Synthetic X-ray and Radio Observations of 3D MHD Jets in Clusters

**Introduction**

Synthetic images are generated from 3D MHD simulations of supersonic jets in a realistic cluster environment. We test extracting physical quantities from the images using simple commonly used analysis techniques. Two models are compared; a jet turned off after 26 Myr (Relic) and an intermittent jet toggled every 13 Myr (I13). Synthetic images of synchrotron, thermal bremsstrahlung, and inverse Compton emission by scattering of CMB photons (IC) are presented.

**Calculation Details**

The simulations presented were computed on a 600 x 480 x 480 zone (1 kpc per zone) grid by O'Neill & Jones, 2008 (O&J). The Mach 30 jets are driven into a Double-$\beta$ density profile cluster with an NFW dark matter potential. The cluster medium was set at hydrostatic equilibrium and then a Kolmogorov spectrum density perturbation of ~10% was added. Cosmic ray electrons (CRs) are injected, subjected to first order Fermi acceleration at shocks and passively advected with the flow. Radiative cooling and adiabatic advection of CRs was included. Synthetic images were generated from computed emissivities by a ray casting algorithm.

**Cosmic Ray Spectrum**

The average CR spectrum (red) can vary significantly in shape from local spectra. IC spectra from a line of sight (or especially the total observation) reflects an average of CR spectra more than a local spectrum.

**Spectral Energy Distribution**

The IC emission in the AGN plasma dominated region becomes the predominant emission above 20 keV. The Relic AGN plasma IC spectrum has a break $\Delta \alpha = 1$ at 25 keV. The I13 AGN plasma IC has no break over these photon energies.

**Conclusions**

- A $\beta$-profile fit subtracted at low photon energies emphasizes the X-ray cavities (first described by Clarke, et. al., 1997). Scaling this profile to higher photon energies is a poor fit to the thermal X-ray profile due to the presence of AGN heated cluster gas. The residuals from subtracting the scaled fit from the higher energy total X-ray observation could not reliably be interpreted as IC.
- An estimate of the pdV work done to create the cavities was calculated from the observations to be $5 \times 10^{60}$ ergs for the Relic and $7 \times 10^{60}$ ergs for I13. O&J compute $7 \times 10^{60}$ and $9 \times 10^{60}$ ergs for the Relic and I13 respectively directly from the simulations.
- The Relic has a break in the IC spectra at 25 keV. IC lifetime at this energy is 460 Myr. A representative magnetic field in the AGN plasma dominated region at this time is ~1 $\mu$G. The synchrotron lifetime with this field is 1.8 Gyr. The spectral break is therefore due to CRs encountering stronger magnetic fields in the past.
- "Ripples" (described in Perseus by Fabian, et. al., 2006) are easily seen in the I13 jet. These correspond to sound waves generated by the jet turning on and off.

**Reference & Acknowledgement**

O'Neill, S. M., Jones, T. W., 2008 (in preparation)
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