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ORIGINAL ARTICLE

A class of exact isotropic solutions of Einstein's equations and relativistic stellar models in general relativity

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Abstract In this paper we have studied a particular class of exact solutions of Einstein's gravitational field equations for spherically symmetric and static perfect fluid distribution in isotropic coordinates. The Schwarzschild compactness parameter, GM/c^2R, can attain the maximum value 0.1956 up to which the solution satisfies the elementary tests of physical relevance. The solution also found to have monotonic decreasing adiabatic sound speed from the centre to the boundary of the fluid sphere. A wide range of fluid spheres of different mass and radius for a given compactness is possible. The maximum mass of the fluid distribution is calculated by using stellar surface density as parameter. The values of different physical variables obtained for some potential strange star candidates like Her X-1, 4U 1538–52, LMC X-4, SAX J1808.4 − 3658 given by our analytical model demonstrate the astrophysical significance of our class of relativistic stellar models in the study of internal structure of compact star such as *self-bound* strange quark star.

Keywords General relativity · Relativistic astrophysics · Exact solution · Isotropic coordinates · Perfect fluid sphere · Compact stars · Relativistic stars · Equation of state

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1 Introduction

The search for exact solutions of Einstein's field equations with certain geometry that satisfy physical constraints has been remaining the subject of great interest to the researchers. Such findings are also important in relativistic astrophysics because they enable the distribution of matter in the interior of stellar object to be modeled in terms of simple algebraic relations. Due to the strong nonlinearity of Einstein's field equations and the lack of a comprehensive algorithm to generate all solutions, it becomes difficult to obtain new exact solutions. A well number of exact solutions of Einstein's field equations are known to date but not all of them are physically relevant in the description of relativistic structure of compact stellar objects. Now there exist a number of comprehensive collections (Delgaty and Lake 1998; Stephani et al. 2003) of static, spherically symmetric solutions which provide a useful guide to the literature.

Since the pioneering work of Oppenheimer and Volkoff (1939) the analysis and determination of maximum mass of very compact astrophysical objects has been a key issue in relativistic astrophysics. There are several astrophysical objects such as normal matter neutron star (bound by gravity) or self-bound strange quark star (bound by the strong interaction) where one needs to consider equation of state (EOS) of matter involving energy densities of the order of $10^{15}\ \mathrm{g\,cm^{-3}}$ or higher, exceeding the normal nuclear matter density. The strange star with surface energy density greater than the normal nuclear matter density has maximum mass almost the same but the radius is less than as that of neutron stars, with higher compactness parameter (Weber et al. 2012). Compact objects like neutron stars or strange stars may be classified on the basis of mass-radius relation (Haensel et al. 1986). Recent observations show that the estimated mass and radius of several compact objects such as

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