Astron. Astrophys. 148, 151–154 (1985)

ASTRONOMY AND ASTROPHYSICS

Discovery of flare activity on the low luminosity red dwarf system G9–38 AB

B. R. Pettersen[1,2]

[1] McDonald Observatory, University of Texas at Austin, USA
[2] Institute of Mathematical and Physical Sciences, University of Tromsø, N-9000 Tromsø, Norway

Received December 5, 1984; accepted February 6, 1985

Summary. High speed photoelectric photometry in the *U*-filter revealed twenty-four stellar flares on G9–38 AB in 4.5 h. An average of 5 flares per hour makes this star one of the most frequently flaring stars in the solar neighbourhood. Eleven percent of the *U*-filter flux received from the system is due to flare generated photons. This is a small value compared to other flare active systems of similar luminosity, such as UV Cet and V780 Tau. The average flare decay time is close to that of V780 Tau, but twice as large as that of UV Cet.

Key words: flare stars – photometry

1. Introduction

The visual binary G9–38 = LHS 2076 = GJ 1116 contains two very late type red dwarf stars that are separated by 3.″4. The parallax value of 0.″192 (Harrington and Dahn, 1980) places both components on the main sequence, using the photometric data of Table 1. These data also imply effective temperatures below 3000 K and bolometric luminosities near 1/1000 that of the Sun, using the empirical relationships by Pettersen (1983a). The masses of the stars, as estimated from the mass-luminosity relation ($\sim 0.1\,M_{\odot}$), are very close to the lower limit for objects that are powered by nuclear energy sources. According to current theories, the components of G9–38 must be fully convective.

Assuming the total mass of the pair to be $0.2\,M_{\odot}$, the present separation suggests an orbital period of about 160 yr. Thus G9–38 may be considered a well separated version of the prototype flare star binary UV Cet. The orbital period of that system is about 27 yr. Photometrically the two binaries are quite similar, as can be seen from Table 1. The major difference is the magnitude difference between the components, which is somewhat larger in G9–38. The brighter components of both systems are very nearly identical.

The optical spectra between 3500 Å and 6500 Å are almost identical for the two systems (Pettersen et al., 1985). TiO bandheads are equally strong, as are those of CaH, MgH, and CaOH. The presence of the triatomic molecule CaOH is an independent confirmation of the low photospheric temperature estimate. The Ca II H and K lines and the hydrogen Balmer lines show prominent emission, but the lines are twice as strong in G9–38 AB as in UV Cet AB. The spectroscopic recordings can be found in Pettersen et al. (1985).

Send offprint requests to: B. R. Pettersen (Tromsø-address)

Table 1. Photometric data for G9–38 AB and UV Cet AB

Star	M_V	$U-B$	$B-V$
G9–38 AB	15.06		1.87
UV Cet AB	14.92	1.09	1.85
G9–38 A	15.47		1.84
G9–38 B	16.33		1.93
UV Cet A	15.45		
UV Cet B	15.95		

2. Observations

G9–38 AB was observed on three nights in December 1983 with the 2.1 Struve reflector at McDonald Observatory. A computer controlled high-speed photometer was used to collect data through the *U*-filter. At an apparent *U* magnitude well below 16 the count rate is low, and a 5 s integration was needed. The detailed observing log is given in Table 2.

During 4.5 h of observations we detected 24 flares, the characteristics of which are given in Table 3. The time of maximum is only accurate to within the time resolution of 5.125 s. Column 4 gives the rise time of the flares from the pre-flare intensity level to maximum, and the next column gives the time elapsed from maximum till the intensity of the flare light reached half of the maximum intensity. The flare amplitude in intensity units measured relative to the quiet star,

$$\text{Flare amplitude} = \frac{(I_{\text{quiet+flare}} - I_{\text{quiet}})}{I_{\text{quiet}}}$$

and the standard deviation of the measurements of the quiet star flux, are given in the next two columns. The last column contains the *U*-filter energy emitted during each flare event. This quantity is determined by multiplying the relative energy of the flare, R.E., by the flux emitted from the quiescent star, L_U, in absolute units. The first quantity, R.E., is obtained by numerically integrating the flare light curve

$$\text{R.E.} = \int I_f(t)\,dt\,,$$

where $I_f(t)$ is the time behavior of the flare normalized to the flux received from the quiet star. The relative energy, R.E., therefore expresses the energy of the flare in terms of the energy rate of the quiet star.

The second quantity, L_U, the absolute luminosity of the star in the *U* bandpass, can be estimated from Moffett's (1974) determi-

Table 2. Observing log. Total effective monitoring time = 16087 s = 4.489 h

Date (UT)	Monitoring intervals (UT)	Effective obs. time	No. of flares
7 Dec 1983	11:26:52–11:27:54, 11:30:12–11:49:30, 11:51:43–12:11:48, 12:13:41–12:30:25, 12:32:28–12:40:50	3931 s	6
8 Dec 1983	10:05:13–10:23:50, 10:24:57–10:50:44, 10:52:37–11:31:03, 11:33:11–12:02:19, 12:04:17–12:20:56, 12:23:15–12:36:09, 12:36:55–12:43:34	8890 s	11
10 Dec 1983	10:21:13–10:22:15, 10:24:12–10:30:42, 10:33:26–11:20:20	3266 s	7

nation of the energy output of a zeroth absolute magnitude star. *Assuming* $U-B=1.09$ for G9–38 implies $M_U=18.02$ (Table 1) and $L_U=2.3\,10^{27}$ erg s^{-1}.

This method of calculating the absolute energy of flares implicitly assumes that the energy distributions of flares and that of the quiet star are the same. This is certainly not true, as can be seen from flare colours and their time behavior (Pettersen, 1983b). Without multicolour observations this method is the best available, and the results are consistent with and may be compared to those of other flare stars analysed in the same fashion.

Table 3. U-filter flare characteristics for G9–38 AB

Flare no.	Date (UT)	Flare maximum	t_{rise}	$t_{0.5}$	Flare ampl.	Noise σ/I_0	$\log E_u$ (erg)
1	7 Dec 1983	11:42:09	5 s	10 s	5.53	0.07	29.43
2	7 Dec 1983	12:09:19	10	15	0.36	0.08	28.36
3 A	7 Dec 1983	12:16:50	10	–	1.22	0.08	29.49
3 B	7 Dec 1983	12:17:21	–	20	1.32	0.08	
4	7 Dec 1983	12:24:01	36	46	0.58	0.08	28.78
5	7 Dec 1983	12:28:22	30	20	0.75	0.09	28.82
6	7 Dec 1983	12:35:27	15	7	1.30	0.09	28.87
7 A	8 Dec 1983	10:31:47	15	–	1.04	0.08	29.27
7 B	8 Dec 1983	10:32:12	–	23	1.34	0.08	
8	8 Dec 1983	10:54:50	20	62	0.47	0.07	28.72
9	8 Dec 1983	11:09:22	5	5	0.46	0.07	28.21
10	8 Dec 1983	11:34:03	10	25	0.26	0.05	28.72
11	8 Dec 1983	11:37:28	10	5	0.39	0.05	28.06
12	8 Dec 1983	11:39:05	20	20	1.00	0.05	29.16
13	8 Dec 1983	11:58:02	20	92	1.09	0.04	29.33
14 A	8 Dec 1983	12:04:22	5	5	0.90	0.04	29.16
14 B	8 Dec 1983	12:04:53	5	7	1.38	0.04	
15	8 Dec 1983	12:25:38	26	36	0.40	0.05	28.68
16 A	8 Dec 1983	12:29:24	5	56	1.92	0.05	
16 B	8 Dec 1983	12:31:37	5	5	0.44	0.05	29.48
16 C	8 Dec 1983	12:32:44	10	5	0.50	0.05	
17 A	8 Dec 1983	12:38:37	36	12	40.03	0.06	
17 B	8 Dec 1983	12:42:18	15	9	15.13	0.06	>30.51
17 C	8 Dec 1983	12:42:38	5	15	9.29	0.06	
18	10 Dec 1983	10:21:23	< 5	< 5	1.21	0.04	28.36
19	10 Dec 1983	10:28:08	5	5	0.21	0.06	27.96
20	10 Dec 1983	(10:33:20)	–	41	0.23	0.07	>28.57
21	10 Dec 1983	10:39:35	10	10	0.17	0.08	28.06
22	10 Dec 1983	10:52:03	20	5	0.31	0.10	28.32
23	10 Dec 1983	11:10:46	10	5	0.40	0.12	27.96
24	10 Dec 1983	11:12:49	10	5	4.42	0.13	29.37

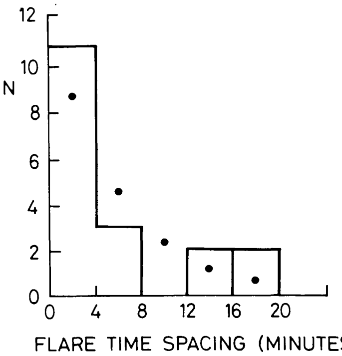

Fig. 1. The frequency distribution of time intervals between flares on G9–38 AB. The dots represent expected values from a Poisson process with the same average value as that of the observed distribution

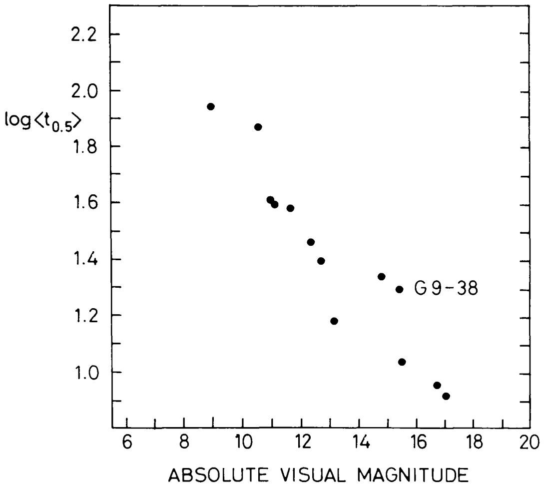

Fig. 3. The empirical relationship between average flare decay timescale and the absolute visual magnitude of the stars. The location of G9–38 AB is identified

3. Discussion

3.1. Flare frequency and time distribution

The detection of 24 flare events in 4.5 h implies an average of one flare every 11 min. The time intervals between successive flares actually observed vary between 1 and 20 min. The average inter-flare spacing for uninterrupted observing intervals is 6.1 ± 6.1 min. The frequency distribution is shown in Fig. 1. The expected distribution from a Poisson process is marked as dots, and a chi square test does not reject the null hypothesis that flares are randomly distributed in time (see e.g. Pettersen et al. 1984 for the method of analysis).

3.2. Flare time scales

The average rise time for the flares observed is 14 ± 9 s, and the average decay time is 20 ± 21 s. The frequency distributions of the time scales are shown in Fig. 2, together with Poisson distributions for the average values quoted. Chi square tests do not detect significant differences between the observed distributions and Poisson distributions at 95% confidence level.

Figure 3 shows the relationship between the flare decay time and the absolute visual magnitude of the stars, with G9–38 included.

3.3. The cumulative flare energy distribution

The flare activity of G9–38 has been analysed using the method introduced by Gershberg (1972). Figure 4 shows the cumulative distribution of flare energy versus flare frequency. Flares smaller than about 10^{28} erg tend to avoid detection, but more energetic flares are apparently large enough for all of them to be recorded. The linear portion of the cumulative distribution is defined by flares with $E \gtrsim 10^{28}$ erg. The scatter is considerable. A least square fit to the data points yield

$$\log(N/T) = 14.36 - 0.61 \log E_U,$$

where T is in s and E_U is in ergs. This relation may be combined with the definition of the cumulative number of flares, N, to show that the accumulated amount of flare energy per unit of time, $\Sigma P/T$, including unobserved small flares below the detection limit, is given by

$$\frac{\Sigma P}{T} = \frac{10^a}{L_U} \frac{b}{1-b} (E_{\max}^{1-b} - E_{\min}^{1-b}),$$

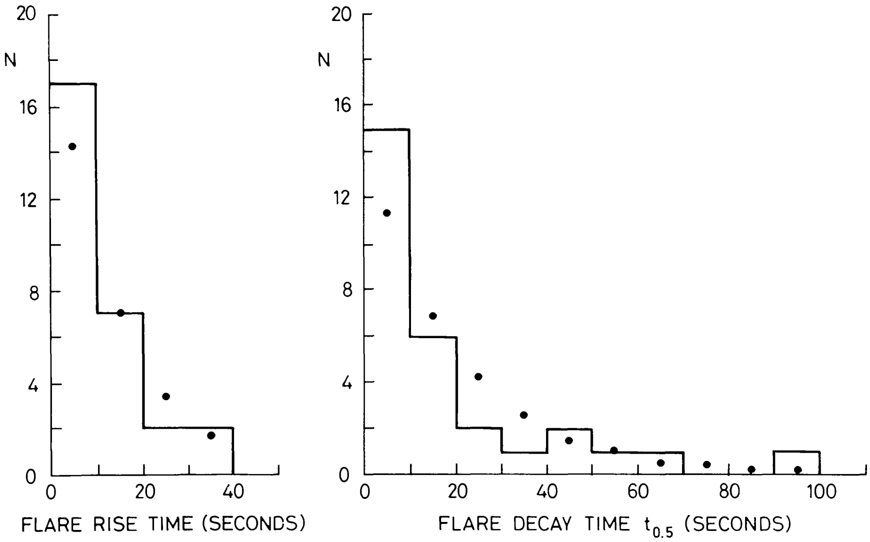

Fig. 2. Frequency distributions of rise times (left) and decay times (right) for flares on G9–38 AB. The dots represent expected values from Poisson processes with the same average values as those of the observed distributions

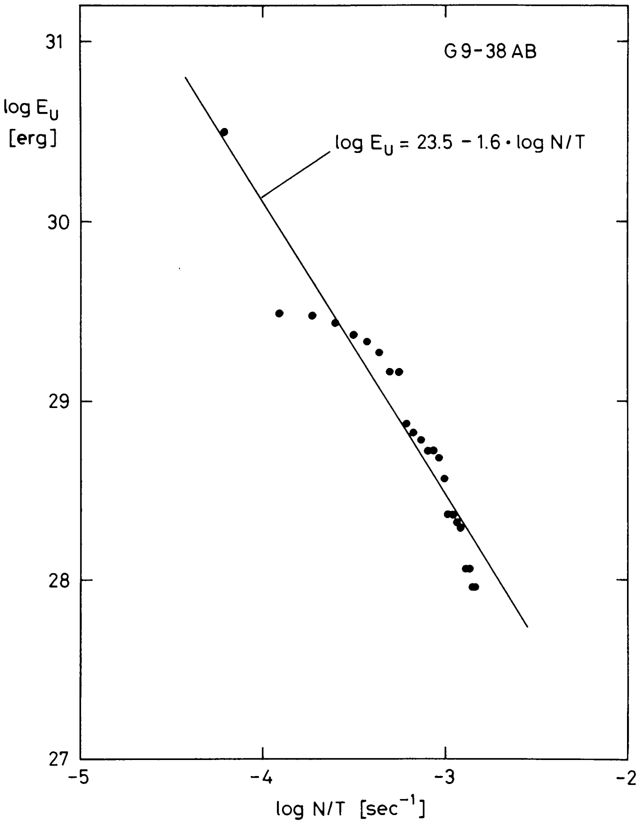

Fig. 4. The cumulative distribution of flare energy in the U-filter versus flare frequency, based on twenty-four flares on G9–38 AB

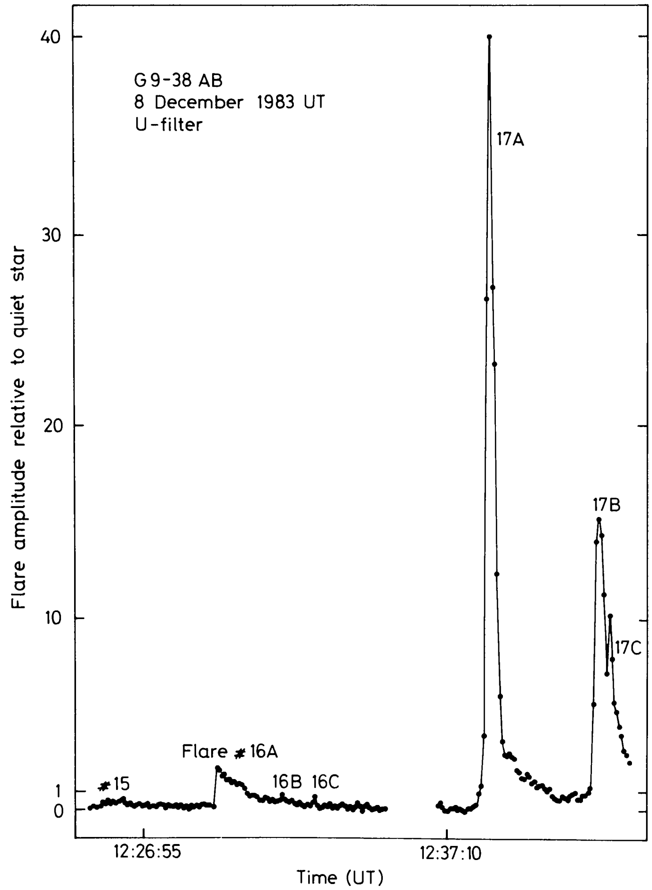

Fig. 5. Complex flare events on G9–38 AB, including the largest flare reported in Table 3. Each datapoint represents 5 s integration time

where $a = 14.36$, $b = 0.61$, $E_{max} = 3\ 10^{30}$, and $E_{min} = 9\ 10^{27}$. We find

$$\frac{\Sigma P}{T} = 0.11 .$$

This is a small value compared to that of the UV Cet system, which was determined to be four times larger by Lacy et al. (1976). Another low luminosity system, V780 Tau, also produced flare energy comparable to that of UV Cet (Pettersen, 1983c). It is interesting that we are now accumulating data for very similar stars that show quite different activity levels. It is puzzling, however, that G9–38 has stronger emission lines than UV Cet when its flare activity level is lower. It may be a violation of a well accepted relationship, but may also have been caused by strong flare activity during the spectrum observation.

Acknowledgements. It is a pleasure to acknowledge the hospitality of Professor David S. Evans during my visits to Texas. The generosity of the Director of McDonald Observatory, Dr. Harlan J. Smith, in making telescope time available, and the efficient support of the observatory staff, is greatly appreciated. Financial support through a Senior Visiting Fulbright Scholarship made this work possible.

References

Gershberg, R.E.: 1972, *Astrophys. Space Sci.* **19**, 75
Harrington, R.S., Dahn, S.S.: 1980, *Astron. J.* **85**, 454
Lacy, C.H., Moffett, T.J., Evans, D.S.: 1976, *Astrophys. J. Suppl.* **30**, 85
Moffett, T.J.: 1974, *Astrophys. J. Suppl.* **29**, 1
Pettersen, B.R.: 1983a, in *Activity in Red-Dwarf Stars*, eds. P.B. Byrne, M. Rodonò, Reidel, Dordrecht, p. 17
Pettersen, B.R.: 1983b, in *Activity in Red-Dwarf Stars*, eds. P.B. Byrne, M. Rodonò, Reidel, Dordrecht, p. 239
Pettersen, B.R.: 1983c, *Astron. Astrophys.* **120**, 192
Pettersen, B.R., Cochran, A.L., Barker, E.S.: 1985 (in preparation)
Pettersen, B.R., Coleman, L.A., Evans, D.S.: 1984, *Astrophys. J. Suppl.* **54**, 375