Quantum Amplitudes and Classical Gravity

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Also Based on “Classical Solutions and their Double Copy in Split Signature”
With Donal O’Connell, David Peinador Veiga, Ricardo Monteiro.

arXiv: 2012.11190.

X NexT PhD Workshop, 29/03/2021

Classical observables from amplitudes

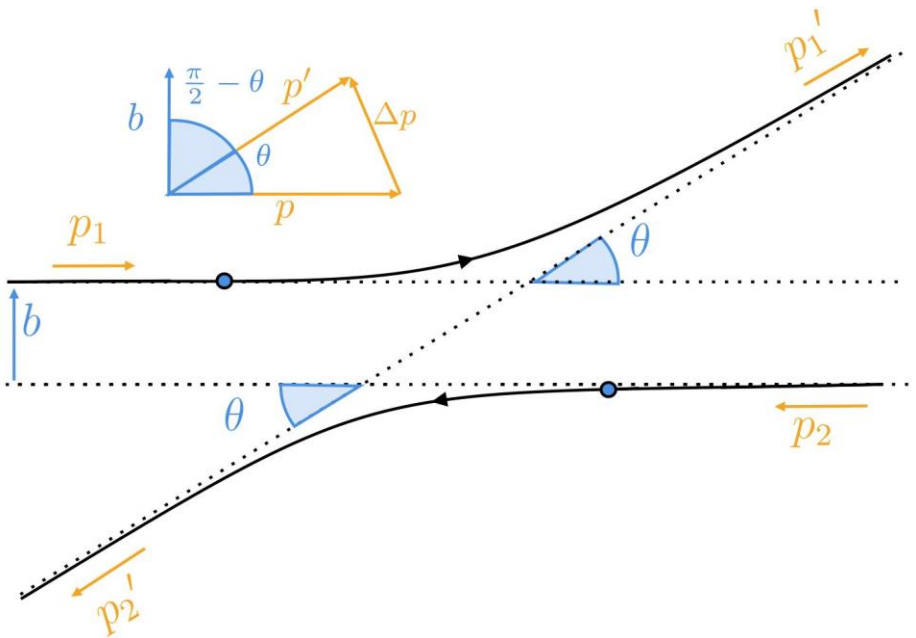
- Classical gravity/EM from amplitudes: $\Delta p^\mu,\ \Delta s^\mu,\ F^{\mu\nu}_{\rm rad},\ \Psi^{\alpha\beta\gamma\delta}_{\rm rad}$

Kosower, Maybee & O'Connell, 2018
Maybee, O'Connell & Vines, 2019

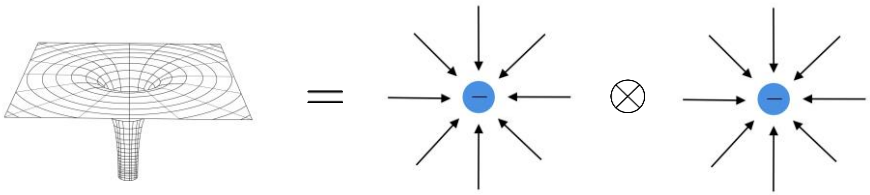
$$\Delta p_1^\mu = \int d^4q\,\delta(p_1\cdot q)\delta(p_2\cdot q)e^{-ib\cdot q}\left[q^\mu i\mathcal{A}(p_1\to p_1+q)\right.$$
$$\left. + \int d^4l\,\delta(p_1\cdot l)\delta(p_2\cdot l)l^\mu\mathcal{A}^*(p_1+q_1\to p_1+l)\mathcal{A}(p_1\to p_1+l)\right]$$

Classical change in momentum

Taken in the classical limit!
"$\hbar\to 0$"



Double copy duality



Bern, Carrasco & Johansson, 2008
Monteiro, O'Connell & White, 2014

$$b_\perp^\mu = \Pi^\mu{}_\nu (b + i a_1 + i a_2)^\nu$$

$$\Delta p^\mu_{\text{Kerr}} = -\frac{2 m_1 m_2 G_N}{\sinh w} \text{Re}\left[\frac{\cosh 2w\, b_\perp^\mu + 2i \cosh w \varepsilon^{\mu\nu\rho\sigma} u_{1\rho} u_{2\sigma} b_{\perp\nu}}{b_\perp^2}\right] + \mathcal{O}(G_N^2 a_1^2 a_2^\infty)$$

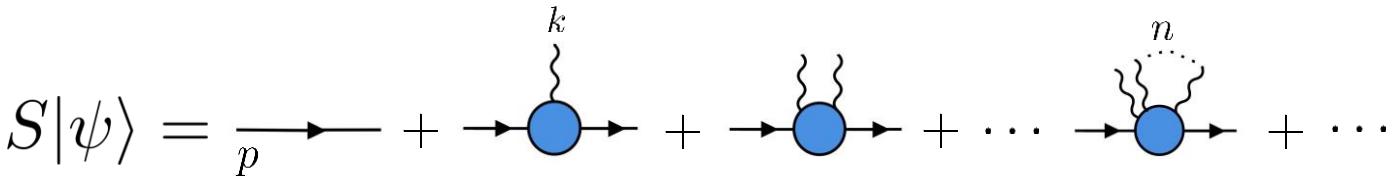
Vines, 2017
Arkani-Hamed, Huang & O'Connell, 2019

Guevara, Ochirov & Vines, 2018

$\Rightarrow \Delta p^\mu_{\text{Schw.}} \propto G_N^4$ Determined up to 3 loops!

Bern, Parra-Martinez, Roiban, Ruf & Shen, 2021

We want to compute curvature invariants



Lorentz invariant phase space

$$S|\psi\rangle = \int d\Phi(p)\varphi(p) \exp\left(\sum_h \int d\Phi(k)\, \delta(2p\cdot k)\, i\mathcal{M}^{(3)}_{-h}(k)\, a^\dagger_h(k)\right)|p\rangle$$

Initial state wavepacket

$$\langle\psi|S^\dagger \Psi(x) S|\psi\rangle = 2\kappa\, \mathrm{Re} \int d\Phi(k)\delta(2p\cdot k) i\mathcal{M}^{(3)}_{+}(k)\, |k\rangle^4\, e^{-ik\cdot x}$$

"Weyl spinor"

$$\kappa = \sqrt{32\pi G_N}$$

$$\mathcal{M}^{(3)}_h = -\kappa\,(p\cdot\varepsilon_h(k))^2$$

Monteiro, O'Connell, Peinador-Veiga & **MS**, 2020

Conclusion

QFT is useful for classical Physics too!

- Better understanding of loop computations
- Emitted radiation for bound states?
- Inclusion of spin effects

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Thank you!