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A LONG-TERM PHOTOMETRIC STUDY OF THE PMS STAR V391 Cep

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V391 Cep is a pre-main sequence (PMS) star located in the dark clouds northwest of the emission nebula NGC 7129. The star was discovered as a strong H_α emission source in our objective prism survey (Semkov and Tsvetkov 1986). Our photographic photometry (Semkov 1993a) suggests that the star is irregular variable with amplitude of about 2 magnitudes. The optical spectrum of V391 Cep obtained in 1992 (Semkov 1993b) shows the main spectral characteristics of the Classical T Tauri stars (CTTs). The star is surrounded with a small cometary nebula seen on deep red and infrared images. V391 Cep is also included in the list of H_α emission stars (No 71) published by Kun (1998). The position of the star (J2000.0) in the Aladin Sky Atlas is R.A. = $21^h40^m27^s.62$ and Dec = $66°35'22''.2$.

The CCD photometric data presented in this paper are the continuation of our photographic investigation of V391 Cep (Semkov 1993a). Observations were made with three telescopes: the 2-m RCC and 50/70/172 cm Schmidt telescopes of the National Astronomical Observatory Rozhen (Bulgaria) and 1.3-m RC telescope of the Skinakas Observatory[1] of the Institute of Astronomy, University of Crete (Greece). The first CCD observations of V391 Cep in the period 1993-1996 ware made with SBIG ST6 camera attached to the 2-m RCC telescope. Since 1997 Photometrics CCD cameras with 2-m RCC and 1.3-m RC telescopes and SBIG ST8 camera with 50/70 cm Schmidt telescope were used. The technical parameters and chip specifications for used cameras are summarized in Table 1. The typical exposure times are 60-120 sec for R_C and I_C, 120-180 sec for V and 300 sec for B and U filters. All frames ware taken through a standard Johnson-Cousins set of filters. All frames obtained with Photometrics cameras are bias subtracted and flat fielded. CCD frames obtained with ST6 and ST8 cameras are dark subtracted and flat fielded. Aperture photometry was performed using IDL based DAOPHOT routines.

In order to facilitate transformation from instrumental measurements to the standard system a sequence of seven comparison stars in the field of V391 Cep was calibrated in $UBVR_CI_C$ bands. Calibration was made during seven clear nights, four with 1.3-m RC telescope and three with 2-m RCC telescope. Standard stars from Landolt (1992) were used as reference. At least six standard fields in different air masses were observed every night. Table 2 contains the measured $UBVR_CI_C$ magnitudes and corresponding mean errors of the mean for comparison sequence. The stars are labeled from A to G in order

[1]Skinakas Observatory is a collaborate project of the University of Crete, the Foundation for Research and Technology - Hellas, and the Max-Planck-Institut für Extraterrestrische Physik.

of their V-band magnitude. The standards ranging from V=12.$^{\rm m}$730 to V=16.$^{\rm m}$691 and from $B-V$=0.$^{\rm m}$632 to $B-V$=1.$^{\rm m}$349. The finding chart of the comparison sequence is presented in Fig. 1. The field is $6' \times 6'$, centered on V391 Cep. North is at the top and east to the left. The chart is retrieved from the STScI Digitized Sky Survey Second Generation Red.

Table 1: CCD cameras and chip specifications

Telescope	2-m RCC	2-m RCC	1.3-m RC	50/70 cm Scm
CCD type:	ST-6	AT200	CH360	ST-8
Chip:	TC-241	SITe SI003AB	SITe SI003B	KAF 1602E
Size:	375×242	1024×1024	1024×1024	1530×1020
Pixel size:	23×27 μm	24×24 μm	24×24 μm	9×9 μm
Scale:	$0\farcs30 \times 0\farcs34$/pixel	$0\farcs33$/pixel	$0\farcs5$/pixel	$1\farcs1$/pixel
Field:	$1\farcm5 \times 2\farcm0$	$5\farcm6 \times 5\farcm6$	$8\farcm5 \times 8\farcm5$	$28' \times 18\farcm7$
Gain:	$6.7e^-$/ADU	$4.93e^-$/ADU	$5.3e^-$/ADU	$2.3e^-$/ADU
RON:	3.1ADU/rms	3.9ADU/rms	2.6ADU/rms	6.2ADU/rms

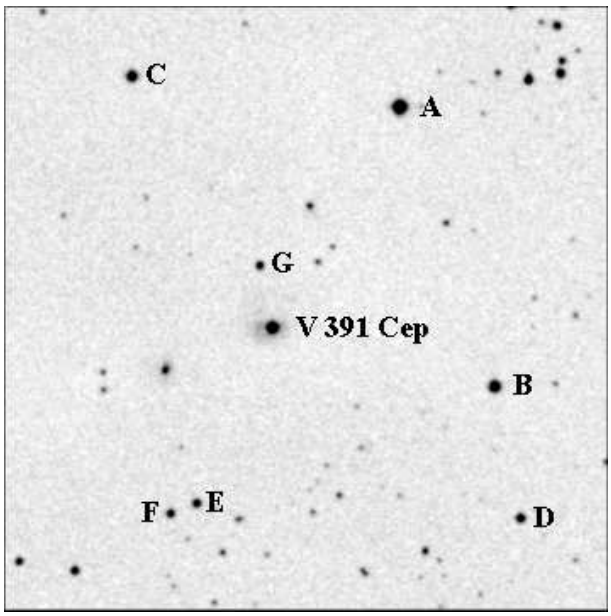

Figure 1. A finding chart of the comparison sequence in the field of V391 Cep

The results from our CCD photometric observations are given in Table 3. The table contains Date, Julian Date, V magnitude, $U-B$, $B-V$, $V-R_C$ and $V-I_C$ indices and telescope used. Fig. 2 shows the long-term B-band light curve of V391 Cep in the whole period of observations (1984-2002). In the figure the filled circles denote our photographic observations (Semkov 1993a) and the open circles denote CCD photometric data from this paper. A considerable change of the amplitude of brightness of V391 Cep is seen from Fig. 2. Since 1986 the amplitude of brightness (B-band) decrease gradually from 2.$^{\rm m}$1 to 0.$^{\rm m}$3 at the present time. It is generally accepted that CTTs are surrounded with an

Table 2: Photometric data for $UBVR_CI_C$ comparison sequence.

Star	V	σ_V	I_C	σ_I	R_C	σ_R	B	σ_B	U	σ_U
A	12.730	.029	11.980	.025	12.358	.027	13.429	.076	13.676	.045
B	14.089	.021	13.348	.034	13.728	.015	14.721	.054	14.856	.064
C	14.500	.037	13.643	.032	14.057	.026	15.339	.052	15.708	.028
D	15.721	.019	14.697	.035	15.189	.048	16.722	.033	17.487	.098
E	16.272	.022	14.780	.040	15.539	.015	17.555	.028	–	–
F	16.429	.014	14.903	.036	15.703	.016	17.626	.072	–	–
G	16.691	.037	15.142	.042	15.881	.048	18.040	.038	18.377	.112

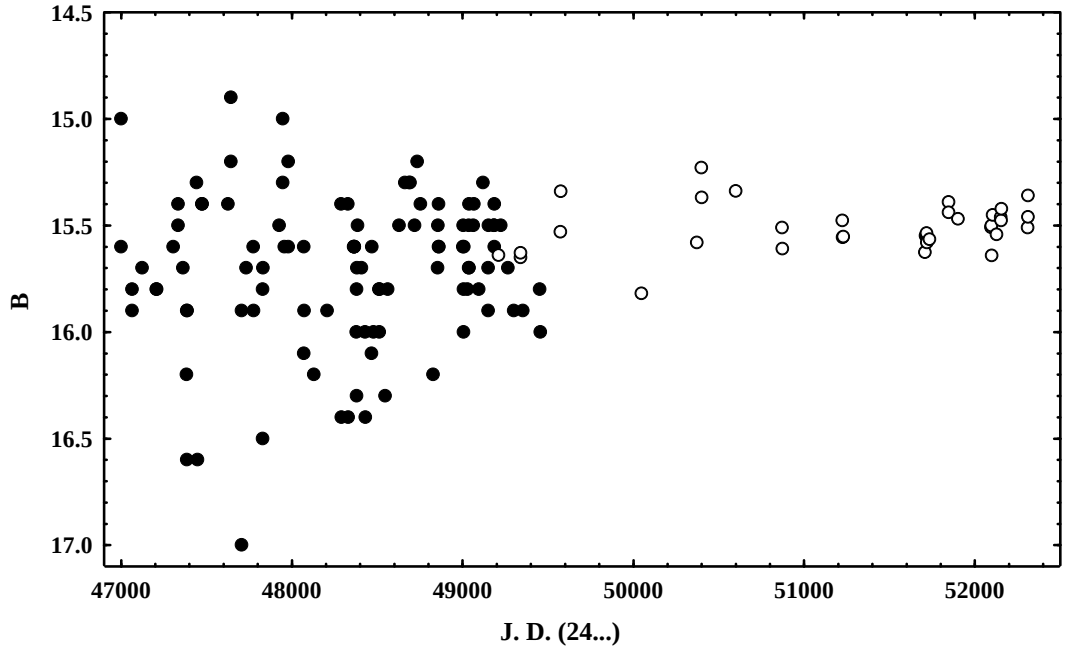

Figure 2. *B*-band light curve of V391 Cep in the period 1984-2002

extended circumstellar disks and such change in activity of V391 Cep can be caused by an irregular accretion rate.

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Table 3: Photometric observations of V391 Cep in the period August 1993 - February 2002

Date	J.D. (24...)	V	$U-B$	$B-V$	$V-R_C$	$V-I_C$	Tel.
12.08.1993	49212.425	14.34	–	1.30	0.85	–	2m
13.08.1993	49213.378	14.38	–	–	–	–	2m
14.08.1993	49214.369	14.33	–	–	–	–	2m
18.12.1993	49340.322	14.39	–	1.26	0.86	1.82	2m
19.12.1993	49341.267	14.41	–	1.22	0.81	1.69	2m
7.08.1994	49572.398	14.53	–	–	0.98	1.83	2m
8.08.1994	49573.435	14.42	–	1.11	0.97	1.79	2m
10.08.1994	49575.436	14.21	–	1.13	0.88	1.70	2m
26.11.1995	50048.420	14.56	–	1.26	0.95	1.80	2m
15.10.1996	50372.418	14.34	–	1.24	0.82	1.58	2m
11.11.1996	50399.405	14.17	–	1.06	0.85	1.53	2m
13.11.1996	50401.369	14.32	–	1.05	0.95	1.57	2m
2.06.1997	50601.539	14.120	–	1.219	0.823	1.685	2m
28.02.1998	50872.590	14.301	−0.110	1.209	0.850	1.779	2m
1.03.1998	50873.598	14.357	−0.080	1.253	0.870	1.784	2m
4.03.1998	50876.635	14.285	–	–	–	–	2m
16.02.1999	51225.621	14.255	−0.060	1.222	0.878	1.796	2m
17.02.1999	51226.577	14.363	−0.050	1.193	0.873	1.787	2m
21.02.1999	51230.592	14.339	–	1.215	0.858	1.750	2m
8.03.2000	51611.655	14.374	–	–	–	–	2m
13.06.2000	51709.485	14.407	−0.286	1.220	0.845	1.767	1.3m
14.06.2000	51710.497	14.314	–	–	0.825	1.704	1.3m
15.06.2000	51711.493	14.313	–	–	–	1.705	1.3m
16.06.2000	51712.490	14.349	–	1.200	–	1.736	1.3m
21.06.2000	51716.512	14.374	–	1.178	–	1.749	1.3m
21.06.2000	51717.392	14.366	–	–	–	1.804	1.3m
22.06.2000	51718.449	14.372	–	1.174	0.849	1.727	1.3m
23.06.2000	51719.448	14.346	–	1.191	0.837	–	1.3m
24.06.2000	51720.384	14.382	–	1.198	–	1.729	1.3m
11.07.2000	51736.507	14.363	−0.283	1.203	0.843	1.731	1.3m
29.10.2000	51847.379	14.23	–	1.16	0.80	1.77	Scm
30.10.2000	51848.419	14.30	–	1.14	0.84	1.81	Scm
24.12.2000	51903.287	14.33	–	1.14	0.82	1.80	Scm
27.05.2001	52057.492	14.22	–	–	–	1.72	Scm
5.07.2001	52095.559	14.307	−0.258	1.202	0.837	1.709	1.3m
6.07.2001	52097.298	14.325	–	1.176	–	1.730	1.3m
8.07.2001	52099.293	14.386	–	1.255	–	1.751	1.3m
16.07.2001	52106.536	14.287	–	1.164	–	1.706	1.3m
7.08.2001	52128.528	14.322	–	1.220	–	1.737	1.3m
1.09.2001	52153.592	14.303	–	1.159	–	–	1.3m
2.09.2001	52154.575	14.327	–	1.150	–	1.762	1.3m
5.09.2001	52157.546	14.287	–	1.136	–	1.770	1.3m
5.02.2002	52311.261	14.30	–	1.21	0.85	1.82	Scm
6.02.2002	52312.259	14.21	–	1.15	0.82	1.79	Scm
7.02.2002	52313.247	14.29	–	1.17	0.84	1.81	Scm