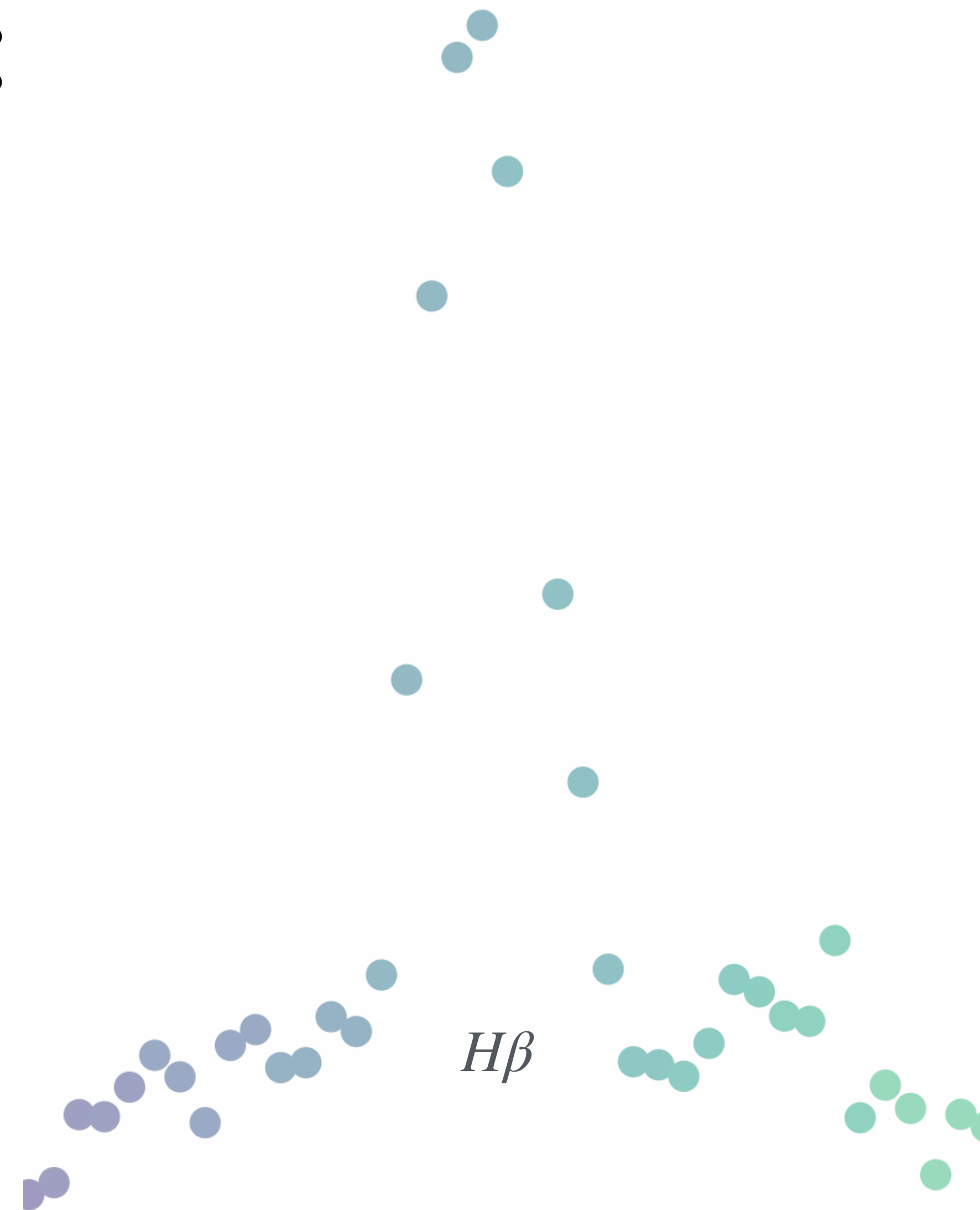


Fully Convective M Dwarfs: Variability in Magnetically Sensitive Balmer Emission Lines



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Gif made with [chromatic](#)

Exoplanets around M Dwarfs

Good



Size makes it easier to detect planets via transit planet depth



Size makes it easier to detect planets via doppler shifts



Habitable Zone closer in, so likely to find Earth-analogs

Not so Good



Stellar surface features such as spots can complicate transit depths and radial velocity measurements



High energy irradiance is large and can zap a planetary atmosphere.



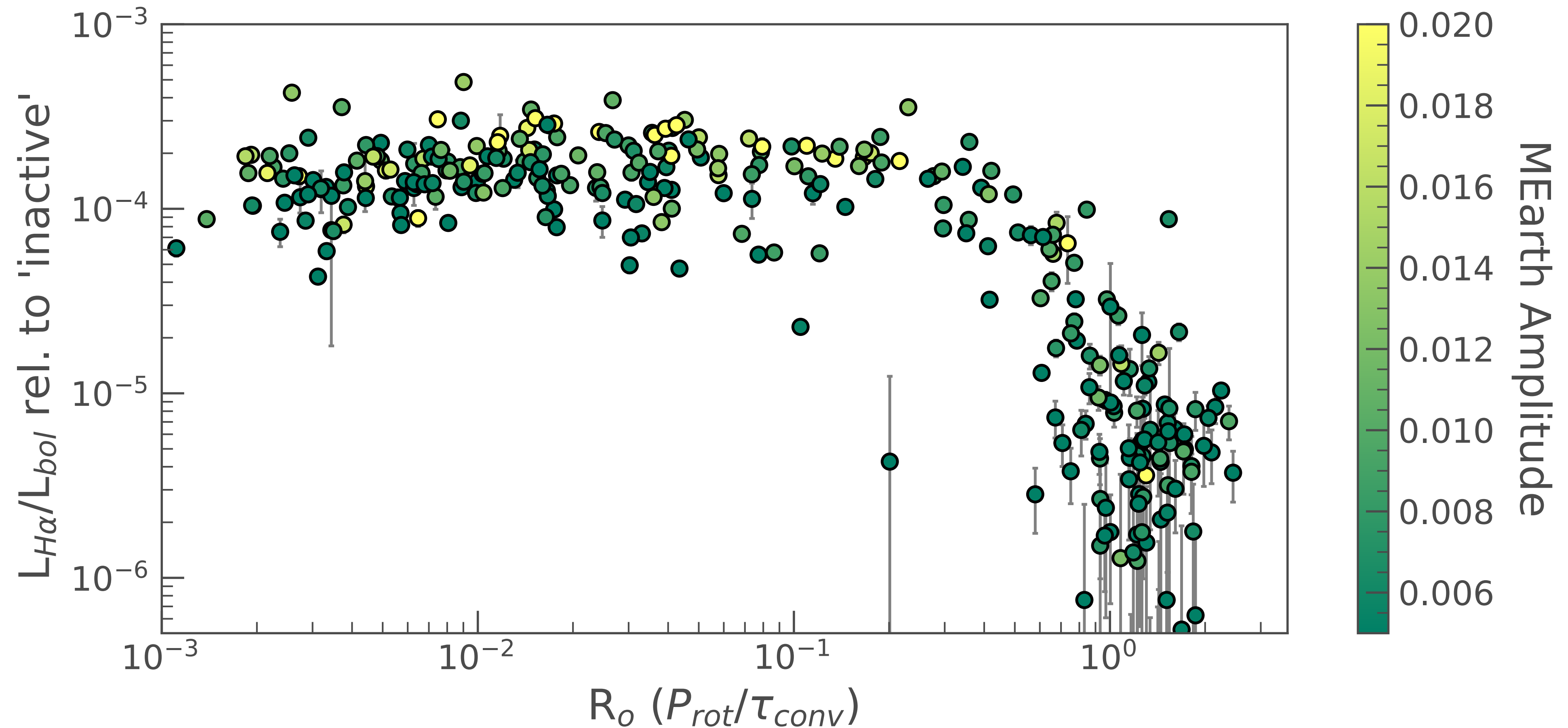
Average photosphere may not be represented by the transit chord

Observing M Dwarf magnetic activity and its variability provides insights into their stellar dynamos, high energy radiation, and impact on exoplanet detection and characterization.

Outline/Summary

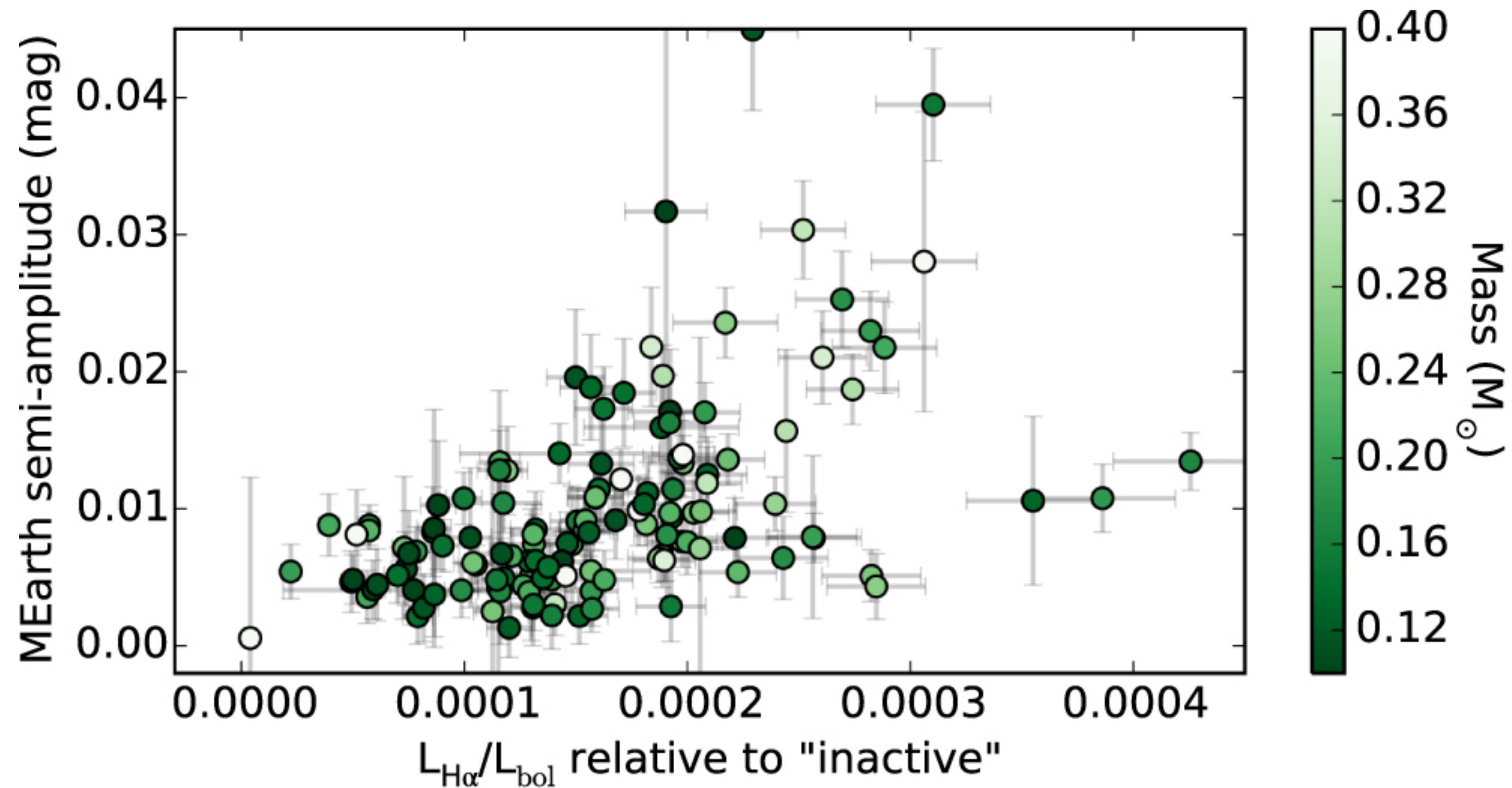
- Background -
 - The comparisons of magnetic field activity proxies have some scatter.
- Sample -
 - Fully convective M Dwarfs observed with TESS and OSMOS (spectrograph)
- Results/Discussion -
 - There is intrinsic variability in Balmer lines (larger for higher order)
 - Some variability not captured by optical photometry but heating mechanism may be the same

$H\alpha$ luminosity relation to Rotation Period and spot photometric amplitude



Data From: Newton et al. 2017

H α luminosity relation to spot photometric amplitude



Newton et al. 2017

Starspots relation to Rotation Period

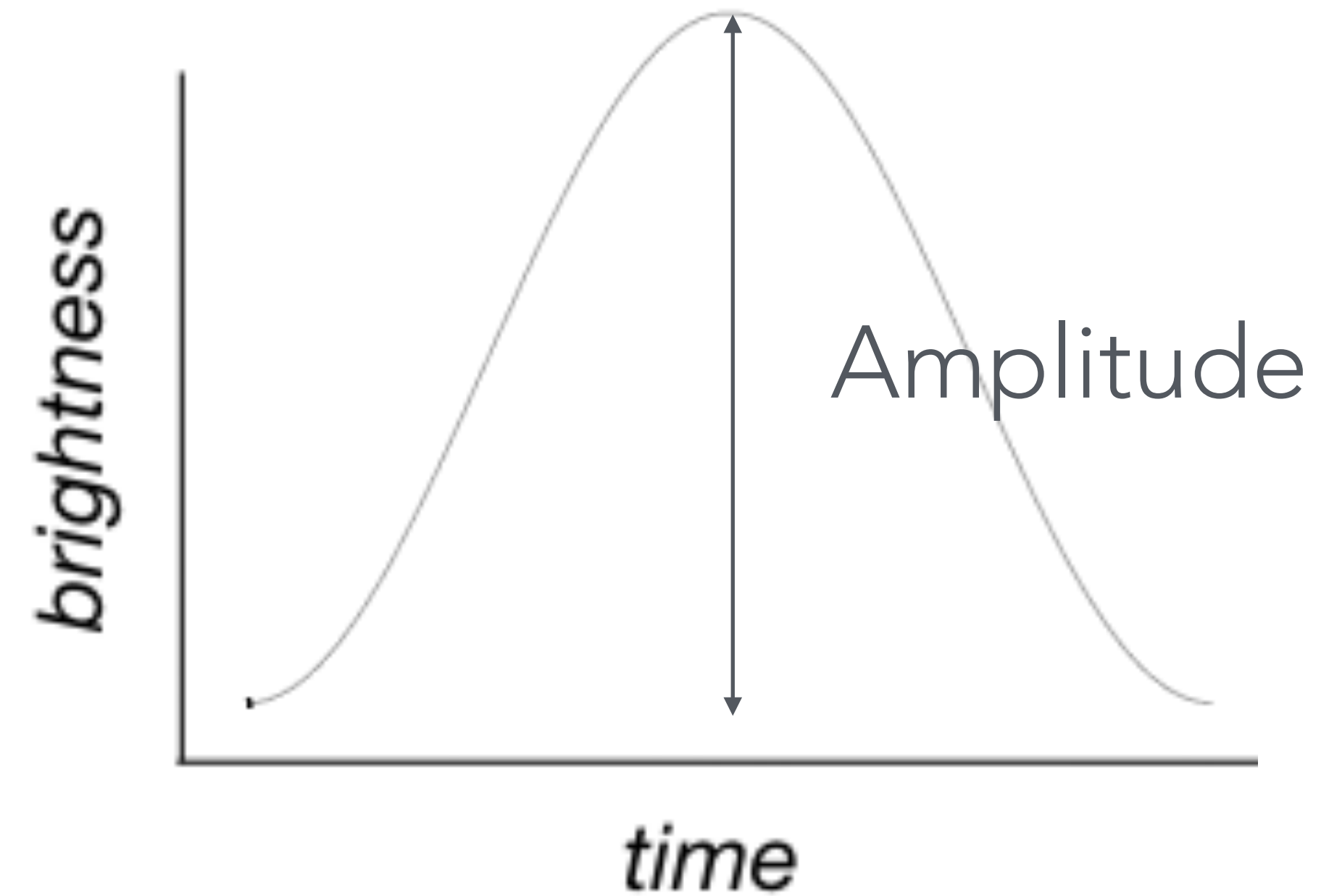
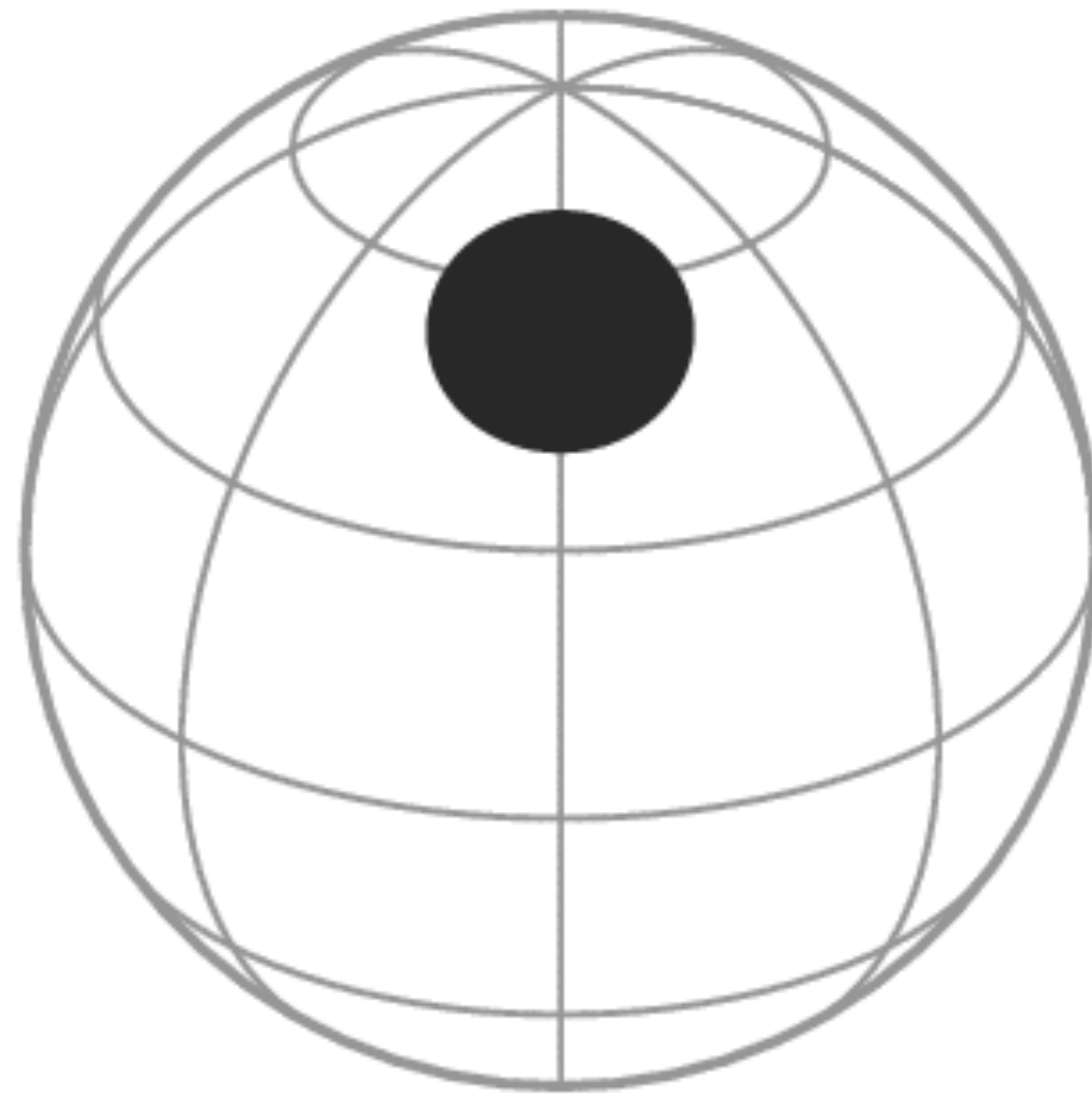
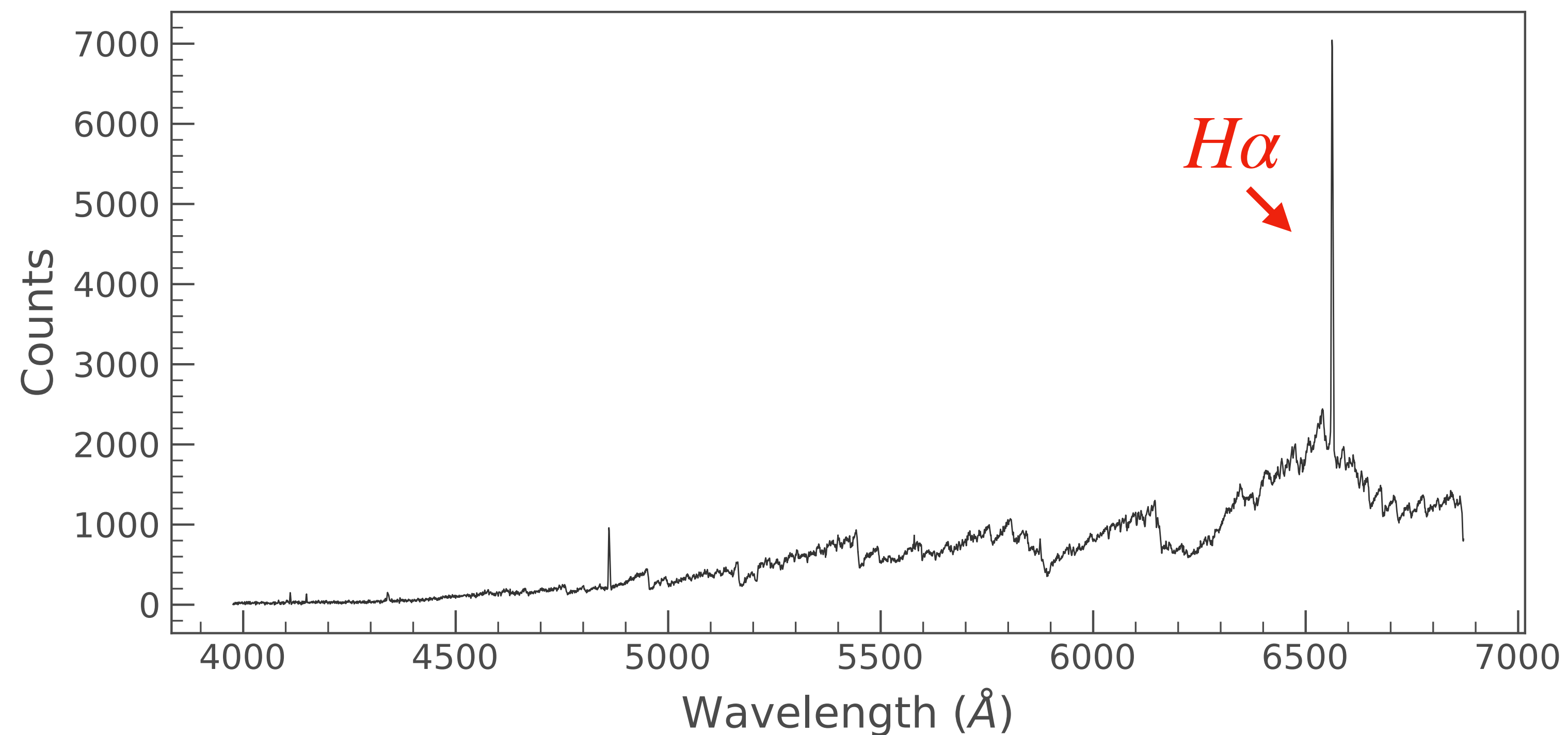
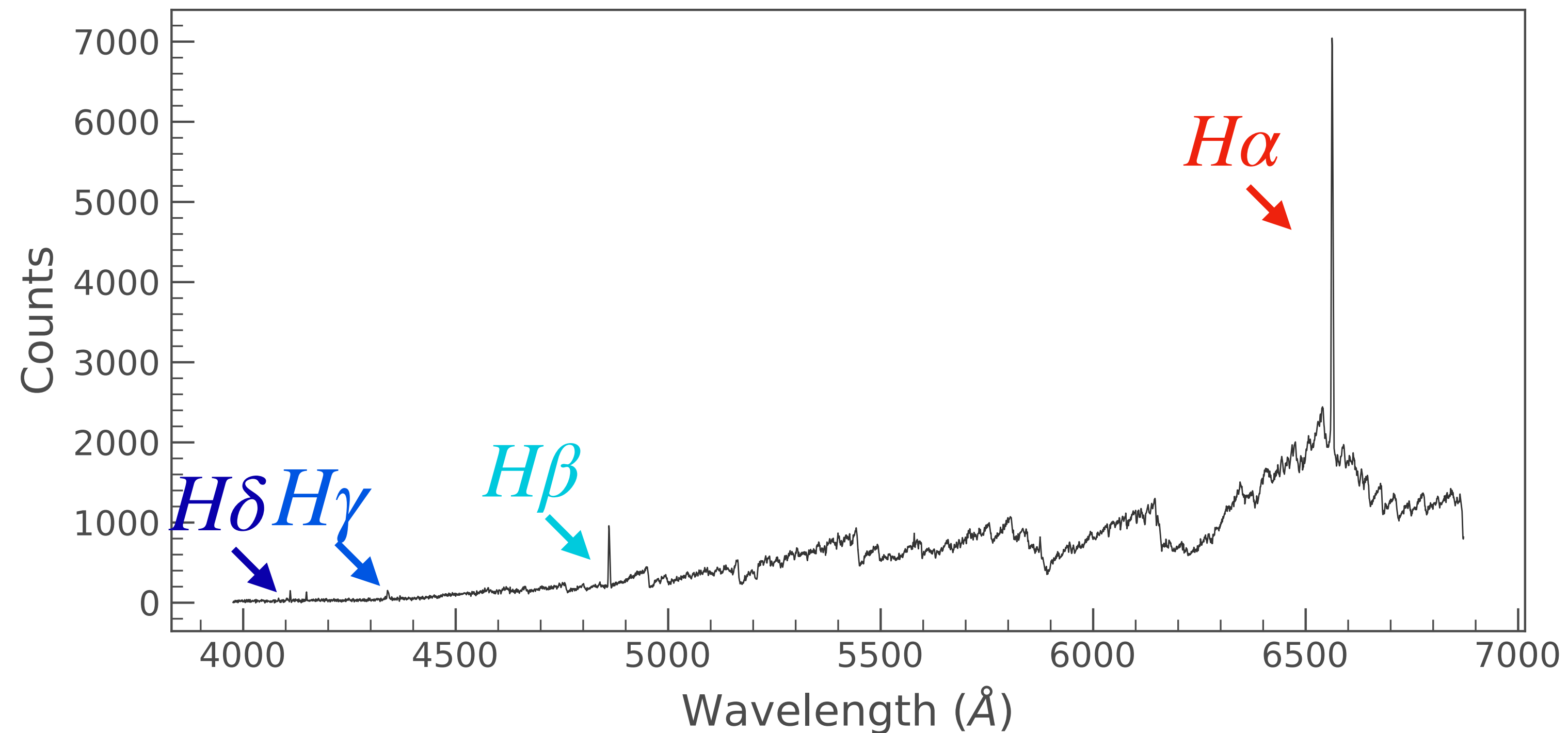


Image Credit: [© James Davenport](#)

$H\alpha$ Emission in M Dwarf spectrum

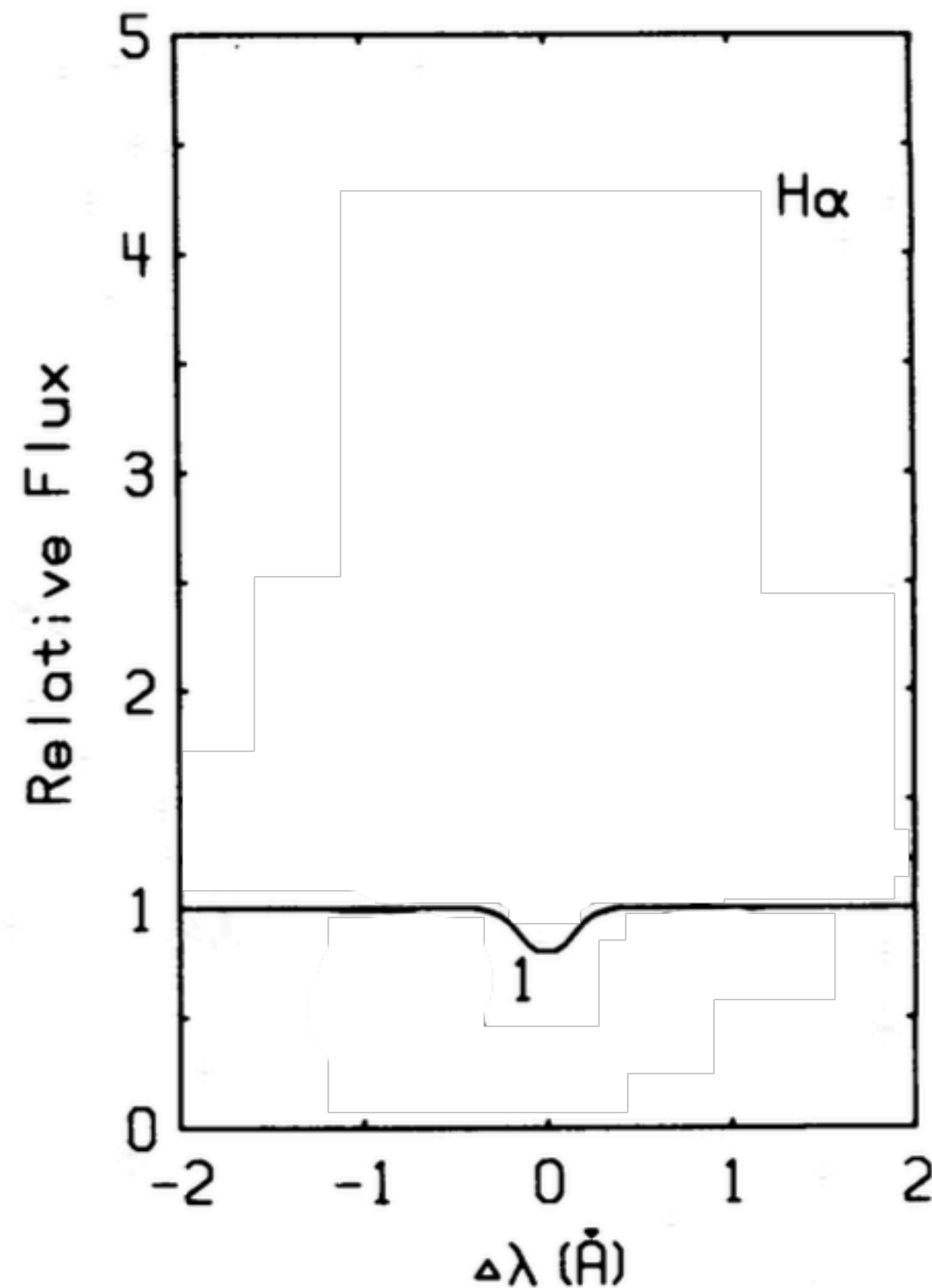


Balmer Emission in M Dwarf spectrum



$H\alpha$ becomes an emission line due to Chromospheric heating

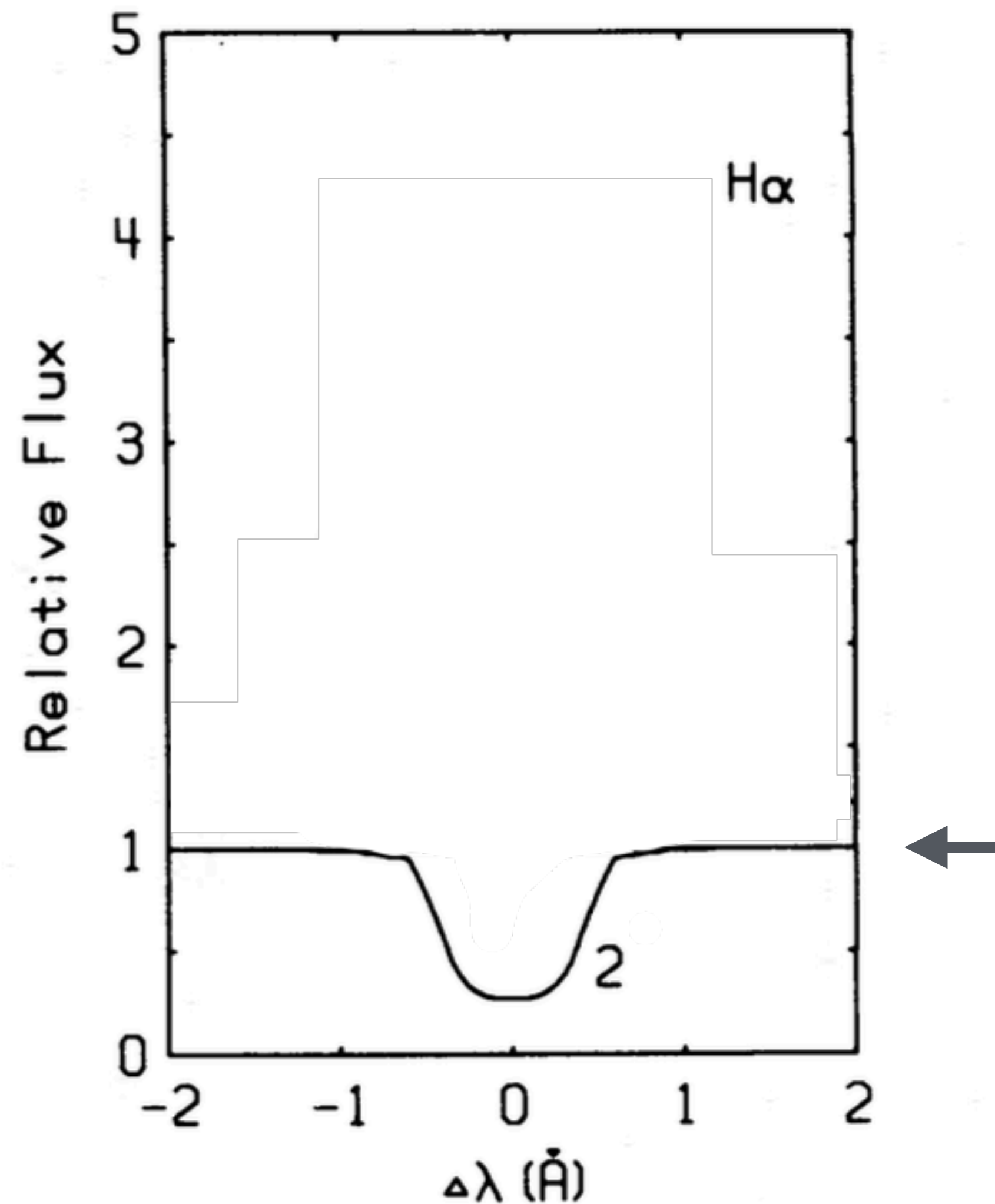
Cram & Mullan 1979 Models



Quiescent state of $H\alpha$ in Stars:
Absorption (photoionization) ←

$H\alpha$ becomes an emission line due to Chromospheric heating

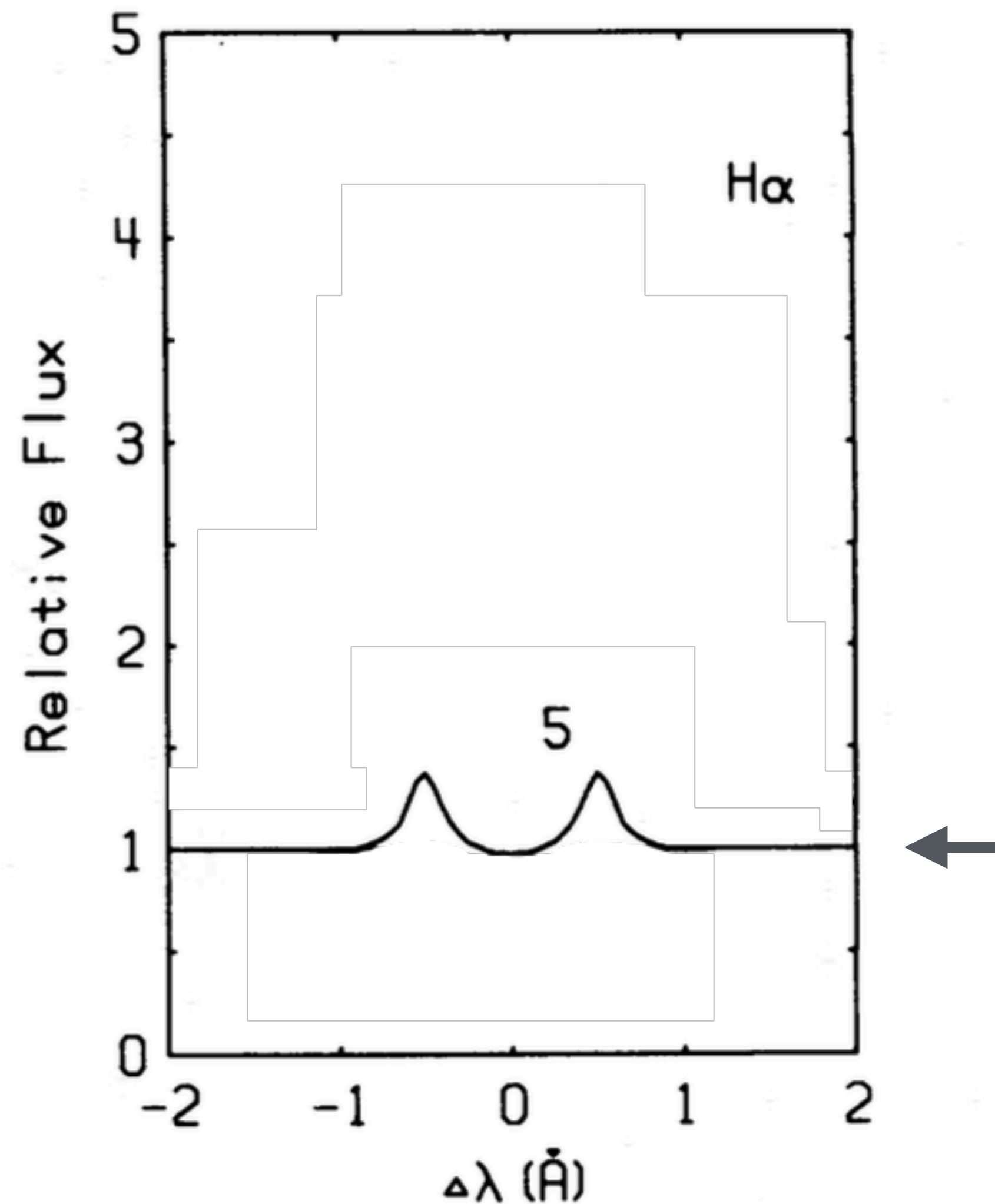
Cram & Mullan 1979 Models



Non-thermal heating of
Chromosphere:
Maximum Absorption

H α emission might arise from collisional excitation

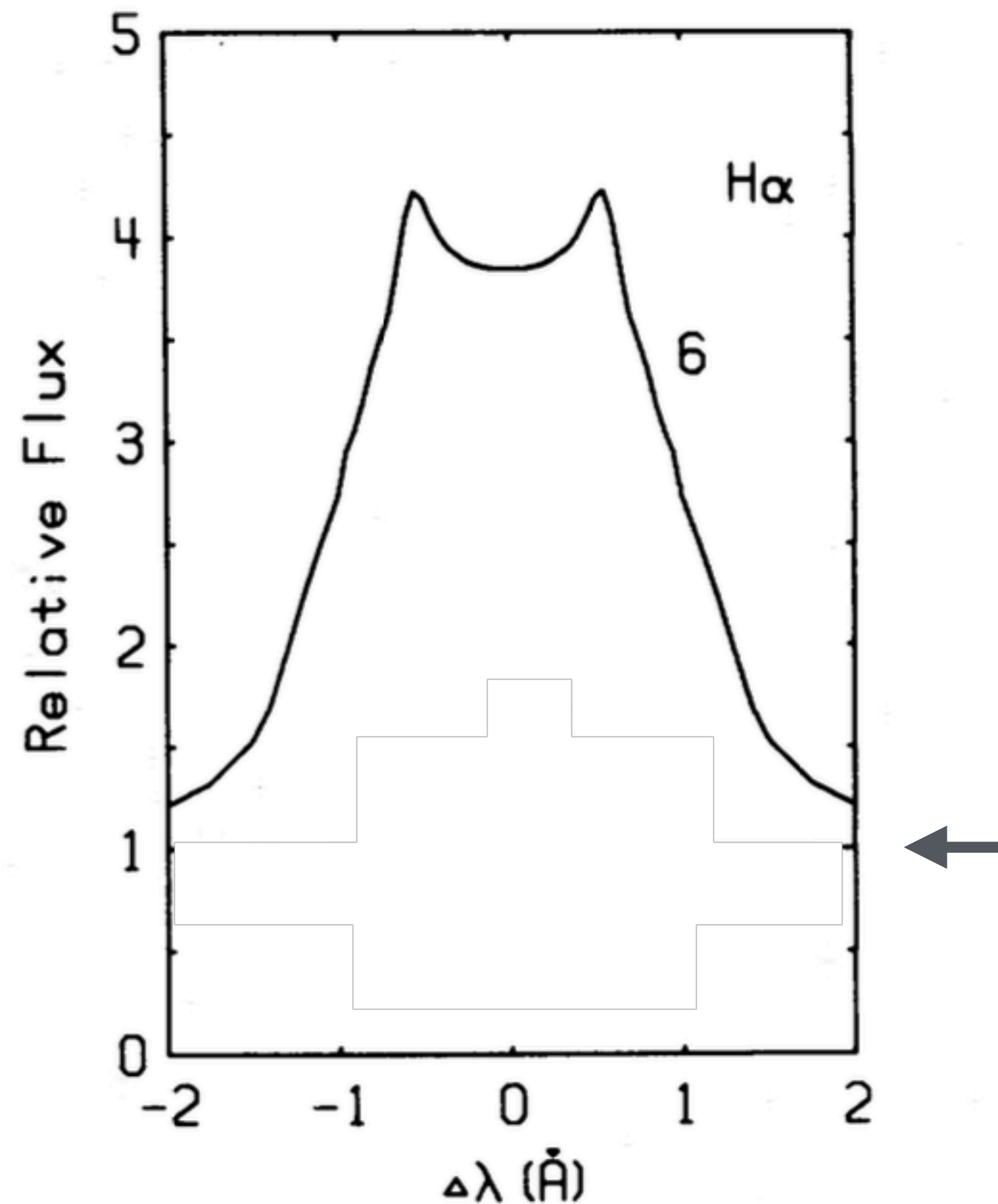
Cram & Mullan 1979 Models



Non-thermal heating of
Chromosphere:
Emission lines at edges

H α emission might arise from collisional excitation

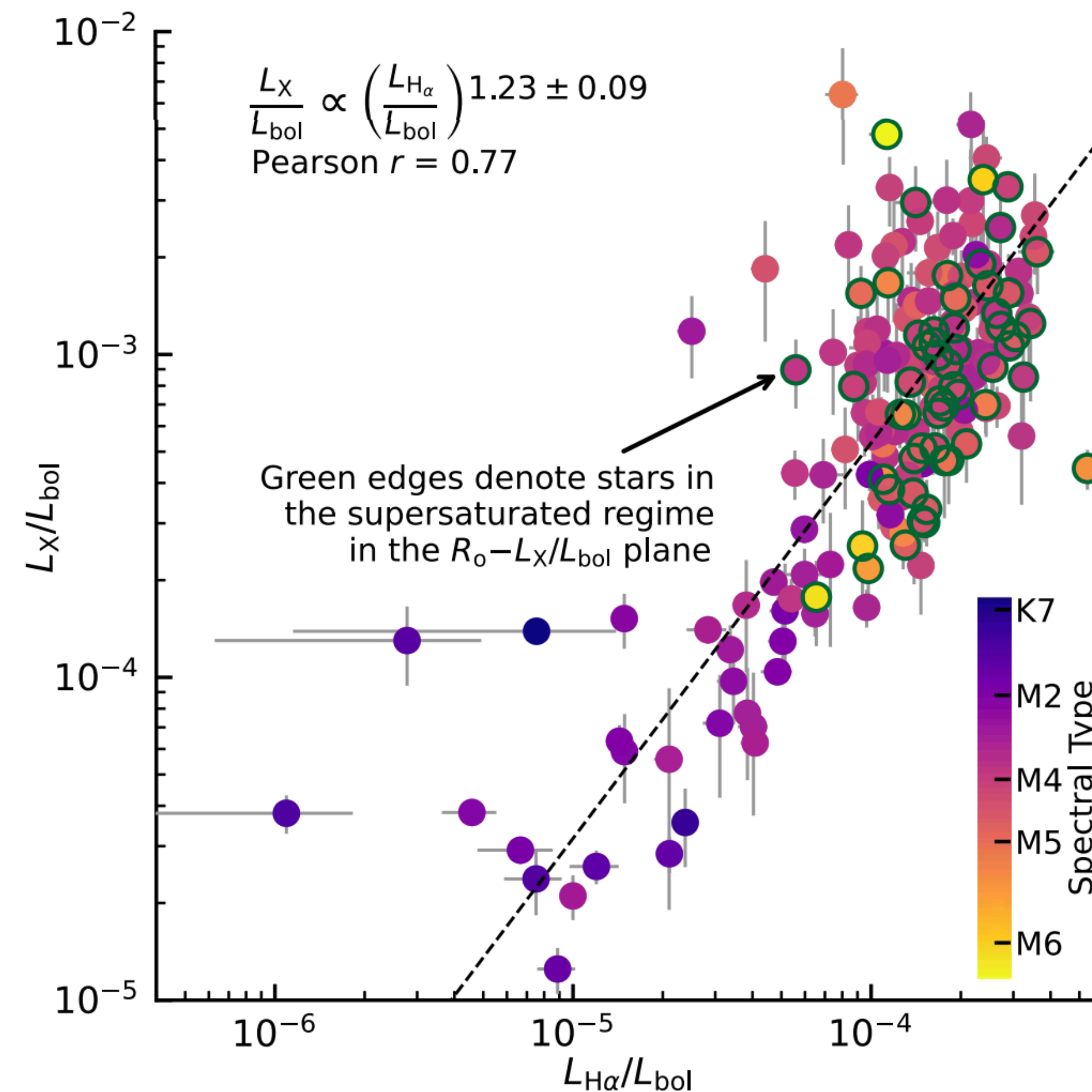
Cram & Mullan 1979 Models



Non-thermal heating of
Chromosphere:
Net line Emission

Photo-ionization and Recombination

e.g.: Back heating from Coronal X-rays can also heat the chromosphere (Kowalski et al. 2017)



Núñez et al. 2024

Taking contemporaneous time-series data to investigate the relationship between $H\alpha$ and photometric variability

Contemporaneous Sample

Fully Convective M Dwarfs, $V > 16$ magnitudes, $P < 10$ days and in northern hemisphere.

TESS

TESS-point Web Tool

This tools is provided by the TESS GI team to assist the community in planning and proposing.

Note: updated with Cycle 7 sectors 84 - 96. See our [sectors page](#) for more information.

Me

Find TESS Observability of Single Target

This will return a table for your target showing which TESS sectors it is observable in, and which camera, CCD, and pixels it will be on.

Name

TIC ID

R.A & Dec.

Find TESS Observability of

This will return a table for **each target** sho

Upload a CSV file containing only RA, DEC

First select a file: No file cho

Find if Targets are Observa

This will return a table for **all targets** show

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First select a file: No file cho



Contemporaneous Sample

Fully Convective M Dwarfs, $V > 16$ magnitudes, $P < 10$ days and in northern hemisphere.

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OSMOS

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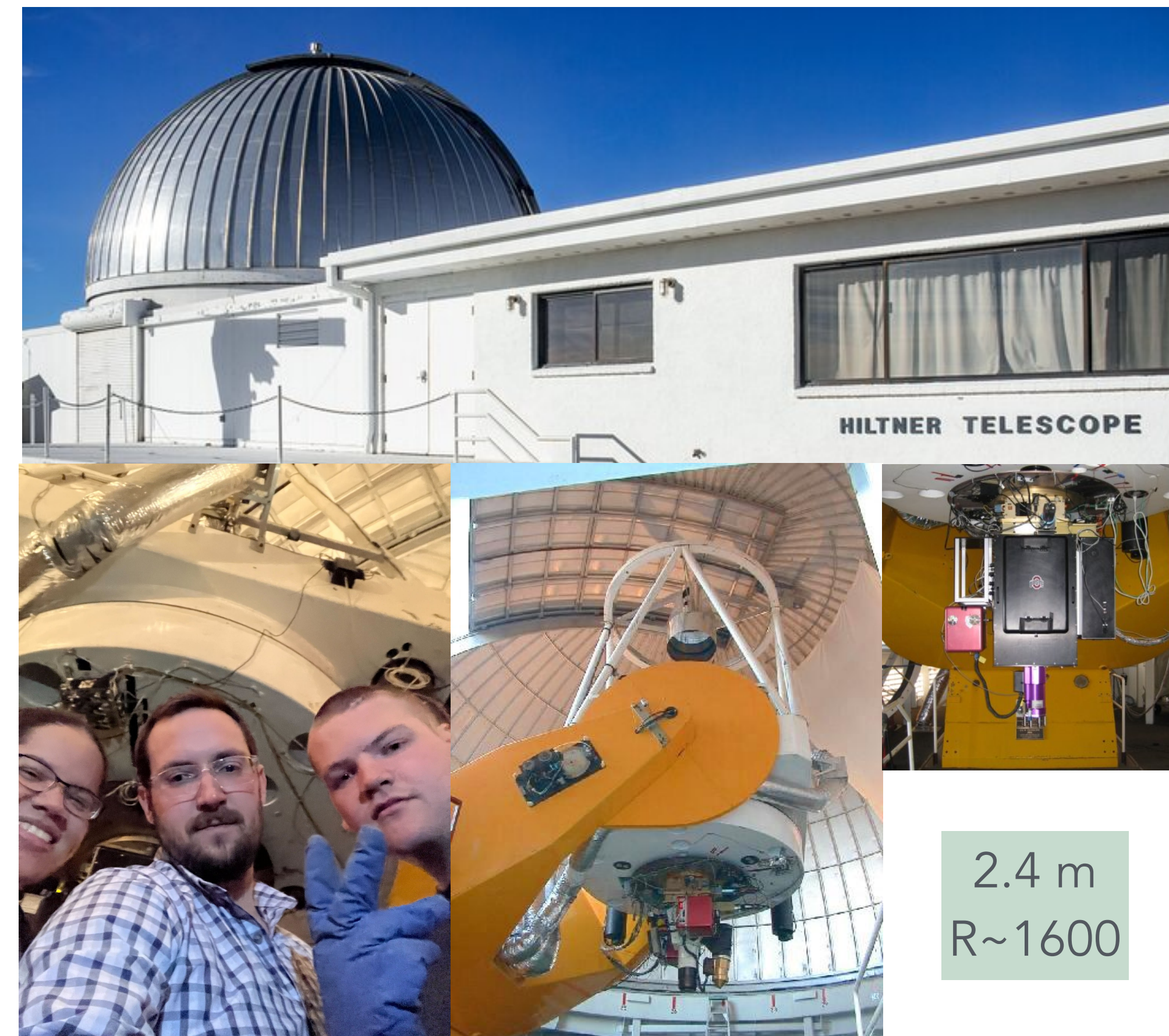
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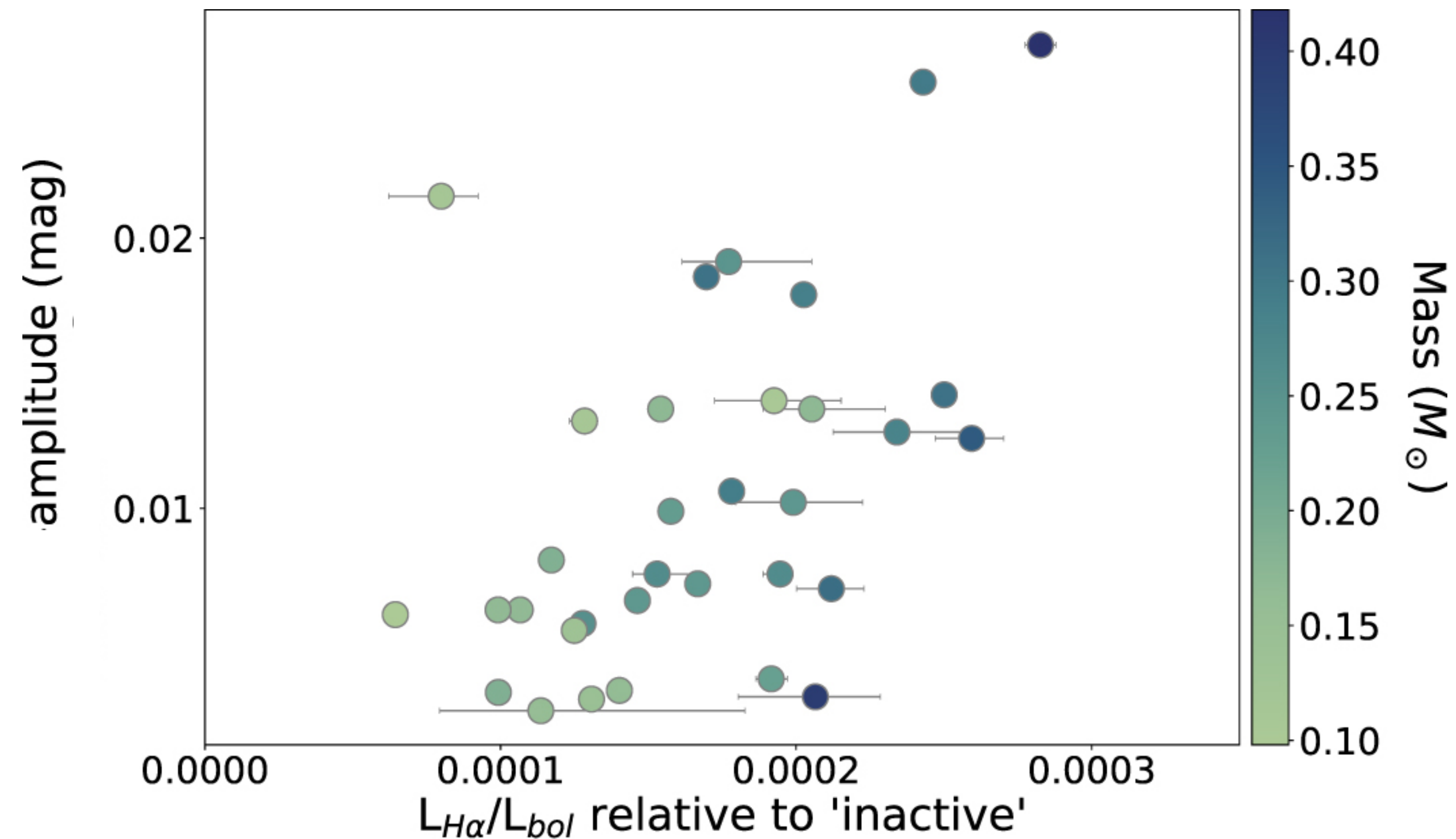
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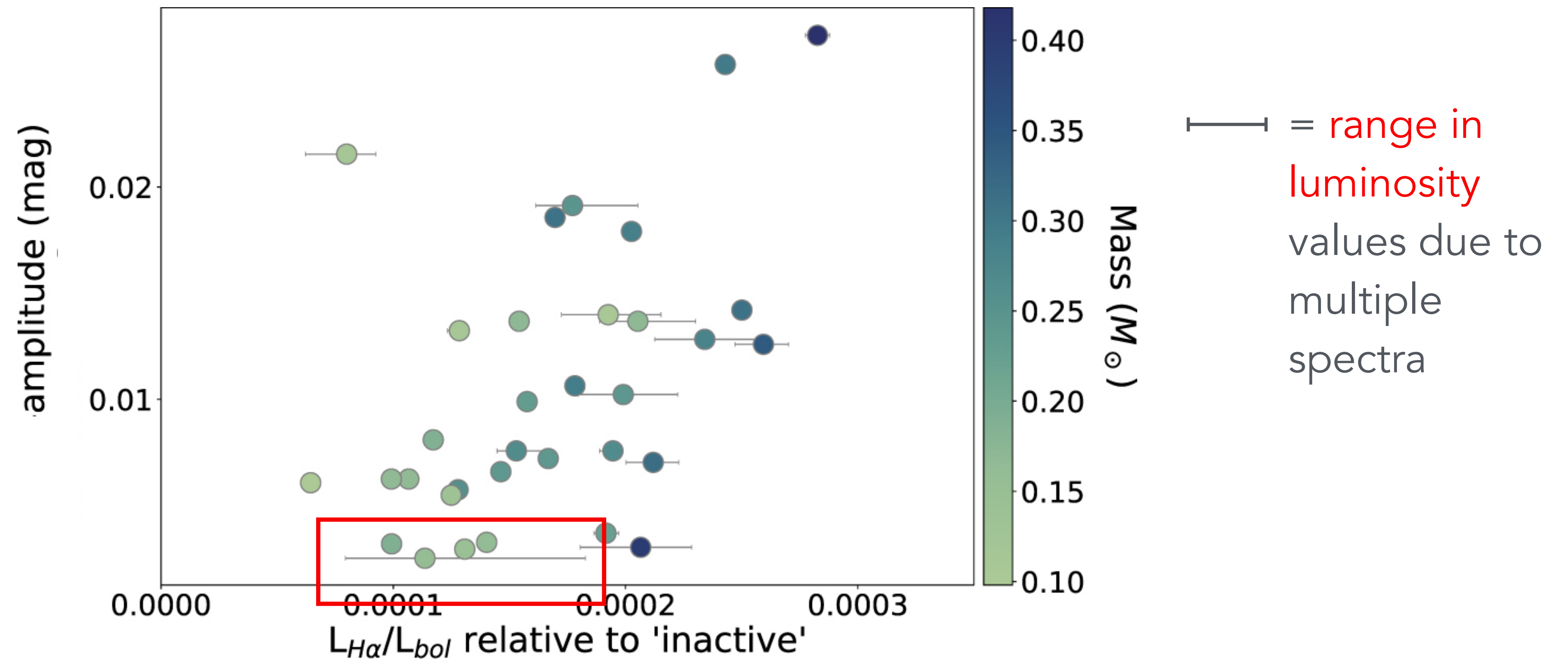
2.4 m
R~1600

$H\alpha$ luminosity relation to spot photometric amplitude is weakly positive



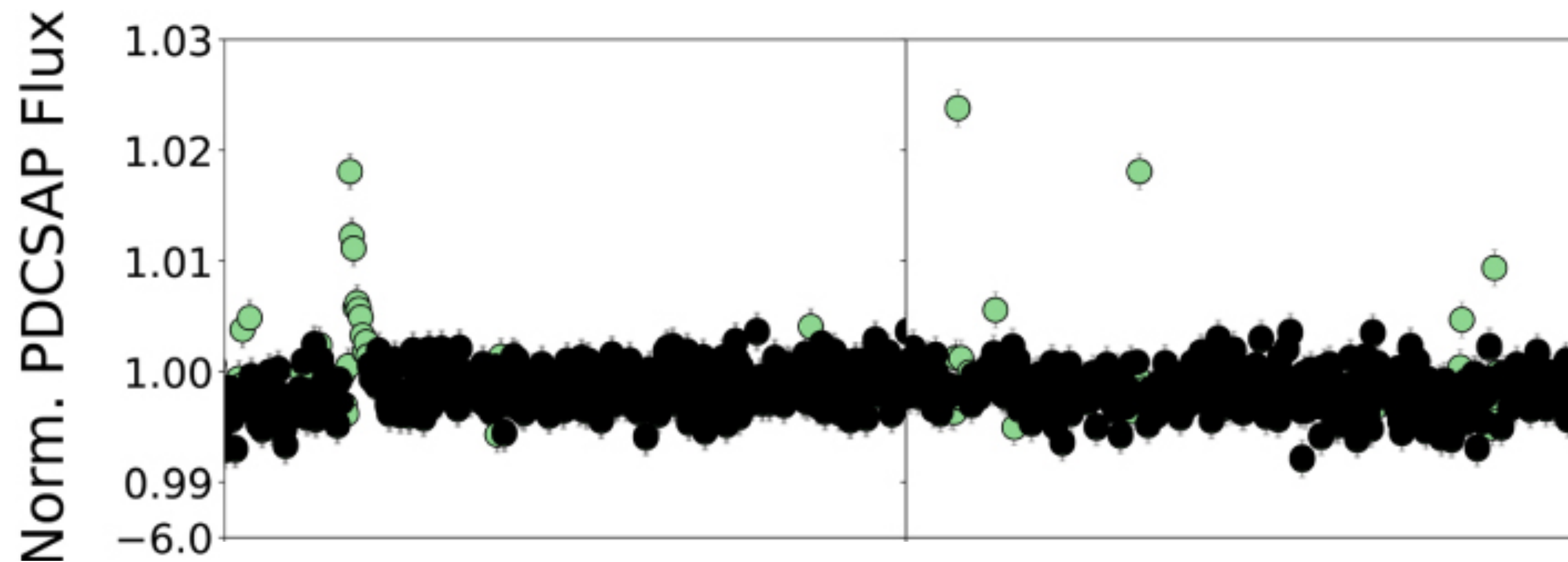
$H\alpha$ luminosity varies in the short time scale

(Kruse+10, Lee+10, Bell+12, Medina+22, Duvvuri+23, Kumar+23, Garcia Soto+23)



Garcia Soto et al. 2023

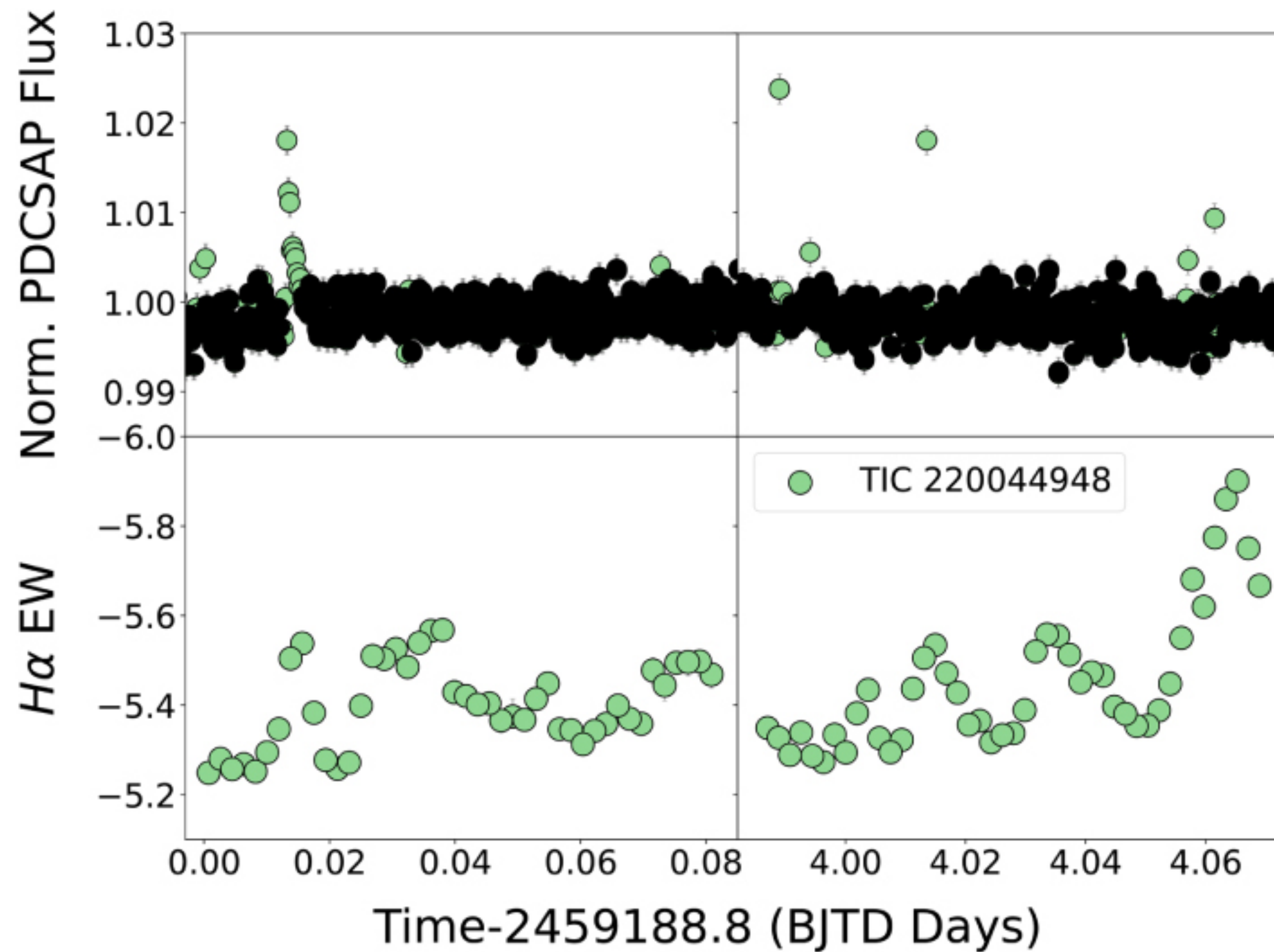
$H\alpha$ luminosity varies in the short time scale



Time-2459188.8 (BJTD Days)

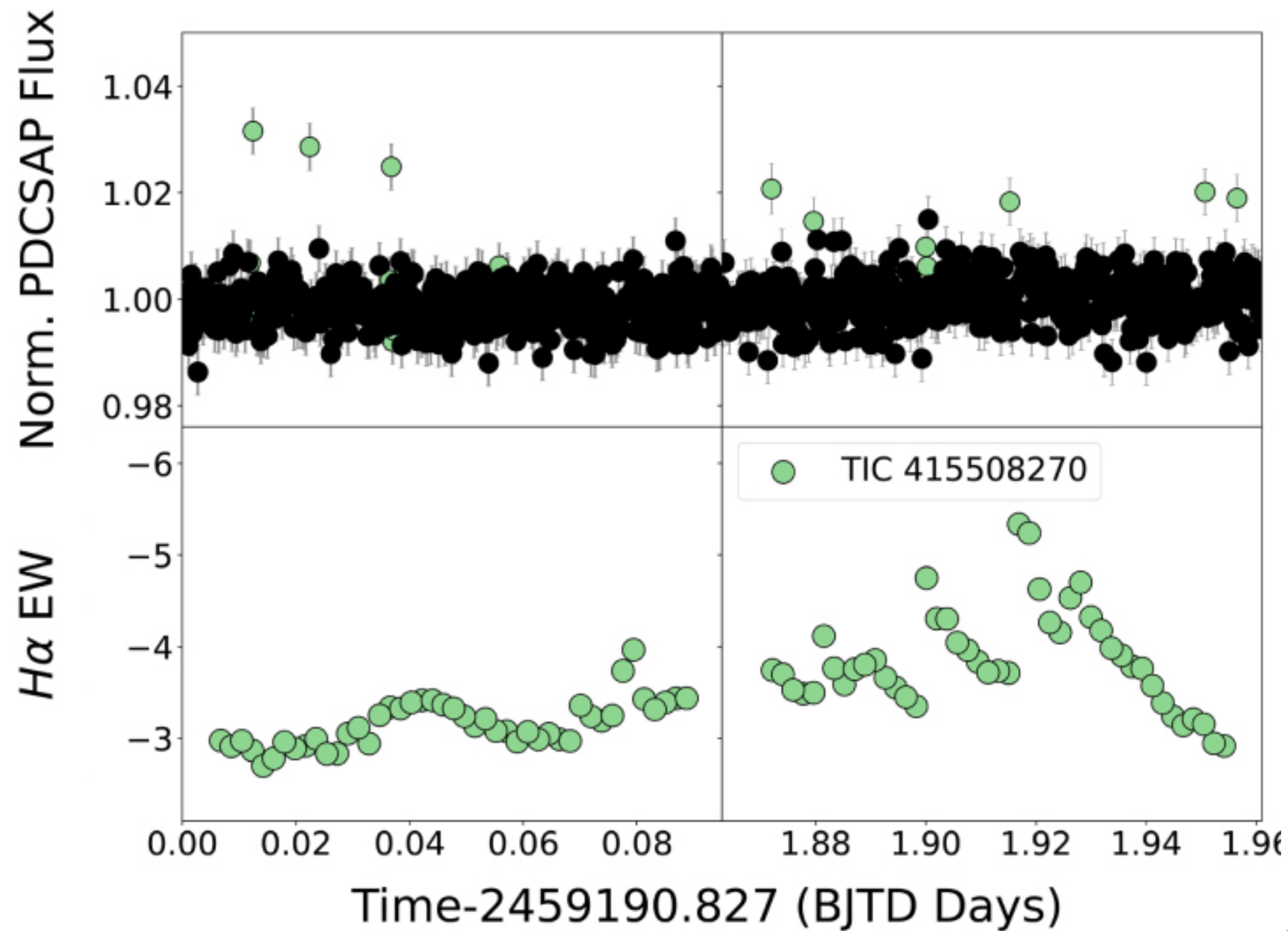
Garcia Soto et al. 2023

$H\alpha$ luminosity varies in the short time scale



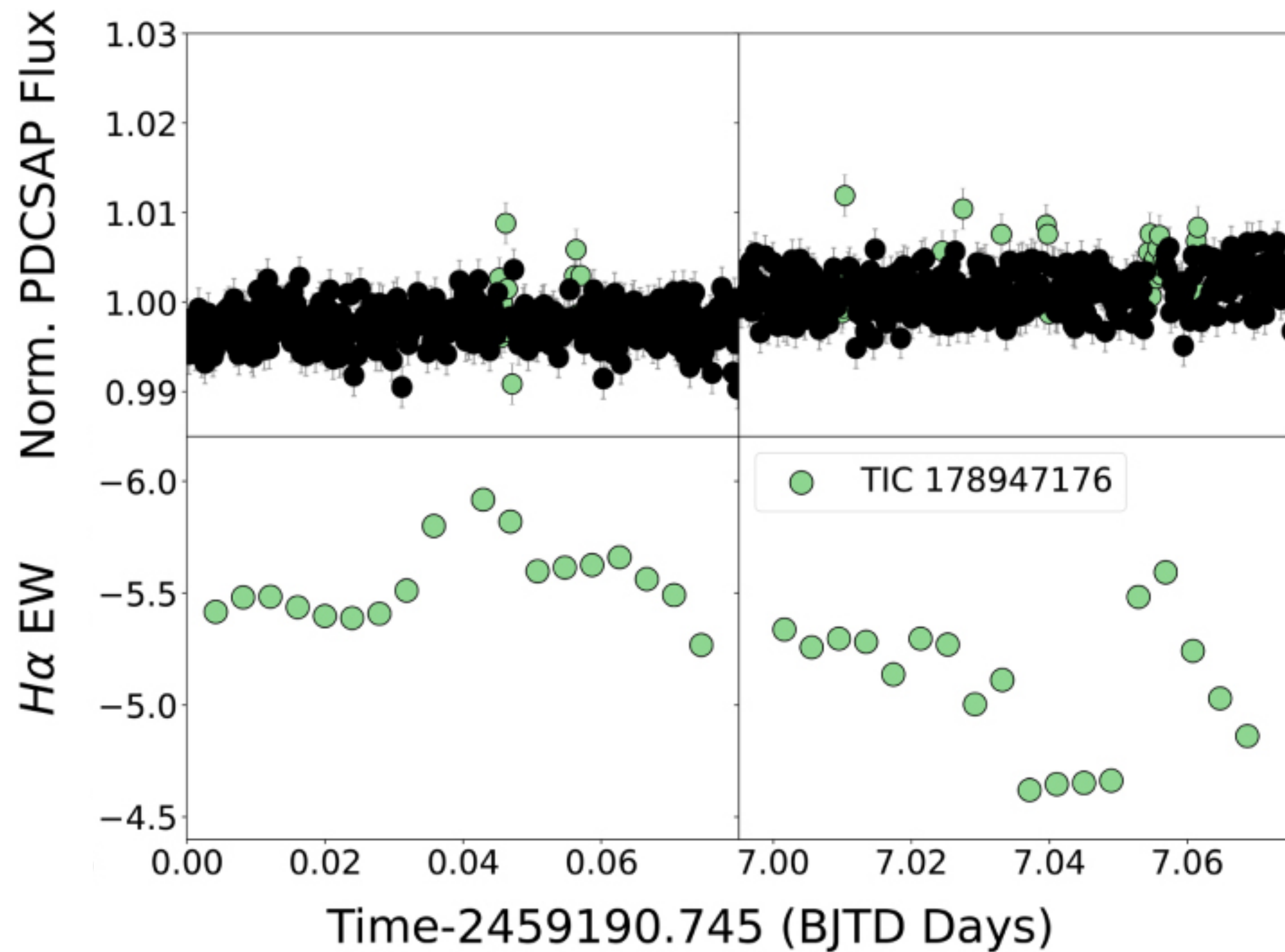
Garcia Soto et al. 2023

$H\alpha$ luminosity varies in the short time scale



Garcia Soto et al. 2023

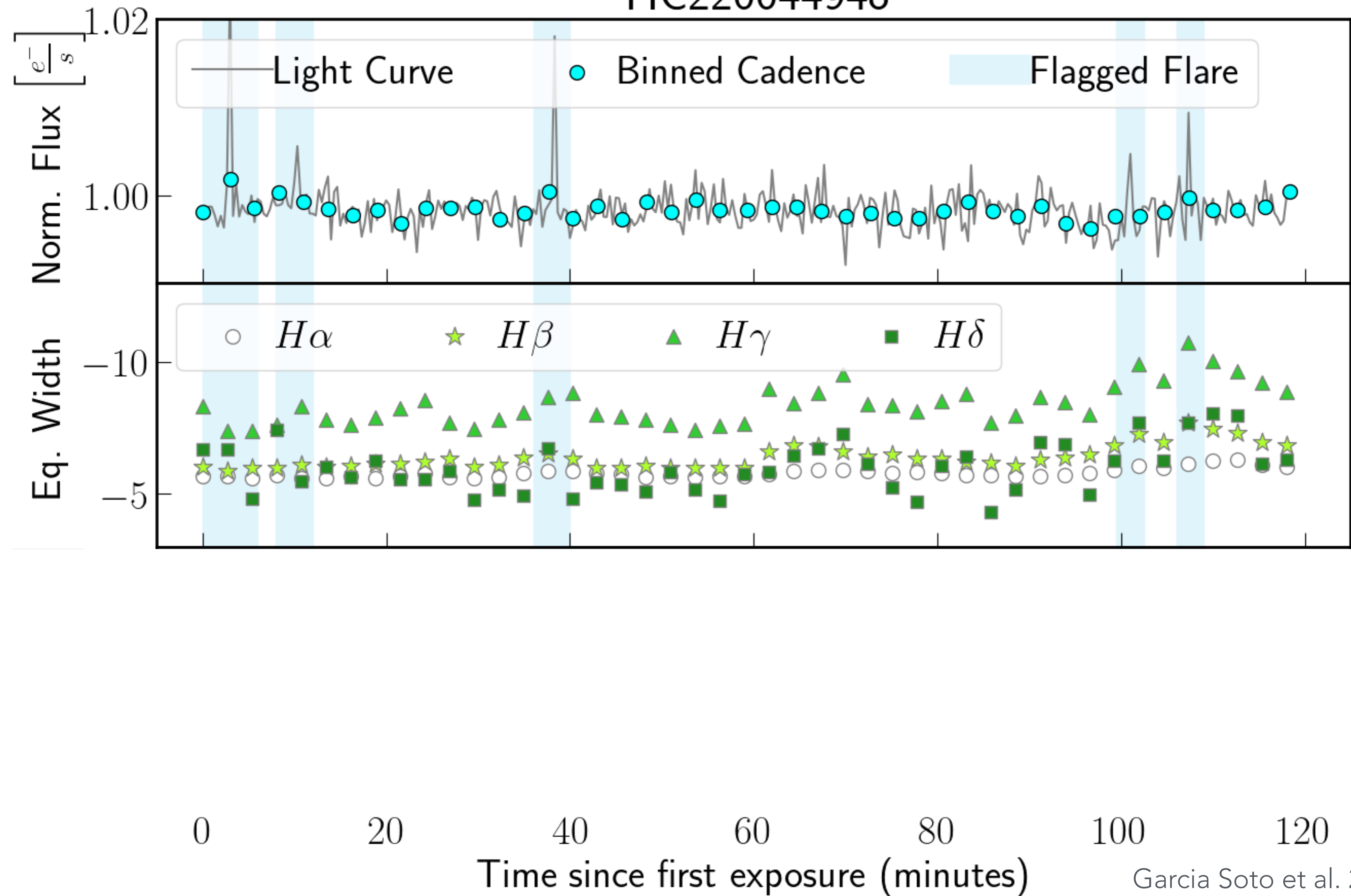
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Garcia Soto et al. 2023

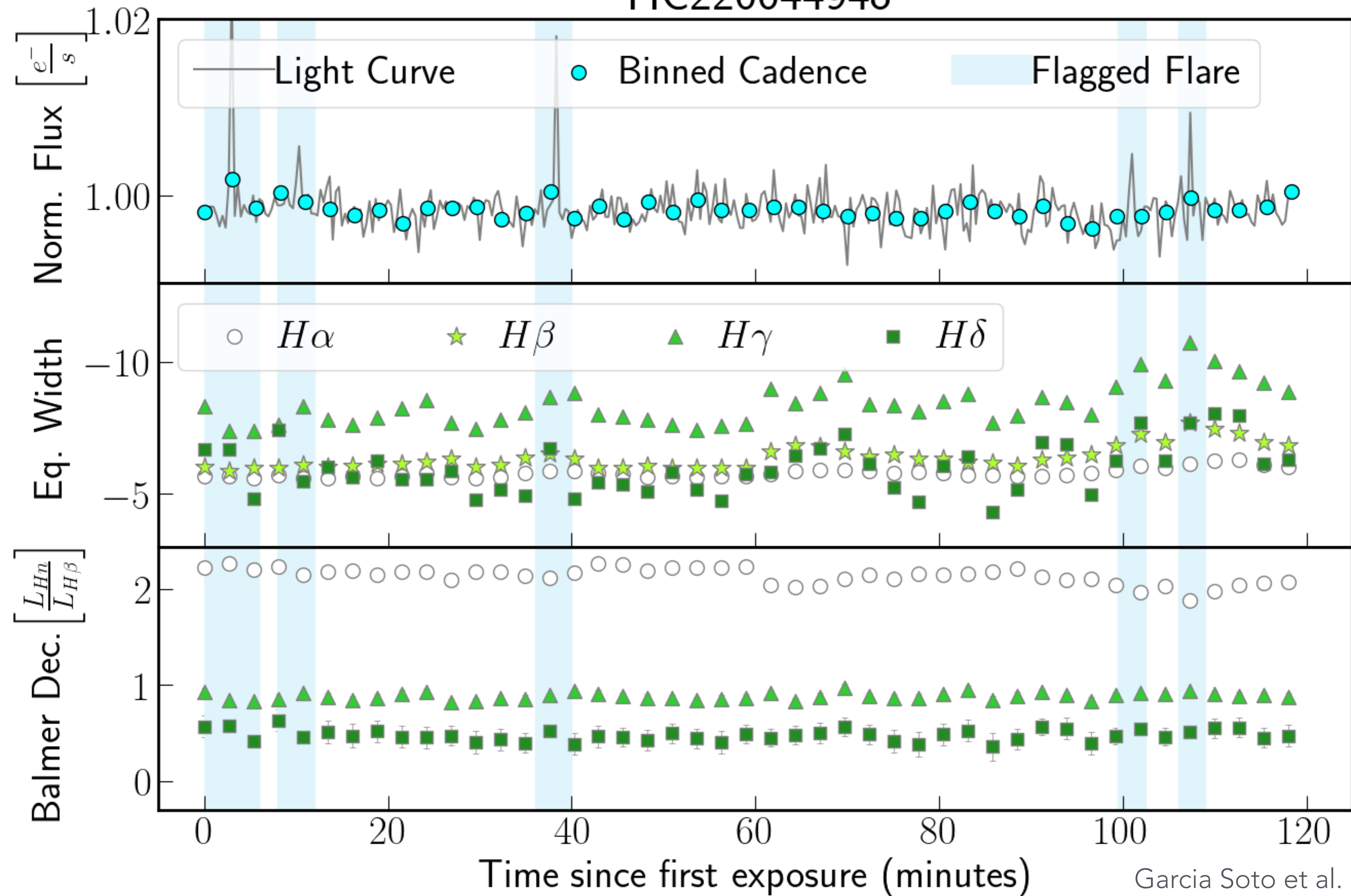
The short-timescale variability of $H\alpha$ emission means that it is not a useful proxy for spot-related modulation in most Fully Convective M Dwarfs.

TIC220044948

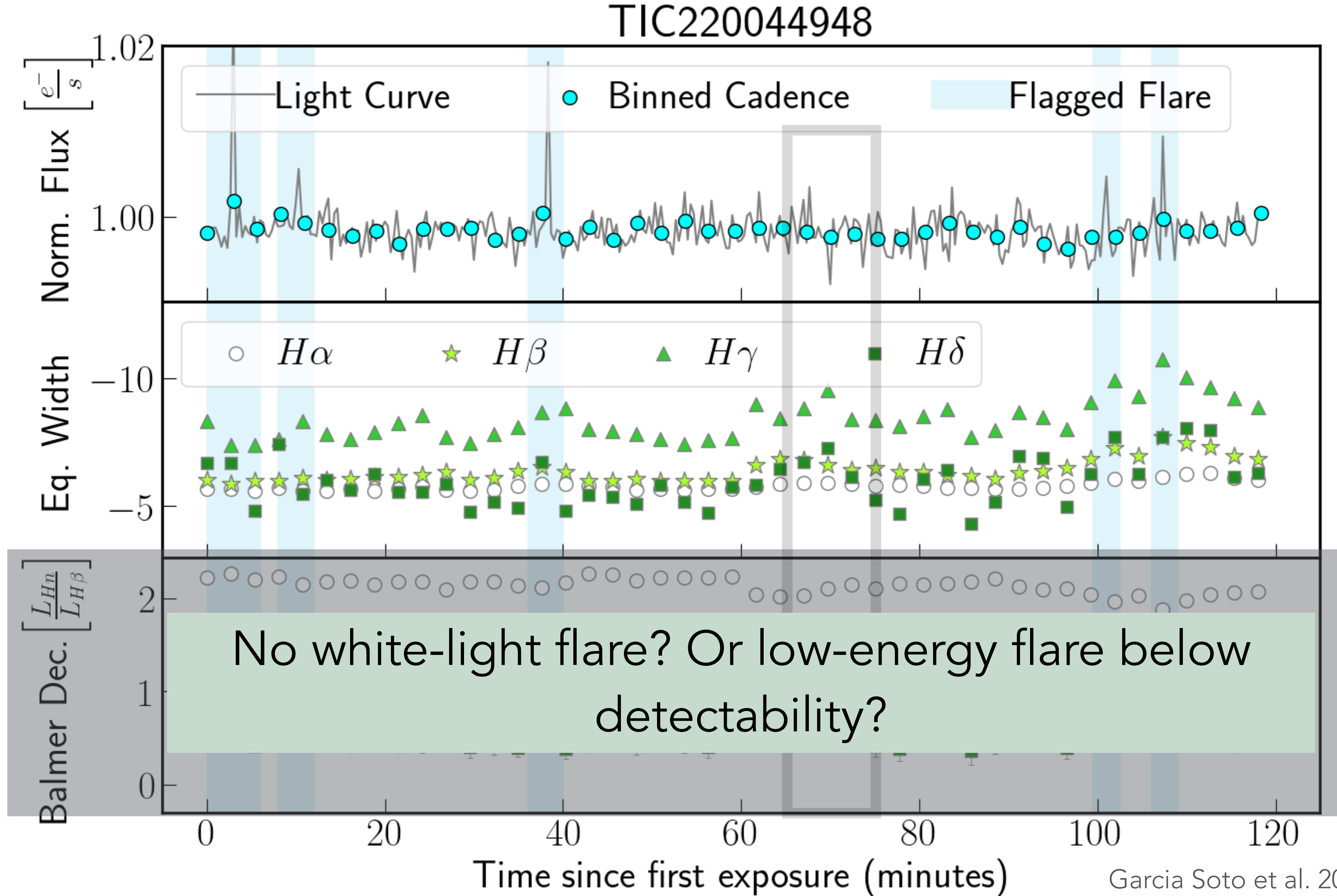


Garcia Soto et al. 2024, in prep.

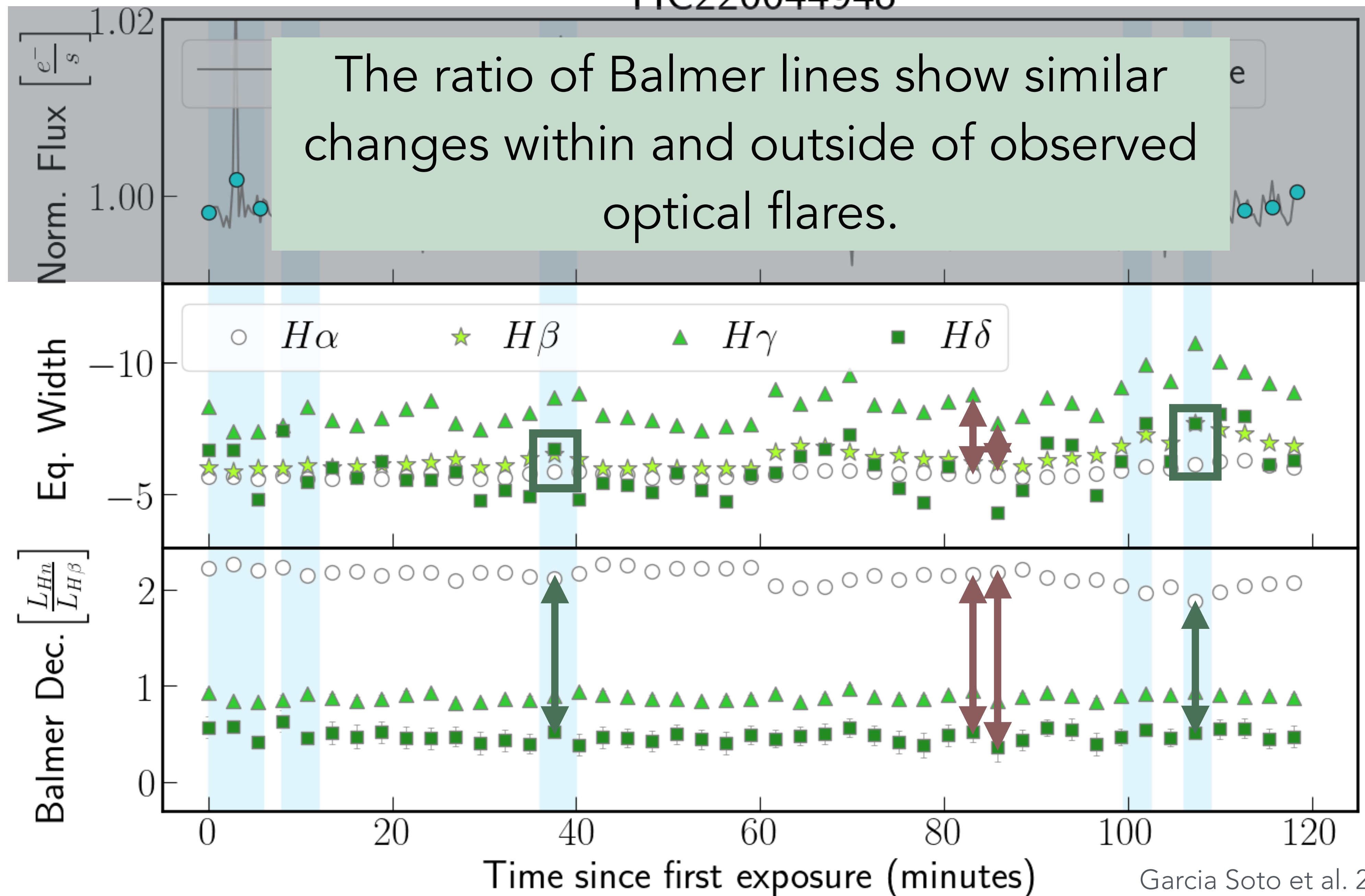
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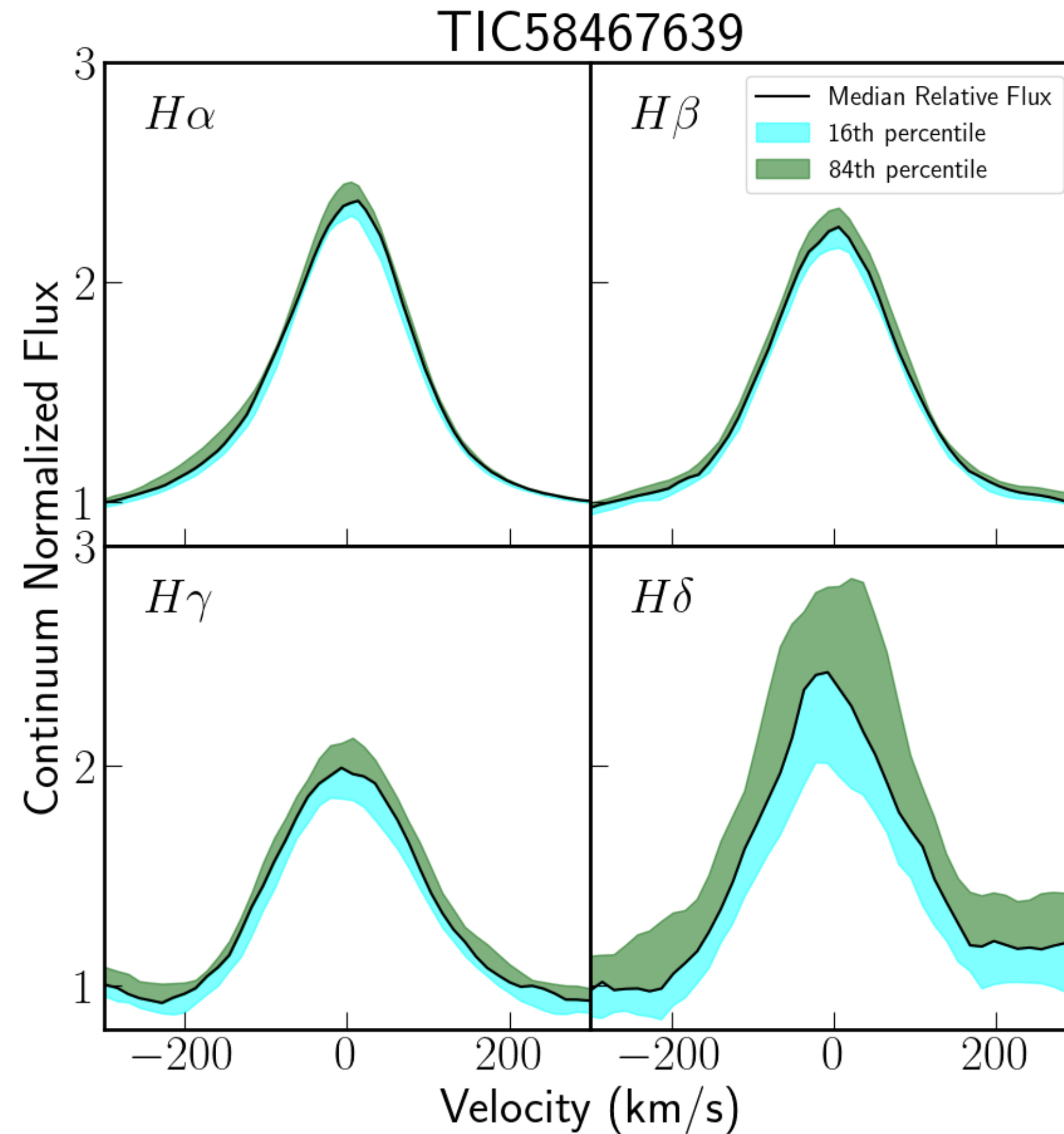


Garcia Soto et al. 2024, in prep.



Significant variability in Balmer lines are not captured by optical photometry
And
The ratio of Balmer lines show similar changes within and outside of observed optical flares.

We visually see larger variability in $H\delta$: Is it Real?

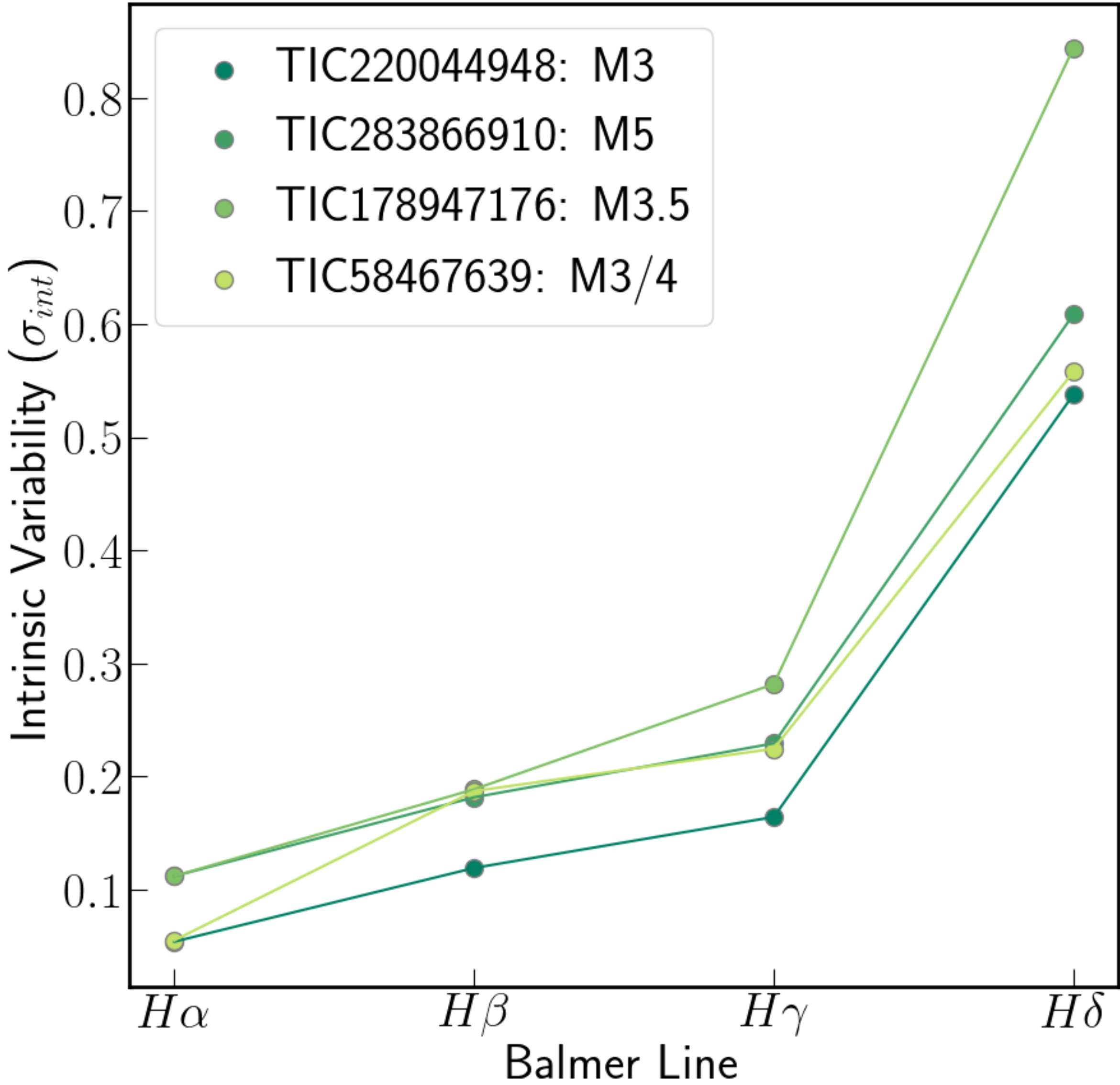


Garcia Soto et al. 2024, in prep.

Fractional Intrinsic Variability: Accounting for Errors and SNR

$$\sigma_{intrinsic} = \frac{\sqrt{\sigma_{observed}^2 - \sigma_{measurement}^2}}{|\text{Median}(measurement)|}$$

- $\sigma_{measurement}$ is the error in equivalent width (EW)
- $\sigma_{observed}$ is the 16th - 84th percentile of the observed EWs.

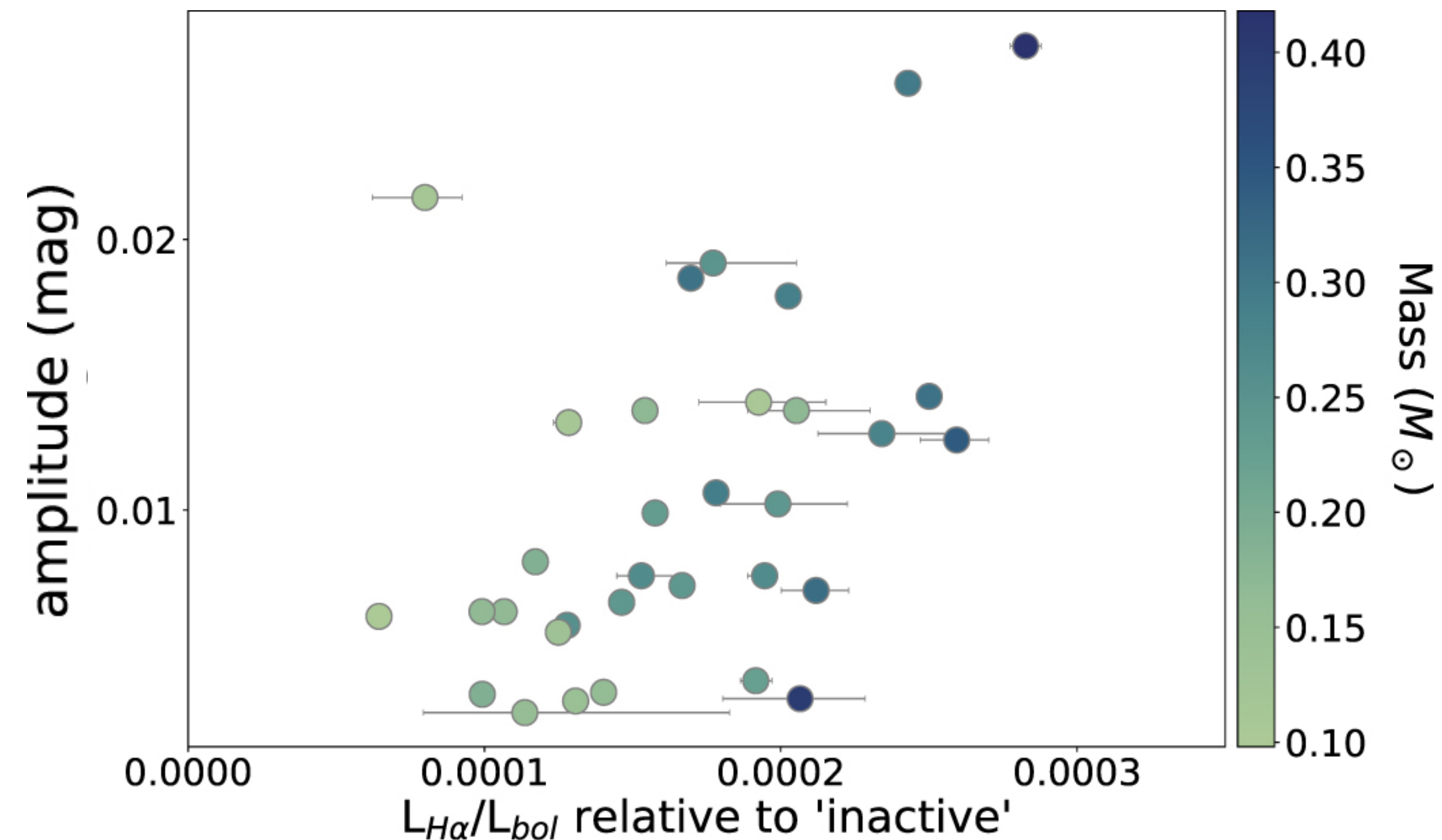


Garcia Soto et al. 2024, in prep.

***Fractional intrinsic variability increases
towards higher order Balmer lines***

Conclusions/Summary

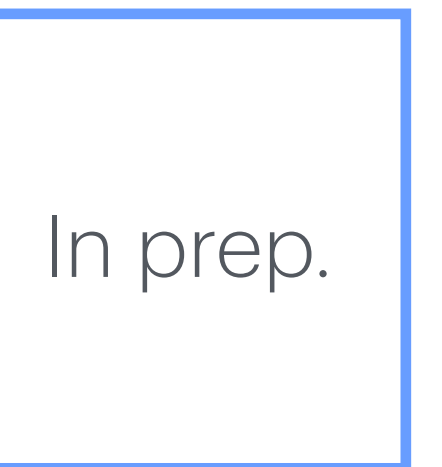
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 - The comparisons of magnetic field activity proxies have some scatter, which can depend on variability and internal mechanisms.



Paper 1

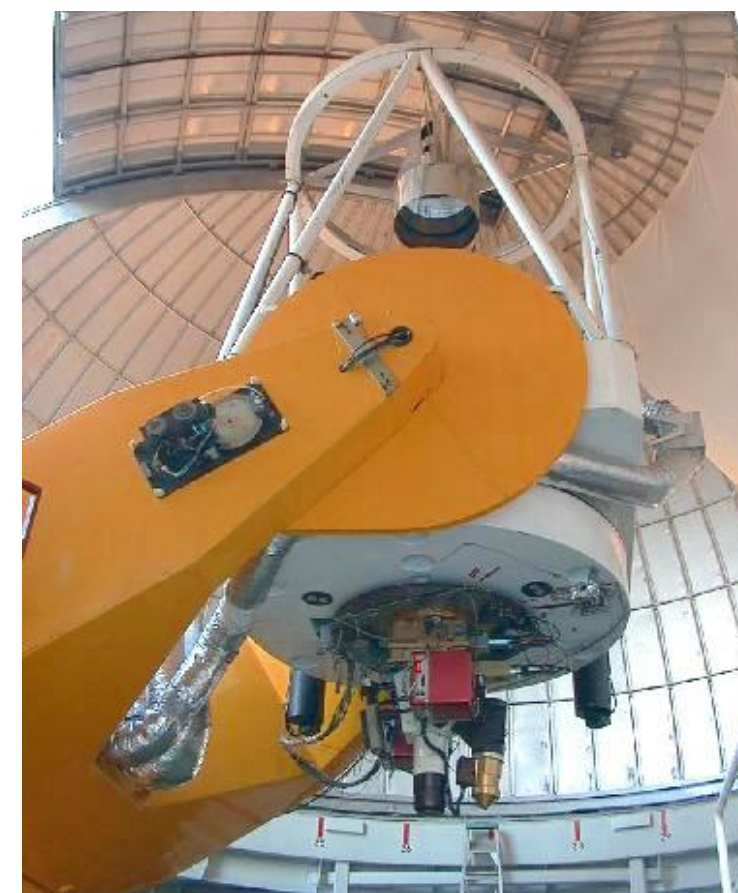


Paper 2



Conclusions/Summary

- Background -
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- Sample -
 - Contemporaneous photometry and spectroscopy using TESS and a ground-based spectrograph, OSMOS.
 - Fully convective M Dwarfs, $V > 16$ magnitudes, $P < 10$ days and in northern hemisphere.



Paper 1



Paper 2

In prep.

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- Results/Discussion -
 - Significant variability in Balmer lines are not captured by optical photometry
 - The ratio of Balmer lines show similar changes within and outside of observed optical flares.
 - Intrinsic variability increases towards higher order Balmer lines.

Paper 1



Paper 2

In prep.