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Photometric observations of pre-main sequence objects*,**

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Abstract. — We present the observational data of a photometric monitoring of 24 pre-main sequence objects: T Tauri stars, Ae/Be Herbig stars and some unclassified objects. Observations were carried out from July 1988 to August 1992, using the $UBV(RI)_c$ system. Variability with time scales from days to years and amplitudes in the V band larger than 0.1 mag is found for a part of this sample. The analysis of the possible causes of this variability are discussed in separate papers (Fernández & Eiroa 1995a, b).

Key words: stars: variable — stars: pre-main sequence

1. Introduction

Most of the young stars are characterized by some kind of variability (e.g. Appenzeller & Mundt 1989; Thé et al. 1994). The study of their sometimes erratic, sometimes regular, behaviour casts some light on the processes taking place in these objects and their interaction with the stellar environment. Such a study needs a large quantity of observational data which enables us to characterize in detail the variability of the stars. With this aim of monitoring the brightness variations on a sample of pre-main sequence stars, we carried out a photometric observational program from July 1988 to August 1992. Our sample includes 14 T Tauri stars, 7 Ae/Be Herbig stars and 3 unclassified objects from the catalogs of Herbig & Rao (1972) and Herbig & Bell (1988). The time interval allows us to search for optical continuum variability with time scales from days to years. In addition, the large quantity of observational data constitutes a significative sample to study changes in the active regions responsible of the variability and to confirm the constancy of brightness of some stars.

Here we present the observational results; the analysis of the variability and its possible origins are discussed elsewhere (Fernández & Eiroa 1995a, b).

*Based on observations collected at the 1.52 m telescope of the Estación de Observación de Calar Alto, Intituto Geográfico Nacional, Spain, which is jointly operated by the I.G.N. and the Consejo superior de Investigaciones Cientificas through the Instituto de Astrofísica de Andalucía; at the 1.23 m telescope of the German-Spanish Astronomical Center, Calar Alto, operated by the Max-Plank Institut für Astronomie, Heidelberg, jointly with the Spanish National Comission for Astronomy and at the Jacobus Kapteyn Telescope, operated on the island of La Palma by the Royal Greenwich Observatory in the Observatorio del Roque de los Muchachos of the Instituto de Astrofísica de Canarias, Spain

**Tables 3 to 26 are only available in electronic form at the CDS via anonymous ftp 130.79.128.5.

Table 1. Log of observations

Dates	Julian dates (2440000+)	Telescope
4-13 July 1988	7347–7356	1.52 m
14-21 August 1988	7388–7395	1.52 m
29 May-7 June 1989	7676–7685	1.23 m
14-23 May 1990	8026–8035	1.52 m
18-25 August 1990	8122–8129	1.52 m
17-30 June 1991	8425–8438	1.52 m
1-8 July 1991	8439–8446	1.52 m
6-19 August 1991	8475–8488	JKT (1 m)
29 Aug.-5 Sept. 1991	8498–8505	1.23 m
12-19 Nov. 1991	8573–8580	1.52 m
4-10 August 1992	8839–8845	JKT (1 m)

2. Observations

The observations were carried out with the 1.52 m telescope at the Estación de Observación de Calar Alto (E.O.C.A., Spain), the 1.23 m telescope at the German-Spanish Astronomical Center, Calar Alto (Spain), and the 1m Jacobus Kapteyn Telescope (JKT) at the Observatorio del Roque de los Muchachos (Canary Islands, Spain).

Table 2. The comparison stars of our sample ordered by increasing right ascension. In Cols. 1 and 2 the name of the stars are indicated: the prefix *Cx* denotes the best comparison star chosen among a previous sample of selected comparison stars and in Col. 2 the corresponding pre-main sequence object object is indicated. Columns 5 to 9 contain their brightness in the V band and colour indexes

Name		Coordinates		V	$(B-V)$	$(U-B)$	$(V-R)$	$(V-I)$
Comparison	Star	α(2000)	δ(2000)					
C2	V594 Cas	0 44 30.71	61 46 50.0	9.68	0.18	-0.08	0.12	0.25
C4	LkH$_{\alpha}$264	2 57 33.61	20 01 03.9	9.90	0.76	0.32	0.36	0.72
C3	LkH$_{\alpha}$325	3 30 08.58	30 22 44.6	11.06	0.73	0.14	0.37	0.74
C3	LkH$_{\alpha}$330	3 45 20.41	32 28 42.1	11.62	0.73	0.22	0.39	0.82
C2	V773 Tau	4 12 59.53	28 29 18.2	11.44	1.48	1.33	0.99	2.00
C2	AS 205	16 11 13.77	-18 40 00.4	12.33	0.71	0.46	0.44	0.90
C1	V1121 Oph	16 48 53.72	-14 26 39.6	12.18	0.65	-0.22	0.44	0.92
C1	VV Ser	18 28 33.55	0 02 25.9	12.28	0.89	0.37	0.49	1.00
C2	AS 310	18 33 25.11	-5 00 26.8	13.60	0.83	0.07	0.50	1.03
C2	AS 353	19 20 55.21	11 08 52.8	11.47	0.77	0.30	0.40	0.79
C1	LH$_{\alpha}$483-41	19 26 50.06	23 52 41.0	12.40	0.59	0.07	0.36	0.70
C2	WW Vul	19 26 57.66	21 09 01.7	9.32	0.30	0.02	0.20	0.43
C2	LkH$_{\alpha}$228	20 24 35.95	42 15 26.9	11.79	0.89	0.56	0.46	0.90
C1	LkH$_{\alpha}$191	20 58 52.62	43 54 51.0	12.51	0.80	0.31	0.44	0.87
C2	V1331 Cyg	21 01 13.21	50 24 06.9	12.44	0.83	0.42	0.42	0.82
C1	LkH$_{\alpha}$321	21 01 55.22	49 42 39.4	11.60	0.55	0.04	0.30	0.59
C4	LkH$_{\alpha}$324	21 02 52.10	50 19 40.1	12.48	0.68	0.15	0.33	0.66
C5	LkH$_{\alpha}$349	21 36 26.54	57 37 00.9	11.08	1.49	1.52	0.82	1.62
C2	BD+65° 1637	21 43 50.37	66 08 48.0	12.27	0.61	0.06	0.38	0.81
C2	LkH$_{\alpha}$234	21 43 50.37	66 08 48.0	12.27	0.61	0.06	0.38	0.81
C7	LkH$_{\alpha}$233	22 34 27.0	40 45 54	9.71	0.00	-0.07	0.02	0.06
C4	DI Cep	22 57 20.31	58 41 05.8	10.76	0.67	0.17	0.34	0.70
C3	MWC 1080	23 16 55.71	60 55 26.7	9.30	1.35	1.35	0.71	1.40
C4	BM And	23 37 54.29	48 19 32.7	11.79	1.14	0.82	0.58	1.16

A log of the observing periods and telescopes used is indicated in Table 1.

During 1988 the 1.52 m telescope was equipped with a one channel photomultiplier with a dry-ice cooled EMI 9816 photomultiplier tube and it was then substituted by a Butler C 31034 A photomultiplier tube. The equipment has been described by Lahulla & Pensado (1982). Stars were observed through a 24″ diaphragm and sky background was measured about 60″ apart. The 1.23 m telescope was equipped with a one channel photomultiplier with a dry-ice cooled Butler C 31034 A photomultiplier tube. The equipment is similar to that mentioned for the 1.52 m telescope. Stars were observed through a 21″ diaphragm and sky background was measured about 40″ apart. The People's photometer on the 1 m JKT is a two-channel photometer equipped with two EMI 9658 photomultipliers called Romeo and Juliet. While observing the star with Romeo, Juliet measures a sky background at $\Delta\alpha = 0''$ and $\Delta\delta = +175''$, then the channels are swapped to measure the star through Juliet and the sky through Romeo (for details see Dick & Jones 1988). This acquisition mode yields two independent measurements, one in each channel. We have to point out that for some stars (LkH$_{\alpha}$228 and LkH$_{\alpha}$324 in August 1991 and LkH$_{\alpha}$234 in August 1992) there is an offset between the Romeo and Juliet measurements, this offset is of the same order as the observational error and it is due to the nebula close to each object. The apertures used were 28″. Integration times of 30 s for each measurement were used in 1988; later integration times were chosen in order to achieve a signal/noise ratio of 100 (which implies an error of 0.01 mag, see Henden & Haitchuck 1982).

The observations were carried out using the $UBV(RI)_c$ photometric system. This system provides a wide wavelength range, which allows us to compare the variability at quite different wavelengths.

For the transformation to the standard system, we observed between 12 and 25 standard stars each night, taken from the list of Neckel & Chini (1980). In order to reproduce the Cousins RI extension we took the tabulated values of Taylor et al. (1989). The data reduction has been made following the algorithm of Harris et al. (1981).

To study variability with amplitudes down to 0.1 mag we decided to observe two comparison stars for each object, in order to make use of the advantage of smaller errors of the differential photometry. After the data reduction one of these stars was chosen to calculate the difference in magnitudes between the object and the selected comparison star. This star was chosen by its constancy of brightness and its $(B-V)$ colour index, close to that of the object. The brightness in the V band of the selected comparison stars and their colour indexes are indicated in Table 2; these stars are designated by a C, a number and the name of the corresponding pre-main sequence object. The coordinates of the comparison stars are also indicated in Table 2 and finding charts can be provided by the author after request. These coordinates have been obtained from *The Guide Star Catalog. Version 1.1*[1], except for C7 $LkH_{\alpha}233$ for which they were taken from the Palomar Observatory Sky Survey. The errors of the differential photometry are about 0.02 or 0.03 mag for the $BV(RI)_c$ bands and about 0.05 mag for the U band. Some objects have a $(B-V)$ colour index outside the range defined by the standard stars: $LkH_{\alpha}330$, $LkH_{\alpha}349$, $LkH_{\alpha}325$, V1121 Oph and BM And. For $LkH_{\alpha}191$ it must be mentioned that due to its location in the North America Nebula (NGC 7000) it was not easy to substract an appropriate background. The observational errors for these objects are likely to be larger.

3. Results

Our sample includes 14 T Tauri stars ($LkH_{\alpha}264$, $LkH_{\alpha}325$, $LkH_{\alpha}330$, V773 Tau, AS 205, V1121 Oph, AS 353, $LkH_{\alpha}228$, $LkH_{\alpha}191$, V1331 Cyg, $LkH_{\alpha}321$, $LkH_{\alpha}349$, DI Cep and BM And), 7 Ae/Be Herbig stars (V594 Cas, VV Ser, WW Vul, BD 65° +1637, $LkH_{\alpha}234$, $LkH_{\alpha}233$ and MWC 1080) and 3 unclassified objects (AS 310, $LH_{\alpha}483$-41 and $LkH_{\alpha}324$). Tables 3 to 26 show the entire set of measurements, the objects being ordered by right ascension (1950 equinox). Their numbers in the Herbig & Bell (1988) catalog are indicated in the table captions. In the tables we quote the difference in magnitudes between the object and the selected comparison star. The first column contains the Julian Date of observations and Cols. 2 to 6 lists the differences of brightness in the V band and the differences in the $B-V$, $U-B$, $V-R$ and $V-I$ colours, respectively. For those observing runs carried out with the JKT, measurements obtained with Romeo are tabulated first and then those obtained with Juliet.

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[1] *The Guide Star Catalog* (GSC) was prepared by the Space Telescope Science Institute.