Black Holes and Quasars

1. Introduction

This report describes the research performed by Brian Punsly and collaborators in cooperation with ICRANet in 2012. There were two lines of research. The first 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 related directly to constraints on the initial state and boundary conditions on numerical models of black hole driven jets.. The second area of research is based on using the jet in the Galactic black hole, GRS 1915+105, as a test case for black hole driven jets.

2. AGN Environments and the Launching of Jets

In 2011, the research was concentrated on the nature of the broad emission line gas in AGN that launch relativistic jets. I am also leading collaborations to perform high frequency (high resolution), time resolved VLBA observations of broad absorption line quasars. Broad absorption line quasars have weak or no central engine for powerful radio jets with the jets rarely strong enough to make it out of the host galaxy. As principal investigator, in collaboration with Paola Marziani and Giovanna Stirpe at Istituto Nazionale di Astrofisica and Shaohua Zhang, we were granted telescope time on the VLT of the European Southern Observatory to study the Hβ line widths of quasars with broad high ionization absorption line flows for the first time. This is a follow-up to previous work with Shaohua Zhang on quasars with low ionization broad absorption lines that indicated narrow Hβ line widths consistent with polar outflows (Punsly and Zhang 2010)..

2a. Asymmetric Line profiles in Blazars

The Astrophysical Journal Letter, describes the paradoxical occurrence of redward asymmetric broad emission lines in blazars which have relativistic jets point nearly pole-on towards earth. Hence these are the most blueshifted objects in the known Universe**.** They also have the most redshifted known wings in their broad emission lines. This odd occurrence of redshifted structures within a highly blushifted system provides valuable clues to the origin of relativistic jets in some quasars.

Abstract: Multi-Epoch Observations of the Redwing Excess in the Spectrum of 3C279:

It has been previously determined that there is a highly significant correlation between the spectral index from 10 GHz to 1350 Å and the amount of excess luminosity in the red wing of quasar CIV λ1549 broad emission lines (BELs). Ostensibly, the prominence of the red excess is associated with the radio jet emission mechanism and is most pronounced for lines of sight close to the jet axis. Studying the scant significant differences in the UV spectra of radio loud and radio quiet quasars might provide vital clues to the origin of the unknown process that creates powerful relativistic jets that appear in only a few percent of quasars. In this study, the phenomenon is explored with multi-epoch observations of the MgII λ2798 broad line in 3C 279 which has one of the largest known redwing excesses in a quasar spectrum. The amount of excess that is detected appears to be independent of all directly observed optical continuum, radio or submm properties (fluxes or

polarizations). The only trend that occurs in this sparse data is: the stronger the BEL, the larger the fraction of flux that resides in the redwing. It is concluded that more monitoring is needed and spectropolarimetry with a large telescope is essential during low states to understand more.

2b. VLBA Observations of Sub-Parsec Structure in Mrk 231: Interaction between a Relativistic Jet and a BAL Wind

I am leading an effort to study Mrk 231 at the highest resolution. It is the nearest broad absorption line quasar and we have proven that it conforms with the idea of a polar broad absorption line outflow (instead of the popular notion of an equatorial outflow) that was developed in Punsly (1999a,b). This research and proposal is being done in collaboration with Cormac Reynolds (Curtin University of Technology, Department of Imaging and Applied Physics), Christopher P. O'Dea (Department of Physics, Rochester Institute of Technology) and Joan Wrobel (NRAO, Socorro).

2b.1. Large VLBA Proposal Approved

We have been approved annually for the past few years for a very aggressive observation this object.

Abstract

We propose VLBA monitoring at 8.4, 15, 22 and 43 GHz of a high frequency flare in the nearby quasar MRK231. The “target of opportunity" observation (ToO) would be triggered by a flare detected by VLA monitoring at 22 and 43 GHz (see related proposal). The primary goals would be to detect a 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).

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 3.5×10^{17} cm. We propose to 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.

2b2. VLBA Observations of Parsec Scale Structure of the “Radio Loud” BALQSO FIRST J1556+3517

I am also leading an effort to study FIRST J1556+3517at the high resolution. It is one of the nearest broad absorption line quasar and we have proven (Ghosh and Punsly 2007) that it conforms with the idea of a polar broad absorption line outflow (instead of the popular notion of an equatorial outflow) that was developed in Punsly (1999a,b). The first epoch observations are complete the second epoch observations are stil in the proposal review cycle..This proposal was done in collaboration with Cormac Reynolds (Curtin University of Technology, Department of Imaging and Applied Physics), and Christopher P. O'Dea (Department of Physics, Rochester Institute of Technology).

ABSTRACT FROM ACCEPTED PROPOSAL: We propose VLBA observations at 1.8, 5, 8.4 and 15 GHz of the Broad Absorption Line Quasar FIRST J1556+3517 ("the first radio loud BALQSO"). The primary goal would be to resolve the flat spectrum radio core for the first time. Determination of the radio jet direction, in consort with the knowledge that the jet is relativistic and viewed in a pole-on orientation and the known PA of the optical continuum polarization tightly restrict the quasar geometry. This will allow us to directly constrain the relative orientations of the "dusty torus" (scattering surface), accretion disk and the broad absorption line outflow. We also propose multiple frequency observations to look for free-free absorption that might arise from the local environment of the accretion disk or the BAL wind gas itself. If the jet is resolved by the VLBA, this observation would be the first data point in a search for component motion. If the jet is not resolved, the incredibly compact nature of the relativistic outflow indicates a severe kinematical environment.

3. GRS 1915+105 as a Laboratory for Studying Black Hole Driven Jets

I am currently embarked on a research program to study the Galactic black hole jet in GRS 1915+105. There is much confusion in this field because it is led by scientist not familiar with the history of astrophysical jets or the theory of black holes. There are two large projects that were developed to understand the relationship of the energy output to the state of the accretion flow when the jets are launched. The first paper was published early this year: Punsly (2012)

Abstract from Punsly, B. A Multi-component Analysis Indicates a Positronic Major Flare in GRS 1915+105;

A modeling strategy that is adapted to the study of synchrotron-self absorbed plasmoids that was developed for the quasar, Mrk 231, in Reynolds et al (2009) is applied to the microquasar GRS 1915+105. The major flare from December 1993 shows spectral evidence of three such self-absorbed components. The analysis yields an estimate of the power that is required to eject the plasmoids from the central engine that is independent of other estimates that exist in the literature for different flares. The technique has an advantage since the absorbed spectrum contains an independent constraint provided by the optical depth at each epoch of observation. The modeling procedure presented here self-consistently determines the dimensions of the radio emitting plasma from the spectral shape. Thus, structural dimensions are determined analytically that can be much smaller than interferometer beam-widths. A synthesis of the time evolution of the components allows one to address the fundamental uncertainties in previous estimates. First, the plasma is not protonic, but it is comprised of an electron-positron gas. The minimum electron energy is determined to be less than six times the electron rest mass energy. The analysis also indicates that

the plasmoids are ejected from the central engine magnetically dominated. The temporal behavior is one of magnetic energy conversion to mechanical energy as the plasmoids approach equipartition. The time dependent models bound the impulsive energy flux, Q, required to eject the individual major flare plasmoids from the central engine to, 4.1×10^{37} ergs/sec < Q < 6.1×10^{38} ergs/sec.

The estimates of the power of the ejections allowed for the development of a more ambitious project with Jerome Rodriguez of Laboratoire AIM, CEA/DSM-CNRS-Universit\'{e} Paris Diderot, IRFU SAp, F-91191 Gif-sur-Yvette, France. Our paper is in review with ApJ

ABSTRACT from The Relationship Between X-ray Luminosity and Major Flare Launching in GRS~1915+105:

We perform the most detailed analysis to date of the X-ray state of the Galactic black hole candidate GRS~1915+105 just prior to (0 to 4 hours) and during the brief (1 to 7 hour) ejection of major (superluminal) radio flares. A very strong model independent correlation is found between the 1.2 keV - 12 keV X-ray flux 0 to 4 hours before flare ejections with the peak optically thin 2.3 GHz emission of the flares. This suggests a direct physical connection between the energy in the ejection and the luminosity of the accretion flow preceding the ejection. In order to quantify this concept, we develop techniques to estimate the intrinsic (unabsorbed) X-ray luminosity, $L_{intrinsic}$, from RXTE ASM data and to implement known methods to estimate the time averaged power required to launch the radio emitting plasmoids, Q (sometimes called jet power). We find that the distribution of intrinsic luminosity from 1.2 keV - 50 keV, $L_{intrinsic}$ (1.2 - 50), is systematically elevated just before ejections compared to arbitrary times when there are no major ejections. The estimated Q is strongly correlated with $L_{intrinsic}$ (1.2 - 50), 0 to 4 hours before the ejection, the increase in $L_{intrinsic}$ (1.2 - 50), in the hours preceding the ejection and the time averaged $L_{intrinsic}$ (1.2 - 50), during the flare rise. Furthermore, the total time averaged power during the ejection (Q + the time average of $L_{intrinsic}$ (1.2 - 50), during ejection) is strongly correlated with $L_{intrinsic}$ (1.2 - 50), just before launch with near equality if the distance to the source is ≈ 10 kpc.

2012 List of Publications and Submissions

Punsly, Brian; Multi-Epoch Observations of the Redwing Excess in the Spectrum of 3C279: in review ApJ Letters

Punsly, B. A Multi-component Analysis Indicates a Positronic Major Flare in GRS 1915+105, The Astrophysical Journal, Volume 746, 91 (2012).

Punsly, B. and Rodriguez, J. The Relationship Between X-ray Luminosity and Major Flare Launching in GRS~1915+105 ApJ in Review