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Nuclear Physics B 732 (2006) 224–242
NUCLEAR PHYSICS B

Standard-like model building on type II orientifolds

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Received 22 September 2005; accepted 28 October 2005

Available online 16 November 2005

Abstract

We construct new standard-like models on type II orientifolds. In type IIA theory on $\mathbf{T}^6/(\mathbb{Z}_2 \times \mathbb{Z}_2)$ orientifold with intersecting D6-branes, we first construct a three-family trinification model where the $U(3)_C \times U(3)_L \times U(3)_R$ gauge symmetry can be broken down to the $SU(3)_C \times SU(2)_L \times U(1)_{Y_L} \times U(1)_{I_{3R}} \times U(1)_{Y_R}$ gauge symmetry by the Green–Schwarz mechanism and D6-brane splittings, and further down to the SM gauge symmetry at the TeV scale by Higgs mechanism. We also construct a Pati–Salam model where we may explain three-family SM fermion masses and mixings. Furthermore, we construct for the first time a Pati–Salam like model with $U(4)_C \times U(2)_L \times U(1)' \times U(1)''$ gauge symmetry where the $U(1)_{I_{3R}}$ comes from a linear combination of $U(1)$ gauge symmetries. In type IIB theory on $\mathbf{T^6}/(\mathbb{Z}_2 \times \mathbb{Z}_2)$ orientifold with flux compactifications, we construct a new flux model with $U(4)_C \times U(2)_L \times U(2)_R$ gauge symmetry where the magnetized D9-branes with large negative D3-brane charges are introduced in the hidden sector. However, we cannot construct the trinification model with supergravity fluxes because the three $SU(3)$ groups already contribute very large RR charges. The phenomenological consequences of these models are briefly discussed as well.

PACS: 11.25.Mj; 11.25.Wx

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0550-3213/$ – see front matter
doi:10.1016/j.nuclphysb.2005.10.031

1. Introduction

The major goal of string phenomenology is to construct four-dimensional models with the features of the Standard Model (SM), which connect the string theory to realistic particle physics. Due to the advent of D-branes [1], we can construct consistent four-dimensional chiral models with non-Abelian gauge symmetry on type II orientifolds. Chiral matter can appear: (i) due to the D-branes located at orbifold singularities with chiral fermions appearing on the worldvolume of such D-branes [2,3]; (ii) at the intersections of D-branes in the internal space [4] with T-dual description in terms of magnetized D-branes [5].

On type IIA orientifolds with intersecting D6-branes, a large number of non-supersymmetric three-family standard-like models and grand unified models, which satisfy the Ramond–Ramond (RR) tadpole cancellation conditions, were constructed [6–12]. However, there generically exist two problems: the uncanceled Neveu–Schwarz–Neveu–Schwarz (NSNS) tadpoles and the gauge hierarchy problem. On the other hand, the first supersymmetric models [13,14] with quasi-realistic features of the supersymmetric standard-like models have been constructed in type IIA theory on $\mathbf{T^6}/(\mathbb{Z}_\mathbf{2}\times\mathbb{Z}_\mathbf{2})$ orientifold with intersecting D6-branes. Then, supersymmetric standard-like models, Pati–Salam like models, $SU(5)$ models as well as flipped $SU(5)$ models have been constructed systematically [15–19], and their phenomenological consequences have been studied [20–22]. In addition, supersymmetric constructions on other type IIA orientifolds were also discussed [23].

In spite of these successes, the moduli stabilization in open string and closed string sectors is still an open problem even if some of the complex structure parameters (in the type IIA picture) and dilaton fields may be stabilized due to the gaugino condensation in the hidden sector in some models (see, e.g., [22]). The supergravity fluxes give us another way to stabilize the compactification moduli fields by lifting continuous moduli space of the string vacua in an effective four-dimensional theory (see, e.g., [24]) because it introduces a supergravity potential. In this paper, for flux model building, we only consider the type IIB orientifolds. The intersecting D6-brane constructions correspond to the models with magnetized D-branes where the role of the intersecting angles is played by the magnetic fluxes on the D-branes on the type IIB orientifolds. In [25,26], the techniques for consistent chiral flux compactifications on type IIB orientifolds were developed, and the dictionary for the consistency and supersymmetry conditions between the two T-dual constructions was given. However, due to the Dirac quantization conditions, the supergravity fluxes impose strong constraints on consistent model building, since they contribute large positive D3-brane charges and then modify the global RR tadpole cancellation conditions significantly. Therefore, no explicit supersymmetric chiral standard-like models were obtained in [25,26]. In type IIA orientifolds with flux compactifications, it has been recently shown that the RR, NSNS and metric fluxes could contribute negative D6-brane charges, and then relax the RR tadpole cancellation conditions [27,28]. But we will not consider it in this paper.

By introducing the magnetized D9-branes with large negative D3-brane charges in the hidden sector, the first three-family and four-family standard-like models with one unit of quantized flux were obtained [29,30]. These constructions are T-dual to the supersymmetric models of intersecting D6-branes on $\mathbb{Z}_2 \times \mathbb{Z}_2$ orientifold with the $Sp(2)_L \times Sp(2)_R$ or $Sp(2f)_L \times Sp(2f)_R$ gauge symmetry in the electroweak sector, respectively [18] (for the corresponding non-supersymmetric models, see [11]). Recently this kind of models has been studied systematically [31]. Moreover, considering the magnetized D9-branes with large negative D3-brane charges in the SM observable sector, a lot of new models have been constructed [32], for example, many new models with one unit of quantized flux, the first three- and four-family models with two