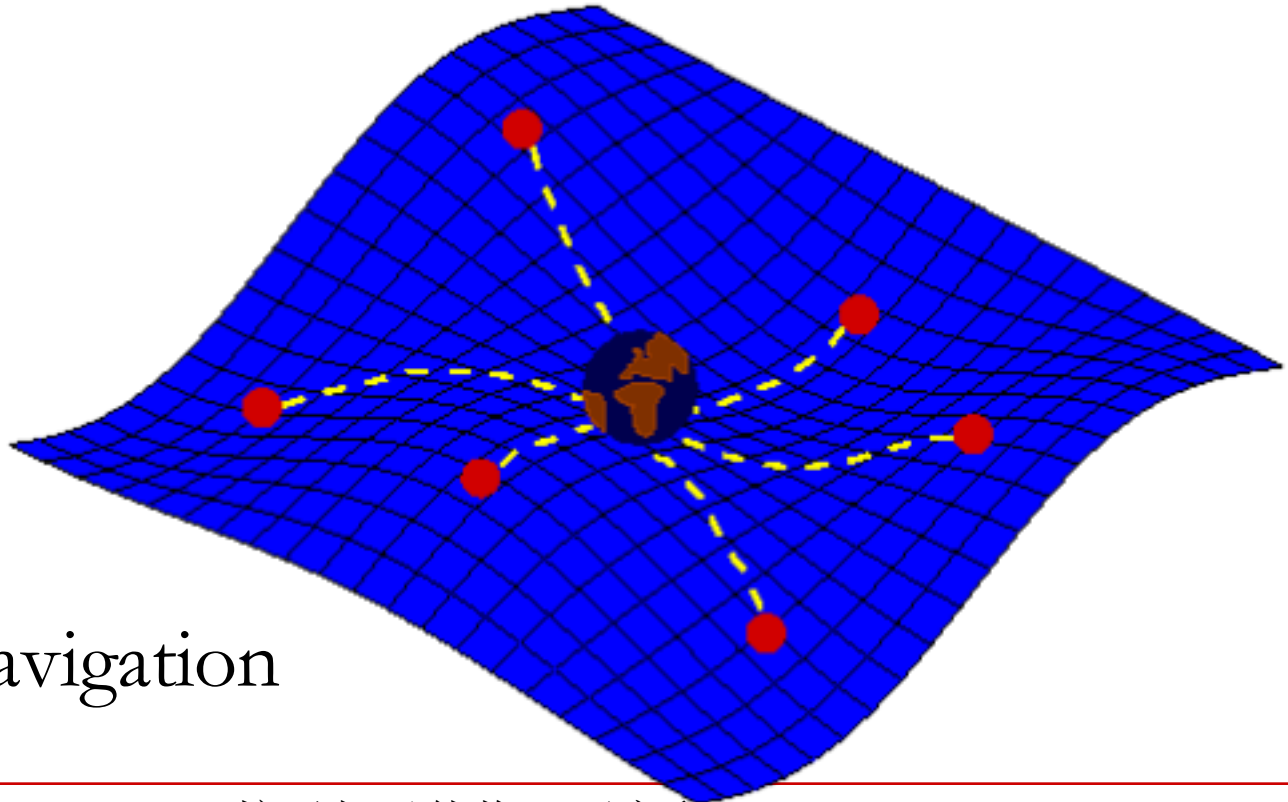
Shift of pulse
Rankin et al. 2006



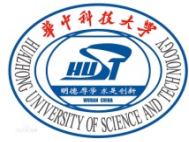


It influences on all applications based on pulsar timing measurement

- Test of GR
- Pulsar Timing Array

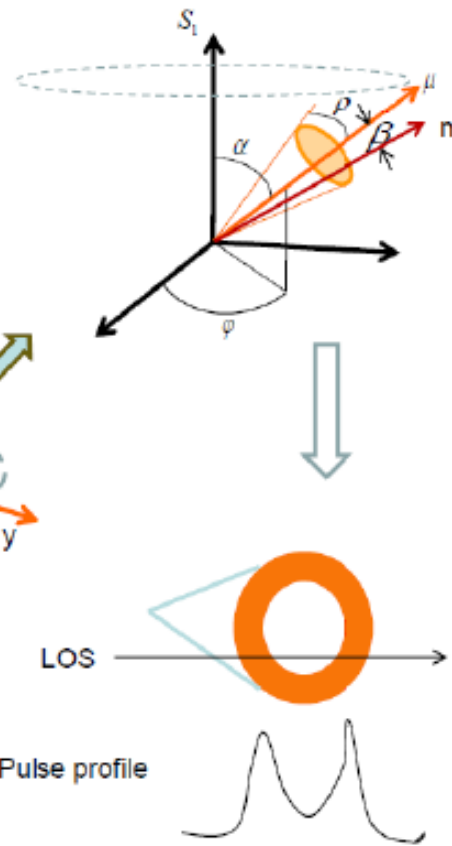
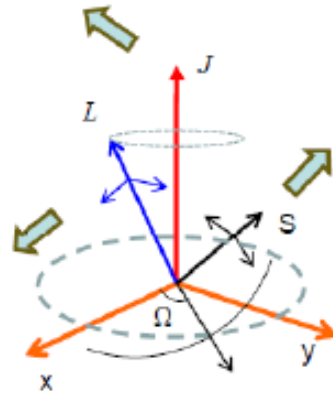
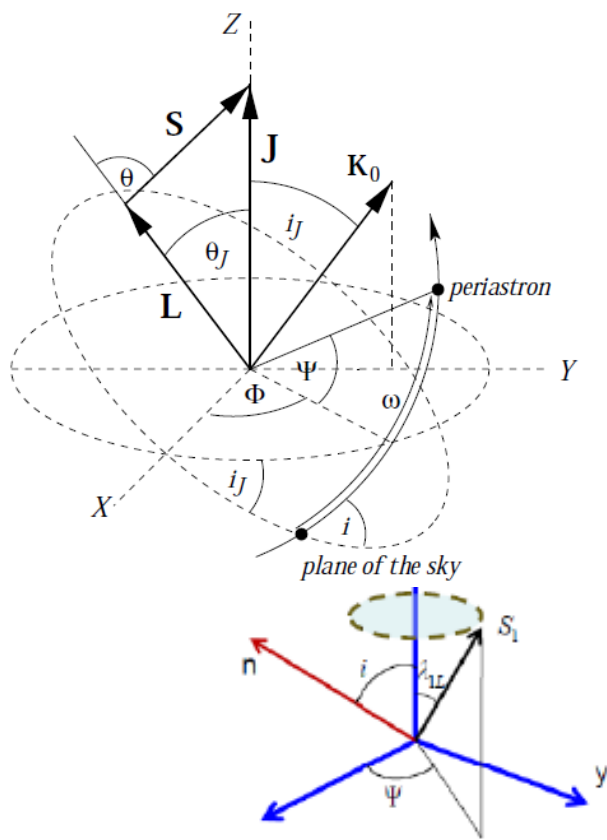


- Navigation



Long & short, each is difficult enough

- But put them together may be easier
- **Ultra-compact binary system**
- Long-term noise
- Short-term shift
- **BUT**, it has been identified as a **singular pulsar**

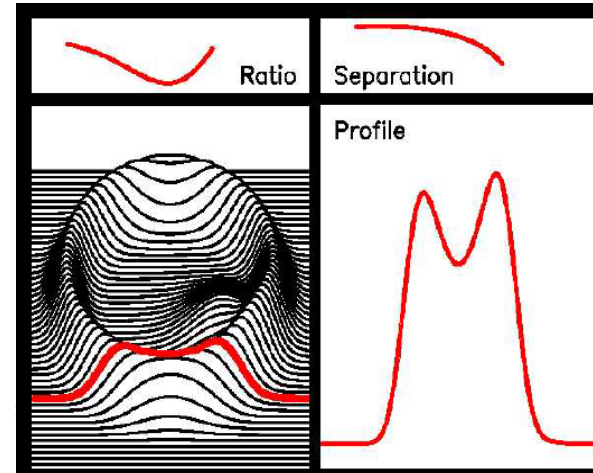


$$\mathbf{n} = \sin i \mathbf{i} + \cos i \mathbf{k} = (\sin i, 0, \cos i).$$

$$\mathbf{n}' = R(-\lambda)R(\Psi)\mathbf{n},$$

$$\tan \Theta(t) = n'_y(t)/n'_x(t)$$

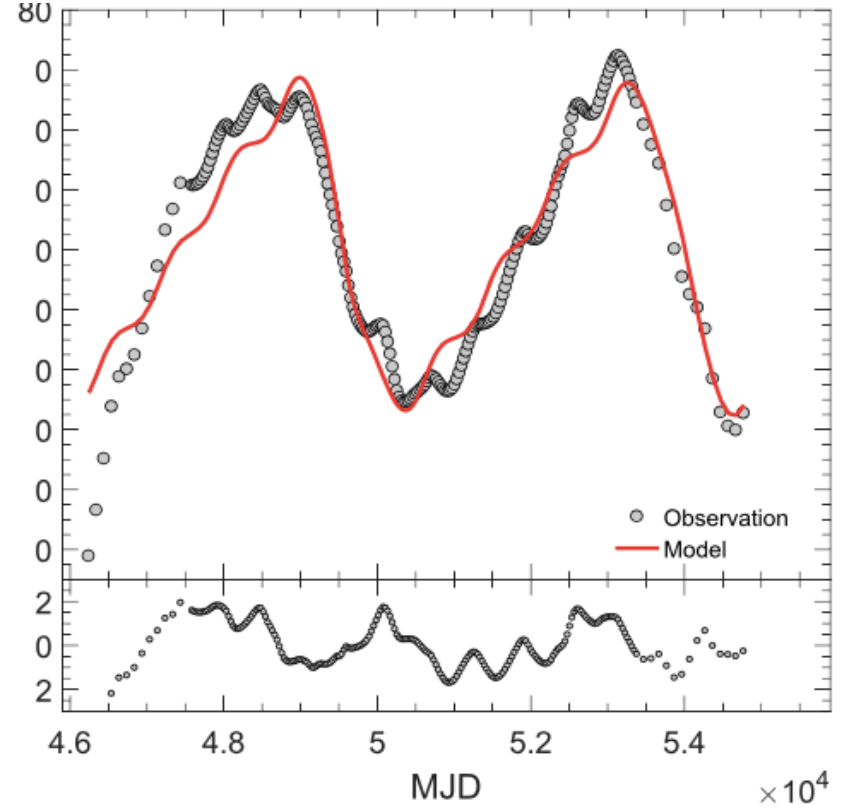
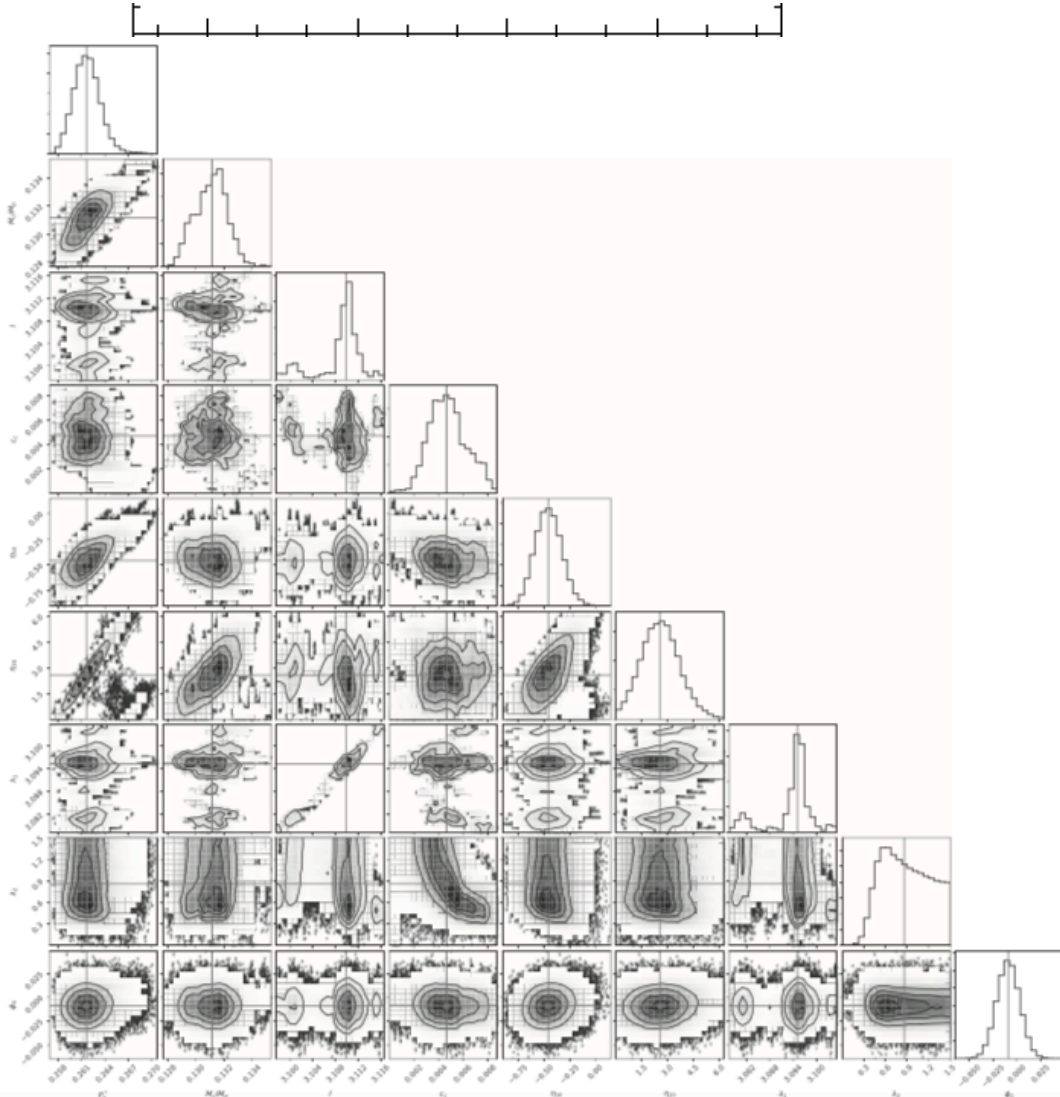
$$\text{粒子 } \dot{\Omega}_p = \frac{L(4 + 3m_c/m_p)}{2r^3} \hat{\mathbf{L}}$$

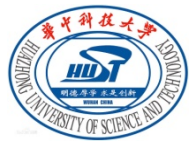


Fitting result

Parameters Obtained by Fitting the Long-term Timing Noise^a

P_b^* (hr)	M_c/M_p	I (rad)	c_c	η_{10} (rad)	η_{20} (rad)	λ_1 (rad)	λ_2 (rad)	ϕ_0 (rad)
0.262 ± 0.002^a	0.130 ± 0.001	3.110 ± 0.002	$0.0047^{+0.0018}_{-0.0014}$	-0.46 ± 0.13	$2.58^{+1.11}_{-1.09}$	$3.095^{+0.002}_{-0.007}$	$0.86^{+0.41}_{-0.33}$	-0.009 ± 0.01

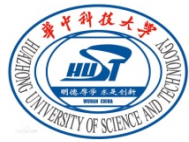




PSR B0919+06 might be
an ultra-compact binary of $P_b=14\text{min}$

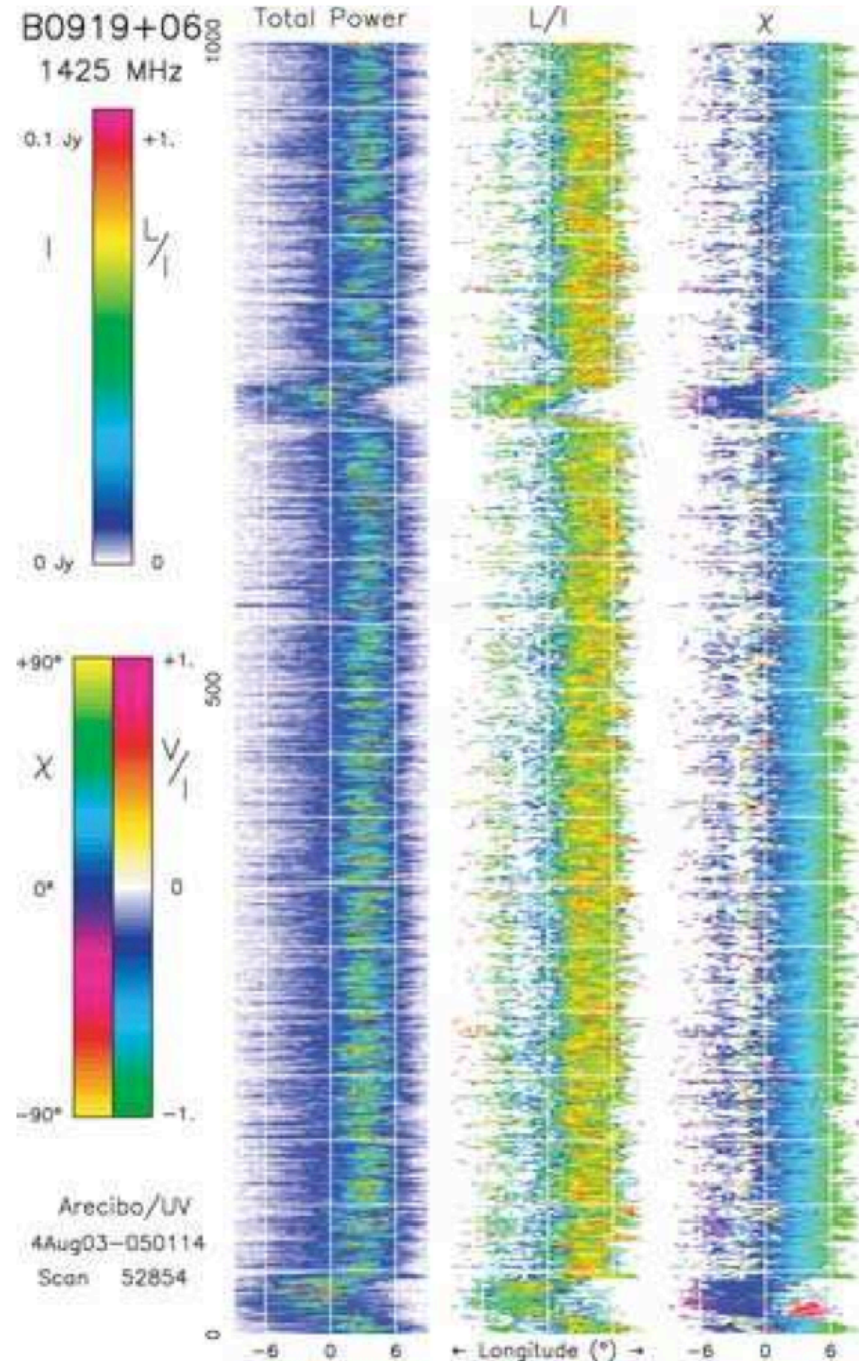
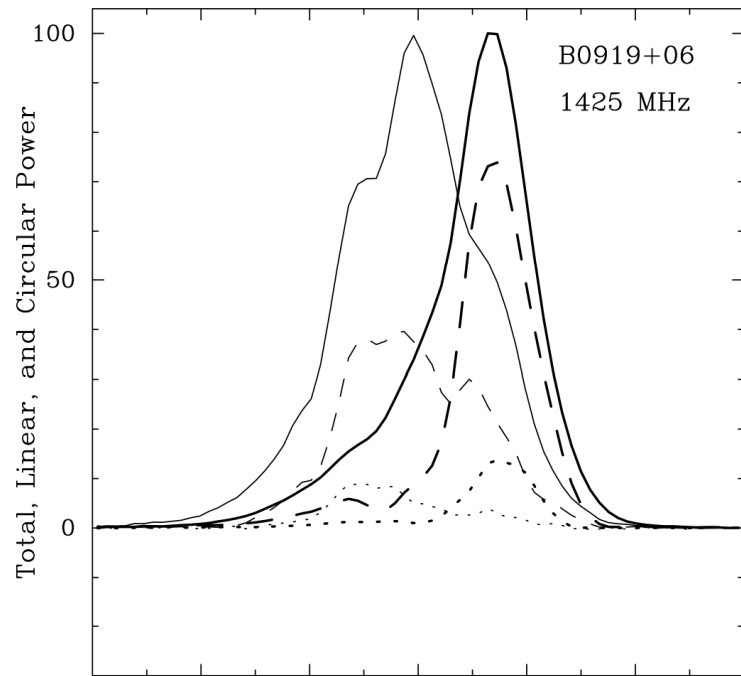
How to test the existence of such an
ultra-compact binary ?

Finding orbital modulation to the time
of arrival of this pulsar



Are such shifts periodic ?

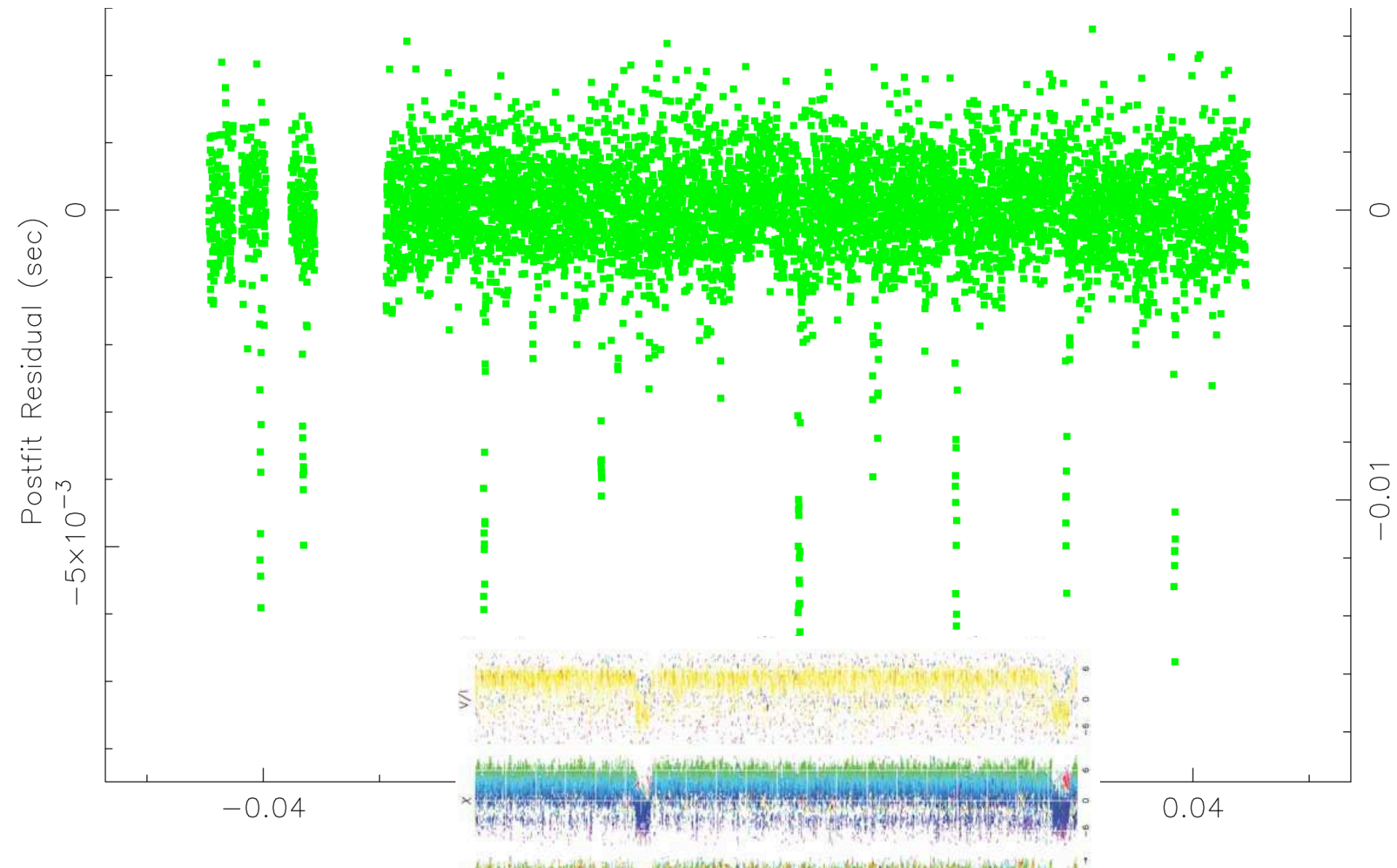
Previous observation of Shift of pulse is not sufficient

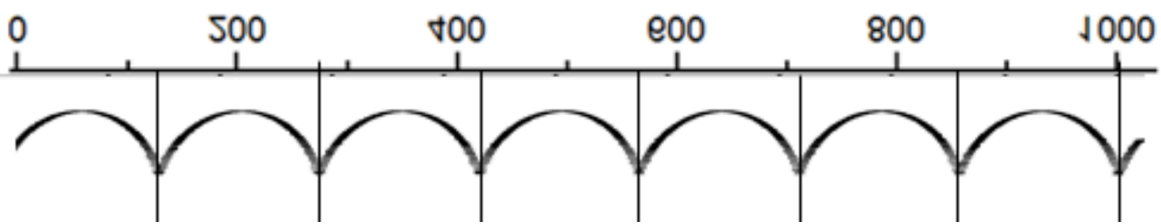
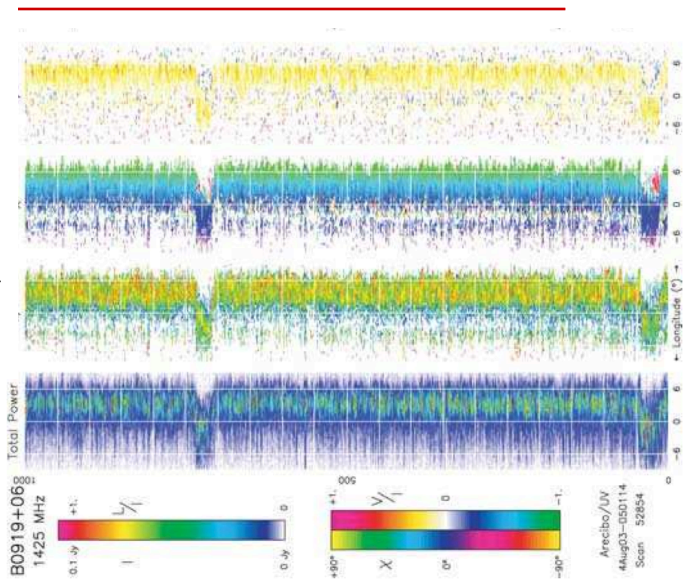
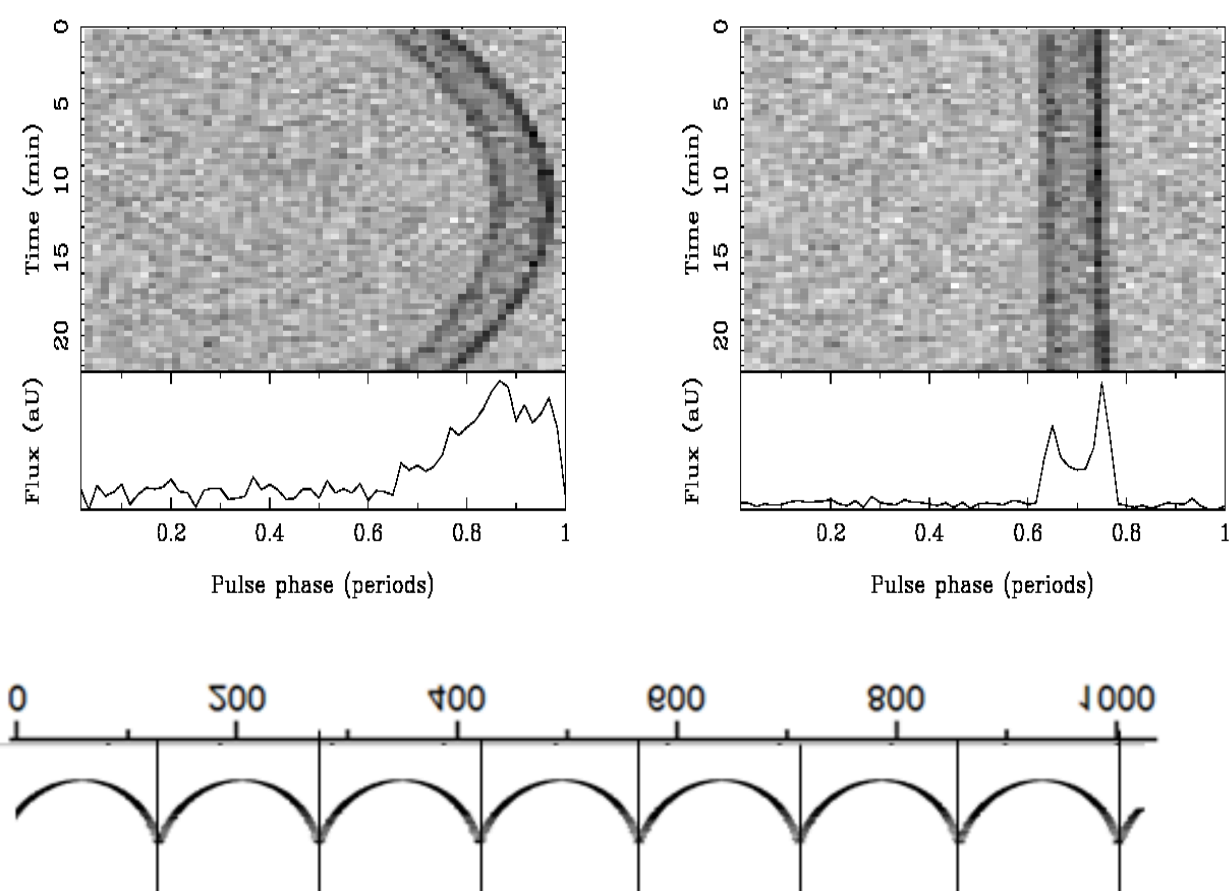


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A continuous observation with time scale covering several Pb is needed

Our Arecibo data displayed in short-term timing residual





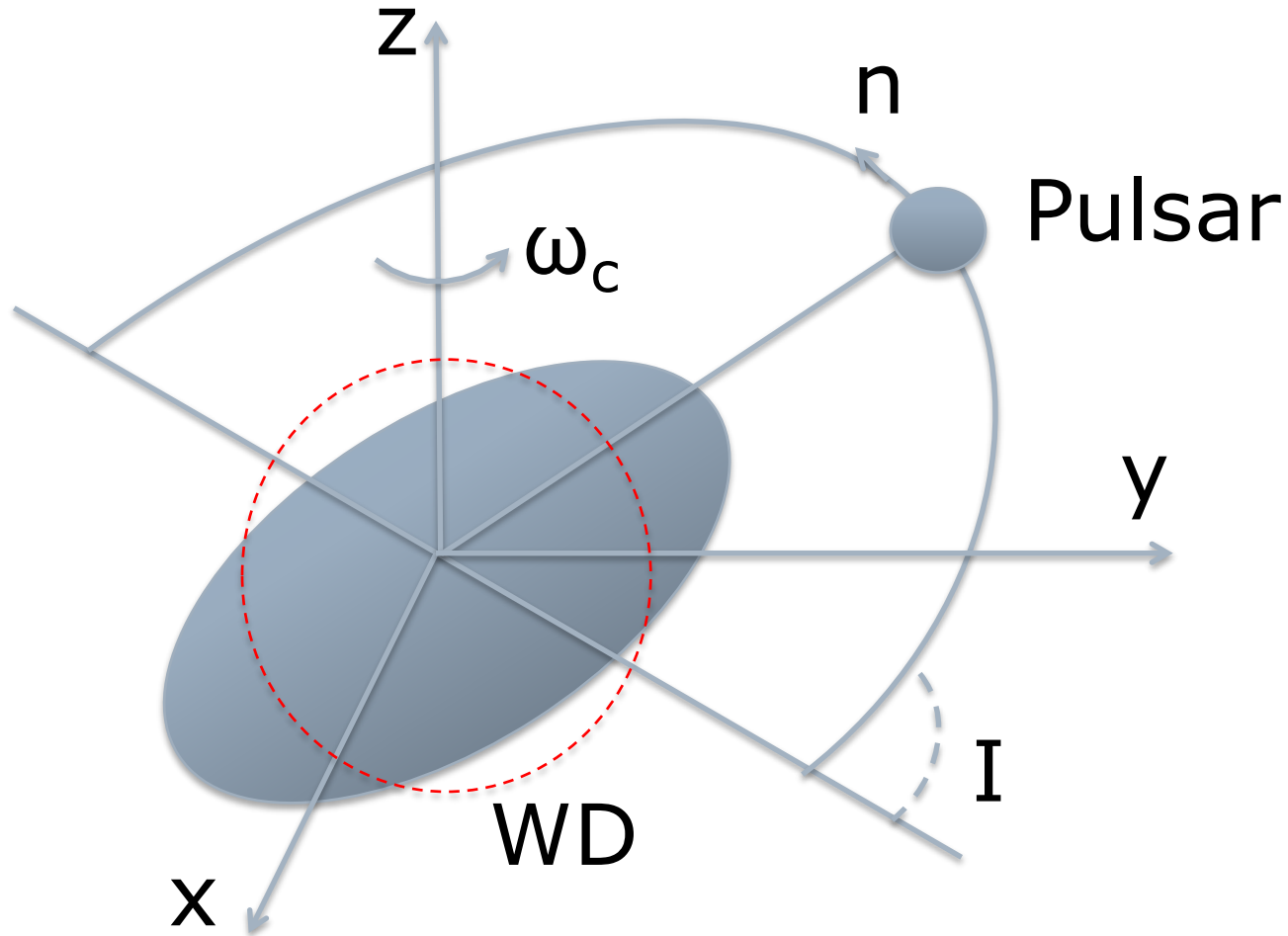
$$\Delta_R = x[(\cos U - e) \sin \omega + (1 - e^2)^{1/2} \sin U \cos \omega]$$

Periodic vs quasi-periodic

asymmetry in shift, quasi-periodicity, sharpness

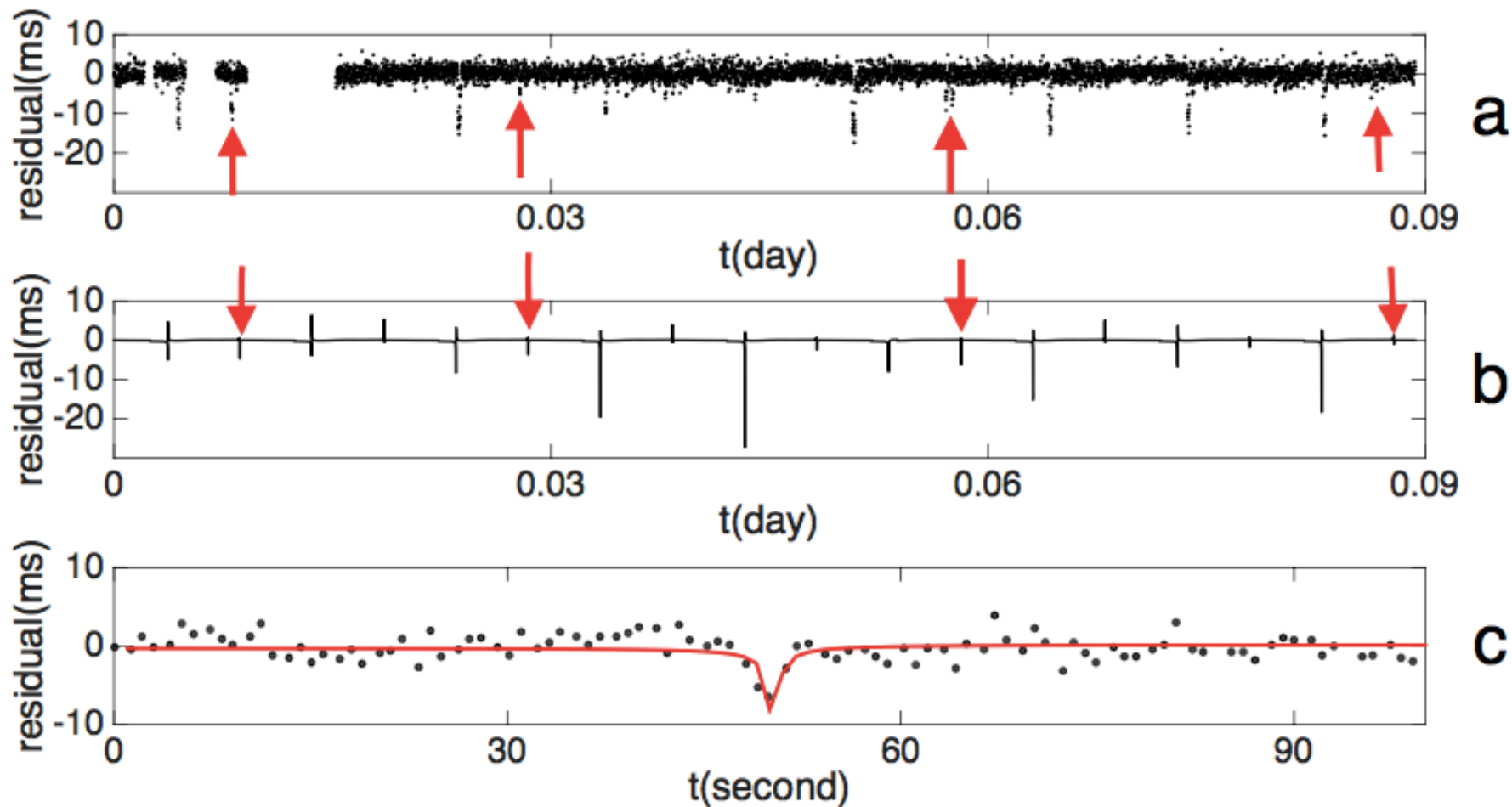


Tide force in ultra-compact binary



Parameters obtained by fitting of single pulse observation

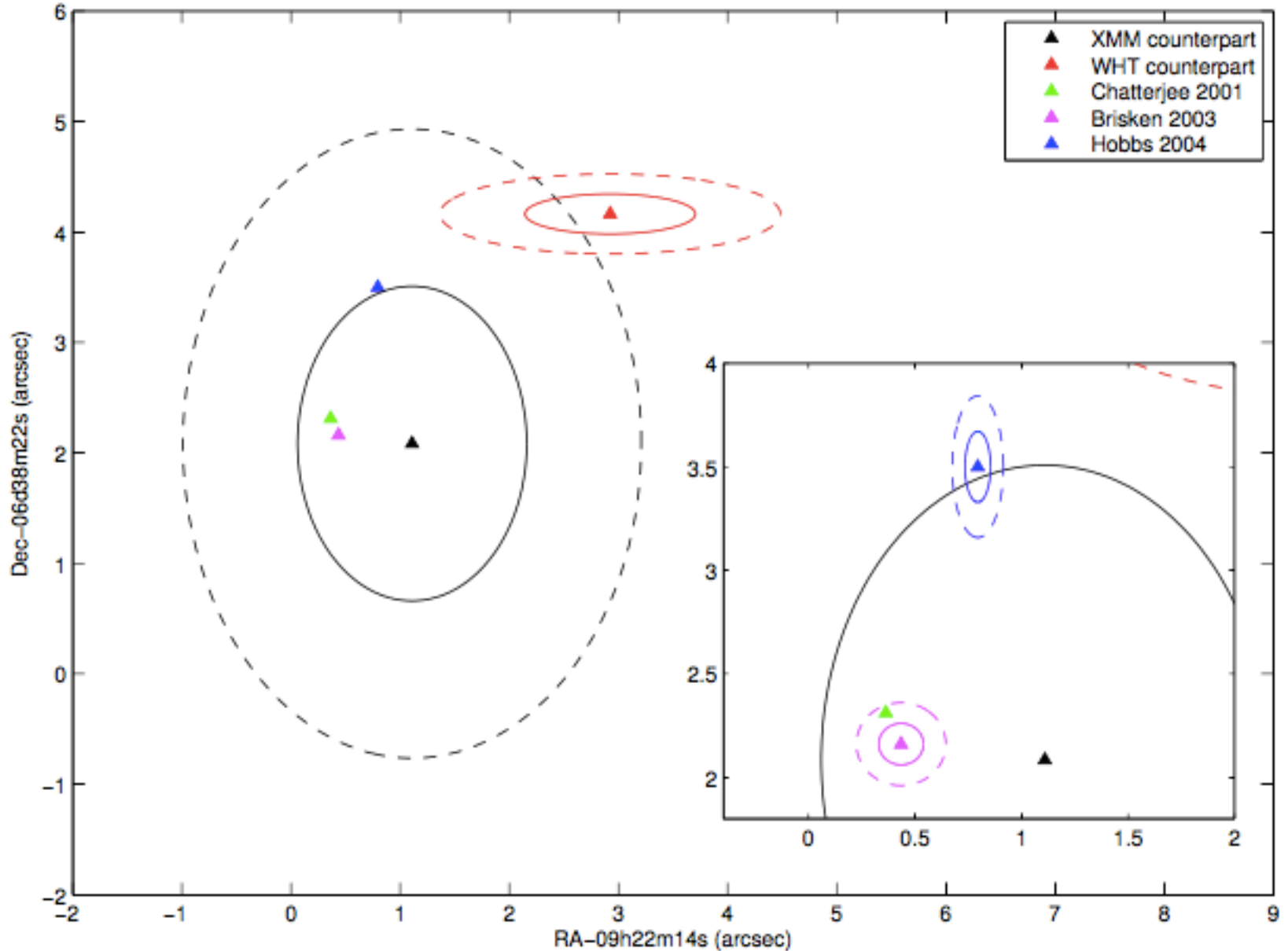
P_b (s)	e	M_p (M_\odot)	M_c (M_\odot)	n/ω_c	R_c (cm)	M_0 (rad)	λ_2 (rad)	η_2 (rad)	ϕ (rad)	λ_{BG} (rad)
855.5	0.152	1.15	0.16	1.37	3.2×10^9	5.5	2.0	4.54	0.85	1.56

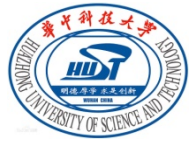




Optical counterpart ?

William Herschel Telescope at u,g,r





Our Progress in finding UCBs

Pb=109 min (2000)

Pb=93 min (2012)

Pb=14min

2001 started

2006 magnetars

2014 Arecibo

2016 WHT

2018a ApJ 855,35

2018b Gemini



Thank you for your attention !