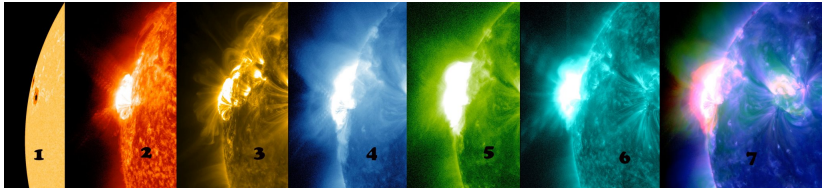


# Investigating the origin of flares in A-type stars



**May Gade Pedersen**



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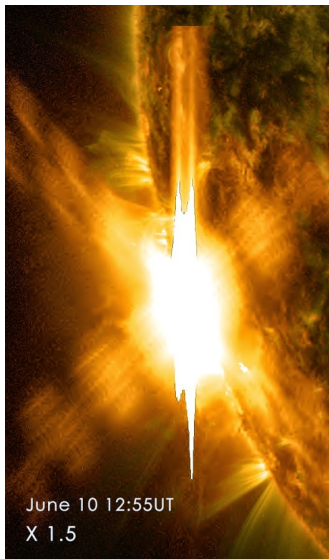
**KU LEUVEN**

## 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?

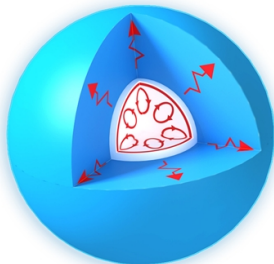
## Normal A-type stars

- Shallow convective envelopes
- Weak, large scale magnetic fields
- Weak stellar winds

## Balona (2012 & 2013)

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

> 1.5 solar masses



Credit: Adapted from [www.sun.org](http://www.sun.org)

# Why do they flare?

## 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

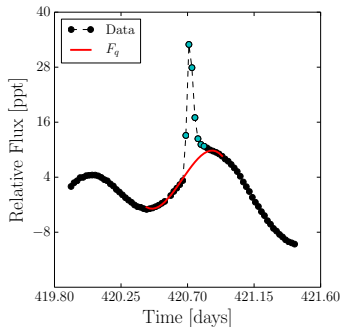
## Detection criteria:

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

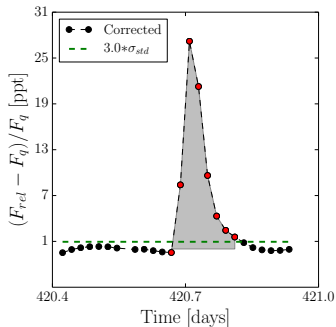
*Walkowics et al. 2011*

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

$F_{\text{rel}}$ : Flux of the flare lightcurve  
 $F_q$ : Quiescent flux



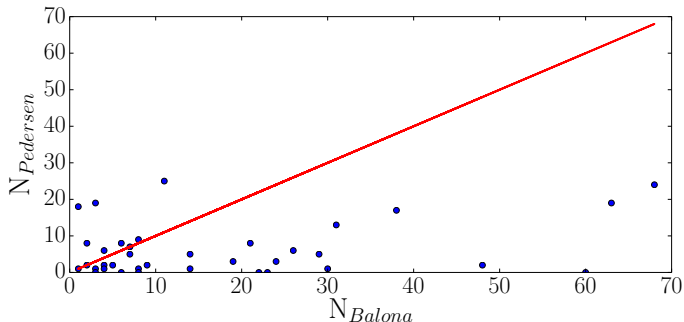
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Investigating the origin of flares in A-type stars

### 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)

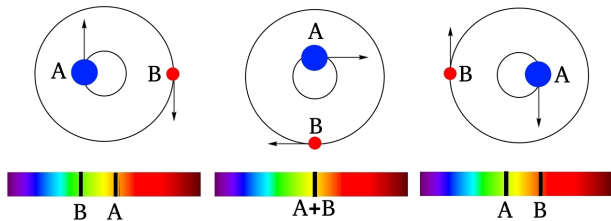
**No Ap/Bp stars**





# Spectroscopy

## Radial Velocities



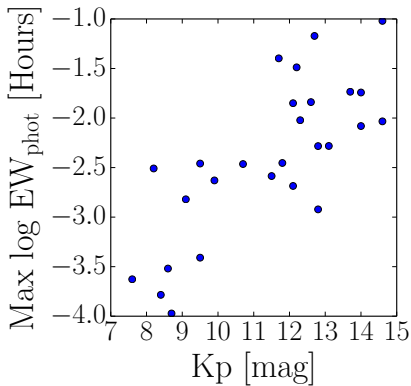
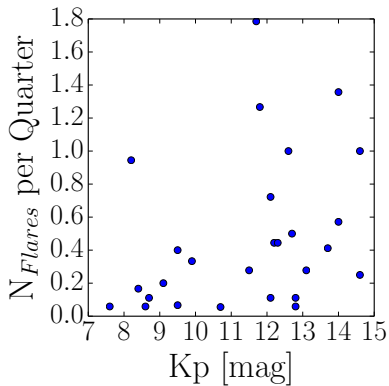
$\geq 2$  RV measurements for 18 stars

11 SB1 binaries

5 single stars

2 unknown

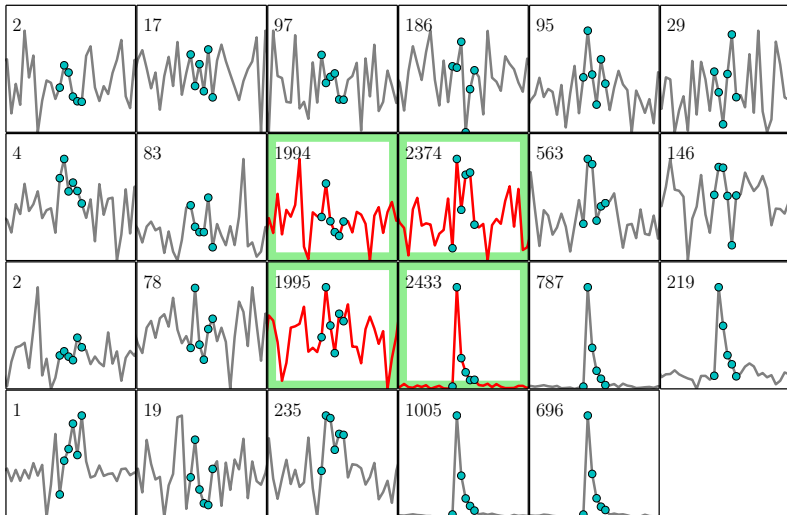
# Contamination?



# Contamination?

Contamination example

5 stars

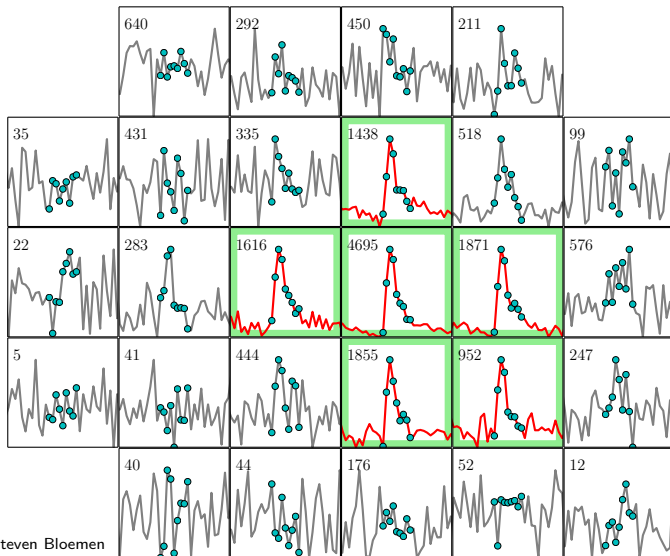


Inspiration from Steven Bloemen

# Contamination?

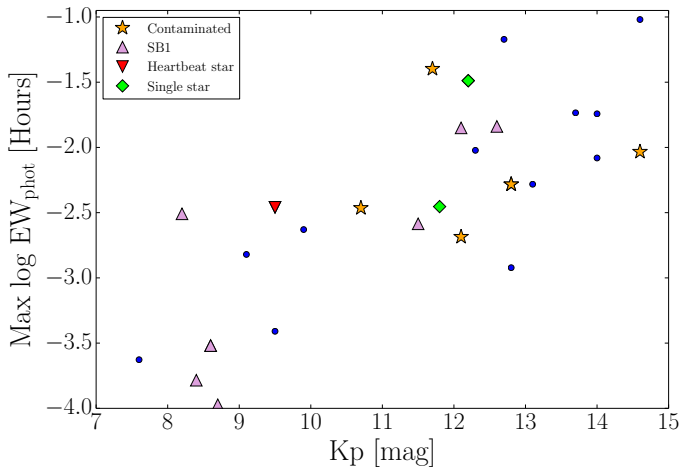
Non-contamination example

14 stars



Inspiration from Steven Bloemen

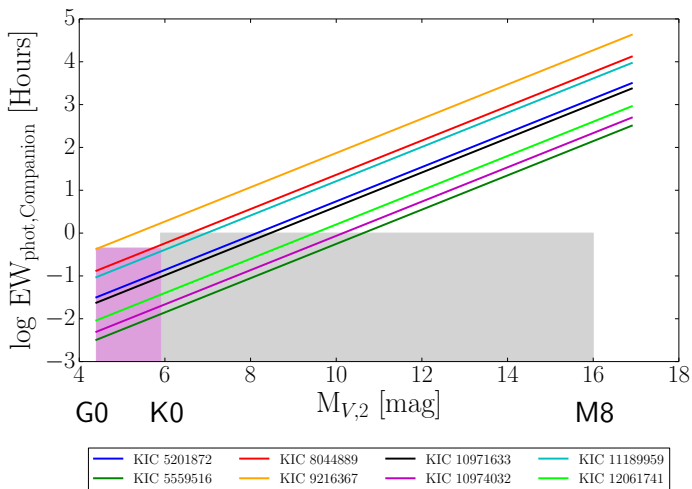
# Results



# Cool companion?

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

Purple box: Max  $EW_{\text{phot}}$  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**

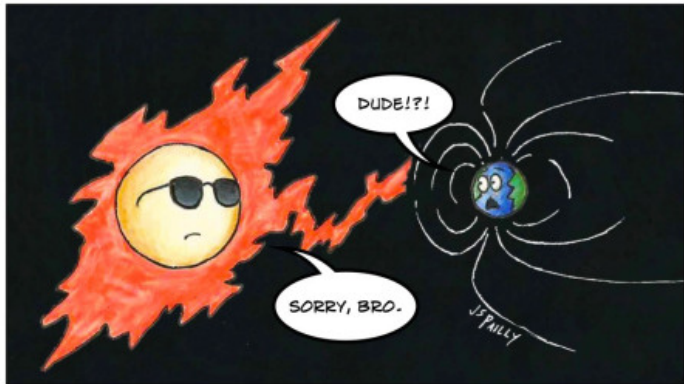
**Need additional spectra (4 stars)**

**UV spectra from Swift for 3 stars**

**Investigate possible circumstellar origin**

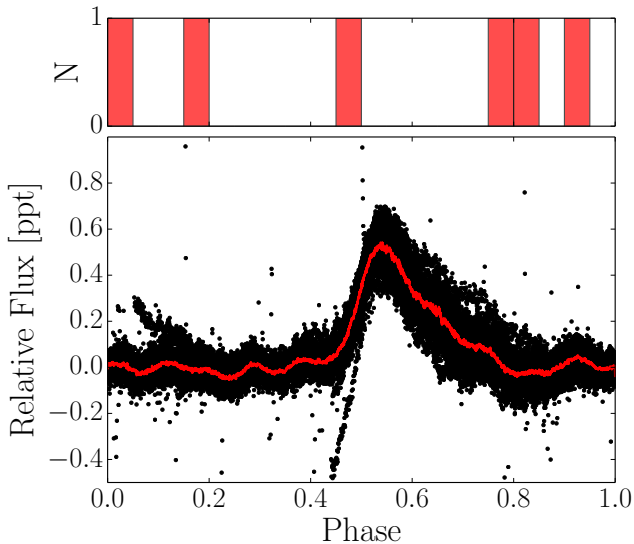


Thanks for your attention!



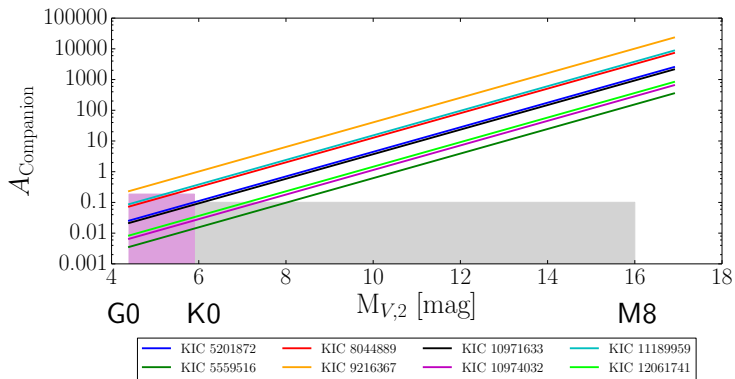
# Extra slides

## Heartbeat star



# Extra slides

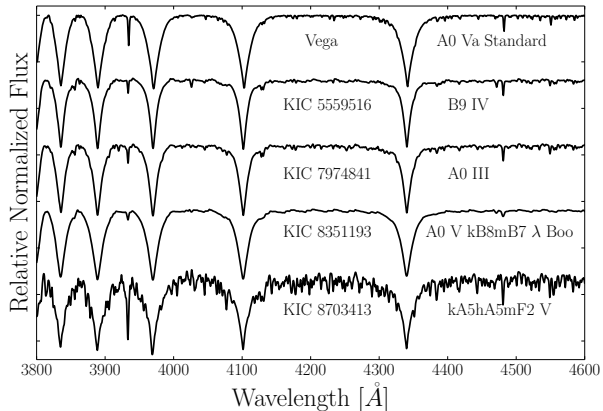
Cool companion?



### The Morgan-Keenan (MK) classification system

#### Classification:

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



# Extra slides

## Photometric equivalent width vs duration

