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Compact stars in minimal dilatonic gravity

The Structure and Signals of Neutron Stars, from Birth to Death

Florence, 28. 03. 2014

The basic lesson from cosmology:

GR and the Standard Particles Model are not enough !

- One may add some new content: Dark matter, Dark energy
- One may modify GR: simplest modifications are F(R) and MDG
- Some combination of the above possibilities may work ?

What about the Star Physics ???

Do we have the same problem :

EOS versus gravity modification???

Maybe we need both pisibilities simultaneously ???

Plan of the talk:

- **Minimal dilatonic gravity (MDG)**
- **The basic equations of SSSS in MDG**
- **The boundary conditions for SSSS in MDG**
- **Neutron SSSS with simplest EOS in MDG**

SSSS = Static Spherically Symmetric Stars

Minimal dilatonic gravity (MDG)

$$\mathcal{A}_{g,\Phi} = \frac{c}{2\kappa}\int d^4x\sqrt{|g|}\left(\Phi R - 2\Lambda U(\Phi)\right)$$

O'Hanlon: PRL,1972,

PPF: Mod. Phys. Lett. 2000; gr-qc/0202074; PRD 2013.

Brans-Dicke with ω = 0

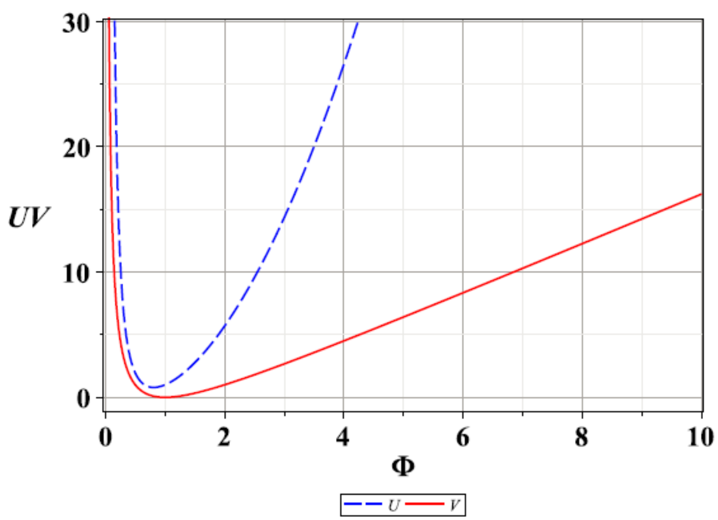
Locally equivalent to f(R): $$\mathcal{A}_{f(R)} = \frac{c}{2\kappa}\int d^4x\sqrt{|g|}f(R)$$

Withholding potentials:

PPF: PRD 2013:

No ghosts! No tachions !

$$V'(\Phi) = \tfrac{2}{3}\Big(\Phi U'(\Phi) - 2U(\Phi)\Big)$$



The basic equations of SSSS in MDG

PF: arXiv:1402.281

Generalized TOV

$$
\begin{aligned}
m' &= 4\pi r^2 \epsilon_{eff}/\Phi, \\
\Phi' &= -4\pi r^2 p_{\Phi}/\Delta, \\
p'_{\Phi} &= -\frac{p_{\Phi}}{r\Delta}\left(3r - 7m - \frac{2}{3}\Lambda r^3 + 4\pi r^3 \frac{\epsilon_{eff}}{\Phi}\right) - \frac{2}{r}\epsilon_{\Phi}, \\
p' &= -\frac{p+\epsilon}{r}\frac{m + 4\pi r^3 p_{eff}/\Phi}{\Delta - 2\pi r^3 p_{\Phi}/\Phi},
\end{aligned}
$$

$$
\begin{aligned}
\epsilon_{eff} &= \epsilon + \epsilon_{\Lambda} + \epsilon_{\Phi}, \\
p_{eff} &= p + p_{\Lambda} + p_{\Phi}
\end{aligned}
$$

$$
\Delta(r) = r - 2m(r) - \frac{1}{3}\Lambda r^3
$$

ALL NOVEL

$$
\begin{aligned}
\epsilon_{\Lambda} &= \frac{\Lambda}{8\pi}\Big(U(\Phi) - \Phi\Big) \\
p_{\Lambda} &= -\frac{\Lambda}{8\pi}\left(U(\Phi) - \frac{1}{3}\Phi\right) \\
V'(\Phi) &= \tfrac{2}{3}\Big(\Phi U'(\Phi) - 2U(\Phi)\Big)
\end{aligned}
$$

$$
\begin{aligned}
\epsilon_{\Lambda} &= -p_{\Lambda} - \frac{\Lambda}{12\pi}\Phi\,; && \longleftarrow \text{CEOS} \\
\epsilon_{\Phi} &= p - \frac{1}{3}\epsilon + \frac{\Lambda}{8\pi}V'(\Phi) && \longleftarrow \text{DEOS} \\
&+ \frac{p_{\Phi}}{2}\,\frac{m + 4\pi r^3 p_{eff}/\Phi}{\Delta - 2\pi r^3 p_{\Phi}/\Phi}\,; \\
\epsilon &= \epsilon(p) && \longleftarrow \text{MEOS}
\end{aligned}
$$

The boundary conditions for SSSS in MDG

PF: arXiv:1402.281

Assuming: $r_c = 0$

$$m(0) = m_c = 0, \quad \Phi(0) = \Phi_c, \quad p(0) = p_c,$$
$$p_\Phi(0) = p_{\Phi c} = \frac{2}{3}\left(\frac{\epsilon(p_c)}{3} - p_c\right) - \frac{\Lambda}{12\pi} V'(\Phi_c).$$

SSSS edge: $P = 0 \Rightarrow r^*$

$$m^* = m(r^*; p_c, \Phi_c), \quad \Phi^* = \Phi(r^*; p_c, \Phi_c),$$
$$p^*_\Phi = p_\Phi(r^*; p_c, \Phi_c).$$

Cosmological horizon: r_U

$$r \in [r^*, r_U] \quad p \equiv 0 \text{ and } \epsilon \equiv 0$$
$$r_U: \ \Delta(r_U; p_c, \Phi_c) = 0,$$

$$\Phi(r_U; p_c, \Phi_c) = 1 \quad \longleftarrow \quad \text{De Sitter vacuum}$$

$$F_\Phi(p_{\Phi c}, p_c, \Phi_c) = 0, \quad F_\Lambda(p_c, \Phi_c) = 0. \quad \longleftarrow \quad \text{Two specific MDG relations}$$

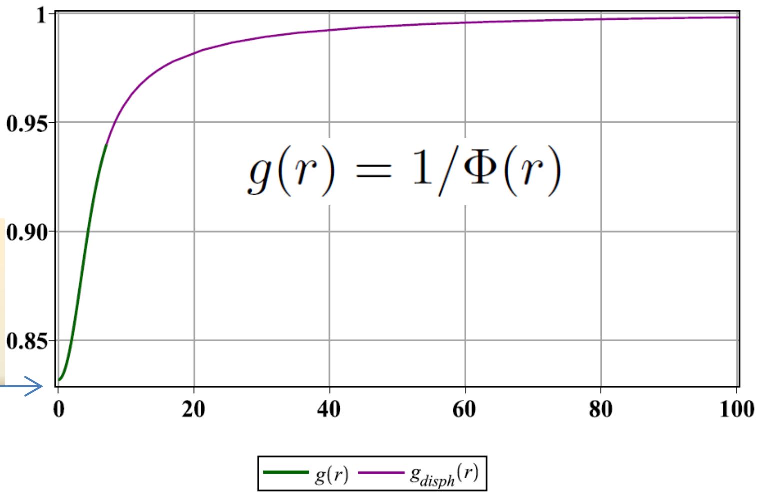
One parametric (p_c) family of SSSS – as in GR and the Newton gravity !

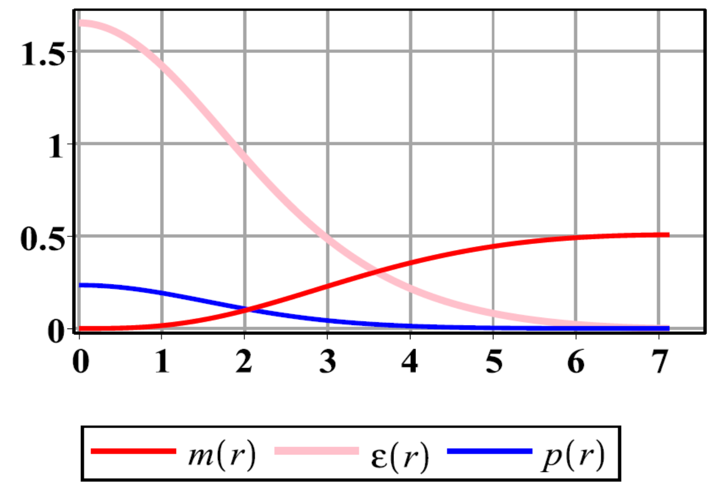
Chandrasechkar (1935), TOV (1939) MEOS in MDG

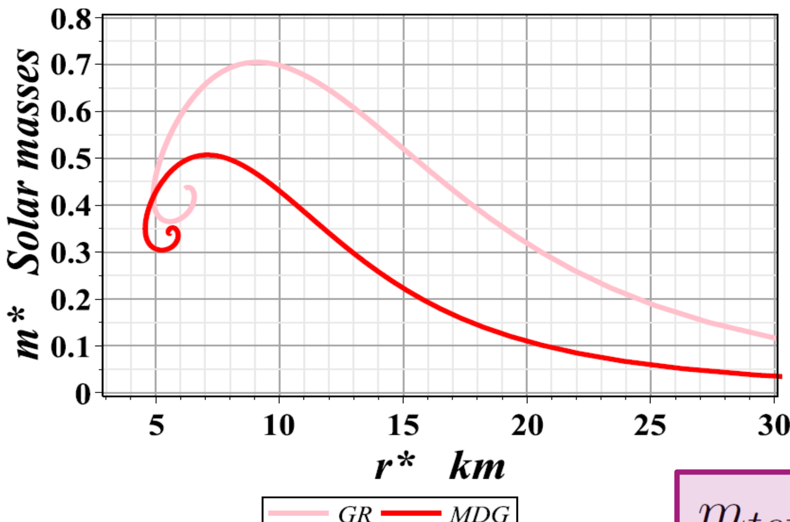
PF: arXiv:1402.281

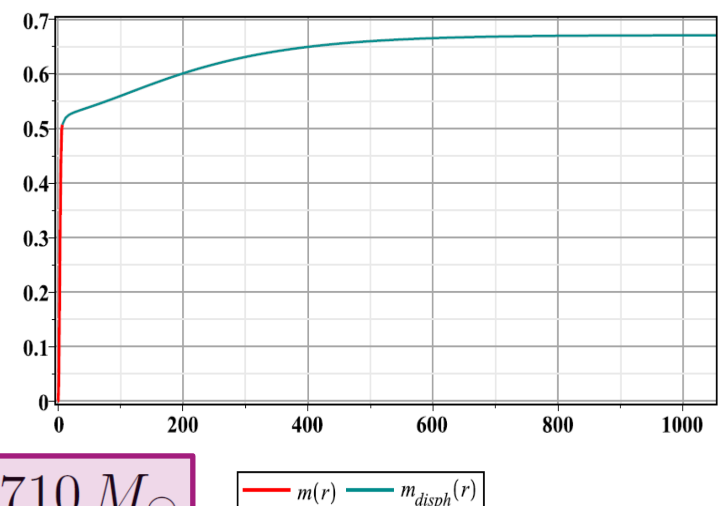
$$\epsilon = \frac{1}{4\pi}(\sinh t - t), \quad p = \frac{1}{12\pi}(\sinh t - 8\sinh(t/2) + 3t).$$

17% weaker gravity

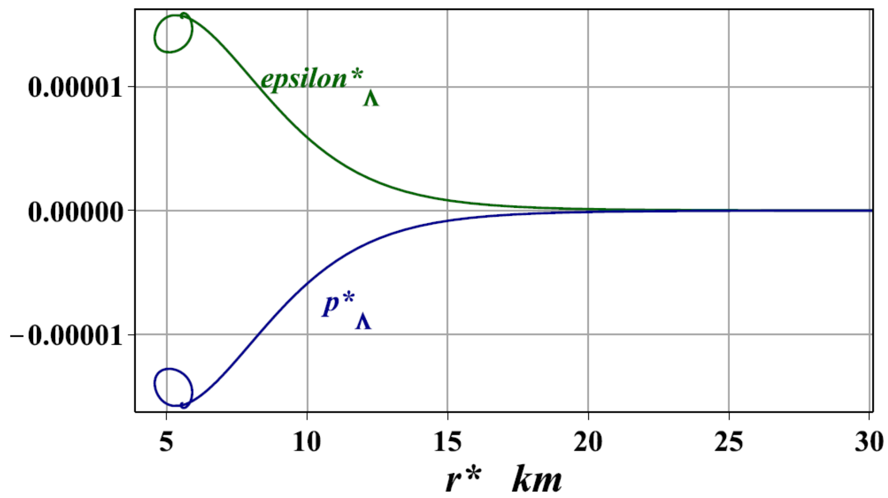


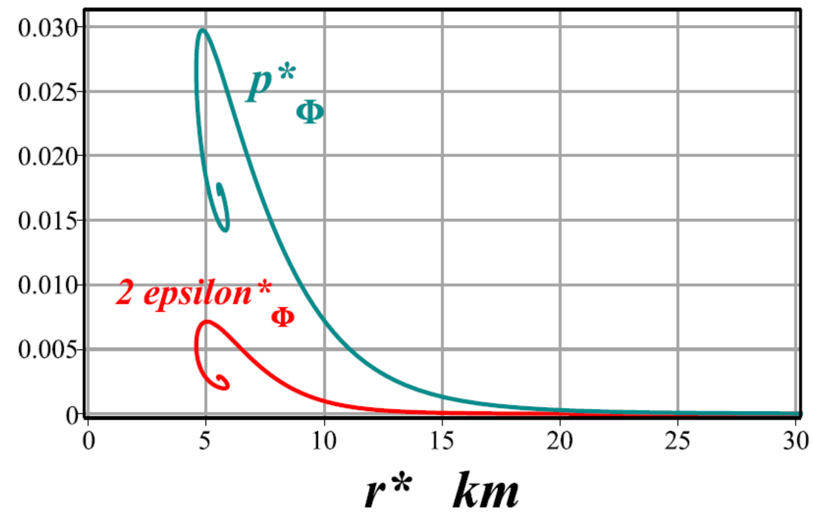


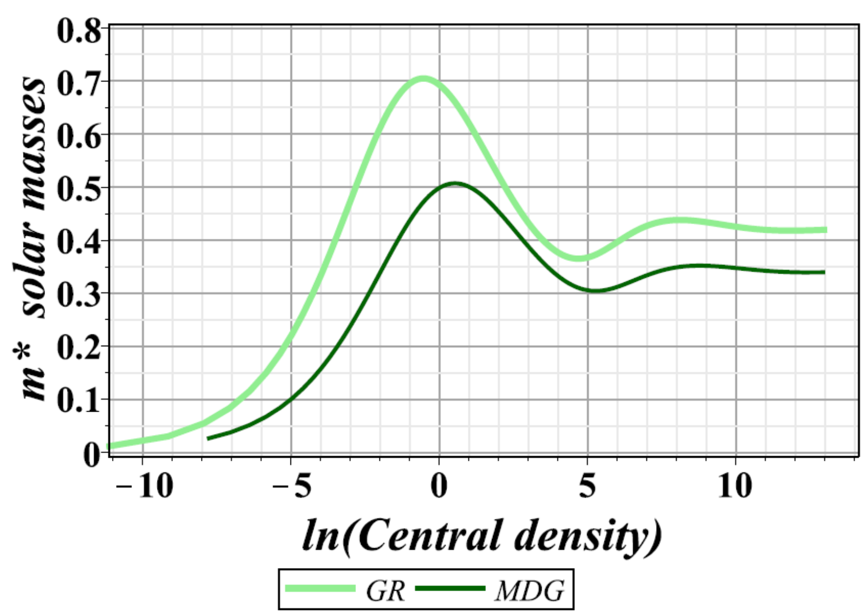




$$m_{total} \approx 0.6710\, M_{\odot}$$







In MDG we have the same stability properties of SSSS as in GR

Conclusion

Most probably we need to look

simultaneously and coherently

for **a realistic EOS**

and

for **a realistic withholding cosmological potential**

which are able to describe the variety of

cosmological, astrophysical, gravitational and star phenomena

at different scales.

MICHELANGELO Buonarroti, 1511:
Separation of Light from Darkness

Thank you !