

Relativistic Iron Features from X-Ray Illuminated Spots and the Measure of the Black Hole Mass in AGN

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Narrow spectral features in the 5–6 keV range were recently discovered in the X-ray spectra of a few Active Galactic Nuclei. We propose that these features originate from localized spots occurring on the surface of an accretion disc following its illumination by flares. Detailed calculations of the temporal and spectral properties of these features in our proposed model can be found in Dovčiak et al. (2004). Comparison of the computed profiles with observed features can help to estimate parameters of the system. In principle this method can provide a powerful tool to measure the mass of super-massive black holes in Active Galactic Nuclei. By comparing our calculations with the *Chandra* and *XMM-Newton* results, we show, however, that spectra from present generation X-ray satellites are not of good enough quality to fully exploit the method and determine the black hole mass with sufficient accuracy. This task has to be deferred to future missions with both large sensitivity and high energy resolution, such as *Constellation-X* and *Xeus*.

§1. The method

Relativistic iron line profiles may provide a powerful tool to measure the mass of the black hole in Active Galactic Nuclei (AGNs) and Galactic black hole systems. To this aim, Stella (1990) proposed to use temporal changes in the line profile following variations of the illuminating primary source. Along the same line, Matt and Perola (1992) proposed to employ, instead, variations of the integrated line properties such as equivalent width, centroid energy and line width. These methods are very similar conceptually to the classical reverberation mapping method, widely and successfully applied to optical broad lines in AGNs. Sufficiently long monitoring of the continuum and of the line emission is however required, as well as large enough signal-to-noise ratio, and in practice these methods have not provided many results yet.

A simple, direct and potentially robust way to measure the black hole mass would be available if the line emission originates at a given radius and azimuth, as expected if the disc illumination is provided by a localized flare just above the disc (possibly due to magnetic reconnection), rather than a central illuminator or an extended corona. If the resulting ‘hot spot’ co-rotates with the disc and lives for at least a significant part of an orbit, by fitting the light curve and centroid energy of

the line flux, the inclination angle θ_o and the orbit radius could be derived (radius in units of the gravitational radius r_g). Assuming Keplerian rotation, the orbital period is linked with radius in a well-known manner (Bardeen et al. 1972). The equation for the orbital period then contains the black hole mass M_\bullet explicitly, and so this parameter can be determined. A detailed description of the method can be found in Dovčiak et al. (2004).

§2. Observations

Recently, the discovery of narrow emission features in the X-ray spectra of some AGNs (NGC 3516: Turner et al. 2002; ESO 198-G024: Guainazzi 2003, Bianchi et al. 2004; NGC 7314: Yaqoob et al. 2003; Mrk 766: Turner et al. 2004) has renewed interest in hot spots. A tentative explanation (even if admittedly not the only possible one) for these features, typically observed in the 5–6 keV energy range, is in fact in terms of iron emission produced in a small range of radii and distorted by joint action of Doppler and gravitational shift of photon energy. Iron lines would be produced by localized flares which illuminate the underlying disc surface, producing the line by fluorescence. Indeed, the formation of magnetic flares on the disc surface is one of the most promising scenarios for the X-ray emission of AGNs. A particularly strong flare, or one with a very large anisotropic emission towards the disc, could give rise to the observed features. Small width of the observed spectral features implies that the emitting region must be small, and that it is seen for only a fraction of the entire orbit (either because the flare dies out, or because emission goes below detectability).

If the flares co-rotate with the disc and if they last for a significant part of the orbit, it may be possible by observing their flux and energy variations with phase to determine the orbital parameters, and thence M_\bullet .

A detailed comparison between the model and the observations can be found in Dovčiak et al. (2004) where some parameters of the systems are estimated in the assumption that the observed narrow features are the blue horn of an orbiting spot, the rest of the profile being too faint to be detected. Unfortunately, the quality of the XMM-Newton and Chandra data is not good enough to allow the full exploitation of the method, which has then to wait for future X-ray satellites, like *Constellation-X* and *Xeus*.

References

- 1) Bardeen, J. M., Press, W. H. and Teukolsky, S. A., *Astrophys. J.* **178** (1972), 347.
- 2) Bianchi, S. et al., submitted to *Astron. Astrophys.* (2004).
- 3) Dovčiak, M., Bianchi, S., Guainazzi, M., Karas, V. and Matt, G., submitted to *Mon. Not. R. Astron. Soc.* (2004).
- 4) Guainazzi, M., *Astron. Astrophys.* **401** (2003), 903.
- 5) Matt, G. and Perola, G. C., *Mon. Not. R. Astron. Soc.* **259** (1992), 433.
- 6) Stella, L., *Nature* **344** (1990), 747.
- 7) Turner, T. J. et al., *Astrophys. J.* **574** (2002), L123.
- 8) Turner, T. J., Kraemer, S. B. and Reeves, J. N., *Astrophys. J.* (2003), in press; astro-ph/0310885.
- 9) Yaqoob, T., George, I. M., Kallman, T. R., Padmanabhan, U. et al., *Astrophys. J.* **596** (2003), 85.