

The Evolution of Long-Term Stellar Photometric Variability from Kepler Photometry



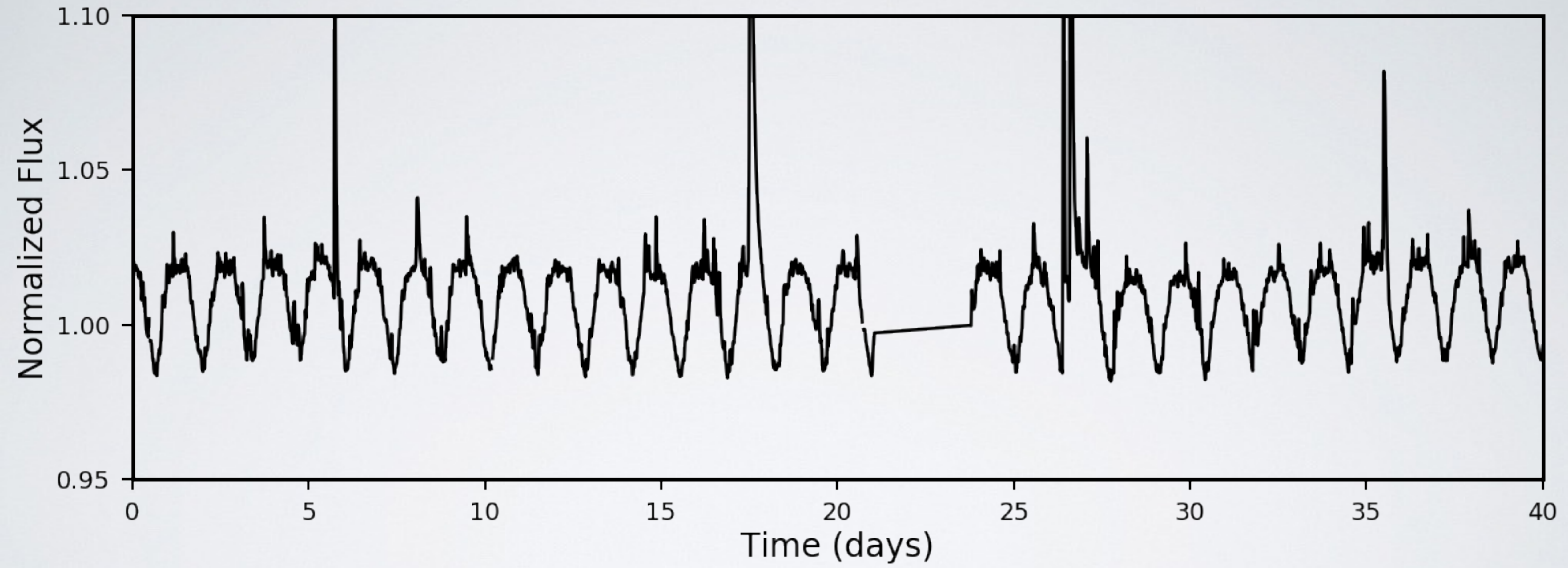
THE UNIVERSITY OF
CHICAGO



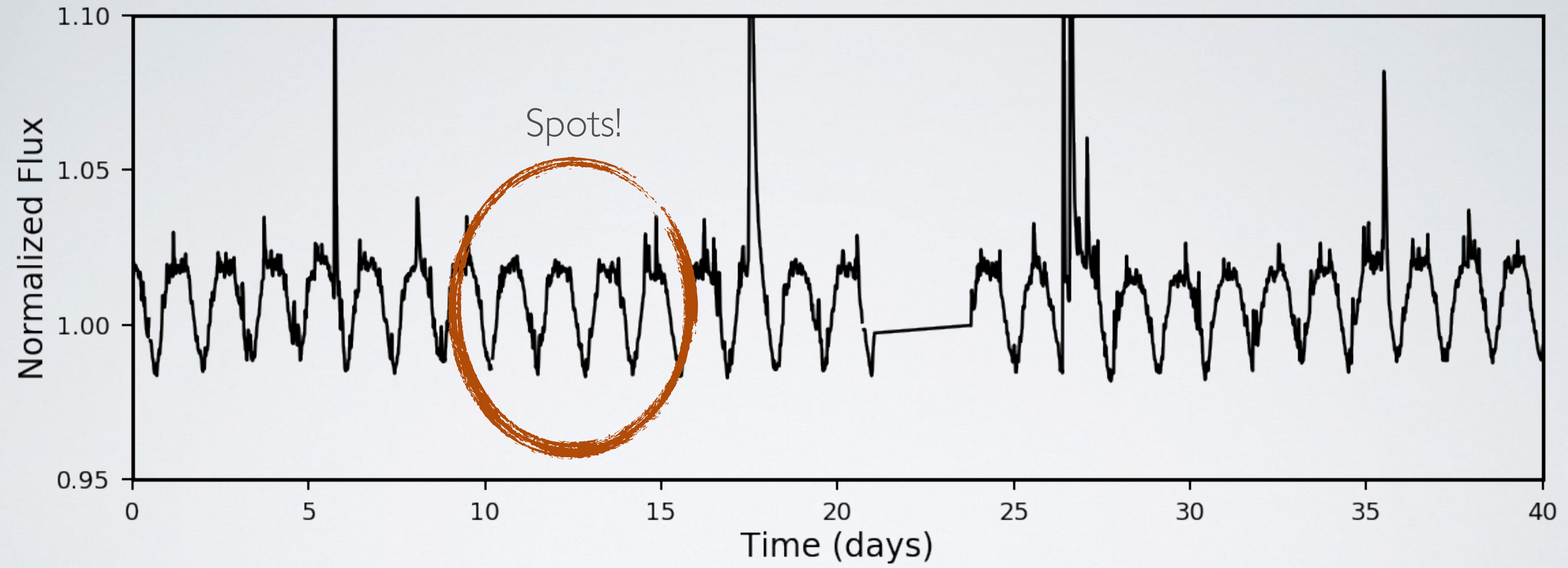
UNSW
SYDNEY

Benjamin Montet
NASA Sagan Fellow
KITP/Exostar
23 May 2019

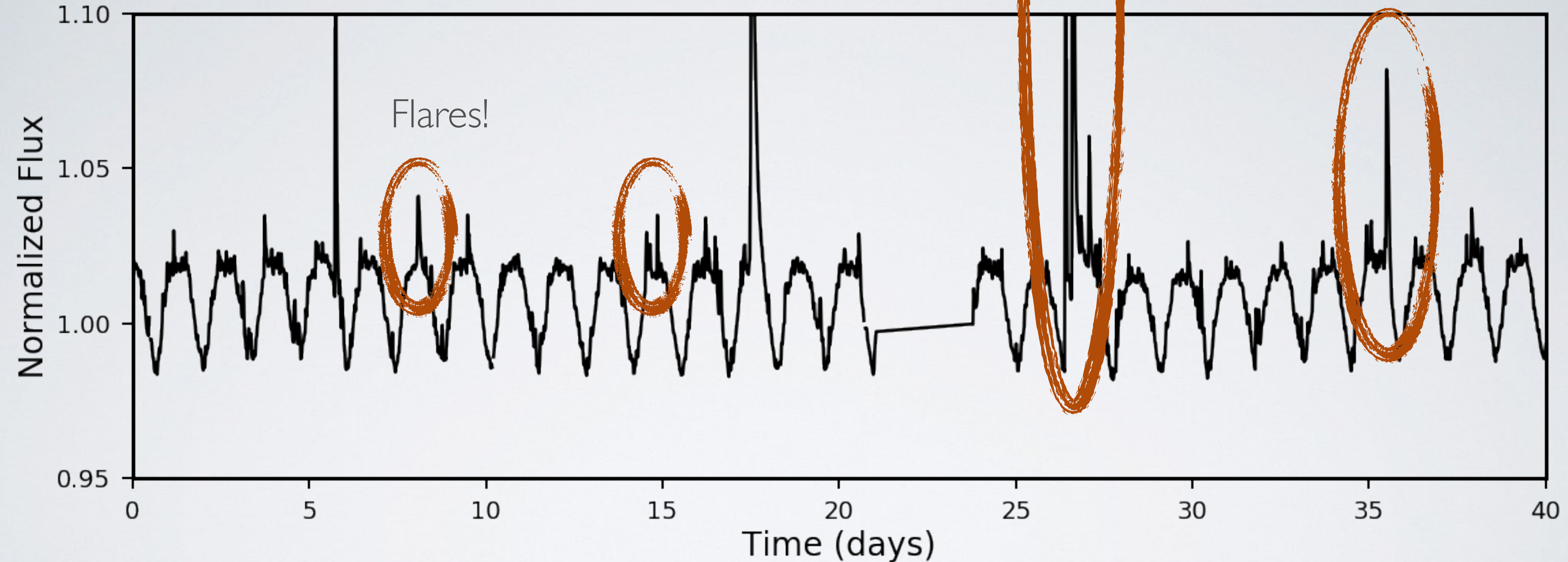
Observing Stellar Activity with *Kepler*



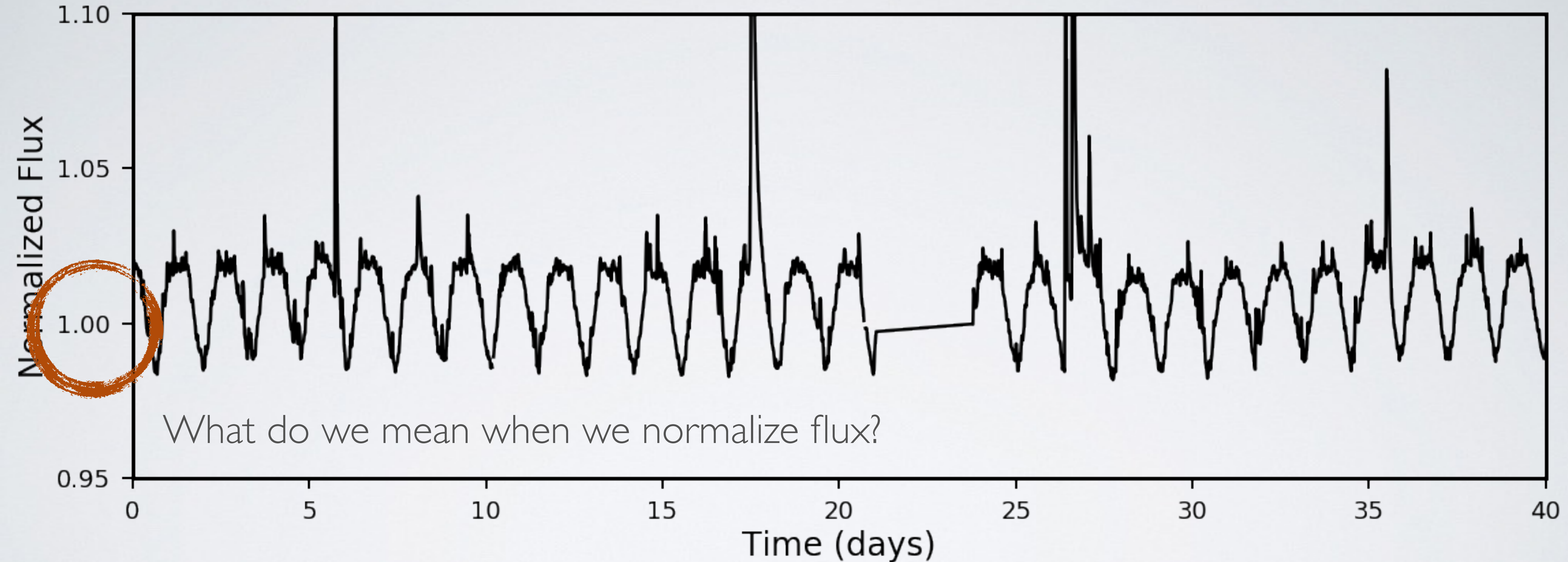
Observing Stellar Activity with *Kepler*



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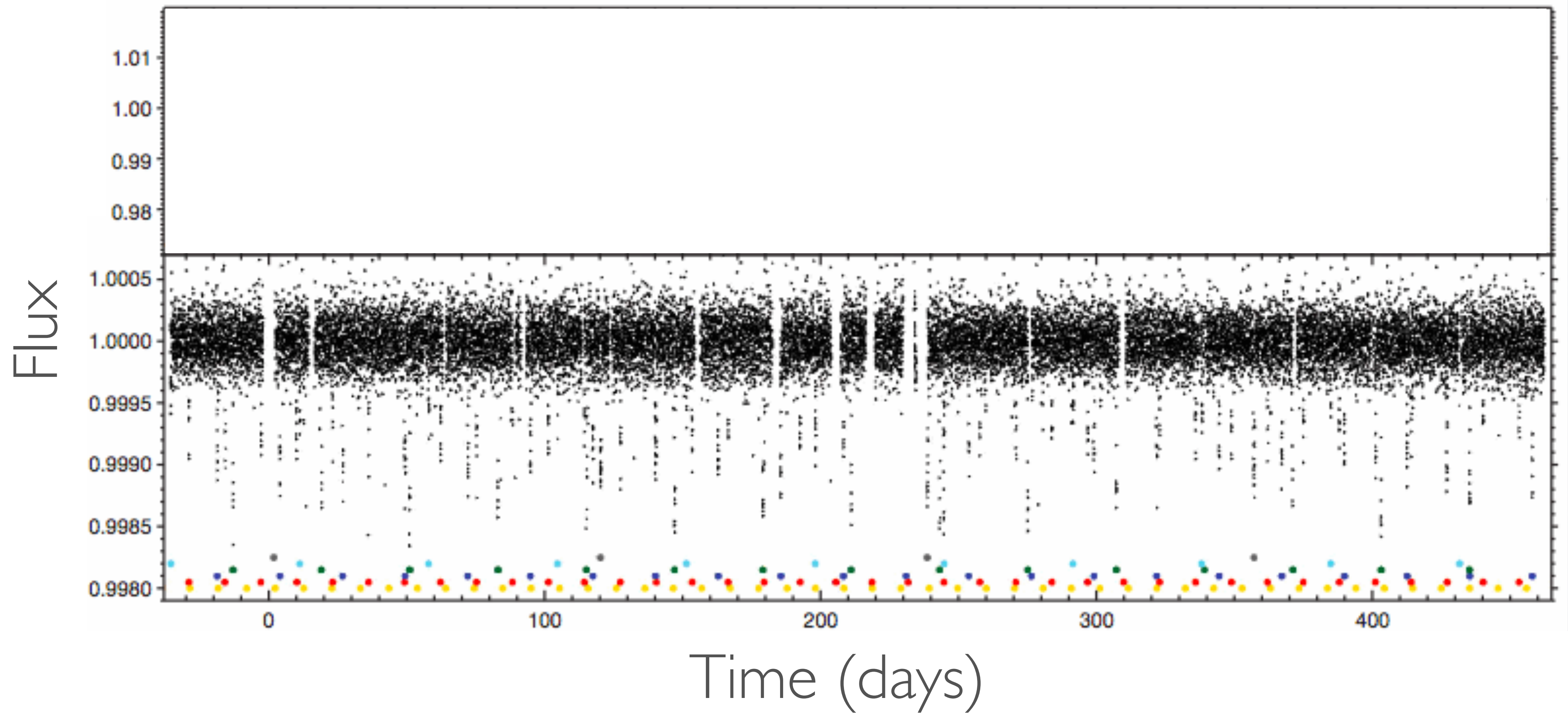


Observing Stellar Activity with *Kepler*

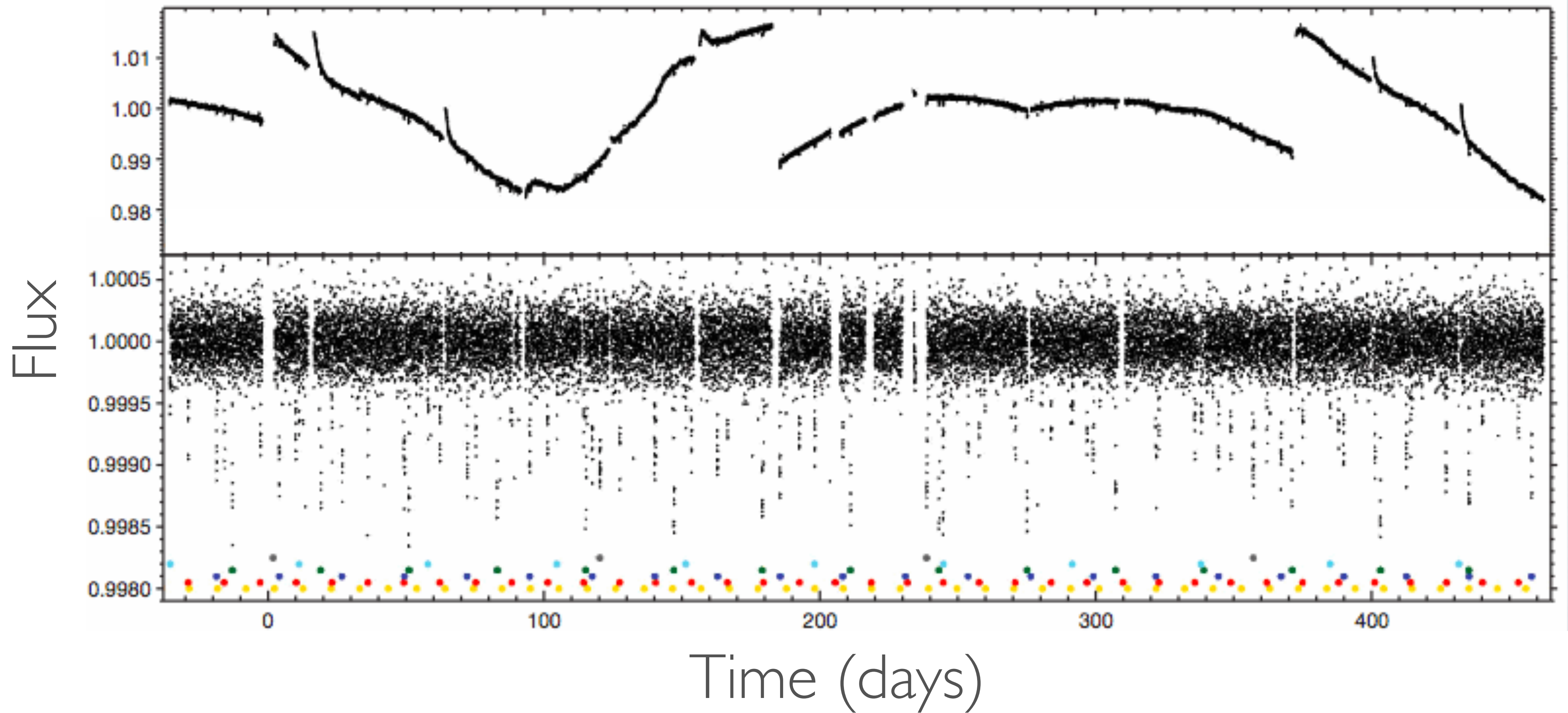


Why do we bother to normalize in the first place?

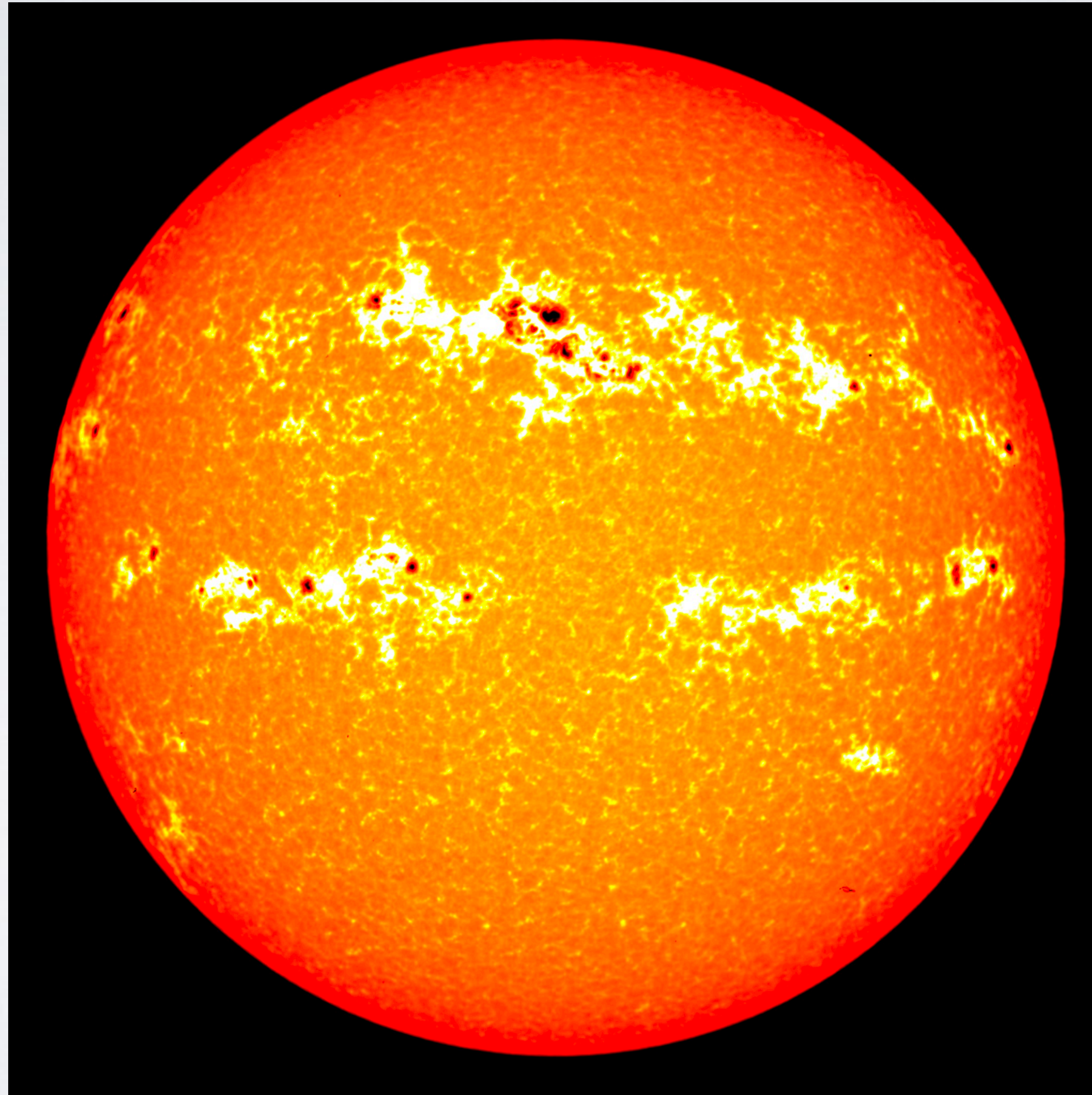
Photometry with *Kepler*



Photometry with *Kepler*



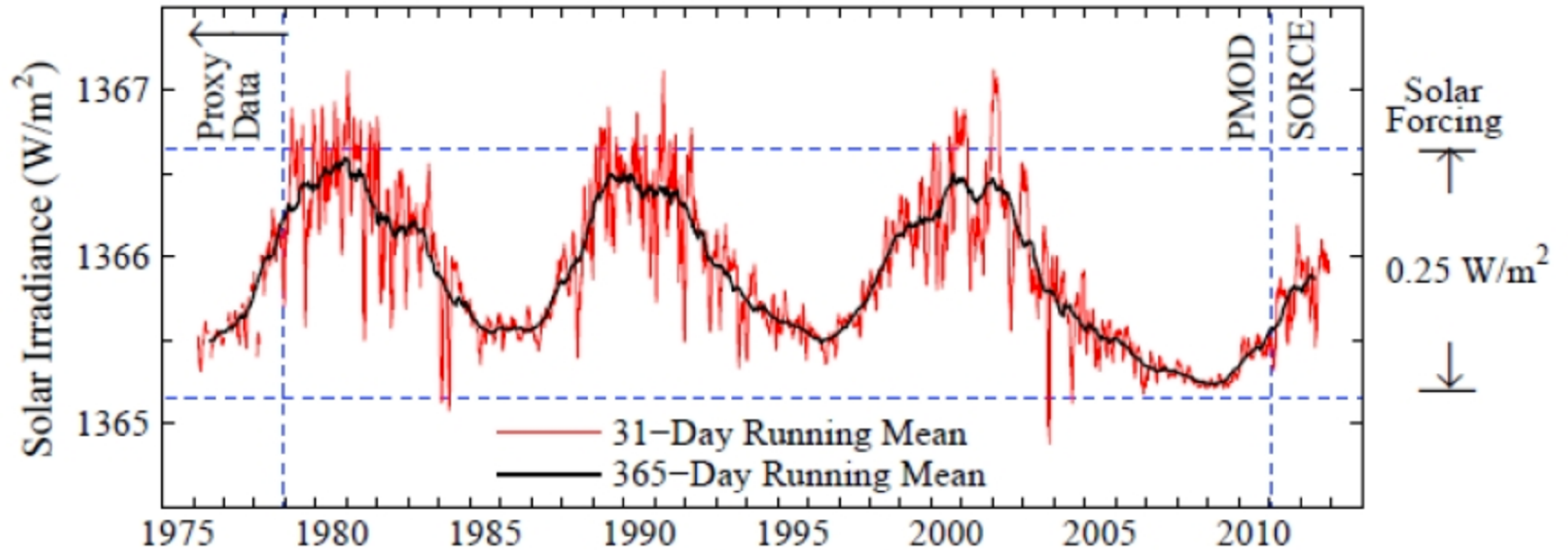
All stars are variable stars



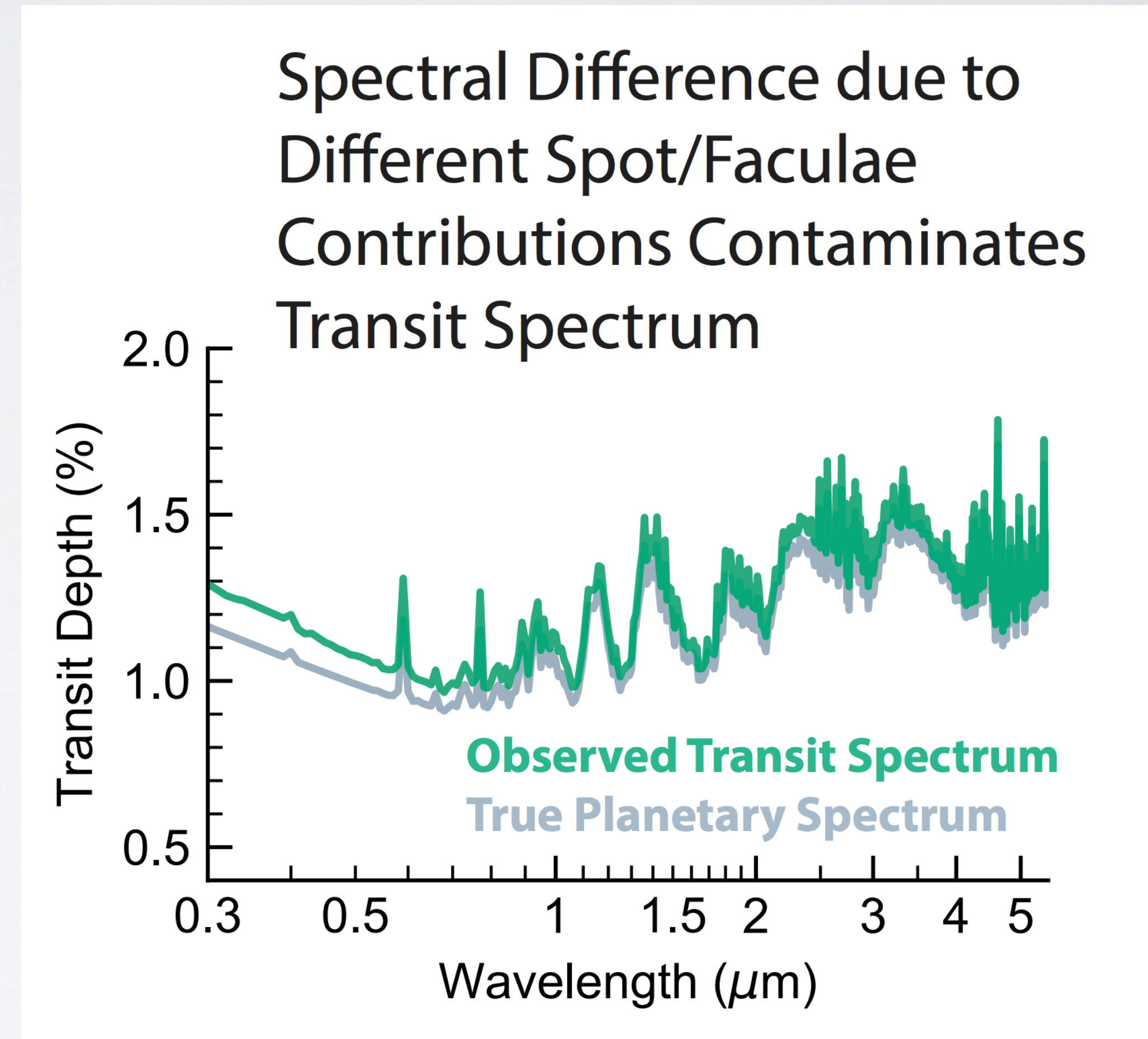
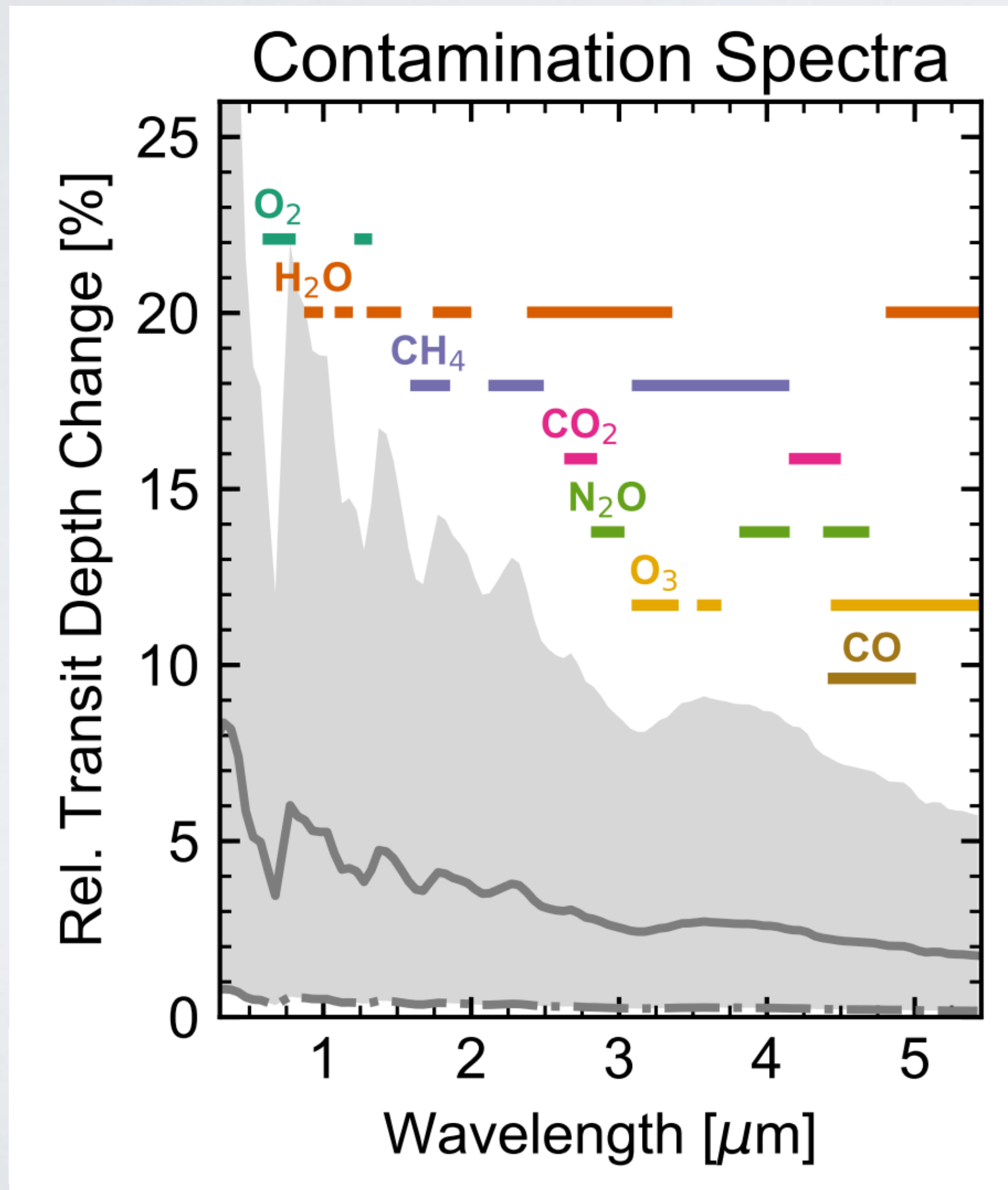
NASA SORCE

Stellar activity via photometry

Total Solar Irradiance

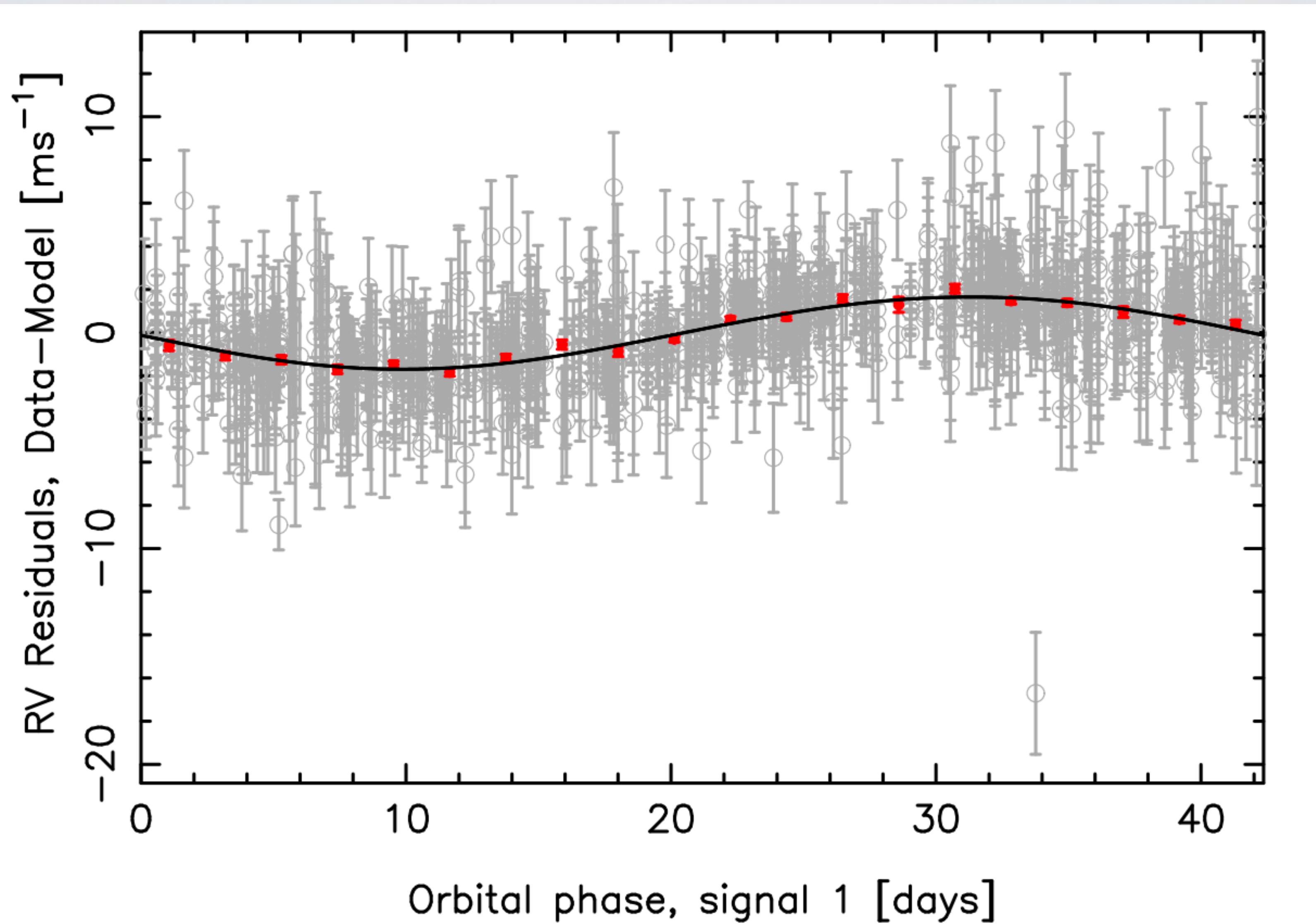


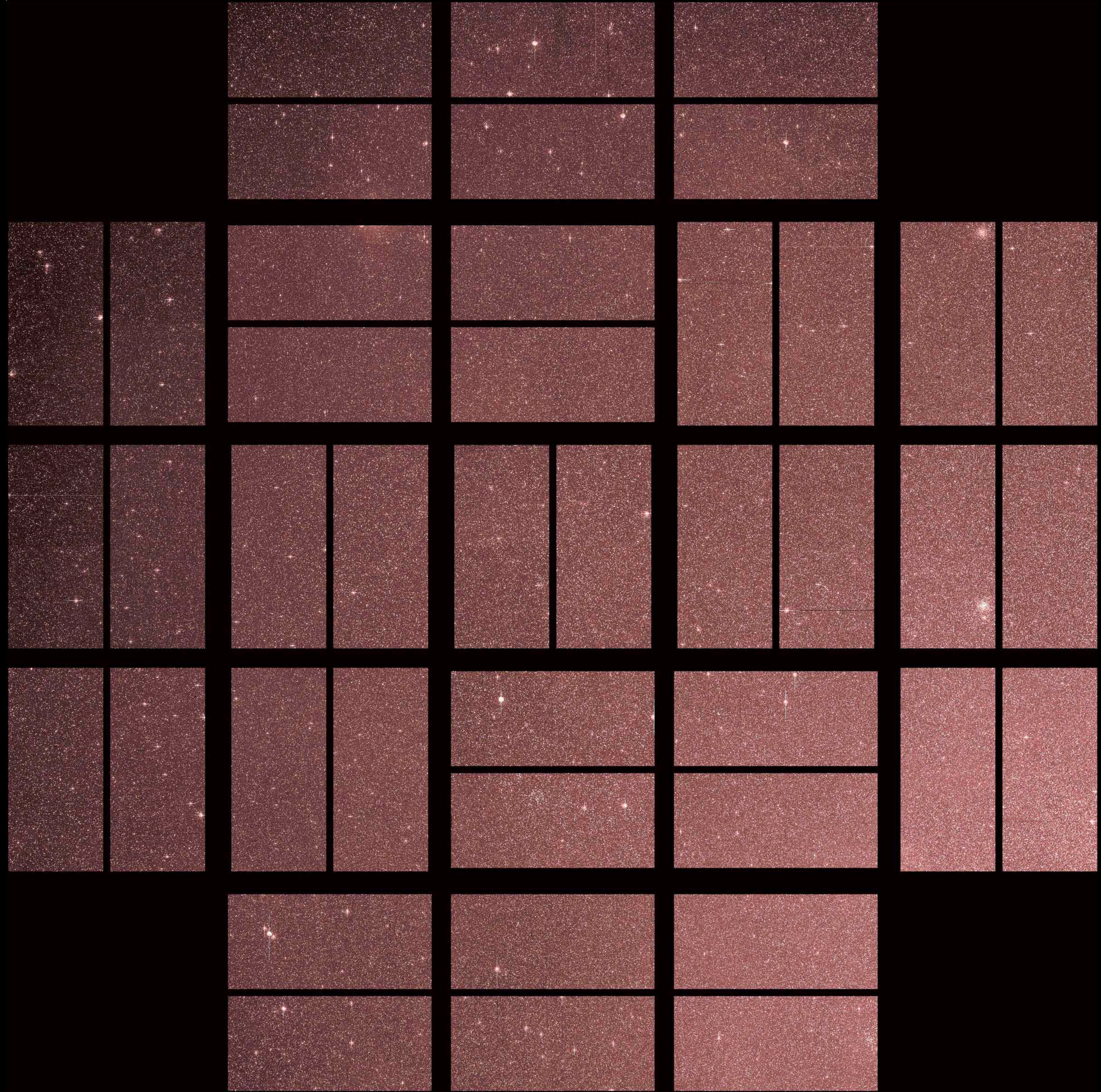
Spots and faculae affect our interpretation of planetary atmospheres



Rackham et al. (2018)

Challenges in finding planets

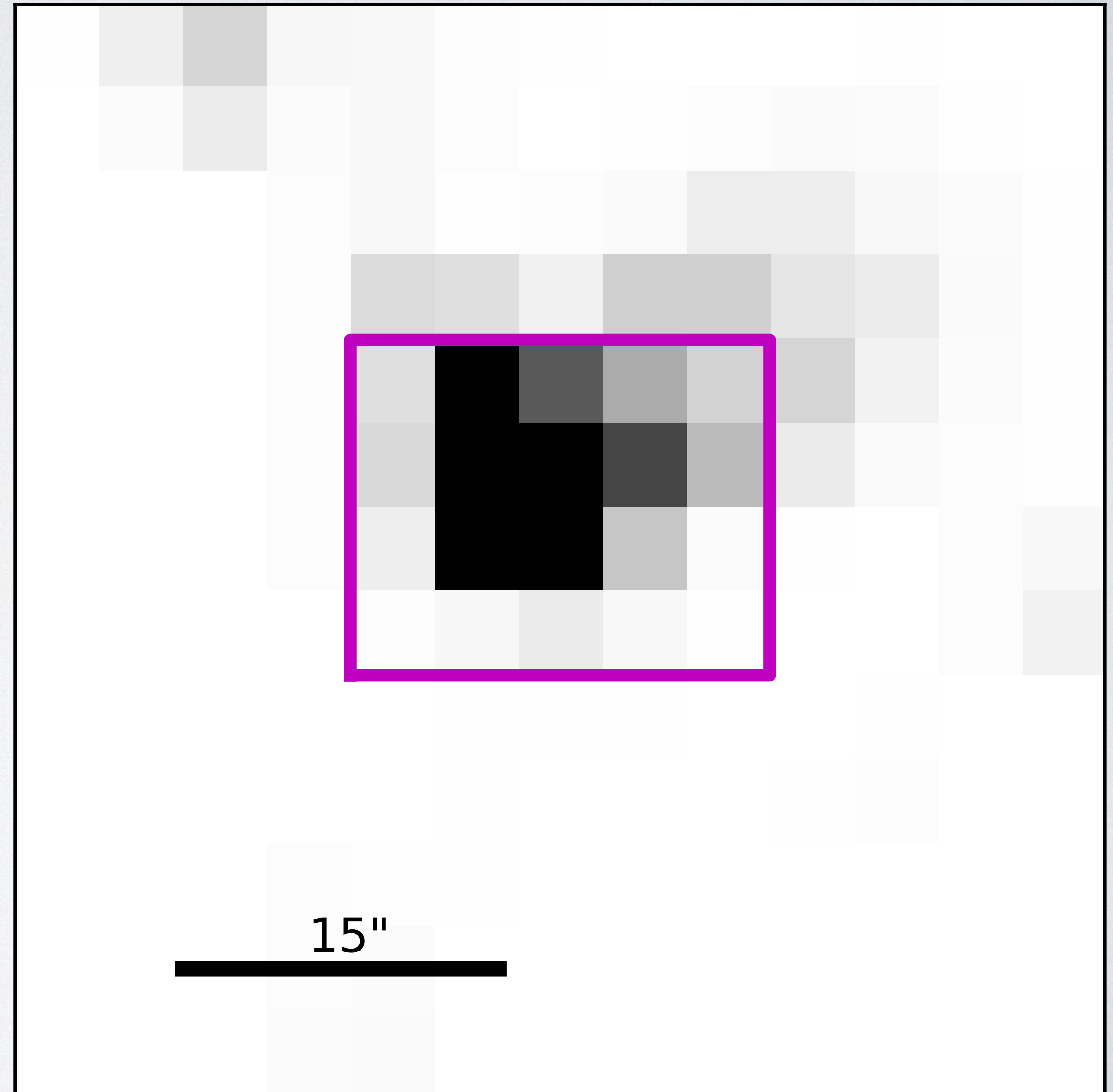


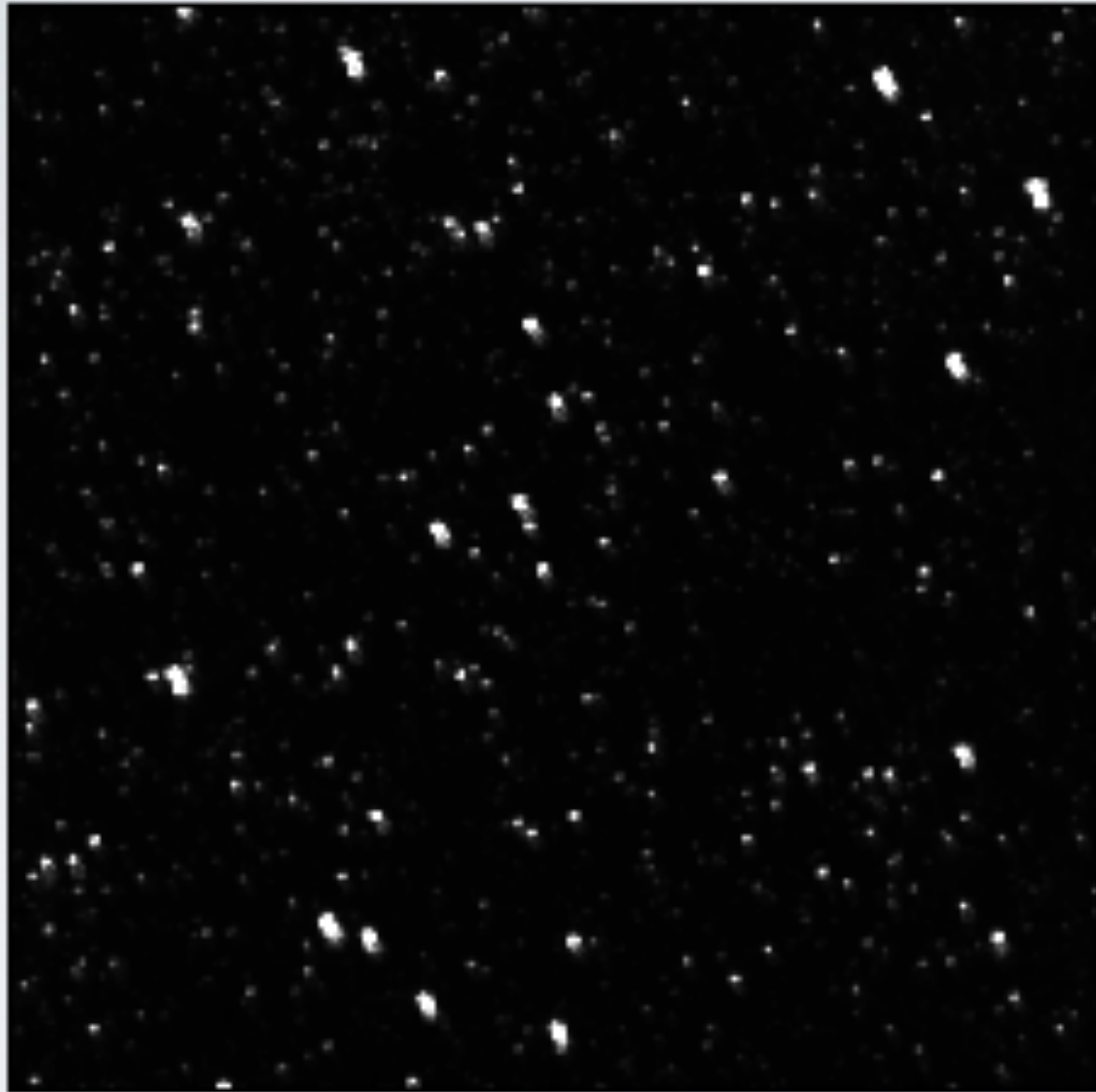


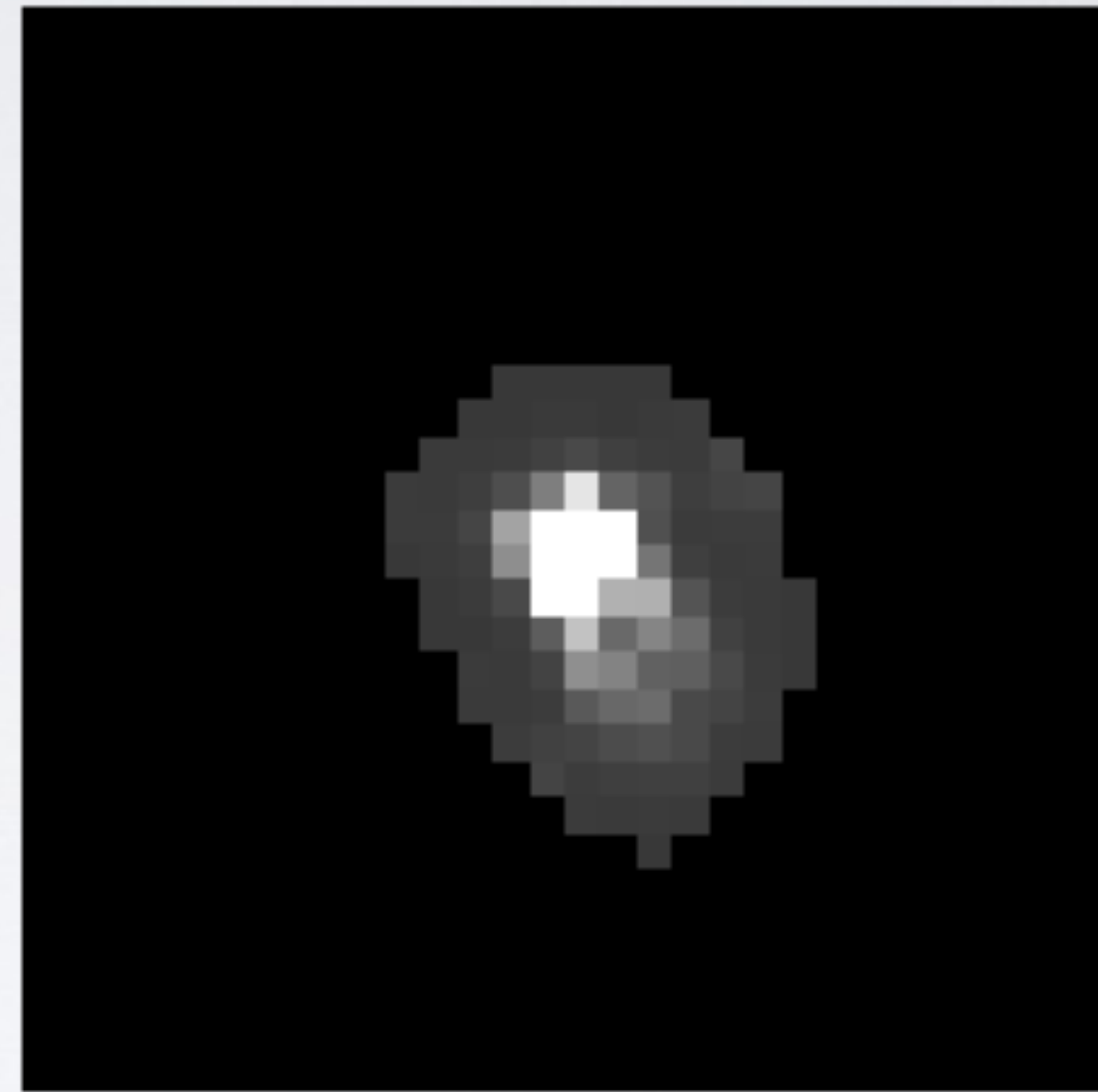
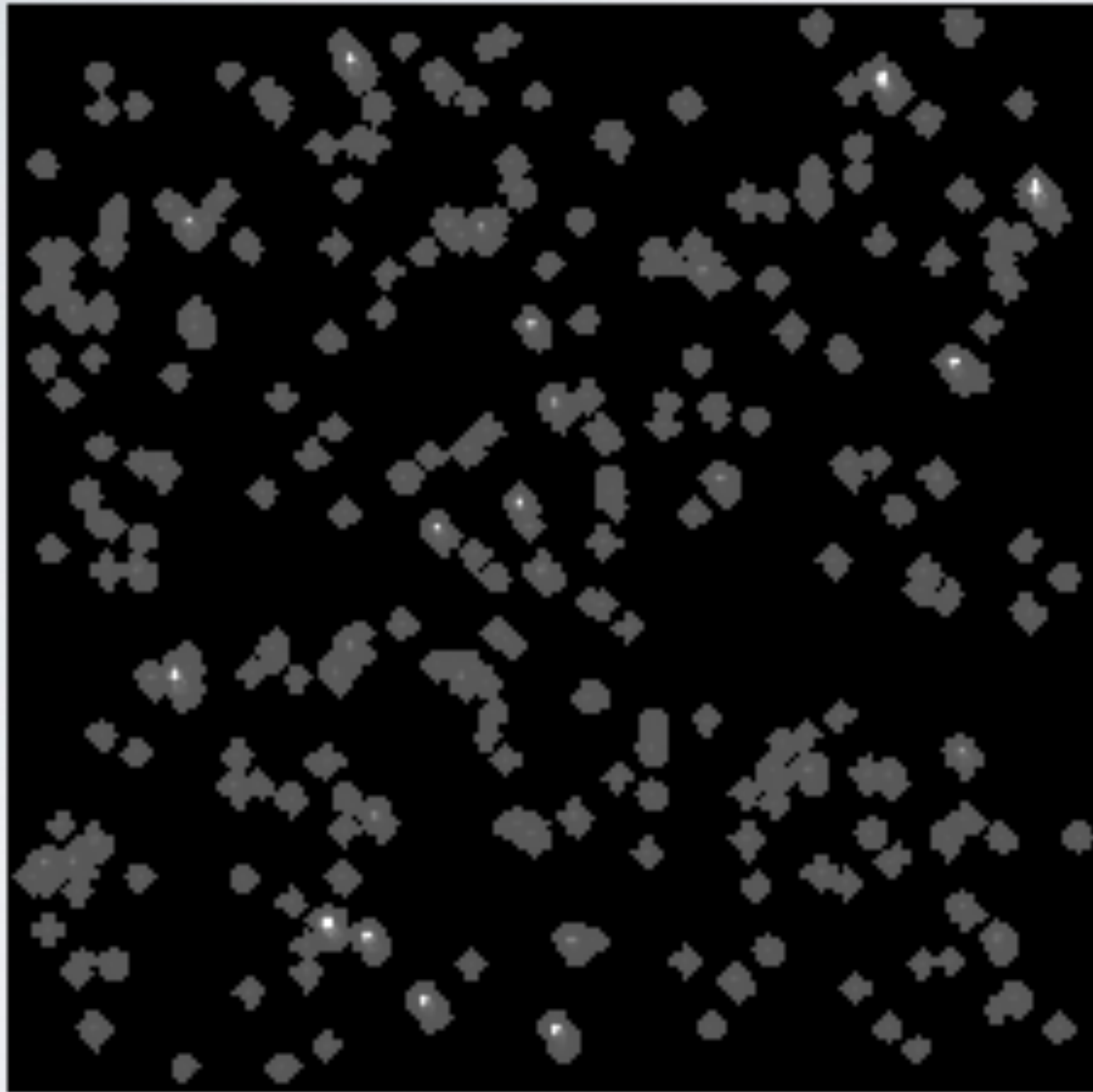
Benefits of Full Frame Images

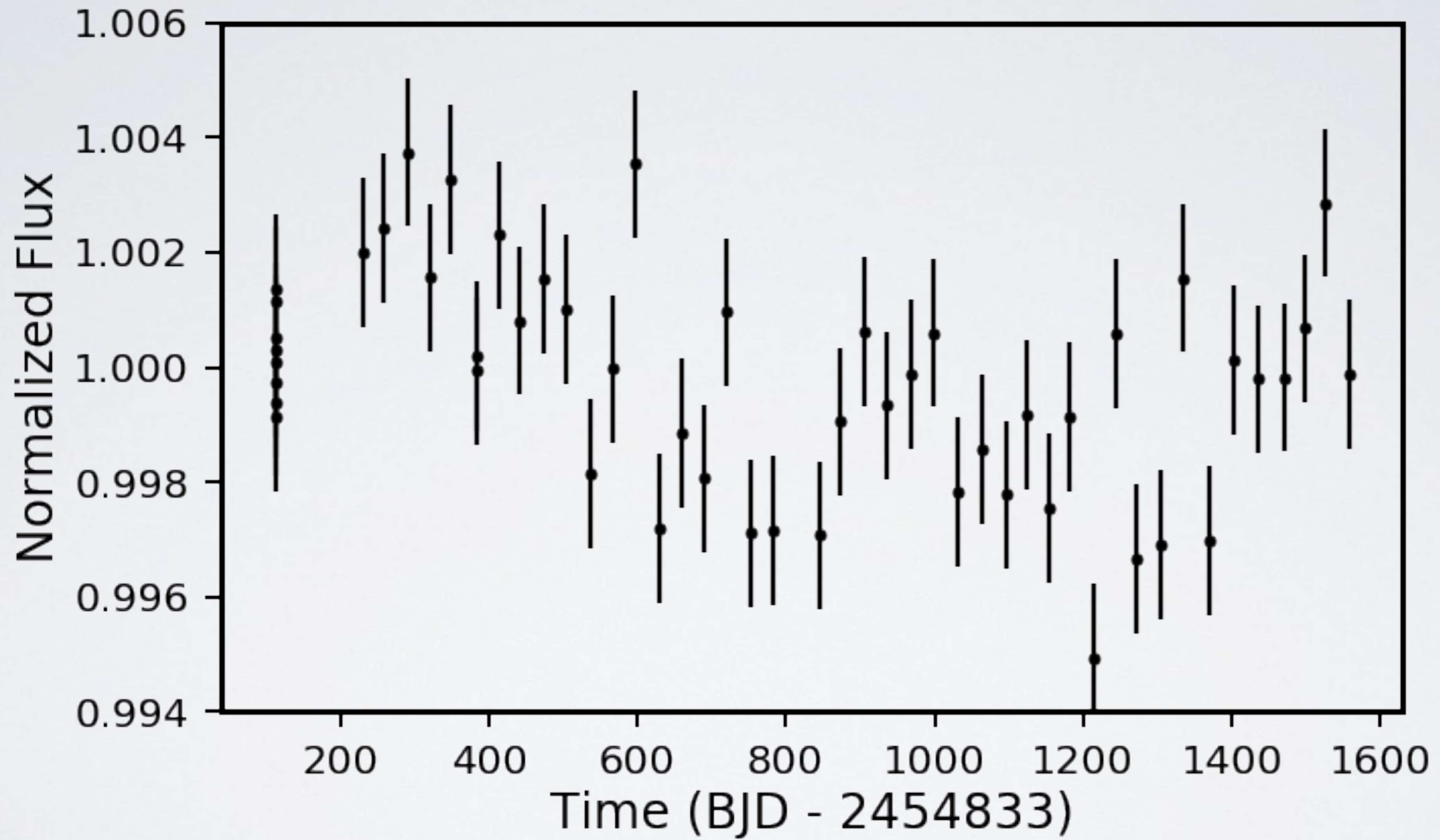


Benefits of Full Frame Images

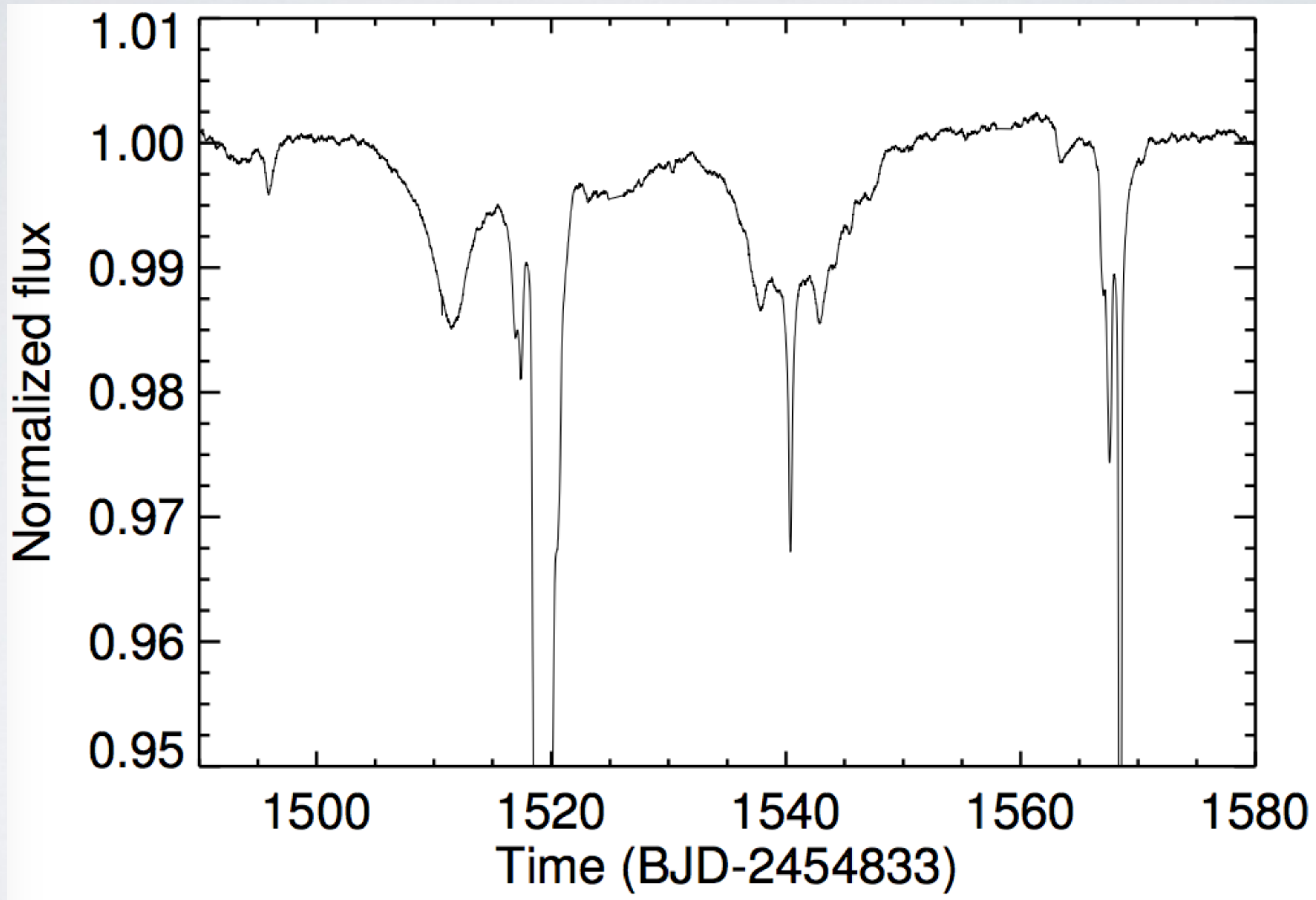






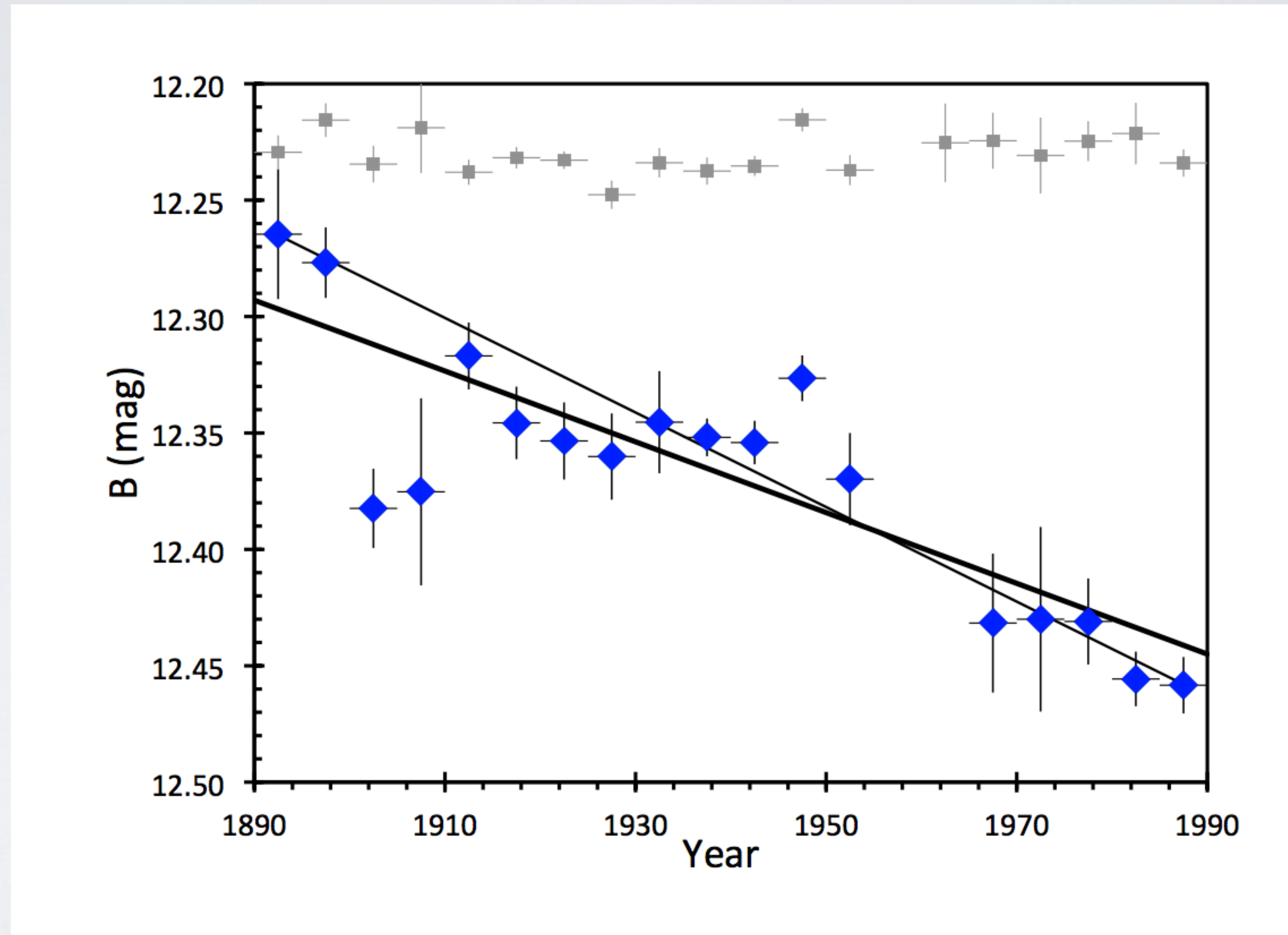


KIC 8462852



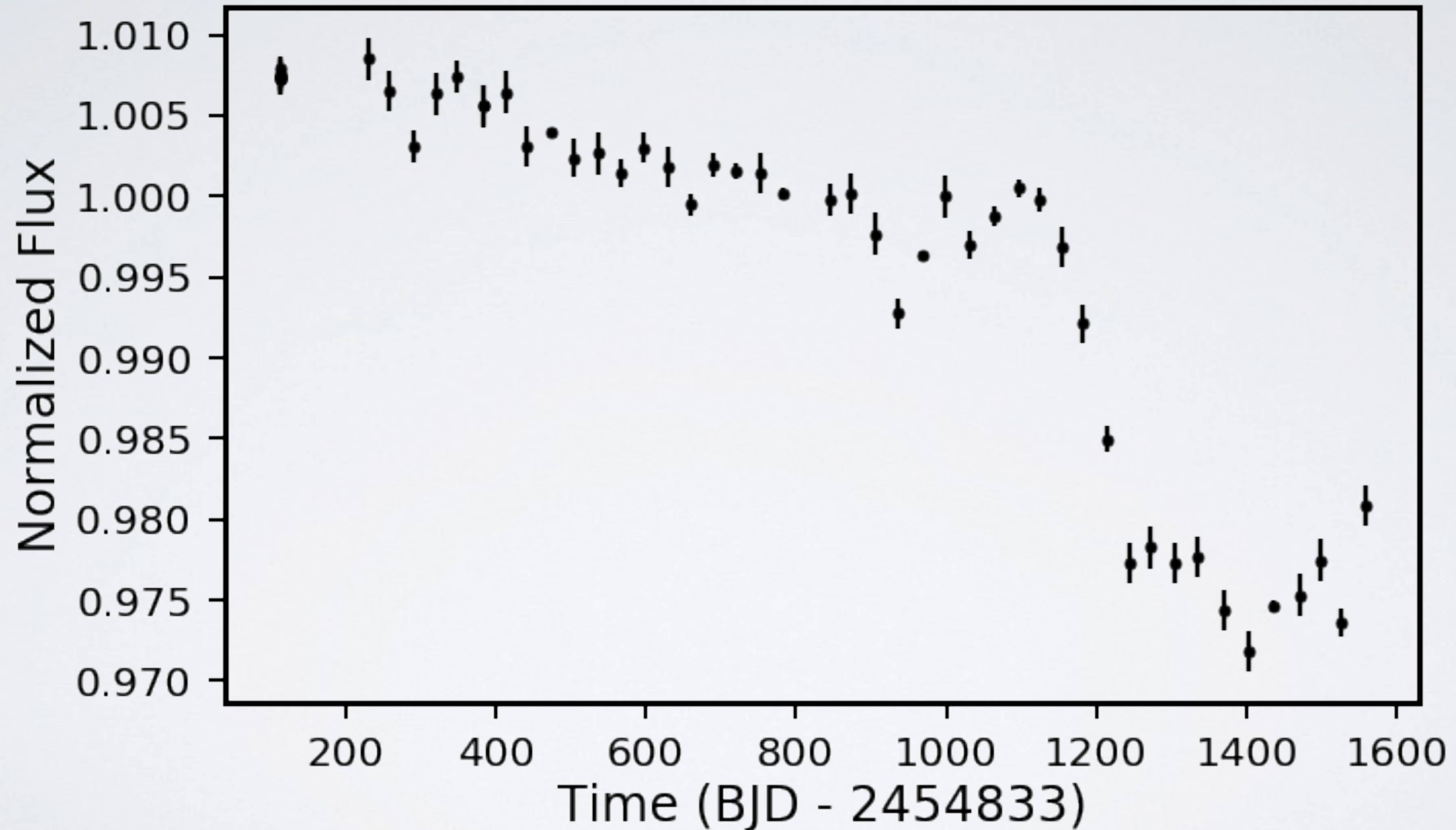
Boyajian et al. (2016)

KIC 8462852 may be dimming in time



Schaefer (2016)

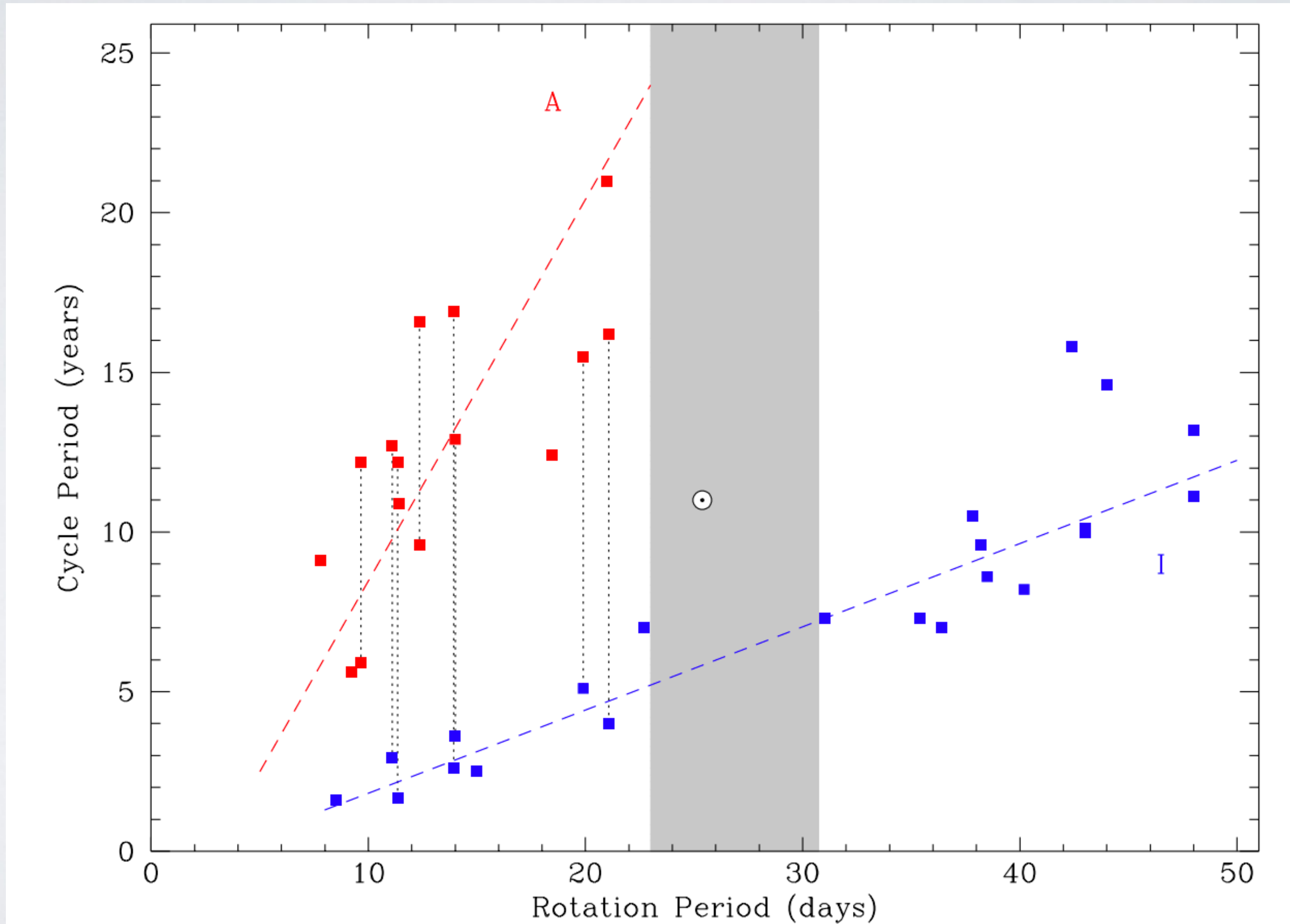
KIC 8462852 faded throughout the *Kepler* mission



Data from Montet and Simon (2016)

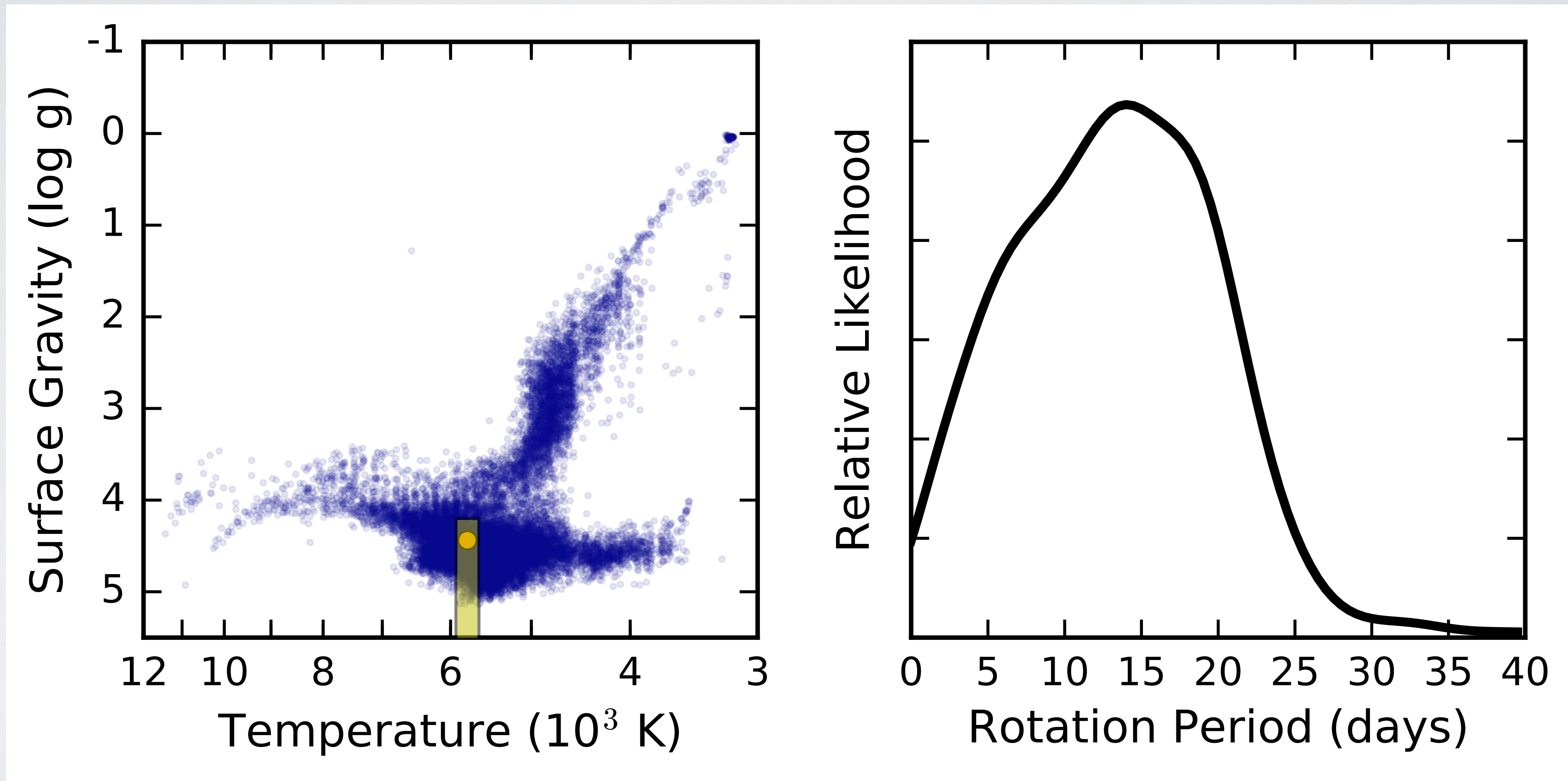
github.com/benmontet/f3

Stellar activity is data-limited



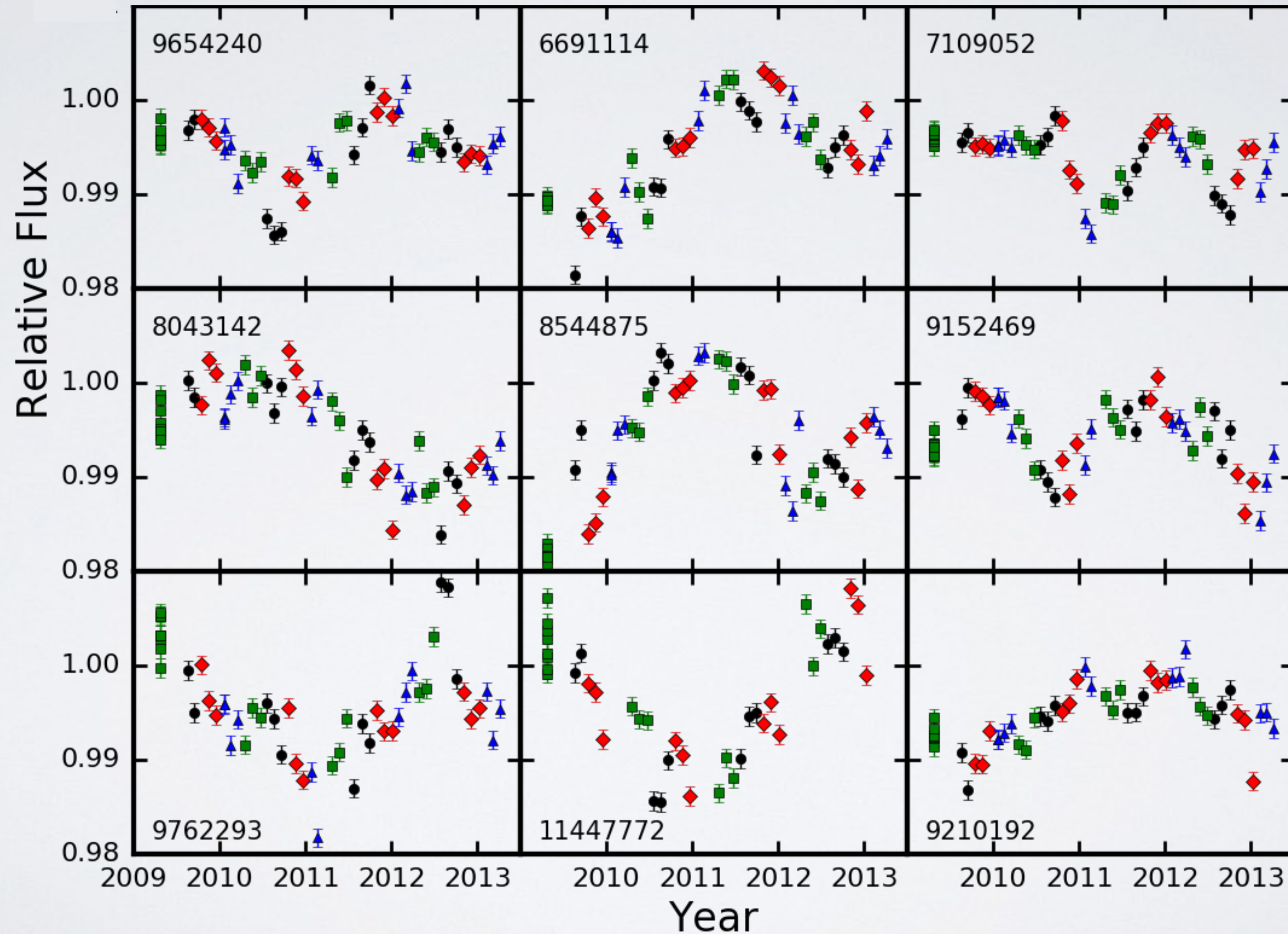
Metcalfe et al.
2016

Kepler observed thousands of Sun-like stars



Montet, Tovar, and Foreman-Mackey (2017)

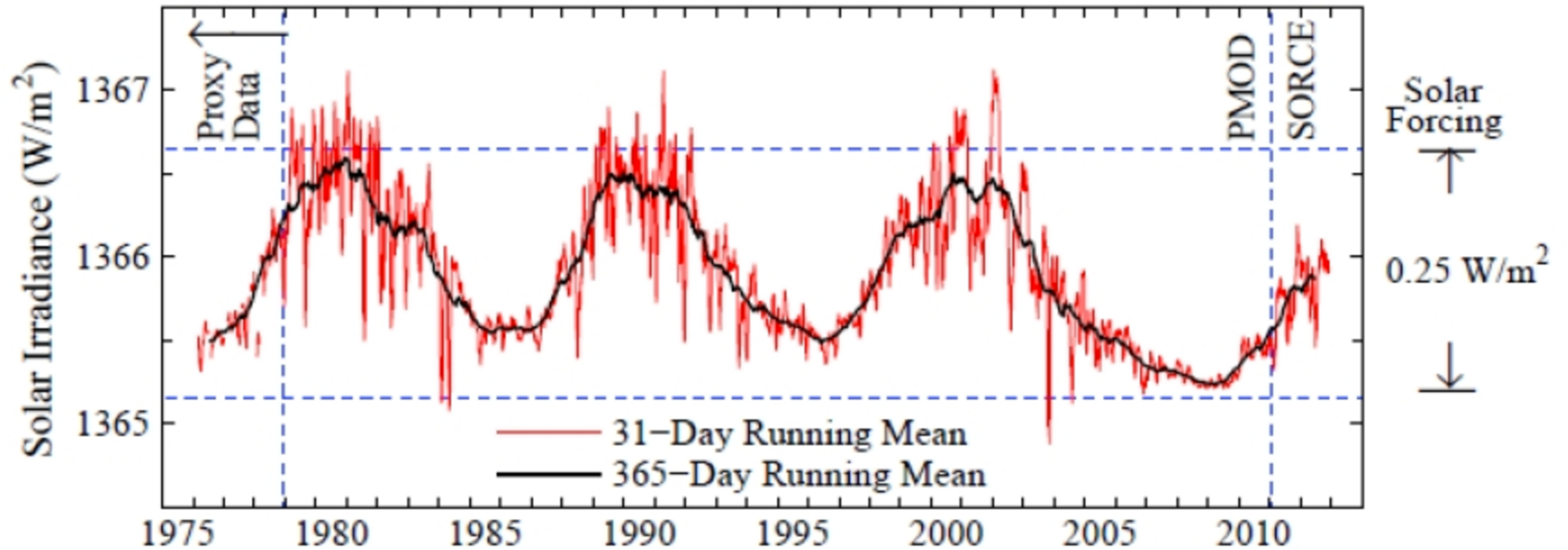
Variable Sun-like stars



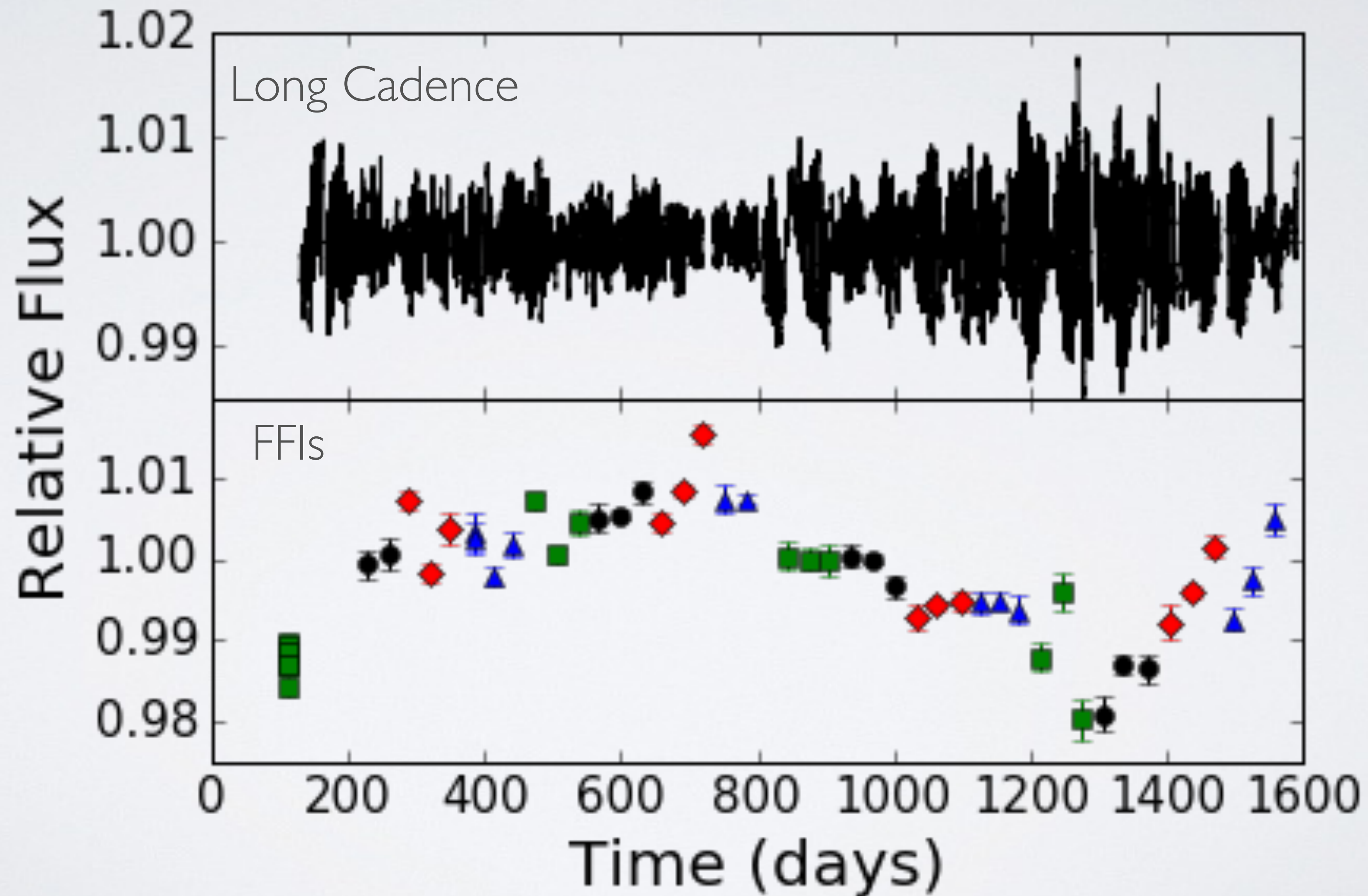
Montet, Tovar, and
Foreman-Mackey
(2017)

Stellar activity via photometry

Total Solar Irradiance

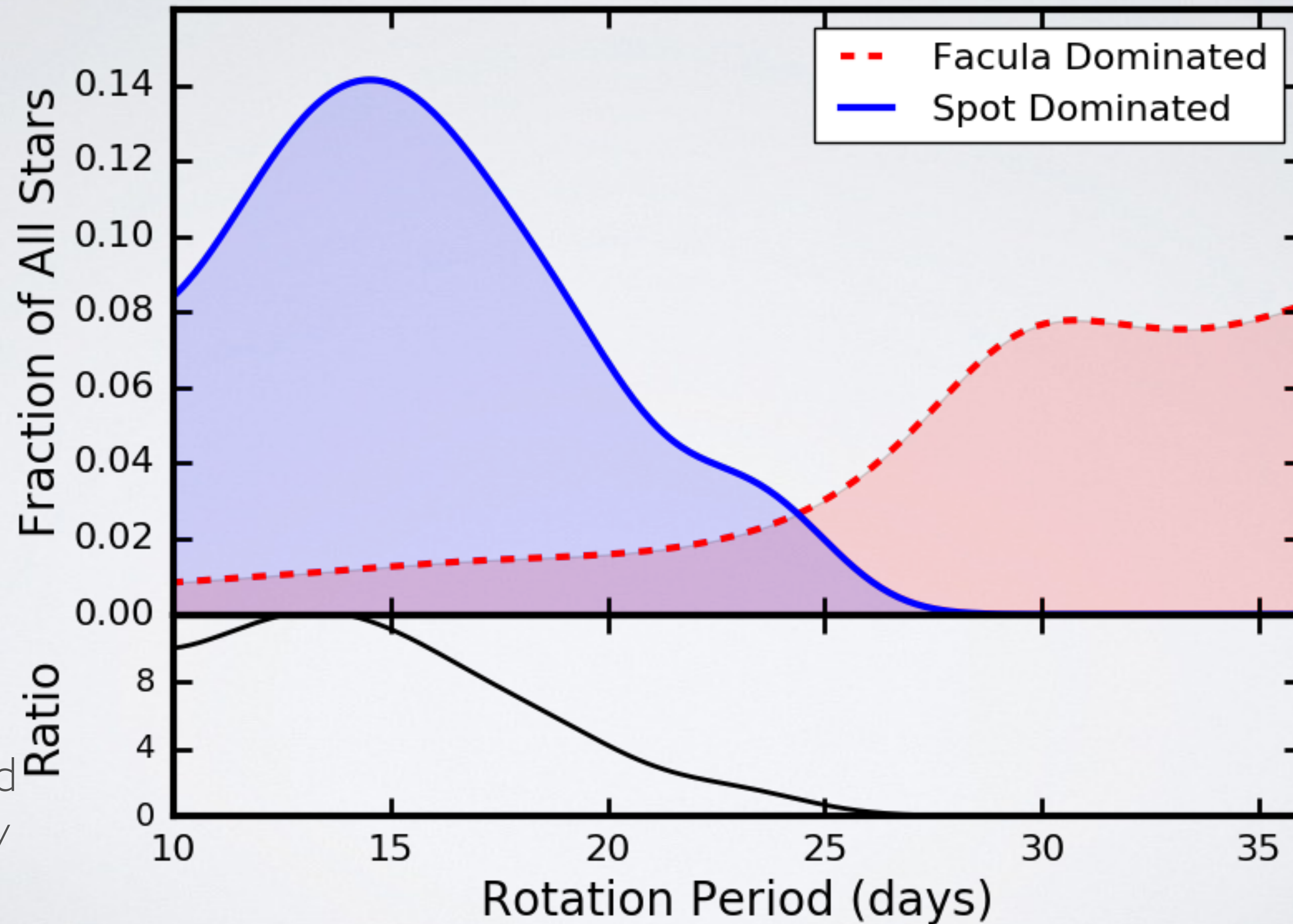


Comparing long-term variability to spots

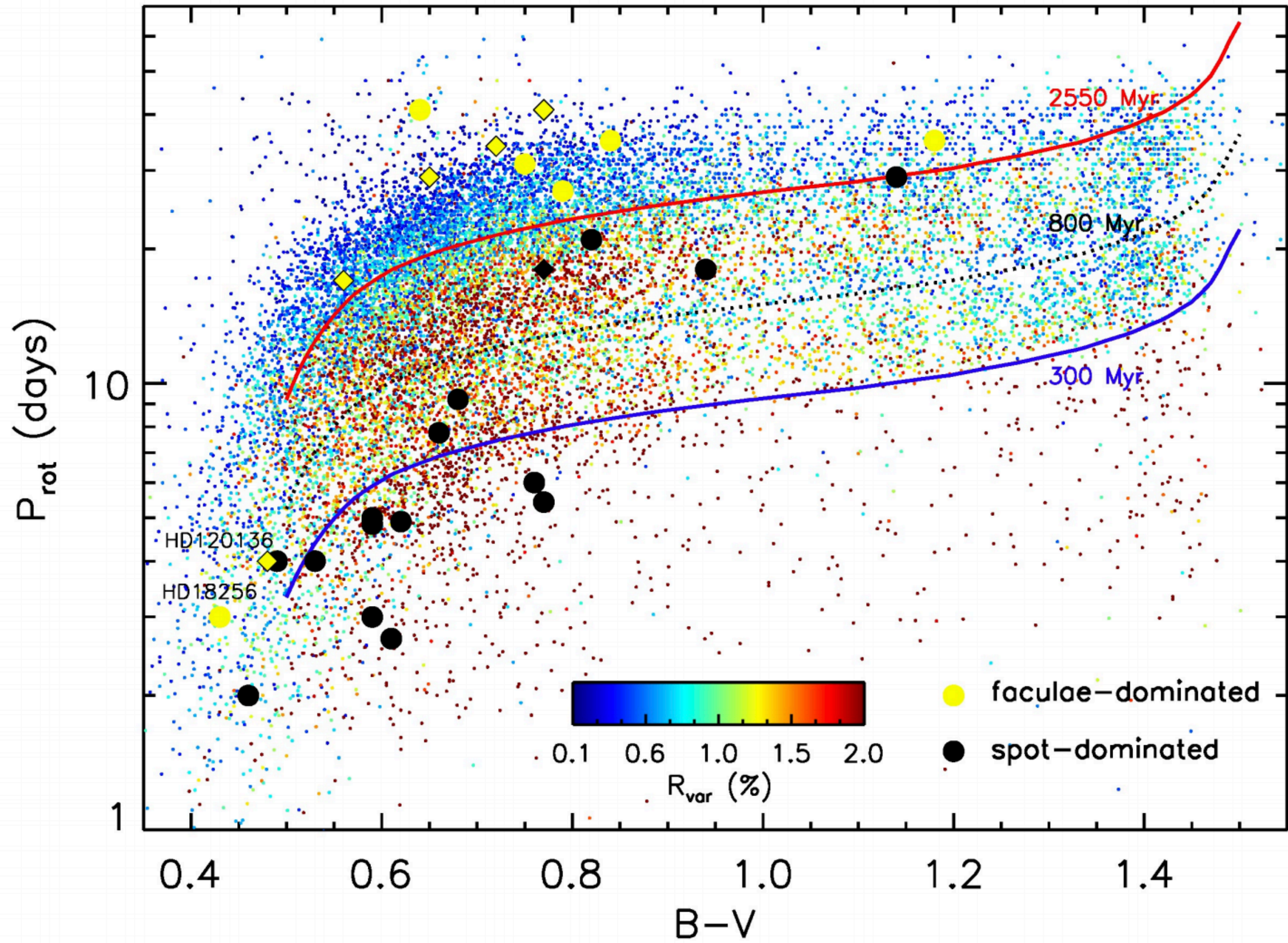


Montet, Tovar, and
Foreman-Mackey
(2017)

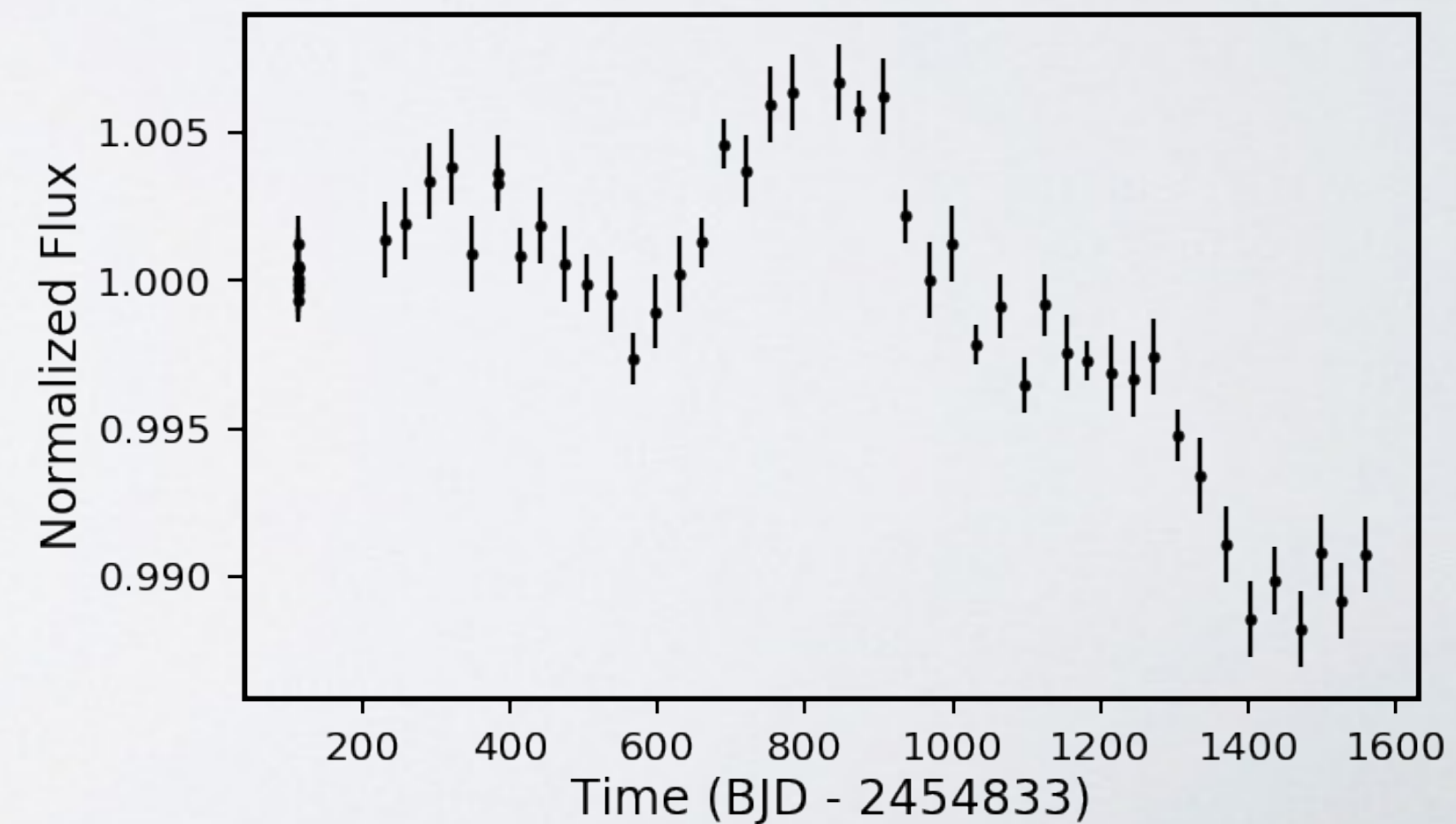
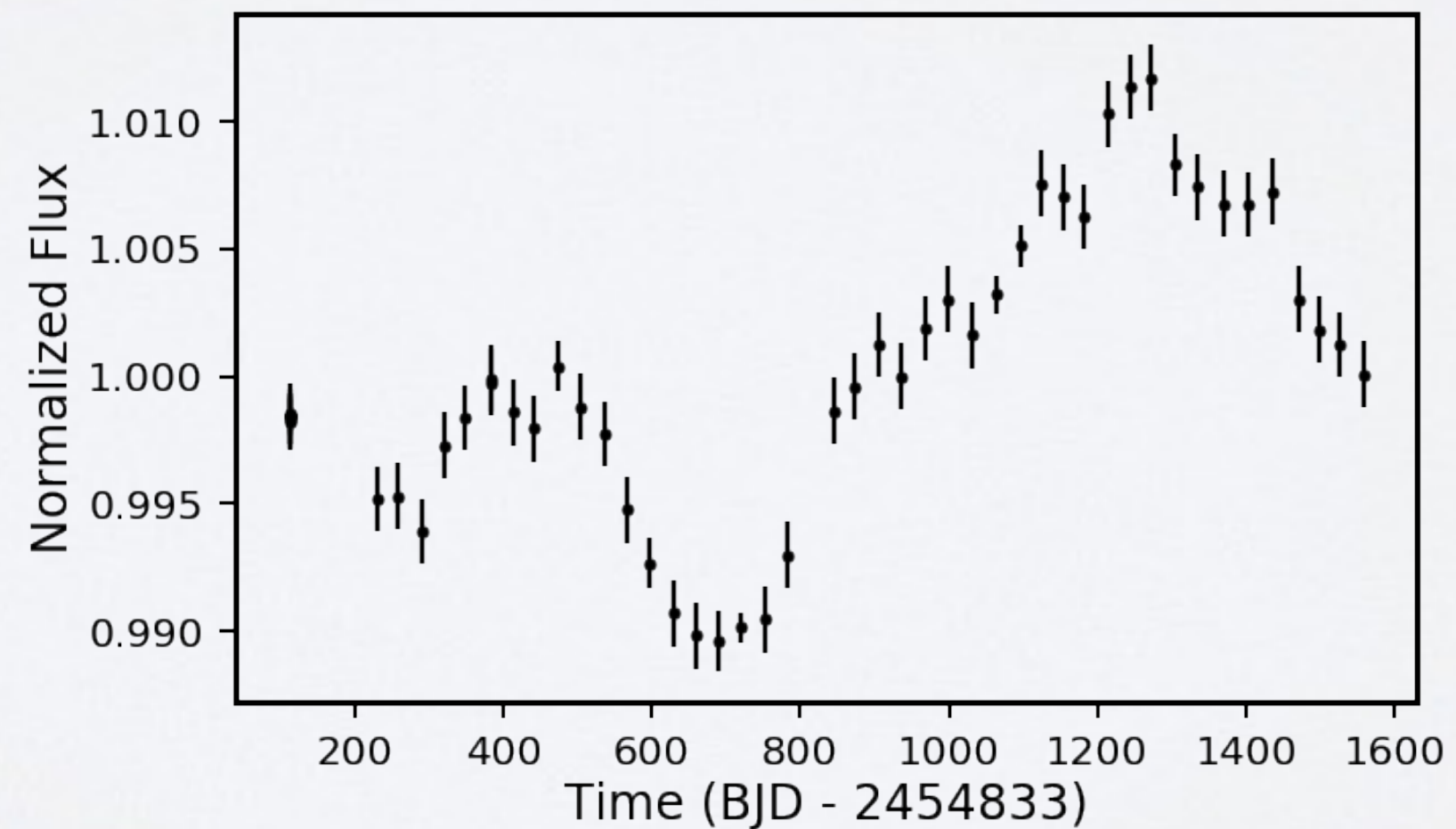
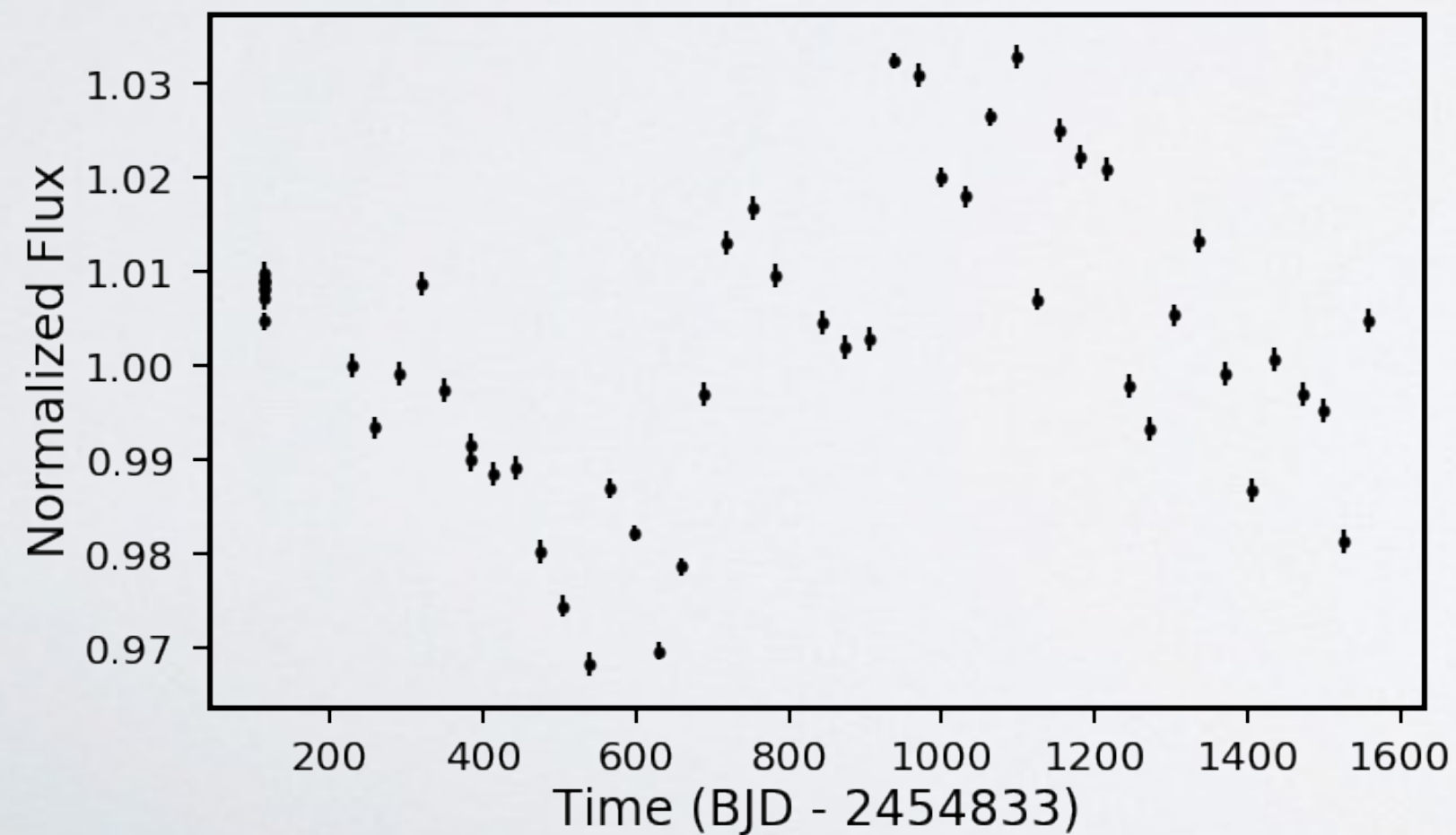
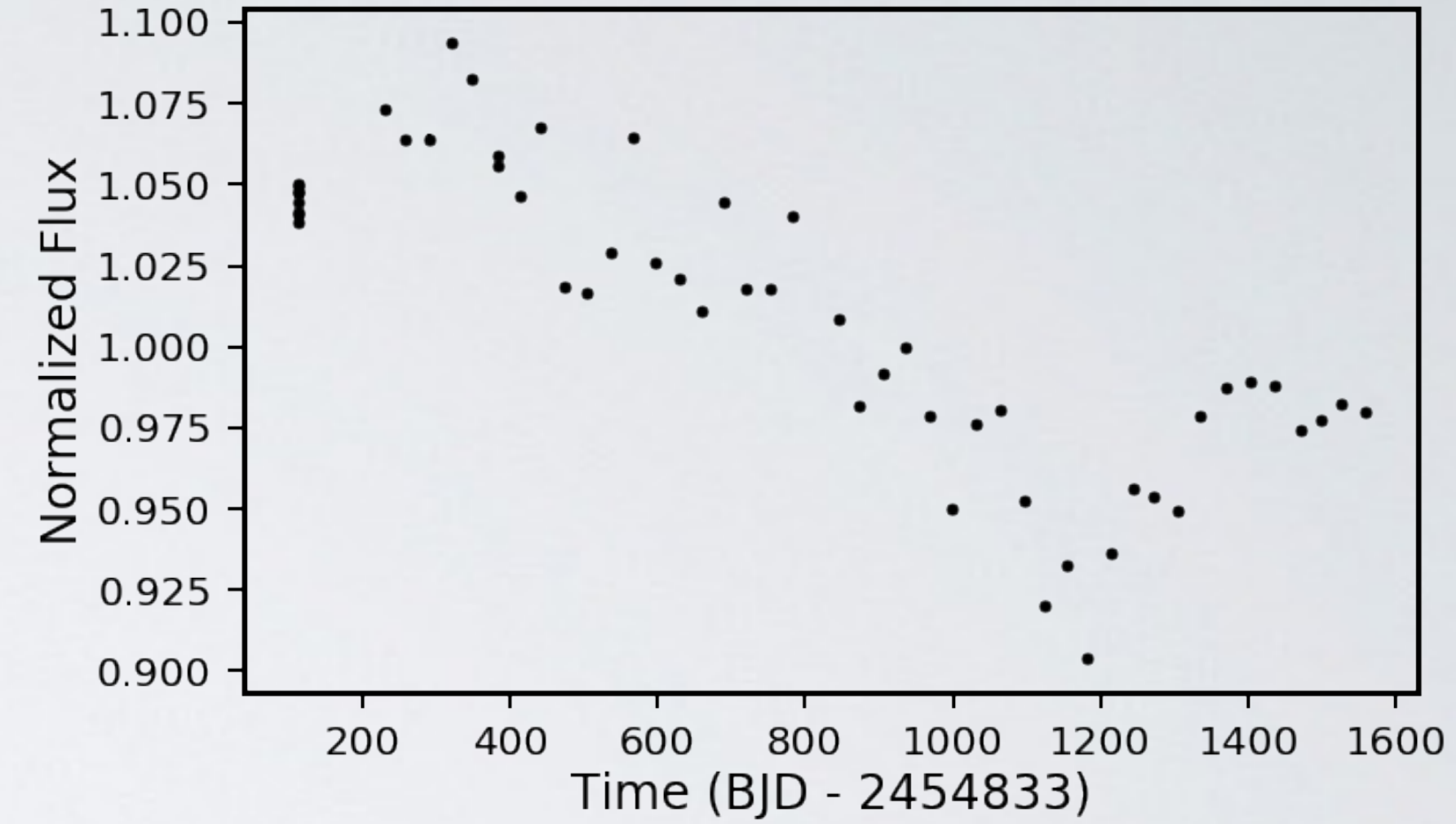
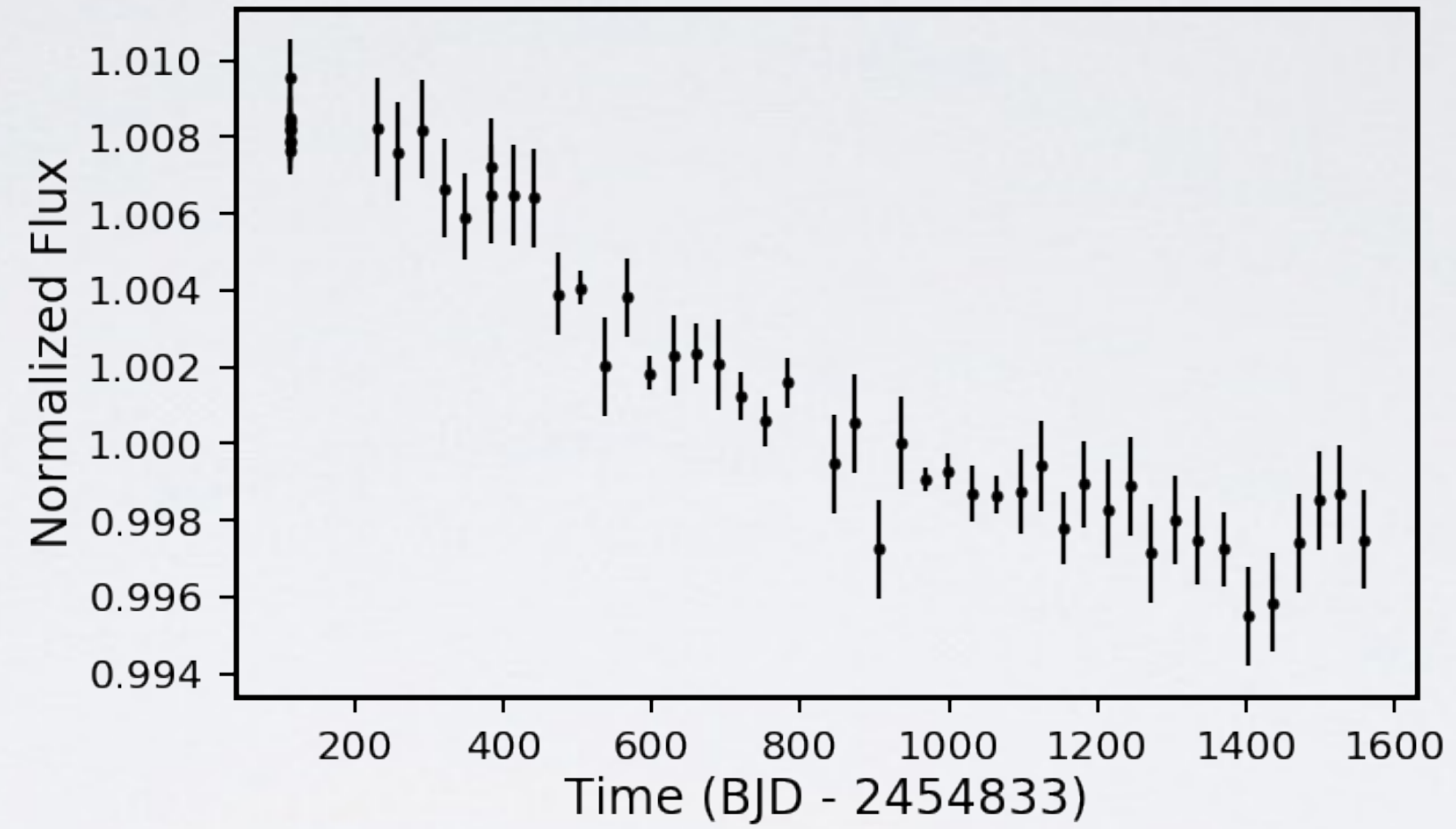
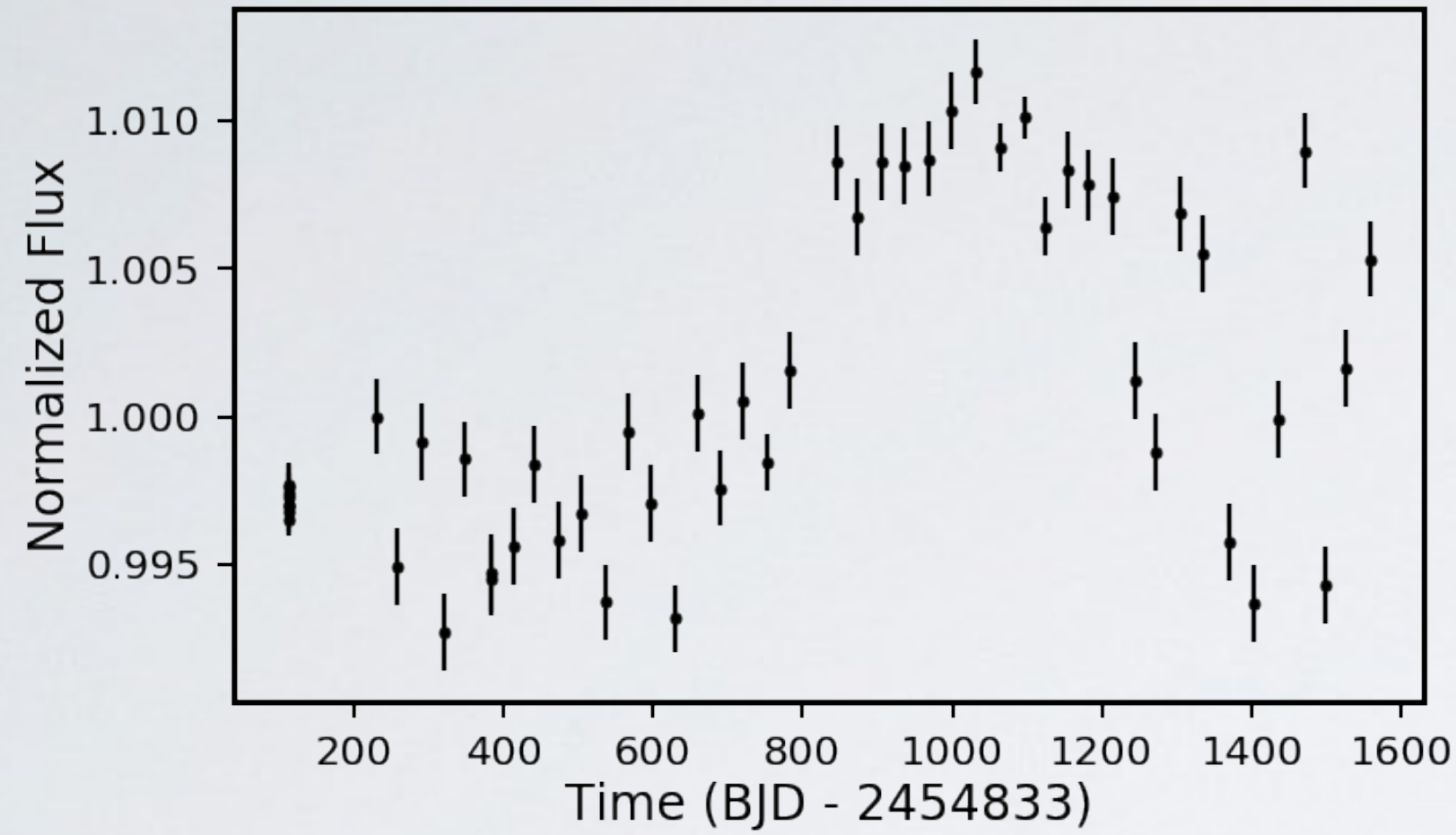
Rapid and slow rotators behave differently



Montet, Tovar, and
Foreman-Mackey
(2017)

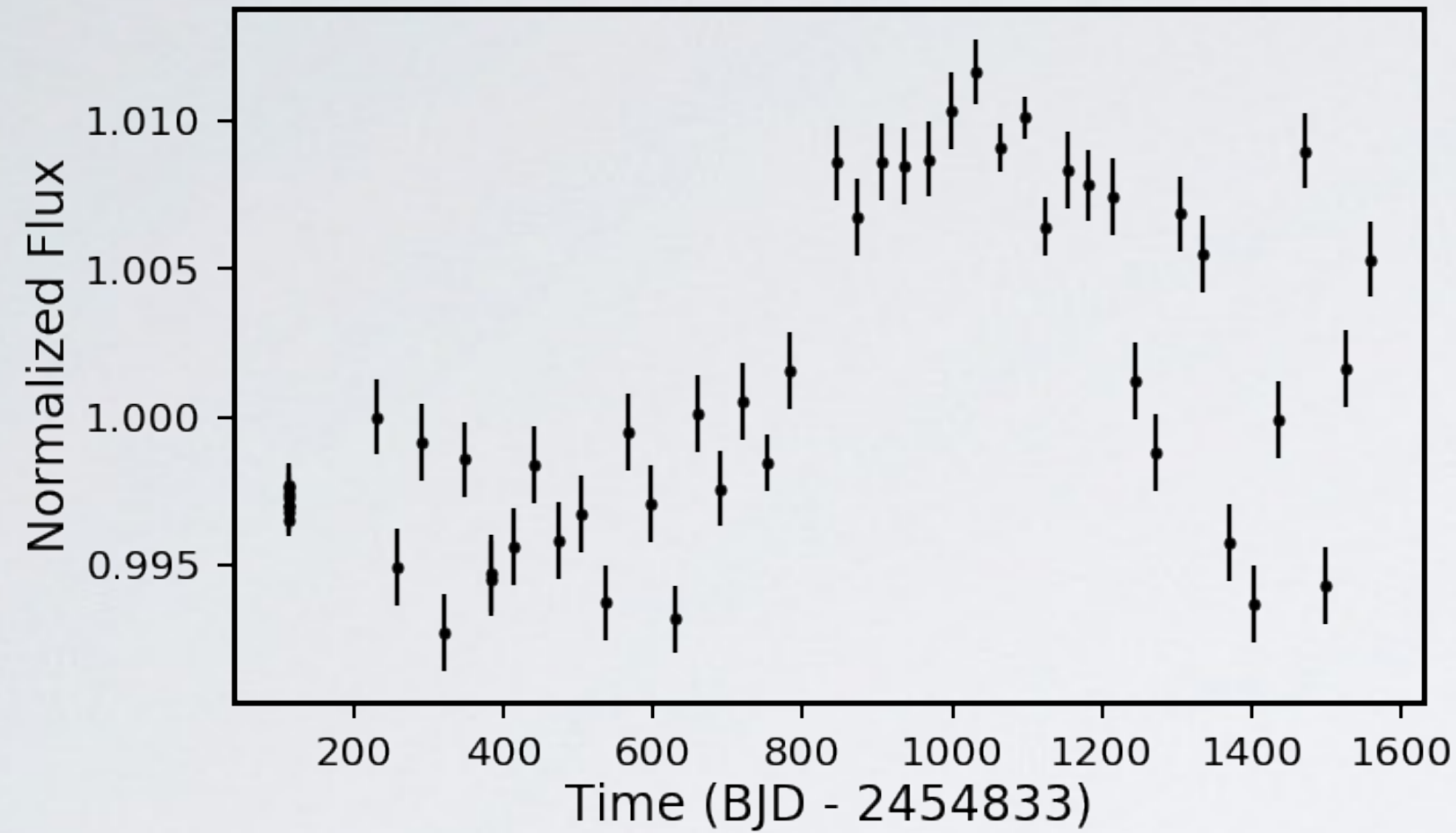


The future: stellar activity across the H-R diagram

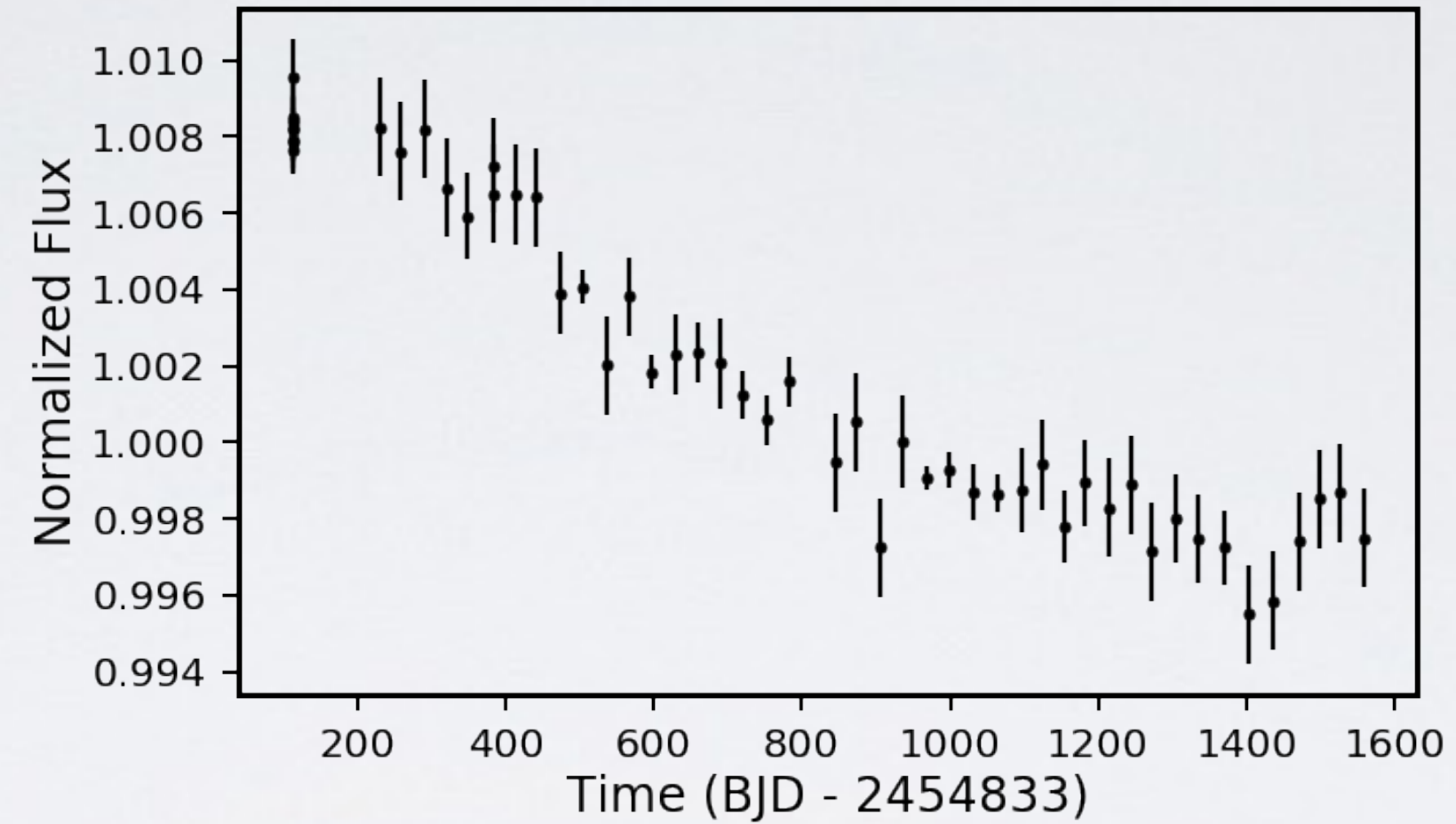


The future: stellar activity across the H-R diagram

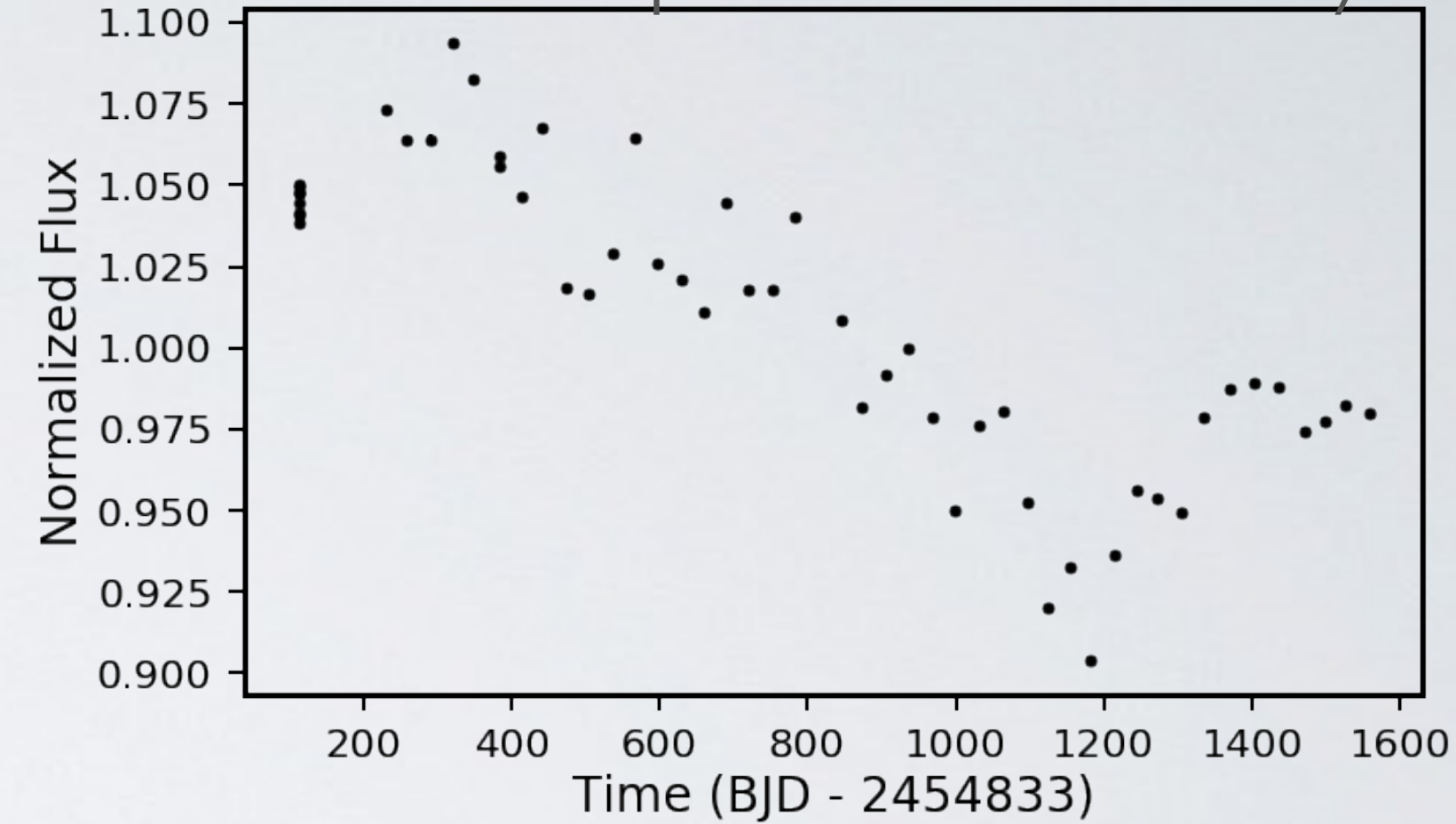
Late G dwarf



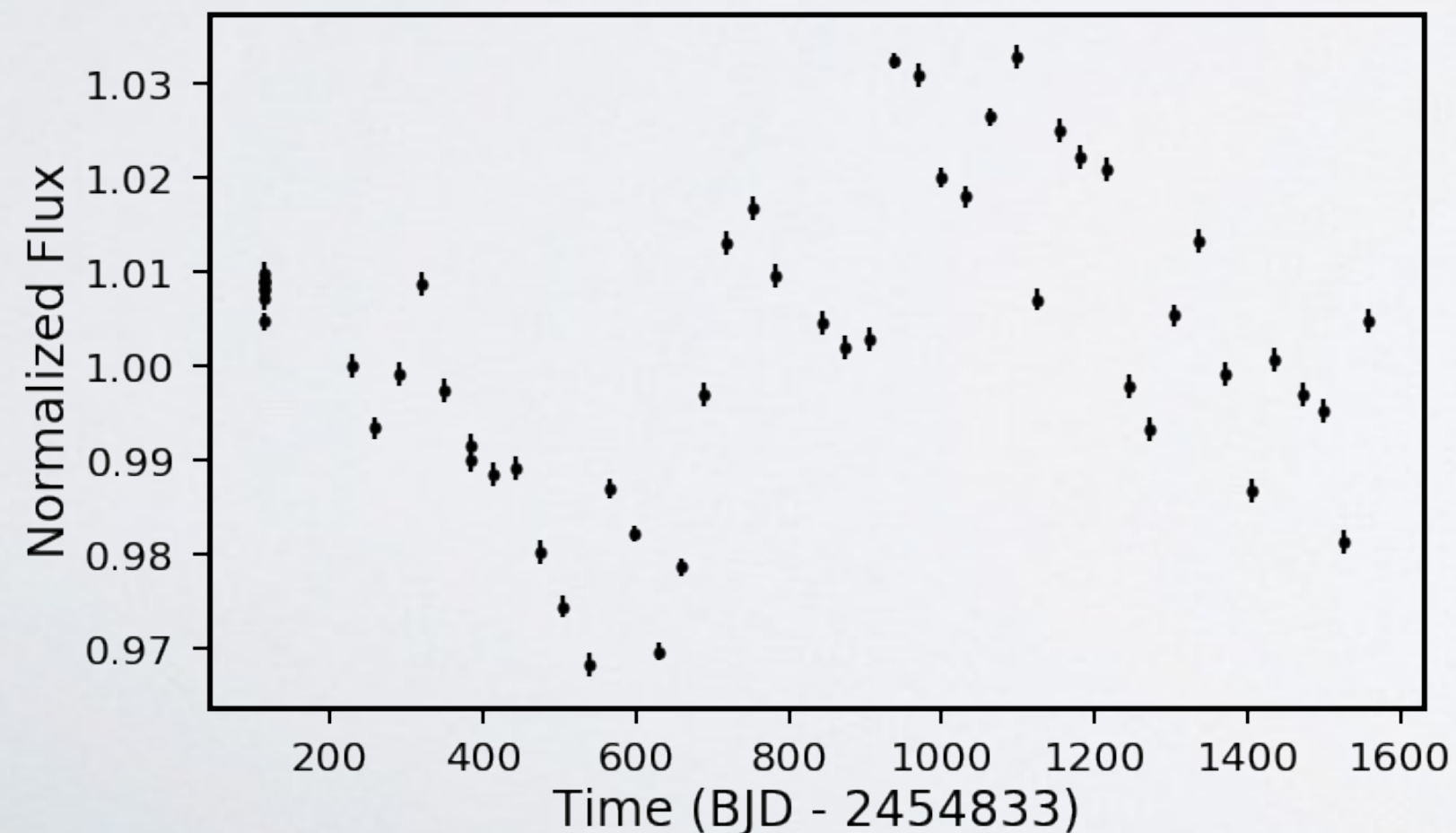
F star



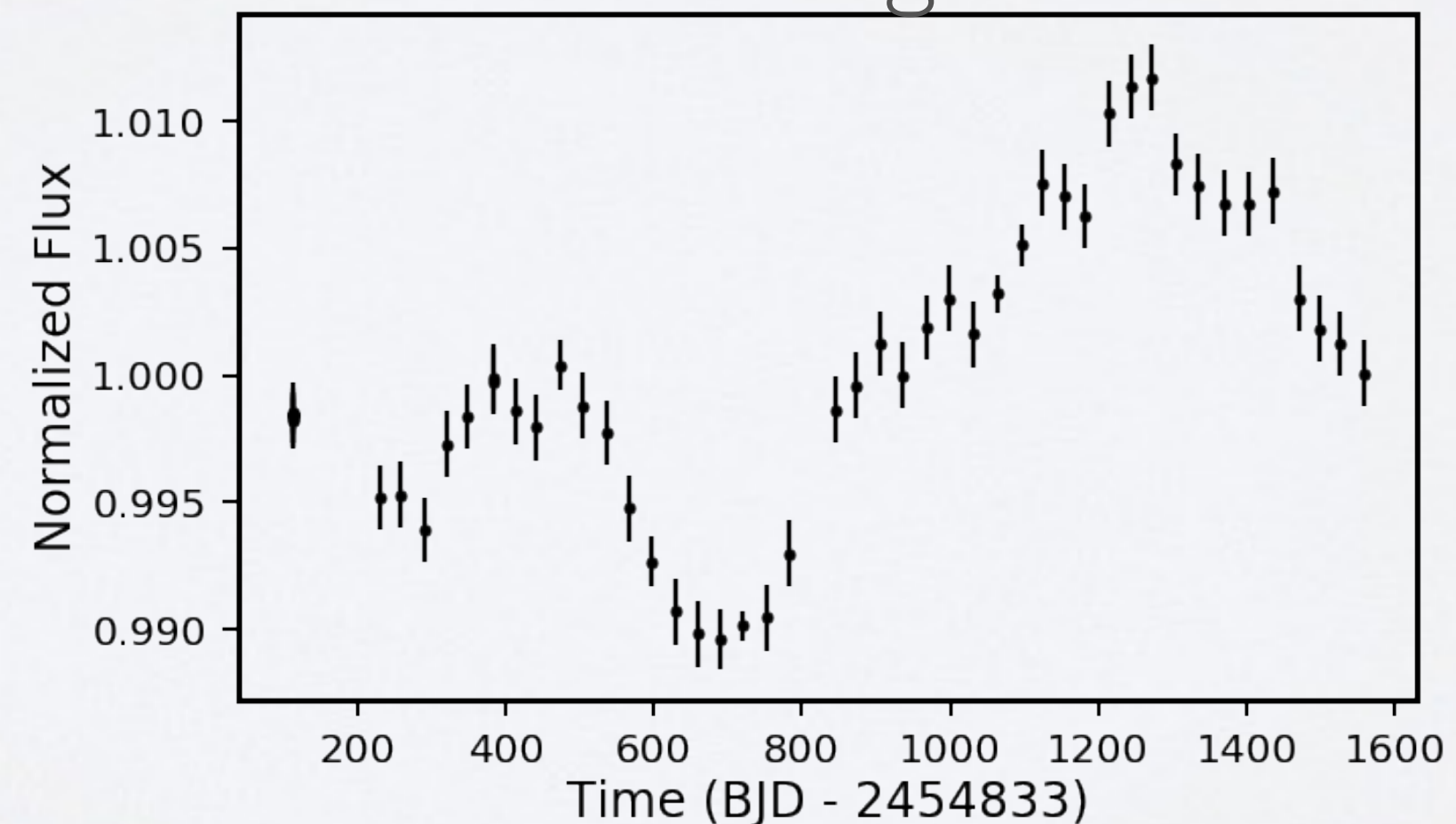
K dwarf/probable binary



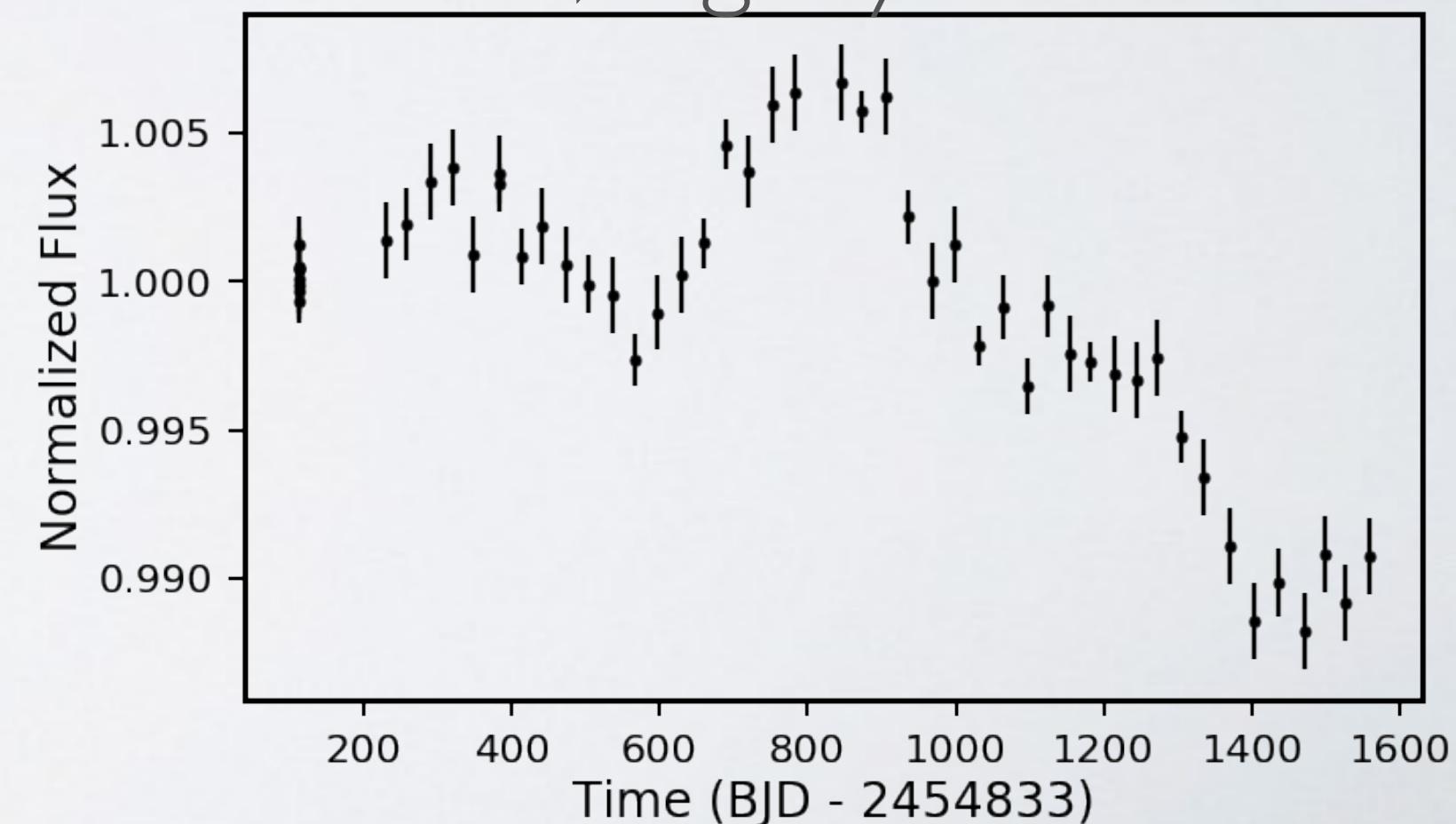
K dwarf



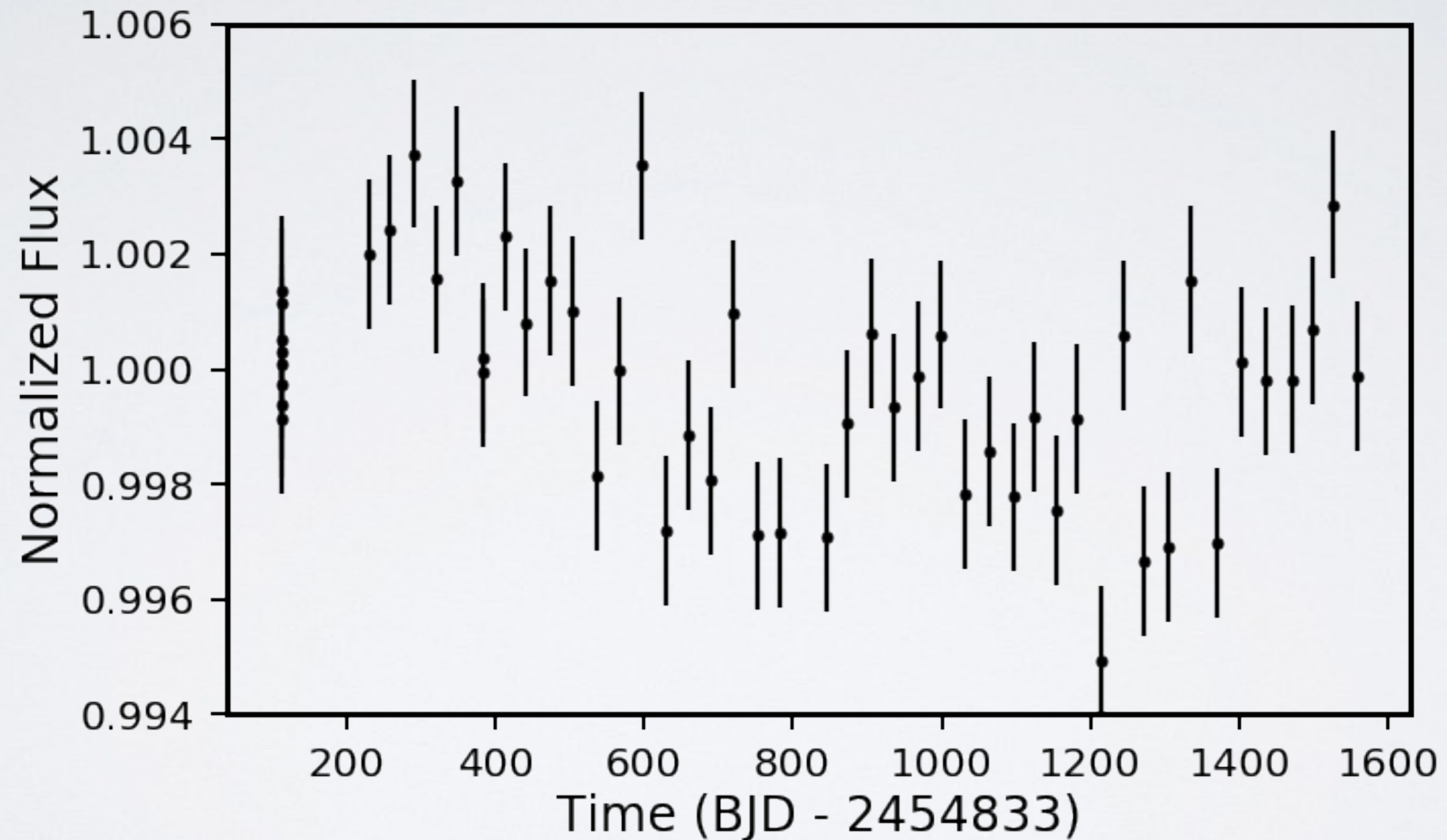
G subgiant



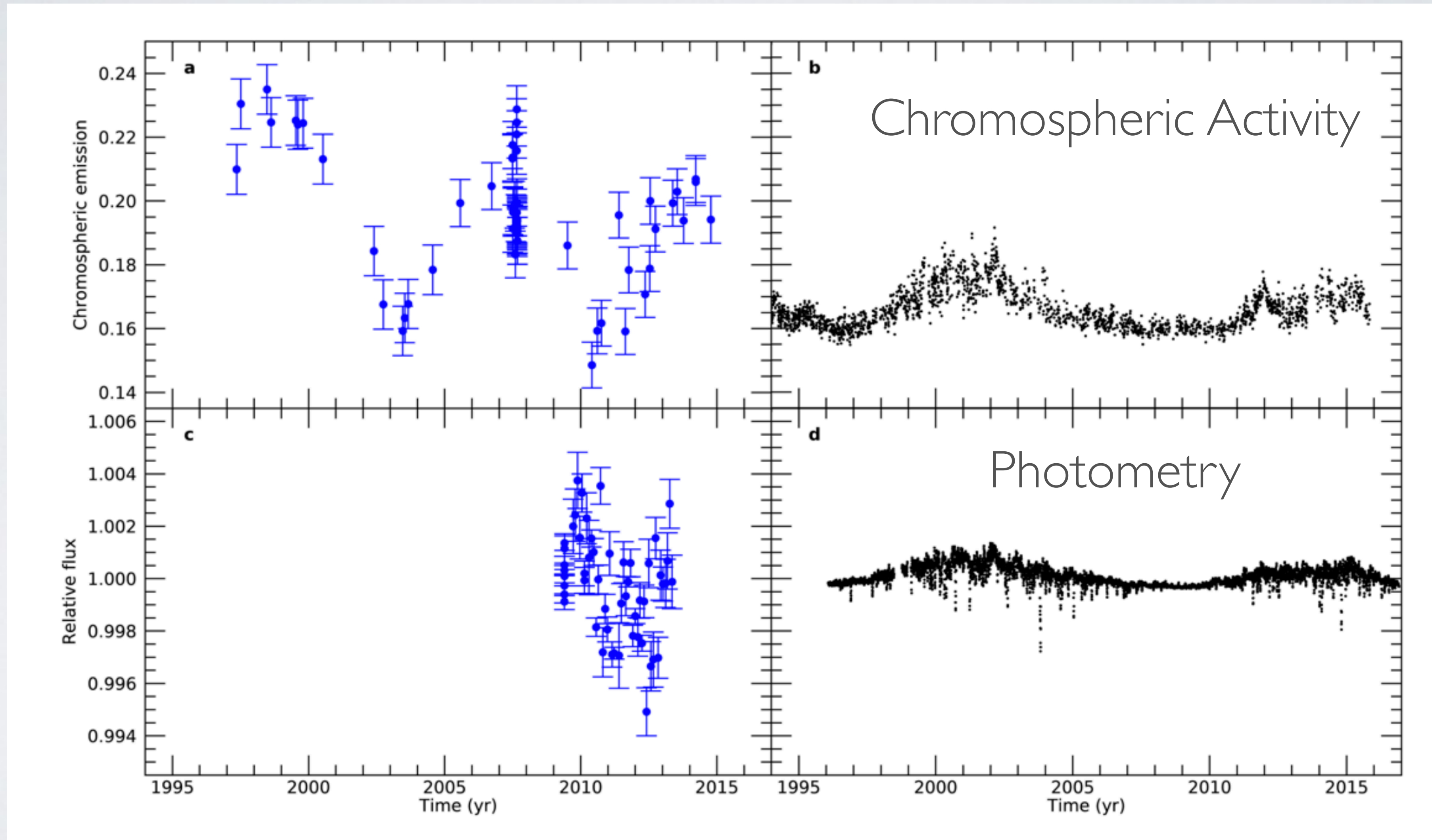
F star, slightly evolved



Learning from Individual Stars: KIC 8006161/Doris



KIC 8006161 compared to the Sun



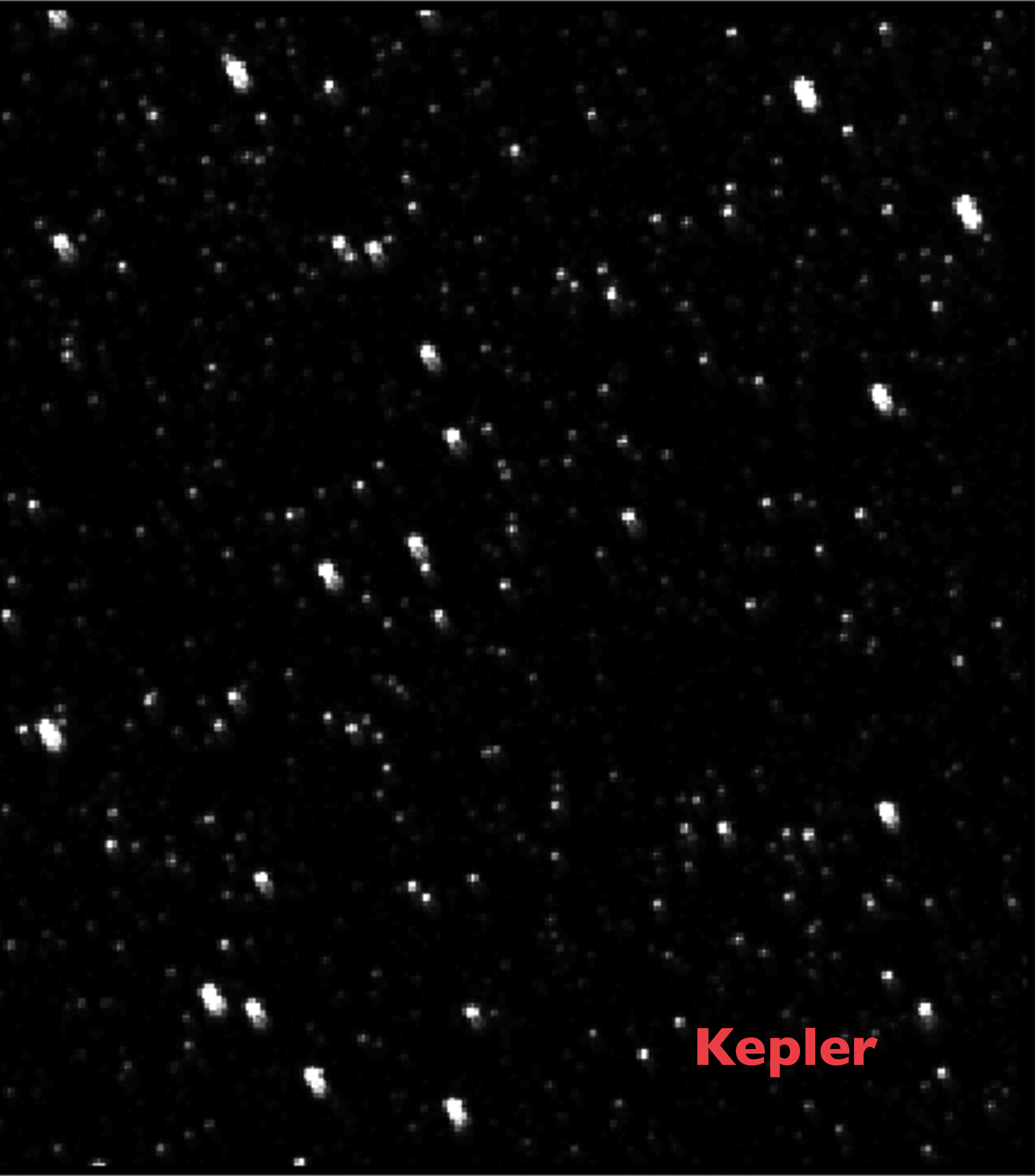
If you give a star some metals...

Increasing the metallicity of a Sun-like star will increase the opacities, which in turn will increase the temperature gradient. This means that the criterion for convection is satisfied deeper in the star (Schwarzschild 1906).

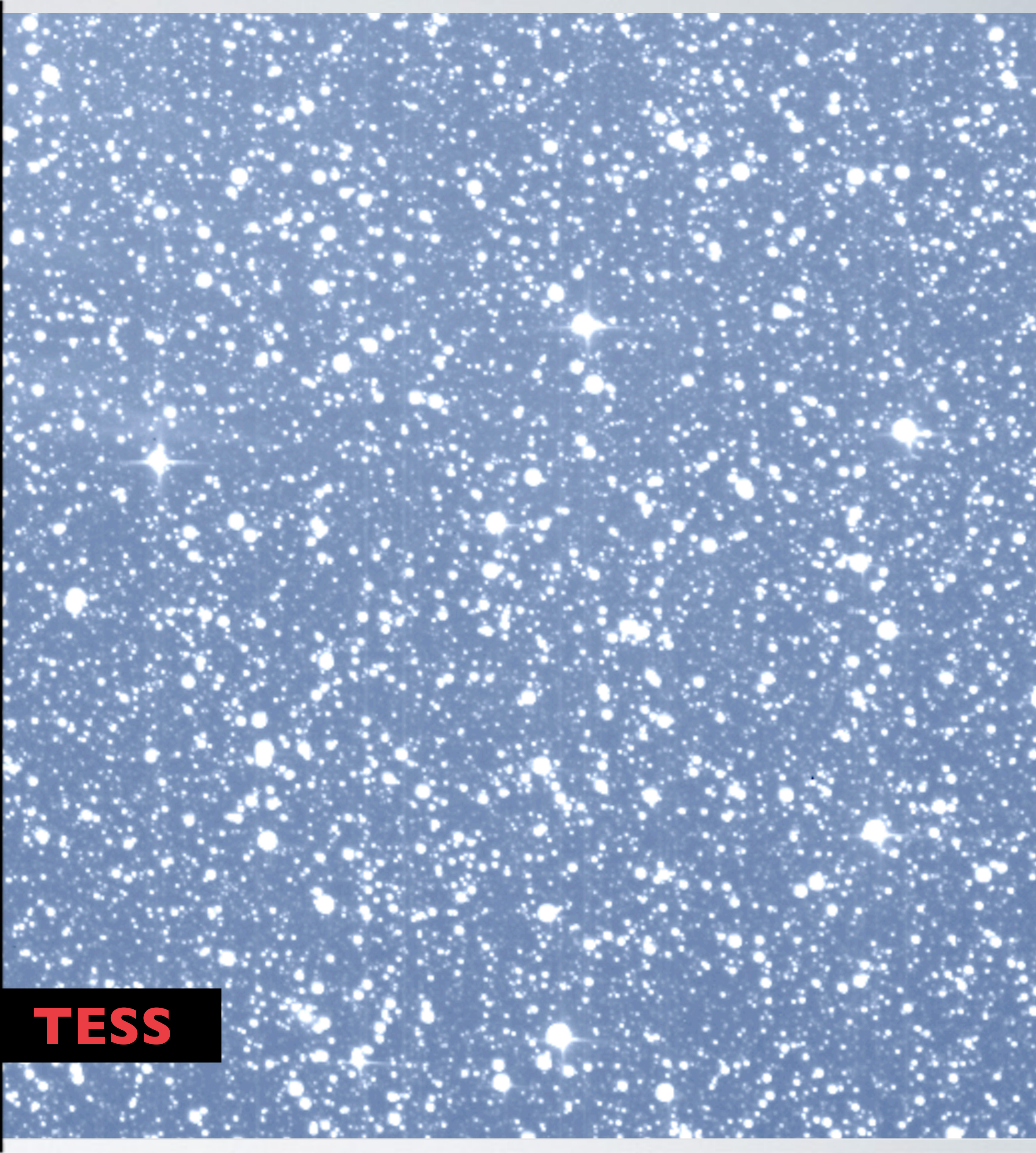
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Theoretical studies have shown that a deeper convection zone leads to a longer convective turnover time near the base of the outer convection zone (Brun et al. 2017) and thus stronger differential rotation (Bessolaz & Brun 2011) in the same region. Stronger differential rotation will lead to a stronger dynamo



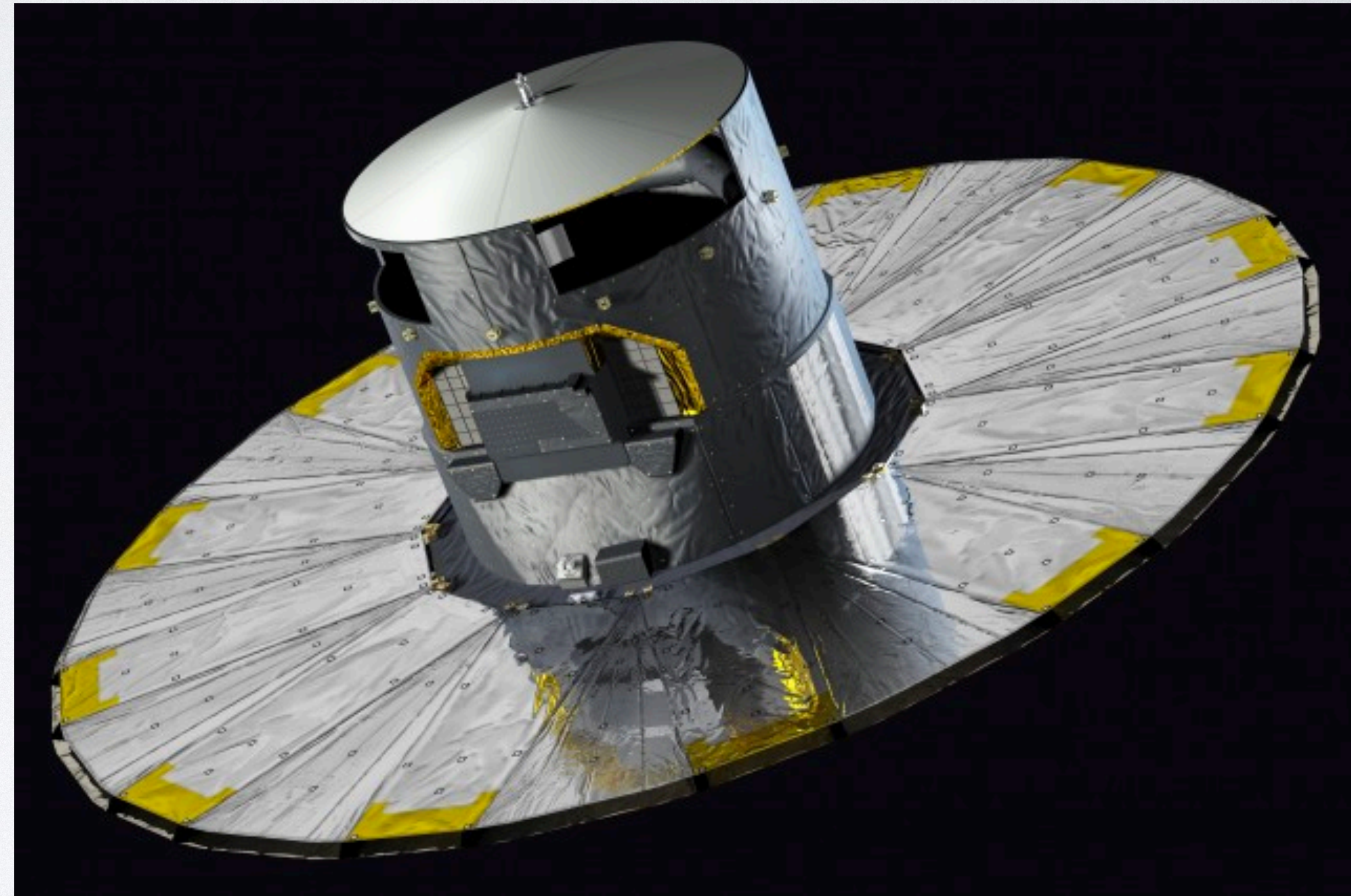
Kepler



TESS

The future: Gaia

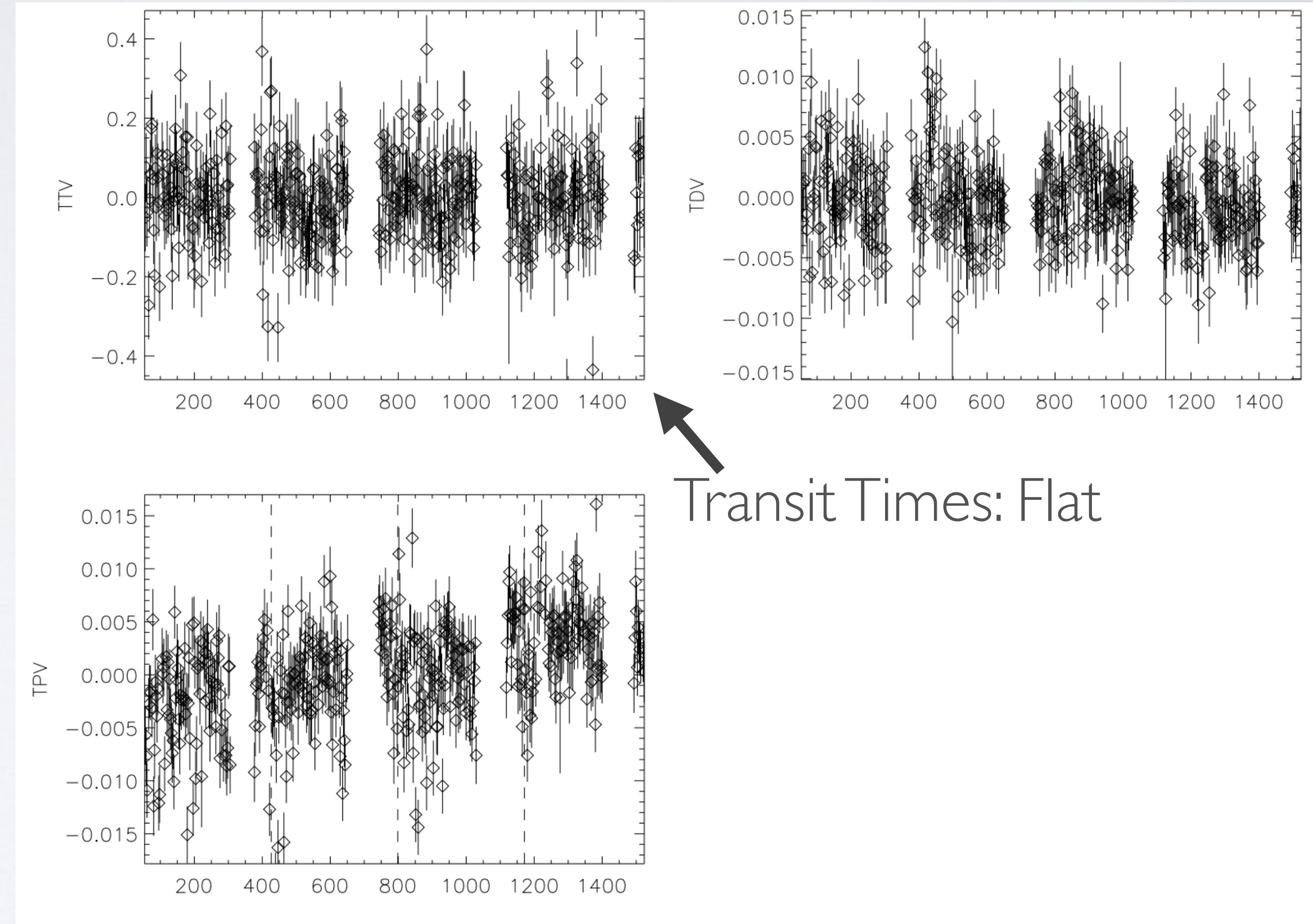
- 2-3 mmag precision
- 1-2 month cadence
- 10 year time baseline!
- Combine long-term photometry with rotation periods from TESS, especially for high ecliptic latitudes
- Worse than dedicated surveys but many more stars



Stellar activity as a limitation in planet parameters

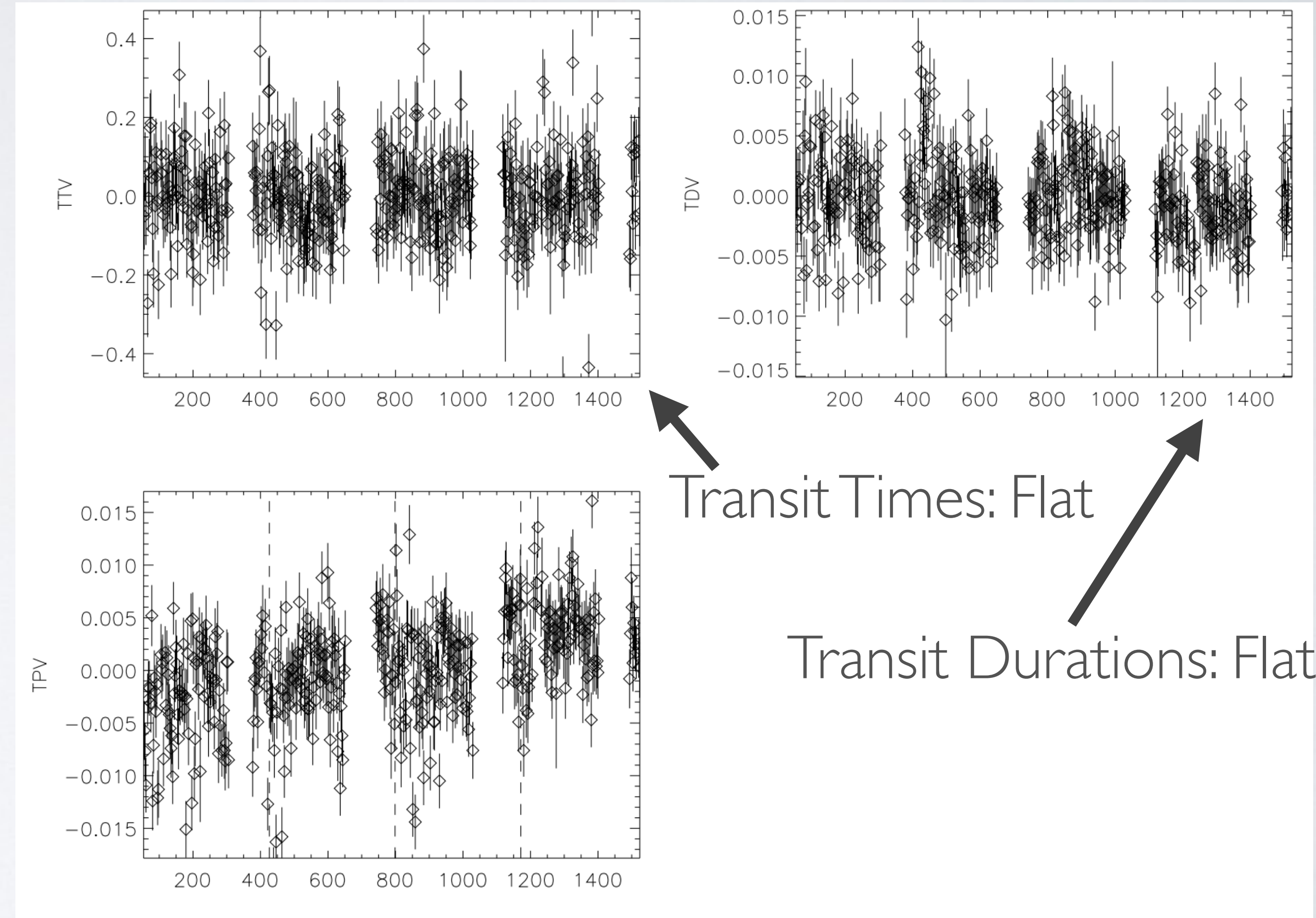
with Millholland (Yale) and Fabrycky (Chicago)

Stellar activity as a limitation in planet parameters



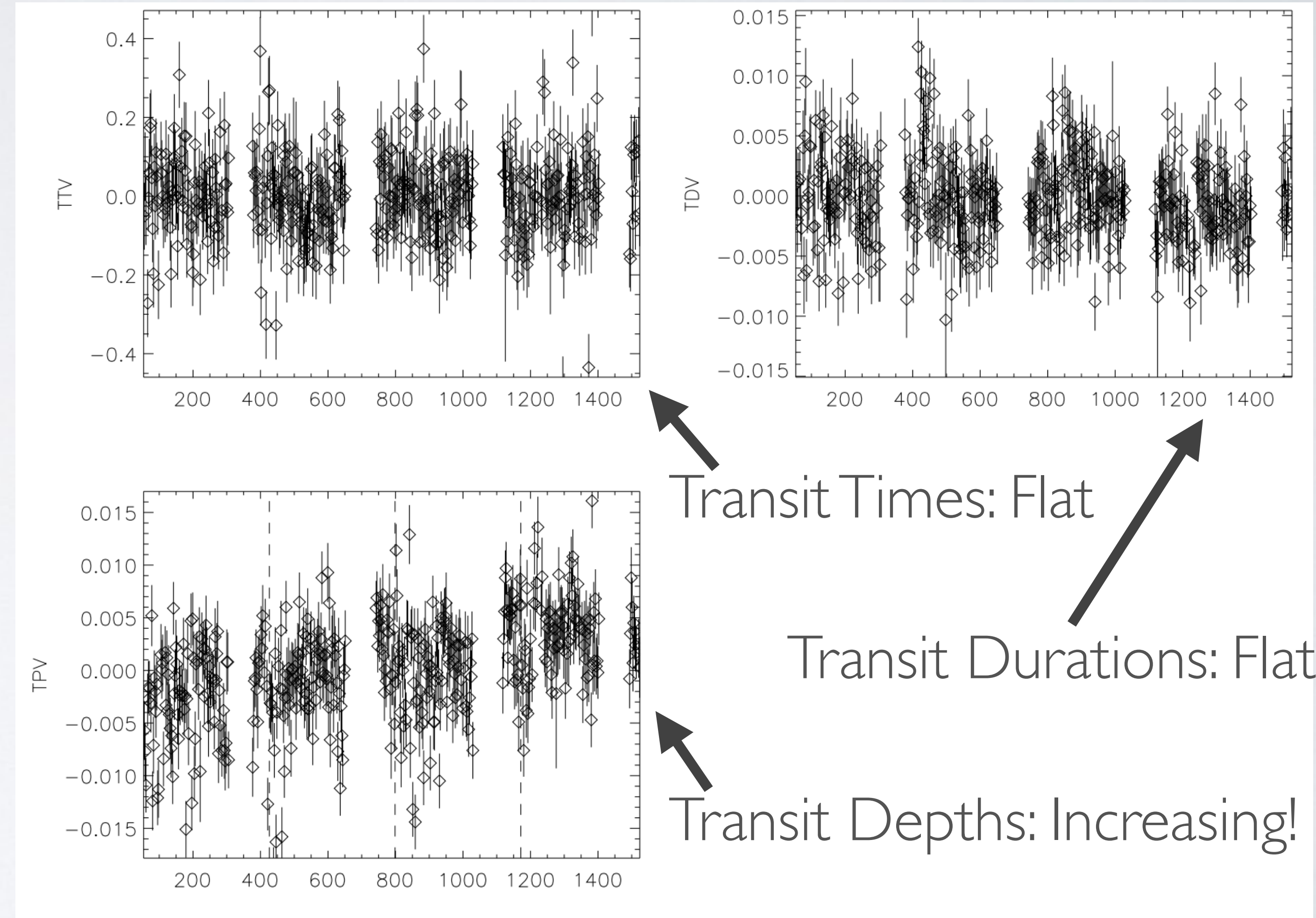
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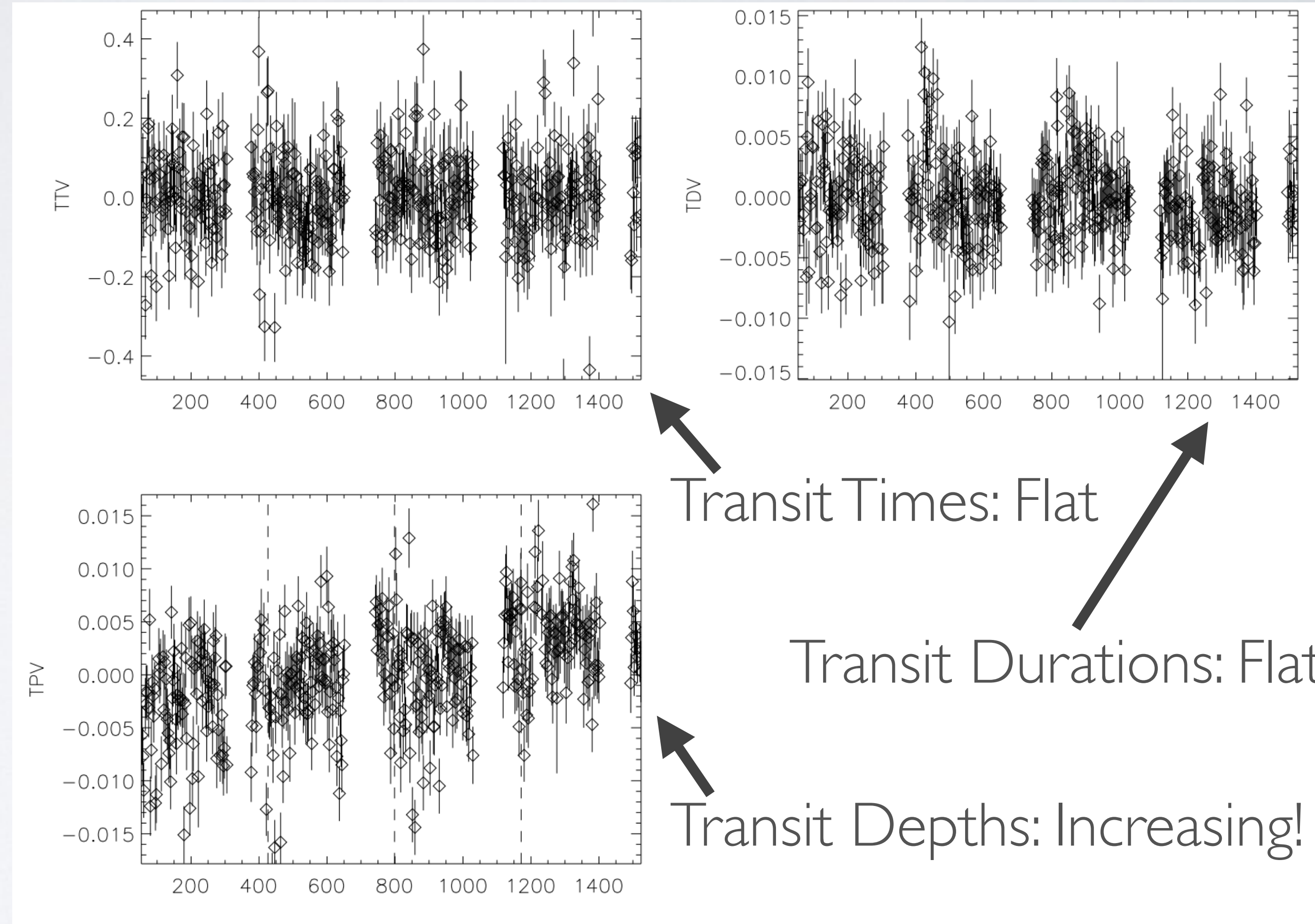
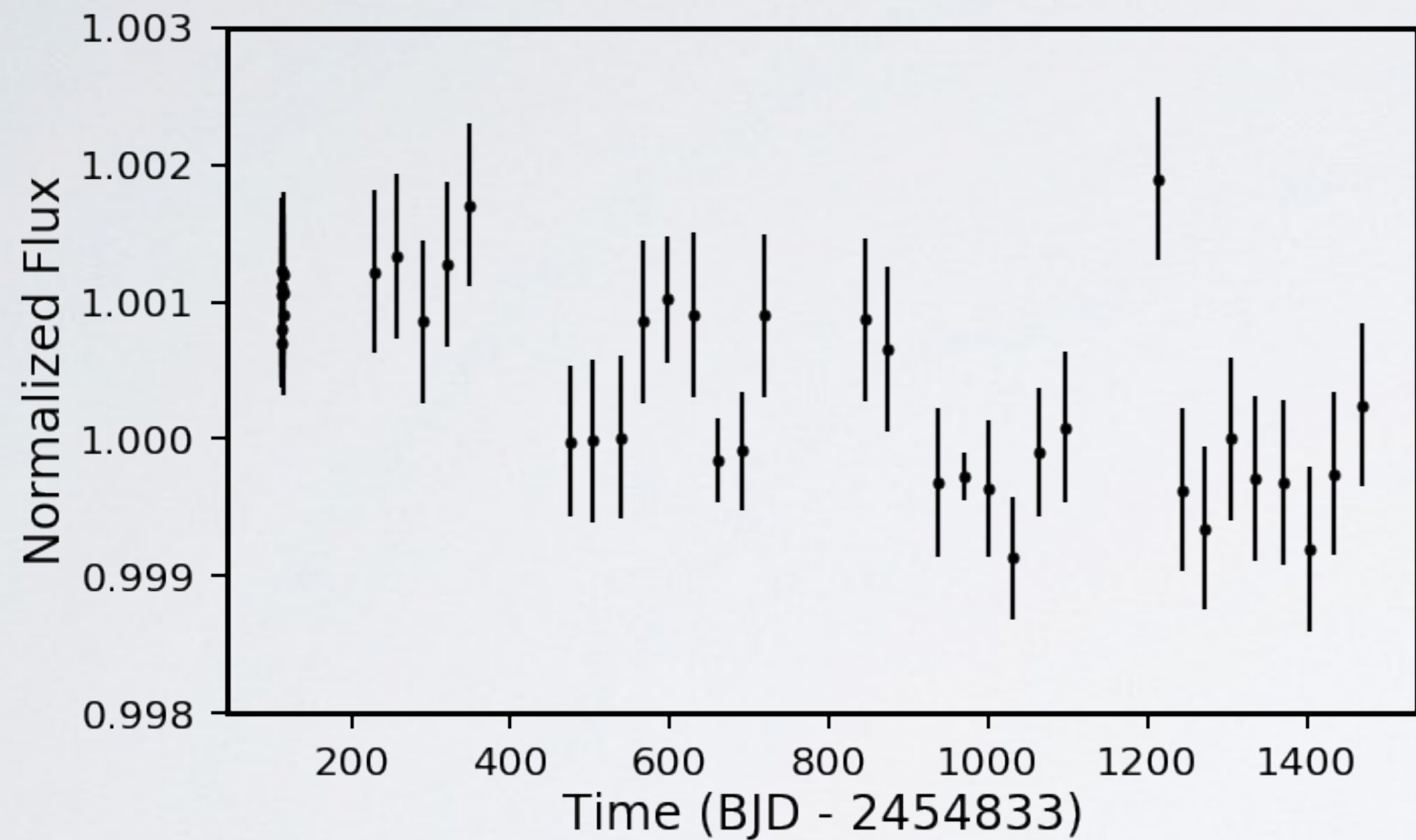
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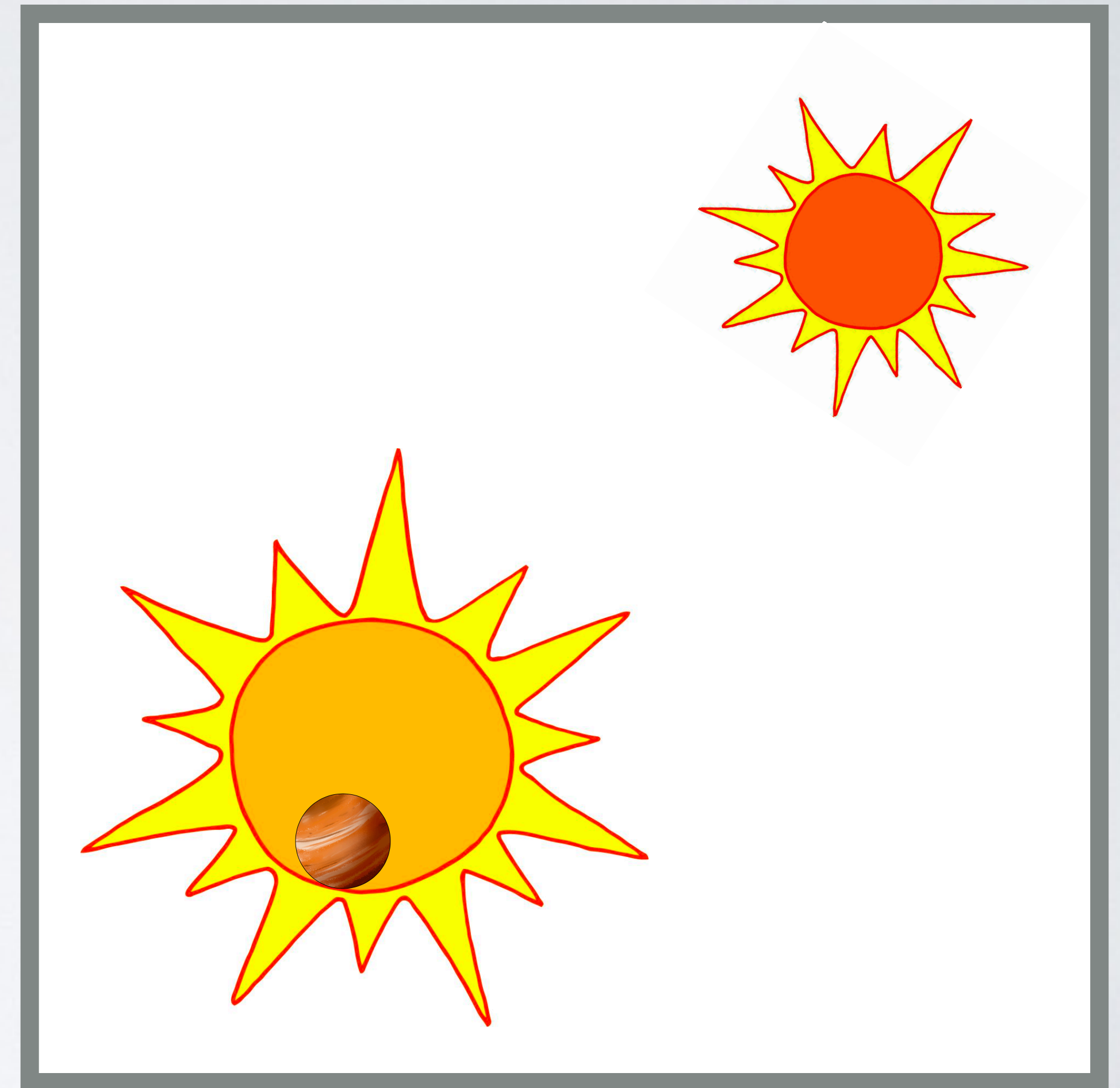
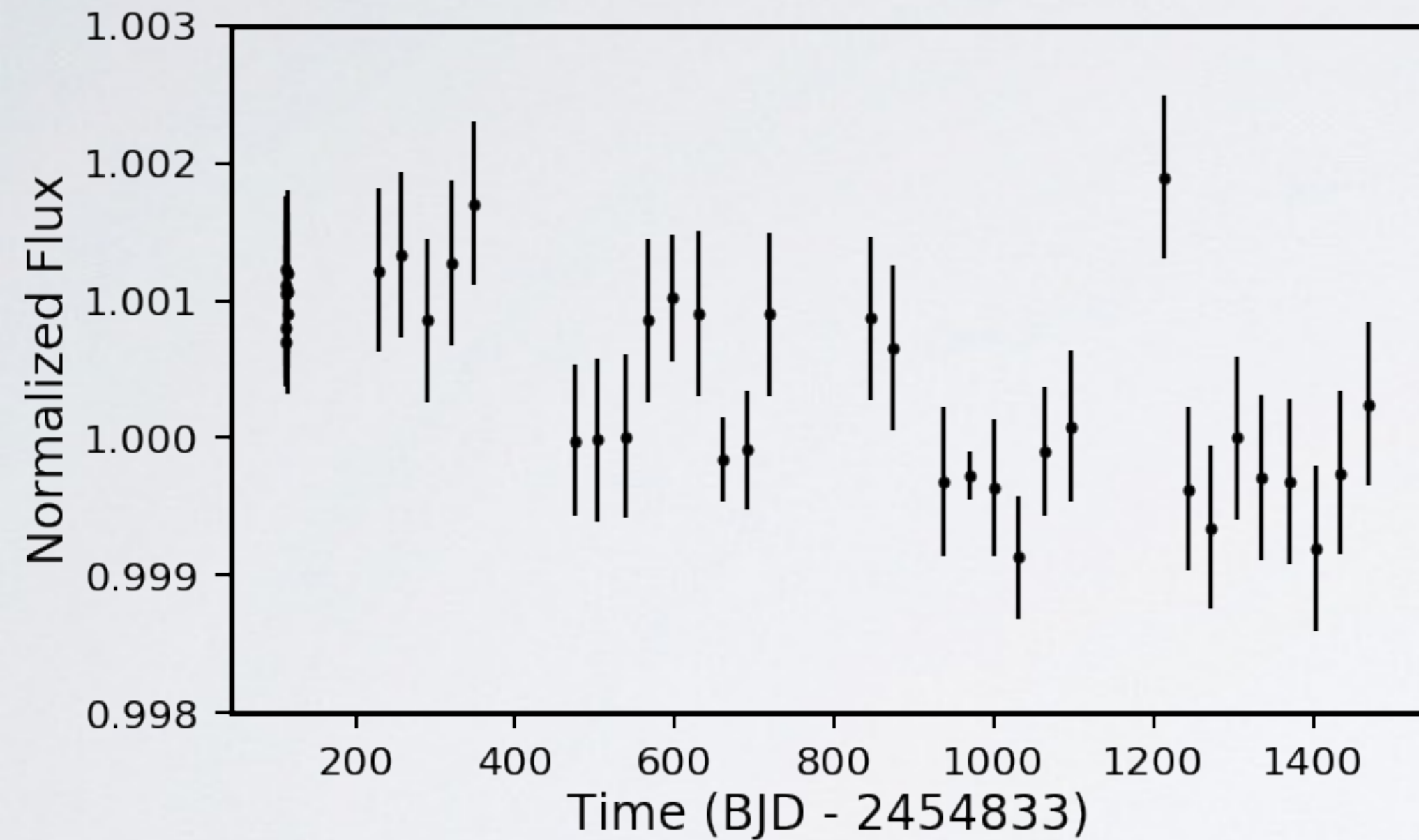
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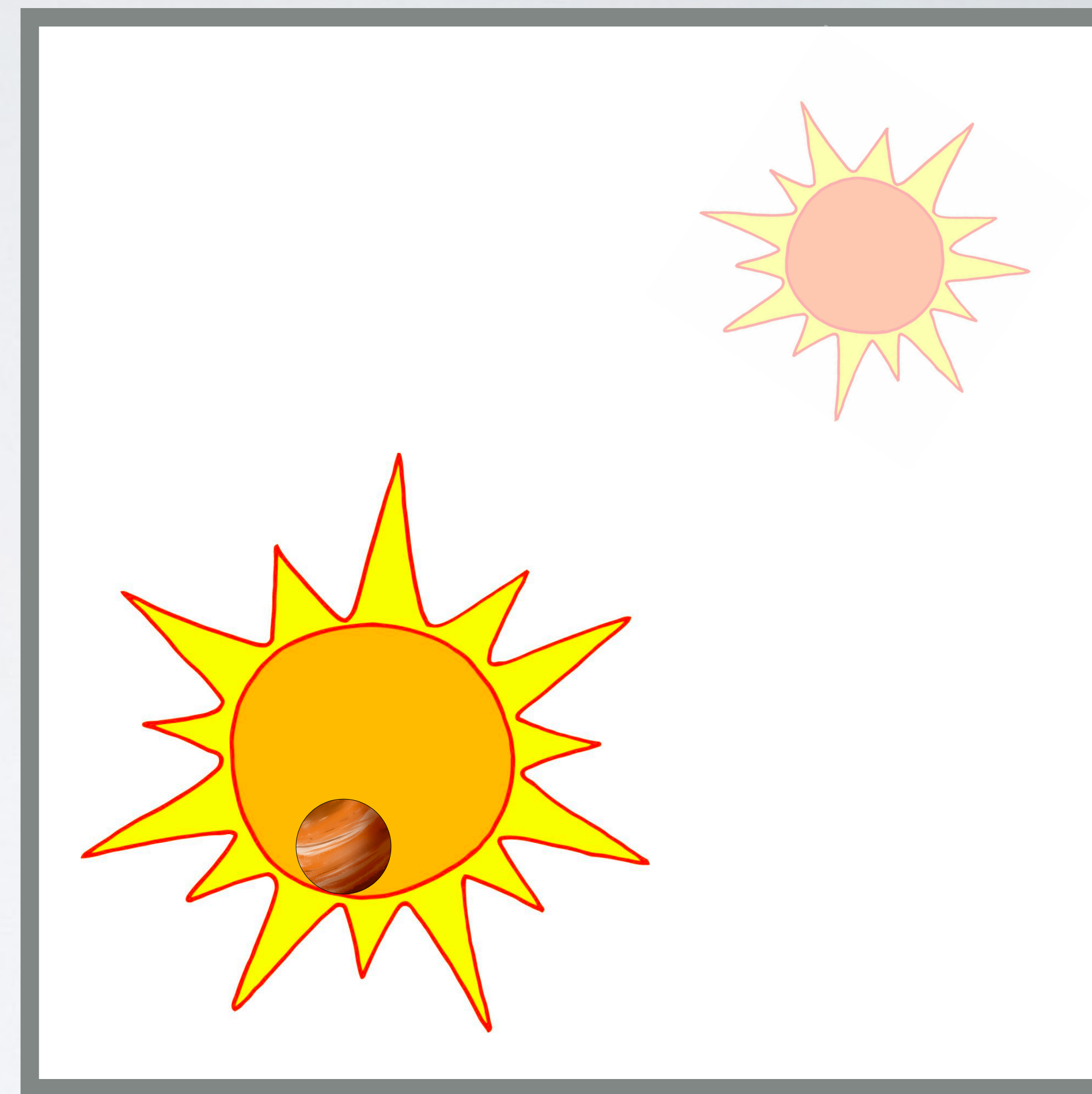
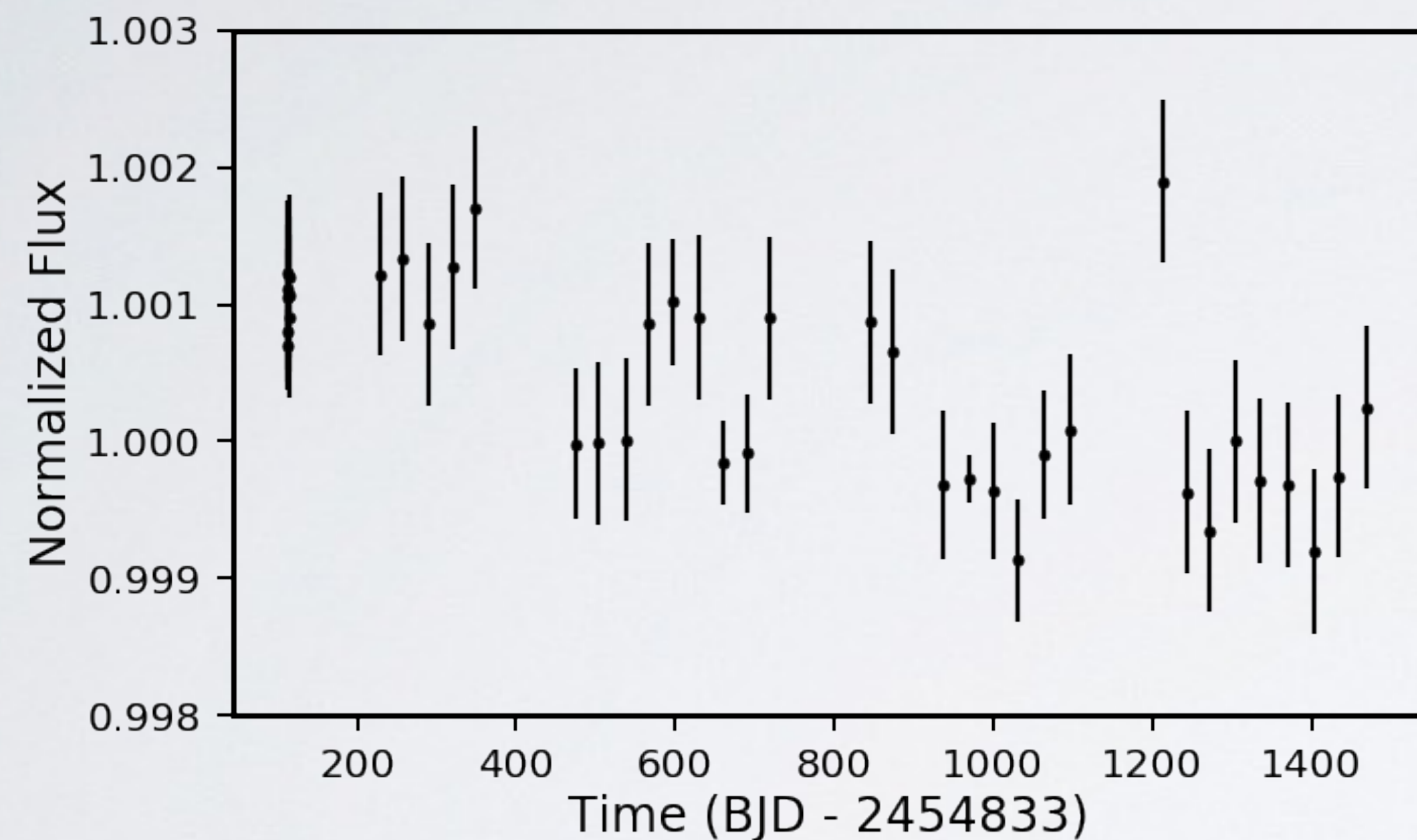
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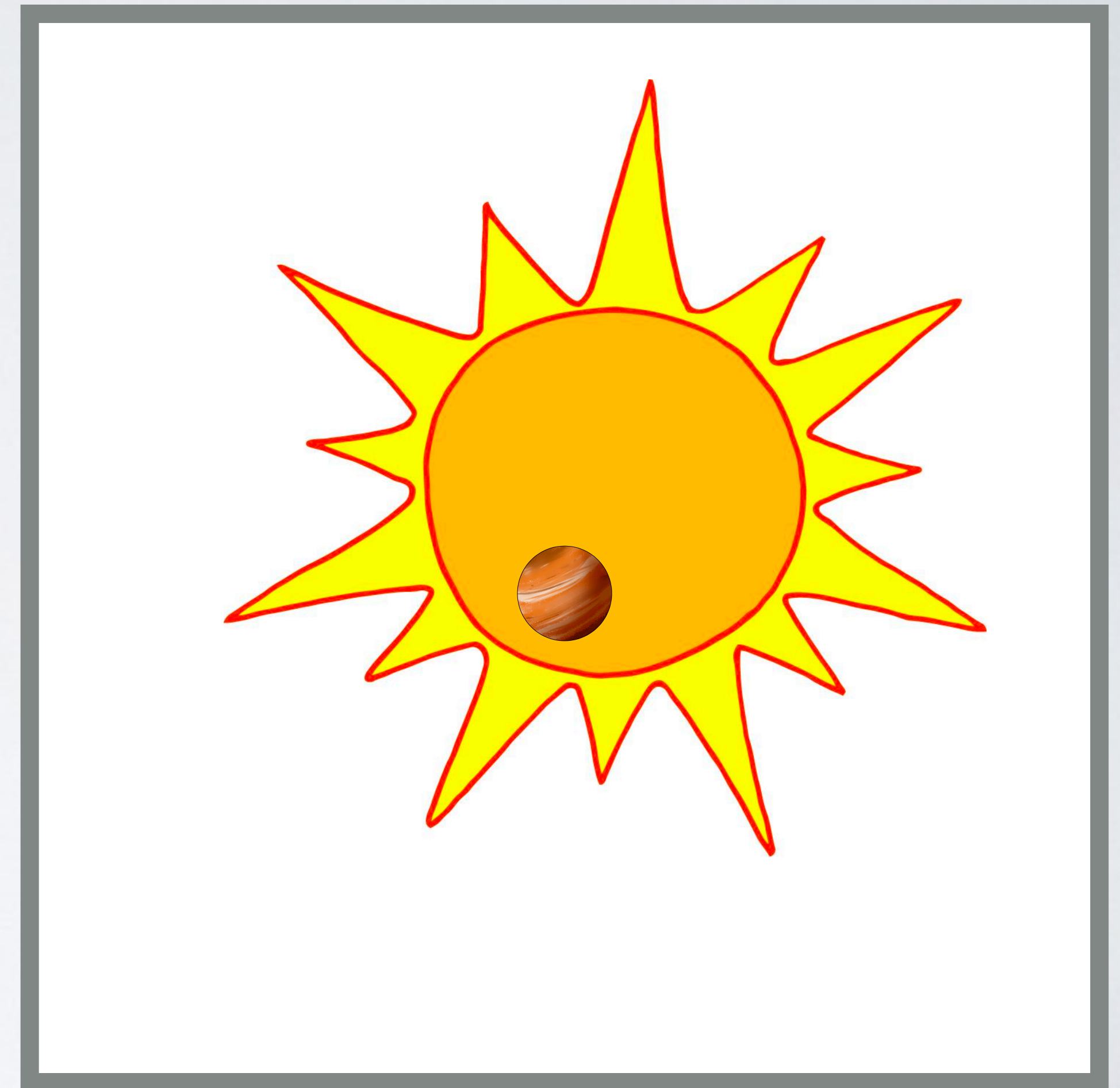
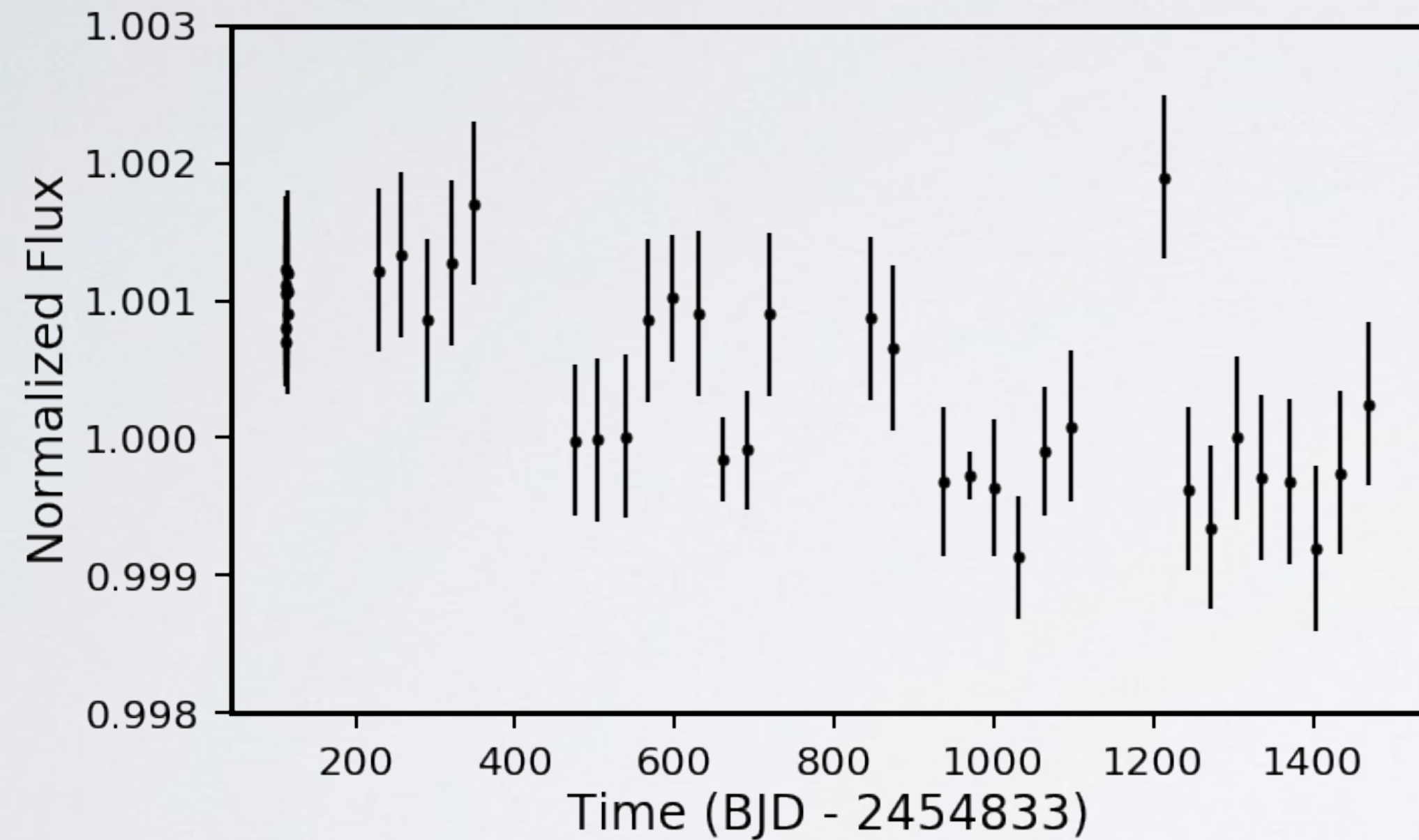
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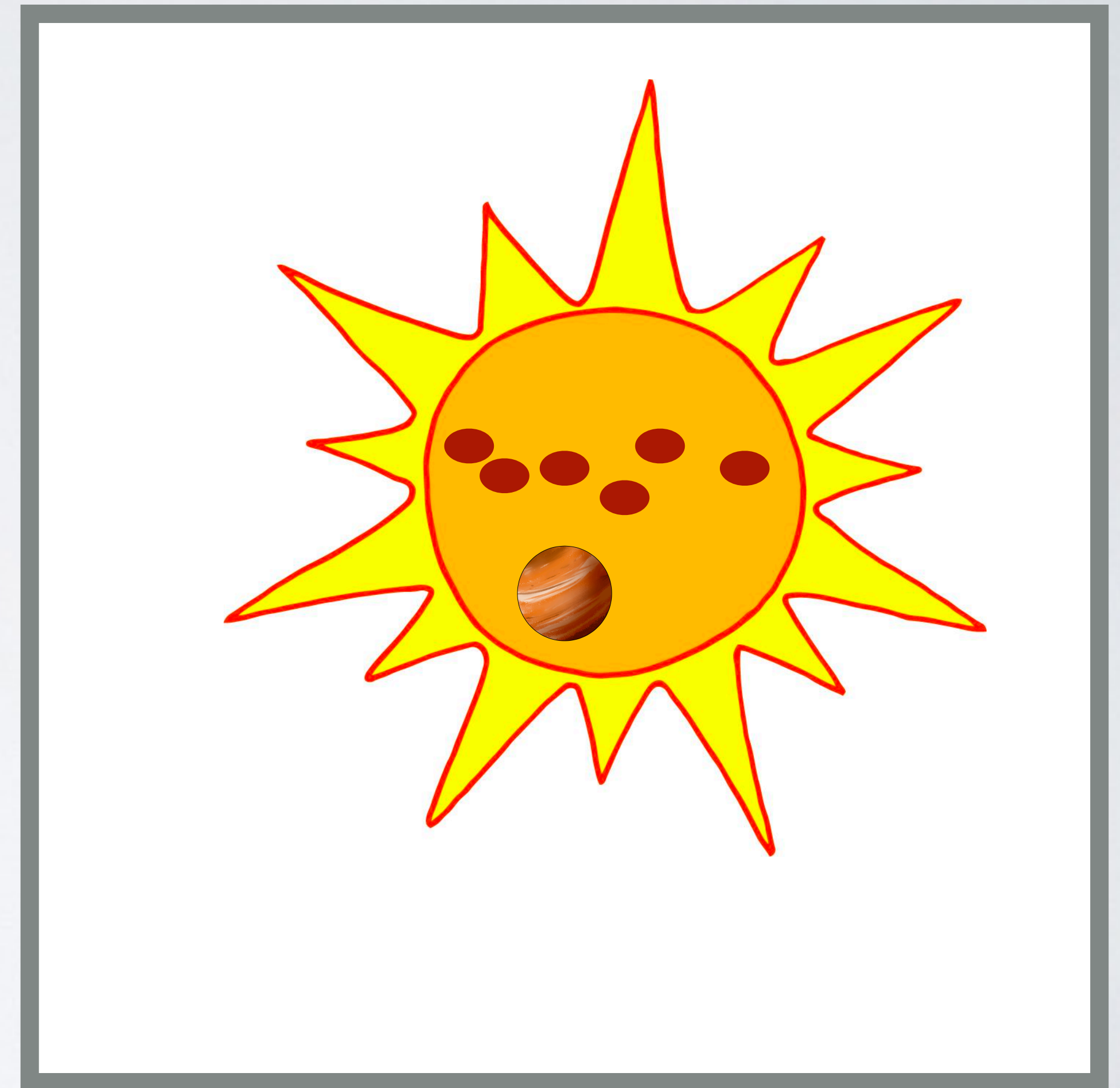
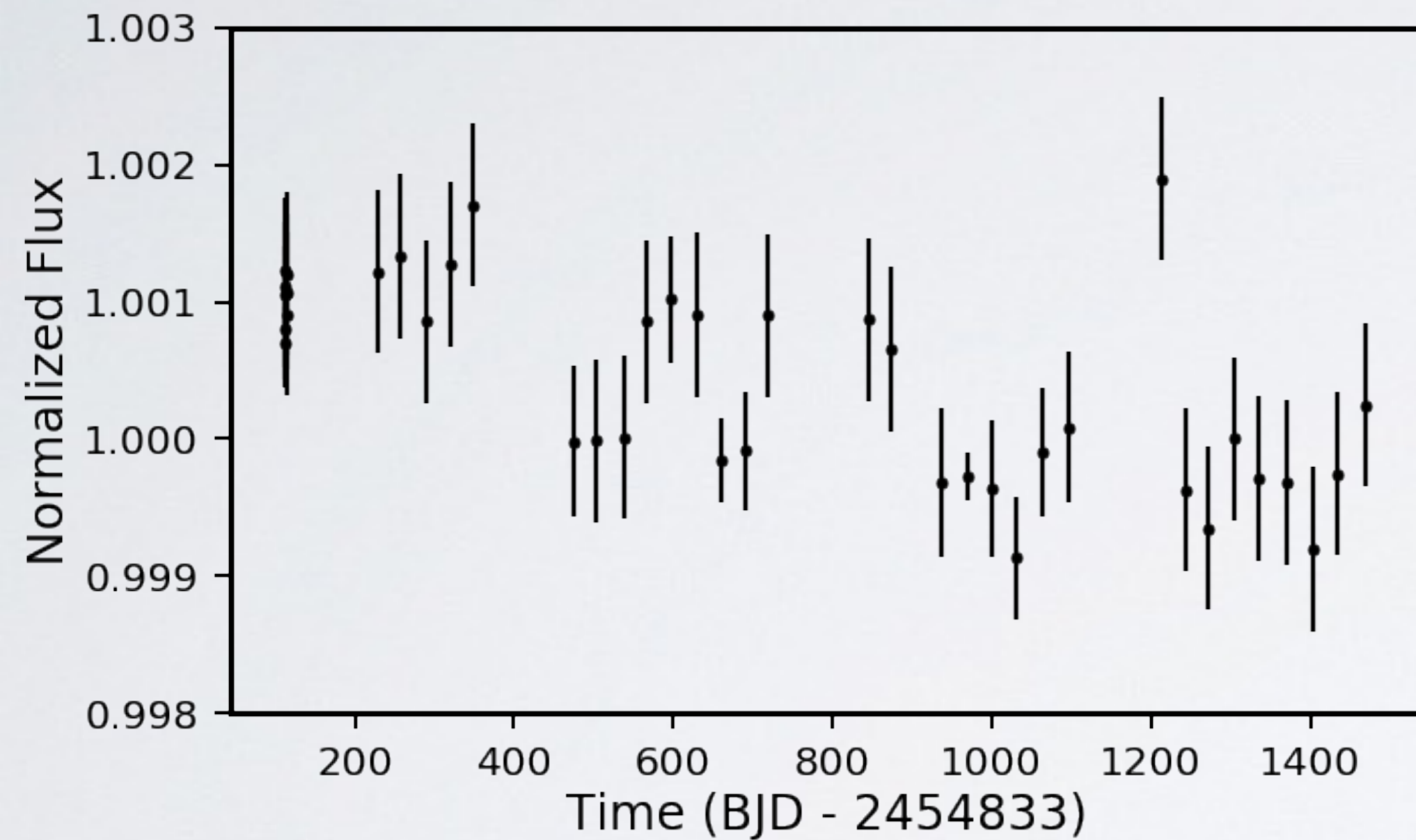
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Stellar activity as a limitation in planet parameters



with Millholland (Yale) and Fabrycky (Chicago)

Stellar activity as a limitation in planet parameters



with Millholland (Yale) and Fabrycky (Chicago)

Kepler full-frame images can be used to recover long-term variability for stars

We find a transition between spot- and facula-dominated Sun-like stars at a rotation period of ~ 20 days

Beware stellar activity in your radius ratios!

Have ideas of how to use *Kepler* FFIs for your science?
Let's talk!

Thank you!