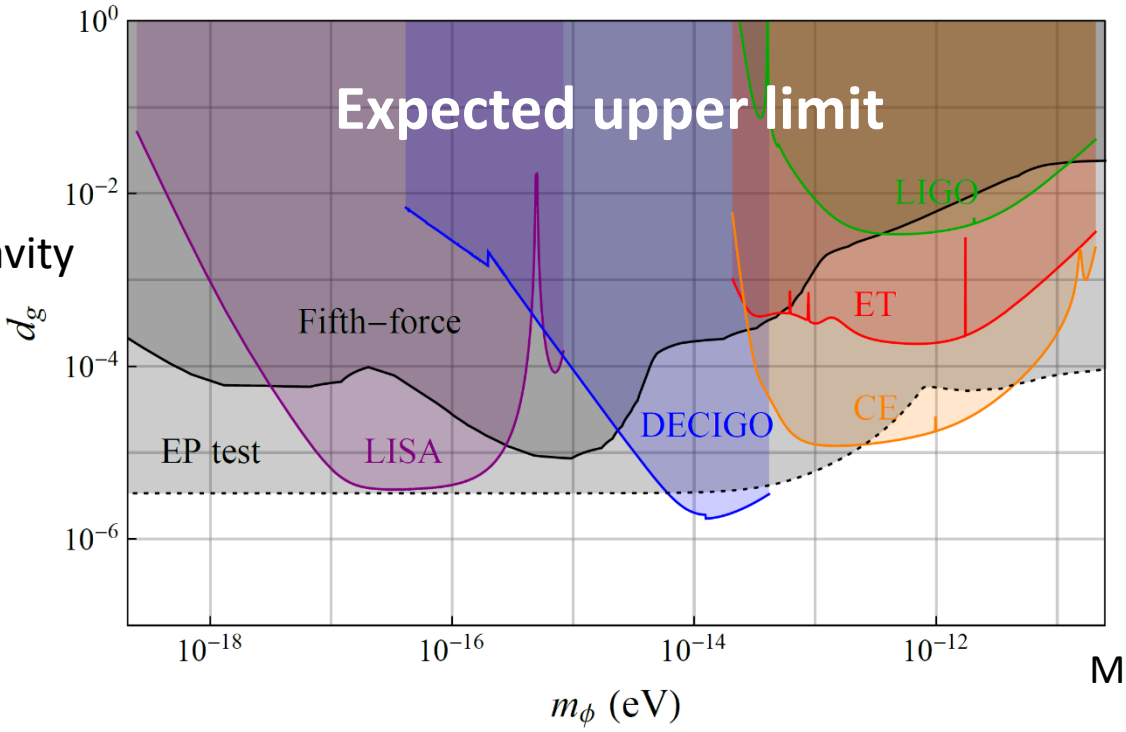
Upper limit on the scalar field dark matter from LIGO third observation run (D03)

Teruaki Suyama (Tokyo Tech)

Collaborators: Kouki Fukusumi (Tokyo Tech)
Soichiro Morisaki (ICRR)

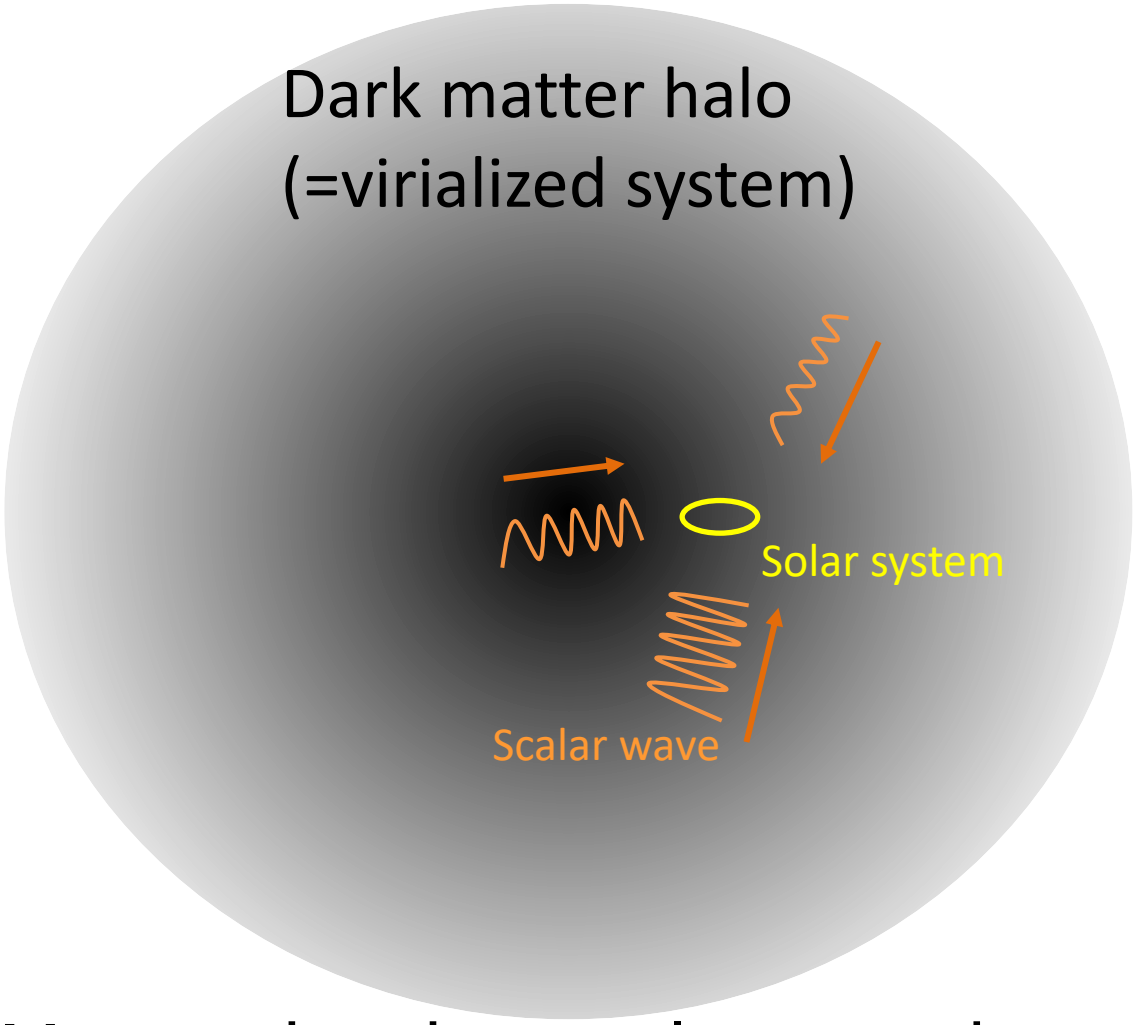
Scalar force/gravity



Morisaki, TS 2019

Dark matter may be detected by the interferometers!

Ultralight scalar field as dark matter



DM = stochastic, nearly monochromatic classical wave

Signal of the scalar field

Damour, Donoghue, '10

$$\mathcal{L}_{\phi-\mathrm{SM}} = \kappa\phi \left[\frac{d_e}{4e^2} F_{\mu\nu}F^{\mu\nu} - \frac{d_g \beta_3}{2g_3} G^A_{\mu\nu} G^{A\mu\nu} - \sum_{i=e,u,d} (d_{m_i} + \gamma_{m_i} d_g) m_i \bar{\psi}_i \psi_i \right]$$

EM field

Gluon field

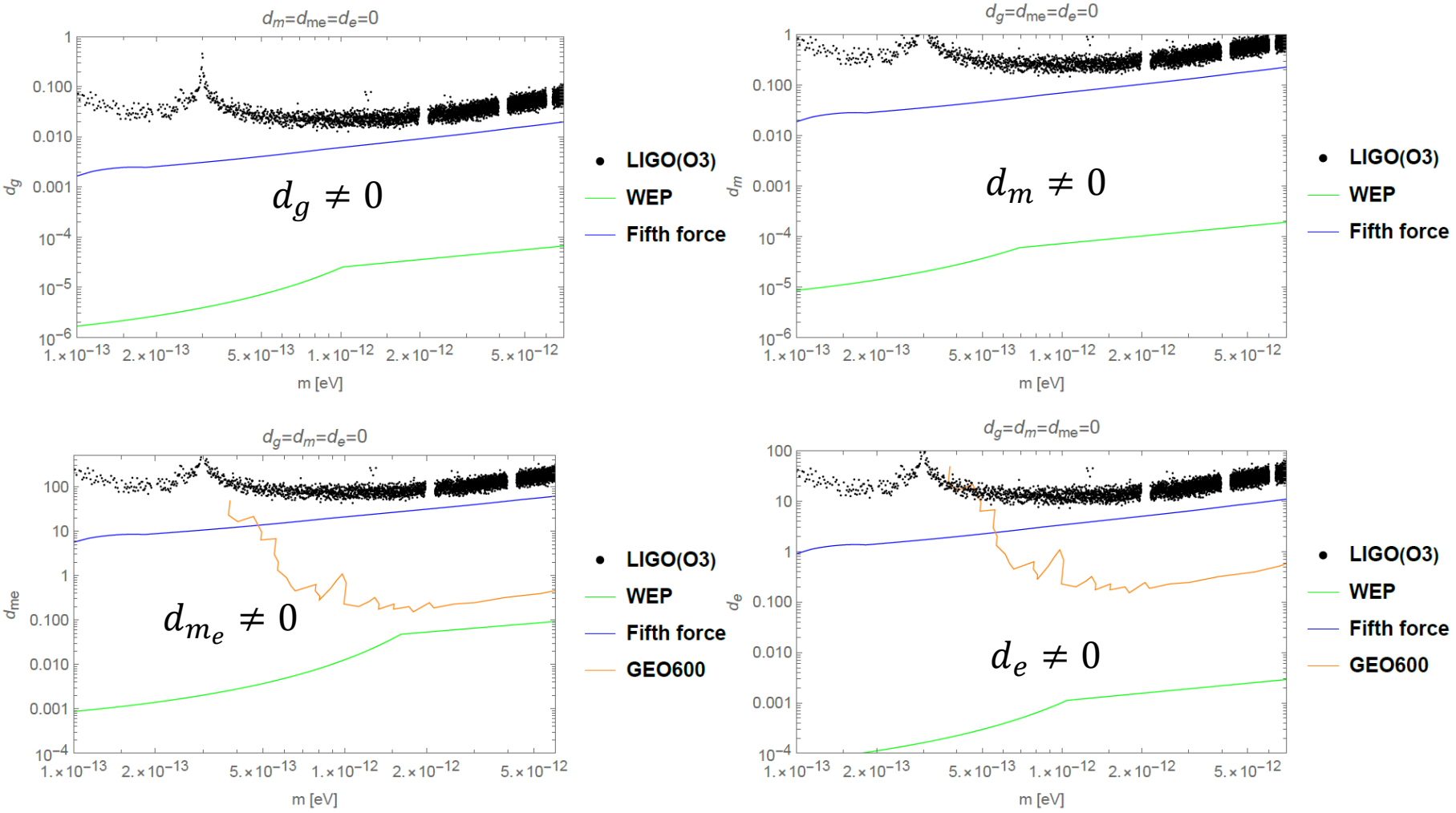
Quark field

$\kappa = \sqrt{4\pi G}$, d_g, d_{m_i}, d_e are dimensionless constant.

- Time variation of the physical constants
- Time variation of the mass of the body
- (stochastic) oscillations of the mirror's position

We formulated cross correlation of the signals between the two detectors by including velocity distribution of dark matter and its anisotropy.

Upper limits on the coupling constants



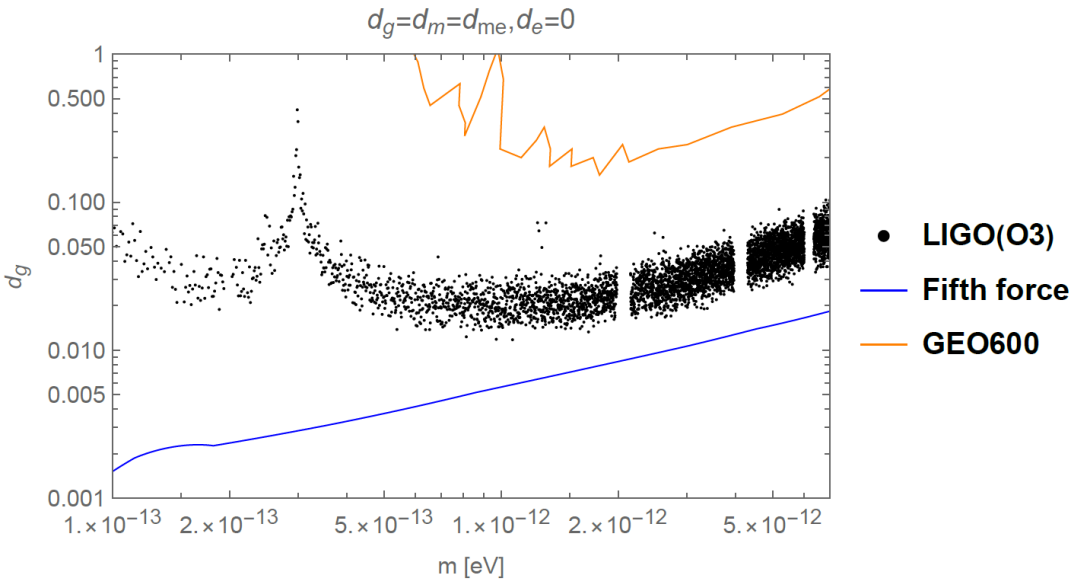
Nonminimal coupling model

$$S[\tilde{g}_{\mu\nu}, \Phi, \Psi] = \int d^4x \sqrt{-\tilde{g}} \left(\frac{1}{16\pi G}\tilde{R} - \frac{1}{2}\tilde{g}^{\mu\nu}\partial_\mu\Phi\partial_\nu\Phi - \kappa^{-1}\zeta\tilde{R}\Phi - \frac{M^2}{2}\Phi^2 \right) + S_m[\tilde{g}_{\mu\nu}, \Psi]$$

ζ: dimensionless parameter

$$d_g = d_{m_e} = d_{m_{u,d}} = \frac{2\zeta}{\sqrt{1+12\zeta^2}}, \qquad d_e = 0.$$

No WEP constraint



Upgraded LIGO will soon reach the fifth force constraint.