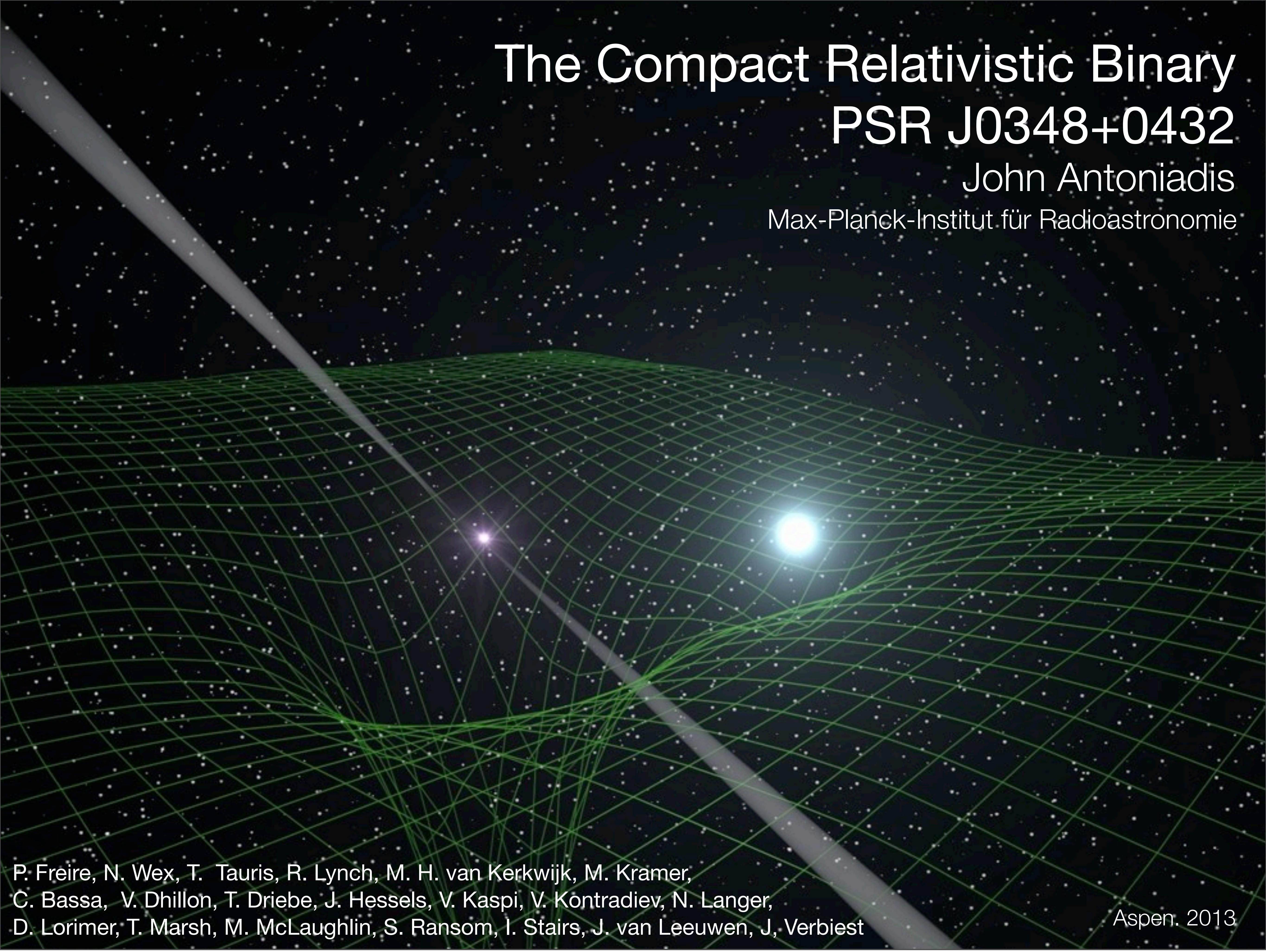


The Compact Relativistic Binary PSR J0348+0432

John Antoniadis
Max-Planck-Institut für Radioastronomie

P. Freire, N. Wex, T. Tauris, R. Lynch, M. H. van Kerkwijk, M. Kramer, C. Bassa, V. Dhillon, T. Driebe, J. Hessels, V. Kaspi, V. Kontradiev, N. Langer, D. Lorimer, T. Marsh, M. McLaughlin, S. Ransom, I. Stairs, J. van Leeuwen, J, Verbiest

Aspen. 2013

PSR J0348+0432

Discovery & Properties

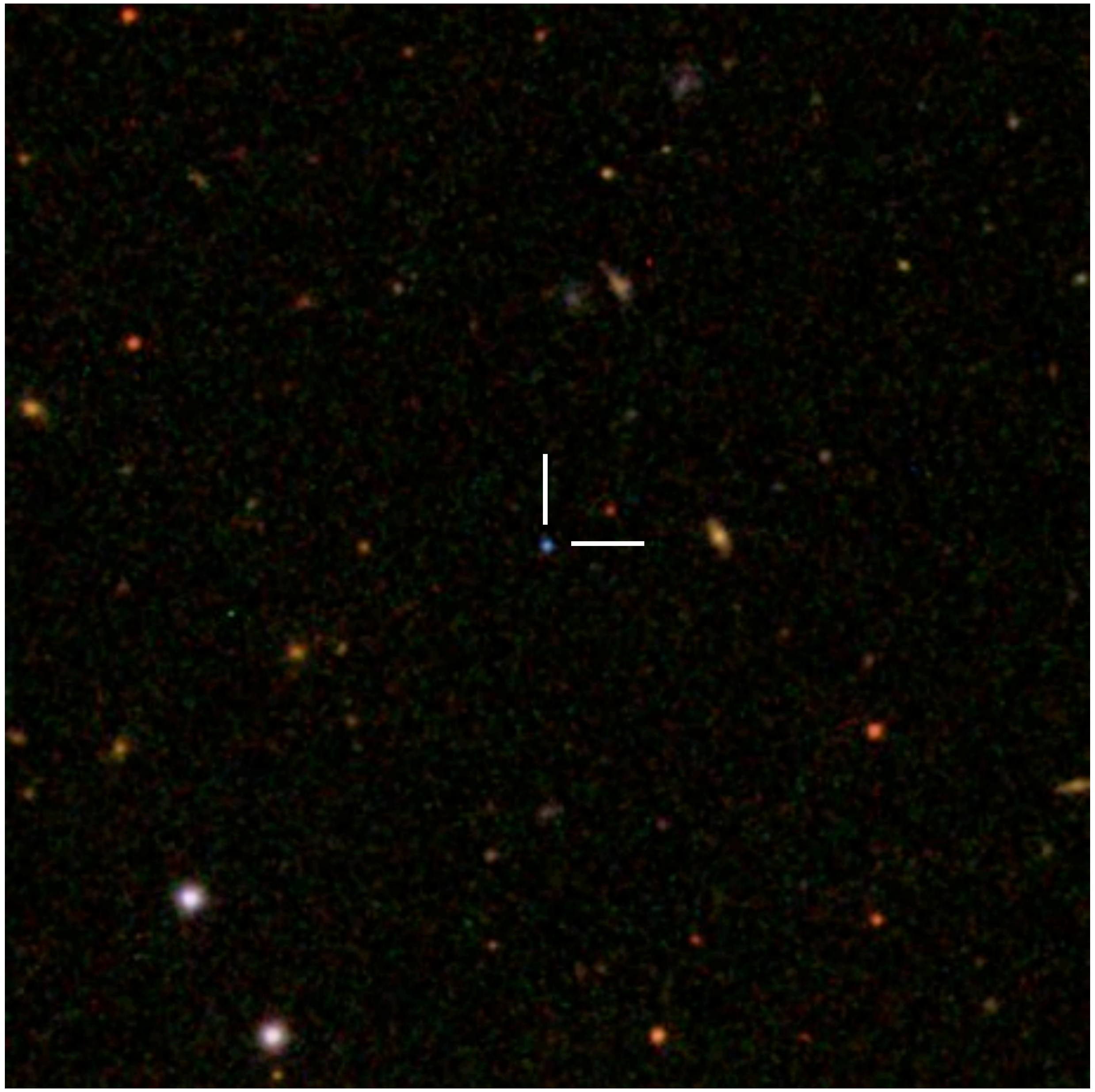
A Recent GBT Pulsar Discovery

$P_{\rm spin} \sim 39\,{\rm ms}$

$P_{\rm b} \sim 2.46\,{\rm h}$

$M_{\rm c} \geq 0.08\,{\rm M}_{\odot}$

Discovery & basic parameters:
Lynch *et al. ApJ*, V. 763, p. 81 (2013)
Astro-ph:1209:4296



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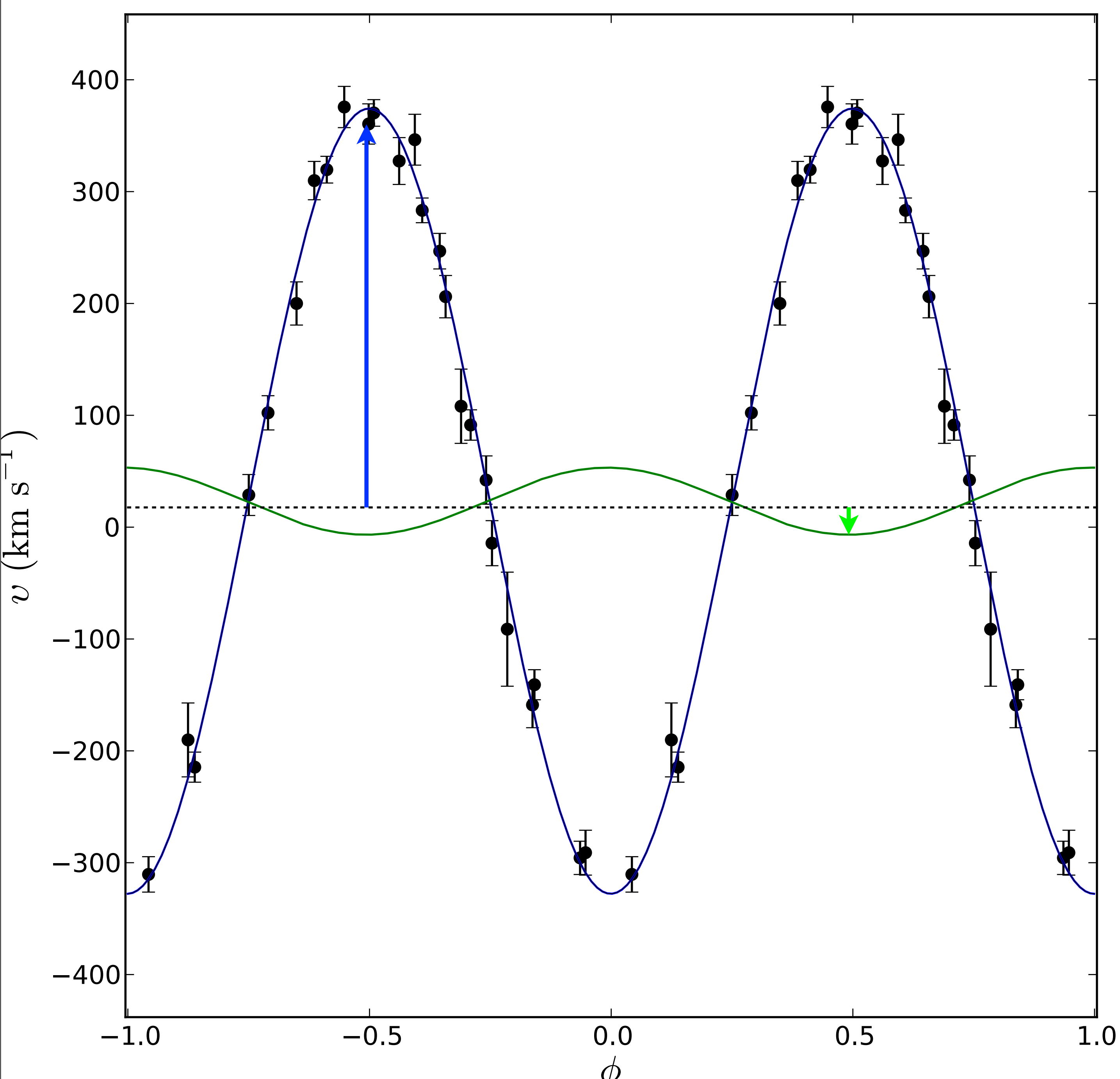
Optical Observations

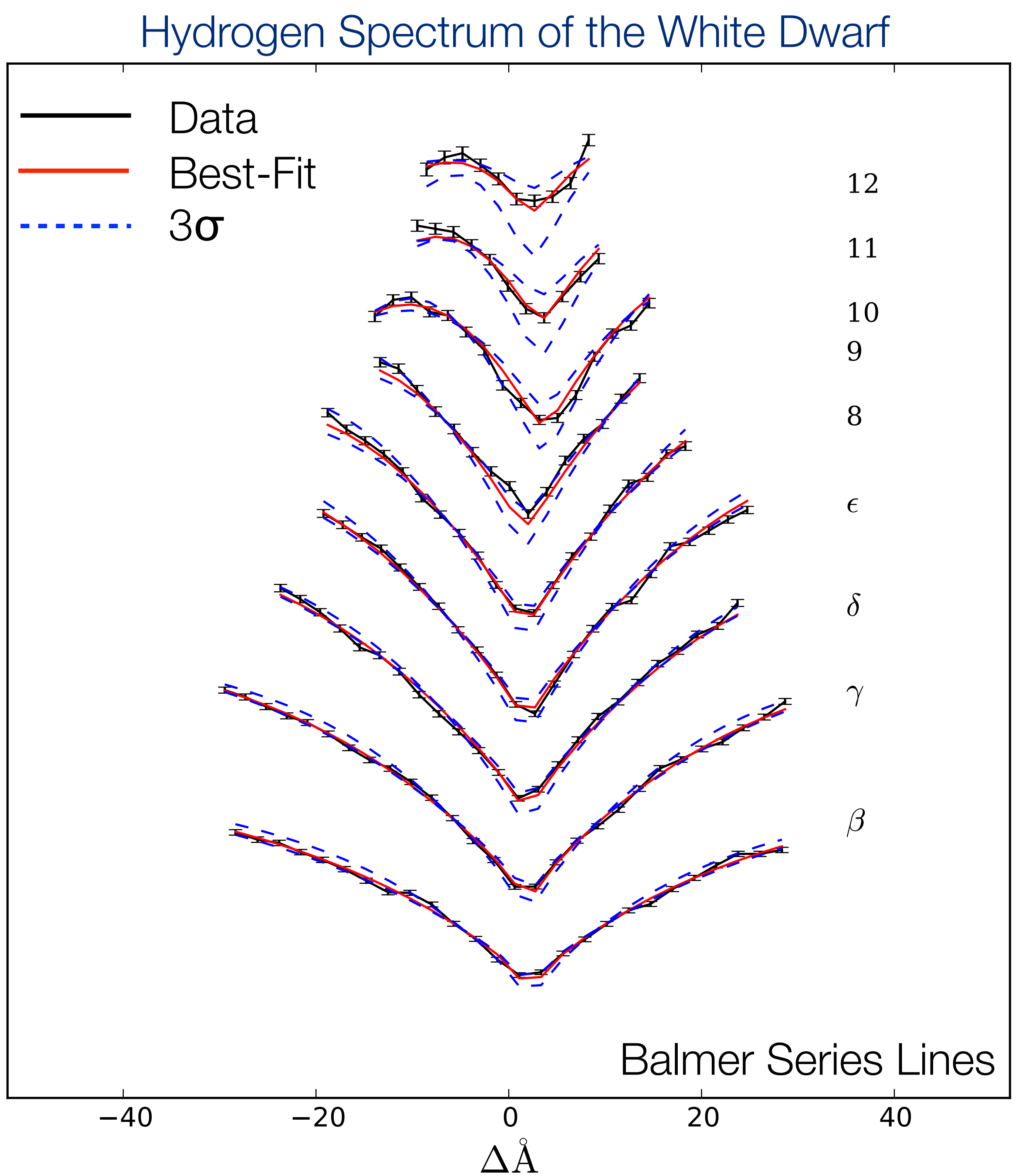


$$K_{\rm WD} = 351 \pm 4\,{\rm km\,s^{-1}}$$

$$K_{\rm PSR} = 30.008235 \pm 0.00016\,{\rm km\,s^{-1}}$$

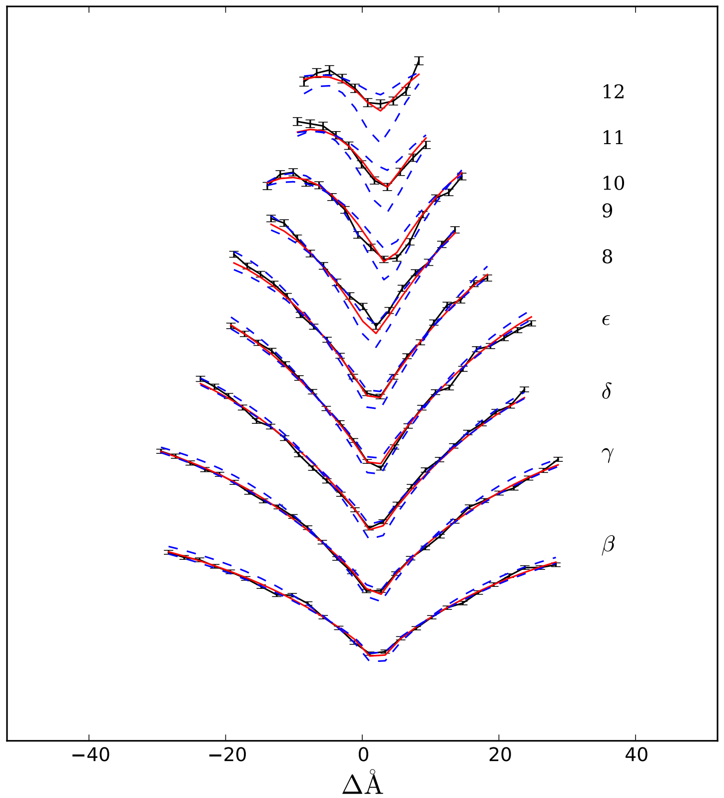
$$q \equiv M_{\rm PSR}/M_{\rm WD} = K_{\rm WD}/K_{\rm PSR}$$
$$= 11.70 \pm 0.13$$

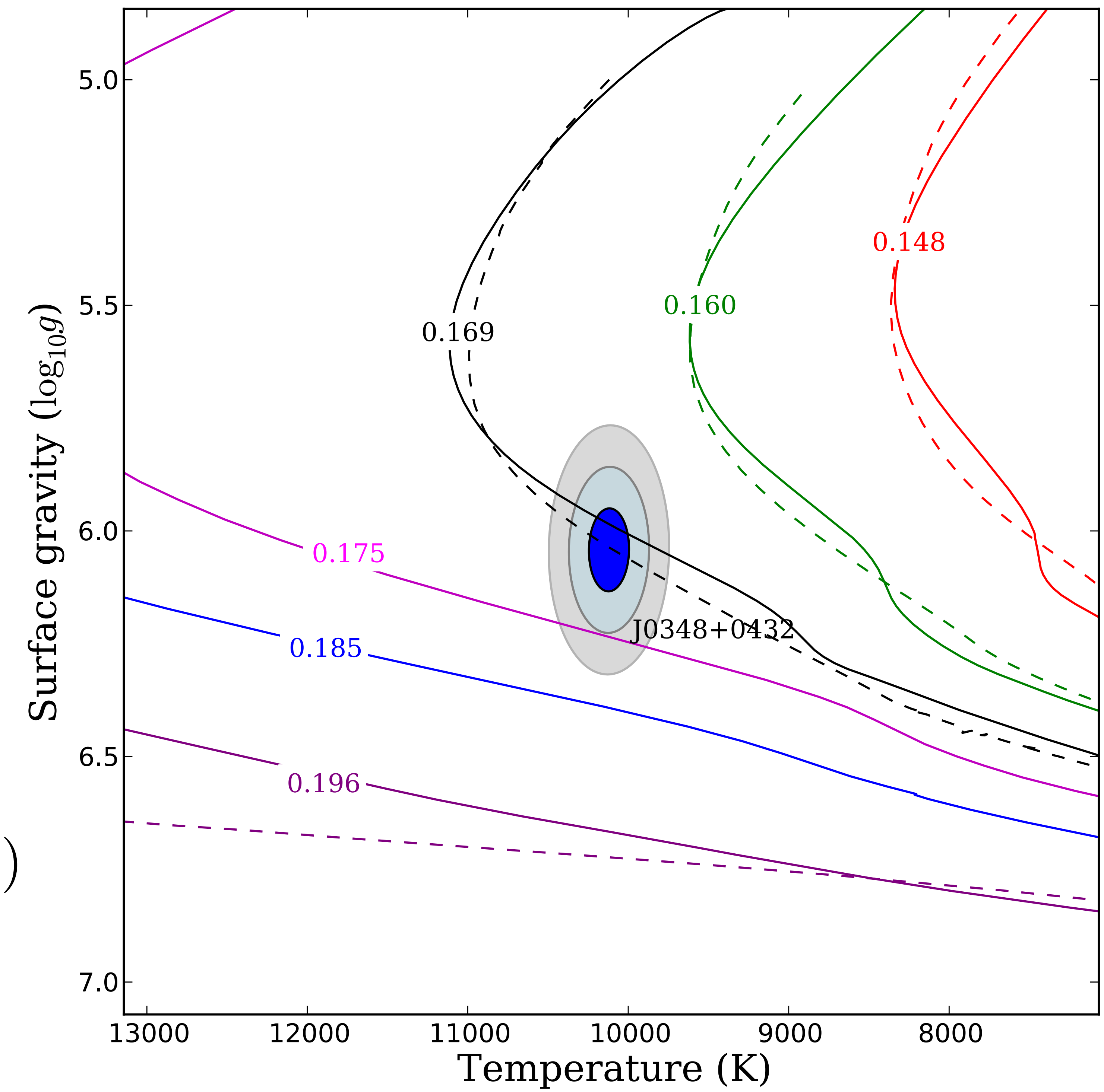
PSR J0348+0432
Optical Observations



PSR J0348+0432

Results (1)



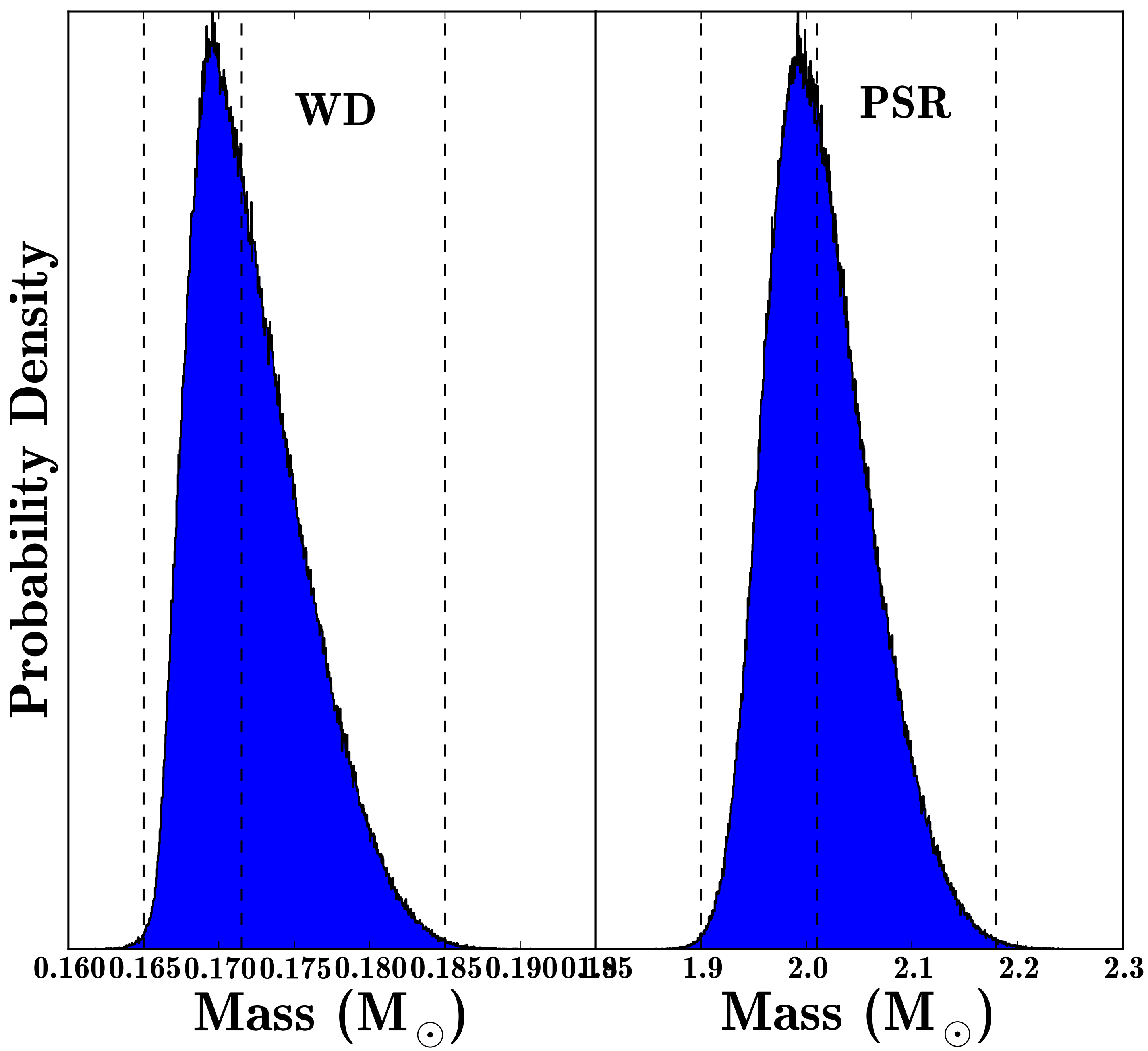


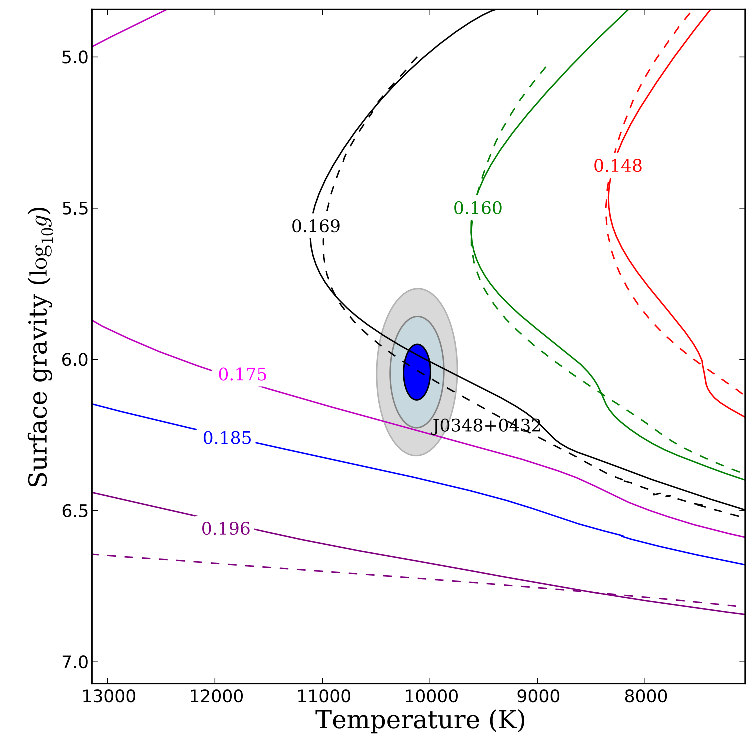
$$T_{\text{eff}} = (10130 \pm 30_{\text{stat}} \pm 65_{\text{sys}})\,\text{K}$$

$$\log g = (6.045 \pm 0.032_{\text{stat}} \pm 0.065_{\text{sys}})$$

PSR J0348+0432

Results (1)





$$M_{\rm WD} = 0.172 \pm 0.003\,{\rm M}_\odot$$

$$0.165 - 0.185\,{\rm M}_\odot\ (99.72\%\ {\rm C.L.})$$

$$M_{\rm PSR} = 2.01 \pm 0.04\,{\rm M}_\odot$$

$$1.90 - 2.15\,{\rm M}_\odot\ (99.72\%\ {\rm C.L.})$$

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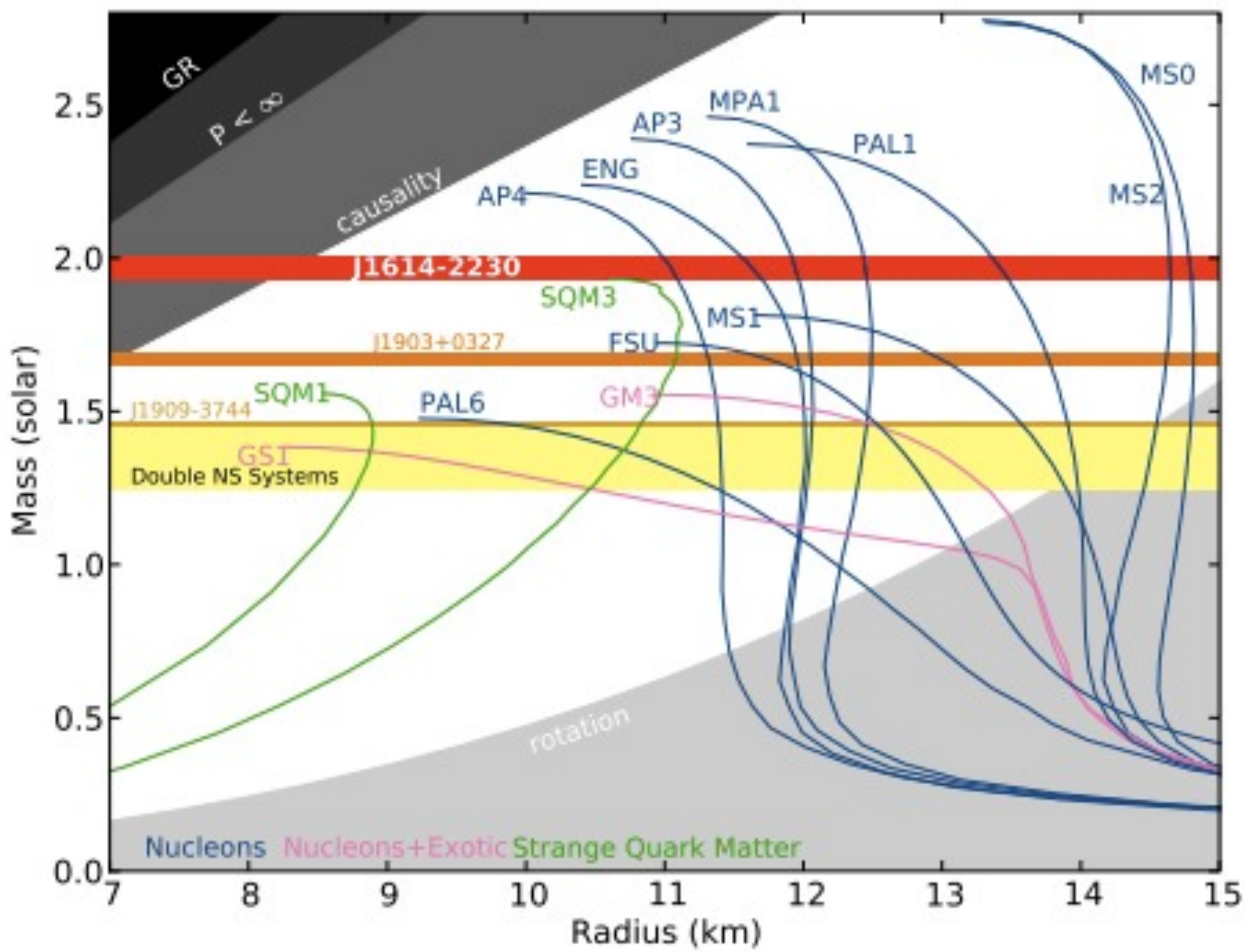
PSR J0348+0432
Results (1)

* Only the second NS with a precisely determined mass ~ 2 solar masses
* Independent method
* Relevant for EOS (Demorest *et al.* 2010)



PSR J0348+0432

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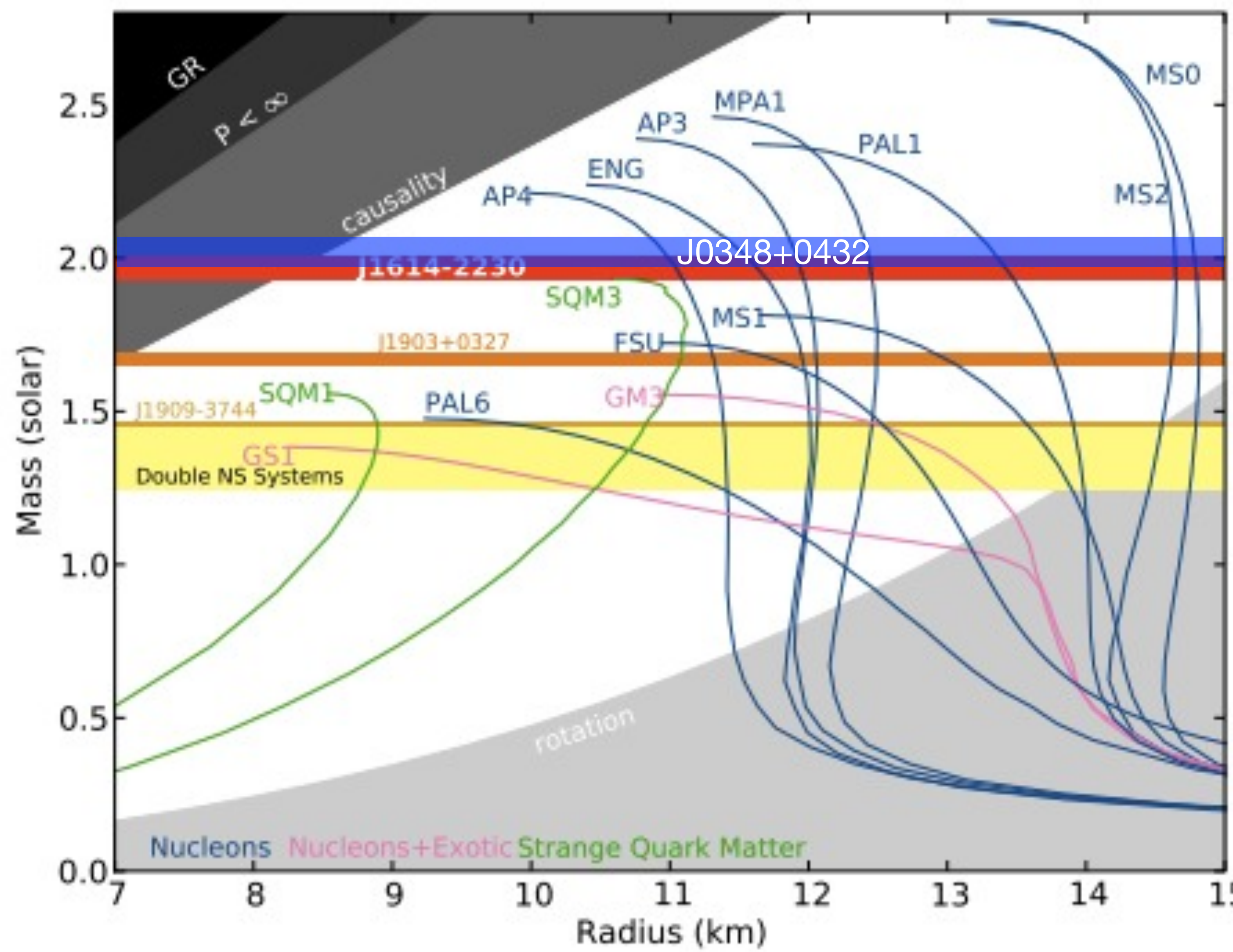

PSR J0348+0432

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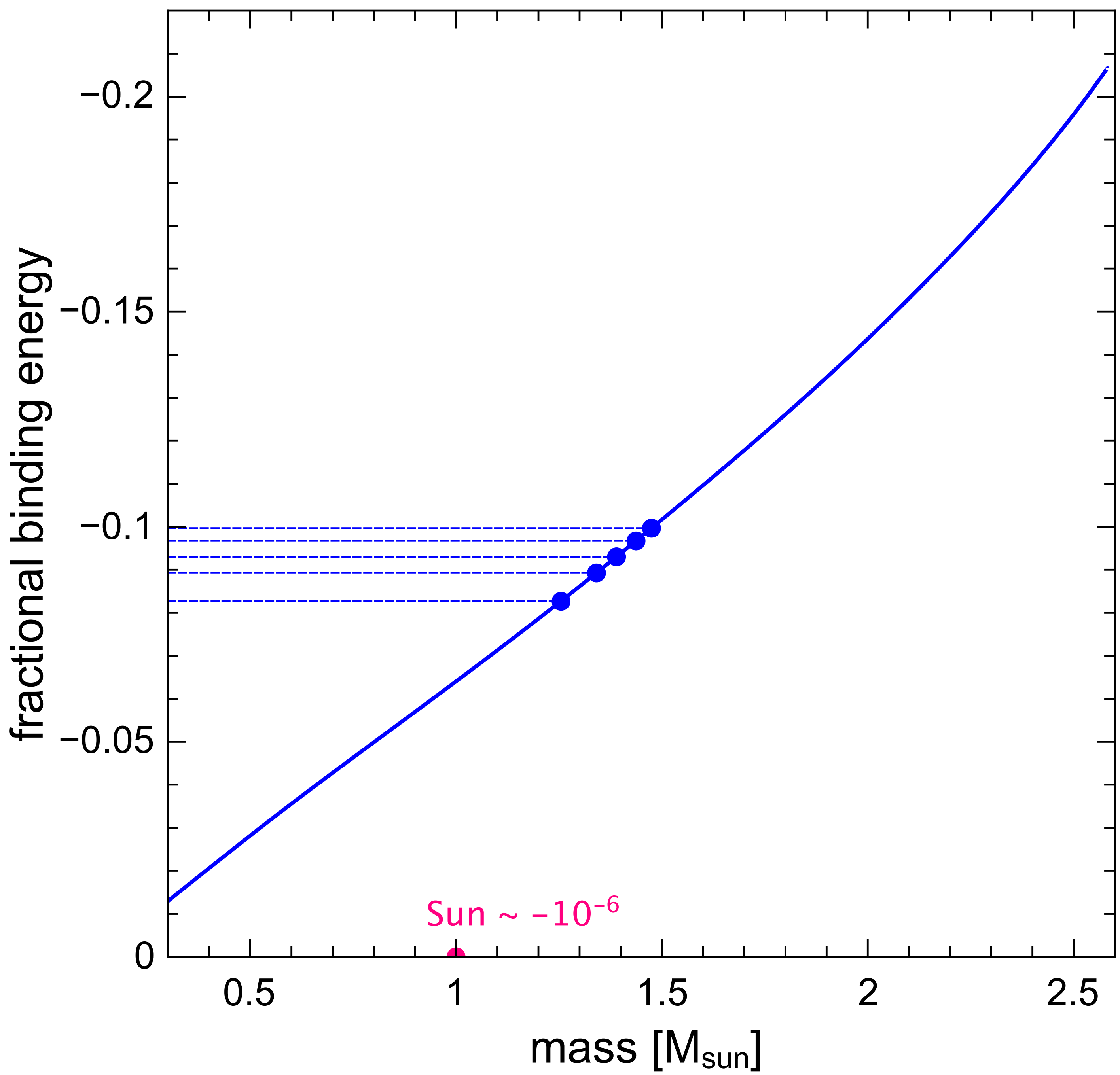

PSR J0348+0432

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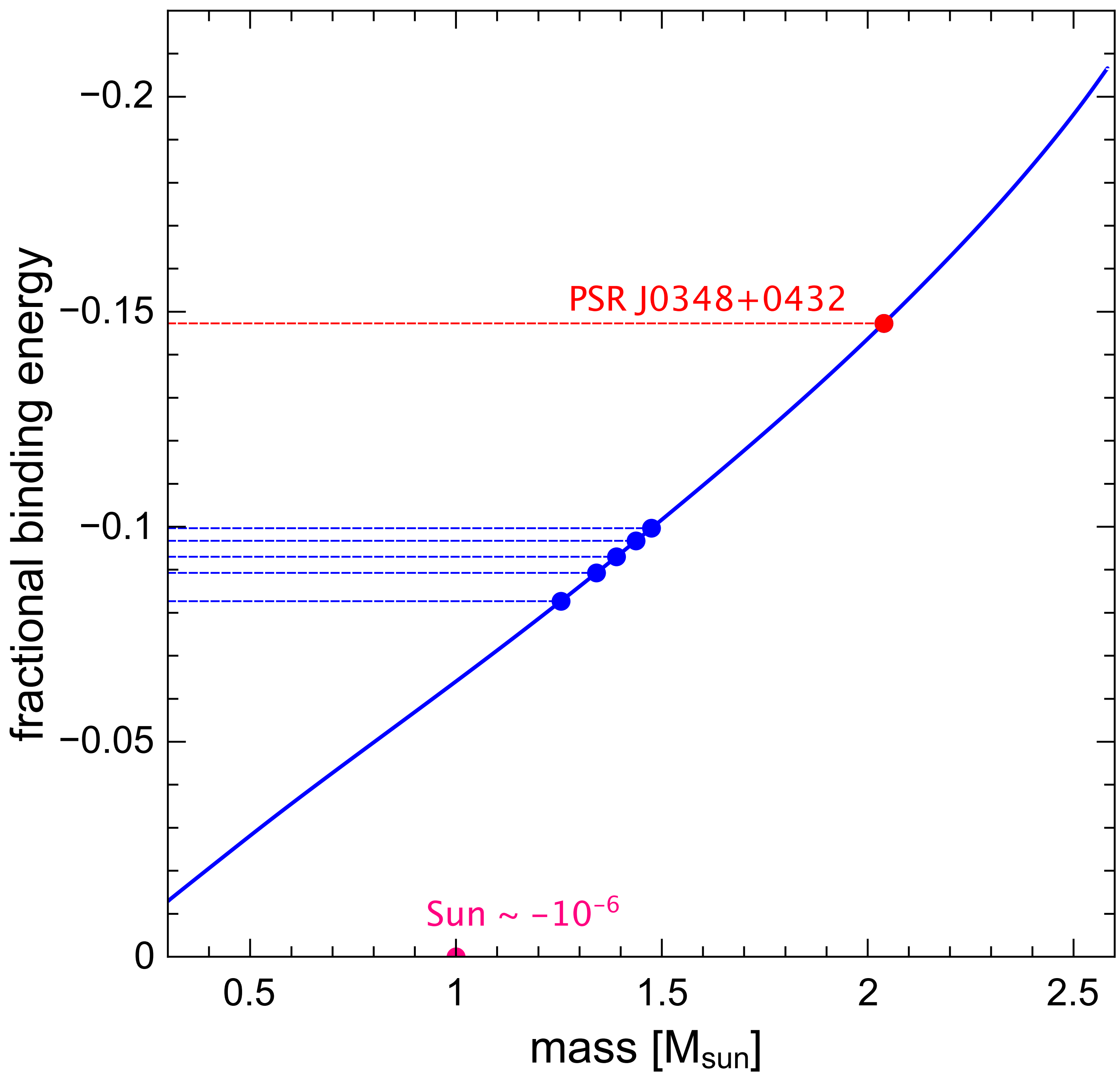

PSR J0348+0432

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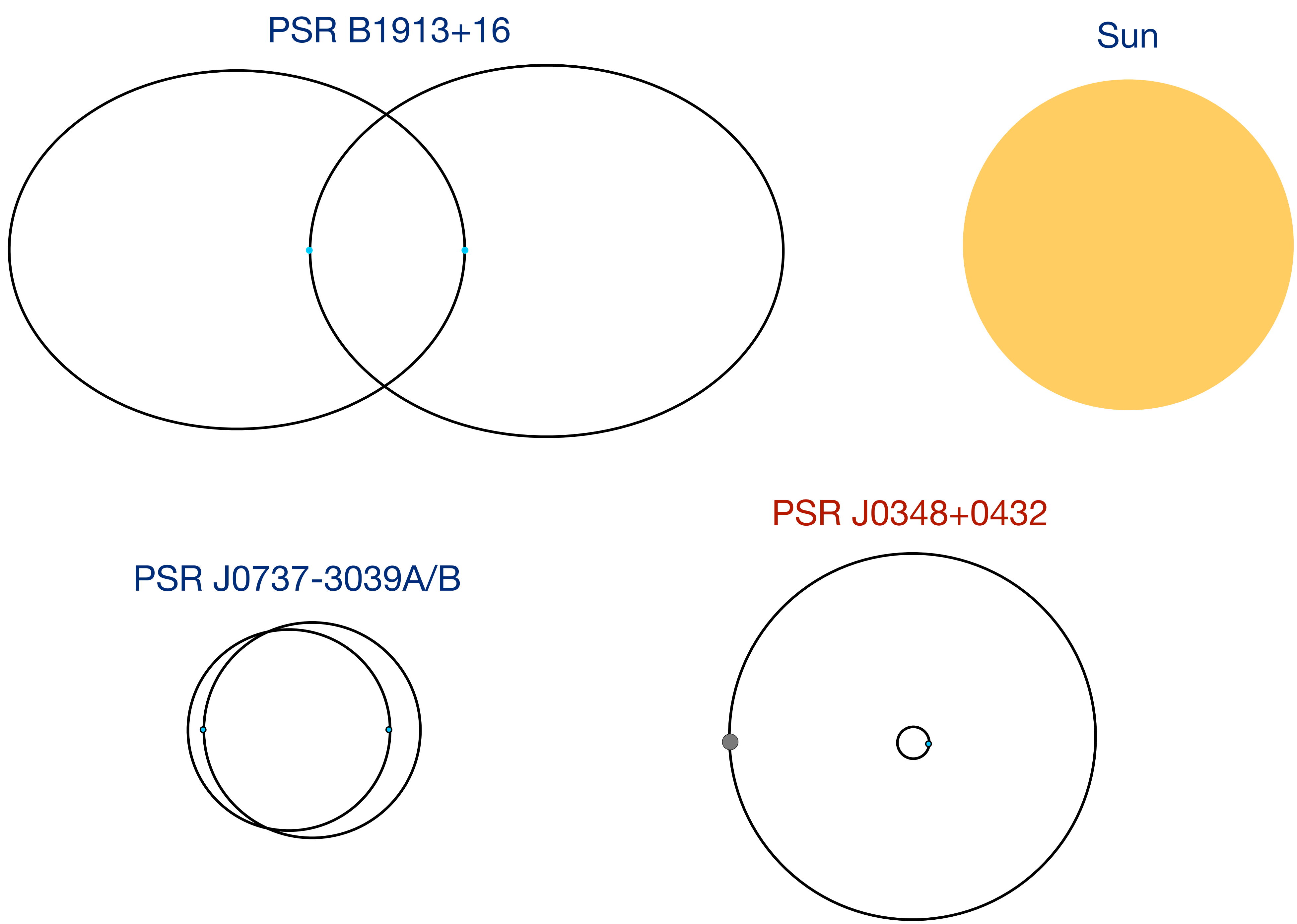

PSR J0348+0432

Radio Observations

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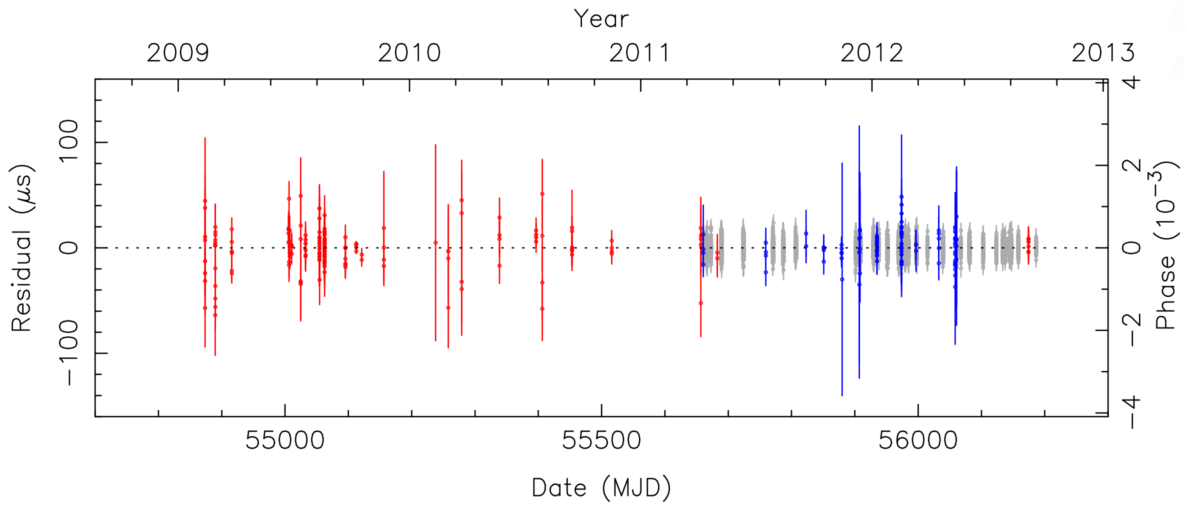
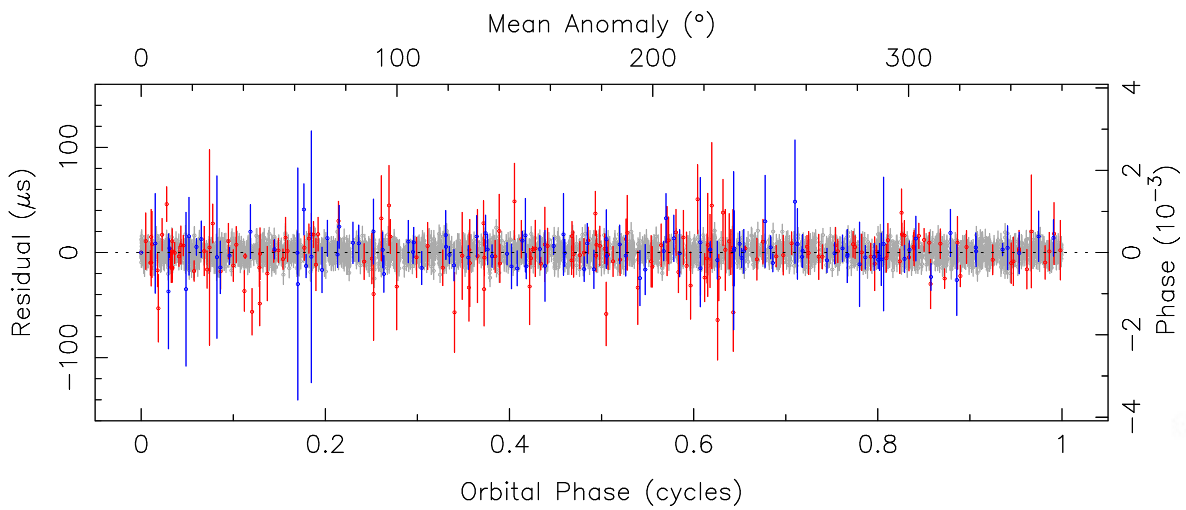
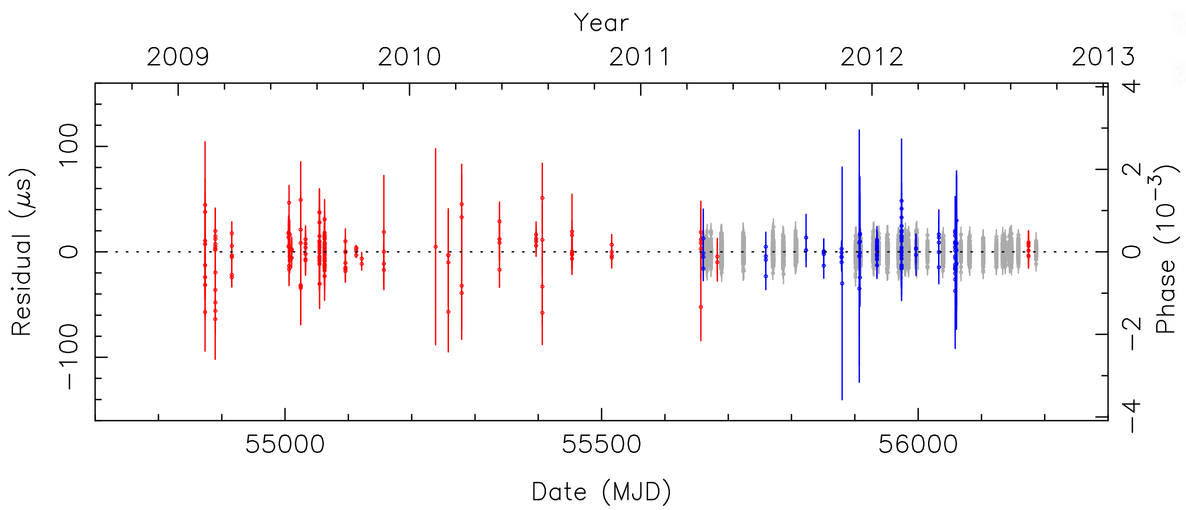


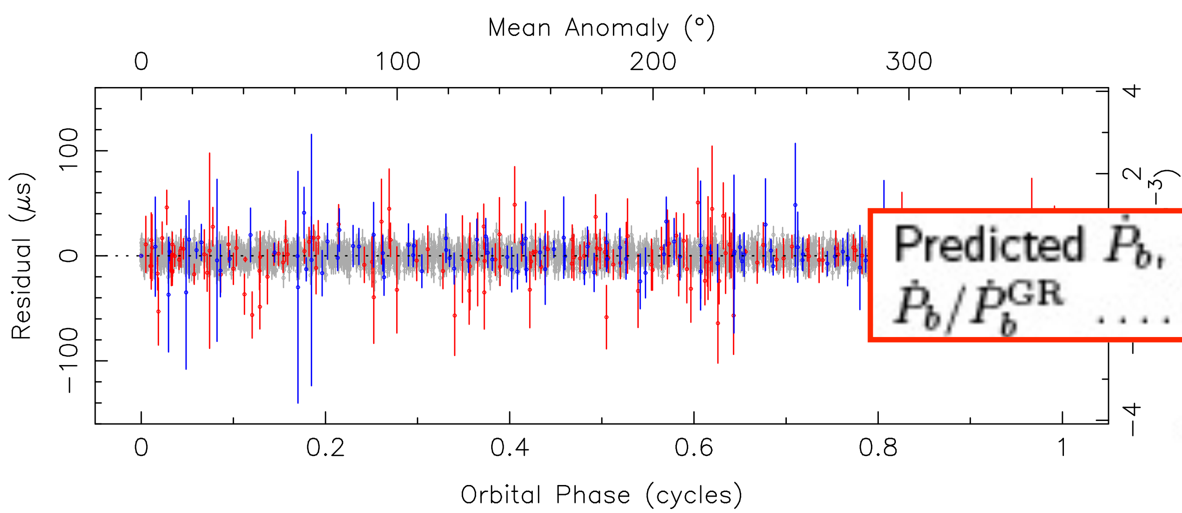


Derived Parameters	
Galactic Longitude, l	$183^\circ\!.3368$
Galactic Latitude, b	$-36^\circ\!.7736$
Distance, d (kpc)	2.1
Total Proper Motion, μ (mas yr^{-1})	5.4(4)
Spin Period, P (ms)	39.1226569017805(5)
First Derivative of Spin Period, $\dot{P}$ (10^{-18}s s^{-1})	0.24073(4)
Characteristic Age, τ_c (Gyr)	2.6
Transverse magnetic field at the poles, B_0 (10^9G)	3.1
Rate or rotational energy loss, $\dot{E}$ (10^{32} erg s^{-1})	1.6
Mass Function, f ($M_\odot$)	0.000286778(4)
Mass ratio, $q \equiv M_{\rm PSR}/M_{\rm WD}$	11.70(13)
Orbital inclination, i (°)	40.1(6)
Pulsar Mass, $M_{\rm PSR}$ ($M_\odot$)	$2.03^{+0.03}_{-0.03}$
Total Mass of Binary, $M_{\rm T}$ ($M_\odot$)	$2.20^{+0.03}_{-0.03}$
Predicted $\dot{P}_b$, $\dot{P}_b^{\rm GR}$ (10^{-12} s^{-1})	$-0.262(8)$
$\dot{P}_b/\dot{P}_b^{\rm GR}$	1.06 ± 0.17
Time until coalescence, τ_m (Gyr)	~ 0.4

PSR J0348+0432

Radio Observations





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Orbital inclination, i (°)	40.1(6)
Pulsar Mass, M_{PSR} ($M_\odot$)	$2.03^{+0.03}_{-0.03}$
	$^{+0.03}_{-0.03}$
	62(8)
$\dot{P}_b/\dot{P}_b^{GR}$	1.06 ± 0.17
Time until coalescence, τ_m (Gyr)	∼ 0.4

Predicted $\dot{P}_b$, $\dot{P}_b^{GR}$ (10^{-12} s s^{-1})	−0.262(8)
$\dot{P}_b/\dot{P}_b^{GR}$	1.06 ± 0.17

Thursday, January 24, 2013

Max-Planck-Institut für Radioastronomie

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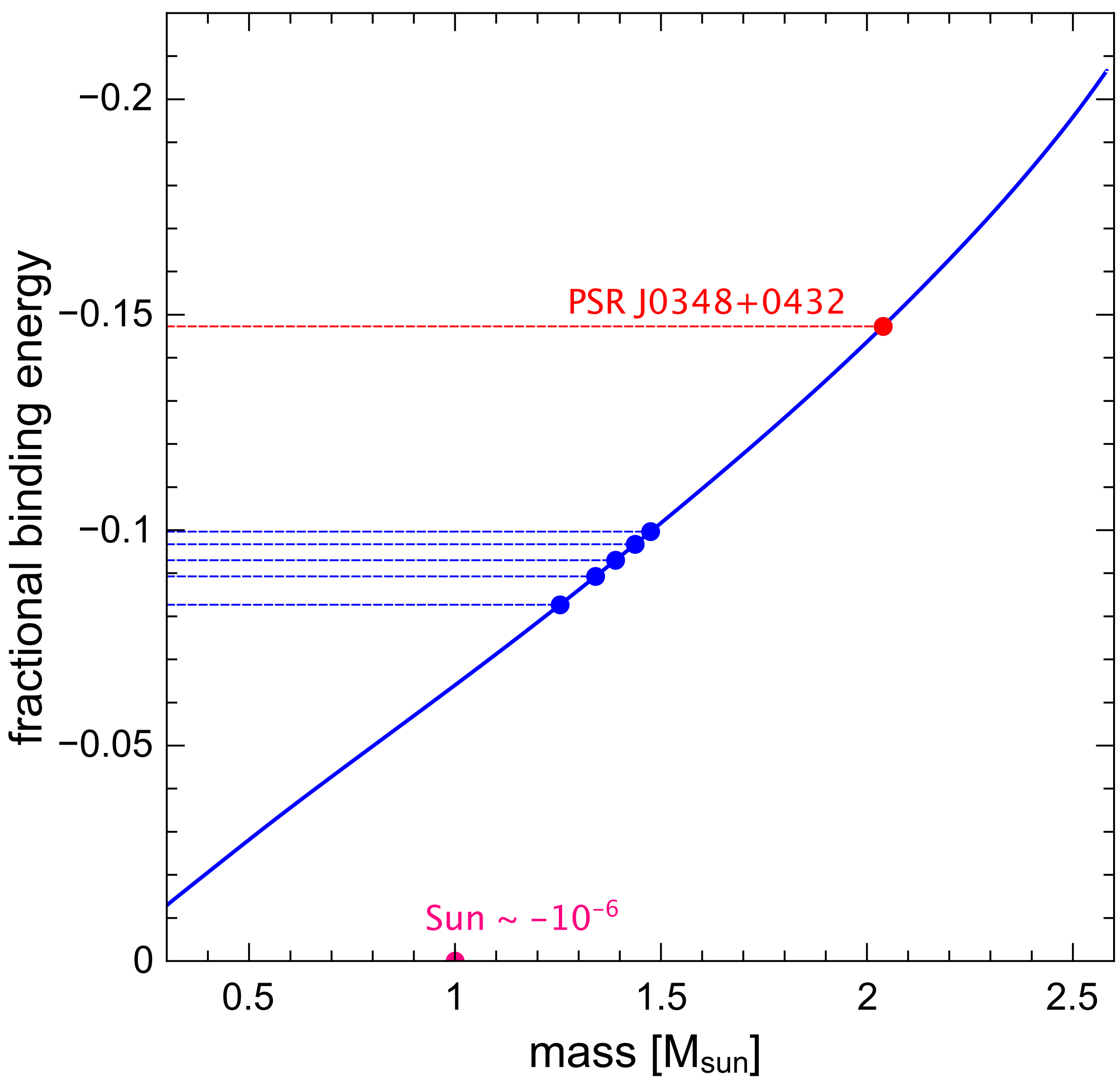
PSR J0348+0432
Results (2)



2 solar mass neutron star in a highly relativistic binary

Orbited by a weakly self-gravitating object

Extra fields that mediate gravity may have a field-dependent coupling with matter
(T. Damour & G. Esposito-Farèse *PhR letters* 1993,
T. Damour & G. Esposito-Farèse *PhR D* 1996)

Violation of the Strong Equivalence Principle that results in emission of dipolar gravitational radiation

$$\dot{P}_{\rm b}^{\rm dipole} \simeq -\frac{4\pi^2 G_*}{c^3 P_{\rm b}} \frac{m_{\rm p} m_{\rm c}}{m_{\rm p} + m_{\rm c}} (\alpha_{\rm p} - \alpha_{\rm c})^2$$

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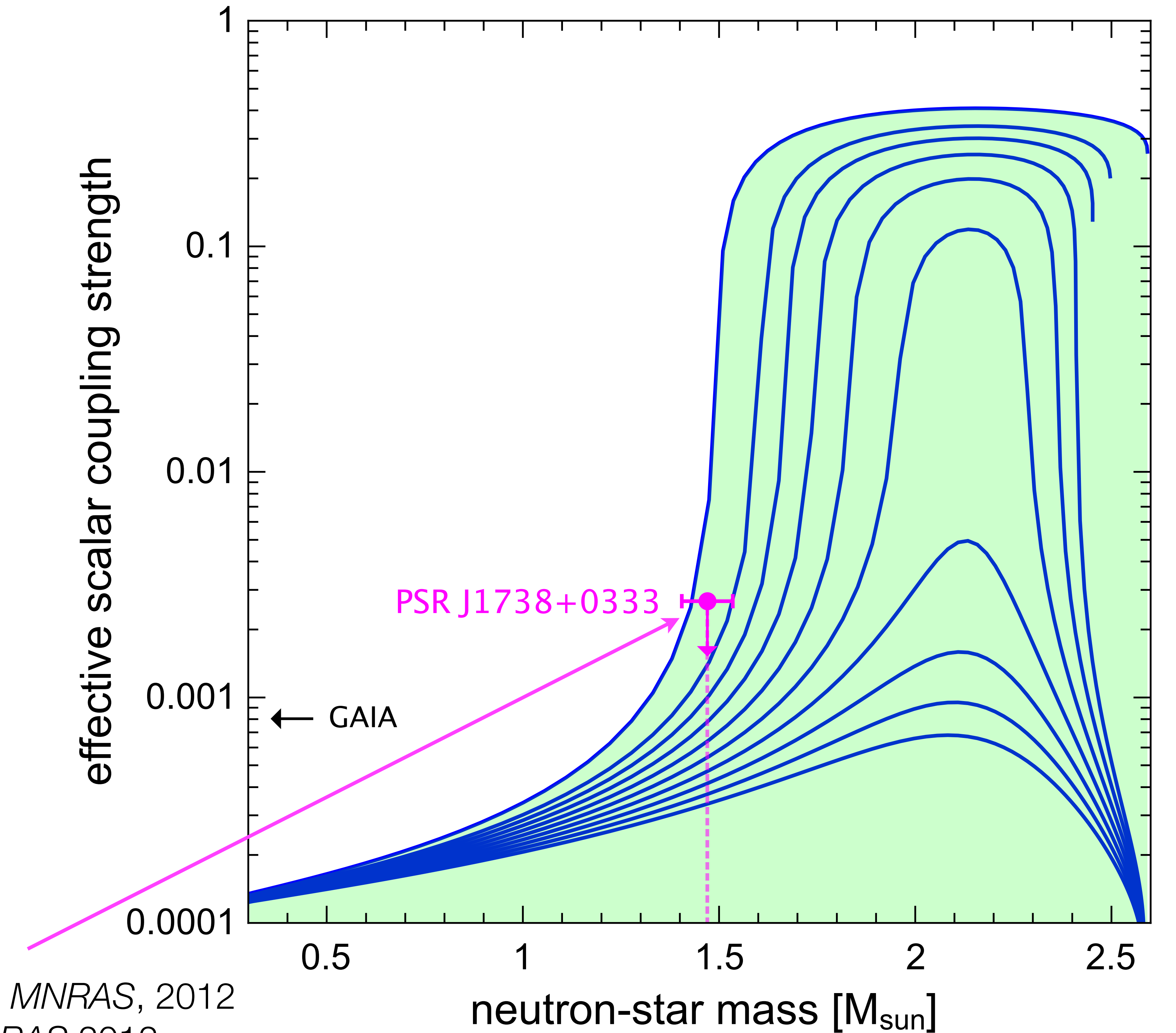
Results (2)

Example: Scalar-Tensor gravity



Antoniadis et al., *MNRAS*, 2012
Freire et al. , *MNRAS* 2012

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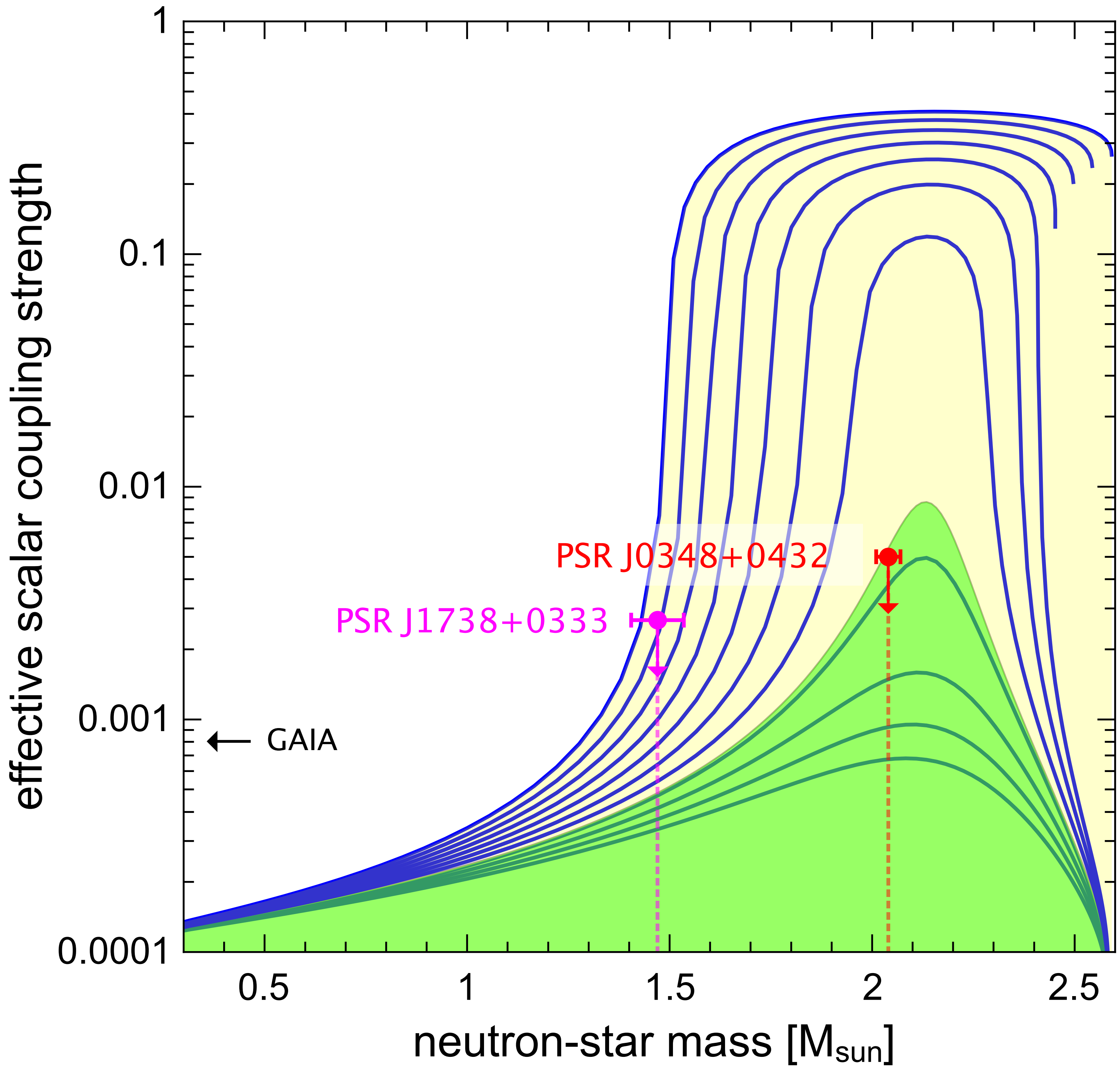
Results (2)



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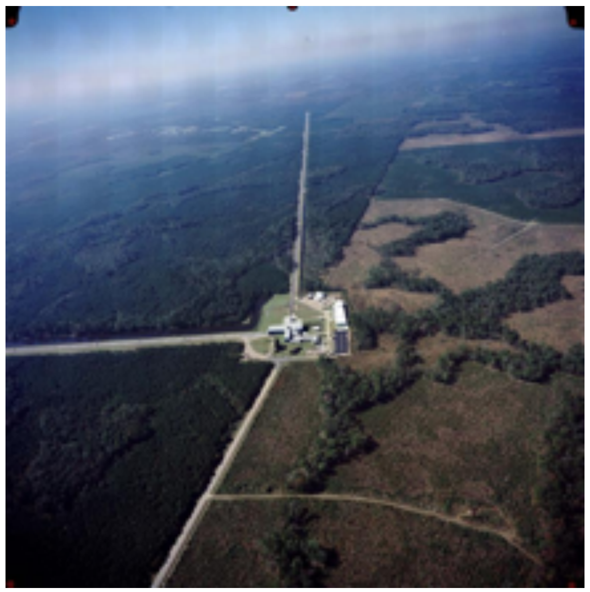
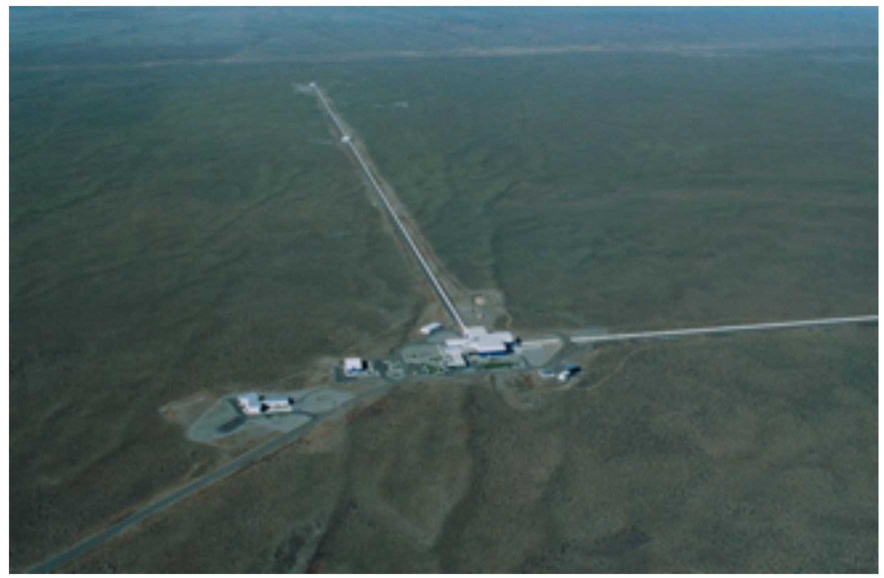
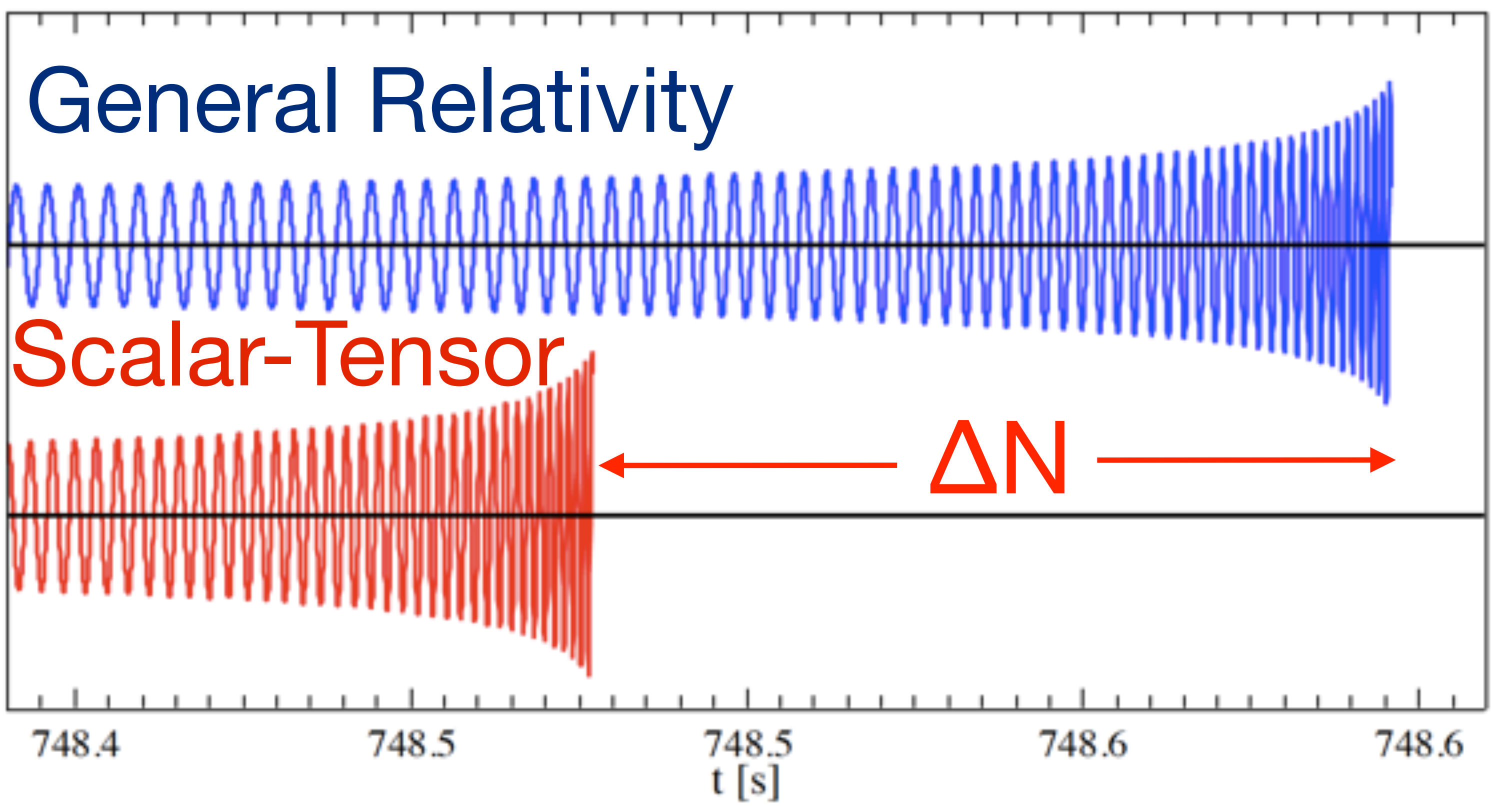
Results (2)

GW detectors







Will 1994, Damour & Esposito-Farèse *PhR D* (1998)

- Dipolar radiation can lead to significant differences in the phase evolution of the in-spiral
- GW templates constructed within the framework of GR could fail to detect the signal

J0348+0432: $\Delta N < 0.5$

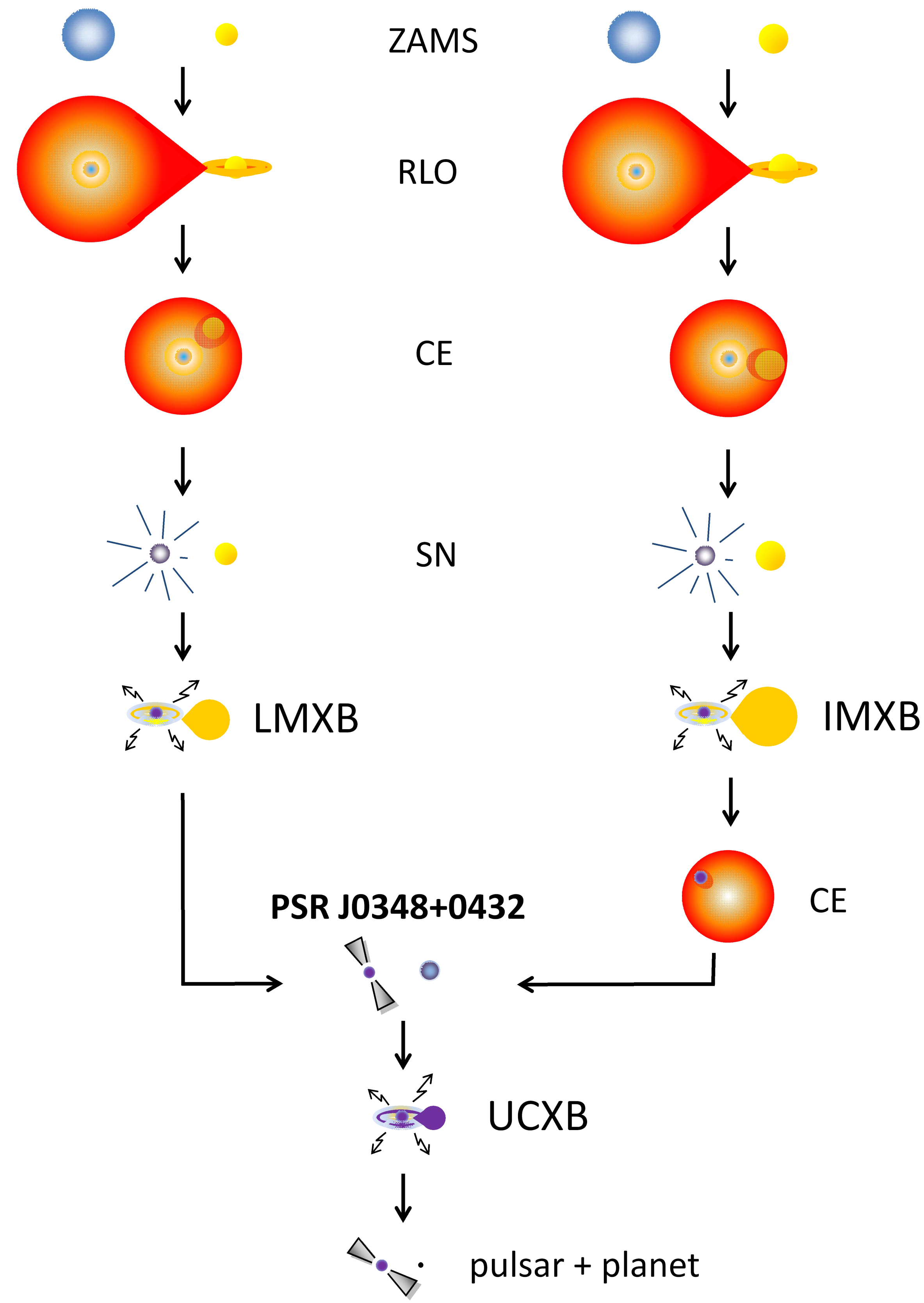
PSR J0348+0432

Results (3)

∗ Orbital period, spin period, high B-field point to CE evolution

∗Implication --> NS was born massive

∗Mwd contradicts the standard CE but the binary could still be explained with hypercritical accretion



Summary

2 solar mass NS in a relativistic orbit sensitive to hypothetical phenomena outside GR that were thus far undetectable

Measurement of orbital period decay agrees with GR

Supports the use of GR templates for ground-based GW experiments

Stringent Constraints on the equation-of-state of matter at ultra-high densities

The first known case of a direct progenitor of an Ultra-Compact X-Ray Binary (Inspiral timescale ~400 Myr)

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für Radioastronomie

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Summary

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