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ON THE INTERIOR OF THE NEUTRON STAR —— II. THE ROLE OF DENSITY VARIATION PARAMETER λ AT DENSITIES 10^{15}, 10^{16} g cm^{-3}

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A B S T R A C T

With the assumption, the physical 3-space t=constant in a superdense star is spheroidal and the matter-density on the b0undary surface of the configuration $\rho_a = 2 \times 10^{14}$ g cm^{-3} (~ the average matter density in a neutron star) Vaidya and Tikekar (1982) proposed an exact relativistic model for a neutron star. They suggested that their model can describe the hydrostatic equilibrium conditions in such a superdense star with densities in the range of 10^{14} — 10^{16} g.cm^{-3}. Based on this model Parui and Sarma (1991) estimated the maximum limit of the density variation parameter λ for a stable neutron star (both for charged and uncharged) which is equal to 0.68 ie. $\lambda_{max} = 0.68$

In this paper we have shown variation of central density per unit equilibrium radius (ρ_0 / a) , variation of mass, upper limit of density variation parameter λ both for charged and uncharged neutron stars at densities 10^{15} , 10^{16} g.cm^{-3} , respectively.We have obtained $\lambda_{max} = 0.68$ i.e. the same as before. The important is that the duration of stability among the neutron star's constituents around λ_{max} will be shorter and shorter at higher densities as we proceed near the centre of the neutron star. In case of charged neutron star once stability among the constituents established, then unstability appears gradually maintaining linear relation between change in central density per unit equilibrium radius and change in mass whereas in case of uncharged neutron ster, linear relation does not maintain.

I. INTRODUCTION

Present theoretical works and astrophysical observations help us to know more details of the interior of the neutron star at the density range 10^{14} g cm^{-3} . But we, so far, know very little about the interior at densities 10^{15} ,10^{16} g.cm^{-3} and more. Many models on neutron star have been done. Important one is Vaidya-Tikekar model (1982). In their model they introduce an exact relativistic model of neutron star assuming 3-space t=constant is a spheriodal with K = -2 and density at the boundary $\rho_a = 2 \times 10^{14}$ g.cm^{-3}. Using this model we have calculated variation of central density per equilibrium radius both for uncharged (Parui and Sarma 1991 , hence called Paper I) and charged (Parui 1992 — called Paper II) neutron star and estimated maximim limit of density variation parameter λ which is $\lambda_{max} = 0.68$ for both cases.

In Vaidya-Tikekar model, they suggested that their model can describe the hydrostatic equilibrium conditions in such a superdense star with densities in the range of 10^{14} — 10^{16} g cm^{-3}. The aim of the present uinvestigation is :

i) to verify the limit of $\lambda_{max} = 0.68$ established by Parui and Sarma (Paper I) at densities 10^{15}, 10^{16} g.cm^{-3}, respectively,

ii) also to verify this λ_{max} limit at density 10^{17} g.cm (if we relax our physical conditions)

iii) to find the significant role of λ_{max} limit at greater densities of 10^{14} g.cm^{-3} in the interior of superdense star like neutron star.

2. EQUATIONS AND MATTER DENSITY RELATIONS

For a spherical distribution of matter in the form of a perfectm fluid at rest, Einstein's field equation gives the relation between the matter density and the geometry of the associated physical 3-space governed by the parameter 'R' and 'K'. If the density variation parameter λ denotes the ratio of the matter density at the boundary of a star to the matter density at its centre, it is then possible to estimate the size of the configuration for different values of ' λ ' and ' K ', if the order of magnitude of the density on the boundary is known.

With physical 3-space t=constant is spheroidal Vaidya and Tikekar have discussed the space-time in details and the metric describing such space-time can be written (cf. Vaidya and Tikekar 1982) as

$$ds^2 = e^{\nu} dt^2 - \left[1 - Kr^2/R^2\right]\left[1 - r^2/R^2\right]^{-1} dr^2 - r^2 \left(d\theta^2 + \sin^2\theta \, d\beta^2\right) \qquad (1)$$

where $\nu = \nu(r)$, $x^1 = r$, $x^2 = \theta$, $x^3 = \beta$, $x^4 = t$

' R ' and ' K ' are constants and for $K < 1$, the metric (1) is regular and positive definite at all points $r^2 < R^2$.

UNCHARGED NEUTRON STAR CASE

For K = -2 , the metric describing the solution of the field equations explicitly is

$$ds^2 = \left[B\left(1 - \tfrac{2}{3}z^2\right)^{3/2} + A\left(1 - \tfrac{4}{9}z^2\right)\right]^2 dt^2 - \frac{3 - 2z^2}{z^2} dr^2 - r^2\left(d\theta^2 + \sin^2\theta \, d\beta^2\right) \qquad (2)$$

where $z^2 = 1 - r^2/R^2$, A , B are constants of integration. As we are considering the perfect fluid distribution represented by metric (1) when $K < 1$, $K \neq 0$, the energy momentum tensor

$$T_{ik} = \left(\rho + \frac{p}{c^2}\right) u_i u_k - \frac{p}{c^2} g_{ik} \qquad (3)$$

and Einstein field equation

$$R_{ik} - \tfrac{1}{2} g_{ik} R = -\frac{8\pi G}{c^2} T_{ik} \qquad (4)$$

give the density (ρ) and pressure (p) relation for an equilibrium situation with the metric (1) as

$$\left(\frac{8\pi G}{c^2}\right)\rho = \frac{3(1-k)}{R^2}\,\frac{(1-kr^2/3R^2)}{(1-kr^2/R^2)^2}, \qquad (5)$$

$$\left(\frac{8\pi G}{c^2}\right)\frac{p}{c^2} = \frac{(1-r^2/R^2)}{(1-kr^2/R^2)}\left[\frac{\nu'}{r}+\frac{1}{r}\right]-\frac{1}{r^2}\ ; \qquad (6)$$

together with the consistency condition $\left(T^1_1 = T^2_2\right)$ of the form

$$(1-r^2/R^2)(1-kr^2/R^2)\left(\nu''+\tfrac{1}{2}\nu'-\frac{\nu'}{r}\right)-\frac{2(1-k)r}{R^2}\left(\tfrac{1}{2}\nu'+\frac{1}{r}\right) + \frac{2(1-k)}{R^2}\left(1-\frac{kr^2}{R^2}\right)=0 \qquad (7)$$

where $\nu' = \dfrac{d\nu}{dr}$

If we denote the matter density at r = 0 by ρ_0 expression (5) becomes

$$\left(\frac{8\pi G}{c^2}\right)\rho_0 = \frac{3(1-k)}{R^2} \qquad (8)$$

As $K < 1$, the central density ρ_0 is positive and if $0 < K < 1$, ρ remains positive in the spherical region $r^2 < 3R^2/K$ which imposes a restriction on the size of the configuration that can be waived out by considering $K < 0$.

So, on the boundary r = a the expression (5) gives

$$\left(\frac{8\pi G}{c^2}\right)\rho_a = 3(1-k)\left[1-\frac{ka^2}{3R^2}\right]\Big/ R^2(1-ka^2/R^2)^2, \qquad (9)$$

$$\lambda = \rho_a/\rho_0 = \left(1-\frac{ka^2}{3R^2}\right)\Big/\left(1-\frac{ka^2}{R^2}\right) < 1 \qquad (10)$$

Thus the field in the exterior region $r \geq a$ is described by the Schwarzschild's exterior metric

$$ds^2 = \left(1-\frac{2m}{r}\right)dt^2-\left(1-\frac{2m}{r}\right)^{-1}dr^2-r^2\left(d\theta^2+\sin^2\theta\, d\beta^2\right) \qquad (11)$$

But the metric (1) should be continuous with the metric (11) as we cross the boundary.

Satisfying the boundary condition that the fluid pressure must vanish at $r = a$ and the physical conditions

$$\rho_0 > 0 \ , \quad p_0 > 0 \ , \quad \left(\rho_0 - \frac{3p_0}{c^2} \right) \geq 0$$

we obtain the following relations (cf. Paper I)

$$\frac{a^2}{R^2} = \left(6\lambda - 1 - \sqrt{1 + 24\lambda} \right) / 6k\lambda \tag{12}$$

$$m/a = \frac{3}{2} \left(a^2/R^2 \right) / \left(1 + 2a^2/R^2 \right) \tag{13}$$

$$A = \frac{3}{2} \left(1 - 2a^2/R^2 \right) \left(1 - a^2/R^2 \right)^{-1/2} \left(1 - \frac{2m}{a} \right)^{1/2} \tag{14}$$

$$B = \frac{\sqrt{3}}{2} \left(1 + \frac{4a^2}{R^2} \right) \left(1 + \frac{2a^2}{R^2} \right)^{-1/2} \left(1 - \frac{2m}{a} \right)^{1/2} \tag{15}$$

$$R^2 = 3(1-k) \Big/ \left(\frac{8\pi G}{c^2} \right) \rho_0 \tag{16}$$

CHARGED NEUTRON STAR CASE

For a charged perfect fluid the energy momentum tensor is

$$T^i_k = (p + \rho) v^i v_k - p\,\delta^i_k - F^{i\lambda} F_{k\lambda} + \frac{1}{2} \delta^i_k F_{mn} F^{mn} \tag{17}$$

where 'p' is the pressure ; 'ρ' , matter density ; 'v^i', the unit time-like four velocity field of the fluid ; F_{ik}, the components of the electromagnetic field tensor satisfying Maxwell's equations :

$$F_{ik,j} + F_{kj,i} + F_{ji,k} = 0$$

$$\frac{\partial}{\partial x^j} \left(F^{ij} \sqrt{-g} \right) = 4\pi \sqrt{-g}\, J^i \ , \tag{18}$$

with $J^i = \sigma v^i$

where J^i is the four current vector and σ is the charge density. Since we are considering the static field i.e. $v^i = (0, 0, 0, e^{-\nu/2})$ there is only a radial electric field and a non vanishing component of F_{ik} is F_{14} which can be written as

$$F_{14} = \frac{-e^{\nu/2}}{r^2} \left[\left(1 - kr^2/R^2\right) / \left(1 - r^2/R^2\right) \right]^{1/2} \int_0^r 4\pi\sigma \,. \left[\left(1 - kr^2/R^2\right) / \left(1 - r^2/R^2\right) \right]^{1/2} dr \tag{19}$$

Similarly

$$-F_{41} F^{41} = E^2(r) \tag{20}$$

where $E(r)$ can be interpreted as the field intensity.

From (19) and (20) we can write

$$4\pi\sigma = \frac{1}{r^2} \left[\frac{d}{dr} \left(r^2 E\right) \right] \left(1 - r^2/R^2\right)^{1/2} \left(1 - kr^2/R^2\right)^{-1/2} \tag{21}$$

and the total charge contained within the sphere of radius 'r' is

$$Q(r) = 4\pi \int_0^r \left(1 - \frac{kr^2}{R^2}\right)^{\frac{1}{2}} \left(1 - r^2/R^2\right)^{-1/2} \sigma r^2 dr \tag{22}$$

Thus the Einstein-Maxwell equation gives

$$E^2 - 8\pi p = \left[\frac{1-k}{R^2} - \frac{\nu'}{r} \left(1 - r^2/R^2\right) \right] \left(1 - kr^2/R^2\right)^{-1}, \tag{23}$$

$$E^2 + 8\pi p = \left[\frac{\nu''}{2} + \frac{\nu'^2}{4} + \frac{\nu'}{2r} \right] \left(1 - r^2/R^2\right) \left(1 - kr^2/R^2\right)^{-1} - \frac{(1-k)r}{R^2} \left[\frac{\nu'}{2} + \frac{1}{r} \right] \left(r - kr^2/R^2\right)^{-2}, \tag{24}$$

$$E^2 + 8\pi\rho = \frac{3(1-k)}{R^2} \left(1 - \frac{k}{3} \frac{r^2}{R^2}\right) \left(1 - kr^2/R^2\right)^{-2} \tag{25}$$

From equations (23), (24), and (25) it is seen that we have four variables p , ρ , ν , and E^2.

Choosing the free variable be E^2 as

$$E^2 = \frac{\alpha^2 r^2}{R^4 (1 - kr^2/R^2)^2} \tag{26}$$

where 'α' is a constant,

the matter density, pressure, and charge density are found to be (cf. Paper II, Patel and Pandya (1986))

$$8\pi\rho = \frac{(k^2 - 10k + 6) + (4k - k^2) z^2}{2 R^2 (1 - k + kz^2)^2} , \tag{27}$$

$$8\pi p = \frac{Az\left[k - 3 + \frac{2k(7-k)}{3(k-1)} z^2\right] + B\left(1 - \frac{k}{k-1} z^2\right)^{1/2}\left[k - 1 + \frac{k(7-k)}{k-1} z^2\right]}{R^2(1-k+k^2)\left[Az\left\{1 - \frac{2k}{3(k-1)} z^2\right\} + B\left\{1 - \frac{k}{k-1} z^2\right\}^{3/2}\right]} + \frac{k(k+2)(1-z^2)}{2R^2(1-k+kz^2)^2} , \tag{28}$$

$$4\pi\sigma = \frac{\alpha}{R^2} (1 - z^2)^{1/2} (3 - 5k - 5kz^2)(1 - k + kz^2)^{-5/2} \tag{29}$$

where

$$\alpha = k(k+2)/2$$

and the range for 'K' is $K \leq -2$.

We now consider the case of a spherical charged perfect fluid distribution which extends to a finite radius $a < R$. Then the interior metric (1) should match with the external Reissner-Nordström metric as

$$ds^2 = \left(1 - \frac{2m}{r} + \frac{q^2}{r^2}\right) dt^2 - \left(1 - \frac{2m}{r} + q^2/r^2\right)^{-1} dr^2 - r^2 (d\theta^2 + \sin^2\theta \, d\phi^2) \tag{30}$$

across the boundary $r = a$. Here 'm' and 'q' represent the total mass and total charge of the sphere, respectively.

If we denote $Q(a) = q$ and using (22) we can write

$$q^2 = \frac{\alpha^2 a^6}{R^4 (1 - ka^2/R^2)^2} = \frac{k(k+2)\, a^6}{2R^4 (1 - ka^2/R^2)^2} \qquad (31)$$

satisfying the boundary conditions

$$e^{\nu(a)} = (1 - a^2/R^2)(1 - ka^2/R^2)^{-1} = 1 - \frac{2m}{a} + \frac{q^2}{a^2}$$

fluid pressure must vanish at r=a, and the physical requirements $p_0 > 0$, $\rho_0 > 0$ and $(\rho_0 - 3p_0) \geq 0$, we get the following relations :

$$8\pi \rho_0 = 3(1-k)/R^2 , \qquad (32)$$

$$8\pi p_0 = \frac{A(k^2+2k+9)(1-k)^{1/2} + 3B(5k+1)}{R^2[A(k-3)(1-k)^{1/2} - 3B]} , \qquad (33)$$

$$\frac{a^2}{R^2} = \frac{k - 4 + 12\lambda(1-k) - \sqrt{(k-4)^2 + 24\lambda(1-k)(2-5k)}}{12\lambda k(1-k)} , \qquad (34)$$

$$m/a = \frac{a^2/R^2}{2(1 - ka^2/R^2)} \left[(1-k)(1-ka^2/R^2) + k(k+2)a^2/2R^2\right], \qquad (35)$$

$$B = \frac{2k(7-k)a^2/R^2 - (k^2+2k+9) + \dfrac{k(k+2)a^2/R^2}{2(1-ka^2/R^2)}\left[3-k-2ka^2/R^2\right]}{-6\left[(1-k)(1-ka^2/R^2)\right](1-a^2/R^2)^{-1/2}} , \qquad (36)$$

$$A = \frac{\left(\dfrac{1-a^2/R^2}{1-ka^2/R^2}\right)^{\frac{1}{2}} - B\left[\dfrac{(1-ka^2/R^2)}{1-k}\right]^{3/2}}{\dfrac{(1-a^2/R^2)^{1/2}}{3(1-k)}\left(3-k-2ka^2/R^2\right)} \qquad (37)$$

3. RESULTS AND DISCUSSIONS

We have taken the matter density on the boundary r = a of the charged and uncharged superdense star as $\rho_a = 10^{15}$, 10^{16} g cm^{-3} respectively and choosing values for $\lambda = \rho_a/\rho_0$ and for each choosen values of λ, using the relations mentioned above we calculate 'ρ_0', 'R', 'a', 'm', 'q' with the assumed value of ρ_a. We then estimate the central density per unit radius i.e. radius density, and other relevant parameters as shown in in Table I, and II. From our calculations we see that central pressure is positive at λ_{max}. From the tabulated data (Table I, & II) and also from Fig. 1. it is seen that radius density has a minimum when λ attains the maximum permissible value 0.68 (estimated by Parui and Sarma (1991)) i.e., λ_{max} = 0.68 is same at densities 10^{15}, 10^{16} g cm^{-3} for both the charged and uncharged neutron star with the corresponding mass and charge given below :

Density	K = -2	K = -3	K = -3	
	mass	mass	mass	charge
10^{15} g cm^{-3}	0.70172 $M_\odot$	0.3944 $M_\odot$	0.7297 $M_\odot$	0.5114
10^{16} "	0.2219 $M_\odot$	0.1247 $M_\odot$	0.2306 $M_\odot$	0.1616
10^{17} "		0.0394 $M_\odot$	0.0729 $M_\odot$	0.0511

It is also seen from above that at λ_{max} the mass of the charged neutron star is $\simeq$ 1.85 times the mass of uncharged of that.

In Fig. 2 & 3 we have shown variation of (ρ_0 / a), (m/a) against λ. It is seen that at densities 10^{16} g cm^{-3}, and above the variation in central density (ρ_0 / a) is always more than the variation in mass (m / a). Fig. 4 represents the variation of radius density (ρ_0 / a) against m / $M_\odot$. It shows that the duration of stability around the λ_{max} becomes shorter and shorter as we consider higher densities near the centre. In case of charged neutron star once stability established among the neutron star constituents, unstability appears among them gradually maintaining a linear relation between (ρ_0 /a) and (m / a) where as in case of uncharged neutron star it does not follow.

If, however, we relax the physical requirements $\rho_0 > 0$, $p_0 > 0$, $(\rho_0 - 3p_0) \geqslant 0$, the restriction on 'a/R', we can go for higher densities and here I have considered the higher density as 10^{17} g cm^{-3}. I have seen that in case of uncharged and charged neutron star at this density i.e. 10^{17} g cm^{-3} the value of λ_{max} is same as before i.e. λ_{max} = 0.68. It is also seen from Fig 4. that the duration of stability among the constituents at this density is very short than that of at 10^{15}, 10^{16} g cm^{-3}, and variation in radius density becomes sharper (does not maintain linear relation). This means that as we proceed near the centre for higher densities, the duration of stability around λ_{max} becomes much more short and (ρ_0/a) becomes more sharp.

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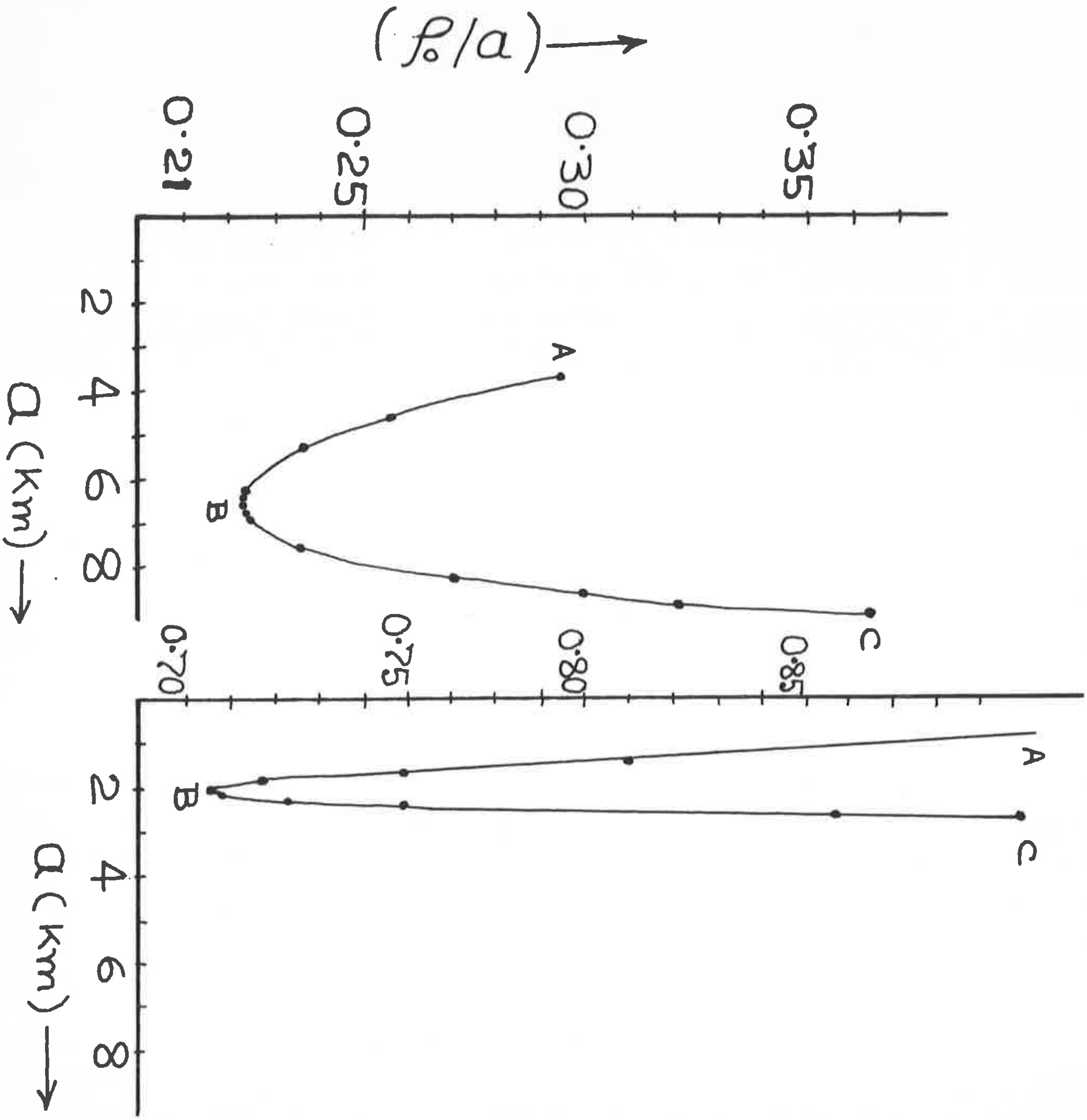
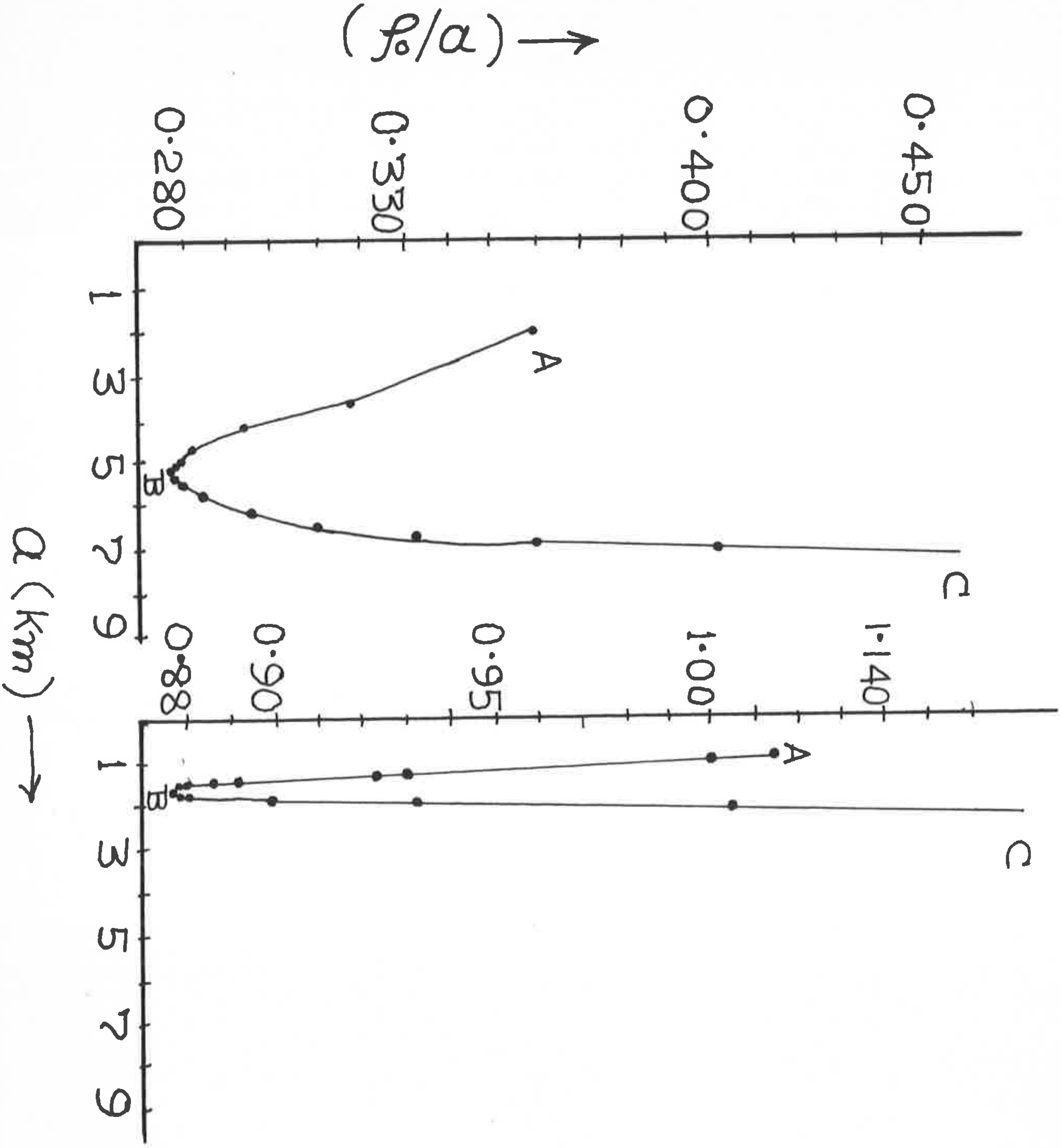


(ρ_0/a) →
0·21
0·25
0·30
0·35
A
B
C
a (km) →
2
4
6
8
0·70
0·75
0·80
0·85
A
B
C
a (km) →
2
4
6
8



(fo/a)
0·280
0·330
0·400
0·450
1
3
5
7
9
A
B
C
a (km)
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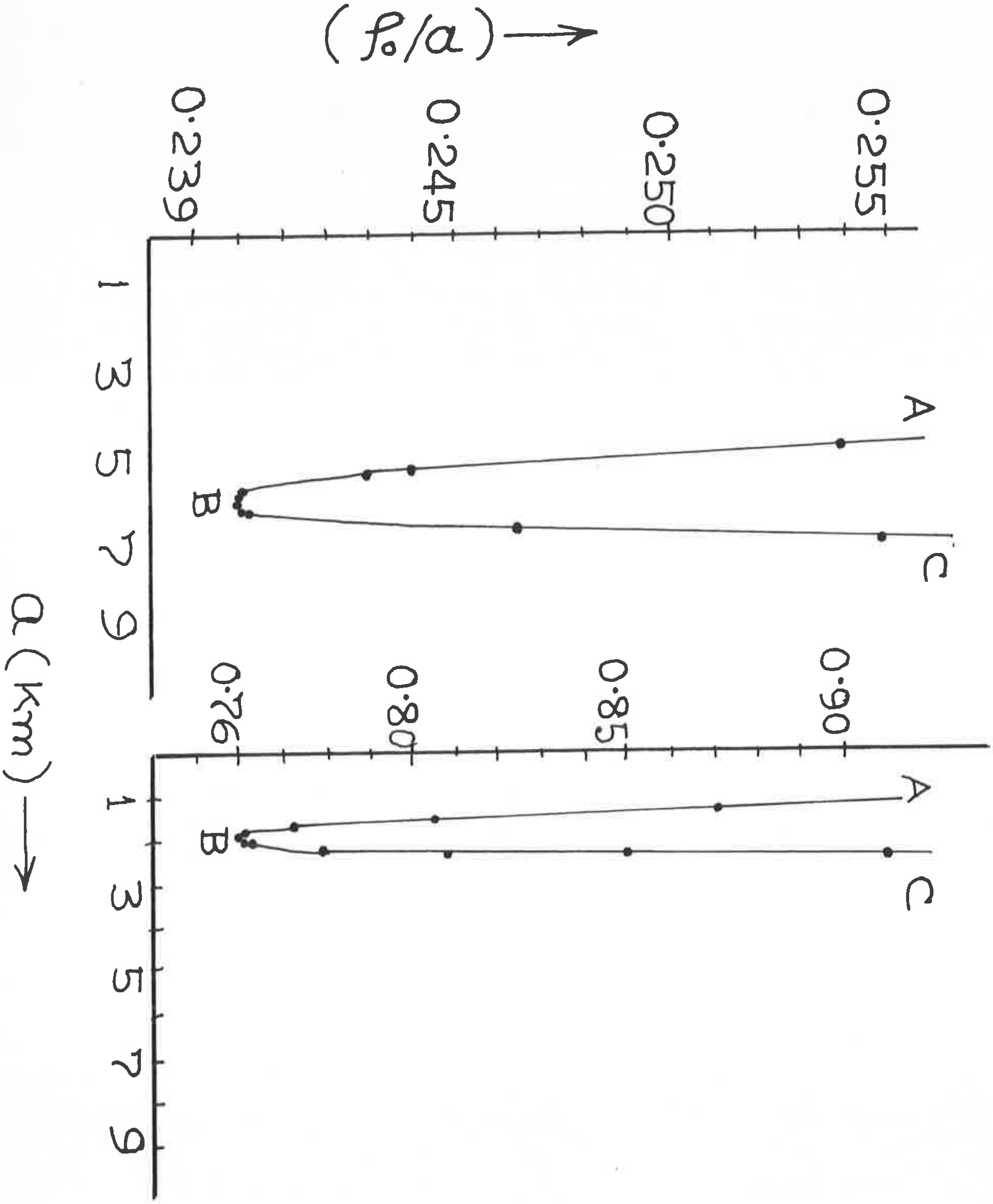
0·90
0·95
1·00
1·140
1
3
5
7
9
A
B
C



(f₀/a) →
0·239
0·245
0·250
0·255
0·76
0·80
0·85
0·90
A
B
C
1
3
5
7
9
a (km) →

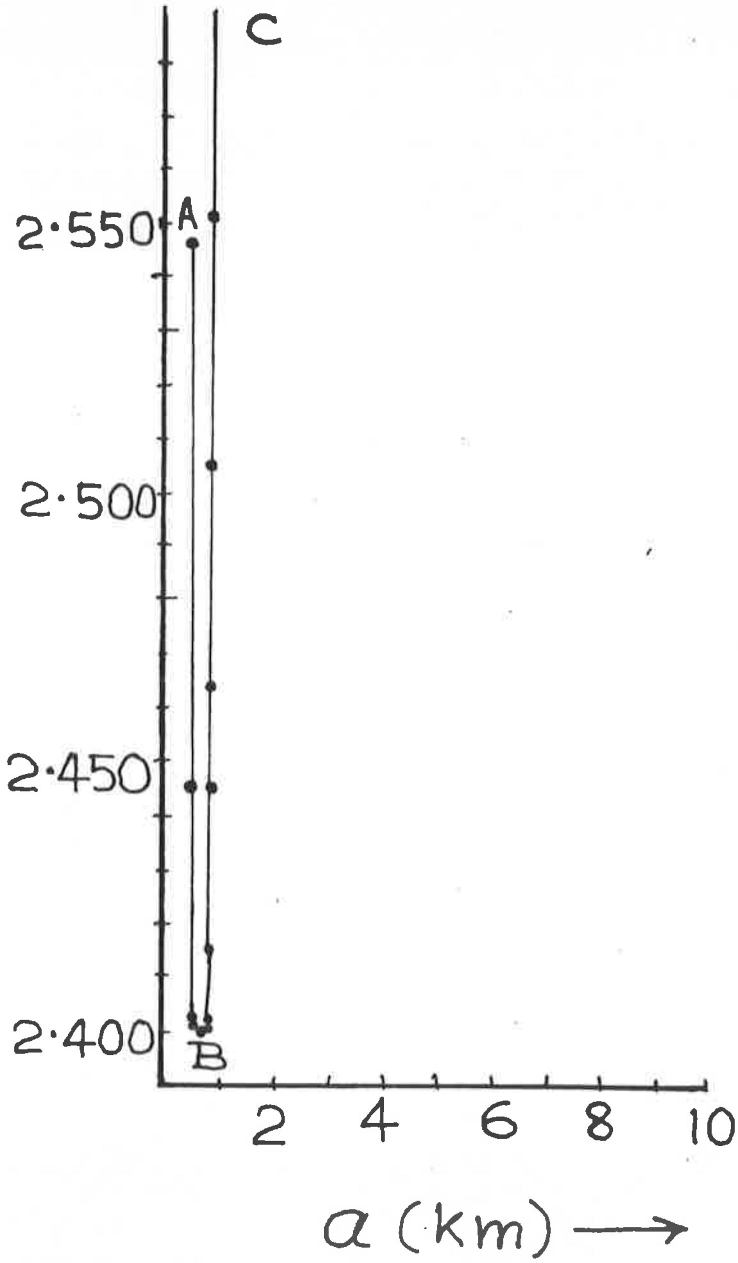
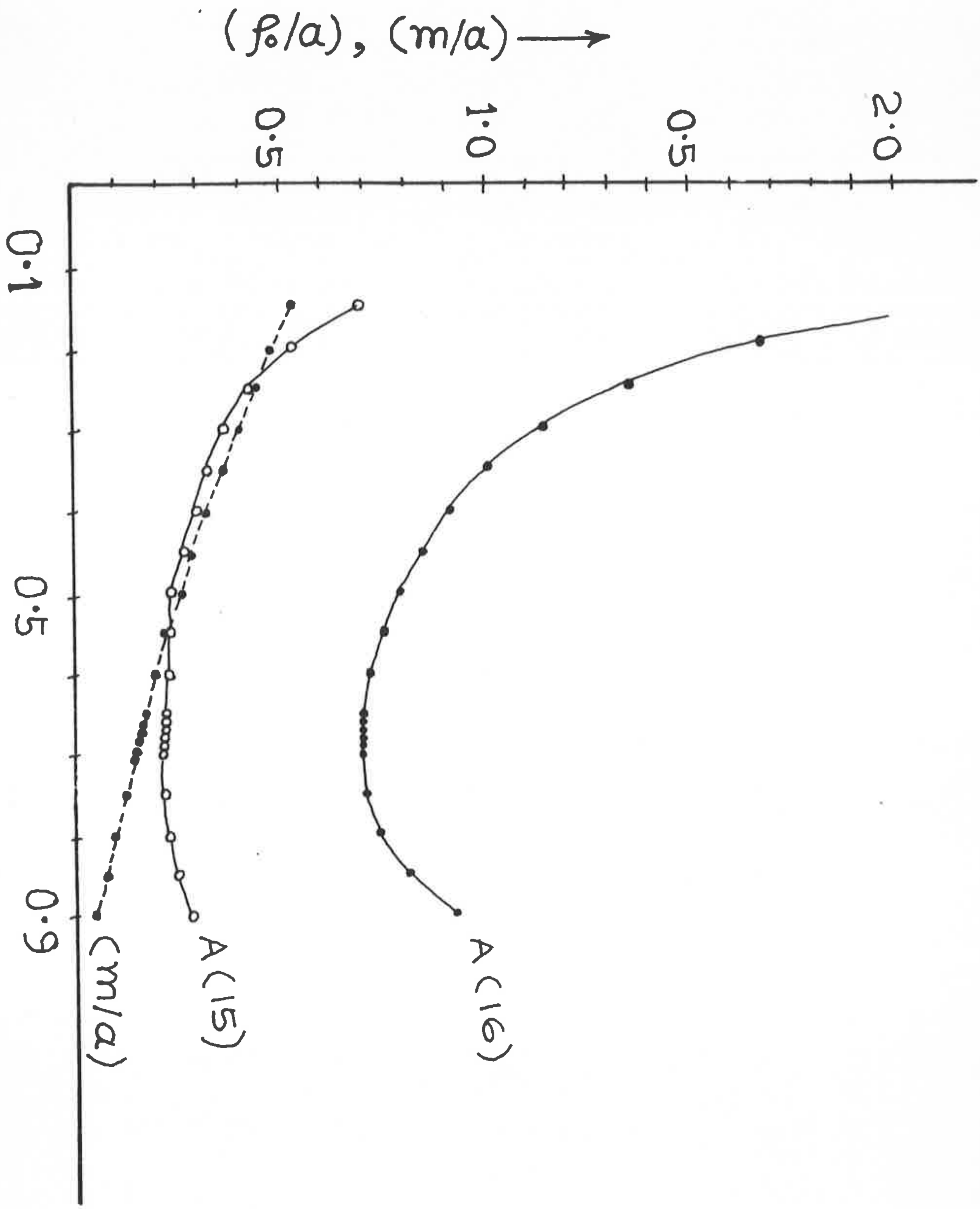


Fig - 19


(f_0/a), (m/a) →
2·0
0·5
1·0
0·5
0·1
0·5
0·9
λ →
A(16)
A(15)
(m/a)

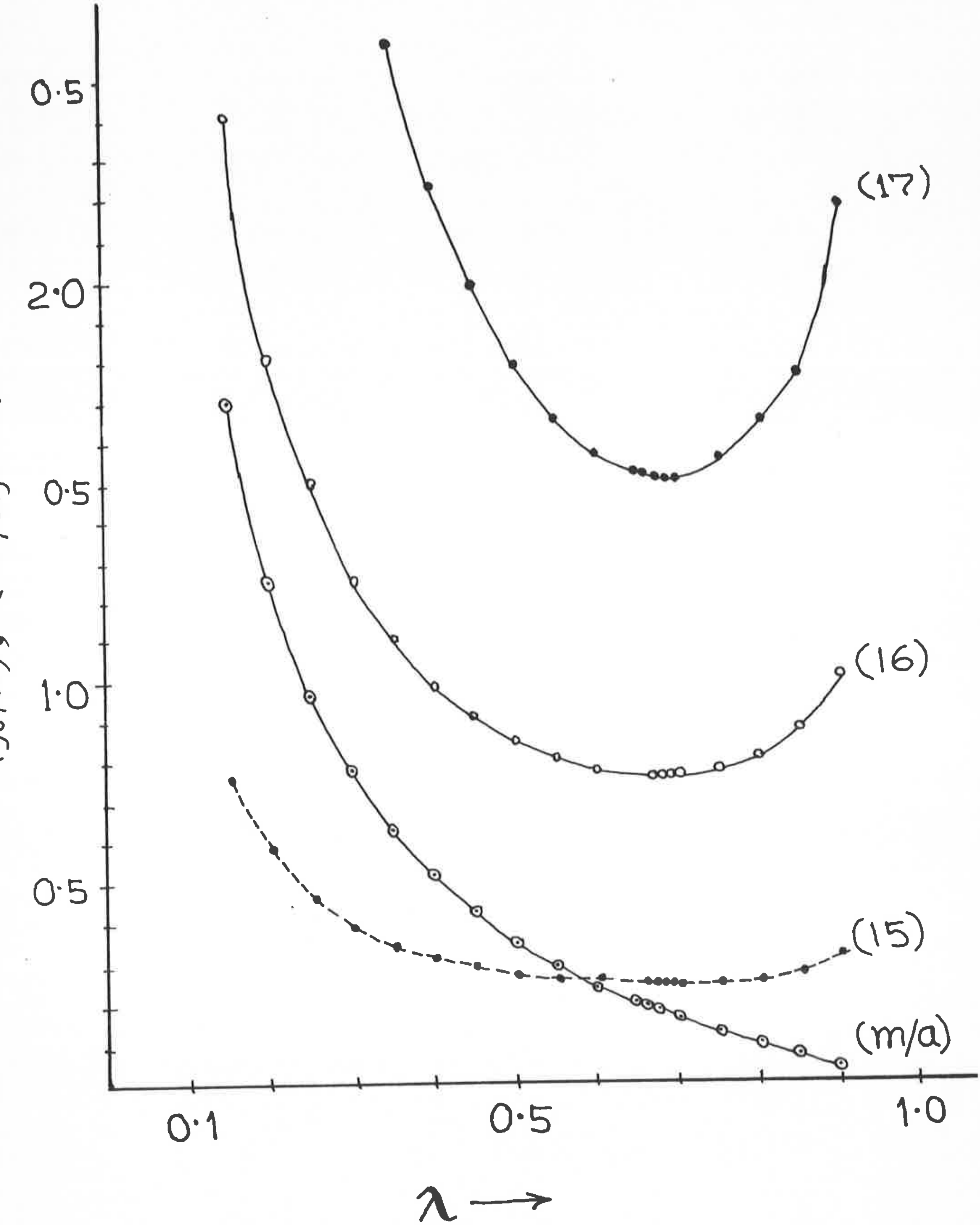


Fig-3

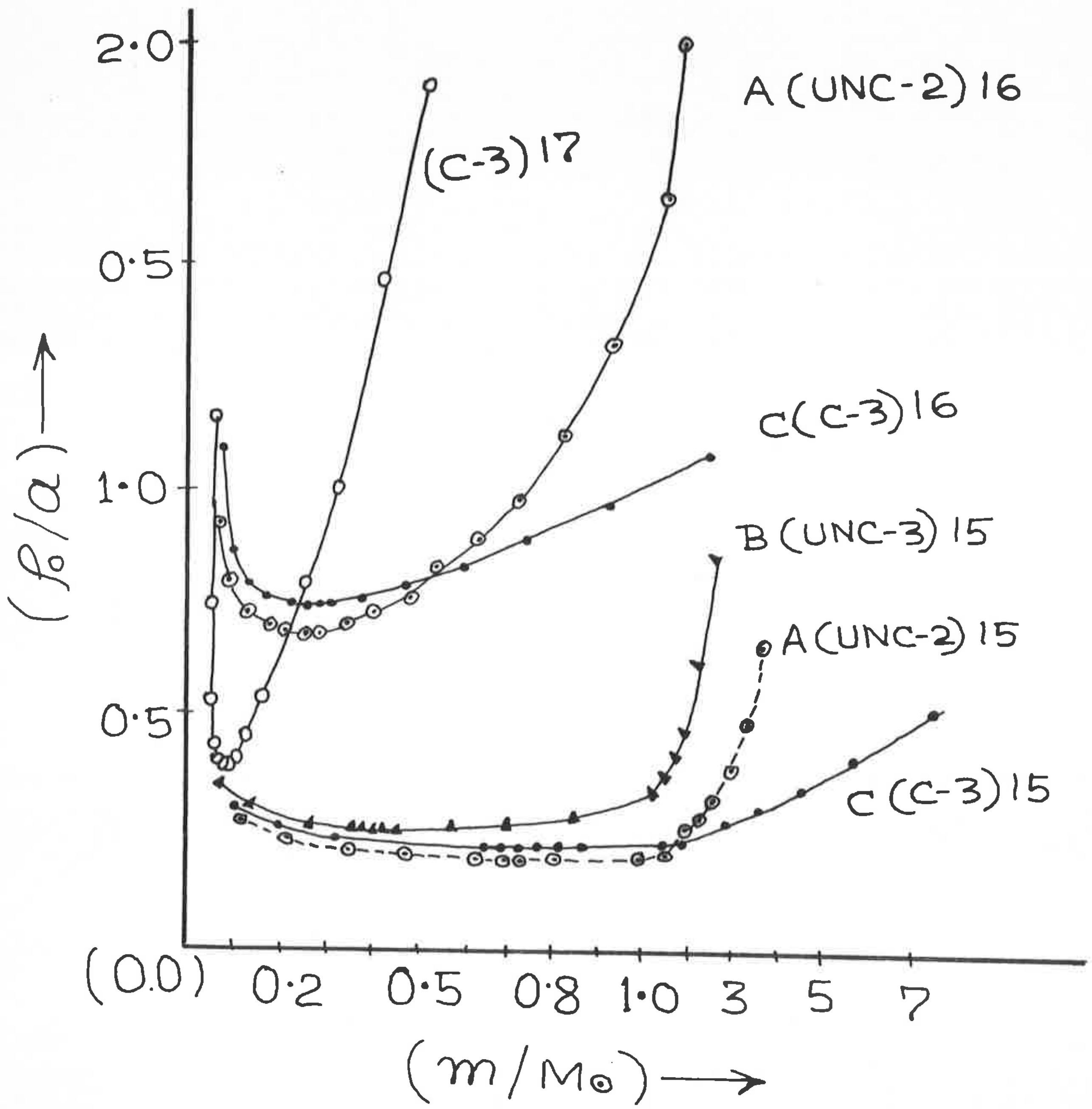

2·0
0·5
1·0
0·5
A (UNC-2) 16
(C-3) 17
C (C-3) 16
B (UNC-3) 15
A (UNC-2) 15
C (C-3) 15
(ρ_0/a)
(0.0)
0·2
0·5
0·8
1·0
3
5
7
$(m/M_\odot)$

Fig- 4

FIGURE CAPTIONS :

Fig. 1 Neutron star radius density (ρ_0 / a) as a function of radius ($r = a$)

1(a) & 1(b) - for $\rho_a = 10^{15} gcm^{-3}$ and $10^{16} g\ cm^{-3}$ respectively with $K = -2$ (uncharged)

1(c) - for $\rho_a = 10^{15} g\ cm^{-3}$ and 1(d) - for $\rho_a = 10^{16}\ g\ cm^{-3}$ with $K = -3$ (uncharged)

1(e) - for $\rho_a = 10^{15}\ g\ cm^{-3}$ and 1(f) - for $\rho_a = 10^{16}\ g\ cm^{-3}$ with $K = -3$ (charged)

1(g) - for $\rho_a = 10^{17}\ g\ cm^{-3}$ with $K = -3$ (charged)

A $\longrightarrow$ B = Pre-stable neutron star state around

B = Stable neutron star with minimum

B $\longrightarrow$ C = Neutron star stages

Fig. 2 Variation of (ρ_0 / a) , (m / a) are plotted against λ for uncharged neutron star with $K = -2$ for $\rho_a = 10^{15}$, $10^{16}\ g\ cm^{-3}$.

A (15) $\longrightarrow$ for $10^{15}\ g\ cm^{-3}$

A (16) $\longrightarrow$ for $10^{16}\ g\ cm^{-3}$

Fig. 3. Variation of (ρ_0 / a) , (m / a) as a function of λ for charged neutron star with $K = -3$ at densities 10^{15}, $10^{16} g\ cm^{-3}$

(15) $\longrightarrow$ for $10^{15}\ g\ cm^{-3}$

(16) $\longrightarrow$ for $10^{16}\ g\ cm^{-3}$

(17) $\longrightarrow$ for $10^{17}\ g\ cm^{-3}$

(19)

Fig. 4 Radius density of charged and uncharged neutron star as a function of mass ($m / M_\odot$)

A(UNC-2) 15 = for uncharged neutron star with $K = -2$, $\rho_a = 10^{15} g\ cm^{-3}$

A(UNC-2) 16 = same for $K = -2$ and $\rho_a = 10^{16} g\ cm^{-3}$

B(UNC-3) 15 = for uncharged neutron star with $K = -3$ and $\rho_a = 10^{15}\ g\ cm^{-3}$

C(c-3) 15 = for charged neutron star with $K = -3$ and $\rho_a = 10^{15}\ g\ cm^{-3}$

C(C-3) 16 = same with $K = -3$ and $\rho_a = 10^{16} g\ cm^{-3}$

C(C-3) 17 = same with $K = -3$ and $\rho_a = 10^{17} g\ cm^{-3}$

TABLE 1. Radius density, masses and equilibrium radii of uncharged neutron corresponding to K= -2, ρ_a = 10^{15}, 10^{16} g cm^{-3}

Sl No	λ	a/R	10^{15} g. cm^{-3} R in km	a in km	ρ_0/a	$m/M_\odot$	10^{16} g cm^{-3} R in km
1.	0.90	0.1810	20.8070	3.7660	0.2950	0.1177	6.5797
2.	0.85	0.2271	20.2212	4.5920	0.2562	0.2183	6.3945
3.	0.80	0.2690	19.6169	5.2769	0.2369	0.3392	6.2034
4.	0.75	0.3089	18.9942	5.8677	0.2272	0.4782	6.0065
5.	0.70	0.3483	18.3499	6.3912	0.2235	0.6345	5.8027
6.	0.69	0.3562	18.2183	6.4893	0.22333	0.6678	5.7611
7.	0.68	0.3641	18.0859	6.5850	0.22332	0.7017	5.7192
8.	0.67	0.3720	17.9524	6.6783	0.22349	0.7361	5.6770
9.	0.66	0.3800	17.8179	6.7708	0.22378	0.7714	5.6346
10.	0.65	0.3880	17.6824	6.8609	0.2242	0.8073	5.5917
11.	0.60	0.4290	16.9887	7.2881	0.2286	0.9970	5.3723
12.	0.55	0.4716	16.2654	7.6717	0.2367	1.2018	5.1436
13.	0.50	0.5173	15.5085	8.0225	0.2370	1.4221	4.9042
14.	0.45	0.5567	14.7126	8.1905	0.2713	1.5933	4.6525
15.	0.40	0.6218	13.8712	8.6251	0.3052	1.9124	4.3864
16.	0.35	0.6841	12.9753	8.8772	0.3218	2.1825	4.1032
17.	0.30	0.7571	12.0128	9.0949	0.3665	2.4698	3.7988
18.	0.25	0.8457	10.9661	9.2743	0.4313	2.7755	3.4678
19.	0.20	0.9592	9.8084	9.4085	0.5314	3.0996	3.1017
20.	0.15	1.1167	8.4944	9.4859	0.7028	3.4429	2.6861

TABLE I. Contd

10^{16} g cm^{-3}		
a in km	ρ_0/a	m/M$_\odot$
1.1909	0.9329	0.0372
1.4521	0.8101	0.0690
1.6687	0.7491	0.1072
1.8554	0.7186	0.1512
2.0210	0.70682	0.2006
2.0521	0.70623	0.2112
2.0823	0.70620	0.2219
2.1118	0.7067	0.2335
2.1411	0.7076	0.2439
2.1695	0.7091	0.2552
2.3047	0.7231	0.3153
2.4257	0.7495	0.3797
2.5369	0.7883	0.4496
2.5900	0.8579	0.5037
2.7274	0.9166	0.6046
2.8070	1.0178	0.6900
2.8760	1.1590	0.7809
2.9328	1.3638	0.8776
2.9752	1.6805	0.9801
2.9996	2.2225	1.0886

TABLE II . Radius density, masses and equilibrium radii of charged neutron star with K= -3 , ρ_a = 10^{15}, 10^{16}, 10^{17} g cm^{-3} respectively

Sl No	λ	a/R	10^{15} g cm^{-3} R in Km	a in Km	ρ_0/a	$m/M_\odot$	10^{16} g cm^{-3} R in Km	a in Km
1.	0.90	0.1459	24.0246	3.5052	0.3169	0.1019	7.5972	1.1084
2.	0.85	0.1829	23.3484	4.2706	0.2754	0.1959	7.3834	1.3504
3.	0.80	0.2166	22.6516	4.9061	0.2548	0.3166	7.1627	1.5514
4.	0.75	0.2486	21.9387	5.4540	0.2444	0.4659	6.9353	1.7241
5.	0.70	0.2802	21.1946	5.9387	0.2405	0.6473	6.7001	1.8777
6.	0.69	0.2865	21.0367	6.0270	0.24046	0.6873	6.6520	1.9058
7.	0.68	0.2929	20.8837	6.1168	0.24040	0.7297	6.6037	1.9342
8.	0.67	0.2992	20.7296	6.2023	0.24064	0.7728	6.5549	1.9612
9.	0.66	0.3056	20.5737	6.2873	0.2409	0.8179	6.5059	1.9802
10.	0.65	0.3120	20.4173	6.3702	0.2415	0.8645	6.4565	2.0144
11.	0.60	0.3447	19.6163	6.7617	0.2464	1.1251	6.2032	2.1382
12.	0.55	0.3788	18.7812	7.1143	0.2555	1.4362	5.9391	2.2497
13.	0.50	0.4152	17.9068	7.4349	0.2690	1.8119	5.6626	2.3511
14.	0.45	0.4545	16.9879	7.7210	0.2878	2.2660	5.3720	2.4416
15.	0.40	0.4981	16.0163	7.9777	0.3133	2.8268	5.0648	2.5228
16.	0.35	0.5474	14.9820	8.2011	0.3483	3.5293	4.7377	2.5934
17.	0.30	0.6049	13.8706	8.3903	0.3972	4.4350	4.3863	2.6532
18.	0.25	0.6745	12.6620	8.5405	0.4683	5.6485	4.0041	2.7007
19.	0.20	0.7632	11.3252	8.6434	0.5784	7.3692	3.5813	2.7333
20.	0.15	0.8856	9.8080	8.6859	0.7675	10.0472	3.1015	2.7467

TABLE II.. Contd.

10^{16} $g\,cm^{-3}$		10^{17} $g.\,cm^{-3}$			
ρ_0/a	$m/M_\odot$	R in km	a in km	ρ_0/a	$m/M_\odot$
1.0024	0.0322	2.4024	0.3505	3.1698	0.0102
0.8711	0.0612	2.3348	0.4270	2.7548	0.0196
0.8057	0.1001	2.2650	0.4906	2.5478	0.0316
0.7733	0.1472	2.1931	0.5452	2.4454	0.0465
0.7608	0.2046	2.1187	0.5937	2.4058	0.0647
0.7604	0.2173	2.1035	0.6026	2.4047	0.0687
0.7603	0.2306	2.0882	0.6116	2.4042	0.0729
0.7610	0.2442	2.0728	0.6202	2.4065	0.0772
0.7620	0.2587	2.0573	0.6287	2.4097	0.0818
0.7637	0.2734	2.0417	0.6370	2.4150	0.0864
0.7794	0.3557	2.9616	0.6761	2.4647	0.1125
0.8081	0.4540	1.8780	0.7114	2.5555	0.1436
0.8506	0.5728	1.7907	0.7435	2.6900	0.1816
0.9101	0.7166	1.6988	0.7721	2.8781	0.2266
0.9909	0.8938	1.6016	0.7977	3.1337	0.2826
1.1016	1.1159	1.4982	0.8201	3.4837	0.3529
1.2563	1.4023	1.3870	0.8390	3.9728	0.4434
1.4810	1.7861	1.2662	0.8540	4.6835	0.5648
1.8293	2.3302	1.1325	0.8643	5.7847	0.7368
2.4271	3.1770	0.9808	0.8686	7.6751	1.0047