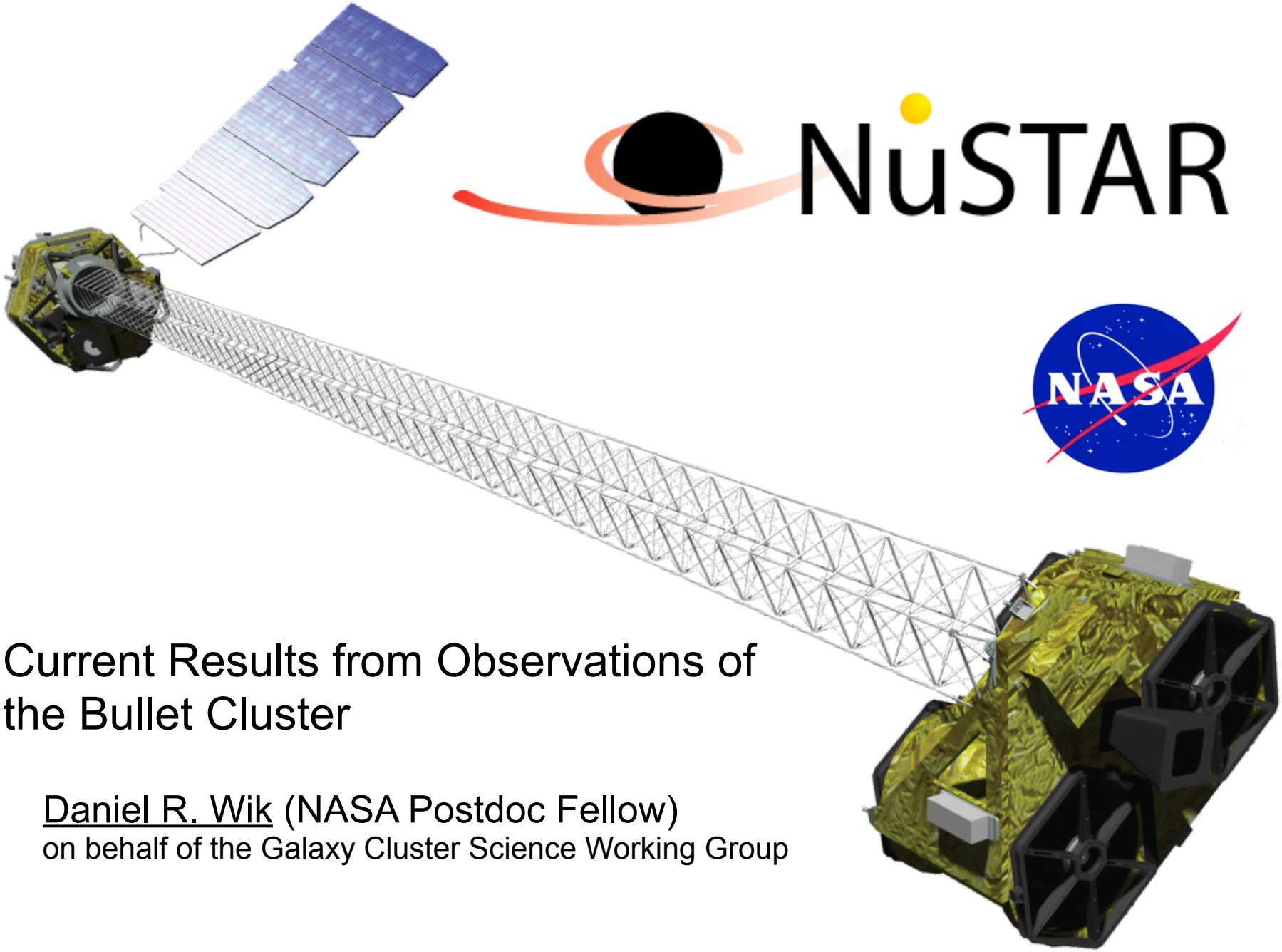


NuSTAR

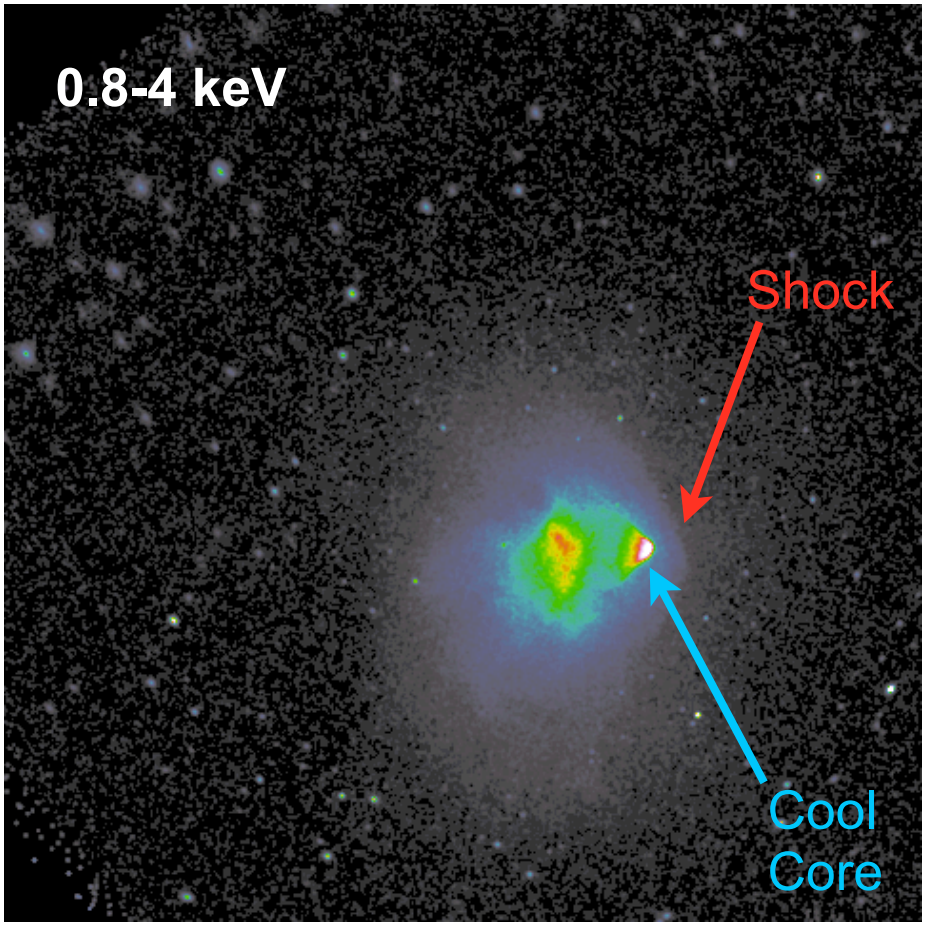
NASA

Current Results from Observations of the Bullet Cluster

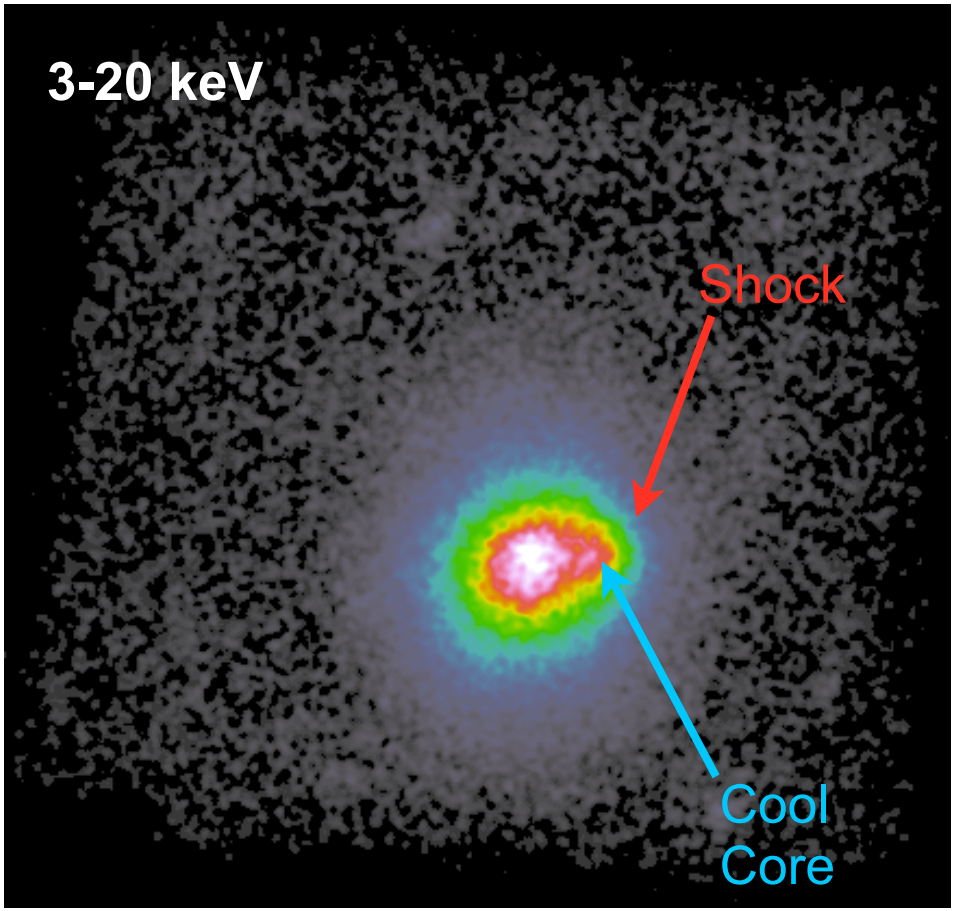
Daniel R. Wik (NASA Postdoc Fellow)
on behalf of the Galaxy Cluster Science Working Group

The Bullet Cluster

Chandra
500 ks



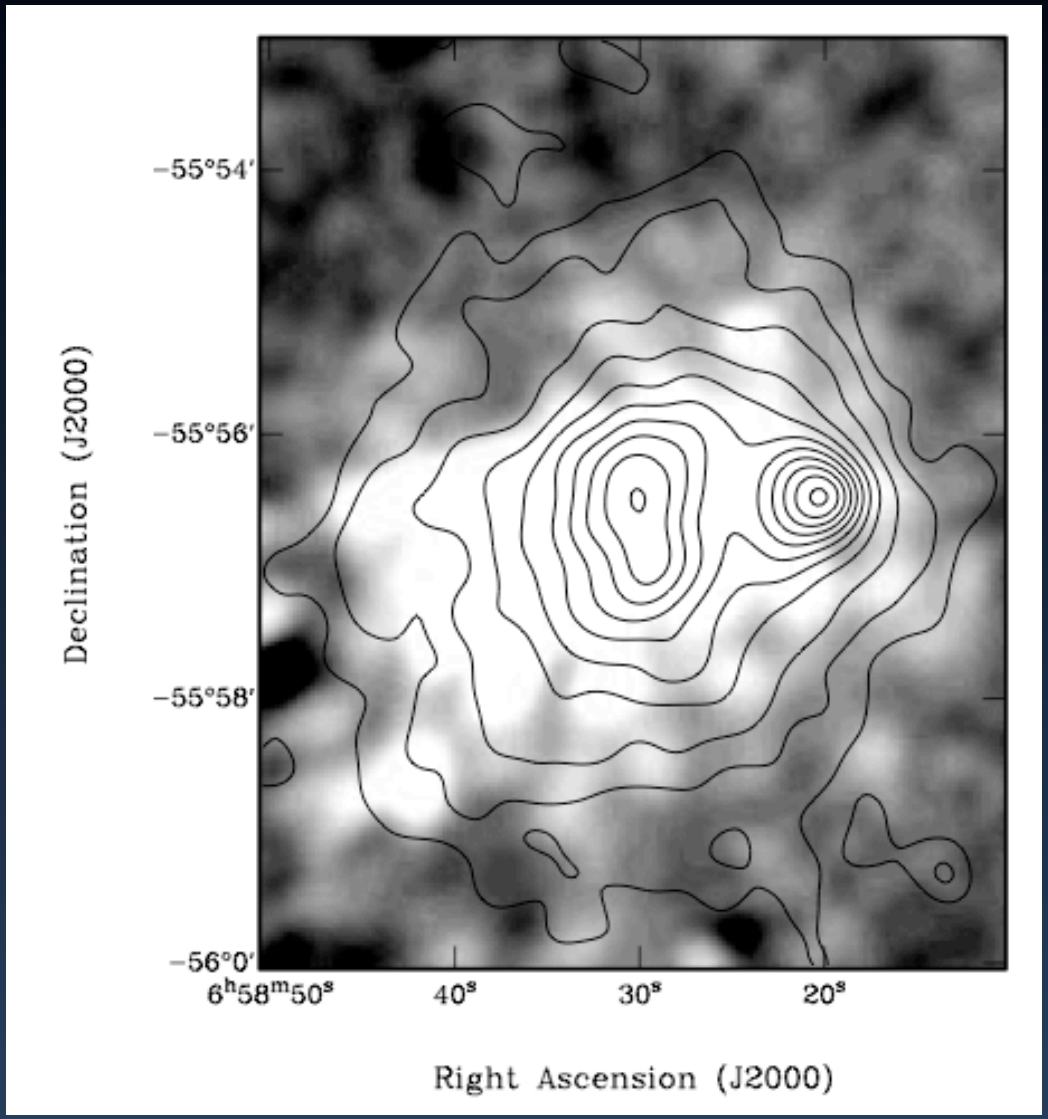
NuSTAR
266 ks (FPMA+FPMB, 532 ks)



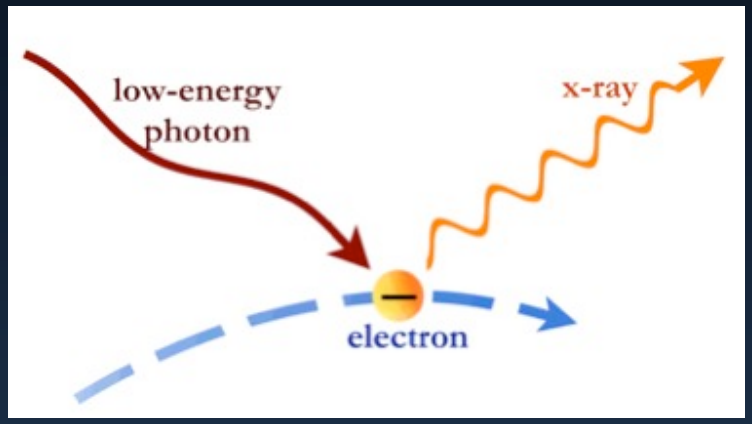
courtesy M. Markevitch

Bullet Cluster (1E 0657-56)

Radio Halo



Energy in Relativistic Phase Unknown

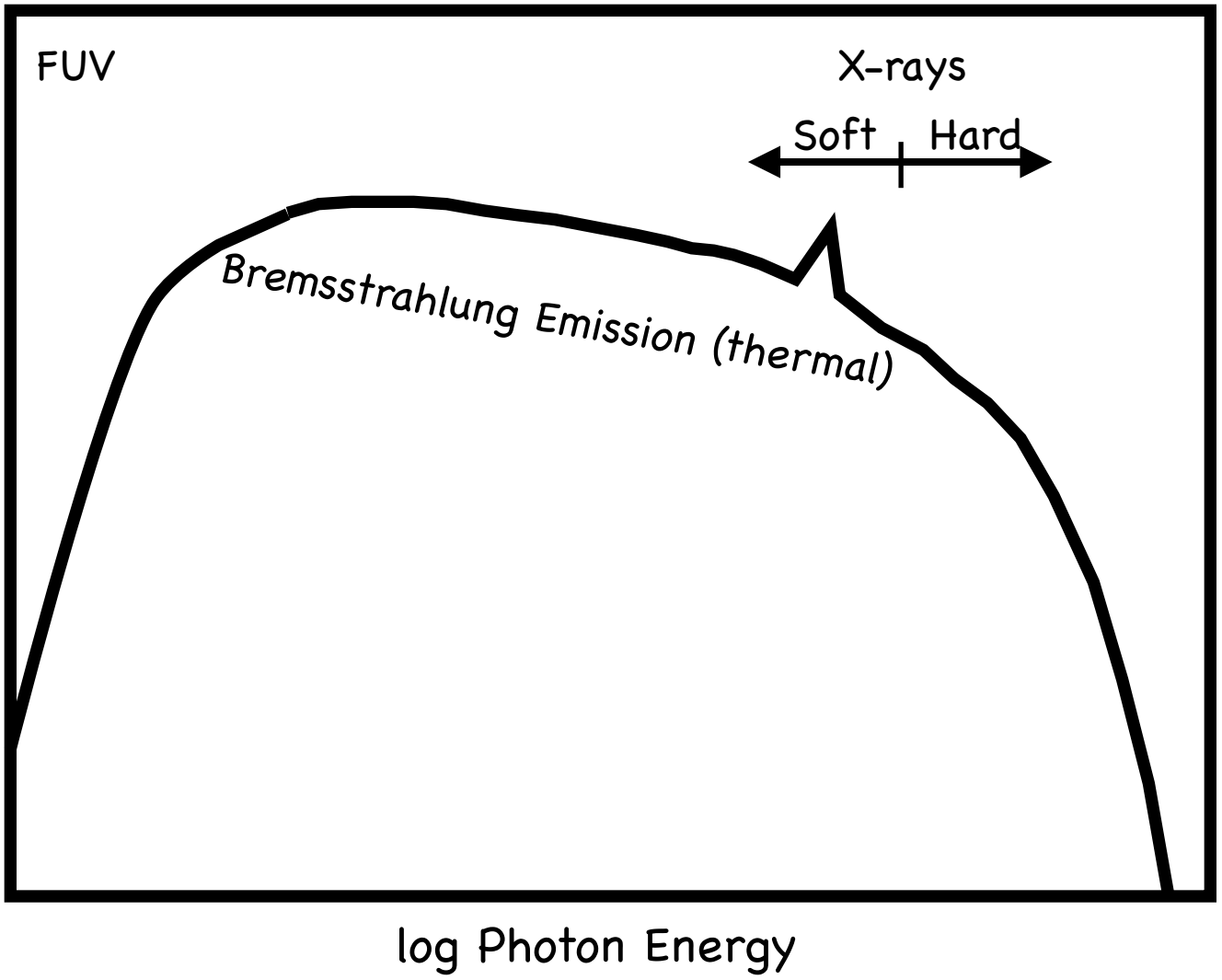


Inverse Compton Scattering

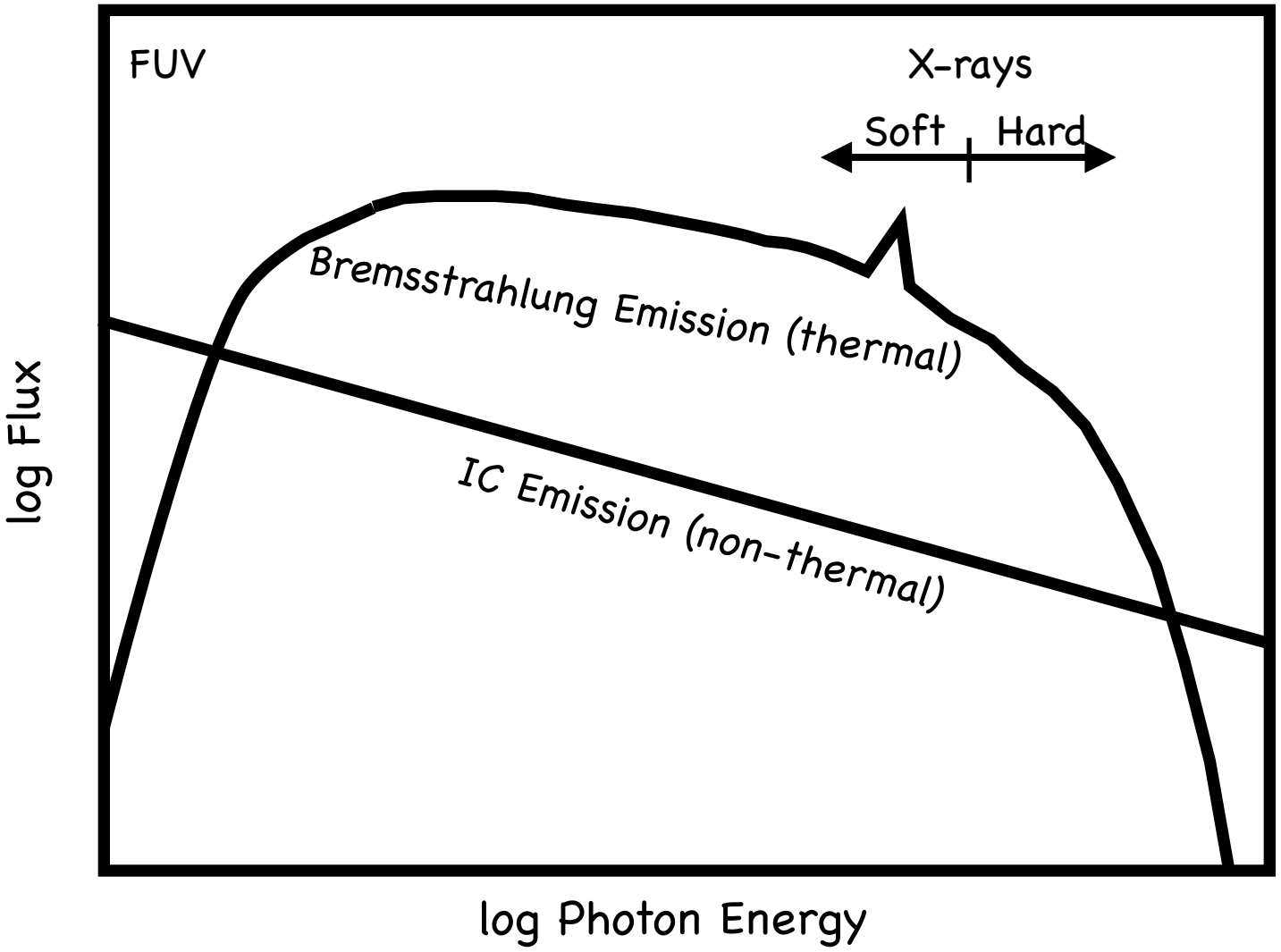
Contours: X-ray
Greyscale: Radio (1.3 GHz)

Liang et al. (2000)

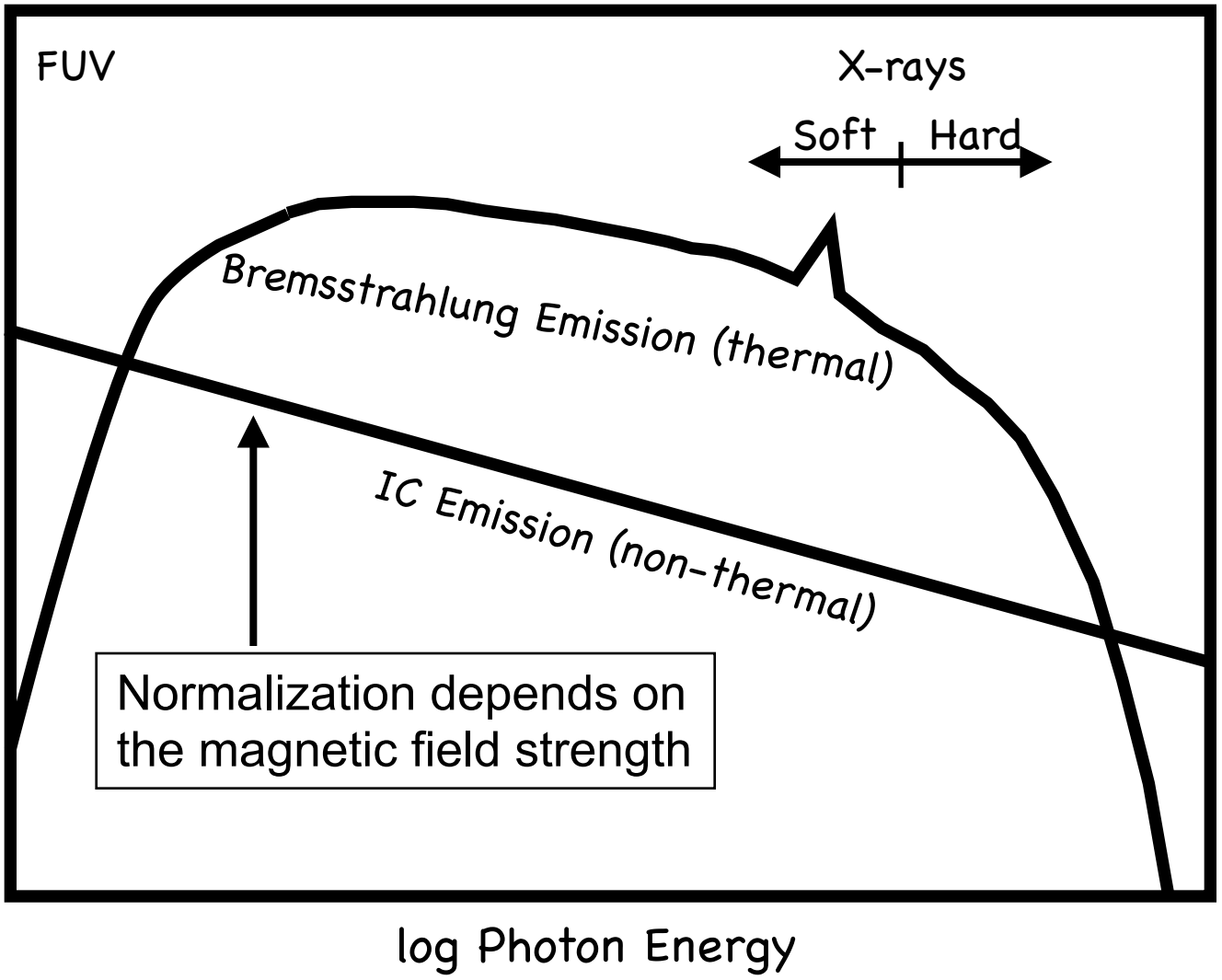
Detecting Diffuse Inverse Compton Emission



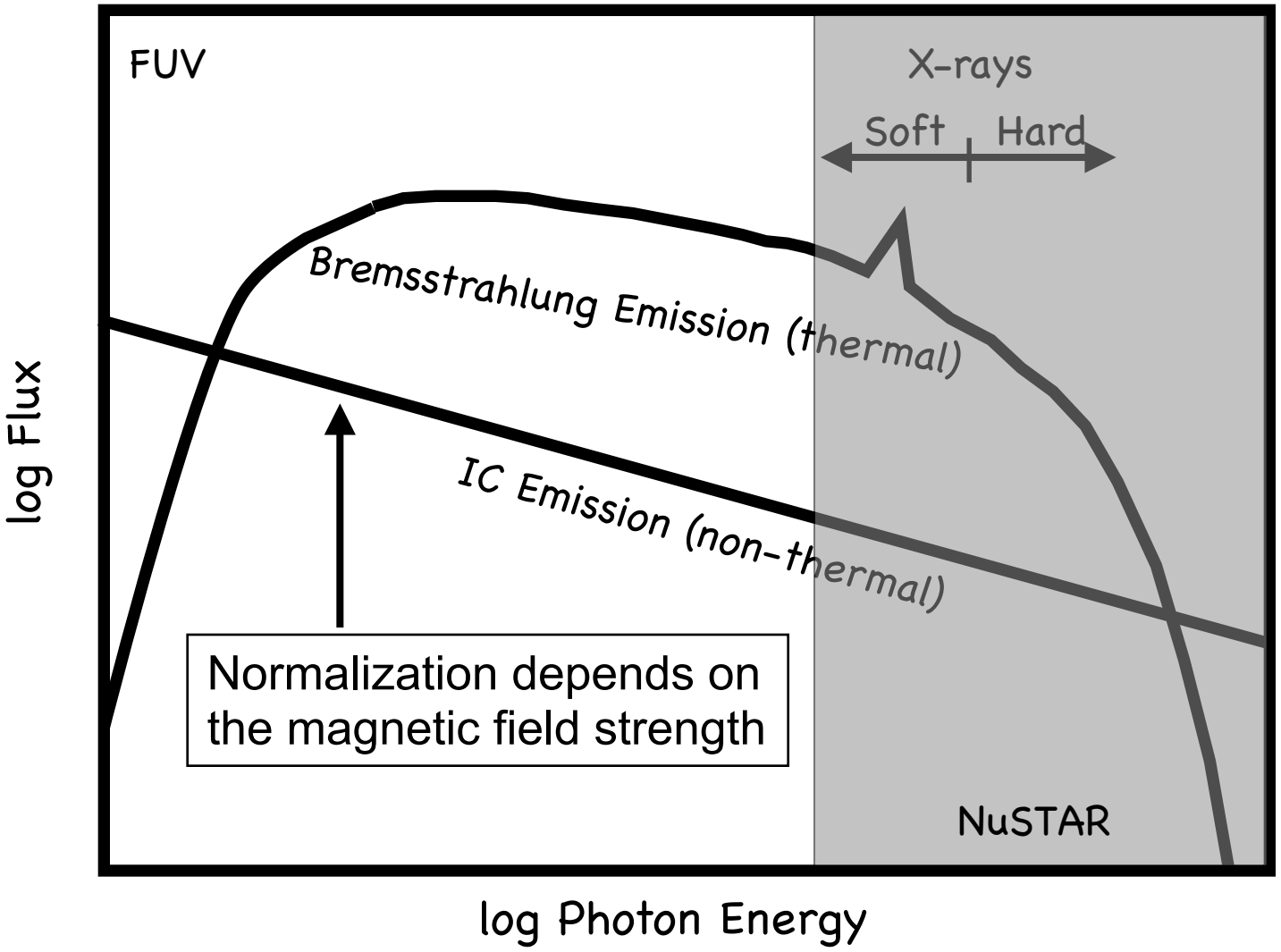
Detecting Diffuse Inverse Compton Emission



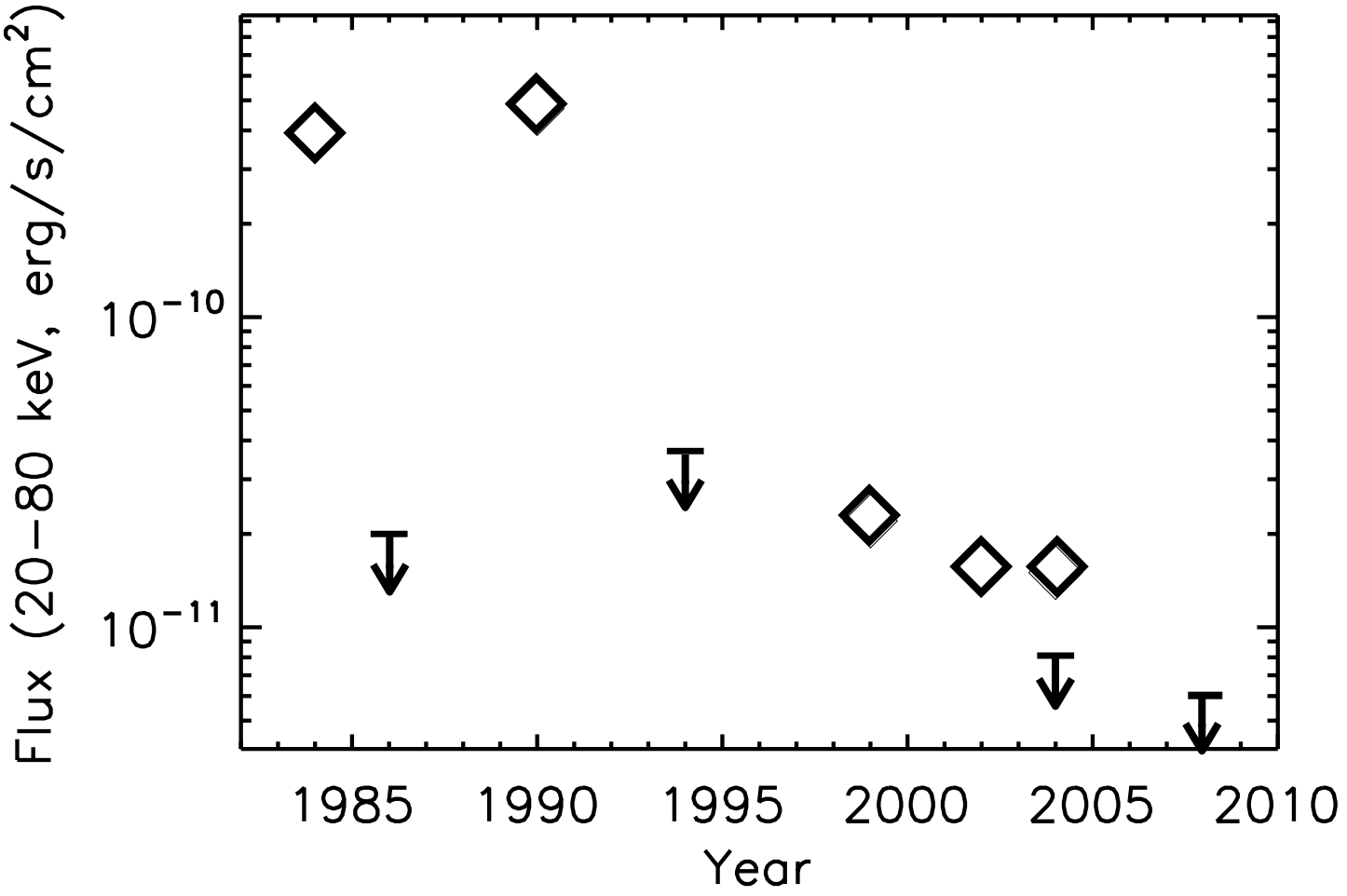
Detecting Diffuse Inverse Compton Emission



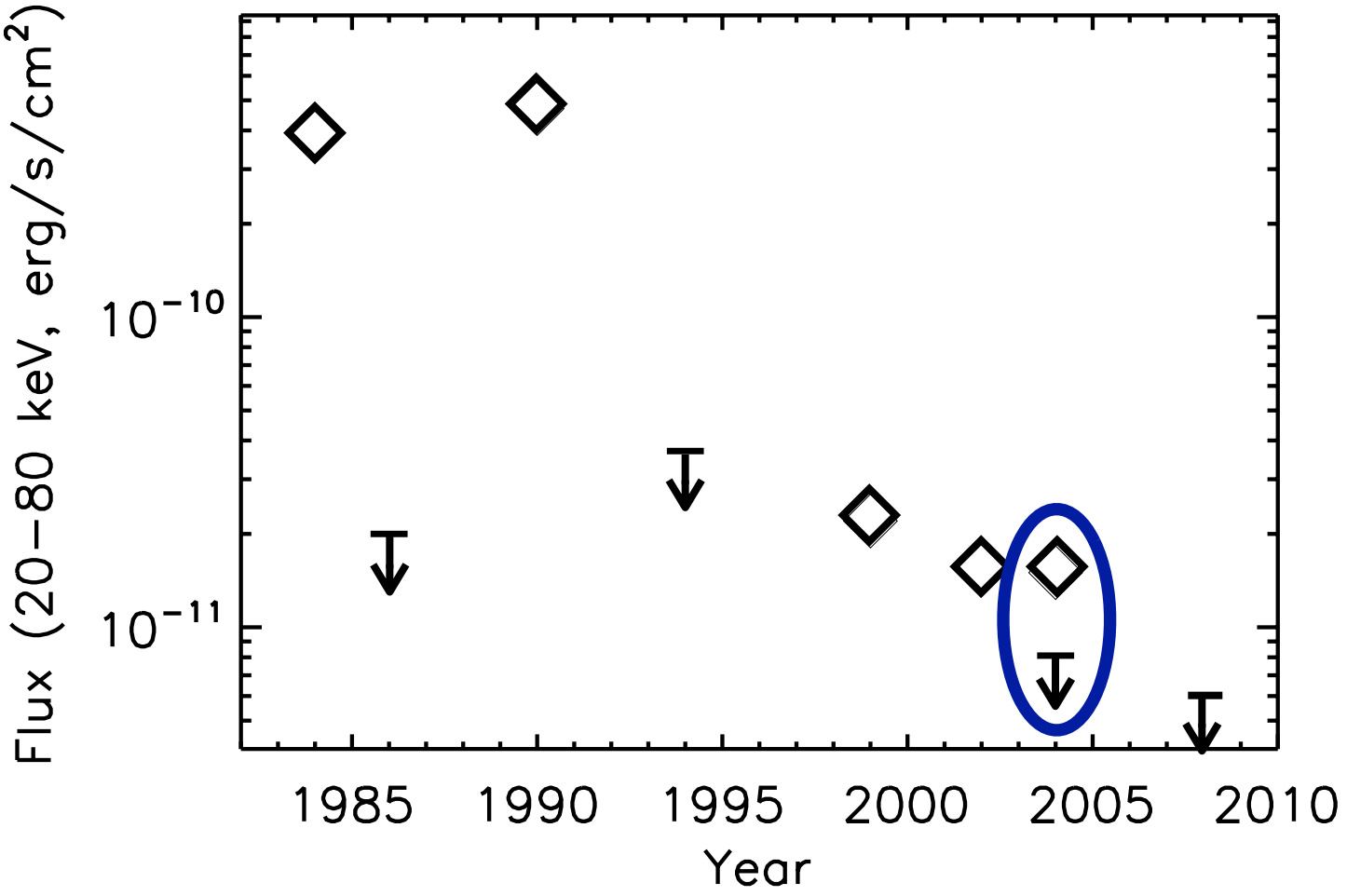
Detecting Diffuse Inverse Compton Emission



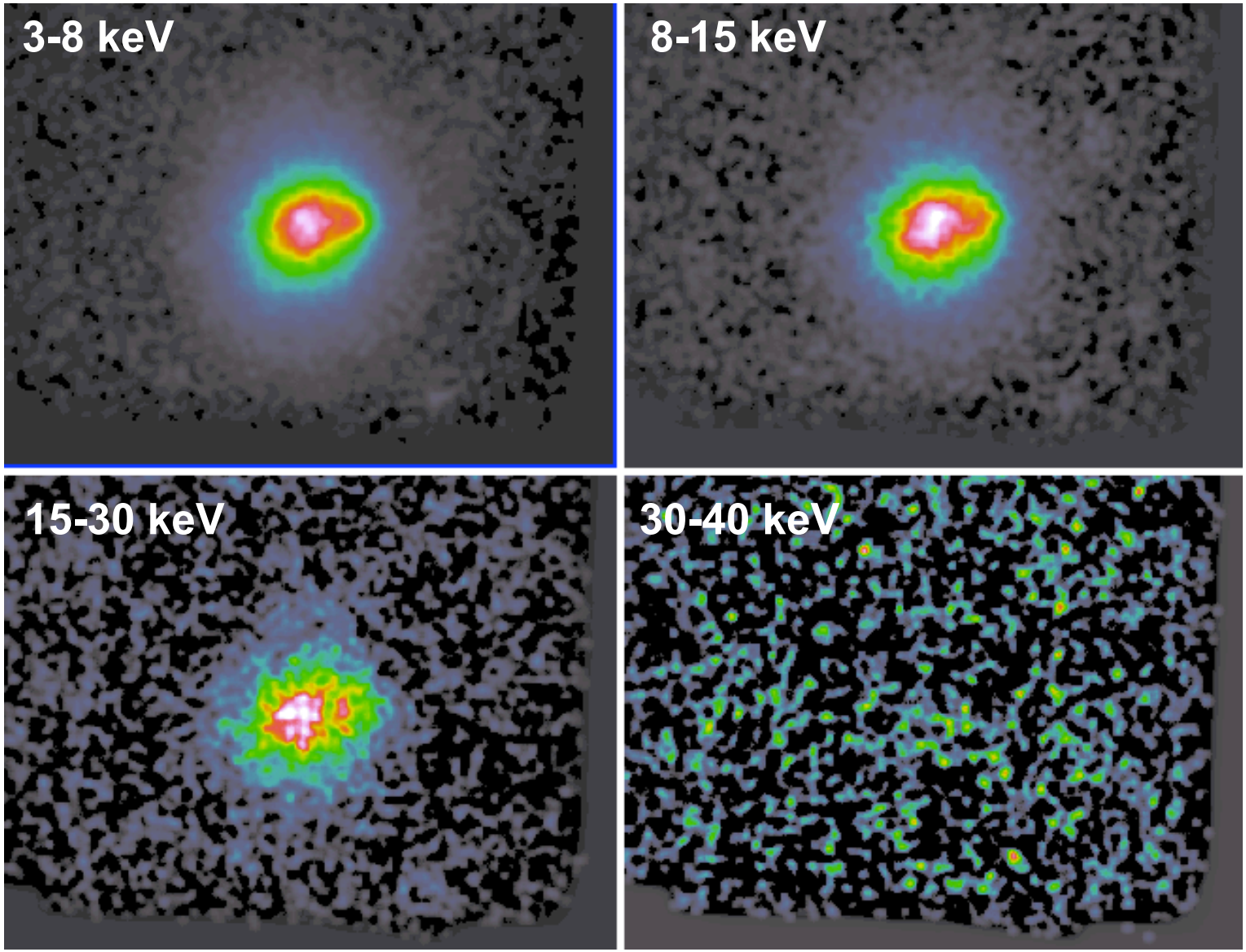
The Coma Cluster - History of a Non-thermal Excess



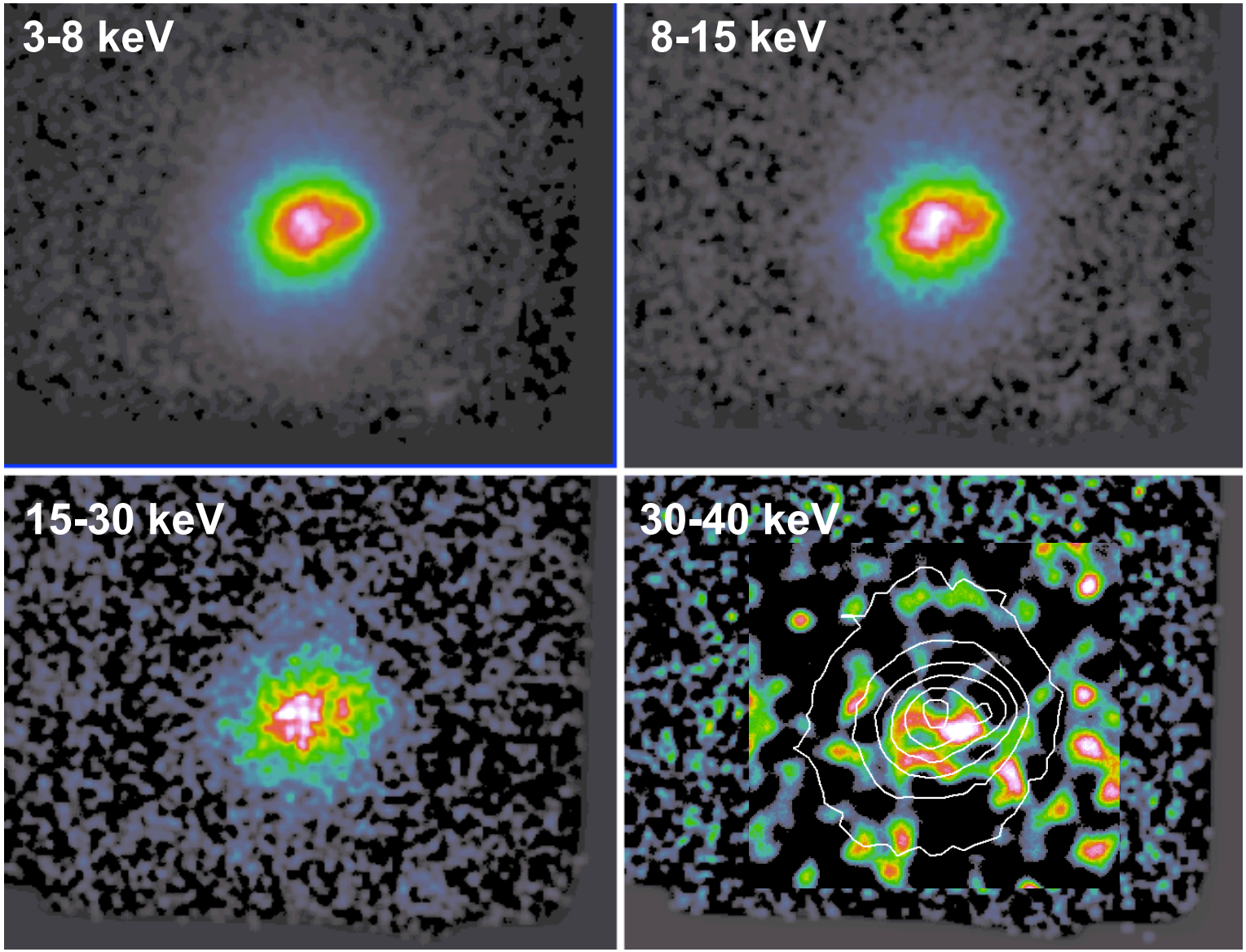
The Coma Cluster - History of a Non-thermal Excess



Background-subtracted images

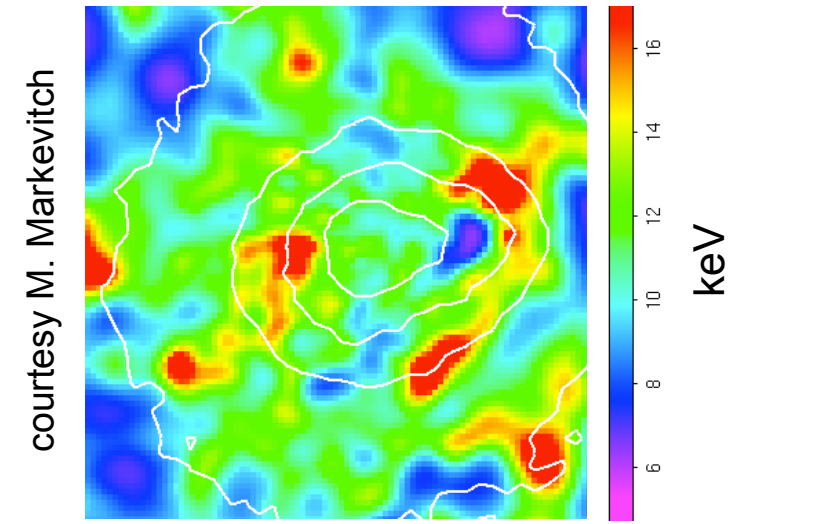


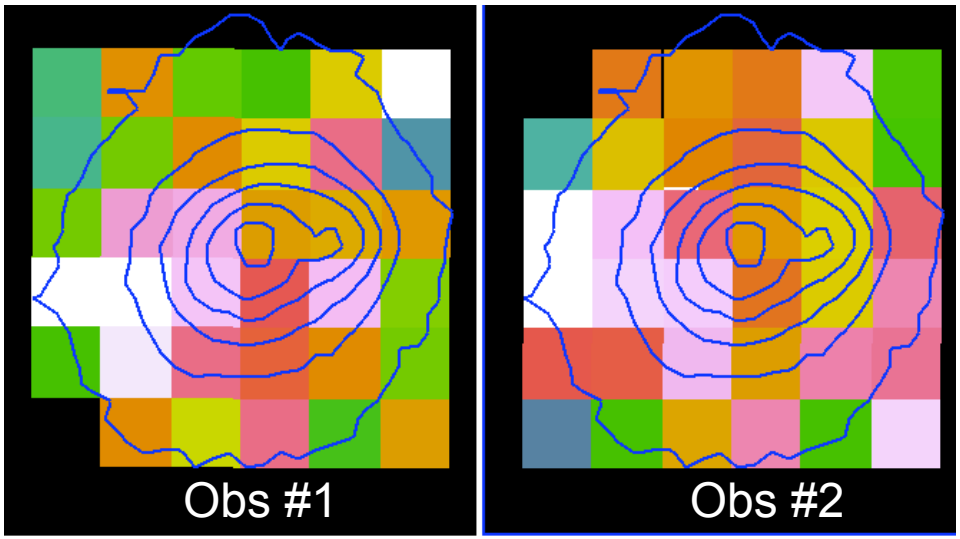
Background-subtracted images

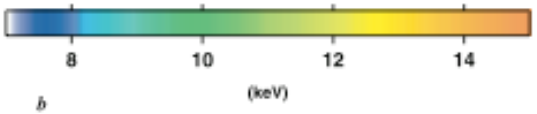


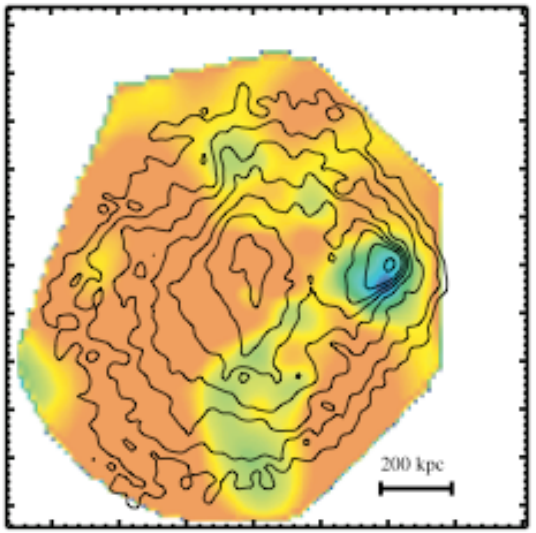
Bullet Cluster kT map

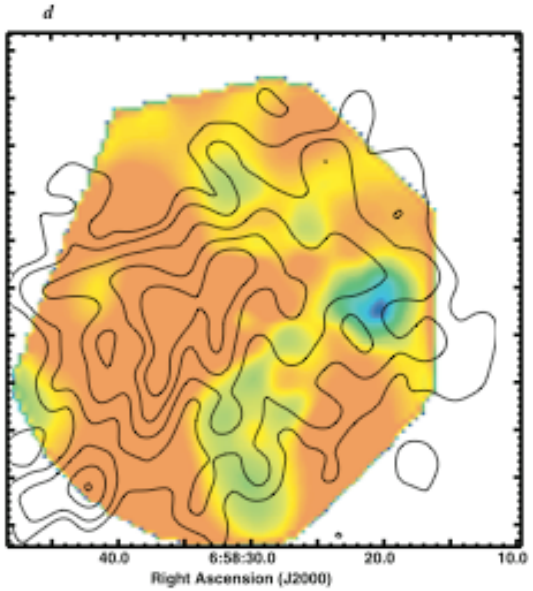
NuSTAR







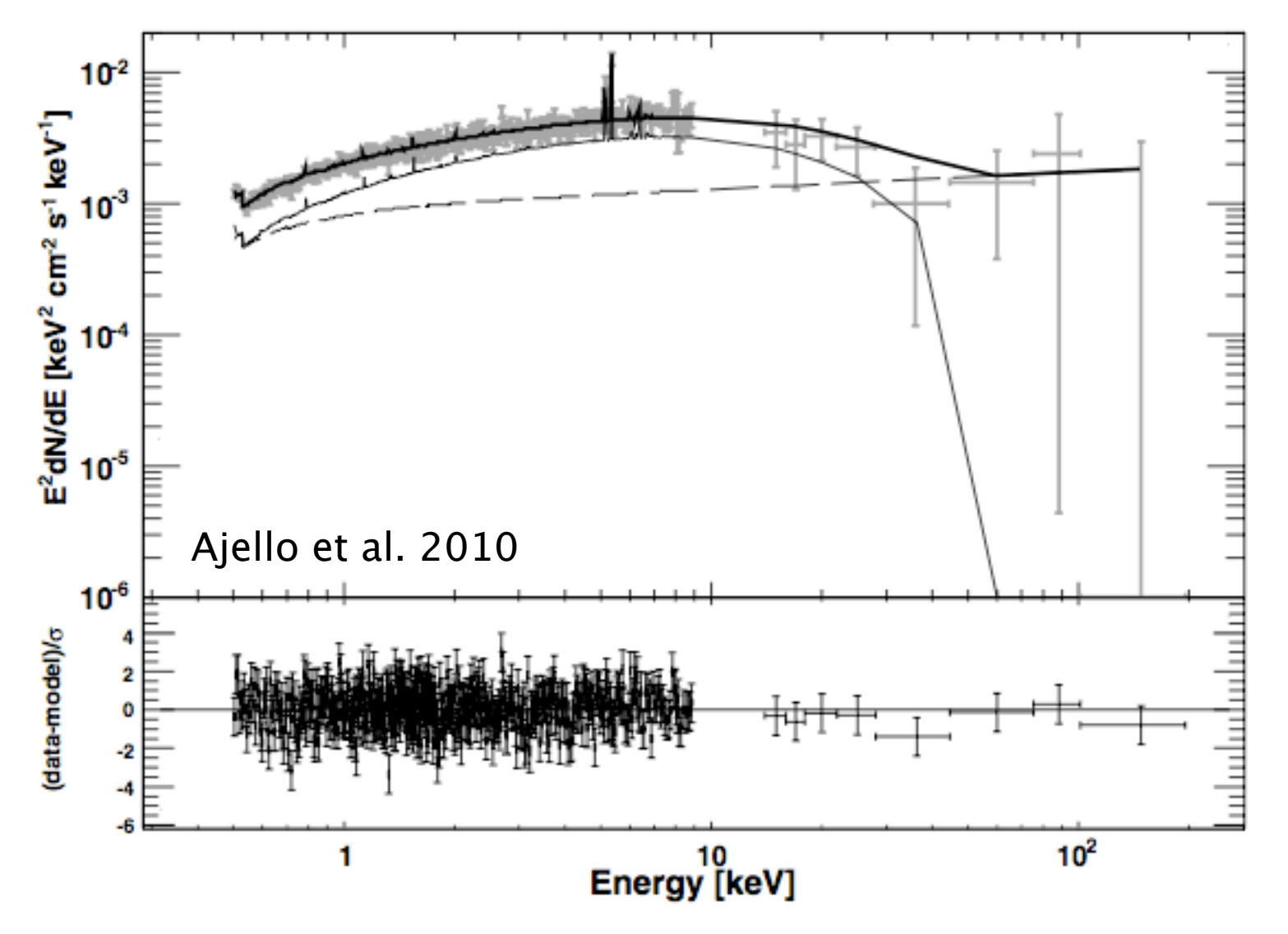




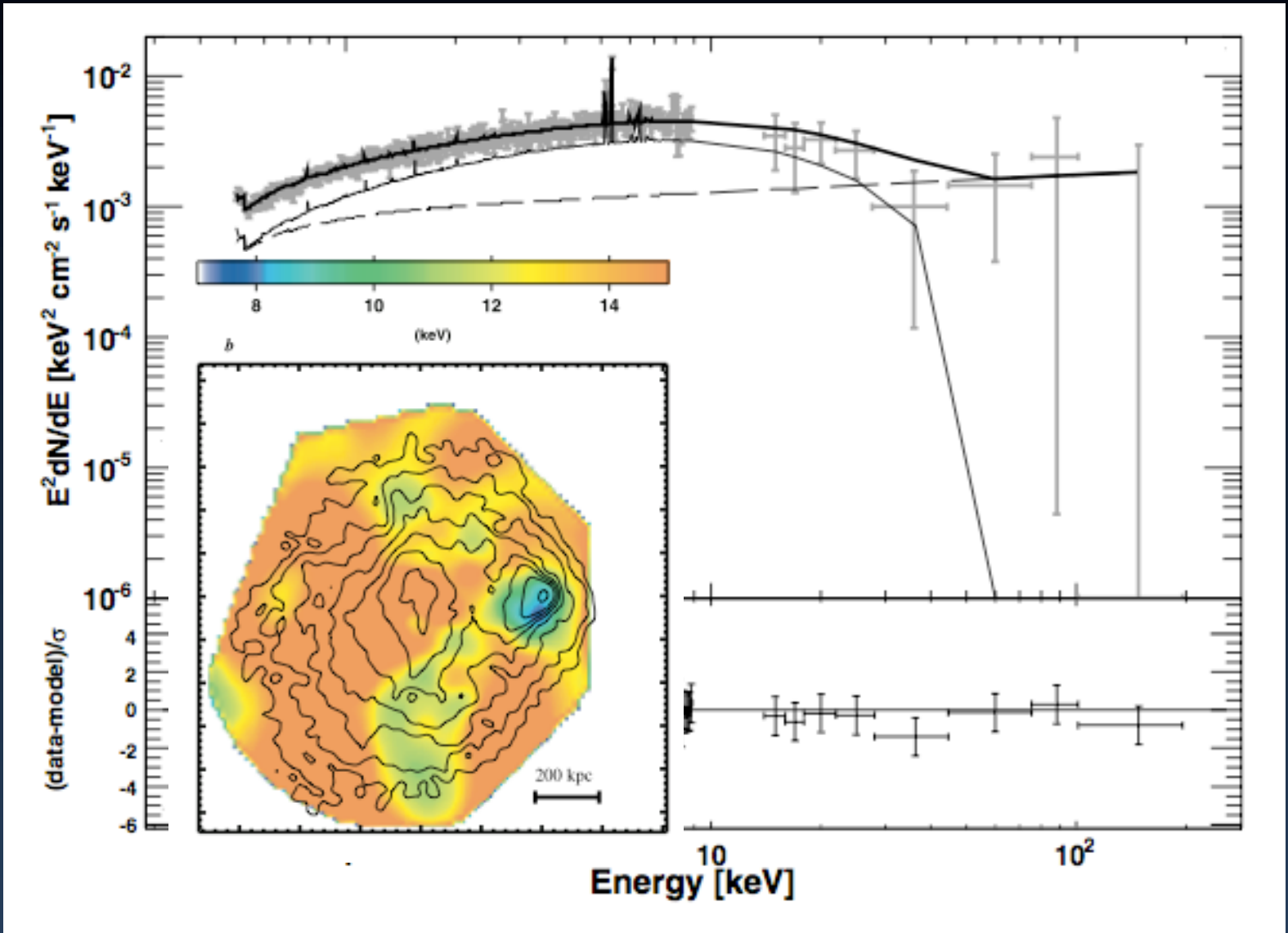
Govoni et al. 2004

Radio Halo contours

Bullet Cluster – the View with Swift



Bullet Cluster – the View with Swift



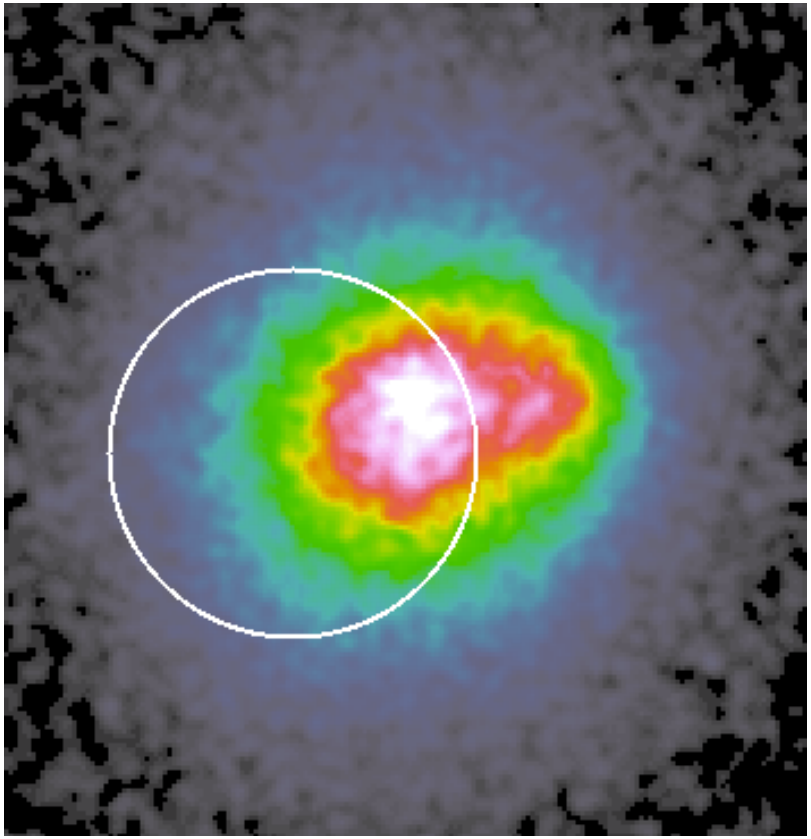
IC Fit: Center on radio halo and avoid cool core

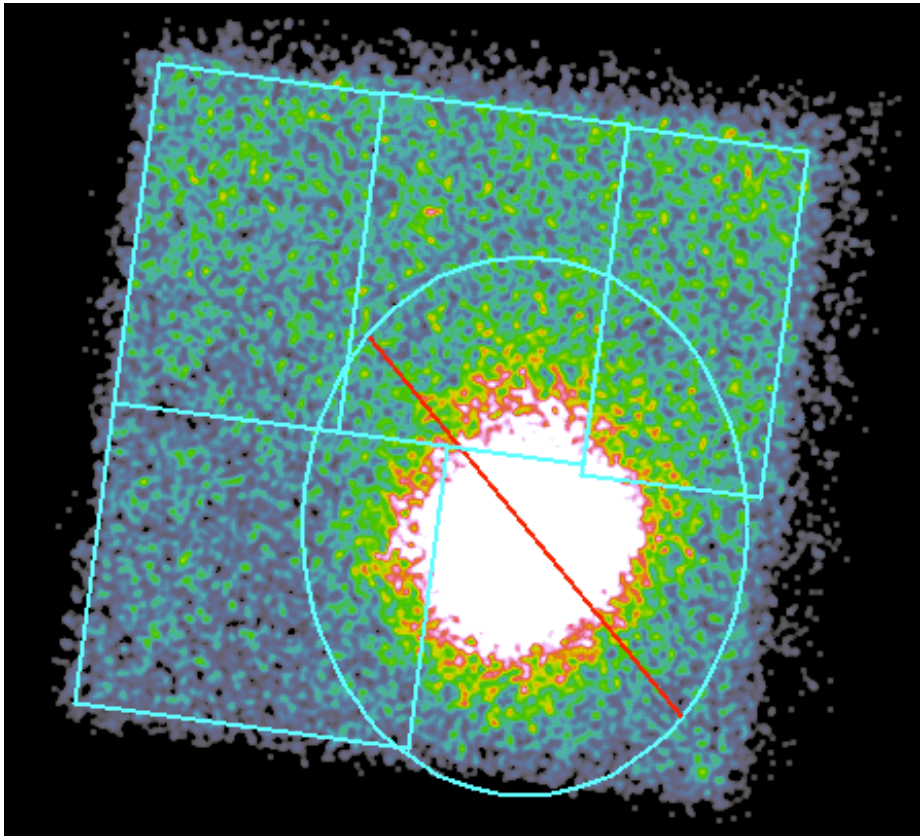
Source:

Maximize S/N while avoiding bullet to the west

Background regions:

For each focal plane, 4 spectra fit simultaneously to produce a model bgd for the source region using `nuskybgd`





IC Fit: Center on radio halo and avoid cool core

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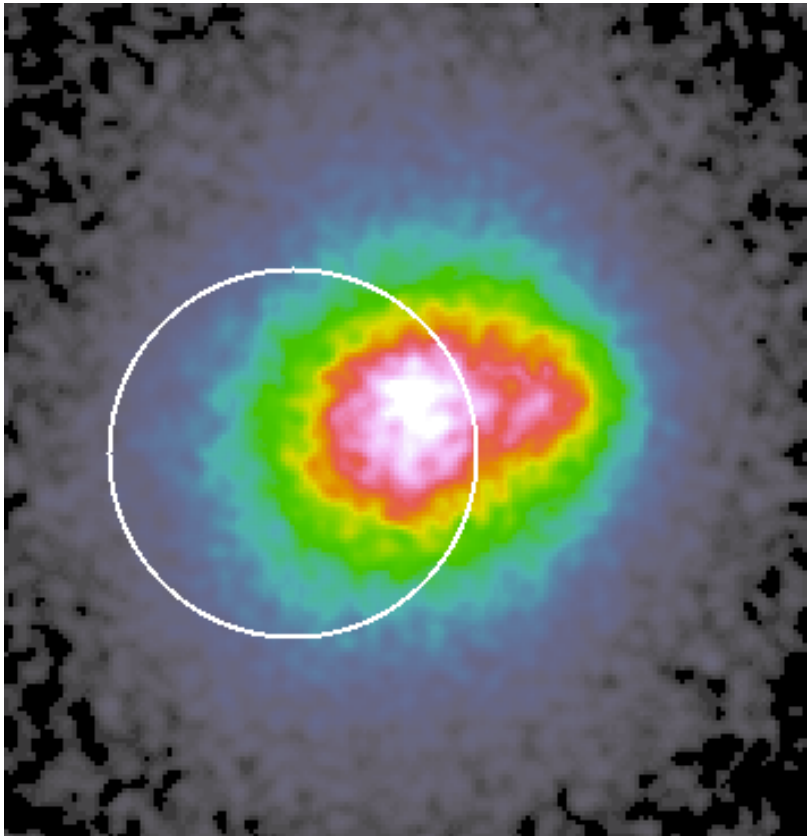

Background regions:

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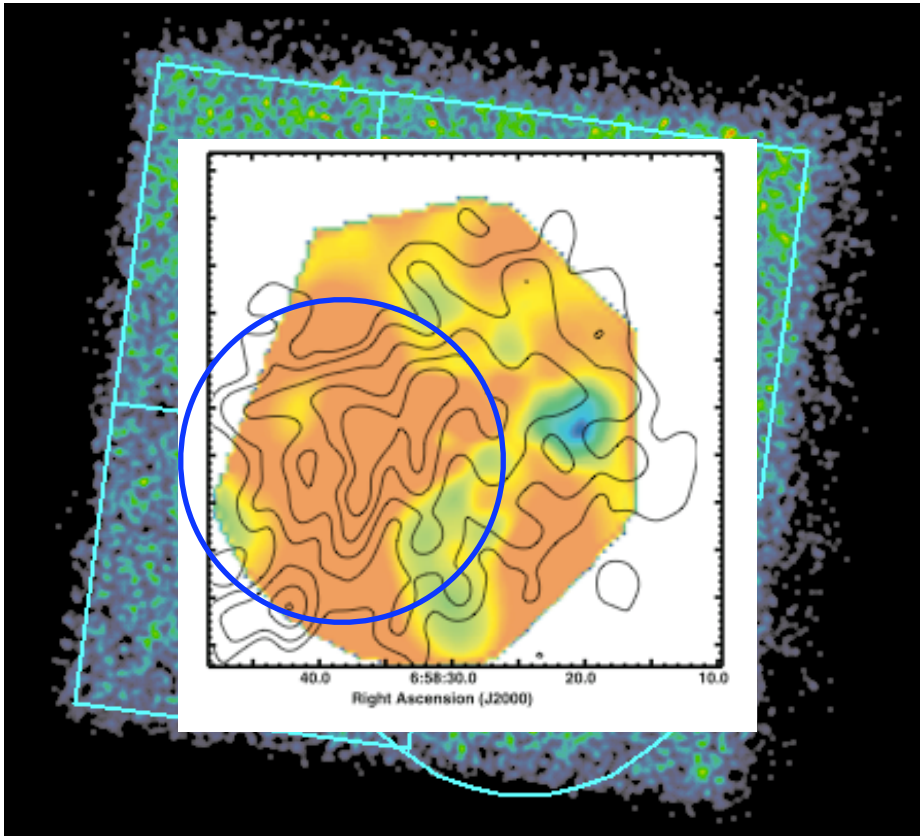
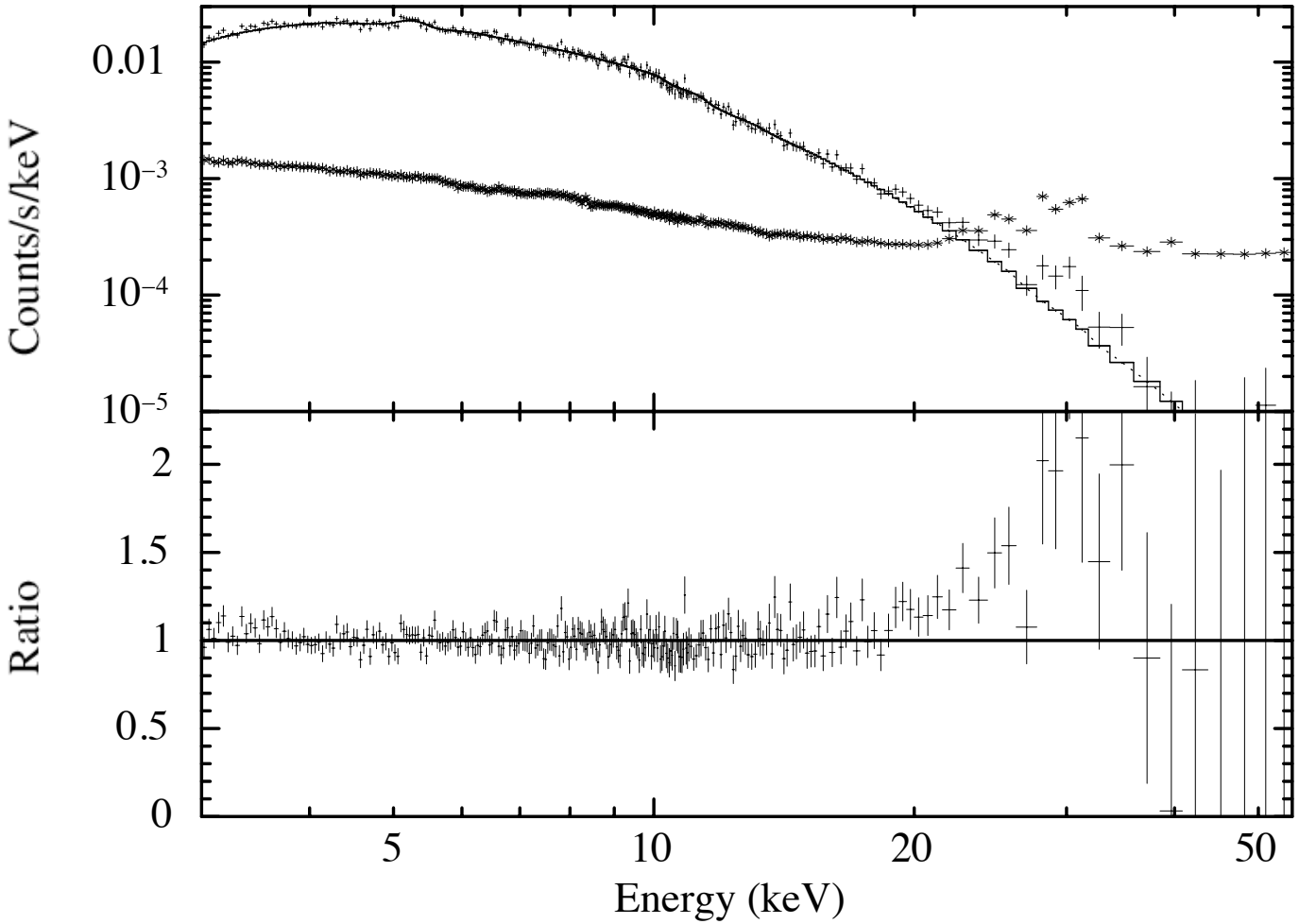


Do we see Inverse Compton?

Single kT fit



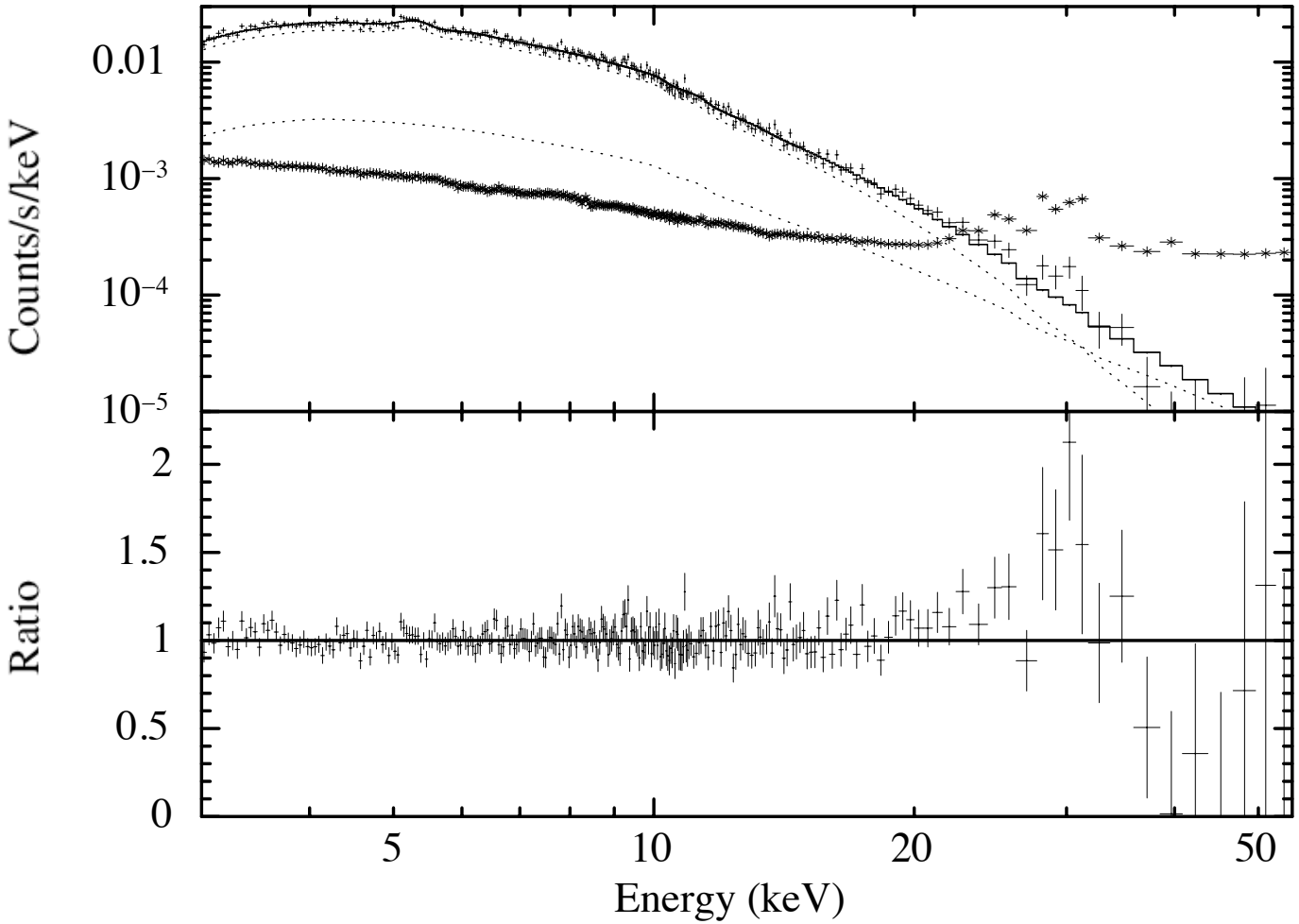
Chi^2/dof
630.5/584

kT
13.9 keV

Norm
7.05e-3

Do we see Inverse Compton?

T+IC fit



Chi^2/dof
607.0/583

kT
12.7 keV

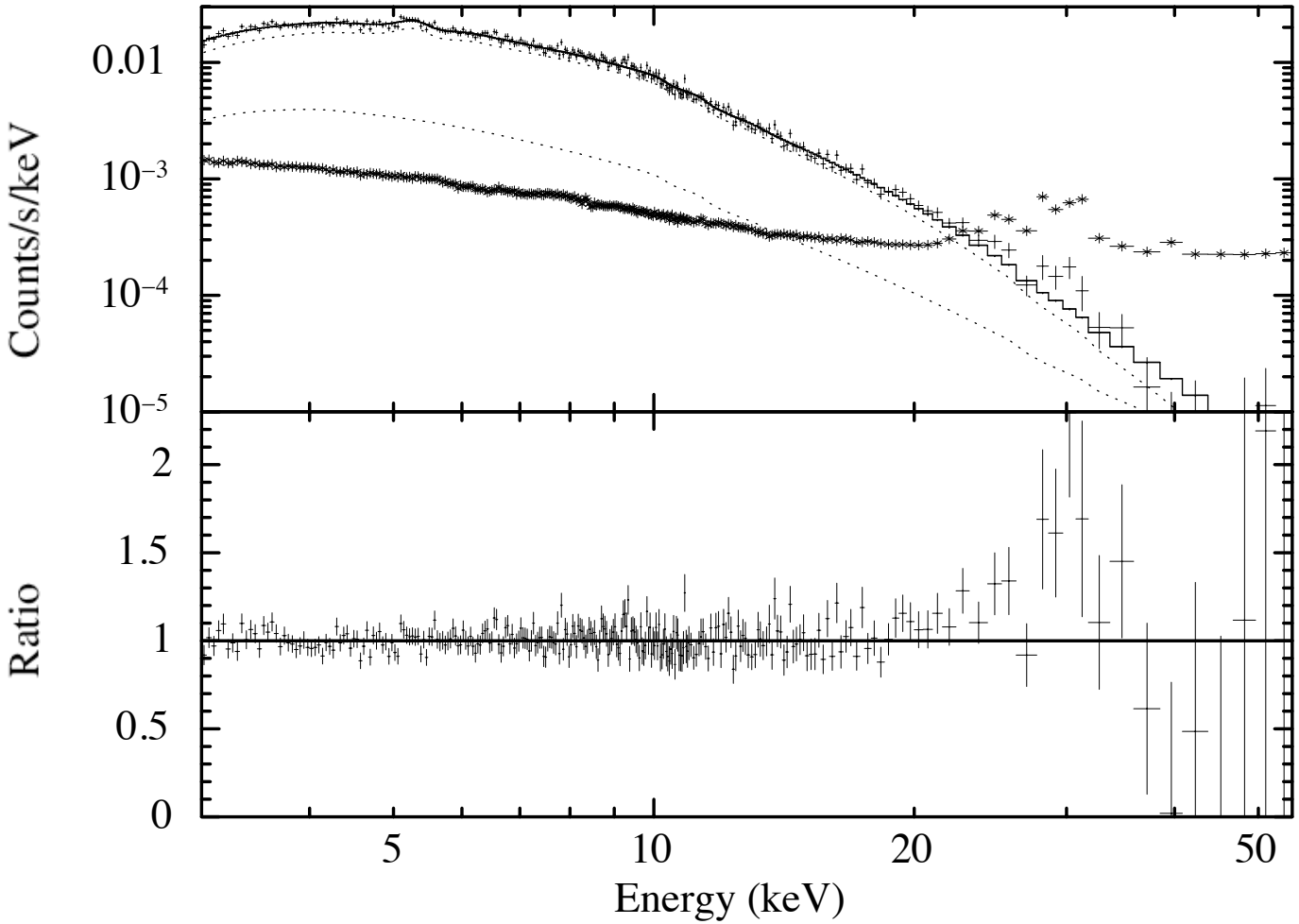
Norm
6.16e-3

index
1.86 fixed

Norm
2.71e-4

Do we see Inverse Compton?

T+IC fit



Chi^2/dof
603.8/582

kT
14.3 keV

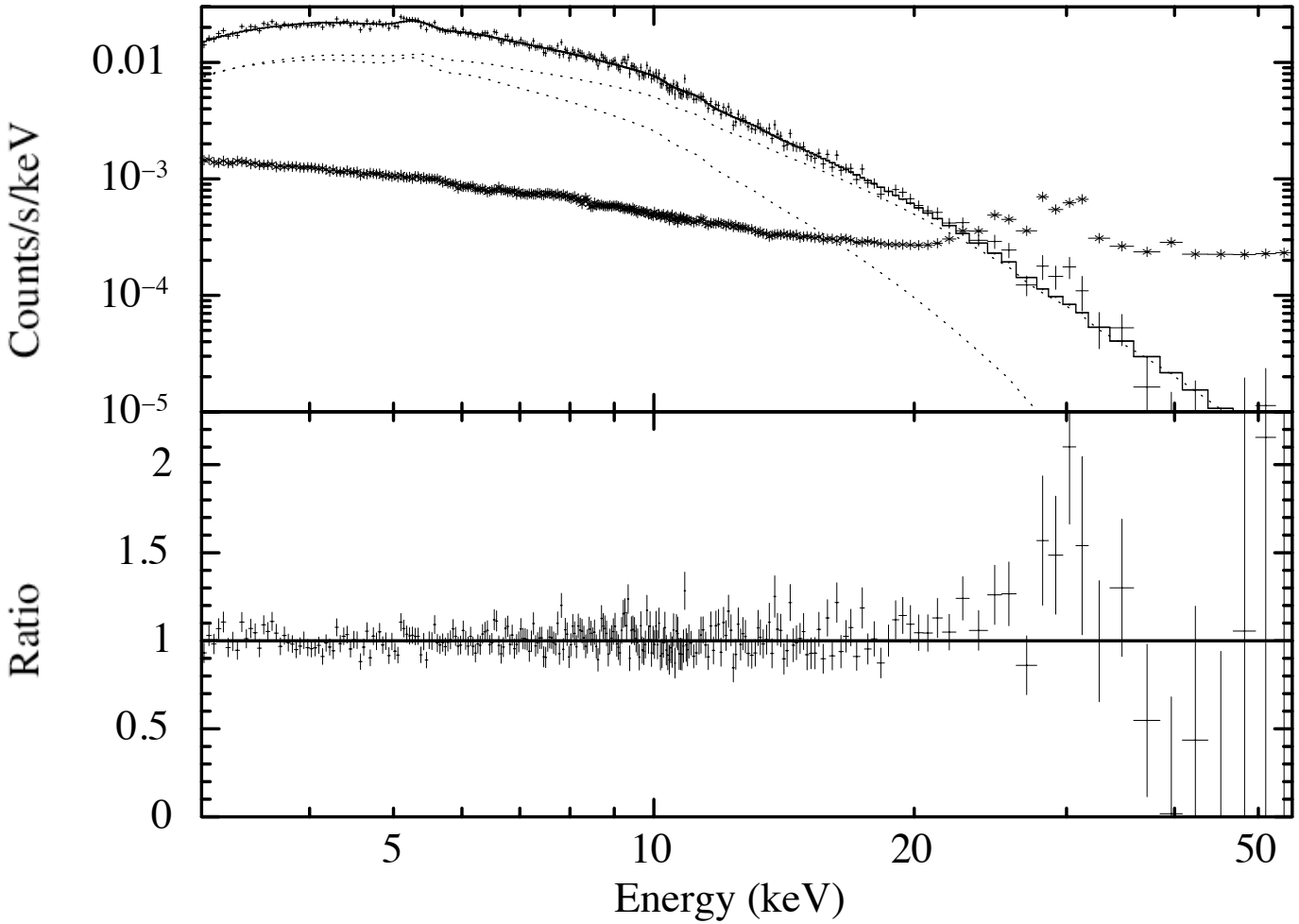
Norm
5.79e-3

index
2.28 free

Norm
6.03e-4

Do we see Inverse Compton?

Two Temperature fit



Chi^2/dof
599.7/582

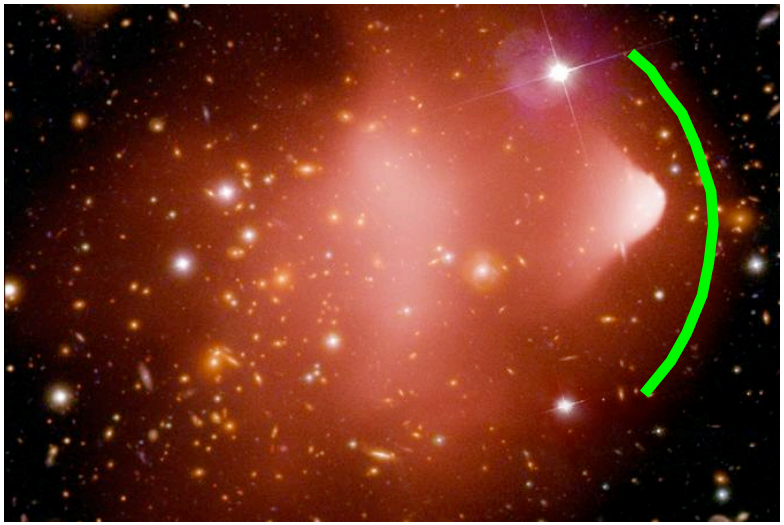
kT
8.2 keV

Norm
3.99e-3

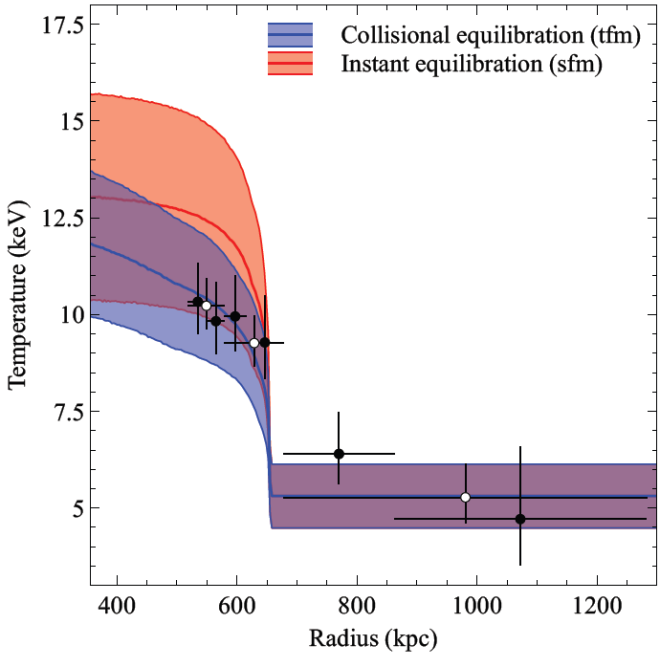
kT
20.9 keV

Norm
3.49e-4

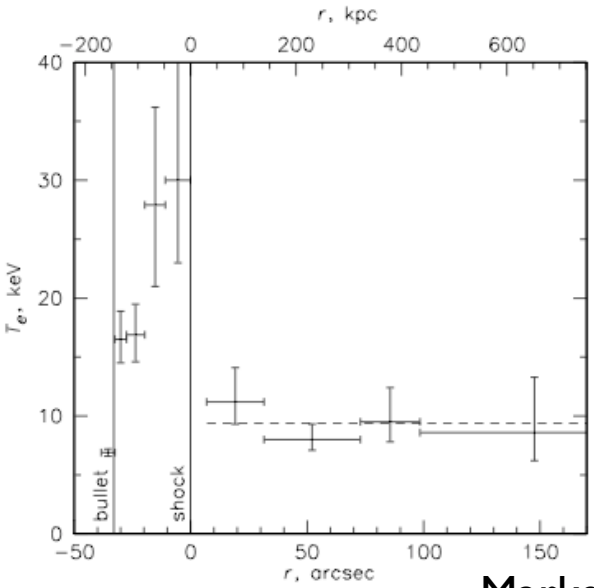
The Shock driven by the Bullet

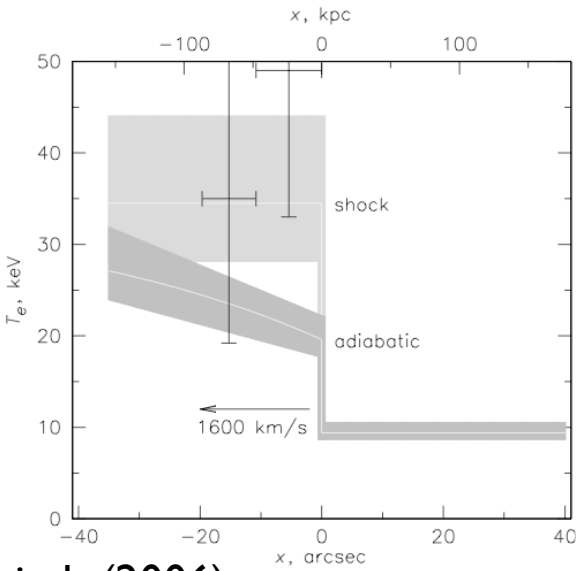


Bow-Shock in A2146



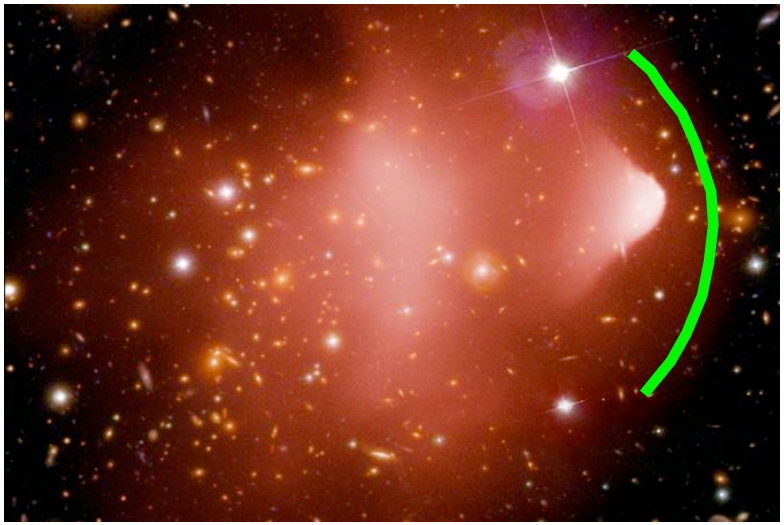
Russell+2012

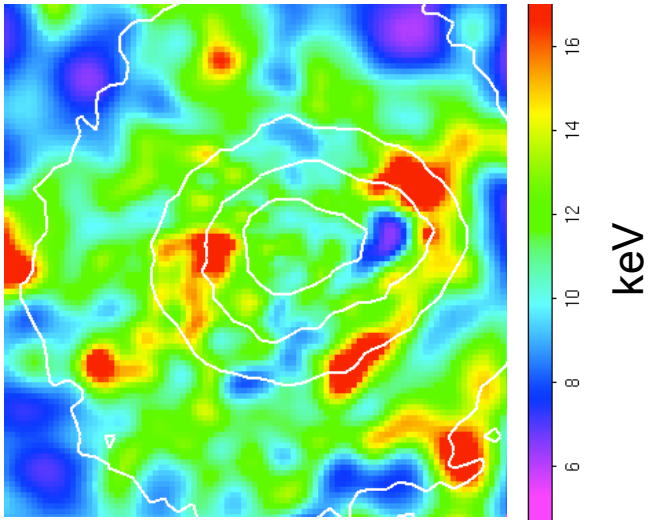


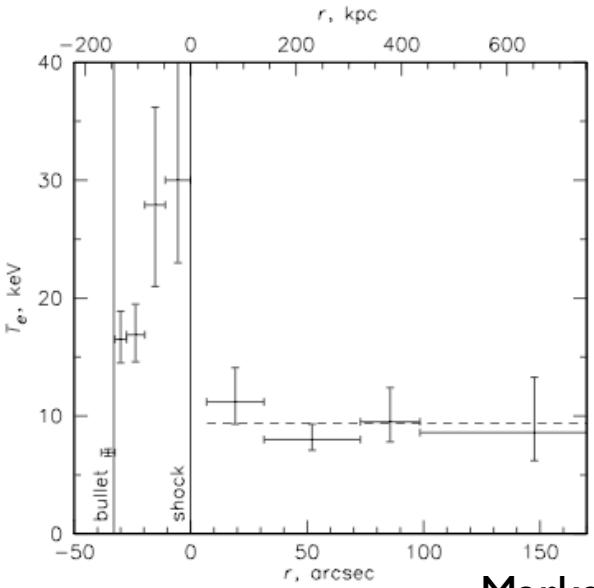


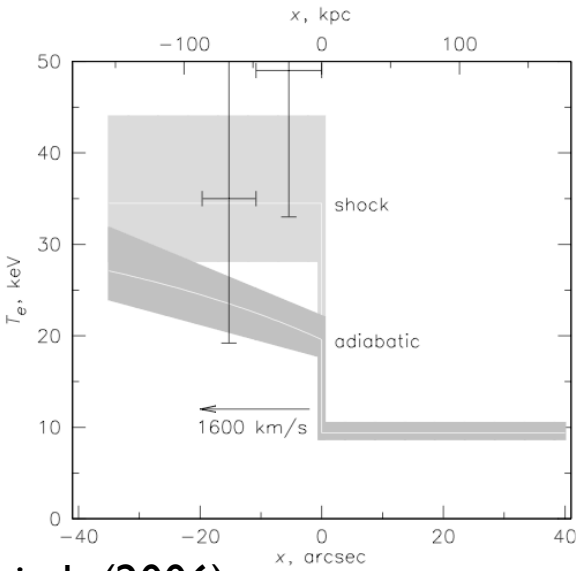
Markevitch (2006)

The Shock driven by the Bullet







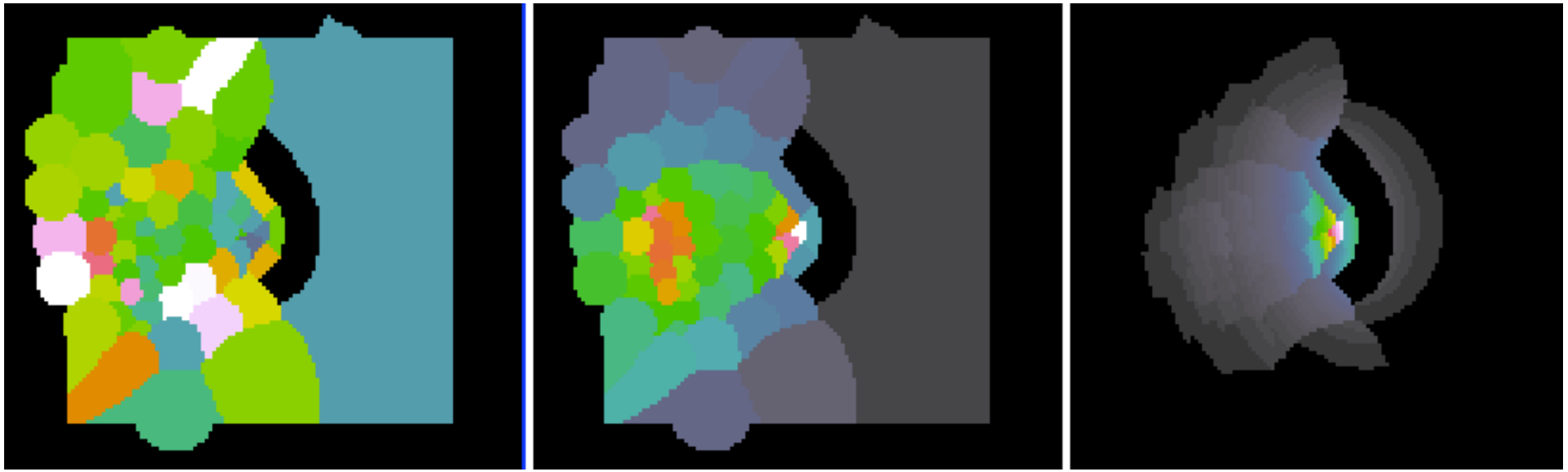


Markevitch (2006)

The Shock driven by the Bullet

Chandra fitting

Norm weighted by NuSTAR PSF

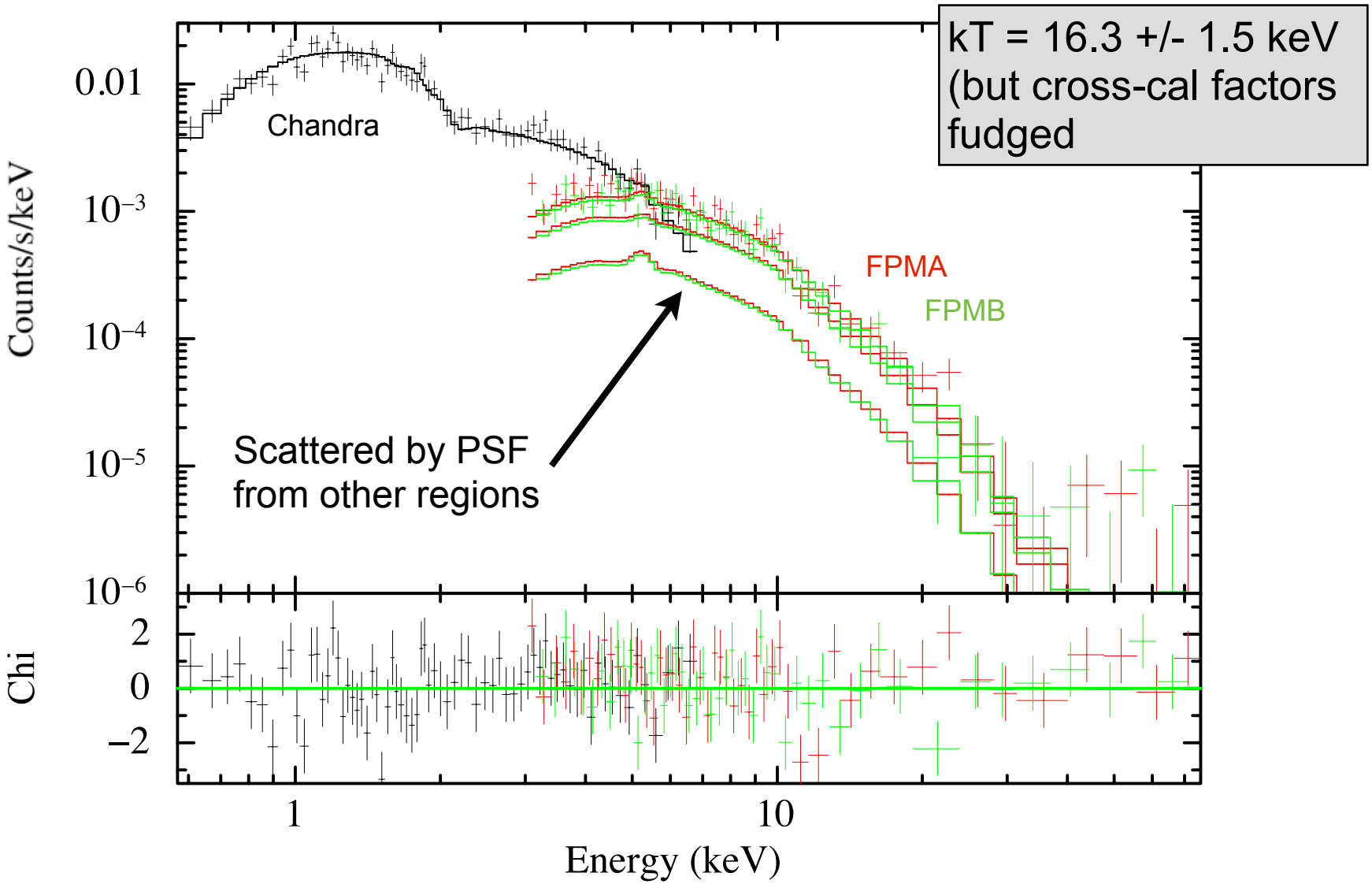


kT

Norm

(to account for emission scattered into shock region)

The Shock driven by the Bullet

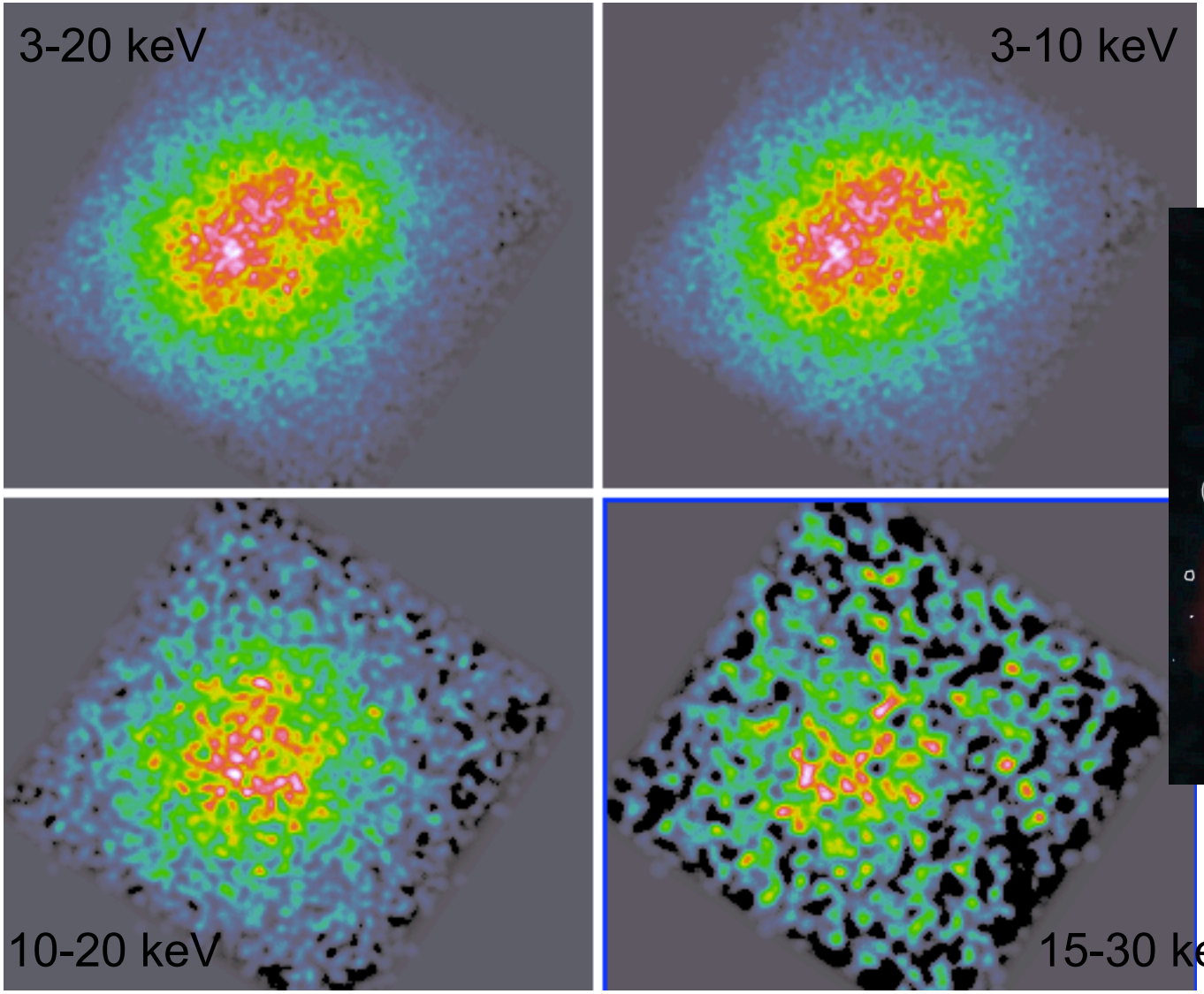


Summary

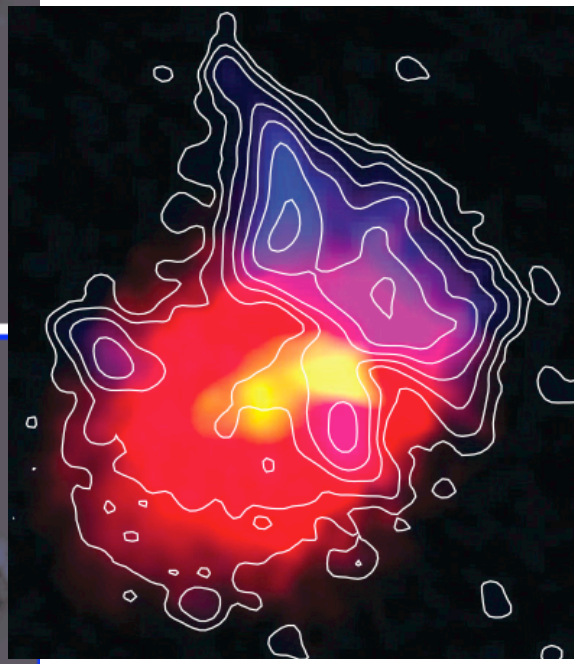
NuSTAR

- on inverse Compton...
  - reasonable 2T model adequate
  - confirm multi-T with Chandra temperature map check
- on shocks...
  - appears possible to get precise kT estimates, even for low surface brightness regions
  - mission cross-calibration for *diffuse* emission crucial

A2256, first 53 ks

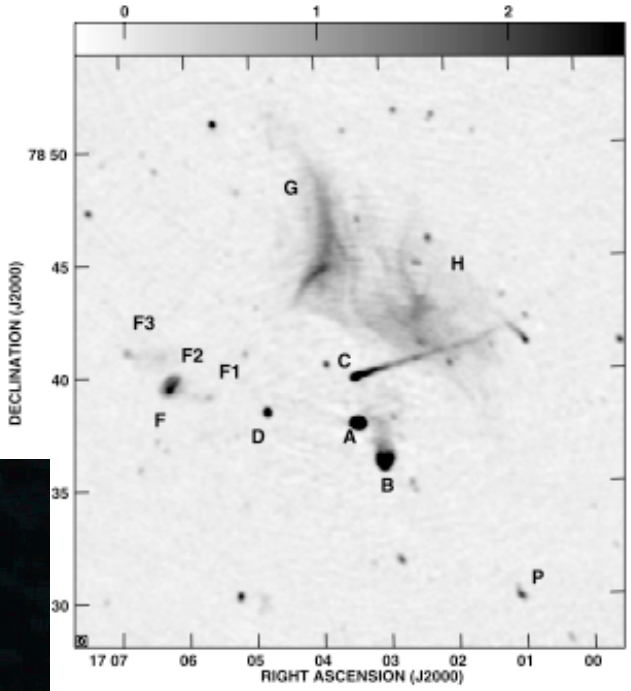


Chandra



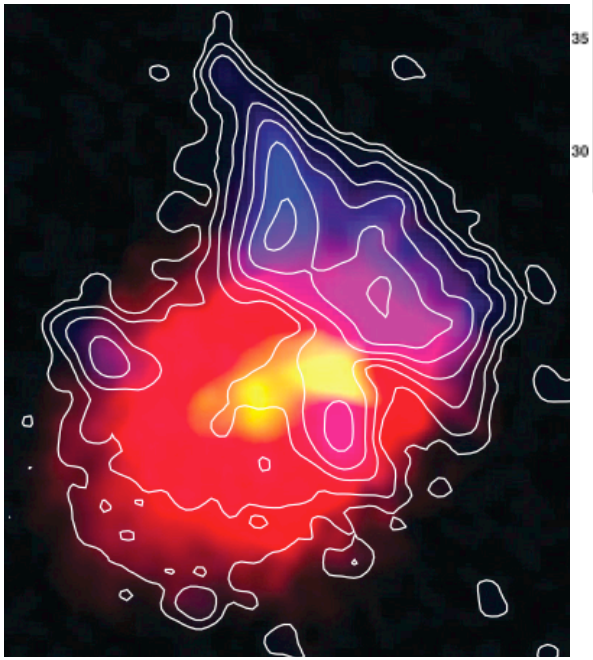
A2256, 53 ks + 57 ks

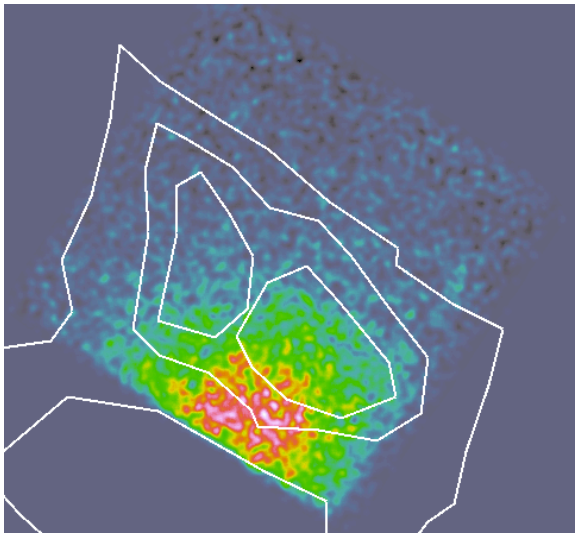
VLA



Clarke et al. (2006)

Chandra





3-20 keV