

# Group Report: KTH Phenomenology and Theory

Henrik Melb us & Sofia Sivertsson  
Partikeldagarna 2008, Stockholm, Sweden



ROYAL INSTITUTE  
OF TECHNOLOGY

Department of Theoretical Physics,  
Royal Institute of Technology (KTH),  
Stockholm, Sweden

October 16-17, 2008

## Presentation of the research group

# Presentation of the research group

## The research group

- Tommy Ohlsson, professor (head of research group)
  - Håkan Snellman, professor emeritus
  - Michal Malinský, postdoc
  - He Zhang, postdoc
  - Henrik Melbéus, PhD student
  - Sofia Sivertsson, PhD student
  - Johannes Bergström, diploma student
- 
- Ohlsson is also the director of graduate studies at the Department of Theoretical Physics

# Former members

## Career of PhD students

- Mattias Blennow, June 2007  
postdoc at Max-Planck-Institut für Physik, Munich
  - ▶ funded by first the Swedish Research Council and then Marie Curie fellow under FP7
  - ▶ in the group of Georg Raffelt
- Tomas Hällgren, September 2007  
fund analyst, Capital Research, Stockholm

## Other former members

- Max Tegmark, PhD student 1990-1994
- Johan Linde, PhD student 1992-1997
- Thomas Konstandin, postdoc 2005-2007
- Evgeny Akhmedov, guest professor 2006

## International collaboration

Our international collaborators consist of the following people and their research groups:

- Prof. Evgeny Kh. Akhmedov, Max-Planck-Institut für Kernphysik, Heidelberg, Germany
- Prof. Samoil M. Bilenky, Joint Institute for Nuclear Research, Dubna, Russia
- Prof. Paolo Gondolo, The University of Utah, Salt Lake City, USA
- Prof. Steve King, University of Southampton, Southampton, UK
- Prof. Manfred Lindner, Max-Planck-Institut für Kernphysik, Heidelberg, Germany
- Prof. Zhi-Zhong Xing, Chinese Academy of Sciences, Beijing, China
- Dr. Stefan Antusch, Max-Planck-Institut für Physik, Munich, Germany
- Dr. Stefano Bertolini, SISSA, Trieste, Italy
- Dr. Mattias Blennow, Max-Planck-Institut für Physik, Munich, Germany
- Dr. Joakim Edsjö, Stockholm University, Stockholm, Sweden
- Dr. Thomas Konstandin, Universitat Autònoma de Barcelona, Barcelona, Spain
- Dr. Davide Meloni, Università di Roma Tre, Rome, Italy
- Dr. Thomas Schwetz, CERN, Geneva, Switzerland
- Dr. Francesco Terranova, INFN Laboratori Nazionali Frascati, Frascati, Italy
- Dr. Walter Winter, Universität Würzburg, Würzburg, Germany

# Future major events and present scientific engagements

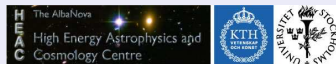
## Event



- Astroparticle Physics – A Pathfinder to New Physics – AlbaNova, Stockholm, March 30-April 30, 2009
  - ▶ Nordita program: long workshop with ample time for research
  - ▶ approx. 30 participants

## HEAC

The group is a participant of HEAC (AlbaNova High Energy Astrophysics and Cosmology Centre), which is an excellent research center funded by the Swedish Research Council



## Research topics

- Neutrino physics (with strong implications in astroparticle physics and cosmology)
  - ▶ neutrino flavor transitions
  - ▶ non-standard interactions
  - ▶ flavor symmetries
  - ▶ renormalization group running
- Physics beyond the Standard Model
  - ▶ extra dimensions
  - ▶ Grand Unified Theories (GUTs)
- Astrophysics and Cosmology
  - ▶ leptogenesis and baryogenesis
  - ▶ phase transitions
  - ▶ dark matter
- Hadron Physics

In addition: neutrino model-building, supernova neutrinos, deconstruction of extra dimensions, neutrinos and gamma rays from WIMP annihilations, Kaluza–Klein dark matter, scale invariance, unparticle physics

# Grand challenges in particle physics

- Does the Higgs particle exist?
- What is the nature of dark matter?
- Are there any supersymmetric particles?
- Are there more than three spatial dimensions?
- Why is there more matter than anti-matter in the Universe?
- How does the Sun burn and how do neutrinos affect the thermonuclear processes in the Sun?
- What is the nature of neutrino masses?
- Are neutrinos their own antiparticles?
- What is the absolute neutrino mass scale?
- What about unparticle physics?



# Major publications

- Series Expansions for Three-Flavor Neutrino Oscillation Probabilities in Matter, JHEP 04, 078 (2004) [cited 76 times]  
E. Akhmedov, R. Johansson, M. Lindner, T. Ohlsson, T. Schwetz
- Three Flavor Neutrino Oscillations in Matter, JMP 41, 2768 (2000) [cited 67 times]  
T. Ohlsson, H. Snellman
- Neutrino Oscillations with Three Flavors in Matter: Applications to Neutrinos Traversing the Earth, PLB 474, 153 (2000) [cited 50 times]  
T. Ohlsson, H. Snellman
- Role of Matter Density Uncertainties in the Analysis of Future Neutrino Factory Experiments, PRD 68, 073007 (2003) [cited 31 times]  
T. Ohlsson, W. Winter
- Non-standard Hamiltonian Effects on Neutrino Oscillations, EPJC 49, 1023 (2007) [cited 29 times]  
M. Blennow, T. Ohlsson, W. Winter

# Present research work

- Approximative Two-Flavor Framework for Neutrino Oscillations with Non-Standard Interactions

T. Ohlsson

- Non-Standard Interaction Effects at Reactor Neutrino Experiments  
(see presentation by H. Zhang)

T. Ohlsson, H. Zhang

- Solving the SUSY Flavor and CP Problems with Non-Abelian Family Symmetry and Supergravity

M. Malinský

- Accurate Calculations of the WIMP Halo around the Sun and Prospects for Gamma Ray Detection

S. Sivertsson

# Future research work

- Unparticle Self-Interaction at the LHC

J. Bergström, T. Ohlsson

- Perturbative Estimates of Lepton Mixing Angles in GUT Models

M. Malinský

- Phenomenology and Models for Non-Standard Interactions

M. Malinský, T. Ohlsson, H. Zhang

- Neutrino Fluxes from Kaluza–Klein Dark Matter Annihilations

H. Melbésu, T. Ohlsson

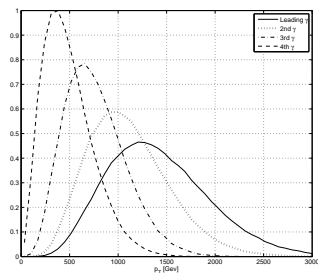
- Dark Stars in the Early Universe

S. Sivertsson

# Unparticle Self-Interaction at the LHC

Johannes Bergström and Tommy Ohlsson:

Unparticle physics is the physics of a hidden conformal sector coupled to the Standard Model. If the conformal sector is strongly coupled to itself, it will mediate processes such as  $gg, q\bar{q} \rightarrow U^* \rightarrow U^*U^* \rightarrow 4\gamma, 4l, 2\gamma 2l$  with enormous cross sections at the LHC. We determine the allowed cross sections and relevant distributions.

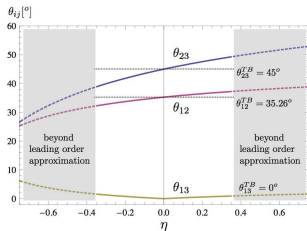


**Figure:** The  $p_T$  distribution for  $p_T$  ordered photons in unparticle  $q\bar{q} \rightarrow 4\gamma$  events at the LHC.

# Perturbative Estimates of Lepton Mixing Angles in GUT Models

Stefan Antusch, Steve King, and Michal Malinský:

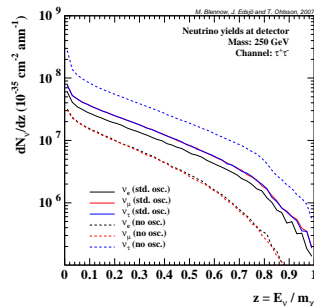
Neutrino masses and mixing parameters are usually predicted at a high scale of the order of  $10^{12} - 10^{14}$  GeV and various renormalization effects must be included before comparing to the experimental data. Popular models of flavor account for the observed approximate tri-bimaximal (TB) lepton mixing by speculating that neutrinos alone are TB with just small contributions from the charged leptons along the lines of the GUT quark-lepton similarity. The question that is whether one can learn anything about the GUT-scale setting from the observables. Such information would be very helpful for model building.



# Neutrino Fluxes from Kaluza–Klein Dark Matter Annihilations

Mattias Blennow, Henrik Melb us, and Tommy Ohlsson:

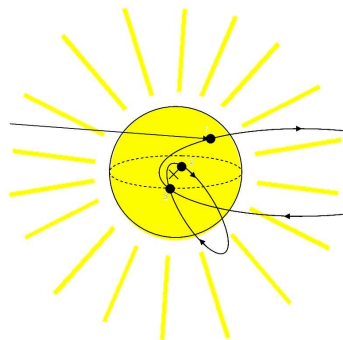
We study models of Kaluza–Klein dark matter, where the dark matter candidate is a higher-dimensional excitation of some Standard Model field. Dark matter could be trapped in the gravitational potential of the Sun or Earth and annihilate, leading to both direct and indirect fluxes of neutrinos. Our aim is to determine the experimental signatures of these annihilations, taking neutrino oscillations into account in a full three-flavor Monte Carlo framework.



# Dark Stars in the Early Universe

Paolo Gondolo and Sofia Sivertsson:

In the early Universe, the dark matter density was much higher than today. In the case of WIMP dark matter, the first stars might have had phases, where the dark matter was the major energy resource, hence the name “dark stars”. We investigate how the young pop. III stars captures WIMPs from their surrounding dark matter halos, in order to observe how the energy released from dark matter annihilations affect the stars at different stages.



# Research funding



- The Royal Swedish Academy of Sciences (KVA)
- The Swedish Research Council (VR)
- The Göran Gustafsson Foundation
- The Royal Institute of Technology (KTH) [internal]



# Additional material

## Publications 2008

- M. Blennow, J. Edsjö, and T. Ohlsson  
Neutrinos from WIMP Annihilations Obtained Using a Full Three-Flavor Monte Carlo Approach  
J. Cosmol. Astropart. Phys. 01 (2008) 021  
arXiv:0709.3898 [hep-ph]
- M. Blennow, D. Meloni, T. Ohlsson, F. Terranova, and M. Westerberg  
Non-Standard Interactions Using the OPERA Experiment  
Eur. Phys. J. C 56 (2008) 529-536  
arXiv:0804.2744 [hep-ph]
- M. Blennow and T. Ohlsson  
Approximative Two-Flavor Framework for Neutrino Oscillations with Non-Standard Interactions  
arXiv:0805.2301 [hep-ph]
- M. Blennow, T. Ohlsson, and J. Skrotzki  
Effects of Non-Standard Interactions in the MINOS Experiment  
Phys. Lett. B 660 (2008) 522-528  
hep-ph/0702059

## Publications 2008

- A. Hernandez, T. Konstandin, and M.G. Schmidt  
Effective Action in a General Chiral Model: Next to Leading Order Derivative Expansion in the Worldline Method  
Nucl. Phys. B 793 (2008) 425-450  
arXiv:0708.0759 [hep-th]
- S.J. Huber and T. Konstandin  
Production of Gravitational Waves in the nMSSM  
J. Cosmol. Astropart. Phys. 05 (2008) 017  
arXiv:0709.2091 [hep-ph]
- T. Hällgren, T. Konstandin, and T. Ohlsson  
Triplet Leptogenesis in Left-Right Symmetric Seesaw Models  
J. Cosmol. Astropart. Phys. 01 (2008) 014  
arXiv:0710.2408 [hep-ph]
- H. Melb eus and T. Ohlsson  
Searches for Hyperbolic Extra Dimensions at the LHC  
J. High Energy Phys. 08 (2008) 077  
arXiv:0806.1841 [hep-ph]
- T. Ohlsson and H. Zhang  
Non-Standard Interaction Effects at Reactor Neutrino Experiments  
arXiv:0809.4835 [hep-ph]