12. SPECTROGRAPHIC OBSERVATIONS OF AI VELORUM

By Livio Gratton

AI Velorum was discovered by E. Hertzsprung (1) in 1931 on plates taken at Johannesburg; he found it to be an RR Lyrae variable with a period of $0^d{\cdot}1116$, but later on F. Zagar (2) and A. van Hoof (3) showed that the light curve is very irregular. G. Herbig (4) found that more or less the same kind of irregularities are present in the radial-velocity curve as well.

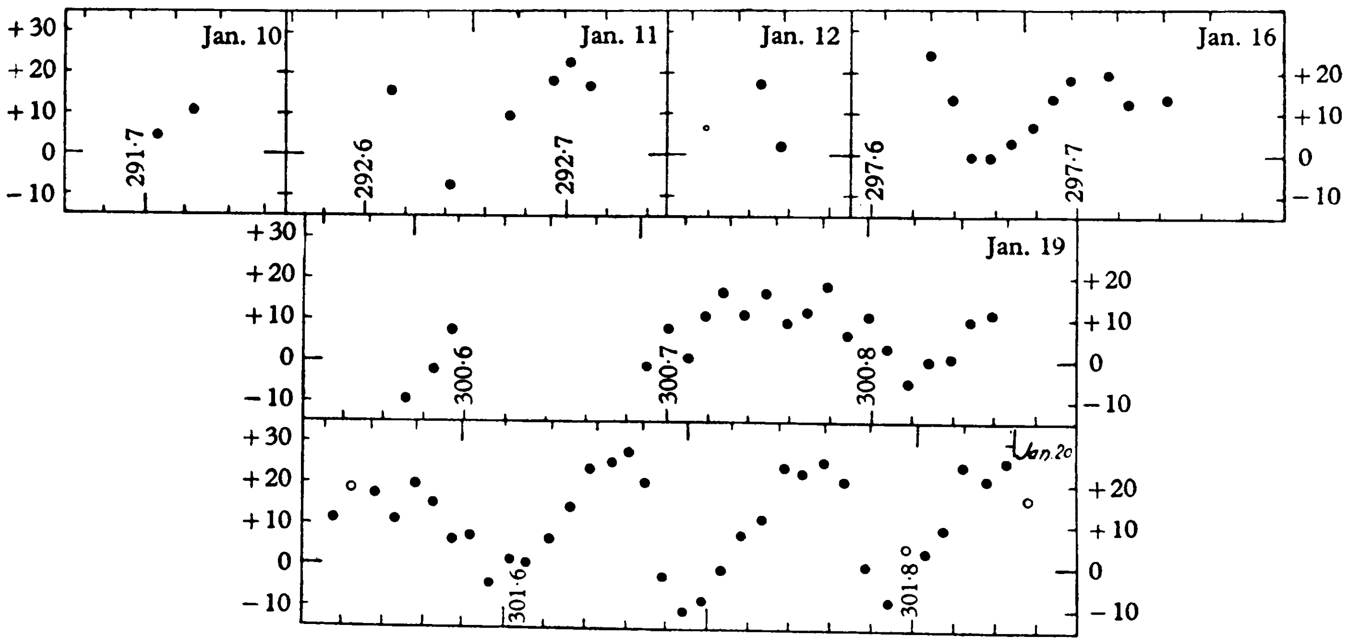

Fig. 1.

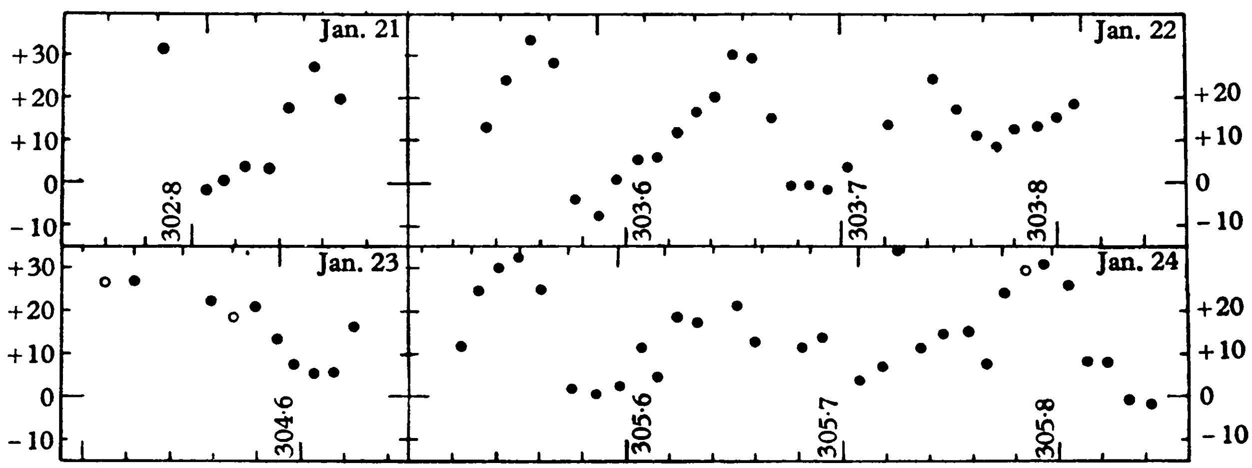

Fig. 2.

In 1950 the star was observed spectroscopically at the Observatory of Bosque Alegre by the author and C. J. Lavagnino (5); during four nights it was possible to observe from sunset to dawn, thus covering completely more than three cycles; on four more nights only one cycle was observed, while on other nights it was possible to obtain only a few scattered observations. Usually about eleven or twelve spectra, each with ten minutes exposure time, were taken during each cycle; the dispersion was about 40 A./mm. (grating) and the spectra were slightly widened by trailing.

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One hundred and fifty plates were measured for radial velocity using always the same lines both for the star (32 lines) and for the comparison spectrum; all but a few were measured twice, by the author and by Mr Lavagnino. The probable error of each final radial velocity was about 1·5 km./sec. The results are shown in Figs. 1 and 2.

Spectral types were estimated on all plates by the author, using the criteria of the *Atlas of Stellar Spectra* (6) for A stars; the spectrum was found to vary in a perfectly synchronous way with the radial velocity (Fig. 3), the maximum velocity being coincident with the most advanced spectral type and vice versa.

From the figures it is evident that the variation of the radial velocity curve is due to the fact that the amplitude and the period of the main variation are themselves variable with a period somewhat longer than three main cycles; it is clear that this is the beat period between two oscillations; the main variation (with a period of $0^{d}\cdot 1116$) and another

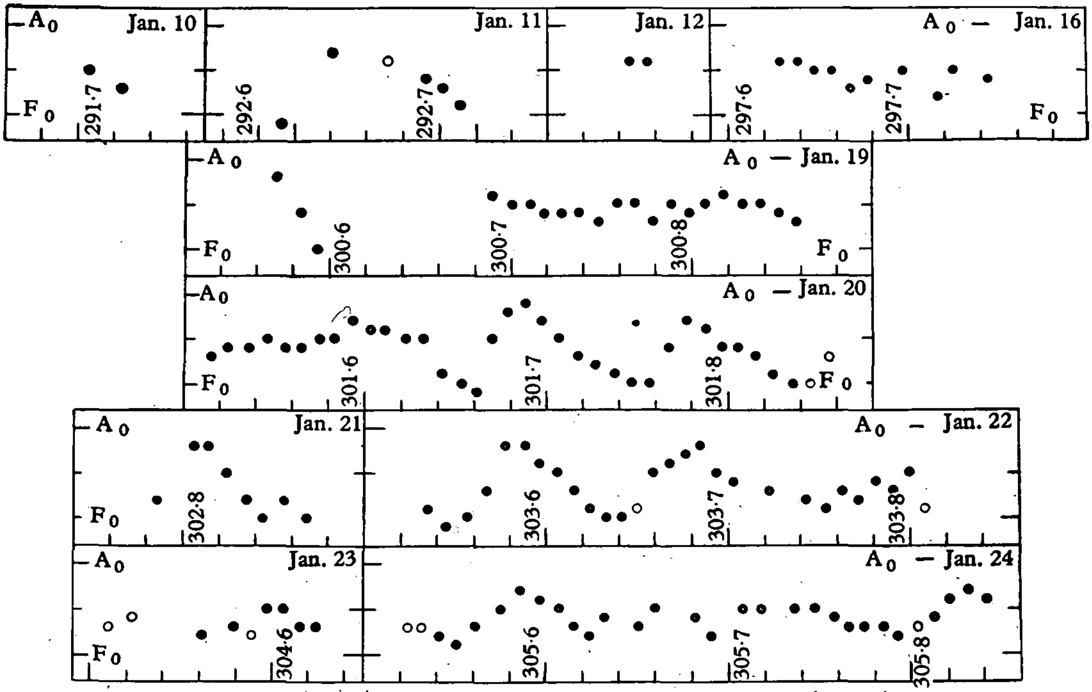

Fig. 3.

with a shorter period. In order to find the length of the beat period, from the curves the phase ϕ_m was determined (relative to the main variation) at which the radial velocity reached its median value on the descending branch. The predicted times of the minima of the radial velocity curve have been computed by means of Hertzsprung's formula

$$t_{\text{min.}} = 2426142\cdot 210 + 0\cdot 111574E,$$

valid for the light maxima.

It was found that the phases ϕ_m could be very well represented by means of the simple sine formula (see Fig. 4, upper half, dots),

$$\phi_m = -0^{d}\cdot 016 - 0^{d}\cdot 014 \cos 2\pi\psi,$$

where ψ, the phase of the beat period, is given by

$$\psi = 2^{d^{-1}}\cdot 625(J.D. - 2433291\cdot 417).$$

The beat period is thus $0^{d}\cdot 381$.

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The amplitude of the radial velocity curve varies in the same period and can also be represented by a simple sine curve (see lower part of Fig. 4).

During the spectrographic observations a series of photometric observations of the star was made by Dr R. Jaschek at La Plata, unfortunately these observations were not very accurate and could be used only for a check of the spectrographic results. It could be shown in this way that the light variations followed the same general pattern; moreover the phase at which the brightness reached its median value in the ascending branch coincided exactly with ϕ_m. In the upper part of Fig. 4 the points obtained from Jaschek's light curves were entered as open circles.

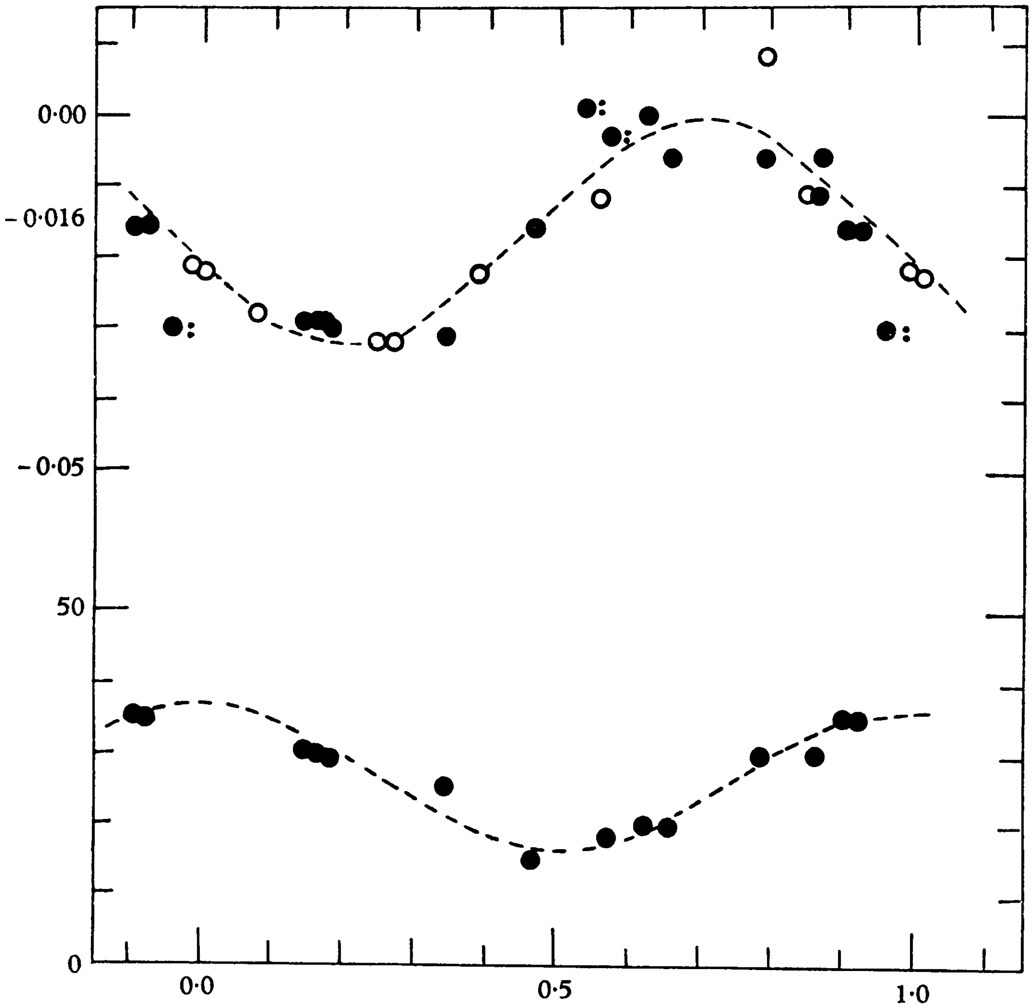

Fig. 4.

This paper was being prepared when a letter was received from Th. Walraven (7) containing some results of his photo-electric observations of AI Velorum made in 1951. Walraven's results are in perfect agreement with those obtained from the radial velocities; his value of $0^d{\cdot}3792$ for the beat period does not differ significantly from the present one, taking into account the lower relative accuracy of the radial velocity. Computing from his formula the phase of median brightness on the descending part of the light curve, an excellent agreement is again found with ϕ_m. Walraven found also evidence for two shorter periods, which cannot be found in the spectrographic material; some apparently irregular variations of the spectrum might be, however, connected with these.

These observations show that AI Velorum is doubtless a very interesting object and may prove to be very important in various respects. The excellent agreement in phase

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between light and radial-velocity curves for both the main and the beat period is highly significant, although it cannot be commented upon here.

The remarkable beat period of $0^d{\cdot}38$ shows that the star is pulsating with two periods of about $0^d{\cdot}112$ and $0^d{\cdot}086$, the corresponding amplitudes being of the same order. It is well known that many RR Lyrae variables show two periods which combine to give a beat period, which is, however, rather large (from 60 to 1000 times the main period); this is in satisfactory agreement with the simplified theory of the coupling of two modes (8). According to this theory, if a star possesses two modes whose frequencies are in the ratio 1:2, approximately, and if the first of them is excited, a second frequency equal to the difference of the two will be excited by resonance. According to this kind of coupling the star will ultimately pulsate with two almost equal frequencies; one obtains thus rather long beat periods in agreement with observations.

This kind of coupling, however, cannot hold in the case of AI Velorum, due to the large difference between the excited frequency and, consequently, to the shortness of the beat period. It is therefore possible that the observations of AI Velorum might oblige us to revise the theory of excitation and coupling of modes in a pulsating star, which is of course, admittedly, in a quite provisional state.

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13. EMISSION LINES IN THE SPECTRA OF LONG-PERIOD VARIABLE STARS

By Paul W. Merrill. (*Presented by* I. S. Bowen)

It is remarkable that bright hydrogen lines, requiring 13 volts for their production, should appear in the spectra of objects as cool as long-period variables. The reversing layer and the photosphere, with temperatures of about 2000°, have nothing like the necessary amount of energy to offer. The curious irregularities in the Balmer series do not yield the interpretation; it is now clear that they are due to absorption by overlying gases. This fact indicates one important item, namely, that the origin of the bright lines is not in an extended outer atmosphere, but in a level lying near, and even partly below, the photosphere.

The bright lines of neutral metallic atoms that have been identified include those of Mg, Al, Si, Sc, Ca, Mn, Fe, Co, Ni, Ga, Zr, and In. Among the ionized lines are those of Ca, Ti, Mn, Fe, and Sr, and probably the Mg II lines near 2800 A. The Mg II lines cannot be observed directly because the Earth's atmosphere shuts them out, but their presence is inferred by fluorescent effects. Forbidden lines of Fe II also are present, but the occurrence of those of other elements is doubtful.

One point about the behaviour of the numerous bright lines should be emphasized.

Their relative intensities are not symmetrical with respect to the maximum of the light curve, or in fact with respect to any other phase. (Some text-books are in error on this point.)

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