Zwischenbericht (Sachbericht)

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Förder-Nr.:	VH-NG-006-2
Titel des Vorhabens:	Particle Physics and Cosmology: Beyond the two Standard Models
Federführender Wissenschaftler:	Dr. Laura Covi
Federführendes Helmholtz-Zentrum:	Deutsches Elektronen-Synchrotron DESY
Weitere beteiligte Helmholtz-Zentren	
Beteiligte Universitäten und andere Partner:	University of Padua
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Project VH–NG–006: 2008 Activity Report

April 2009

Group Members (2008)

- Group Leader: Laura Covi (DESY)
- Postdoctoral Fellows: Marieke Postma (DESY) until June 2008
  Fumihiro Takayama (DESY) from September 2008
  Pasquale Di Bari (INFN, Padova) from October 2007
- Diploma/Ph. D. Students: Michael Grefe (DESY) Dipl. St. until September 2008,
  Ph. D St. from November 2008
  Jasper Hasenkamp (DESY) Dipl. St. from April 2008
  Cecelie Hector (DESY) Ph.D. St. from September 2008

The members of the group VH–NG–006 "Particle Physics and Cosmology" have been working on several topics in the field of Particle Physics and Cosmology. Here we report about the activities and publication list in 2008 and early 2009.

Dark Matter and indirect detection (L. Covi, P. Di Bari, M. Grefe, J. Hasenkamp, F. Takayama)

If Dark Matter is a very weakly interacting particle, it may be unstable and then it may be possible to identify the DM particle thanks to its decay channels and branching ratios. In the case of a decaying gravitino within models with bilinear R-parity violation, the main decay channels are into a lepton and electroweak gauge or Higgs boson. We investigated the neutrino signal in these models, coming directly from decay into neutrino and photon/Z boson and indirectly from the Z, W, Higgs boson or tau lepton fragmentation [1]. After including the effect of neutrino oscillations, the energy spectra are equal in the tau and muon neutrino channels and characterised by up to three different peaks corresponding to the decays into neutrino with photon, Z and Higgs bosons. Unfortunately present neutrino detectors do not have sufficient energy resolution to disentangle the peaks and the overall statistics of the signal is poor. The best signal-to-background ratio is in the tau neutrinos along the zenit direction. Another very weakly interacting Dark Matter candidate is the axino, which may also become unstable if R-parity is broken, but with different decay channels depending on the model [2].

If instead R-parity is conserved, strong constraints on the NLSP nature arise from Big Bang Nucleosynthesis. These bounds disappear if the NLSP relic density before decay is sufficiently low. This density is naturally suppressed for a coloured or electromagnetically charged NLSP like the stop or the stau. We have therefore recomputed the number density of a charged relic, including the Sommerfeld effect [3]. We found that even the enhanced annihilation due to the strong force is not sufficiently effective to bypass completely the BBN bounds. Nevertheless a stop NLSP below 700 GeV is allowed if its lifetime is shorter than 100 s.

Another possible DM candidate, within models with the see-saw mechanism, is an almost decoupled RH neutrino species N_{DM} with mass around 100 GeV. It can be produced from non-adiabatic conversions of the other thermalized RH neutrinos with mass lower than M_{DM}, if a non-renormalizable operator is added to the minimal type I see-saw lagrangian [4].

Leptogenesis (P. Di Bari)

We performed a general analysis that reveals new aspects of the leptogenesis bounds on neutrino masses and on the reheat temperature of the Universe [5]. After revisiting a known effect coming

from an unbounded term in the total CP asymmetry, we showed that an unbounded term in the flavoured CP asymmetries has a stronger impact. It relaxes the lower bound on the reheat temperature down to 10^8 GeV for $(M_2 - M_1)/M_1 = \mathcal{O}(1 - 100)$ and for a mild tuning of the parameters in the see-saw orthogonal matrix. We studied the conditions for the validity of the usual N_1-dominated scenario and found that except for the two effective RH neutrino scenario, recovered for $M_3 >> 10^{14}$ GeV, and for values $M_2 < \mathcal{O}(10^{11})$ GeV, the final asymmetry is more naturally dominated by the contribution from N_2-decays.

We applied these results to models where SO(10)-inspired mass conditions are imposed on the Dirac neutrino mass matrix and light neutrino masses are generated through the type I see-saw mechanism [6]. It is well-known that thermal leptogenesis through the decays of the lightest right-handed neutrinos encounters serious difficulties in those models, but these can be circumvented when the production from the next-to-lightest right-handed neutrinos and flavor effects are properly taken into account.

Inflation in SUGRA (L. Covi, C. Hector, M. Postma)

We have continued to study inflationary model-building within the context of supergravity. In models derived from string theory, the problem of realising inflation is strongly connected to the stabilisation of the moduli fields and to the question of up-lifting supersymmetric Anti-deSitter or Minkowski vacua to the observed de Sitter one. We have explored the interplay between the stabilisation mechanism and the inflationary sector [7] and tried to implement chaotic inflation with different moduli stabilisation mechanisms finding that a viable model can be obtained only at the cost of a fine-tuned moduli sector [8]. Moreover we considered the possibility of stabilise the moduli and having inflation directly in a de Sitter phase: in this case the Kähler sectional curvature along the inflationary trajectory and more in general the sGoldstino field direction has to be sufficiently positive. This condition is very similar to the one for general metastable de Sitter, but it is even more stringent the higher the value of the vacuum energy during inflation [3]. We are now working on explicit model building in this type of scenarios and on identifying specific observational signatures, like non-gaussianities.

We have also investigated the possibility of cosmic string formation in the case of racetrack inflation coupled to matter fields as realised in the D3/D7 brane system [10]. We find that strings may form before or at the onset of racetrack inflation, but they are then inflated away, while string formation at the end of inflation is prevented by the presence of the moduli sector. As a consequence, no cosmic strings survive in racetrack inflation.

Workshops

In February 2008 the first HGF-Project Workshop took place in Padova organised by Pasquale Di Bari. During 3 days, we had plenary review talks by S. Matarrese, J. Lesgourges, M. Quiros, E. Roulet, H. Murayama and E. Kolb and many interesting talks by the participants on inflation, leptogenesis, dark matter and neutrinos in cosmology [11]. The meeting has been very successful and allowed to strengthen the link between the Padova and DESY groups. Moreover we hosted at DESY and co-organised the ENTApP Dark Matter Visitor Programme for 2008 [12]. The programme brought together approximately 30 Dark Matter experts and young researchers and was characterised by lively and very detailed discussion sessions.

2009 Plan (L. Covi, P. Di Bari, M. Grefe, C. Hector, F. Takayama)

We are nearing the end of the project and we are planning to bring some of the planned research projects to conclusions in 2009. We are going to concentrate on inflationary model building and signals of gravitino Dark Matter at colliders.

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