University of New Jersey, and Herman Weyl Professor Robert MacPherson. Speakers were Danielle Basset and Toen Castle of the University of Pennsylvania, Leslie Greengard of New York University, Vladimir Itskov of Pennsylvania State University, and Don Sheehy of the University of Connecticut.

MacPherson gave the mini-symposium “What is Topology?” in May, moderated by Institute Director and Leon Levy Professor Robbert Dijkgraaf. Former Member Randall Kamien discussed topology and liquid crystals, and former Member Raúl Rabádán of Columbia University talked about how topology modifies our understanding of evolution and disease.

The following contains brief descriptions of some of the activities and discoveries in the School’s Computer Science and Discrete Math group led by Herbert H. Maass Professor Avi Wigderson.

Information and communication complexity and coding 
Information complexity attempts to generalize Claude Shannon’s sixty-year-old theory from the classical one-way theory to the interactive exchange of information between two parties. This topic has been one of the hottest research topics in the theory of computation in the past few years. Information complexity interacts with the well studied communication complexity, and has generated applications and challenging open problems.

Shannon proved that one-way communication protocols can be compressed to their information contents, which in this case is the entropy of the message one player needs to send the other. For general communication protocols and tasks, information complexity emerged as the right notion of “information contents.” Comparing it with the communication cost (bit complexity) in optimal communication protocols of general interactive tasks is a central challenge in attempts to generalize Shannon’s theorem to the interactive setting.

Another basic question deals with error correction and the amount of redundancy needed to overcome noise across the communication channel. Again, Shannon resolved this problem for one-way communication in the 1950s, and attempts to generalize it to the interactive setting are very challenging.

Several works of Visiting Professor Ran Raz and Member Gillat Kol (some joint with Weizmann Institute student Anat Ganor) represent major breakthroughs on these problems. In one paper, they are able to prove that in the interactive setting, the “capacity” of a noisy channel is smaller than in Shannon’s one-way model, namely, that redundancy for the same amount of error must be significantly larger. In two other papers, they show that there can be an exponential gap between the communication complexity and information complexity of a protocol. This later result has a surprising implication, which resolves a thirty-year-old question in communication complexity. They show that for some communication tasks, “economy of scale” is possible. Namely, solving k independent instances of a given communication problem can be done with far less than a factor k increase in communication over the cost of one instance. Despite being independent, the communication solving these k instances can magically be “merged” to obtain this savings.

Locally correctable and testable codes 
Locality in the theory of error correction has arisen from a variety of motivations within the theory of computation (including program checking, probabilistically checkable proofs, hardness of approximation, pseudorandomness, and hardness amplification). The study of codes with these local testing and decoding properties had a significant effect on coding theory as well. The main parameter governing locality is the number of (randomly chosen) queries made to a corrupted code word. The trade-offs of this parameter with classical parameters of codes like rate and distance have been extremely important, and our understanding is far from complete.

Member Noga Ron-Zewi, last-year Member Or Meir, and Rutgers professors Swastik Kopparty and Shubhangi Saraf (both former Members) made significant improvements to the state-of-art. For both testing and decoding, new codes were designed with rate approaching 1 (namely, negligible redundancy), for which the number of queries needed is sub-polynomial! All previous constructions with such query complexity have extremely poor rate, whereas constant rate codes could only work with polynomials many queries in the block-length. The design of the new codes follows along the lines of zig-zag product constructions.

Sum-of-squares lower bounds 
The sum-of-squares (also known as SoS/Lasserre/Parillo) hierarchy of convex relaxations is the strongest algorithmic technique known for a wide variety of optimization and statistical learning problems. Proving limits on its power, in the form of integrality gaps for high degree (or many rounds) of this framework, is an important challenge, especially for the average-case complexity of natural problems.

The planted clique problem is the task to discover a large clique hidden in an Erdős-Rényi random graph. It has attracted attention, both as a benchmark for a variety of approximation algorithm techniques, as well as an average-case hardness assumption with applications to cryptography, economics, sequencing, and community detection in large networks.

The best-known polynomial time algorithms can only find such a clique if its size is roughly the square root of the graph size n (whereas statistically but inefficiently a clique of logarithmic size can be found). A result of last-year Member Raghu Meka, Massachusetts Institute of Technology student Aaron Potechin, and Wigderson proves that d-round SoS algorithms cannot discover a clique of size roughly the dth root of n. Thus, restricting these algorithms to polynomial time, namely constant d, almost surely cannot find a hidden clique of size smaller than a polynomial in n. The