X-Ray Outbursts of AXPs and SGRs

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Abstract. We show that the X-ray enhancement light curves of transient AXP/SGRs can be reproduced by the active fallback disk model. We solve the diffusion equation for the relaxation of a disk that has been pushed back by a soft gamma-ray burst. Our preliminary results indicate that a critical temperature around 1500 K leads to a thermal-viscous instability in the fallback disks of all AXP/SGRs. The effect of the instability on the light curves are different for transient and persistent sources due to different pre-burst disk conditions in these systems.

Keywords: pulsars: individual (AXPs) — stars: neutron – X-rays: bursts —accretion, accretion disks
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INTRODUCTION

Anomalous X-Ray Pulsars (AXPs) and Soft Gamma-Ray Repeaters (SGRs) constitute a young neutron star population whose X-ray luminotities (10^{34} - 10^{36} erg/s) are much higher than their spindown powers. Some AXP/SGRs show transient behavior. During an outburst, the X-ray luminosity of the transient sources increase from $\sim 10^{33}$ erg/s to a maximum that is in the L_X range of persistent AXP/SGRs. The fallback disk model [1, 2] helps explain the optical, IR and X-ray observations of persistent AXP/SGRs in both quiescent and enhancement phases, by including active, accreting fallback disks [3 - 6]. X-ray luminosity, period, period derivative, and statistical distribution of AXP/SGRs can also be explained with fallback disks and dipole fields of $\sim 10^{12} - 10^{13}$ G [7]. Using numerical fits to the data, it was shown that the decay light curve of transient AXP XTE J1810-197 could be due to a viscous disk instability at critical temperatures of ~1000-2000K [8]. We test this idea by applying the same model to the X-ray outburst data of other transient AXP/SGRs.

THE NUMERICAL MODEL

We solve the disk diffusion equation [9] as was described in [8]. In the model, the X-ray enhancement is assumed to be triggered by a soft gamma-ray burst by pushing the inner-disk matter to larger radii. The pile-up and the extended disk are represented by a Gaussian $\Sigma = \Sigma_{max} \exp[-(r-r_0)^2/(\Delta r)^2]$ and a power-law $\Sigma = \Sigma_0 (r_{in}/r)^p$ surface density distribution. The evolution of the disk depends on the viscosity, the initial surface density distribution and the efficiency of irradiation of the disk by the X-rays from the neutron star, represented by C. For a viscous disk, the power index p of the surface-density profile is $\sim 3/4$. The inner radius is kept constant at approximately the Alfven radius. We employ the α-prescription for the kinematic viscosity [10]. The critical temperature

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T_{crit} determines the border between the hot ($\alpha = \alpha_{hot}$, $T > T_{crit}$) and cold ($\alpha = \alpha_{cold}$, $T < T_{crit}$) regions of the disk.

RESULTS AND DISCUSSION

The model fit for the X-ray outburst light curve of SGR 1627-41 is presented in Figure 1. The parameters that produced this fit are as follows: $r_{in} = 2 \times 10^9$ cm, $r_0 = 1 \times 10^{10}$ cm, $\Sigma_{max} = 40$ g cm^{-2}, $\Sigma_0 = 2.5$ g cm^{-2}, $\Delta r = 2.4 \times 10^8$ cm, $\alpha_{hot} = 0.1$, $\alpha_{cold} = 0.038$, $T_{crit} = 1350$ K, $C = 1.5 \times 10^{-4}$. Model parameters α_{cold}, α_{cold} and T_{crit} are expected to remain the same for all sources. The values of these model parameters are similar to those obtained for AXP XTE J1810-197 [ertanerkut2008]. A detailed work including other transient AXP/SGRs (AXP CXO J164710.2-455216 and SGR 0501+4516) will provide better constains on the main disk parameters [11].

There are several difficulties in testing the model curves at luminosities very close to the quiescent level of the transient sources ($\sim 10^{33}$ erg/s). For instance, at such low luminosities, a significant part of the X-ray luminosity comes from outside of the observational band. Moreover, intrinsic cooling of the neutron star could contribute to the total luminosity in quiescence, depending on the age of the source. All these possible effects at low luminosities are discussed in [11].

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