A particle acceleration site in the Coma cluster?

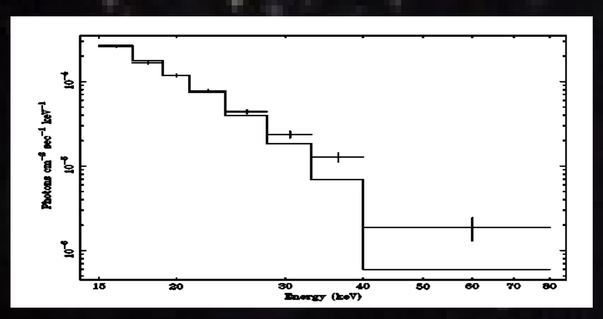
D. Eckert, N. Produit, A. Neronov & T. J.-L. Courvoisier

INTEGRAL Science Data Centre, Geneva, Switzerland

Observatoire astronomique de l'Université de Genève, Geneva, Switzerland

Tentative evidence for a hard X-ray non-thermal excess

• Beppo-SAX observations of the cluster showed an excess in hard X-rays (Fusco-Femiano et al. 2004):

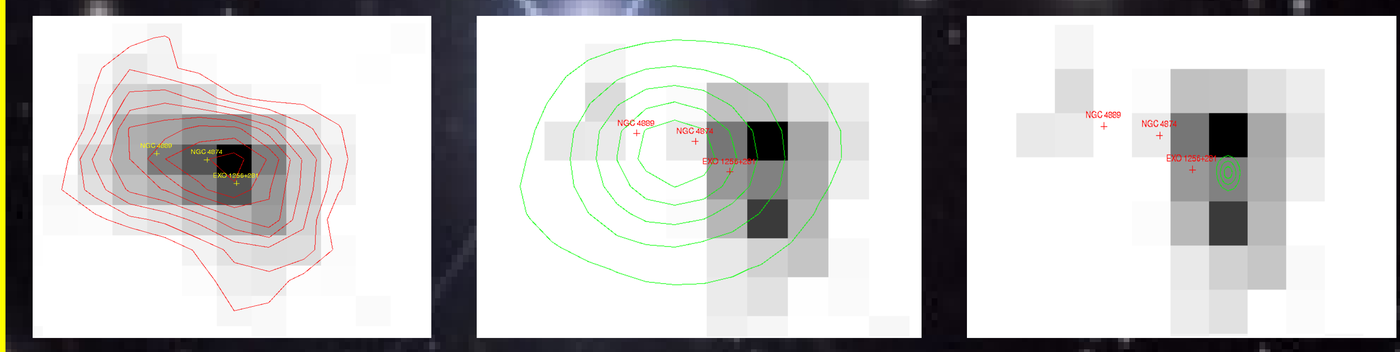


• The most popular interpretation for this excess involves IC scattering of the mildly relativistic (E~GeV) electrons that produce radio haloes with the CMB

• However, this result is controversial (Rossetti & Molendi 2004), and the hard X-ray instrument on board Beppo-SAX was non-imaging, so contribution of point sources could not be excluded

INTEGRAL observation of the Coma cluster

• INTEGRAL observed the Coma cluster for a total of 1.1 Ms. The angular resolution of the ISGRI hard X-ray imager (12 arcmin) allowed us to resolve the source spatially.



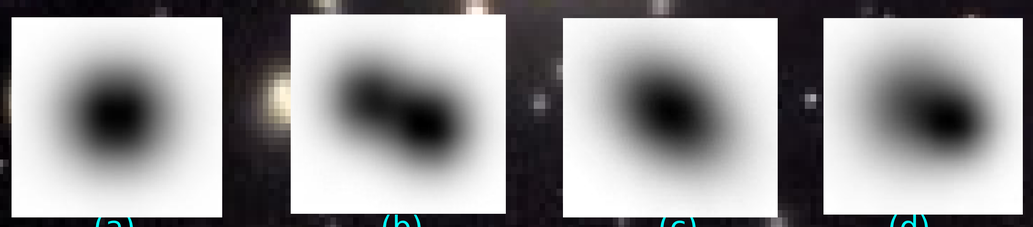
➔ ***Left**: INTEGRAL significance image of the Coma cluster with 3-10σ contours overlayed. The 3 brightest X-ray point sources are also displayed.*

➔ ***Center:** INTEGRAL image substracted from the 1-10 keV XMM-Newton surface brightness profile (green). Significant residuals are found South-West (SW) of the cluster core.*

➔ ***Right:** Same as previous. The green contours show the position of the INTEGRAL excess with 1,2 and 3σ error contours. It is clear that the excess cannot be easily explained by any known X-ray point source.*

Models for the hard X-ray morphology of the cluster

• We fitted the source with different morphology models:



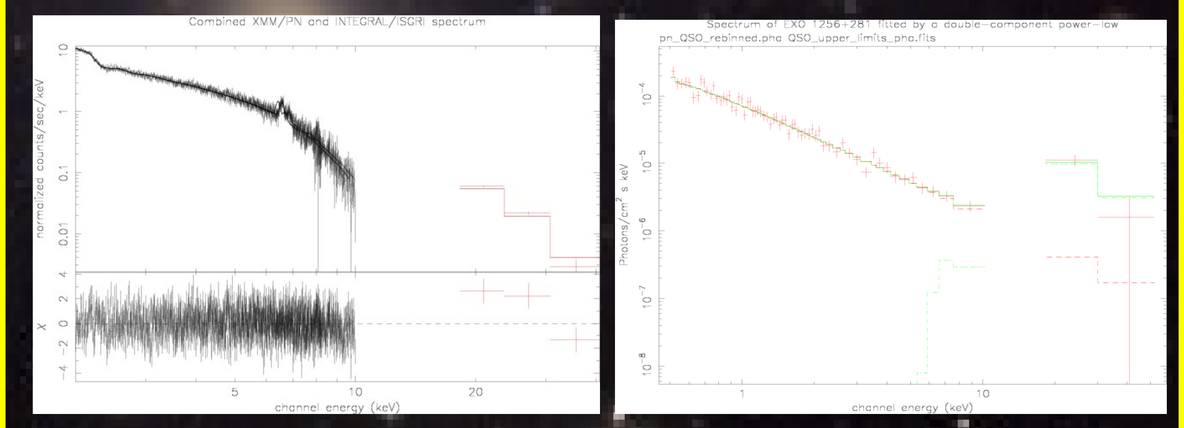
➔ *Best fits to the morphology of the source with (a) a single point-source, (b) a double point source , (c) an ellipse-shaped extended source and (d) a source with the morphology of the 1-10 keV emission plus an additional point source at the SW.*

• The single point source model gives χ^2_{red}=1.91, which shows that the source is extended. The centroid is displaced compared to the centroid of the XMM image by ~4 arcmin because of the significant excess in the SW.

• The ellipse model (c) gives the best fit, χ^2_{red}=1.23. The size of the major axis is a=17±1 arcmin, which is significantly larger than the core of the cluster (10 arcmin). The (d) model also gives an acceptable fit.

INTEGRAL spectrum of the cluster

• We extracted the INTEGRAL spectrum of the extended source, as well as the XMM spectrum in the corresponding region.

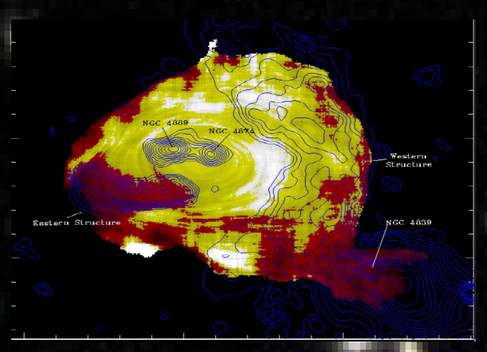


➔ ***Left:** Combined XMM-INTEGRAL spectrum of the cluster. The low statistics at high energies doesn't allow us to conclude on the existence or not of a non-thermal hard X-ray excess.*

➔ ***Right:** Flux of the INTEGRAL SW excess compared to the X-ray spectrum of the nearest bright X-ray point source, EXO 1256+281. The combined fit requires a very high intrinsic absorption ($n_H > 10^{24}$ cm^{-2}) and a steep spectral index ($\Gamma \geq 3.0$), which makes the association of the SW excess with this point source very unlikely.*

Very hot gas in this region of the cluster...

• Since there is no obvious counterpart for an additional point source at the position of the INTEGRAL emitting region SW of the cluster core, we considered 2 possible explanations for this excess: thermal emission from a very hot region and non-thermal IC scattering from relativistic electrons.

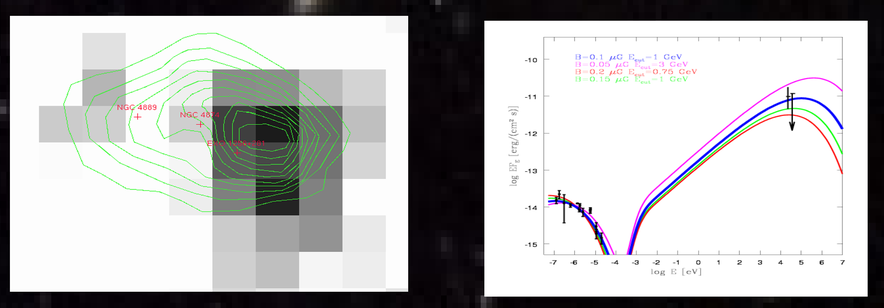


➔ *Temperature map of the cluster (from Neumann et al. 2003, A&A 400, 811). It shows the presence of a hotter (kT ≥ 10 keV) region SW of the cluster core that coincides spatially with the INTEGRAL SW excess.*

• Our analysis shows that the presence of hot gas (kT = 12 ± 2 keV) can explain the flux observed by INTEGRAL in this region.

... Or non-thermal emission?

• If the emission from this region is due to IC scattering of relativistic electrons on the CMB, we expect to see a spatial correlation between the HXR and radio emission, that is interpreted as synchrotron emission from the same population of eletrons.



➔ ***Left:** INTEGRAL image susbtracted from the 1-10 keV thermal profile with 1.4 Ghz radio contours from the Effelsberg 100-m telescope in green (Deiss et al. 1997, A&A 321, 55). The maximum of the radio emission exactly corresponds to the INTEGRAL SW excess, which suggests that the emission is due to the same population of electrons.*

➔ ***Right:** Spectrum of the radio emission combined with the HXR flux of the SW region, fitted by a synchrotron-IC model from a population of GeV electrons with cut-off power-law. The fit predicts a magnetic field B ~ 0.1 μG.*