INTEGRAL/RXTE OBSERVATIONS OF CEN A

Richard E. Rothschild, John Tomsick[1], Jörn Wilms[2], Rüdiger Staubert, Sara Benlloch[3], Werner Collmar[4], Greg Madejski[5], Sandrine Deluit[6], and Harish Khandrika[7]

[1]Center for Astrophysics and Space Sciences, University of California, San Diego, La Jolla, CA, USA
[2]Department of Physics, University of Warwick, Coventry, UK
[3]Institut für Astronomie und Astrophysik, Tübingen, Germany
[4]Max-Planck-Institut für extraterrestrische Physick, Garching, Germany
[5]Stanford Linear Accelerator Center, Menlo Park, CA, USA
[6]Centre d'Etude-Spatiale des Rayonnements, Toulouse, France
[7]Department of Physics, University of California, Berkeley, Ca, USA

ABSTRACT

INTEGRAL and *RXTE* performed three simultaneous observations of the nearby radio galaxy Centaurus A in March, 2003, January, 2004 and February, 2004. When combined with earlier archival *RXTE* results, we find the power law continuum flux and the line-of-sight column depth varied independently by 60% between 2000 January and 2003 March. Taking X-ray spectral measurements from satellite missions since 1970 into account, we discover a variability in the column depth between (1 and 1.5)$\times 10^{23}$ cm^{-2}, and suggest that variations in the edge of a warped accretion disk viewed nearly edge-on might be the cause. Direct comparison of *INTEGRAL* and *RXTE* results finds that all instruments agree, except for *INTEGRAL*/ISGRI which consistently finds a power law index greater by $\sim$0.2.

Key words: Radio galaxies; Centaurus A; X-rays.

1. INTRODUCTION

The three *RXTE* observations of Cen A — the nearest radio galaxy — in 1996, 1998, and 2000 (Rothschild et al., 1999; Benlloch et al., 2001) and five from *BeppoSAX* in 1997-2000 (Grandi et al., 2003) found the spectrum to be characterized by an absorbed ($N_H \sim 10^{23}$ cm^{-2}) power law ($\Gamma \sim 1.80$) with Fe line emission and no evidence for a reflection component. These multiple observations yielded evidence for $\sim$50% flux variations from one observation to the next with little if any spectral shape changes.

2. OBSERVATIONS AND RESULTS

INTEGRAL and *RXTE* observed Cen A three times as part of the *INTEGRAL* AO-1 and *RXTE* AO-7 proposal cycles in March, 2003 and early 2004 with the goal of intercalibration and extension of the measurement of the continuum beyond 200 keV. The *INTEGRAL* analysis was based upon release OSA 4.2 from the *INTEGRAL* Science Data Center. Approximately 20% systematics errors have been added to the JEM-X data and 3–9% systematics have been added to ISGRI data to represent the level of understanding of the instrument response, while none have been added to SPI. PCA data for all observations were limited to PCU2. Systematic errors of 0.3% have been included in the PCA data along with additions to the spectral model for known systematic effects. None have been added to the HEXTE data.

Table 1: Mean Cen A Spectral Parameters

	PCU2	HEXTE	JEM-X	ISGRI
$\langle N_{\rm H}\rangle$	$15.9^{+0.3}_{-0.2}$		$13.8^{+5.5}_{-4.6}$	
$\langle\Gamma\rangle$	1.83±0.01	1.83±0.07	1.80±0.17	2.01±0.09
	SPI	*RXTE*	*INTEGRAL*	
$\langle N_{\rm H}\rangle$		15.8±0.2	$17.7^{+3.6}_{-3.3}$	
$\langle\Gamma\rangle$	1.78±0.17	1.82±0.01	1.94±0.07	

$\langle N_{\rm H}\rangle$ in units of 10^{22} cm^{-2}

The two missions' data sets were fit separately to the spectral model const*phabs*(power + gauss). JEM-X did not detect the iron line whereas PCA did. Fig. 1 shows the best fit spectral histograms for the two *RXTE* and three *INTEGRAL* instruments, and Table 1 gives the mean best fit values for $N_{\rm H}$ and Γ. We have observed factor of two flux variability in Cen A without correlated spectral changes. The column density varied by 50% independently of the flux or power law index. No break in the power law continuum is detected below $\sim$140 keV.

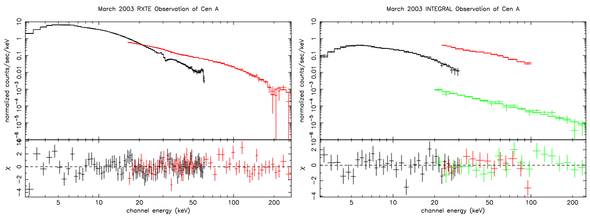

Figure 1. The March 2003 Cen A counts histograms from RXTE (Left) with PCA in black and HEXTE in red, and INTEGRAL (Right) with JEM-X in black, ISGRI in red, and SPI in green. The chi per energy bin versus energy for fitting to an absorbed power law is displayed below each histogram. The relative normalizations are with respect to PCA and JEM-X, respectively.

The ISGRI best fit power law indices were 0.2±0.1 larger than the indices found by the *RXTE* instruments.

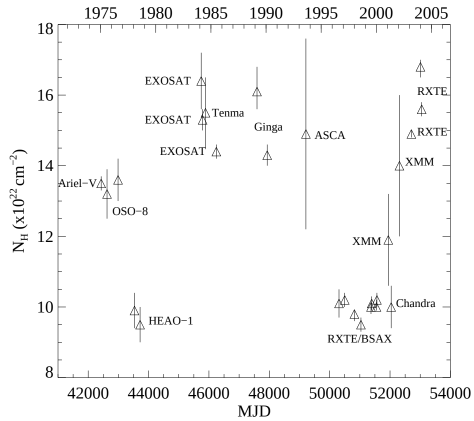

Figure 2. History of line of sight column depth to Cen A from 1975 to the present utilizing Ariel-V, OSO-8, HEAO-1, EXOSAT, Tenma, Ginga, ASCA, BeppoSAX *(Grandi et al., 2003),* RXTE *(present paper),* Chandra, *and* XMM-Newton.

3. VARIABLE OBSCURATION

Over the last 3 decades, Cen A has been observed from space by nearly all X-ray and gamma ray missions. Fig. 2 shows the measured values of the inferred column density, $N_{\rm H}$, since 1975 (see also Risaliti, Elvis, & Nicastro, 2002). The lower value of $\sim$10$\times$$10^{22}$ cm^{-2} is seen to occur twice in this time period, with the higher value of $\sim$15$\times$$10^{22}$ cm^{-2} seen the rest of the time. The first occurrence of the lower value was detected by only HEAO-1 in 1978, while the second was was seen by *RXTE*, *Chandra*, and *BeppoSAX*. The range of high values of $N_{\rm H}$ seen from $\sim$(13.5 to 17)$\times$$10^{22}$ cm^{-2} is broader than the range of lower values, (9.5 to 10.2)$\times$$10^{22}$ cm^{-2}, and this might indicate that the lower values represent the baseline for judging variations in column depth. The times of increased absorption could represent dense ($\sim 10^{22}$ cm^{-2}) clouds transiting the line of sight, or variable structure in the outer edges of the obscuring accretion disk or molecular torus.

If the $\sim$9 year duration of the higher level of absorption seen in the center of Fig. 2 represents a cloud, and if, as discussed by Wang et al. (1986), it resides in the broad line region at 10^{17} cm from the central object and has velocity of 500–1000 km/s, its diameter would be $\sim$$10^{17}$ cm — the size of the entire broad line region. If we assume a more reasonable cloud of diameter of 10^{13} cm and $N_{\rm H} = 5 \times 10^{22}$ cm^{-2}, then its velocity would be a meager 0.3 km/s and would place the cloud far beyond the core region. A cloud-based explanation appears to be untenable.

The second possibility is variable structure in the outer edge of the disk. This could be characterized as a non-uniform edge structure that rotated through the line of sight as the outer disk rotated or just stochastic variations in disk structure. Assuming a $2$$\times$$10^8M_\odot$ black hole (Silge et al. , 2005), 20 pc radius accretion disk (Schreier et al., 1998), and Kelperian motion, the velocity of the outer edge of the disk is $\sim$ 7×10^6 cm s^{-1} and the circumference is $\sim$ 4×10^{21} cm. A point on the edge will travel $2$$\times$$10^{15}$ cm in 8 years, or less than a millionth of the circumference. Thus, the required structure is quite small with respect to the disk, and is not out of the question.

Another possible explanation is precession of the warped accretion disk (Schreier et al., 1998) creating a variable absorption. The lower column depth would represent the time when the edge of the disk raised or lowered to allow a more direct view of the emission region, and the higher values could be associated with the edge of the disk returning to attenuate the X-ray emission.

ACKNOWLEDGMENTS

RER acknowledges the support of NASA contract NAS5-30720 and NSF international grants NSF_INT-9815741 and NSF_INT-0003773 for fostering the UCSD/Tübingen collaboration.

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