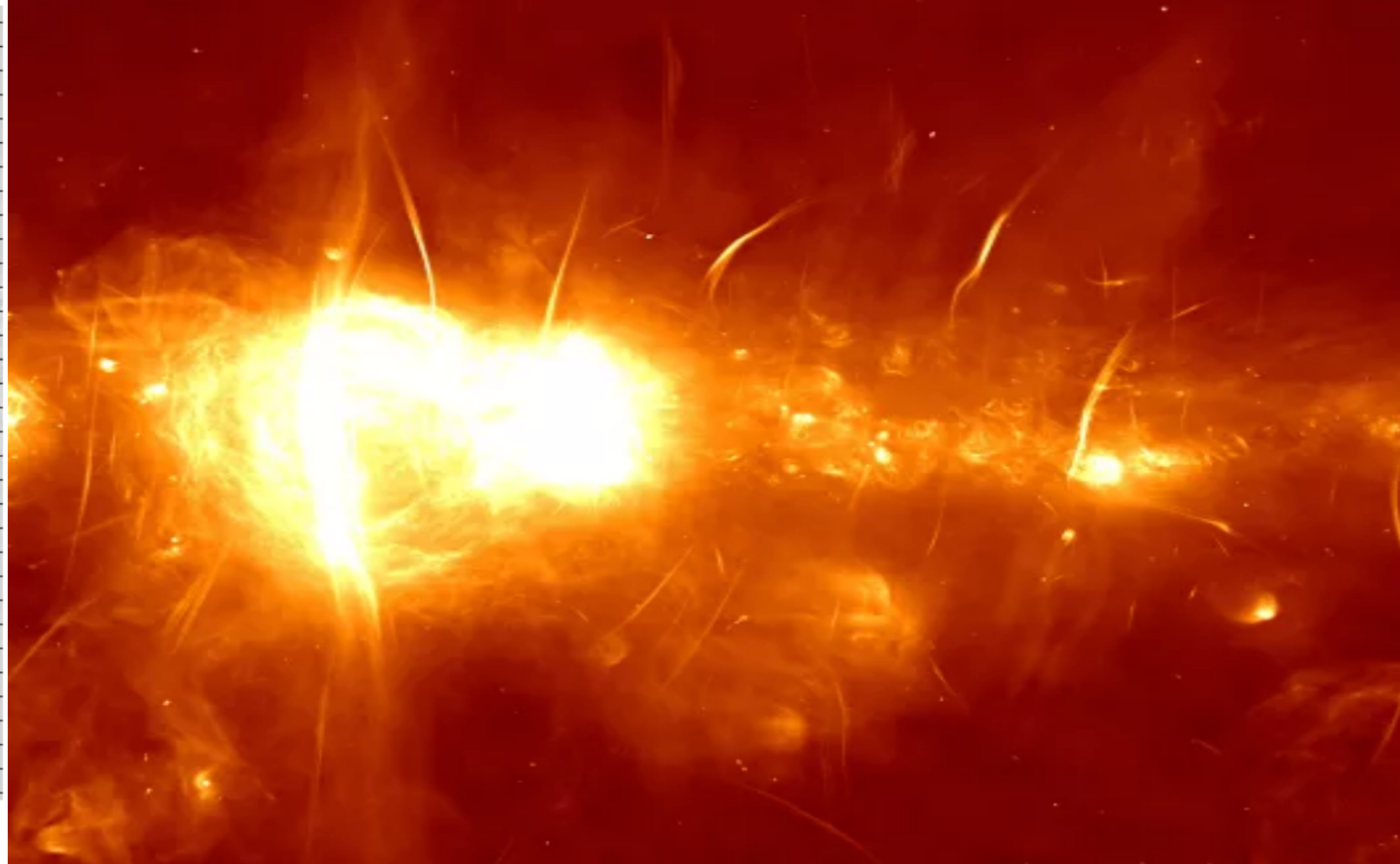
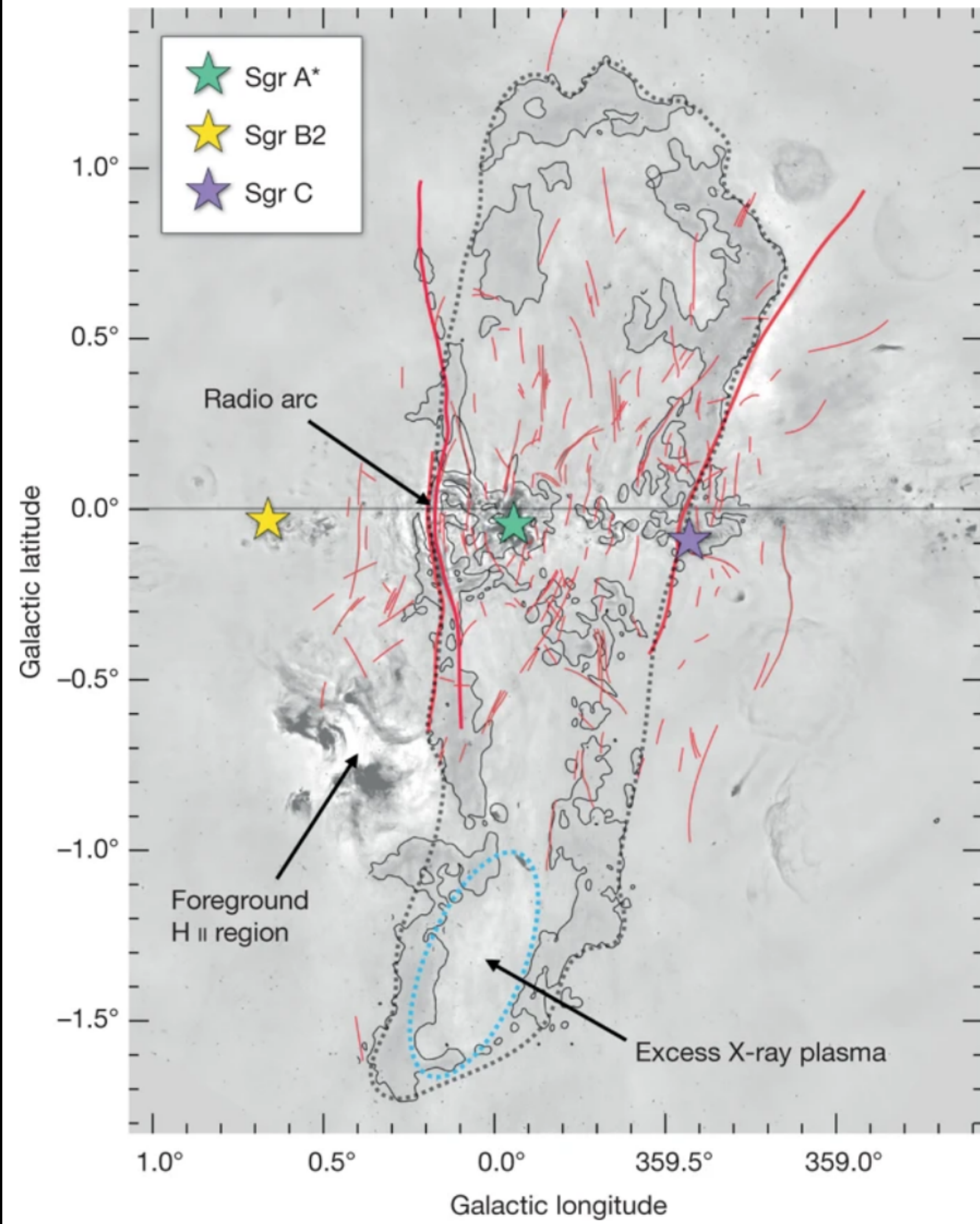


Fine Morphology of Galactic Center Non-thermal Filaments Revealed by Deep Chandra Observation

Shuo Zhang
Einstein Fellow
Boston University

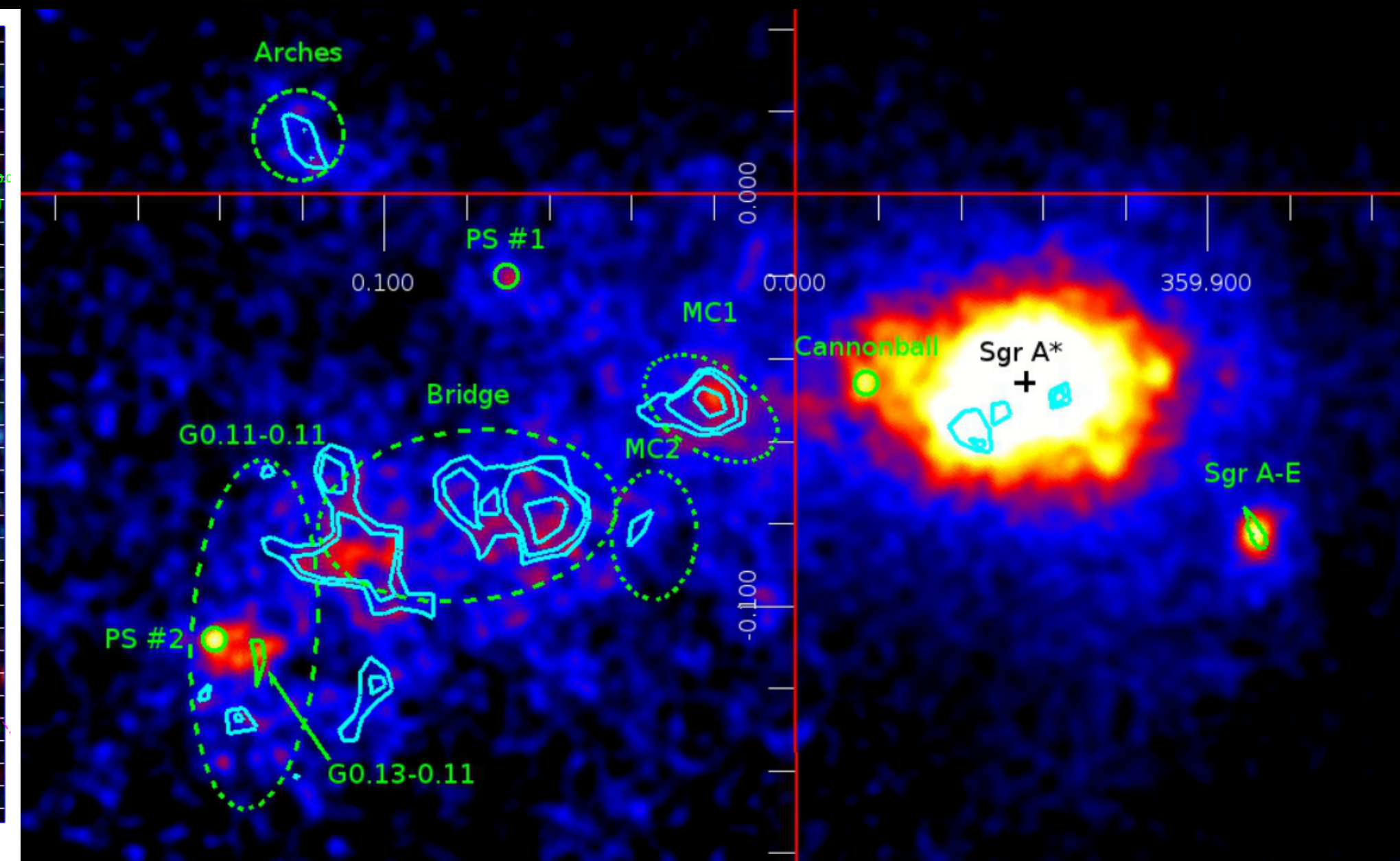
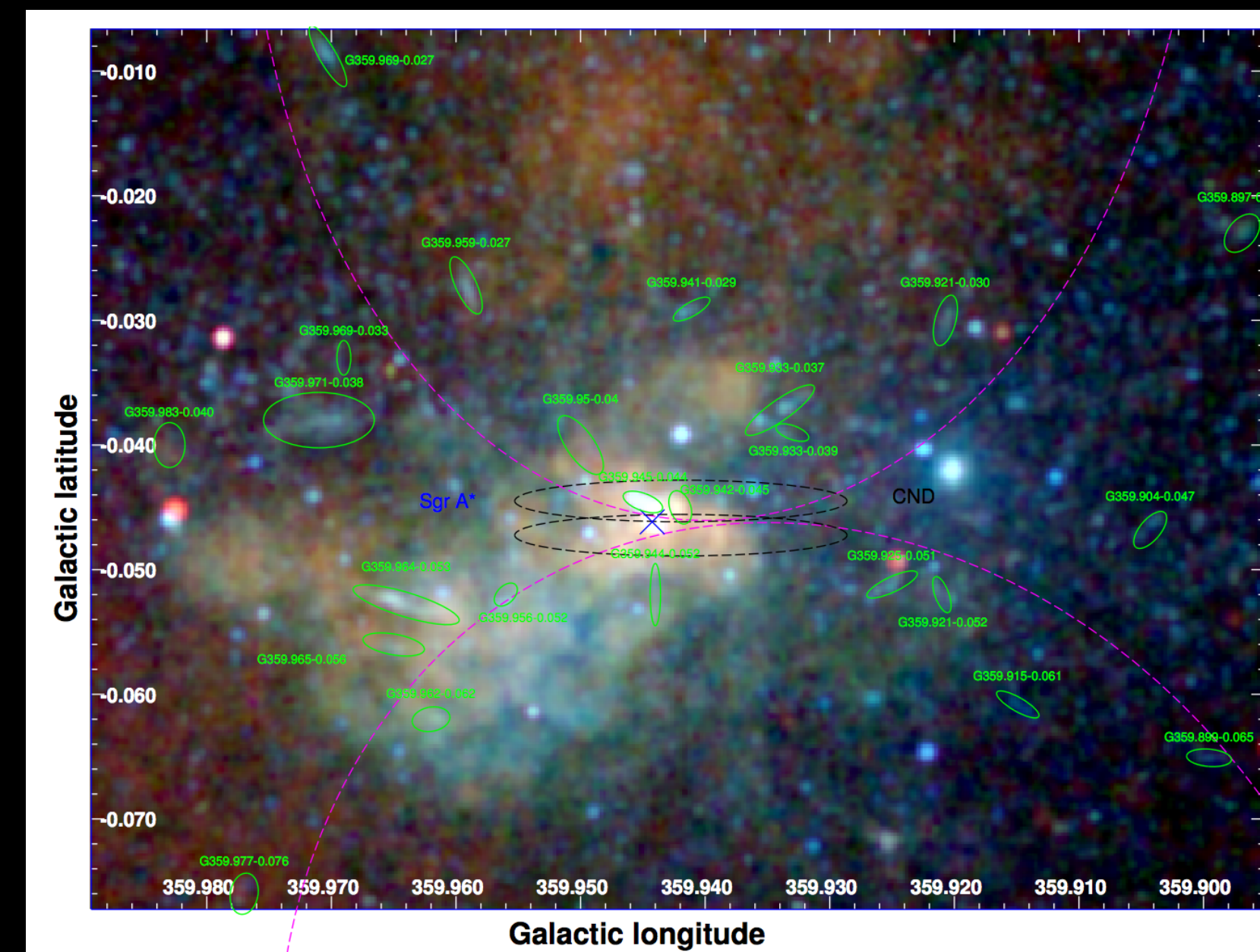
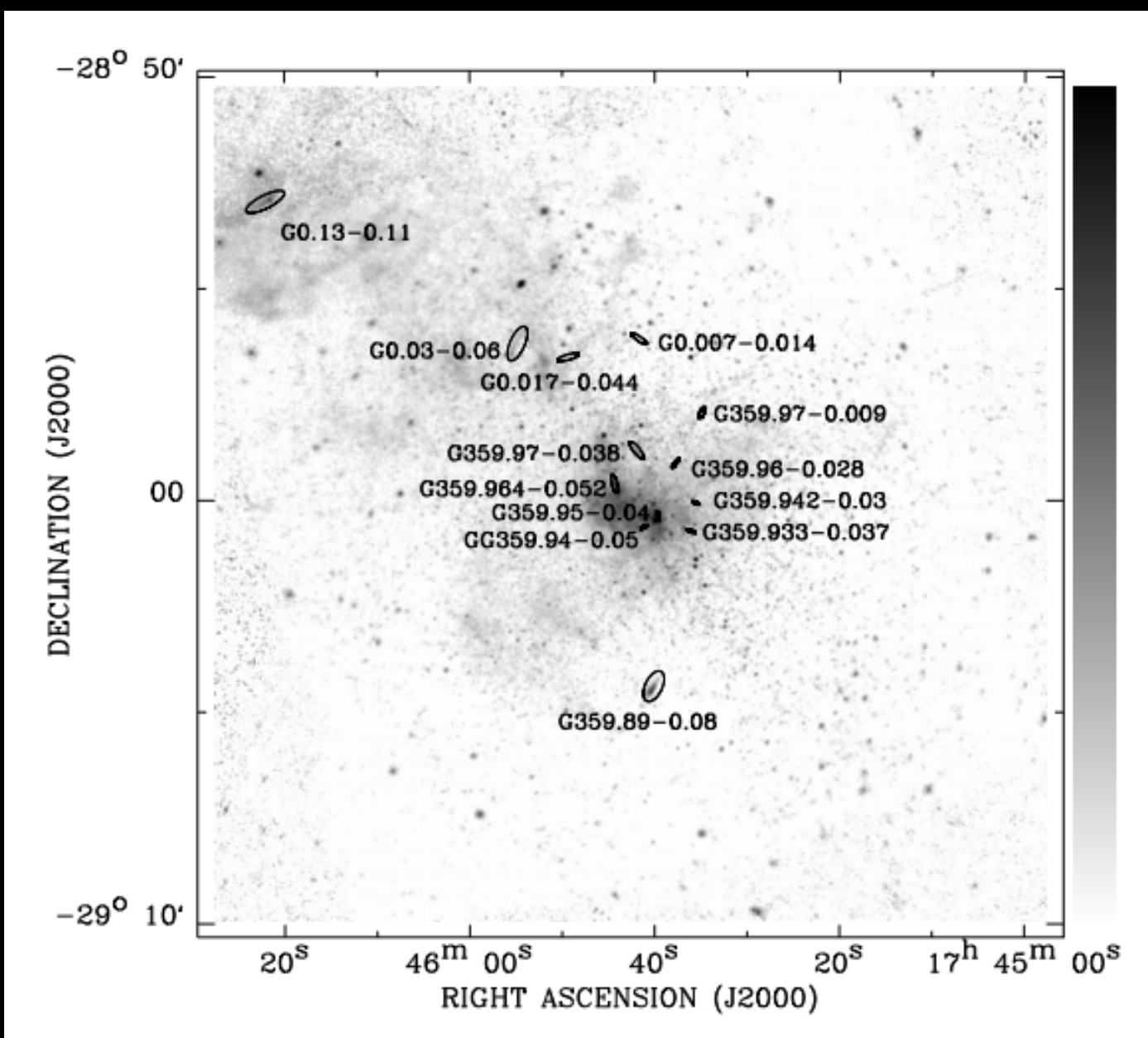


**Meerkat revealed >100 radio filaments within 430 pc of Galactic Center
Tracing locally+globally **ordered magnetic field** and **relativistic particles****



**MeerKAT shows association btw filaments and radio/X-ray bubbles
 The event which generates the bubbles could be source of the relativistic particles
 that illuminate radio filaments**

Survey of Galactic Center X-ray Filaments using Chandra, XMM-Newton and NuSTAR

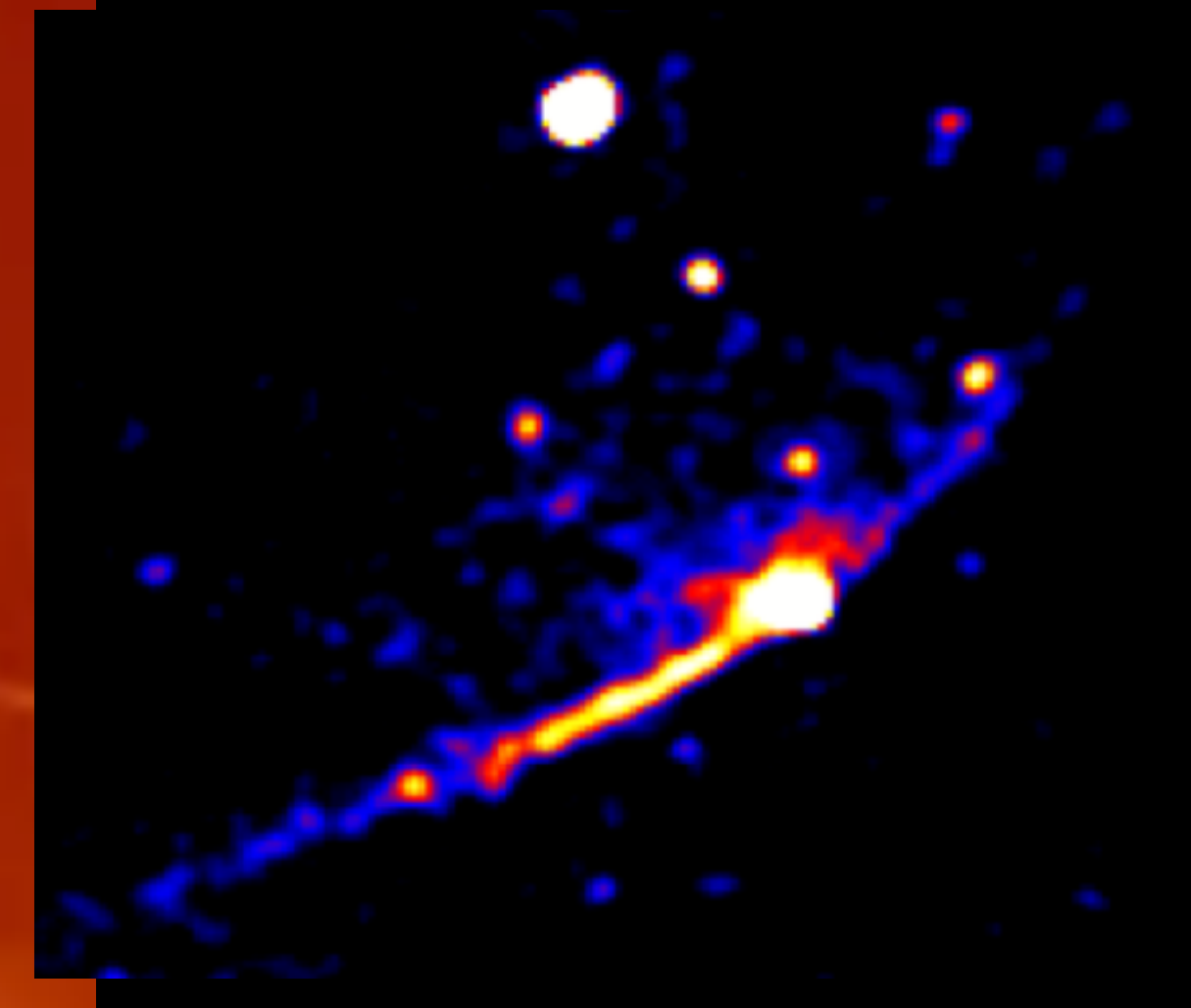


17 filaments by Chandra
Johnson, Dong & Wang 2009

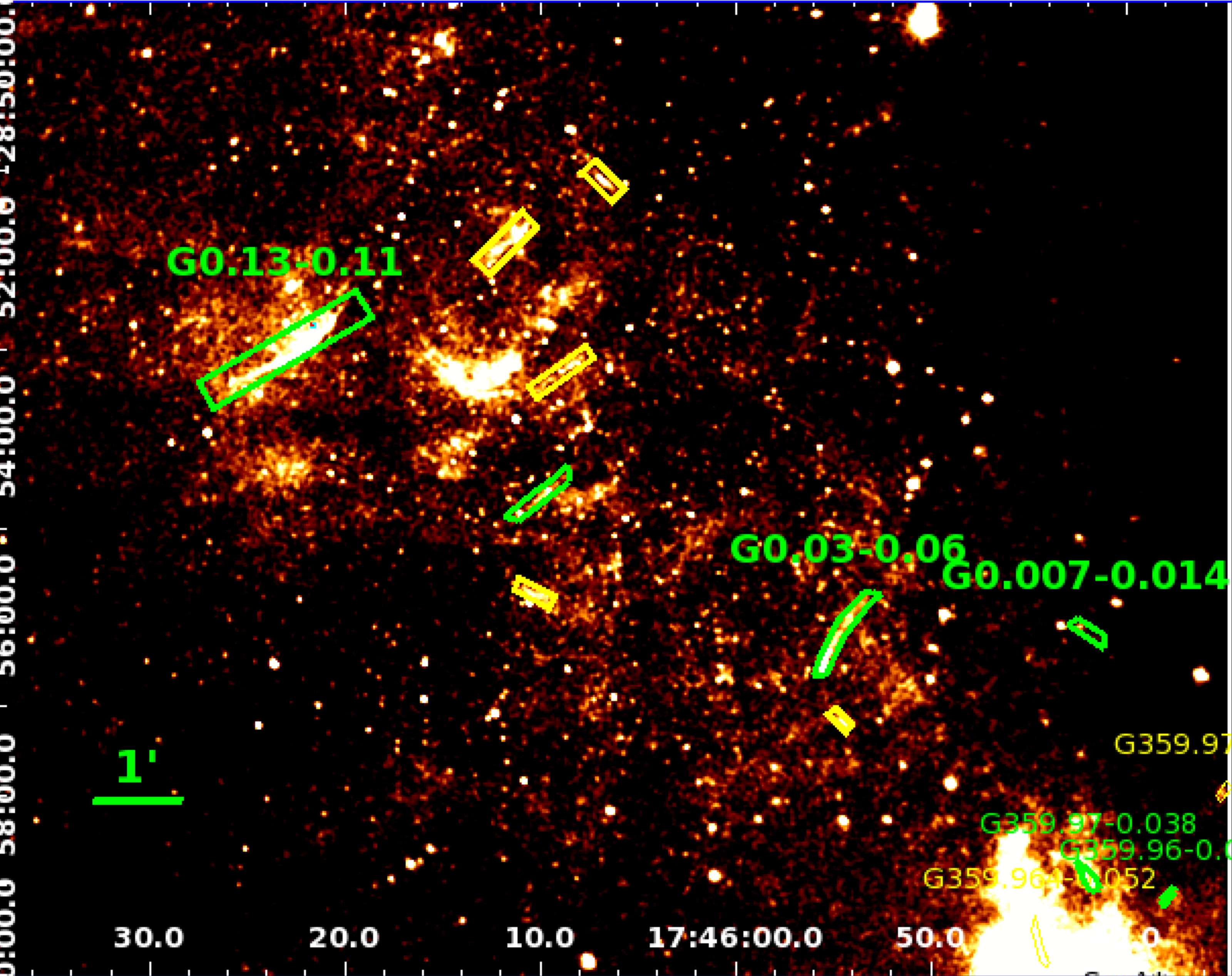
> 20 filaments detected by XMM
Ponti+ 2015

4 hard X-ray filaments by NuSTAR
Zhang+ 2014, Nynka+ 2015, Mori+ 2015

Filaments within 430 pc of the Galactic Center



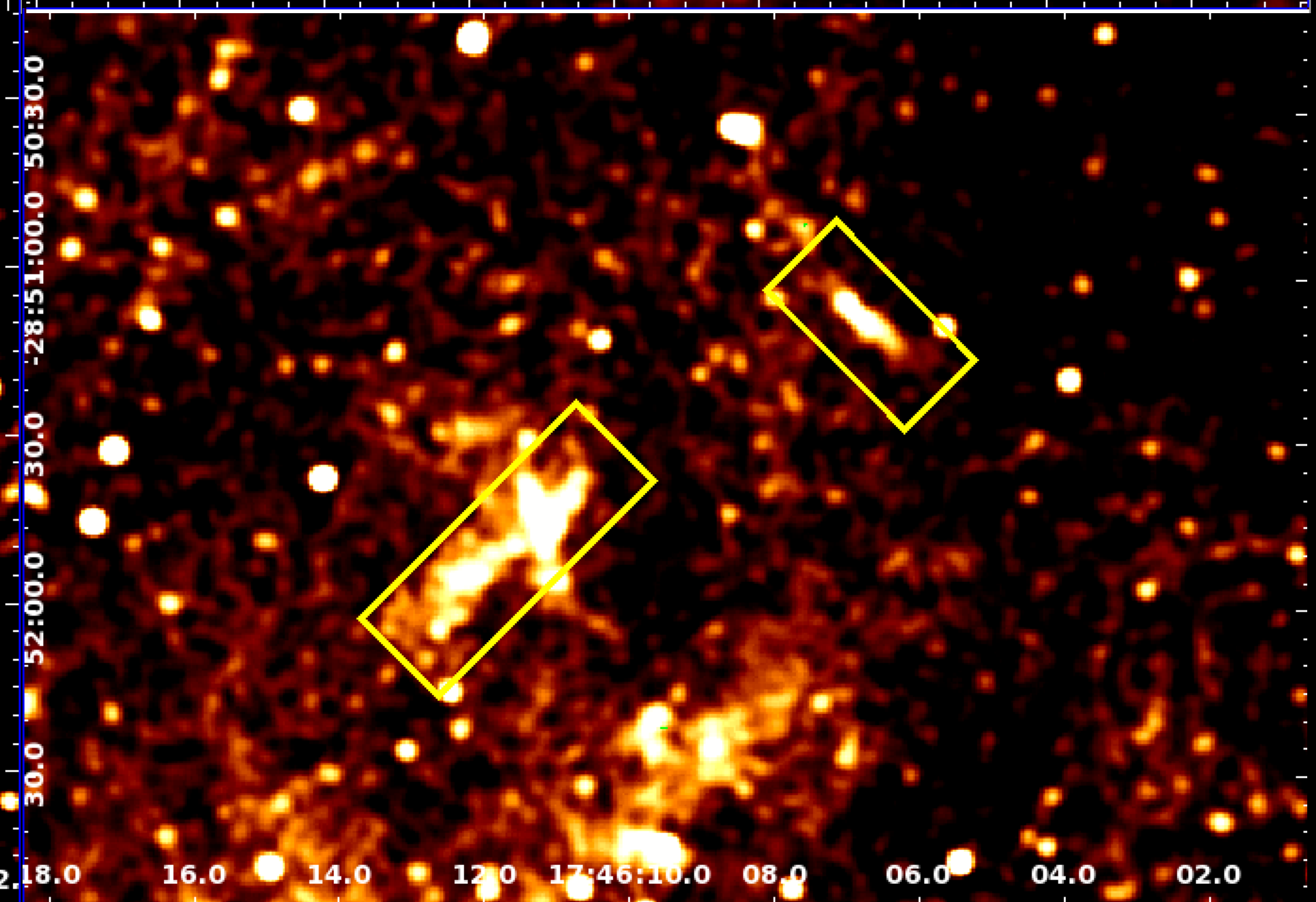
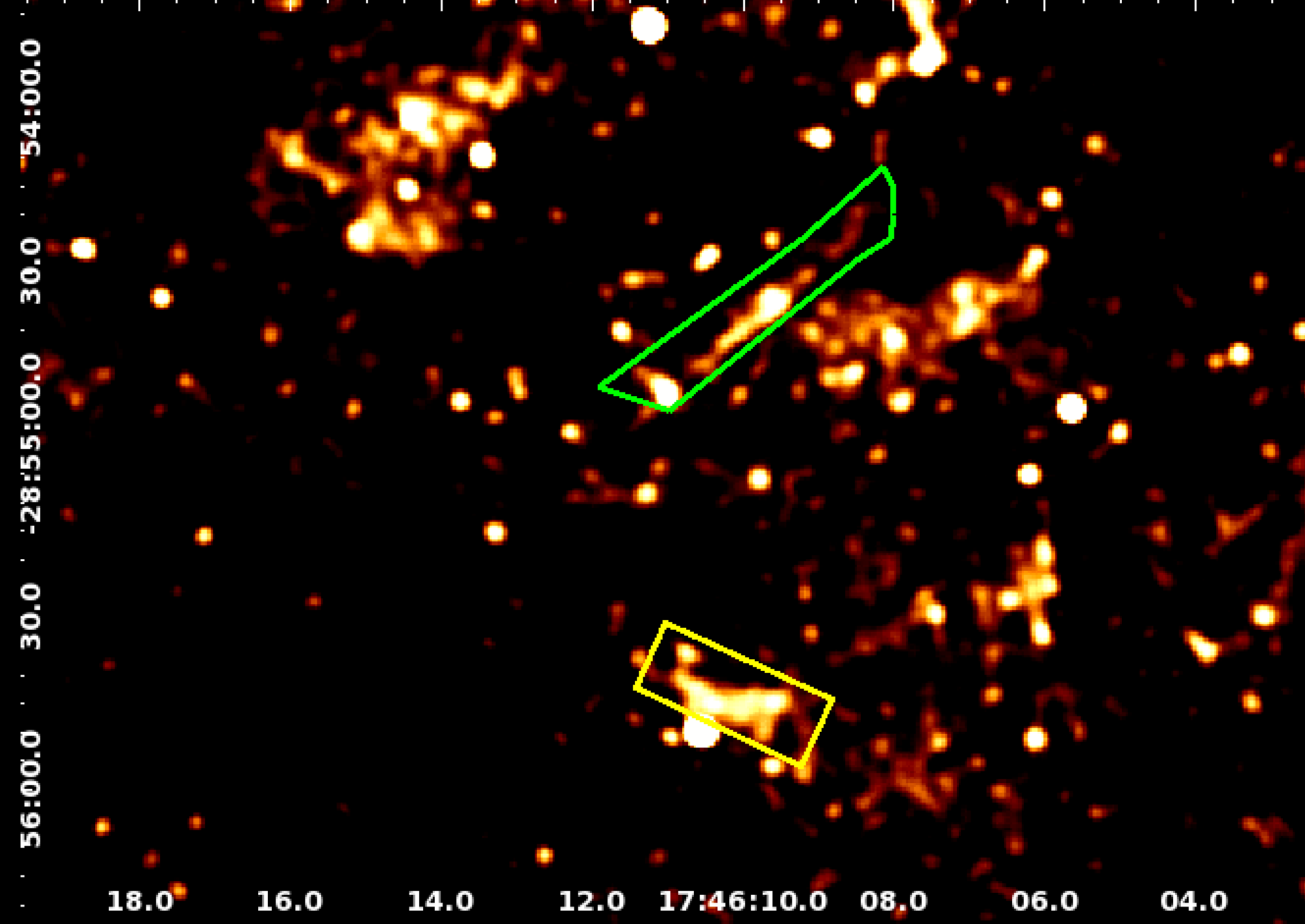
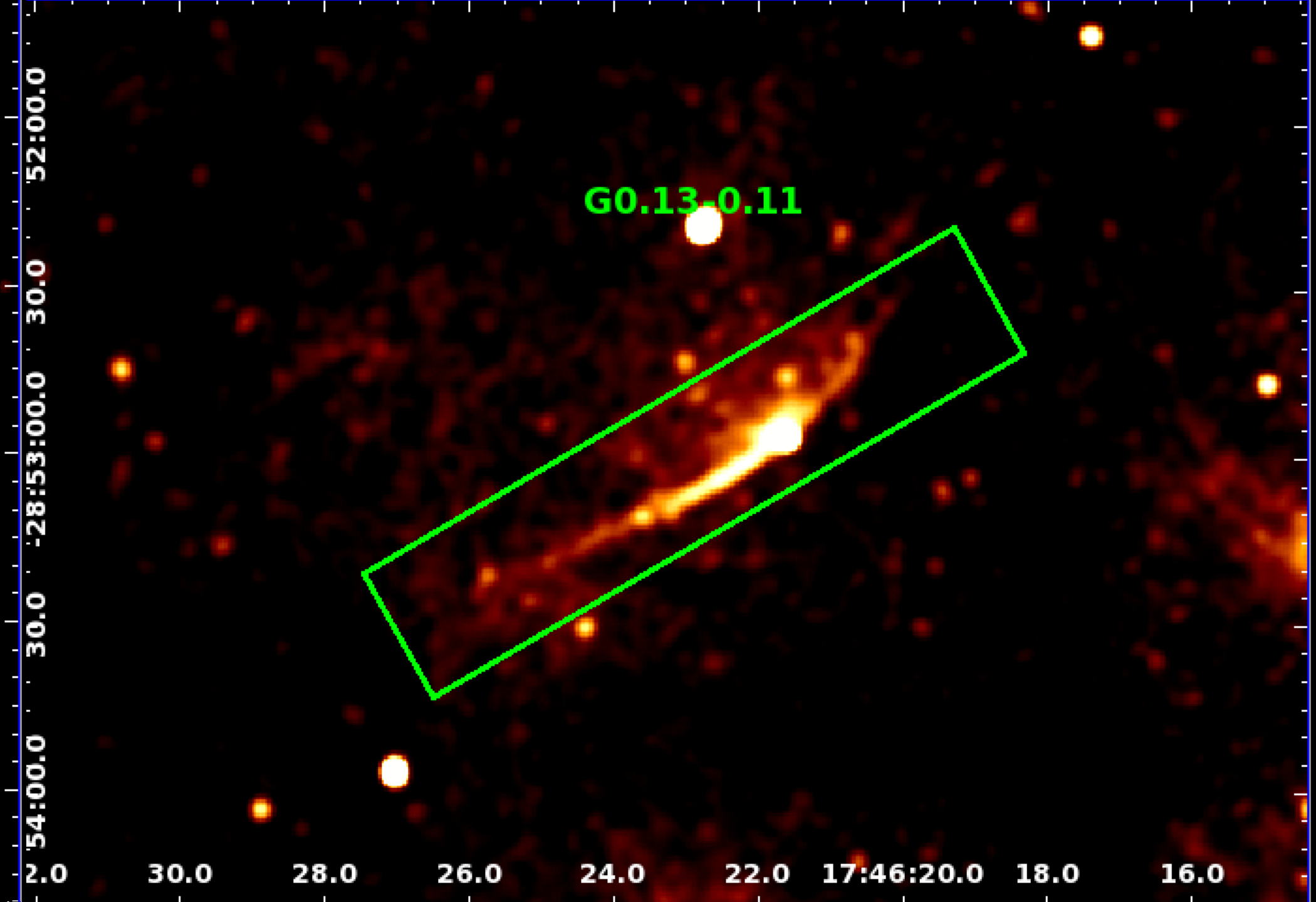
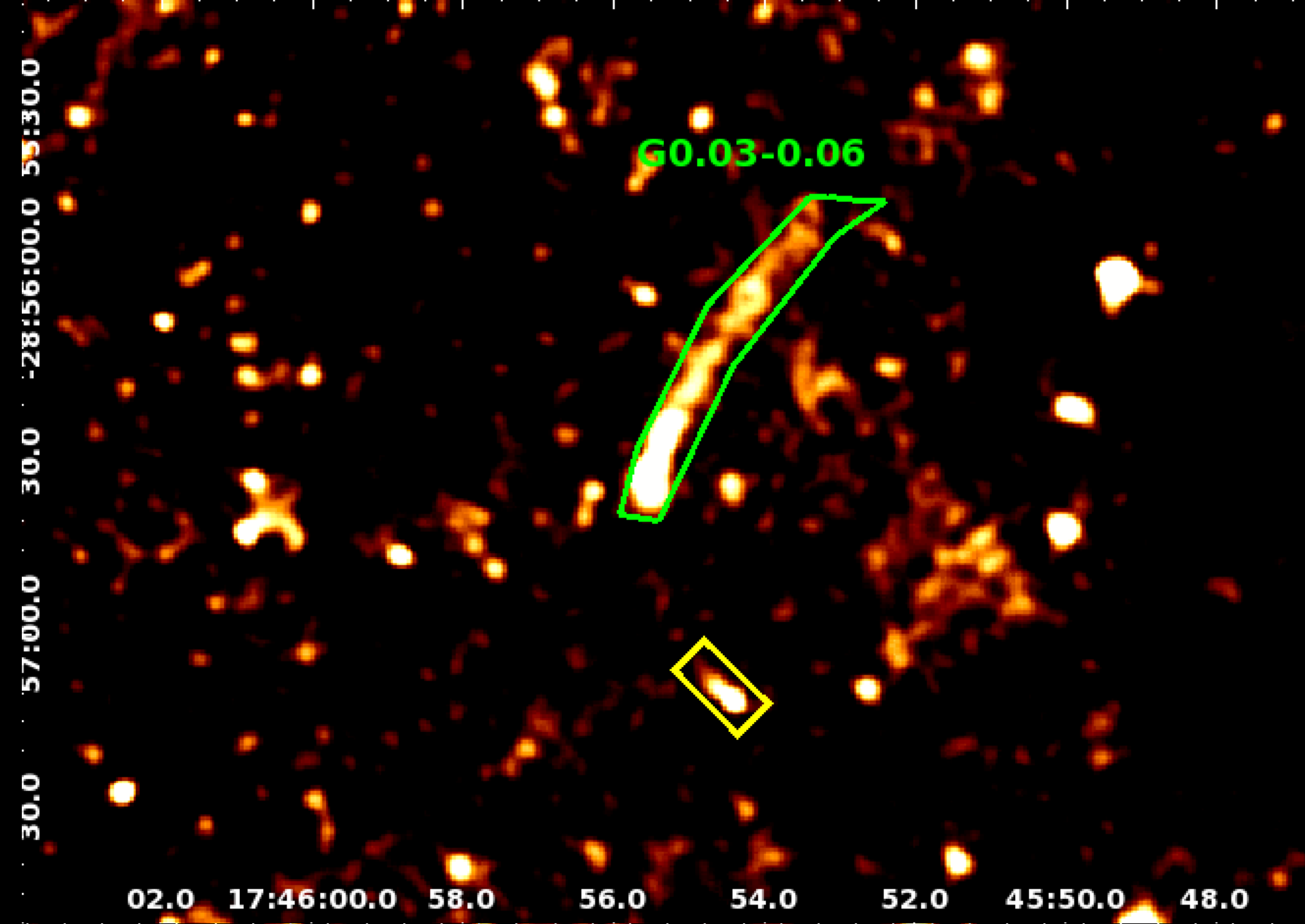
	Radio Filament	X-ray Filament
Number	$\gtrsim 100$	$\gtrsim 20$
Length	tens of pcs	a few pcs
Polarization	Detected	—
Feeding source	GeV electrons	TeV electrons
Origin of CRs	Particle acceleration/ dark matter annihilation	Particle acceleration/ secondary products of hadronic process

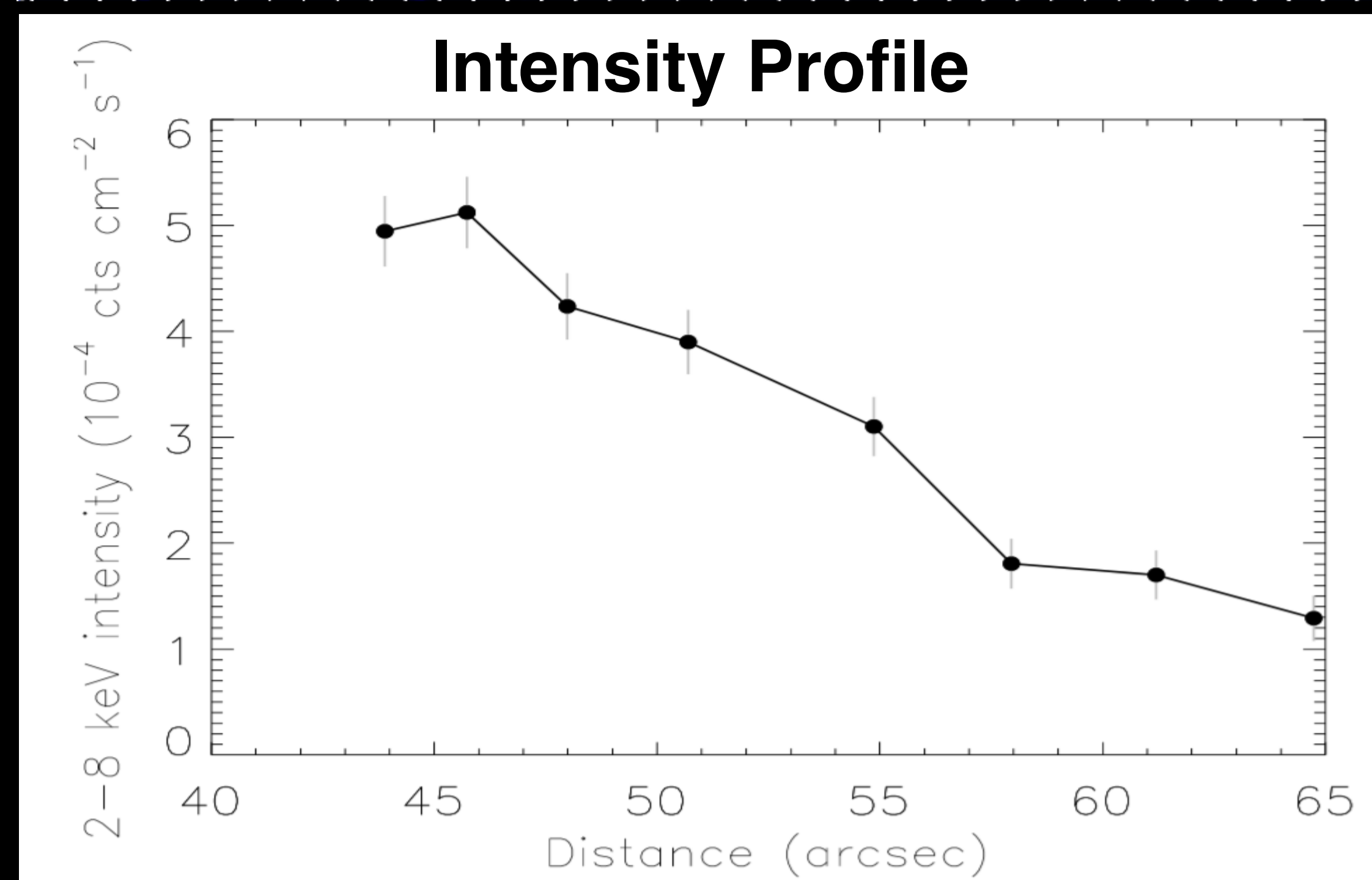
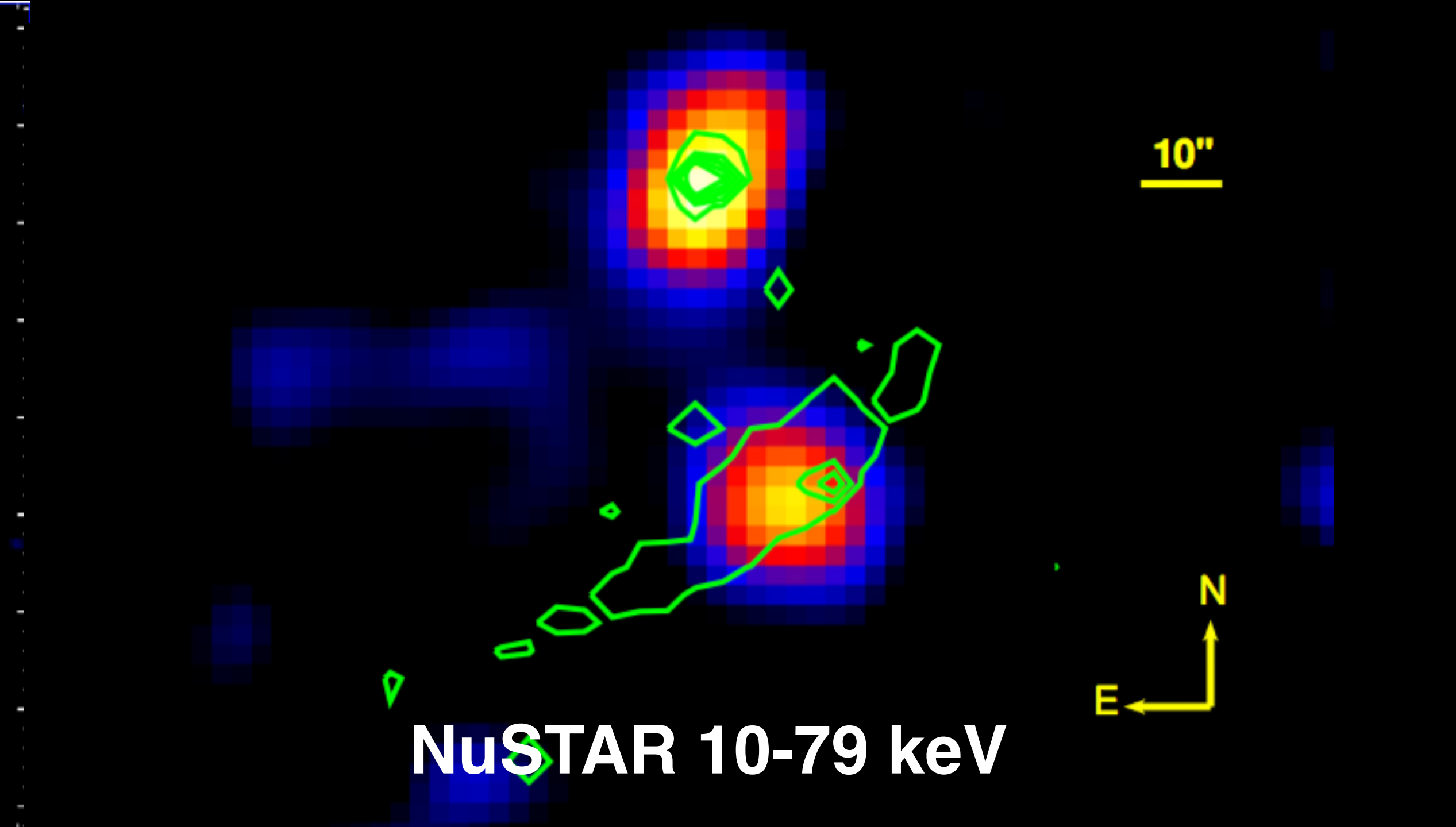
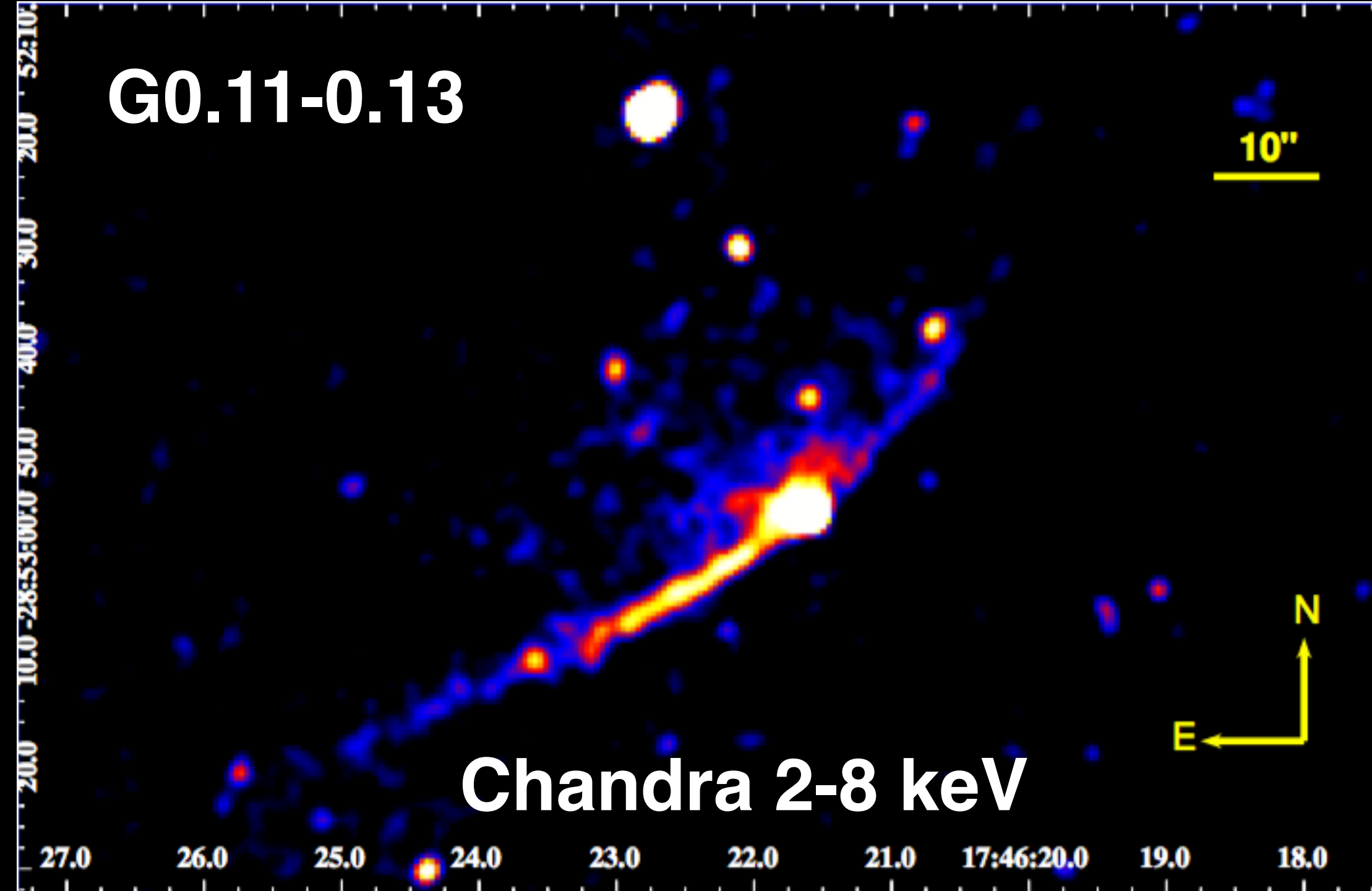


Most recent Chandra Sgr A* Complex observation from 2015-2017 (PI: Clavel): 10 observations, 460 ks

- More than 10 X-ray filaments captured in this dataset, some of which could be newly discovered (needs further verification).
- With approved 150 ks NuSTAR observation for this region in 2020 spring, targeted at studying filaments (PI: Zhang)

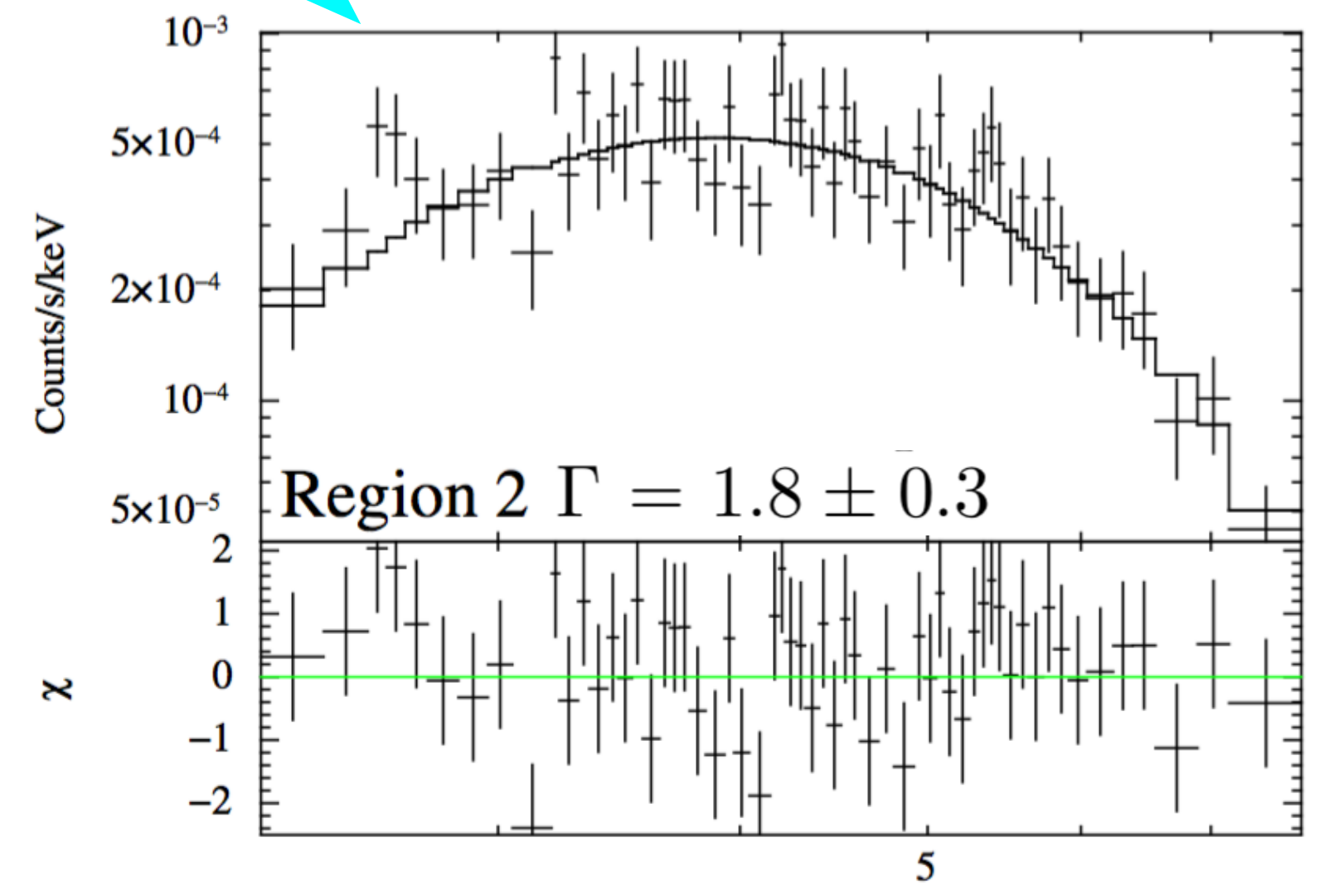
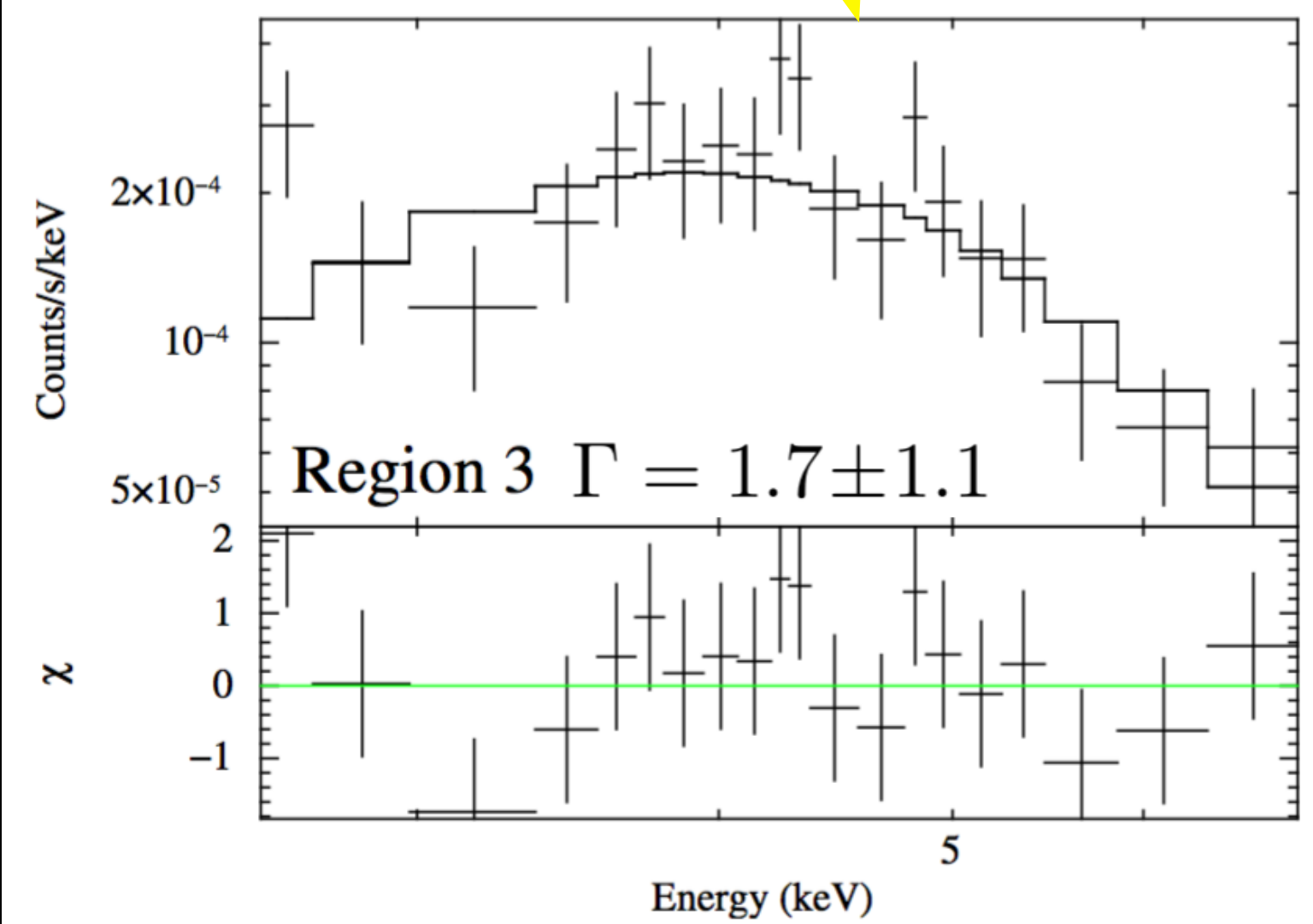
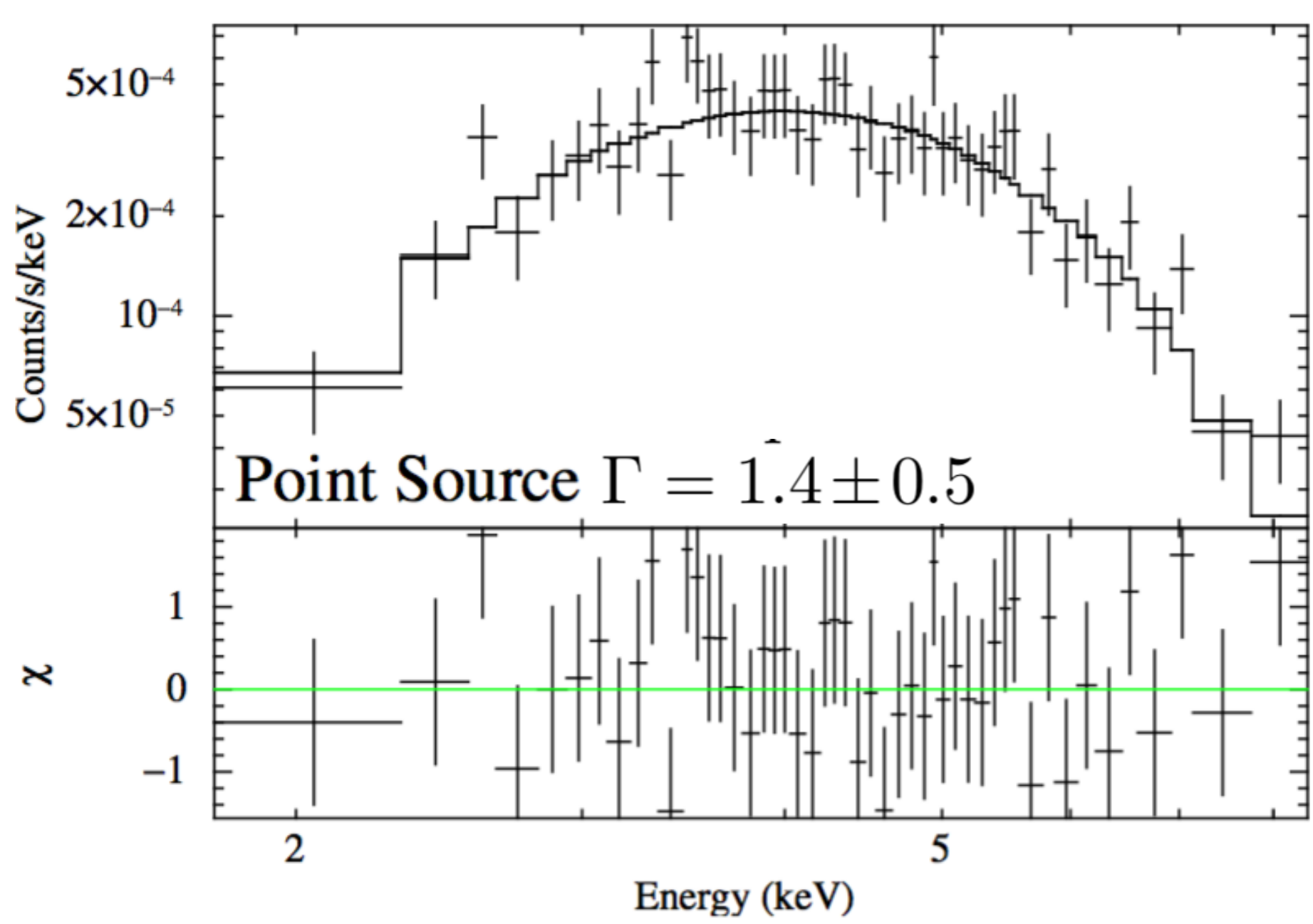
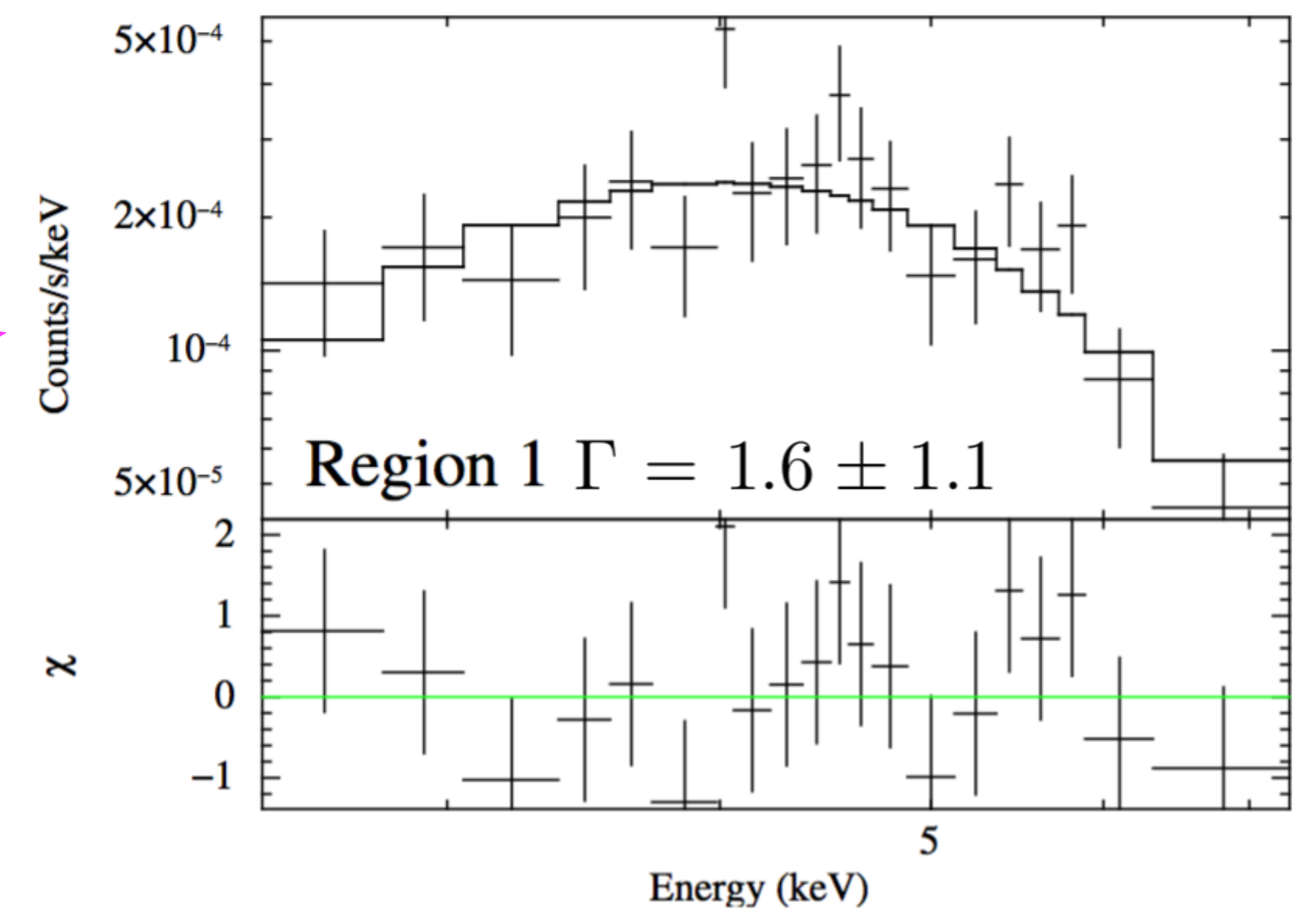
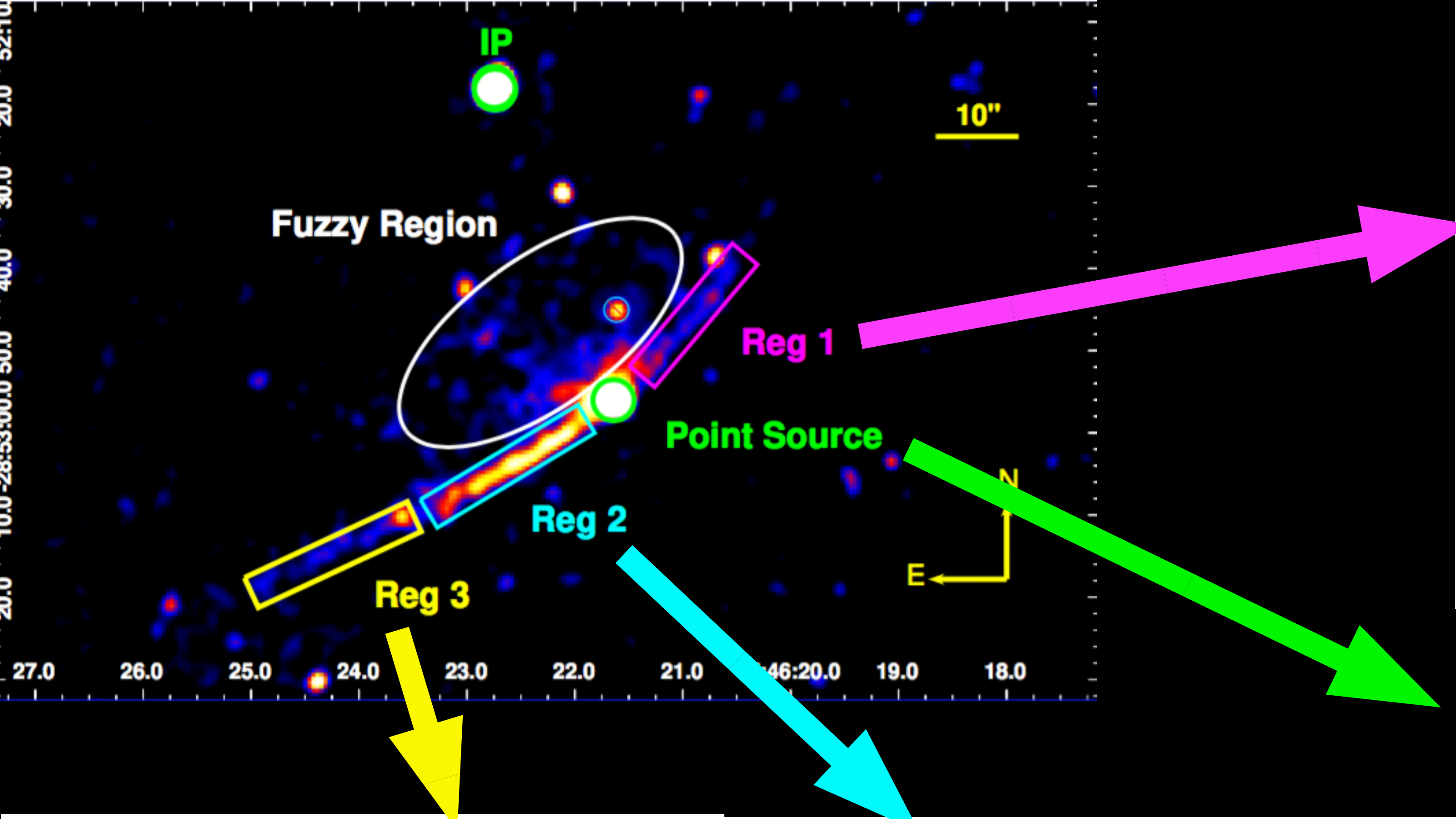
Mosaic of the 10 observations totaling 460 ks exposure



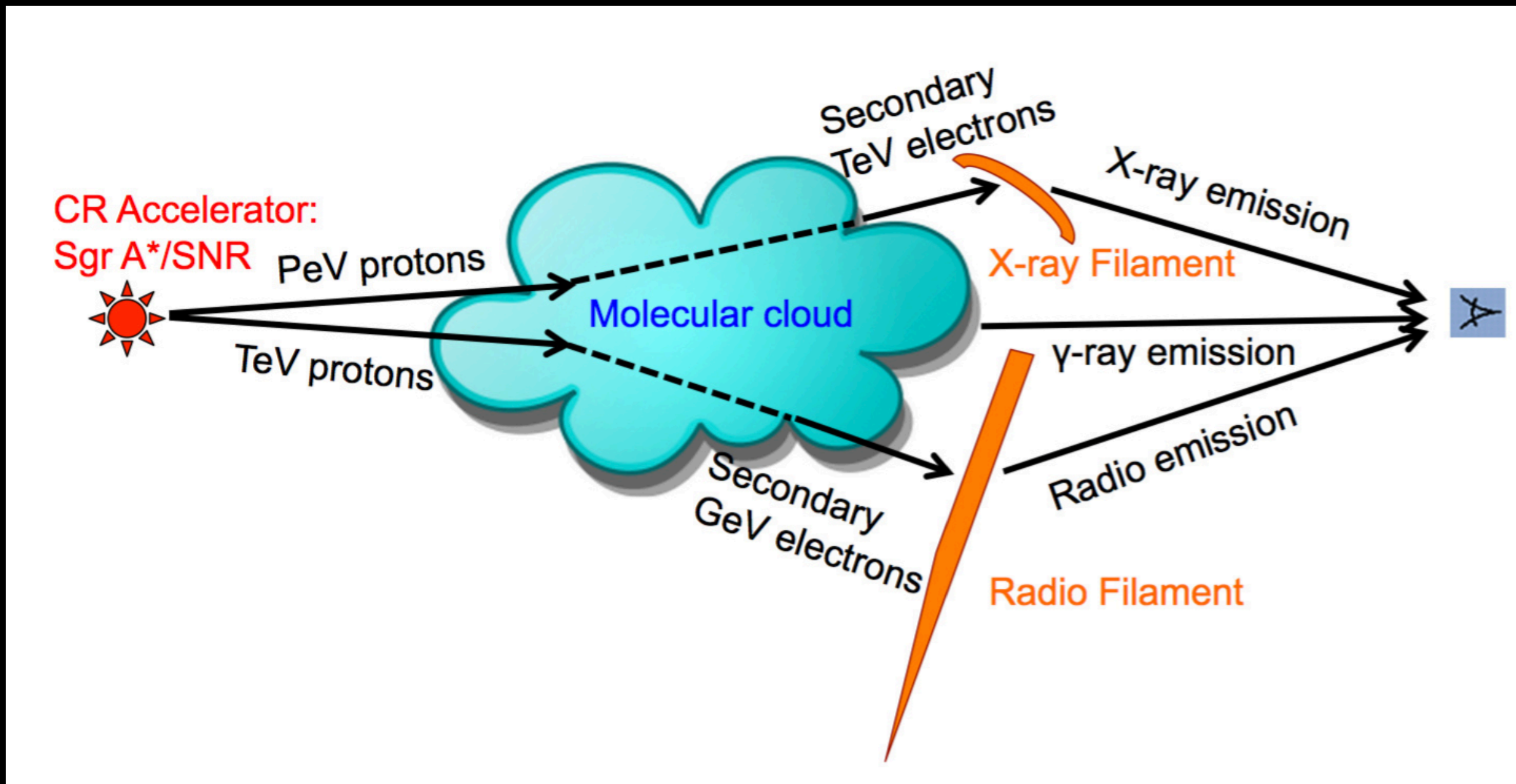


Length = 3.4 pc
Width = 0.1 pc
Distance to Sgr A* ~ 30 pc
Right next to Radio Arc
A point source detected in the middle
shows slight curvature
sharp edge on one side,
while more fuzzy on the other side

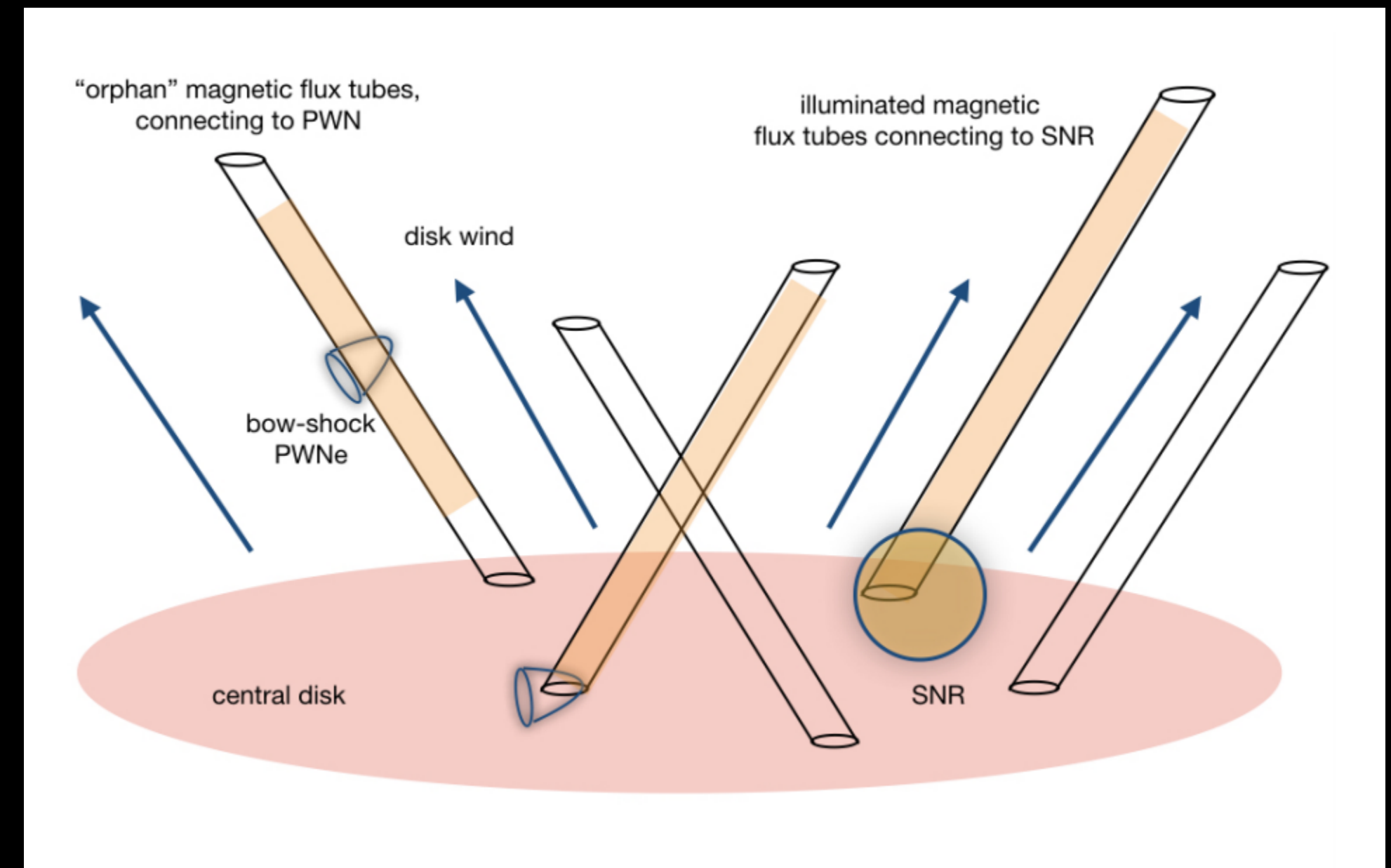
Zhang+ 2019, under review



Origin of relativistic electrons from hadronic process, connected to SMBH activity (Zhang+ 2014, 2019)



Origin of relativistic electrons from direct acceleration, connected to PWN + SNR (Barkov+ 2019a, b)



To answer...

- What are the sources of the GeV/TeV particles feeding radio/X-ray filaments in the Galactic Center, PWN, SNR, and/or SMBH?
- How is such ordered magnetic field structure formed?
- What fraction of the X-ray filaments share the same origin as the radio filaments?

We need...

- A systematic comparison between Chandra and MeerKAT deep Galactic center observations
- Future high spatial resolution and high-throughput X-ray missions like Lynx