The analysis of multicolor photometric observations of X-ray novae KV Uma and KT Eri

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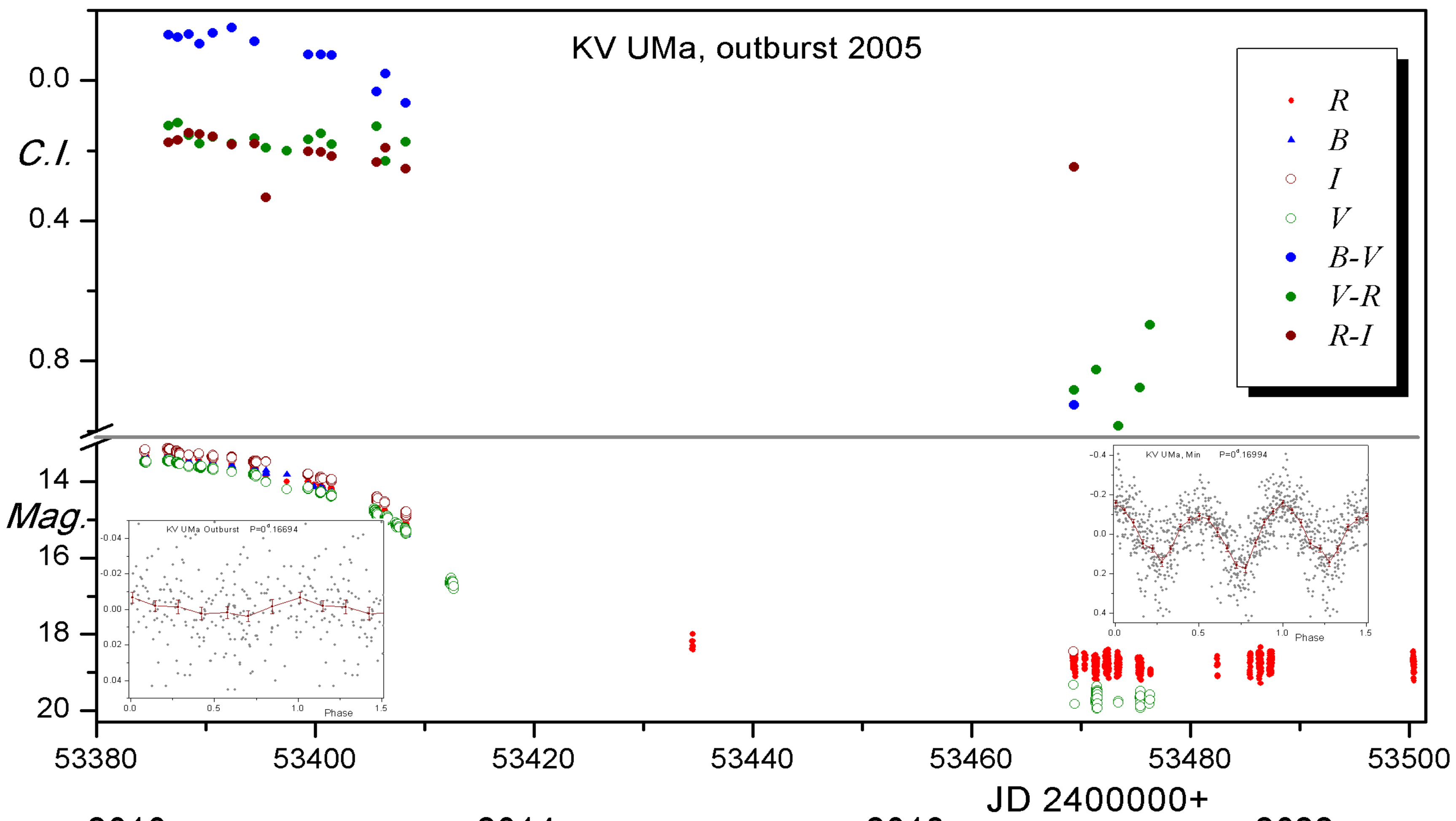

The X-ray binary XTE J1118+480 = KV UMa belongs to a class of low-mass transient X-ray binary systems with black holes. An X-ray outburst of KV UMa was detected from the RXTE satellite on 2000 March 29. At the same time the optical brightness of the system had grown by ≈6^m from V ≈ 18.8^m in quiescence to V ≈ 12.9^m at maximum.

Observations of KV UMa were performed over three seasons in 2005. Our observations were carried out during the second outburst of the object, which occurred in January 2005. Our observations began during the active phase. At this time, the light curve shows a weakly expressed wave with the period equal to the orbital one, i.e. 4 hours 5 minutes **(Fig.1).** After a gap in observations, we continued the study already in a state close to quiescence. The nature of the variability has changed dramatically. We see double wave per orbital period. We interpret our results by the fact that during an outburst, partial eclipses or changes in the visibility of the emitting region on the accretion disk around the relativistic component or jet can be observed. In quiescence, on the contrary, the variability caused by the ellipticity of the secondary component dominates and we see a double wave per period. The mathematical modeling we performed for this star is given in the paper by Cherepashchuk et al. (2019).

Note that the color indices of the system also increased in the quiescence, the radiation of the object became more red, due to the increased contribution from the secondary stellar component.

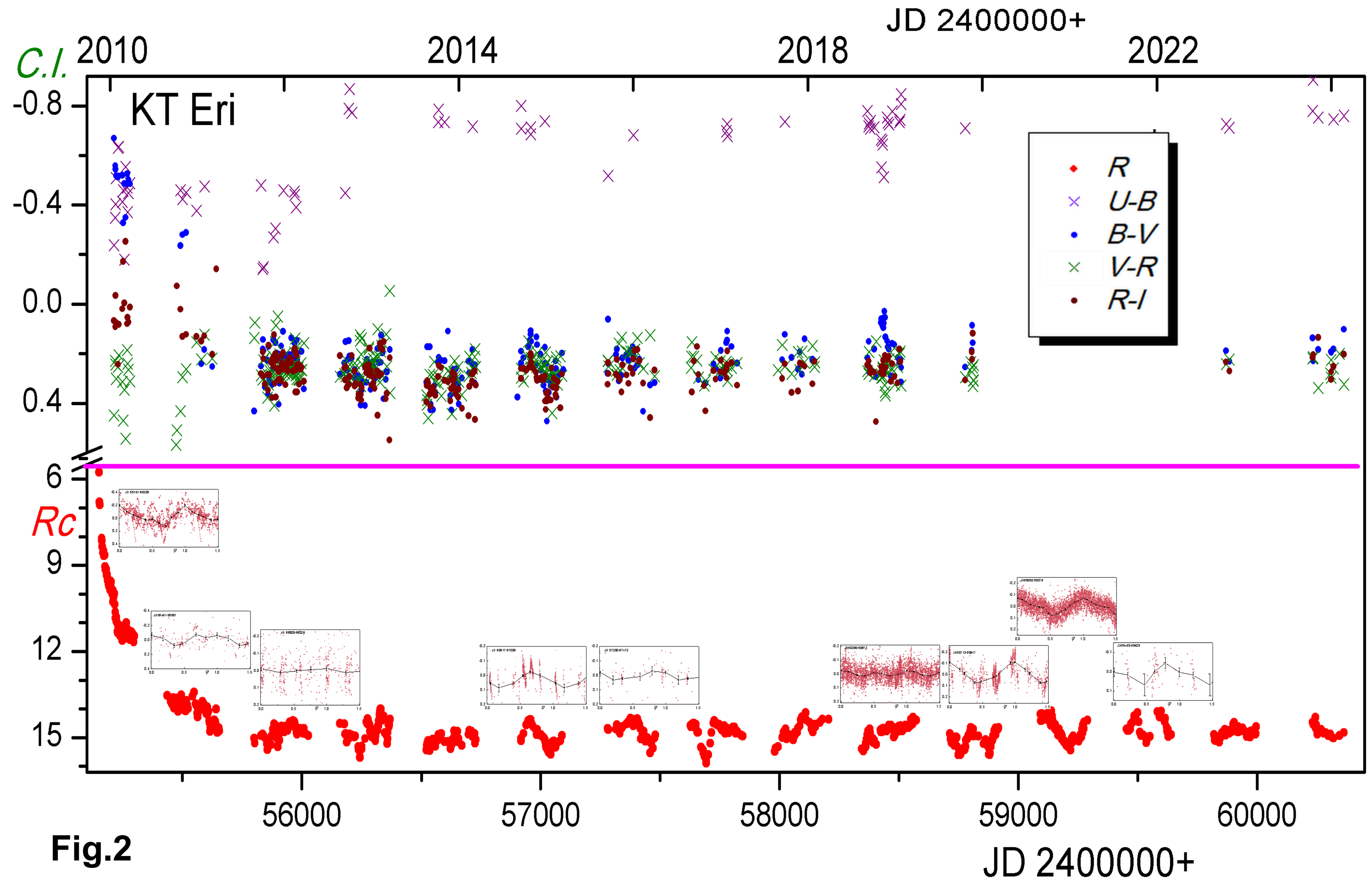

Fig.2

KT Eri was discovered by K. Itagaki on 2009 November 25.536 UT at 8.1^m already during the brightness decline. Hounsell et al. (2010a) found that the object showed the outburst on 2009 November 14.67 UT. Although several properties of KT Eri make it similar to RNe, no previous outburst was detected (Schaefer, 2022).

From the Swift archive, we found that KT Eri was a very luminous SSS until about 300 d after the outburst (see, also Ness et al. 2014). Thus, unlike KV UMa, this was a source of soft X-ray radiation.

The light curves and color indices are shown in **Fig. 2**. It is visible that after reaching quiescence state, the star exhibited brightness variability with an amplitude of up to 1^m with a characteristic time of about 1 year or less. The color indices did not change significantly during this time.

The known parameters of KT Eri:

The outburst maximum 2009/11/14 — *i=58°±5 (Ribeiro et al. 2013)*

Amplitude (V mag) ~9^m — *Distance 5.1 kpc (Gaia)*

t_2 ~ 6^d; t_3 = 14.7^d (Hounsell et al. 2010b) — *E(B-V)=0.08 mag (Ragan et al. 2009)*

Absolute magnitude M = +0.7±0.3 — *Class CN(RN?)*

Orbital period 2.61595^d (Schaefer, 2022) — *$\dot{M}$~3.5×10^{-7} M yr^{-1}(Schaefer, 2022)*

M_{WD}=1.25 ±0.03; M_{RD}=1.0±0.2 (M_{Sun})

Epoch of conjunction:2455491.323 (Schaefer, 2022)

Half-amplitude of radial velocities: 58.4±7 km/s (Schaefer, 2022)

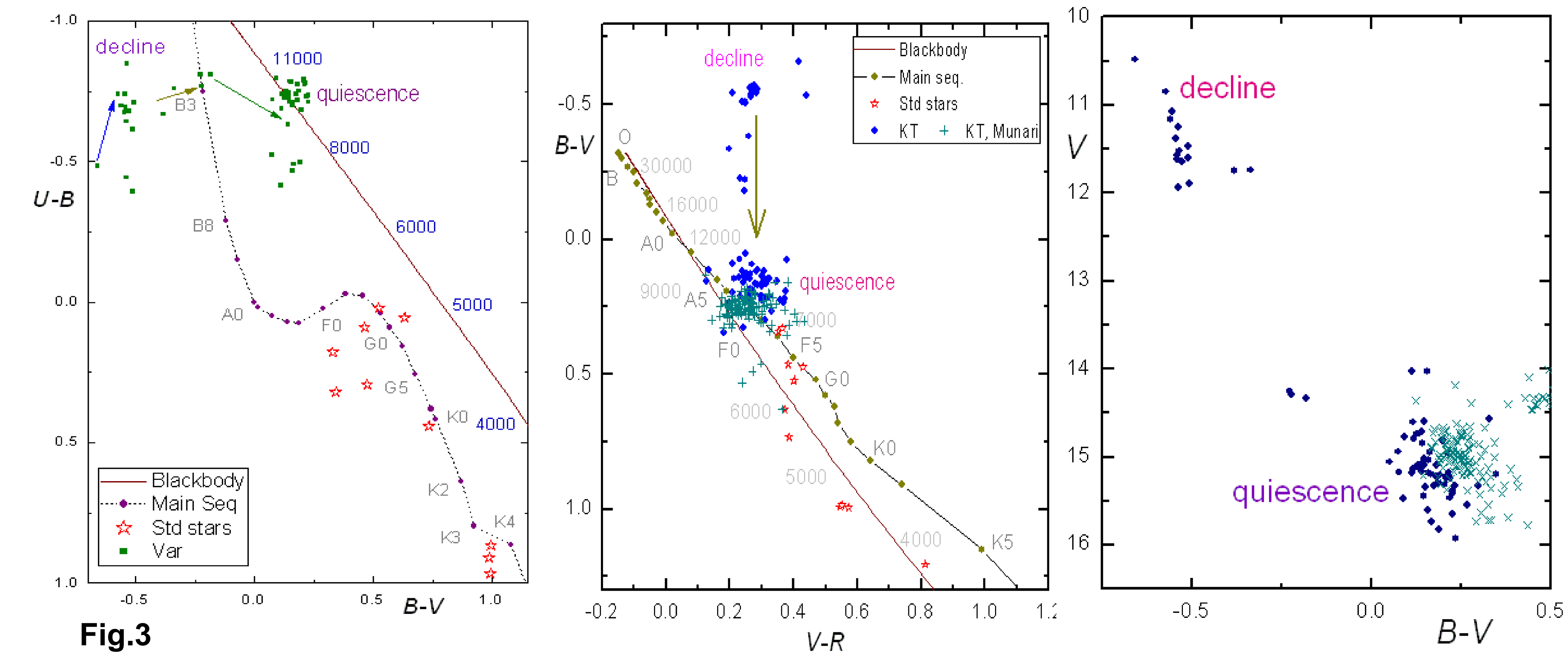

Fig.3

The object's track on the two-color diagrams and on the color-magnitude diagram (analog of the Hertzsprung-Russell diagram).

The B-V color indices increased after the outburst. **(Fig.3)** At quiescence, the object is near the black body line with a color temperature of about 9000 K. Note that the Nova KV UMa has more significant changes in color indices. In that case, the accretion rate onto the black hole during the outburst was significantly higher than at quiescence. Accordingly, the changes in color indices were more significant than in the system with the white dwarf KT Eri. The color-magnitude diagram also shows that after the outburst, the color indices increased.

The problem of finding periodic brightness variations.

For a long time, no specific period was known for the KT Eri. Various researchers have estimated the average values of period from 0.093 to 752 days. Schaefer (2022) first confidently found the orbital period by analyzing the results and data of spectral observations by Munari, et al. (2014); Walter et al. (2012).

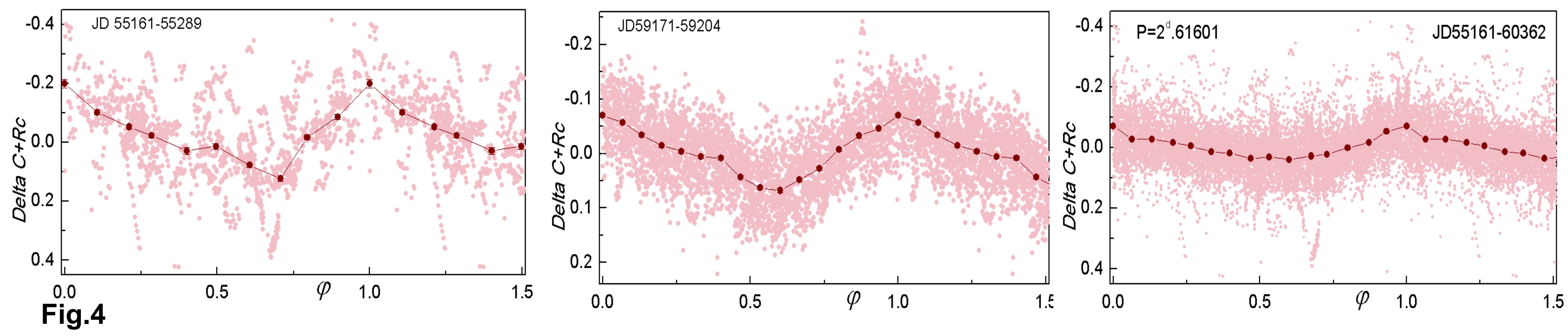

Fig.4

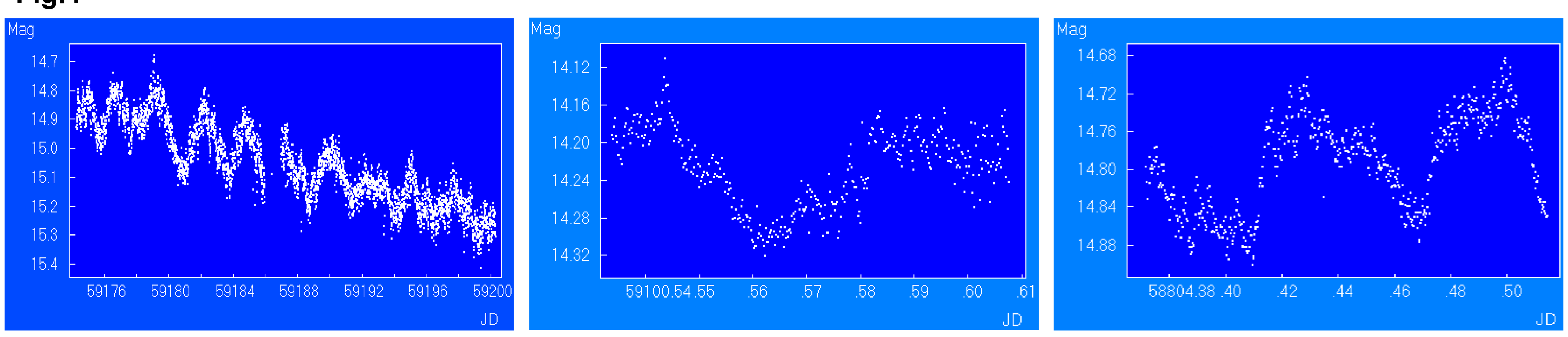

Fig.5

Schaefer (2022) also detected this period from the TESS photometric data, sector 32, 2020. This period was not detected in other seasons.

We have a series of several thousand observations obtained at different telescopes in Slovakia, Crimea and the Asiago Observatory. We added TESS, ZTF, AAVSO observations. The general trend and slow brightness variations that occurred during each season were subtracted from the resulting combined series. After subtracting this variability, we performed a Fourier periodicity analysis for each season of the object's visibility. Typically, this interval was about 200 days.

The most confident period value was found from the TESS data (as well as it was done by Schaefer). However, this period was detected in some other seasons as well. During the brightness decline in 2010 this orbital wave was also confidently determined. The phase curve constructed with this period are shown in the inner windows at **Fig. 2**. Those seasons in which the period was not detected are not plotted in the insets. Also in **Fig. 4** the phase curves for two seasons and for the entire series from 2010 to 2024 (right) are shown.

Fig. 5 shows the light curve based on TESS data and our data within the same time interval (25 days). The curves obtained during the night (several hours of monitoring) are to the right. The irregular variability prevents the detection of orbital wave during the period search. Only by using a large number of observations we managed to detect a periodic wave caused by the orbital motion in the system in certain time intervals.

It can be assumed that in addition to the orbital period, the object may simultaneously have several independent periodic oscillations associated with the rotation of the WD or its pulsations. Fast irregular variability during the night is possibly associated with accretion processes. Slow waves can be caused by the activity of the red dwarf and the existence of cycles in it similar to the solar ones. It is possible that the absence of a clear periodicity (except for the orbital wave, which is not always registered) occurs due to the simultaneous presence and superposition of all these (and other) processes occurring in the interacting binary system. We assume that more modern mathematical methods are required that will be able to detect all independent periodic frequencies in our data series.

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