Theoretical Challenges Dark Energy Detection

Jerome Gleyzes,
Jet Propulsion Laboratory, California Institute of Technology

Jet Propulsion Laboratory
California Institute of Technology

Theoretical Challenges

Non Linearities

Non Linearity and multiples sources

$$\phi_{\rm tot} = \phi_A + \phi_B + \phi_\Delta$$

Departure from superposition

- Chameleon

Standard approach: if $m_B \ll m_A$, B does not modify force from A

- Vainshtein

Violation of Equivalence Principle

Hiramatsu et al, '13 : mass dependent screening of Source A close to Source B

Confirms Standard approach when $m_B \ll m_A$

What happens far away from sources?

- Saddle points?
- Special regions with three sources? Geometry dependence of Vainshtein

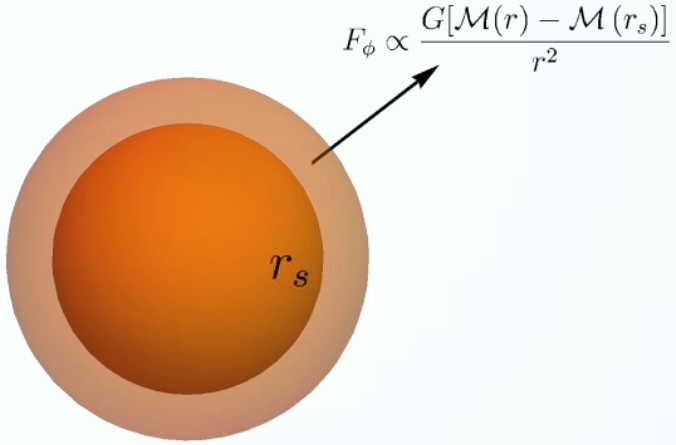
Bloomfield et al '15

Non Linearity and shape dependence

- Chameleon

Thin shell effect → shape dependence?

Burrage et al '17: increased force for shapes that minimize some internal dimension



Credit: Burrage and Sakstein, '17

- Vainshtein

Non linear term $\sim \left[(\partial_i \partial_j \phi)^2 - (\Delta\phi)^2\right]$

Bloomfield et al '15: screening depends on geometry

- **Planar:** no screening
- **Cylindrical:** suppression r/r_V
- **Spherical:** suppression $(r/r_V)^{3/2}$

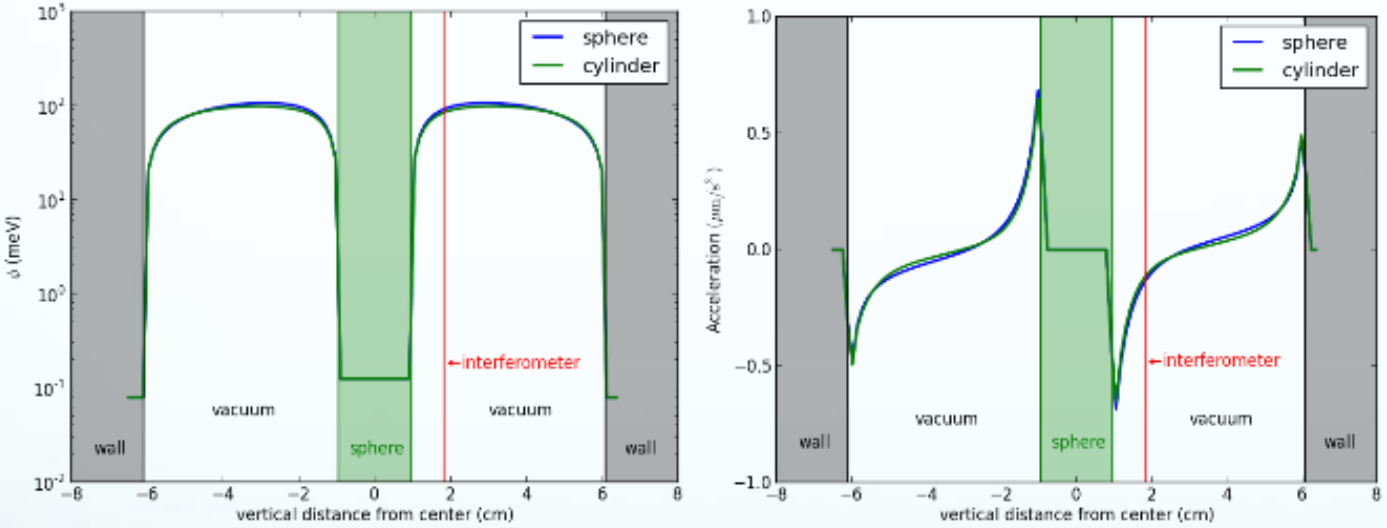
$$\left[(\nabla_\mu \nabla_\nu \phi)^2 - (\Box\phi)^2\right]$$

Ultra relativstic sources?

Boundary Conditions

- Chameleon

  Short ranged inside dense object: shielded from exterior

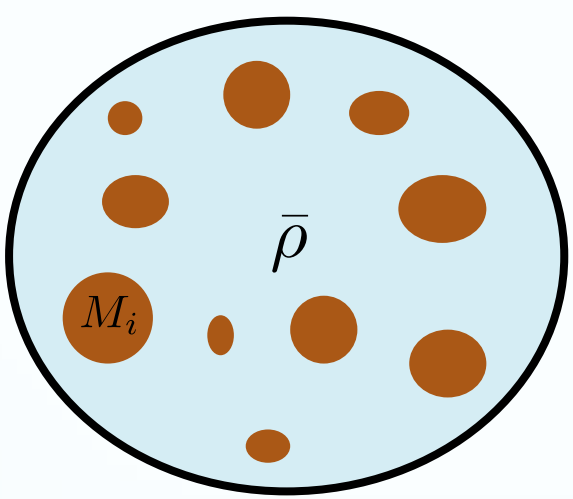


Credit: Elder et al '16

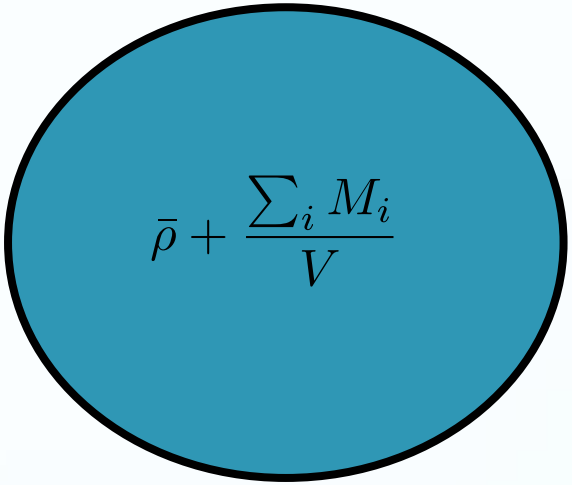
Ideal for lab experiments
see e.g. *Hamilton et al '15*

What about open space? How to set boundary conditions? No Birkhoff theorem

Boundary Conditions



?
=



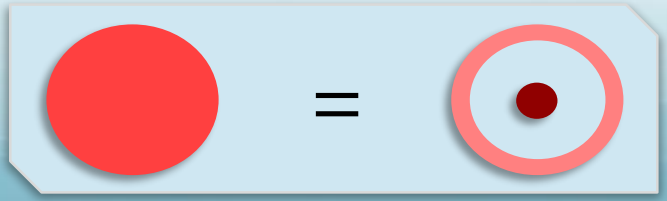
$$\Delta\phi + N(\phi) = \alpha\left[\bar{\rho} + \frac{\sum_i M_i}{V}\right]$$

Far from sources

$$\Delta\phi \simeq \alpha\left[\bar{\rho} + \frac{\sum_i M_i}{V}\right]$$

- **Chameleon:** *not* true due to thin shell effect $\longrightarrow V(\phi)$
- **Vainshtein:** for Galileons, EOM $\nabla \cdot G(\phi) \sim \rho \longrightarrow$ Birkhoff theorem?

Spherical Symmetry:



Other geometries?

Theoretical Challenges

Broader Picture

Testing Screening

Screening is model dependent

- Universal/Common behaviors?

  Deviation from inverse square law?

  Violation of equivalence principle?

  Difference photon – massive particles?

- Connection to Cosmology difficult

  How to interpret parameters?

Interplay with Cosmology

- Non linear regime demands N-Body simulations

  Model dependent

  Implementation in dark matter codes → thin shell effect accounted for?

- Effective approach linear theory

  Only one code needed (e.g. hi-class)

  Extensions to treat screening?

Conclusion

In practice, screening is difficult:

No superposition of solutions

Strong geometry dependence

Backreaction problems can complicate boundary conditions

More generally, testing screening is even harder:

Very model dependent

Connection to cosmology not always obvious

} Effective description?