An X-ray survey of galactic Wolf-Rayet stars

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Introduction

A Wolf-Rayet (W-R) star is predicted as a final evolutionary stage of a massive star, which is thought to be a progenitor of a long-duration gamma-ray burst. Recently, a binary system including a W-R star as one of the stellar components is attracting a considerable attention, as a candidate to cause a merging and then cause extreme eruption. Massive binaries composed by a W-R star and a OB star have the highest temperature plasma, produced by the collision of the winds. Colliding wind binary is the best testing ground for plasma shock physics, because plasma properties vary with binary separations.

Data selection & Analysis

We have examined Chandra, XMM-Newton and Suzaku archive data, which cover about 320 W-R stars in 550 W-R stars identified in our Galaxy (Crowther et al. 2011), in order to clarify the nature of the W-R stars. In order to plasma temperature and column density with high accuracy, we selected high flux source above 10^{-12} erg/s/cm^2 at 0.5 - 10 keV. We first fit the spectra by an absorbed collisional equilibrium plasma (APEC) model.

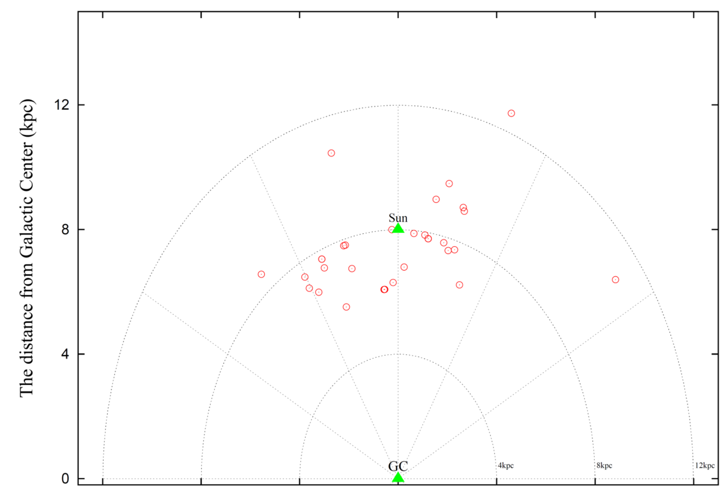


Fig.1 Spatial distribution of our samples

Results

In the following figures, the color of red, green, blue and pink mean **WN type W-R binary**, **WC-type W-R binary**, **single WN-type W-R star** and **another massive binary** (O+O, LBV+WR) respectively

We found that at least two of the stars, known as single W-R stars, have hot plasma component with a temperature of about 2MK (Fig.2).

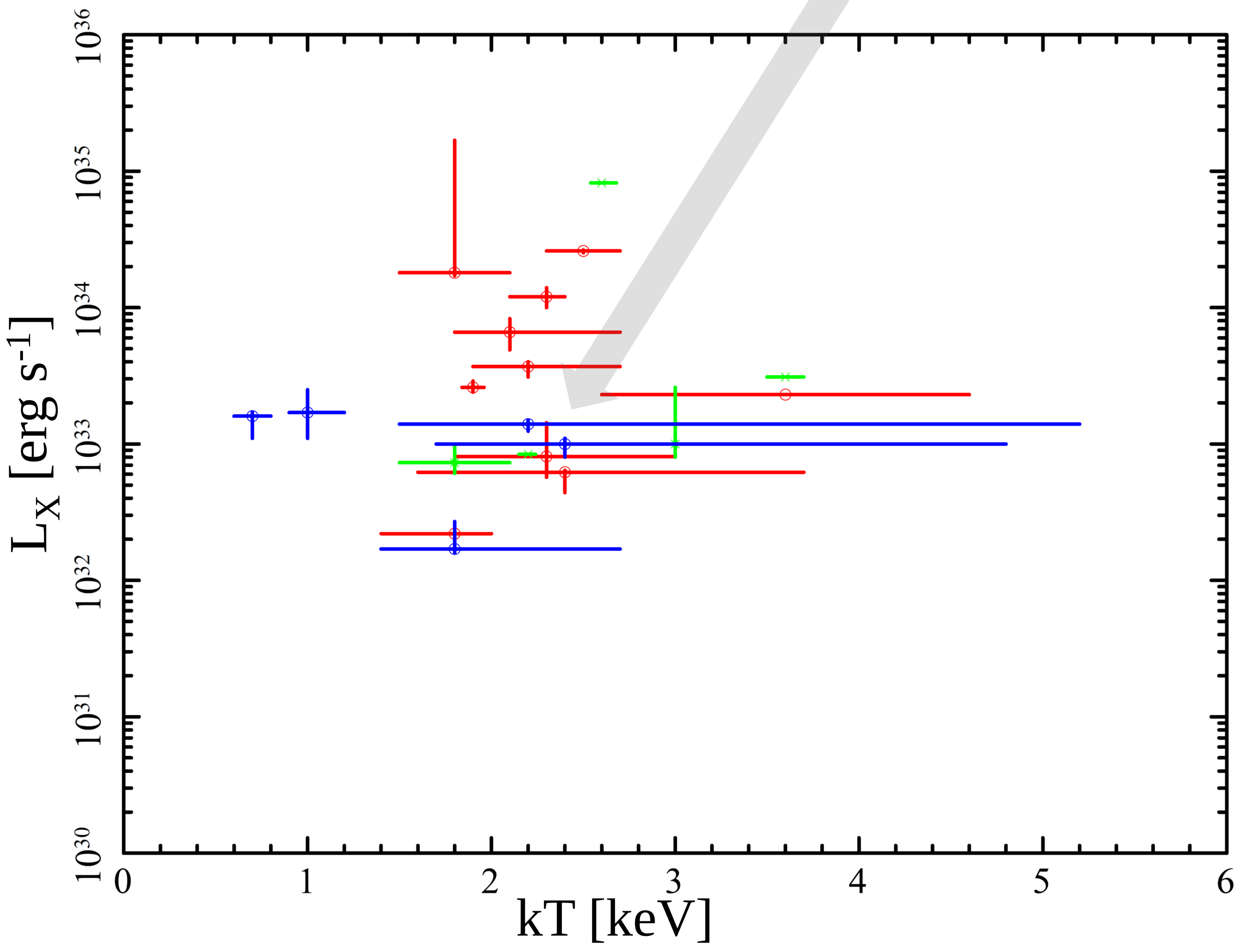
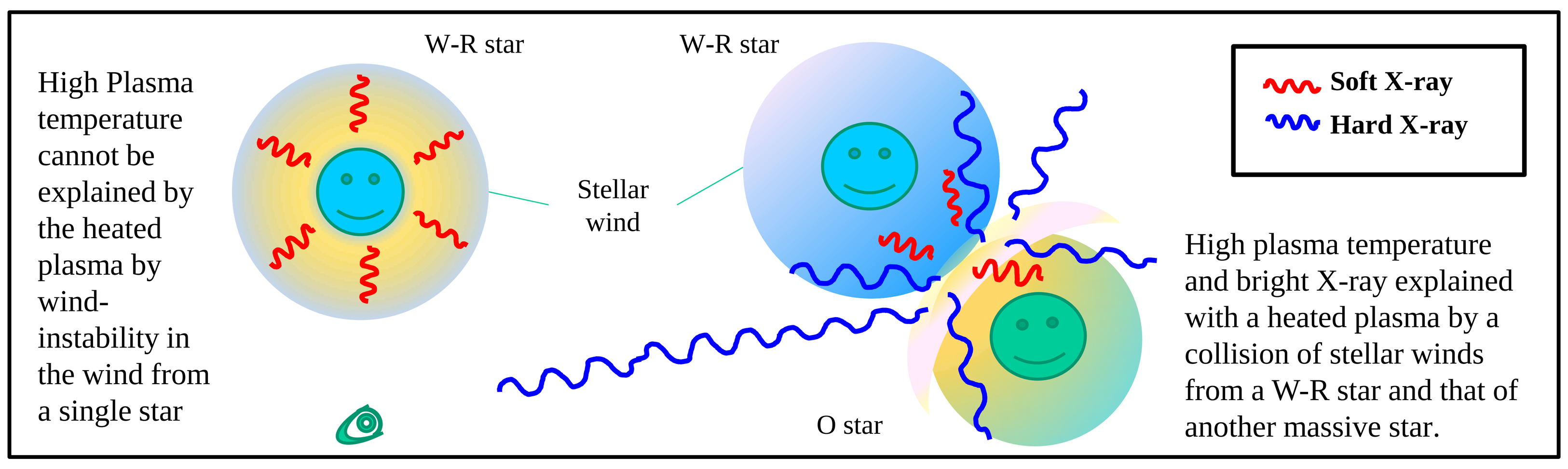


Fig.2 Plasma temperature vs. L_X

Fig.3 X-ray difference between single star and binary



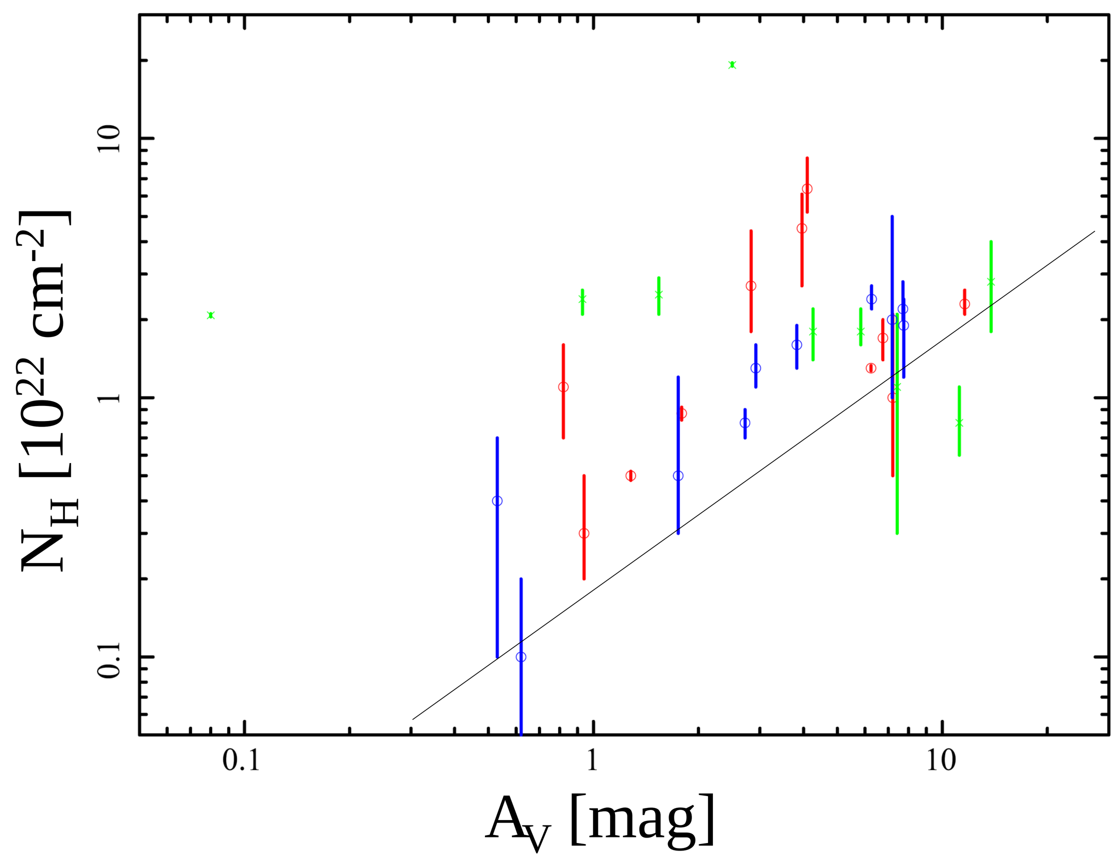


Fig.4 Av vs. N_H

The relation between the X-ray and visual extinction (N_H and A_V) is a key to understand the gas to-dust ratio of the interstellar medium around W-R star, since X-ray and optical–IR photons are mainly absorbed and scattered by interstellar gas and dust, respectively. The N_H/A_V ratio of 2.4 is roughly higher than that of MS stars(1.79: Predehl & Schmitt, 1995). This indicates that gas-rich environment.

We can perform a qualitative check on the X-ray energetics, as mentioned above, by considering two extremes: (a) highly radiative (χ>1) and (b) adiabatic colliding wind shocks (χ<1). The dimensionless parameter $\chi = \tau_{cool}/\tau$ was introduced by Stevens et al. (1992) , where τ_{cool} is the timescale of cooling and τ is the timescale of the gasdynamics. However, we need more sample in order to discussion.

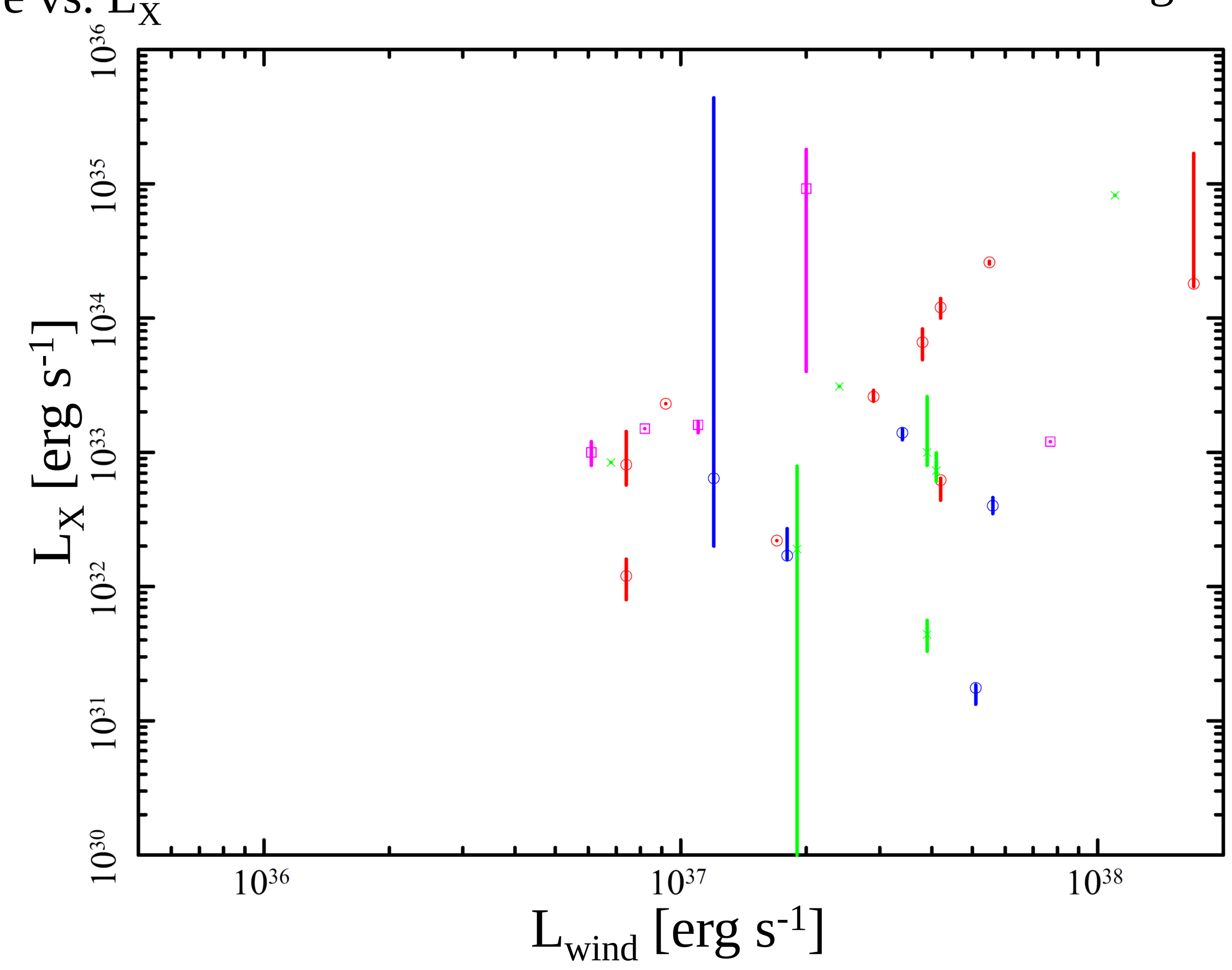


Fig.5 X-ray vs. wind luminosity for massive star. In the case of radiative shocks, $L_X \propto L_{wind}$ (the stellar wind luminosity =1/2 dM/dt V_∞^{-2}).

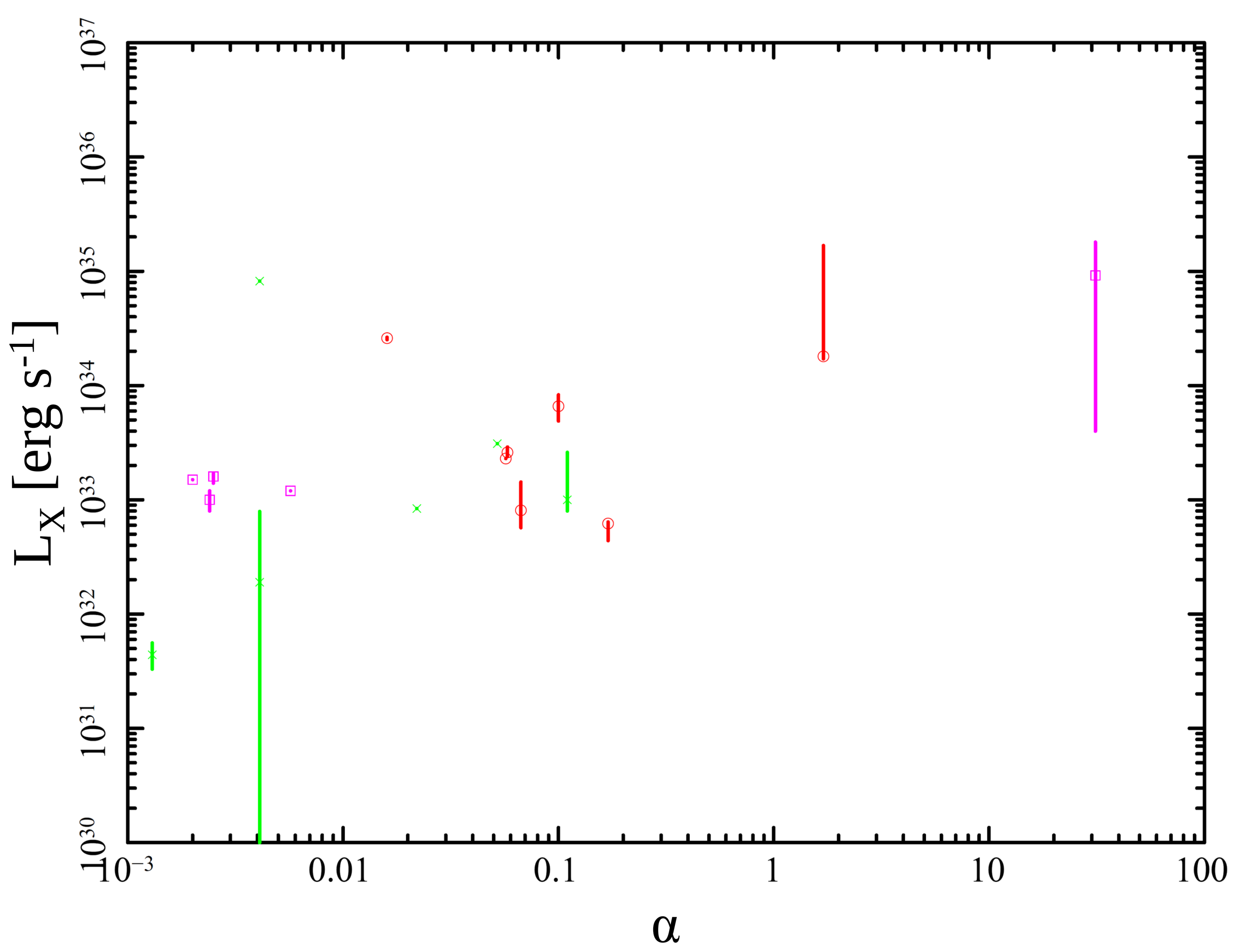


Fig.6 X-ray vs. wind shock parameter α for massive binaries. In the case of adiabatic shocks, LX $\propto \alpha$ = dM/dt^2 V_∞^{-3} a^{-1}(Luo et al. 1990;Myasnikov & Zhekov 1993). There exists a scaling law for the X-ray luminosity with dM/dt, V_∞ and binary separation (a)

Summary

We found that at least two of the stars, known as single W-R stars, have hot plasma component with a temperature of about 2MK, which cannot be explained by the heated plasma by wind-instability in the wind from a single star. This is alternatively explained with a heated plasma by a collision of stellar winds from a W-R star and that of another massive star (an O star, and so on) in a binary system. This is demonstrating that a hard X-ray survey is effective to know the real binarity in W-R stars.