Astronomical and Astrophysical Transactions
Vol. 22, Nos. 4–5, August–October 2003, pp. 487–494

USE OF PHOTOGRAPHIC PLATE ARCHIVES FOR STUDYING THE LONG-TERM BEHAVIOUR OF THE PLEIADES FLARE STARS

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(Received December 6, 2002)

As a result of the cooperation between the Sofia Sky Archive Data Center (Bulgaria) and Bamberg Observatory (Germany), Royal Observatory of Edinburgh (UK), Konkoly Observatory (Hungary), Strasbourg Observatory, Institute of Astronomy in Cambridge (UK), etc., a programme for investigation of the long-term behaviour of the Pleiades active dwarf stars (in particular, flare stars) is in progress. Existing plates in the Pleiades are found in different European plate archives, made since the end of the nineteenth century, by the searching tool of the wide-field plate database (http://www.skyarchive.org), which provides detailed information for astronomical plate archives all over the world, as well as for plates themselves. We investigate the Pleiades flare stars (UV Cet-type stars) included in the flare Stars database and identified in the USNO A2.0 catalogue. 68 Pleiades plates are already digitized with different scanning machines such as PDS 1010 (Sofia), PDS 2020 (Münster), SUPER COSMOS (Edinburgh), APM (Cambridge), UMAX 3000 (Budapest) and Epson (Berlin).

Keywords: UV Cet-type stars; Astronomical databases and catalogues; Open clusters and associations; The Pleiades

1 INTRODUCTION

Investigations of the long-term variability in active red dwarf stars have been carried out only for a limited number of stars. One of the first such investigations was made by Mirzoyan (1977) who noted the cyclic recurrence of the flare activity in two groups of the Pleiades flare stars with a duration of about two decades. The analyses of the long-term light curves of several red dwarfs in the solar vicinity show that their photographic magnitude

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ISSN 1055-6796 print; ISSN 1476-3540 online
DOI: 10.1080/1055679031000139415

variations range from 0.2 to 1.0 m with a typical time scale from 10 to 60 years (Pettersen *et al.*, 1992; Mavridis and Avgolupis, 1993; Bondar, 1995; Alekseev, 2001). The long-term brightness variations in general are interpreted as chromospheric activity in a certain stage of the evolution of the red dwarf stars. The observed spottedness effect is differential, and for a long-term and large plate collection it would be possible to detect brightness differences if they exist. According to discussions on the stellar magnetism of low-mass stars (Drake *et al.*, 1996), the solar-type dynamo mechanism which generates a large-scale solar-type magnetic field should be replaced by the turbulent dynamo mechanism that should not be cyclic.

In order to solve this problem a study of the spottedness of late-type stars and a search for the existence of activity cycles of late dwarf stars is especially important. Before 1963 there was no systematic photographic monitoring of flare stars. That is why only the wide-field plate archives containing plates from the beginning of astrophotography can supply the required long period for the search. Gershberg (1998) also appealed to owners and keepers of photographic monitoring plate archives to use them to study the long-term brightness variations of flare stars.

2 RESEARCH PROGRAMME

According to the existing data in CDS (http://simbad.u-strasbg.fr/Simbad) and WEBDA (http://obswww.unige.ch/webda/), the Pleiades open cluster (M45) is one of the most studied stellar clusters in the Galaxy. This young open cluster (7×10^7 years) is a constant target for study of the stellar evolution stages. The major population of the Pleiades consists of red dwarfs, which have an important role in the identification of faint cluster members for deriving the complete luminosity function. Most of the red dwarf stars are flare stars (UV Cet-type stars). The total number of the known Pleiades flare stars according to the flare stars database (Tsvetkova *et al.*, 1995) is 547, bearing in mind that, for some stars published as flare stars, better observations are needed to confirm their membership of the flare star class of variables according to Tsvetkova and Tsvetkov (1989). The statistical evaluation of the total number of flare stars in the Pleiades (registered and not registered up to now) is about 1000 (Hambaryan *et al.*, 1990). Taking this in consideration we think that the Pleiades is a good and accessible sample for studying long-term brightness variations in the red dwarf stars and, in particular, in the flare stars.

In the framework of the collaboration with several European astronomical institutions we obtained access to different Pleiades wide-field photographic plates from the archives in Bamberg, Sonneberg, Potsdam, Rozhen, Edinburgh, Byurakan, Konkoly, Cluj, Cambridge and Bordeaux, having an unprecedentedly large time scale since 1885. Detailed information on the archival Pleiades plates was provided by the wide-field plate database (WFPDB) created in Bulgaria and available at http://vizier.u-strasbg.fr/viz-bin/VizieR?-source = VI/90 and http://www.skyarchive.org. At the present the WFPDB compiles information for 25% of the more than 2,000,000 astronomical plates that exist and are stored in 337 archives.

Using the WFPDB search resources we found 3950 Pleiades plates made in the period 1885–1998 (Tab. I) and this gives us the opportunity to obtain an almost continuous photometric data set for the red dwarf stars in the cluster. The time distribution of the plates is given in Figure 1. We have scanned 68 plates, with the following scanners: SUPER COSMOS (Edinburgh), PDS 2020 (Münster), PDS 1010 (Sofia), APM (Cambridge),

TABLE I List of the WFPDB Archives Containing the Pleiades Plates.

WFPDB telescope identifier	*Location of the archive*	*Telescope type*	*Years of operation*	*Number of plates*
ALG033	Floirac, France	Astrograph	1891–1975	27
ASI040	Asiago, Italy	Schmidt	1958–1992	185
ASI067	Asiago, Italy	Schmidt	1965–1992	691
BAM014A	Bamberg, Germany	Camera	1928–1938	340
BOR033	Floirac, France	Astrograph	1893–	12
BOR038	Floirac, France	Camera	No data	6
BUC038	Bucharest, Romania	Refractor	1930–	18
COP045	Brorfelde, Denmark	Schmidt	1966–	12
CRI017A	Crimea, Ukraine	Camera	1948–1965	10
CRI040A	Crimea, Ukraine	Astrograph	1947–1950	1
CRI040B	Crimea, Ukraine	Astrograph	1951–1984	4
CLU020	Cluj, Romania	Refractor	No data	9
CLU050	Cluj, Romania	Reflector	1952–1957	2
HAR041	Cambridge, Massachusetts, USA	Refractor	1909–1932	220
HAR061A	Cambridge, Massachusetts, USA	Refractor	1893–1895	37
HEI040A	Heidelberg, Germany	Astrograph	1900–1981	32
HEI040B	Heidelberg, Germany	Astrograph	1900–1981	35
KIE040A	Kiev, Ukraine	Astrograph	1950–1996	54
KIS105	Kiso, Japan	Schmidt	1977–	33
KON060	Budapest, Hungary	Schmidt	1962–	559
POT025	Potsdam, Germany	Schmidt	1948–1956	13
POT030	Potsdam, Germany	Refractor	1879–1930	4
POT050	Potsdam, Germany	Schmidt	1952–1970	4
RGO033	Cambridge, UK	Astrograph	1981–1986	4
RGO066	Cambridge, UK	Astrograph	1957–1988	4
RGO100	Cambridge, UK	Reflector	1984–	31
ROE040	Edinburgh, UK	Schmidt	1962–1974	57
ROE040P	Edinburgh, UK	Schmidt	1962–1974	50
ROM060	Edinburgh, UK	Schmidt	1967–	17
ROZ050	Sofia, Bulgaria	Schmidt	1979–	408
ROZ200	Rozhen, Bulgaria	Ritchey-Chretien	1979–	5
SID124	Edinburgh, UK	Schmidt	1973–	16
SON006A	Sonneberg, Germany	Camera	1941–1953	73
SON006B	Sonneberg, Germany	Camera	1953–1962	54
SON006C	Sonneberg, Germany	Camera	1956–1962	1
SON006E	Sonneberg, Germany	Camera	1956–	376
SON006F	Sonneberg, Germany	Camera	1956–	1
SON006G	Sonneberg, Germany	Camera	1957–	1
SON006K	Sonneberg, Germany	Camera	1958–	1
SON006O	Sonneberg, Germany	Camera	1958–	96
SON007C	Sonneberg, Germany	Camera	1963–1965	182
SON007D	Sonneberg, Germany	Camera	1963–1965	5
SON008A	Sonneberg, Germany	Camera	1925–1939	6
SON017	Sonneberg, Germany	Camera	1923–1971	10
SON030	Sonneberg, Germany	Schmidt	1960–1976	28
SON040A	Sonneberg, Germany	Astrograph	1938–1945	4
SON040B	Sonneberg, Germany	Astrograph	1960–	6
SON040C	Sonneberg, Germany	Astrograph	1961–	6
SON050	Sonneberg, Germany	Schmidt	1952–	72
TAU134	Tautenburg, Germany	Schmidt	1960–	97
TOR060	Torun, Poland	Schmidt	1962–	40

UMAX 3000 (Konkoly) and Epson (Berlin). The main information about the scanning machines used and the scanned plates is given in Tables II and III. A comparison of the plates scanned with different scanning machines is being carried out in order to make clear the application of different scanning machines for photometry and astrometry.

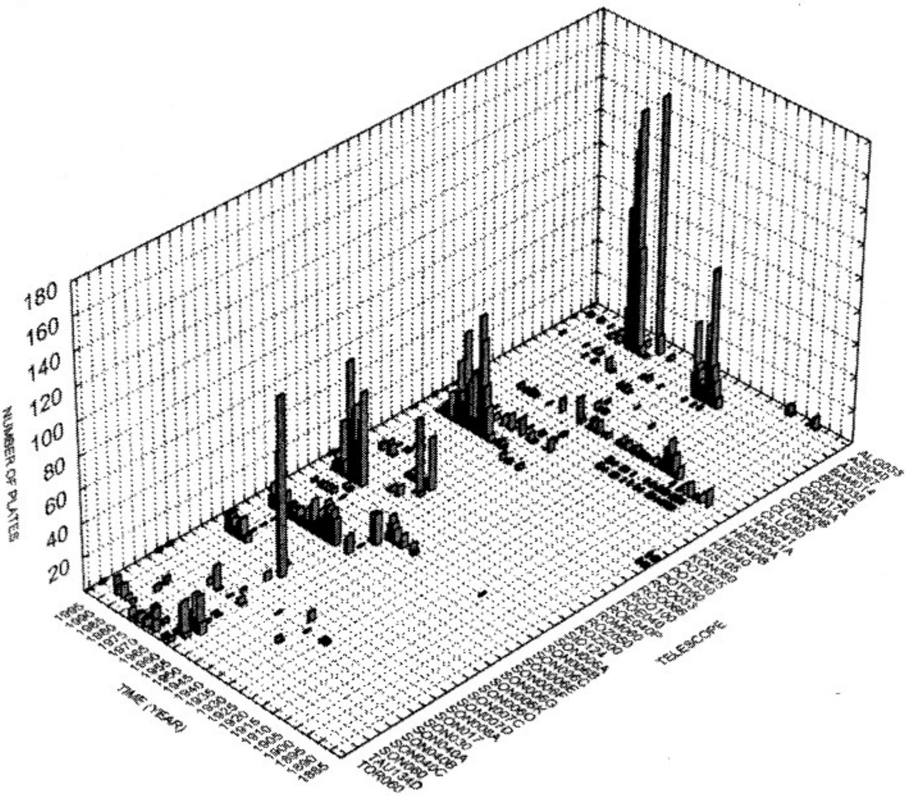

FIGURE 1 Time distribution of the Pleiades plates for the archives included in the WFPDB.

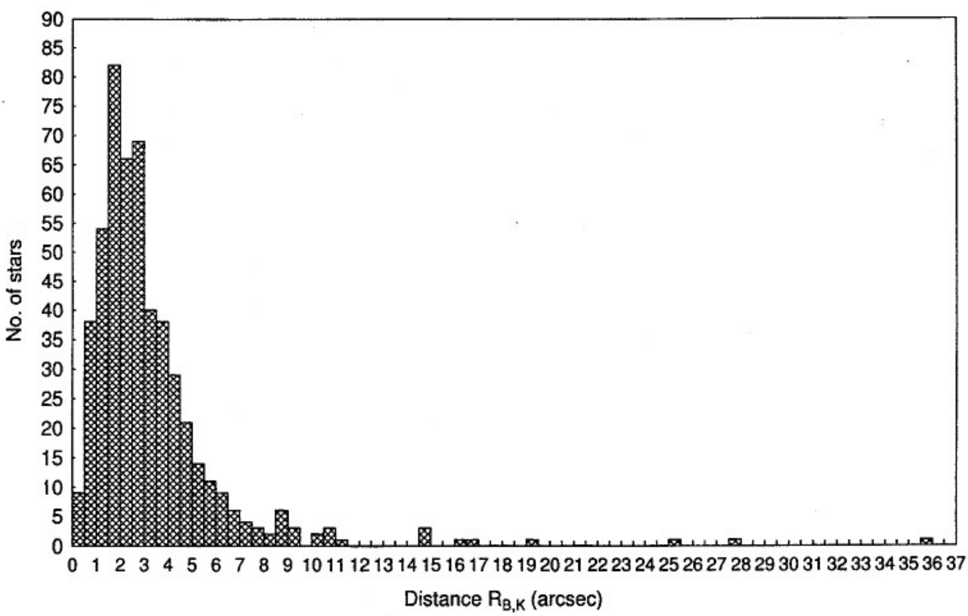

FIGURE 2 Distribution of the distances $R_{B,K}$ for HCG flare stars.

TABLE II Characteristics of the Used Scanning Machines.

Scanning machine	*Location*	*Type*	*Scan step (μm)*
SUPER COSMOS	Royal Observatory, Edinburgh, UK	High-precision microdensitometer	10
PDS 2020	University of Münster, Germany	High-precision microdensitometer	10
PDS 1010	Institute of Astronomy, Sofia, Bulgaria	High-precision microdensitometer	10
UMAX 3000	Konkoly Observatory, Budapest, Hungary	Flat-bed	8
Epson	DLR, Berlin, Germany	Flat-bed	16
APM	Institute of Astronomy, Cambridge, UK	High-precision microdensitometer	8

TABLE III List of the Scanned Plates (Note that the CdC Bordeaux plates have not so far been included in the WFPDB and therefore they have no WFPDB identifier).

WFPDB plate identifier	*Date of observation*	*Scanning machine*
BOR033	November 30, 1901	APM
BOR033	November 30, 1901	APM
BOR033	November 30, 1901	APM
BOR033	November 30, 1901	APM
BOR033	January 29, 1962	APM
BOR033	October 9, 1962	APM
BOR033	November 21, 1962	APM
BOR033	December 4, 1962	APM
BOR033	December 5, 1962	APM
BOR033	October 21, 1963	APM
BOR033	December 1, 1977	APM
BOR033	October 23, 1978	APM
BOR038 102000	September 17, 1980	APM
BOR038 112000	September 17, 1980	APM
BOR038 152000	January 13, 1982	APM
BOR038 162000	January 14, 1982	APM
BOR038 172000	January 14, 1982	APM
BOR038 18	December 18, 1963	APM
CLU020 000003	February 19, 1952	UMAX 3000
CLU020 000007	October 26, 1953	UMAX 3000
CLU020 000008	October 27, 1953	UMAX 3000
CLU020 000078	September 25, 1955	UMAX 3000
CLU020 000448	Missing date	UMAX 3000
CLU020 000473	July 27, 1956	UMAX 3000
CLU020 000474	July 18, 1956	UMAX 3000
CLU020 000475	July 27, 1956	UMAX 3000
CLU020 000476	July 28, 1956	UMAX 3000
KON060 000833	November 25, 1965	UMAX 3000
KON060 002767	October 29, 1968	UMAX 3000
KON060 002878	January 12, 1969	UMAX 3000
KON060 002877	January 11, 1969	UMAX 3000
KON060 003868	December 26, 1970	UMAX 3000
KON060 003898	February 1, 1971	UMAX 3000
KON060 003928	February 27, 1971	UMAX 3000
KON060 003929	May 24, 1971	UMAX 3000
KON060 004180	September 22, 1971	UMAX 3000
POT030 000153	December 4, 1885	PDS 2020, Epson
POT030 000154	March 18, 1886	PDS 2020, Epson

TABLE III (*Continued*)

WFPDB plate identifier	*Date of observation*	*Scanning machine*
POT030 000155	March 23, 1886	PDS 2020, Epson
POT030 000206	December 4, 1888	PDS 2020, Epson
POT030 000209	December 5, 1888	PDS 2020, Epson
POT050 000041	September 5, 1953	PDS 2020, UMAX 3000
POT050 000039	September 5, 1953	PDS 2020, UMAX 3000
POT050 000040	September 5, 1953	PDS 2020, UMAX 3000
POT050 000045	September 5, 1953	PDS 2020, UMAX 3000
POT050 000048	February 22, 1954	PDS 2020, UMAX 3000
POT050 000077	February 4, 1954	PDS 2020, UMAX 3000
POT050 000121	November 15, 1955	PDS 2020, UMAX 3000
POT050 000447	November 7, 1964	PDS 2020, UMAX 3000
POT050 000465	February 18, 1966	PDS 2020, UMAX 3000
ROE040 000134	November 26, 1962	UMAX 3000
ROE040 000537	December 28, 1965	UMAX 3000
ROE040 000538	December 28, 1965	UMAX 3000
ROE040 000540	January 17, 1966	UMAX 3000
ROE040 000541	January 17, 1966	UMAX 3000
ROE040 000547	February 14, 1966	UMAX 3000
ROE040 001012	October 17, 1969	UMAX 3000
ROE040 001013	October 17, 1969	UMAX 3000
ROE040 001026	November 4, 1969	UMAX 3000
ROE040 001182	January 19, 1969	UMAX 3000
ROE040 001262	October 26, 1971	UMAX 3000
ROE040 001279	November 16, 1971	UMAX 3000
ROE040 001363	December 7, 1972	UMAX 3000
ROE040 001587	December 14, 1973	UMAX 3000
ROE040 001588	December 14, 1973	UMAX 3000
ROE040 001869	March 29, 1972	UMAX 3000
SID124 008935	December 8, 1983	SUPER COSMOS
SID124 008960	December 23, 1983	SUPER COSMOS

3 COORDINATES OF THE PLEAIDES FLARE STARS

The results of the joint flare stars optical monitoring programme since 1963, in which eight observatories (Tonantzintla, Asiago, Byurakan, Konkoly, Sonneberg, Abastumani, Rozhen, and Palomar) took part up to 1981, have been presented in the catalogue and identification charts of the Pleiades flare stars by Haro *et al.* (1982) (HCG stars) for 519 flare stars with very rough coordinates and magnitudes. More precise coordinates of the Pleiades flare stars have been provided in the catalogue by Kazarovets (1993), available via VizieR (http://vizier.u-strasbg.fr/cgi-bin/VizieR?-source=J/other/PZ/23.141). Kazarovets (1993) measured with Ascorecord the coordinates on a Crimean astrograph plate obtained on January 31, 1973, with Eq., J1950.0. Because of problems in the star identification in such a crowded field as the Pleiades, the coordinates are not sufficiently correct for automated photometric measurements. This is one reason for recalculating the coordinates for all UV Cet-type stars found in the Pleiades for which charts have been published.

On UKST plate R 8935 obtained on December 8, 1983, we measured the coordinates of the UV Cet stars from the catalogue by Haro *et al.* (1982) and of 13 stars (Table 4) included in the flare stars database (Tsvetkova *et al.*, 1995), using the SUPER COSMOS microdensitometer and the USNO A2.0 catalogue of astrometric standards (Monet *et al.*, 1998) at http://www.nofs.navy.mil). The results have been given by Borisova *et al.* (2002). A comparison between our calculated coordinates and those of Kazarovets (1993), converted to Eq., J2000.0 without proper motion correction was made. Using the existing differences in RA

TABLE IV Coordinates of the Additional Pleiades Flare Stars from the Flare Star Database, not included in the Catalogue by Haro *et al.* (1982). The Hertzsprung (1947) H II Numbers are Given.

GCVS number	*H II number*	*RA J2000.0*	*DEC J2000.0*
	378	03 44 33.65	+23 41 24.4
V0851TAU		03 45 10.25	+24 23 31.0
V0859TAU		03 45 12.36	+22 41 53.5
V0854TAU		03 45 27.45	+23 37 59.5
V1041TAU	738	03 45 39.33	+23 45 17.5
V0853TAU		03 46 31.25	+22 18 22.4
	1332	03 47 13.47	+23 42 53.7
	1451	03 47 32.55	+24 36 17.4
V1048TAU	2381	03 49 36.64	+23 29 08.4
V0877TAU		03 49 48.38	+22 10 50.9
NSV01377	2870	03 55 51.40	+23 19 47.0
V1051TAU	2984	03 51 16.81	+23 49 38.1
V1054TAU	3096	03 51 39.24	+24 32 58.6

and D and the small-angle (less than 1′) approximation we calculated the distances between the star positions from our and Kazarovets (1993) coordinates $R_{B,K}$. The histogram of the distribution of $R_{B,K}$ for all 519 HCG stars in intervals of 0,5 arcsec is presented in Figure 2. The histogram tail is quite uneven. It spreads with zero data over long intervals. So we cut $R_{B,K}$ larger than 17 arcsec. The hypothesis that the data have a log-normal distribution with parameters estimated by the maximum-likelihood estimation method ($m = 2.487$ and $\sigma^2 = 0.49$) satisfies the χ^2-test for goodness of fit with a fixed level of significance of 5% ($\alpha = 0.05$).

For 15 stars, $R_{B,K}$ is in the interval from 10 to 36 arcsec. Some data for these stars is given in Table 5. Most of these stars are among the faintest flare stars in the region of the Pleiades, which have shown a large amplitude when they flare up (more than 3 m). The existing membership data for only five stars on the list gives membership probability around 0.00, excluding the HCG 15 star with different probability given by Stauffer *et al.* (1991), 0.46, and Jones

TABLE V Stars with Great Differences in the Coordinate Measurements.

HCG number	*Other designation*	$R_{S,K}$ *(arcsec)*	$R_{B,K}$ *(arcsec)*	$R_{B,K}$ *(arcsec)*	*Membership probability (Stauffer et al., 1991)*	*Magnitude at minimum (Haro et al., 1982)*
7	B466	16.5	35.6	42.2	—	16.5 pg
10	AB485	13.9	27.4	26.1	—	21 pg
15	K17	16.7	16.1	6.3	0.46	17.3 pg
24	T35b	11.6	10.4	6.3	0.04	19.8 pg
60	B343	19.3	10.6	21.0	—	21.0 pg
89	B236	27.3	14.5	36.2	—	18.8 pg
116	T4	9.2	25.2	39.0	—	20.9 pg
184	T77	10.3	10.7	6.5	0.00	19.8 U
217	B354	10.2	11.0	5.4	0.00–0.66	20.2 pg
243	A4	11.8	10.4	6.8	—	(17.2 pg)
334	AB482	4.0	14.6	4.2	—	(17.5 pg)
340	T49b	2.6	19.2	16.4	—	>22.0 U
469	B530	1.9	16.7	10.2	—	>21.0 U
478	B260	4.4	10.6	2.0	—	>18.0 pg
518	A134	1.7	14.5	15.2	—	17.8 pg

(1983), 0.76, and the HCG 217 star with contradiction information in Tables 1 and 3 in the work of Stauffer *et al.* (1991) from 0.00 to 0.66. For this sample of stars we made a comparison with the given coordinates in the paper by Stauffer *et al.* (1991). For this sample of stars we made a comparison with the given coordinates in Stauffer *et al.* (1991) with Eq.,\,J1950.0, Ep.,\,1973.09 and our coordinates. The distance between the star position from our estimations and those of Stauffer *et al.* (1991), converted to Eq.,\,J2000.0 (designated with $R_{B,K}$ and the distance between the star position from Stauffer *et al.* (1991) estimations and those of Kazarovets (1993) (designated with $R_{S,K}$) without proper motion corrections are presented in Table 5. Possible reasons for the great differences in the star positions are their faintness, difficult identification in crowded field, proper motion influence, binary system motion and the different coordinate measurement methods.

Acknowledgements

M. T. and K. T. are very grateful to Professor U. Heber and Professor I. Bues for help and hospitality, and to the Alexander von Humboldt Foundation for support. A. B., M. T. and K. T. thank Professor L. Balazs for hospitality at the Konkoly Observatory and K. Stavrev for some corrections and advice. This work was carried out under the framework of the joint research project 436 BUL/113 with the Deutsche Forschung Gemeinschaft and COST action 283.

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