White light flare rates of M5-L5 dwarfs using *K2* data

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Abstract

The *K2* mission's unique combination of wide area coverage and continuous time coverage over months has enabled us to study white light flare rates of cool stars of various spectral types. We have shown that the white light flares are ubiquitous in some late-M and early L dwarfs. Some early L dwarfs are even capable of producing superflares with bolometric flare energies greater than 10^{33} erg despite having lower effective temperatures. We update our results on the white light flare rates of very-low-mass stars with a wide range of spectral types: M5-L5, obtained by using both short cadence (∼1 min) and long cadence (∼30 min) *K2* data. We analyze the possible relation between flare rates of very-low-mass stars in our sample and different properties like spectral type, age, etc. Strong magnetic fields of order of 5-10 kilogauss are required to explain the most energetic flares. Using constraints on magnetic fields from the biggest flares, we discuss the nature and evolution of the magnetic dynamo on very-low-mass stars. Our results will be helpful in predicting the number of flares on the low-mass cool stars which will be observed by future photometric surveys like *TESS*.

Sample

Table : Target information

EPIC	Name	Sp. Type	# flares
248856413	GJ 3636	M5.0	113
248601792	GJ 3631	M5.4	179
201885041	Wolf 359	M6.0	201
248695811	2MASS J10204406+0814234*	M6.0	12
212090371	LHS 2090	M6.5	201
206050032	LHS 523	M6.5	50
206135809	2MASS J22021125-1109461	M6.5	50
211332457	2MASS J08352366+1029318	M7.0	11
248602543	2MASS J10444483+0556131*	M7.0	19
211046195	2MASS J03350208+2342356	M7.0	22
249639465	2MASS J15072779-2000431	M7.5	28
206053352	2MASS J22145070-1319590	M7.5	26
212826600	2MASS J13322442-0441126	M7.5	31
200164267	TRAPPIST-1	M8.0	39
210764183	2MASS J03264453+1919309	M8.0	36
228754562	2MASS J12215066-0843197	M8.5	18
201658777	2MASS J12212770+0257198	L0	11
228730045	2MASS J12321827-0951502	L0	11
249903099	2MASS J15485834-1636018	L0	0
249343675	2MASS J15230657-2347526	L0	1
	WISEP J190648.47+401106.8**	L1	21
249914869	2MASSW J1507476-162738	L5	0
210327027	2MASS JJ03552337+1133437	L5	0

*Only long cadence data is available for this target.
** It was observed by primary *Kepler* mission.

Bolometric flare energy distribution in each spectral type

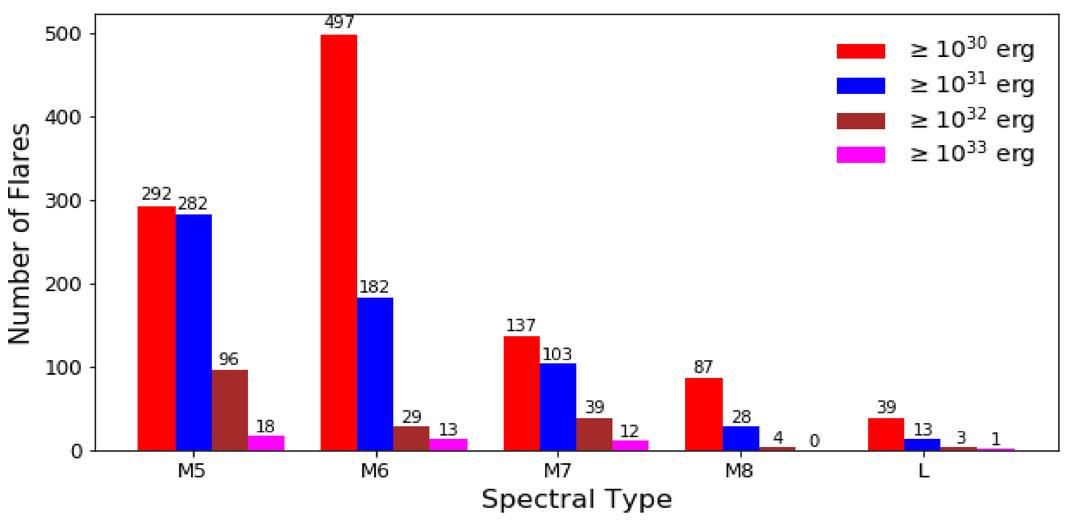

Figure : Bolometric flare energy distribution in each spectral type.

Flare frequency distribution of cool objects. I.

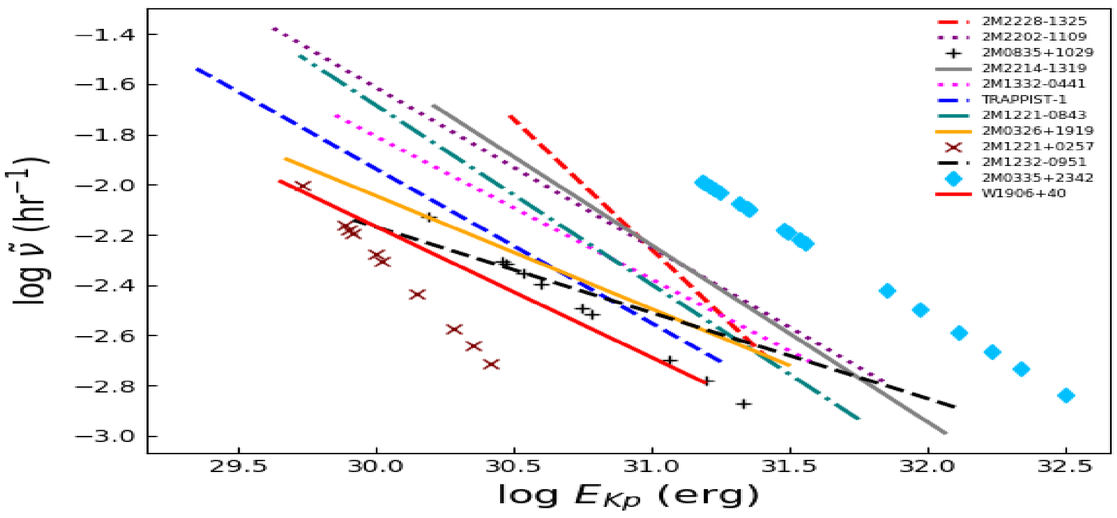

Figure : Updated flare frequency distribution of objects in Paudel et al. 2018. The new energies are calculated using distances from *Gaia* DR2, if available. E_{Kp} is *Kepler* flare energy and $\tilde{\nu}$ is the cumulative frequency of flares having energy $\geq E_{Kp}$. Each line represents the fit to equation: $\log \tilde{\nu} = \alpha$ - $\beta \log E_{Kp}$.

Flare frequency distribution of cool objects. II.

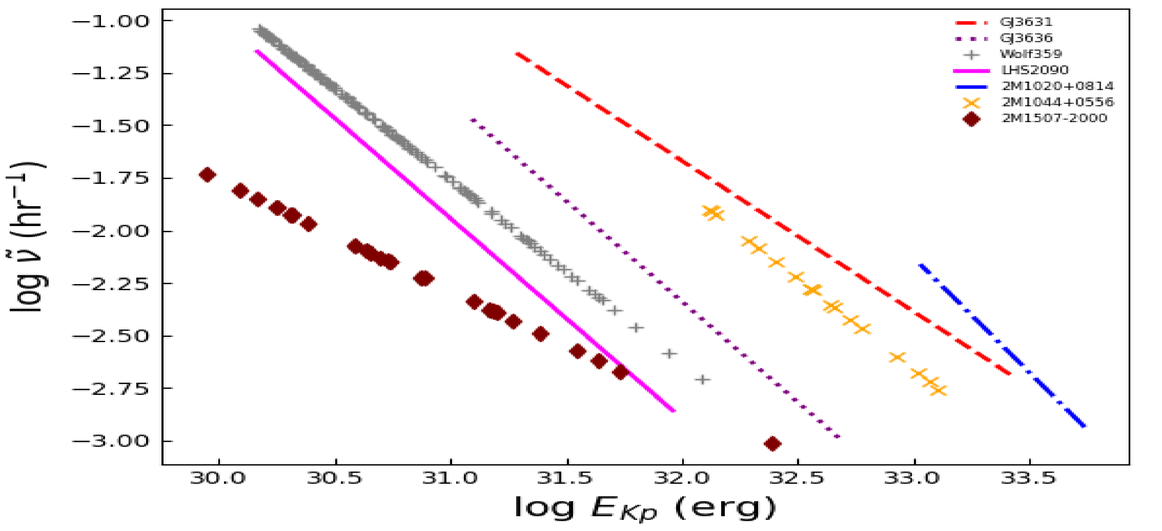

Figure : Flare frequency distribution of objects in Paudel et al. 2018b (in prep). E_{Kp} is *Kepler* flare energy and $\tilde{\nu}$ is the cumulative frequency of flares having energy $\geq E_{Kp}$. Each line represents the fit to equation: $\log \tilde{\nu} = \alpha$ - $\beta \log E_{Kp}$.

Average flare frequency distribution of each spectral type

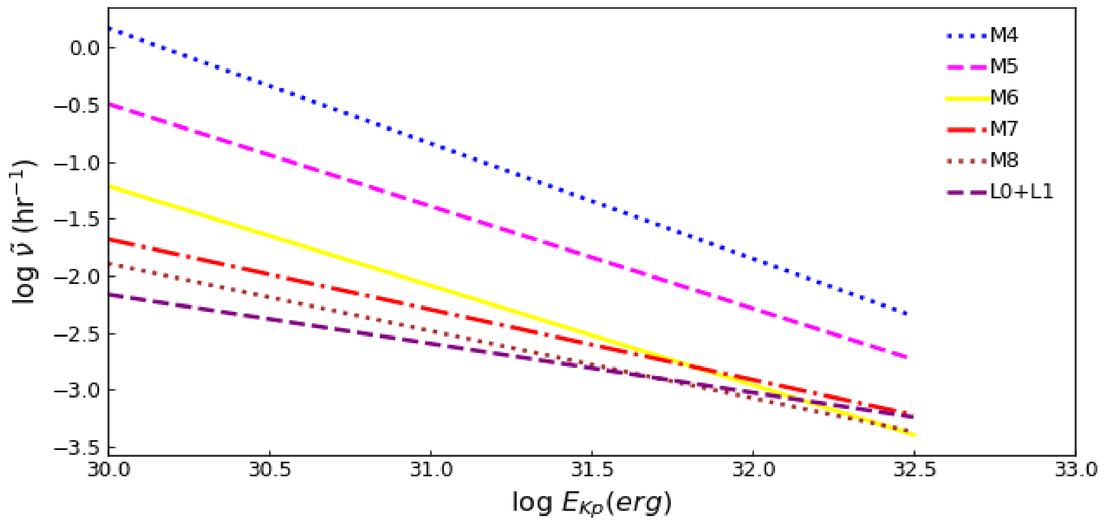

Figure : Comparison of average flare rates of each spectral type. Average flare rates of objects having same spectral type are computed, irrespective of their ages. The flare rates of M4 spectral type are taken from Hawley et al. 2014.

Conclusions

- The average flare rates decrease with decreasing effective temperature.
- The difference in flare rates of M4 & M5, and M5 & M6 spectral types is almost same in case of both observed low and high energy flares. This information might be helpful in constraining age of the objects, when their rotation periods are known.
- The slopes of the lines representing flare frequency distribution are shallower in case of cool objects. The shallower slopes of such objects is due to reduced electrical conductivity caused by the cooler temperatures.
- No flares are observed on spectral types ≥ L2, in *K2* data.

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