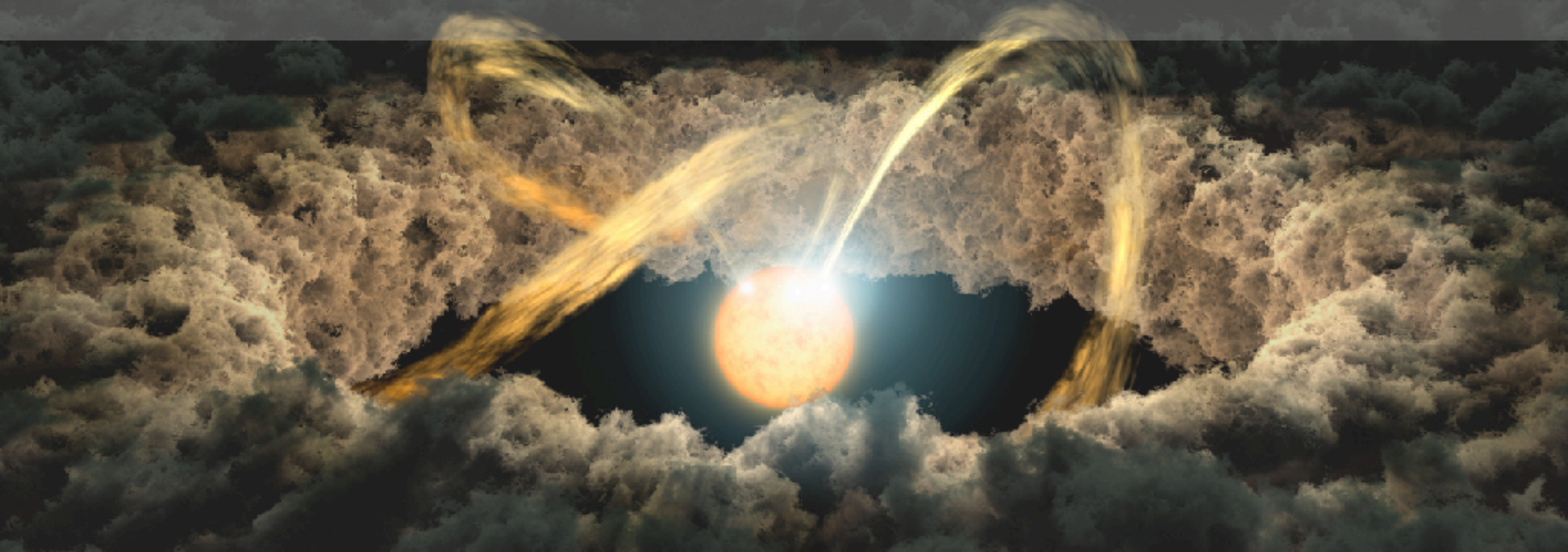
# Characterizing Accretion Variability with HST and Simulations



Connor Robinson

Catherine Espaillat (Boston University), James Owen (Imperical College London), Fred Adams (University of Michigan)

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Image credit: NASA/JPL-Caltech

# Characterizing Accretion Variability with HST and Simulations

- How does accretion vary?
- What causes different types of accretion variability?

Image credit: NASA/JPL-Caltech

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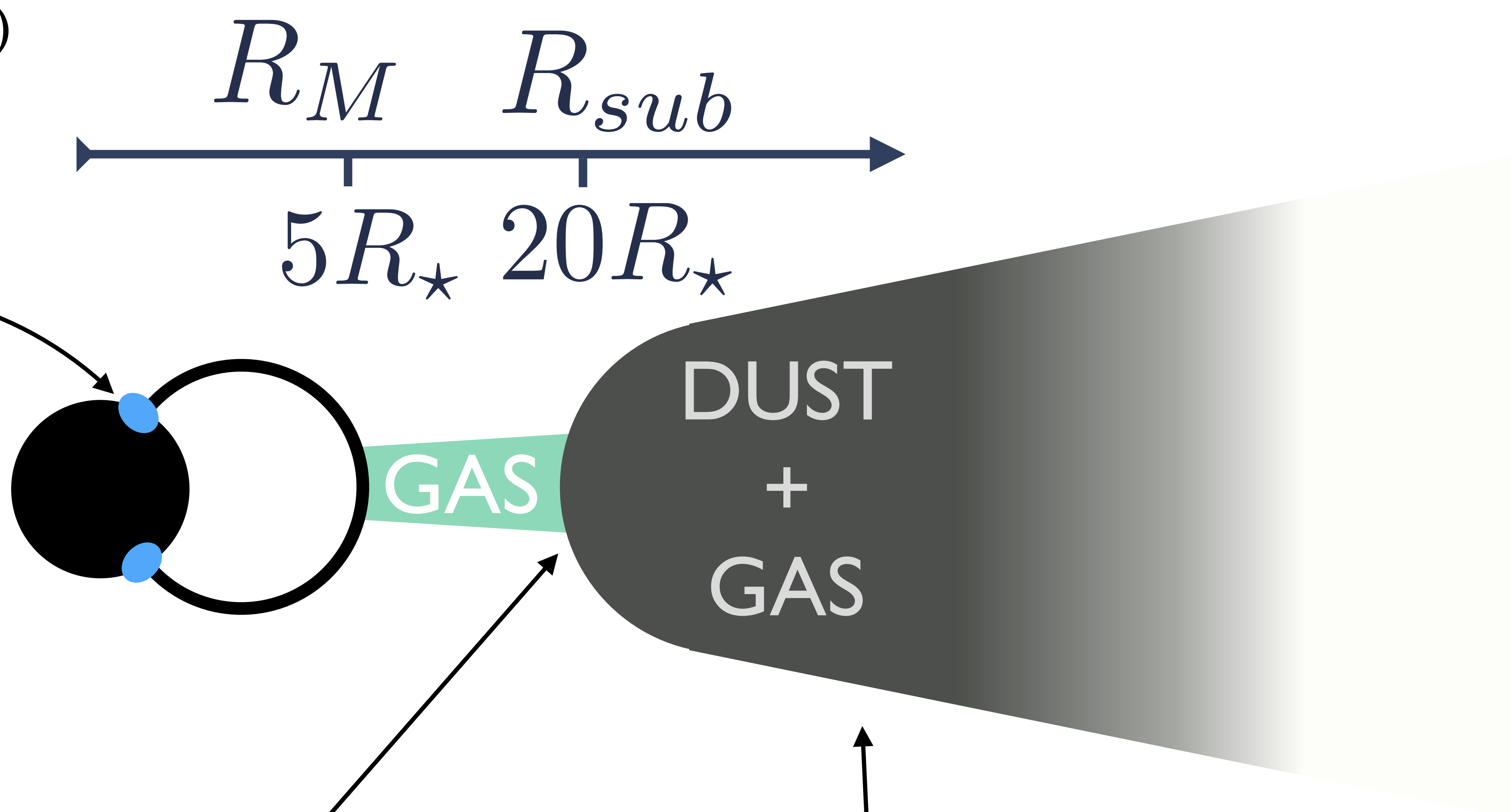
# Canonical view of magnetospheric accretion

Magnetic fields on T Tauri stars are quite strong (~1-2kG at the surface e.g., Johns-Krull et al. 2004)




UV/Optical continuum excess + lines from accretion

NIR continuum excess from illuminated wall at sublimation temperature

IR + mm excess from dusty disk

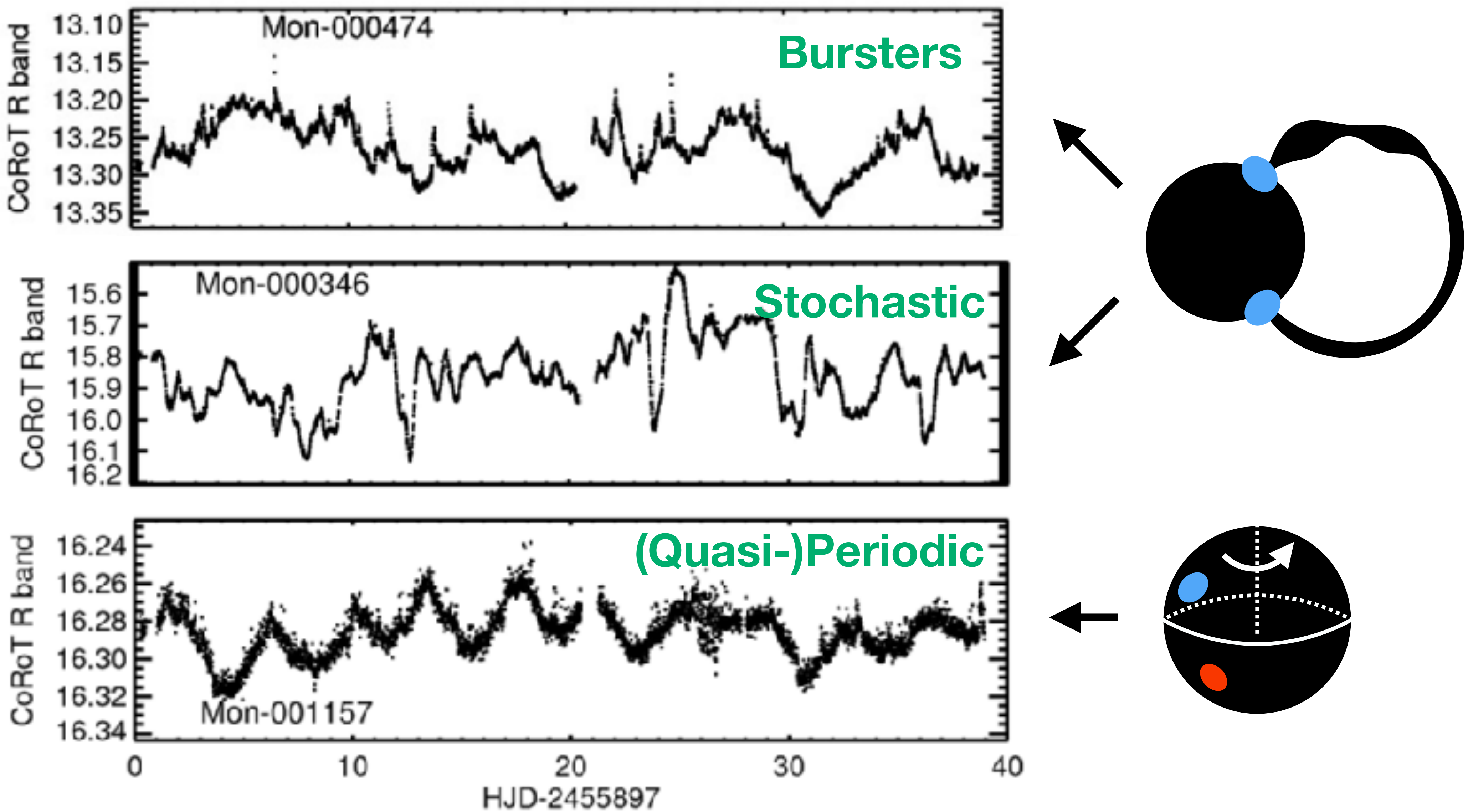
(For a review, see Hartmann et al. 2016)

# Variability is extremely common in CTTS

~95% of stars with disks also shown variability identifiable with K2 (Cody et al. 2018)

Young stars have been categorized using optical light curves based on the periodicity and symmetry of their short timescale variability.

Much of the variability is caused by changes in the mass accretion rate.



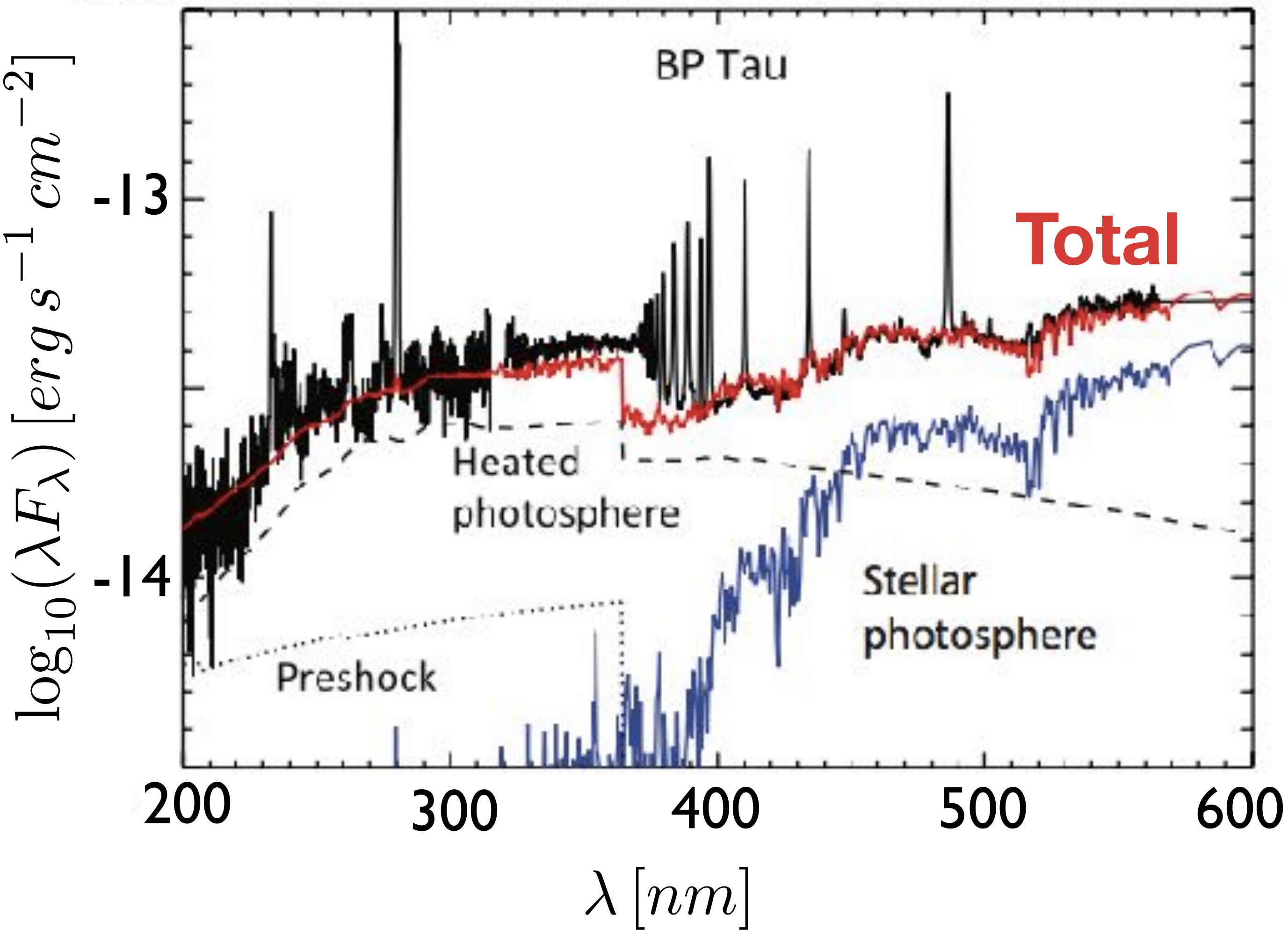

Cody et al. (2014)

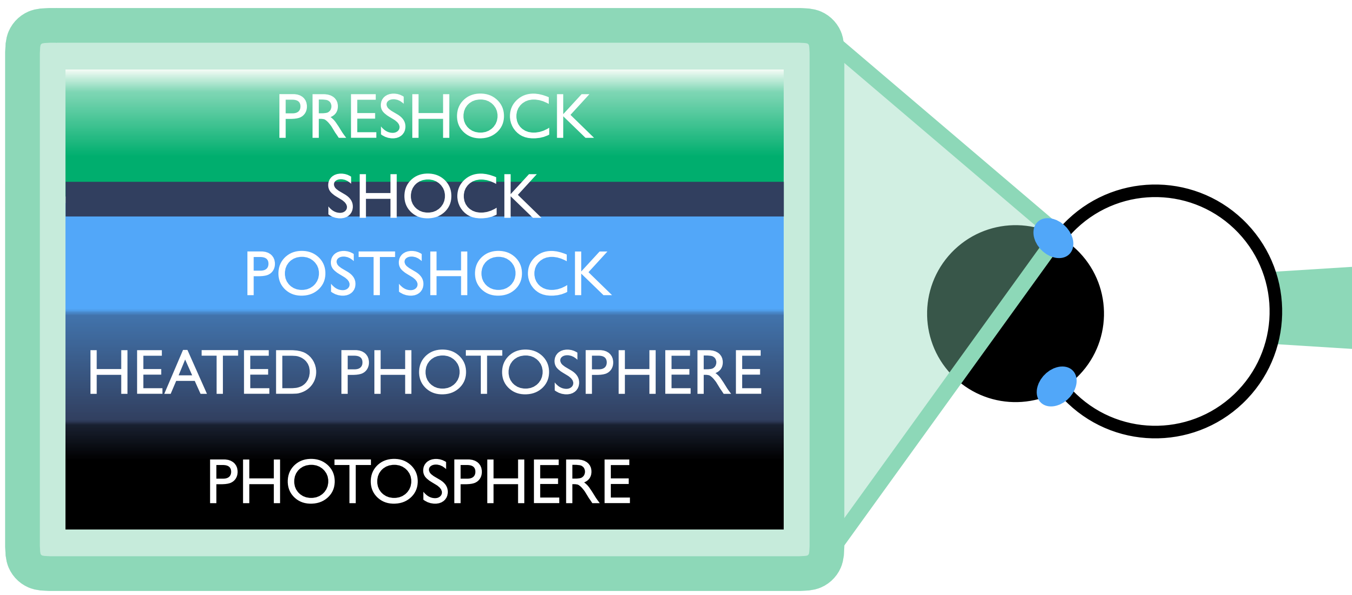
# One direct method of probing accretion behavior: Modeling UV spectra

Updated version of the Calvet et al. (1998) radiative transfer accretion shock models

1D nLTE slab model

Scale model emission by fraction of star covered by accretion column

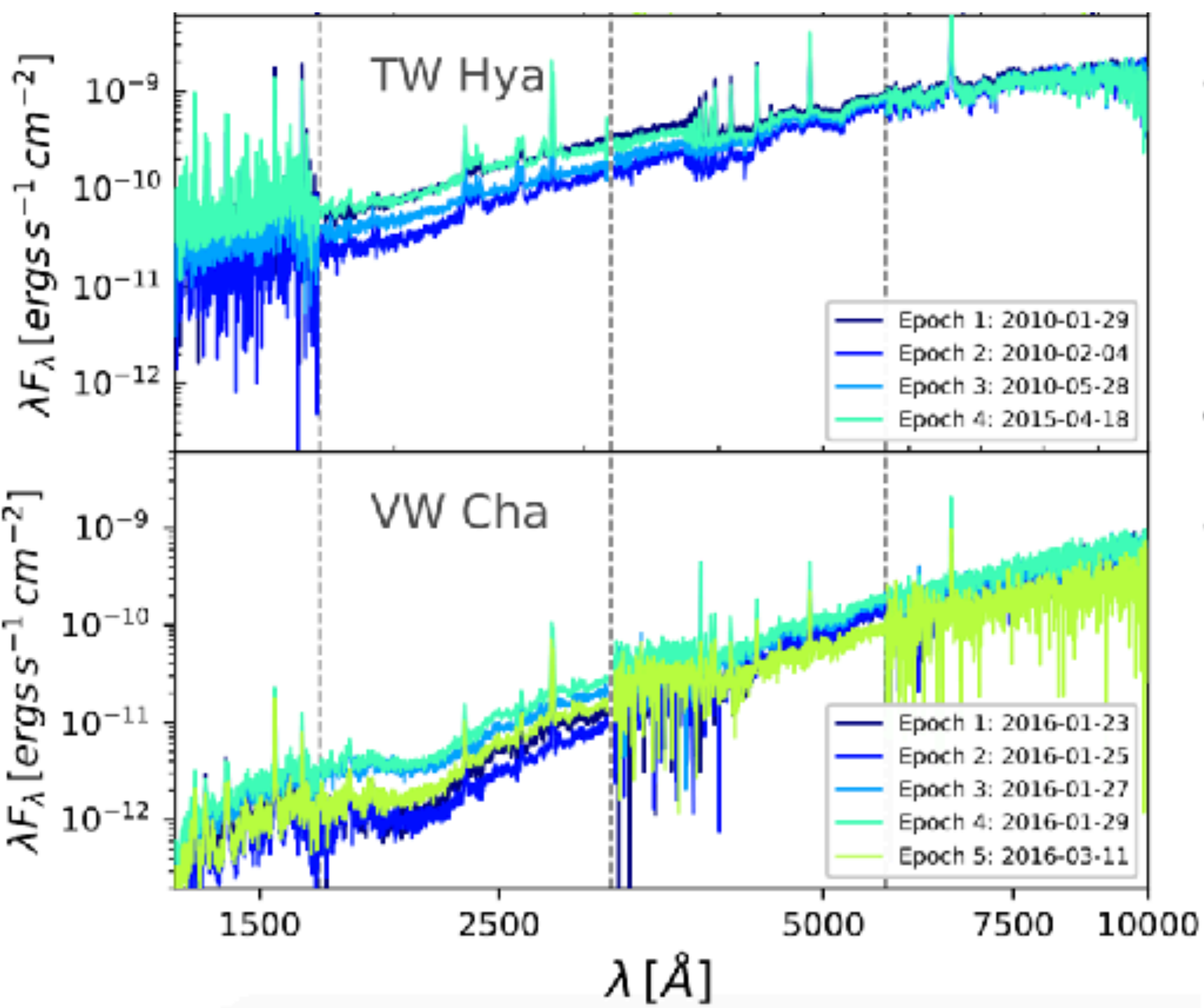


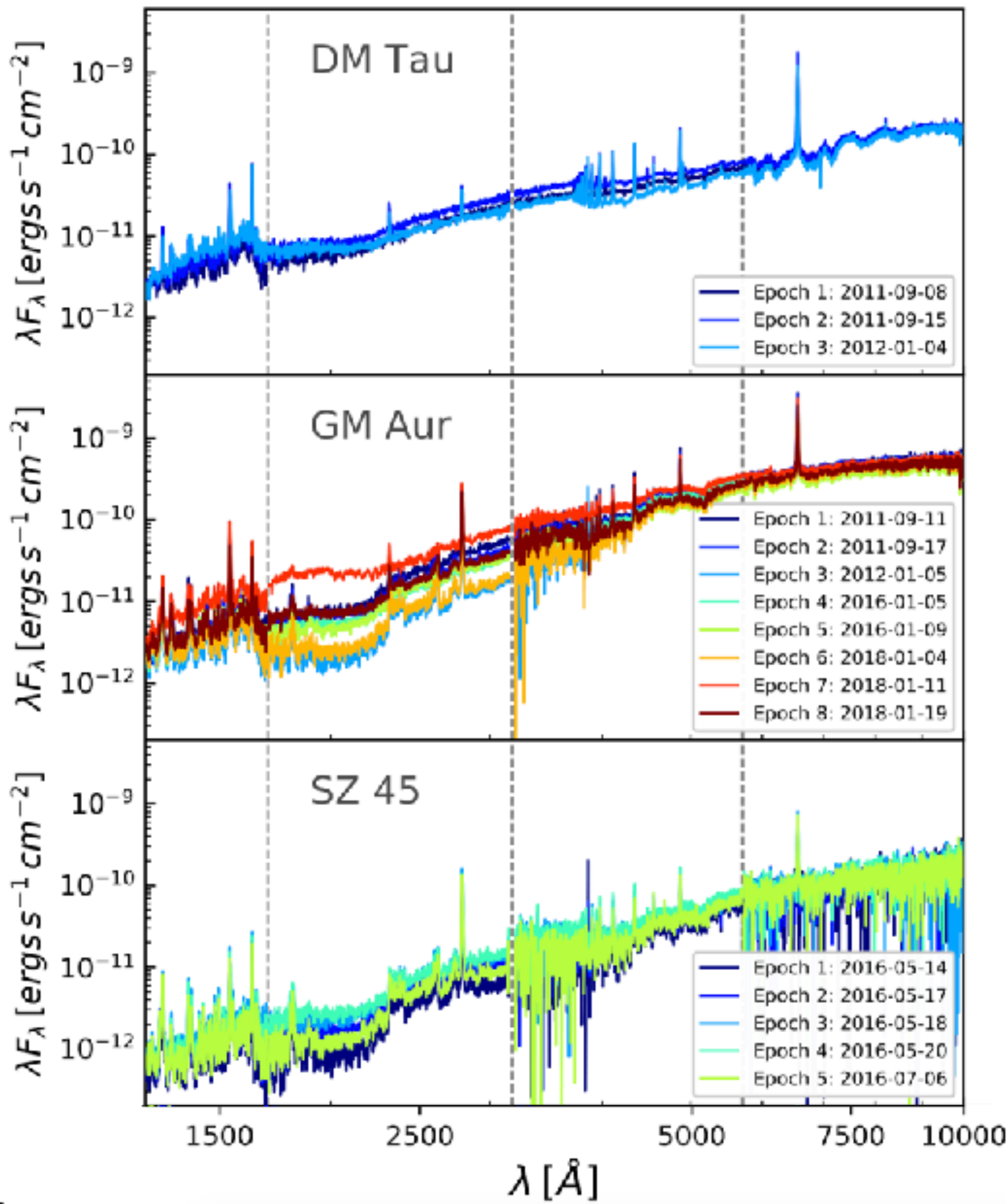




Hartmann, Herczeg & Calvet (2016)

# Sample is comprised of 25 HST STIS spectra

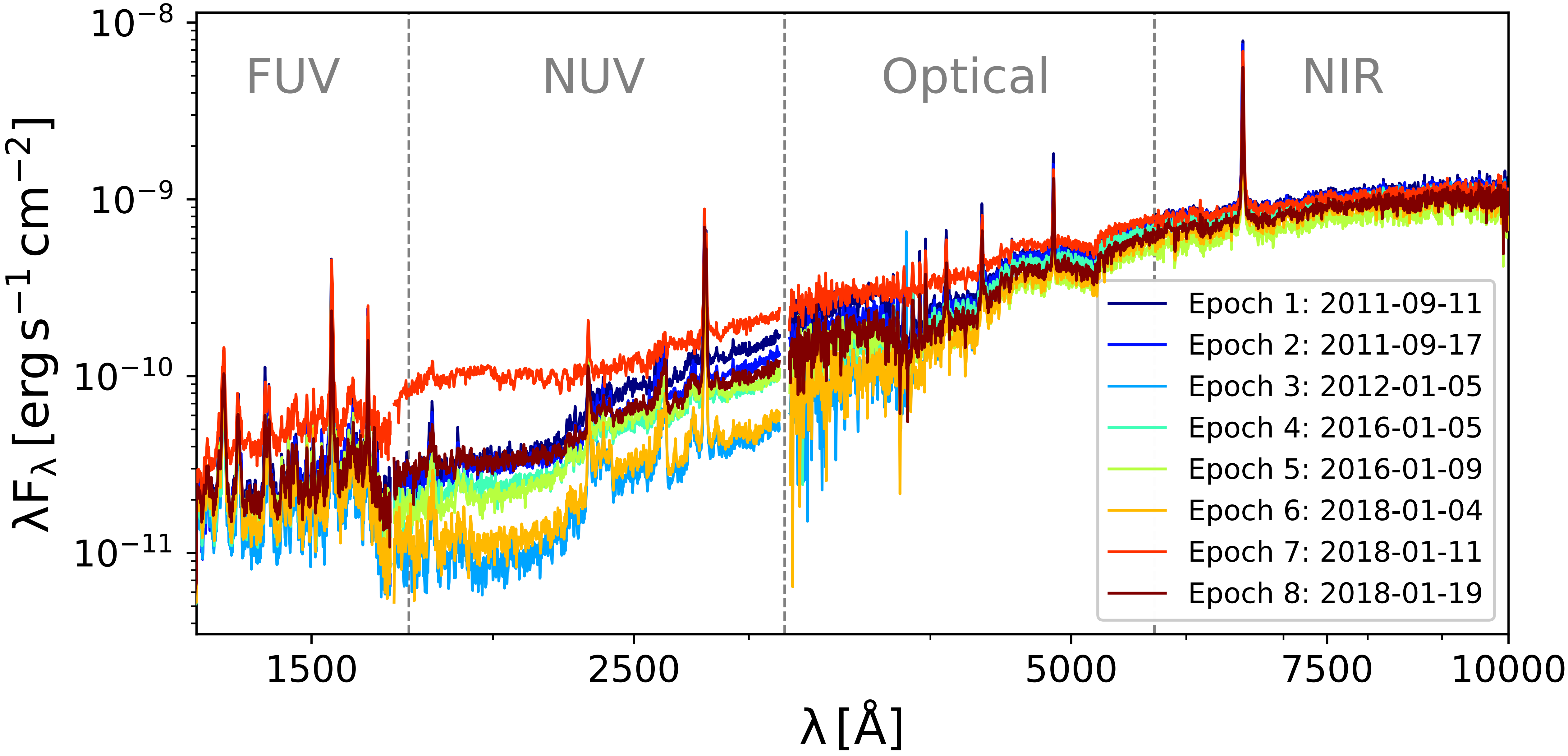
- Typical changes in mass accretion rate of up to ~2x over week long timescales.
- Moderate surface coverage, typically around 20% with the largest contributions from lowest density columns



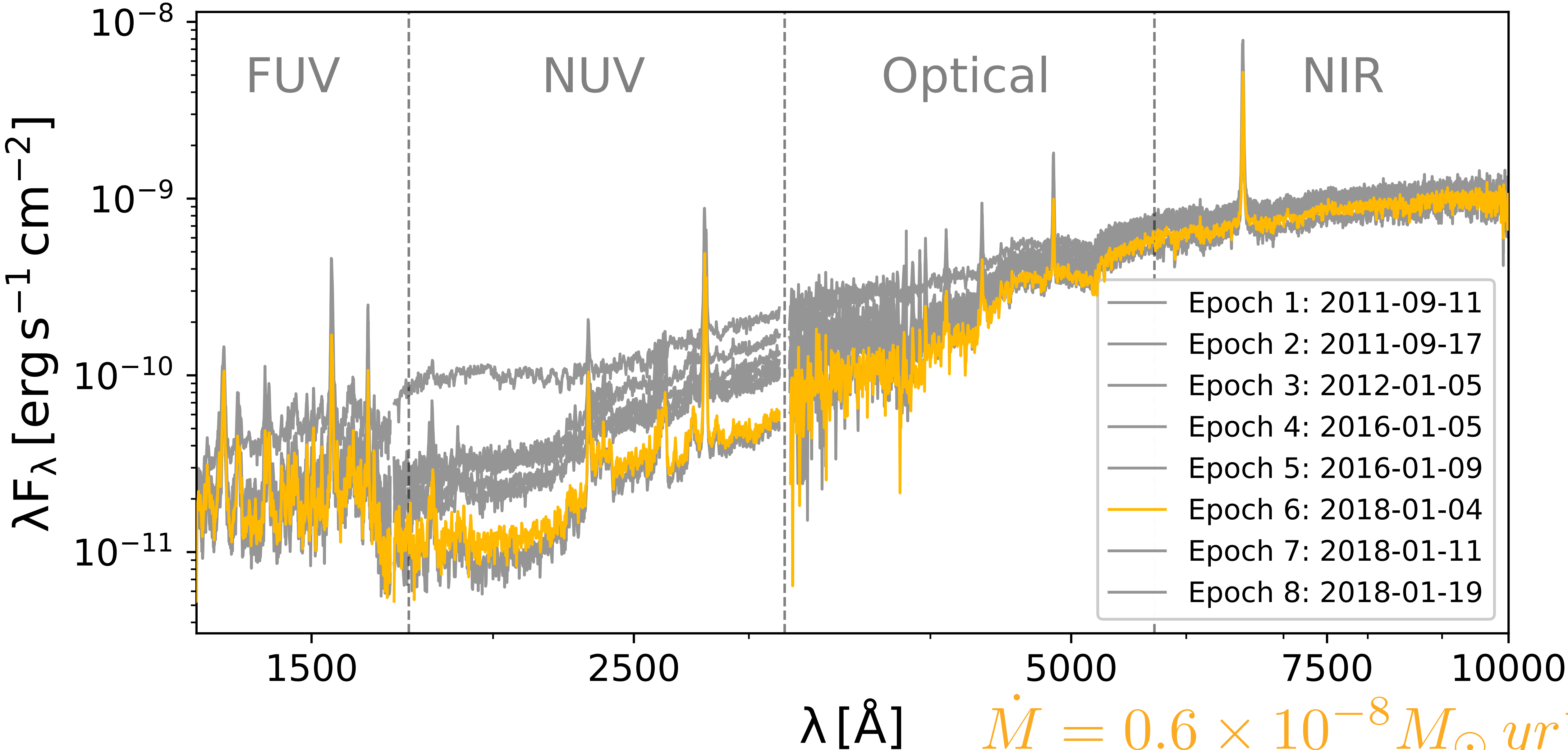

Robinson & Espaillat (2019)

# Catching a large accretion burst in GM Aur:




Robinson & Espaillat (2019)

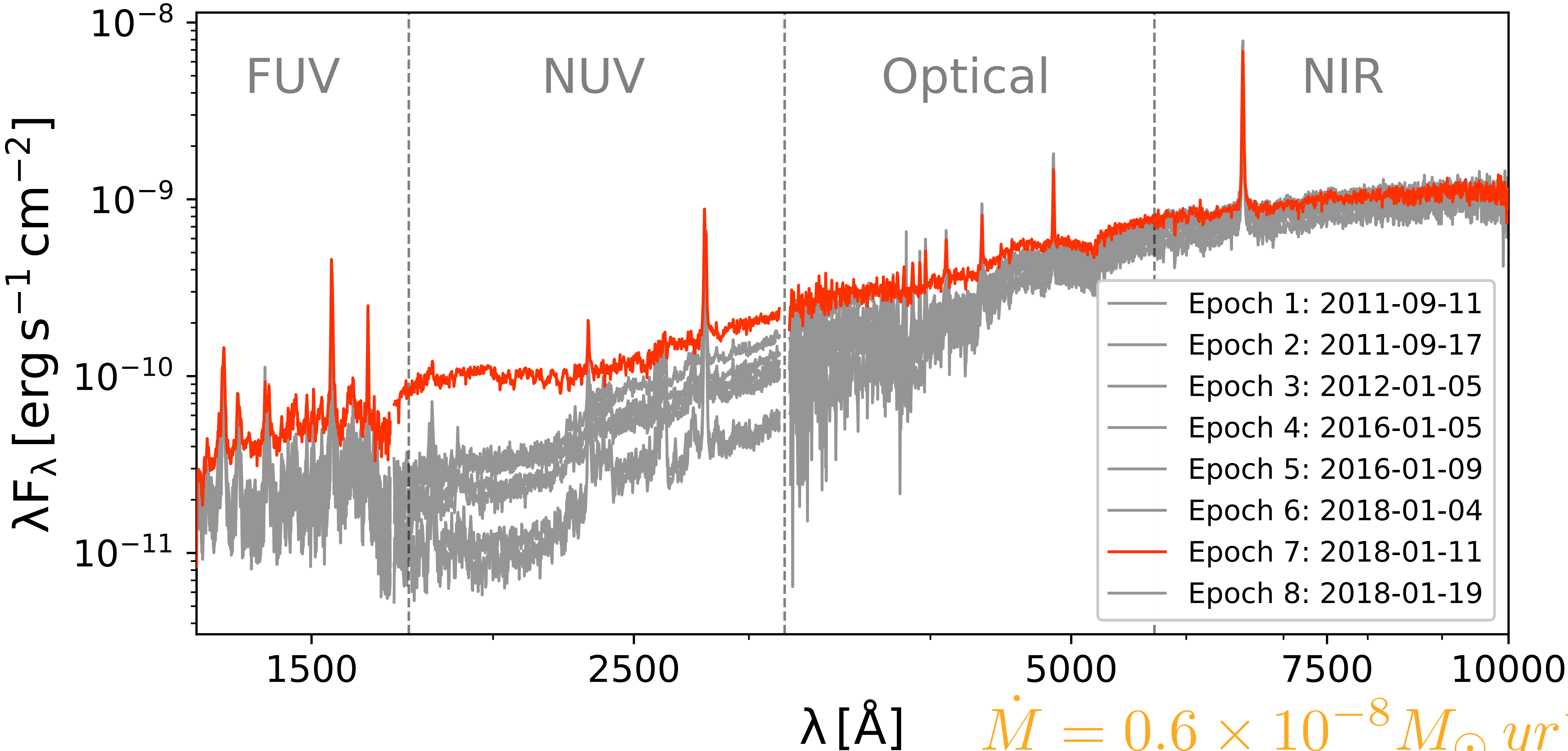
# Catching a large accretion burst in GM Aur:
## 7 days before the accretion burst




$\dot{M} = 0.6 \times 10^{-8} M_{\odot}\, yr^{-1}$

Robinson & Espaillat (2019)

# Catching a large accretion burst in GM Aur:
## During the accretion burst



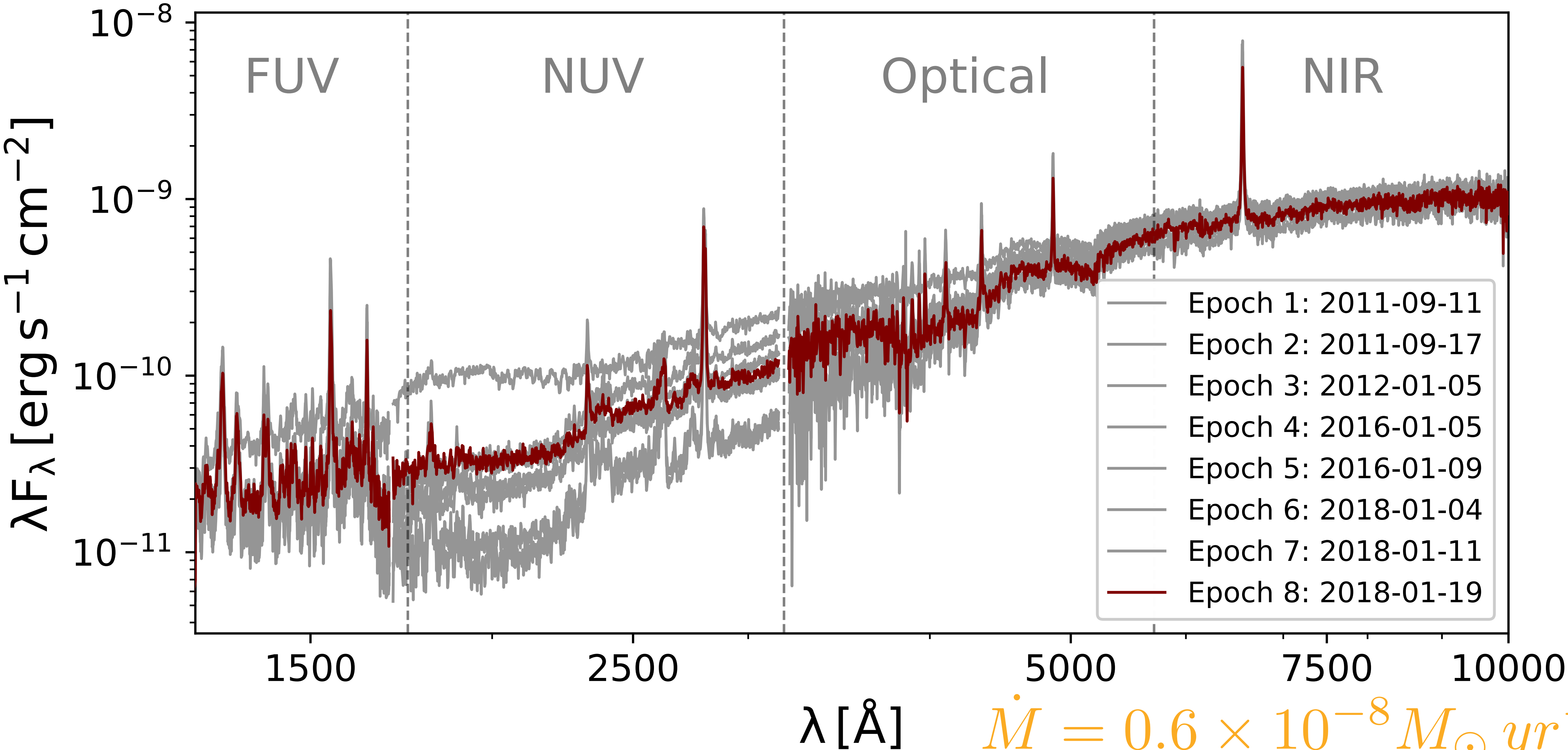

$\dot{M} = 0.6 \times 10^{-8} M_\odot\, yr^{-1}$

$\dot{M} = 2.0 \times 10^{-8} M_\odot\, yr^{-1}$

Robinson & Espaillat (2019)

# Catching a large accretion burst in GM Aur:

## 8 days after the accretion burst



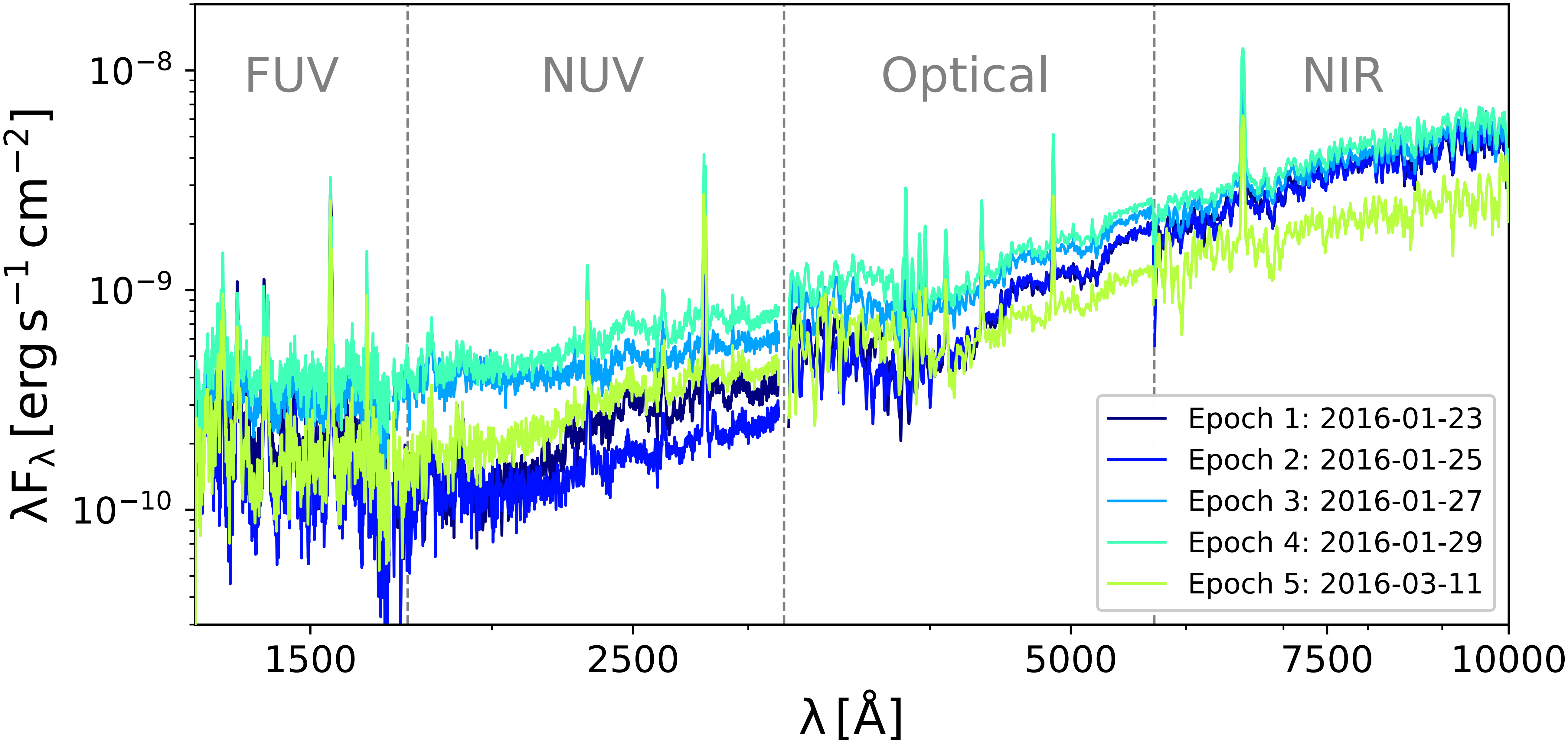

$\dot{M} = 0.6 \times 10^{-8} M_\odot\, yr^{-1}$

$\dot{M} = 2.0 \times 10^{-8} M_\odot\, yr^{-1}$

$\dot{M} = 1.0 \times 10^{-8} M_\odot\, yr^{-1}$

Robinson & Espaillat (2019)

# VW Cha shows intriguing behavior in the optical/NIR




Robinson & Espaillat (2019)

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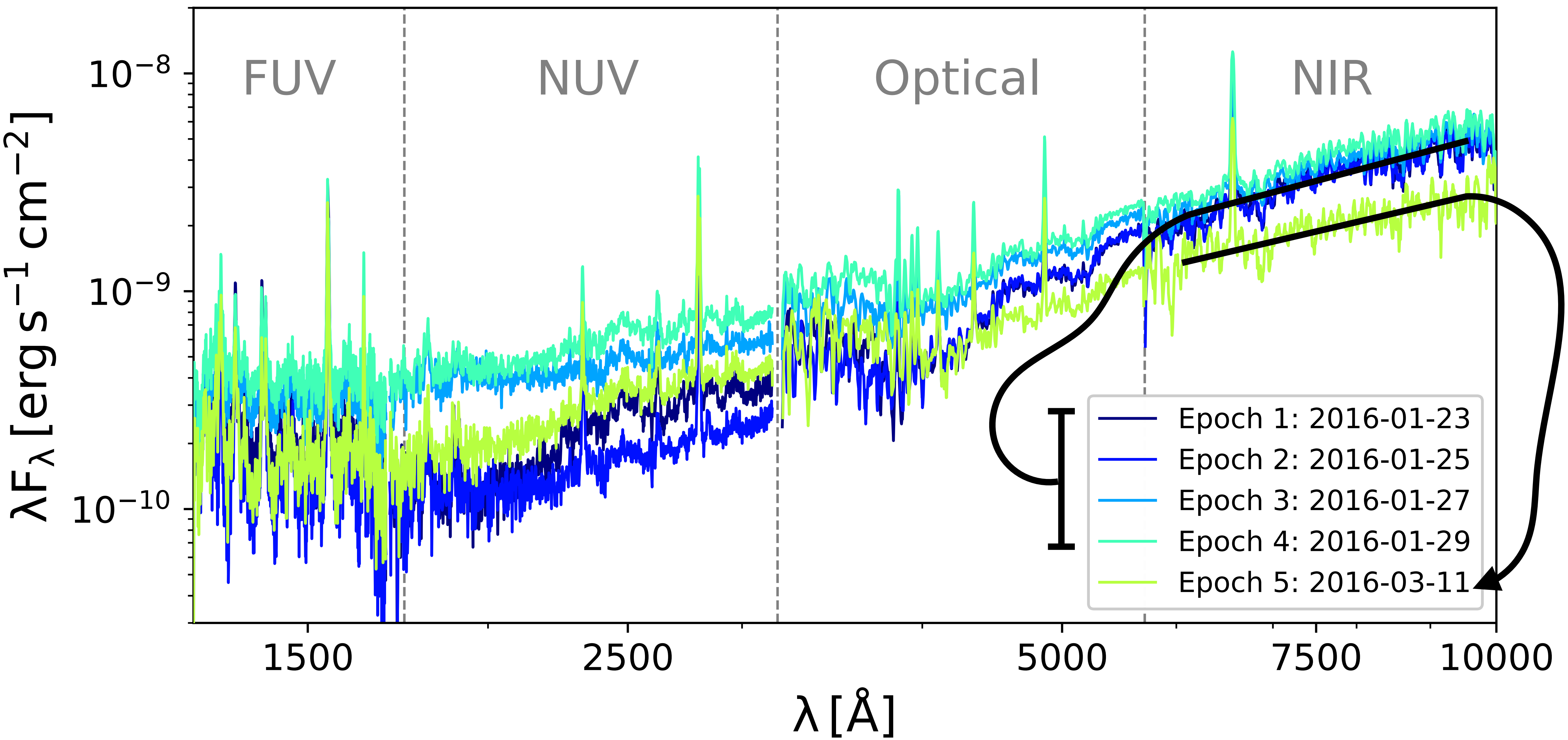



Epoch 5 FUV + NUV look comparable to other epochs.
NIR + optical a factor of ~2 lower.

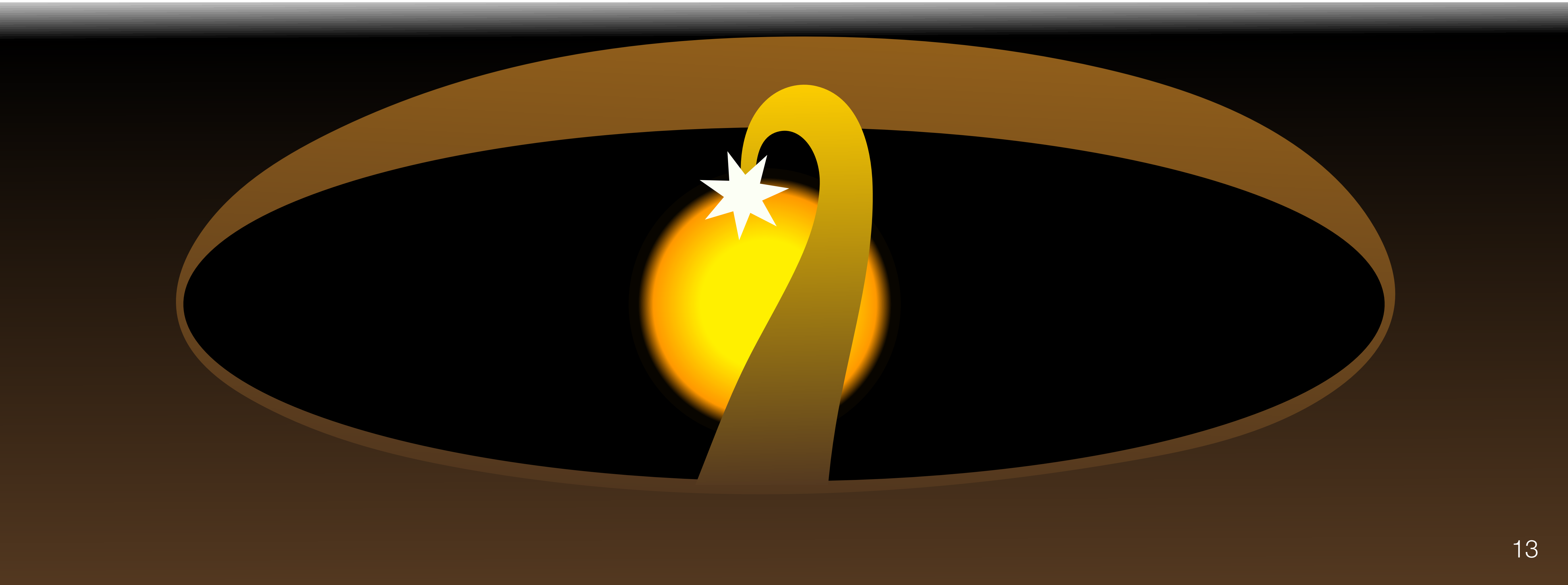
Robinson & Espaillat (2019)

# VW Cha Scenario:
# Occultation by accretion column

Chance alignment of well-collimated accretion column blocks large regions of undisturbed photosphere, but not shocked region during Epoch 5

Observed characteristics match observations:
Typical FUV + NUV excess, but reduced NIR + Optical

**Does require dust to be present near the magnetospheric truncation radius**
— Consistent with Ingleby (2015) results for GM Aur and Stauffer et al. (2017) in Upper Sco



# Characterizing Accretion Variability with HST and Simulations

- How does accretion vary?
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Image credit: NASA/JPL-Caltech



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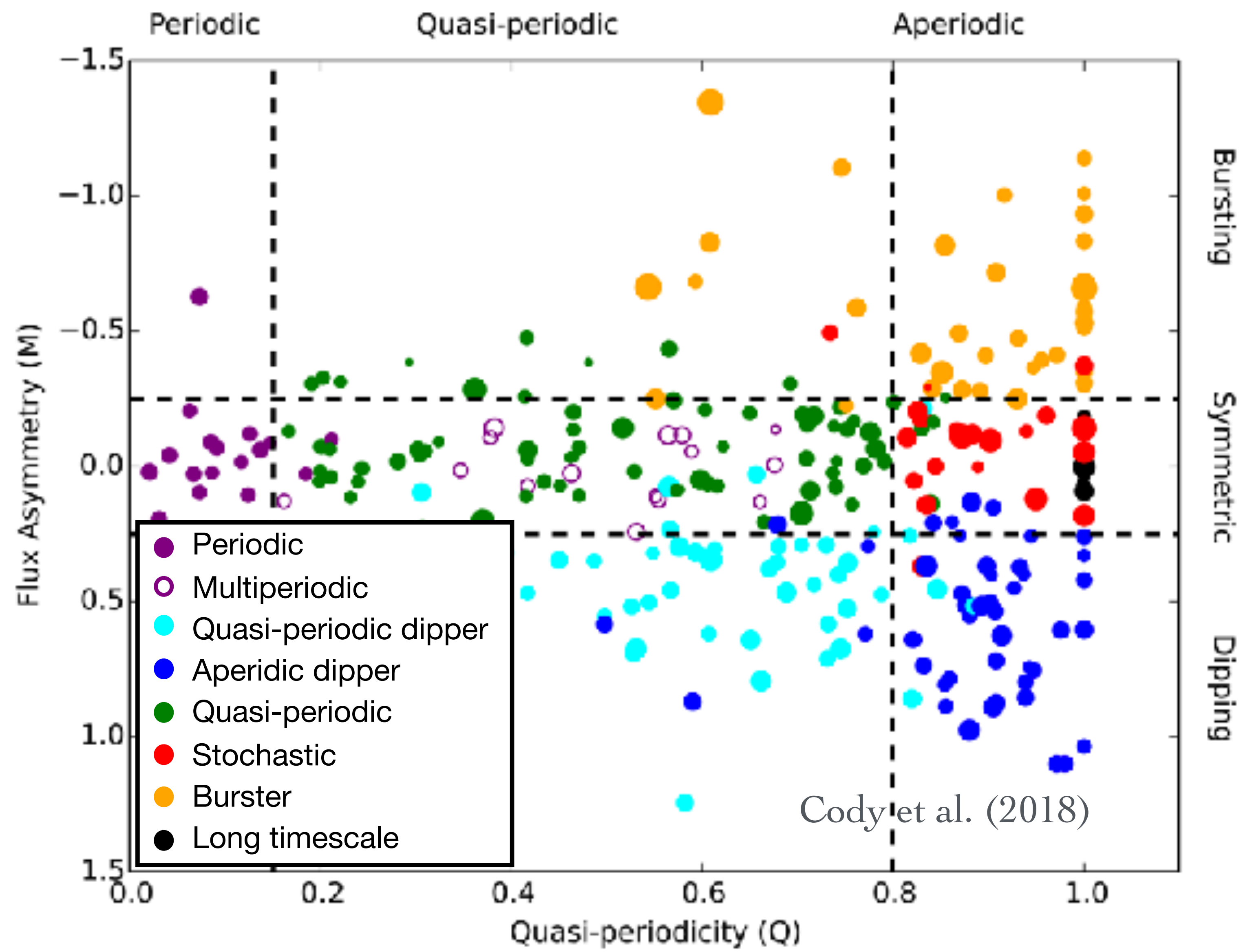
# Empirical accretion variability classes from photometric surveys

**Month long monitoring campaigns using K2/ CoRoT**

**Regions include Upper Sco/Oph and NGC 2264**

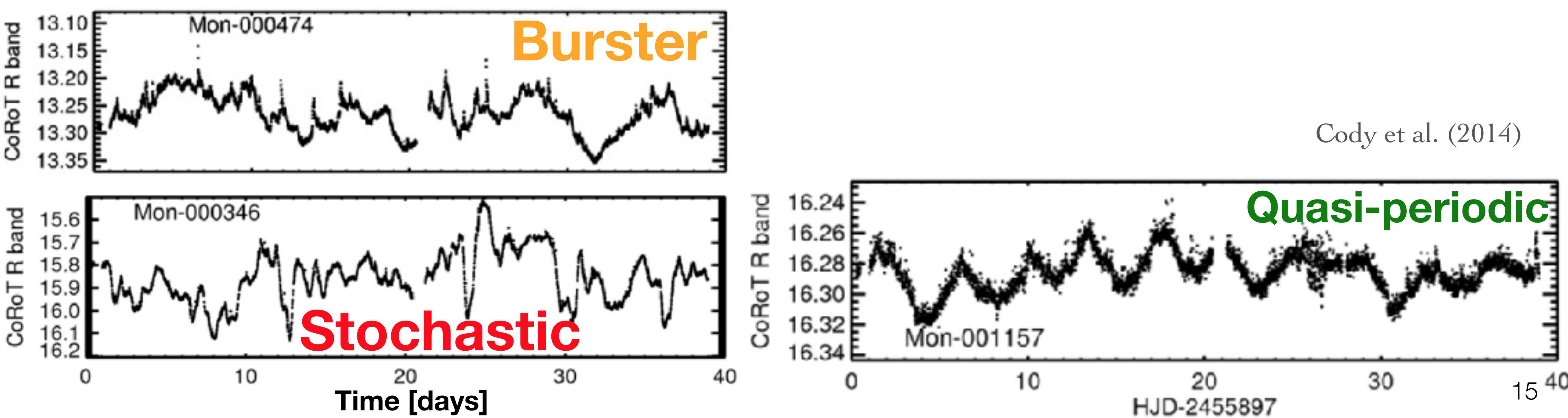
**More bursty**

**More dips**



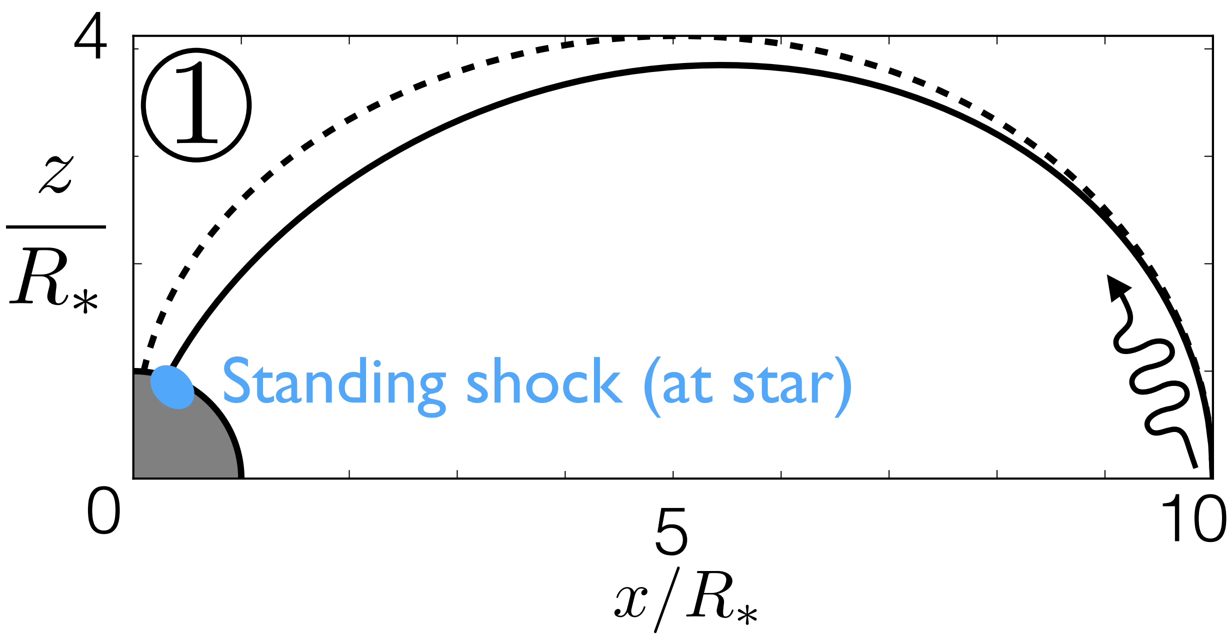

**More periodic**

**More stochastic**



# Producing synthetic observations with simulations of the accretion column

Introduce density perturbations via a driving function at the inner edge of the disk in a 1D HD simulation of the accretion column



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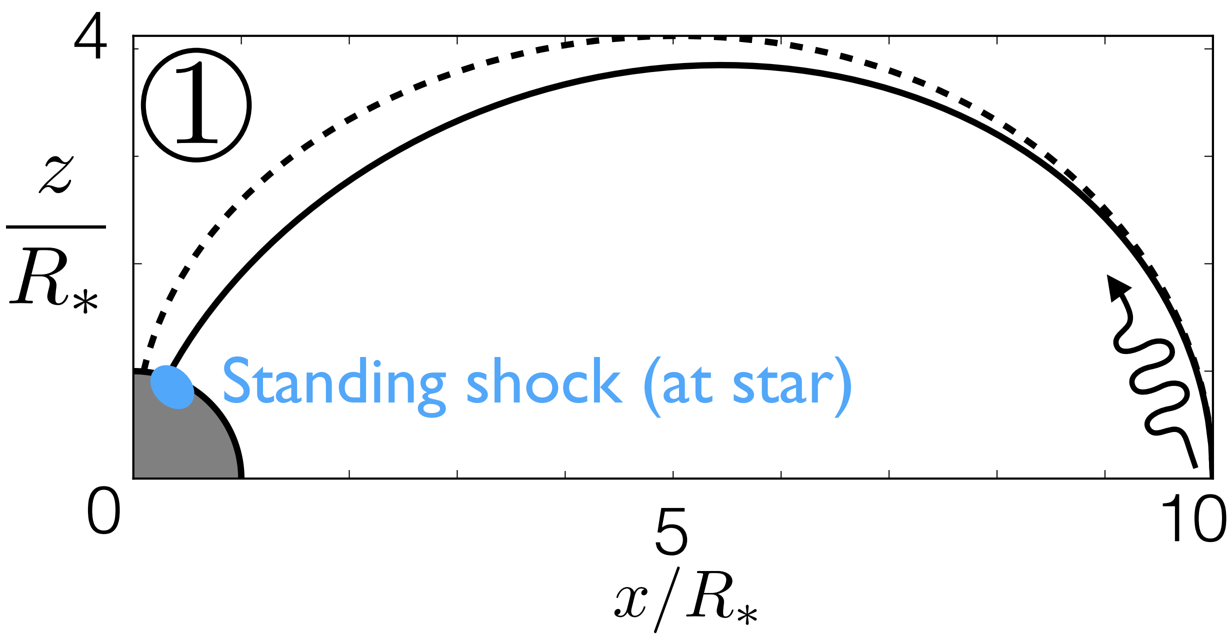
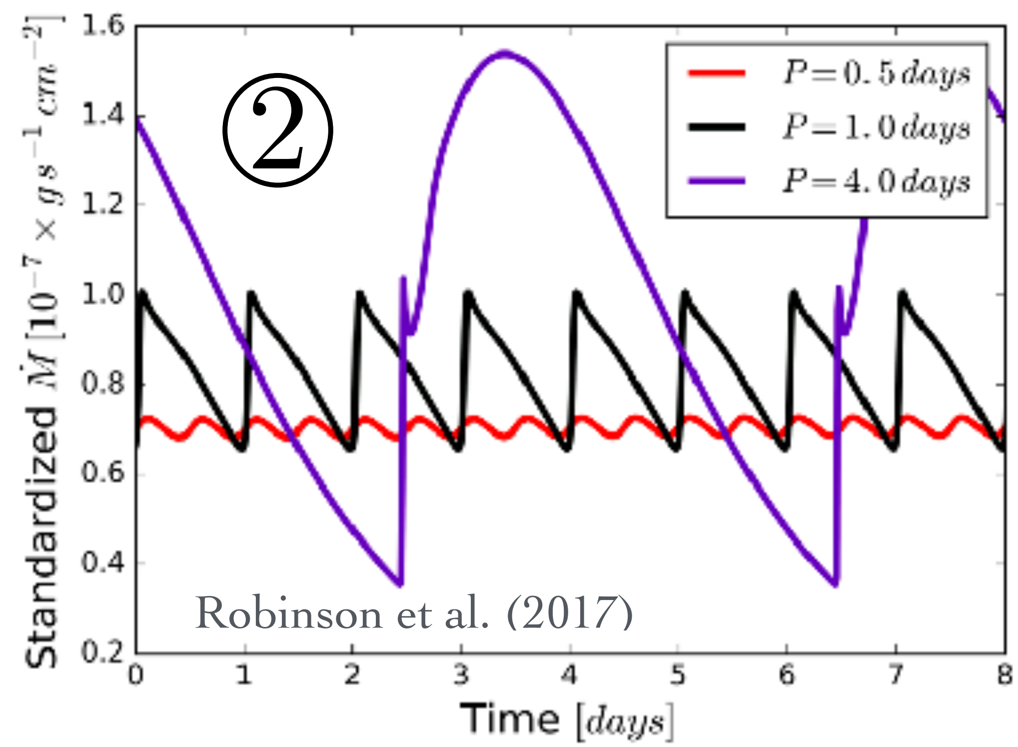



Driving function + system parameters set the accretion behavior at the star



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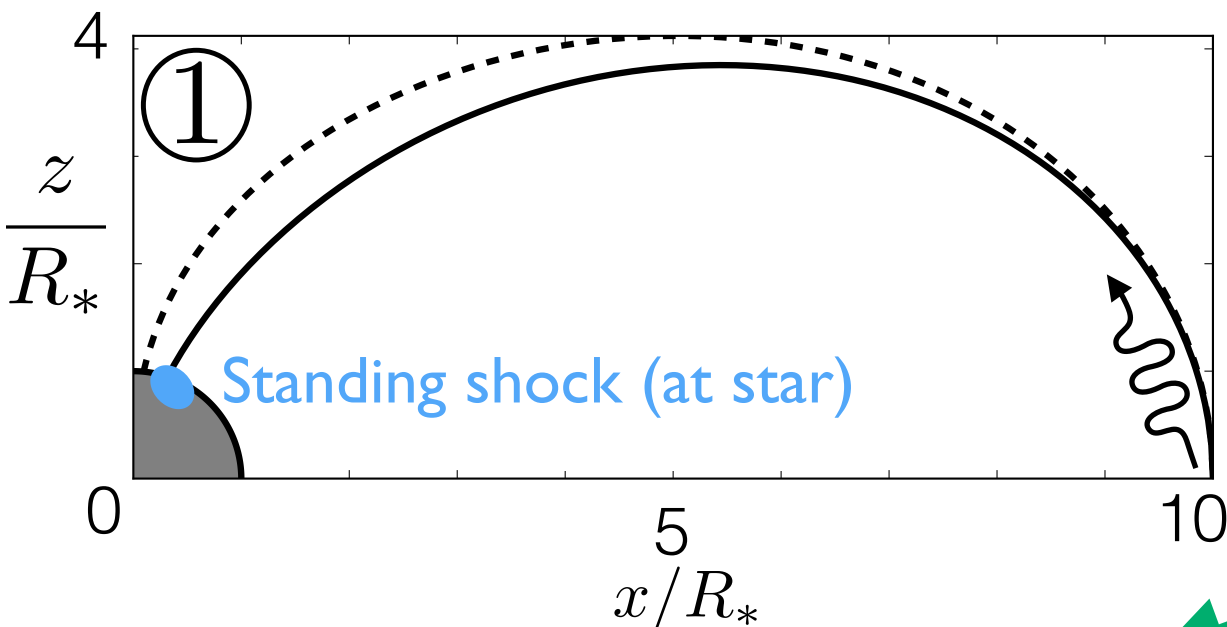


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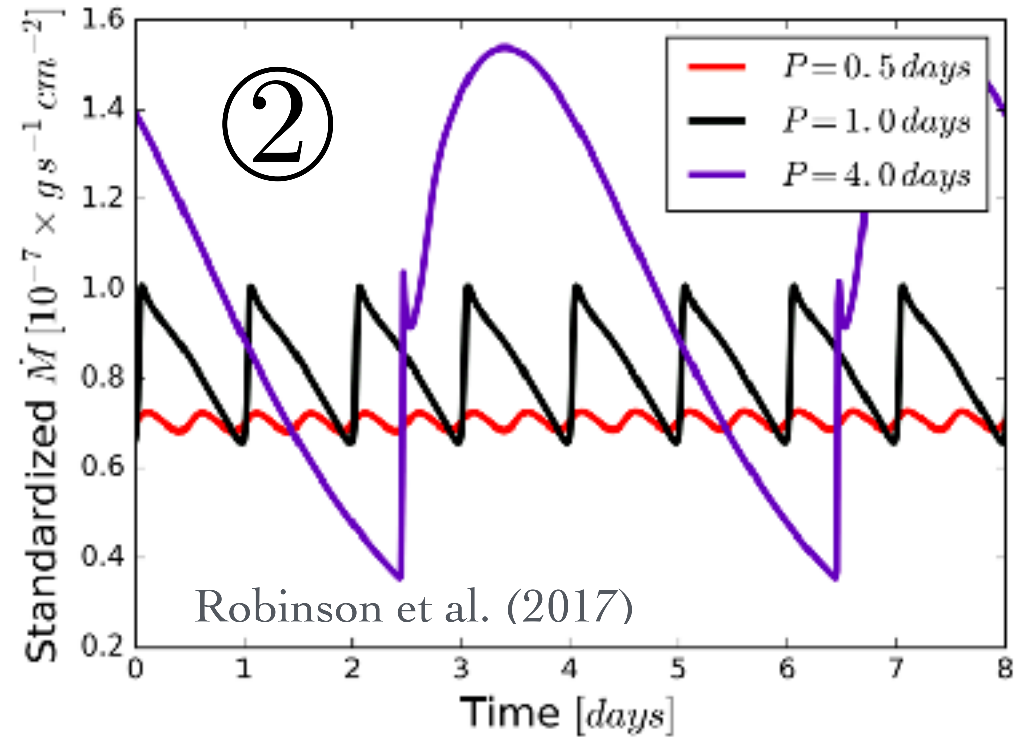


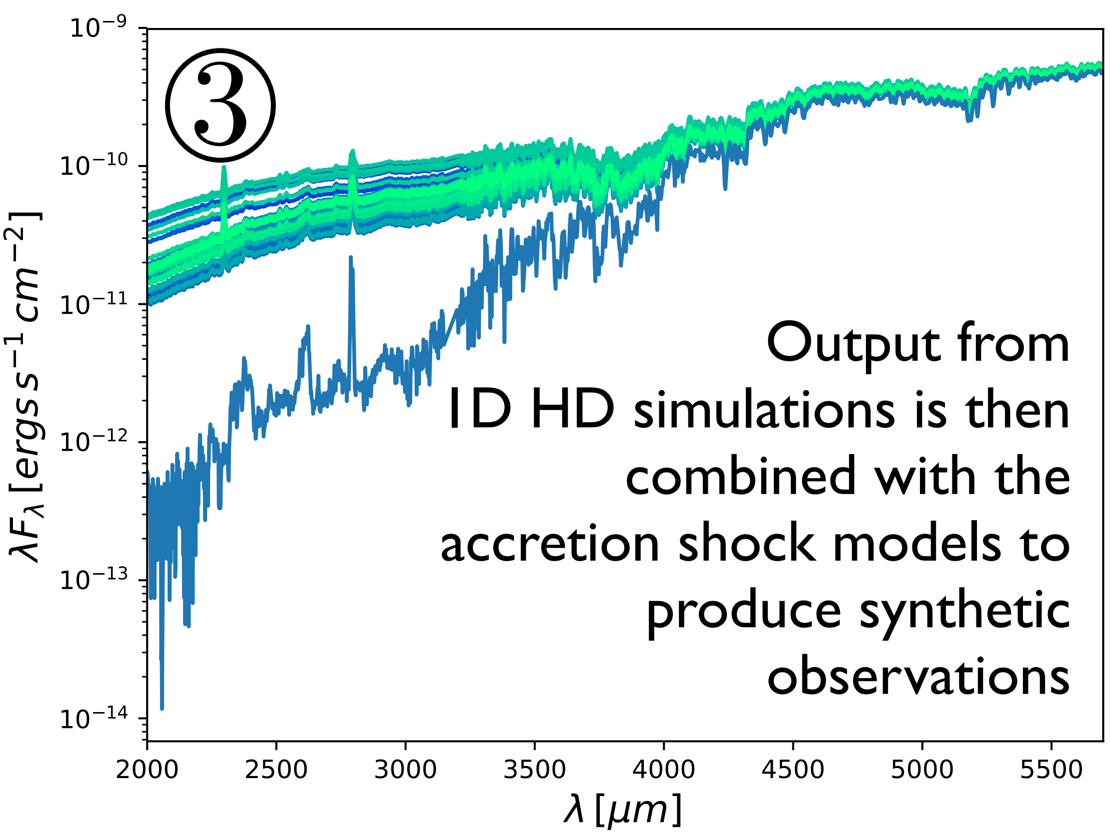


Output from 1D HD simulations is then combined with the accretion shock models to produce synthetic observations

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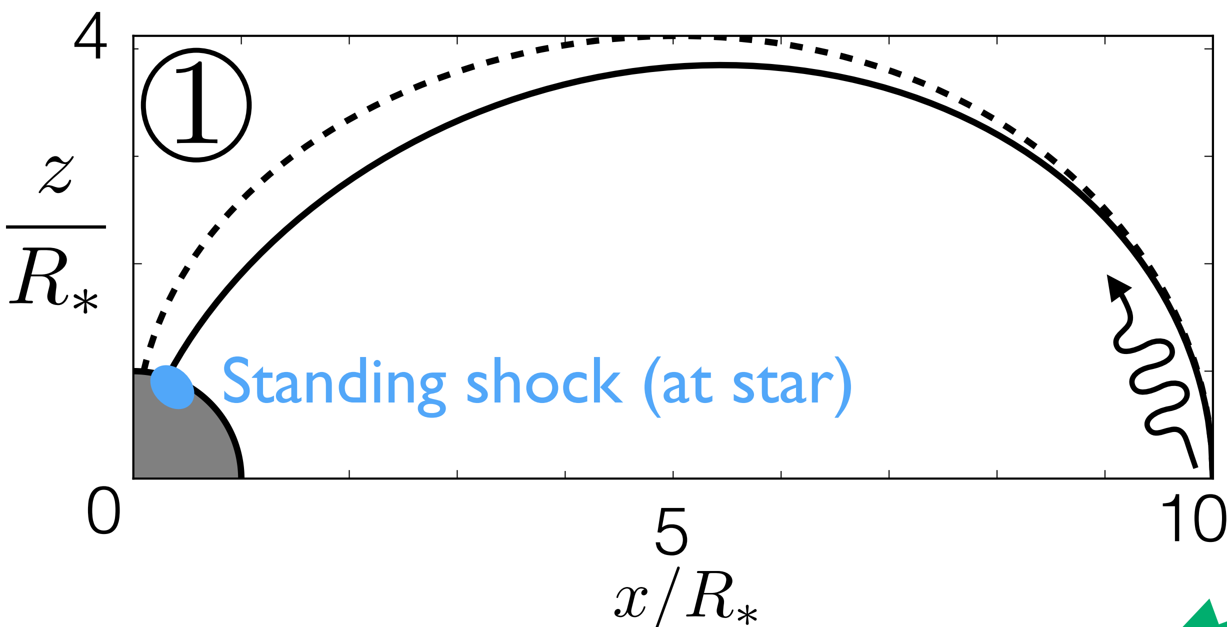


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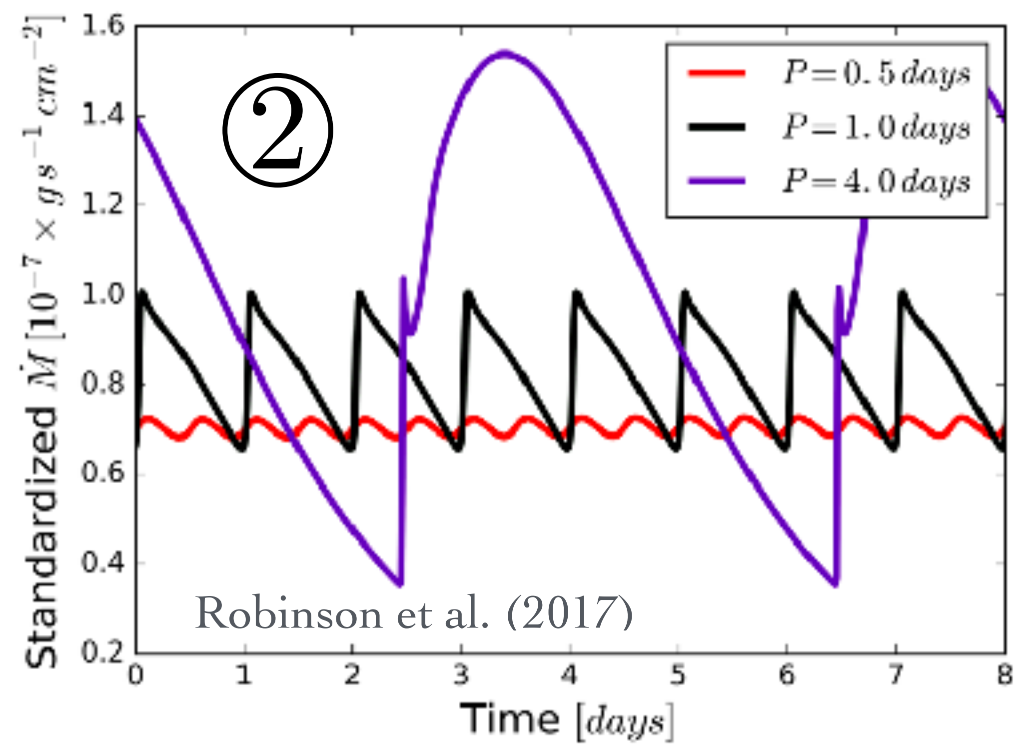


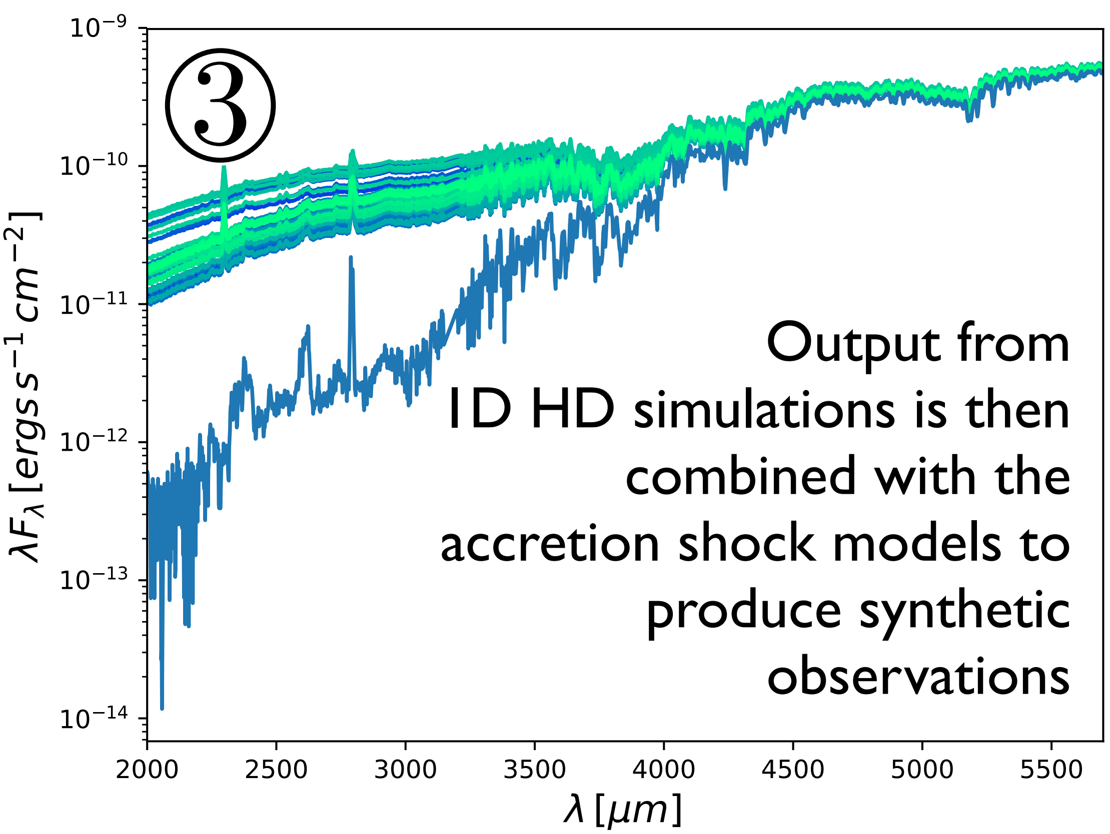


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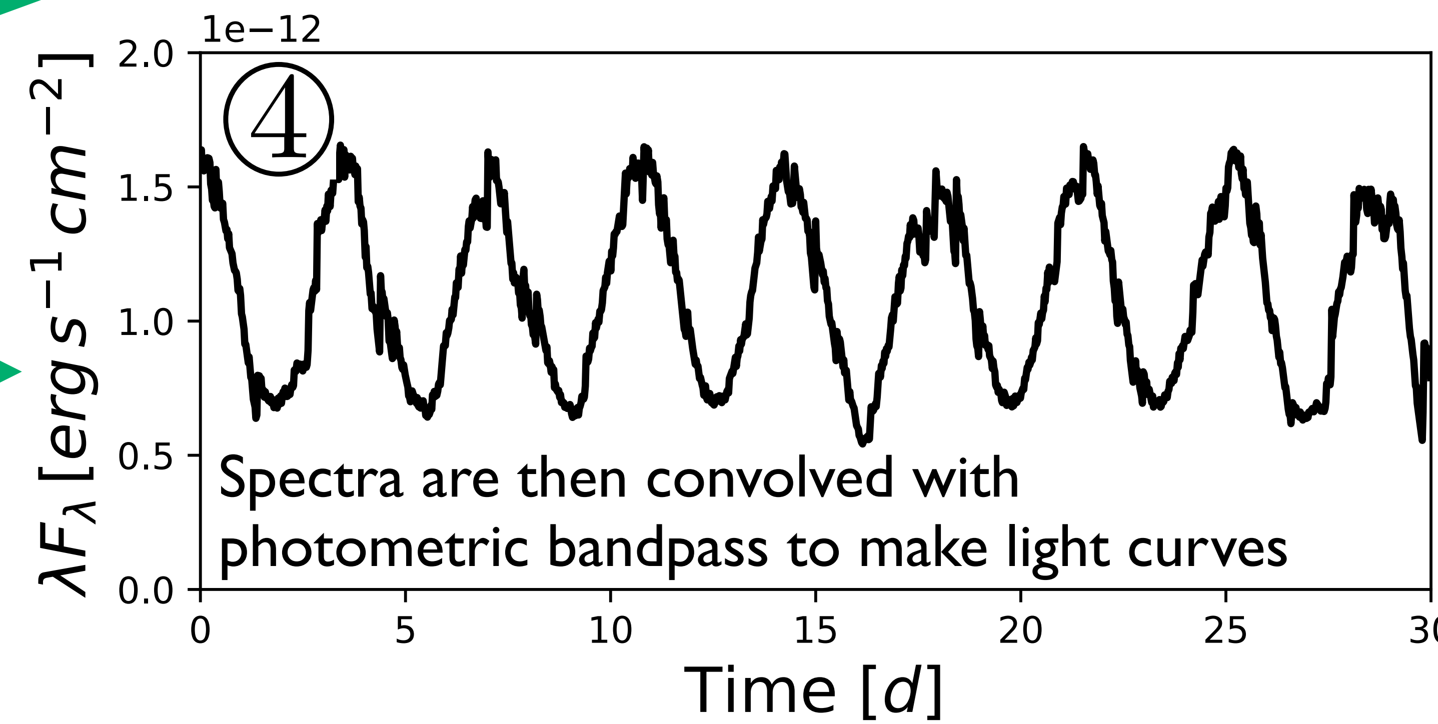
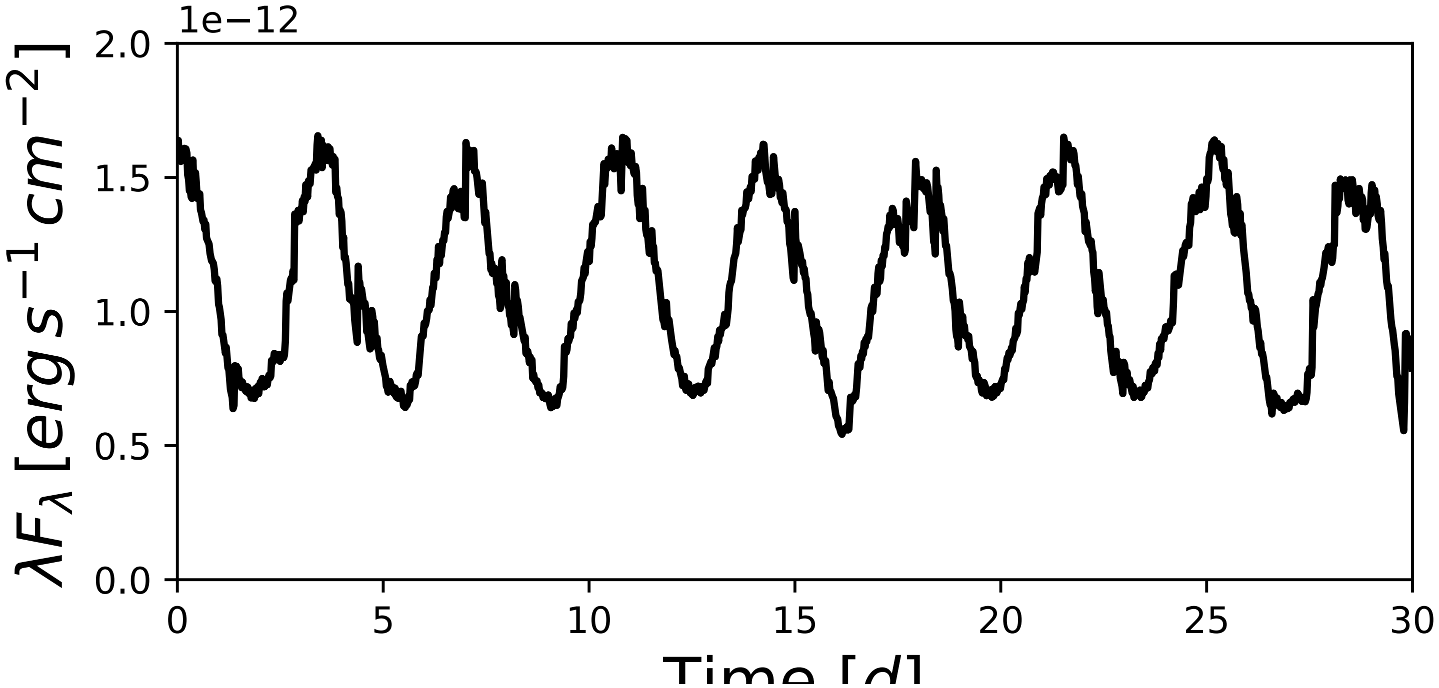



Spectra are then convolved with photometric bandpass to make light curves

# Example synthetic light curves created using a turbulent driving function

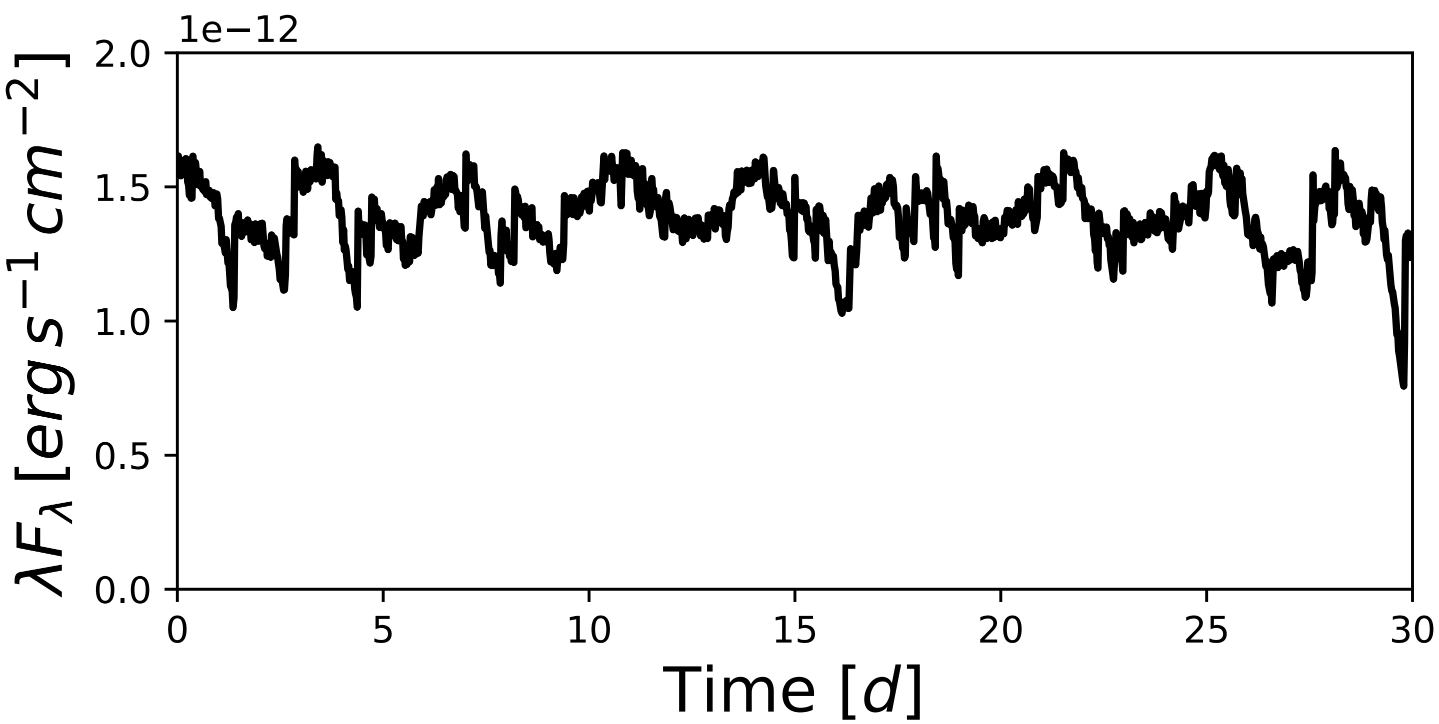



$i = 40^\circ$ → Viewing inclination

$\Gamma = 0$ → Octupole/Dipole magnetic field components

$R_{disk} = 5R_{star}$ → Magnetic truncation radius

$A = 0.1$ → RMS of the turbulent driving function




$i = 10^\circ$

$\Gamma = 0$

$R_{disk} = 5R_{star}$

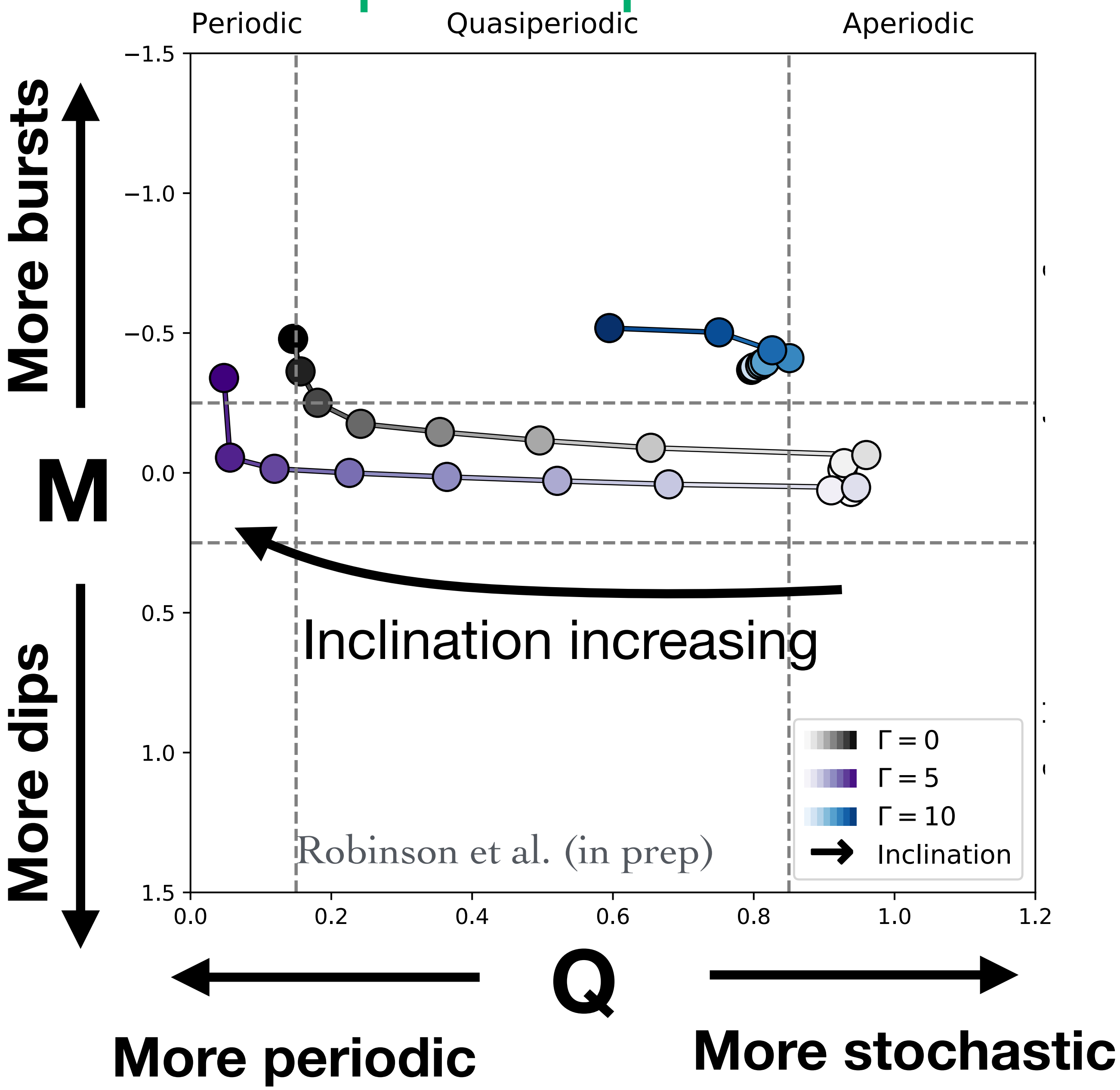
$A = 0.1$

These parameters, along with the stellar mass, have the largest effect on our synthetic light curves

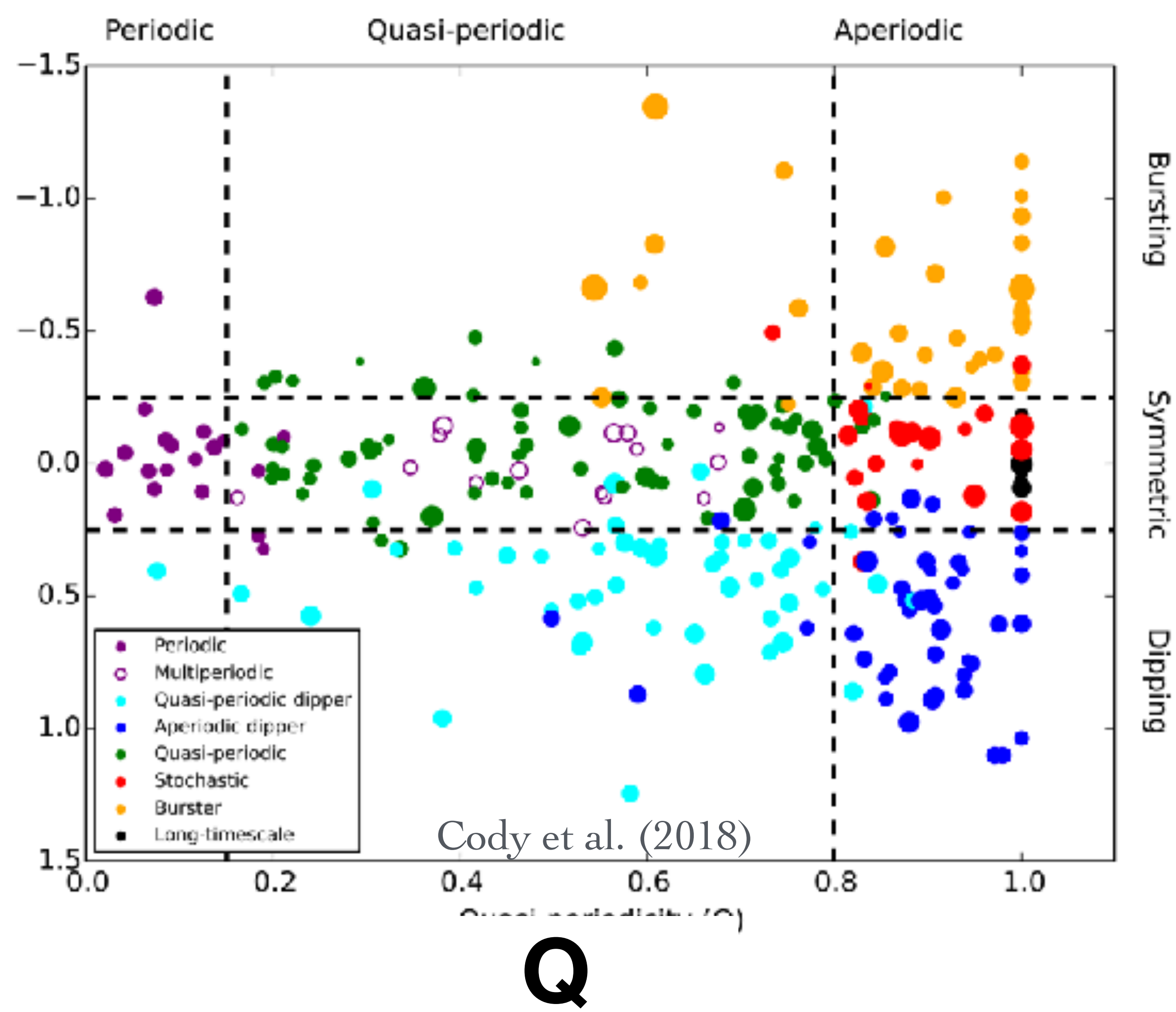
# Work in progress: Comparisons against observation using classification metrics

## Simulations

Octupole/Dipole ratio



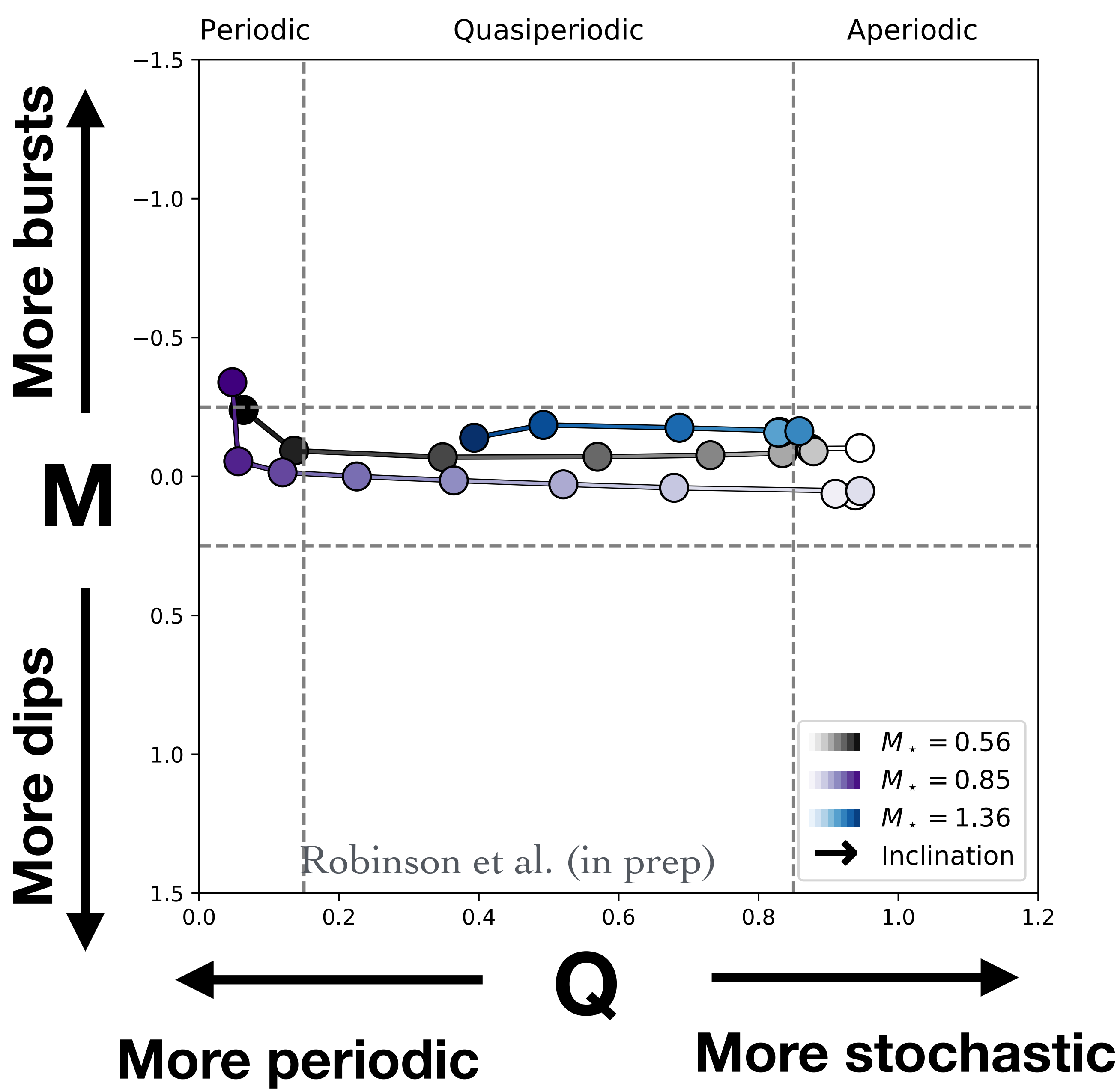

## K2 observations



# Work in progress: Comparisons against observation using classification metrics

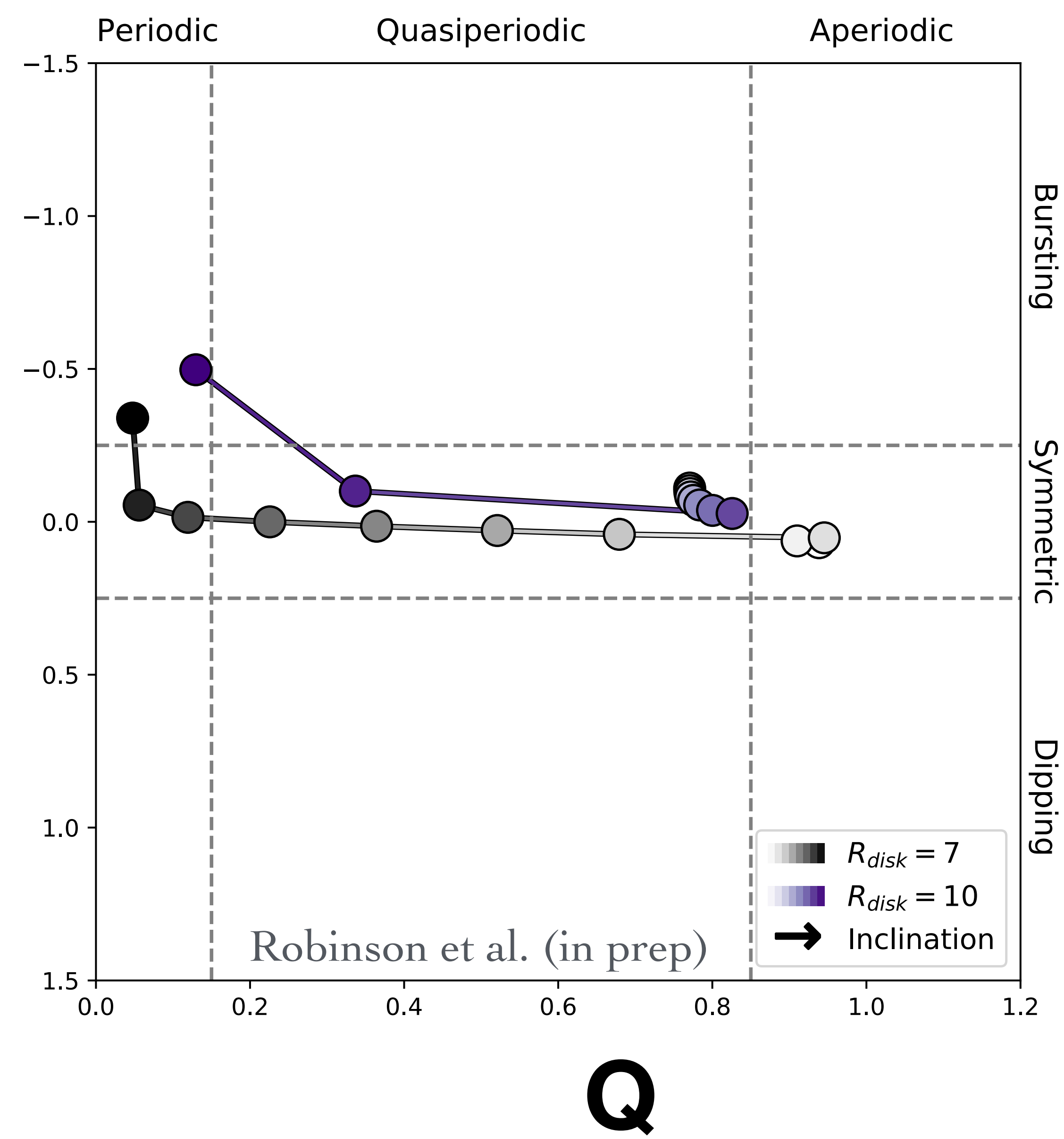
**Simulations**

Stellar mass




**Simulations**

Inner disk radius



# Characterizing Accretion Variability with HST and Simulations

## How does accretion vary?

Typical changes in the mass accretion rate are factors of ~2x with 1 week cadences

We caught an accretion burst (GM Aur) which showed an increase of a factor of ~4x in the accretion rate and ~10x in the NUV flux

Our observations of VW Cha suggest the presence of dust near the truncation radius

## What causes different types of accretion variability?

Magnetic field geometry, inclination, turbulence, and stellar parameters have an effect on variability class.

Work is underway to reproduce observed distribution of variability classes.