VARIABLE X-RAY ABSORPTION IN NGC 4151

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1. Introduction

The medium energy X-ray spectrum of the Seyfert galaxy NGC 4151 is characterised by a hard power-law continuum, a variable low-energy cut-off and iron line and edge features. Holt *et al.* (1980) found the spectral form below 4 keV to be incompatible with absorption in a uniform screen of cold gas and interpreted the apparent soft X-ray excess in terms of a partial covering model. However, recent observations point to a somewhat different description of the X-ray absorbing medium present in the nucleus of this galaxy.

2. The *EXOSAT* observations

EXOSAT observed NGC 4151 on a total of 24 occasions in the period July 1983 to March 1986 during which time the medium energy X-ray flux varied by a factor of ten. Significant spectral variations were also exhibited and there was evidence for a softening of the X-ray spectrum as the flux increased. A spectral fitting analysis indicated that the slope of the underlying power-law continuum remained fairly constant and that the spectral variations were attributable to changes in the soft X-ray attenuation present in the spectrum of NGC 4151. This in turn implies changes in the effective line-of-sight column of absorbing gas. Further details of the *EXOSAT* observations and results are discussed by Yaqoob, Warwick & Pounds (1988).

3. The *GINGA* observations

NGC 4151 was observed on a number of occasions in 1987 with the large area proportional counter (LAC) on *GINGA*. The first observation made at the end of May, when the source was in a relatively low intensity state, revealed the continued presence of the soft X-ray excess in the source spectrum (*cf. EINSTEIN SSS* observations, Holt *et al.* 1980; *EXOSAT* observations, Pounds *et al.* 1986; Perola *et al.* 1986; Yaqoob *et al.* 1988). Holt *et al.* (1980) were the first to interpreted this feature in terms of a partial covering model and, from spectral fitting to *EINSTEIN SSS* data, found that 90% of the X-ray source was

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 182–183.

https://doi.org/10.1017/S0074180900140756 Published online by Cambridge University Press

covered by an absorbing screen of column density $\sim 6 \times 10^{22}$ cm^{-2} with the remaining fraction being relatively unobscured and hence giving rise to the observed excess of soft photons. In comparison the *GINGA* spectrum required a very similar covered fraction but a much larger column density ($\sim 14 \times 10^{22}$ cm^{-2}). Holt *et al.* discuss a model in which there are typically 2 clouds along individual lines-of-sight to the central source; this then gives a natural explanation of the observed 10% leakage in terms of Poissonian fluctuations in this number. Unfortunately, in terms of this simple description, it is difficult to explain the constancy of the covering fraction whilst the thickness of the absorbing screen shows very marked changes.

Further *GINGA* observations were made in Nov/Dec 1987. The first of these revealed a very similar X-ray flux and spectrum to that measured by *GINGA* in May. However, an observation approximately two weeks later showed a significant increase in the X-ray luminosity of the source and also a marked softening of the spectrum below 6 keV. This is fully consistent with the earlier results from *EXOSAT*.

4. Discussion

The observational results outlined above indicate that, in NGC 4151, the effective gas column density is sensitive to the luminosity of the central source. This can be explained in terms of a changing ionization structure in a relatively warm photo-ionized medium (the 'warm absorber' model, Halpern 1984). Furthermore, the implication is that the soft X-ray excess in NGC 4151 arises, not from partial covering, but from the partial or complete ionization of the atoms responsible for the soft X-ray opacity of the absorbing medium (predominantly Mg, Si, S and Ar in the case of the 1-4 keV band). An investigation of a warm absorber model applied to NGC 4151 (Yaqoob *et al.* 1988) suggests that spectral changes with X-ray flux of the observed form can be obtained if the ionization parameter, U, appropriate to the bulk of the X-ray absorbing gas varies from 0.2 to 1.4.

Where might the X-ray absorbing medium in NGC 4151 be located? If the density is $\sim 10^{9.5}$ cm^{-3} (i.e. a typical value inferred for the broad-line emitting clouds), the X-ray absorbing clouds lie just within the inner edge of the broad-line region as defined by Clavel *et al.* (1987). However if, for example, the density is as high as 10^{12} cm^{-3} then the gas will be situated at a radius of only 10^{15} cm. NGC 4151 may therefore represent the first source in which relatively cold dense clouds have been detected very close to the active nucleus, as envisaged in recent studies by Ferland & Rees (1988).

5. References

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