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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

TOPICAL SEMINAR ON WEAK INTERACTIONS

26 - 29 June 1973

(SUMMARIES)

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HOT STARS AND (eν) (eν) ASTROPHYSICAL

Hong-Yee Chiu

Institute for Space Studies, New York, NY, USA.

In this paper we review the current knowledge on stellar evolution processes, with emphasis on obtaining astrophysical evidence for the (eν)(eν) interaction. It is concluded that for the most massive stars (mass $> 20\ \odot$) the stellar structure theory is fairly well developed: a) the helium and other abundancies are well known, b) they possess radiative envelopes which can be calculated accurately from fundamental principles, c) their structure is such that uncertainties in nuclear reaction rates do not cause appreciable uncertainties in their structure from hydrogen throughout carbon burning, d) their brightness allows more accurate observational work to be performed, e) blue members of stars of this mass range ($> 20\ \odot$) are at H and He burning stages, in which neutrino processes are not important, while red members are at carbon burning stage, in which the neutrino processes are not important.

Next it is concluded that the stellar structure theory for white dwarfs is also very well understood and, for observed luminosities of white dwarfs greater than 0.1 $L_\odot$ ($L_\odot$ = solar luminosity), neutrino processes contribute considerably to the energy dissipation processes.

The neutrino processes are then reviewed; they are all derived from the (eν) (eν) interaction. There are four chief neutrino processes: a) the pair annihilation process ($\gamma \gtrless e^- + e^+ \rightarrow \nu + \bar{\nu}$), important at $\tau > 6 \times 10^8\ ^oK$ and low density; b) the photoneutrino process ($\gamma + e^- \rightarrow e^- + \nu + \bar{\nu}$) is important at low density, $\tau \sim 10^8\ ^oK - 6 \times 10^8\ ^oK$; c) the plasma processes ($[\gamma] \rightarrow \nu + \bar{\nu}$, $[\gamma]$ is a photon embedded in an electron gas medium) which is important at high densities at all temperatures; d) the bremsstrahlung process ($e^- + (Z,A) \rightarrow e^- + (Z,A) + \nu + \bar{\nu}$) which is important in the exceedingly high density regime ($\rho > 10^7$ g/cm^3). In regimes of importance, the neutrino rates exceed optical luminosities by order of magnitudes.

The occurrence of neutrino processes greatly shortens the lifetime of certain stars like: a) the red component of massive stars burning carbon ($\tau \sim 6 \times 10^8\ ^oK$); b) white dwarfs with luminosities $> 0.1\ L_\odot$. It has been found that the theoretical ratio of the numbers of blue to red massive stars is consistent with observed ratio in clusters only if the neutrino processes (photoneutrino and annihilation processes) are taken into account (the observed ratio is from 4 to 8, the theoretical ratio without $(e\nu)$ $(e\nu)$ interaction is < 1.7, that with $(e\nu)$ $(e\nu)$ is 6). The small number of samples of stars cited (~ 16 stars in total), however, enables one to place a reliable lower limit $10^{-2}\, g_\beta^2$ on the coupling constant, where g_β^2 is the theoretical value of the coupling constant. (Note that the ν-energy loss rates are directly proportional to the coupling constant.)

On the other hand, if bright white dwarfs ($L > 1 L_\odot$, called ultraviolet dwarfs since their chief emission is in the ultraviolet regime) exist, they can provide another test of the theory. Unfortunately, no ultraviolet dwarfs have been found. Although this statistic is consistent with the existence of the $(e\nu)$ $(e\nu)$ interaction (the predicted lifetime of ultraviolet dwarfs is as short as 10^3 years at one stage), this is not satisfactory as a rigorous test. Instead, attention is paid to less luminous ultraviolet dwarfs (luminosity less than $1 L_\odot$). It is found that if the coupling constant is increased by 10^2, there will be a significant drop in the number of brighter white dwarfs ($L > 0.05\, L_\odot$, say) and a substantial increase in the number of faint white dwarfs ($L < 0.05\, L_\odot$). A comparison with the observed number of white dwarfs in star clusters thus gives an upper limit of the coupling constant as $100\, g_\beta^2$.

It is therefore concluded from astrophysical evidence that $(e\nu)(e\nu)$ interactions do exist, and the coupling constant determined astrophysically lies between the limits

$$\frac{1}{100}\, g_\beta^2 < g^2 < 100\, g_\beta^2 \quad .$$