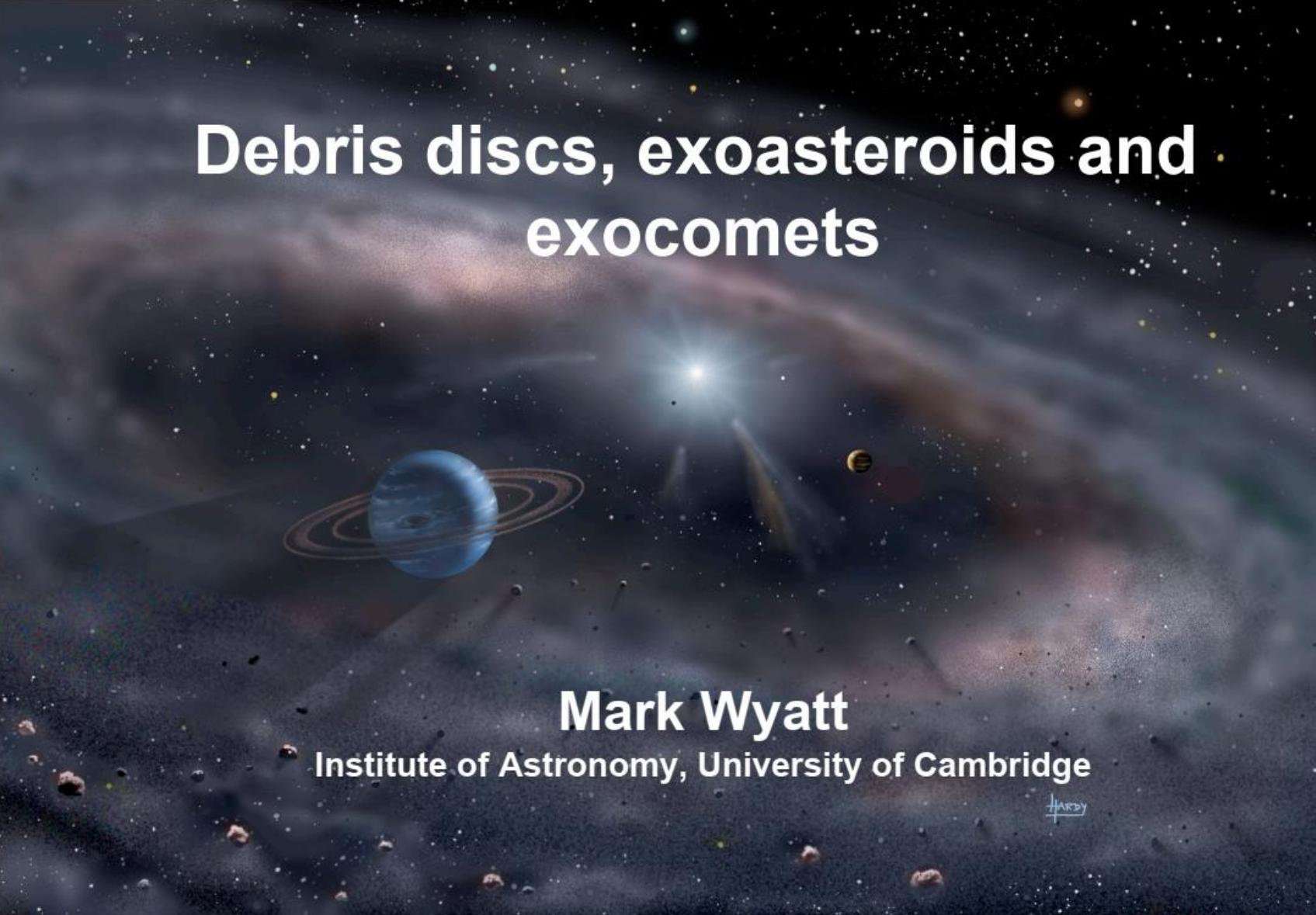


Exoasteroid impact flares: past and future optical observations at Maidanak

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1985-2012 – UBAI (Tashkent)
2012-present – INASAN (Moscow)

6th MUM, Tashkent Uzbekistan
01-03 Nov 2021

Debris discs, exoasteroids and exocomets



Mark Wyatt

Institute of Astronomy, University of Cambridge

HARDY

exosystem population

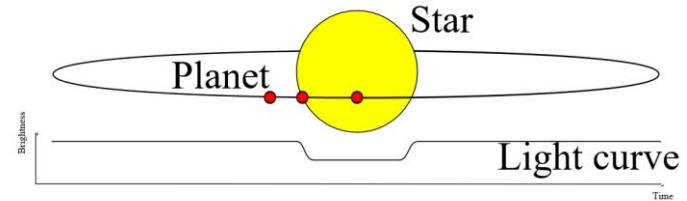
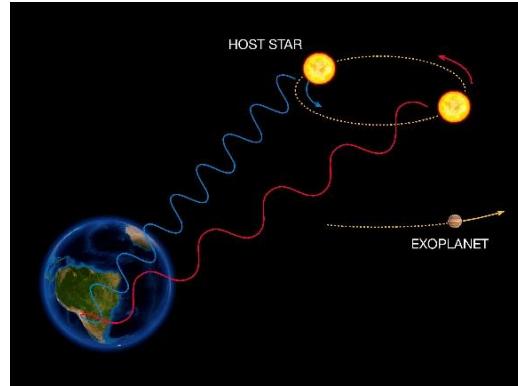
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exo-planets (discovered in 1995)	1-10	$\sim 5 \times 10^3$
exo-comets (discovered in 1987)	$\sim 10^{3-4}$	$\sim 5 \times 10^2$
exo-asteroids (discovered in 2013)	$\sim 10^{5-6}$	$= 2 \times 10^0$

expectation for optic (if impact of exoasteroid)

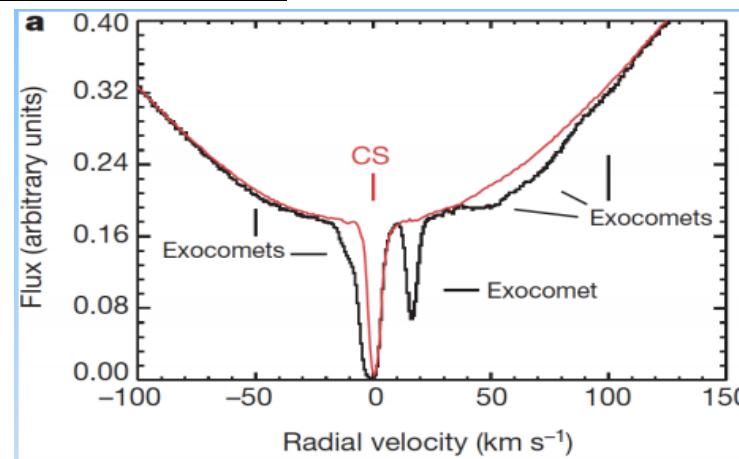
Exoasteroid typical sizes in km (No. of similar asteroids in Solar System)	Exoasteroid kinetic energy in Joule, dense 5 g/cm ³ velocity 10 km/sec (energy in Erg)	Comparison between exoasteroid kinetic energy and star flare energy (star flare analogs)
1 km (~ 750 000)	10^{20} (10^{27})	Typical Solar flares
10 km (~ 10 000)	10^{23} (10^{30})	Powerful Solar flares
100 km (~ 200)	10^{26} (10^{33})	Typical Solar vicinity UV Cet type flares
1000 km (~ 1)	10^{29} (10^{36})	Flare stars in clusters and aggregates. Episodic Superflare on stars.

detection methods

exoplanet:
spectra/doppler
photometry/transit



exocomet:
spectra/FEB



exoasteroid:
photometry/flare
(exoimpact flares)



exoimpact flares observed in IR

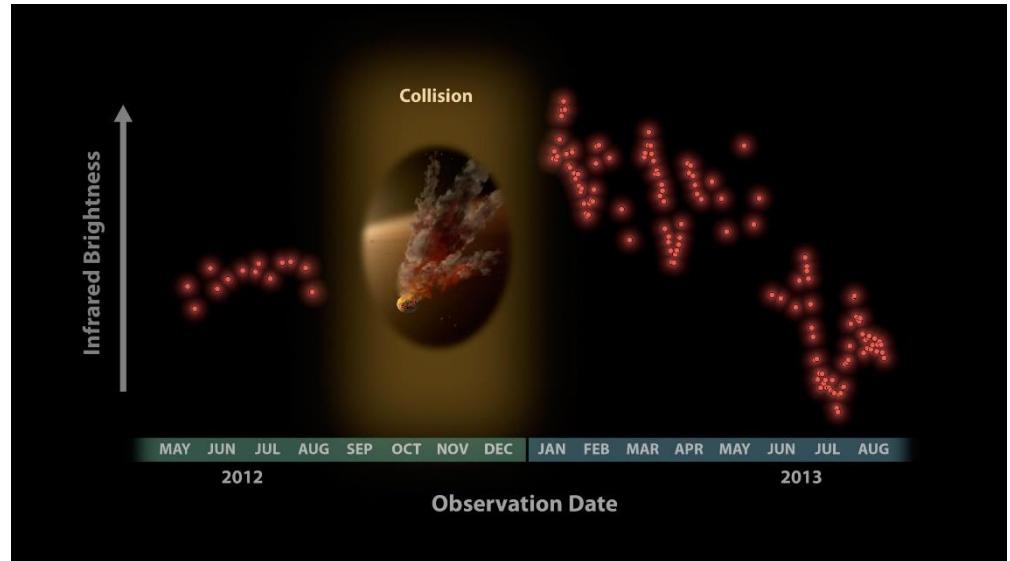
Flare-1 (Meng+ 2014)

Spitzer: 3.6 and 4.5 μ m

ID8 NGC2547 (2012-2013)

asteroid size ~ 180 km

asteroid density ~ 3700 kg/m³



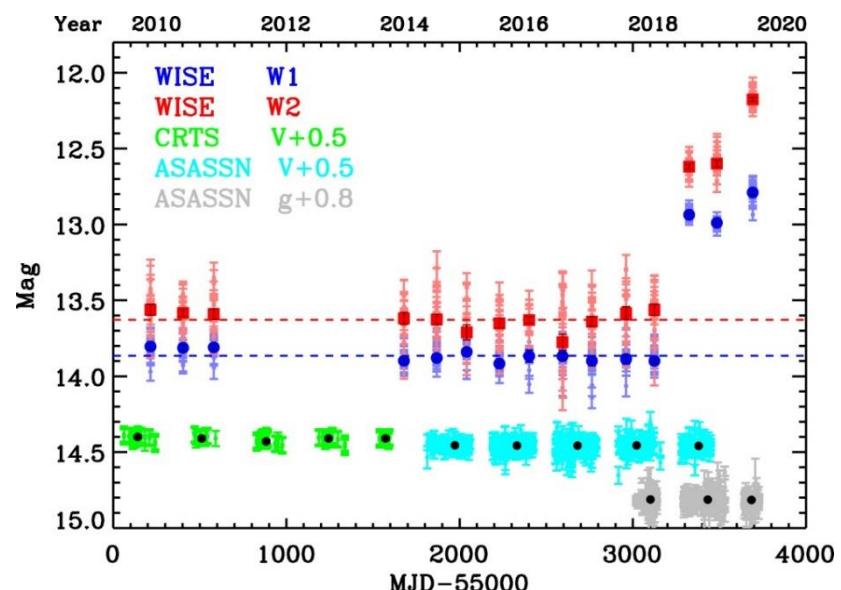
Flare-2 (Wang+ 2019)

WISE: 3.4 and 4.6 μ m

WD 0145+234 (2018-2019)

asteroid size few $\times 10^1$ km

dust mass $\sim 3 \times 10^{15} - 3 \times 10^{17}$ kg



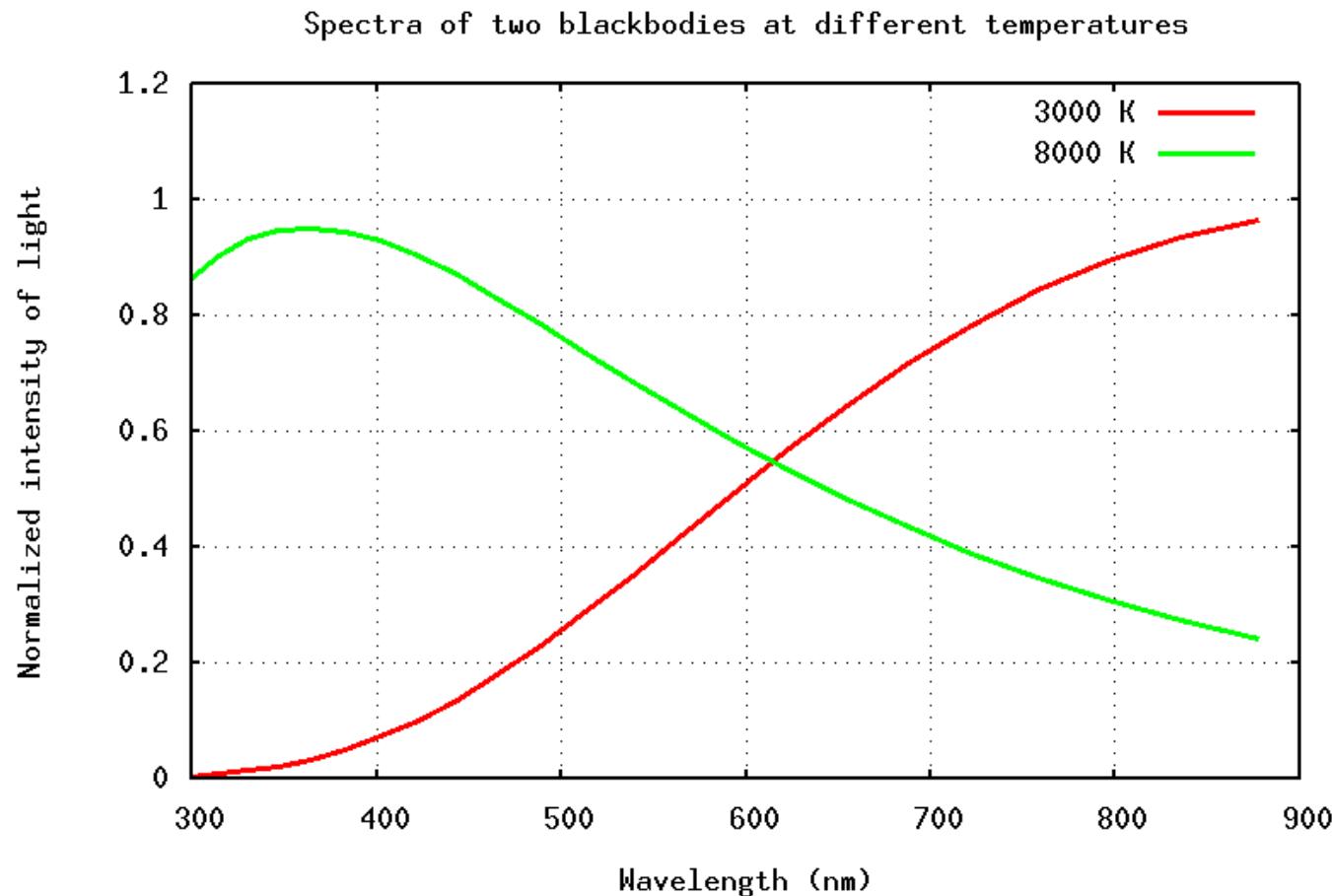
optic:

UV Cet type flares

exoimpact flares

“blue” SED

“red” SED



UU CrB: single F8 V
 Strömgren + Kron photometry
 1 red flare (Olson 1980)

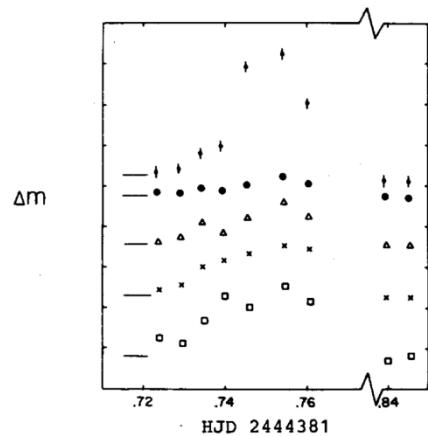


Figure 1: Light curve of the flare in HD 137050. Top to bottom, infrared to ultraviolet. Curves have been shifted vertically for clarity; Δm = HD 137050 - reference, and steps are 0.1 mag. Quiescent light levels are indicated by horizontal lines. Mean errors are shown on the I - curve, and are somewhat smaller in other colors.

1980 May 21
 7 points
 > 40 minutes

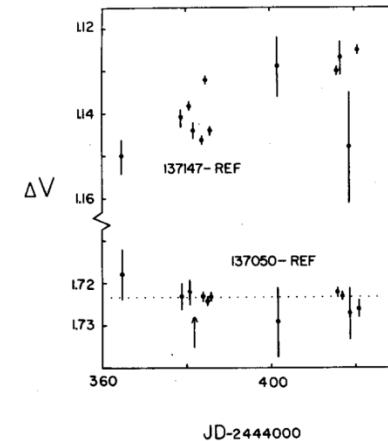


Figure 2: Differential visual magnitudes for U Cr B comparison star (above) and flare star (below). Vertical arrow marks the time of the flare. Nightly mean errors are shown.

amplitudes:

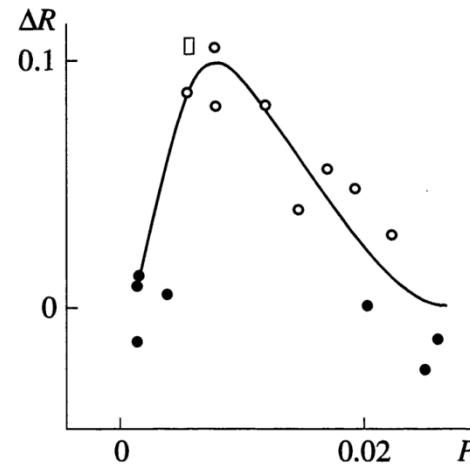
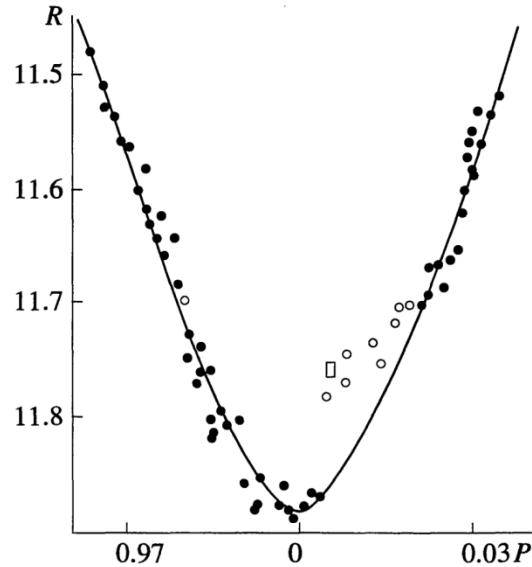
$$\Delta I : \Delta V = 0.30 : 0.05$$

colors:

$$uvby + I$$

difficult to compare

FF Ori: eclipsing binary B8 V + F0 IV-III
 UBVR photometry
 2 red flares (Zakirov 1993, 1996)



1991 Oct 26
 1 point
 ~2 minutes

1992 Oct 22
 8 points
 63 minutes

Fig. 5. Light curve of the flare in FF Ori in the red.

Fig. 4. Portion of the primary minimum of FF Ori in the red (open symbols are flares).

amplitudes:

$$\Delta R \approx 0.1$$

UVB – no changes

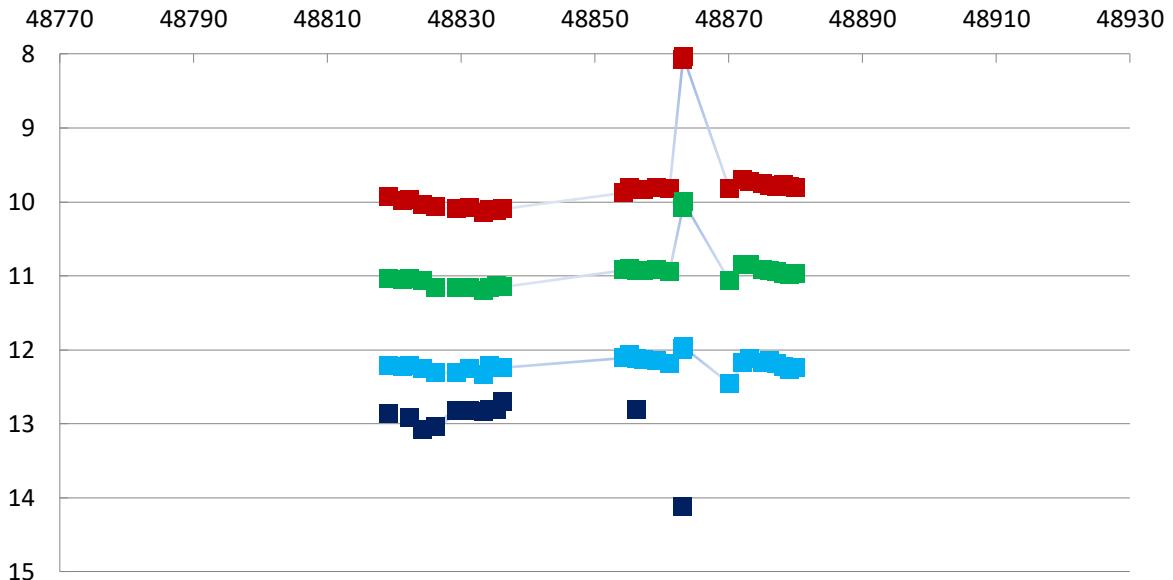
colors:

Min I

$$(V-R) \approx 0.25$$

flare color

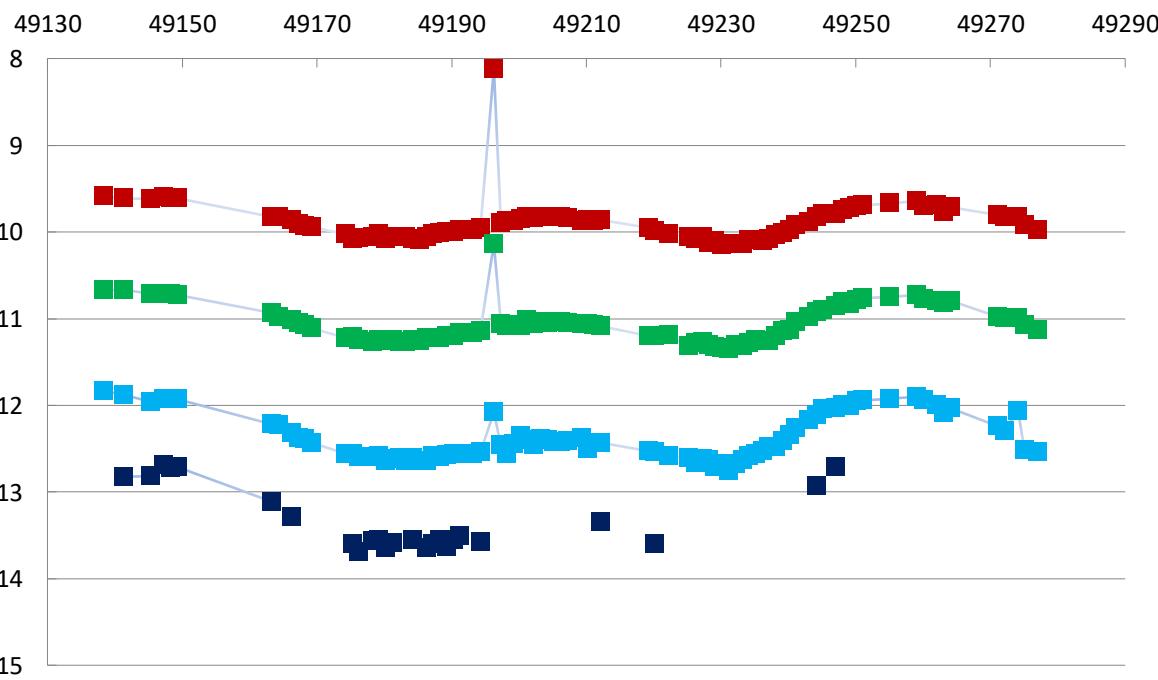
$$(V-R) \approx 0.31$$



1992 Aug 28

68 minutes

3 BVR + 1 U points



optic: “red flare” on stars

STATISTICS:

3 objects / 5 flares

UU CrB (1) FF Ori (2) IX Oph (2)

7×10^{35} 10^{36} $> 10^{39}$ (erg)

RELIABILITY:

4 observers / 3 telescopes / 2 observatories

FEATURES:

star/system

F-K type

(2 binary systems)

duration

> 30 min

(slow flares)

recurrence

2 objects

(~1 year recurrence)

«3-REDNESS»:

red maxima

(maximum in R/I)

red amplitudes

($\Delta R > \Delta V > \Delta B > \Delta U$)

red colors

(IX Oph: U-B, B-V, V-R ~ 2 mag)

“red flares” on IX Oph (Ibrahimov 2019)

Таблица 1: Амплитуды и цвета красных вспышек IX Oph.

JDH24..	ΔU	ΔB	ΔV	ΔR	$U - B$	$B - V$	$V - R$
48863.1799	–	0.231	0.936	1.822	–	1.906	1.994
48863.1853	-1.252	0.220	0.951	1.827	2.121	1.932	1.984
48863.2271	–	0.252	1.022	1.869	–	1.971	1.955
49196.3041	–	0.303	0.939	1.791	–	1.943	2.014
<i>Average</i>	-1.3	0.25	0.96	1.83	2.1	1.94	1.99

maximum: $\Delta R \approx 1.8$

amplitudes: $\Delta R : \Delta V : \Delta B : \Delta U \approx +1.8 : +1.0 : +0.3 : -1.3$

colors: $(U-B) \approx (B-V) \approx (V-R) \approx +2.0$

“3-redness” for IX Oph flares:

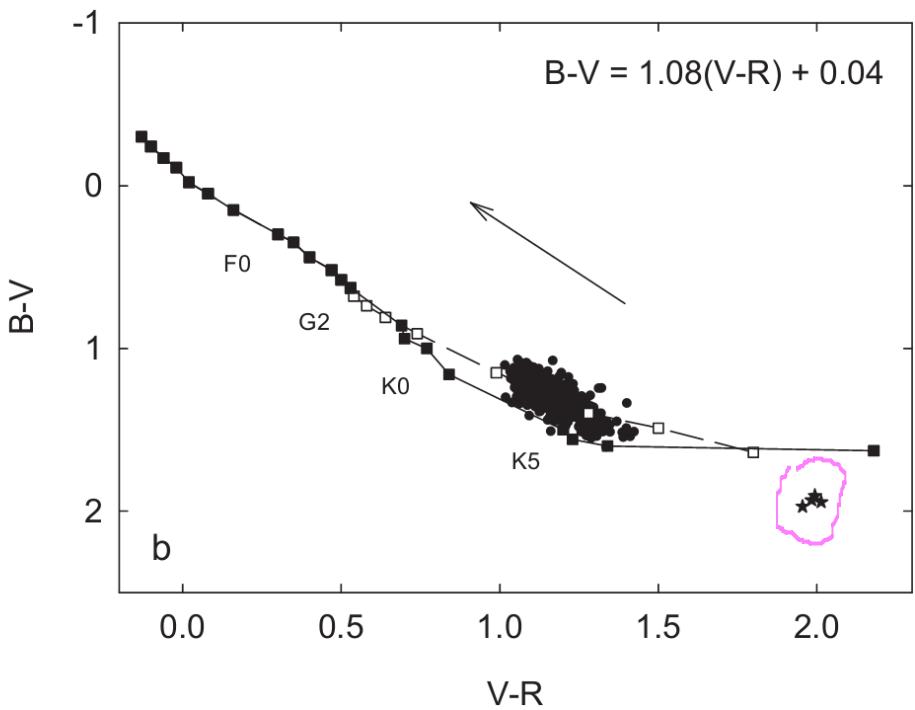
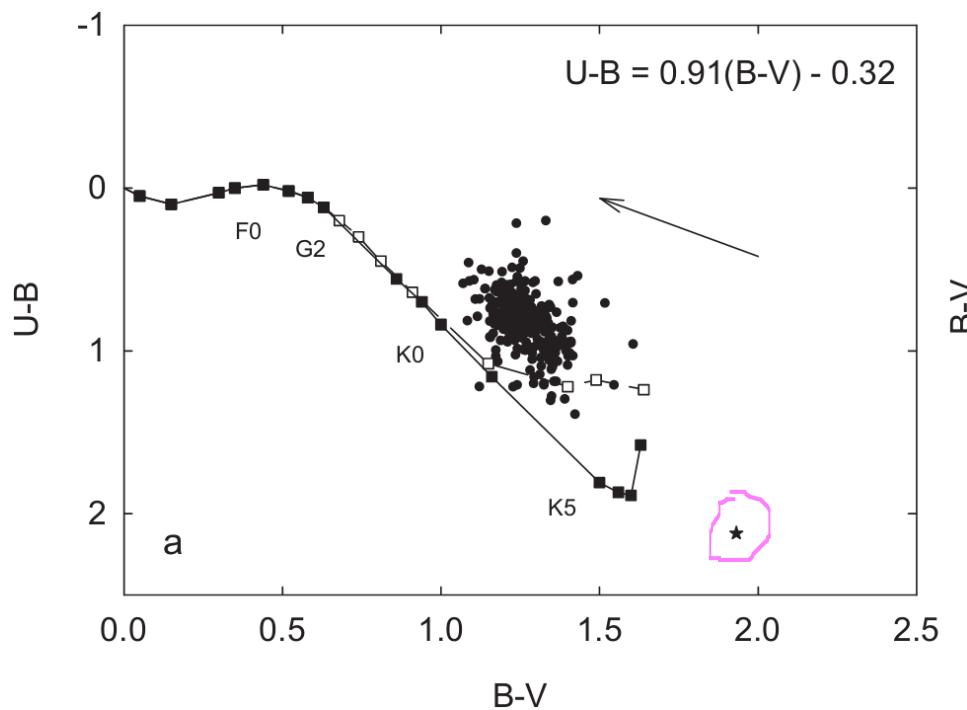
redness-1 “red” maximum

redness-2 “red” amplitude distribution (opposite to UV Cet flares)

redness-3 “red” colors

IX Oph: (U-B, B-V) and (B-V, V-R) diagrams

Maidanak 1987-2003



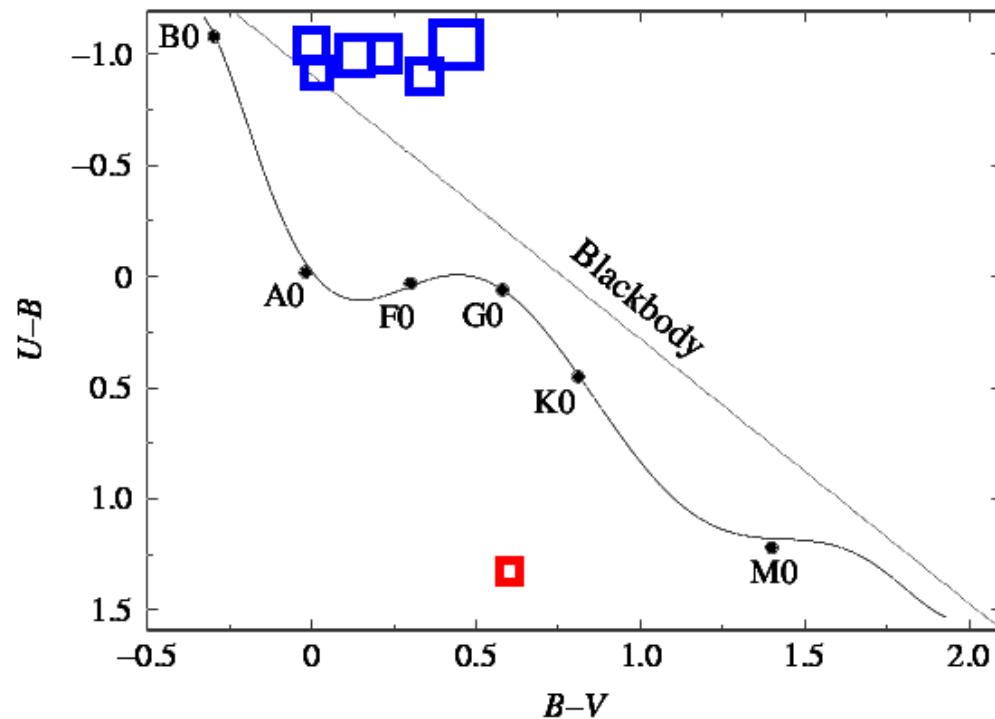
red colors:

ok

blue colors:

excess $(U-B) \approx -0.3$

(U-B, B-V) diagram: intrinsic flare colors
UV Cet type stars vs. IX Oph



UV Cet-star colors
IX Oph colors

Gershberg 2015
Ibrahimov 2019

red flares = exoimpact flares



exosystem population

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kepler

HR-diagram for flare stars

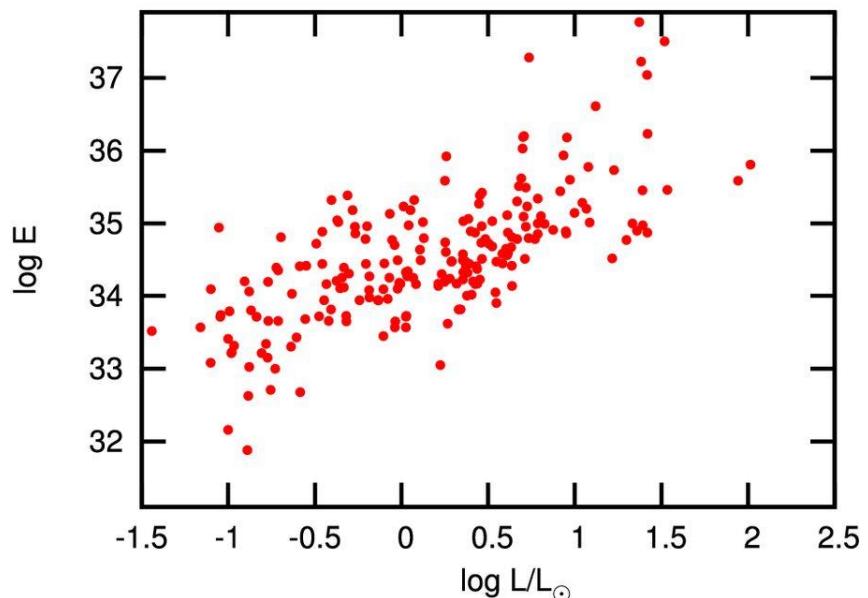
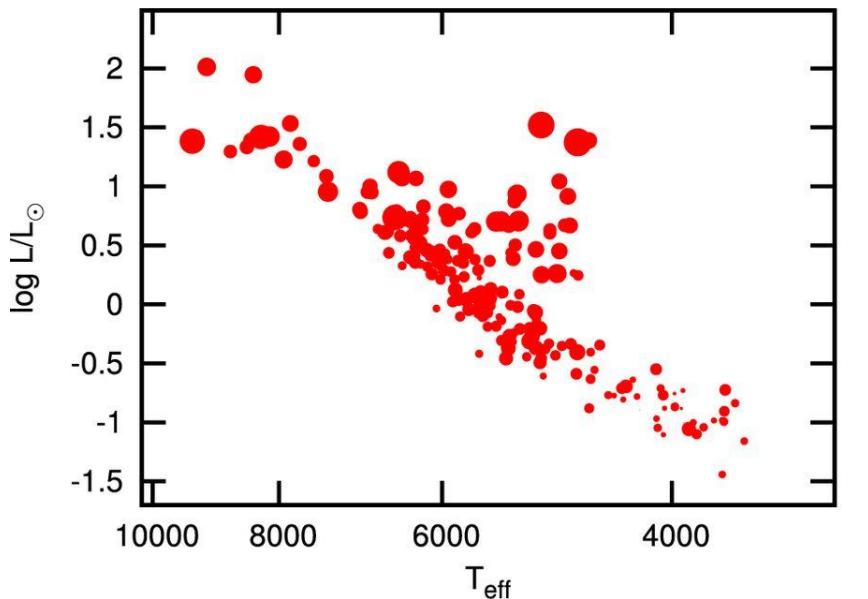
flares:

~ 3500 (Balona 2015)

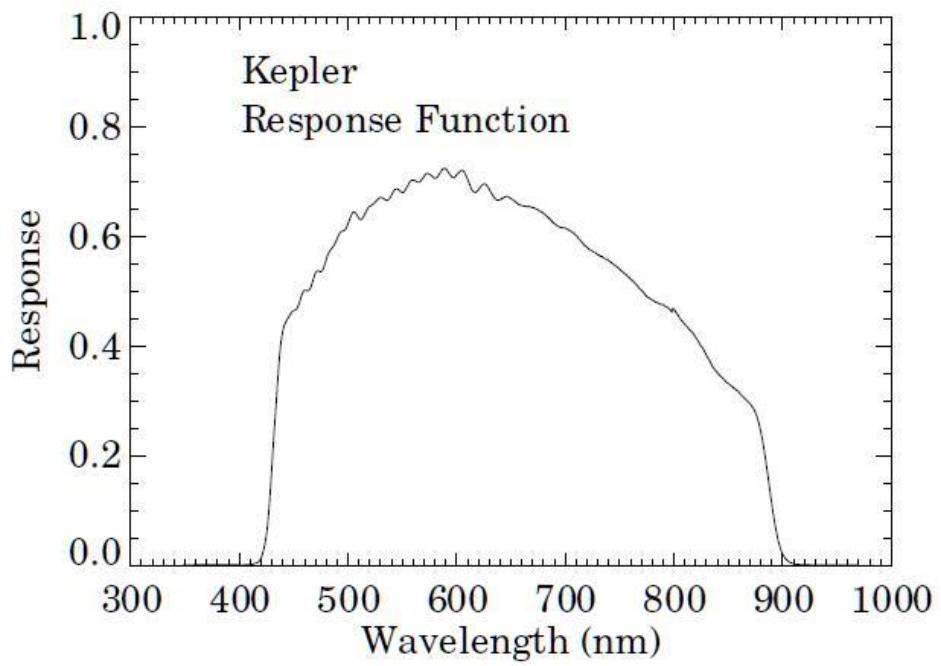
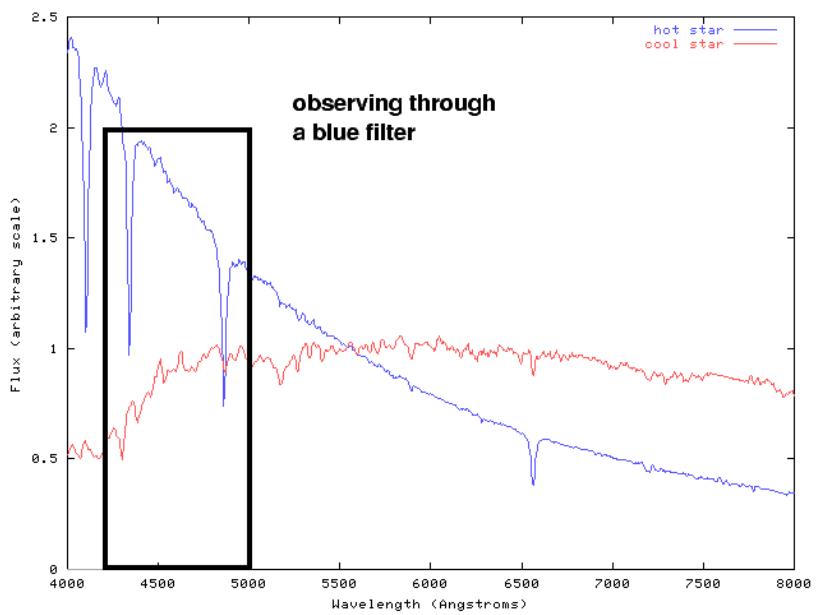
superflares:

~ 1500 (Maehara+ 2015)

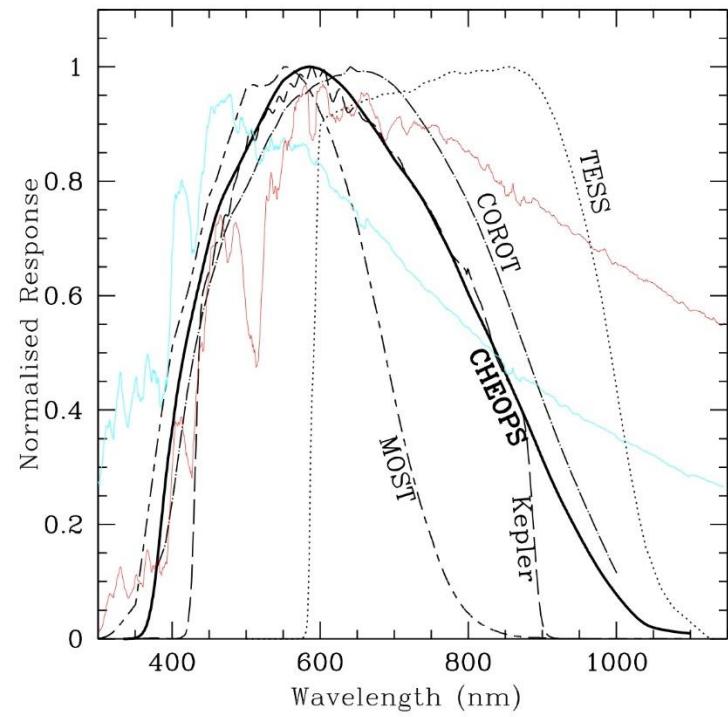
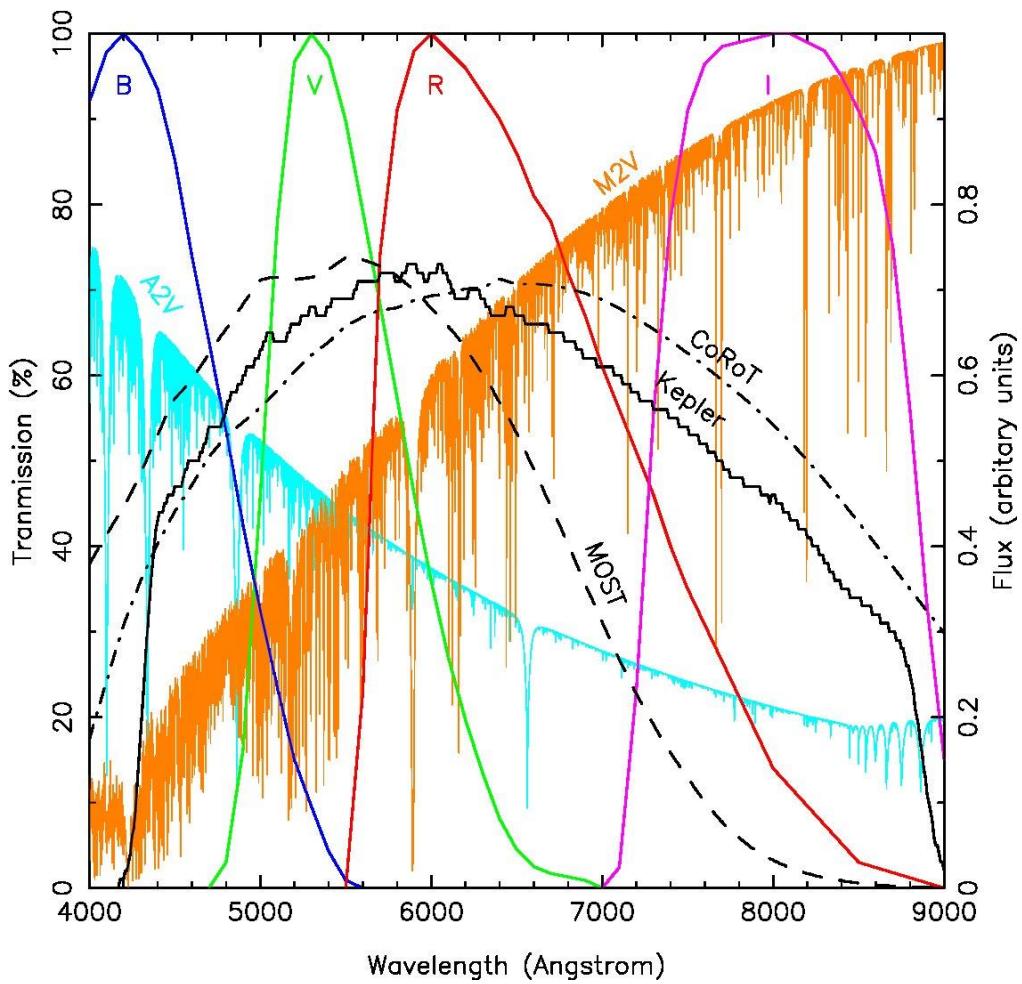
distribution on flare energy



kepler vs past-time pg/B surveys



recent space photometric missions: they are color-indifferent !



space photometric missions:

if color-indifference
(no sense for blue/red flares),

flare contamination
(impact flare contamination)
could be happening

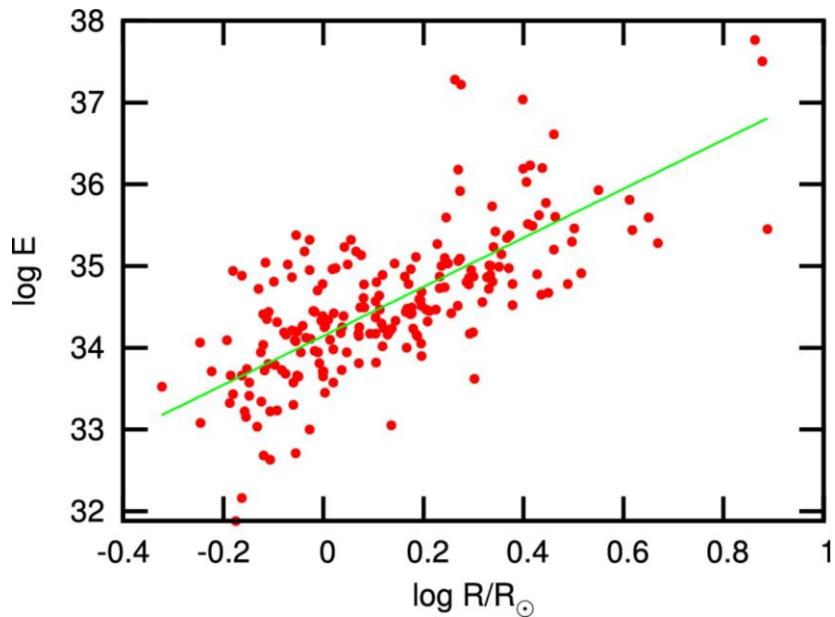
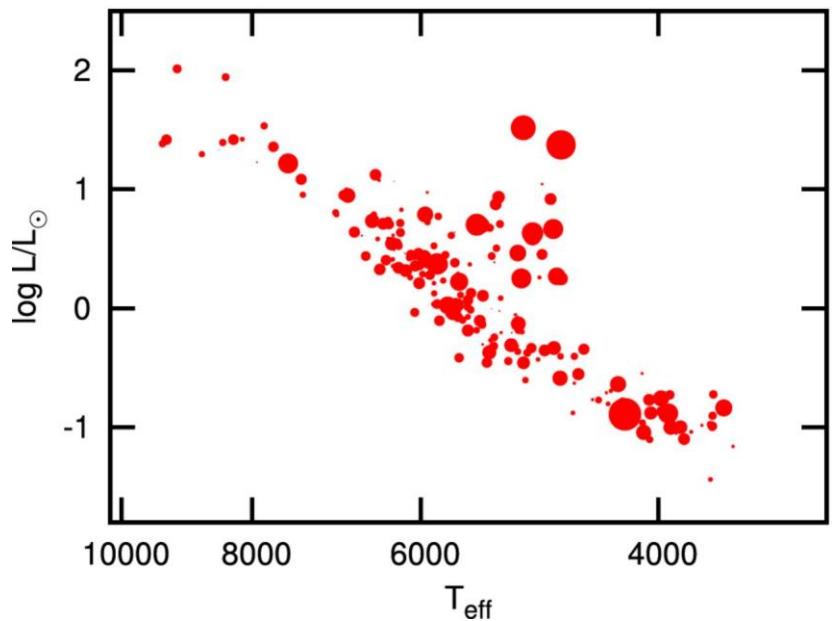
analogy:
stellar contamination

impact flare contamination: how to detect ?

kepler:

distribution on
flare duration

distribution on
flare energy –
size of the star



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conclusions

2 new definitions are supposed for exosystem science:

- “red flares” on stars (5 flares/ 3 objects)
- “impact flare contamination”

red flare interpretation is suggested:

red flare is an impact flare of exoasteroid

method to detect impact flares in optic is proposed:

- using space data and impact flare contamination
- no. of exoasteroids: increase by an order of mag is expected

MAIDANAK-past

MAIDANAK-future

discovery of exoimpacts in optic

increase a no. of exoimpacts by an order of mag
(from ~5 to ~50)

THANK YOU !

Sincerely,
Mansur Ibrahimov