

# A Radio Pulsar Spinning at 716 Hertz

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Green Bank Telescope,  
West Virginia

## Observations

GBT: 100-m dish  
Central Freq.: 1950MHz  
Spigot Backend [6]:  
- Up to 800MHz of bandwidth  
- 82us/16-bit sampling  
- 1024 lags (freq. channels)  
- Data rate: 90GB/hr.

The huge collecting area of the GBT and the wide bandwidth of the Spigot data recorder were pivotal in the discovery of these intrinsically weak sources.

## Millisecond Pulsars

Millisecond pulsars (MSPs) are formed when an old neutron star is spun up by the accretion of matter from a companion star (transfer of angular momentum).

Globular clusters are excellent breeding grounds for MSPs because the enormous stellar densities of their cores promote exchange interactions that can form binaries capable of creating MSPs.

There are ~110 pulsars known in the Galactic globular cluster system. Remarkably, half of these are contained in only two clusters: Terzan 5 and 47 Tuc.

## Terzan 5

Terzan 5 is a massive and dense globular cluster, located 8.7+/- 2 kpc from Earth, near the Galactic center [7,8].

Based on its high predicted stellar interaction rate [5] and the diffuse steep spectrum radio emission found in its core [3], Terzan 5 has been suspected of harbouring many MSPs, perhaps more than anywhere else in the Galaxy!

Terzan 5 is now known to contain 33 pulsars (Fig 4), including a number of highly eccentric binaries as well as the five fastest-spinning pulsars known in the Galactic globular cluster system [1,2,4].

## Summary

- Using the Green Bank Telescope, we have discovered PSR J1748-2446ad (a.k.a. Ter5ad) the **fastest-rotating neutron star** known [1] (appearing in Science Express online on Thursday January 12th, 2006).
- Ter5ad is a **716-Hz/1.396-ms eclipsing binary** radio pulsar in the rich, dense globular cluster Terzan 5. It is in a highly circular 1.1-day orbit with a > 0.14 Msun companion.
- The fast rotation of Ter5ad **constrains its radius to be < 16 km**, assuming its mass is less than 2 Msun (Fig 1).
- The spin rate of Ter5ad is also an important input for models that propose **gravitational radiation** as a mechanism for limiting the rotation rate of neutron stars [10,11].
- The difficulty in detecting this pulsar, due to its very low flux density (~80uJy at 2 GHz) and high eclipse fraction (~40% of the orbit), **suggests that even faster-spinning neutron stars exist**.

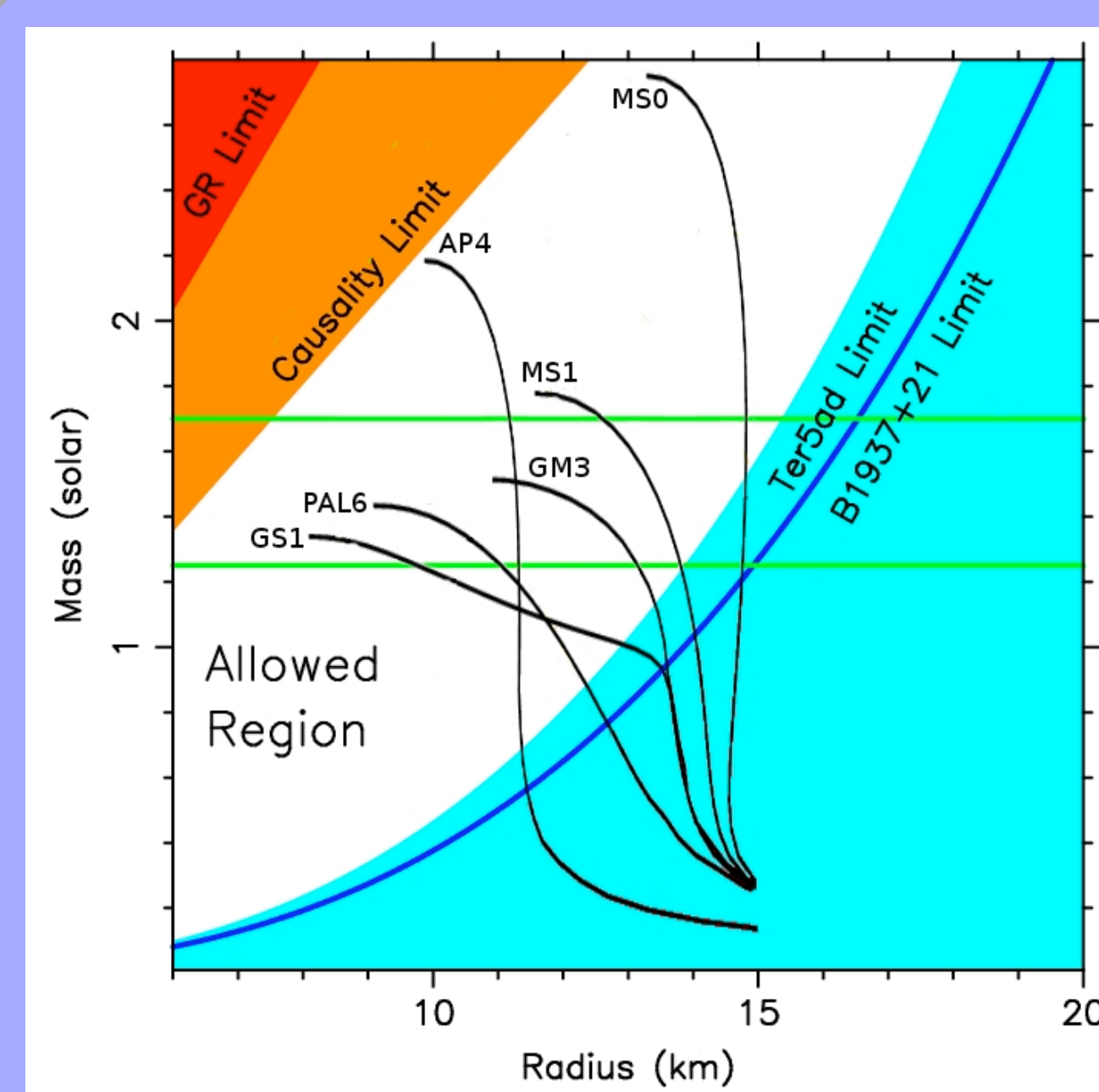


Fig 1. Mass-radius diagram for neutron stars, adapted from Fig. 2 of [9]. The light blue regions are inaccessible to Ter5ad/B1937+21 due to their rapid rotation rates. The green horizontal lines mark the upper and lower limits of well-measured neutron star masses. The tracks of various proposed equations of state are plotted in black.

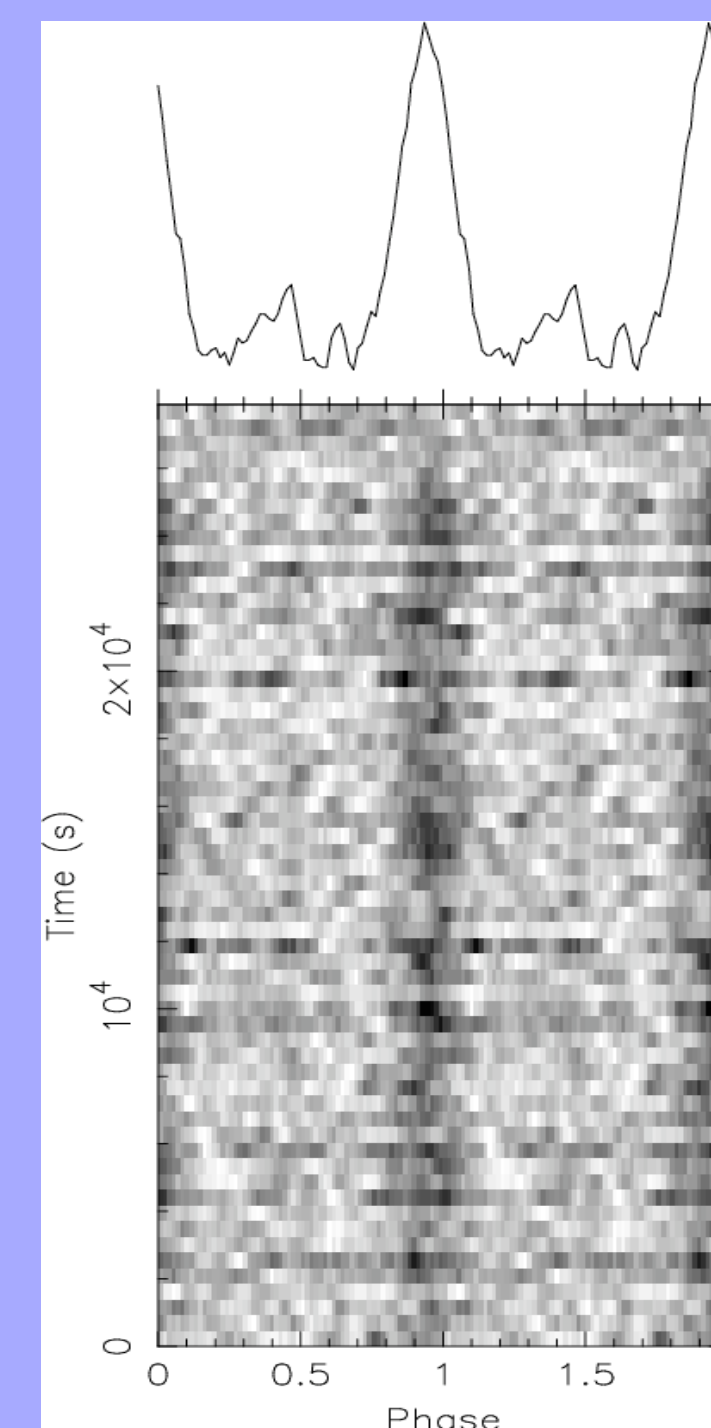


Fig 2. ~7-hr observation of Ter5ad with GBT+Spigot. The pulse strength as a function of time is plotted on the vertical axis. The cumulative pulse profile is shown on top, with two pulse cycles plotted for clarity.

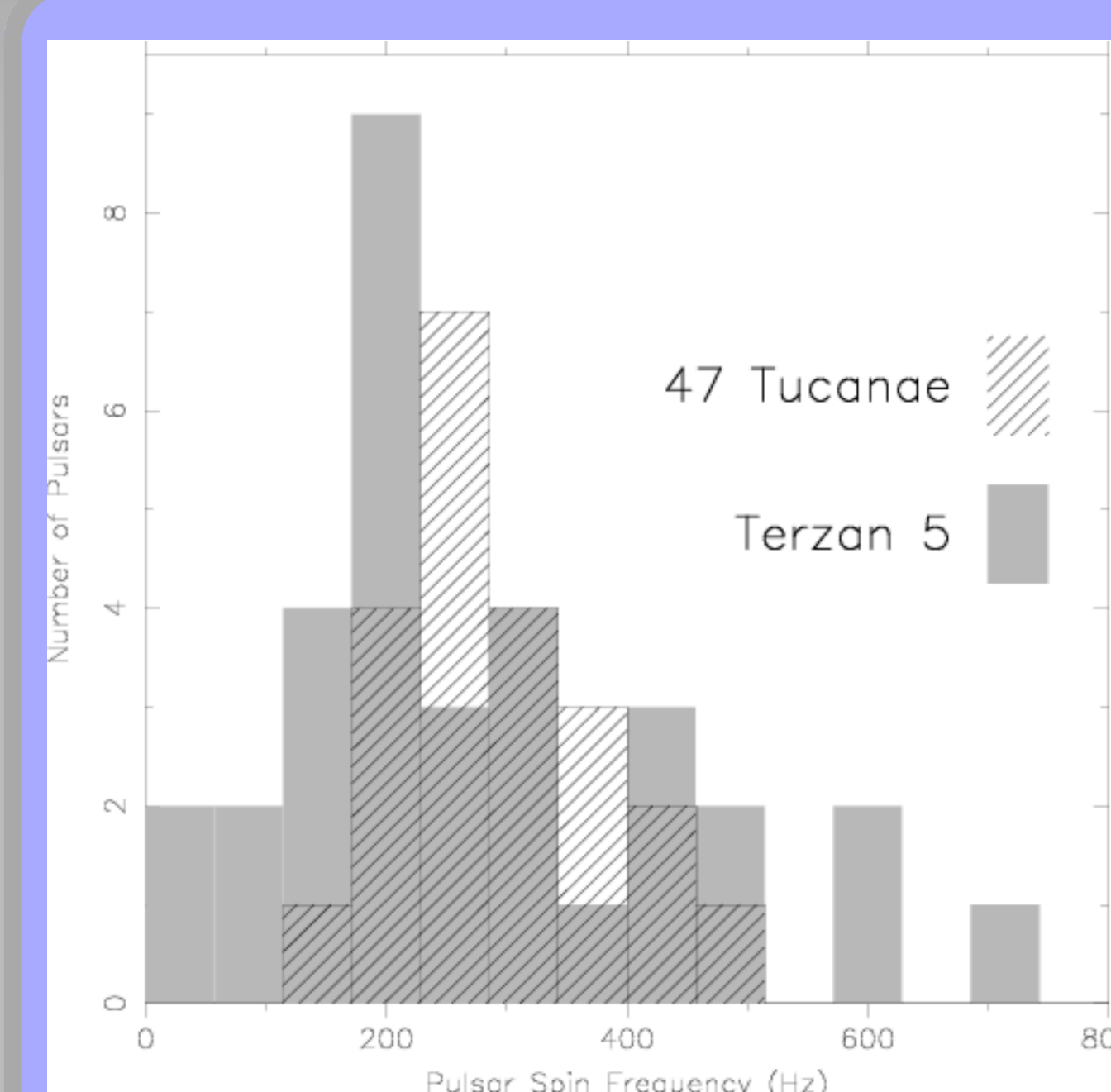


Fig 3. Comparison of the Ter5 and 47 Tuc spin frequency distributions. The Terzan 5 pulsars have a wider distribution, including the five fastest pulsars known in the globular cluster system.

## Fastest-Spinning Radio Pulsars

Pulsar Name	Spin Freq. (Hz)	Porb (days)	M2 (Msun)	Eclipse Fraction	Location
J1748-2446ad	716.358	1.0944	0.14	0.4	Terzan 5
B1937+21	641.931		Isolated		Gal. Plane
B1957+20	622.123	0.3819	0.021	0.1	Gal. Plane
J1748-2446O	596.435	0.2595	0.035	0.05	Terzan 5
J1748-2446P	578.496	0.3626	0.37	0.4	Terzan 5
J1843-1113	541.812		Isolated		Gal. Plane
J0034-0534	532.714	1.5892	0.14	0	Gal. Plane
J1748-2446Y	488.243	1.17	0.14	0	Terzan 5
J1748-2446V	482.507	0.5036	0.12	0	Terzan 5
J0023-7203J	476.048	0.1206	0.020	0.1	47 Tuc

Tab 1. A compilation of the ten fastest-spinning pulsars known. Five of the ten fastest-spinning pulsars show eclipses, suggesting an important fraction of the fastest pulsars may be difficult to detect because of obscuration from intra-binary material. Also, five of the ten fastest-spinning pulsars are found in the globular cluster Terzan 5.

## Terzan 5's Pulsars

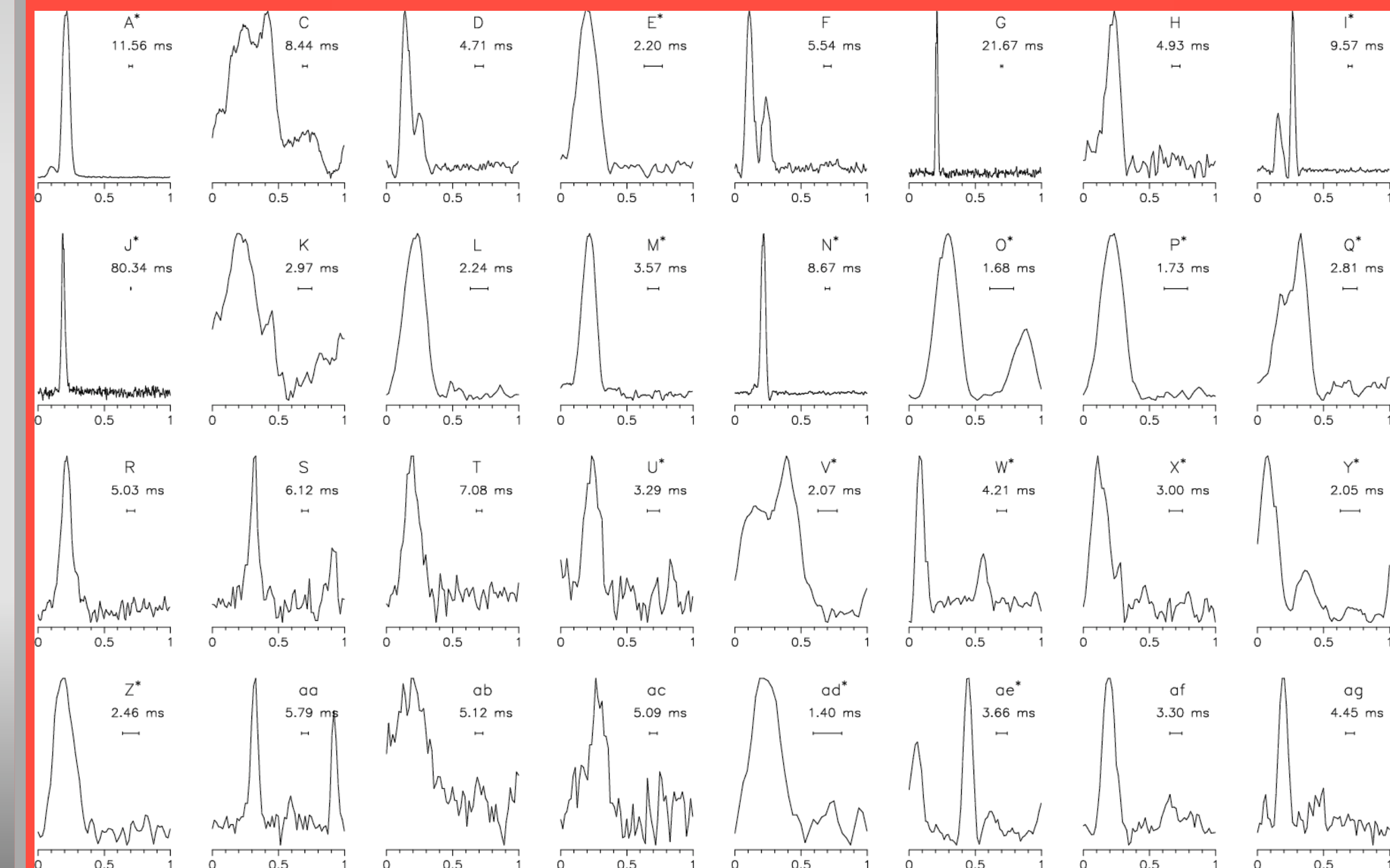


Fig 4. Pulse profiles for 17 binary (marked with \*) and 15 isolated pulsars in Terzan 5. These are high signal to noise average profiles made by combining numerous observations. The horizontal bars show the effective time resolution.

## Acknowledgements & References

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