SOLVING THE MYSTERY OF THE PERIODICITY IN THE SEYFERT GALAXY NGC 6814

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ABSTRACT. The reports of periodic X-ray emission from the Seyfert galaxy NGC 6814 have motivated a number of exotic models for the active nucleus. Our ROSAT observation shows that while the nucleus of NGC 6814 is indeed an X-ray emitter, the periodicity is due to another source, most likely a Galactic accreting binary system, $\sim$ 37 arc min away.

1. Introduction

The Seyfert galaxy NGC 6814 has been a subject of much recent study due to its unique variability behavior, being the only AGN so far in which a clear periodicity is seen in the X-ray flux. The existence of the $\sim$ 12,100 second period was first detected in the EXOSAT Medium Energy detector (ME; Mittaz and Branduardi-Raymont 1989; Fiore, Massaro, and Barone 1992) and then confirmed in *Ginga* observations (Done *et al.* 1992). A number of interpretations were advanced for the periodicity, all based on orbital motion. These included, among others, gravitational lensing of X-ray emitting hot spots on an accretion disk by the central black hole (Abramowicz *et al.* 1991), or a captured star orbiting the black hole (Syer, Clarke, and Rees 1991; Sikora and Begelman 1992). The combination of very rapid ($\sim$ 50 sec) drops in the X-ray flux (Kunieda *et al.* 1990), short period, and large X-ray luminosity observed in NGC 6814 gave strong support for the black hole paradigm in AGN. Clearly, better understanding of this unusual object was needed, and to that end, we observed the field of NGC 6814 with the ROSAT X-ray satellite.

2. Observations and Results

The observation of NGC 6814 was conducted with the ROSAT X-ray telescope Position Sensitive Proportional Counter starting on March 31, 1993. It lasted for 180 ks of running time, and yielded $\sim$ 38 ks of useful data. Figure 1 shows the X-ray image over the 2 degree diameter field of view in the full 0.1–2.4 keV bandpass of the instrument. The observation was centered within a few arc sec of the optical position of NGC 6814 nucleus, which is at RA(2000) = $19^h42^m40.4^s$, Dec(2000) = $-10^o19'25''$. The positional coincidence of the strong X-ray source within a few arc sec from the the center of the image confirms that the nucleus of NGC 6814 is indeed the X-ray emitter.

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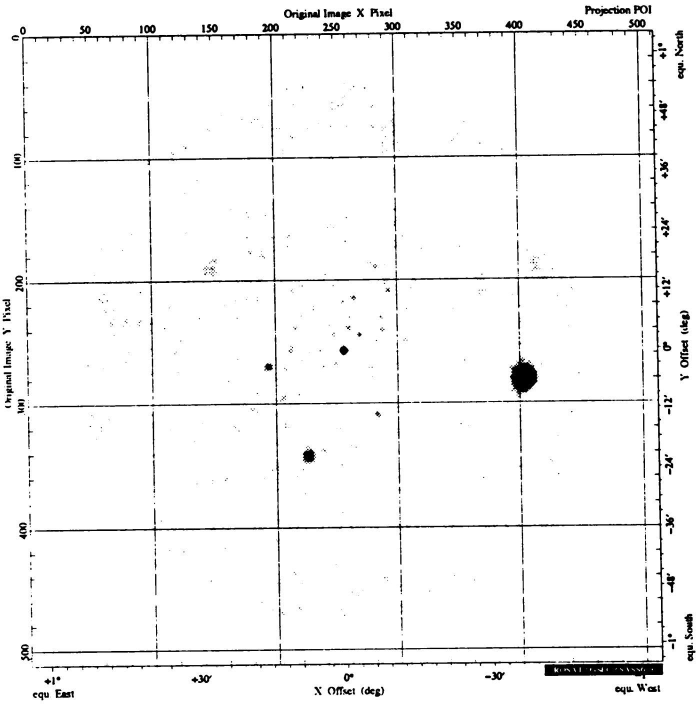

Figure 1. ROSAT PSPC image of the NGC 6814 field. The Seyfert galaxy NGC 6814 is the on-axis source, while the periodic X–ray emitter is 37′ off-axis (The image of this second source is smeared by the degraded off-axis point spread function.)

The ROSAT image reveals another bright point source $\sim$ 37 arc min away, strongly distorted by the off-axis point spread function. The position derived from the ROSAT image is RA(2000) = $19^h40^m13^s$, Dec(2000) = $-10°25'30''$, where we estimate the position error to be $\sim$ 30 arc sec, primarily because the off-axis image distortion as well as partial obscuration by the PSPC window supporting rib. We extracted light curves for both sources and tested them for periodicity in the 10,000 – 15,000 sec range by repeatedly folding the light curve, and measuring the significance of deviations from a constant by the L-statistic (related to χ^2 but following an F distribution; see Davies 1990; Done *et al.* 1992). Figures 2a and b show the L statistic for NGC 6814 and the second source; the $\sim$ 12,000 second periodicity is clearly not associated with the Seyfert galaxy but with the off-axis source. In fact, the best fitting period of 12,142 s (see Fig. 2) is exactly that determined from the most recent *Ginga* observation of the NGC 6814 region (Done *et al.* 1992). We thus conclude that it is the second, off-axis source that is the origin of periodic X–ray emission.

The spectrum of this second source, derived from background-subtracted data, is well modeled as a black body plus a power law, absorbed by matter with Solar abundances. The fit yields a temperature of $kT_{bb} = 63 \pm 11$ eV and power law energy index of $\alpha = 0.1 \pm 0.25$, absorbed by an equivalent hydrogen column density of $N_H = 0.76 \pm 0.23 \times 10^{21}$ cm^{-2}. The black body contributes ~ 45 % of the 0.2 – 2 keV flux, with the power law contributing the rest. The 0.2 – 2 keV flux averaged over the entire observation is ~ 6×10^{-12} erg cm^{-2} s^{-1}, with ~ 20% uncertainty due to a partial obscuration by the PSPC support ribs. This flat power law index is in fact quite similar to that seen by *Ginga* for the spectrum from the NGC 6814 region (Kunieda *et al.* 1990; Turner *et al.* 1992. We estimate that the 2–10 keV flux, using the extrapolation of the ROSAT spectrum, is only ~ 1.7×10^{-11} ergs cm^{-2} s^{-1}, several times lower than the mean *Ginga* flux. However, this value is quite uncertain, since the overall source spectrum is likely to be more complex than we infer here. The nucleus of NGC 6814, on the other hand, shows a power law spectrum typical of other AGN, with a power law index $\alpha = 0.79(+0.44, -0.33)$, absorbed by $N_H = 1.4(+0.5, -0.7) \times 10^{21}$ cm^{-2}, consistent with the Galactic value. The mean 0.2 – 2 keV flux of NGC 6814 measured in our ROSAT observation is 7.1 $\times 10^{-13}$ erg cm^{-2} s^{-1}.

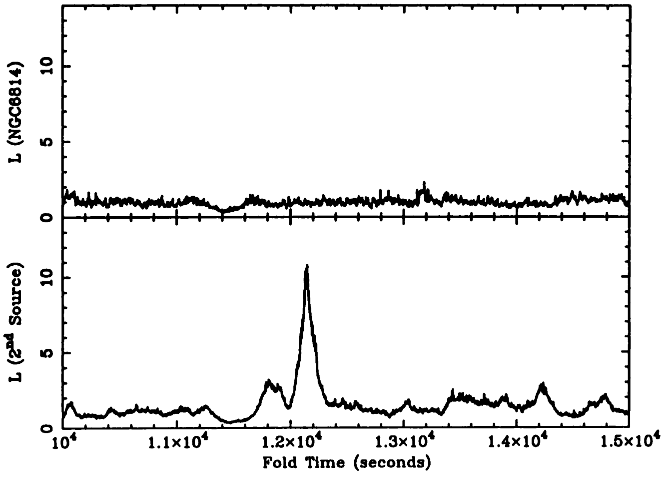

Figure 2. Value of L-statistic tests for periodicity over the range of 10,000 s to 15,000 s for NGC 6814 (a, top) and off-axis source (b, bottom). The 12,142 s period is clearly a property of the off-axis source.

3. Discussion

Our observation shows that the X-ray emission with ~ 12,100 sec periodicity, previously attributed to the Seyfert 1 galaxy NGC 6814, is due to an unrelated object that is located ~ 37 arc minutes from the nucleus of NGC 6814. Why wasn't it discovered earlier? Of course the limited spatial resolution of collimated proportional counter instruments such as HEAO-A2, *Ginga* LAC, and EXOSAT ME precluded separation of X-ray emission from the two sources, especially given the fact that the off-axis source definitely is, and NGC 6814 is likely to be variable. Likewise, the EXOSAT Low Energy telescope was not sensitive enough, and the *Einstein* Observatory IPC had too small of a field of view. A sensitive, large field-of-view imaging instrument such as ROSAT PSPC was necessary for the identification.

Our discovery eliminates a lot of difficulties with modeling of X-ray emission from NGC

6814. The flat ($\alpha \sim 0.4$) *Ginga* X–ray spectrum (Kunieda *et al.* 1990; Turner *et al.* 1992) was quite unusual for an AGN, and $\alpha \sim 0.8$ is more typical. The inferred periodicity required fine-tuning of the source geometry, and the rapid drop of flux observed in the *Ginga* data (Kunieda *et al.* 1990; Done *et al.* 1992) implied an extremely compact source. Finally, the strength and rapid variability of the Fe K line flux (Kunieda *et al.* 1990) required a substantial amount of ionized material very close to the central source, and so a strong gravitational redshift was inferred to reconcile this with the measured line energy (Turner *et al.* 1992). These observational features will now have to be reconciled with another class of an X–ray source.

What is the other source? An optical follow-up (Rosen *et al.* 1993; see also Halpern 1993) indeed shows that indeed, there is a variable object at the ROSAT position, which has the expected $\sim$ 12,140 sec period. The optical spectrum of it shows strong He II 4686 line emission, as well as possible cyclotron features, which are strongly suggestive that it is a magnetized CV system in our own Galaxy, consisting of a white dwarf fueled by accretion from a companion star. In fact, the ROSAT X–ray spectrum is typical of such systems (Cordova 1993).

We recognize that the observational data from what was thought to be NGC 6814 was considered a "rosetta stone" for the black hole paradigm for the structure of AGN, but we stress that the inferences from X–ray variability of Seyfert galaxies as a class are unaffected by this finding. These sources often exhibit non-periodic large amplitude variability on time scales of thousands of seconds (cf. McHardy 1989), and the removal of NGC 6814 does not substantially change the strong support that the rapid X–ray variability provides for the black hole hypothesis in AGN (see, e.g., Fabian 1992).

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