### Neuroreceptor Activation by Vibration-Assisted Tunneling

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#### Goal of Google Quantum Artificial Intelligence Lab

Map hard optimization problems that arise in machine learning to Hamiltonian problems that can be solved more efficiently using quantum annealing.





#### How does Quantum Annealing work?



Define:  $H(t)=(1-t/T) H_B + t/T H_P$ 

 $H_B$ : initial Hamiltonian with known and easily preparable ground state

 $H_P$ : Hamiltonian whose ground state encodes the solution to a given instance of an optimization problem



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#### Programming a Quantum Annealing Chip



Energy/Objective:  $E(s_1, \dots, s_N) = \sum_{i=1}^N h_i s_i + \sum_{i < j=1}^N J_{ij} s_i s_j$   $s_i \in \{-1, +1\}$ 

Input:  $h_i, J_{ij} \in \mathbb{R}$ 

**Output:** solution bit string

 $\boldsymbol{s}^{\star} = \operatorname{argmin} E(\boldsymbol{s}_1, \cdots, \boldsymbol{s}_N)$ 



# Open system quantum mechanical models required to describe realistic settings





# Relation between Quantum Al and Quantum Biology

- Can we borrow quantum biology ideas such as the "goldilocks" principle to build better quantum optimization chips?
- Since quantum resources are useful to AI do biological nervous systems employ them?



Is there a relation between quantum phenomena and consciousness?

Experimental inaccessibility of consciousness

Can not measure a modeled level of consciousness

Valid methodological pathway is to experience a richer portfolio of conscious states is by ingesting psychoactive substances



Can be done in a safe and even healthy way



#### Yawanawa Tribe

A culture that holds the exploration of altered states of consciousness in high regard

### Location of main Yawanawa village

Amazonas









#### 200+ entheogenic and medicinal plants 95% unknown to Western botanists



Ayahuasca (Uni)



Rapé

Sananga, Muka, ...



Kambô



### **Provocative Statement**

Is it possible that a miraçao (ayahuasca vision) should partly be accounted for in ontological and not just in psychological terms?

The brain by virtue of being a physical substrate participates in information exchange with the environment by fundamental physical interactions. Information gained through these processes may not just travel via the "official" visual, auditory or other sensory pathways. Thus a psychedelic experience report is in part explained by assuming that such information is received, amplified, processed and recorded in memory traces.



#### **G** Protein Coupled Receptor





Serotonin-Protein Therapeutic Applications

- Antidepressants
- Antipsychotics
- Anorectics
- Antiemetics
- Gastroprokinetics
- Antimigraine Agents
- Hallucinogen
- Entactogens

Palczewski et al. Science 289, 739-745 2000



# Electron transfer from a donor to receptor site in a G Protein Coupled Receptor



 $\Delta E = \hbar \omega$ 

#### Inelastic Electron Tunneling Spectroscopy



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#### Inelastic Electron Tunneling Spectroscopy



Average current given by current operator

### $M = \langle \psi_i | \hat{M} | \psi_f \rangle = M_e + M_{in}$

J. Kirtley, D. J. Scalapino, and P. K. Hansma, Phys. Rev.B 14, 3177 (1976)

W. A. Phillips and C. J. Adkins, Philosophical Magazine Part B 52, 739 (1985)

A. K. Sleigh, W. A. Phillips, C. J. Adkins, and M. E.Taylor, Journal of Physics C: Solid State Physics 19, 6645 (1986)

L. Turin, Journal of Theoretical Biology 216, 367 (2002)



#### **Elastic contribution**

$$M_{i,f} = \int_0^l d^3 x \, \Psi_f^* \, \widehat{M}_e \Psi_{\rm i} \qquad \qquad \widehat{M}_e = \left(\frac{2\alpha_0 \, \hbar^2}{2m_e}\right)$$

$$= \left(A^2 \frac{\hbar^2 \,\alpha_0}{m_e} \,e^{-\alpha_0 d}\right)$$



#### Inelastic contribution

$$\begin{split} M_{i,f} &= \int_0^l d^3 x \, \Psi_f^* \, \widehat{M}_{in} \Psi_i \\ &= \left( \frac{A^2}{L^2} \right) e^{-\alpha_0 d} e^{iq \cdot R} \int_0^r \int_0^{2\pi} \int_0^d r dr d\theta dz \, e^{iq \cdot r'} U(r,\theta,z) \end{split}$$

Interaction Potential  $U(r') = \frac{e Z_e}{4 \pi \varepsilon_0 \varepsilon_r} \frac{u \cdot (R - r')}{(|R - r'|)^3}$ 



#### Inelastic Electron Tunneling Spectroscopy

Luca Turin's Notation

$$I_{j} = \sum_{i=1}^{N} I_{i,j} \propto \sum_{i=1}^{N} q_{i}^{2} (\Delta x_{i,j})^{2}$$

 Partial charges and displacement and were calculated using density functional theory (using Gaussian)

#### Tests with 5-HT2A agonists





## Tests with 5–HT2A agonists <sub>2C-X</sub>





# Tests with 5–HT2A agonists DO-X





#### **Tests with 5-HT1A agonists** Azaspirones



Buspirone (Buspar)





Tandospirone







Ipsapirone

Gepirone



#### **Tests with 5-HT1A agonists** Azaspirones



Ipsapirone Eptapirone Zalospirone Umesspirone Buspirone Gepirone Tandospirone Prospirone

Potency



# Isotopologues for validation by behavior based drug discrimination





#### Summary

- Protein activation involves tunneling junctions
- Applied Turin's theory of vibration assisted tunneling
- Simulated IETS using DFT
- Obtained properly ordered potencies using IETS
- Proposed test molecules for behavior based validation
- Began large scale testing with Glaxo Smith Kline



### Thank you!

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