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Radial Velocity Variation of the 2.3-μm CO Band of α Orionis

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Abstract

We report the results of 12 years of observations on the radial velocity variation of the 2.3-μm (4330 cm^{-1}) carbon monoxide absorption lines (first overtone vibration-rotation 2-0 band, R18–R31) of α Orionis (Betelgeuse, M1-2Ia-Iab) using a Fourier transform spectrometer located in the coudé room of the Okayama Astrophysical Observatory's 1.88-m telescope. The mean radial velocity and peak-to-peak amplitude were estimated as 24 $km\,s^{-1}$ and 7 $km\,s^{-1}$, respectively. However, the variation period could not be determined because the observational frequency data was insufficient.

Key words: Radial velocity, Carbon monoxide lines, α Orionis

1. Introduction

Alpha Orionis (α Ori; Betelgeuse, M1-2Ia-Iab) is a long-period variable with a variation period that is generally believed to be 2100 days and a V-magnitude variable range of 1.0–2.0. Once, it was regarded as an ecliptic binary; however, now its variability is believed to occur by absorbing materials related to its pulsation. The radial velocity variation was observed with metal lines in the visual region by Smith et al. (1989). This study attempted the same observations in the near infrared region.

2. Observations

Observations were performed using a Fourier transform spectrometer (FTS) located in the coudé room of the 1.88-m reflector at the Okayama Astrophysical Observatory. The spectral range and nominal resolution of the analyzed spectra were 4000–7000 cm^{-1} and 0.03 cm^{-1}, respectively.

The radial velocity variation of the selected 2.3-μm (4330 cm^{-1}) carbon monoxide absorption lines (CO 2-0 band, R18–R31) of α Ori was measured. The spectral resolution is the maximum resolving power of the spectrometer, that is, 0.03 cm^{-1}. Owing to small instrumental errors in the wavenumber, wavenumbers were calibrated using 240 slim telluric absorption lines (for example, CH_4, H_2O, and CO_2) (Tanaka *et al*., 1992).

Figure 1 shows the infrared spectra of α Ori. The broad absorption lines correspond to the object, and the sharp narrow lines correspond to telluric. The resolution is reduced from the nominal value by apodization; however, a resolution of approximately 100,000 is shown by the sharp narrow telluric lines. On the other hand, large scintillation in winter causes a poor signal-to-noise ratio and reduces spectral resolution. The spectral line width of α Ori is broad up to the corresponding radial velocity of 13–14 $km\,s^{-1}$ (half-half width). This results in poor bisection accuracy of the spectral line when determining its wavenumber.

3. Radial Velocity Variation

Table 1 shows the total observational data. Radial velocities were obtained by the mean Doppler shift of 14 absorption lines R18–R31 of the CO first overtone vibration-rotation (2-0) band. The rest wavenumbers of the absorption lines were calculated by Mohler (1955) using the

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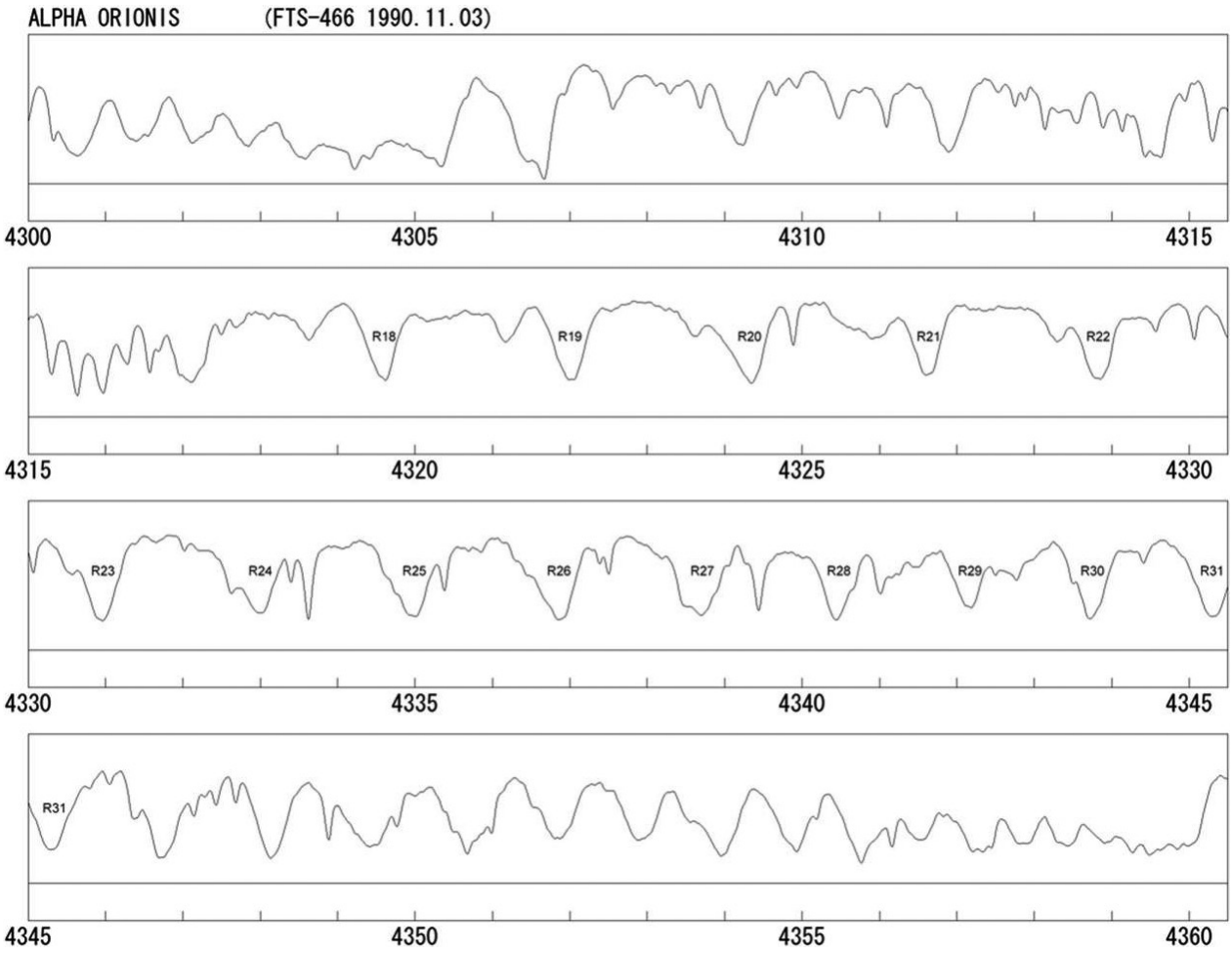

Figure 1: An example of the infrared spectrum of α Ori with the R-branch of the CO band.

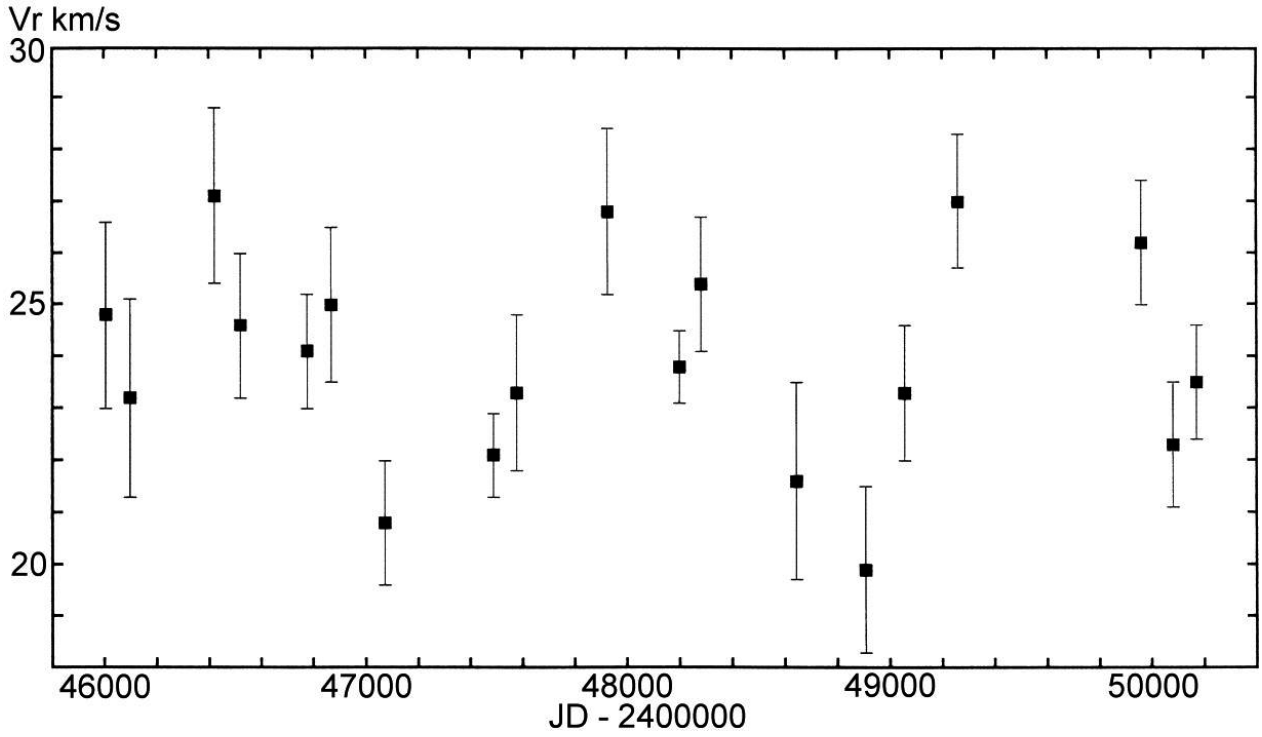

Figure 2: Radial velocity variation of the 2.3-μm CO absorption lines. The vertical lines are error bars.

Table 1: Total Observational Data.

The nominal spectral resolution is 0.03 cm^{-1}, except for FTS242, which has a resolution of 0.06 cm^{-1}. *Vt* denotes the calculated terrestrial orbital velocity toward α Ori, and *Vs* denotes the observational radial velocity. Error indicates the internal error (standard deviation). $Vr = Vs - Vt$ represents the final radial velocity of the CO absorption lines. *Vr* includes the calibration error on the wavenumber.

No	Date (UT)	JD240000+	*Vt* km s^{-1}	*Vs* km s^{-1}	*Vr* km s^{-1}
FTS242	1984.11. 1	46006.286	−21.43	+ 3.4±1.7	+24.8±1.8
256	1985. 1.30	46095.985	+19.20	+42.4±1.9	+23.2±1.9
272	1985.12.20	46420.134	+ 0.20	+27.3±1.7	+27.1±1.7
283	1986. 3.29	46518.958	+28.55	+53.1±1.3	+24.6±1.4
289	1986.12.12	46777.238	− 3.75	+20.4±1.0	+24.1±1.1
303	1987. 3.14	46869.008	+28.87	+53.9±1.5	+25.0±1.5
317	1987.10. 2	47071.333	−28.06	− 7.3±1.2	+20.8±1.2
410	1988.11.20	47486.277	−14.01	+ 8.1±0.8	+22.1±0.8
413	1989. 2.18	47575.973	+25.23	+48.5±1.5	+23.3±1.5
444	1990. 2. 2	47924.946	+20.12	+46.9±1.5	+26.8±1.6
466	1990.11. 2	48198.240	−21.40	+ 2.4±0.6	+23.8±0.7
503	1991. 1.25	48282.041	+17.15	+42.8±1.2	+25.4±1.3
563	1992. 1.20	48642.010	+14.80	+36.4±1.9	+21.6±1.9
603	1992.10. 9	48905.315	−27.12	− 7.2±1.6	+19.9±1.6
620	1993. 3.10	49056.962	+28.54	+51.8±1.3	+23.3±1.3
638	1993. 9.27	49258.276	−28.54	− 1.5±1.3	+27.0±1.3
685	1995. 8.31	49961.309	−26.92	− 0.8±1.2	+26.2±1.2
700	1995.12.30	50082.200	+ 5.22	+27.5±1.2	+22.3±1.2
730	1996. 3.26	50168.973	+28.75	+52.2±1.0	+23.5±1.1

molecular constants by Plyler *et al*. (1952) (Table 2).

A remarkable radial velocity variation was detected (Figure 2). The mean radial velocity was calculated as 24 km s^{-1}, and the peak-to-peak amplitude was estimated to be approximately 7 km s^{-1}. The variation period is shorter than the conventional light variation period of 2100 days. Therefore, the origin of the radial velocity variation of the CO lines must be considered from another point of view.

4. Comparison to New Photometric Variability Observations

Recently, precise photometric observations with a photodiode were carried out by Ohgane (2022). His conclusion of the last 21 years of observations is that the principal variation period is 405 days, unlike the conventional value of 2100 days.

Regrettably, because his observational period does not fall within our own, a direct comparison of spectral

Table 2: Adopted Wavenumbers of the CO Lines.

Line	Wavenumber cm^{-1}
R18	4319.63
19	4322.05
20	4324.39
21	4326.66
22	4328.86
23	4330.98
24	4333.03
25	4335.00
26	4336.90
27	4338.73
28	4340.49
29	4342.17
30	4343.77
31	4345.30

and photometric observations is impossible. However, it is reasonable to suggest that the velocity variation period is shorter than the conventional one.

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