Superflare and starspot activity of solar-type stars studied from photometric and spectroscopic data

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Superflares are flares that release total energy 10-10^4 times greater than that of the largest solar flares ever observed (~10^{32} erg). Recent Kepler-space-telescope observations found more than 1000 superflares on a few hundred solar-type (G-type main sequence) stars (e.g., Maehara+2012 Nature; Shibayama+2013 ApJS; Maehara+2015 EpS). Our statistical analyses of such large number of superflares indicate that the frequency distribution to the flare energy of the superflare show power-law distribution (dN/dE $\propto$ E^a with a ~ -2) and this distribution is almost consistent with that of the Sun. Many of the superflare stars show quasi-periodic brightness variations with the typical period of from one to a few tens of days and the typical amplitude of from 0.1 to 10% (Notsu+2013 ApJ). We have conducted spectroscopic observations of such superflare stars with Subaru/HDS and Apache Point 3.5m telescope. We measured the projected rotation velocity (v sin i) and the intensity of chromospheric lines (e.g., Ca II H&K, Ca II 8542A, Ha6563A), and support that the brightness variations are caused by the rotation of superflare stars with large starspots (Notsu+2015a&2015b PASJ, 2018 in prep).
On the basis of these results, we can estimate rotation period and starspot coverage from these brightness variations, and discuss stellar properties of superflare stars (Notsu+2013 ApJ; Maehara+2017 PASJ). The size distribution of starspots shows the power-law distribution which is on the same line of the size distribution of relatively large sunspots. The frequency-energy distributions for flares originating from spots with different sizes are the same for solar-type stars with superflares and the Sun.
These results suggest that the magnetic activity on solar-type superflare stars and the Sun are caused by the same basic physical processes. Future long-term monitoring of the chromospheric activity and research on possible coronal mass ejections accompanying with superflares will give us an insight on the effects of superflares on (exo)planetary environments, and possible extreme space weather events on the Earth (e.g., Airapetian+2016 Nature Geosciences; Lingam&Loeb 2017 ApJ).

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