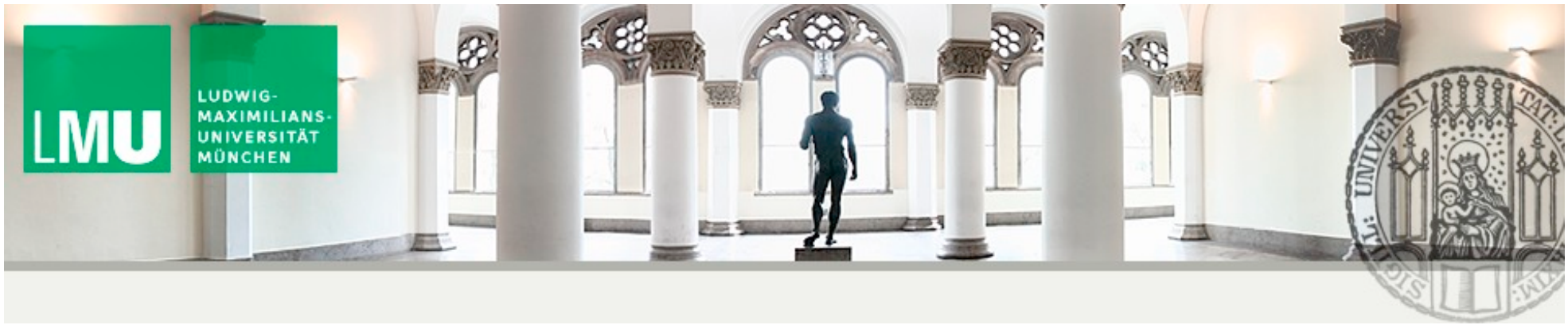
LMU

MAX-PLANCK-GESELLSCHAFT

20 Years of String Theory In Munich

Dieter Lüst, LMU (ASC) and MPP Garching



Course Summer Term 2025 at LMU

Outline (preliminary)

08. May: Intersecting Brane Worlds Models (Chios, 2004)

15. May: Moduli Stabilisation and Entropy Maximization in Type II Calabi-Yau compactifications (Eurostrings Cambridge, 2006)

21. May: String Amplitudes for the LHC in D-brane Compactifications (Dublin, 2009)

28. May: Emergent String Geometry from Particles Species (Corfu, 2011)

12. June: Strings and non-commutative/non-associative geometry (Corfu, 2012)

18. June: Classical and Quantum Black Hole Hair (Cuba, 2016)

3. July: Higher Spin Theories, AdS Distance and the Swampland (StringPheno CERN, 2019)

10. July: Minimal Black Holes and Species Thermodynamics (Harvard, 2023)

17. July: Swampland and Dark Relations (Sifnos, 2024)

Intersecting Brane Models

(8. May 2025)

Primary Goals:

- Derive the (supersymmetric) Standard Model from String Compactifications.
- Derive the couplings and the low energy effective action of the SM fields.

State of the art in 2003/2004:

- Heterotic string constructions: Calabi-Yau compactifications, orbifolds, fermionic and bosonic constructions.
- Effective SUGRA models, SUSY breaking by non-perturbative gaugino condensation.

Intersecting Brane Models

(8. May 2025)

Further progress in the field:

- Moduli stabilization and SUSY breaking by fluxes (KKLT)
- F-theory compactifications
- Swampland constraints (exclusion from bottom-up)

Yet no fully complete derivation of the SM from string theory.

Intersecting Brane Models

(8. May 2025)

C.~Bachas,
``A Way to break supersymmetry,''[arXiv:hep-th/9503030 [hep-th]].

R.~Blumenhagen, L.~Görlich, B.~Körs and D.~Lüst,
``Noncommutative compactifications of type I strings on tori with magnetic background flux,''
JHEP \textbf{10} (2000), 006 [arXiv:hep-th/0007024 [hep-th]].

C.~Angelantonj, I.~Antoniadis, E.~Dudas and A.~Sagnotti,
``Type I strings on magnetized orbifolds and brane transmutation,''
Phys. Lett. B \textbf{489} (2000), 223-232 [arXiv:hep-th/0007090 [hep-th]].

L.~E.~Ibanez, F.~Marchesano and R.~Rabadan,
``Getting just the standard model at intersecting branes,''JHEP \textbf{11} (2001), 002
[arXiv:hep-th/0105155 [hep-th]].

R.~Blumenhagen, B.~Körs, D.~Lüst and T.~Ott,
``The standard model from stable intersecting brane world orbifolds,''
Nucl. Phys. B \textbf{616} (2001), 3-33 [arXiv:hep-th/0107138 [hep-th]].

M.~Cvetic, G.~Shiu and A.~M.~Uranga,
``Chiral four-dimensional N=1 supersymmetric type 2A orientifolds from intersecting D6 branes,'' Nucl. Phys. B \textbf{615} (2001), 3-32
arXiv:hep-th/0107166 [hep-th]].

R.~Blumenhagen, B.~Körs, D.~Lüst and S.~Stieberger,
``Four-dimensional String Compactifications with D-Branes, Orientifolds and Fluxes,''
Phys. Rept. \textbf{445} (2007), 1-193 [arXiv:hep-th/0610327 [hep-th]].

Moduli Stabilisation and Entropy Maximisation in Type II Calabi-Yau Compactifications

(15. May 2025)

Primary Goals:

- Stabilization of all moduli and mass generation for all scalar field
- Breaking of space-time supersymmetry
- Search for de Sitter vacua with a small positive cosmological constant

State of the art in 2003/2004:

- Construction of flux vacua for type IIB (GKP)
- Non-perturbative superpotentials (also known from heterotic strings in the 90's)
- KKLT anti-brane uplift (also known from DT)

Moduli Stabilisation and Entropy Maximisation in Type II Calabi-Yau Compactifications

Further progress in the field: (15. May 2025)

- A lot of challenges for KKLT were identified:
  - Stability problems of the anti-brane uplift, tadpole constraints, scale separation, …
  - Swampland constraints against de Sitter and scale separation
  - General quantum gravity arguments against de Sitter
- Many explicit KKLT constructions
- Swampland: the Dark Dimension scenario

Still a lot of controversial debate about KKLT and de Sitter vacua. So after 22 years the issue is not yet settled !

Moduli Stabilisation and Entropy Maximisation in Type II Calabi-Yau Compactifications

(15. May 2025)

T.~R.~Taylor and C.~Vafa,
``R R flux on Calabi-Yau and partial supersymmetry breaking,''
Phys. Lett. B \textbf{474} (2000), 130-137 [arXiv:hep-th/9912152 [hep-th]].

S.~Gukov, C.~Vafa and E.~Witten,``CFT's from Calabi-Yau four folds,''
Nucl. Phys. B \textbf{584} (2000), 69-108
[erratum: Nucl. Phys. B \textbf{608} (2001), 477-478][arXiv:hep-th/9906070 [hep-th]].

P.~Mayr,``On supersymmetry breaking in string theory and its realization in brane worlds,''
Nucl. Phys. B \textbf{593} (2001), 99-126 [arXiv:hep-th/0003198 [hep-th]].

R.~Bousso and J.~Polchinski,
``Quantization of four form fluxes and dynamical neutralization of the cosmological constant,'' JHEP \textbf{06} (2000), 006 [arXiv:hep-th/0004134 [hep-th]].

G.~Curio, A.~Klemm, D.~Lüst and S.~Theisen,
``On the vacuum structure of type II string compactifications on Calabi-Yau spaces with H fluxes,''Nucl. Phys. B \textbf{609} (2001), 3-45 [arXiv:hep-th/0012213 [hep-th]].

S.~B.~Giddings, S.~Kachru and J.~Polchinski,
``Hierarchies from fluxes in string compactifications,'' Phys. Rev. D \textbf{66} (2002), 106006 [arXiv:hep-th/0105097 [hep-th]].

R.~Blumenhagen, D.~Lüst and T.~R.~Taylor,
``Moduli stabilization in chiral type IIB orientifold models with fluxes,''
Nucl. Phys. B \textbf{663} (2003), 319-342 [arXiv:hep-th/0303016 [hep-th]].

S.~Kachru, R.~Kallosh, A.~D.~Linde and S.~P.~Trivedi,
``De Sitter vacua in string theory,'' Phys. Rev. D \textbf{68} (2003), 046005 [arXiv:hep-th/0301240 [hep-th]].