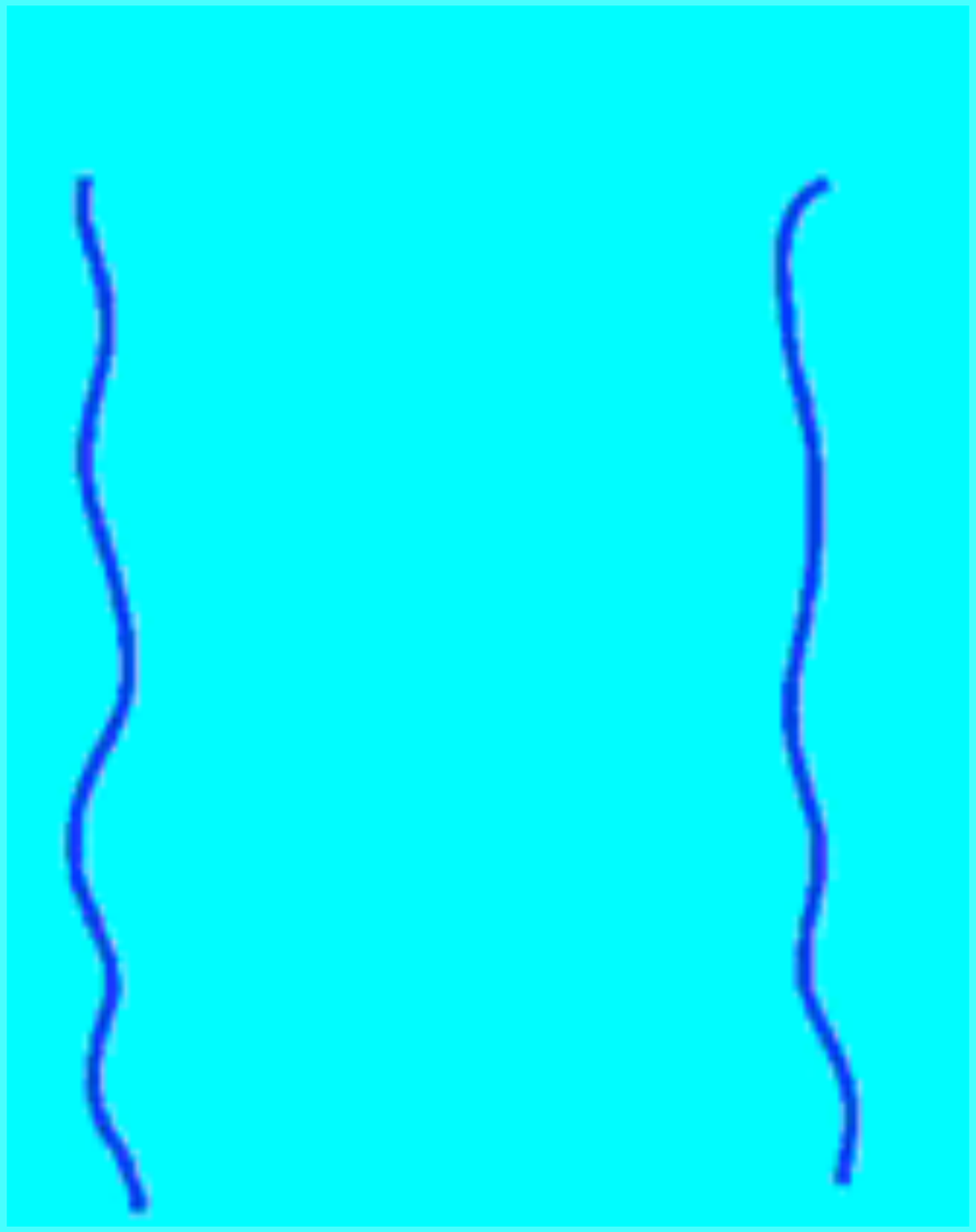
Back to the Heterotic String

Bert Schellekens

NIKHEF Jaarvergadering, 17-12-2010



Matter coupled to string gravity

Must be made of strings.
Two options: closed or open

- Closed Strings: ***“Heterotic String”***
- Open Strings: ***“Orientifolds”***

Non-perturbative: M-theory, F-theory, ...

Co-authors

- With Michele Maio:
  Permutation Orbifold of N=2 Minimal Models
  Permutations of Heterotic Gepner Models (in progress)

- With Pascal Anastasopoulos, George Leontaris and Robert Richter:
  SU(5) D-brane realizations, Yukawa Couplings and Proton Stability

- With Beatriz Gato-Rivera
  Asymmetric Gepner Models (Revisited)
  Asymmetric Gepner Models II: Heterotic Weight Lifting
  Asymmetric Gepner Models III: B-L Lifting

What can we expect to learn about the Standard Model?

"The hope is that the constraints imposed on such theories solely by the need for mathematical consistency are so strong that they essentially determine a single possible theory uniquely, and that by working out the consequences of the theory in detail one might eventually be able to show that there must be particles with precisely the masses, interactions, and so on, of the known elementary particles: in other words, that the world we live in is the only possible one."

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From "The Problems of Physics" by Antony Legget (1987)

http://www.ru.nl/thef/research/research/

The research programme aims at describing and elucidating the present and future experimental baryonic data. This involves partial-wave analysis of nucleon-(anti)nucleon scattering data and the construction of nucleon-nucleon, nucleon-hyperon and hyperon-hyperon potentials, using theoretical concepts such as chiral symmetry and effective Lagrangians. A spin-off of this programme is the study of nuclear and hyperonic matter in the context of neutron stars.

- **The landscape of string vacua**
  Staff involved: Bert Schellekens (creator of the landscape).

  String theory is a model of fundamental physics whose building blocks are one-dimensional extended objects called strings, rather than the zero-dimensional point-particles that form the basis for the Standard Model of particle physics. The goal of the research is to find among all the possible string vacua the ones that incorporate the known laws of physics. The idea of the landscape of string vacua is based on the anthropic principle, which states that fundamental

Eternally Existing Selfreproducing Chaotic Inflationary Universe.
Andrei Linde
1986

"...enormously large number of compactifications …
should be considered as a virtue of these theories"

Chiral Four-Dimensional Heterotic Strings from Selfdual Lattices.
W. Lerche, D. Lust, A.N. Schellekens
1986

“This number is of order 10^{1500}!”

Four-dimensional Strings.
A.N. Schellekens (CERN).
Uppsala EPS conference, 1987

“There is no logical reason why the “theory of everything”
should have a unique vacuum”

1998

The Anthropic landscape of string theory.
Leonard Susskind (Stanford U., Phys. Dept.). Feb 2003

The Emperor's Last Clothes? Overlooking the String Theory Landscape.
A.N. Schellekens Jul 2008. 87 pp.

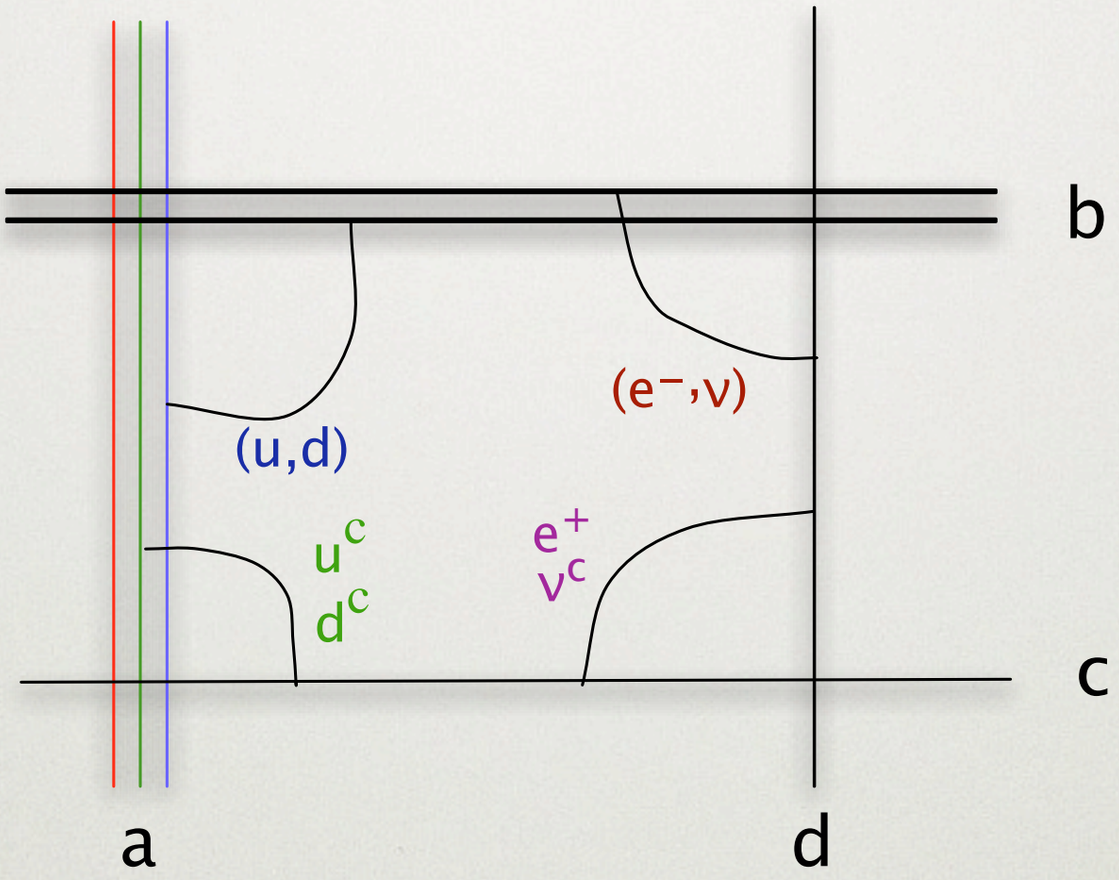
So what *can* we expect to learn about the Standard Model?

Distributions = Naturalness

- Gauge Hierarchy
- Fermion mass hierarchies
- Neutrino masses
- Suppression of proton decay
- ....

Standard Model From Orientifolds

The Madrid Model*



(*) Ibanez, Marchesano, Rabadan (2000)

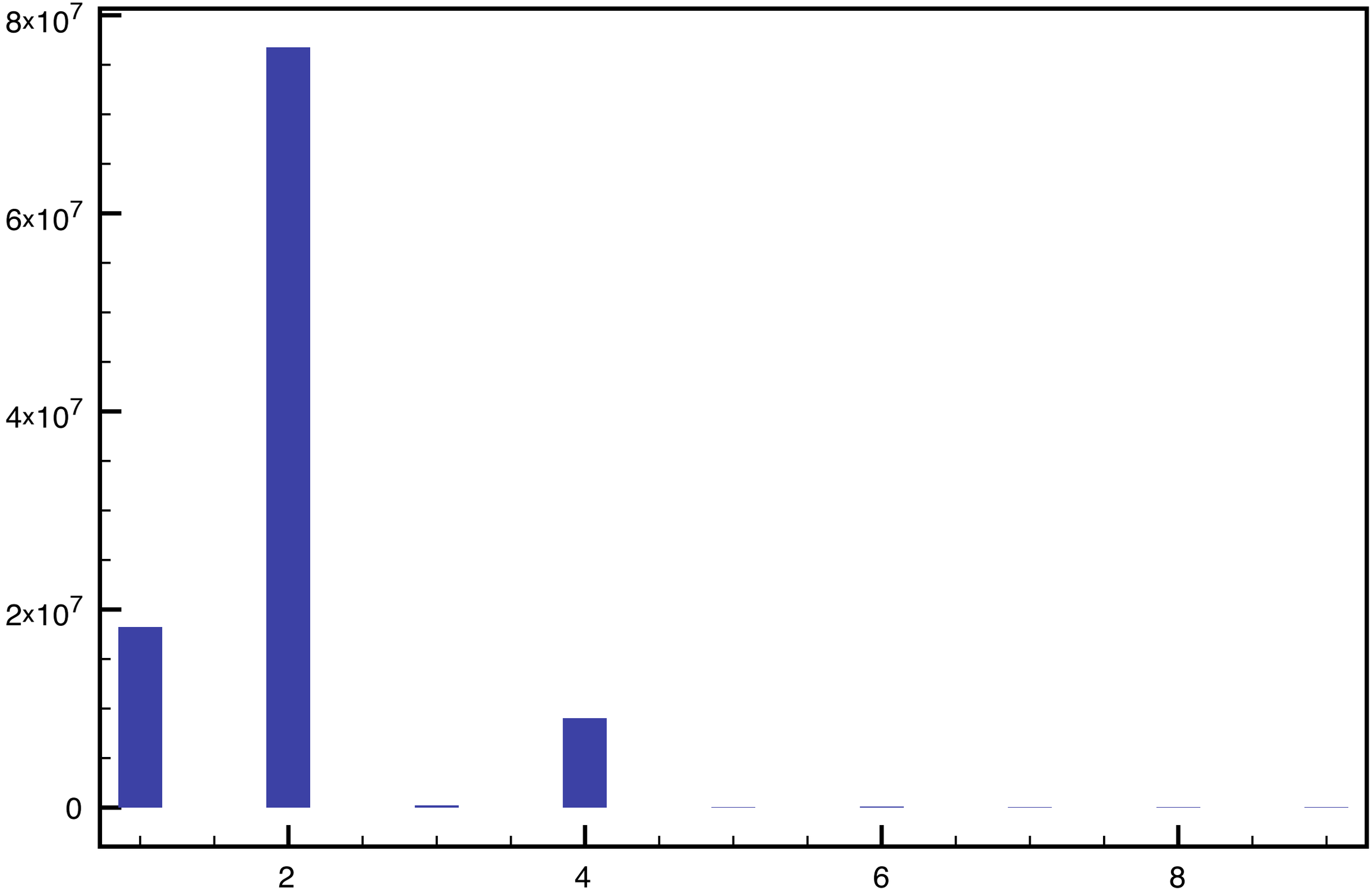
First realization of this picture was found at NIKHEF

(With Lennaert Huiszoon and Tim Dijkstra (2004))

Signal-to-noise ratio $\sim 10^{-12}$

About 200.000 “events”.

(Supersymmetric standard model “modulo moduli”)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6x10^7
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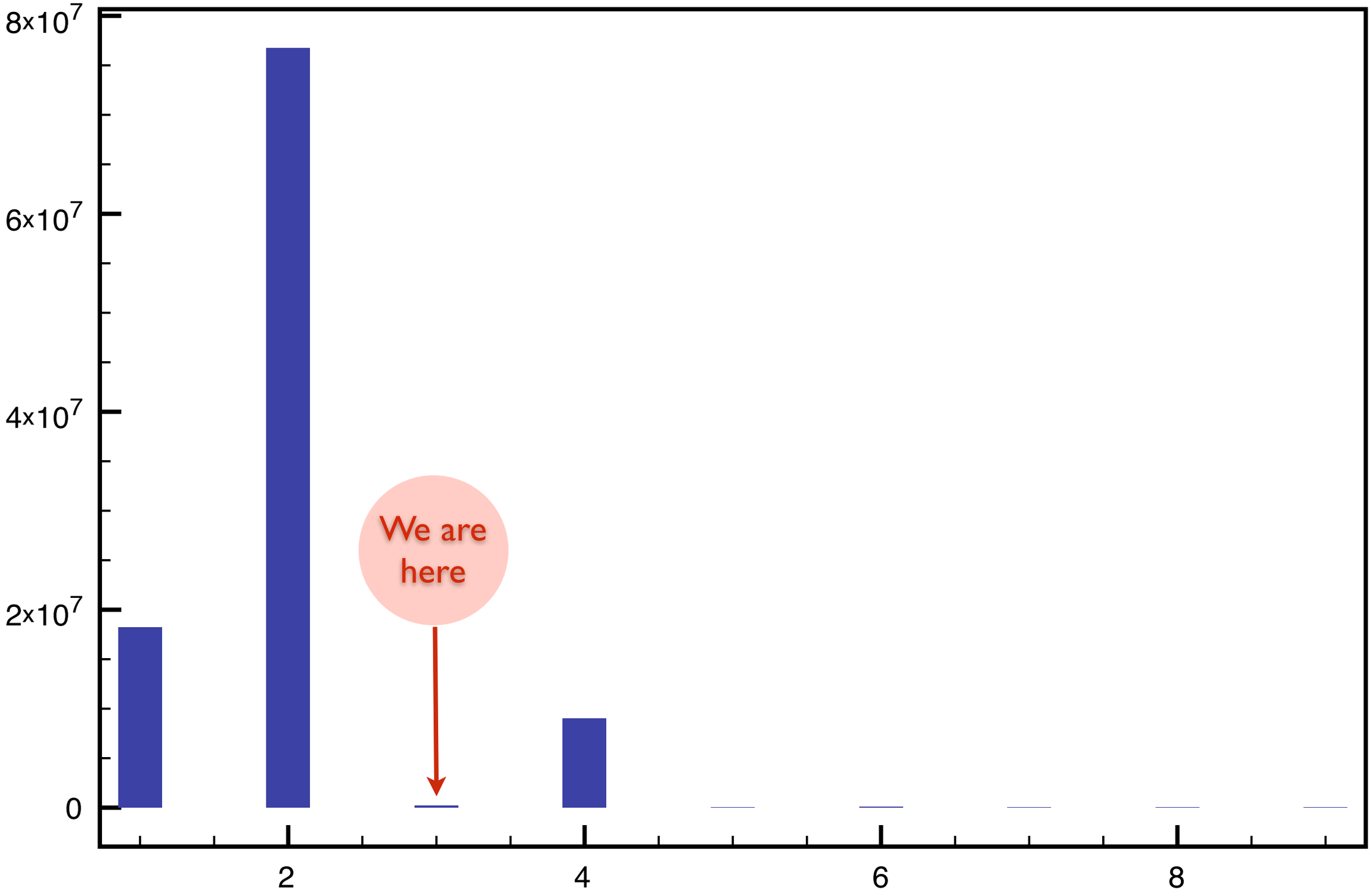
8×10^7
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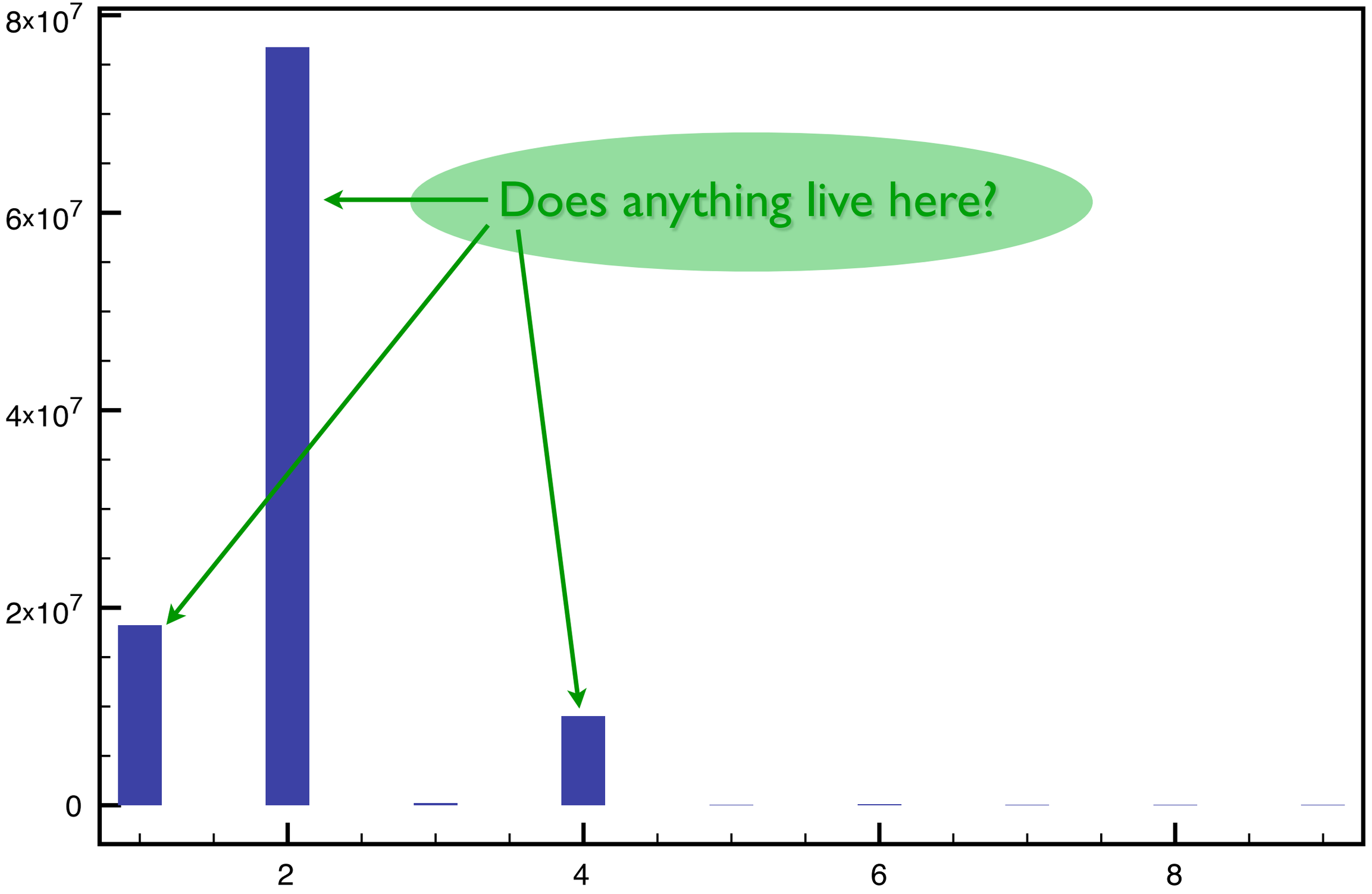
We are here


8x10^7
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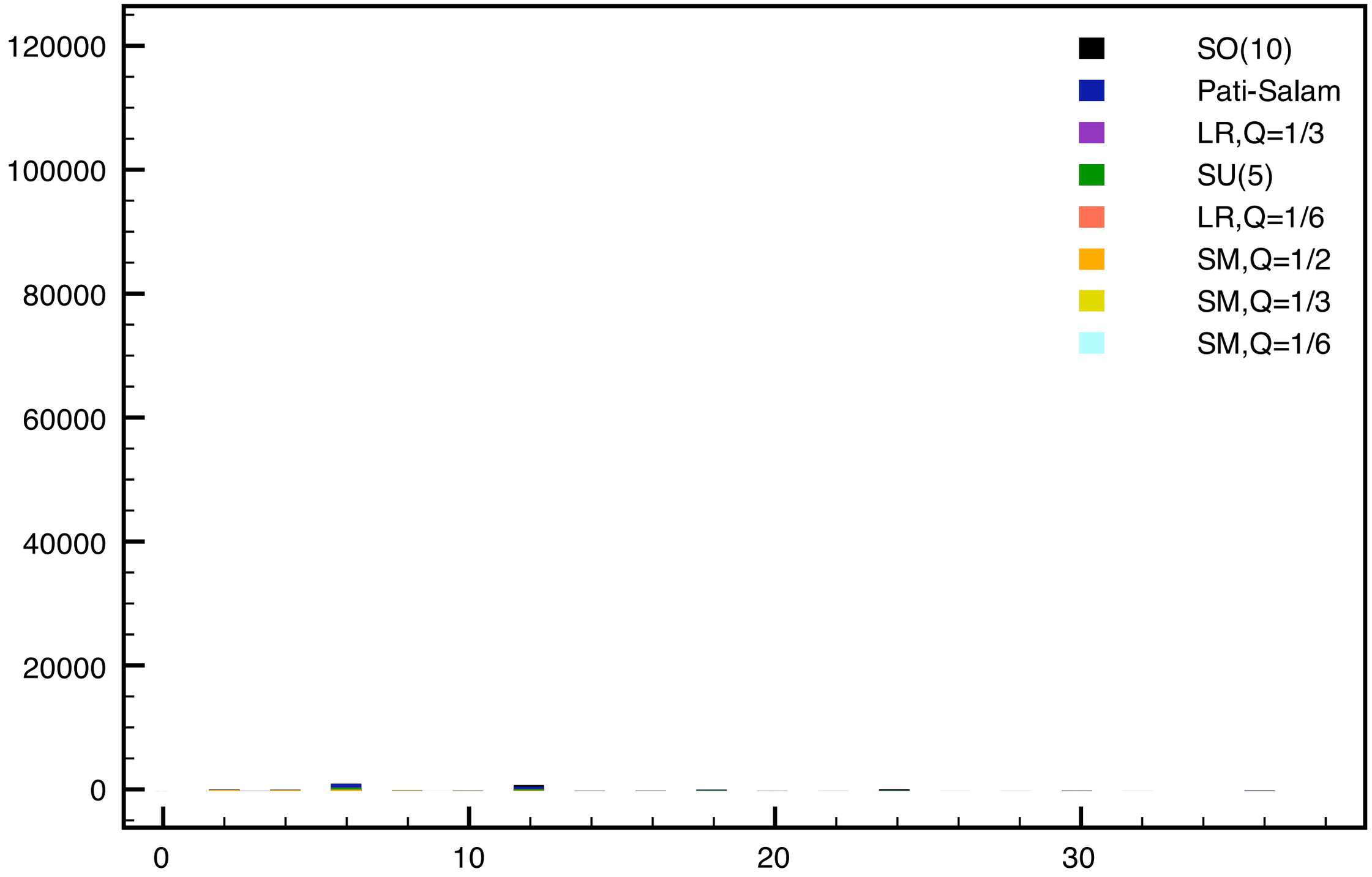
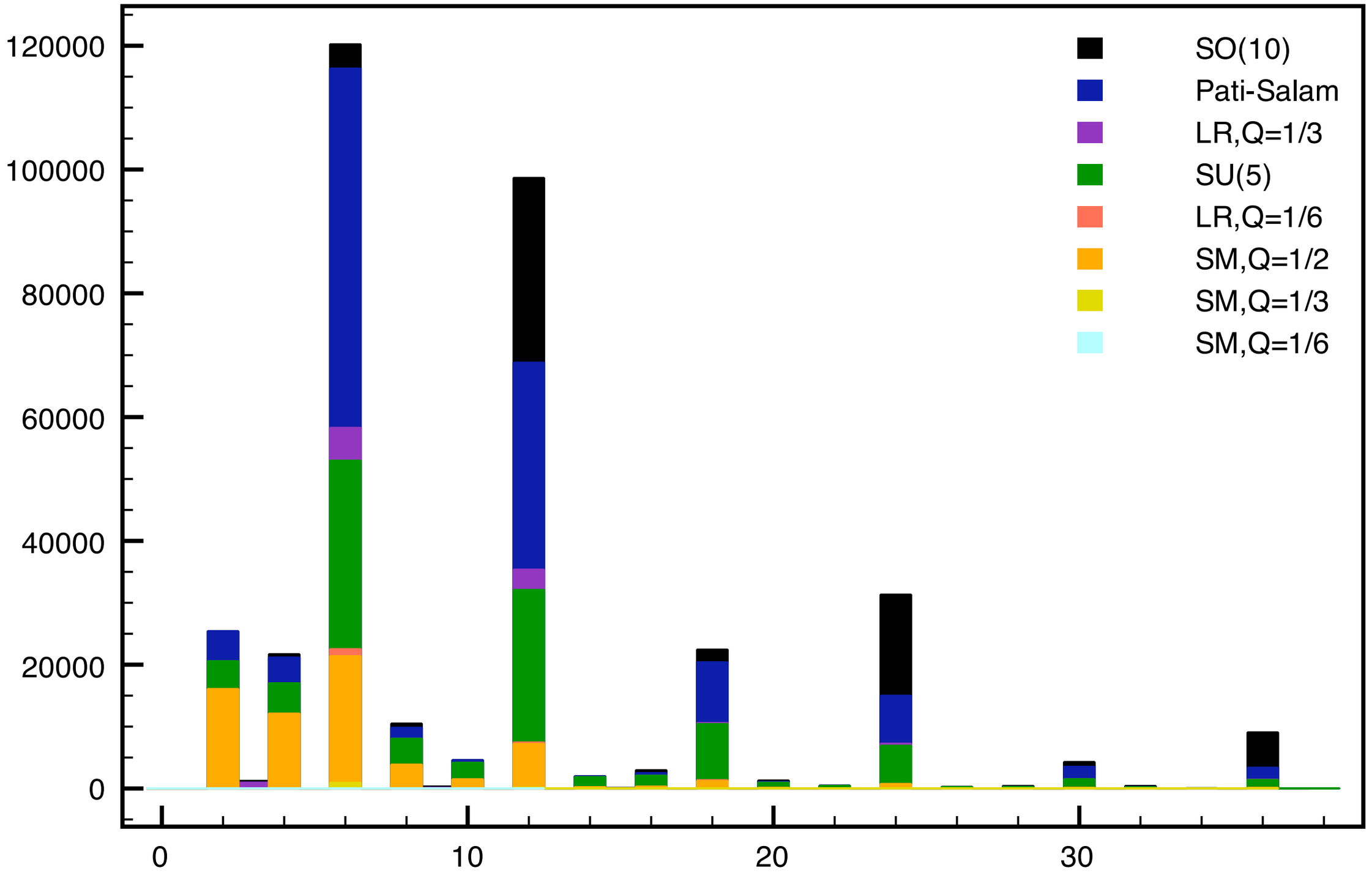
Does anything live here?

Standard Model from Heterotic Strings

With S. Yankielowicz (CERN, 1989)




120000
100000
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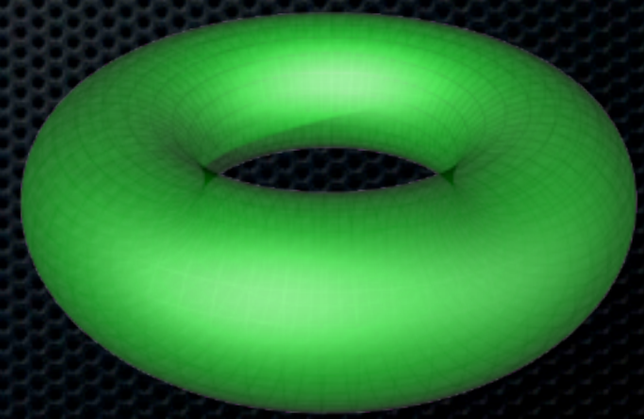
SO(10)
Pati-Salam
LR,Q=1/3
SU(5)
LR,Q=1/6
SM,Q=1/2
SM,Q=1/3
SM,Q=1/6

Heterotic strings

- Closed strings (cylinder)

- Left- and right-moving modes can be treated separately
- Non-trivial constraints at one loop (torus)



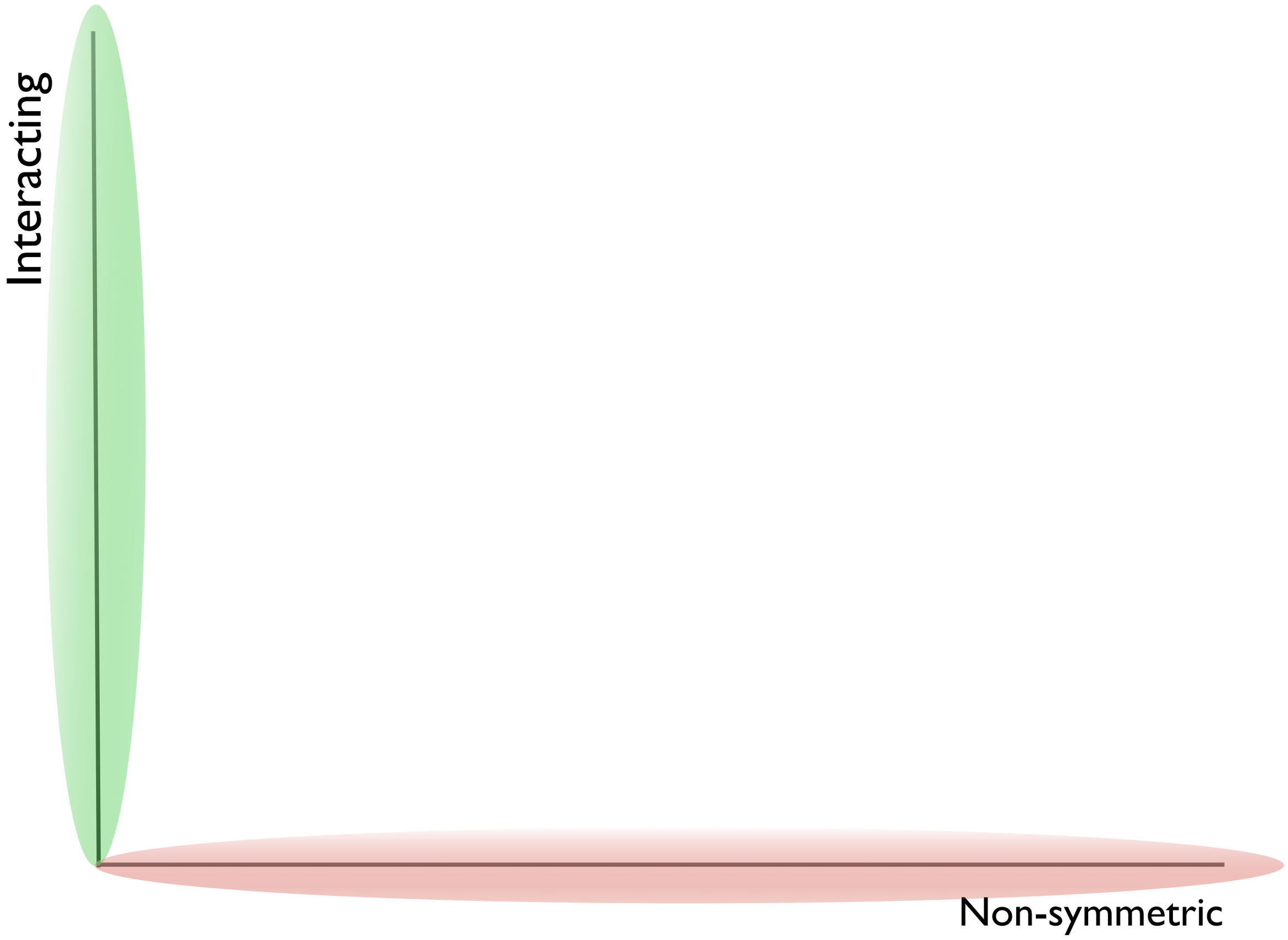
Two classes of solutions

- Use free field theory in 2 dimensions, treat modes non-symmetrically

- Treat left- and right almost* symmetrically, but use interacting field theories (D. Gepner, 1987)

(*) Bosonic String Map (Lerche, Lüst, A.N.S. 1986)

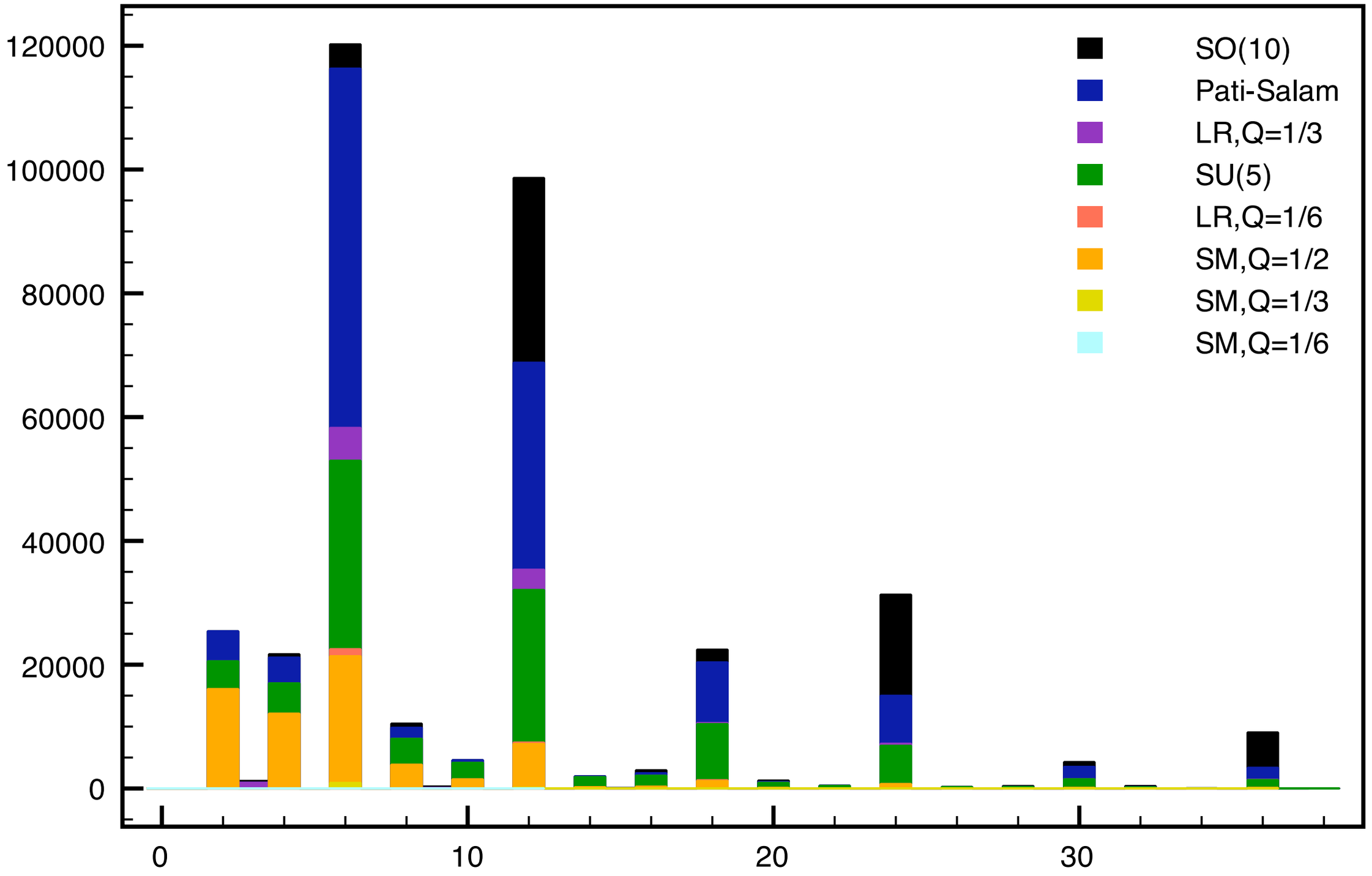
Automatically N families of (16)'s of SO(10)


Interacting
Non-symmetric

Interacting

?

Non-symmetric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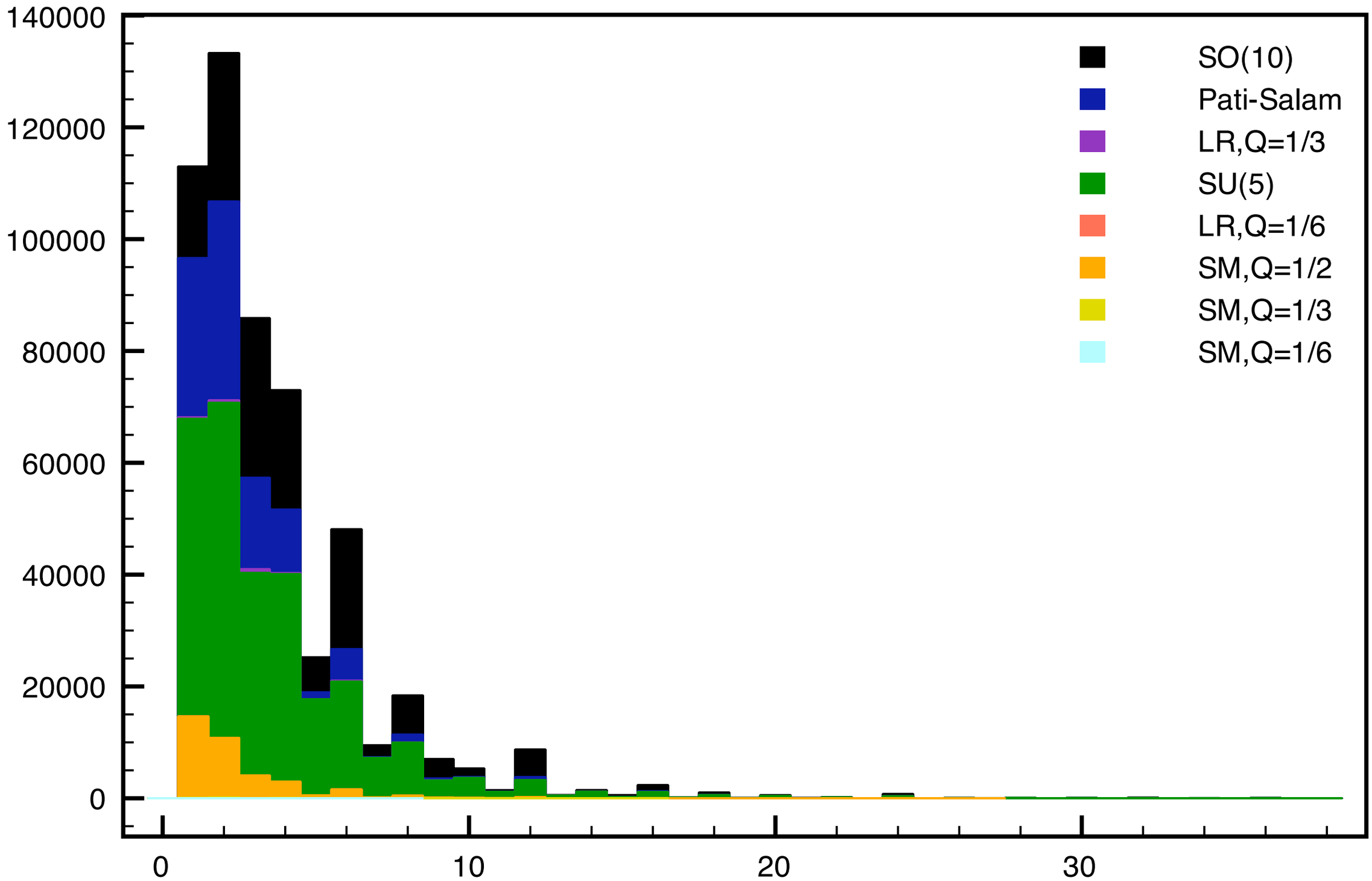
Heterotic Weight Lifting (with B. Gato-Rivera, 2010)