Theory – Astroparticle Physics

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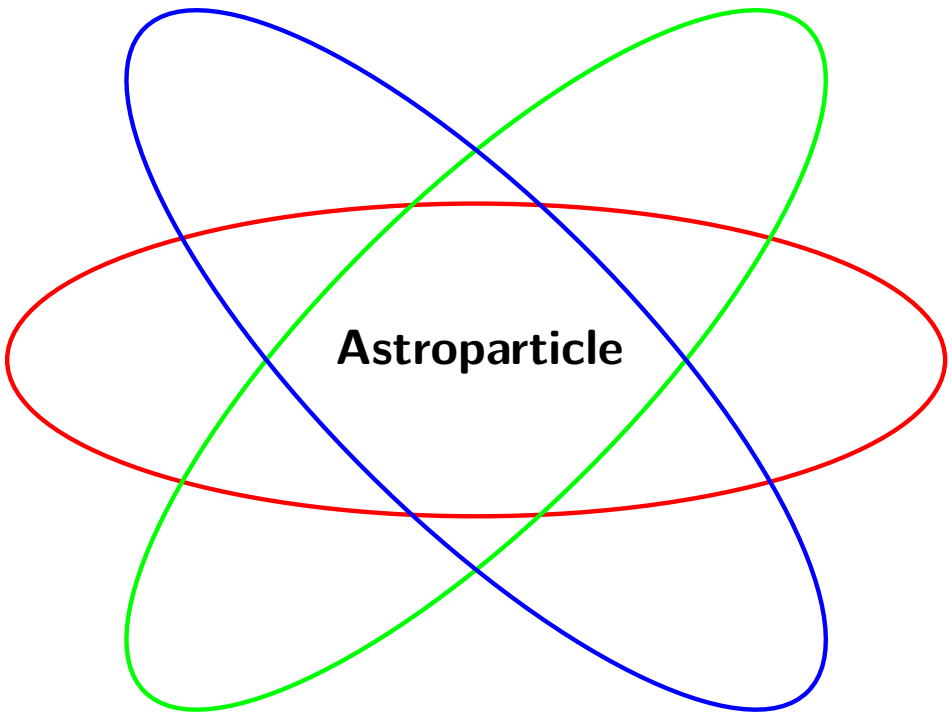
May 16, 2024

Swedish
Research
Council

Knut och Alice
Wallenbergs
Stiftelse

Astroparticle Physics

- Interdisciplinary research area at the interface of:
  Particle Physics,
  Astrophysics,
  Cosmology



Key questions in Astroparticle Physics

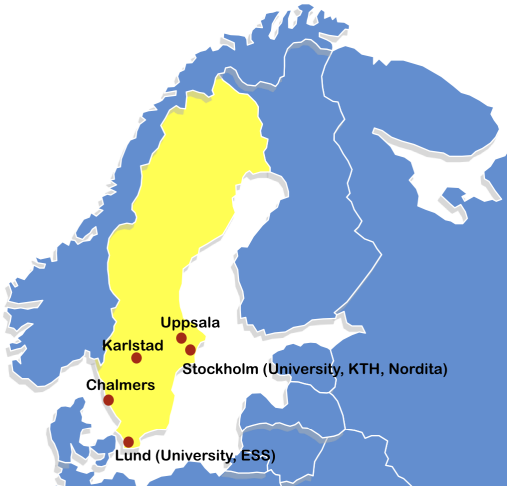
1. What is the universe made of? In particular: what is **dark matter**? What is **dark energy**?
2. What are the properties of **neutrinos**? What is their role in cosmic evolution?
3. What is the origin of **cosmic rays**? What is the view of the sky at **extreme energies**?
4. What do **gravitational waves** tell us about General Relativity and cosmology?
5. What caused our Universe to become dominated by matter and not **anti-matter**?
6. Can we probe deeper into the **earliest phases** of our Universe's existence?

"An answer to any of these questions would mark a major break-through in understanding the universe and would open an entirely new field of research on its own"

Astroparticle Physics European Consortium (APPEC) roadmap

The Swedish landscape

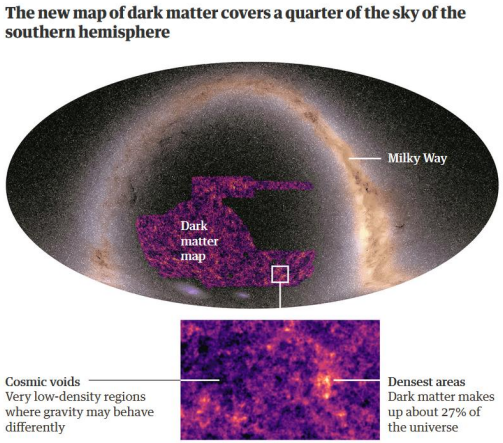
- Sweden is active in the field since its very early stages
- Seven research institutes involved (plus potentially the ESS)
- The theoretical research we perform in astroparticle physics addresses all key questions listed above
- Important feature of our research in the field is a tight collaboration between theory and experiment (fostered by existing funding schemes and "direct involvement" of theoreticians in "data interpretation" for, e.g. XENON, CRESST, COSINUS, IceCube, DUNE, LISA, etc...)



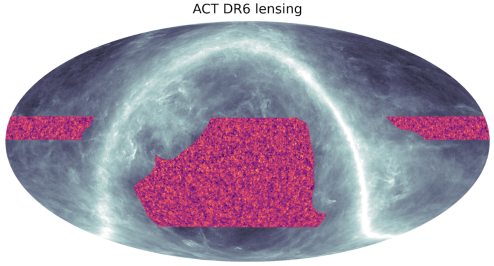
Dark Matter (highlights)

- PIs: M. Berg. (KU), L. Bergström (SU), M. Blennow (KTH), R. Catena (Chalmers), Sandhya Choubey (KTH), J. Edsjö (SU), R. Enberg (UU), K. Freese (SU), T. Linden (SU), D. Marsh (SU), S. Moretti (UU), T. Ohlsson (KTH) , R. Pasechnik (LU), F. Wilczek (SU)

- Particle physics models for dark matter
- Theory of dark matter direct detection in nuclear and electron recoil experiments (interdisciplinary research involving nuclear and solid state physics)
- Theory of dark matter indirect detection via decay and annihilation
- Theory of dark matter production in particle accelerators and beam dump/fixed target experiments
- Axion theory, astrophysics and cosmology



Dark Energy Survey Consortium

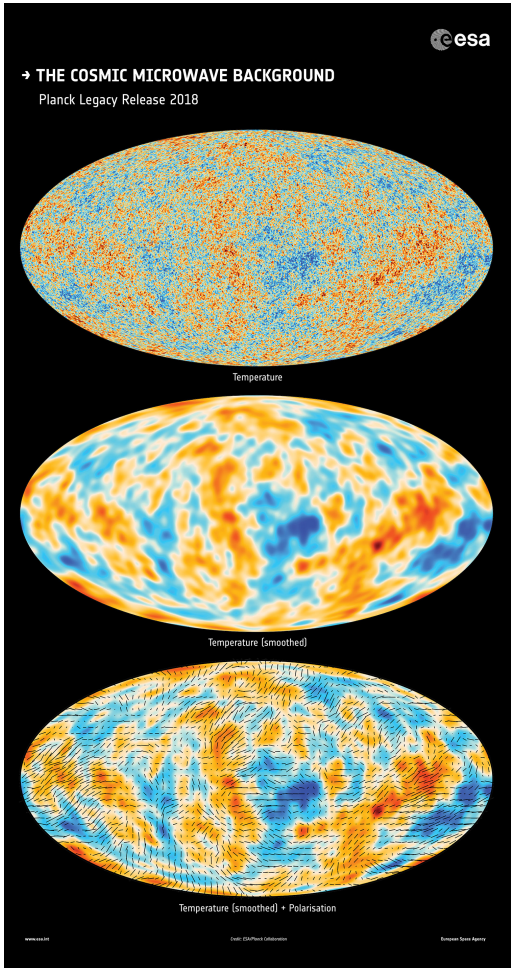


ACT Collaboration

Dark Energy, Modified Gravity, and Large Scale Structures (highlights)

- PIs: M. Berg. (KU), R. Catena (Chalmers), U. Danielsson (UU), K. Freese (SU), F. Hassan (SU), H. Peiris (SU), J. Jasche (SU), E. Mörtsell (SU), F. Niedermann (Nordita)

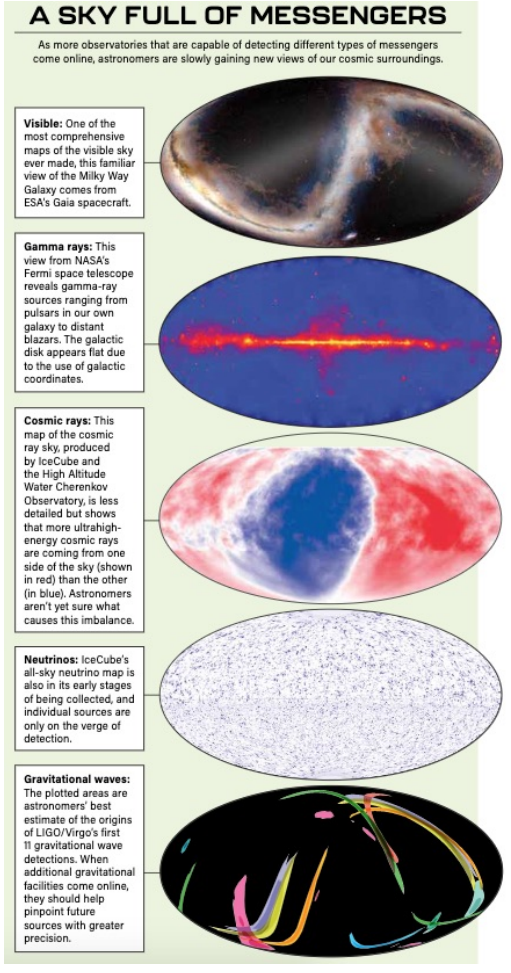
- Theories of dark energy
- Bimetric gravity theories
- Neural networks for the modelling of large scale cosmological structures
- Theories of inflation and the large scale cosmological structures
- Simulations of large scale structure formation: impact of neutrino mass and dark matter particle properties



Neutrinos (highlights)

- PIs: M. Blennow (KTH), R. Catena (Chalmers), Sandhya Choubey (KTH), J. Edsjö (SU), R. Enberg (UU), S. Moretti (UU), T. Ohlsson (KTH), R. Pasechnik (LU), J. Rathsman (UU), F. Wilczek (SU)

- Neutrino masses and oscillations
- Non-standard neutrino interactions
- Sterile neutrinos
- Coherent neutrino-nucleus scattering
- Neutrino portals to dark matter
- Neutrinos from dark matter annihilation
- Neutrinos from cosmic ray interactions in the Sun
- Neutrinos is astrophysics and cosmology

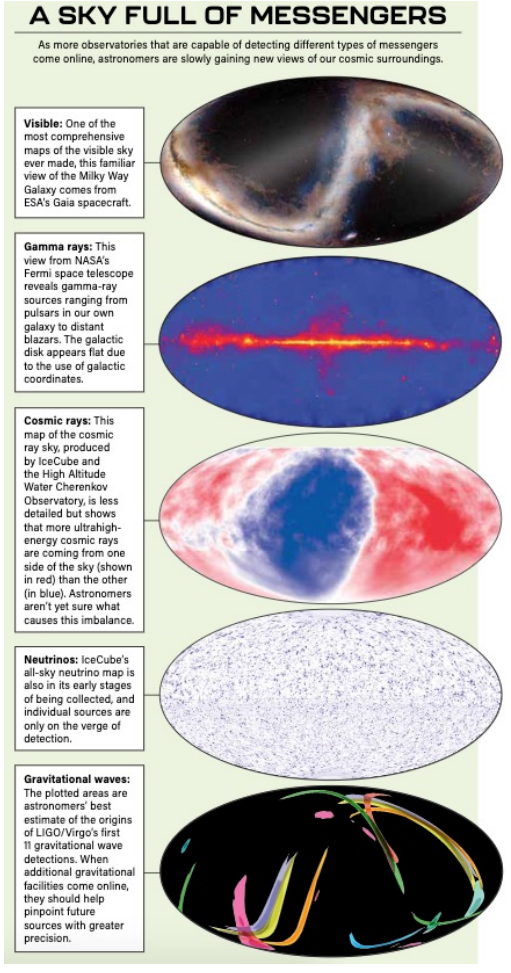


Credit: Arwen Rimmer

Gravitational Waves and Phase Transitions (highlights)

- PIs: U. Danielsson (UU), R. Enberg (UU), H. Johansson (UU), R. Pasechnik (LU), J. Rathsman (UU), S. Rosswog (SU)

- Electroweak phase transition
- Baryogenesis
- Gravitational wave emission in compact binary mergers
- Numerical relativity
- Computational methods for gravitational wave emission based on gauge/gravity duality



Credit: Arwen Rimmer

Participation in international commissions

- Sweden is actively involved in two important commissions related with astroparticle theory:

- **EuCAPT**: D. Marsh (SU), Vice Director

- **EuCAPT**: R. Catena (Chalmers), council member

- **IUPAP**: R. Catena (Chalmers), member of C4 commission

Funding opportunities

- Main funding opportunities for theoretical astroparticle physics in Sweden:
  - Swedish Research Council (individual grants award around 4 MSEK over 4 years)
  - Knut and Alice Wallenberg Foundation (research grants involve 3-5 PIs, and award around 25 MSEK over 5 years)
  - EU
- In Sweden, a PhD student costs about 4MSEK, including direct and indirect costs
- Faculty positions are not associated with continuous funding for students and postdocs from the host university as in, e.g. Germany
- This implies that in Sweden a PI in theoretical astroparticle physics rarely leads a research group with more than one PhD student and/or one postdoc

Summary

- Our research in theoretical astroparticle physics is aligned with APPEC priorities

- Main research areas include
  - Dark Matter
  - Dark Energy, Modified Gravity, and Large Scale Structures
  - Neutrinos
  - Gravitational Waves and Phase Transitions

- More than 20 permanent researchers (PIs) are engaged in these research activities

- PIs are mainly funded by individual grants from the Swedish Research Council and "network grants" from the Knut and Alice Wallenberg Foundation