Stellar flares with ARIEL

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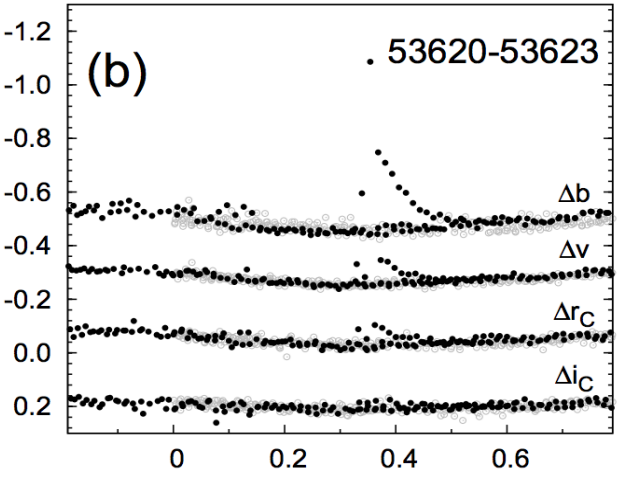
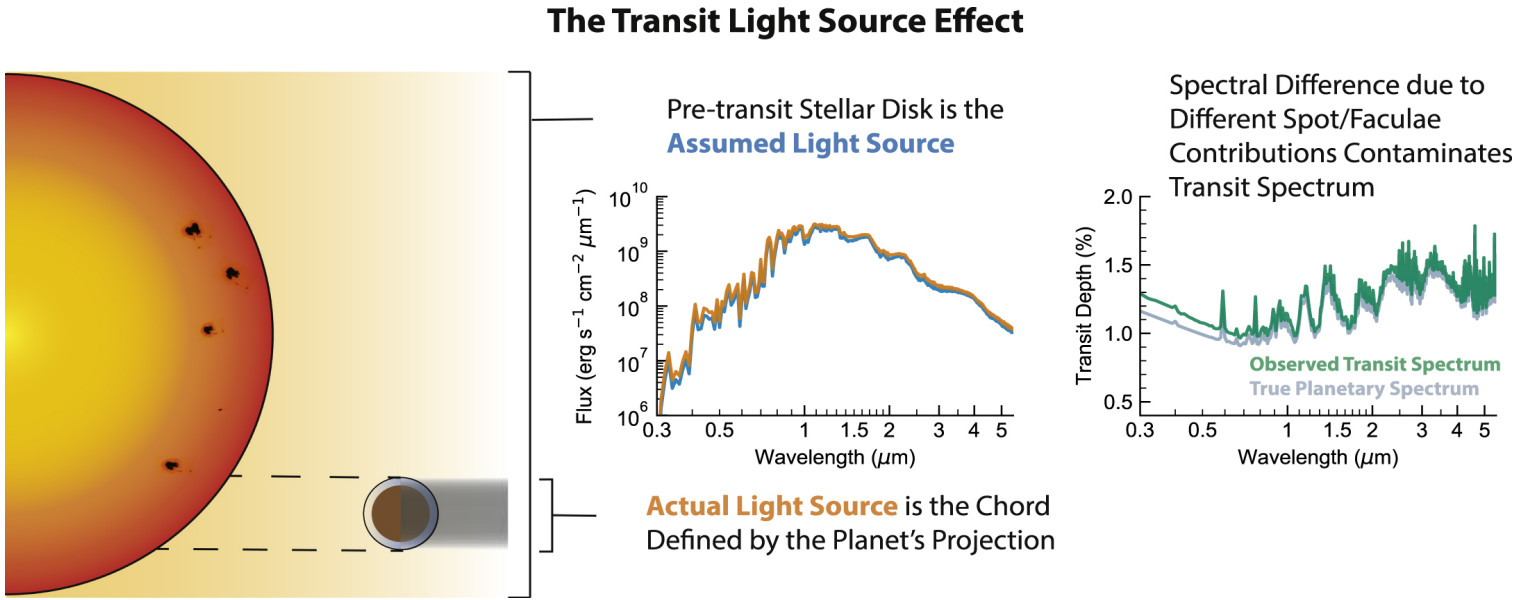
Stellar activity as noise

- Photospheric starspots have small contribution to light variations in the IR regime
- Flares are also more prominent at shorter wavelengths



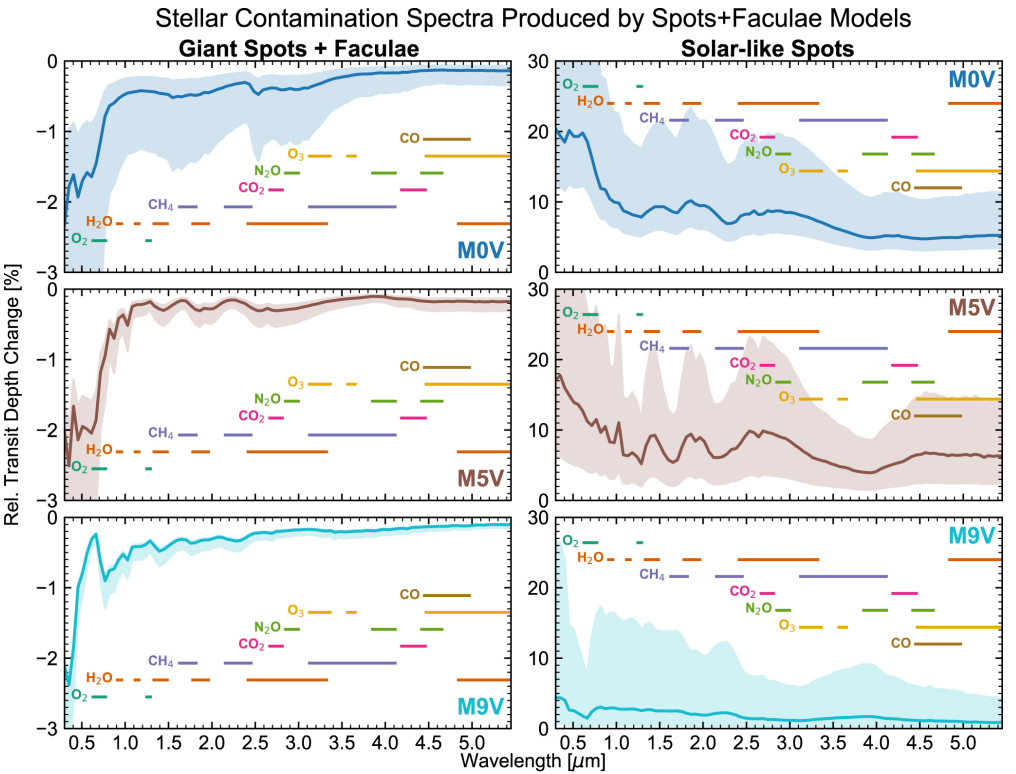
Flare of an M-dwarf in multiple passbands

- A possible problem: with transit spectroscopy the removed spectral source is the whole stellar disk, but different activity contribution can cause contamination even in IR regime



Rackham, Apai, Giampapa 2018

- A possible problem: with transit spectroscopy the removed spectral source is the whole stellar disk, but different activity contribution can cause contamination even in IR regime
- This can reach a level of 10+% depending on wavelength and spot configuration

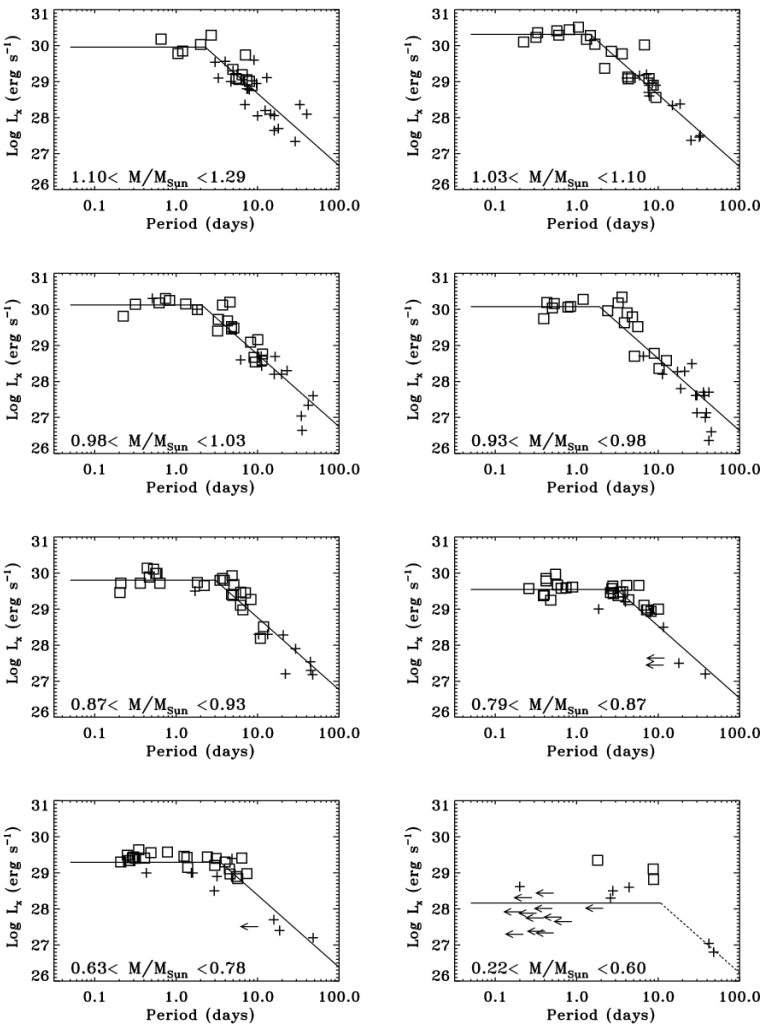


Rackham, Apai, Giampapa 2018

ARIEL & stellar activity

- Magnetic activity is an important property of young, fast-rotating stars
- This can have serious consequences on their exoplanets

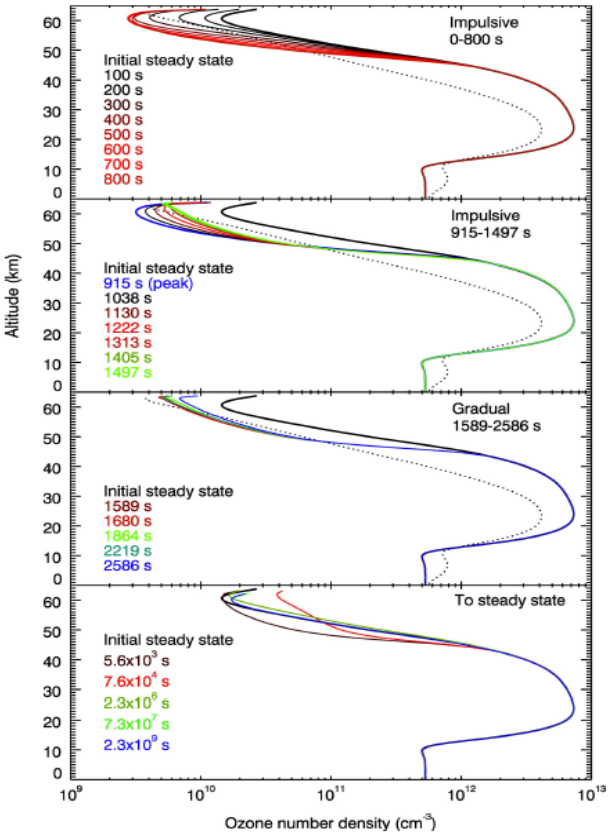
What remains to study for later stages of star/planetary system evolution?



Rotation (age) vs. X-ray luminosity

ARIEL & stellar activity

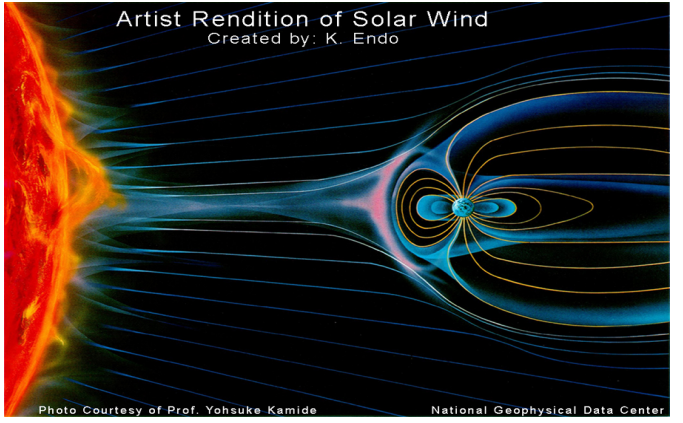
- Magnetic activity is an important property of young, fast-rotating stars
- This can have serious consequences on their exoplanets
- Some models already exist discussing the effects of activity on planets, but not much is known on the additive effects and observational confirmation is also missing



Model of the atmospheric changes of an Earth-like planet due to a large flare event (Segura et al. 2010)

ARIEL & stellar activity

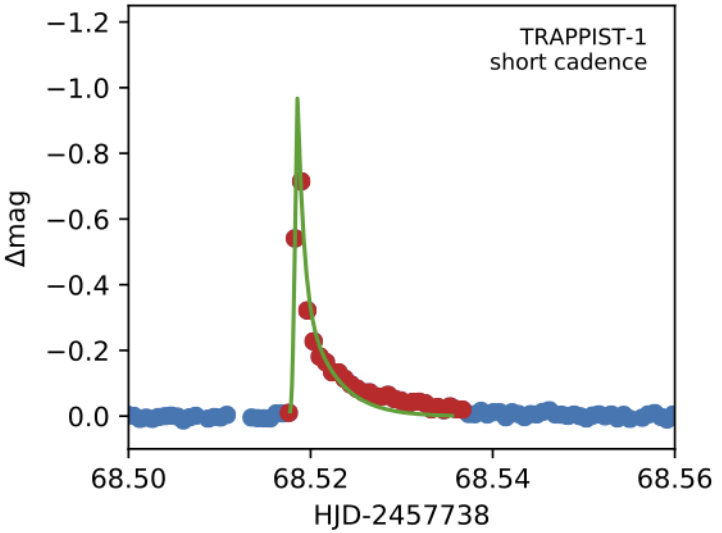
- The interaction of exoplanets and stellar magnetism is crucial for planetary evolution and for the search for life
- Can the system harbor life on long term? (first signs of life on Earth dates back to 4Gyr, although complex life based on eukaryotic cells took much longer time to form)

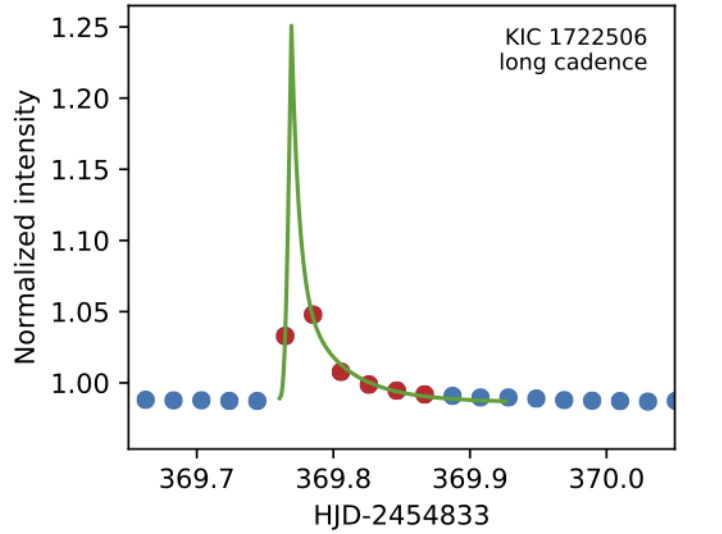


ARIEL & stellar activity

High resolution photometry can be crucial for fast transients – e.g. determining flare parameters: energy estimation depends heavily on sampling! - fast photometry available with ARIEL seems promising...

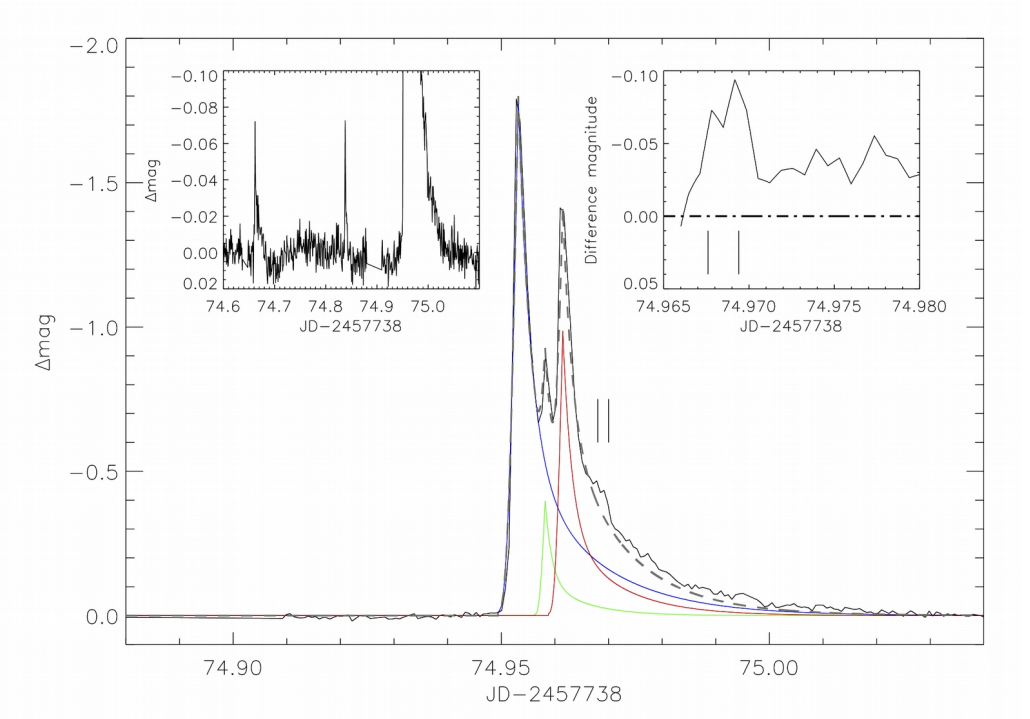
Flare analysis with machine learning on Kepler light curves: energy estimation of long cadence events can be nasty...





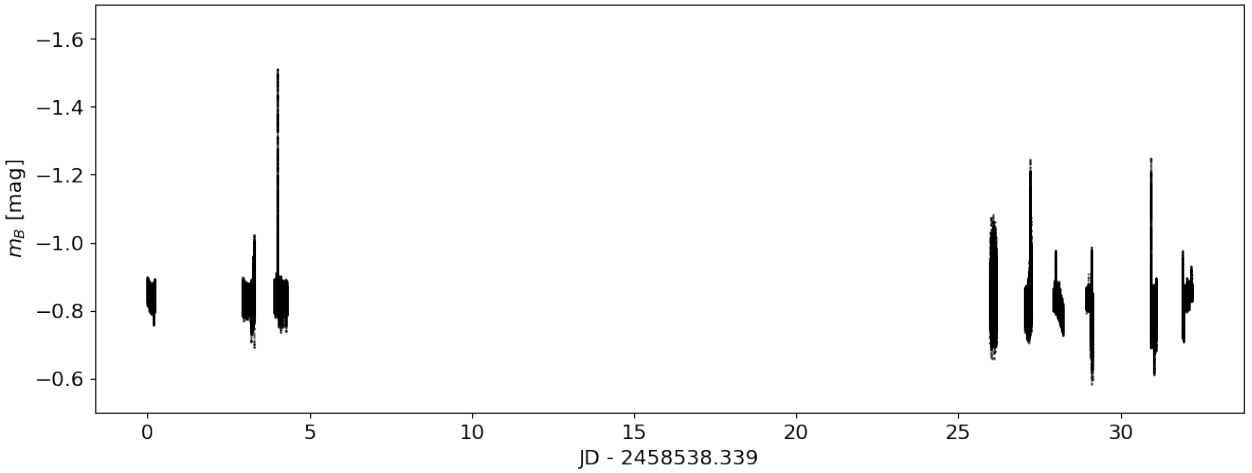
ARIEL & stellar activity

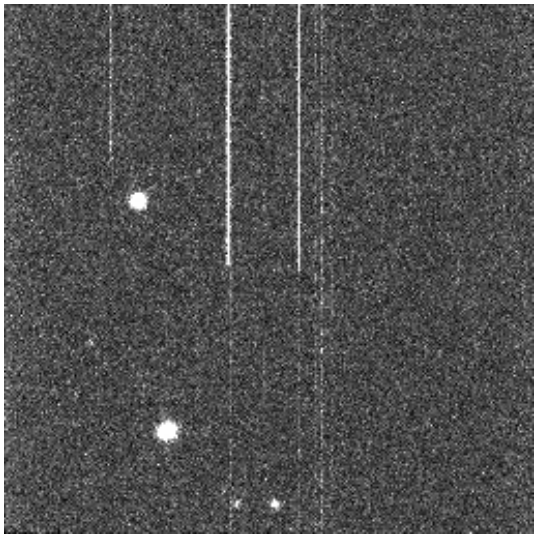
There could be several smaller events (microflares) that we are missing, that we see e.g. on the Sun



Ground test for fast photometry

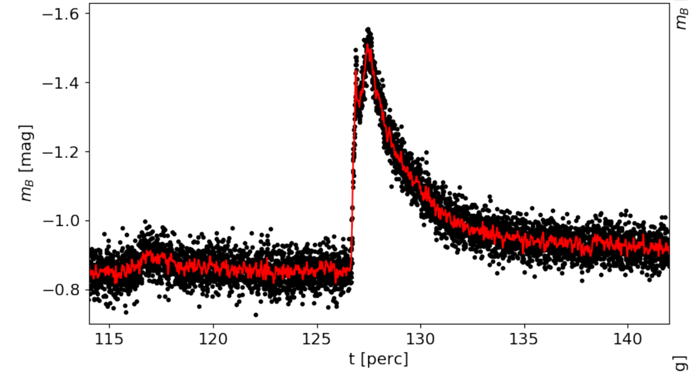
- AD Leo (B~10^{m}, M3V)
- B filter (target will be fainter, but larger flare amplitudes)
- 0.3s exposures - ~0 readout time
- 3 weeks of observing time (10 usable nights)
- 600.000 data points



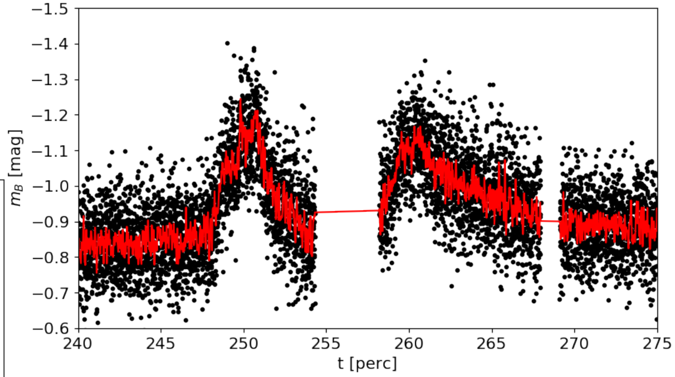


roughly real-time animation of data aquisition

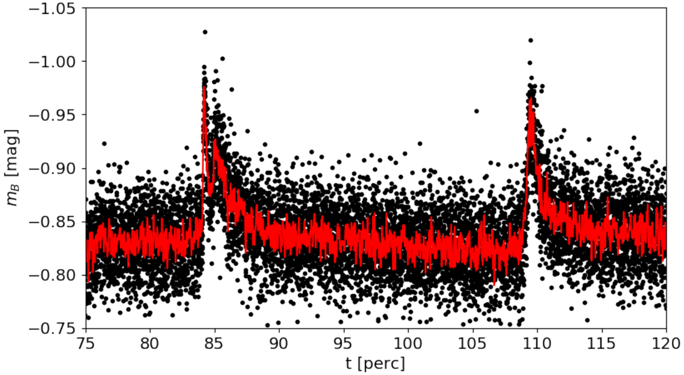
A flare “zoo”



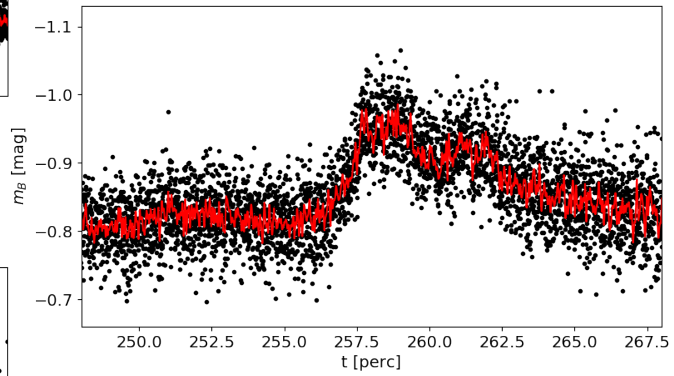
m_B [mag]
t [perc]



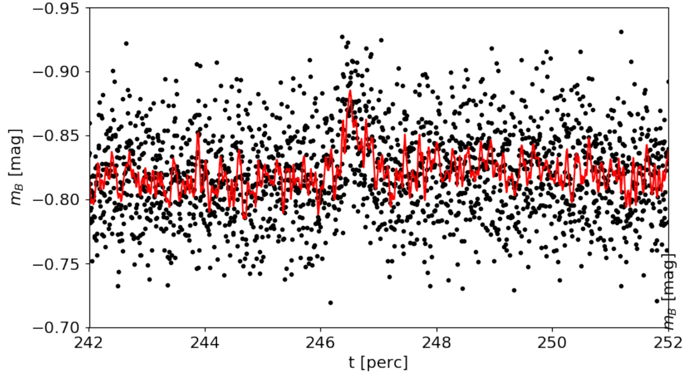
m_B [mag]
t [perc]



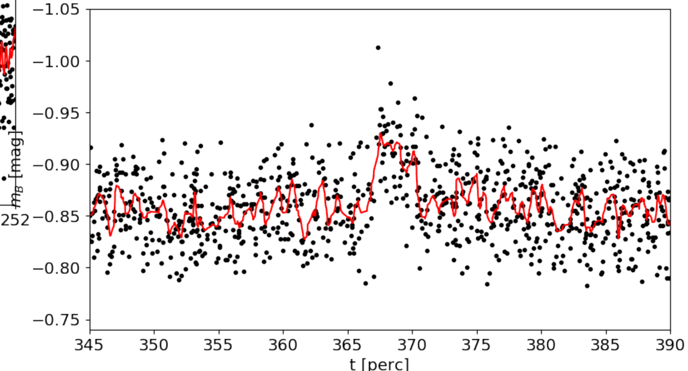
m_B [mag]
t [perc]



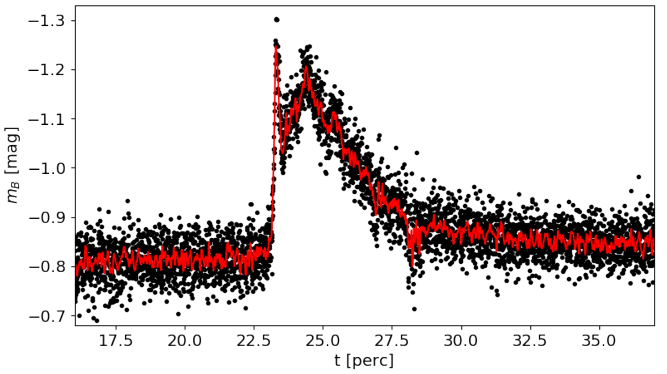
m_B [mag]
t [perc]



m_B [mag]
t [perc]

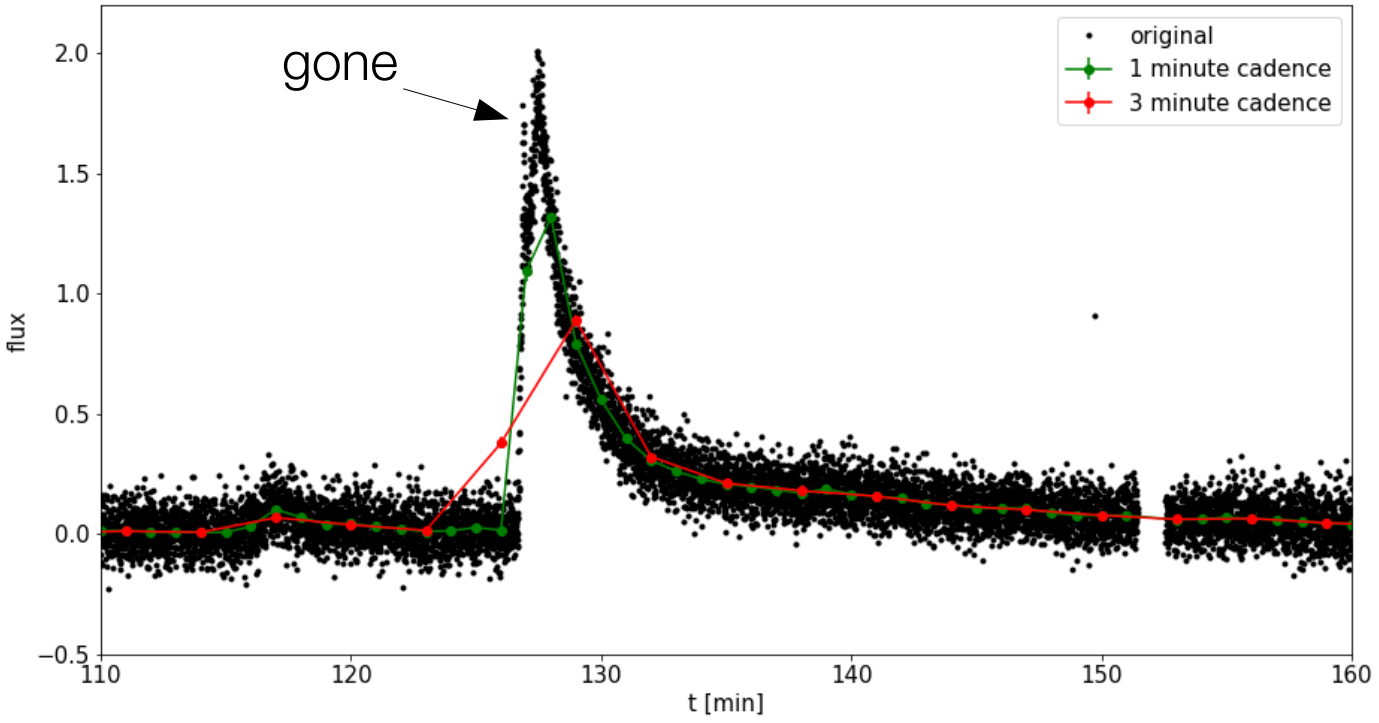


m_B [mag]
t [perc]

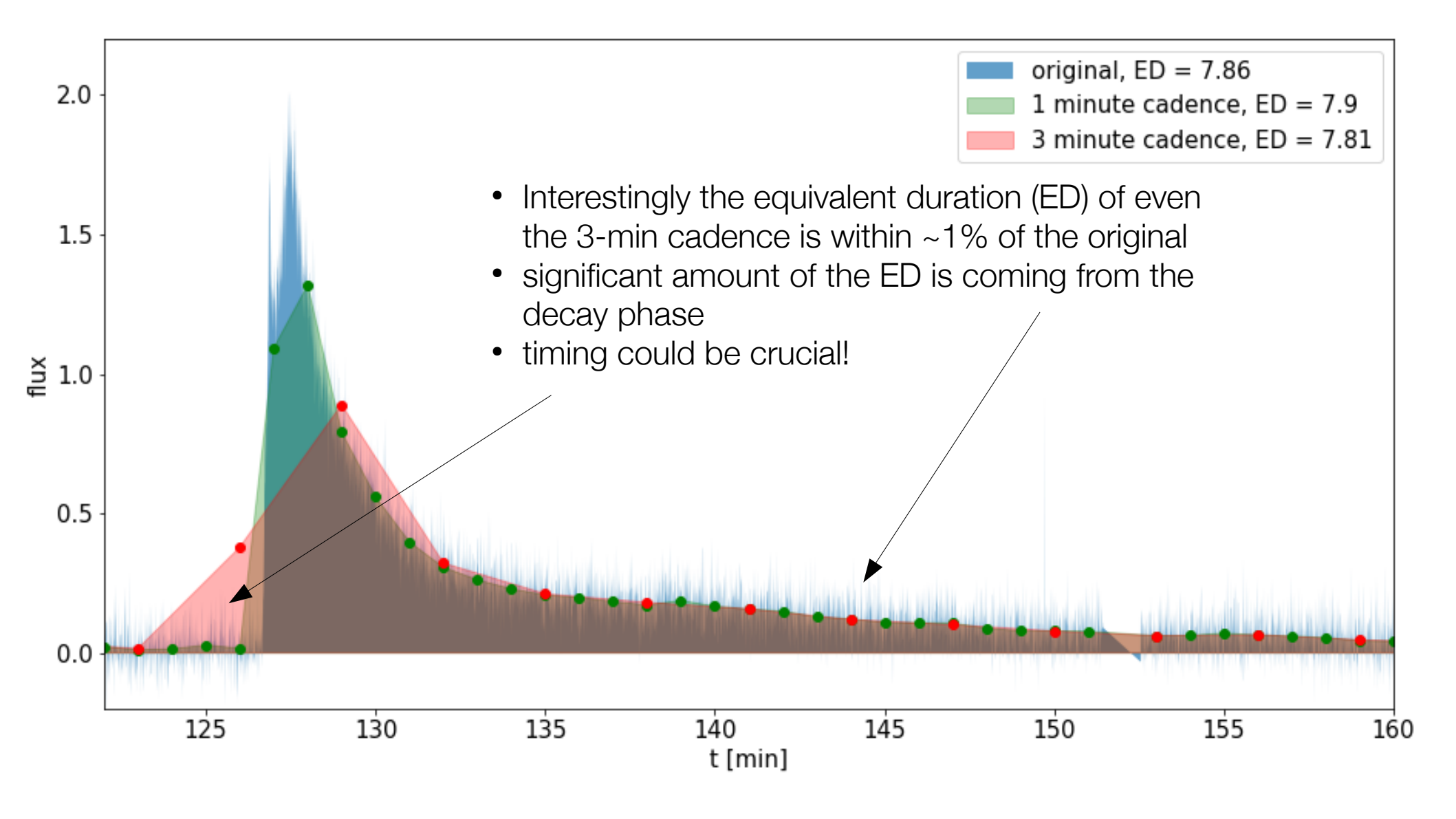


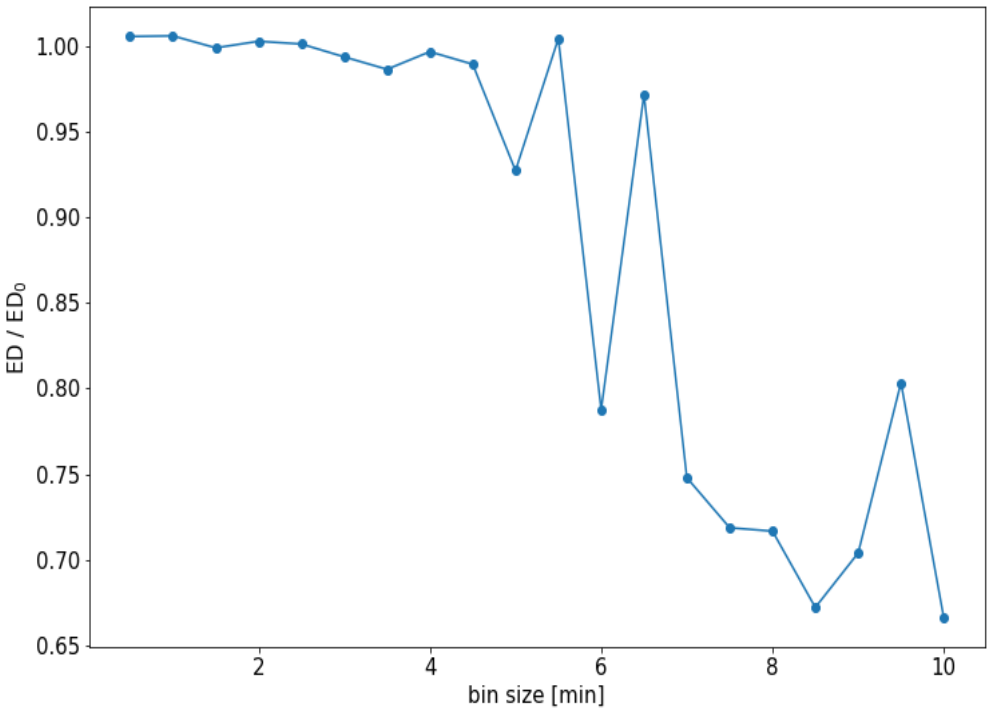
m_B [mag]
t [perc]

What do we gain/lose with longer exposures?

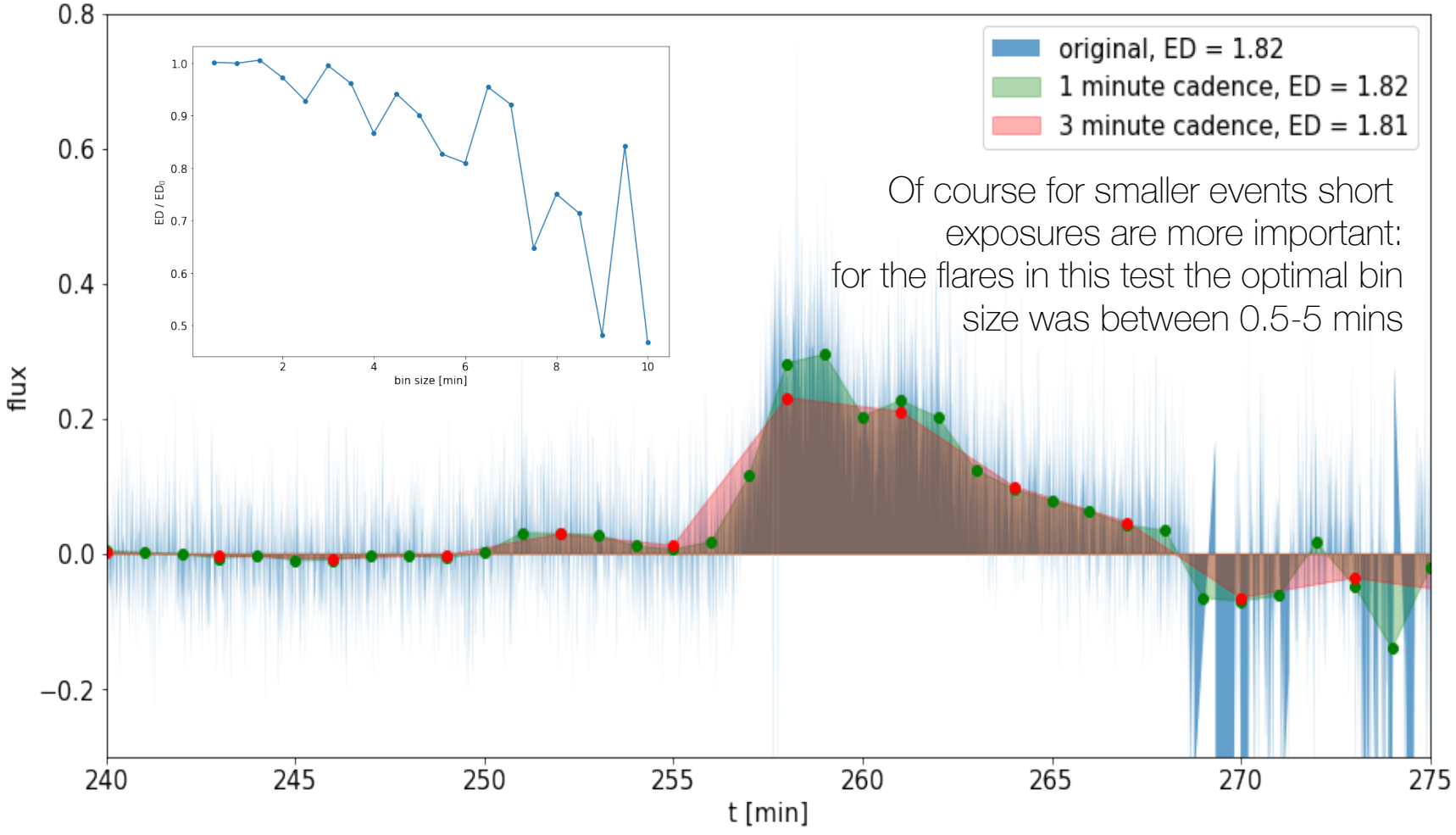


data rebinned to 1 and 3-minute cadence


original, ED = 7.86
1 minute cadence, ED = 7.9
3 minute cadence, ED = 7.81
• Interestingly the equivalent duration (ED) of even the 3-min cadence is within ~1% of the original
• significant amount of the ED is coming from the decay phase
• timing could be crucial!
flux
t [min]
2.0
1.5
1.0
0.5
0.0
125
130
135
140
145
150
155
160



for this event we get the same energy (within few %) up to 4 min cadence!


original, ED = 1.82
1 minute cadence, ED = 1.82
3 minute cadence, ED = 1.81
Of course for smaller events short exposures are more important: for the flares in this test the optimal bin size was between 0.5-5 mins
flux
t [min]
ED / ED0
bin size [min]

What did we learn?

- For the few observed events 0.5-5 min cadence is enough

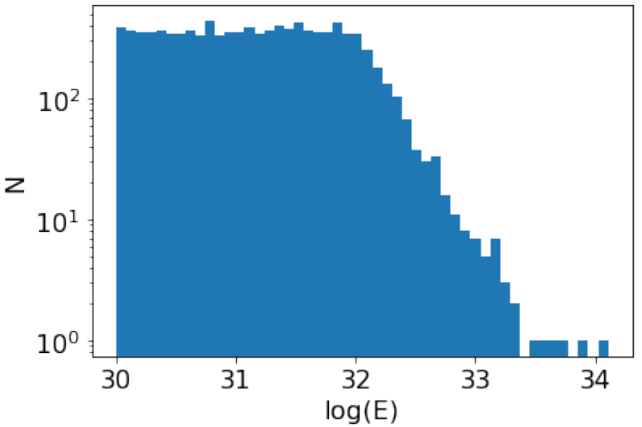
  BUT
- Small events were not detected due to higher noise level

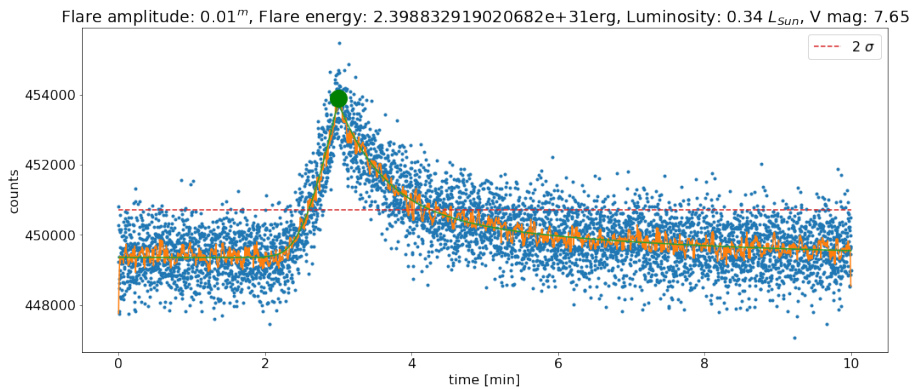
  (telescope/atmosphere/camera limitations)

What is the smallest detectable flare with ARIEL?

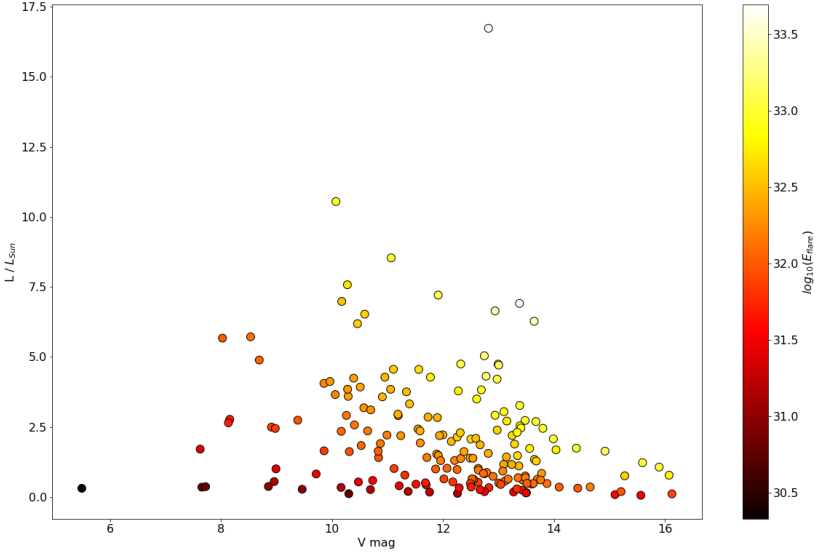
For this test we:

- sampled artificial flares with a realistic energy distrubution;
- added them to light curves of ARIEL targets;
- added Gaussian noise based on expected count rates (as √N Poisson noise) of the stars with 10Hz readout;
- Checked if the event is detectable with a 2σ limit

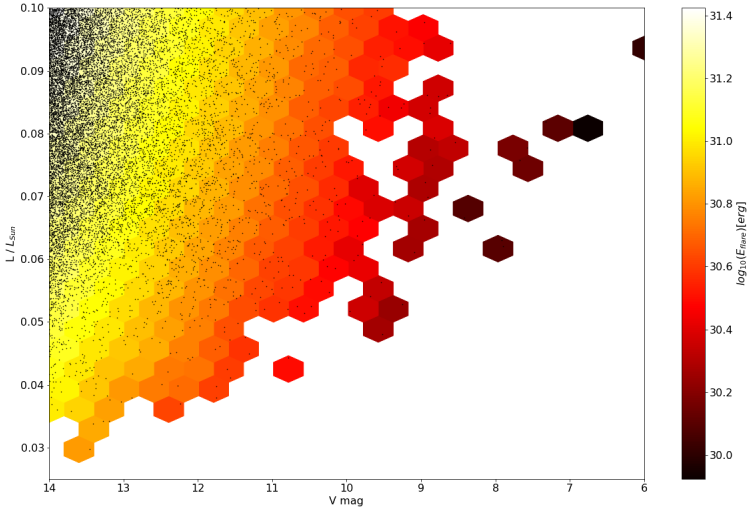




- For solar-like we expect to see only mainly the strongest eruptions
- For M-dwarfs we can probably observe even smaller events with good time resolution



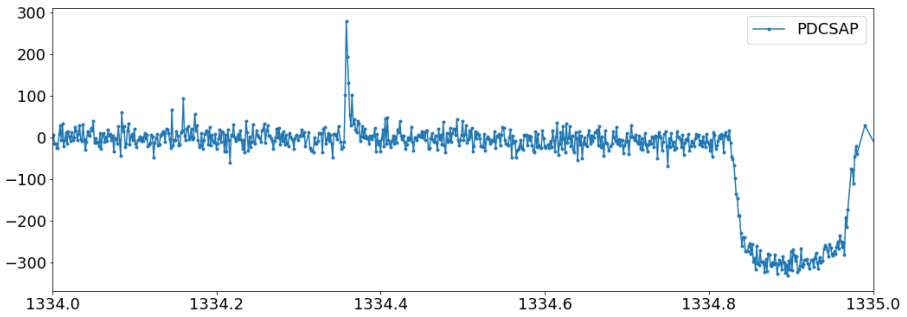
ARIEL target list

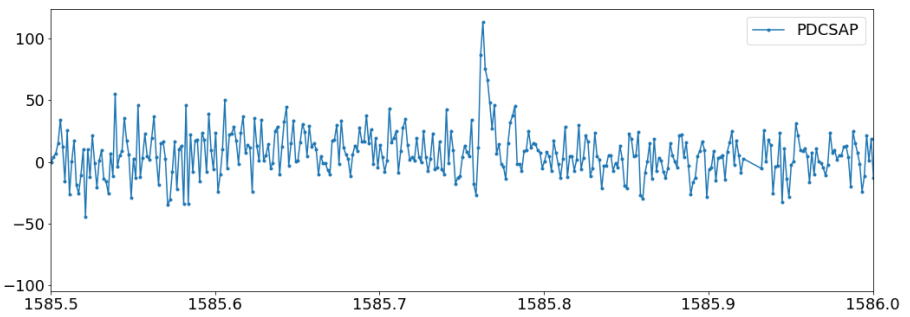


Gaia stars with
L < 0.1 L_Sun && V < 14 mag

Quick check of TESS data of ARIEL targets:

- ~350 targets
- ~130 short cadence light curve, 160 full-frame image data (with some overlap in targets)
- only a handful small flares -> the main science is probably not in danger





Conclusion

- For solar-like targets flares probably won't affect ARIEL's main science (but we don't know much about flare behaviour in IR yet)
- We can learn a lot about late-type targets: weaker, earlier unseen events can be detected with fast photometry