Using the 5000 qubit D-Wave quantum annealer for improved near-surface characterization

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Dept. Applied Mathematics, EEMCS

Delphi Consortium Meeting, The Hague

Thursday, June 2, 2022

Delphi Consortium

TU Delft

What can quantum computing do for you today?

A first-of-its-kind application to residual statics estimation and other opportunities in geosciences

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About

- Simulation & optimization, HPC, quantum computing
- 6 PhDs, QAIMS lab +4PhDs, BSc/MSc student projects
- Past and ongoing collaborations

Quantum computing

Hype or reality ?

Quantum computing

Article

Quantum supremacy using a programmable superconducting processor

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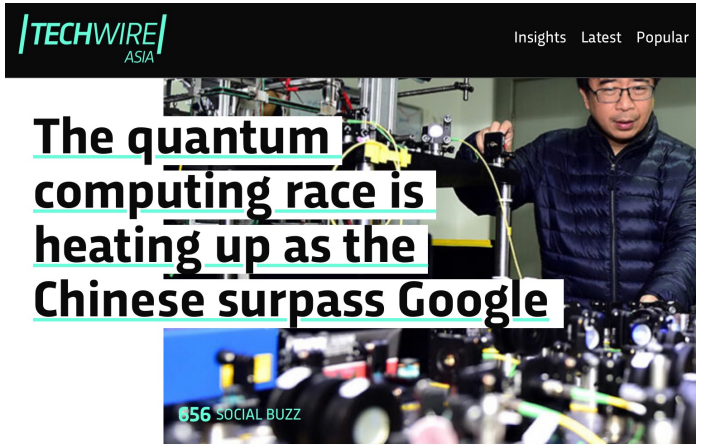
Hype or reality ?

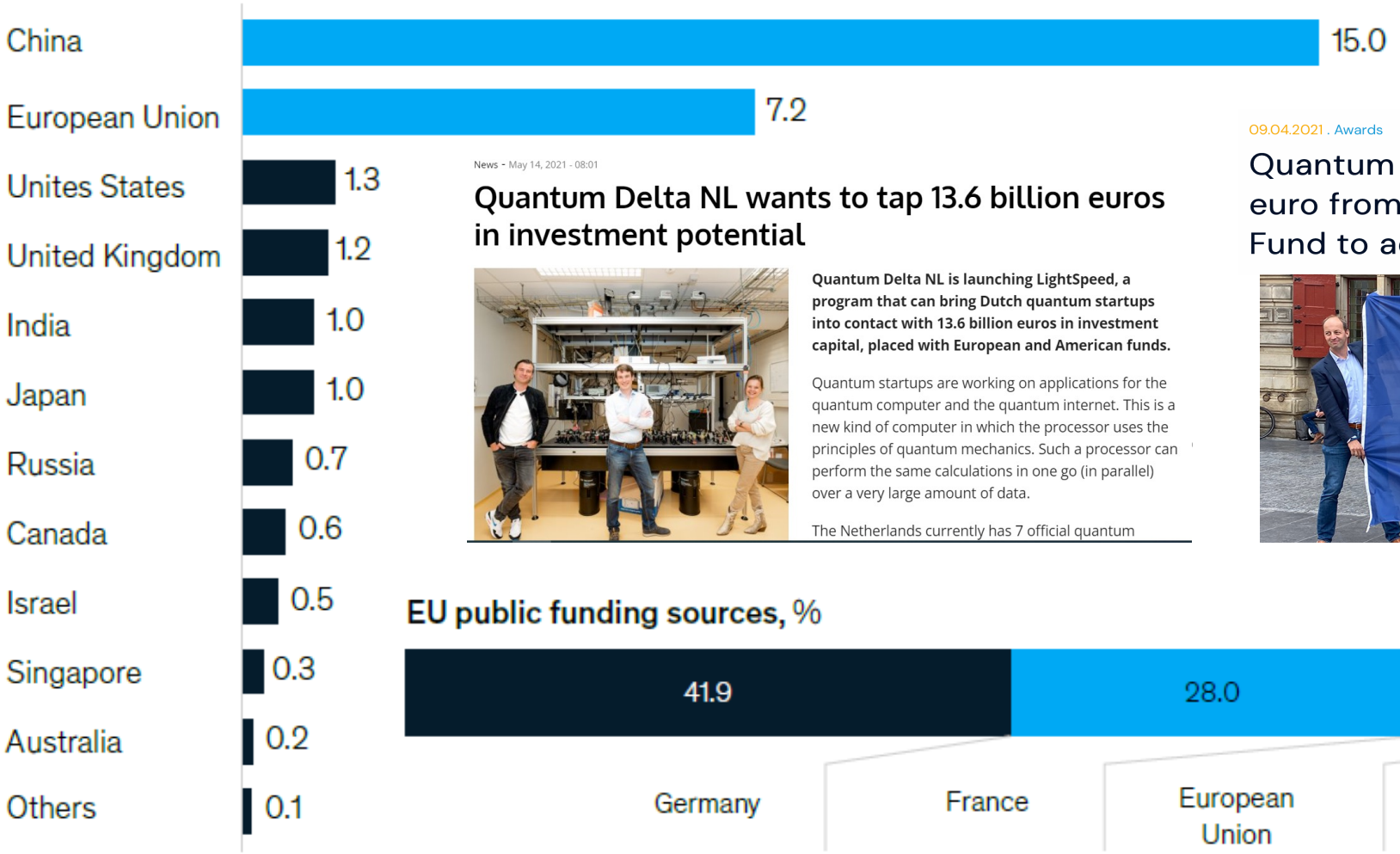


Chinese quantum computer surpasses Google's 'quantum supremacy'.

By **Dashveenjit Kaur** | 20 July, 2021

- **China is unveiling a super-advanced 66-qubit quantum supercomputer called "Zuchongzhi"**
- **The Chinese team claims that it has solved a problem in just over an hour that would otherwise take the world's most powerful classical supercomputer eight years to crack.**

Quantum computing



News - May 14, 2021 - 08:01

Quantum Delta NL wants to tap 13.6 billion euros in investment potential

Quantum Delta NL is launching LightSpeed, a program that can bring Dutch quantum startups into contact with 13.6 billion euros in investment capital, placed with European and American funds.

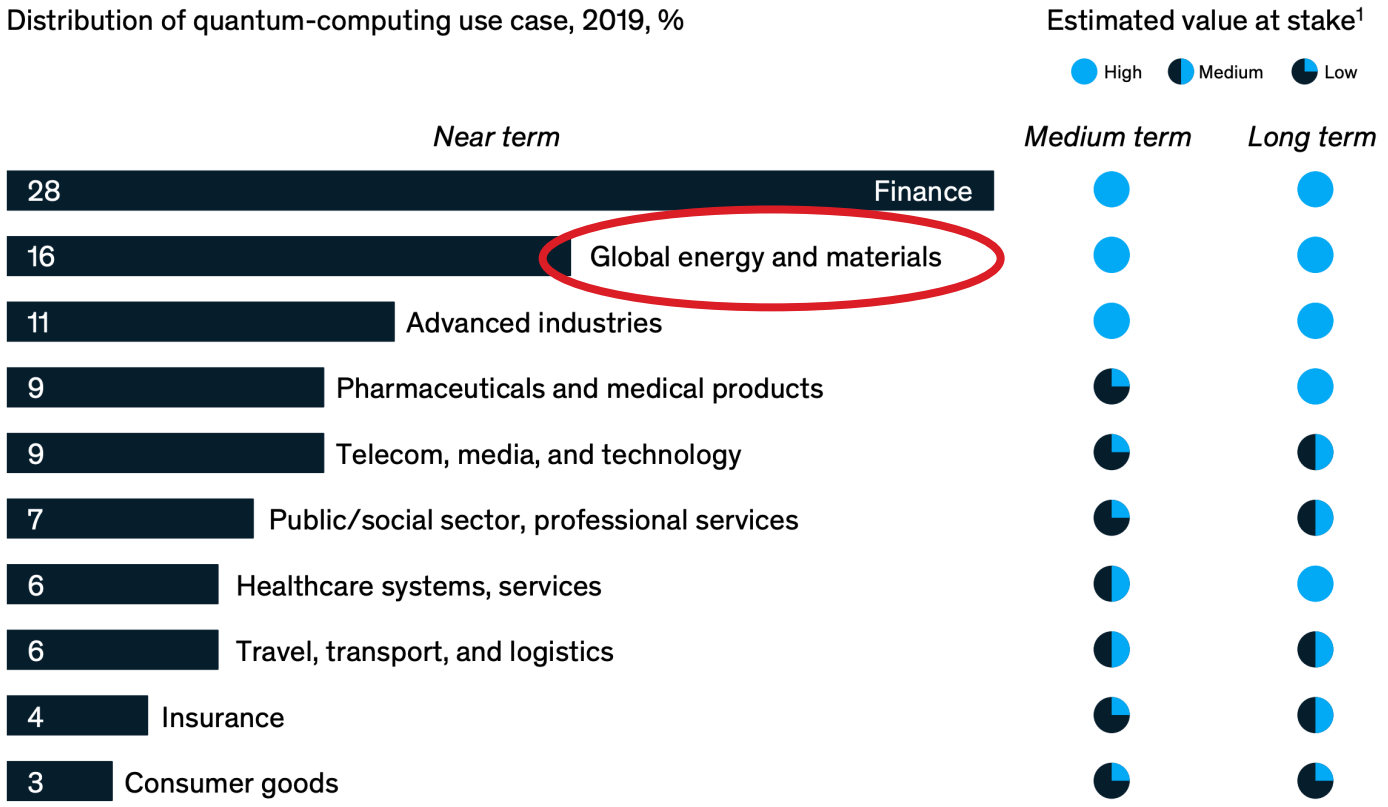
Quantum startups are working on applications for the quantum computer and the quantum internet. This is a new kind of computer in which the processor uses the principles of quantum mechanics. Such a processor can perform the same calculations in one go (in parallel) over a very large amount of data.

The Netherlands currently has 7 official quantum

09.04.2021 . Awards

Quantum Delta NL awarded 615 million euro from Netherlands' National Growth Fund to accelerate quantum technology

Quantum-computing use cases per industry



1. Approximate timing for medium term is by the year 2025; for long term, by the year 2035. Experts consider these values at stake to be a snapshot in time. Fully developed quantum computing will lead to additional value within and shifts between industry verticals.

Source: Expert interviews; McKinsey analysis

Gate/circuit model
Universal/programmable
~ 100 qubits
TRL 4-5 (TRL 9 expected 2035)
Few use cases/algorithms

Quantum Annealing
Task specific (optimization)
5000+ qubits
TRL 8-9
Many use cases

(theoretical) speed-up

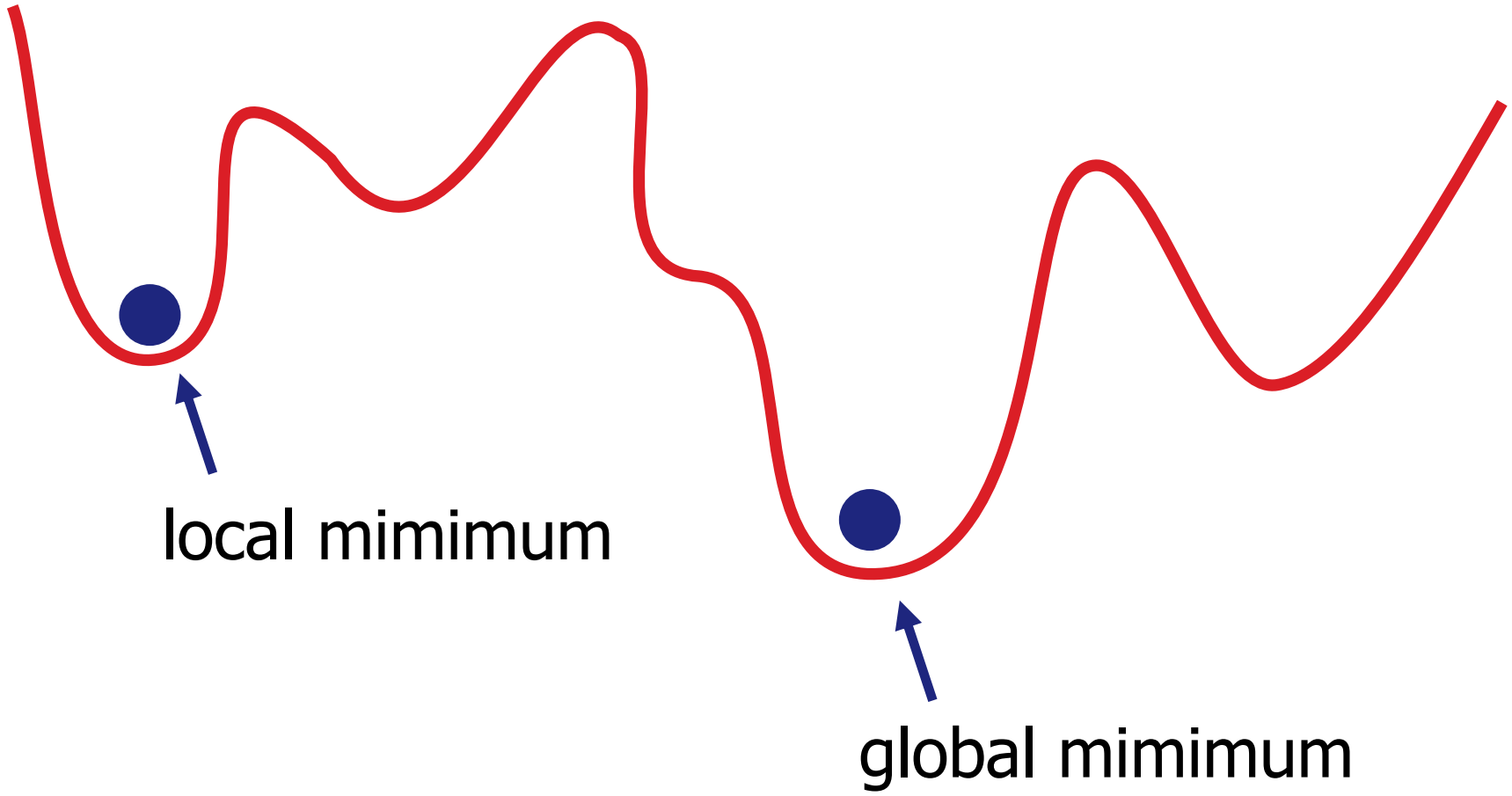
optimal solutions

Sources: https://www.fz-juelich.de/ias/jsc/EN/Research/ModellingSimulation/QIP/QTRL/_node.html
Michielsen K., FZ Jülich: Quantum Annealing for Optimization and Classification | D-Wave Qubits 2021

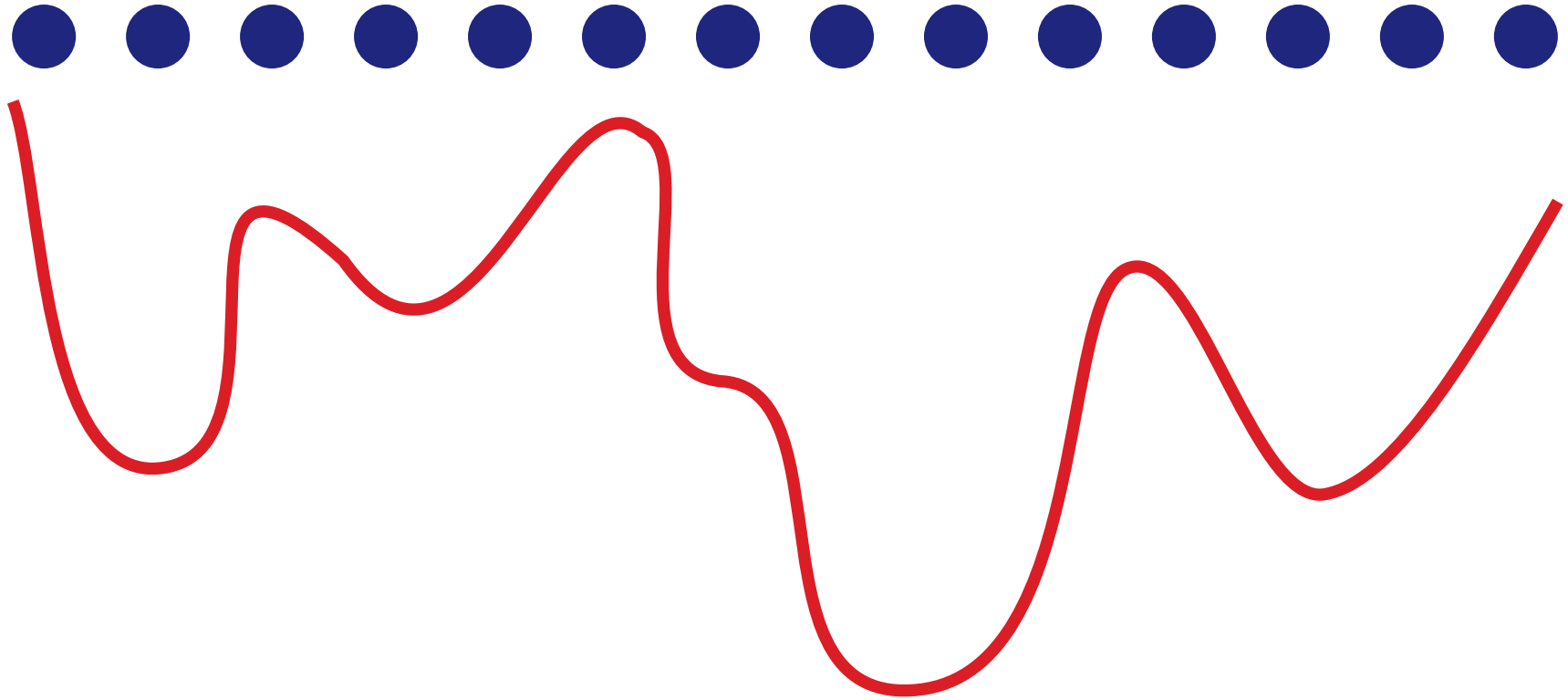
Outline

- Quantum annealing 101
- Residual statics estimation using quantum annealing
- Outlook and opportunities for collaboration

Local versus global optima



Brute force sampling



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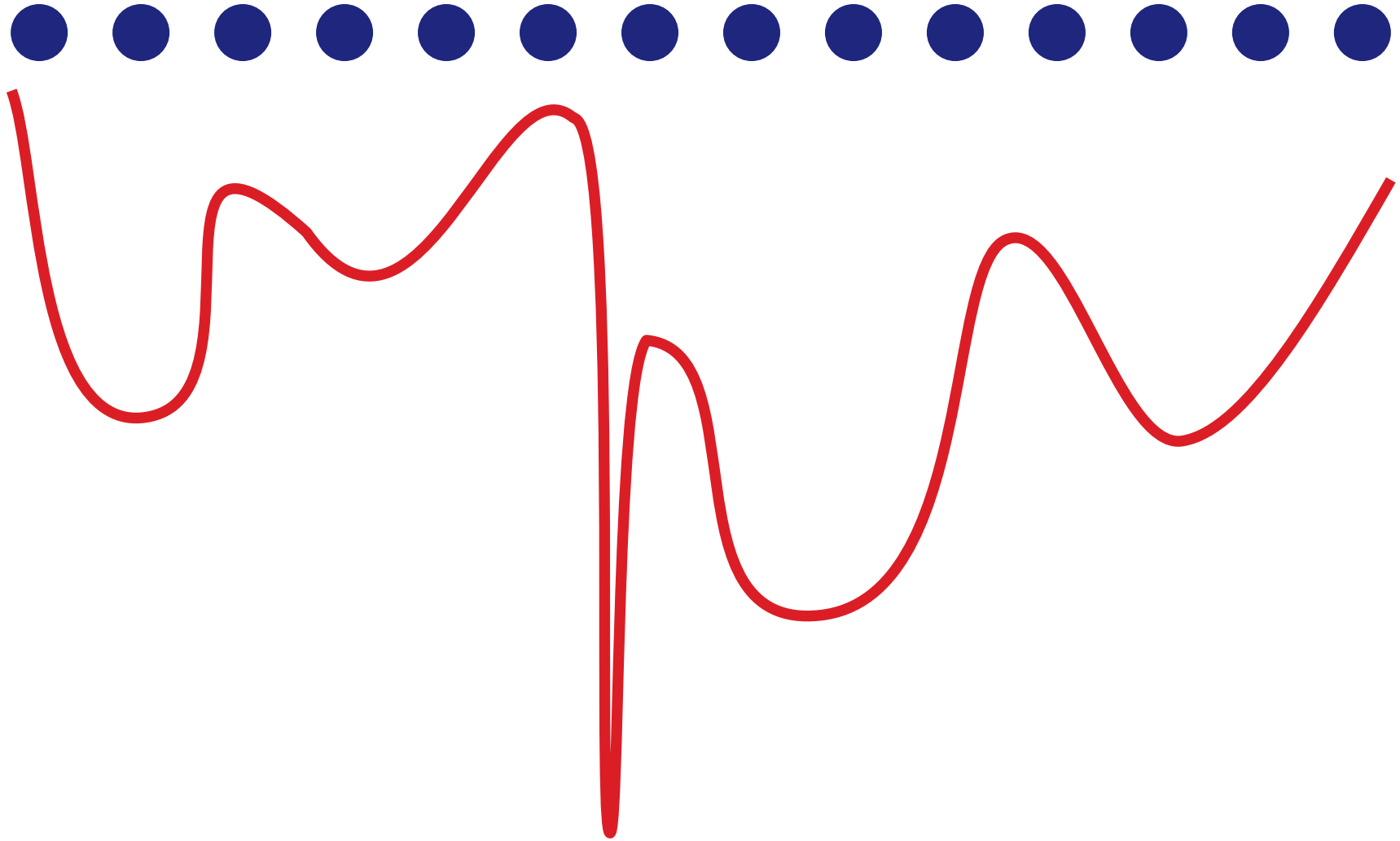
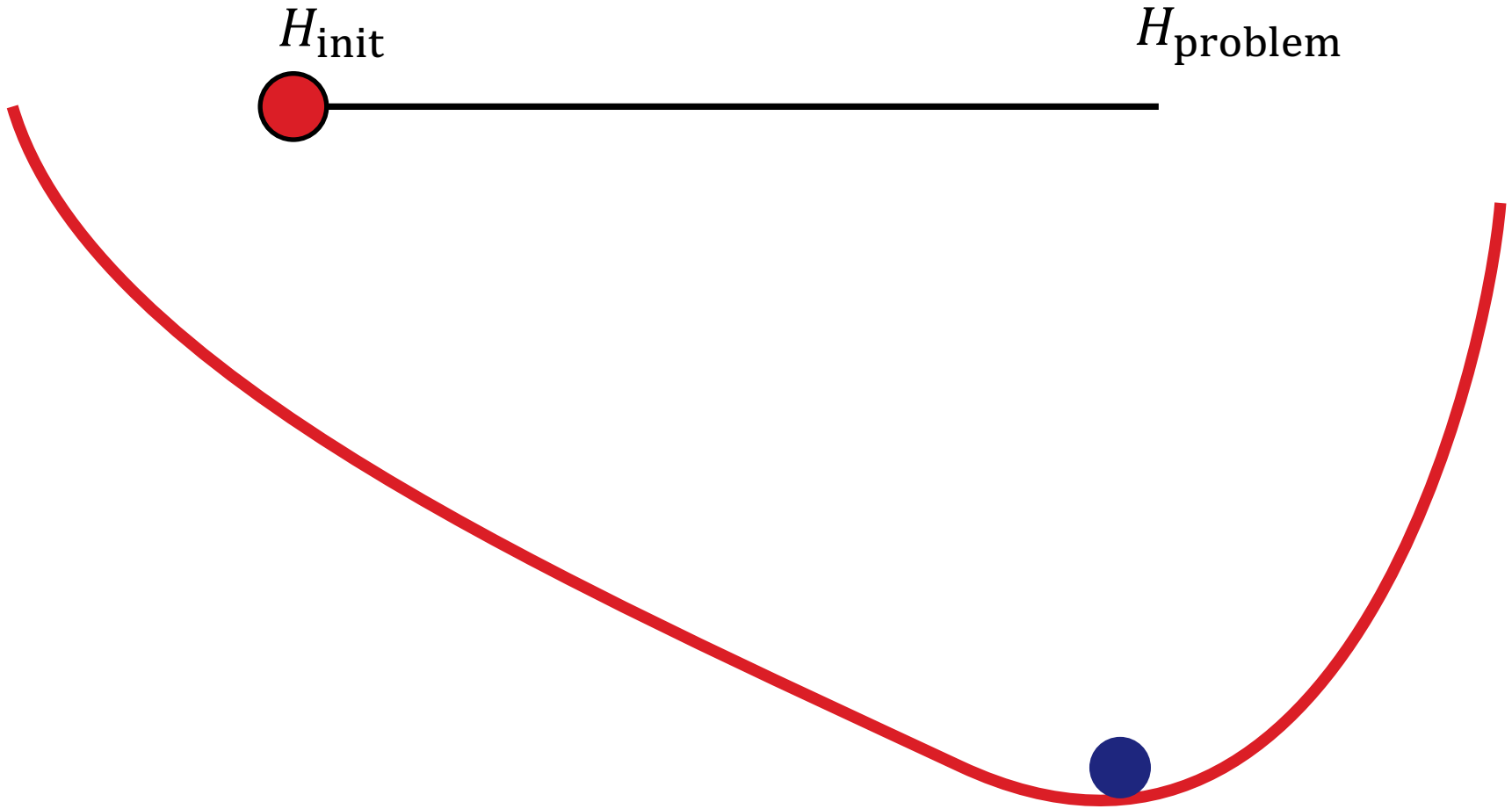
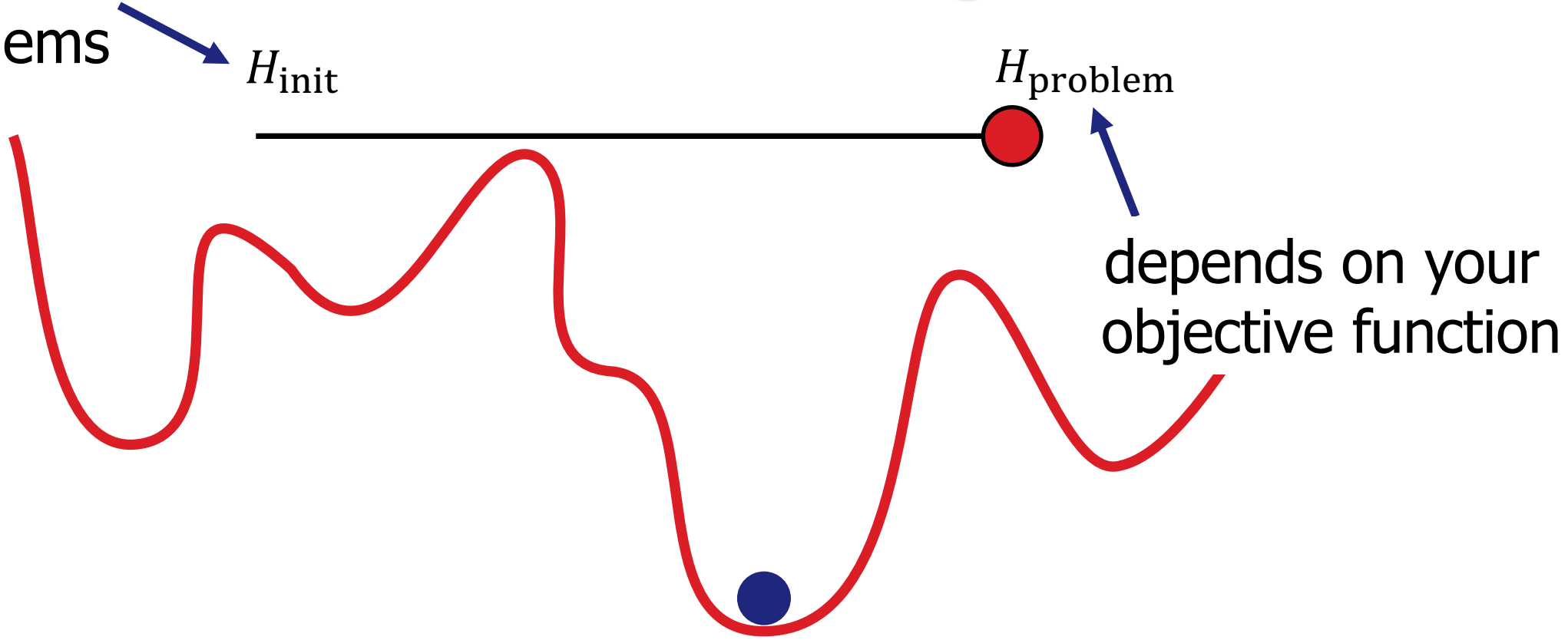


Quantum annealing



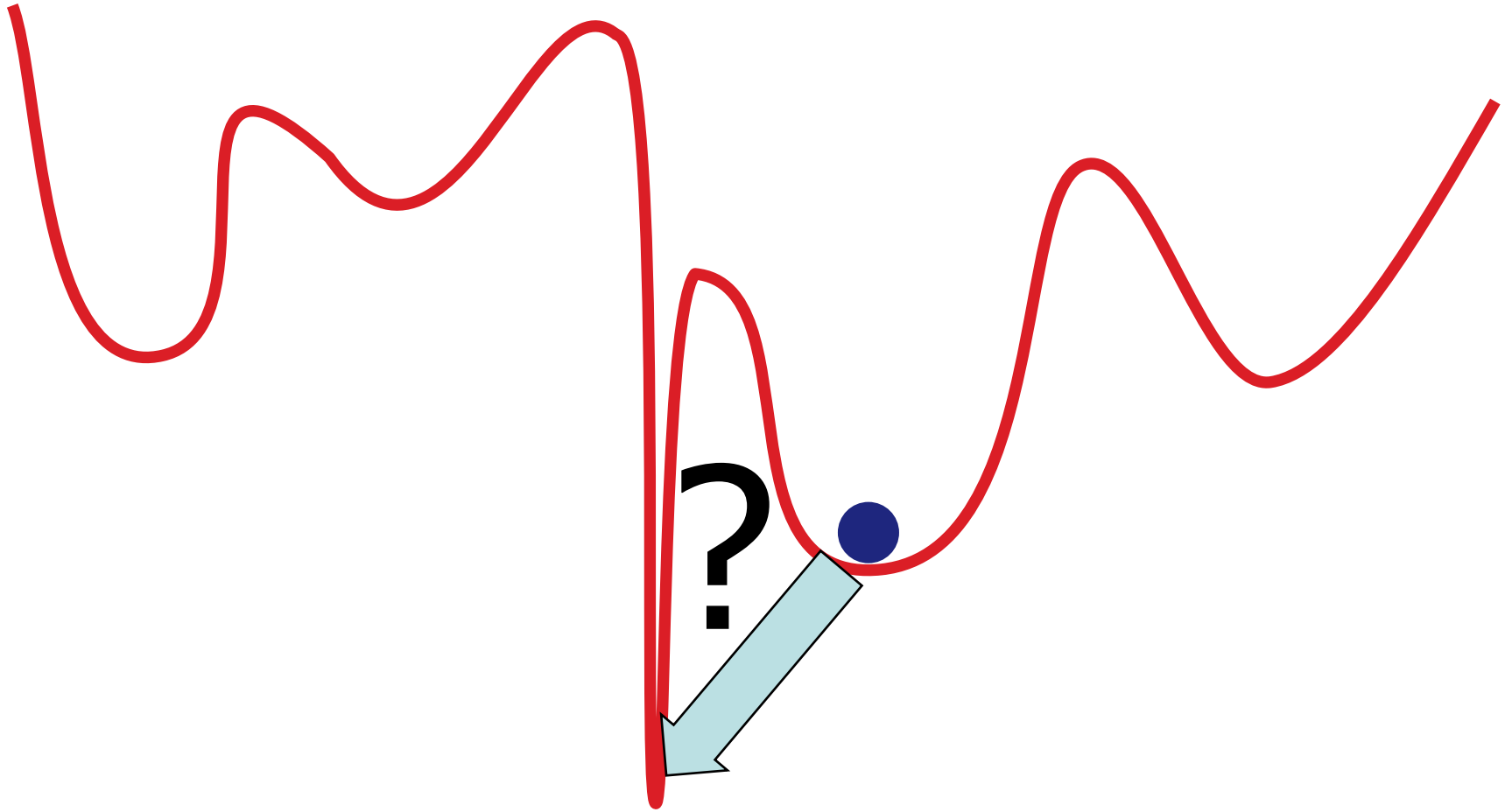
Quantum annealing

same for
all problems



depends on your
objective function

Quantum tunneling



Outline

- Quantum annealing 101
- Residual statics estimation using quantum annealing
- Outlook and opportunities for collaboration

Stan v.d. Linde
Matthias Möller

TU Delft

Niels Neumann
Frank Phillipson

TNO

Marcin Dukalski
Diego Rovetta

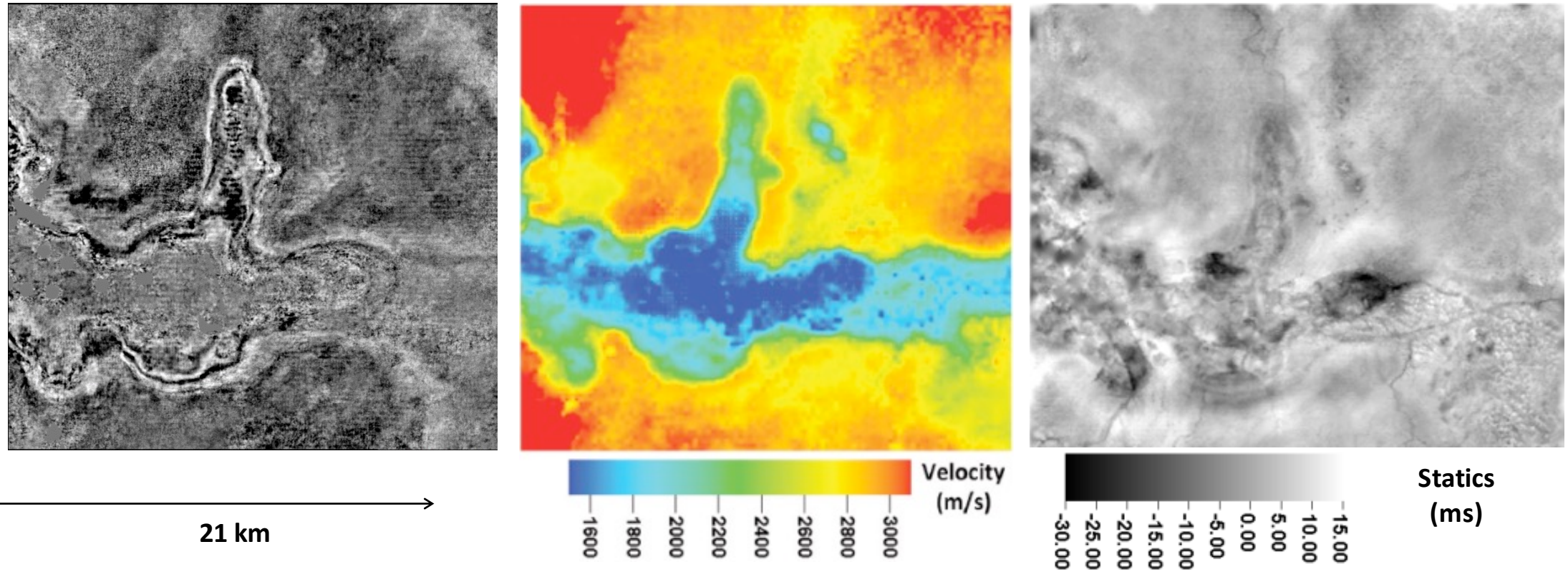
Further information

- Talk and paper at

☞ M. Dukalski
June 7, 2022
10:10-10:30 AM

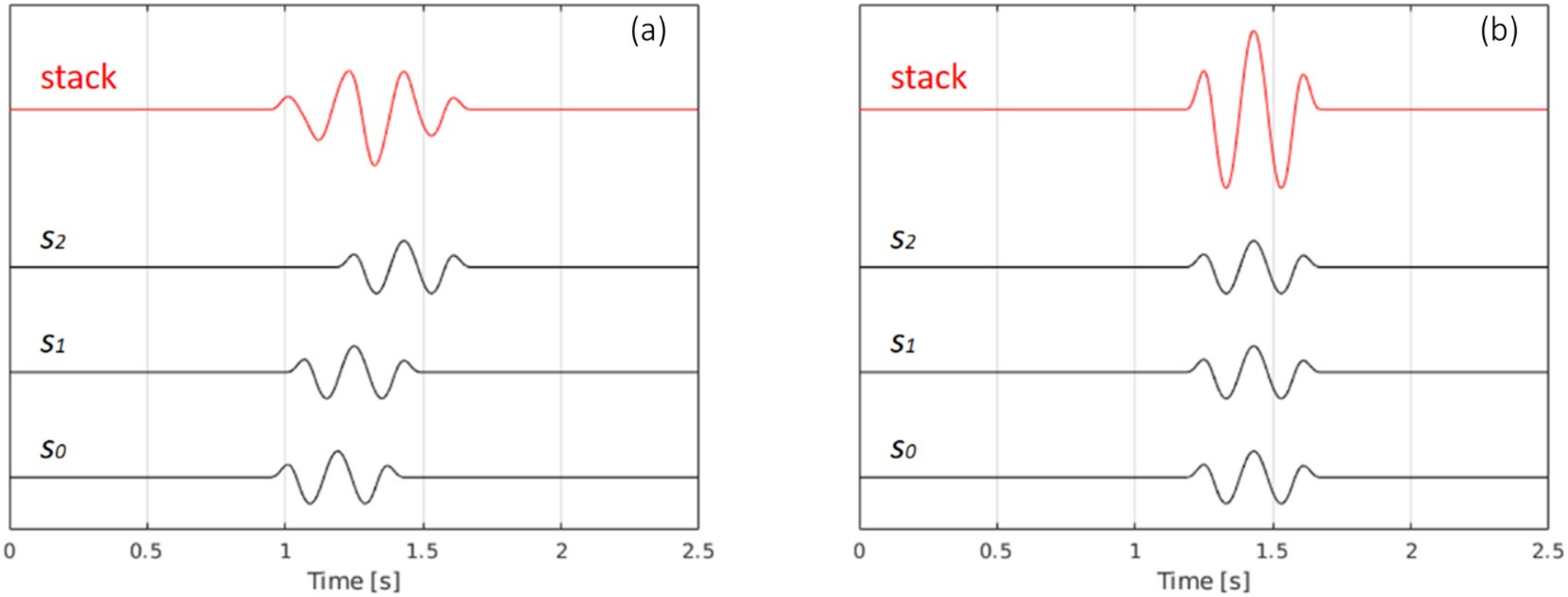
- Recordings on Youtube

Refraction residual statics estimation (RRSE)



Source: Colombo, D., F. Miorelli, E. Sandoval Curiel, and D. Rovetta, pQC: A novel approach for robust automatic near-surface analysis in low-relief geology, The Leading Edge 35 (11), 952-960.

Stack-power maximization in a nutshell



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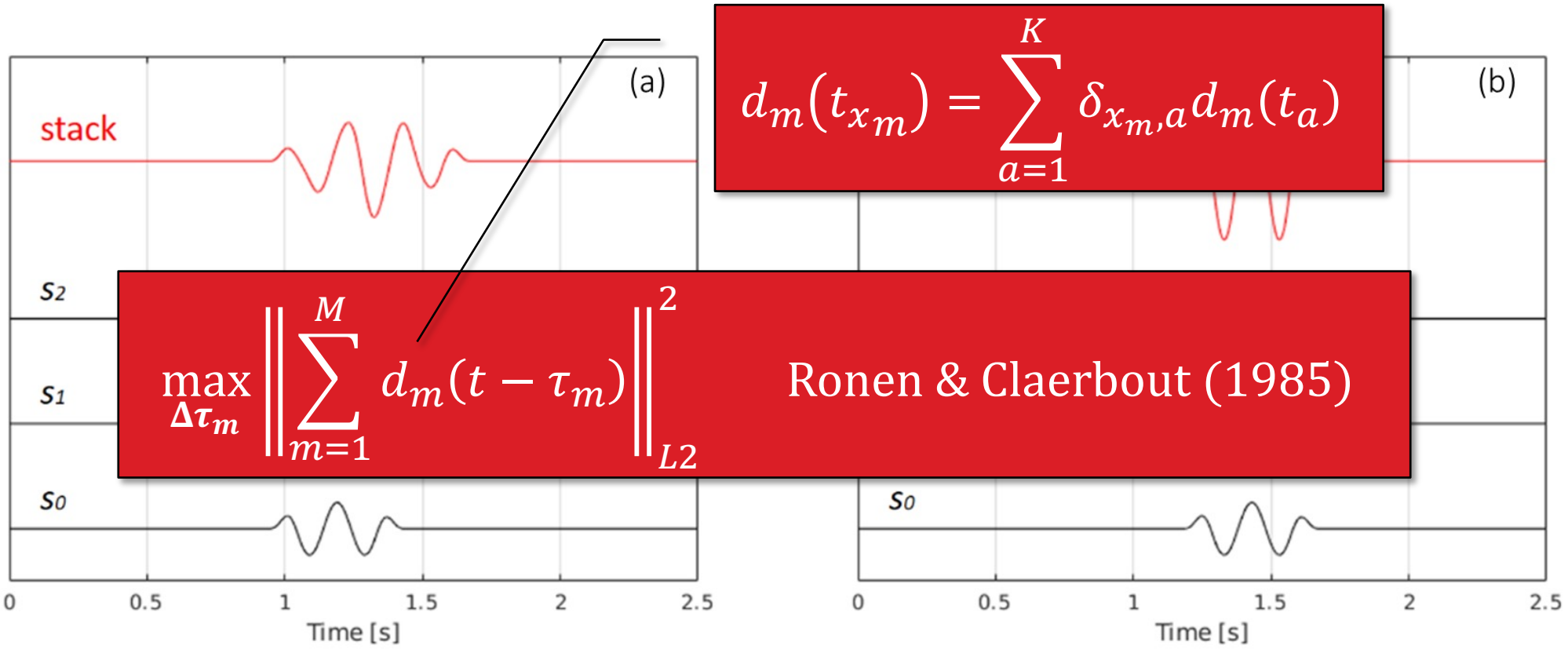
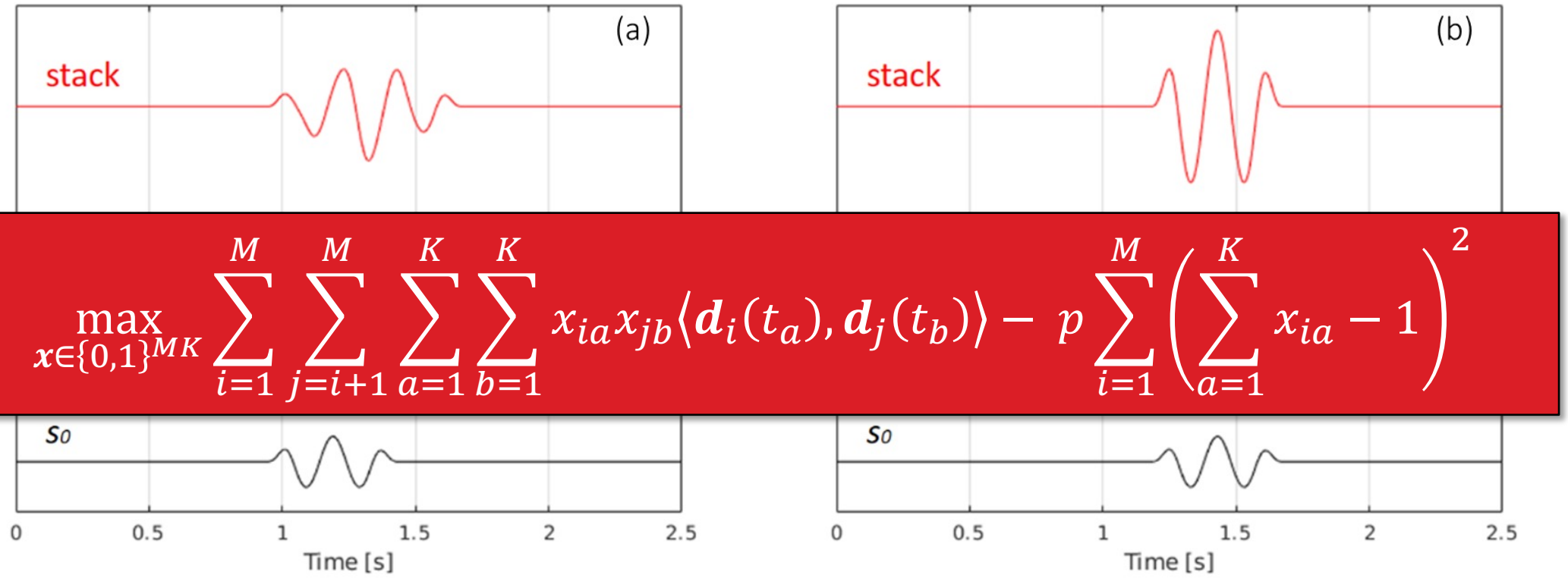
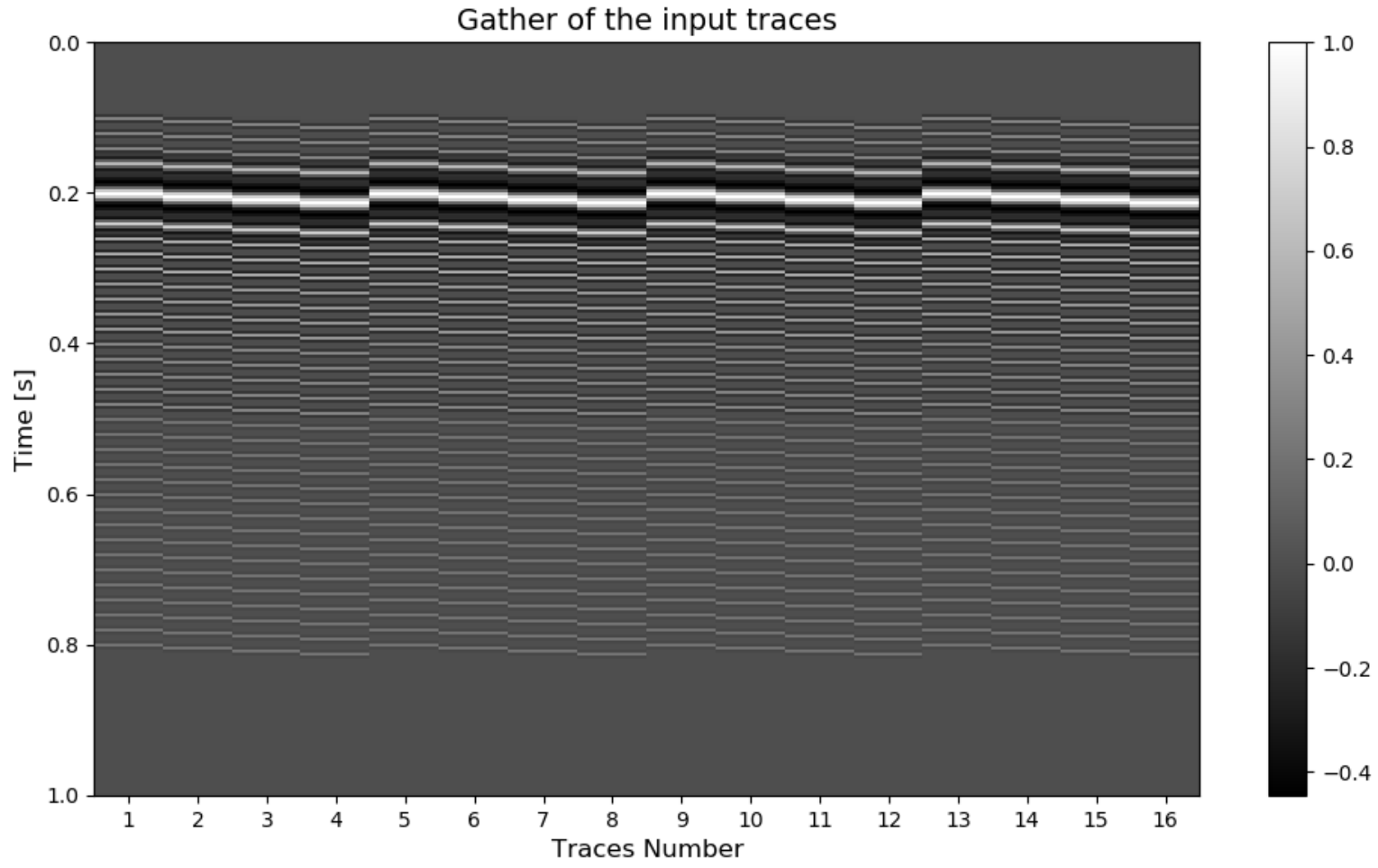


Stack-power maximization on a quantum annealer



$$\max_{\boldsymbol{x}\in\{0,1\}^{MK}} \sum_{i=1}^{M}\sum_{j=i+1}^{M}\sum_{a=1}^{K}\sum_{b=1}^{K} x_{ia}x_{jb}\langle \boldsymbol{d}_i(t_a), \boldsymbol{d}_j(t_b)\rangle - p\sum_{i=1}^{M}\left(\sum_{a=1}^{K} x_{ia} - 1\right)^2$$

Synthetics: 16 traces, 4 shifts – problem size 4^{16}



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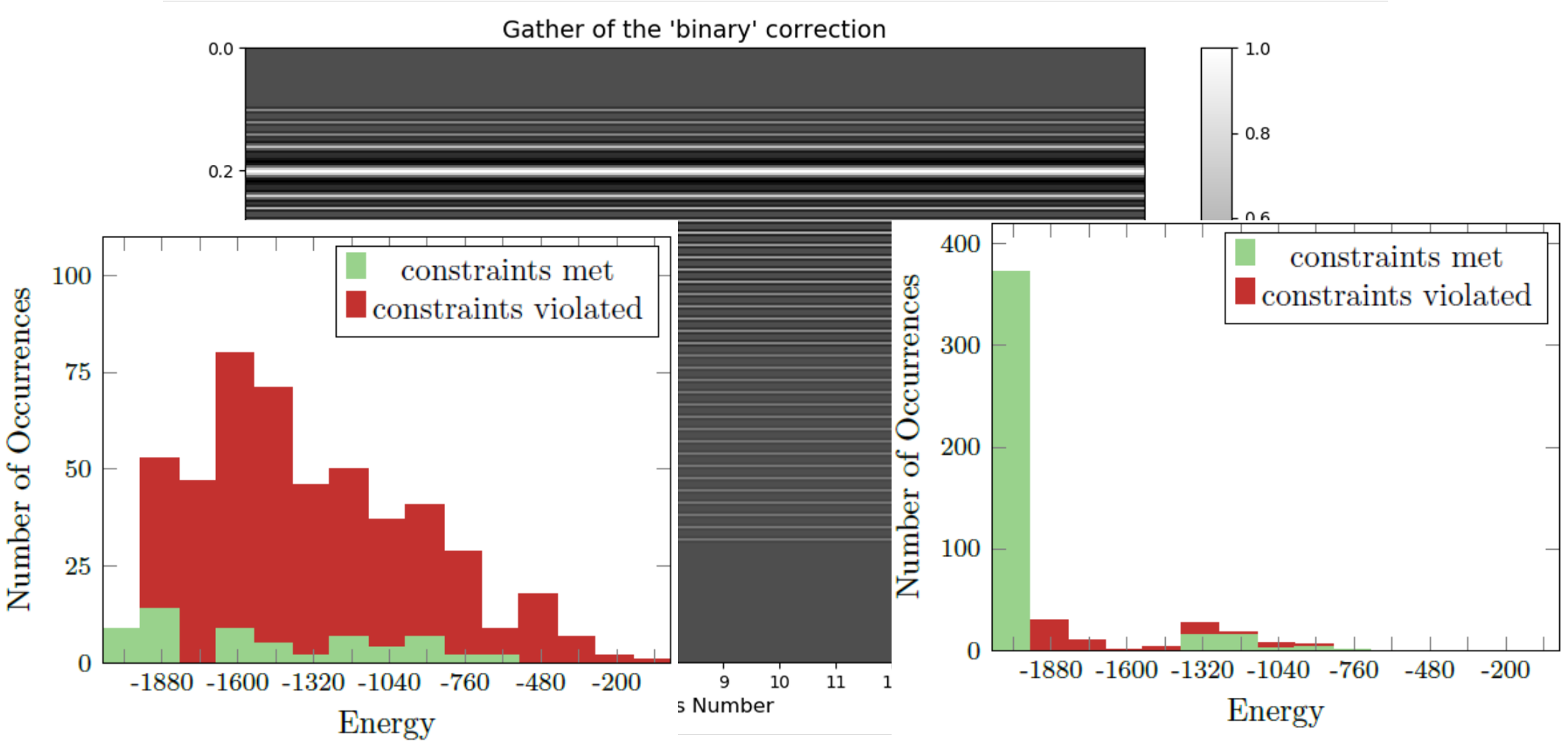

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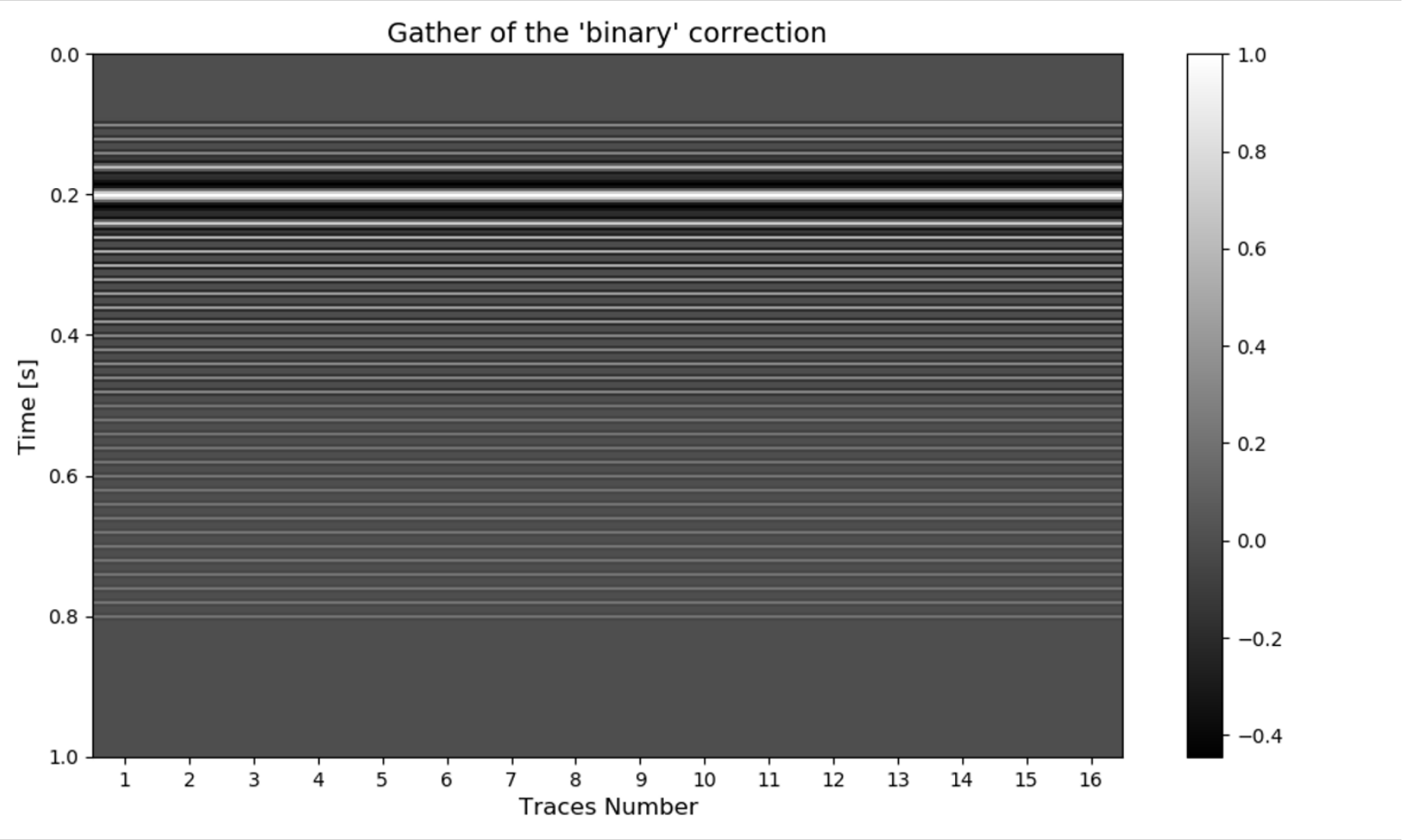
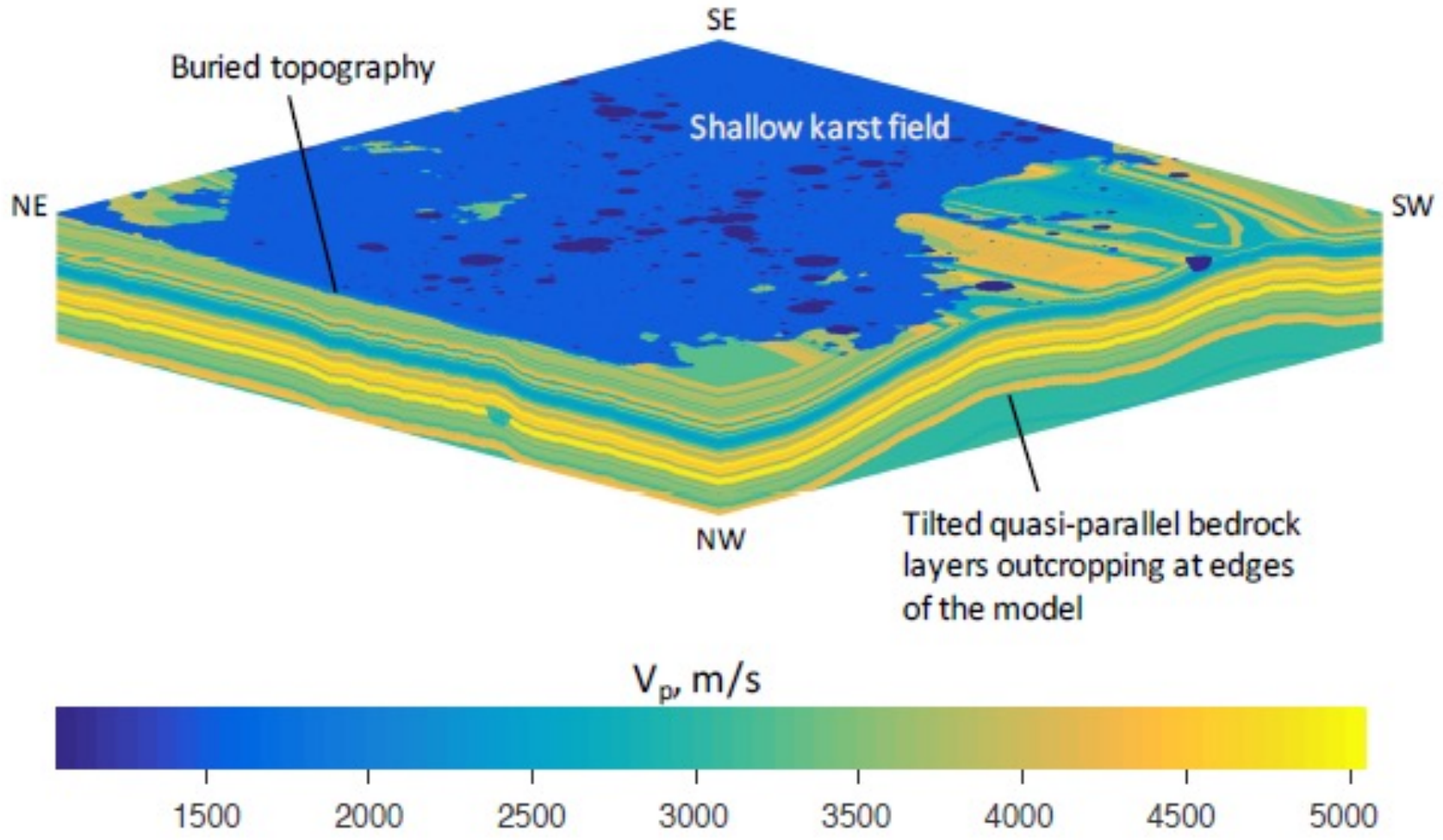
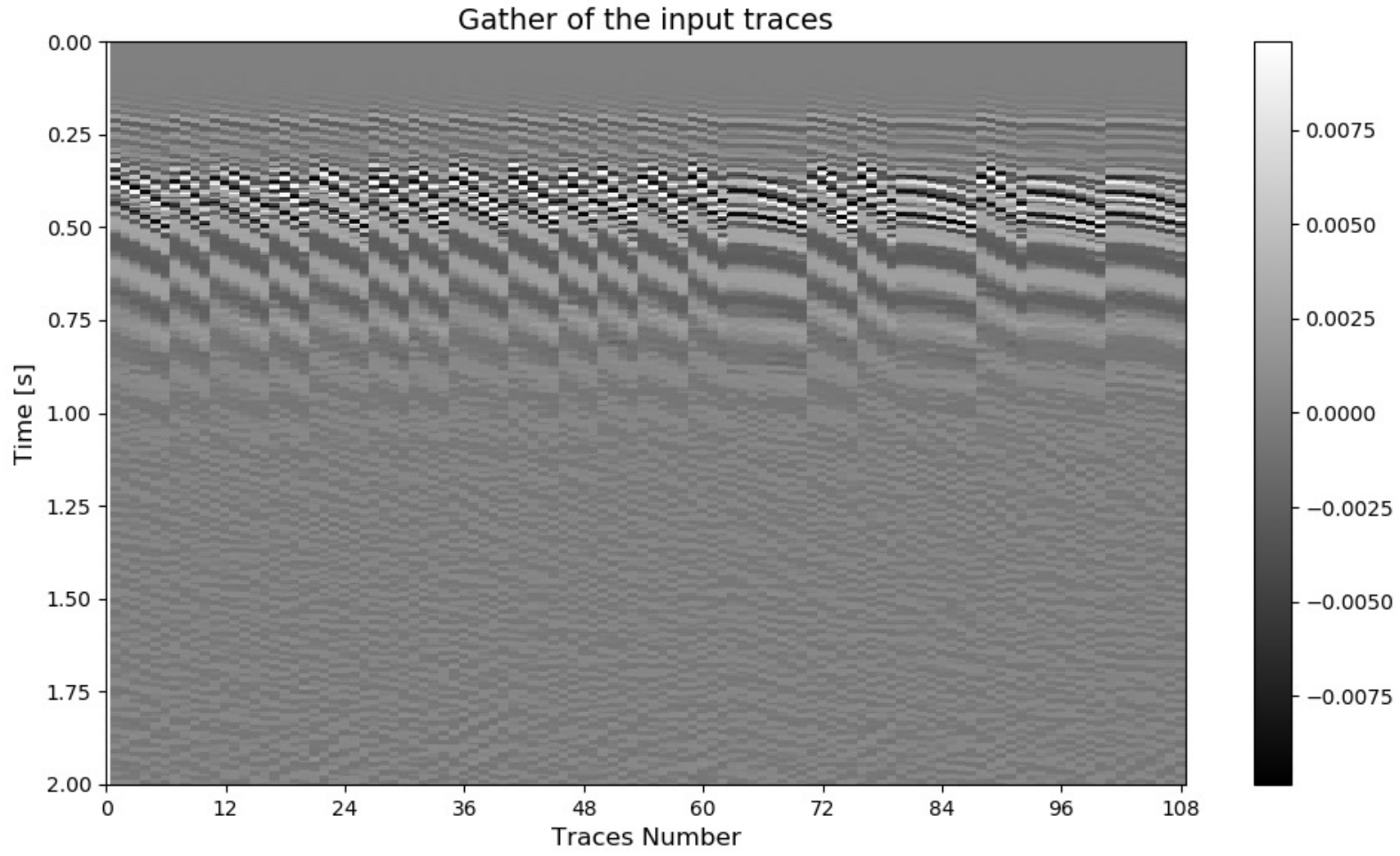


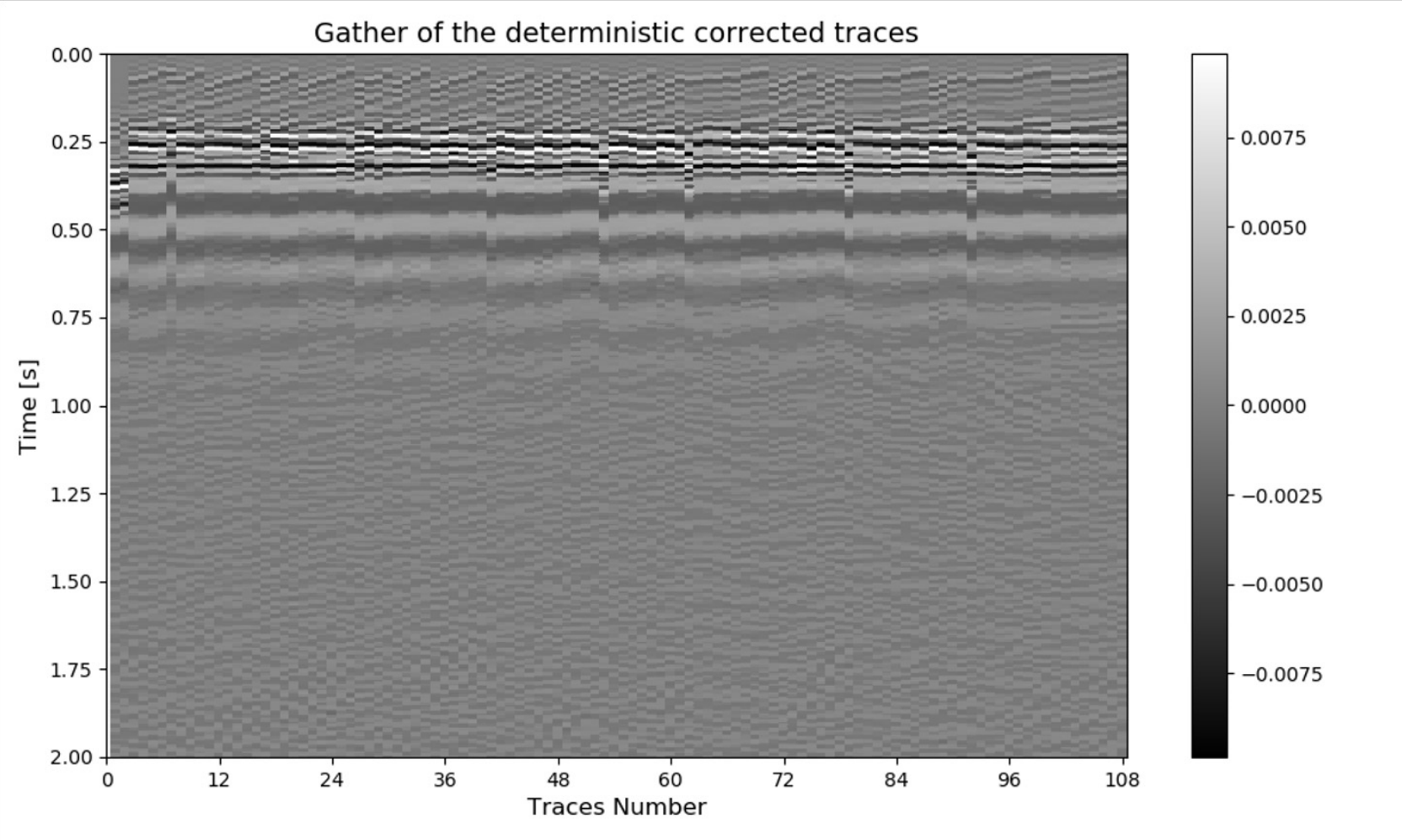
SEAM Arid model – problem size 16^{108}



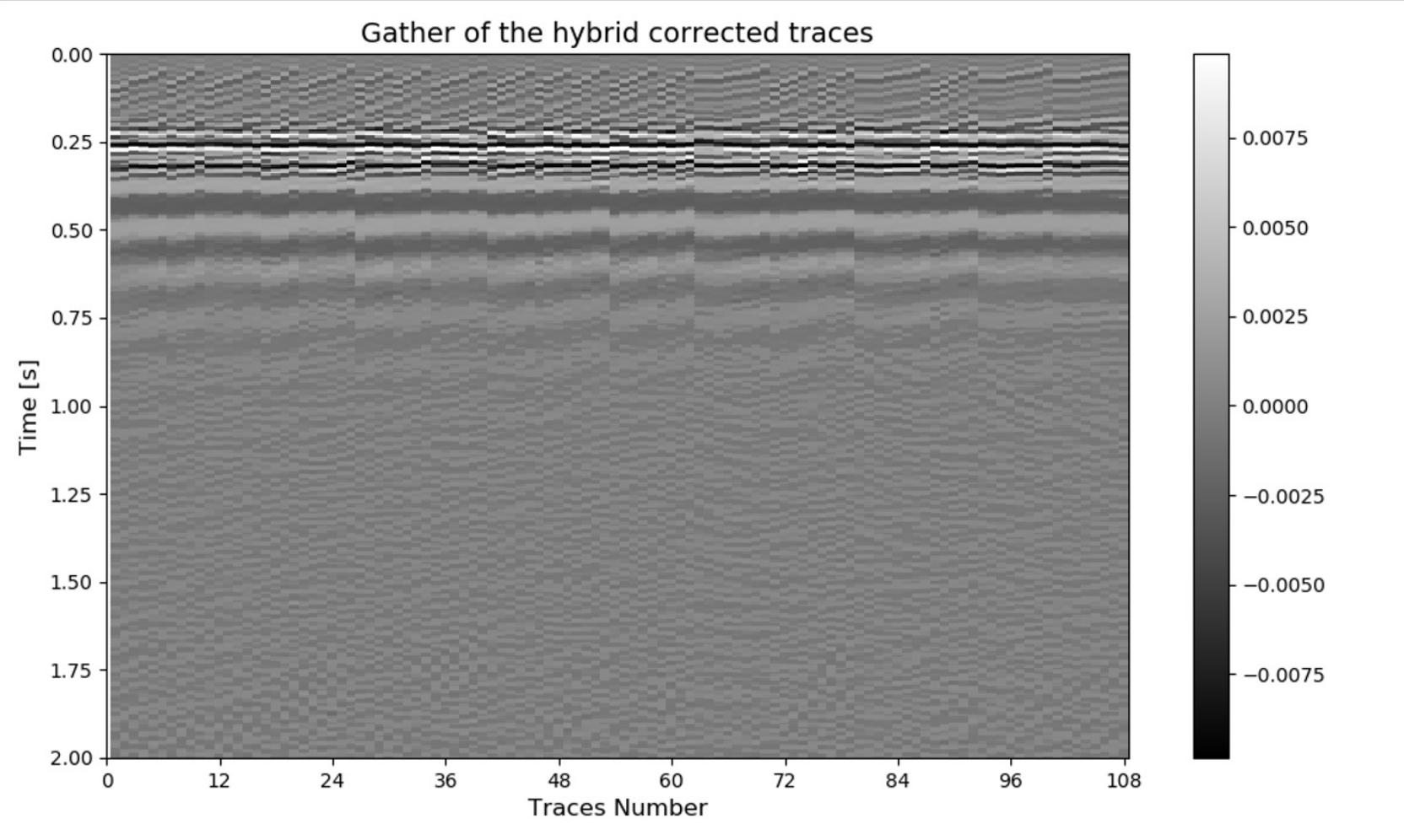
SEAM Arid model: inputs



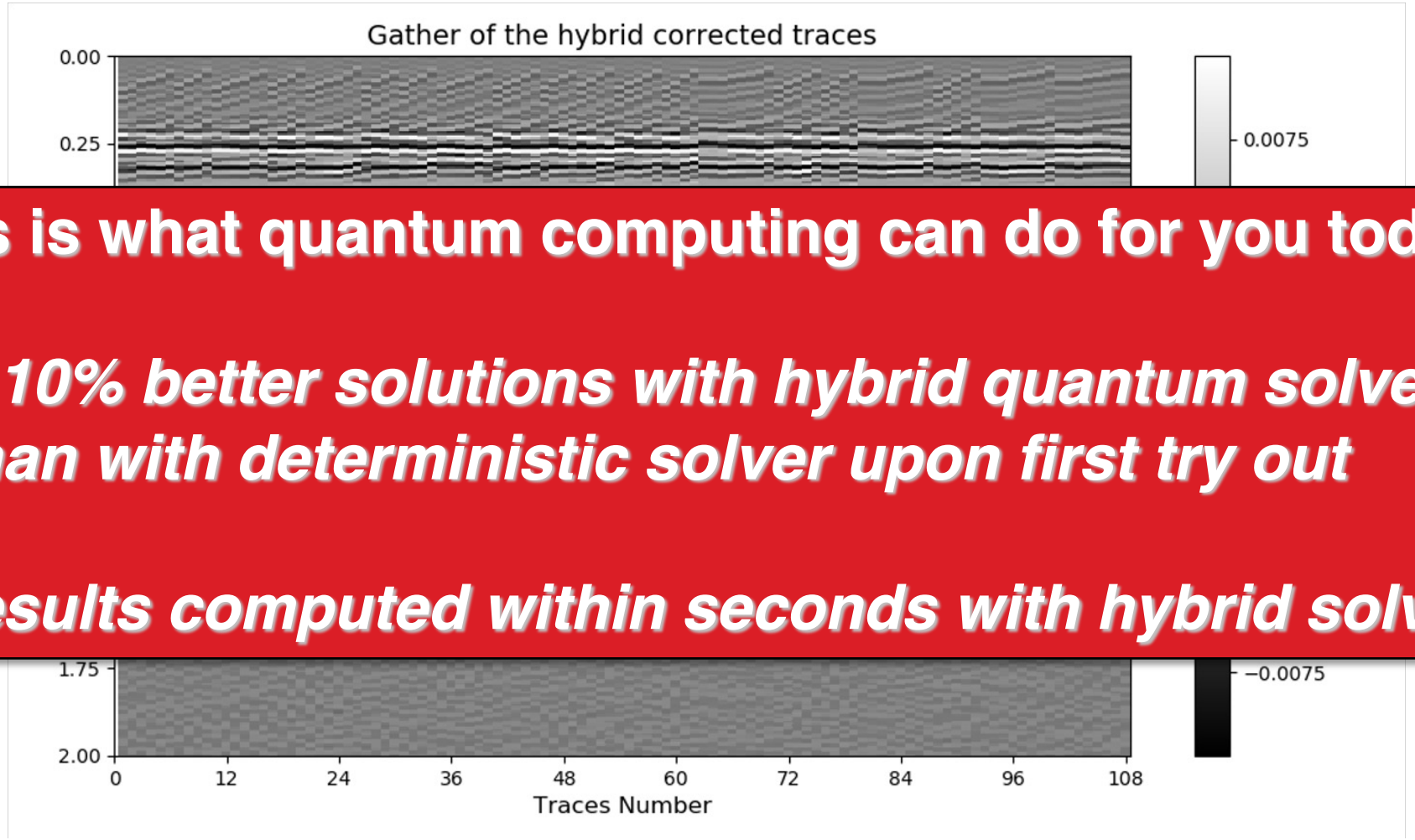
SEAM Arid model: deterministic output



SEAM Arid model: hybrid quantum output



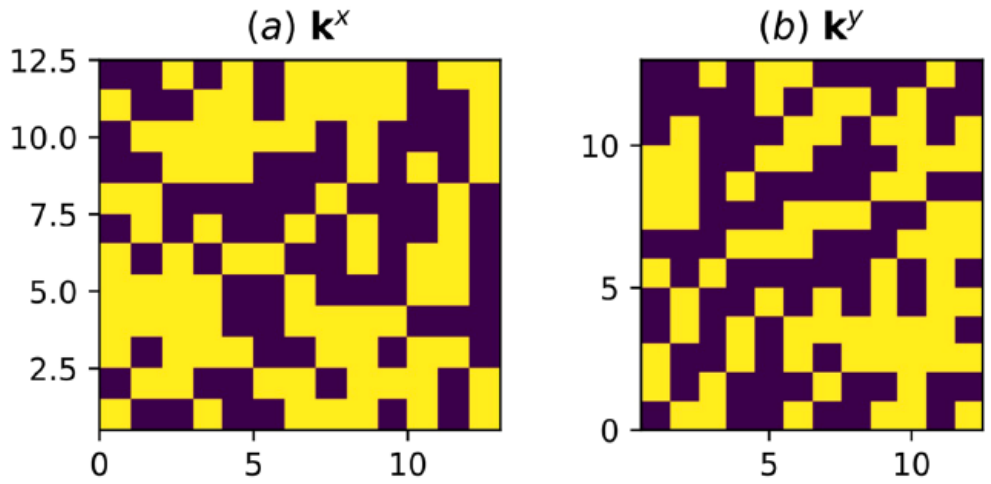
SEAM Arid model: hybrid quantum output

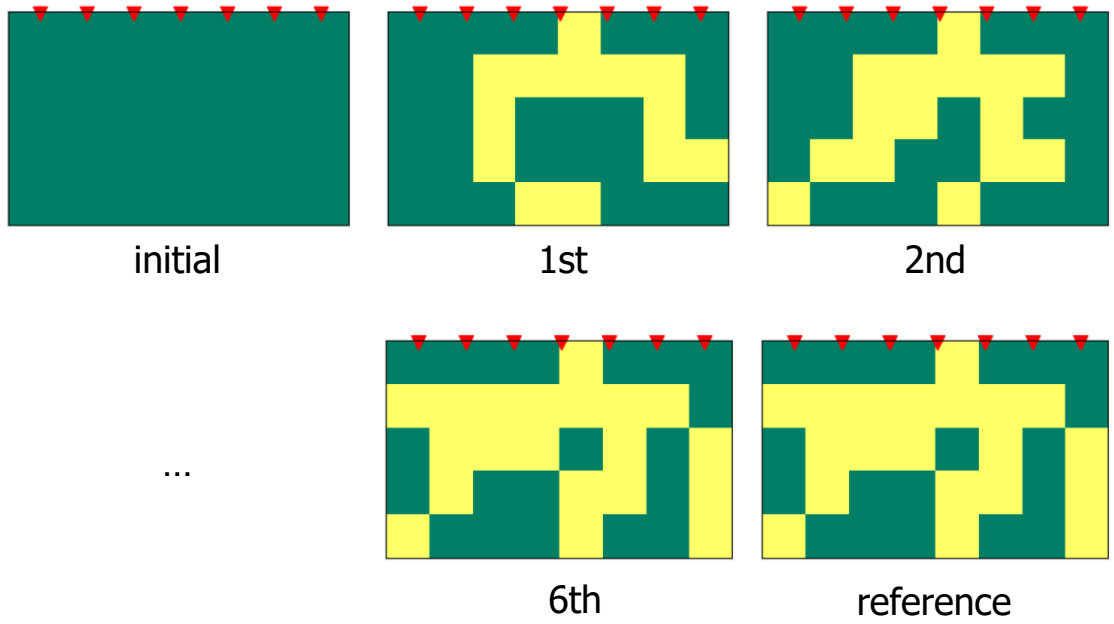


This is what quantum computing can do for you today

- ***~ 10% better solutions with hybrid quantum solver than with deterministic solver upon first try out***
- ***results computed within seconds with hybrid solver***

This is just the beginning …

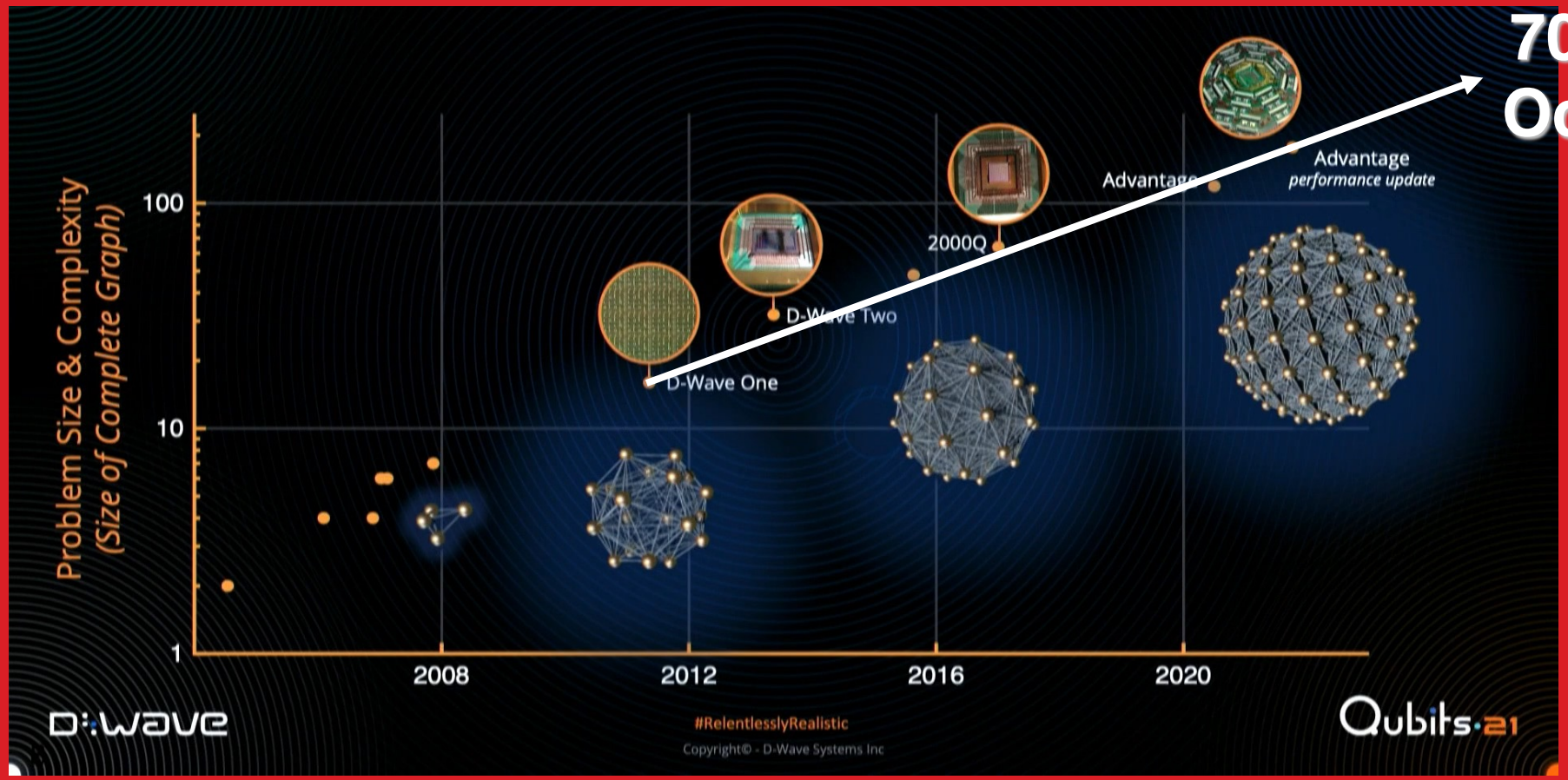




O'Malley (2018) *An approach to quantum-computational hydrologic inverse analysis.* Sci. Rep.

Greer and O'Malley (2020) *An approach to seismic inversion with quantum annealing. SEG Conference*

… with more to come in the next years



7000+ qubits
October 2022

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NWO OTP consortium

- Geophysical applications
- Practical quantum algorithms

Thank you!

Delphi Consortium

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