On the stability of initial epochs and photometric periods in light variations of weak-line T Tauri stars

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Abstract

We present the results of a long-term photometric monitoring campaign for a sample of T Tauri stars with weak emission lines (WTTS) in a star-forming region in Taurus-Auriga. All stars show periodic light variations, which may be caused by the presence of cold photospheric spots. Variations of the amplitude and the shape of the folded light curves are discussed. A fundamental result of the analysis of rotation modulation is the stability of initial epochs and photometric periods of 21 WTTS in the interval from 2 to 13 years.

1. Introduction

Weak line T Tauri stars are late-type stars associated with star-forming regions in molecular clouds, the first of which were discovered in the Lick CaII survey (Herbig et al. 1986) and in an X-ray survey (Feigelson et al. 1987). These WTTS stars are distinguished by the presence of significant Li abundances, strong chromospheric emission, and none of the excesses common to the classical T Tauri stars (CTTS). Strongly enhanced absorption of LiI λ6707Å is specific for all WTTS, indicating the youth of these objects. The properties of WTTS have been described by Walter et al. (1988).

Some periodic processes in the light curves of various WTTS have been revealed in several special photometric campaigns (see a compilation by Bouvier 1990 and Grankin 1994). Now the list of Tau-Aur WTTS with periodic light variations includes about 30 stars. The values of their photometric periods are in the range from 0.7 to 30 days, and their amplitudes are in the V range from $0.^{m}06$ to $0.^{m}60$. The periodic variations of these objects can be interpreted as the rotational modulation of the stellar flux by a group of dark surface spots.

A detailed analysis of the selected WTTS photometric variability showed that their spotted regions are often large (typically 10% of the stellar surface) and much colder than the surrounding photosphere (the temperature difference is typically in the range 700° K to 1000° K). Properties of the group of spots for these WTTS are similar to those of RS CVn and BY Dra stars (Bouvier & Bertout 1989; Bouvier et al. 1995; Grankin et al. 1995).

The best example of a WTTS with periodic light variations is V410 Tau. The most detailed photometric investigation of this star was made by Petrov et al. (1994) (see also Vrba et al. 1988; Herbst 1989). One of the most interesting results of the analysis of rotational modulation of V410 Tau is the stability of the initial epoch and photometric period over an interval of 8 years. Petrov et al. (1994) analyzed the data obtained by Grankin and Melnikov at Mt. Maidanak from 1986 to 1993 and found a period $P = 1.^{d}872095 \pm 0.^{d}000022$, with ephemeris of minimum brightness $JD_{min} = 2446659.4389 + P * E$, where E is an integer number. Thus, the light curve was more or less stable during a few years, with the exception of 1990/91, when the amplitude of the light variations increased gradually during 1-2 months.

Later the photometric period stability for 10 WTTS in the interval 1992-1995 and for 6 WTTS in the interval 1985-1995 was found (Grankin 1994; Grankin 1996). Thus, a preliminary analysis of some selected WTTS long-term observations showed that the periodic component in the light variations of the stars has the following peculiarities:

- it is shown by most WTTS;
- it is stable at time-intervals from 2 months till a few years;
- it fits best the models of stars with cold spots.

These peculiarities allow us to suppose that in the case of WTTS we deal with solar-type activity. In this connection the study of the spotted rotation modulation properties of a substantial WTTS population on the timescale of several years is of great interest.

In this paper we present the results of our long-term photometric monitoring of 21 WTTS in the Tau-Aur complex with well-known periods aimed at determining the lifetimes of cool spots on the star's surfaces.

2. Results

The BVR observations were obtained during six runs from August 22, 1990 to December 29, 1995, at the Mt. Maidanak Observatory, Uzbekistan, using a 0.48m or 0.60m telescope equipped with a pulse counting FEU-79 photomultiplier tube with a 28" or 17" diafragm. Exposure times ranged from 20 to 120 seconds, depending on the filter and on the object brigthness. For determining the transformation to the standard system, some 5 standard stars were observed several times each night. The observations were reduced using the standard procedures developed by Nikonov (1976). The mean error of one observation of a program star is typically $\pm 0.^{m}01$ in V, B-V, and V-R. The Maidanak BVR Photometry Data Bank is at Tashkent Astronomical Institute and available to all interested persons.

The analysis of the photometric behaviour of 21 WTTS's within 1-13 years has led to the following conclusions:

- Most stars are variable in their average brightness in V ($\overline{V}$) on scales from a few hundredths to one tenth of a magnitude.
- The amplitude of the light variations (ΔV) can change considerably from season to season. For

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Table 1: Taurus-Auriga WTTS with well-known periods

Name	Interval observ.	Initial epoches JDH 2440000+	Period (day)	Epoch of observ. 1900+
DI Tau	1987-1993	7002.9	7.64	87-93
V410 Tau	1986-1993	6659.4389	1.872095	86-93
V819 Tau	1982-1993	5197.35	5.5354	90-93 *
V827 Tau	1981-1993	4896.0	3.75886	81-93 *
V830 Tau	1982-1993	5252.57	2.74079	82-93 *
V836 Tau	1982-1993	5252.3	6.755	82,90-93 *
TAP 26	1992-1995	8619.6	0.7135	92-94
TAP 29	1990-1995	5998.7	5.6638	90-95 *
TAP 31	1992-1995	8850.32	1.529	92-93
TAP 35	1992-1995	8858.5	2.734	92-93
TAP 40	1992-1995	8859.8	1.5548	92-93
TAP 41	1992-1995	8857.6	2.4272	92-93, 95
TAP 45	1992-1995	8859.5	9.909	92-93
TAP 49	1992-1995	8857.2	3.32	92
TAP 56	1990-1993	8179.8	2.236	90-93
TAP 57	1992-1995	8848.7	9.345	92-95
Anon 1	1992-1995	8951.7	6.493	92-95
LkCa 1	1993-1995	9212.8	2.497	93-94
LkCa 2	1992-1995	9951.4	1.364	95
LkCa 4	1985-1993	6299.6	3.3745	85,92-93 *
LkCa 11	1992-1995	8953.7	1.5396	92-95

(*) it was used both our observations and others

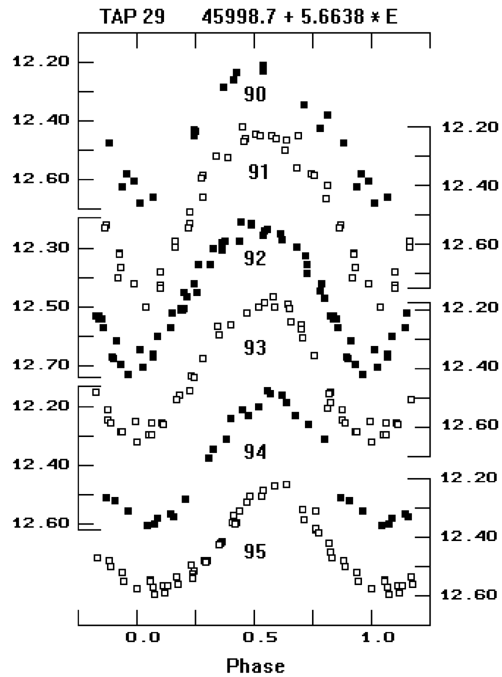

Fig. 1.— Phase diagrams for light curve in the V filter for TAP 29

example, that of TAP 41 changes on a scale from $0^{m}.1$ to $0^{m}.4$.

- The observational season when a star shows the largest amplitude of the light variations is almost always before the season when it shows the smallest ΔV. In other words, the amplitude of the light variations shows sudden changes within 1-2 months.
- The strong decrease of the amplitude of the periodic process or its complete disappearance result in the $V_{\max}$ decrease.
- The periodic process keeps its amplitude and the initial epoch for a few years (see Table 1). Then the periodic process changes its phase and shape. The periodic process amplitude is minimal while these changes occur.

Table 1 contains the interval of observations, the initial epoch, the photometric period and the epoch of observations when the initial epoch and the period are unchangeable. Table 1 shows that 8 stars keep their periods and the initial epoch within 1-2 years and 6 stars keep those within 3-4 years. Moreover, TAP 29, DI Tau, and V410 Tau keep their periods and the initial epoch for 6, 7, and 8 years, respectively! Phase diagrams for light curves in the V filter for TAP 29 is displayed in Figure 1.

When adding some observations from other observational programs of LkCa 4, V819 Tau, V827 Tau, V830 Tau, and V836 Tau, one can see that these stars keep their periods and initial epochs for 9-13 years. Grankin et al. (1995) suggested that this stability seemed to be due to the long-living "active" longitudes where extensive spotted regions persist. Note, that the persistence of these extensive spotted regions does not exclude at all some individual spots and their groups appearance within the regions. The appearance of individual spots and their groups can result in the remarkable change of the shape and amplitude of the periodic process from season to season. This is accompanied by some changes in the average brightness ($\overline{V}$) and the magnitude in the star light maximum. However, the period and initial epoch stability of the folded light curves depends on the lifetime of an active region, but not on that of individual spots or their groups. All the above facts lend support to the existence of stellar activity cycles on WTTS.

To find and study these stellar activity cycles we are planning to continue a LOng-Term Observations of young solar-type Stars (LOTOS). We are going to include into the LOTOS programme some stars of different spectral types (from G to M) and of different ages (from $1 * 10^7$ to $200 * 10^7$ yrs). We hope that the successful realization of the programme will shed some light on the following questions:

- What is the range of rotation periods of young stars?
- Is there any relation between the axial rotation period and the other star parameters such as its age, mass, spectral type, etc.?
- What are the properties of the extensive spotted regions and how do these properties evolve in time?
- Is there any dependence of the degree of "spottedness" on a star's age and/or its axial rotation

period?

- Are there any stellar activity cycles on young stars and how long are they?
- Is there any real relation between the rotation period and the level of activity?

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