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Hillary Pan

Gabriel Hitchcock

Eydon Thomashow

Oberlin Lab Profiles

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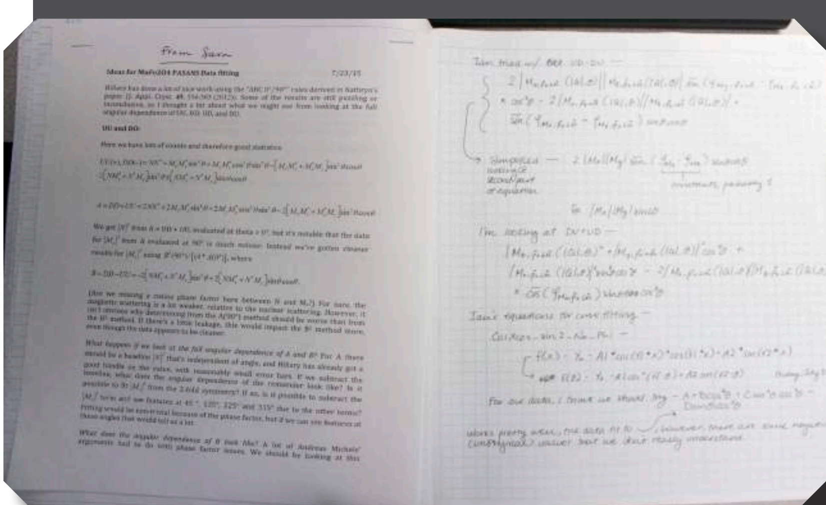
Hillary Pan
OC '18
Physics
New York, New York

Writers: *Gabriel Hitchcock & Eydon Thomashow*
Photographer: Mel Xu

Research in professor Dr. Yumi Ijiri's lab is aimed at understanding the molecular forces governing nanoparticles. Specifically, her work is concerned with understanding how and why these tiny magnetic particles are structured the way they are, and how that structure determines the ways in which they interact with their environment. Professor Ijiri has several student assistants working in her lab. Among them is Hillary Pan, sophomore, *Synapse* student liaison, and Physics major to be.

Nanoparticles are, as their name suggests, tiny particles, being between 1×10^{-7} and 1×10^{-9} meters in size. Because of their infinitesimal size, they display dramatically different behavior from chemically identical macromolecules, a characteristic which has engendered a great deal of research over the years. Depending upon how they are synthesized, nanoparticles can be homogenous (made of the same stuff) or have a core of one material and a shell of another. This relatively simplistic composition places them in a unique niche for technical applications. For example, their size and magnetic qualities make them ideal for drug delivery systems, where their circulation in the body can be controlled by a magnetic field. Furthermore, these characteristics also make them a candidate for superdense data storage, where their magnetic orientation can be set and interpreted as a 0 or 1, lending them to binary encoding. However, these are technological developments, whereas Ijiri takes a more reductionist approach: exploring their structure. The investigative interest of Ijiri's lab is to understand the shell and core structure of these nanoparticles. The nanoparticle in question, manganese ferrite, has been shown to have an especially intriguing magnetic profile.

In order to study these manganese ferrite nanoparticles, Ijiri's lab analyzes data provided by the National Institute of Standards and Technology (NIST) in Maryland. This lab uses a technique known as polarized analyzed small-angle neutron scattering (PASANS). SANS techniques rely on the unique quality of neutrons to detect structures at the nanoscale. Unlike X-ray scattering, neutron scattering does not damage the nanoparticle, allowing the same sample to be analyzed numerous times. This is extremely valuable, as these samples are not cheap. Furthermore, because neutrons are uncharged, they do not interact with the electron cloud that surrounds each atom of the nanoparticle. This allows for precise readings of atoms with very small atomic numbers. The ability of neutrons to make these detections depends upon their spin states. In order to understand this concept, we must first briefly delve into what a neutron is.



Neutrons are one of two familiar subatomic particles located in the nucleus of an atom. These neutral particles share this space with protons, their positively charged neighbors. While protons determine the atomic number of an atom (such as hydrogen, which is 1), neutrons determine the neutron number. When summed, these values give the atomic mass number. Carbon, for example, has an atomic mass number of 12, representing six protons and six neutrons. However, a less stable isotope, C-13, has an additional neutron. Thus, neutrons are responsible for the isotopic quality of some atoms. Protons and neutrons are not, however, the only players in the nucleus. Indeed, neutrons themselves are composed of three elementary subatomic particles called quarks. A quark is 10^{-19} meters from end to end, and can be one of six types. Neutrons, however, are formed of only two of these types, known as the up and down-quark. An up-quark is defined as having an upward angular momentum, and a down-quark the reverse. Angular momentum can be conceptualized as the spin of an object around its axis. In this way, the Earth can be said to have a definite spin angular momentum, as it spins around its own axis. The collective spins of these quarks, then, establishes the spin of the neutron, which can be in any direction relative to the position of the quarks. This spin, known as the neutron magnetic moment, is exploited to probe atomic structures.

At NIST, PASANS data is obtained by the following processes:

1. A sample of nanoparticles is loaded into the supermirror

2. The supermirror, which is formed of magnetic and non-magnetic layers, is able to regulate the spins of an incoming beam of neutrons by exerting a magnetic force on them. This polarization is then optimized in order to maximize the number of neutrons in one spin state over another. Thus, most of the neutrons will have the the same magnetic moment, either up or down.

3. While the supermirror polarizer the neutrons to one spin state, the aptly named flipper reverses these states with an efficiency of 95%. Together, these devices allow for the neutron beam to have a reliably known incident wave vector, or initial spin.

4. Upon collision with the sample, the neutron's spin is altered by the magnetic properties of the nanoparticle. Thus, PASANS data is collected under four possible conditions: Up Up, Up Down, Down Up, or Up Up. The first orientation describes the incident spin state, or the spin of the neutron regulated by the supermirror. The second orientation describes the state after scattering, or collision with the sample.

5. Next, the beam passes through a chamber of pressurized helium gas, known as the H3 cell, which absorbs neutrons of a single desired spin state.

5. The beam collides with a 2D detector, from which the spin states of the neutrons are recorded.

From these data, Ijiri's lab hopes to define the structure of thesev nanoparticles. That is where Hillary Pan comes in. Pan's role is to graph the data and find fits and trends using a modeling software called Igor Pro. By applying older models, Pan is able to compare the core and shell structure of magnesium ferrite to known nanoparticle structures. Manganese ferrite is unique in that it doesn't match the same models as those with which Yumi has previously worked with, such as cobalt ferrite and iron oxide. This quandary is what fuels the lab's efforts to continuously analyze these data and devise new models.