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# Superflares in G, K and M Type Dwarfs



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## Introduction

Light curve data from stars, captured by the Kepler satellite, provide insights into stellar flares. Superflares of energies above  $5 \times 10^{34}$  erg are observed. We perform a statistical analysis and search for environments under which flares occur more frequently and with higher energies. Magnetic activity is confirmed to be key for flare generation.

## Superflare Sample

Kepler observations of light curves from G, K and M type dwarfs in quarters 0 to 6 are used.

**Total amount of stars:** 117661

**Superflaring stars:** 380

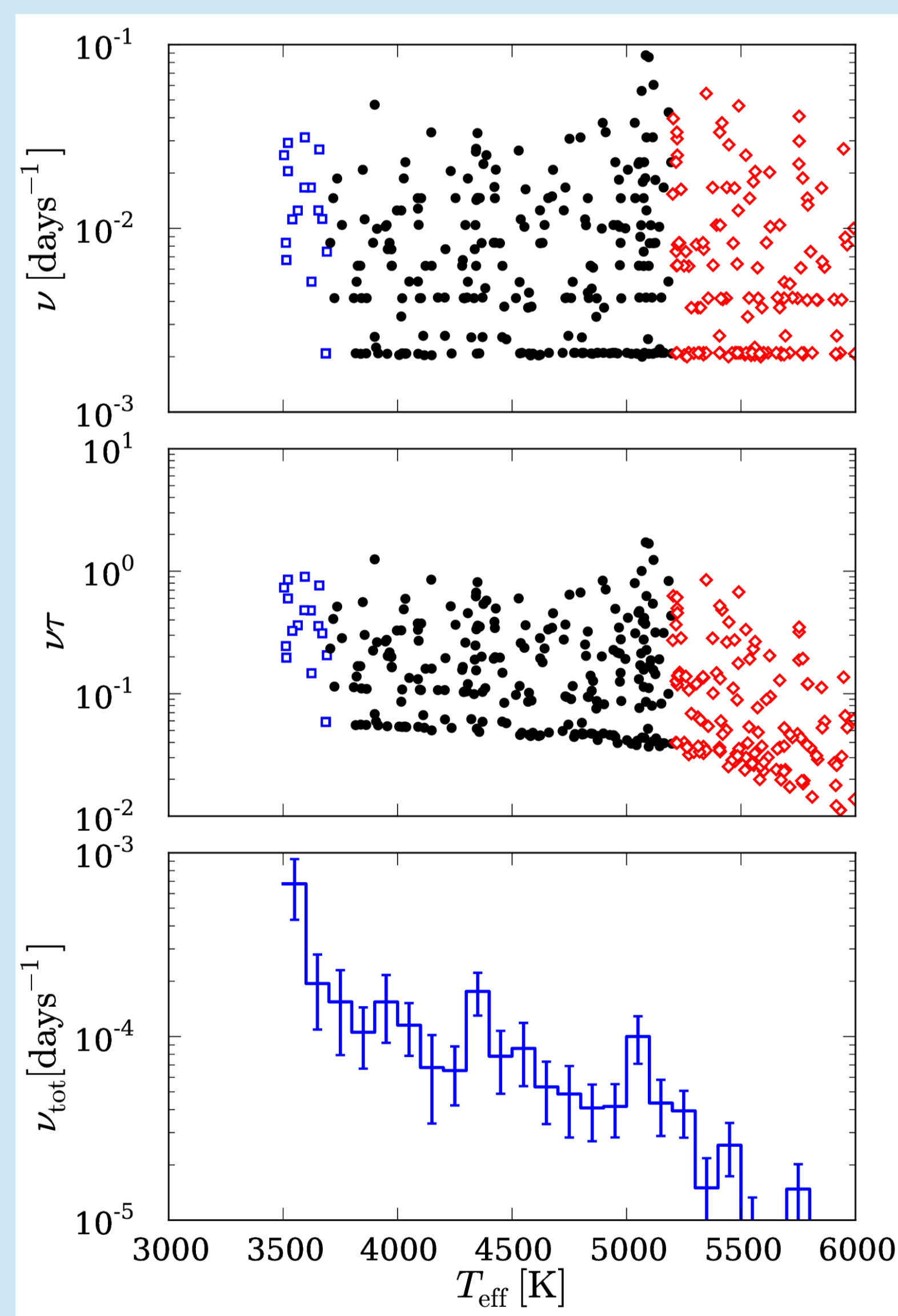
**Superflare events:** 1690

## Analysis

- Rate of superflare occurrence for individual stars:  $\nu = n_{\text{flares}}/t_{\text{observation}}$
- Normalized rate:  $\nu\tau$   
 $\tau$ : convective turnover time
- Inverse Rossby number:  $Ro^{-1} = \tau/P_{\text{rot}}$   
→ non-dimensionalized rotation rate

To find any correlation between physical parameters of the stars and the superflare rate, we need to consider averages in intervals of e.g. the effective temperature  $T_{\text{eff}}$  or the inverse Rossby number. The averaged superflare occurrence rate in such intervals we denote as  $\nu_{\text{tot}}$ .

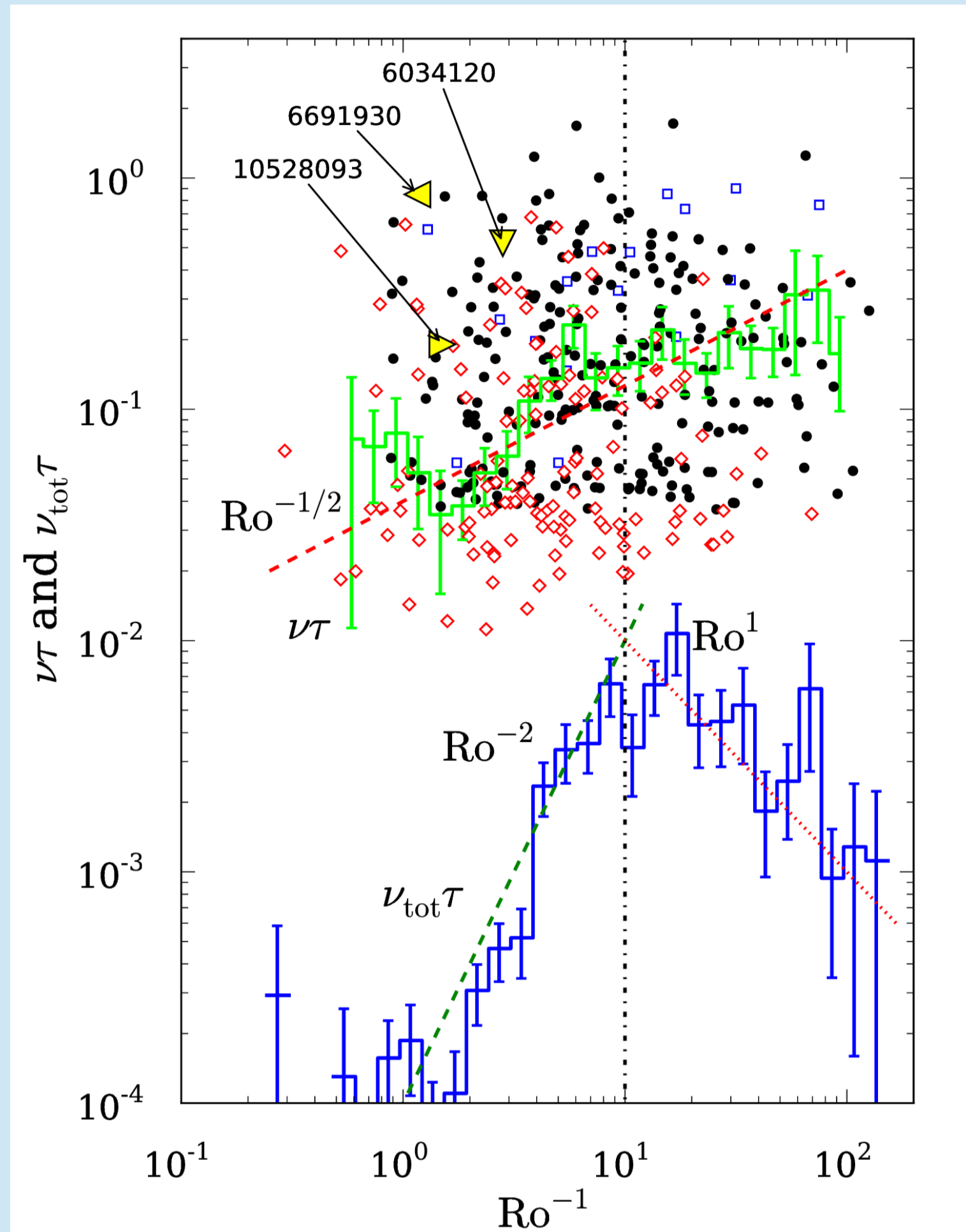
## Temperature



**upper panel:** superflare rates for each star  
**central panel:** normalized superflare rate  
**lower panel:** binned averages of the superflare rate including non-flaring stars

With increasing temperature the superflare rate decreases, which is expected from calculations by *Kitchatinov & Olemskoy (2011)* who showed a decrease in dynamo number with  $T_{\text{eff}}$ .

## Rotation Rate



**scatter plot:** normalized superflare rates  
**upper histogram:** averaged normalized superflare rate  
**lower histogram:** averaged normalized superflare rate including non-superflaring stars

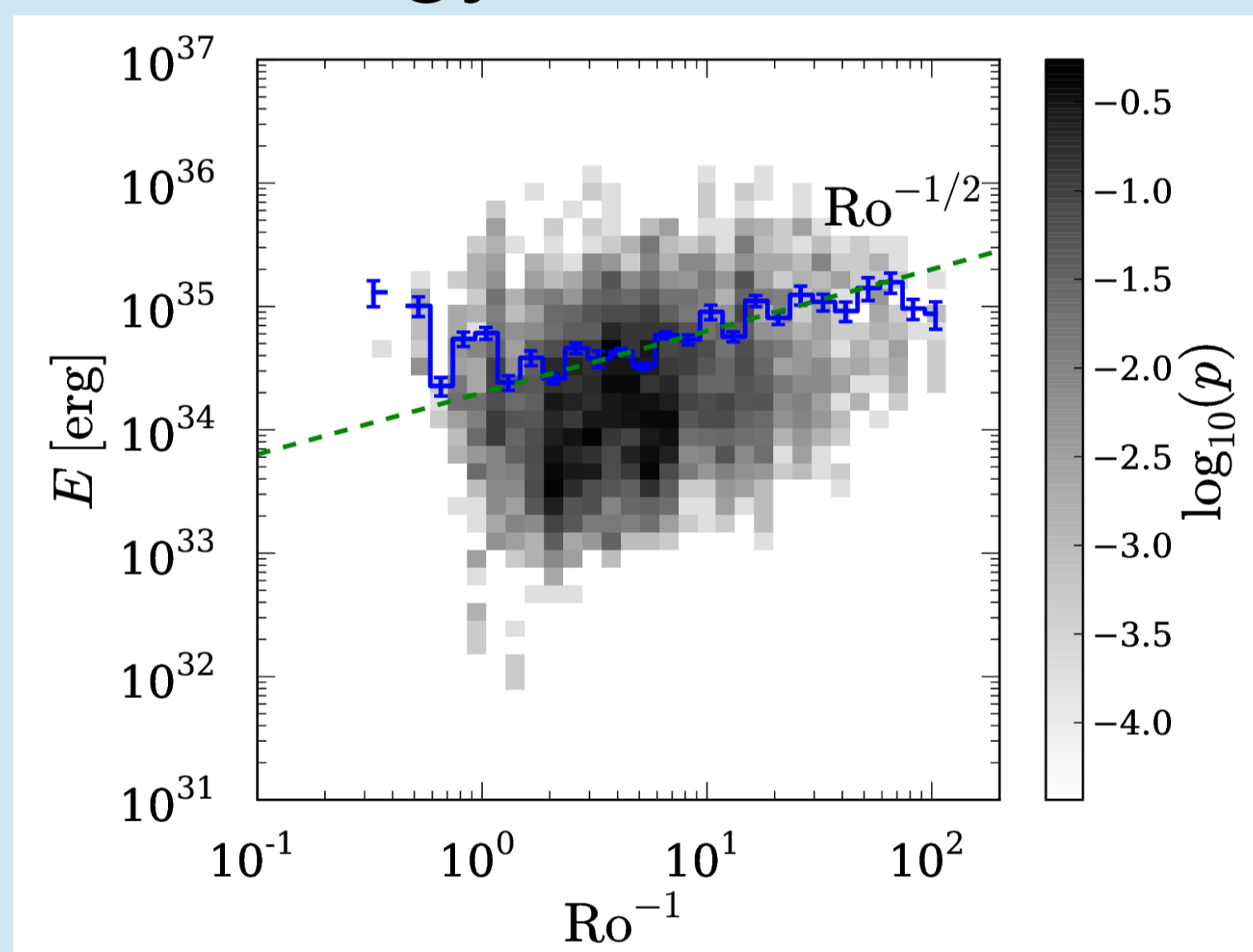
Two regimes are found:

$Ro^{-1} \leq 8.4$ : quadratic increase

$Ro^{-1} > 8.4$ : linear decrease

The break at  $Ro^{-1} \approx 8.4$  agrees with *Pizzolato et al. (2003)* and *Wright et al. (2011)* who find a quadratic increase of X-ray luminosity. Above the break point stellar activity is saturated.

## Flare Energy



**1-D histogram:** averaged flare energy in intervals of the inverse Rossby number  
**2-D histogram:** relative population of flares with given inverse Rossby number and energy

Dynamo activity increases with the shearing rate, which is a consequence of the rotation. For fast rotators we observe more energetic flares.

## References

- Kitchatinov, L. L., & Olemskoy, S. V. 2011, MNRAS, 411, 1059
- Pizzolato, N., Maggio, A., Micela, G., Sciortino, S., & Ventura, P. 2003, A&A, 397, 147
- Wright, N. J., Drake, J. J., Mamajek, E. E., & Henry, G. W. 2011, ApJ, 743, 48

**This work:**

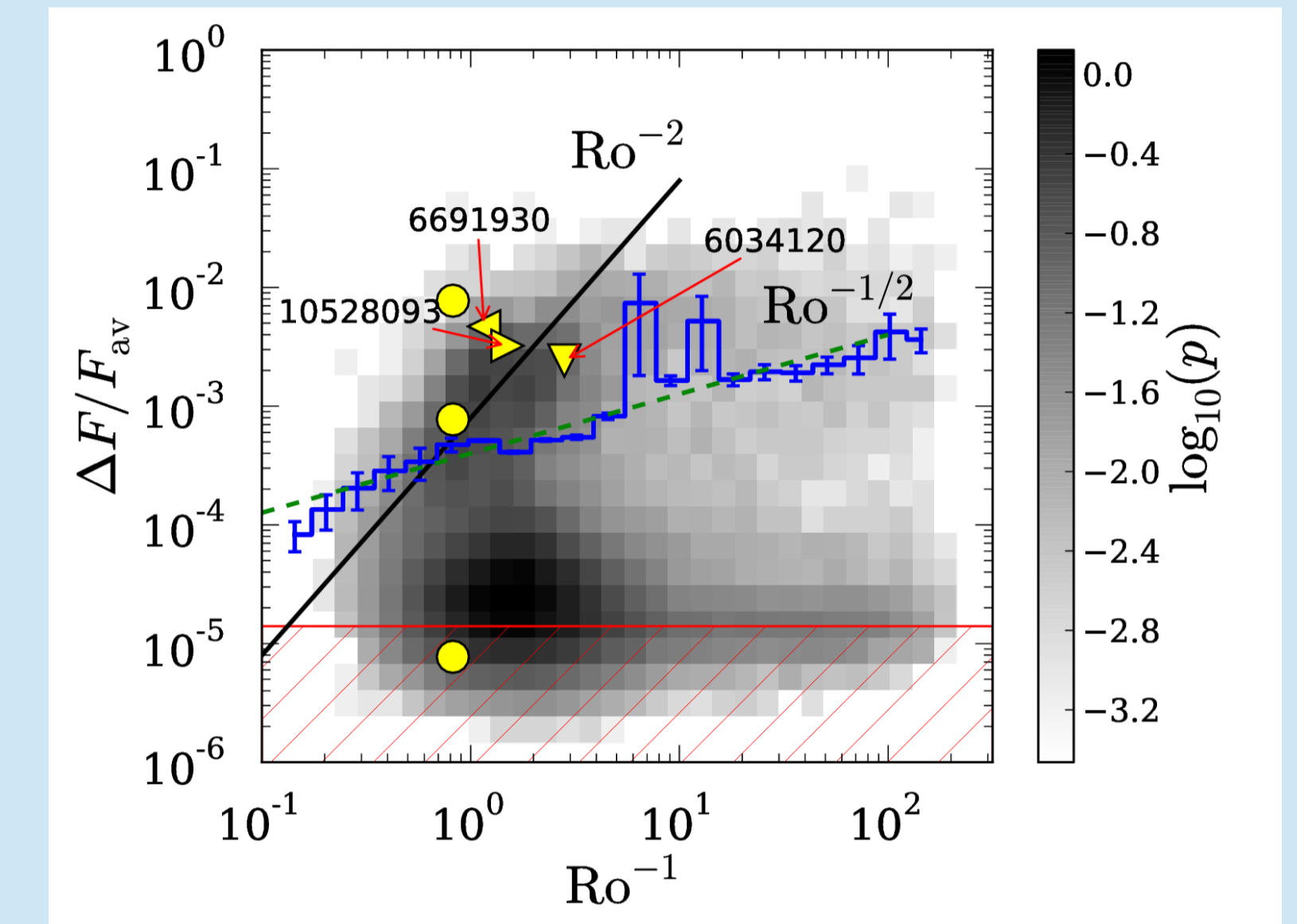
ApJ, 792:67 (2014)

Arxiv:1405.1453

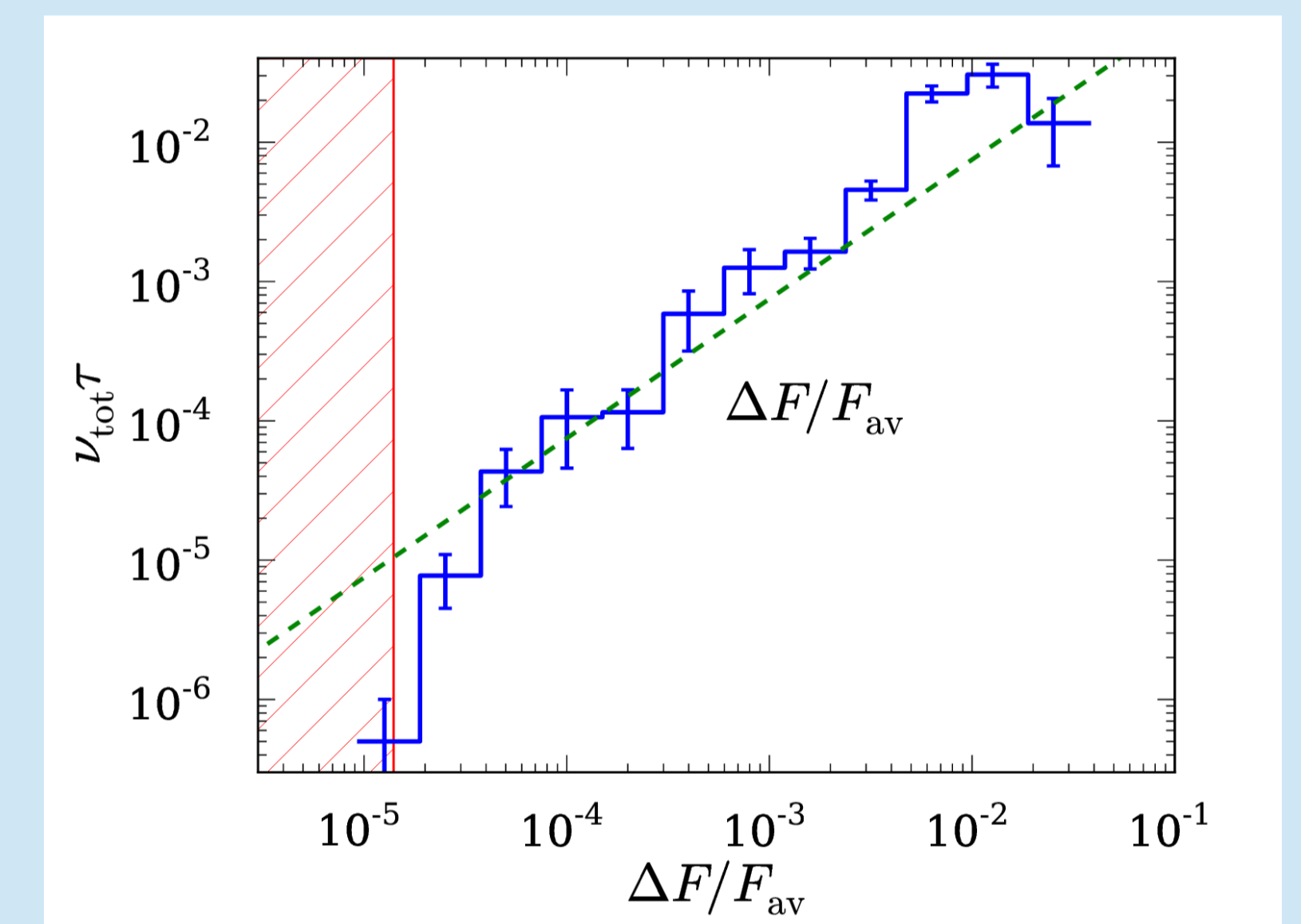


## Spot Coverage

Strong magnetic fields are manifested through star spots. Spot coverage can be inferred from periodic brightness variations. We use the relative brightness variation  $\Delta F/F_{\text{av}}$  as proxy of star spot coverage.



**1-D histogram:** averaged brightness variation in dependence of the inverse Rossby number  
**2-D histogram:** probability distribution function of  $\Delta F/F_{\text{av}}$  and  $Ro^{-1}$



Normalized superflare occurrence rate including all stars in dependence of the relative brightness variation.

Increased rotation rate leads to increased magnetic activity and star spot coverage, which leads to higher superflare rates.

## Conclusions

- Superflare rates decrease with effective temperature.
- Rates increase with rotation rate up to a saturation point.
- Average flare energy increases with rotation rate.
- Rotation rate enhances magnetic activity.
- Fast rotators show higher spot coverage.
- Magnetic fields are essential for flares.

## Contact

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