The accretion zone in very low mass objects: Insights from spectrophotometric monitoring

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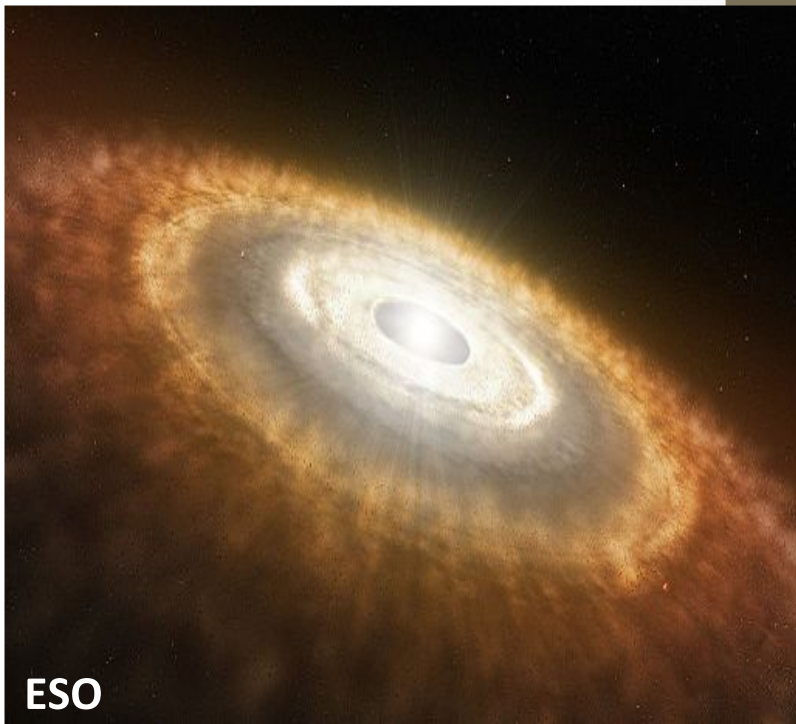
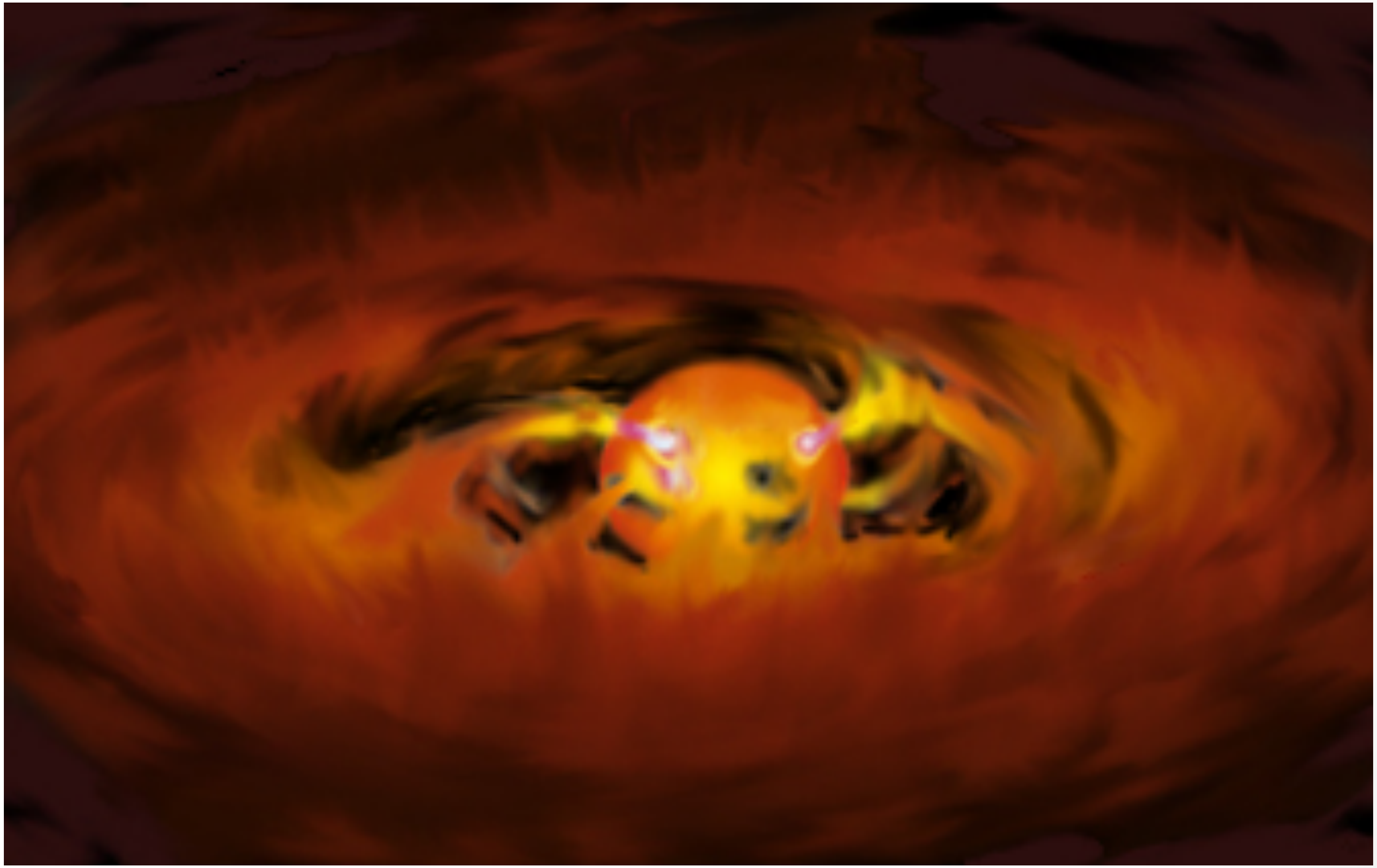


ESA/ESTEC, 27-29 OCTOBER 2015

Sources of variability

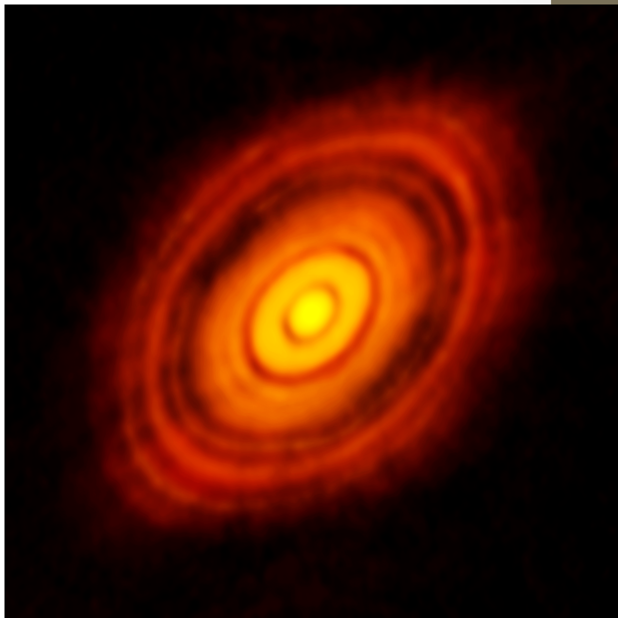


http://pixgood.com/t-tauri-star.html

Motivation

- How do young stars vary and why?

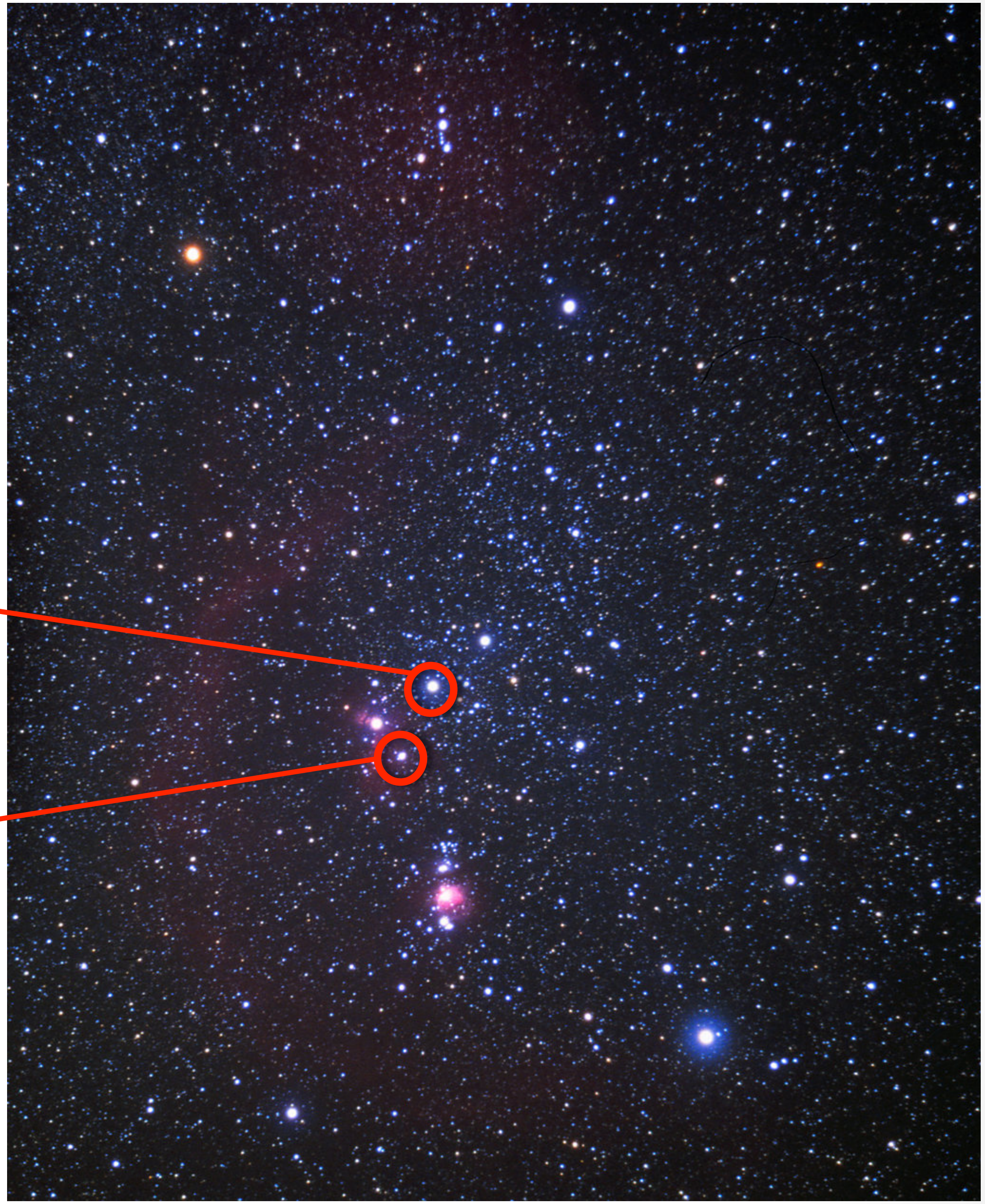
- Why not use interferometry?
  - Works well with bright systems that are easy to resolve – most stars are not


ALMA (ESO/NAOJ/NRAO)

- Time – domain observations are capable of tracing spatial information for less massive, dim objects

Targets

Low mass: < 0.4 Msol
Highly variable:
0.1 - 1.0 mag



Epsilon Ori – 4 stars

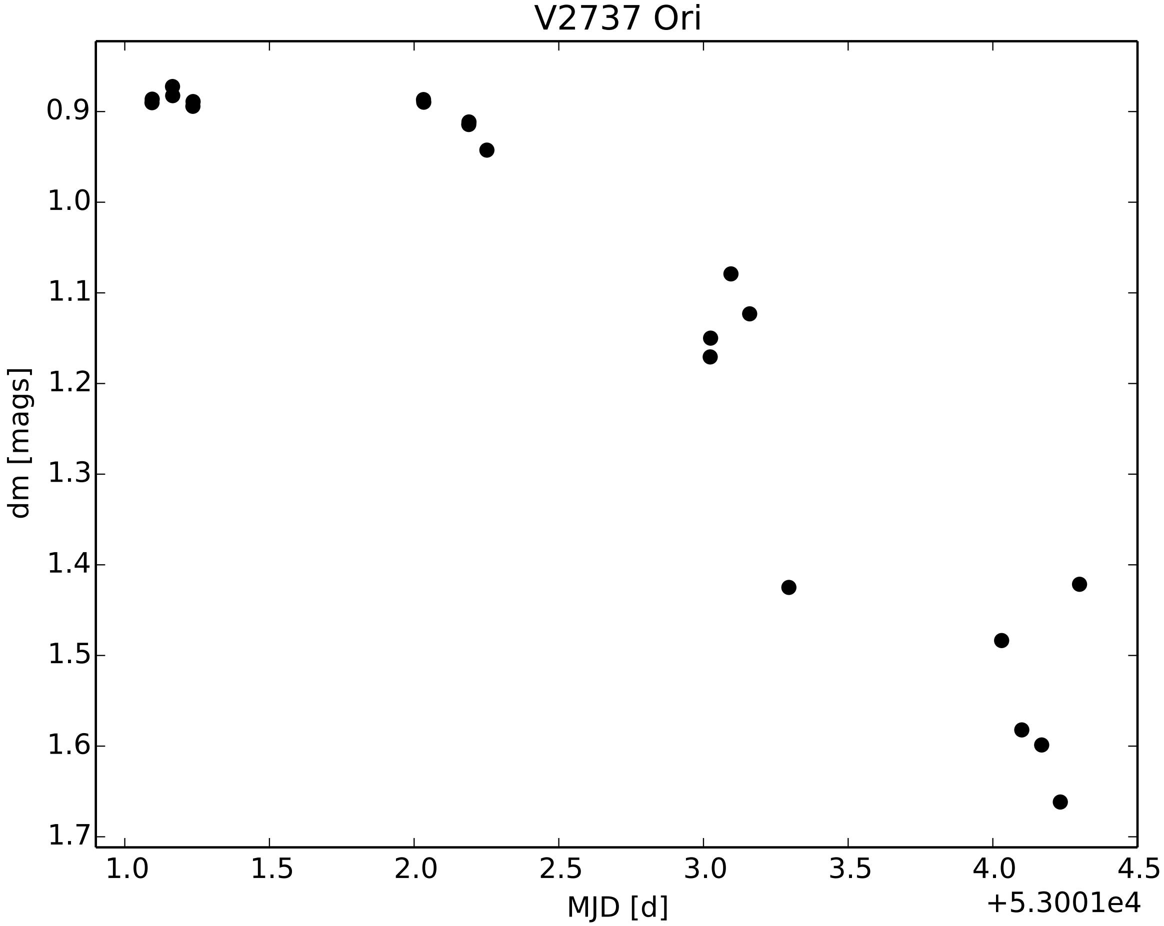
Sigma Ori – 3 stars

Observations

- ESO - VLT/FORS2 instrument on the 8.2 m UT1 (Antu) telescope
- Simultaneous photometry and spectroscopy in the I-band
- 4 consecutive nights, 28-31 Dec 2003
- Total of 150 images and 115 extracted spectra

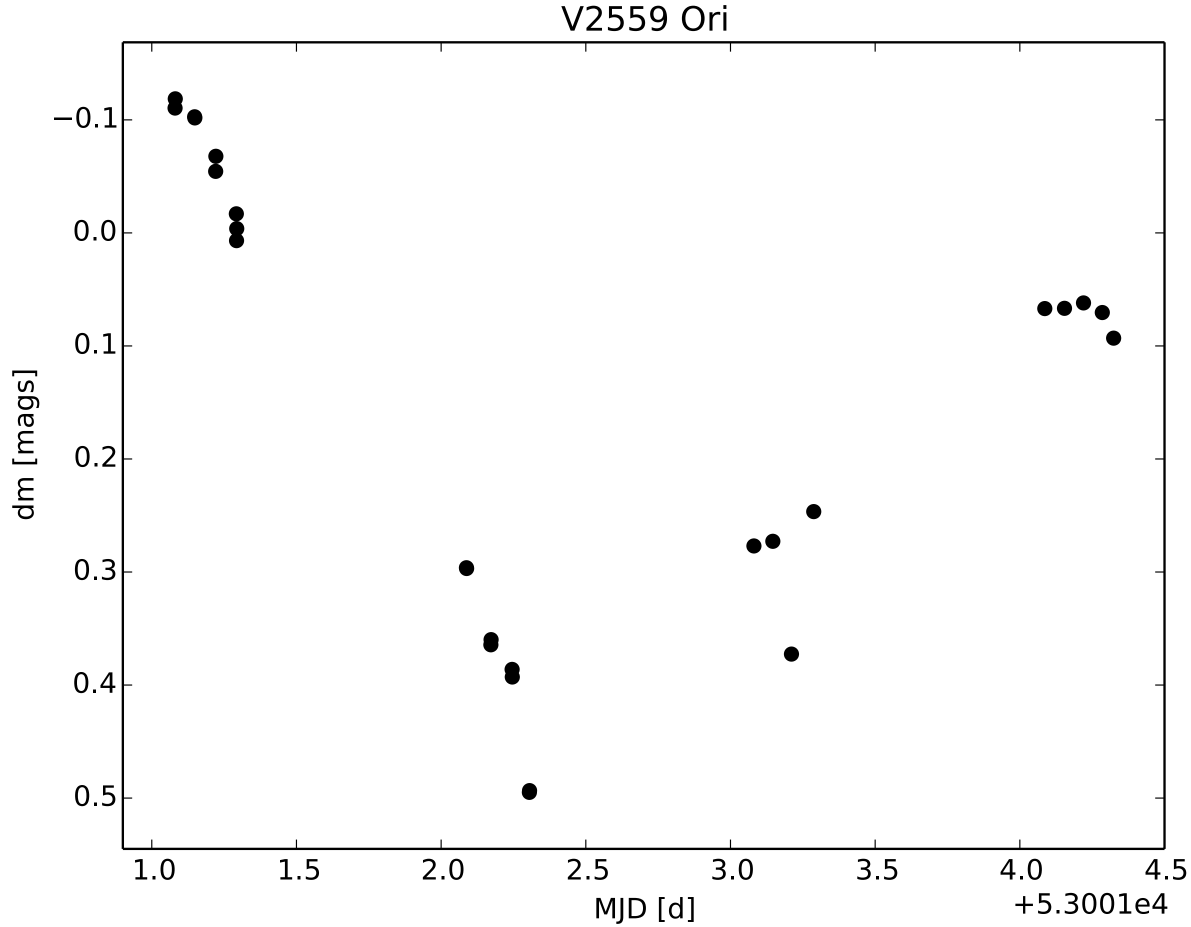
ESO

Sigma Ori – V2737



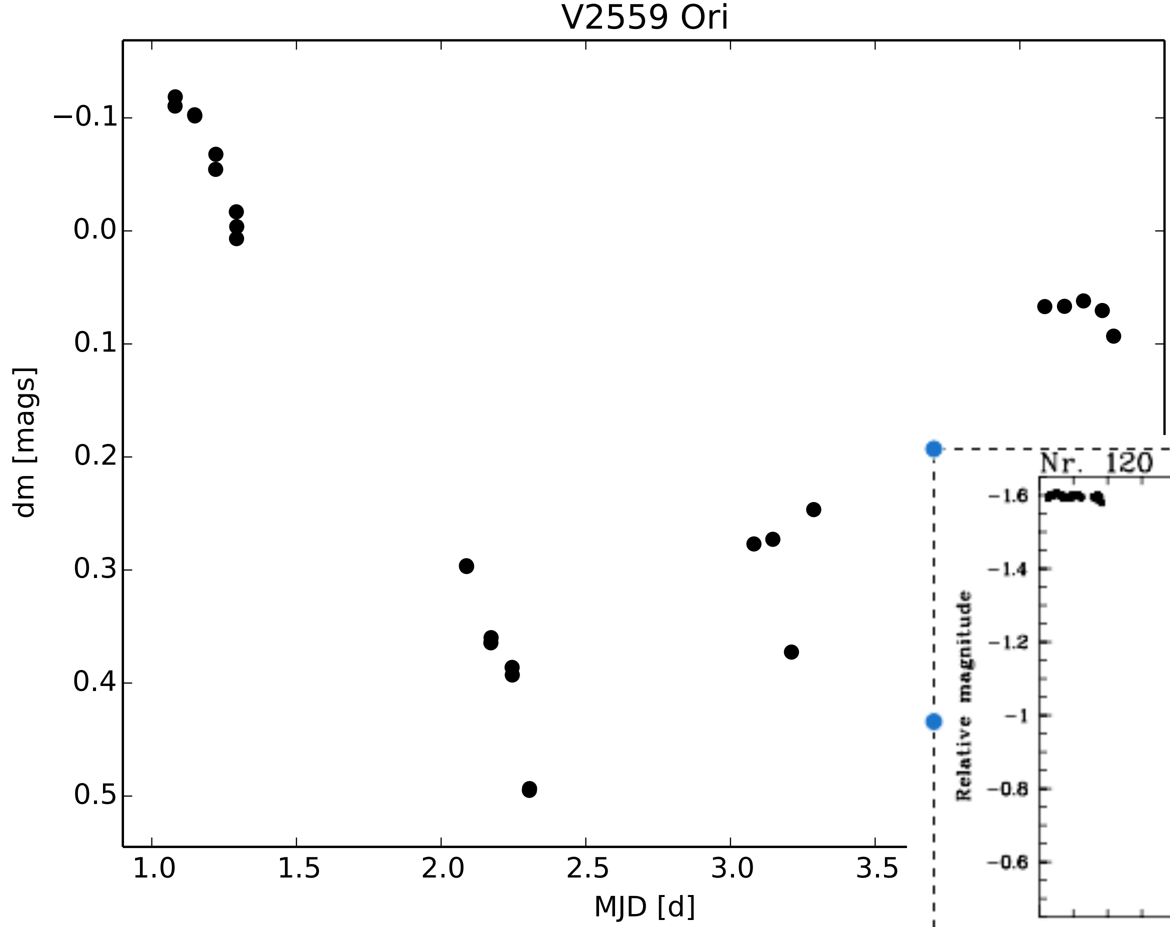
Amplitude: 0.79 mag

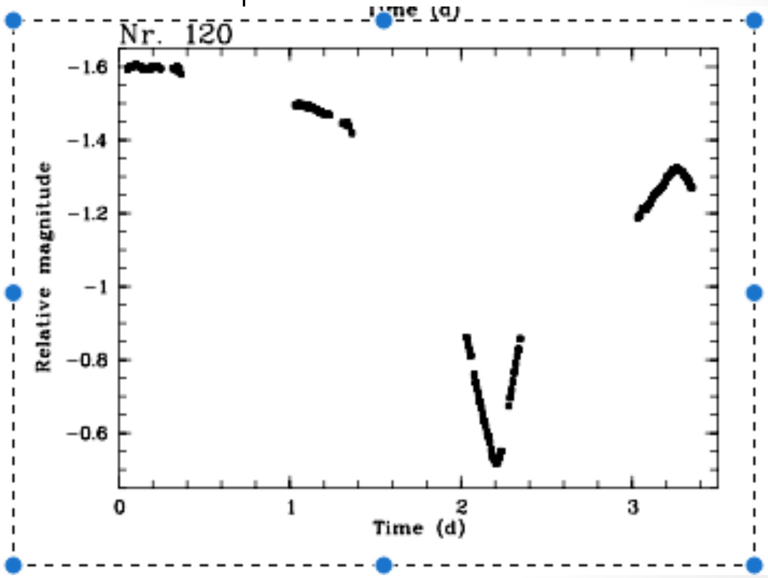
Epsilon Ori – V2559



Amplitude: 0.61 mag

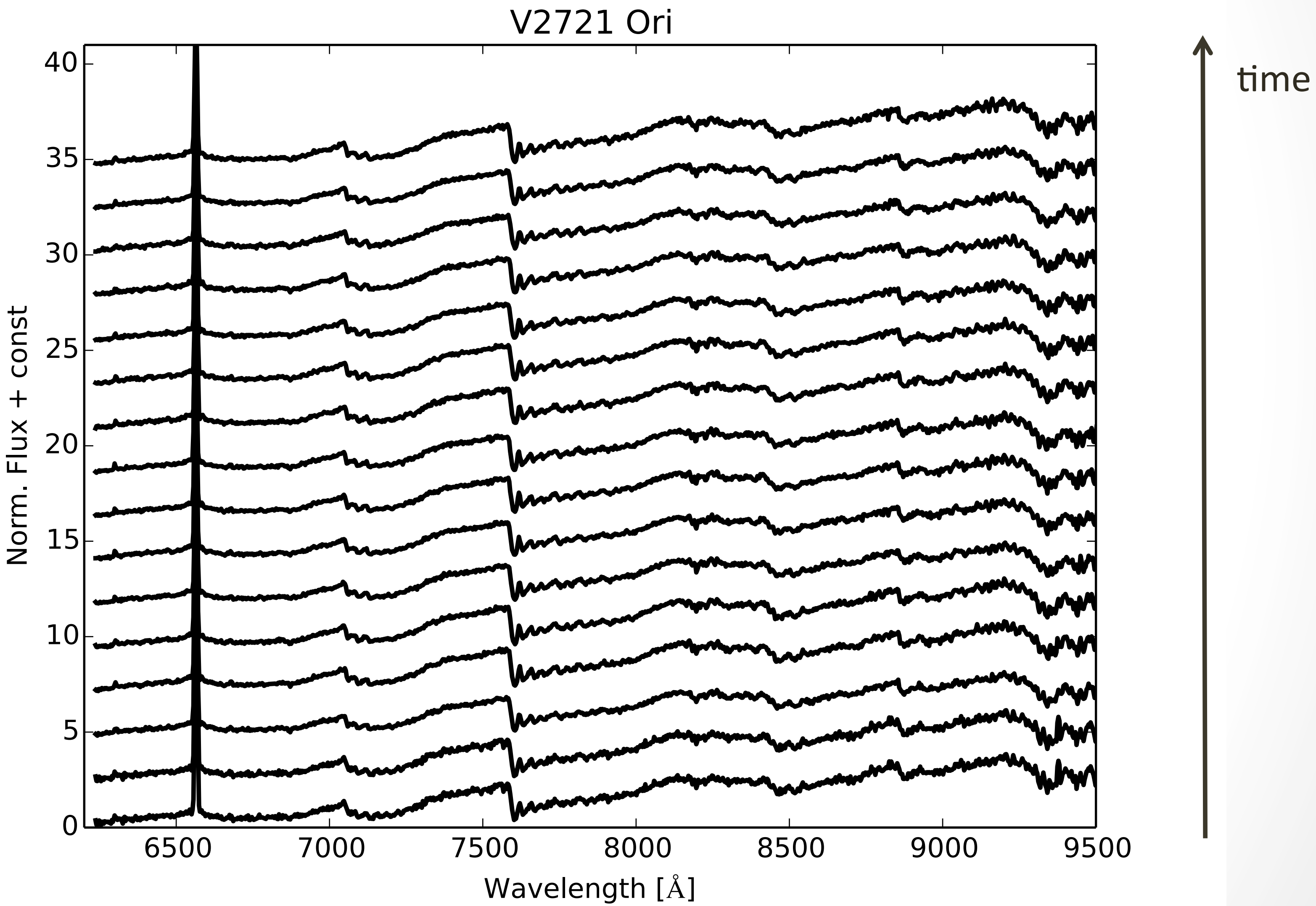
Epsilon Ori – V2559



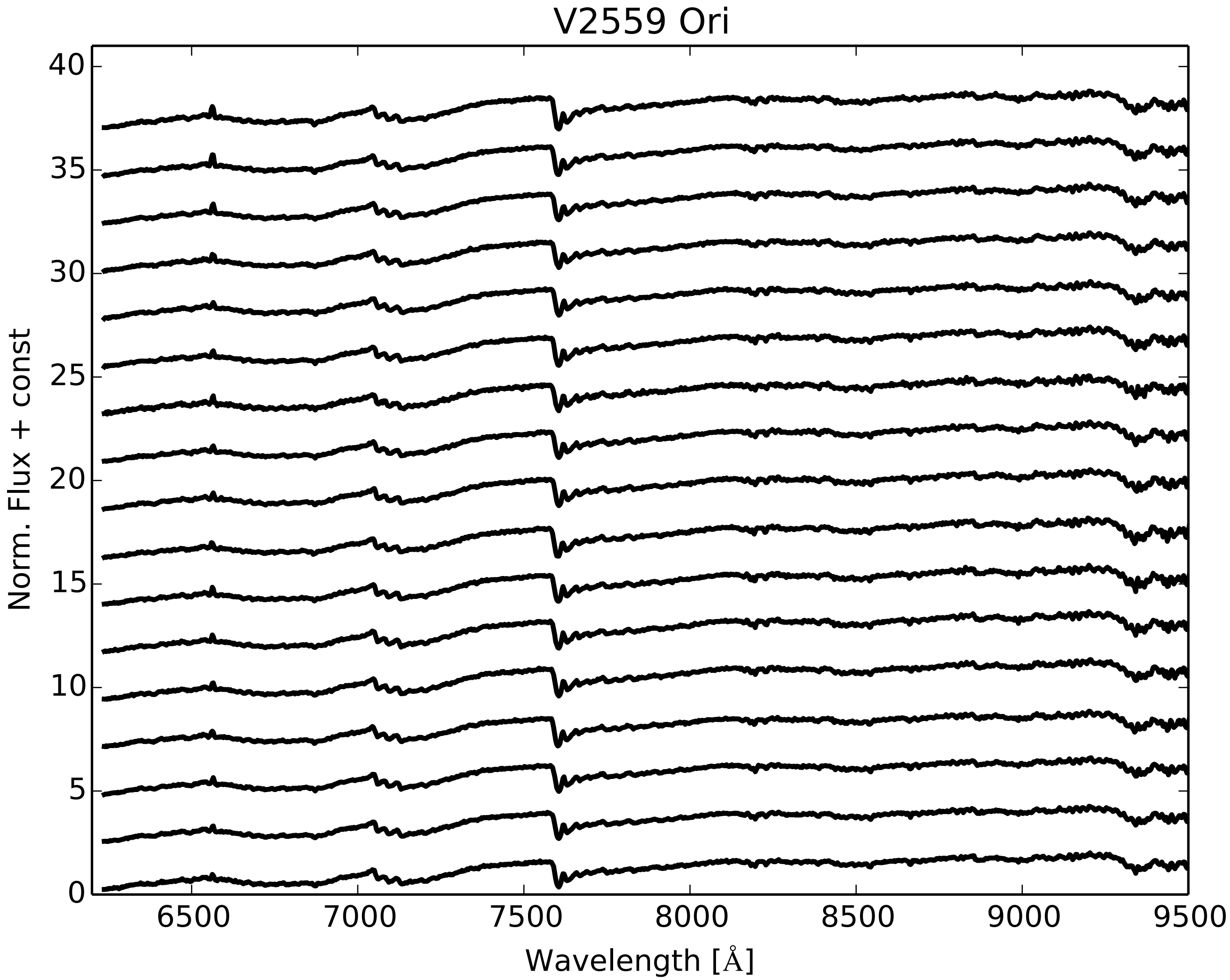


Amplitude: 0.61 mag

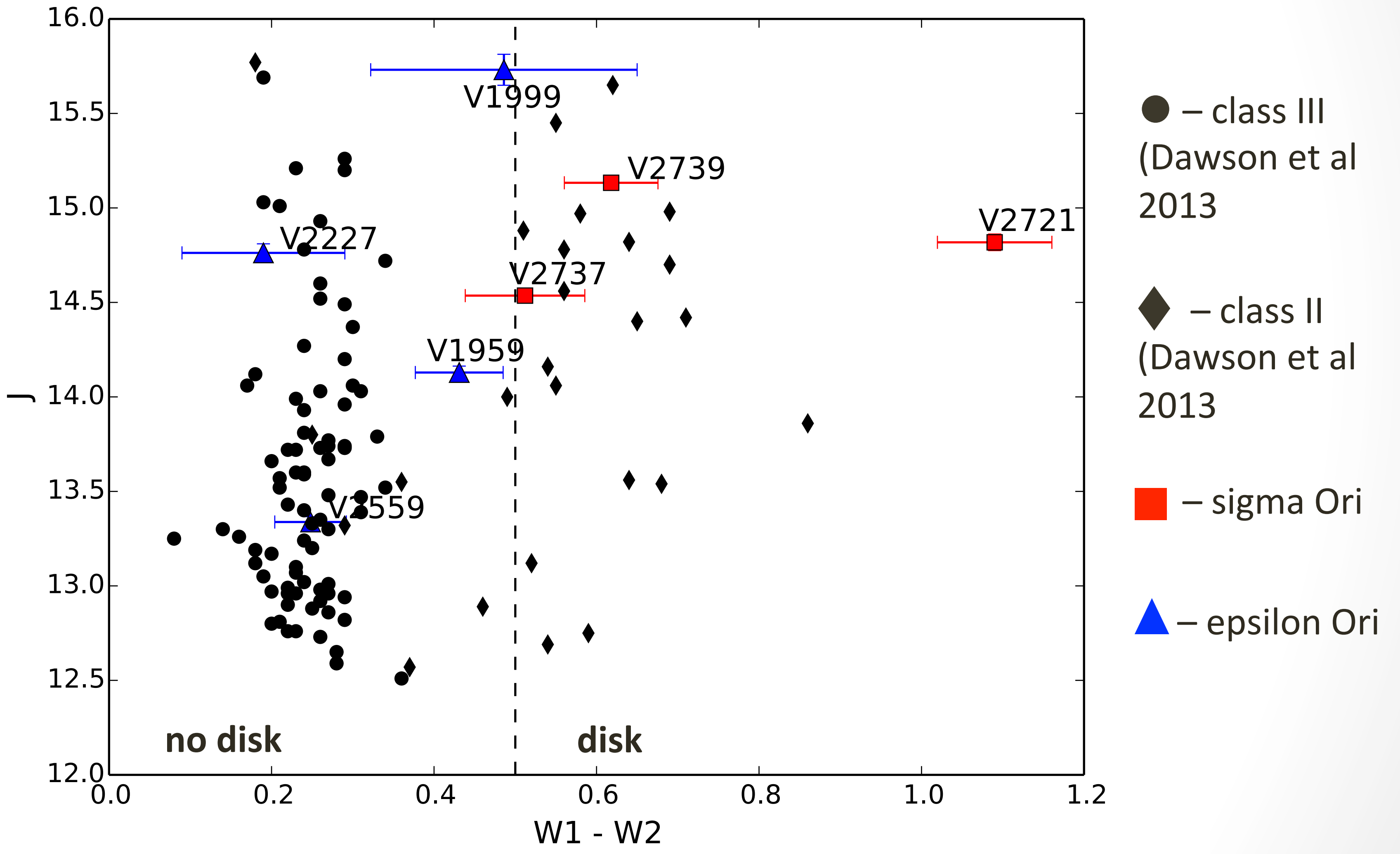
Sigma Ori – V2721



Epsilon Ori – V2559



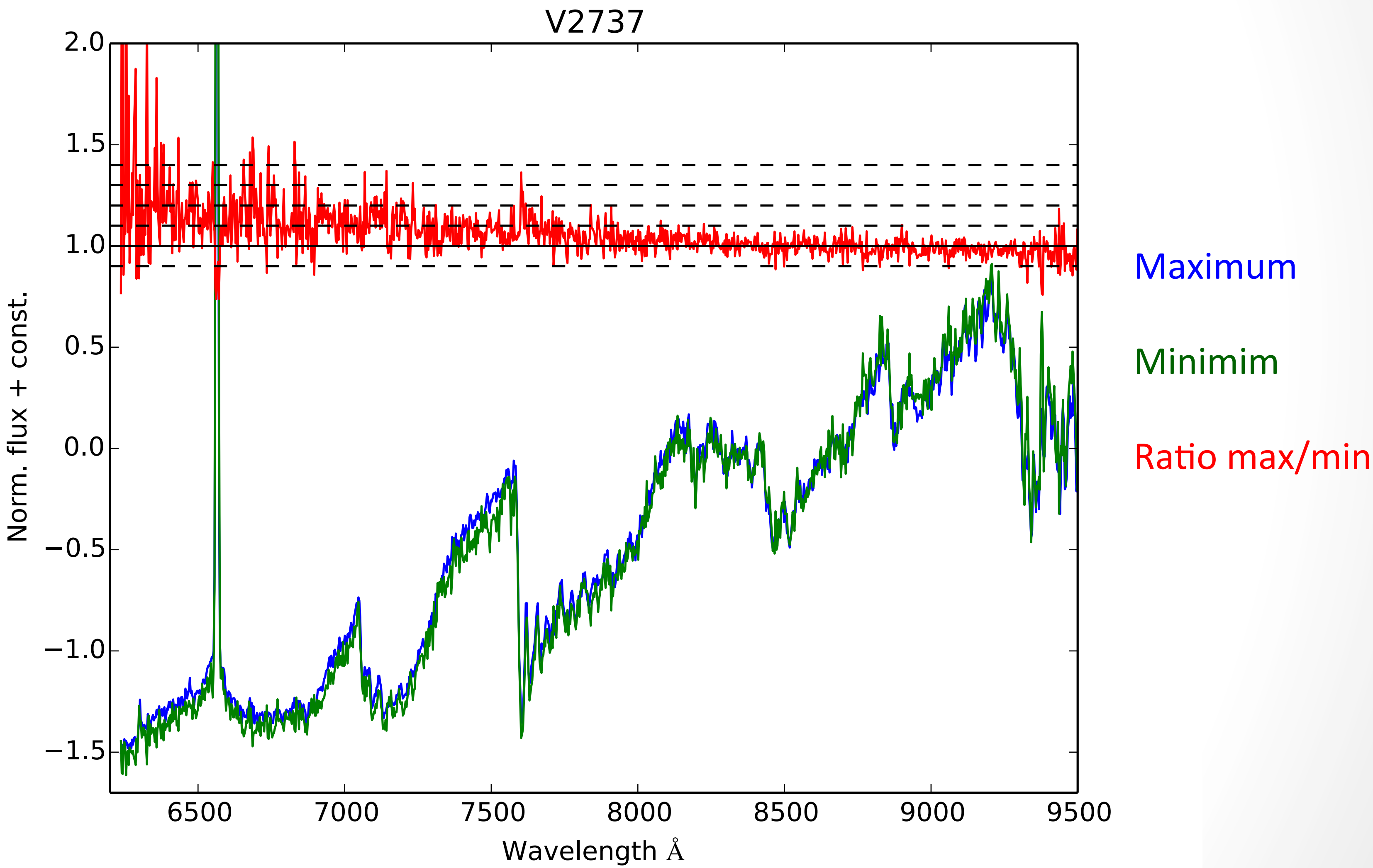
Class II or Class III ?



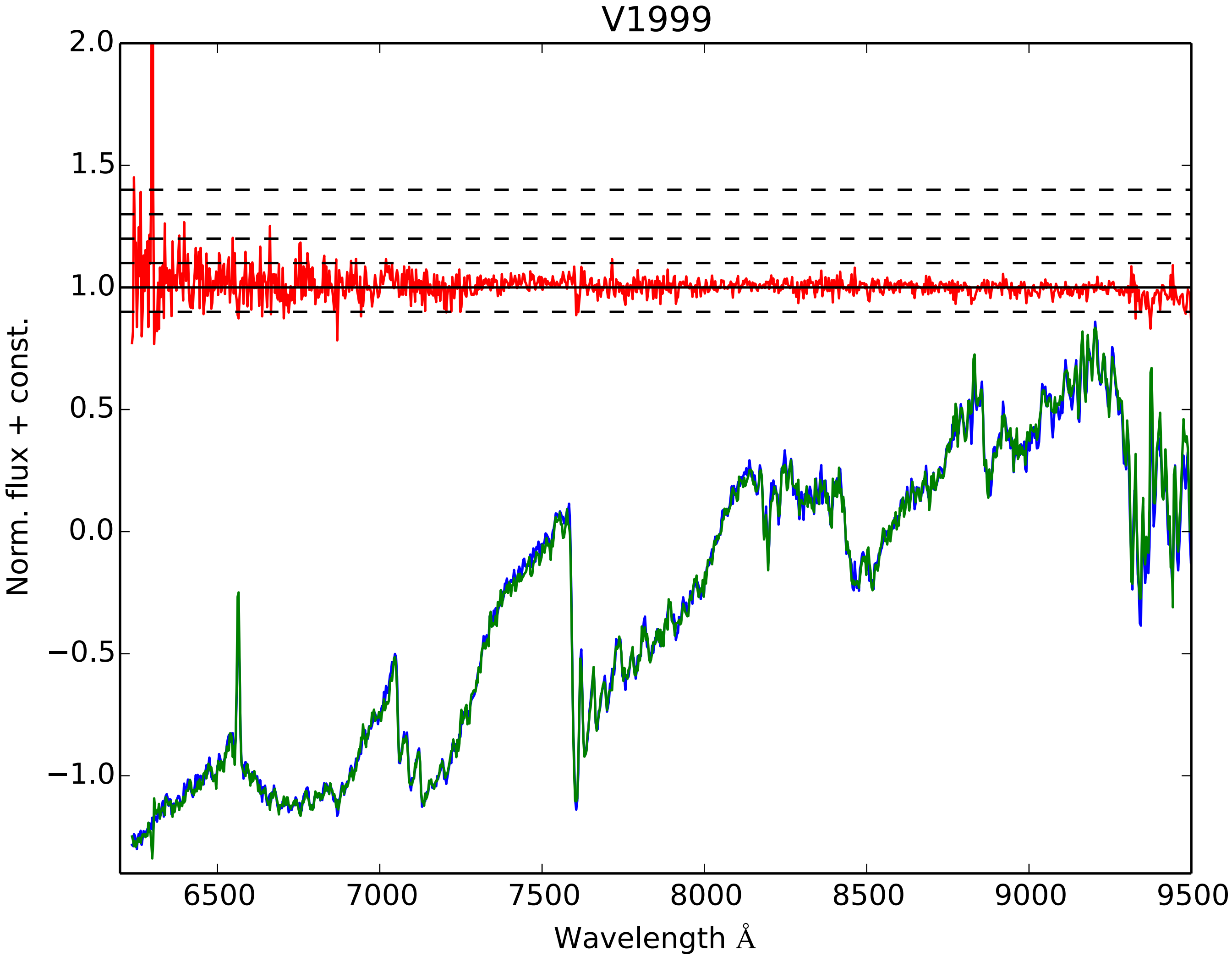
How do the spectra change?

- Visual examination – no significant difference
- Apply spectral classification using the PC3 index from Matrin et al. 1999
  - All targets have spectral type between M3-M5
  - Spectral type does not change by more 0.5 subtypes
- Compare the spectra corresponding to maximum and minimum in the lightcurve to look for colour changes?

Sigma Ori – V2737



Epsilon Ori – V1999



Possible explanations?

- Hot spots – material from disk accretes onto the star, causing a hot spot on the stellar surface

$$A = -2.5\log\left(\frac{F\_star}{f * F\_spot + (1-f) * F\_star}\right)$$

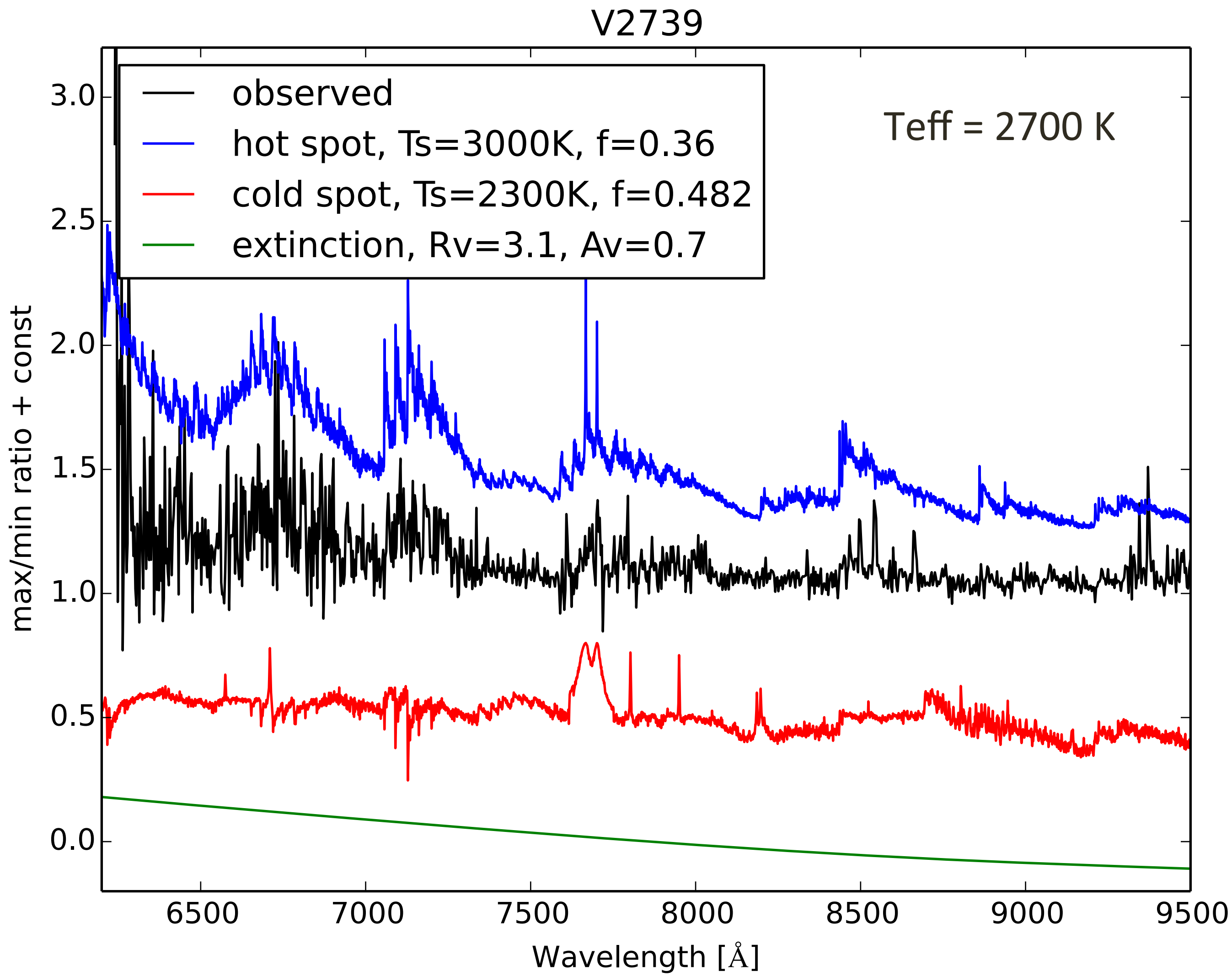
- Cold spots – produced by stellar magnetic activity

- Variable extinction – inhomogeneity in the disk, causing variable extinction along the line of sight

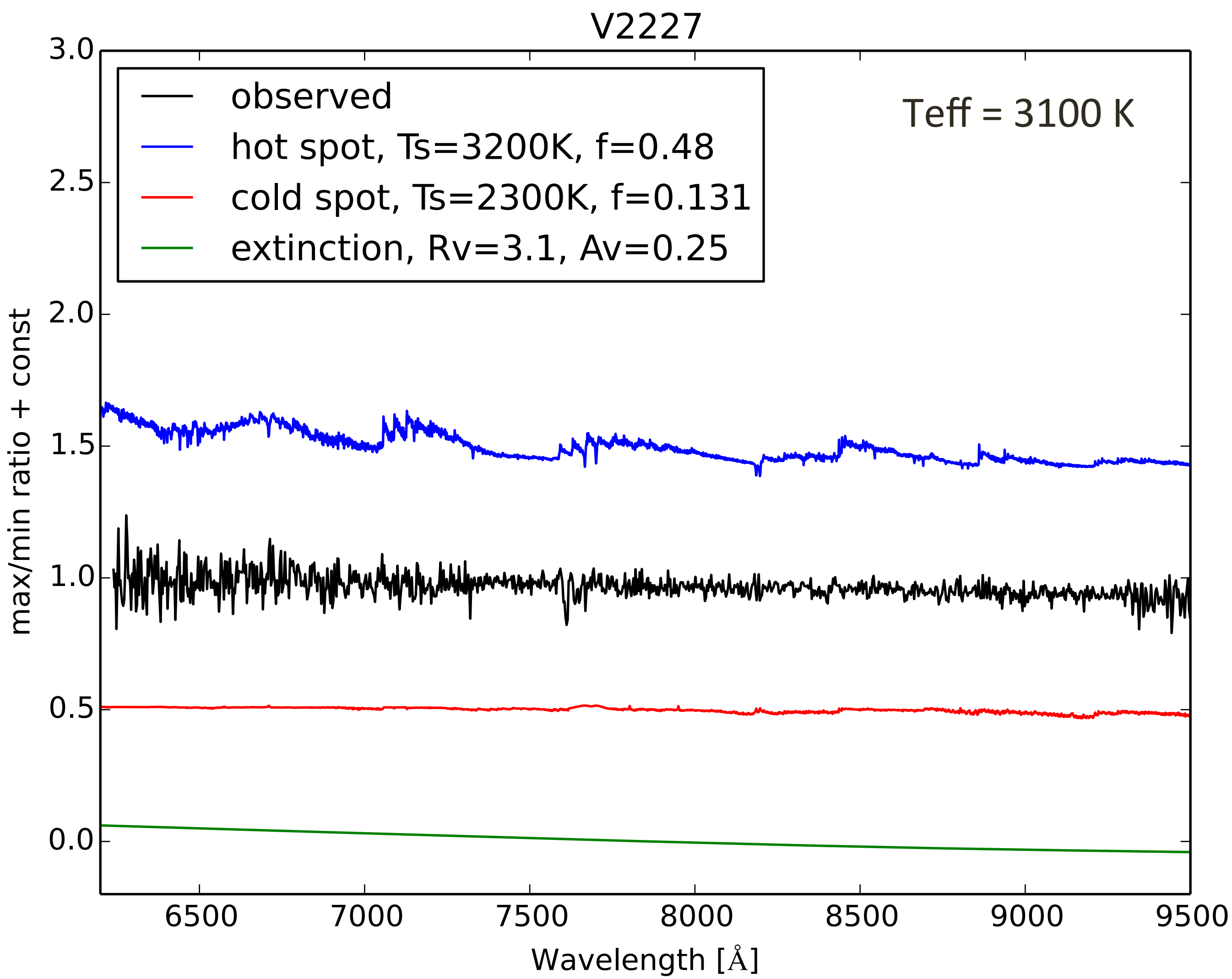
    - Interstellar extinction law (Cardelli et al 1989):

      $A_\lambda / A_V =$ a + b/R_V , where a and b are functions of wavelength

Results


V2739
observed
hot spot, Ts=3000K, f=0.36
cold spot, Ts=2300K, f=0.482
extinction, Rv=3.1, Av=0.7
Teff = 2700 K
max/min ratio + const
Wavelength [Å]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
6500
7000
7500
8000
8500
9000
9500

Results

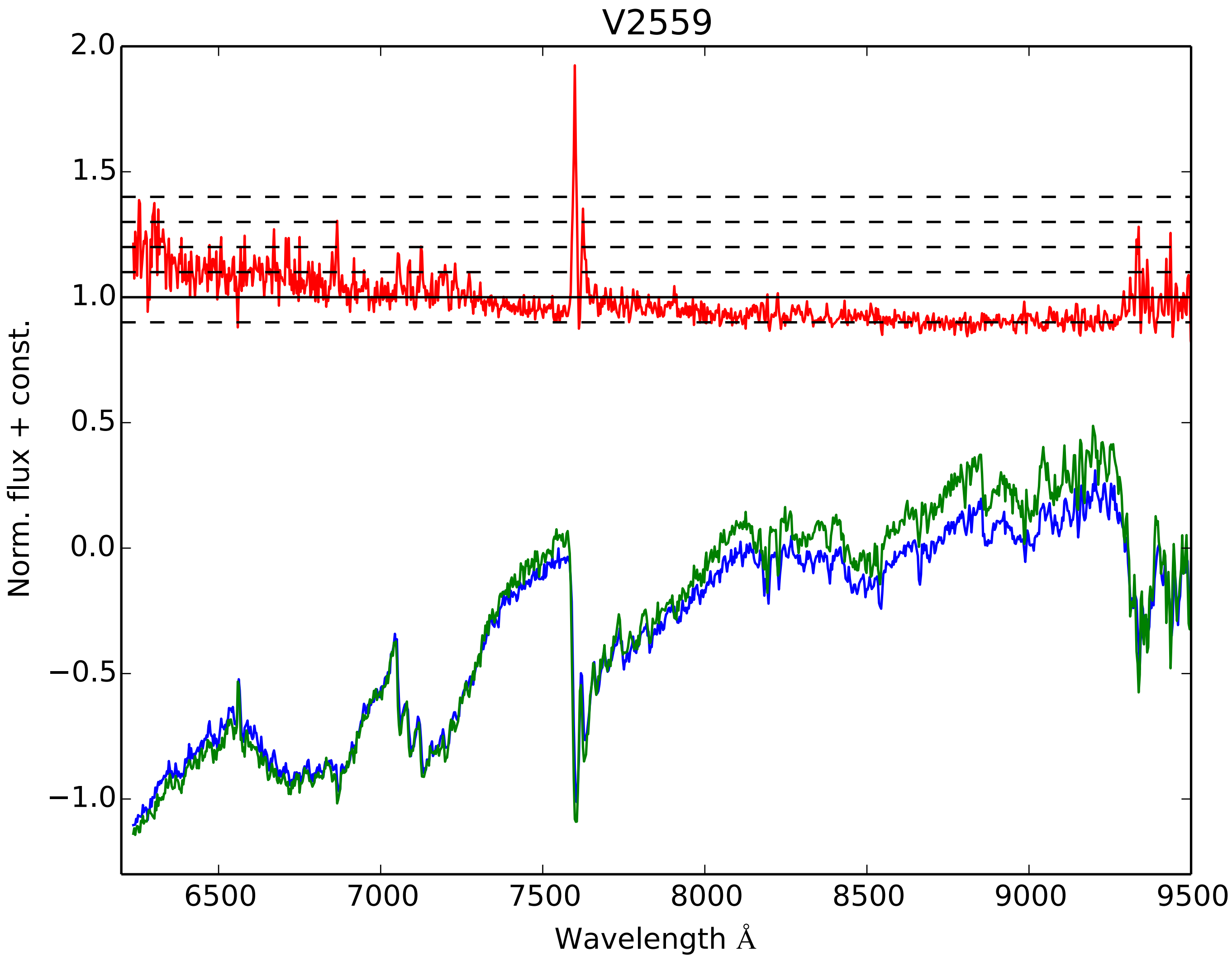

V2227
observed
hot spot, Ts=3200K, f=0.48
cold spot, Ts=2300K, f=0.131
extinction, Rv=3.1, Av=0.25
Teff = 3100 K
max/min ratio + const
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6500
7000
7500
8000
8500
9000
9500
Wavelength [Å]

What did we learn?

- High level photometric variability, similar to higher mass T Tau stars
- Bluer when brighter, redder when dimmer
- Hot spot temperature close to photosphere, large filling factors
- Stars with no evidence for disks or accretion still show high photometric variability

Side note:
Epsilon Ori objects similar to KIC 8462852…….aliens?

Epsilon Ori – V2559



Hα equivalent width (EW)

$$EW = \sum \left(\frac{F\_line}{F\_cont} - 1 \right) d\lambda$$

For ongoing accretion: Hα EW > 25 A
(Barrado y Navascue´s & Martin 2003)

Target	Average Hα EW [A]
V2737	30.83
V2721	97.10
V2739	95.73
V2227	5.92
V1999	13.62
V1959	12.35
V2559	3.01