

Superdense Matter in the Universe

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What are we talking about ?

A regime far from terrestrial laboratory data, roughly everything above up to the highest density present anywhere in the Universe...

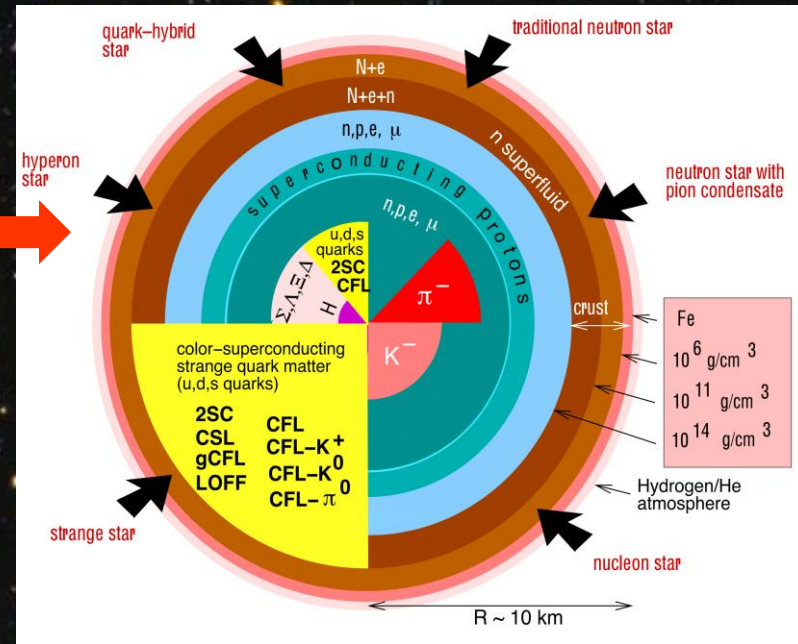
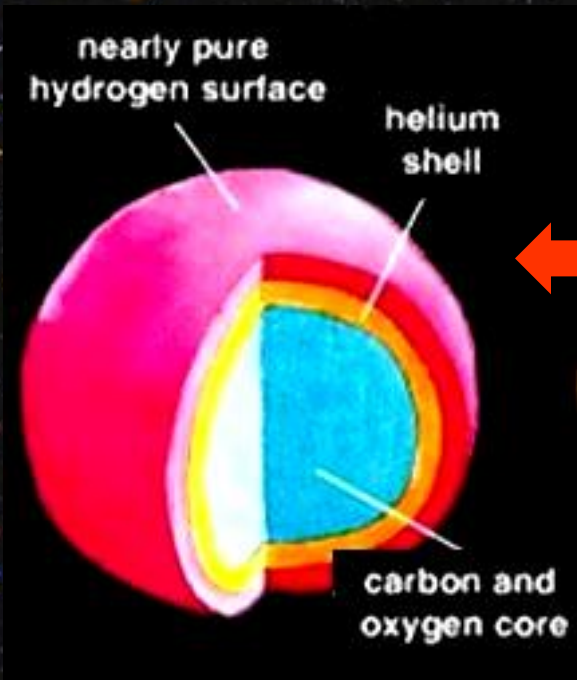
$$\rho \sim 10^6 \text{ g cm}^{-3}$$

The ultimate value may be around

$$\rho \sim 10^{15} \text{ g cm}^{-3}$$

before matter disappears beyond an event horizon...

(Astro)physical realizations : white dwarfs and “neutron” stars



Millennium problems (one of many)

What is the nature of neutron stars and dense nuclear matter? What is the origin of the elements in the cosmos? What are the nuclear reactions that drive stars and stellar explosions?

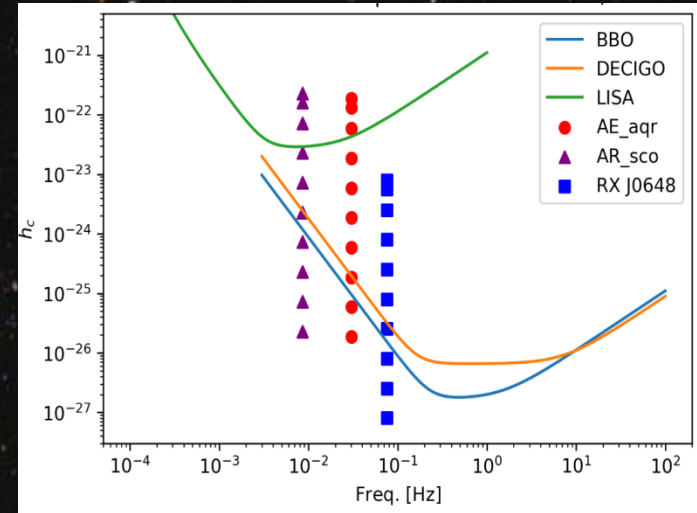
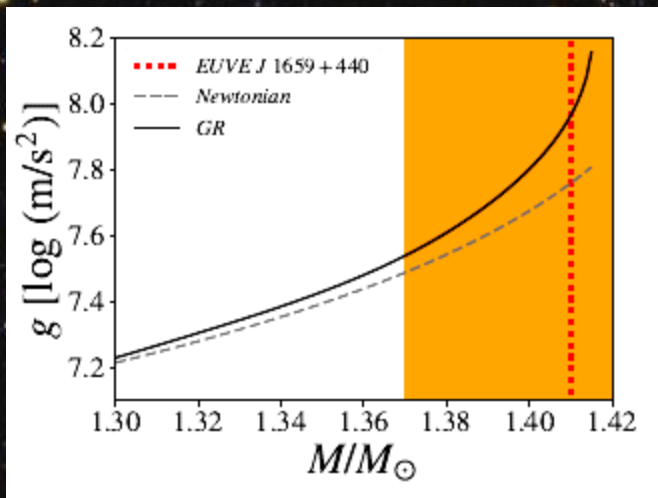
Our extended Research Group (CompStar Brazil) is composed of 4 PI (headed by M. Malheiro/ITA), 10 Research Associates, 6 Posdocs and 12 Graduate students from ITA, INPE, IAG-USP, IFSP, UFABC, UNIFESP, and UNESP, all from SP State
+ a large number of collaborators (Frankfurt U., La Plata U., Roma/ICRA, CBPf, etc.)

Some problems we are working on, and some of the findings of the CompStar Brazil SP State group financed by FAPESP...

White Dwarfs

- Structure : high magnetic fields + GR + rapid rotation

Magnetic deformation of WDs
may lead to their GW detection
(M.F. Sousa, J.C.N. Araújo & J. Coelho)



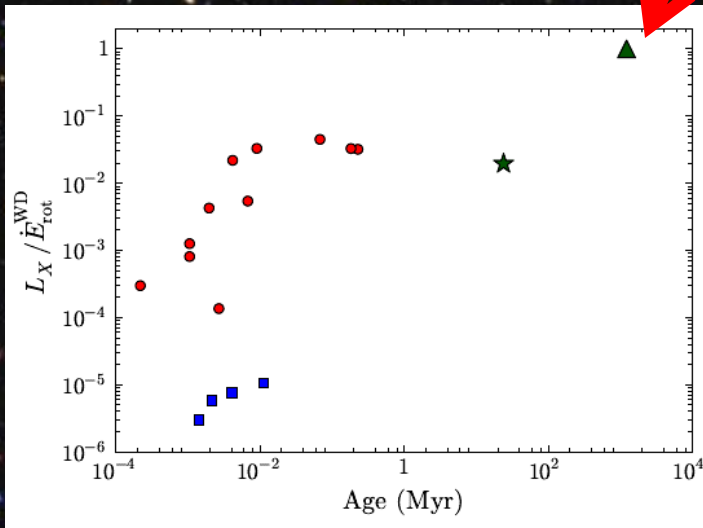
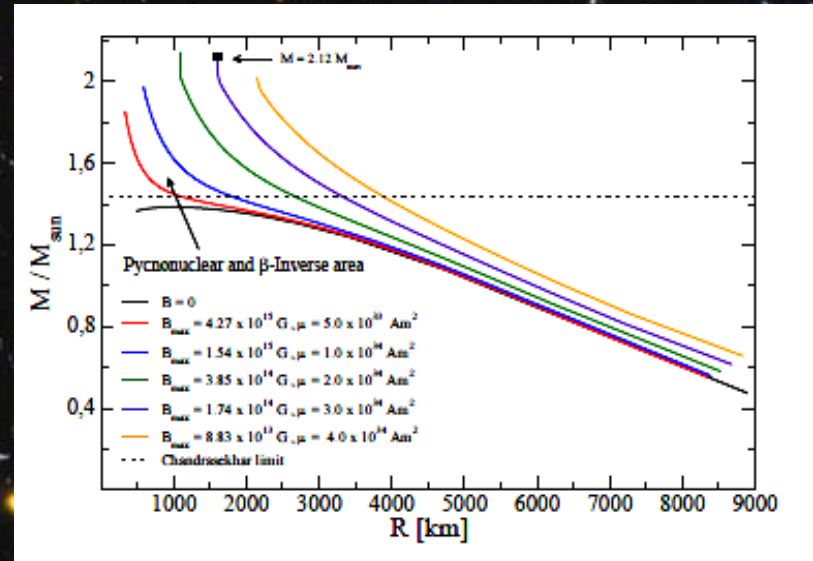
GR is important in massive, actual WDs
(G. Carvalho, R. Marinho & M. Malheiro)

White Dwarfs (continued)

SuperChandrasekhar masses in WDs can be sustained by huge (internal) B (E. Otoniel, R. Lobato, M. Malheiro, B. Franzon, S. Schramm & F. Weber)

(is this related to very luminous Type Ia supernovae ?...)

SGR 0418+5729



Moreover, massive, magnetized WDs can pulse, some may be "hidden" among the *magnetar* group (a LOT of discussion here...) (M. Malheiro, R. Ruffini & J. Rueda)

(More recent work by S. Borges, C.V. Rodrigues & M. Malheiro)

“Neutron” stars: pulsars



- Braking indexes evolve and young pulsars show this

$$\dot{\nu} = -K\nu^n$$

$K=K(t)$? extra torques?

$$n = \frac{\ddot{\nu}\nu}{\dot{\nu}^2}$$

Picks extra terms

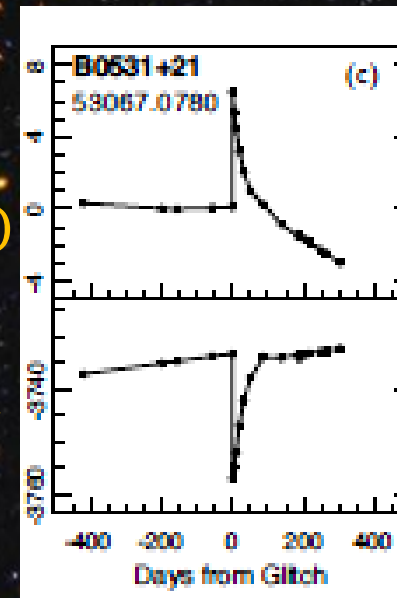
PSR	n
Crab	2.51(1)
Vela	1.4(2)
B0540-69	2.140(9)
B1509-58	2.839(1)
J1846-0258	2.65(1)
J1119-6127	2.684(2)
J1734-3333	0.9(2)
J1833-1034	1.8569(6)

Quantum vacuum friction acts as an extra $n=1$ term

(J. Coelho, J. Pereira & J.C.N. de Araújo) *Deep connection with fundamental physics*

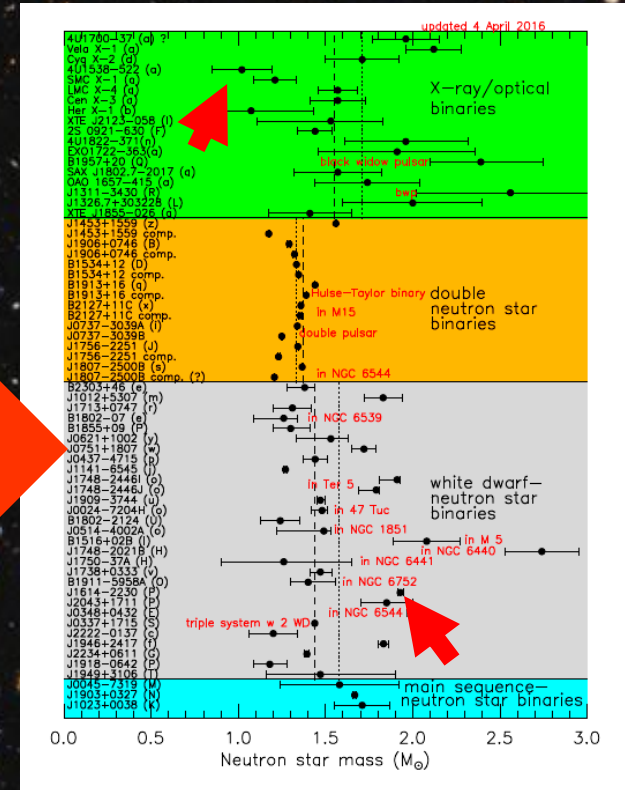
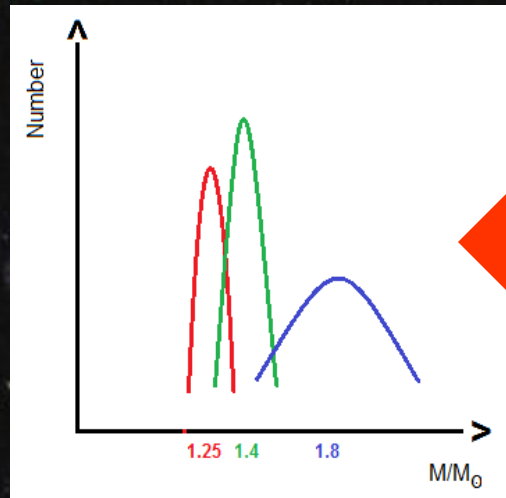
Glitches (sudden discontinuities in the slowdown) could be related to the *core* of the pulsars (not the crust): phenomenological vortex motion (H. Oliveira, R. Marinho, G. Carvalho, N. Magalhães, S. Ladislau & C. Frajuca)

Braking index “jumps” across a glitch is a signature of spin-B misalignment (J. E. Horvath)



“Neutron” stars (continued)

Bayesian inference :
 “1.4 M_{\odot} only” is untenable,
 There are three peaks at
 1.25, 1.4 and 1.8 M_{\odot}
 (R.Valentim, L.S. Rocha,
 J.E. Horvath)



Anisotropic exact SS models (self-bound): stability
 (J. Arbañil, M. Malheiro, M. GB de Avellar, A. Bernardo, L.S. Rocha)

Nuclear processes in Astrophysics: Recent progress

V. Liccardo¹, M. Malheiro¹, M. S. Hussein^{1,2,3}, B. V. Carlson¹, and T. Frederico¹

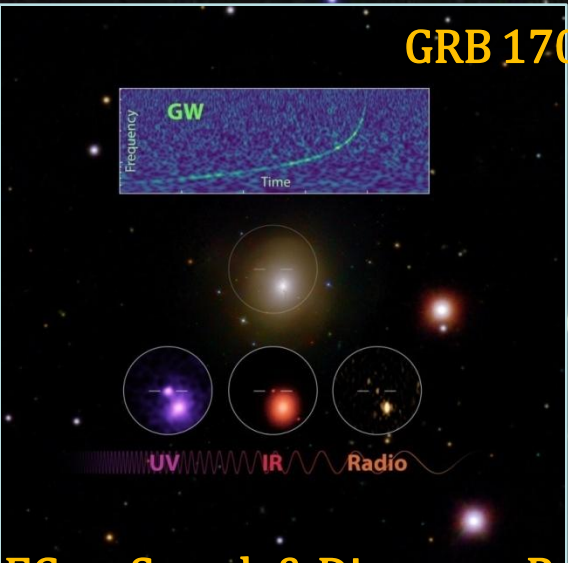
¹ ITA-Instituto Tecnológico de Aeronáutica, Praça Marechal Eduardo Gomes, 50 - Vila das Acácias, CEP 12.228-900 São José dos Campos - SP - Brasil

² Instituto de Estudos Avançados, Universidade de São Paulo C. P. 72012, 05.508-970 São Paulo - SP - Brazil

³ Instituto de Física, Universidade de São Paulo, C. P. 66318, 05.314-970 São Paulo - SP - Brazil

“Neutron” stars: hints from GW/GRBs (cont.)

GRB 170817 : what if stars were “exotic” ?



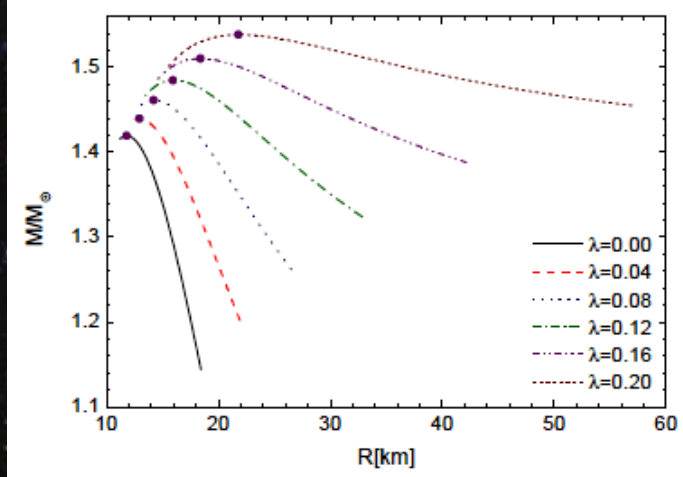
Nucleosynthesis from SS-SS mergers
 SQM → hadrons → nuclei @ freezout $A > 200??$
 (L. Paulucci, A. Bernardo, J.E. Horvath+ collaborators)

what made the signal last “long” after merger?
 Tidal polarizability studies
 (L.Paulucci, J.E. Horvath with E.Ferrer & V. Incera (CUNY))

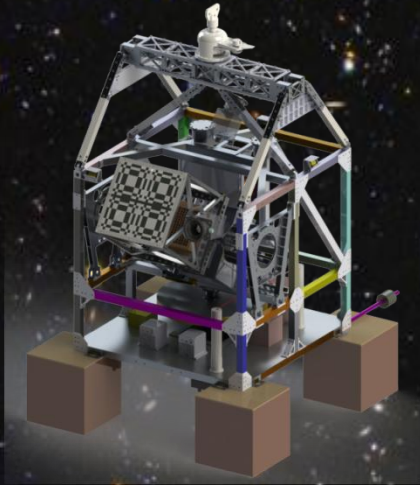
DECam Search & Discovery Program for Optical Signatures of Gravitational Wave Events (DESGW)
 PI: M. Soares-Santos (Brandeis) 1 event/month

GW signal in Alternative Theories of Gravitation
 Structure of neutron stars
 (M. Alves J.C..N. de Araújo, O. Aguiar, G. Carvalho,
 P. Moraes, M. Malheiro, R. Lobato, E. Otoniel
 & R. Marinho)

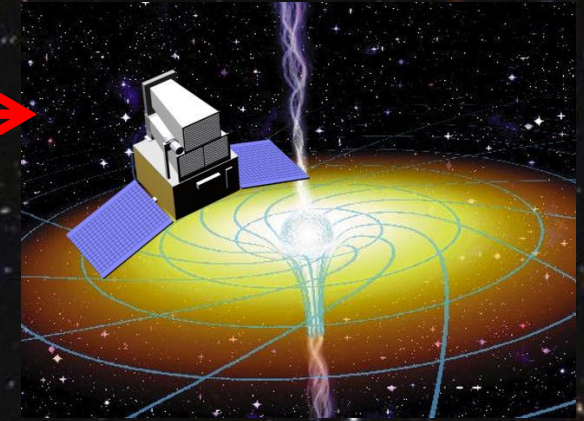
$$f(R, T)$$



“Neutron” stars (and BHs): observational studies



← ProtoMIRAX & MIRAX
Instruments :
Imaging @ ~100 keV →

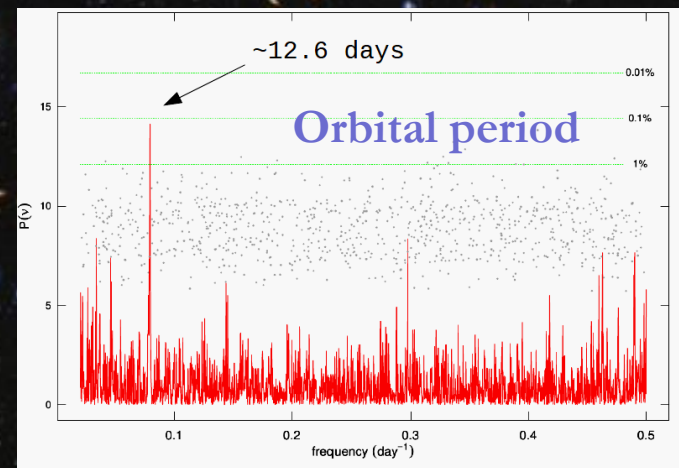


Observations of 1E 1740.7-2942 BH candidate with
XMM, NuSTAR & INTEGRAL
(F. Stecchini, J. Braga & F. DAmico)

$M \sim 4.2M_{\odot}$

$D \sim 8.5 \text{ kpc}$

“lightest” measured BH

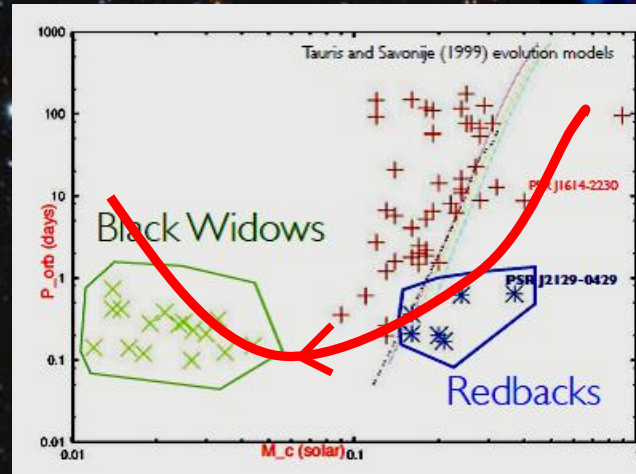


“Neutron” stars: evolution in binaries

Relativistic “spider” systems (black widows/redbacks)

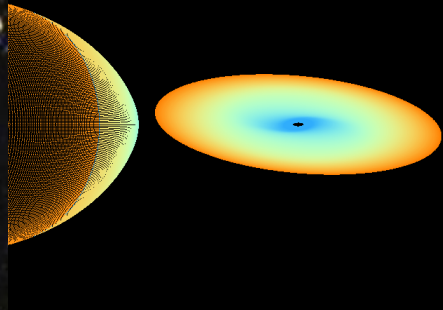
New evolutionary paths for irradiated
+ wind donors

(J.E. Horvath, O.Benvenuto, M.A De Vito)



PSR 1957+20
ablating its
companion

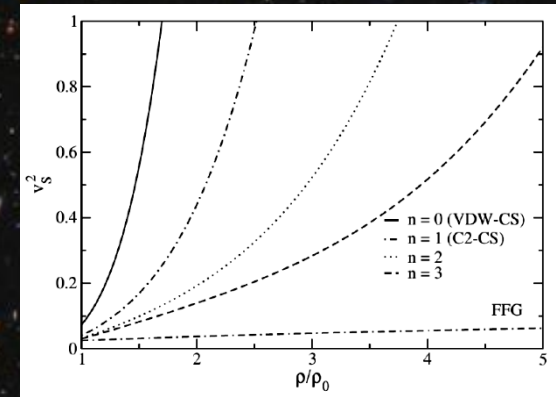
$$M_{psr\ 1957+20} = 2.4 \pm 0.12 M_{\odot}$$



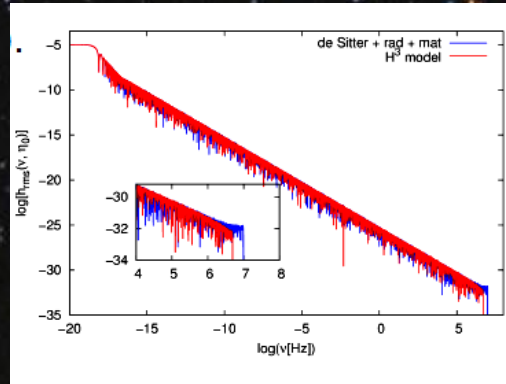
Observations of Her X-1 with XMM (twisted & tilted disc)
(M. Castro, J. Braga)

Several other studies...

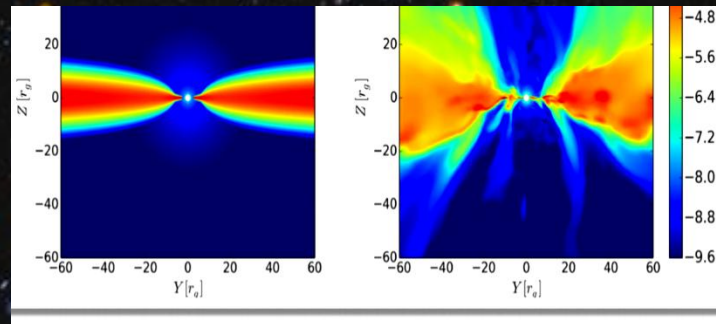
Nuclear matter theory : effective interactions and hardness
(M. Dutra, O. Loureço, C. Lenzi)



Relict GW background
(M. Alves)

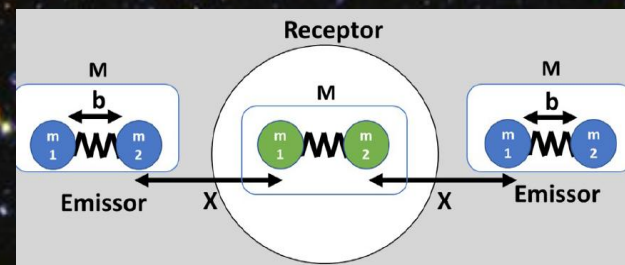


Astrophysical plasmas
(E. Rempel, D. Teixeira)



Thin magnetized disk simulations around a BH

Measurements of GW velocity
(C. Frajuca)



A sample of relevant publications

- * **The Influence of Quantum Vacuum Friction on Pulsars**
J. Coelho, J. Pereira and J.C.N. de Araujo, *ApJ* 823, 97 (2016)
- * **Understanding the Evolution of Close Binary Systems with Radio Pulsars**
O. Benvenuto, M.A. De Vito and J.E. Horvath, *ApJL* 786, L7 (2014)
- * **SGRs and AXPs as rotation powered massive white dwarfs**
M. Malheiro, R. Ruffini and J. Rueda, *PASJ* 64, 56 (2012)
- * **Stellar equilibrium configurations of compact stars in $f(R, T)$ theory of gravity**
P. Moraes, J. Arbañil and M. Malheiro, *JCAP* 6, 005(2016)
- * **The protoMIRAX Hard X-ray Imaging Balloon Experiment**
J. Braga, F. D'Amico, M. Avila, A V. Penacchioni, J. R. Sacahui, V.A. de Santiago Jr.,
F. Mattiello-Francisco, C. Strauss and M.A. A. Fialho, *A&A* 580, A108 (2015)
- * **The masses of neutron stars**
J.E. Horvath and R. Valentim, in *Handbook of Supernovae*, Springer, 1317 (2017)

Thank you !