Detection of Diffuse Non-Thermal Emission in (Cool) Clusters and Groups with Chandra

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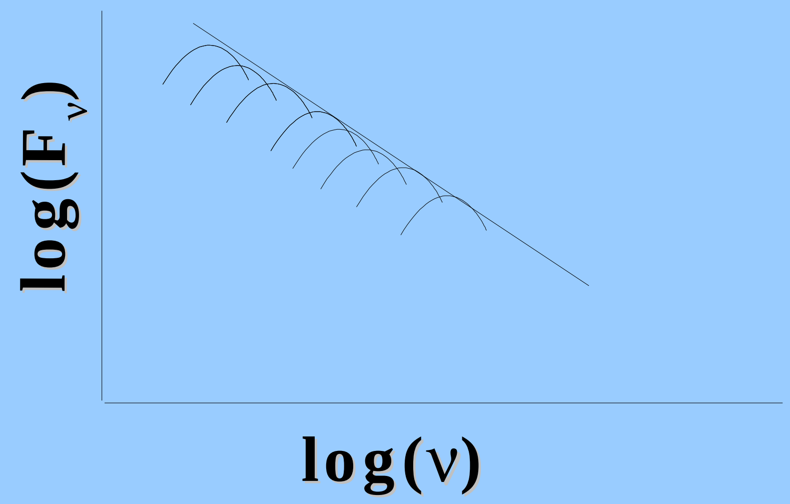
Outline

- Introduction: Diffuse NT Emission
- Problems with Hard X-ray Detectors
- Chandra and Diffuse NT Emission?!?
- Diffuse NT Emission in Cool Clusters
- IC1262 Results
- Future Work/Conclusions

Diffuse Non-thermal Emission

Synchrotron emission

$$\nu_{peak} = \left(\frac{\gamma^2 eB}{2\pi m_e c} \right)$$



Inverse Compton Scattered Photons

$$\epsilon = \left(\frac{4\gamma^2 \epsilon_b}{3} \right),$$

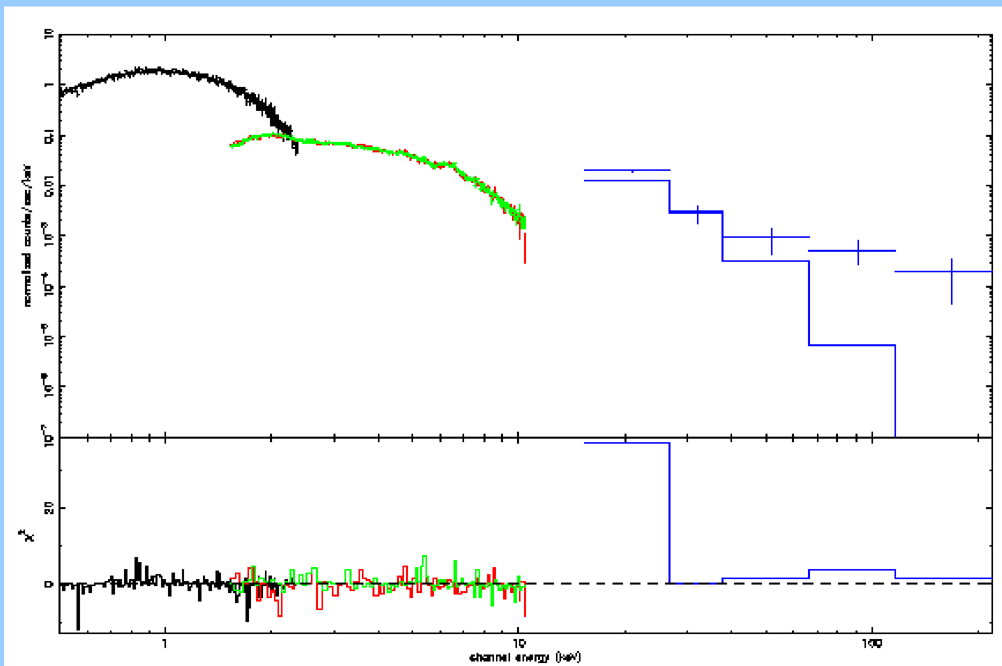
$$\epsilon_b \approx 6.64 \times 10^{-7} keV$$

$$for\, CMB\, photons\, (2.73 keV)$$

Problems with Hard X-ray Detectors

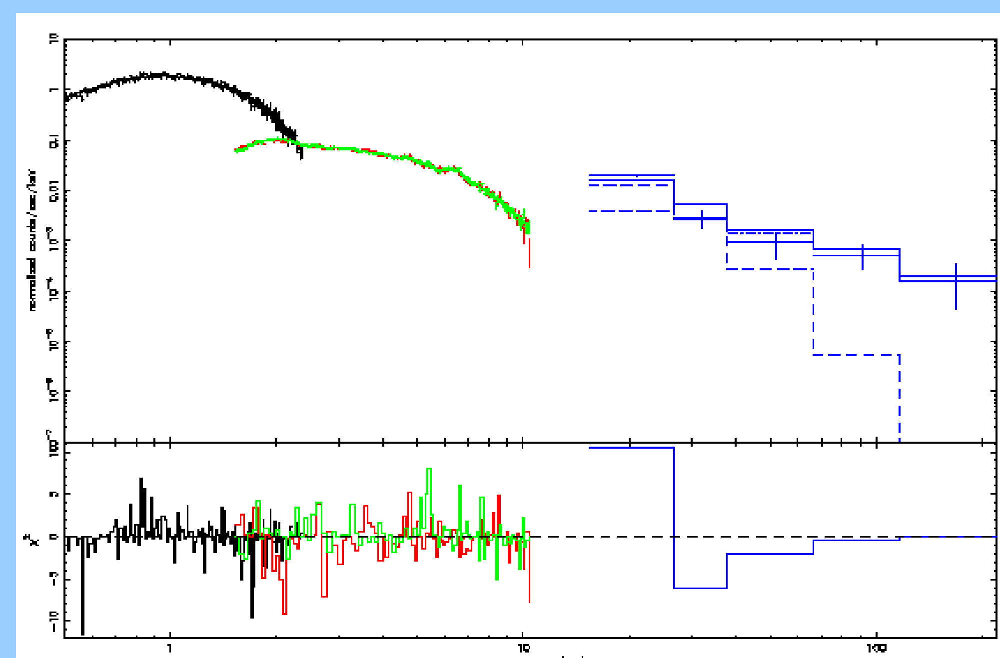
- No Spatial Resolution (therefore susceptible to contamination)
- Sensitive to flatter spectra (AGN)
- Examples:
  - Coma - Longer observation shows no detection (Rosetti & Molendi 2004). PDS detection is above upper-limit determined with the PCA.
  - A754 - Hard excess is well fit by spectrum of 26W20
  - A2163 - Given $^{1.4}_{.3}$ ~1.18, $S_{1.4}$ ~155 mJy, B~0.9 G (Eq.), the Hard X-ray flux is only 1.15 x 10^{-7} photons cm^{-2} s^{-1} keV^{-1} @ 15 keV

A754 and 26W20



A thermal fit to the spectrum of A754 shows a clear excess in the PDS…

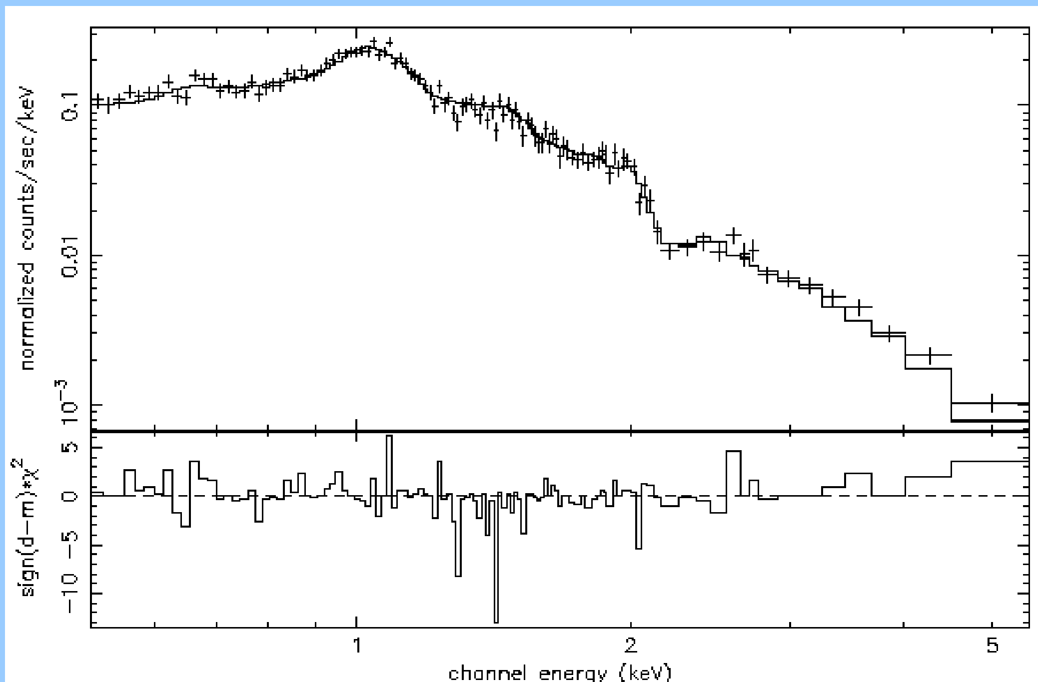
However, including a power-law component for 26W20 eliminates the hard excess.



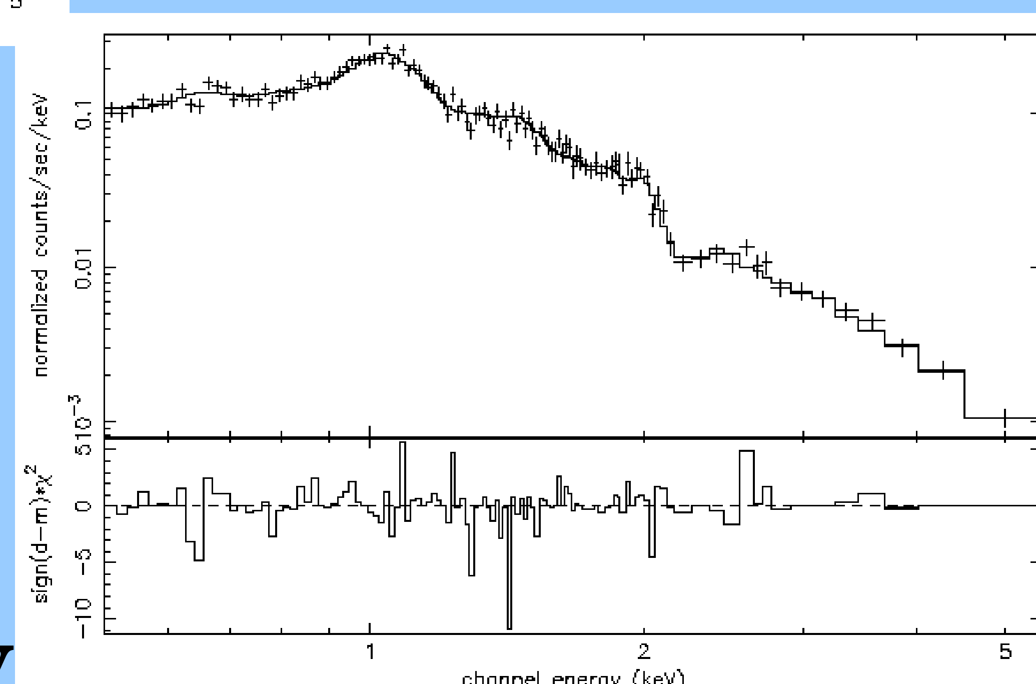
Why Chandra?!?

- Low, well defined Background
- Not susceptible to contaminating AGN
- Simulations suggest diffuse NT emission exists in cool clusters as well as hot clusters (Miniati et al 2001)
- Possible to isolate regions of analysis - shock fronts, radio emission, etc...

Simulation of a 60 ks observation of a 1.5 keV plasma with a power-law component (Γ_X = 2.2 & ~20% Thermal Flux)



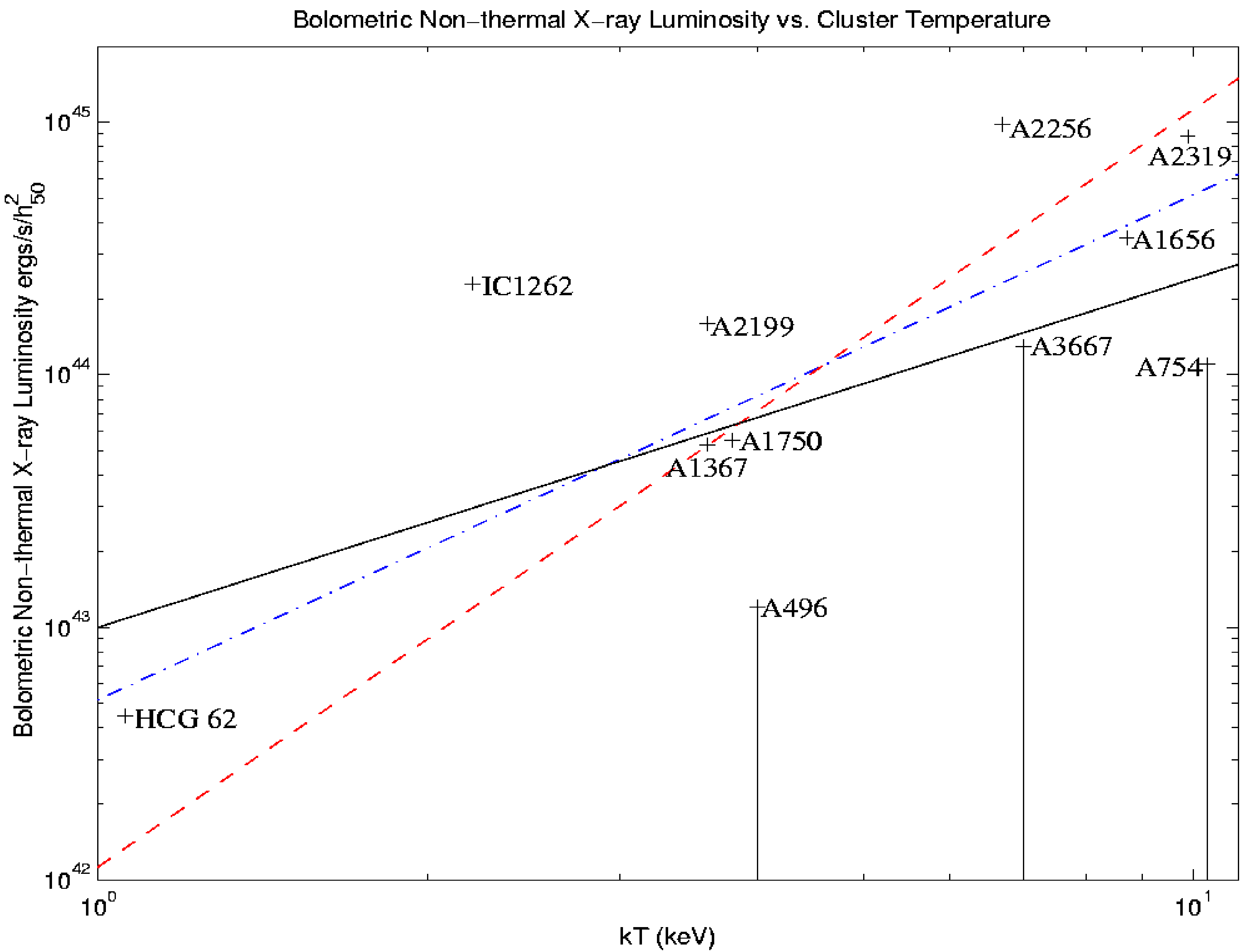
Fitted with a single APEC model



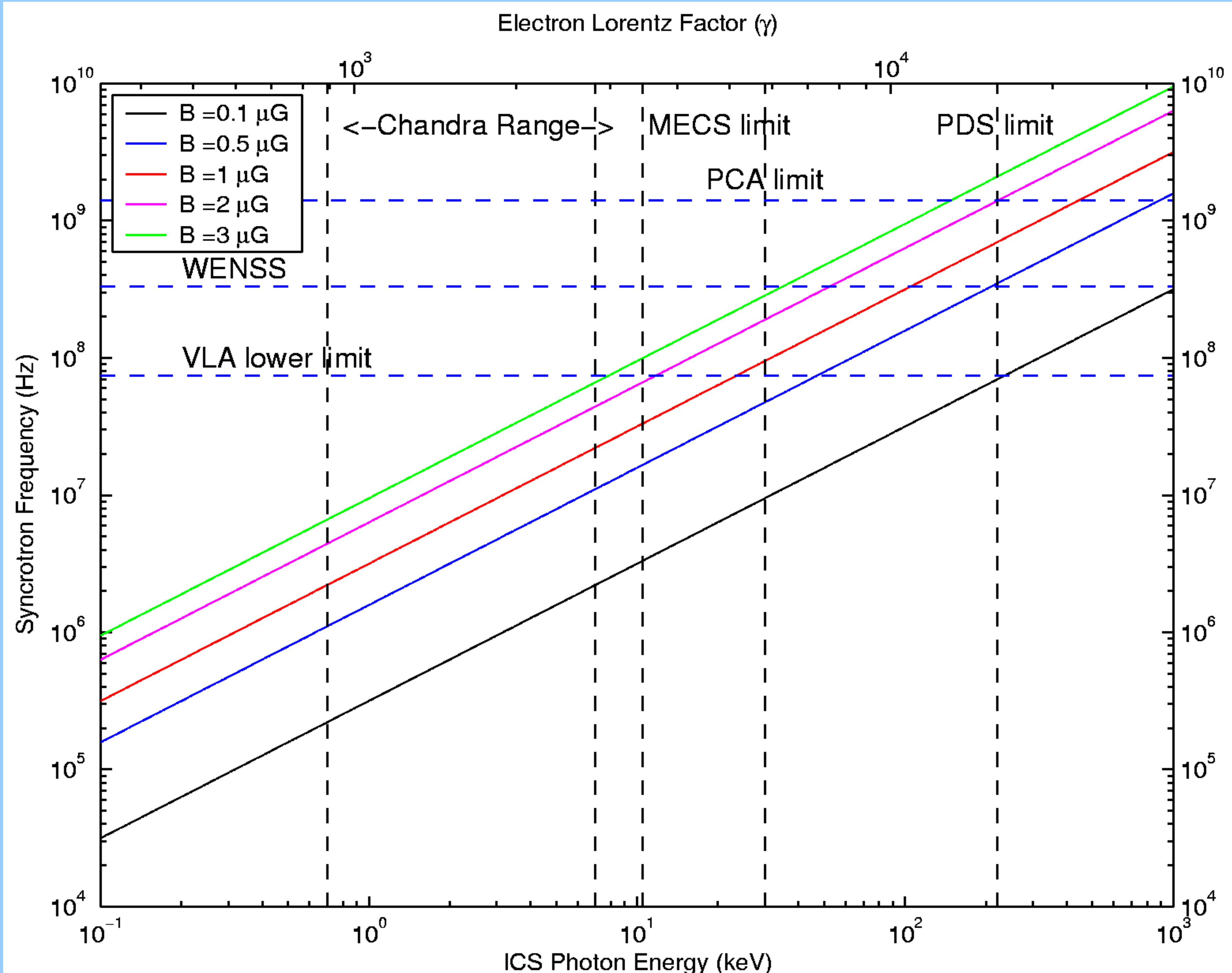
Fitted with APEC+Power-law

NT Emission In Cool Clusters

- Detections:
  - IC1262 - Chandra (Hudson & Henriksen 2003)
  - HCG-62 - ASCA (Fukazawa et al 2001)
- Needed to constrain L_{NT} vs kT relationship. L_{NT} vs kT relationship can be used to determine population of electrons (primary or secondary).
- Hard excess can be detected in the ~7 keV range in cool Clusters.
- Probes lower Lorentz Factor electron population (Detections for steep spectra may be possible in the X-ray, but not in radio).

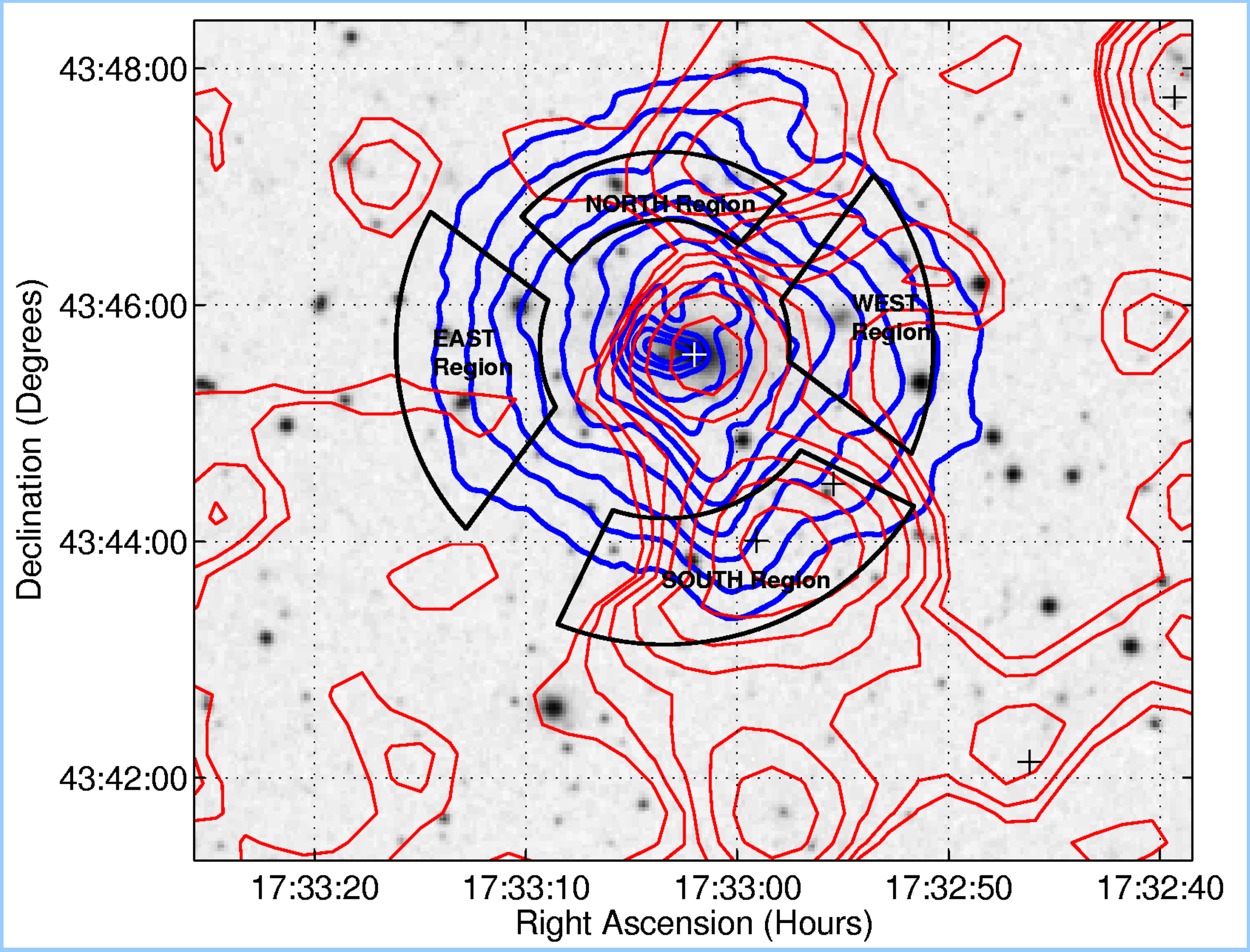


Bolometric Non−thermal X−ray Luminosity vs. Cluster Temperature
Bolometric Non−thermal X−ray Luminosity ergs/s/h$_{50}^{2}$
kT (keV)
10^{42}
10^{43}
10^{44}
10^{45}
10^{0}
10^{1}
A2256
A2319
A1656
IC1262
A2199
A3667
A754
A1750
A1367
A496
HCG 62

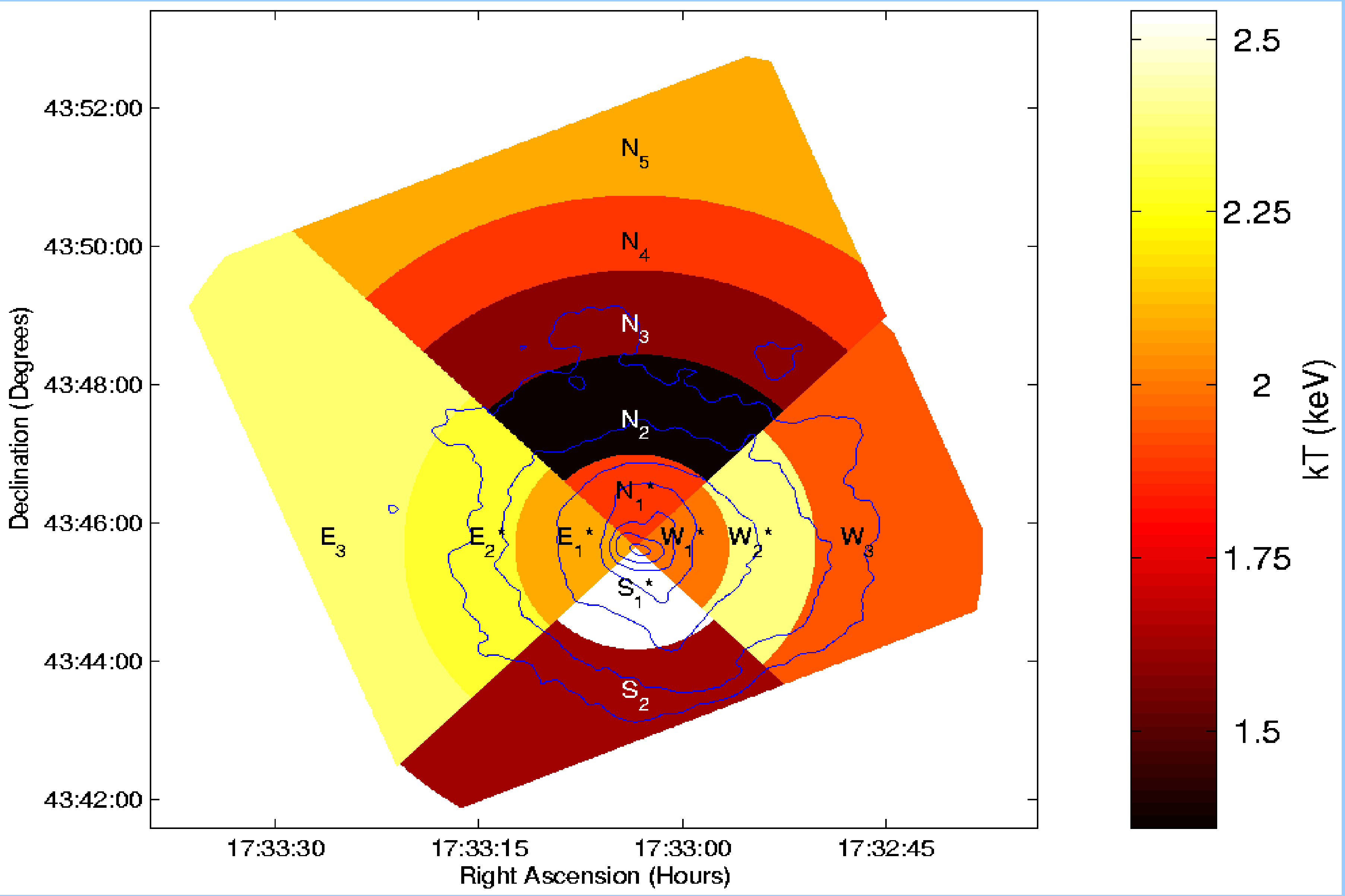


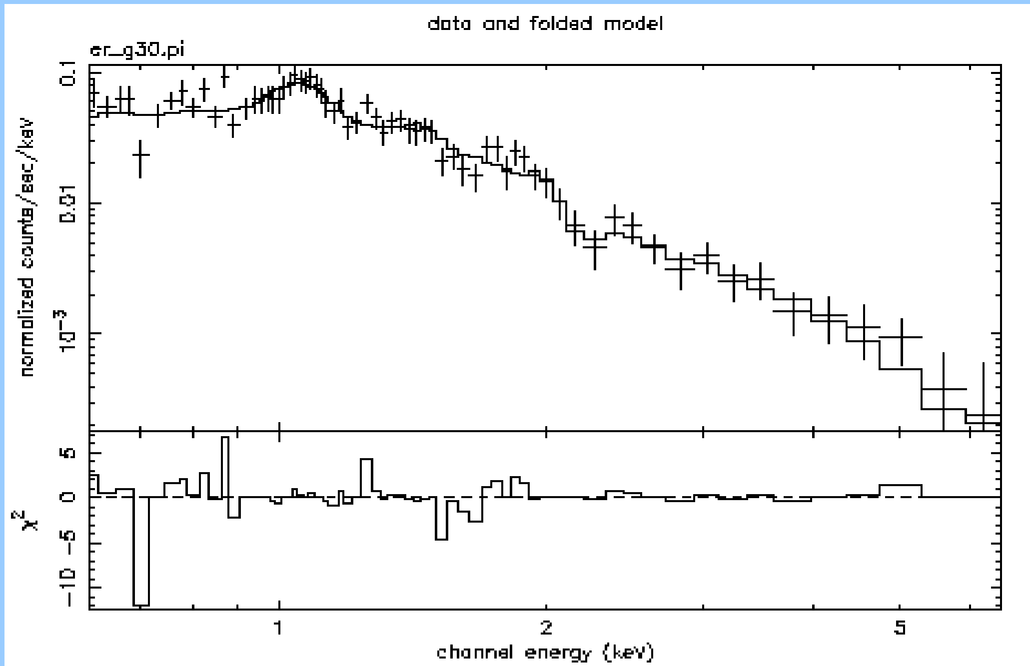
Electron Lorentz Factor (γ)
10^3
10^4
B =0.1 μG
B =0.5 μG
B =1 μG
B =2 μG
B =3 μG
<–Chandra Range–>
MECS limit
PCA limit
PDS limit
WENSS
VLA lower limit
Syncrotron Frequency (Hz)
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
10^{-1}
10^0
10^1
10^2
10^3
ICS Photon Energy (keV)

DSS Image of IC1262
ACIS and NVSS Contours



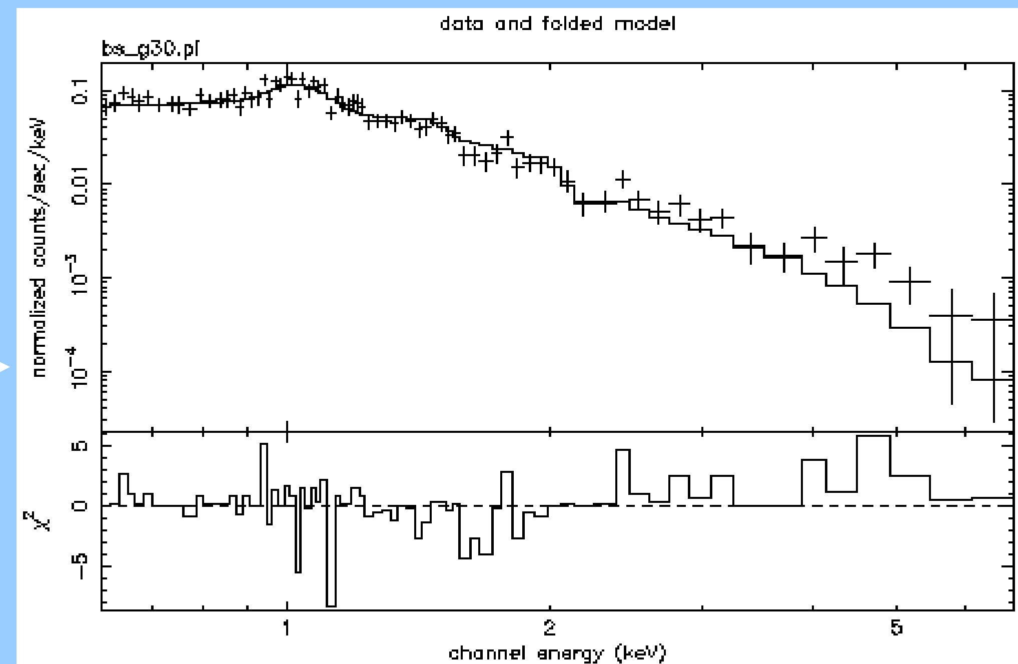
Temperature Map of IC1262

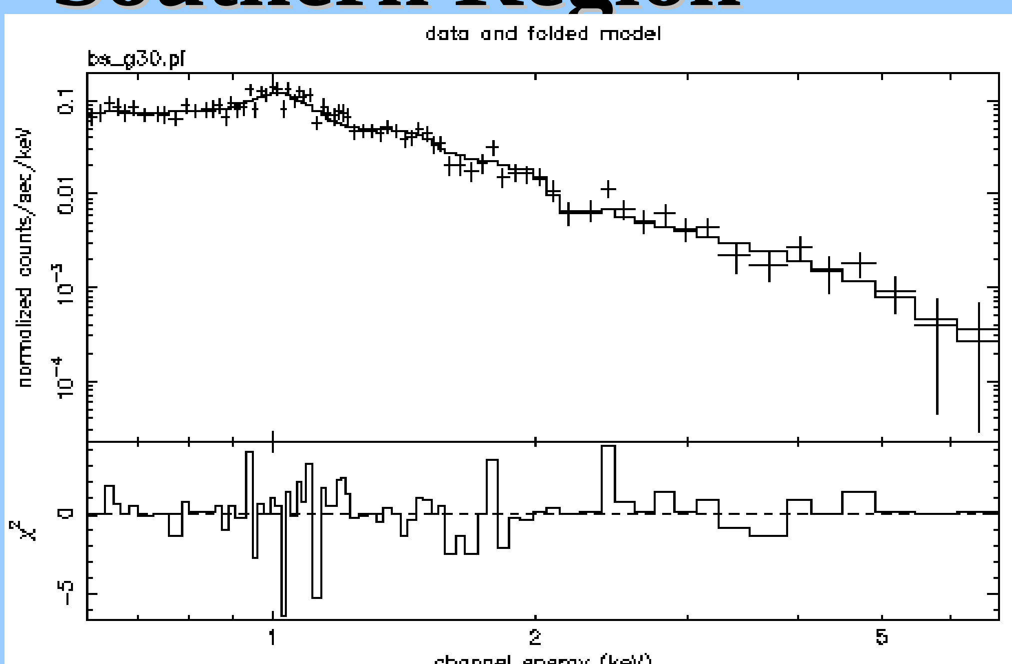




Single Thermal Fit to Eastern Region

Single Thermal Fit to Southern Region





Thermal + Power-law Fit to Southern Region

IC1262

IC1262 compared to simulations by Miniati et al (2001).

Photon Index($_{x}$)

IC1262 = 2.1-2.3

Primary electrons > 2.1 (increasing with distance from the shock)

Secondary electrons < 2.1

Bolometric Flux (0.13 - 100 keV)

IC1262 (NT emission) = (6-10) x 10^{-13} ergs cm^{-2} s^{-1}

Primary electrons = (10 - 48) x 10^{-13} ergs cm^{-2} s^{-1}

Secondary electrons = 1.9 x 10^{13} ergs cm^{-2} s^{-1}

IC1262

From the spectral models of the S_2 regions, we determine the sound and Alfvén speed in the plasma. Assuming a magnetic field of 1 G, we can calculate the compression factor for a modified shock from the observed photon index.

Our Parameters are:

$$\Gamma_X = 2.21^{+0.14}_{-0.15} \rightarrow \alpha = 1.21^{+0.08}_{-0.08}$$

$$kT_{S1} = 2.54^{+0.26}_{-0.22} keV$$

$$kT_{S2} = 1.60^{+0.08}_{-0.10} keV$$

Our best fit photon index implies a compression factor of r = 2.27-2.32. For a Shock with this compression factor, the temperature ratio T_{sh}/T_{unsh} = 2.1-2.2, inconsistent with T_{S1}/T_{S2} = 1.4-1.8. Possibly a modified shock (T_{msh}/T_{unsh} = 1.3-1.6).

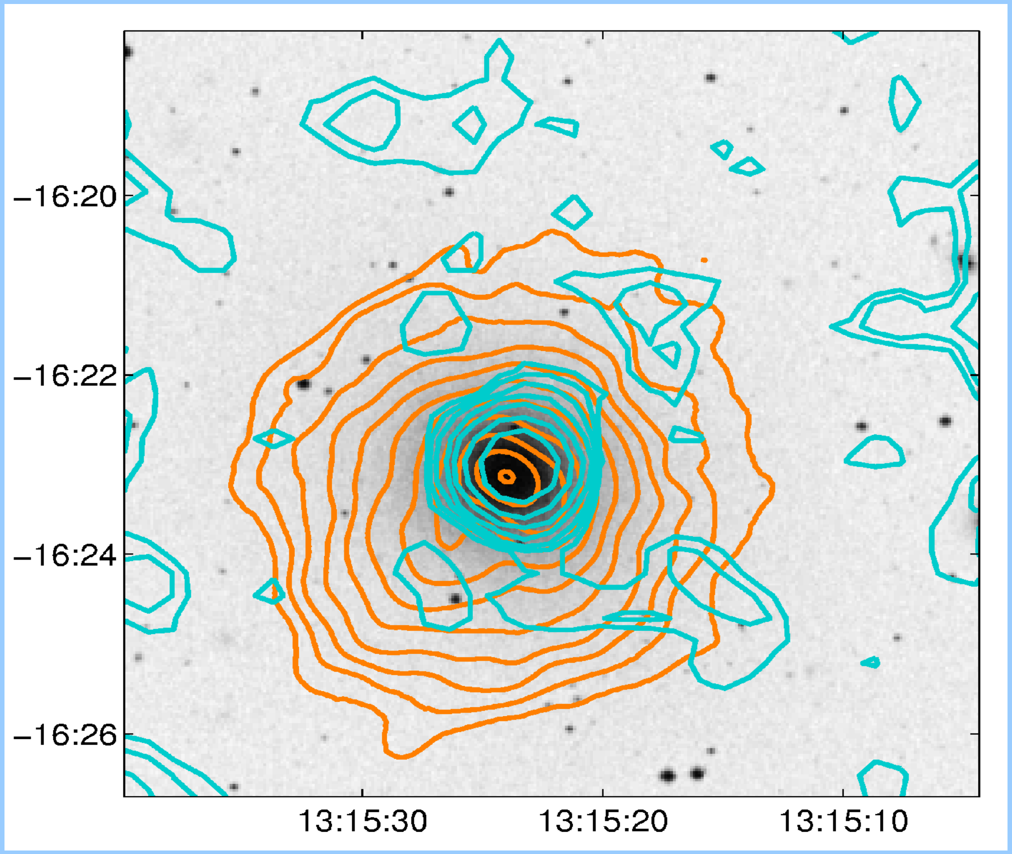
Conclusions

- **Diffuse Emission exists in Cool Clusters.**
- **Chandra can detect and isolate Diffuse NT emission in Cool Clusters.**
- **Diffuse NT emission from cool clusters can be used to determine the population of emitting electrons.**

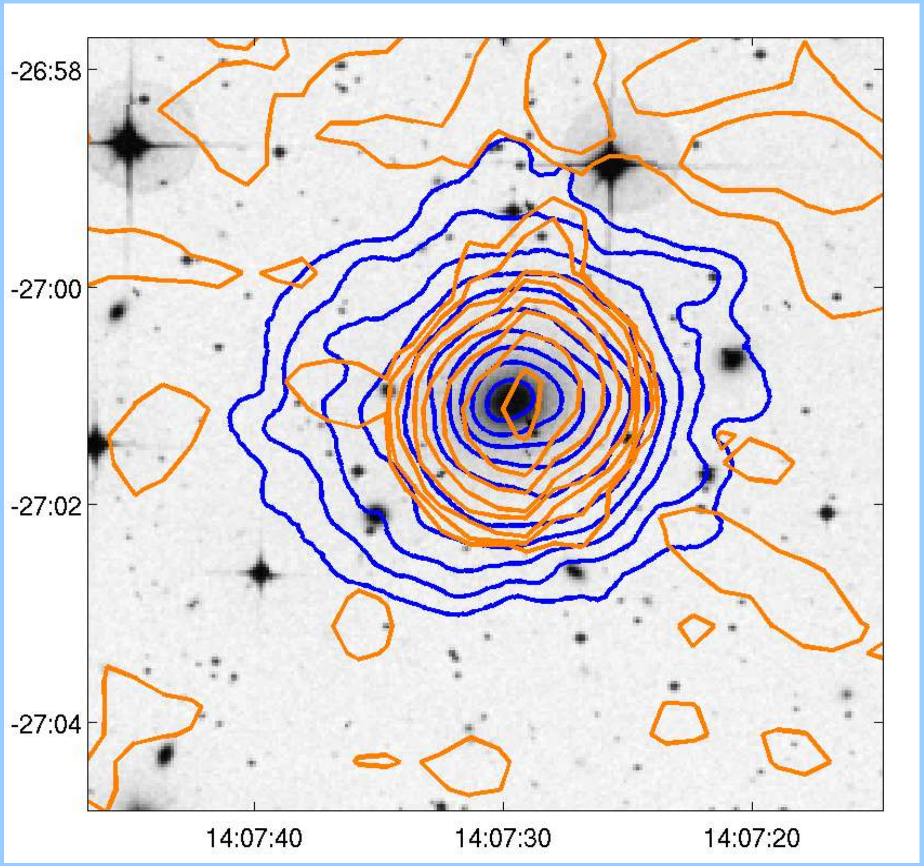
Future Work

Survey of Chandra Observations of Cool Clusters and Groups... and some Hot ones too...

WP23



A3581



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