NuFlavour Workshop

Cosener's House June 8-10, 2009

Summary of the Leptogenesis Section:

Review Talk - Asmaa Abada

Discussion - Enrico Nardi

June 10, 2009

Leptogenesis:

A class of scenarios where the Universe baryon asymmetry $(Y_{\Delta B})$ is produced from a lepton asymmetry $(Y_{\Delta L})$ generated in the decays of the heavy singlet *seesaw* Majorana neutrinos. Successful leptogenesis must be able to explain:

$$Y_{\Delta B} \equiv \frac{n_B - \bar{n}_B}{s} = (8.75 \pm 0.23) \times 10^{-11}$$

[WMAP 5yrs, BAO, SN-IA]
[BBN: Light Elements Aboundances]

Asmaa review talk:

- Observations : Neutrino masses and BAU
- Little Historical review
- Motivation, Requirements (Sakharov conditions:
  1. $\not{B}$ & $\not{L}$; 2. $\not{C}\&\not{CP}$; 3. Deviations from thermal equilibrium).
- Connection with the Seesaw mechanism, and different types of Seesaw (Type I, II and III)

Basic Leptogenesis Mechanism (Seesaw type I):

- The One Flavour Approximation: Constraints
  - If light ν are degenerate $\epsilon = 0$
  - If light ν are hierarchical, upper limit on the CP asymmetry:
    Davidson Ibarra limit: $\epsilon \leq \frac{3M_1}{16\pi}\frac{\sqrt{\Delta}m^2_{atm}}{v^2}$
- Leptogenesis with flavours:
  - Additional sources of CP violation
  - Can have successful leptogenesis in the case of degenerate light neutrinos
  - Flavours open a wider range for the washout parameter $\tilde{m}_1$ (extremely small values allowed)
  - There is NO BOUND on absolute scale of light neutrinos from the requirement of successful leptogenesis!
- Leptogenesis with heavy flavours N_2 and N_3:
  - N_1 decoupled regime
  - N_1 strongly coupled regime

SUSY Leptogenesis, beyond type 1 seesaw and beyond the seesaw

- SUSY Leptogenesis
  - The SUSY seesaw model and supersymmetric leptogenesis
  - Alternative mechanisms: Soft Leptogenesis (TeV Scale)
  - Alternative mechanisms: Affleck-Dine
- Different types of Seesaw:
  - Type I seesaw (standard: $SU(2)_L$ singlets Majorana neutrinos)
  - Type II seesaw ($SU(2)_L$ triplet + singlet)
  - Type III seesaw (fermion triplet)
- Dirac Leptogenesis
  - Leptogenesis without lepton number violation

DISCUSSION

1. Under what conditions low & high energy $\not{CP}$ can be connected?

In leptogenesis $Y_{\Delta B}$ and low energy $\not{CP}$ phases are generally unrelated

[G.C.Branco& al. NPB617,(2001); S.Davidson, J.Garayoa, F.Palorini, N.Rius PRL99,2007; JHEP0809,2008.]

In most cases, to enforce a relation one needs to impose rather unnatural and/or *ad hoc* conditions

Example

Casas-Ibarra parameterization for the N Yukawa couplings **[NPB618 (2001)]**

$$\lambda_{\alpha K} = \frac{1}{v}\left[U^\dagger \sqrt{m_\nu} \cdot R \sqrt{M_N}\right]_{\alpha K}; \qquad R = \frac{v}{\sqrt{m_\nu}} \cdot U^T \cdot \lambda \cdot \frac{1}{\sqrt{M_N}}$$

Assuming that R is real

EN,Nir,Roulet,Racker,JHEP0601,2006

1: [$\epsilon = 0$, but $\epsilon_\alpha \neq 0$, and thus $Y_{\Delta B} \neq 0$]

2: ϵ_α depends only on the ν-mix-matrix U, and a complete relation is established.

However, there is no simple way to enforce a real R !

2. If $\not{CP}_L$ & $\not{L}$ are observed, is it obvious to believe in leptogenesis?

Prove vs. Disprove vs. Circumstantial Evidences for LG

- Experimental detection of $0\nu2\beta$ decays and/or $\not{CP}_L$ in the lepton sector will strengthen the case for leptogenesis – but will not prove it.

- If a quasi degenerate or IH ν-spectrum is established, failure of revealing $0\nu2\beta$-decays will disfavor LG. (In the DH case no $0\nu2\beta$ signal is expected.)

- Failure of revealing $\not{CP}_L$ will not disprove LG.

  (However, if a sizeable $\theta_{13} \neq 0$ is established, this would pose some questions. . . .)

- Observation of low energy $\not{CP}_L$ will not result in any quantitative direct connection with the LG CP asymmetries

  (but will certainly strengthen the case for LG).

- Finally, LHC + EDM experiments will be able to establish or falsify EWB. This will indirectly determine the relevance of future LG studies.

3. Can one get additional informations in the context of LFV?

Can one get additional informations in the context of flavor symmetries?

- Neutrinos: The hierarchy is milder than for charged fermions
  (the spectrum could be quasi-degenerate)
- Two mixing angles are large and one maybe maximal.
- Are these hints for a non-Abelian flavor symmetry in the ν sector?

Non-Abelian flavor symmetry

$\Downarrow$

Large reduction in the number of parameters (seesaw)

$\Downarrow$

New connections between LE observables and HE quantities

$\Downarrow$

Yes. In the context of flavor symmetries more information can be available