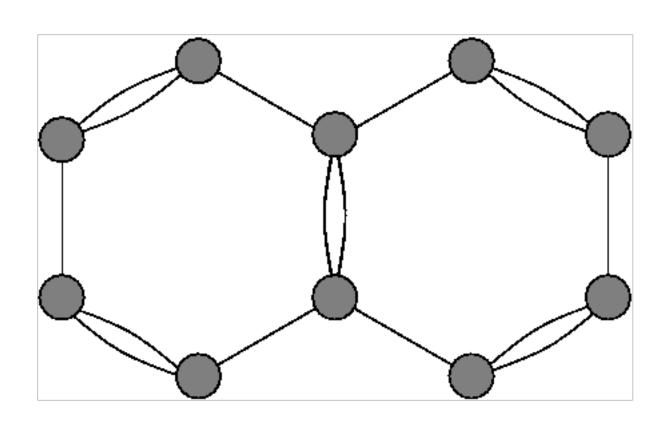


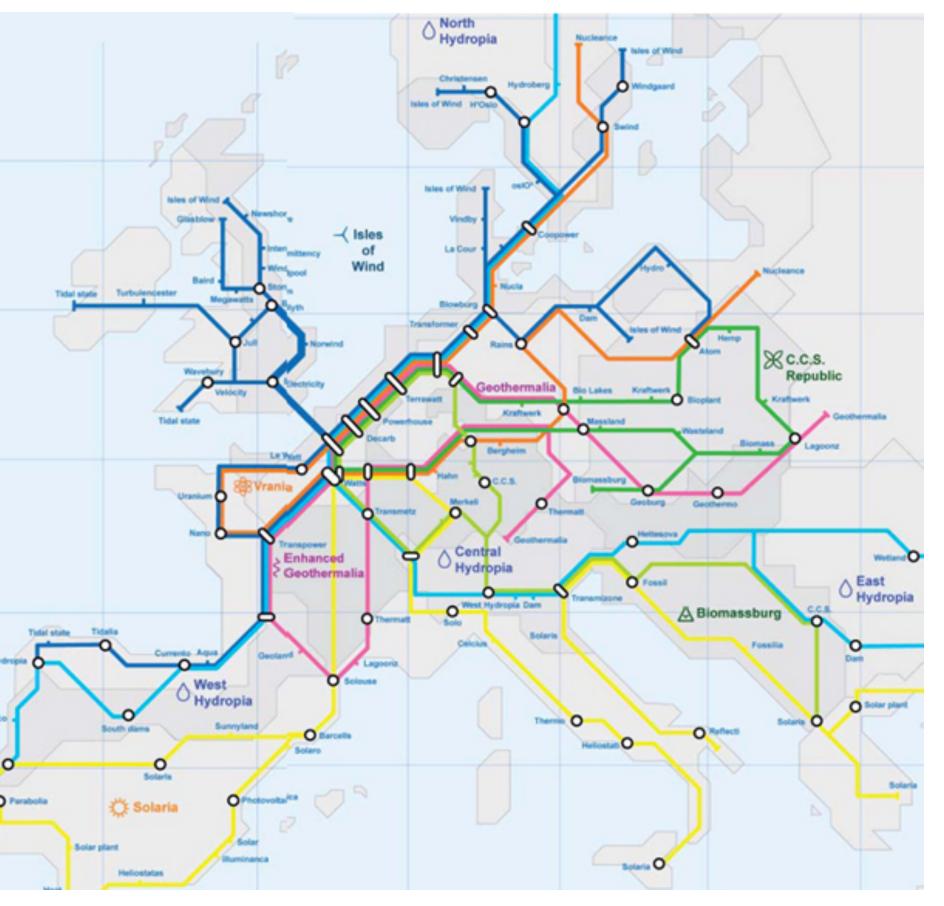


Quantum Graphs

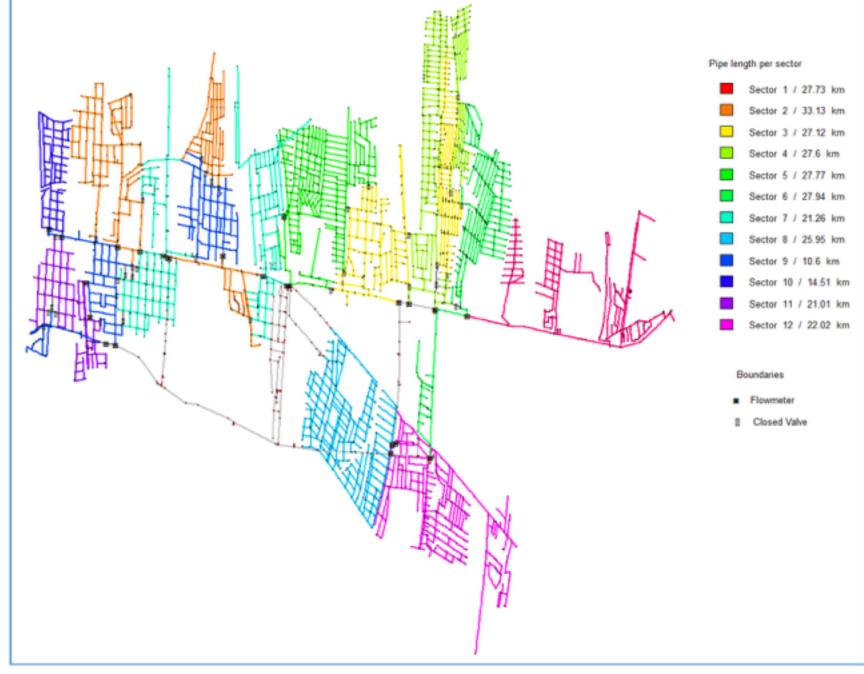
1930s to model the spectrum of free electrons in organic molecules



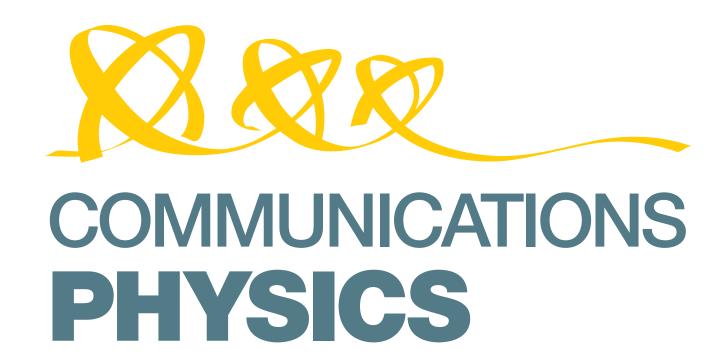
power networks



water networks







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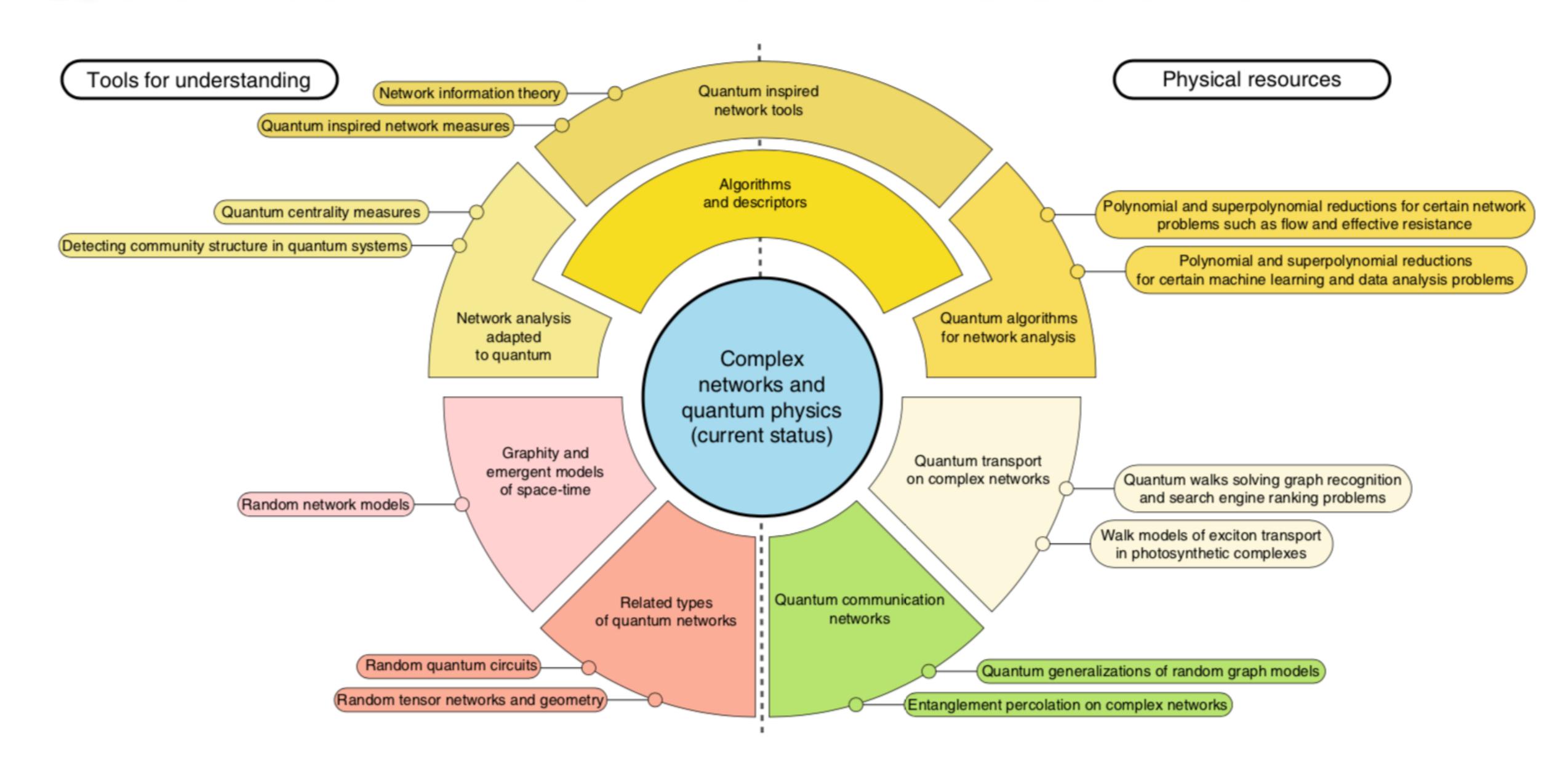
Complex networks from classical to quantum

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Recent progress in applying complex network theory to problems in quantum information has resulted in a beneficial cross-over. Complex network methods have successfully been applied to transport and entanglement models while information physics is setting the stage for a theory of complex systems with quantum information-inspired methods. Novel quantum induced effects have been predicted in random graphs—where edges represent entangled links—and quantum computer algorithms have been proposed to offer enhancement for several network problems. Here we review the results at the cutting edge, pinpointing the similarities and the differences found at the intersection of these two fields.

Tools for understanding Physical resources Network information theory Quantum inspired network tools Quantum inspired network measure Algorithms and descriptors nomial and superpolynomial reductions for certain network Quantum centrality measures problems such as flow and effective resistance etecting community structure in quantum system Polynomial and superpolynomial reductions or certain machine learning and data analysis problems Quantum algorithms Network analysis for network analysis adapted to quantum Complex networks and quantum physics (current status) Graphity and Quantum transport emergent models on complex networks Quantum walks solving graph recognition of space-time and search engine ranking problems Random network models Walk models of exciton transport in photosynthetic complexes Quantum communication of quantum networks Random quantum circuits Quantum generalizations of random graph models andom tensor networks and geometr Entanglement percolation on complex networks







Interestingly, the same tools can then be appropriately modified to apply to traditional complex networks, suggesting the existence of a framework—network information theory—suitable for application to both classical and quantum networked systems^{32,41,42.} This bidirectional cross-over is carving out a coherent path forward built fundamentally on the intersection of these two fields (see Box. 1).





This **bridge between complex network theory and quantum theory** provides a powerful tool to investigate the critical properties of a quantum system.

 $[\dots]$

Unexpected quantum effects emerging from network effects have been reported.



... any algorithm for

a quantum computer can be translated into a quantum walk on a graph—and, in addition, quantum walks have been widely studied in the realm of **quantum search on graphs**, in both continuous and discrete time via coined walks (see e.g.,^{58–61} in particular, the **graph optimality results**⁶⁶).

[...]

... developments in a quantum version of

Google's Page-Rank^{8–10} has been seen, providing a practical solution to overcome the degeneracy issues affecting the classical version and enhancing node ranking in large networks.



Community detection, and in general mesoscopic structure detection, has been widely studied in the literature of classical complex networks^{95,96}.

 $[\dots]$

The cross-pollination of community detection with quantum mechanics is in two levels.

 $[\ldots]$

These methods augment

current ad hoc approaches to partitioning nodes in quantum transport systems with enhanced methods based on community detection algorithms.