RevMexAA (Serie de Conferencias), **9**, 334–335 (2000)

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

AN EXTENDED MULTI-ZONE MODEL FOR THE MCG–6-30-15 WARM ABSORBER

R. Morales and A. C. Fabian

Institute of Astronomy, Cambridge, UK

and

C. S. Reynolds

JILA, University of Colorado, USA

RESUMEN

El absorbedor tibio y variable que fue visto por *ASCA* en el espectro en rayos-X de MCG–6-30-15, muestra un comportamiento temporal complejo en el cual la profundidad óptica del O VIII está anticorrelacionado con el flujo, mientras que el del O VII no cambia. Las observaciones del *BeppoSAX* han puesto en duda la explicación en términos de un absorbedor con dos zonas. Estas muestran un comportamiento más complicado en el borde del O VII. La explicación que ofrecemos para las observaciones de *ASCA* y *BeppoSAX* requiere de un modelo simple de fotoionización y la presencia de una tercera zona, intermedia, con una etapa de baja luminosidad. En la práctica, los absorbedores tibios son probablemente regiones extendidos con varias zonas donde, dependiendo de la luminosidad, sólo una parte produce los bordes de absorción.

ABSTRACT

The variable warm absorber seen with *ASCA* in the X-ray spectrum of MCG–6-30-15 shows complex time behaviour in which the optical depth of O VIII anticorrelates with the flux whereas that of O VII is unchanging. The explanation in terms of a two zone absorber has since been challenged by *BeppoSAX* observations. These present a more complicated behaviour for the O VII edge. The explanation we offer for both *ASCA* and *BeppoSAX* observations requires a very simple photoionization model together with the presence of a third, intermediate, zone and a period of very low luminosity. In practice warm absorbers are likely to be extended, multi-zone regions of which only part causes directly observable absorption edges at any given time depending on the value of the luminosity.

Key Words: **GALAXIES: ACTIVE — GALAXIES: INDIVIDUAL MCG–6-30-15 — GALAXIES: SEYFERT — X-RAYS: GALAXIES**

1. COMPARISON *ASCA* - *BEPPOSAX* OBSERVATIONAL RESULTS

To explain the behaviour of the O VII and O VIII edges during their long-look *ASCA* observation of the nearby (z=0.008) Seyfert 1 galaxy MCG–6-30-15, Otani et al. (1996) adopted a multizone model. Orr et al. (1997) raised the possibility of a more complex warm absorber: the large value for τ(O VIII) during epoch 1[1] (1.7 ± 0.5, 1σ uncertainty) was inconsistent with the values at all other epochs.

These two observational results for τ(O VIII) have been plotted versus luminosity in 0.1–10 keV in Figure 1 (Morales, Fabian, & Reynolds 2000). The only discrepancy between both sets of data is the result for epoch 1.

[1] The epochs in the *BeppoSAX* observation are chronologically numerated (i.e., number 1 corresponds to the first epoch of the observation, etc.).

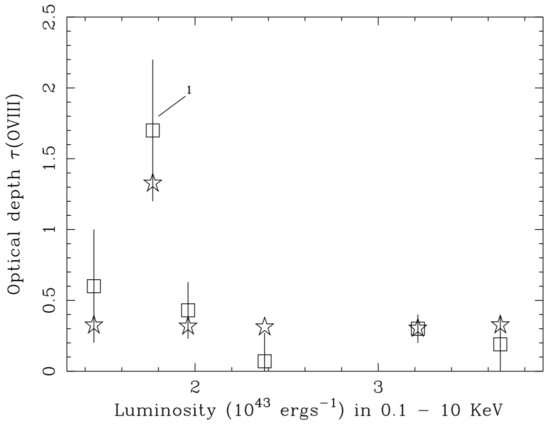

Fig. 1. Comparison *BeppoSAX* data (squares) with the model computations (stars) for the following warm absorber parameters: WA1: distance to the ionizing source, $R = 1.0 \times 10^{17}$ cm, line-of-sight distance through the warm absorber, $\Delta R = 3.0 \times 10^{14}$ cm, and electron density $n_e = 4 \times 10^{7}$ cm^{-3}. WA3: $R = 4 \times 10^{17}$ cm, $\Delta R = 7 \times 10^{16}$ cm, and $n_e = 5 \times 10^{5}$ cm^{-3}.

2. TIME DEPENDENT PHOTOIONIZATION CODE

The state of the inner absorber has been modelled using a time dependent photoionization code for oxygen (Reynolds 1996). The model has been compared against the photoionization code CLOUDY (Ferland 1996) in the case of a plasma in photoionization equilibrium (see Morales et al. 2000 for a detailed description of the code and the comparison).

3. APPLICATION TO THE MCG–6-30-15 WARM ABSORBER

The model we propose to explain both *ASCA* and *BeppoSAX* observations consists of:
(a) warm absorber 1 $\equiv$ WA1 (inner warm absorber) with: $R < 1.4 \times 10^{17}$ cm, $n > 2 \times 10^{7}$ cm^{-3} and $\Delta R \simeq 10^{14}$ cm
(b) warm absorber 2 $\equiv$ WA2 (outer warm absorber) with: $R > 3 \times 10^{18}$ cm, $n < 2 \times 10^{5}$ cm^{-3} and $\Delta R \simeq 10^{14}$ cm
(c) warm absorber 3 $\equiv$ WA3 with radius and density values between those of WA1 and WA2. Its expected behaviour would be: (1) When $L \approx 0.4 \times 10^{43}$ erg s^{-1}, the ionization parameter $\xi \approx 50$ erg cm s^{-1}, giving a high value for f_{O8}, (2) when $L \approx (1, 5) \times 10^{43}$ erg s^{-1}, then $\xi \approx 150, 750$ erg cm s^{-1}. For these high values of ξ, oxygen is practically fully stripped and therefore there is a very small contribution to the optical depth for O VIII. An example of the results obtained is presented in Figure 1.

This work has been supported by PPARC and Trinity College (R.M.) and by the Royal Society (A. C. F.). C. S. R. thanks support from Hubble Fellowship grant HF–01113.01–98A; grant awarded by the Space Telescope Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., for NASA under contract NAS 5-26555. C. S. R. also thanks support from NASA under LTSA grant NAG5-6337.

REFERENCES

Ferland, G. J. 1996, Hazy, A Brief Introduction to Cloudy, University of Kentucky, Department of Physics and Astronomy Internal Report
Morales, R., Fabian, A. C, & Reynolds, C. S. 2000, MNRAS, in press
Orr, A., Molendi, S., Fiore, F., Grandi, P., Parmar, A. N, & Owens, A. 1997, A&A, 324, L77
Otani, C., et al., 1996, PASJ, 48, 211
Reynolds, C. S. 1996, Ph.D. thesis, University of Cambridge, UK

R. Morales and A. C. Fabian: Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK (rm, acf@ast.cam.ac.uk).
C. S. Reynolds: JILA, University of Colorado, Campus Box 440, Boulder, CO 80309–0440 USA (chris@rocinante.colorado.edu).

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco