FLEXIBLE TIMING CROSS-CALIBRATION WITH THE CRAB PULSAR

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IACHEC Meeting

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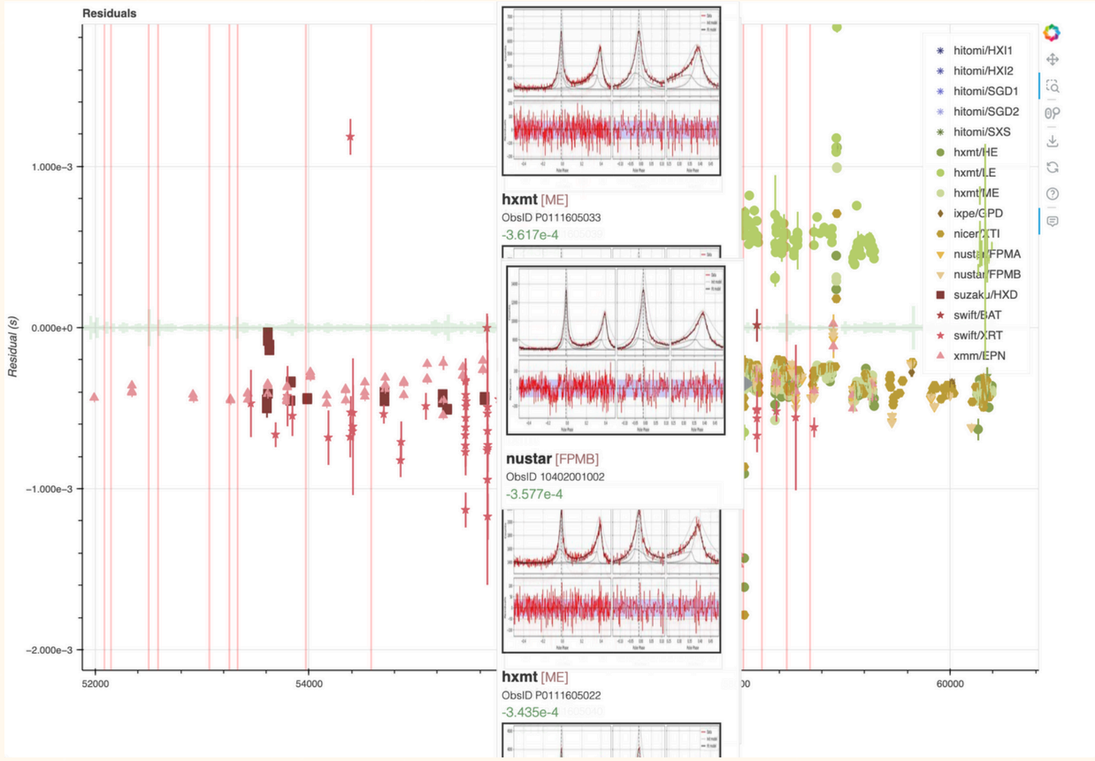
AIMS

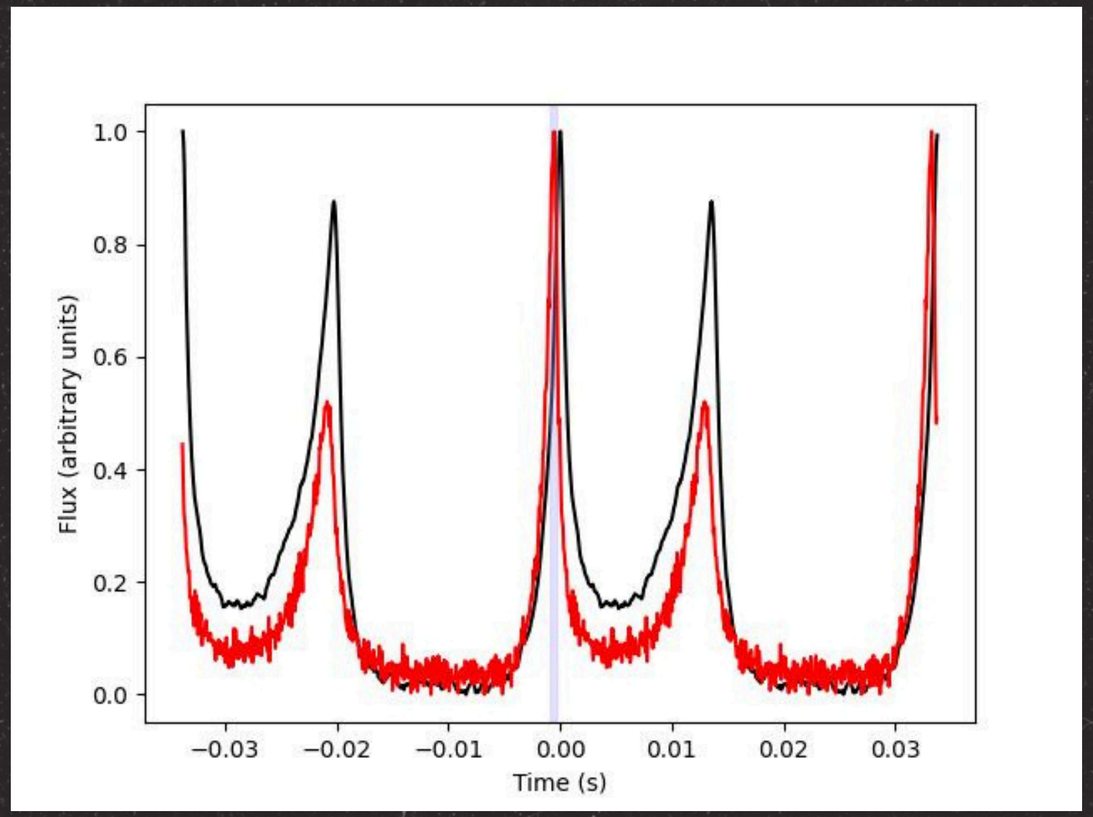
Creating an automatic web-based browsable interface that tracks the timing calibration of all missions using the Crab (+ other pulsars)
Using a single code, one can avoid the subtle differences that can be introduced by independent processing

WHY the Crab?
Bright, constantly monitored. Used for the calibration of most missions already!



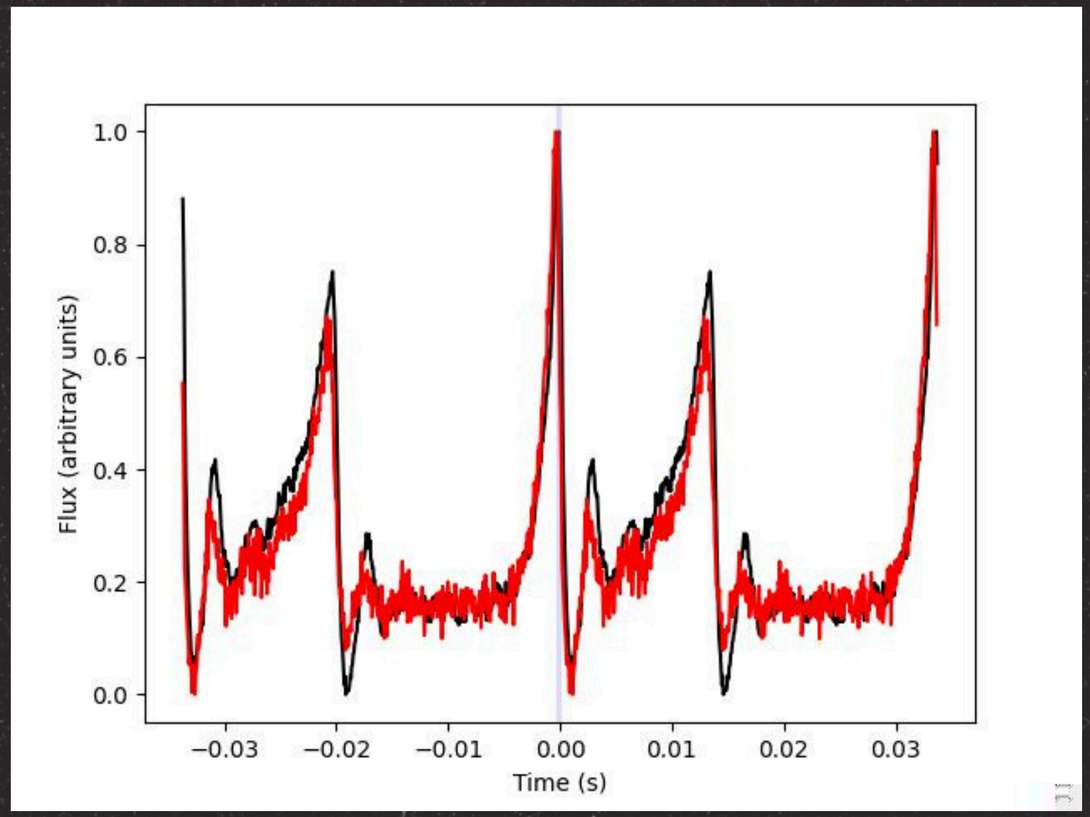
TOA CALCULATION

Usual method: a delay between the folded profile and a template



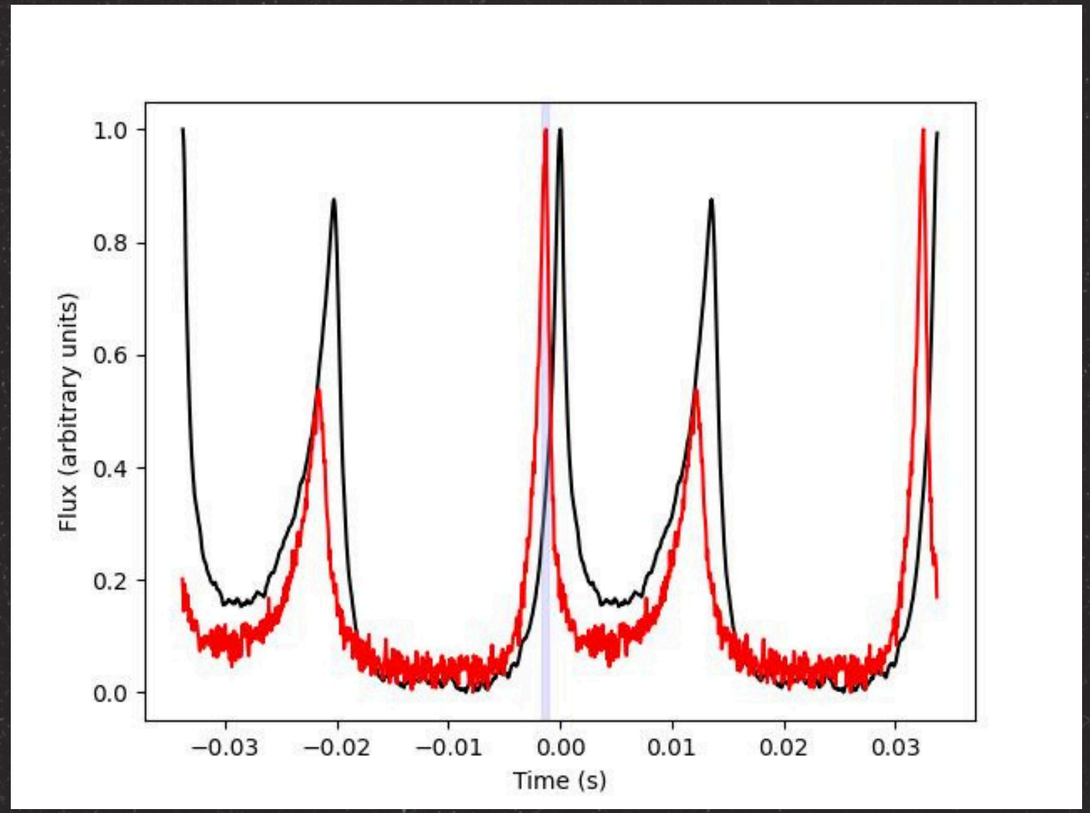
PROFILES CAN CHANGE!

Profile changes, e.g. for **energy-dependence** or **dead time**, need to be taken into account



CONSISTENCY IS KEY

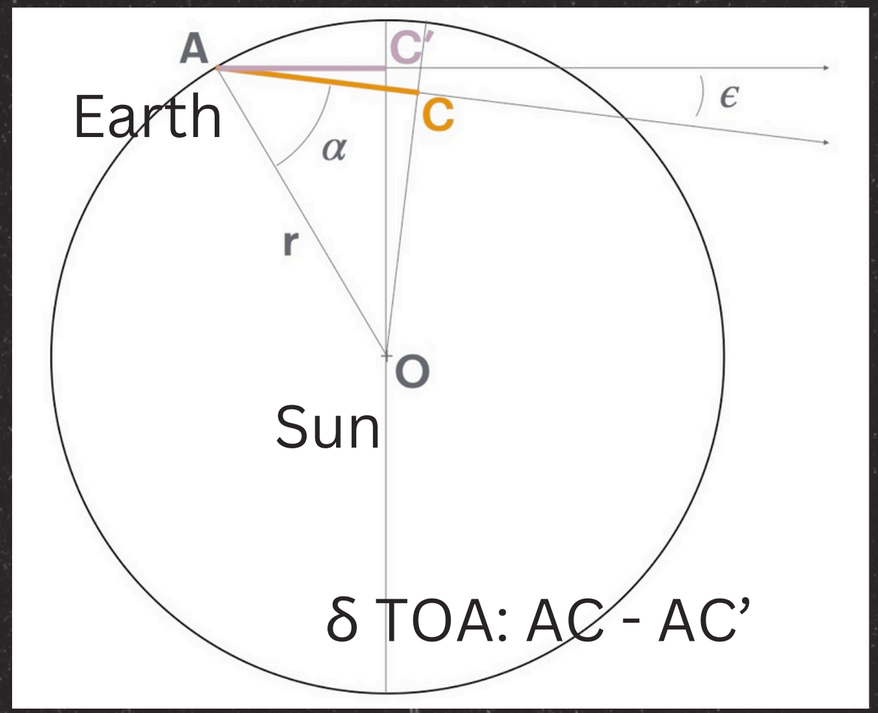
Small errors of **source position**, different **ephemerides**, can create significant errors in delay measurements (~msecs)

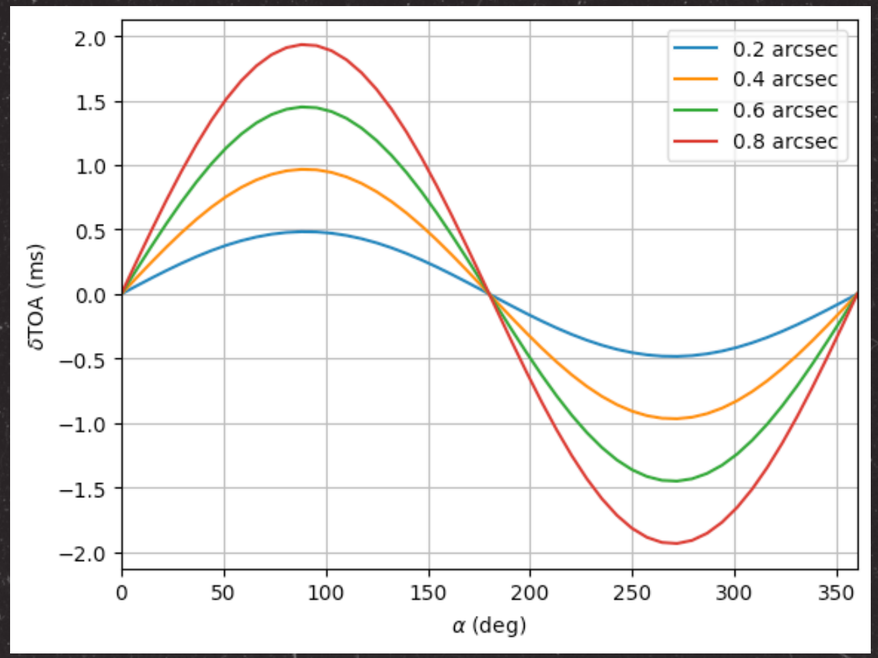


EPHEMERIS ISSUES

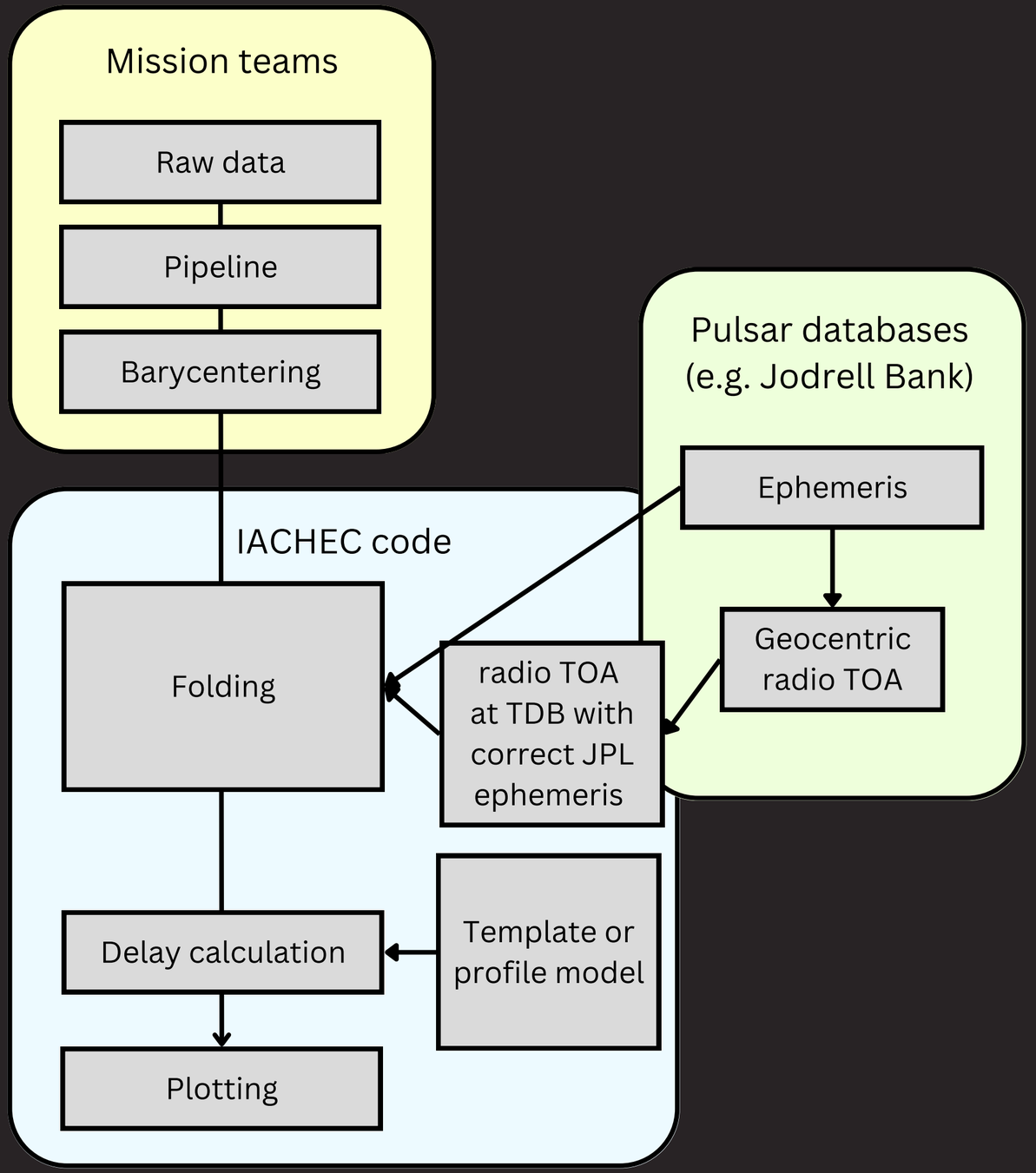
Using different JPL ephemerides and/or source positions can lead to TOA shifts by milliseconds.

Usual requirement: use the same JPL ephemeris and the same exact source position for everything, ignore proper motion. BAD and unfeasible.





TOA Extractor



HOW THE CODE WORKS

Mission teams provide **barycentered** data, with the agreed ephemeris and source position. Pulsar databases provide the spin (and orbit when relevant) **parameters** and **TOAs.**

Data format

Barycentered Event lists in FITS formats:

Extensions:

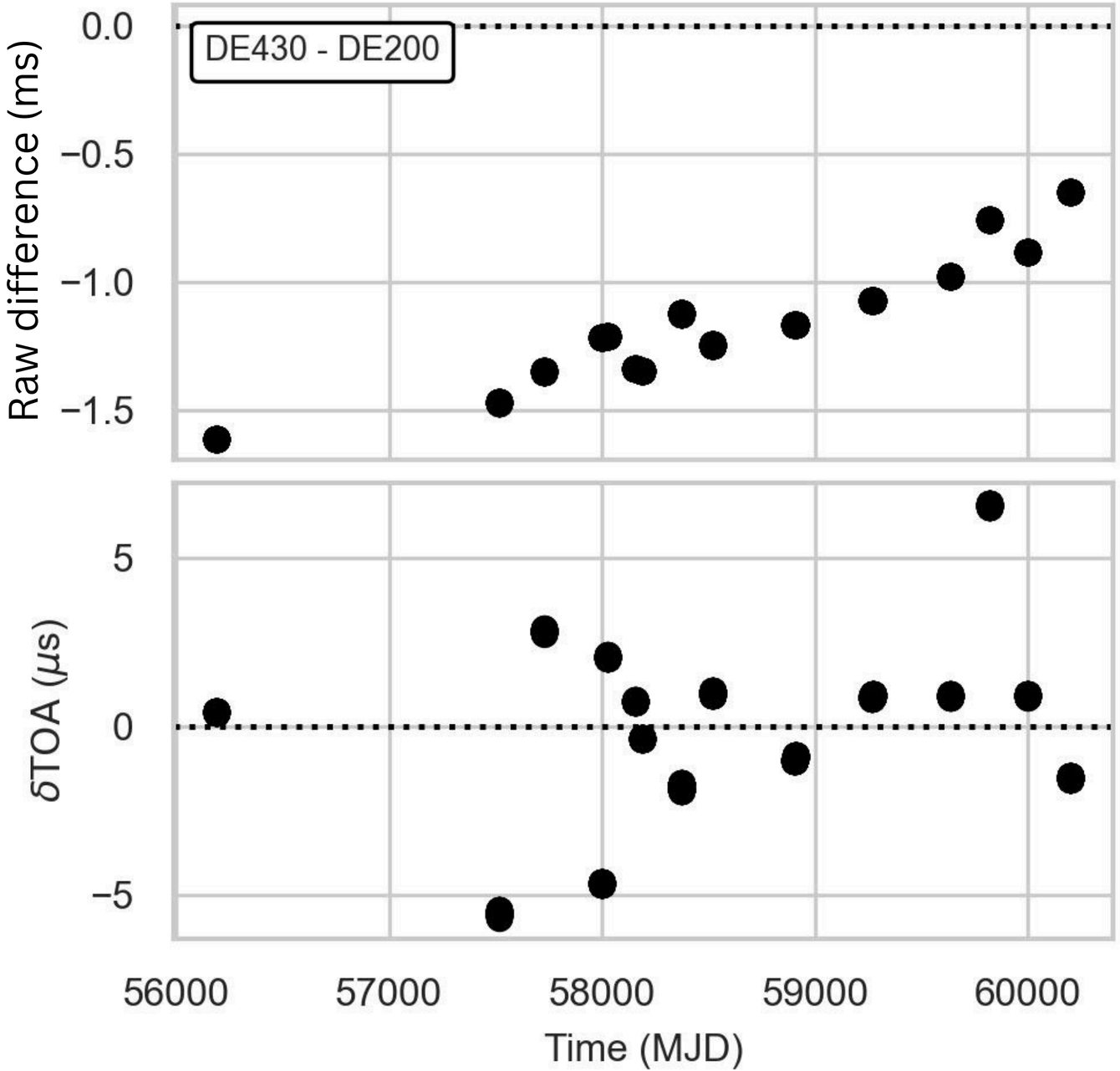
1. EVENTS (extension 1)
    - TIME column
    - (optional: ENERGY)
    - Keywords:
        - MJDREF, TIMEZERO
        - TIMESYS, TIMEREF, PLEPHEM
        - **RA_OBJ, DEC_OBJ pointing to barycentering coords**
2. (Optional): GTI

Ephemeris correction

First step: **Convert Jodrell Bank ephemeris to the same JPL ephemeris as the data**

How?

- Generate fake Geocentric TOAs using JB ephemeris and DE200
- **Fit** the timing solution using another JPL ephemeris, and **get correct timing solution for X-ray observation**
- Test: compared TOAs b.w. data barycentered with DE200 and DE430. Errors ~4us



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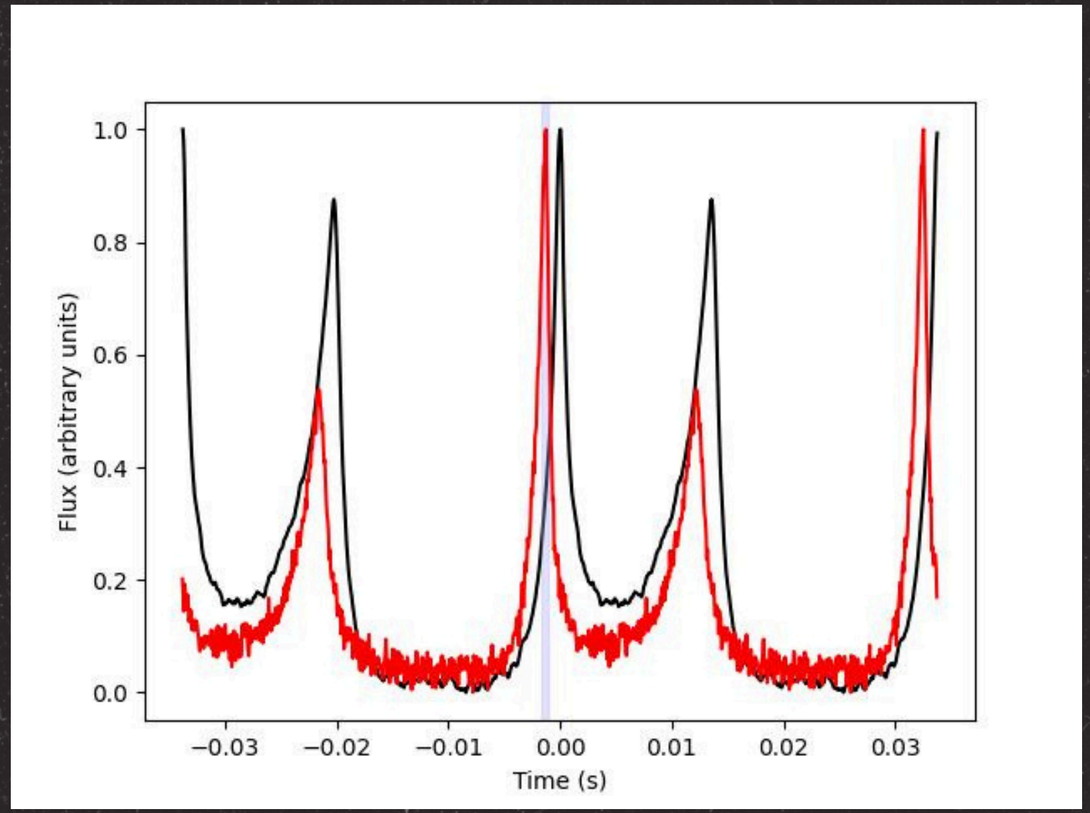
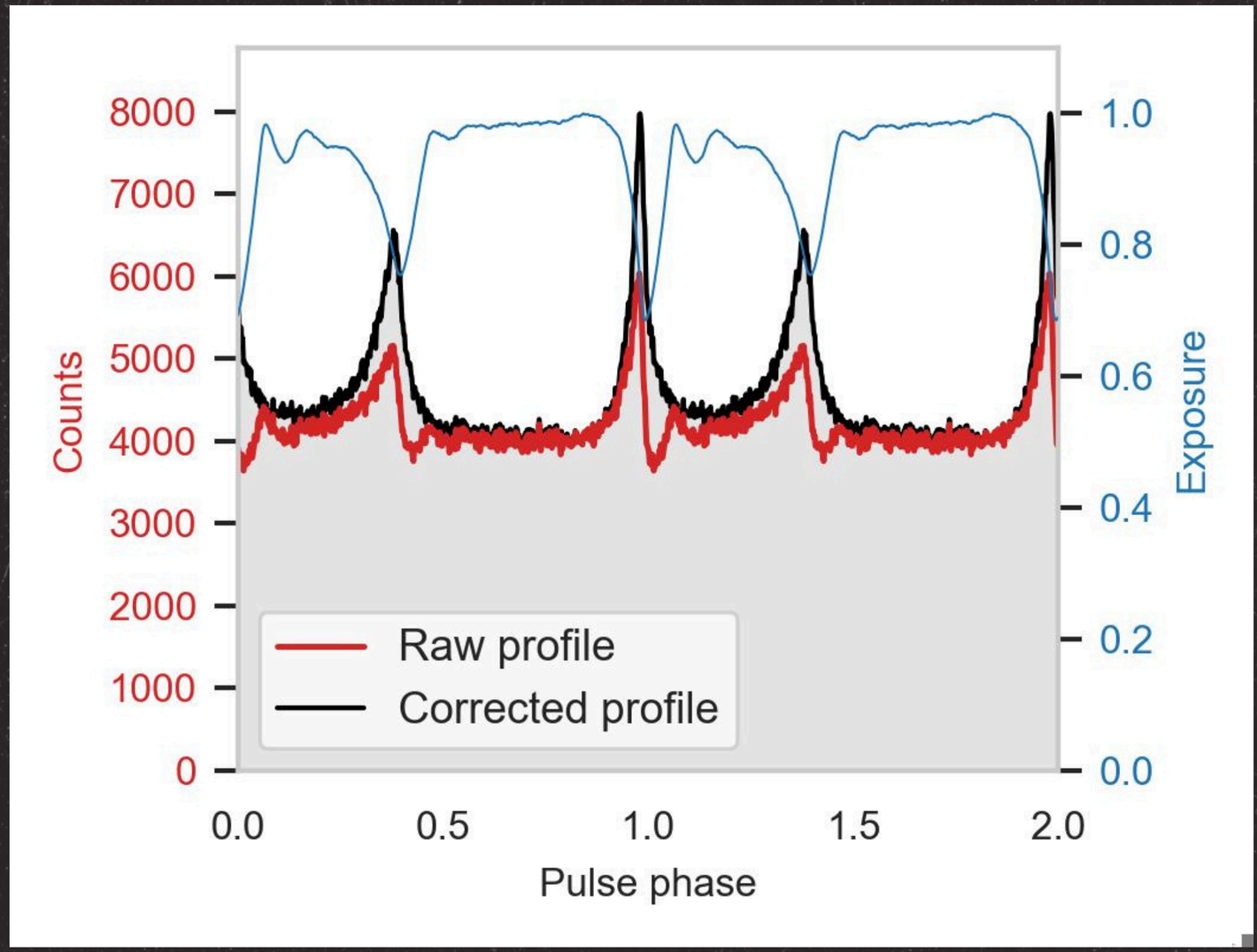
TOA CALCULATION?

Basic: the usual cross-correlation/FFTFIT method. *Having a correct template*, it's the most robust. However: rigid assumptions



INTERLUDE: DEADTIME CORRECTION

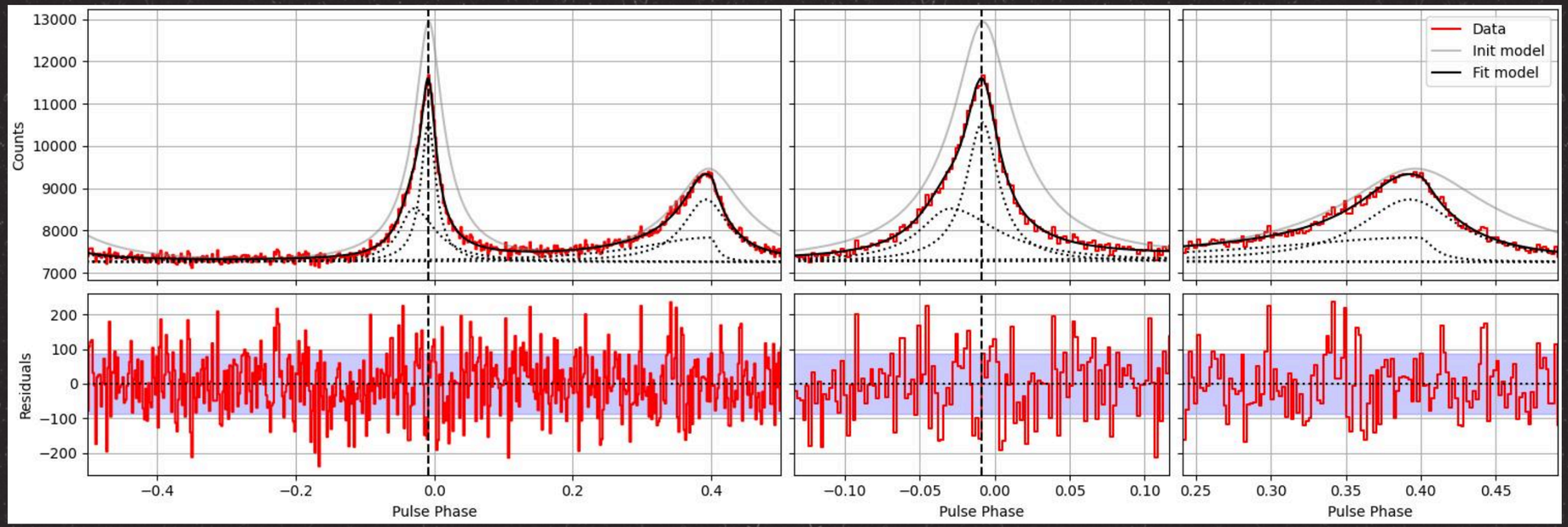
Use deadtime correction based on PRIOR column (see pulse_deadtime_fix on Github)

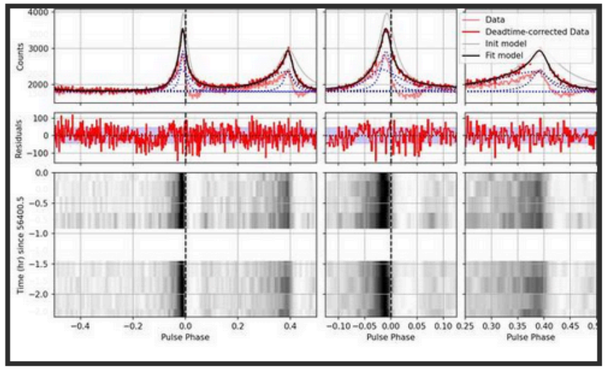


TOA CALCULATION

Two peaks, each as combination of symmetric Lorentzian + asymmetric Lorentzian

Gives numbers for each peak, uniquely identifies peaks, more flexible, only less rigorous in ideal case.



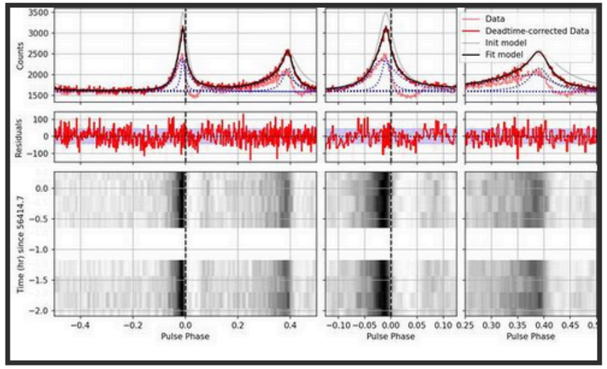


nustar [FPMB]

ObsID 10013037008

nu10013037008B_src1_de430.evt

-329±11 us



nustar [FPMB]

ObsID 10013039002

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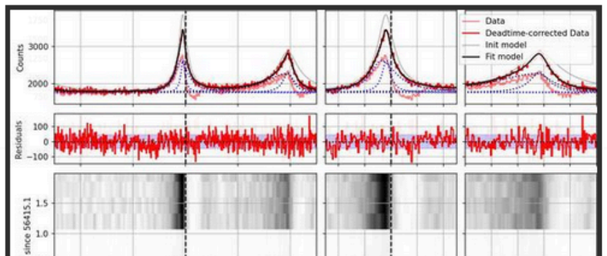
-325±14 us



2000

58000

60000

MJD

- axaf/HRC-DE405
- glast/LAT-DE405
- hitomi/HXI1-DE200
- hitomi/HXI2-DE200
- hitomi/SGD1-DE200
- hitomi/SGD2-DE200
- hitomi/SXS-DE200
- ixpe/GPD-DE200
- ixpe/GPD-DE430
- nicer/XTI-DE430
- ninjasat/GMC-DE200
- nustar/FPMA-DE200
- nustar/FPMA-DE430
- nustar/FPMB-DE200
- nustar/FPMB-DE430
- suzaku/HXD-DE200
- swift/BAT-DE200
- swift/XRT-DE430
- xmm/EPN-DE200

Type People Modified

Name	Owner	Last m...	File size
raw_data	me	May 12, 2022	—
IXPE	me	Apr 30, 2022	—
XRT	me	Nov 9, 2021	—
HXMT	me	Oct 20, 2021	—
NICER	cphu0821@g...	May 13, 2021	—
BAT	me	May 3, 2021	—
Suzaku	yukikatsu.ter...	Apr 27, 2021	—
Hitomi	me	Apr 26, 2021	—
XMM	srosen@scio...	Apr 20, 2021	—
NuSTAR	me	Sep 15, 2020	—
README	me	3:51 PM	2 KB
Get Residuals.ipynb	me	3:15 PM	250 KB

TOAextractor

Public

Pin Unwatch 1 Fork 1 Star 2

main 2 Branches 14 Tags Go to file t Add file Code

matteobachetti Merge pull request #22 from matteobachetti/fix_very_long... 54911a4 · 1 minute ago 181 Commits

.github/workflows	Make windows test experimental	11 months ago
docs	First draft	4 years ago
licenses	First draft	4 years ago
toa_extractor	Fix syntax	20 minutes ago
.gitignore	First draft	4 years ago
.readthedocs.yml	First draft	4 years ago
MANIFEST.in	First draft	4 years ago
README.rst	First draft	4 years ago
pyproject.toml	First draft	4 years ago
setup.cfg	Update dependencies; fix issue with recent Bokeh	10 months ago
setup.py	First draft	4 years ago

About

A pipeline to extract TOAs from X-ray observations of the Crab pulsar and others. Mostly for cross-calibration purposes

Readme
Activity
2 stars
1 watching
1 fork

Releases 11

Release v0.3.3 Latest
on Jul 20, 2024

+ 10 releases

Packages

No packages published
Publish your first package

RESOURCES

TOA calculation code:
https://github.com/matteobachetti/TOAextractor

Deadtime correction code:
https://github.com/matteobachetti/pulse_deadtime_fix

What next?

More missions

Add all new missions to the archive

Policy Change

Choose your ephemeris, but update header keywords!

Web app

Current system based on Google Colab works, but can be improved

Crab science

Systematic study of Crab pulse profile at different energies, and possible radio/X delays (extend previous work by IACHEC members)

Paper status

- Focused on the method, but there is a hint of very interesting science.
- Need introduction
- Need paragraphs of data preparation by all co-authors
- Need discussion of results