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A Family of Well Behaved Uncharged Model of Vaidya–Tikekar Type Super-Dense Star

Jitendra Kumar and Amit Kumar Prasad

Center for Applied Mathematics
Central University of Jharkhand, Brambe
Ranchi (Jharkhand)-835205, India
Email: jitendark@gmail.com; amitkarun5@gmail.com

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Abstract: In the present article a model of well-behaved uncharged super-dense star with surface density 2×10^{14} gm/cm^3 is developed by considering a static spherically symmetric metric with t= const hyper surfaces as hyperboloid. So far well-behaved model described by such metric could not be obtained for uncharged fluid. Maximum mass of the star is found to be $0.343121M_\Theta$ and the corresponding radius is 9.576299 Km. The red shift at the centre and on the surface are given as 0.076792 and 0.031726 respectively.

Key Words: Exact solutions, Uncharged fluids, Super-dense stars, General relativity.

1. Introduction

In short, the uncharged fluids so far obtained are not well behaved. In the present article authors have developed a uncharged super-dense models of above kind which are well behaved. Well behaved formality of models means the models satisfying the conditions $c^2\rho \geq p \geq 0, \frac{dp}{dr} < 0, \frac{d\rho}{dr} < 0,$ $\frac{p}{c^2\rho} < 1,\ \frac{dp}{c^2 d\rho} < 1,\ \ \frac{d}{dr}\left(\frac{p}{c^2\rho}\right) < 0, \frac{d}{dr}\left(\frac{dp}{c^2 d\rho}\right) < 0$, where ρ and p denote the energy density and pressure of the source material. Also $\frac{dp}{d\rho}$ denotes the velocity of sound in through the model.

2. Field Equations

Let us consider the metric to be

$$ds^2 = -e^{\lambda} dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right) + e^{\nu} dt^2, \tag{2.1}$$

where the functions $\lambda(r)$ and $\nu(r)$ are to satisfy the Einstein field equation for perfect fluid distributions

$$R_j^i - \frac{1}{2}R\delta_j^i = -\kappa\left[\left(c^2\rho + p\right)v^i v_j - p\delta_j^i\right], \tag{2.2}$$

where $\kappa = \dfrac{8\pi G}{c^4}$, ρ, p and v^i denote energy density, fluid pressure and flow vector of the fluid, respectively.

The field equation (2.2) with respect to the metric equation (2.1) give[1]

$$8\pi T_1^1 = -\frac{\nu'}{r}e^{-\lambda} + \frac{\left(1 - e^{-\lambda}\right)}{r^2}, \tag{2.3}$$

$$8\pi T_2^2 = 8\pi T_3^3 = -\left[\frac{\nu''}{2} - \frac{\lambda'\nu'}{4} + \frac{\nu'^2}{4} + \frac{\nu' - \lambda'}{2r}\right]e^{-\lambda}, \tag{2.4}$$

$$8\pi T_4^4 = \frac{\lambda'}{r}e^{-\lambda} + \frac{\left(1 - e^{-\lambda}\right)}{r^2}. \tag{2.5}$$

At the pressure free interface $r = a$ the charged fluid sphere is expected to join with the Reissner-Nordstrom metric

$$ds^2 = -\left(1 - \frac{2m}{r} + \frac{e^2}{r^2}\right)^{-1} dr^2 - r^2\left(d\theta^2 + \sin^2\theta d\phi^2\right) + \left(1 - \frac{2m}{r} + \frac{e^2}{r^2}\right)dt^2, \tag{2.6}$$

where m is the gravitational mass of the distribution such that $m = \mu(a)$, while

$$\mu(a) = \frac{\kappa}{2}\int_0^a \rho(r) r^2 dr, \tag{2.7}$$

$\mu(a)$ is the mass[2].

The space-time with its hyper surface $t =$ constant as hyperboloid is characterized by the metric (2.1) with the metric potential g_{11} as [3-10]

(2.8)
$$e^{\lambda} = \frac{\left(K + Cr^2\right)}{K\left(1 + Cr^2\right)}, \;\; K > 1 \;\; ,$$

where K is parameter and C being a constant[11-12].

Now from the equations (2.3), (2.5) and (2.8), we get

(2.9)
$$\frac{\left(K + Cr^2\right)}{K\left(1 + Cr^2\right)}\left[-\frac{2y'}{ry} + \frac{C(K-1)}{\left(K + Cr^2\right)}\right] = -\kappa p \, ,$$

(2.10)
$$\frac{C(K-1)\left(3 + Cr^2\right)}{K\left(1 + Cr^2\right)^2} = \kappa c^2 \rho \, ,$$

where $e^{\upsilon} = y^2$ and y satisfies the isotropy condition $\left(T_1^1 = T_2^2 = T_3^3\right)$

(2.11)
$$\left(K + Cr^2\right)\left(1 + Cr^2\right)y'' - \frac{1}{r}\left[\left(K + Cr^2\right)\left(1 + Cr^2\right) + (K-1)Cr^2\right]y' + (K-1)C^2r^2 y = 0 \, .$$

Now the equation (2.11) can be written as

(2.12)
$$\left(1 - X^2\right)\frac{d^2y}{dX^2} + X\frac{dy}{dX} + \alpha y = 0 \, ,$$

where $\alpha = (1 - K)$ and

(2.13)
$$X = \sqrt{\frac{K}{(K-1)}}\sqrt{1 + \frac{Cr^2}{K}}, \;\; K > 1 \;\; .$$

Here we consider $K > 1$, then $X > 1$ and we adopt a different approach to get a solution, which as follows

(2.14)
$$y(X) = \left(X^2 - 1\right)Z(X),$$

which sends the equation (2.12) to the equation

(2.15)
$$\frac{d^2Z}{dX^2} + IZ = 0 \, ,$$

where

(2.16)
$$I = \frac{\alpha}{\left(1 - X^2\right)} - \frac{\left(2 + 3X^2\right)}{4\left(1 - X^2\right)^2}.$$

In the present equation (2.15) can be solved easily if set $K = \frac{7}{4}$ consequently the equations (2.13) and (2.16) now read as

(2.17)
$$X = \sqrt{\frac{\left(7 + 4Cr^2\right)}{3}},$$

(2.18)
$$I = -\frac{5}{4\left(1 - X^2\right)^2},$$

and the equation (2.15) takes the form

(2.19)
$$Z'' - \frac{5}{4\left(1 - X^2\right)^2} z = 0,$$

which admits the solution

$$Z(X) = (X + 1)\left[C_1\left|\frac{X + 1}{X - 1}\right|^{(\beta - 0.5)} + C_2\left|\frac{X + 1}{X - 1}\right|^{(-\beta - 0.5)}\right],\ \beta = \frac{3}{4}.$$

Now from the equation (2.14), we have

(2.20)
$$y(X) = \left(X^2 - 1\right)(X + 1)\left[C_1\left|\frac{X + 1}{X - 1}\right|^{(\beta - 0.5)} + C_2\left|\frac{X + 1}{X - 1}\right|^{(-\beta - 0.5)}\right],$$

which can be written in term of r using the equation (2.17) as (2.21)

$$y(r) = \frac{4\left(1 + Cr^2\right)}{3}\left(\sqrt{\frac{\left(7 + 4Cr^2\right)}{3}} + 1\right)\left[C_1\left|\frac{\sqrt{\frac{\left(7 + 4Cr^2\right)}{3}} + 1}{\sqrt{\frac{\left(7 + 4Cr^2\right)}{3}} - 1}\right|^{(\beta - 0.5)} + C_2\left|\frac{\sqrt{\frac{\left(7 + 4Cr^2\right)}{3}} + 1}{\sqrt{\frac{\left(7 + 4Cr^2\right)}{3}} - 1}\right|^{(-\beta - 0.5)}\right].$$

The corresponding expression for energy density and pressure can be had from the equations (2.9), (2.10), and (2.21) as

(2.22) $$\kappa c^2\rho = \frac{3C\left(3+Cr^2\right)}{7\left(1+Cr^2\right)^2}\ ,$$

(2.23) $$\kappa p = -\frac{\left(7+4Cr^2\right)}{7\left(1+Cr^2\right)}\left[-\frac{2y'}{ry}+\frac{3C}{\left(7+4Cr^2\right)}\right].$$

Now $p_{(r=a)} = 0$ gives

(2.24) $$\frac{C_2}{C_1} = \frac{DN\left|\dfrac{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1}{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}-1}\right|^{(\beta-0.5)} - N_1N_3\left|\dfrac{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1}{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}-1}\right|^{(\beta-0.5)} + D_1}{N_1N_3\left|\dfrac{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1}{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}-1}\right|^{(-\beta-0.5)} - DN\left|\dfrac{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1}{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}-1}\right|^{(-\beta-0.5)} + D_2}\ ,$$

where

$$D = \left(\frac{4\left(1+Ca^2\right)}{3}\right)^{\left(\frac{1}{4}\right)}\left(\sqrt{\frac{\left(7+4Ca^2\right)}{3}}+1\right),\ N = \frac{3}{\left(7+4Ca^2\right)}$$

$$N_1 = \left(\frac{4\left(1+Ca^2\right)}{3}\right)^{\left(\frac{1}{4}\right)} + \frac{\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}\left(\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1\right)}{2\left(\dfrac{4\left(1+Ca^2\right)}{3}\right)^{\left(\frac{3}{4}\right)}}\ ,$$

$$N_2 = \frac{2\left(\dfrac{4\left(1+Ca^2\right)}{3}\right)^{\left(\frac{1}{4}\right)}\left(\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}+1\right)}{\left(\sqrt{\dfrac{\left(7+4Ca^2\right)}{3}}-1\right)^2}\ ,$$

$$N_3 = \frac{8\left(7+4Ca^2\right)}{21\left(1+Ca^2\right)\sqrt{\dfrac{7+4Ca^2}{3}}}\ ,$$

$$D_1 = N_2 N_3 (\beta - 1) \left| \frac{\sqrt{\frac{(7+4Ca^2)}{3}} + 1}{\sqrt{\frac{(7+4Ca^2)}{3}} - 1} \right|^{(\beta - 1.5)},$$

$$D_2 = N_2 N_3 (\beta + 1) \left| \frac{\sqrt{\frac{(7+4Ca^2)}{3}} + 1}{\sqrt{\frac{(7+4Ca^2)}{3}} - 1} \right|^{(-\beta - 1.5)}.$$

The expression for the density and pressure gradient can be written as

(2.25) $$\kappa c^2 \frac{d\rho}{dr} = C^2 r \left[-\frac{6(5+Cr^2)}{7(1+Cr^2)^3} \right],$$

(2.26)

$$\kappa \frac{dp}{dr} = C^2 r \left[\left[\frac{\left[y(r) \left[\begin{array}{l} \left[\left\{ \begin{array}{l} N_4 \left(M_5 + \frac{C_2}{C_1} M_6 \right) \\ + M_4 N_5 \end{array} \right\} - \left\{ \begin{array}{l} N_7 \left(M_8 - \frac{C_2}{C_1} M_9 \right) \\ + M_7 N_6 \end{array} \right\} \right] \frac{8(7+4Cr^2)}{21(1+Cr^2)\sqrt{\frac{(7+4Cr^2)}{3}}} + \\ M_{10} \{ N_4 N_5 - N_7 N_6 \} \end{array} \right] - \left[(N_4 N_5 - N_7 N_6)^2 \frac{32}{21(1+Cr^2)} \right] \right]}{(y(r))^2} \right] + \frac{24}{(7+4Cr^2)^2} \right],$$

where

$$N_4 = \left(\frac{4(1+Cr^2)}{3} \right)^{\left(\frac{1}{4}\right)} + \frac{\sqrt{\frac{(7+4Cr^2)}{3}} \left(\sqrt{\frac{(7+4Cr^2)}{3}} + 1 \right)}{2 \left(\frac{4(1+Cr^2)}{3} \right)^{\left(\frac{3}{4}\right)}},$$

$$N_5 = \left[(\beta - 0.5) \left| \frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1} \right|^{(\beta-0.5)} + (\beta + 0.5)\frac{C_2}{C_1} \left| \frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1} \right|^{(-\beta-0.5)} \right],$$

$$N_6 = \left[(\beta - 0.5) \left| \frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1} \right|^{(\beta-1.5)} - (\beta + 0.5)\frac{C_2}{C_1} \left| \frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1} \right|^{(-\beta-1.5)} \right],$$

$$N_7 = \frac{2\left(\frac{4(1+Cr^2)}{3}\right)^{\left(\frac{1}{4}\right)} \left(\sqrt{\frac{(7+4Cr^2)}{3}}+1\right)}{\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2},$$

$$M_4 = \frac{1}{2}\left[\frac{\left(\frac{4(1+Cr^2)}{3}\right)^{\left(\frac{3}{4}\right)} \left[\frac{\frac{4}{3}+\frac{4}{3}\left(\sqrt{\frac{(7+4Cr^2)}{3}}+1\right)}{\left(\frac{(7+4Cr^2)}{3}\right)^{\frac{-1}{2}}} \right] - 2\left[\frac{\left(\frac{4(1+Cr^2)}{3}\right)^{\frac{-1}{4}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}+1\right)}{\sqrt{\frac{(7+4Cr^2)}{3}}} \right]}{\left(\frac{4(1+Cr^2)}{3}\right)^{\left(\frac{3}{2}\right)}} + \frac{2}{3}\left(\frac{4(1+Cr^2)}{3}\right)^{\frac{-3}{4}} \right],$$

$$M_5 = \frac{-8(\beta-0.5)}{3\sqrt{\frac{(7+4Cr^2)}{3}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2} \left| \frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1} \right|^{(\beta-1.5)},$$

$$M_6 = \frac{8(\beta+0.5)}{3\sqrt{\frac{(7+4Cr^2)}{3}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2}\left|\frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1}\right|^{(-\beta-1.5)},$$

$$M_7 = \frac{2\left[\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2\left[\frac{2}{3}\left(\frac{4(1+Cr^2)}{3}\right)^{\frac{-3}{4}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}+1\right)+\frac{4}{3}\left(\frac{4(1+Cr^2)}{3}\right)^{\frac{1}{4}}\left(\frac{(7+4Cr^2)}{3}\right)^{\frac{-1}{2}}\right] - \left[\frac{8}{3}\left(\sqrt{\frac{(7+4Cr^2)}{3}}+1\right)\left(\frac{4(1+Cr^2)}{3}\right)^{\frac{1}{4}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)\left(\frac{(7+4Cr^2)}{3}\right)^{\frac{-1}{2}}\right]\right]}{\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^4},$$

$$M_8 = \frac{-8(\beta-0.5)(\beta-1.5)}{3\sqrt{\frac{(7+4Cr^2)}{3}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2}\left|\frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1}\right|^{(\beta-2.5)},$$

$$M_9 = \frac{8(\beta+0.5)(\beta+1.5)}{3\sqrt{\frac{(7+4Cr^2)}{3}}\left(\sqrt{\frac{(7+4Cr^2)}{3}}-1\right)^2}\left|\frac{\sqrt{\frac{(7+4Cr^2)}{3}}+1}{\sqrt{\frac{(7+4Cr^2)}{3}}-1}\right|^{(-\beta-2.5)},$$

$$M_{10} = \frac{\frac{8}{7}\left[8(1+Cr^2)\sqrt{\frac{(7+4Cr^2)}{3}}-(7+4cr^2)\left\{\frac{4}{3}\frac{(1+Cr^2)}{\sqrt{\frac{(7+4Cr^2)}{3}}}\right\}+2\sqrt{\frac{(7+4Cr^2)}{3}}\right]}{(1+Cr^2)^2(7+4cr^2)},$$

The expression for velocity of sound can be had from the equations (2.25) and (2.26) as

(2.27) $$\frac{dp}{c^2 d\rho} = \frac{dp/dr}{c^2 d\rho/dr}$$

and the expression of mass

(2.28) $$m(r) = \frac{r}{2}\left[1 - \frac{(7 + 4Cr^2)}{7(1 + Cr^2)}\right],$$

such that

$$e^{-\lambda} = 1 - \frac{2m}{r} + \frac{q^2}{r^2}.$$

3. Physical Conditions to be Satisfied

The physical validity of the charged fluid sphere (CFS) depends upon the following conditions (called reality conditions or energy conditions) inside and on the sphere $r = a$ such that

(i) $\rho > 0, \quad 0 \le r \le a,$

(ii) $p > 0, \quad r < a,$

(iii) $p = 0, \quad r = a,$

(iv) $dp/dr < 0, \quad d\rho/dr < 0, \quad 0 < r < a$

(v) $c^2\rho \ge p$ weak energy condition (WEC) or $c^2\rho \ge 3p$ strong energy condition (SEC) $0 \le r \le a$.

(vi) The velocity of sound $(dp/d\rho)^{1/2}$ should be less than that of light throughout the CFS ($0 \le r \le a$).

(vii) $\dfrac{d}{dr}\left(\dfrac{p}{c^2\rho}\right) < 0.$

(viii) $\dfrac{d}{dr}\left(\dfrac{dp}{c^2 d\rho}\right) < 0.$

(ix) The adiabatic constant $\gamma = \left(\left(\frac{c^2\rho + p}{p}\right)\left(\frac{dp}{c^2 d\rho}\right)\right) > 1$.

Beside the above the smooth joining with the Reissner- Nordström metric, requires the continuity of e^{λ}, e^{υ} and q across the pressure free interface $r = a$ and we get

(3.1) $$\frac{7(1+Ca^2)}{(7+4Ca^2)} = 1 - \frac{2m(a)}{a} + \frac{e^2}{a^2},$$

(3.2) $$y^2 = 1 - \frac{2m(a)}{a} + \frac{e^2}{a^2},$$

(3.3) $$p_{(r=a)} = 0.$$

The condition (3.1) is automatically satisfied due to the preposition (2.6) however (3.2) and (3.3) can provide the unique values of arbitrary constants C_1 and C_2.

4. Conclusion

So, we have been successful in obtaining the uncharged analogues of neutral fluid by considering a spherically symmetric metric with t = const as hyperboloid $K = \left(\frac{7}{4}\right)$ which is well behaved for $0 < Ca^2 \leq 0.3259$. Maximum mass and the corresponding radius are found to be 0.343121 M_Θ and 9.576299 Km for $Ca^2 = 0.3259$. The red shift at the centre and on the surface are given as 0.076792 and 0.037879 respectively. The adiabatic constant(γ) always more then 4/3, which is sufficient condition for the stability of the model. Heintzmann and Hillebrandt[13] proposed that neutron star models with anisotropic equation of state are stable if γ > 4/3. In the absence of charge the model reduces to the model obtained by Gupta and Jasim[3].

$$D = \frac{8\pi G}{c^2}a^2\rho,\ P = \frac{8\pi G}{c^4}a^2 p,$$
$$c = 2.997\times10^{10}\,cm/s, G = 6.673\times10^{-8}\,cm^3/gs^2, M_\Theta = 1.475km$$

where γ denotes the adiabatic constant and it is given by the expression $\gamma = \left(\left(\frac{c^2 \rho + p}{p} \right) \left(\frac{dp}{c^2 d\rho} \right) \right)$. z_0 *and* z_a are red shift at the centre and surface $r = a$ respectively. q stands for charge.

Table1: $Ca^2 = 0.007$

$Radius = 1.550058 Km, M = 0.001571 M_{\Theta}, z_0 = 0.001767, z_a = 0.001015$							
X	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.000016	0.009	0.008953	0	0.150447	0.001737	86.74692
0.2	0.000015	0.008998	0.008953	0	0.150442	0.001667	90.37198
0.4	0.000013	0.008993	0.008954	0	0.150424	0.001458	103.3186
0.6	0.00001	0.008985	0.008955	0	0.150396	0.00111	135.6846
0.8	0.000006	0.008973	0.008956	0	0.150355	0.000623	241.4125
1	0	0.008958	0.008958	0	0.150301	0	Inf

Table 2: $Ca^2 = 0.01$

$Radius = 1.850827 Km, M = 0.002671 M_{\Theta}, z_0 = 0.002523, z_a = 0.001446$							
x	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.000032	0.012857	0.012762	0	0.150637	0.002474	61.03306
0.2	0.000031	0.012854	0.012762	0	0.150629	0.002375	63.58682
0.4	0.000027	0.012843	0.012763	0	0.150605	0.002076	72.70729
0.6	0.00002	0.012826	0.012766	0	0.150564	0.001579	95.50795
0.8	0.000011	0.012802	0.012768	0	0.150506	0.000886	169.9882
1	0	0.012772	0.012772	0	0.150429	0	Inf

Table 3: $Ca^2 = 0.1$

$Radius = 5.683255 Km, M = 0.075315 M_{\Theta}, z_0 = 0.024715, z_a = 0.013521$							
x	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.00291	0.128571	0.119842	0	0.155919	0.022633	7.045012
0.2	0.002777	0.128229	0.119898	0	0.155861	0.021657	7.352728
0.4	0.002387	0.127211	0.120049	0	0.155674	0.018768	8.450453
0.6	0.001767	0.125541	0.12024	0	0.155314	0.014076	11.18929
0.8	0.000955	0.123261	0.120395	0	0.154709	0.00775	20.11606
1	0	0.120425	0.120425	0	0.153769	0	Inf

Table 4: $Ca^2 = 0.2$

$Radius = 7.788896 Km, M = 0.189235 M_{\Theta}, z_0 = 0.048364, z_a = 0.025218$							
x	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.010624	0.257143	0.225271	0	0.160953	0.041315	4.056675
0.2	0.010078	0.255777	0.225542	0	0.160883	0.039403	4.243922
0.4	0.008514	0.251745	0.226204	0	0.160614	0.033818	4.909944
0.6	0.006127	0.245242	0.226862	0	0.159975	0.024983	6.563333
0.8	0.003192	0.236586	0.22701	0	0.158709	0.013492	11.92217
1	0	0.22619	0.22619	0	0.156507	0	Inf

Table 5: $Ca^2 = 0.3$

$Radius = 9.257469 Km, M = 0.31142 M_{\Theta}, z_0 = 0.071058, z_a = 0.035438$							
x	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.021969	0.385714	0.319807	0	0.165272	0.056957	3.066963
0.2	0.020715	0.382647	0.320501	0	0.165225	0.054137	3.217194
0.4	0.017196	0.373667	0.32208	0	0.164952	0.046019	3.749394
0.6	0.012042	0.359428	0.323301	0	0.164082	0.033504	5.061399
0.8	0.00606	0.34096	0.322779	0	0.162086	0.017774	9.281191
1	0	0.319527	0.319527	0	0.158377	0	Inf

Table 6: $Ca^2 = 0.3259$

$Radius = 9.257469 Km, M = 0.31142 M_{\Theta}, z_0 = 0.071058, z_a = 0.035438$							
x	(P)	(D)	$(D-3P)$	(q)	$dp/c^2 d\rho$	P/D	γ
0	0.025391	0.419014	0.342841	0	0.16629	0.060597	2.910492
0.2	0.023904	0.415397	0.343683	0	0.166254	0.057546	3.055321
0.4	0.019754	0.404827	0.345567	0	0.16599	0.048795	3.567786
0.6	0.013738	0.388142	0.346927	0	0.165065	0.035395	4.82859
0.8	0.006854	0.366645	0.346082	0	0.162868	0.018695	8.874689
1	0	0.341915	0.341915	0	0.158737	0	Inf

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