Network theory: from statistical mechanics to random complex geometries

Network theory characterizes the structure of networks describing interacting complex systems, such as the brain or the molecular networks in the cell.

The field has started almost twenty years ago, together with the significant increase data on interacting complex systems such as the Internet or the molecular network in the cell.

The statistical mechanics approach has dominated the beginning of this field since it provides the natural way to characterize these complex structures between randomness and order.

Recently, it is becoming clear that network geometry will be essential for enhancing our understanding of complexity, having many practical implications for data mining, routing of packets in the Internet, ect.

Moreover, at the fundamental level, uncovering the relation between network geometry and complexity, might provide new venue for cross-fertilization between network theory and quantum gravity.

In these 15 lectures I will give an overview of the results obtained so far, relating network theory, network geometry, quantum network states and quantum statistics.

Lesson 1

Introduction to complex networks

Lesson 2

Universalities:

Small-world network and growing scale-free networks

Explanation of the master equation approach for deriving exact master equations

Lesson 3

Bose-Einstein condensation in complex networks

Lesson 4

Fermi-Dirac distribution for description of growing Cayley trees

Lesson 5-6

Entropy and network ensembles

Lesson 7

Ising model on scale-free networks

Lesson 8

Quantum critical phenomena in scale-free networks

Lesson 9

Introduction to network geometry

Lesson 10

Emergent d=2 network geometry

Complex Quantum Network Geometry in d=2

Lesson 11

Quantum Network Geometry in d dimensions

Generalized degrees distribution for at infinite temperature

Lesson 12

Generalized degree distribution at finite temperature

Lesson 13-14

Summary on Quantum Network Geometries

Lesson 15

Overview and discussion