Separating Realism from Ontology

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Scientific Realism

- Scientific Realism (canonically) asserts that
  - well established theories tend to be approximately true.
  - scientific objects posited by well established theories tend to refer to something in the external world.

➢ Scientific realism, thus understood, is linked to an endorsement of the ontology that is posited by the given scientific theory.

String Dualities

➢An important feature of String theory: string dualities.

- Dual theories are empirically equivalent to each other.
- Dual theories differ in fundamental characteristics.

➢Dualities are properties of formulations of the full string theory.
➢They are a means of reaching beyond the perturbative regime.

Duality relations will be assumed to be exact in this talk.

The Web of String-Dualities

- T-duality links one type of superstring theory to a different type with
  - an inverted compact radius of an extra dimension,
  - exchanged transversal momenta and winding modes on that dimension.

- S-duality links one type of superstring theory to a different type with
  - an inverted value of the string coupling.

A web of string dualities connects the 5 types of superstring theory:

Type I –**S**— Het. SO(32) –**T**— Het.E_8x E_8 --- M-Th. --- Type IIA –**T**— Type IIB =**S**

Another Duality: Gauge/Gravity Duality

AdS/CFT correspondence:

a duality between:

- a string theory on d-dimensional AdS space (an empty space with a negative cosmological constant)

and

- a (d-1)-dimensional conformal field theory (CFT) on the boundary of AdS.

➢AdS/CFT is a well established conjecture.

➢It might be a special case of a general gauge/gravity duality.

➢However, the field-theoretical dual to de Sitter space (which has the positive cosmological constant we actually observe) has not been found.

Duality and Scientific Realism

Question: Can Scientific Realism be upheld in light of string dualities?

•Ontological scientific realism is normally understood to assert the reality of one specific ontology.

•Structural realism, as long as it aims at being a form of fundamental realism, asserts that specific identifiable structural characteristics are approximately true.

➢But none of this seems to work in the context of string dualities as string dualities connect theories with radically different ontologies and structural characteristics.

- Different dimension of fundamental objects (T-duality, S-duality to M-theory)
- Different gauge symmetry (T-duality, S-duality via M-theory)
- Different dimension of background space (AdS/CFT, S-duality to M-theory)
- Different geometry of background space (AdS/CFT)
- Gravity and no gravity (AdS/CFT)

Common Core Realism

Matsubara, Rickles, Huggett and Wüthrich, De Haro and Butterfield propose the following:

A search for what is real about theories with dualities should focus on the common core that is shared by all dual theories:

The ontology attributable to the common core provides a natural basis for realist commitment.

De Haro and Butterfield also consider that some considerations may favour one of the duals (e.g. M-theory) in a way that singles out the ontology of that dual for realist commitment.

The Common Core in De Haro-Butterfield

Theory: describes a system by ascribing to it:

•numerically measurable **quantities *Q*** like position or momentum.

•**states *S*** of the system. Each state assigns values to the quantities.

•a **dynamics *D*** that specifies the allowed sequences of states.

Duals are empirically equivalent:

They share the same quantities, states, and dynamics.

⇒The triple T=(*Q,S,D)* is the **Core Theory** that deserves realist commitment.

➢The duals are **"models"** of the core theory. Their extra structure does not merit realist commitment as long as there is no convincing reason to prefer one of the dual models over the others.

A Different Take on the Issue

- We propose a substantially different perspective on the issues of ontology and scientific realism in the face of dualities.

- The view we propose not only
  - provides a more adequate view on the question of scientific realism in the case of string dualities,

  but also
  - is very helpful for understanding the issue of realism in the context of the selection a tensor product structure in quantum mechanics.

- The two issues are related in interesting and instructive ways.

Since this talk circles around the emergence of spacetime (and in light of time constraints), I will focus on the case of string dualities.

Realism and the No Miracles Argument

➢It is a central motivation for scientific realism to explain why scientific prediction is successful (NMA).

⇒To play that role, realism must be based on a concept of theory that can be the basis for extracting empirical predictions.

Theories as Compression mechanisms

- Dennett (1992) frames scientific theories as compression mechanisms that allow to represent data sets in terms of substantially fewer bits of information.

- Linking this view to scientific realism, a no miracles argument would be based on the observation that a given theory is a successful compression mechanism.

- The definitions of theory thus should be of a kind the does represent it as a compression mechanism.

➢ The question thus is whether the definition of theory as a triple satisfies this condition.

How to calculate String Theory

In String theory,

•One does not know a full formulation of the theory.

  – There is no known “model”- independent formulation of equations of motion.

•Starting point for the formulation of a calculable theory is a perturbative expansion in terms interacting strings.

•The duality relations that connect the types of string theory and thereby establish them as empirically equivalent representations (“models”) of the theory are the only means of reaching out beyond the “models” ’ perturbative regime.

⇒As it stands, the dual “models” are the only basis for quantitative calculations of string theory.

The triple in ST and compression

- What is known about string theory provides no basis for viewing a triple of states, quantities and dynamics as a compression mechanism without relying on “models” of the theory.
  - This may or may not change once one has a full understanding of the theory.
  - The dual models may be an essential element of spelling out the full theory.

=> The compression requirement cannot be said to be satisfied by the common core in the context of ST.

Dualities and Classical Limits

Another issue suggests attributing a pivotal role to the models when expressing realist commitment to string theory:

•The fact that there is a web of dualities is a crucial characteristic of string theory that cannot be read off the common core.

- Only once one has one model, is it possible to infer duality relations to others.
- But the duality structure determines the theory's classical limits.

⇒The duality structure seems to be a crucial characteristic of the theory that itself deserves realist commitment.

Defining Realism

- ➢ Realist commitment should be to a theory that serves as a compression mechanism and represents or implies the duality structure.
- ➢ In the case of ST, this may imply that it needs to include all dual representations.

? But what is the real ontology then?

- ➢ Proposal: there is no real ontology of the fundamental theory.
  - Ontology plays a different role than to provide a basis for realist commitment at the fundamental level.
  - The ontologies of the duals give us an intuitive understanding of the way the fundamental theory connects to what we can observe.
  - ➢To spell out that role, ontology must be separated from fundamental realist commitment.

Classical Limits and String Dualities:

Dualities lead from near-classical to deep quantum:

•S-duality leads from a weak coupling (near classical) to a strong coupling (deep quantum).

•T-duality leads from a situation where velocity can be – nearly - continuously changed (near classical) to a situation where allowed transversal momenta are far apart (deep quantum).

•AdS/CFT leads

- from a situation where curvature is small (near classical) to a strongly coupled CFT (deep quantum) ,
- from a weakly coupled CFT (near classical) to a situation where curvature is high (deep quantum).

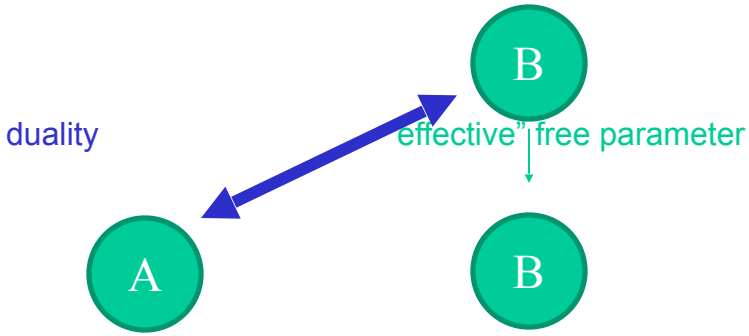
Classical Limits and String Dualities:

➢ Dualities establish that there are several very different classical limits of string theory.

- String Dualities establish that models with entirely different classical limits are empirically equivalent.
- One model close to a classical limit corresponds to another one far away from its classical limit.
- By moving from one model to its dual, one identifies a different classical limit of the same theory.

Deep quantum regime:

Near classical limit:



Classical Limits and Ontology

- Fundamental string theory has several classical limits.
- Each of them is “pointed at” by the near-classical limit of one of the types of string theory.

➢ The ontology of a given type of string theory thus links our intuitive observational perspective to the full theory by pointing at the way in which the latter assumes features that can be related to our intuitions about objects in space and time.

➢ In the deep quantum regime, none of the concepts deployed for characterising a near-classical limit (individual strings, space, ..) keep their fundamental significance.

⇒ The ontologies of the duals pointing at the near-classical limits are entirely decoupled from realist commitment.

The Role of Ontology

⇒ If we spell out the ontology of a type of string theory near its classical limit, we understand how the theory would link to an effective theory if we actually lived close to that classical limit:

- We get the right gauge structure of the effective theory.
- We get the right spectrum of elementary objetcs.
- We get the right brane structure.

…

Effective Theories and Ontology

- At lower energies, the fundamental theory can be described by a tower of effective QFTs.

➢ Those theories are spatio-temporal, which means that some intuitions about the world are retained in the effective theory.

➢ An effective theory typically has one classical limit.

⇒ The ontology has a chance to characterize the effective theory in an unequivocal way.

If it does, the ontology may provide a basis for realist commitment at the effective level (=> effective realism).

⇒ Ontology and realist commitment may appear wedded to each other at the effective level.

! Realist commitment at the level of effective theories is different from realist commitment at the fundamental level.

The Proposal:
Separate Ontology from Realist Commitment

- **Ontology** is about the way our observational perspective is linked to the theory.
  - ➢ Spelling out the ontology starts from an observational perspective.
    - An ontology is linked to a specific classical limit.
    - The ontology we are committed to depends on the near classical limit our system happens to be in.

➢ **Observer-based ontology**

The Proposal:
Separate Ontology from Realist Commitment

- **Realism** is about the commitment to the theory's (approximate) truth.
  - ➢ Spelling out the real theory does not start from observation but merely needs to explain observation.
    - Realism neither selects one dual nor reduces to a common core.
    - Rather, it takes the full theory as specified by individual "models" as its basis of realist commitment.
    - It does not insist on any real ontology.

➢ **Observer-independent reality**

Conclusion

In order to fully grasp what a correct fundamental theory amounts to, we need to understand two things:

1.What the theory per se amounts to.

2.How the theory relates to the specific environment we observe and derive our intuitions from.

➢The first issue is observer-independent. The second is not.

➢Realism addresses 1.

➢Ontology addresses 2.

➢In low energy effective theories, the two issues may look closely related.

➢In fundamental string theory, they fall apart.