A Bose-Einstein Condensate Computer

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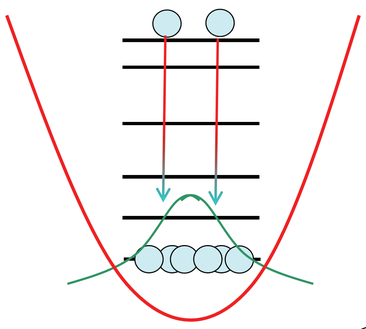
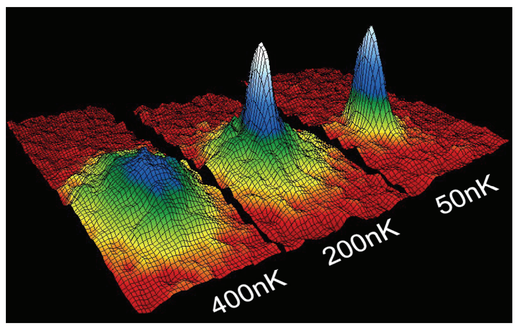
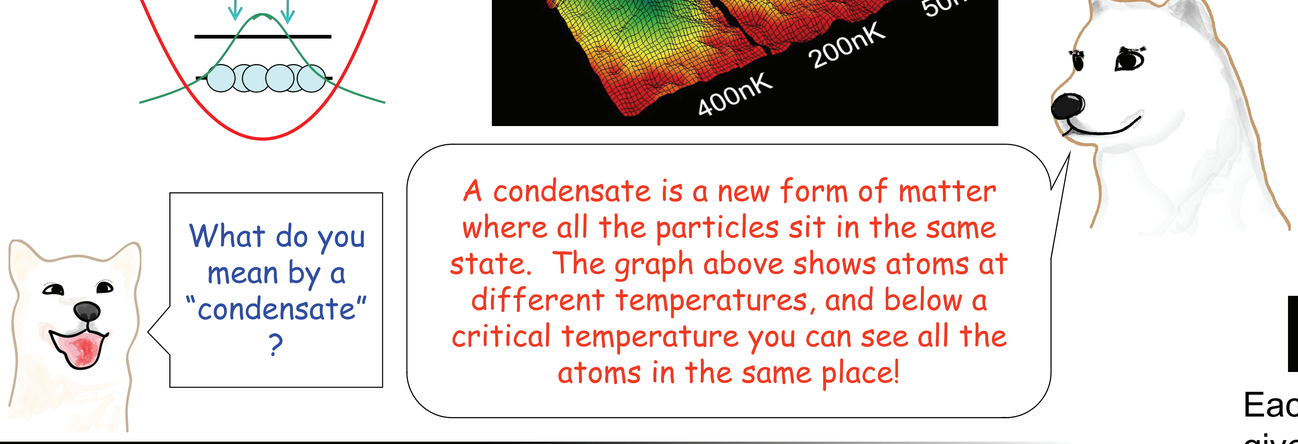
What's BEC?

In a BEC, the system has a large concentration of particles in the system ground state. Furthermore, due to bosonic final state stimulation, the speed of cooling is enhanced by a factor N+1, where there are N particles in the final state.



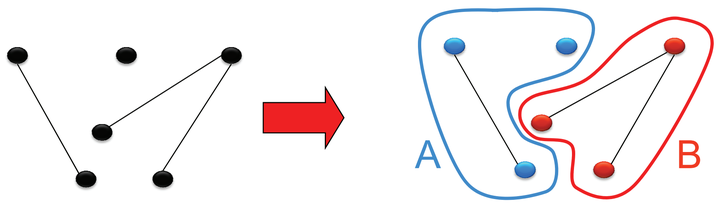


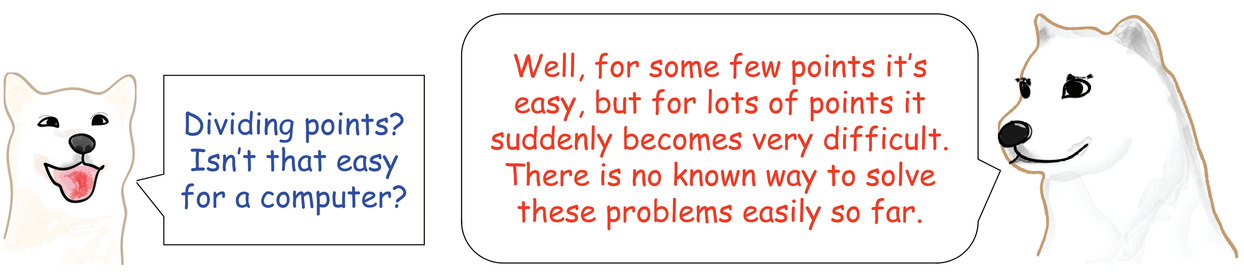


NP-complete problems as cost minimization

Example: The Graph Partitioning Problem (GPP)

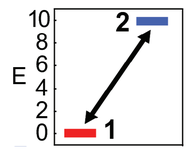
Given 2*N* points with arbitrary connections between them, divide the points into two groups (A and B) of *N* points, minimizing the number of connections between them. Any kind of NP-complete problem can be formulated as GPP.

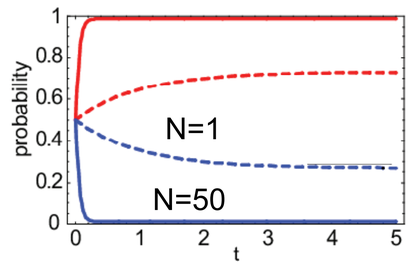




Cooling to thermal equilibrium

2 level system

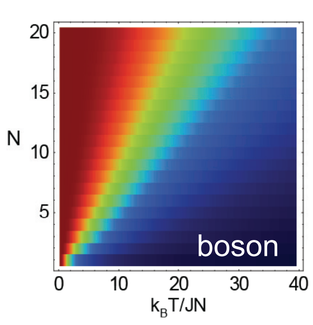


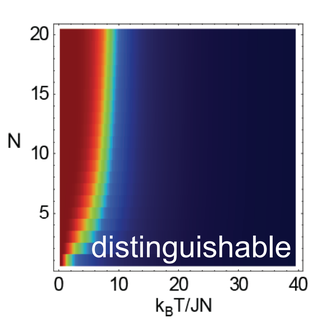


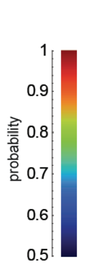
Due to final state stimulation, the speed of cooling for large boson number is increased.

2 site Ising model

At thermal equilibrium bosons have a larger ground state population



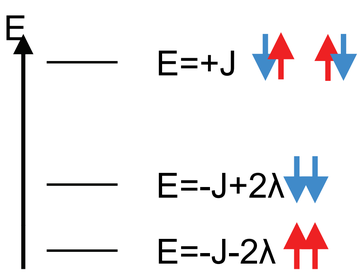




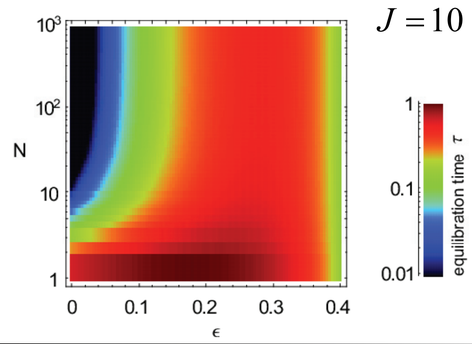
probability of getting ground state on a single site

$$H = -JS_1S_2 - \lambda N(S_1 + S_2)$$

$$J = 10 \;\; \lambda = 0.5$$

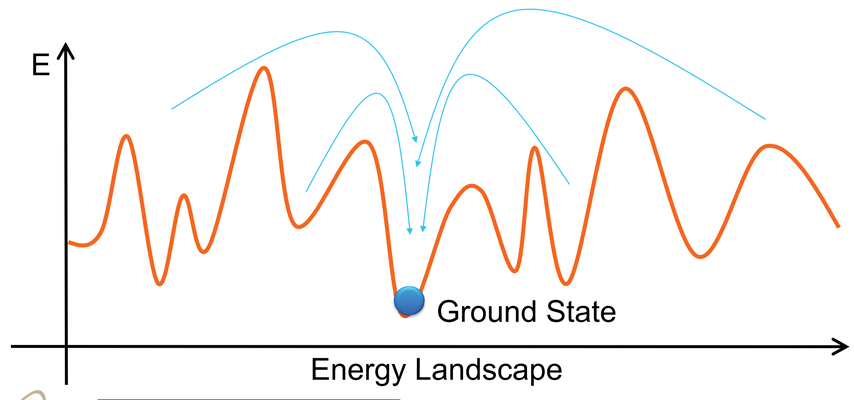


Cooling time for boson number N and error



How is this useful for computation?

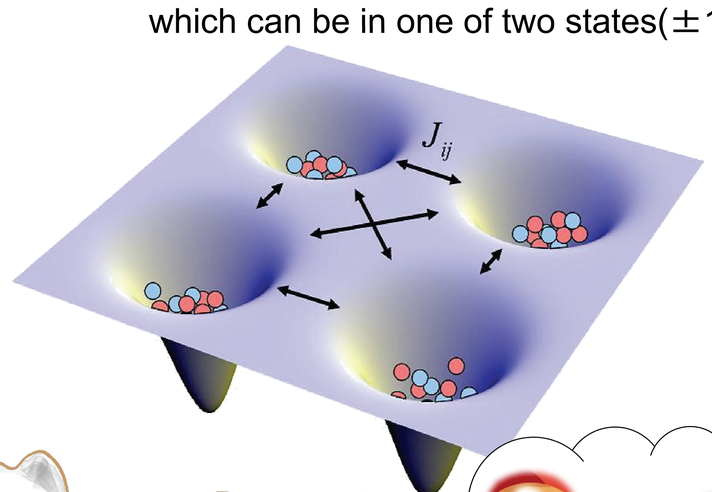
NP-complete problems can be typically formulated as a cost minimization problem.

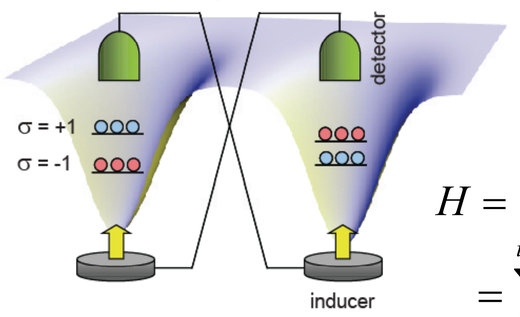


Device idea

Each site is correspondent to a point in the given GPP, and has N bosons, each of which can be in one of two states(±1).

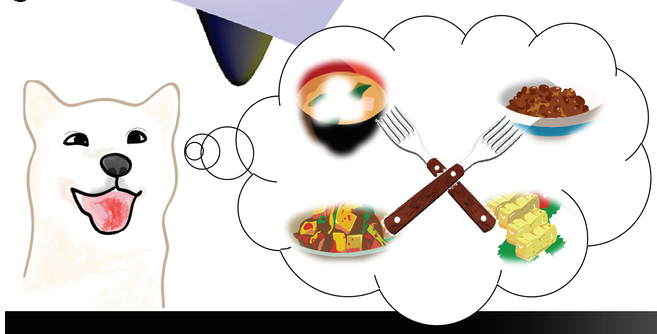
Interactions between sites are created externally via feedback loop





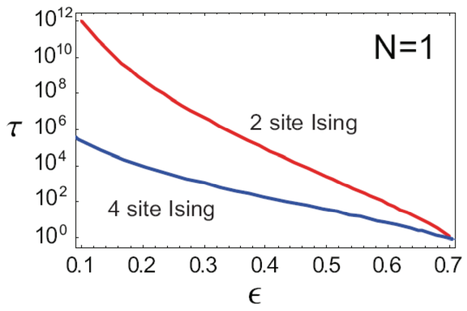
$$H = \sum_{i,j=1}^{M} J_{ij} S_i S_j = \sum_i B_i(S) S_i$$

$$S_i = \sum_{k=1}^{N} \sigma_i^k$$

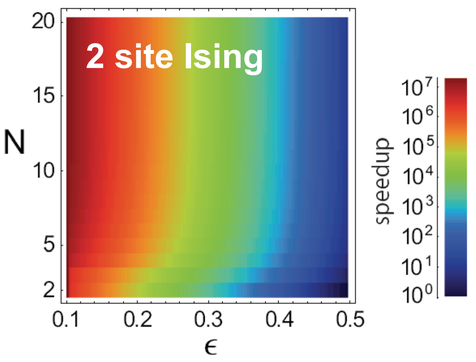


By replacing each site with a large number of bosons, we have a large ground state population and the cooling speed is enhanced. The problem is then to find the ground state of the Hamiltonian H.

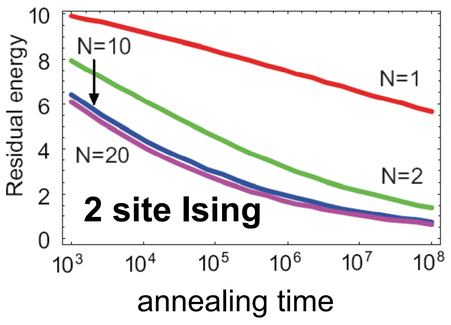
Direct Ising model simulation



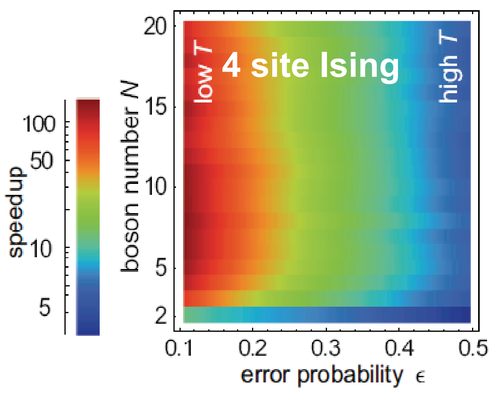
Equilibriation time for standard Ising model (above).

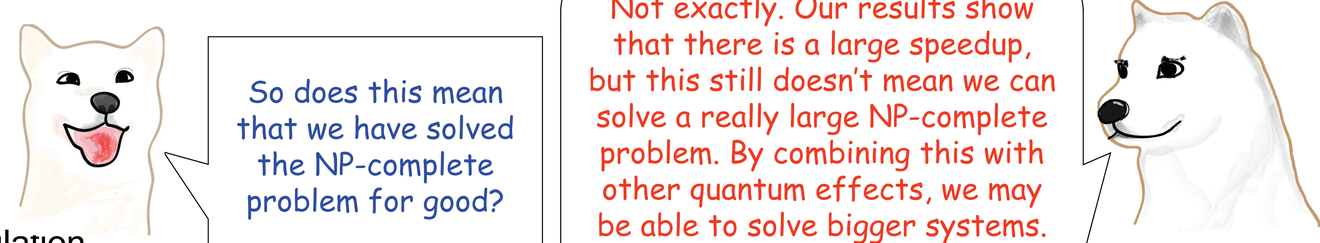


Speedups obtained using bosons for 2 and 4 site Ising models.



The system is also compatible with an exponential thermal annealing procedure.





Conclusions

- Bosons speed up the equilibriation time of the Ising model by final state stimulation. An enhanced ground state population is present due to bosonic statistics.
- The scaling with site number is probably a (large) constant, since no quantum coherence is present in the system. Introducing quantum coherence may help this.

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