Distinguishing Dark Energy from Modified Gravity

- Define an effective energy-momentum tensor of missing matter:

$$T^{\mu\nu}_{\text{eff dark}} \equiv \frac{1}{8\pi G} G^{\mu\nu} - \sum_{\text{known } a} T^{\mu\nu}_{a}$$

If the visible sectors satisfy the equivalence principle then necessarily

$$\left(T^{\mu\nu}_{\text{eff dark}}\right)_{;\nu} = 0$$

SB, arXiv:0707.0692;
Hu & Sawicki, arXiv:0708.1190

Then any visible dynamics can be "explained" by effective dark dynamics that is assumed to affect the visible species by Einstein equations.

Linearly:
Kunz & Sapone, astro-ph/0612452;
Zukin & Bertschinger, arXiv:0801.2431

Most generally:
SB, arXiv:0707.0692;
Hu & Sawicki, arXiv:0708.1190

- <u>Nevertheless, modified gravity can be detected</u>, in view of its **conceptual distinctions** from GR:
  1. Some dark species may couple non-covariantly to the metric $g_{\mu\nu}$, which controls the dynamics of the visible species.
  2. The gravitational action may be not $S_{\text{grav}} = \frac{1}{16\pi G}\int d^4x\sqrt{-g}R$

Detecting Modified Gravity

- If gravity is not governed by general relativity then:
  1. The inferred effective dark dynamics is expected to violate the equivalence principle. Then we could observe that
     a. The inferred laws for local dark dynamics depend on the distribution of visible matter

        (This dependence should be more drastic than what could be explained by possible non-gravitational coupling between dark and visible matter.)

        SB, arXiv:0707.0692;
        Hu & Sawicki, arXiv:0708.1190

     b. The inferred dark dynamics is superluminal

        (Yet note that superluminality is physically admissible and may coexist with regular general relativity, e.g., Babichev, Mukhanov, Vikman 07)

  2. Propagation of gravitational waves may deviate from predictions of the Einstein equations

     Kahya and Woodard 07

(Of course, there are complimentary, non-cosmological, tests for general relativity: Hulse-Taylor pulsar, frame-dragging, etc.)