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X-RAY ECLIPSE OF THE AGN IN NGC 1365: MEASURING THE SOURCE SIZE

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RESUMEN

Presento un estudio sobre la variabilidad extraordinaria de la absorción en rayos-X de la galaxia Seyfert oscurecida NGC 1365. Una campaña con *Chandra* de seis observaciones cortas en 10 días reveló un eclipse de la fuente de rayos-X en dos días. Ademas, el análisis de la variabilidad espectral de una observación con duración de 60 ks con XMM-Newton, cuando la fuente estaba en un estado Compton-delgado, reveló la transición de una nube oscurecedora con $N_H \sim 3 \times 10^{23}$ cm^{-2} in $\sim$ 60 ks. Estas observaciones restrigen el tamaño de la fuente de rayos-X a $< 10^{14}$ cm y la distancia hacia la nube oscurecedora a $< 10^{16}$ cm.

ABSTRACT

I present a study of the extraordinary X-ray absorption variability of the obscured Seyfert Galaxy NGC 1365. A Chandra campaign of six short observations within ten days revealed an eclipse of the X-ray source in two days. Furthermore, an analysis of the spectral variability in a 60 ks long XMM-Newton observation, when the source was in a Compton-thin state, revealed a transition of an obscuring cloud with $N_H \sim 3 \times 10^{23}$ cm^{-2} in $\sim$ 60 ks. These observations constrain the X-ray source size to $< 10^{14}$ cm and the distance of the obscuring cloud to $< 10^{16}$ cm.

Key Words: galaxies: active — X-rays: galaxies

1. INTRODUCTION

The geometry, structure and dimensions of the circumnuclear absorber in Active Galactic Nuclei are not well understood. In particular, it is not clear whether the obscuring material lay at parsec-scale distance from the central source, or much closer in.

Variability of X-ray absorbing column density N_H is a powerful tool to investigate this issue: if the X-ray absorber is made of clouds moving with Keplerian velocity around the central black hole, the observation of changes in N_H put constraints on the location and size of the clouds.

A systematic study of obscured ($N_H > 10^{22}$ cm^{-2}) Seyfert Galaxies with multiple hard X-ray observations revealed that N_H variability on time scales from months to years is almost ubiquitous (Risaliti et al. 2002). This result imply that the circumnuclear absorber is clumpy, and suggests the possibility of investigating such variations at shorter timescales, in order to put strong constraints on the distance of such clouds.

One of the most promising objects for this study is the nearby (D$\sim$ 19 Mpc) obscured Seyfert galaxy NGC 1365, which has shown an exceptional X-ray variability in the hard X-rays, with several observed spectral changes from Compton-thick, reflection dominated states (column density $N_H > 10^{24}$ cm^{-2}) to Compton thin states ($N_H = 2-5 \times 10^{23}$ cm^{-2} (Risaliti et al. 2005).

The fastest transition has been observed during a Chandra campaign of six short (15 ks) observations, each performed every two days, for a total monitoring of ten days. The spectra from the first three observations are shown in Figure 1. While during the first observation the source was in a Compton-thin state, with $N_H \sim 4 \times 10^{23}$ cm^{-2}, the second observation shows a much fainter and harder spectrum, with a prominent iron Kα line (equivalent width EW$\sim$ 1.5 keV), typical of reflection dominated, Compton-thick ($N_H > 10^{24}$ cm^{-2}) states.

This extreme variation is due to a Compton-thick cloud crossing the line of sight towards the X-ray source. Assuming that this cloud is moving with Keplerian velocity, we can estimate the size of the X-ray source, D, and the distance of the circumnuclear absorber, R , which turn out to be $D < 10^{14}$ cm and $R < 10^{16}$ cm (see Risaliti et al. 2007 for more details).

The fast absorption variability observed during the Chandra campaign prompted us to analyze past long XMM-Newton observations in order to search for N_H variations within the single observations.

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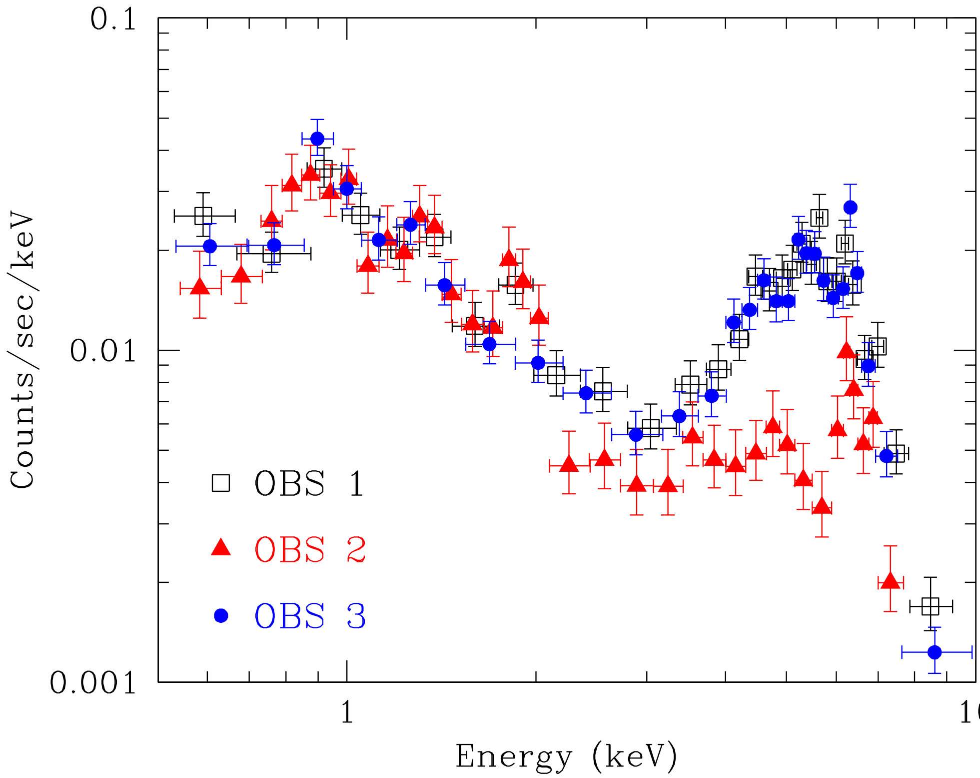

Fig. 1. Spectra from the first three Chandra observations of NGC 1365, taken once every two days. The second observation caught the source in a reflection-dominated state, while the other spectra show the intrinsic emission absorbed by a column density $N_H \sim \times 10^{23}$ cm^{-2}.

Here we report on the results of this analysis, which revealed a variation in the spectral state due to a cloud with $N_H \sim 3 \times 10^{23}$ cm^{-2} crossing the line of sight in ~ 50 ks.

2. FAST N_H VARIATION: A CLUMPY AND COMPACT ABSORBER.

In order to search for possible N_H variations during single observations, we analyzed the hardness ratio light curves of a long (60 ks) XMM-Newton observation. The hardness ratio is defined using a soft energy band which includes the photoelectric cut-off (in our case, 2–5 keV), and a hard band at higher energies (7–10 keV). A small column density variation should change the flux in the soft band (the average N_H in this observation is 2–3$\times 10^{23}$ cm^{-2}) leaving unaltered the hard band flux.

The light curve is shown in Figure 2. A clear spectral change is detected. We then extracted three spectra from the three spectral intervals highlighted in the figure. We performed a complete spectral analysis of each interval, leaving all the spectral parameters (and, in particular, the spectral slope and the absorbing column density) free to vary. The result, shown in the lower panel of the figure, is a highly significant column density variation, while all the other spectral parameters remain constant within the errors.

Assuming that the observed variation is due to a cloud crossing the line of sight, we can further investigate this scenario with a more detailed time-resolved spectral analysis, based on the following points:
(1) We extract ten spectra from ten intervals of 6 ks each, in order to better monitor the spectral variation.
(2) We assume that the continuum component is constant during the whole 60 ks observation, as suggested by the analysis of the three ~ 20 ks intervals.
(3) We model the continuum with a two-component absorber: the first component covers the whole source, while the second one covers a fraction f_C of the x-ray source. The column densities of the two components are the same in all the spectra, while the covering fraction is free to vary in each single spectrum.

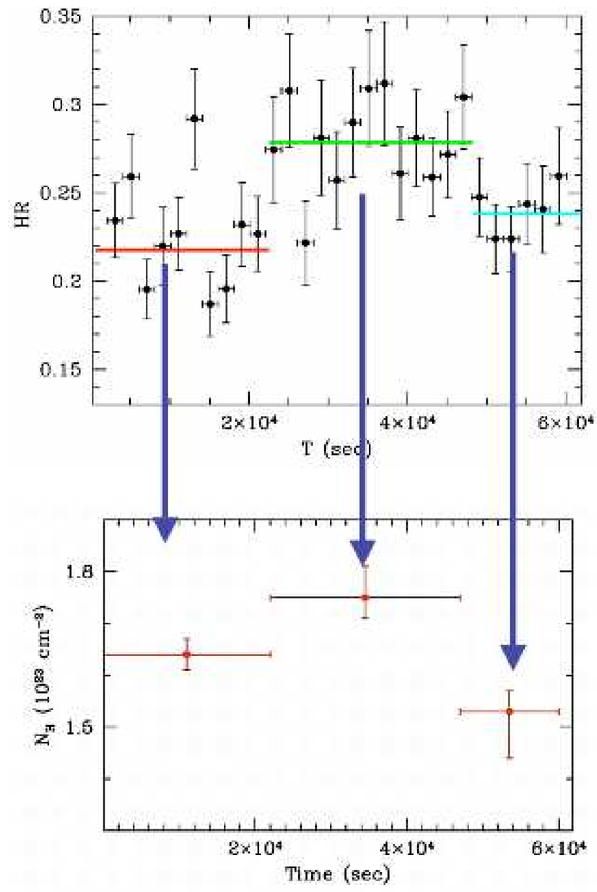

Fig. 2. Upper panel:hardness ratio (2–5 keV/7–10 keV) light curve of a 60 ks XMM-Newton observation of NGC 1365. Lower panel: best fit values of the absorbing column density obtained from a spectral fitting (with all the continuum parameters free to vary) of each of the three indicated time intervals.

The results of the fit are shown in Figure 3: we detect a highly significant variation of covering factor, with an initial increase from ~ 0 up to $\sim 70\%$, and then a decrease back to $\sim 0\%$. The best fit column density of the complete absorber is $N_H \sim 1.1 \times 10^{23}$ cm^{-2}, while for the partial coverer we find $N_H \sim 3 \times 10^{23}$ cm^{-2}.

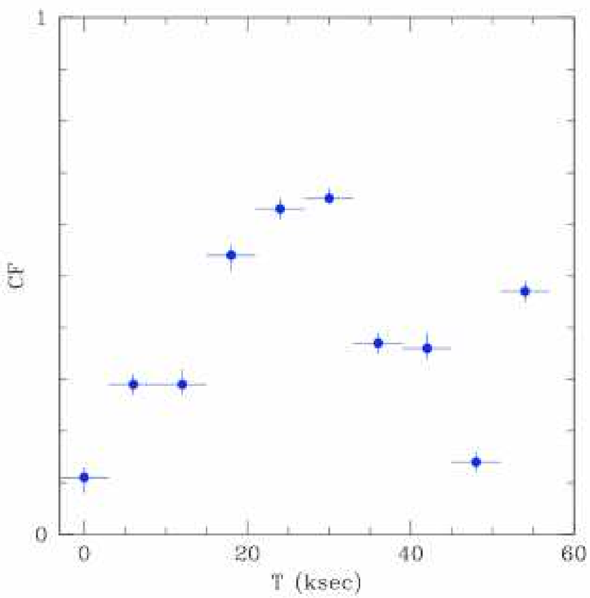

Fig. 3. Covering factor variation of the obscuring cloud crossing the line of sight during the XMM-Newton 60 ks-long observation of NGC 1365.

This is the first direct detection of a cloud crossing the line of sight in an obscured AGN, and suggests the possibility to extend this type of study to other sources. Indeed, without analyzing the hardness ratio light curve of NGC 1365 it is still possible to obtain a satisfactory fit of the spectrum of the whole observation, without any strong residual feature. Therefore, it is possible that other sources with XMM-Newton observations contain occultation events in their spectra, which have not yet been discovered. We plan to extend the analysis described here to a sample of ∼15 bright Seyfert 2s with long XMM-Newton observations.

REFERENCES

Risaliti, G., Elvis, M., & Nicastro, F. 2002, ApJ, 571, 234

Risaliti, G., Elvis, M., Fabbiano, G., Baldi, A., & Zezas, A. 2005, ApJ, 623, L93

Risaliti, G., et al. 2007, ApJ, 659, L111