

**Title:** Alumni Stories: Astrid Eichhorn

**Speakers:** Astrid Eichhorn

**Collection/Series:** Beyond Perimeter - Alumni 25th Anniversary Event

**Date:** September 25, 2025 - 4:10 PM

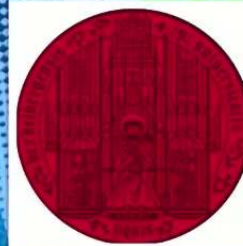
**URL:** <https://pirsa.org/25090075>

# Beyond Perimeter: a journey in search of the building blocks of spacetime

*Physics, People and Perimeter*

Perimeter Institute, "Beyond Perimeter, Alumni 25th anniversary event"  
September 25, 2025  
Astrid Eichhorn

*Image credit:*  
Children's book "Young scientists", Hanser publishing,  
chapter "Physics: Answers to fundamental questions, Astrid Eichhorn"

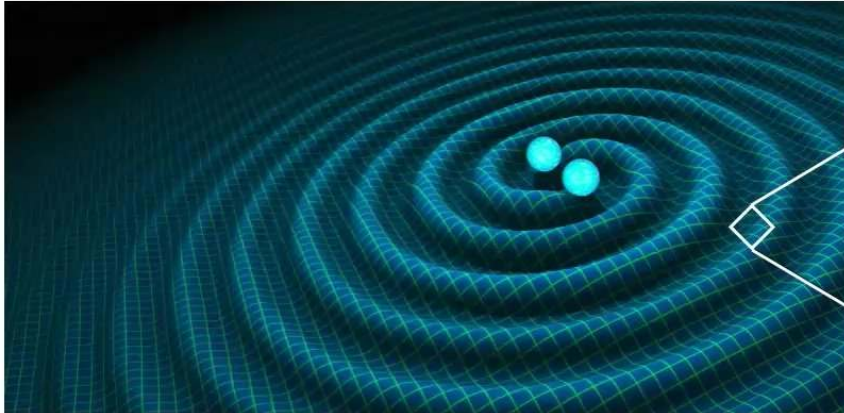


UNIVERSITÄT  
HEIDELBERG  
ZUKUNFT  
SEIT 1386



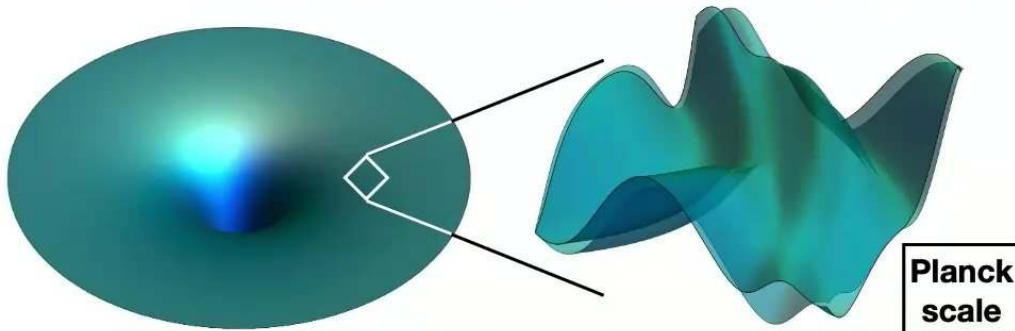
European Research Council

# What are the fundamental building blocks of spacetime?

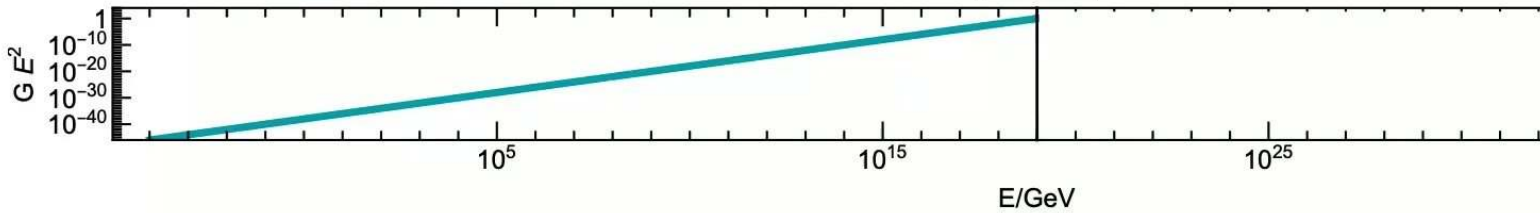


quantum superpositions (path integral)

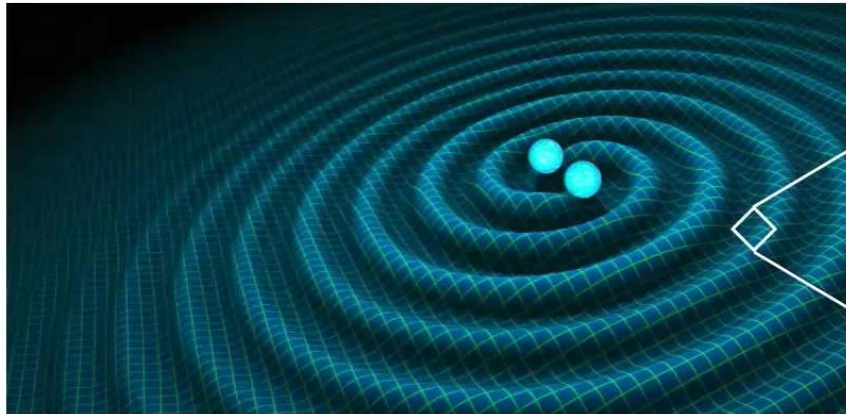
field  $\leftrightarrow$  particle (graviton)



Planck scale

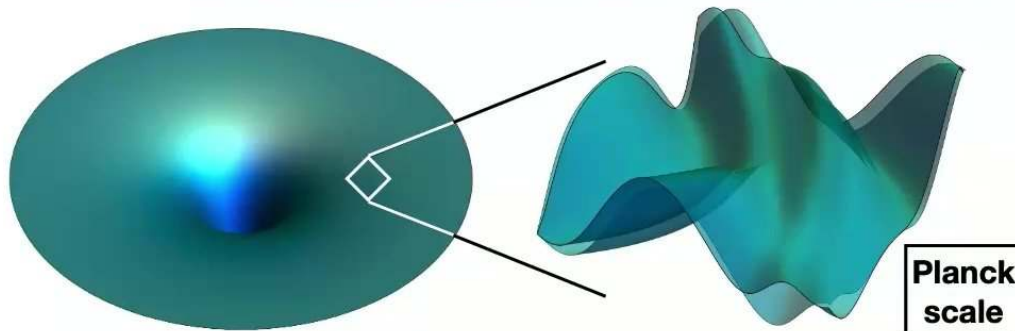


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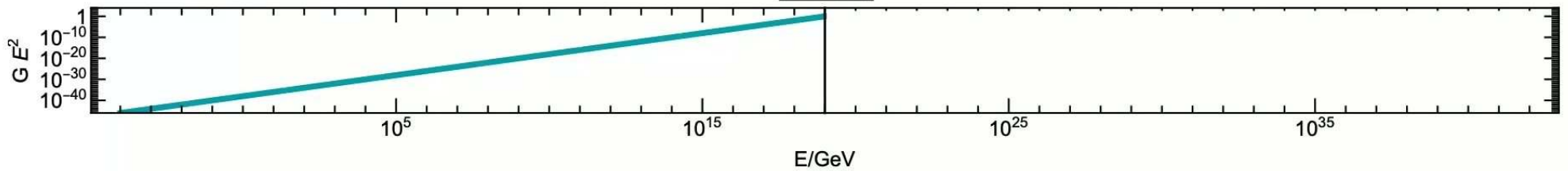
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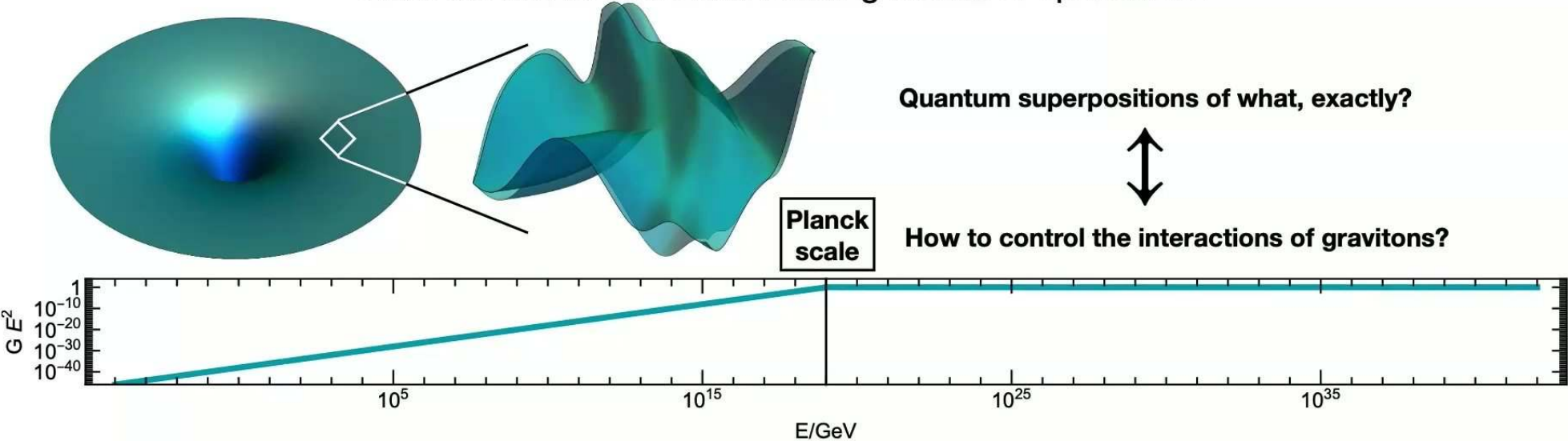
Quantum superpositions of what, exactly?



How to control the interactions of gravitons?



What are the fundamental building blocks of spacetime?

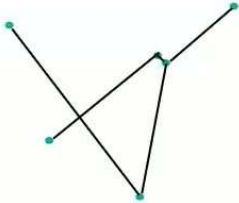


Three ideas:

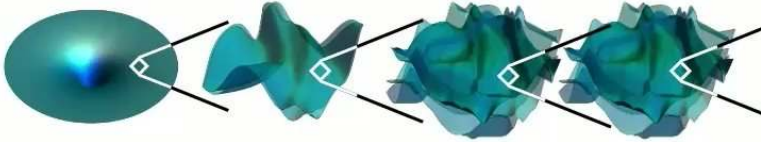
1) non-locality  
(strings, AdS/CFT)



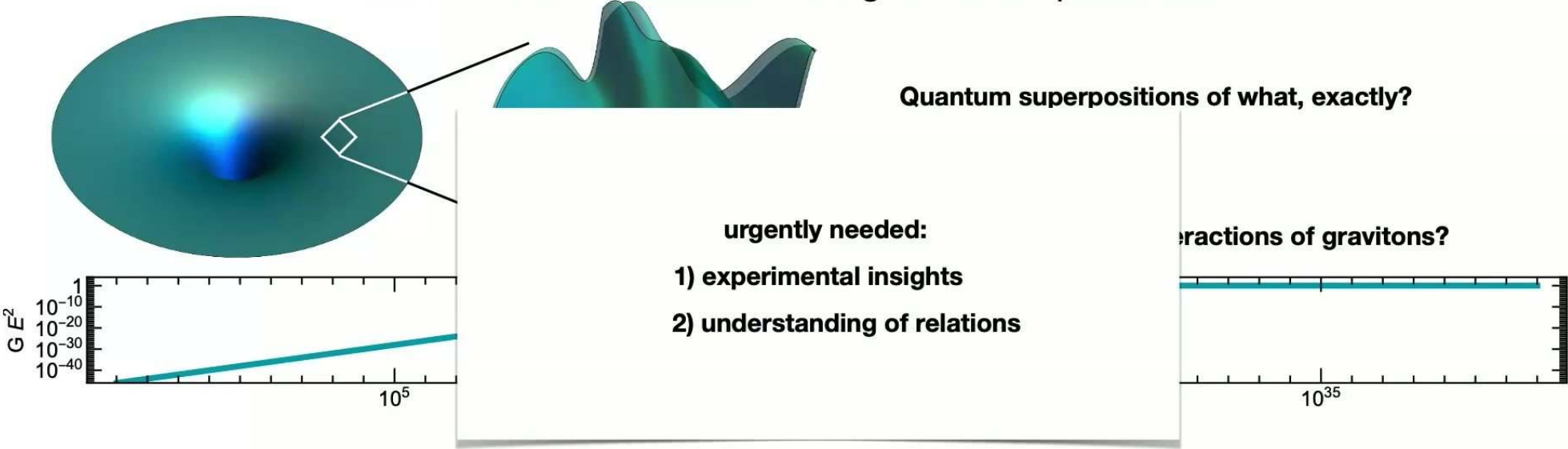
2) discreteness  
(causal sets, LQG & spin foams)



3) scale symmetry  
(asymptotic safety)



# What are the fundamental building blocks of spacetime?

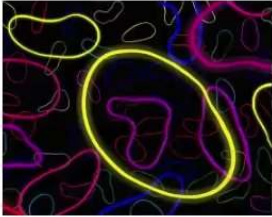


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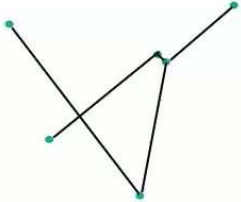
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## Three ideas:

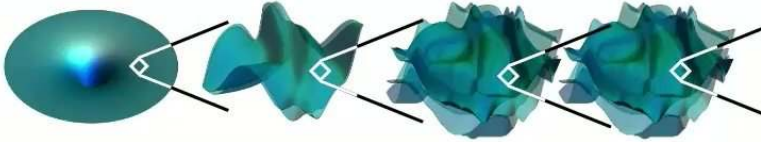
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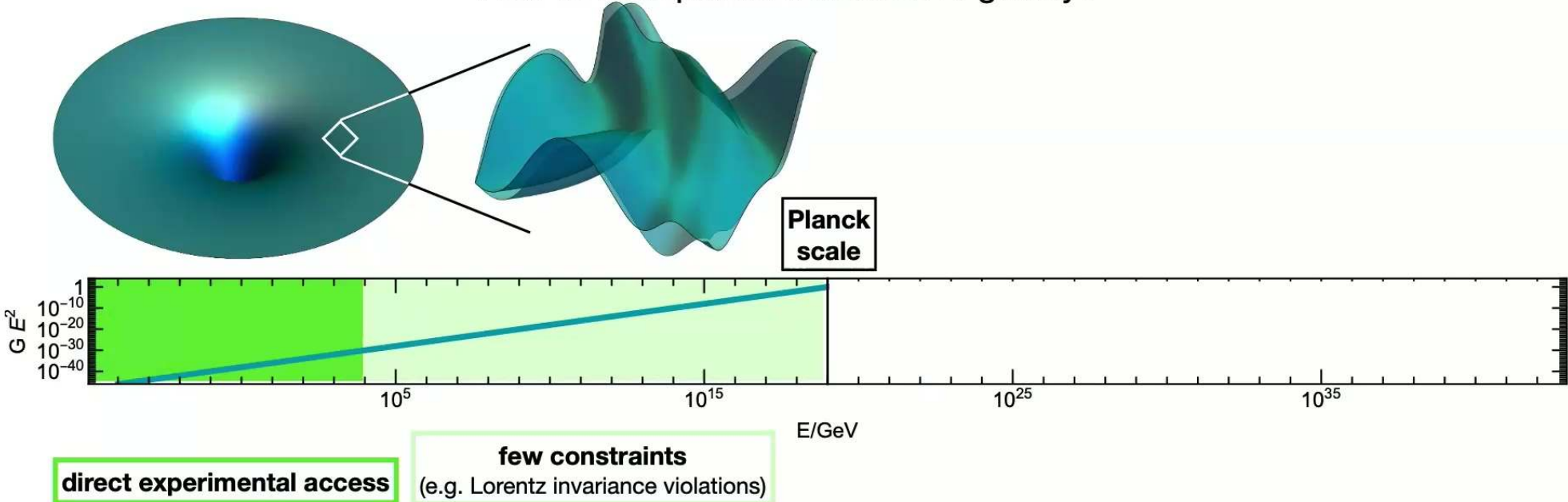
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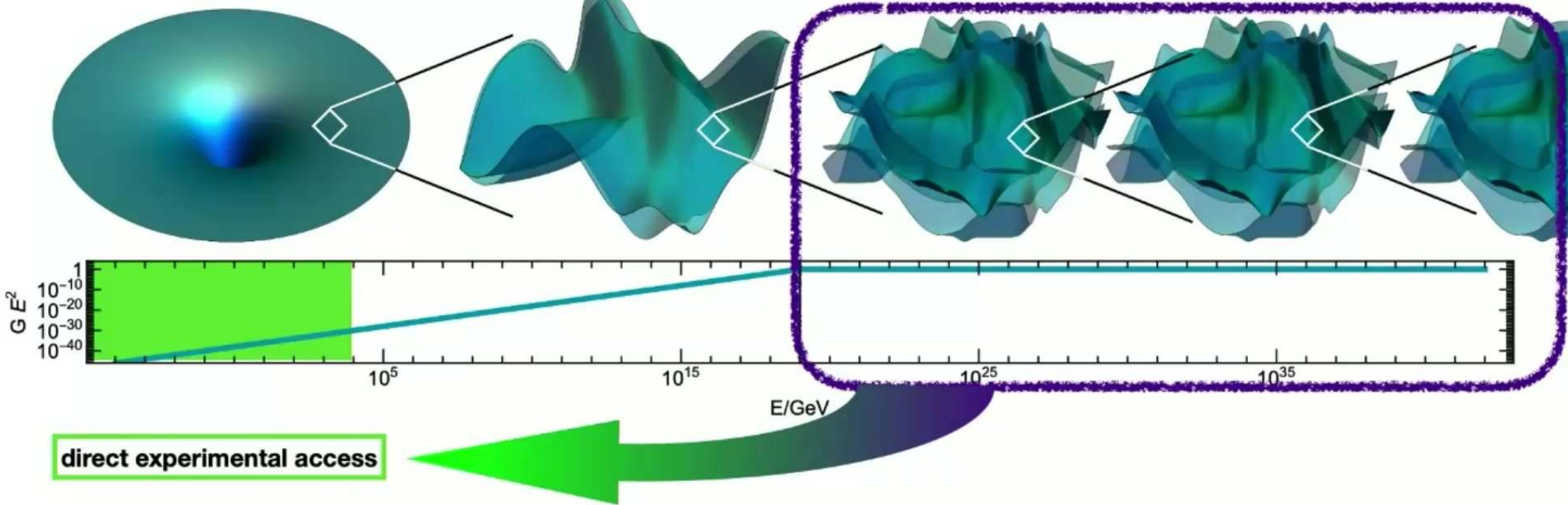
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# How to test quantum theories of gravity?



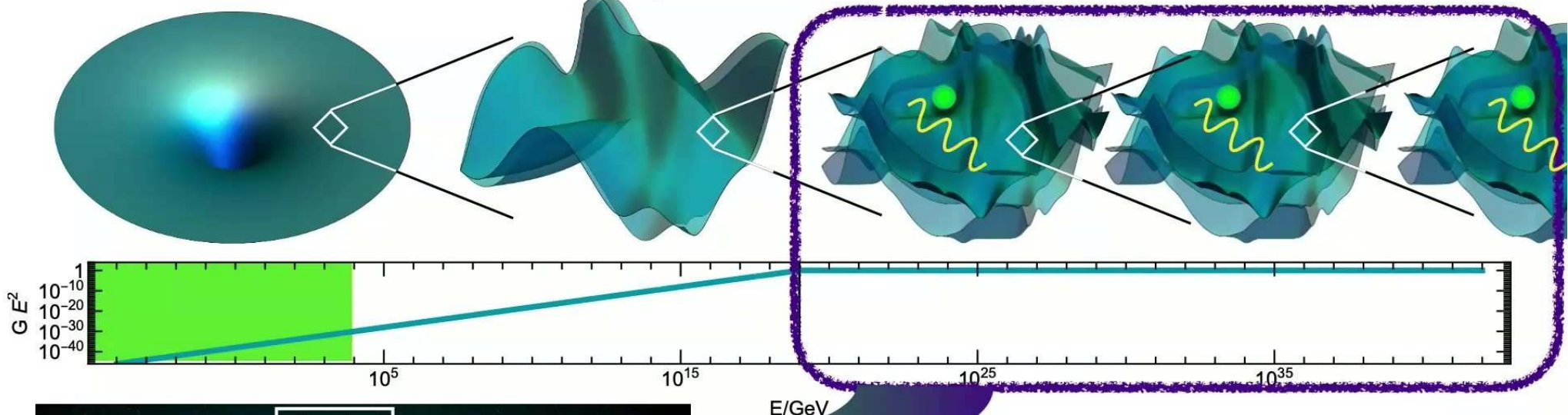
# How to test quantum theories of gravity?



**idea 1: macrophysics emerges from microphysics**  
⇒ can calculate testable large-scale properties from fundamental theory



# How to test quantum theories of gravity?



**Standard Model & beyond**

**idea 1: macrophysics emerges from microphysics**  
 ⇒ can calculate testable large-scale properties from fundamental theory

**idea 2: "matter matters": interplay of quantum gravity and matter determines properties of matter (e.g., Standard Model, dark matter)**

# “Matter matters”: the first step

PHYSICAL REVIEW D **89**, 084035 (2014)

## Matter matters in asymptotically safe quantum gravity

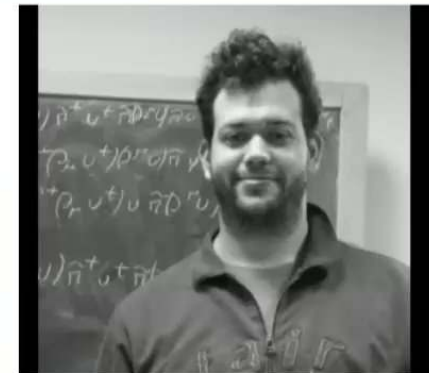
Pietro Donà,<sup>1,\*</sup> Astrid Eichhorn,<sup>2,†</sup> and Roberto Percacci<sup>1,‡</sup>

<sup>1</sup>*International School for Advanced Studies, via Bonomea 265, 34136 Trieste, Italy and  
INFN, Sezione di Trieste*

<sup>2</sup>*Perimeter Institute for Theoretical Physics, 31 Caroline Street N, Waterloo, N2L 2Y5 Ontario, Canada  
(Received 14 February 2014; published 8 April 2014)*

### ACKNOWLEDGMENTS

We thank A. Codello, G. D’Odorico and C. Pagani for sharing some of their results prior to publication. P. D. thanks the Perimeter Institute for hospitality during this work. This research was supported in part by Perimeter Institute for Theoretical Physics. Research at Perimeter Institute is supported by the Government of Canada through Industry Canada and by the Province of Ontario through the Ministry of Research and Innovation.



# “Matter matters”: the journey & the people

2014: Imperial College

2016: Heidelberg University



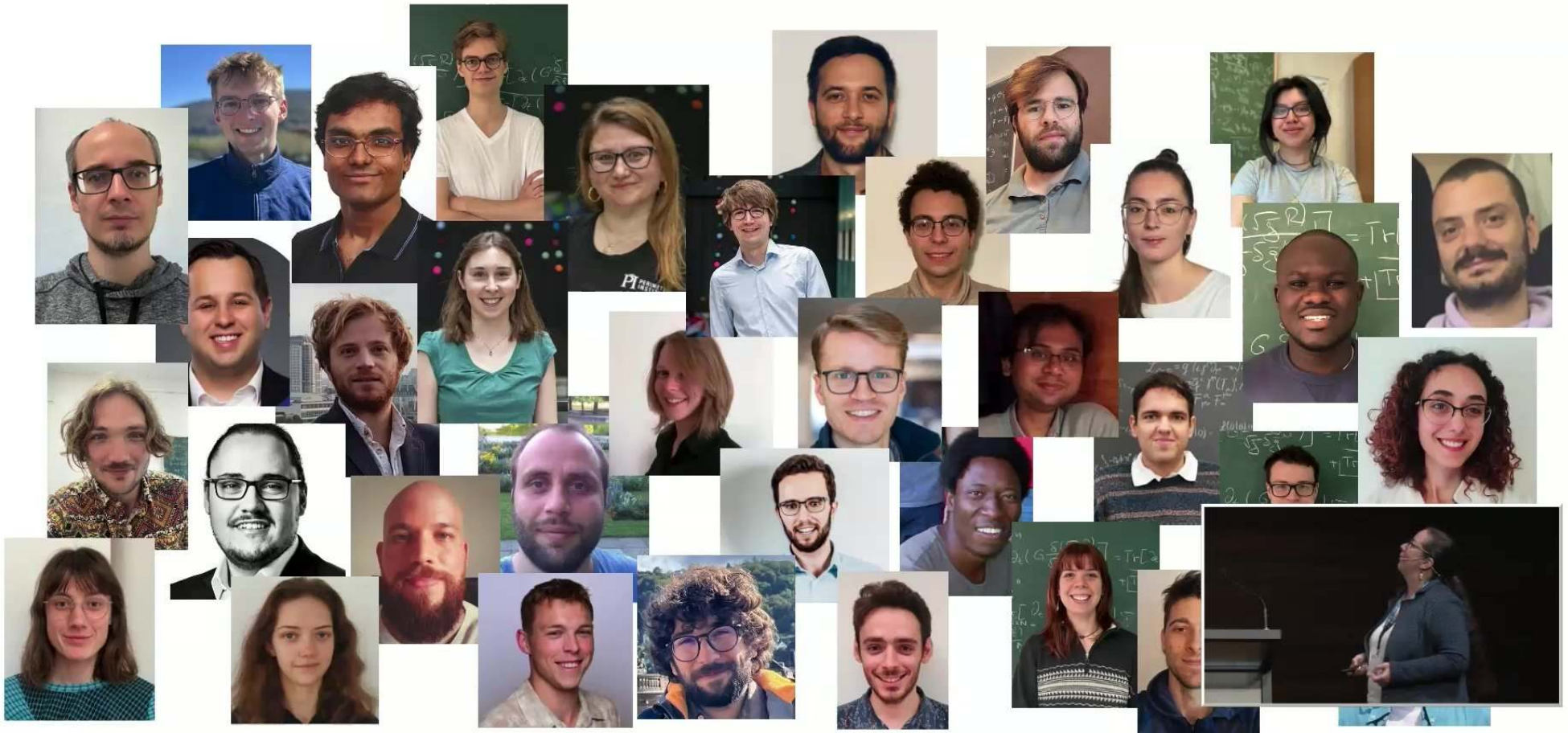
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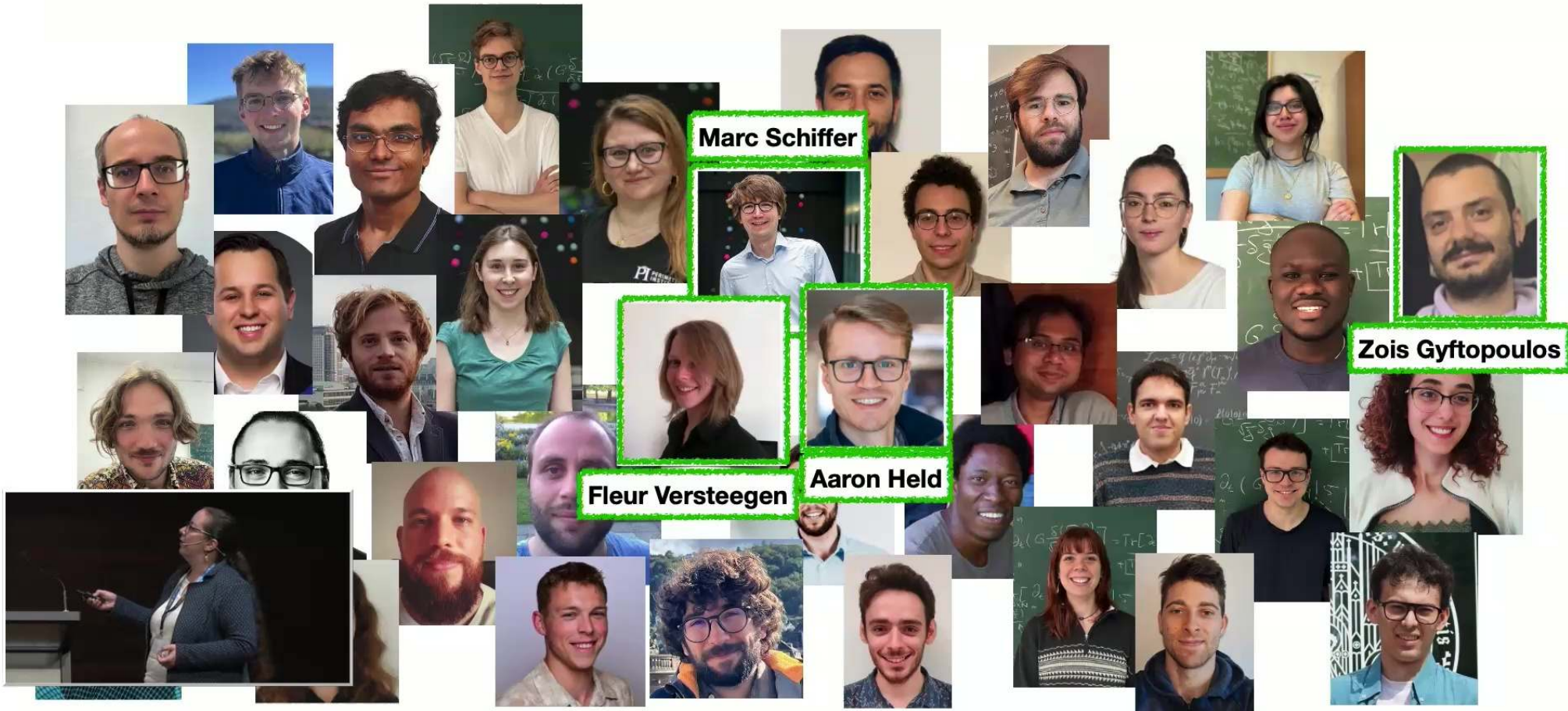
# “Matter matters”: key developments & current status - a lightning overview

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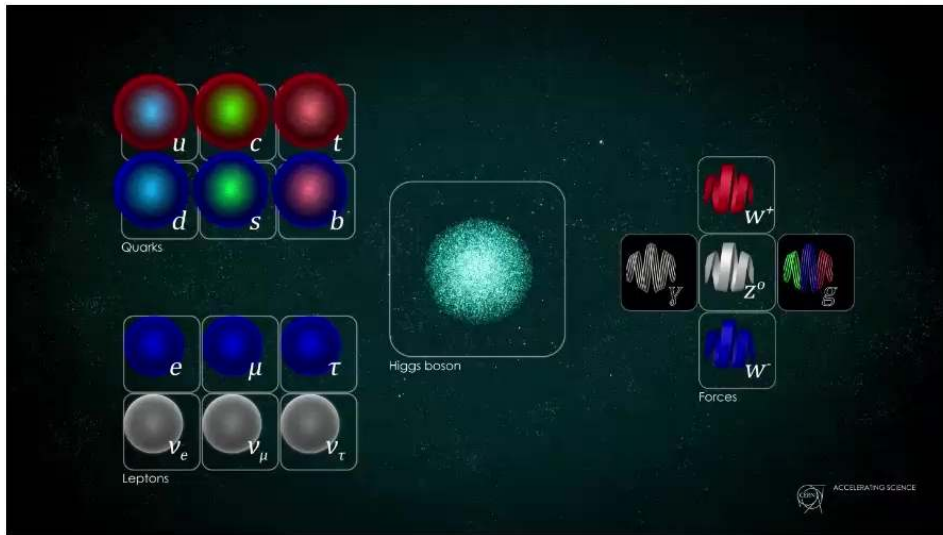
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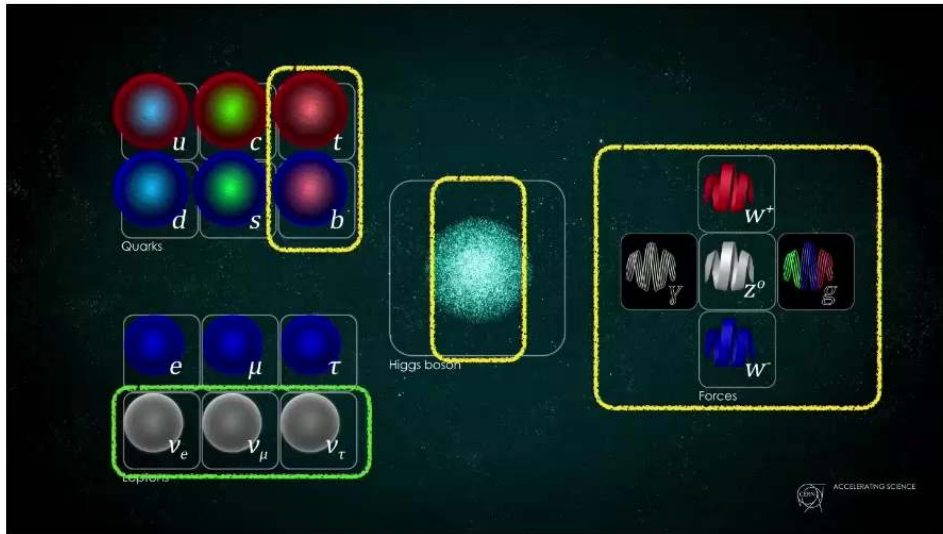
## “Matter matters”: key developments & current status - a lightning overview



enhanced symmetry at (trans) Planckian scales  
fixes some properties of the Standard Model at all scales



# “Matter matters”: key developments & current status - a lightning overview



**Result 1:**  
**“heavy” Standard Model**

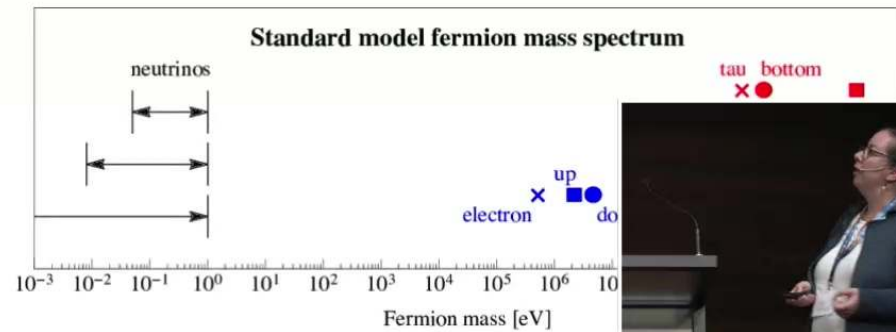
[Harst, Reuter '11; Shaposhnikov, Wetterich '09, AE, Held '17, '18, AE, Versteegen '17, AE, Schiffer '19]

**Landau-pole in U(1) sector solved**  
**⇒ several couplings bounded from above**

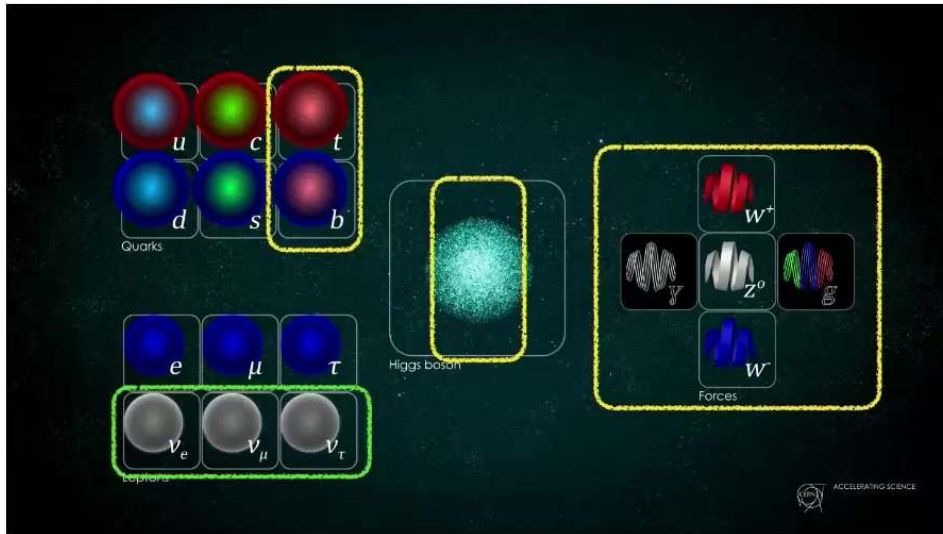
**Result 2:**  
**neutrino sector**

[Held, PhD thesis '19; Kowalska, Pramanick, Sessolo '22; AE, Held '22; de Brito, AE, Pereira, Yamada '25; AE, Gyftopoulos, Held '25]

**neutrinos dynamically light,**  
**because their coupling to the Higgs**  
**is suppressed by quantum gravity**



# “Matter matters”: key developments & current status - a lightning overview



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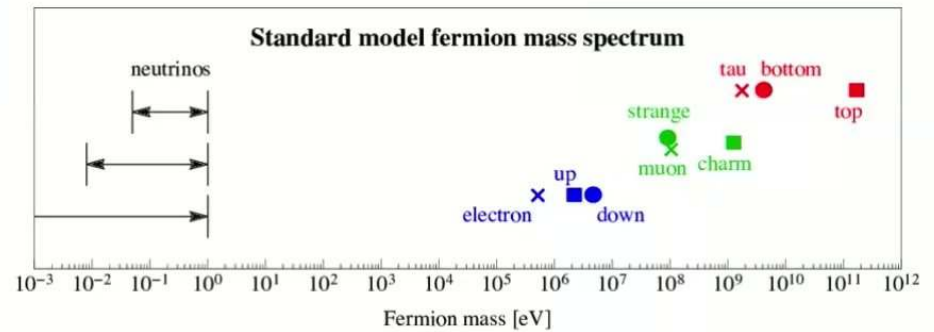
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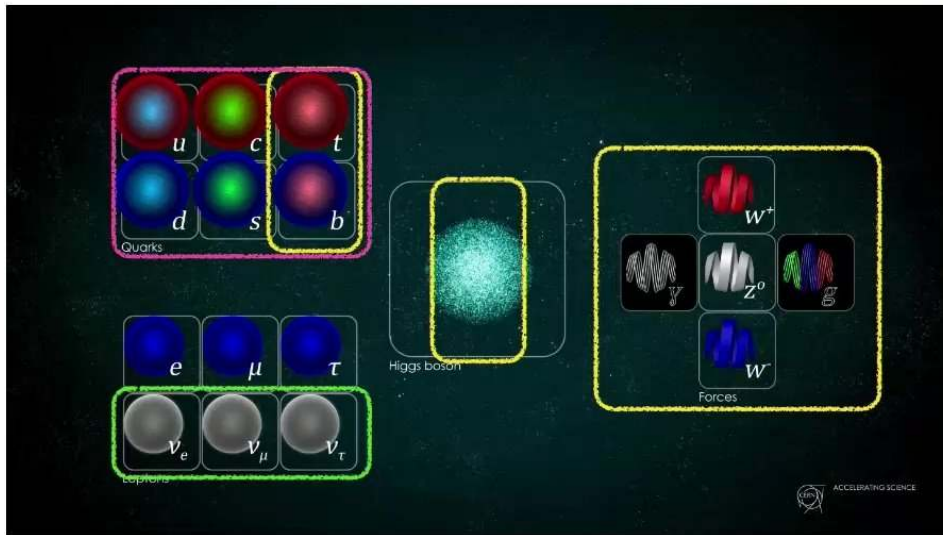
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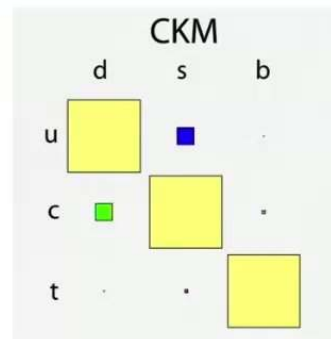
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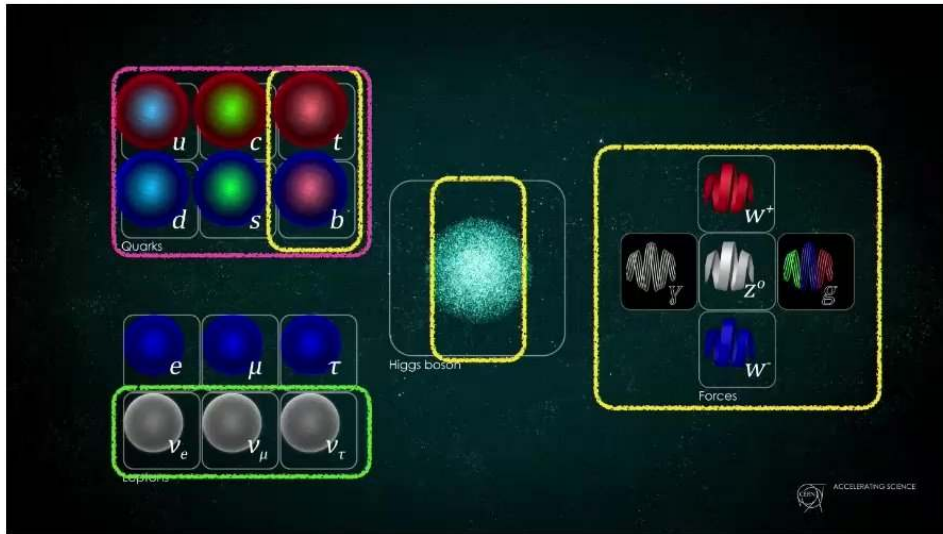
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**Result 3:**  
mixing matrices

[Alkofer, AE, Held, Nieto, Percacci, Schröfl '20; AE, Gyftopolous, Held '25]



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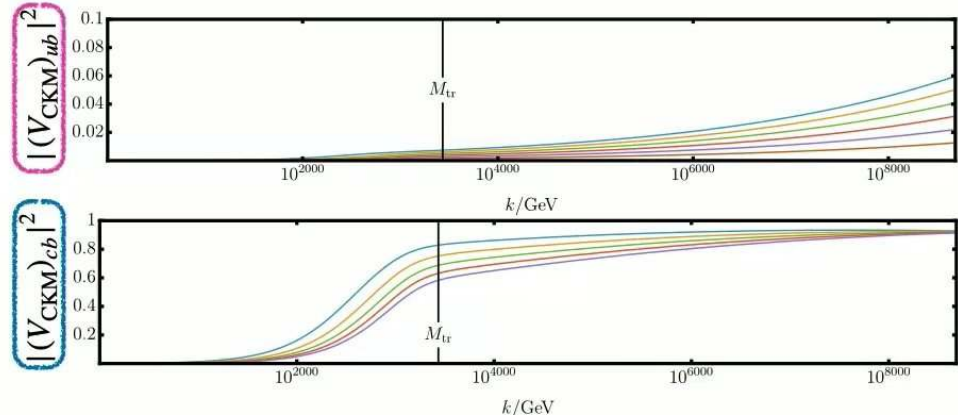
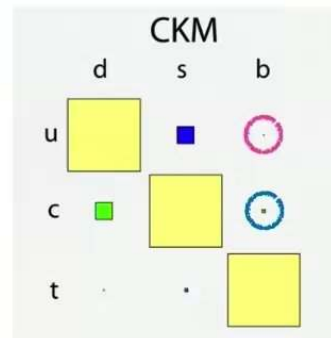
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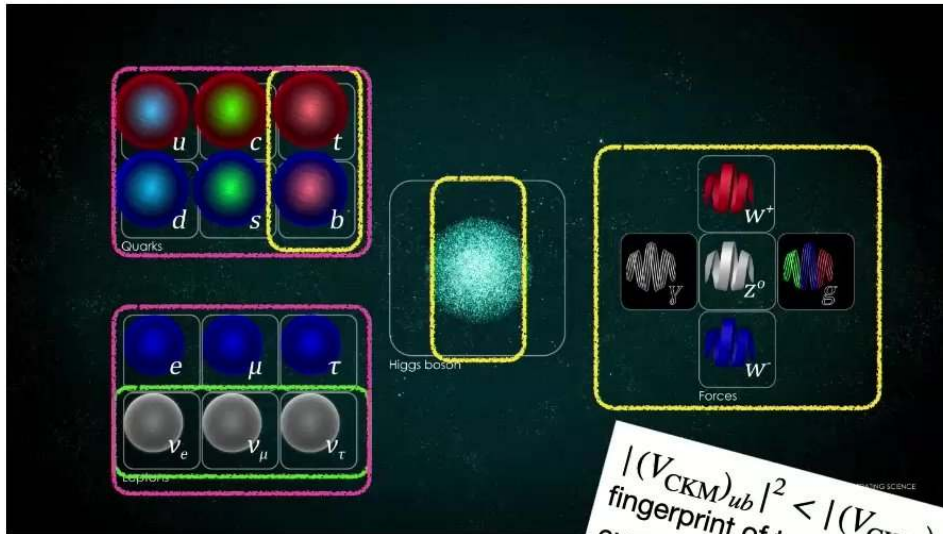
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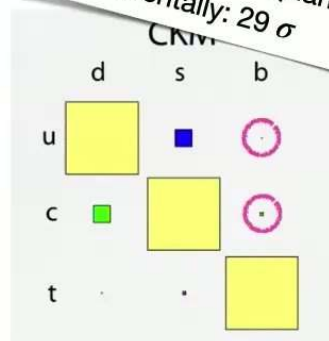
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fingerprint of transplanckian physics,  
experimentally:  $29 \sigma$

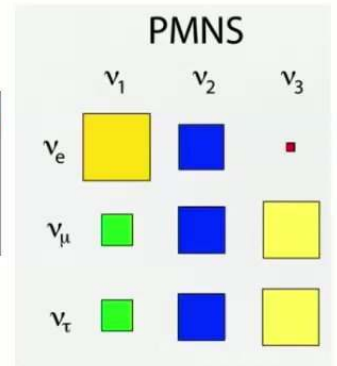
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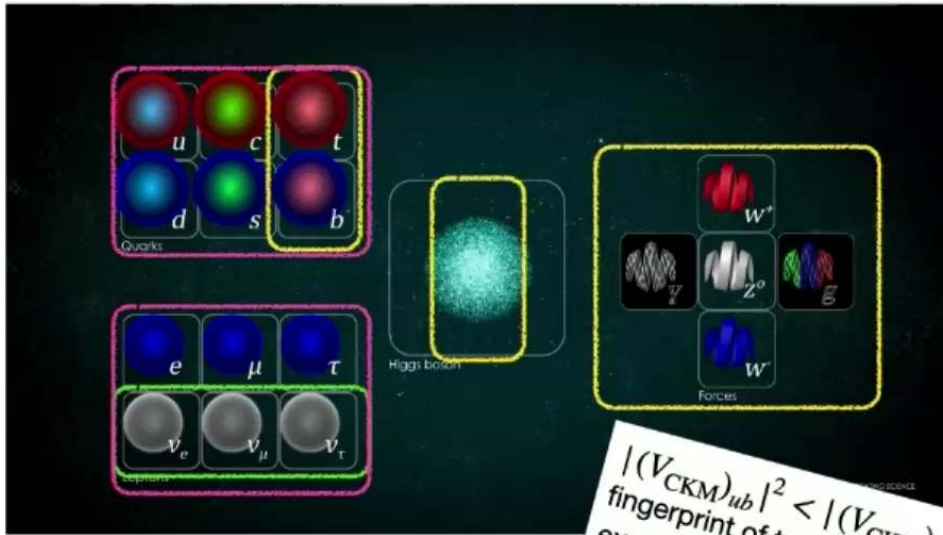
**near-diagonal structure of CKM**  
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**near-diagonal structure of PMNS**  
**would emerge**  
**if neutrinos were heavy.**



# “Matter matters”: key developments & current status - a lightning overview



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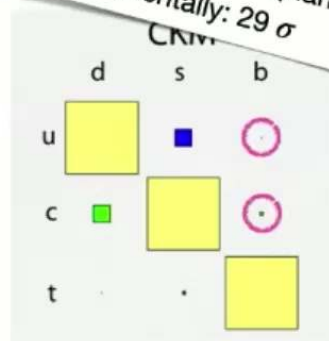
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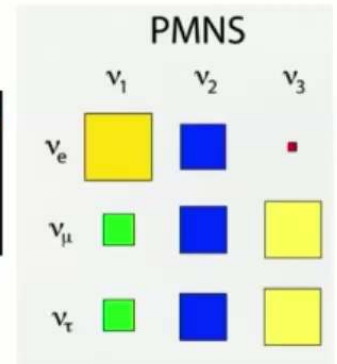
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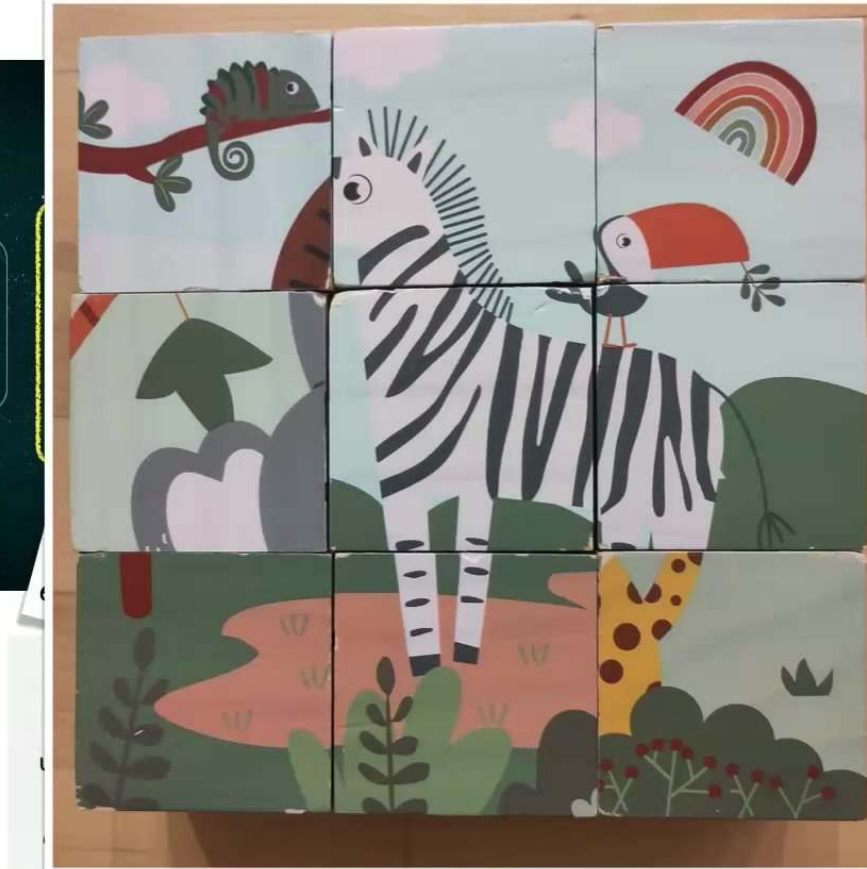
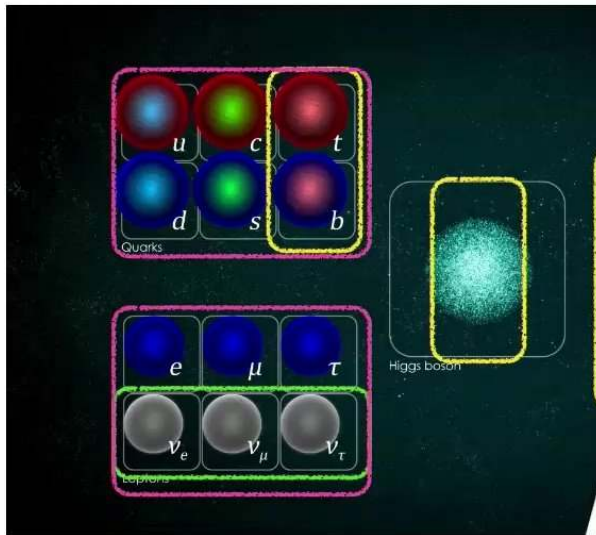
**near-diagonal structure of CKM is emergent because of result 1**



**near-diagonal structure of PMNS would emerge if neutrinos were heavy. Prevented by result 2.**



# “Matter matters”: key developments & current status - a lightning o



st, Reuter '11  
Held '17, '18

ed  
from above

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Higgs  
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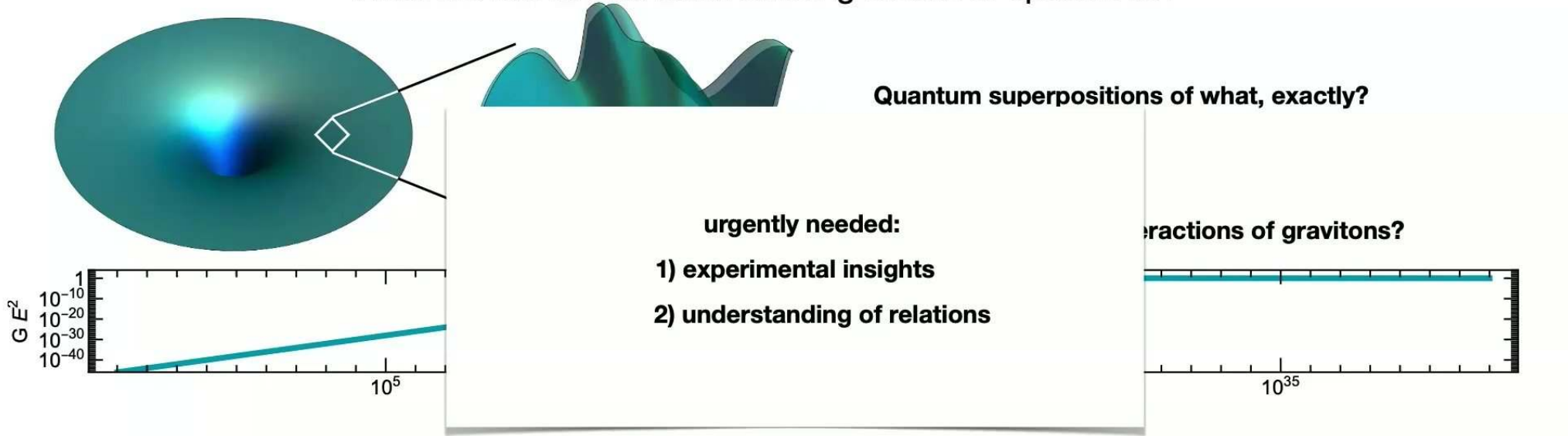
structure of PMNS

heavy.  
2.

PMNS

	$\nu_1$	$\nu_2$	$\nu_3$
$\nu_e$	Yellow	Blue	Red
$\nu_\mu$	Green	Blue	Yellow
$\nu_\tau$	Green	Blue	Yellow

# What are the fundamental building blocks of spacetime?

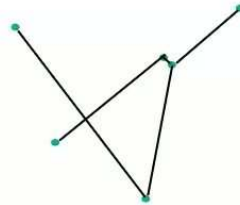


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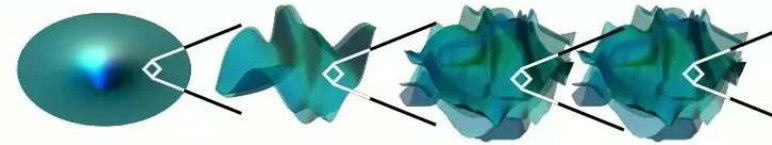
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## Breaking down barriers between approaches: building a community



PI PERIMETER INSTITUTE

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### Renormalization Group Approaches to Quantum Gravity

Home / Events / renormalization group approaches quantum gravity

PIRSA ID: C14020

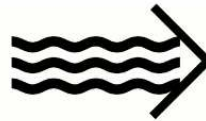
Event Type: Conference

Scientific Area(s): Quantum Gravity

End date: 2014-04-25

**Scientific Organizers:**

Bianca Dittrich, Perimeter Institute  
Astrid Eichhorn, Perimeter Institute  
Daniele Oriti, Albert Einstein Institute  
Roberto Percacci, SISSA



### Workshop series

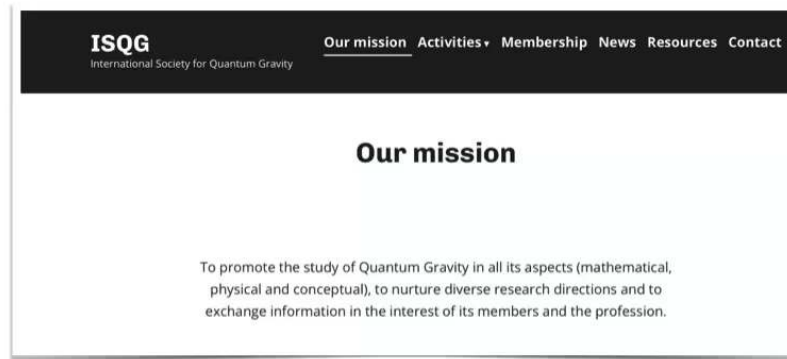
**“Quantum spacetime and the Renormalization Group”**  
with Dario Benedetti & Frank Saueressig & Alessia Platania

- Nordita, Sweden 2015
- Lorentz Center, The Netherlands, 2017
- Bad Honnef, Germany, 2018 \*
- Denmark/online, 2020
- Sardinia, Italy, 2023
- Heidelberg, Germany, 2025

\* first discussions about an “International society of quantum gravity”

... several years later:

(chairs:  
Bianca Dittrich,  
Daniele Oriti)



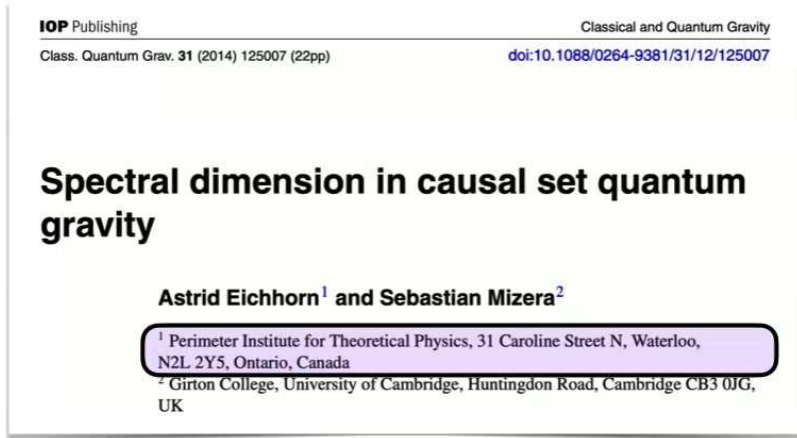
ISQG  
International Society for Quantum Gravity

[Our mission](#) [Activities](#) [Membership](#) [News](#) [Resources](#) [Contact](#)

### Our mission

To promote the study of Quantum Gravity in all its aspects (mathematical, physical and conceptual), to nurture diverse research directions and to exchange information in the interest of its members and the profession.

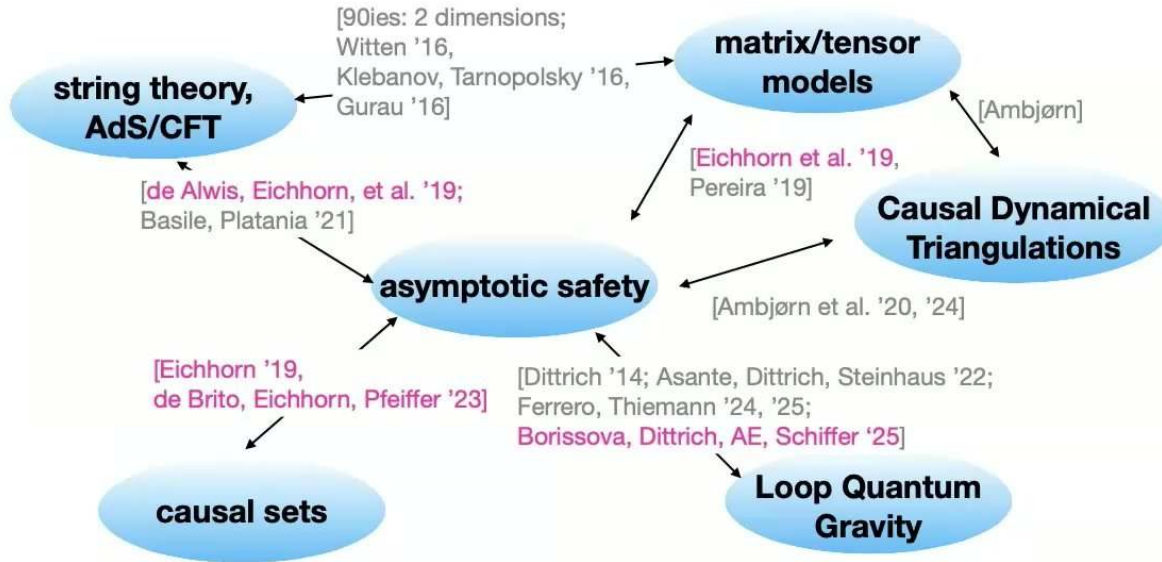
## Breaking down barriers between approaches: first steps



*Acknowledgments:* We thank Fay Dowker, Joe Henson, Rafael Sorkin and Sumati Surya for helpful discussions. We would like to express our thanks to Sumati Surya for a careful reading of this manuscript and for providing helpful comments. (S. M. thanks Perimeter Institute for hospitality during this work) and Girton College, Cambridge for support. This research was supported in part by Perimeter Institute for Theoretical Physics. Research at Perimeter Institute is supported by the Government of Canada through Industry Canada and by the Province of Ontario through the Ministry of Research and Innovation.

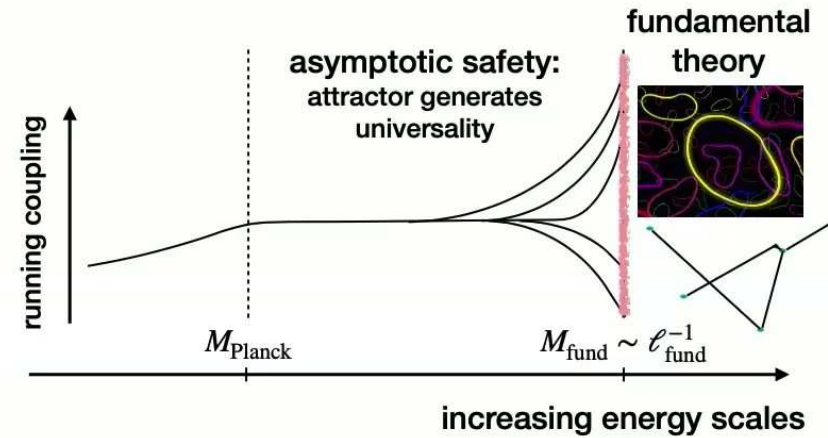


## Breaking down barriers between approaches: next steps



## Example: asymptotic safety as a universal regime

[de Alwis, Eichhorn, Held, Pawłowski, Schiffer, Versteegen '19]

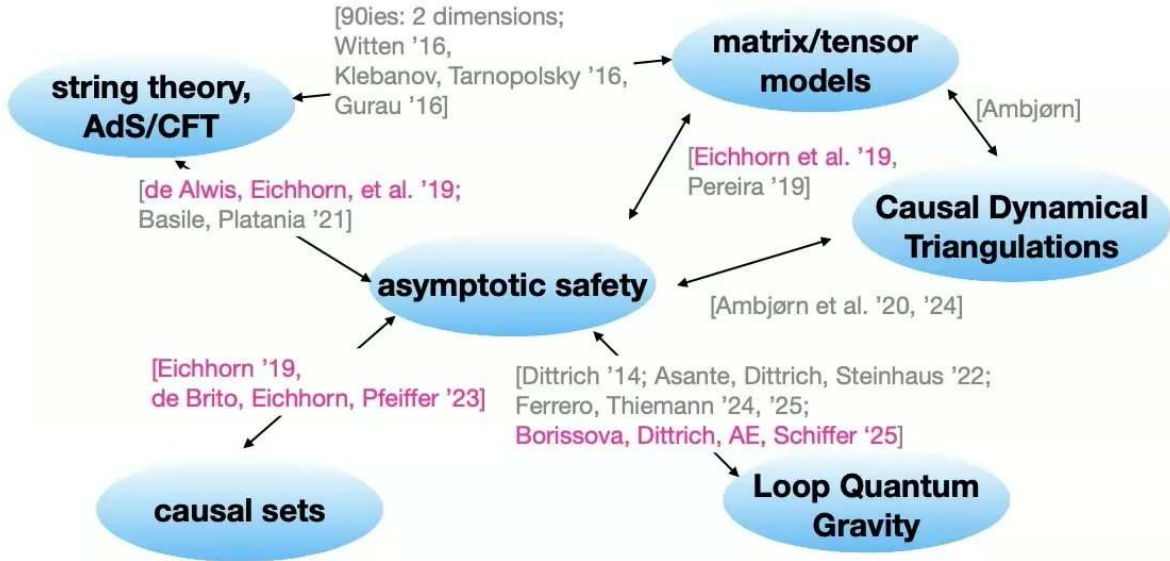


### Frontiers of Quantum Gravity: shared challenges, converging directions<sup>1</sup>

Jan de Boer<sup>a</sup> Bianca Dittrich<sup>b</sup> Astrid Eichhorn<sup>c</sup> Steven B. Giddings<sup>d</sup> Steffen Gielen<sup>e</sup>  
Stefano Liberati<sup>f</sup> Etera R. Livine<sup>g</sup> Daniele Oriti<sup>h</sup> Kyriakos Papadodimas<sup>i</sup> Antonio D.  
Pereira<sup>j</sup> Mairi Sakellariadou<sup>k</sup> Sumati Surya<sup>l</sup> Herman L. Verlinde<sup>m</sup>

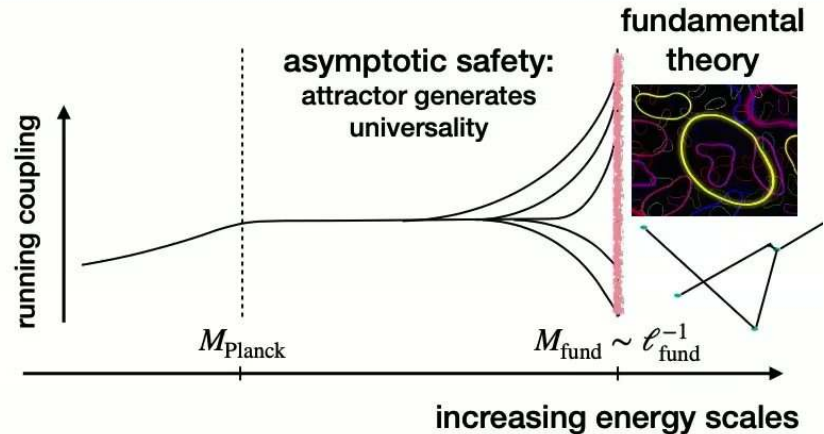


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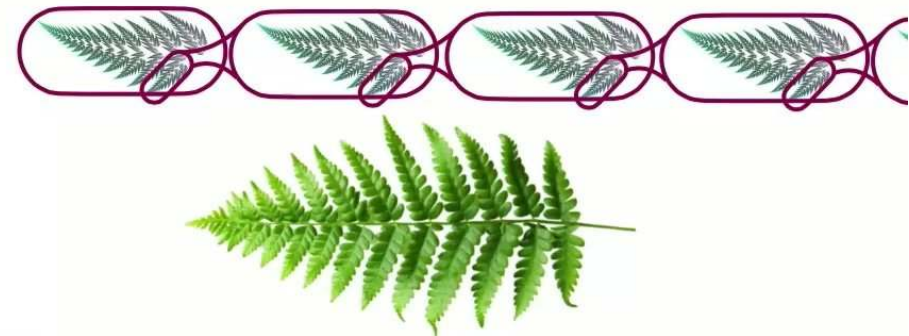


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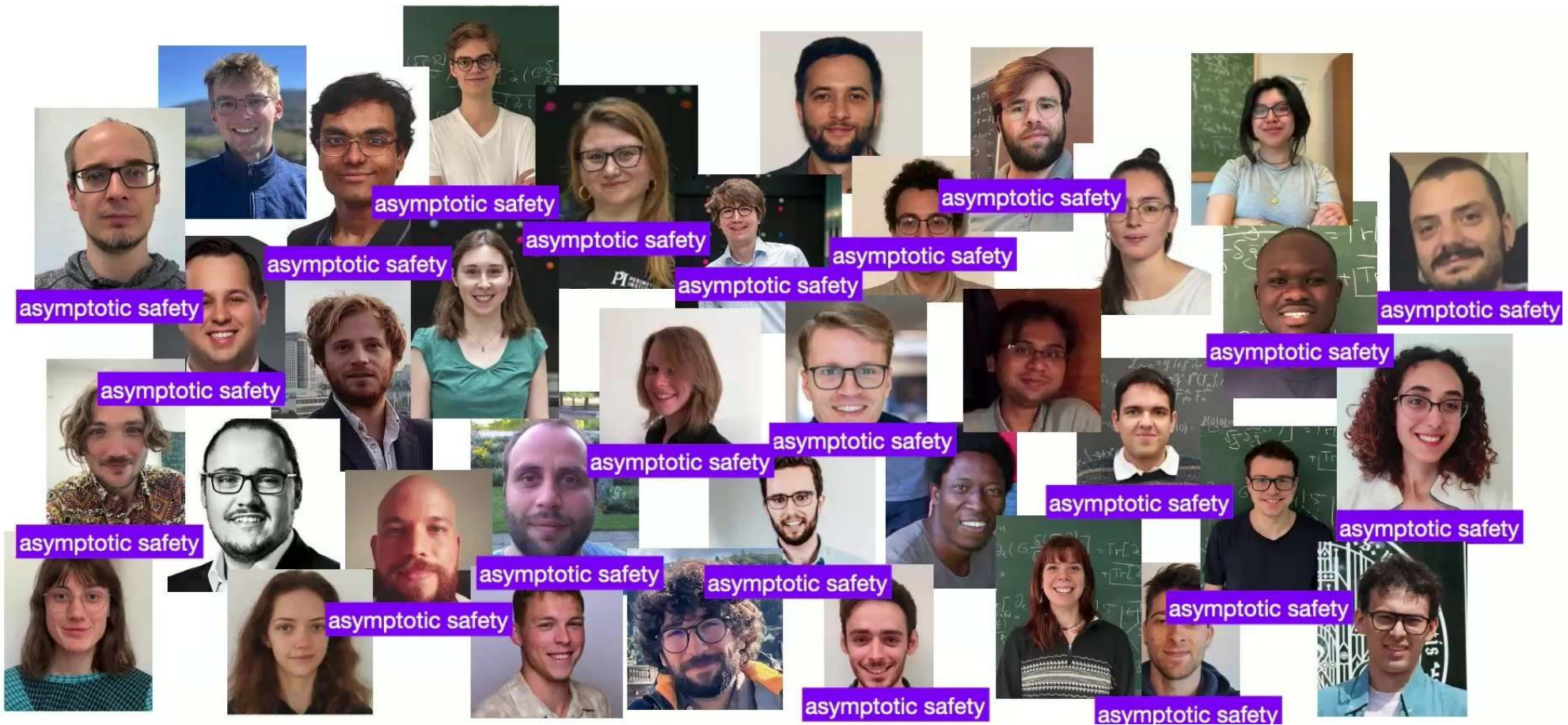
Analogy: approximate scale symmetry in Nature:



Frontiers of Quantum Gravity: shared challenges, converging directions<sup>1</sup>

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# A new generation that is fluent in several approaches



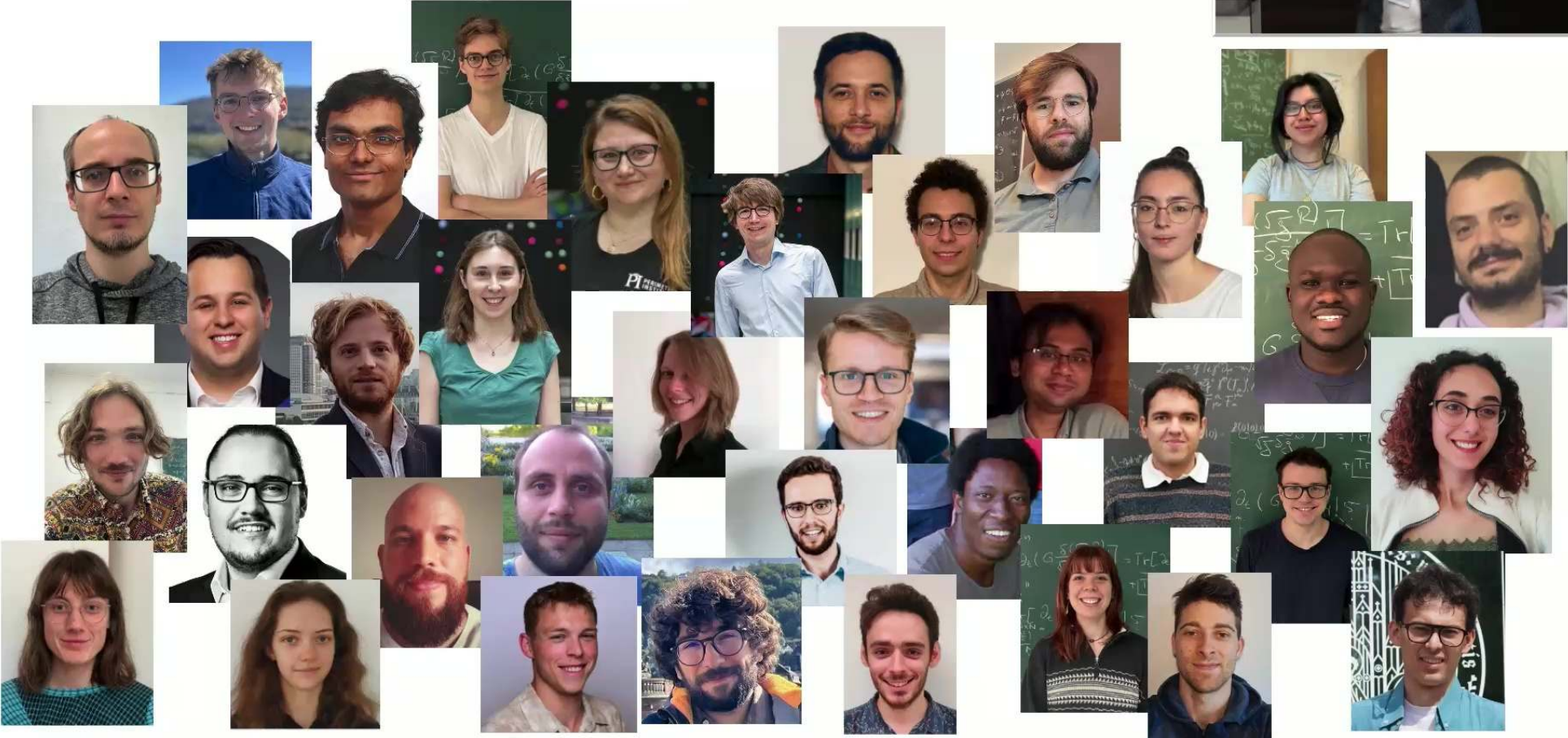


# Mentorship: my personal take

Trust

Challenge

Safe space



Thanks to...

Former & current research team members for their enthusiasm, work and dedication!



Perimeter Institute for supporting my journey and making each time I visit an inspiring and stimulating time!

you for your attention!

