PHY680 (Advanced Nonperturbative QFT):
Introduction to the dynamics of supersymmetric QFTs

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YITP seminar room (Math 6-125), Tu-Th 11:30am–12:50pm, Fall '23

In this class we will cover several aspects of supersymmetric quantum field theory, mostly in four spacetime dimensions, but with excursions to other dimensions as well. We will use supersymmetry as a crutch to learn both qualitative and quantitative lessons about quantum field theory dynamics. The subject has also deep connections to modern mathematics, but our emphasis will be on the physics.

Below is a list of the topics that I plan to cover. This selection is probably too long to fit in a semester, so the last few items are somewhat tentative.

(a) Review of the basics of supersymmetric kinematics.

(b) Holomorphy and non-renormalization theorems.

(c) Dynamics of $\mathcal{N} = 1$ supersymmetric gauge theories for different gauge groups and matter content. Seiberg duality.

(d) $\mathcal{N} = 2$ field theories and Seiberg-Witten theory.

(e) Superconformal field theories. Representation theory and the superconformal index. The (super)conformal bootstrap.

(f) The $(2, 0)$ 6d theory and its compactifications to four dimensions. Theories of class $\mathcal{S}$ and the AGT correspondence.

(g) The SCFT/VOA correspondence.

(h) Three-dimensional mirror symmetry for $\mathcal{N} = 4$ theories.

Prerequisites. Everyone is welcome, but it's unlikely you will get much out of this class unless you have already taken at least a full year course in QFT, or have mastered that material by yourself (at the level say of Peskin-Schroeder or Srednicki). I will assume that you are comfortable with writing Lagrangians with scalars, fermions and gauge fields and the basic ideas about renormalization (e.g. that you can compute a simple one-loop Feynman integral and know what β functions and anomalous dimensions are). The basic kinematics of supersymmetry will be reviewed in class, but I will have to be quick because I want to get to dynamical aspects as soon as possible. So some previous exposure to the basics of 4d susy (e.g. how to write susy Lagrangians in $\mathcal{N} = 1$ superspace) would be helpful, but if you are a novice don't panic – for our purposes this will be mostly a matter of learning a few notational tricks. If you want to get a head start, a quick self-study of the first 50 pages of the book by Wess and Bagger (without necessarily going through all the detailed calculations) would be more than enough.