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BLTP Bogoliubov Laboratory of Theoretical Physics

ICIMAF

Neutron Star Mass and Radius Relation

Student: Lismary de la Cardiad Suárez González[1]

Supervisor: David Alvarez Castillo[2]

[1]Instituto de Cibernética, Matemática y Física (ICIMAF), Habana,Cuba

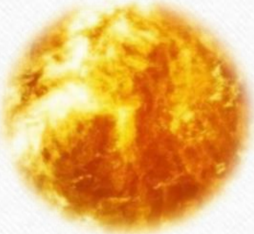
[2]JINR

Stellar remnants

$1M_{\odot} \lesssim M \lesssim 4M_{\odot}$

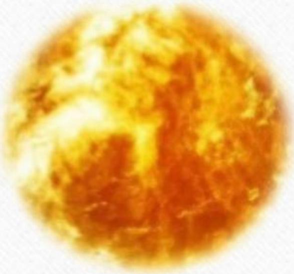
White dwarfs

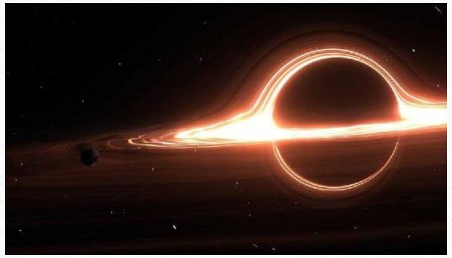
$10M_{\odot} \lesssim M \lesssim 25M_{\odot}$



Neutron stars

$M \gtrsim 25M_{\odot}$





Black holes

Compact Objects

S. L. Shapiro and S. A. Teukolsky, Black holes, white dwarfs, and neutron stars: The physics of compact objects. New York, NY: Wiley, 1983

Neutron Stars (NS)

$$M \sim 1.5 M_{\odot}$$
$$R \sim 10 Km$$
$$\rho \sim (10^7 - 10^{15})\ g/cm^3$$
$$T \sim (10^5 - 10^{11}) K$$
$$B \sim 10^{9-15} G$$

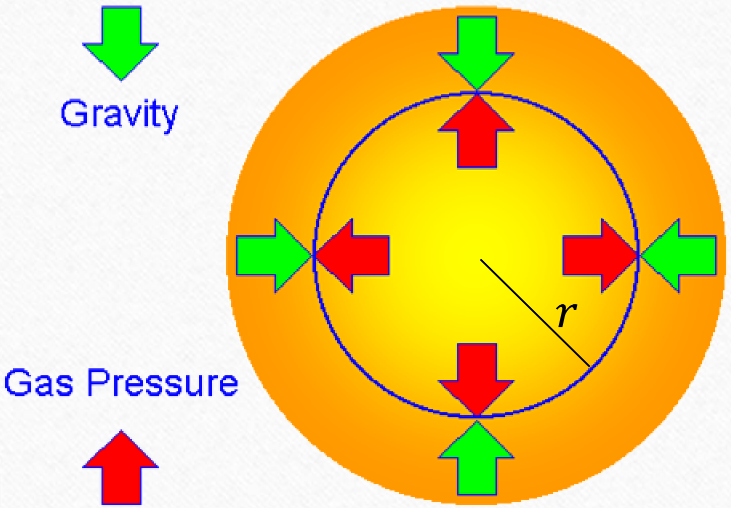
The effect of general relativity are important in NS

$$\frac{GM}{c^2 R} \sim 0.2$$

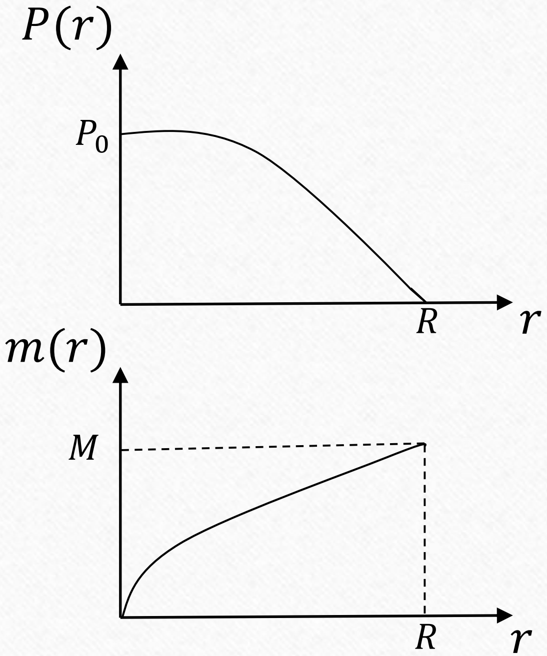
S. L. Shapiro and S. A. Teukolsky, Black holes, white dwarfs, and neutron stars: The physics of compact objects. New York, NY: Wiley, 1983

M. Camenzind, Compact Objects in Astrophysics: White Dwarfs, Neutron Stars and Black Holes.Astronomy and Astrophysics Library, Springer Berlin Heidelberg, 2007.

Hydrostatic equilibrium. Tolman–Oppenheimer–Volkoff equation (TOV)



In general, the stars maintain their shape thanks to the balance between the force of gravity, which pushes matter towards the center, and the pressure that pushes matter outward.



$$\frac{dP}{dr} = -\frac{GE(r)m(r)}{r^2}\underbrace{\left(1+\frac{P(r)}{E(r)}\right)\left(1+\frac{4\pi r^3 P(r)}{m(r)}\right)}_{\text{Special relativity corrections}}\underbrace{\left(1-\frac{2Gm(r)}{r}\right)^{-1}}_{\text{General relativity corrections}}$$

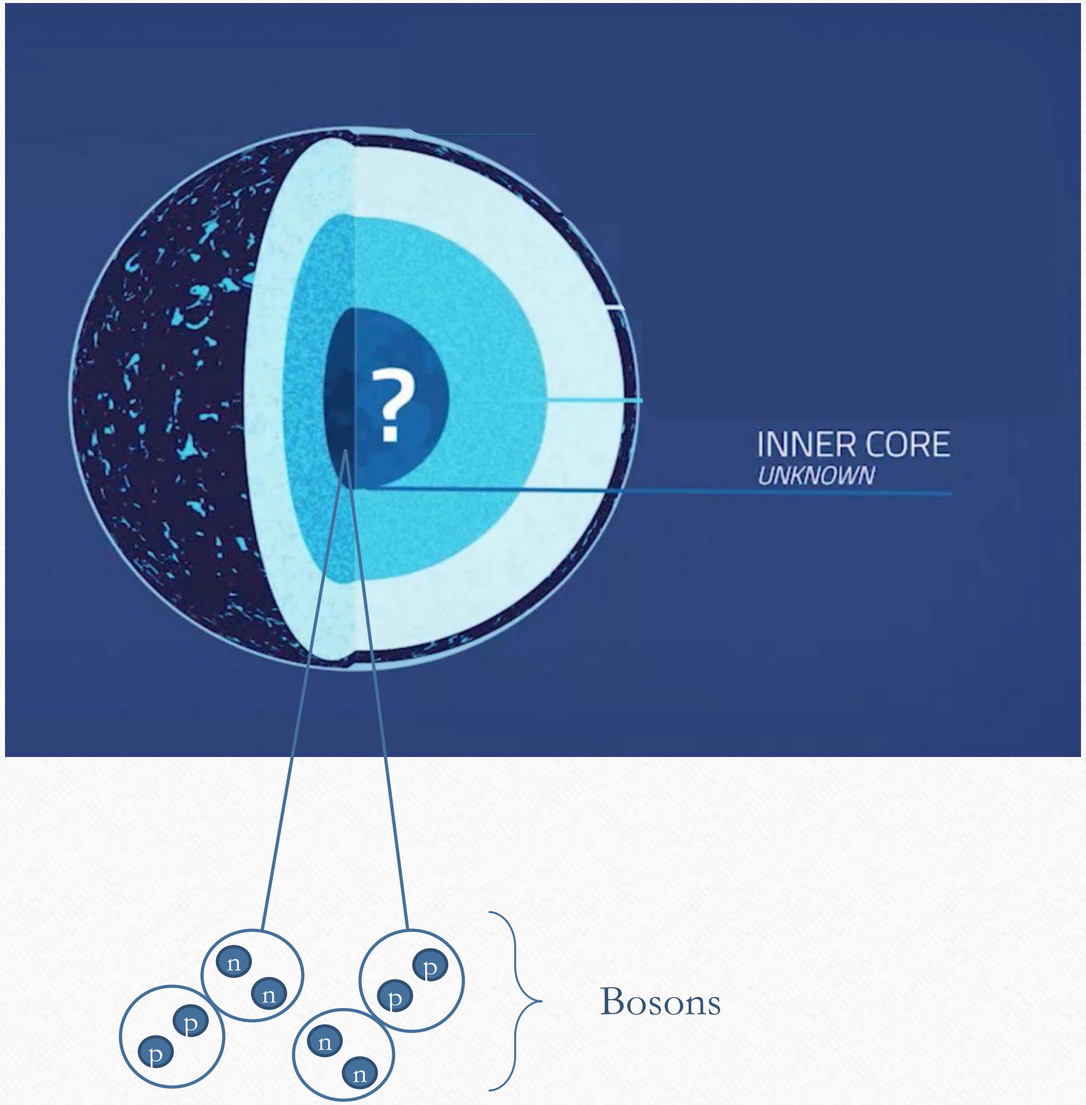
$$\frac{dm}{dr} = 4\pi r^2 E(r)$$

Equation of state (EoS)

$$E = E(P(r))$$

Richard R. Silbar and Sanjay Reddy, Neutron stars for undergraduates, Am. J. Phys.,Vol. 72,No. 7, July 2004.

Internal structure of NS and Boson Stars (BS).

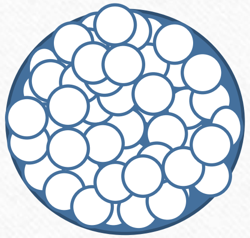


A lot of exotic particles and phases have been conjecture to exist in NS interiors

In particular, it has been proposed that, at some stage of the NS evolution, it might contain bosons formed up by the pairing of neutrons and protons in the crust and core.

Limit case of a star completely full of bosons

Boson Stars



[1]Page D, Prakash M, Lattimer J M and Steiner A W 2011PoSXXXIVBWNP005 (Preprint1110.5116)

[2] Shternin P S, Yakovlev D G, Heinke C O, Ho W C G and Patnaude DJ 2011mnras412L108–L112 (Preprint1012.0045)

[3] Chavanis P H and Harko T 2012Phys. Rev.D86064011 (Preprint1108.3986)

[4] S. Latifah, A. Sulaksono and T. Mart, Phys. Rev. D,90(12) (2014) 127501

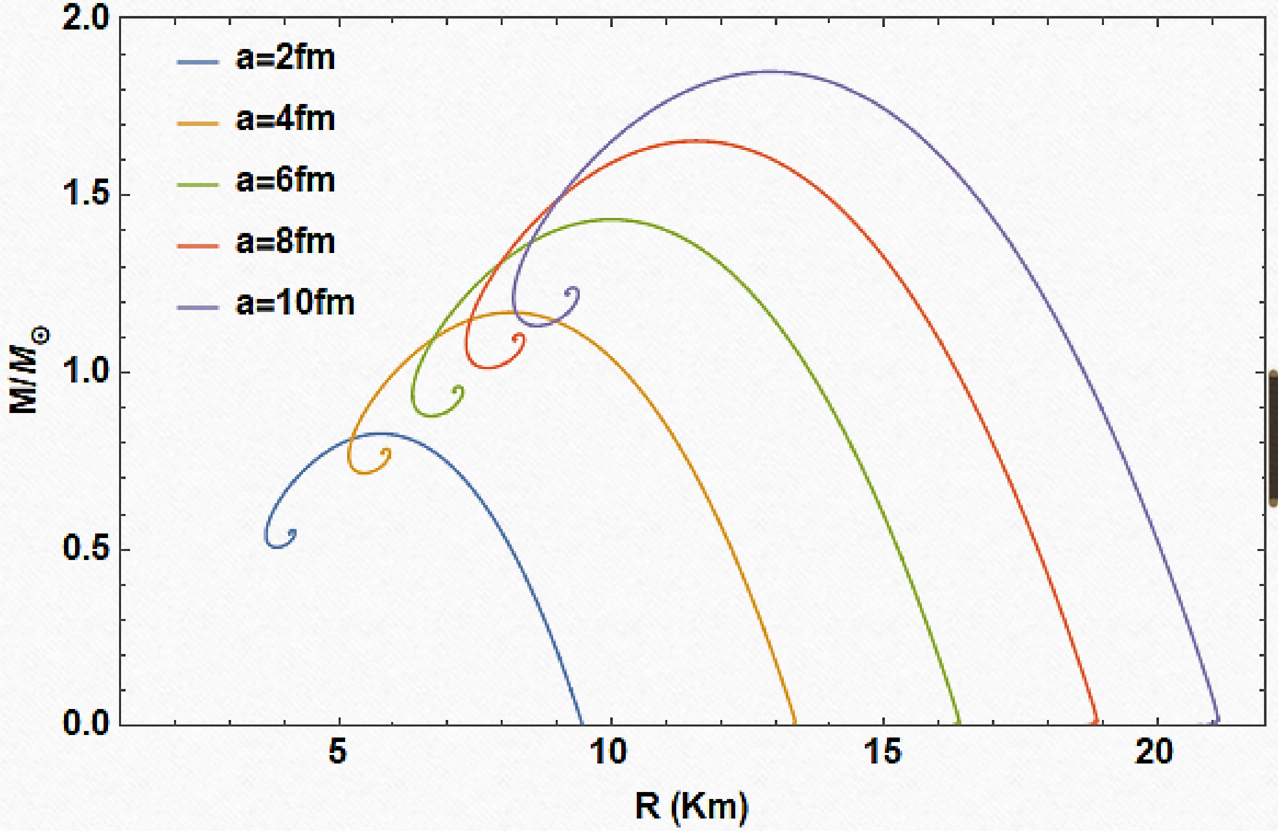
Mass-Radius Relation for BS

Equation of state (EoS)

$$T = 0$$

$$P = \frac{2\pi a}{m}\rho^2 \qquad E = \frac{2\pi a}{m}\rho^2 + m\rho$$

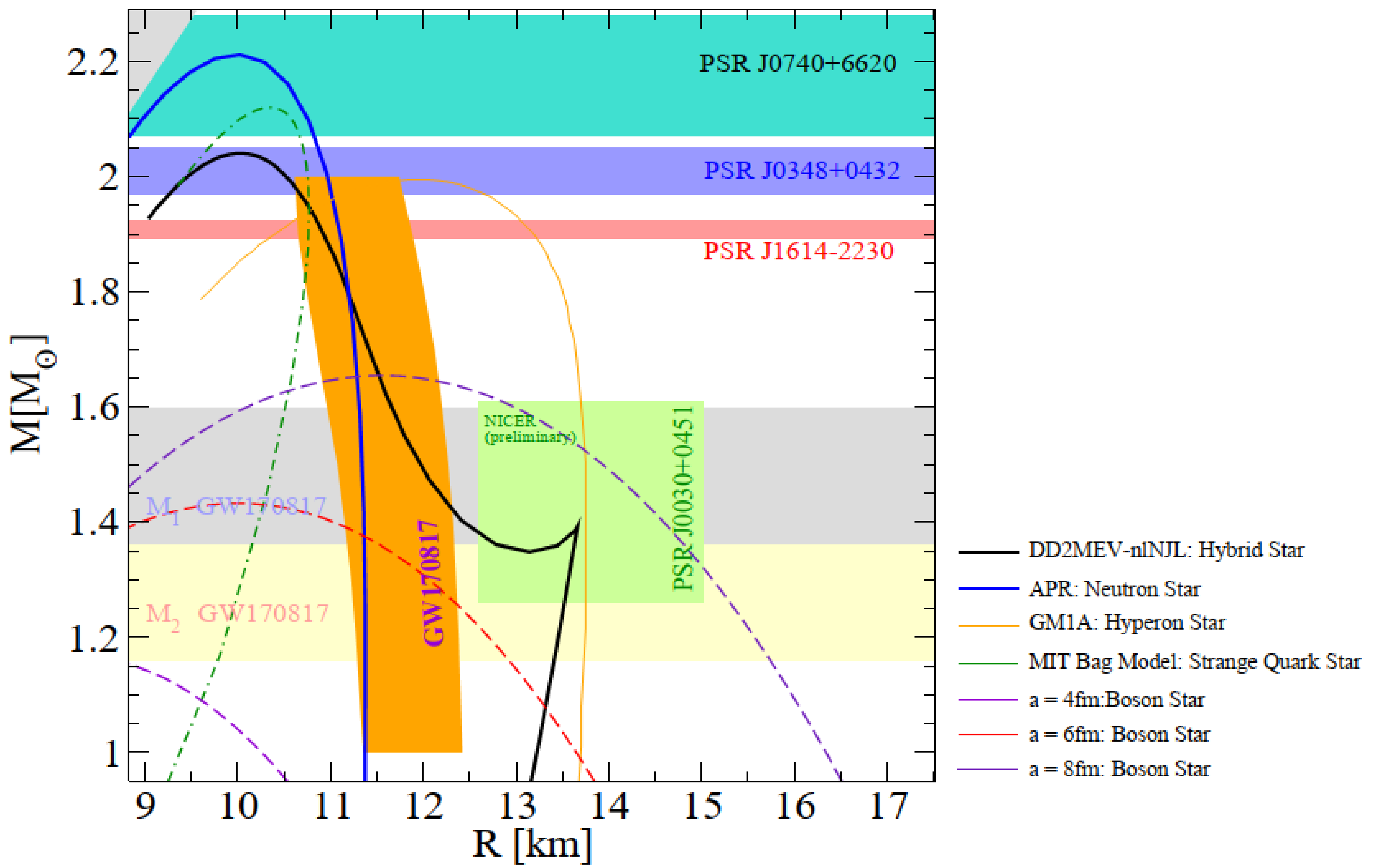
$$m = 2m_n$$



a (fm)	R (Km)	$M_{max}/M_\odot$	R_{max} (Km)
2	5.76	0.83	9.46
4	8.17	1.17	13.37
6	10.02	1.43	16.36
8	11.59	1.65	18.88
10	12.87	1.85	21.10

S. Latifah, A. Sulaksono and T. Mart, Phys. Rev. D,90(12) (2014) 127501

Mass-Radius Relation for Compact Stars



Next Step → Gravitational Waves (GW)

To study other possible scenarios for the event GW170817

$$Boson\ Star \leftrightarrow Neutron\ Star$$
$$Boson\ Star \leftrightarrow Hyperon\ Star$$
$$Boson\ Star \leftrightarrow Quark\ Star$$
$$Boson\ Star \leftrightarrow Hybrid\ Star$$
$$Boson\ Star \leftrightarrow Boson\ Star$$

$$M_2 \sim (1.16 - 1.36)$$
$$M_1 \sim (1.36 - 1.60)$$

Conclusions

- ❖ We solved the Tolman–Oppenheimer–Volkoff equation for different compact objects and we obtained the mass-radius relation.
- ❖ We got that increasing the strength of the interaction we can obtain BS of greater mass and radius compatible with the results of the event GW170817.
- ❖ This massive BS will allow for scenarios in which GW170817 event features a BS as a least one of the component.


THANK
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BOLZÏN
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