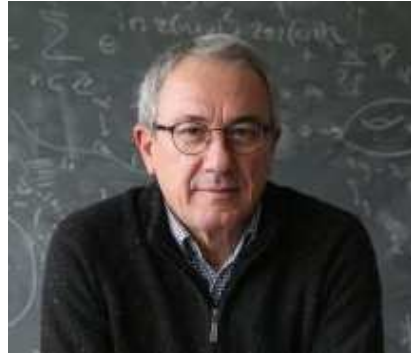


# QFT and Strings

Kyriakos Papadodimas  
CERN Theory Retreat  
Les Houches 2015

# Staff



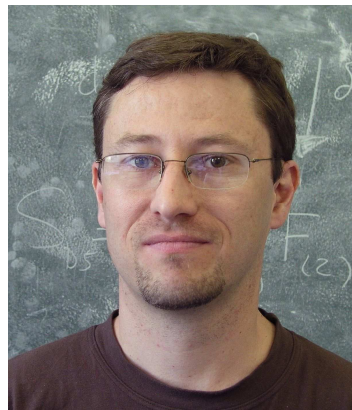
Luis Alvarez-Gaume



Wolfgang Lerche



Kyriakos Papadodimas



Boris Pioline



Slava Rychkov

# New Fellows



Borun Chowdhury



Daniel Krefl



Ricardo Monteiro

# Fellows



Ioannis Florakis



Dennis Klevers



Noppadol Mekareeya



Miguel Paulos



Marine Samsonyan



Alessandro Vichi

# Joao Penedones

visiting TH until Jan 2016



AdS/CFT, conformal bootstrap, ...

## **Group activities**

Journal club: Monday 2pm

String/QFT Seminar: Tuesday 2pm

Winter school on String theory and QFT: 1st week of February

TH-institutes:

M-theory and string theory, February 2016

Emergence Institute, Summer 2016 (together with COS, LAT)

What is “formal theory”?

**QFT** (at strong coupling)

QCD, BSM physics?, condensed matter

**Quantum Gravity**

physics at Planck scale, black holes, cosmology



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fundamental principles, mathematical physics, string phenomenology

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**AdS/CFT**: QFT  $\Leftrightarrow$  gravity

# Developments and challenges

(a personal selection)

# CFTs, conformal bootstrap

$$\sum_k \text{[Cross diagram]} = \sum_k \text{[Wavy diagram]}$$

Non-perturbative constraints for CFTs  
(spectrum/correlators) — (in various dimensions, SUSY or not, etc.)

Numerical results for specific CFTs (3d Ising model, ...)

Lorentzian OPE

Bootstrap and emergence of bulk in AdS/CFT, consistency of CFTs and AdS-gravity

# SUSY QFT

Supersymmetric localization

$$\int [dA_\mu] e^{-S[A_\mu]} \Rightarrow \int [d\lambda] e^{-S_{\text{BPS}}[\lambda]}$$

**Exact** computation of observables (all orders in perturbation theory + instanton corrections)

Partition function, correlation functions, superconformal indices

Window to non-perturbative physics, dualities between QFTs

Families of 3d/4d SCFTs, geometry of conformal manifolds

## Other QFT developments

**Integrability** spectrum of planar  $\mathcal{N} = 4$  SYM  
correlators using integrability

IIB AdS string dual of planar  $\mathcal{N} = 4$  ?

## Amplitudes

# String theory fundamentals

Dualities, non-perturbative physics

Topological strings

Higher loop computations in string perturbation theory

Counting of BPS black hole microstates, wall crossing

# **String phenomenology**

compactifications of string theory, phenomenology

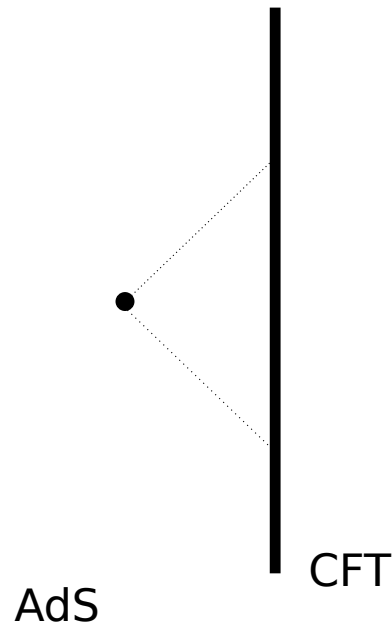
F-theory, non-perturbative IIB string theory and geometry

SUSY breaking, inflation in string theory, de Sitter vacua

Consistency of KKLT and string landscape



# Gravity and Quantum Mechanics



AdS/CFT: spacetime (and gravity) are emergent

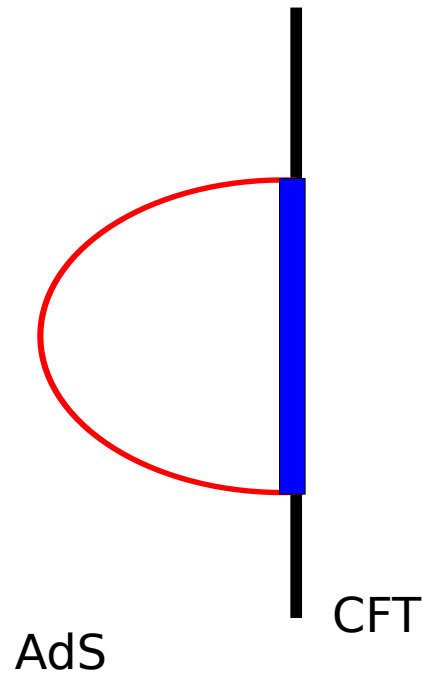
Locality is approximate (BHs, cosmology)

How exactly do we understand emergence of bulk from boundary? New tools: entanglement, quantum information

# Entanglement and spacetime

Ryu Takayanagi

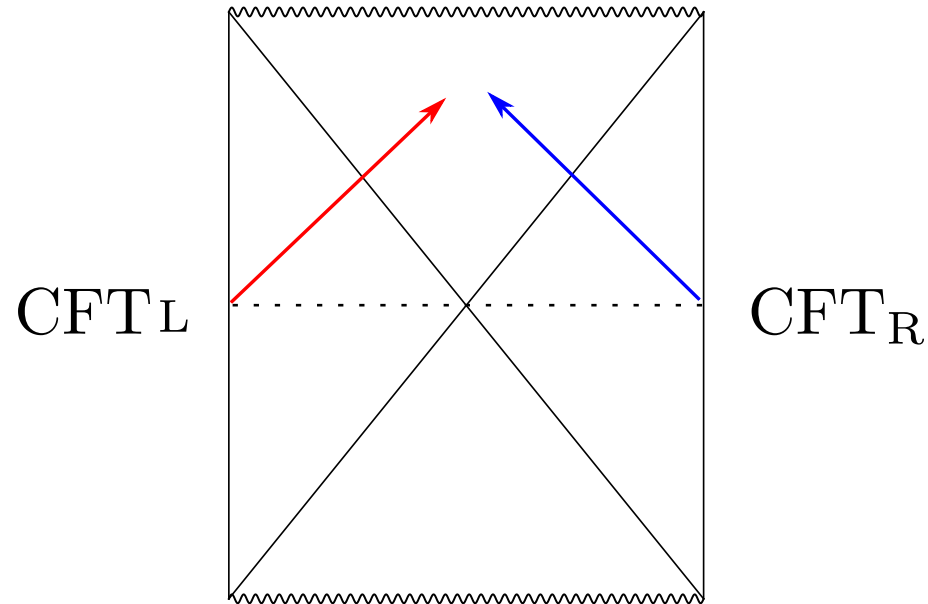
$$S = A/4G$$



$$S = -\text{Tr}(\rho \log \rho).$$

Consider  $\rho \rightarrow \rho + \delta\rho \Rightarrow \delta S = \delta E \Rightarrow$  Einstein equations

**ER=EPR**



Entanglement = Wormhole

$$H = H_L + H_R$$

$$|\Psi\rangle = \sum_E \frac{e^{-\frac{\beta E}{2}}}{\sqrt{Z}} |E\rangle_L \otimes |E\rangle_R$$

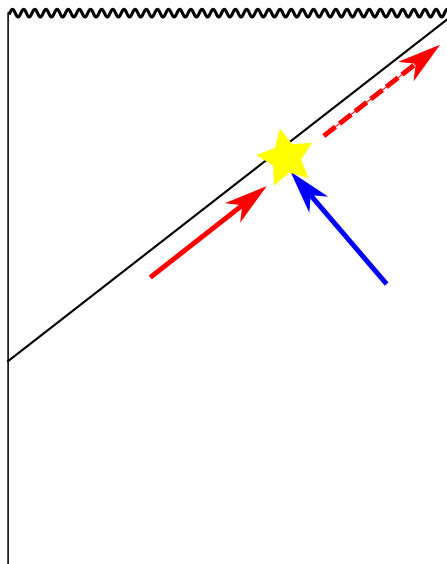
## Dynamics and thermalization

Quark Gluon Plasma  $\Leftrightarrow$  Black Hole

Hydrodynamics of QGP, transport coefficients

Time dependent collapse, AdS instabilities

**Quantum Chaos:** transplanckian collisions near horizon  $\Rightarrow$   
Lyapunov exponent for plasma



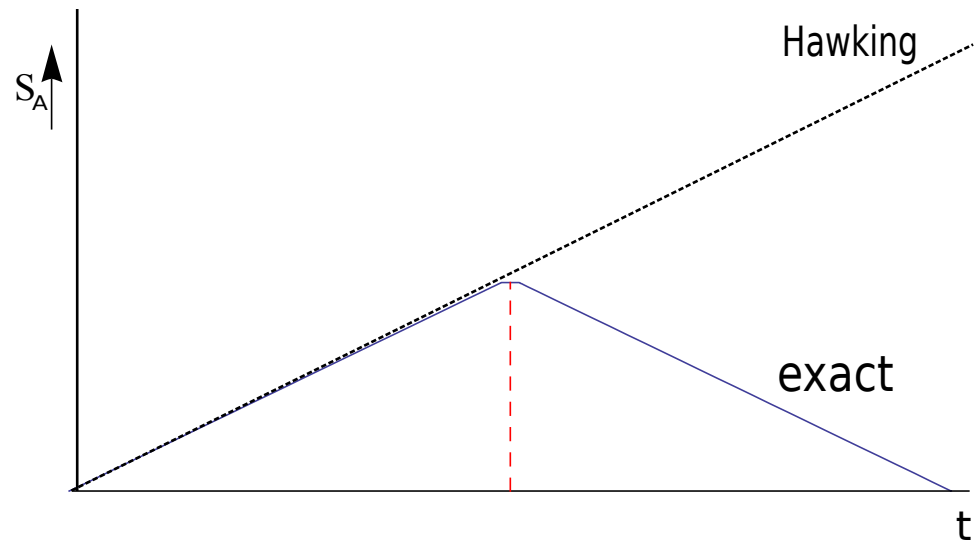
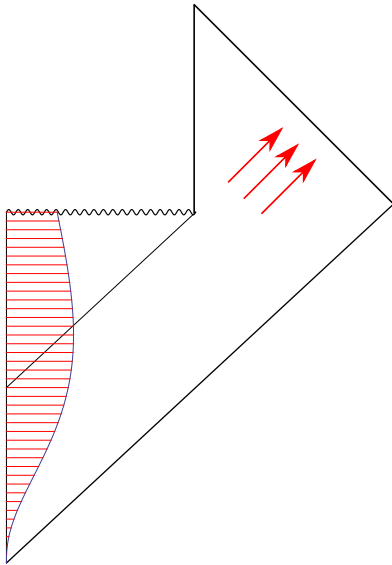
## **What I am thinking about:**

Quantum aspects of Black Holes

Holography (emergence of locality in AdS/CFT, flat/dS holography)

Aspects of non-perturbative QFT (SUSY, CFTs)

# Black hole info paradox

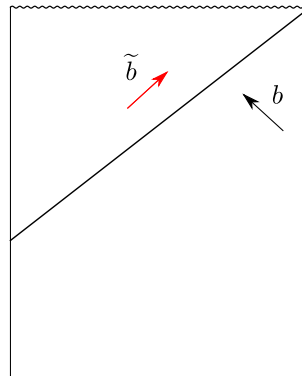


Firewall/fuzzball: Unitarity inconsistent (?) with smooth interior.

Is there spacetime behind the horizon?

## Black hole interior in AdS/CFT

Concrete proposal on how to reconstruct the black hole interior in AdS/CFT.



Towards a resolution of firewall/info paradox, in progress...

Relevance of BH interior for thermalization?

Probing the black hole singularity

Thank you