

25 projects in string theory – choose one!

Contents

1	Projects	2
1.1	Conformal field theory in two dimensions: fundamental aspects	2
1.2	Conformal field theory in two dimensions: KZ equation	2
1.3	Conformal field theory in two dimensions: Monster symmetry	2
1.4	Path integrals versus operators	2
1.5	Supersymmetry	2
1.6	String phenomenology	2
1.7	String cosmology	2
1.8	String philosophy?	2
1.9	Cosmological constant problem	2
1.10	String-inspired point particles	2
1.11	Quantization of gauge systems: BRST	2
1.12	Hawking radiation and information paradox	2
1.13	Anomalies – quantum effects that break gauge symmetry	2
1.14	Curved extra dimensions: Calabi-Yau	2
1.15	String theory and number theory	2
1.16	Cosmic strings	2
1.17	String theory, quarks and gluons	2
1.18	D-branes: fluid dynamics	2
1.19	D-branes: materials physics	2
1.20	Can string theory help with the foundations of quantum mechanics?	2
1.21	String theory, representation theory and statistical physics	2
1.22	String theory and computer science	2
1.23	New formulations of superstring theory	2
1.24	One graviton = two gluons?	2

General comments

The objective of these is to get a little deeper into one topic than in Polchinski.

1 Projects

- 1.1 Conformal field theory in two dimensions: fundamental aspects
- 1.2 Conformal field theory in two dimensions: KZ equation
- 1.3 Conformal field theory in two dimensions: Monster symmetry
- 1.4 Path integrals versus operators
- 1.5 Supersymmetry
- 1.6 String phenomenology
- 1.7 String cosmology
- 1.8 String philosophy?
- 1.9 Cosmological constant problem
- 1.10 String-inspired point particles
- 1.11 Quantization of gauge systems: BRST
- 1.12 Hawking radiation and information paradox
- 1.13 Anomalies – quantum effects that break gauge symmetry
- 1.14 Curved extra dimensions: Calabi-Yau
- 1.15 String theory and number theory
- 1.16 Cosmic strings
- 1.17 String theory, quarks and gluons
- 1.18 D-branes: fluid dynamics
- 1.19 D-branes: materials physics
- 1.20 Can string theory help with the foundations of quantum mechanics?
- 1.21 String theory, representation theory and statistical physics
- 1.22 String theory and computer science
- 1.23 New formulations of superstring theory
- 1.24 One graviton = two gluons?

References

- [1] R. Blumenhagen and E. Plauschinn, "Introduction to conformal field theory : with applications to String theory," Lect. Notes Phys. **779** (2009) 1.
- [2] J. McGreevy, "TASI lectures on quantum matter (with a view toward holographic duality)," arXiv:1606.08953 [hep-th].
- [3] J. McGreevy, "Whence QFT?", föreläsningsanteckningar till kurs på University of California at San Diego (2014): <http://physics.ucsd.edu/~mcgreevy/s14/239a-lectures.pdf>

- [4] "Lundamodellen", som den heter på skånska:
https://en.wikipedia.org/wiki/Lund_string_model
 är inbyggd i standardmjukvaran Pythia i partikelfysik:
<http://home.thep.lu.se/~torbjorn/Pythia.html>
 Sådana här varianter tycker jag är mer förståeliga:
 A. Casher, H. Neuberger and S. Nussinov, "Chromoelectric Flux Tube Model of Particle Production," *Phys. Rev. D* **20** (1979) 179. doi:10.1103/PhysRevD.20.179
- [5] O. Aharony and Z. Komargodski, "The Effective Theory of Long Strings," *JHEP* **1305** (2013) 118 doi:10.1007/JHEP05(2013)118 [arXiv:1302.6257 [hep-th]].
- [6] "The LQG Landscape", bloggdiskussion
<https://golem.ph.utexas.edu/distler/blog/archives/000855.html>
- [7] R. C. Helling, "Lessons from the LQG string," hep-th/0610193.
- [8] H. Nicolai, K. Peeters and M. Zamaklar, "Loop quantum gravity: An Outside view," *Class. Quant. Grav.* **22** (2005) R193 doi:10.1088/0264-9381/22/19/R01 [hep-th/0501114].
- [9] T. Nishioka, S. Ryu and T. Takayanagi, "Holographic Entanglement Entropy: An Overview," *J. Phys. A* **42** (2009) 504008 doi:10.1088/1751-8113/42/50/504008 [arXiv:0905.0932 [hep-th]].
- [10] F. Pastawski and J. Preskill, "Code properties from holographic geometries," arXiv:1612.00017 [quant-ph].
- [11] R. Bousso, "Universal Limit on Communication," arXiv:1611.05821 [hep-th].
- [12] R. Bousso, "Flat space physics from holography," *JHEP* **0405** (2004) 050 doi:10.1088/1126-6708/2004/05/050 [hep-th/0402058].
- [13] M. Freedman and M. Headrick, "Bit threads and holographic entanglement," arXiv:1604.00354 [hep-th].
- [14] A. Cappelli, E. Castellani, F. Colomo and P. Di Vecchia, "The birth of string theory," Obs: de flesta av kapitlen finns på arXiv, t.ex. Ramonds på <https://arxiv.org/abs/0708.3656>, med kommentaren om Neveu-Schwarz artikel "I remain to this day baffled by their lack of acknowledgment of the seminal role of my work."
- [15] "Elemental Ideas – String Theory Part Two", Video från Cambridge, <http://www.cambridge-tv.co.uk/elemental-ideas-string-theory-part-two/>
- [16] C. Angelantonj and A. Sagnotti, "Open strings," *Phys. Rept.* **371** (2002) 1 Erratum: [*Phys. Rept.* **376** (2003) no.6, 407] doi:10.1016/S0370-1573(02)00273-9, 10.1016/S0370-1573(03)00006-1 [hep-th/0204089].
- [17] C. Itzykson and J. M. Drouffe, "Statistical Field Theory. Vol. 2: Strong Coupling, Monte Carlo Methods, Conformal Field Theory, And Random Systems," Cambridge, UK: Univ. Pr. (1989) 405-810
- [18] E. H. Fradkin, "Field Theories of Condensed Matter Physics," *Front. Phys.* **82** (2013) 1.
- [19] E. S. Fradkin and A. A. Tseytlin, "Nonlinear Electrodynamics from Quantized Strings," *Phys. Lett.* **163B** (1985) 123. doi:10.1016/0370-2693(85)90205-9
- [20] K. Peeters, P. Vanhove and A. Westerberg, "Towards complete string effective actions beyond leading order," *Fortsch. Phys.* **52** (2004) 630 doi:10.1002/prop.200310155 [hep-th/0312211].
- [21] N. Berkovits, "Origin of the Pure Spinor and Green-Schwarz Formalisms," *JHEP* **1507** (2015) 091 doi:10.1007/JHEP07(2015)091 [arXiv:1503.03080 [hep-th]].

- [22] J. Bjornsson, "Multi-loop amplitudes in maximally supersymmetric pure spinor field theory," JHEP **1101** (2011) 002 doi:10.1007/JHEP01(2011)002 [arXiv:1009.5906 [hep-th]].
- [23] J. Bjornsson and M. B. Green, "5 loops in 24/5 dimensions," JHEP **1008** (2010) 132 doi:10.1007/JHEP08(2010)132 [arXiv:1004.2692 [hep-th]].
- [24] O. A. Bedoya and N. Berkovits, "GGI Lectures on the Pure Spinor Formalism of the Superstring," arXiv:0910.2254 [hep-th].
- [25] K. Peeters, "Introducing Cadabra: A Symbolic computer algebra system for field theory problems," hep-th/0701238 [HEP-TH].
Hemsida: <http://cadabra.science/>
- [26] J. Fuchs, "Affine Lie algebras and quantum groups: An Introduction, with applications in conformal field theory," (1992), Cambridge.
- [27] J. Cohn, D. Friedan, Z. a. Qiu and S. H. Shenker, "Covariant Quantization of Supersymmetric String Theories: The Spinor Field of the Ramond-neveu-schwarz Model," Nucl. Phys. B **278** (1986) 577. doi:10.1016/0550-3213(86)90053-2
- [28] O. Schlotterer, "Scattering amplitudes in open string theory" (2011), avhandling på LMU München,
https://edoc.ub.uni-muenchen.de/13381/1/Schlotterer_Oliver.pdf
- [29] P. Di Francesco, P. Mathieu, D. Senechal, "Conformal Field Theory" (1992)
<http://www.springer.com/gp/book/9780387947853>
- [30] P. H. Ginsparg, "Applied Conformal Field Theory," hep-th/9108028.
- [31] T. Gannon, "Moonshine beyond the MonsterThe Bridge Connecting Algebra, Modular Forms and Physics," (2010), Cambridge.
- [32] S. Kachru, "Elementary introduction to Moonshine," arXiv:1605.00697 [hep-th].
- [33] S. Rychkov, "EPFL Lectures on Conformal Field Theory in $D \geq 3$ Dimensions," doi:10.1007/978-3-319-43626-5 arXiv:1601.05000 [hep-th].
- [34] A. Svensson, "Path Integral for the Hydrogen Atom: Solutions in two and three dimensions" (2016), examensarbete på KaU, fulltext från DiVA:
<http://kau.diva-portal.org/smash/record.jsf?pid=diva2%3A947133&dswid=1483003935491>
- [35] P. Cartier and C. DeWitt-Morette, "Functional IntegrationAction and Symmetries," (2010), Cambridge.
- [36] H. Kleinert, "Path Integrals in Quantum Mechanics, Statistics, Polymer Physics, and Financial Markets," World Scientific, Singapore, 2004
- [37] H. Kleinert, "Gauge fields in condensed matter. Vol. 2: Stresses and defects. Differential geometry, crystal melting," Singapore, Singapore: World Scientific (1989) 744-1456
- [38] S. P. Martin, "A Supersymmetry primer," Adv. Ser. Direct. High Energy Phys. **21** (2010) 1 [hep-ph/9709356].
- [39] I. J. R. Aitchison, "Supersymmetry in Particle Physics. An Elementary Introduction," Cambridge, UK: Univ. Pr. (2007) 222 p
- [40] L. E. Ibanez and A. M. Uranga, "String theory and particle physics: An introduction to string phenomenology,"

- [41] E. Kiritsis, “String theory in a nutshell,” Princeton University Press, 2007
- [42] R. Dawid, “String theory and the scientific method,” (2013), doi:10.1017/CBO9781139342513
- [43] J. Polchinski, “Why trust a theory? Some further remarks (part 1),” arXiv:1601.06145 [hep-th].
- [44] J. Conlon, “Why string theory?,” (2016).
- [45] D. Baumann and L. McAllister, “Inflation and String Theory,” arXiv:1404.2601 [hep-th].
- [46] S. Kachru, R. Kallosh, A. D. Linde, J. M. Maldacena, L. P. McAllister and S. P. Trivedi, “Towards inflation in string theory,” JCAP **0310** (2003) 013 doi:10.1088/1475-7516/2003/10/013 [hep-th/0308055].
- [47] P. A. R. Ade *et al.* [Planck Collaboration], “Planck 2015 results. XX. Constraints on inflation,” Astron. Astrophys. **594** (2016) A20 doi:10.1051/0004-6361/201525898 [arXiv:1502.02114 [astro-ph.CO]].
- [48] L. A. Anchordoqui *et al.*, “String Resonances at Hadron Colliders,” Phys. Rev. D **90** (2014) no.6, 066013 doi:10.1103/PhysRevD.90.066013 [arXiv:1407.8120 [hep-ph]].
- [49] J. Kretzschmar [ATLAS and CMS Collaborations], “Searches for extra dimensions with the ATLAS and CMS detectors,” Nucl. Part. Phys. Proc. **273-275** (2016) 541. doi:10.1016/j.nuclphysbps.2015.09.080
- [50] The ATLAS collaboration [ATLAS Collaboration], “Search for supersymmetry with two and three leptons and missing transverse momentum in the final state at $\sqrt{s}=13$ TeV with the ATLAS detector,” ATLAS-CONF-2016-096.
- [51] J. Polchinski, “The Cosmological Constant and the String Landscape,” hep-th/0603249.
- [52] S. Weinberg, “The Cosmological Constant Problem,” Rev. Mod. Phys. **61** (1989) 1. doi:10.1103/RevModPhys.61.1
- [53] C. Schubert, “Perturbative quantum field theory in the string inspired formalism,” Phys. Rept. **355** (2001) 73 doi:10.1016/S0370-1573(01)00013-8 [hep-th/0101036].
- [54] F. Bastianelli and P. van Nieuwenhuizen, “Path integrals and anomalies in curved space,” (2006), Cambridge.
- [55] M. Berg, I. Buchberger and O. Schlotterer, “String-motivated one-loop amplitudes in gauge theories with half-maximal supersymmetry,” arXiv:1611.03459 [hep-th].
- [56] M. Henneaux and C. Teitelboim, “Quantization of gauge systems,” Princeton, USA: Univ. Pr. (1992) 520 p
- [57] Z. Bern, L. J. Dixon, F. Febres Cordero, S. Höche, H. Ita, D. A. Kosower, D. Maître and K. J. Ozeren, “The BlackHat Library for One-Loop Amplitudes,” J. Phys. Conf. Ser. **523** (2014) 012051 doi:10.1088/1742-6596/523/1/012051 [arXiv:1310.2808 [hep-ph]].
- [58] J. J. M. Carrasco, “Gauge and Gravity Amplitude Relations,” arXiv:1506.00974 [hep-th].
- [59] H. Kawai, D. C. Lewellen and S. H. H. Tye, “A Relation Between Tree Amplitudes of Closed and Open Strings,” Nucl. Phys. B **269** (1986) 1.
- [60] S. Kachru, R. Kallosh, A. D. Linde and S. P. Trivedi, “De Sitter vacua in string theory,” Phys. Rev. D **68** (2003) 046005, [hep-th/0301240].
- [61] G. T. Horowitz and J. Polchinski, “Gauge/gravity duality,” In *Oriti, D. (ed.): Approaches to quantum gravity* 169-186 [gr-qc/0602037].

- [62] S. He and O. Schlotterer, "Loop-level KLT, BCJ and EYM amplitude relations," arXiv:1612.00417 [hep-th].
- [63] A. K. Ridgway and M. B. Wise, "Static Spherically Symmetric Kerr-Schild Metrics and Implications for the Classical Double Copy," Phys. Rev. D **94** (2016) no.4, 044023 doi:10.1103/PhysRevD.94.044023 [arXiv:1512.02243 [hep-th]].
- [64] L. Alvarez-Gaume and E. Witten, "Gravitational Anomalies," Nucl. Phys. B **234** (1984) 269. doi:10.1016/0550-3213(84)90066-X
- [65] M. B. Green and J. H. Schwarz, "Anomaly Cancellation in Supersymmetric D=10 Gauge Theory and Superstring Theory," Phys. Lett. **149B** (1984) 117. doi:10.1016/0370-2693(84)91565-X
- [66] A. Strominger and C. Vafa, "Microscopic origin of the Bekenstein-Hawking entropy," Phys. Lett. B **379** (1996) 99 doi:10.1016/0370-2693(96)00345-0 [hep-th/9601029].
- [67] B. R. Greene, "The elegant universe: Superstrings, hidden dimensions, and the quest of the ultimate theory," New York, USA: Norton (1999) 448 p
- [68] H. Skarke, "String dualities and toric geometry: An Introduction," Chaos Solitons Fractals **10** (1999) 543 doi:10.1016/S0960-0779(98)00161-1 [hep-th/9806059].
- [69] D. Morrison, "Computing with Calabi-Yau manifolds", med övningar av Andreas Braun, <https://nms.kcl.ac.uk/sakura.schafer-nameki/GGI/scheduleSchool.html>
- [70] J. Nekovar, "Analytic Number Theory" (2004), <https://webusers.imj-prg.fr/~jan.nekovar/co/ln/el/>
(Jag hittade Nekovars kurs från att titta igenom alla anteckningar ned till nummer 49 på http://www.numbertheory.org/ntw/lecture_notes.html)
- [71] T. Apostol, "Modular Functions and Dirichlet Series in Number Theory", 2nd ed., Springer-Verlag, 1990.
- [72] H. Iwaniec, "Spectral methods of automorphic forms" (1995), American Mathematical Society.
- [73] J. Polchinski, "Introduction to cosmic F- and D-strings," hep-th/0412244. https://en.wikipedia.org/wiki/Cosmic_string
- [74] V. E. Hubeny, S. Minwalla and M. Rangamani, "The fluid/gravity correspondence," arXiv:1107.5780 [hep-th].
- [75] S. A. Hartnoll, A. Lucas and S. Sachdev, "Holographic quantum matter," arXiv:1612.07324 [hep-th].
- [76] F. Quevedo, "Is String Phenomenology an Oxymoron?," arXiv:1612.01569 [hep-th].
- [77] Römer, "Anomalien" (1997, på tyska) <http://www.itp.uni-hannover.de/saalburg/Lectures/roemer.pdf>