

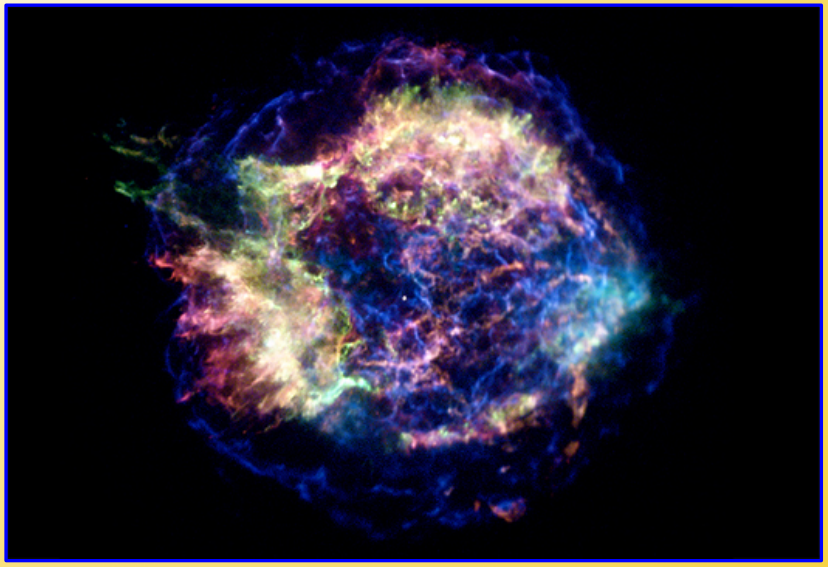
Theory Group at the University of Milano

Astronuclear Physics of Compact Stars





Probing neutron star properties with large pulsar glitches

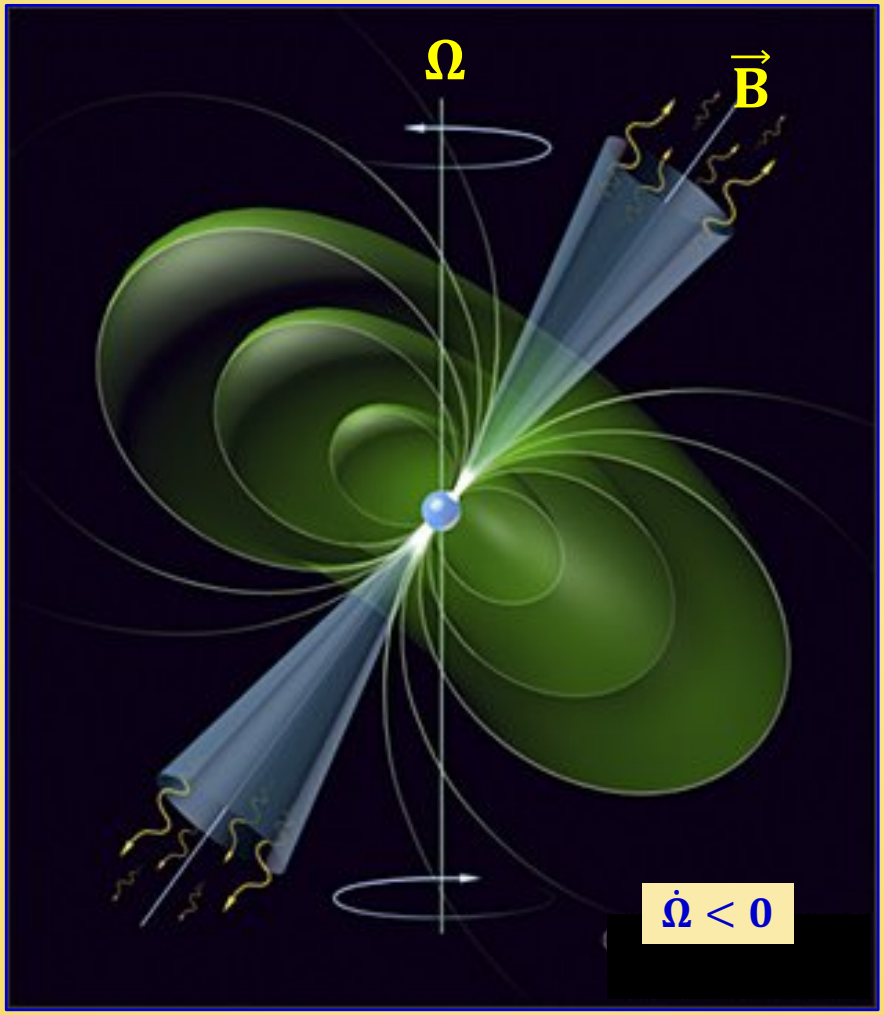


Pierre M. Pizzochero

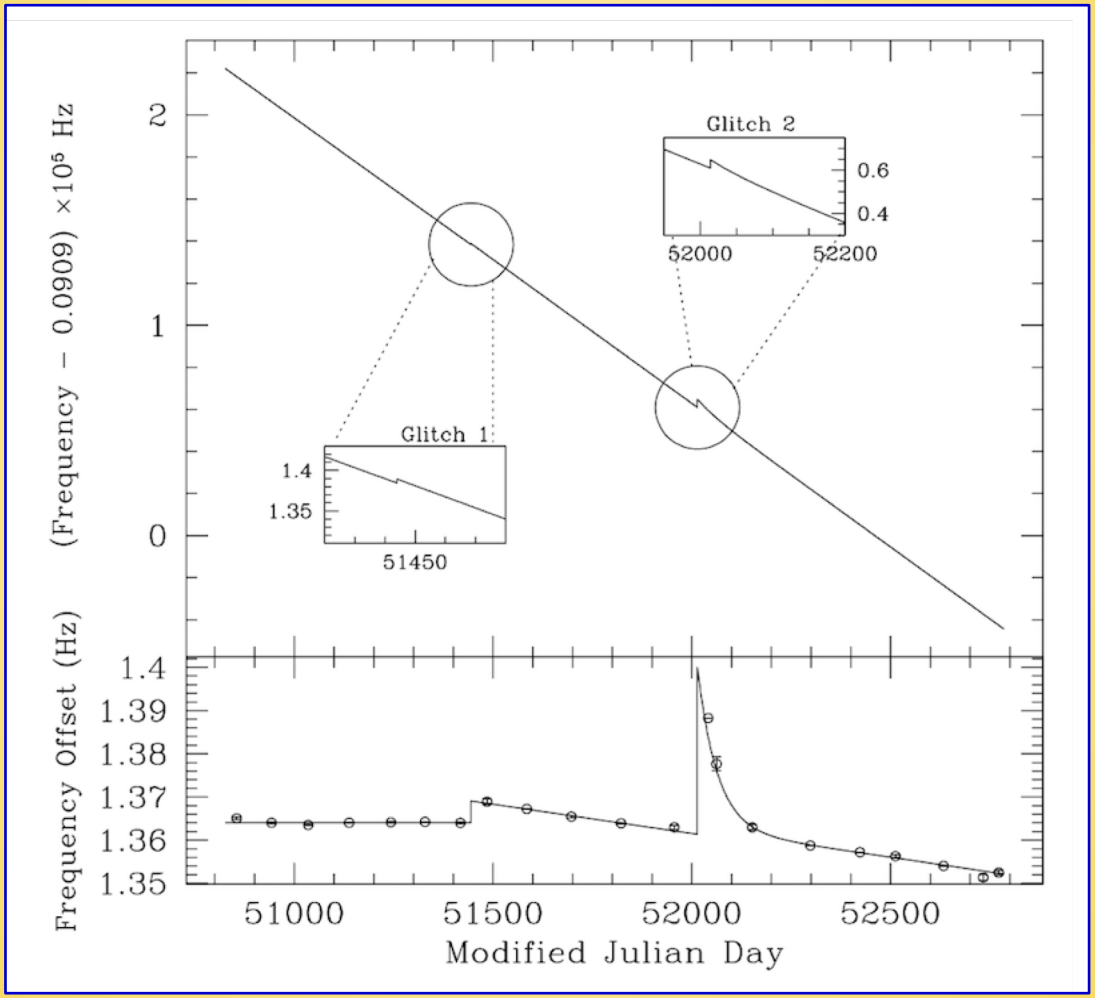
Astro-Siesta

IASF Milano, 17/05/2018

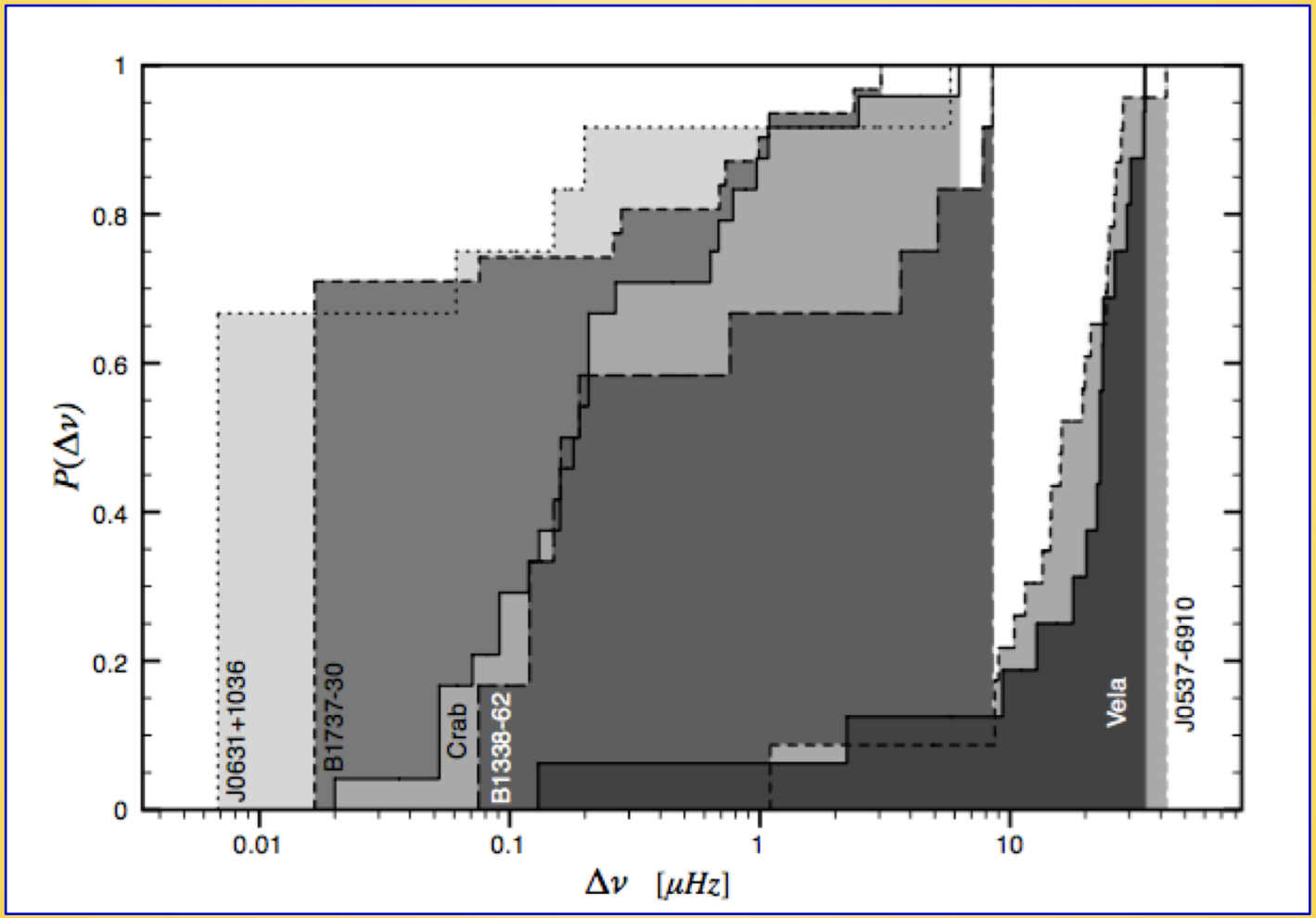
I - *Glitches* in rotating neutron stars



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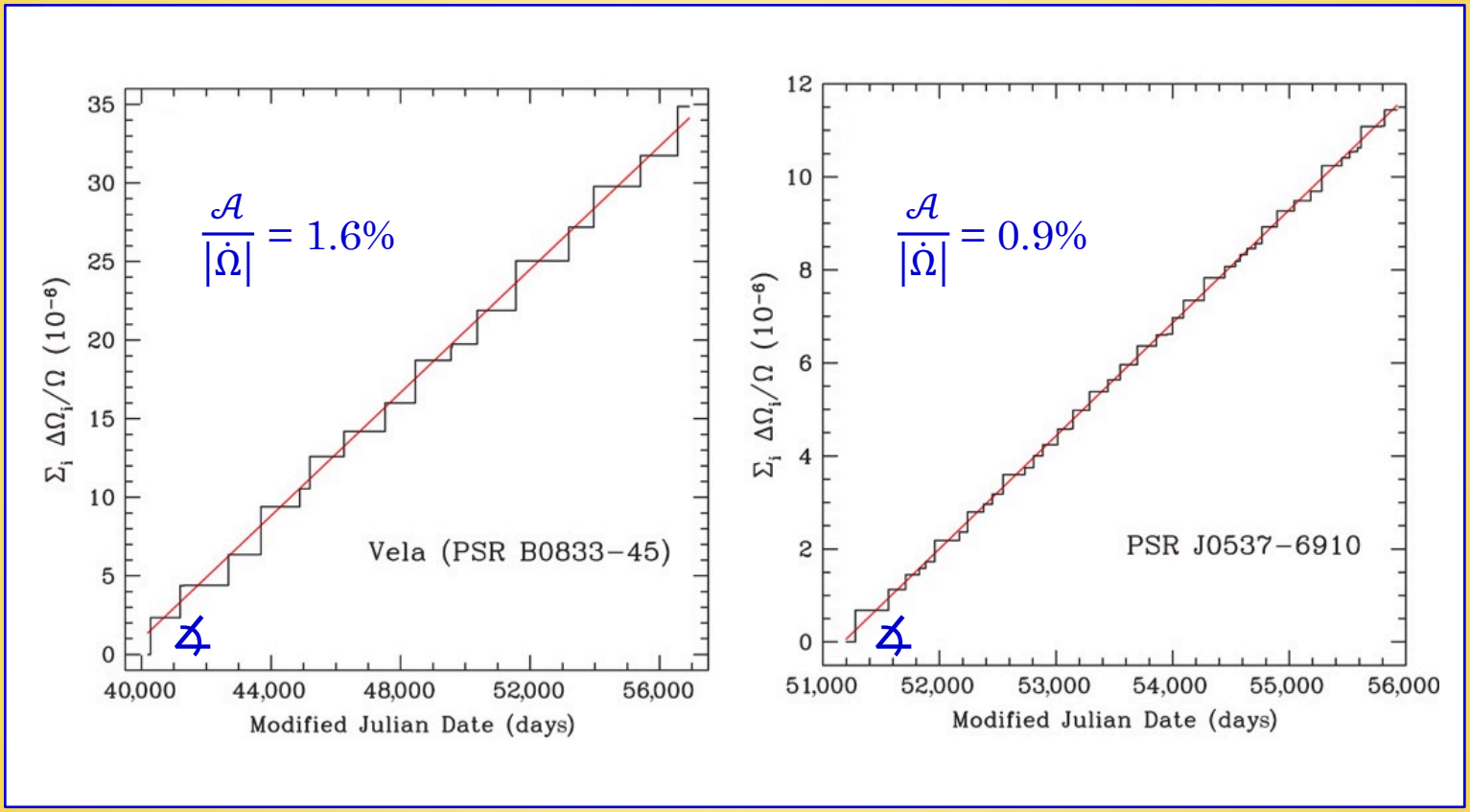


I - *Glitches* in rotating neutron stars



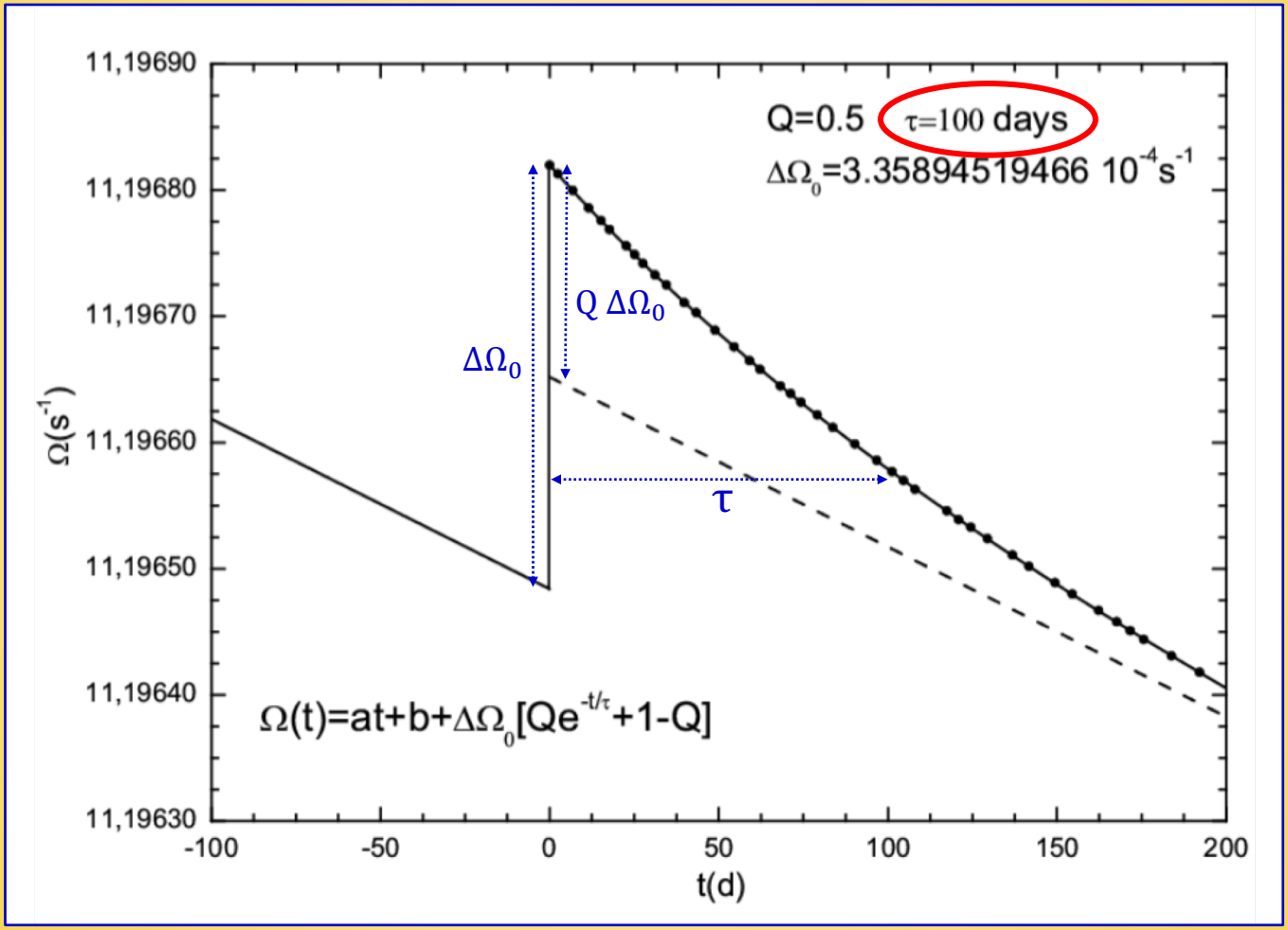
(Espinoza et al, 2011)

I - *Glitches* in rotating neutron stars

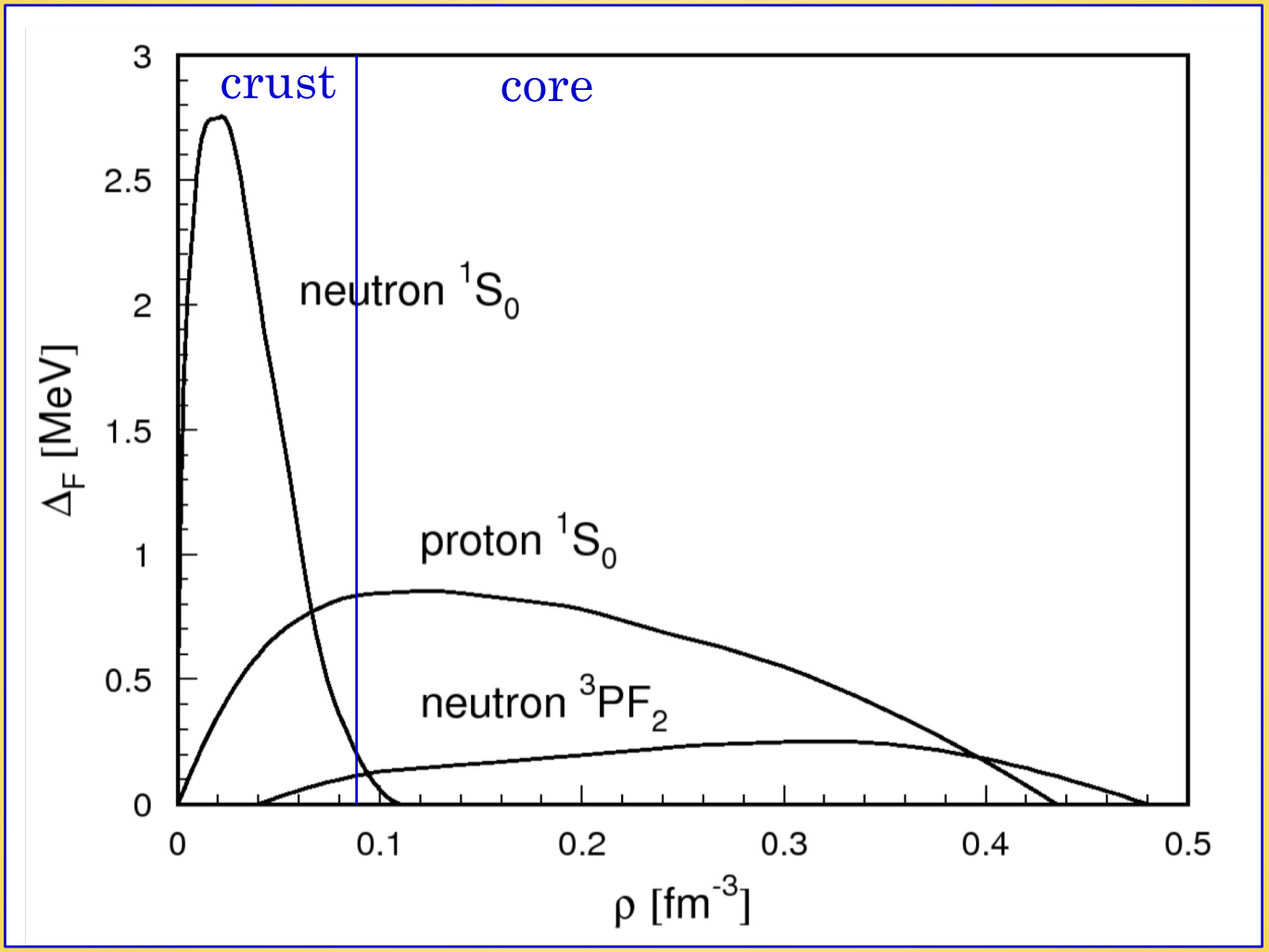


(Ho et al, 2015)

II - *Superfluidity* in neutron star interiors

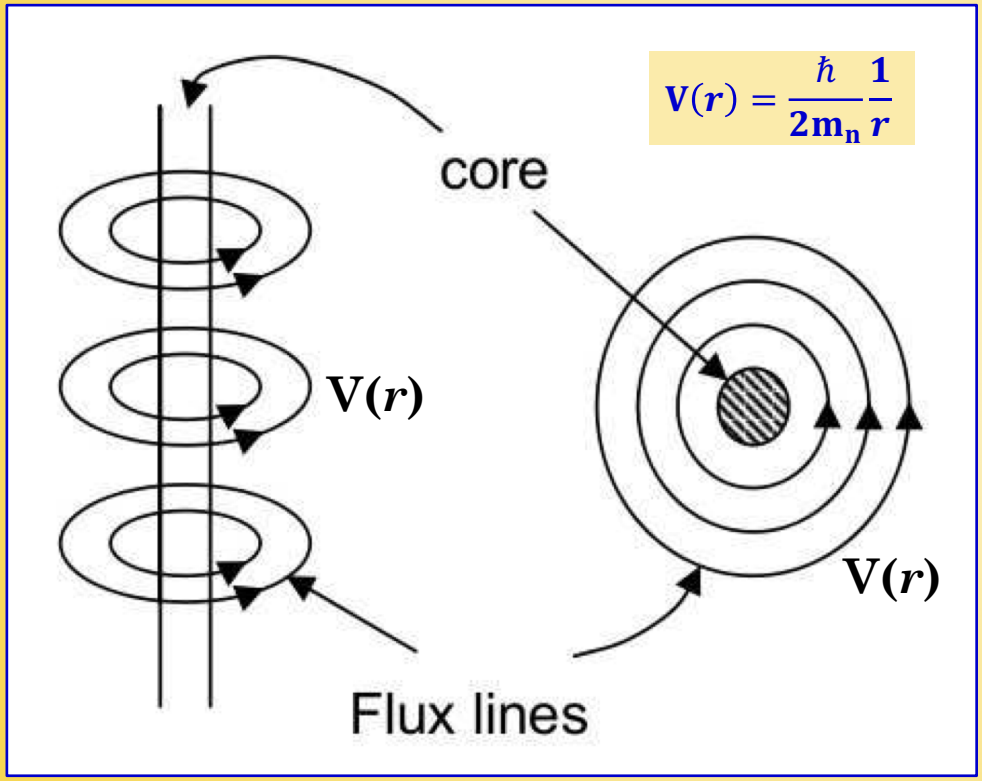


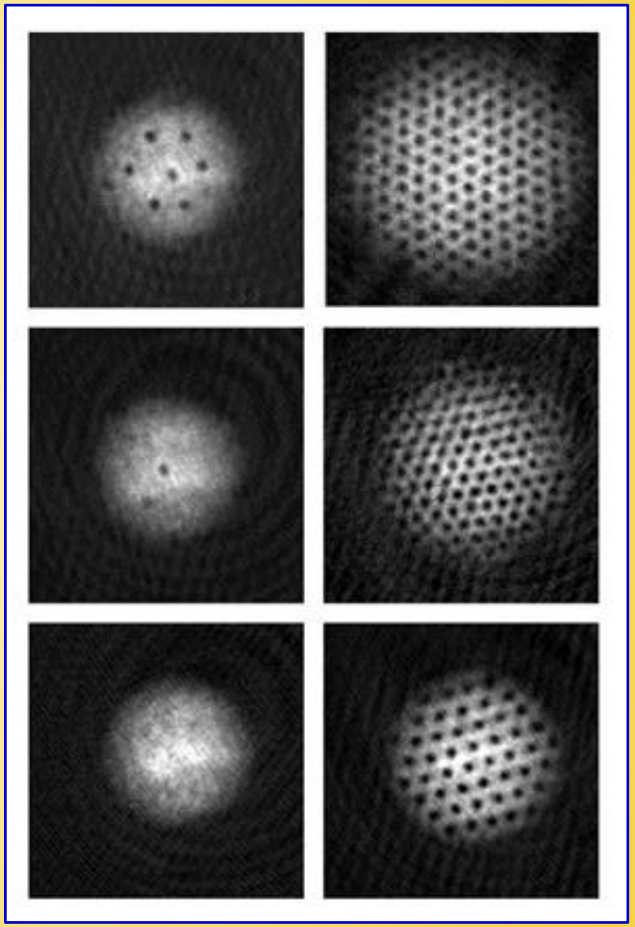
II - *Superfluidity* in neutron star interiors



(Lombardo et al, 2000)

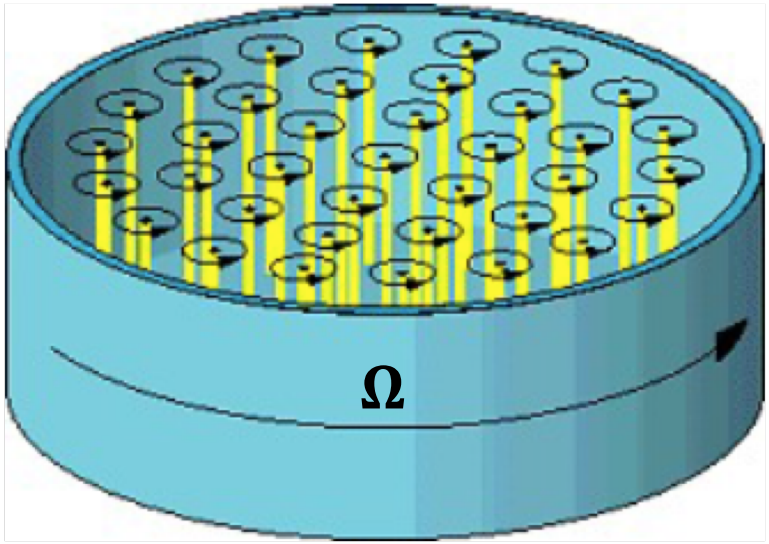
II - *Superfluidity* in neutron star interiors



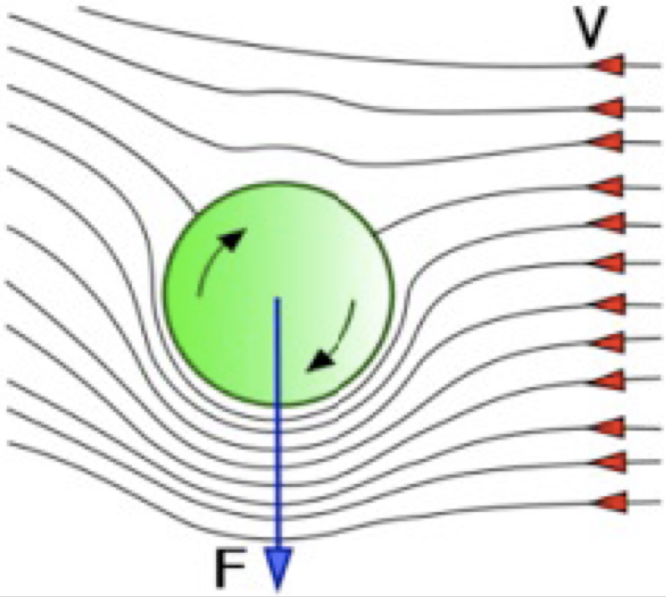


II - *Superfluidity* in neutron star interiors

$n_v \propto \Omega$

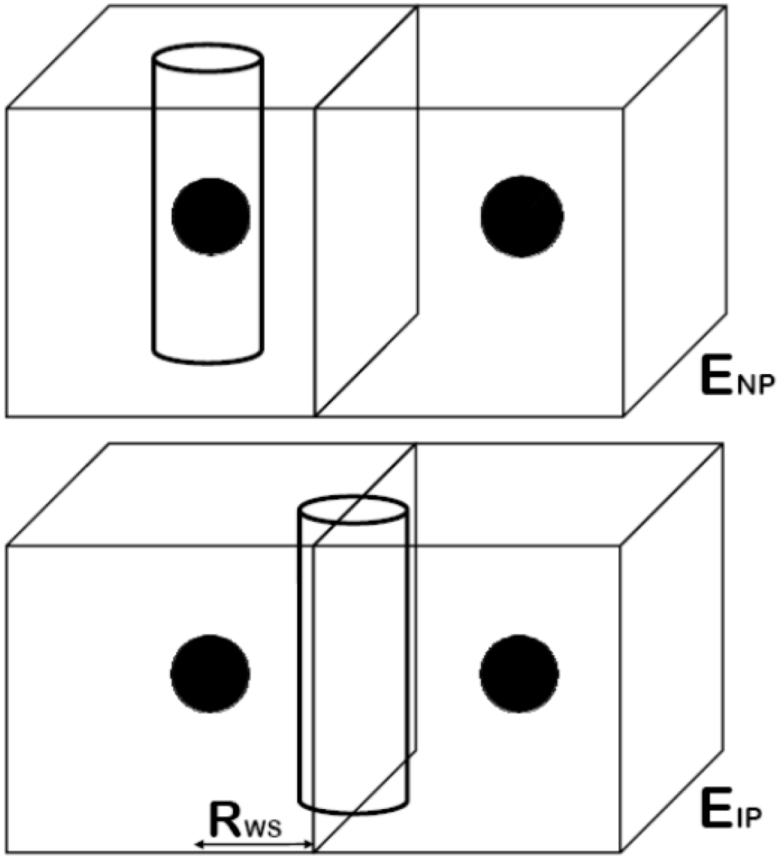


$\langle V_s(r) \rangle = \Omega\, r$



$F_{mag} \propto \rho_s |\vec{V}_L - \vec{V}_s|$

III - Vortex *pinning* in the inner crust



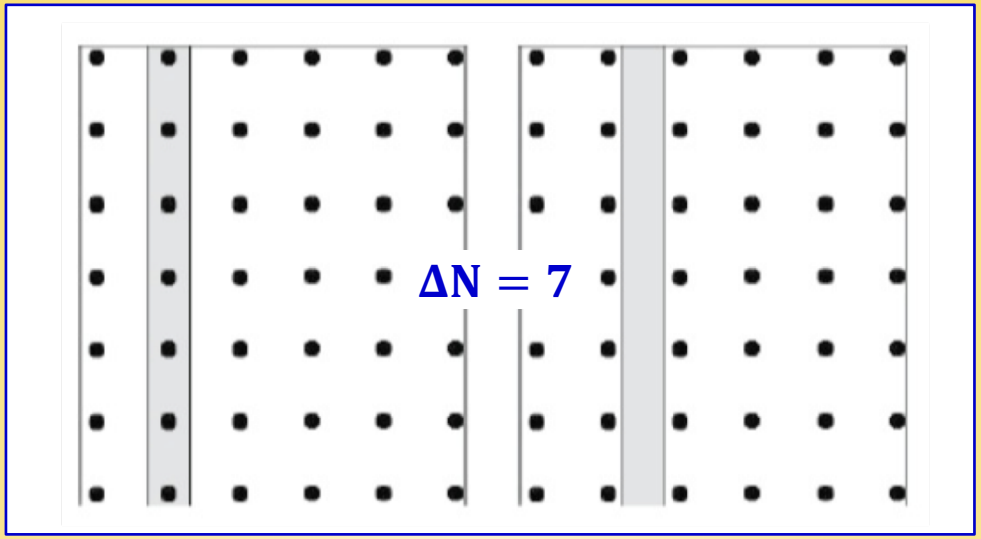
LDA

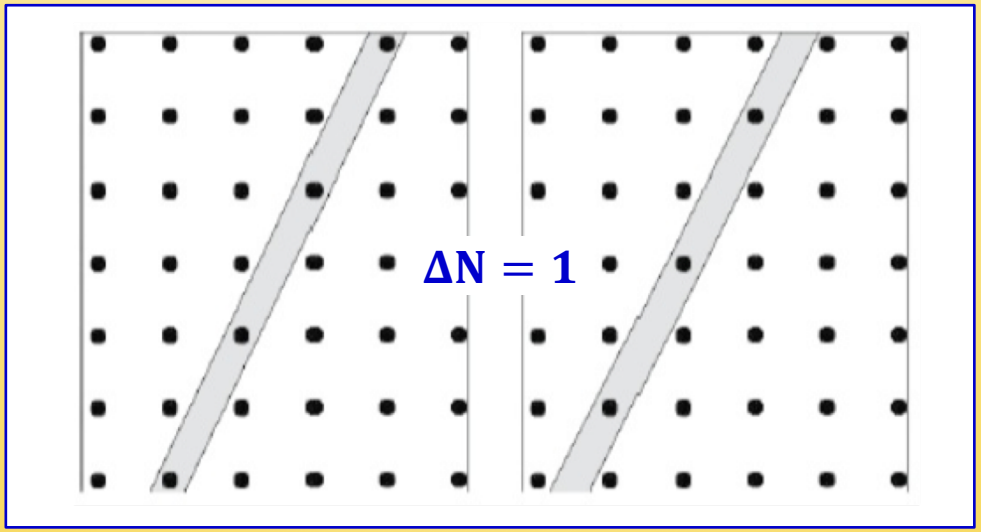
$$E_{pin} = E_{NP} - E_{IP}$$

$$F_{pin} = \frac{E_{pin}}{R_{ws}}$$

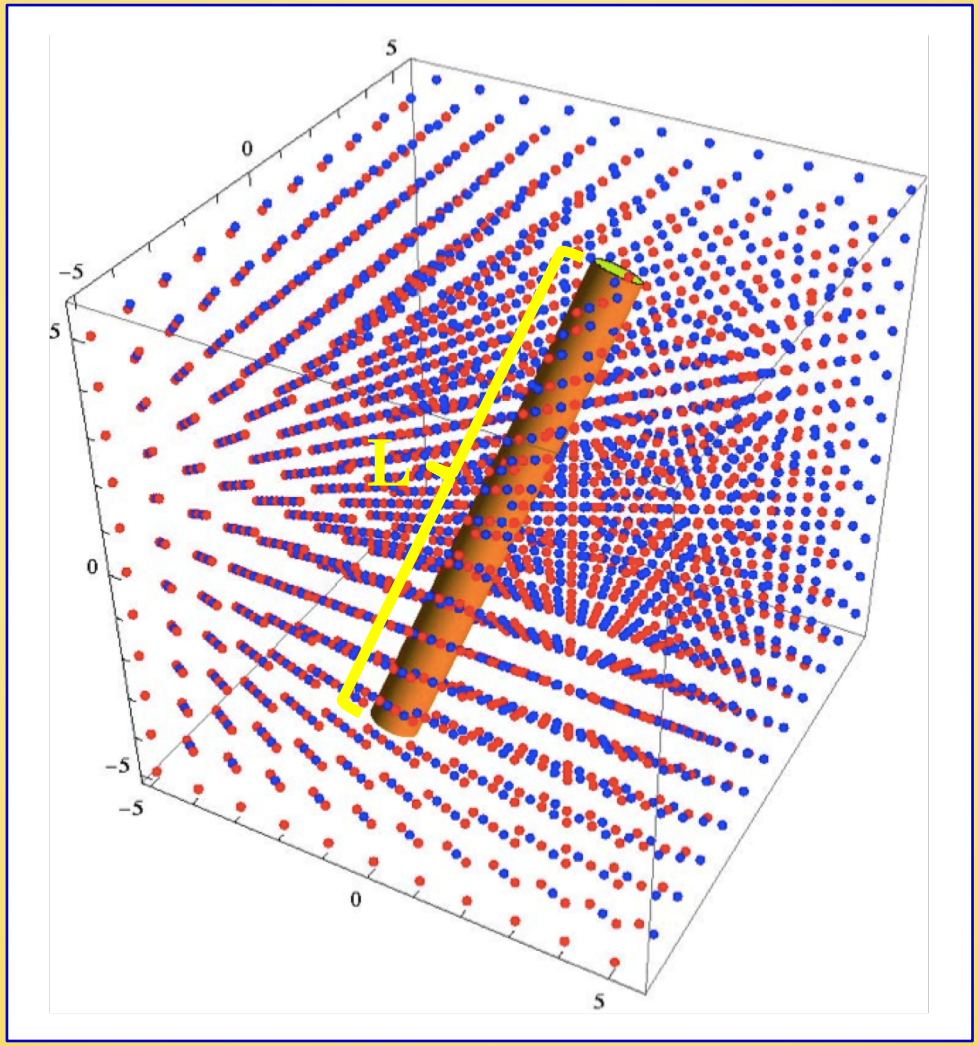
(Donati & PMP, 2004, 2006)

III - Vortex *pinning* in the inner crust



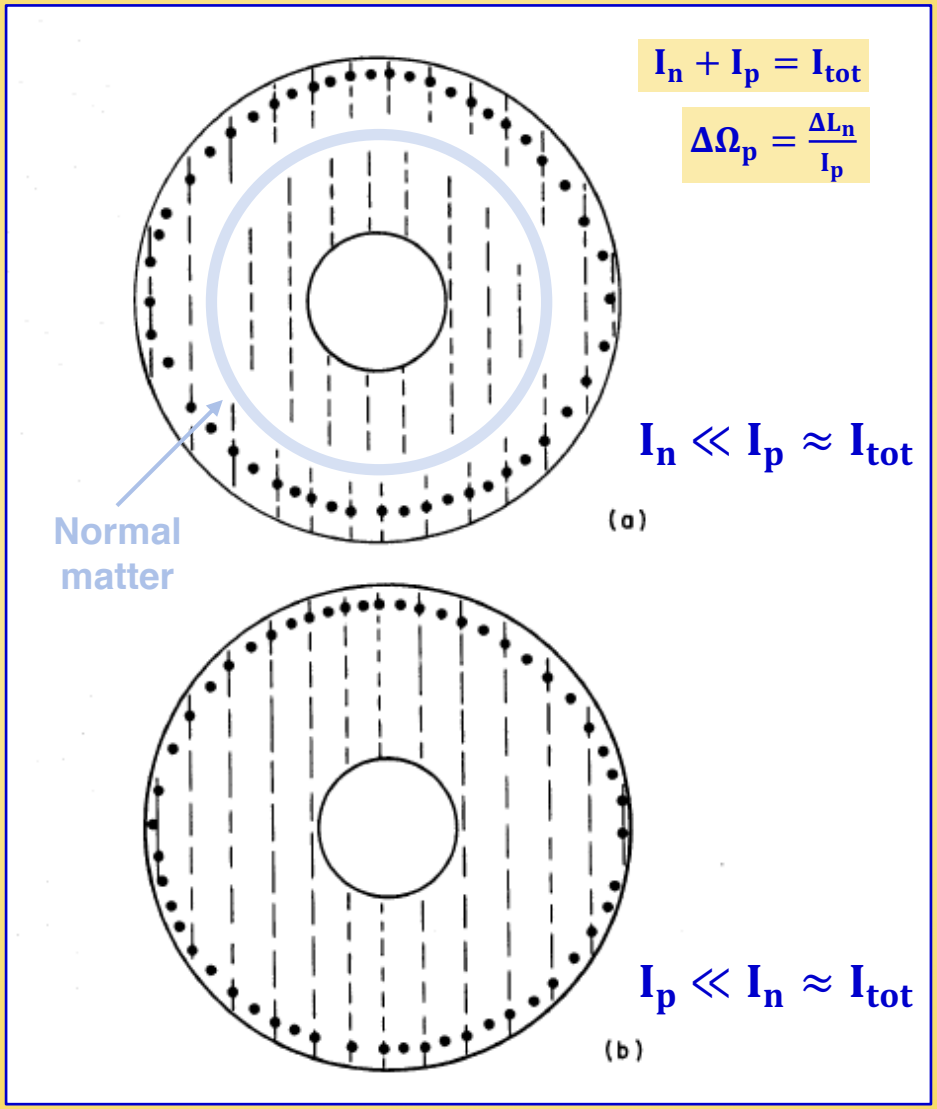


III - Vortex *pinning* in the inner crust



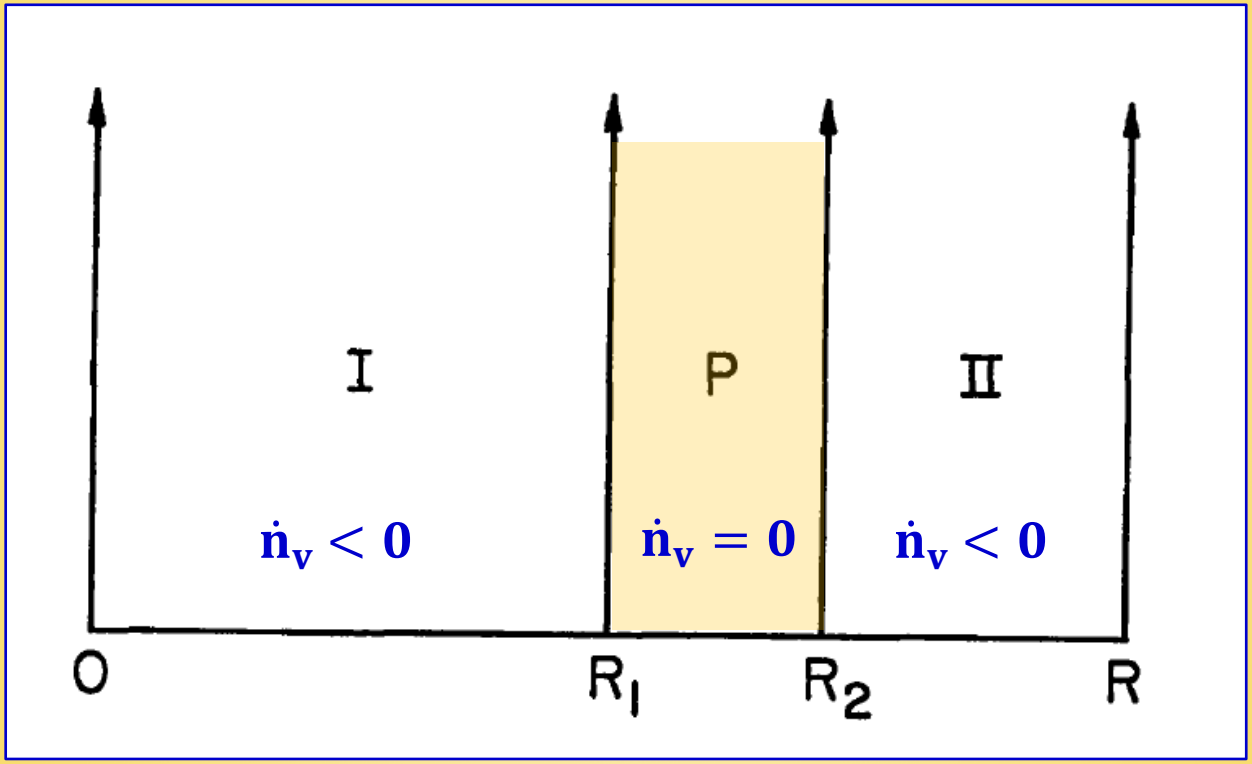
(Seveso, PMP, Grill & Haskell, 2016)

IV - Vorticity reservoir: *standard* scenario



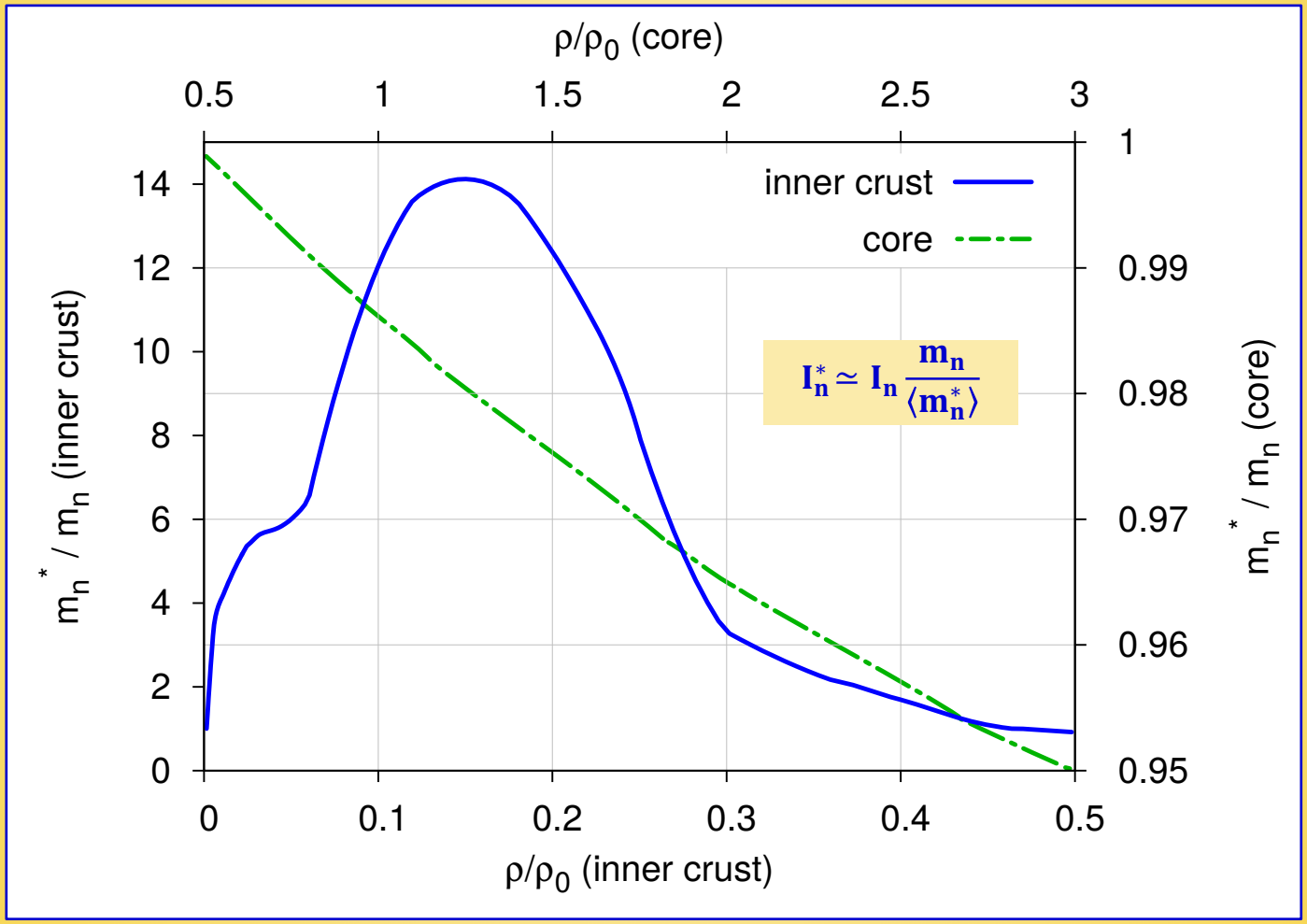
(Ruderman, 1976)

IV - Vorticity reservoir: *standard* scenario



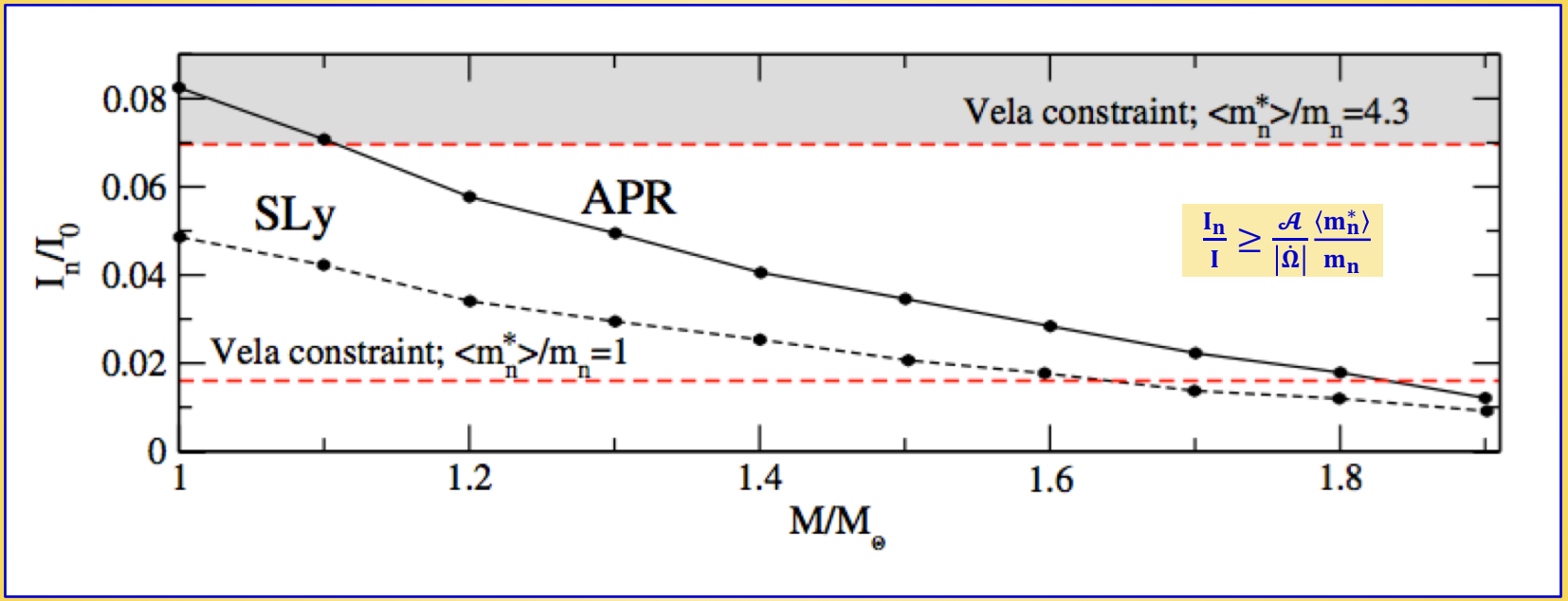
(Pines et al, 1980)

IV - Vorticity reservoir: *standard* scenario



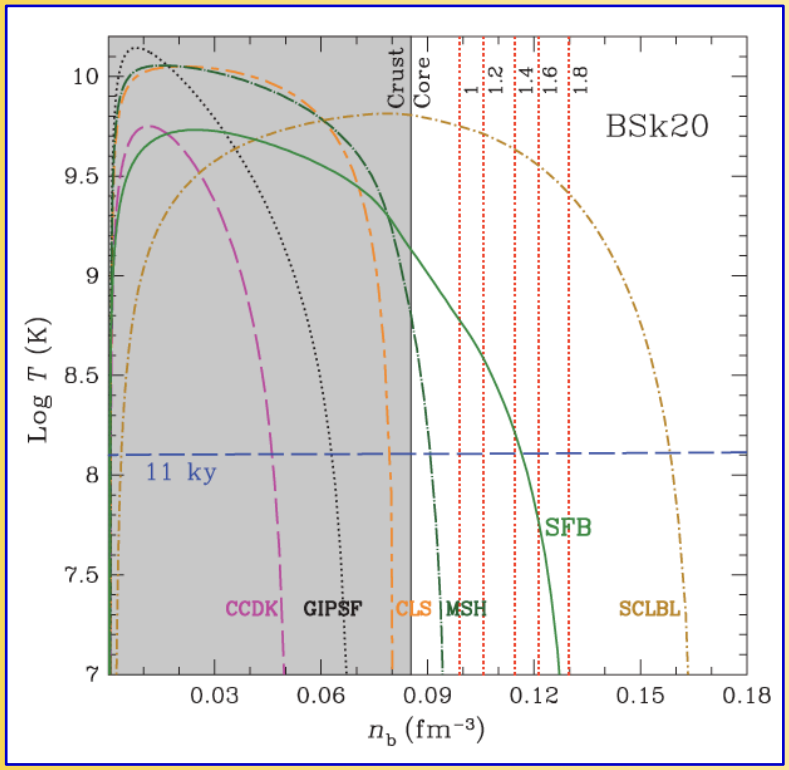
(Chamel, 2012)

IV - Vorticity reservoir: *standard* scenario

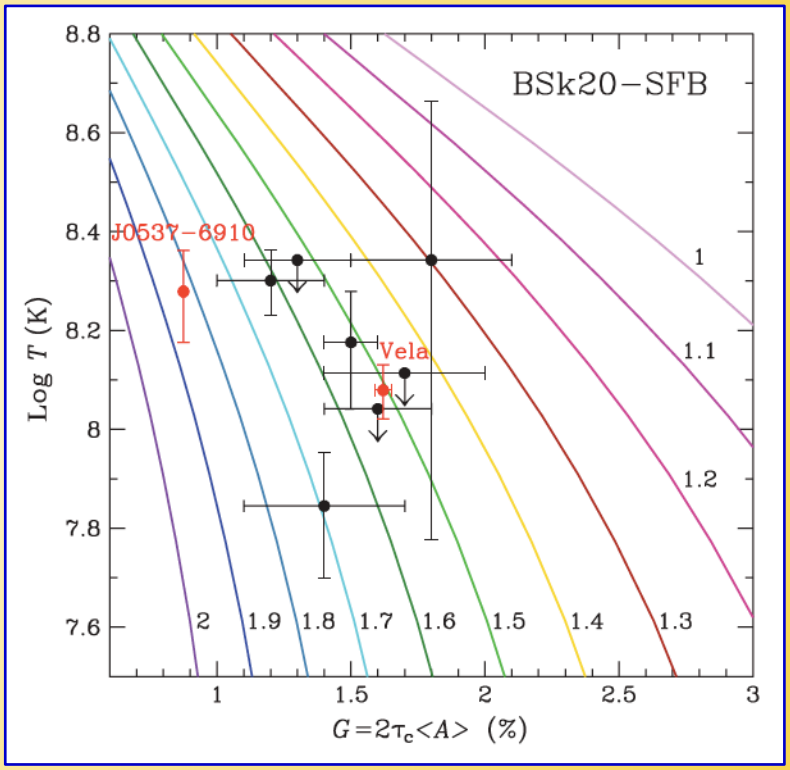


(Andersson et al, 2012)

IV - Vorticity reservoir: *standard* scenario

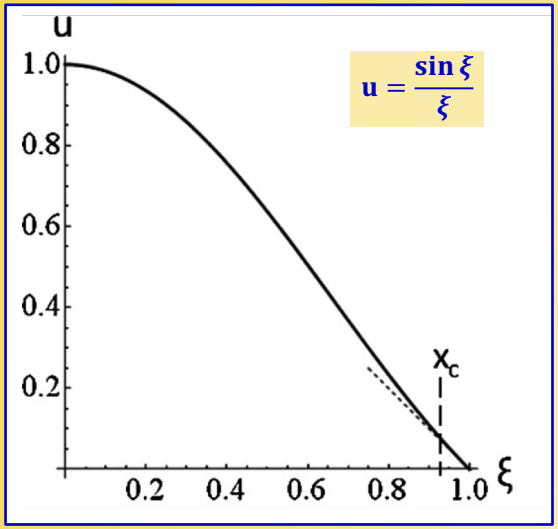


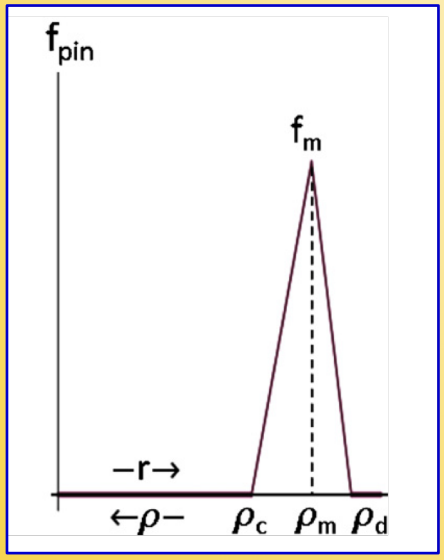
(Ho et al, 2015)



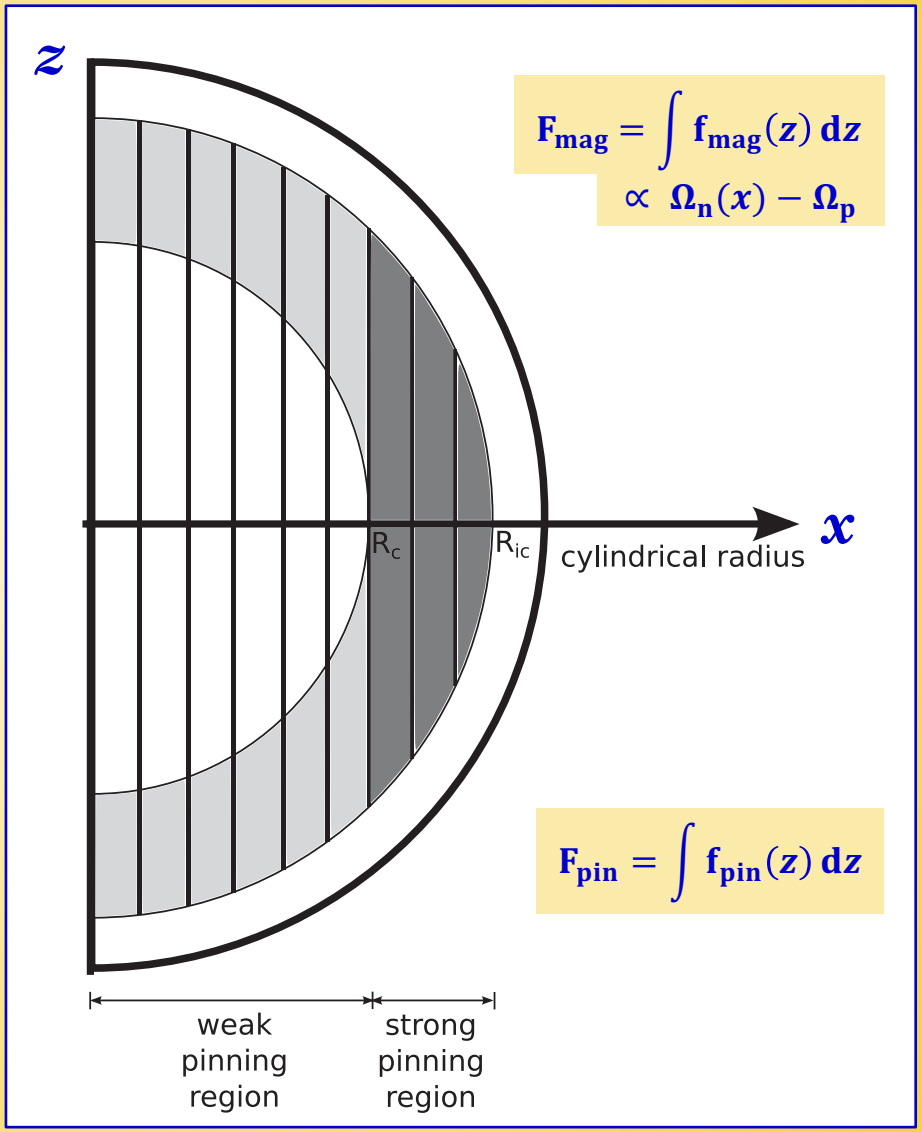
(Ho et al, 2015)

V - Vorticity reservoir: new *pinning* paradigm



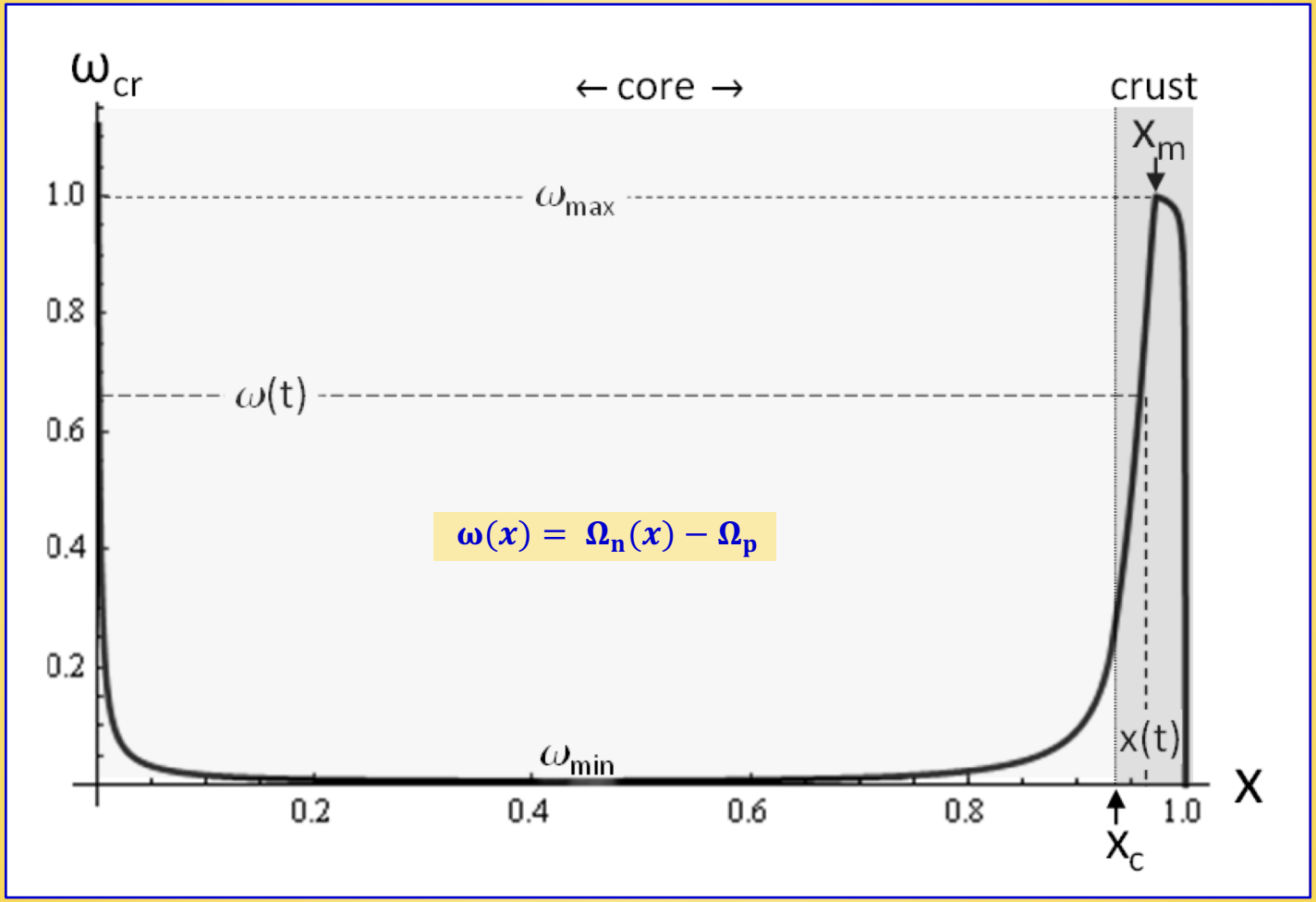


(PMP, 2011)



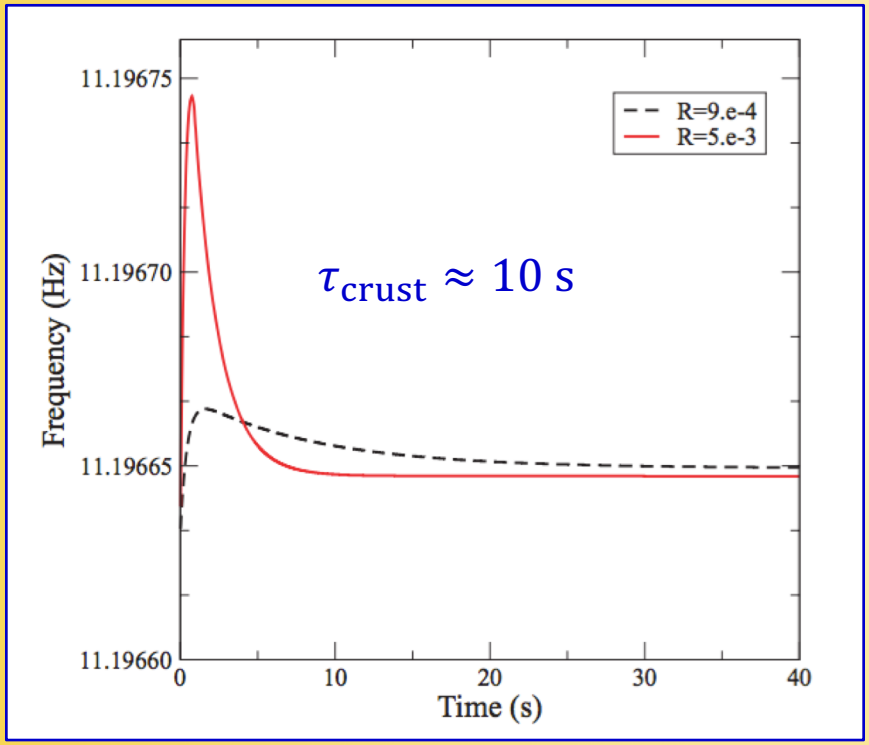
(Seveso, PMP & Haskell, 2012)

V - Vorticity reservoir: new *pinning* paradigm

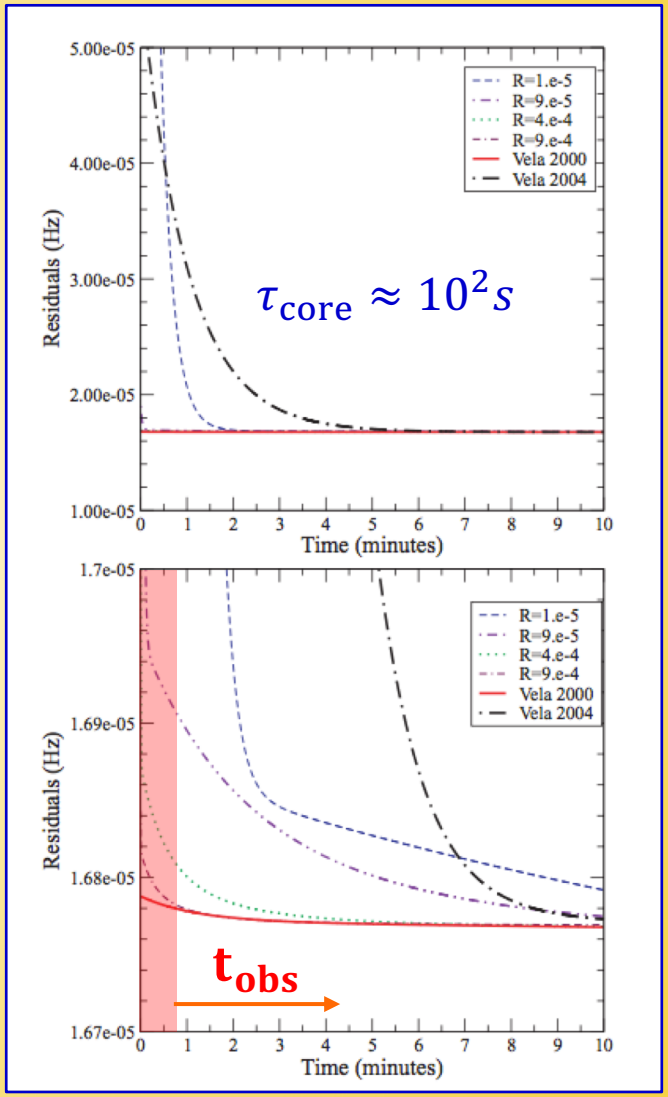


(PMP, 2011)

V - Vorticity reservoir: new *pinning* paradigm

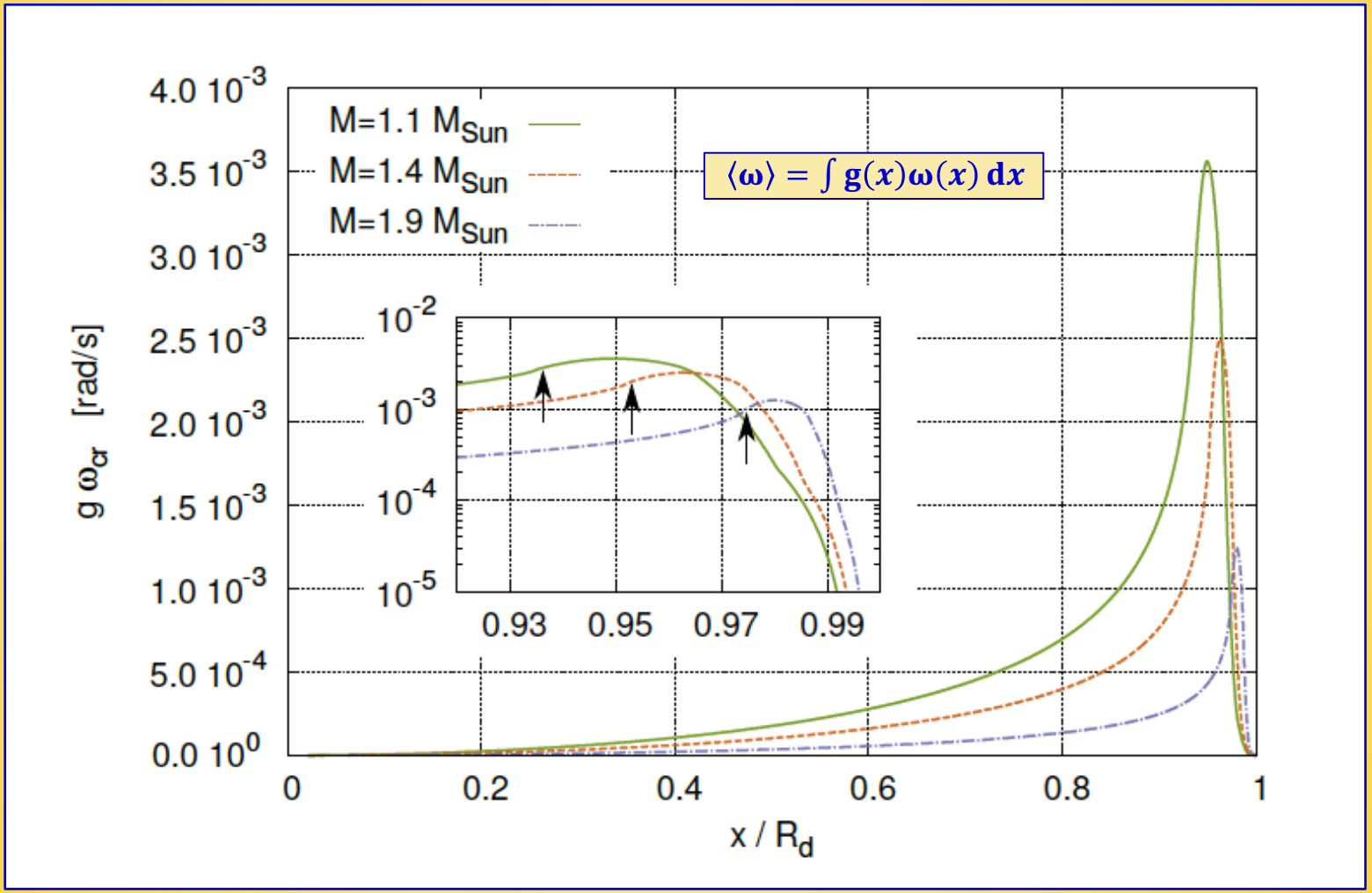


(Haskell, PMP & Sidery, 2012)



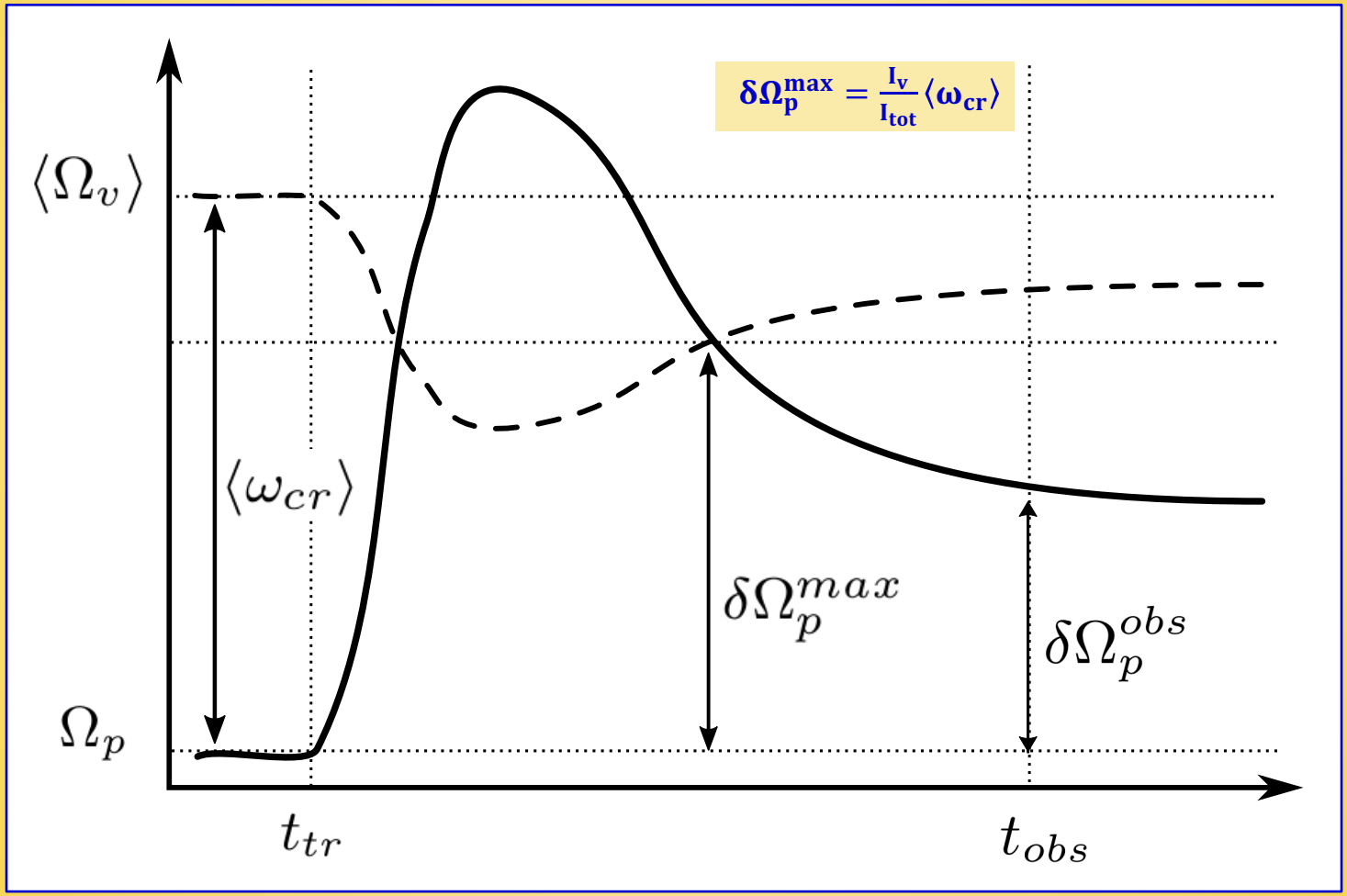
(Haskell, PMP & Sidery, 2012)

VI - *Entrainment* and vorticity reservoir



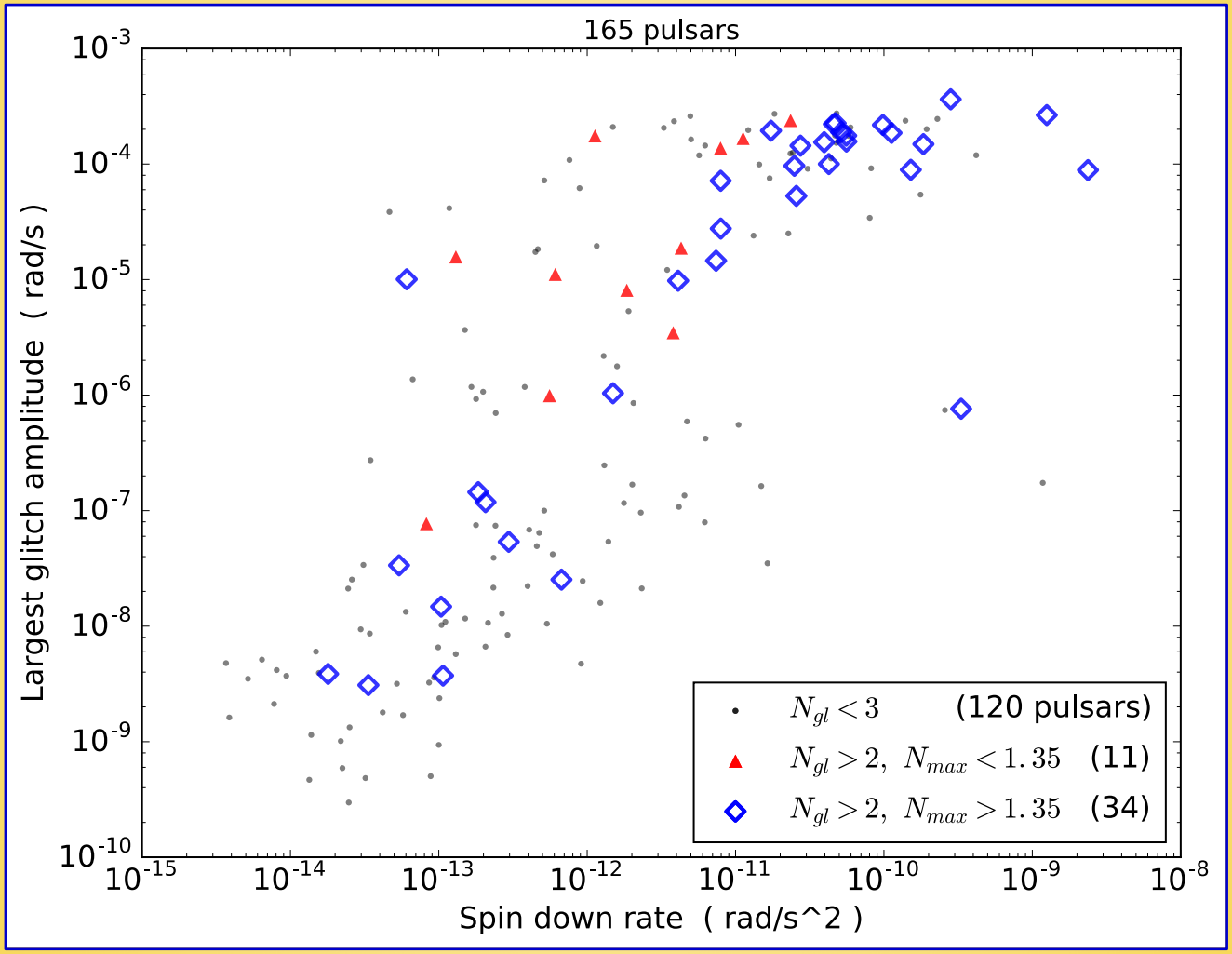
(Antonelli & PMP, 2017)

VI - *Entrainment* and vorticity reservoir

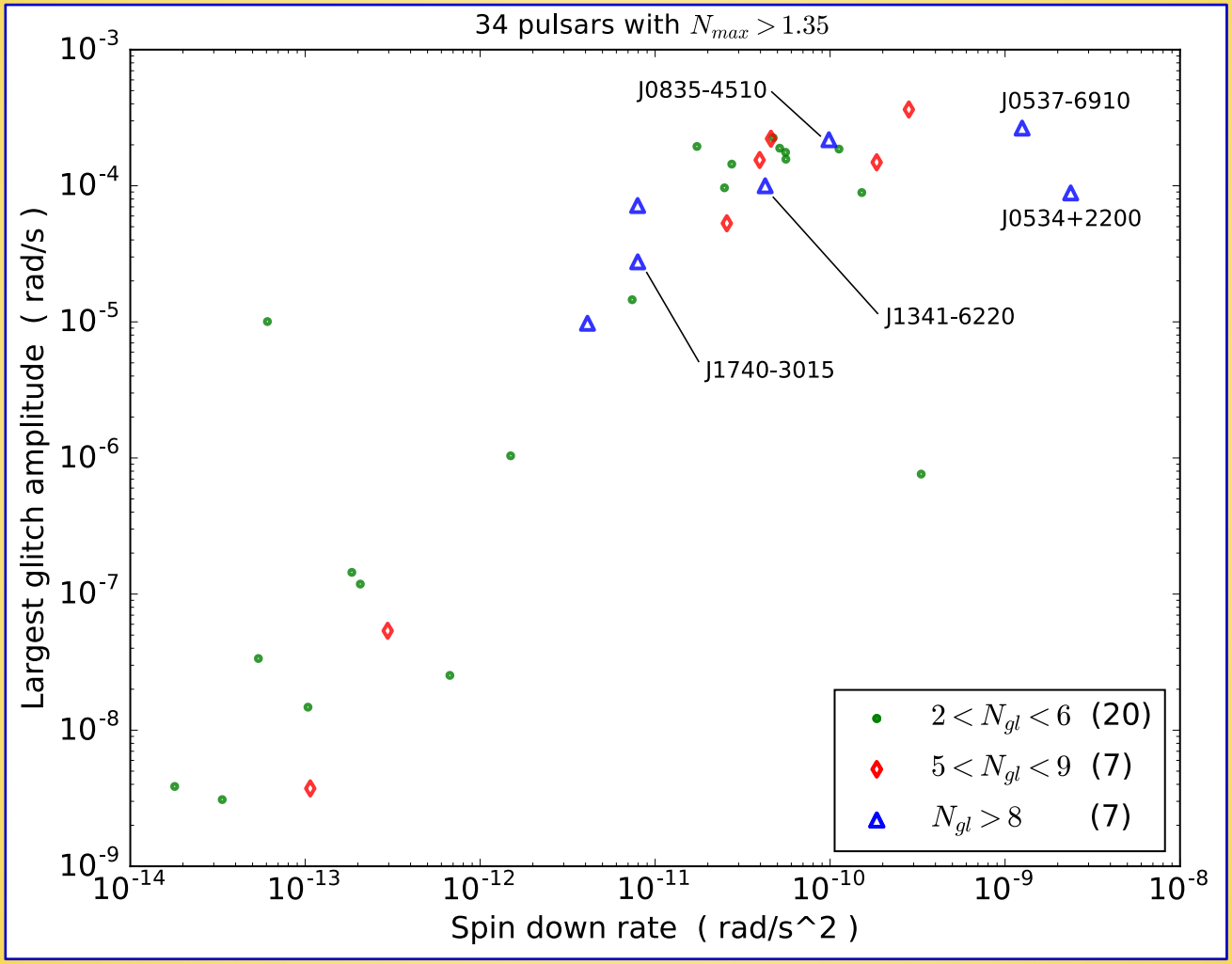


(Antonelli & PMP, 2017)

VII - Observations of the *maximum* glitch



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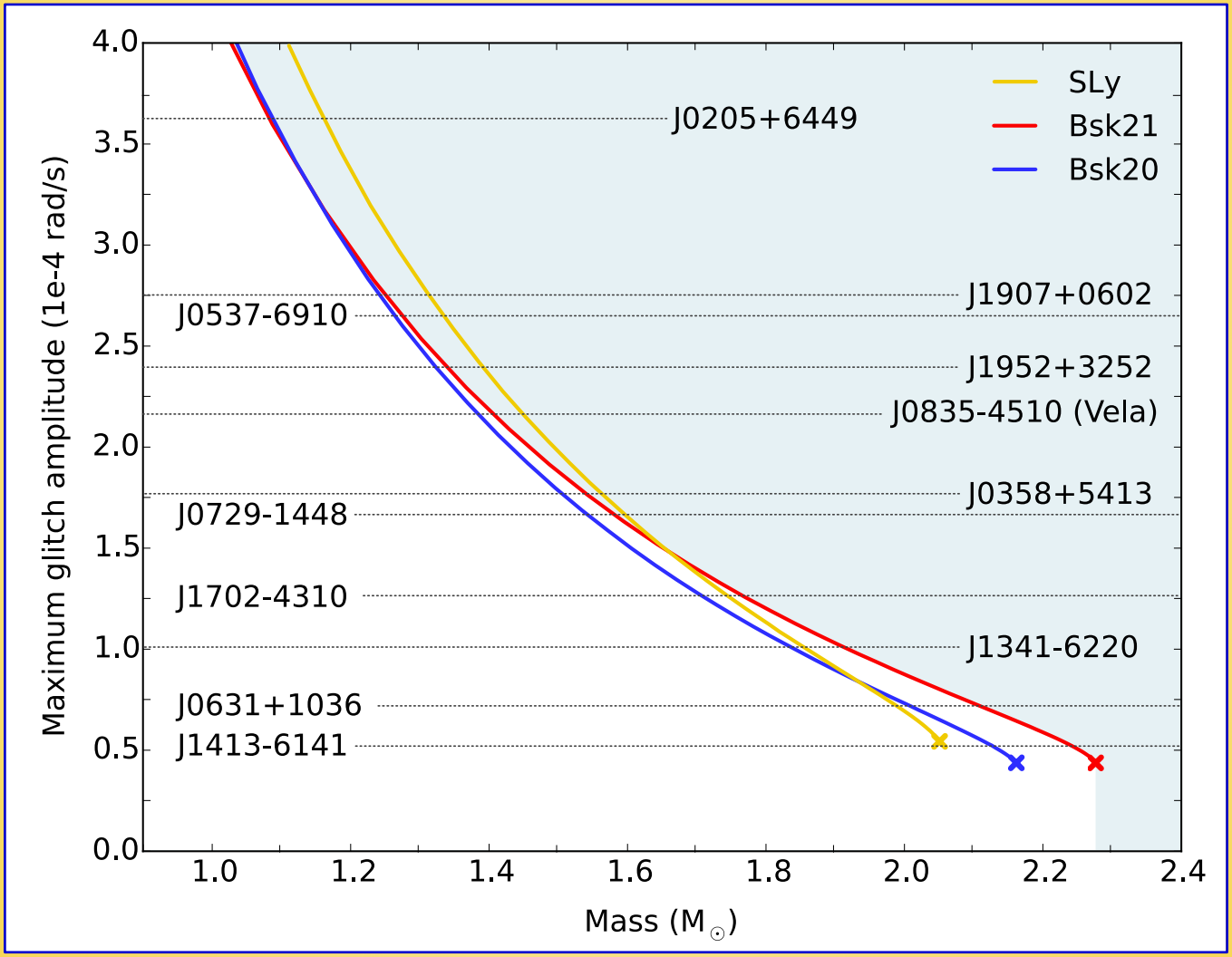
VII - Observations of the *maximum* glitch

$t_{act} = \Delta\Omega / \mathcal{A}$ $\omega^* = |\dot{\Omega}|\, t$

J-name	$\lvert\dot{\Omega}\rvert$ (10^{-4} rad yr^{-1} s^{-1})	$\mathcal{A}_a$ (10^{-4} rad yr^{-1} s^{-1})	$\Delta\Omega$ (10^{-4} rad s^{-1})	$\omega^{\star}_{act}$ (10^{-4} rad s^{-1})	$\omega^{\star}_{pre}$ (10^{-4} rad s^{-1})
J0205+6449	88.97	0.63 ± 0.11	3.63 ± 0.38	508 ± 125	88 ± 20
J0537-6910	394.97	3.41 ± 0.06	2.65 ± 0.25	307 ± 34	-
J0631+1036	2.51	0.04 ± 0.01	0.72	41 ± 11	2.91 ± 0.03
J0835-4510	31.07	0.50 ± 0.01	2.17	134 ± 2	101
J1048-5832	12.49	0.22 ± 0.03	1.55	86 ± 11	28.1 ± 0.4
J1105-6107	7.86	0.12 ± 0.03	0.97 ± 0.01	62 ± 10	21.3 ± 3.23
J1341-6220	13.43	0.22 ± 0.02	1.00	59 ± 4	12.5 ± 1.3
J1413-6141	8.10	0.13 ± 0.02	0.53	32 ± 3	25.8 ± 0.9
J1420-6048	35.47	0.47 ± 0.03	1.86 ± 0.01	138 ± 9	112 ± 9
J1709-4429	17.56	0.25 ± 0.05	1.76 ± 0.02	121 ± 14	59 ± 4
J1730-3350	8.65	0.11 ± 0.02	1.44	107 ± 16	97.2 ± 0.7
J1801-2451	16.25	0.28 ± 0.03	1.89	106 ± 8	62.5 ± 0.5
J1803-2137	14.91	0.29 ± 0.03	2.25	116 ± 10	95.8 ± 0.1
J1826-1334	14.49	0.20 ± 0.04	2.22	159 ± 24	19.0 ± 0.1
J1932+2220	5.47	0.25 ± 0.05	1.94	42 ± 7	50 ± 1
J2021+3651	17.63	0.31 ± 0.06	1.57	89 ± 17	24.9
J2229+6114	58.23	0.30 ± 0.05	1.49 ± 0.01	282 ± 45	74.5 ± 0.5

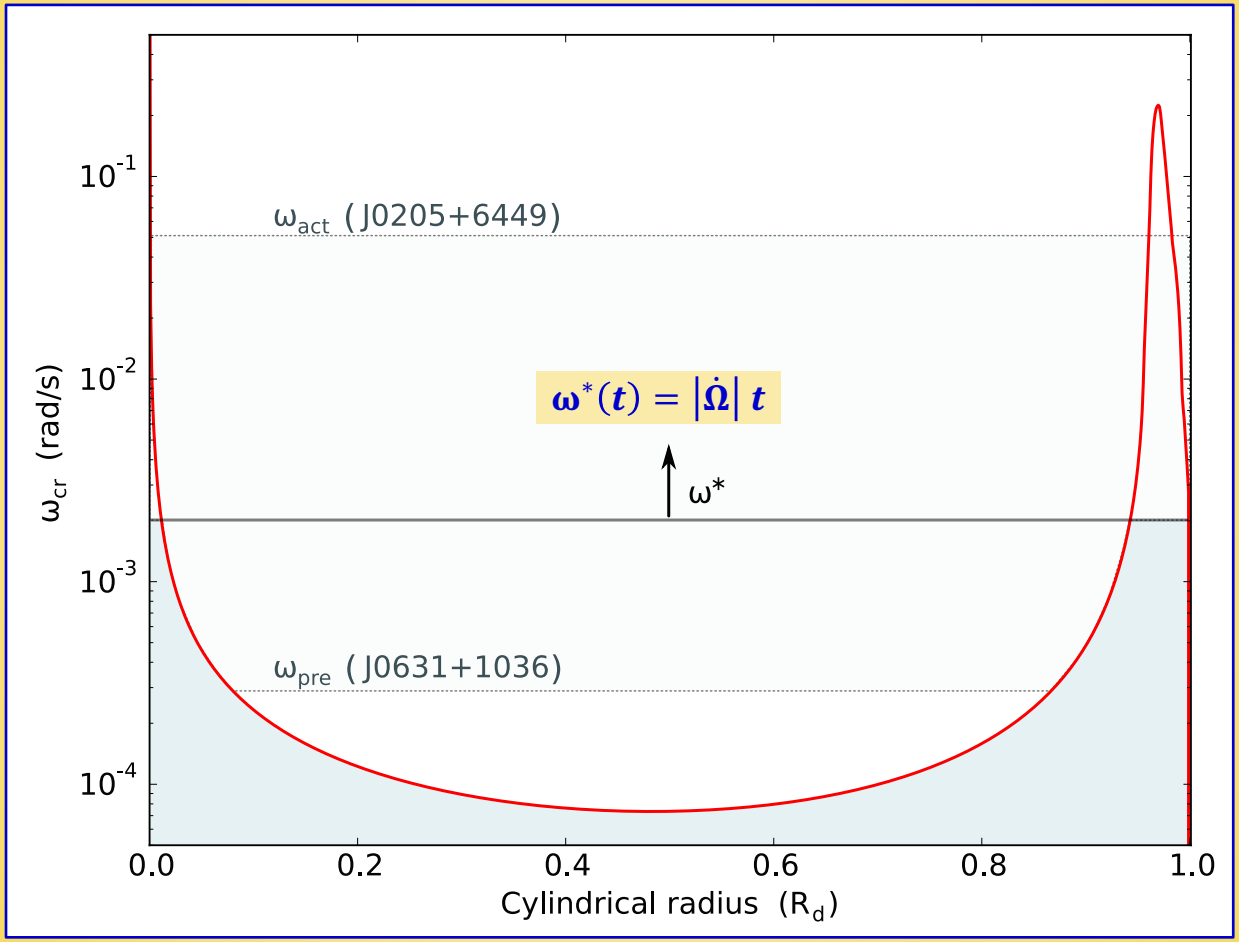
(PMP, Antonelli, Haskell & Seveso, 2017)

VIII - Estimating NS *masses* from observations



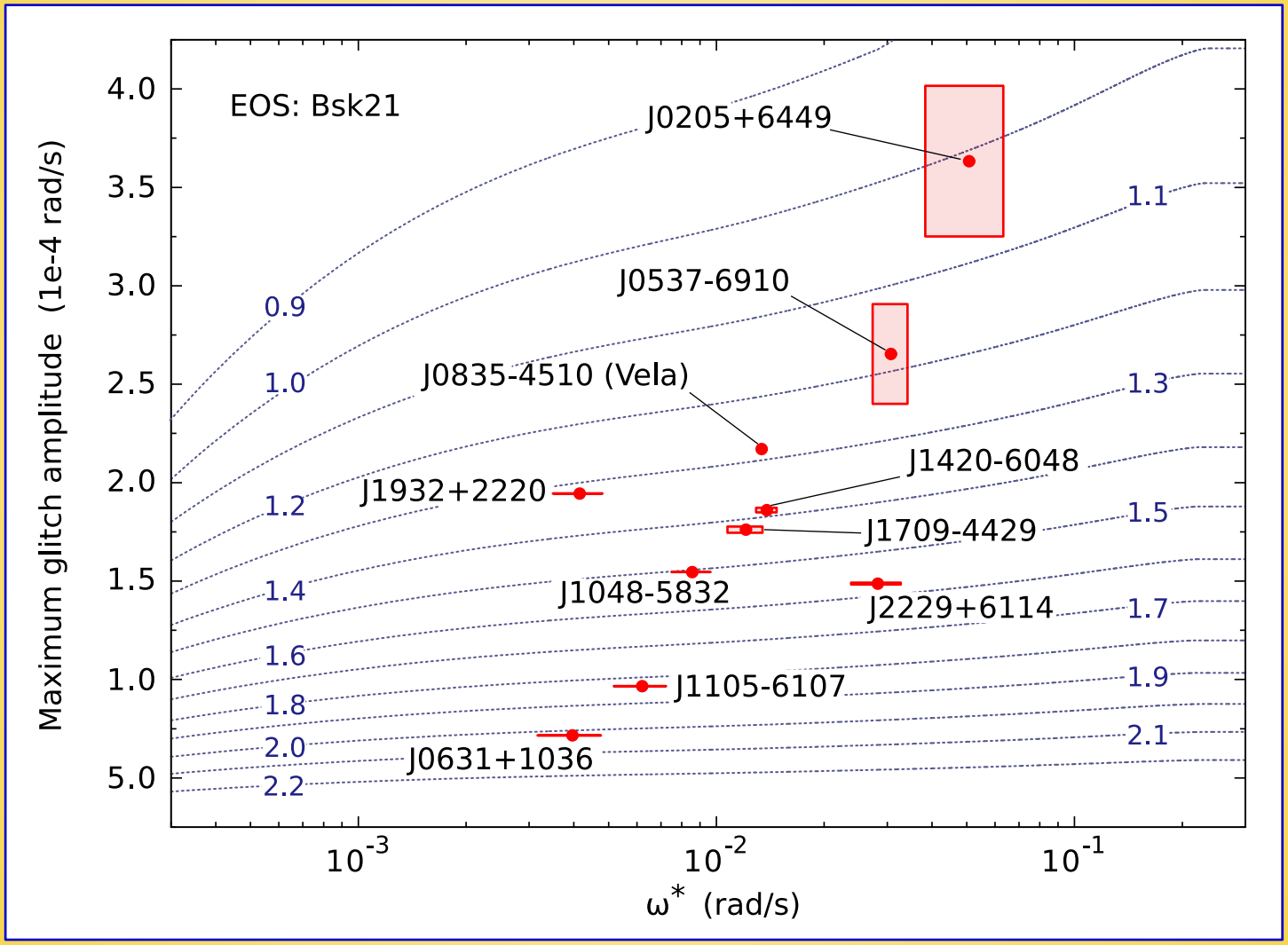
(PMP, Antonelli, Haskell & Seveso, 2017)

VIII - Estimating NS *masses* from observations



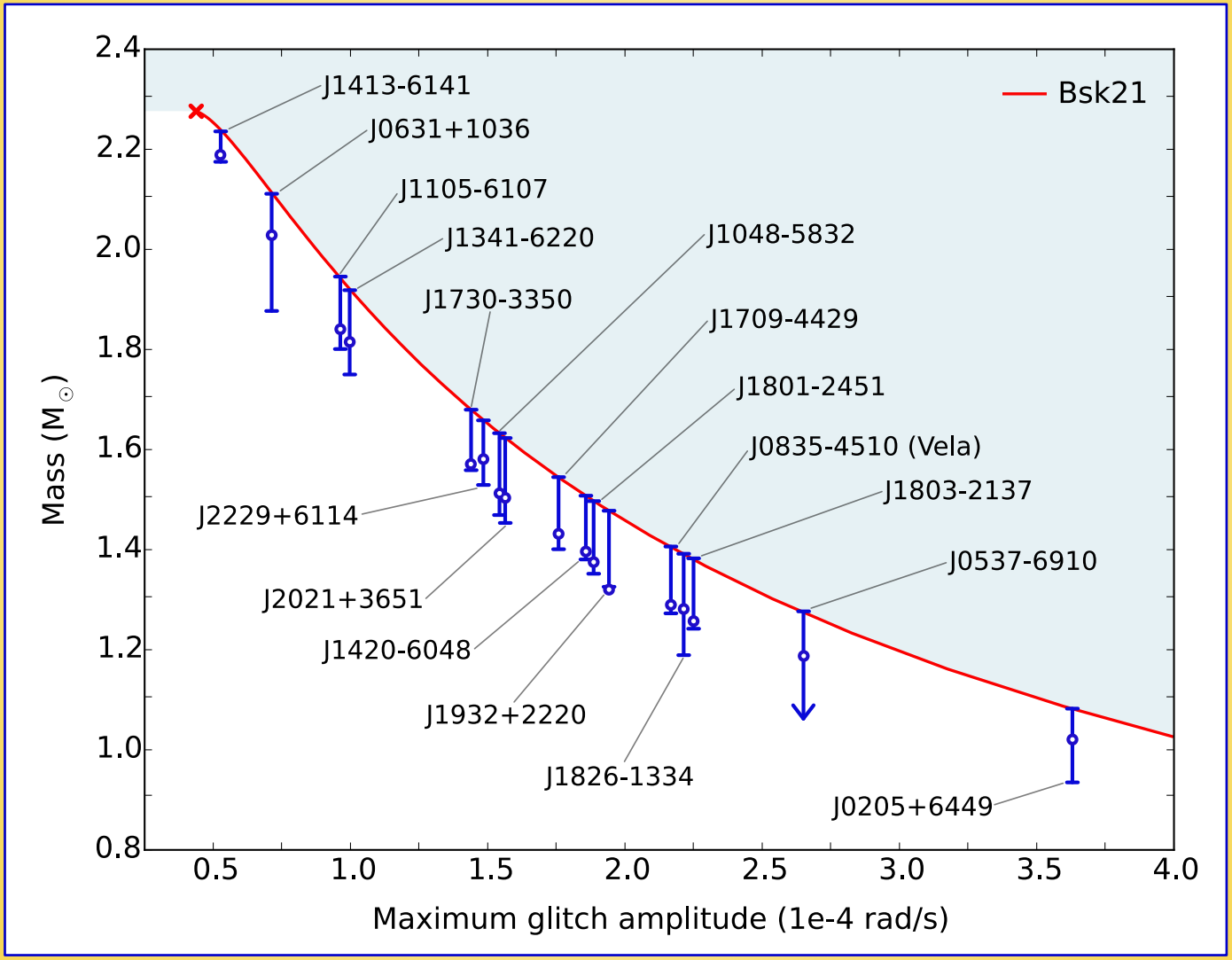
(PMP, Antonelli, Haskell & Seveso, 2017)

VIII - Estimating NS *masses* from observations



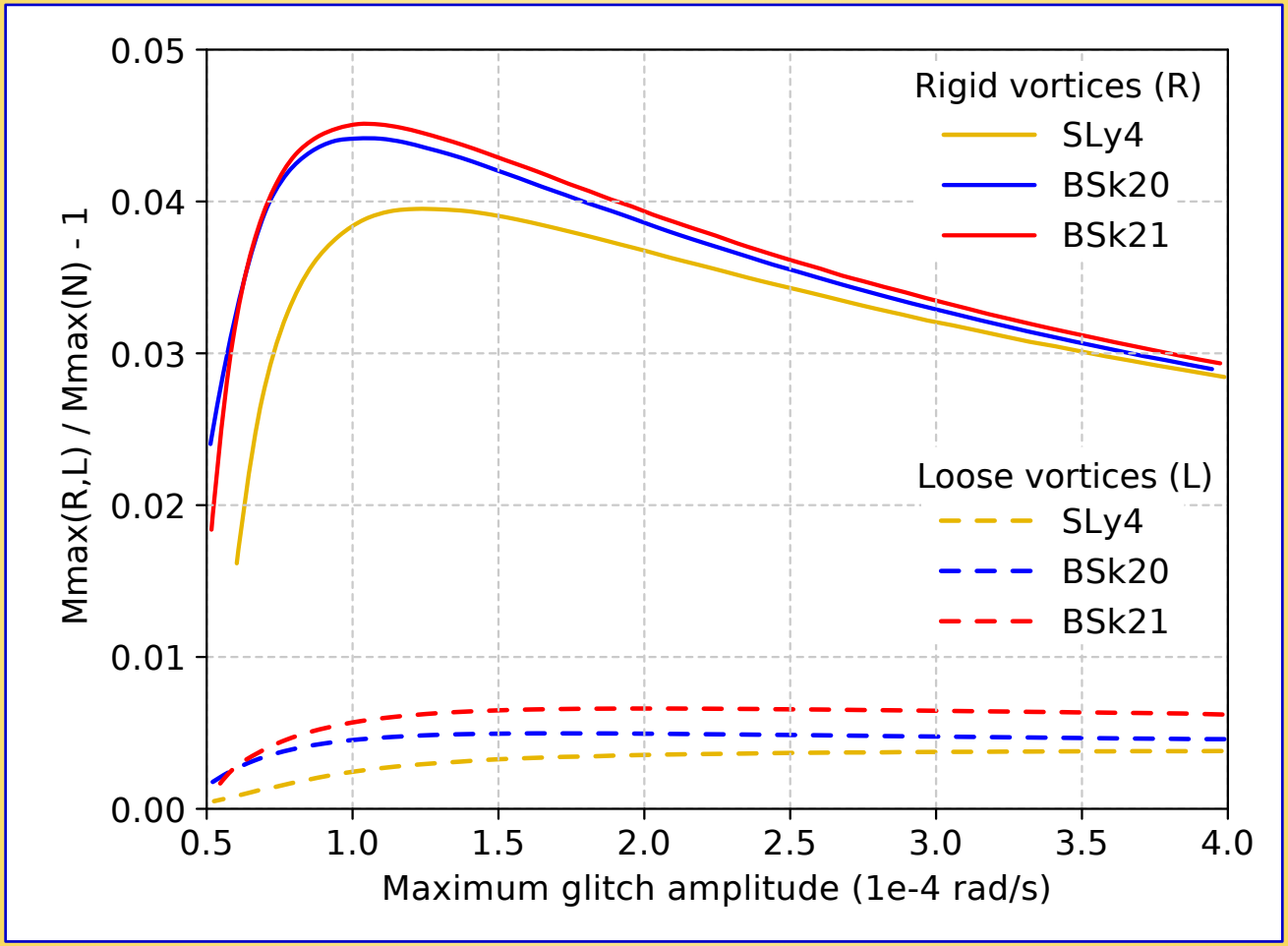
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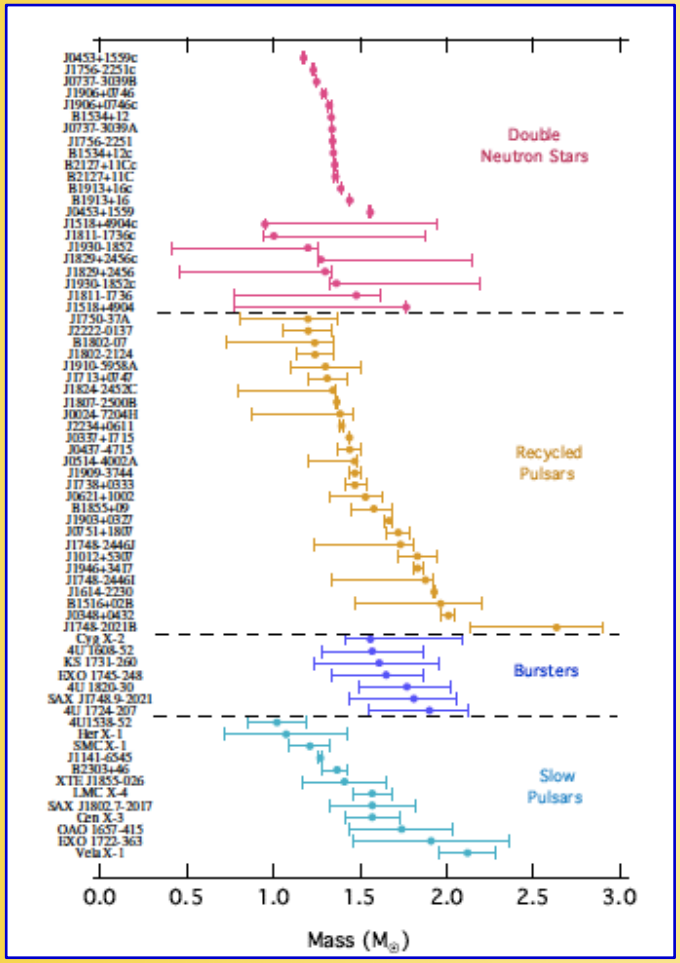
(PMP, Antonelli, Haskell & Seveso, 2017)

VIII - Estimating NS *masses* from observations

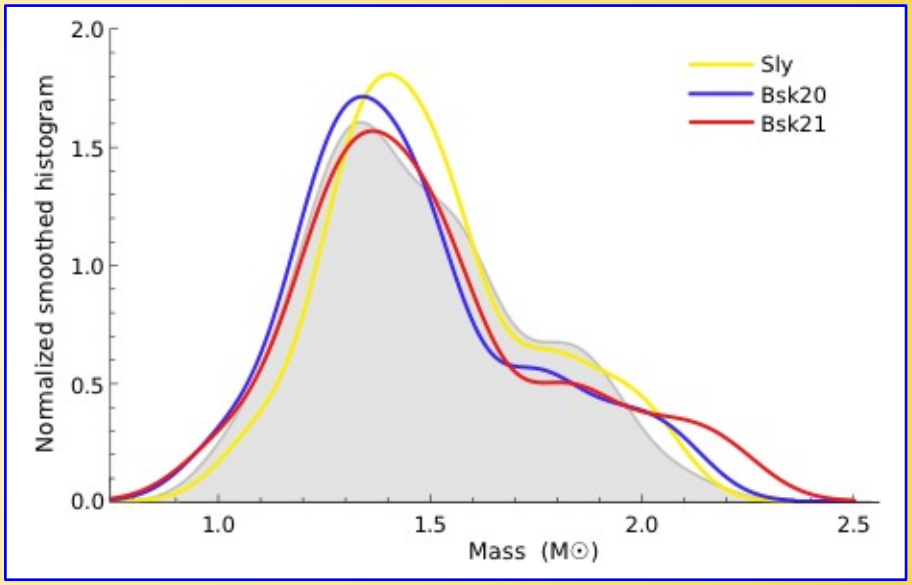


(Antonelli, Montoli & PMP, 2018)

VIII - Estimating NS *masses* from observations



(Özel & Freire, 2016)



(Antonelli, Gherardi & PMP, in progress)


comp
star
PHAROS
THE MULTI-MESSENGER
PHYSICS AND ASTROPHYSICS
OF NEUTRON STARS