MAXI が見つけた謎のフレア天体 HD347929 の正体

The nature of the giant flare star HD347929 detected with MAXI/GSC

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Introduction

With MAXI/GSC, we have unexpectedly detected X-ray flares from a K2 type variable star HD347929 twice.
It has a large amplitude in V-band variation of about 0.5 mag, having the maximum magnitude of 9.2 and the minimum of 8.7 (Pojmanskiet al. 2002-2005). The size of the starspot is estimated to be 20% of the surface area of the star, providing the variation is due to appear and disappear of a starspot and the spot is not observable at all at V band.

A star with such large optical amplitude is quite limited to the most active stars even in the magnetically active stars (RS CVn stars, T Tauri stars, and dMe stars). However, the variation period of HD347929 (34 days) is significantly longer than the typical period of such active stars, 2–7 days (see Yamazaki et al. 2015 and the above section in this paper). In general, short rotation period is thought to be an essential parameter to amplify magnetic fields, as well as deep convection zone. Then this source might be a counterexample for the scenario. Then we aimed to reveal the nature of HD347929 by conducting precise spectroscopy in optical band.

MAXI observations

The Monitor of All-Sky X-ray Image (MAXI; Matsuoka et al. 2009) is a mission of an all-sky X-ray monitor operated in the Japanese Experiment Module (JEM; Kibo) on the International Space Station (ISS). It scans a source on the sky once per 92 min orbital cycle, and enables us to search for transient events such as giant stellar flares effectively.

Transient X-ray events were detected with MAXI/GSC from the region consistent with HD347929 twice. The first event was detected at the 2 scan transits from UT 2010-06-27 08:27 to 2010-06-27 09:57 at the 5-sigma level and the second one was at the 3 scan transits from UT 2013-05-19 18:09 to 2013-05-20 00:21.

We summarize the fundamental parameters of the flare sources and the dates of each flare in table 3.1 respectively. Ang figure 3.2 , 3.2 shows GSC light curves of all the detected flares in the 2–10 keV band with the time span which we extracted the data for the source significance check and spectral analysis. We first fit the spectra with an absorbed thin-thermal plasma model (wabs*mekal : Mewe et al. 1985, 1986, Kaastra 1992, Liedahl et al. 1995).

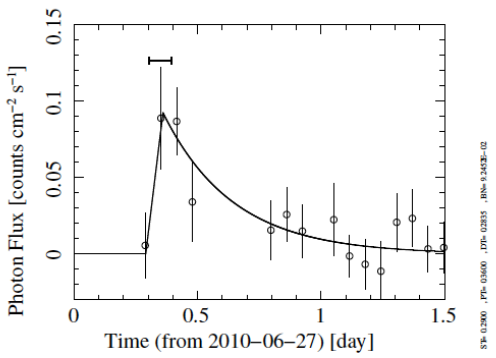

Figure 3.1: The flare light curve on 2010-06-27. The horizontal bar on the light-curve indicates the time span during which we extracted the data for the source significance check and the spectral analysis.

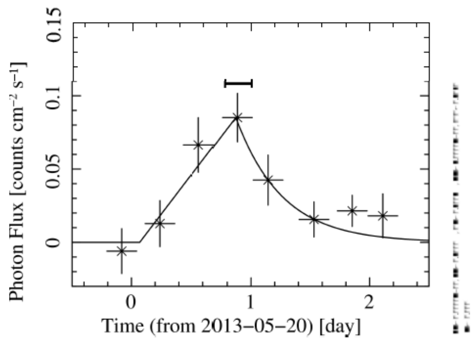

Figure 3.2: The flare light curve on 2013-05-20

Table 3.1: The flare parameter of HD347929

	DATE UT	confidence peak (J2000)	KT [keV]	Fx $\times 10^{-10}$ [ergs $s^{-1} cm^{-2}$]	e-time [ks]
Flare1	2010-06-27 08:27	18 08 00, +19 36 00	>2	$10^{+5.0}_{-0.5}$	$20\ ^{+18}_{-20}$
Flare2	2013-05-19 18:09:45	18 07 00, +19 38 60	3^{+4}_{-1}	$9.5^{+2.1}_{-5.2}$	33^{+45}_{-22}

Optical spectroscopy with GAOES

Gunmma Astronomical Observatory (GAO) has an eye piece system even on its 150 cm main telescope which is the third largest telescope in japan for the public star gazing. GAOES (Gunma Astronomical Observatory Echelle Spectrograph) is a high resolution spectrograph with an echelle grating.

In order to seach the nature of HD 347929, we conducted the spectroscopic observations for the wavelengths of 4924–7520Å. We executed 9 nights observations which start on 2014-07-19, 2014-09-17, 2014-09-19, 2014-10-11, 2014-10-17, 2014-11-01, 2014-11-05, 2014-11-6, and 2014-11-08 in JST.

In order to determine precisely the surface magnetic field (log g), the turbulent velocity (v_t), iron abundance ([Fe/H]), lithium abundance (A(Li)) and the rotation velocity (v_{rot} sin i), we used the data in the night of 2014-09-19 in JST only, which showed the highest signal-to-noise.

For the radial velocity (velocity in the line of sight: v_{rad}), we used the all data of 9 observations. We used the software MPFIT in the package SPTOOL for the data analysis, following the method by Takeda & Kawanomoto (2005). SPTOOL is the data-analysis software developed by Takeda, and is originally based on ATLAS9/WIDTH9 by Kurucz (1993). Table 3.2 summarizes the parameters of HD 347929 that we have estimated.

And we calculated the stellar radius R, the bolometric luminosity L_{bol}, distance D and mass M. (Table 3.3)

Table 3.2: The parameters determined with the optical spectroscopy

Parameter		Value
Fe/H		-0.10±0.3
log g	[cm s^{-2}]	2.7 ±0.2
v_t	[km s^{-1}]	1.8±0.1
v_{rot} sin$i$	[km s^{-1}]	10±0.2
A(Li)		1.9±0.3
$W_{H\alpha}$	[Å]	2.4

Table 3.3: The stellar parameters

Parameter		Value
v_{rot}	[km s^{-1}]	≥8.5
R	[$R_\odot$]	5.8–13
L_{bol}	[$L_\odot$]	11–44
D	[pc]	202–429
M	[$M_\odot$]	1.8–4.9

Discussion

・Binary or not?

We searched the radial velocity of HD347929 through whole period in V band variation, but it is consistent with constant and no variation along with the periodicity was found. This shows that HD347929 is unlikely to be a binary system.

・The comparison to the stellar evolution model

We estimated mass and age from observational results against that from the stellar evolution model (Bressan et al. 1993). We obtained the stellar mass M using the radius R and the surface gravitational acceleration g. Taking account of the equivalent width of the H α emission-line of 2.4Å, HD 347929 must be a WTT star (Fernandes et al. 1995). WTT stars are generally several Myrs old (Hillenbrand & Meyer 1999).

・Location

Above sections, we have obtained the picture that HD347929 is in the phase before main-sequence. In general, stars are born in a molecular cloud, and then disperse. This means that as younger the star is, as concentrates with each other, locating near star forming regions or molecular clouds.

At first, we searched star-forming regions which lies near HD347929. However, instead, we found that HD347929 locates in a torus-shaped area called Gould Belt, where many young stars are densely populated (Guillout 1998). Fig4:1 indicates the location of HD

347929, superimposed in the surface density map of stars (Guillout et al. 1998a Fig.3) which are identified with ROSAT All Sky survey and Tycho catalog (Hoeg et al. 1997). The map is shown in Galactic coordinates. The location of Gould Belt is shown with the dashed white line. We also plotted the location of HD 347929 on the sketch of Gould Belt geometry projected on the Galactic plane (Guillout et al. 1998b Fig.2) in figure 4.2. Here, we adopted 202–426 pc as the range of the distance of HD 347929, as obtained.

From both the consideration from the coordinates and the distance, we can say that HD347929 is in the Gould Belt. Since the Gould Belt is the region where young stars are clustered in, it supports the argument that HD347929 is a young star.

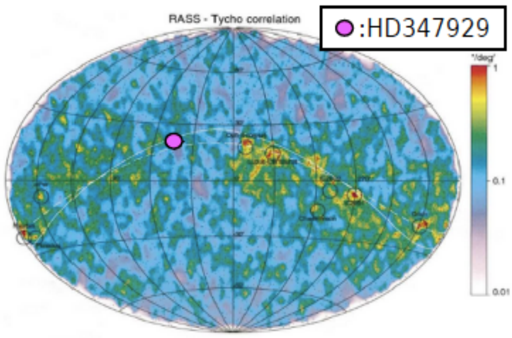

Figure 4.1: Guillout et al.(1998)b Fig.3

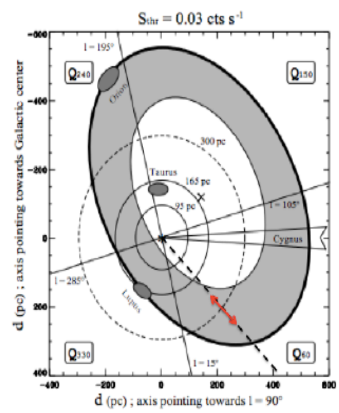

Figure 4.2: Guillout et al.(1998)b Fig.2. The red arrow is range of the distance of HD347929)

・X-ray flares

We derived the X-ray peak fluxes for the two detected flares as shown in Table 3.1. The X-ray fluxes of both the flares in the 2–20 keV band were 25 times larger than the persistent one. Now, since we have a little bit smaller limit for the distance than before, we can show the range for the X-ray luminosity and Emission Measure. The obtained ranges are shown in Table 4.1.

Table 4.1: The flare parameters based on the estimated distance

	Lx 10^{33}[ergs s^{-1}]	EM 10^{57}[cm^{-2}]	V 10^{36}[cm^{3}]	loop size 10^{12} [cm]
Flare1	$4.9^{+2.5}_{-2.5} - 22^{+11}_{-11}$	$0.37^{+39}_{-0.28} - 1.7^{+17}_{-1.3}$	<53	<12
Flare2	$4.7^{+1.0}_{-2.6} - 21^{+4.7}_{-12}$	$1.2^{+3.1}_{-0.88} - 5.4^{+14}_{-3.9}$	$0.093^{+0.53}_{-0.093} - 0.42^{+24}_{-0.42}$	$2.3^{+6.5}_{-2.0} - 3.8^{+11}_{-3.4}$

Both of the X-ray luminosity are much larger than the biggest X-ray flare ever observed from isolated young stars, that is, $L_X = 3 \times 10^{32}$ ergs s^{-1} from TWA-7 (Uzawa et al. 2011). Furthermore, it is comparable to, or maybe even larger than, the one of the biggest X-ray flare ever observed from stars, that is, $L_X = 5 \times 10^{32}$ ergs s^{-1} from II Peg (Yamazaki et al. 2015). This result indicates that such an energetic flare can happen even on an isolated star.