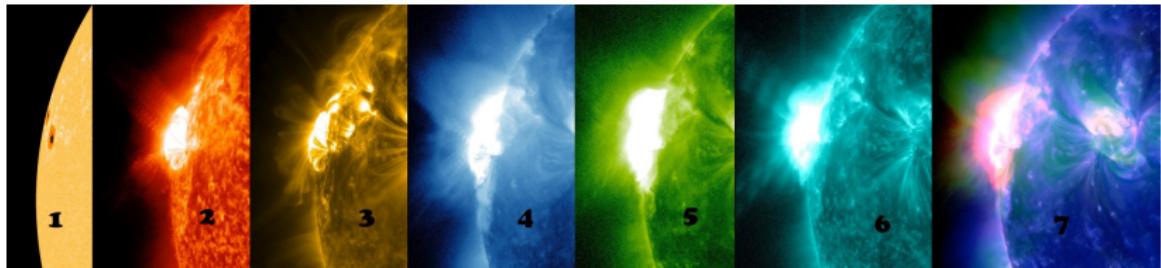


Investigating the origin of flares in A-type stars



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Conny Aerts

KU LEUVEN

Flares are

- Large explosions in stellar atmospheres
- Magnetic reconnection
- Colliding, turbulent stellar winds

Requirements

- Convective envelopes
- Large scale magnetic fields, or
- Radiatively driven winds



Credit: NASA/SDO

Motivation

What about A-type stars?

Normal A-type stars

- Shallow convective envelopes
 - Weak, large scale magnetic fields
 - Weak stellar winds
- > 1.5 solar masses



Balona (2012 & 2013)

- 33 flaring A-type stars
- Q0-Q6/Q12

Credit: Adapted from www.sun.org

Possible explanations

- Spectral classification is wrong
- Cool companion
- Circumstellar material/infalling bodies
- Instrumental
- Contamination

Flare sample:

- All 33 stars

Data:

- All Q0-Q17 *Kepler* LC lightcurves
- Spectra of 22 stars, 16 w. > 1 epoch
- Pixel data

Flare detection

Criteria and photometric equivalent width

Walkowics et al. 2011

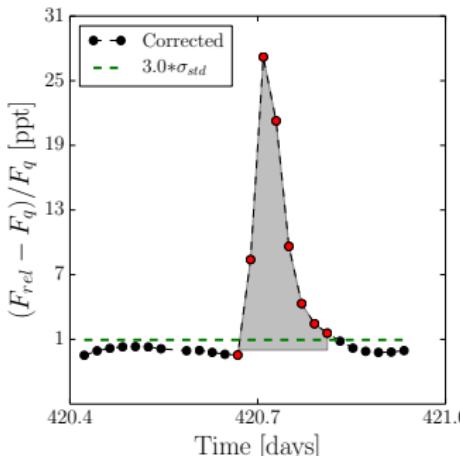
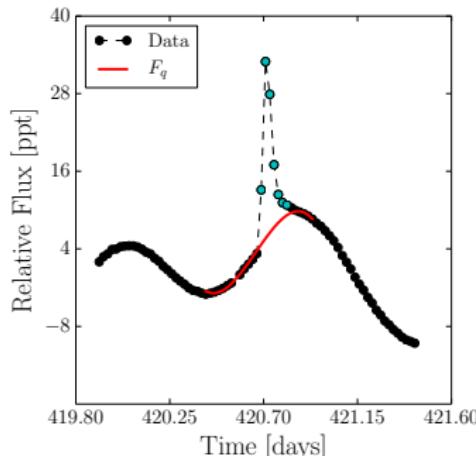
Detection criteria:

- ① ≥ 3 data points w. exp. decay above $3\sigma_{std}$
- ② Duration < 10 h
- ③ Fully resolved in SC

$$EW_{\text{phot}} = \int \frac{F_{\text{rel}} - F_q}{F_q} dt$$

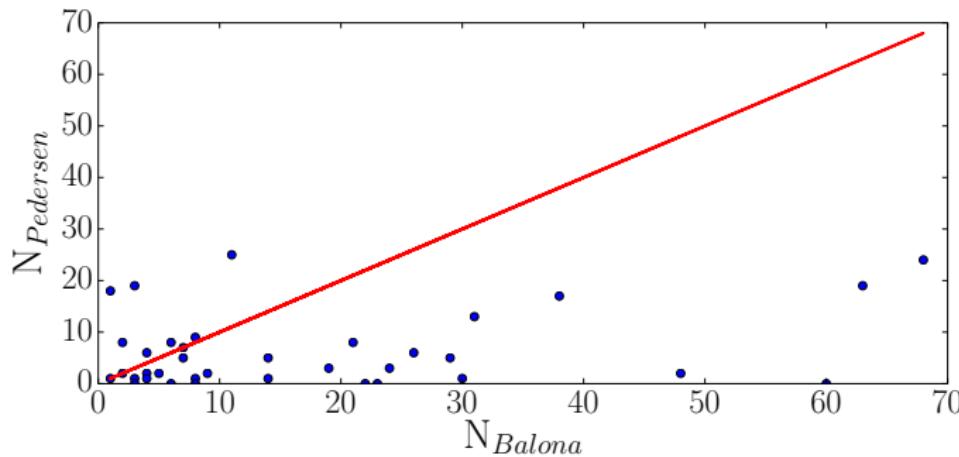
F_{rel} : Flux of the flare lightcurve

F_q : Quiescent flux



Number of detected flares:

- $N_{\text{Pedersen}} < N_{\text{Balona}}$: 23 stars (6 w. 0 flares)
- $N_{\text{Pedersen}} > N_{\text{Balona}}$: 7 stars
- $N_{\text{Pedersen}} = N_{\text{Balona}}$: 3 star



Spectroscopy

The Fibre-fed Echelle Spectrograph (FIES) spectra

The Nordic Optical Telescope

$$R = 25000 - 46000$$

Spectra of 22 stars:

- 1 epoch: **6 stars**
- 2 epochs: **3 stars**
- 3 epochs: **13 stars**

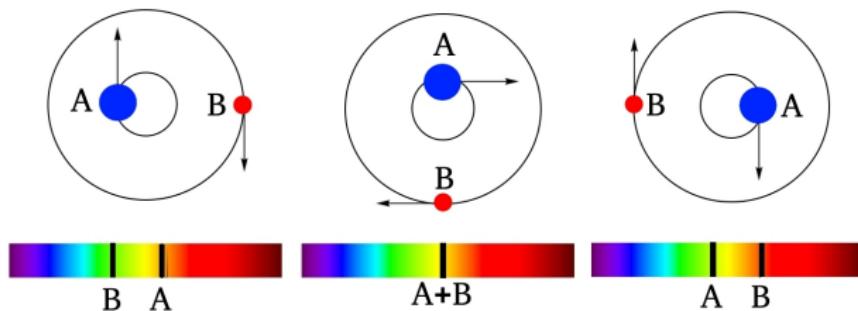
Confirm: All within activity quiet range (B9-A8)

No Ap/Bp stars



Spectroscopy

Radial Velocities



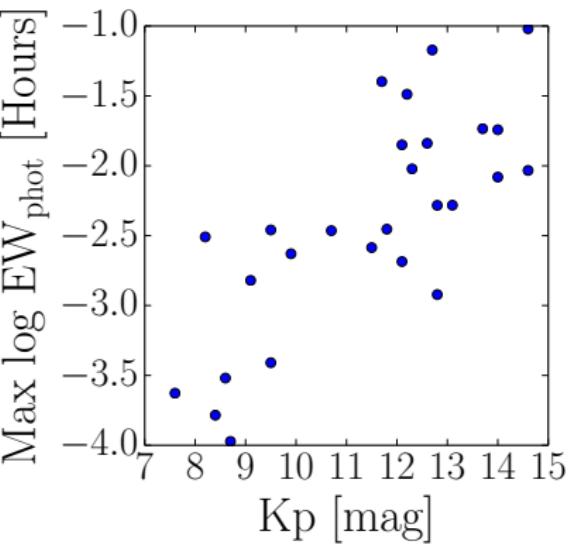
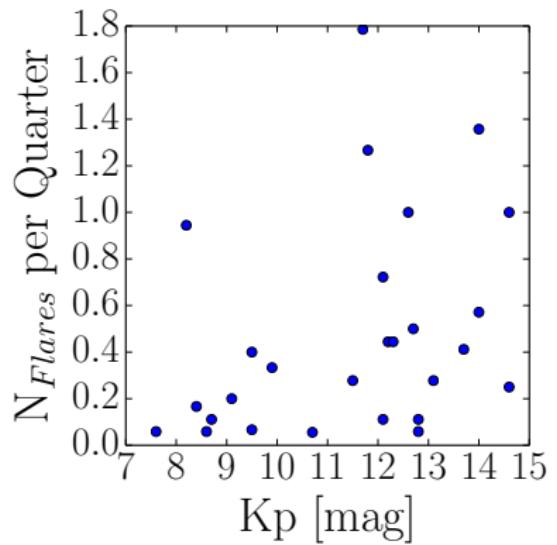
≥ 2 RV measurements for 18 stars

11 SB1 binaries

5 single stars

2 unknown

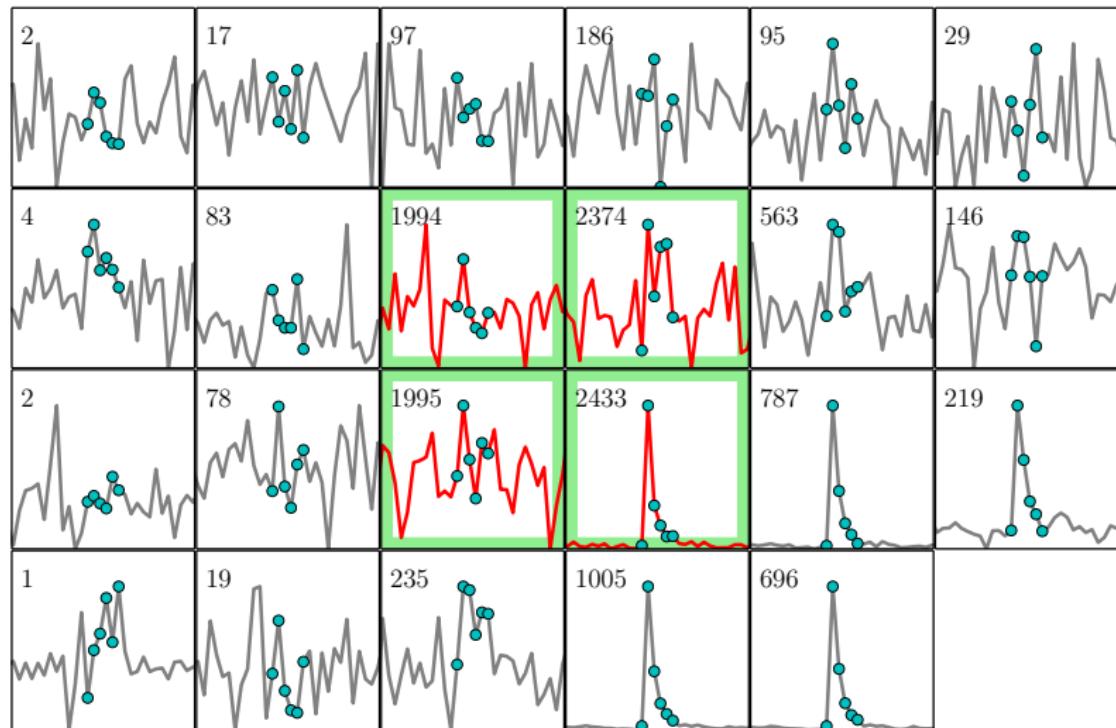
Contamination?



Contamination?

Contamination example

5 stars

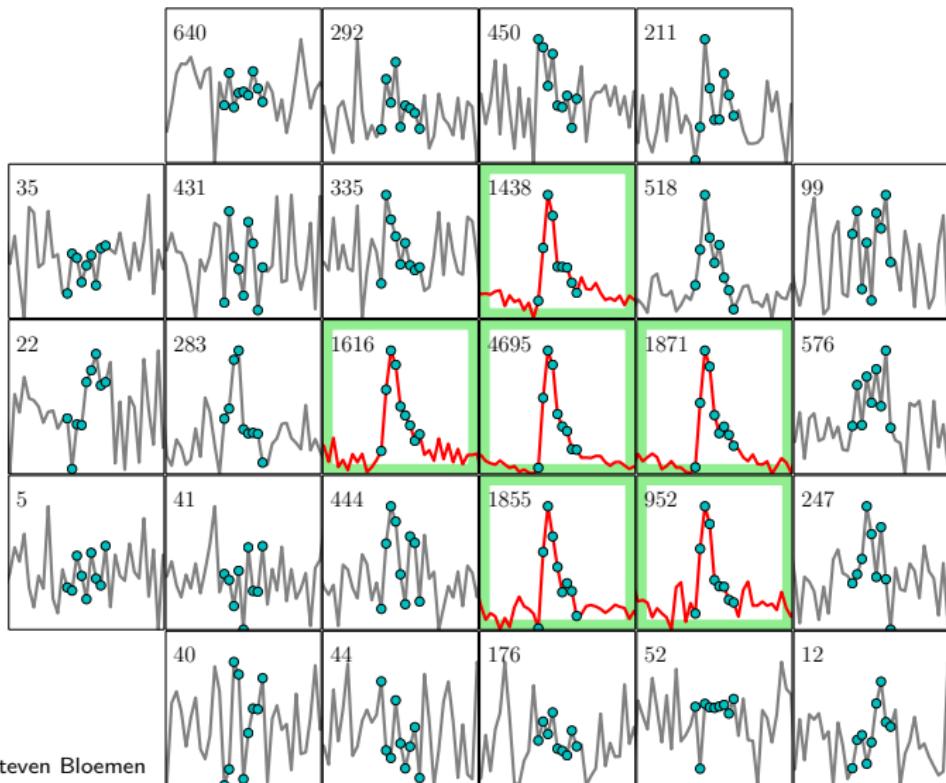


Inspiration from Steven Bloemen

Contamination?

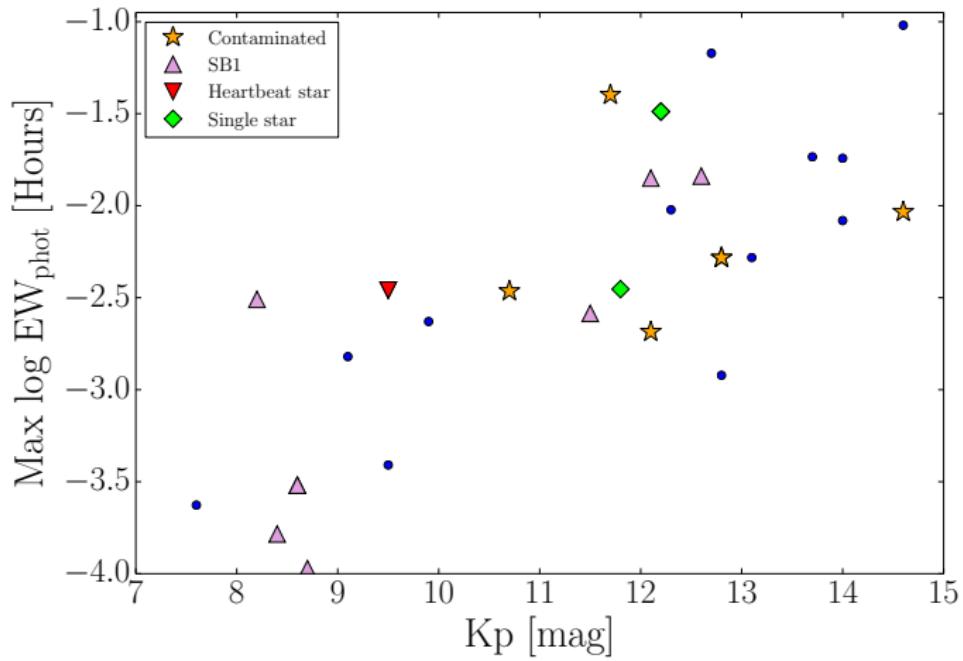
Non-contamination example

14 stars



Inspiration from Steven Bloemen

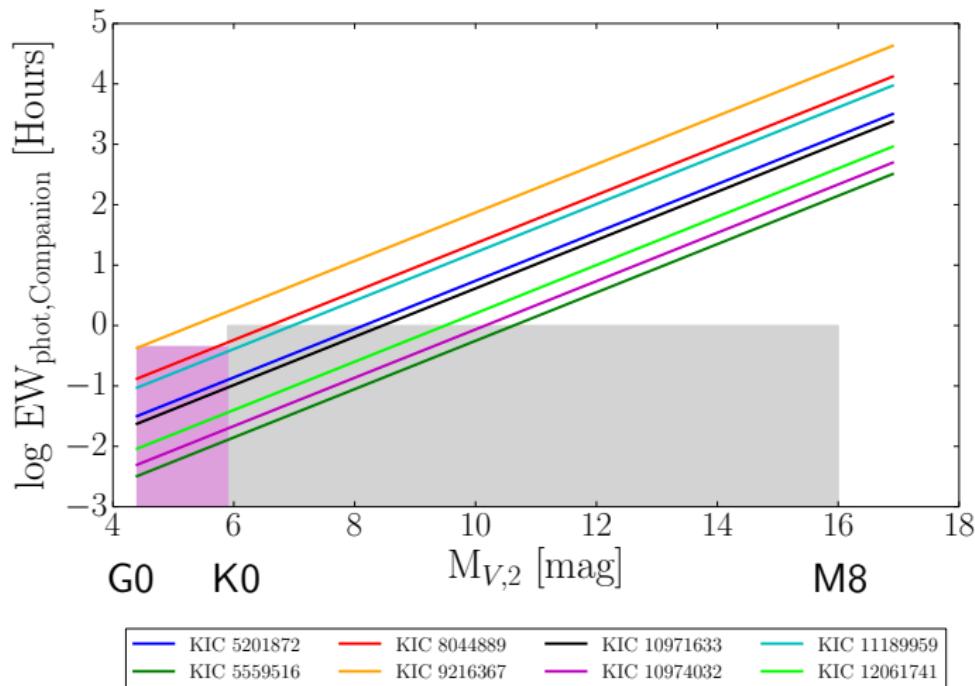
Results



Cool companion?

Gray box: Maximum of median EW_{phot} of KM-dwarfs (Walkowics et al. 2011)

Purple box: Max EW_{phot} of G-type superflare star KIC 9603367 (Shibayama et al. 2013)



Flares are detected (large discrepancies)

Within the activity quiet spectral range, no Ap/Bp stars!

Starting out with:

33

0 flare stars \Rightarrow 27

Binaries \Rightarrow 19

Contamination \Rightarrow 14

Cool companion origin possible

**Note! Not yet even a single example of a truly intrinsically
flaring, normal A-type star**

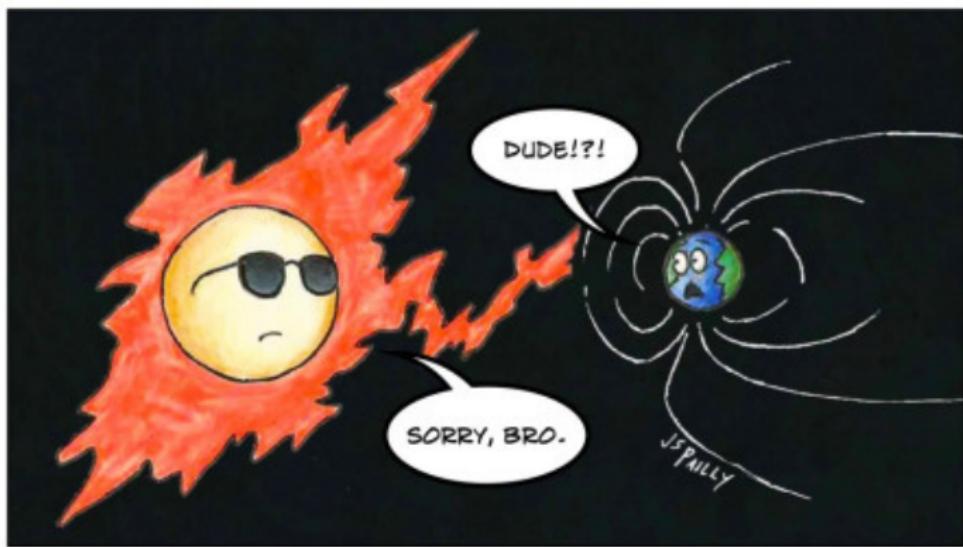
Further pixel analysis

Need additional spectra (4 stars)

UV spectra from Swift for 3 stars

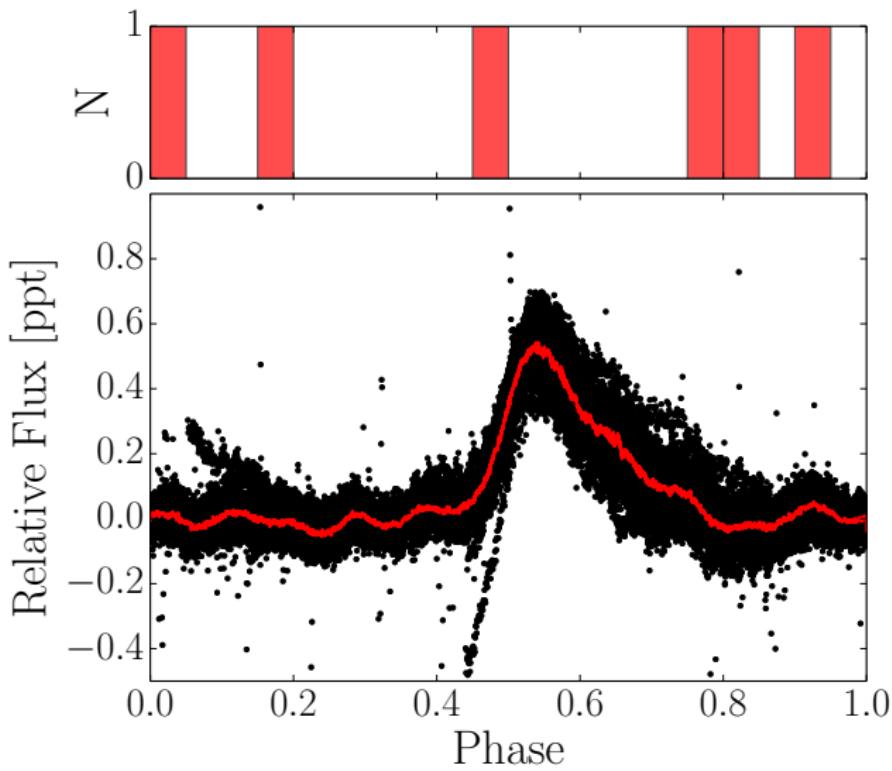
Investigate possible circumstellar origin

Thanks for your attention!



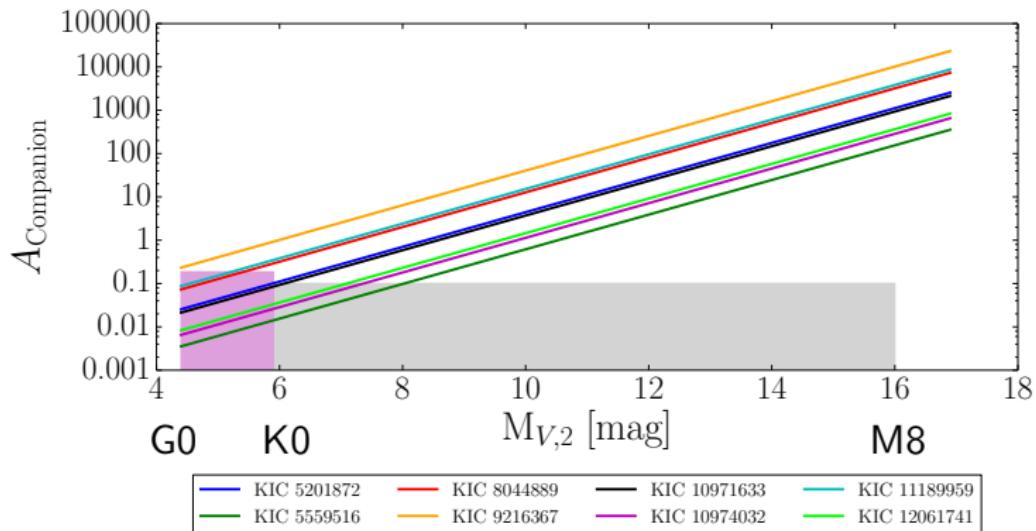
Extra slides

Heartbeat star



Extra slides

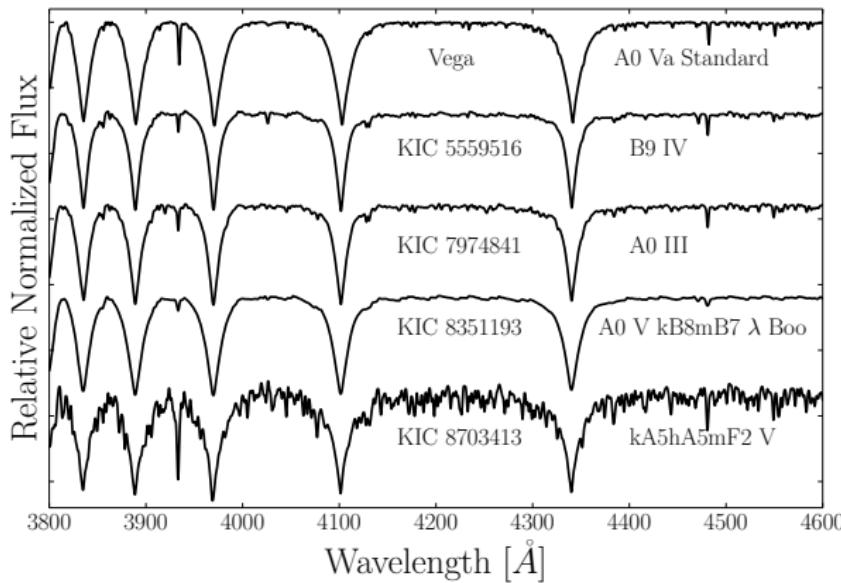
Cool companion?



The Morgan-Keenan (MK) classification system

Classification:

- Normal, main-sequence: 11 A0-A3, 6 A4-A8



Extra slides

Photometric equivalent width vs duration

