Theory: Dark matter, gravitational physics and astro-physical phenomena

Austrian Landscape

likely incomplete list

TH groups working on Dark Matter (topical focus)

- Suchita Kulkarni (University of Graz) (pheno of strongly interacting DM)
- Axel Maas (University of Graz) (strongly interacting DM on lattice)
- Josef Pradler (HEPHY & University of Vienna) (DM pheno, cosmo)

TH groups working on gravitational physics

- Stefan Fredenhagen (University of Vienna) (string theory)
- Daniel Grumiller (TU Wien) (gauge gravity duality)
- Axel Maas (University of Graz) (quantum gravity sims)
- Anton Rebhan (TU Wien) (QFT, gauge theories)

TH groups working on astrophysical phenomena

- Oliver Hahn (University of Vienna) (cosmology, numerical sims)
- Simon Plätzer (University of Graz) (event generators for astro)
- Anita Reimer (University of Innsbruck) (cosmic rays)

Astrophysics (cosmic rays)

Current / Long-term goals / Future facilities

Feedback received: not suitable to be steered by EPPSU

=> concerning strategic questions: own Astroparticle Physics panels

=> highly interested in collaborations with particle physics groups on overlapping/ interdisciplinary topics

Astroparticle Physics Roadmap

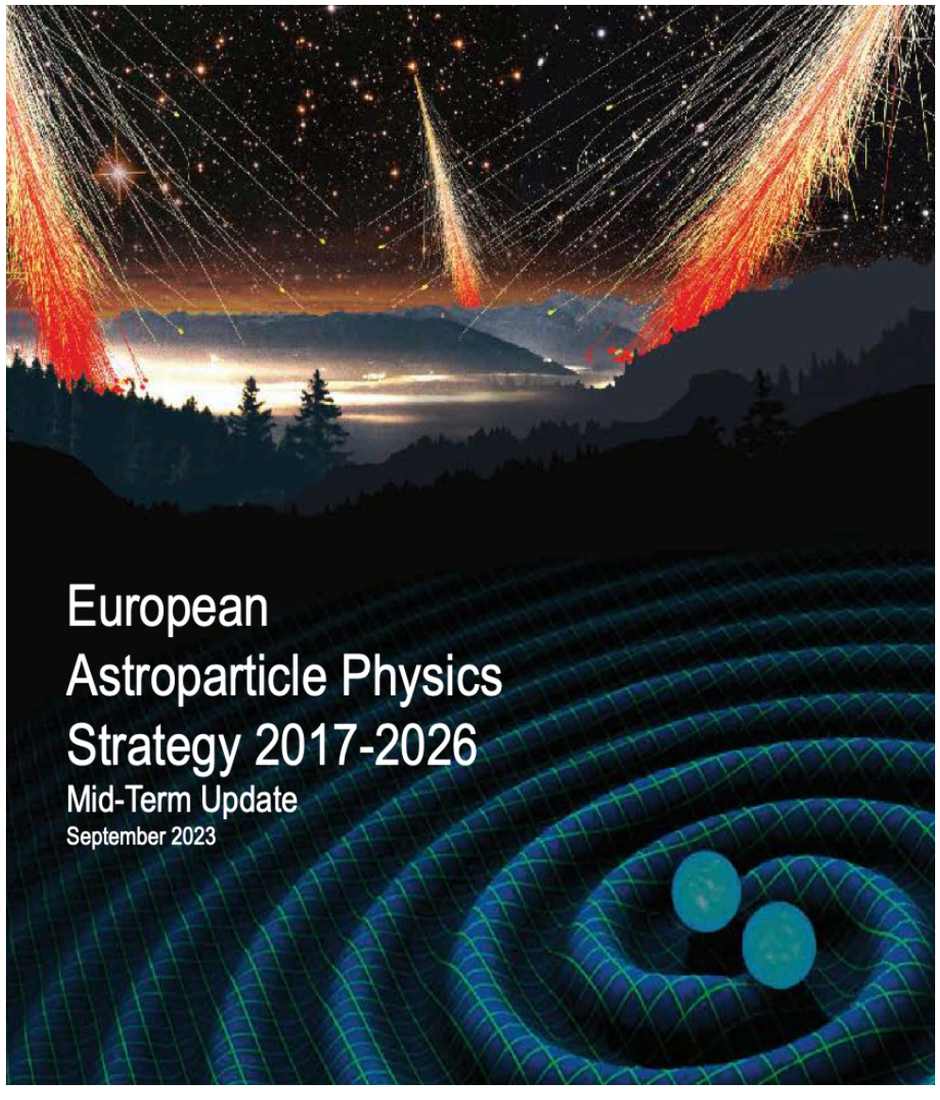
Astroparticle Physics European Consortium (APPEC)

overlaps may exist

Austria is a consortium member

=> releases European Strategy on
Astroparticle Physics

=> see Indico attachements



Specifically for theory (since 2020)

European Consortium for Astroparticle Theory (EuCAPT): hub to increase the exchange of ideas and knowledge and to coordinate scientific and training activies in the field of astroparticle physics theory.

https://www.eucapt.org/

(HEPHY and University of Vienna are members)

Gravitational physics (Grumiller/Fredenhagen/Rebhan)

Gauge/gravity duality and applications thereof

- Gauge/gravity duality string theory, black holes, non-perturbative QFT, spacetime and asymptotic symmetries, anomalies, ...

  groups by Fredenhagen (U Vienna), Grumiller, Rebhan (TU Wien), possibly future professor as of 2025 (TU Wien) [open call June-September 2024]

relevant future experimental data:

- heavy ion collisions at low, intermediate, and high energies
- gravitational wave experiments resolving memory effects
- gravitational wave experiments resolving primordial gravitational waves
- gravitational wave experiments resolving black hole finestructure
- multi-messenger observations of neutron star collisions
- ... in principle, any experiment involving strong interactions

  (QCD processes, strong gravity regime, strongly correlated electron systems, inflation, ...)

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Gauge/gravity duality and applications thereof

- Gauge/gravity duality string theory, black holes, QFT, asymptotic symmetries, anomalies, ...
- Example I: Strong coupling physics QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, holographic superconductors, viscous fluids, ...

recent local example projects:

- Light particles in string and holographic frameworks (2022-2026)
  FWF, 400,000 €, Anastasopoulos
- Generalized SYK/JT correspondence (2021-2025)
  FWF, 360,000 €, Grumiller
- Anomalous interactions of holographic hadrons (2024-2026)
  FWF, 440,000 €, Rebhan

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- Strong coupling physics QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, ...
- Example II: Scattering amplitudes flat space holography, celestial holography, Carroll holography, gravitational waves, memory effects, Mellin amplitudes, ...

recent local example projects:

- Black hole soft hair and celestial holography (2021-2022)
  FWF START, 1,200,000 €, Donnay
- Carrollian physics and holography (2024)
  ESI Programme, 40,000 €, Donnay, Fredenhagen, Grumiller et al.
- Carrollian gravity and black holes (2023-2027)
  FWF, 410,000 €, Grumiller

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- Strong coupling physics QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, ...
- Scattering amplitudes flat space, celestial and Carroll holography, gravity waves, memory effects, ...
- Example III: Quantum information holographic entanglement entropy, chaos bound, holographic complexity, quantum energy conditions, holographic quantum error correction, quantum extremal surfaces, ER=EPR, ...

recent local example projects:

- Quantum physics and gravity (2017)
  ESI Programme, 40,000 €, Aspelmeyer, Brukner, Grumiller et al.
- Quantum energy conditions in two dimensions (2020-2023)
  FWF, 280,000 €, Grumiller
- Entanglement entropy and (non-AdS) holography (2016-2019)
  FWF, 330,000 €, Grumiller

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- Strong coupling physics QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, ...
- Scattering amplitudes flat space, celestial and Carroll holography, gravity waves, memory effects, ...
- Quantum information holographic entanglement entropy, chaos bound, holographic complexity, ...
- Example IV: Quantum gravity AdS/CFT, bulk reconstruction, black hole microstates, information paradox, black hole evaporation, soft hair, singularities, (pre-)thermalization, ...

recent local example projects:

- Strings 2022
  Conference, 350,000 €, Fredenhagen, Grumiller et al.
- Soft Heisenberg hair on horizons (2018-2022)
  FWF, 330,000 €, Grumiller
- Higher Spin Gravity and Holography (2024-2027)
  FWF, 320,000 €, Lovrekovic

Gravitational physics (Grumiller/Fredenhagen/Rebhan)

Gauge/gravity duality and applications thereof

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- Strong coupling physics QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, ...
- Scattering amplitudes flat space, celestial and Carroll holography, gravity waves, memory effects, ...
- Quantum information holographic entanglement entropy, chaos bound, holographic complexity, ...
- Quantum gravity (A)dS/CFT, bulk reconstruction, black hole microstates, information paradox, ...
- Example V: Cosmology dS/CFT, inflation, cosmological correlation functions, brane cosmology, ...

no local examples — cosmology big gap in Austrian landscape

Gravitational physics (Grumiller/Fredenhagen/Rebhan)

Gauge/gravity duality and applications thereof

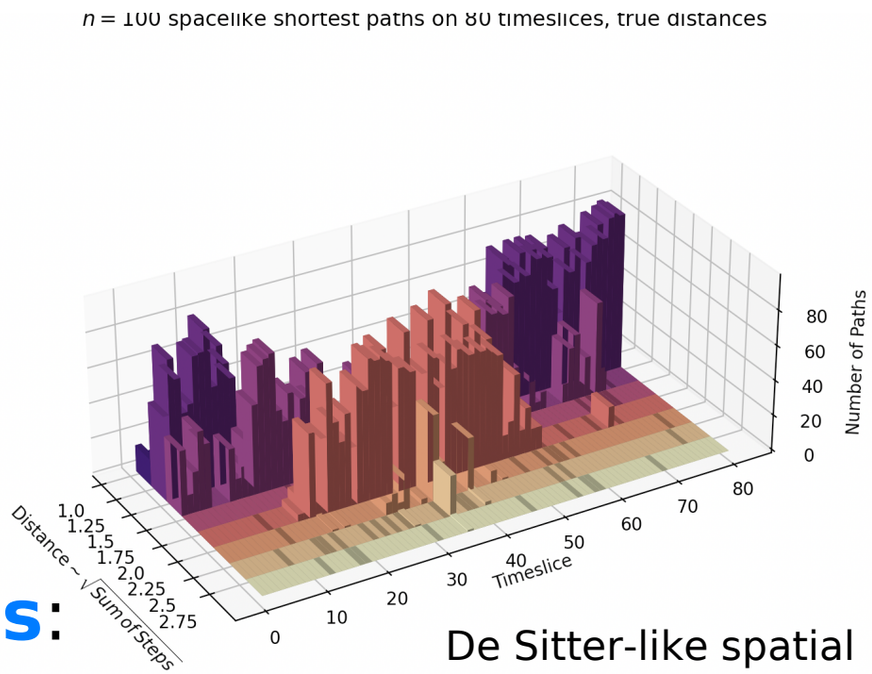
- **Gauge/gravity duality** string theory, black holes, QFT, asymptotic symmetries, anomalies, ...
- **Strong coupling physics** QCD, non-abelian plasmas, neutron stars, cold atoms, strange metals, SYK, ...
- **Scattering amplitudes** flat space, celestial and Carroll holography, gravity waves, memory effects, ...
- **Quantum information** holographic entanglement entropy, chaos bound, holographic complexity, ...
- **Quantum gravity** (A)dS/CFT, bulk reconstruction, black hole microstates, information paradox, ...
- **Cosmology** dS/CFT, inflation, cosmological correlation functions, brane cosmology, ...

- More than enough research avenues for rest of the century
- Adequate local expertise on theory front
- Most pertinent future experiments: (heavy ion) colliders, gravitational wave observatories

Gravitational physics (Maas)

Quantum gravity simulations

- (Causal) Dynamical triangulation as lattice regulated Einstein-Hilbert gravity [e.g. 2204.00859]
  - Numerical simulations
- Build-up of (sub)group at University of Graz with **aims**:
  - Effective description
    - FMS-augmented PT [1908.02140]
  - Self-bound gravitons as dark matter candidates [2202.05117]
  - Quantum black hole (scattering)
  - Quantum cosmology [2202.05117]



De Sitter-like spatial geodesic distances from simulations Maas, Plätzer, Pressler (unpublished)

Gravitational wave Signal: LISA, ET

Event generators (Plätzer)

HEP <-> Astro

current:

apply event generators for strongly interacting dark matter

future:

extend amplitude evolution and resummation to cover gravitational amplitudes

advance event generators to applications beyond colliders (cosmic rays including transport, neutrino experiments)

priorities:

intensify exchange between low-energy hadronic physics and event generators, as well as forward physics at the LHC

promote cross talk between astro-particle physics and collider phenomenology

an engagement in gravitational wave physics is desirable to open up a sustainable program in this direction

Dark Matter (Pradler, Kulkarni)

more generally: theoretical astroparticle physics

current / future:

Pradler: ERC-funded program (till 2028) on new signal components in dark matter direct detection and self-interacting dark matter;

additional (continuing) works on: DM production in the early universe, cosmological probes of New Physics (CMB, 21cm, Neff) , Astrophysical probes of New Physics (stellar cooling, indirect detection); Pheno of sub-GeV DM (intensity frontier, direct detection), Pheno of dark photons, axions, Primordial nucleosynthesis; Baryogenesis scenarios connected to DM; interests in early Universe gravitational wave production

Kulkarni: collider analysis of strongly interacting dark matter scenarios

priorities:

Top priority is to understand nature of Dark Matter: prioritize models that can be tested with current and near-future experiments.