Backreacting w/ the background field method

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+ Cheung, Rothstein, Shah, Wilson-Gerow

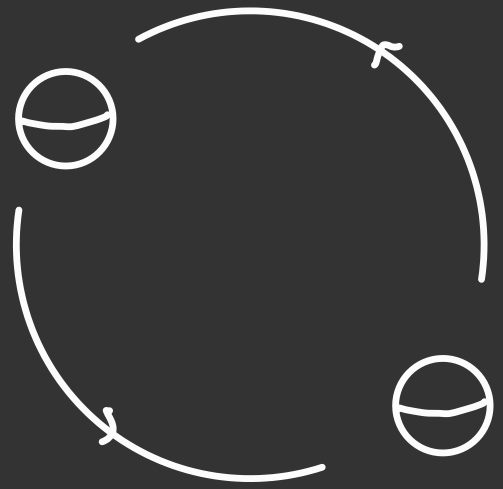
Correlators @ Cortona '23

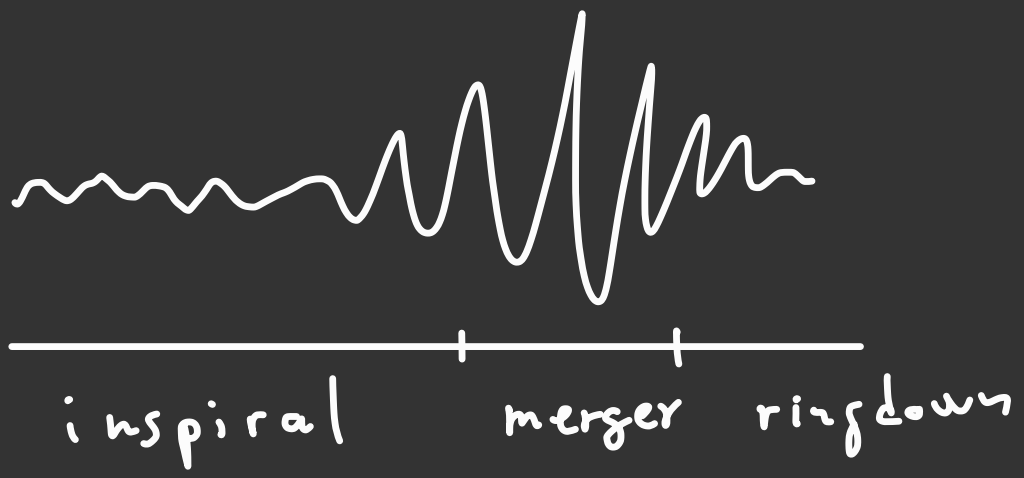
Motivation

LIGO/VIRGO

$10^1 \sim 10^5$ Hz

$\lambda = \frac{m_1}{m_2} \sim 1$





PN $\frac{v^2}{c^2} \sim \frac{Gm}{r} << 1$

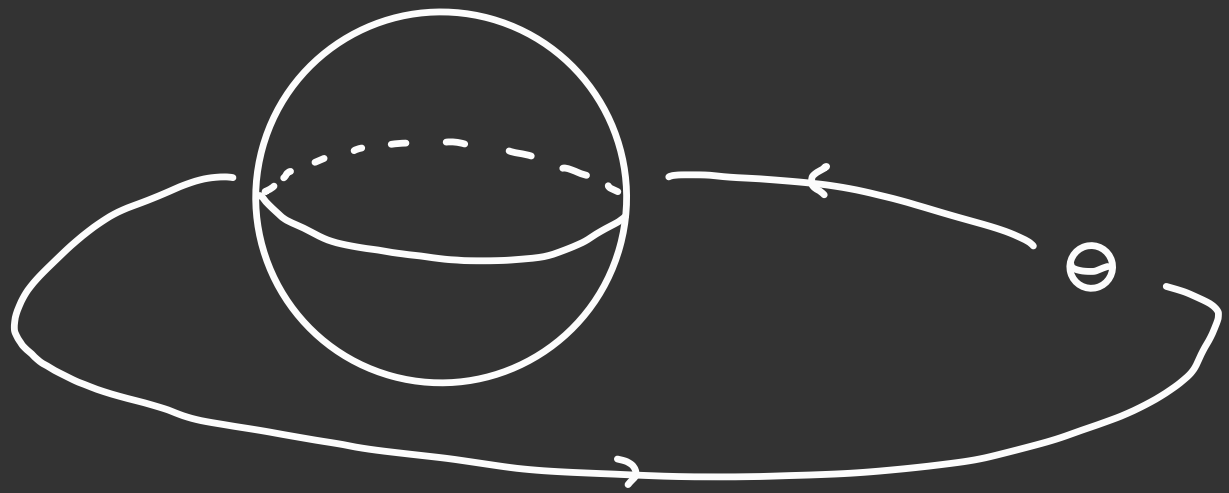
PM $\frac{G\Lambda}{r} << 1$

Motivation

LISA

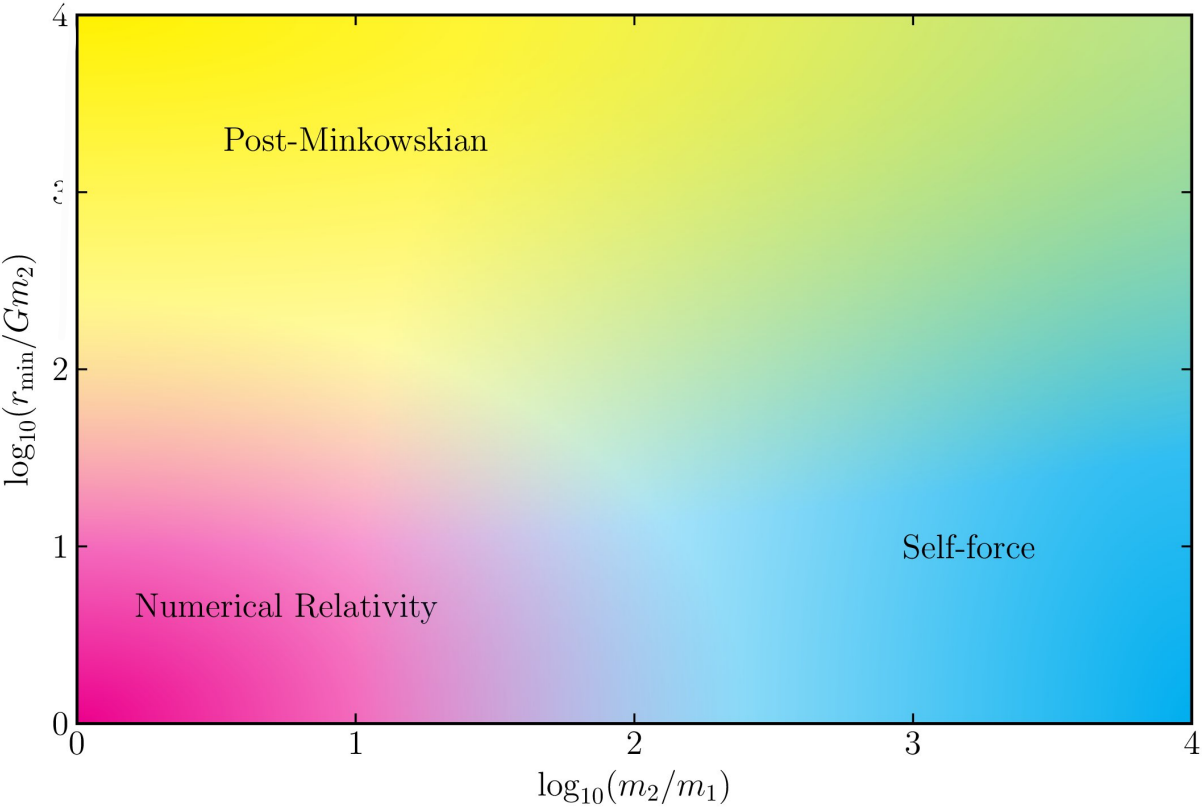
$10^{-5} - 10^{0}$ Hz

$\lambda = \frac{m_1}{m_2} \sim 10^{-4}$



EMRI

- Relativistic PN X
- Strong field PM X
- Large Hierarchy NR X


Post-Minkowskian
Numerical Relativity
Self-force
$\log_{10}(r_{\rm min}/Gm_2)$
$\log_{10}(m_2/m_1)$
0
1
2
3
4

Gravitational Self Force

- Leading order SF $\sim \lambda^0$

  "Geodesic in Schwarzschild"

- 1SF $\sim \lambda^1$

  "Backreaction of light body on itself"

Gravitational Self Force

- On-shell action OSF

$$\ddot{\bar{x}}^\mu + \Gamma^\mu_{\alpha\beta}\dot{\bar{x}}^\alpha\dot{\bar{x}}^\beta = 0$$

$$I^\circ = m_2 \int \bar{g}^{\text{schw}}_{\mu\nu}\, \dot{\bar{x}}^\mu \dot{\bar{x}}^\nu \, d\tau$$

$$\frac{\partial I^\circ}{\partial T} \sim \Omega \qquad \frac{\partial I^\circ}{\partial J} = \chi$$

- 1SF

"geodesic source" "graviton prop"

1 SF = 1 classical loop

$\Pi \langle h(x)\, h(y) \rangle = \delta(x,y)$

$\Pi \bar{h} = 0$

$$\langle h(x)\, h(y) \rangle = \sum_{n,\ell} \frac{\bar{h}(x)\, \bar{h}^{*}(y)}{E - E_{n,\ell}}$$

LISA CHALLENGE = 1 CLASSICAL LOOP.

Why work on this?

- Experiment!
- Interesting QFT problem.
- New fun arena to apply QFT/EFT

Our setup

- Interacting wl

$$S = \frac{1}{16\pi G}\int d^4x\, R + \sum_{i=4,H} m_i \int d\tau$$

- Usual approach

$$x_i^{\hat{}} = b_i^{\hat{}} + u_i^{\hat{}}\tau + \delta x_i^i$$

$$g_{\mu\nu} = \eta + h_{\mu\nu}$$

EMREFT

- $g_{\mu\nu} = g^{sch}_{\mu\nu} + h_{\mu\nu}$

$x_H = u_H \tau + \delta x_H$

$x_L = \overline{x_L} + \delta x_L$

↑ geodesic solution

- Effective action

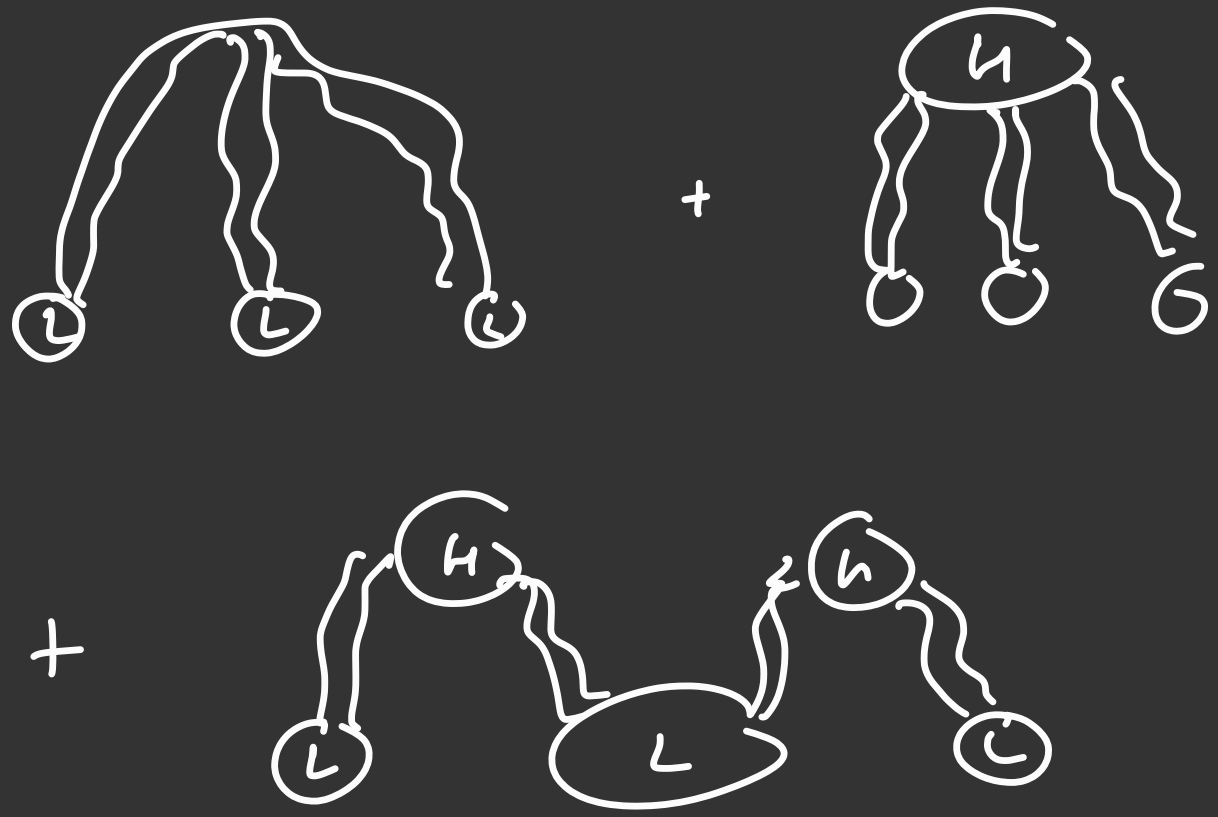
$$S = \int h \Box h + h \overline{T}_L + \delta\Gamma \frac{1}{\partial_\tau^2} \delta\Gamma$$

Recoil op ↗

Feynman Rules @ ISF

- ISF on-shell action

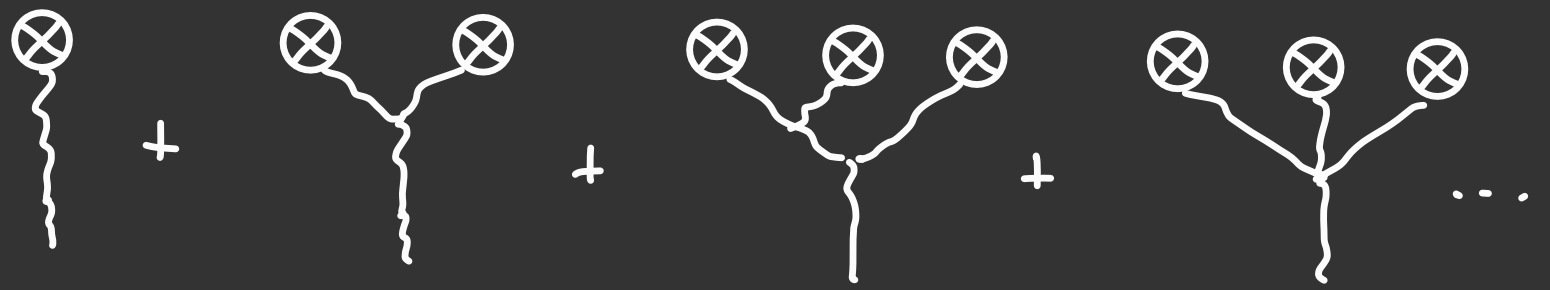
Onshell action @ 25F



Classical resumation

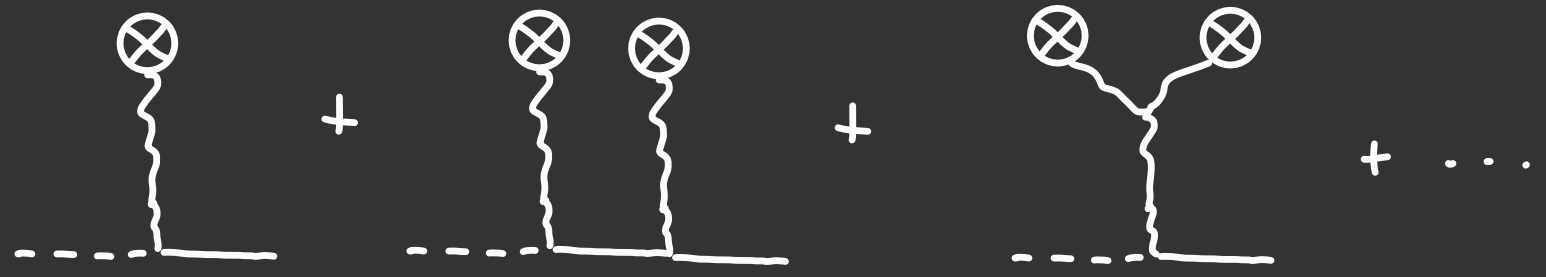
D.H

$g^{sch}_{\mu\nu}$ =



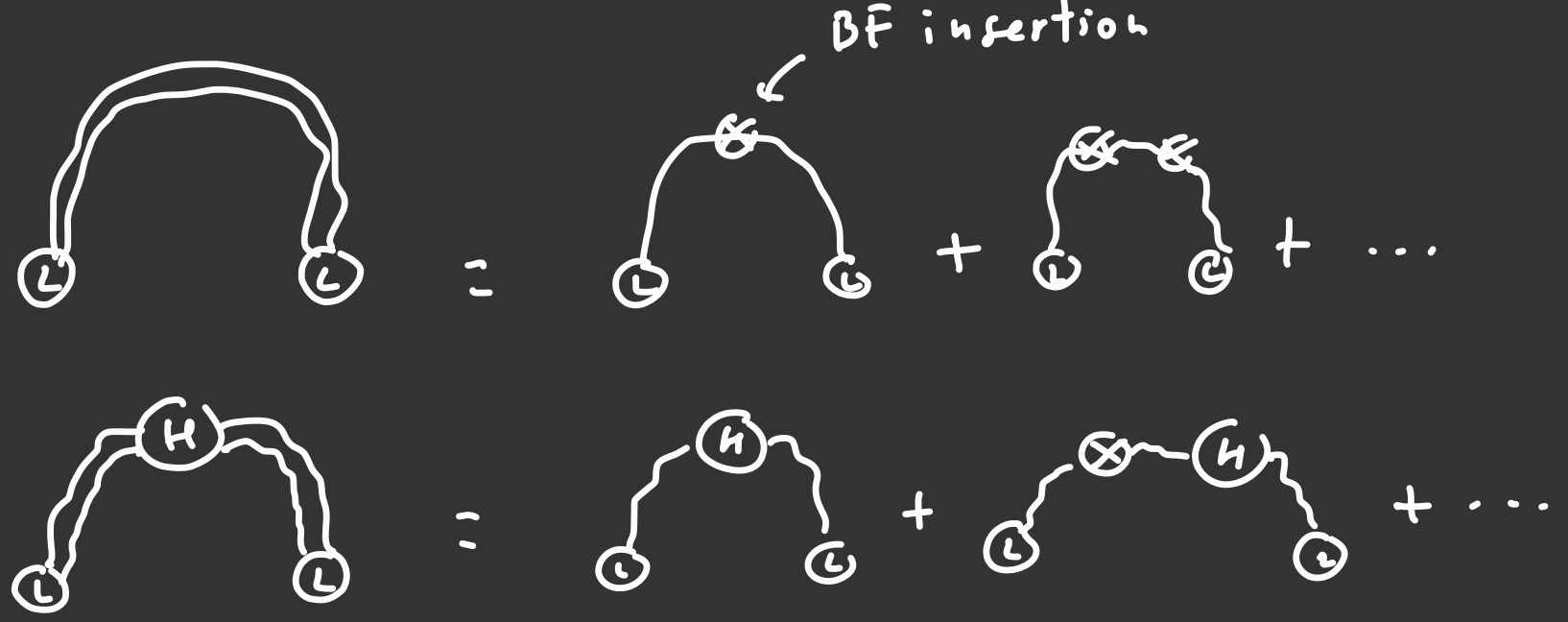
• Also geodesics

$\overline{X}_L$ =



PM + SF = BFM + Recoil !

- State of the art 4PM G^4



- Huge simplification.

Summary

- New EFT for extra mass ratios
- Recoiling backgrounds ✓
- Reproduced SOA @ 1SF
- Checked @ 2SF
- Important problem