Exploring New Metallic Quantum Spin Liquids

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Motivation

- Discover novel metallic materials which host quantum spin liquid (QSL) state.
- Tune the crystal structure for an existing system and control the interaction between magnetic spins.
- Utilize the newly discovered materials in quantum computing/communication.

Project Description

- Suppress the ferromagnetic ground state in pyrochlore-lattice-based metals and induce antiferromagnetic interaction between magnetic atoms.

Context

- Current quantum spin liquid candidates are all insulating materials, i.e., electrons are not moving freely.
- We target at realizing magnetic frustration in metallic materials and then induce quantum spin liquid state by tuning the structure.
- The success of this project will enable people to investigate how QSL state behave in metallic phases and contribute to the understanding of unconventional superconductivity.

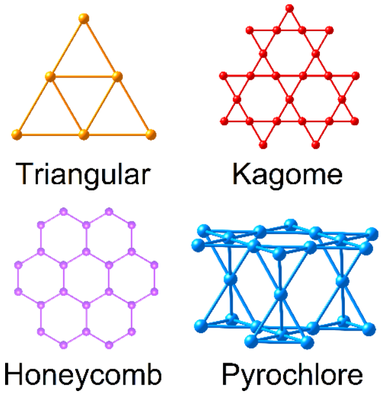

Figure 1. Typical structural motifs for quantum spin liquids.

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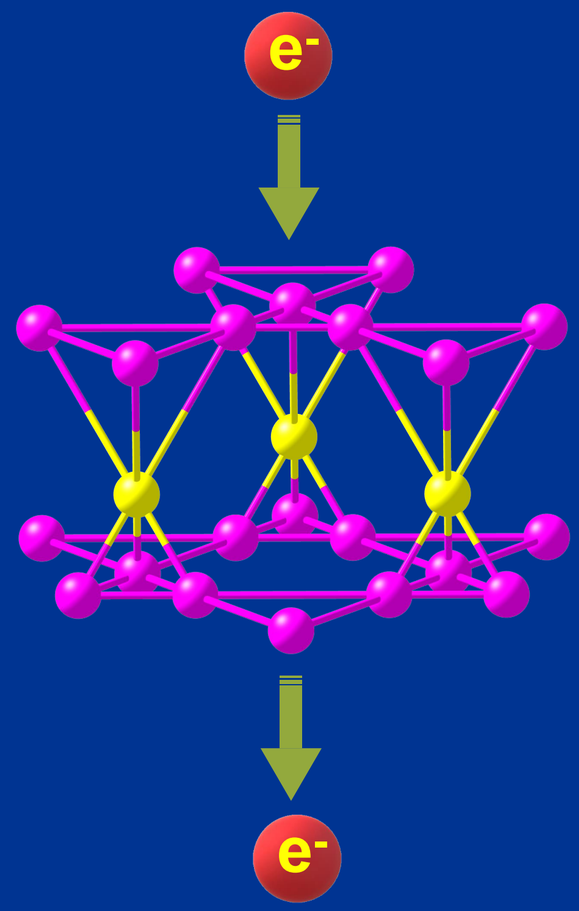
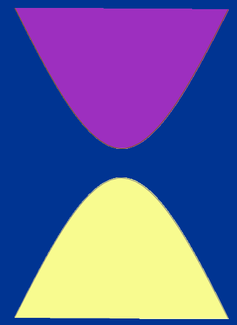
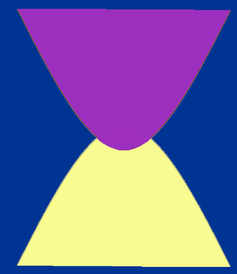
This research aims to explore a special type of ***magnetic materials***, i.e., quantum spin liquids, in ***metallic*** matters.





Past: Insulator



Now: Metal?

Project Deliverables

- The project will allow us to understand how ferromagnetic coupling between magnetic atoms are affected by doping on magnetic/non-magnetic sites.
- Antiferromagnetic interaction generated by doping the parent materials will also indicate what the optimal chemical environment would be for the investigating system.
- This funding will allow us to investigate an unexplored territory of metallic quantum spin liquid candidates.
- After the completion of this project, we will be able to utilize the data we generated to apply for grants from NSF and/or DOE.

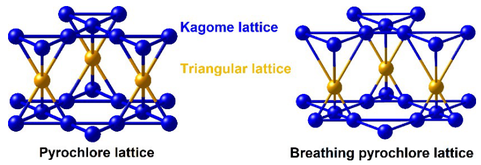


Figure 2. Regular and breathing pyrochlore lattices which are both great candidate structures for QSL.

- At the 6-month and 1-year milestones, we are expecting to finish the syntheses and characterizations of the materials in which doping happens on non-magnetic and magnetic sites, respectively.

Potential Impact

- At the completion of this project, the boundary of the field will be pushed forward while relevant collaborations will be set up within and out of Pitt between the PI and other researchers in various departments.
- This research will not only enable the PI to expand the field of quantum spin liquids to intermetallic area, but also allow the research on various quantum states in the proposed systems, such as band topology and superconductivity. It will also facilitate the collaboration between the PI's group and national labs on neutron scattering studies.

References

- Broholm, C., Cava, R. J., Kivelson, S. A., Nocera, D. G., Norman, M. R., Senthil, T. Quantum Spin Liquids. *Science* 2020, 367, eaay0668.
- Chamorro, J.R., McQueen, T.M. and Tran, T.T., 2020. Chemistry of quantum spin liquids. Chemical Reviews, 121(5), pp.2898-2934.

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