Pulsar Timing at Xinjiang Astronomical Observatory

WANG Na
Outline

- The Back Ground
- Main Results from Pulsar timing
- Prospect of Future
The Back Ground — the Site

- Construction start from 1991, complete at the end of 1993
- 76 km to the south Urumqi,
- On Tianshan Mountain, called Nanshan
- Altitude: 2080 m
The Back Ground — the Group

The Young Staffs:
- LIU Zhiyong
- YUAN Jianping
- ZHOU Xia
- GAO Mingfei

Post-Doc
- ZHU Chunhua

The Students:
- YAN Wenming
- CHEN Jianling
- GAO Zhifu
- WANG Jingbo
- ZHU Cui
- QIAN Maofei
- ZHAO Kuntao
The Back Ground — the Group

The Ex-students:

- ZOU Weizhen
- YAN Zhen
- LA Dongsheng
- DONG Jiang
- ZHOU Renxi
- JIANG Wei
## The Back Ground — De-dispersion

<table>
<thead>
<tr>
<th></th>
<th>FB</th>
<th>PDFB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Center Frequency (MHz)</strong></td>
<td>1540</td>
<td>muti-freq</td>
</tr>
<tr>
<td><strong>Digitization (bit)</strong></td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total Bandwidth (MHz)</strong></td>
<td>320</td>
<td>8, 16, 32, 64, 128, 256, 512, 1024</td>
</tr>
<tr>
<td><strong>Configuration</strong></td>
<td>2x128x2.5</td>
<td>pulsar / spectrum</td>
</tr>
</tbody>
</table>
The Back Ground — De-dispersion

![Graphs showing PDFB and FB](image-url)
### The Back Ground — What we experienced

<table>
<thead>
<tr>
<th>Original</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>◇ Room temperature Rx</td>
<td>◇ Cryogenic Rx</td>
</tr>
<tr>
<td>◇ FB</td>
<td>◇ PDFB</td>
</tr>
<tr>
<td>◇ 4 mJy</td>
<td>◇ 0.4 mJy</td>
</tr>
<tr>
<td>◇ 74 pulsars monitored</td>
<td>◇ ~300 pulsars monitoring</td>
</tr>
<tr>
<td>◇ Single pulsars</td>
<td>◇ MSPs</td>
</tr>
<tr>
<td>◇ Timing</td>
<td>◇ Timing +Scint+Poln</td>
</tr>
</tbody>
</table>
Main Results from Pulsar Timing System

From a timing system, you can do:

- Glitches
- Timing noise
- Proper motion measurements
- Scintillation
- Power spectrum
- Single pulse
- Pulsar searching
- RRATS
- Polarization
Main Results — Detected Glitches

- Observations from 2000 ~ 2009
- 50 Glitches in 23 pulsars
- The first known glitch for 14 pulsars
  - Giant glitch in PSR B2334+61
  - Frequent glitching pulsars
  - Various glitch recovery
  - Slow glitches
  - Tiny glitches
Main Results — Detected Glitches:
giant glitch in PSR B2334+61

Glitch epoch (MJD) 53615(6)
Δν_ Gül / ν (10^-6) 20.5794(12)
Δν / ν 0.156(4)
Δν_p / ν_p 0.011
τ_d1 (days) 21.4(5)
τ_d2 (days) 147(2)
Q 0.00751(5)
rms (ms) 1.72

Yuan et al., ApJL, 719, 111-115
Main Results — Detected Glitches: giant glitch in PSR B2334+61

- Recovery: vortex creeping Alpar et al. (1993)
- Oscillation period $\sim 364(5)$ days
- Tkachenko oscillation of superfluid vortex array (Ruderman 1970, Popov 2008), $P_T \sim 1.77 R_6 P^{1/2}$ yr $\sim 1.24 R_6 \sim 1$ yr
Main Results — Detected Glitches: Frequent glitching pulsars

- PSR B0531+21* (the Crab pulsar)
- PSR J0537–6910
- PSR B0833–45 (the Vela pulsar)
- PSR B1046–58
- PSR B1338–62
- PSR B1757–24
- PSR B1758–23
- PSR B1737–30*
- PSR B1800–21*

(*: detected glitches at Ur)
Main Results — Detected Glitches
Frequent glitching pulsars: the Crab Pulsar

- 2008 Apr: the largest frequency jump
- Decayed with a time constant 25 d
- Large permanent increase in slowdown rate
- No obvious change in pulse profile

Wang et al, 2011, in preparing
**Main Results — Detected Glitches: Frequent glitching pulsars: the Crab Pulsar**

<table>
<thead>
<tr>
<th>Precursor glitch (yyymmdd)</th>
<th>Post-glitch span (yyymmdd-yyymmdd)</th>
<th>Braking index</th>
</tr>
</thead>
<tbody>
<tr>
<td>041122</td>
<td>051111-060818</td>
<td>2.440(4)</td>
</tr>
<tr>
<td>080423</td>
<td>090428-100901</td>
<td>2.572(2)</td>
</tr>
</tbody>
</table>

Xu & Qiao (2001): Varying particle wind strength, in addition to the magnetic dipole braking may account for a braking index less than 3.
Main Results — Detected Glitches: Frequent glitching pulsars: the Crab Pulsar

- A total sample of 18 interglitch intervals
- The mean interglitch interval 419 days
- Well described by Poisson distribution
- Essentially different from Vela pulsar

The Crab pulsar

The Vela pulsar
Main Results — Detected Glitches: Frequent glitching pulsars: the Crab Pulsar

- Activity parameter $A_g$ is the net angular momentum loss due to glitching over some observing time span.
- A long-term indicator of glitch effect.
- No evident change of $A_g$, despite the more frequent glitching.

Persistent Change in slowdown rate
Main Results — Detected Glitches:
Frequent glitching pulsars: PSR B1737-30

- 22 glitches in 20 years of monitoring, with fractional jump in amplitude:

- Glitches in PSRs J0537−6910, B0833−45, B1046−58 and B1800−21 vary in a large ranges, including PSR 1737−30

- PSRs B0531+21, B1338−62, B1757−24 and B1758−23 more even in glitch amplitude

Main Results — Detected Glitches:
Various glitch recovery

- Vela like permanent change in frequency derivative: PSRs B1800—21, B1823—13, B1046—58, B1610—50, B1706—44, B1727—33
- Others have no permanent change: PSRs B1338—62, J1617—5055, B1737—30, J1708—4009, B1757—24, J2021+3651
Main Results — Detected Glitches: Slow glitches

Also see Shabanova, 2000
Main Results — Detected Glitches:
Tiny glitches

Main Results — mode changing: PSR B0329+54

图 3.8: 两次典型的观测轮廓序列，其中分别包括了正常模式和反常模式，每个轮廓的积分时间为3分钟，右图为对应相对强度$R$。紫色的轮廓分别为正常模式和反常模式的叠加的累积轮廓，红色的圆圈表示过渡点。
Main Results — mode changing: PSR B0329+54

Main Results — mode changing: PSR B0329+54

- Time sequence of $R$ for quasi-continuous observation from 2004 March 12-20 (left) and March 23-31 (right).
- The integration time for individual profiles is 1 minutes.
Main Results — mode changing: PSR B0329+54

R for Separated Observation
Main Results — mode changing: PSR B0329+54

R Distribution

Continuous data

Separated obs.

Normal Mode
R = 0.546 +/- 0.002

Abnormal Mode
R = 1.168 +/- 0.008
Main Results — Applications of Pulsar Timing

- Pulsar Navigation
- Time Scale
Main Results — theoretical studies

Numerical simulation of the electron capture process in a magnetar interior
Z. F. Gao, N. Wang, J. P. Yuan, L. Jiang and D. L. Song

Evolution of superhigh magnetic fields of magnetars

The effects of intense magnetic fields on Landau levels in a neutron star
Z. F. Gao, N. Wang, D. L. Song J. P. Yuan and C. K. Chou
2011, Astrophys Space Sci. Accepted

Physics on huge X-ray luminosity of magnetars
Q. H. Peng, Z. F. Gao, N. Wang, H. Tong, and C. K. Chou,
11-th Symposium on Nuclei in the Cosmos 19-23 July 2010 Heidelberg. Germany,
2011, Proceedings of Science ID: PoS(NIC XI) 176
Prospect of Future – Large telescope
Prospect of Future – Specification

Structure: Reflectors + Roller raceway type elevation-azimuth antenna pedestal
Prospect of Future – Specification

- Main reflector
  - Shaped Gregorian telescope
  - Active surface
  - Main reflector rms ≤ 0.3mm
  - Single panel: inner 65m ≤ 0.08mm, 65–110m ≤ 0.1mm

- Sub-reflector:
  - 6 degrees of freedom
  - rms ≤ 0.05mm
Prospect of Future – Specification

**Change feed horn:**
- Rotary table: change receiver <10 min
- Sub-reflector deflexion: change receiver <10 sec
Prospect of Future – Specification

- **Wide band digital receiver**
  - UHF (feed forward)

- **Backend / data sampling**
  - Pulsar / spectrum (PDFB)
  - Total power back end
  - VLBI back end
## Prospect of Future – Specification

### Receiver system

<table>
<thead>
<tr>
<th>Band</th>
<th>Freq Range (GHz)</th>
<th>Wave length (cm)</th>
<th>Receiver Temp(K)</th>
<th>System Temp.(K)</th>
<th>Efficiency (optimum position)</th>
<th>Poln</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHF</td>
<td>0.3 - 1</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>48%</td>
<td>linear</td>
</tr>
<tr>
<td>L</td>
<td>1 – 2</td>
<td>20</td>
<td>14</td>
<td>40</td>
<td>60%</td>
<td>linear</td>
</tr>
<tr>
<td>S</td>
<td>2 – 4</td>
<td>10</td>
<td>15</td>
<td>45</td>
<td>60%</td>
<td>linear</td>
</tr>
<tr>
<td>X</td>
<td>4 – 12</td>
<td>4</td>
<td>20</td>
<td>60</td>
<td>55%</td>
<td>linear</td>
</tr>
<tr>
<td>K</td>
<td>12 – 36</td>
<td>1</td>
<td>30</td>
<td>75</td>
<td>40%</td>
<td>linear</td>
</tr>
<tr>
<td>V</td>
<td>36 – 75</td>
<td>0.7</td>
<td>60</td>
<td>170</td>
<td>30%</td>
<td>linear</td>
</tr>
<tr>
<td>W</td>
<td>75 – 110</td>
<td>0.3</td>
<td>100</td>
<td>180</td>
<td>12%</td>
<td>linear</td>
</tr>
</tbody>
</table>
Prospect of Future – Specification

- Sensitivity of 110m will be 20 times higher than 25m
- China VLBI (CVN) sensitivity:
  - CVN+110m: improve 1.8 times
  - CVN+110m+65m: improve 3 times

<table>
<thead>
<tr>
<th>CVN 基线长度</th>
<th>站点</th>
<th>北京50米</th>
<th>云南40米</th>
<th>上海25米</th>
</tr>
</thead>
<tbody>
<tr>
<td>乌鲁木齐25米</td>
<td>2460 km</td>
<td>2476 km</td>
<td>3249 km</td>
<td></td>
</tr>
<tr>
<td>上海佘山25米</td>
<td>1114 km</td>
<td>1920 km</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>云南昆明40米</td>
<td>2158 km</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
</tbody>
</table>
Prospect of Future – Science

- Structure of galaxies and special radio sources
- Spectrum
- Pulsars
- High precision VLBI: Geodetic and astrometry
- Survey
- Spacecraft orbit measurement in VLBI mode
- Deep space autonomous navigation
- Pulsar time scale

Welcome for discussion
Prospect of Future — the Site

QiTai Radio Telescope

QTRT, QTT

2011-5-9, Beijing
Prospect of Future – the Site

- Basin 1.5km X 2 km
- Altitude of surrounding mountains: 1860-2250m
- Altitude of bottom of the basin 1730-1830m
Prospect of Future – the Site

Elevation of mountains
Prospect of Future — the Site

<table>
<thead>
<tr>
<th>Wind speed</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤4 m/s (gentle breeze)</td>
<td>63.7%</td>
</tr>
<tr>
<td>≤6 m/s (moderate breeze)</td>
<td>88.4%</td>
</tr>
<tr>
<td>≤8 m/s (fresh breeze)</td>
<td>95.8%</td>
</tr>
<tr>
<td>≥17 m/s (fresh gale)</td>
<td>0.079%</td>
</tr>
</tbody>
</table>
Prospect of Future – the Site

Temperature range

![Temperature graph](image)

- Highest temperature: 25.2°C
- Lowest temperature: -28.9°C
Prospect of Future — the Site

RFI

![Graph showing RFI levels over frequency range](image-url)
Prospect of Future – Progress

2010 March 29, Local government agreed 50m RMB support
Prof Feng from Shanghai Jiao Tong University write to Xinjiang local leader

2010 August 1, Present replied:
Starting at a higher point

110m+active surface

2011 April 25: passed experts’ evaluation

Xinjiang and CAS agreed pushing this project together, seeking for support
Prospect of Future – Progress

- Land acquisition
- Site planning
- Water, power supply, road, telecommunication
- Receiver scheme
- Telescope control
- RFI protect zone