

Long Distance Properties of Perturbative Quantum Gravity

Ryo Saotome
University of Michigan

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arXiv:1109.0270 (with R. Akhoury and G. Sterman)

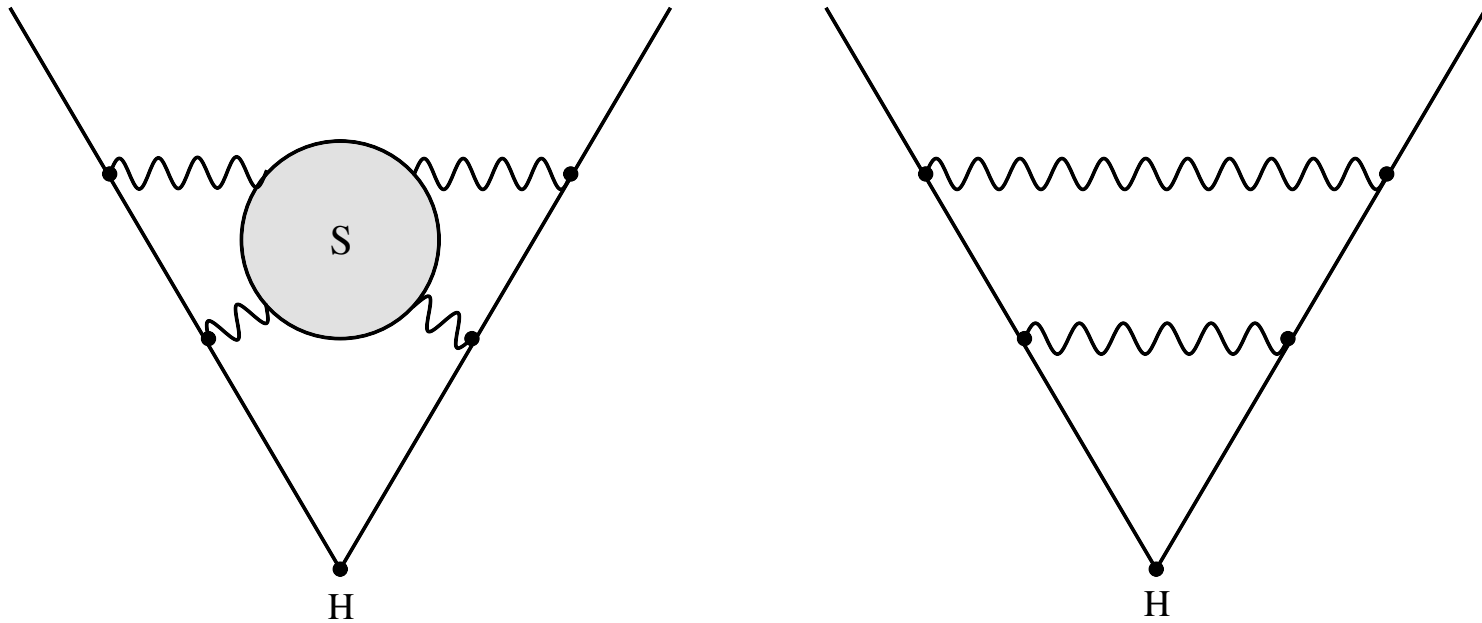
Why study infrared behavior of quantum gravity?

- Short distance behavior difficult to probe
 - String theory better tool than perturbative quantum gravity in this regime
- Has been argued that long distance gravitational effects dominate high-energy small angle scattering [Giddings, Gross and Maharana]
 - String effects are subdominant
 - IR behavior of gravity may be important in black hole creation

Power Counting

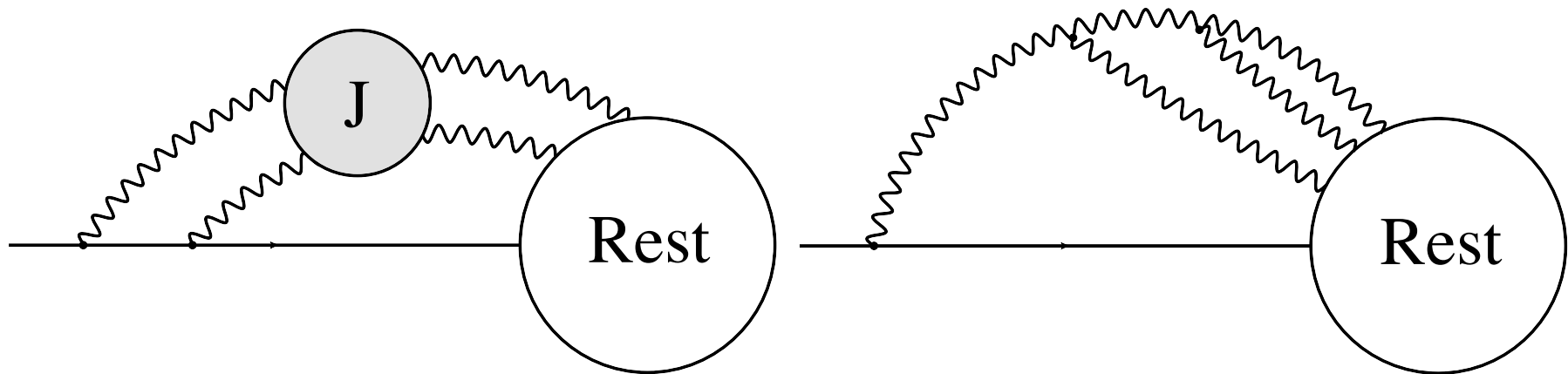
- Two types of infrared divergences
 - Soft Divergences
 - Collinear Divergences
- “Normal variables”
 - Set of variables that vanish when IR divergence occurs
- Power counting in these variables can identify what Feynman diagrams are soft/collinearly divergent

Soft Divergences



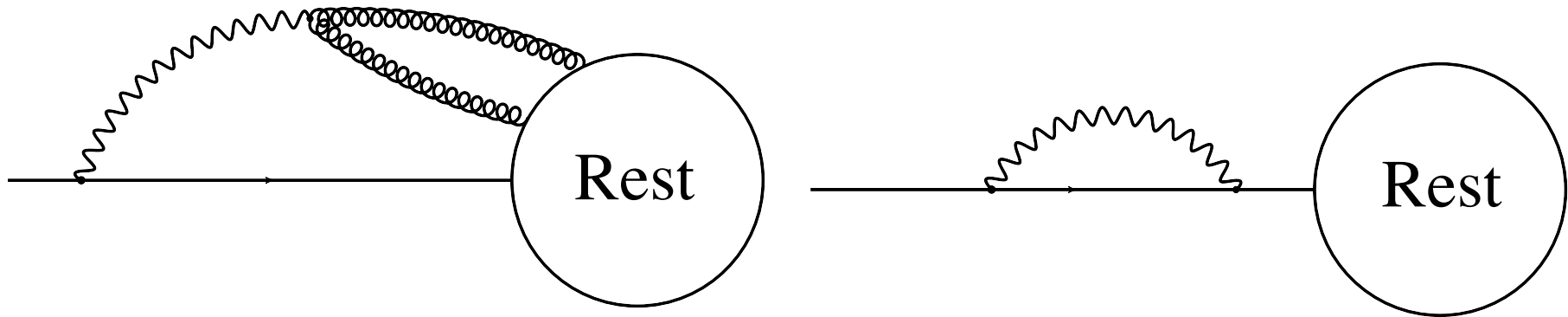
- Only diagrams with three point couplings to finite momentum lines have logarithmic soft divergences
 - i.e. Ladder and Crossed Ladder diagrams

Collinear Divergences



- Only diagrams with no internal jet loops and only three point vertices have logarithmic collinear divergences
 - Includes but not limited to ladders/crossed ladders

Not Collinearly Divergent

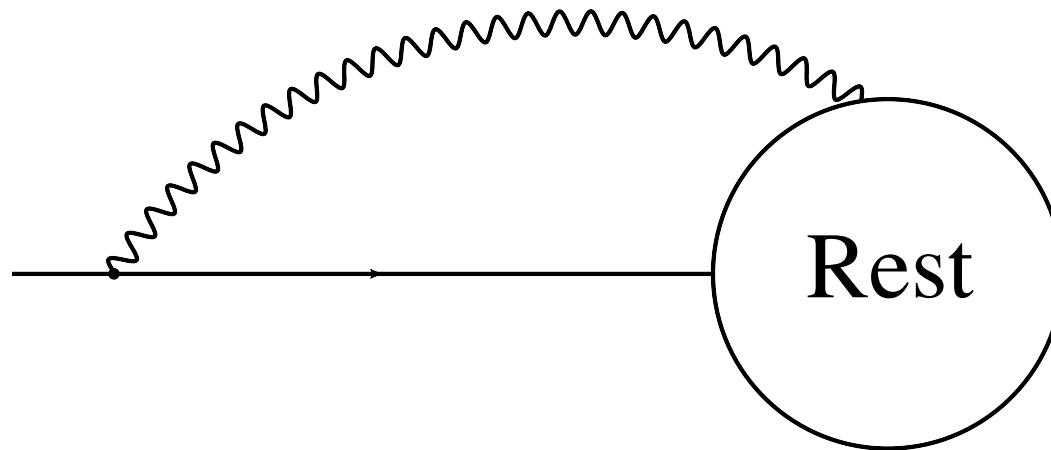


- Not collinearly divergent:
 - Gravitons mixed with S.M. particles
 - External leg corrections

Do Collinear Divergences Cancel?

- Cancellation of collinear divergent **ladder/crossed ladder diagrams in the eikonal approximation** has been shown **[Weinberg]**
 - In contrast with massless QED and QCD
- Does this cancellation extend to all collinearly divergent diagrams beyond the eikonal approximation?

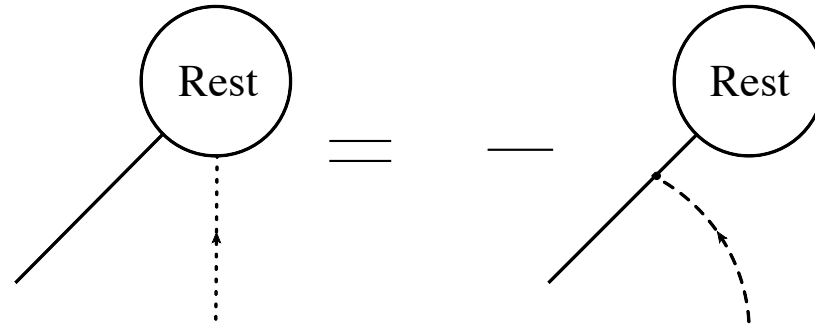
Ward Identity



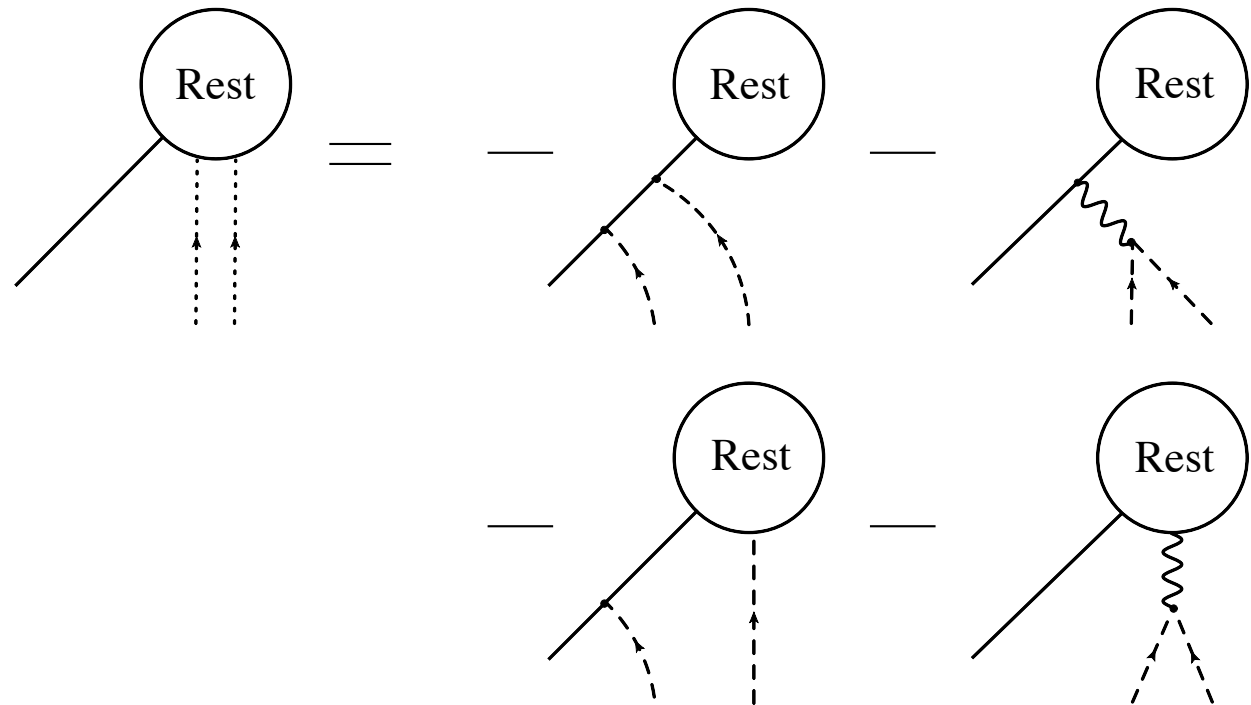
- To leading order in the normal variables, gravitons collinear with an external leg can be treated as **longitudinally polarized and on-shell**
 - On-shell Ward identity can be used
- Ward Identity (for our purposes):
The sum of all of possible insertions of a graviton line collinear with an external line is zero

Sketch of Cancellation

- One graviton case



- Two graviton case



Summary

- We have characterized all diagrams which are infrared divergent in perturbative quantum gravity
 - Only ladder, crossed ladder diagrams have soft divergences
 - Only jets with no internal loops and only three point vertices have collinear divergences
- Collinear divergences cancel in gravitational amplitudes all loop orders
 - Can be used to check conjectured relations between gravity and gauge theory amplitudes [Boucher-Veronneau, Dixon]