Session 3: Diagnostics of High Gravity Objects with X- and Gamma Rays

3-1. White Dwarfs and Neutron Stars

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SUPER-EDDINGTON SOURCES IN GALAXIES

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1. Introduction

Imaging X-ray observations have resolved X-ray sources in many nearby 'normal' galaxies. These sources are associated with different galaxian component, including: bulge and globular clusters(LMXB, e.g. in M31); the disk/arm component (LMXB, HMXB, SNR, SN, ISM shells); and low-luminosity AGN (see reviews in Fabbiano 1989; 1995; 1996). A number of these sources have X-ray luminosities in excess of the Eddington luminosity for 1 $M_{\odot}$ accreting object ($\sim 1.3 \times 10^{38}$ergs s^{-1}), and have been called Super-Eddington sources. Nearly 100 Super-Eddington sources have been reported so far, based on *Einstein* and *ROSAT* images (see Fabbiano 1989; 1995; 1996; Makishima 1994). The number of these sources increases with the maximum distance of the galaxy sample considered (e.g. Read et al 97). This is in part due to confusion, but it is also true that considering the larger sample of galaxies one obtains in a larger volume of space the amount of these relatively rare sources would increase as well.

Super-Eddington sources may occur in nuclear regions as well as elsewhere in a galaxy. They can reach luminosities of 10-100$\times L_{Edd}$. If they are single accreting objects, this points to $\geq 10 M_{\odot}$ black holes.

2. Nuclear Super-Eddington Sources

Bright point-like X-ray sources are normally associated with AGN. What we are concerned here with are sources with X-ray luminosities $\sim 10^{40}$ergs s^{-1}. This type of sources is sometimes associated with low-luminosity Seyfert or LINER nuclei (e.g. NGC4594, Fabbiano and Juda 1997), and their likely explanation is sub-Eddington accretion on a very massive nuclear black hole ($M \sim 10^{7-8} M_{\odot}$).

K. Koyama et al. (eds.), The Hot Universe, 93-96.

However, there are at least two instances in which the nature of the nuclear source is not totally understood, and a Super-Eddington accretion binary is a possibility. One such instance is the bright ($L_X \sim 10^{39}$ergs s^{-1}) source at the nucleus of M33 (Long et al 1981). This source was seen to vary with *Einstein* (Peres et al 1989), and later ASCA spectra showed a remarkable similarity with the spectra of galactic black hole candidates rather than those of AGN (Takano et al 1994). The variable X-ray source at the nucleus of NGC 3628 (Dahlem et al 1995) is the other example, although in this case the ASCA spectra may favor an AGN interpretation (Yaqoob et al 1995).

3. Non-nuclear Super-Eddington Sources

The majority of Super-Eddington sources in spiral galaxies is not in the nuclei. Before we speculate on their nature, we need to understand if these sources are individual point-like sources, unresolved extended emission regions, or unresolved source complexes. We have examples of all these categories, sometimes occurring in the same galaxy. In the Scd galaxy IC 342, 3 Super-Eddington sources ($L_X \sim 10^{39}$ergs s^{-1}) were discovered with the *Einstein* IPC (Fabbiano and Trinchieri 1987). One of these sources - at the nucleus - was later resolved into three sub-Eddington components plus diffuse emission with a higher resolution *ROSAT* HRI observation (Bregman et al 1993). However, another source (IC 342 A) was later found to vary with ASCA, confirming its nature as individual source (Okada et al 1994). The temporal/spectral characteristics of this source are very similar to those of LMXB, suggesting that we are indeed in the presence of an accreting black hole in a binary system (Makishima 1994). Variability also points to single objects (and thus black hole candidates) in source B of NGC 1313 (Petre et al 1994), and source X-3 in the Antennae galaxy (Fabbiano et al 1997). In the Antennae galaxy (the merging pair NGC 4038/4039), 12 sources, all more luminous than $4 \times 10^{39} ergs\ s^{-1}$ were detected with the *ROSAT* HRI, including the variable source X-3. Although 3 of these sources look point-like, the majority is likely to be part of complex emission regions, and to be perhaps due to bubbles of hot gas in star-forming regions (Fabbiano et al 1997).

There is a class of Super-Eddington sources, which are convincingly identified with SN or young SNR (see Fabbiano 1996). They include SN1980k in NGC 6946 (Canizares et al 1982), SN1978k in NGC 1313 (Schlegel et al 1996), SN1986j in NGC 891 (Bregman & Pildis 1992), and SN1993j in M81 (Zimmerman et al 1994). The large X-ray luminosity of these sources can be explained with either the interaction of a reverse shock with the ejecta, or the interaction of the SN shock with surrounding clouds (Schlegel et al

1996).

4. Future Prospects

Super-Eddington sources are clearly exceptional and interesting objects. To progress in our understanding of their nature we need to be able to study their temporal and spectral behaviour and to associate them accurately with galaxian features.

With the imminent AXAF launch (27 Aug. 1998), we are in a very good position to study these sources. We will be able to obtain spectra and spatial information with good statistics from sources in nearby galaxies (at a distance of 5 Mpc, 10^{39}ergs s^{-1} correspond to 2000 cts/10ks, and the 1/2 arcsec AXAF beam corresponds to a linear size of 12 pc). We will be able to identify accurately any such source with galaxian features out to 50 Mpc, where the AXAF beams corresponds to 120 pc.

XMM (due to be launched in Dec. 1999) will have four times the AXAF count rate, and thus will give us very good spectra and timing data on sources in nearby galaxies, but its beam is 15 arcsec, 30 times that of AXAF. This larger beam means that confusion becomes a serious problem: at a distance of 50 Mpc, this beam corresponds to a significant fraction of a galaxy (3.6 kpc). HTXS, which is currently in planning in the USA, with a projected launch around year 2007, is expected to have five times the XMM throughput, and a similar beam. Thus, while very detailed studies of sources in nearby galaxies will be possible, confusion will impede studying sources in galaxies outside of a few Mpc radius.

To really move forward in this field, we need to combine high throughput with high angular resolution. A Large X-ray Telescope, with a $\sim$10 sqmeter collecting area and arcsec resolution (see Elvis and Fabbiano 1997) would open up the study of Super-Eddington sources with CCD-type spectra (1000 cts) out to 50 Mpc. This prospect is probably closer than I believed before attending this meeting. ESA is taking an active role in pushing forward such a mission (XEUS, see Turner, this volume).

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References

Bregman, J.N., Cox, C.V., Tomisaka, K. 1993, Ap. J., 415, L79
Bregman, J.N., and Pildis, R.A. 1992, Ap. J., 380, L107
Canizares, C.R., Kriss, G.A., Feigelson, E.D. 1982, Ap. J., 253, L17
Dahlem, M., Heckman, T.M., Fabbiano, G. 1995, Ap. J., 442, L49
Elvis, M., and Fabbiano, G. 1997, in 'Next Generation X-ray Observatory', Workshop Proc., Univ. of Leicester, M.D.L. Turner ed., p. 33

Fabbiano, G. 1989, ARA&A, 27, 87
Fabbiano, G. 1995, in 'X-ray Binaries', W.H.G. Lewin et al eds., (Cambridge: University Press), p.390
Fabbiano, G. 1996, in 'Roentgenstrahlung from the Universe', MPE Report No.263, H.U. Zimmerman, J.E. Truemper and H. Yorke eds., p.347
Fabbiano, G., and Juda, J.Z. 1997, Ap. J., 476, 666
Fabbiano, G., Schweizer, F., Mackie, G. 1997, Ap. J., 478, 542
Fabbiano, G. and Trinchieri, G. 1987, Ap. J., 315, 46
Long, K.S., D'Odorico, S., Charles, P.A., Dopita, M.A. 1981, Ap.J., 246, L61
Okada, K, Mihara, T., and Makishima, K. 1994, in 'Horizon of X-ray Astronomy', F. Makino and T. Ohashi eds., (Tokyo: Universal Academy Press), p.515
Makishima, K. 1994, in 'Horizon of X-ray Astronomy', F. Makino and T. Ohashi eds., (Tokyo: Universal Academy Press), p. 171
Peres, G., Reale, F., Collura, A., Fabbiano, G. 1989, Ap. J., 336, 140
Petre, R., Okada, K., Mihara, T., Makishima, K., and Colbert, E.J.M. 1994, PASJ, 46, L115
Read, A.M., Ponman, T.J., Strickland, D.K. 1997, MNRAS, 286, 626
Schlegel, E.M., Petre, R., Colbert, E.J.M. 1996, Ap. J. 456, 187
Takano, M., Mitsuda, K., Fukazawa, Y., Nagase, F. 1994, Ap. J., 436, L47
Yaqoob, T., Serlemitsos, P.J., Ptak, A., Mushotzky, R., Kunieda, H. and Terashima, Y. 1995, Ap. J., 455, 508
Zimmerman, H.U. et al 1994, Nature, 367, 621

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