Geometry and Swampland

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1 Overview of the Field

Understanding the structure of quantum gravity is one of the most ambitious goals of fundamental physics. A concrete and particularly well developed framework to address specific questions of quantum gravity is string theory. String theory is consistently defined in ten dimensions, six of which should be curled up in some small internal compact manifold. The geometry of the internal compactication space is key in our understanding the prediction of string theory for the four-dimensional world we observe. The study of the internal compaction space has opened up far reaching connections between string theory and cutting-edge mathematics. The most famous example are Calabi-Yau manifolds. More recently, new very interesting connections have appeared in the context of Generalised Geometry, a generalized version of Riemannian geometry called generalized complex geometry, first developped by Hitchin.

Recently, there has been great interest in determining criteria which differentiate between effective low-energy field theories which can be consistently completed in the ultraviolet into quantum gravity, said to be in the 'Landscape', from theories which appear consistent but nonetheless defy such a coupling to quantum gravity, the so-called 'Swampland'. A number of such criteria, or Swampland Conjectures, have been proposed in the literature and attracted considerable interest in the high energy physics community. If confirmed, they have profound consequences for physics and cosmology, such as for the structure of large field inflation in early-time cosmology, or for the mechanism responsible for the observed late-time acceleration of the universe, to name but the most striking ones. On the other hand, the Swampland Conjectures translate, in the context of string theory, into conjectures regarding the structure of possible compactifications, or string geometries.

String theory is therefore in a unique position to quantitatively test - and possibly refine such general Swampland Conjectures. This Scientific Program of the workshop was to study these intriguing connections between general properties of quantum gravity and the geometry of string compactifications. What made this workshop rather unique is that it focused on the detailed interplay between the physics of the Swampland Conjectures and the mathematical structures underlying the effective field theories obtained in string theory.

2 Open Problems and goals of the workshop

The main goal of the workshop was to bring together leading physicists and mathematicians to explore the mathematical foundations of the recent Swampland Conjectures in the context of string theory. Specifically, we addressed the following points:

- Extend the analysis of the Swampland Conjectures to the topical realm of compactifications on generalized Calabi-Yau manifolds
- Achieve a better understanding of degeneration limits in moduli spaces of string compactifications and their relation to the Swampland Distance Conjecture
- Systematically explore the boundaries of the string landscape in the non-perturbative regime via geometrisation of dualities

3 Presentation Highlights in a virtual environment

The workshop started with two review talks, one on swampland and the other on generalized geometry. They served the purpose of introducing the swampland and generalised geometry communities with the ideas developed by the other, and generated fruitful discussions.

A virtual workshop is hardly comparable to a fully in-person meeting in terms of scientific interactions. However, we organised several events to foster interaction in the virtual environment which were a great success. On one hand, in addition to technical talks and reviews, we also scheduled an open discussion session everyday from Tuesday to Friday of one hour and a half long. This means that a big fraction (30%) of the workshop duration was dedicated to the discussion sessions on the central topics of the swampland programme. In the spirit of the workshop, there was also a discussion dedicated to exchanging tools between the two communities. The discussions started with a brief 20 min presentation of some invited discussion leader, to put in context the topic and highlight open questions, followed by an open discussion where everybody was invited to participate. The discussions were very lively and typically continued during the coffee break or via slack. They were a great success. On the other hand, we had several social events to encourage more informal interactions. First, during each coffee break we encourage people to move to Gather Town. Secondly, on Thursday after all the talks we had a 'Gather Town cocktail event" playing the role of the usual conference dinner of in-person events. We even had a conference speech from one of the key participants.

4 Scientific Progress Made

- The workshop served as a bridge between two communities: swampland and generalised geometry.
- There were many lively discussions about scale separation, since this is a clear point of overlap between both communities. The swampland community learnt that certain tools of generalised geometry can help to study the KK spectrum and determine if a given vacuum exhibits scale separation. On the other hand, the generalized geometry community understood the motivations for the no-scale separation swampland conjecture.
- There was also an active but constructive discussion about DGKT [1] which is a proposal for a scale-separated vacuum. Different researchers shared their views and pointed out interesting open problems present in the model. This might lead to future publications.
- The analysis of the asymptotics of the moduli space is both of interest for swampland and geometry. There were several presentations about studying the infinite distance limits and proposing new ways to go beyond the state-of-the-art.
- There was a very lively discussion about the status of de Sitter vacua in string theory (which are conjectured not to exist, according to swampland criteria). The strengths and weaknesses of different constructions were highlighted and discussed in depth.

5 Outcome of the Meeting

The workshop had a very high attendance, with order of 150 participants at every talk. This implies that most participants were attending all the talks, which is quite impressive given the virtual format. The discussion

sessions were particularly lively, and went on during the breaks in Gather Town and, afterwards, in Slack. The feedback from all the community was extremely positive, we received comments like e.g. ”It was one of the most interesting workshops I have been to for years, content-wise”. It is quite fair to say that the workshop was a total success in terms of mixing both communities and having very productive discussions.

We also announced the launching of a mentoring program targeted at members of under-represented groups. This was very well received, and we collected a list of people willing to help in the organisation, as well as potential mentors and mentees.

References

[1] O. DeWolfe, A. Giryavets, S. Kachru and W. Taylor, “Type IIA moduli stabilization,” JHEP **07** (2005), 066 doi:10.1088/1126-6708/2005/07/066 [arXiv:hep-th/0505160 [hep-th]].