The question of habitability around TRAPPIST-1

Krisztián Vida

Zs. Kővári, A. Pál, K. Oláh, L. Kriskovics

Konkoly Observatory

14th Potsdam Thinkshop, 2017

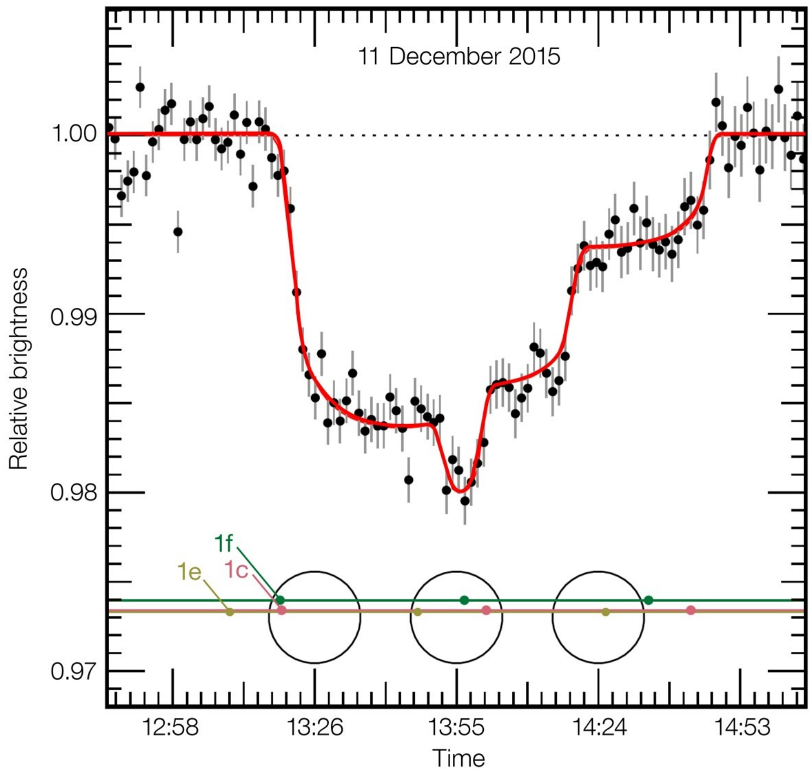
CSFK

TRAPPIST-1 and the search for exoplanets around M-dwarfs

Recently planet surveys concentrate on late-type objects:

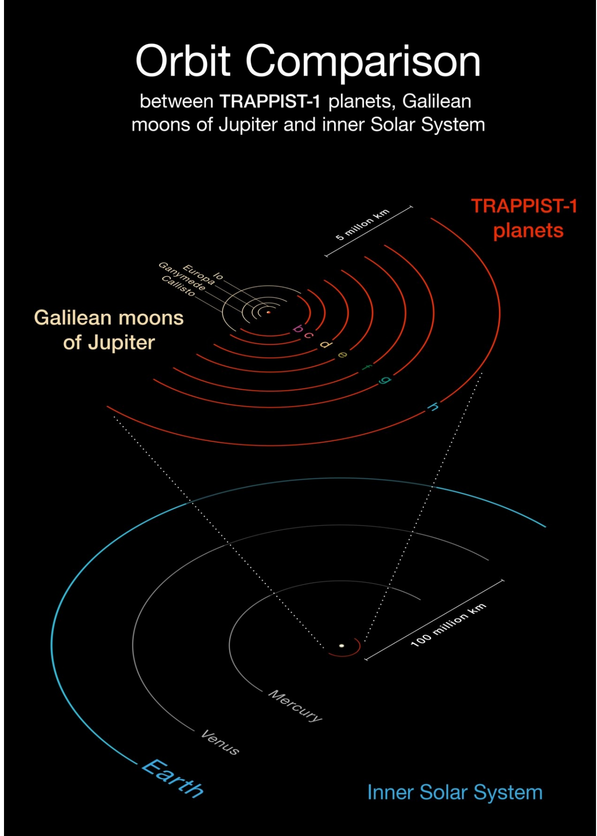
- they are numerous
- planets are easier to detect
- easier to find Earth-like planets

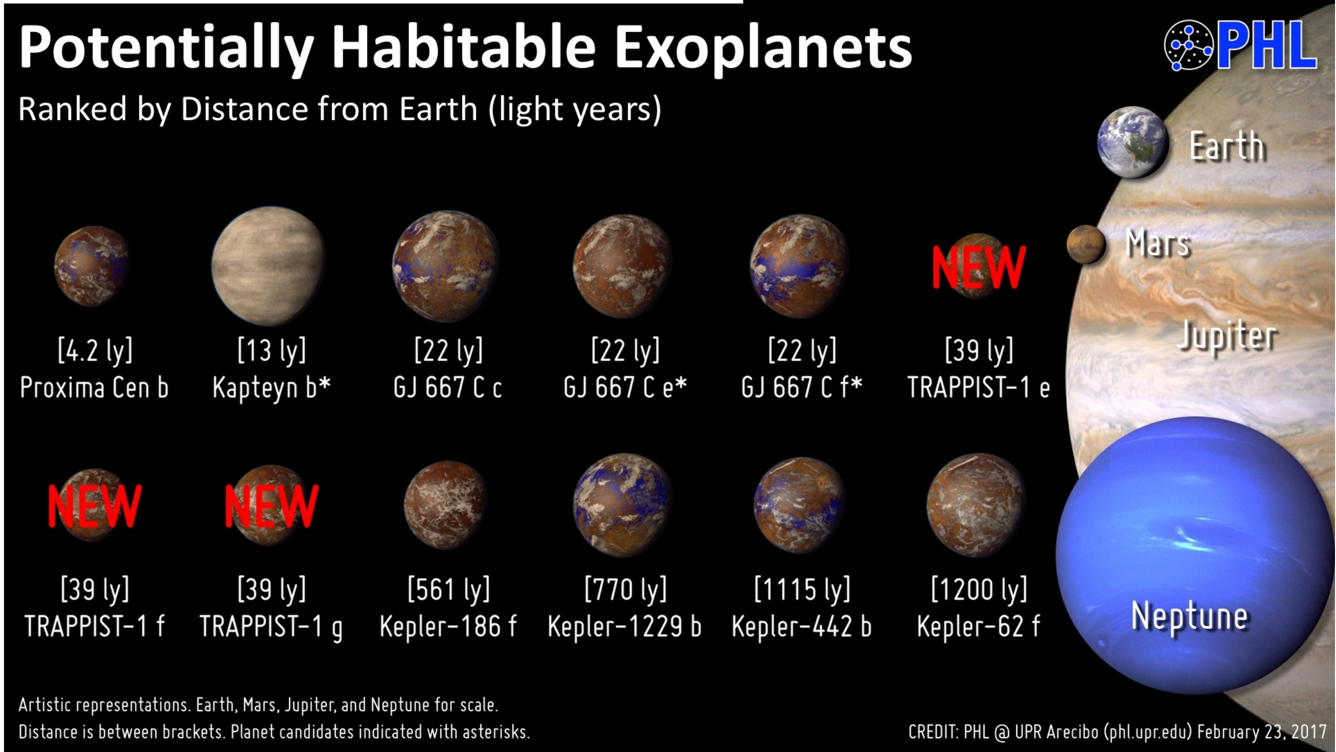
TRAPPIST-1 (M8) is one of the recent finds



What makes it special?

- TRAPPIST-1 hosts 7 terrestrial planets, of these 3 are in the habitable zone (can have liquid water)
- highly increased the number of known habitable-zone planets

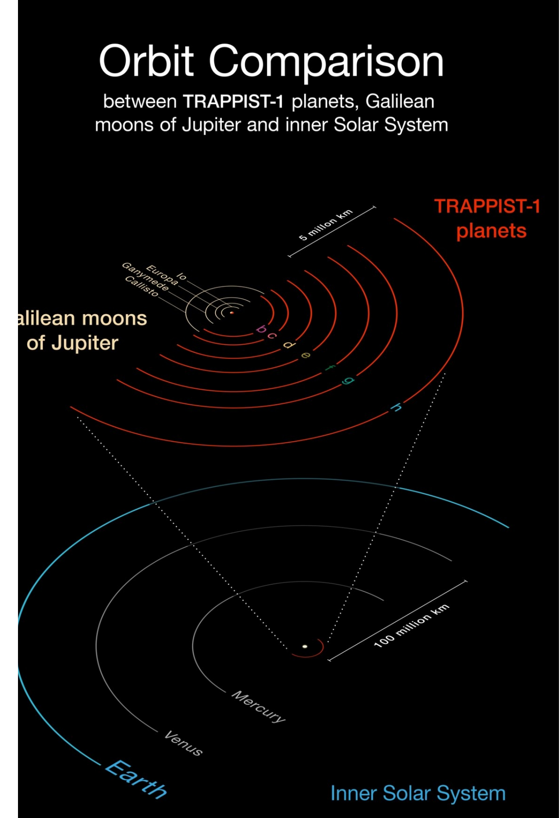


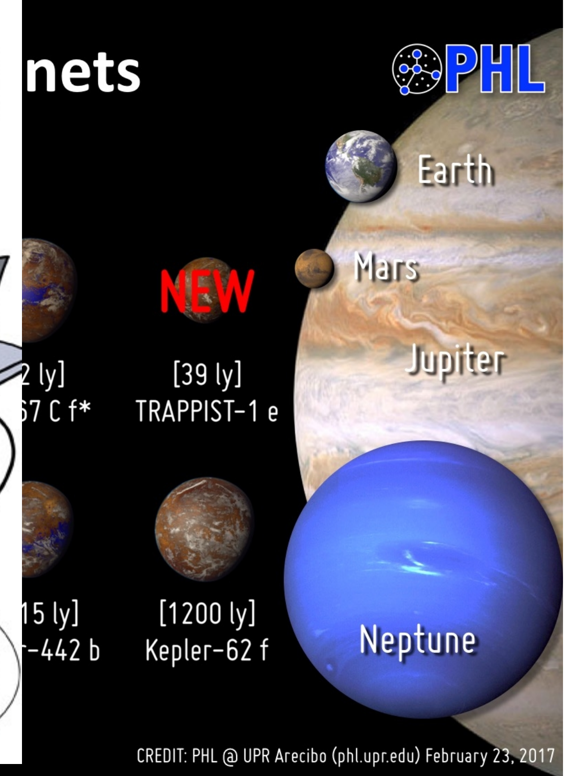


What makes it speci

- TRAPPIST-1 hosts 7 ter
  are in the habitable zon
- highly increased the nur
  zone planets

also great for
outreach :)





What makes it special?

- TRAPPIST-1 hosts 7 terrestrial planets, of these 3 are in the habitable zone (can have liquid water)
- highly increased the number of known habitable-zone planets
- → the question asked in every *muggle** article:

when are we going there?

* here: non-astronomer

What makes it special?

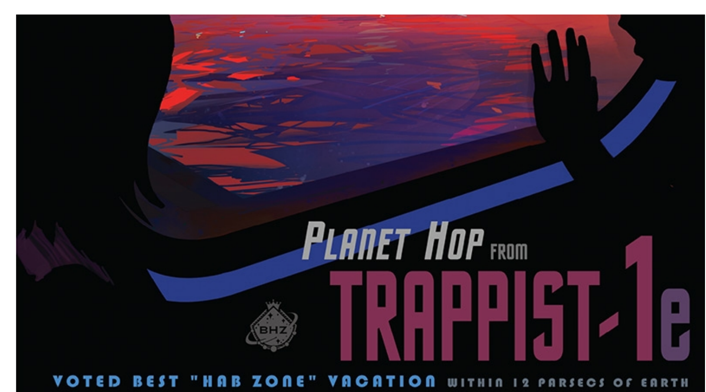
- TRAPPIST-1 hosts 7 terrestrial planets, of these 3 are in the habitable zone (can have liquid water)
- highly increased the number of known habitable-zone planets
- → the questio

when are we go

The scientific programme will highlight the most recent observational and theoretical work in the field including, but not limited to, the following topics:

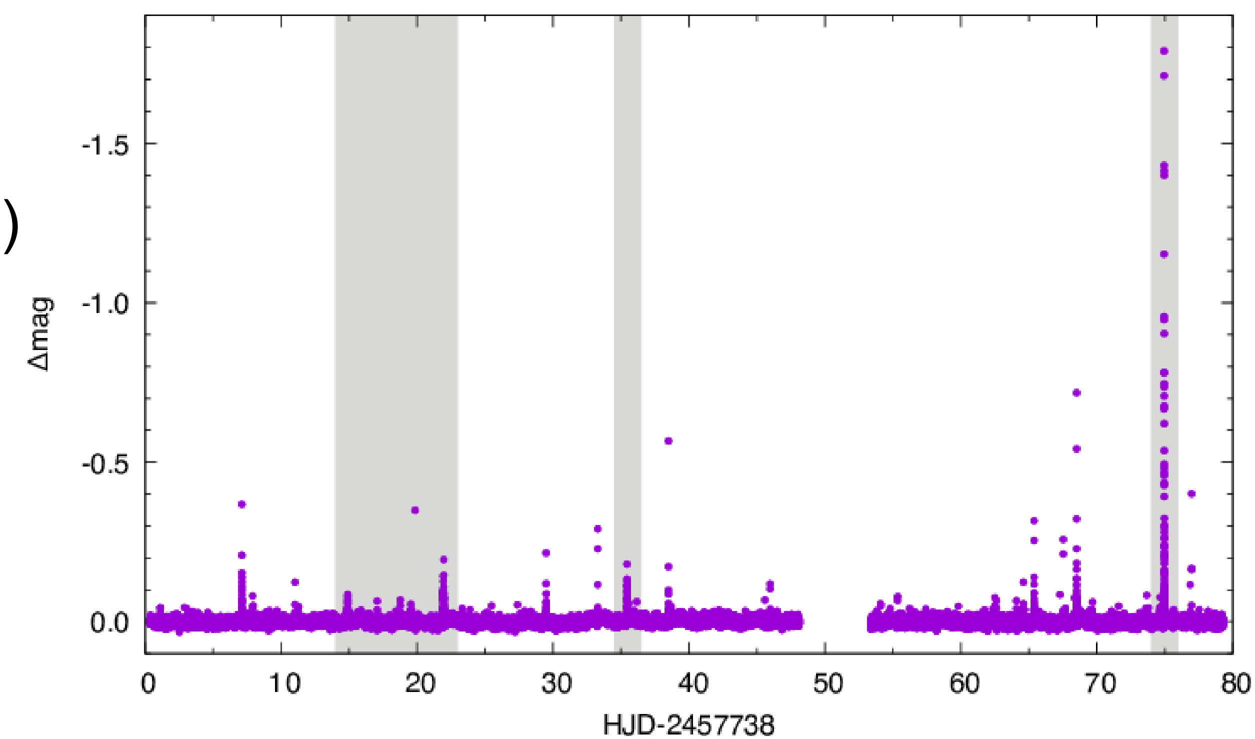
- the origin of stellar magnetic fields
- magnetic field geometry and evolution in pre-main-sequence stars
- magnetic fields, rotation, and differential rotation on the main sequence
- the role of small-scale magnetic fields in stellar atmospheres
- global dynamos, activity cycles, and the rotation-activity-age relation in solar-type stars
- magnetic fields in massive stars and magnetically-confined winds
- magnetic star/planet and disk/planet interaction
- magnetism in the late stages of stellar evolution
- future perspectives in theory and observational facilities

Stellar activity research is not about finding life, but rather finding out what destroys it...

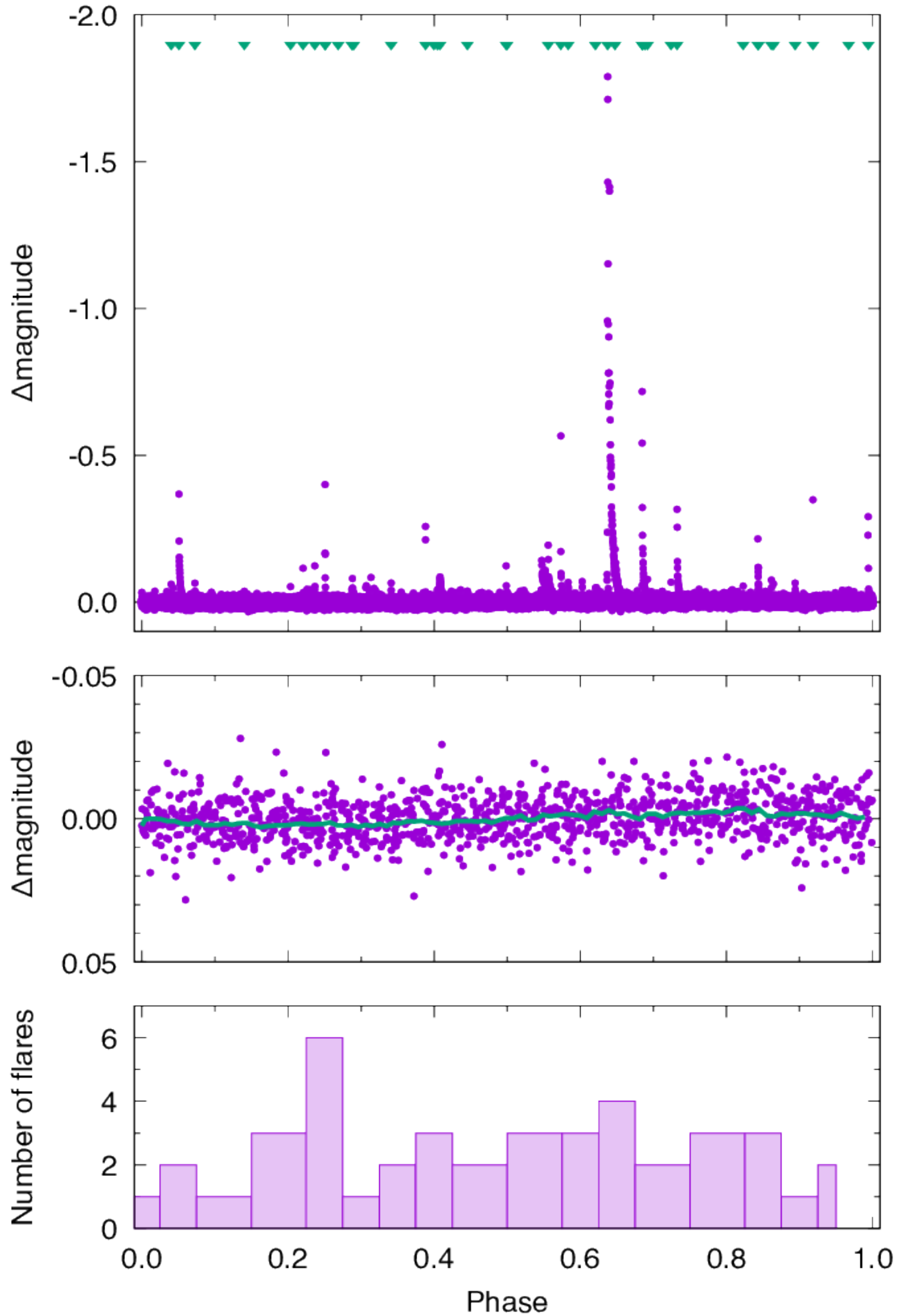


The K2 data

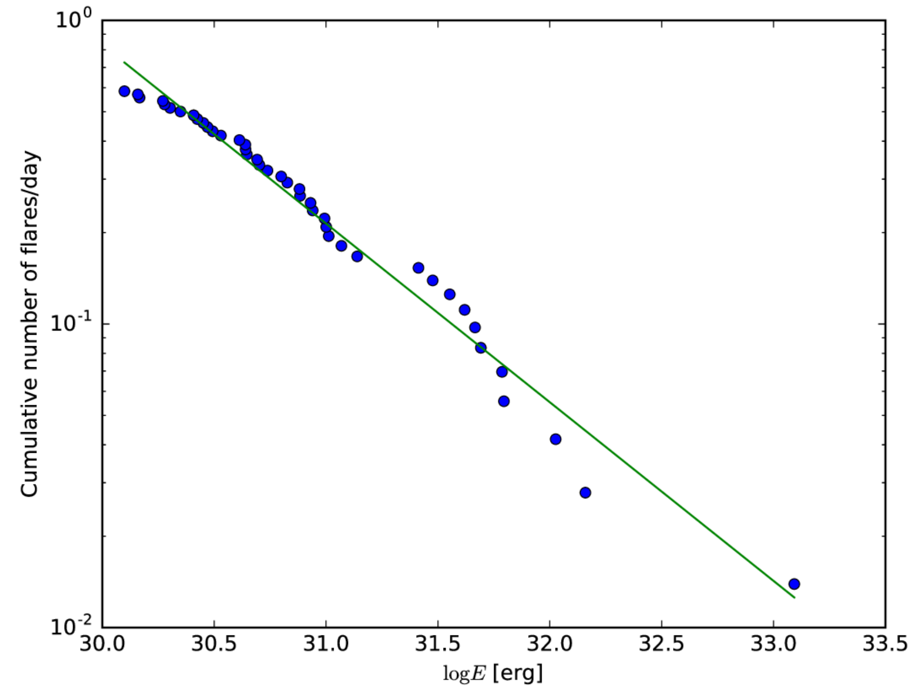
- The Kepler telescope obtained ~80 day-long precise light curve of TRAPPIST-1 in the K2 mission
- These uncalibrated raw pixel data are available to the community
- We found P_{rot}=3.295 days (cf. Gillon et al. 2016 had 1.4 days from ground photometry, that is consistent with vsini=6km/s, Spitzer data gives a third period (R. Roettenbacher, priv. comm. (coffee break)))



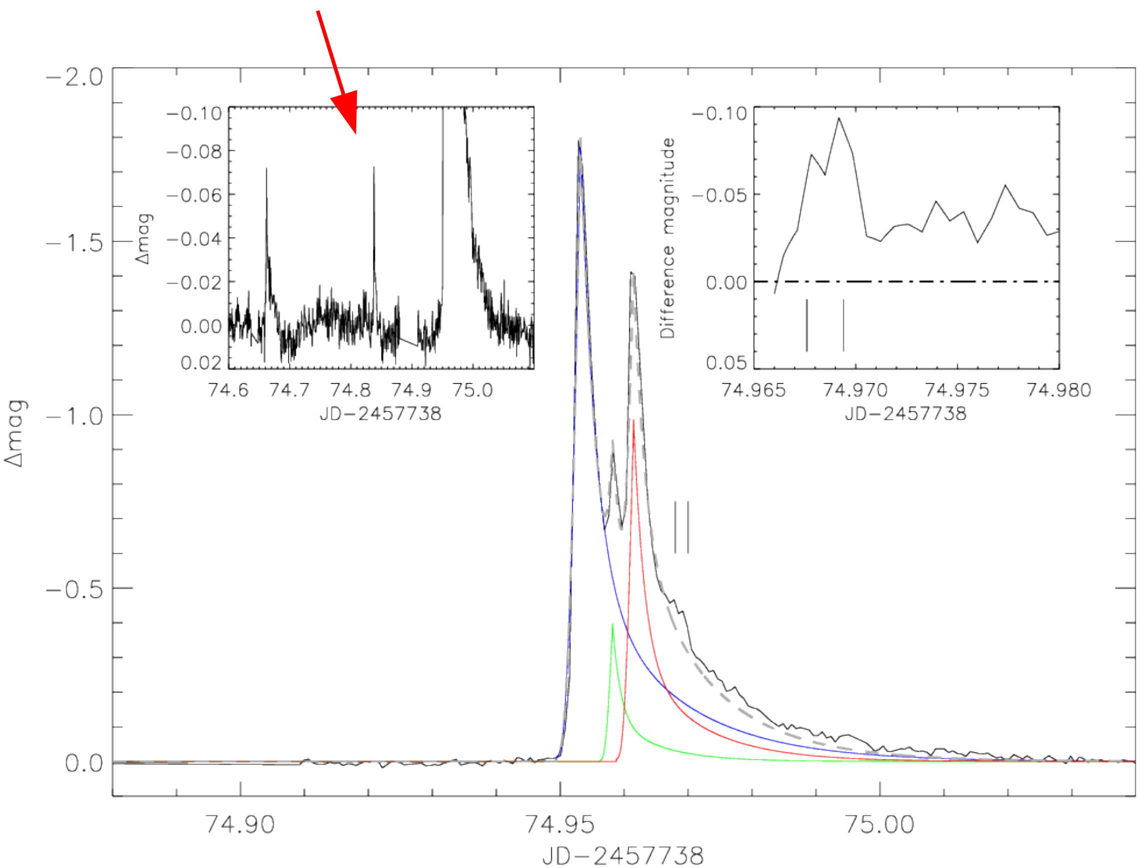
- Flares are found at every phase
- bit higher frequency at light curve minimum (~0.25 phase)
- strongest flares at maximum (0.55-0.75)
- Similar to V374 Peg, Vida et al. 2016

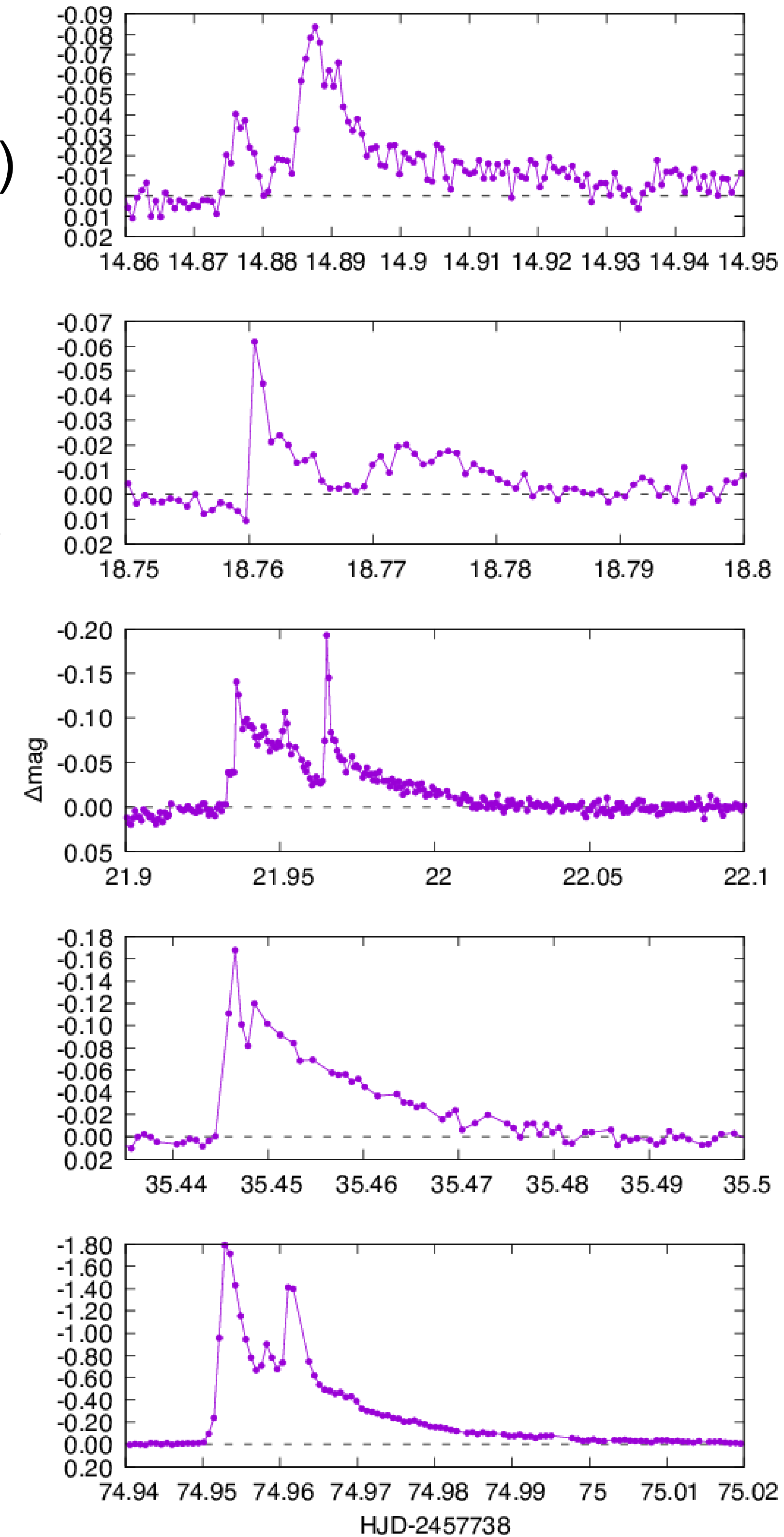


- Flares with ~1.26×10^{30}..1.24×10^{33} erg energies
- Flare energy distribution is often described by the relation $dN(E) \propto E^{-\alpha} dE$
- Fitting the slope of the cumulative energy distribution, yields 1-α, that is often used to describe flare energy dissipation
- α=1.59 suggests mostly non-thermal flares similarly to more active M-dwarfs (e.g. Proxima Cen has α=1.68, see Davenport et al. 2016)

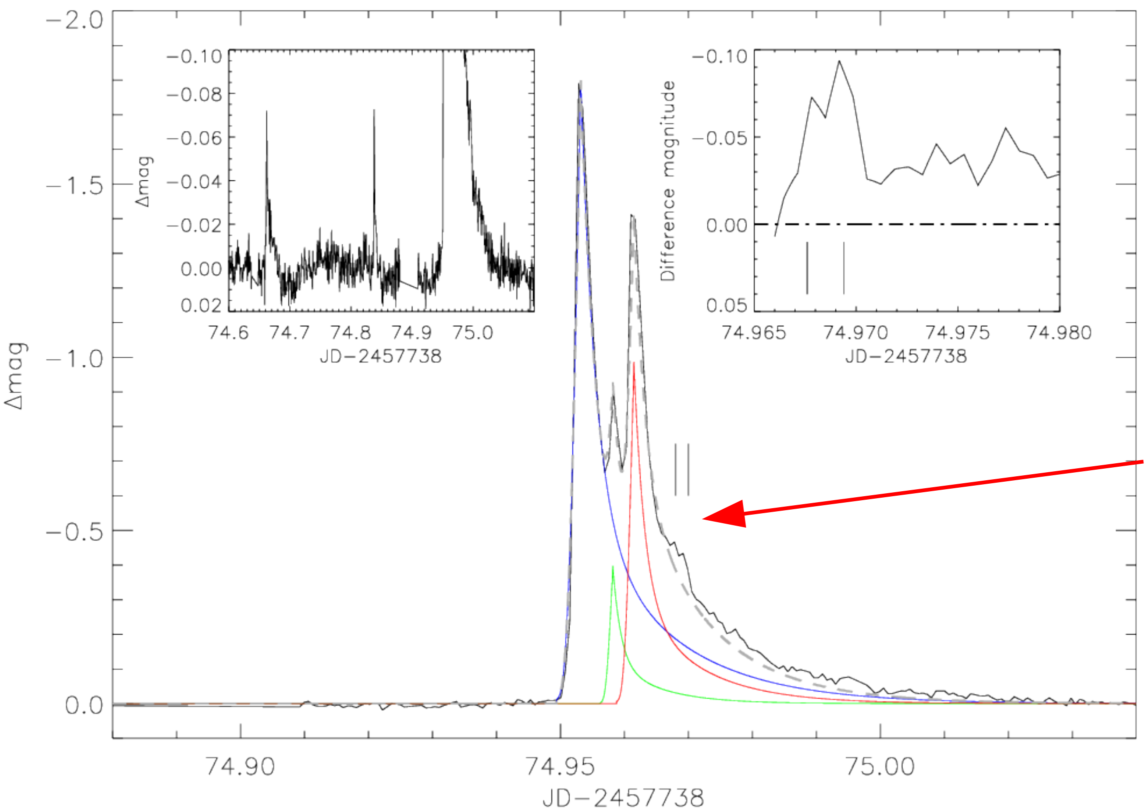


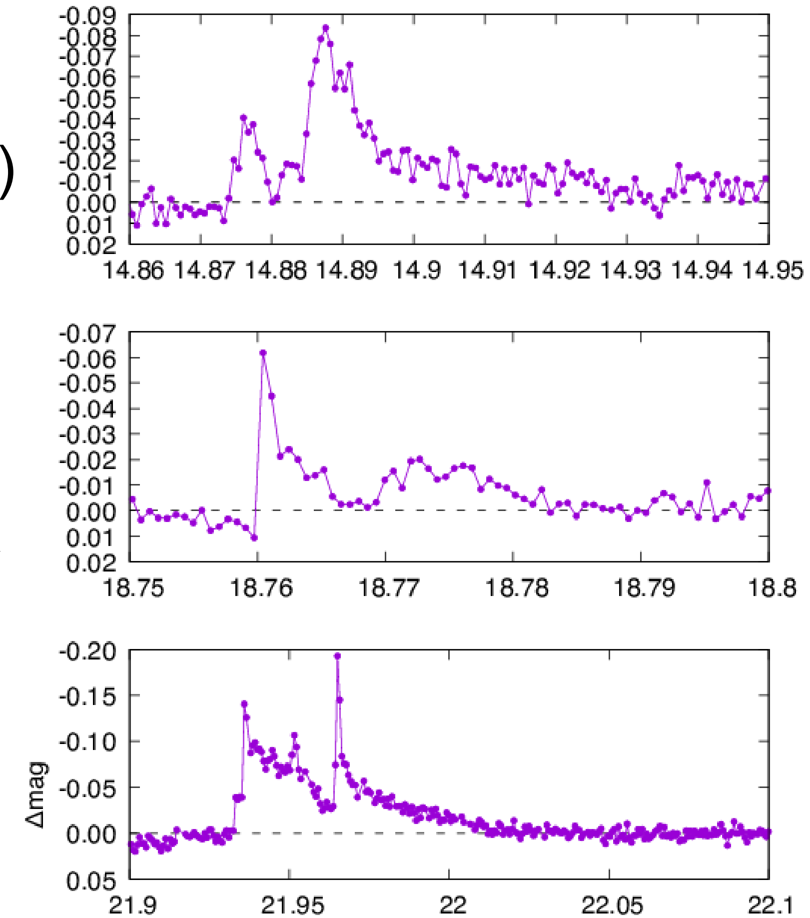
- There are several flares in the light curve (42)
- Some of them are complex eruptions
- One strong (Δmag=1.8) complex event
- ~with the energy of the Carrington-event
- Could be a sympathetic eruption triggered by an earlier one

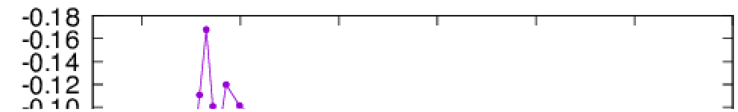




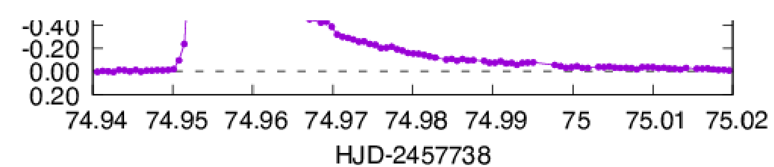
- There are several flares in the light curve (42)
- Some of them are complex eruptions
- One strong (Δmag=1.8) complex event
- ~with the energy of the Carrington-event
- Could be a sympathetic eruption triggered by an earlier one



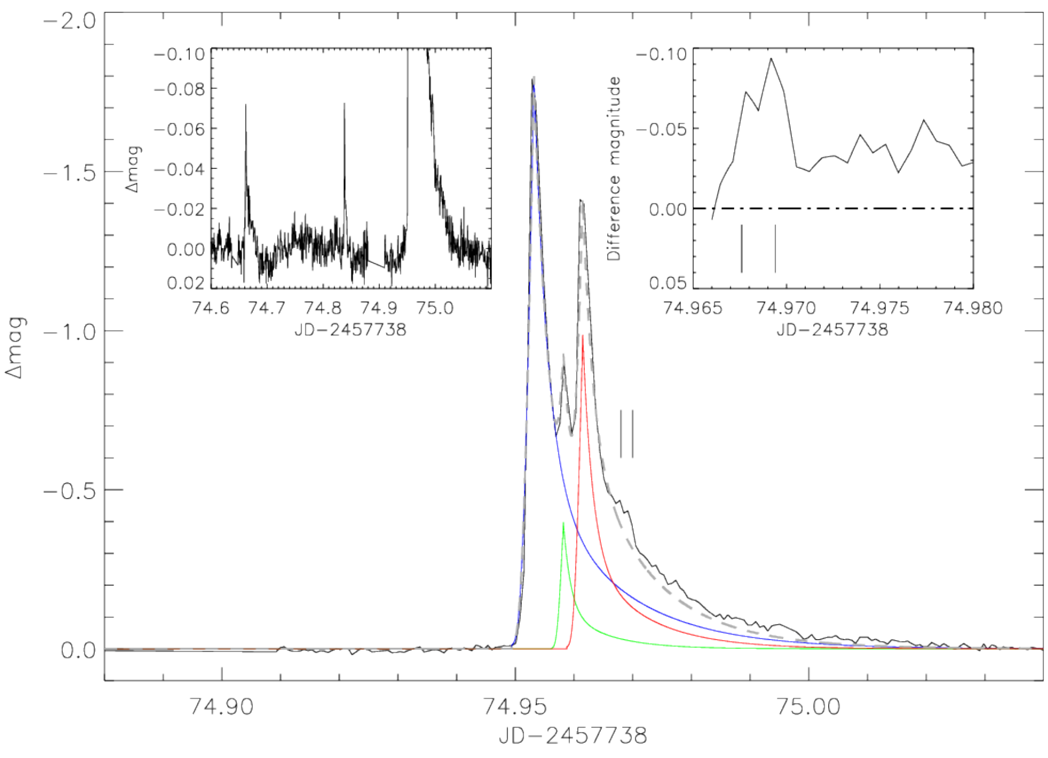




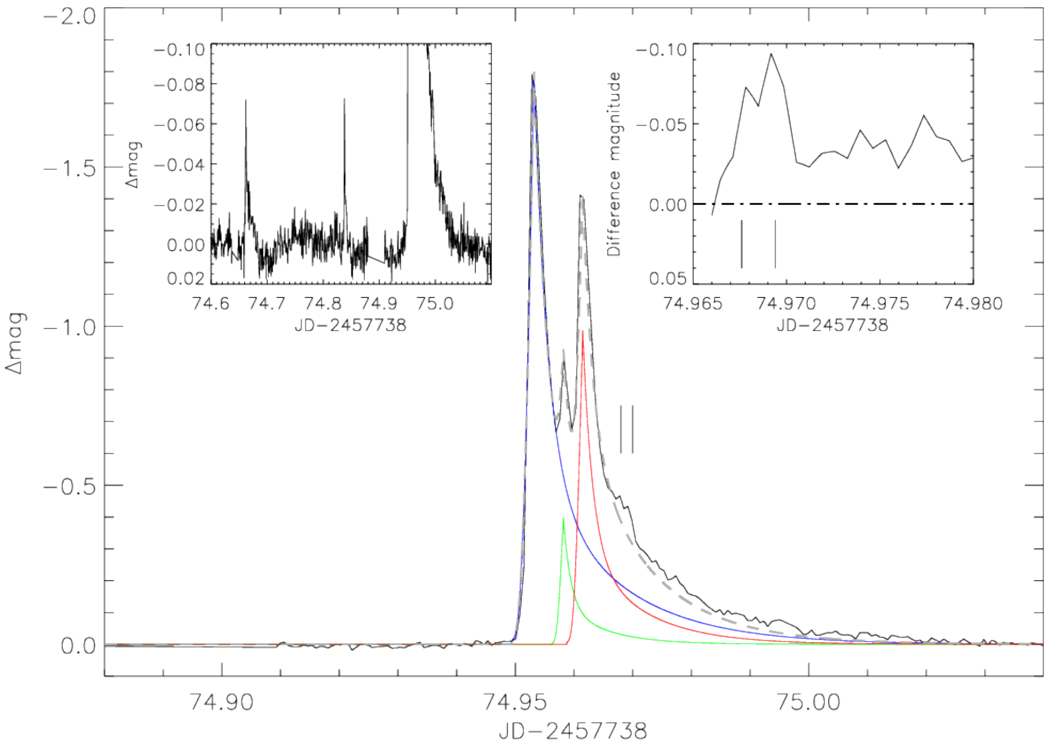
Fun fact: the time scale of the smaller eruptions is compatible with a CME hitting one of the planets



- Venot et al. (2016): based on the 1985 flare of AD Leo (dV~0.5mag): the atmospheres of two hypothetical orbiting super-Earths would be significantly & irreversibily altered.
- Steady state would be reached in ~30 000 years, but large eruptions are more frequent → constantly changing atmosphere



- Venot et al. (2016): based on the 1985 flare of AD Leo (dV~0.5mag): the atmospheres of two hypothetical orbiting super-Earths would be significantly & irreversibily altered.
- Steady state would be reached in ~30 000 years, but large eruptions are more frequent → constantly changing atmosphere
- An eruption of this scale temporarily changes the habitable zone limits from 0.024-0.049AU to 0.048-0.097AU (very crude estimation)



Bad news

- Flares can threat habitability:
  - can erode atmospheres
  - directly harm life on the surface

Bad news

- Flares can threat habitability:
  - can erode atmospheres
  - directly harm life on the surface

Good news

- UV radiation could be absorbed by photochemical reactions in the high atmosphere and might not even reach surface
- a strong enough magnetic field could shield the planets

Bad news

- Flares can threat habitability:
  - can erode atmospheres
  - directly harm life on the surface
- Kay et al. (2016): Earth-like planets would need ~10..100G
- Vidotto et al (2013): even more, up to 1000G (Earth has ~0.5G)

  → quite unlikely

Good news

- UV radiation could be absorbed by photochemical reactions in the high atmosphere and might not even reach surface
- a strong enough magnetic field could shield the planets

- The flaring activity raises doubts on Earth-like life in the TRAPPIST-1 system
- BUT there might be still chance for life
  - e.g. tardigrade on Earth survive basically everything
  - life could survive under surface of underwater (harder to detect)

- The flaring activity raises doubts on Earth-like life in the TRAPPIST-1 system
- BUT there might be still chance for life
  - e.g. tardigrade on Earth survive basically everything
  - life could survive under surface of underwater (harder to detect)
  - O'Malley-James&Kaltenegger (2016) suggested protective bioluminescence: this could be detected by its correlation with eruptions!

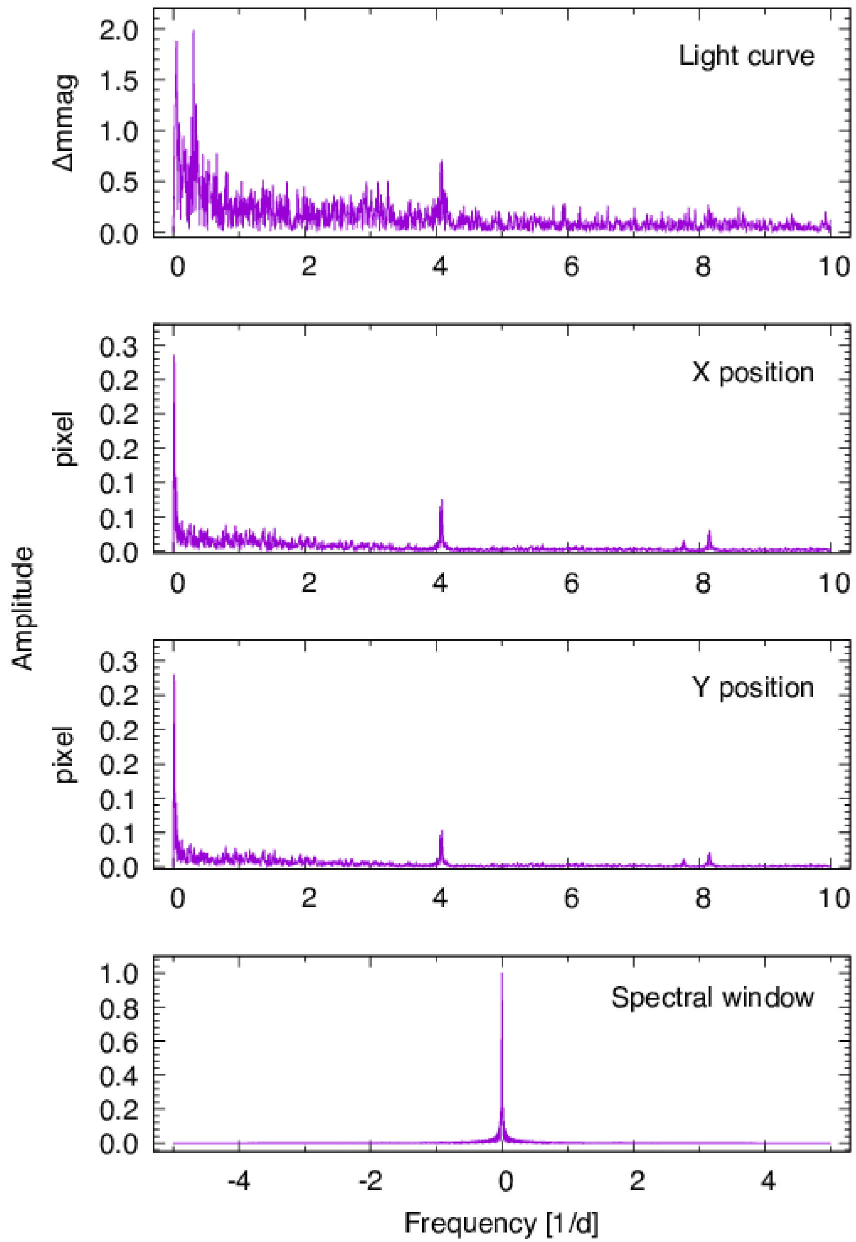
Figure 1. An example of coral fluorescence. Coral fluorescent proteins absorb near-UV and blue light and re-emit it at longer wavelengths (see e.g. Mazel & Fuchs

- The flaring activity raises doubts on Earth-like life in the TRAPPIST-1 system
- BUT there might be still chance for life
  - e.g. tardigrade on Earth survive basically everything
  - life could survive under surface of underwater (harder to detect)
  - O'Malley-James&Kaltenegger (2016) suggested protective bioluminescence: this could be detected by its correlation with eruptions!
  - the age of the system (3-8Gyr) could make life possible: earliest life on Earth dates back to 4Gyr (although complex life took longer time to form)

Figure 1. An example of coral fluorescence. Coral fluorescent proteins absorb near-UV and blue light and re-emit it at longer wavelengths (see e.g. Mazel & Fuchs

Conclusions

- The K2 light curve shows several flares, some of these complex eruptions
- The strongest flare has an energy of ~10^{33} ergs, approx. like the Carrington event
- The activity of TRAPPIST-1 is probably disadvantageous for hosting life (especially one we know on Earth)
- the atmospheres of the planets are constantly altered
- but this does not necessarily rule out possibility of life
- As always: more observations needed
- At this point, we know basically nothing about the impact on stellar activity on exoplanets...


Light curve
Δmmag
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
X position
pixel
0.3
0.2
0.2
0.2
0.1
0.1
0.0
0
2
4
6
8
10
Amplitude
Y position
pixel
0.3
0.2
0.2
0.2
0.1
0.1
0.0
0
2
4
6
8
10
Spectral window
1.0
0.8
0.6
0.4
0.2
0.0
-4
-2
0
2
4
Frequency [1/d]