АСТРОФИЗИКА

ТОМ 29 АВГУСТ, 1988 ВЫПУСК 1

УДК 524.338.6

V1589 CYG—B19—A FOREGROUND dMe FLARE STAR IN THE DIRECTION OF NGC 7000

B. R. PETTERSEN, M. K. TSVETKOV, S. L. HAWLEY, L. A. COLEMAN, A. S. AMIRKHANIAN

Received 20 January 1988
Accepted 30 March 1988

Abstract. Photographic and photoelectric flare observations of V1589 Cyg=B19 show that flare durations from minutes to hours, with amplitudes up to 2 magnitudes in the U-filter, occur on this star. Only major events are recorded with photographic techniques due to low time resolution and inability to detect small flare amplitudes. The colours, spectral type and presence of emission lines suggest that V1589 Cyg is a dM4.5e flare star. Photometric and spectroscopic parallaxes suggest a distance of 23—32 parsecs, thus excluding the possibility of it being a member of the stellar aggregate in the North America Nebula.

1. *The flare history of V1589 Cyg.* During the 1970's a major observing program was carried out with Schmidt telescopes at the Byurakan Astrophysical Observatory with the purpose of studying flare activity in stars of the North America-Pelican Nebulae, also identified as NGC 7000 and IC 5068—70. Multiple exposures on the same plate allowed detection of flares and sometimes time resolved recordings of flare light curves. In Table 1 (see also Fig. 1) we have compiled a list of flares recorded on the star Byurakan 19 (B 19) from thesis works of M. K. Tsvetkov [1] and L. K. Erastova [2], and from a contribution by N. D. Melikian [3]. Two events are similar to slow flares in Haro's classification. The flare activity of B19 was discovered by Tsvetkov in 1973, and was reported in IBVS No. 1002 in 1975. The star was subsequently named V1589 Cyg [4]. Finding charts can be found in [5]. Altogether six flares have been detected in the course of 848.4 hours of photographic multi-exposure monitoring, predominantly through an ultraviolet filter. Five flares were seen during 1973—74 as a result of 488.1 hours of monitoring. The remaining 360.3 hours of observations made in 1972 and during 1975—80 produced only one flare. This may indicate that the frequency of large flares on V1589 Cyg varies with time.

Table 1

PHOTOGRAPHIC FLARES ON V1589 Cyg=B19

Date	Amplitude (mag)	Telescope (BAO)	References
19 August 1973	2.9 *U*	40″	[1]
4 September 1973	1.7 *U*	40	[2]
18 June 1974	0.9 *U*	40	[2]
28 „ „	1.3 *U*	40	[1]
	0.4 *pg*	21	[2]
19 August 1974	1.6 *U*	40	[1]
29 October 1980	1.2 *U*	40	[3]

Notes — Total monitoring time = 848,4 hours
Time resolution ≃ 10 min

For the purpose of photoelectrically confirming the flare activity, and to investigate if shorter duration events occur on this star, we observed V1589 Cyg with a computer controlled high-speed photometer on 0.76 m and 2.1 m telescopes at McDonald Observatory. 4.3 hours of U-filter monitoring (see Table 2) revealed only one flare, the light curve of which is shown in Fig. 2. At an amplitude of 0.74, this spike flare represents an emitted U-filter energy of $4 \cdot 10^{30}$ ergs. It is evident from existing observations that many small flares have escaped detection during the photographic observations, both because of low time resolution (10 minutes usually) and inability to reliably detect flare-ups with small amplitudes. The photographic observations do show, however, that very large flares occur on V1589 Cyg from time to time. Amplitudes of up to 2 magnitudes and flare durations up to one hour (see Fig. 1) suggest that equivalent flare energies of 10^4 sec are not unique. This corresponds to 10^{33} ergs for flares on V1589 Cyg.

2. *Spectroscopy.* The first spectral information about V1589 Cyg came from objective prism (4°) observations with the 1 m Schmidt telescope at the Byurakan Astrophysical Observatory. H-alpha was seen in emission both in 1973 and 1977, apparently of varying strength. Inspection of the plate revealed a weaker line in 1973 than on several occasions in 1977, We note that the photographic flare frequency was much higher in 1973 than in 1975—80.

Cassegrian spectra at 200 A/mm of V1589 Cyg were obtained on 11 and 12 August 1978 with a vidicon detector (PAR OMA I) on the 2.6 m telescope at the Byurakan Astrophysical Observatory. Details are given in Table 3. The spectra were wavelength calibrated and showed

Table 2

PHOTOELECTRIC U-FILTER FLARE MONITORING OF V1589 Cyg=B19

Date	Start (UT)	End (UT)	Δt (sec)	σ/I_0	Telescope (McD)
1 September 1983	$06^h01^m40^s$	$06^h55^m40^s$	3240	0.15	30″
2 " "	03 43 30	05 23 30	2400	0.14	30
26 October 1986	03 38 40	04 38 40	3600	0.07	82
27 " "	03 29 05	04 42 05	4380	0.06	82
28 " "	03 19 51	03 50 51	1860	0.06	82

Notes — Total monitoring time = 15480 sec = 4.3 hours
Time resolution = 5 sec.

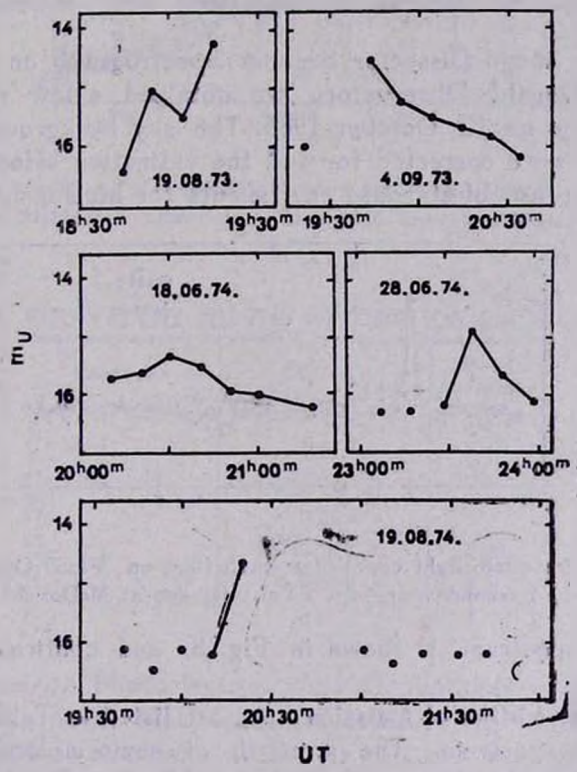

Fig. 1. A display of photographically detected flares on V1589 Gyg, observed with a time resolution of about 10 minutes using the 1 m Schmidt telescope at Byurakan Astrophysical Observatory.

the Ca II H and K lines and the hydrogen Balmer lines in emission. Photospheric features like Ca I 4226 A and several TiO bandheads sug-

gested an M dwarf nature. However, since detector response, background signals and extinction effects were not corrected for in these observations, further quantitative information could not be extracted from the spectra.

Table 3

SPECTROSCOPY OF V1589 Cyg = B19

Date	Start (UT)	Exp (min)	Dispersion/ Resolution	Spectral range	Instrument
11 August 1978	01^h55^m	15	200 A/mm	5500—7750 A	BAO 2.6 m + OMA
12 " "	19 00	15	200 A/mm	3600—5850 A	" " "
12 October 1985	02 37	15	11 A	3600—6600 A	McD 2.7 m + IDS

Note — BAO = Byurakan Astrophysical Observatory: McD = McDonald Observatory

Using the Image Dissector Scanner Spectrograph on the 2.7 m telescope at McDonald Observatory we obtained a low resolution cassegrain spectrum on 12 October 1985. The sky background and instrument response were corrected for and the extinction effects were handled through the use of standard coefficients for McDonald Observatory.

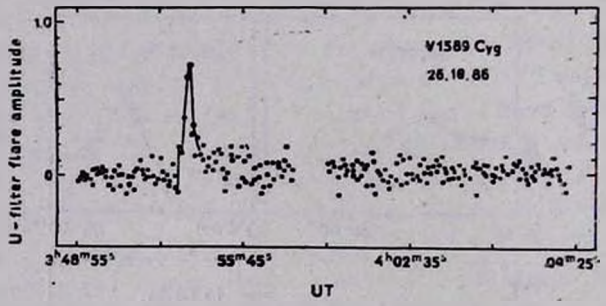

Fig. 2. Photoelectric light curve of a small flare on V1589 Gyg, observed with a time resolution of 5 seconds using the 2.1 m telescope at McDonald Observatory.

The resulting spectrum is shown in Fig. 3, and confirms the previous observations.

Equivalent widths of emission lines are listed in Table 4, as measured from this spectrum. The strength of some molecular bandheads correlates with spectral type for M dwarfs. Empirical relations established from observations of a number of M dwarfs [6] suggest that the spectral type of V1589 Cyg is dM4.5e. A list of identified molecular bandheads is given in Table 5.

Likewise, the strength of some molecular bandheads correlates with absolute visual magnitude. MgH and CaH are not very useful due to

noisy non-linear relationships. Measurements of bandheads of the TiO α and γ systems at 4761 A, 4954 A and 6162 A, and CaOH features at 5455 A and 6170 A yield $M_V = 11.5 \pm 0.3$. At $V = 13.65$ this implies a spectroscopic parallax of $\pi_{spec} = 0.038 \pm 0.005$ arcsec.

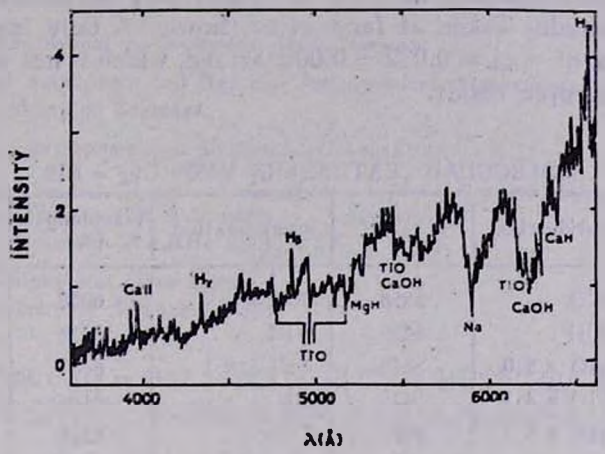

Fig. 3. The spectrum of V1589 Gyg from 3600 A to 6600 A, obtained with the 2.7 m telescope at McDonald Observatory. Emission lines and molecular features are identified.

Table 4

EQUIVALENT WIDTHS OF EMISSION LINES

Feature	EW (A)	Balmer decrement
Ca II K	20 ± 4	—
Ca II H + H_ε	19 ± 3.5	—
H_δ	8 ± 2	0.6
H_γ	10.5 ± 1.5	0.85
H_β	6.0 ± 0.5	1.0
H_α	2.5:	1.7:

3. *Photometry.* Photoelectric *UBVR* photometry was done with the 91 cm telescope at McDonald Observatory on 13 October 1985. The transformation equations from the instrumental to the standard system are well behaved, but extinction coefficients were determined from a rather narrow airmass range. The results are

$$V = 13.65 \pm 0.01,$$
$$U - B = 1.08 \pm 0.13,$$
$$B - V = 1.56 \pm 0.05,$$
$$V - R = 1.68 \pm 0.02.$$

The V-magnitude agrees well with the photographic result of $V = 13.70 \pm 0.07$ [1]. and the colours are typical for a dM4.5e star. They suggest absolute visual magnitudes of 11.1 (from $B - V$) and 11.3 (from $V - R$). The scatter of colou-magnitude diagrams for M-dwarfs is considerable, so these estimates may be uncertain by more than 0.5 magnitude. Taken at face value, however, they imply a photometric parallax of $\pi_{phot} = 0.032 \pm 0.009$ arcsec, which is not contradictory to the spectroscopic result.

Table 5

MOLECULAR FEATURES IN V1589 Cyg = B19

Wavelength (A)	Identification	Wavelength (A)	Identification	Wavelength (A)	Identification
4352	TiO	5358	TiO α 4.4	6058	TiO γ 4.3
4546	AlH	5430	AlH	6083	MgH + VO
4584	TiO α 3.0	5448	TiO α 0.1	6162	TiO γ 0.0
4626	TiO α 4.1	5473	CN	6186	TiO γ 0.0
4668	TiO α 5.2	5497	TiO	6214	TiO γ 0.0
4761	TiO α 2.0	5530	CaOH	6230	CaOH
4788	MgH	5600	TiO β 0.0+CN	6240	TiO γ 1.1
4806	TiO α 3.1	5759	TiO α 0.2	6268	TiO γ 3.6
4936	CN	5810	TiO α 1.3	6276	TiO γ 1.1
4954	TiO α 1.0	5847	TiO γ 1.0	6322	TiO γ 2.0
4999	TiO α 2.1	5924	TiO γ 2.1	6358	TiO γ 3.1
5167	TiO α 0.0	5951	TiO γ 2.1	6385	CaH
5184	MgH	6003	TiO γ 3.2	6415	CaOH
5211	MgH	6038	CaOH	6448	TiO γ 4.2
				6520	TiO

4. *Conclusions.* The photometric and spectroscopic results suggest that V1589 Cyg belongs to the solar neighbourhood at a distance of 23—32 parsecs. This excludes the possibility of it being a member of the stellar aggregate in the North American Nebula. The colours, spectral type and presence of emission lines compare well with other flare stars in the solar vicinity. The flare data demonstrate that V1589 Cyg has produced flares of U-filter erergy from $4 \cdot 10^{30}$ ergs to $1 \cdot 10^{33}$ ergs. There is indication that the flare frequency of large flares varies with time.

5. *Acknowledgements.* It is a pleasure to thank Professor L. V. Mirzoyan for his kind attention, assistance in the investigations carried out, and allocating observing time at the Byurakan Astrophysical Ob-

servatory, and to Dr. Harlan J. Smith for making facilities available at McDonald Observatory. At Byurakan, U. Hanni and P. Traat assisted with the observations, and Dr. A. Kaazik helped setting up the Optical Miltichannel Analyzer (OMA), made available from the Institute of Astrophysics and Atmospheric Physics of the Estonian Academy of Sciences.

Institute of Theoretical Astrophysics, Oslo, Norway

Department of Astronomy and National Astronomical Observatory,
Bulgarian Academy of Sciences.

Department of Astronomy and McDonald Observatory,
Austin, USA

Department of Physics and Astronomy,
University of Arkansas at Little Rock, USA

Byurakan Astrophysical Observatory
Armenian Academy of Sciences, USSR

V1589 CYG = B19 — ВСПЫХИВАЮЩАЯ ЗВЕЗДА ПЕРЕДНЕГО ФОНА В НАПРАВЛЕНИИ NGC 7000

Б. Р. ПЕТЕРСЕН, М. К. ЦВЕТКОВ, С. Л. ХОУЛИ, Л. А. КОЛЕМАН, А. С. АМИРХАНЯН

Фотографические и фотоэлектрические патрульные наблюдения вспыхивающей звезды V 1589 Лебедя = B19 показывают, что у этой звезды происходят вспышки продолжительностью от нескольких минут до нескольких часов с амплитудами до двух звездных величин в U-цвете. Фотографическим методом регистрируются только большие вспышки из-за недостаточного временного разрешения и невозможности регистрировать вспышки с малой амплитудой. Цвета, спектральный тип и присутствие эмиссионных линий показывают, что V 1589 Лебедя — вспыхивающая звезда dM4, 5e. Фотометрические и спектроскопические параллаксы дают расстояние 23—32 парсек, исключая таким образом возможность того, что данная звезда является членом звездного агрегата в туманности «Северная Америка».

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