PULSAR TIME AND PULSAR TIMING at KALYAZIN , RUSSIA

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- Precise timing of millisecond binary pulsars was started at Kalyazin radio astronomical observatory since 1996. (Tver' region, Russia -37.650 EL; 57.330 NL).

- Binary pulsars: J0613-0200, J1020+1001, J1640+2224, J1643-1224, J1713+0747, J2145-0750, as well as isolated pulsar B1937+21, are among the Kalyazin Pulsar Timing Array (KPTA).

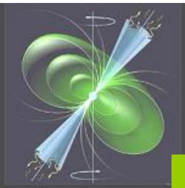
- The pulsar B1937+21 is being monitored at Kalyazin observatory (Lebedev Phys. Inst., Russia-0.6 GHz) and Kashima space research centre (NICT, Japan-2.2 GHz) together since 1996.

<u>Main aim is:</u>

- a) to study Pulsar Time and to establish long life space ensemble of clocks, which could be complementary to atomic standards;
- b) to detect gravitational waves extremely low frequency, which are generated Gravity Wave Background – GWB

Radio Telescope RT-64
(Kalyazin, Russia)

Main reflector diameter	64 m
Secondary reflector diameter	6 m
RMS (surface)	0.7 mm
Feed – Horn (wideband)	5.2 x 2.1 m
Frequency range	0.5 – 15 GHz
Antenna noise temperature	20K
Total Efficiency (through range)	0.6
Slewing rate	1.5 deg/sec
Receivers for frequency:	0.6; 1.4; 1.8; 2.2; 4.9; 8.3 GHz

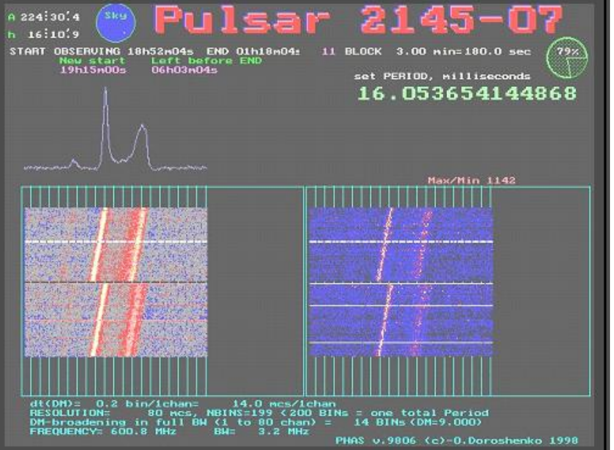


Pulsar

Radio telescope RT-64

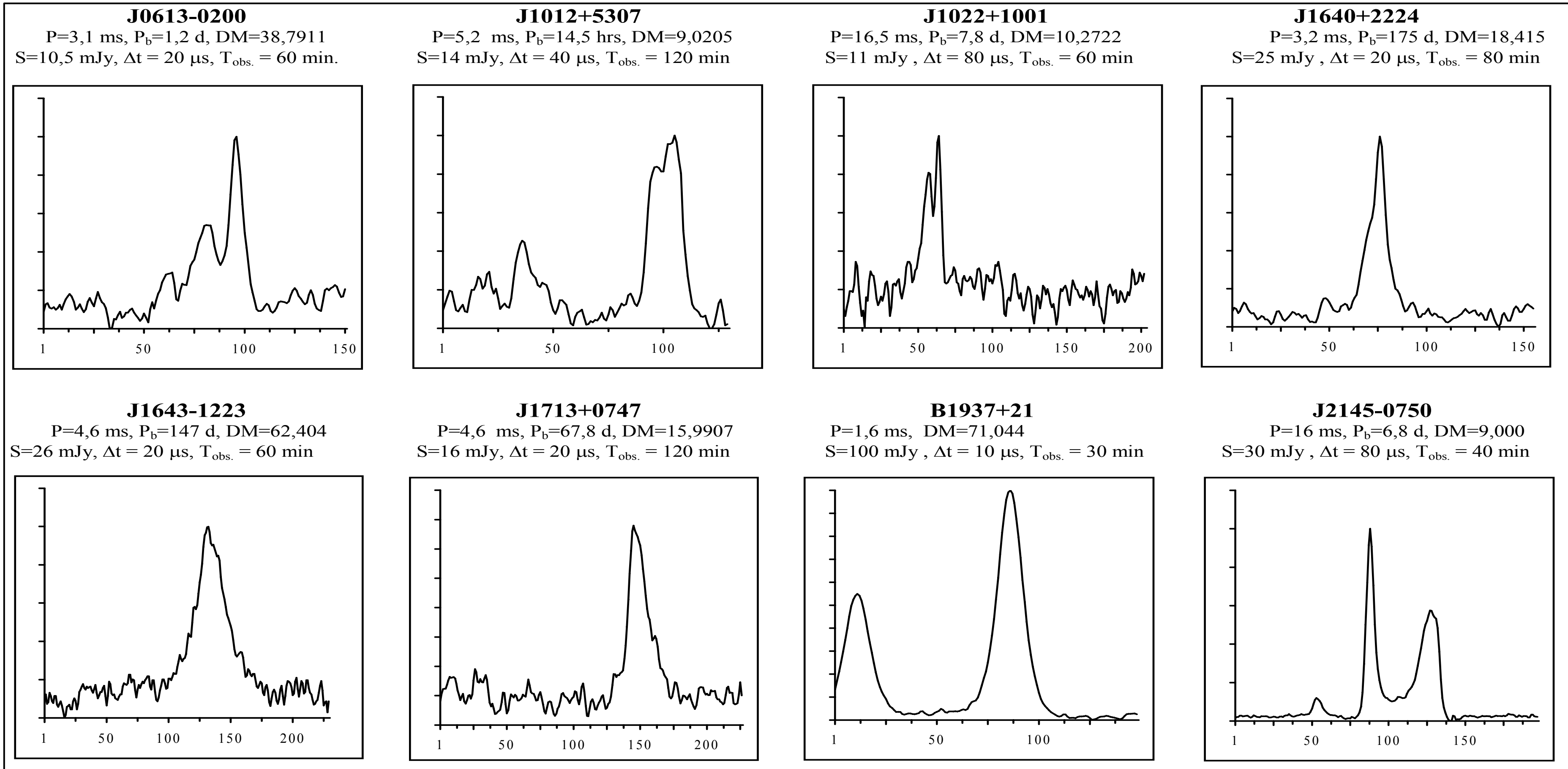
Signal of pulsar J2145-0750

on the monitor



Kalyazin pulsar timing complex

Mean Pulse Profiles of Kalyazin Pulsar Timing Array (KPTA) pulsars at 600 MHz by 64-m dish and filter-bank receiver



Pulsars profiles at 600 MHz (Δf = 3,2 MHz , 2 polarization).

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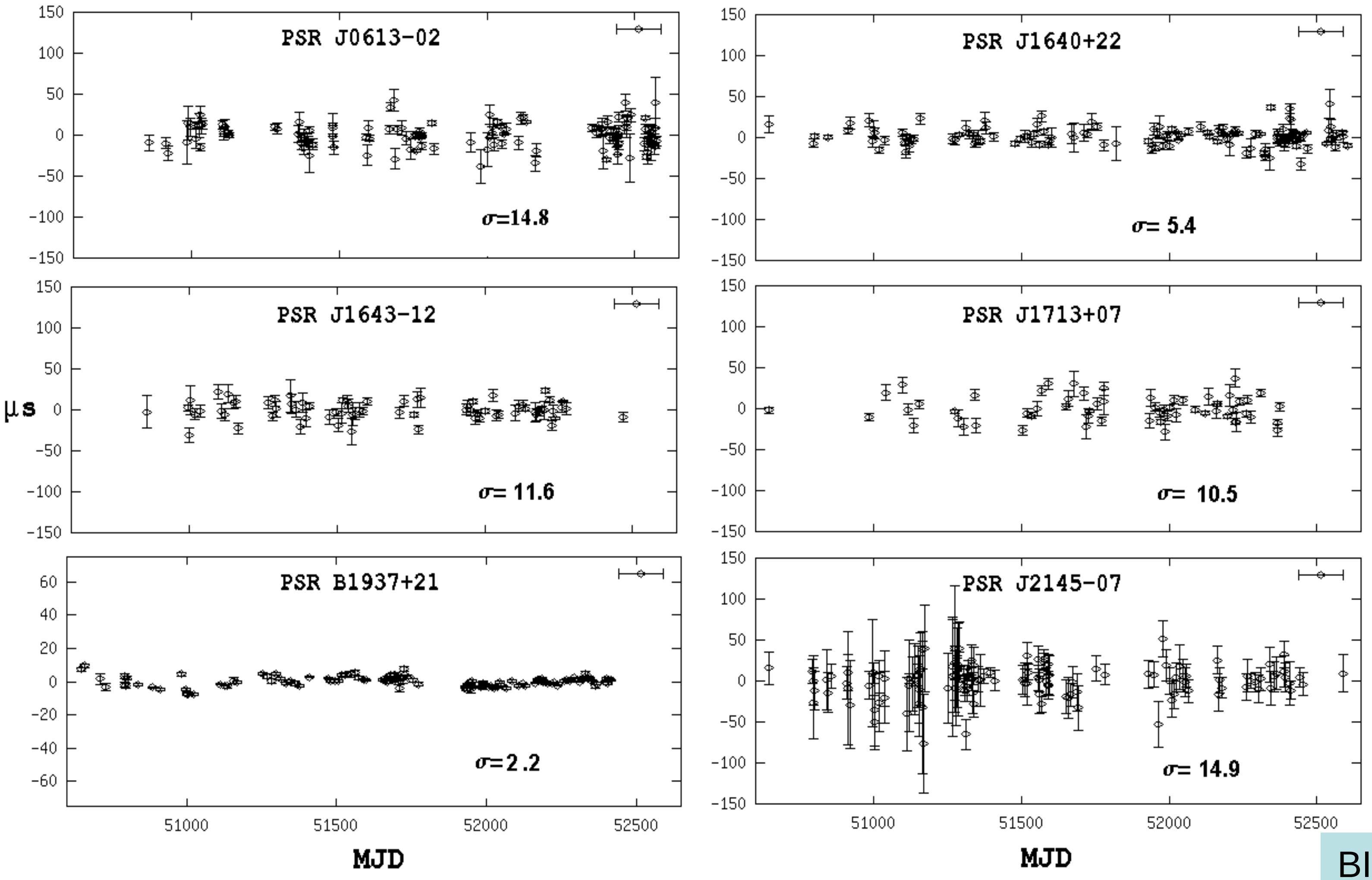
TOA Residuals of Millisecond Pulsars :B1937+21, J0613-0200, J1640+2224, J1643-1224, 1713+0747, J2145-0750



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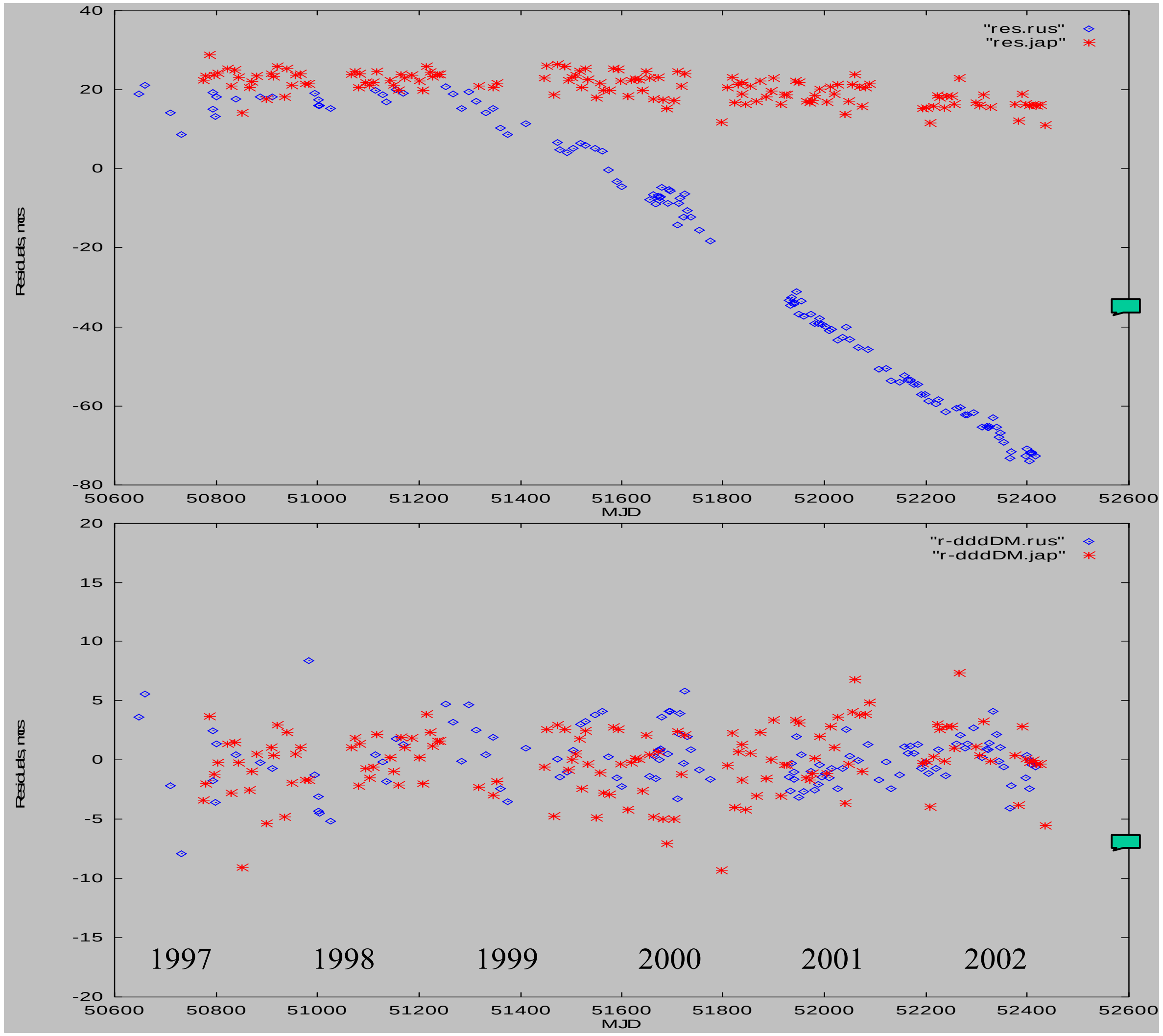
Joint Kalyazin-Kashima pulsar 1937+21 timin



Kashima – 2,3 GHz

Kalyazin – 0,6 GHz

$DM_{1997} = 71{,}031$

$DM_{2002} = 71{,}021$

Residuals before correction for secular DM variations to B1937+21

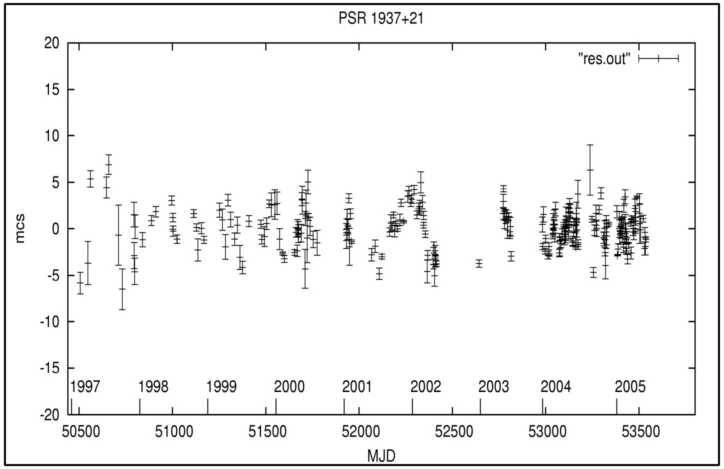
Residuals after correction for secular DM variations to B1937+21

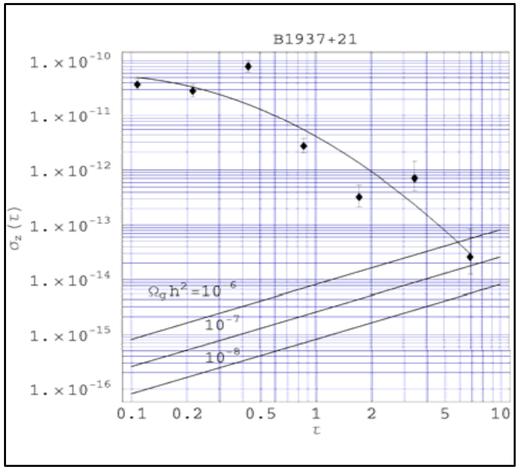
RMS = 1,8 мкс

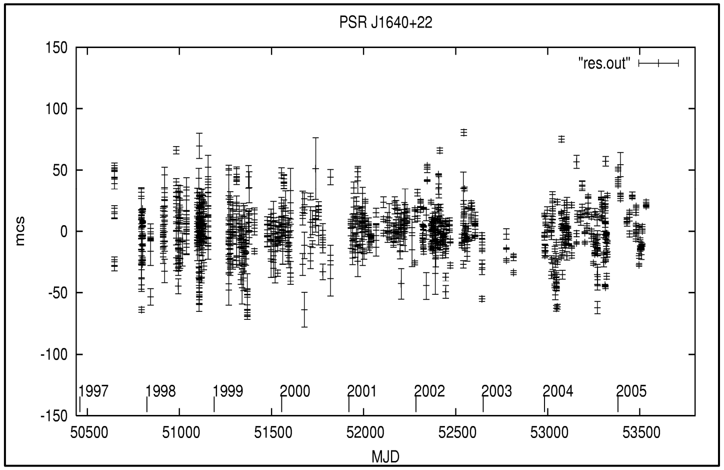
$\Delta f/f \sim 9 \cdot 10^{-15}$

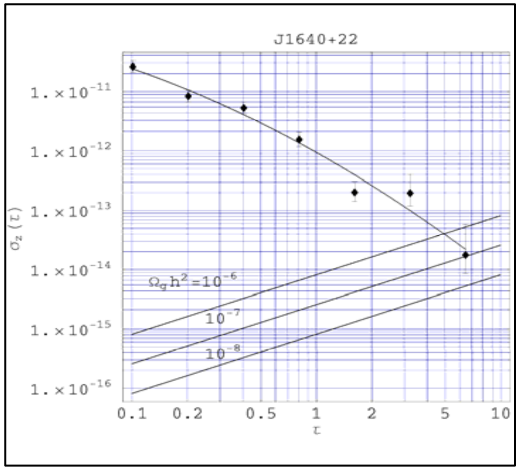
Ilyasov, Imae, Hanado, Oreshko, Potapov, Rodin, Sekido// Astron. Lett. Sov. v.31, p.30 (2005)

LONG TIME INTERVAL TOA RESIDUALS and ALLAN VARIANCE of PSR SPIN ROTATION FREQUENCY: J1640+2224, B1937+21 from KALYAZIN TIMING









TOA Residuals and Allan Variance of PSR : B1937+21 (upper) and J1640+2224 (lower)
(Kalyazin timing at 0.6 GHz)

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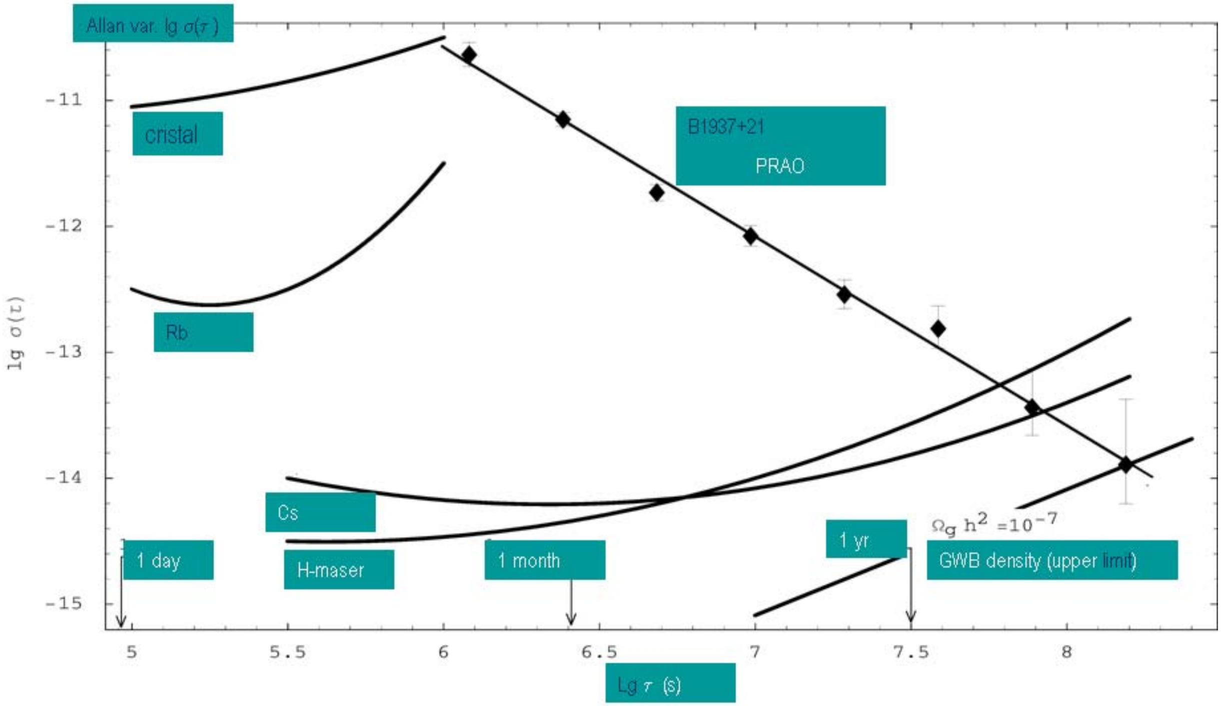
Allan Variance for the Millisecond Pulsar B1937+21 and other Time Standards



After ten years monitoring of B1937+21 its timing noise is looking as "white phase noise" with RMS about 1.8 μs.(Fractional instability is about 6.10^{-15}). After these data and timing results of binary pulsar J1640+2224 gravitational natural GWB upper limit should be reduced till to less than $\Omega_g h^2 < 10^{-7} - 10^{-9}$.

Secular changes of DM toward millisecond pulsar B1937+21 were revealed after long time two frequency timing observations (Kalyazin – 0,6 and Kashima – 2.3 GHz).

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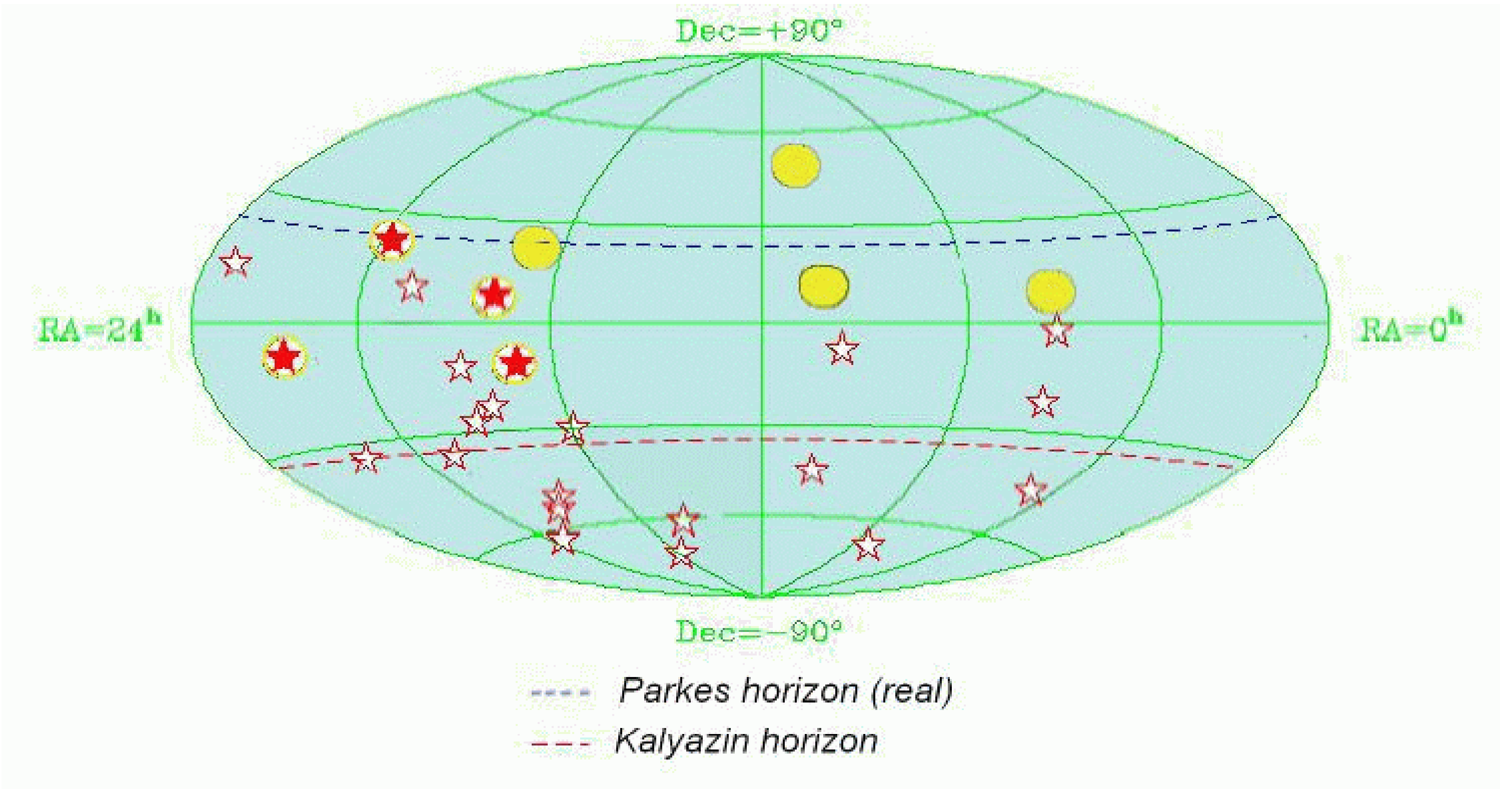
Millisecond Reference Pulsars and their Sky Allocation



Combined Pulsar Timing Array (PTA): Kalyazin (KPTA)
(IPTA - ?proto time frame?) Parkes (PPTA)

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Signal /Noise Ratio (SNR) of Reference Pulsars

(Aef = 2000 sq.m, t observ. = 3000 s , Treciv ~ 20K

PSR	P ms	f MHz	B MHz	T_s=(T_A+T_R)K	S mJy	SNR
B1855+09	5.3621	408	3.9	203.0	31	12.0
		611	6.0	112.0	(16.3)	14.4
		1413	27.0	26.4	4.3	33.6
		2695	10.0	21.3	1.5	8.8
B1937+21	1.5578	408	3.9.	151.0	240	124.6
		611	6.0	93.0	(100)	104.5
		1413	27.0	24.1	16	136.9
		2695	10.0	20.8	4.0	24.1
J1640+2224	3.1633	408	3.9	92.0	37	31.5
		611	6.0	72.0	(16)	21.6
		1413	27.0	21.4	3	28.9
		2695	10.0	20.3	0.7	4.3
J1713+0750	4.5701	408	3.9	130.0	36	21.7
		611	6.0	85.0	(16)	18.3
		1413	27.0	23.1	3	26.8
		2695	10.0	20.6	0.8	4.9

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Working Party 7D

Draft new report

Radio observations of pulsars for precision timekeeping

(Question ITU-R 205/7)

Scope

This Report examines the possibility of using high-precision timing radio observations of millisecond pulsars for constructing and maintaining new pulsar-based astronomical time scales. No changes in the Radio Regulations are needed to enable this activity.

1 Introduction

Pulsars are identified with strongly magnetized, rapidly-rotating neutron stars……….

……

6 Conclusions

This report answers Question ITU-R 205/7, which was formulated for exploring the use of high-precision timing observations of millisecond pulsars for constructing and maintaining new pulsar-based astronomical time-scales PT and DPT.

1) At present (2006), the preferred frequency bands for high-precision timing observations of radio pulsars for the purpose of *precision timekeeping* are the radio astronomy service bands 1 400-1 427 MHz, and either 406.1-410 MHz or 608-614 MHz, and/or the 2690 to 2700 MHz band.

2) The threshold levels for interference detrimental to high-precision pulsar timing are those given in Table 2 of Recommendation ITU-R RA.769 for single-dish continuum observations.

3) The aforementioned, preferred, radio-astronomy service bands do not require any change in frequency allocations or in sharing arrangements with any of the active services sharing the bands with the radio astronomy service.

4) At present (2006), the final goal of providing a new, long-term, stable time-scale by using the most appropriate pulsars as reference clocks is by making precision timing observations of the pulsars B1855+09, B1937+21, J1640+2224 , J1713+0750, J0437-4715, J0613-0200, J1024-0719, J1744-1134 and J1907-3744. This list of objects will undoubtedly be augmented in time.

CONCLUSION

- Several of the most appropriate pulsars now are B1937+21, J1640+2224, J1713+0750 and B1855+09. They can be used as high-stable reference space clocks with the final goal of providing a new long – term stable time-scale.
- Most of leading world radio astronomical observatories now are involved in pulsar timing (Arecibo, Green Bank , Jodrell Bank, Kalyazin, Kashima, Nancey, Parkes).
- High precision timing observations of reference millisecond pulsars, assigned for precision timekeeping as space astronomical reference clocks, can be made in preferred frequency band, allocated for the radio astronomy service band 1400-1427MHz, and either 400-406 or 608-614 MHz.
- The detrimental threshold level for precise pulsar timing are the same which defines by Recommendation ITU-R for single-dish continuum observations.
- Long-term timing monitoring of very stable reference pulsars by the largest radio telescopes in the world should be encouraged with the goal to provide the International Celestial Pulsar Timing Array (ICPTA), in particular for space navigation.
- Time scale based upon reference pulsars should be established to provide a new astronomical time scale with high long-term stability.

Thank you for attention !!

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