# THE QUARK

Brought to you by The Society of Physics Students

# Nuclear Magnetic Resonance

*By Akash Maheshwari*

Have you ever had a chemistry class and wondered how scientists are certain that a certain molecule possesses a certain bonding configuration? Through a sophisticated way to measure the spins of different atoms called nuclear magnetic resonance, scientists can effectively determine a molecule's structure to a high degree of accuracy.

If we have a sample of a hydrocarbon and we burn it in the presence of excess oxygen, we can measure the amounts of products produced. Analyzing these results and using stoichiometry, we can conclusively determine the molecular formula of a compound. However, there can be a nearly infinite number of ways to rearrange those same atoms in different conformations to produce compounds with very different properties. Nuclear Magnetic Resonance (NMR) is therefore a very powerful tool that can be utilized to elucidate the bonding structure of a compound.

It had been determined that the nuclei of some atoms behave like magnets. A charge that has motion can generate a magnetic field. Nuclei have a charge, so they must also have a spin in order to generate a magnetic field. However, only atoms that have an odd mass number or an odd number of protons have a spin; organic chemists typically use C13 or H1 NMR for this reason. We will focus on the spin of C13 atoms to illustrate how NMR works.

A carbon nuclei has an inherent spin in its natural state. When a strong external magnetic field is applied to a sample of the unknown compound, the carbon nuclei can either align their spins parallel to the magnetic field or antiparallel to the magnetic field. The majority of nuclei orient themselves with the magnetic field

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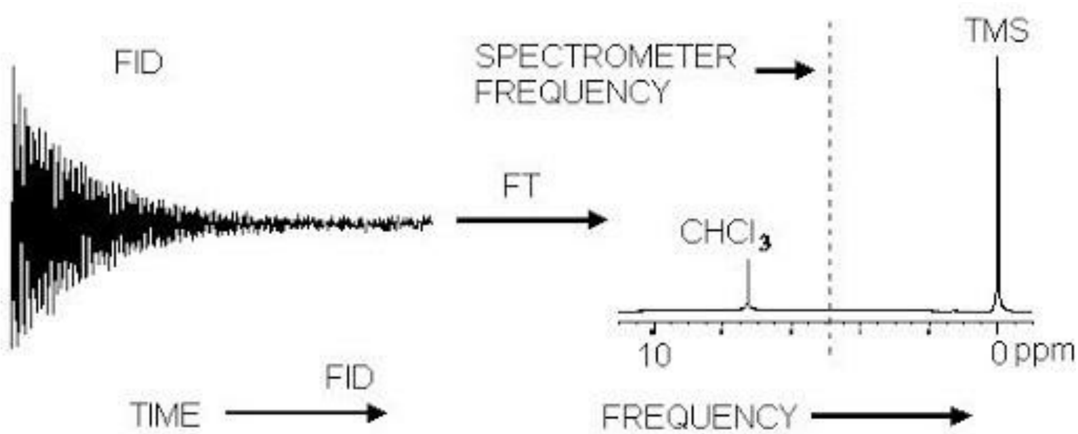
## About The Quark

The Quark is a monthly newsletter provided by the Public Relations Committee of the Society of Physics Students (SPS). Our goal is to help new students become more familiar with the Physics Department and give returning students more insight on aspects of the department they might not have been aware about.

If you have any questions about The Quark or SPS, you can email our Public Relations Officer (shanmuga.shivakumar@ttu.edu) since this state is lower in energy and hence more favorable. Nevertheless, some atoms exist in the antiparallel state. If a photon that matches the energy difference between the two states is absorbed by a nuclei in the lower energy state, that nuclei can be promoted to the higher energy state by 'flipping' its nuclear spin. If the photon is in the radio frequency range, this spin flip will occur. By irradiating a sample with radio frequency energy so that all nuclei will flip their spin, we can develop a technique to measure the differences between these atoms. Since not all carbon nuclei are present in the same electronic environment, different carbons will absorb energy at slightly different frequencies as a result of their arrangement in a molecule. A typical FT-NMR machine will measure the specific and different frequencies of energy released as a nuclei drops from a higher to lower energy form. Different radio frequencies are emitted depending on the chemical environment and the resulting signal of radio frequency versus time will have a distinct interference pattern called the Free Induction Decay (FID). The frequencies measured can be obtained from the signal by using a Fourier transform of the time-based data [1].




Effect of the Fourier Transform on a Free Induction Decay

The resulting NMR spectrum can be used to determine specific properties of molecules and is one of the most important tools in determining molecular structure. However, the applications of NMR extend far beyond viewing molecules. In fact, the utilization of NMR in the field of medicine has been one of the most influential technological innovations ever made. Hospitals around the world have begun using Magnetic Resonance Imaging (MRI) in order to diagnose patients with a high level of accuracy. The patient is placed in a large cavity surrounded by a strong magnetic field. The patient is then irradiated by radio frequency energy which is absorbed by protons in the body's tissues. Most living tissues are made of water so protons are present nearly everywhere in the body, albeit in different concentrations and different chemical environments. When the protons emit the energy they previously absorbed at slightly different frequencies, a machine can be used to analyze these frequencies. A computer can produce an image based on the proton density of different tissues which allows medical personnel to see through the body's tissues and detect any abnormalities. The many uses of NMR in the field of science demonstrates how essential and intriguing this technology is.

# Professor of the Month: Dr. Stefan Estreicher

*By Ivan Cornejo*

Dr. Stefan Estreicher is a Paul Whitfield Horn Professor and a man of many tastes. He has written many papers and a book on the history of wine and is currently conducting research on how to manipulate the properties of semiconductors using specific defects. He received his Master's at the University of Geneva (Switzerland) and his PhD from the University of Zürich (also in Switzerland), and then became a postdoc and instructor at Rice University. He joined Texas Tech in 1986 and has thus been with the Physics department for 34 years.

### Why study semiconductors?

At the heart of every piece of electronic technology lie components made from doped semiconductors such as Si or GaN. They serve as the driving force behind the 'magic' of modern life. Doping (adding specific impurities at specific sites) allows the control of the electrical and optical properties of the material. But specific defects could be used to control their thermal properties as well: this is one of Estreicher's current research interests. He is a theorist who uses 'first-principles' methods to calculate the characteristics of defects in these materials, and predict how various defect structures could be used to manipulate material properties.

### What kind of research do you do outside of the physics department?

Outside of physics, Dr. Estreicher studies the history of wine. Although he cannot describe himself as a sommelier, he does consider himself to be quite the 'history buff' for wine. He has written multiple papers and encyclopedia entries on the subject. He is also the author of a book over the history of wine, titled Wine: From Neolithic Times to the 21st Century. You can find a free pdf copy of this book at www.ebookee.com.

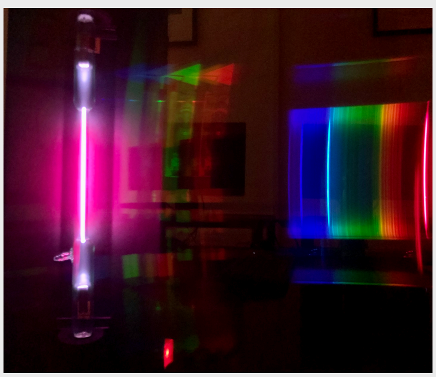
### What advice would you give to incoming and current physics undergrad students?

The advice Dr. Estreicher has for Physics (under)graduates who have an interest in a specific field of physics is to check the websites of our professors in this field to find out what type of research they are involved in and how active they are. Make appointments, talk to these professors, and find out about any common research interests. Get involved in research early, if possible as an undergraduate, and then

## Astronight Coming February 28th!

The Texas Tech Department of Physics and Astronomy will be hosting Astronight, with a special talk from Dr. Thomas Maccarone; *From GPS to Leap Years: Astronomers as the World's Timekeepers* on February 28th!

At 8 p.m., come participate in cool physics/astronomy activities, astronomy trivia, and telescope viewing (weather permitting)!



Scan the barcode for more information!

stick to it for a while. Become co-author on a paper. The earlier you start, the better off you will be in the long run. "You learn more 'through your fingers' by getting involved in research. This is something you don't learn so much in class." Dr. Estreicher encountered students who are very imaginative in research but do not perform so well in a formal classroom environment - and vice versa. Once involved in research, students should participate in topical conferences whenever possible. This is how you meet other scientists in your field and make useful connections.

# Hard at Wok: How Scientists Make Fried Rice

*By Ian Garcia*

One of the many highlights of Chinese cuisine is fried rice. Although it is a staple to most Asian dishes, traditional fried rice is surprisingly hard to cook. In fact, most home stovetops cannot reach the temperature required to cook rice in this traditional manner. The heat used can be up to 1200°C, whereas most residential electric stovetops max out at just under 300°C. To have the rice withstand this enormous amount of heat without burning, chefs must undergo rigorous tossing motion throughout the process, resulting in about 64.5% of all Chinese restaurant chefs reporting shoulder discomfort, with 2 out of 18 being forced to leave their jobs due to the pain. By studying the act of wok stir-fry cooking, PhD student Hungtang Ko and Dr. David L. Hu wish to find the ideal manner for making fried rice in order to inspire stir-fry robotics or exoskeletons to reduce the injury shared amongst Chinese chefs.

To analyze the intricate process of wok tossing kinematics, these researchers utilized the Fourier transform, a process designed to dissect intricate processes into their component functions. Chefs that had around 20 years of experience and specialized in stir fry were filmed across Taiwan and the Chinese Henan Province. Their motions were separated into two simpler motions; the shift of the wok left and right across the stove, and the shift of the wok back and forth. Simulations were then created to replicate the tiny cycles so they may be analyzed further.

In simulations replicating the motions, researchers found that the wok must be circulated at a certain "perfect" frequency; if the frequency of circulation is too low, the rice doesn't get enough momentum to move around to avoid burning, but if the frequency is too high, then  valuable energy is wasted, as rice grains only come in contact with the wok ever so often. The frequency required for the best rice toss coincides exactly with how often the rice flies and lands on the wok, with each sharp movement being executed just as most of the rice comes into contact with the wok, sending it flying from the hot temperature to the significantly cooler air. Another important aspect of the simulation is that both axis of shifting must occur at the same frequency, slightly out of phase with one another, as to create a circular motion. If they were in perfect sync, the wok would simply shift diagonally, and no rice tossing would occur.

Unfortunately, walking down the street for a perfectly made fried rice dish featuring the wok and robotic arm is far from reality. Spyce, a restaurant in Boston, uses rotating drums to stir cooking food at a frequency of .5 Hz, or 2 rotations per second, is six times less than what is needed for the professional wok toss. Even the machine that best replicates the motion, one shown off in Singapore in 2014, only rotates at a frequency of 2 Hz. This is still too low to allow for airborne food. As robotic technology increases in efficiency and strength, we may be able to one day see easier lives for Chinese chefs, or even the spread of wok stir fry across the world, without needing decades of experience for a proper dish.

# Student Spotlight: Amber Wang

*By Gage Eichman*

From a young age, Amber Wang has always had an interest in STEM, but in particular, she has been fascinated in medical physics, and has always been driven to learn more, but not without a cost. She had moved to Lubbock, Texas from Taiwan at the age of 15 in order to obtain more educational opportunities. This was a large shift for her, having to overcome not only cultural boundaries, but a steep language barrier as well. Throughout her high-school years, while battling with this cultural imbalance, she attended Coronado and participated in many extracurricular activities, including many different University Interscholastic League (UIL) events.

Amber's interest in physics stems from two main sources. The first of these is her father, who works as a nuclear engineer. This helped Amber become immersed in science and engineering from a young age. Along with her father's career, Amber's grandmother was diagnosed with cancer when she was young. This led Amber to wonder how physics and science could be used to solve medical problems, like her grandmother's. She actually found out about medical physics while learning more about cancer online. Thus, Amber's passion for biophysics, and in particular medical physics, was born.

This passion for biophysics is what led Amber to enroll at Texas Tech University. With its biophysics program, Health Sciences Center, locality, and all-around friendly environment, Amber applied to Texas Tech University in 2015.


This passion for biophysics is what caused Amber to seek further education, leading her to enroll at Texas Tech in 2015. She picked Tech partially because of the locality, friendly environment, and the internationally renowned Health Sciences Center, but mostly for the biophysics program. Currently, Amber is taking junior level physics courses while conducting biophysics research with Dr. Huang.

Apart from her academics, Amber is also involved in many organizations at Texas Tech such as Women In Physics, the Society of Physics Students, and the Taiwanese Student Association. Amber explains that these organizations help her share a common passion in topics that she is interested in, with others who are equally as interested. In the case of the Taiwanese Student Association, Amber recounts that it is a way to connect back to her cultural roots from a place that is so far away from her childhood home. “Lubbock is not Taiwan, but it's fun to be able to participate in events that, traditionally, I am used to.” Apart from student organizations, Amber also plays the guitar, and participates in Sanda fighting, a type of mixed martial arts. Amber also gives back to the community by participating in charity organizations where she helps terminally ill and disabled children with art, namely face painting and sculpting.

After graduating, Amber plans to attend graduate school to achieve her master’s in medical physics. Specifically, Amber plans on entering the field to conduct treatment planning or medical imaging. Amber explains medical physics as the physics behind most medical treatments. As a specific example, she cites cancer treatments. While a doctor can diagnose and provide the treatment, a medical physicist is the person who accurately finds the size of the tumor, the dosage required for treatment, how many visits are required, and so forth.

After achieving her master’s, Amber plans on joining a health organization like Doctors Without Borders or the World Health Organization (WHO), so that she can give medical care to those who don’t have proper access to medical treatment.

Amber's final words of advice are ones of wisdom. To quote Amber, “Don’t be afraid to take on a challenge”. She explains that hard things in life are inevitable, so don’t be afraid to jump feet first into them.

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