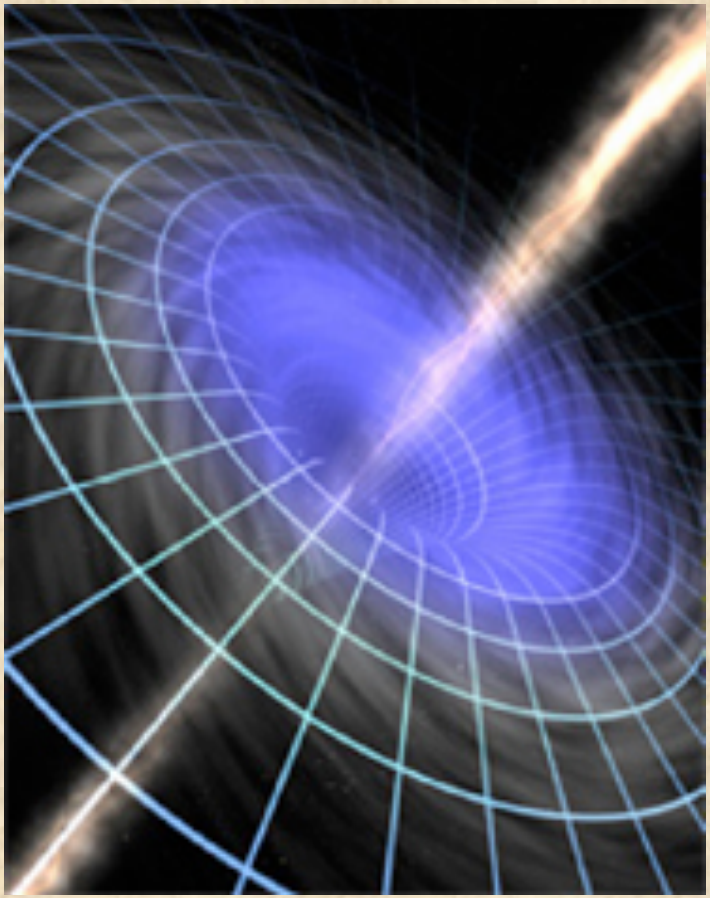


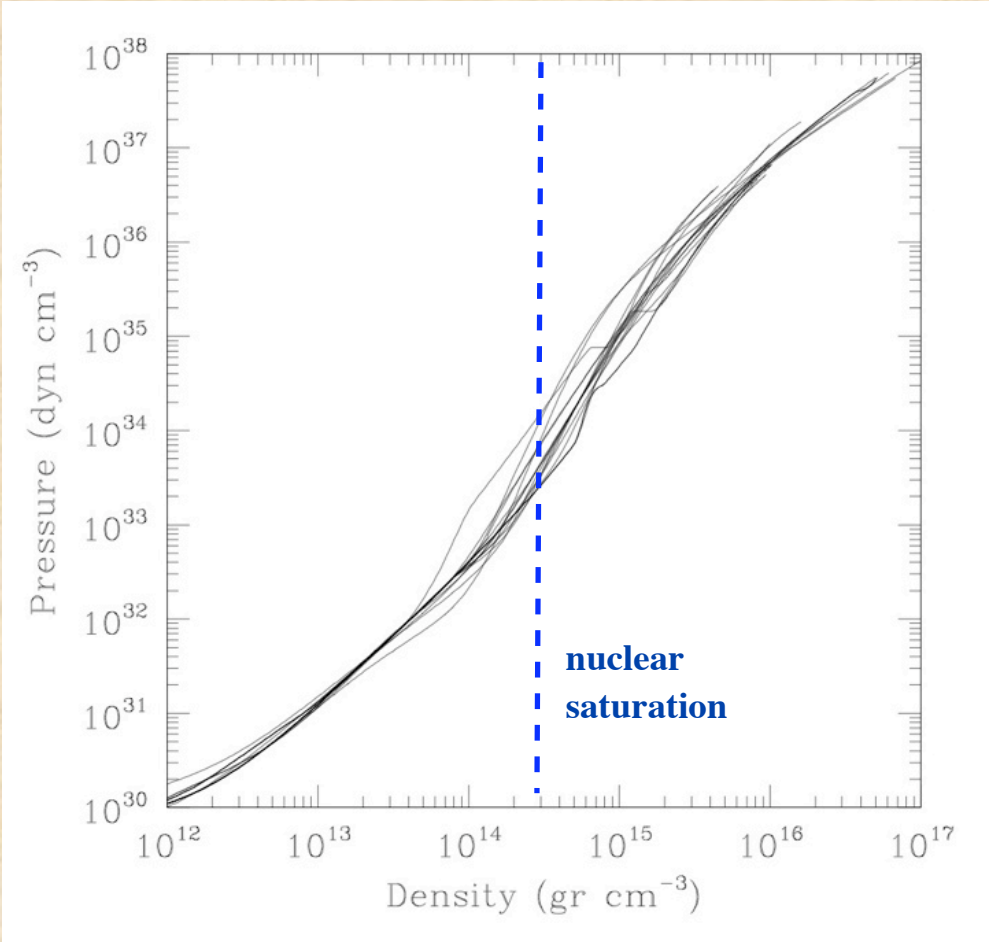
Neutron Stars as Test Beds of Strong-Field Gravity

Dimitrios Psaltis

University of Arizona

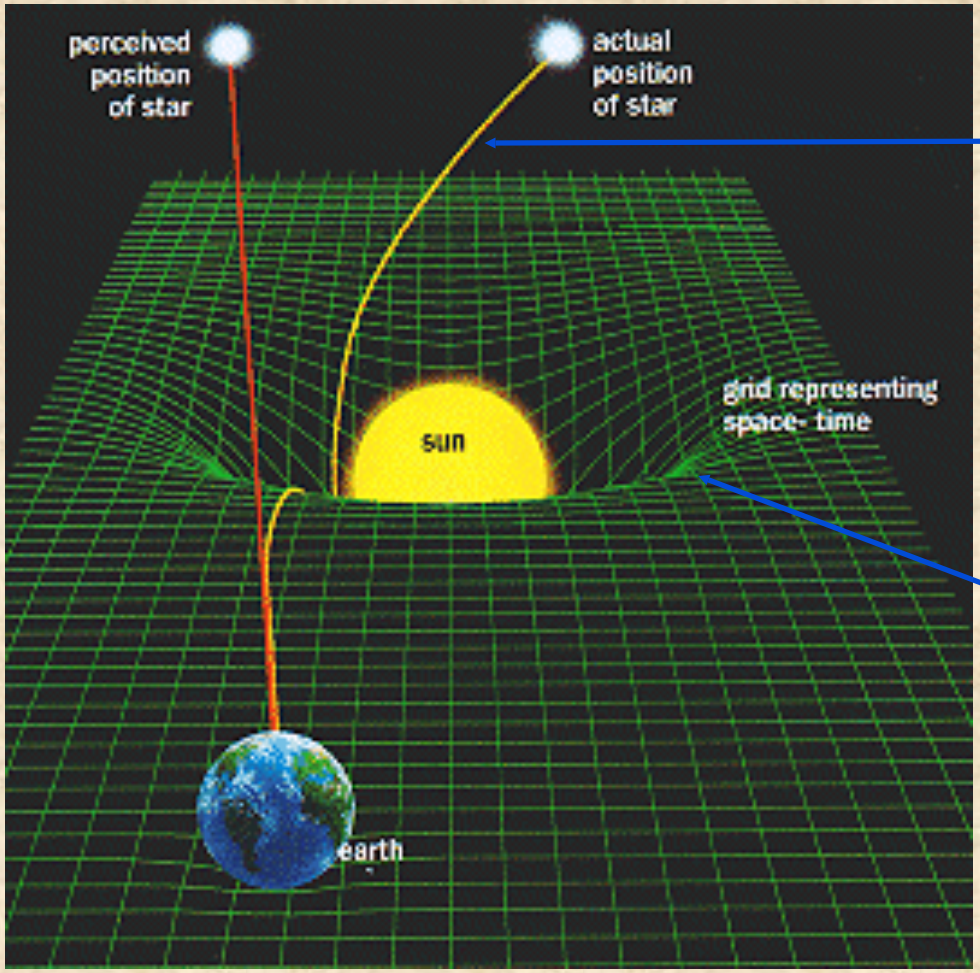
Living Reviews in Relativity, 2008, arXiv:0806:1531

Neutron Stars probe matter at densities ~100 times larger than what is well understood



but they probe gravitational fields ~10^{13} times stronger

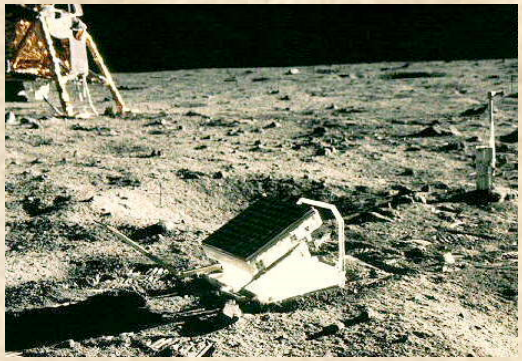
General Relativity has been Tested in Intermediate Field Strengths

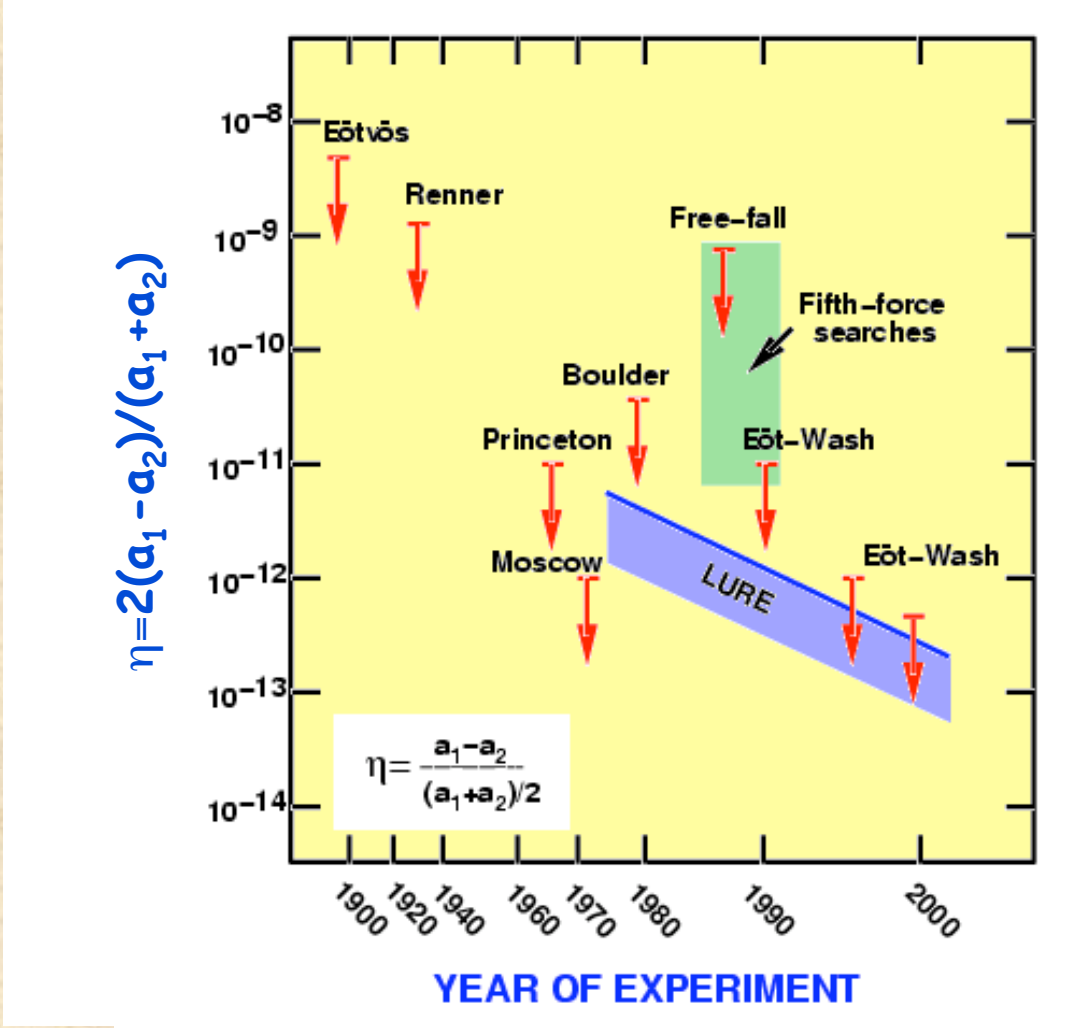


The Equivalence Principle

The Einstein Field Equation

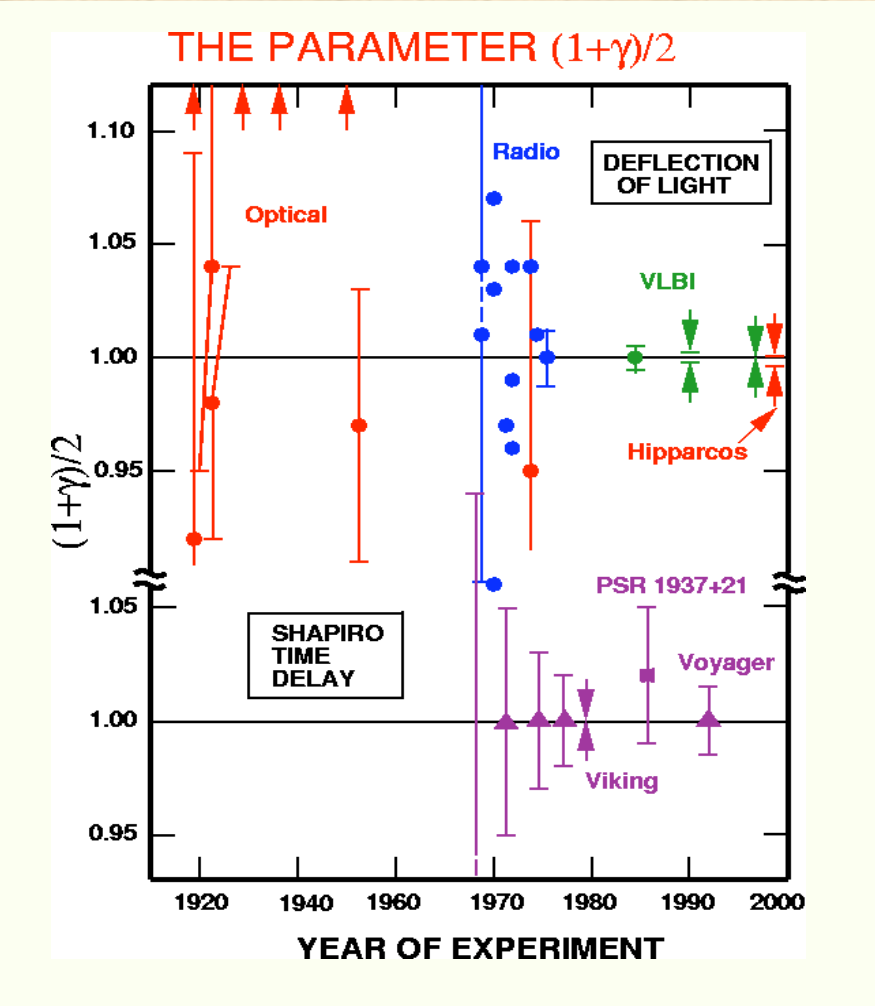
➢ The Equivalence Principle Has Been Tested to a Very High Degree



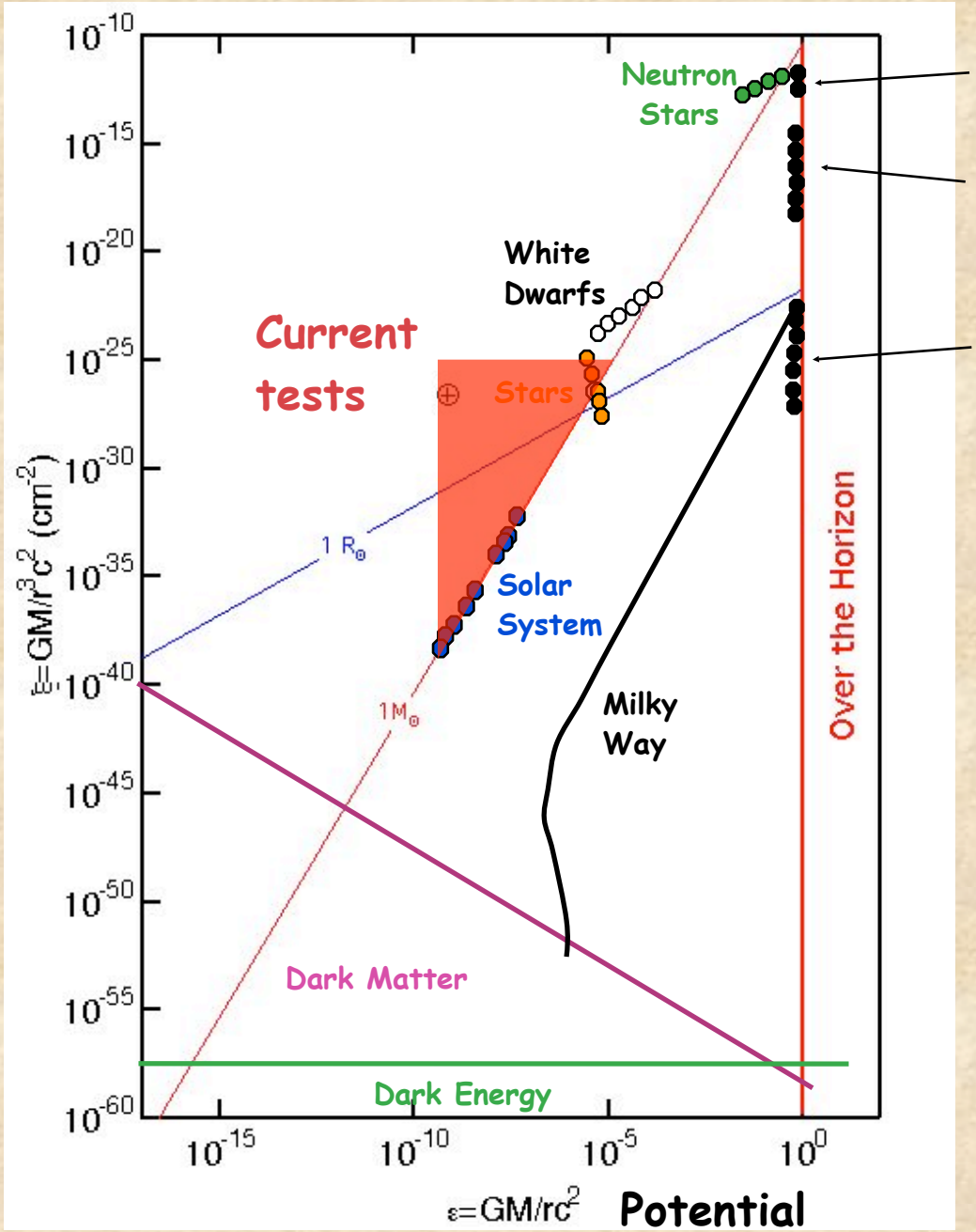


Will 2001

- The Einstein Field Equation has been tested to ~10^{-4}



PPN Metric: $$ds^2 = -\left(1 - 2\frac{GM}{rc^2}\right)dt^2 + \left(1 + \gamma\frac{2GM}{rc^2}\right)dr^2 + r^2 d\Omega$$



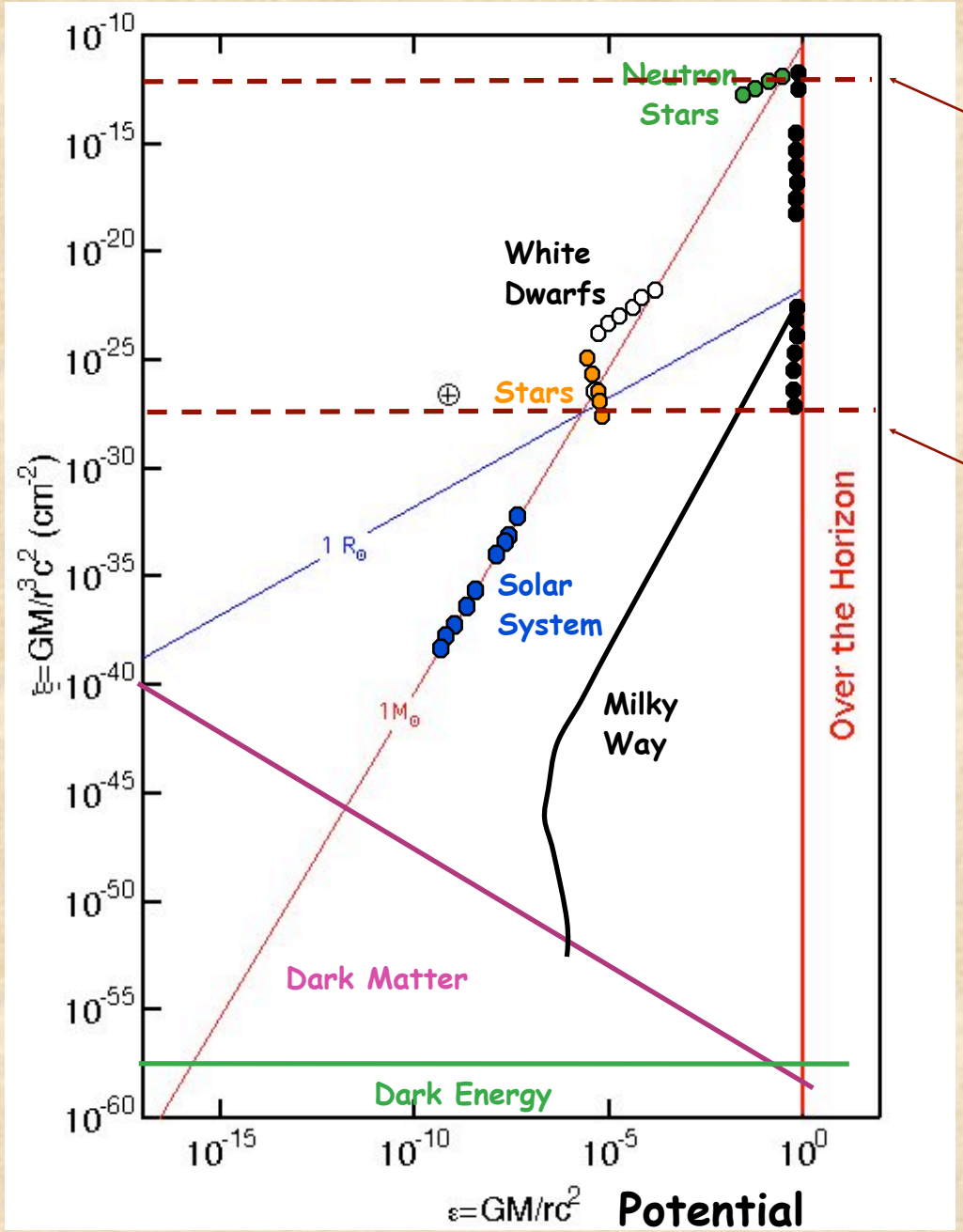
X-ray Binaries

Intermediate Mass Black-Holes

Active Galactic Nuclei

Gravitational Fields In Astrophysical Systems

Psaltis 2008

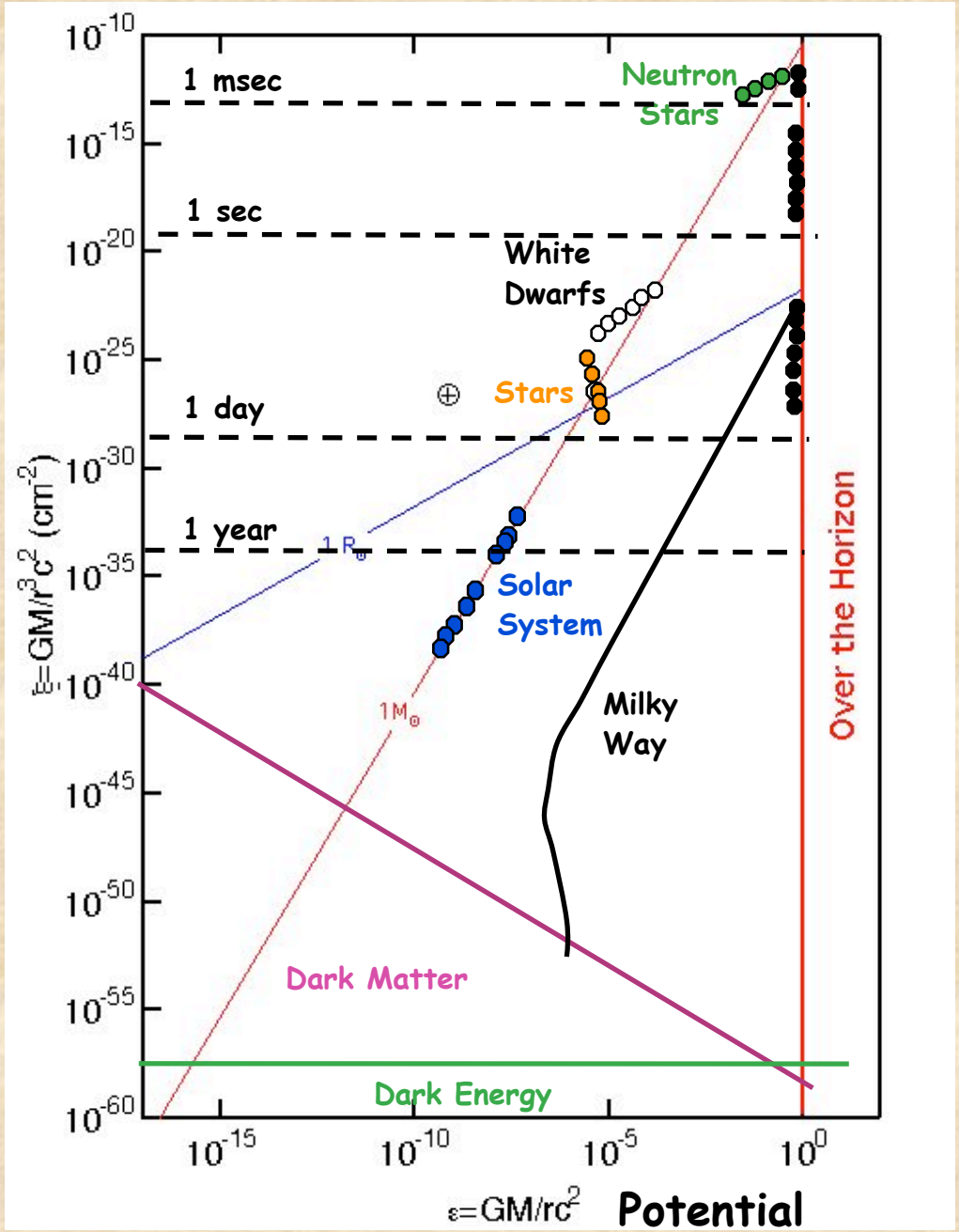


EW Baryogenesis

Nucleosynthesis

Gravitational Fields In Cosmology

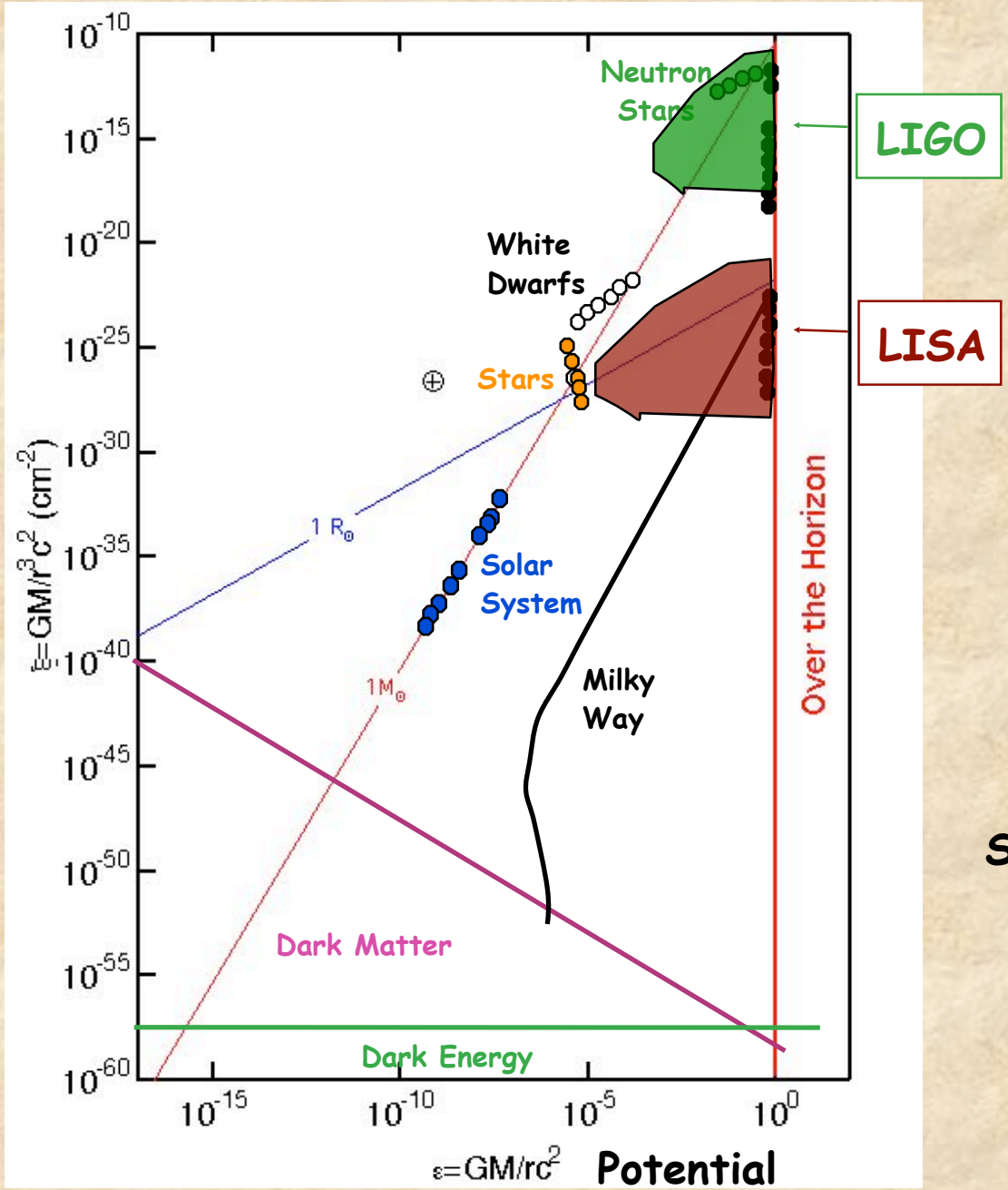
Psaltis 2008



Fast X-ray timing!
(AXTAR & IXO)

How to Probe the Strong Gravitational Fields

Psaltis 2008



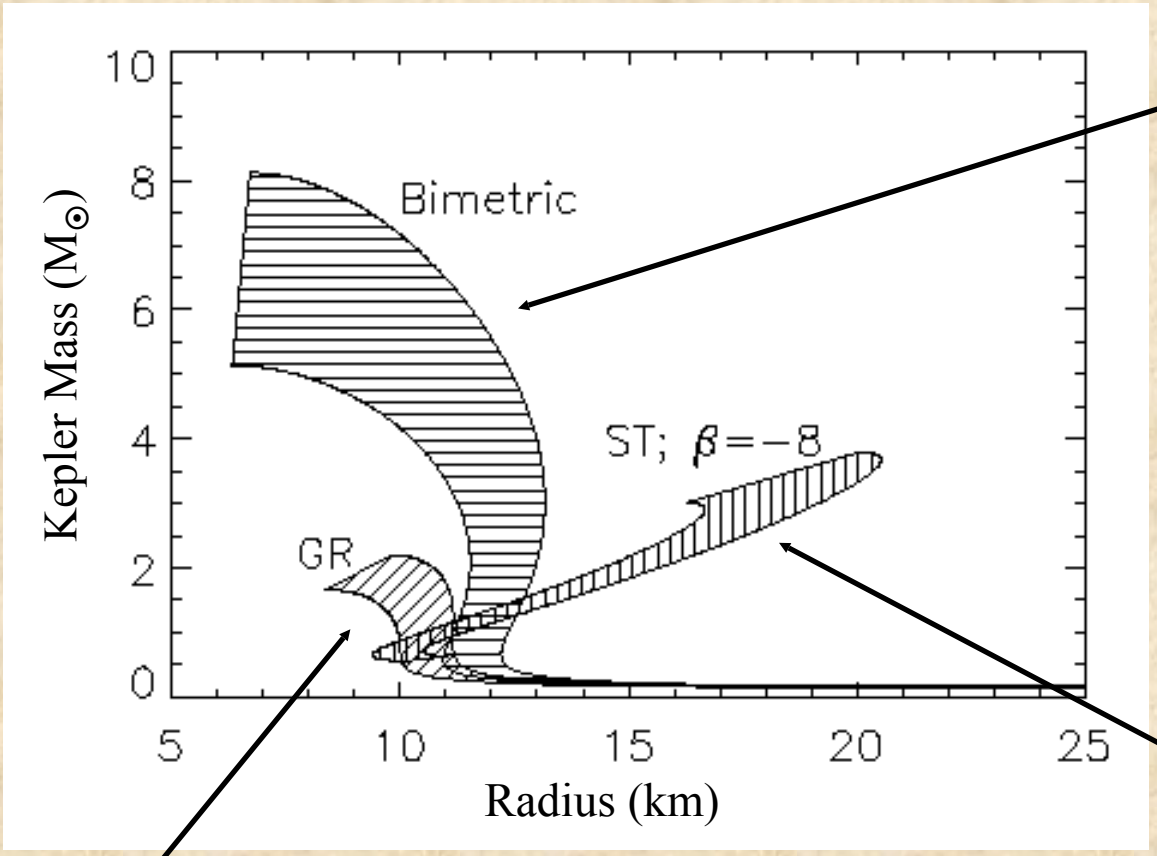
Fast X-ray timing!
(AXTAR & IXO)

High-Frequency
Gravitational Waves
(e.g.,LIGO, GEO600)

How to Probe the
Strong Gravitational Fields

Psaltis 2008

NEUTRON STARS IN ALTERNATIVE GRAVITY THEORIES



DeDeo & Psaltis 2003

Rosen's Theory

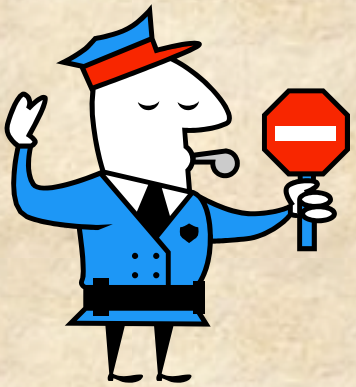
(prior geometry)

Scalar-Tensor

(dynamical)

General Relativity

- All theories consistent with solar system tests!
- Uncertainty due to gravity larger than EOS!



We have to be very careful when playing with Einstein's equation…

(aka a lesson learned from Cosmology)

Cosmic acceleration can be produced by

$$S = \frac{1}{16\pi G}\int d^4x\sqrt{-g}\left(R - \frac{\mu^2}{R}\right)$$

Carroll et al. 2004

But:

Universe unstable to small perturbations!

Dolgov & Kawasaki 2003; Sawicki & Hu 2007

Post-Newtonian corrections do not depend on μ!! $(\gamma = 1/2)$

Chiba 2003; Erickek et al 2006

Stars are unstable to small perturbations!!!

Seifert & Wald 2007; Seifert 2007

Cosmic acceleration can be produced by

$$S = \frac{1}{16\pi G}\int d^4x\sqrt{-g}\left(R - \frac{\mu^2}{R}\right)$$

Carroll et al. 2004

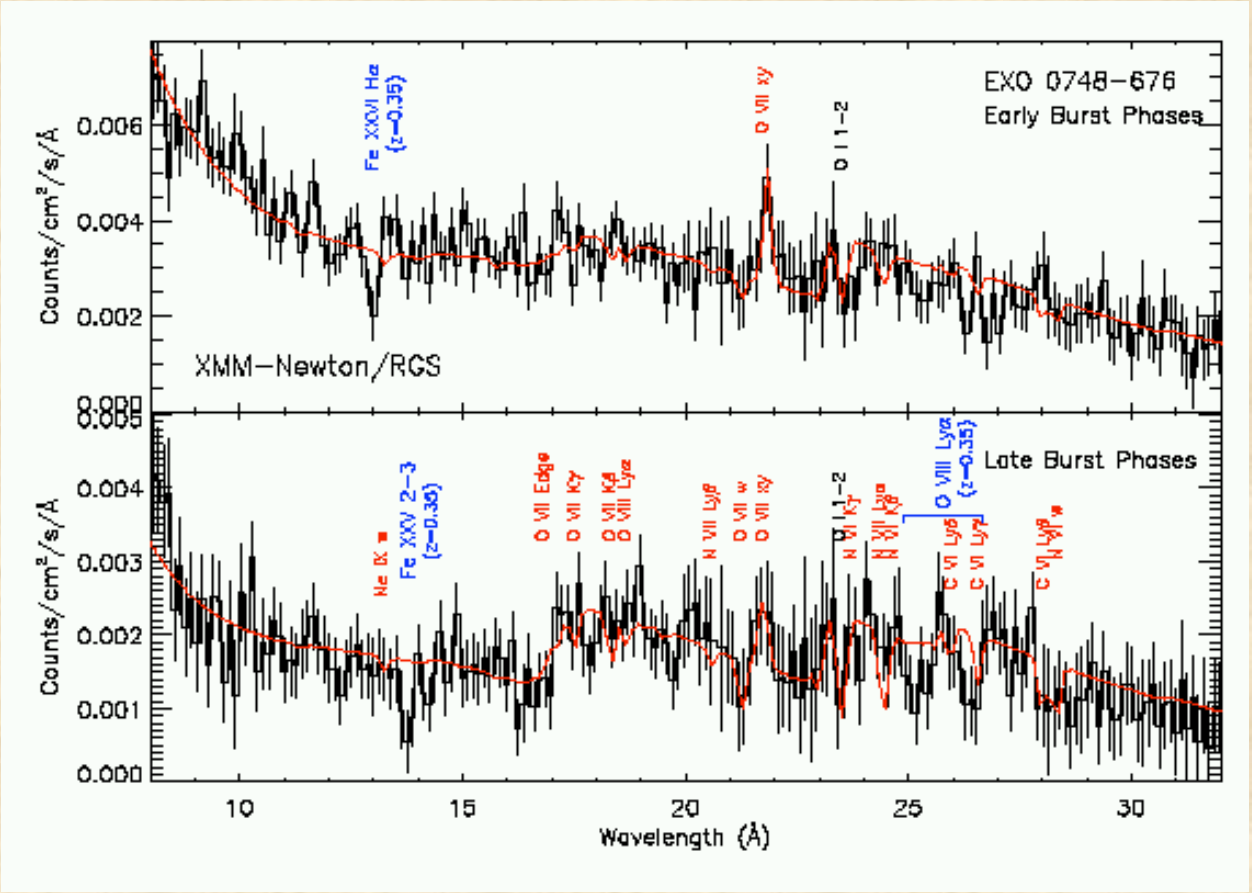
Solution to these problems requires

- fine tuning
- a chameleon field
- perturbative localization

DeDeo & Psaltis 2008

GRAVITATIONALLY REDSHIFTED LINES

Redshift for EXO 0748-676: $\delta\lambda/\lambda=0.35$

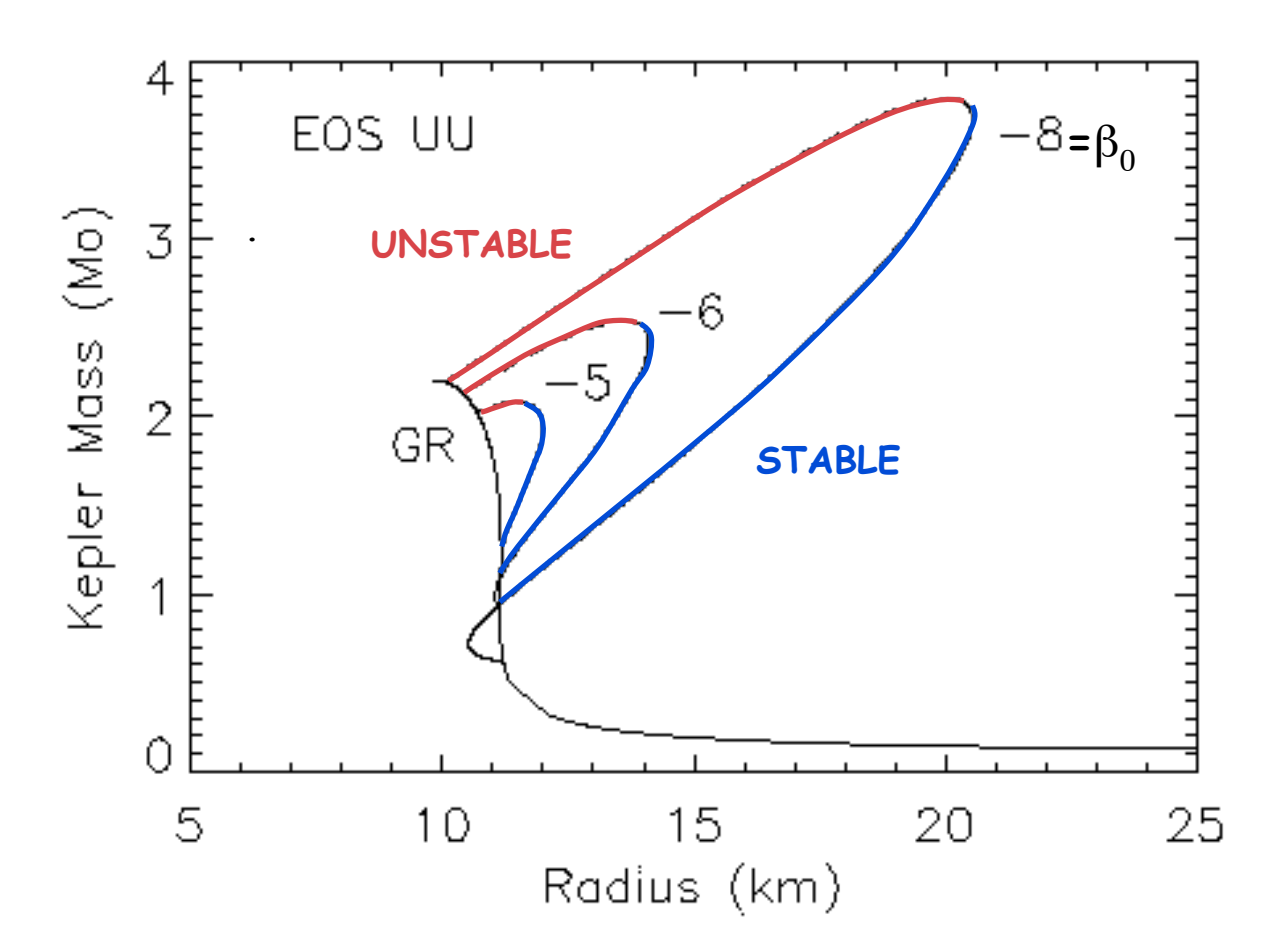


Cottam et al. 2002

Bonus: Neutron Stars are Spherically Symmetric

(when slowly rotating)

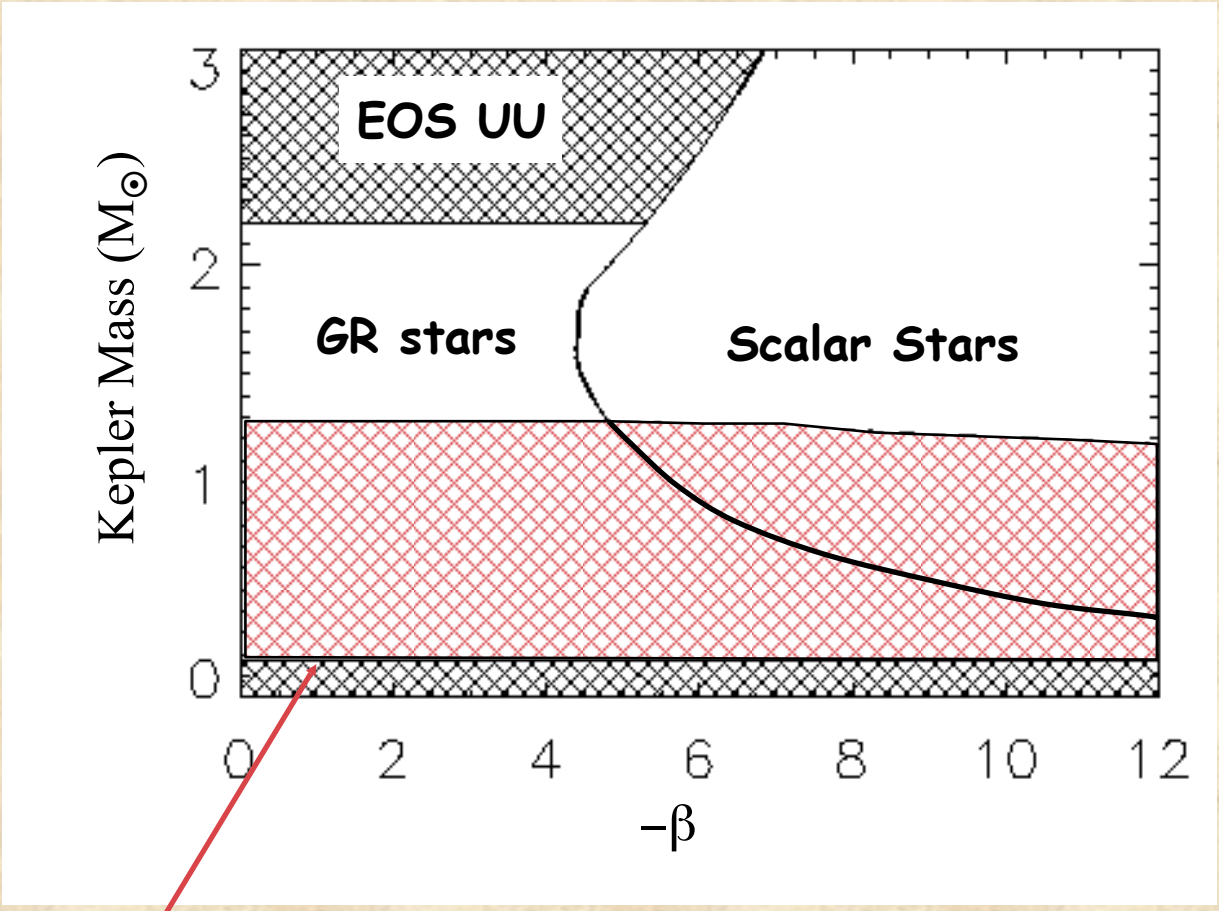
NEUTRON STARS IN SCALAR-TENSOR GRAVITY



DeDeo & Psaltis 2003

Scalar Stars can become Large and Massive

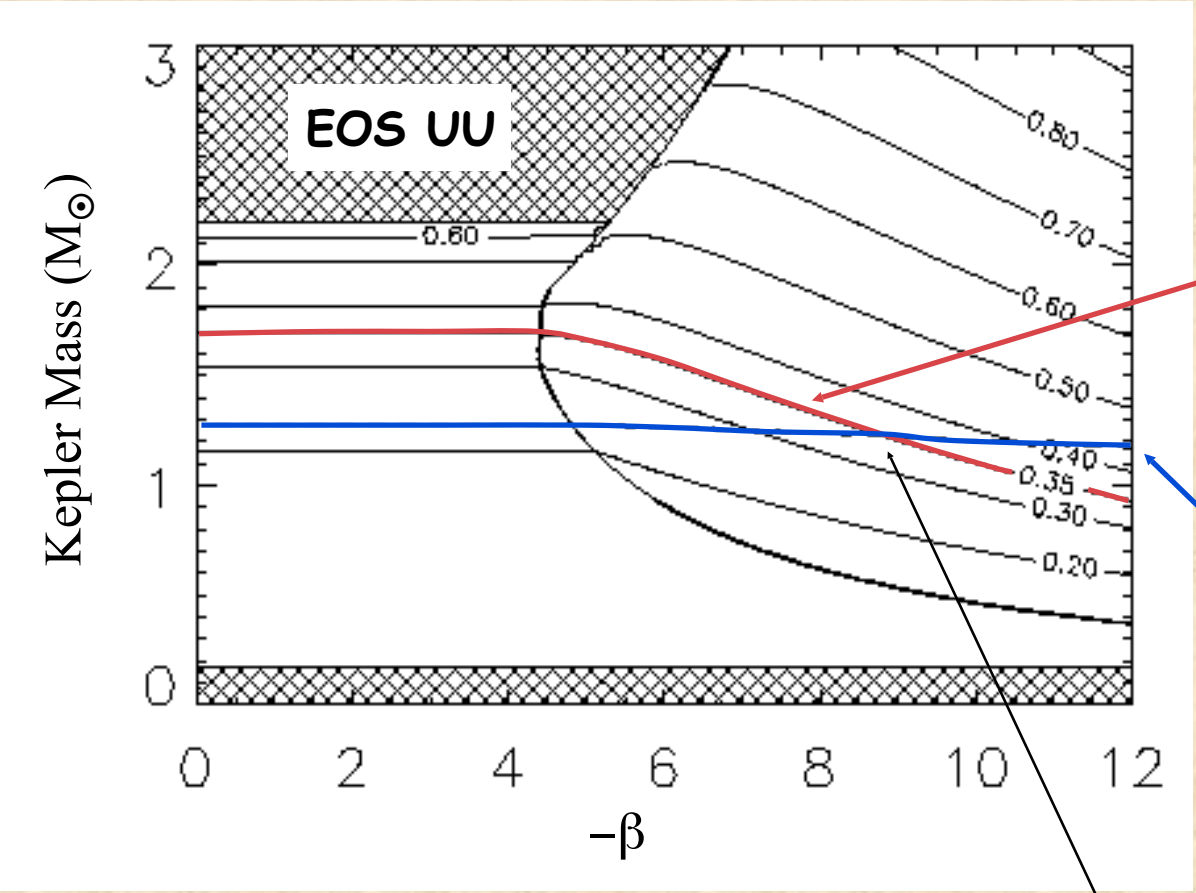
NEUTRON STARS IN SCALAR-TENSOR GRAVITY II



DeDeo & Psaltis 2003

Baryonic Mass < $1.4M_\odot$

LIMITS FROM GRAVITATIONAL REDSHIFTS



z=0.35

$M_{baryon} > 1.4 M_\odot$

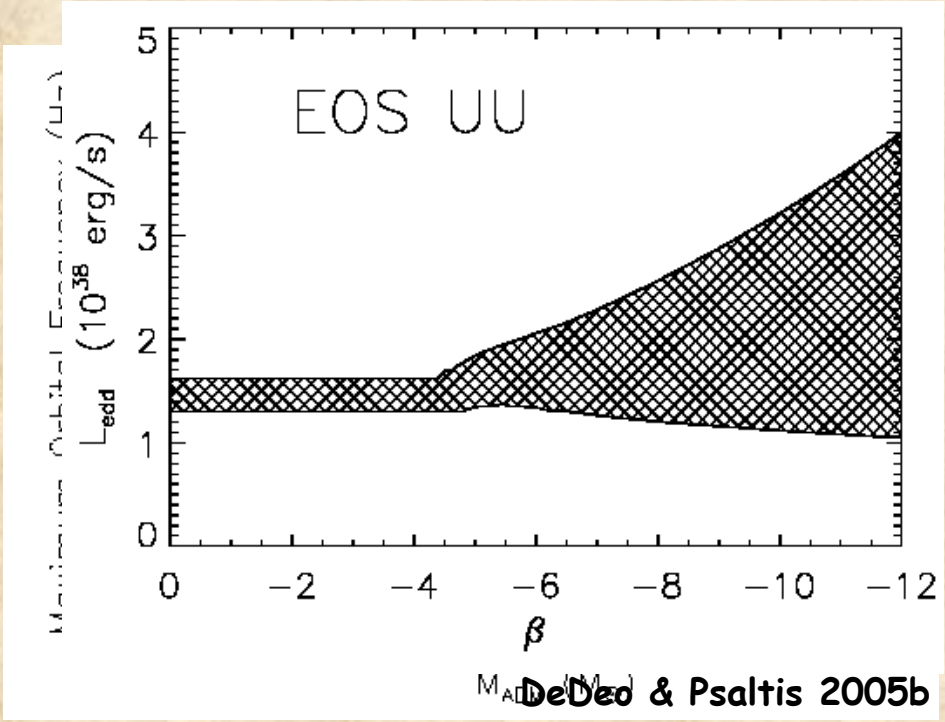
DeDeo & Psaltis 2003

Limit: $-\beta < 9$

If the mass of EXO 0748-676 is measured, limits will become tighter

Other tests with Neutron Stars

- Quasi-Periodic Oscillations
- Eddington-Limited Bursts
- Pulsar Glitches
- Neutron-Star Cooling
- Maximum Spin Frequency



DeDeo & Psaltis 2005b

DeDeo & Psaltis 2005a