Quantum Gravity in the Collider

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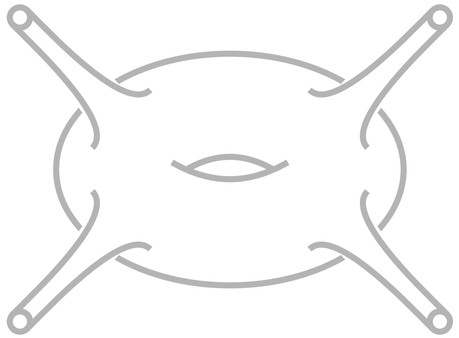
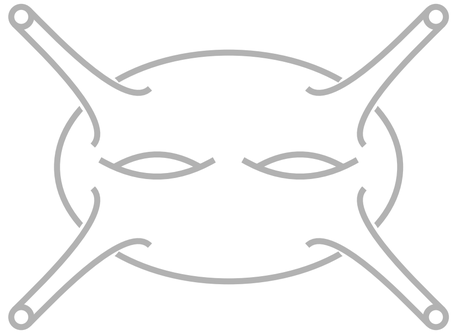
University of Amsterdam



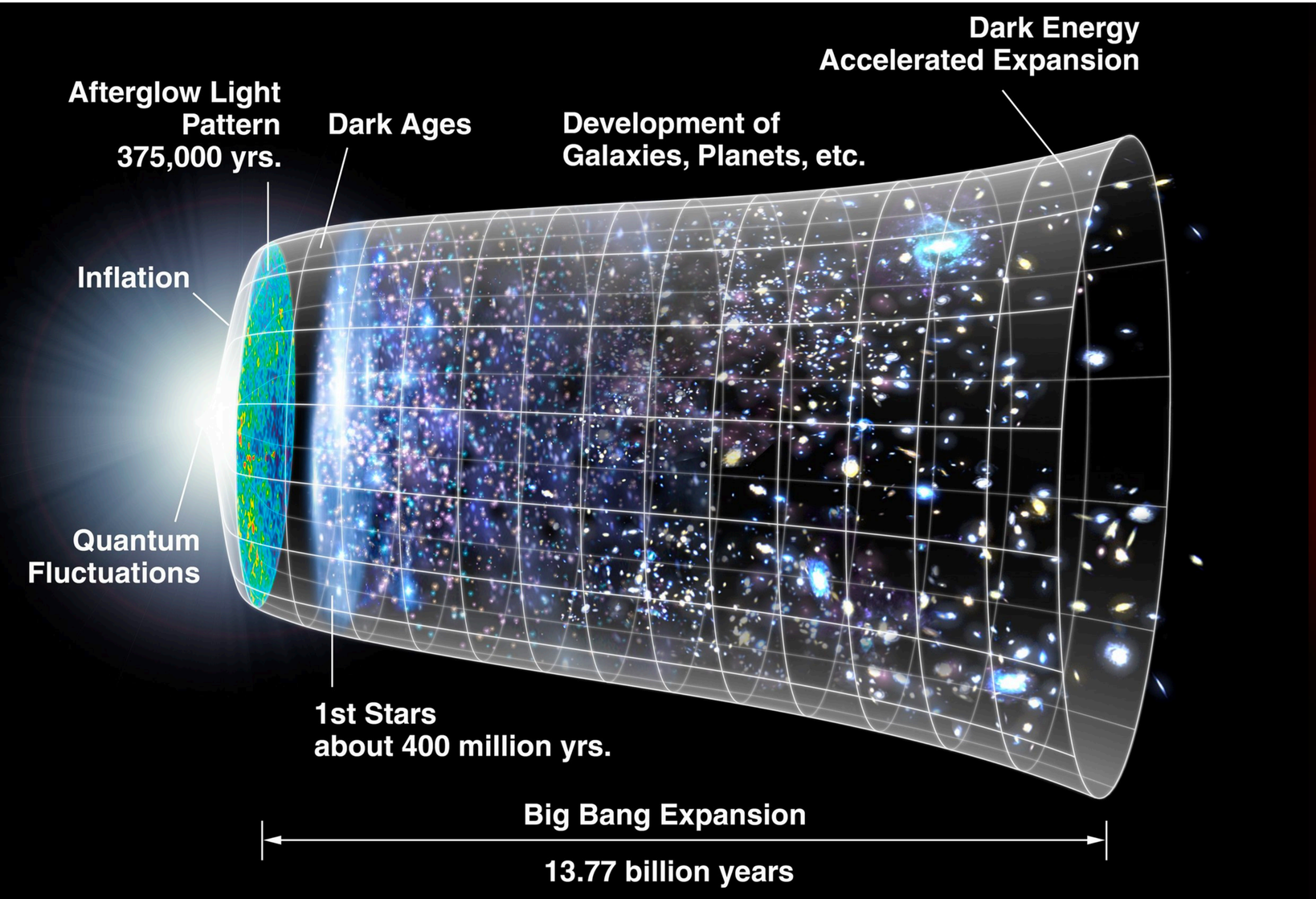


EPS-HEP, 07.07.2025

Many thanks

- To EPS-HEP for the honor of this award
- To all my teachers, collaborators and mentors
- To all my friends all around the world
- To my parents and siblings
- To the people at large, whose generous contribution allows the pursuit of curiosity driven science
- To my wife Elena and son Arthur whose support over the years has been indispensable
- ...

Our life depends on quantum gravity



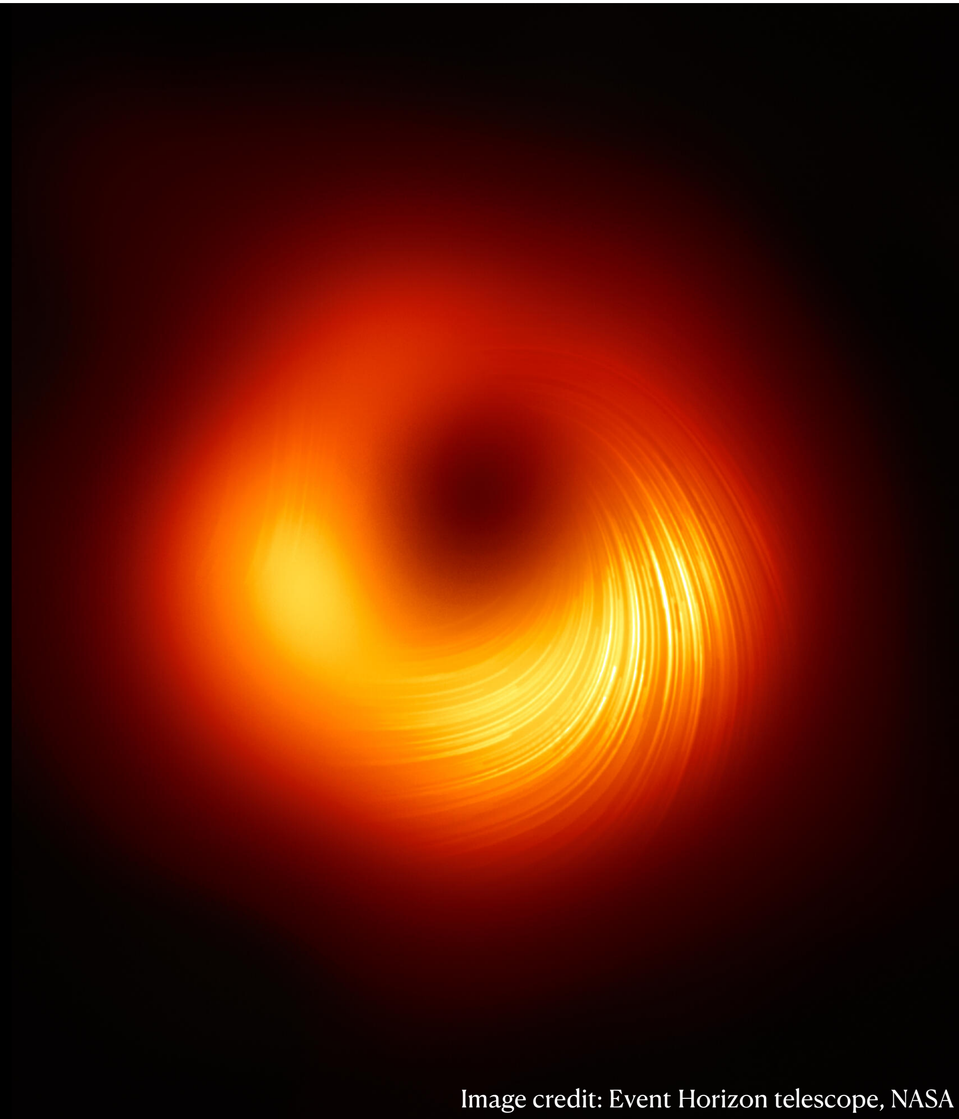


Image credit: Event Horizon telescope, NASA

Theory to the rescue

Any theory of quantum gravity has to be

- compatible with all known experimental data
- internally consistent

This is a very tall order

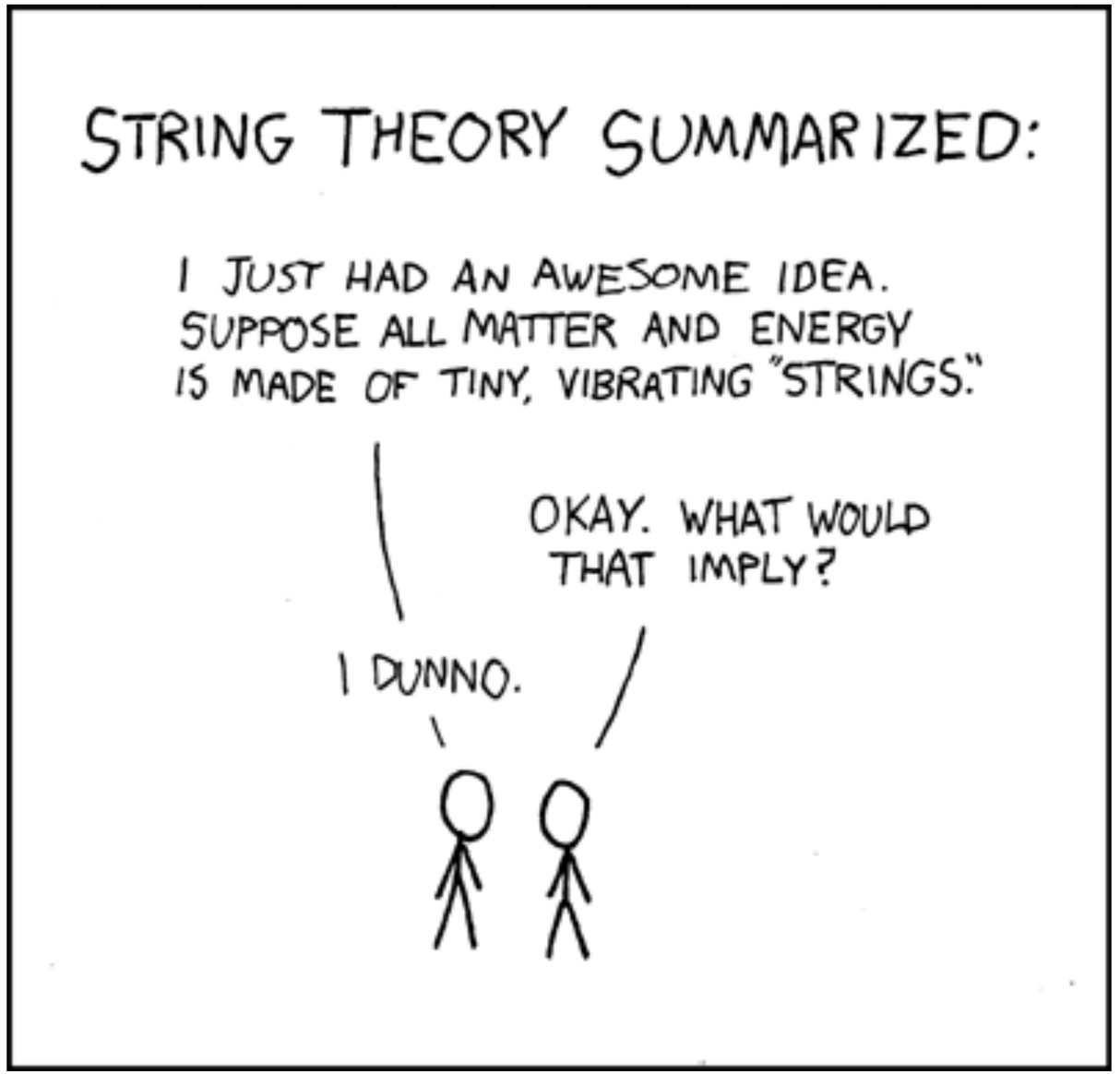
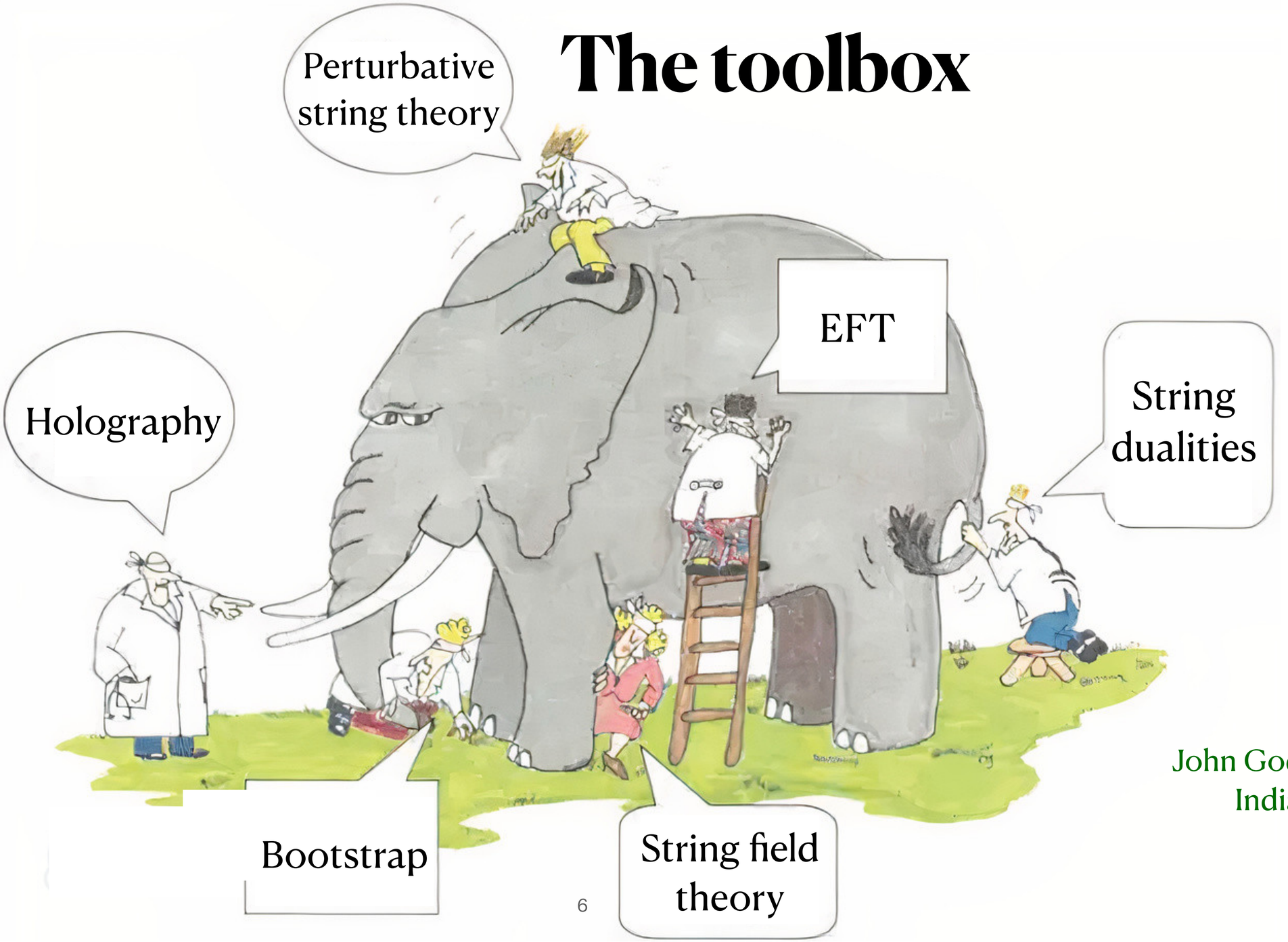


Image credit: Randall Munroe/xkcd

The toolbox



John Godfrey Saxe 1872, Indian parable

Image credit: Renee Guzlas

String theory is computationally hard

- Highly symmetric situations
- New computational machinery
- Extract general lessons

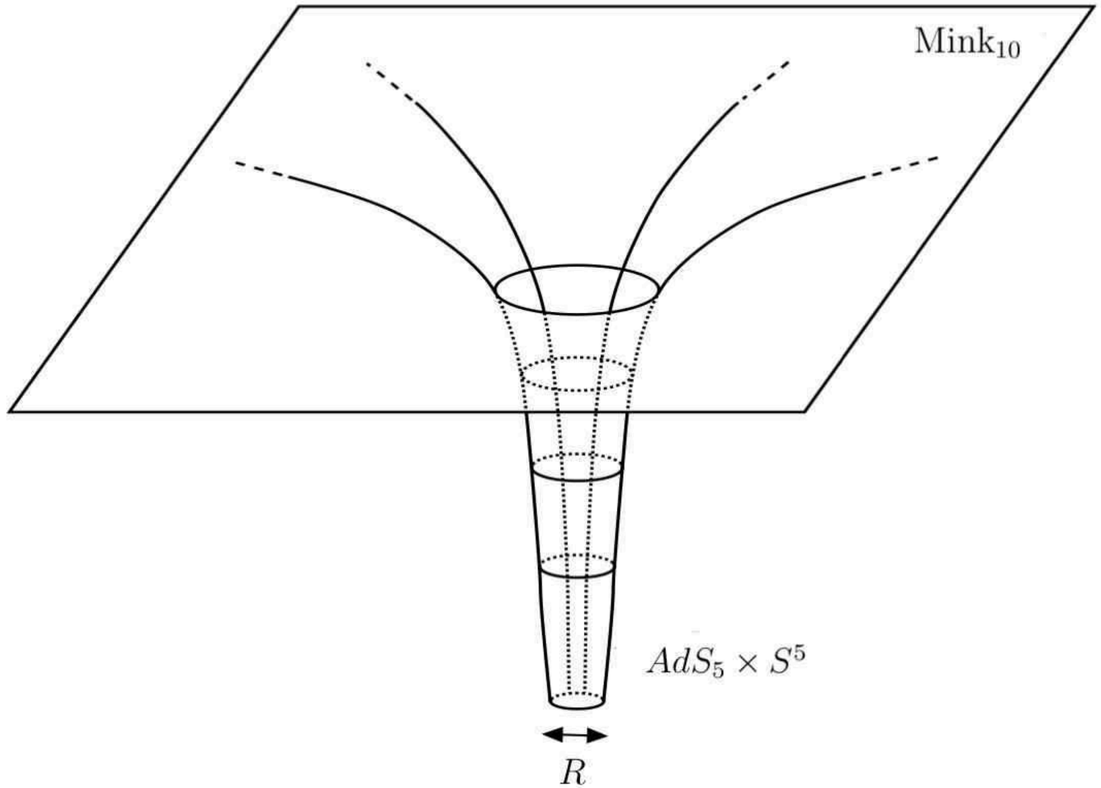
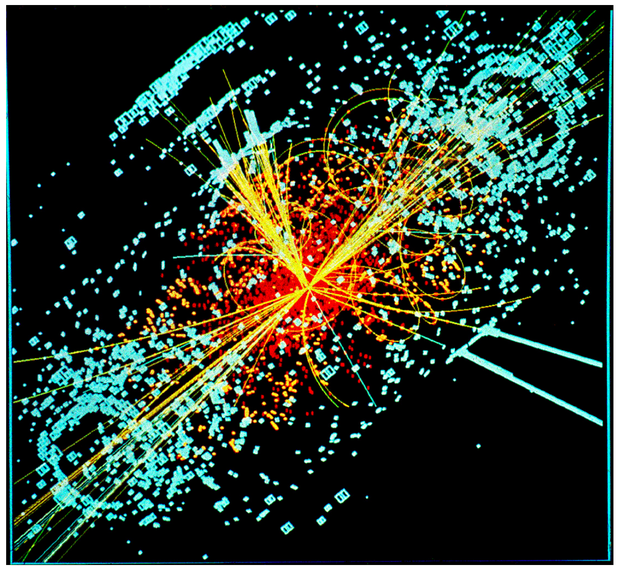


Image credit: D. Mateos

Quantum gravity in the collider



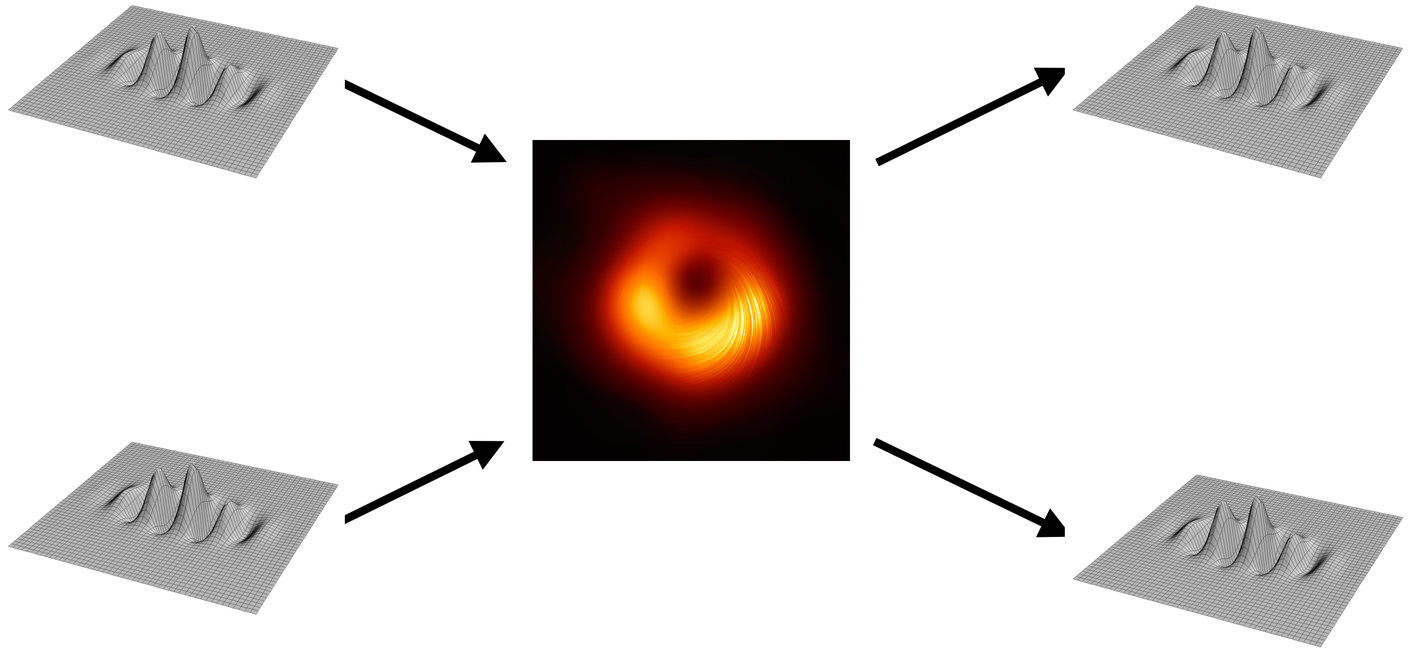
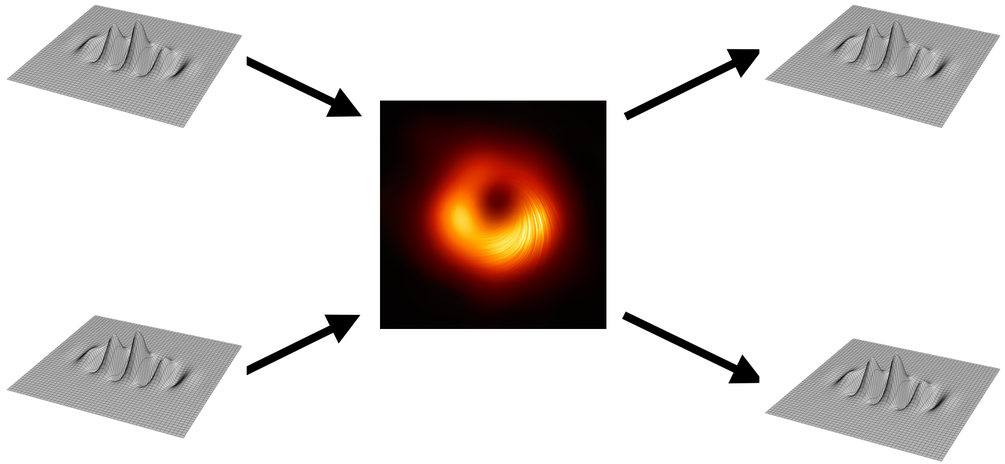
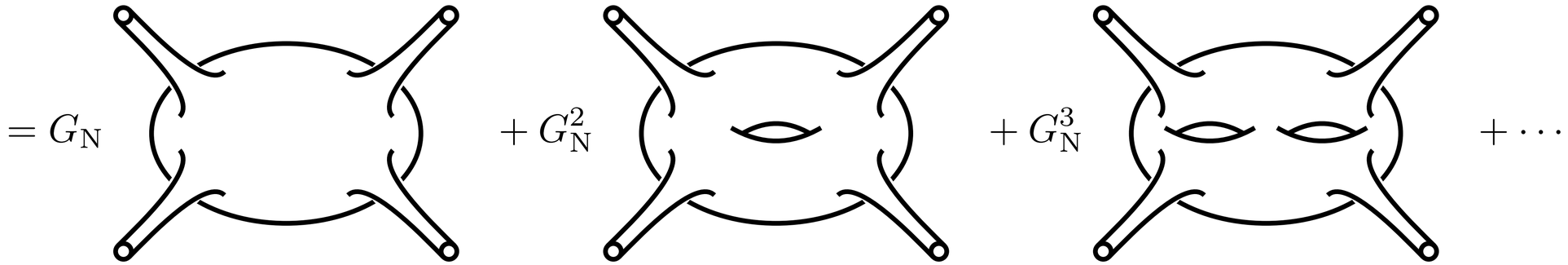


Image credit: D. Mateos

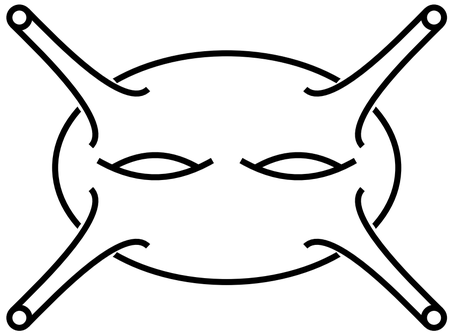
String theory works just like QFT





Stringy Feynman diagrams

- Only one diagram per loop
- Contains infinitely many massive particles



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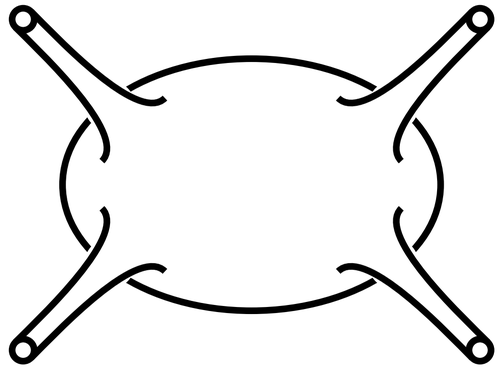
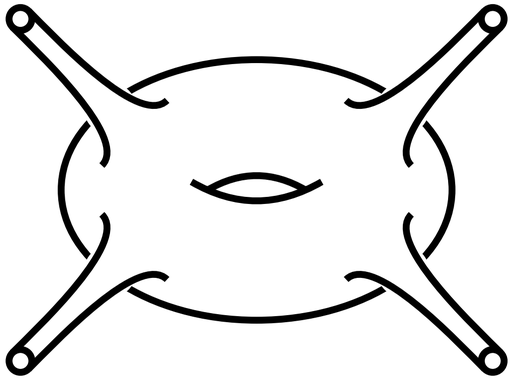
Some complicated integral

Computing the integrals



$$= (\text{polarizations}) \times \frac{\Gamma(-\frac{\ell_s^2 s}{4})\Gamma(-\frac{\ell_s^2 t}{4})\Gamma(-\frac{\ell_s^2 u}{4})}{\Gamma(1+\frac{\ell_s^2 s}{4})\Gamma(1+\frac{\ell_s^2 t}{4})\Gamma(1+\frac{\ell_s^2 u}{4})}$$

Virasoro - Shapiro amplitude ‘69

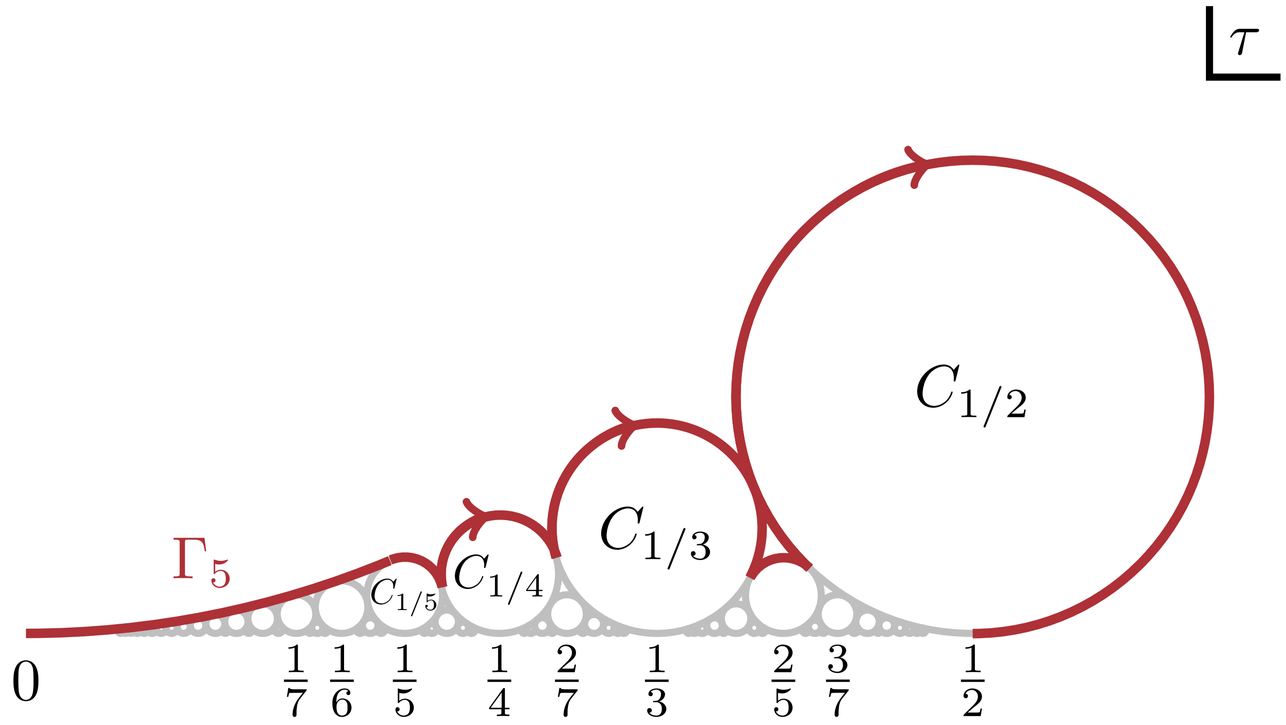


= much more complicated than polylogs...

???

One loop

Baccianti, Chandra, **LE**, Hartman, Mizera '22 - ... : Hardy-Littlewood circle method from analytic number theory can be generalized to compute one-loop diagram



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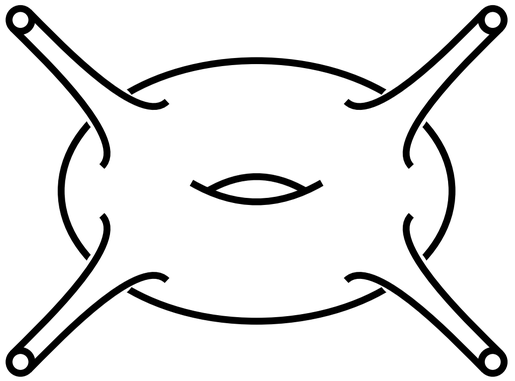

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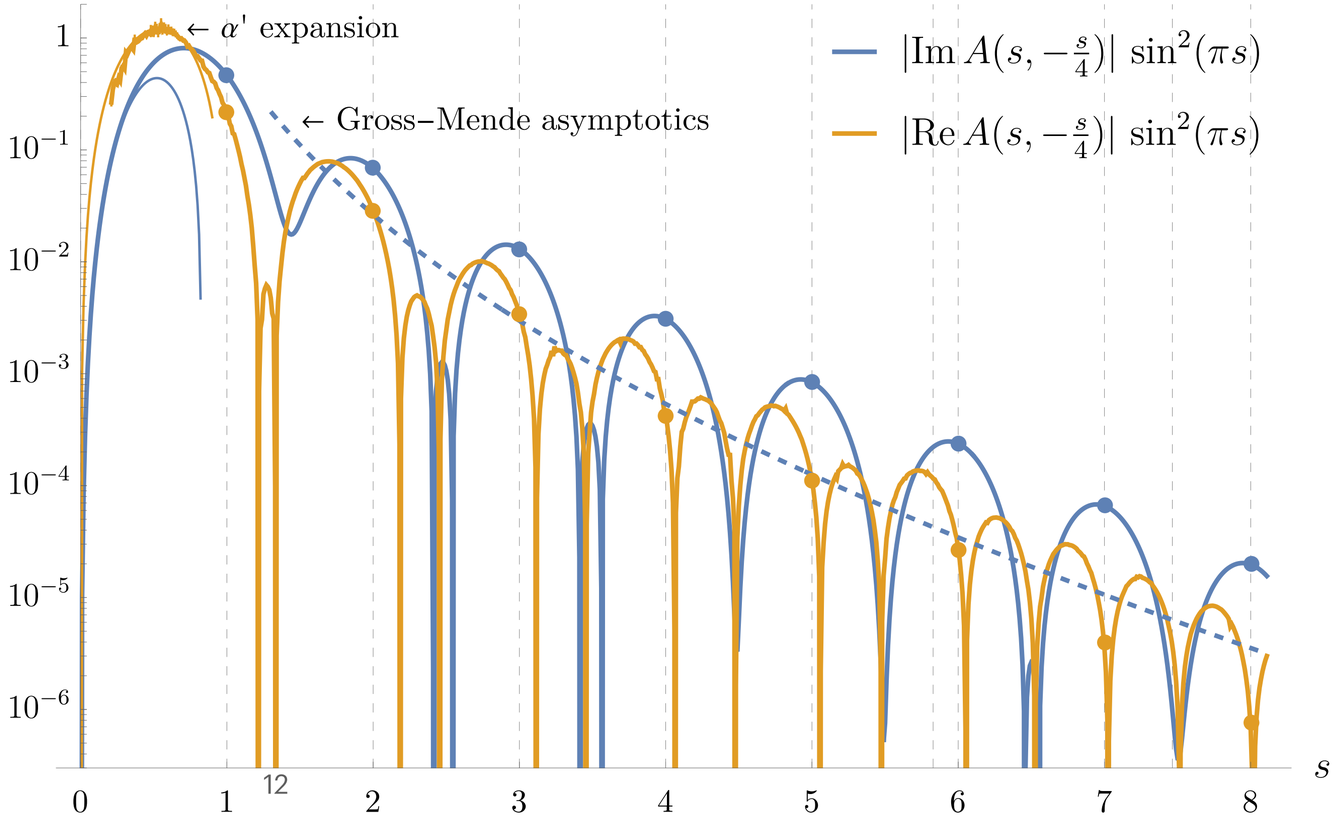


How does string theory differ from QFT?

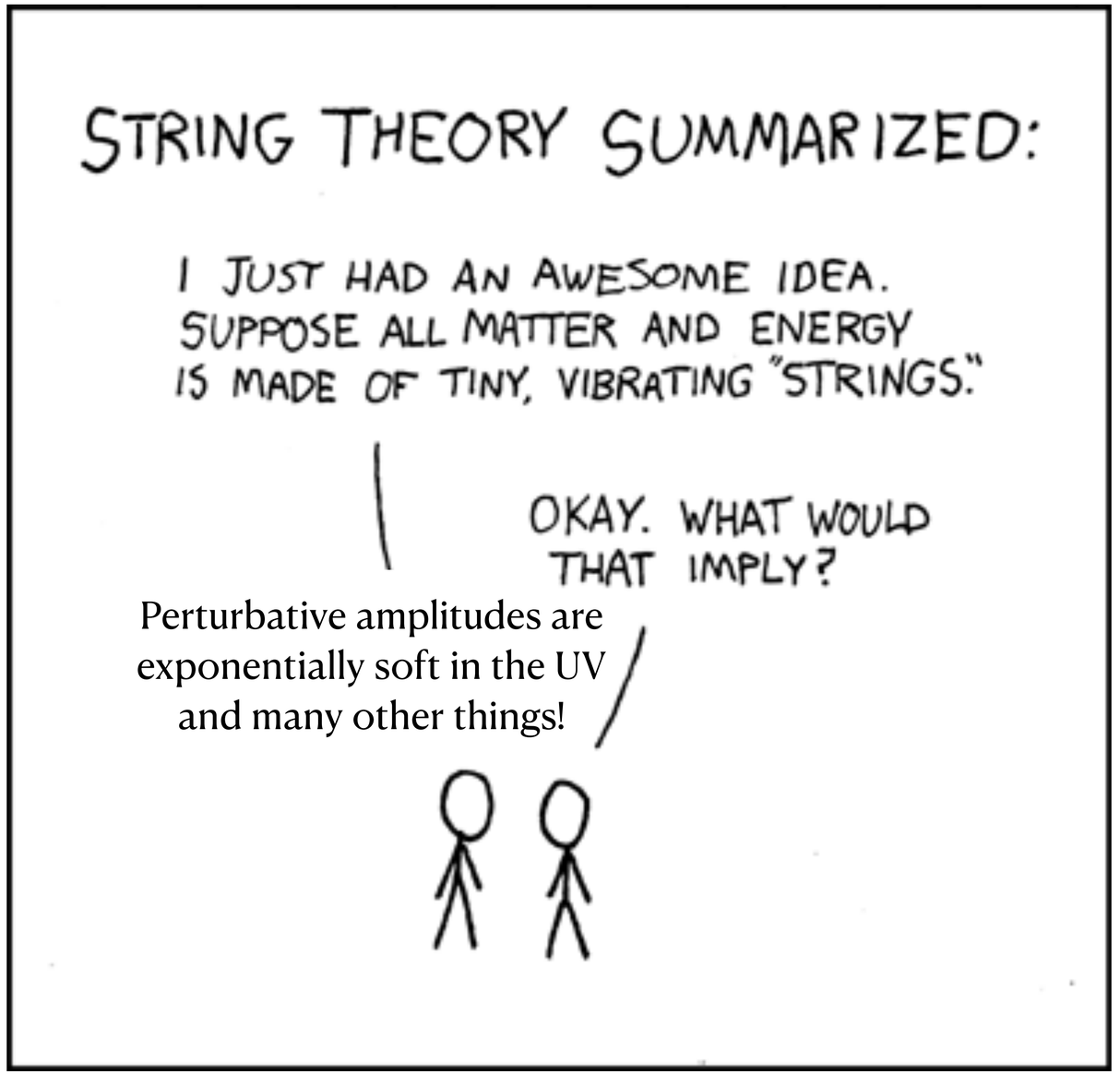
- UV finite

- Exponentially soft for large energies

$$\mathscr{M}_L \sim \exp\left(-\frac{s}{L+1} f(\theta)\right) \times \text{subleading}$$

Gross, Mende '87

- General feature of string theory!



Thank you!

Image credit: Randall Munroe/xkcd