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THE CONTINUOUS SPECTRUM OF AG PEGASI

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The spectral energy distribution for the symbiotic star AG Peg has been established over the wavelength range 3300-25,000 A. A theoretical spectrum derived for a system with an M4 III star and a hydrogen plasma at T_e = 30,000°K agrees well with observation.

The variable star AG Pegasi belongs to a small group of celestial objects called nova-like or symbiotic stars. The notable peculiarity of these stars is that their spectrum exhibits highly conflicting characteristics. The absorption spectrum consists mainly of TiO bands and the λ4227 line of Ca I, which would indicate spectral type M3. On the other hand, the spectrum contains fairly strong emission lines of He II, [O III], and other ions. Radiation corresponding to a very high temperature would be required to excite these lines. So far no convincing explanation has been given of this peculiarity in the spectrum of symbiotic stars. It has recently been shown [1] that the energy distribution observed in the spectral range 3300-5000 A can be regarded as the combined radiation of a star and of ionized hydrogen with T_e = 30,000°K. This investigation suffered, however, from the comparatively short spectral range that was utilized.

In the present paper the energy distribution in the continuous spectrum of Ag Peg is investigated over the spectral region from 3300 to 25,000 A.

Observations were secured of the spectrum of AG Peg with different instruments, depending on the spectral region.

a) For the wavelength range 3300-6500 A, the SP-79 slitless spectrograph (dispersion 180 A/mm) was used in August, 1964 [1] to obtain seven spectrograms of AG Peg on Kodak 103a-O plates and eight spectrograms of the A2 V star GC 30719, which was adopted as the comparison star. The spectrograms cover the range 3300-5000 A. Furthermore, during September and October, 1964 four spectrograms were secured with the SP-72 spectrograph (80 A/mm) on Kodak 103a-O plates together with two spectrograms with the ASP-11 spectrograph (33 A/mm), using the 50-inch telescope of the Crimean Astrophysical Observatory; and three spectrograms were obtained with the SP-72 spectrograph on Kodak 103a-F plates. Spectra of the comparison star GC 30719 were secured at the same time to eliminate instrumental distortions of the energy distribution. The results of all these observations were averaged to establish the energy distribution in the region 3300-6500 A.

b) For the wavelength range 0.6-1.1 μ, the energy distribution was obtained with a diffraction spectrometer mounted at the Cassegrain focus of the 125-cm telescope of the Shternberg Astronomical Institute, on October 12, 1964. A 600 line/mm grating was used in the spectrometer. A photomultiplier with an electronic image converter was used as the radiation detector. The contact image converter with its refrigerated cesium oxide photocathode transforms infrared into visible radiation, which is then recorded by an FÉU-64 photomultiplier. Radiation is transmitted from the screen of the image converter to the photomultiplier cathode by a special light-guide which is in optical contact with both the image-converter screen and the photomultiplier cathode.

The spectrum was recorded with a 2-sec time constant at a rate of about 14 A/sec; the spectral width of the exit slit about 70 A. The record was made on the tape of a PS-1-02 electronic potentiometer.

Six records of the spectrum of AG Peg were made. The stars α Lyr and β And were recorded as comparison stars. The spectral energy-distribution curve for AG Peg was obtained by averaging over all the records.

c) The energy distribution in the region 0.8-2.5 μ was observed on October 15, 1964, with an infrared prism spectrometer mounted at the focus of the Nasmyth reflector. A LiF prism was used, with a lead sulfide photoconductive cell cooled by dry ice as the detector. The basic parameters of the spectrometer are given in [2]; of the intensifying circuitry, in [3]. The spectrum was recorded with a 20-sec time constant, at a rate of 35 A/sec. The spectral width of the exit slit was $0.18\,\mu$; the linear width, 2.5 mm. The width of the entry slit was 1 mm. The spectral resolving power $\lambda/\Delta\lambda$ was about 10. The record was made on the tape of a PS-1-02 electronic potentiometer. Four records were obtained. The signal/noise ratio for a single record was approximately 10 near $1.6\,\mu$.

As a comparison, star β Peg was recorded immediately after AG Peg. The intensity ratio Ag Peg/β Peg was found to remain constant within the error of measurement. Comparisons were made in the transparency windows 1.1-1.3, 1.4-1.8, and $2.0\text{-}2.4\,\mu$; the H_2O absorption bands were excluded. The air masses were equal to 1.5 for AG Peg and 1.2 for β Peg. With these air masses the dependence on zenith distance of the ratios of the infrared transparency coefficient at different wavelengths outside the absorption bands is small enough to be neglected, to the accuracy of these observations.

In order to establish the relative energy distribution in the spectra of AG Peg and β Peg, their records were compared with tracings of the solar spectrum as recorded on October 4, 1964, with an air mass of 1.6 and the reflector equipped with the same spectrometer operating under the same recording conditions (rate, slits, time constants). For recording the sun the telescope was covered by a screen containing 20 holes 4 mm in diameter, and additional electrical attenuation was introduced into the intensifying circuit.

The relative energy distributions in different spectral regions were matched in such a way that their intensity coincided in common portions of the spectrum.

The data secured on the radiant intensity distribution in the continuum had to be freed of interstellar-absorption effects. This process requires knowledge of the distance to AG Peg. Here and subsequently we shall assume that the system AG Peg consists of a late-type star, a highly extended gaseous envelope, and a source of exciting radiation. We shall also suppose that the absorption spectrum corresponds to a normal M4 III star having $M_{vis} = -0^{\mathrm{m}}.4$. At the time of our observations the brightness of AG Peg was $m_V = 7^{\mathrm{m}}.9$. As we shall show presently, only half the radiation at λ 5500 A belongs to the M4 III star. In this event the distance to AG Peg would be 500 pc. According to [4] the interstellar absorption would be $A_{vis} = 0^{\mathrm{m}}.25$. This estimate agrees well with the value $A_{vis} = 0^{\mathrm{m}}.3$ found previously [1]. The value $A_{vis} = 0^{\mathrm{m}}.25$ has been adopted to remove interstellar-absorption effects from the observed energy distribution in the continuum.

In Fig. 1, the heavy curve represents the relative energy distribution in the continuum of AG Peg.

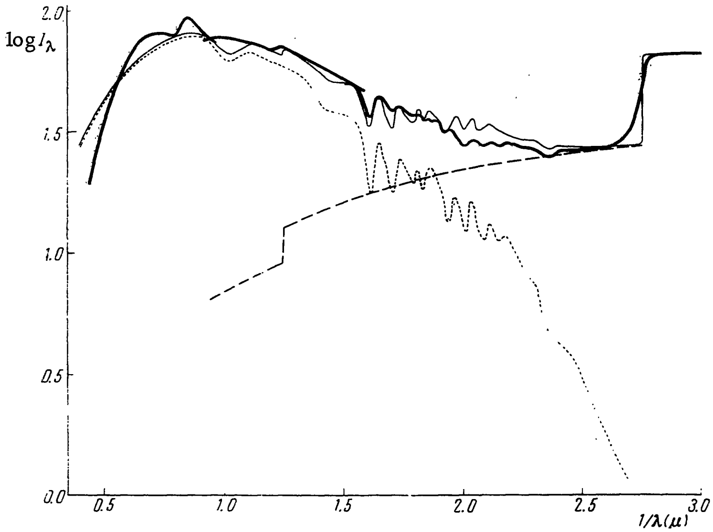

Fig. 1. Heavy curve) spectral energy distribution of AG Peg; dotted curve) spectral energy distribution of an M4 III star; dashed curve) spectral energy distribution of ionized hydrogen at $T_e = 30{,}000°K$; light curve) theoretical energy distribution for AG Peg.

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It has the following properties:

a) Sharp increases in the brightness occur beyond the limits of the hydrogen series – the Paschen and especially the Balmer jumps.

b) Absorption bands belonging to the TiO molecule occur in the spectral regions with $\lambda < 6500$ A, which were recorded photographically. At longer wavelengths, details in the spectrum are lost because of the low resolution of the photoelectric recording devices.

The same figure shows the radiant energy distribution for a system consisting of a cool M4 III star and ionized hydrogen at $T_e = 30{,}000$°K. The energy distribution in the ionized-hydrogen continuum has been adopted from [5]. For the M4 III star the energy distribution was found as follows. The mean of the energy distributions in spectra published in [6] for two stars over the wavelength range 6500-4000 A was taken as a basis. The energy distribution was then extended to 10,000 A on the basis of [7]. Finally, in the long-wave region the energy distribution was assumed to follow a Planck curve for $T = 2800$°K, which provides the best fit to the energy distribution in the range 10,000-4000 A. The spectral energy distribution obtained in this way for the M4 III star is shown by the dotted curve in Fig. 1. The best agreement between the observed spectral energy distribution of AG Peg and the energy distribution of the system consisting of ionized hydrogen gas and a cool star is obtained if the two sources have the intensity ratio $I_{\mathrm{M4\,III}}/I_{\mathrm{gas}} = 0.49/0.51$ at $\lambda = 5500$ A. This ratio decreases with decreasing wavelength. The theoretical energy distribution obtained in this way for the spectrum of AG Peg is indicated by the thin solid curve in Fig. 1.

The figure shows that the agreement between the observed and theoretical energy distribution for the spectrum of AG Peg is quite good. This agreement confirms the earlier result [1] that the main contribution to the radiation for $\lambda > 3300$ A comes from the M star and the gaseous envelope. On the other hand, slight differences are observed between the observed and theoretical radiant intensities in the region $\lambda \approx 4500$ A. The differences could arise from observational error, and also from the effect of the radiation of a hot component responsible for exciting and ionizing the hydrogen gas. But the small disparity of the curves in Fig. 1 suggests that radiation from a hot component would not play a large part in the spectral region observed. Further observations would be necessary to identify the hot component.

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