String Theory compactifications

6 2-hr courses
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String theory is consistently defined in ten dimensions, six of which should be curled up in some small “internal” compact manifold. The procedure of linking this manifold to four-dimensional physics is called string compactification, and in these lectures we will review it quite extensively. We will start with a very brief introduction to string theory, in particular we will work out its massless spectrum and show how the condition on the number of dimensions arises. We will then dwell on the different possible internal manifolds, starting from the simplest to the most relevant phenomenologically. We will show that these are most elegantly described by an extension of ordinary Riemannian geometry termed generalized geometry, first introduced by Hitchin. We shall finish by discussing (partially) open problems in string phenomenology, such as the embedding of the Standard Model and obtaining de Sitter solutions.

Program

1. Introduction to low energy limit of string theory
    a. Bosonic string
    b. Superstring
    c. D-branes and orientifold planes
2. Compactifications without fluxes

a. Toroidal compactifications
b. Dualities
c. Calabi-Yau compactifications
d. Effective 4D theories

3. Compactifications with fluxes

a. Introduction to fluxes
b. G-structures

4. Generalized geometry

a. Generalized complex geometry
b. Application to string compactifications

5. Compactifications in generalized geometries

a. Effective 4D theories
b. Supersymmetric vacua
c. Dualities and non-geometric fluxes
d. U-duality and exceptional generalized geometry

6. Open problems in phenomenology

a. Embedding the Standard Model
b. Moduli stabilization and stringy corrections to 4D theory
c. De Sitter vacua

Bibliography

- Introduction to string theory:

- Michael Green, John H. Schwarz and Edward Witten (1987) "Superstring theory", Cambridge University Press.
- Polchinski, Joseph (1998) "String Theory". Cambridge University Press Johnson, Clifford (2003). "D-branes". Cambridge: Cambridge University Press, or his lectures online "D-brane primer,'' hep-th/0007170.
- Becker, Katrin, Becker, Melanie, and Schwarz, John H. (2007) "String Theory and M-Theory: A Modern Introduction". Cambridge University Press.
- Kiritsis, Elias (2007) "String Theory in a Nutshell". Princeton University Press.

- Compactifications with and without fluxes: great deal of what will be coveres is in the review paper (where the original references can be found):

- M. Graña, "Flux compactifications in string theory : a comprehensive review", Phys. Rept. 423: 91-158, 2006, hep-th/0509003.

- More details on CY compactifications

- P. Candelas, "Lectures on Complex Manifolds," published in Superstrings' 87, Proceedings of the 1987 ICTP Spring School, pp. 1-88.

-Review on generalized complex geometry for physicists with emphasis on application to flux compactifications

- P. Koerber, "Lectures on Generalized Complex Geometry for Physicists," Fortsch. Phys. 59, 169 (2011), arXiv:1006.1536 [hep-th]

- Generalized Geometry in mathematics:

- N. Hitchin, "Generalized Calabi-Yau manifolds," Quart. J. Math. Oxford Ser. 54 281 (2003), arXiv:math/0209099 [math.dg]
- M. Gualtieri, "Generalized complex geometry," arXiv:math/0401221 [math.dg]

- Generalized geometry in physics:

- M. Graña, R. Minasian, M. Petrini and A. Tomasiello, "Supersymmetric backgrounds from generalized Calabi-Yau manifolds," JHEP 0408, 046 (2004) arXiv:hep-th/0406137
- M. Graña, R. Minasian, M. Petrini and A. Tomasiello, "Generalized structures of N=1 vacua," JHEP 0511, 020 (2005) arXiv:hep-th/0505212

- Compactifications on generalized geometries in physics:

- M. Graña, J. Louis and D. Waldram, "Hitchin functionals in N=2 supergravity," JHEP 0601, 008 (2006) arXiv: hep-th/0505264
- M. Graña, J. Louis and D. Waldram, "SU(3) x SU(3) compactifications and mirror duals of magnetic fluxes," JHEP 0704, 101 (2007) arXiv: hep-th/0612237

- Dualities (only T-duality) and non-geometric fluxes

- B. Wecht, "Lectures on Nongeometric Flux Compactifications", Class. Quant. Grav., 2007, 24, S773-S794, arXiv:0708.3984 [hep-th]

- Exceptional generalized geometry:

- C. M. Hull, "Generalised geometry for M-theory," JHEP 0707, 079 (2007) hep-th/0701203
- P. P. Pacheco and D. Waldram, "M-theory, exceptional generalized geometry and superpotentials," JHEP 0809, 123 (2008), arXiv:0804.1362 [hep-th]
- M. Graña, J. Louis, A. Sim and D. Waldram, "E7(7) formulation of N=2 backgrounds," JHEP 0907, 104 (2009) arXiv:0904.2333 [hep-th]

-The part on phenomenology is discussed in the review on flux compactifications. Since 2005 there were lots of developments, but there are no new reviews. A review on the difficulties in obtaining de Sitter vacua at the classical level is

- T. Wrase and M. Zagermann, ``On Classical de Sitter Vacua in String Theory,'' Fortsch. Phys. 58, 906 (2010) [arXiv:1003.0029 [hep-th]].