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Discovery of Flare Activity on the Very Low Luminosity Red Dwarf G 51-15

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Summary. Flare activity has been discovered on G 51-15, the intrinsically second faintest star known, and the faintest one with hydrogen Balmer lines in emission. A comparison of the two faintest stars known with other flare stars indicates that they are considerably less flare active than CN Leo or UV Cet. A possible explanation may be that a star's age is important to its flaring rate, but this is difficult to quantify from existing data on low luminosity dwarfs.

Key words: flare stars – photometry – low luminosity stars

I. Introduction

The proper motion star G 51-15 was demonstrated to be a nearby red dwarf by Dahn et al. (1972). At $V=14.81$ and with a well determined parallax (Harrington and Dahn, 1980), it is at a distance of 3.5 pc and has an absolute visual magnitude of 17.0. This makes G 51-15 the second intrinsically faintest star known among those that have reliable parallaxes and photoelectric magnitudes measured.

Liebert (1976) obtained low resolution scans over the entire visual spectrum of G 51-15. The Ca II H and K lines and the hydrogen Balmer lines are prominently in emission. The underlying spectrum is that of a very late M dwarf, dominated by TiO bands at yellow-red wavelengths. Also present is a CaOH band at λ 5550 Å. Both of these features are stronger in G 51-15 than in CN Leo (=Gliese 406), which indicates an effective temperature less than the 2800 K determined for CN Leo by Pettersen (1980).

The positioning of G 51-15 near the main sequence, its low luminosity and the prominent emission lines are all criteria that meet those used by Andersen and Pettersen (1975) to identify flare star candidates among the solar neighbourhood stars. The strength of the Hα emission also indicates that flare activity should take place on G 51-15. An empirical relationship discovered by Gershberg and Shakhovskaya (1971), and applied by Pettersen (1975), indicates a more active flare star the stronger its Hα emission. G 51-15 was therefore considered a good candidate for flare activity.

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Table 1. U-filter monitoring of G 51-15

Date (UT)	Start (UT)	Stop (UT)	Remarks
08 April 1980	03 17 54	04 13 05	1 flare
09 April 1980	03 18 48	04 31 35	4 flares
10 April 1980	03 10 44	03 56 00	1 flare
11 April 1980	03 10 41	04 42 25	3 flares

NOTE - Total monitoring $4^h24^m58^s$.

Table 2. Flare characteristics, G 51-15

Flare no.	Date (UT) 1980	Flare Max UT	Flare amplitude U-mag.	Intensity	noise level	Relative flare energy*	Flare durations† Rise	Decay
1	08 April	03 46 26	1.2	2.0	0.27	2.2	10	215
2	09 April	03 36 54	1.4	2.5	0.15	0.7	10	87
3		03 40 45	2.9	13.0	0.15	8.0	10	236
4		03 45 58	1.2	1.9	0.15	6.5	10	490
5		04 19 16	0.6	0.7	0.28	1.0	<5	125
6	10 April	03 24 04	0.7	0.8	0.17	0.5	<5	82
7	11 April	03 19 29	0.8	1.1	0.27	1.5	15	123
8		03 21 32	3.7	29.8	0.27	9.5	10	144
9		03 55 27	0.8	1.2	0.30	0.5	15	62

NOTES - *The relative flare energy represents the integral under the flare light curve in units of minutes

†Flare durations are given in units of seconds.

II. Observations

We observed G 51-15 with the 2.1 m Struve reflector and a computer controlled high speed photometer at McDonald Observatory. With $B-V=2.06$, we expect a U-magnitude close to 18th. Even on a moonless night such a faint object required 5 s integration time to give a signal-to-noise ratio of about 5 in the U-filter. This means that only flares larger than about 0.5 mag could be detected, and only the major ones with confidence.

We monitored G 51-15 through a U-filter over time intervals of about one hour on several nights in April 1980, as detailed in Table 1. Nine flares were detected in 4^h25^m of observations, the largest one with an amplitude of 3.7 mag in the U-filter (Table 2). All major flares occurred in groups, as shown in Figs. 1 and 2. They are classical spike type flares with rapid increase and decay,

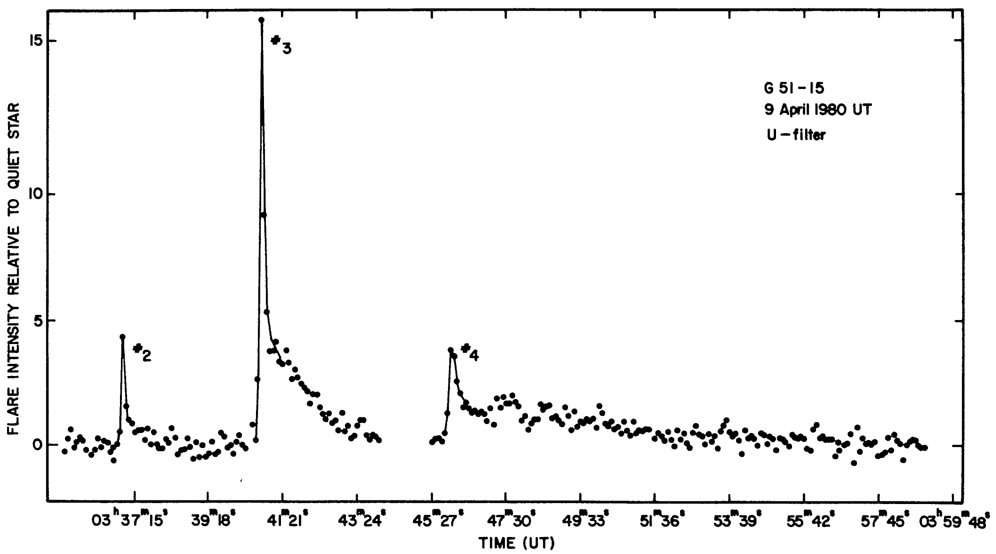

Fig. 1. A group of flares observed on G 51-15 through a *U*-filter. Detailed information on the flares are given in Table 2

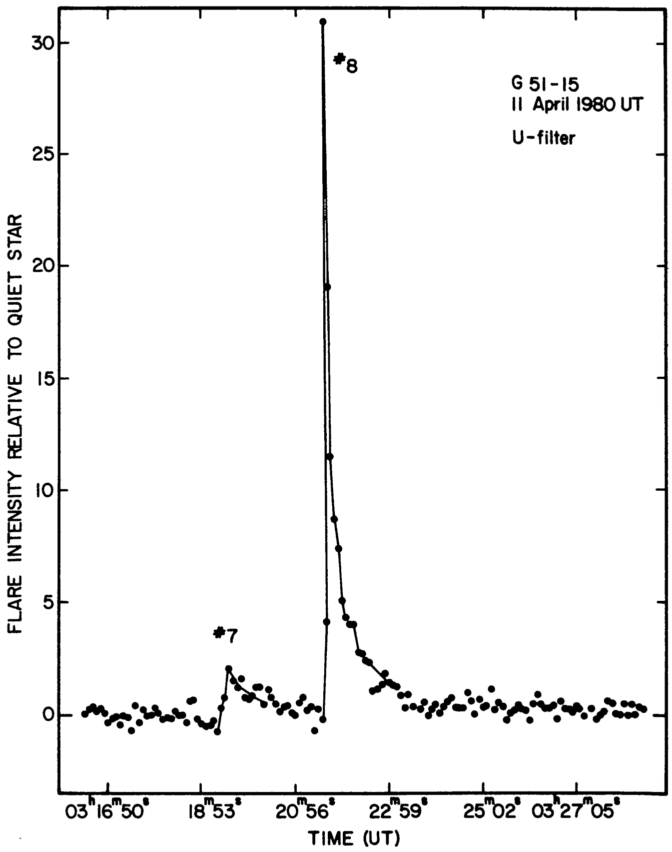

Fig. 2. The largest flare observed on G 51-15, with a precursor-like event occurring two minutes earlier. Detailed flare information is found in Table 2

and sometimes a detectable slower tail which lasts for a few minutes. All flares had rise times less than 15 s, and two were not time resolved at our integration time of 5 s. The rapid part of the flare decay was generally over within 30 s, after which a more gradual and noisy decrease took place.

III. Discussion

Adding up the flux contributions from all observed flares, and comparing this with the total flux received from the quiescent star during our observations, we find that about 10% of the flux measured through the *U*-filter was due to flare activity. Because of the poor detection limit for flares on this faint star we have most likely lost several flares with amplitudes comparable to the noise level. We have also lost in the noise the slow decay part of the observed flares. Our value for the flare activity level of G 51-15 is therefore a lower limit, but we estimate that the relative error is less than 50%. A larger flare sample is required for a full flare energy distribution analysis (Gershberg, 1972) to be made.

Our preliminary estimate of the flare activity level on G 51-15 is considerably lower than what is observed in other low luminosity flare stars, i.e. CN Leo, UV Ceti. Respectively, about 50% and 20% of the *U*-band fluxes from these stars are due to flaring (Lacy et al., 1978; Pettersen, 1978). They are spectroscopically very similar to G 51-15 but have a somewhat larger luminosity.

The faintest star known, van Biesbroeck 10 = Gliese 752 B, was observed spectroscopically by Herbig (1956). During one of his 4.5 h exposures a flare apparently occurred. However, no photometric light curve of any flare on van Biesbroeck's star is available, and the classification of this high proper motion star as a flare star is therefore based only on Herbig's spectroscopic observation. Nothing is known about the flare activity level of van Biesbroeck's star, but it is unusual among flare stars in that it does not show hydrogen Balmer lines in emission outside of flares. Pettersen and Griffin (1980) have demonstrated that three other non-emission line flare stars show abnormally low flare activity rates.

The flare light curves obtained from G 51-15 are a discovery of flare activity on the intrinsically faintest star with hydrogen emission lines. G 51-15 is therefore the faintest star up to now for which flare light curves are available. Both van Biesbroeck's star and G 51-15, the two stars of lowest luminosity among the solar neighbourhood flare stars, appear to be less active than one would expect from a comparison with other low luminosity flare stars. We can only suggest that this is an age effect, but such a statement is difficult to quantify from existing data for low luminosity dwarfs. A larger sample among the very low mass stars in the solar neighbourhood should be studied in order to understand this problem.

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