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8. A new variable star. During late winter – early spring, 2014, a recently discovered variable star GSC 4560-02157, in the constellation of Ursa Minor, was observed at the Tien Shan Observatory of the Kazakhstan Astrophysical Institute, located in the mountains to the south of Almaty city, approximately in 60 km to the north of Cholpon-Ata (Kyrgyzstan). The star features complex physical variability along with regular eclipses. During the night of February 28 – March 1, the star was observed non-stop for almost 9 hours. The table (right) presents the most important data points derived from these observations. The time in the table is the mean solar time for the Almaty time zone.

At times of the primary minimum, the star's properties correspond to the K0 spectral type.

Plot the light curve. At the time axis, mark times of minimal brightness in the primary minima and in the secondary minimum. Knowing that the Julian date 2456949.000 begins at today's (October 18) Greenwich noon, label the times of minimal brightness with their Julian dates, with three digits after the decimal point.

One of simplified models describing the event assumes that the process involves two stars only. From your analysis of the light curve in the frame of such a model, determine the spectral types (for example, that of the Sun is G2) of the larger (1) and smaller (2) components as well as the ratio of the radii of the larger (R_1) and smaller (R_2) components. Illustrate the solution with necessary figures.

Almaty and Cholpon-Ata are in the same time zone.

T	m
22 h 00 m (February 28)	14.92
22 h 12 m	15.08
22 h 24 m	15.41
22 h 36 m	15.44
22 h 48 m	15.37
23 h 00 m	15.12
23 h 12 m	14.92
23 h 30 m	14.89
00 h 00 m (March 1)	14.80
00 h 18 m	14.78
00 h 42 m	14.80
01 h 00 m	14.82
01 h 24 m	14.85
01 h 48 m	14.96
02 h 12 m	14.72
02 h 30 m	14.72
03 h 12 m	14.63
03 h 36 m	14.65
04 h 15 m	14.77
04 h 25 m	14.84
04 h 36 m	15.10
05 h 00 m	15.43
05 h 12 m	15.32
05 h 24 m	15.05
05 h 36 m	14.90
05 h 48 m	14.75
06 h 12 m	14.73
06 h 48 m	14.70

SPECTRA OF A PLANETARY NEBULA "CAT EYE" AND ITS CENTRAL STAR

Introduction:

Planetary nebula NGC 6543 ("Cat eye") played its special part in the history of astrophysics. On August 16, 1865, an English amateur astronomer William Huggins looked at it with a spectroscope and, as he writes, "did not see an expected total spectrum, but only one bright line!" Shortly after it was resolved into two lines with the wavelengths of 4959 e and 5007 e. Huggins assigned it to a new element "nebulium".

Later it was found out that these are "forbidden" lines of doubly ionized oxygen that were never observed before - neither in terrestrial laboratory nor in stars. Unlike "permitted" lines, only a very thin gas emits such lines.

Recall that if an atom is neutral, then a Roman numeral I follows the symbol of its chemical element, if the atom lost one electron then it is Roman II, etc.... for example, the neutral nitrogen is N I, the ionized nitrogen is N II. In notation of forbidden line the symbols of atoms and ions are taken in square brackets, for example: the ionized nitrogen is [N II], doubly ionized oxygen is [O III].

The spectrum of the central star generating the nebula NGC 6543 and exciting its glow, as well as the spectrum of the nebula itself were obtained in the course of study of the late stages of stellar evolution. The high-resolution spectrograph of the 6-meter telescope of SAO was used. The star and a peripheral part of the nebula were alternately projected onto

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its slit. These positions of the slit marked by a sign ' * ' for the first one and by a sign ' @ ' for the second one in Fig 1a, 1b, 1c.

Task:

The upper parts of Fig. 1a, 1b, 1c show the parts of spectra as intensity vs wavelength given from the mentioned regions. In each of them the interesting lines are selected, and their profiles of are presented in the lower fragments as a relation between intensity and radial velocity. The figures show also the values of radial velocities measured by the tops of profiles of separate lines.

Determine which lines belong to the star and which to the nebula; fill in the appended table: Lines in the spectra of NGC 6543 and its central star:

Figure	Lines belonging to the nebula	Lines belonging to the star
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2a

2b

2c

What is the difference between them?

What can be said about the character of motion in the nebula and in the star's atmosphere from the form of the line profiles?

Estimate the velocity of these motions.