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

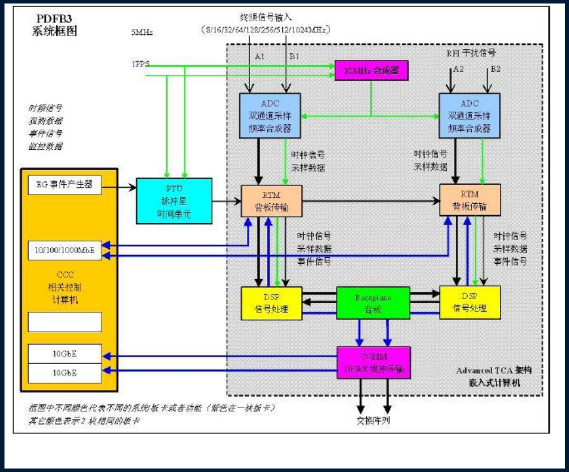
The Back Ground — the Group

The Ex-students:

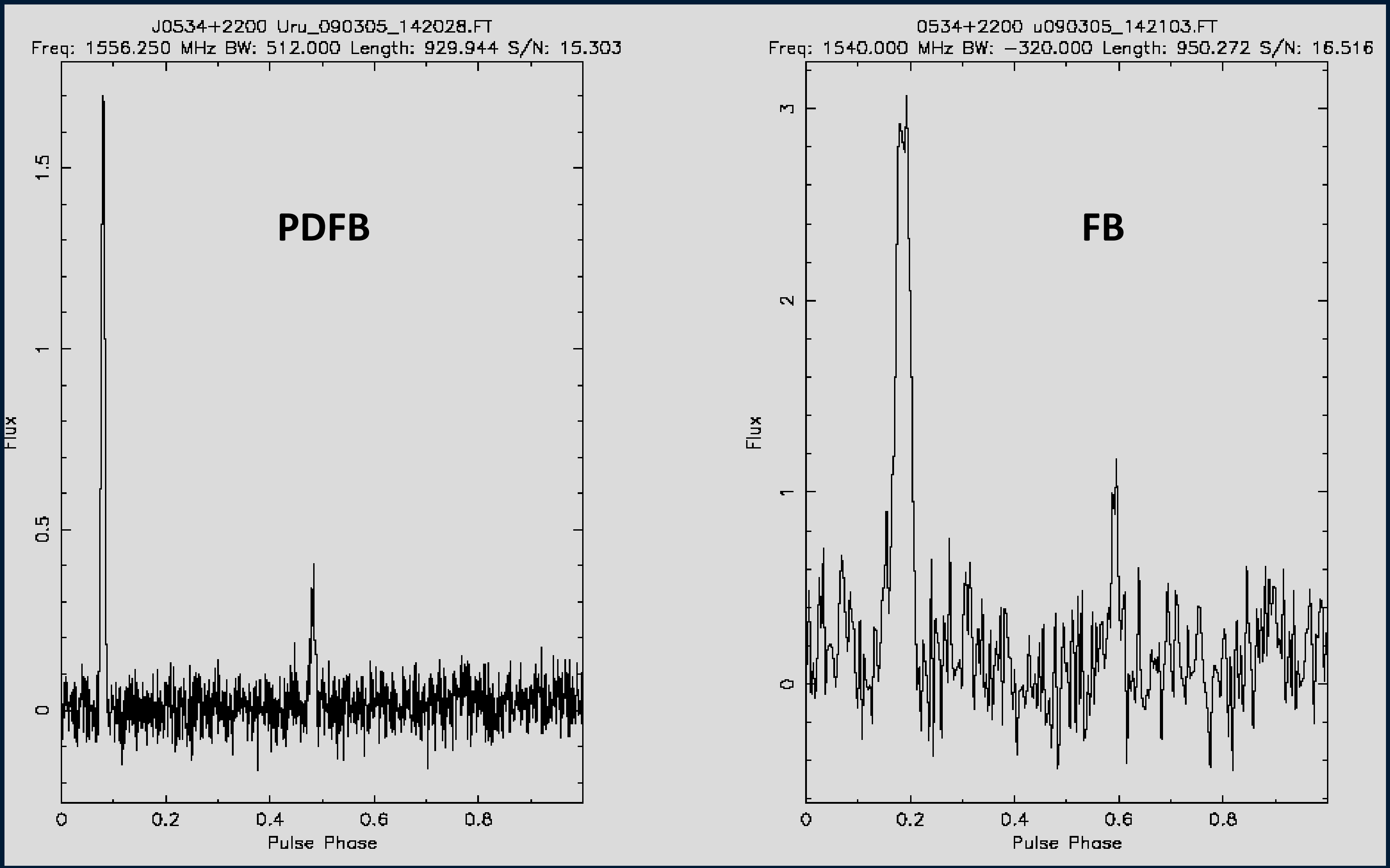
- ZOU Weizhen
- YAN Zhen
- LA Dongsheng
- DONG Jiang
- ZHOU Renxi
- JIANG Wei

The Back Ground — De-dispersion

	FB	PDFB
Center Frequency (MHz)	1540	muti-freq
Digitization (bit)	2	9
Total Bandwidth (MHz)	320	8, 16, 32, 64,128, 256, 512, 1024
Configuration	2x128x2.5	pulsar / spectrum



The Back Ground — De-dispersion



The Back Ground — What we experienced

Original	Present
Room temperature Rx	Cryogenic Rx
FB	PDFB
4 mJy	0.4 mJy
74 pulsars monitored	~300 pulsars monitoring
Single pulsars	MSPs
Timing	Timing +Scint+Poln

Main Results from Pulsar Timing System

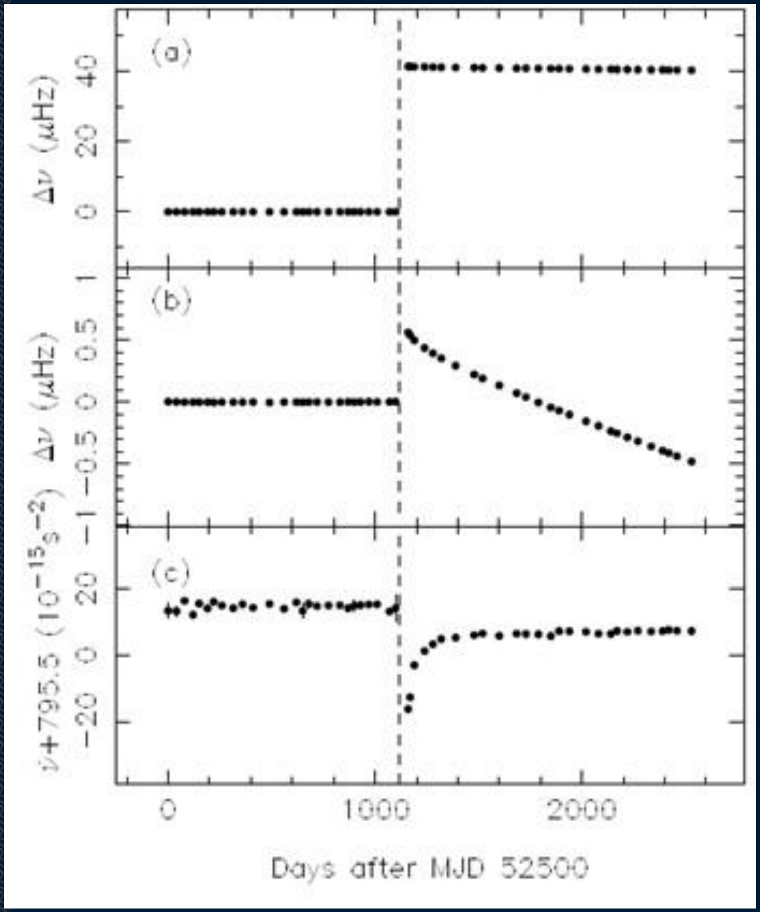
From a timing system, you can do:

- 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

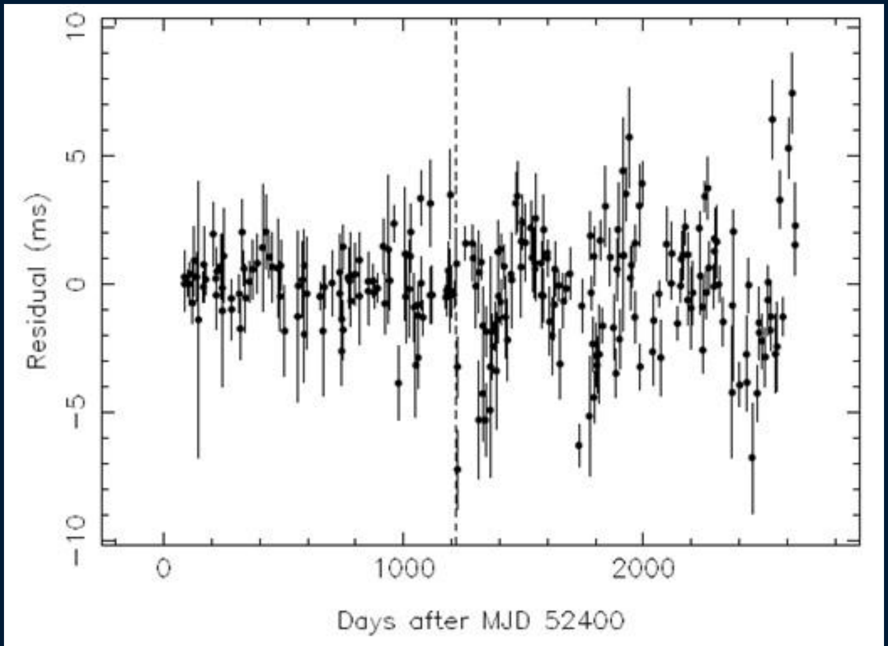


Glitch epoch (MJD)	53615(6)
$\Delta\nu_g/\nu\,(10^{-6})$	20.5794(12)
$\Delta\dot{\nu}_g/\dot{\nu}$	0.156(4)
$\Delta\dot{\nu}_p/\dot{\nu}_p$	0.011
τ_{d1}(days)	21.4(5)
τ_{d2}(days)	147(2)
Q	0.00751(5)
rms(ms)	1.72

Yuan et al., ApJL, 719,111-115

Main Results — Detected Glitches: giant glitch in PSR B2334+61

Timing residual



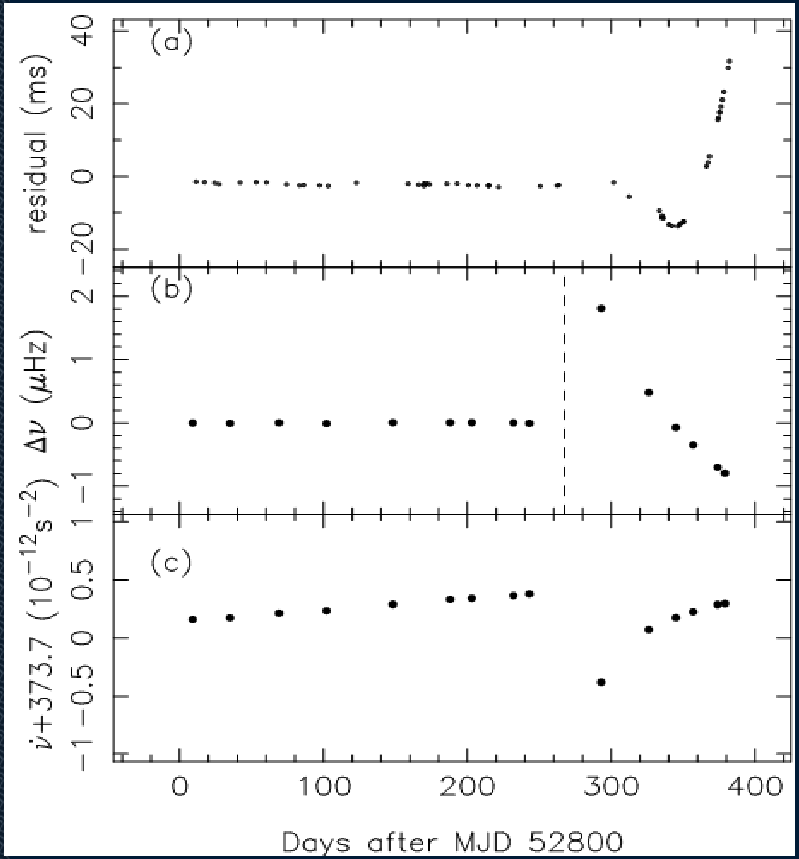
- Recovery: vortex creeping Alpar et al. (1993)
- Oscillation period ~ 364(5) days
- Tkachenko oscillation of superfluid vortex array (Ruderman 1970, Popov 2008), $P_T \sim 1.77 R_6 P^{1/2}$ yr $\sim 1.24 R_6 \sim 1$ yr

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

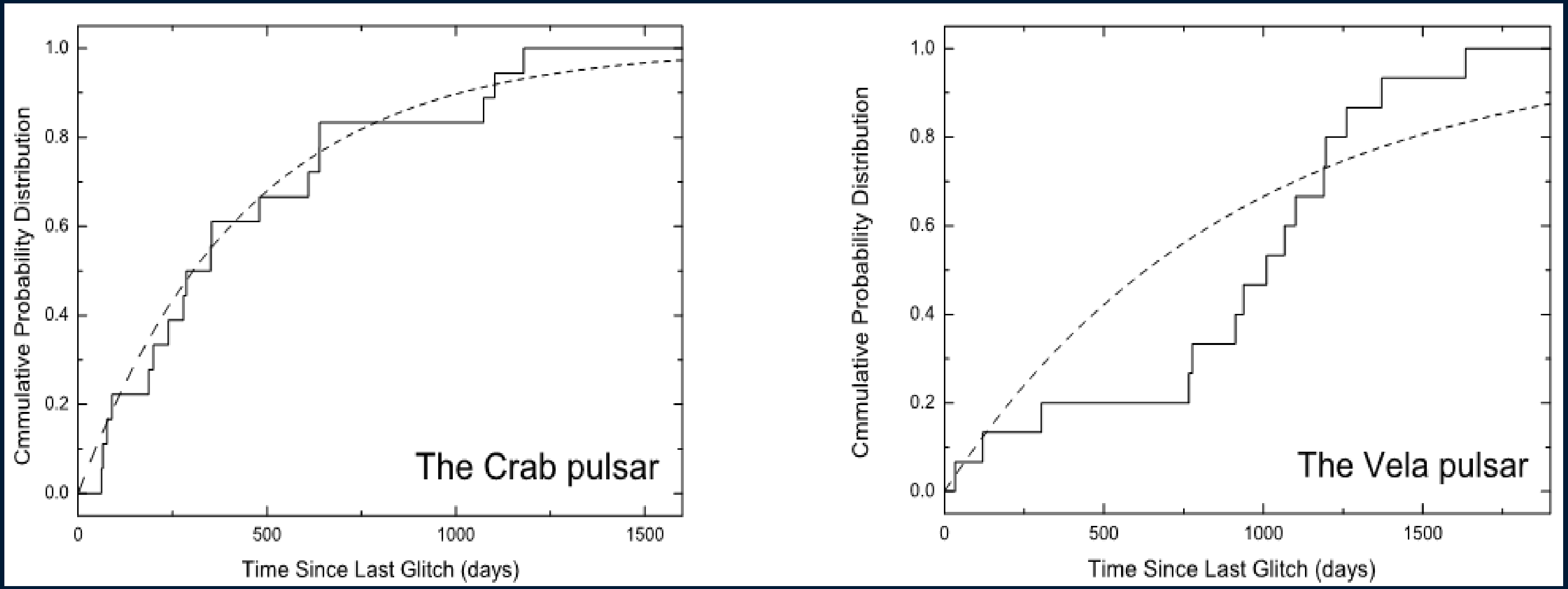
Precursor glitch (yymmdd)	Post-glitch span (yymmdd-yymmdd)	**Braking index**
041122	051111-060818	2.440(4)
080423	090428-100901	2.572(2)

- 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:

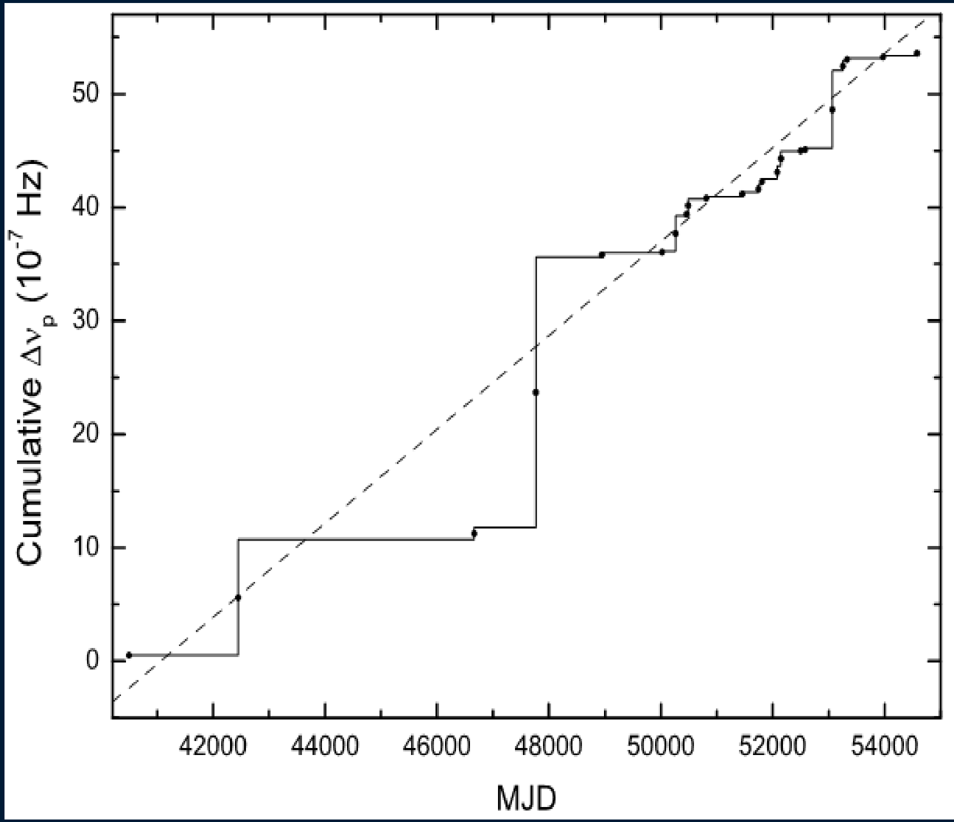
Frequent glitching pulsars: the Crab Pulsar

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



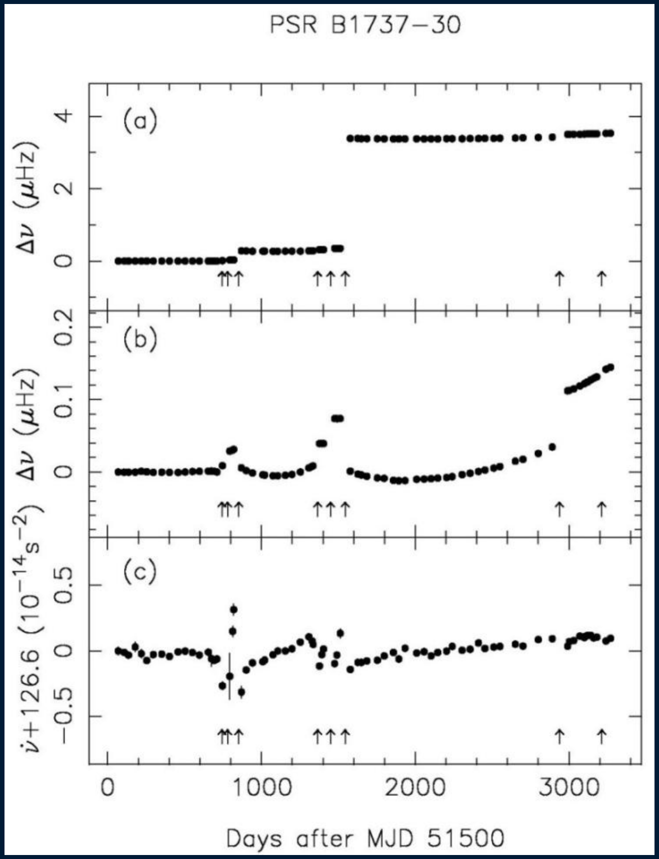
Main Results — Detected Glitches:
Frequent glitching pulsars: the Crab Pulsar

- Activity parameter Ag 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 Ag, despite the more frequent glitching



Persistent Change in slowdown rate

Main Results — Detected Glitches:
Frequent glitching pulsars: PSR B1737-30

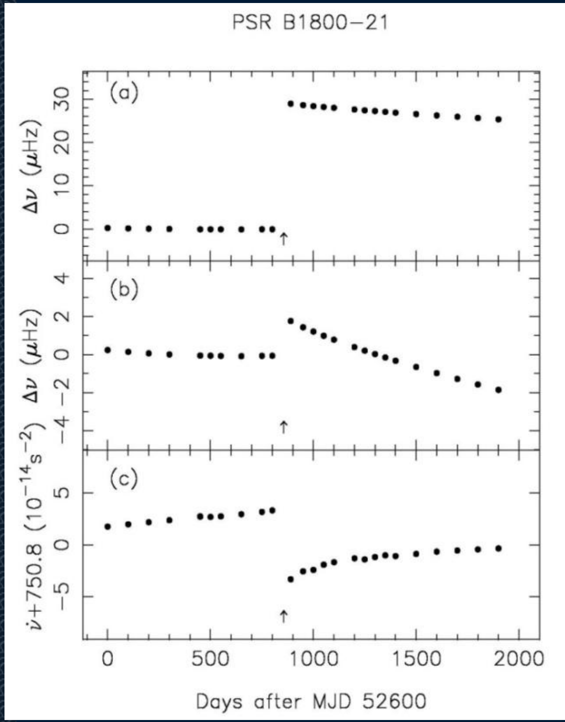


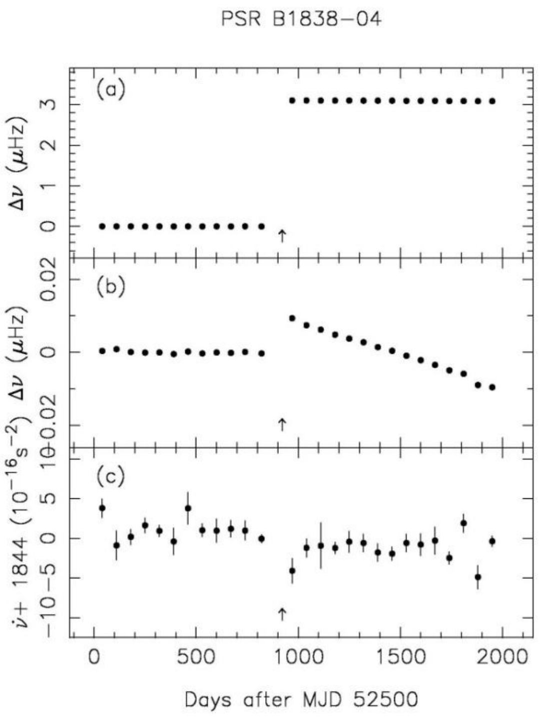
- 22glitches in 20 years of monitoring, with fractional jump in amplitude: 1.85×10^{-6}
- Glitches in PSRs J0537−6910, B0833−45, B1046−58 and B1800−21 vary in a large ranges, **including PSR 1737—30**
- PSRs B0531+21, B1338−62, B1757−24 and B1758−23 more even in glitch amplitude

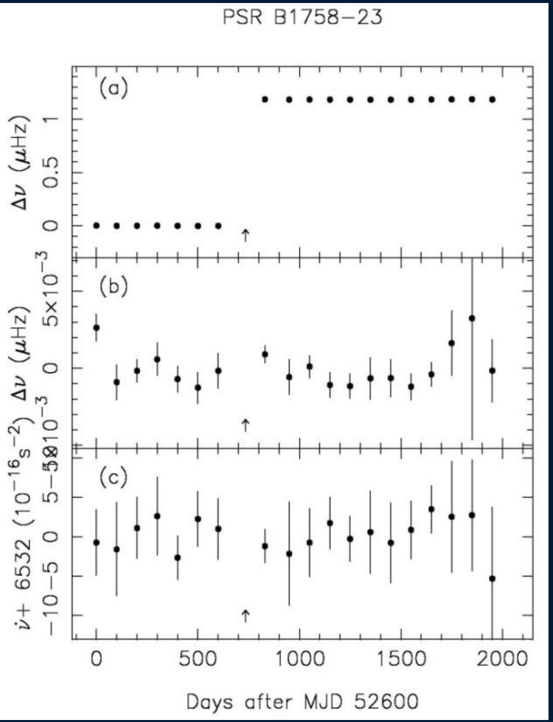
Zou et al. 2008, MNRAS, 384, 1063
Yuan, et al. 2010, MNRAS, 289-304

Main Results — Detected Glitches:

Various glitch recovery



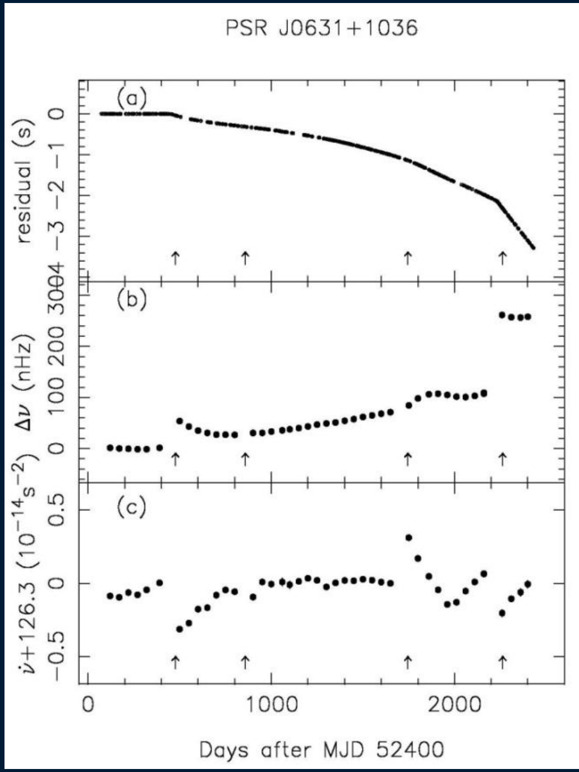


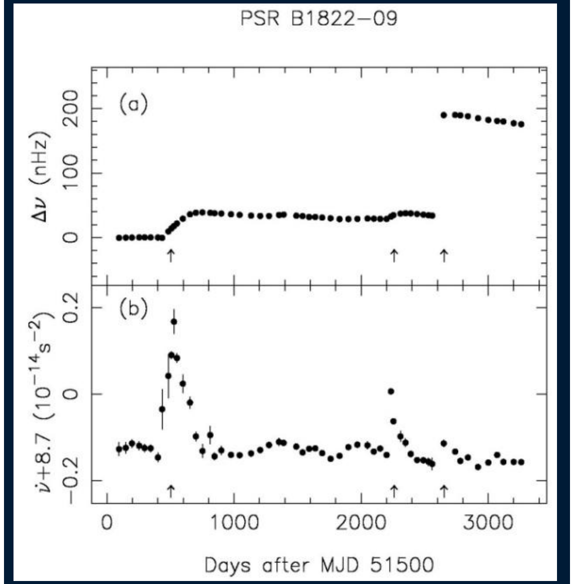


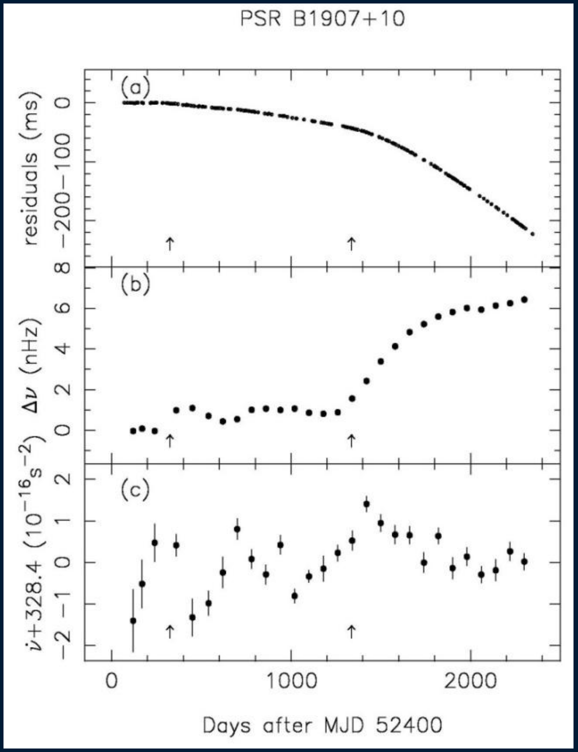
- Vela like permanent change in frequency derivative: PSRs B1800—21, B1823—13, B1046—58, B1610—50, B1706—44, B1727—33
- Others have no permanent change: PSRs B1338—62, J1617—5055, B1737—30, J1708—4009, B1757—24, J2021+3651

Main Results — Detected Glitches:

Slow glitches



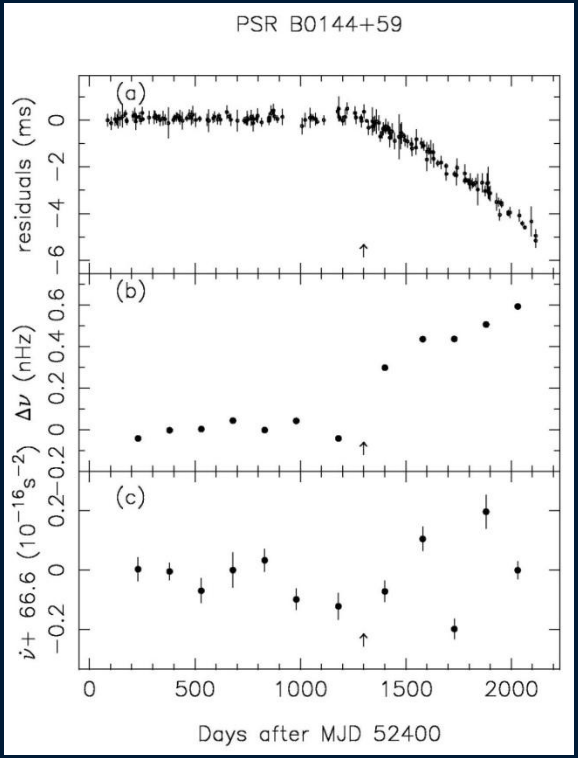


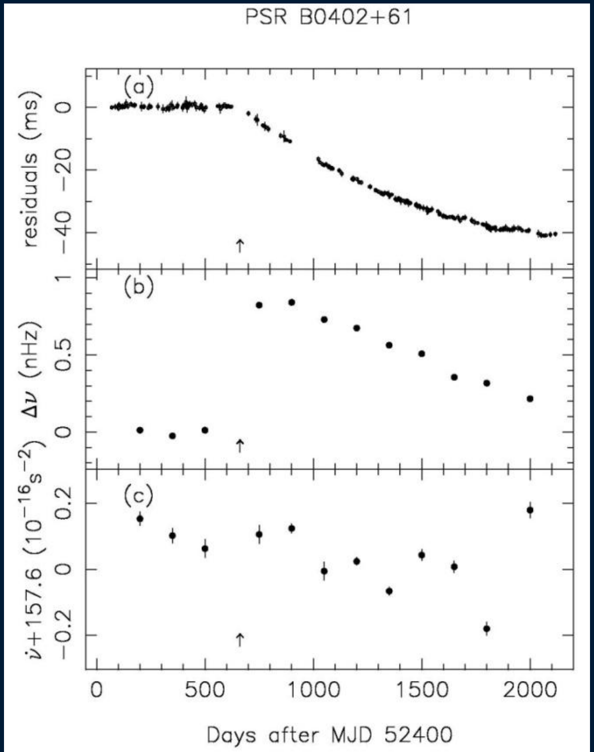


Also see Shabanova, 2000

Main Results — Detected Glitches: $(10^{-11} < \Delta\nu/\nu < 10^{-9})$

Tiny glitches





PSRs B0144+59, B0402+61, B0525+21, J1705−3423, B1815−14, B1900+06, B1907+10 and B2224+65 (Yuan, et al. 2010, MNRAS, 289-304)

Main Results — mode changing: PSR B0329+54

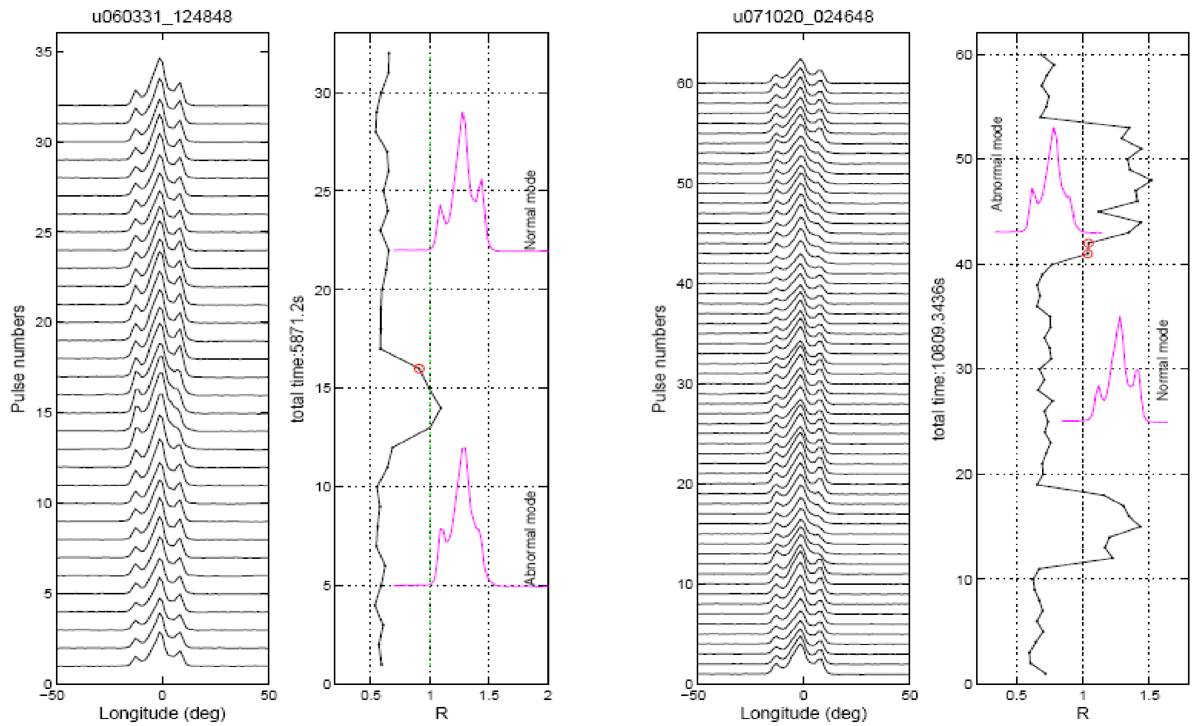
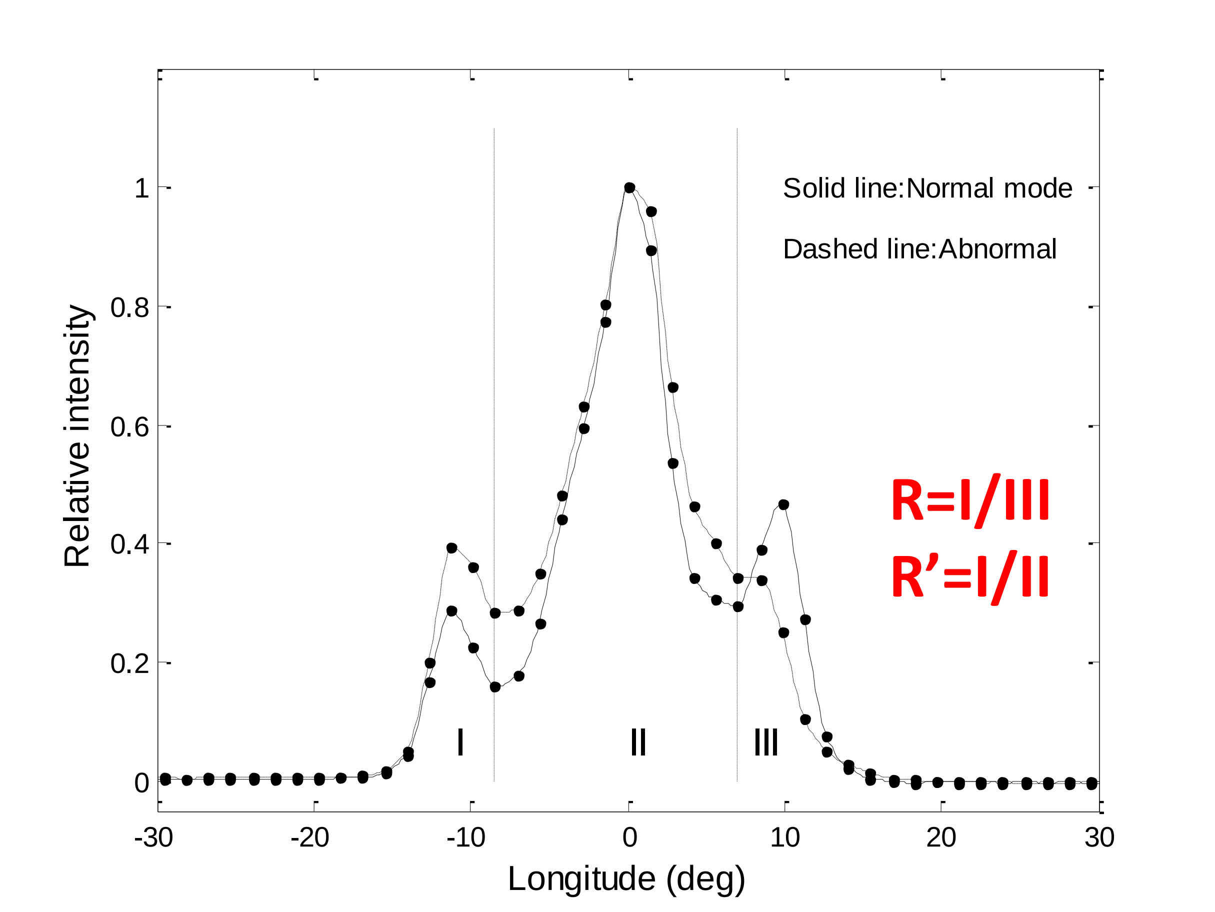


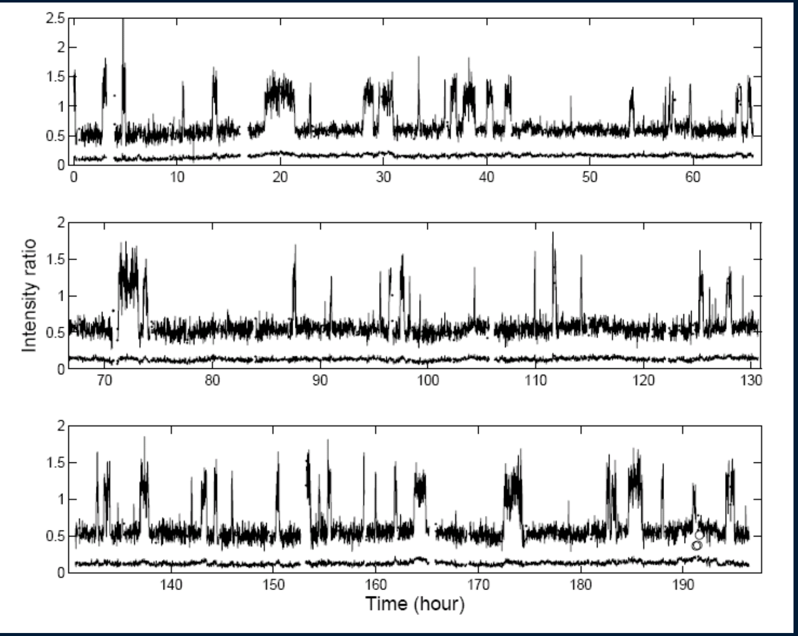
图 3.8: 两次典型的观测轮廓序列，其中分别包括了正常模式和反常模式，每个轮廓的积分时间为3分钟，右图为对应相对强度R。紫色的轮廓分别为正常模式和反常模式的叠加的累积轮廓，红色的圆圈表示过渡点。

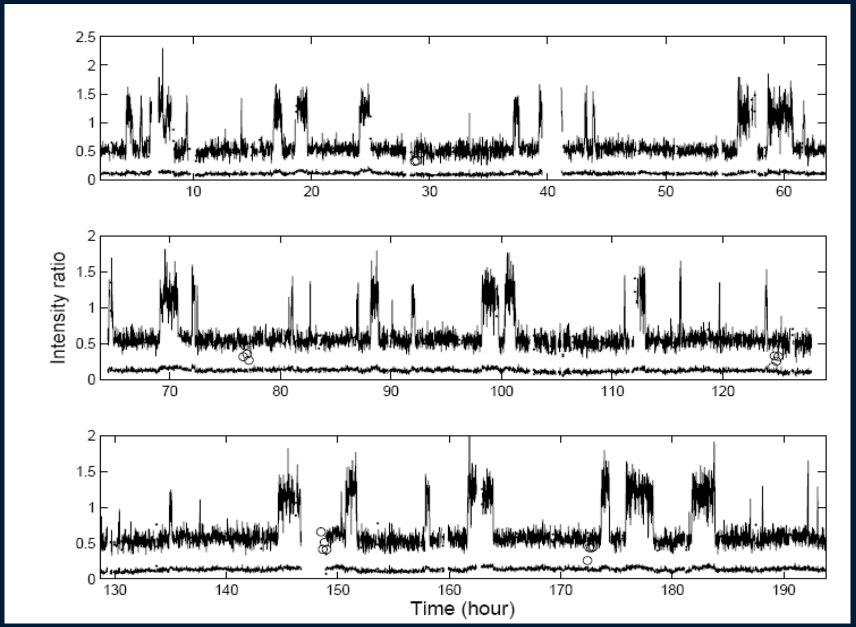
Main Results — mode changing: PSR B0329+54



Chen et al. 2011, ApJ, Submitted

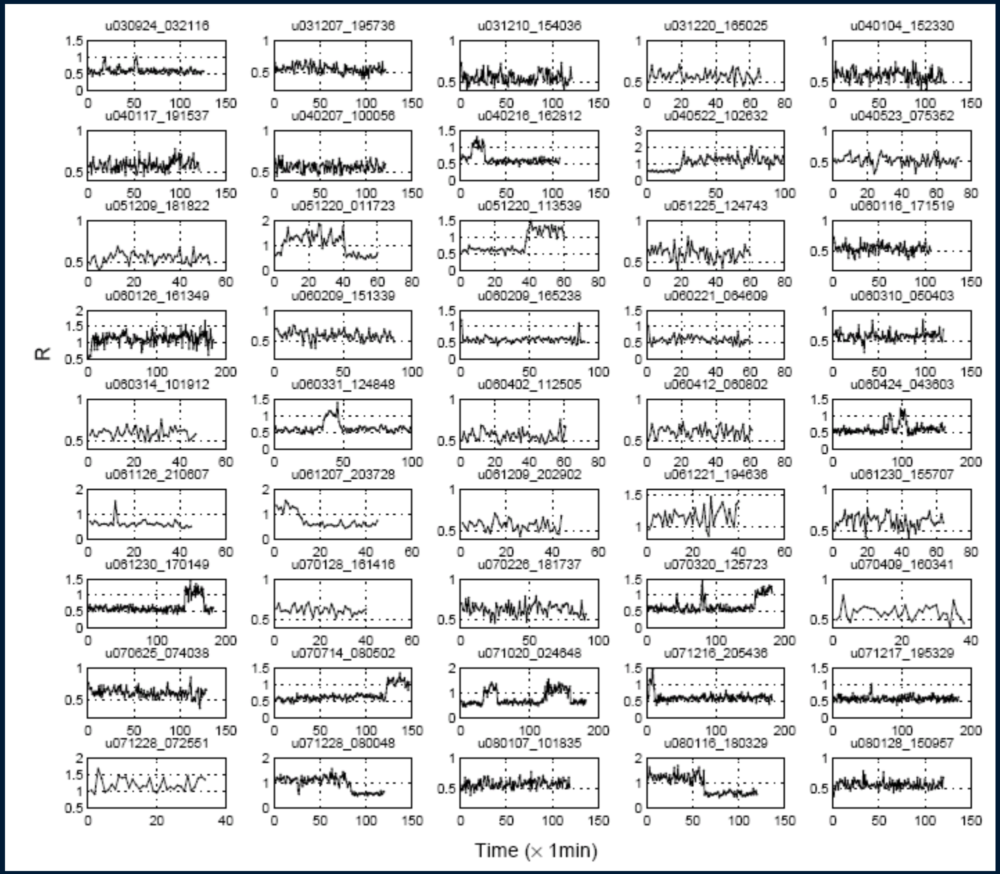
Main Results — mode changing: PSR B0329+54





- Time sequence of R for quasi-continuous observation from2004 March 12-20 (left) and March 23-31 (right).
- The integration time for individual profiles is 1 minutes.

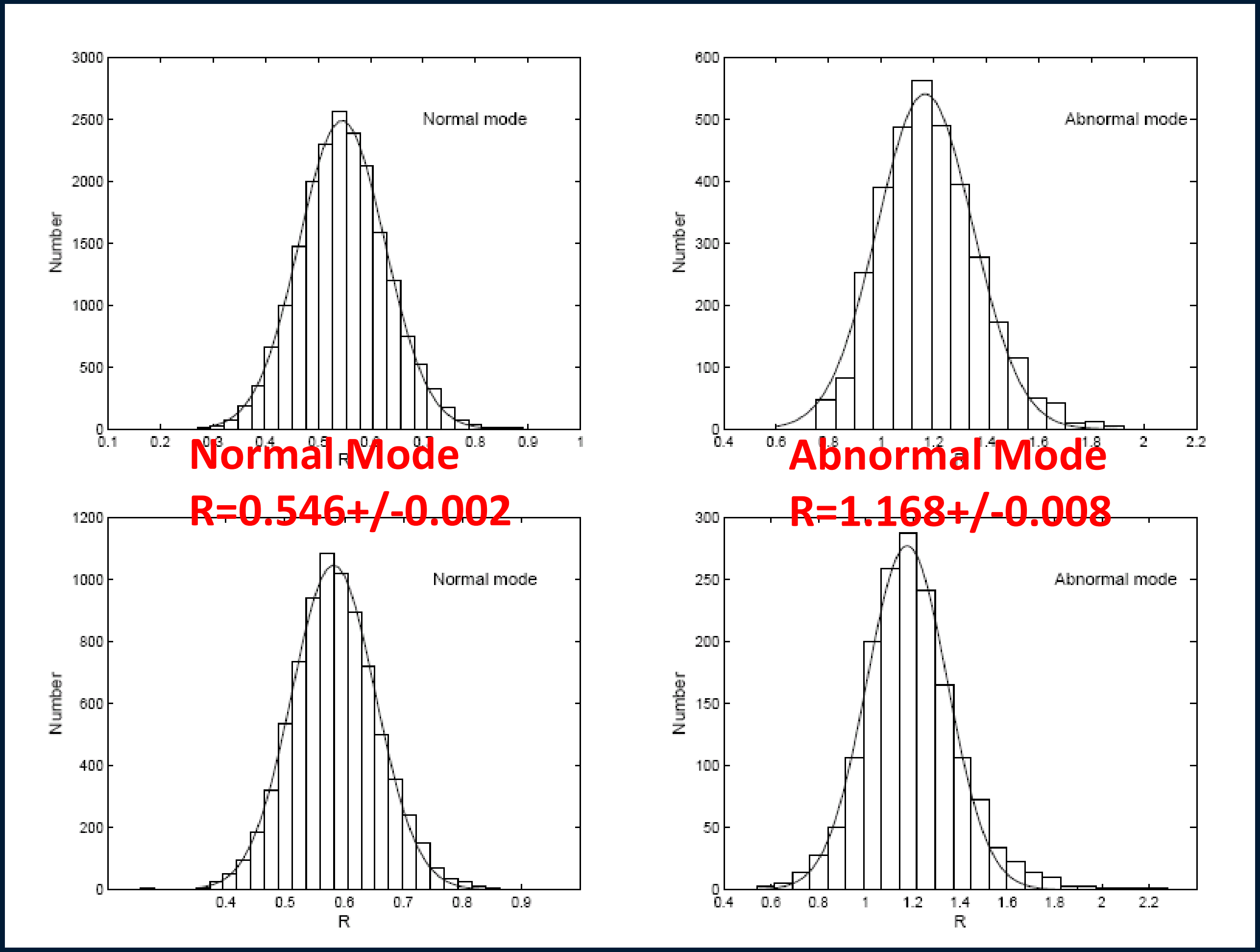
Main Results — mode changing: PSR B0329+54



R for Separated Observation

Main Results — mode changing: PSR B0329+54

R Distribution



Continuous data

Separated obs.

Main Results — Applications of Pulsar Timing

- Pulsar Navigation
- Time Scale

Main Results — theoretical studies

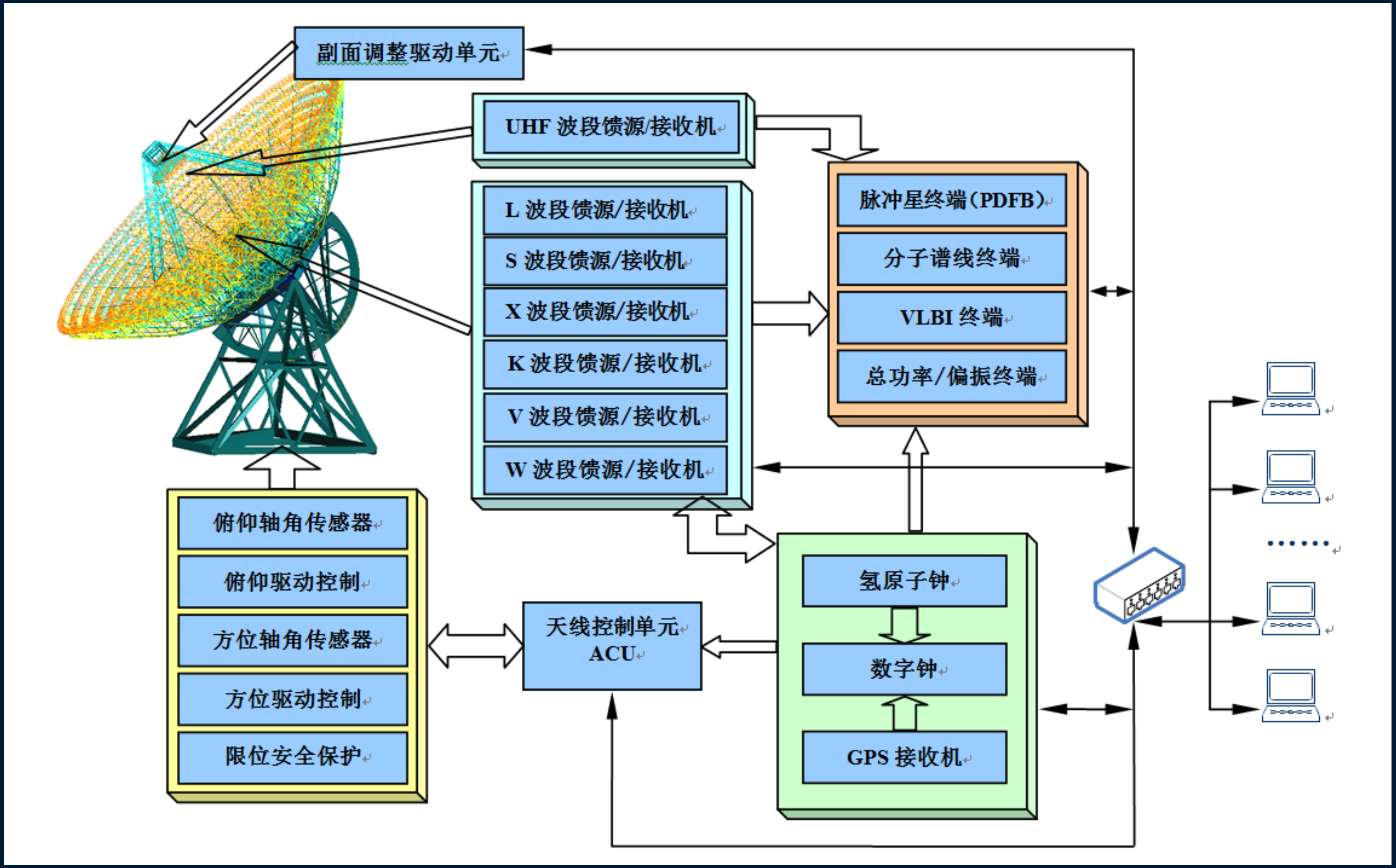
Numerical simulation of the electron capture process in a magnetar interior
Z. F. Gao, N. Wang, J. P. Yuan, L. Jiang and D. L. Song
2011, Astrophys Space Sci., 332, 129-138.

Evolution of superhigh magnetic fields of magnetars
Z. F. Gao, N. Wang, J. P. Yuan, L. Jiang,D.L. Song and E. L. Qiao
2011, Astrophys Space Sci., 333, 427-435.

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

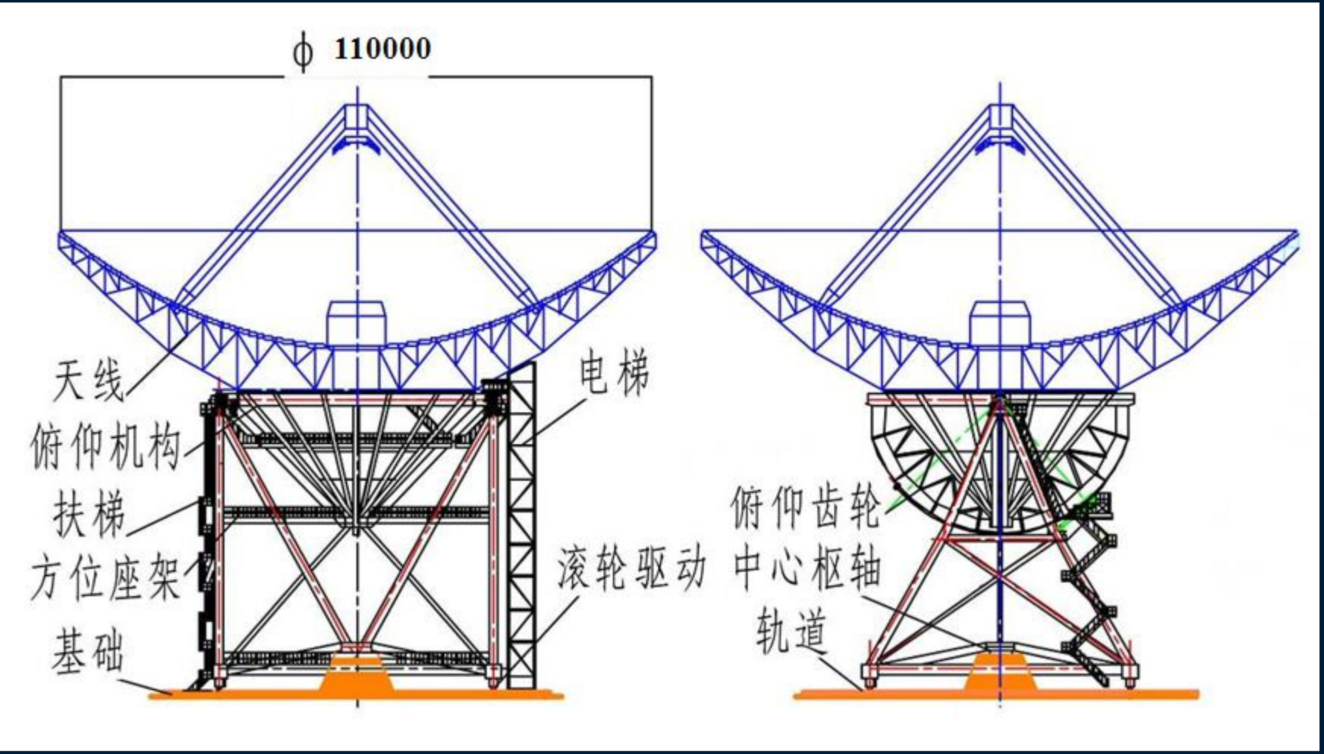
Physics on huge X-ray luminosity of magnetars
Q. H. Peng, Z. F. Gao, N. wang, H. Tong, and C. K. Chou,
11-th Symposium on Nuclei in the Cosmos 19-23 July 2010 Heidelberg. Germany,
2011, Proceedings of Science ID: PoS(NIC XI) 176

Prospect of Future – Large telescope



Prospect of Future – Specification

Structure: Reflectors + Roller raceway type elevation-azimuth antenna pedestal



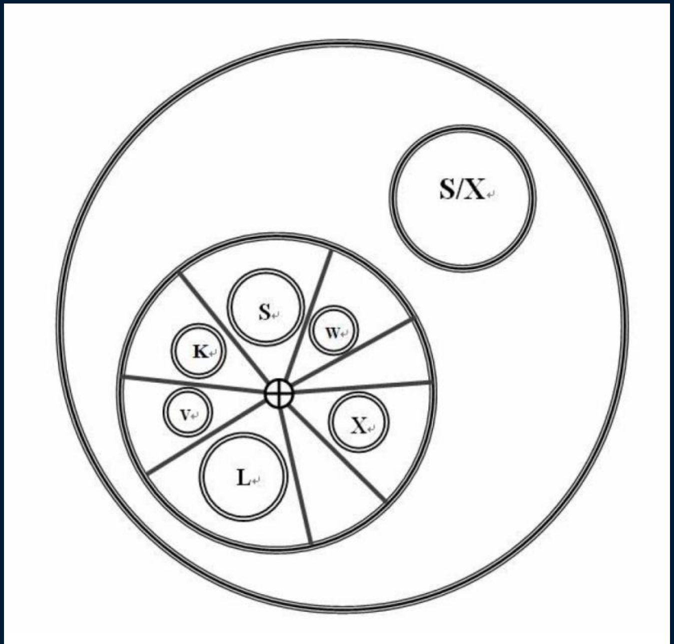
Prospect of Future – Specification

- 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

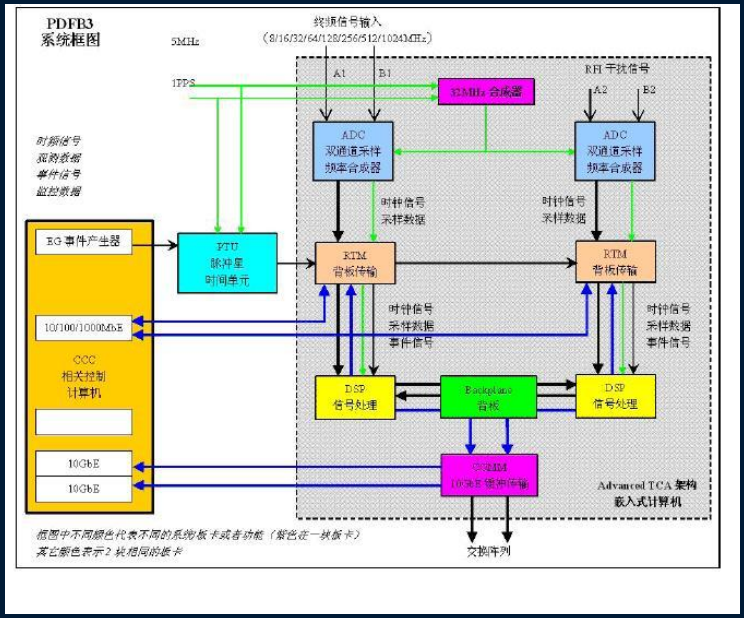
◈ **Change feed horn:**

- Rotary table: change receiver <10 min
- Sub-reflector deflexion: change receiver <10 sec



Prospect of Future – Specification

- **Wide band digital receiver**
  - UHF（feed forward）
  - L、S、X、K、V、W（L~W: feed back）— challenge!!
- **Backend / data sampling**
  - Pulsar / spectrum (PDFB)
  - Total power back end
  - VLBI back end



Prospect of Future – Specification

Receiver system

Band	Freq Range (GHz)	Wave length (cm)	Receiver Temp(K)	System Temp.(K)	Efficiency (optimum position)	Poln
UHF	0.3 - 1	40	40	60	48%	linear
L	1 – 2	20	14	40	60%	linear
S	2 – 4	10	15	45	60%	linear
X	4 – 12	4	20	60	55%	linear
K	12 – 36	1	30	75	40%	linear
V	36 – 75	0.7	60	170	30%	linear
W	75 – 110	0.3	100	180	12%	linear

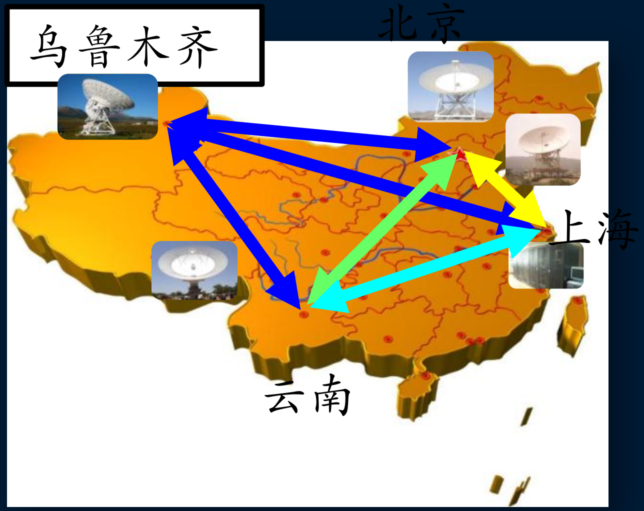
Prospect of Future – Specification

- 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

CVN基线长度			
站点	北京50米	云南40米	上海25米
乌鲁木齐25米	2460 km	2476 km	3249 km
上海佘山25米	1114 km	1920 km	★
云南昆明40米	2158 km	★	★

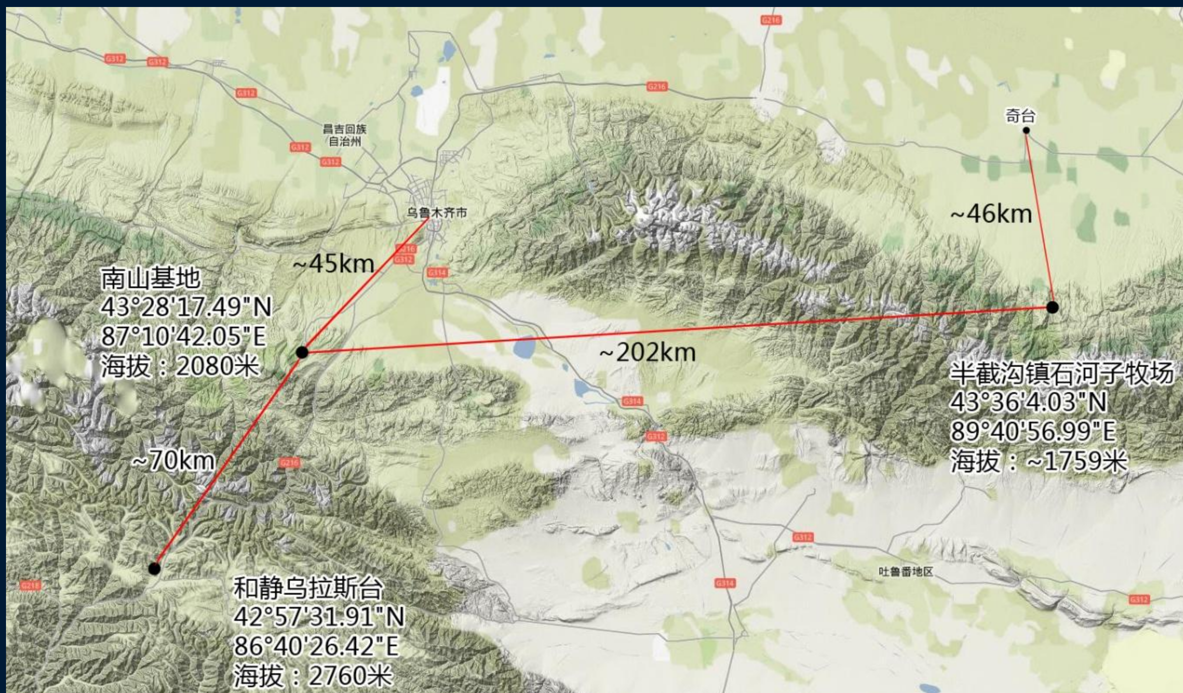


Prospect of Future – Science

- 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

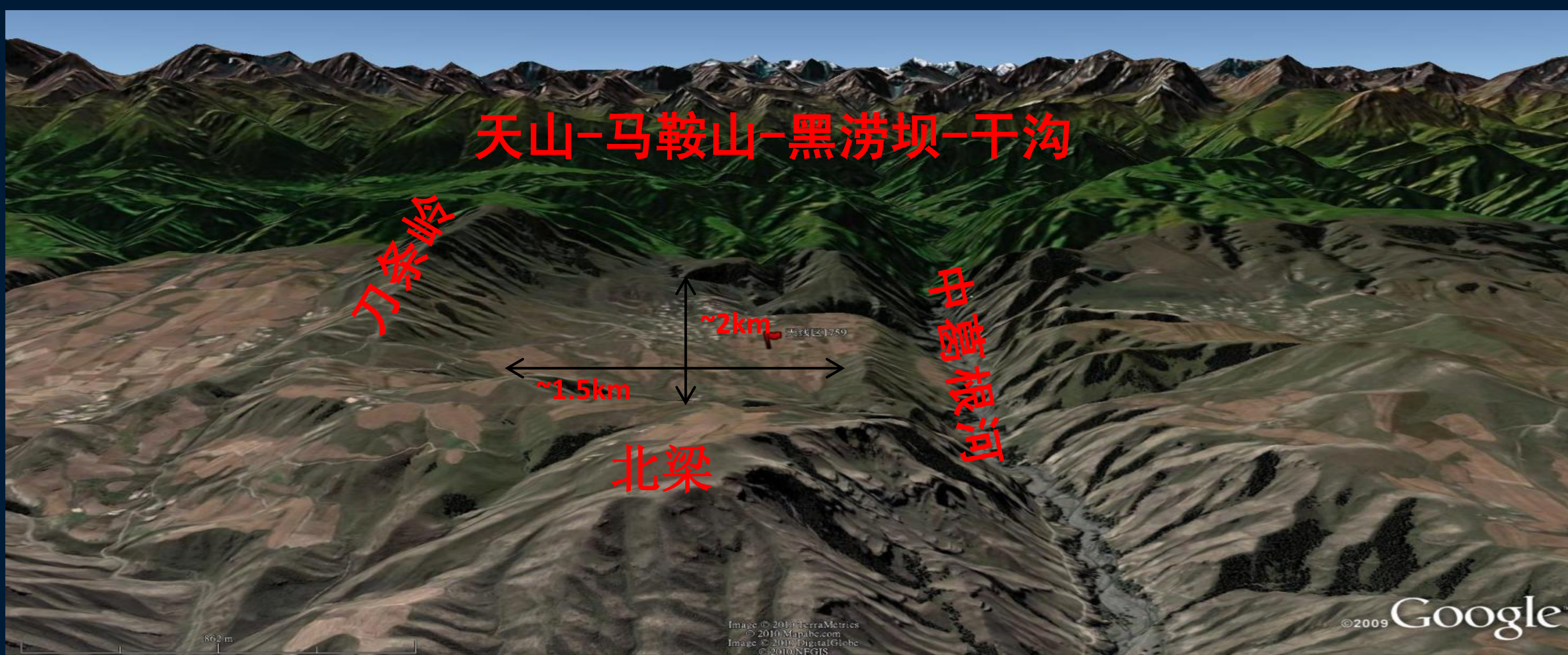


QiTai Tadio Telescope

QTRT, QTT

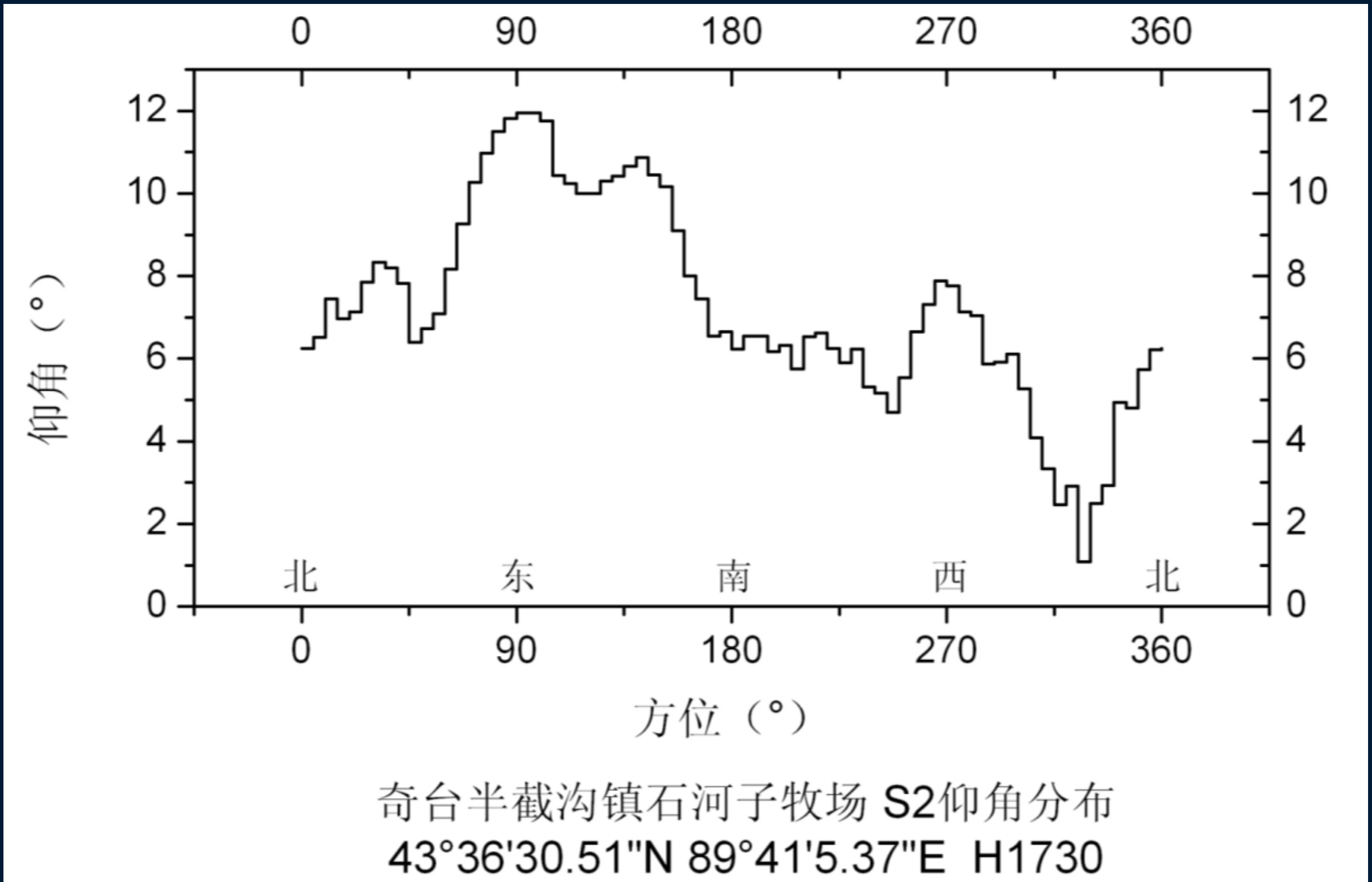
Prospect of Future – the Site

- Basin 1.5km X 2 km
- Altitude of surrounding mountains: 1860-2250m，
- Altitude of bottom of the basin 1730-1830m

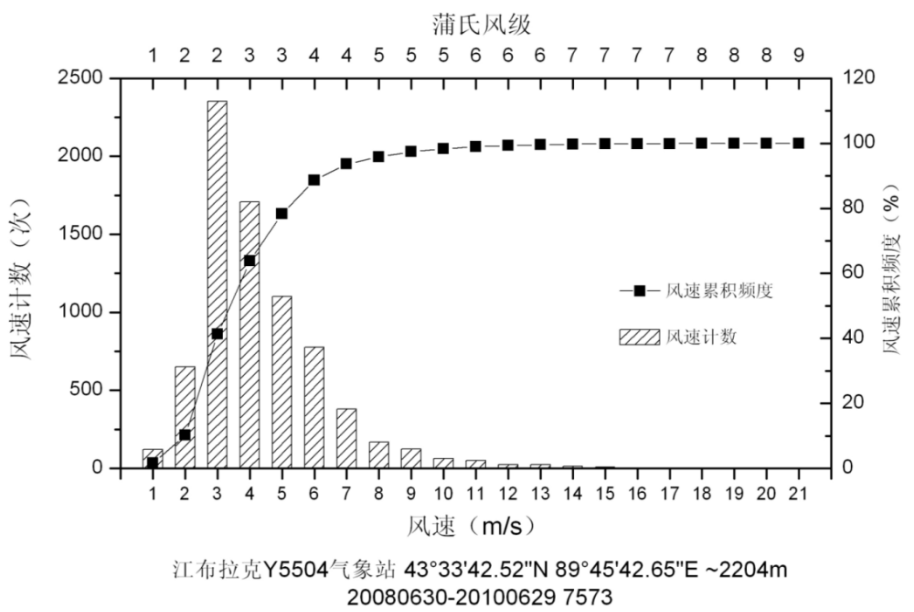


Prospect of Future – the Site

Elevation of mountains



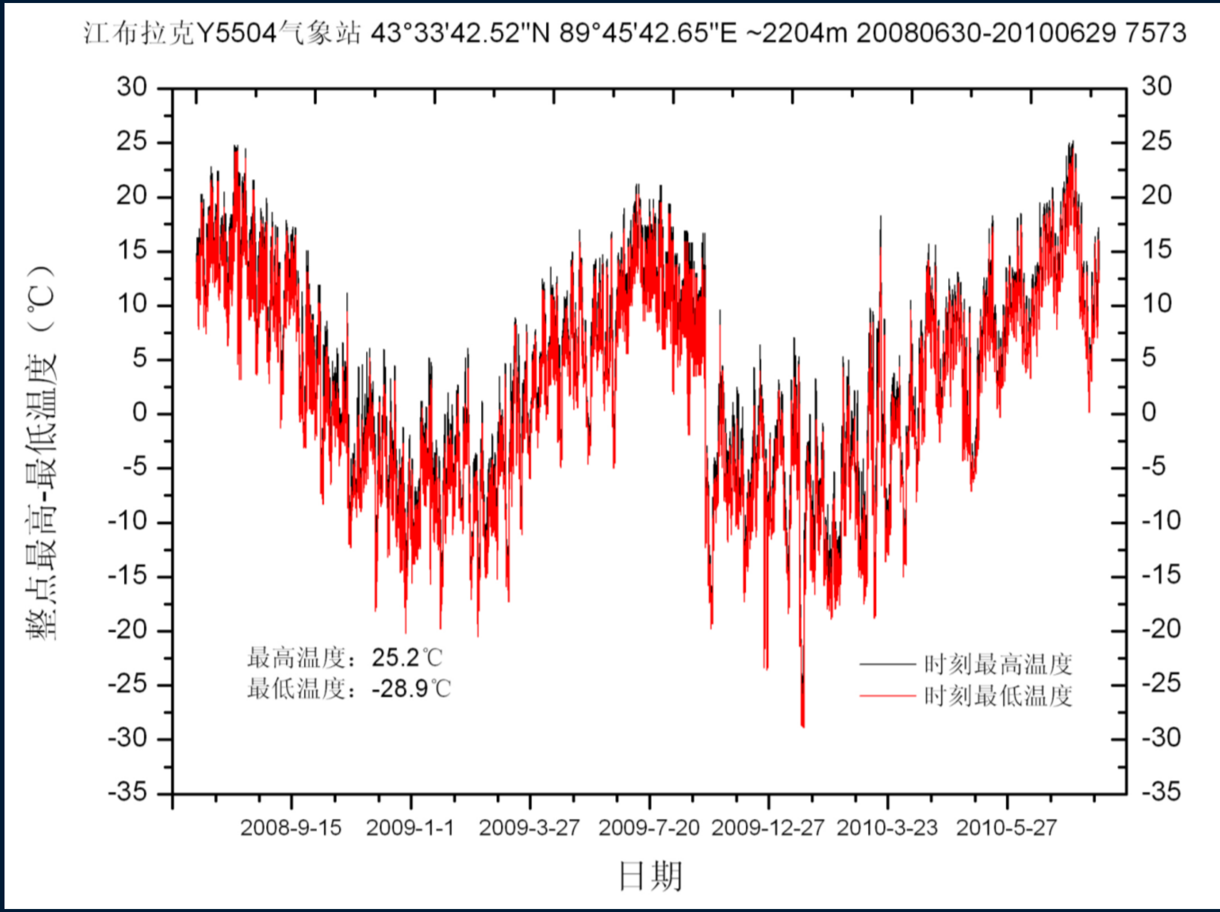
Prospect of Future – the Site



Wind speed	ratio
≤4m/s（gentle breeze）	63.7%
≤6m/s（moderate breeze）	88.4%
≤8m/s（fresh breeze）	95.8%
≥17m/s (fresh gale)	0.079%

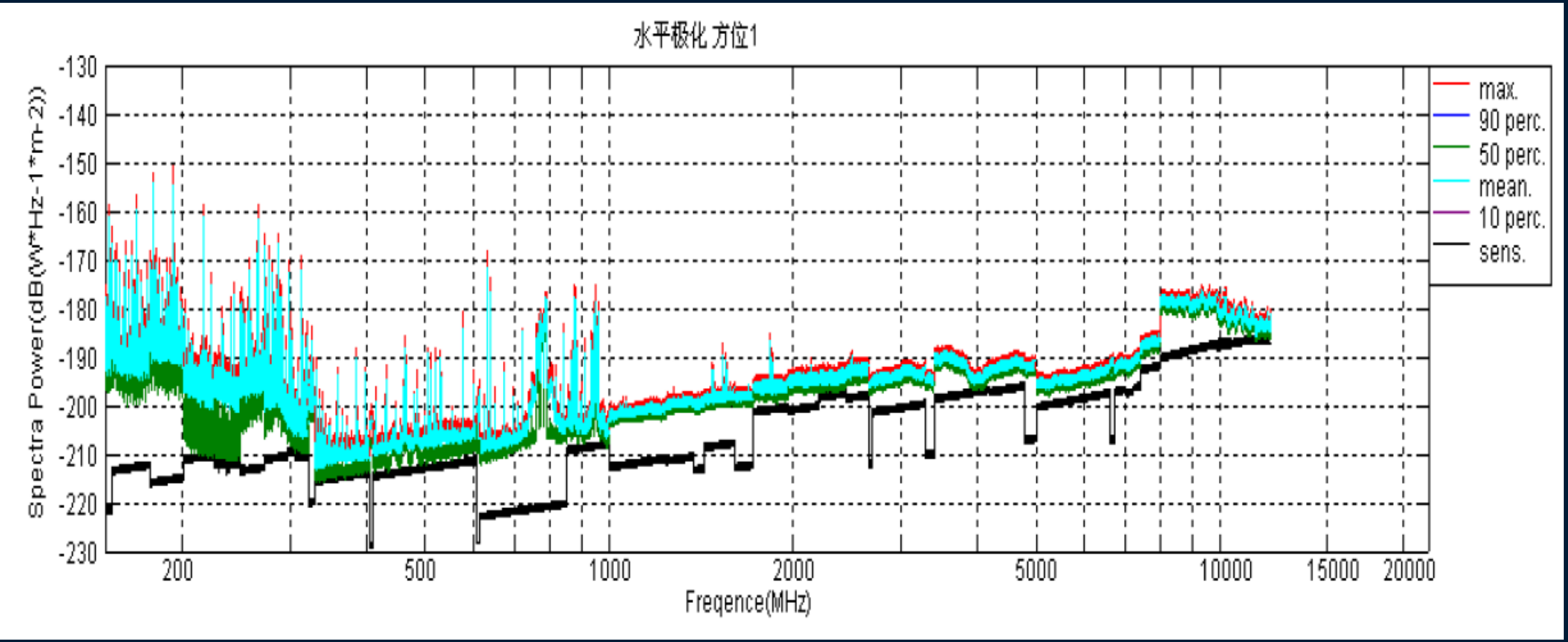
Prospect of Future – the Site

Temperature range

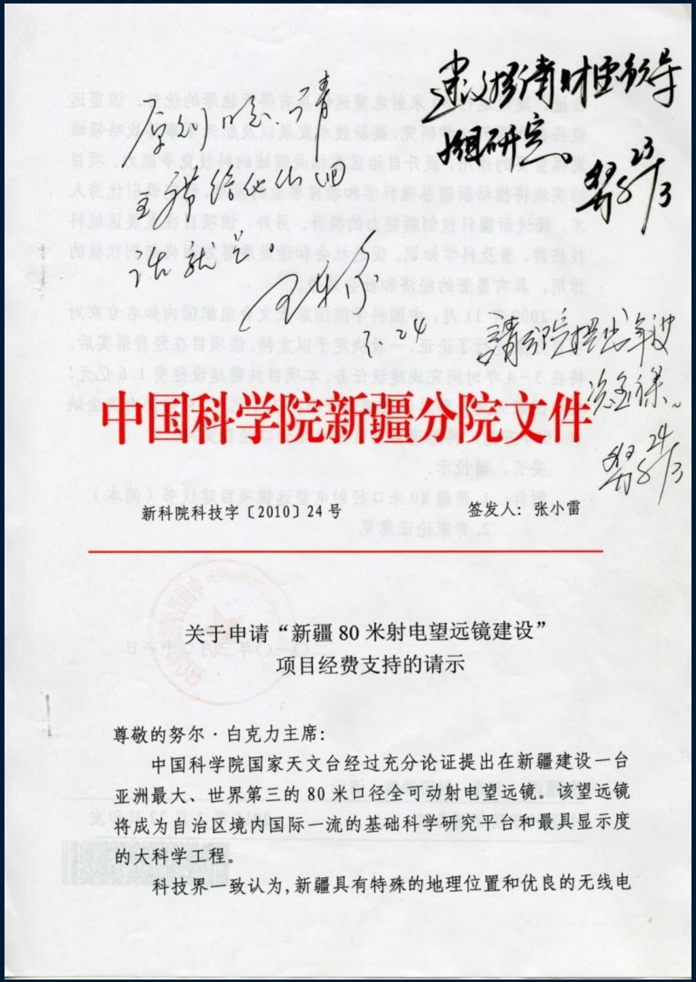


Prospect of Future – the Site

RFI



Prospect of Future – Progress



中国科学院新疆分院文件

新科院科技字〔2010〕24号　　签发人：张小雷

关于申请"新疆80米射电望远镜建设"
项目经费支持的请示

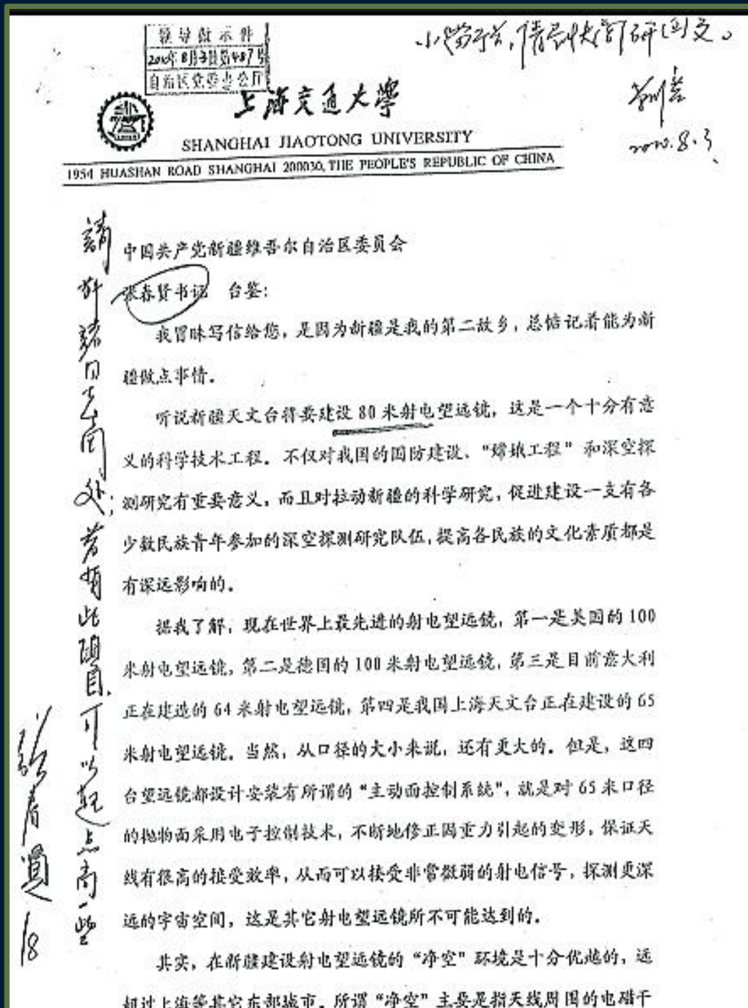
尊敬的努尔·白克力主席：

中国科学院国家天文台经过充分论证提出在新疆建设一台亚洲最大、世界第三的80米口径全可动射电望远镜。该望远镜将成为自治区境内国际一流的基础科学研究平台和最具显示度的大科学工程。

科技界一致认为，新疆具有特殊的地理位置和优良的无线电

2010 March 29, Local government agreed 50m RMB support

Prospect of Future – Progress



上海交通大学
SHANGHAI JIAOTONG UNIVERSITY
1954 HUASHAN ROAD SHANGHAI 200030, THE PEOPLE'S REPUBLIC OF CHINA

中国共产党新疆维吾尔自治区委员会

张春贤书记 台鉴：

我冒昧写信给您，是因为新疆是我的第二故乡，总惦记着能为新疆做点事情。

听说新疆天文台将要建设 80 米射电望远镜，这是一个十分有意义的科学技术工程。不仅对我国的国防建设，"嫦娥工程"和深空探测研究有重要意义，而且对拉动新疆的科学研究，促进建设一支有各少数民族青年参加的深空探测研究队伍，提高各民族的文化素质都是有深远影响的。

据我了解，现在世界上最先进的射电望远镜，第一是美国的 100 米射电望远镜，第二是德国的 100 米射电望远镜，第三是目前意大利正在建造的 64 米射电望远镜，第四是我国上海天文台正在建设的 65 米射电望远镜。当然，从口径的大小来说，还有更大的。但是，这四台望远镜都设计安装有所谓的"主动面控制系统"，就是对 65 米口径的抛物面采用电子控制技术，不断地修正因重力引起的变形，保证天线有很高的接受效率，从而可以接受非常微弱的射电信号，探测更深远的宇宙空间，这是其它射电望远镜所不可能达到的。

其实，在新疆建设射电望远镜的"净空"环境是十分优越的，远超过上海等其它东部城市。所谓"净空"主要是指天线周围的电磁干

- Prof Feng from Shanghai Jiao Tong University write to Xinjiang local leader
- 2010Augest 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