SPECTRAL AND PHOTOMETRIC RESEARCHES OF RY TAU

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ABSTRACT. The results of analysis of the total light curve of the classic T Tauri type star RY Tau were presented. For a time at last 48 years a brightness of the star is characterized by fluctuations with amplitude about $\Delta V \sim 1^{\rm m}$, with characteristic time about 300 days. Firstly we were showed, that in an interval of $1983-2004$ in V-band light variability of the star has cyclic character with the period of 377 ± 10 days. After the deepest minimum in 1995 there was some change in system therefore, since, fluctuations with amplitude about $1^{\rm m}$ are continued, the phase of the period found before this minimum showed some displacement.

On the IUE archive data base we have studied a spectrum of RY Tau in the UV range. For $1979-1990$ spectral observations we have measured relative intensities, FWHM (full wide at half middle) and equivalent widths of the relatively strong emission lines, as Mg II λ2800Å, S II, O I λ1334Å, C II λ1403Å, Si V λ1454Å, C IV λ1546Å, He II λ1640Å, etc. A variability of the line intensities of Mg II λ2800Å emission and absorption components with period 23.2±0.3 days was discovered. Some variability of emission line intensities from night to night was obtained.

Key words: stars: photometry, total light curve, UV spectroscopy: emission lines, individual: RY Tau.

1. Introduction

RY Tau is one of brightest classical T Tauri type stars (CTTS), with irregular light variability and a moderate emission spectrum. After unusual brightening in 1983/1984 from 11^m to 9^m in V (Herbst and Stine 1984, Zajtseva et al.1985) the star has been high interest of investigators for photometric and spectroscopic observations. Full light curve for $1965-1985$ was investigated by Herbst (1986) which have showed that a light of the star is varied with period larger 20 year. There are many works to find a periodicity in the light variations of the star. Some periods were reported on timescales from 5 to 66 days, but none was confirmed after (Zajtseva 1986, Herbst et al.,1987, Herbst and Korett, 1988, Bouvier et al., 1993, Bouvier et al., 1995).

Spectral type obtained by Herbig (1977) and Cohen and Kuhi (1979) as $K1IV-V$, Cabrit et al. (1990) as $G2$ and Petrov et al. (1996), as $G1-2IV$. The equivalent width of the H_α emission is about 20 Å, H_β sometimes in emission, sometimes in absorption, while higher Balmer lines are always in absorption. The flux radiated in H_α and IR CaII emission lines remained the same, in spate of the $\Delta V = 1^m$ difference in the continuum flux (Petrov et al., 1999). On the HST/STIS repeated observations of RY Tau Gomez de Castro and Verdigo (2007) the stellar wind physical parameters had been obtained.

In this work we have reporting results of the analysis a summary light curve for periodicity and UV spectral variability of RY Tau.

2. Summary light curve

2.1. Search of periodicity.

The summary light curve of RY Tau has been carried out on the observations of the different authors from Wesleyan University database (Herbst et al., 1999), and also in archive (Grankin et al., 2007). In total for the analysis it has been used about 1800 individual UBV measurements received in $1962-2005$.

On the Fig.1 the summary light curve of the star, carried out in a time interval of 1962-2004 is presented. Apparently, up to unusual increase of brightness in 1983 of the star light carries irregular character: was observed often weakening with different amplitudes, average value of the light in different seasons had been varied. The common character of the light variability RY Tau is corresponded IV photometric type of variability on the scheme of classification (Ismailov, 2004). According to results of observations of Petrov et al. (1999) and in 1996 a brightness of the star the same as and during the period, after 1983, continued fluctuations in an interval $9.^m5-10.^m8$. As already have noted

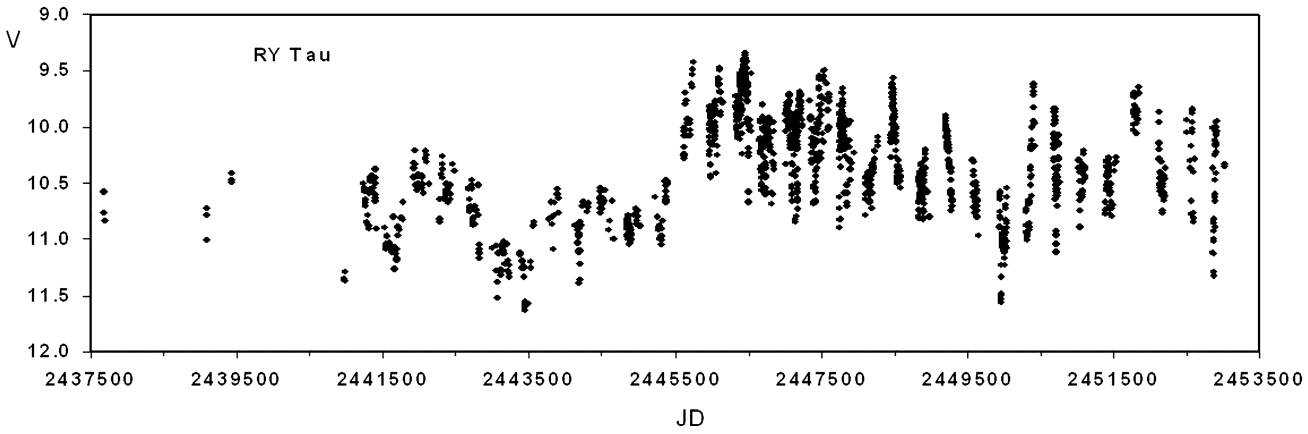

Figure 1: Summary V-light curve of RY Tau for 1962-2004.

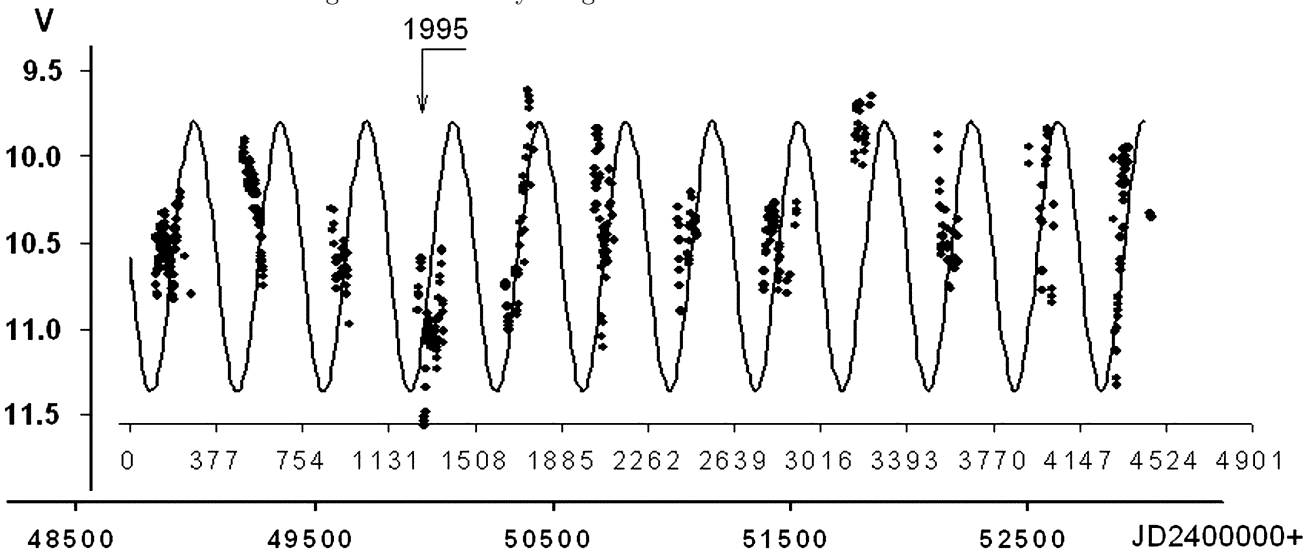

Figure 2: The fragment of light curves in range $1992-2004$. V-values fitted with sinusoidal curve with period 377 days (solid line). A characteristic minimum in 1995 marked with the arrow.

many authors, after unusual increase of light since 1983 (JD 2445618), a character of variability a brightness of the star has a little changed: fluctuations with amplitude about 1m with characteristic time of 300-400 day was observed. After of this time the light variability of the star began to have cyclic character. As it is visible from Fig.1 a mean value of the V-magnitudes is slow change with characteristic time about 11 years, where superimposed fluctuations with amplitudes about 1m with characteristic time at 350 days. This feature of the light curve demands detailed search of the possible periodic component on the light curve.As we see from Fig.1 in different time intervals a brightness of the stars are carried cyclic character, but sometimes under irregular events this cyclic variability is destroyed. For carry out statistical fourye analysis all measurements we have divided into 3 separate massive with different quantity of the data, and for each of massive has been search of the period separately. The first file contains all data before event of 1983, the second - from 1983 up to 1996 (JD 2450318), and the third - from 1996 on 2004. For performance of the statistical frequency analysis we use a method Scargle (1982) which later advanced by Horne and Balinas (1986). For all frequencies interval $0-1\ d^{-1}$ we have find a maximal peak in $\nu = 0.00265 \pm 0.00005 d^{-1}$, which is corresponded to the period $P_1 = 377^d \pm 10^d$.

In Fig.2 a fragment of light curves in range $1992-2004$ was presented. V-values fitted with sinusoidal curve with period 377 days (solid line). A characteristic minimum in 1995 marked with the arrow.

In Fig3 phase diagrams for period 377 day have presented. In the up panel all measurement before 1983 and on the second panel all data after 1983 are described. We can see that before to event 1983 periodicity is not clear, but after 1983 obtained periodicity are well described all data's. It is showed that after 1983 events a character of the light variability of the

star is changed. After the deepest minimum in 1995 there was some change in system therefore, since, fluctuations with amplitude about 1^m are continued, the phase of the period founded before to this minimum was shows some displacement.

It is necessary to pay attention to that fact, that variation of average value V-magnitudes in different years can considerably deform the common picture of short-term periodicity. For exception of the contribution of a long-term component of light variation we have deducted season (a time interval in the year which less than 6 month) average values Va from all V-values of the given season and get the parameter $\Delta m_V = V - Va$. Obtained all data Δm_V divided to two massive M1 and M2 and periodicity for each its was searched. In booth of this massive we had obtained new period $P_2 = 146 \pm 3$ days with confidence at 40%. Possible there is a seasonal periodicity of the star.

2.2. UV spectral researches.

The UV spectrum of the star has been investigated on the spectrograms taken from IUE archive data. It has been used 14 SWP and 86 LWP type spectrograms. Spectral resolution is at 6 Å. For avoiding the account of interstellar reddening in spectral lines, and also additional mistakes because of heterogeneity of the received spectrograms we applied a classical method of processing of spectrograms in which measurement is made in relative units: after setting of a level of the spectral continuum the central depths (residual - intensity) $R_\lambda = 1 - I/I_0$ and half widths ($(\Delta\lambda_{1/2}$ - FWHM) of lines were determined. There, I - an absolute intensity at top of the line, I_0 - an absolute intensity of line at the level of continuum. In such measurements the mainly error in intensity of the line arises because of wrong carrying out of a level of the spectral continuum. Therefore, we carried out procedure of setting of the spectral continuum level very carefully, achieving a constancy of carrying out of a continuum through stable points of the spectrum. On the standard stars measurements mean deviations are in intensity at 5 %, and in half widths at 15-20 %.

In Fig.4 time variability of residual intensities R_λ for unresolved doublet MgIIλ2800 Å lines was presented. It is shows that for 10 year observations R_λ shows variability both from day to day and for a long time with characteristic time 5-6 year.

More rich massive contained 86 points of the parameter R_λ for emission lines MgIIλ2800 Å. We have carried out a periodogram, and have found a period 23.2 ± 0.3 days with more than 30% confidence. In Fig.5 phase diagram of the R_λ for lines MgII λ2800 Å was presented.

3. Conclusions.

1. Firstly we have showed that in a time interval of $1983 - 2004$ in V-band light of the star has cyclic character variations with the period of 377 ± 10 days, moreover a periodic radiation of the star sometimes was destroyed by flare like events.

2. After the deepest minimum in 1995 there was some change in system therefore, since, fluctuations with amplitude about 1m are continued, the phase of the period founded before to this minimum was shows some displacement.

3. After cleaning of average values of brightness for each year we have find a seasonal period of variability 146 ± 3 days.

4. Some variability of emission line intensities from night to night was obtained. For UV spectral range we have determined a periodical variability of intensities of MgIIλ2800 Ålines with period $P = 23.3 \pm 0.3$ days.

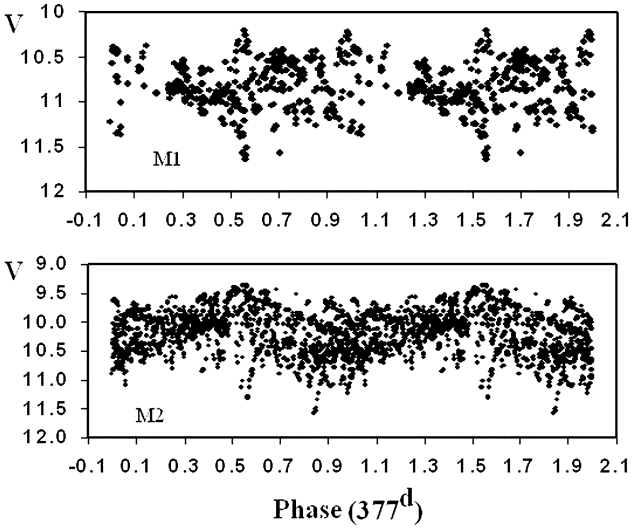

Figure 3: Phase diagrams for period 377 day have presented. In the up panel all measurement before 1983 and on the second panel all data after 1983 are described.

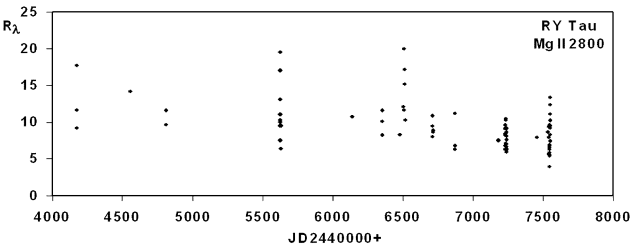

Figure 4: Time variability of intensities R_λ for MgIIλ2800 Å emission lines in the spectrum of RY Tau.

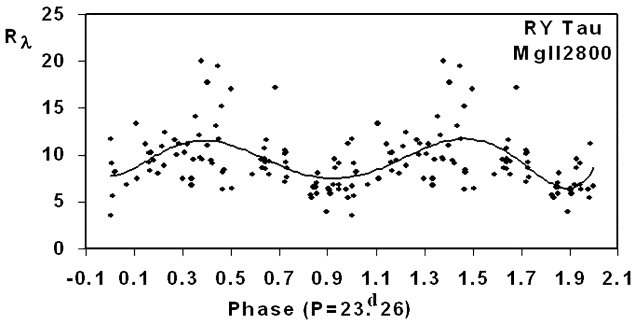

Figure 5: Phase diagram variations of the parameter R_λ for MgIIλ2800 Å emission.

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