KIT Mastermesse 2022

Felix Kahlhoefer
Institute for Theoretical Particle Physics (TTP)
Karlsruhe Institute of Technology

Quick introduction

Junior professor at KIT since April 2022

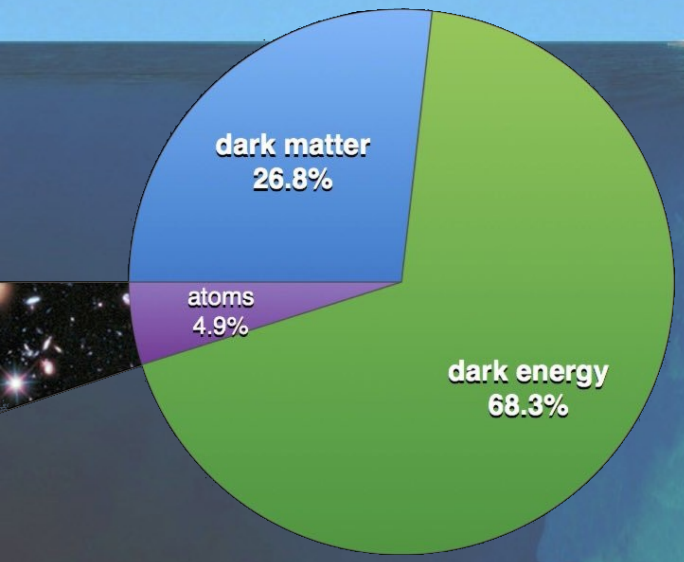
Emmy Noether Junior Research Group “Analysis Tools for the Dark Matter Interpretation of Recent Experiments and Cosmological Observations (ADMIRE & CO)”

Postdocs: Tomas Gonzalo, Alessandro Morandini

PhD students: Nicoline Hemme, Sowmiya Balan

Looking to recruit up to two master students to start in July or October

Research topics

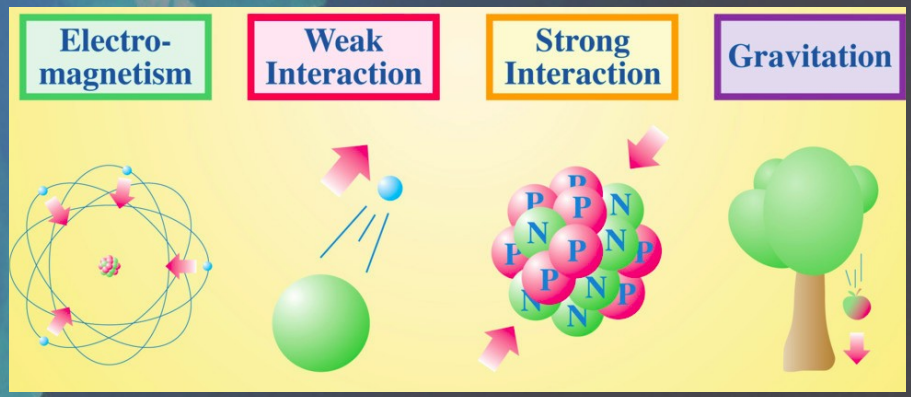


What is the nature of dark matter?

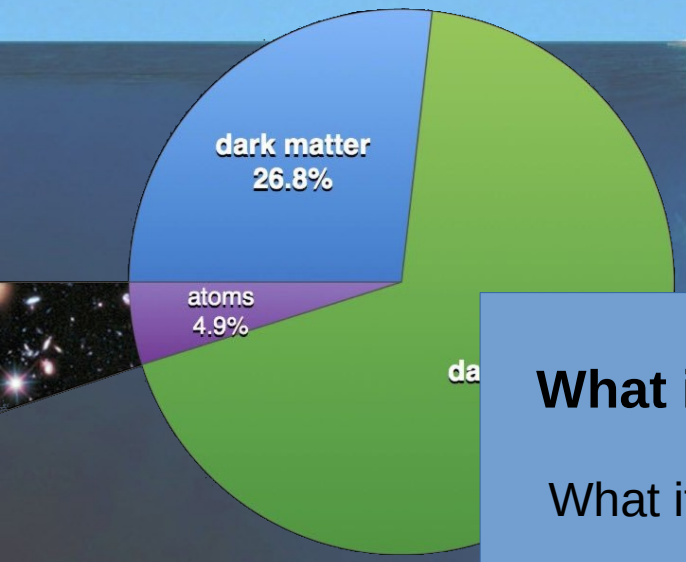
- **What we know:** dark matter exists and constitutes the dominant form of matter in the Universe
- **What we don't know:** any of its properties

Are there more than four fundamental forces in nature?

- **What we know:** if there exist any undiscovered forces, they must be short-range and extremely weak
- **What we don't know:** what kind of exchange particle can give rise to such a force?



Research topics



What is the nature of dark matter?

- **What we know:** dark matter exists and constitutes

What if these two questions are connected?

What if dark matter interacts via an unknown force?

Many exciting predictions:

Exotic resonances and long-lived particles at colliders

Observable deviations in precision measurements

Signatures of dark matter interactions in cosmology

Are there ture?

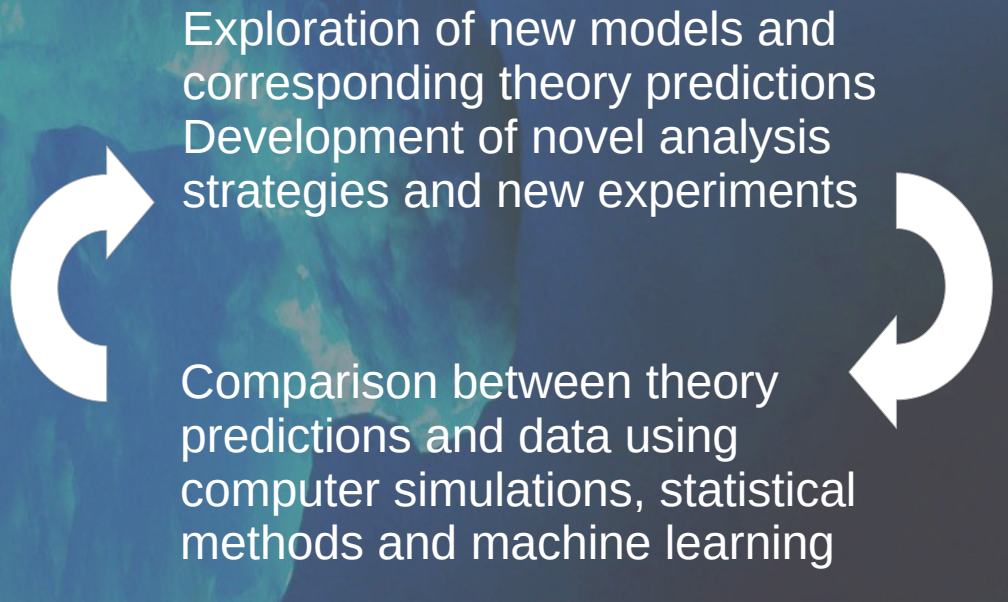
- **What we k** undiscover range and

- **What we don't know:** what kind of exchange particle can give rise to such a force?

Research methods

To discover dark matter and new fundamental forces requires input from many different fields

- Theoretical particle physics
- Experimental particle physics
- Cosmology
- Astrophysics



Exploration of new models and corresponding theory predictions
Development of novel analysis strategies and new experiments

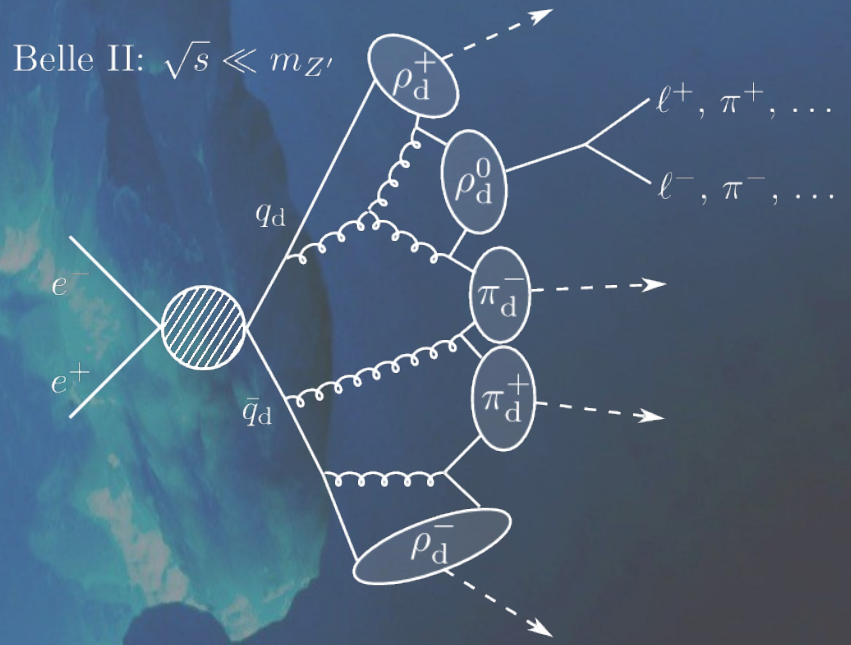
Comparison between theory predictions and data using computer simulations, statistical methods and machine learning

Example topic 1:
Solving the inverse problem with machine learning

Dark matter models with new mediators predict many exciting signatures at accelerators

But how do we reconstruct the properties of dark matter once a signal has been observed?

Promising approach: Modern machine-learning techniques (e.g. likelihood-free inference)



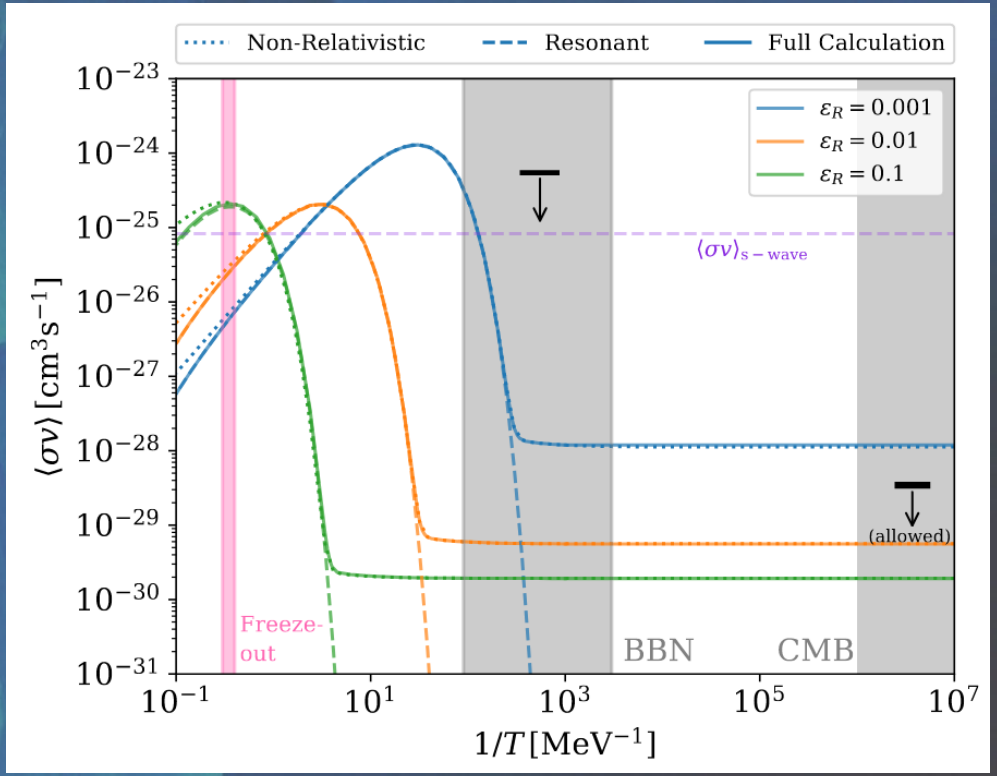
Example topic 2:
Cosmological constraints on sub-GeV dark matter

Much effort has gone into the search for dark matter at the GeV-TeV scale

New frontier: Search for lighter dark matter particles

Not only laboratory constraints matter, essential to understand also cosmological constraints

- Cosmic Microwave Background
- Big Bang Nucleosynthesis
- Structure formation



Need to develop new analysis strategies in order to identify viable models