Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 109 (2018) 180-194 EISSN 2392-2192

Some new models of anisotropic compact stars with quadratic equation of state

Manuel Malaver

Maritime University of the Caribbean, Department of Basic Sciences, Catia la Mar, Venezuela

E-mail address: mmf.umc@gmail.com

ABSTRACT

In this paper, we studied the behavior of relativistic objects with anisotropic charged matter distribution considering a prescribed form for the gravitational potential Z(x) which depends on an adjustable parameter n. The equation of state presents a quadratic relation between the energy density and the radial pressure. New exact solutions of the Einstein-Maxwell system are generated. A physical analysis of electromagnetic field indicates that is regular in the origin and well behaved. We show as a variation of the adjustable parameter n causes a modification in the charge density, the radial pressure and the mass of the stellar object.

Keywords: Relativistic objects, Gravitational potential, Adjustable parameter, Electromagnetic field, Exact solutions, Einstein-Maxwell system

1. INTRODUCTION

The study of the ultracompacts objects and the gravitational collapse is of fundamental importance in astrophysics and has attracted much since the formulation of the general theory of relativity. One of the fundamental problems in the general theory of relativity is finding exact solutions of the Einstein field equations [1,2]. Some solutions found fundamental applications in astrophysics, cosmology and more recently in the developments inspired by string theory [2]. Different mathematical formulations that allow to solve Einstein´s field

(Received 22 August 2018; Accepted 06 September 2018; Date of Publication 07 September 2018)

equations have been used to describe the behaviour of objects submitted to strong gravitational fields known as neutron stars, quasars and white dwarfs [3-5].

The physics of configurations of superdense matter is not well understood and many researchs of strange stars have been performed within the framework of the MIT bag model [6]. In this model, the strange matter equation of state (EOS) has a simple linear form given by $P = \frac{1}{3}(\rho - 4B)$ where is the energy density ρ, P is the isotropic pressure and B is the bag constant. Many researchers have used a great variety of mathematical techniques to try to obtain exact solutions for quark stars within the framework of MIT-Bag model; Komathiraj and Maharaj [6] found two new classes of exact solutions to the Einstein-Maxwell system of equations with a particular form of the gravitational potential and isotropic pressure. Malaver [7,8] also has obtained some models for quark stars considering a potential gravitational that depends on an adjustable parameter. Thirukkanesh and Maharaj [9] studied the behavior of compact relativistic objects with anisotropic pressure in the presence of the electromagnetic field. Maharaj et al. [10] generated new models for quark stars with charged anisotropic matter considering a linear equation of state. Thirukkanesh and Ragel [11] obtained new models for compact stars with quark matter. Sunzu et al. found new classes of solutions with specific forms for the measure of anisotropy [12]

The first detailed models of strange stars, based on a more realistic EOS of strange quark matter, taking into account strange quark mass and the lowest order QCD strong interactions, were constructed by Haensel et al. [13], who considered also specific features of accretion on strange stars. Similar results were presented somewhat later by Alcock et al. [14], who additionally proposed scenarios of the formation of strange stars and analyzed strange stars with the normal crust.

Local isotropy, as it has been shown in recent years, is a too stringent condition, which may excessively constrain modeling of self-gravitating objects. Of course no astrophysical object is entirely composed of perfect fluid. The theoretical investigations [15–18] made in the last few decades back about more realistic stellar models show that the nuclear matter may be locally anisotropic at least in certain very high density ranges ($\rho > 10^{15}$ g cm^3), where the relativistic treatment of nuclear interactions in the stellar matter becomes important. Bowers and Liang [19] first generalized the equation of hydrostatic equilibrium for the case local anisotropy. Cosenza et al. [20,21], Bayin [22], Krori et al. [23], Herrera and Ponce de León [24], Herrera et al. [25,26], Dev and Gleiser [27,28], Ivanov [29,30], Mak and Harko [31, 32], Malaver [33-38] and Pant et al. [39] have studied the effect of local anisotropy on the bulk properties of spherically symmetric static general relativistic compact objects.

Over the years the continuously growing interests enable researchers to develop mathematically simple exact analytical models of self-bound strange stars together with a particular choice of the equation of state and different metric potentials (Gokhroo and Mehra [40], Mak and Harko [41], Chaisi and Maharaj [42], Sharma and Maharaj [43], Varela et al. [44], Takisa and Maharaj [45], Rahaman et al. [46], Kalam et al. [47], Thirukkanesh and Ragel [48-50], Ngubelanga et al. [51], Sunzu [52], Thirukkanesh et al. [53], Bhar et al. [54], Murad [55], Malaver [56,57]). In particular, Feroze and Siddiqui [58,59] and Malaver [33, 35,60] consider a quadratic equation of state for the matter distribution and specify particular forms for the gravitational potential and electric field intensity

The objective of this paper is to obtain new exact solutions to the Maxwell-Einstein system of field equations for charged anisotropic matter in static spherically symmetric spacetime with a quadratic equation of state and a prescribed form for the gravitational potential *Z(x)* proposed for Malaver [33] which depends on an adjustable parameter n. We have obtained a new classes of static spherically symmetrical models for relativistic stars in presence of an electromagnetic field. This article is organized as follows, in Section 2, we present Einstein´s field equations. In Section 3, we make a particular choice of gravitational potential Z(x) that allows solving the field equations and we have obtained new models for charged anisotropic matter.

In Section 4, a physical analysis of the new solutions is performed. Finally in Section 5, we conclude.

2. EINSTEIN FIELD EQUATIONS

We consider a spherically symmetric, static and homogeneous and anisotropic spacetime in Schwarzschild coordinates given by

$$ds^2 = -e^{2\nu(r)}dt^2 + e^{2\lambda(r)}dr^2 + r^2(d\theta^2 + \sin^2\theta d\varphi^2) \tag{1}$$

where $\nu(r)$ and $\lambda(r)$ are two arbitrary functions.

We are considering an anisotropic fluid in the presence of electromagnetic field. The components of energy momentum tensor is given by

$$T_{00} = -\rho - \frac{1}{2}E^2 \tag{2}$$

$$T_{11} = p_r - \frac{1}{2}E^2 \tag{3}$$

$$T_{22} = T_{33} = p_t + \frac{1}{2}E^2 \tag{4}$$

where ρ is the energy density, p_r is the radial pressure, E is electric field intensity and p_t is the tangential pressure, respectively. The Einstein-Maxwell equations take the form

$$\frac{1}{r^2}\left(1-e^{-2\lambda}\right) + \frac{2\lambda'}{r}e^{-2\lambda} = \rho + \frac{1}{2}E^2 \tag{5}$$

$$-\frac{1}{r^2}\left(1-e^{-2\lambda}\right) + \frac{2\nu'}{r}e^{-2\lambda} = p_r - \frac{1}{2}E^2 \tag{6}$$

$$e^{-2\lambda}\left(\nu'' + \nu'^2 + \frac{\nu'}{r} - \nu'\lambda' - \frac{\lambda'}{r}\right) = p_t + \frac{1}{2}E^2 \tag{7}$$

$$\sigma = \frac{1}{r^2} e^{-\lambda} (r^2 E)' \tag{8}$$

where primes represent differentiation with respect to r and σ is the charge density. Using the transformations $x = cr^2$, $Z(x) = e^{-2\lambda(r)}$ and $A^2 y^2(x) = e^{2\nu(r)}$ with arbitrary constants A and c>0 suggested by Durgapal and Bannerji [61], the Einstein field equations that governs the gravitational behaviour of a charged anisotropic sphere can be written as

$$\frac{1-Z}{x} - 2\dot{Z} = \frac{\rho}{c} + \frac{E^2}{2c} \tag{9}$$

$$4Z\frac{\dot{y}}{y} - \frac{1-Z}{x} = \frac{p_r}{c} - \frac{E^2}{2c} \tag{10}$$

$$4xZ\frac{\ddot{y}}{y} + (4Z + 2x\dot{Z})\frac{\dot{y}}{y} + \dot{Z} = \frac{p_t}{c} + \frac{E^2}{2c} \tag{11}$$

$$p_t = p_r + \Delta \tag{12}$$

$$\frac{\Delta}{c} = 4xZ\frac{\ddot{y}}{y} + \dot{Z}\left(1 + 2x\frac{\dot{y}}{y}\right) + \frac{1-Z}{x} - \frac{E^2}{c} \tag{13}$$

$$\sigma^2 = \frac{4cZ}{x}\left(x\dot{E} + E\right)^2 \tag{14}$$

$\Delta = p_t - p_r$ is the measure of anisotropy and dots denote differentiation with respect to x. With the transformations of [61], the mass within a radius r of the sphere take the form

$$M(x) = \frac{1}{4c^{3/2}}\int_0^x \sqrt{x}\rho(x)dx = \frac{1}{4c^{3/2}}\int_0^x \sqrt{x}\left(\rho_* + E^2\right)dx \tag{15}$$

where $\rho_* = \left(\frac{1-Z}{x} - 2\dot{Z}\right)c$ and $\rho = \rho_* + E^2$

In this paper, we assume a quadratic equation of state relating the radial pressure to the energy density given by

$$p_r = \alpha\rho^2 \tag{16}$$

where α is an arbitrary constant

3. CLASSES OF MODELS

In order to solve Einstein field equations, we have chosen specific forms for the gravitational potential Z and the electrical field intensity E. Following Malaver [33] and Nasim and Azam [62] we have taken the forms

$$Z(x) = (1-ax)^n \tag{17}$$

$$\frac{E^2}{2c} = \frac{\xi x}{(1+ax)^2} \tag{18}$$

where a and ξ are arbitrary real constants and n is the adjustable parameter. The potential is regular at the origin and well behaved in the interior of the sphere. The electric field intensity E is continuous, reaches a maximum and then it diminishes in the surface of the sphere. We have considered the particular cases for n = 1, 2.

For case n=1, using (17) and (18) in eq.(9), we obtain

$$\rho = \frac{3a^3cx^2 + (6a^2 - \xi)cx + 3ac}{(1+ax)^2} \tag{19}$$

Substituting (19) in eq.(16), the radial pressure can be written in the form

$$p_r = \frac{\alpha\left[3a^3cx^2 + (6a^2 - \xi)cx + 3ac\right]^2}{(1+ax)^4} \tag{20}$$

Using (19) in (15), the expression of the mass function is

$$M(x) = \frac{\sqrt{x}}{\sqrt{c}}\left(\frac{2a^4x^2 + 2(a^3 - \xi a)x - 3\xi}{4a^2(ax+1)}\right) + \frac{3\xi \arctan(\sqrt{ax})}{4a^2\sqrt{ac}} \tag{21}$$

and for the charge density we have

$$\sigma^2 = \frac{2\xi c^2(1-ax)(3+ax)^2}{(1+ax)^4} \tag{22}$$

With (17), (18) and (20), eq. (10) becomes

$$\frac{\dot{y}}{y}=\frac{\alpha\left[3a^3cx^2+\left(6a^2-\xi\right)cx+3ac\right]^2}{4(1-ax)(1+ax)^4}-\frac{\xi x}{4(1-ax)(1+ax)^2}+\frac{a}{4(1-ax)} \tag{23}$$

Integrating (23), we obtain

$$y(x)=c_1(1+ax)^{A_*}(-1+ax)^{B}e^{-\frac{Cx^2+Dx+E}{96a^3(1+ax)^3}} \tag{24}$$

where c_1 is the constant of integration and

$$A_*=\frac{\xi\left(-24a^2\alpha c+\xi\alpha c-4a\right)}{64a^3}$$

$$B=-\frac{144a^4\alpha c-24\xi a^2\alpha c+\xi^2\alpha c+16a^3-4\xi a}{64a^3}$$

$$C=72\alpha ca^4+3\xi a^2\alpha c+12a^3,\ D=144\alpha a^3c-3\xi a\alpha c+24a^2$$

$$E=72a^2\alpha c-2\xi\alpha c+12a$$

Substituting (17), (18) and (24) in eq. (13), the measure of anisotropy is given by

$$\Delta=4cx(1-ax)\left[\begin{array}{l}\frac{\left(A_*^2-A_*\right)a^2}{(1+ax)^2}+\frac{2A_*a^2B}{(ax+1)(ax-1)}+\frac{\left(B^2-B\right)a^2}{(ax-1)^2}\\ -\frac{C}{48a^3(1+ax)^3}+\frac{2Cx+D}{16a^2(1+ax)^4}-\frac{Cx^2+Dx+E}{8a(1+ax)^5}\\ -\frac{2Ca^2x^3+\left(4A_*C+4BC+D\right)a^2x^2+\left(2A_*Da^2+2BDa^2-4A_*C+4BCa-2C\right)x+2BDa-2A_*Da-D}{96a^3(ax+1)^4(ax-1)}\\ +\frac{Ca^2x^4+\left(2A_*C+2BC+D\right)a^2x^3+\left(2A_*Da^2+2BDa^2-2A_*Ca+2BCa+Ea^2-C\right)x^2+\left(2A_*Ea^2+2BEa^2-2A_*Da+2BDa-D\right)x+2BEa-2A_*Ea-E}{32a^3(ax+1)^5(ax-1)}\end{array}\right]$$

$$-\frac{2A_*a^2cx}{(1+ax)}+\frac{2a^2Bcx}{1-ax}+\frac{cx(Cx+D)}{48a^2(1+ax)^3}-\frac{cx\left(Cx^2+Dx+E\right)}{16a(1+ax)^4}-\frac{2c\xi x}{(1+ax)^2} \tag{25}$$

The metric functions can be written as

$$e^{2\lambda(r)} = \frac{1}{1-ax} \tag{26}$$

$$e^{2\nu(r)} = A^2 c_1{}^2 (1+ax)^{2A} (-1+ax)^{2B} e^{-\frac{Cx^2+Dx+E}{48a^3(1+ax)^3}} \tag{27}$$

The metric for this model is

$$ds^2 = -A^2 c_1^2 \left(1+ar^2\right)^{2A} \left(-1+ar^2\right)^{2B} e^{-\frac{Cr^4+Dr^2+E}{48a^3\left(1+ar^2\right)^3}} dt^2 + \frac{dr^2}{\left(1-ar^2\right)} + r^2 (d\theta^2 + \sin^2\theta d\varphi^2\,) \tag{28}$$

With n = 2, we can find the following analytical model

$$\rho = \frac{-5a^4cx^3 - 4a^3cx^2 + \left(7a^2 - \xi\right)cx + 6ac}{(1+ax)^2} \tag{29}$$

$$p_r = \frac{\alpha\left[-5a^4cx^3 - 4a^3cx^2 + \left(7a^2 - \xi\right)cx + 6ac\right]^2}{(1+ax)^4} \tag{30}$$

$$M(x) = \frac{\sqrt{x}}{\sqrt{c}}\left(\frac{-4a^5x^3 + 2\left(2a^3 - \xi a\right)x - 3\xi}{4a^2(ax+1)}\right) + \frac{3\xi\arctan\left(\sqrt{ax}\right)}{4a^2\sqrt{ac}} \tag{31}$$

$$\sigma^2 = \frac{2\xi c^2 (1-ax)^2 (3+ax)^2}{(1+ax)^4} \tag{32}$$

$$e^{2\lambda(r)} = \frac{1}{(1-ax)^2} \tag{33}$$

$$e^{2\nu(r)} = A^2 c_2^2 (1+ax)^{2F} (-1+ax)^{2G} e^{\frac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{12a^3(ax+1)^3(1-ax)}} \tag{34}$$

$$\Delta = 4x(1-ax)^2\left[\begin{array}{l}\dfrac{F^2a^2-Fa^2}{(1+ax)^2}+\dfrac{Fa^2G}{a^2x^2-1}\left(\begin{array}{l}-\dfrac{5Hx^4+4Ix^3+3Jx^2+2Kx+L}{24a^3(ax+1)^3(ax-1)}+\\ \dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{8a^2(ax+1)^4(ax-1)}+\\ \dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{24a^2(ax+1)^3(ax-1)^2}\end{array}\right)\\ +\dfrac{G^2a^2-Ga^2}{(ax-1)^2}+\dfrac{2Ga}{ax-1}\left(\begin{array}{l}-\dfrac{5Hx^4+4Ix^3+3Jx^2+2Kx+L}{24a^3(ax+1)^3(ax-1)}+\\ \dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{8a^2(ax+1)^4(ax-1)}+\\ \dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{24a^2(ax+1)^3(ax-1)^2}\end{array}\right)\\ -\dfrac{20Hx^3+12Ix^2+16Jx+2K}{24a^3(ax+1)^3(ax-1)}+\dfrac{5Hx^4+4Ix^3+3Jx^2+2K+L}{4a^2(ax+1)^4(ax-1)}\\ +\dfrac{5Hx^4+4Ix^3+3Jx^2+2Kx+L}{12a^2(ax+1)^3(ax-1)^2}-\dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{2a(ax+1)^5(ax-1)}\\ -\dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{4a(ax+1)^4(ax-1)^2}-\dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{12a(ax+1)^3(ax-1)^3}\\ -\dfrac{5Hx^4+4Ix^3+3Jx^2+2Kx+L}{24a^3(ax+1)^3(ax-1)}+\dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{8a^2(ax+1)^4(ax-1)}\\ +\dfrac{Hx^5+Ix^4+Jx^3+Kx^2+Lx+M}{24a^2(ax+1)^3(ax-1)^2}\end{array}\right]$$

$$-2a(1-ax)\left[\begin{array}{l}1+\dfrac{2aFx}{(ax+1)}+\dfrac{2Gax}{(ax-1)}-\dfrac{5Hx^5+4Ix^4+3Jx^3+2Kx^2+Lx}{12a^3(ax+1)^3(ax-1)}\\ +\dfrac{Hx^6+Ix^5+Jx^4+Kx^3+Lx^2+Mx}{4a^2(ax+1)^4(ax-1)}+\dfrac{Hx^6+Ix^5+Jx^4+Kx^3+Lx^2+Mx}{12a^2(ax+1)^3(ax-1)^2}\end{array}\right] \quad \ldots.(35)$$

$$+2a-a^2x-\frac{2\xi x}{(1+ax)^2}$$

c_2 is the constant of integration. Again for convenience we have let

$$F=-\frac{5\xi\alpha c}{8a},\ G=-\frac{5}{2}ac\alpha+\frac{5\xi\alpha c}{8a},\ H=-150a^9\alpha c,\ I=-300a^8\alpha c$$

$$J=6a^7\alpha c+30\xi a^5\alpha c+6a^6,\ K=318a^6\alpha c+24\xi a^4\alpha c+18a^5-3\xi a^3$$

$$L=168a^5\alpha c-42\xi a^3\alpha c+2\xi^2 a\alpha c+18a^4-6\xi a^2$$

$$M=6a^4\alpha c-36\xi a^2\alpha c+\xi^2\alpha c+6a^3-3\xi a$$

The metric for this model is

$$ds^2 = -A^2 c_2^2 \left(1+ar^2\right)^{2F} \left(-1+ar^2\right)^{2G} e^{\frac{Hr^{10}+Ir^8+Jr^6+Kr^4+Lr^2+M}{12a^3(1+ax)^3(1-ax)}} dt^2 + \frac{dr^2}{\left(1-ar^2\right)^2} + r^2(d\theta^2 + \sin^2\theta d\varphi^2) \quad (36)$$

The figures 1,2,3,4 and 5 represent the graphs of P_r , ρ , σ , $M(x)$ and the square of speed of sound v_{sr}^2 respectively with $\alpha = 1/4$, n = 2, $\xi = 1$, a = 0.2, c = 1 and a stellar radius of r = 1 km. In order to maintain the causality, the square of speed of sound defined as $v_{sr}^2 = \frac{dP_r}{d\rho}$ should be in the range $0 \le v_{sr}^2 \le 1$ in the interior of the star.

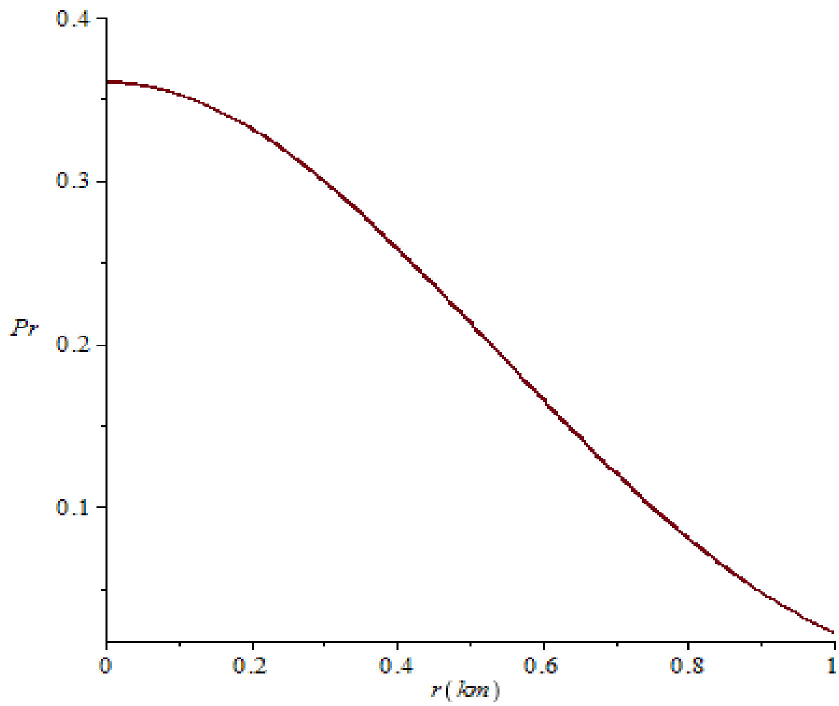

Fig. 1. Radial pressure

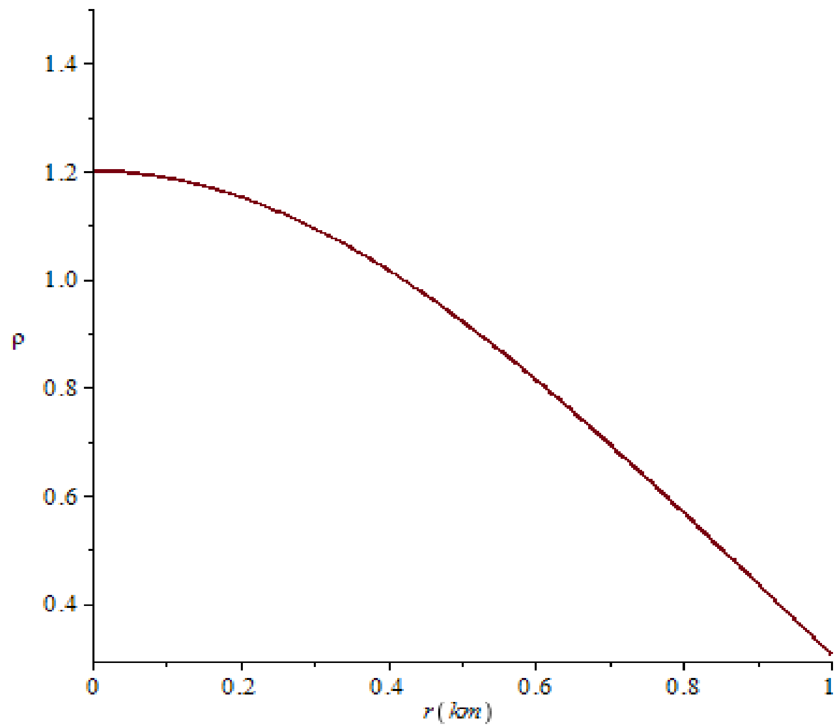

Fig. 2. Energy density

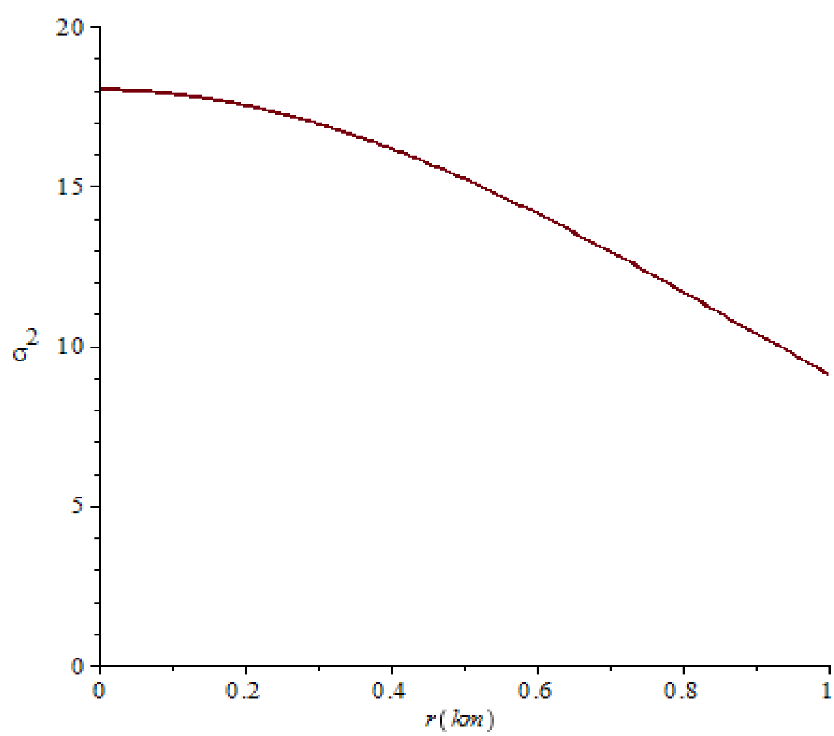

Fig. 3. Charge density

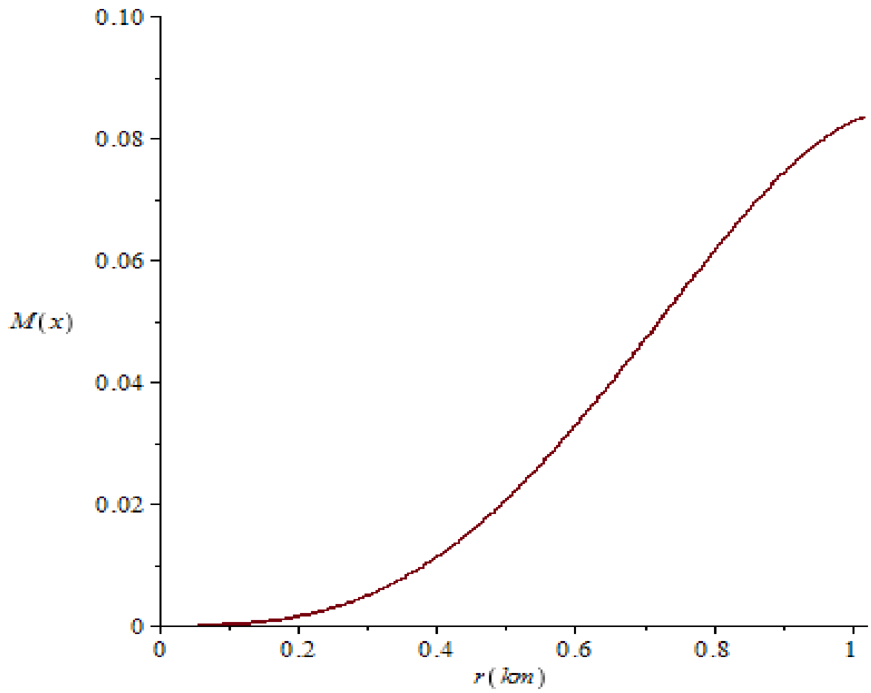

Fig. 4. Mass function

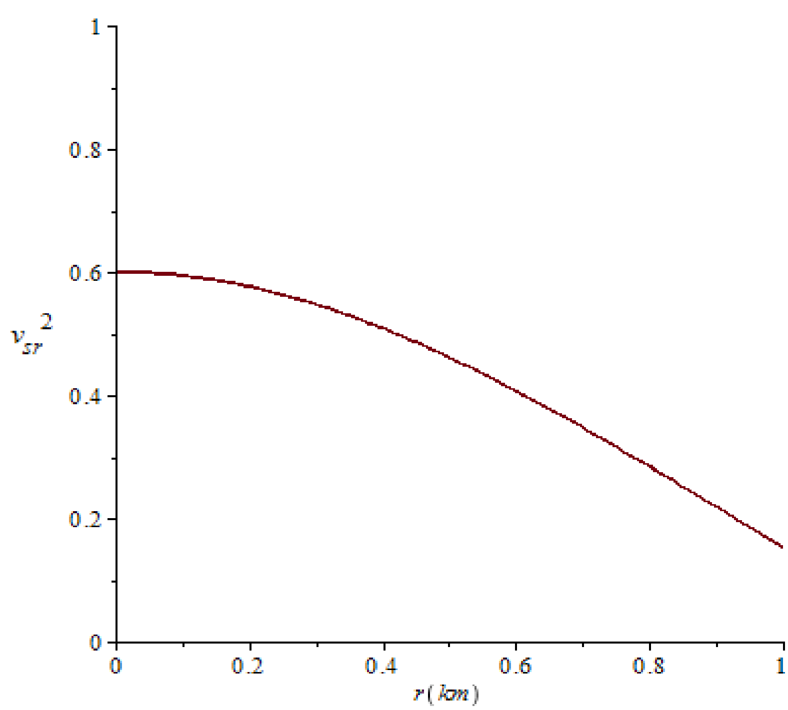

Fig. 5. Radial speed of sound

4. PHYSICAL FEATURES OF THE NEW MODELS

In order for a solution of Einstein field equations to be physically acceptable, the following conditions should be satisfied [48-63]:

(i). The metric potentials should be free from singularities in the interior of the star.

(ii). The radial pressure and density must be finite and positive inside of the fluid sphere.

(iii). $P_r > 0$ and $\rho > 0$ at the origin.

(iv). Monotonic decrease of the energy density and the radial pressure with increasing radius.

The new models satisfy the Einstein-Maxwell system of field equations (9)-(14) and constitute another new family of solutions for anisotropic charged matter with quadratic equation of state. The physical variables are expressed in terms of elementary functions which allows a detailed analysis of the physical behavior of the compact star.

With $n = 1$,the gravitational potentials are regular at the origin since $\left(e^{2\lambda(r)}\right)'_{r=0} = \left(e^{2\nu(r)}\right)'_{r=0} = 0$ and $e^{2\lambda(0)} = 1$, $e^{2\nu(0)} = A^2 c_1^2 e^{-\frac{E}{48a^3}}$; these imply that the metric functions are regular in r=0 .In the center $P_r(0) = 9\alpha a^2 c^2$ and $\rho(0) = 3ac$, therefore the radial pressure and the energy density will be non-.negative at the center. For the case n=2, $e^{2\lambda(0)} = 1$ and $e^{2\nu(0)} = A^2 c_2^2 e^{\frac{M}{12a^3}}$, in the origin $\left(e^{2\lambda(r)}\right)'_{r=0} = \left(e^{2\nu(r)}\right)'_{r=0} = 0$. Again the gravitational potential is regular at r=0 and $P_r(0) = 36\alpha a^2 c^2$, $\rho(0) = 6ac$. In these new solutions, the anisotropy parameter $\Delta(0) = 0$ at $r = 0$ and the mass function is a strictly increasing function, continuous and finite and the charge density is continuous and behaves well inside of the sphere.

In Figure 1, the radial pressure is finite and decreasing with the radial coordinate. In Figure 2, that represent energy density we observe that is continuous, finite and monotonically decreasing function. In Figure 3, the charge density σ is not singular at the origin, non-negative and decreases In Fig. 4, the mass function is increasing function, continuous and finite. In Fig. 5, the condition $0 \leq v_{sr}^2 \leq 1$ is maintained inside the stellar interior, which is a physical requirement for the construction of a realistic star [63].

5. CONCLUSIONS

In this work, we have generated new exact solutions to the Einstein-Maxwell system considering a gravitational potential Z what depends on an adjustable parameter n and an equation of state that presents a quadratic relation between the energy density and the radial pressure. The new obtained models may be used to model relativistic stars in different astrophysical scenes. The charged relativistic solutions to the Einstein-Maxwell systems presented are physically reasonable. The charge density σ is nonsingular at the origin and the radial pressure is decreasing with the radial coordinate. The mass function is an increasing function, continuous and finite and the condition $0 \leq v_{sr}^2 \leq 1$ is maintained inside the stellar interior. The gravitational potentials are regular at the center and well behaved.

We show as a modification of the parameter n of the gravitational potential affects the electrical field, charge density and the mass of the stellar object. The models presented in this article may be useful in the description of relativistic compact objects with charge, strange quark stars and configurations with anisotropic matter.

References

[1] Kuhfitting, P.K. Some remarks on exact wormhole solutions, *Adv. Stud. Theor. Phys.* (2011) 5, 365-367

[2] Bicak, J. Einstein equations: exact solutions, *Encyclopedia of Mathematical Physics* (2006), 2, 165-173.

[3] Malaver, M. (2013). Black Holes, Wormholes and Dark Energy Stars in General Relativity. *Lambert Academic Publishing*, Berlin. ISBN: 978-3-659-34784-9.

[4] Tolman, R.C. Static solutions of Einstein's Field Equations for spheres of fluid, *Phys Rev* (1939), 55, 364-373.

[5] Oppenheimer, J.R. and Volkoff, G. On massive neutron cores, *Phys. Rev*. (1939), 55, 374-381.

[6] Komathiraj, K. and Maharaj, S.D. *Int. J. Mod. Phys* (2007), D16, pp. 1803-1811.

[7] Malaver, M. *Revista Integración* (2009), 27(2), 125-133.

[8] Malaver, M. *AASCIT Communications* (2014), 1, 48-51.

[9] Thirukkanesh, S. and Maharaj, S.D. Charged anisotropic matter with linear equation of state, *Class. Quantum Gravity* (2008), 25, 235001.

[10] Maharaj,S.D, Sunzu, J.M and Ray, S. *Eur Phys. J. Plus* (2014), 129, 3.

[11] Thirukkanesh, S. and Ragel, F.C. *PRAMANA - Journal of physics* (2013), 81(2), 275-286.

[12] Sunzu, J.M, Maharaj, S.D and Ray, S. *Astrophysics Space Sci* (2014), 354, 517-524.

[13] Haensel, P, Zdunik, J.L and. Schaefer, R. *Astrophys. J.* (1986), 160, 121.

[14] Alcock, C, Farhi, E. and Olinto, A. *Astrophys. J.* (1986), 310, 261.

[15] Ruderman, R. A. *Rev. Astr. Astrophys* (1972), 10, 427.C

[16] Canuto, V. *Annual Review of Astronomy and Astrophysics* (1974), 12, 167.

[17] Canuto, V. *Annual Review of Astronomy and Astrophysics* (1975), 13, 335.

[18] Canuto, V. *Annals of the New York Academy of Sciences* (1977), 302, 514.

[19] Bowers, R.L and Liang, E.P.T. *Astrophys. J.* (1974), 188, 657.

[20] Cosenza, M., Herrera, L., Esculpi, M and Witten, L. *J. Math. Phys* (1981) 22, 118.

[21] Cosenza, M., Herrera, L., M. Esculpi, L. Witten, *Phys. Rev. D* 25, 2527 (1982).

[22] Bayin, S.S. *Phys. Rev.* (1982), D 26, 1262 .

[23] Krori, K.D., Borgohaiann, P. and Devi, R. *Can. J. Phys* (1984), 62, 239.

[24] Herrera, L. and Ponce de León, J. *J. Math. Phys* (1985) 26, 2302.

[25] Herrera, L., Prisco, A.D., Ospino, J and Fuenmayor. E. *J. Math. Phys* (2001), 42, 2129

[26] Herrera, L., Ospino, J. and Prisco, A.D. *Phys. Rev. D* 77 (2008), 027502 .

[27] Dev, K. and Gleiser, M. *Gen. Relativ. Gravit* (2002), 34, 1793.

[28] Dev, K. and Gleiser, M. *Gen. Relativ. Gravit* (2003), 35, 1435.

[29] Ivanov, B.V. *Int. J. Theor. Phys* (2010), 49, 1236.

[30] Ivanov, B.V. *Eur. Phys. J. C* (2017), 77(11), 738.

[31] Mak, M.K. and Harko, T. *Chin. J. Astron. Astrophys* (2002) 2, 248.

[32] Mak, M.K. and Harko, T. *Proc. R. Soc. Lond* (2003) A 459, 393.

[33] Malaver, M. *Frontiers of Mathematics and Its Applications* (2014), 1(1), 9-15.

[34] Malaver, M. *Open Science Journal of Modern Physics* (2014), 1(1), 6-11.

[35] Malaver, M. *World Scientific News* (2016), 57, 70-80.

[36] Malaver, M. *American Journal of Astronomy and Astrophysics* (2013), 1(4), 41-46.

[37] Malaver, M. *World Applied Programming* (2013), 3, 309-313.

[38] Malaver, M. *Int. J. Modern Physics and Application* (2015), 2(1), 1-6.

[39] Pant, N., Pradhan, N. and Malaver, M. *Int. J. Astrophys. Space Sci* (2015) 3(1), 1-5.

[40] Gokhroo, M.K and Mehra, A.L. *Gen. Relat. Grav* (1994) 26(1), 75-84.

[41] Mak, M.K and Harko, T. *Int. J. Mod. Phys*, D13 (2004) 149-156.

[42] Chaisi, M and Maharaj, S.D. *Gen. Relativ. Gravit* (2005) 37, 1177.

[43] Sharma, R. and Maharaj, S.D. Mon. *Not. R. Astron. Soc* (2007) 375, 1265.

[44] Varela, V., Rahaman, F., Ray, S., Chakraborty, K. and Kalam, M. *Phys. Rev.* (2010) D 82, 044052.

[45] Takisa, P.M. and Maharaj, S.D. *Astrophys. Space Sci* (2012) 343, 569.

[46] Rahaman, F., Sharma, R., Ray, S., Maulick, R. and Karar, I. *Eur. Phys. J* (2012) C 72, 2071

[47] Kalam, M., Usmani, A.A., Rahaman, F., Hossein, S.M., Karar, I. and Sharma, R. *Int. J. Theor. Phys* (2013) 52, 3319.

[48] Thirukkanesh, S. and Ragel, F.C. *Pramana J. Phys* (2012) 78, 687.

[49] Thirukkanesh, S. and Ragel, F.C. *Pramana J. Phys* (2013) 81, 275.

[50] Thirukkanesh, S. and Ragel, F.C. *Astrophys. Space Sci* (2014) 354, 415.

[51] Ngubelanga, S.A., Maharaj, S.D. and Ray, S. *Astrophys. Space Sci* (2015) 357, 40.

[52] Sunzu, J. *Global Journal of Science Frontiers of Research: A. Physics and Space Science* (2018), 18(2).

[53] Thirukkanesh, S., Govender, M. and Lortan, D.B. *Int. J. Mod. Phys* (2015) D 24, 1550002

[54] Bhar, P., Murad, M.H. and Pant, N. *Astrophys. Space Sci* (2015) 359, 13.

[55] Murad, M.H. *Astrophys. Space Sci* (2016) 361, 20.

[56] Malaver, M. *Research Journal of Modeling and Simulation* (2014) 1(4), 65-71

[57] Malaver, M. *Int. J. Modern Physics and Application* (2016) 3(1), 6-13.

[58] Feroze, T. and Siddiqui, A. *Gen. Rel. Grav* (2011), 43, 1025-1035.

[59] Feroze, T. and Siddiqui, A. *J. Korean Physical Society* (2014), 65(6), 944-947.

[60] Malaver, M. *World Scientific News* (2017), 86(3), 333-344.

[61] Durgapal, M.C and Bannerji, R., *Phys. Rev.* (1983) D27, 328-331.

[62] Nasim, A. and Azam, M. *Eur. Phys. J.C.* (2018), 78:34

[63] Delgaty, M.S.R and Lake, K. *Comput. Phys. Commun.* (1998) 115, 395