Mapping the non-thermal emission in Coma cluster of galaxies using the FeXXV/FeXXVI line ratio

J. Nevalainen[1] & D. Eckert[2]

[1] Helsinki University Observatory, Finland

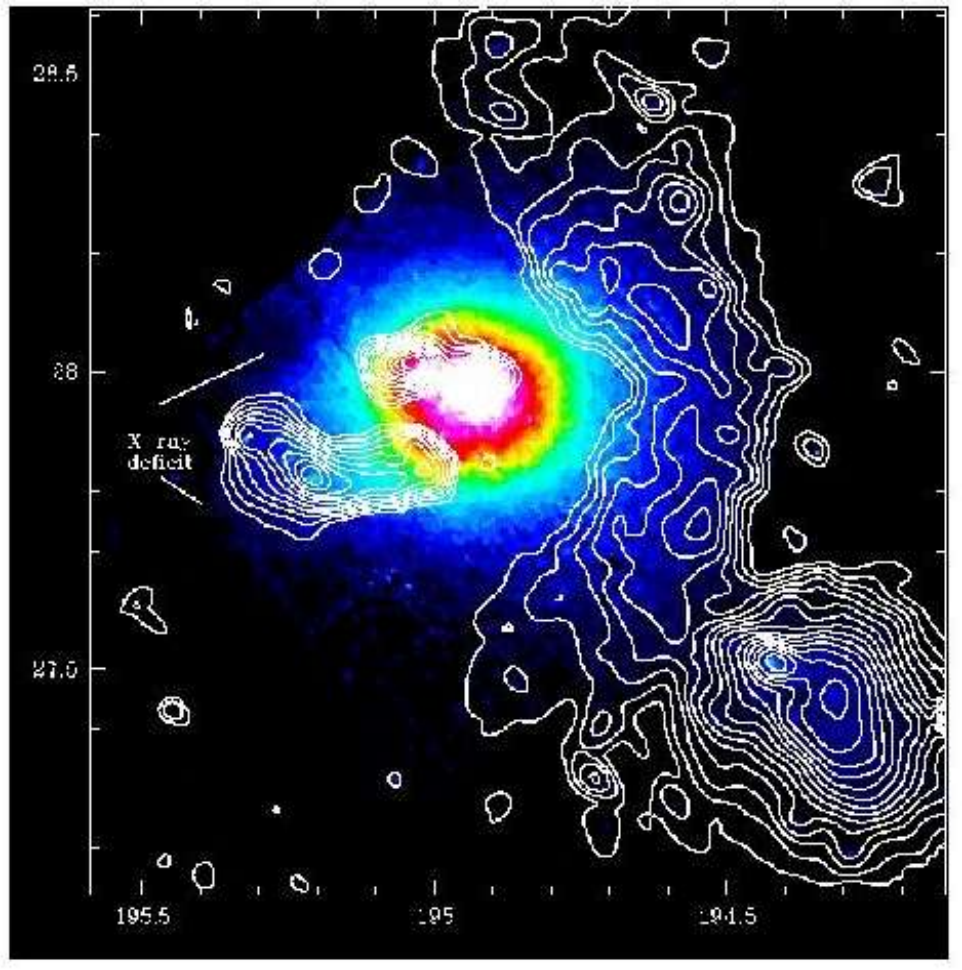
[2] ISDC, Geneva, Switzerland

Evidence for non-thermal activity in Coma

RXTE and BeppoSAX 20-80 keV band excess emission:

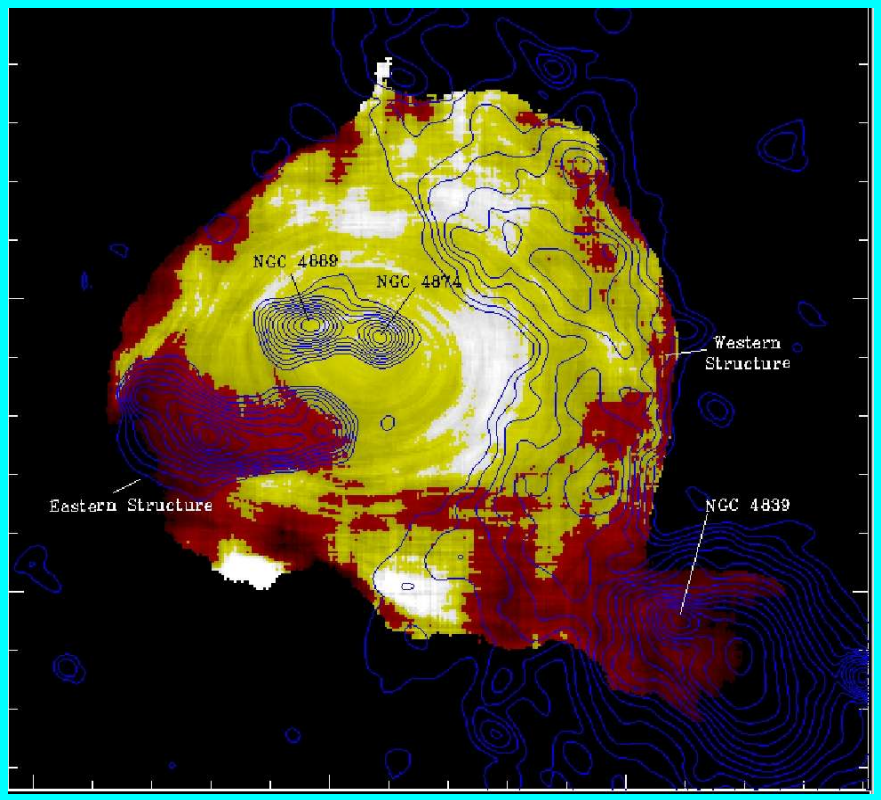
- RXTE (Rephaeli & Gruber, 2002, ApJ, 579, 587) 6σ
- BeppoSAX (Fusco-Femiano et al., 2004, ApJ, 602, L73) 5σ
- BeppoSAX (Nevalainen et al. , 2004, ApJ, 698, 166) 2σ
- BeppoSAX (Rossetti & Molendi, 2004, A&A, 414, 41) 0-2 σ
- (see Rephaeli et al, 2008, Space Science Reviews, 134, 1-4, 71, and references therein)

Coma XMM observation of Neumann et al., 2003, A&A 400, 811



- Excess 0.5-2.0 keV band emission between the Coma center (NGC4874) and NGC 4839

Temperature map

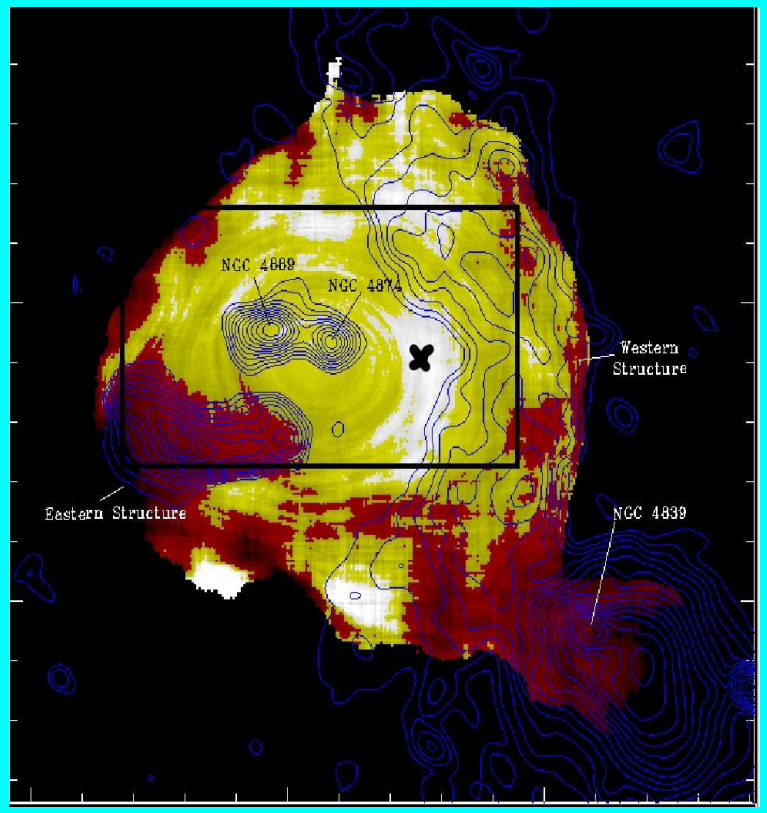


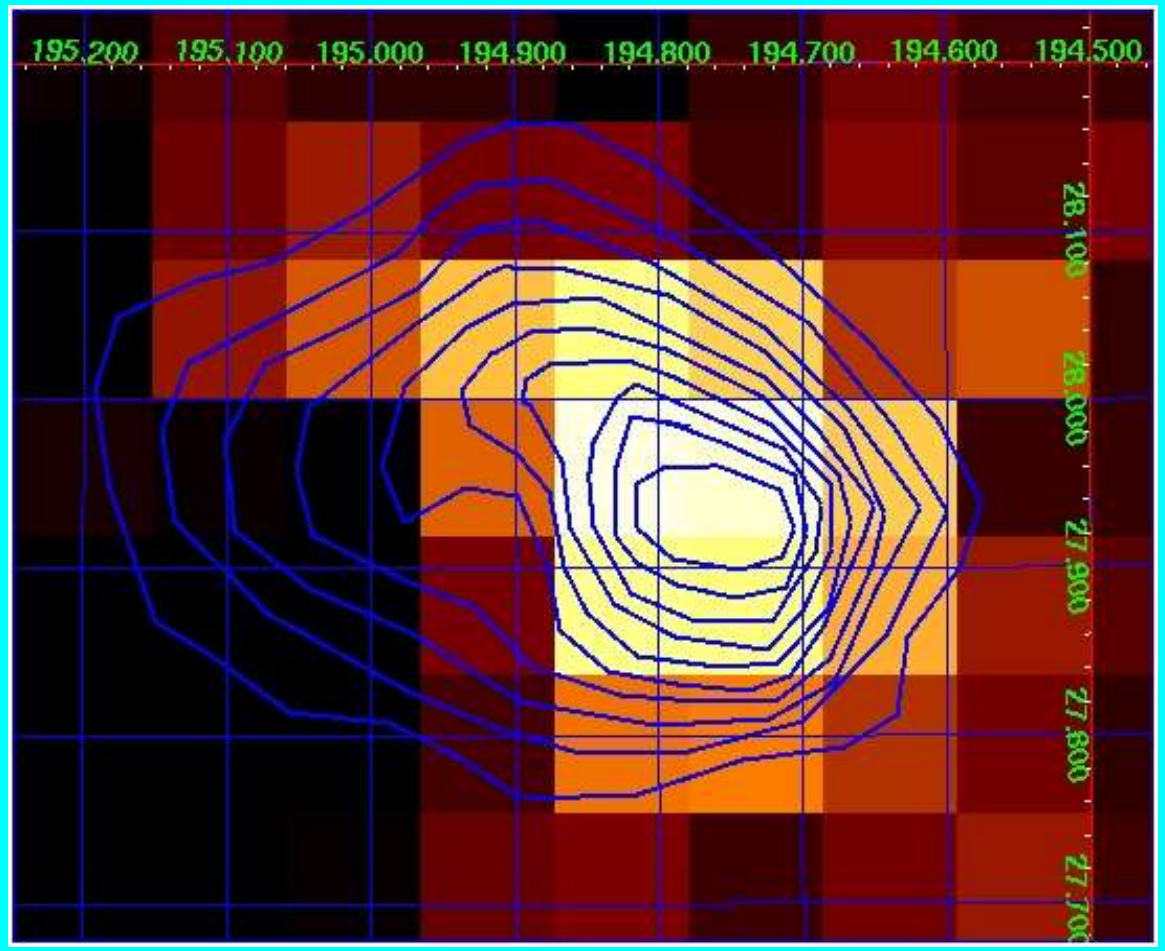
- Hot region in front of the excess
- heated by compression or shock waves due to infall of substructure around NGC 4839
- infall direction co-incides with a filament in the Great Wall

INTEGRAL ISGRI observation

Eckert et al, 2007, A&A, 470, 835 (see poster H.8)

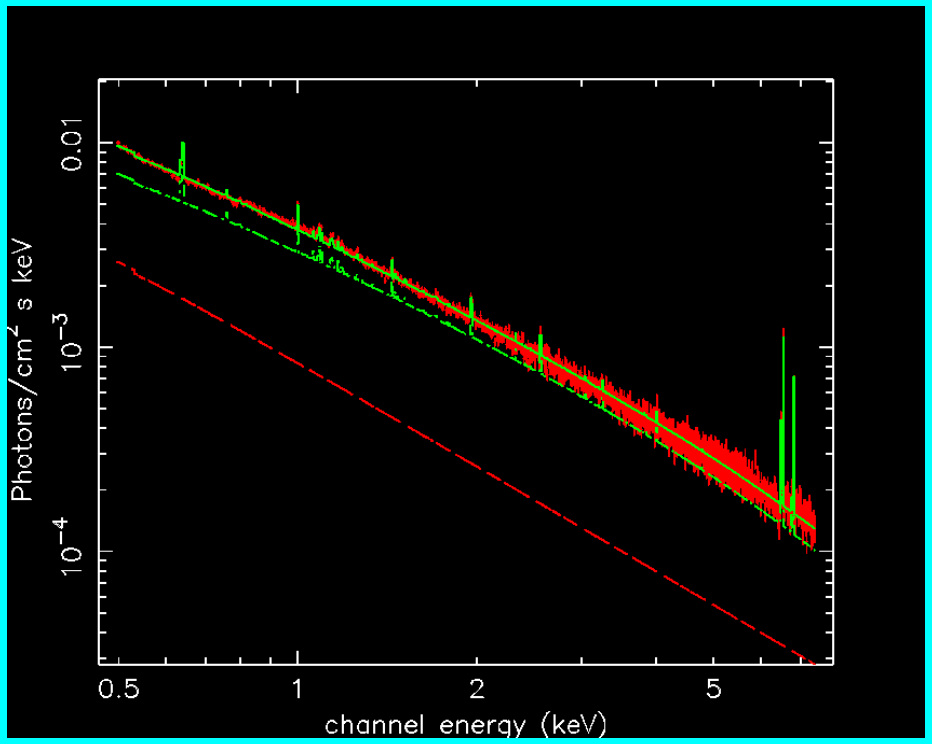
- ISGRI SW 15-60 keV excess image of Coma : peak 10' offset from cluster center
- Radio 1.4 GHz halo contours (Deiss et al. 1997, A&A, 321, 55)
- Radio and HXR peaks co-incide → same electron population produces both → Strong case for IC/CMB (Eckert et al., 2008 in prep.)





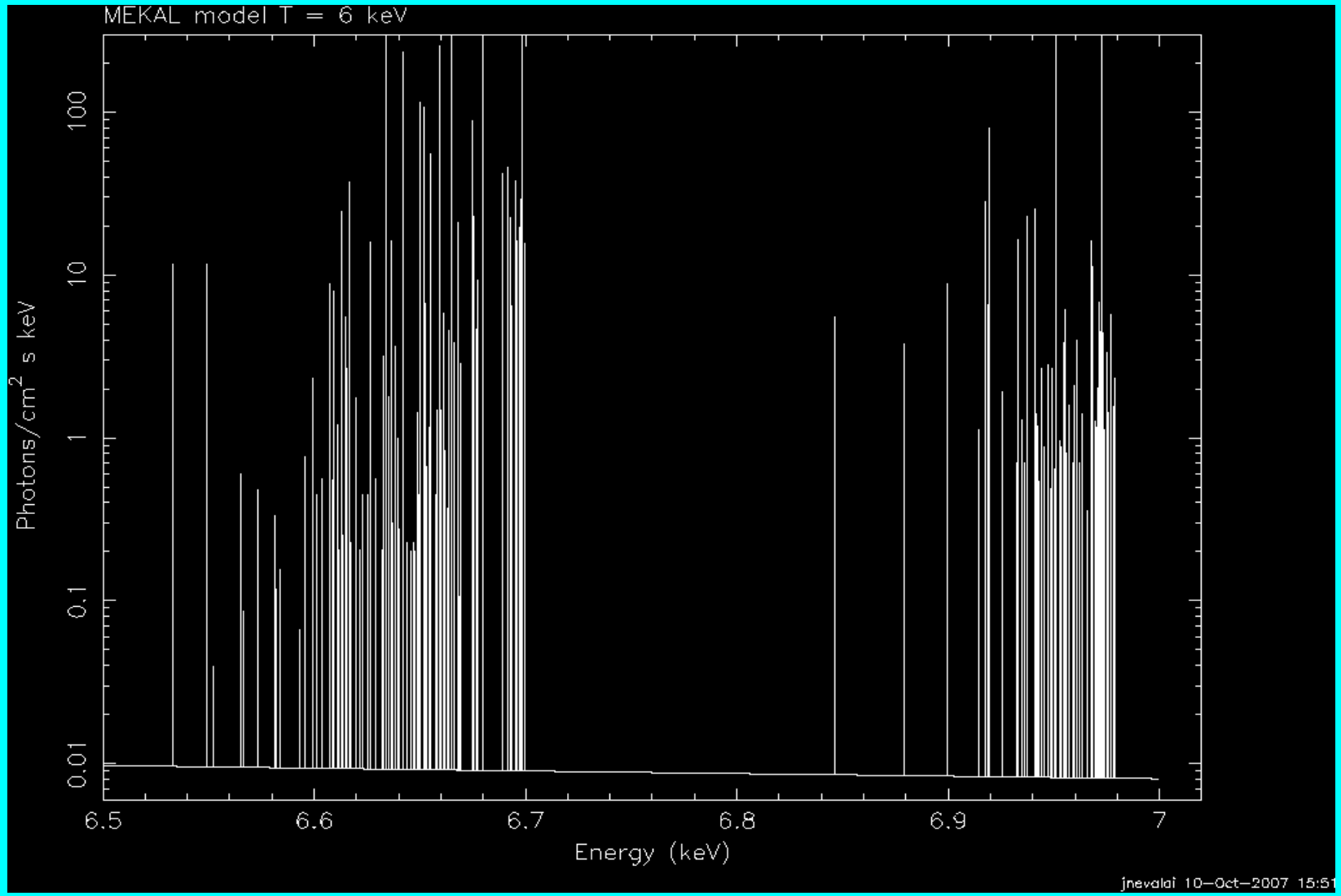
Continuum bias

- if power-law emission at low level (~10%) AND
- if power-law shape similar to that of 9 keV bremsstrahlung in 0.5-7.0 keV band (α_{ph} ~ 1.5-2.0)
- then thermal emission + power-law ~ thermal emission with a different temperature



XMM data of Coma from box 12

Kα transitions



ion: FeXXV
helium-like

ion: FeXXVI
hydrogen-like

- at XMM-Newton resolution Δ E ~100 eV:

  Kα forest blends into a Gaussian line

- ratio measured by modeling the

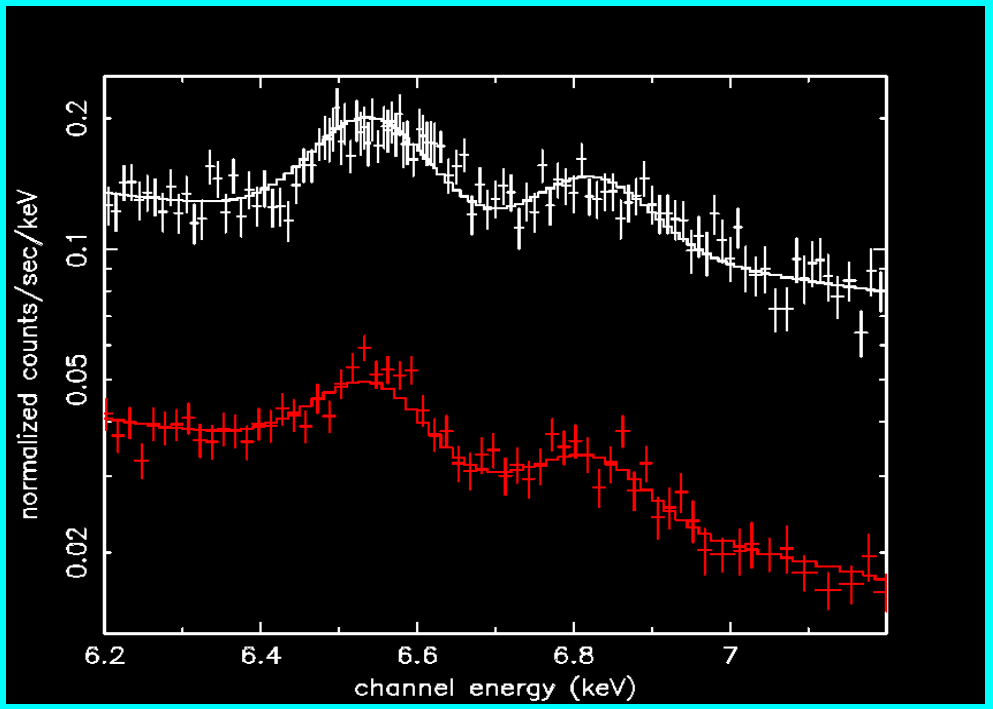
  Fe line forests with 2 Gaussians

- ratio gives T

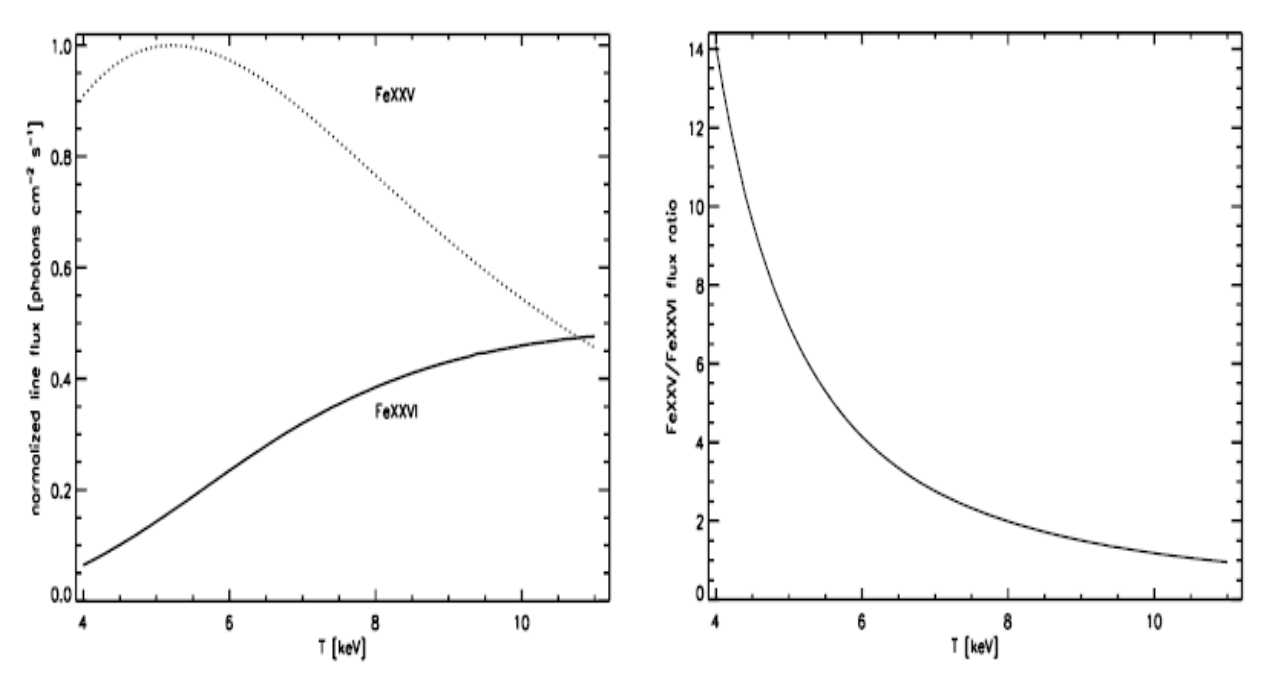
- T independent of continuum details

→ T almost calibration-independent

Coma 5'x5' box



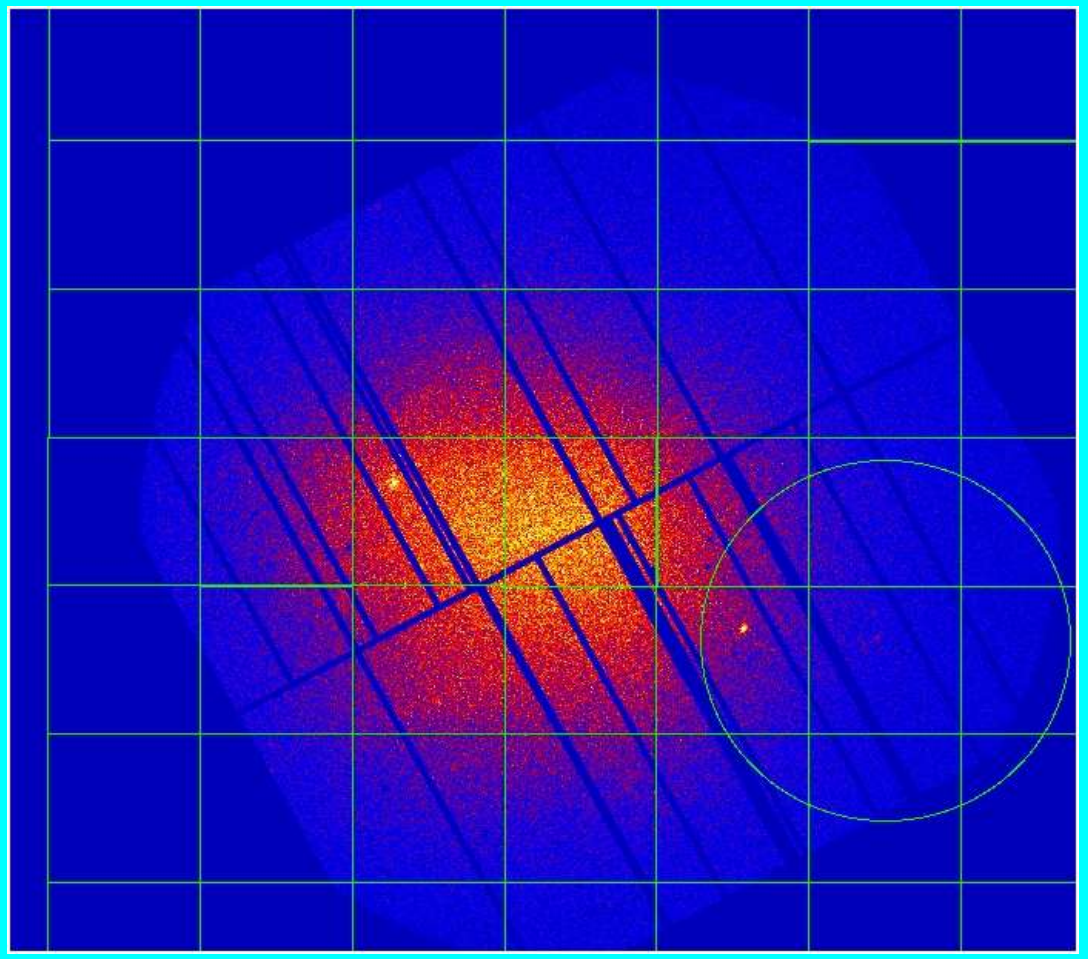
FeXXV/FeXXVI line ratio model using MEKAL code (Nevalainen et al., 2003, ApJ, 584, 716)



Coma: application

- line flux measurement requires long exposures, usually not available
- Coma central regions covered with ~10 pointings, combined exposure time ~100ks
- 5'x5' = 140 kpc x 140 kpc grid
- PN + MOS spectra of each box

  in each pointing co-added

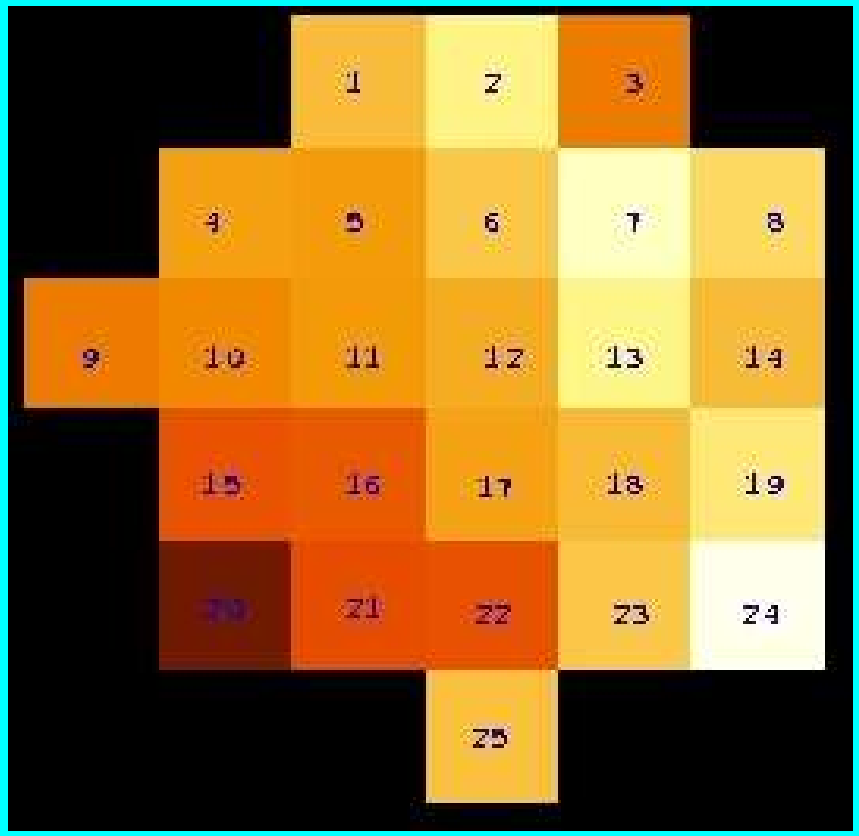


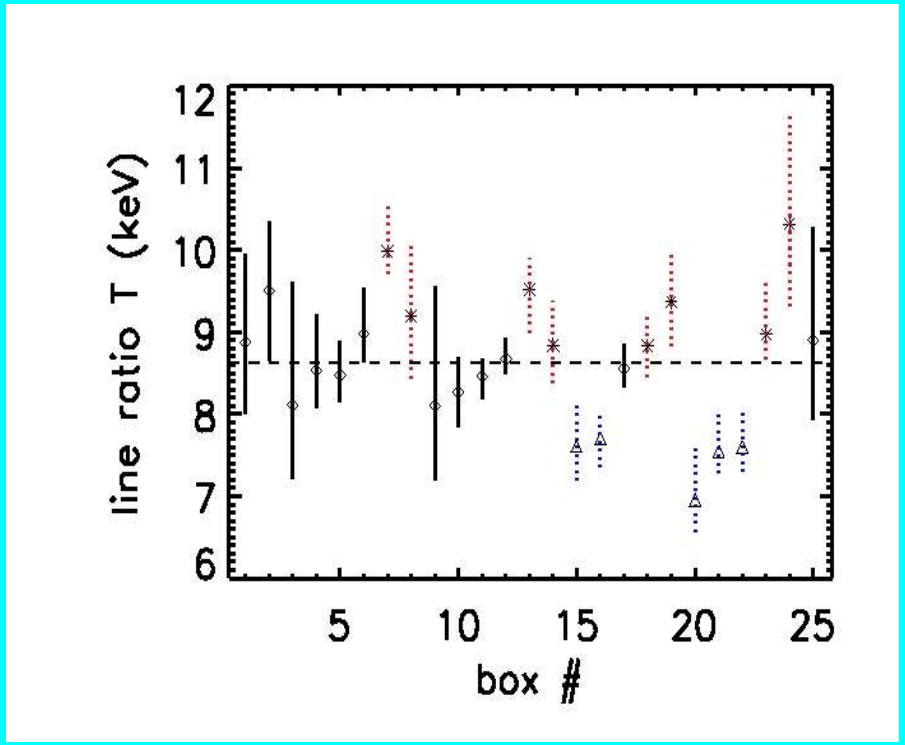
XMM-Newton PN image, obsid: 0153750101
circle shows the INTEGRAL SW excess region from Eckert et al., 2007,

line ratio T

- line ratio in 5'x5' boxes measured with 10-40% precision →
- T measured with 5-20% precision
- cool SE region (as in Arnaud et al, 2001, A&A, L67)
- ~hot SW region: Merger shock heating?

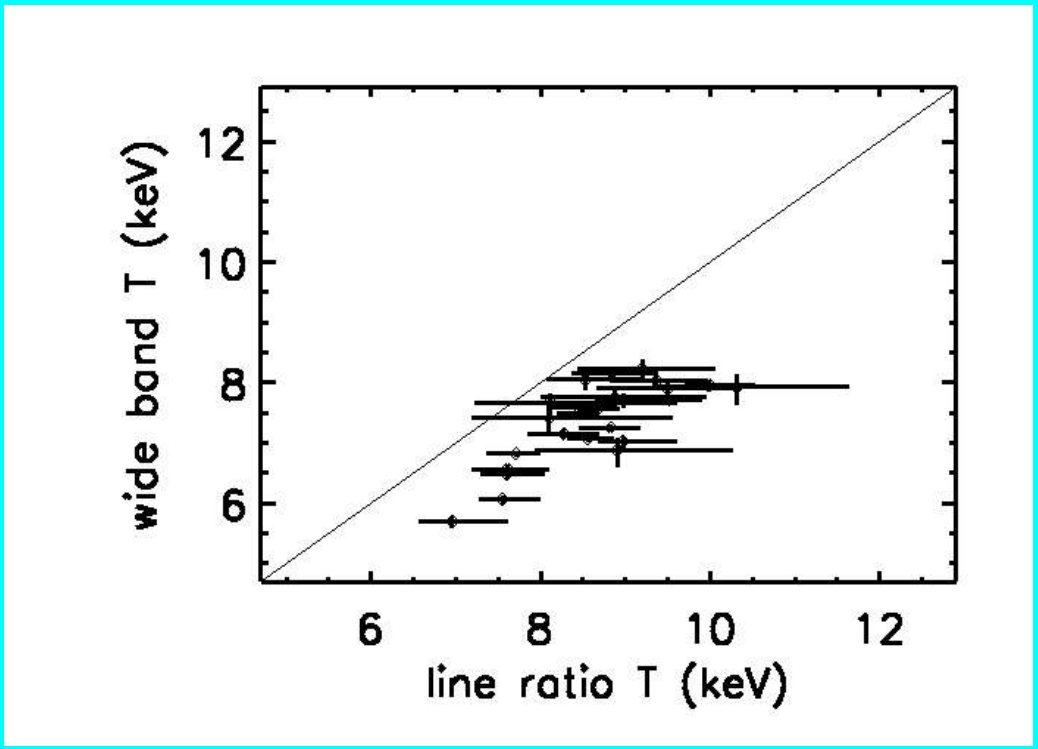
line ratio T map





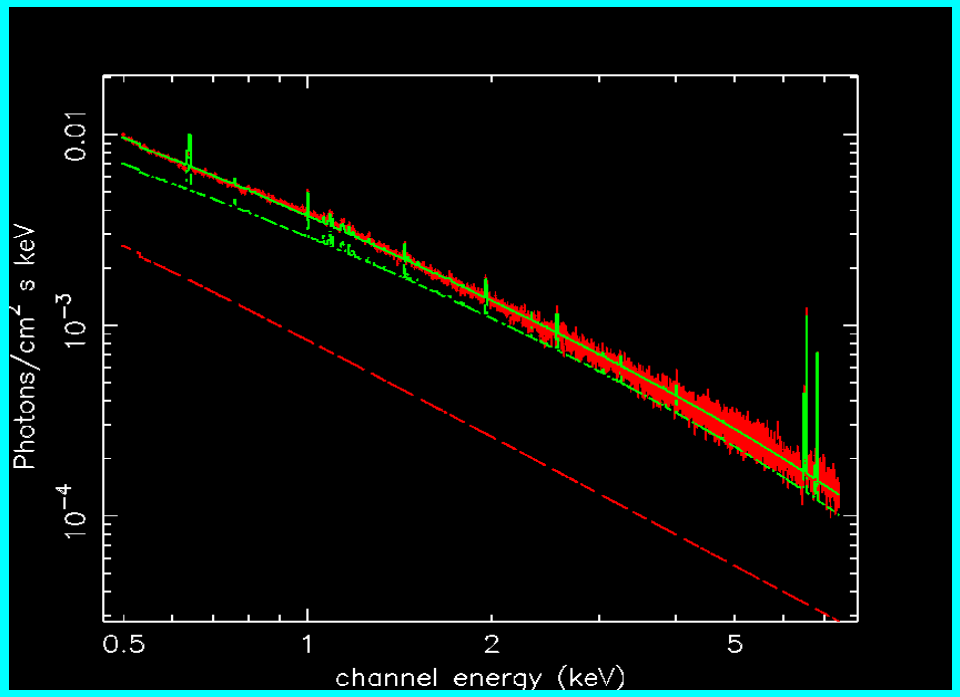
Line ratio v.s. Continuum

- Wide band = 0.5-7.4 keV band single T mekal fits
- Wide band T lower by 0.5-2 keV = 5-20% →
- Need additional component in the model



MEKAL + Power-law

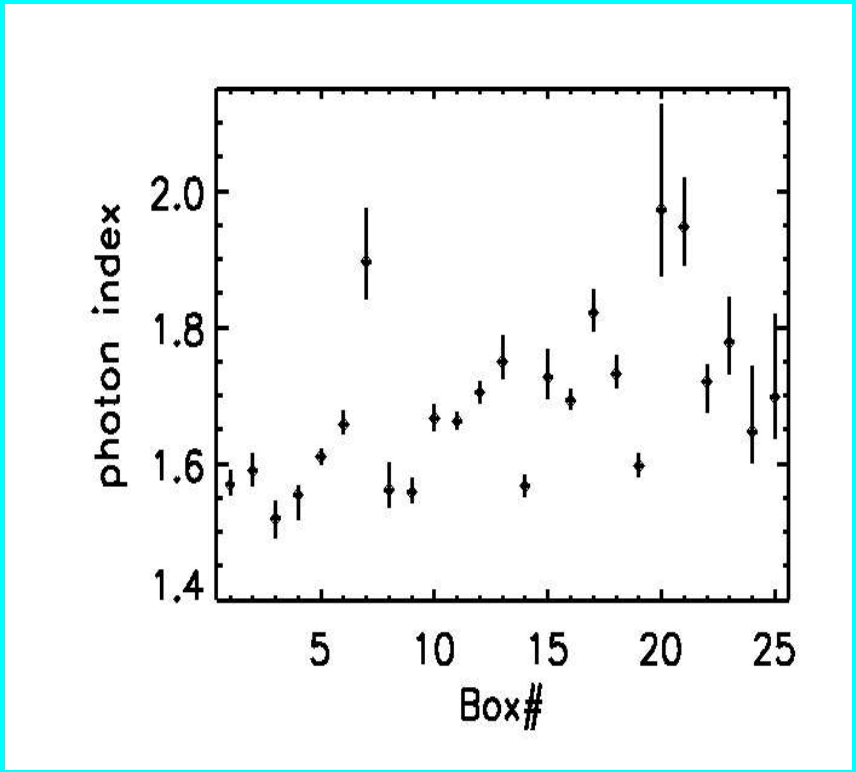
- added power-law component to the model
- constrain T with the line ratio measurement
- fit data with a composite model, fits OK
- mekal + mekal also OK: cannot distinguish thermal and non-thermal nature of the excess emission by the spectral fit alone

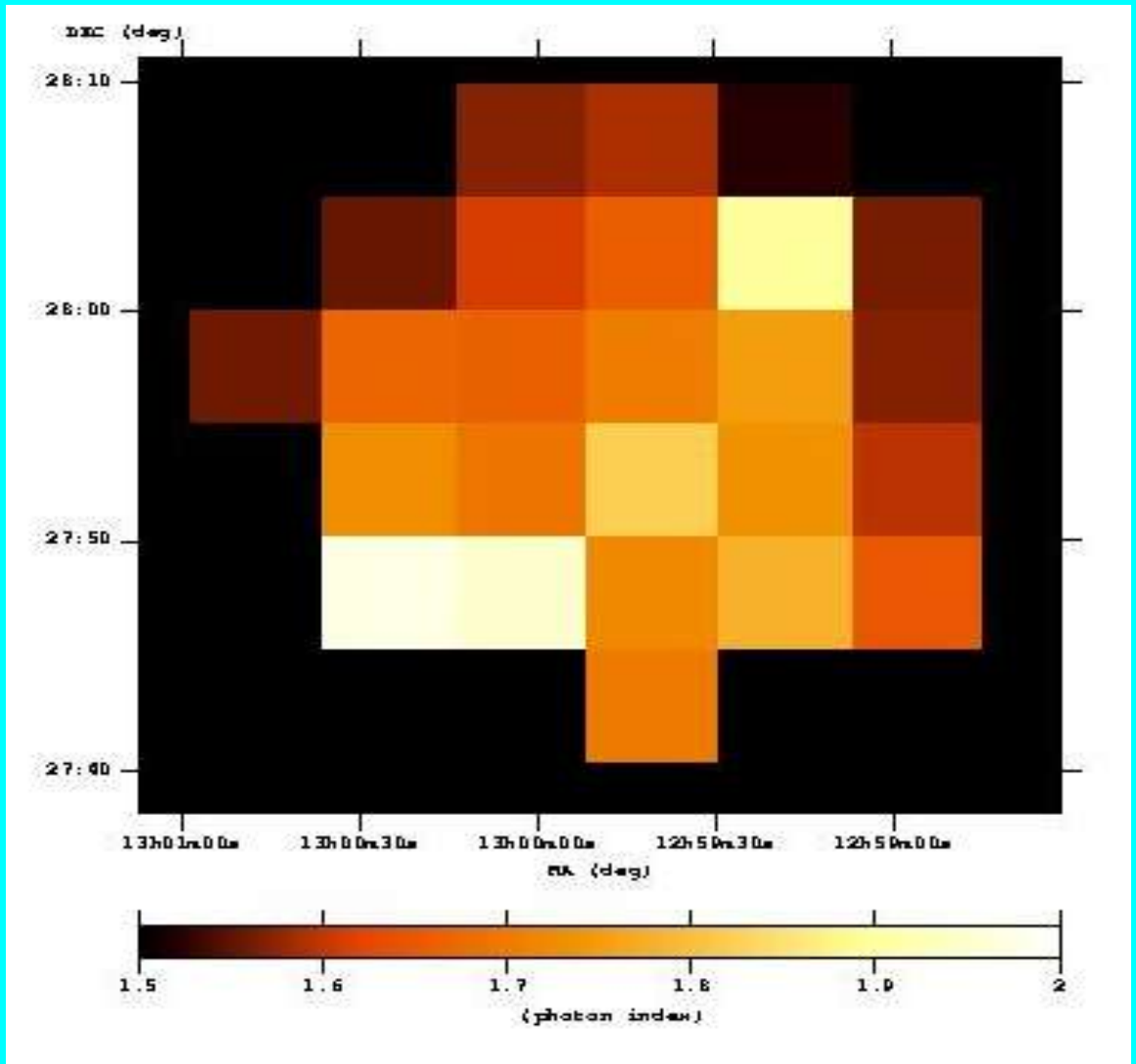


Coma box 12

Photon index

- α_{ph} ~1.5-2.0
- no clear structure in the SW region

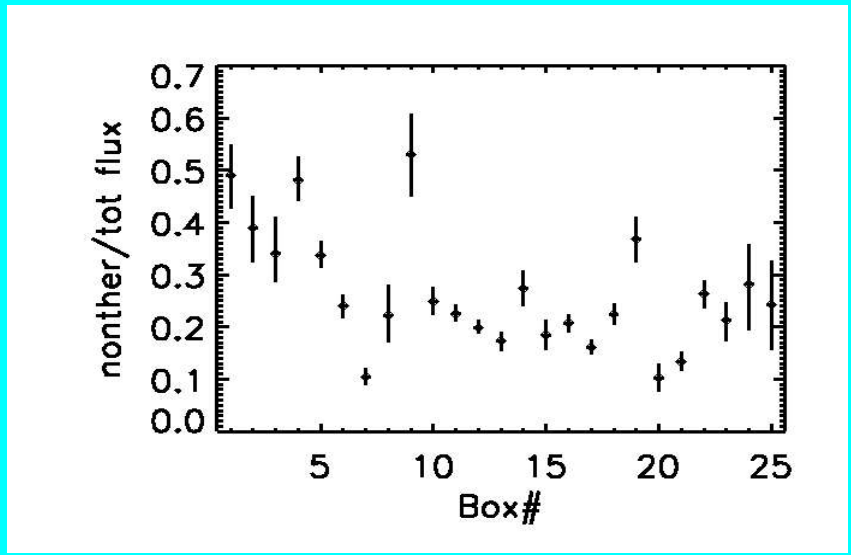


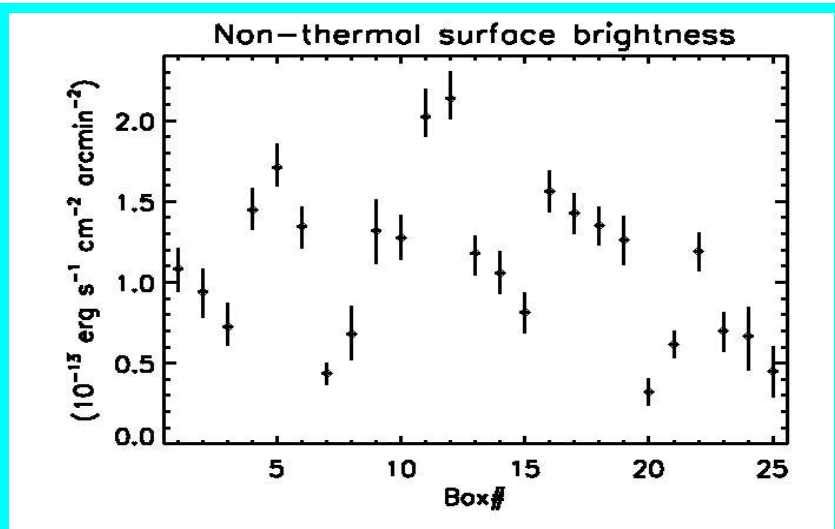


Non-thermal flux

- non-thermal flux ~20% of the total flux
- non-thermal flux ~10^{-13} erg s^{-1} cm^{-2} $arcmin^{-2}$ in the 0.5- 7.4 keV band
- centered on thermal peak, not radio → 150-300 kpc offset needs to be explained

non-thermal surface brightness





Two relativistic electron populations?

- 15-60 keV band non-thermal emission centered at the location of the peak of radio emission $\rightarrow$
- the same electron population produces radio emission via synchrotron process (must have a magnetic field) and hard X-rays via the Inverse Compton of CMB photons
- lower energy (0.5-7.4 keV) non-thermal emission peaks not at the radio peak, but at the cluster center $\rightarrow$ another relativistic electron population
- accumulation of old mergers in the center? $\rightarrow$ ageing and steepening
- α_{ph} ~1.5-2.0 (relativistic electron population index p ~ 2.0-3.0)

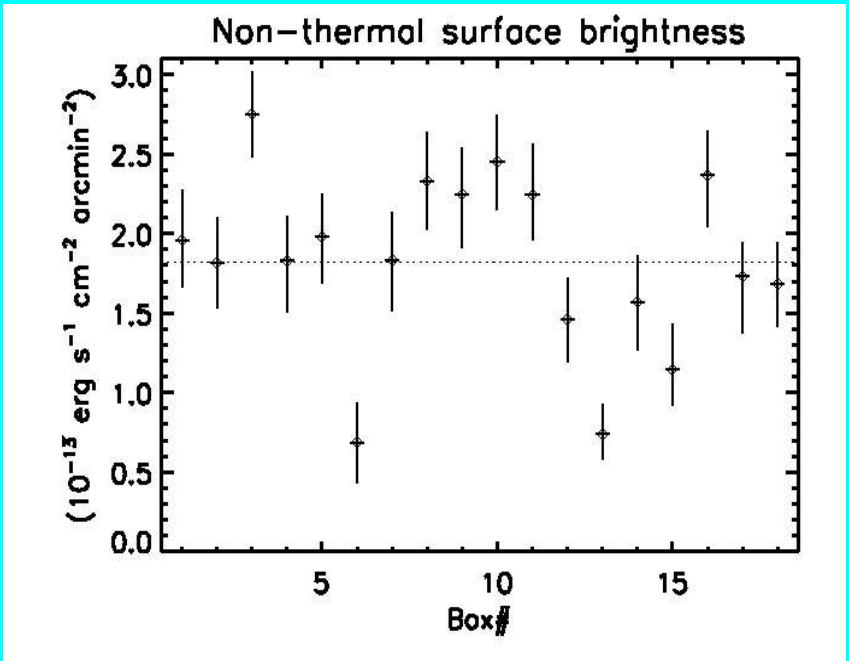
consistent with merger calculations of Sarazin 1999 (ApJ, 520, 529)

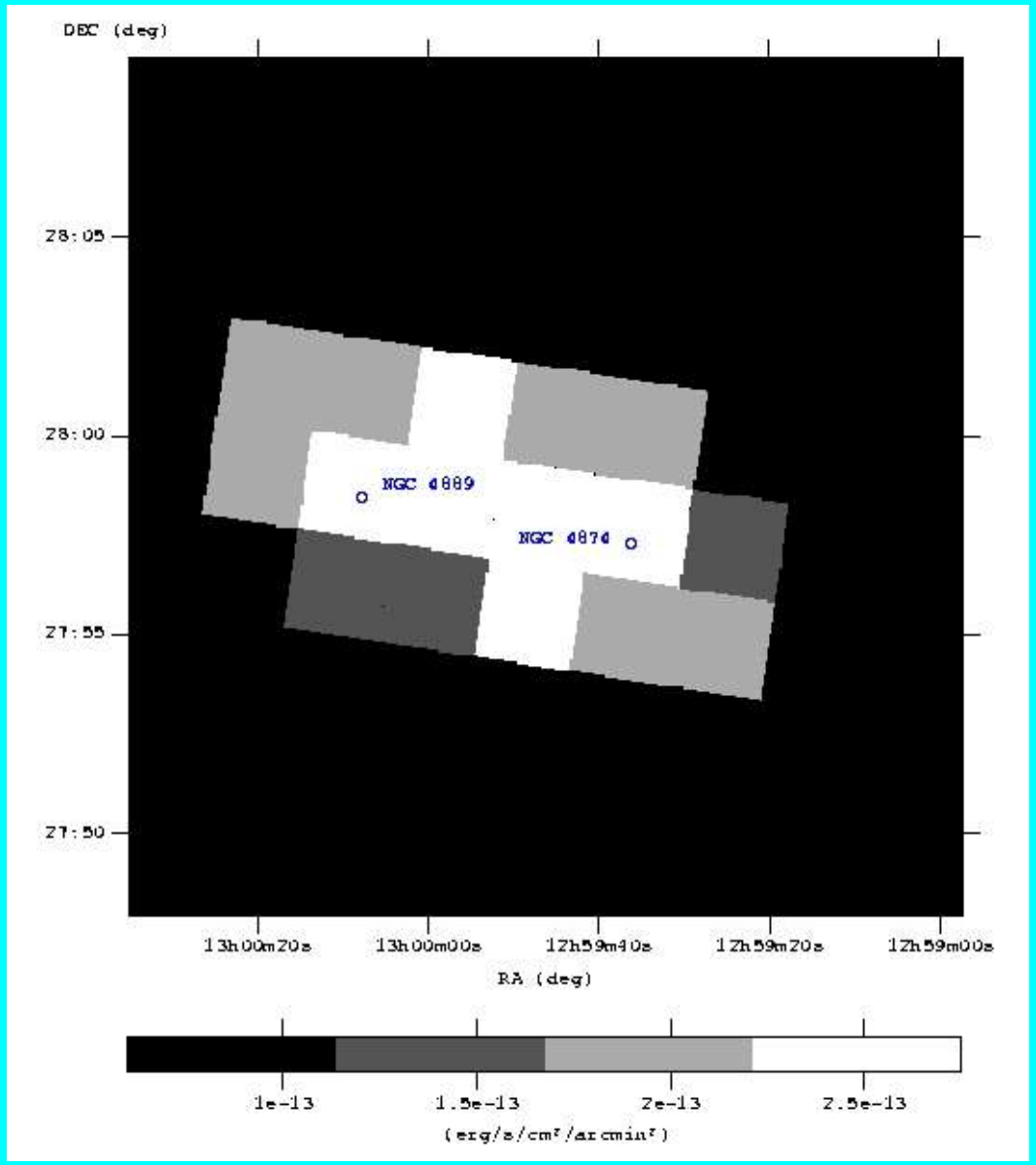
Thermal?

- Core with better resolution

  (2.5' = 70kpc)

- Continuous excess between the central galaxies





Conclusions

- FeXXV/FeXXVI line flux ratio can be used to separate the excess X-ray emission component in Coma at 150 kpc resolution
- Non-thermal flux ~ 20% of the total
- Photon index 1.5-2.0
- XMM peak offset from ISGRI peak by 150-300 kpc
- Thermal nature of the excess not ruled out at the moment