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The Moment of Inertia of the Binary Pulsar J0737-3039A: Constraining the Nuclear Equation of State

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The Binary Pulsar J0737-3039

	$P_{\rm orb}$(h)	e	M_A	M_B	P_A(ms)
PSR J0737-3039	2.45	0.088	1.34	1.25	22.7
PSR 1913+16	7.75	0.617	1.44	1.39	59

[Burgay *et.al.*, 2003; Lyne *et.al.*, 2004]

- Know orbital angular momentum L
- Know spin Ω of A

$\Longrightarrow$ Measure spin-orbit coupling (relativistic deviation from Newtonian orbit; probably measurable within next few years)

$\Longrightarrow$ Measure spin angular momentum $S = I\Omega$ of primary A

$\Longrightarrow$ Measure moment of inertia I

- But: for given M_A and Ω_A, I function of Equation of State (EoS) only

$\Longrightarrow$ Measurement of I provides constraint on EoS

Given measurement of I to within 10%, say, can we distinguish different nuclear EoSs or classes of EoSs?

Nuclear Equations of State

- Class I
  - Non-relativistic many-body calculations
  - 'Realistic' models of two- and three-nucleon interactions
  - APR [Akmal *et.al.*, 1998] ; FPS [Lorenz *et.al.*, 1993]

- Class II
  - Relativistic mean-field approximations
  - MS1 [Muller & Serot, 1996] ; GM3 [Glendenning & Moszkowski, 1991]

- Class III
  - Strange quark matter
  - SQM1, SQM3 [Prakash *et.al.*, 1995]

Models of Rotating Stars

- Construct numerical models of rotating neutron stars with $M = M_A$ and $\Omega = \Omega_A$
  - Solve PDEs...
  - But

$$\frac{\Omega}{\Omega_{\rm max}} < 0.0035$$

where $\Omega_{\rm max} \approx (GM/R^3)^{1/2}$

$\Longrightarrow$ Stars very close to being spherical

- Can account for rotation to first order in Ω
  - Neglect deformation [Hartle, 1967]
  - Solve ODEs...
  - Error ($\sim 0.1\%$) smaller than that resulting from interpolations in EoS

Results for J0737-3039A...

Class	EOS	$M_{\rm max}/M_\odot$	J	I	I/MR^2	ρ_c	$M_0/M_\odot$	$M_0^c/M_\odot$	R	GM/c^2R
I	APR	2.20	3.42	1.24	0.348	9.61	1.47	1.37	11.56	0.1707
	FPS	1.80	3.14	1.14	0.358	12.1	1.48	1.37	10.92	0.1809
II	MS1	1.82	4.61	1.66	0.326	6.81	1.45	1.34	13.87	0.1424
	GM3	1.56	4.14	1.49	0.325	9.10	1.46	1.35	13.12	0.1502
III	SQM1	1.56	2.72	0.982	0.474	15.1	1.55	1.44	8.830	0.2236
	SQM3	1.99	3.91	1.41	0.459	7.00	1.50	1.40	10.76	0.1836

- J in units of 10^{47}g cm^{2}s^{-1}
- I in units of 10^{45}g cm^2
- ρ_c in units of 10^{14}g cm^{-3}
- R in units of km

$\Longrightarrow$ Measurement of I to within 10%...

- ...could distinguish classes I and II
- ...could constrain free parameters in class III