Flares from Kepler:

an Empirical Flare Template
from the M dwarf GJ 1243

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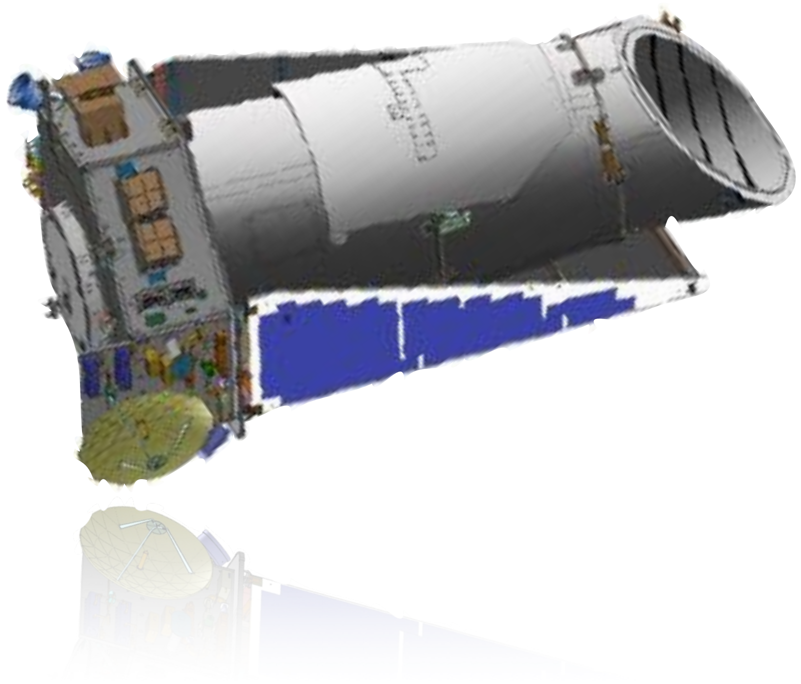
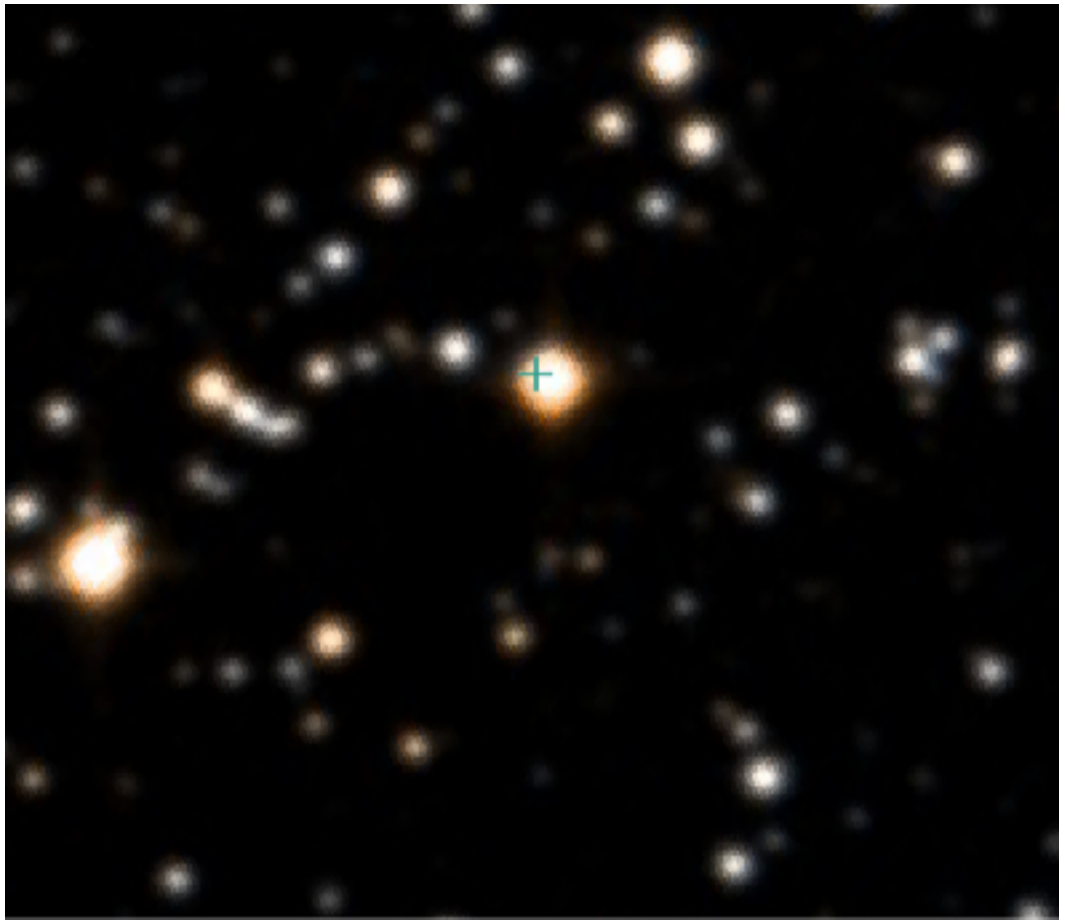
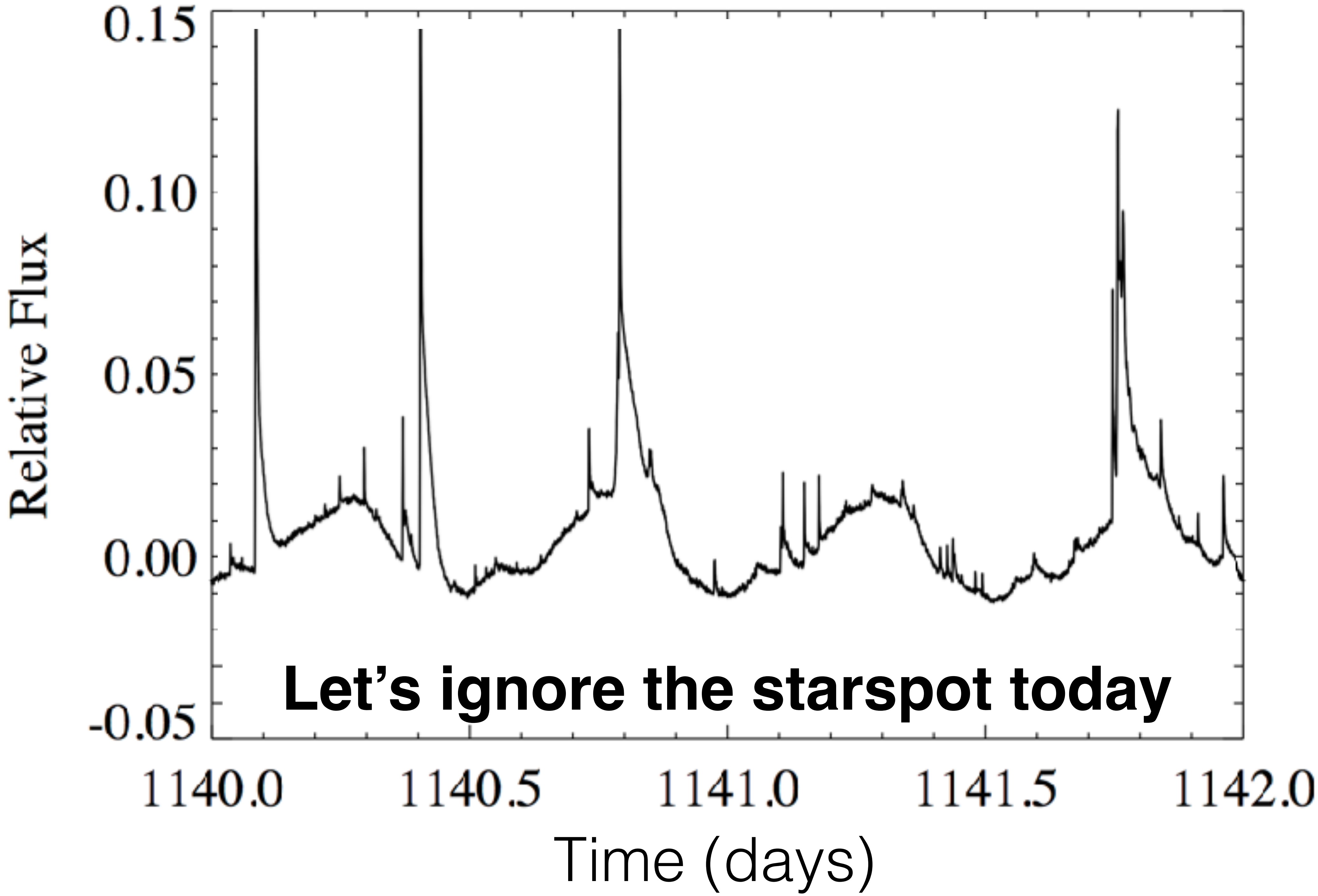
GJ 1243, M4





GJ 1243, M4

P_{rot}=0.59 days, ~300days 1-min data



Davenport et al. (2014)

GJ 1243, M4

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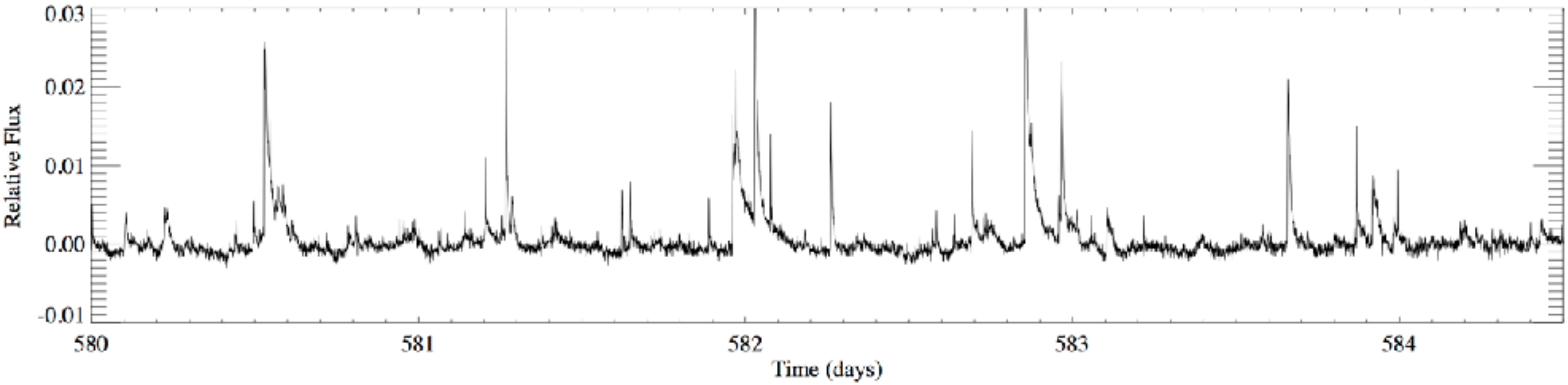
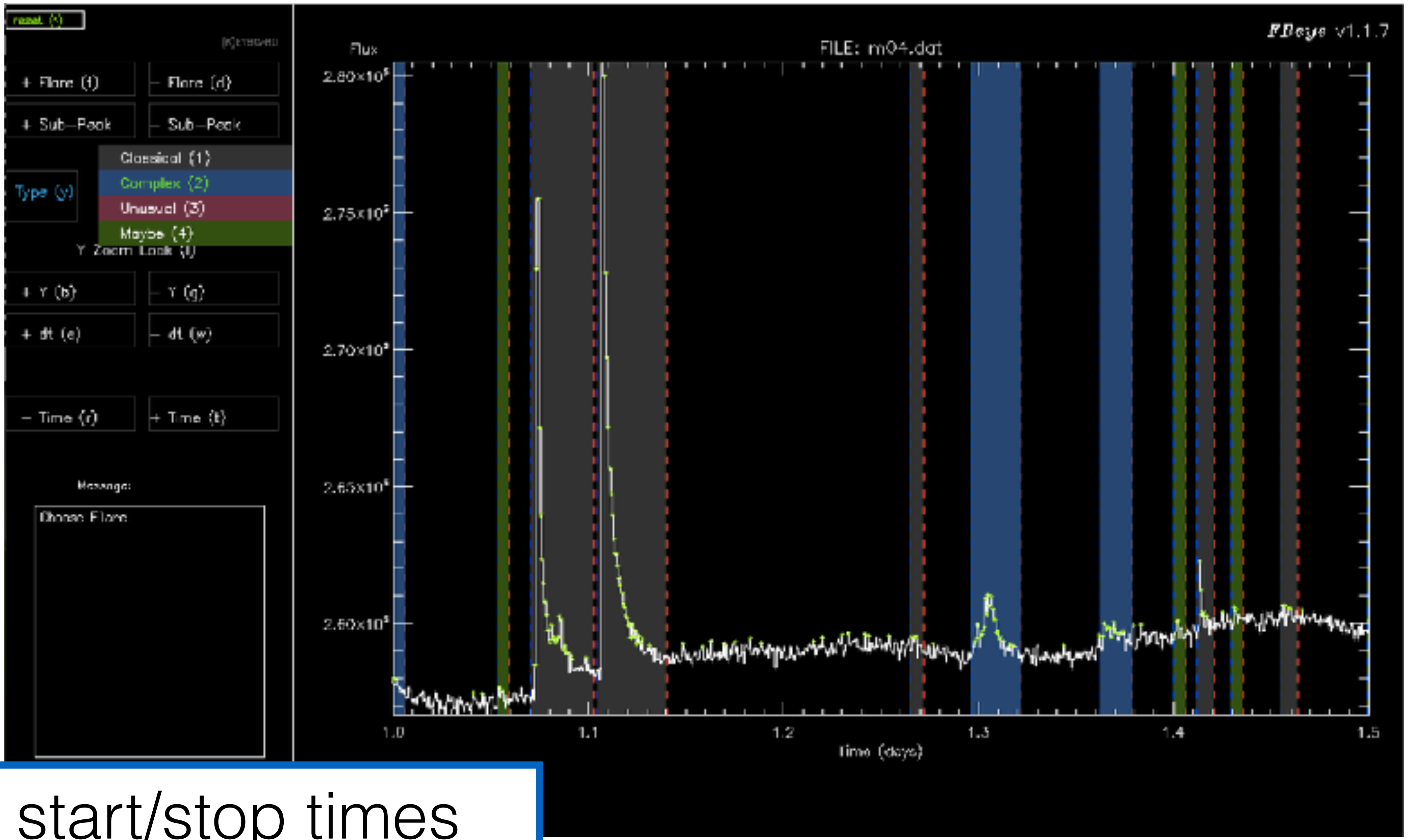


starspot removed with median

Flares By EYE (FBEYE)

IDL code

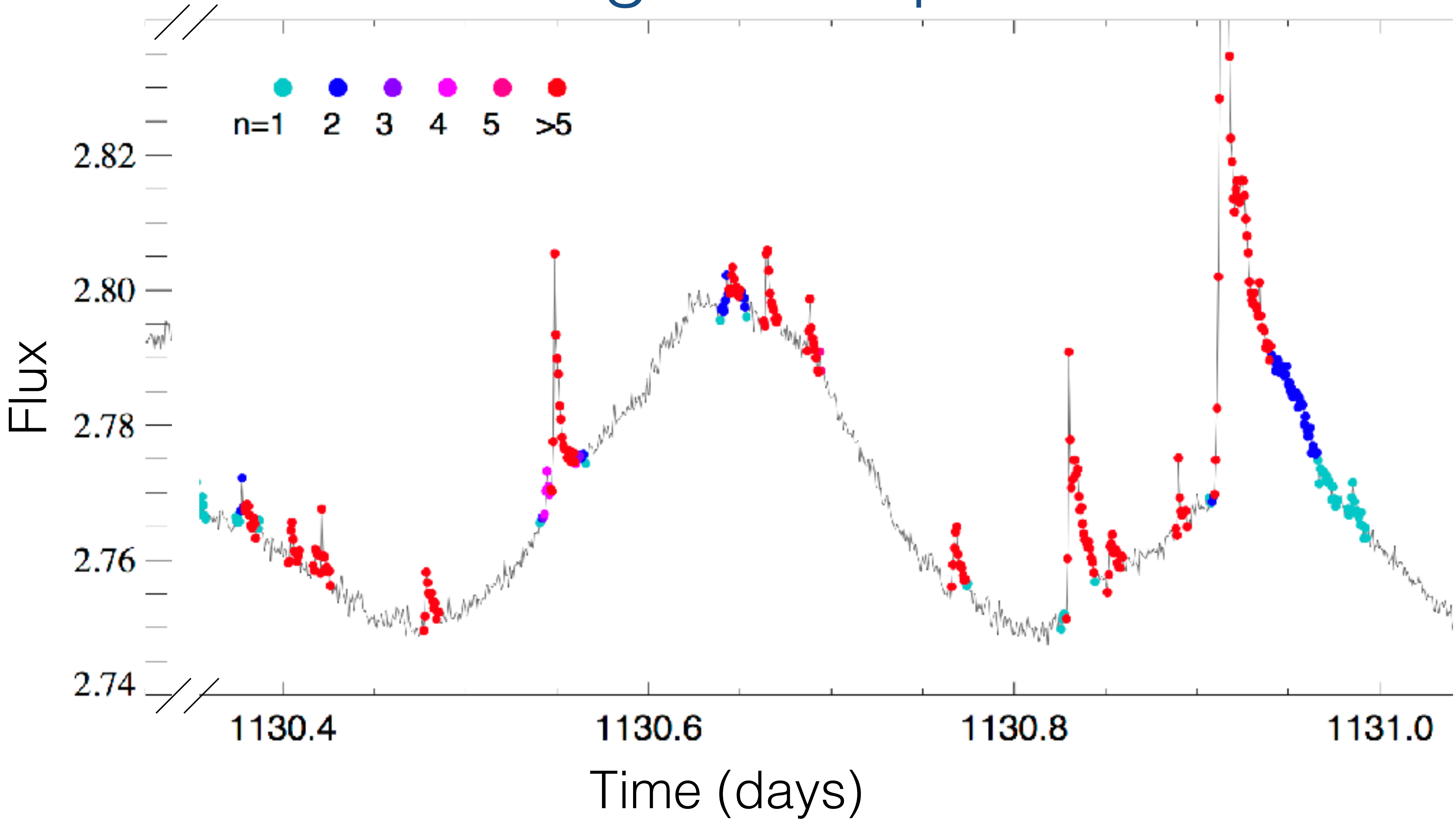


- Pick flare start/stop times
- Assign classifications
- Help train "autofinder"

github.com/jradavenport/FBeye

Davenport et al. (2014)

Interesting to compare users



Davenport et al. (2014)

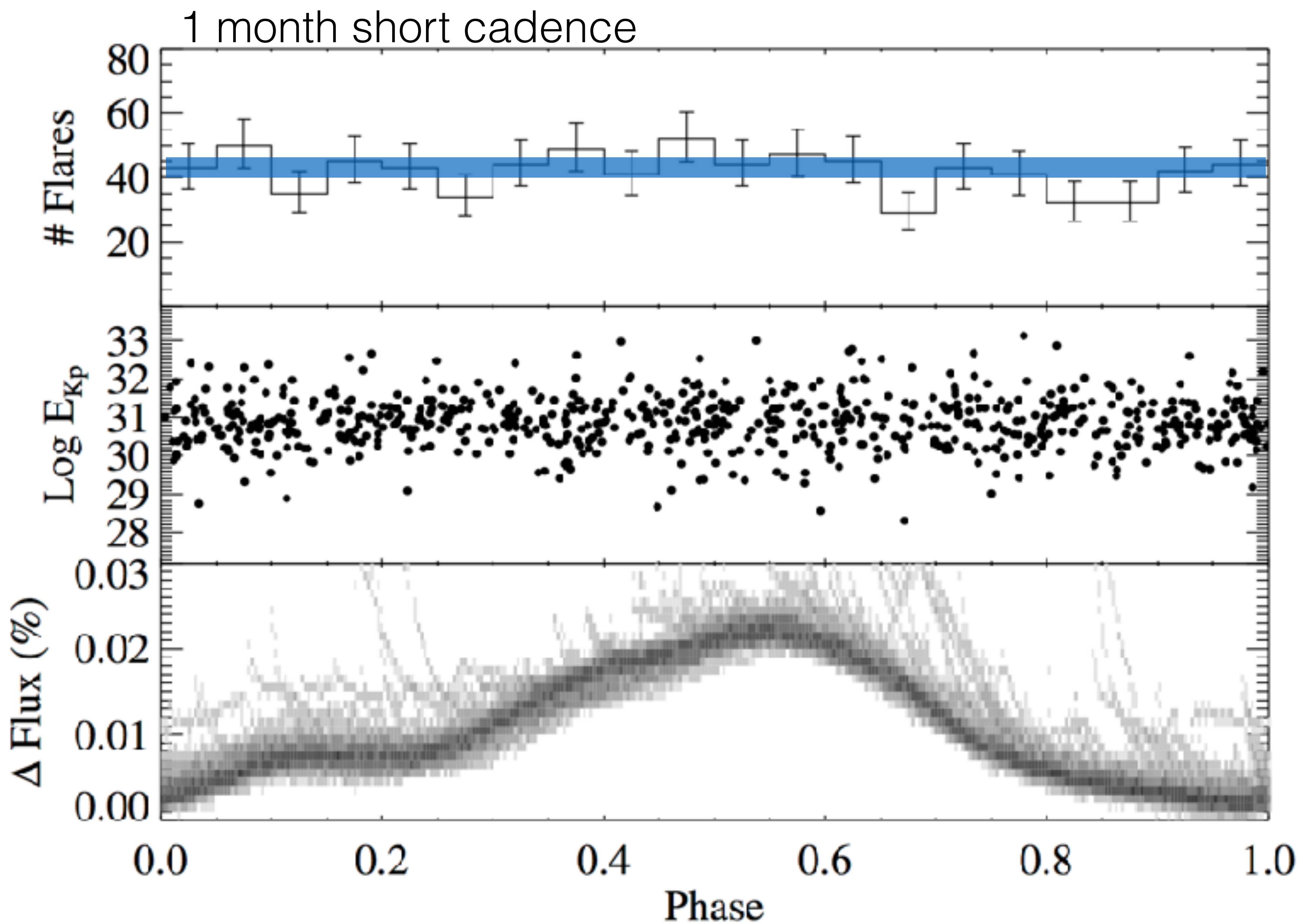
Large Flare Sample!

- **6107 unique flares**, spanning 300 days of data
  most for any star, besides the Sun!
- 15% flares are "complex"
  higher % for large energy flares
- wide energy range: Log E = 28-33 erg
  large solar flares around 1E32 erg

Hawley et al. (2014)

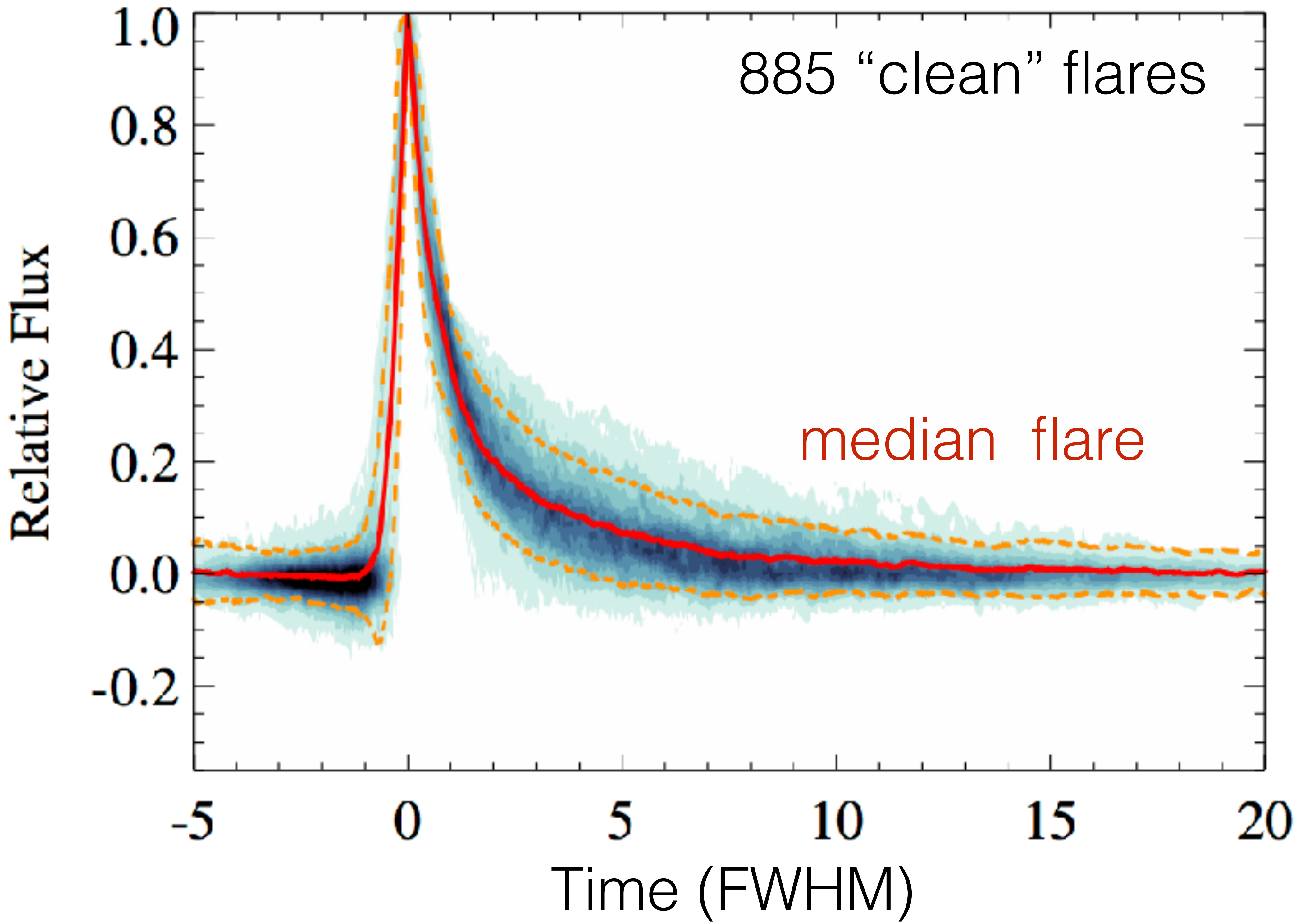
Davenport et al. (2014)

No correlation between flares & starspot



Hawley et al. (2014)

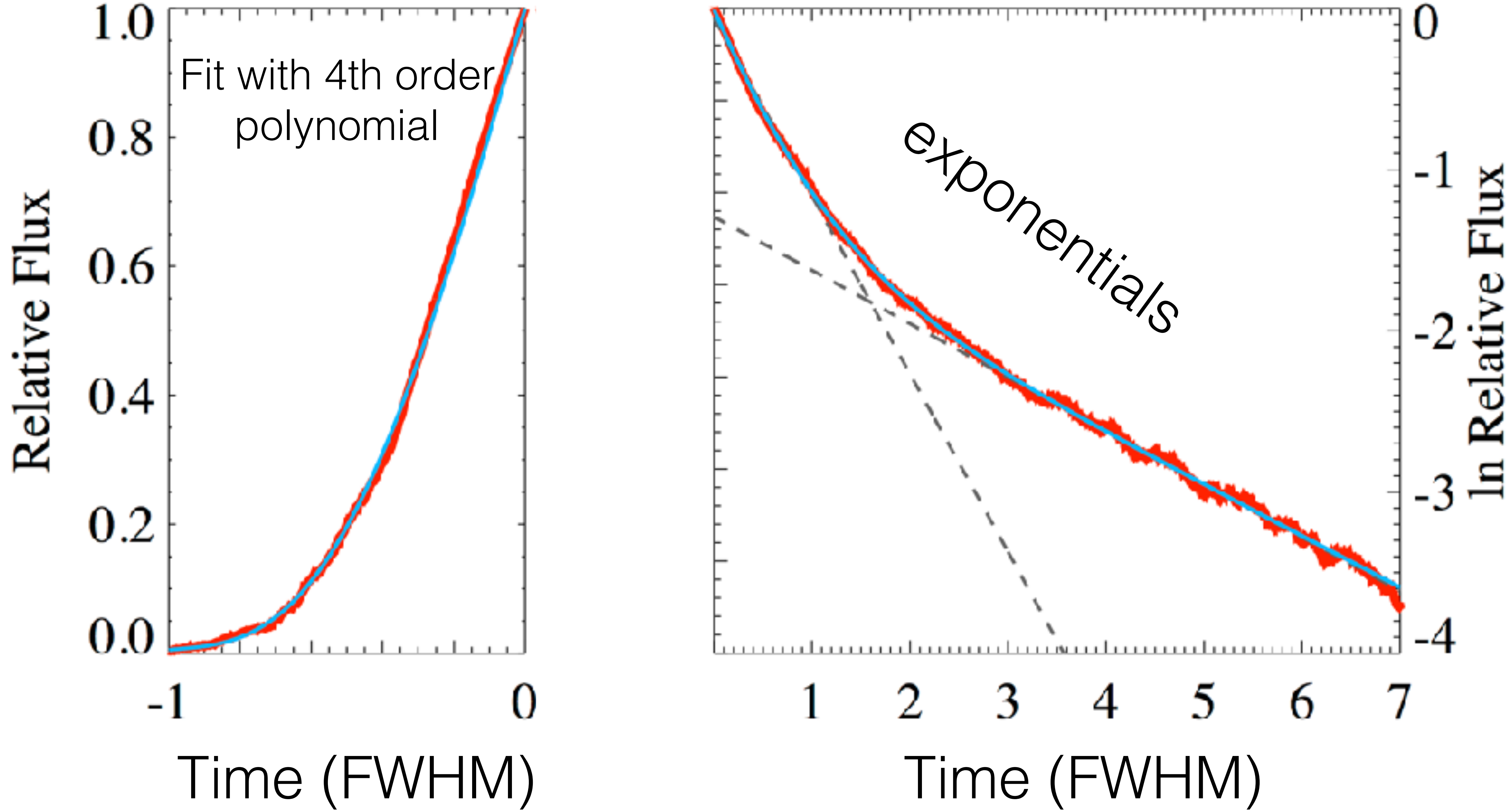
Flare Template: Study Morphology



Davenport et al. (2014)

Rise Phase

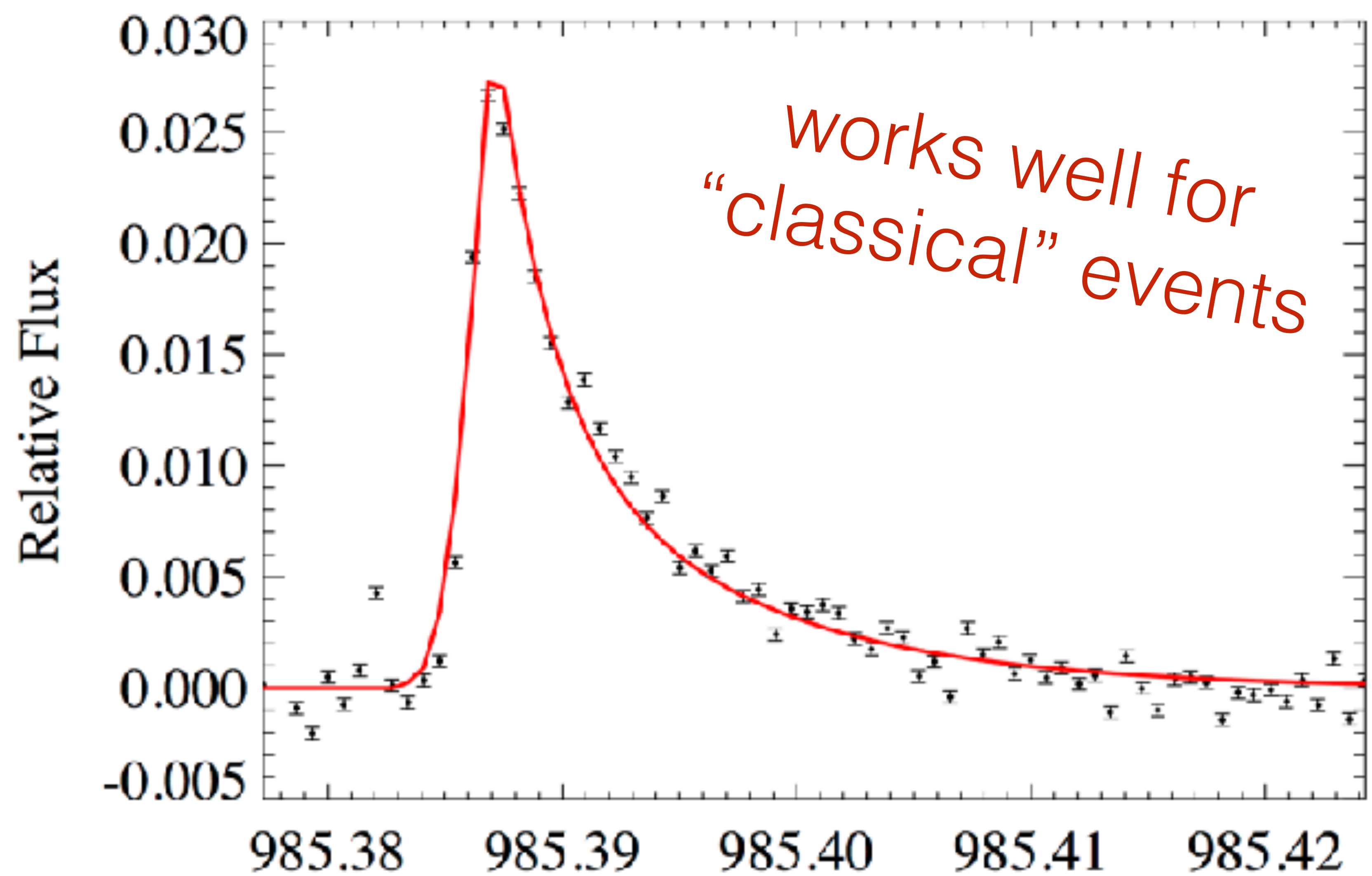
2 Decay Phases



<u>Energy budget:</u>
rise=20%,
decay1=41%,
decay2=39%

Davenport et al. (2014)

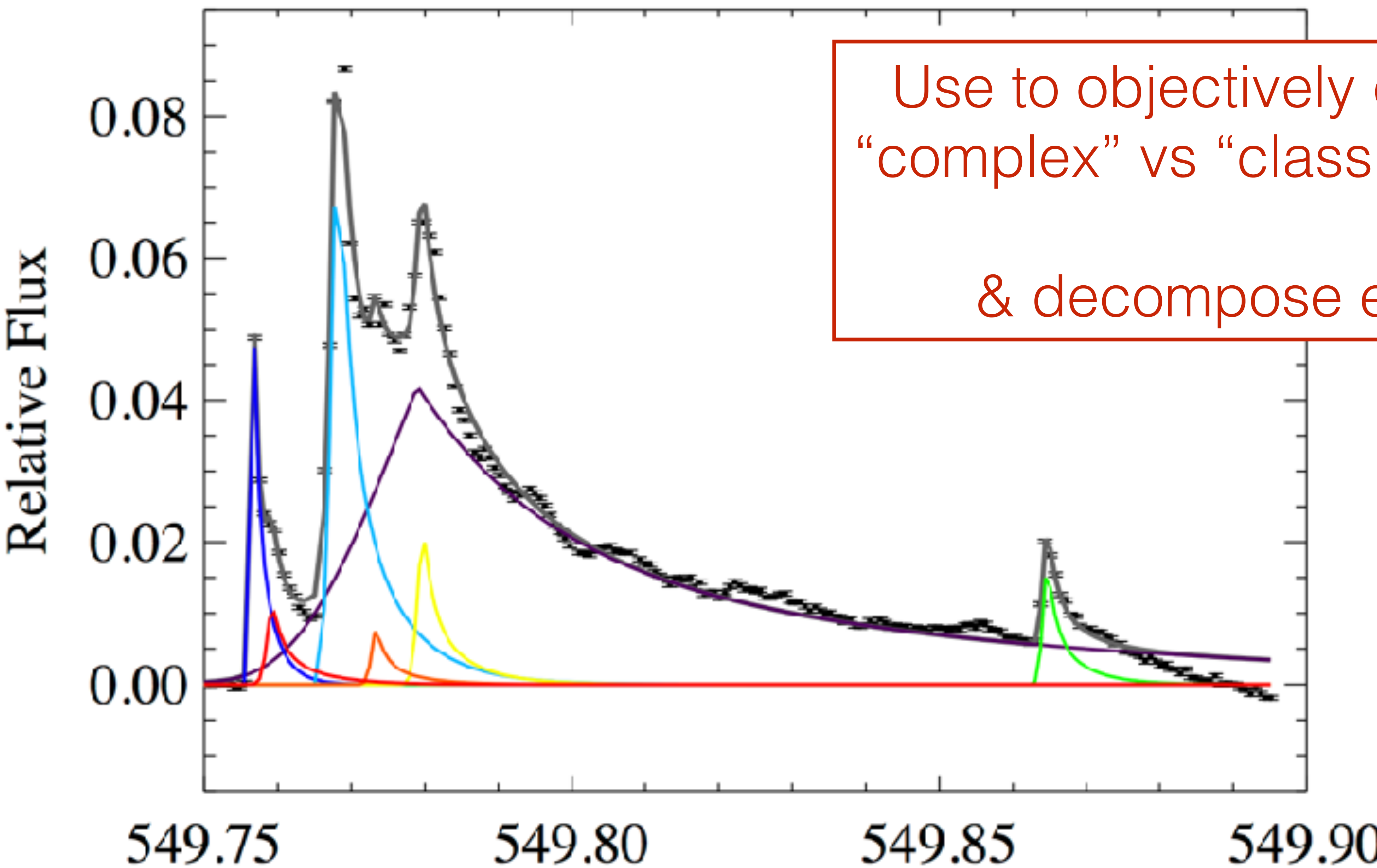
Flare Fitting



Time (days)

Davenport et al. (2014)

Complex Flare Fitting



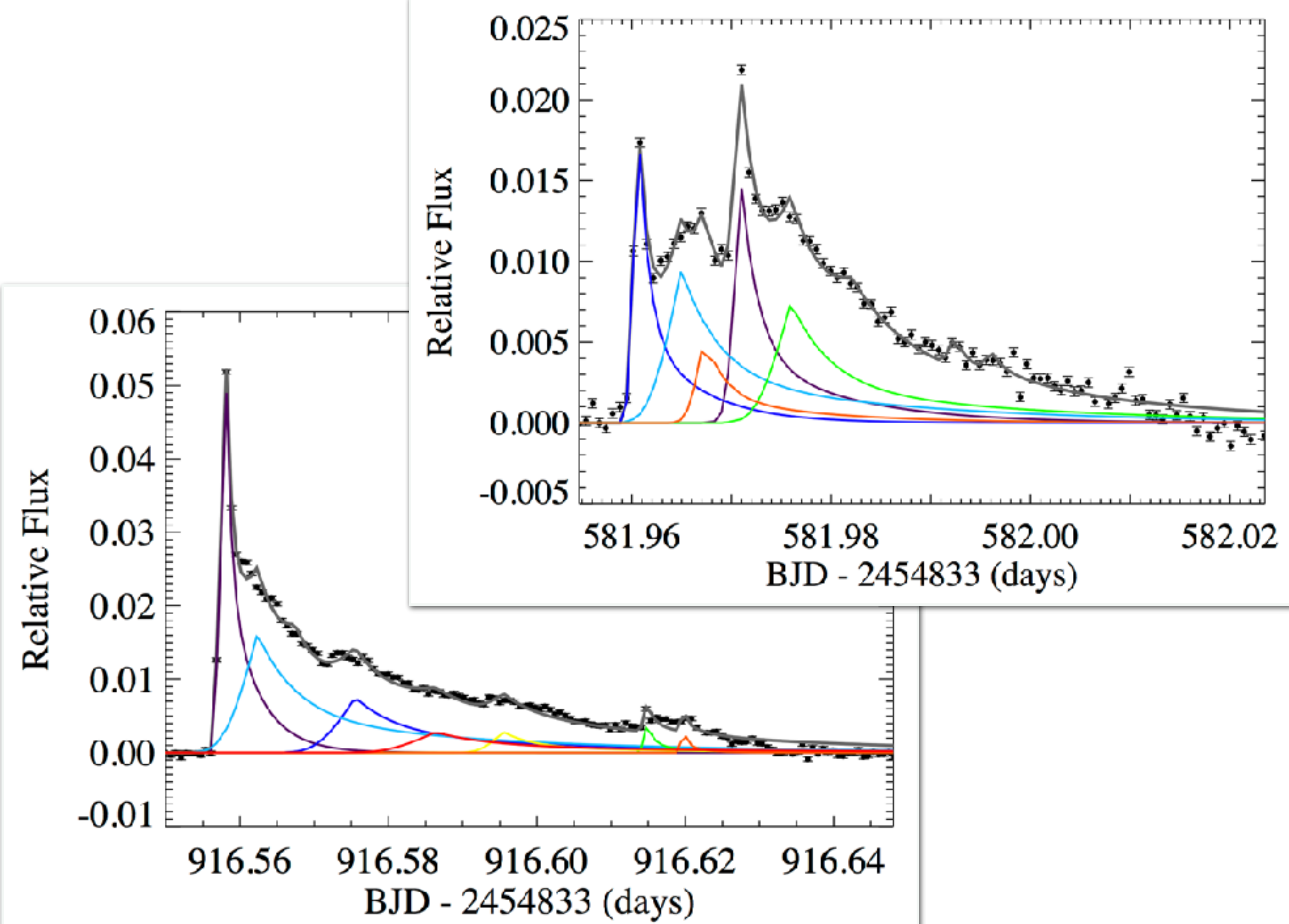
Time (days)

Use to objectively determine "complex" vs "classical" events

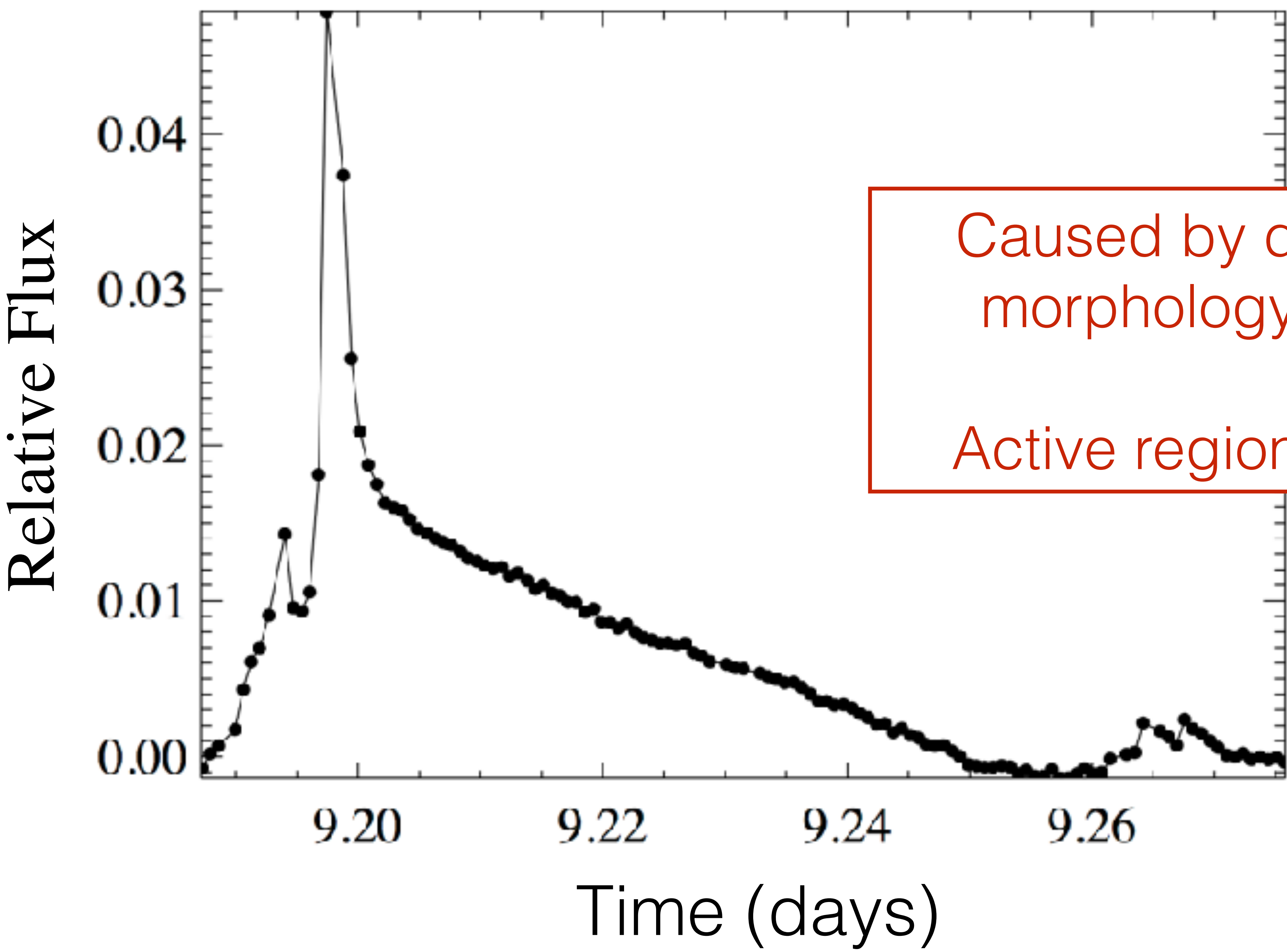
& decompose events!

Maybe one of the flares in Pugh+2015?

Davenport et al. (2014)


0.025
0.020
0.015
0.010
0.005
0.000
-0.005
Relative Flux
581.96
581.98
582.00
582.02
BJD - 2454833 (days)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
Relative Flux
916.56
916.58
916.60
916.62
916.64
BJD - 2454833 (days)

Some flares *not* well fit by template

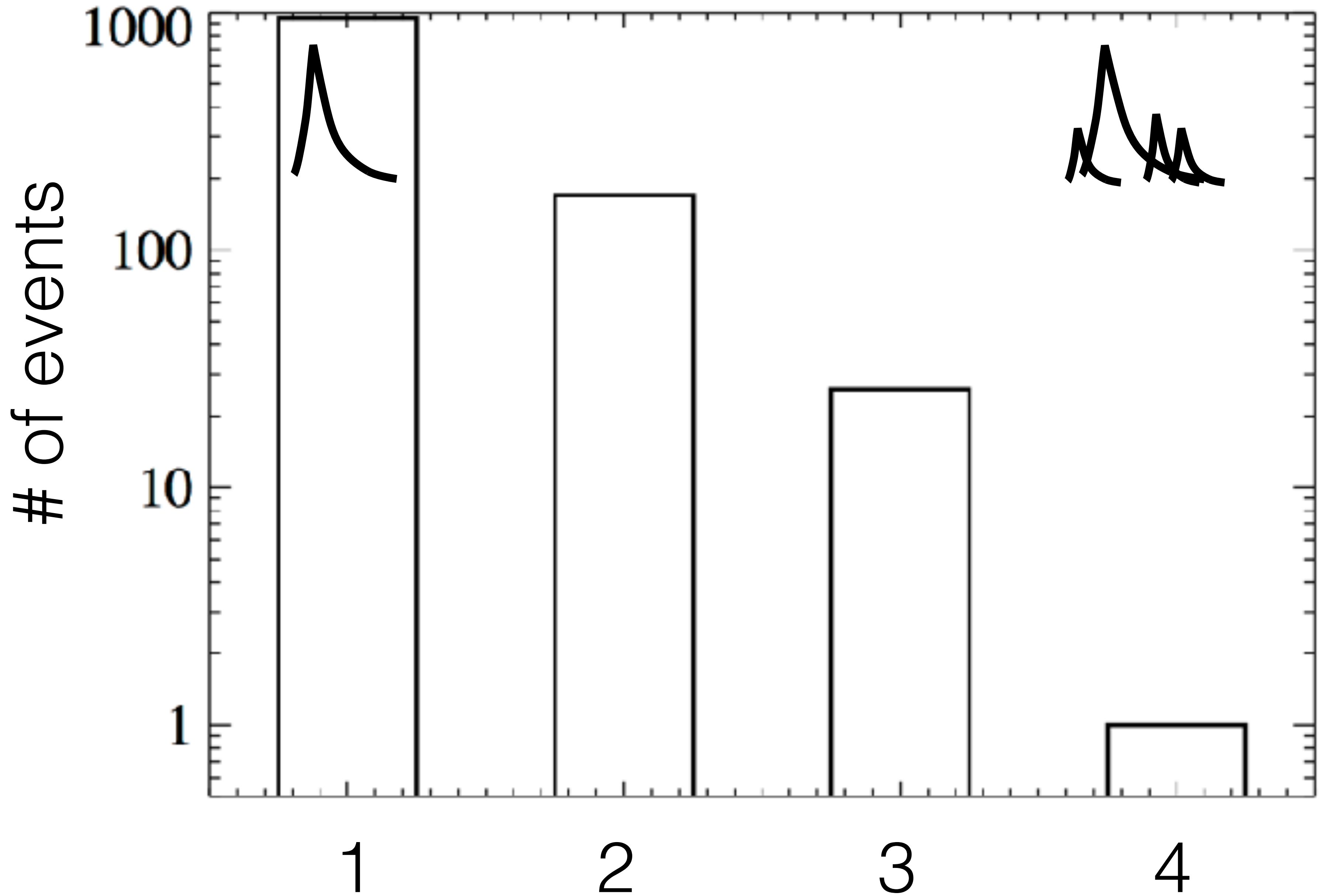


Caused by different physical morphology (e.g. arcade)?

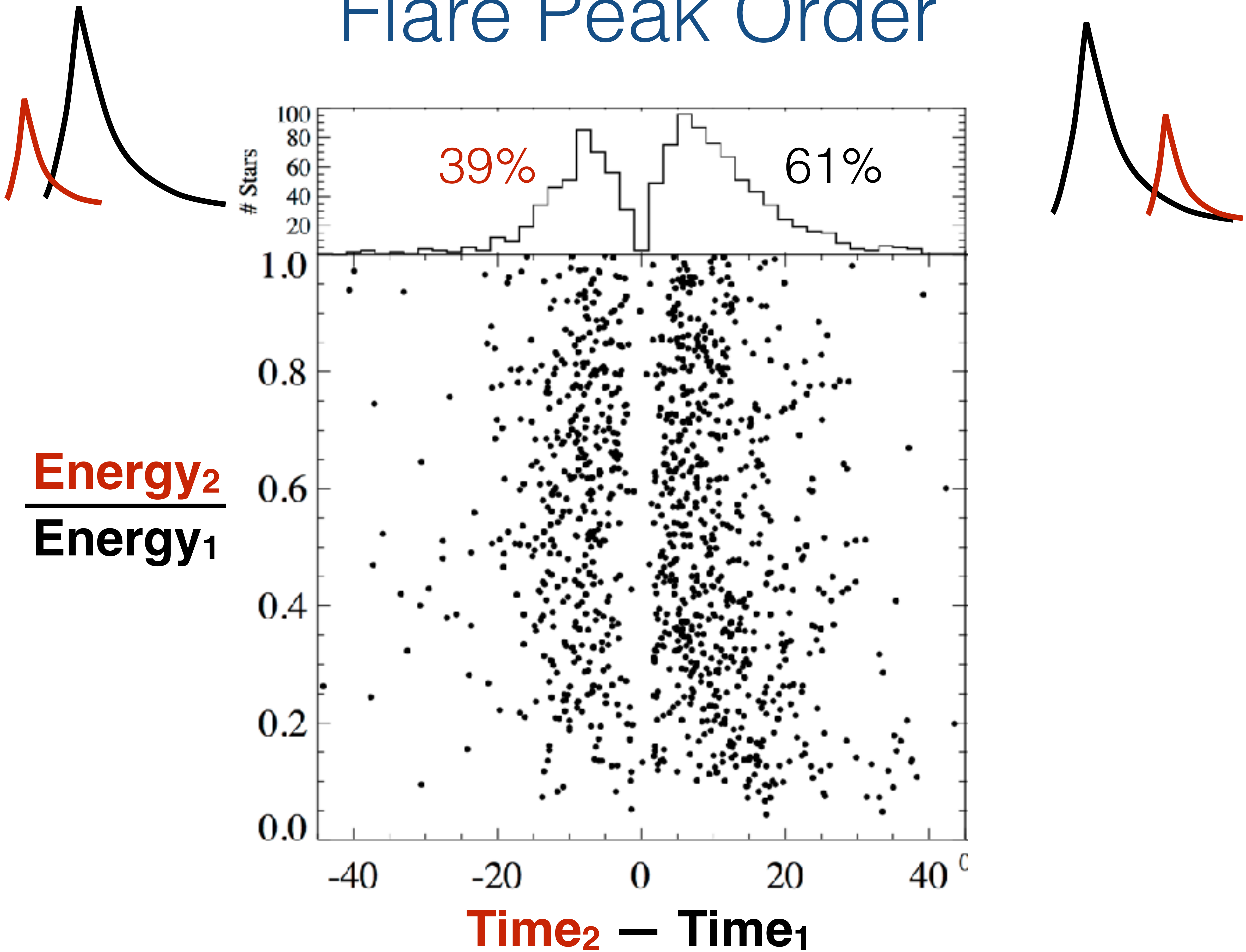
Active region rolling off limb?

Davenport et al. (2014)

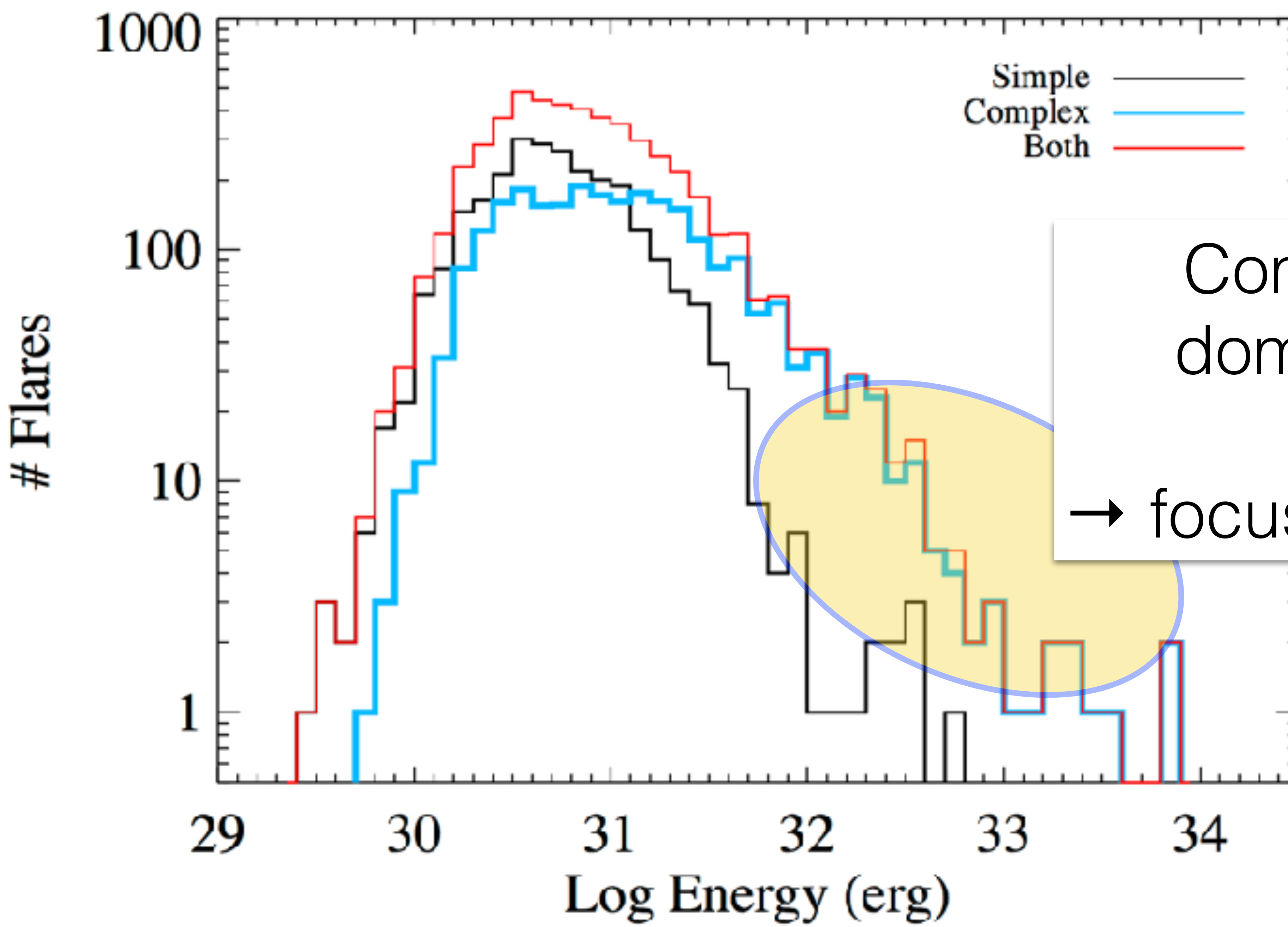
of Flare Components



Flare Peak Order

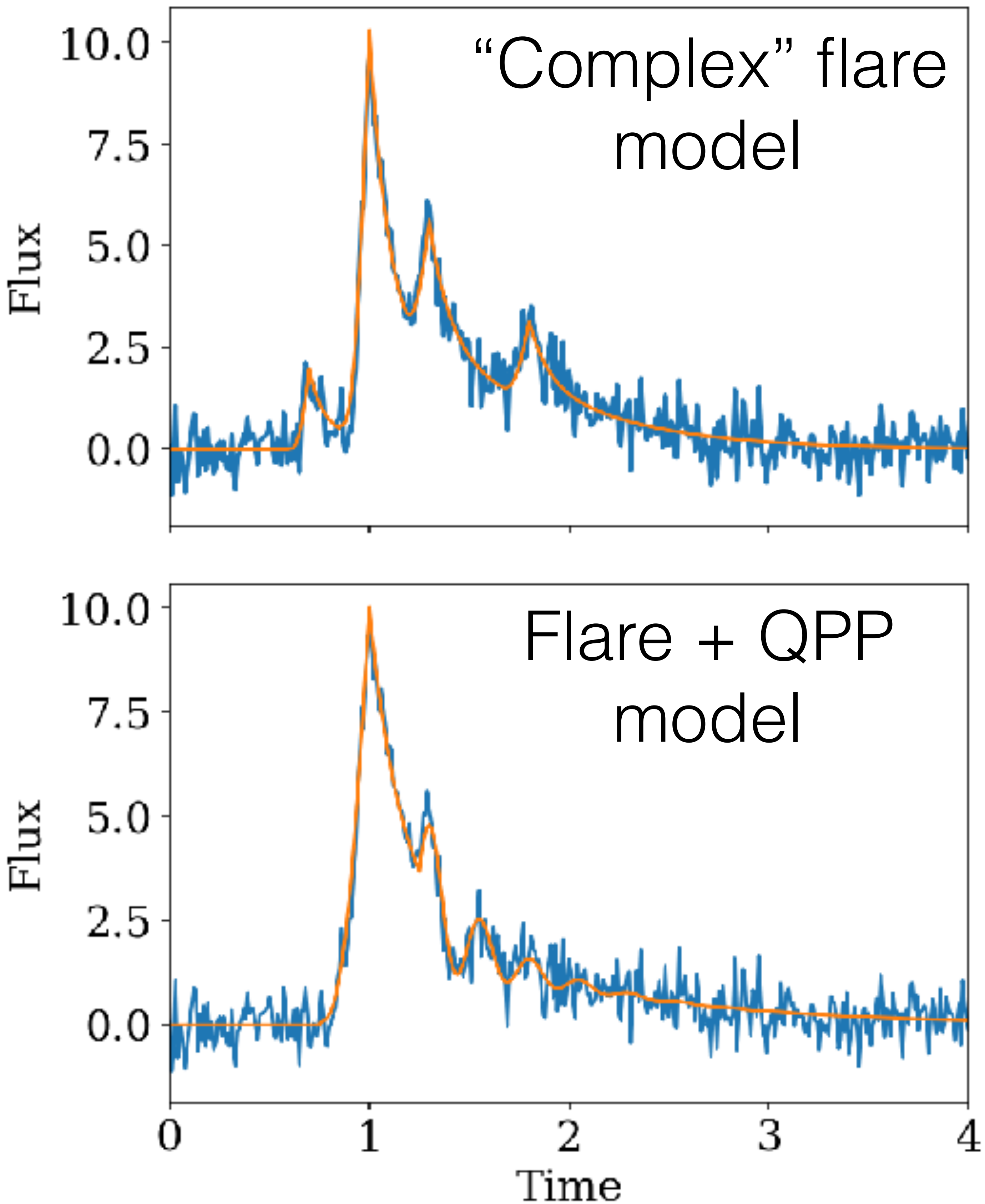


Flare Energy Distribution



Complex events dominate at high

→ focus for QPP search



For GJ 1243, I’m not sure we can tell the difference…
too *many* flares!

As Christoffer Karoff said in introduction

But: are there extreme/edge cases where each model is very clear?

Some new(ish) work

THE KEPLER CATALOG OF STELLAR FLARES

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[2]NSF Astronomy and Astrophysics Postdoctoral Fellow

ABSTRACT

A homogeneous search for stellar flares has been performed using every available *Kepler* light curve. An iterative light curve de-trending approach was used to filter out both astrophysical and systematic variability to detect flares. The flare recovery completeness has also been computed throughout each light curve using artificial flare injection tests, and the tools for this work have been made publicly available. The final sample contains 851,168 candidate flare events recovered above the 68% completeness threshold, which were detected from 4041 stars, or 1.9% of the stars in the *Kepler* database. The average flare energy detected is $\sim 10^{35}$ erg. The net fraction of flare stars increases with $g-i$ color, or decreasing stellar mass. For stars in this sample with previously measured rotation periods, the total relative flare luminosity is compared to the Rossby number. A tentative detection of flare activity saturation for low-mass stars with rapid rotation below a Rossby number of ~0.03 is found. A power law decay in flare activity with Rossby number is found with a slope of -1, shallower than typical measurements for X-ray activity decay with Rossby number.

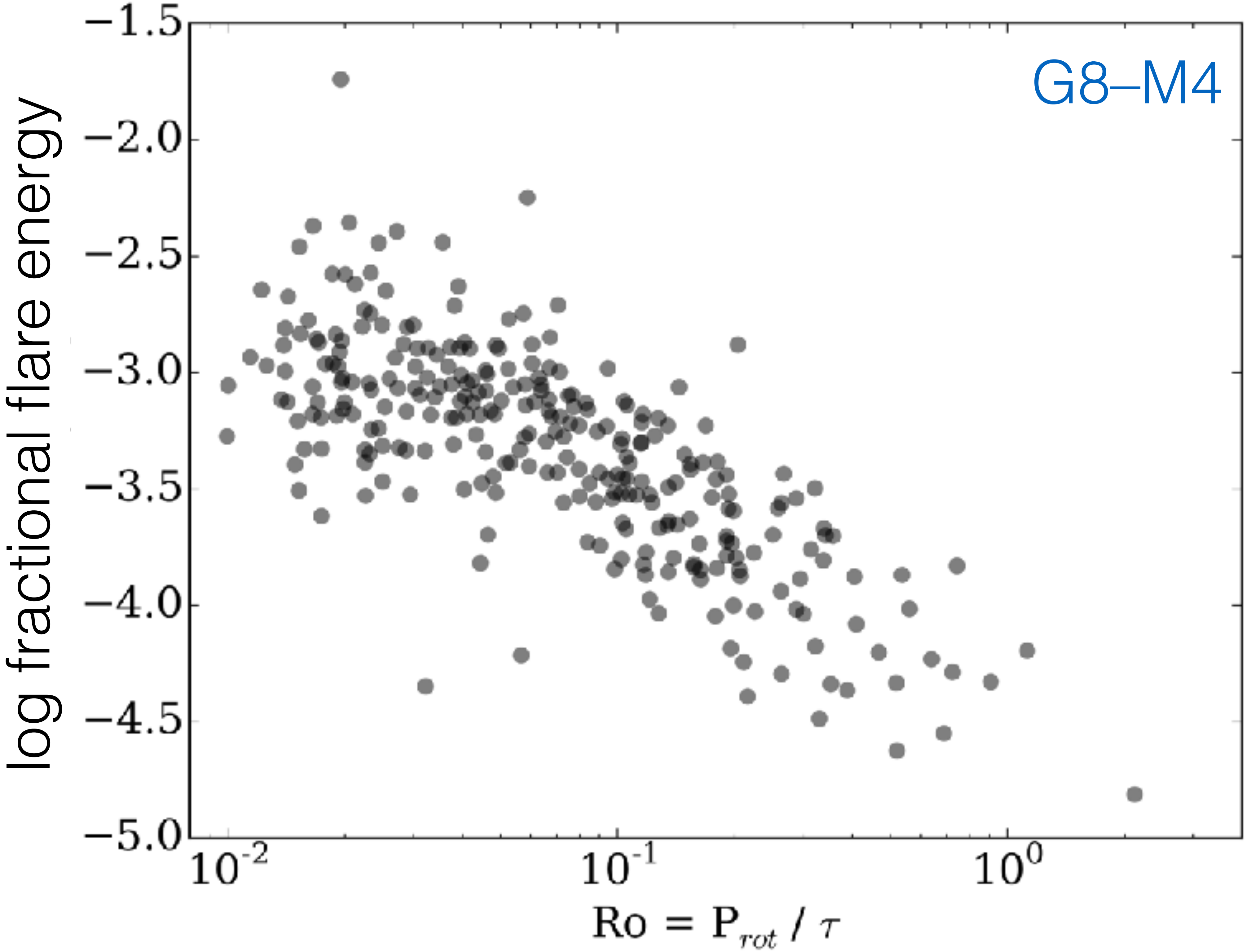
1. INTRODUCTION

Flares occur on nearly all main sequence stars with outer convective envelopes as a generic result of mag-

as a means for constraining the age of field stars (e.g. Parsamyan 1976, 1995).

The duration of a star's life that it produces frequent large spots and flares may dramatically affect planetary,

Flare Activity vs. Rossby Number



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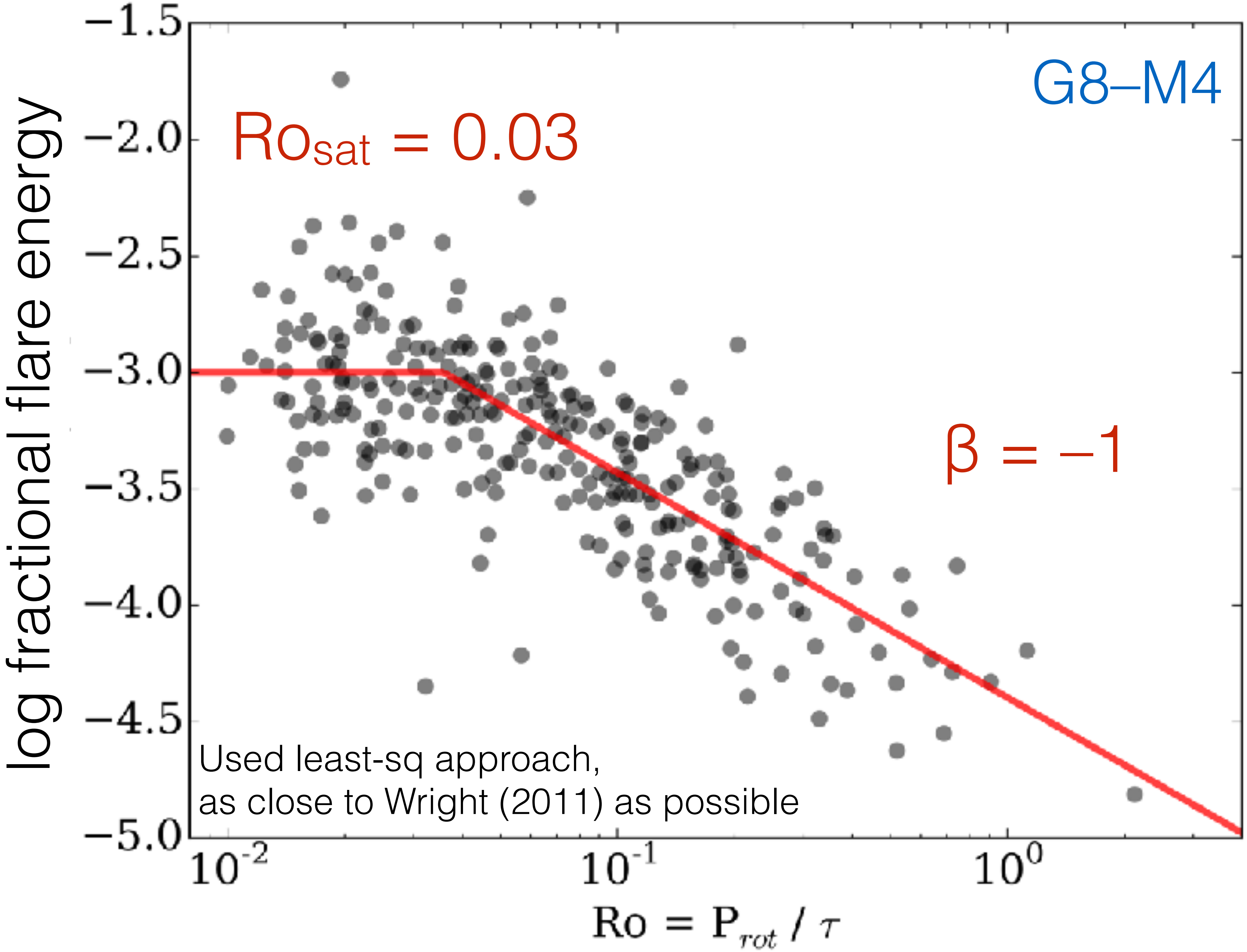
Flare Activity vs. Rossby Number



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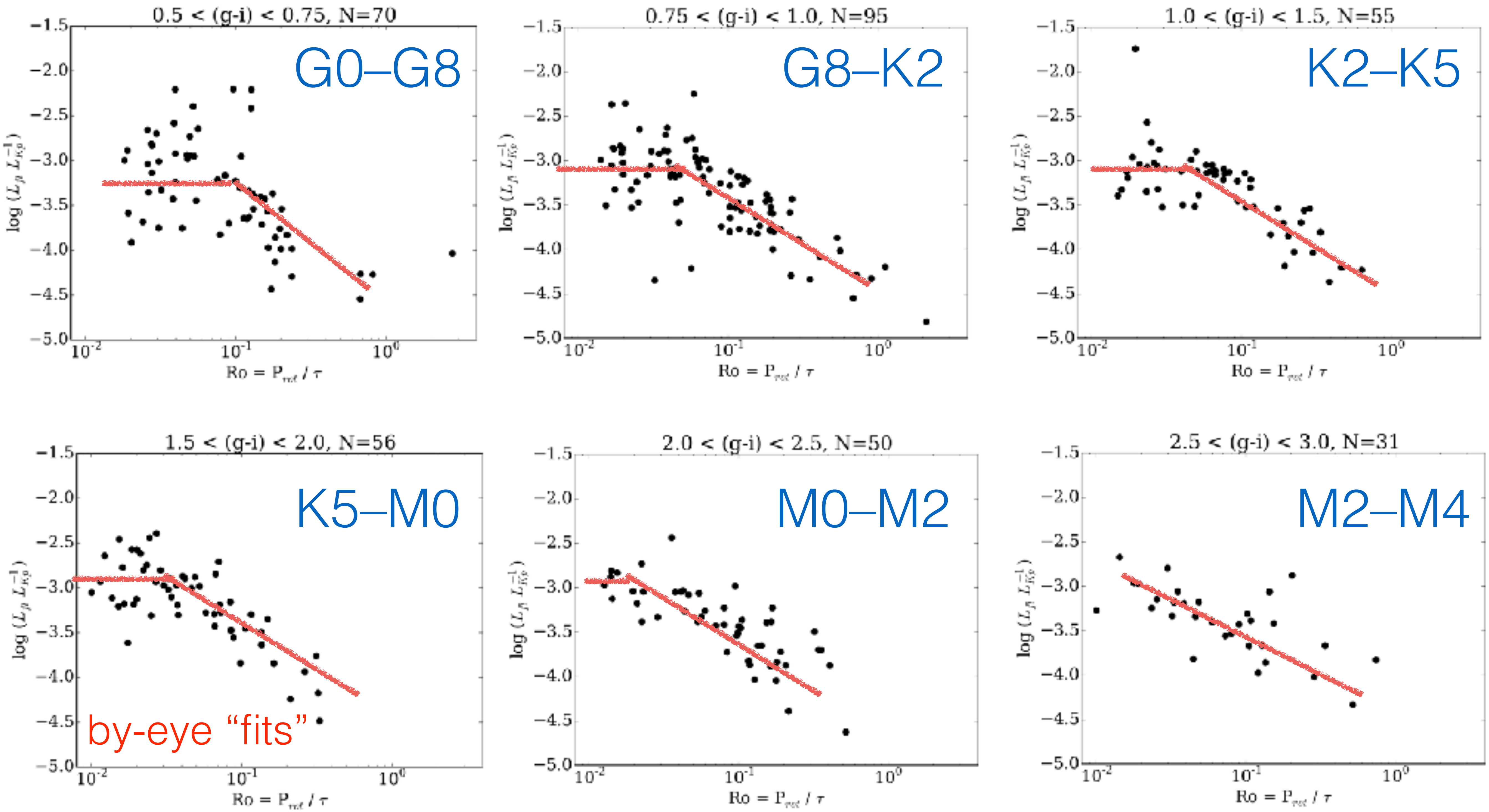
Evolution with Spectral Type?



Work in Progress: Flare(t,M)

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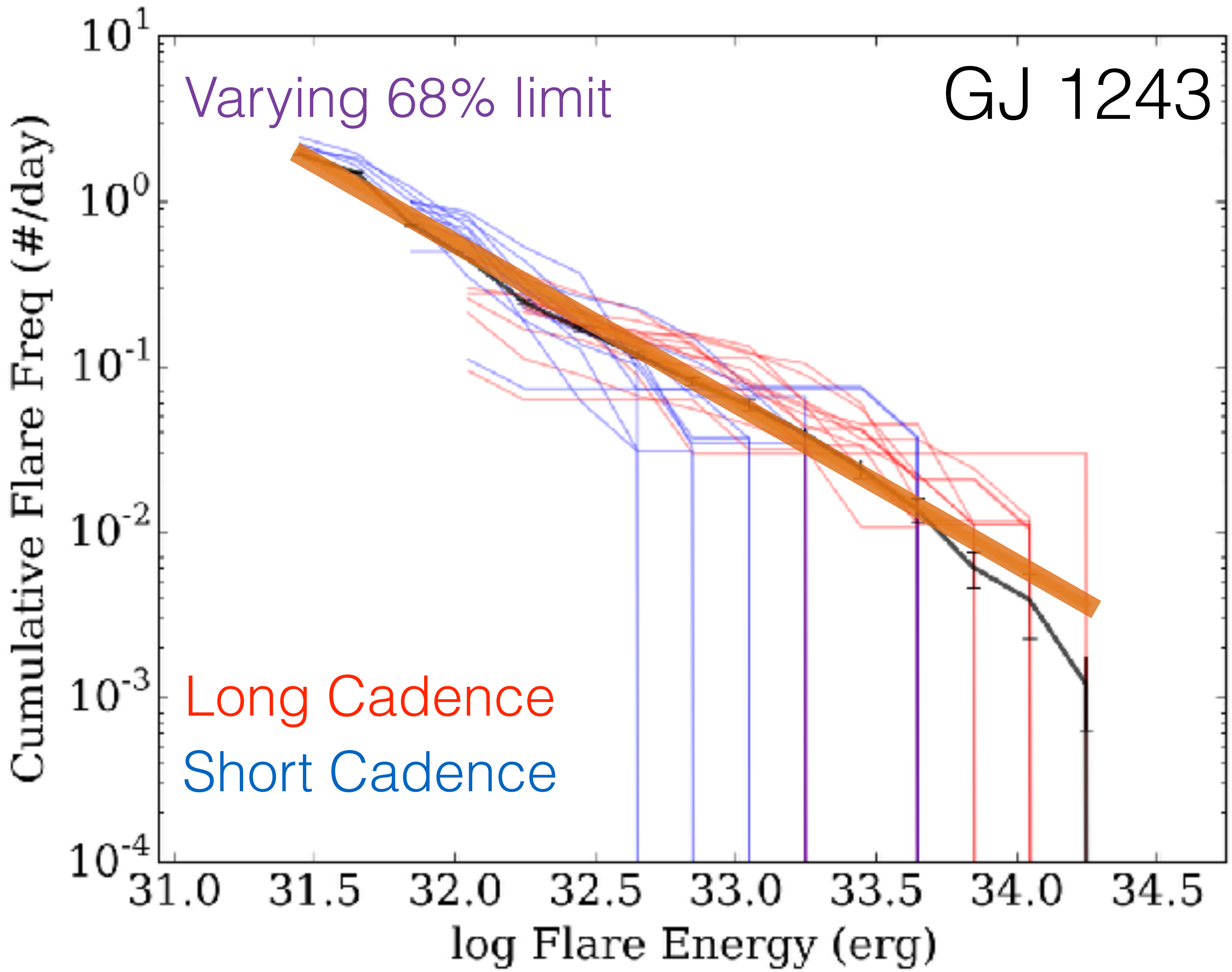
Flare Frequency Distribution - Power law

Automated & Human agree well



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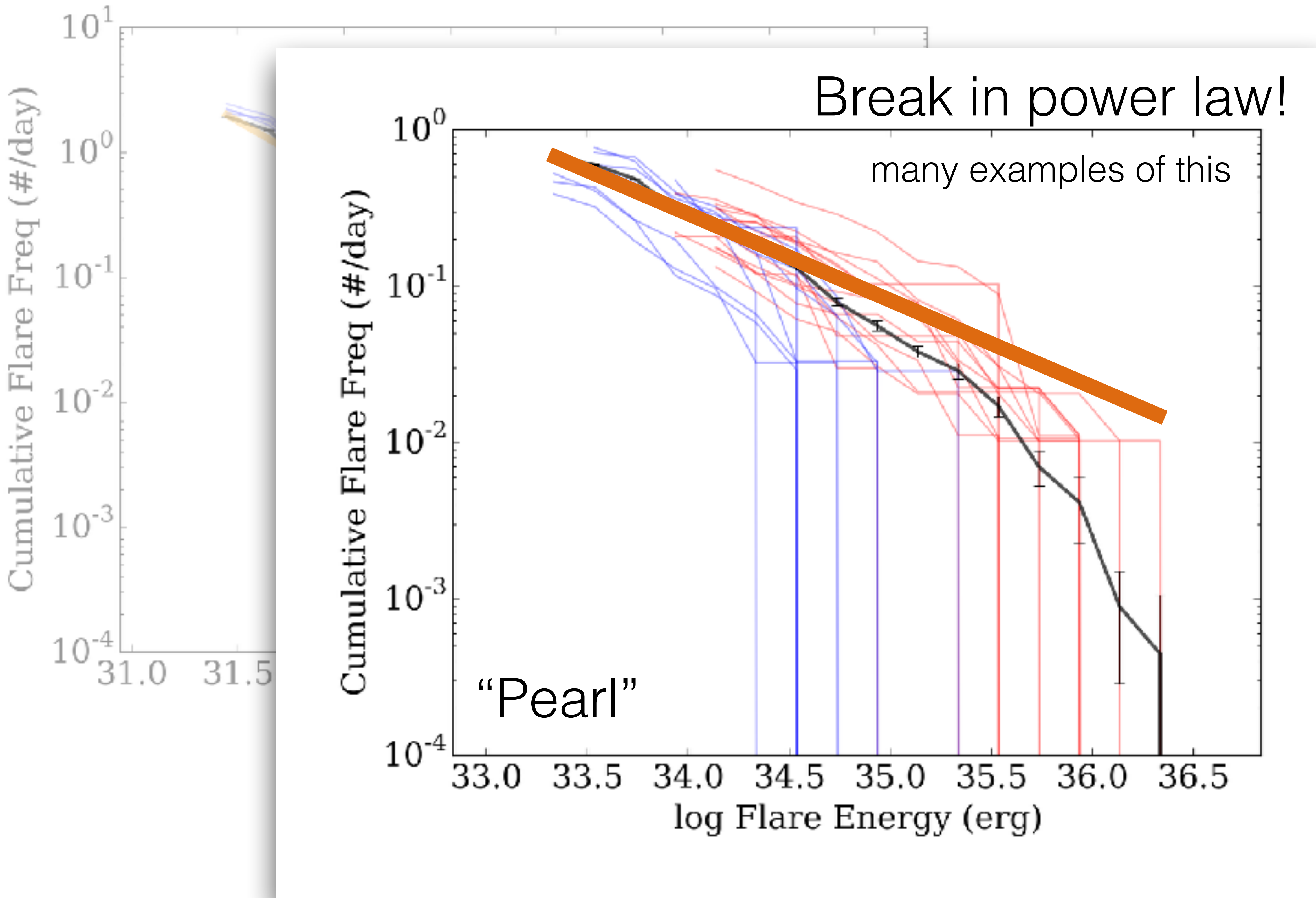
Flare Frequency Distribution - Power law



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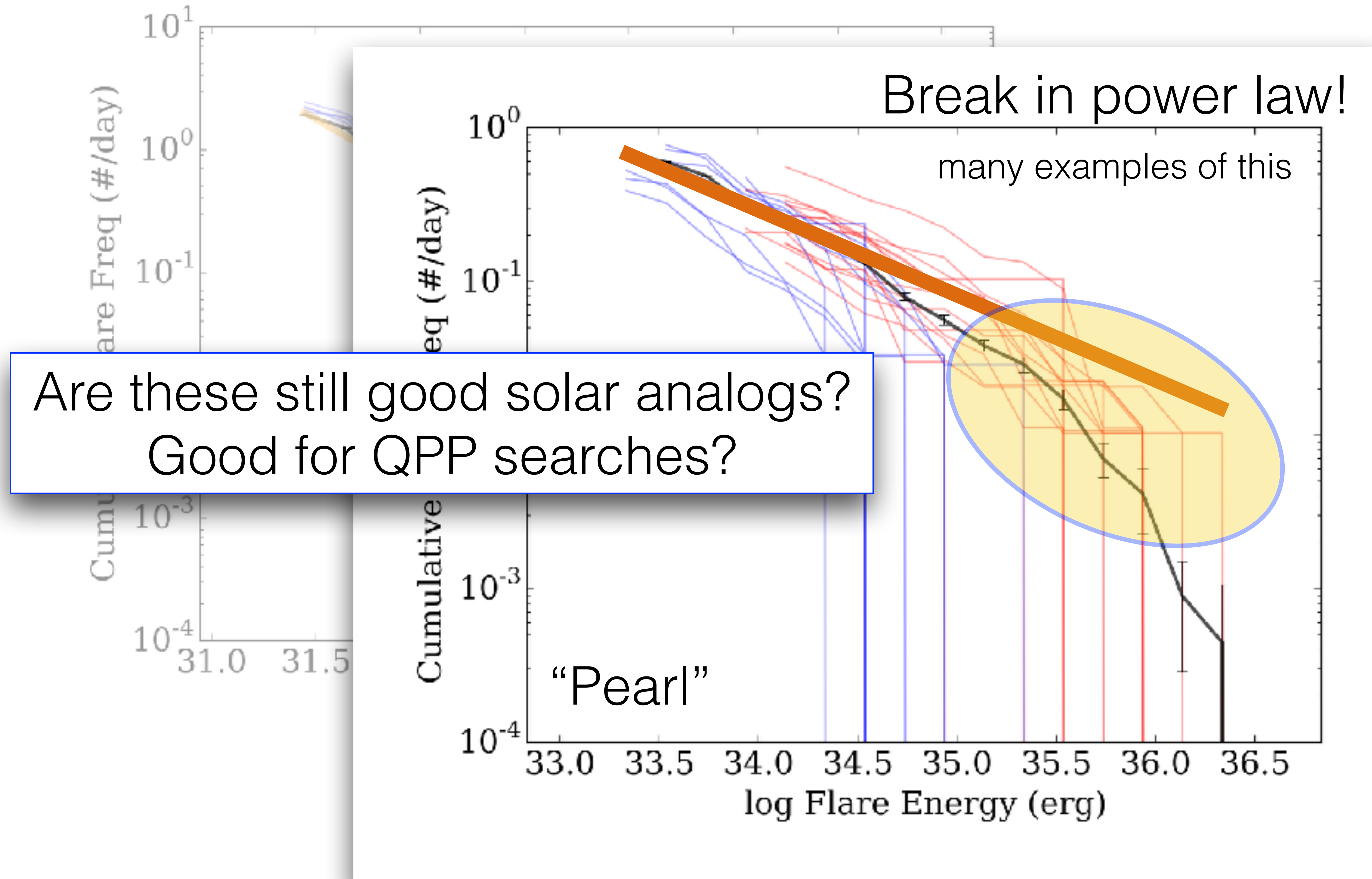
Flare Frequency Distribution - Power law



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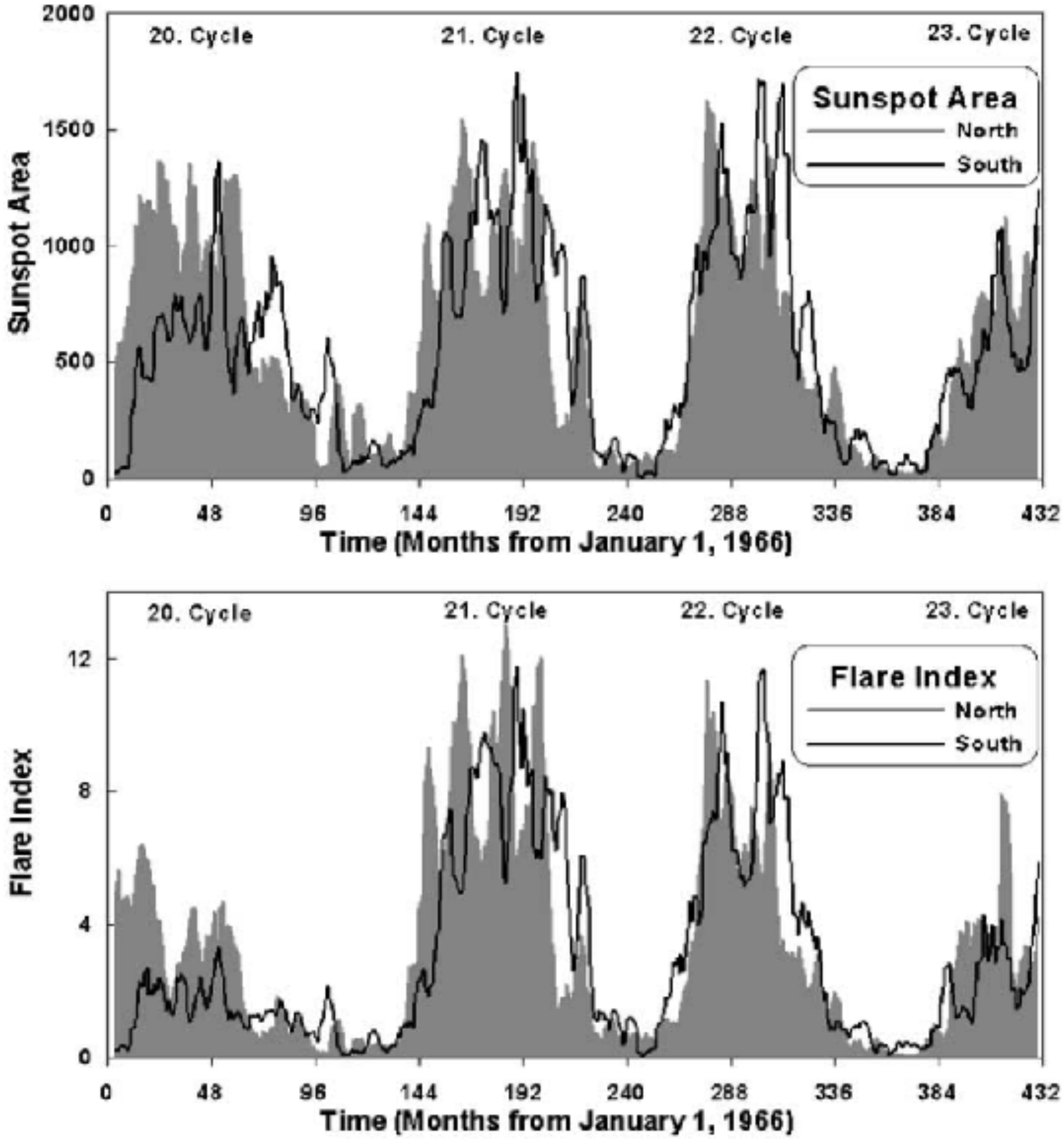
Activity Cycles

A. Özgüç, et al. (2003), SoPh



See also S-index, Ca II H&K, TSI, etc…

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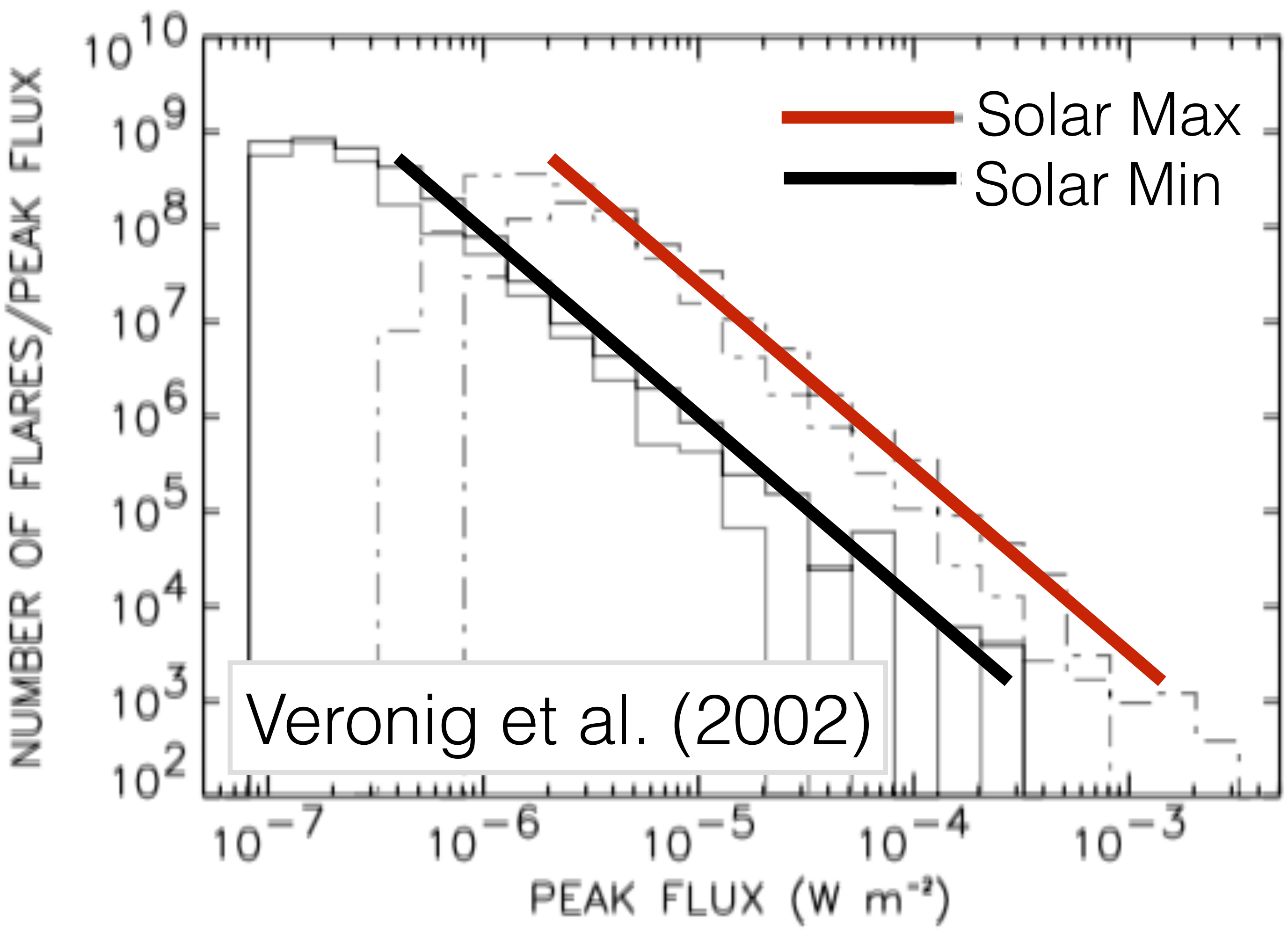
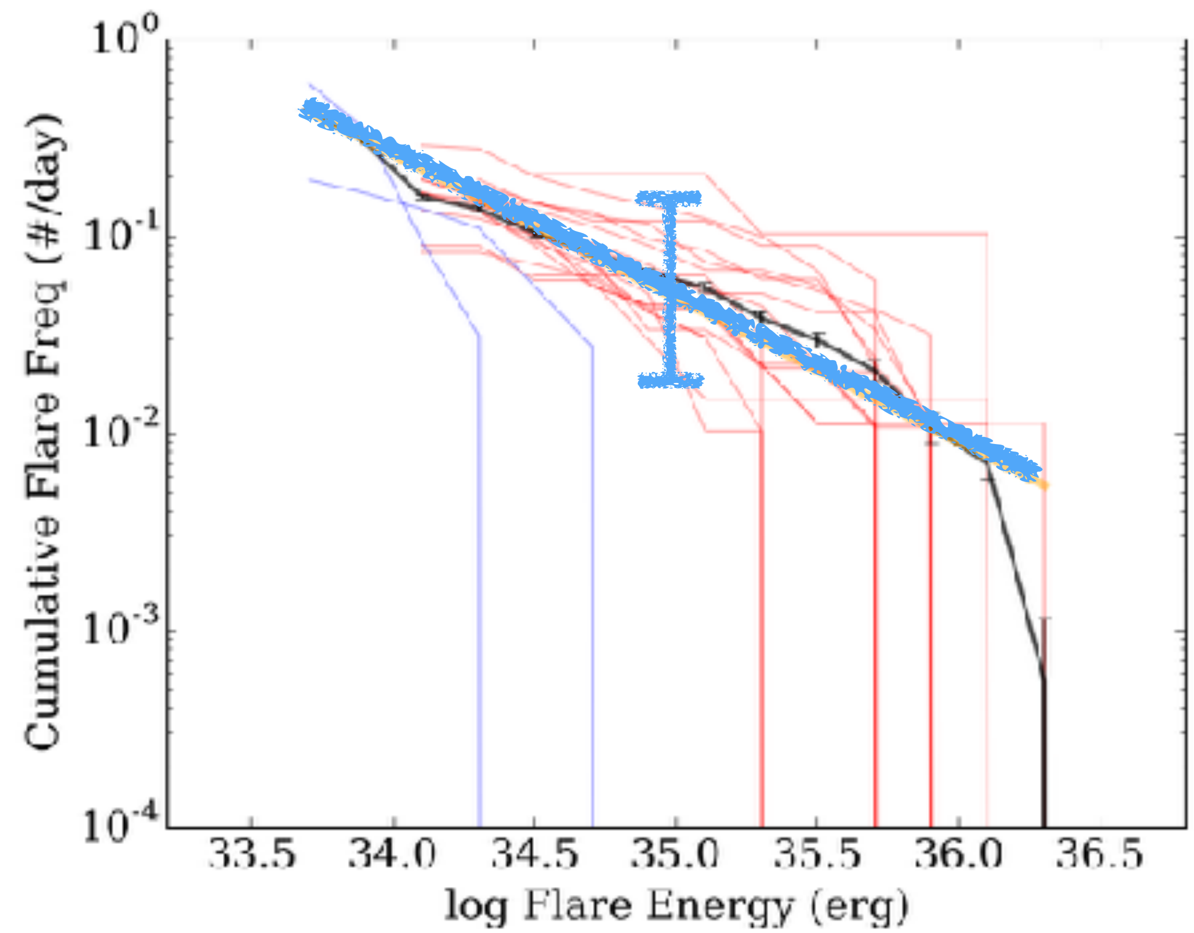
Activity Cycles from Flares

Flare rate varies by an **order of magnitude** between active/quiet Sun!





This is a goal of mine in 2017(ish)

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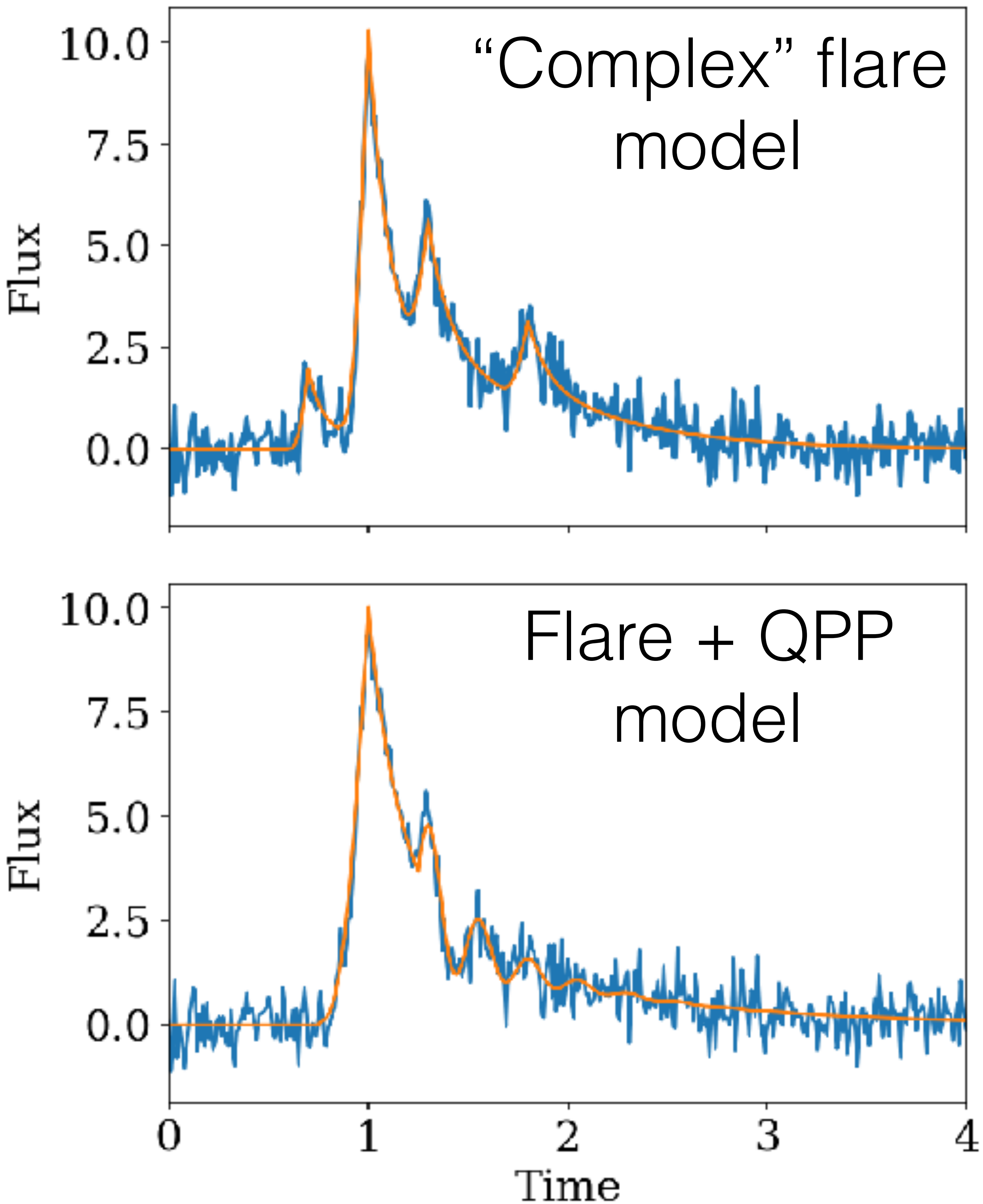
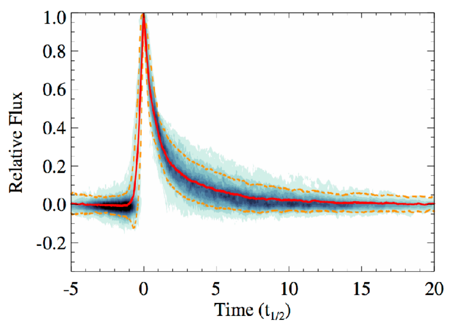
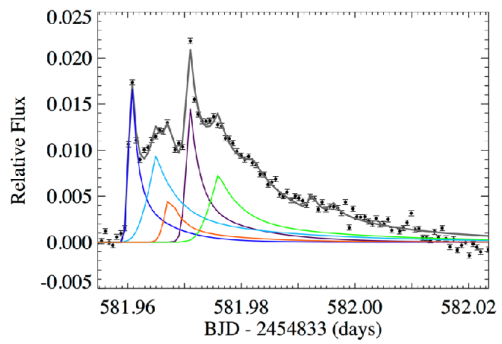
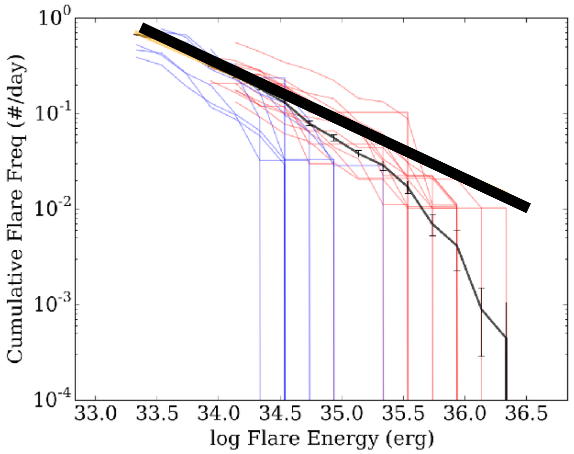


Can statistics save us?
(large samples, careful fitting)

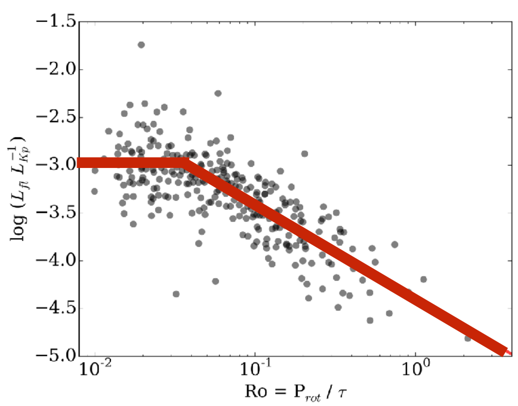
Summary







- empirical template!
- useful for deconstructing
- **QPP's, odd morphologies?**



- Homogeneous sample of flare rates & energy distributions
- **Breaks in power law**

- Evolution with rotation/Rossby number
- Saturation regime (?)
- **Flares useful metric for magnetic activity level**
- **activity cycles?**