五年来征程于大江南北，FPS像“宣传队和播种机”一样点燃脉冲星之“火”。

—— 摘自《FPS5会议文集》

Chandrasekhar的科学人生及其启示

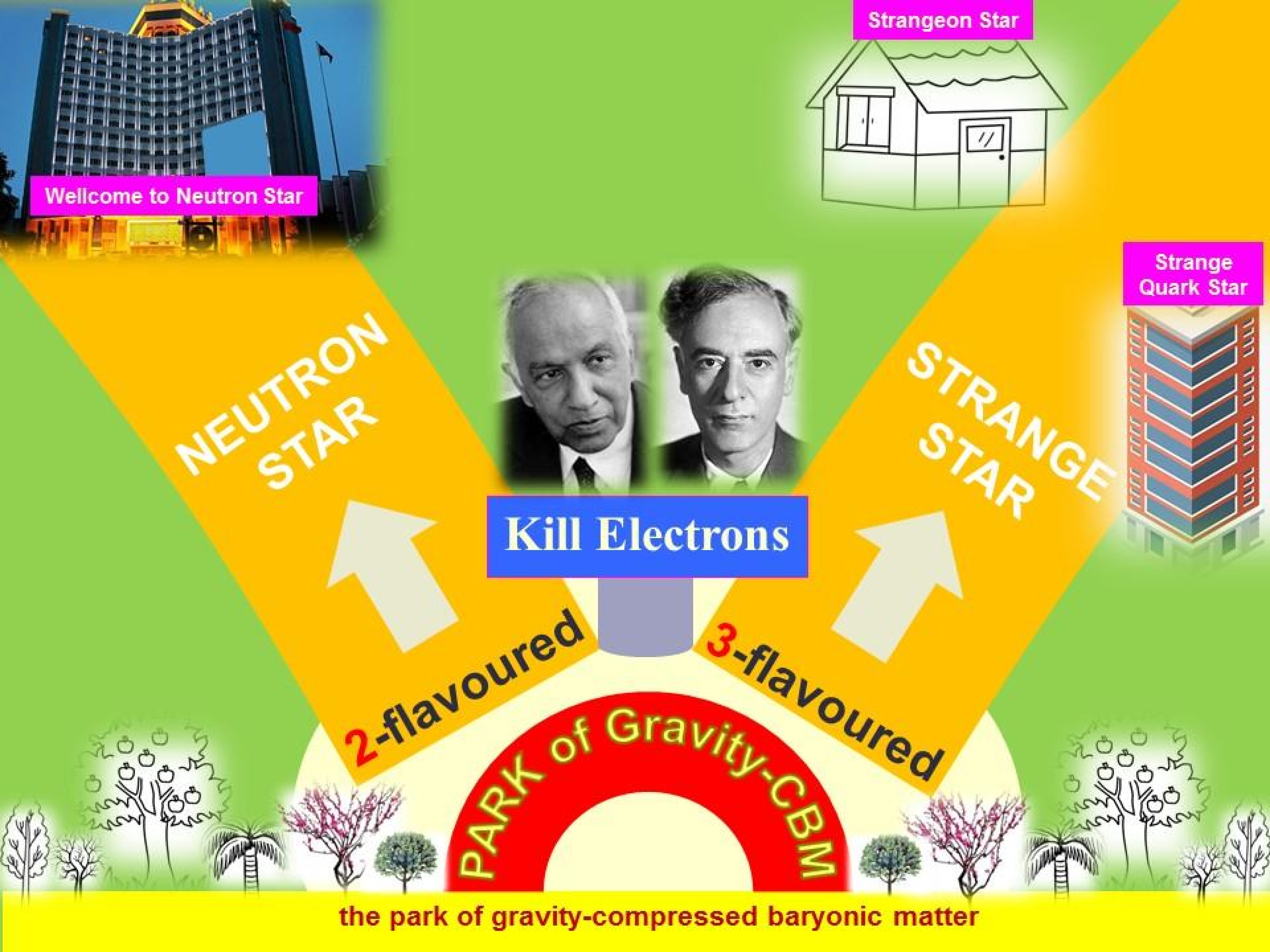
Renxin Xu (徐仁新)[1,2]

[1]School of Physics, [2]KIAA; PKU

(北京大学物理学院)

"FPS11"

Aug. 3-5, 2022; Xiangtan University


Wellcome to Neutron Star
Strangeon Star
Strange Quark Star
NEUTRON STAR
STRANGE STAR
Kill Electrons
2-flavoured
3-flavoured
PARK of Gravity-CBM
the park of gravity-compressed baryonic matter

Chandrasekhar：兴趣广泛而多产

力学、流体力学、MHD；稳定性；黑洞；恒星…

1 √ 1943RvMP...15....1C 1943/01 cited: 4895
Stochastic Problems in Physics and Astronomy
Chandrasekhar, S.

2 1961hhs..book.....C 1961 cited: 4789
Hydrodynamic and hydromagnetic stability
Chandrasekhar, Subrahmanyan

3 1983mtbh.book.....C 1983 cited: 1863
The mathematical theory of black holes
Chandrasekhar, S.

4 1960ratr.book.....C 1960 cited: 1802
Radiative transfer
Chandrasekhar, Subrahmanyan

5 1939isss.book.....C 1939 cited: 1358
An introduction to the study of stellar structure
Chandrasekhar, Subrahmanyan

6 1969efe..book.....C 1969 cited: 1144
Ellipsoidal figures of equilibrium
Chandrasekhar, Subrahmanyan

7 1943ApJ....97..255C 1943/03 cited: 1098
Dynamical Friction. I. General Considerations: the Coefficient of Dynamical Friction.
Chandrasekhar, S.

8 1950ratr.book.....C 1950 cited: 999
Radiative transfer.
Chandrasekhar, Subrahmanyan

9 1942psd..book.....C 1942 cited: 694
Principles of stellar dynamics
Chandrasekhar, Subrahmanyan

10 1964ApJ...140..417C 1964/08 cited: 689
The Dynamical Instability of Gaseous Masses Approaching the Schwarzschild Limit in General Relativity.
Chandrasekhar, S.

11 1953ApJ...118..116C 1953/07 cited: 639
Problems of Gravitational Stability in the Presence of a Magnetic Field.
Chandrasekhar, S.; Fermi, E.

12 √ 1931ApJ....74...81C 1931/07 cited: 620
The Maximum Mass of Ideal White Dwarfs
Chandrasekhar, S.

REVIEWS OF

MODERN PHYSICS

VOLUME 15, NUMBER 1 page: 1 ~ 89 JANUARY, 1943

Stochastic Problems in Physics and Astronomy

S. CHANDRASEKHAR
Yerkes Observatory, The University of Chicago, Williams Bay, Wisconsin

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CHAPTER I. THE PROBLEM OF RANDOM FLIGHTS	3
1. The Simplest One-Dimensional Problem: The Problem of Random Walk	3
2. Random Walk With Reflecting and Absorbing Barriers	5
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THE MAXIMUM MASS OF IDEAL WHITE DWARFS

By S. CHANDRASEKHAR

ABSTRACT

The theory of the *polytropic gas spheres* in conjunction with the equation of state of a *relativistically degenerate electron-gas* leads to a *unique value for the mass of a star* built on this model. This mass ($=0.91\odot$) is interpreted as representing the upper limit to the mass of an ideal white dwarf.

In a paper appearing in the *Philosophical Magazine*,[1] the author has considered the density of white dwarfs from the point of view of the theory of the polytropic gas spheres, in conjunction with the degenerate non-relativistic form of the Fermi-Dirac statistics. The expression obtained for the density was

$$\rho = 2.162 \times 10^6 \times \left(\frac{M}{\odot}\right)^2 , \tag{1}$$

where $M/\odot$ equals the mass of the star in units of the sun. This formula was found to give a much better agreement with facts than the theory of E. C. Stoner,[2] based also on Fermi-Dirac statistics but on uniform distribution of density in the star which is not quite justifiable.

In this note it is proposed to inquire as to what we are able to get when we use the relativistic form of the Fermi-Dirac statistics for the degenerate case (an approximation applicable if the number of electrons per cubic centimeter is $> 6 \times 10^{29}$). The pressure of such a gas is given by (which can be shown to be rigorously true)

$$P = \frac{1}{8}\left(\frac{3}{\pi}\right)^{\frac{1}{3}} \cdot hc \cdot n^{4/3} , \tag{2}$$

where h equals Planck's constant, c equals velocity of light; and as

$$n = \frac{\rho}{\mu H(1+f)} , \tag{3}$$

[1] 11, No. 70, 592, 1931.

[2] *Philosophical Magazine*, 7, 63, 1929.

μ equals the molecular weight, 2.5, for a fully ionized material, H equals the mass of hydrogen atom, and f equals the ratio of number of ions to number of electrons, a factor usually negligible. Or, putting in the numerical values,

$$P = K\rho^{4/3} , \tag{4}$$

where K equals 3.619×10^{14}. We can now immediately apply the theory of polytropic gas spheres for the equation of state given by (4), where for the exponent γ we have

$$\gamma = \frac{4}{3} \text{ or } 1 + \frac{1}{n} = \frac{4}{3} \text{ or } n = 3 .$$

We have therefore the relation[1]

$$\left(\frac{GM}{M'}\right)^2 = \frac{(4K)^3}{4\pi G} ,$$

or

$$M = 1.822 \times 10^{33} ,$$
$$= .91\odot \text{ (nearly)} . \tag{5}$$

As we have derived this mass for the star under ideal conditions of extreme degeneracy, we can regard 1.822×10^{33} as the maximum mass of an ideal white dwarf. This can be compared with the earlier estimate of Stoner[2]

$$M_{\text{max}} = 2.2 \times 10^{33} , \tag{6}$$

based again on uniform density distribution. The "agreement" between the accurate working out, based on the theory of the polytropes, and the cruder form of the theory is rather surprising in view of the fact that in the corresponding non-relativistic case the deviations were rather serious.

Trinity College
Cambridge
November 12, 1930

[1] A. S. Eddington, *Internal Constitution of Stars*, p. 83, eq. (57.3.)

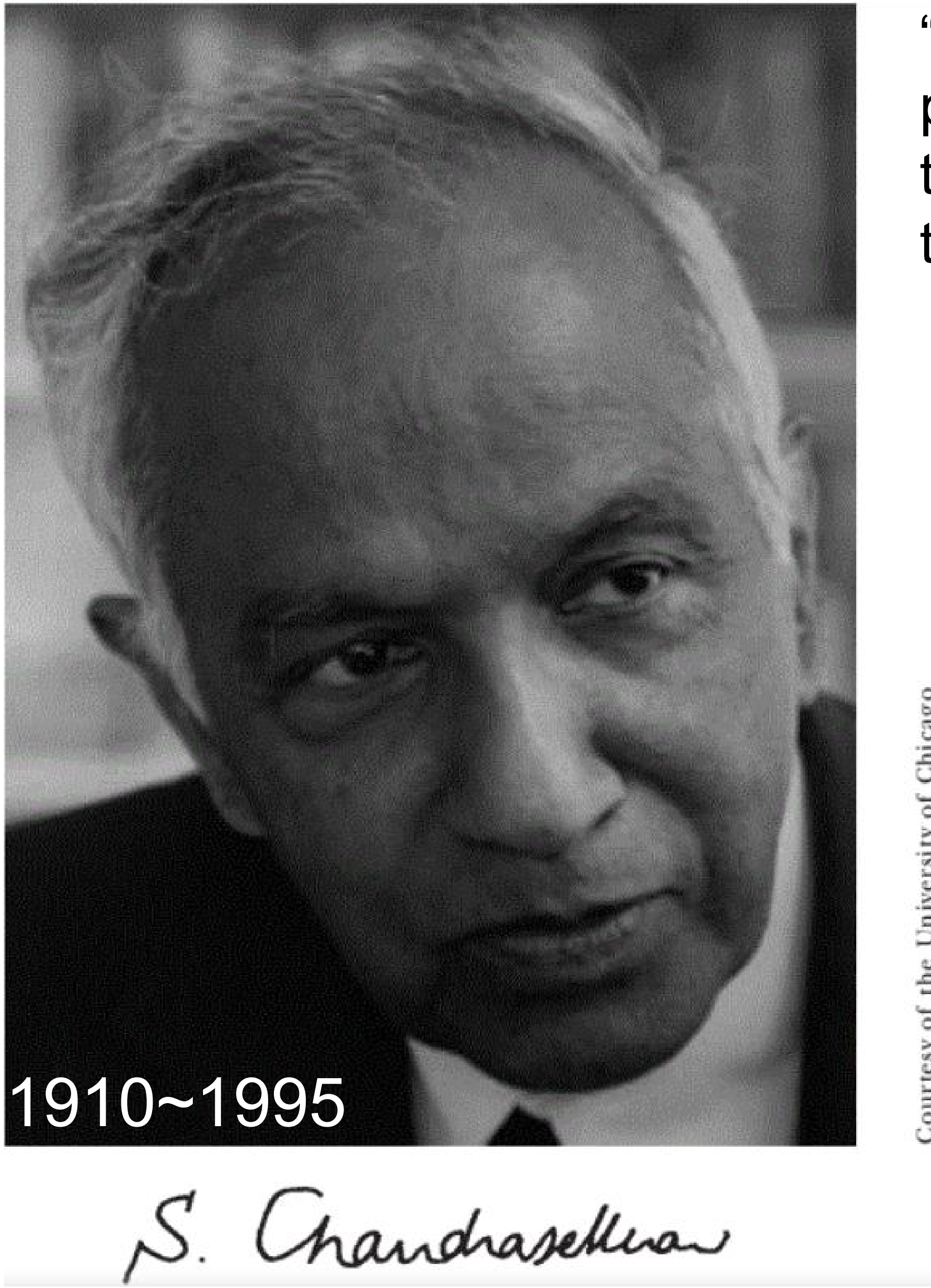
[2] *Philosophical Magazine*, 9, 944, 1930.

Chandrasekhar：狭义相对论天体物理

- 生于印度Lahore, 1910年
- 1925: Presidency College
- 1928: Sommerfeld访问/交谈
- 1929: 毕业/发表处女作“The Compton scattering and the new statistics”

剑桥大学R. Fowler的研究生

- 1931: 推广导师工作 $\Rightarrow M_{\max}$!



"for his theoretical studies of the physical processes of importance to the structure and evolution of the stars"

Nobel Prize in Physics (1983)

对于冷物质，状态方程反映压强P和密度ρ之间的关系：

$$\mathrm{d}U = -P\,\mathrm{d}V$$

$$U = N_e\,\bar{\varepsilon}$$

n_e → p

$$\varepsilon = p^2/(2m_e)\text{: Fowler}$$

$$\varepsilon = (c^2p^2+m_e^2c^4)^{1/2}!$$

(Special Relativity)

Chandrasekhar：沐浴于时代气息中

从小即受"原子"论与量子论发展初期的熏陶

- 1897年：J. J. Thomson测量电子荷质比e/m
- 1909年：Geiger和Marsden用α粒子轰击金箔
- 1911年：Rutherford提出原子"有核模型"
- 1913年：Bohr提出原子模型
- Planck 1900, Einstein 1905, Compton 1923
- 1924年： de Broglie提出"物质波"概念
- 1925年： Pauli提出"不相容"原理
- 1925年： Heisenberg创立"矩阵力学"
- 1926年： Schroedinger给出"波动力学"

- 1910年生, 1915年大学且与Sommerfeld、Heisenburg等交谈
- 1929年：发表**本研**论文
- 1931年（叔得诺奖次年）：发表导致诺奖论文

Chandrasekhar一生的启示

- 保持对自然好奇的童心，努力追求真理
- 关注前沿动态，把握时代气息
- 从历史定位角度正确认识学术论文的发表

与君共勉

谢谢!