NAOC 中国科学院国家天文台 NATIONAL ASTRONOMICAL OBSERVATORIES , CAS

CRAFTS The Commensal Radio Astronomy FAST Survey FAST多科学目标同时扫描巡天

Prospects of pulsar timing and discoveries using FAST

Weiwei Zhu
(on behave of the FAST early science team)
National Astronomical Observatories, CAS
CSQCD VII, CUNY Advance Research Center, NY

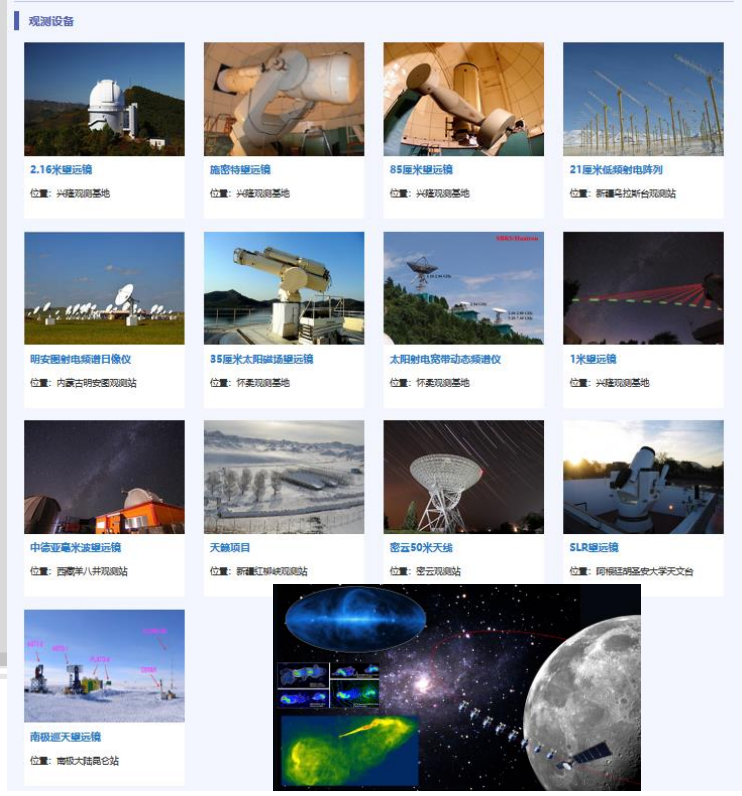
Outline

- Introducing NAOC and FAST
- What is the FAST telescope good for?
- Prospects of FAST pulsar timing
- Recent Pulsar discoveries

中国科学院国家天文台

NATIONAL ASTRONOMICAL OBSERVATORIES , CAS

- Chinese Academy of Science
- Major observatories:
  - YunNan Observatory
  - XinJiang Observatory
  - GuiZhou Observatory
  - NIAOT
- +7 observing sites
- 7 divisions cover Astronomy from Radio to X-ray



What is FAST

(Five-hundred-meter Aperture Spherical radio Telescope)

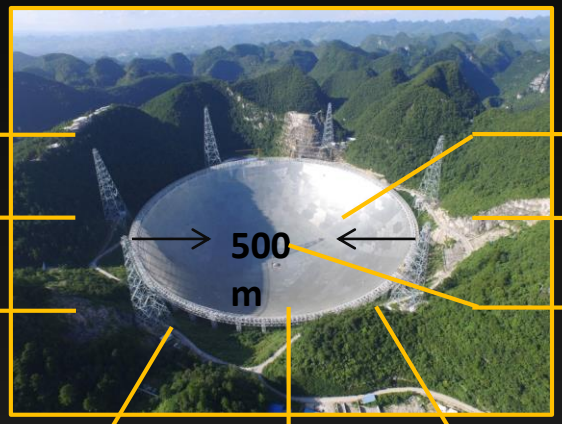
spec: Karst Depression
time: 2011-2016
cost: 1.1495B Yuan (0.18B$)

World's largest single dish radio telescope

FAST collecting area≈ 30x football fields

What is FAST

Active surface, suspended receiver system



Surrounded by ridges

Karst depression

Collecting area
250,000 m²

6 suspension tower

6 cable

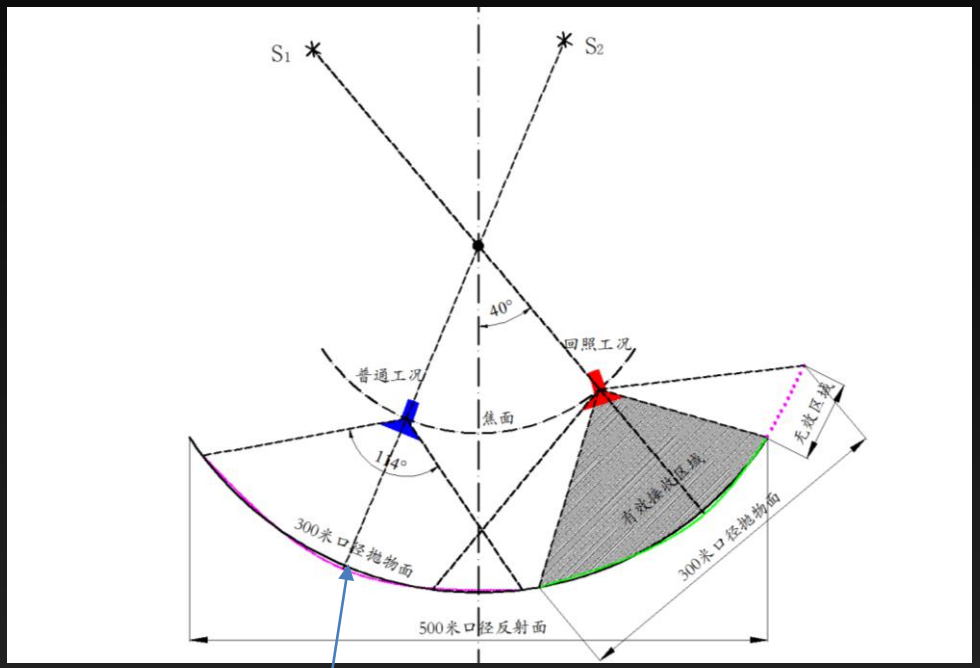
1 suspended cabin

2225
actuator

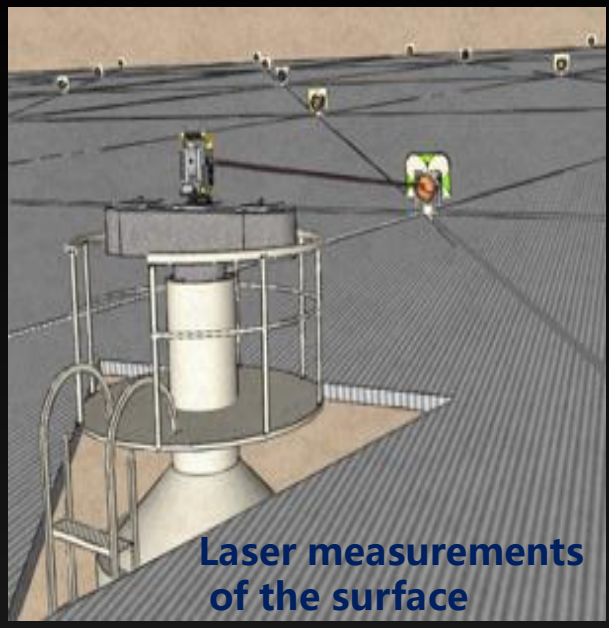
4450
Triangular
reflective
panels

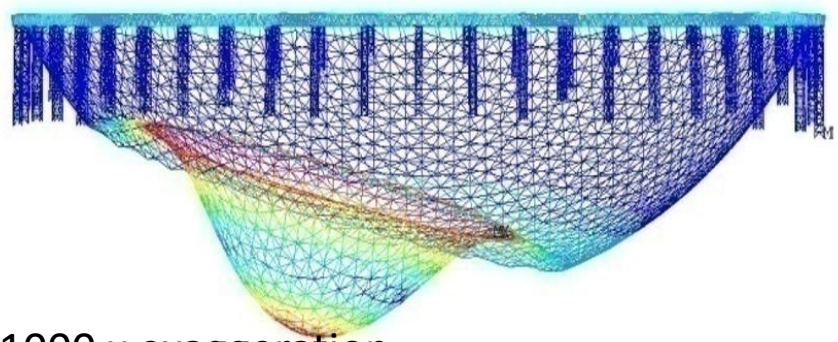
6670
Main
frame
cable

How FAST works



0.47m





1000 x exaggeration

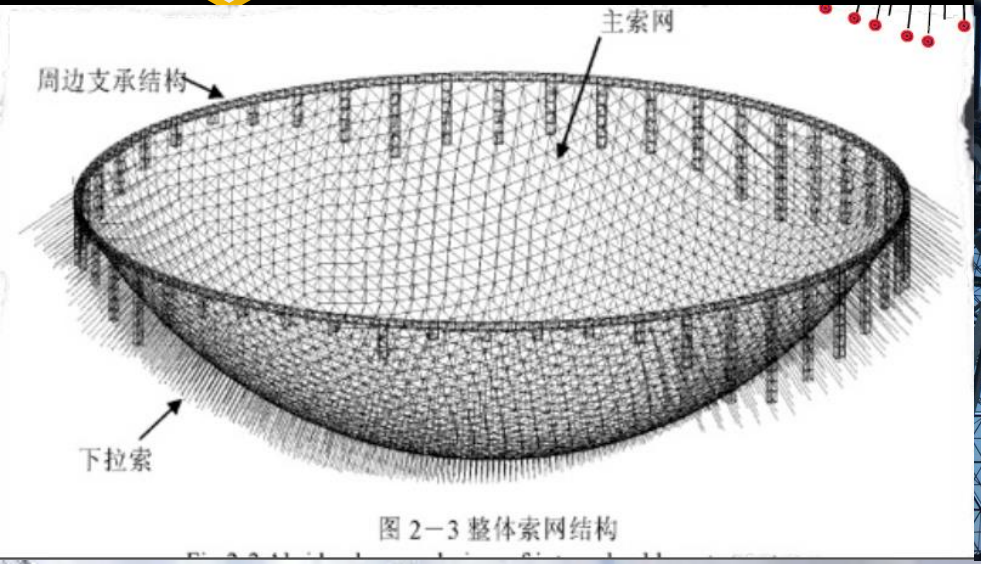
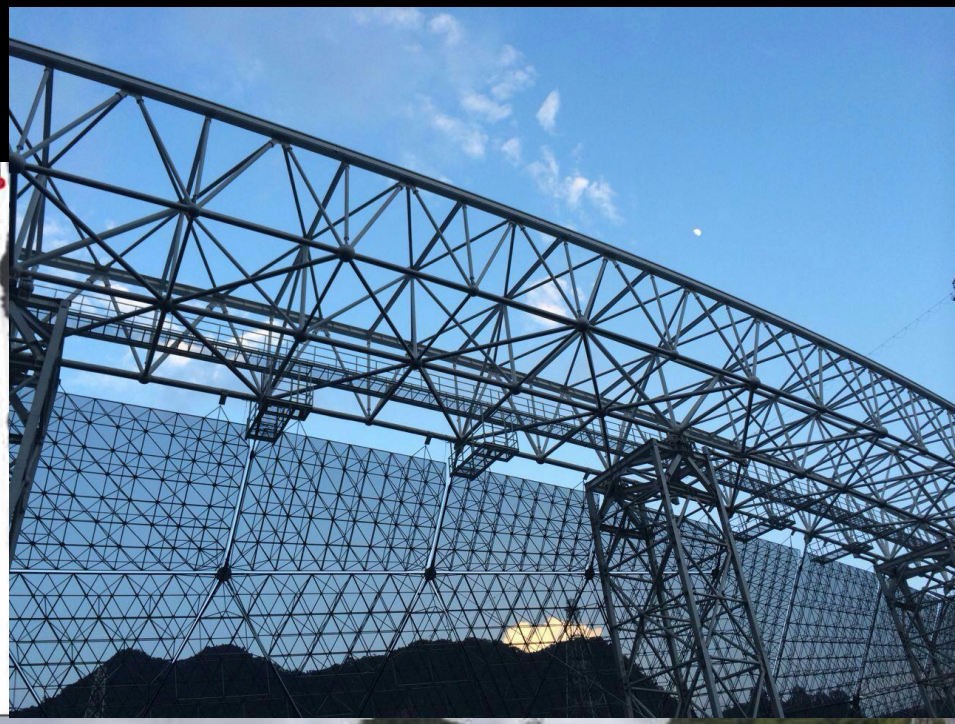


图 2—3 整体索网结构



The FAST site

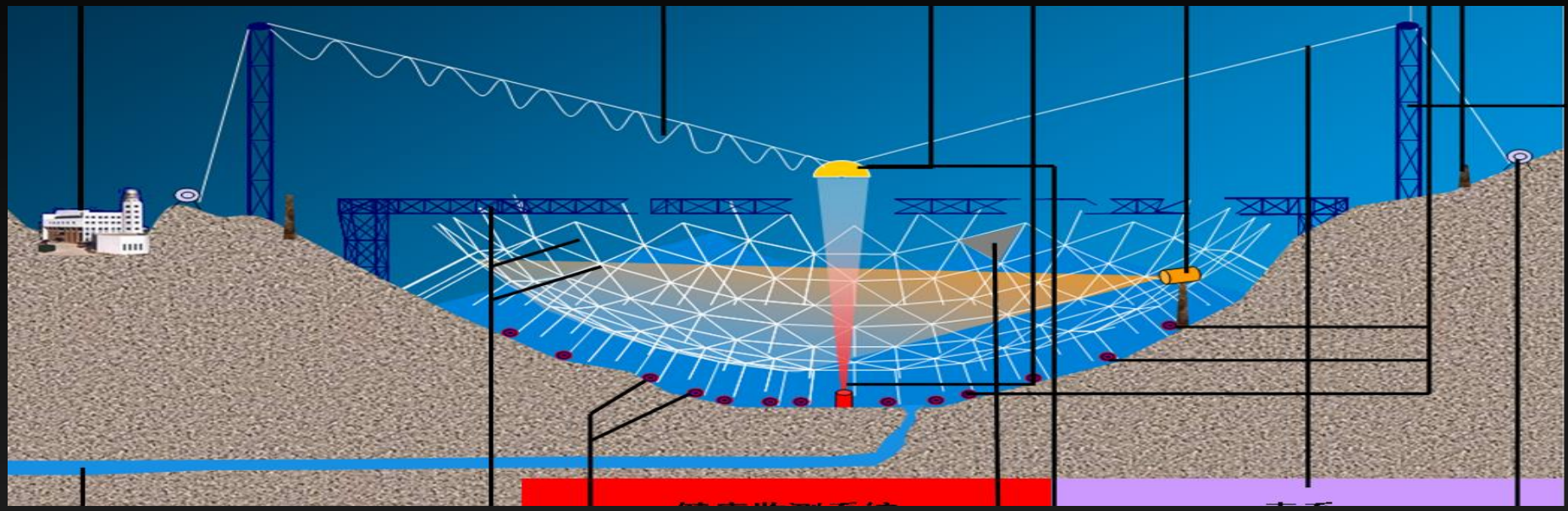
Closest to be Spherical

Natural Water Draining

No major villages within 5 km radius

Best site selected from 300 possible sites

Telescope systems



Main specifications

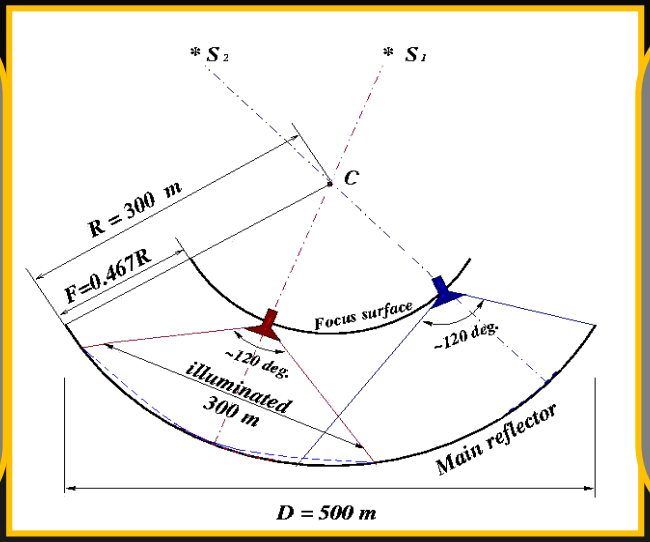
Surface: 500m

Illuminated are: 300m

Focus Ratio: 0.4611

Dec range: 40° from zenith

Op freq: 70MHz - 3GHz



Sensitivity (L): 2000m^2/K

Resolution (L): 2.9′

N beam(L): 19

Slew time: < 10 min

pointing: 8″

In L band (21cm)
FAST Gain ~ 13-17
Arecibo Gain ~8-10
FAST ~ 1.5 Arecibo


2005.10


2010.12


2012.03


2013.03


2014.03


2015.03


2016.03

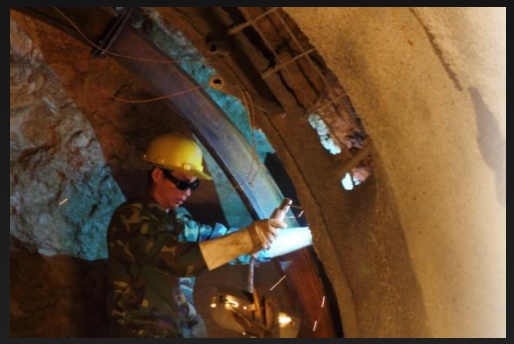

2016.07












www.ptjp.gov.cn


星辰天缘大酒店
XINGCHEN TIANYUAN GRANDHOTEL

What is FAST good for ?

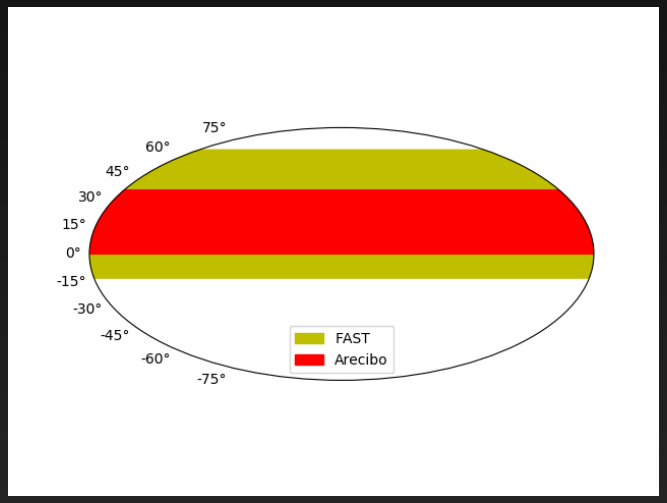
Sensitivity (Gain): FAST ~ 1.5-2 x Arecibo

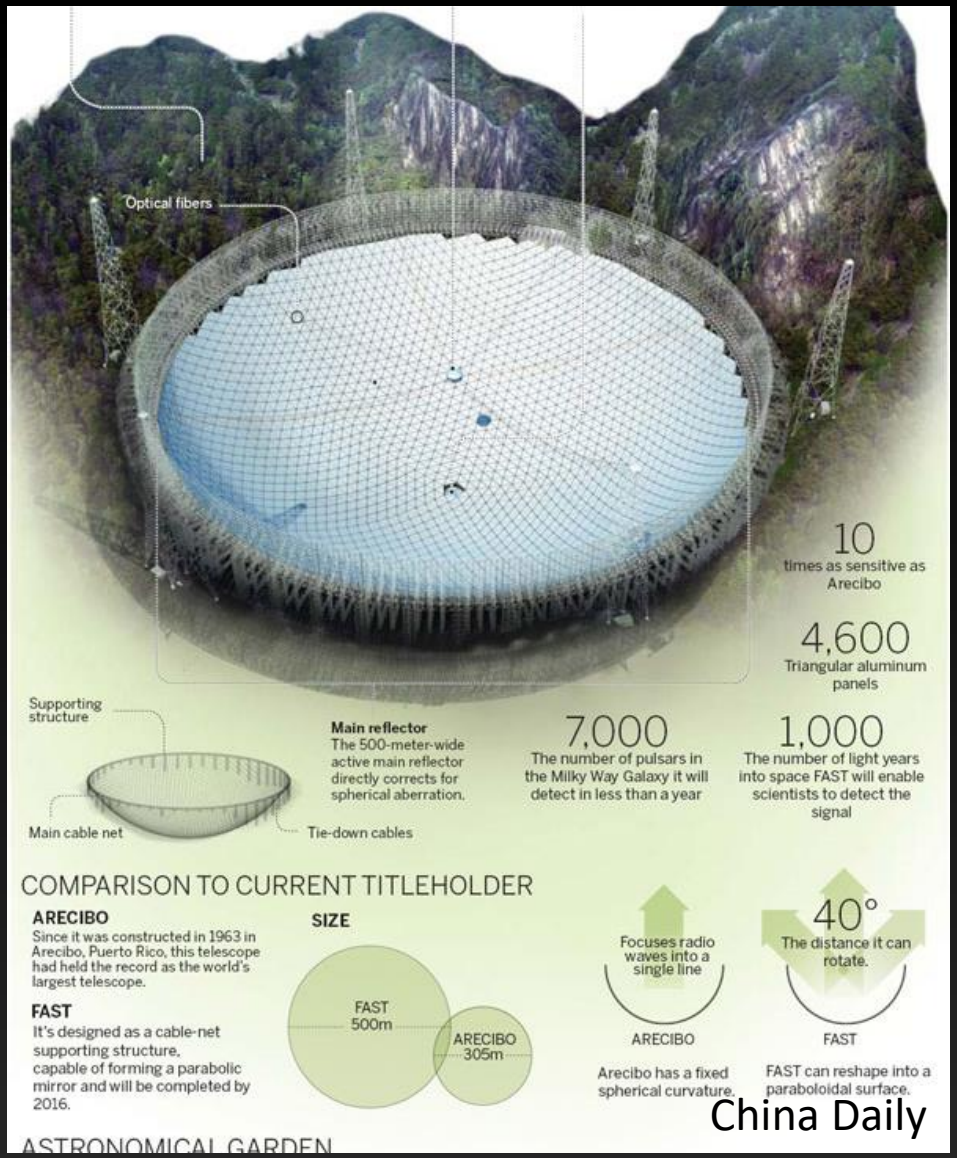
Arecibo observable sky: Dec in 0-39 deg

FAST observable sky: Dec in -14-66 deg

Arecibo Num beams: 7

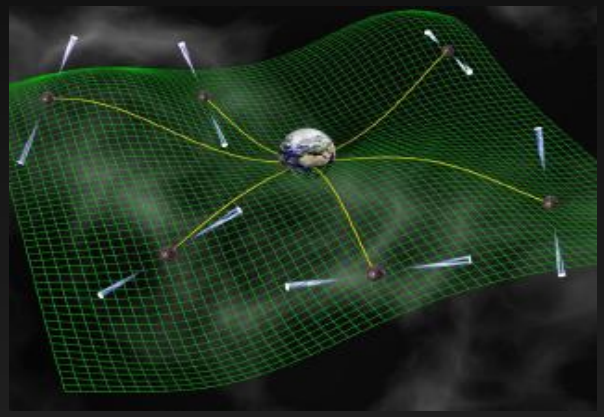
FAST Num of Beams:19 (3x survey speed)



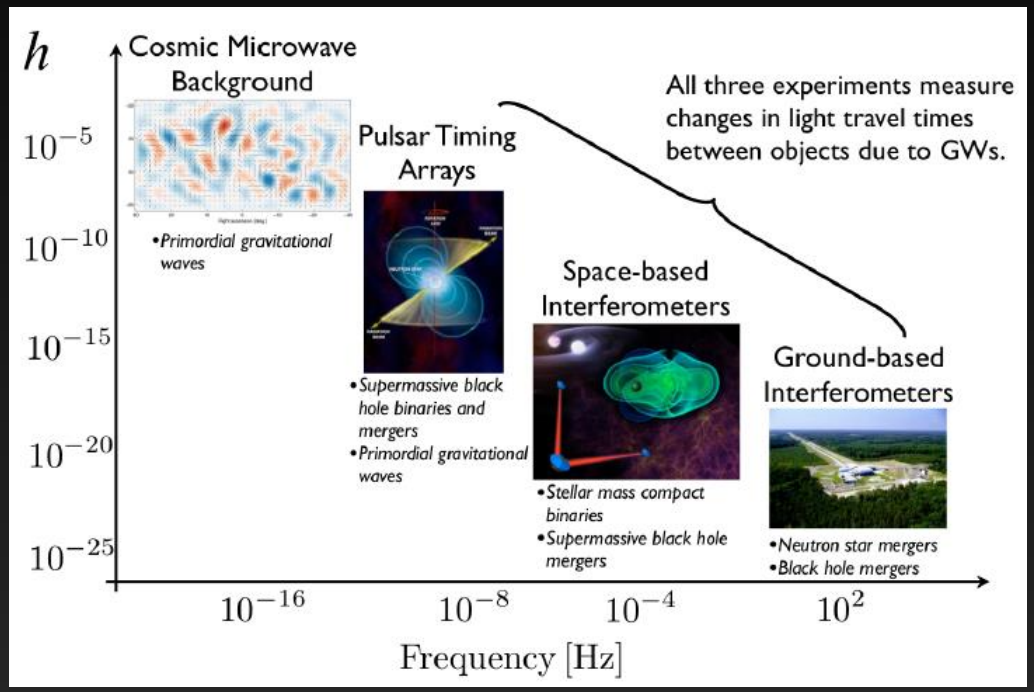


Pulsar Timing and Gravitational Waves

- Gravitational Waves：New Window of Astronomy
- Pulsars could be used to detect nanoHz GWs



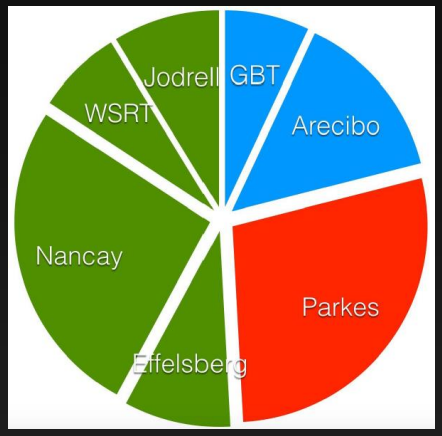
Pulsar Timing Array



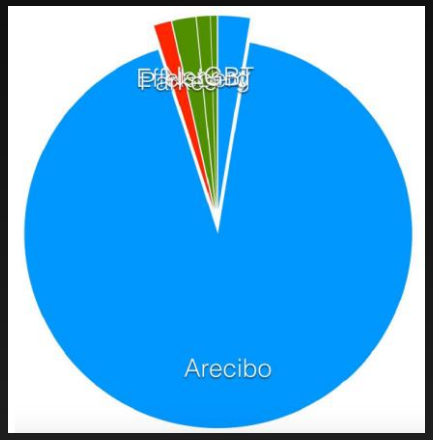
Pulsar Timing for detecting GW

- 2 x sensitivity -> 2 x timing precision

$$\sigma_{\mathrm{TOA}} \simeq \frac{W}{\mathrm{S/N}} \propto \frac{S_{\mathrm{sys}}}{\sqrt{t_{\mathrm{obs}}\Delta f}} \times \frac{P\delta^{3/2}}{S_{\mathrm{mean}}}.$$



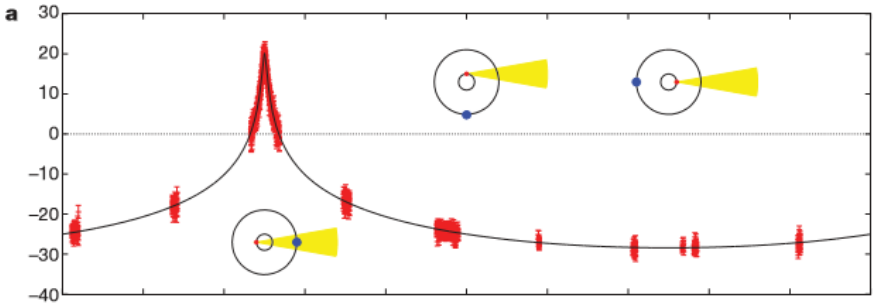
Hours of Observation in IPTA

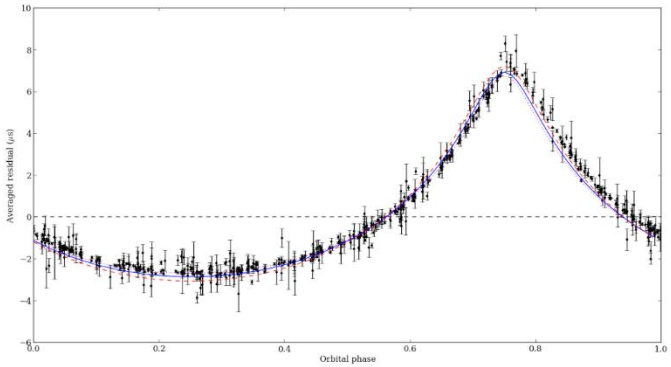


Sensitivity contributions in IPTA

Pulsar Timing and Shapiro Delay

- Depend on inclination angle: $\Delta_{\mathrm{SB,max}} \sim 2M_c \ln(\frac{1}{1-\sin i})$
  - Max delay for ~89 deg inclination: ~100us
  - Max delay for ~70 deg inclination: ~10us

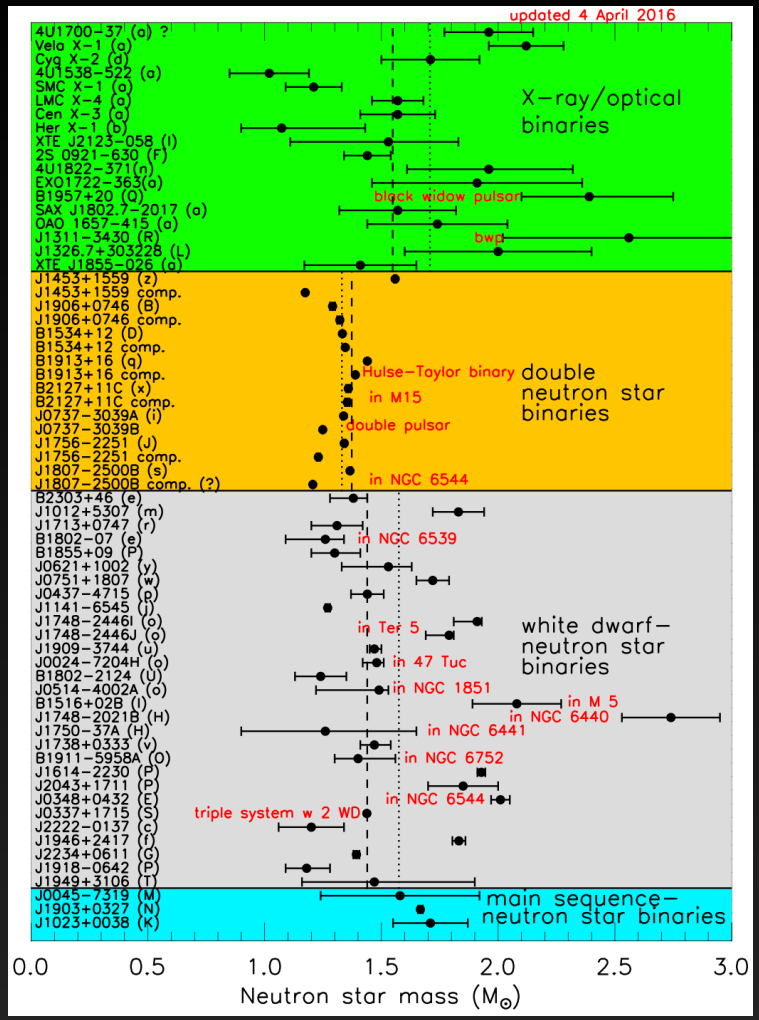




PSR J1713+0747 Shapiro Delay

Pulsar Timing and Mass Measurements

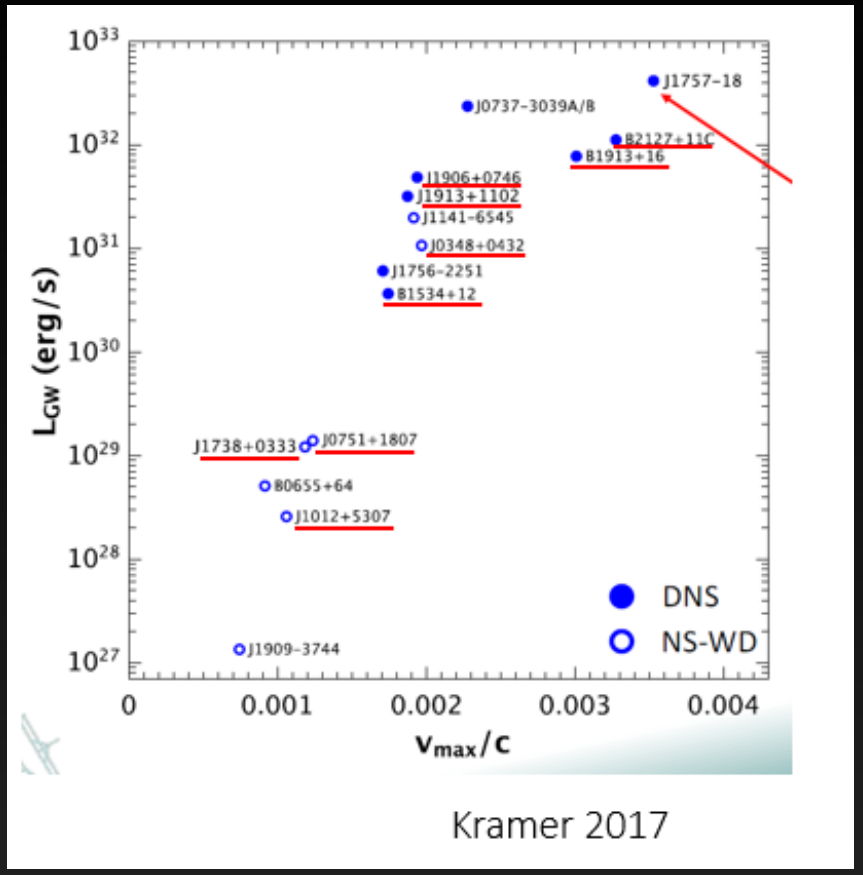
- FAST will:
  - Discover more pulsar binaries
  - Improve Shapiro delay measurements
  - Precisely time more pulsars than Arecibo



Pulsar Timing and GR test

- FAST can see most known DNS
- FAST can see the Triple system (SEP test)

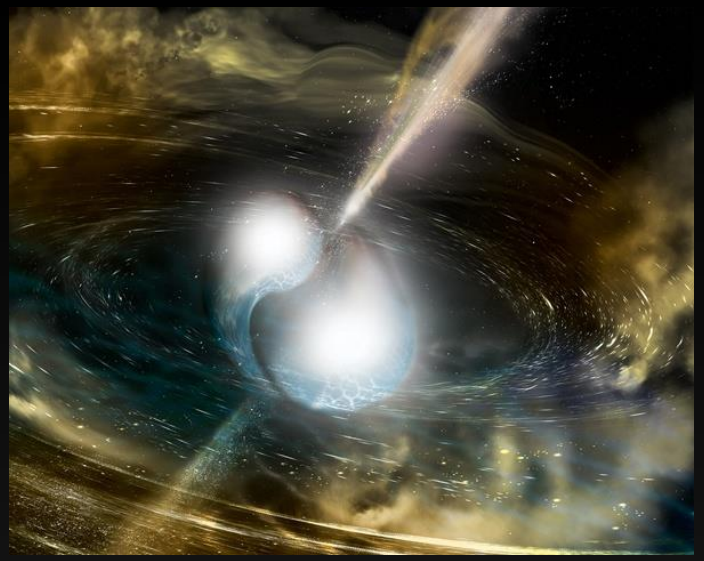
Ransom et al. Nature 2014



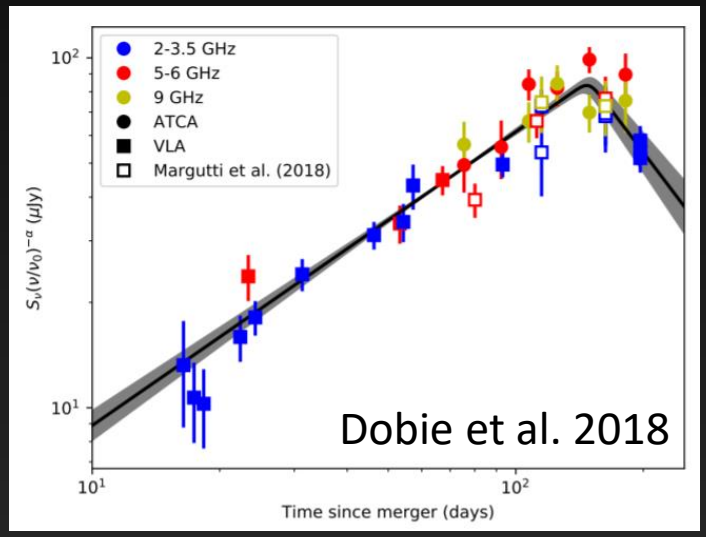
Kramer 2017

FAST follow up LIGO-GW events

- GW170817 DecJ: −23° 22′ 53.3
- Outside FAST field of View

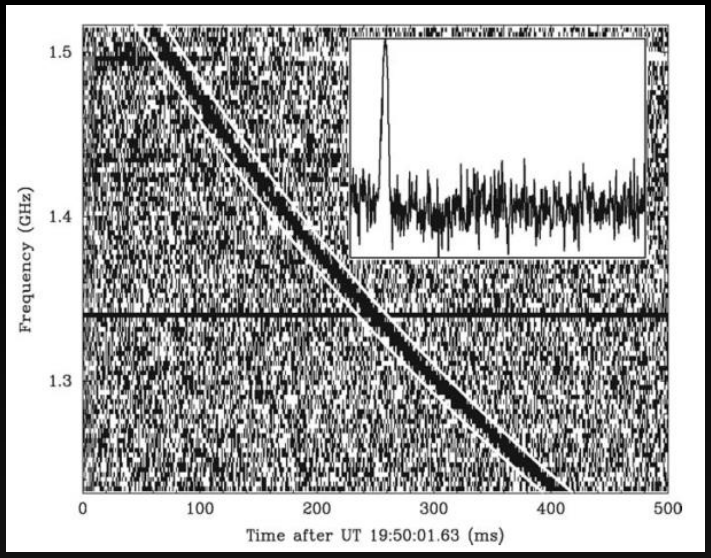


- FAST will follow up future GW events in its FOV

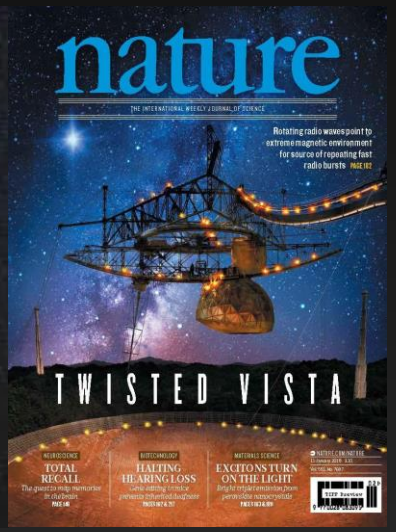


FAST and Fast Radio Bursts

- FAST can see 12/31 published FRBs
- FAST can see the FRB121102 (repeating FRB)
- FAST could detect ~50 FRBs/yr



Lorimer et al. Nature 2007



Commensal Radio Astronomy FAST Survey

CRAFTS

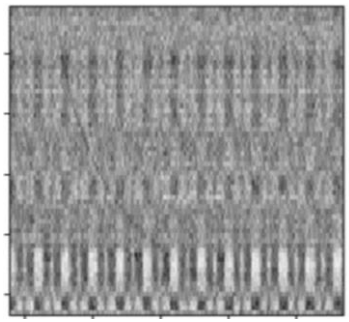
~2000 hour drift-mode observations with 19 beams

Commensal Pulsar +H1 survey

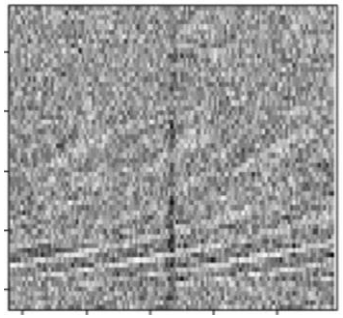
Expect to discover 500-1000 new pulsars

PI: Di Li

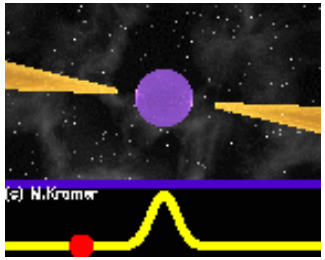
Challenges in FAST pulsar search



Search Algorithm



sifting



Pulsar Data

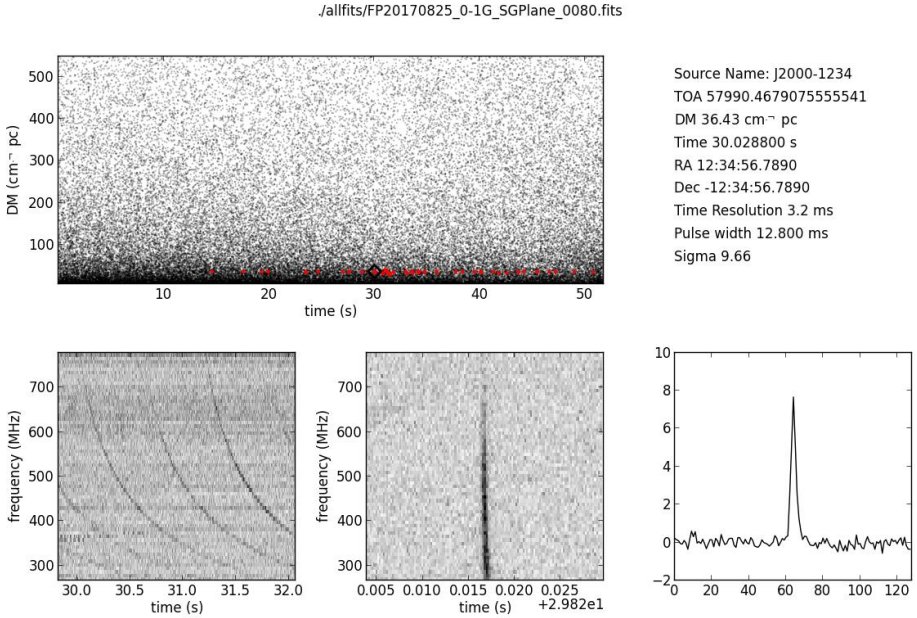
Pulsar candidates

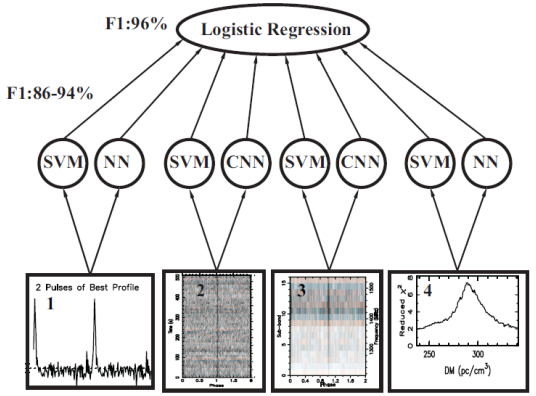
Pulsars

FAST pulsar data
->**2 PB/month**
3GB/s

Pulsar search ->
3 Million candidates/month

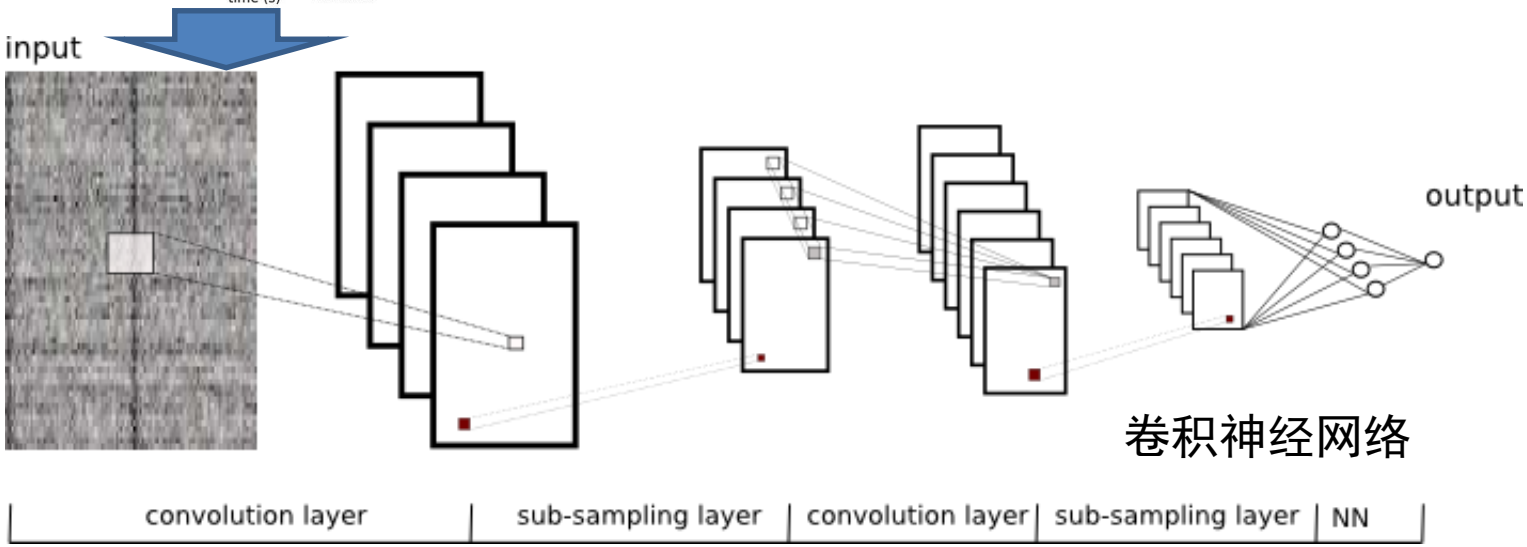
Novel AI driven pulsar searches





PICS: Pulsar Imaged-based Classification System

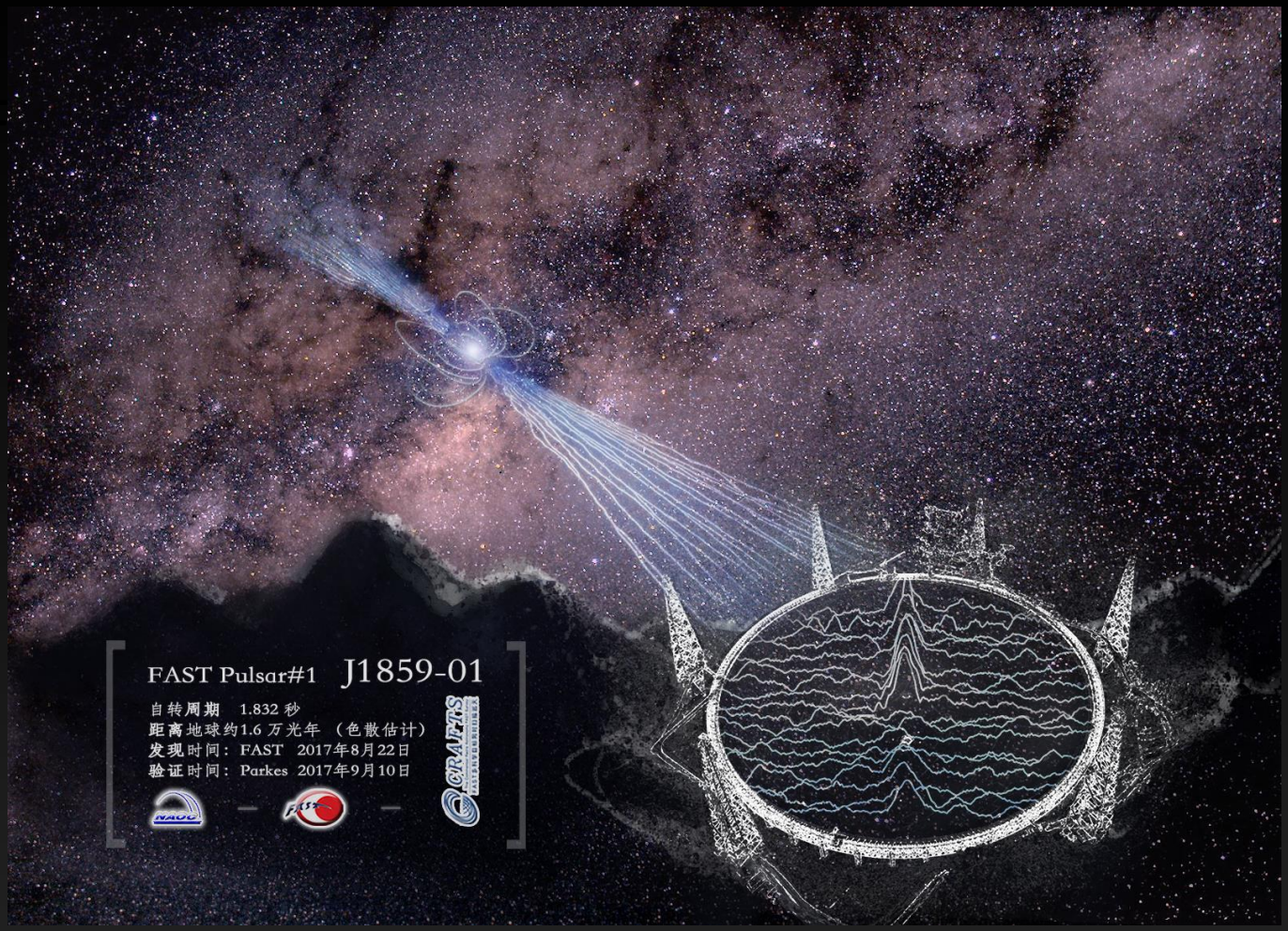
Zhu et al. 2014, ApJ, 781, 117



卷积神经网络

Pulsar Searches: Initial Results

- F

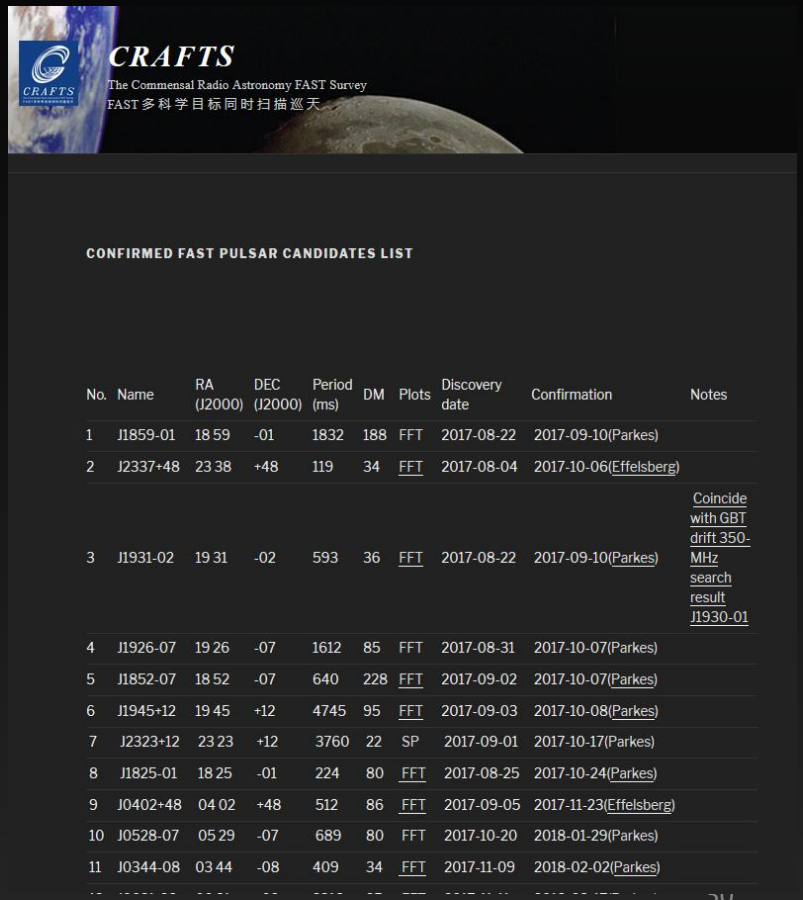


NAOC 2017 Oct

Pulsar Searches: Initial Results

http://crafts.bao.ac.cn/pulsar/pulsar-search/

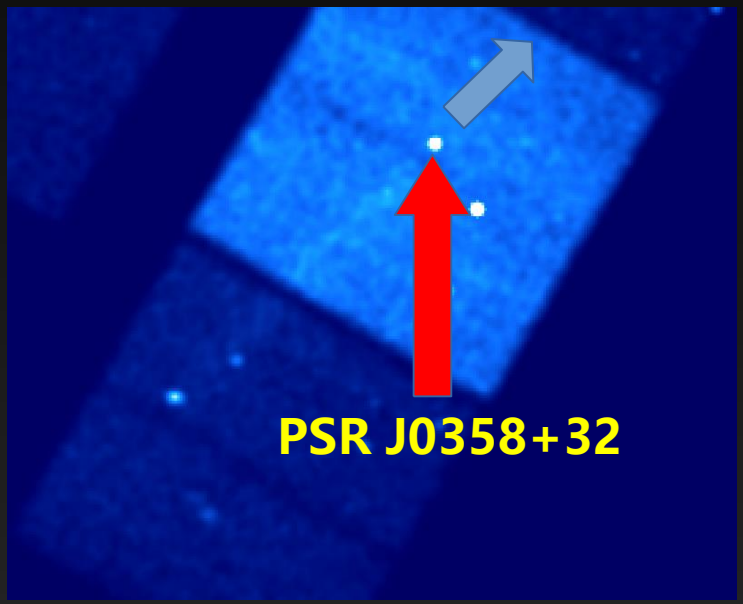
- 43 confirmed new pulsars
- 2 MSPs and 1 Binary pulsar
- 1 intermittent pulsar
- 2 RRATs



No.	Name	RA (J2000)	DEC (J2000)	Period (ms)	DM	Plots	Discovery date	Confirmation	Notes
1	J1859-01	18 59	-01	1832	188	FFT	2017-08-22	2017-09-10(Parkes)	
2	J2337+48	23 38	+48	119	34	FFT	2017-08-04	2017-10-06(Effelsberg)	
3	J1931-02	19 31	-02	593	36	FFT	2017-08-22	2017-09-10(Parkes)	Coincide with GBT drift 350-MHz search result J1930-01
4	J1926-07	19 26	-07	1612	85	FFT	2017-08-31	2017-10-07(Parkes)	
5	J1852-07	18 52	-07	640	228	FFT	2017-09-02	2017-10-07(Parkes)	
6	J1945+12	19 45	+12	4745	95	FFT	2017-09-03	2017-10-08(Parkes)	
7	J2323+12	23 23	+12	3760	22	SP	2017-09-01	2017-10-17(Parkes)	
8	J1825-01	18 25	-01	224	80	FFT	2017-08-25	2017-10-24(Parkes)	
9	J0402+48	04 02	+48	512	86	FFT	2017-09-05	2017-11-23(Effelsberg)	
10	J0528-07	05 29	-07	689	80	FFT	2017-10-20	2018-01-29(Parkes)	
11	J0344-08	03 44	-08	409	34	FFT	2017-11-09	2018-02-02(Parkes)	

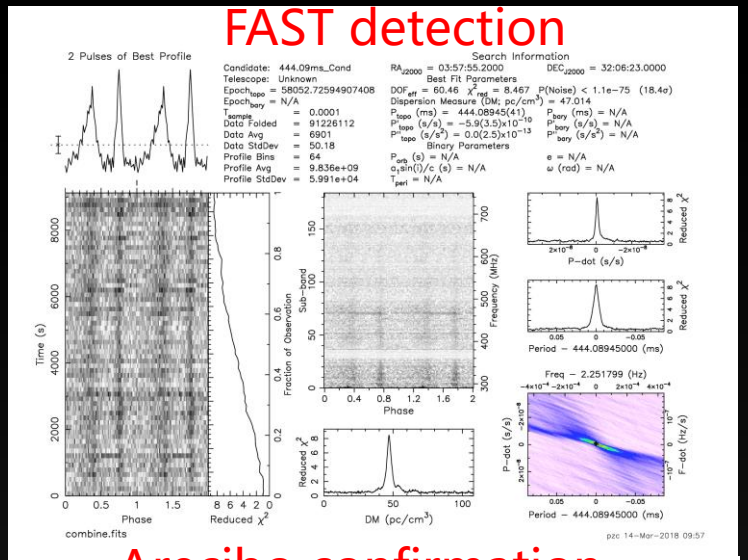
Taurus Pulsar

- A Gamma-ray pulsar with X-ray tail
- Very high apparent proper motion
- Potentially a very nearby pulsar

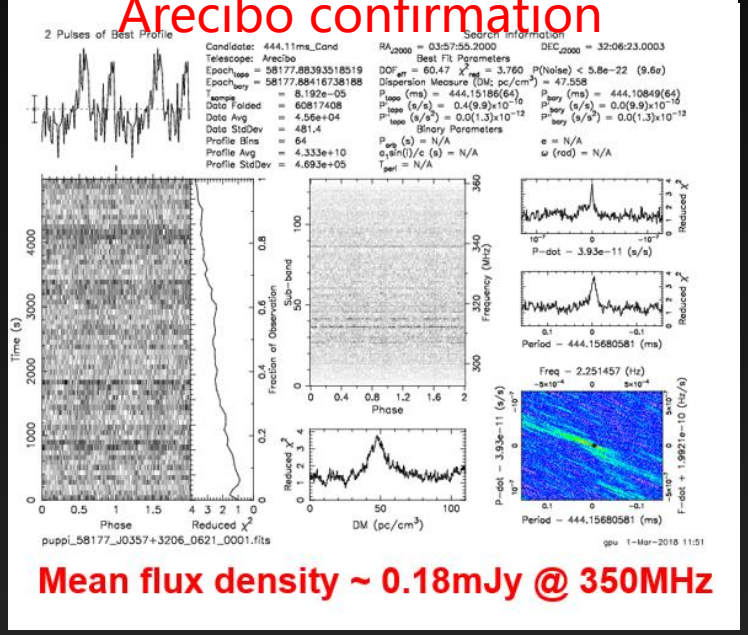


X-ray image from CXO

FAST detection

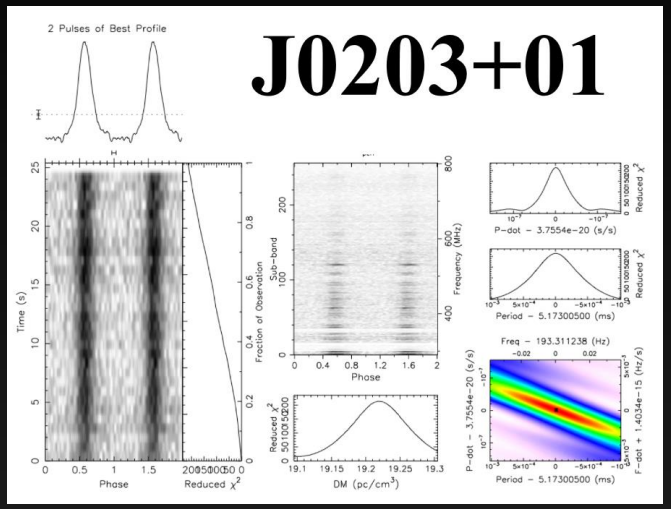


Arecibo confirmation

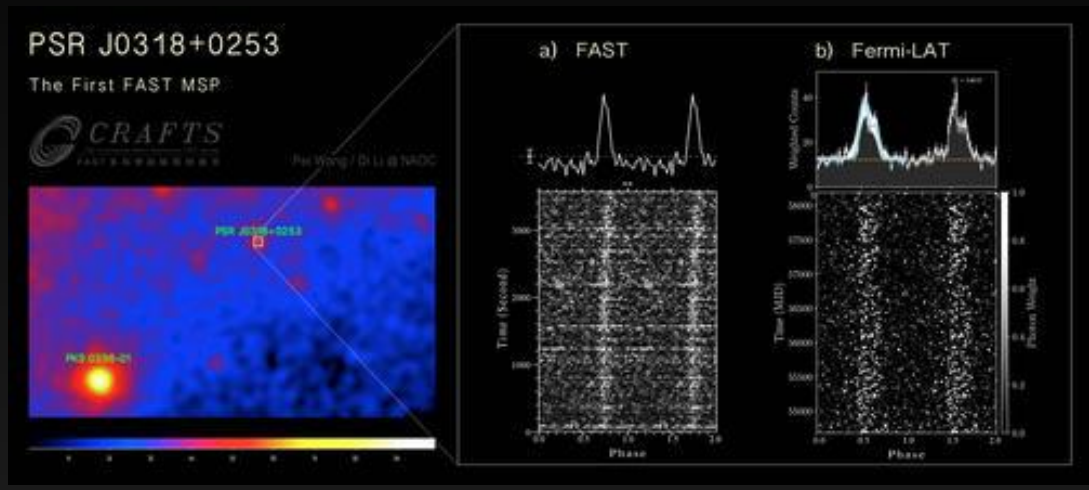


Mean flux density ~ 0.18mJy @ 350MHz

Initial Results: Millisecond pulsars

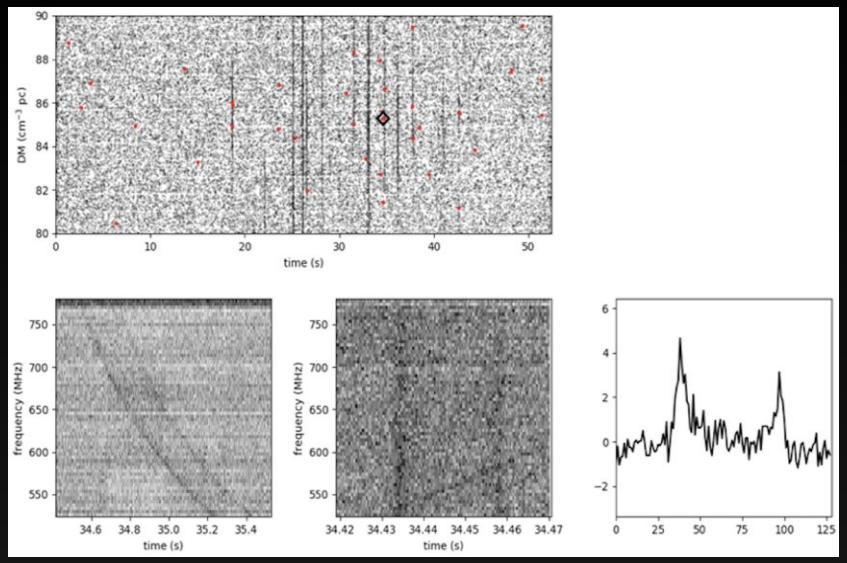


MSP discovered by FAST drift scan

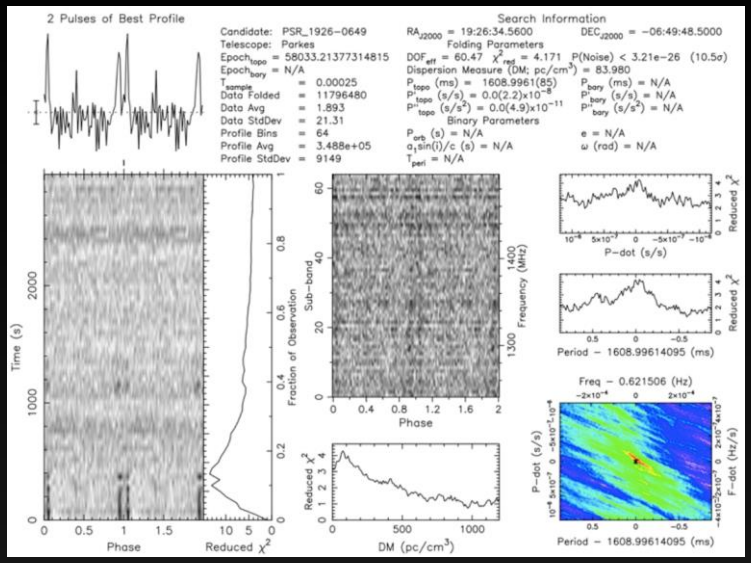


FAST and fermi LAT collaborations
ATel #11584: Pei Wang, Di Li, Weiwei Zhu et al. 2018

Initial results: special pulsars



FAST discovery plot by AI driven searches

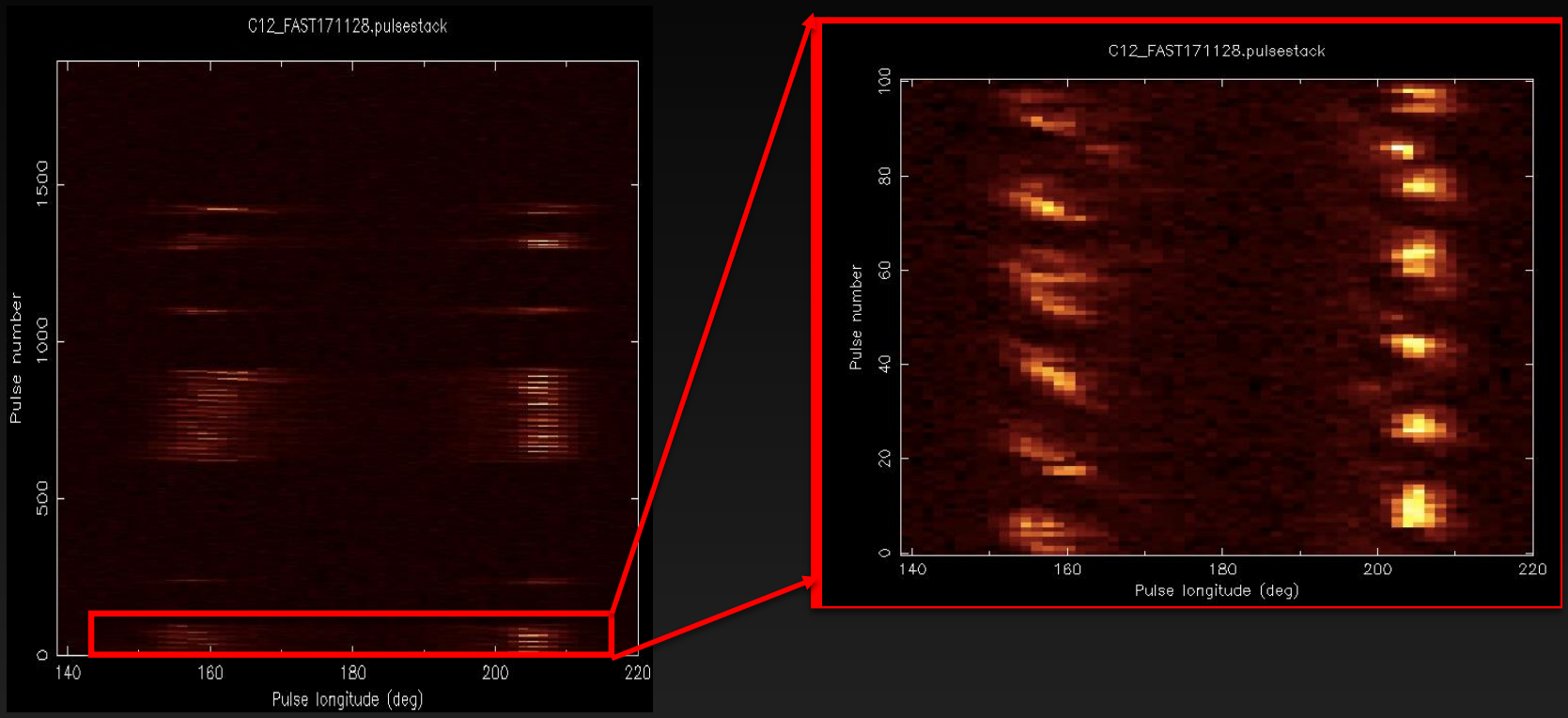


Pulsar Intermittent; Parkes observation

PSR J1946-0629

Initial results: special pulsars

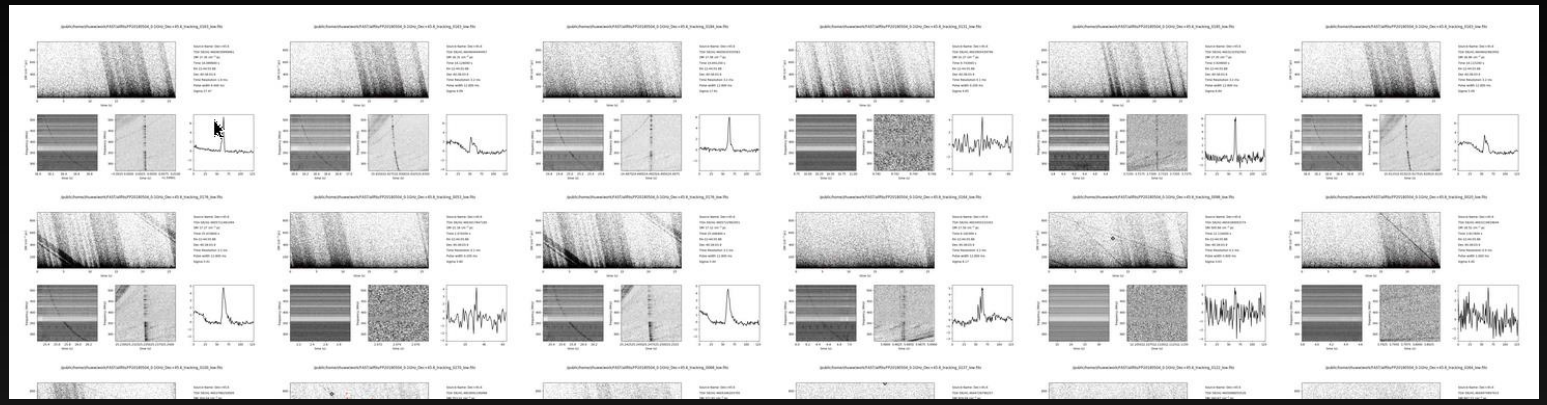
- FAST tracking observation



PSR J1946-0629

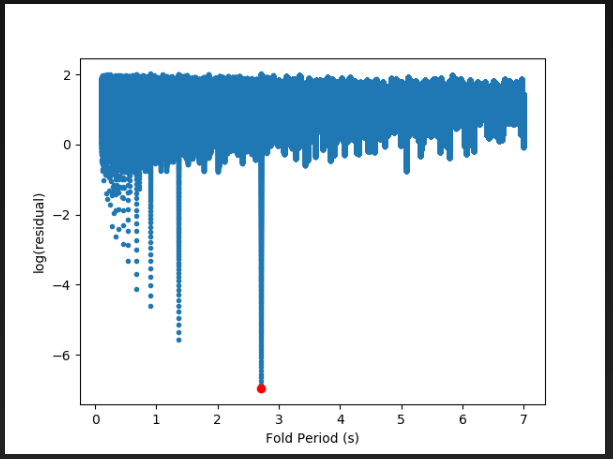
Initial results: special pulsars

- Rotating Radio Transients (RRATs)



FAST detected 9 pulses in 2 hour tracking of PSR J 0941+45

The largest common denominator of the pulse interval is 2.1714s



We Are Hiring

https://jobregister.aas.org/ad/36a9fd10

https://jobregister.aas.org/ad/3ddc1f4c

Recruitment for FAST Staff Scientists in NAOC

... dili@nao.cas.cn URL: Scientific Staff for **FAST** in NAOC Country: China Publish Date: ... for outstanding young scientists from overseas to work on **FAST** related subjects. The position offered can be tenure-track with ...

shihui - 2018-05-29 09:37

Senior Commissioning Scientist for FAST, NAOC

... the Five-hundred-meter Aperture Spherical radio Telescope (**FAST**) is the largest single-dish radio telescope in the world. Enabled by more ... measurement-control system (unique on this scale), **FAST** forms a mobile 300 meters parabolic surface in real time, making it the ...

shihui - 2018-04-02 09:07

1. **The FAST Outstanding Young Fellowship** requires the applicants to be within 5 years of their PhD and will be subjected to a Mega-science center review. The contract is for 2 to 3 years, with an annual salary between health and social insurance.

2. **The CAS Young Fellow** requires the applicants to be within 5 years of their Pl including time spent as a PhD candidate. The CAS Young Fellow will be reviewed at the

3. **The National Young Fellow** requires the applicants to have a minimum of 3 subjected to a competitive NSFC-organized review at the national level.

Apply to Job

Attention To: Di Li
Title: Dr.
Institution/Company: National Astronomical C
Street Line 1: 20A Datun Road
Street Line 2: Chaoyang District
City: Beijing
State/Province: Beijing
Zip/Postal Code: 100101
Country: China
Phone: +861064806305
Email: dili@nao.cas.cn
URL: Scientific Staff for FAST in NAOC

We Are Hiring

"I just want to make a difference for the city I live in," mayoral candidate Claudia Sheinbaum Pardo says.

in Mexico City, which has a metropolitan population of more than 20 million people. She saw the city's water crisis up close when she re-entered city politics in 2015 as the president of Tlalpan, a southern city district where taps routinely run dry.

Now, Sheinbaum Pardo is making water and mobility centerpieces of her campaign. Mexico City occupies a former lake, drained by the Spanish during the colonial period. Today, urban sprawl has covered almost the entire former lakebed, and most of the city's water is pumped from beneath it. "We've overexploited the aquifer, and as a result, the city is sinking," Sheinbaum Pardo says.

The unstable ground makes earthquakes more dangerous; during the destructive temblor on 19 September 2017, an elementary school collapsed in Tlalpan. Previous administrations have postponed tackling the problem, says Noyola Robles, a water expert. "Claudia understands the issue. I think her proposals will be solid and feasible." She has proposed overhauling the distribution network to fix a plague of leaks, building treatment plants to recycle water, investigating sources of water outside the city, and subsidizing rainwater collection systems.

Mexico City also lags in public transportation. Those who can afford it buy cars; 70% of the city's greenhouse gas emissions come from vehicles, Sheinbaum Pardo says. She proposes investing in bus lines, light-rail trains, and even cable cars, while reducing use of overcrowded informal systems, such as collective vans; she also wants stricter emission standards for cars. Both her transportation and water plans, she says, aim to reduce inequality in access and services.

Sheinbaum Pardo's academic background comes through in her detail-heavy presentations and stump speeches. Competing candidates have called her "arrogant." Besides assailing her close ties to López Obrador, they point to the school collapse and increasingly visible drug crime in southern Mexico City as failings of her administration in Tlalpan. Still, a recent poll found that 40% of those surveyed planned to vote for her; the second and third place candidates didn't crack 20%.

Will Sheinbaum Pardo parlay her likely stint as mayor into a national political career? She won't say, but insists that she would be happy to return to her research at UNAM. She continues to advise a handful of graduate students, squeezing in the work on Sunday afternoons. "I'm not particularly attracted to a political career," she says. "I just want to make a difference for the city I live in." ■

PHOTO: ZHANG JIAN/XINHUA/ZUMA PRESS

INTERNATIONAL MOBILITY

China takes new steps to lure science talent from abroad

Generous funding and the chance to lead projects are helping attract foreign scientists

By **Dennis Normile**, *in Shanghai, China*

When astronomer Marko Krčo was offered a chance to help commission the world's largest radio telescope, he didn't hesitate. "It's a once in a lifetime opportunity," says Krčo, who has Serbian and U.S. citizenship and earned his Ph.D. from Cornell University. In 2016, Krčo became a postdoc at the Chinese Academy of Sciences's National Astronomical Observatories in Beijing; he spends much of this time in a remote corner of Guizhou province in southwest China, where the Five-hundred-meter Aperture Spherical radio Telescope was completed in 2016 (*Science*, 30 September 2016, p. 1488). "Whether professionally or privately, every day yields a new challenge or a new insight," Krčo says.

The Chinese government, eager to sustain the country's rapid emergence as a scientific superpower, is opening the door wider for people like him. On 22 May, the Ministry of Science and Technology issued guidelines that encourage science ministries and commissions to consult foreign experts and attract non-Chinese to full-time positions within China. In a striking change, foreign scientists are now allowed to lead public research projects.

In the past decade, China has aimed to build up its scientific capacity by luring back some of the tens of thousands of Chinese scientists working abroad. The latest measures emphasize that non-Chinese talent is also welcome. Drafted in December 2017 but not previously made public, they are "a confirmation of things that have been going on for a while," says Denis Simon, an expert on China's science policy at Duke Kunshan University, a Chinese branch campus of the Durham, North Carolina–based Duke University.

Simon says foreign scientists are drawn by China's increased spending on R&D, which is rising twice as fast as its economic growth. Increasingly ambitious big science projects, such as a massive particle accelerator now under study, are a lure as well, says Cao Cong, a science policy specialist at the University of Nottingham Ningbo, a Chinese affiliate of the U.K. university. The opportunity for foreign scientists to serve as principal investigators for publicly funded programs is a significant new incentive, says Liang Zheng, who studies science and technology policy at Tsinghua University in Beijing.

"There is really only one reason why I moved: the money," says 35-year-old U.S. ecologist Luke Gibson, who trans-

New big science projects, like the world's largest radio telescope, make China an attractive destination.

Published by AAAS

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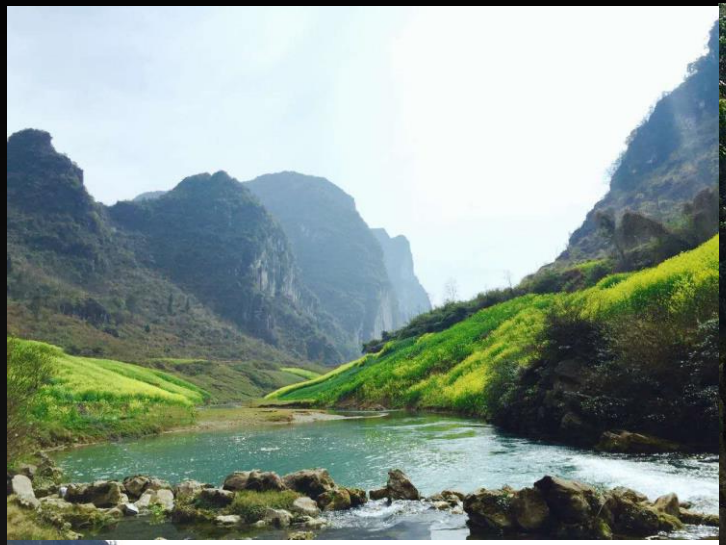

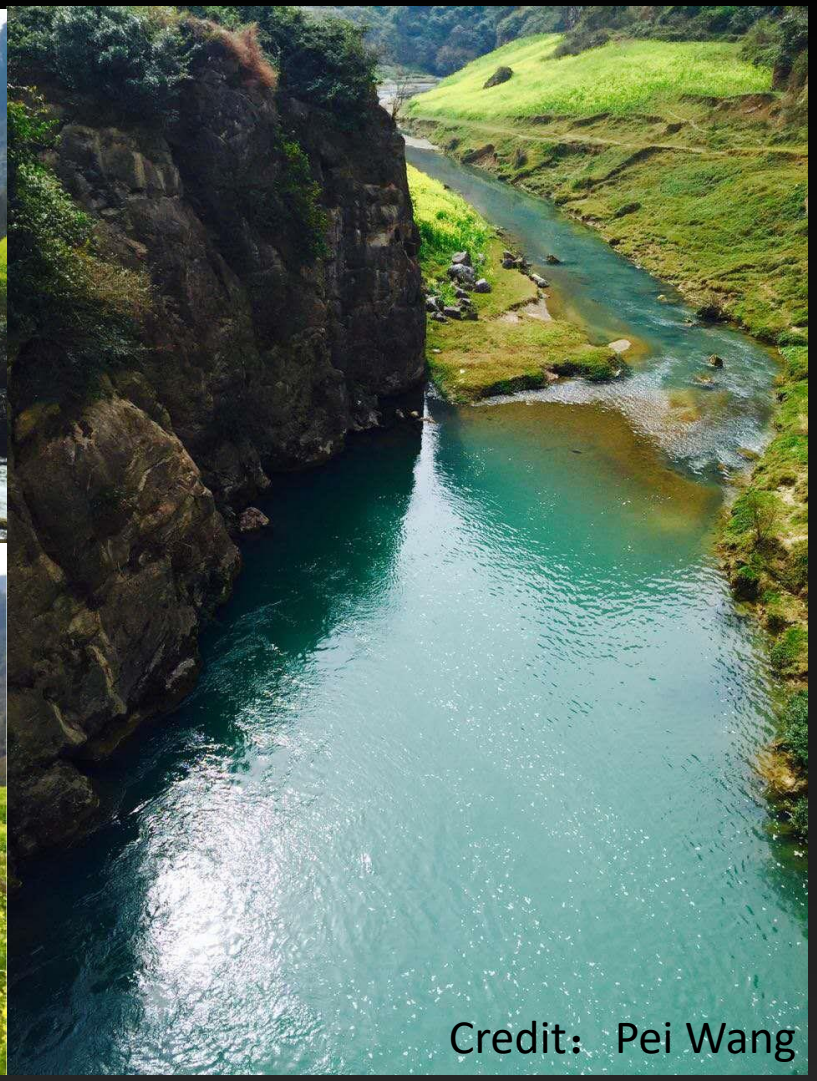

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