Physics Beyond the Standard Model 2007

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1. Topics

In the context of extensions of the standard model, several different topics are studied. The topics include grand unification, supersymmetric phenomenology (i.e. collider and dark matter), early universe, neutrino physics, and string phenomenology. An important question is to see how these various topics are related.

2. Unified theories

$Z_N \times Z_M$ orbifold models admit the introduction of a discrete torsion phase. In [1], we showed that models with discrete torsion have an alternative description in terms of torsionless models. More specifically, discrete torsion can be 'gauged away' by changing the shifts by lattice vectors. Similarly, a large class of the so-called generalized discrete torsion phases can be traded for changing the background fields (Wilson lines) by lattice vectors. We further observed that certain models with generalized discrete torsion are equivalent to torsionless models with the same gauge embedding but based on different compactification lattices. We also presented a method of classifying heterotic $Z_N \times Z_M$ orbifolds.

The seesaw mechanism provides perhaps the most compelling explanation for the observed smallness of neutrino masses. In [2] we analyzed string-derived models which give rise to exact spectra of the standard model spectra (or, more precisely, its minimal supersymmetric extension) at low energies. We found that the seesaw is generic (or 'automatic') in these models.

Supersymmetric theories of grand unification (in short: SUSY GUTs) are typically challenged, if not ruled out, by proton decay. In [5] we identified very simple, anomaly-free discrete symmetries which ensure that the proton is sufficiently long-lived. An interesting feature of these symmetries is that R-parity is embedded in these symmetries rather than a subgroup of $\mathrm{U}(1)_{B-L}$.

We continued our analysis of string-derived models in [6]. It turns out to be fairly easy to find supersymmetric MSSM vacua with R-parity. Moreover, many of the models have a large top Yukawa couplings while other Yukawa couplings are suppressed. Further, there is a D_4 flavor symmetry that helps to solve the supersymmetric flavor problem. An interesting outcome of the analysis is a novel, stringy solution to the MSSM μ problem. These issues are reviewed in [10].

3. Early universe

In [3], we presented a detailed analysis of current constraints on the effective number of relativistic degrees of freedom inferred from cosmic microwave background (CMB) and large scale structure data. We identified various systematic effects and were able to reconcile discrepant results that had previously been reported in the literature, showing that there is presently no evidence for a deviation from the standard model expectation.

In [8], we addressed the question of whether the existing measurements of the CMB monopole and dipole temperatures, taken by the FIRAS instrument in the early 1990s, are accurate enough to not compromise parameter constraints from future CMB data sets. We found that even under the most pessimistic circumstances the effect induced by the experimental errors on the monopole and dipole temperatures is small, and concluded that a more accurate measurement of these quantities will not be necessary.

In [4], leptogenesis scenarios with many 'right-handed' neutrinos were considered. It was found that the lower bound for the reheating temperature can be significantly relaxed with respect to the hierarchical three neutrino case. This is interesting in the context of several, in particular supersymmetric, extensions of the standard model, where the requirement to avoid heavy unstable relics (which may spoil the successful predictions from nucleosynthesis) leads to a preference of low reheating temperatures. These issues are reviewed in [7].

The gravitino is a very interesting dark matter candidate. However, due to the suppressed coupling of the gravitino to the other MSSM particles, the NLSP is typically long-lived and the late NLSP decays threaten the success of Big Bang Nucleosynthesis. In addition charged NLSPs can form bound states, leading to a change of BBN reaction rates. In [9] the impact of catalyzed Big Bang Nucleosynthesis on theories with a gravitino LSP and a charged slepton NLSP was considered.

References

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