DAXA and XGA

Open source Python modules
for transparent and reproducible X-ray Astronomy

Supervisors: Kathy Romer and David Turner
Jessica Pilling

UNIVERSITY OF SUSSEX

XMM2ATHENA

MICHIGAN STATE UNIVERSITY

Introducing XGA and DAXA

- Big thank you to David
- XGA and DAXA are both:
  - Open source Python modules
  - Fully documented
  - Provide a consistent interface for interaction with telescope specific software
- For completely transparent and reproducible science
- Making X-ray astronomy accessible to non-experts

XMM2ATHENA

Introducing XGA and DAXA

Acquiring and Cleaning

Generation and Analysis

Multi-mission dataset

DAXA - Democratising Archival X-ray Astronomy

- Assembles science ready, multi-mission X-ray datasets
- **Acquiring**
  - Can filter observations based on these criteria: position, time, obs id, target type, and object
  - Or entire telescope archives
  - Images and Exposure maps - for some telescopes
- **Cleaning** - for some telescopes
  - Removes bad events
  - Removes events from soft proton flares

XMM-Pointed
ROSAT-Pointed
eROSITA Calibration and Performance Verification
INTEGRAL-Pointed
Swift
Suzaku
Chandra
eROSITA All-Sky DR1
ROSAT All Sky Survey
NuStar Pointed
ASCA

DAXA - Democratising Archival X-ray Astronomy

Class

- attributes

+ methods()

Mission

- all_mission_instruments
- chosen_instruments
- fov
- all_obs_info

+ filter_on_obs_ids()
+ filter_on_positions()
+ filter_on_name()
+ filter_on_target_type()
+ show_allowed_target_types()
+ filter_on_time()
+ filter_on_positions_at_time()
+ download()

US

XMM2ATHENA

DAXA - Democratising Archival X-ray Astronomy


```
import daxa
from daxa.mission import XMMPointed, Chandra, NuSTARPointed
from astropy.coordinates import SkyCoord
```

```
# Coordinates for a source we want to acquire data for
gx_coords = SkyCoord(186.6565, -62.7704, frame='fk5', unit=deg)

# X-ray missions we want data from
xt = XMMPointed()
nt = NuSTARPointed()
ct = Chandra()
```

```
nt.filter_on_positions(gx_coords, Quantity(30, 'arcmin'))
ct.filter_on_positions(gx_coords, Quantity(30, 'arcmin'))
xt.filter_on_positions(gx_coords, Quantity(30, 'arcmin'))
```

Searching for observations at a position in the sky by XMM, NuStar, and Chandra

DAXA - Democratising Archival X-ray Astronomy

Mission 1

Mission 2

⋮

Archive

- missions
- archive_path
- process_success
- process_errors
- process_logs
- source_regions

\+ info()

Assemble(Archive)

Clean(Archive)

US

XMM2ATHENA

XGA - X-ray: Generate and Analyse

- Provide the RA, DEC of a source/ sample of sources
- XGA gets relevant data for each source from your current dataset
- **Generates** images, exposure maps, ratemaps, spectra, and light curves
- Performs further **analyses**:
  - Variability Assessment
  - Temperature
  - Gas Density
  - Surface Brightness
  - Hydrostatic Mass

Generating and Analysing

XMM

eROSITA

XGA - X-ray: Generate and Analyse

Provide a science ready archive of eventlists

Provide region files

Supply the coordinates of the source(s) you want to investigate

Source/ Sample

- ra
- dec
- redshift
- nH
- name
- obs_ids
- instruments
- telescopes

+ get_source_mask()
+ within_region()
+ get_radius()
+ get_products()

*Other sources are available

Star

- distance
- proper_motion
- point_radius

GalaxyCluster

- r500
- richness

+ get_temperature()
+ get_3d_temp_profiles()
+ get_density_profiles()
+ get_hydrostatic_mass_profiles()

US XMM2ATHENA

XGA - X-ray: Generate and Analyse

Source

- •
- •
- •

evtool_image(Source)

expmap(Source)

srctool_spectrum(Source)

Products

- path
- obs_id
- instrument
- telescope
- gen_cmd
- stdout_str
- stderr_str
- energy_bounds

\+ view()

\+ save_view()

US

XMM2ATHENA

XGA - X-ray: Generate and Analyse

Source

evtool_image(Source)

expmap(Source)

srctool_spectrum(Source)

Image and ExpMap

- regions
- smoothed
- data
- radec_wcs

+ coord_conv
+ get_count
+ get_exp

US

XMM2ATHENA

XGA - X-ray: Generate and Analyse

Source

- evtool_image(Source)
- expmap(Source)
- srctool_spectrum(Source)

Spectrum

- rmf_path
- arf_path
- b_path
- b_rmf_path
- b_arf_path
- central_coord
- inn_rad
- out_rad
- grouped
- min_counts
- min_snr
- region
- counts

US XMM2ATHENA

XGA - X-ray: Generate and Analyse


```
from astropy.units import Quantity

import xga
from xga.sources import GalaxyCluster
from xga.generate.esass import evtool_image
```

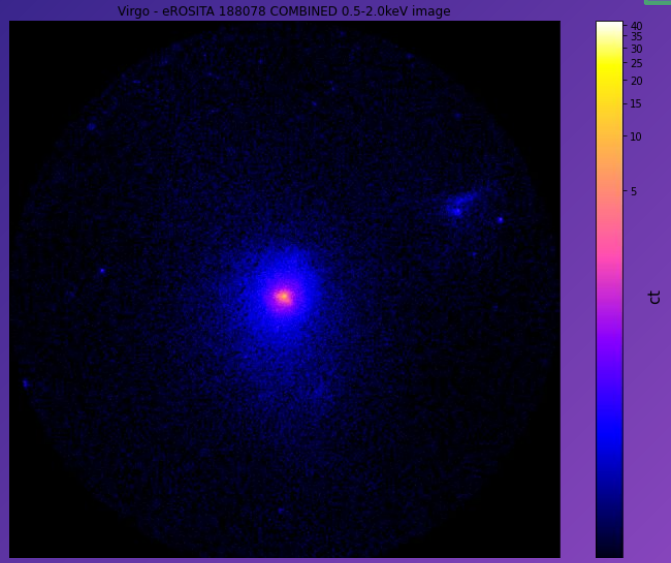
```
src = GalaxyCluster(187.70527, 12.39243, 0.00377,
                    'Virgo', telescope='erosita',
                    search_distance={'erosita': Quantity(3, 'deg')},
                    r500=Quantity(500, 'kpc'), use_peak=False)
```

```
evtool_image(src)
```

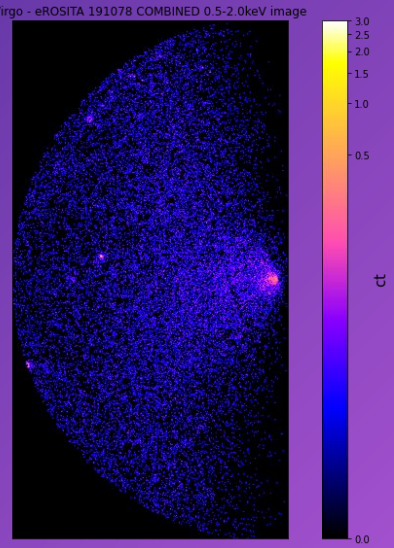
```
images = src.get_images(telescope='erosita')

for img in images:
    mask = src.get_mask('r500', obs_id=img.obs_id, telescope='erosita')[0]
    img.view(mask=mask)
```

XGA - X-ray: Generate and Analyse

500kpc area centred on Virgo



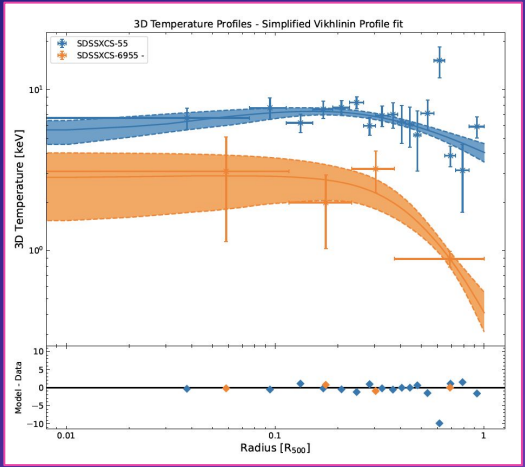
500kpc area centred on Virgo - appearing at the edge of this observation




```
images = src.get_images(telescope='erosita')

for img in images:
    mask = src.get_mask('r500', obs_id=img.obs_id, telescope='erosita')[0]
    img.view(mask=mask)
```

XMM2ATHENA

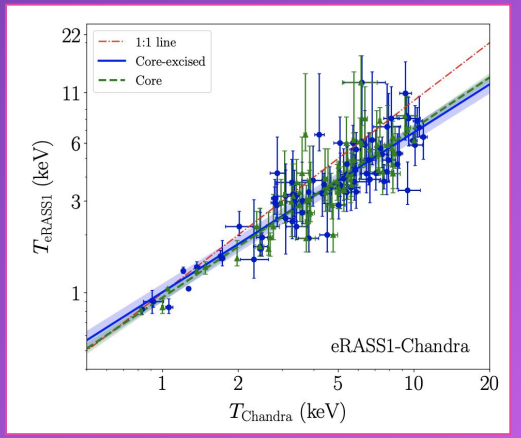
XGA - X-ray: Generate and Analyse



Turner et al., (in prep)

- X-ray temperatures of galaxy clusters can be used for:
  - Measuring Hydrostatic masses
  - Cross-calibration between telescopes
- We verify XGA's functionality by comparing our eROSITA measured temperatures to Migkas et al. 2024

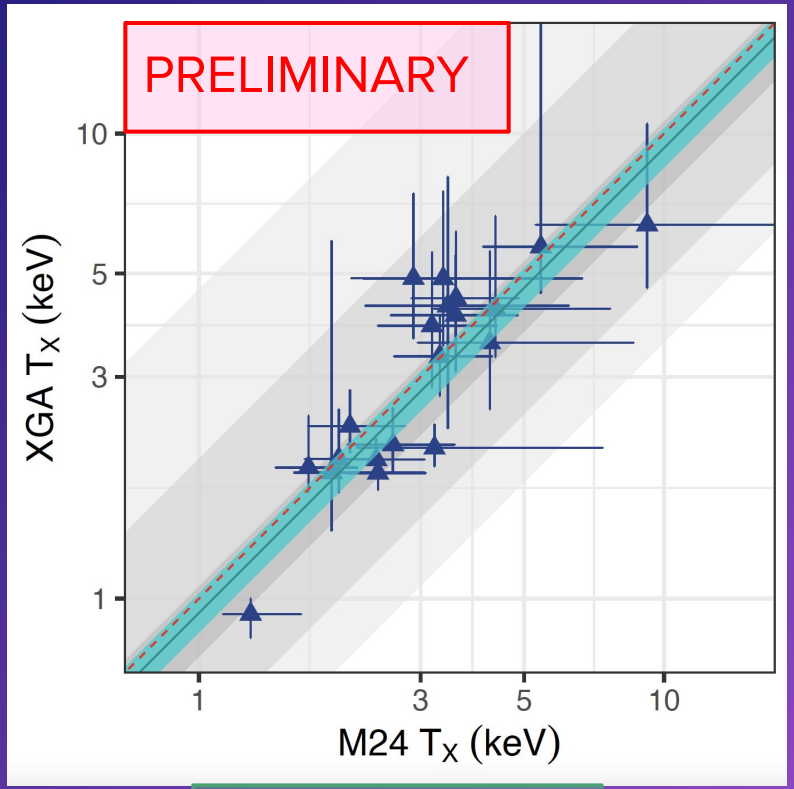
***See Paul Giles' poster for more verifications of XGA analysis**



Migkas et al., 2024

XMM2ATHENA

Measuring Cluster Temperatures with eROSITA



Credit: Paul Giles

- eROSITA temperatures have a 7% offset with Migkas et al. 2024
- We use eRASS:1 r500s
- XGA treats the background by subtracting an annulus from the source spectra - compared to modelling it as in Migkas et al. 2024

XMM2ATHENA

Future Plans

- ❑ Make archives version controlled
- ❑ Adding Athena, XRISM, LEM, AXIS

- ❑ XGA v1 release - includes eROSITA support
- ❑ Adding more analysis options for different X-ray sources
- ❑ Adding background modelling
- ❑ Adding other telescopes

Main aim is to make exploitation of the X-ray archive as accessible as possible.
This will set us up nicely for the launches of new missions.

Thank you for listening

XGA and DAXA are open source Python modules for transparent and reproducible X-ray astronomy.

Consistent interfaces encourage multi-mission analysis, and full exploitation of the X-ray archive.

Visit https://github.com/DavidT3 for the repositories, and links to tutorials.

Contact David at: turne540@msu.edu or Jessica at: J.Pilling@sussex.ac.uk

See Paul's poster: Using XGA to automate the hydrostatic mass analysis for large samples of galaxy clusters

US

XMM2ATHENA

References

Migkas, K. et al. (Jan. 2024). “The SRG/eROSITA All-Sky Survey: SRG/eROSITA

cross-calibration with Chandra and XMM-Newton using galaxy cluster gas

temperatures”. In: arXiv e-prints, arXiv:2401.17297, arXiv:2401.17297. doi:

10.48550/arXiv.2401.17297. arXiv: 2401.17297 [astro-ph.CO].