

Covariant phase spaces beyond diffeomorphism invariance

Marek Liška,

*Dublin Institute for Advanced Studies and
Charles University, Prague*

In collaboration with: Ana Alonso-Serrano

*(Humboldt Universität zu Berlin and Max-Planck-
Institut Für Gravitationsphysik)*

and Luis J. Garay

(Universidad Complutense, Madrid)



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Based on:

- Ana Alonso-Serrano, Luis J. Garay and M.L., CQG 40 (2023),
arXiv:2204.08245
- Ana Alonso-Serrano, Luis J. Garay and M.L., PRD 106 (2022),
arXiv:2206.08746

Motivation

- covariant phase space formalism
 - covariant construction of the symplectic form
 - allows to compute conserved charges in diverse settings (black holes, de Sitter spacetime, BMS asymptotics, ...)
- does it work beyond diffeomorphism (Diff) invariant theories?
- simple and observationally viable example: **Weyl transverse gravity**

General relativity vs Weyl-transverse gravity

GR

- dynamical n-volume $\sqrt{-g}d^n x$
- Diff invariant, $\delta g_{\mu\nu} = 2\nabla_{(\mu}\xi_{\nu)}$
- divergenceless EoMs
- Λ a parameter in the Lagrangian
- Λ not radiatively stable

WTG

- nondynamical n-volume $\omega(x) d^n x$
- WTDiff invariant, $\delta g_{\mu\nu} = \phi g_{\mu\nu}$
 $\delta g_{\mu\nu} = 2\nabla_{(\mu}\xi_{\nu)}, \tilde{\nabla}_{\mu}\xi^{\mu} = 0$
- traceless EoMs
- Λ an integration constant
- Λ radiatively stable

Carballo-Rubio, Garay, García-Moreno, 2022

same classical solutions and equivalent quantisation of linearised theories

WTDiff-invariant covariant phase space

- variation of the Lagrangian

$$\delta\mathcal{L} = A^{\mu\nu}\delta g_{\mu\nu} + A_\psi\delta\psi + \tilde{\nabla}_\mu\theta^\mu$$

- θ^μ symplectic potential \longrightarrow symplectic form \longrightarrow Hamiltonian

Conserved current for gauge transformations

- transverse diffeomorphisms $\delta g_{\mu\nu} = 2\nabla_{(\mu}\xi_{\nu)}, \tilde{\nabla}_\mu\xi^\mu = 0$

- Noether current $j_\xi^\mu = \theta_\xi^\mu - \mathcal{L}\xi^\mu,$

- on-shell $\tilde{\nabla}_\mu j_\xi^\mu = 0$

- $j_\xi^\mu = \tilde{\nabla}_\nu Q_\xi^{\nu\mu} \longrightarrow$ Noether charge

- Weyl transformations $\delta g_{\mu\nu} = \phi g_{\mu\nu}$

- Noether current $j_W^\mu = 0$

Hamiltonian for WTG

- symplectic form for a transverse diffeomorphism and an on-shell perturbation yields the Hamiltonian perturbation

$$\Omega[\delta, \mathcal{L}_\xi] = \delta H_\xi = \int_{\partial\mathcal{C}} \left(\delta Q_\xi^{\nu\mu} - 2\theta^\mu \xi^\nu \right) d\mathcal{C}_{\mu\nu} - \int_{\mathcal{C}} \delta\Lambda \xi^\mu / (8\pi) d\mathcal{C}_\mu$$

- extra volume term compared to the Diff-invariant case

- applied to a Schwarzschild-anti-de Sitter black hole

$$\delta\tilde{M} + \frac{\tilde{\kappa}}{2\pi} \frac{\delta\tilde{\mathcal{A}}}{4} - \frac{4r_+^3}{3} \frac{\delta\Lambda}{8\pi} = 0$$

mass → $\delta\tilde{M}$
temperature → $\frac{\tilde{\kappa}}{2\pi}$
Wald entropy → $\frac{\delta\tilde{\mathcal{A}}}{4}$
thermodynamic volume → $\frac{4r_+^3}{3}$
pressure → $\frac{\delta\Lambda}{8\pi}$

Take home message

- Weyl transverse gravity is a viable alternative to general relativity with some advantages over it
- so far impossible to observationally distinguish them (varying value of the cosmological constant?)
- computational side of things
 - on paper/simple Mathematica notebooks
 - xAct code (or something similar) for computing Noether charges?

Thank you!