

# EXPLORING SHORT-TERM STELLAR ACTIVITY IN M DWARFS: A VOLUME- LIMITED PERSPECTIVE

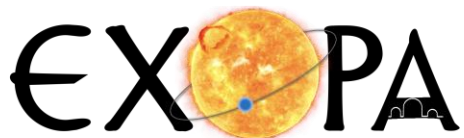
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# OUTLINE



INTRODUCTION TO  
FLARE ANALYSIS



METHODS

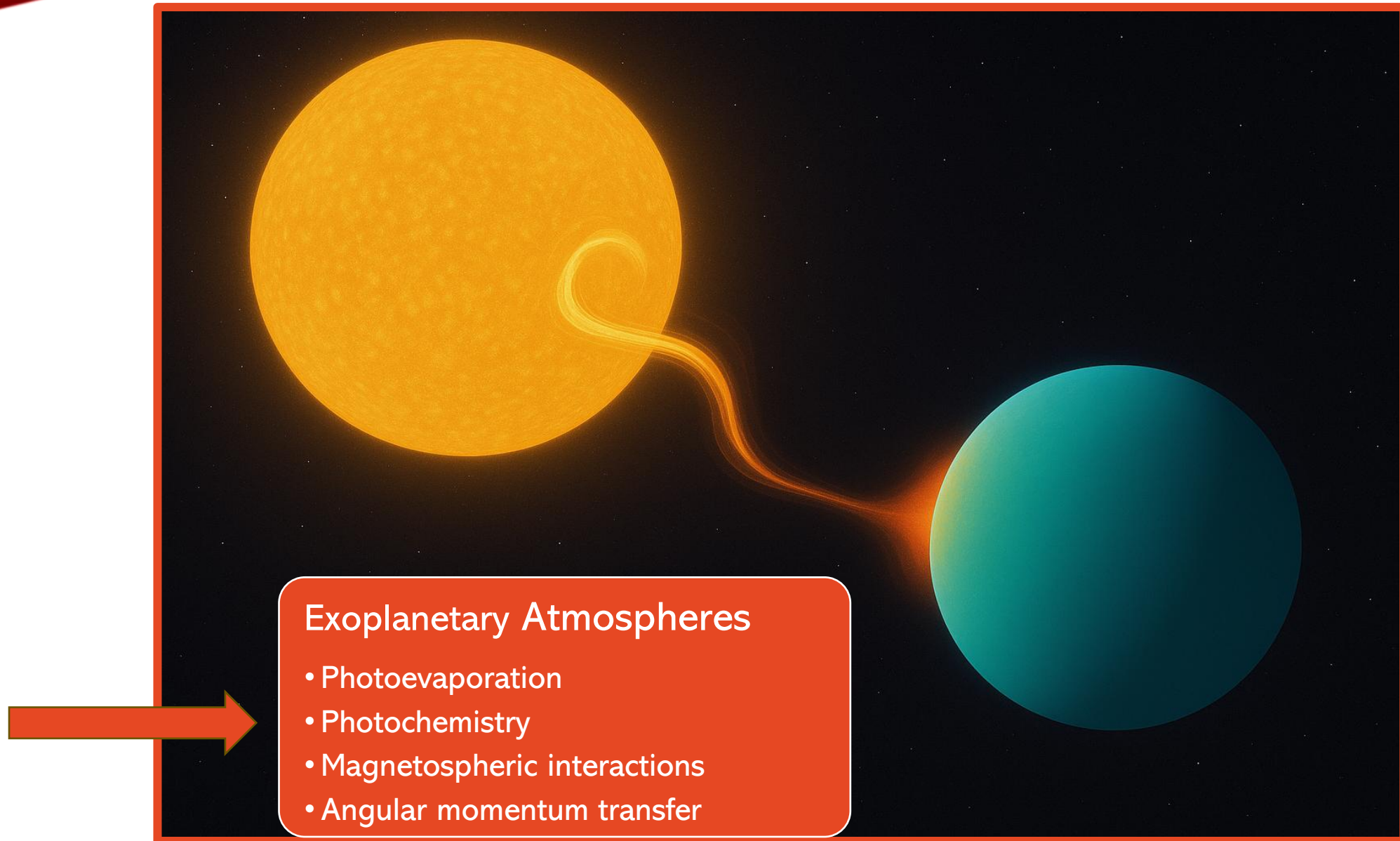
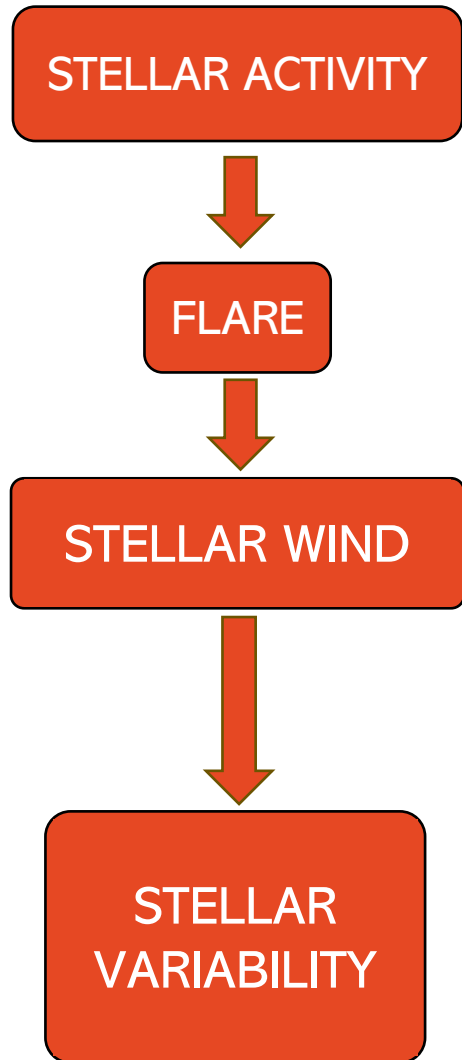


RESULTS

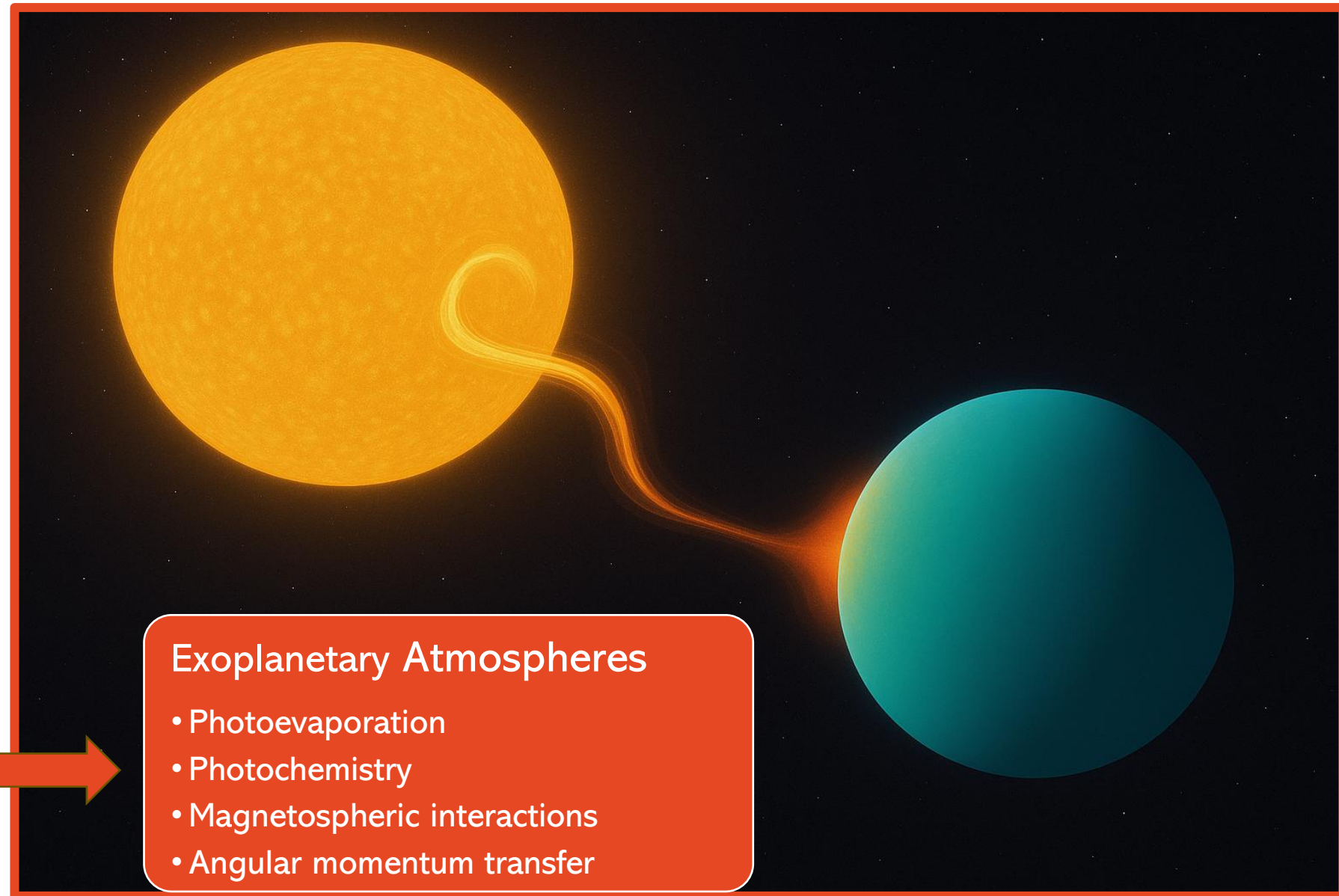
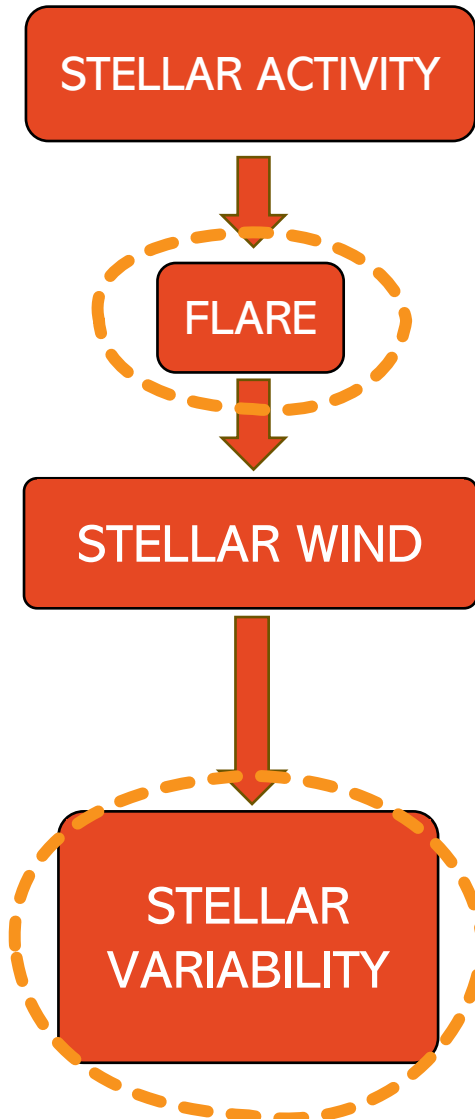


CONCLUSIONS AND  
FUTURE WORKS

# INTRODUCTION



# INTRODUCTION



# INTRODUCTION - FLARE



Flares are sudden, violent bursts of energy that occur on stars.



Caused by magnetic reconnections, when the star's magnetic field and coronal plasma interact.



Observable in a variety of wavelengths, from X-rays to optical radiation and radio.

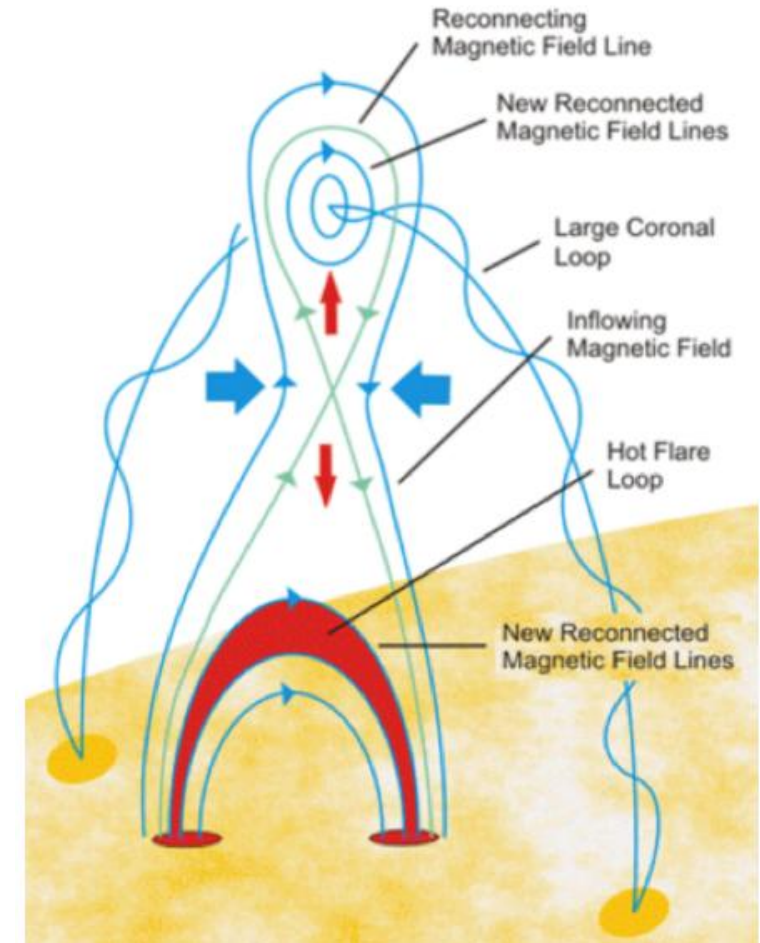


Diagram of a stellar flare

# INTRODUCTION - FLARE



## Optical Band

**Source:** Stellar photosphere.

**Mechanism:** Brightness increase due to magnetic reconnection and electron acceleration.



## X-Ray Band

**Source:** Stellar corona (hottest outer layer).

**Mechanism:** Plasma heated to millions of degrees by magnetic reconnection.



## Radio Band

**Source:** Non-thermal emissions (e.g., synchrotron radiation).

**Mechanism:** Particle acceleration in shocks and plasma waves.

# INTRODUCTION - WHY FLARES?

## 1. Magnetic Dynamo:

- Underlying stellar dynamo mechanisms responsible for generating and sustaining magnetic fields.

## 2. Impacts on Planetary Atmospheres:

- Flares emit high-energy particles and radiation, affecting the chemical composition and stability of nearby planetary atmospheres.
- Intense radiation can strip away atmospheres over time.
- UV radiation from flares can alter atmospheric chemistry.

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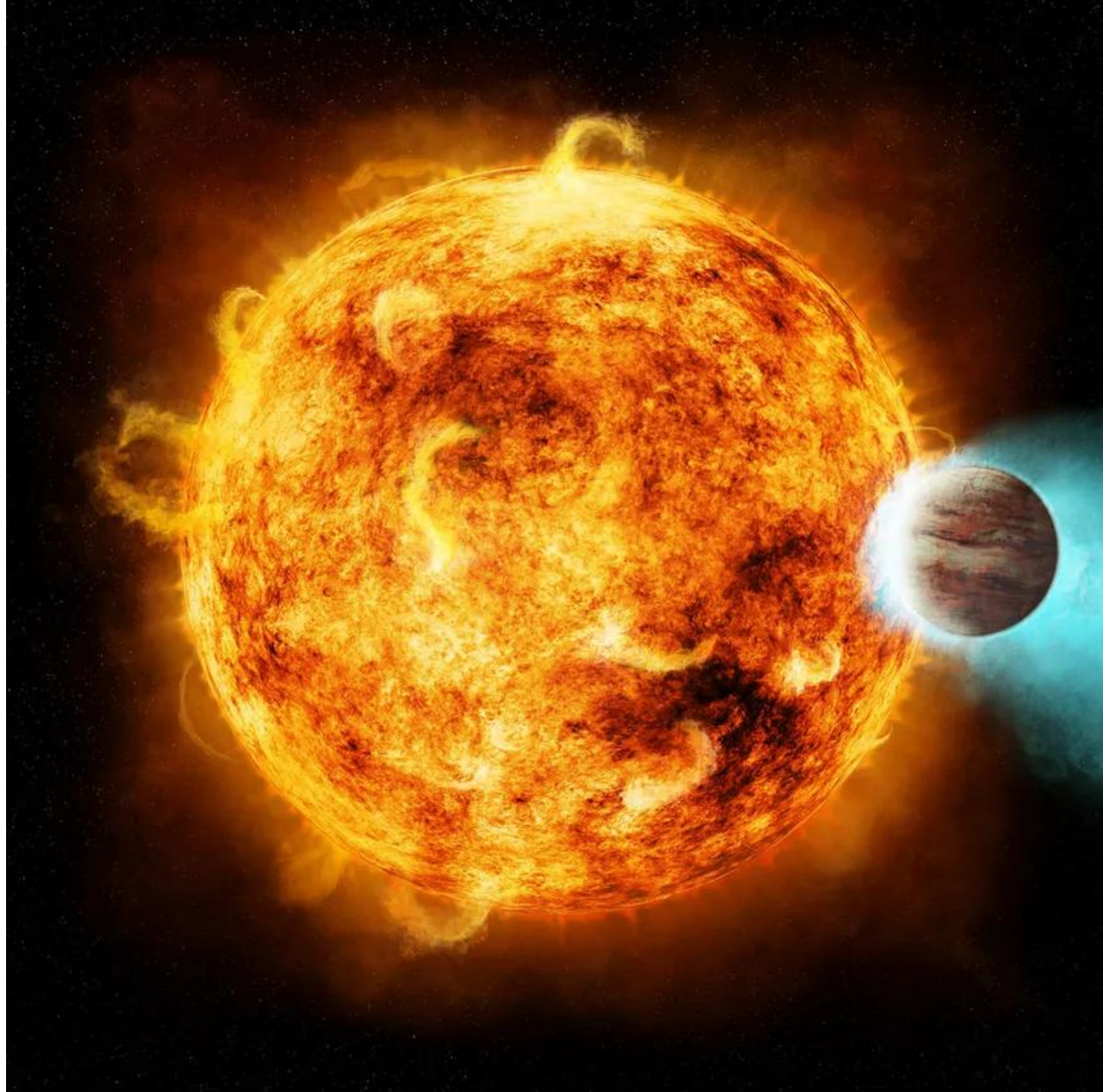
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## INTRODUCTION -

# EXOPLANETARY ATMOSPHERES

- Exoplanets in the habitable zones of flare-active stars (e.g., M-dwarfs) are particularly vulnerable.
- Frequent flare activity could limit the development of life.
- Studying **flare frequency** and **energy** helps assess the true habitability of exoplanets in these systems.



# OBJECTIVES



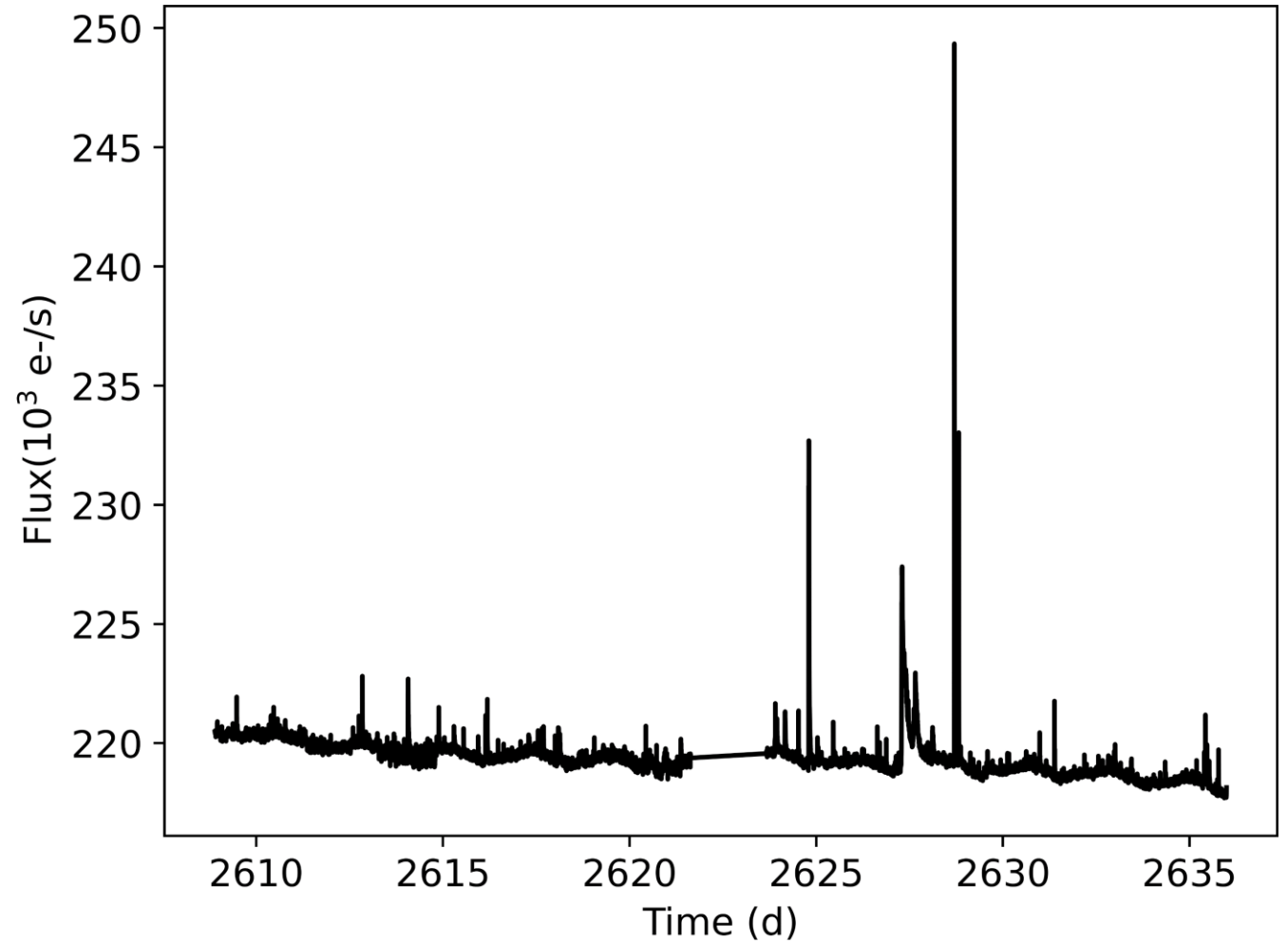
Identifying impulsive events in TESS light curves building on the methodology developed by Colombo et al. (2022).



Determine flare frequency and energy distribution for different stars

# TESS

- **TESS** (Transiting Exoplanet Survey Satellite): a space telescope to detect exoplanets through transit on bright stars.
- TESS is more efficient compared to previous missions.
- **High temporal cadence**
- **Long time baseline**



# METHODS

START: Gaussian Process Regression

Light curve – Gaussian regression

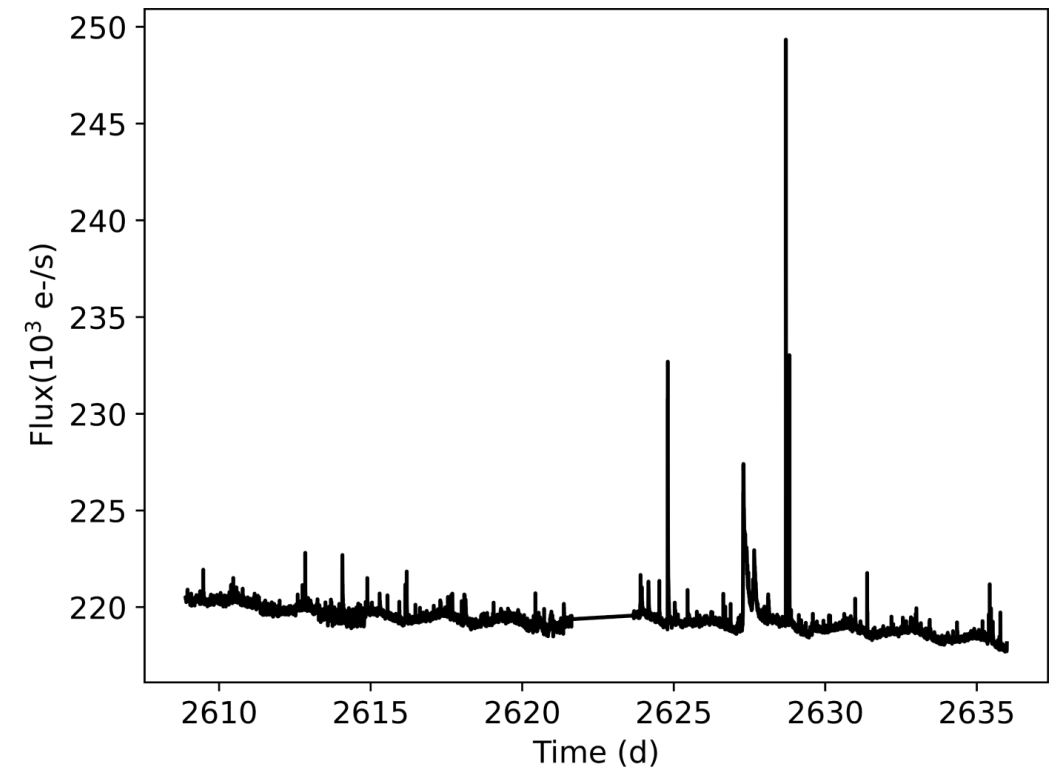
N over  $3\sigma >$  expected?

YES

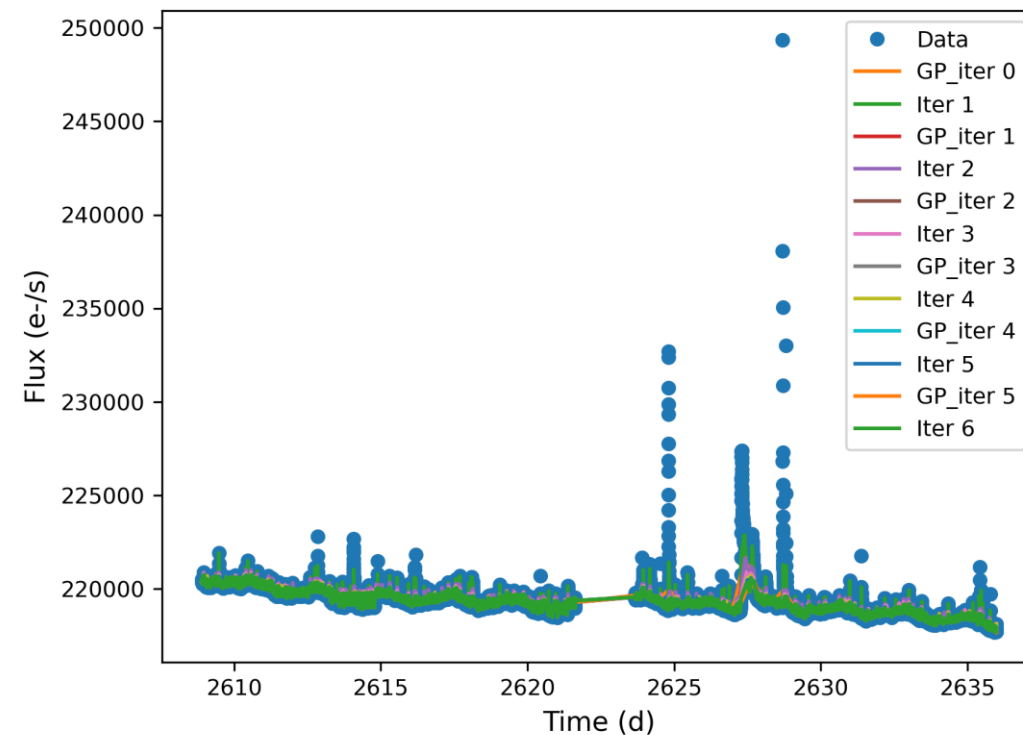
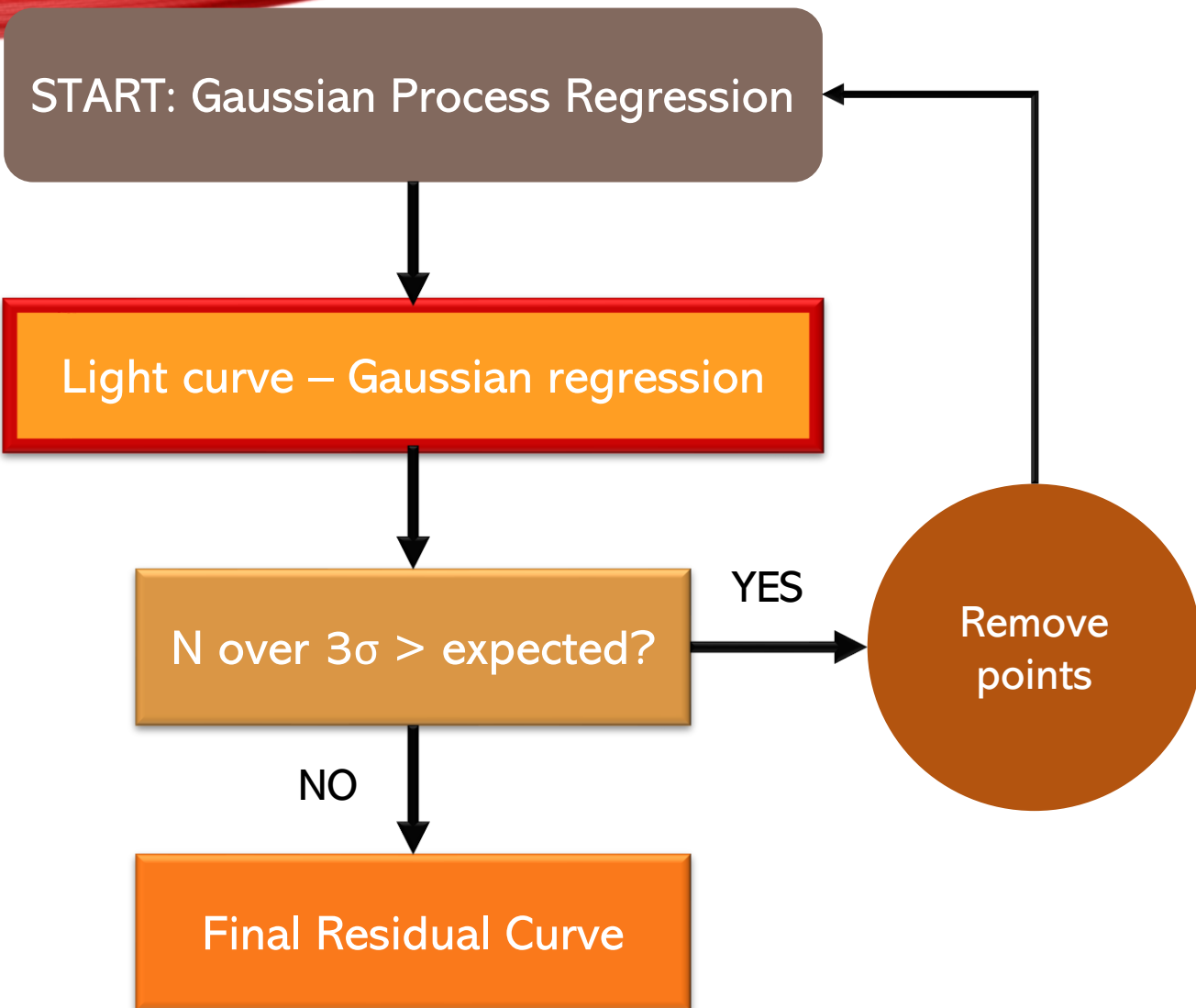
Remove points

NO

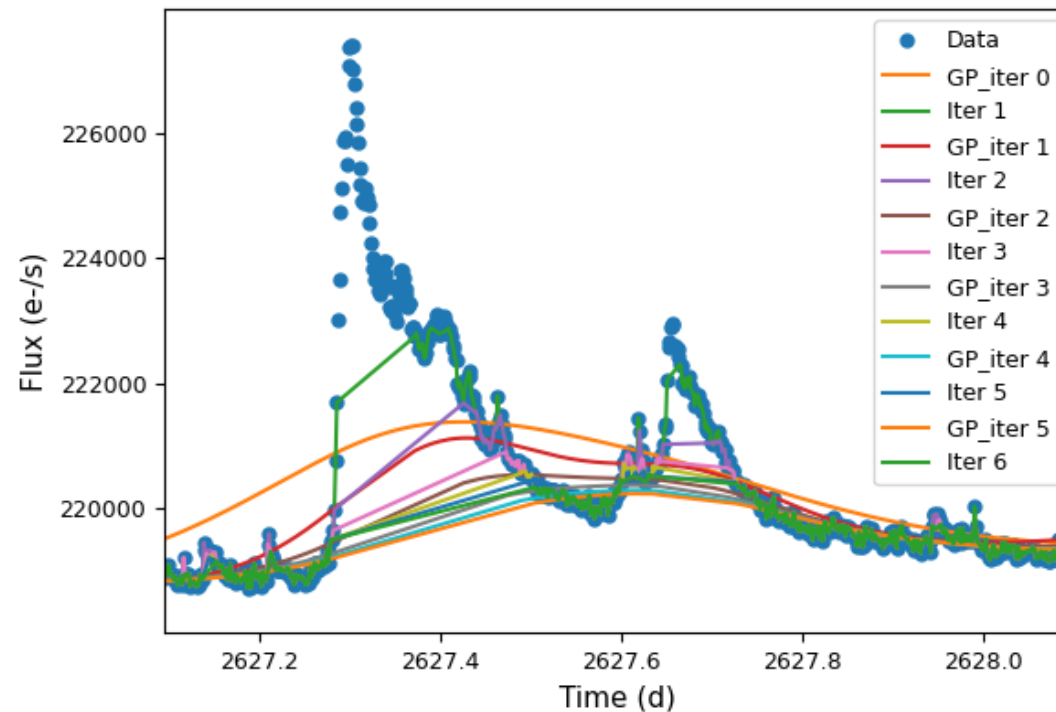
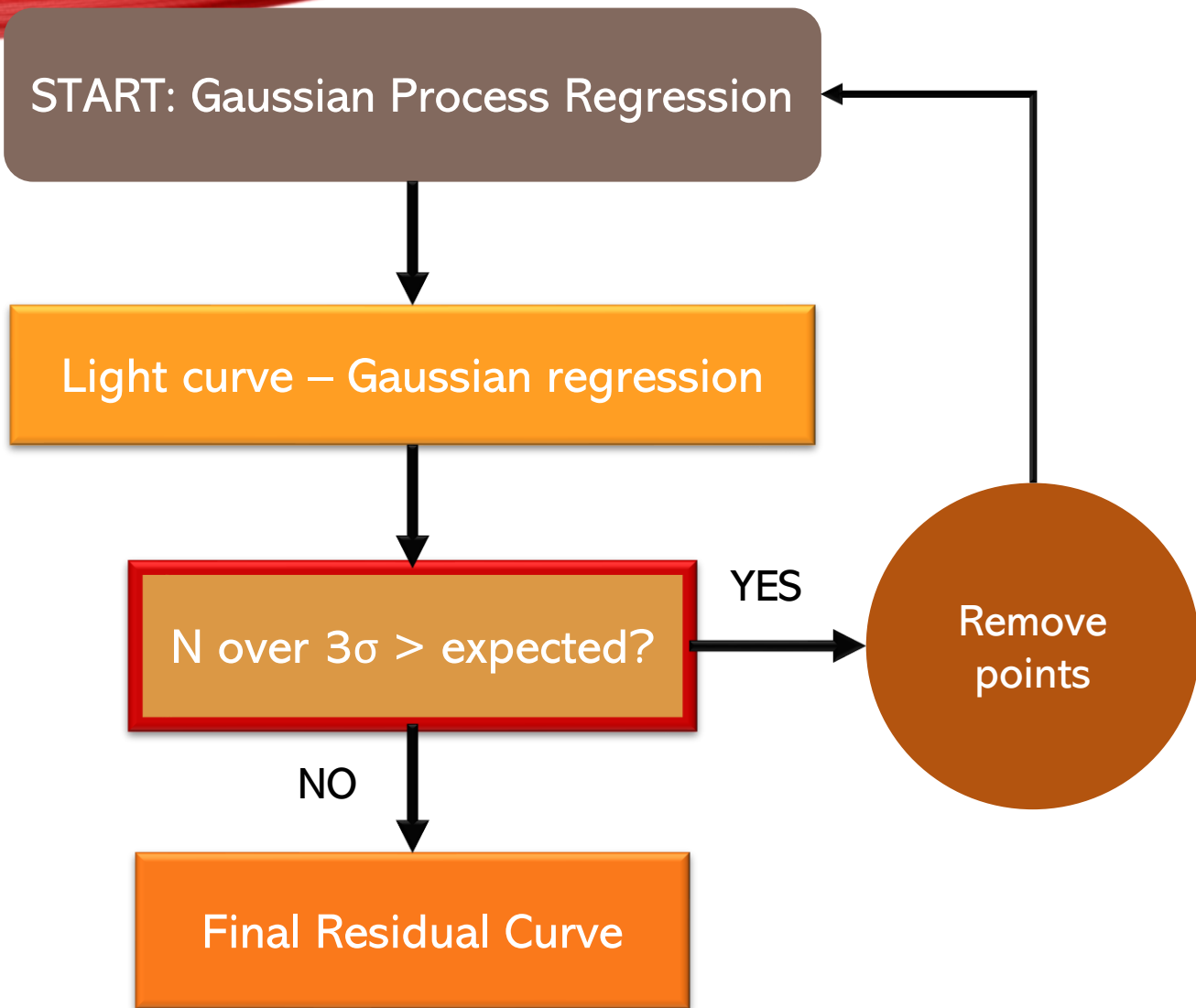
Final Residual Curve



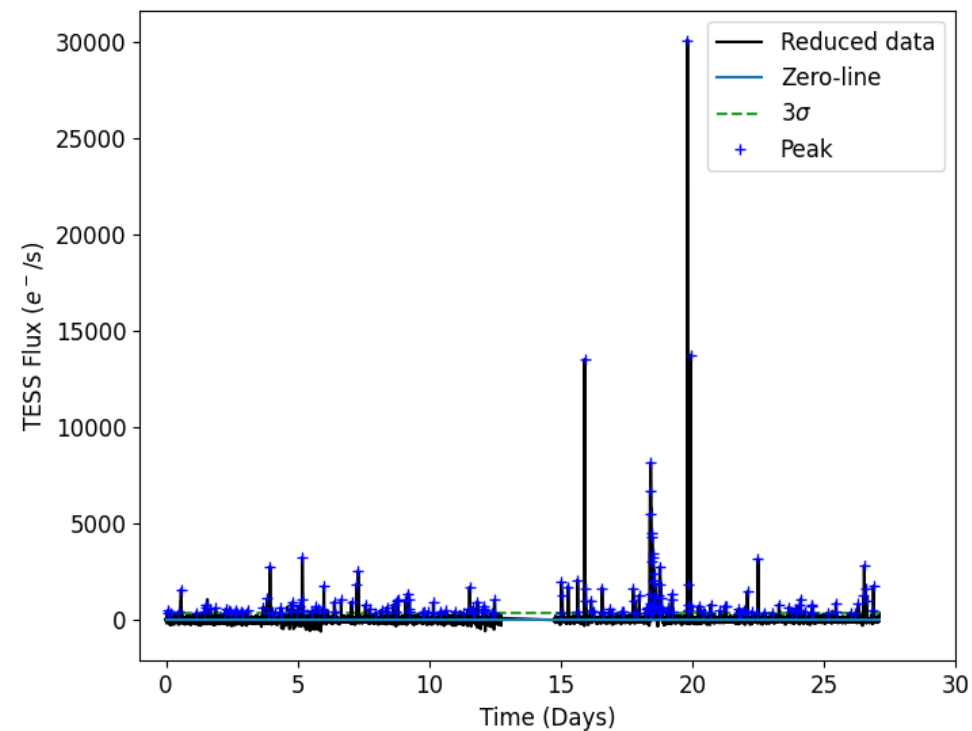
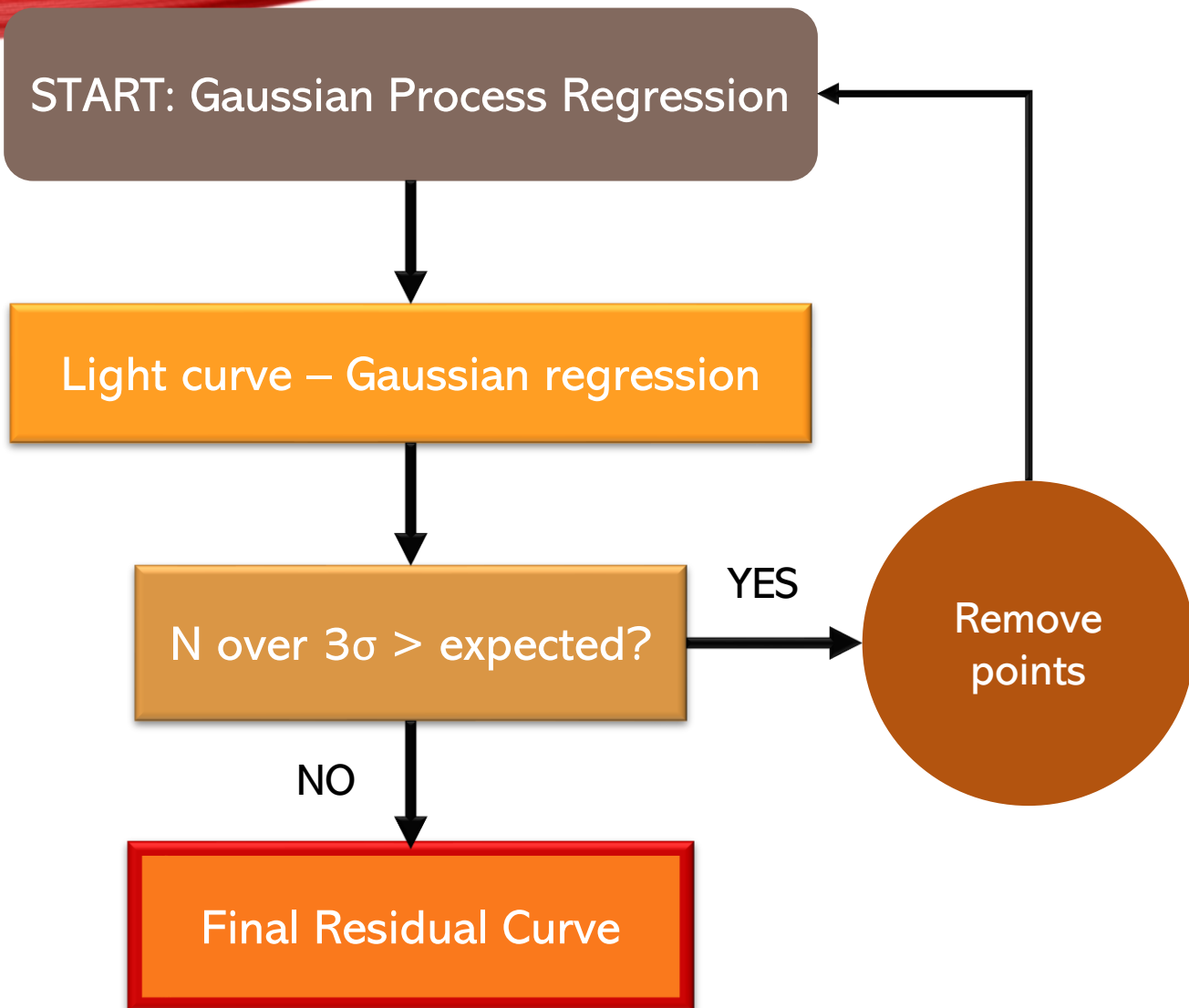
# METHODS



# METHODS



# METHODS



# METHODS

$$F(t) = H(t_0 - t) \cdot A e^{\frac{t-t_0}{t_r}} + H(t - t_0) \cdot A e^{\frac{t_0-t}{t_d}}$$

- Amplitude
- Position in time
- $t_r$  and  $t_d$
- Energy

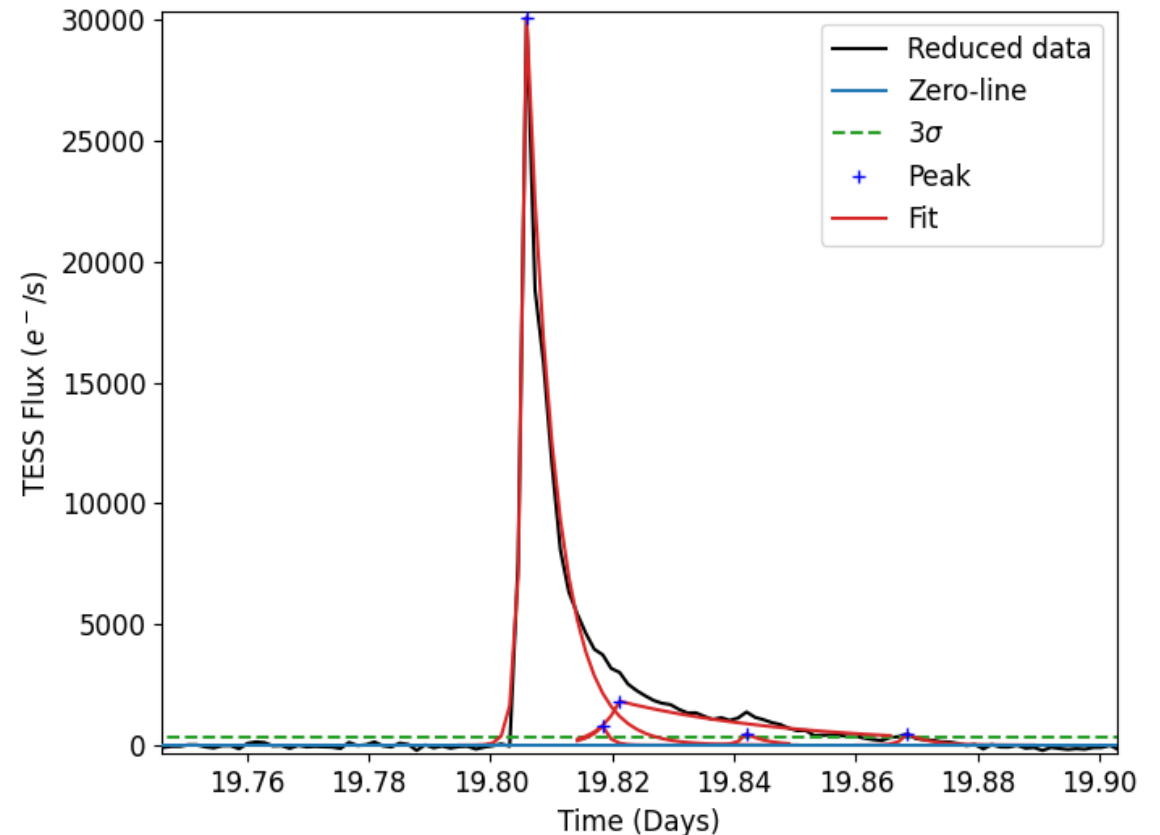


- $H(t_0 - t)$ : The Heaviside function used to transition from the rising part to the decaying part of the function.
- $A$ : The peak of the event.
- $t_r$ : The rise time.
- $t_d$ : The decay time.

## Energy Estimation for Each Event:

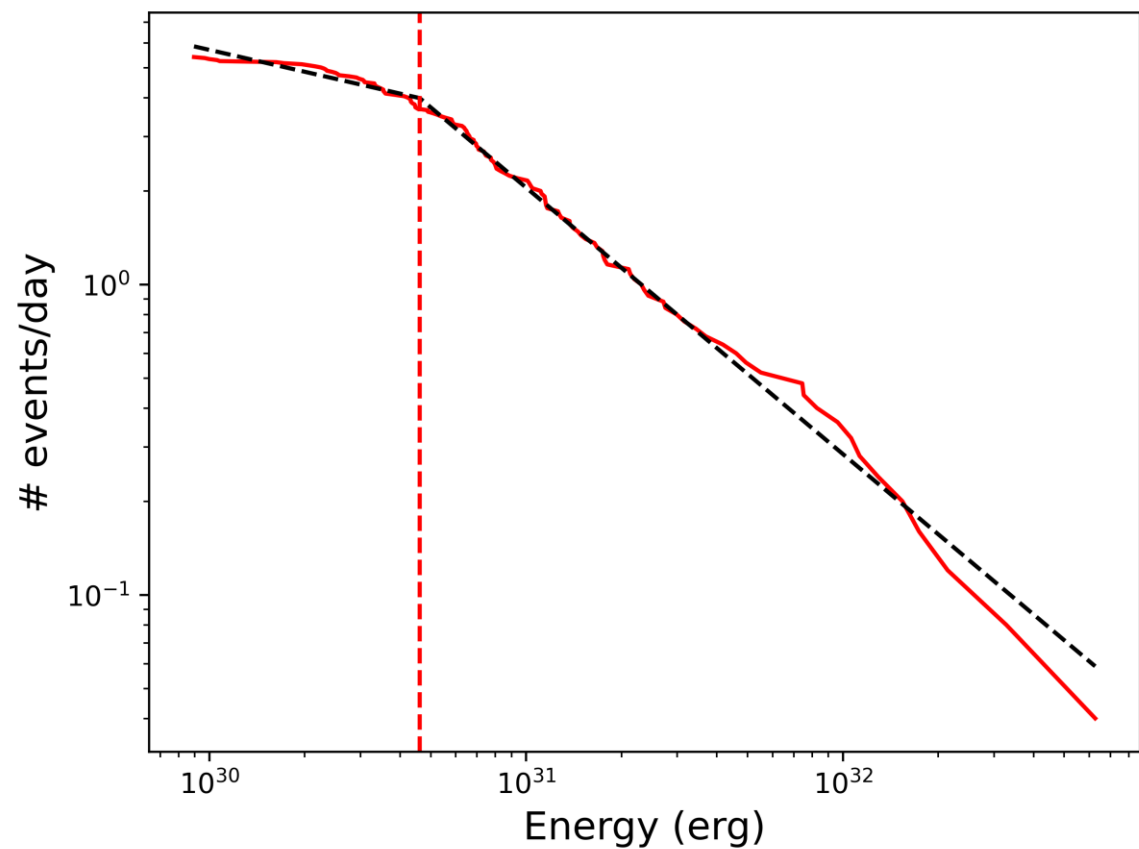
$$E = (A \cdot t_r + A \cdot t_d) \frac{L_{bol}}{L_{TESS}}$$

$L_{bol}$  is the bolometric luminosity for each star.

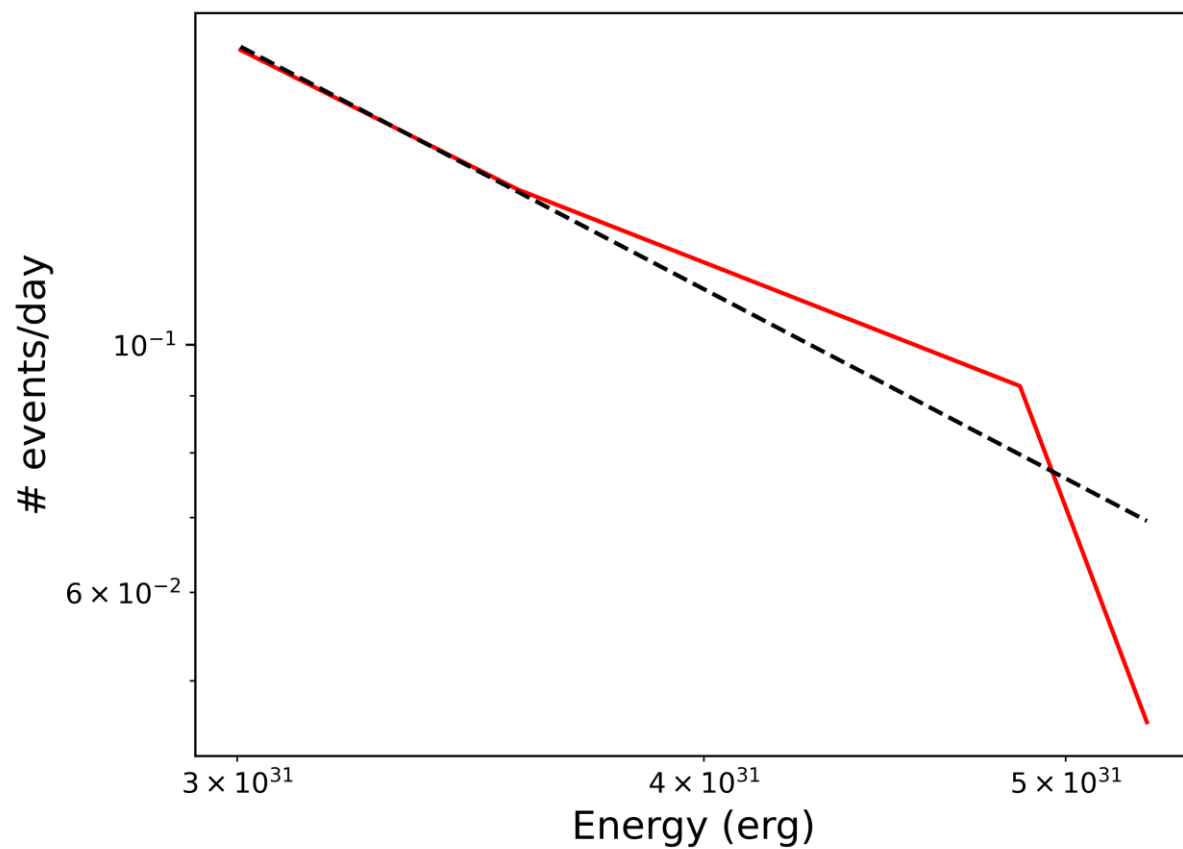


# METHODS – SLOPE AND ENERGY BREAK CALCULATIONS

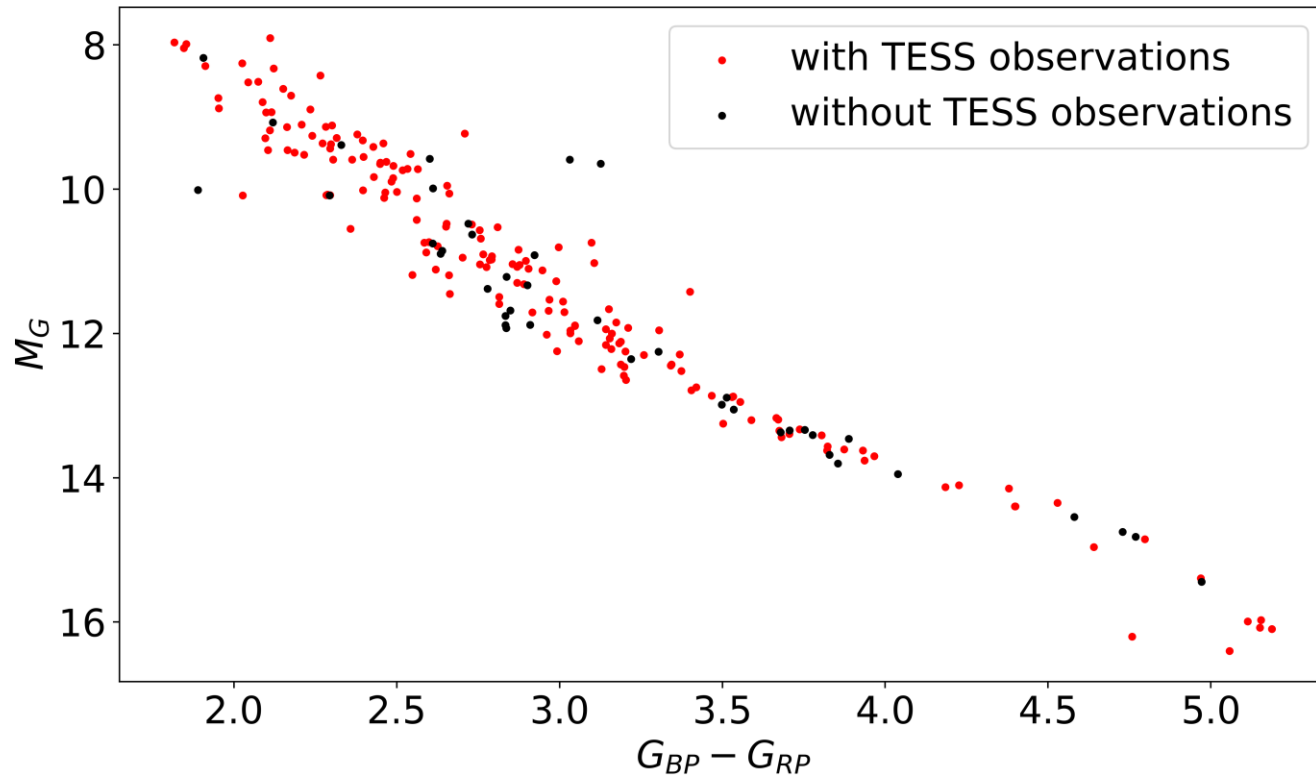
## Two-Segment fit



## One-Segment fit



# RESULTS – THE SAMPLE

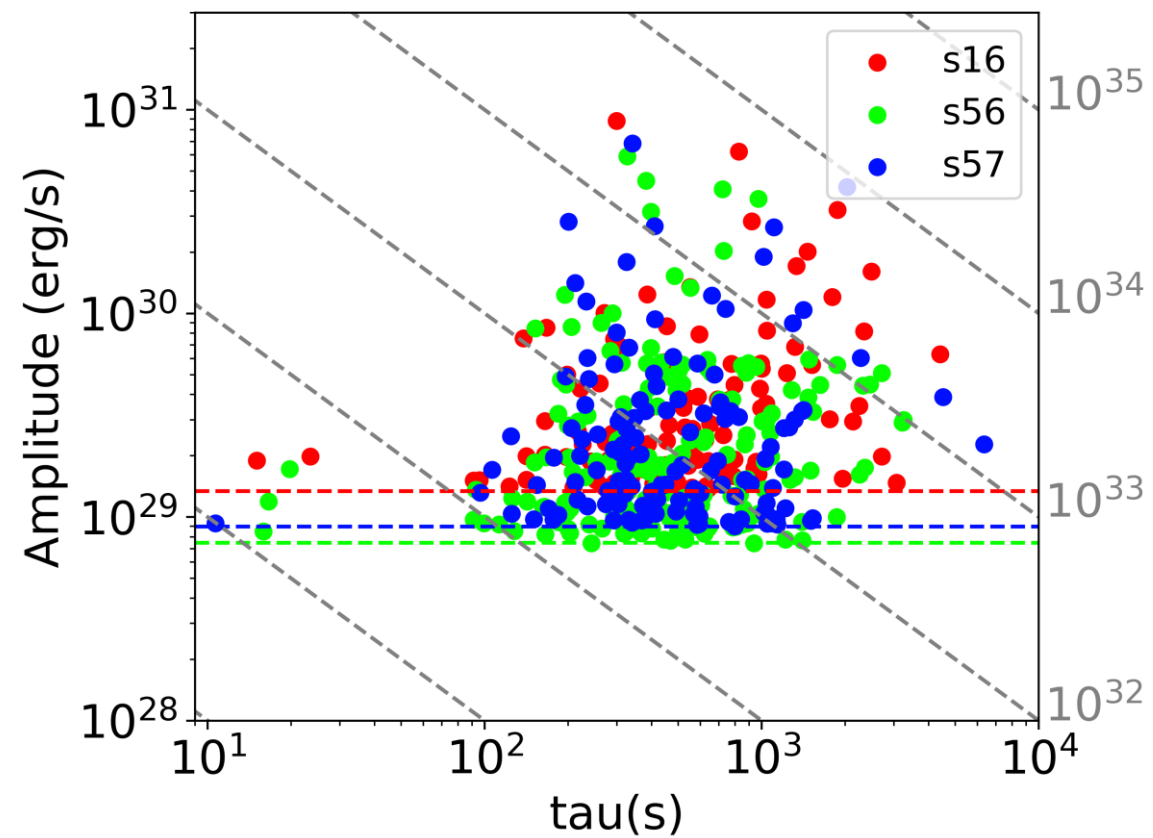
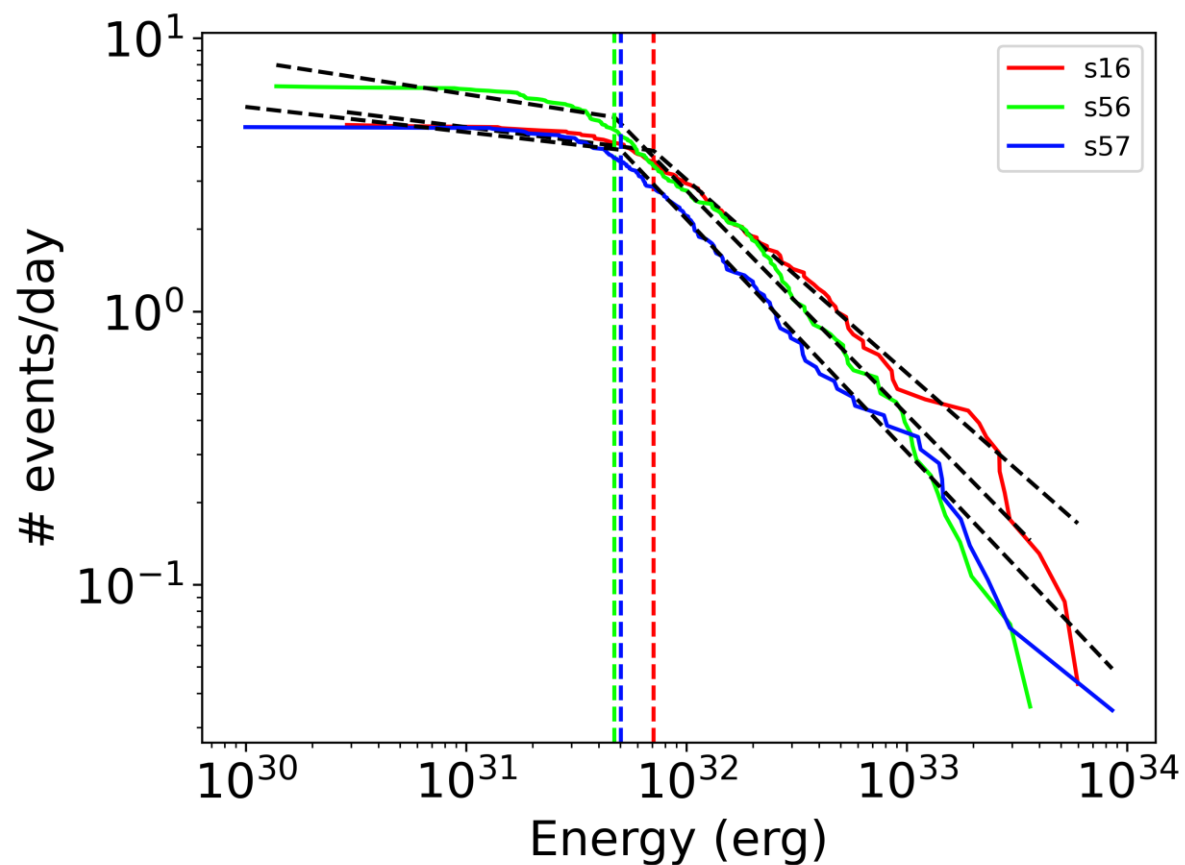


- We analyzed 173 M dwarfs within 10 parsecs
- A total of 751 TESS sectors
- We detected 17229 flares

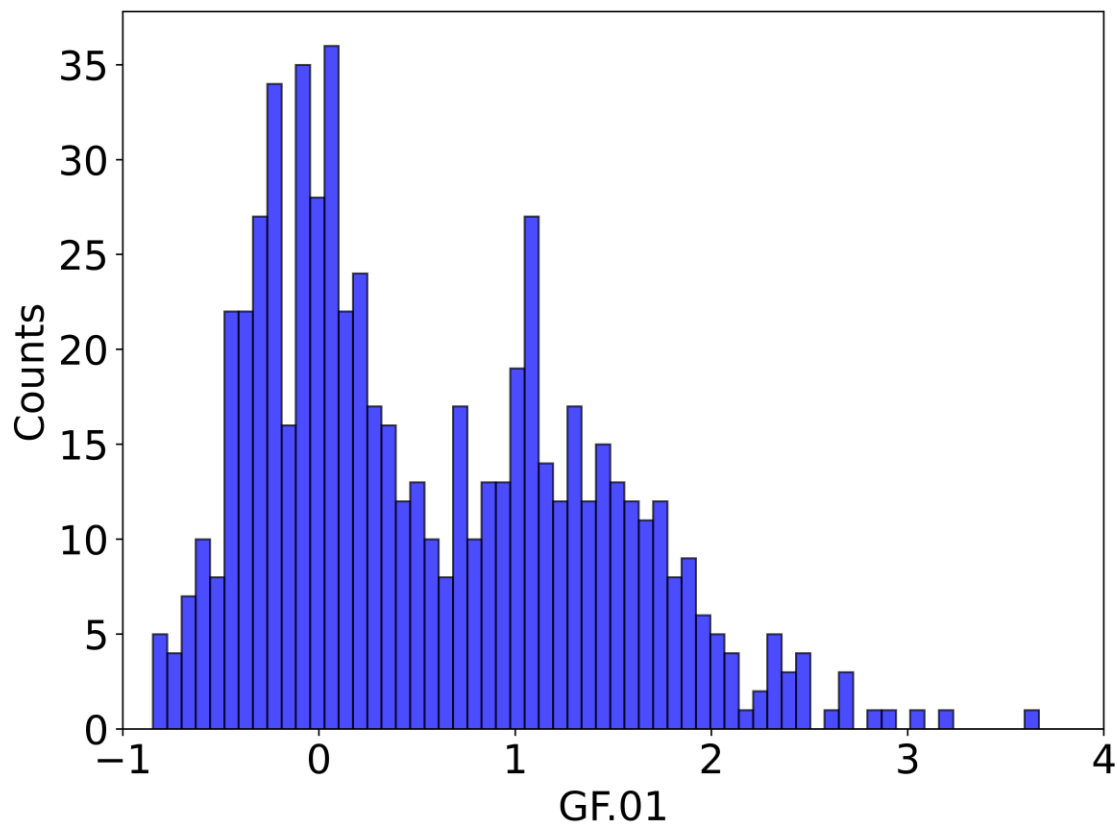
Method	Slopes mean $\pm$ std	# sectors
Two-segment fit	$-1.23 \pm 1.32$	651
One-segment fit	$-0.72 \pm 0.64$	100

# RESULTS – EV LAC

Cumulative frequency energy distributions



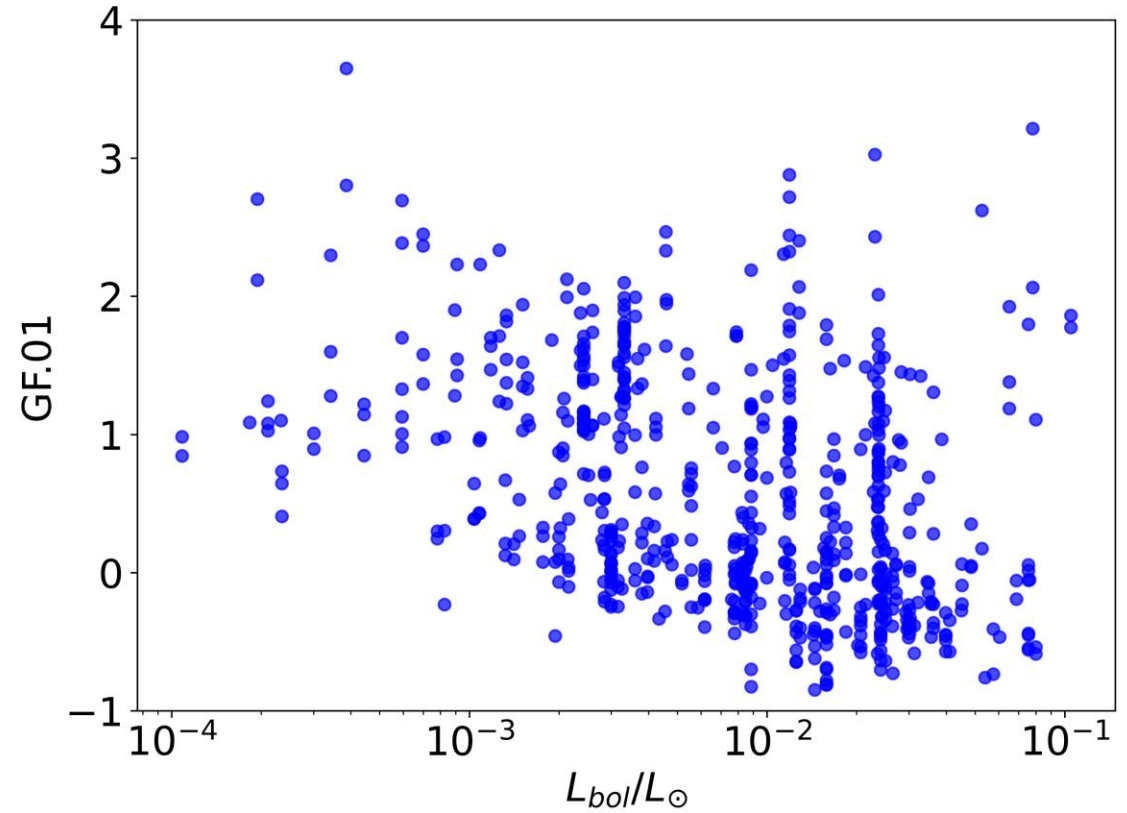
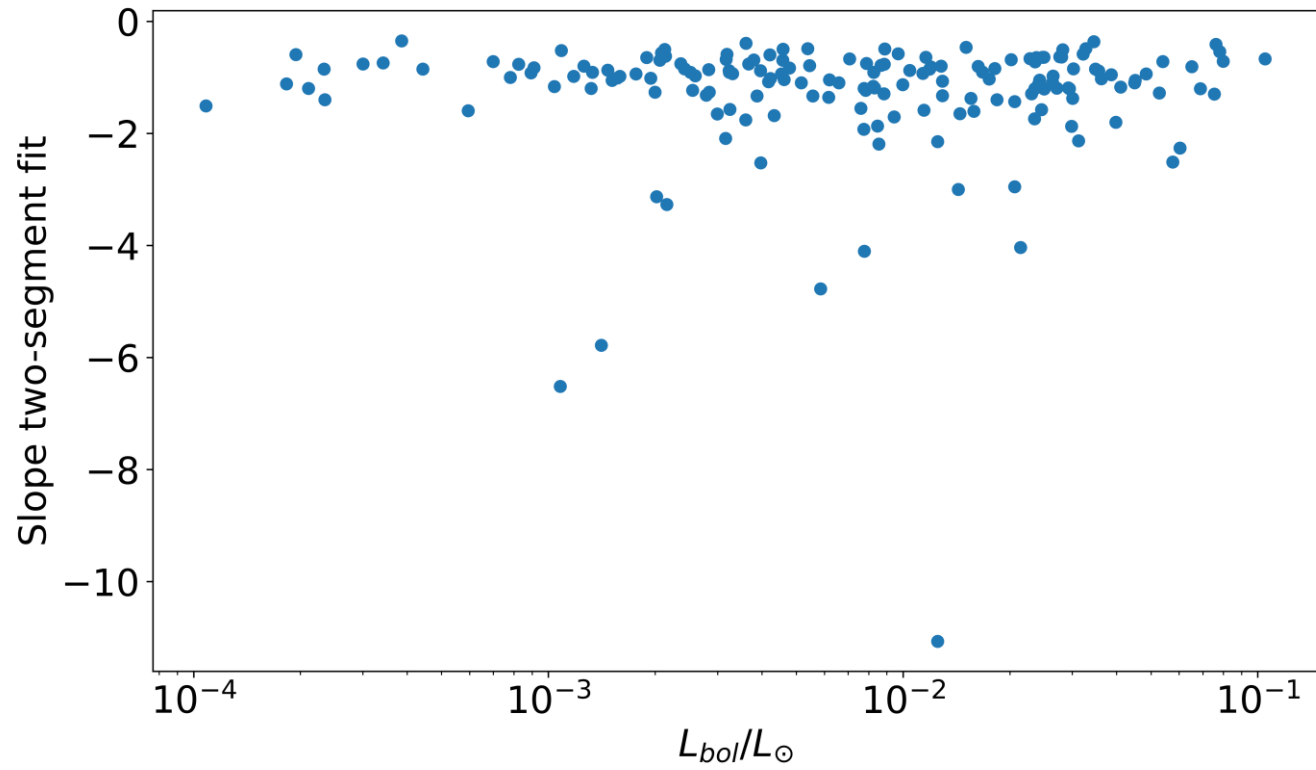
# RESULTS – GF.01



To quantify the activity we introduce GF.01:

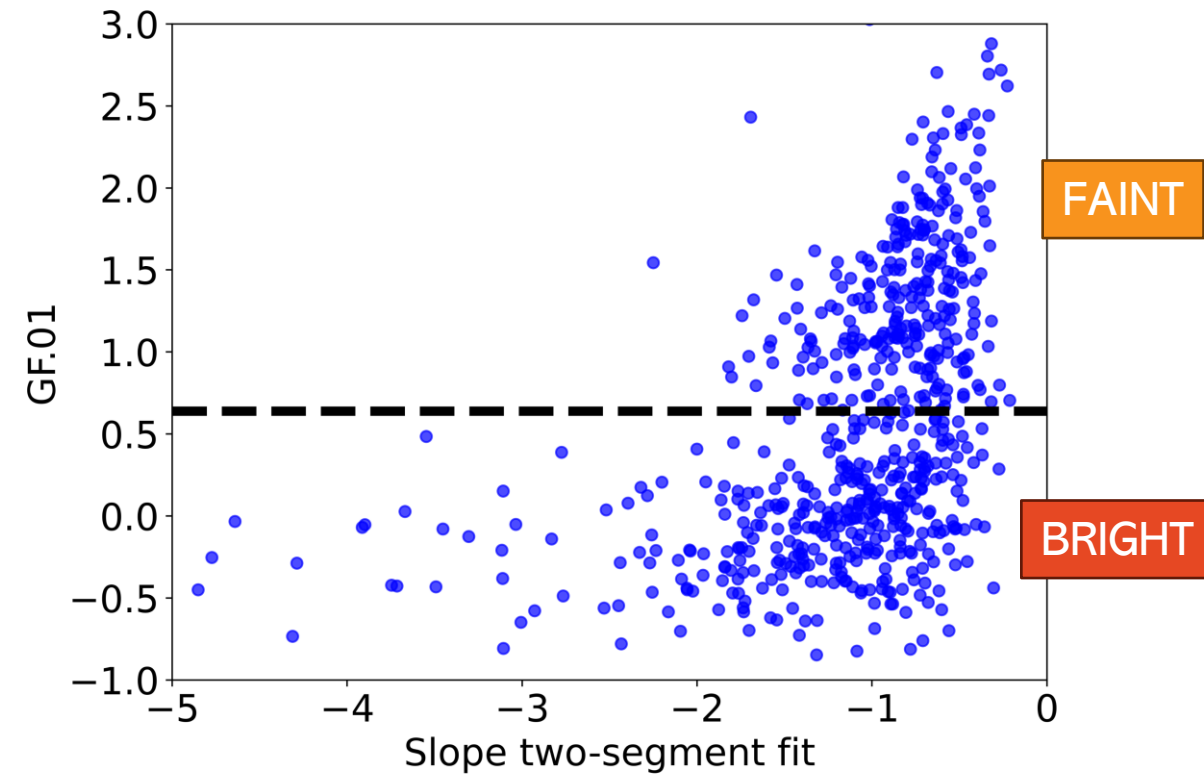
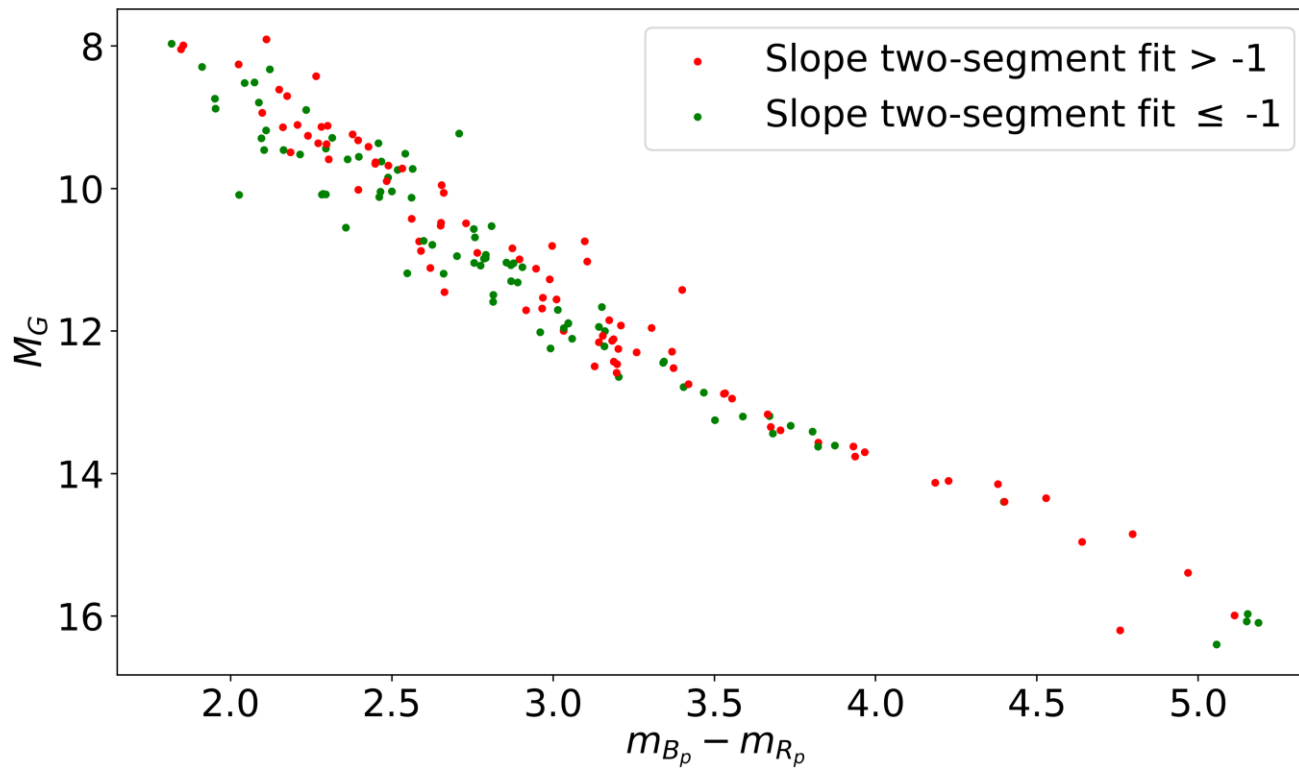
$$GF.01 = \frac{0.1 - q}{m} / L_{bol}$$

# RESULTS



# RESULTS

Flatter Slope  $> -1$   $\rightarrow$  Faint star  $\rightarrow$  High-energy flare dominated  
Steeper Slope  $\leq -1$   $\rightarrow$  Bright star  $\rightarrow$  Low-energy flare dominated



# CONCLUSIONS AND FUTURE WORKS



Activity of faint stars is dominated by a small number of high-energy flares



Activity of bright stars is dominated by a large number of low-energy flares



Apply the analysis to stars with and without planets



Apply the analysis to the MAUVE and ARIEL target list



**THANKS FOR THE ATTENTION!**