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Multifrequency Studies

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MULTIFREQUENCY STUDIES

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The present report concerns the following projects "Multifrequency observations of the BL Lacertae object MK 421"; "EUVE and multifrequency observations of the quasars 3C 273 and 3C 279"; "EUVE observations of the symbiotic star R Aquarii"; and "Morphology of the local HI void and ionization of He in the local ISM".

The common theme of the above projects is UV observations and analysis of a wide range of astrophysical classes or objects, from the diffuse interstellar medium, to symbiotic stars (R Aqr), to active galactic nuclei (AGNs).

Understanding the local (primarily neutral hydrogen or HI) interstellar medium is of great importance to detecting nearby EUV sources. Specifically, the ionization of helium is strongly influencing the extinction in the extreme ultraviolet (EUV) and the optical depth can vary almost by an order of magnitude depending on the degree of ionization of various species including neutral helium (HeI) and singly ionized helium (HeII). The local interstellar medium (ISM) contains a giant void. Understanding the local ISM and the extent of the HI void engulfing the Sun is crucial to our understanding of the EUV emission from nearby strongly EUV-emitting stars like R Aqr, as well as subtracting local absorption effects from absorption effects in distant sources themselves such as quasars, BL Lacertae objects and AGNs in general. A compilation of known properties of the local ISM with appropriate references has been performed.

R Aqr is a symbiotic stellar system comprised of a mass-losing ~ 1 - 2M_o Mira-like long period variable with a 387 day period and a ~ 1M_o hot companion/accretion disk that is believed to give rise to the symmetrical jet seen at UV, optical radio wavelengths (e.g. see Hollis et al. 1991, Solf & Ulrich 1985, and Hollis et al, 1985, respectively). Recent observations of R Aqr have been conducted at continuum wavelengths with the Very Large Array (VLA) at 7 mm that have resolved the stellar components in RAqr (Hollis, Pedelty & Lyon 1998) and a geometrical distance of ~ 200pc has been obtained, confirming that R Aqr is the nearest symbiotic star system to the Sun. The status of the local ISM is, therefore, of great importance in attempting to understand the UV properties of the hot companion in R Aqr and its prominent jet. Here a multifrequency approach is required from both ground observations (e.g. with the VLA) as well as from space-borne observations (with the *International Ultraviolet Explorer—IUE*; and the *Hubble Space Telescope—HST*).

The R Aqr jet has been observed with the VLA B-configuration at two epochs separated by ~ 13.2 yr. Comparison of the resulting 6 cm continuum images show that the radio jet has undergone a lateral counterclockwise rotation of ~ 6° - 12° on the plane of the sky. Comparison of the most recent radio image with a nearly contemporaneous *HST*/FOC ultraviolet image at ~ 2330 A suggests that the UV emission lies along the leading edge of the rotating radio jet (Hollis, Pedelty & Kafatos 1997). This is interpreted

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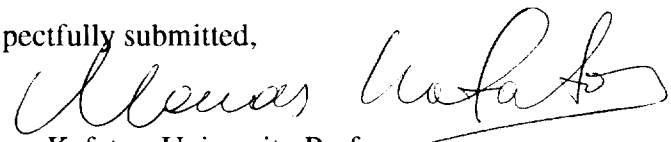
Respectfully submitted,



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as a radiating shock where the UV emitting region is consistent with the adiabatic region in the form of a high-temperature, low-density sheath that surrounds the cooled postshock radio-emitting region (Hollis, Pedelty & Kafatos 1997). An age of ~ 115 years is obtained.

We carried out target-of-opportunity (TOO) observations of four active galactic nuclei (AGNs) expected to be bright EUV sources. Three of the proposed targets have been known to be EUV emitters in previous *Extreme Ultraviolet Explorer* (*EUVE*) observing programs or are similar to previously observed emitters. We chose two representative classes of blazars, known to be objects showing jets, evidence of relativistic beaming, rapid variability and flaring, namely BLLacs (in our case MK 421 and PKS 2155-304) and quasars (in our case 3C 273 and 3C 279). The former show little if any evidence of gaseous material including disks, while the latter (particularly in the case of one of our targets), do. The sources chosen here are two BL Lacs and two QSOs, namely MK 421 & PKS 2155-304 (BL Lacs), 3C 273 (QSO), and 3C 279 (QSO).

The *EUVE* spacecraft (Bowyer et al. 1996) has provided valuable information for both disk and beam models, in concert with other high energy-observations, particularly at gamma-rays. As such, the astrophysical problems addressed by our TOO observations were to provide crucial EUV coverage for TOO sources undergoing gamma-ray flaring to distinguish between beam (e.g. SSC for MK 421, PKS 2155-304) and combination of thermal disk and beam mechanisms (for 3C 273; 3C 279?). Moreover, since blazars often flare unpredictably, TOO observations provide an efficient means to observe them at EUV wavelengths, triggered by gamma-ray observations (at EGRET, TeV energies or both). Blazars are known to undergo flaring, often being in quiescent states for extended periods of time (e.g. PKS 2155-304 which has recently been undergoing a return to a high state). The P.I. has had a history of close cooperation with gamma-ray observers and their programs, especially with the EGRET team having participated in many AGN programs (several multifrequency EGRET programs headed by R.C.Hartman as well as OSSE programs) and having co-authored papers with them (Macomb et al. 1995, Ramos et al. 1997, von Montigny et al. 1997).

Although several AGNs have been known to be EUV sources (Bowyer et al. 1996), an examination of publicly-released *EUVE* observing logs reveals no blazar observations in 1997 and only 2 MkK421 observations in 1996 (several Seyferts were observed in 1996 and one, NGC 4151, in 1997). Yet, as discussed above, *EUVE* observations of blazars can provide important evidence when coupled to other high energy observations. In view of the fact that the *EUVE* observing program will not last for too long, *EUVE* TOO observations of blazars assumed great importance. Our chosen sources represented a reasonable subset of strong *EUVE* sources. The observing program concentrates on two classes of targets, BL Lacs and quasars (two blazars, one of which, 3C 273 likely contains a disk component as described above). Based on previous observations with the *EUVE*, these targets would be observable as TOO. To obtain more efficient coverage, we proposed to observe them as TOO based on gamma-ray flaring. Assuming a TOO event, we expected good S/N in 150 Ksec coverage of each target.

For the observing plan, we proposed 150 Ksec spectrometer and Deep Survey exposures for each TOO source. The *EUVE* observations were to be initiated based on, either, an EGRET flare (all targets) and/or TeV flare (for MK 421). Previous *EUVE* observations of 3C 273 were carried out in the January-February and June-July time

frames, while *EUVE* observations of MK 421 were carried out in the April-May time frame. The TOO specifications including priority order were as follows:

Target	R.A. (2000)	Dec. (2000)	Priority	Expected Flux	Exposure Time
MK 421			1		150 Ksec
3C 273	12 29 6.69	+2 03	2	0.048 cts/sec	150 Ksec
PKS 2155-304			3		150 Ksec
3C 279	12 56 11.17	-5 47	4	0.03 cts/sec?	150 Ksec

The fourth target was a weak EUV source and has not been observed before. In fact, our actual observing program did not cover it. To maximize the number of continuum points, we proposed to observe with the target off-axis by 0.3 deg along the dispersion direction of the SW spectrometer, such that wavelengths below 70 A are brought into the field of view. According to the EGO reference data, such an off-axis angle should shift the spectrum by 8.1 A. Based on previous observations, we expect a target flux of 0.048 counts/sec for 3C 273 with a S/N of ~ 10.

The most favored model for the central engine in AGNs is the supermassive black hole hypothesis (Rees 1978). The observed luminosities range from ~ $10^{44\text{-}45}$ erg /s for objects such as MK 421 and Seyferts to as much as ~ 10^{47} for powerful QSOs such as 3C 273 and 3C 279, a large fraction of the observed bolometric luminosity being, in all likelihood, beamed. As such, these objects are strong X-ray emitters (cf. Makino et al. 1987) and often undergo gamma-ray flaring detected at the EGRET range (Hartman et al. 1992) and in the case of one of two known nearby BL Lacs, MK 421, at TeV energies as well (Punch et al. 1992, Macomb et al. 1995).

In the case of the nearby QSO (blazar) 3C 273, a combination of models is required, including the thermal emission from an accretion disk onto a supermassive black hole detected in the far UV/EUV by *IUE* and *EUVE* (Ramos et al. 1997; Ramos 1997) as well as beamed emission (seevon Montigny et al, 1997). For MK 421, producing photons with what appears to be an unbroken power-law spectrum over more than four orders of magnitude in gamma-rays poses severe constraints on theoretical models (Macomb et al. 1995). Previous campaigns emphasizing radio through X-ray and even gamma-ray observations have generally found that themultiwavelength spectrum is adequately fit by a standard synchrotron self-Compton (or SSC--cf. Jones et al. 1974) model of a relativistic jet (e.g. Makino et al. 1987; Macomb et al. 1995 for the BL Lac object MK 421) or inhomogeneous relativistic jet (Mufson et al. 1990).

In the case of 3C 273, the above observations were interpreted in terms of an EUV-emitting disk that may surround an inner, hot accretion disk, the latter expected to produce copious gamma-rays and X-rays (Ramos et al 1997; see also Ramos' thesis, Ramos 1997). Three attached papers were published dealing with the theory and observations of 3C 273 and MK 421 as well as R Aquarii.