Removing bias in ToA estimates

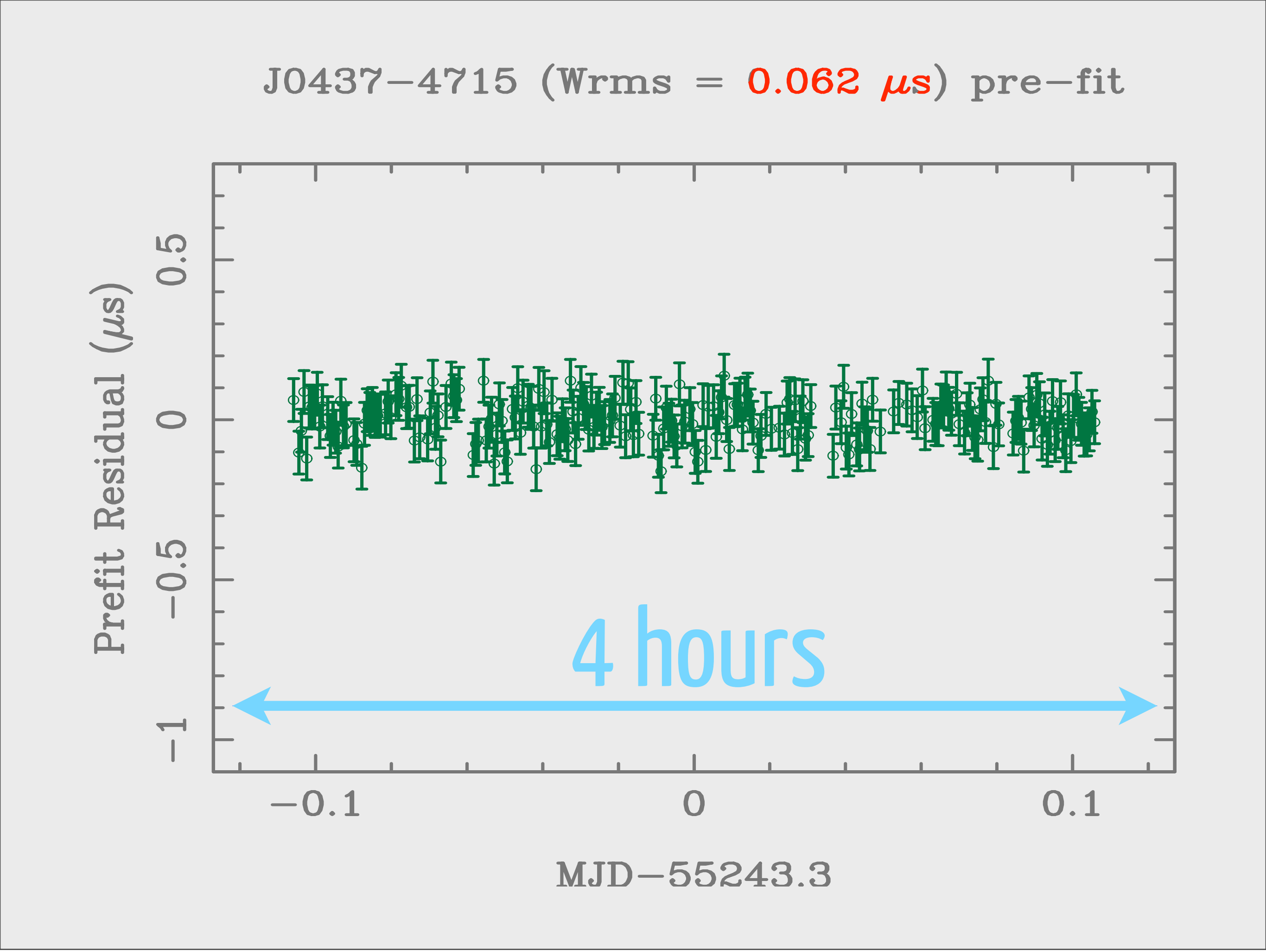
Stefan Osłowski, Willem van Straten,
Matthew Bailes
also: George Hobbs
and Paul Demorest
and others

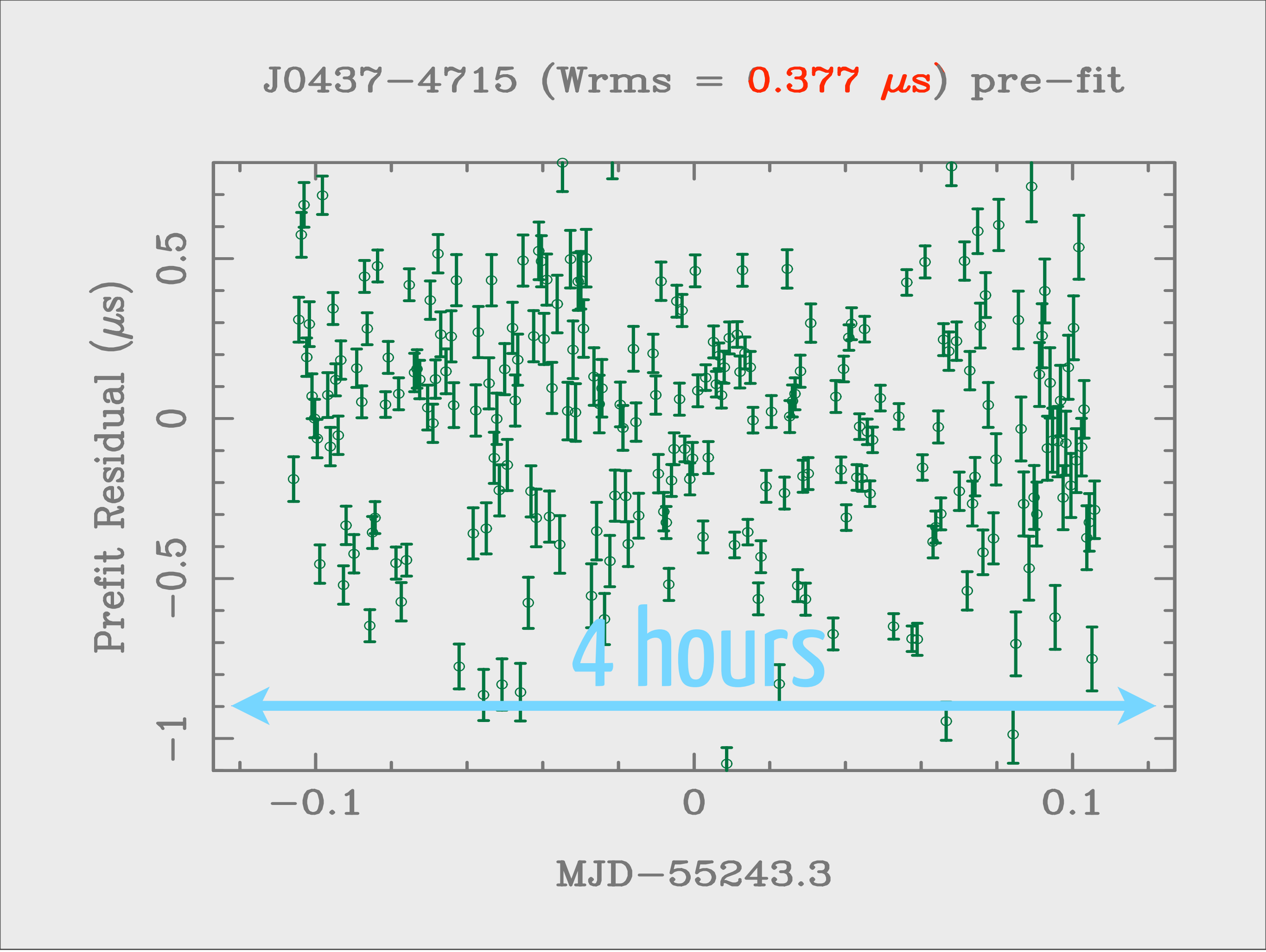
SWINBURNE UNIVERSITY OF TECHNOLOGY

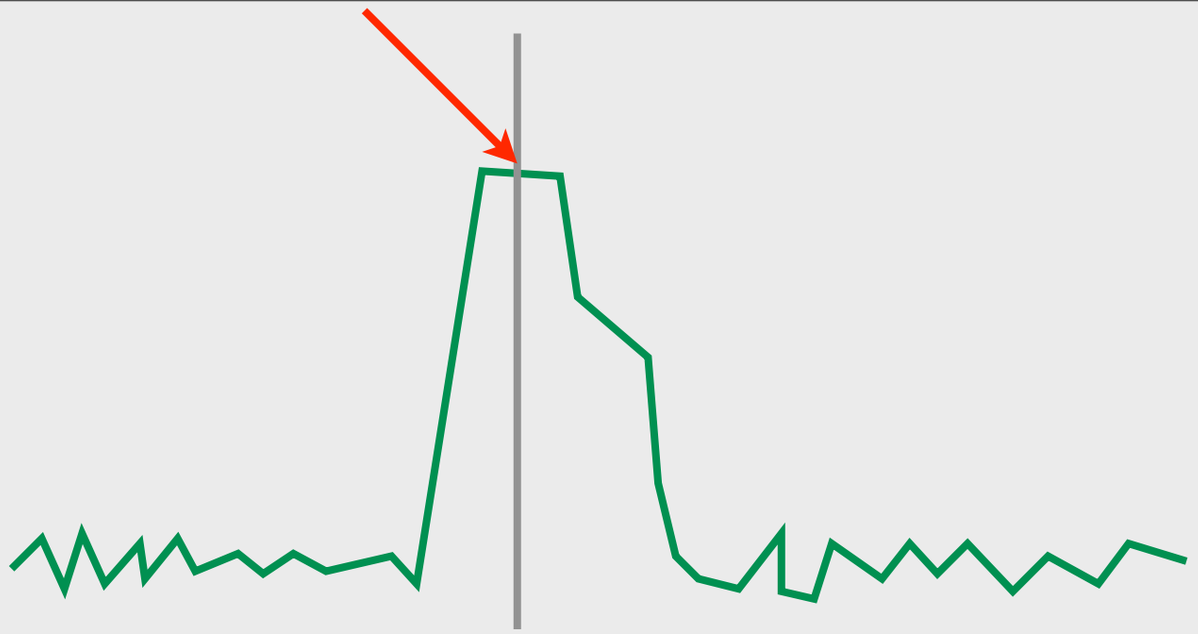
CSIRO

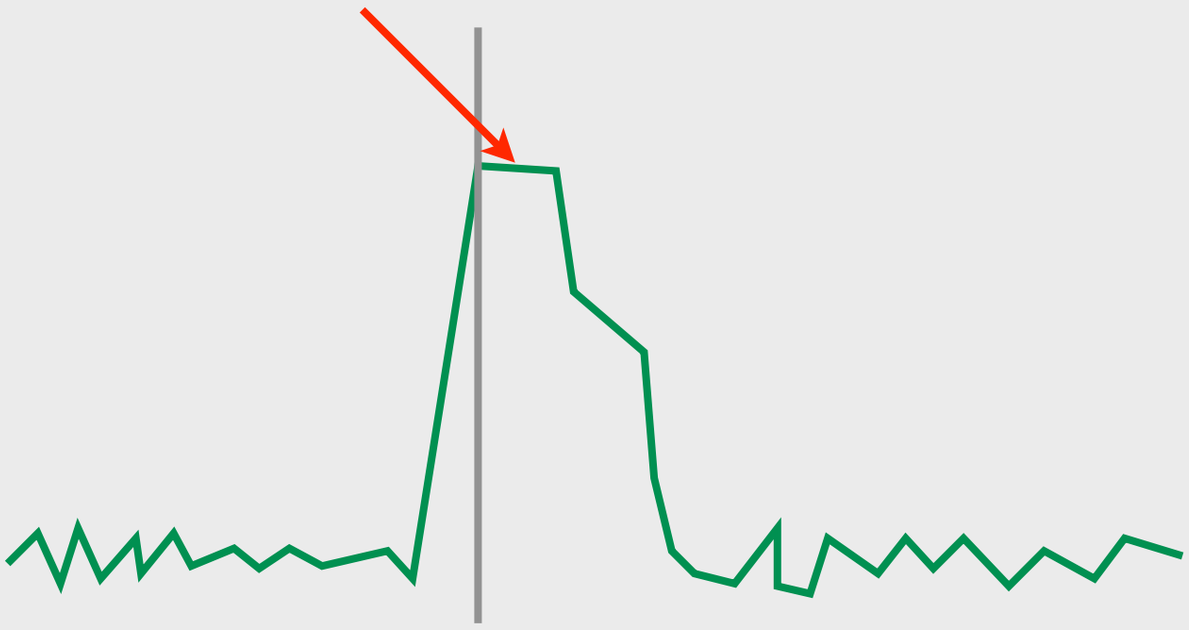
template matching

ToA error: $\frac{\text{width}}{S/N}$

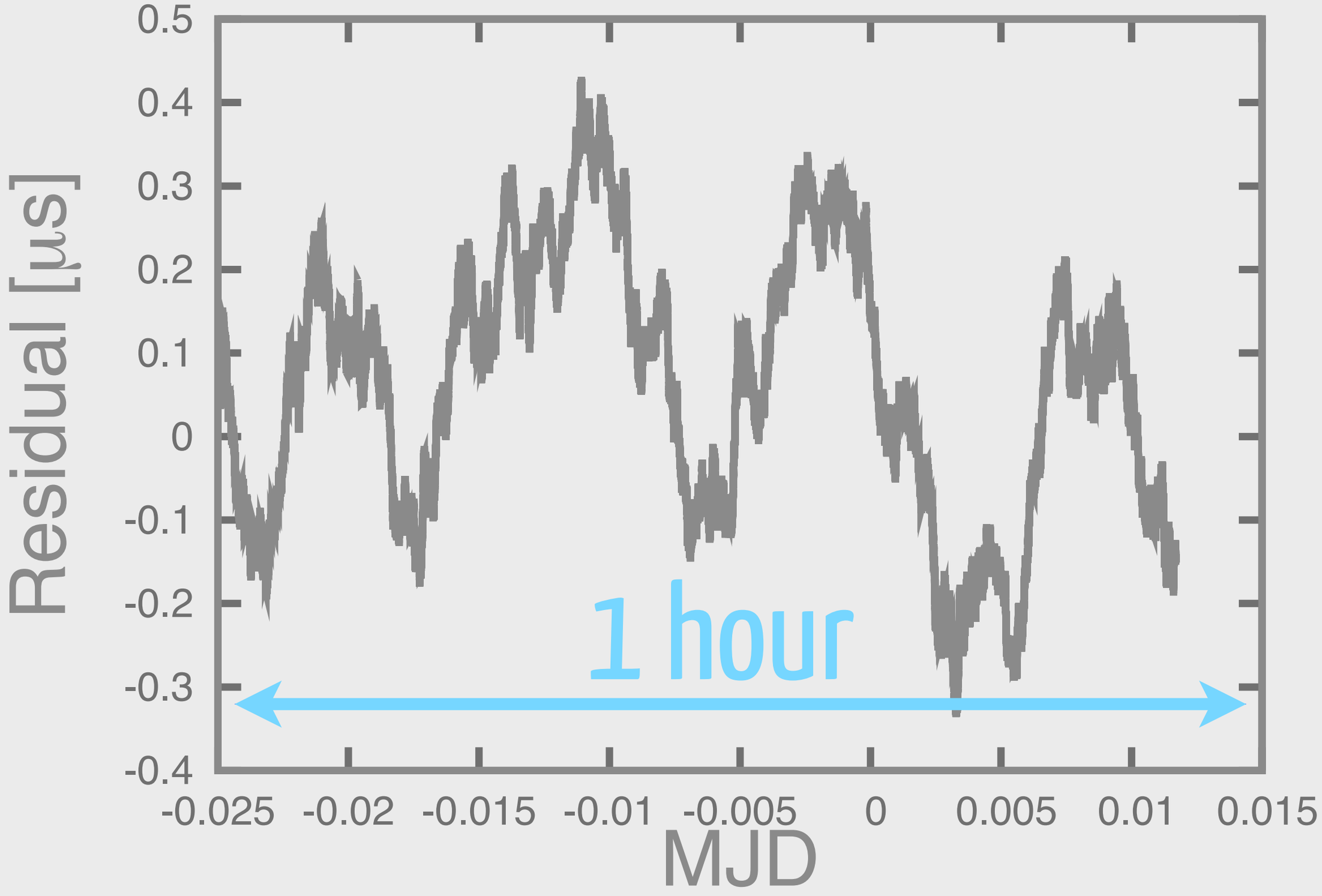

J0437−4715 (Wrms = 0.062 μs) pre−fit
Prefit Residual (μs)
0.5
0
−0.5
−1
−0.1
0
0.1
MJD−55243.3
4 hours

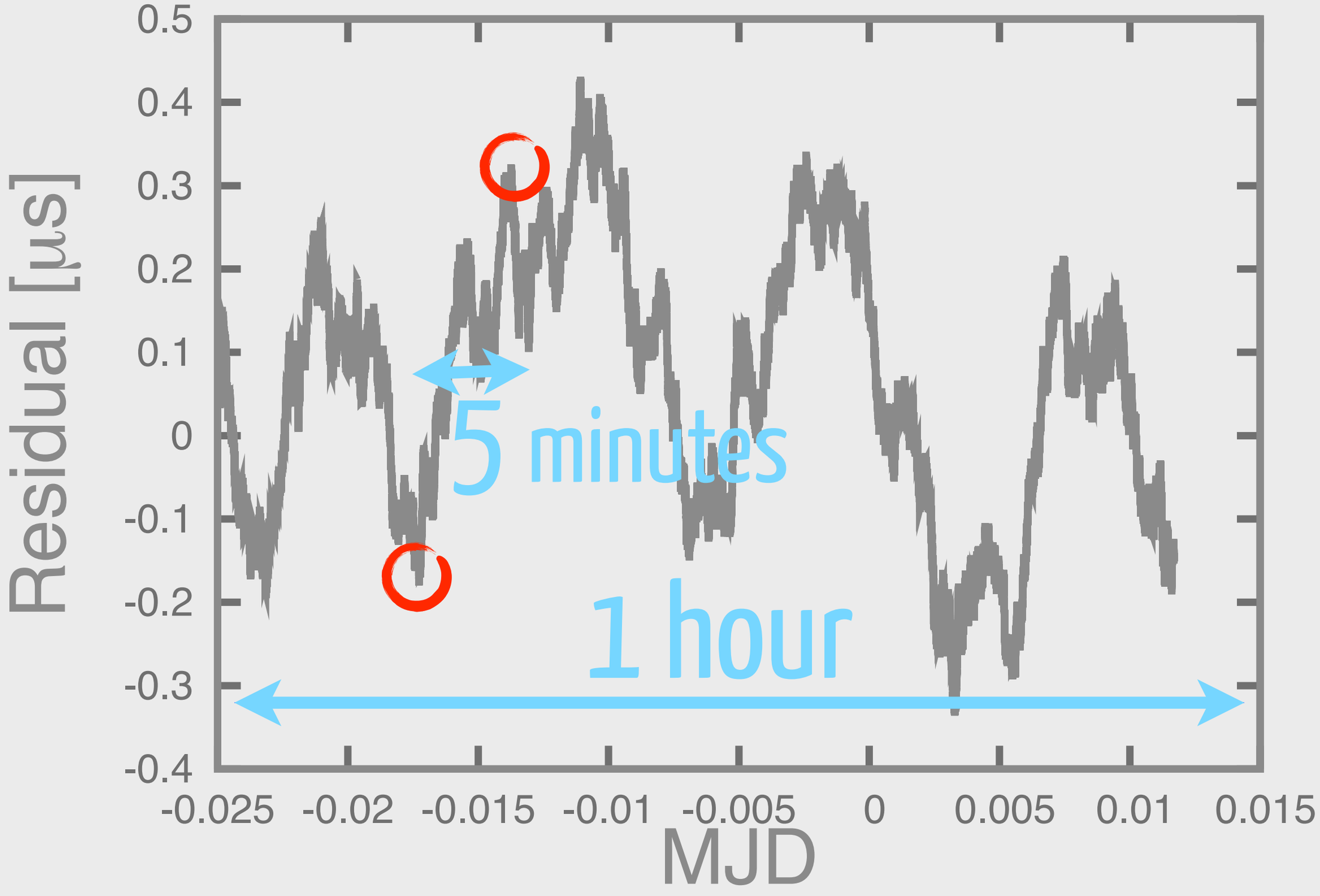

J0437−4715 (Wrms = 0.377 μs) pre−fit
Prefit Residual (μs)
0.5
0
−0.5
−1
4 hours
−0.1
0
0.1
MJD−55243.3





$$P = aT(\phi_0) + b + n(\phi)$$


Residual [μs]
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.025
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
MJD
1 hour


0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Residual [μs]
5 minutes
1 hour
-0.025
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
MJD

0.0 ≤ S/N < ∞ 338ns 39.0

0.0 ≤ S/N < ∞ 338ns 39.0

0.0 < S/N < 4 314ns 34.7

0.0 ≤ S/N < ∞ 338ns 39.0

0.0 < S/N < 4 314ns 34.7

0.0 < S/N < 2 331ns 31.1

0.0 ≤ S/N < ∞ 338ns 39.0

0.0 < S/N < 4 314ns 34.7

0.0 < S/N < 2 331ns 31.1

0.0 < S/N < 1 449ns 14.3

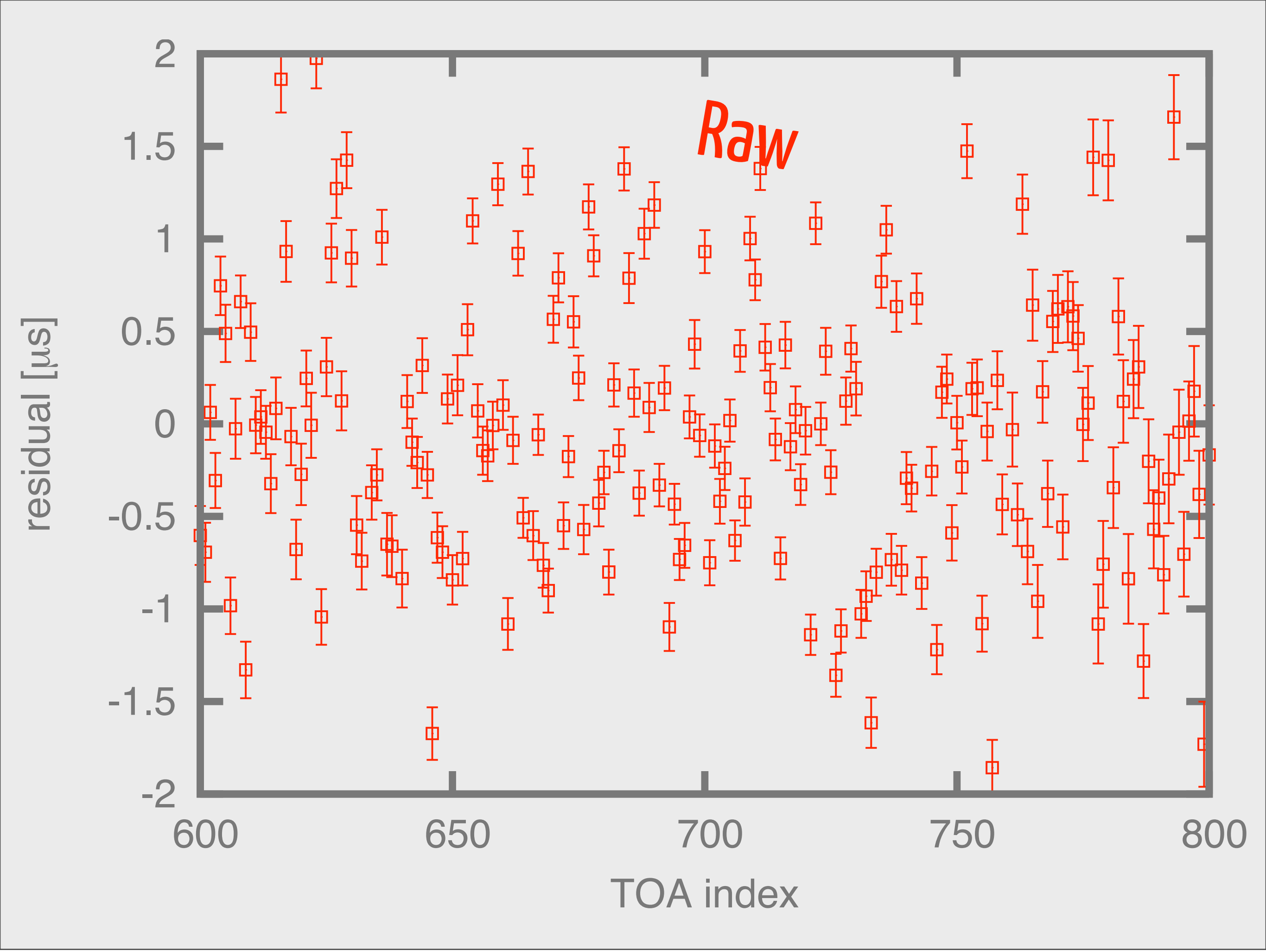
$0.0 \leq S/N < \infty$ 338ns 39.0

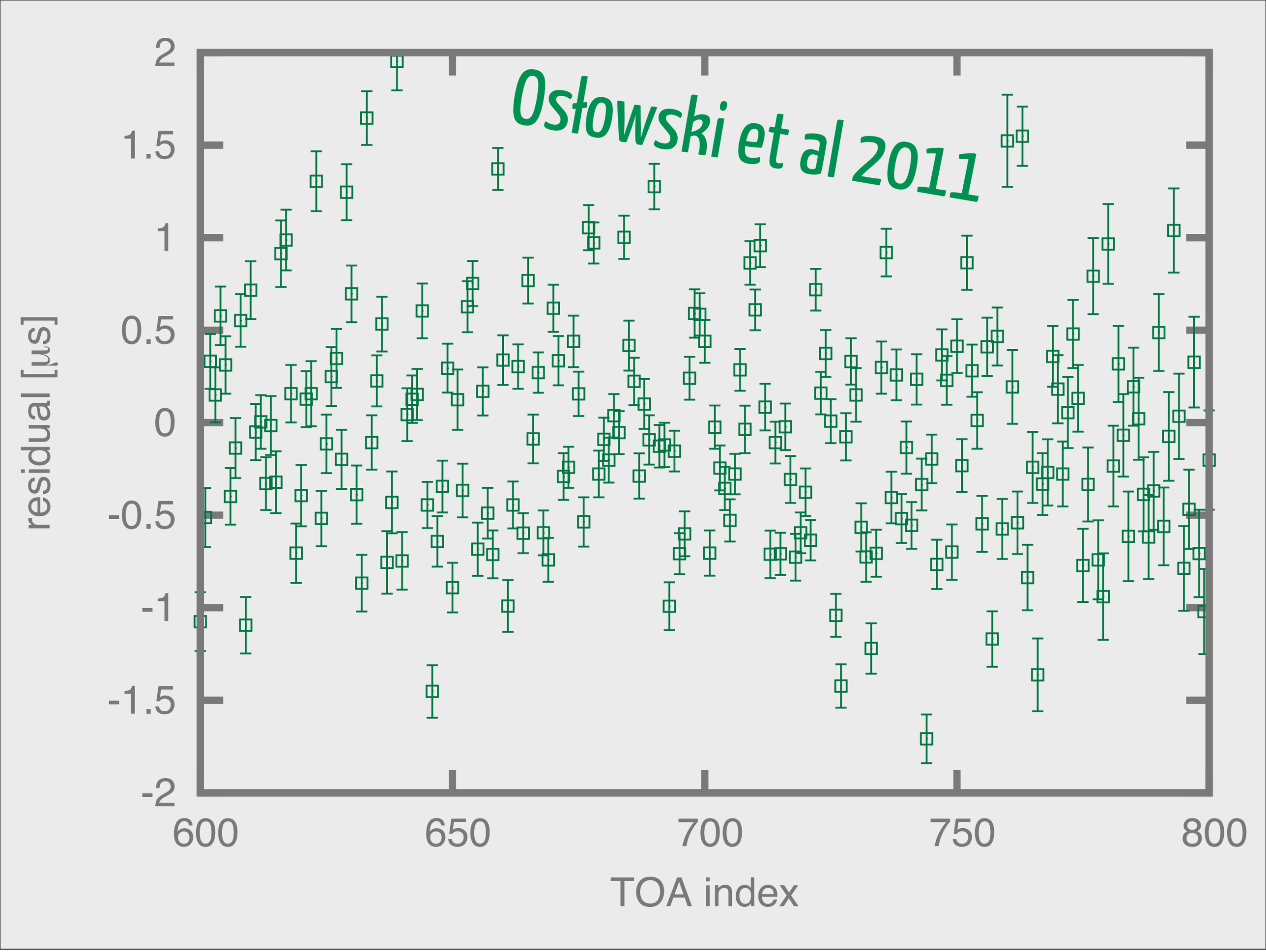
$0.0 < S/N < 4$ 314ns 34.7

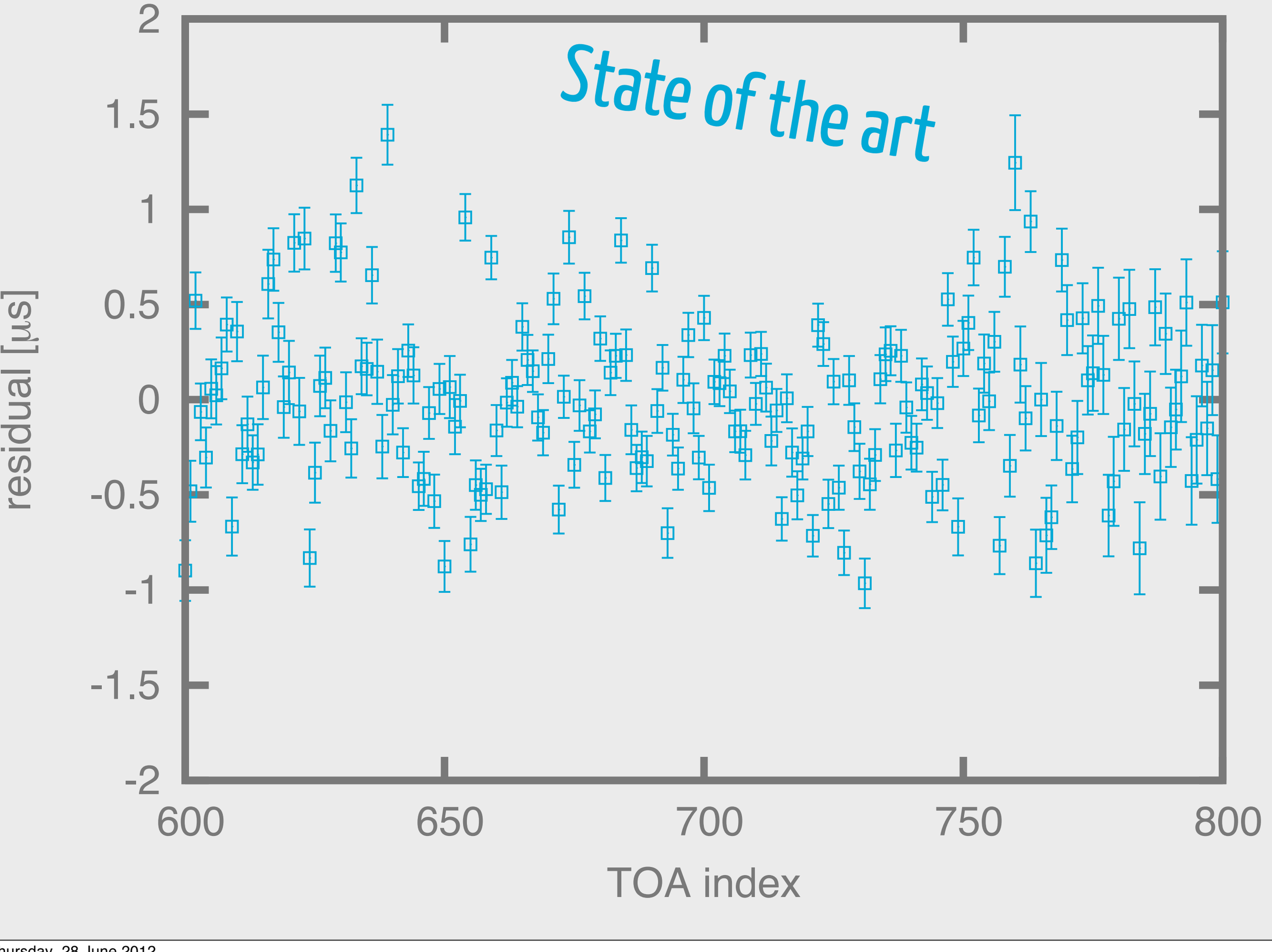
$0.0 < S/N < 2$ 331ns 31.1

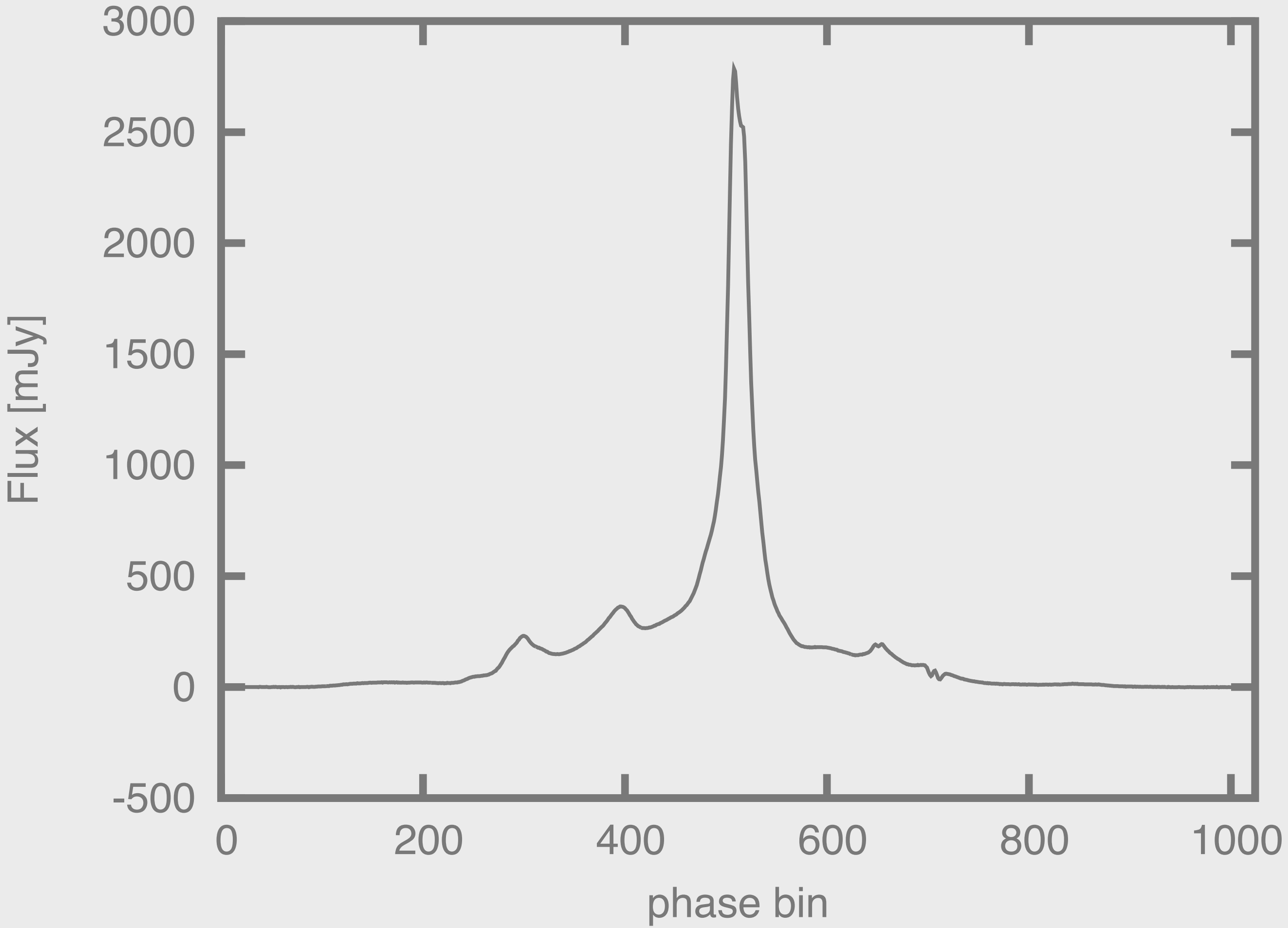
$0.0 < S/N < 1$ 449ns 14.3

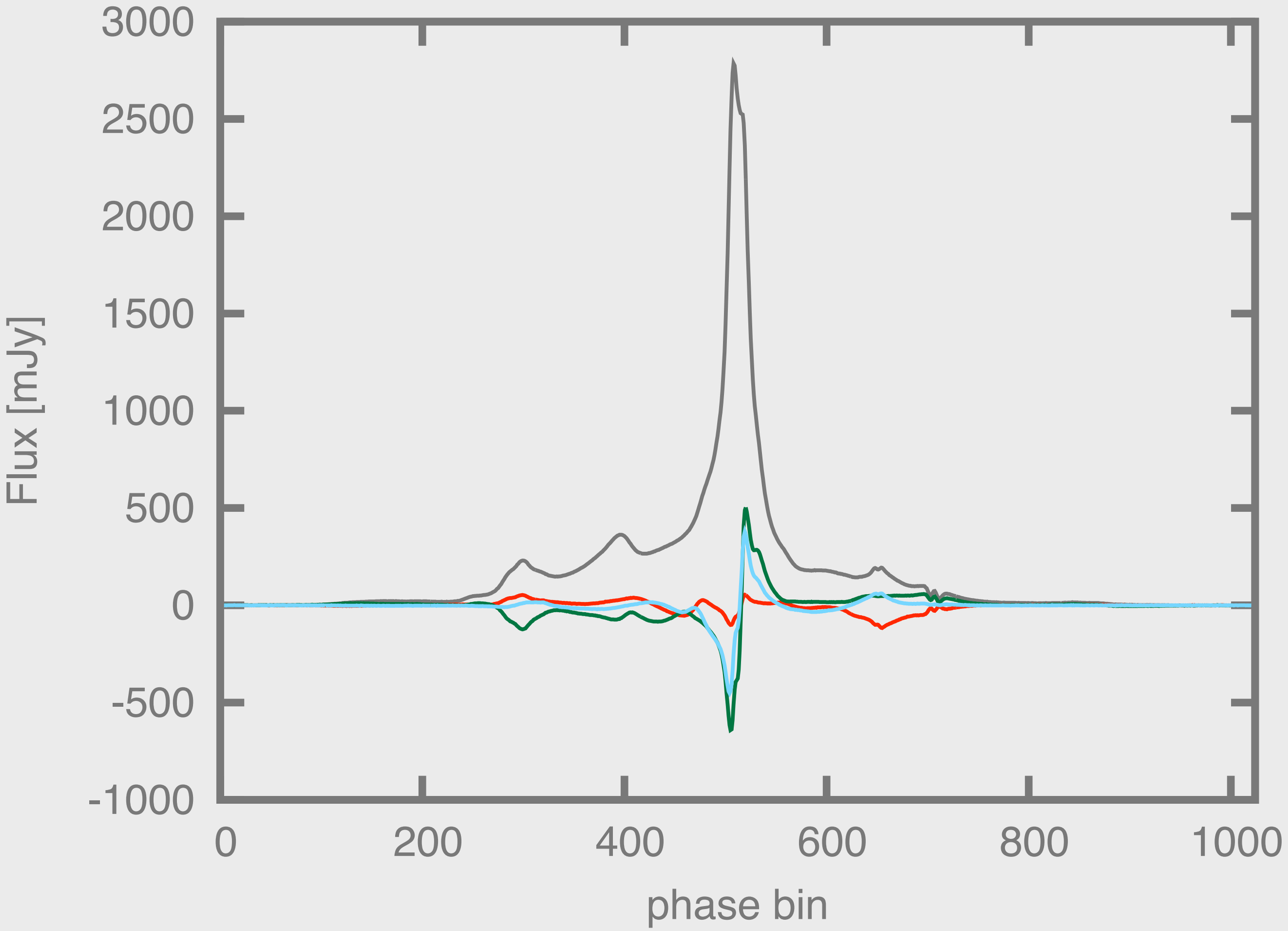
$1.0 \geq S/N \geq \infty$ 340ns 44.9

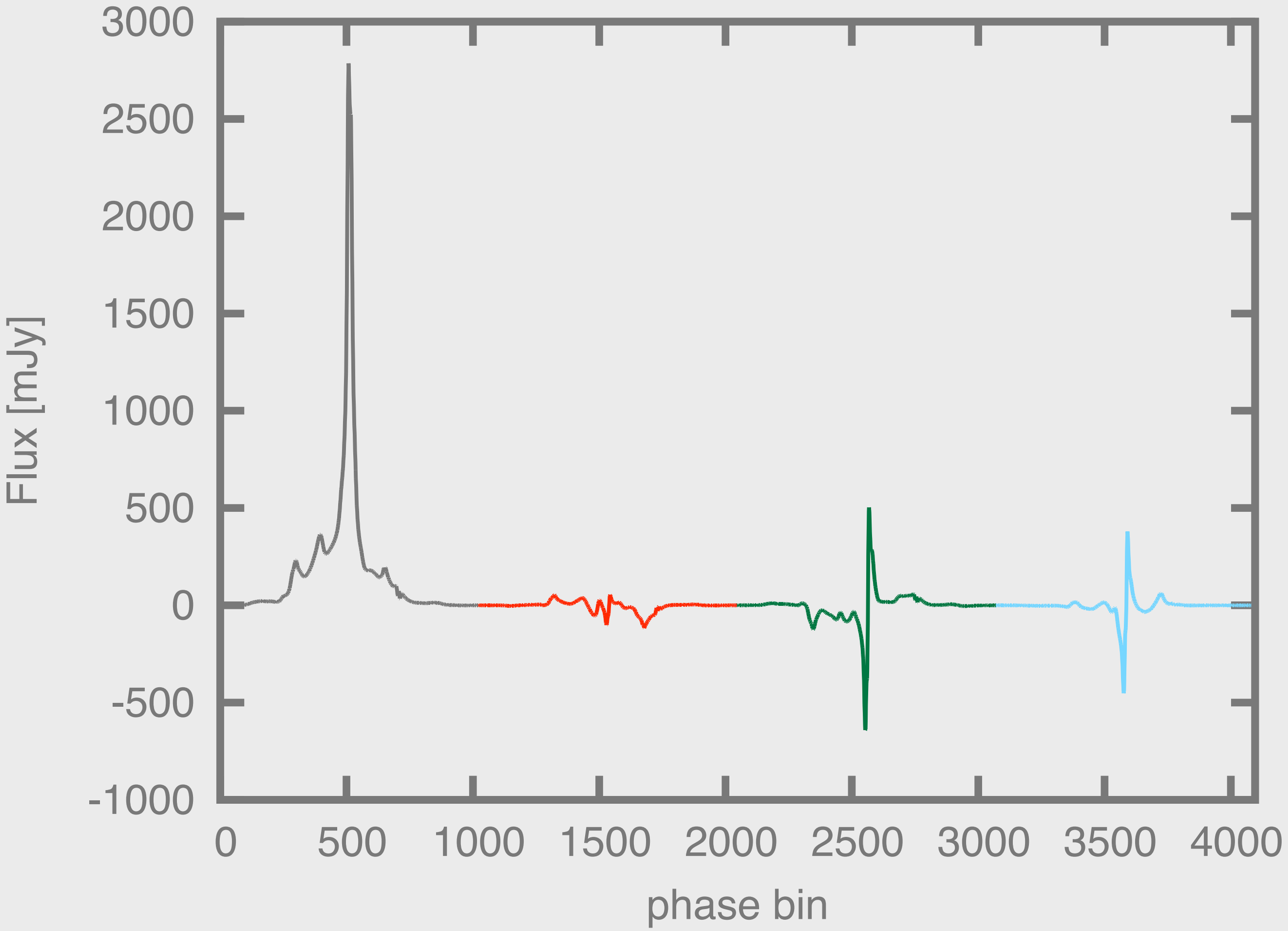

Raw
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
residual [μs]
600
650
700
750
800
TOA index


Osłowski et al 2011
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
residual [μs]
600
650
700
750
800
TOA index


State of the art
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
residual [µs]
600
650
700
750
800
TOA index


3000
2500
2000
1500
1000
500
0
-500
Flux [mJy]
0
200
400
600
800
1000
phase bin


3000
2500
2000
1500
1000
500
0
-500
-1000
Flux [mJy]
0
200
400
600
800
1000
phase bin


3000
2500
2000
1500
1000
500
0
-500
-1000
Flux [mJy]
0
500
1000
1500
2000
2500
3000
3500
4000
phase bin

Conclusions

- SWIMS is likely present in many MSPs
- Implications for observing strategy
- Can we fix it? Pulsar dependent!
- Need a lot of profiles

$$\chi^2 = \sum_{m=1}^{N/2} \sum_{k=0}^{3} |S'(\nu_m) - tr[\boldsymbol{\sigma}_k \boldsymbol{\rho}'(\nu_m)]|^2 \zeta_k^{-2}$$

$$\chi^2 = \sum_{m=1}^{N/2} \sum_{k=0}^{3} |S'(\nu_m) - tr[\boldsymbol{\sigma}_k \boldsymbol{\rho}'(\nu_m)]|^2 \zeta_k^{-2}$$

$$\chi^2 = \sum_{m=1}^{N/2} \sum_{n=1}^{N/2} \| \Delta(\nu_m) C_{mn}^{-1} \Delta(\nu_n) \|$$

$$\Delta(\nu_m) = S'_k(\nu_m) - tr[\sigma_k \rho'(\nu_m)]$$