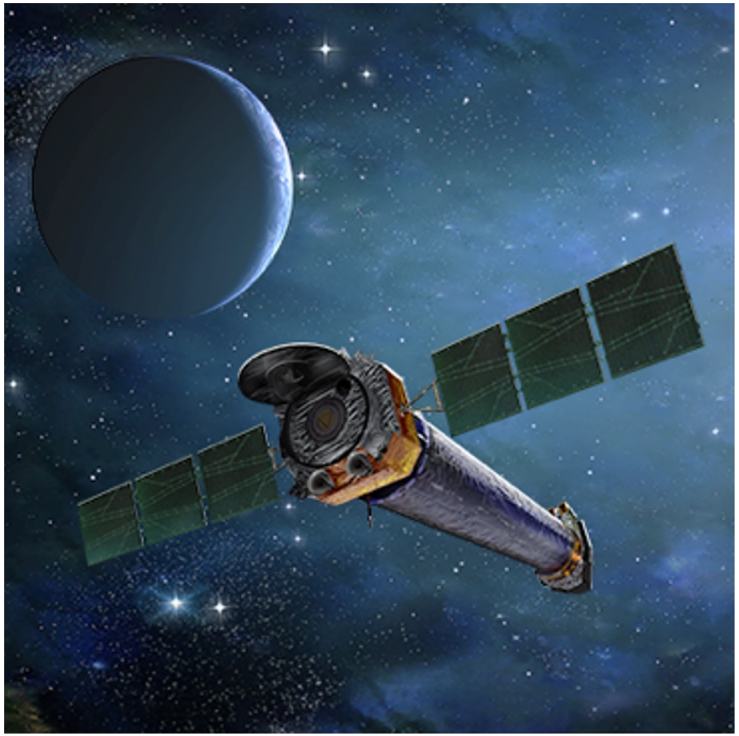
Advancing X-ray Background Modeling for Enhanced Data Analysis

Taweewat Somboonpanyakul
Postdoctoral Researcher at Stanford University

with Steve Allen, Adam Mantz, Anthony Flores,
Justin Myles, Glenn Morris

Outline

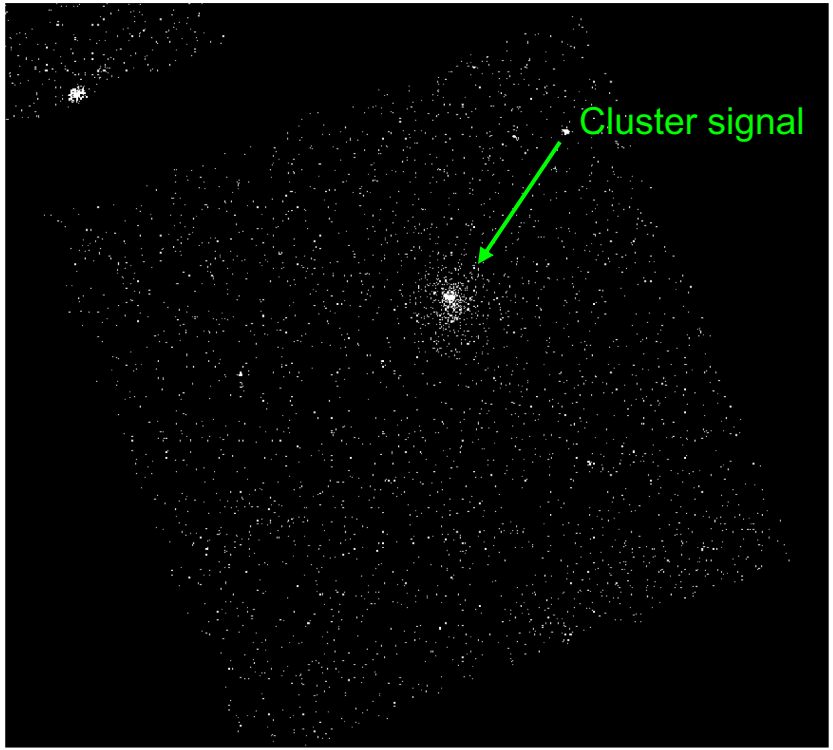
- Why do we care about X-ray background?
- X-ray Background Components
- What has been done so far?
- What are we doing?
- Benefits of the new method
- Lessons learned from this



Chandra X-ray Telescope

Why do we care about X-ray background?

- It is especially important for us since our focus is on faint/extended sources where the X-ray background is comparable to the science signal.



X-ray Background Components

The most important for Chandra!

Sky

Foreground

Hot gas emission from our own Milky Way Halo and Local Hot Bubble

Unresolved Pt Source

Unresolved point sources we could not mask in the field

Particle-induced

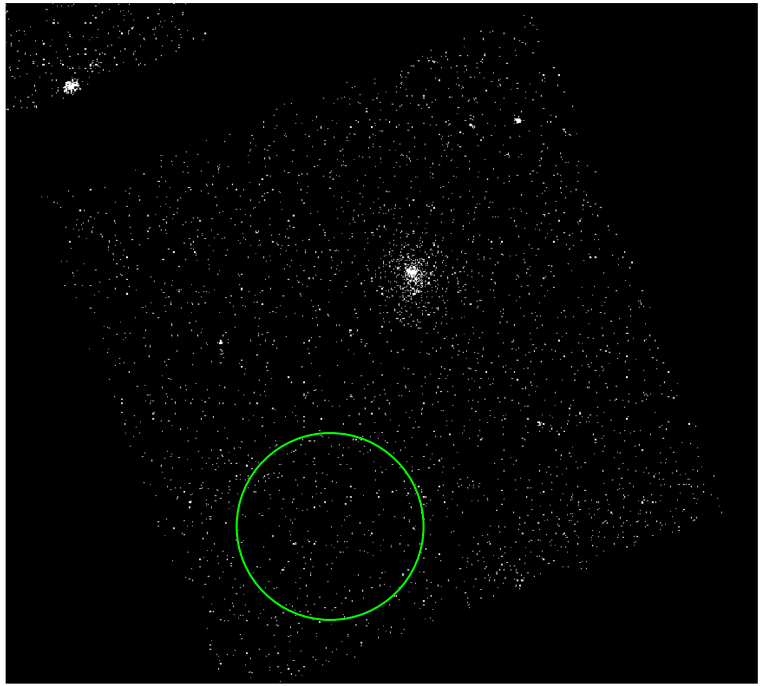
Cosmic-ray

Direct hit, secondary particles, fluorescence lines, temporal variation (based on solar activity)

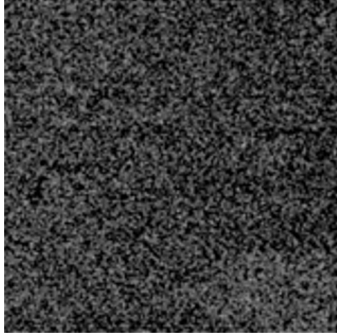
What has been done so far?

If there are nearby regions which are free from the source emission

- We use those on-chip regions as background for subtraction
- **Issue**:
  - A lot of the time, we do not have enough coverage for these regions, especially for nearby or extended sources (i.e. ICM from galaxy clusters)



What has been done so far?



If there is not any regions with no source emission,

- We could use blank-sky background (combined sky background with point sources removed) or stowed background (out of focal position of the telescope) for subtraction.
- **Issue:**
  - Blank-sky: Sky background is an average in all directions, including foreground and unresolved AGN components
  - Stowed: Only include particle-induced events

Challenges with Previous Methods:

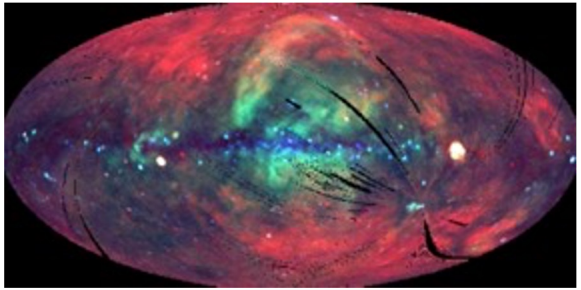
- **Limited Statistics**: Short exposure time on the chip and smaller regions in the blank sky result in small statistics
- **Inaccurate Components**: Difficulty in correctly identifying all components, including the soft foreground and undetected AGN population
- **Loss of Resolution**: The use of modified cstat with background subtraction requires at least 1 count per bin, leading to a reduction in resolution.

What are we doing?

X-ray Background Modeling

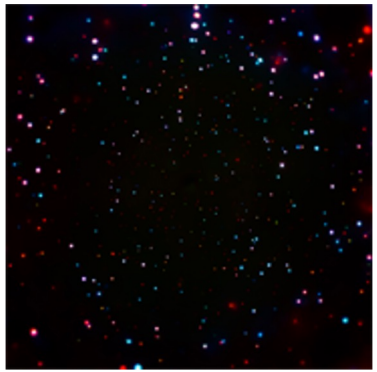
- Model all the X-ray background components based on the information that we have, including

Foreground



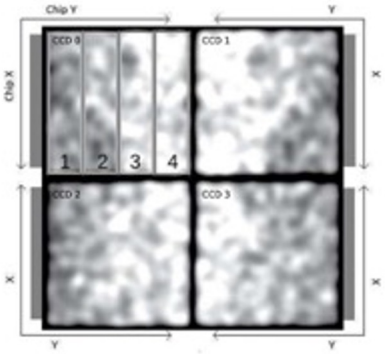
ROSAT soft X-ray background

Unresolved Point Sources



Chandra Deep Field South

Particle-induced



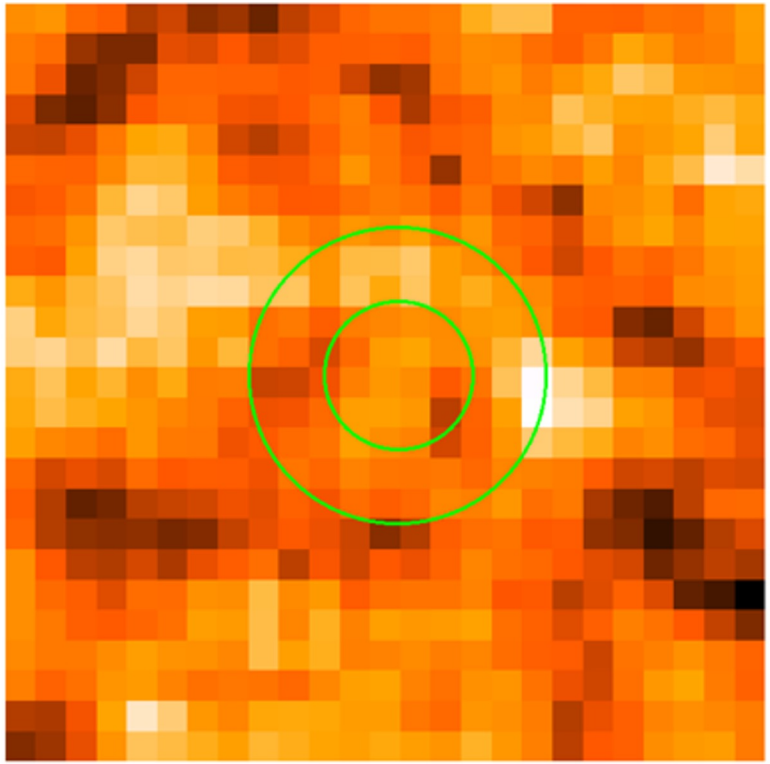
Bartalucci+2014

What are we doing?

Foreground

- Fitting ROSAT Spectra to 3 temperature APEC models to represent the foreground component

ROSAT Image

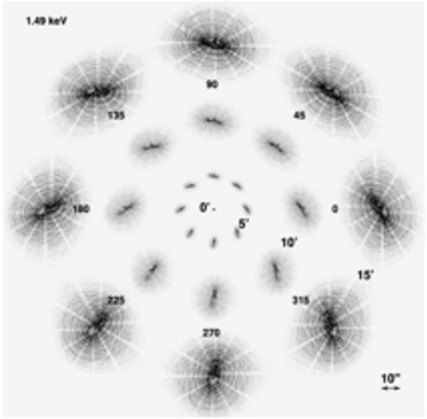


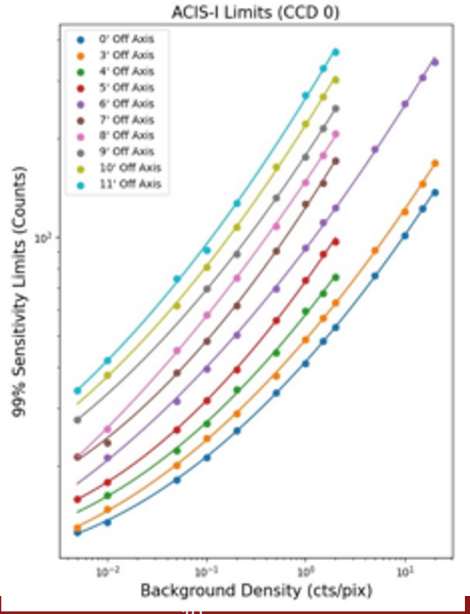
Note: XSPEC Model for foreground component: `apec + phabs*(apec + apec)`

What are we doing?

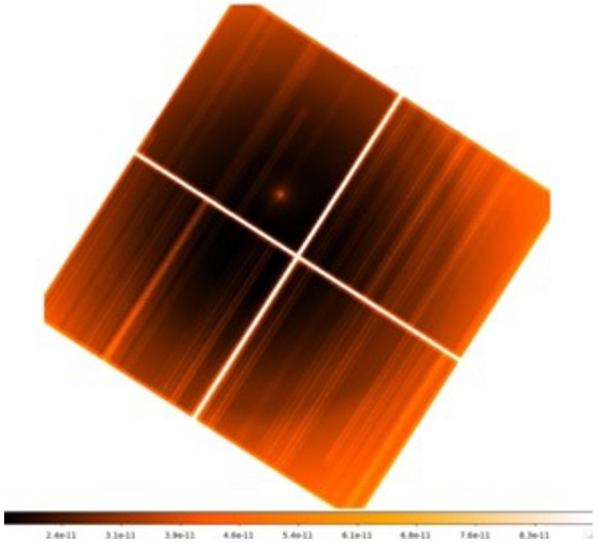
Unresolved Pt Source

- Simulate pt sources to create 99% sensitivity limit based on off-axis angle and background density
- Calculate the brightness of unresolved components





Unresolved AGN normalization map



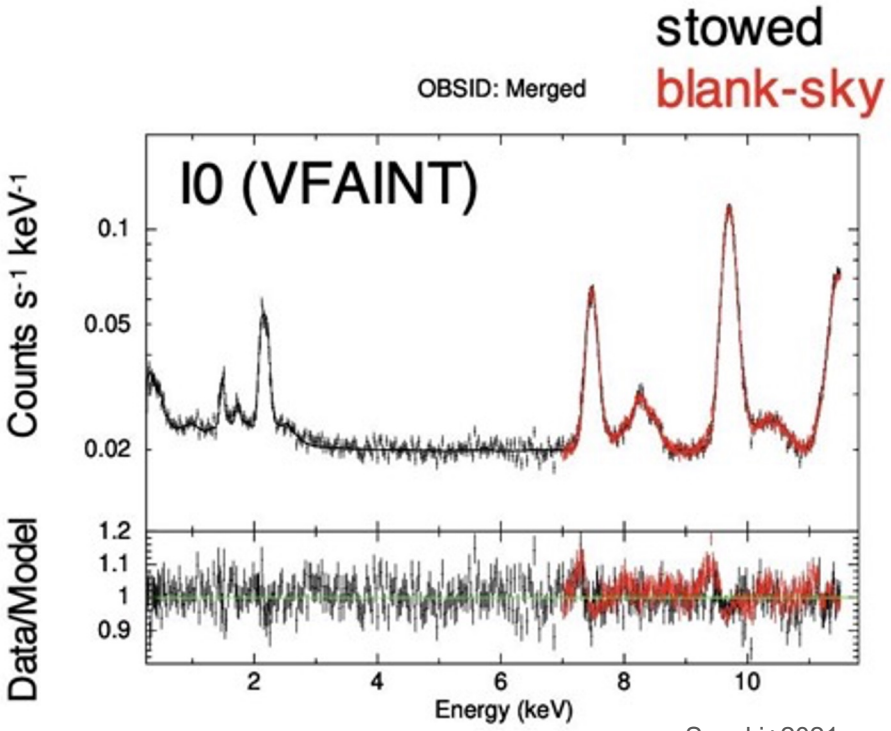
XLF - (Miyaji+2015)

What are we doing?

The spectra are modeled with combination of instrumental lines (Al, Si, Ni, and Au) and continuum components.

Particle-induced

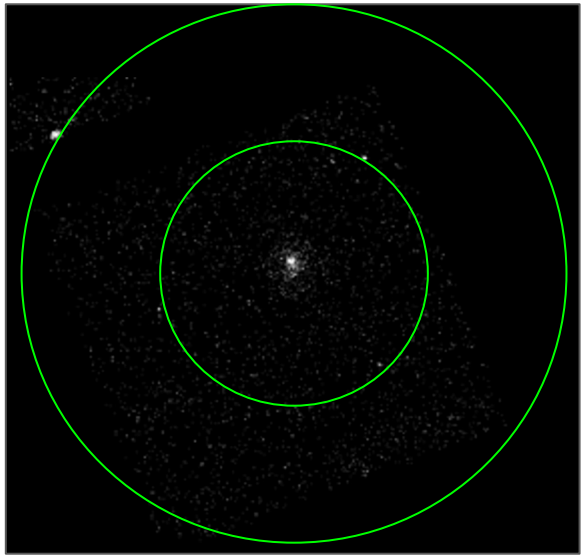
- Chandra have large observations in stowed positions.
- This background is modeled and made available at Suzuki+2021.



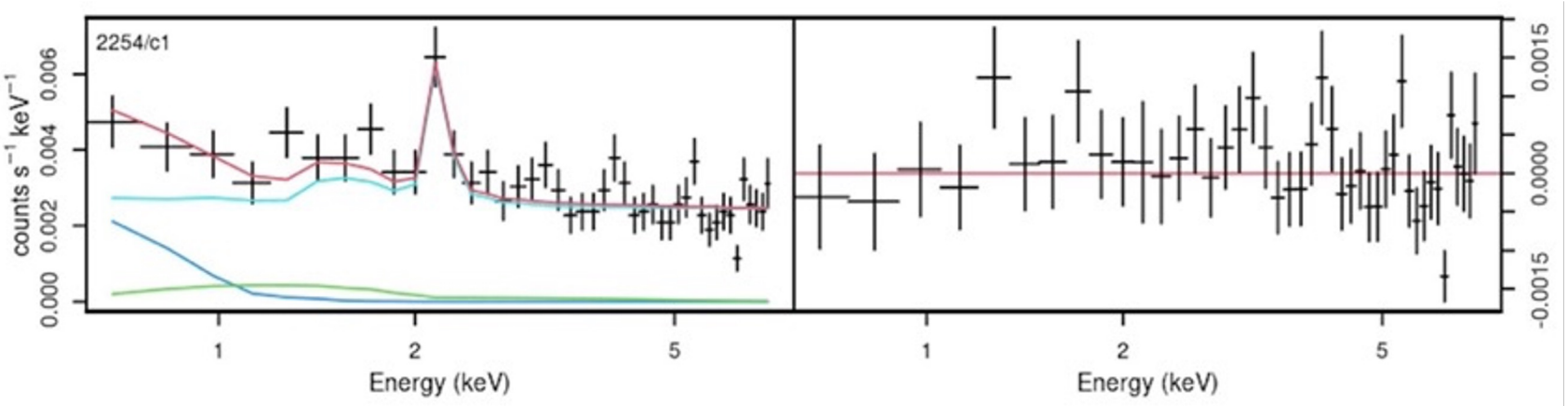
Suzuki+2021

Spectral Analysis of Off-cluster Regions

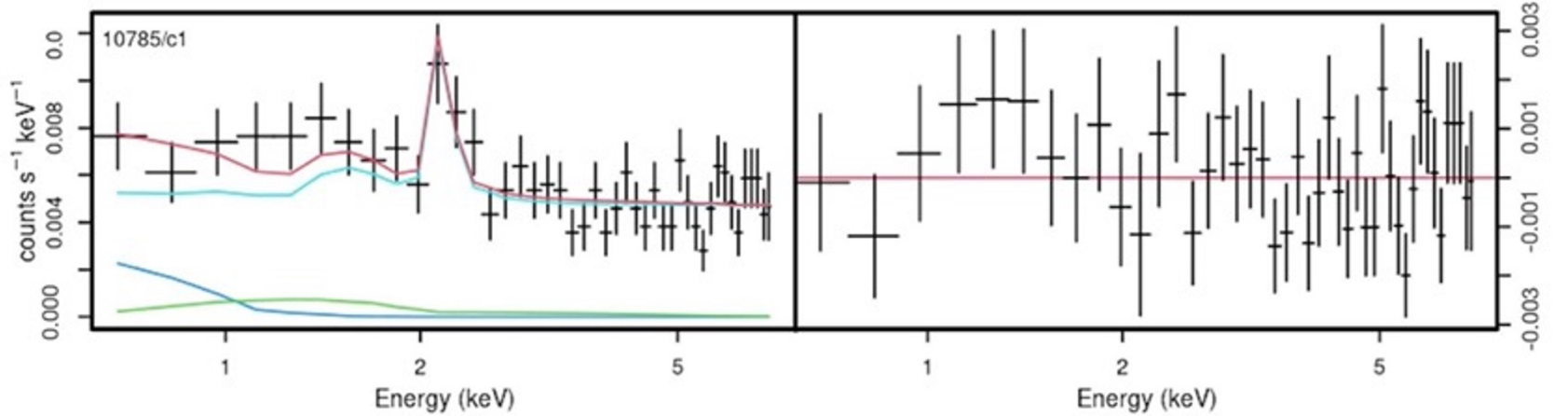
- Combining these three components to create comprehensive background models for spectral analyses.
- We test the model with off-cluster regions (regions without any cluster signals) to evaluate its performance.



ACIS-I

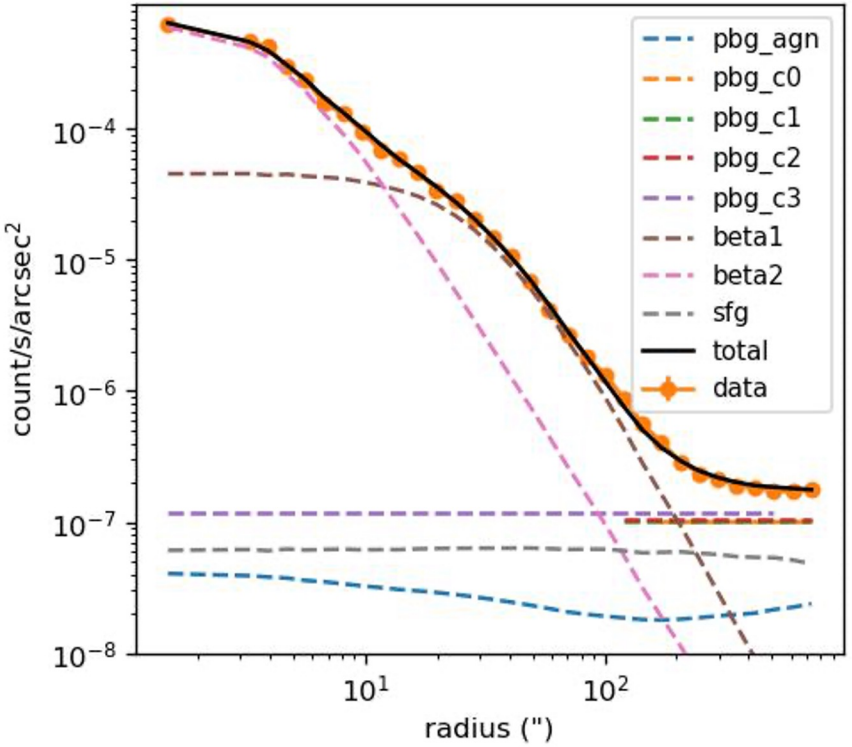


ACIS-I

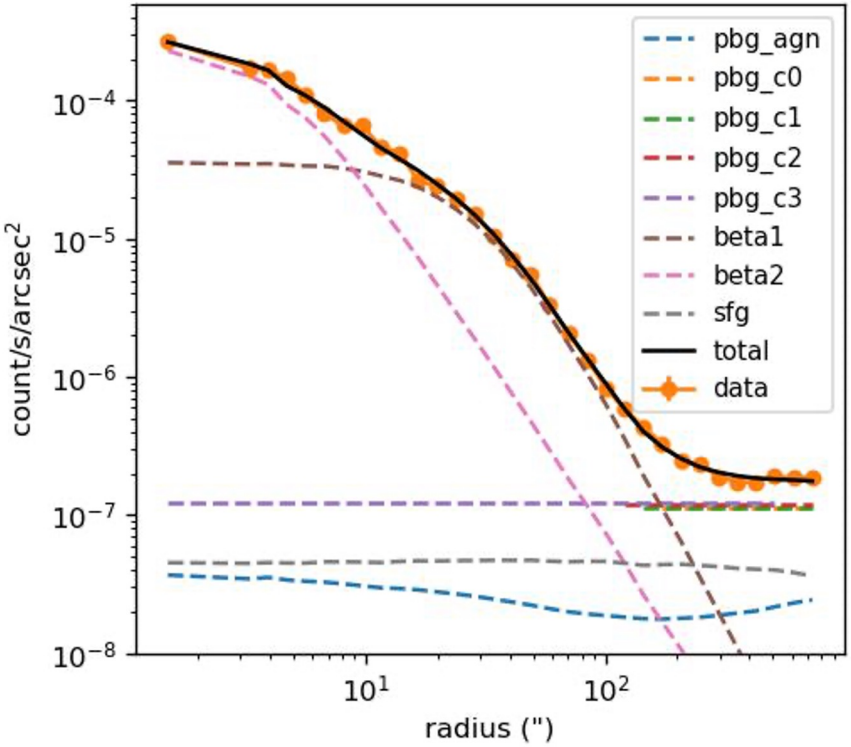


QPB: particle-induced, **SFG**: soft foreground, **AGN**: unresolved pt sources, **Total**: combined

macs0159.8-0849 (z=0.404)



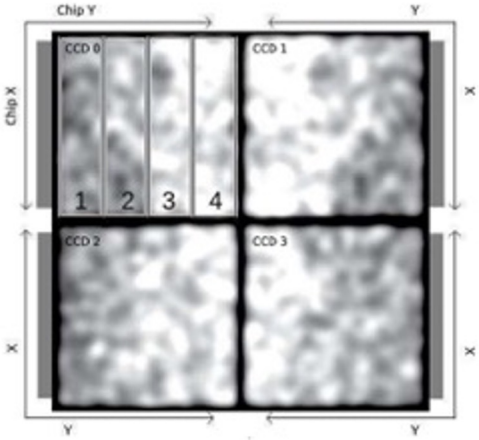
macs0011.7-1523 (z=0.378)



Conclusion

- This method had proven to be surprisingly effective in studying extended objects at large radii or faint objects.
- Background modeling is important in future X-ray missions, as it plays a critical role in obtaining reliable results.
- This approach is not limited to *Chandra*; other missions like *XRISM*, with even smaller field of view (FOV), will require the use of this method to an even greater extent.

ACIS-I photon image of the stowed dataset



Bartalucci+2014