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Preliminary report

THE GRAVITATIONAL MICROLENS INFLUENCE ON X-RAY SPECTRAL LINE GENERATED BY AN AGN ACCRETION DISC *

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SUMMARY: The influence of gravitational microlensing on the X-ray spectral line profiles originated from a relativistic accretion disc has been studied. Using a disc model, we show that microlensing can induce noticeable changes in the line shapes when the Einstein ring radius associated with the microlens is of a size comparable to that of the accretion disc. Taking into account the relatively small size of the X-ray accretion disc, we found that compact objects (of about a Solar mass) which belong to the bulge of the host galaxy can produce significant changes in the X-ray line profile of AGN.

1. INTRODUCTION

Thanks to the developing of X-ray telescopes, we are able to investigate the innermost regions of Active Galactic Nuclei (AGNs). The shape of the Fe K_α line in numerous AGNs indicates that an accretion disc is present in the central part (see e.g. Nandra *et al.* 1997, 1999, Fabian *et al.* 2000, Reevese 2001). This line is probably produced in the very compact region near the Black Hole (BH) (Iwashawa *et al.* 1999, Nandra *et al.* 1999) and can provide very relevant information about the kinematics and the physical conditions around the BH.

Popović *et al.* (2001) have recently studied the influence of microlensing on the optical and UV Broad Emission Lines (BEL), founding that microlensing can induce significant changes in the line profiles. The X-ray emitting region in AGNs is more compact than the optical one, and consequently the microlensing effects should be stronger. The influence of microlensing on X-ray continuum emission originating in an accretion disc was analized by Yonehara *et al.* (2000).

In this paper we present some preliminary results about the influence of microlensing on the Fe Kα line generated by a relativistic accretion disc in the Schwarzschild metric.

2. MODEL

Our computations will be based in a relativistic accretion disc model in the Schwarzschild metric (Fabian *et al.* 1989). When gravitational microlensing is included in this model, the line shape is given by

$$\frac{F_\nu}{F_0} =$$

$$\int_{R_{in}}^{R_{out}} \int_{-\pi/2}^{\pi/2} \epsilon(r) \cdot (\frac{\nu}{\nu_e(r,\phi)})^3 \cdot I(r,\phi,\nu) \cdot A(r,\phi)\; dr\; d\phi$$

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where $\nu_e(r, \phi)$ is the emitted frequence and $\epsilon(r) = r^{-q}$ is the emissivity. $I(r, \phi, \nu)$ is the intensity emitted at frequency ν at a point of the disc with coordinates r, ϕ (for more details see, e.g., Fabian et al. 1995).

The amplification caused by microlensing is given by the function

$$A(r, \phi) = \frac{u^2(r, \phi) + 2}{u(r, \phi)\sqrt{u^2(r, \phi) + 4}}, \quad (4)$$

where $u(r, \phi)$ corresponds to the angular separation between the lens and the source in units of the Einstein Ring Radius (ERR). It is obtained from

$$u(r, \phi) = \frac{\sqrt{(r\,cos\,\phi\,cos\,i - r_0\,cos\,\phi_0)^2 + (r\,sin\,\phi - r_0\,sin\,\phi_0)^2}}{\eta_0},$$

r_0 being the radial distance of the microlens from the disc center, ϕ_0 the azimuthal position of the microlens and η_0 the ERR expressed in gravitational radii, $\Re_g = GM/c^2$, units.

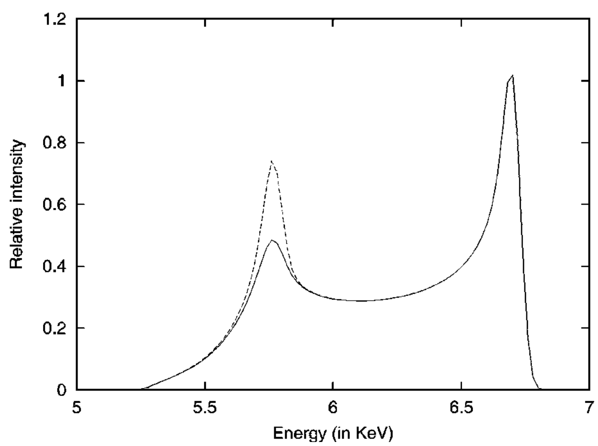

Fig. 1. *Influence of microlensing on the Fe Kα line originated by an accretion disc with parameters: i = 32 $R_{inn} = 20\Re_g$, $R_{out} = 50\Re_g$ and emissivity q=-3. The parameters of the gravitational microlens are: $R_0 = 50\Re_g$, $\phi_0 = 90°$, ERR=10 $\Re_g$.*

3. RESULTS AND CONCLUSION

In Figures 1-4 we show several examples corresponding to a disc with parameters: $i = 32$, $R_{inn} = 20\Re_g$, $R_{out} = 50\Re_g$ and emissivity q=-3.

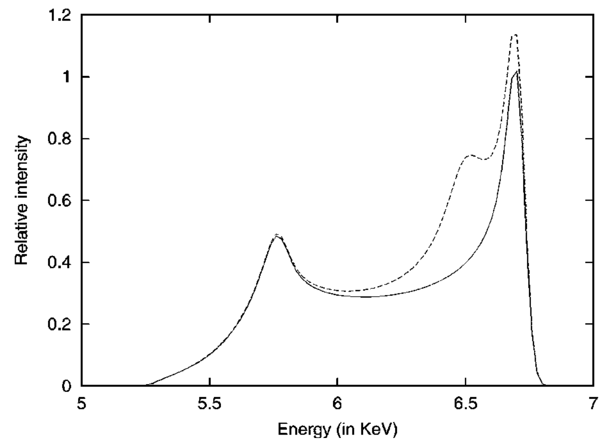

Fig. 2. *The same as in Fig. 1, but for $R_0 = 50\Re_g$, $\phi_0 = 40°$, ERR=20 $\Re_g$.*

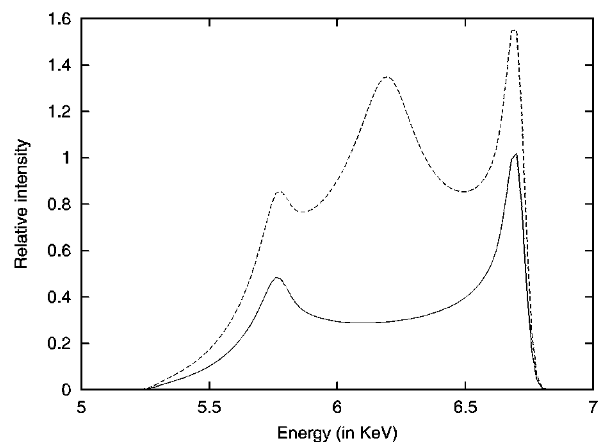

Fig. 3. *The same as in Fig. 1, but for $R_0 = 50\Re_g$, $\phi_0 = 0°$, ERR=70 $\Re_g$.*

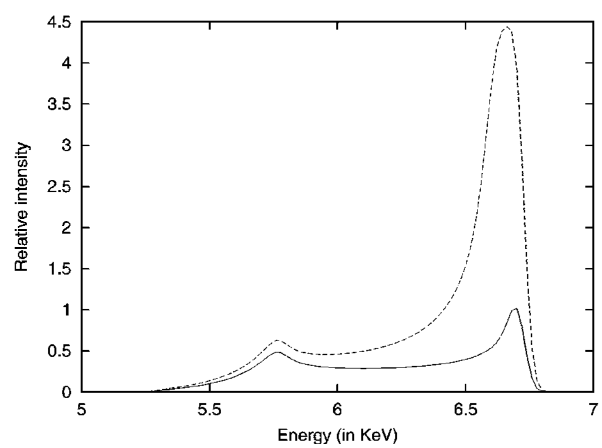

Fig. 4. *The same as in Fig. 1, but for $R_0 = 50\Re_g$, $\phi_0 = -40°$, ERR=70 $\Re_g$.*

As one can see in Figs. 1-4, even a microlens of small ERR (several gravitational radii) can produce significant changes in the line profile of the Fe Kα line. Taking this into account we use Eq. (8) from Popović *et al.* (2001) to study what kind of objects in the bulge of the host galaxy of the AGN could induce microlensing in the X-Ray lines. We suppose that the mass of the BH is $M_{BH} \approx 10^8 M_{\odot}$. The results for two different distances of the microlens to the center of the AGN are shown in Table 1.

Table 1. *ERR and corresponding masses for several microlens at distances of 1 and 2 kpc from the galaxy center*

ERR in $\Re_g$	M (D=1kpc)	M (D=2kpc)
5	3.52	1.76
10	14.10	7.05
20	56.24	28.12
50	352.52	176.26
100	1406.08	703.04

Taking into account that the dimensions of bulges are of about several kpc, one can conclude from Table 1, that relatively small objects (of about a solar mass) in the bulge surrounding an AGN could induce microlensing amplification in the X-Ray emission lines generated by the accretion disc.

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REFERENCES

Bao, G., Hadrava, P., Ostgaard, E.: 1994, *Astrophys. J.* **435**, 55.
Fabian, A.C., Rees, M.J., Stella, L., White, N.E.: 1989, *Mon. Not. R. Astron. Soc.* **238**, 729.
Fabian, A.C., Iwasawa, K., Reynolds, C.S., Young, A.J.: 2000, *PASP*, **112**, 1145.
Fontan, C., Calivani, M., Felice, F., Čadež, A.: 1997, *PASJ*, **49**, 159.
Iwashawa, K., Fabian, A.C., Young, A.J., Inoue, H., Matsumoto, C.: 1999, *Mon. Not. R. Astron. Soc.* **306**, L19.
Nandra, K., George, I.M., Mushotzky, R.F., Turner, T.J. and Yaqoob, T.: 1997, *Astrophys. J.* **477**, 602.
Nandra, K., George, I.M., Mushotzky, R.F., Turner, T.J. and Yaqoob, T.: 1999, *Astrophys. J.* **523**, L17.
Popović, L.Č., Mediavilla, E.G., Muñoz, J.: 2001, *Astron. Astrophys.* **378**, 295.
Popović, L.Č., Mediavilla, E.G., Muñoz, J., Jovanović, P.: 2002, In preparation.
Reeves, J.N., Turner, M.J.L., Pounds, K.A., O'Brien, P.T., Boller, Th., Ferrando, P., Kendziorra, E., Vercellone, S.: 2001, *Astron. Astrophys.* **365**, L134.
Yonehara, A., Mineshige, S., Manmoto T., Fukue, J., Umemura, M., Turner, E.L.: 2000, *Adv. Space Res.* **25**, 493.
Wandal, A., Peterson, B.M., Malkan, M.A.: 1999, *Astrophys. J.* **526**, 579.

УТИЦАЈ МИКРОГРАВИТАЦИОНОГ СОЧИВА НА ЛИНИЈЕ ИЗ X-ДОМЕНА ЕМИТОВАНИХ ИЗ АКРЕЦИОНОГ ДИСКА*

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Претходно саопштење

У раду се разматра утицај гравитационог микросочива на профил Fe Kα спектралне линије која је емитована из акреционог диска галаксије са активним језгром. Показује се да гравитационо микросочиво може изазвати значајне промене у профилу када је његов Ајнштајнов радиус упоредив са димензијама диска. Узимајући у обзир да је диск који зрачи у X-домену релативно малих димензија (неколико гравитационих радиуса), објекти релативно малих маса (реда Сунчеве масе) који припадају халоу галаксије могу изазвати значајне промене у облику линије.

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