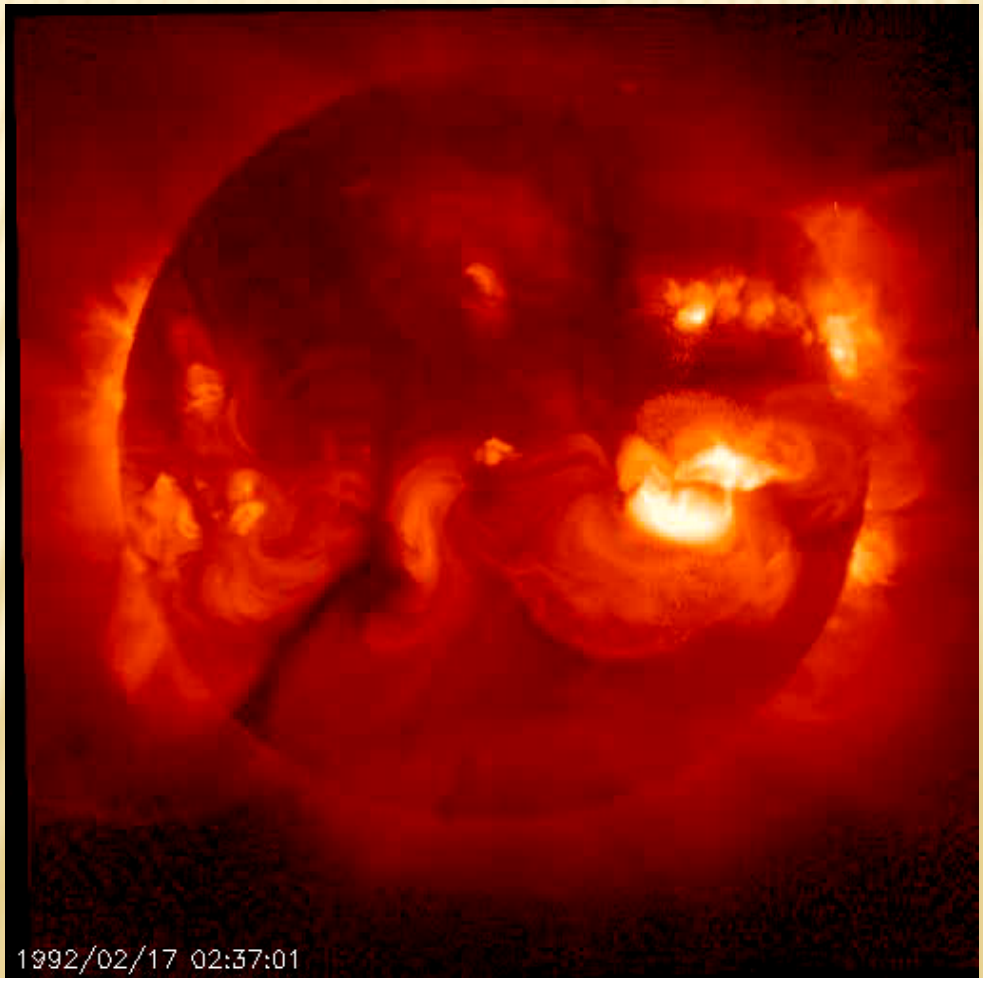
X-ray study of stellar flares
~ Seven Year's Monitoring with MAXI/GSC ~

Yohko Tsuboi　Chuo Univ. on behalf of the MAXI Team



Maehara et al. Nature 2012

LETTER

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Superflares on solar-type stars

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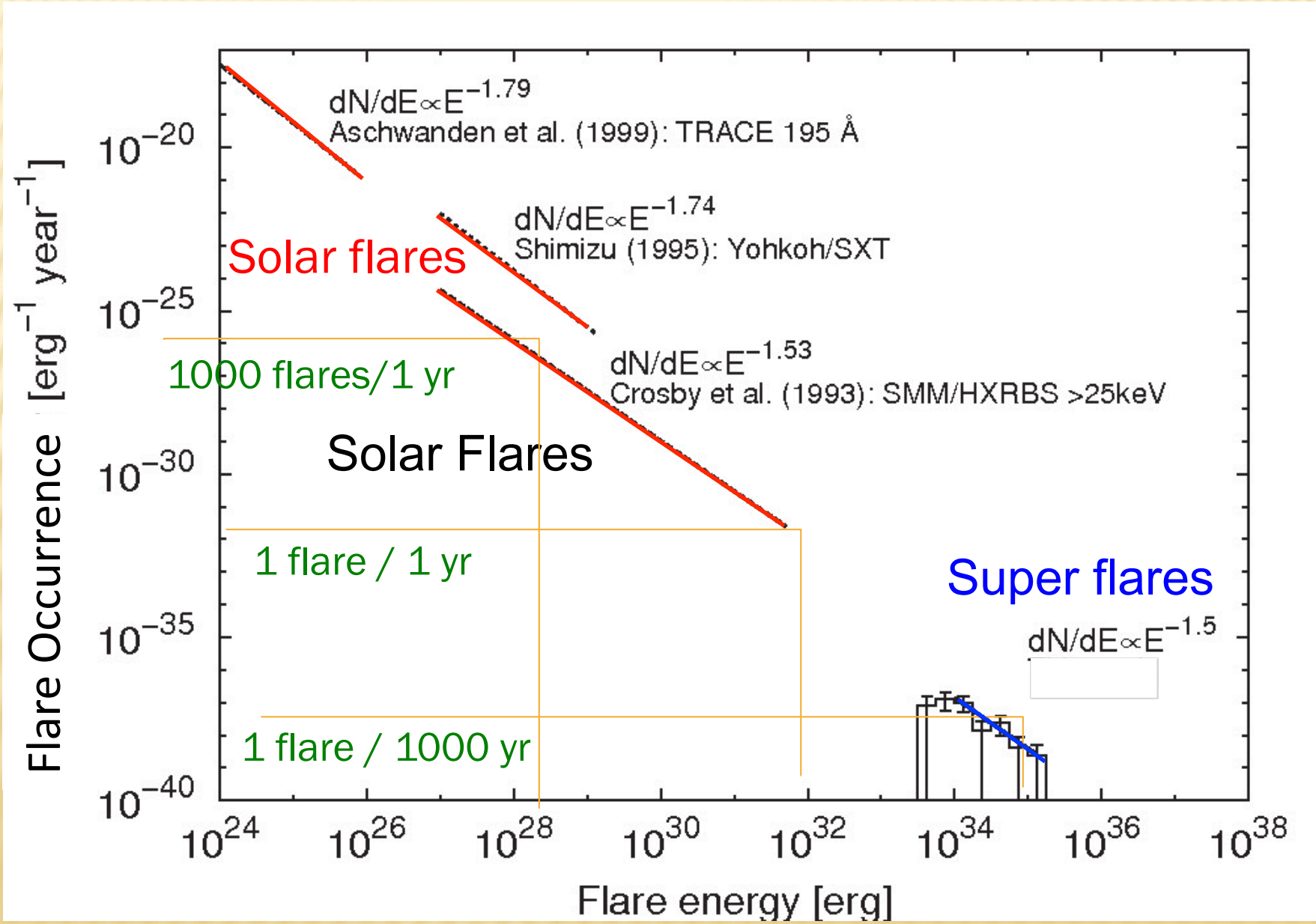
Solar flares are caused by the sudden release of magnetic energy stored near sunspots. They release 10^{29} to 10^{32} ergs of energy on a timescale of hours[1]. Similar flares have been observed on many stars, with larger 'superflares' seen on a variety of stars[2,3], some of which are rapidly rotating[4,5] and some of which are of ordinary solar type[3,6]. The small number of superflares observed on solar-type stars has hitherto precluded a detailed study of them. Here we report observations of 365 superflares, including some from slowly rotating solar-type stars, from about 83,000 stars observed over 120 days. Quasi-periodic brightness modulations observed in the solar-type stars suggest that they have much larger starspots than does the Sun. The maximum energy of the flare is not correlated with the stellar rotation period, but the data suggest that superflares occur more frequently on rapidly rotating stars. It has been proposed that hot Jupiters may be important in the generation of superflares on solar-type stars[7], but none have been discovered around the stars that we have studied, indicating that hot Jupiters associated with superflares are rare.

We searched for stellar flares on solar-type stars (G-type main-sequence stars) using data collected by NASA's Kepler[8] mission during the period from April 2009 to December 2009 (a brief summary of our flare search method is described in the legend of Fig. 1 and more detail is provided in Supplementary Information). We used the effective temperature ($T_{\rm eff}$) and the surface gravity ($\log(g)$) available from the Kepler Input Catalog[9] to select solar-type stars. The selection criteria are as follows: $5{,}100\,{\rm K} \leq T_{\rm eff} < 6{,}000\,{\rm K}$, $\log(g) \geq 4.0$. The total numbers of solar-type stars are 9,751 for quarter 0 of the Kepler mission (the length of observation period is about 10 d), 75,728 for quarter 1 (33 d), 83,094 for quarter 2 (90 d) and 3,691 for quarter 3 (90 d).

We found 365 superflares (flares with energy $>10^{33}$ erg) on 148 solar-type stars (light curves of each flare are summarized in Supplementary Fig. 8 and properties of each flare star are listed in Supplementary Table 1). The durations of the detected superflares are typically a few hours, and their amplitudes are generally of order 0.1–1% of the stellar luminosity. The bolometric luminosity and total bolometric energy of each flare were estimated from the stellar radius,

Flare occurrence of solar flares and super flares on G type stars

Maehara et al. (2012)



How large flares can a star have?

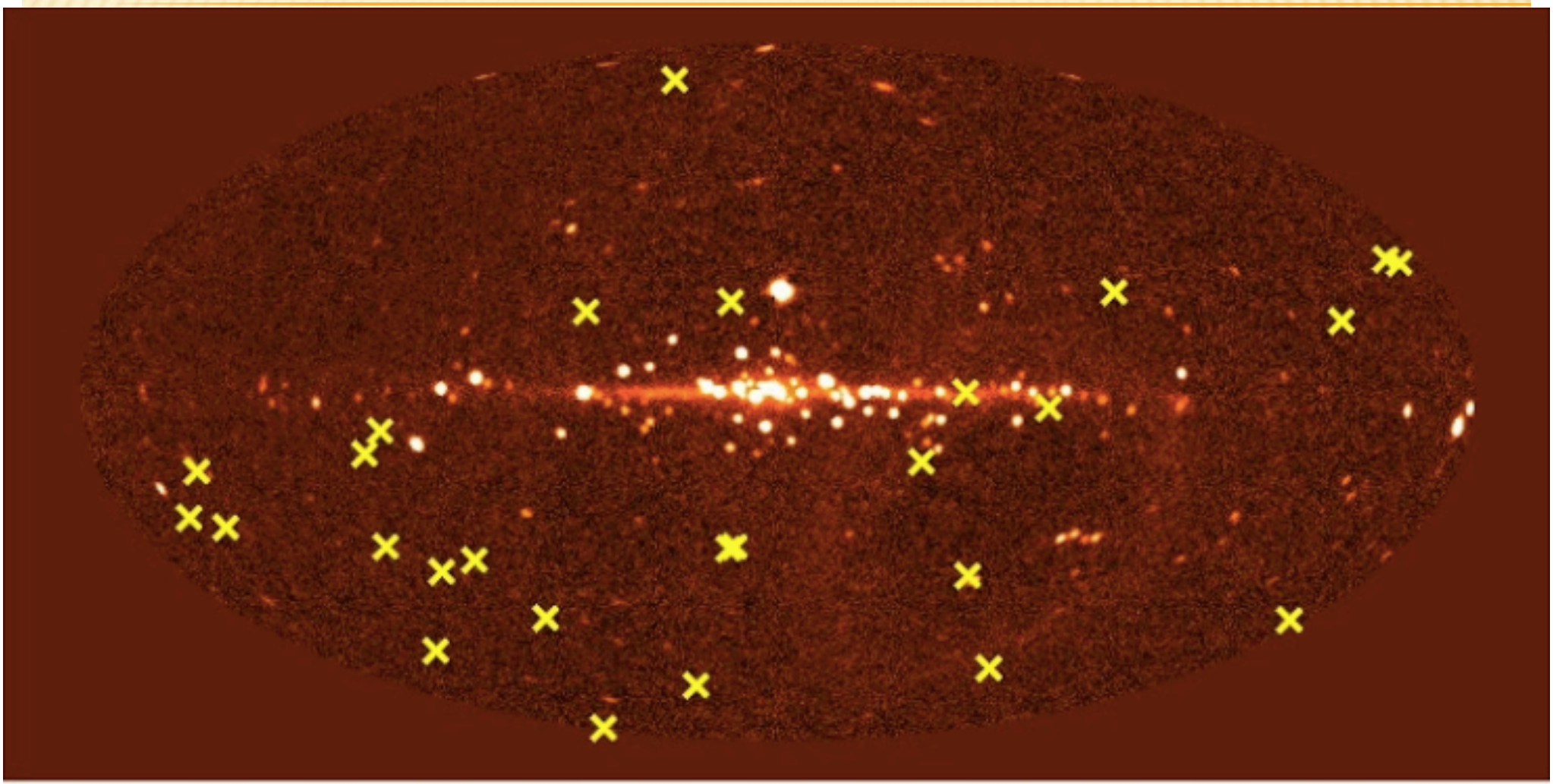
How is a such flare?

→ We don't know even such fundamental question.

→Search of the huge X-ray flares with MAXI

RESULTS

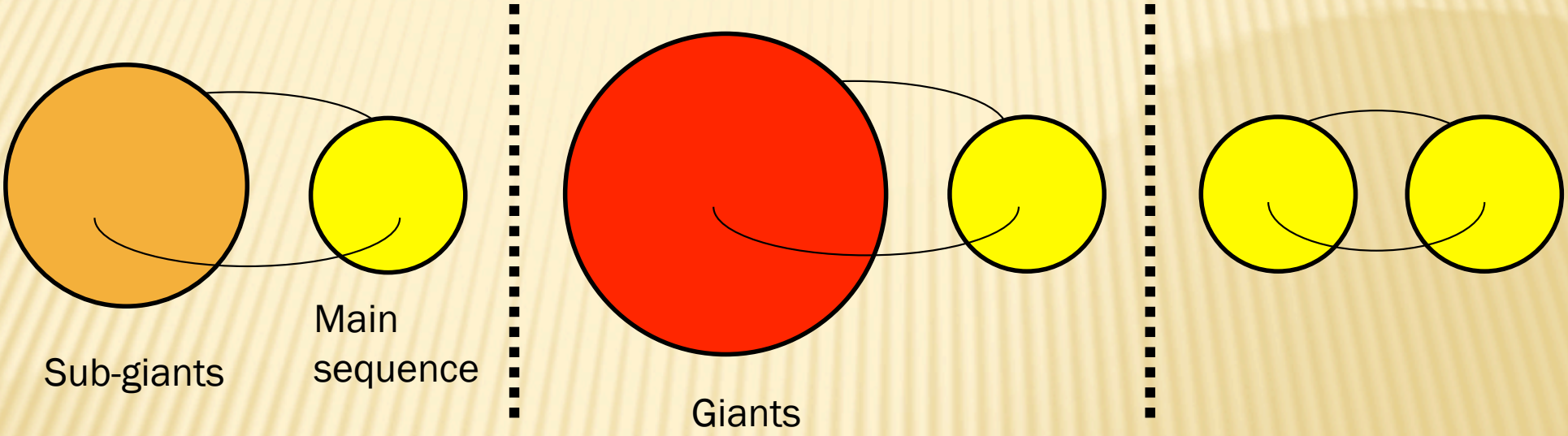
◇Detected Stellar Sources



27 objects were detected in 7 years

◇MAXI star Categories

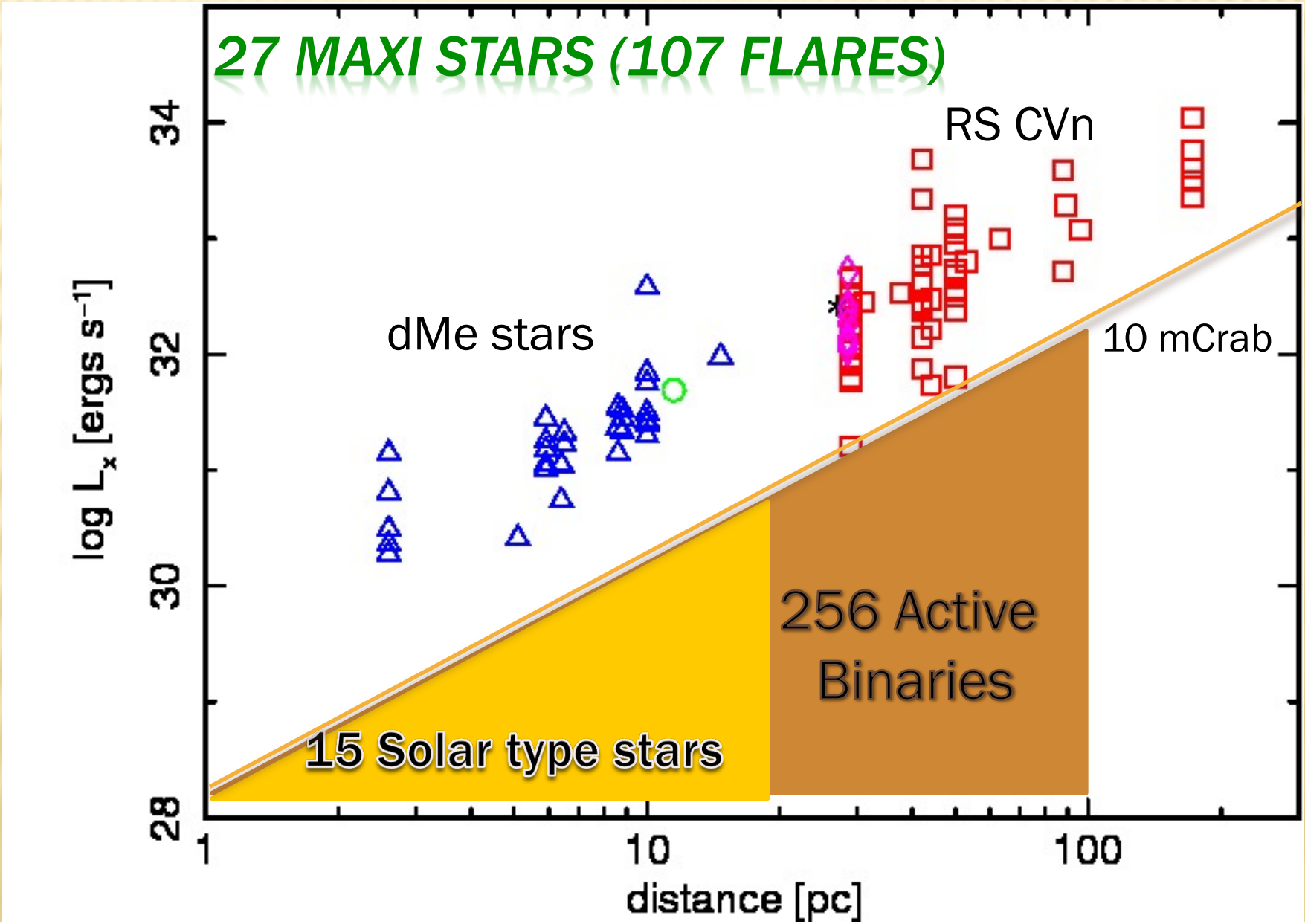
1. Active Binary



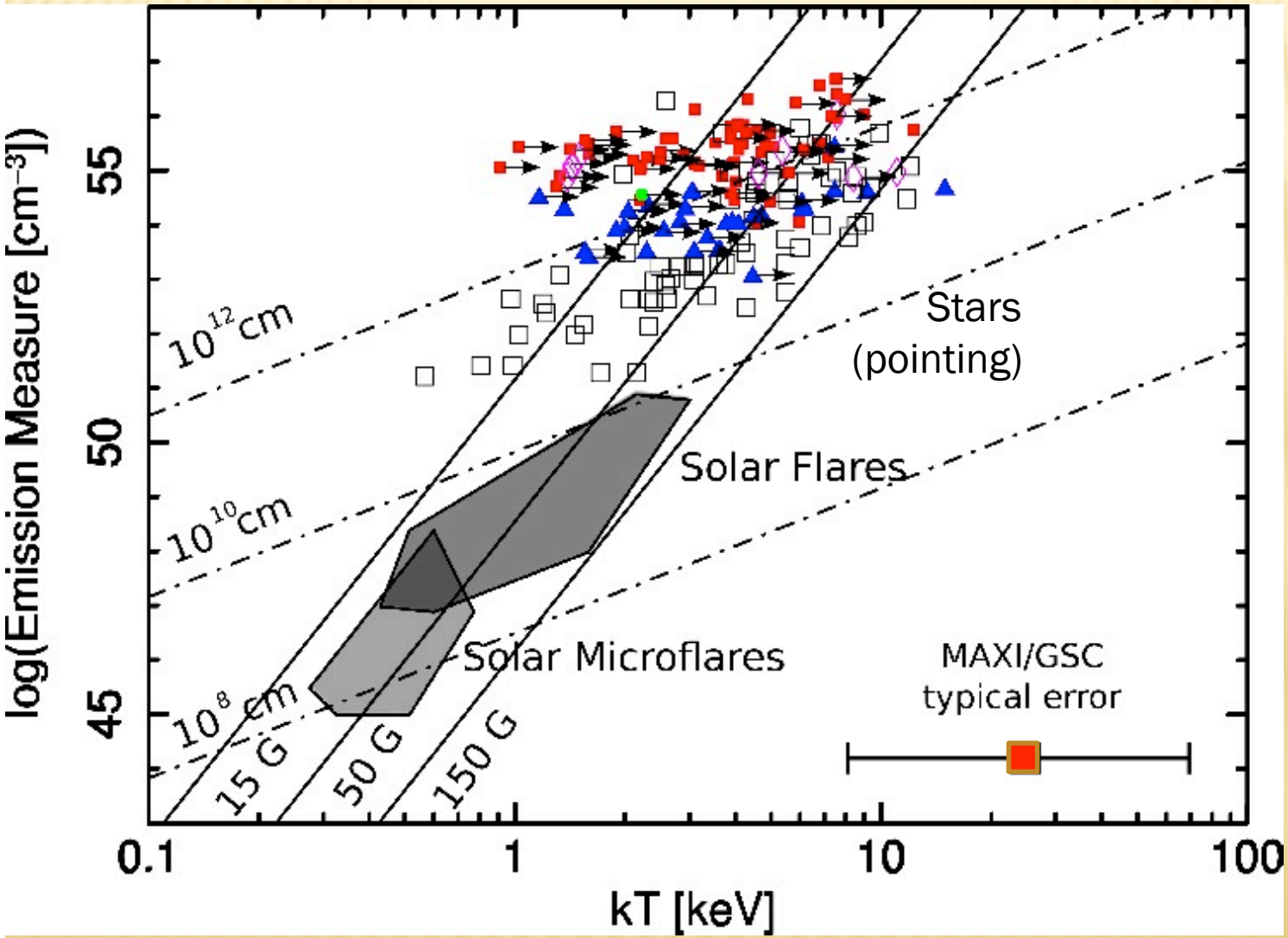
2. Single active stars

- dMe stars, a dKe star
- YSOs

Flare samples obtained in 7years of MAXI
~Lx vs. distance~



◇kT vs Emission Measure



MAXI sources

: RS CVn

: Algol

: YSOs

: dMe

: dKe

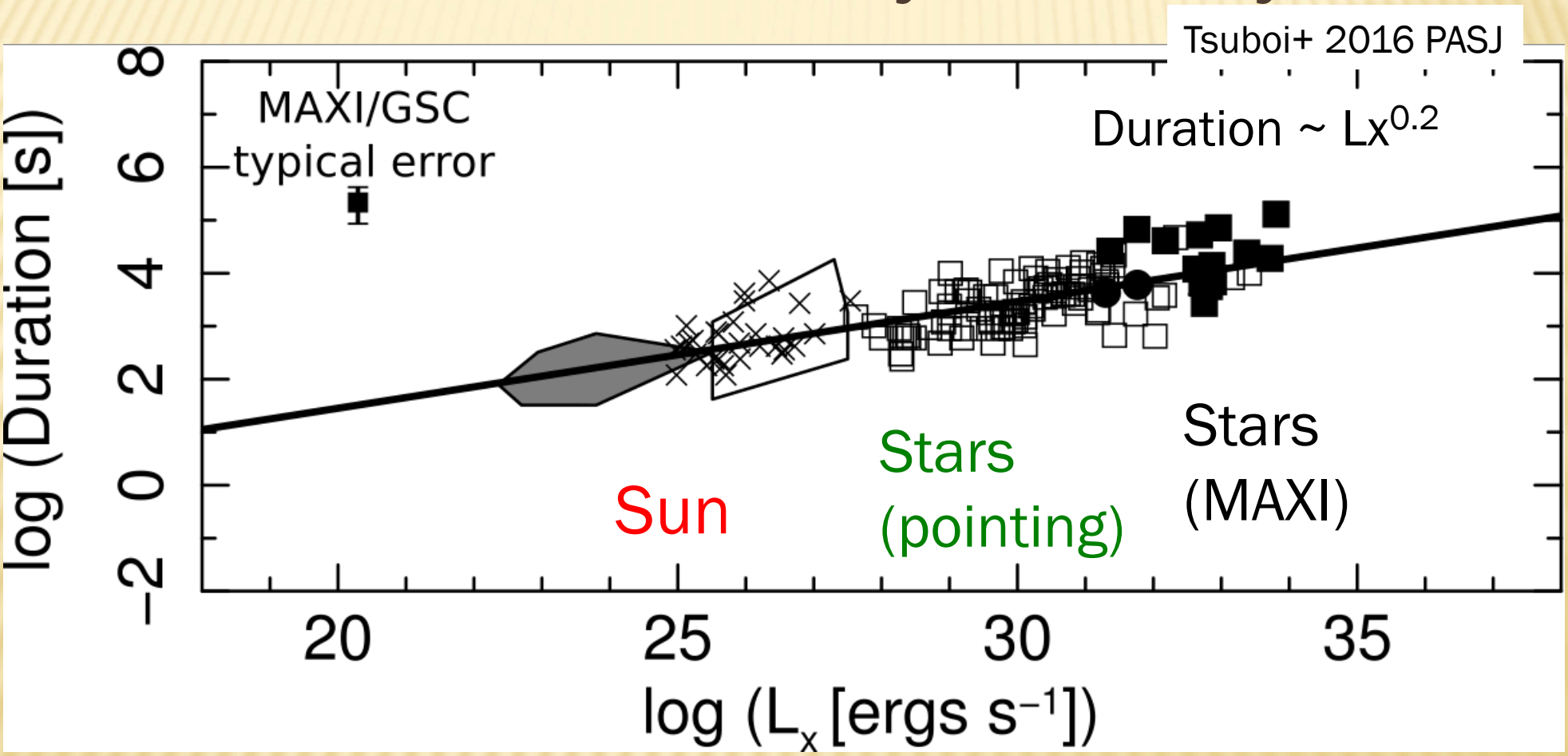
Rstar

dMe : ~0.8 R_{solar}

RS CVn: 6 R_{solar}

Shibata & Yokoyama 1999 , Feldman et al. 1995 , Shimizu 1995

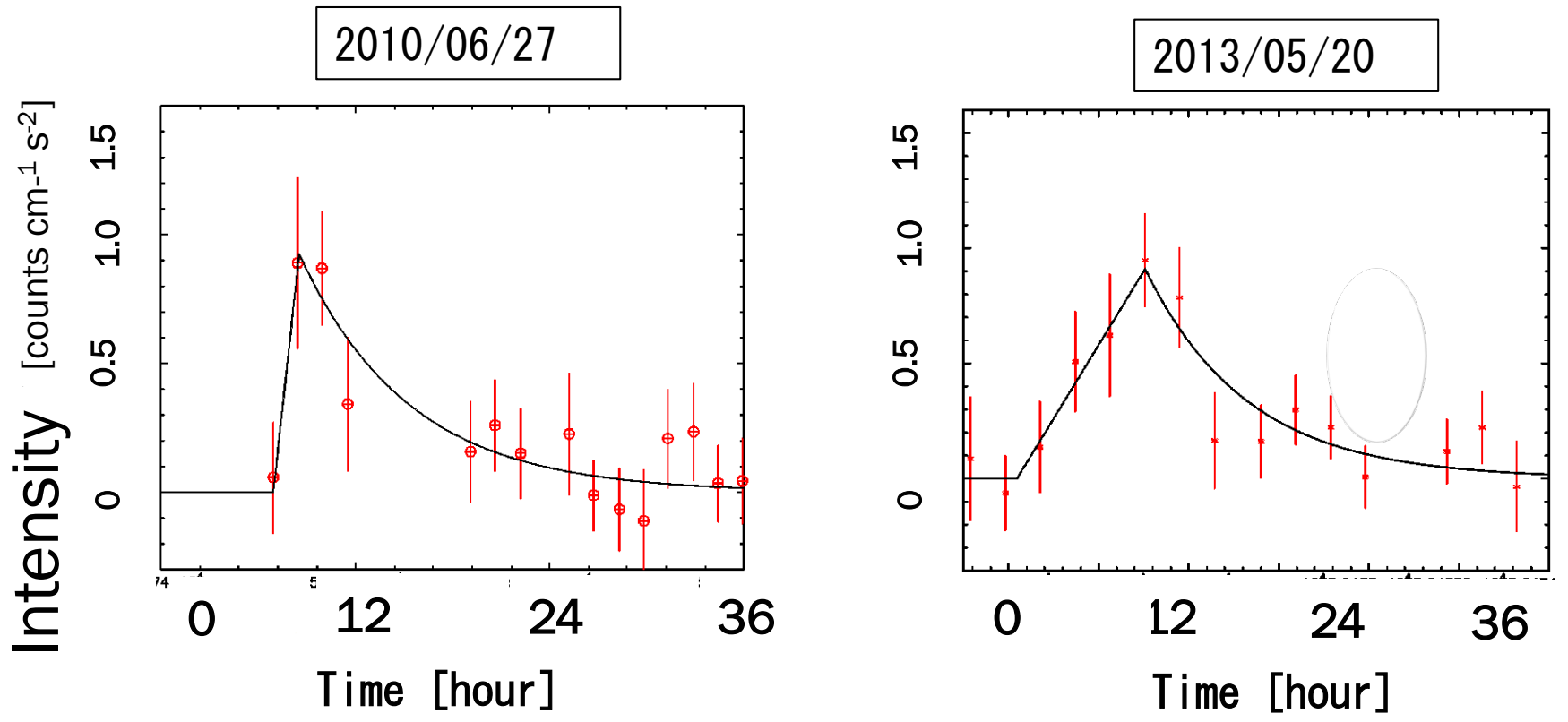
The flare duration vs. the bolometric X-ray luminosity



On the trend from solar flares – stellar flares detected with pointing observation → universal correlation?

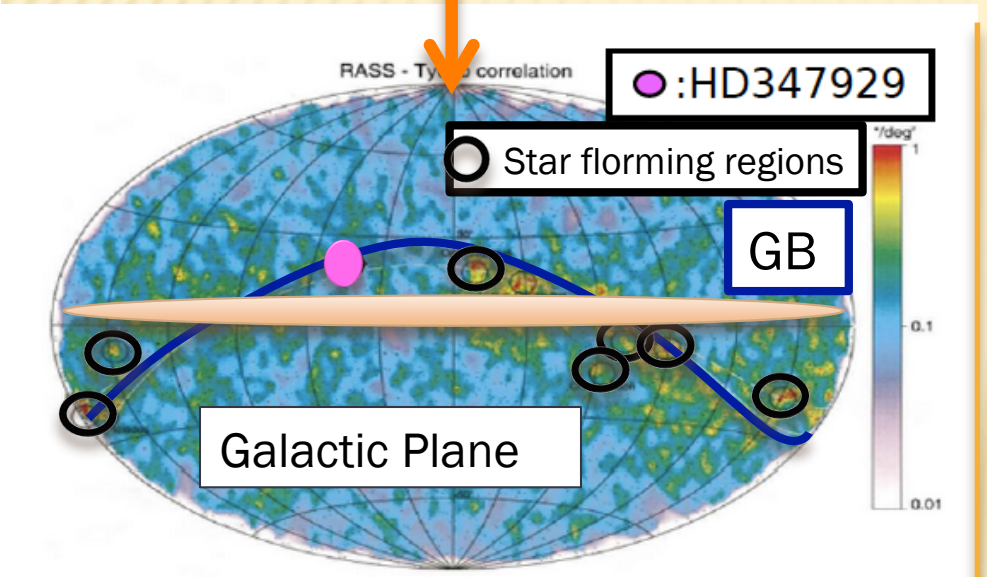
SERENDIPITOUS SOURCE, HD347929

Flares serendipitously detected with MAXI/GSC from HD347929

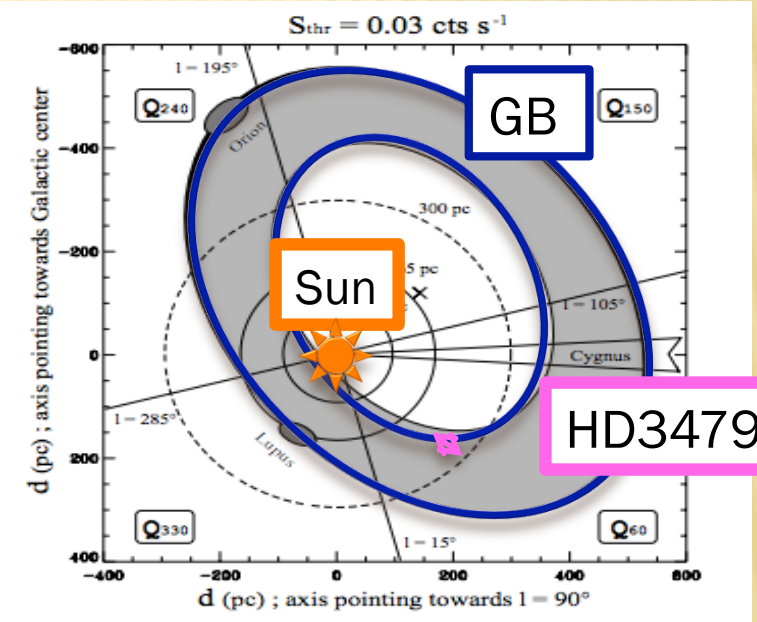


The age of HD347929

Gould Belt(GB): A Torus Clustering Young Stellar Objects, Famous Star Forming Regions with Ages 10^4-10^6 years



RASS with GB



Sketch of GB geometry projected on the Galactic plane

HD327929 is on GB ⇒ YSO

X-ray luminosity in flare states of HD347929

D = 251 (237–267) [pc] (from GAIA)

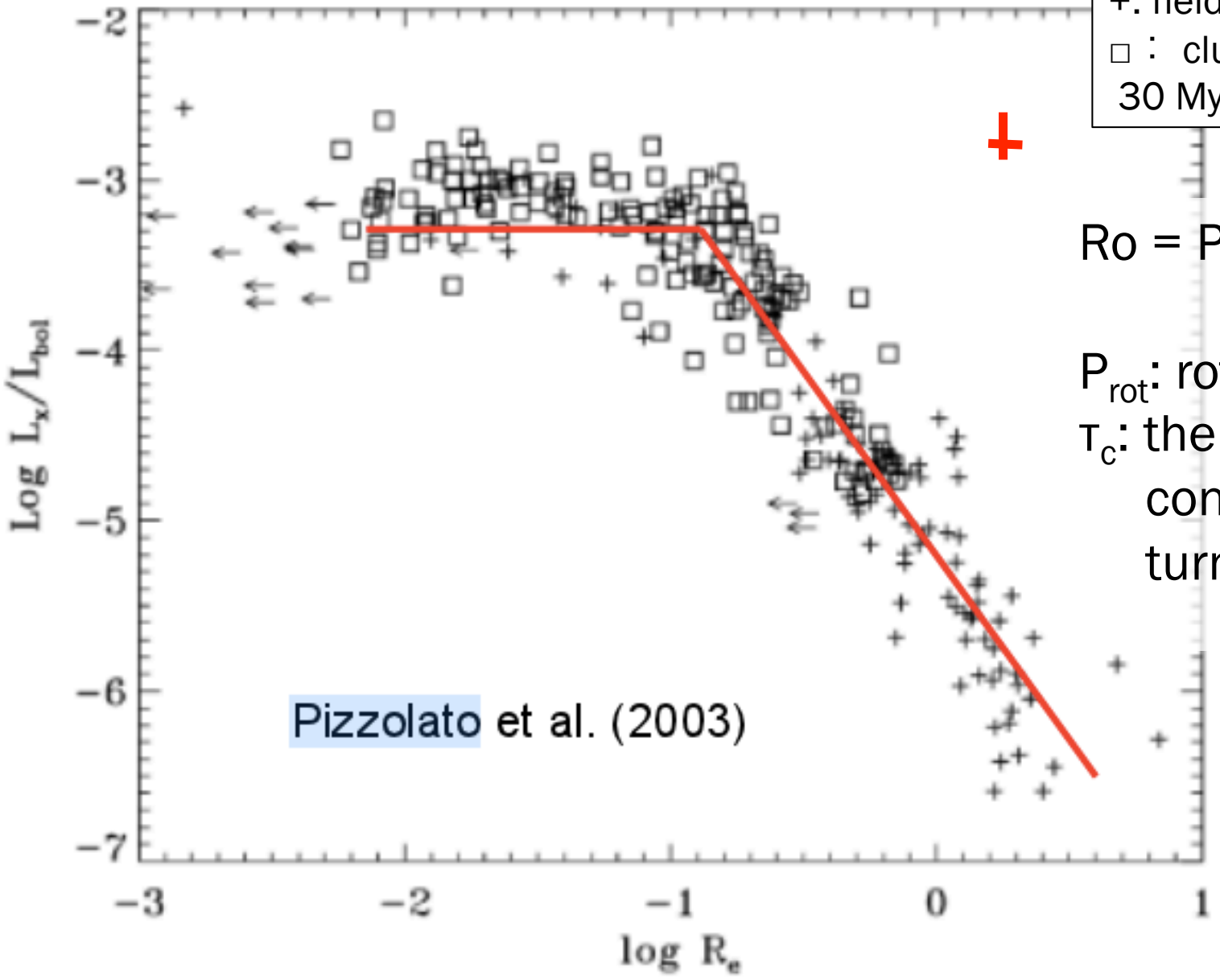
$L_X = 8\ (7–9) \times 10^{33}$ [erg s^{-1}]

One of the highest ever recorded from stars

The highest ever recorded from single stars!!!

cf) GT Mus (active binary): 1×10^{34} [erg s^{-1}] / TWA-7(single) : 3×10^{32} [erg s^{-1}]

L_x/L_{bol} vs. Rossby number



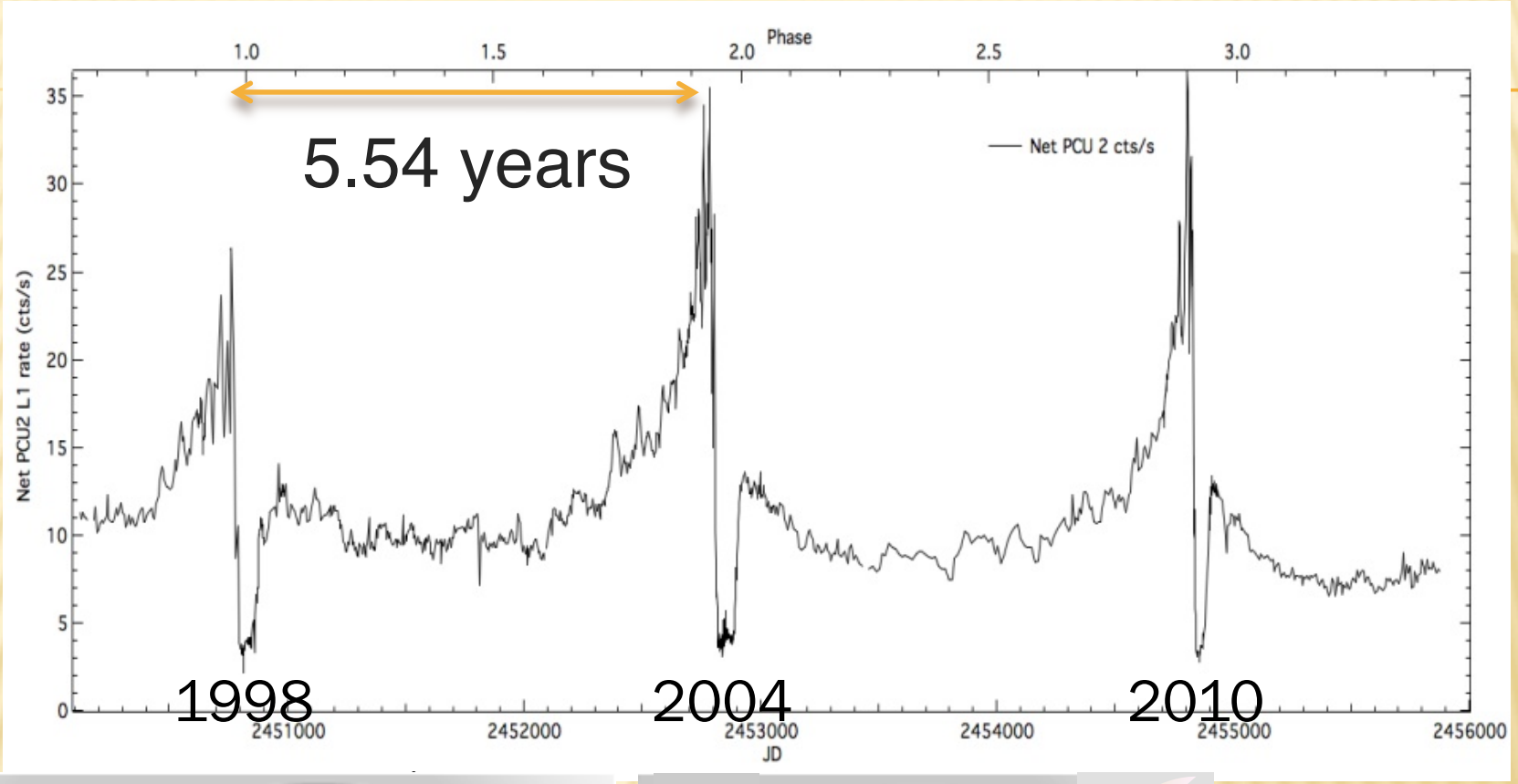
Ro = P_{rot}/τ_c

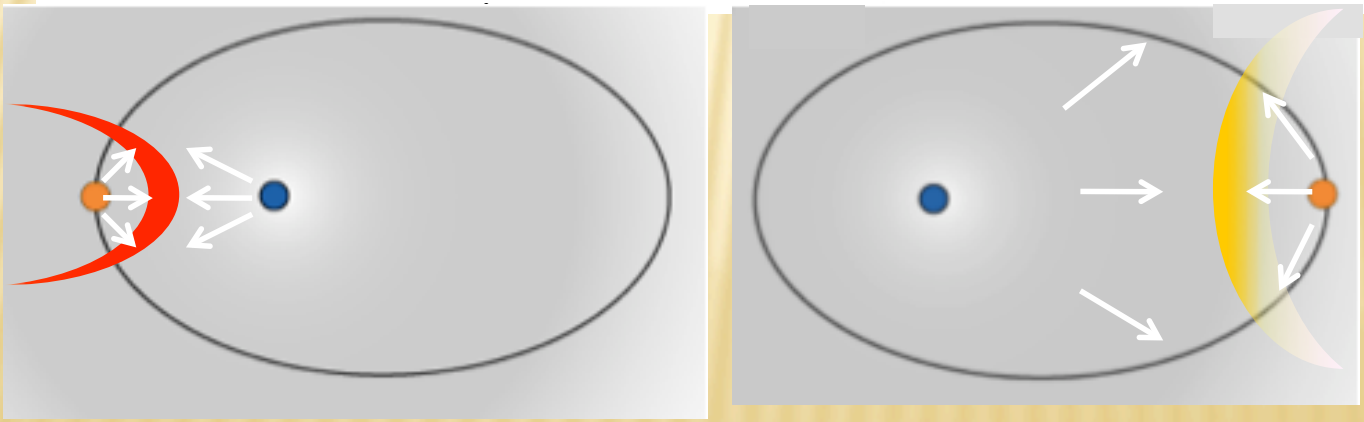
P_{rot}: rotation period

τ_c: the local convective turnover time

ETA CARINAE

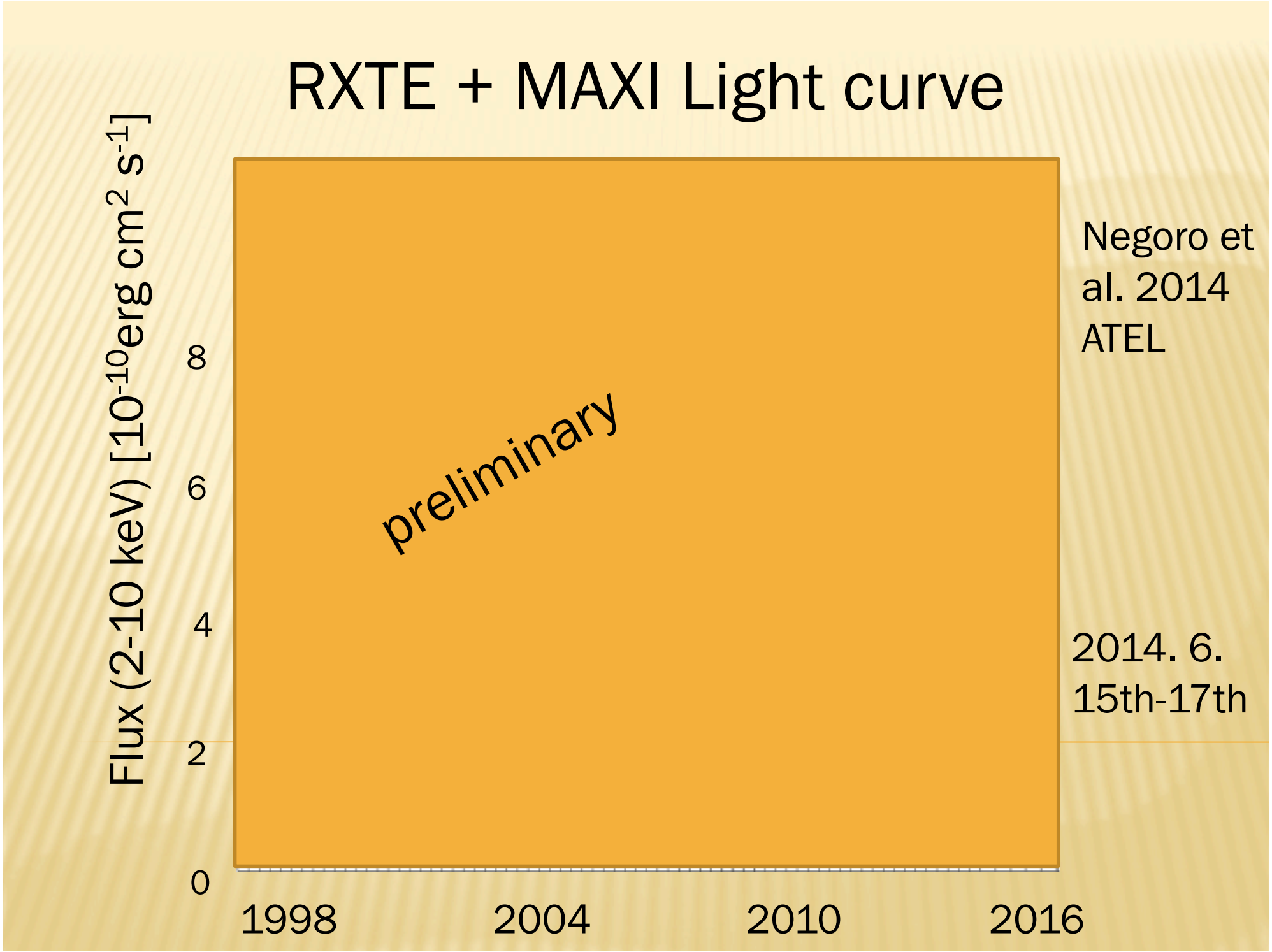
X-ray light curve of η Car (LBV+WR)





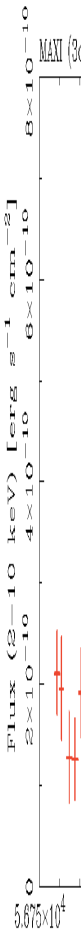
Hamaguchi+ 14

RXTE + MAXI Light curve



Negoro et al. 2014 ATEL

2014. 6. 15th-17th



◇Summary

- 107 flares from 27 low-mass stars.
- dMe stars within 10 pc are all detected.
- No flare is detected from G type main sequence stars within 20 pc so far.
- A universal trend is seen in the flare duration vs. the bolometric X-ray luminosity
- Serendipitous huge flare source
- The highest X-ray flare ever recorded from Eta Carinae