Universität Bielefeld

Fundamental Improvements to Pulsar Timing

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Introduction

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- Optimal ToA bandwidth
- Different template possibilities
  1. Data-derived, Analytic, Data-derived and smoothed
  2. Frequency-resolved vs. Frequency-scrunched
  3. 2D approach by Pennucci
- ToA correlation methods
  1. FDM
  2. PGS
  3. GIS

Pulsars and Telescopes

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Pulsars

J0218+4232 J1713+0747
J1939+2134 J2145-0750

Telescope Parameters

Tel	BW	Freq	nchan	nbin
EFF	200	1347.5	128	1024->256
WSRT	160	1380	512->128	256
NANCAY	512	1484	128	2048->256
JBO	400	1532	1600(400)->100	256

Epochs of all observations

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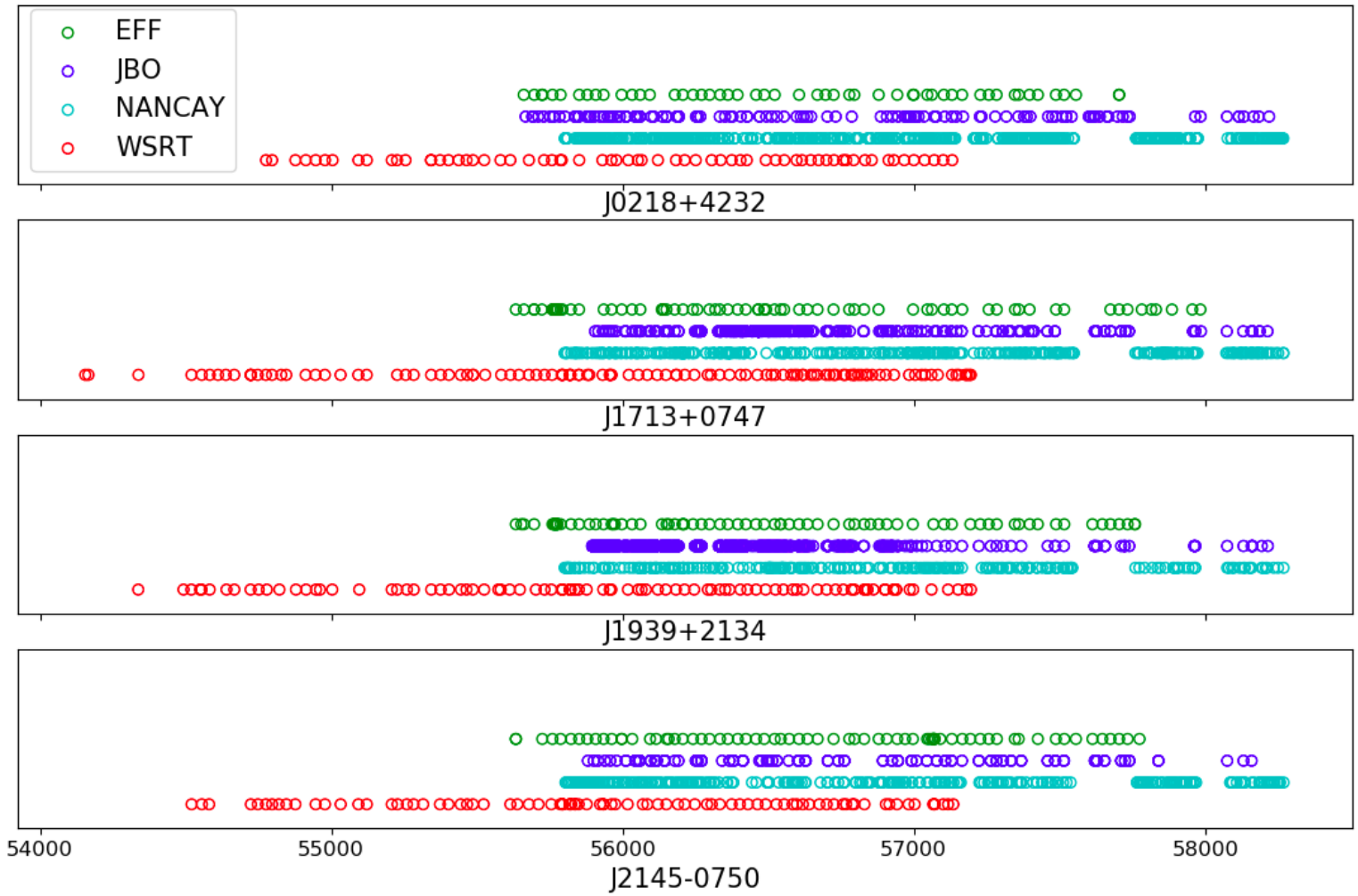

Optimal ToA Bandwidth Analysis

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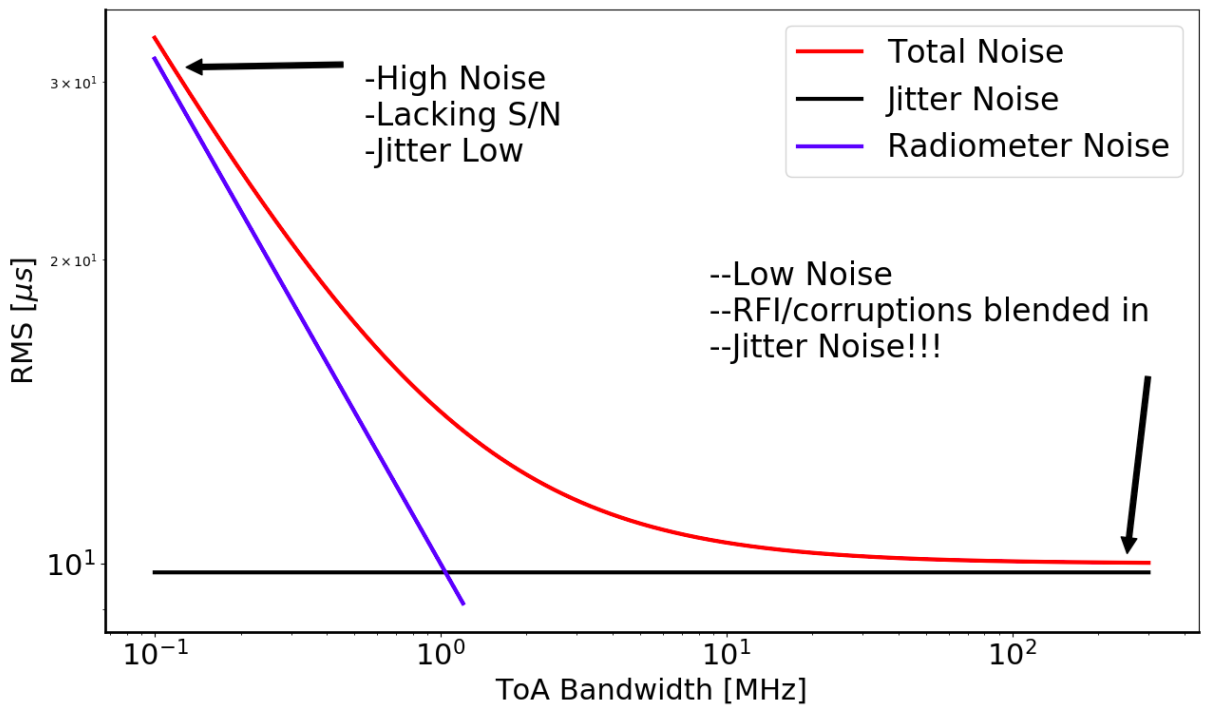
The total RMS uncertainty σ^2_{total} is consisted of two components:

$$\sigma^2_{total}(T_{int}, BW) = \sigma^2_{JN}(T_{int}) + \sigma^2_{RN}(T_{int}, BW) \qquad (2.1)$$



ToA optimising pipeline

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Why

For ToAs derived from Frequency-resolved data, Residuals are scattered because of low flux, S/N and so on.

How

1. GOF criterion(0.5-1.5)
2. Median standard deviation(With Caterina's code)
3. Fitting the residual with Gaussian distribution model and remove non-Gaussian ToAs.
4. S/N criterion

ToA optimising pipeline

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Take J1713+0747 from JBO as an example:

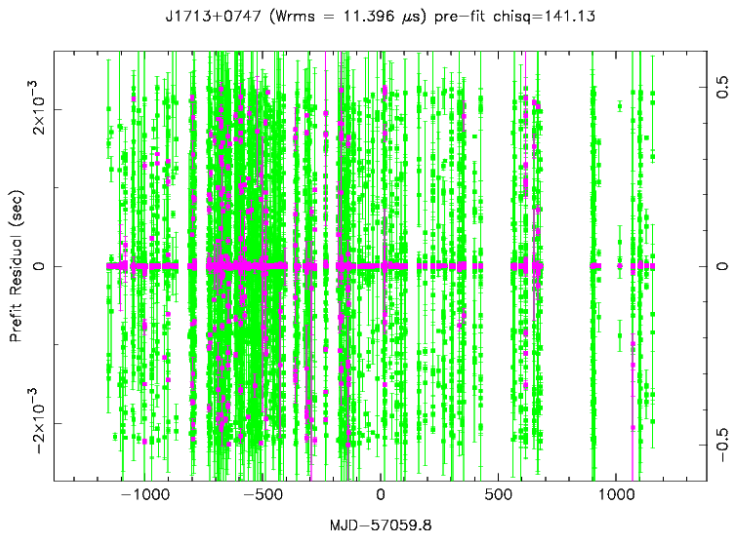

Figure 2.1: Before Outlier Rejection

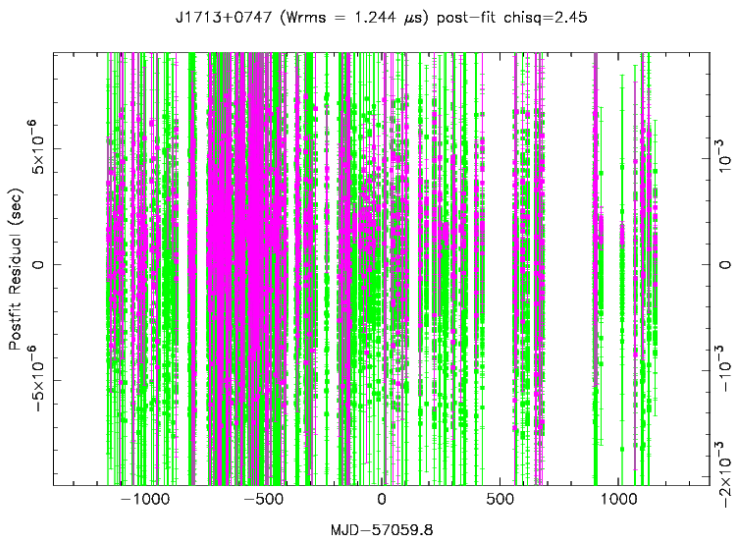

Figure 2.2: After Outlier Rejection

Jitter Noise of J1713+0747

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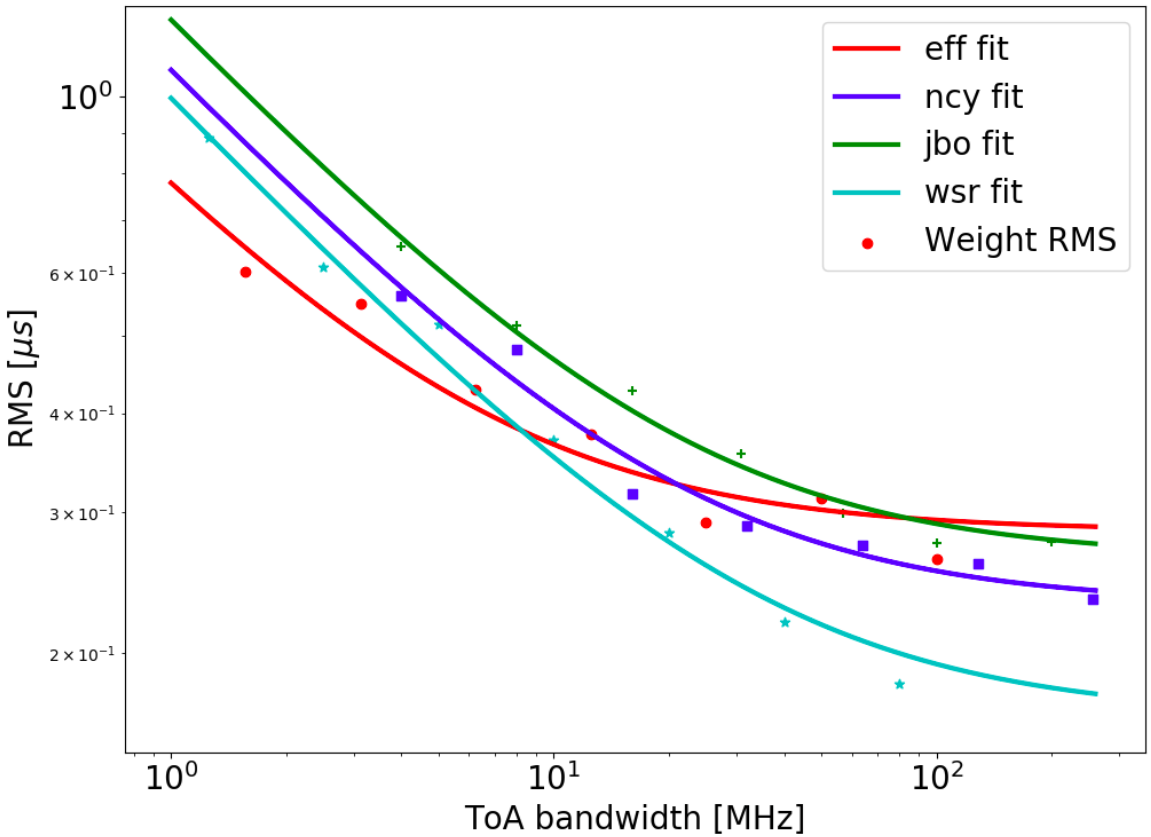

ON-GOING

Jitter Noise Level:

285 ns(eff), 230 ns(ncy), 263 ns(jbo), 166 ns(wsrt)

Jitter Noise of J0218+4232

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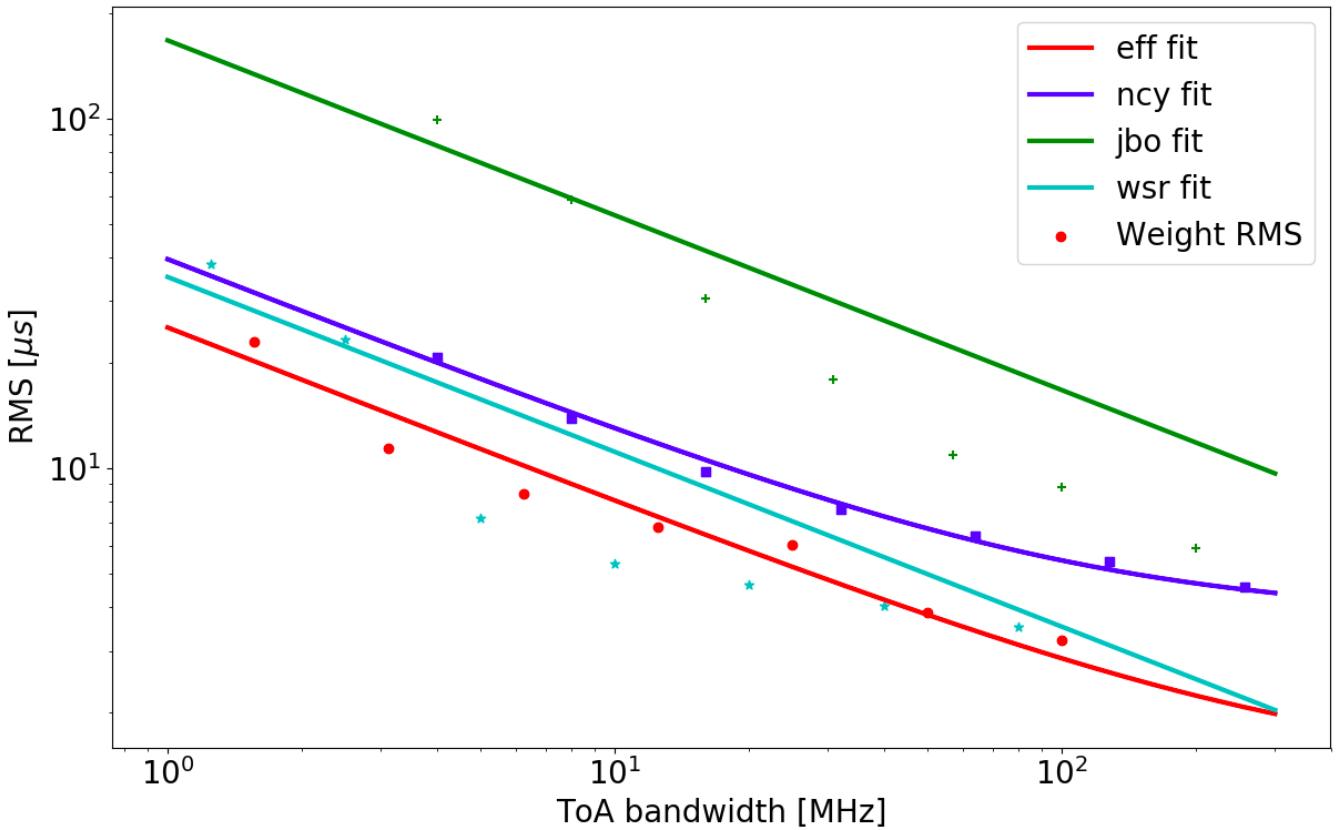

Jitter noise not detected

Jitter Noise of J2145-0750

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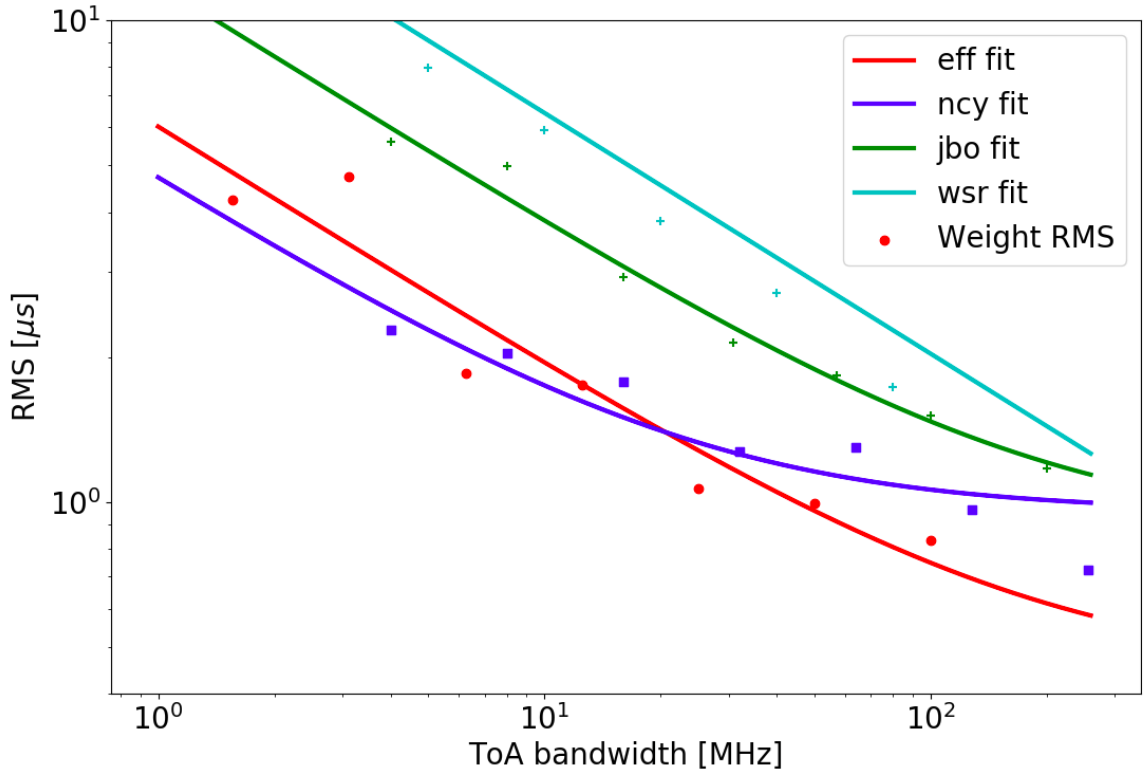

ON-GOING

Jitter Noise Level:

446 ns(eff), 950 ns(ncy), 870 ns(jbo), 0.067ns(wsrt)

Compare different template possibilities

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Frequency scrunched templates

- Data-derived
- Analytic noise-free
- Data-derived and smoothed

Frequency resolved templates

- Data-derived
- Data-derived and smoothed
- Gaussian and Basic-Spline model(Timothy Pennucci)

Compare ToA creation routines

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1. Fourier domain with Markov chain Monte Carlo(FDM)
   FDM makes use of a Monte-Carlo approach to determine the uncertainties.

2. Fourier Phase Gradient(PGS)(default in pat)
   PGS uses a linear fit to determine the uncertainties.

3. Gaussian Interpolation Shift(GIS)
   TOAs can be determined to within approximately 1/10 of the width of an individual phase bin.

Challenges & Future considerations

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Challenges

1. Residuals derived from different telescopes and pulsars vary significantly, which is harder to build a uniform fitting method
2. The length, Frequency and BW of observations are not uniform

Summary

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Optimising "simple" ToA creation algorithms: pulsar- and telescope-dependent

1. We have written a pipeline to deal with Residuals from Frequency-resolved templates.
2. Still to do: compare correlation algorithms, templates in detail.
3. We had compared different ToA creation algorithm, and plan to compare them in detail at the optimal ToA bandwidth.
4. More data are welcome!

Thank You!

Vielen Dank!

Jun Wang