University of Exeter

Quantum computing – part 2

Stefano Scali

Postdoctoral research fellow

University of Exeter

Quantum computing – part 2

Stefano Scali

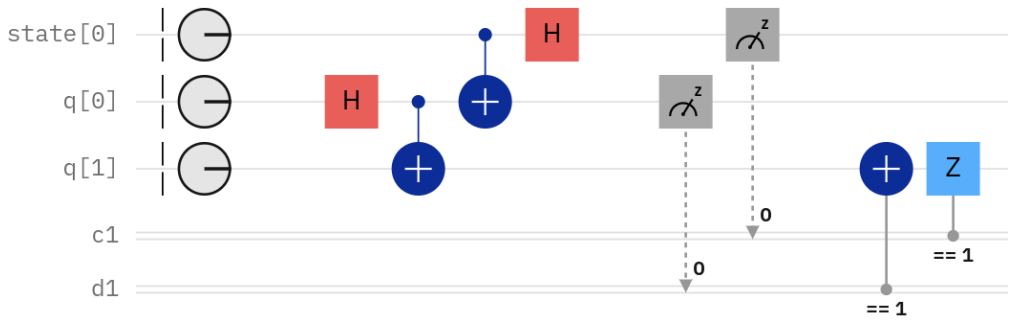
Postdoctoral research fellow

Cosa facciamo

- Come si scrive un circuito quantistico → **IBM Q experience**
- Come se ne calcola il risultato → **carta e penna**
- Quali problemi vale la pena studiare → **“complexity theory”**
- Esempio di algoritmo → **quantum topological data analysis via DOS estimation**
  (di ‘facile’ realizzazione in questa era pre-FTQ, nessuna pretesa di quantum advantage)

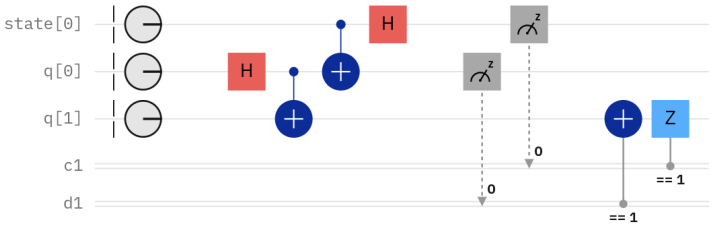
Come si scrive un circuito quantistico → IBM Q experience

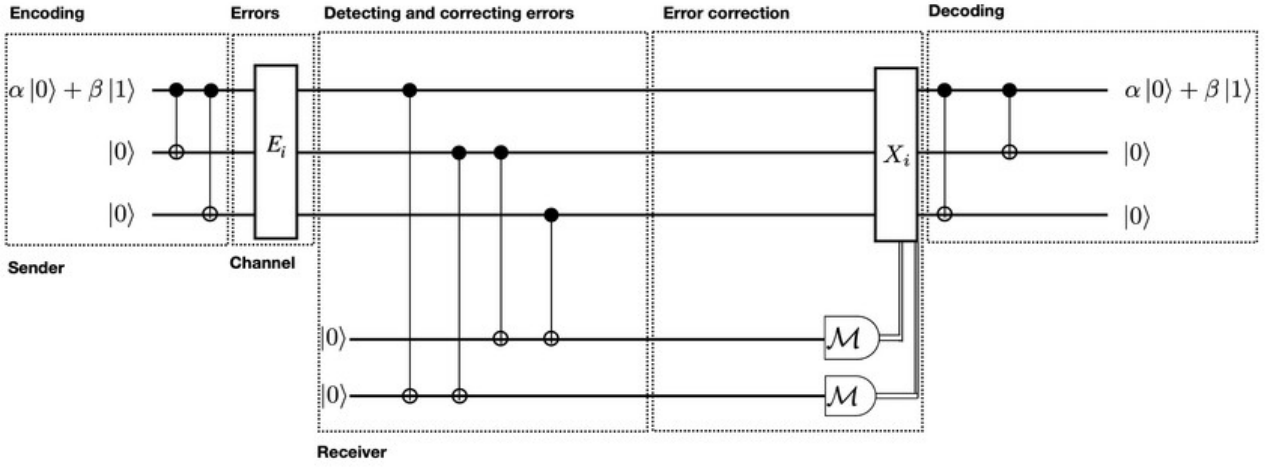
https://quantum.ibm.com/composer



Come se ne calcola il risultato → carta e penna

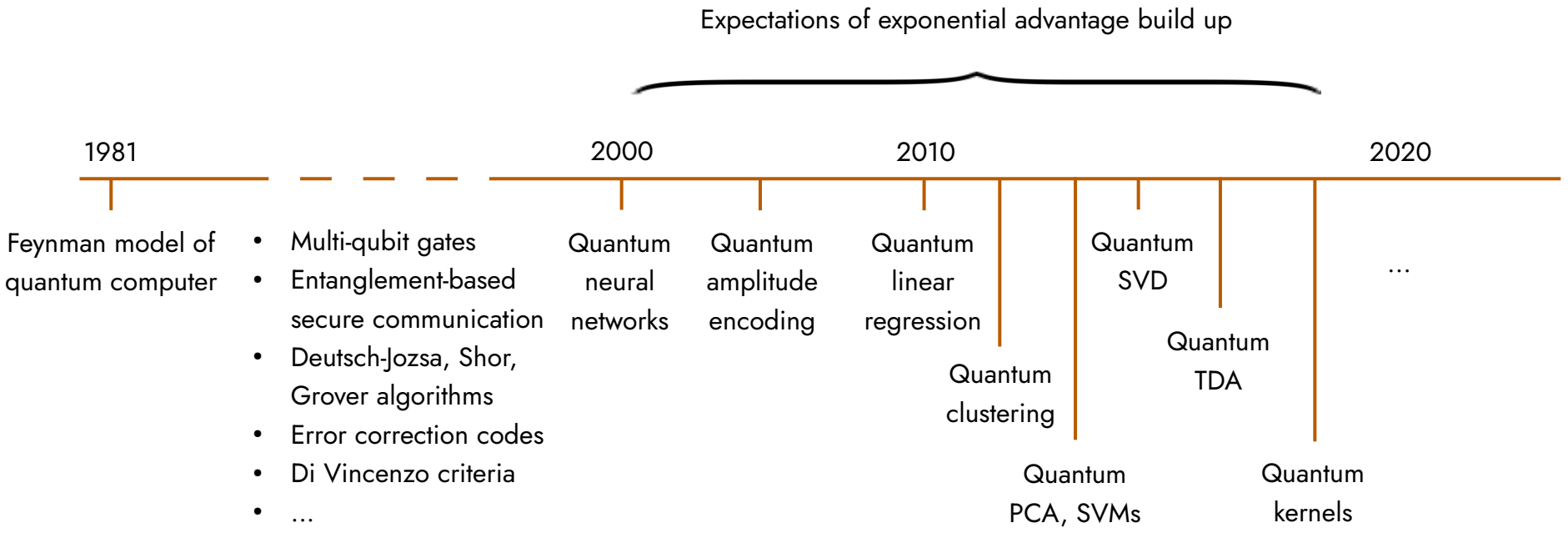
Il principio di funzionamento di questo circuito e' usato quotidianamente per fare quantum error correction!





Quali problemi vale la pena studiare → "complexity theory"

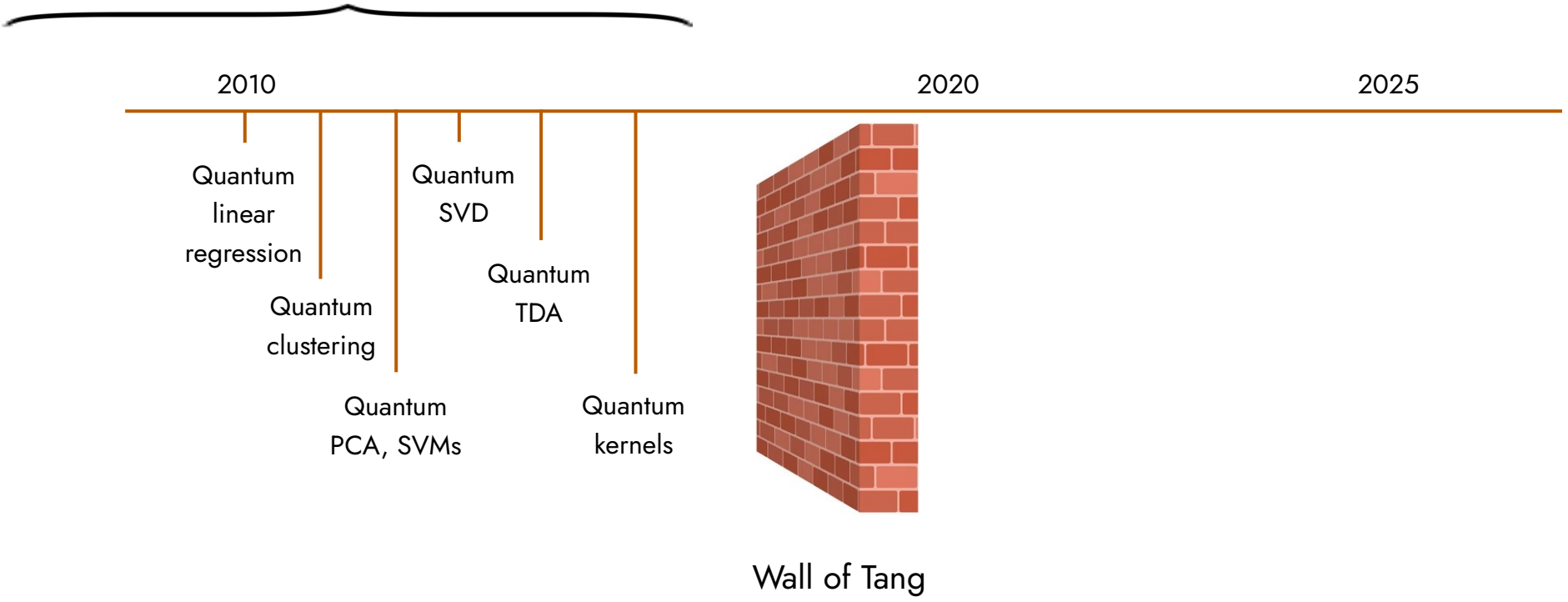
*Vedran Djunko inspired



Quali problemi vale la pena studiare → “complexity theory”

*Vedran Djunko inspired

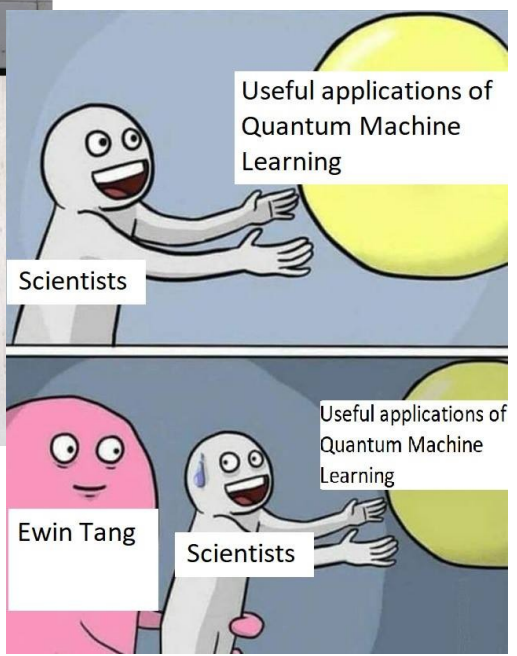
Expectations of exponential advantage build up



Quali problemi vale la pena studiare → “complexity theory”

*Vedran Djunko inspired

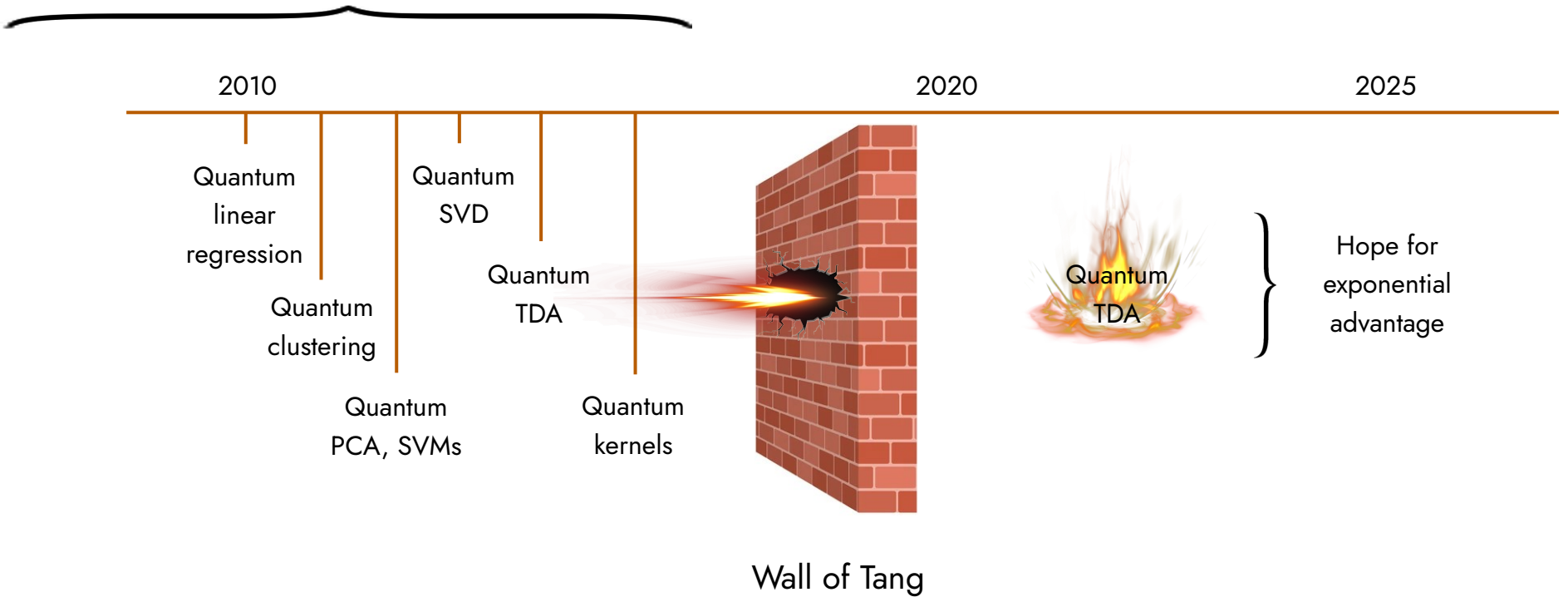
Ewin Tang *dequantized* pretty much everything she could find but…



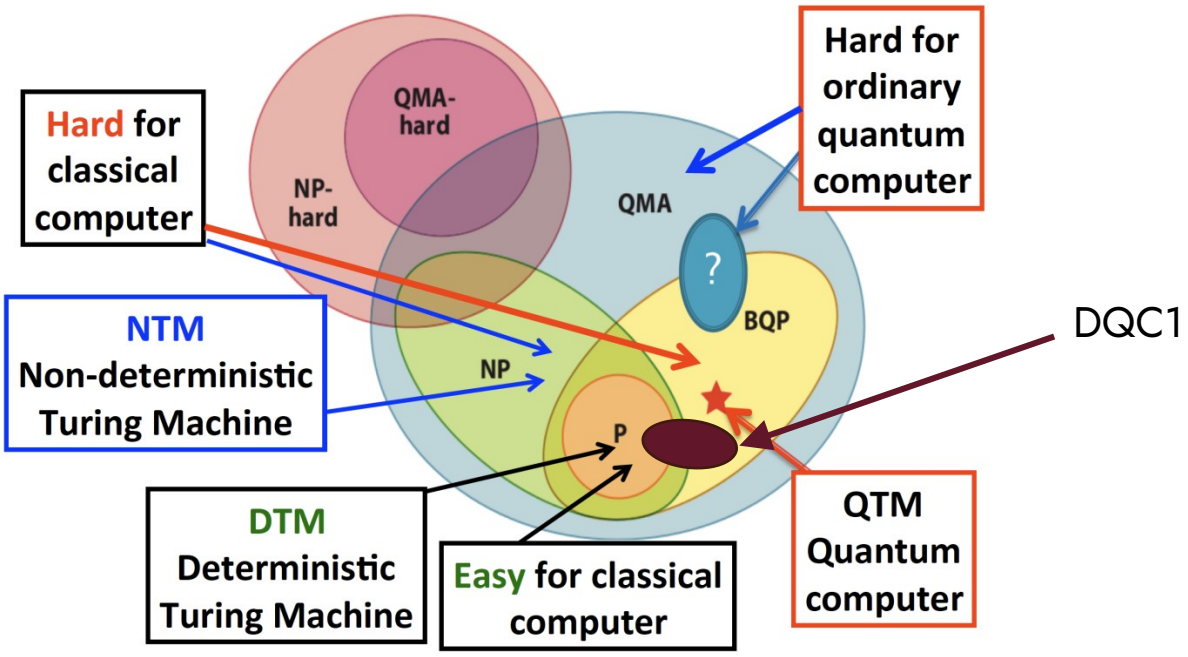
Quali problemi vale la pena studiare → “complexity theory”

*Vedran Djunko inspired

Expectations of exponential advantage build up

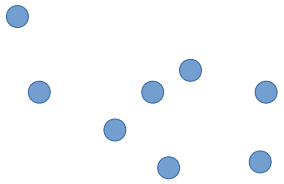


Quali problemi vale la pena studiare → “complexity theory”

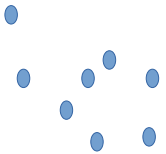


*arxiv1610.02208

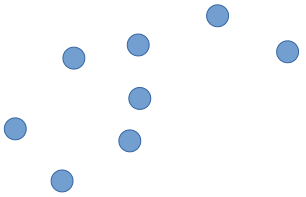
Esempio di algoritmo → quantum topological data analysis via DOS estimation



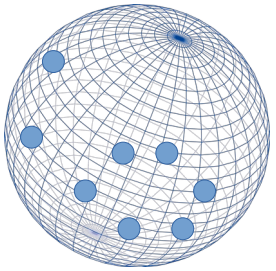
Data



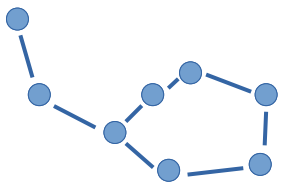
Rescales

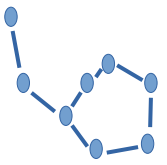


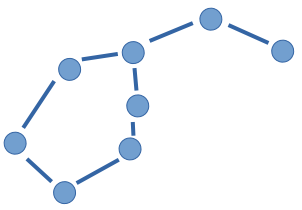
Rotations

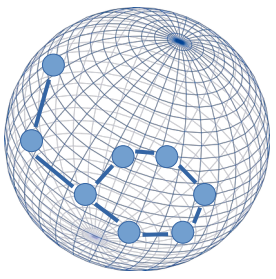


Continuous transformations



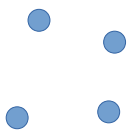




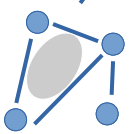


The topological features of the data are robust to transformations and noise!

Esempio di algoritmo → quantum topological data analysis via DOS estimation



Data



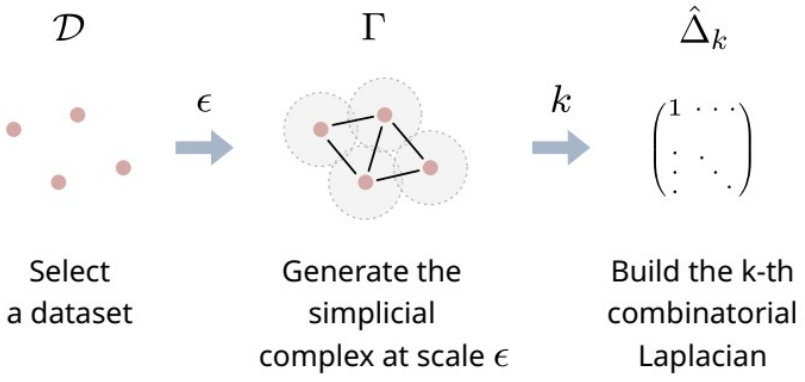
Simplicial complex

Some topological features (the "holes") of the simplicial complex are called Betti numbers

$$|0001\rangle + |0010\rangle + |0100\rangle + |1000\rangle + |0011\rangle + |0110\rangle + |1100\rangle + |1010\rangle + |1110\rangle$$

Quantum encoding

Esempio di algoritmo → quantum topological data analysis via DOS estimation



The combinatorial Laplacian encodes the "connections" of the k-th simplicial complex

The Betti numbers are estimated as

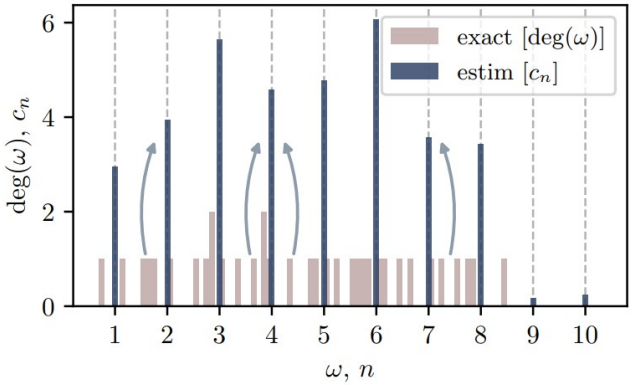
$$\beta_k = |\mathrm{S}_k| - \mathrm{rank}(\hat{\Delta}_k)$$

Esempio di algoritmo → quantum topological data analysis via DOS estimation

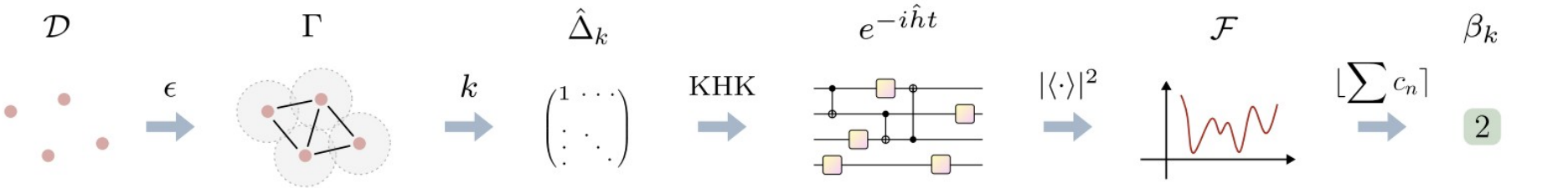
The Betti numbers are estimated as

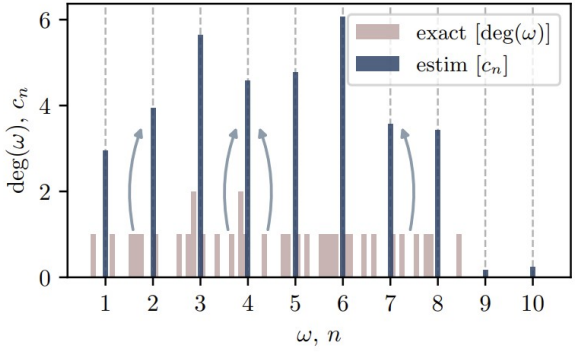
$$\beta_k = |\mathrm{S}_k| - \mathrm{rank}(\hat{\Delta}_k)$$

Spectrum information of the combinatorial Laplacian gives topological information



Esempio di algoritmo → quantum topological data analysis via DOS estimation





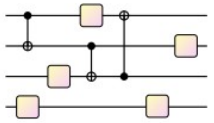
Spectrum information of the combinatorial Laplacian gives topological information

Use the DOS to push some algorithm complexity into classical post-processing

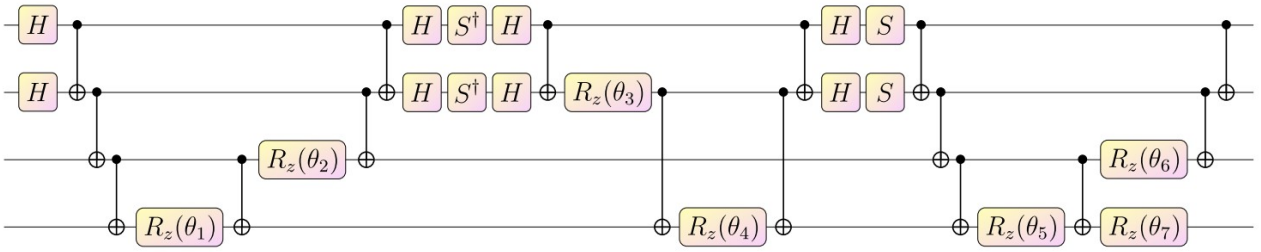
$$S(\omega) = \sum_{\nu} \delta(\omega - \lambda_\nu)$$

Esempio di algoritmo → quantum topological data analysis via DOS estimation

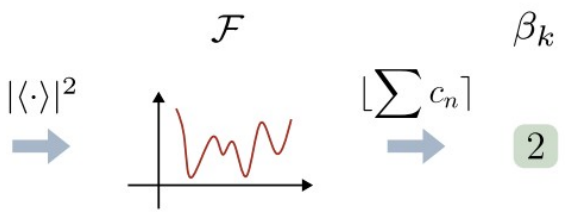
$e^{-i\hat{h}t}$

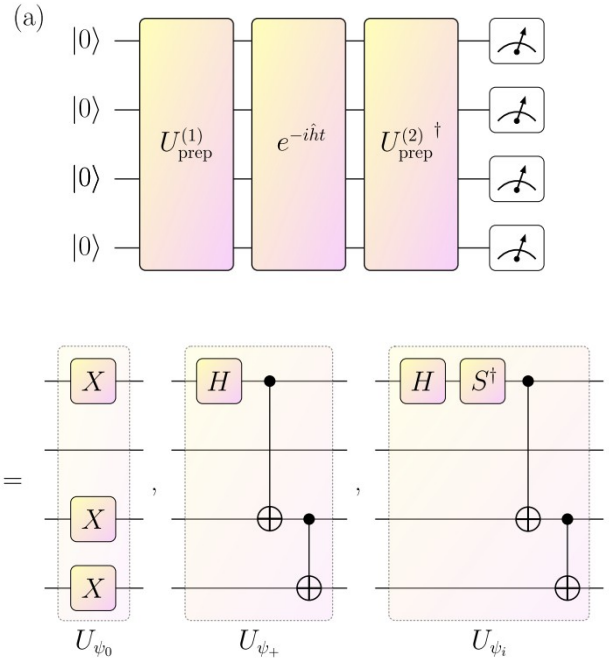


Perform Cartan decomposition (or alternatives)

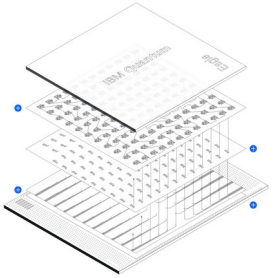


Esempio di algoritmo → quantum topological data analysis via DOS estimation

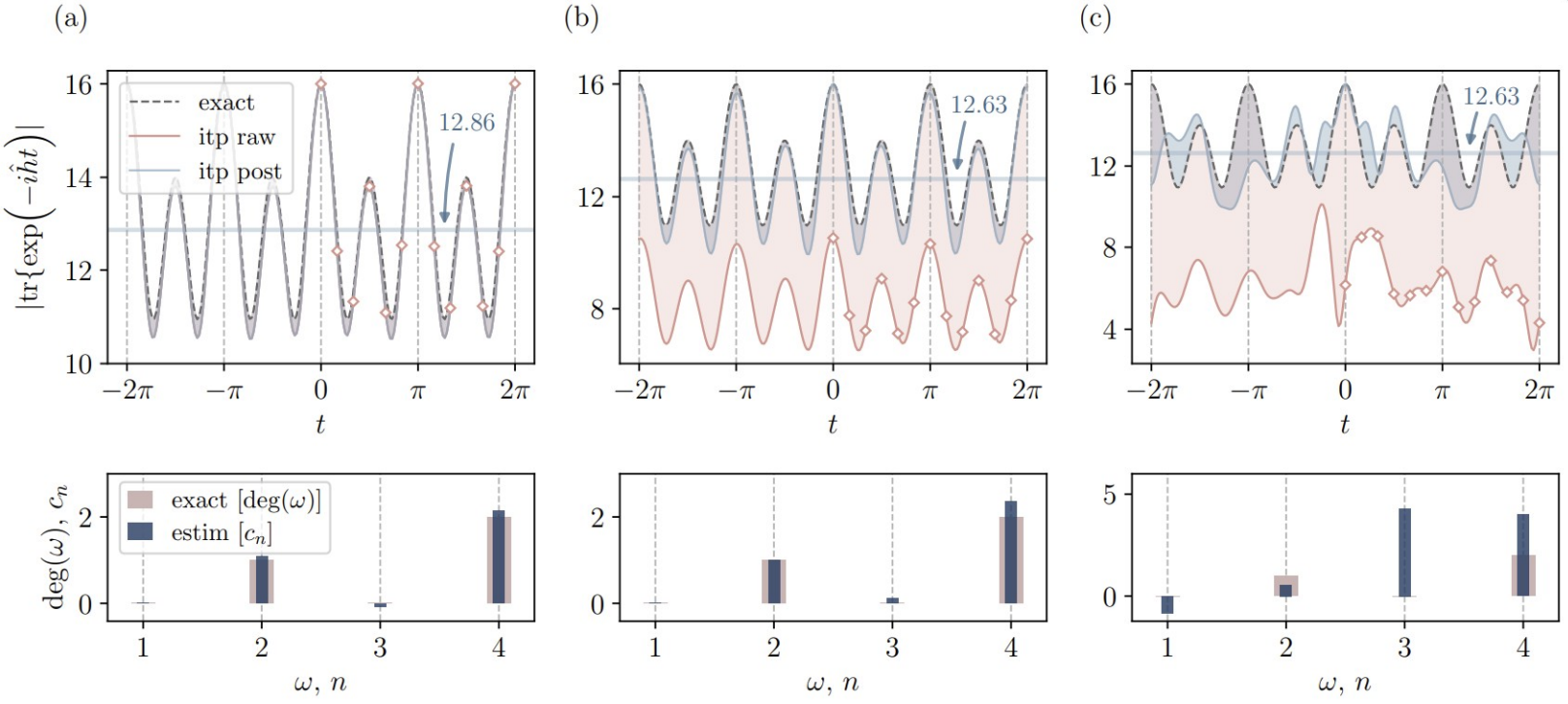




Esempio di algoritmo → quantum topological data analysis via DOS estimation



The results

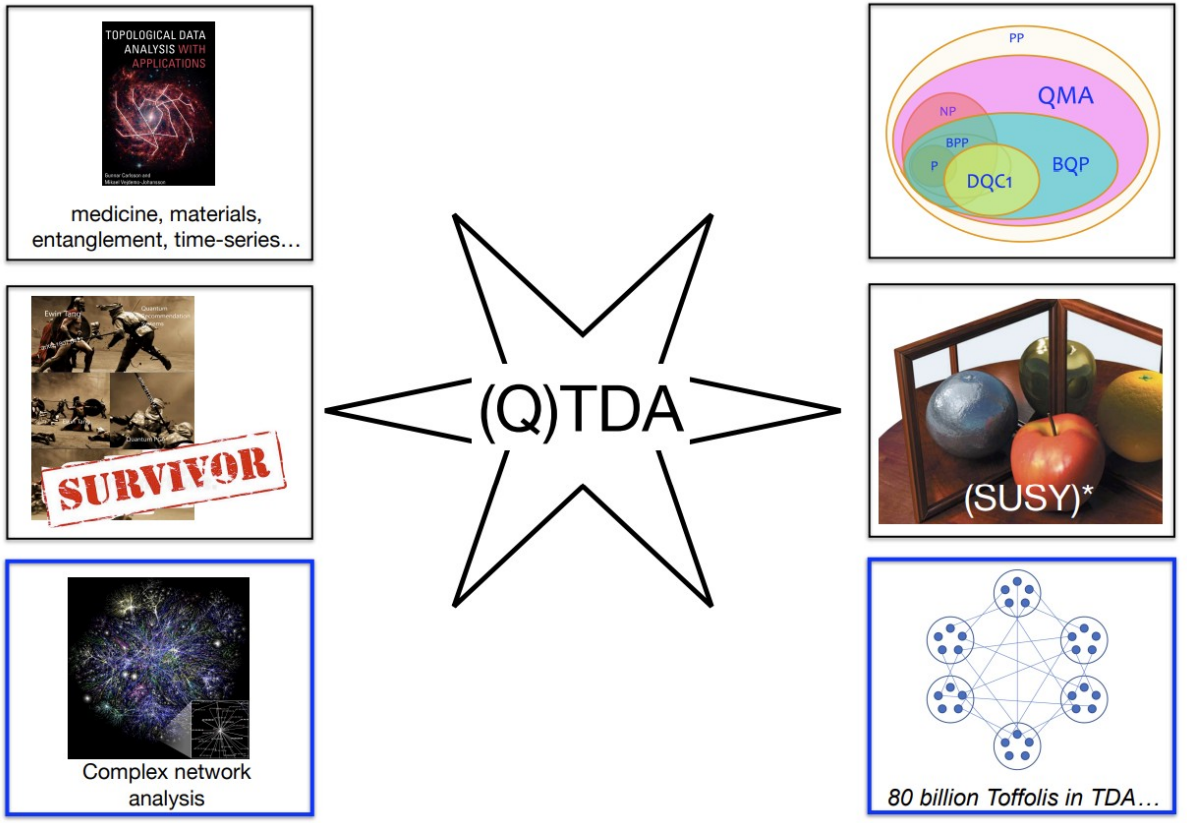


$$\beta_1 = 5 - 3 = 2$$

Esempio di algoritmo → quantum topological data analysis via DOS estimation

	Hadamard (x2)	SWAP non-destructive (x3)	SWAP destructive (x3)	Mirror-type (x3)
cx	210	58	30	26
rz	249	43	15	15
ry	26	3	0	1
h	26	31	5	7
x	1	1	3	3
s (sdg)	0 (2 for imag part)	4	0	4
# gates	~500	~150	~50	~50
measures	1	1	8	4
est. cost	$5100	$4600	$4200	$3600

Promising but still a lot of work to do…



Time for a coffee