Feeding Compact Objects: Accretion on All Scales
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Links Between Z Sources and Atoll Sources

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Abstract. It is known that the Z and atoll sources are two typical types of neutron-star sources in low mass X-ray binaries (LMXBs), which present very different Q-ν relations of lower kHz QPOs. We propose that the Z and atoll sources are two different phases in the evolutionary track of neutron star in LMXBs, instead of two types of distinct sources.

Keywords. LMXBs, Z source, atoll source

1. Introduction

Two typical types of sources, Z and atoll sources, in neutron star (NS) low mass X-ray binaries (LMXBs) describe different tracks in CCDs on different timescales and display distinct $Q-\nu$ relations of lower kHz QPOs (Hasinger & van der Klis 1989, Wang *et al.* 2012, Liu *et al.* 2007). However, the $Q-\nu$ relations of lower kHz QPOs of Sco X-1 displays a mildly similar trend to that of atoll sources (Wang *et al.* 2012). Moreover, recent studies show that the characteristics of both Z and atoll types present in two sources (Ding *et al.* 2011 Ding *et al.* 2010 for a review). In addition, a compilation of RXTE data for three transient atoll sources presents new branch which connects to the top of the C-shaped (atoll) path and forms a horizontal track – turning C-shape into a "Z" when they go down to very low luminosity (Gierliński & Done 2002). These phenomena enlighten the investigation for the links between Z and atoll sources.

2. Links Z with Atoll Sources

Many evidences indicate that there is a connection between Z and atoll sources. We suppose an evolutionary scenario that the LMXBs containing a NS may evolve from a Cyg-like Z phase at the beginning and transform into the Sco-like Z phase. Eventually, they enter into atoll phase, going through a phase characterized by hybrid atoll/Z phase like the sources GX 13+1 (Hasinger & van der Klis 1989, Schnerr *et al.* 2003, Homan *et al.* 2004). The variation of accretion rate dominates the whole process. At the beginning, the matter with high falling velocity releases substantial gravitational energy and forms a radiation dominant inner disk (Frank *et al.* 2002, Camenzind 2007). The accreting material piles up around the NS at high accretion rate (near critical Eddington accretion rate, even supercritical rate), describing a Z-shape track in CCDs. During this process, the disk may puff up and become geometrically thick due to some instabilities (Paczyński & Wiita 1980), resulting in two effects. Firstly, more and more material pile up near the polar cap and bury the magnetic field on NS surface (Zhang & Kojima 2006), which leads to the decrease of magnetic pressure. Furthermore, the viscosity and friction between the accreted matter slow down the falling velocity, resulting in the decrease of ram pressure

and low accretion rate. This scenario is consistent with the atoll phase. Then the NB and FB turn into the IS and banana branch from the Sco-like phase, respectively. Besides, the low accretion rate results in a long timescale for the trace of atoll patterns in CCDs, as well as a wide range of luminosity. Because of the inhomogeneities in the inner accretion disk (Romanova, Kulkarni & Lovelace 2007), the friction is different from here to there. Consequently, the accretion rate may become high at some position, which generates a horizon pattern connecting to the top of the C-shape for atoll sources, consistent with the scenario presenting in Gierliński & Done (2002).

3. Conclusion

We suggest that the Z type and atoll type sources are two phases during different evolutionary phase of NS LMXBs, instead of two distinct sources.

References

Camenzind, M. 2007, *Compact Objects in Astrophysics: White Dwarfs, Neutron Stars, and Black Holes*. Springer-Verlag, Berlin

Ding, G. Q., Zhang, S. N., Wang, N., Qu, J. L., & Yan, S. P. 2011, *AJ*, 142, 34

Frank, J., King, A., & Raine, D. 2002, *Accretion Power in Astrophysics* (Cambridge, UK: Cambridge University Press)

Gierliński, M. & Done, C. 2002, *MNRAS*, 331, L47

Hasinger, G. & van der Klis, M. 1989, *A&A*, 225, 79

Homan, J., Wijnands, R., Rupen, M. P., Fender, R., Hjellming, R. M., di Salvo, T., & van der Klis, M. 2004, *A&A*, 418, 255

Liu, Q. Z., van Paradijs, J., & van den Heuvel, E. P. J. 2007, *A&A*, 469, 807

Paczyńsky, B. & Wiita, P. J. 1980, *A&A*, 88, 23

Romanova, M. M., Kulkarni, A. K., & Lovelace, R. V. E. 2007 (astroph/ 0711.0418)

Schnerr, R. S., Reerink, T., van der Klis, M., Homan, J., Méndez, M., Fender, R. P., & Kuulkers, E. 2003, *A&A*, 406, 221

Wang, J., Chang, H. K., Zhang, C. M. *et al.* 2012, *Astrophysics and Space Science*, 342, 357

Zhang, C. M. & Kojima, Y. 2006, *MNRAS*, 366, 137

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