

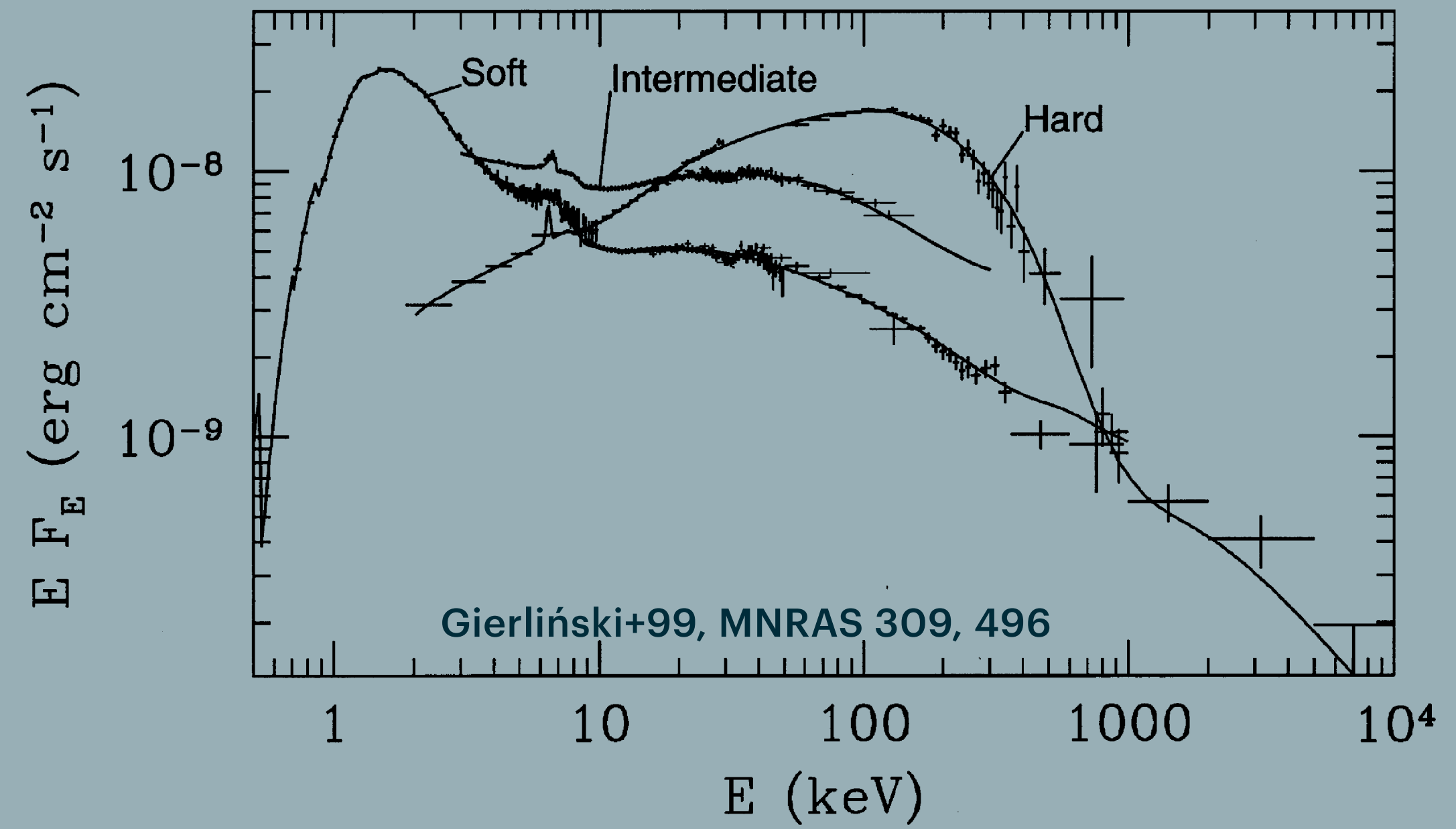
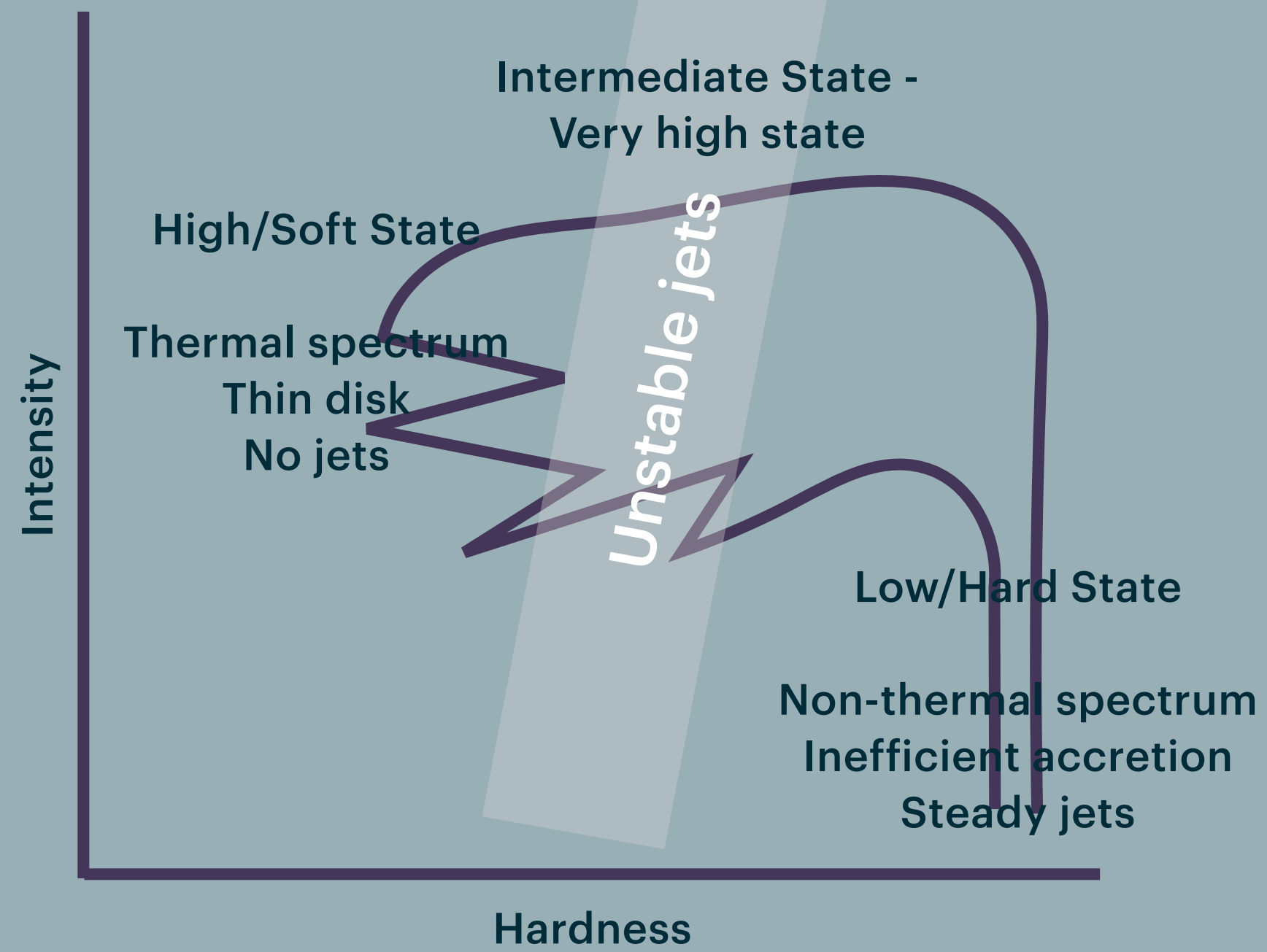
StingraySoftware

SPECTRAL TIMING FOR ALL

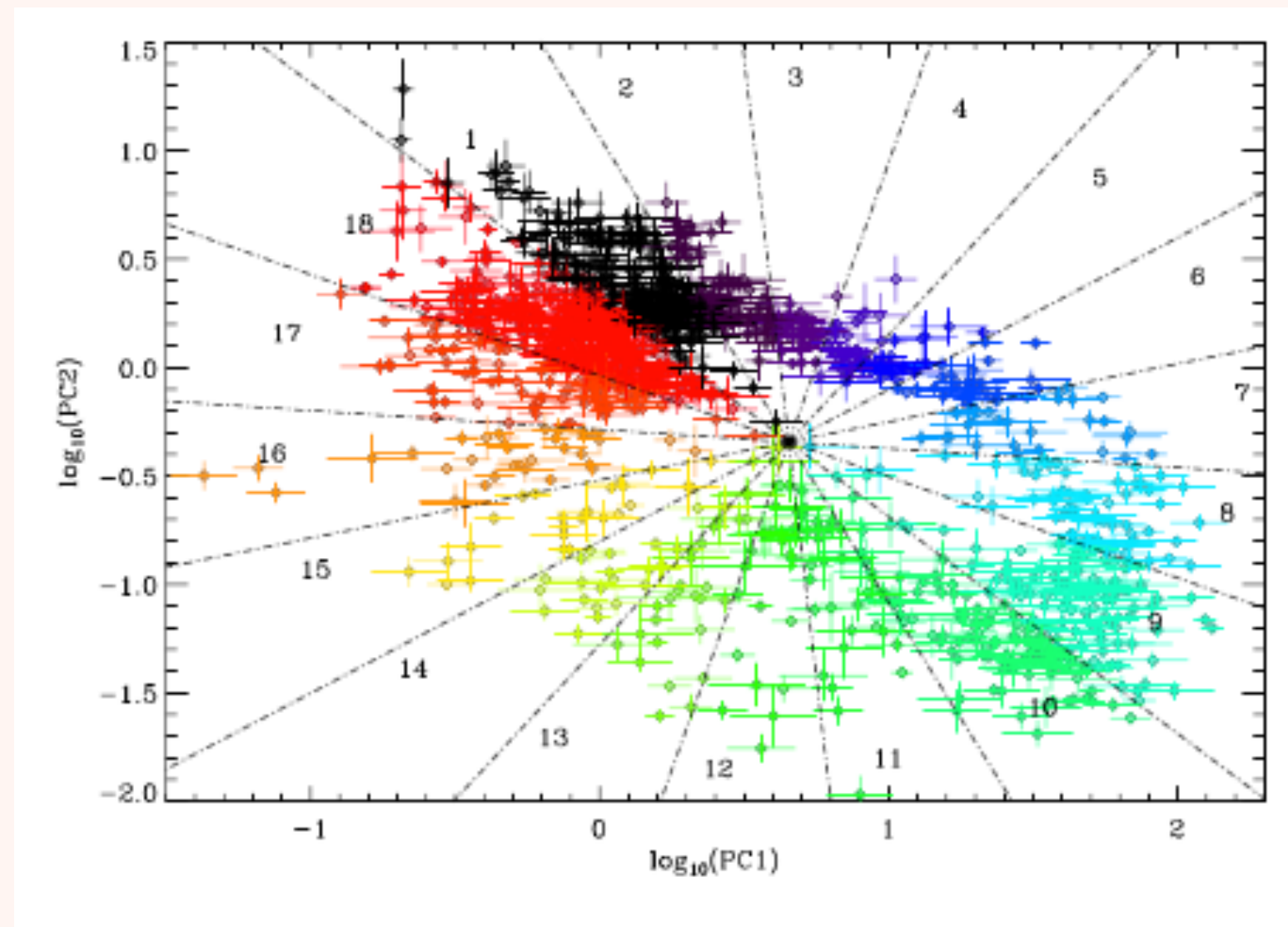


Matteo Bachetti

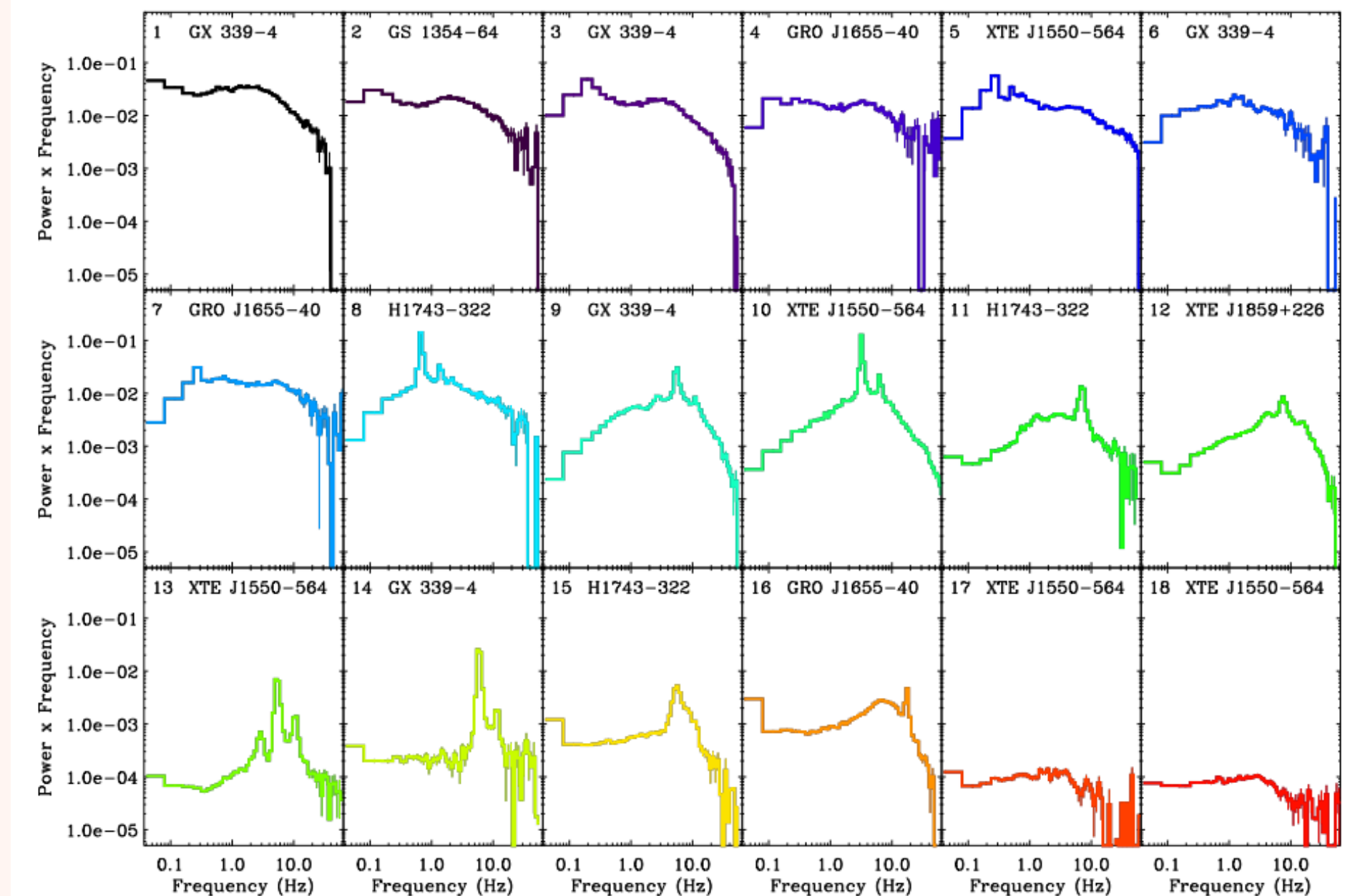
IACHECH TIMING WG



SPECTRA



Heil, Uttley, & Klein-Wolt, MNRAS 448, 3339–3347, 2015.



FAST VARIABILITY

“STANDARD” PRODUCTS WE MIGHT WANT TO HAVE

➤ **“Timing” analysis**

➤ Pulsation searches and timing

➤ Aperiodic variability

➤ **Spectral analysis**

➤ Continuum modeling

➤ Broad lines (e.g. Fe complex, cyclotron lines)

➤ **Polarimetry (be creative!)**

➤ **All mixed together!**

➤ Time lags

➤ Spectral covariance

➤ Phase-resolved spectroscopy

➤ Phase-resolved polarimetry

➤ Energy-resolved polarimetry

➤ Time-resolved-energy-resolved polarimetry
(Whatev’)

“STANDARD” PRODUCTS WE MIGHT WANT TO HAVE

➤ “Timing” analysis

- Pulsation searches and timing
- Aperiodic variability

➤ Spectral analysis

- Continuum modeling
- Broad lines (e.g. Fe complex, cyclotron lines)

➤ Polarimetry (be creative!)

➤ Be instrument aware

- Account for dead time
- Be aware of systematics

➤ All mixed together!

- Time lags
 - Spectral covariance
 - Phase-resolved spectroscopy
 - Phase-resolved polarimetry
 - Energy-resolved polarimetry
 - Time-resolved-energy-resolved polarimetry (Whatever)
-

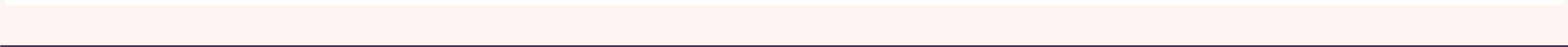
**EXISTING “PUBLIC” SOFTWARE WHEN WE STARTED
(I.E. YOU CAN LOOK AT THE CODE AND READ DOCS, NO NEED TO
ASK THE DEVELOPER IF THEY CAN PLEASE SHARE THEIR CODE)**

Spectral analysis

**Timing analysis
(+ lags)**

Spectral timing

- **Xspec**
- **Sherpa**
- **ISIS**
- **(...)**



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- SITAR, Isisscripts.sl



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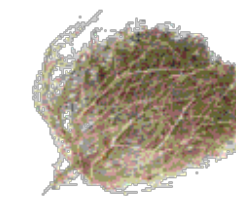
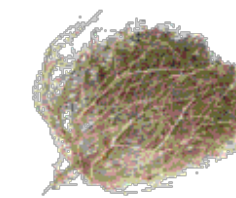
Spectral analysis

Timing analysis
(+ lags)

Spectral timing

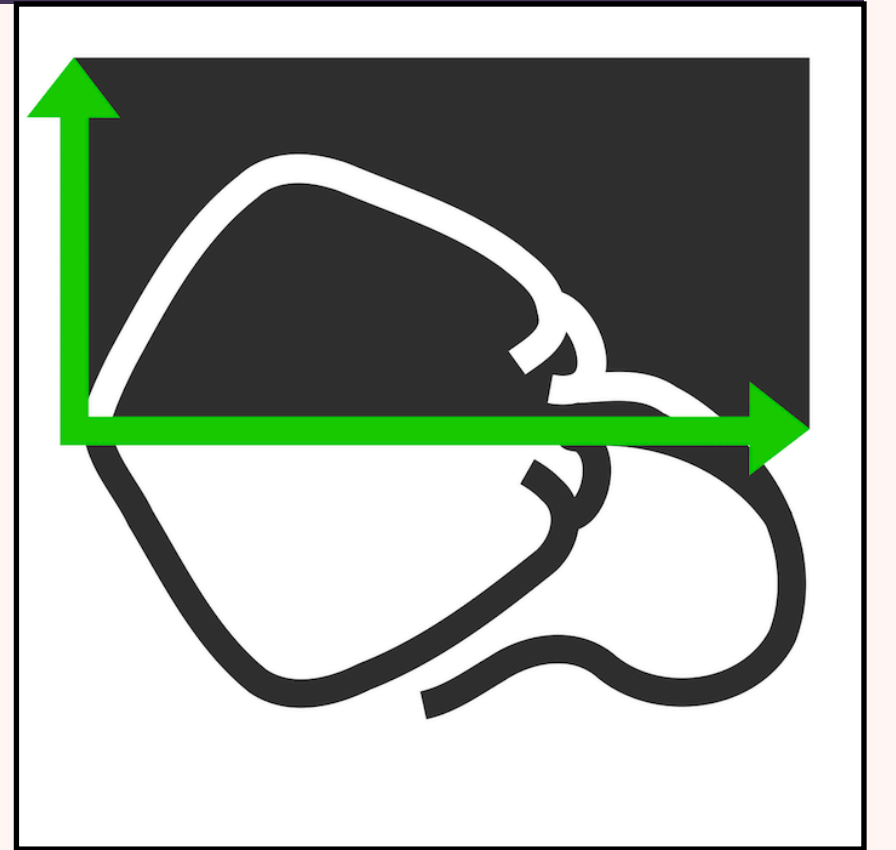
- Xspec
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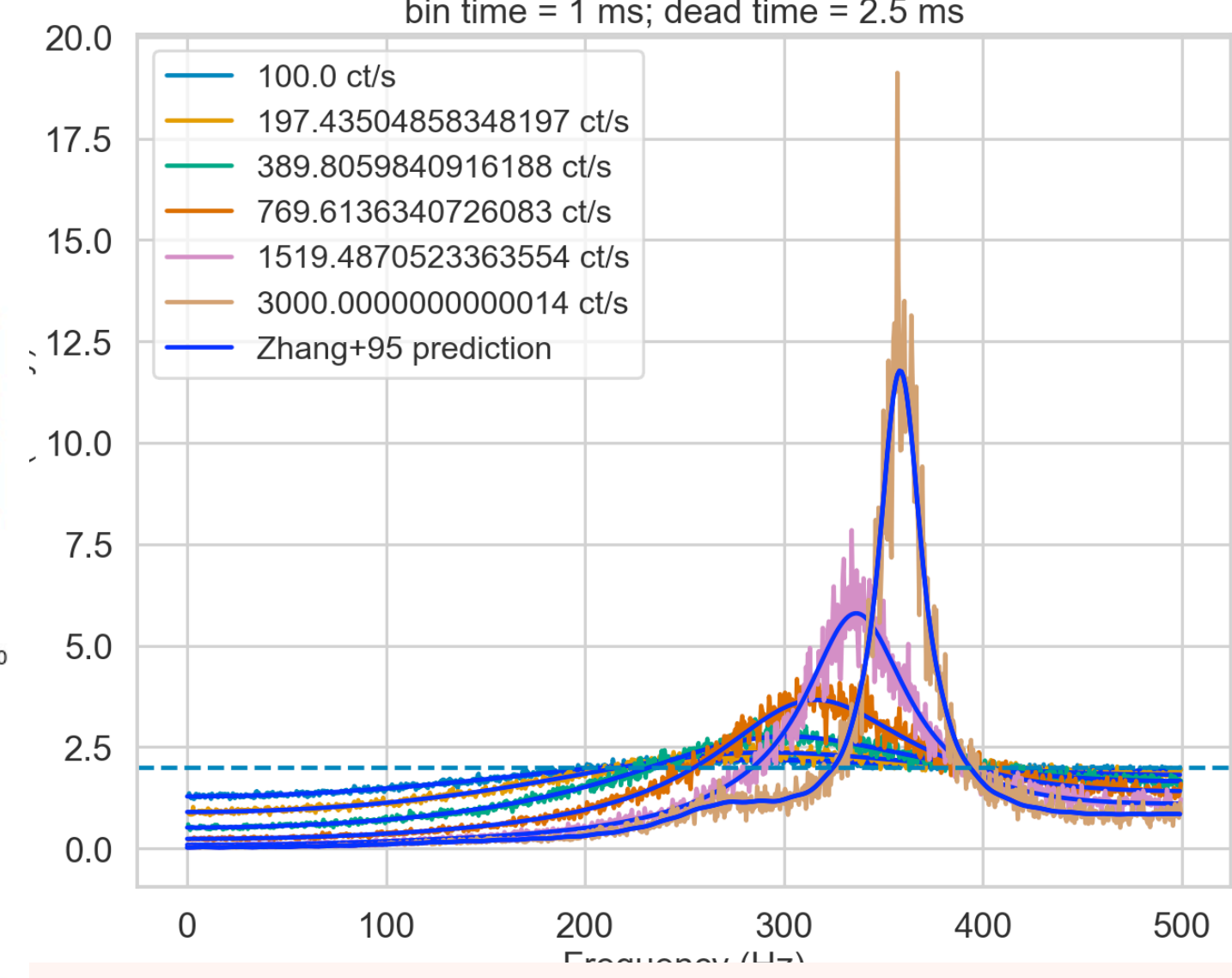
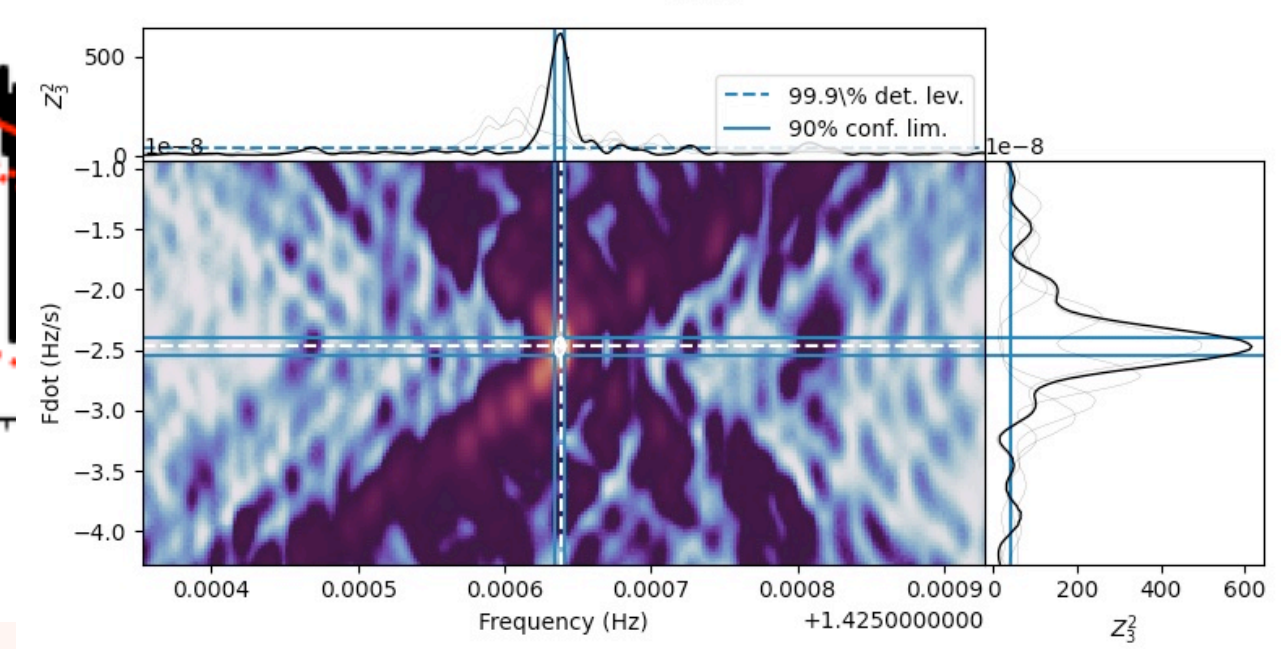
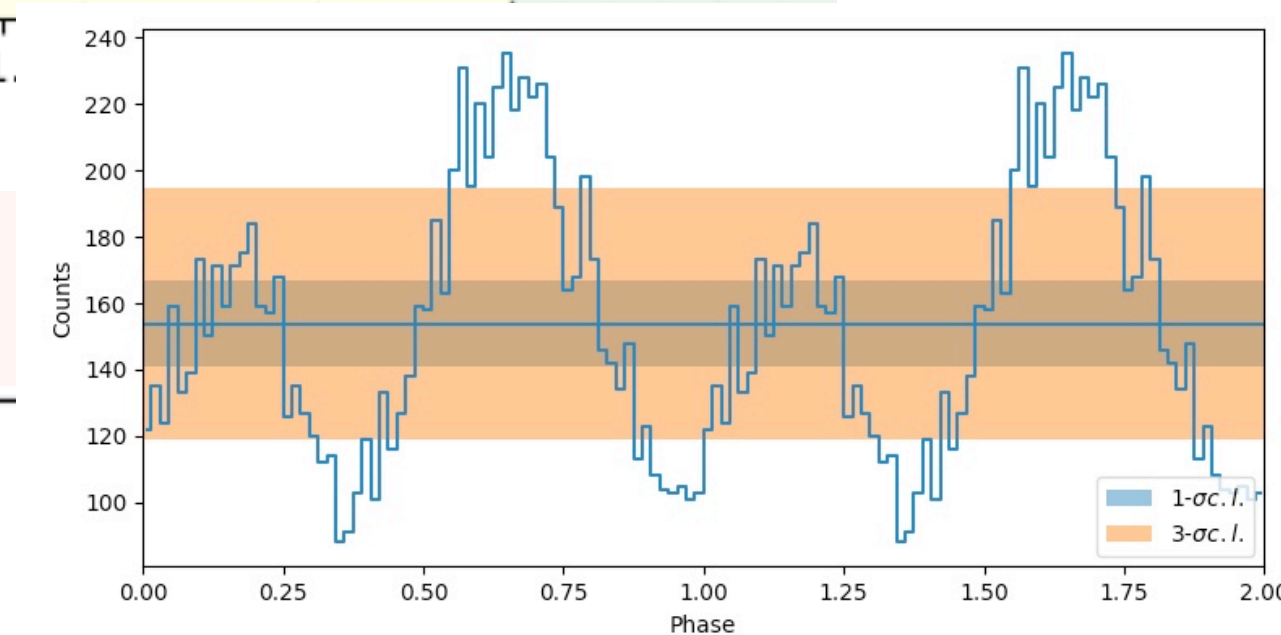
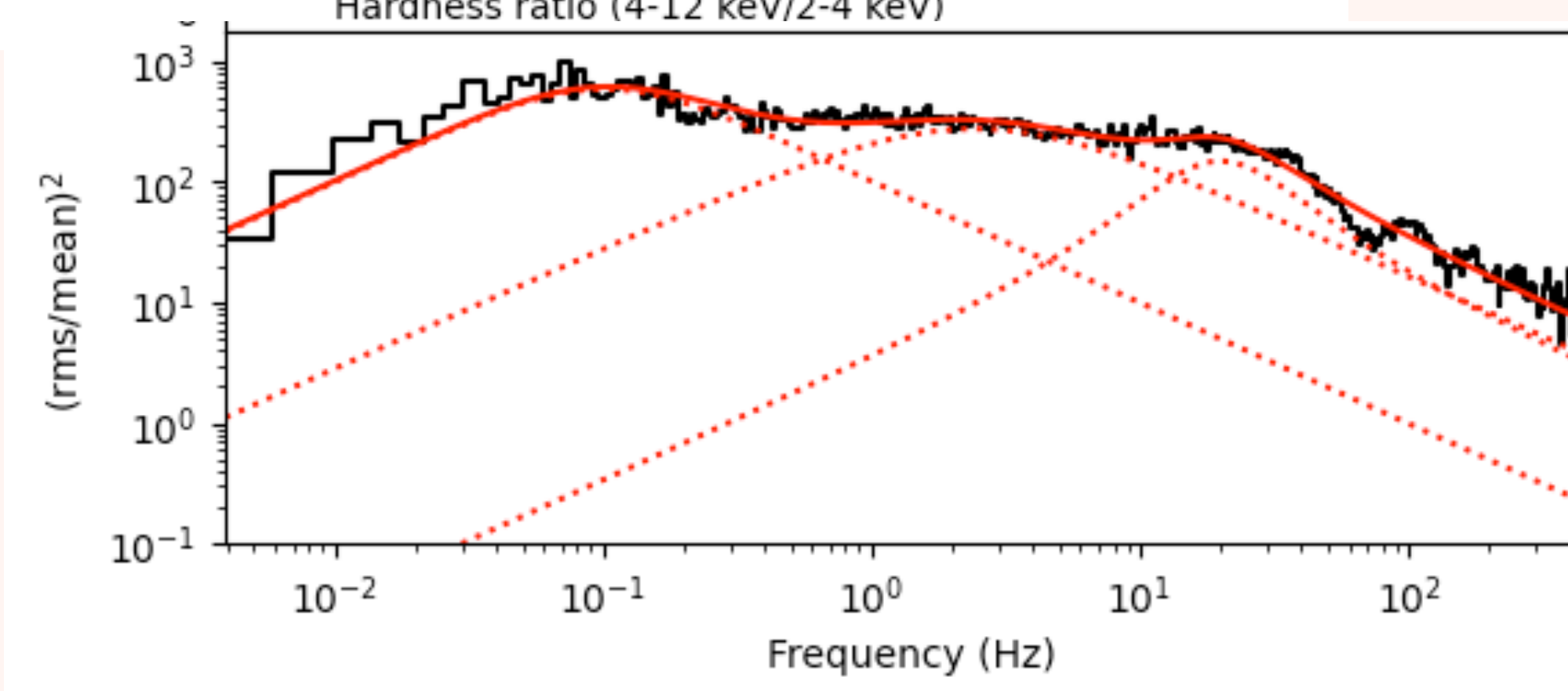
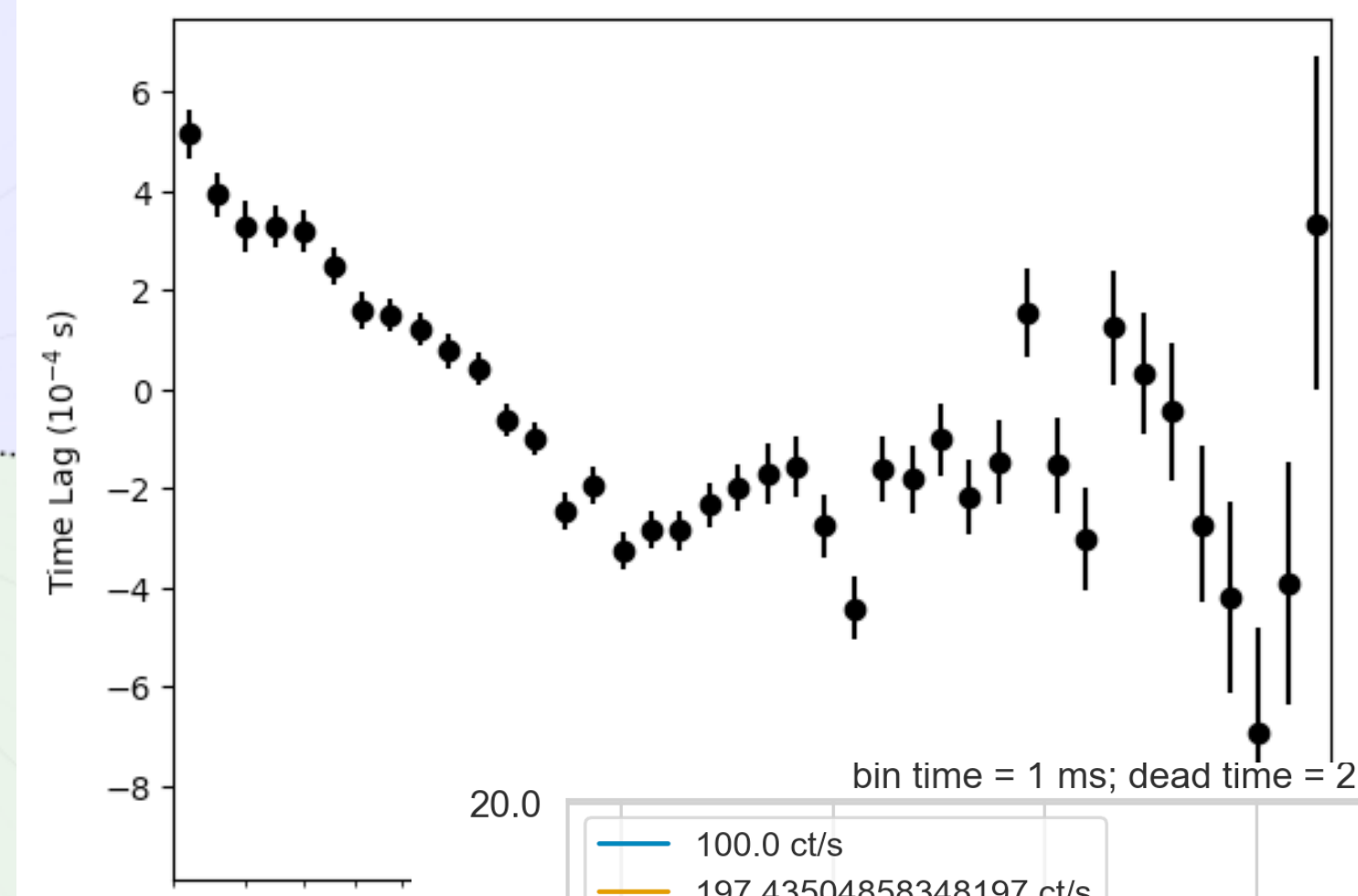
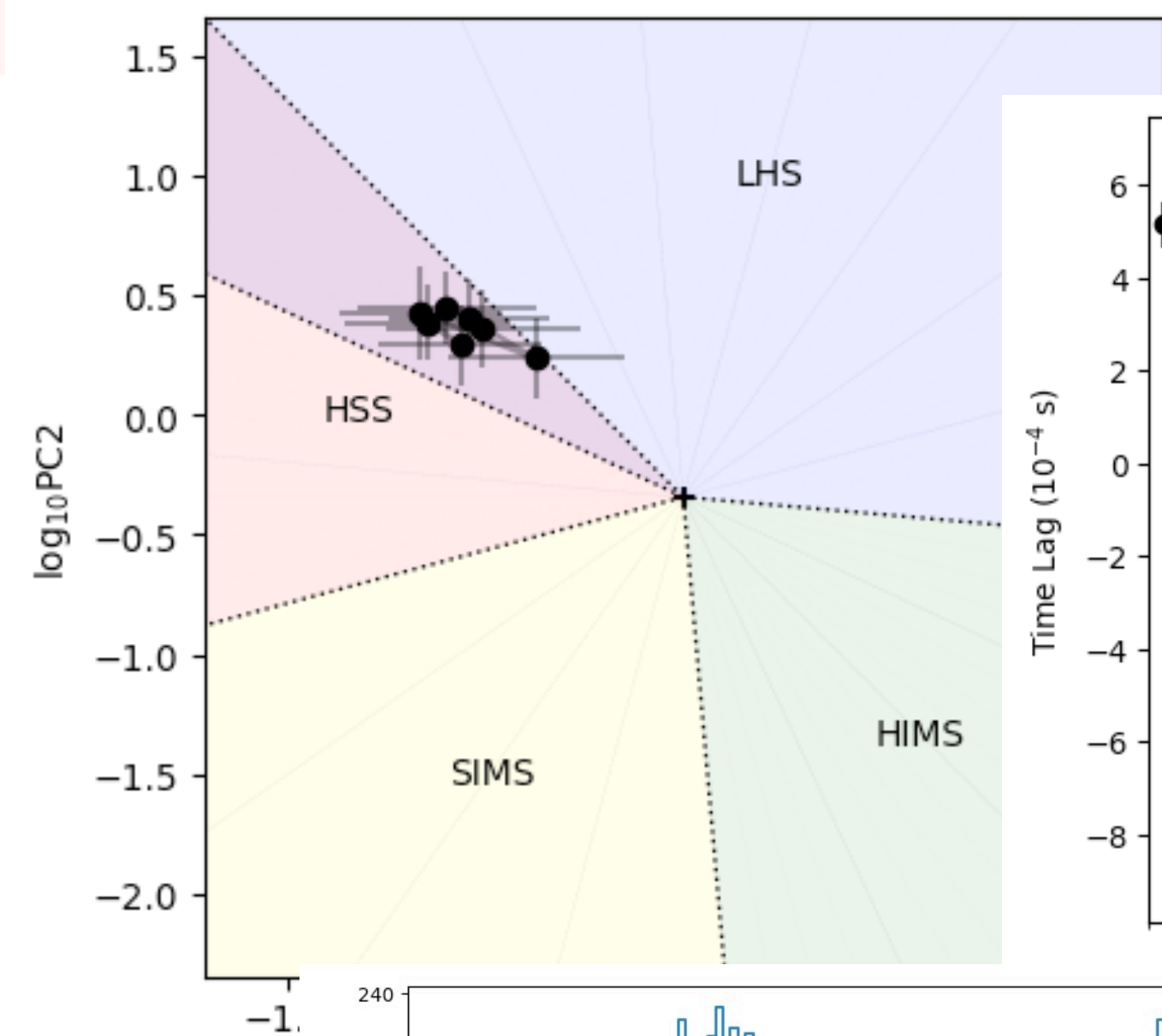
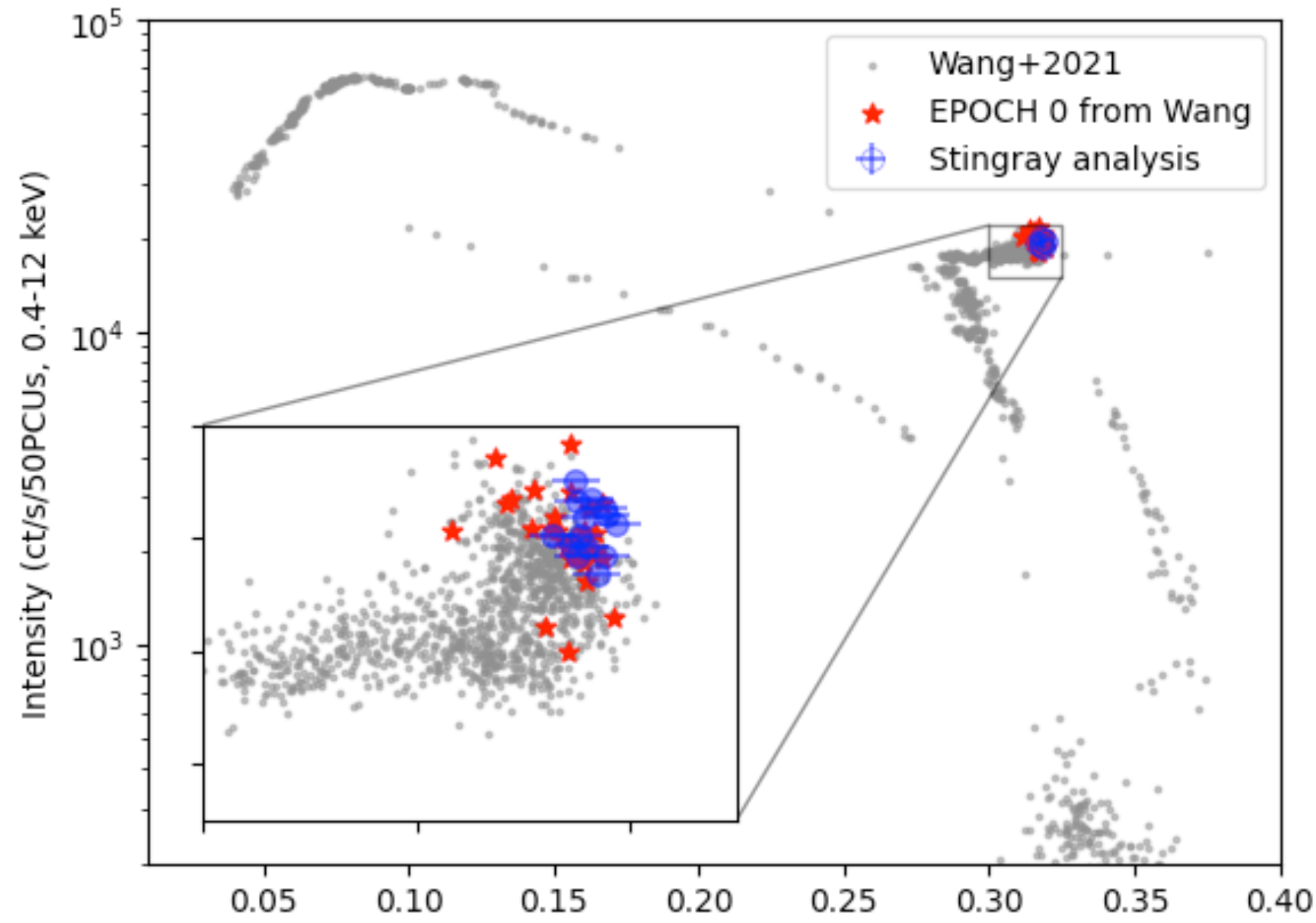
STINGRAY

Astropy-affiliated spectral timing software in Python



➤ Includes:

- Input data from **OGIP FITS files (events, light curves)**
- Exploratory timing products, e.g.
 - Light curves
 - Periodograms
 - Colors, Power colors
- Periodogram modeling (Maximum Likelihood, Bayesian)
- Systematics handling, e.g.
 - Good Time Interval (GTI) support
 - Dead time correction and models
- Spectral timing products, e.g.:
 - Cross products, Time lags
 - Covariance, Coherence, RMS, lag spectra
 - Cross-correlation
 - Bispectra, Bicoherence
 - Phase-resolved QPO spectra
- (Accelerated) Pulsar search methods
 - PDS based
 - Epoch folding/Z/H search



ConfirmCandidates__home_mbachett_P_n

Show task details

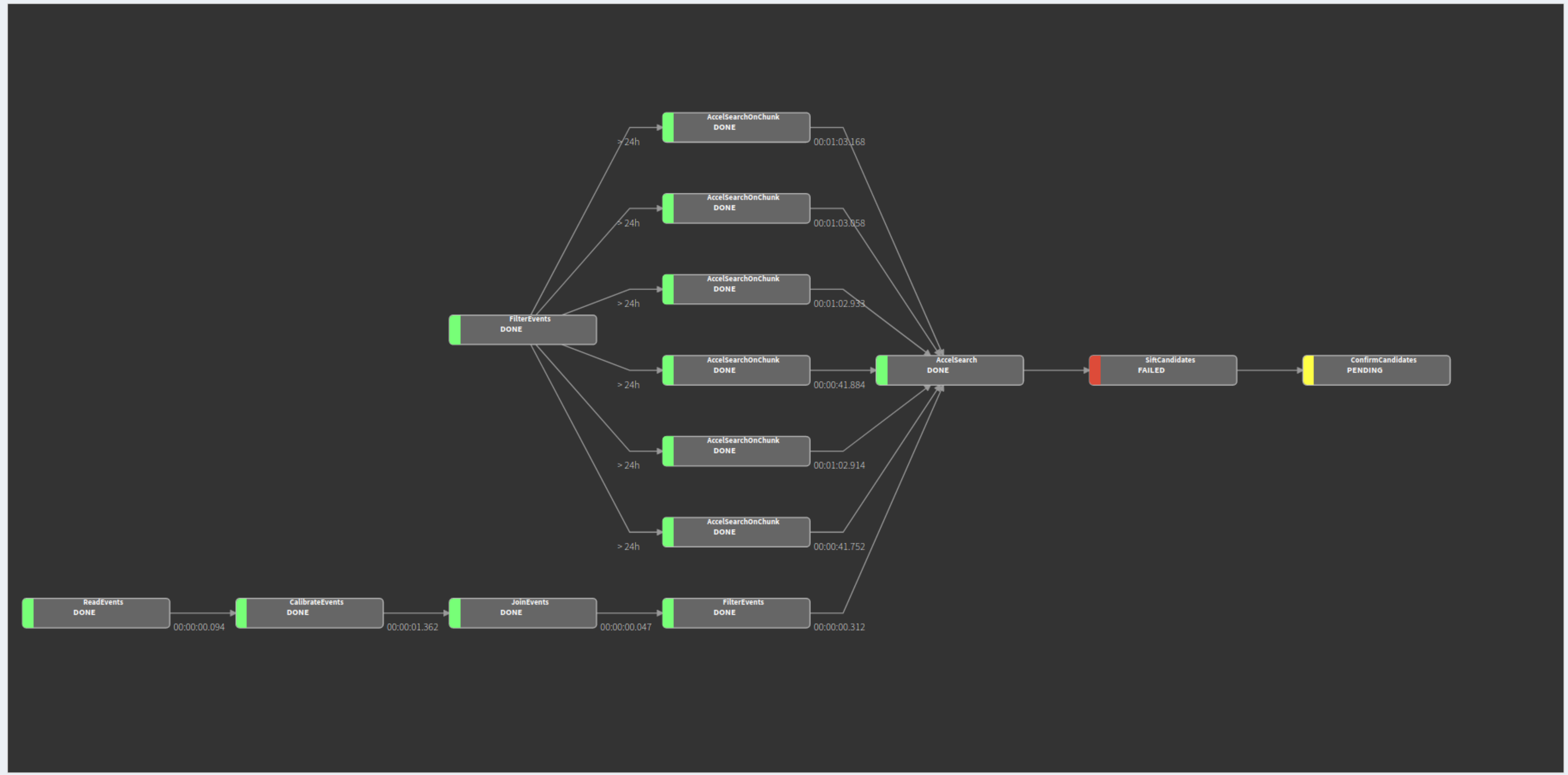
Show Upstream Dependencies

Visualisation Type D3 SVG

Hide Done

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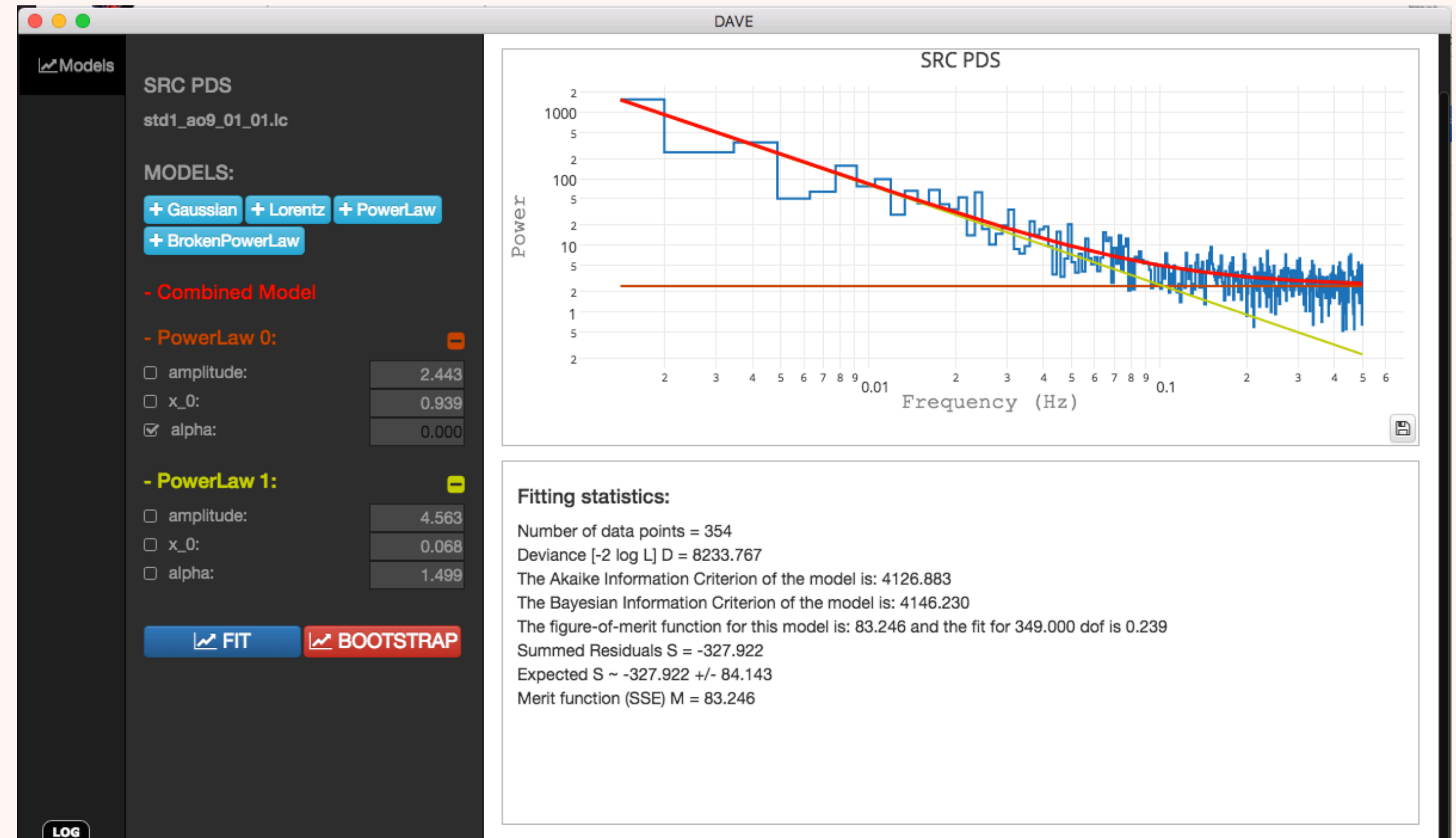
Dependency Graph

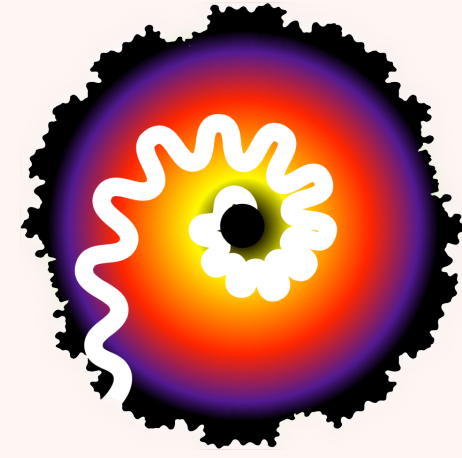




DAVE

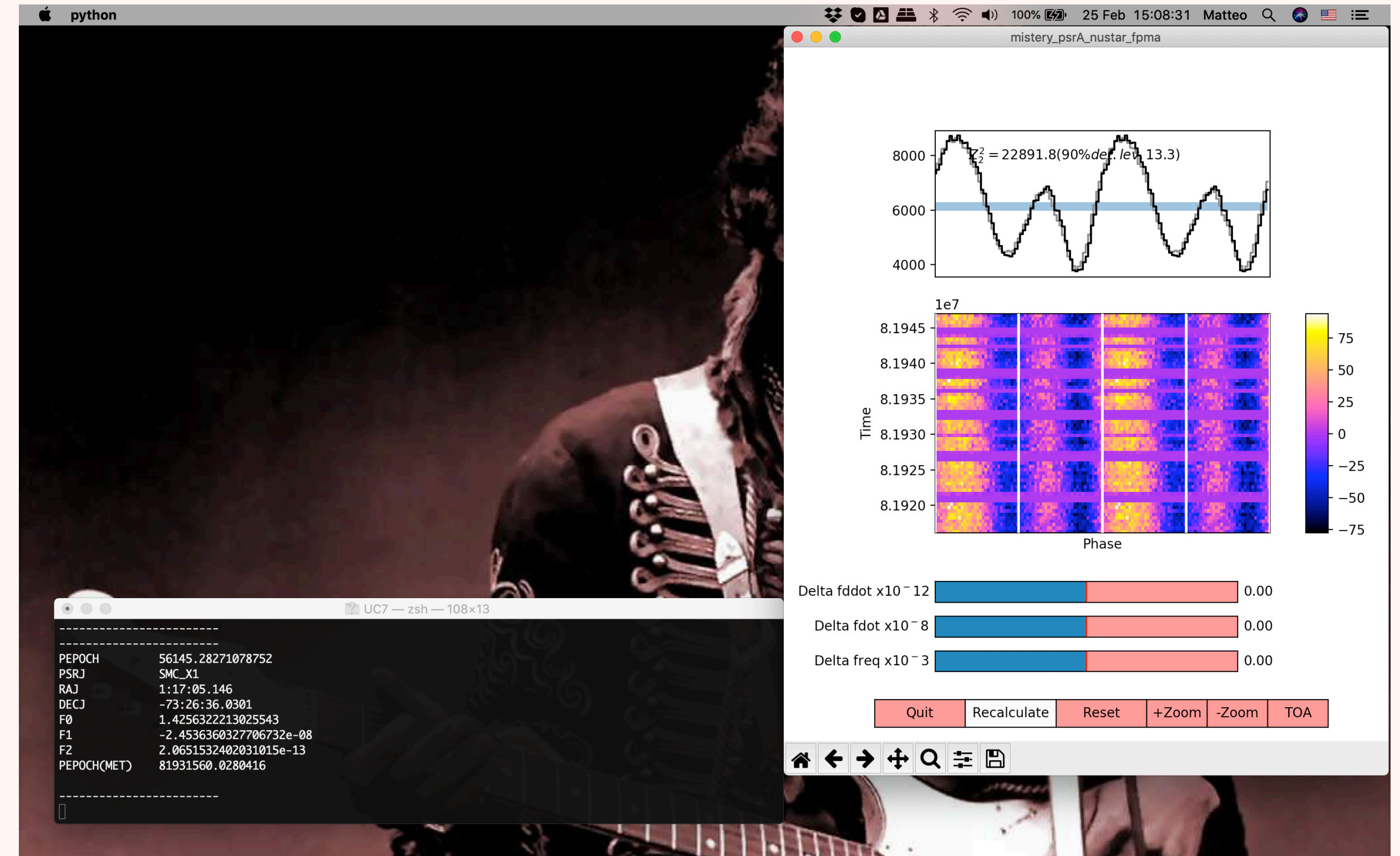
- **ESA-funded GUI for Stingray**
- **Timing exploration made easy**
- **Stingray functionality made interactive (PDS modeling, pulsar searches, lag spectra, etc.)**
- **Issues: currently unmaintained**

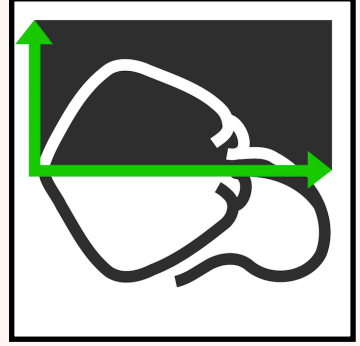




HENDRICS

- **Command line interface to Stingray**
- **“Hides” Python API**
- **Simplifies Batch scripting**
- **Some interactive functionality (for pulsars)**
- **Cutting-edge pulsar searches (some not yet available in Stingray)**

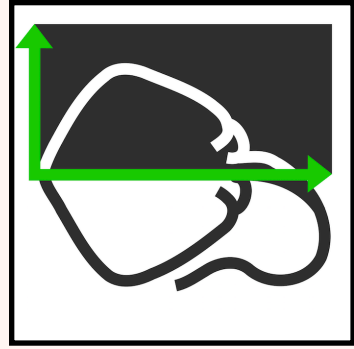




OTHER NOTABLE FEATURES

- **Interoperability with Astropy TimeSeries, LightKurve, Pandas, Xarray**
- **Just-In-Time compilation of computation-intensive operations (via Numba)**
- **Large dataset handling (NICER-ready!)**





RECENT DEVELOPMENT

- Performance improvements for large datasets
- Basic “Polarimetric timing” products
- Advanced pulsar search techniques
- Experimental port to Julia (GSOC 22)
- Improved upper limit estimates
- Non-uniformly sampled data (GSOC 23)
- Expansion of supported missions (notably RXTE)

◆ SpecTemPolar!
PRIN INAF 2019



INAF

ISTITUTO NAZIONALE
DI ASTROFISICA

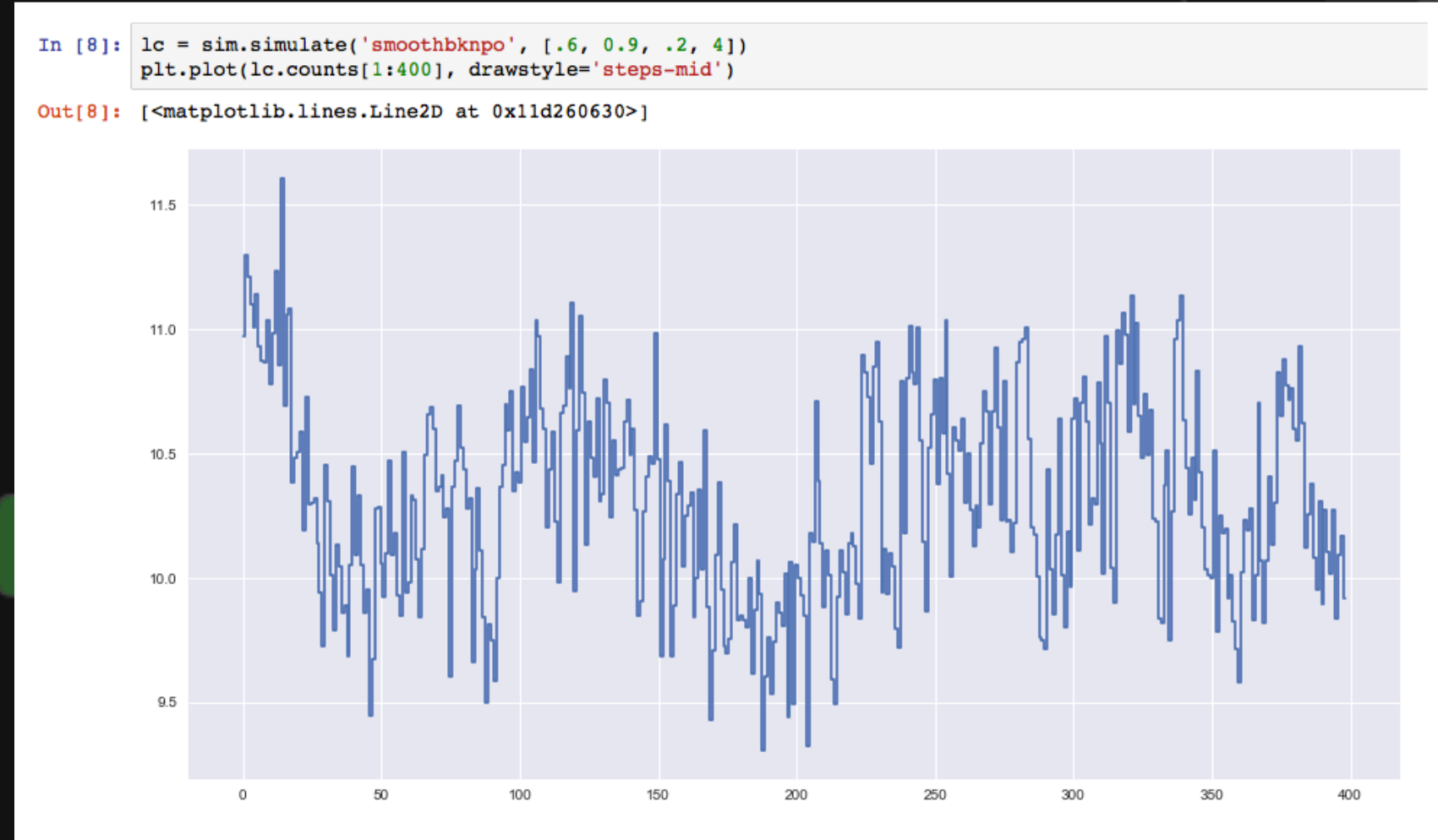
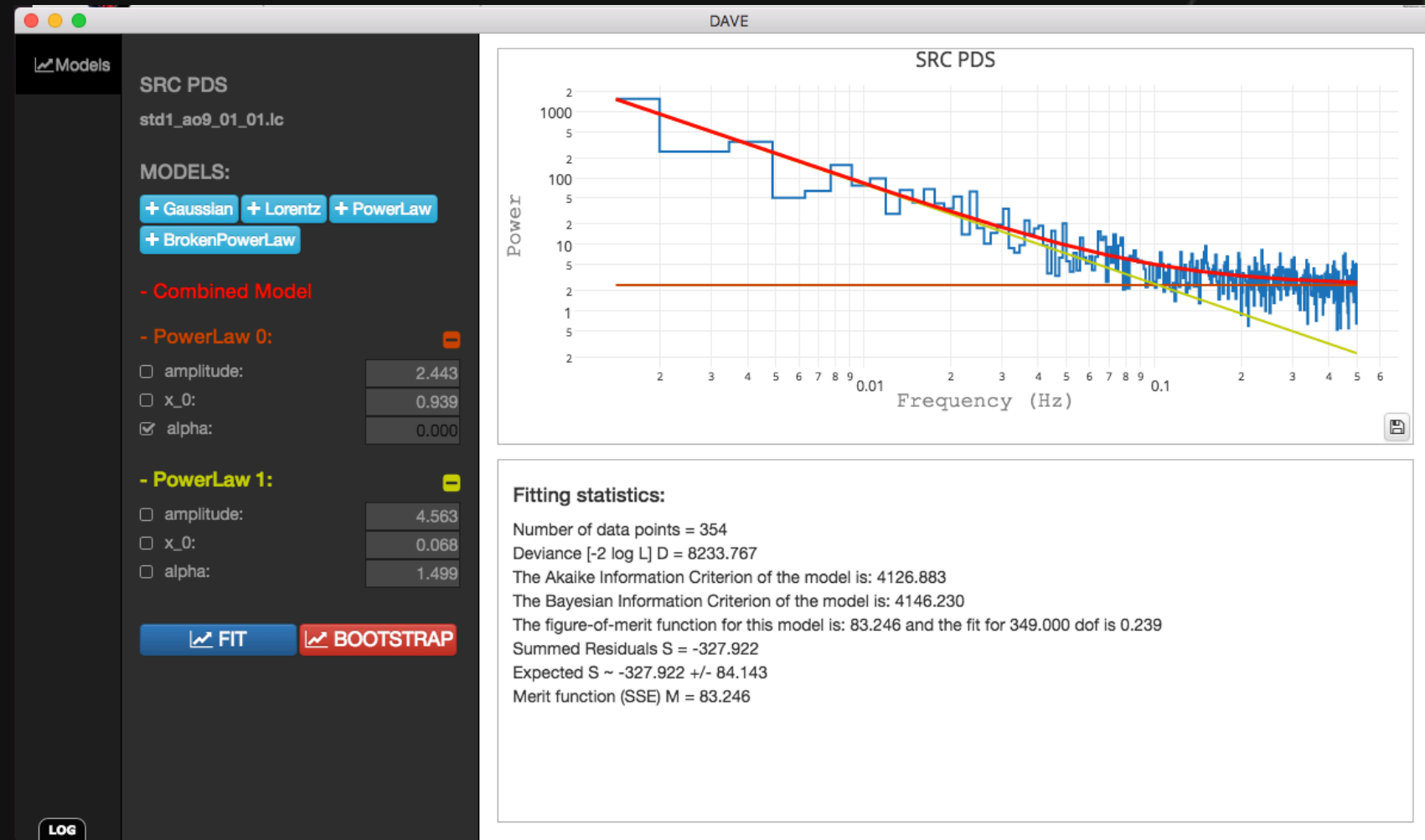


UNIAM
PRIN MIUR 2017



Google Summer of Code
2016-2018, 2020-2024

CONCLUSIONS



Stingray, HENDRICS (+ DAVE): robust, community-maintained, free software

Handles standard data format (FTOOLS compatible)

Standard tools + easy "plug-in" of new functionality

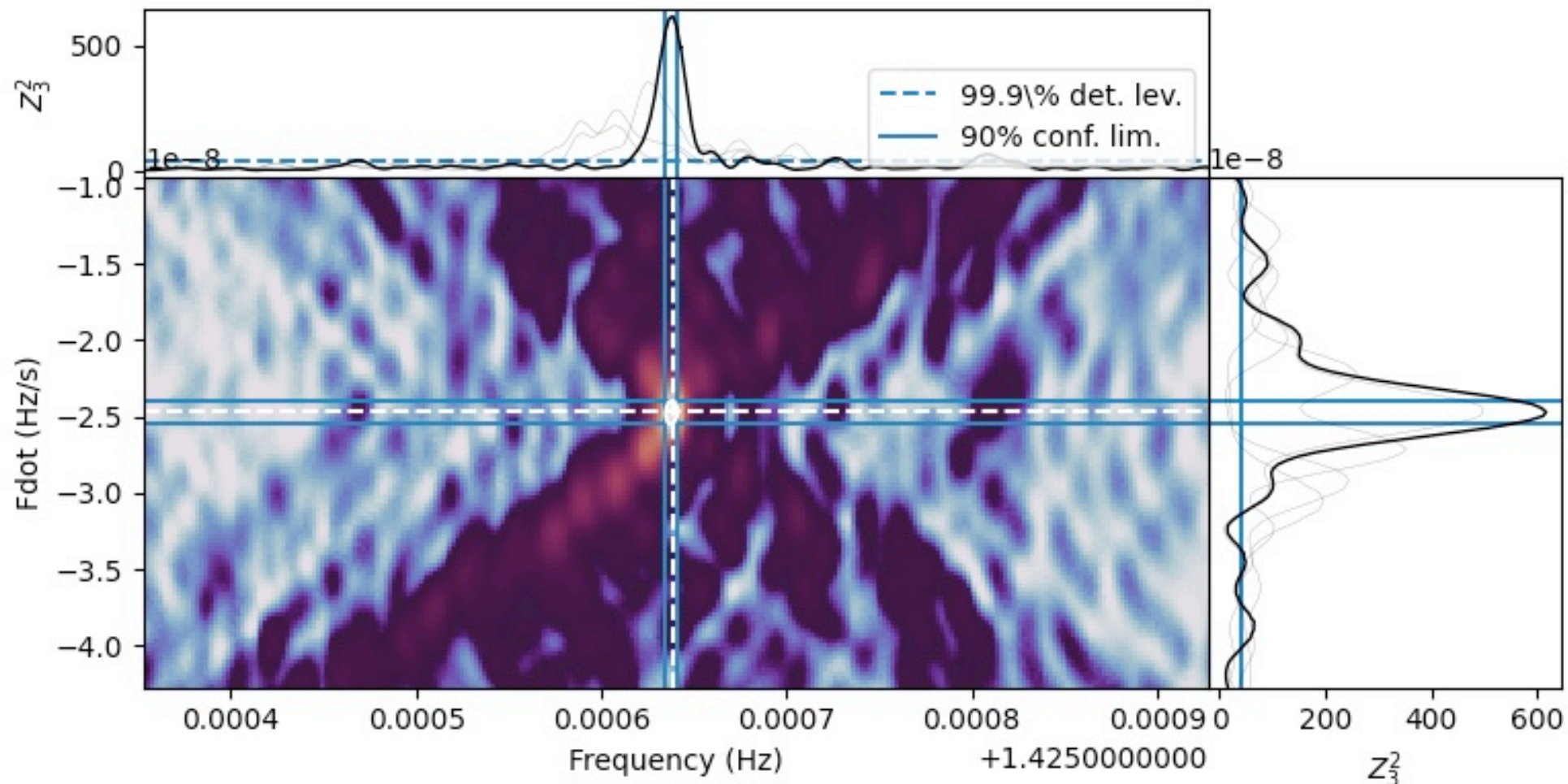
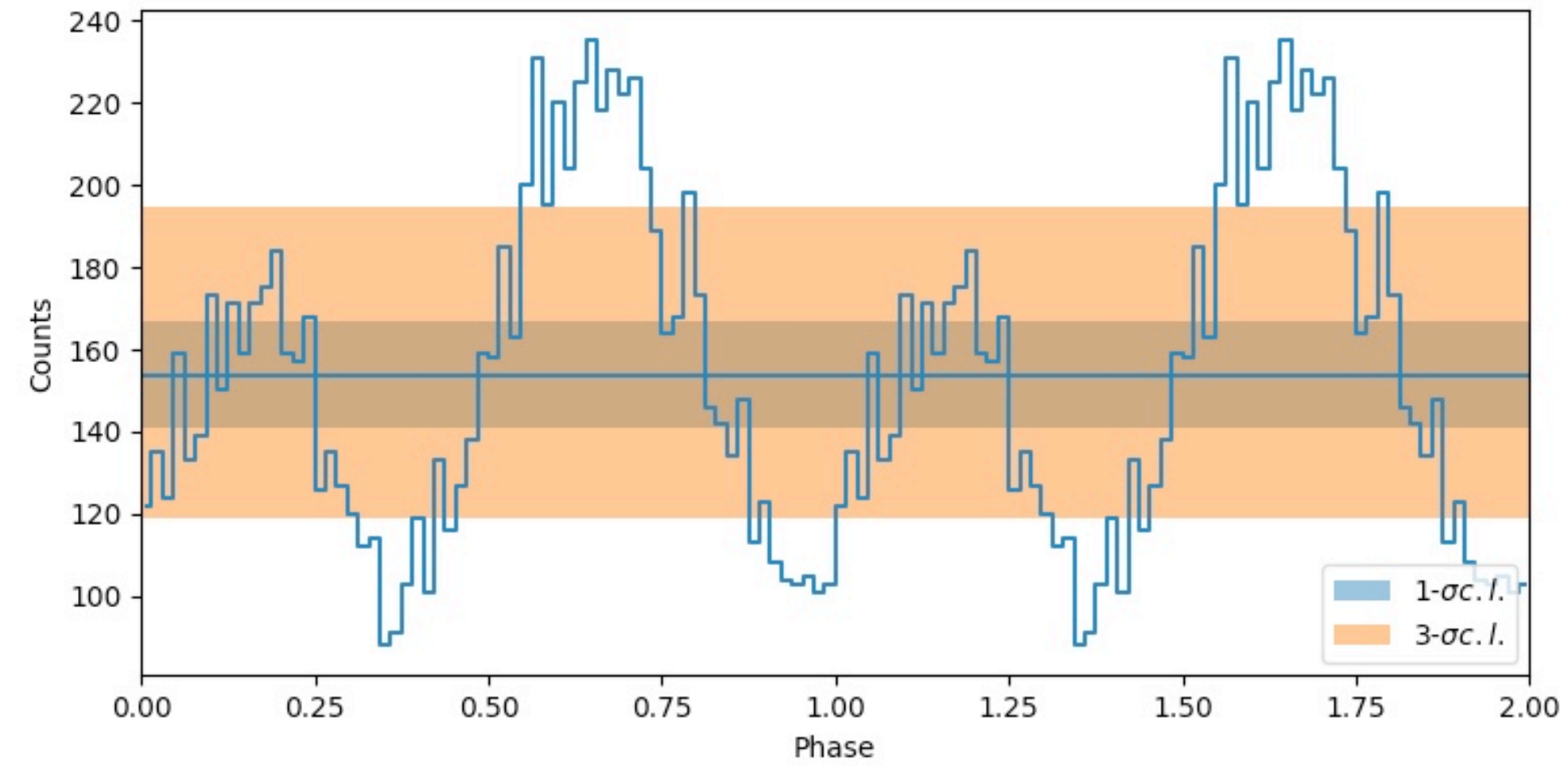
Easy use for newcomers -> docs + GUI

Systematics handling (e.g. dead time correction)

Requires community involvement (help with data formats!) AND funding



ASK FOR A TUTORIAL!



Spectral timing with Stingray

Pulsar searches with HENDRICS and Stingray

X-ray simulations with Stingray

...