



Hybrid Quantum–Classical Approach for Omics Analysis

Q-Seeded Network Epistasis Detection in Autism Spectrum Disorder

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Overview

A hybrid quantum–classical pipeline for detecting epistatic (SNP–SNP interaction) signals in autism spectrum disorder (ASD), using SPARK whole-exome sequencing data and IBM gate-based quantum hardware.

QUBO / PCBO FORMULATION

Cost function over selection :

$$x \in \{0, 1\}^n$$
$$f(x) = \sum_i C_i^1 x_i + \sum_{i < j} C_{ij}^2 x_i x_j + \sum_{i < j < l} C_{ijl}^3 x_i x_j x_l$$

Entropy-Cubo informativeness term ($k = k_{\text{target}}$):

$$C_{ijl}^3 = - \frac{H(x_i, x_j, x_l) - H(x_i, x_j, x_l | y)}{C(k, 3)}$$

Ising mapping → cost Hamiltonian:

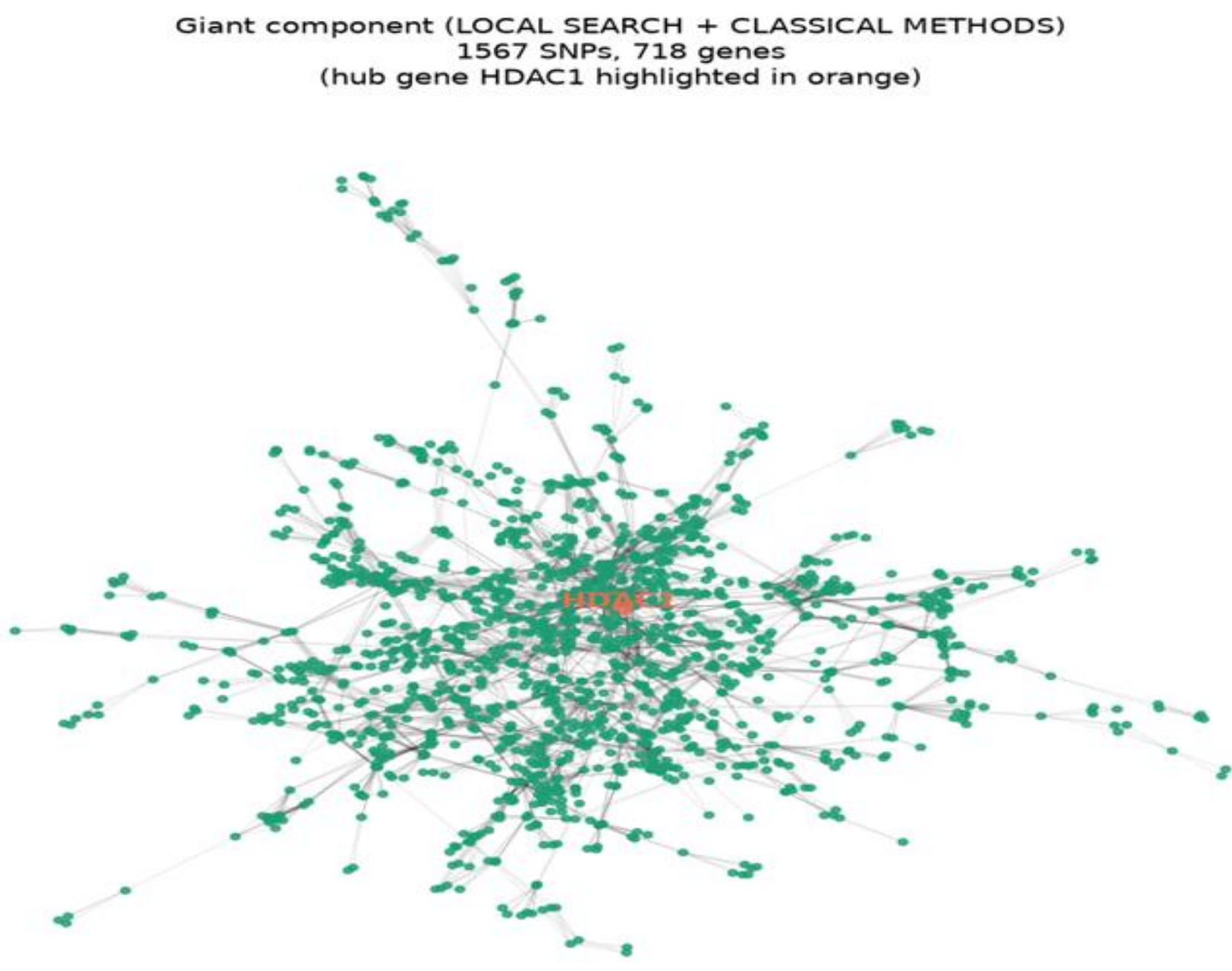
$$x_i = (1 - z_i) / 2$$
$$H_C = \sum_i h_i Z_i + \sum_{i < j} J_{ij} Z_i Z_j + \sum_{i < j < l} K_{ijl} Z_i Z_j Z_l$$

Discussion

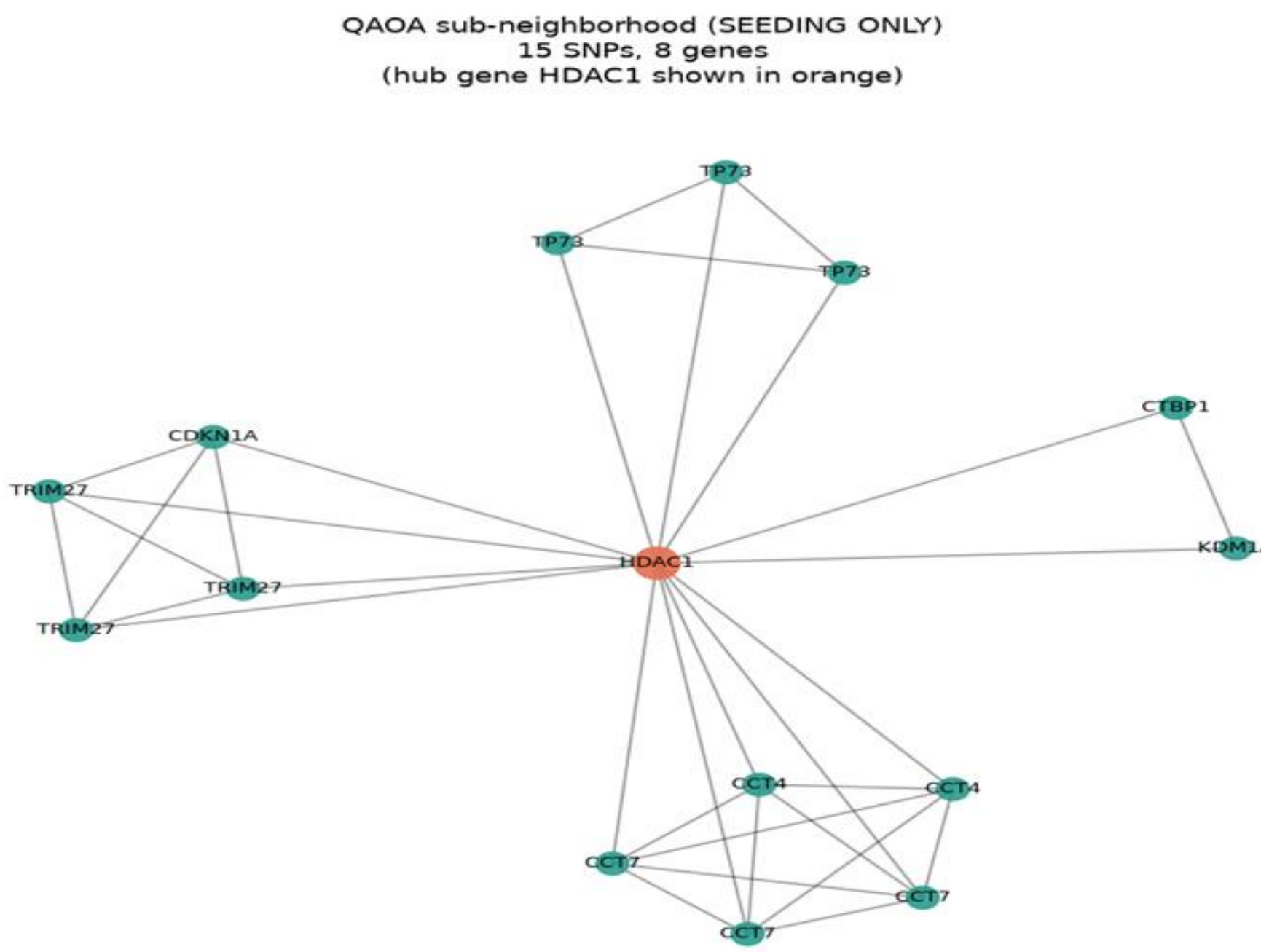
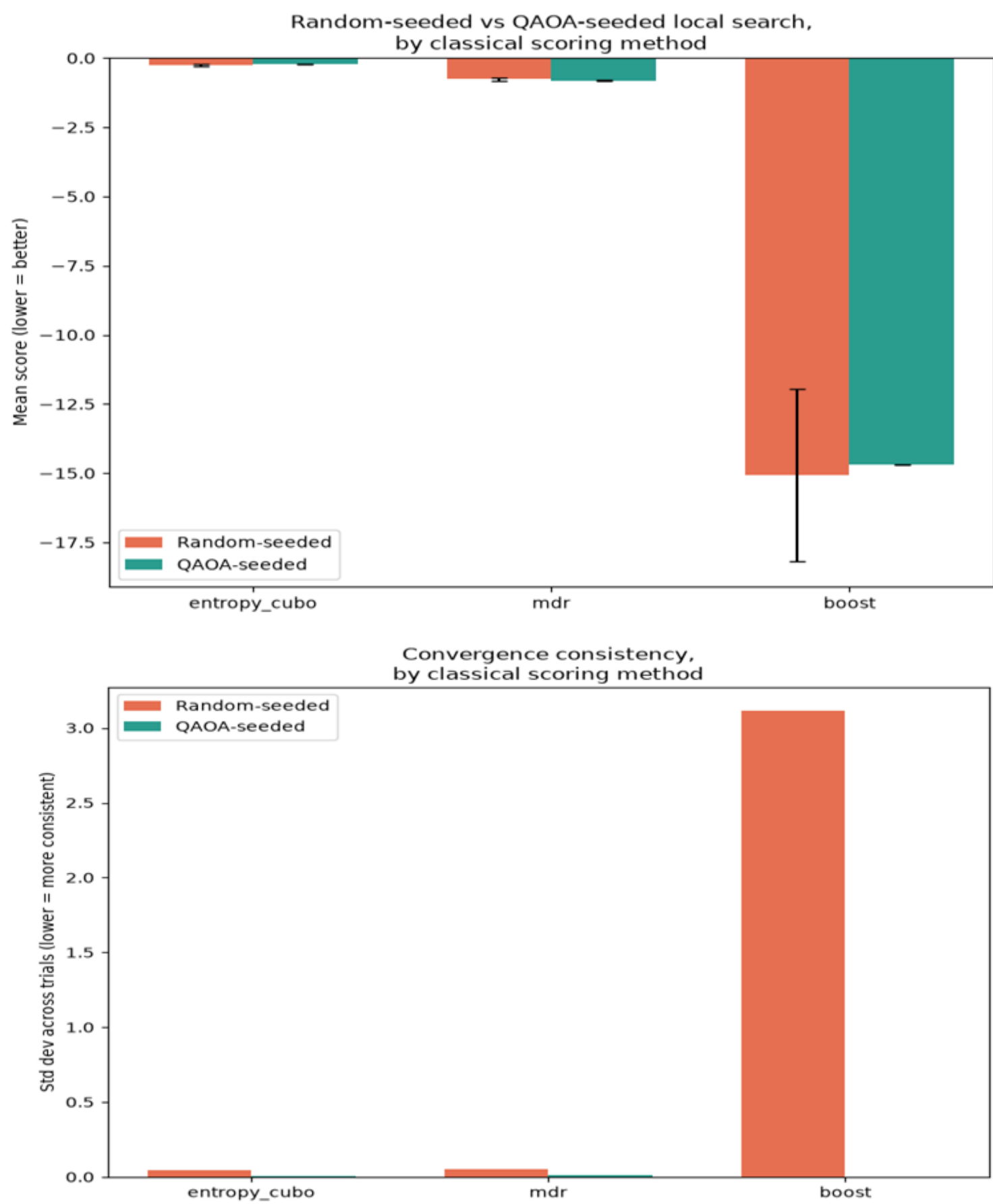
- QAOA's demonstrated value is architectural — consistent, reproducible seeding for classical search (robustness) — not raw top score; we report the weaker z-score honestly rather than only the favorable chart.
- Gate-based quantum advantage for epistasis detection is an open question, not an established result, and we frame every claim accordingly.
- The hardware benchmark yields an empirically measured feasibility ceiling (~15–20 qubits) for this ansatz and depth on current IBM hardware, not a theoretical estimate.
- Co-expression between the two core genes is similar in magnitude in ASD and control tissue — a general excitatory-neuron pattern rather than clear ASD-specific rewiring.

Cross Method Gene Convergence

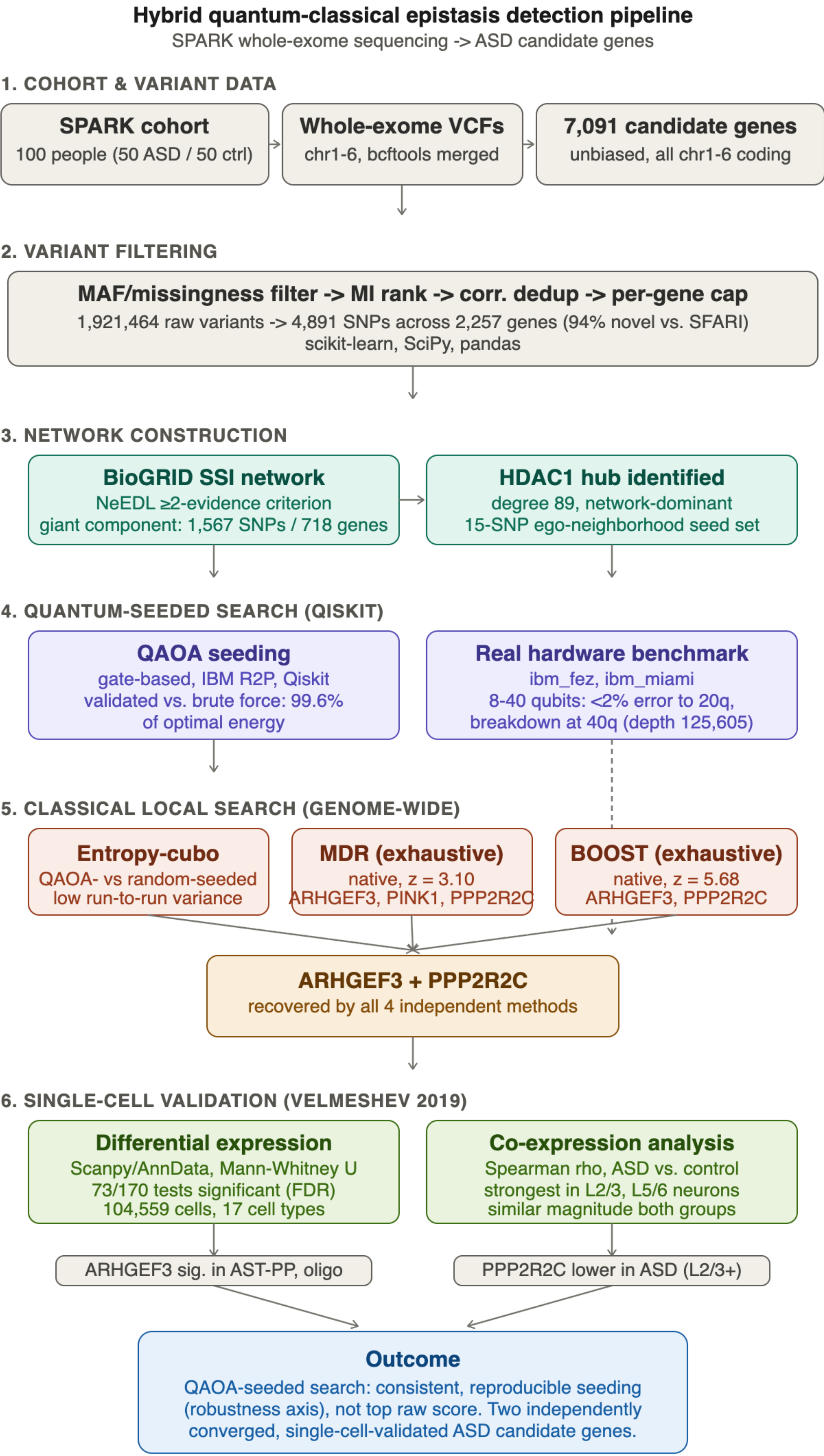
Random-seeded entropy	ARHGEF3, LNX1, TRIM27
QAOA-seeded entropy	ARHGEF3, CCT7, DNMT3A, HDAC1, PFDN6, PPP2R2C, RREB1, TRIM27
Native MDR	ARHGEF3, PINK1, PPP2R2C
Native BOOST	ARHGEF3, PPP2R2C



Results Comparison



Model Pipeline



References

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- [4] Velmshch et al. Science 364(6441):685–689, 2019
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