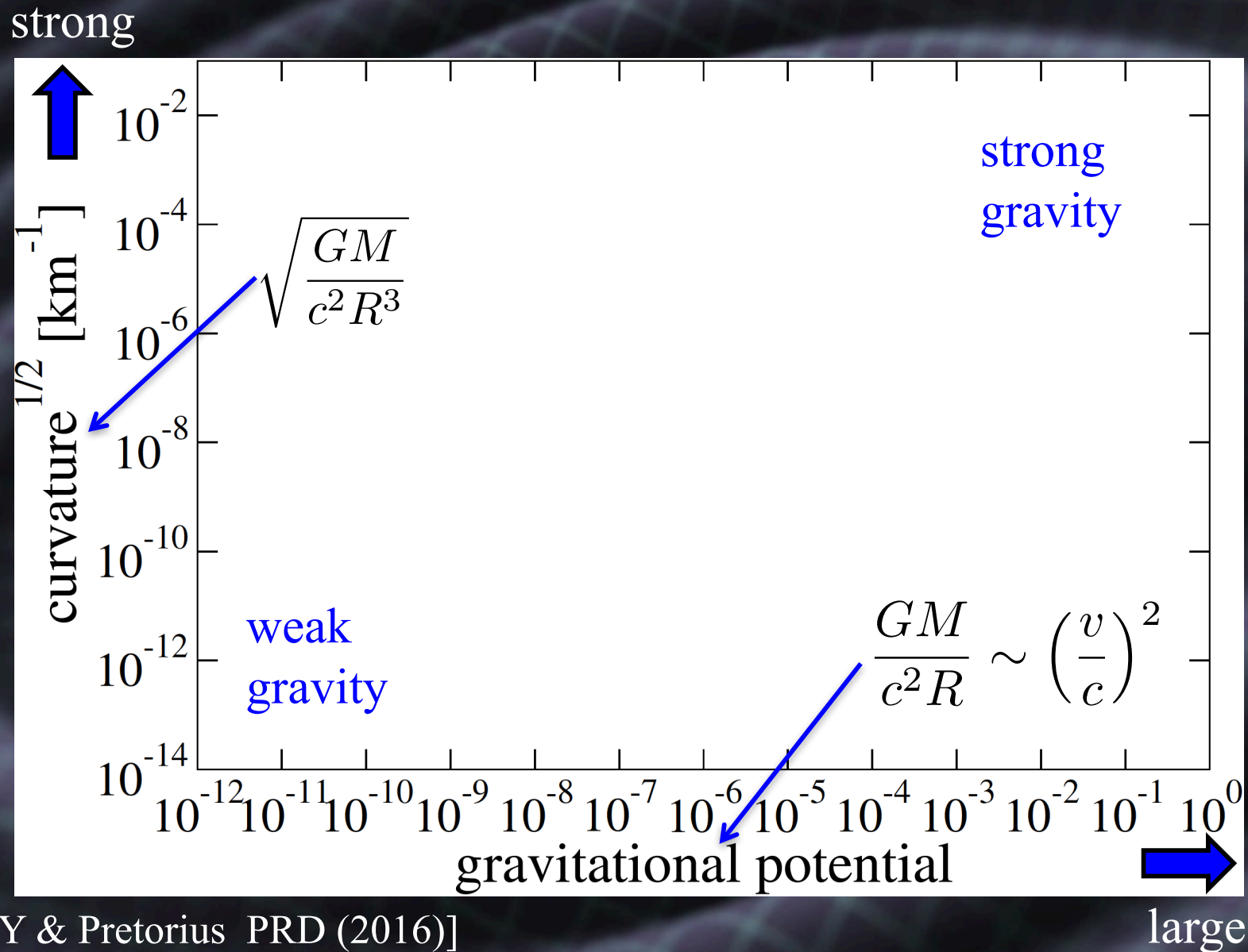


連星パルサーによる重力理論の検証

Kent Yagi
University of Virginia

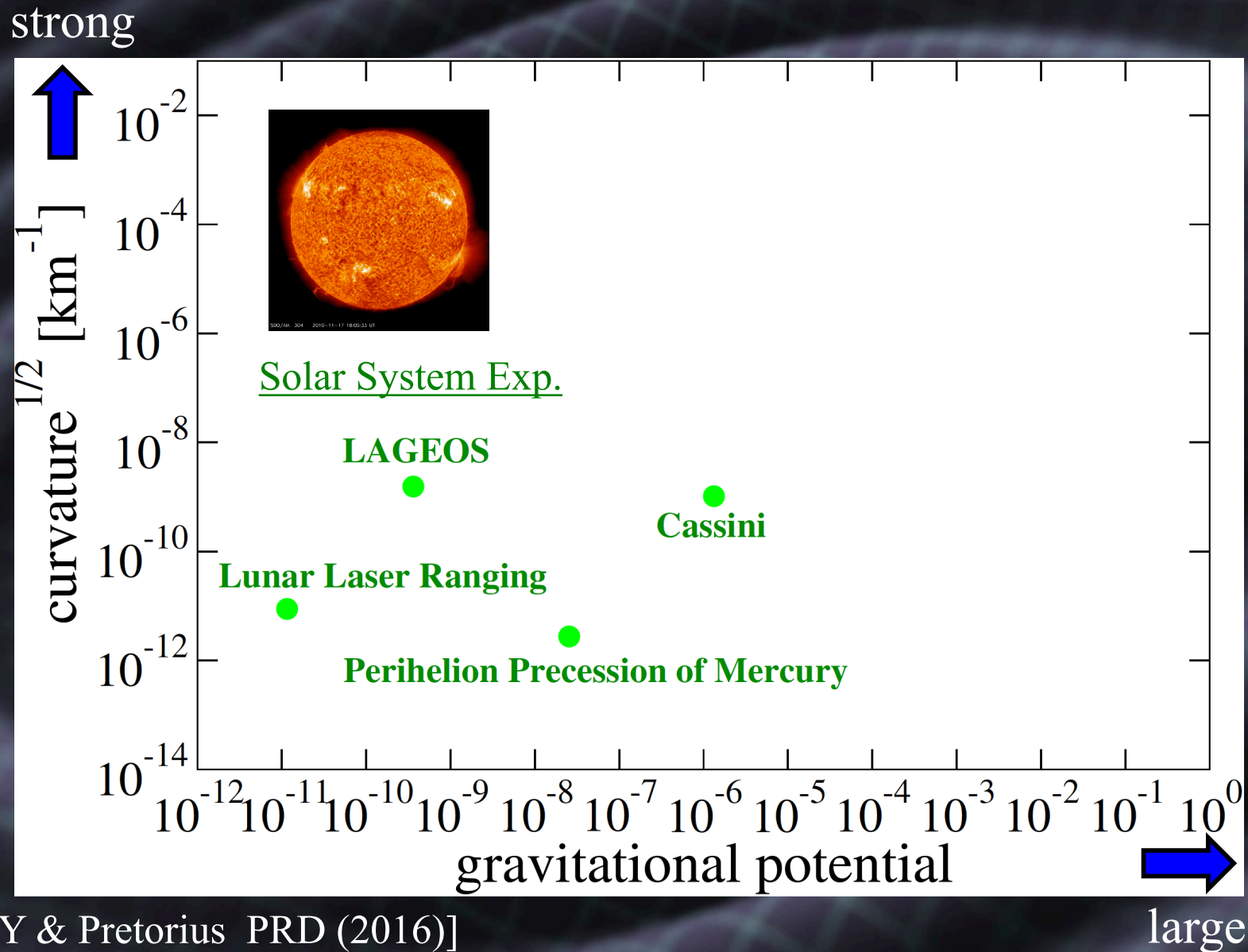
SKA Japan Workshop
January 6th 2018

Various Probes of Gravity



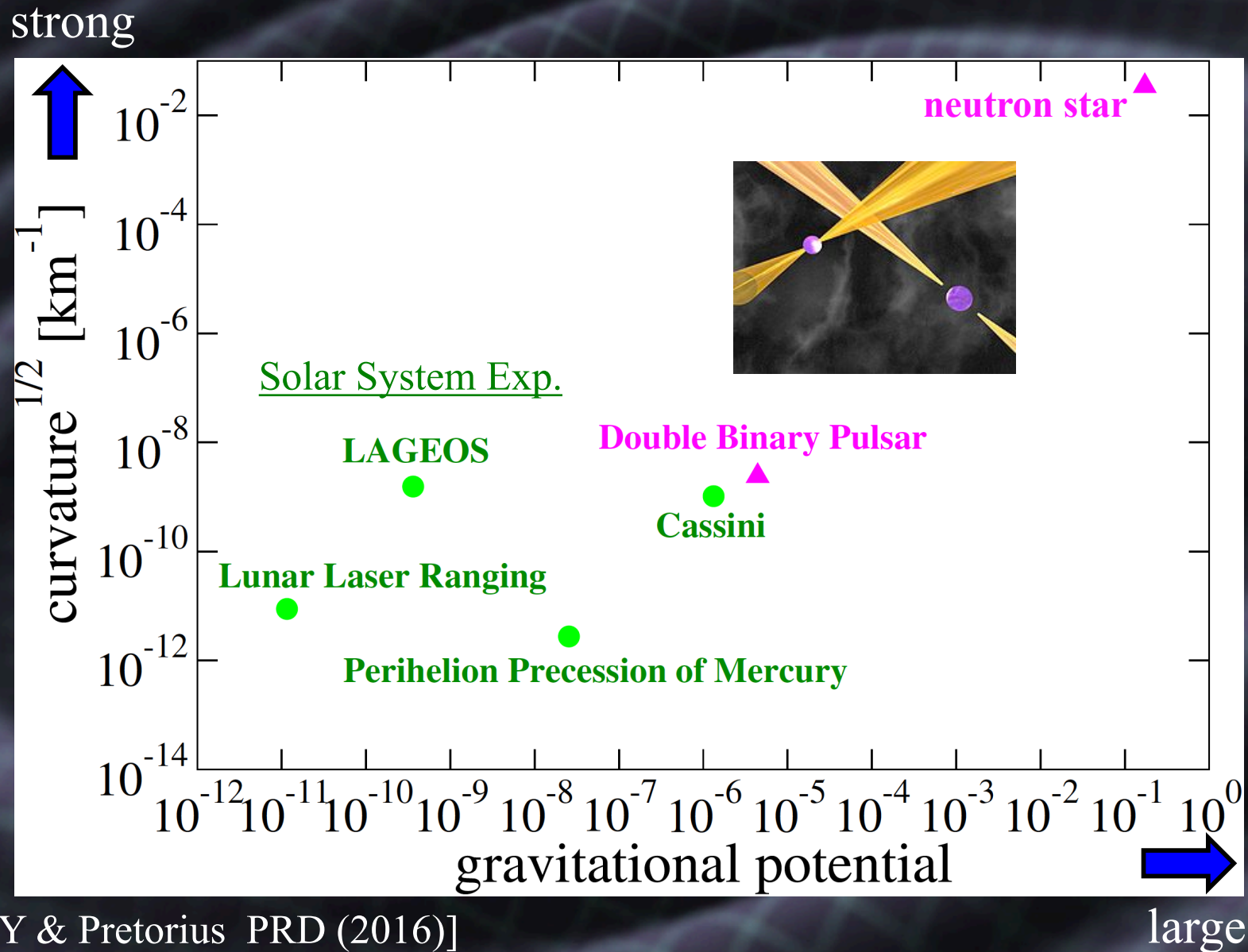
[Yunes, KY & Pretorius PRD (2016)]

Various Probes of Gravity



[Yunes, KY & Pretorius PRD (2016)]

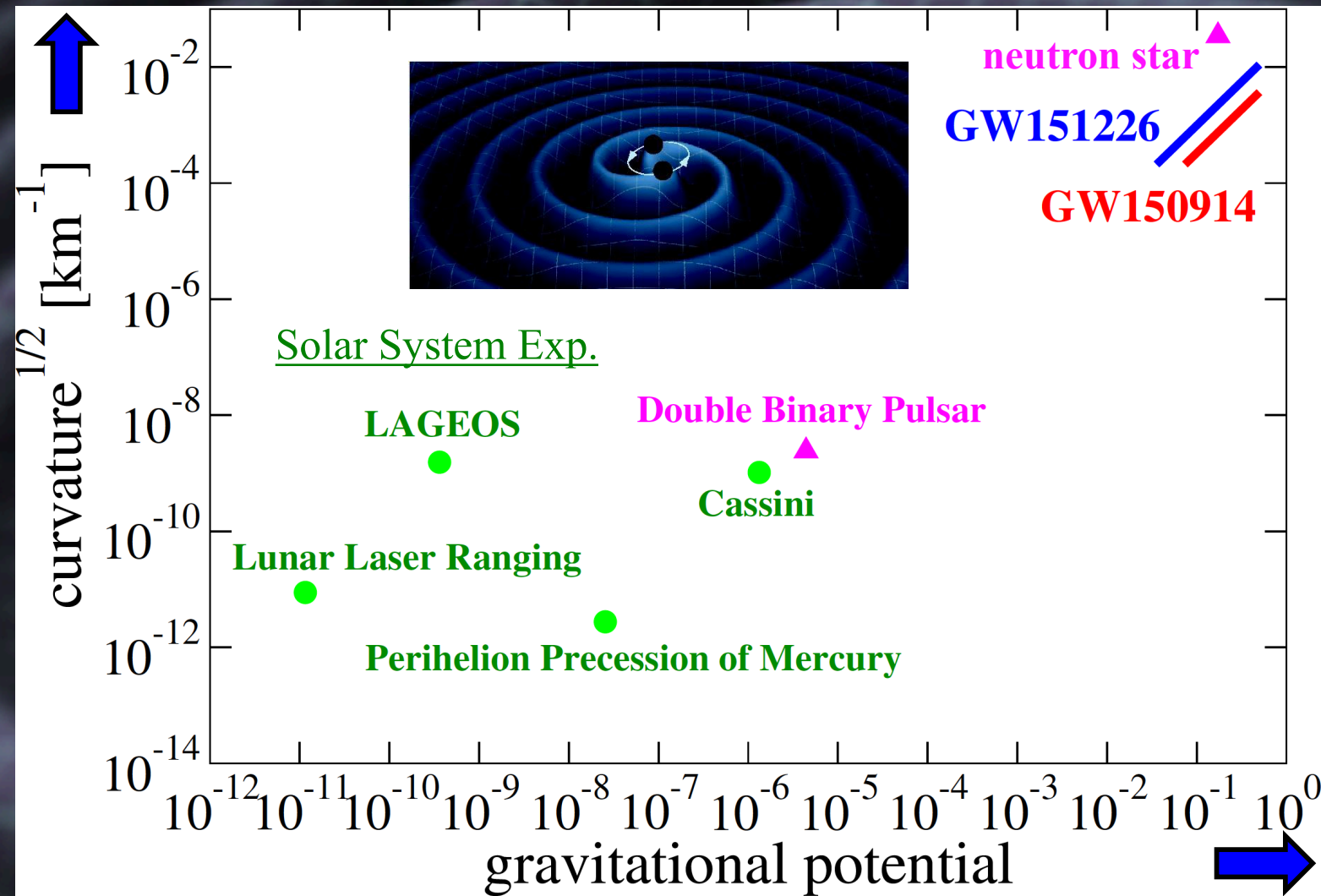
Various Probes of Gravity



[Yunes, KY & Pretorius PRD (2016)]

Various Probes of Gravity

see Narikawa-san's talk



large

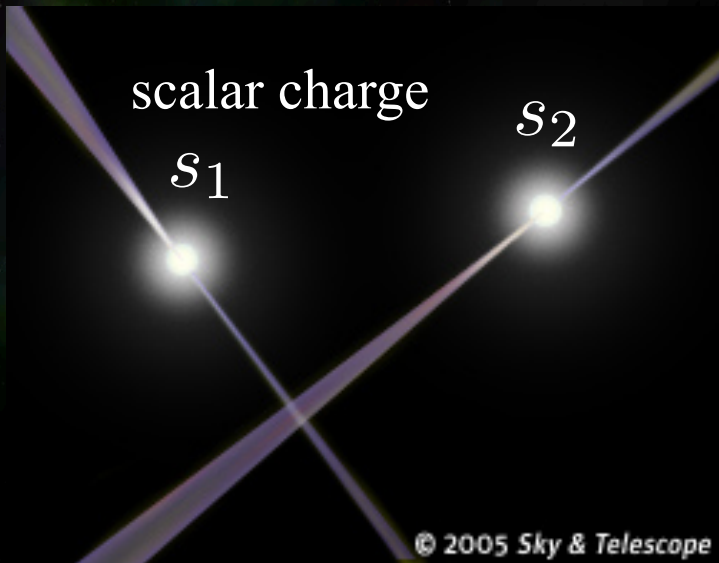
[Yunes, KY & Pretorius PRD (2016)]

Why Binary Pulsars?

Scalar-tensor theories as an example

orbital decay due to gravitational radiation

scalar dipole radiation



$$\frac{\dot{P}_b}{P_b} = \left(\frac{\dot{P}_b}{P_b} \right)_{\text{GR}} \left[1 + A(s_1 - s_2)^2 \left(\frac{P_b}{M} \right)^{2/3} \right]$$

large stellar compactness

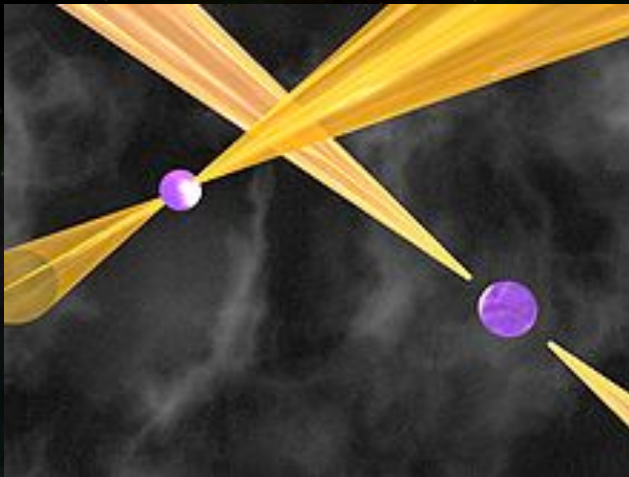
large separation

N post-Newton (PN) correction: $P_b^{-2N/3}$

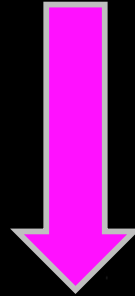
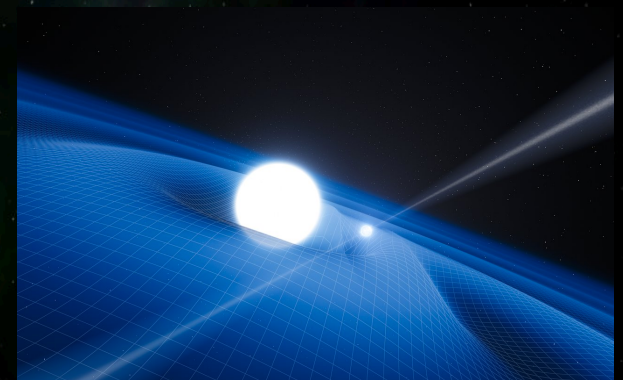
Dipole radiation enters at **-1PN** order

Binary pulsars are powerful for testing **negative PN corrections**.

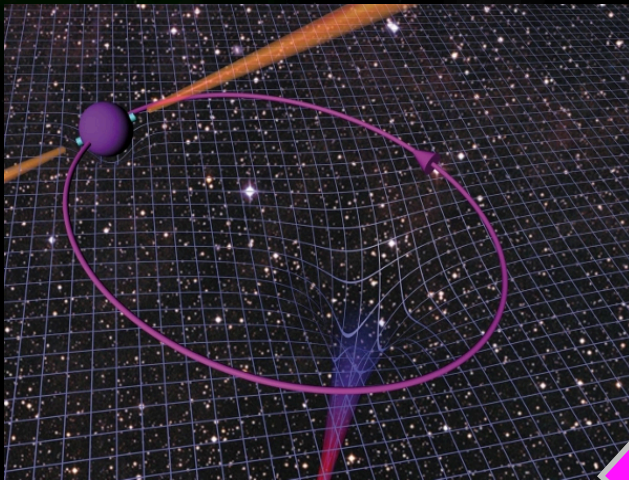
Outline



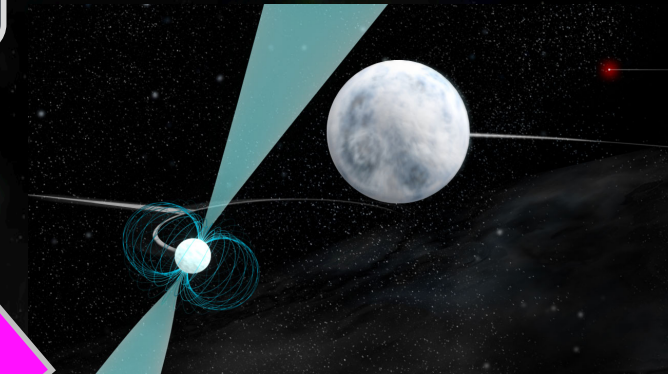
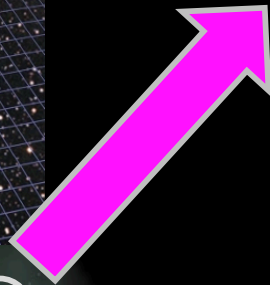
NS/PSR & WD/PSR



General Relativity



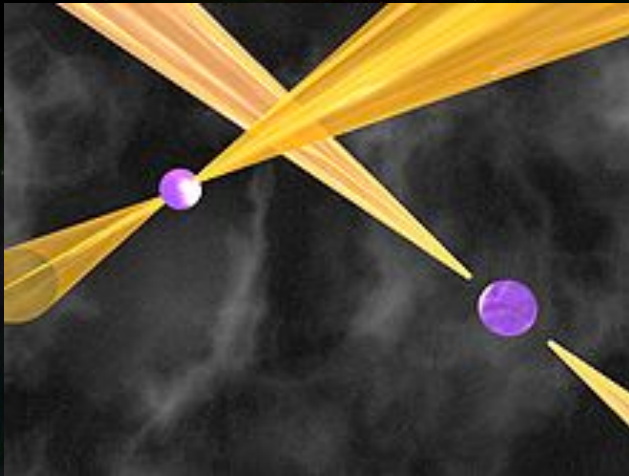
BH/PSR



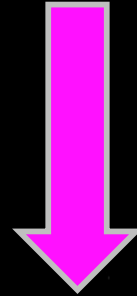
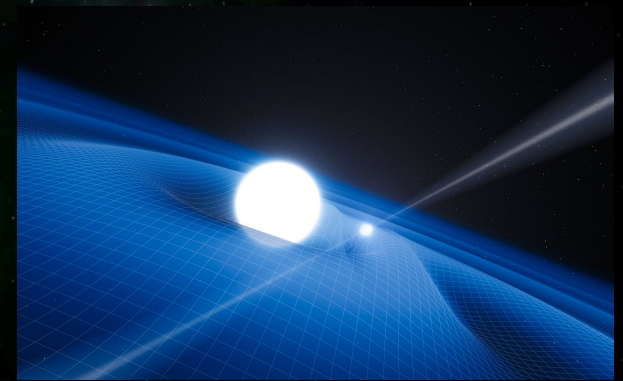
Triple System



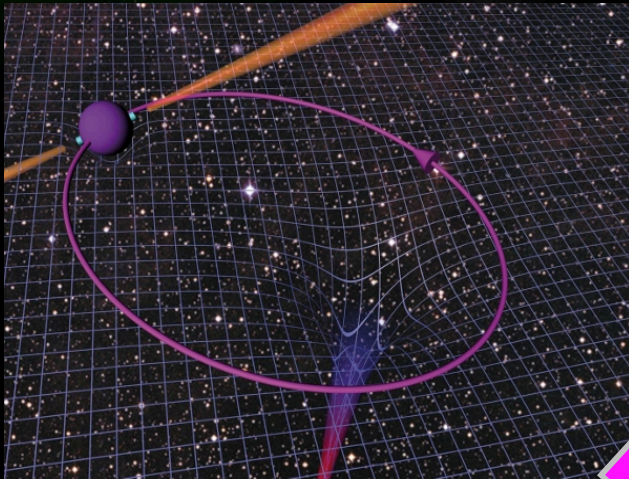
Outline



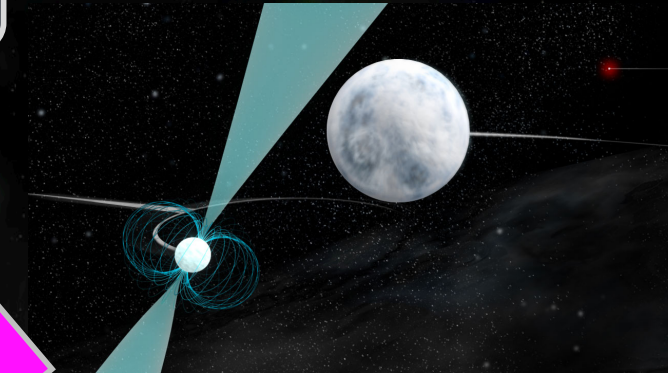
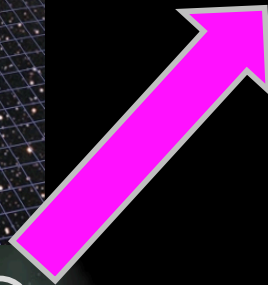
NS/PSR & WD/PSR



General Relativity



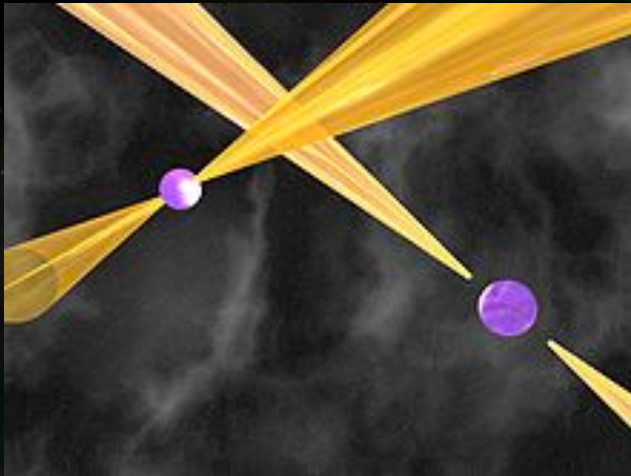
BH/PSR



Triple System

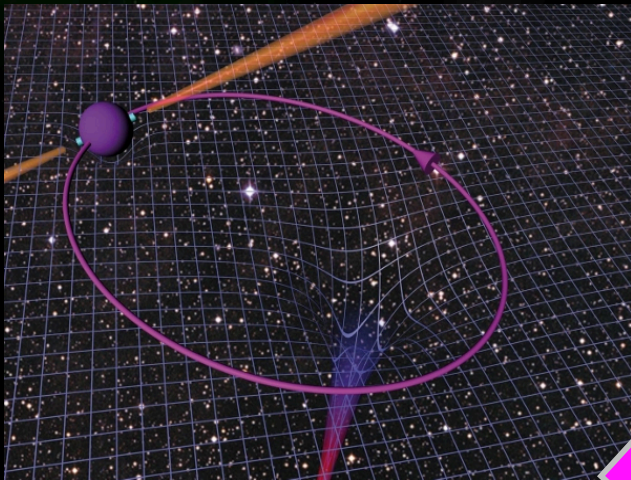
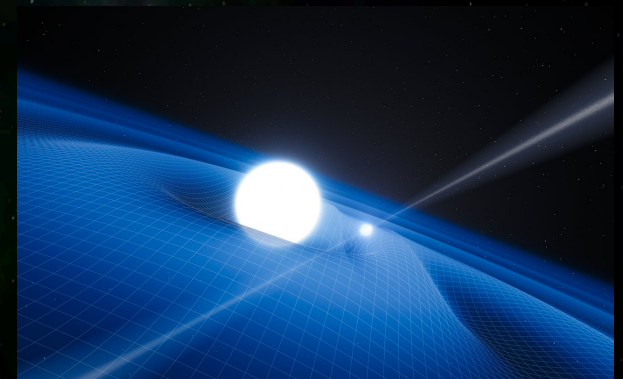


Outline



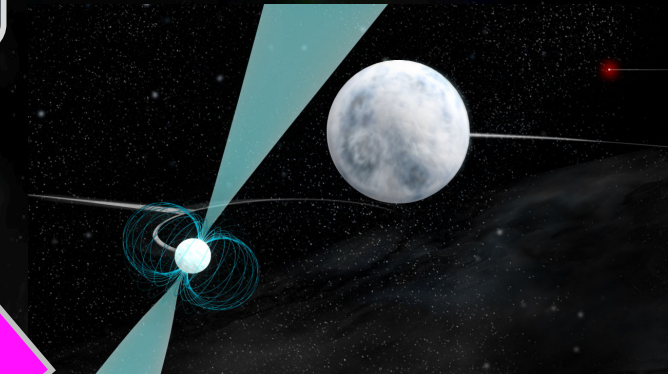
NS/PSR & WD/PSR

- (i) scalar-tensor
- (ii) vector-tensor



BH/PSR

General Relativity



Triple System

(I) Scalar-tensor Theories

[Damour & Esposito-Farese (1992, 1993)]

tensor field $g_{\mu\nu}$

scalar field ϕ

matter couples to gravity via effective metric

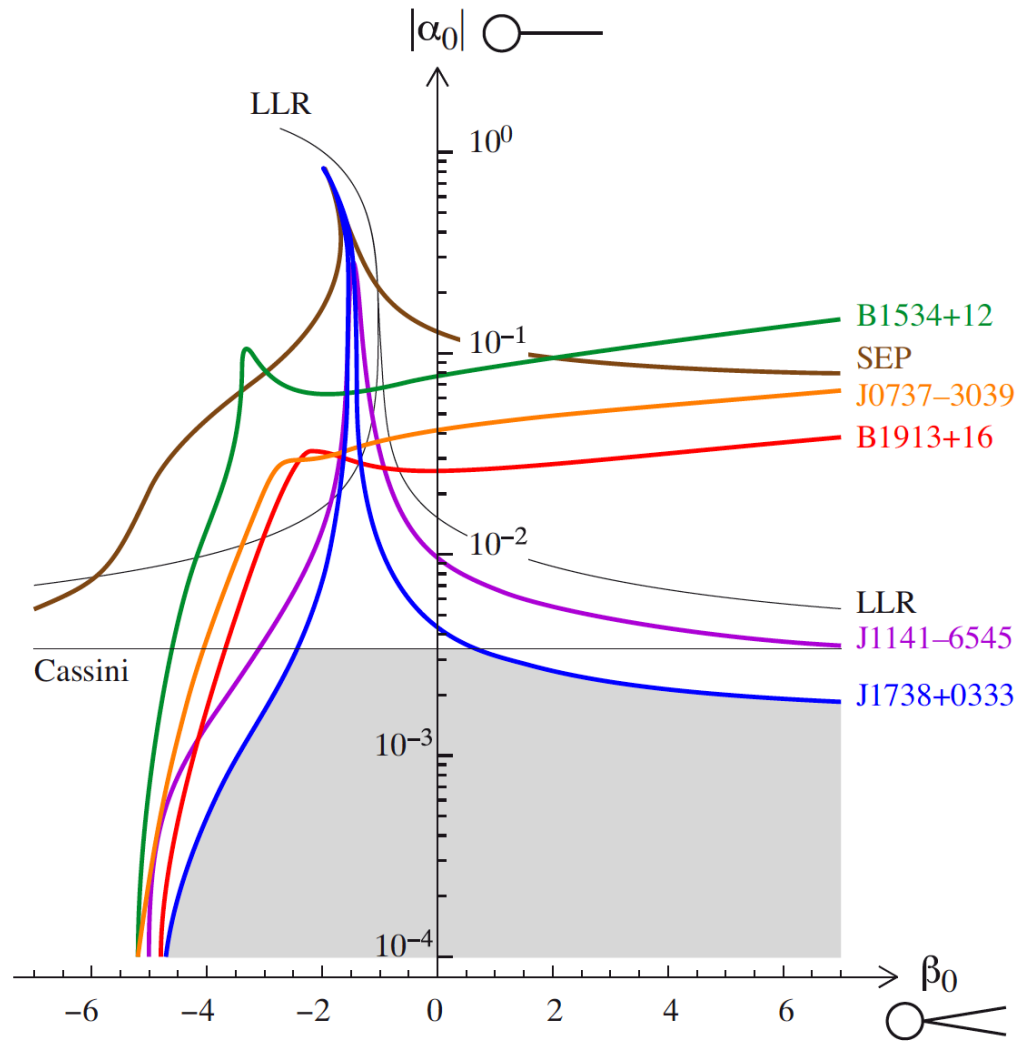
$$\tilde{g}_{\mu\nu} = A(\phi) g_{\mu\nu}$$

background linear couplin

$$\ln A(\phi) \approx \ln A(\phi_0) + \alpha_0(\phi - \phi_0) + \frac{\beta_0}{2}(\phi - \phi_0)^2$$

quadratic coupling

$$(\alpha_0, \beta_0) \rightarrow (0, 0) \quad \text{GR}$$
$$\beta_0 \rightarrow 0 \quad \text{Brans-Dicke}$$



[Freire et al. arXiv: 1205.1450]

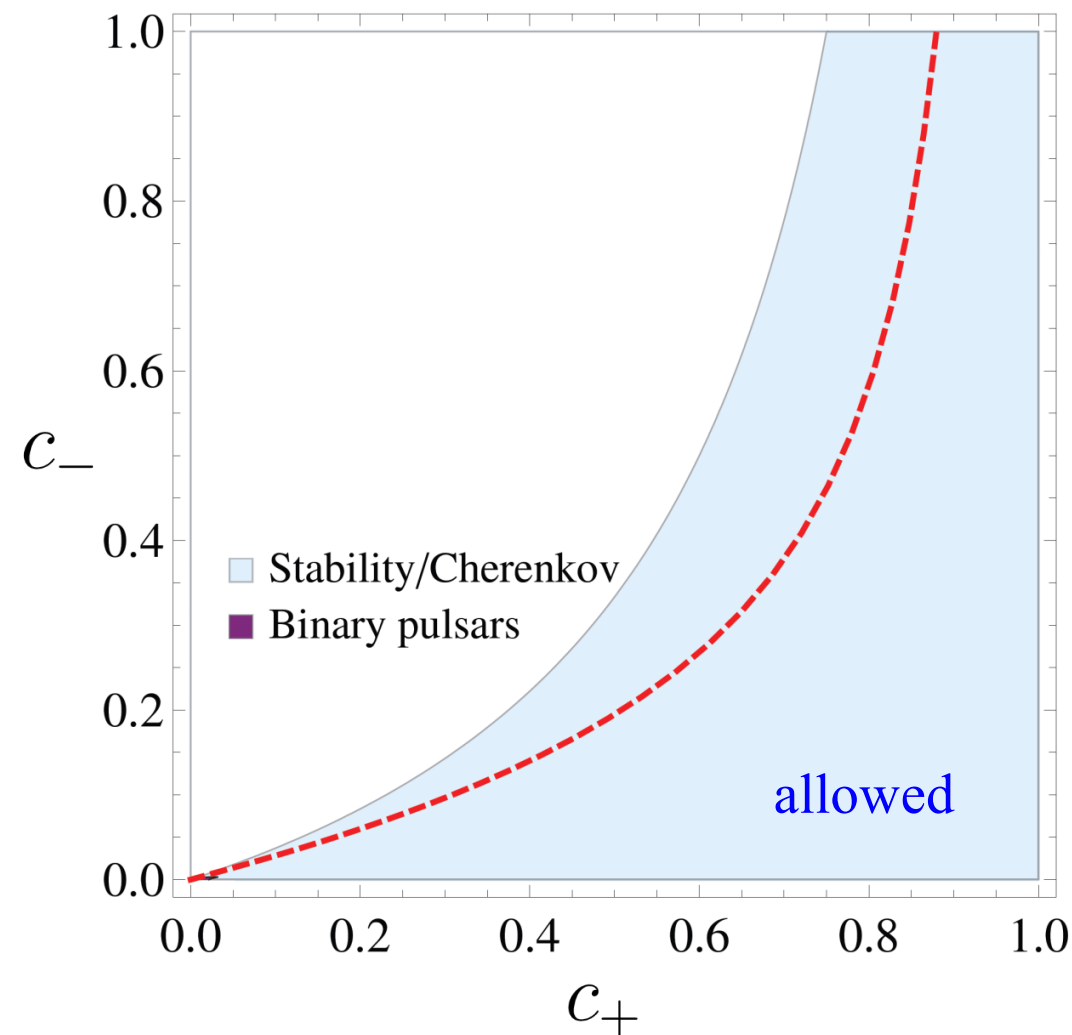
(II) Vector-tensor Theories

Einstein-AEther Theory

- ✓ preferred direction in spacetime
- ✓ gravitational Lorentz violation
- ✓ important Lorentz-violating parameters: (c_+, c_-)
- ✓ vector dipole radiation

[Jacobson (2008)]

(II) Vector-tensor Theories



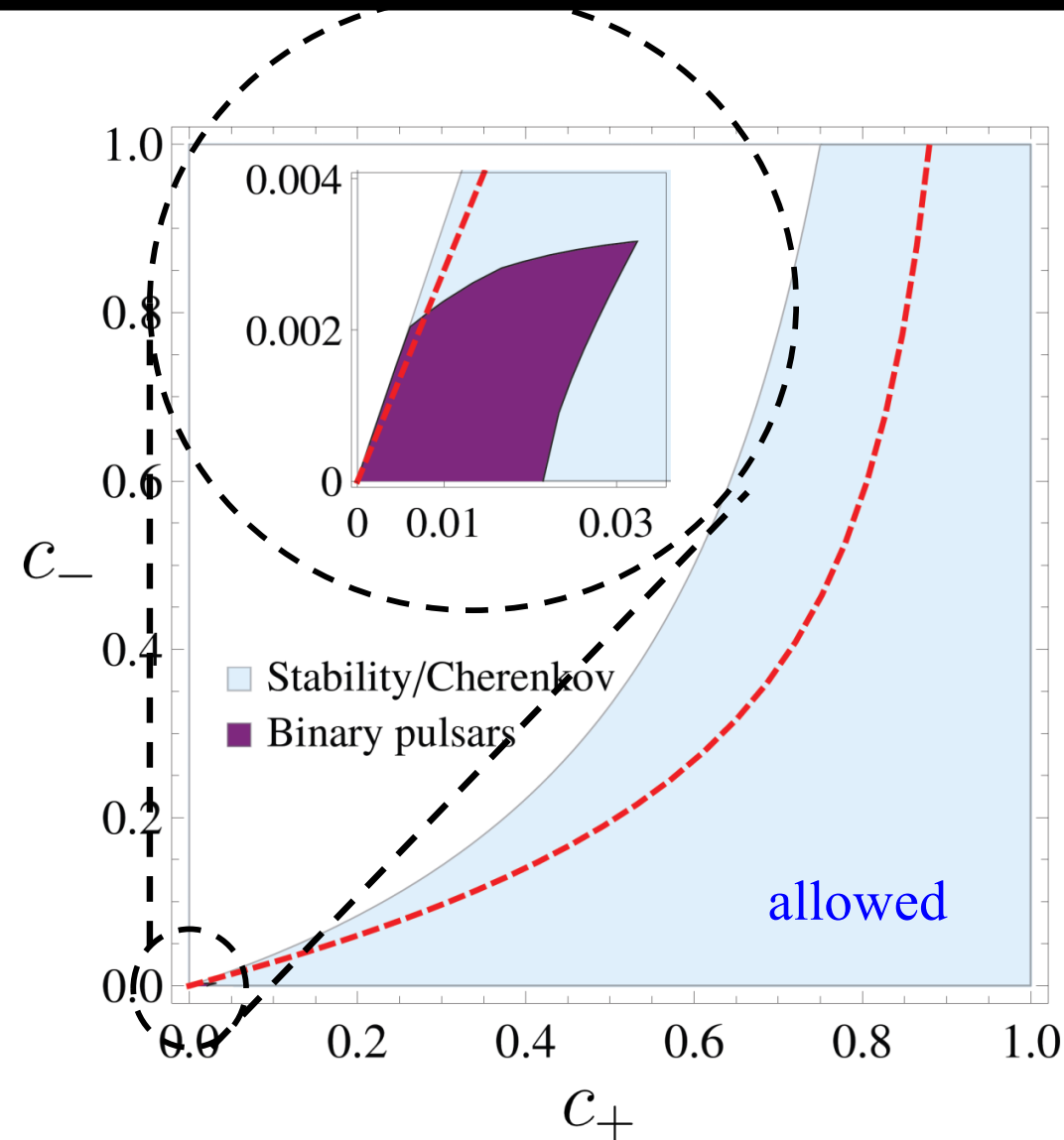
[KY et al. arXiv: 1307.6219, 1311.7144]

Einstein-AEther Theory

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(II) Vector-tensor Theories



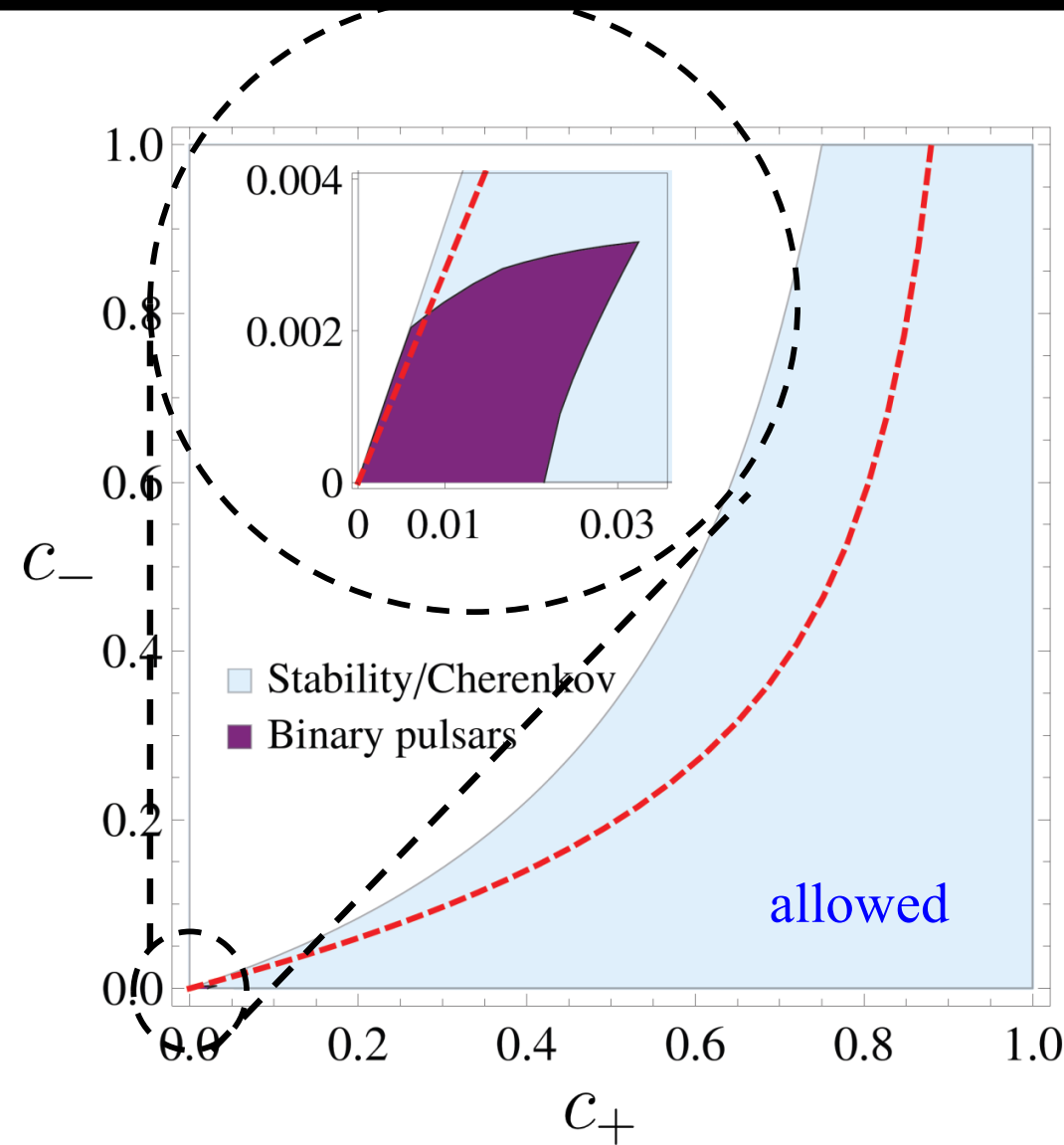
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[KY et al. arXiv: 1307.6219, 1311.7144]

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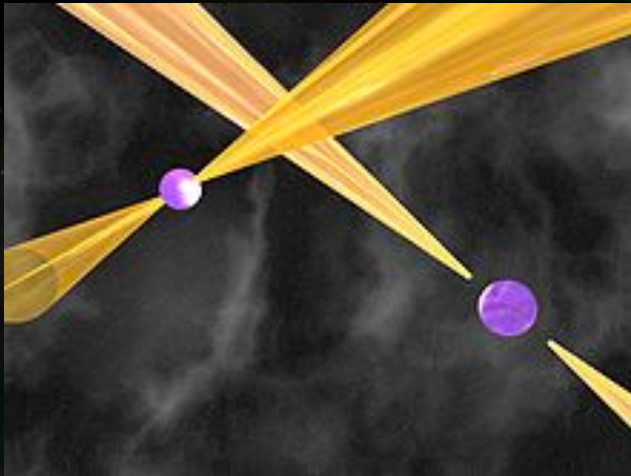
[Jacobson (2008)]

- ✓ GW propagation speed

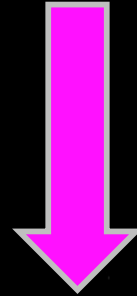
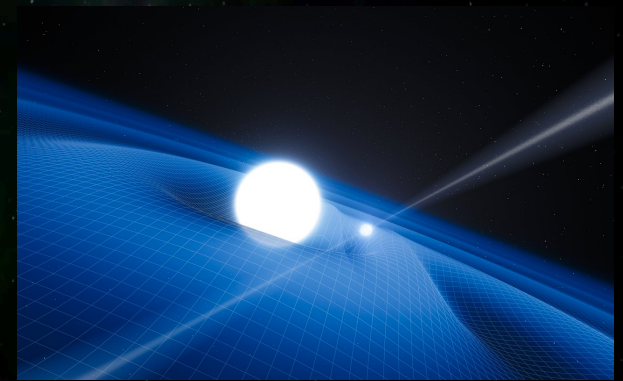
$$v_{\text{GW}} = \frac{c}{1 - c_+}$$

$$\text{GW170817: } c_+ < 7 \times 10^{-16}$$

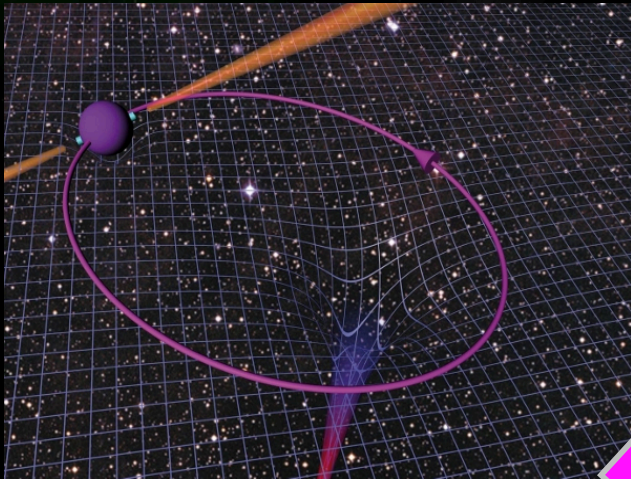
Outline



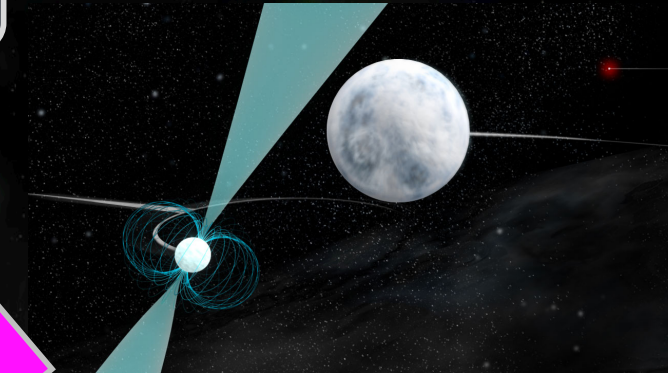
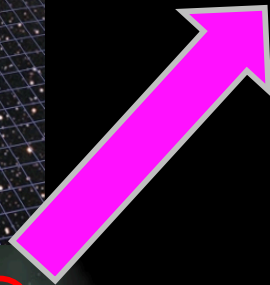
NS/PSR & WD/PSR



General Relativity



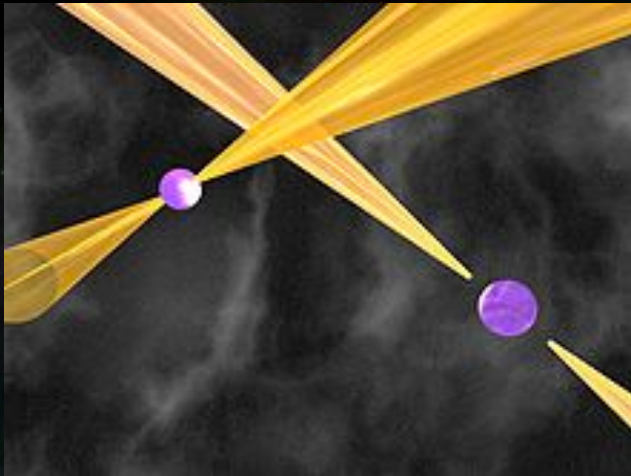
BH/PSR



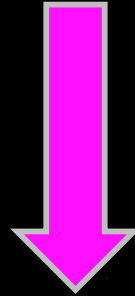
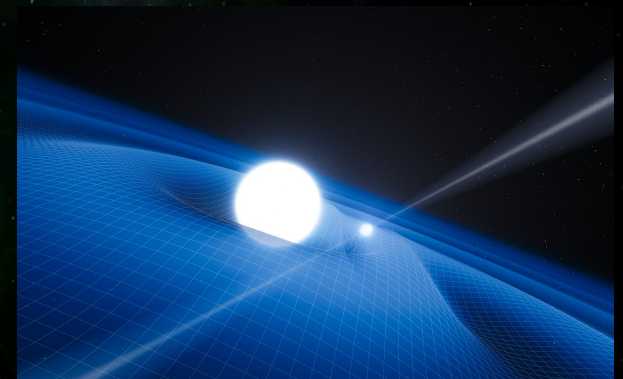
Triple System



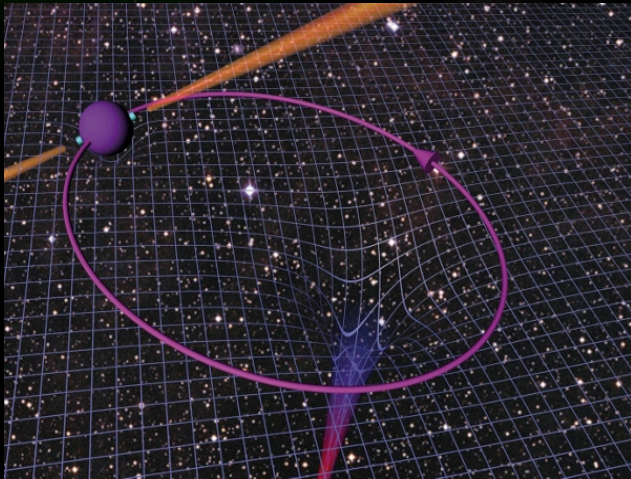
Outline



NS/PSR & WD/PSR

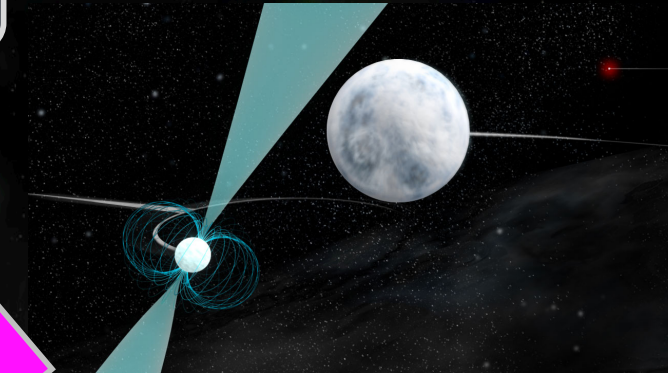


General Relativity



BH/PSR

- (i) scalar-tensor
- (ii) time-varying G



Triple System

(I) Scalar-tensor Theories

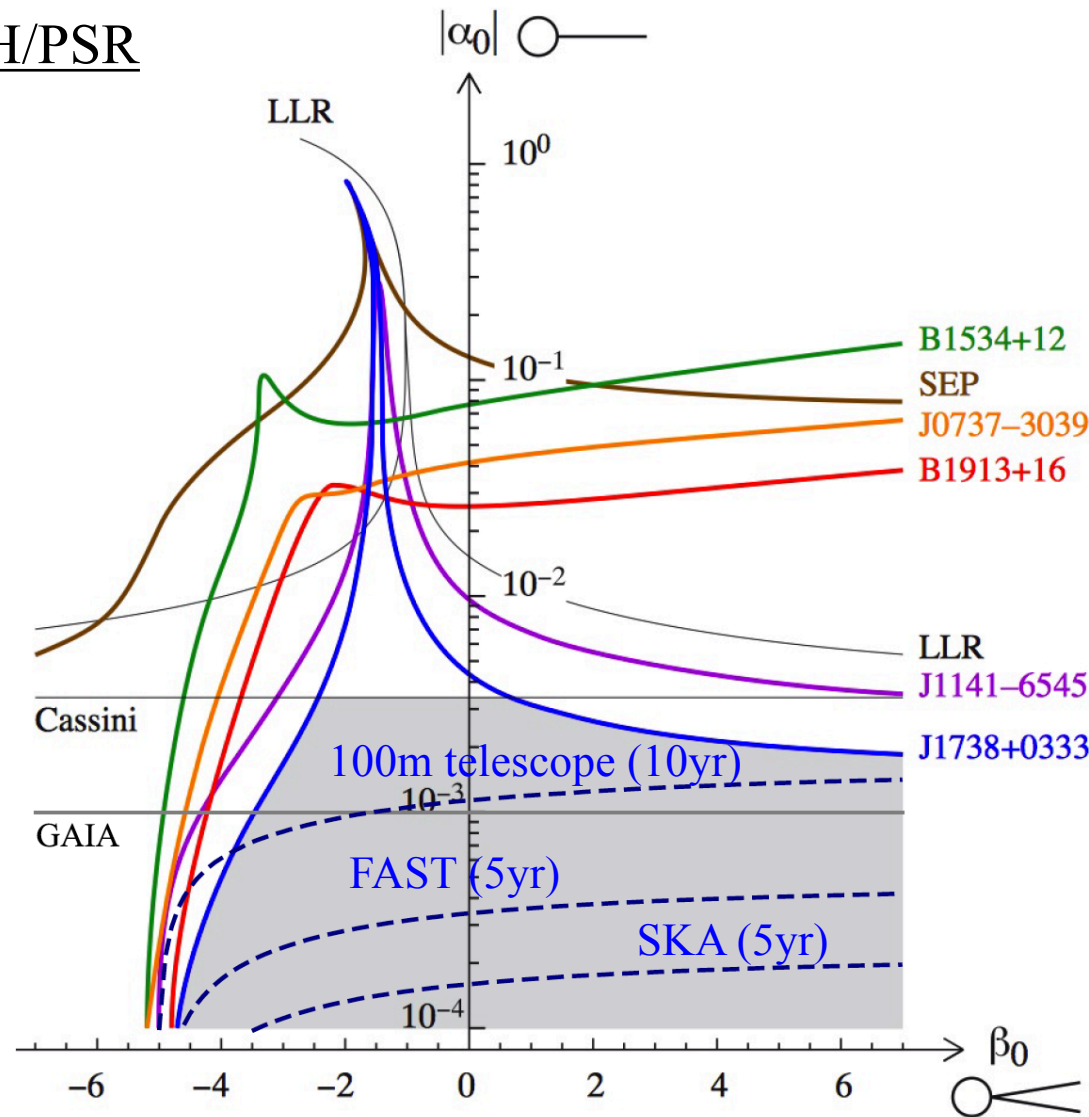
Orbital decay rate measurement with BH/PSR

$$(1.4, 10)M_{\odot}$$

$$e = 0.8$$

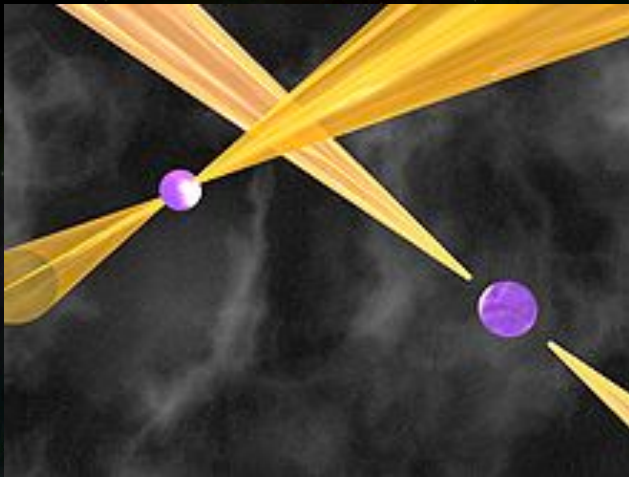
$$P_b = 5 \text{ days}$$

Stringent bounds on scalar-tensor theories with future BH/PSR binaries!

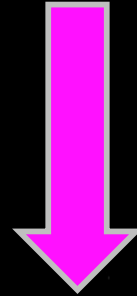
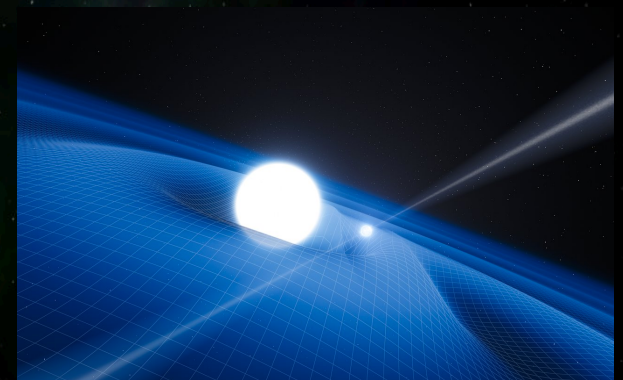


[Wex et al. arXiv:1210.7518]

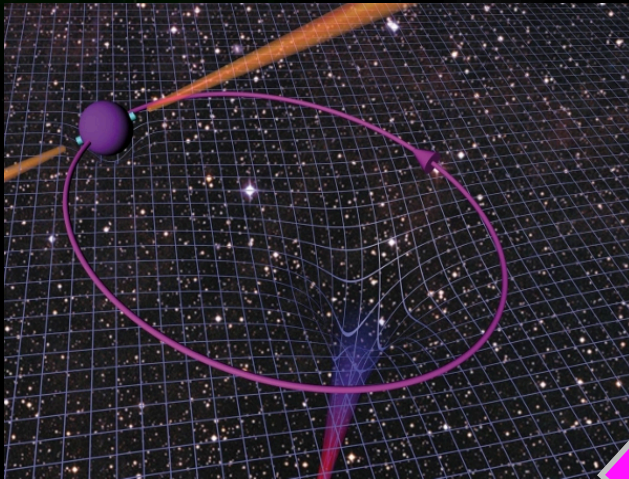
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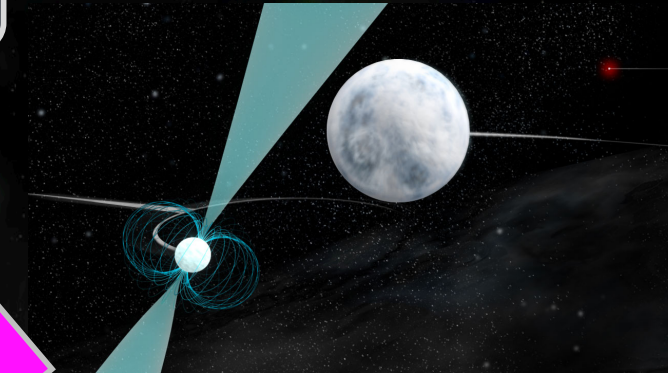
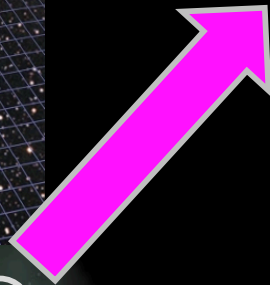
NS/PSR & WD/PSR



General Relativity



BH/PSR



Triple System



Strong Equivalence Principle (SEP)

inertial mass = gravitational mass?

$$m_I a = \frac{m_G M}{r^2}$$

WHITE DWARF

$$a_{WD} = \frac{m_{G,WD}}{m_{I,WD}} \frac{M_{WD}}{r^2}$$

PULSAR J0337+1715

$$a_{NS} = \frac{m_{G,NS}}{m_{I,NS}} \frac{M_{WD}}{r^2}$$

$$\frac{|m_G - m_I|}{m_I} \lesssim 10^{-8}$$

[Shao arXiv: 1602.05725]

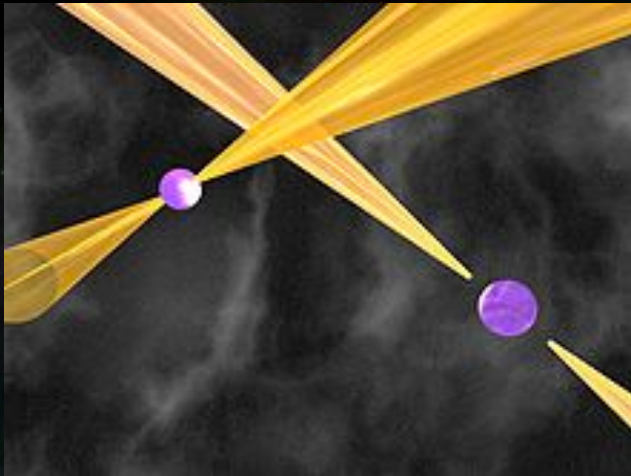
WHITE DWARF

M_{WD}

Stronger than Solar System bounds by 1000 times!

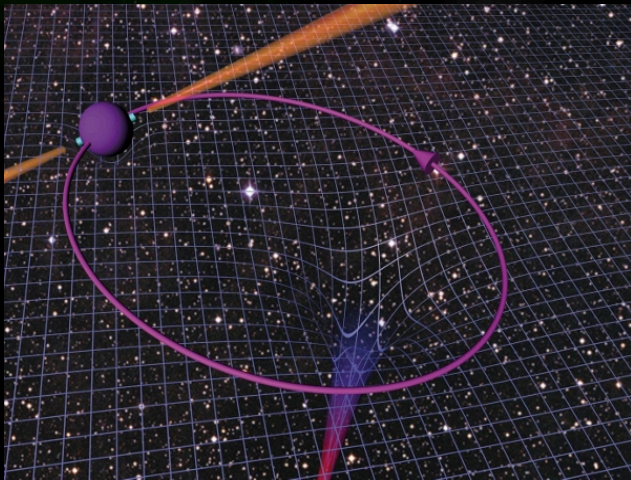
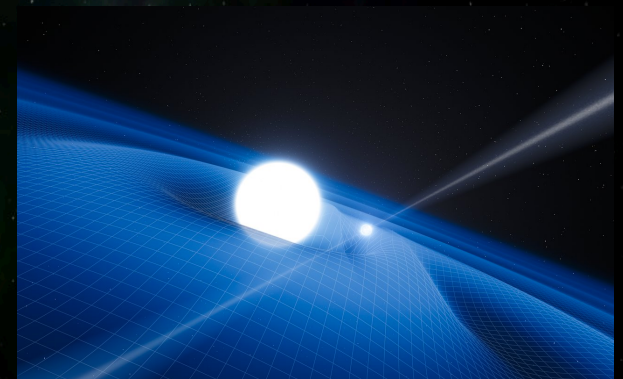
Conclusions

Takeaway



NS/PSR & WD/PSR

- ✓ powerful for constraining **negative PN** corrections
e.g. **scalar dipole radiation**

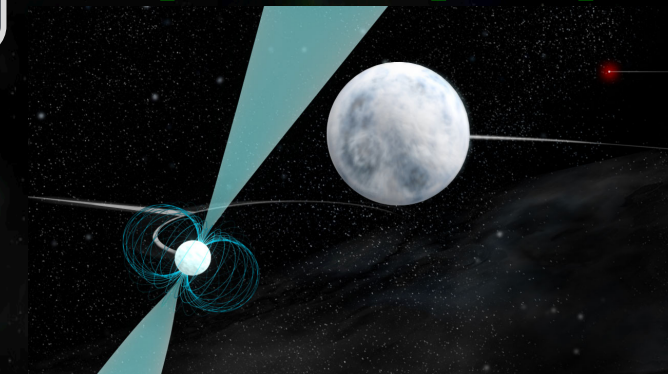


General Relativity

- ✓ tight bounds on **scalar-tensor**, **varying- G** theories

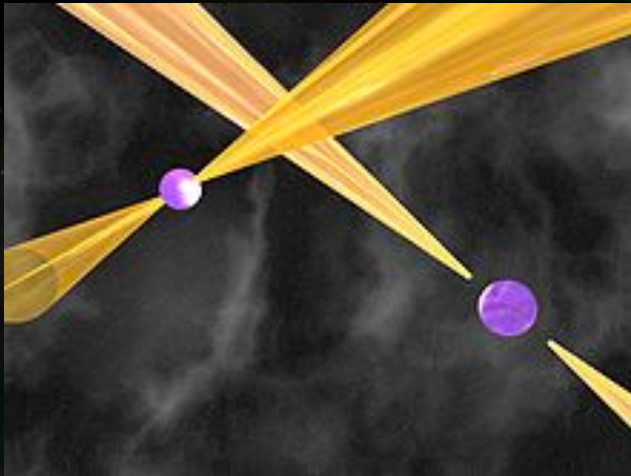
- ✓ ideal for testing **equivalence principle**

BH/PSR



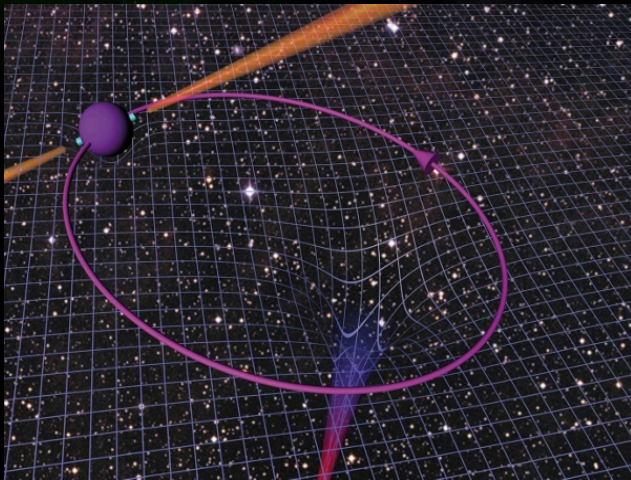
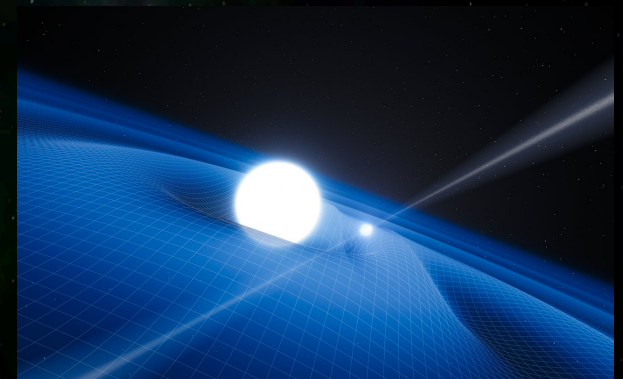
Triple System

Takeaway



NS/PSR & WD/PSR

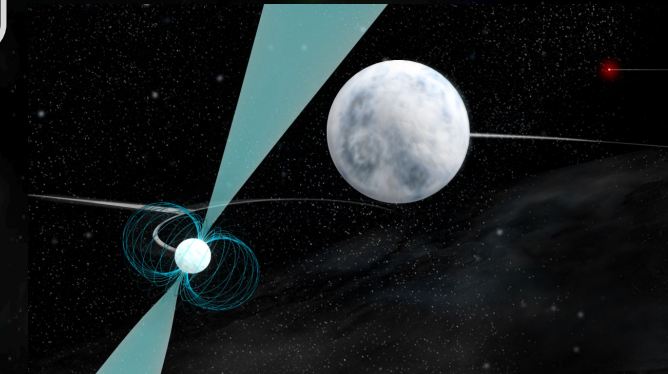
- ✓ powerful for constraining **negative PN** corrections
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General Relativity

- ✓ tight bounds on **scalar-tensor**, **varying- G** theories

- ✓ ideal for testing **equivalence principle**



BH/PSR

Thank You

Triple System