All stationary axi-symmetric local solutions of topologically massive gravity

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Why 3D gravity?

- 3D vs. 2D gravity $\rightarrow$ KISS principle (Albert Einstein)
  - 2D: no gravitons, analog of the horizon area?
  - 3D: black holes and gravitons!
- possible toy model of quantum gravity
- many interesting new theories
  $\rightarrow$ New Massive Gravity, Extended New Massive Gravity, Generalized Massive Gravity, Massive Supergravity, Higher Order Massive Gravity, Born-Infeld Massive Gravity
- Holographic tool

Topologically Massive Gravity

3 dimensional theory: black holes and gravitons

$$I_{TMG} = \frac{1}{16\pi G}\int d^3x\sqrt{-g}\Big[\underbrace{R+\frac{2}{\ell^2}}_{\text{Einstein-Hilbert+CC}}+\underbrace{\frac{1}{2\mu}\varepsilon^{\alpha\beta\gamma}\,\Gamma^{\rho}_{\alpha\sigma}\left(\partial_\beta\Gamma^{\sigma}_{\gamma\rho}+\frac{2}{3}\Gamma^{\sigma}_{\beta\tau}\Gamma^{\tau}_{\gamma\rho}\right)}_{\text{Chern-Simons}}\Big]$$

difficult to find non-trivial solutions
few are known: warped AdS

Topologically Massive Mechanics

Simplification: stationary axi-symmetric TMG (Clement 1994)

Set up: stationary axi-symmetric 3d lineelement + 2d metric $\rightarrow I_{TMG}$

$$I_{TMM} = \int d\rho \, e \left(\frac{1}{2} e^{-2} \dot{\mathbf{X}}^2 - \frac{2}{\ell^2} - \frac{1}{2\mu} e^{-3} \, \epsilon_{ijk} X^i \dot{X}^j \ddot{X}^k \right)$$

simple but difficult to find analytic solutions $\rightarrow$ non-existence results:

- $|\mu\ell| = 1$: Einstein solutions
- $|\mu\ell| = 3$: null warped black hole

Classification of all Solutions

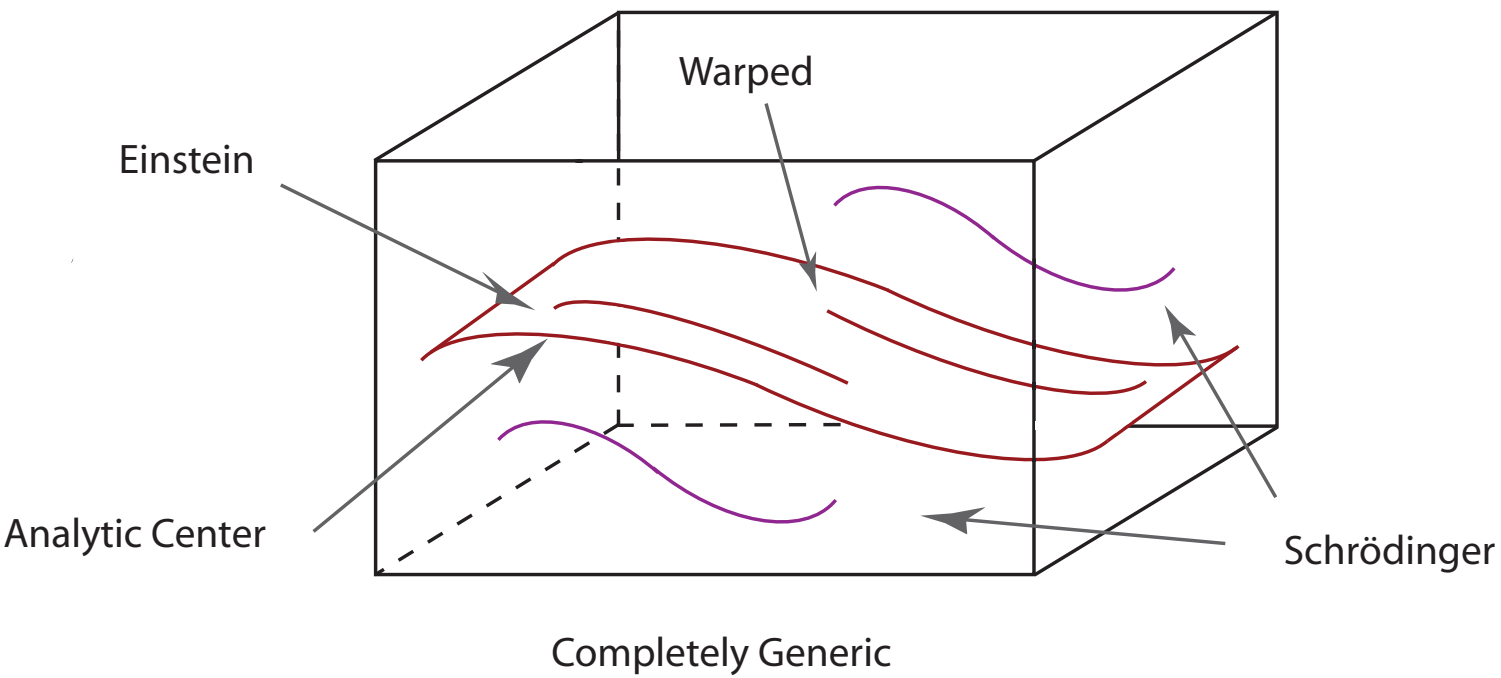
in general: 6d phase space containing a 4d subspace (Einstein, Schrödinger, Warped AdS) $\rightarrow$ classification into 4 sectors:

- **Einstein**: $\ddot{X} = 0$
- **Schrödinger:** $\ddot{X} \neq 0$, linear dependence of $X, \dot{X}, \ddot{X}$
- **Warped:** $\ddot{X}^2 = \dddot{X} = 0$, linear independence of $X, \dot{X}, \ddot{X}$
- **Generic:** these solutions are neither Einstein, Schrödinger nor warped AdS

Generic Sector

The generic sector is described by the constraints: $\ddot{X}^2 \neq 0$ and/or $\dot{X}\ddot{X} \neq 0$

Solving for solutions: numerical analysis



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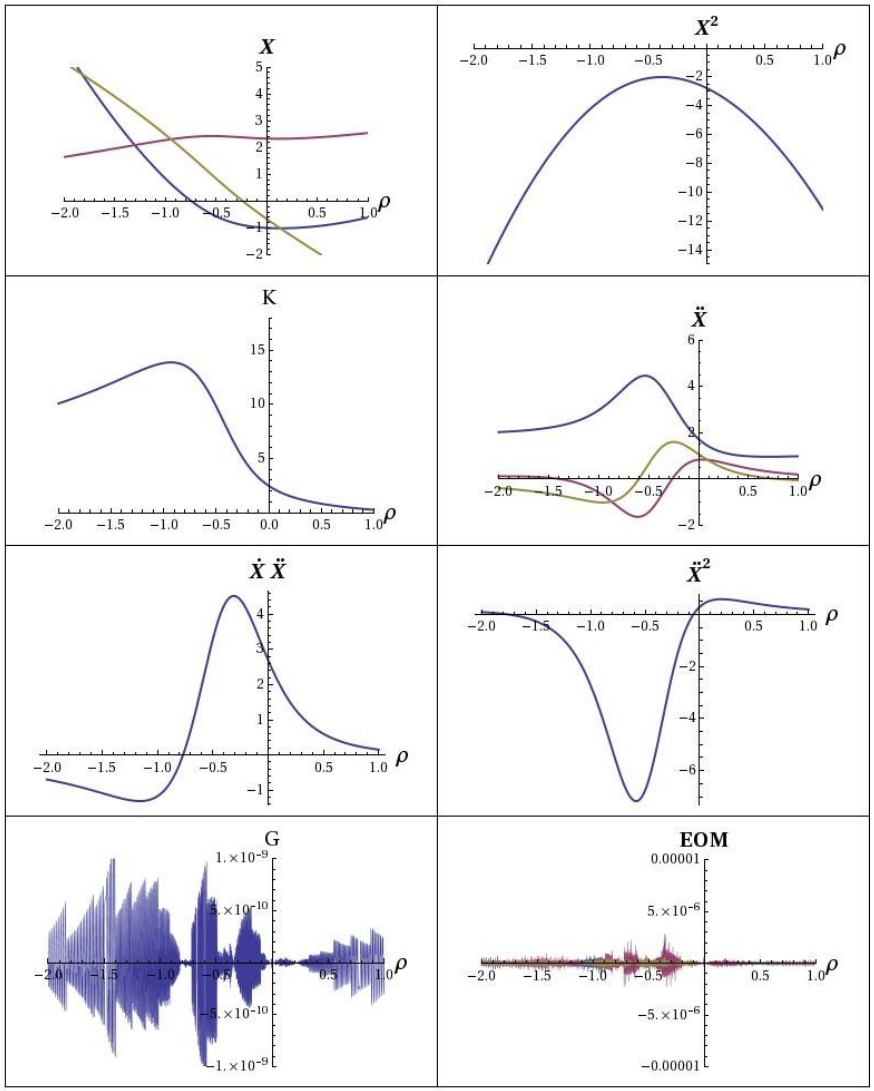
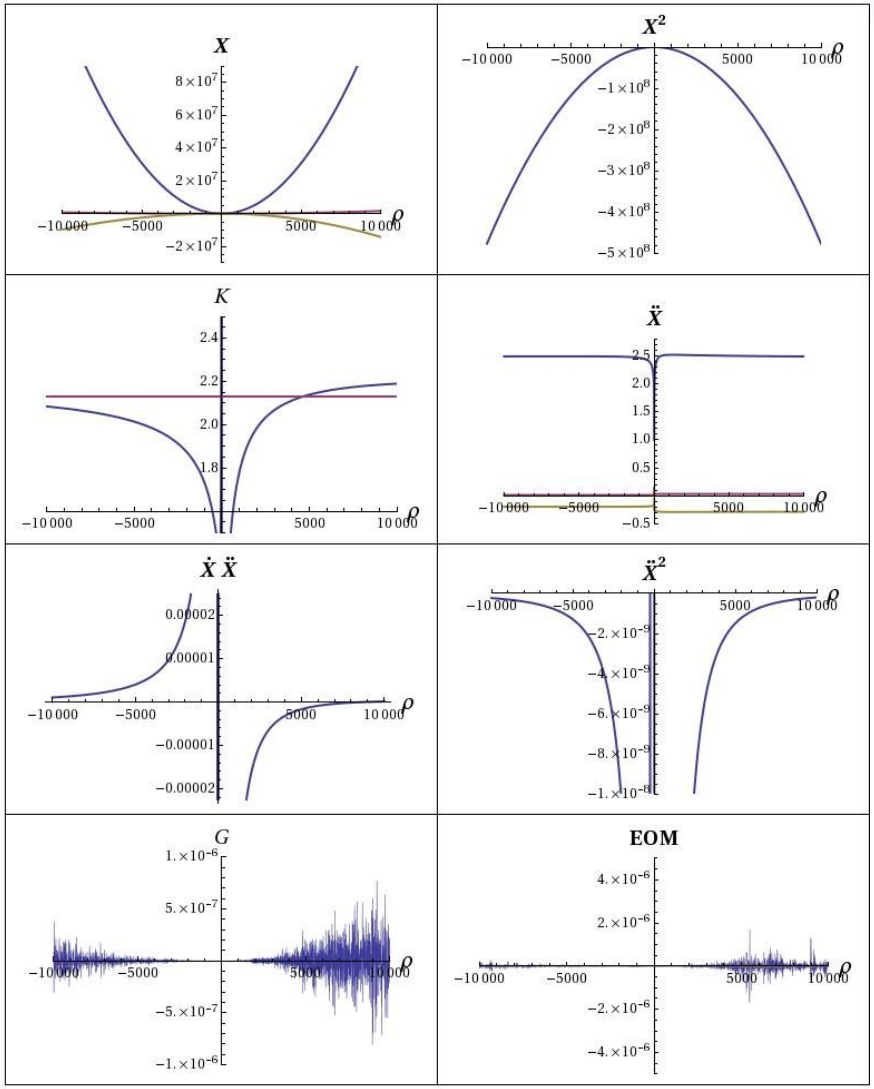
Example for generic solutions

Soliton - no center



Zooming out ...



... evidence for asymptotic warped AdS behaviour

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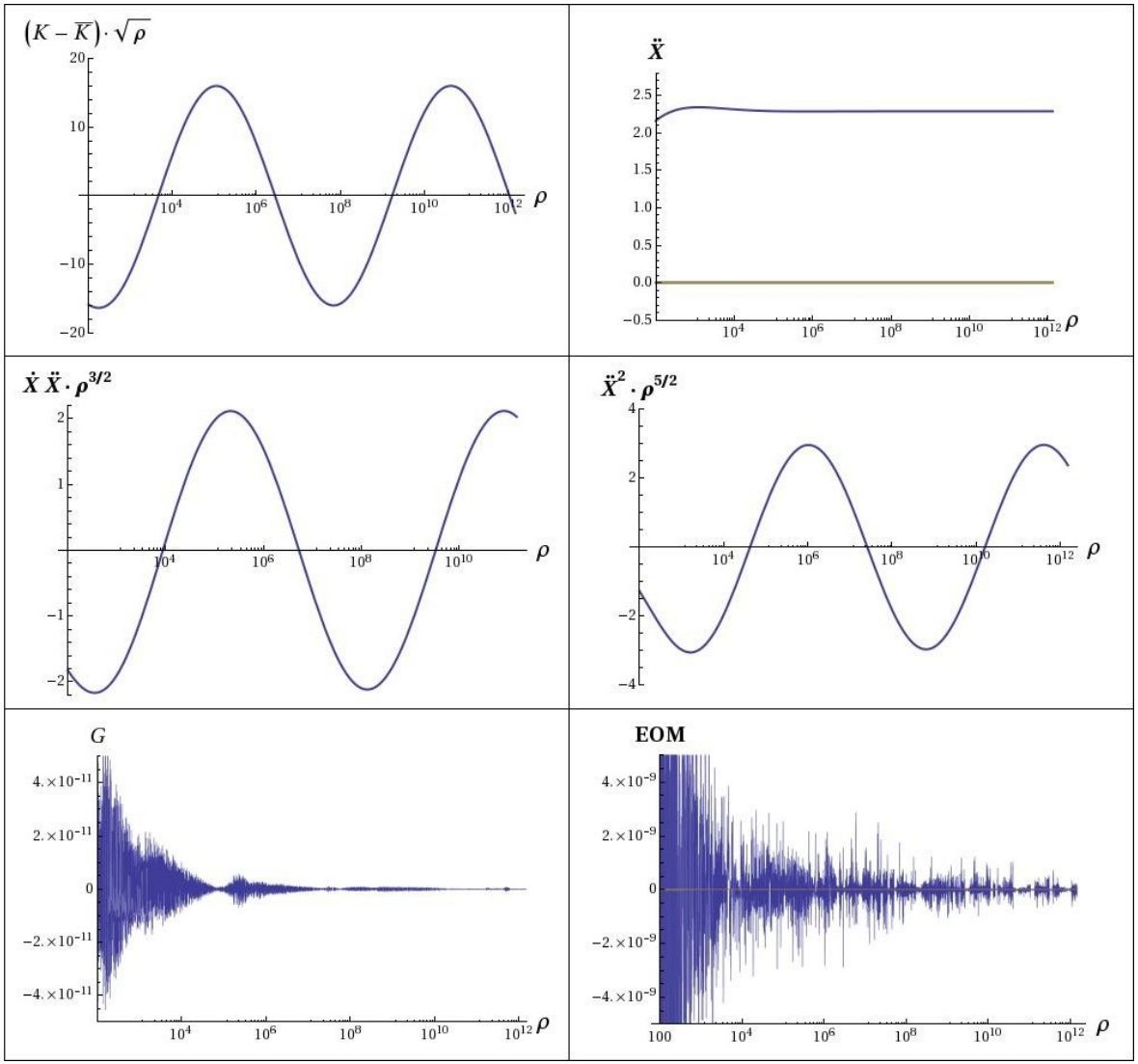
... damped oscillations around warped AdS



Outlook

- Use recipe for other novel 3-dimensional theories of gravity (NMG, GMG, MSG, HOMG, ENMG, BIG)

- still open questions:
  - Topography of landscape of solutions
  - boundary conditions and corresponding asymptotic symmetry group
  - stability?
  - Soliton interpretation as finite energy excitations around WAdS?
  - Soliton asymptotics to AdS or Schrödinger?
  - Kink solutions?

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Thank you for your attention