# Towards the FIRST large sample of X-ray Flaring M-dwarfs


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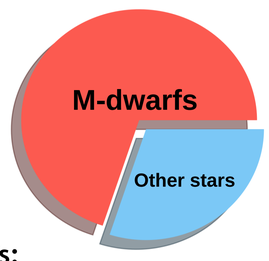
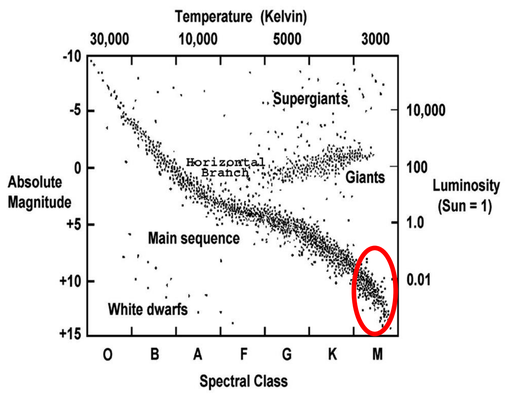
## Background and Introduction: Uniqueness of M-dwarfs

### General properties:



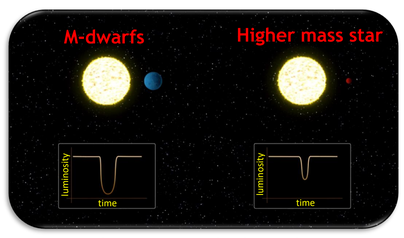

**M-dwarfs:**
- Most abundant: ~70% of stars in our galaxy
- Longest lifespan: up to 100+ Gyr.
- Least massive: ~0.075 $M_\odot$< M <0.6 $M_\odot$
- Coldest: ~2400 K< $T_{eff}$ <3900 K
- Dimmest: ~0.01 $L_\odot$< L <0.1 $L_\odot$

### HR diagram:




HR diagram, Credit: Chandra

### Advantages in Exoplanet Discovery:




Transit detection method, Credit: NASA

- Small star-to-planet mass and size ratio
- Shorter orbital periods

### Magnetic activity:

Prime characteristic of M-dwarfs

A Flaring M-dwarf, Credit: NASA

**Flares:** Energy outbursts events caused by magnetic reconnection

**Significant magnetic activity at X-ray wavelengths could cast a shadow on the possibility of the emergence of life on potential habitable exoplanets orbiting M-dwarfs**

## Open question and science objectives

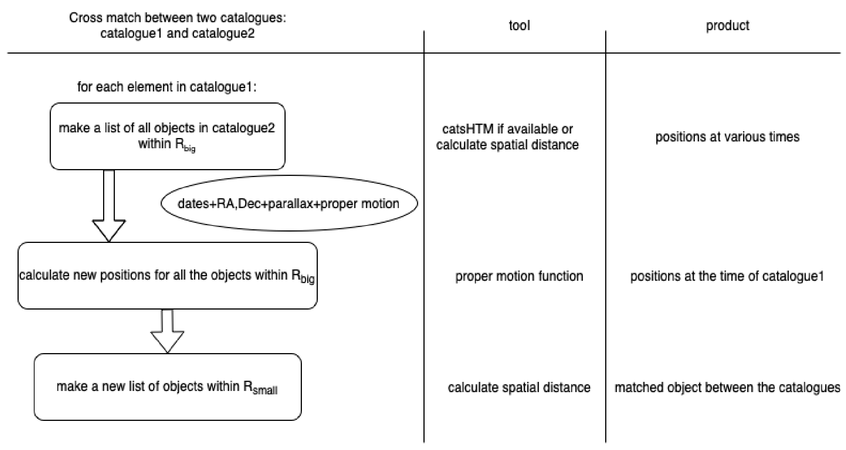
## What is the rate of M-dwarf flares in the X-ray?

### Why we care:
- M-dwarf flares contaminate expected surveys (e.g. ULTRASAT[1])
- Our study could help refine habitability criteria for exoplanets

### Our science objectives:
- **Compute the first large scale sample of X-ray emitting M-dwarfs**
- **Explore their X-ray variability**
- **Study their X-ray flaring characteristics and rates**

## Methodology

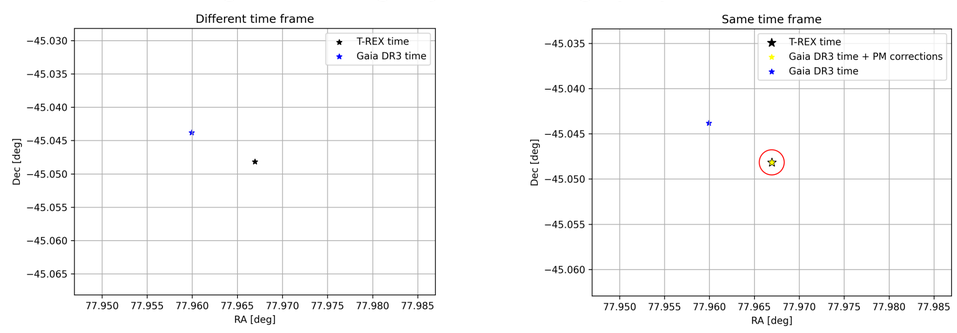
### About our data:
- The **T-REX** catalog[2], a large catalog of X-ray sources with high time and spatial resolutions from 20 years of the Chandra[3] telescope archival data
- We use the **catsHTM**[4] python package that enables us to access and utilize large astronomical catalogs such as Gaia[5]




### Correcting for Proper Motion:

Due to their low luminosity, only nearby M-dwarfs are observed and therefore many of them exhibit high proper motion.

We have developed a code that accurately performs cross-matching between catalogs containing object with high proper motion

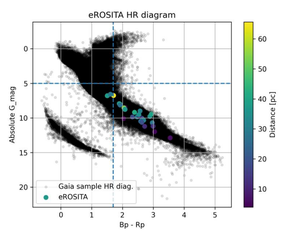



**The necessity of incorporating proper motion calculations:** The cross-match result on a different time frame shows no match, but after proper motion calculation on the same time frame, a match is revealed

## Preliminary results and Future prospects

### Detected X-ray emitting sources:

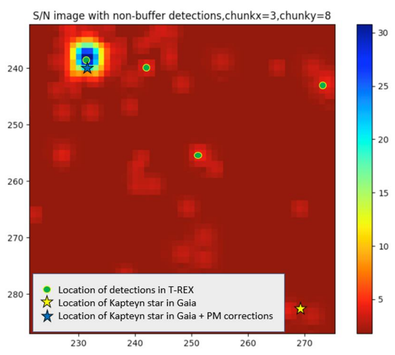
So far, we were able to detect 50 candidates from the **eROSITA**[6] M-dwarfs sample.

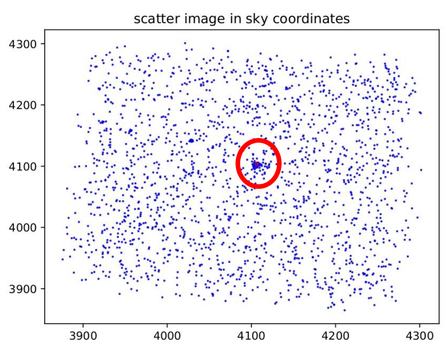



### Example:

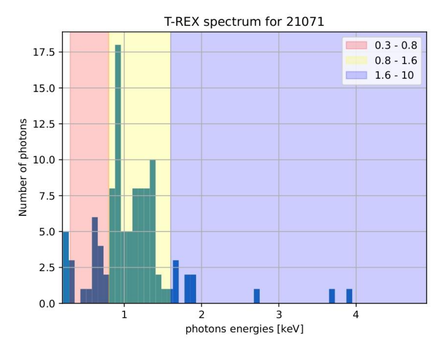
T-REX detection and flare analysis to one of our candidates, The ”Kapteyn star”[7], in our observation ObsID 21071

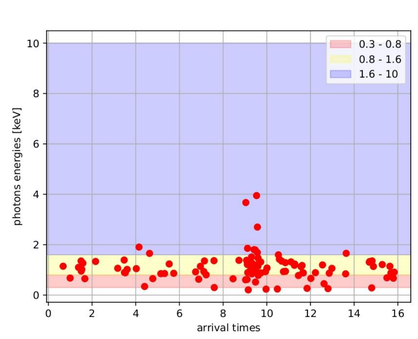
**Detection:** T-REX detection and our candidate are very close, with high SNR and dense photons, indicating an X-ray emitting source.



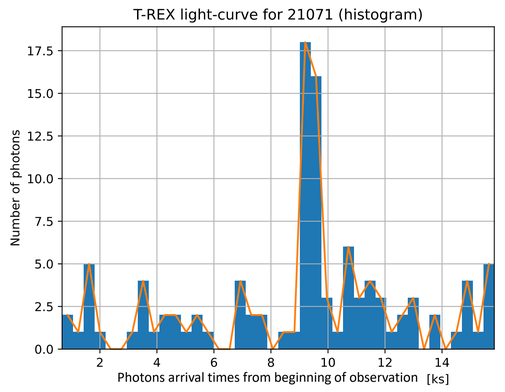




**Spectrum:** T-REX spectrum analysis in three energy bands reveals a dominance of photons within the medium energy range. Notably, a significant number of high-energy photons align with the identified flare event.

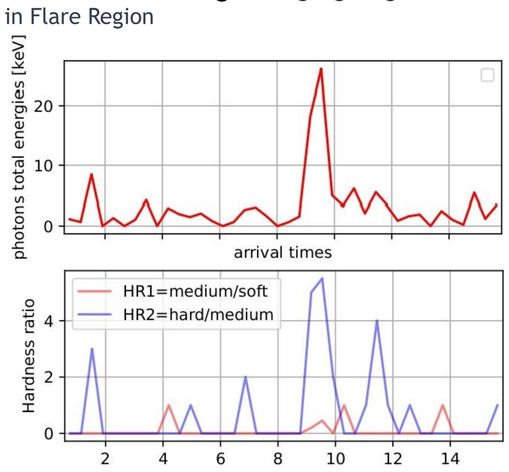



**Flare:** T-REX light curve with a significant linear rise, interpreted as a flare event




**Photons Total Energies:** Highlighting Maximum Energy in Flare Region

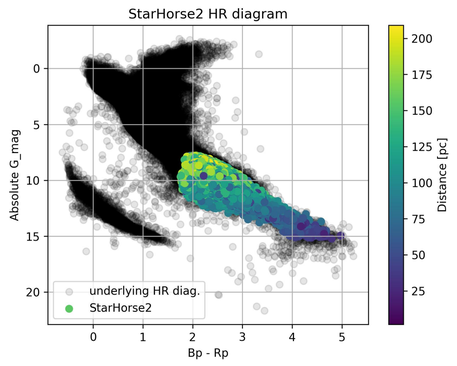



**Hardness ratio:** a plausible hypothesis for harder spectra is flaring activity[6]

**The key point:**
Data from eROSITA does not have sufficient time resolution in order to detect flares while the T-REX catalog provides this time resolution.

### A promising Future:

Cross-matching our entire T-REX data with large catalogs of identified M-dwarfs.
(e.g. TESS[8], LAMOST[9], StarHorse2[10]) may lead to a deeper insights into their X-ray flaring characteristics.
Our goal is to generate a systematic study of X-ray flaring M-dwarfs on a large scale sample.




### References:


[1] Ben-Ami et al., 2022
[2] Soumagnac et al. (in preparation)
[3] Evans et al., 2020
[4] Soumagnac and Ofek, 2018
[5] Brown et al., 2021
[6] Magaudda et al., 2022
[7] Kapteyn, 1897
[8] Paegert et al., 2021
[9] Luo et al., 2022
[10] Anders et al., 2022