FLASH: Quantum Network Research

Daniel Dobos

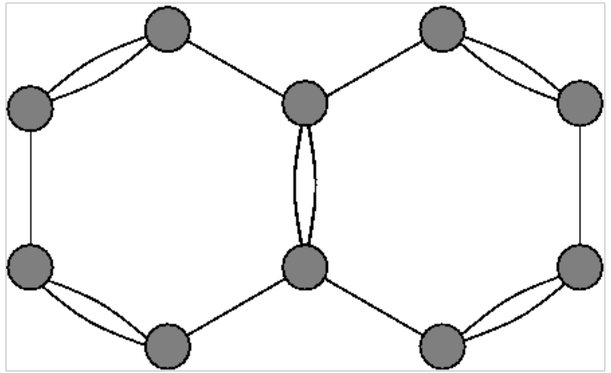
Lancaster University

CERN

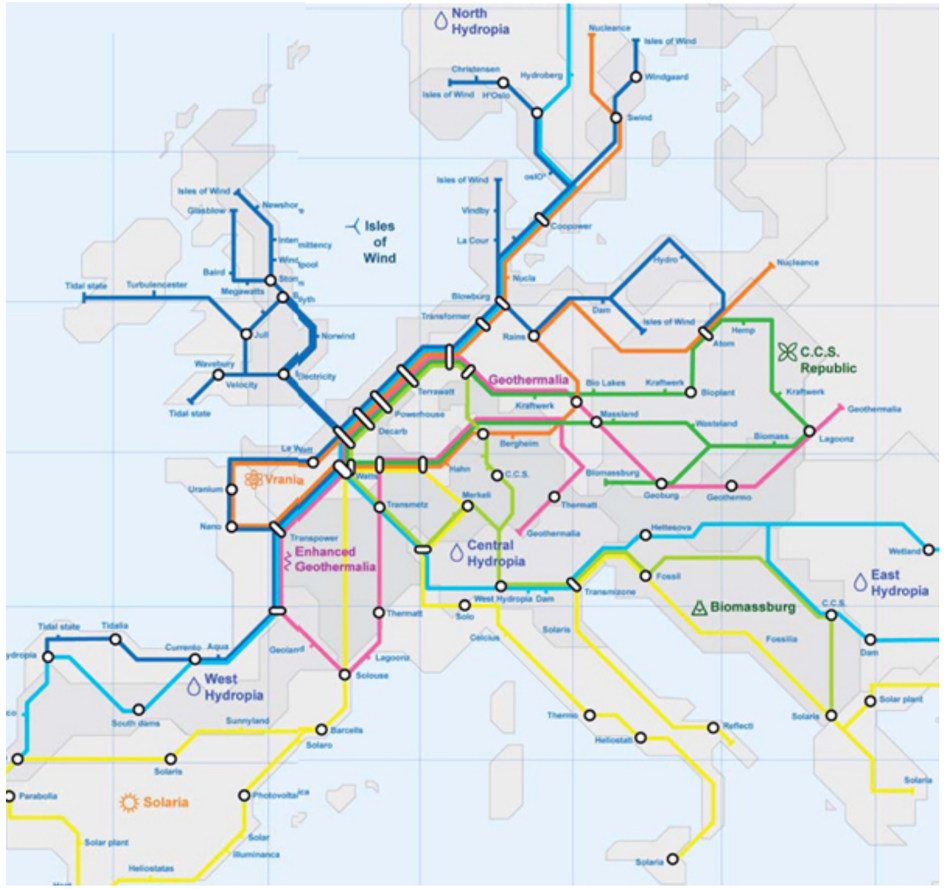
Quantum Graphs

gluoNNet

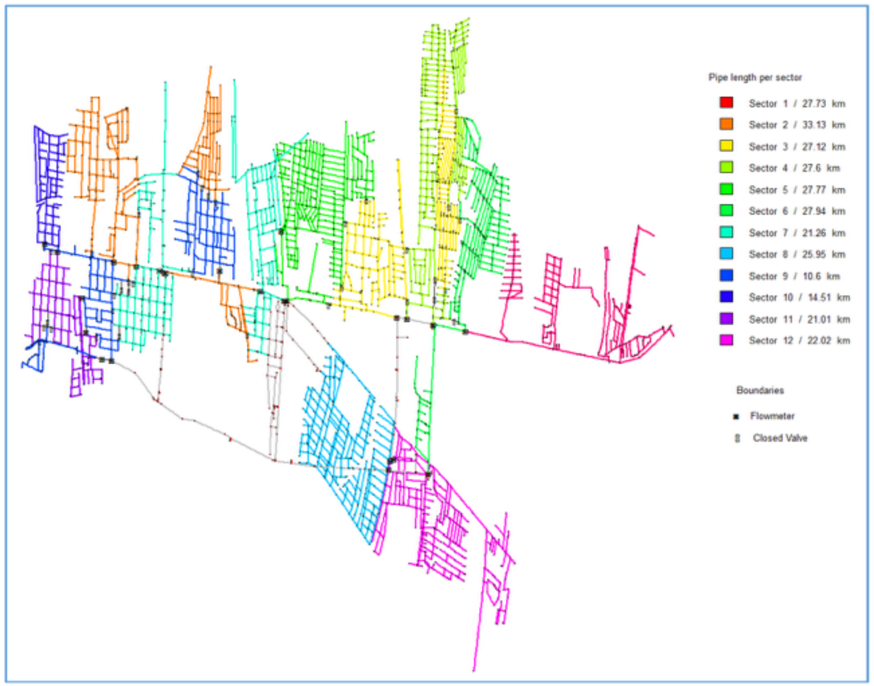
1930s to model the spectrum of free electrons in organic molecules



power networks



water networks



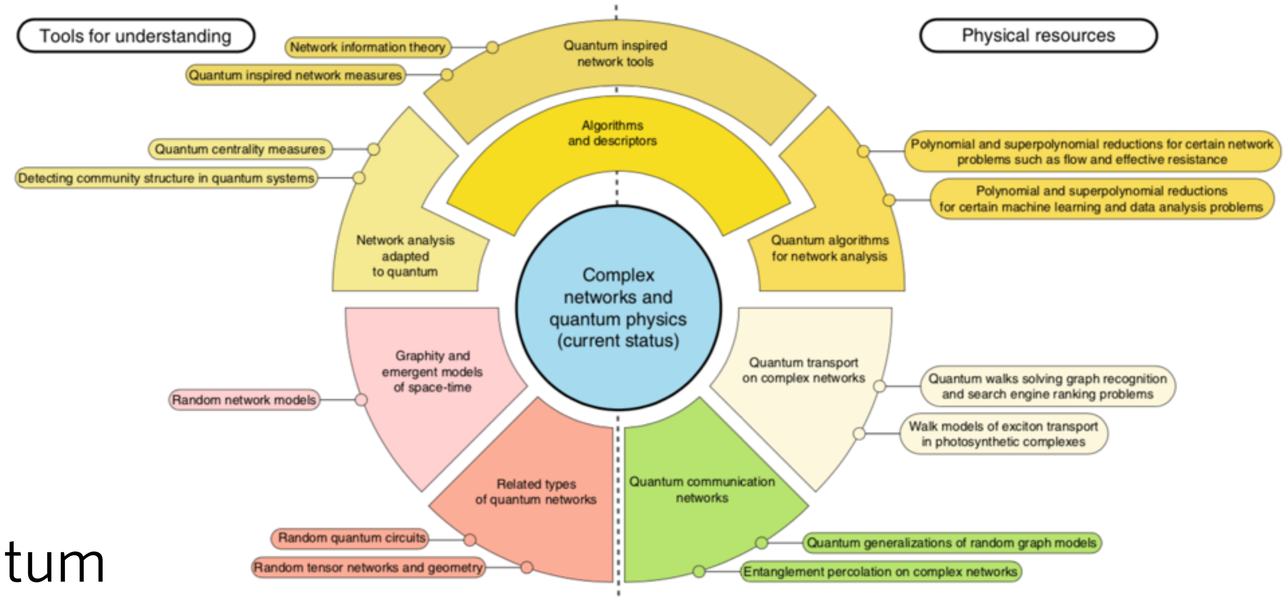
COMMUNICATIONS PHYSICS

REVIEW ARTICLE

https://doi.org/10.1038/s42005-019-0152-6 OPEN

Complex networks from classical to quantum

Jacob Biamonte [1], Mauro Faccin[2] & Manlio De Domenico[3]

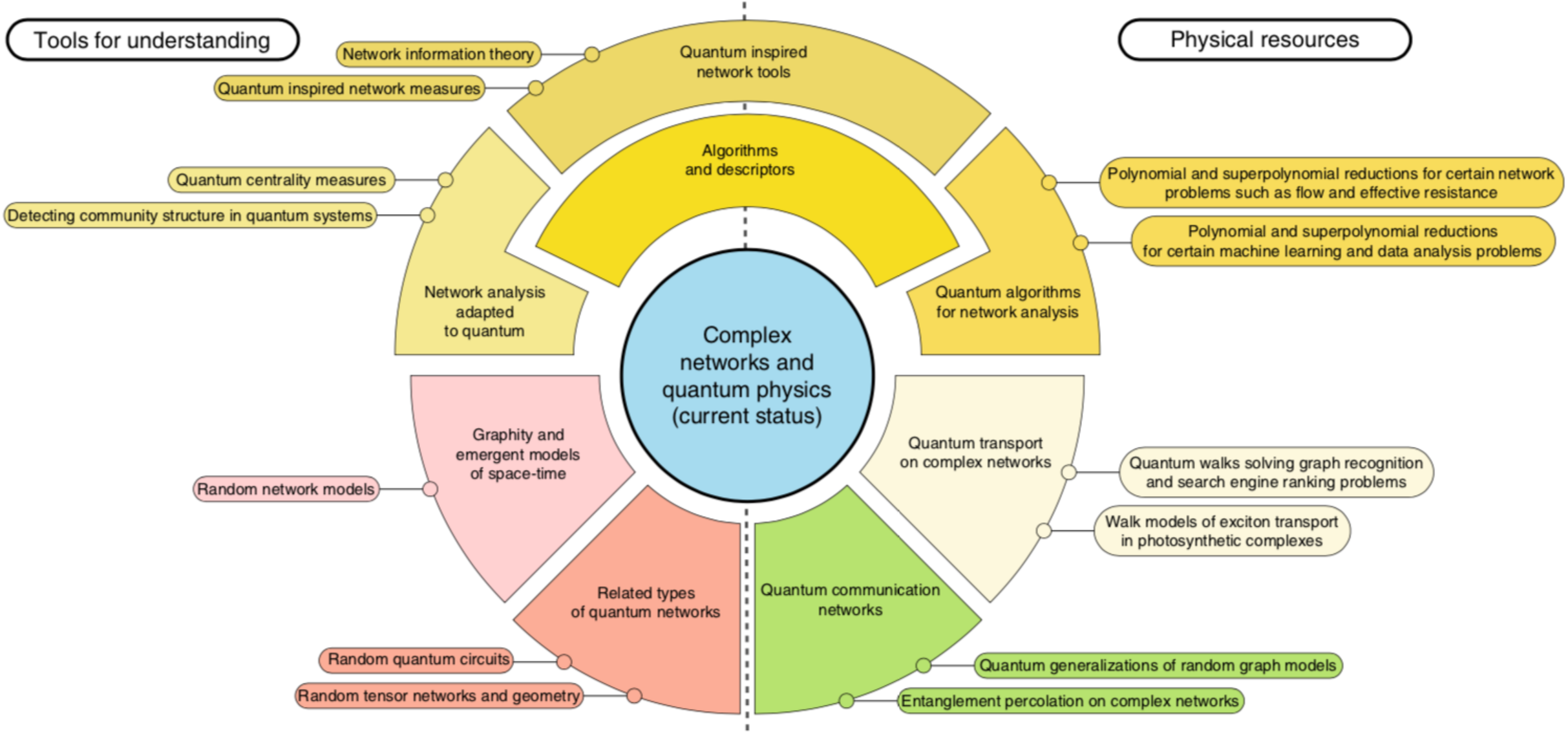


Recent progress in applying complex network theory to problems in quantum information has resulted in a beneficial cross-over. Complex network methods have successfully been applied to transport and entanglement models while information physics is setting the stage for a theory of complex systems with 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.

Quantum mechanics has long been predicted to help solve computational problems in

Quantum Network Research

gluoNNet



Quantum Network Research

gluoNNet

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).

Quantum Network Research

gluoNNet

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

[…]

Unexpected quantum effects emerging from network effects have been reported.

Quantum Network Research

gluoNNet

… 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**.

Quantum Network Research

gluoNNet

Community detection, and in **general mesoscopic structure detection**, has been widely studied in the literature of classical complex networks[95,96].

[…]

The c**ross-pollination of community detection with quantum mechanics** is in two levels.

[…]

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