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Andrea Brini

Quantum Geometry

How can we understand the geometry of a very complicated space? An efficient method is to probe it by counting how many subspaces of a certain type we can possibly fit inside it. For example, we can geometrically tell apart a rugby ball (an ellipsoid) from a miniature cooling tower (a one-sheeted hyperboloid) by asking “how many straight lines can they possibly contain?”: this number is zero for the oval ball, but infinite for the model tower.

As with all things in Maths, when it comes to ramping up the level of difficulty of the question, sky’s the limit. We could for example ask, using the same logic, how to distinguish the quintic (2875 straight lines) and sextic (528 straight lines) Calabi-Yau manifolds, which appear in certain models of quantum gravity containing the minimal number of copies of the electromagnetic field. In general, the information amassed by counting curves of all possible shapes and forms gives a sort of “biometric passport” of a geometric space: on top of their intrinsic value, the curve-counts can be effectively employed to distinguish shapes for which the same enumerative problem gives different answers.

The quest for an effective solution to enumerative questions received impressive momentum from a revolutionary discovery made in the early ‘90s by both physicists and geometers: solving the geometrical problem of counting curves in a given ambient space is tantamount to understanding a class of energy-minimising field configurations of an associated physical model defined on that same space. This surprising connection between Mathematics and Physics puts on a rigorous footing questions in theoretical physics and simultaneously led to a series of remarkable (if conjectural) predictions about the original enumerative problem, often implying its complete solution. I will give a brief survey of some of the main results in the subject, and give a glimpse of current research on the topic.

[ANDREA BRINI](#)