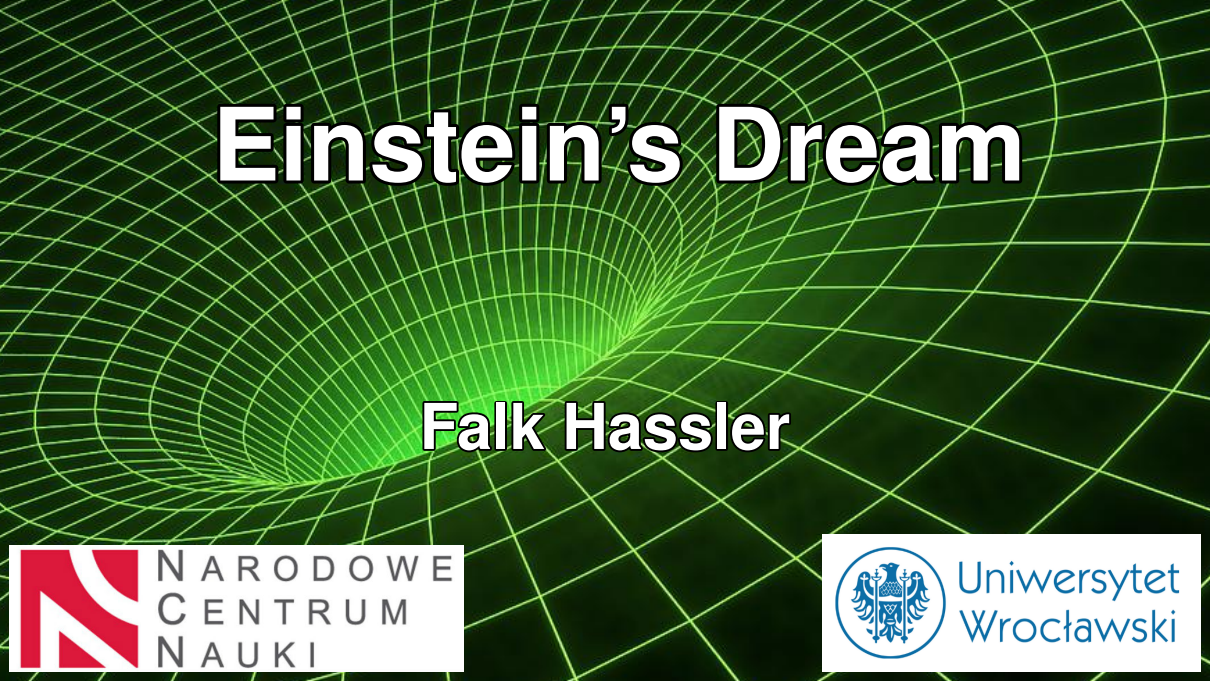
Einstein's Dream

Falk Hassler




The Edge of All We Know

14th September 2015: first observation of gravitational waves

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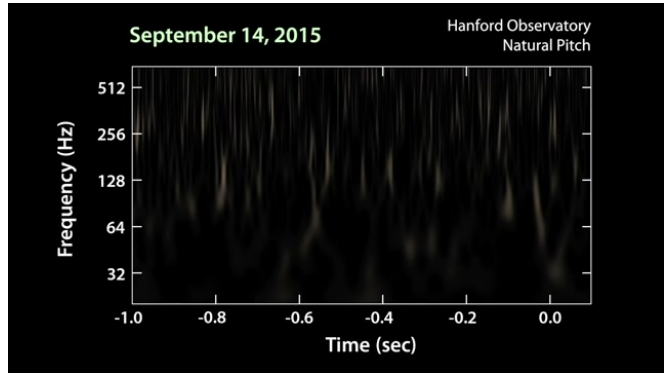

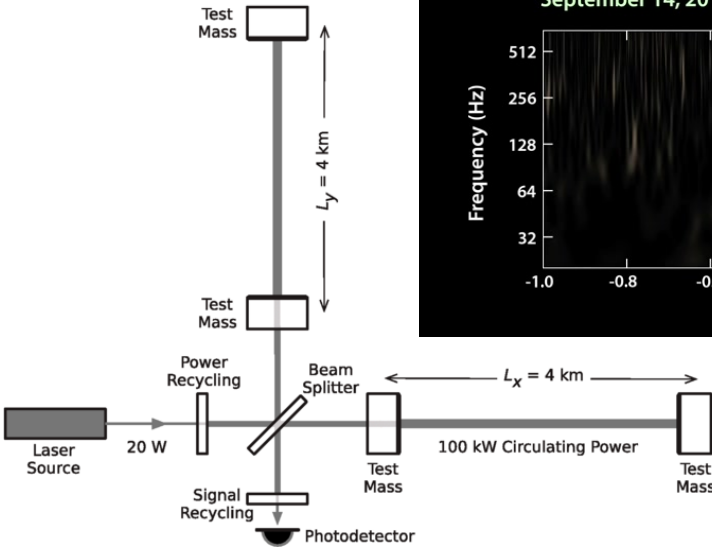

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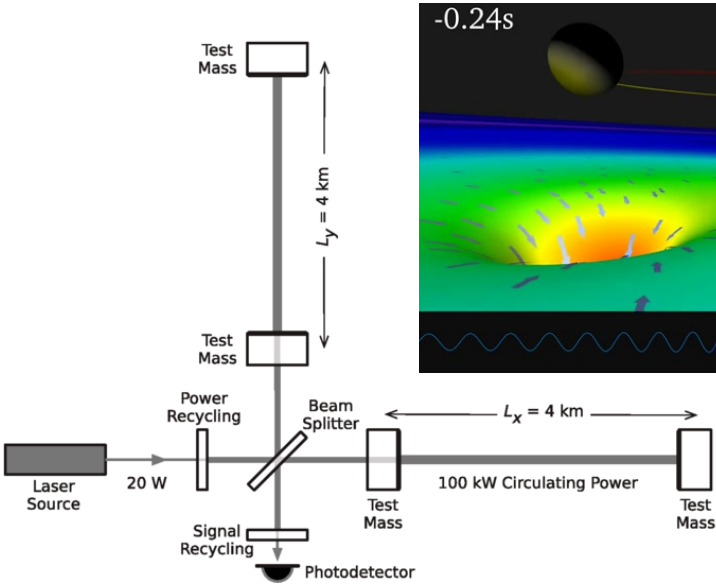

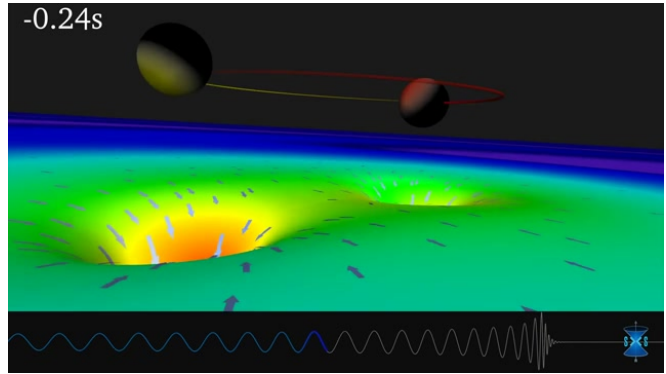

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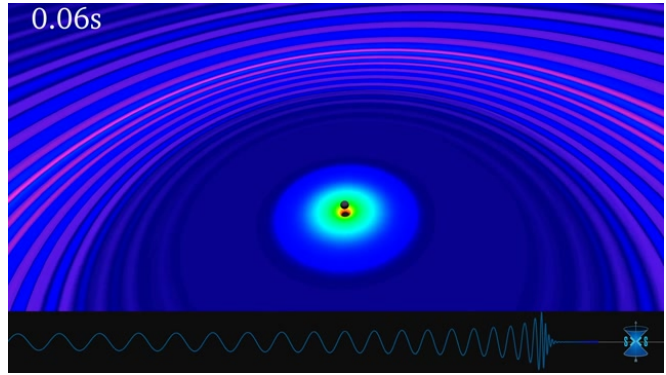
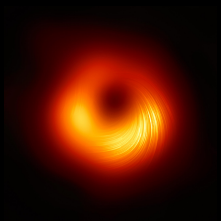
2017



10^{th} April 2019: first image of a black hole ($M87^*$)



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Relativistic Jet

Accretion Disk

Event Horizon

Singularity

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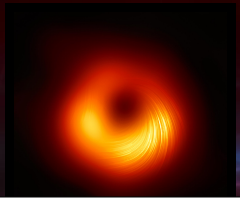

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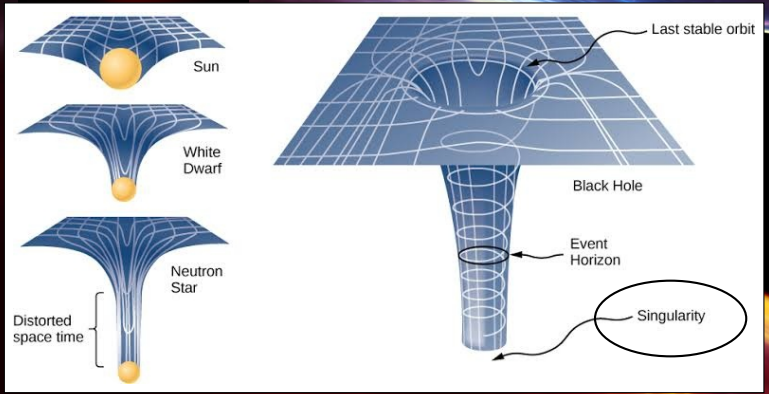

Why all the fuss about the singularity?

- Everything that ever fell into the BH is compressed to a point, the singularity.
- General relativity breaks down and needs to be altered, but how?
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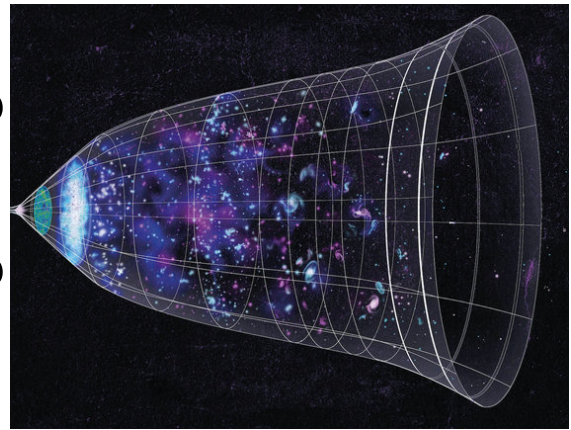
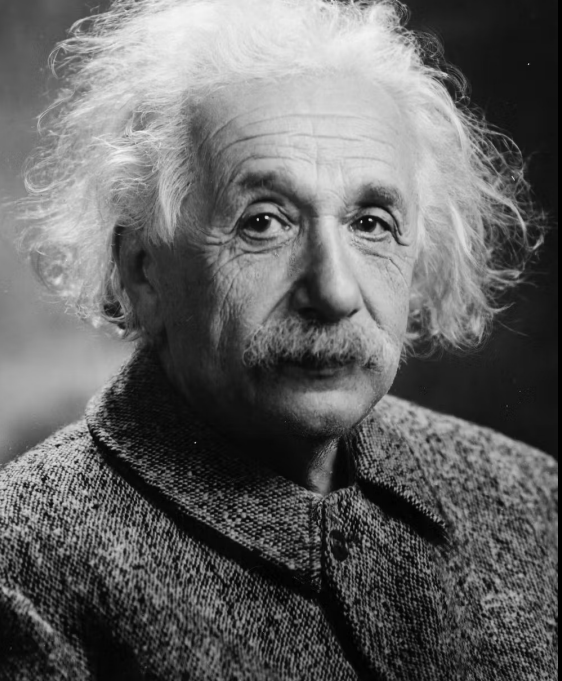
2020

Big Bang



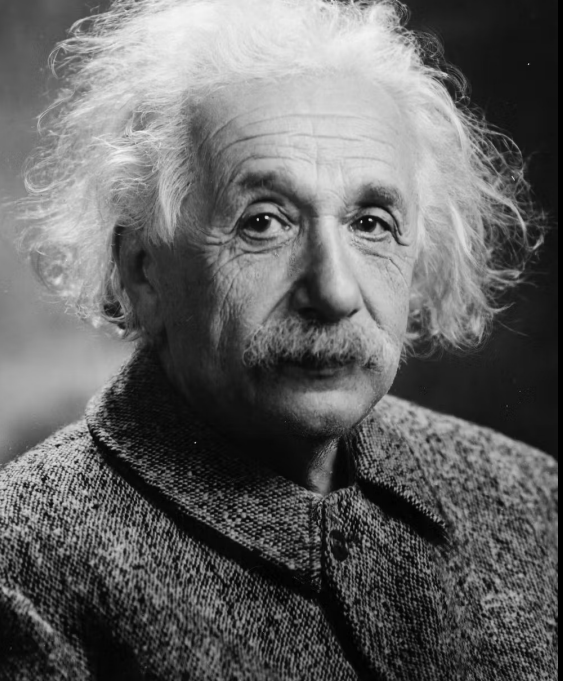

QFT and GR



Special and General Relativity

- speed of light c = cosmical speed limit
- mass-energy equivalence

$$E = mc^2$$



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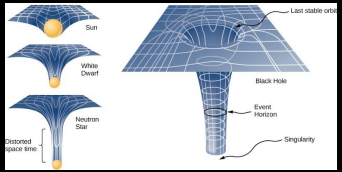

Quantum Mechanics

- nothing is certain
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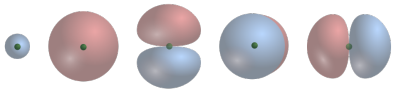

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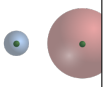
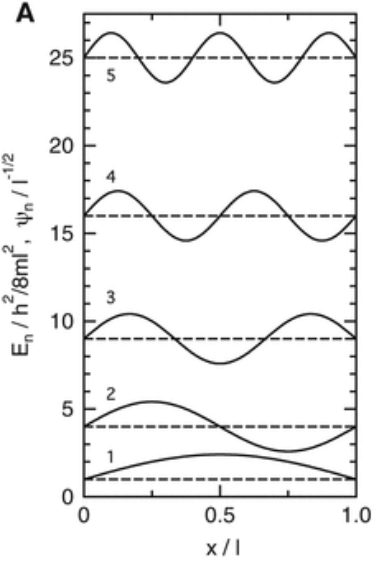
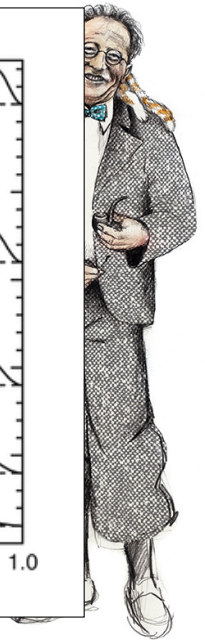


1s 2s

Experiment: Particle in Box





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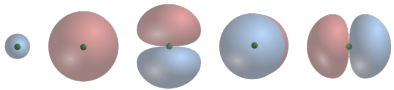
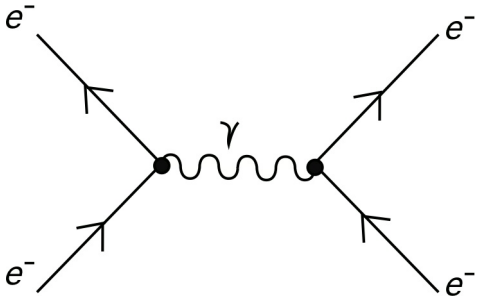
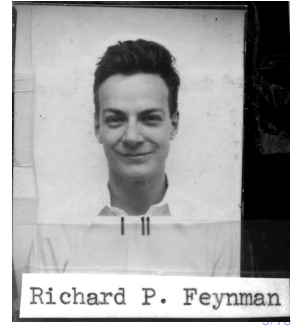


- Can we unify QM and SR?

Quantum Field Theory

- particles can be created and annihilated (destroyed)
- interactions can be drawn as Feynman diagrams





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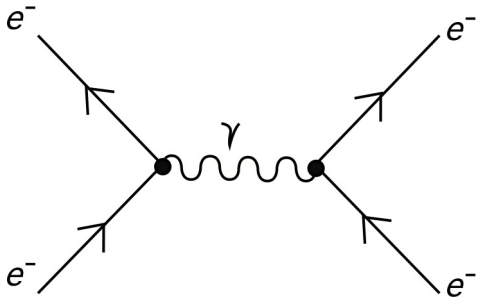
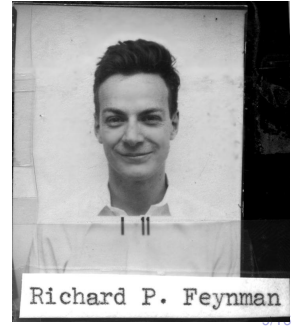


- virtual particles “borrow” energy from vacuum

→ renormalisation



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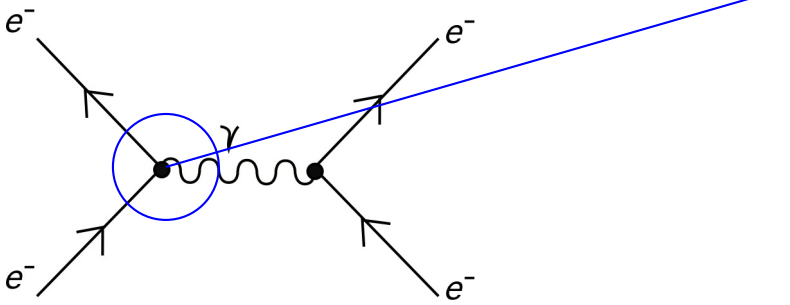

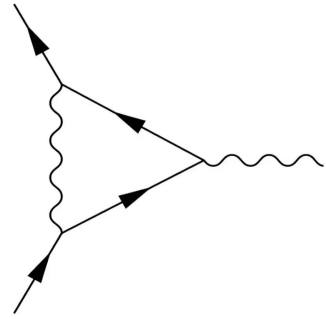

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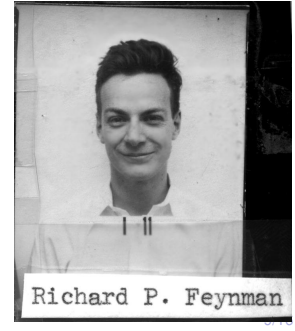
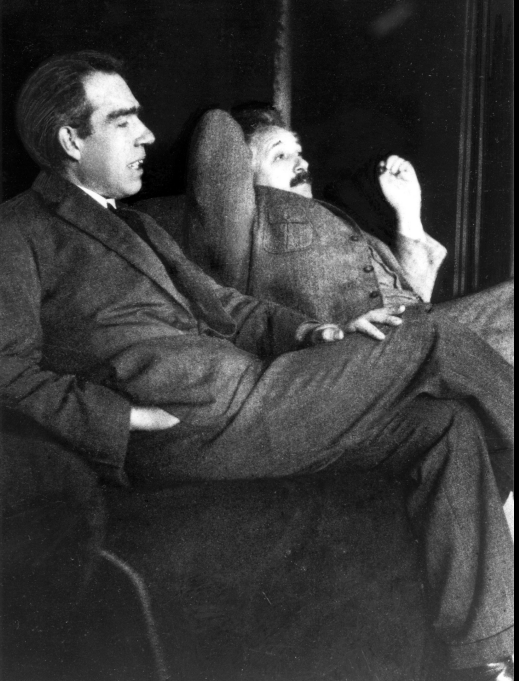
- This is where the trouble starts!





GR is not renormalisable

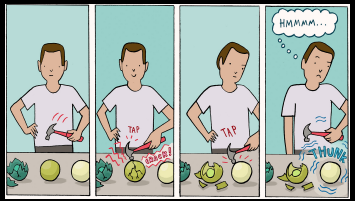
- quantum mechanics corrects (renormalises) Einstein field equations

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \ldots = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- happens for all fundamental forces
- but only for gravity ∞-many corrections

$\rightarrow$ not applicable at

- high energies
- small distances $\sim 10^{-35}$m



Is the singularity an artifact of an incomplete description?

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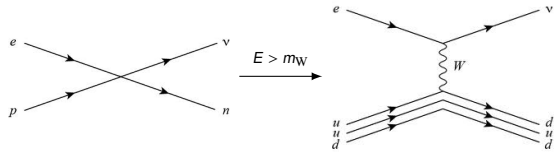
example Fermi theory of β-decay



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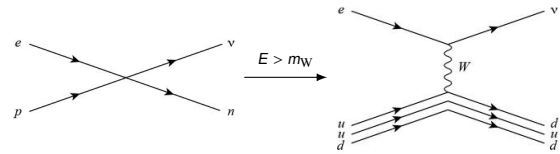
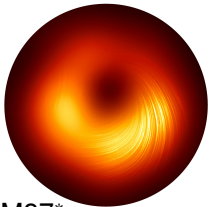


My research is driven by:

- Can we resolve the singularity?
- Effects on the notion of space and time, the fabric of cosmos?
- What are observable consequences?


String Theory

Smaller and smaller and smaller...



M87*

10^{13} length [m]

Smaller and smaller and smaller...

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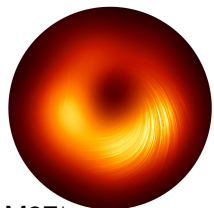

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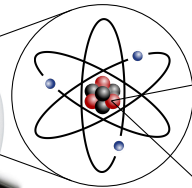

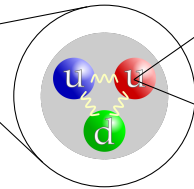

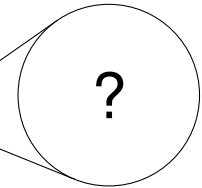

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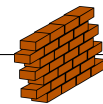
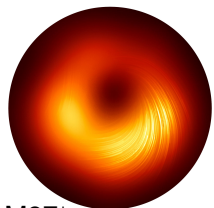


Planck scale

Smaller and smaller and smaller...



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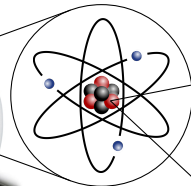

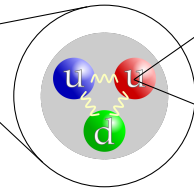

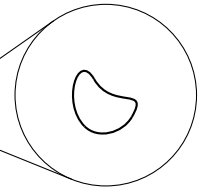

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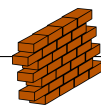

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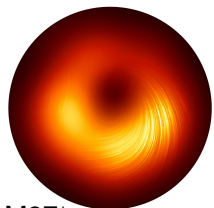

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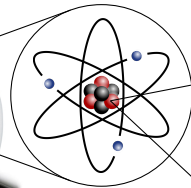

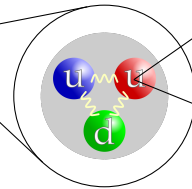

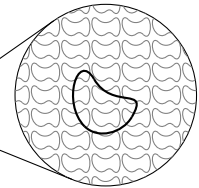

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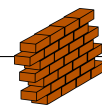
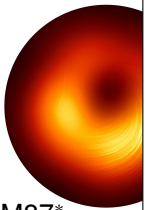


Planck scale

Smaller an



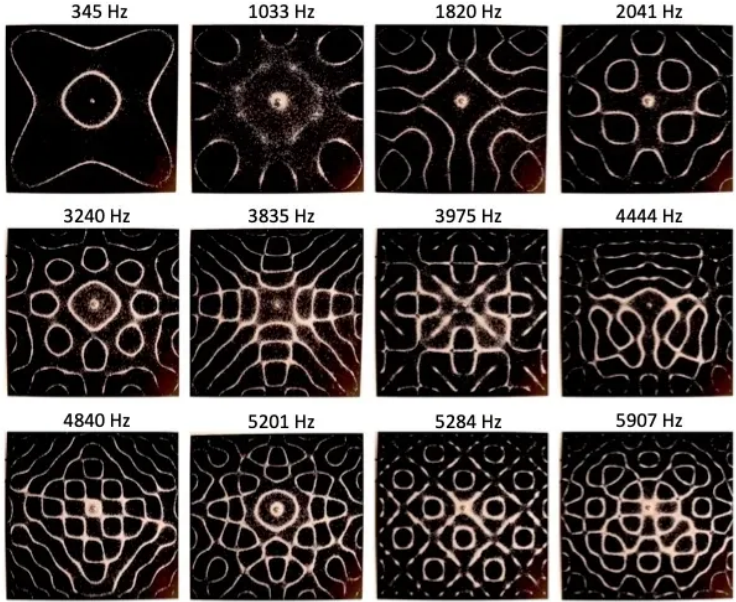
M87*

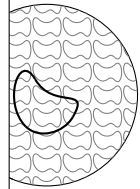
10^{13}

0^{-35}

lanck scale

Experiment: Cymatics





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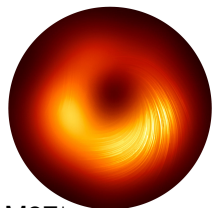

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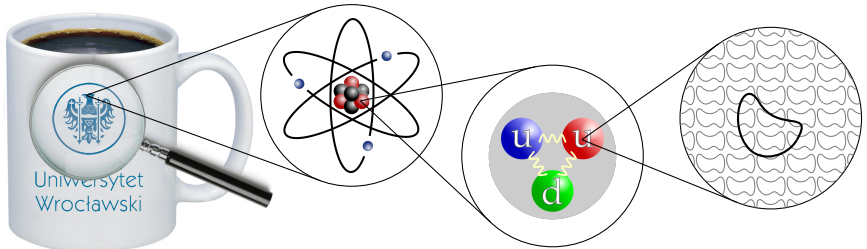

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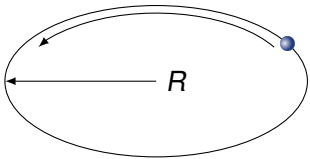
point particles | spacetime **geometry**

strings | **string geometry**

What do we learn from this new paradigm?

Abelian T-duality

point particle

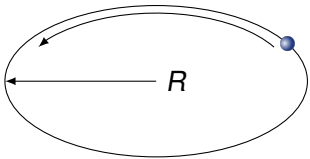


$\neq$

$$E_n \sim \frac{n^2}{R}$$

Abelian T-duality

point particle



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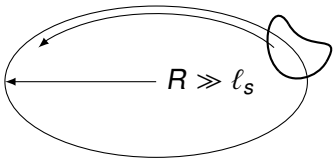
$$E_n \sim \frac{n^2}{R}$$

string



$=$

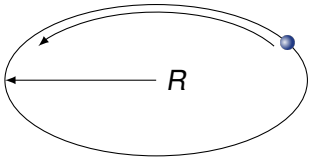
T-duality

$$\frac{\ell_S^2}{R}$$

$$E_{nm} \sim \frac{n^2}{R} + \frac{m^2 R}{\ell_S^2}$$

Abelian T-duality

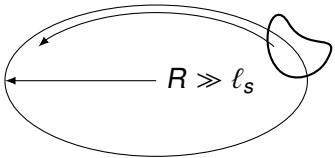
point particle



$\neq$

$$E_n \sim \frac{n^2}{R}$$

string



$=$

T-duality

$$\frac{\ell_S^2}{R}$$

$$E_{nm} \sim \frac{n^2}{R} + \frac{m^2 R}{\ell_S^2}$$

only works for circles and flat tori


Future?

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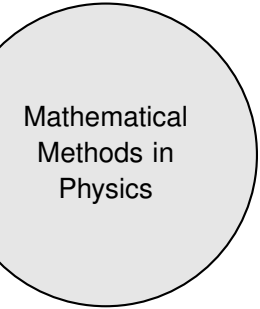

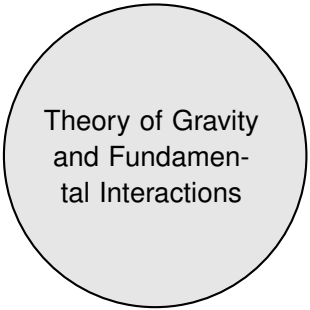

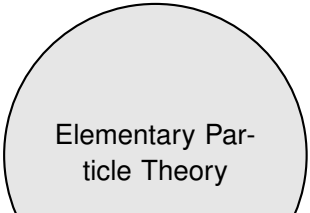

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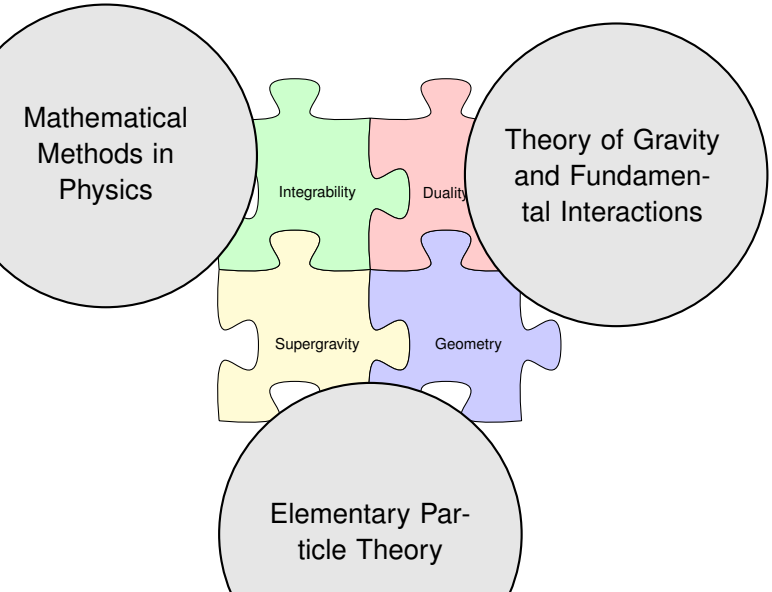

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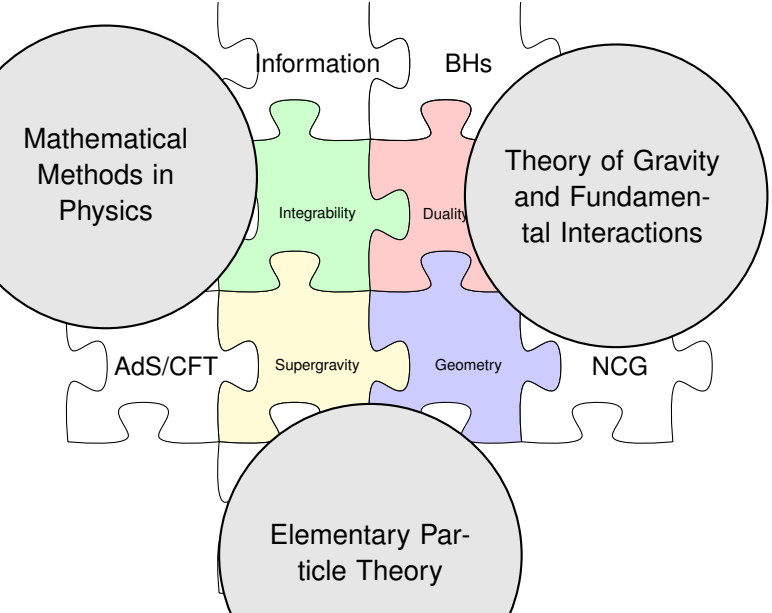

- Work on these topic is done here in Wrocław...
- ...and all over the world.
- SONATA BIS 11 grant

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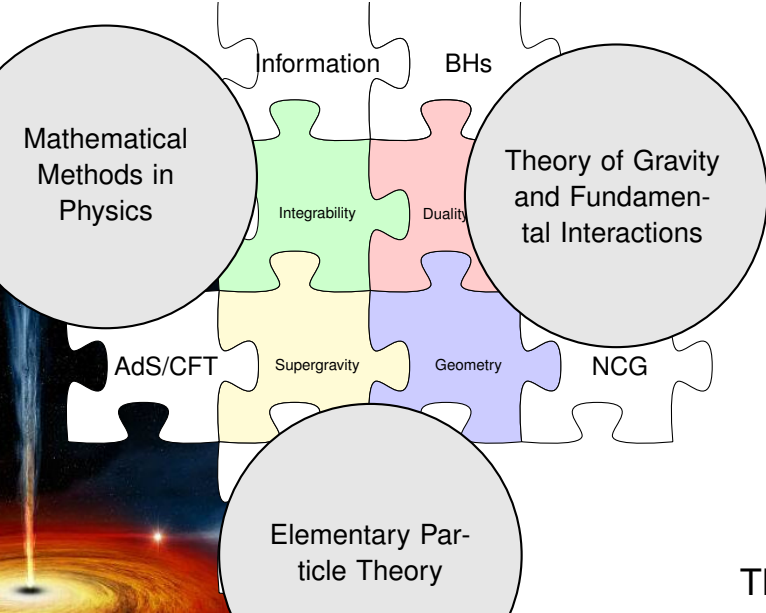

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Thank you for your attention!