Lithium abundances in Super-Flare stars

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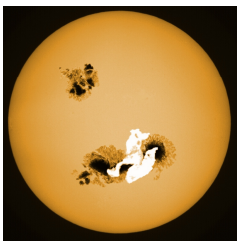
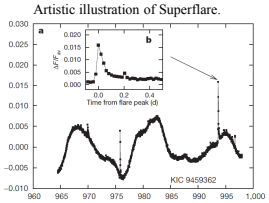
We will report on the abundance analysis of Li in G-type superflare stars which were found by the analysis of Kepler photometric data (c.f. Notsu's presentation). Li is a key element to understand the evolution of the stellar convection zone and BBN nucleosynthesis. We performed the high dispersion spectroscopy of G-type superflare stars by Subaru/HDS, and derived the Li abundances in 10 objects. The derived Li abundances show higher values than that of the Sun in all these objects. We will discuss the reason of these high Li abundances in superflare stars.

Superflare stars discovered by the Kepler data



Artistic illustration of Superflare.



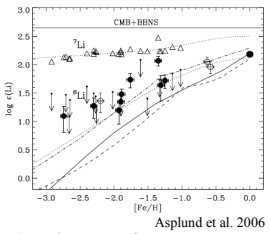
Lightcurve of superflare star KIC945936.
Maehara et al. 2012

Solar flares are the most energetic explosions on the surface of the Sun, and are thought to occur by release of magnetic energy. Flares are also known to occur on various types of stars including solar-type stars. Among them, young stars, close binary stars, and dMe stars sometimes produce ”superflares”, flares whose total energy is 10-10^6 times larger (10^{33-38} erg) than the largest flares on the Sun (10^{32}erg) (Schaefer et al. 2000).

We have already analyzed the data by the Kepler Spacecraft, and discovered 365 superflare events on 148 **solar-type stars** that have the surface temperature of 5,100K < *T*eff < 6,000K, and surface gravity of log *g* > 4.0 (Maehara et al. 2012).

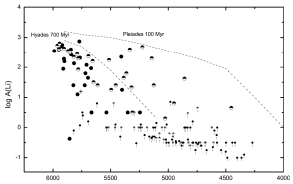
Lithium abundance in the stellar photosphere

Big Bang Nucleosynthesis



Asplund et al. 2006

Age index of young stars



Mishenina et al. 2012

The accurate spectroscopic determination of the Lithium abundance and, in particular, the ^{6}Li/^{7}Li isotopic ratio in stellar atmospheres is of crucial importance for addressing questions about the big bang nucleosynthesis, the chemical evolution of the Galaxy, mixing processes in stellar interiors, and the evolution of extrasolar planetary systems.

In addition, accurate measurements of the lithium abundance in young solar-type stars provide independent and reliable age diagnostics.

High dispersion spectroscopy of Superflare stars

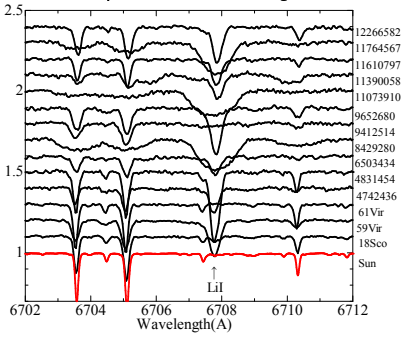
High dispersion spectroscopy was carried out for 24 Superflare stars on 2012 Aug. 6-8, and Sep. 22-25 (S12A-111: P.I. Y.Notsu) using Subaru/HDS. The spectrum covers 6100-8820 Å with a resolving power of 50,000 by 2 × 2 on-chip binning. This spectral range includes lines of Li I (6708), Hα (6563), and Ca II triplet (8498, 8542, 8662). We derived the Li abundances and *v*sin*i* (projected rotational velocity) from those spectra using the atmospheric parameters determined by Kepler Input Catalog (KIC). A half of the targets were proved to be binary systems, and we excluded them in the following analysis.

Stellar parameters and Li abundance

KIC ID	$T_{\rm eff}$	log *g*	[Fe/H]	P	*v* sin *i*	Li
4742436	5628	4.2	-0.72	2.34	2.7	2.4
4831454	5298	4.6	-0.47	5.19	0	3.0
6503434	5714	4.3	-0.42	3.89	5.3	2.3
8429280	4616	4.4	-1.35	1.17	33.7	2.8
9412514	5958	4.2	-0.38	1.85	7.7	2.0
9583493	5445	4.5	-0.73	5.30	5.7	2.9
9652680	5618	4.8	-0.30	1.41	38.8	3.9
11073910	5381	4.6	-0.45	5.57	6.8	2.2
11390058	5785	4.3	-0.42	11.86	2.6	2.6
11610797	5865	4.5	0.07	1.69	25.1	3.9
11764567	5238	4.4	-0.51	20.00	15.2	1.4
12266582	5434	4.3	-0.44	7.14	4.3	2.5

P = period of the brightness variation of target stars (day)

Spectra of Li I (6708 A) region

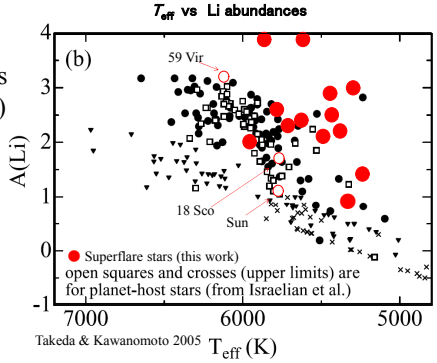


Behaviors of Li abundance

The behavior of the Li abundance in solar-type stars is still unclear. A large diversity (by more than 2 dex) of the Li abundance is seen, despite the similarity of stellar parameters (e.g., Takeda & Kawanomoto 2005). The Li depletion is remarkably seen in the stars whose temperature is lower than the sun.

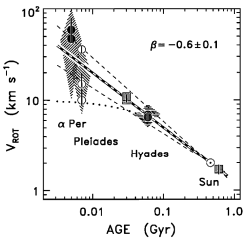
Takeda et al. (2010) proposed that the stellar rotation may be the most important parameter in determining the surface Li content. However, some slowly-rotating Superflare stars show high values of the Li abundance in our analysis.

$T_{\rm eff}$ vs Li abundances

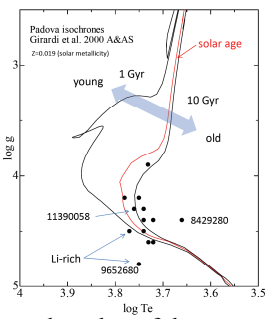


Takeda & Kawanomoto 2005

Are superflare stars young ?



Dependence of the rotational velocity on the age of solar-type stars. (Ayres 1997)

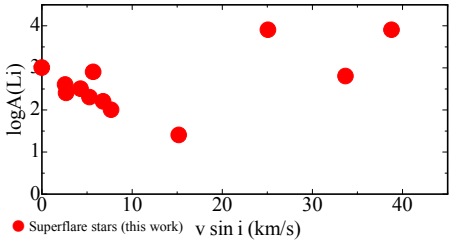


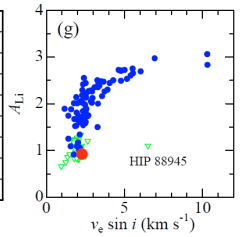
The Li abundance in superflare stars have higher values than that of the sun. Especially, those stars with a very high Li abundance are suggested to have a rapid rotation velocity from large *v*sin*i* and brightness variations having a short period. The stellar rotation is also an index of the age. It seems reasonable to assume that the age of those stars are young.

However, some superflare stars show small *v*sin*i* (slow rotation). This result may indicate that those stars are not young, though the accurate measurement of the inclination is needed. This inconsistency on the age implies the possibility of Li (^{6}Li) production in site of stellar flares (see : Tatischeff & Thibaud 2007).

In order to know the reason of the high Li abundance, it is important to investigate the ratio of ^{6}Li and ^{7}Li in the solar-analog superflare-stars.

v sin i vs Li abundances





Solar analog stars (Takeda et al. 2010)