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September 1968

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Kyoji Nariai*

ABSTRACT

Calculations of the acoustic energy generation for helium rich composition show that the maximum acoustic energy generation is located around 12,000 °K at log g = 4 and 15,000 °K at log g = 6. The author's suggestion in his last paper that a helium star υ Sgr may have a corona seems to be justified. X-ray from a corona around a helium star is strongest when the physical parameters of the star are log g ~ 6 and Te ~ 15,000 °K. But the total energy flux is too small to account for the observed X-ray sources.

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υ Sgr is a single-lined spectroscopic binary with a helium-rich envelope (for references, see NARIAI 1967). This star exhibits a displaced absorption line of Hα for about one quarter of the orbital period, the center of the phase of this phenomenon being the conjunction time. The present author has interpreted this phenomenon to be the result of the flow from the corona through the Lagrangian point (NARIAI 1967). The gas flow is subsonic inside the Lagrangian surface, becomes trans-sonic at the Langragian point, and then expands nearly adiabatically getting cooler and acquiring the translational energy.

Calculations similar to those of Section 3 of the preceding paper (NARIAI 1968) have been made for a helium-rich composition in order to see where the maximum activity occurs in helium stars.

$$q(\tau) = 0.7104 - 0.1331\, e^{-3.4488\tau} \tag{1}$$

which represents the gray atmosphere very well (Labs, 1950) was used in the temperature-depth relation

$$T^4 = \frac{3}{4} T_e^4 (\tau + q(\tau)). \tag{2}$$

Acoustic energy generation rates for helium to hydrogen ratio 400:1 are presented in Figure 1. The excitation temperature for hydrogen, helium, nitrogen, etc. by Hack and Pasinetti (1963) 12,800 °K indicate that this star has a violent convection zone due to helium I ionization, and consequently, a strong corona. A large value of the turbulent velocity (ξ_t = 9 km/sec for He, ξ_t = 18 km/sec for H) also provides evidence for the existence of the convection zone.

The change of the acoustic energy generation rate with the helium-to-hydrogen ratio was calculated and is shown in Figure 2 for T_e = 12,000 °K and log g = 4. Practically speaking, stars at this temperature have coronae if N_{He}/N_H is more than 5.

In the solar corona, the gravitational energy at the bottom is about 10 times larger than the thermal energy. But the energy lost in X-ray radiation from the solar corona is about one-tenth of the energy spent in accelerating the gas and pushing the gas out of the gravitational potential of the sun in the solar wind.

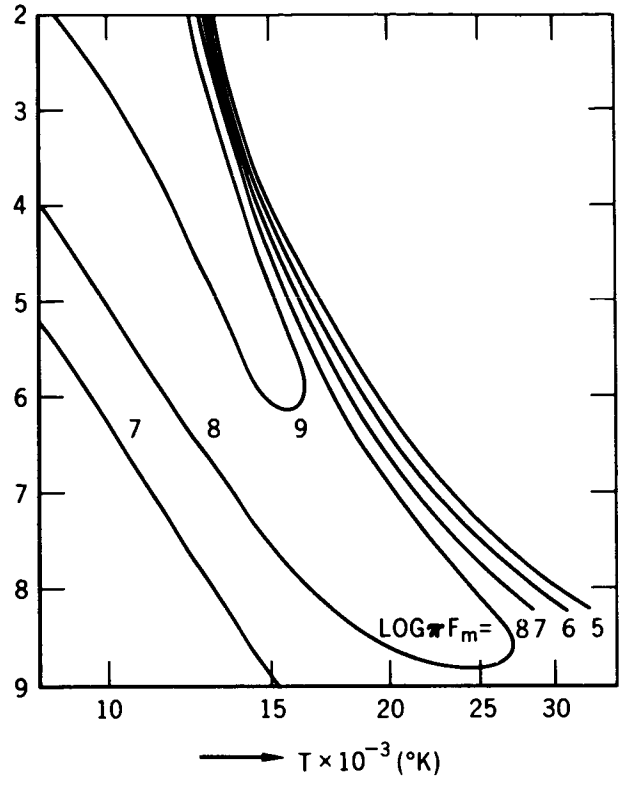

Figure 1–Acoustic Energy Generation Rate for Helium-Rich Atmospheres N_{He}/N_H = 1000/2.5

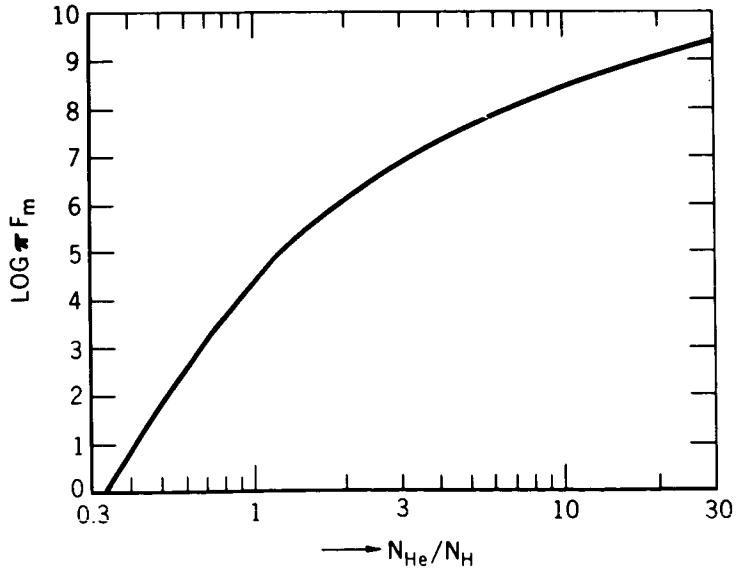

Figure 2–Change of Acoustic Energy Generation Rate with Helium to Hydrogen Ratio at T_e = 12,000 °K and Log g = 4

This means that a higher ratio of gravitational to thermal energy is necessary in order to change the mechanical energy into X-ray radiation. The most promising case would be a helium-rich star with log $g \leq 6$ and $T_e \sim 15{,}000$ °K. A star with a helium-rich composition and with mass $M > 10\ M_\odot$ can take such values in its contraction phase toward the helium main sequence. Assuming an optimistic value of 0.1 for the ratio of the X-ray flux to the energy generation rate in the convection zone, we obtain X-ray radiation of 10^{31} erg sec.$^{-1}$ But, this value still seems to be too small to account for the observed X-ray sources.

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