STRESS TENSOR REGULARIZATION & BH EVAPORATION

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Motivation

Dynamical BH evaporation

Stress tensor regularization

- For a self consistent solution we need to compute the semi-classical Einstein eq.

$$G_{\mu\nu} = 8\pi \left\langle \hat{T}_{\mu\nu} \right\rangle_{ren}$$

- The renormalization of the stress tensor is usually done using point-splitting.

  Hard even for a prescribed background!

Point-splitting

- For simplicity we consider the field squared:

$$\left\langle \hat{\phi}^2 \left(x \right) \right\rangle_{ren} = \lim_{x' \to x} \left[\left\langle \hat{\phi} \left(x \right) \hat{\phi} \left(x' \right) \right\rangle - G_{D.S} \left(x, x' \right) \right]$$

- As a mode-sum

$$\left\langle \hat{\phi}^2 \left(x \right) \right\rangle_{ren} = \lim_{x' \to x} \left[\int_0^\infty d\omega \sum_{l,m} f_{\omega lm} \left(x \right) f_{\omega lm}^* \left(x' \right) - G_{D.S} \left(x, x' \right) \right]$$

Usually not computable practically.

Classical approach

- The approach taken by Candelas, Howard, Anderson and others, add and subtract:

$$\left\langle \hat{\phi}^2(x) \right\rangle_{ren} = \lim_{x' \to x} \left[\int_0^\infty d\omega \sum_{l,m} \left[f_{\omega lm}(x) f_{\omega lm}^*(x') - f_{\omega lm}^A(x) f_{\omega lm}^{A*}(x') \right] \right]$$

$$+ \lim_{x' \to x} \left[\int_0^\infty d\omega \sum_{l,m} f_{\omega lm}^A(x) f_{\omega lm}^{A*}(x') - G_{D.S}(x, x') \right]$$

- Analytic part and numeric part.

- The approximation used was WKB.

New approach

- Given that the background admits some symmetry, one can deduce the singular part from the counter-term.

Example – Stationary metric

- Stationary asymptotically-flat metric, the modes are: $f_{\omega lm}(x) = e^{-i\omega t}\overline{\Psi}_{\omega lm}(r,\theta,\varphi)$

- We choose to split in the direction of the symmetry, namely the time coordinate:

$$\left\langle \hat{\phi}^2(x) \right\rangle_{ren} = \lim_{\varepsilon \to 0}\left[\int_0^\infty d\omega \sum_{l,m} e^{i\omega\varepsilon}\left|\overline{\Psi}_{\omega lm}(r,\theta,\varphi)\right|^2 - G_{D.S}(x,\varepsilon) \right]$$

Example – Stationary metric 2

- Summing over l,m

$$\left\langle \hat{\phi}^2 \left(x \right) \right\rangle_{ren} = \lim_{\varepsilon \to 0} \left[\int_0^\infty F\left(\omega \right) e^{i\omega\varepsilon} d\omega - G_{D.S}\left(x, \varepsilon \right) \right]$$

- Fourier transform!

$$\left\langle \hat{\phi}^2 \left(x \right) \right\rangle_{ren} = \lim_{\varepsilon \to 0} \int_0^\infty \left[F\left(\omega \right) - F^{sing}\left(\omega \right) \right] e^{i\omega\varepsilon} d\omega$$
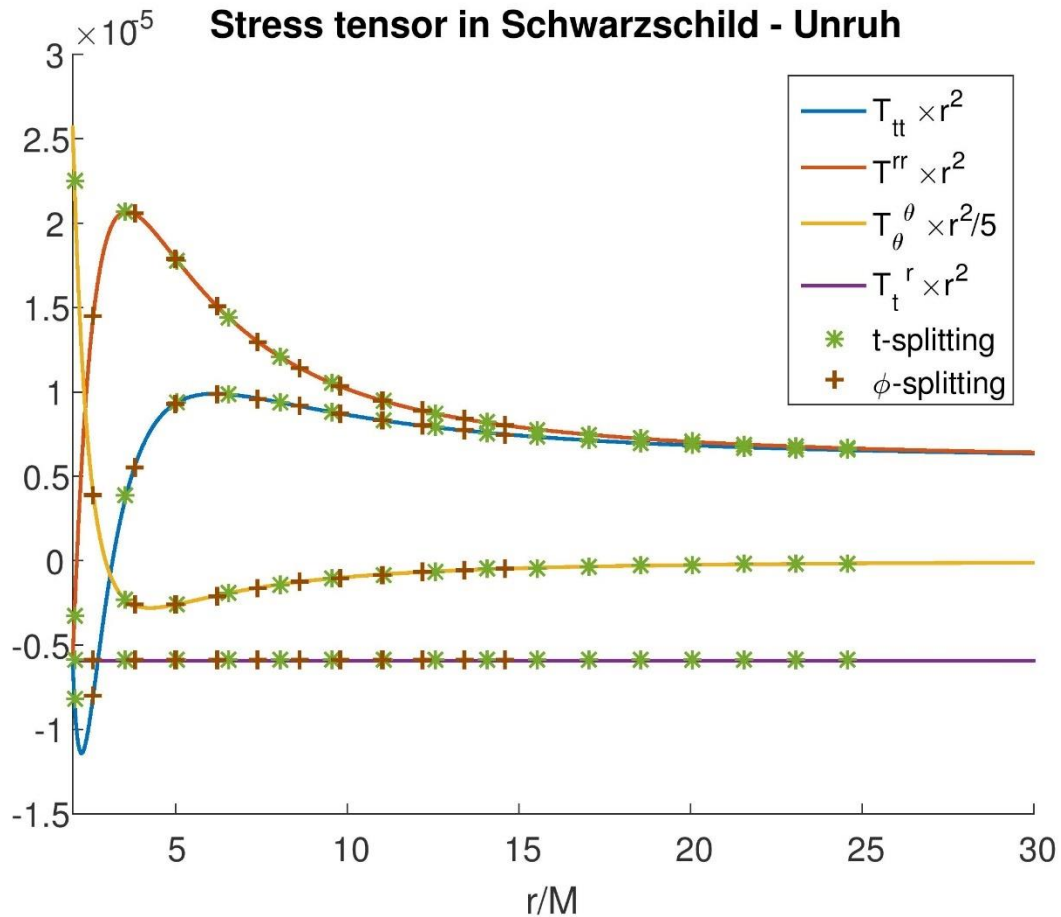
- Interchange the limit with the integral.

Notes

- Interchanging the limit, generalized sums/integrals, stress-tensor etc.

- Same logic can be used for other symmetries. We have implemented it for spherical-symmetry (angular-splitting) and axial-symmetry (azimuthal splitting). More complicated.
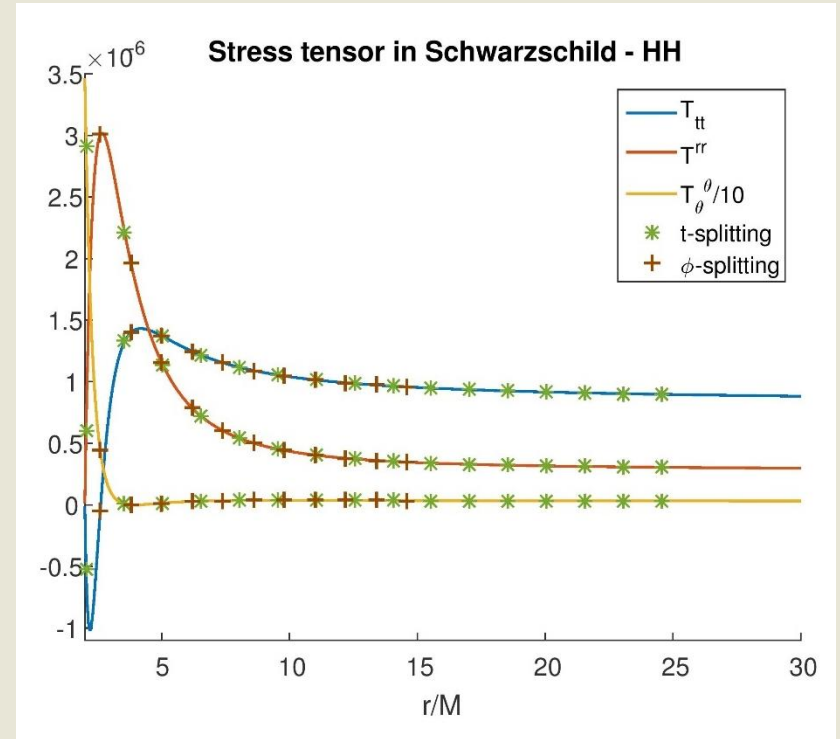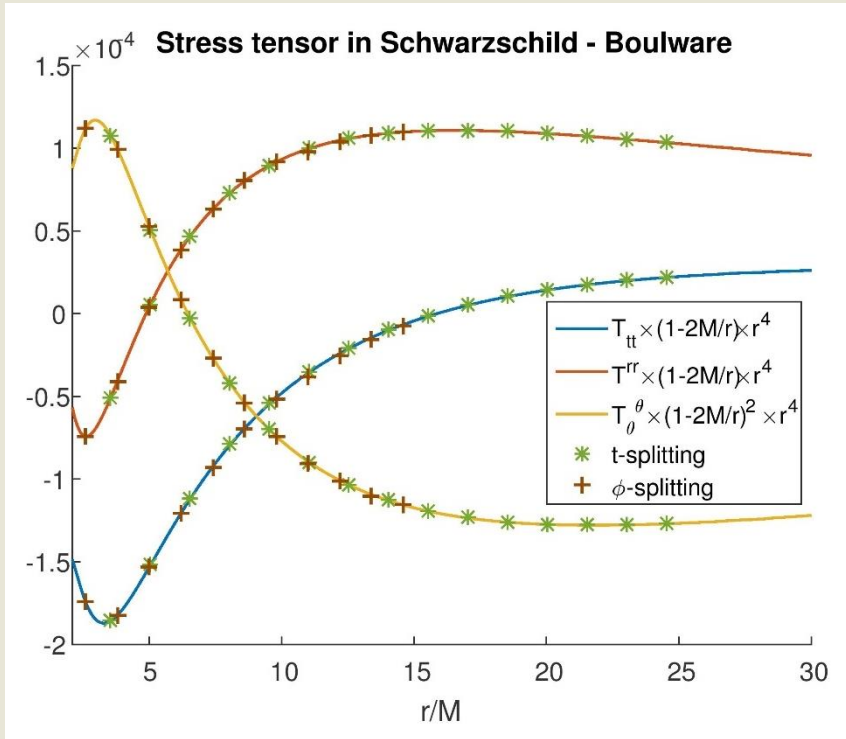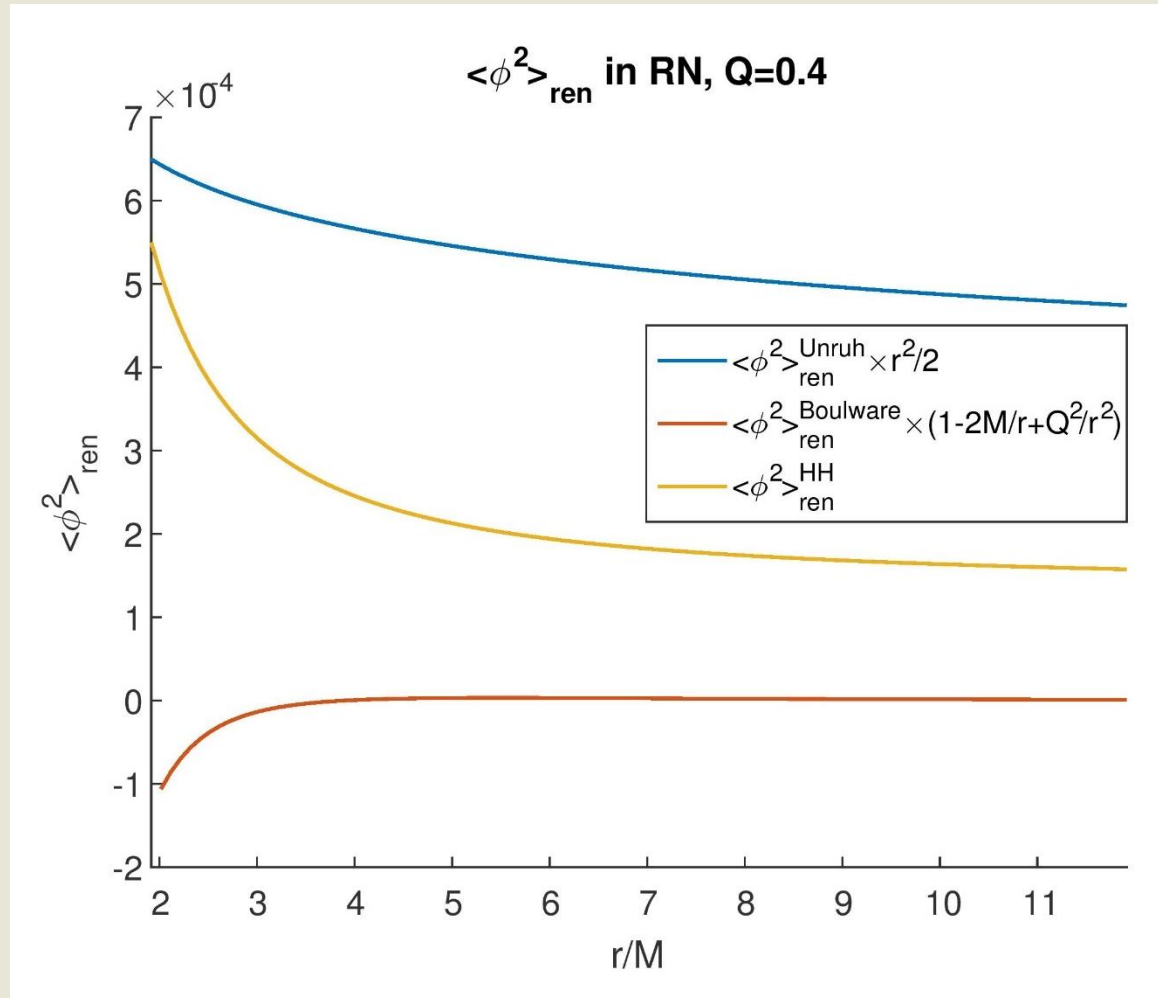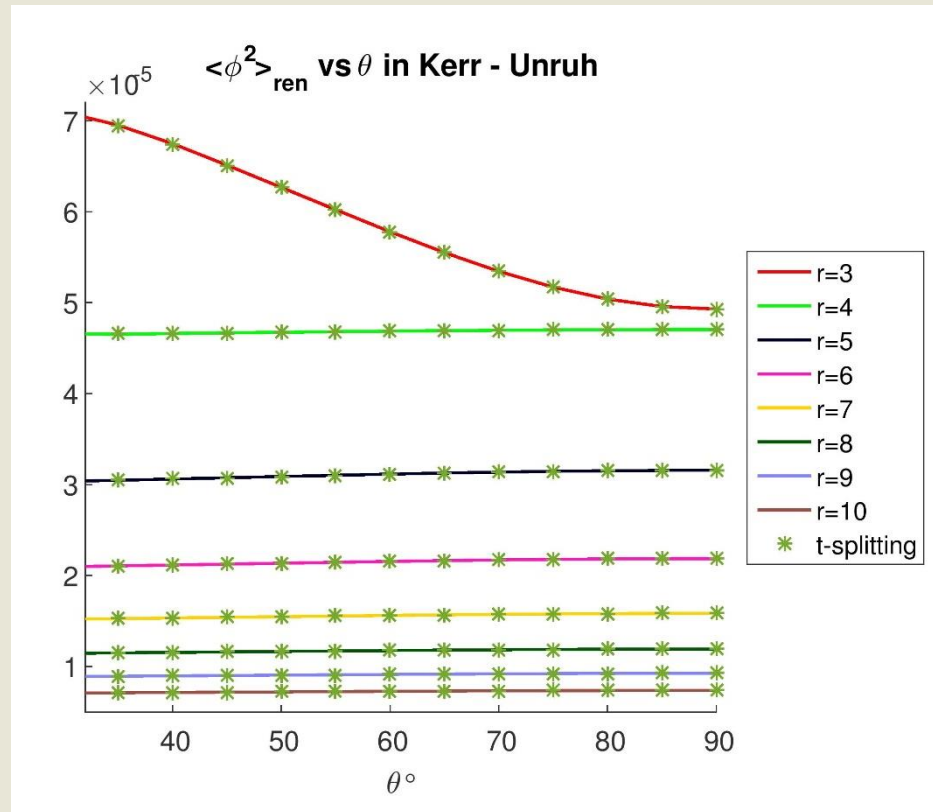
Results

Results

Stress tensor in Schwarzschild - Unruh

Results

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$\langle\phi^2\rangle_{ren}$ in RN, Q=0.4

Legend:
- $\langle\phi^2\rangle_{ren}^{Unruh}\times r^2/2$
- $\langle\phi^2\rangle_{ren}^{Boulware}\times(1-2M/r+Q^2/r^2)$
- $\langle\phi^2\rangle_{ren}^{HH}$

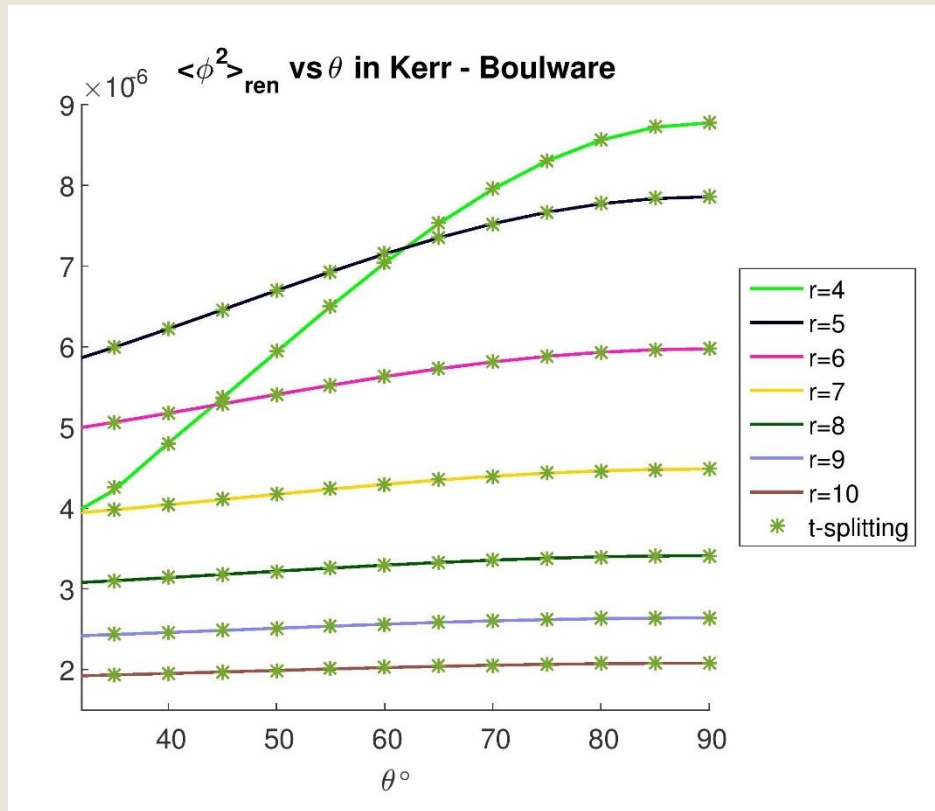y-axis: $\langle\phi^2\rangle_{ren}$

x-axis: r/M

Results – Joint work

Joint work with L. Barack, M. Van De Meent and E. Eilon.

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The important result

One can compute the renormalized stress tensor

given that the background admits a symmetry.

Outlook

- Collapsing null shell – cooperation with Paul

  Anderson.

- Full dynamical BH evaporation.

- Evaporation of rotating BH.

Go down the rabbit hole

Thank you!

Adam Levi