

Frontiers of Theoretical Physics

Lecturers:

David Mateos (coordinator) and Joan Solà

Frontiers of theoretical physics

- Renormalization group.
- Introduction to supersymmetry.
- Gauge/string correspondence.



Part I:
David Mateos

- Grand unified theories.
- Phenomenology of supersymmetric theories.
- Open problems in cosmology.



Part II:
Joan Solà

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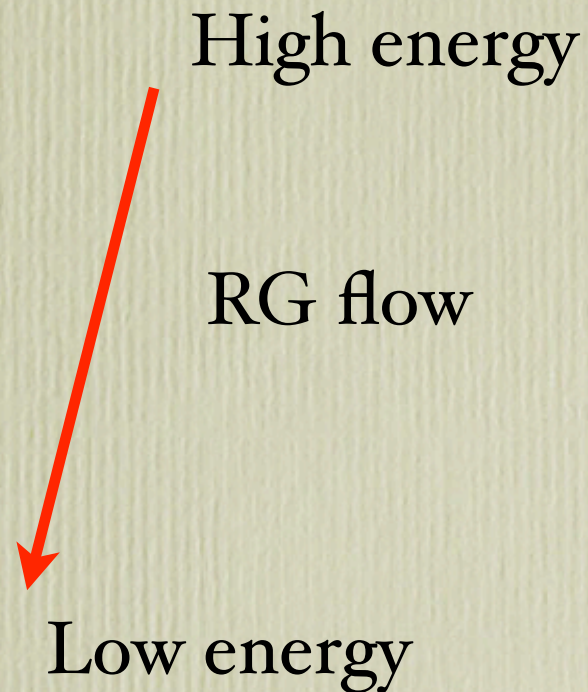
Recommended background:

- ▶ Basic GR and QFT.
- ▶ Elementary Particles
- ▶ Standard Model (simultaneous)

Renormalization group

David Mateos

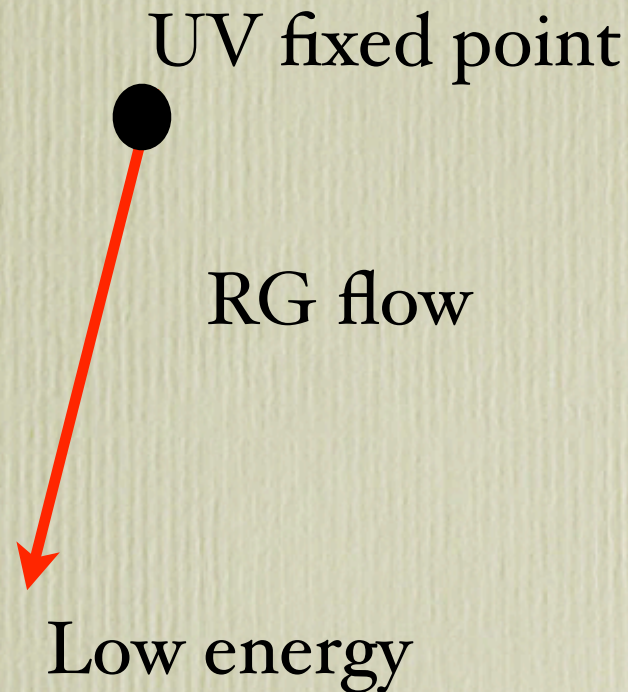
- Physics is organized by scales:



Renormalization group

David Mateos

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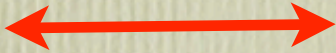


- Modern definition of QFT.

Introduction to supersymmetry

David Mateos

- Fundamental symmetry:

Bosons  Fermions

- Essential ingredient in e.g. string theory.

Phenomenology of supersymmetric theories

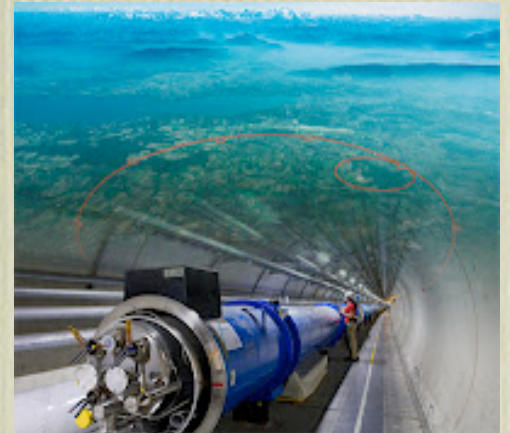
Joan Solà

- Supersymmetry is a nice theory, but how do we “see” it?

Phenomenology of supersymmetric theories

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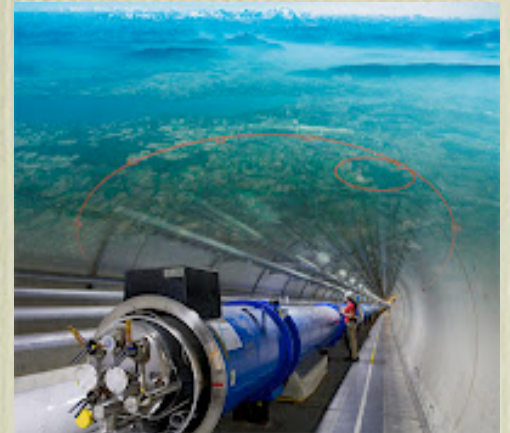
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- Supersymmetry predicts new particles!
 - ▶ Direct SUSY signals: Find new particles.



Phenomenology of supersymmetric theories

Joan Solà

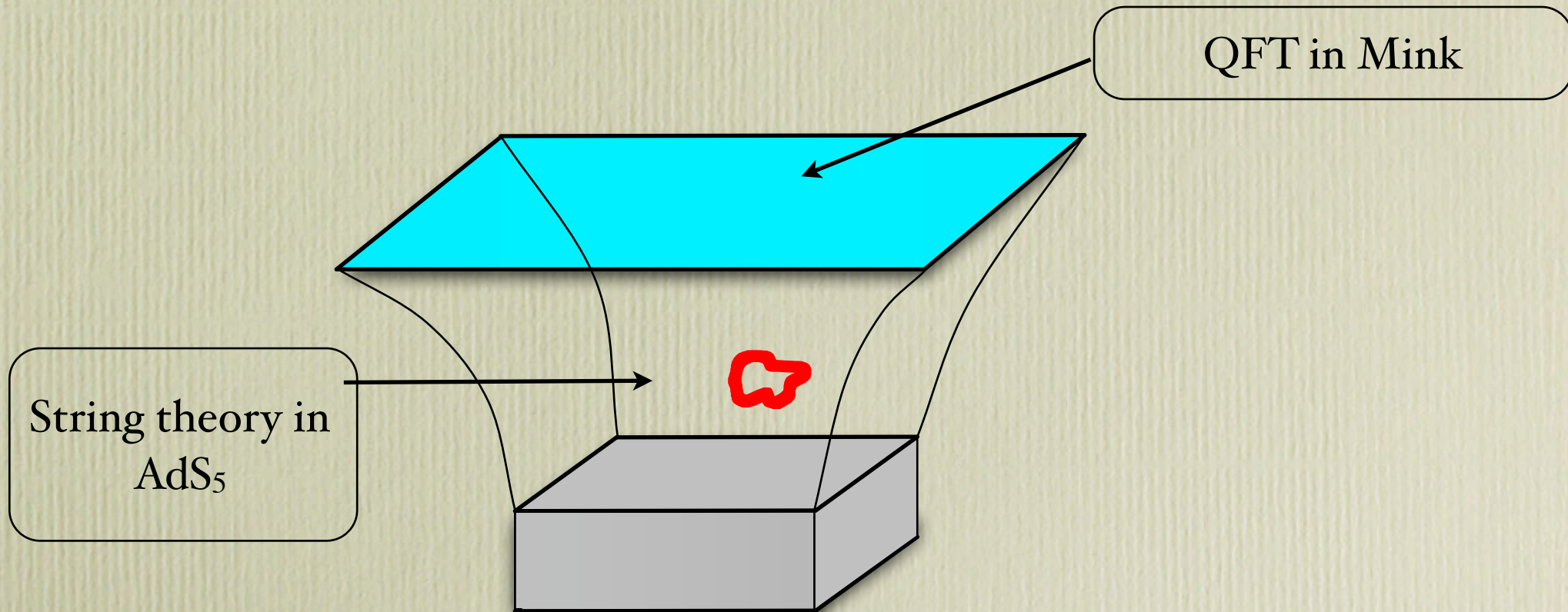
- Supersymmetry is a nice theory, but how do we “see” it?
- Supersymmetry predicts new particles!
 - ▶ Direct SUSY signals: Find new particles.
 - ▶ Indirect SUSY signals: quantum effects to precision physics.



Gauge/gravity correspondence

David Mateos

- Profound equivalence.
- Best definition of Quantum Gravity:



Grand unified theories

Joan Solà

- Standard Model has 3 independent interactions (couplings).
- Is it possible to unify some (or all) the couplings?

Grand unified theories

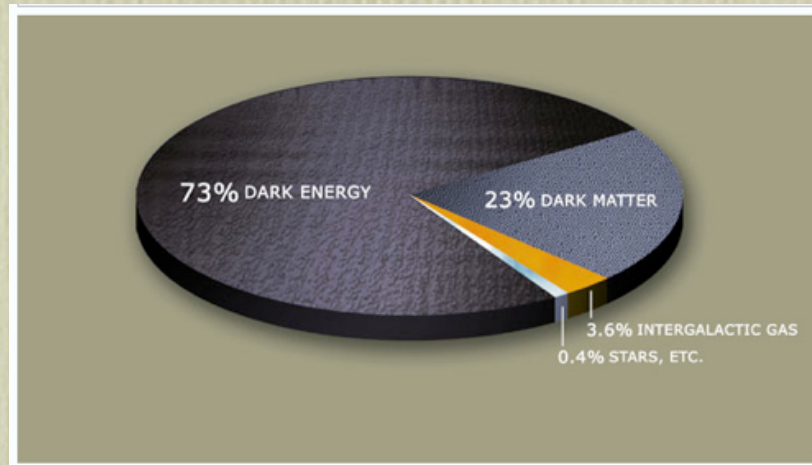
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- Standard Model has 3 independent interactions (couplings).
- Is it possible to unify some (or all) the couplings?
- Example:
 - ▶ Electricity: $\frac{1}{4\pi\epsilon_0}$
 - ▶ Magnetism: $\frac{\mu_0}{4\pi}$
 - ▶ Maxwell's Electromagnetism: $\mu_0\epsilon_0 = \frac{1}{c^2}$

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- Unification conditions for SM group.
- New physical phenomena: proton decay.
- Unification conditions in SUSY models.

Open problems in cosmology

Joan Solà



- Cosmological constant and dark energy: beyond the standard Λ CDM model.
- Current weaknesses and tensions of the standard Λ CDM model.
- Dynamical vacuum energy models.
- Quintessence and phantom dynamical dark energy.
- Dark matter and WIMPs: candidates and thermal history in the early universe.
- Vacuum energy in QFT, formal aspects.

Practical details

- **Language:** English.
- **Schedule:** Mon-Thu from 11:40 to 12:40, room V12M.
- **Duration (approximately):** 12 weeks from Feb 13 to May 18.
- **Distribution:** 6 weeks for each part
- **Evaluation:**
 - ▶ Exercise sheets and/or final interview and/or final exam.
Sheets must be handed in on time or they will NOT be accepted!
 - ▶ Must pass each part separately.
 - ▶ If so then the final grade is the average.
- **Re-evaluation:** In September with similar rules.
- **Bibliography and detailed syllabus:** Each lecturer will tell you.

Questions welcome!