

A Correlation on Stellar Flares  
detected with MAXI  
-Quiescent Luminosity vs. Flare Energy-

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Y. Sugawara, M. Matsuoka and MAXI team

# Index

## Back ground

- What is stellar/solar flares?
- About MAXI (Monitor of All-sky X-ray Image).
- Quiescent X-ray emissions and  
flare occurrence rate distribution.

## Result

- A relation of  $E_{\text{tot,max}}$  and  $L_{\text{x,q}}$

## Discussion

- Prediction of the flare occurrence rate from  $L_{\text{x,q}}$  .

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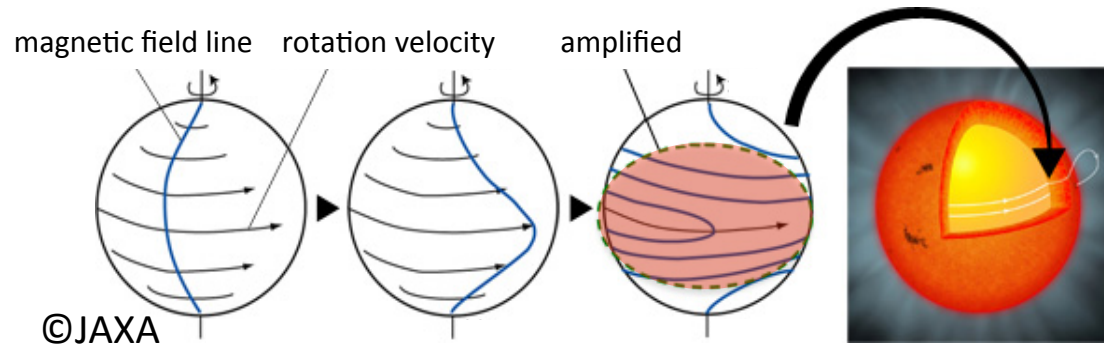
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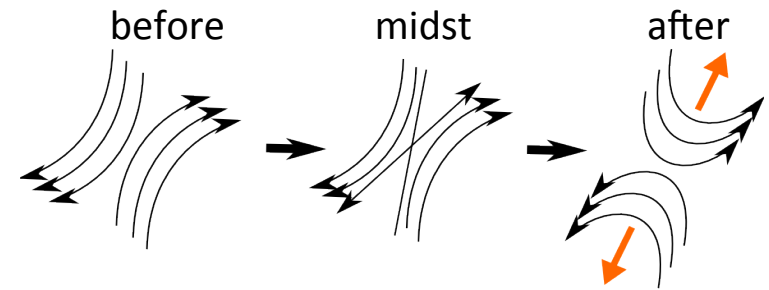
# This is the Solar Flare



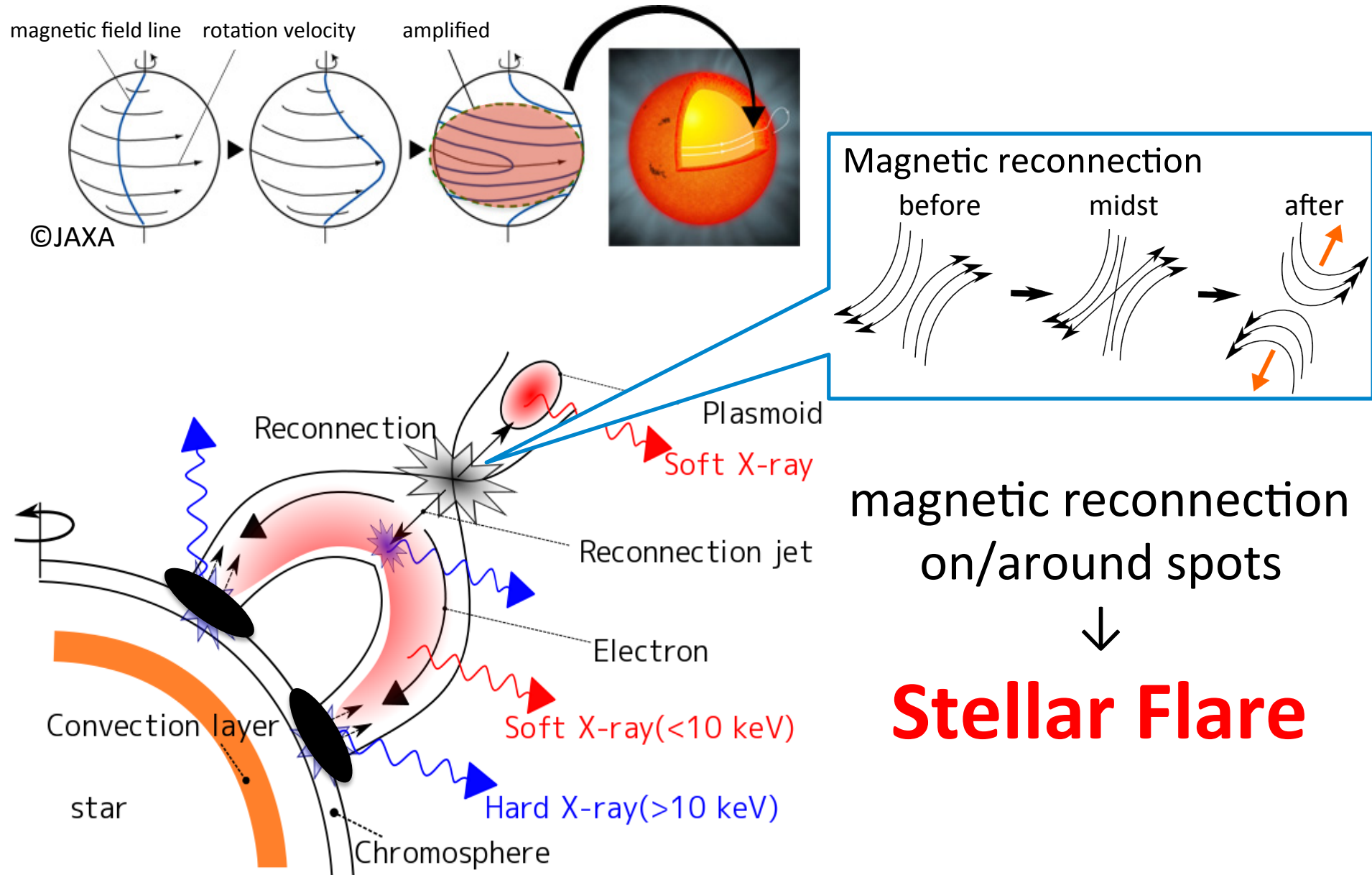
# Stellar X-ray emissions -Flare state-



Magnetic reconnection



# Stellar X-ray emissions -Flare state-



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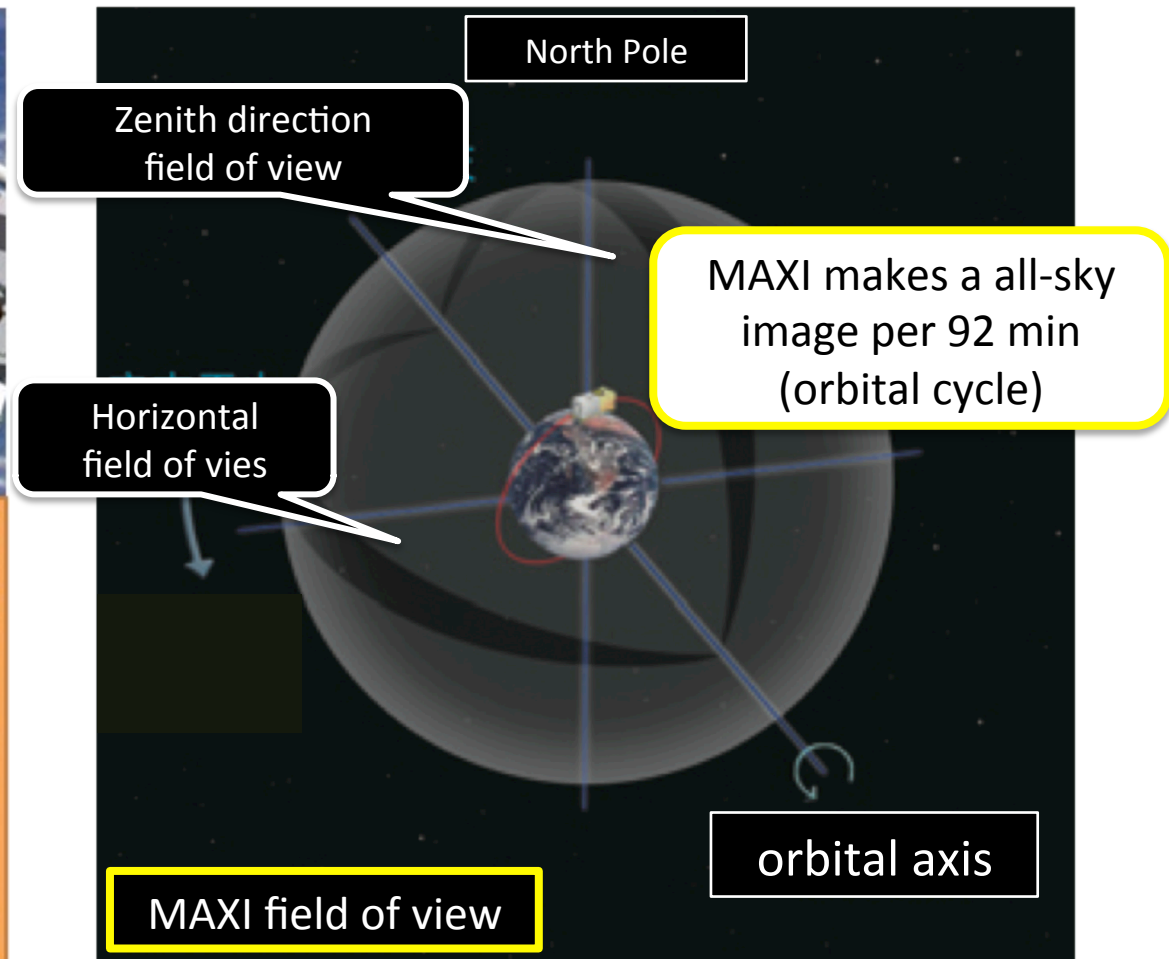
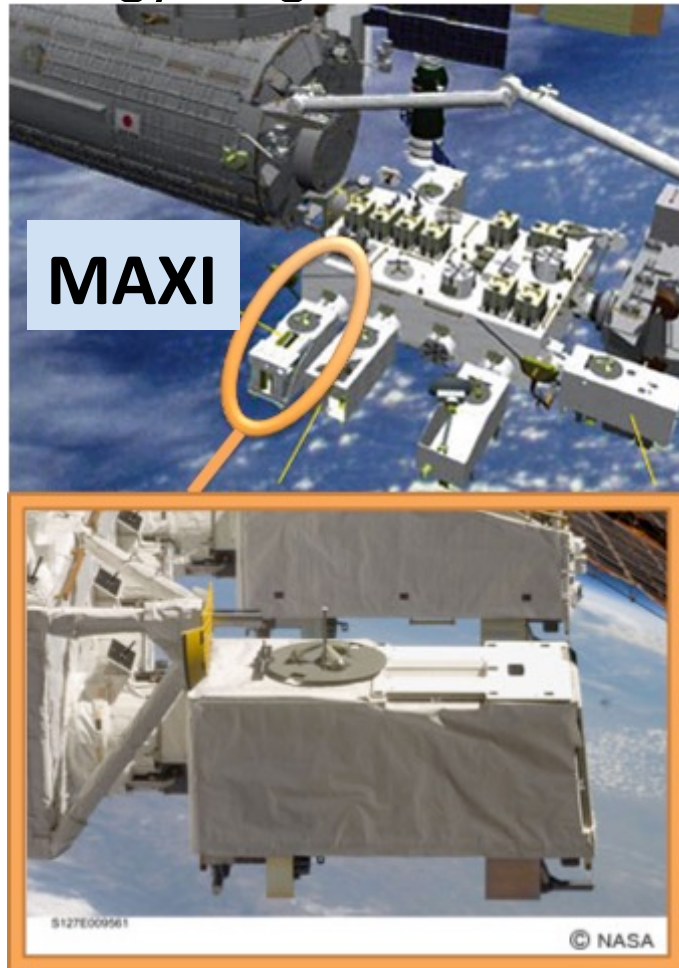
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# MAXI (Monitor of All-sky X-ray Image)

Energy range: 0.5 – 30 keV



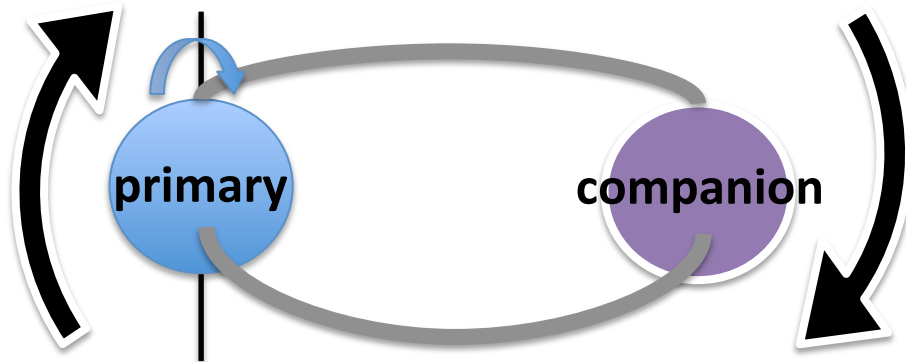
**MAXI have detected many stellar flares.**



# Kind of Flare stars

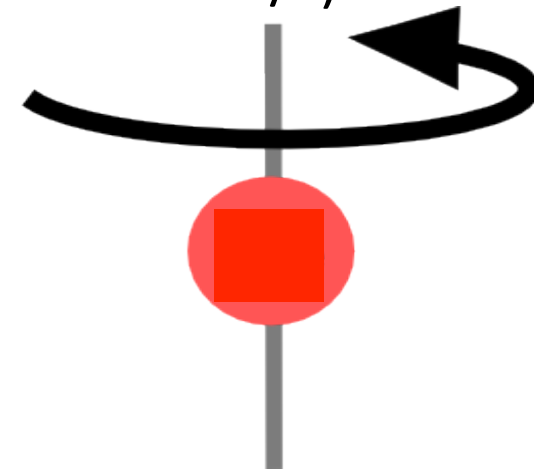
## RS CVn and Algol type

- Close binary
- rotation period = orbital period
- Have active dynamos



## dMe and dKe type stars

- d: dwarf
- M, K : spectral type
- e: H $\alpha$  emission line
- fast rotation velocity  
( $v \sin I > 10 \text{ km/s}$ )



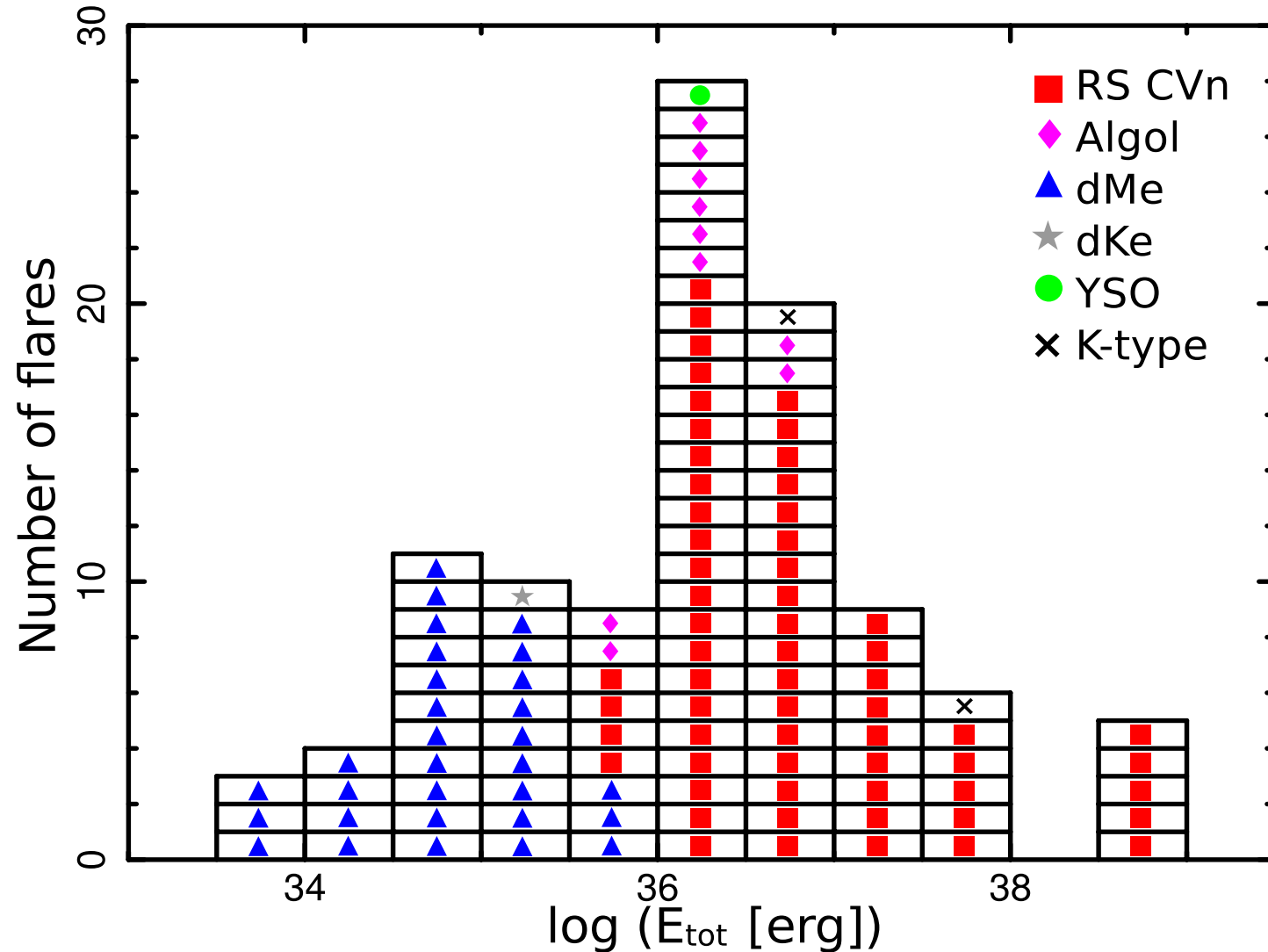
## Young Stellar Objects

- Early stage of evolution
- Have a accretion disk



# Energy Histogram of MAXI detections

**106 stellar flare** from **27 stars** have been detected with MAXI.  
(2009 August - 2016 November)



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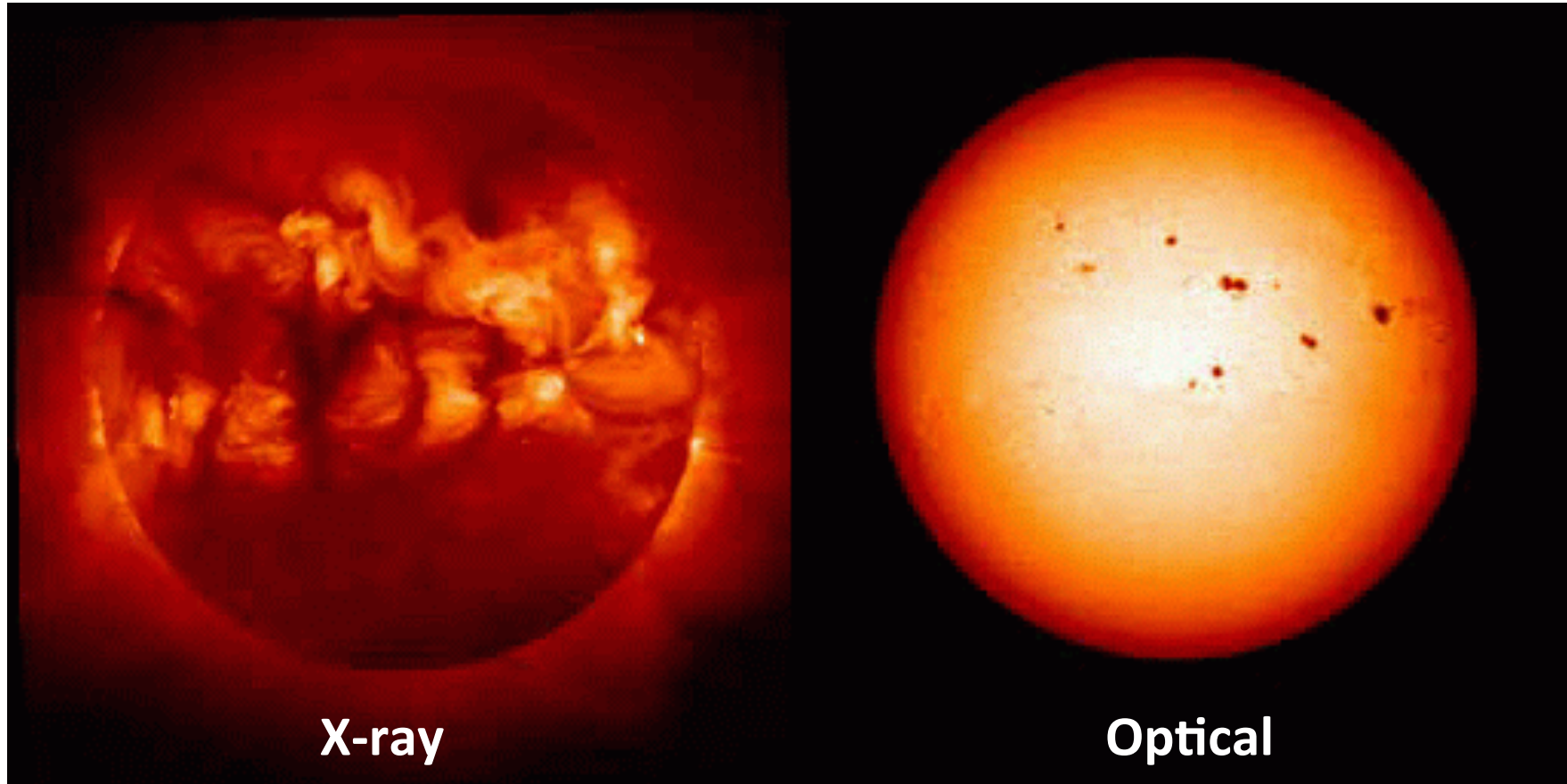
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# Stellar X-ray emissions -Quiescent state-

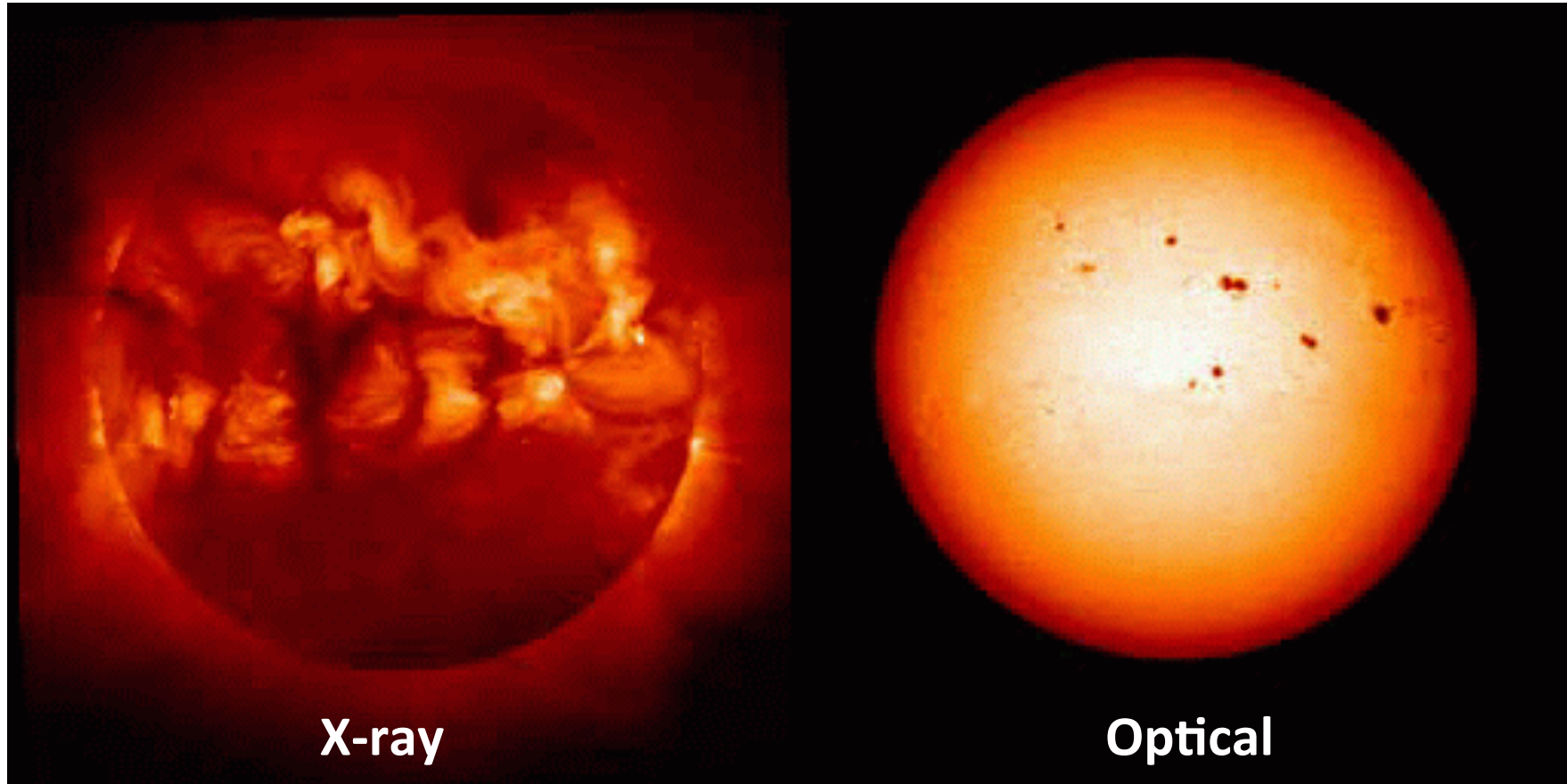
©NAOJ



Quiescent X-ray emissions mainly come from spots.

# Stellar X-ray emissions -Quiescent state-

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Quiescent X-ray emissions mainly come from spots.

**Flare ↔ spots ↔ Quiescent**

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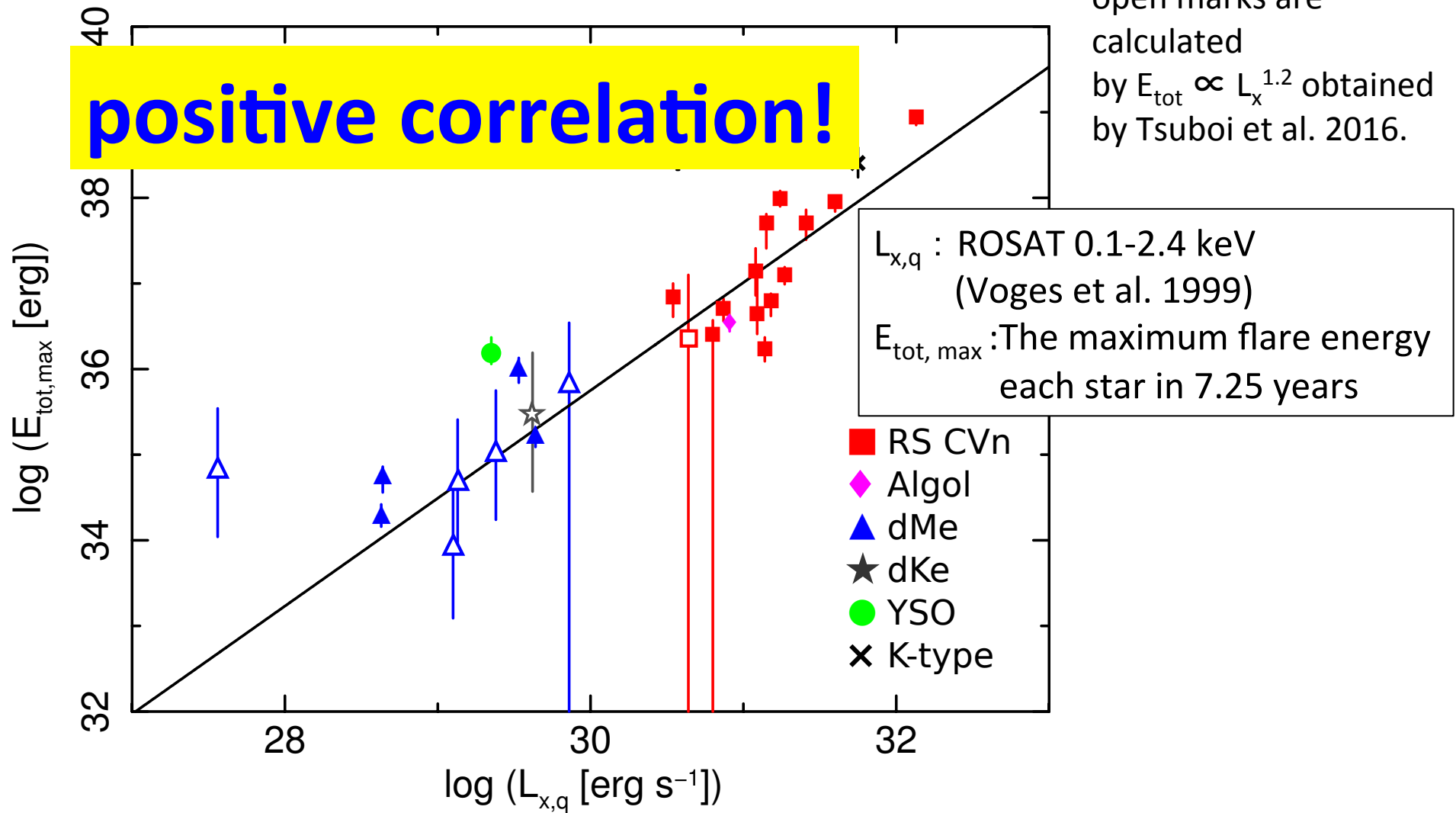
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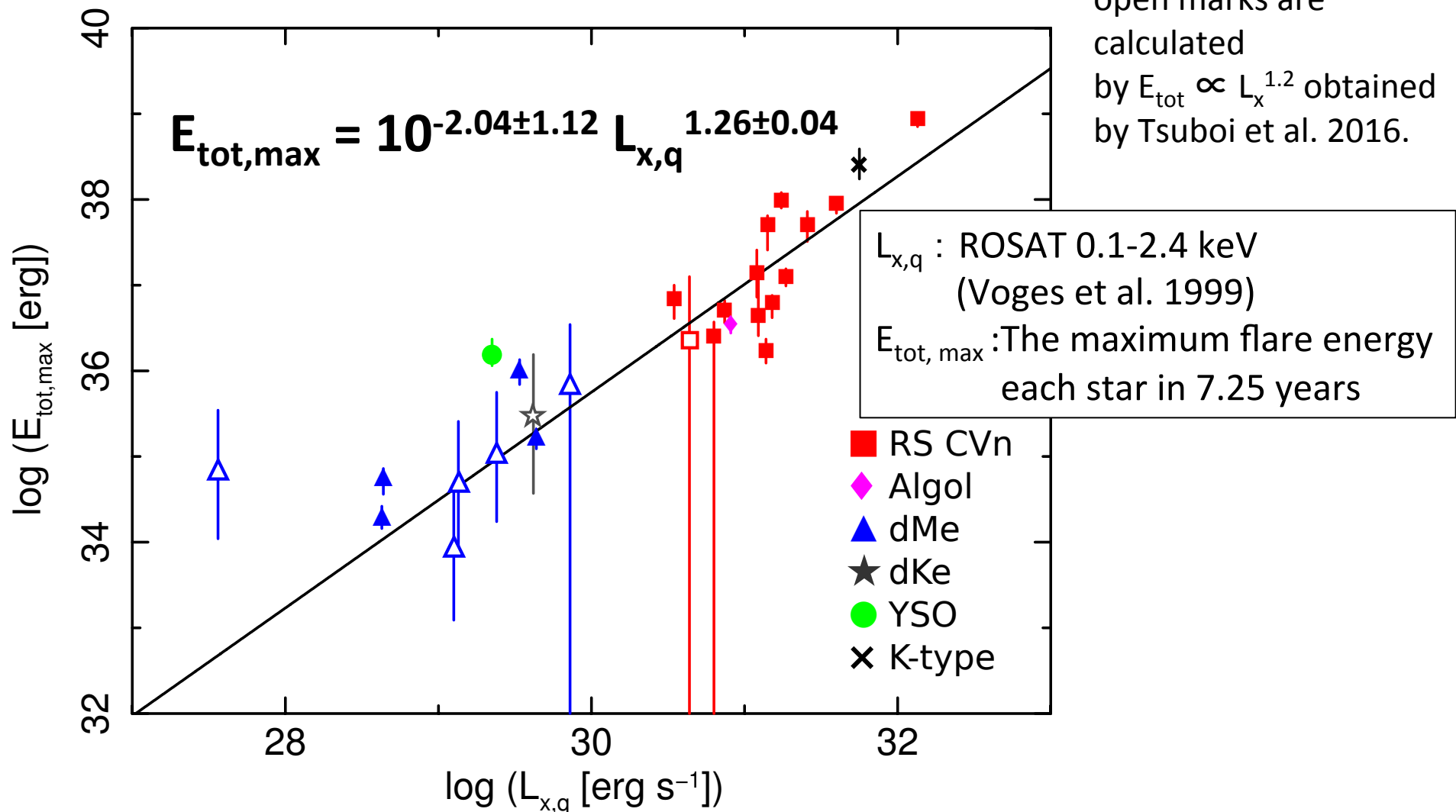
# Result of fitting by power-law

<sup>†</sup>The energy of the open marks are calculated by  $E_{\text{tot}} \propto L_x^{1.2}$  obtained by Tsuboi et al. 2016.



# Result of fitting by power-law

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- $E_{\text{tot,max}}$  in 7.25 years can be predicted from  $L_{x,q}$ .
- $E_{\text{tot,max}} \propto L_{x,q}^{1.26}$  holds regardless of the age and the temperature.



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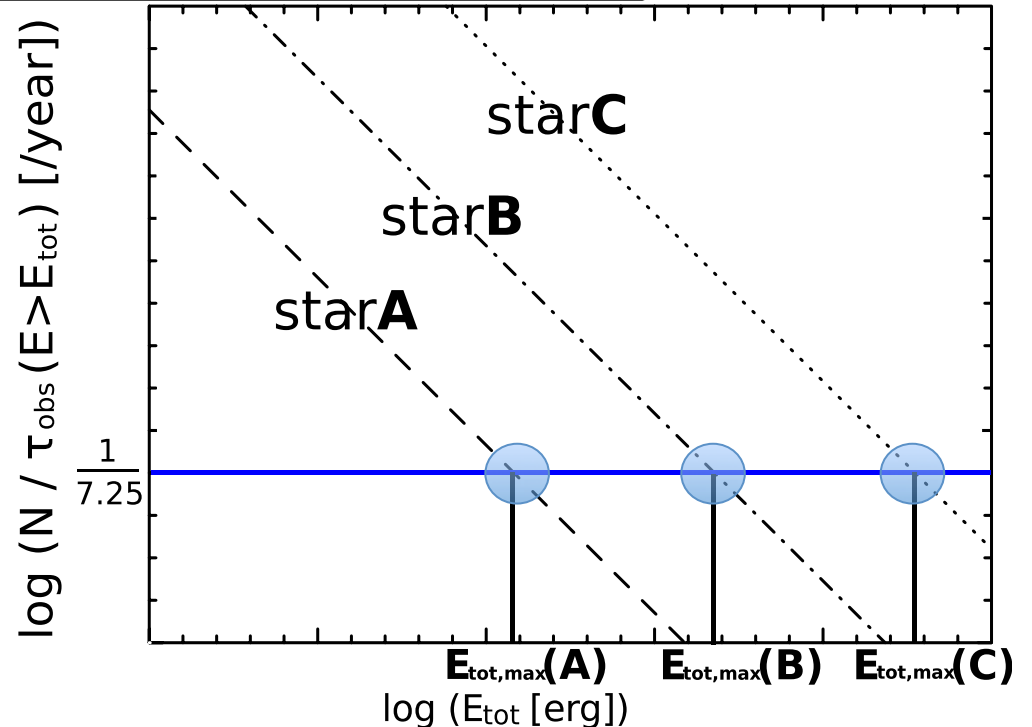
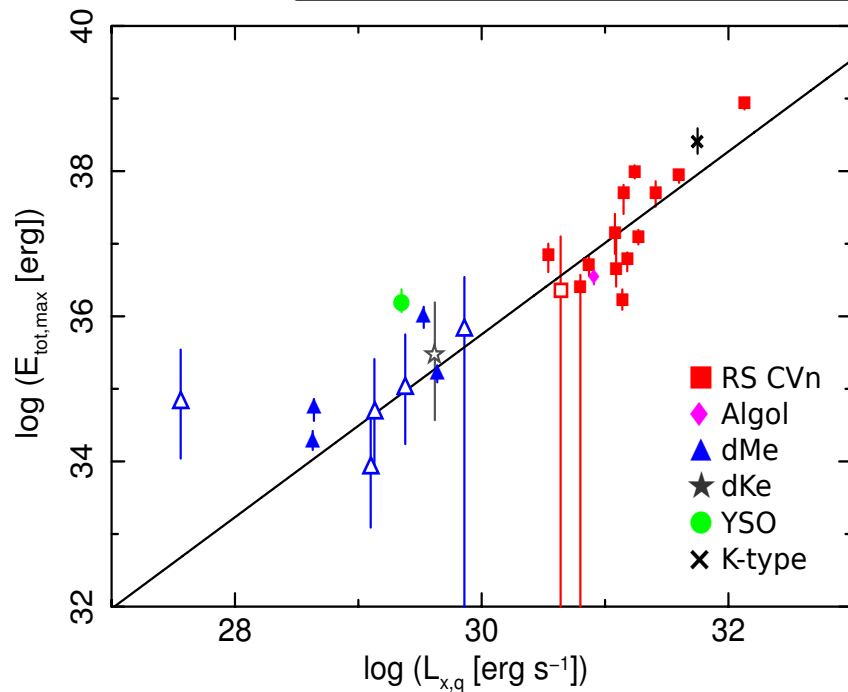
# Prediction of Flare Occurrence Rate

$$\left\{ \begin{array}{l} \frac{1}{7.25 \text{ years}} (E \geq E_{tot, \max}) = A \cdot E_{tot, \max}^{-1.0} \\ E_{tot, \max} = 10^{-2.04} L_{x,q}^{1.26} \end{array} \right.$$

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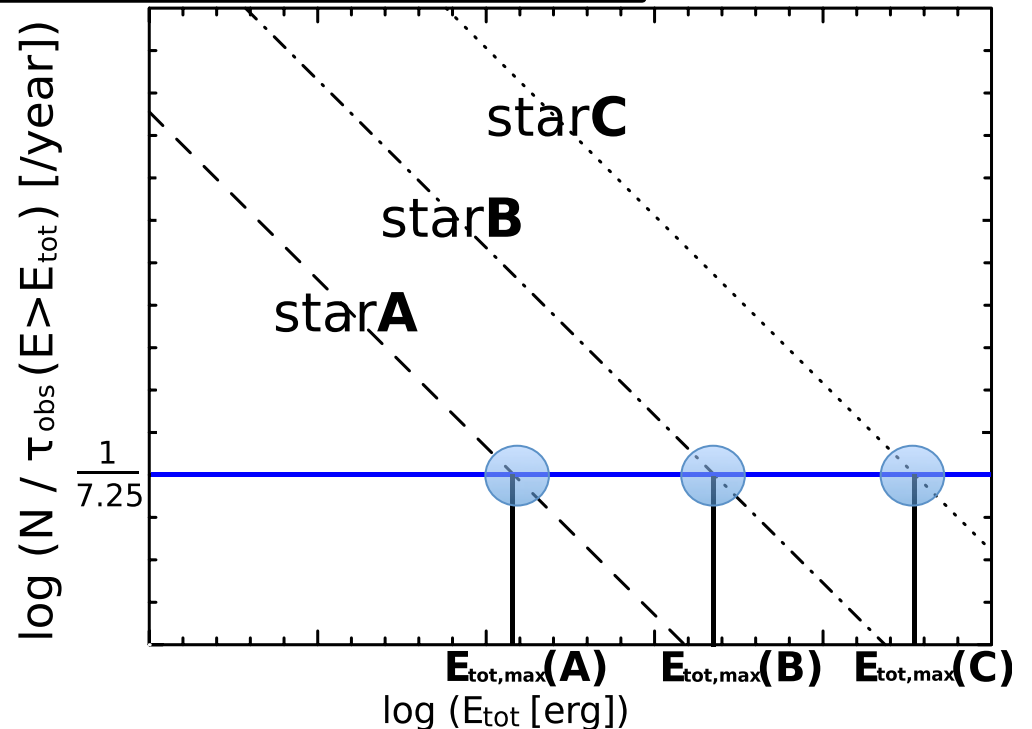
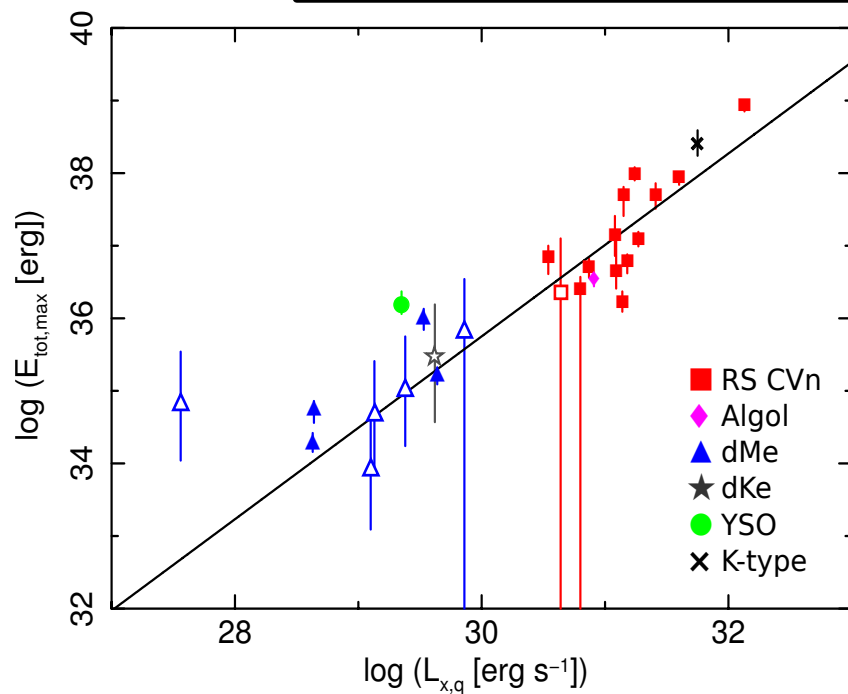
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$$A = 7.58 \times 10^{34} \times \left( \frac{L_{x,q}}{10^{30} \text{ erg s}^{-1}} \right)^{1.26}$$



# We are able to predict the flare occurrence rate distribution from the $L_{x,q}$

$$A = 7.58 \times 10^{34} \times \left( \frac{L_{x,q}}{10^{30} \text{ erg s}^{-1}} \right)^{1.26}$$



# Summary

- MAXI have detected 106 flares from 27 stars in 7.25 years.
- $L_{x,q}$  and  $E_{\text{tot,max}}$  had a positive correlation ( $E_{\text{tot,max}} \propto L_{x,q}^{1.236}$ ).
- We can predict the flare occurrence rate distribution by  $L_{x,q}$ .

# Prospect

- Understand the activity cycle for individual stars.
- Correct more samples to expand the correlation.