Title: The Galileon as a local modification of gravity

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Abstract: TBA

Alberto Nicolis
Columbia University

The Galileon as a local modification of gravity

with R.Rattazzi and E.Trincherini

"local"

local 4D QFT

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local 4D QFT

d << Hubble

General Relativity in the IR

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- "Beautiful" (?)

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- the C.C. problem
- the present acceleration

IR Modifications of GR

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⇒ GR (ca. 1965)

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Assuming:

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- ~~massless~~ → Fierz-Pauli (bad)
- ~~Lorentz invariance~~ → ghost condensate (good)
- ~~locality~~ → DGP (5D) (good and bad)

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Deviations from GR d << Hubble	$\Longleftrightarrow$	effective light scalar dof mixed with metric

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demix $\Rightarrow$ $\mathcal{L} \sim \mathcal{L}_{GR} + \mathcal{L}_\pi + \pi T^\mu{}_\mu$

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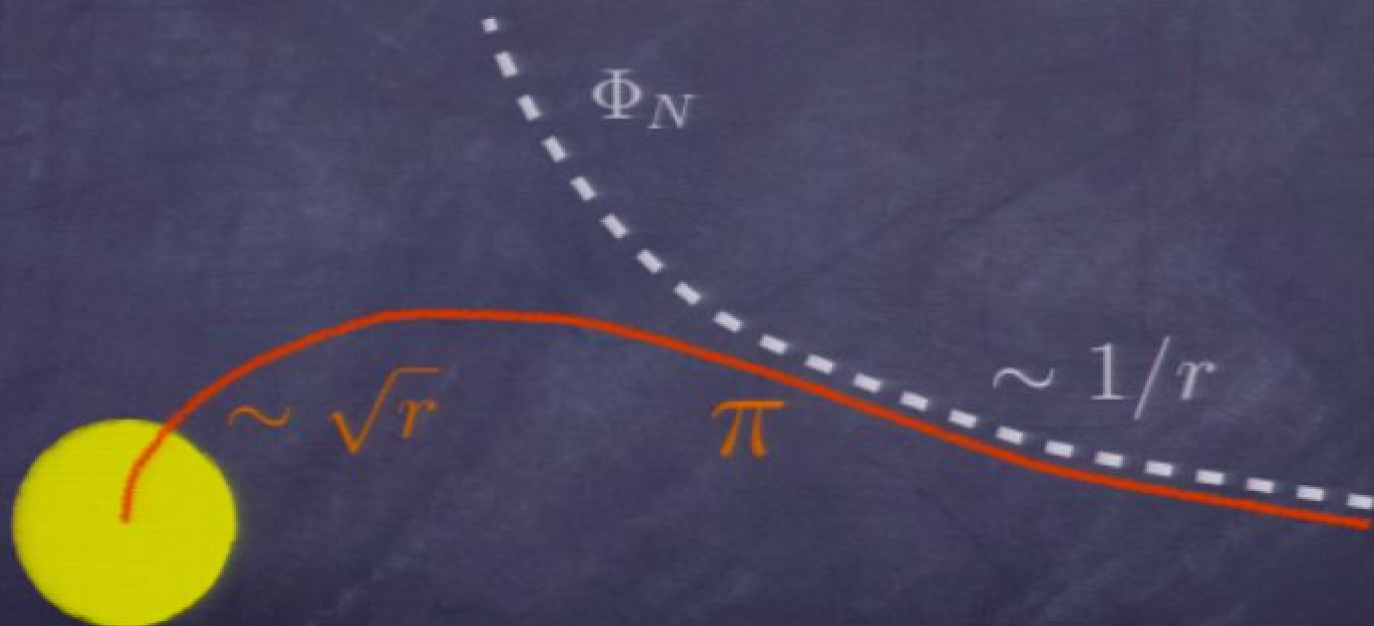

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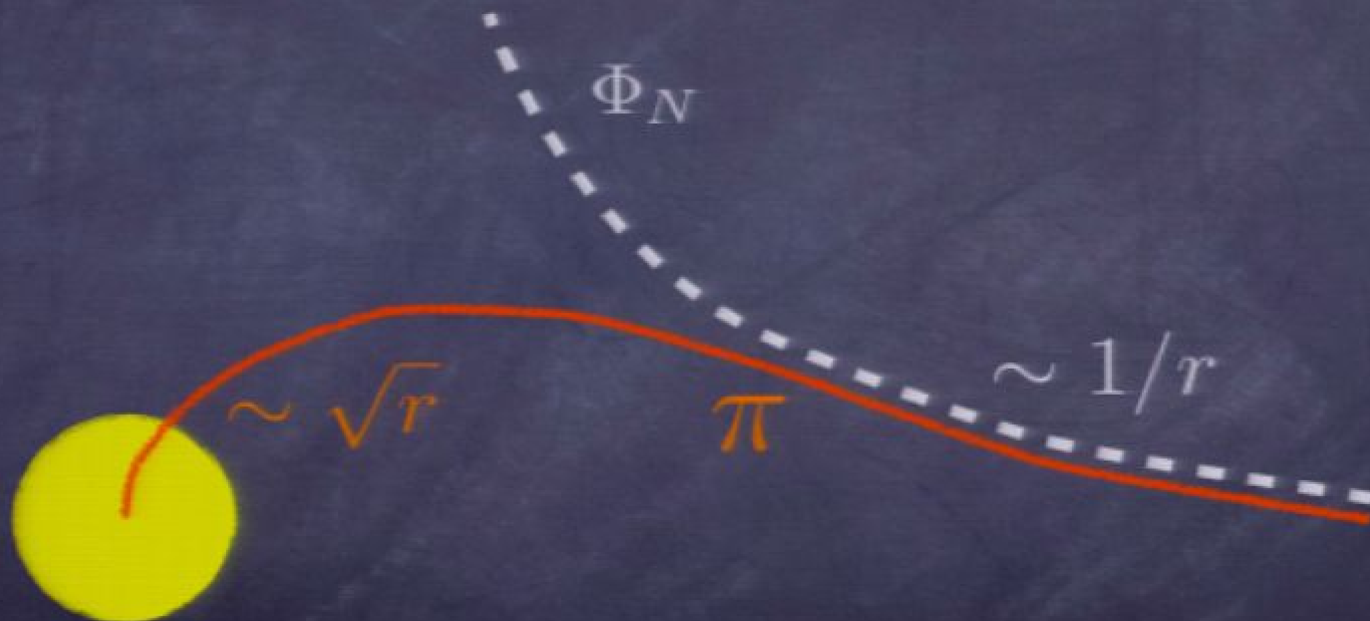

"Vainshtein effect"

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$$h_{\mu\nu}^{\rm phys} = h_{\mu\nu} + \pi\, \eta_{\mu\nu}$$ $\Rightarrow$ deSitter (locally)

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- Start seeing the 5th dimension (non-locality)

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(i.e. universally coupled $\pi T^{\mu}{}_{\mu}$)

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$$ds^2 \simeq \left[1 - \tfrac{1}{2} H^2 \vec{x}^2 + \tfrac{1}{2}(2\dot{H} + H^2)t^2\right](-dt^2 + d\vec{x}^2)$$

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"Physical" Metric:

$$\hat{h}_{\mu\nu} = h_{\mu\nu} + 2\pi\,\eta_{\mu\nu}$$

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⇨ For given $T_{\mu\nu}$ (and bdy. conditions)

$$h_{\mu\nu} = h_{\mu\nu}^{\rm GR}$$

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$$\hat{R}_{\mu\nu} = R_{\mu\nu} - 2\partial_\mu\partial_\nu\pi - \eta_{\mu\nu}\Box\pi$$

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Check: plug π into their EOM

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local matter distribution ⇒ corrections to geometry

$$\Delta R_{\mu\nu} \sim \partial_\mu \partial_\nu \pi$$

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2-derivative EOM

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- Invariance: $\mathcal{L}^{(n)} \to \mathcal{L}^{(n)} + \partial_\mu G^\mu$

Galilean Invariants

$$\mathcal{L}_1 = \pi \tag{34}$$
$$\mathcal{L}_2 = -\tfrac{1}{2}\,\partial\pi\cdot\partial\pi \tag{35}$$
$$\mathcal{L}_3 = -\tfrac{1}{2}\,[\Pi]\,\partial\pi\cdot\partial\pi \tag{36}$$
$$\mathcal{L}_4 = -\tfrac{1}{4}\big([\Pi]^2\,\partial\pi\cdot\partial\pi - 2\,[\Pi]\,\partial\pi\cdot\Pi\cdot\partial\pi - [\Pi^2]\,\partial\pi\cdot\partial\pi + 2\,\partial\pi\cdot\Pi^2\cdot\partial\pi\big) \tag{37}$$
$$\begin{aligned}\mathcal{L}_5 = -\tfrac{1}{5}\big(&[\Pi]^3\,\partial\pi\cdot\partial\pi - 3[\Pi]^2\,\partial\pi\cdot\Pi\cdot\partial\pi - 3[\Pi][\Pi^2]\,\partial\pi\cdot\partial\pi + 6[\Pi]\,\partial\pi\cdot\Pi^2\cdot\partial\pi \\ &+2[\Pi^3]\,\partial\pi\cdot\partial\pi + 3[\Pi^2]\,\partial\pi\cdot\Pi\cdot\partial\pi - 6\,\partial\pi\cdot\Pi^3\cdot\partial\pi\big)\end{aligned} \tag{38}$$

$$\Pi^\mu{}_\nu \equiv \partial^\mu\partial_\nu\pi \qquad\qquad [\cdots] \equiv \mathrm{Tr}\{\cdots\}$$

In conclusion:

$$\mathcal{L}_\pi = \sum_{i=1}^{5} c_i \mathcal{L}_i$$

- Lagrangian very constrained: 5 coeffs.
- thorough analysis of highly symmetric solutions
- for dS and spherical sols.: algebraic problem

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Stable dS self-accelerating solutions

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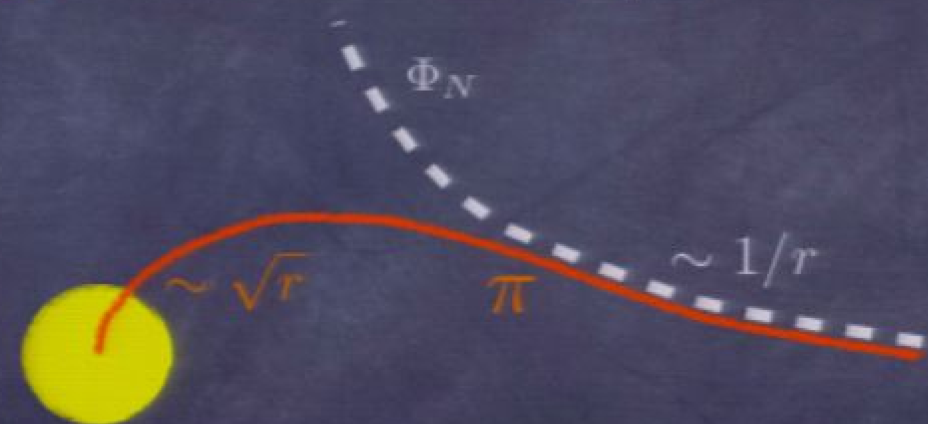
Stable Vainshtein-like spherical sols.



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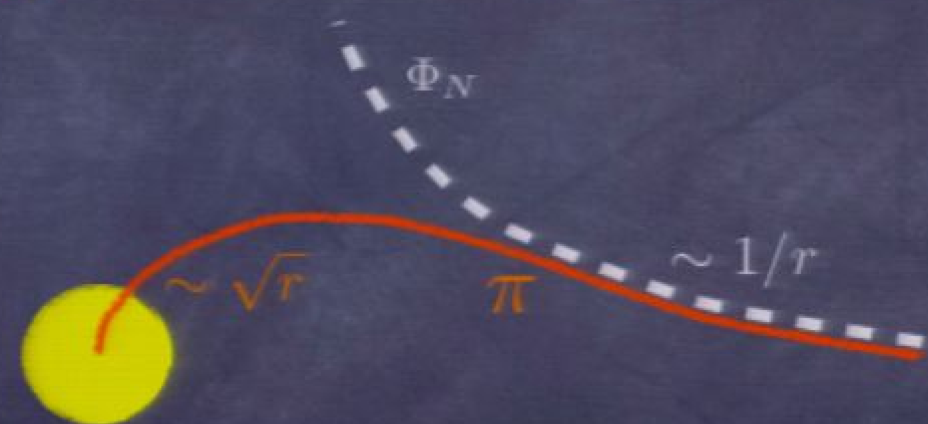

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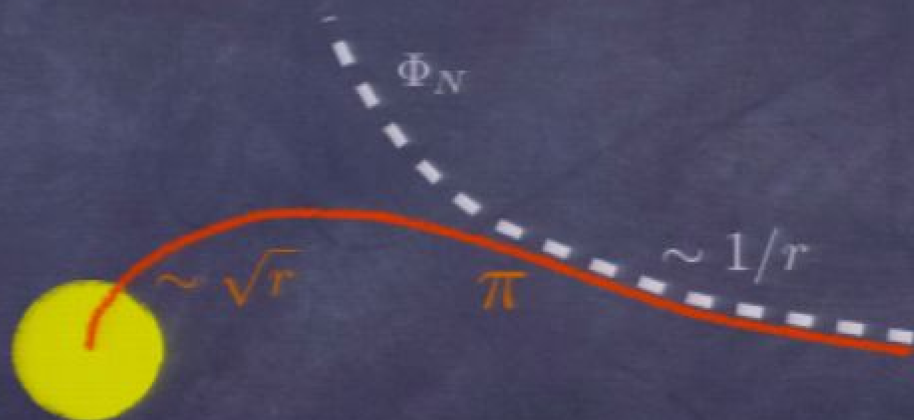

bad news:

Superluminal radial excitations

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⇨ "UV" cutoff $k < H_0$!

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- here: still an open question

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- Stable NEC violation (see next talk)