Brian Punsly

Position: Research Scientist
Period covered: 10/2014-10/2015

<u>I Scientific Work</u>

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Black Holes and Quasars

1. Introduction

This report describes the research performed by Brian Punsly and collaborators in cooperation with ICRANet in 2014-2015. The research was directed at finding environmental factors that are related to the switch-on of the general relativistic engine responsible for a few percent of quasars driving powerful relativistic jets. This is important since this will relate directly to constraints on the initial state and boundary conditions on numerical models of black hole driven jets.

2. Coordinated NUSTAR, XMM and VLBA Multi-Epoch Observations of Mrk 231 During a Radio Flare

I am leading an international effort to study Mrk 231 during a radio flare with the highest resolution radio interformotry and in the X-ray band . This nearby quasar is in the process of transitioning from a radio quiet quasar to a radio loud quasar. A flare was detected during our Arc Minute MicroKelvin array monitoring at 17.6 GHz. This research is being done in collaboration with Cormac Reynolds and Natasha Hurley-Walker (Curtin University of Technology, Department of Imaging and Applied Physics), Christopher P. O'Dea (Department of Physics, Rochester Institute of Technology) and Giovanni Miniutti (Centro de Astrobiología (CSIC–INTA), Dep. de Astrofísica, European Space Astronomy Centre Madrid Spain).

Abstract

On 3/26/2015 we began a target of opportunity VLBA 4 –epoch monitoring at 8.4, 15, 22 and 43 GHz of a high frequency flare in the nearby quasar MRK231. The observations were spread out through May. The primary goals are to detect superluminal motion, estimate the internal energy of

the flare from the spectrum and component sizes, and monitor the temporal evolution in order to understand the energy injection mechanism (rise) and the cooling mechanism (decay). The first three epochs had observations by NuSTAR in addition to VLBA and the last three epochs were observed with XMM. The data is currently being processed.

Background

From previous VLBA studies of MRK231 in Reynolds et al (2009) and other RQ (radio quiet) quasar studies, we have seen that RQ AGN can have relativistic outflows with significant kinetic luminosities (but maybe for short periods of time). So this raises the question what is it that makes some sources RQ and others radio loud (RL)? At a redshift of 0.042, MRK231 is one of the nearest radio quiet quasars to earth. The radio core is perhaps the brightest of any radio quiet quasar at high frequency (22 and 43 GHz). The combination of significant 43 GHz flux density and its proximity to earth makes MRK231 the optimal radio quiet quasar for study with VLBA. No other radio quiet quasar central engine can be explored with such high resolution, so it is ideal for studying the high kinetic luminosity relativistic ejecta in radio quiet quasars. 43 GHz VLBA observations can fully resolve nuclear structure to within 3.5 x 10^{17} cm. We use sensitive high resolution observations to study the temporal evolution of the size and spectrum of a strong flare in MRK231 in order to shed light on why such strong flares cool off and never link to large scale powerful radio lobes.

3. Determining the Location of Relativistic Jet Launching in Quasars

The nature of the causative agent that makes some quasars radio loud (RLQs) has challenged astrophysicists for more than 50 years. It became clear early on that the optical/ultraviolet (UV) spectra of RLQs and radio quiet quasars (RQs) are very similar. Attempts to look for subtle differences involved statistical studies of optical and UV emission line strengths and widths. These emission regions are far from the central engine, many thousand times larger than the central black hole radius, so it is not clear what they tell us as a second order indicator of conditions in the jet launching region. Are they related to the fueling mechanism for radio loudness, the ionization continuum or jet propagation? Consequently, this research path has provided very little understanding of the jet launching mechanism. Seemingly more relevant to the physics of jet launching, the extreme ultraviolet (EUV) continuum, wavelength less than 1100 Angstroms, is created orders of magnitude closer to the central engine and RLQs display significant EUV continuum deficit relative to RQs. We have explored this in a series of new ApJ and MRAS articles.

3A. Evidence of the Dynamics of Relativistic Jet Launching in Quasars

ABSTRACT:

Hubble Space Telescope (HST) spectra of the EUV, the optically thick emission from the innermost accretion flow onto the central supermassive black hole, indicate that radio loud quasars (RLQs) tend to be EUV weak compared to the radio quiet quasars; yet the remainder of the optically thick thermal continuum is indistinguishable. The deficit of EUV emission in RLQs has a straightforward interpretation as a missing or a suppressed innermost region of local energy dissipation in the accretion flow. This article is an examination of the evidence for a distribution of magnetic flux tubes in the innermost accretion flow that results in magnetically arrested accretion (MAA) and creates the EUV deficit. These same flux tubes and possibly the interior magnetic flux that they

encircle are the source of the jet power as well. In the MAA scenario, islands of large scale magnetic vertical flux perforate the innermost accretion flow of RLQs. The first prediction of the theory that is supported by the HST data is that the strength of the (large scale poloidal magnetic fields) jets in the MAA region is regulated by the ram pressure of the accretion flow in the quasar environment. The second prediction that is supported by the HST data is that the rotating magnetic islands remove energy from the accretion flow as a Poynting flux dominated jet in proportion to the square of the fraction of the EUV emitting gas that is displaced by these islands

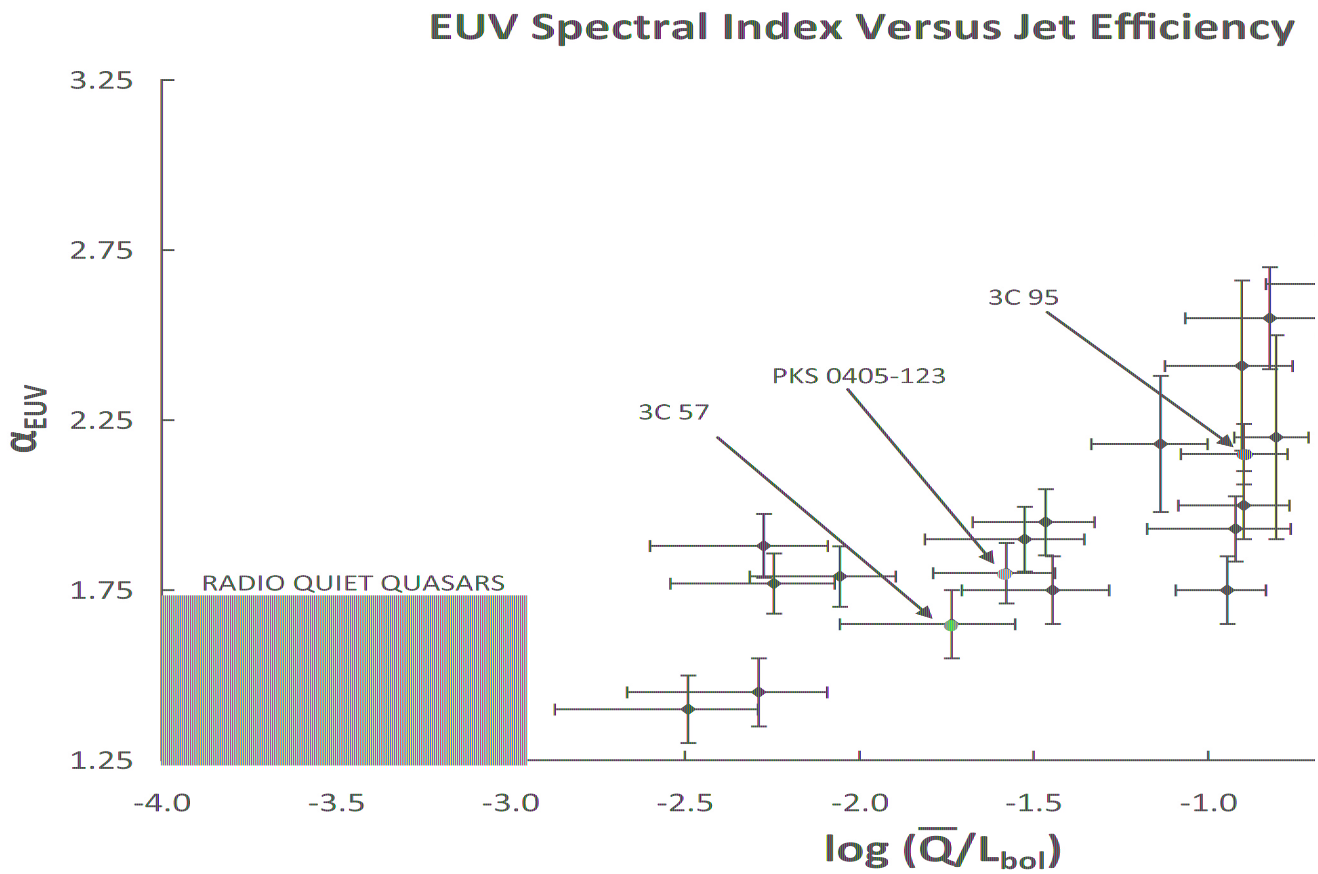

Figure 1. The correlation of the long term time averaged jet power normalized by the bolometric luminosity of the accretion flow in radio loud quasars with the EUV spectral index. A larger spectral index means a steeper spectrum and a larger EUV deficit relative to radio quiet quasar with a spectral index of about 1.57.

3B. The Extreme Ultraviolet Deficit: Jet Connection in the Quasar 1442+101

This research was an attempt to see if the long term time averaged affect described above was evident in the time evolution of an individual radio loud quasar. The collaboration included the efforts from Cormac Reynolds (Curtin University of Technology, Department of Imaging and Applied Physics), Christopher P. O'Dea (Department of Physics and Astronomy, University of Manitoba, Winnipeg, MB R3T 2N2 Canada, Paola Marziani (INAF, Osservatorio Astronomico di

Padova, Italia), Preeti Kharb (Indian Institute of Astrophysics, II Block, Koramangala, Bangalore) and Marianne Vestergaard (Dark Cosmology Centre, Niels Bohr Institute, University of Copenhagen)

ABSTRACT: In previous studies, it has been shown that the long-term time-averaged jet power, *Q*, is correlated with spectral index in the extreme ultraviolet (EUV), α_{EUV} (defined by $F_\nu \sim \nu^{-\alpha}{}_{EUV}$ computed between 700 and 1100 Å). Larger *Q* tends to decrease the EUV emission. This is curious relationship because it connects a long-term average over~106 years with an instantaneous measurement of the EUV. The EUV appears to emit adjacent to the central supermassive black hole and the most straightforward explanation of this correlation is that the EUV-emitting region interacts in real time with the jet-launching mechanism. Alternatively stated, the *Q*– α_{EUV} correlation is a manifestation of a contemporaneous (real time) jet power, Q(t), correlation with α_{EUV}. In order to explore this possibility, this paper considers the time variability of the strong radio jet of quasar 1442+101, which is not aberrated by strong Doppler enhancement. This high-redshift (z = 3.55) quasar is uniquely suited for this endeavor as the EUV is redshifted into the optical observing window allowing for convenient monitoring. More importantly, it is bright enough to be seen through the Lyman forest and its radio flux is strong enough that it has been monitored frequently. Quasi-simultaneous monitoring (five epochs spanning ~40 years) show that increases in Q (t) correspond to decreases in the EUV as expected.

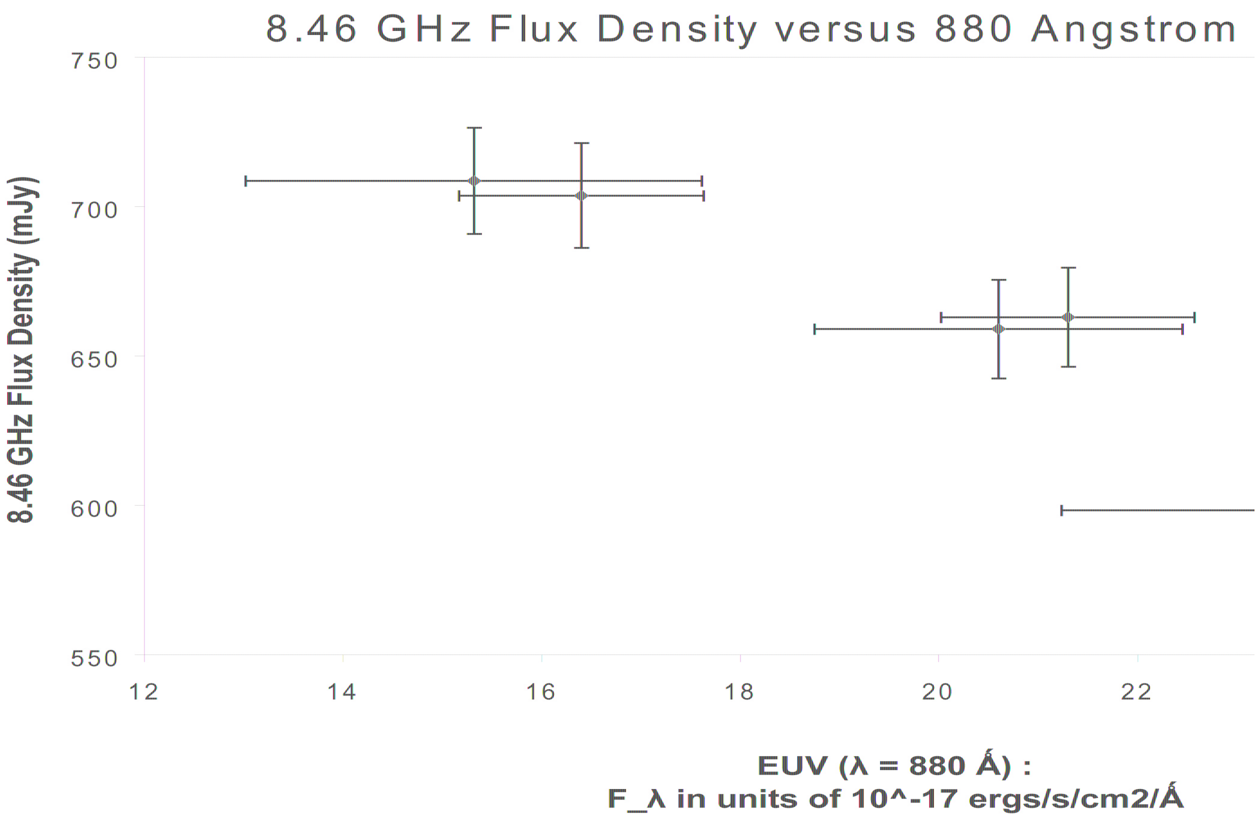

Figure 2. The quasar 1442+101 shows the correlation between jet power and the decrement of EUV emission in real time.

3C. The extreme ultraviolet spectrum of the kinetically dominated quasar 3C 270.

ABSTRACT: Only a handful of quasars have been identified as kinetically dominated, their long-term time-averaged jet power, Q, exceeds the bolometric thermal emission, $L_{\rm bol}$, associated with the accretion flow. This Letter presents the first extreme ultraviolet (EUV) spectrum of a kinetically dominated quasar, 3C 270.1. The EUV continuum flux density of 3C 270.1 is very steep, $F_{\nu} \sim \nu^{-\alpha}{}_{\rm EUV}$, $\alpha_{\rm EUV} = 2.98 \pm 0.15$. This value is consistent with the correlation of $Q/ L_{\rm bol}$, and $\alpha_{\rm EUV}$ found in previous studies of the EUV continuum of quasars, the EUV deficit of radio loud quasars. Curiously, although ultraviolet broad absorption line (BAL) troughs in quasar spectra are anticorrelated with Q, 3C 270.1 has been considered a BAL quasar based on an SDSS spectrum. This claim is examined in terms of the EUV spectrum of OVI and the highest resolution C IV spectrum in the archival data and the SDSS spectrum. First, from [O III]4959,5007 (IR) observations and the UV spectral lines, it is concluded that the correct redshift for 3C 270.1 is 1.5266. It is then found that the standard measure of broad absorption, BALnicity = 0, for Mg II 2800, C IV 1549 and OVI 1032 in all epochs.

2015 List of Publication

Punsly, Brian; Marziani, Paola., The extreme ultraviolet spectrum of the kinetically dominated quasar 3C 270.1 2015 MNRAS 453L 16

Punsly, Brian; Marziani, Paola; Kharb, Preeti; O'Dea, Christopher P.; Vestergaard, Marianne, The Extreme Ultraviolet Deficit: Jet Connection in the Quasar 1442+101 2015 ApJ 812 79

Punsly, B., . Evidence of the Dynamics of Relativistic Jet Launching in Quasars 2015 ApJ 806 47