

EBANDERAS: THE HUNT FOR VARIABLE SOURCES IN THE EROSITA DATA

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on behalf of the
MAGNESIA and
HEAG@OAR groups



XMM2ATHENA
27/2/2024



INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

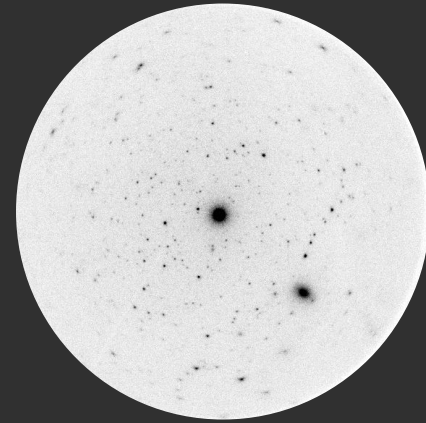


**Institute of
Space Sciences**

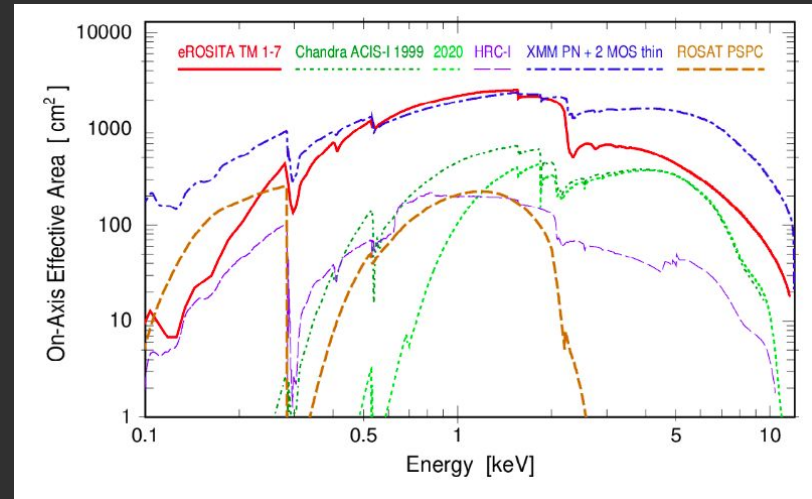


EROSITA (THE REAL ONE, NOT THE HEN)

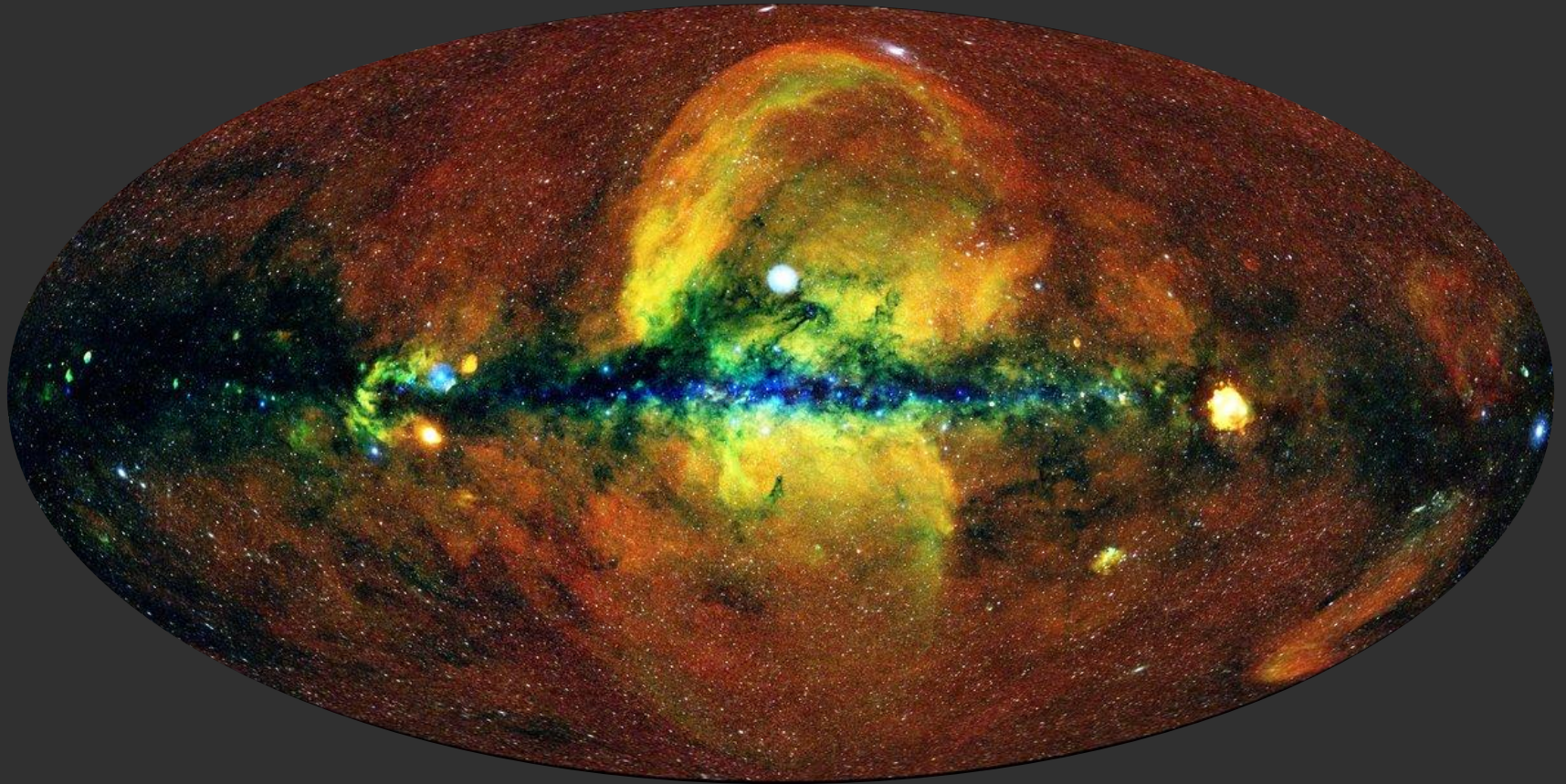
- extended ROentgen Survey with an Imaging Telescope Array
- **Most sensitive all-sky survey in the 0.2–2.3 keV band**
- First all-sky survey in the 2.3–5 keV band



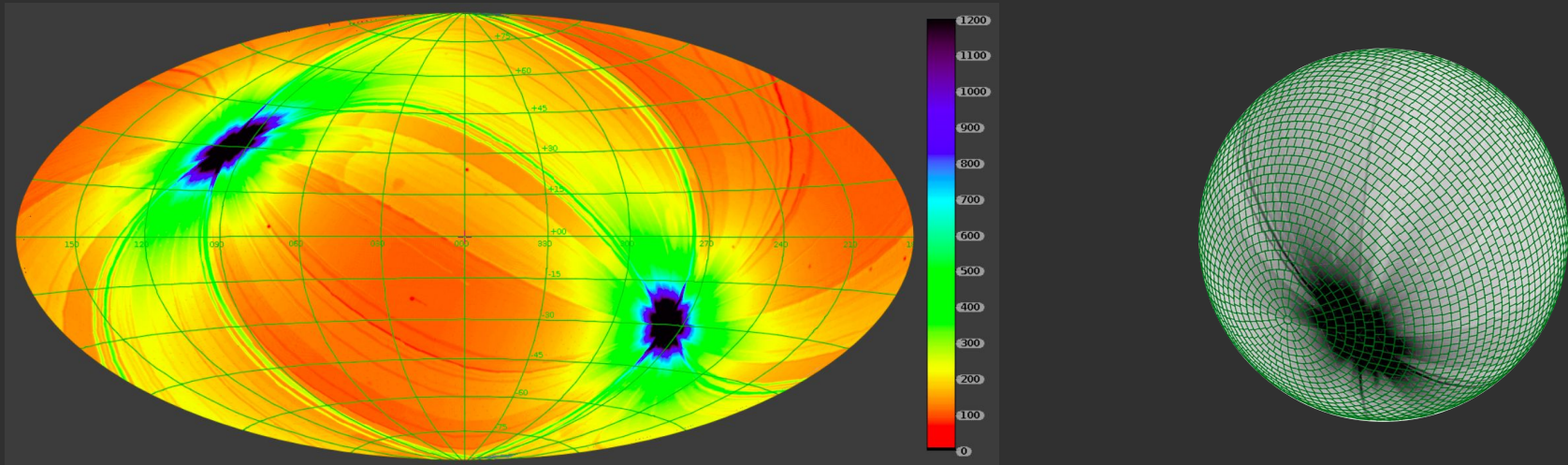
FoV: $1^\circ \times 1^\circ$



THE EROSITA ALL-SKY MAP

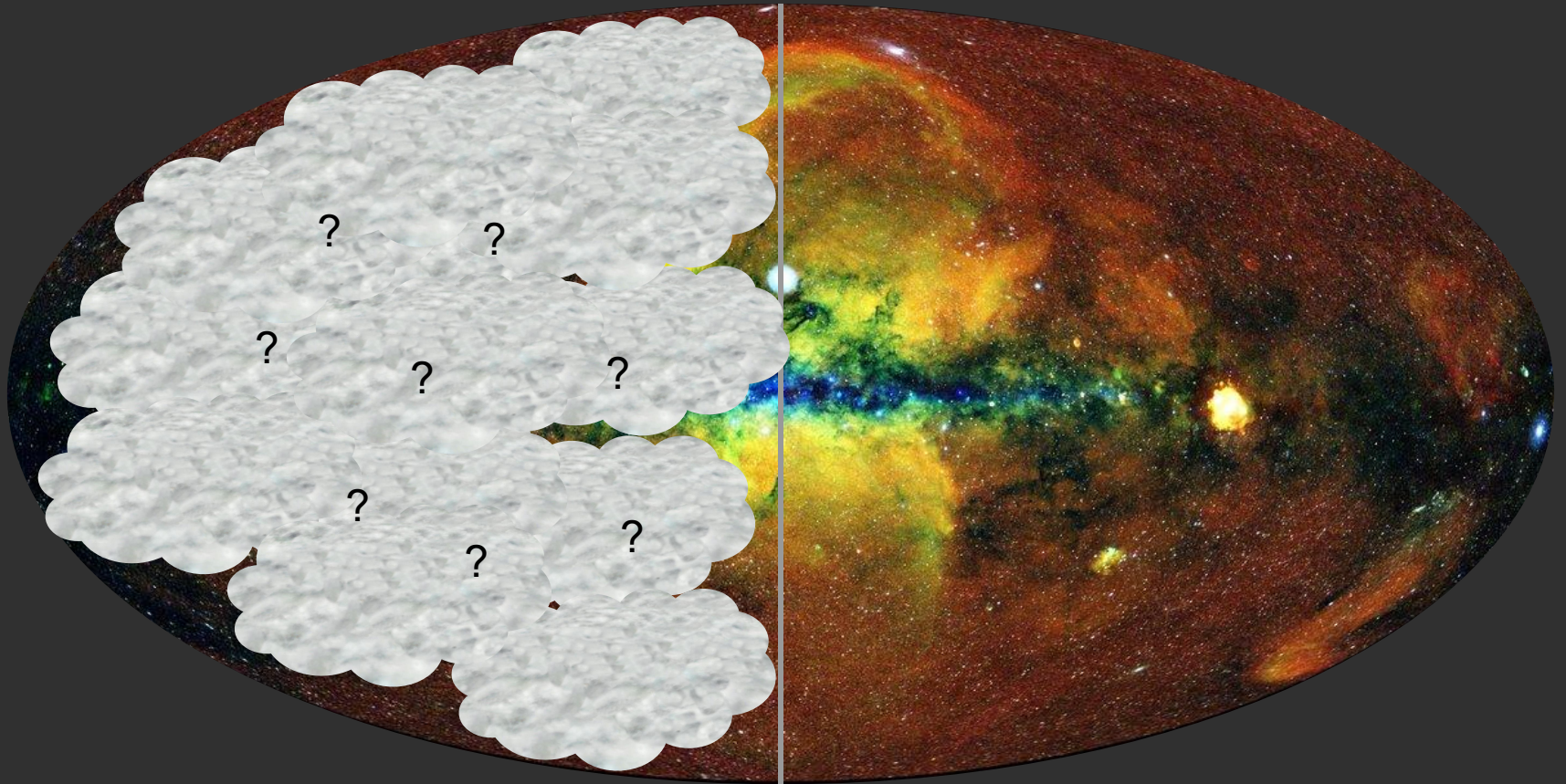


EROSITA: SCAN STRATEGY AND ERASS SKY TILES

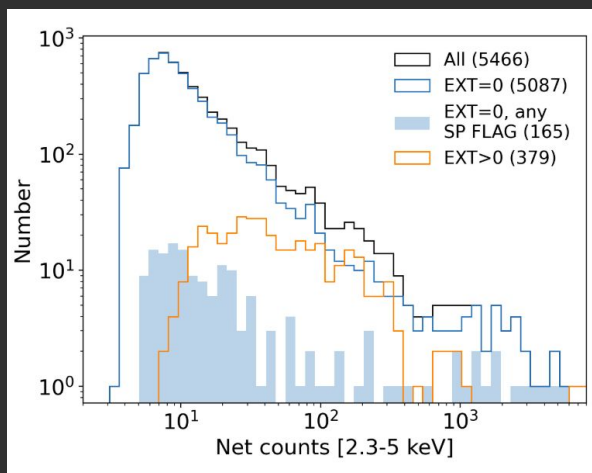
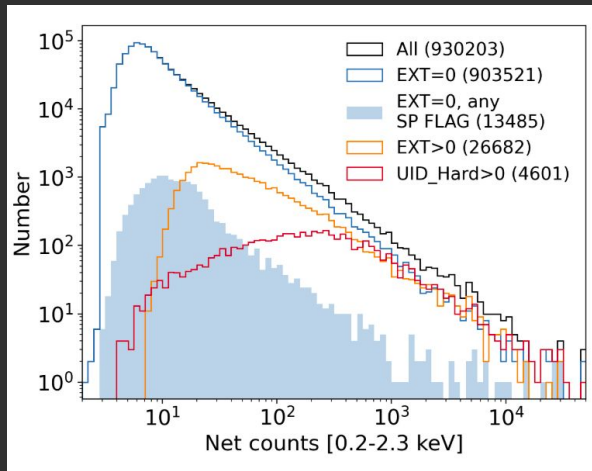


- Scan rate: 0.025 deg s^{-1} . One great circle of sky covered in 4 h (1 eroday)
- 40 s chunks, up to 6 chunks per day
- Longer total exposure (up to $\sim 10 \text{ ks}$) at the ecliptic poles
- Sky divided in 4700 skytiles ($3.6^\circ \times 3.6^\circ$)

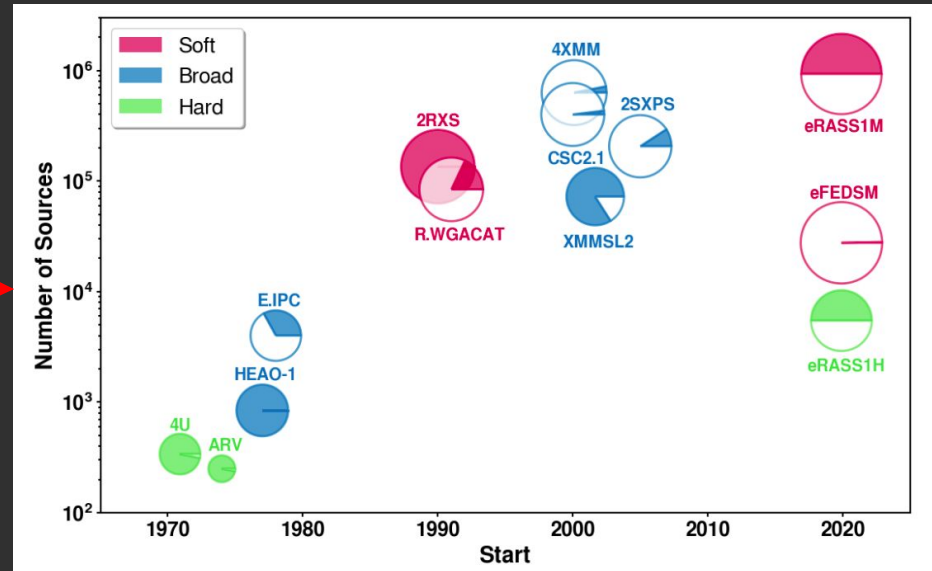
ERASS1: THE GERMAN SKY



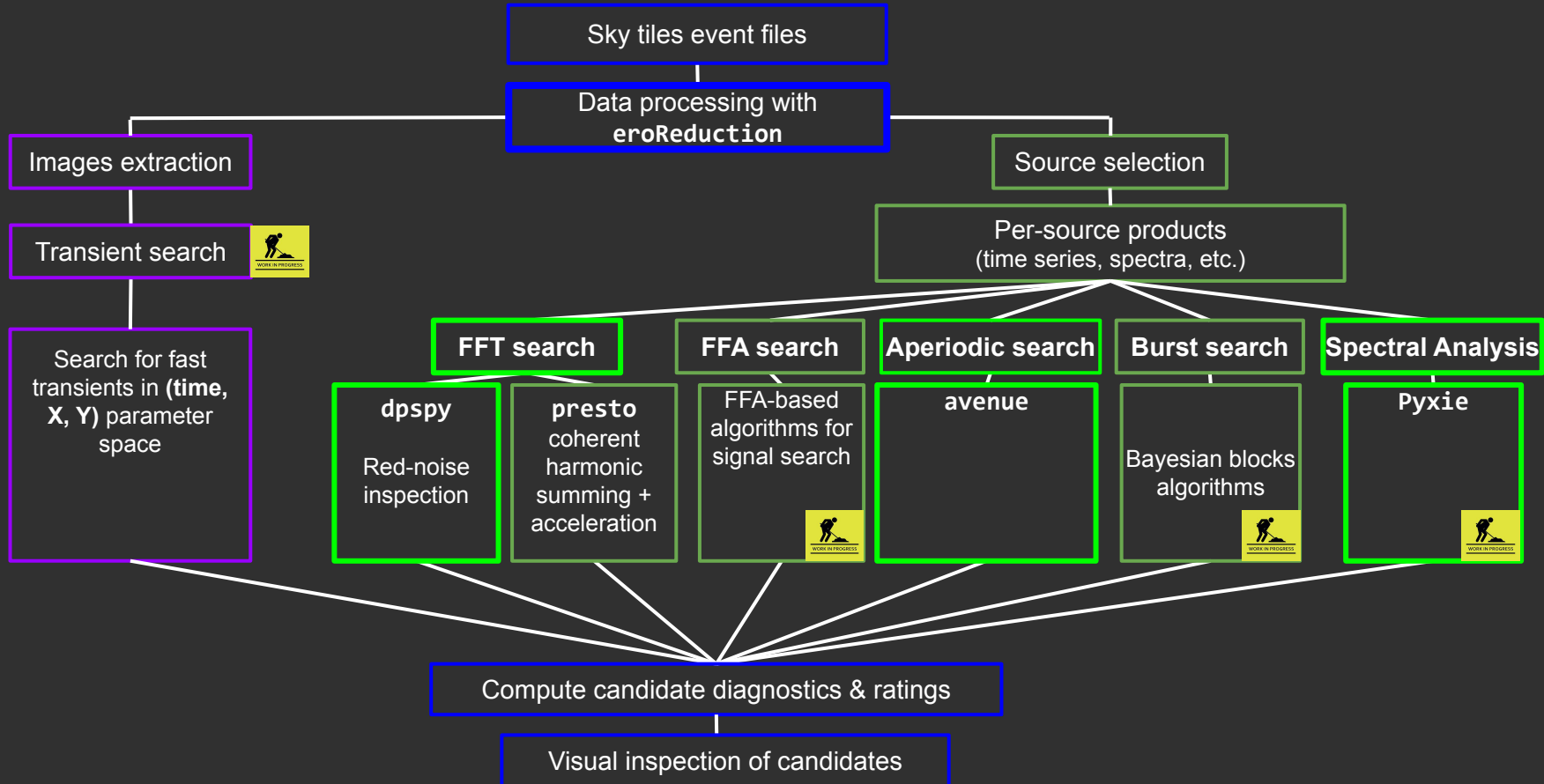
ERASS1: THE LARGEST X-RAY CATALOGUE



Merloni+, 2024

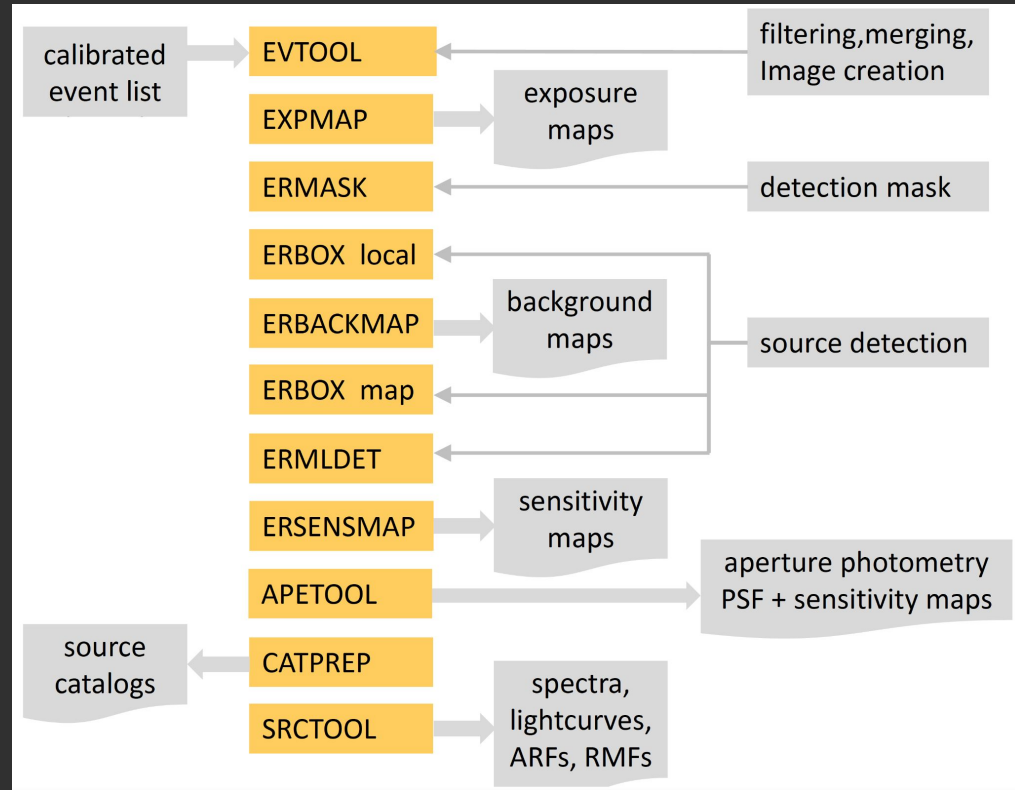


EBANDERAS

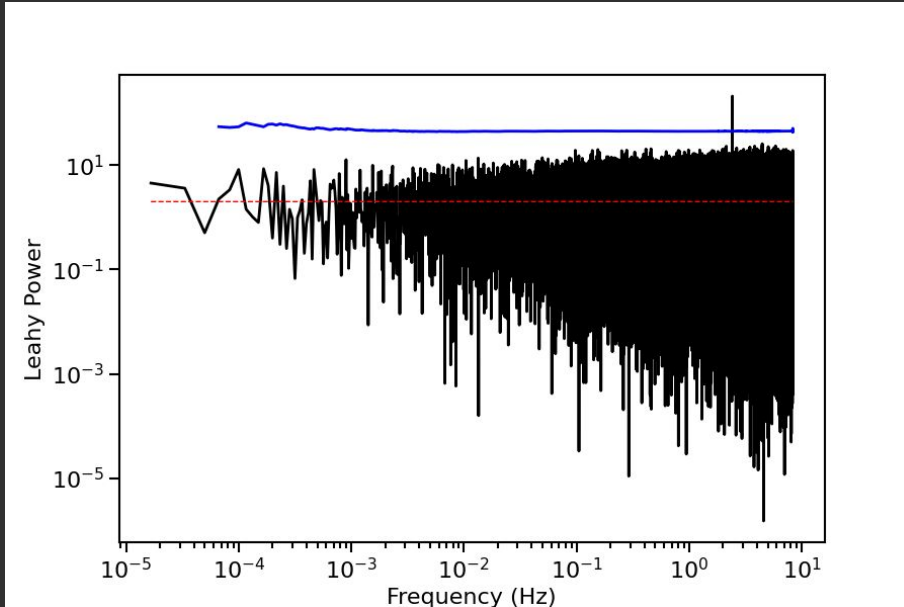


EROREDUCTION AND EROBARY: PREPARING EROSITA DATA FOR TIMING ANALYSIS

- 2 eROSITA-specific modules: **eroReduction** and **eroBary**
- eroReduction: pipeline and single-source modes
- eroBary: wrapper of barycen (like ebarycen), works also with merged evt files

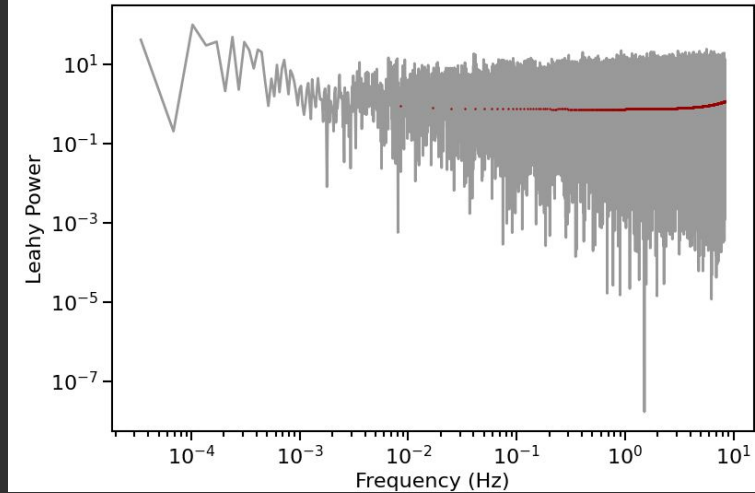
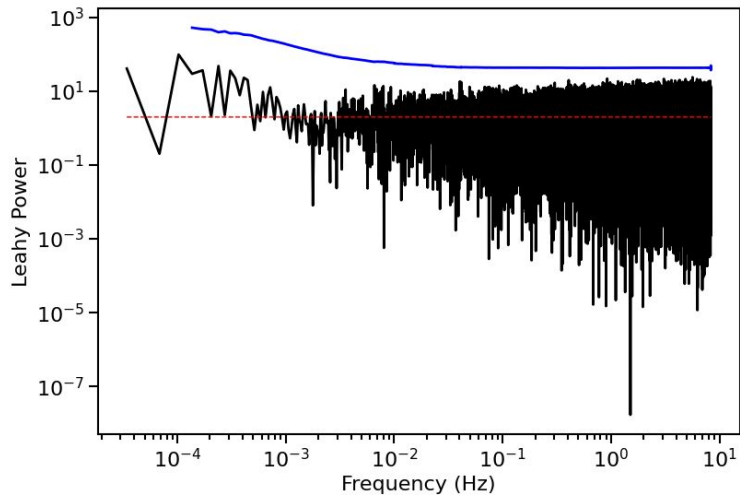


THE SEARCH FOR COHERENT SIGNALS: DPSPY



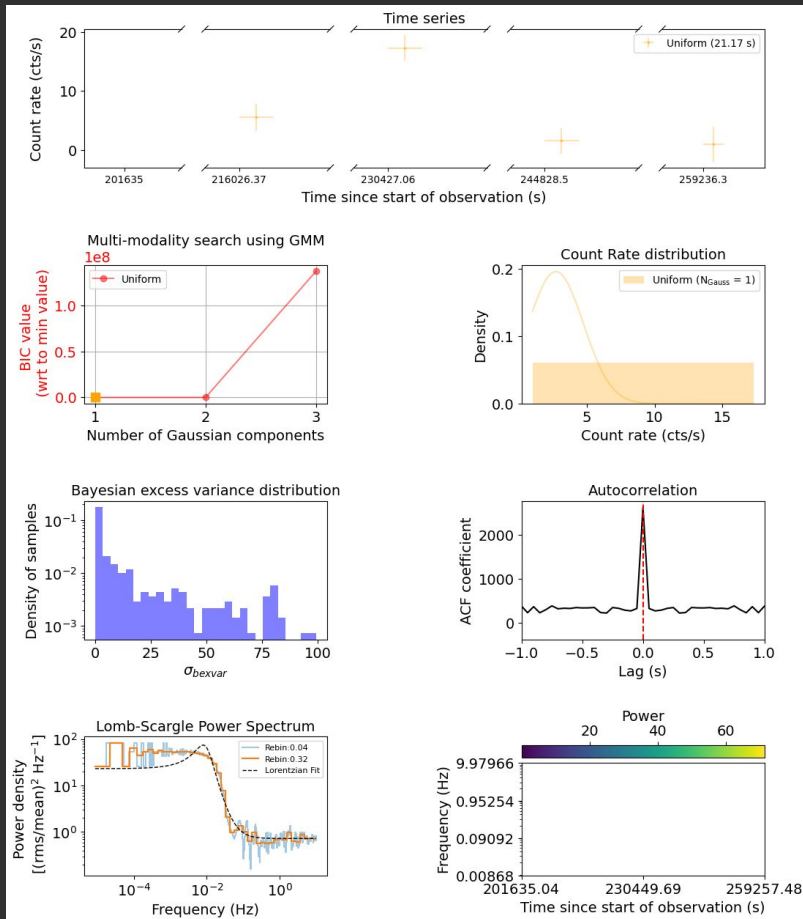
- Python version of the original Fortran dps tool (Israel&Stella 1996)
- [Stingray](#) to compute power spectrum
- Frequency-dependent detection threshold and peak significance computed by the original Fortran code
- Tested for X-ray and (some) optical data

THE SEARCH FOR COHERENT SIGNALS: DPSPY



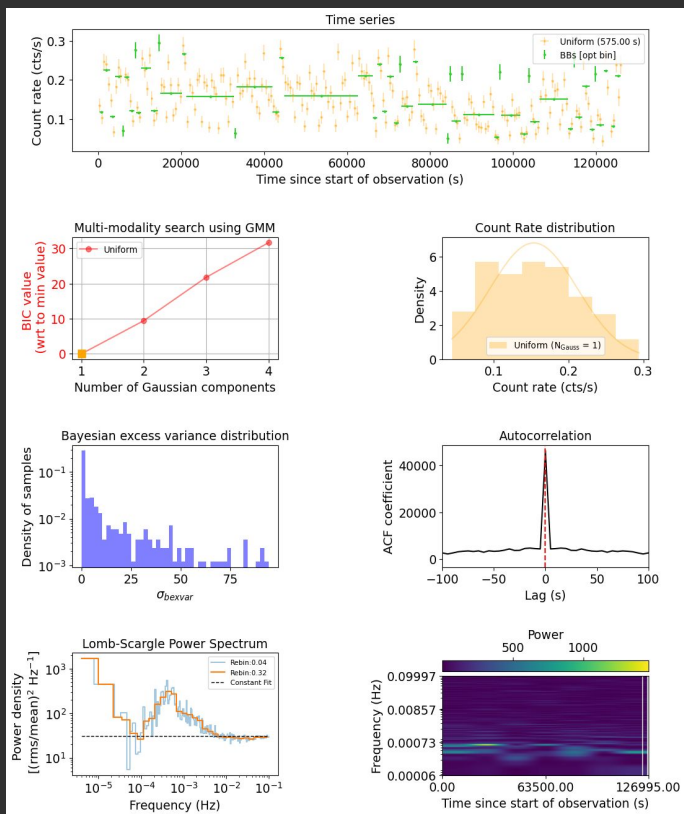
- Two plots when no peaks are detected:
 - PDS with detection threshold
 - PDS with upper limit on the PF of the potential signal

AVENUE: APERIODIC VARIABILITY EXPLORATION

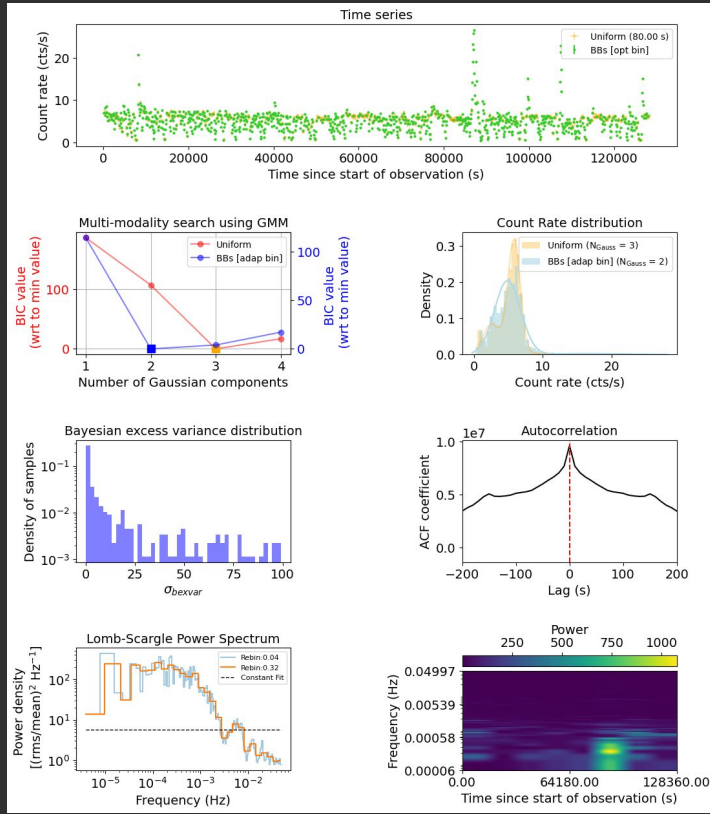


- **A standalone pipeline:**
 - Resamples and fits the time series
 - Computes Bayesian blocks
 - Computes variability statistics
 - Fits GMMs to assess the presence of bimodality (as seen in transitional MSPs).
 - Computes the Autocorrelation function, PDS and a dynamical PDS (for data without gaps)
- **Successfully tested on data from different X-ray instruments**

AVENUE: APERIODIC VARIABILITY EXPLORATION

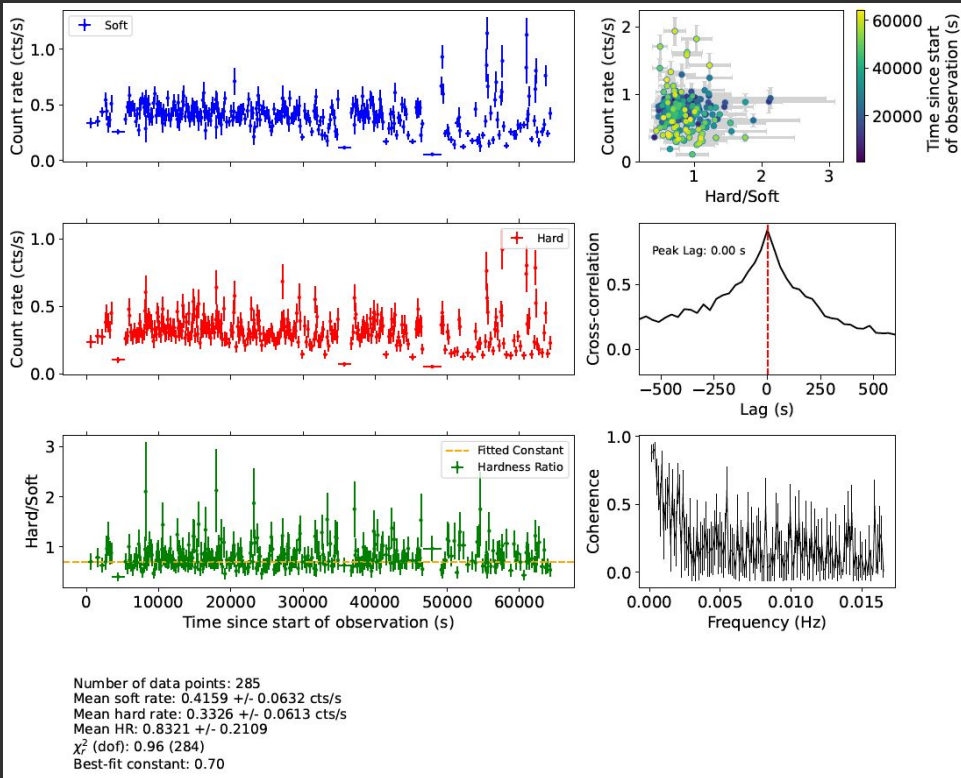


Able to detect **red noise** and **QPOs**
(both in the PS and dynamical PS)



Able to detect the hallmark **variability**
pattern of transitional MSPs in disk state

HR: AN HARDNESS RATIO TOOL



- Study of aperiodic variability vs. energy
- Time series in 2 bands and HR via adaptive rebinning
- HID, checking trends with time
- CCF, computes time lags
- Coherence, to measure linear correlation between time series (Vaughan & Nowak 1997)

MATCH, PYXIE AND MORE TO COME

match

A module to cross-match
the positions with other
catalogues

Pyxie



A Pyxspec-based module
for systematic and
automatic spectral analysis
for multiple sources



FFA-based signal search

An alternative to FFT for the
search of periodic signals

Search for bursts/transients

A module based on the
EXTraS pipeline and on
Bayesian Block algorithms

SUMMARY AND FUTURE

- The eROSITA catalogue is already the largest X-ray catalogue ever-released. **A systematic and automated approach to search for interesting sources is the only reasonable way to exploit the ever-increasing archives.**
- **eBANDERAS** is our **Python pipeline to exploit the eROSITA data**. The data reduction module can be used to simplify the procedure for both a single source and multiple sources in the FoV.
- The **data analysis modules** are written with a **mission-independent** approach and we have already tested them for other X-ray (and some optical) telescopes. More yet to come!
- eBANDERAS is just the beginning. Our **long-term goal** is to **provide the community a user-friendly package that works for as many missions as possible**. Possible next mission: Einstein Probe.

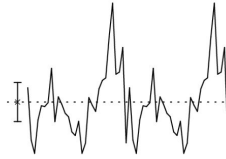
SO LONG AND...



Thanks for all the fish!

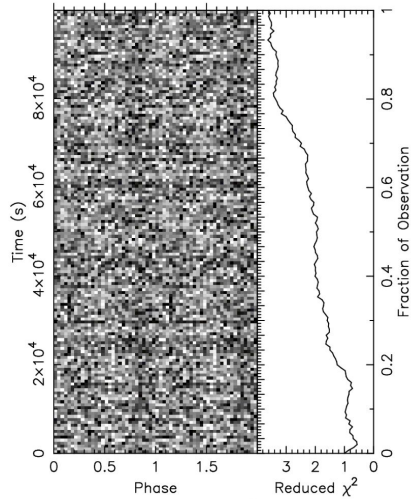
PRESTO

2 Pulses of Best Profile

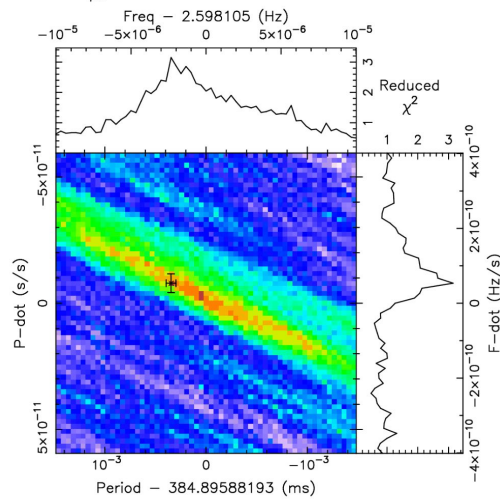


Candidate: ACCEL_Cand_10
 Telescope: eROSITA
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 Epoch_{bary} = 56770.48378118296
 T_{sample} = 0.005
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 Data Avg = 0.1354
 Data StdDev = 0.4398
 Profile Bins = 30
 Profile Avg = 9.011e+04
 Profile StdDev = 358.8

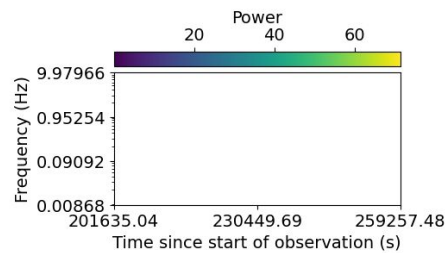
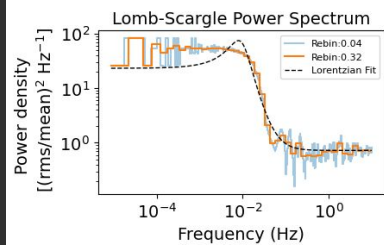
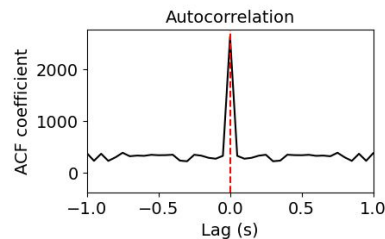
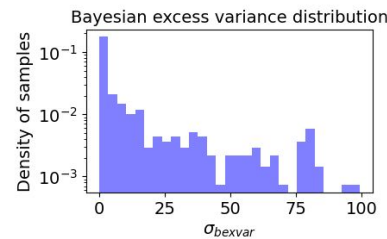
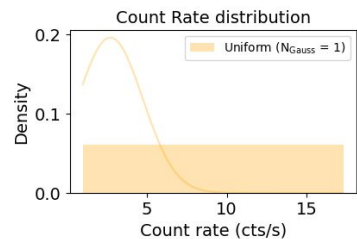
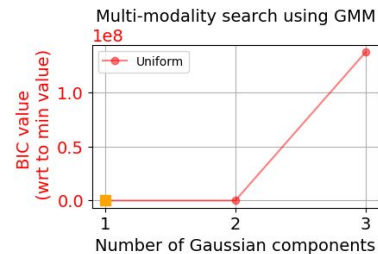
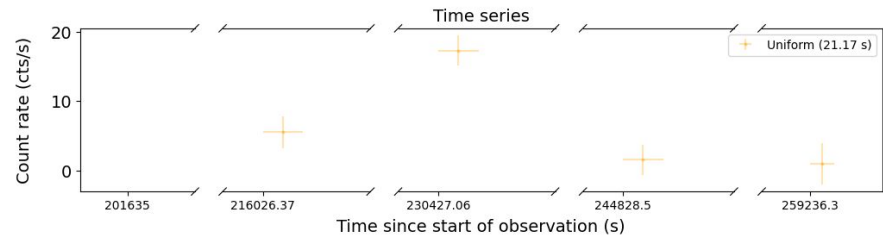
Search Information
 RA_{J2000} = 06:59:48.1830 DEC_{J2000} = 104:57:02.7450
 Best Fit Parameters
 DOF_{eff} = 25.37 $\chi^2_{\text{red}} = 3.602$ P(Noise) < 2.19e-09 (5.9 σ)
 Dispersion Measure (DM) = N/A
 P_{bary} (ms) = 384.896228(48)
 P_{bary} (s/s) = $-7.9(3.7) \times 10^{-12}$
 P_{topo} (s/s²) = N/A
 P_{bary} (s/s²) = $0.0(2.4) \times 10^{-16}$
 Binary Parameters
 e = N/A
 ω (rad) = N/A
 P_{orb} (s) = N/A
 $a_1 \sin(i)/c$ (s) = N/A
 T_{peri} = N/A

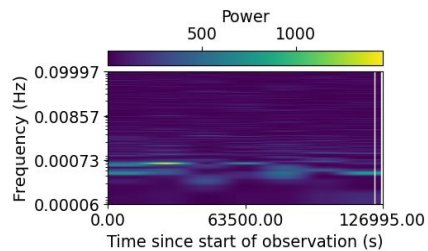
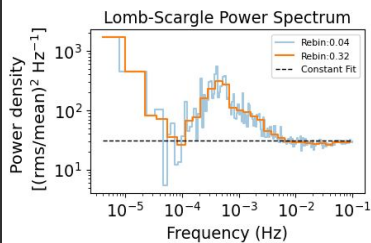
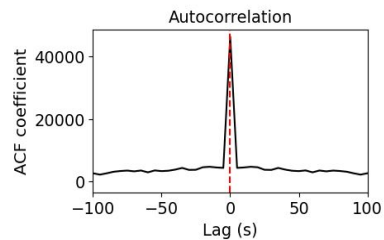
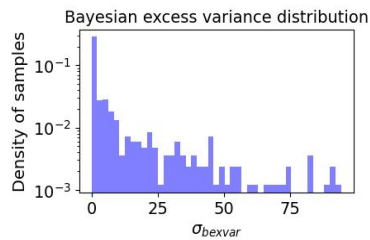
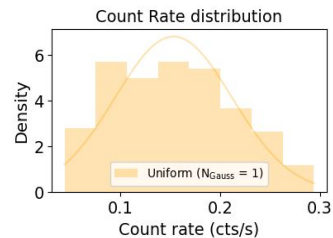
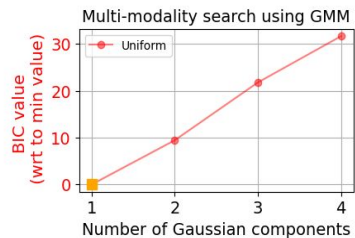
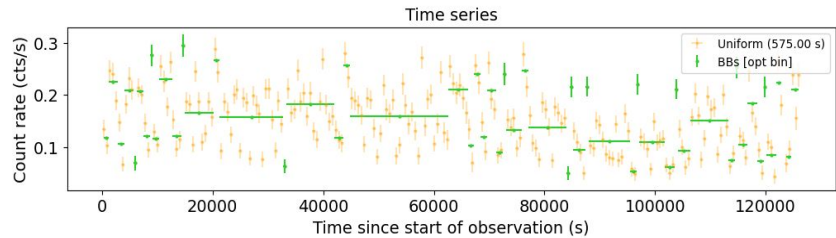


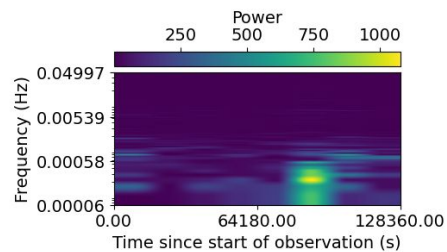
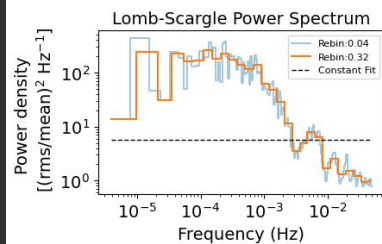
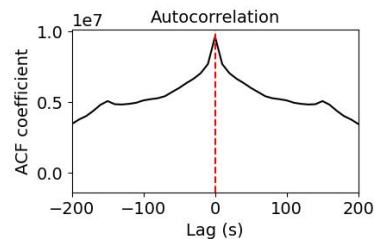
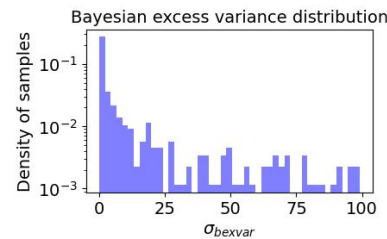
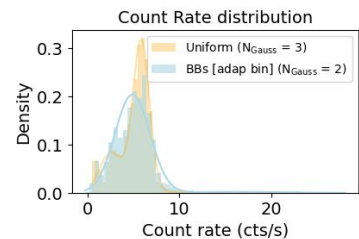
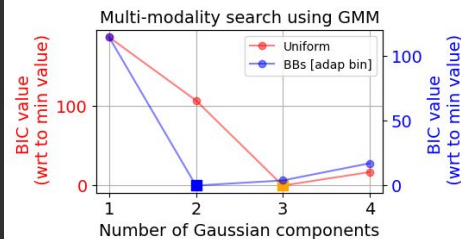
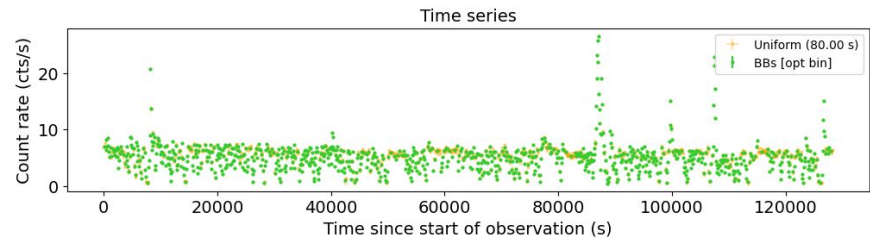
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parent 29-Nov-2023 01:00







BONUS TRACK

Banderas talking with Rosita

