High-Energy Variability of Jetted Active Galactic Nuclei

UMBC

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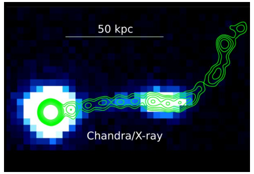
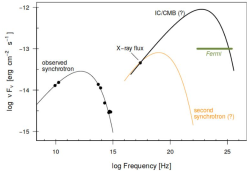
Background

Since *Chandra*'s discovery of 'anomalous' hard x-ray emission from AGN jet PKS0637-752 in 2000, jet modelling has been forced to consider the origins of the second spectral component. The earliest and most prevalent model has been inverse Compton scattering of CMB photons by electrons in the jet (IC/CMB).



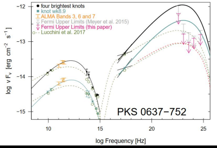


Overview

However, the IC/CMB model has certain requirements and predictions:

- It requires that the jet remain highly relativistic on kpc scales (bulk Lorentz factors Γ ~10)
- It requires that the jet be closely aligned to our line-of-sight
- It predicts high gamma-ray fluxes
- It predicts no significant variability in x-ray flux

In certain cases, the jet requirements demands jets with super-Eddington powers. More importantly, our group has ruled out IC/CMB in numerous high profile cases using *Fermi* to show that the gamma-ray fluxes are significantly below the predictions (Meyer et al. 2013, Breiding et al. 2017).
Despite this, IC/CMB is still frequently cited as the source of 'anomalously' hard x-rays and has been tentatively confirmed in other sources by our group (Meyer et al. 2019). The need for further study is apparent and urgent.



X-Ray Variability

A relatively unexplored avenue of testing the validity of IC/CMB is using *Chandra* to examine the prediction of no significant variability in x-ray flux of the distinct knots. As previously alluded to, because the CMB is a ubiquitous and isotropic photon field, the modeled emission caused by it is predicted to be steady. However, there is observational evidence suggesting that this is not the case.

As part of a larger *Chandra* archival study of x-ray jets of anomalous sources, we have examined sources PKS1928+738 and PKS0920-397 for every variability. Our process involves taking and reprojecting *Chandra* observations and examining the flux from the various knots. We can fit the flux data to determine the spectral index and flux at different epochs and see if we can confirm variability at a high significance level. The timescales on which this variability takes place can characterize the emitting r=region volume and give important insight into jet formation and emission
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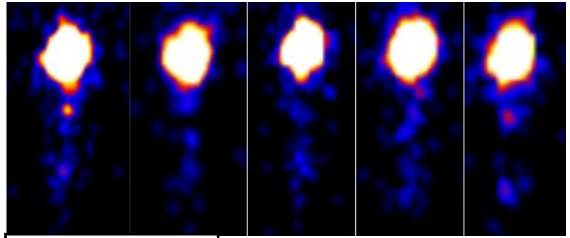
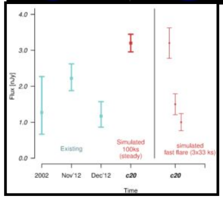
Both PKS1928+738 and PKS0920-397 show strong and significant variability. This directly contradicts the predictions of the IC/CMB model and suggests the need for an alternative model.





(Above) *Chandra* images of PKS0920-397 from observations in 2002 and 2005. Individual features in the jet show obvious changes in brightness.
(Left) Fitted flux values for the different observing epochs (blue) and simulated fluxes for steady emission (red)

Gamma Ray Variability

Regardless of x-ray results, the need for new models to explain gamma-ray emission are clear and present. IC/CMB production of gamma-rays predicts far too high fluxes and thus the emission must originate from a different source of seed photons. This discussion predates the observation of anomalous x-rays and thus has numerous proposed alternatives. The emission could be the result of synchtrotron self-Compton (SSC) or it could be Compton scattering of emission external to the jet (EC).

We focus here on the EC model. There are numerous local sources of photon fields in the vicinity of blazars (AGN closely aligned to our line of sight). Of particular interest are the broad-line region (BLR) and the molecular torus (MT). These sources have different characteristic photons and thus can be distinguished through their electron cooling times.

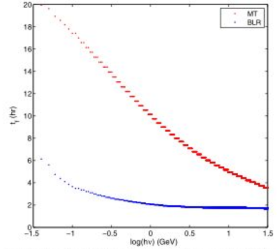


Figure 2. 1/e falling time in the galaxy frame vs. observing energy (GeV) for MT seed photons (red) and BLR seed photons (blue).
(A color version of this figure is available in the online journal.)

If the dominant seed photon source comes from the MT, we expect energy-dependent cooling times. On the other hand, if the BLR is the dominant source, the cooling times should be energy-independent. Work is currently underway to implement an unbinned likelihood analysis to characterize the energy-dependence of these cooling timescales.

Future Work

The x-ray variability studies are currently limited in significance by photon counts. As such, we have sent in a proposal for targeted, long exposure observations necessary to increase the strength of our discovery. We will simultaneously continue to make progress in our project examining gamma-ray variability.