The X-ray luminosities in quiescent phase for superflare stars

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Abstract

Maehara et al. (2012) and Shibayama et al. (2013) have searched for superflares on G-type dwarfs using Kepler data in the optical band. They found that slowly rotating stars, with a spin period of about 20 days like the Sun, caused superflares. It is believed that slowly rotating stars have a low X-ray luminosity and a small magnetic flux. Hence the superflares that occur on slowly rotating stars are strange phenomena. Here, we have searched for $L_{\rm xq}$ of superflare stars, using available X-ray archival data. As the result, we found that 11 stars are in the field of view of XMM-Newton and 7 of them are detected. In addition, we confirmed that 3 stars are identified with sources in the ROSAT All-Sky Survey Faint Source Catalog (Voges et al. 2000). We discovered a positive correlation between $L_{\rm xq}$ and the maximum flare energy during the Kepler observation (1.4 year) $E_{\rm tot,opt}$: $E_{\rm tot,opt} \propto L_{\rm xq}^{1.2}$. In addition, there is no correlation between $L_{\rm xq}$ with $P_{\rm rot}$ for superflare stars. These results indicate that the flare mechanism is common while the generation mechanism of the magnetic fields is different.

Key words: stars:flares—stars:G type dwarfs

1. Introduction

The X-ray emission from stars is associated with the stellar magnetic field. In fact, Pevtsov et al (2003) reported that the quiescent X-ray luminosity are proportional to the magnetic flux. In addition, the quiescent X-ray luminosity declines with increasing rotation periods ($P_{\rm rot}$) for the stars with $P_{\rm rot}$ of more than 7 days. Hence slowly rotating stars have a small magnetic flux. Since flares are caused by releasing magnetic energy, it is believed that slowly rotating stars cannot cause large flares.

However, the large flares occurring on slowly rotating stars were reported by Maehara et al. (2012). Maehara et al. (2012) searched for superflares on G-type dwarfs in optical white light using Kepler data and found superflares on slowly rotating stars with a spin period of about 20 days like the Sun. They derived the total bolometric energy of the superflares and found that the largest values of those for each object do not show any clear correlations with the period of the stellar rotation. This result indicates a different trend from that obtained in X-rays. Therefore we investigate the correlation between the maximum energy of white light flares during Kepler observation (1.4 years)($E_{\rm tot,opt}$) and quiescent X-ray luminosity ($L_{\rm xq}$) for each object.

2. Analysis and result

Target stars are 279 superflare stars reported in Shibayama et al. (2013). To find superflare stars detected in X-rays, we searched for X-ray archival data. As a result, 11 stars were located in the field of view of XMM-Newton and 7 stars were detected. 3 stars were identified with the sources in ROSAT All Sky Survey faint Source catalog. One of the three stars was also detected with XMM-Newton. Except for these stars, 4 stars were in the field of view of Chandra, although no stars were detected. In total, we found 9 superflare stars detected in X-rays. We investigate these stars in this work.

First, we made a light curve for each star to study time variations. We fit each light curve with a constant. As a result, the reduced χ^2 is less than 2.0 for each star. Therefore we consider that these stars are in the quiescent phase. Second, we calculated $L_{\rm xq}$. For the stars detected with significance levels larger than 7σ, we fit the spectra with a thin thermal plasma model to calculate $L_{\rm xq}$. For the other stars, we calculated $L_{\rm xq}$ by using

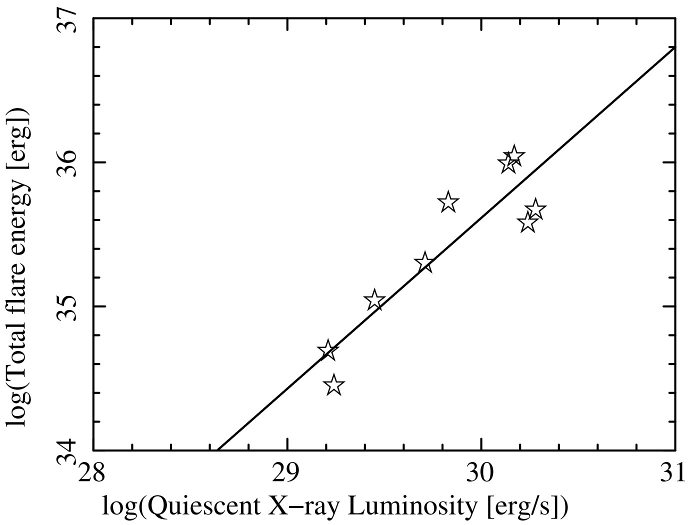

Fig. 1. The relation between $E_{\mathrm{tot,opt}}$ and L_{xq}. The vertical axis is the maximum total flare energy in the observation period (1.4 years) and the horizontal axis is L_{xq}.

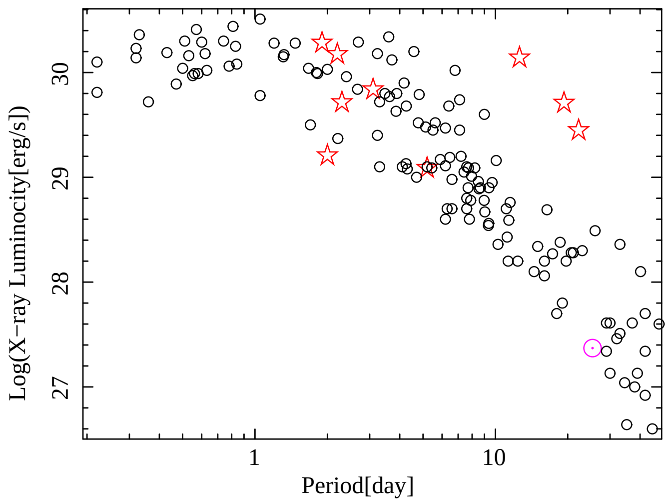

Fig. 2. The relation between L_{xq} and the rotational period. The vertical axis is L_{xq} and the horizontal axis is the rotational period. The stars and the circles indicate superflare stars and the G-type stars on which superflares have not been detected, respectively.

webpimms assuming a thin thermal plasma model; we assume N_{H}, kT and the abundance as 10^{18} cm^{-2}, 1.0 keV, and 0.4, respectively. Consequently, L_{xq} distributed at the range of 10^{29}–10^{31} erg s^{-1}. Figure 1 shows the relation between $E_{\mathrm{tot,opt}}$ and L_{xq}. We found the following relation:

$$E_{\mathrm{tot,opt}} \propto L_{\mathrm{xq}}^{1.2^{+0.3}_{-0.4}} \tag{1}$$

This equation implies that the maximum energy of white light flares is determined by the quiescent X-ray luminosity.

3. Discussion

3.1. Comparing with X-ray relation

In X-rays, Sasaki et al. (2017) investigated the relation between the maximum energy of the X-ray flares ($E_{\mathrm{tot,x}}$) and L_{xq} using MAXI data. They found the following relation:

$$E_{\mathrm{tot,x}} \propto L_{\mathrm{xq}}^{1.26^{\pm 0.04}} \tag{2}$$

In spite of the different energy ranges, both Equation (1) and (2) are roughly proportional to L_{xq}, and the index of L_{xq} are the same within the error ranges. This means that the ratio of the maximum flare energy between white light and X-rays is constant even though the quiescent X-ray luminosity is different.

The target stars of Sasaki et al. (2017) are several types of stars (RS CVn systems, Algol systems, dMe, dKe, Young Stellar Object and K-type variable star). On the other hand, our target stars are only G-type dwarfs. Although target stars are different, we obtained a similar relation with Sasaki et al. (2017). This implies that Equation (1) holds for several types of stars.

4. The difference of superflare stars and non-superflare stars

It is widely known that L_{xq} correlates with P_{rot} among G-type stars on which superflares have not been detected (we called these stars as non-superflare stars) (Pizzolato et al. 2003). On the other hand, among superflare stars, L_{xq} do not correlate with P_{rot} (Figure 2).

In general, rapidly rotating stars generate strong magnetic fields. If the generation mechanism for the magnetic fields of superflare stars is the same as non-superflare stars, we can predict that superflare stars have the same L_{xq}–P_{rot} relation as non-superflare stars. However, our result is inconsistent with this prediction. Hence, we can consider that Figure 2 indicates the possibility that the generation mechanism for the magnetic fields of superflare stars is different from non-superflare stars.

References

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