Session 5. Some Aspects of a Stellar Evolution

Convener: Dr. Yakiv Pavlenko (MAO NASU, Ukraine)

THE SINGULAR SOURCE OF ENERGY OF STARS

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INTRODUCTION

A fundamental suggestion of this work is that the luminosity of stars accounts for, not by the orthodox thermonuclear scenario alone, but the coupled system of the nuclear source and the black hole in their center. In general terms, the black hole (BH) works as a gravitational heat engine, so that the rate of accretion sets the pace for heat release. Such a BH reactor of $M = 10^{-5} M_\odot$ may be competitive in power with the nuclear burning for the Sun over the course of billion years. Apparent deficit of the solar neutrino flux count in favor of the coupled source of energy.

METHODS AND RESULTS

Let us suppose that the small BH exists in the center of a star and explore the consequences stemmed from this hypothesis. We may assume that small relict BH created in the early Universe [2] was captured by star from space or occurred for some another reason. The advanced theoretical treatment of both thermo- and gas-dynamical structure of BH in dense thermostat is that to be still studied in detail. Now, we are interested in the overall picture of the problem.

In the ambient BH atmosphere the radiation pressure is considered to balance the gravity in the equilibrium state. The radiation pressure arises because of the accretion of gas onto the BH when some part α of the original mass-energy of the particles is radiated away. So, in treating the problem the Eddington solution [3] is appropriate to use with a sufficient degree of accuracy. For hydrogen plasma with the Thomson scattering the BH luminosity should be no more than Eddington's limit

$$L_c = \frac{4\pi G m_p c M}{\sigma_T} = 3 \times 10^4 L_\odot \frac{M}{M_\odot}, \tag{1}$$

where G is the gravitational constant, m_p is the proton mass, c is the speed of light, σ_T is the Thomson cross-section and M is the BH mass. If the accretion rate sets the pace for energy release at a level of Eddington's limit, the BH mass growth rate is given by Equation [5]

$$-\varphi(R)\frac{dM}{dt} = \frac{GM}{R}\frac{dM}{dt} = L_c\,, \tag{2}$$

where $-\varphi(R) = \alpha c^2$ is the effective gravitational potential. For a Schwarzschild and a Kerr black hole α is of about 6% and 42%, respectively [4]. The BH mass growth rate may be written as

$$\frac{1}{M}\frac{dM}{dt} = \frac{4\pi G m_p}{\alpha c \sigma_T} = 7 \times 10^{-17} \alpha^{-1}\,\mathrm{sec}^{-1} = (0.5\,\alpha\, Gyr)^{-1}. \tag{3}$$

Surprisingly that in the equilibrium state a BH growth is a long lived process with e-folding rise time of billion years.

As expected, specific boundary conditions have to stabilize the neighborhood of the BH. The stability arises because the gravitational reactor is immersed into huge reservoir of dense heat-retaining matter, of the kind of “prison stability”. The behavior of an unstable mode can be investigated if it is viewed as oscillator. Strong restoring forces are supplied by the radiation pressure with increasing the accretion rate and by the gravity and the outer pressure with its decreasing.

It is pertinent to cite one illustrative example. The contribution of the BH of $M = 10^{-5} M_\odot$ to the total solar luminosity is estimated to be 30% according to (1). The BH size is of about 1 cm, its effective temperature $T_{\rm eff} \sim 10^8$ K, the mass growth rate $\sim 10^{10}$ g/s. Adopting the central density and temperature $\rho = 160$ g/cm^3, $T = 1.5 \times 10^7$ K, as given by Allen [1], we get for the speed of accretion a value of about 10^8 cm/s. The speed of sound at the center of a solar model is equal to 4×10^7 cm/s. Its value increases to 1.1×10^8 cm/s if the more realistic central temperature $T = T_{\rm eff}$ has been adopted, as mentioned above. Hence, it seems likely that the subsonic accretion would result in the vicinity of the BH.

Of great importance that such a low mass BH is capable to initiate the essential rearrangement of solar structure. The striking central temperature peak may produce the convective core.

Within the self-consistent solar model based on the coupled source of energy the thermonuclear burning has decreased in importance with the trend towards smaller thermal and, in particular, neutrino fluxes. This latter presents the most challenging question of contemporary solar physics.

The availability of coupled source of energy may have an immense action on stellar evolution. For above cited example it is easy to see that growth of the BH mass up to 10^{-4} M$_\odot$ tends to increase the solar luminosity by several times in comparison with its present value on a time scale of $\sim 10^9$ years. In all appearance, the truthful stellar evolutionary tracks may differ significantly from those described by the present-day theory based on the orthodox thermonuclear scenario.

The question now arises of whence it follows that black holes can exist in stellar interior? There are not any explanations for this. All we can do is point at the Earth’s life paradigm. Whence came life on the surface of the Earth? No one knows this. However, we live and explore life.

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