第 29 卷 第 4 期
2011 年 10 月

天 文 学 进 展
PROGRESS IN ASTRONOMY

Vol.29, No. 4
Oct., 2011

博士论文摘要选登

低质量X射线双星的长期监测和吸积物理

闫 震*

(中国科学院 上海天文台 星系宇宙学重点实验室，上海 200030)

摘 要：本论文基于X射线空间卫星的多波段监测数据，研究明亮的低质量X射线双星的X射线能谱的演化和态跃迁过程，暂现源在爆发过程中的一些性质以及不同波段的光度的演化和相关关系。暂现源的爆发所涉及的光度范围很大，这对于研究吸积物理具有不可比拟的重要性，可以研究不同的吸积率下的吸积状态以及随着吸积率的演化过程和因果关系。通过这些研究增进我们对吸积物理的理解，尤其是暂现源爆发过程中X射线能谱演化的驱动机制，喷流的性质和X射线能谱态的关系，不同能谱态下的辐射起源等一些尚未完全解决的问题。

首先，我们系统地研究了银河系内明亮的X射线双星在最近十几年中不同的能谱态以及不同的能谱态之间的跃迁。我们通过软X射线（2～12 keV）和硬X射线（15～50 keV）两个能段全天监测器的光变曲线，可以得到X射线双星的长期能谱演化，而利用硬度比可以确定X射线能谱态跃迁。我们的结果不仅证实了从硬态到软态的态跃迁光度和随后的软态的峰值光度正相关关系，而且还发现态跃迁光度和光度的增加率有正相关关系。这两个经验关系表明最亮的硬态和从硬态到软态的态跃迁光度主要是由吸积率的变化率所表征的非稳态吸积过程所主导的。由于这两个相关关系在高光度端没有任何饱和与截断的迹象，表明有更亮的爆发和更亮的硬态在物理上是允许的，可以在银河系内的X 射线双星中被观测到，也许这种明亮的硬态就对应于某些邻近星系中发现的超亮X射线源的谱态。我们对于低质量X射线双星暂现源在十几年间的爆发上升时标的统计研究发现，不同爆发的上升时标近似是一个常数，虽然有很大的弥散。这个结果支持爆发的峰值光度和光度增加率大体上成正比关系的观点。上升时标的大小在几天的量级，而且和轨道周期存在弱的正相关关系，表明上升时标可能对应于吸积盘外区某个半径处的粘滞时标，而且和盘的尺度存在某种相关。

我们还利用Swift卫星，对黑洞暂现源GX 339-4在2010年爆发的从硬态到软态的态跃迁前后，进行了包括紫外、光学和X射线的多波段同时观测。我们发现紫外辐射的流强在爆发开始阶段和0.6～10 keV 的X射线正相关，即$f_{\rm UV} \propto f_{\rm X}^{0.52\pm0.04}$，而且在从硬态到软态的态跃迁大约10 d前，紫外辐射的流强开始下降，此时和X射线辐射的流强反相关。我们认为在这次爆发中硬态的紫外辐射是由喷流主导的，如果硬态喷流的功率越大，它的平谱就能够延伸到更

* **该作者博士毕业时间**：2011 年 7 月； **指导老师**：中国科学院上海天文台余文飞研究员

高的频率。紫外流量的下降表明喷流在态跃迁之前已经开始熄灭，可以用来预测之后的X射线能谱态跃迁。

Monitoring Observations of Low Mass X-ray Binary and Accretion Physics

YAN Zhen

(Key Laboratory for Research in Galaxies and Cosmology, Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China)

Abstract: In this thesis, we have performed the multi-wavelength monitoring observations of Galactic low-mass X-ray binaries and studied the X-ray spectral evolution and spectral state transitions in bright X-ray binaries, the properties of transient sources during the outbursts and the evolution of multi-wavelength emission during the outburst and the relation between different wavelengths. The large dynamical range of X-ray luminosity is invaluable for studying the accretion physics, since we can watch the evolution of the system through the full range of accretion rates and follow causal sequences between them. The results of our study improve our understanding of accretion physics, especially in some unresolved problems, such as the key role in determining the X-ray spectral transitions, the relation between jet and X-ray spectral states and the origin of emission in different X-ray spectral states.

Firstly, we systematically studied the different spectral states and state transitions in the bright Galactic X-ray binaries during the past more than ten years. We could study the long term evolution in different energy bands by using the soft (2–12 keV) and hard (15–50 keV) X-ray monitoring light curves. The hardnessratio of the two energy band can be used to describe the X-ray spectral evolution and define the spectral states and state transitions. We confirmed that the luminosity of hard-to-soft state transition positively correlates with the peak luminosity of following soft state, and also found positively correlation between the luminosity of hard-to-soft state transition and the rate-of-increase of luminosity. These two empirical correlations indicate that the brightest hard state and the hard-to-soft state transition are determined by the non-stationary accretion which is characterised by the rate-of-increase of mass accretion rate. Both correlations do not show any saturation or cut-off in the high luminosity end, which implies that the brighter outbursts and brighter

hard states are permitted by physics and can be observed in the Galactic X-ray binaries, and these phenomena might have been observed in ultra-luminous X-ray sources in nearby galaxies. We then have statistically studied the rise timescales of outbursts in low-mass X-ray binary transients during the past more than ten years. The results shows the rise timescales are nearly constant with large scatter in different outbursts, which supports the positive correlation between the rate-of-increase of luminosity and peak luminosity. We also found that the mean value of rise timescale is about several days and weakly correlates with the orbital period. Our results indicate that the rise timescale may correspond to the viscous timescale at some outer radius in the accretion disc, and somehow correlates with the size of the accretion disc.

We have also performed the analysis of the multi-wavelength observations (including ultraviolet, optical and X-ray) cross the state transition during the 2010 outburst of GX 339-4 by Swift. We found that the UV flux positively correlates with the 0.6–10 keV X-ray in a form of $f_{\rm UV} \propto f_{\rm X}^{0.52\pm0.04}$, and 10 days before the hard-to-soft state transition, UV flux shows a rapid drop, during which the X-ray flux still increases. We argued that the UV emission was dominated by jet during this outburst, and the optically thick spectrum can extend to higher frequency in a more powerful jet in a hard state. The drop in UV flux indicates the jet starts to switch off before hard-to-soft state transition, and could be used to predict the occurrence of the hard-to-soft transition.