Superflares on Solar Type Stars Observed with Kepler

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Space weather study becomes increasingly important for our electronic civilization. One of the main cause of space environmental disturbance is large solar flare. The largest solar flare that our civilization have experienced is Carrington event in 1859, and the total energy of the flare is of the order of 10^{32} erg.

We study superflares (whose total energy is more than 10^{33} erg) on solar type stars with Kepler space telescope and detected 1,547 superflares on 279 solar type stars. Typical frequency of superflare of 10^{34} erg on solar type star is once in 800 years. Our study implies the probability that our Sun exhibits superflare.
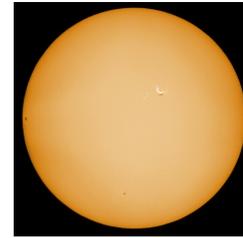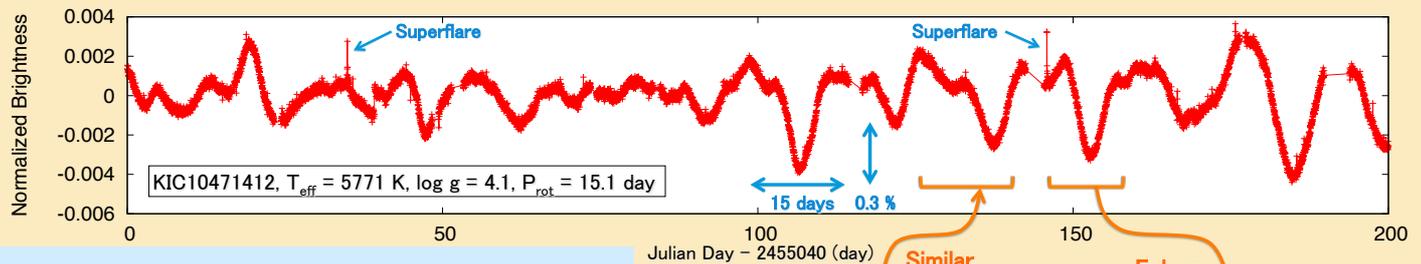
Large solar white light flare
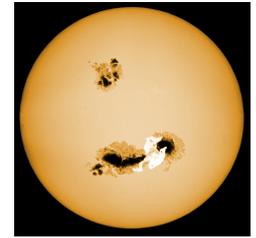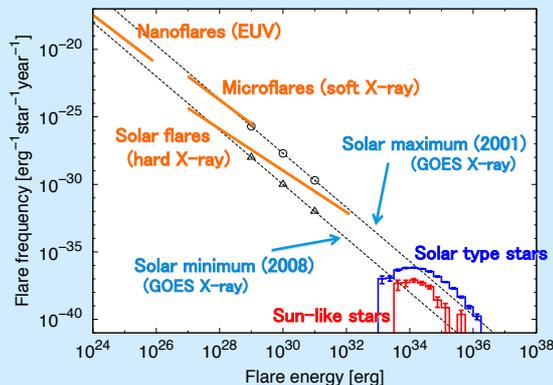
Artistic illustration of superflare

Light Curve of a Superflare Sun-like Star

Solar type star : 5100 K $< T_{eff} <$ 6000 K, log g $>$ 4.0,
Sun-like star : 5600 K $< T_{eff} <$ 6000 K, log g $>$ 4.0, $P_{rot} >$ 10 day

KIC10471412, T_{eff} = 5771 K, log g = 4.1, P_{rot} = 15.1 day

Superflare   Superflare   15 days   0.3 %

Julian Day − 2455040 (day)   Similar   Enlarge

Statistics of Superflare

Kepler space telescope observes photometric light curve of about 80,000 solar type stars. For comparison with solar flare, we define "Sun-like stars" (5600 K $< T_{eff} <$ 6000 K, log g $>$ 4.0, $P_{rot} >$ 10 day). 44 superflares are observed on 19 Sun-like stars. The superflare frequency distribution on Sun-like stars is roughly on the same slope as that of solar flare, and locates between that of solar maximum and minimum. Stars more similar to the Sun ($P_{rot} >$ 20 day) have superflare (Table below)
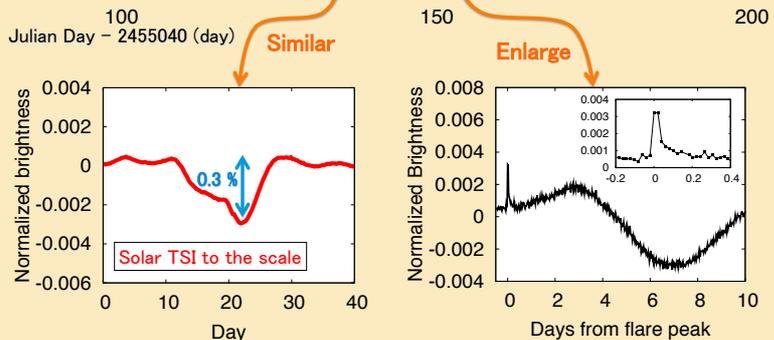

Light curve of the Sun in 2003 (SORCE). Darkening caused by sunspot, which is similar to stellar light curve. This implies existence of stellar spot on superflare stars. Most of superflare stars show spot-like brightness variation. The typical amplitude is 1%, therefore, the typical spot size of superflare stars is 10% of stellar radius. We estimated stellar rotation period from brightness variation period.

Enlarged light curve of a superflare on the superflare star above. The amplitude of this superflare is about 0.3 % of stellar brightness. Typical amplitude of superflare is 1 % of stellar brightness. This is larger than that of solar flare detected from total solar irradiance (0.03%).

Superflares on Sun-like Stars with P_{rot} > 20 days

KeplerID	T_{eff} (K)	log g	$R/R_\odot$	$P_{rot}(day)$	# of flares
5522535	5732	4.3	1.3	20.3	1
7597685	5834	4.6	0.9	21.8	1
8212826	5811	4.2	1.4	26.3	2
9766237	5674	4.6	0.9	21.8	1
9944137	5725	4.6	0.8	25.3	1
11401109	5732	4.5	0.9	29.1	1
Sun	5780	4.4	1.0	28.0	

Number of Flares, Flare Stars and Sample, and Fraction of Flare Stars

T_{eff}	Slowly Rotating ($P_{rot} > 10d$)				Rapidly Rotating ($P_{rot} < 10d$)				Total			
	N_{flare}	$N_{flarestar}$	N_{all}	$f_{flarestar}$	N_{flare}	$N_{flarestar}$	N_{all}	$f_{flarestar}$	$N_{flarestar}$	N_{all}	$f_{flarestar}$	
5100-5600	353	50	14026	0.0036	810	133	1281	0.104	1163	183	15307	0.012
5600-6000	44	19	14325	0.0013	340	77	1825	0.042	384	96	16150	0.0059
	397	69	28351	0.0024	1150	210	3106	0.068	1547	279	31457	0.0089

Superflare on the Sun?

Our study suggests a occurrence of superflare on the Sun. Typical frequency of superflare of 10^{34} erg on Sun-like stars is once in 2000 years. From theoretical point of view, our Sun can store enough magnetic energy to cause superflare of 10^{34} erg within one solar cycle (Shibata et al. 2013). Observationally, large cosmic ray events in 7th and 9th century are found from tree ring (Miyake et al.). Although the source of this cosmic ray is under discussion, this event can be caused by solar superflare. The frequency of these events is consistent with superflare frequency of this study.

In 1989, X15 solar flare caused large scale black out in Quebec, Canada and broke a transformer in USA. If solar superflare occur in this era of electronic communication, estimated damage is very large. Black out and communication failure all over the world and break down of almost all artificial satellite are possible.

Reference

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