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Simultaneous X-ray and optical flares of M dwarfs observed with eROSITA and TESS

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INTRODUCTION:

For the first time ever we have simultaneous data from two all-sky surveys in the optical and X-ray wavebands: The Transiting Exoplanet Survey Satellite (TESS) in the optical band and the extended Roentgen Survey with an Imaging Telescope Array (eROSITA) in X-rays. We use this data to study the variability of M dwarfs with long exposure observations at the southern ecliptic pole. Here, we study a sub-sample consisting of the brightest and most variable M dwarfs that have simultaneous TESS and eROSITA data.

(1.) Ecliptic pole stars → (2.) SCVZ stars → (3.) M dwarfs → (4.) Brightest + most variable X-ray sources

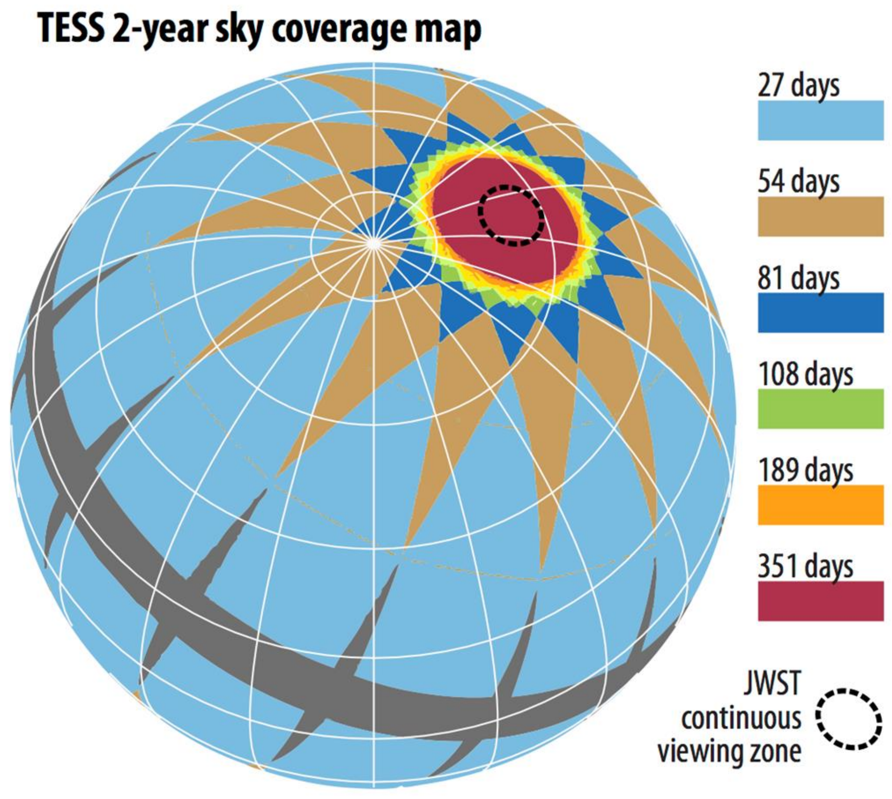


Fig. 1 TESS scanning mechanism
Source: https://tess.mit.edu/

→ TESS tiles the sky in 26 sectors.
→ The observing time is longer where the sectors overlap.

We're interested in the regions with the longest observing time: **The Continuous Viewing Zones (CVZ)** at the ecliptic poles.
eROSITA observations also have the longest exposure times at the ecliptic poles.

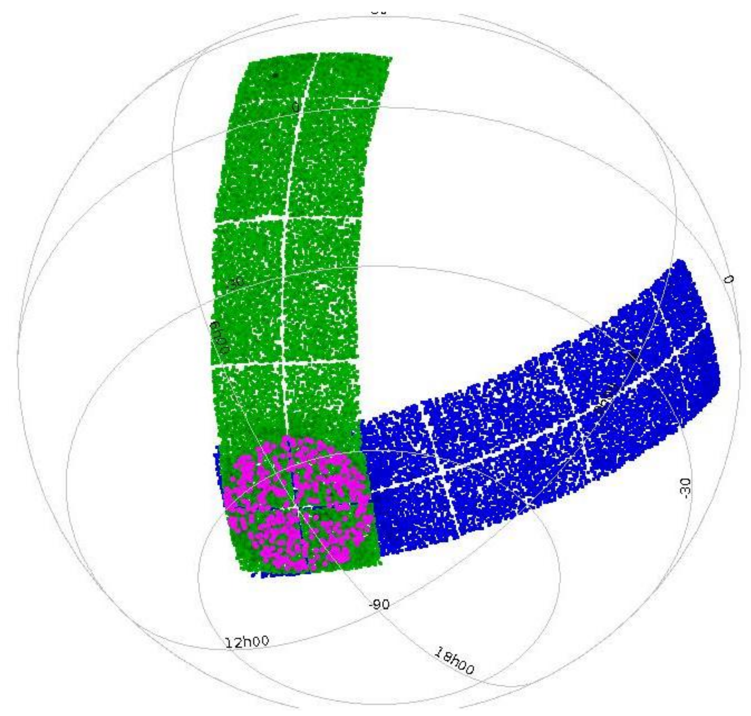


Fig. 2 TESS sectors 2 and 5 in the SCVZ

The CVZs are roughly within 12 degrees of the ecliptic poles.
Only data from the **Southern CVZ (SCVZ)** is used, as the Northern half of the eROSITA survey is in the Russian members' half of the sky*.
Only the eROSITA surveys 2 and 3 (eRASS 2 and eRASS 3) have simultaneous coverage with TESS.

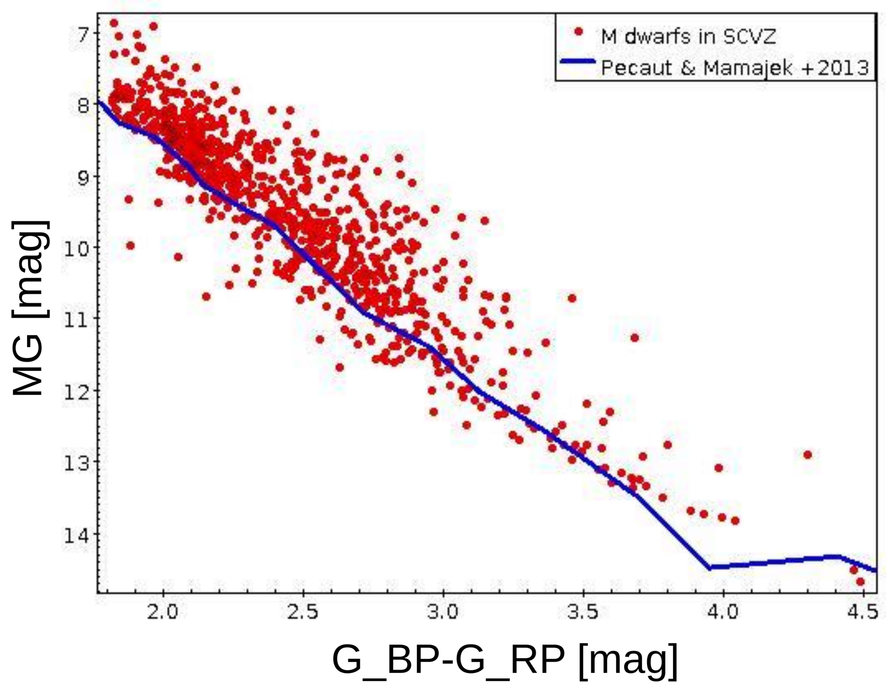


Fig. 3 Colour-Magnitude diagram for M dwarfs in SCVZ along with tracks from Pecaut & Mamajek,2013. *Source:*. *https://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt*

M dwarfs in the SCVZ were identified with the following parameters using Gaia data:

Colour selection: Bp-Rp >= 1.815
SCVZ: Ecliptic latitude <=-78.0°
→ 873 M dwarfs

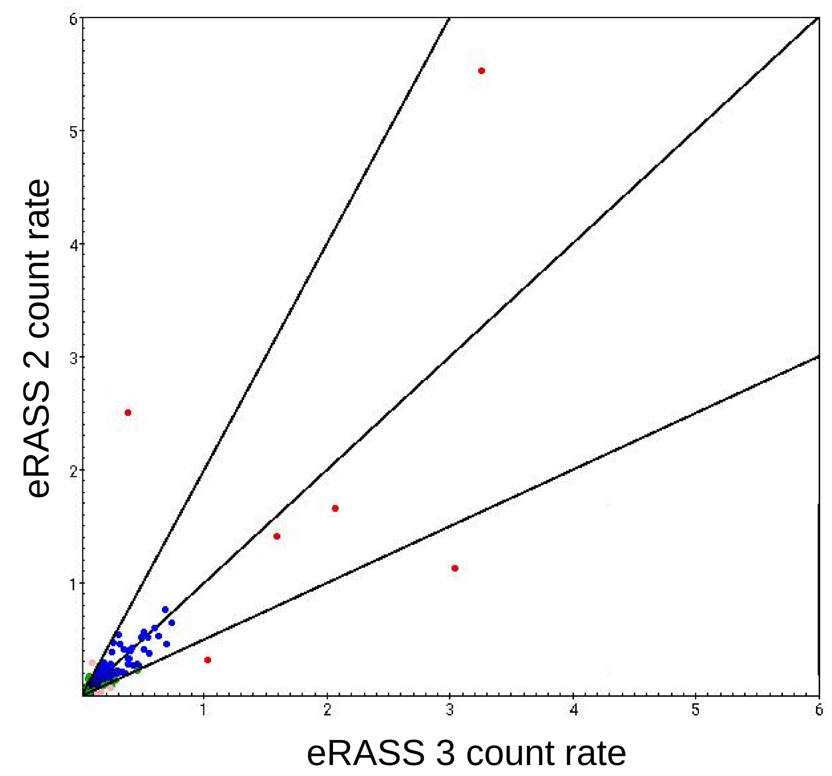


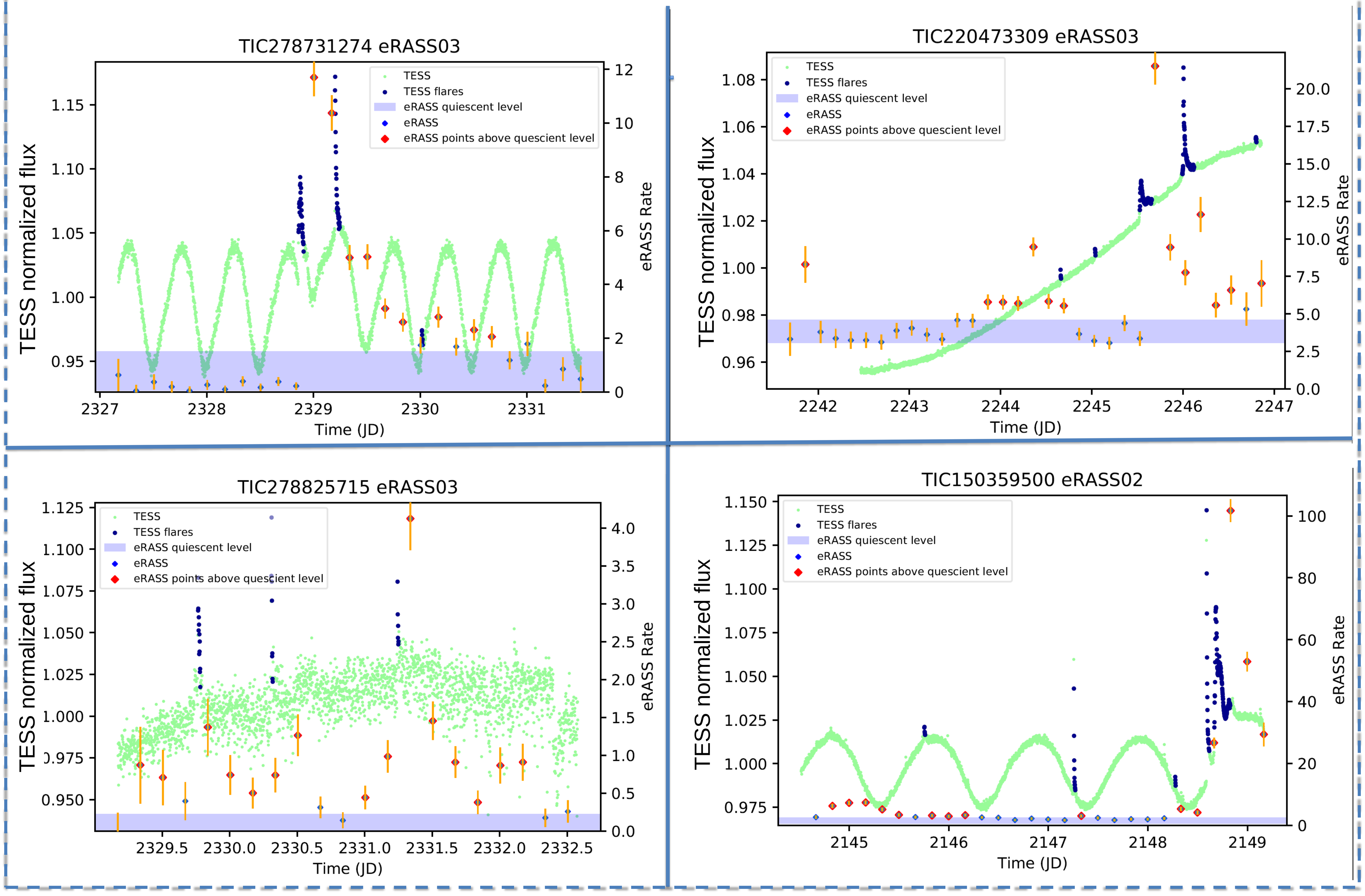
Fig. 4 Brightness variation between eRASS2 and eRASS3.

Stars chosen for the light-curve analysis are:
A). The **brightest** X-ray stars in the sample→ top-right region
B). The stars with **the highest X-ray variability** between the 2 eROSITA surveys → stars farthest away from the line y=x

28 stars were chosen to be the brightest or most variable

A few TESS and eRASS light curves with flares in TESS:

- The TESS light curves have a cadence of 2 min and eRASS light curves have a cadence of 4 hrs.



Key results:

- **42 light curves** have simultaneous TESS and eROSITA data**
- **25** of these have **flares detected in TESS** using the algorithm of Stelzer+16 and Raetz+20.

→ Variability in TESS: Rotational modulation is removed through boxcar smoothing and subsequent subtraction of the smoothed curve. Then flare candidates are identified as upwards outliers. Flare validation includes the use of the Davenport+2014 template. See Stelzer+2016, Raetz+2020 & Stelzer+2022 for details.

→ Variability in eRASS: The eRASS count rates (cts/sec) are divided into equally sized bins and bin size is chosen as the maximum of two optimum bin estimators: the Freedman Diaconis Estimator and the Struges estimator. The X-ray quiescent level (in purple) is defined as the lowest bin that contains more than one eRASS data point and which has its upper boundary above zero. The points which are significantly above the quiescent level are marked in red.

Preliminary conclusions:

- In addition to the joint optical and X-ray flares, variability with no correspondence between the 2 wavebands is seen.
- X-ray flares cannot be detected and quantified in the same manner as the optical flares. This due to the fact that eRASS light curves have lower time-sampling than TESS

*eROSITA data is split such that the Russian members of the collaboration has access to data in the galactic east and German members the galactic west.
**Not all of the expected TESS light curves corresponding to the eRASS observations were available on the MAST database. Some of the available light curves (TESS and eRASS) had no simultaneous coverage due to data gaps in their respective light curves

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