My field is astrochemistry, the study of the molecular composition of the interstellar medium—the gas and dust which exists around stars and forms giant clouds in our galaxy and in other galaxies.

My involvement in this field now seems predetermined. My mother was an industrial chemist and my father, a mechanical and aerospace engineer. My father worked for many years at NASA Lewis (now Glenn) Research Center in Cleveland, Ohio, where I grew up. While I was in grade school, the Apollo program was in full swing, and I benefited from the science material my father brought home from work, as well as the TV broadcasts of the Apollo missions.

My space interests led me to Rice University in Houston, TX, where I majored in chemistry and space physics. I was in a quandry near graduation, as I was not sure what PhD program to pursue. Physics? Chemistry? Astronomy? A fortuitous discussion with my physical chemistry professor at the time, Prof. Robert Curl, brought to my attention the then new discoveries of molecules in space. I consequently have spent my scientific career studying such molecules, both through astronomical observations and laboratory molecular spectroscopy.

Through my combined lab and observing program at radio telescopes, my group has discovered numerous new interstellar molecules. We specialize in creating small, highly reactive species in the laboratory in the gas-phase, in particular those containing a metal or phosphorus atom. We measure the pure rotational spectrum of the molecules and use this data at radio telescopes to search for them in interstellar gas. The very “non-terrestrial” species we have discovered include MgCN, AlNC, FeCN, AlOH, CCP, and VO. One can explain the formation of these unusual molecules by gas-phase chemistry and shock-heating by stars.

A recent problem in astrochemistry has been the discovery of $C_{60}$ “buckyballs” in the interstellar medium. This very large compound was detected by its gas-phase infrared spectrum by astronomers using the Hubble Space Telescope. I was particularly puzzled by this finding because interstellar gas is highly hydrogen-rich, and carbon is a trace element with typically $C/H \sim 10^{-4}$. $C_{60}$ in the terrestrial laboratory is made with a pure carbon starting material, such as laser ablation of graphite. How does this molecule form with 60 carbon atoms in an environment that is overwhelmingly hydrogen, with near equal amounts of nitrogen, oxygen, and carbon? There just didn’t seem a mechanism that could create $C_{60}$ under such conditions, leading astronomers to postulate that it was formed in “hydrogen-deficient” objects. Later observations showed that $C_{60}$ was clearly present in H-rich gas.

I had no real solutions to the $C_{60}$ dilemma, until graduate student Jacob Bernal began studying the possibility of carbon nanotubes in space. His interest led to discussions with Prof. Krishna Muralidharan from Materials Science and Engineering. Prof. Muralidharan pointed out various published papers concerning production of carbon nanostructures from laser ablation and heating of certain materials. One day Jacob came to my office with a paper that showed that nanotubes and nanocaps could be produced by either heating or ablating wafers made of silicon carbide. Apparently such processing removes the silicon atoms from the crystal surface, leaving the carbon atoms in a configuration that forms graphite, and then nanostructures. This process occurs even in the presence of hydrogen. One paper suggested the creation of nanocaps from the 3C polytype of SiC—one of the various crystal structures exhibited by silicon carbide.
When I looked at this paper I was fascinated. SiC dust grains commonly form in material ejected from old stars in their final stages; such dying stars are known locations of C\textsubscript{60}. Studies of bona fide interstellar grains extracted from meteorites show that the 3C polytype is the most common form of SiC in space. When the stars finally die, they send out shock waves through their ejecta containing the SiC grains. The grains would then be abruptly heated, mimicking the lab experiments. The presence of large amounts of hydrogen would not significantly affect the process. Maybe SiC was the source of C\textsubscript{60}?

To prove this hypothesis, we contacted our collaborator Prof. Tom Zega from UA’s Lunar and Planetary Lab (LPL). Tom’s research is the study of dust grains formed in space, which he extracts from meteorites and then chemically analyzes using Transmission Electron Microscopy (TEM). We then devised experiments involving analog 3C SiC dust grains. The grains were heated and then bombarded with high energy ions under vacuum conditions in the TEM, first at Argonne National Lab and then at LPL, simulating the conditions in the ejecta of dying stars. TEM imaging of the disrupted grains, along with a spectroscopic analysis, showed that indeed, the silicon is leached from the surface, creating layered graphitic sheets with 6-membered carbon rings. Where there were surface defects, 5-membered rings formed, creating hemispherical and even spherical structures with diameters matching that of C\textsubscript{60}. To further support our hypothesis, we found grains in meteorites that come from dying stars, which contain disrupted SiC cores almost fully encased by graphite!

We believe we have found a mechanism for the formation of C\textsubscript{60} in space. This result suggests that other carbon nanostructures might be present in large quantities in interstellar gas. The chemistry in space is not as simple as was once thought back in my Rice days. Furthermore, formation of C\textsubscript{60} and other fullerene-like structures may be an important avenue for concentrating interstellar carbon, leading to the rich organic chemistry that is found in molecular clouds and in pristine meteorites.

As Winston Churchill said: “No hour of life is wasted that is spent in the saddle.”

Horses have been a part of my life since I was a child. I started riding lessons when I was barely 8, where I learned the thrill of jumping fences and galloping cross-country. School came first, however, and I didn’t actually own my first horse until I completed graduate school, when I bought an off-the-racetrack thoroughbred. I have owned several horses since that time and have competed in jumping competitions at horse shows for many years.

As I got older, I continued my equestrian education in Dressage. Dressage, which means “training,” began in 400 BC with the Greek general Xenophon, who wrote the first book on classical horsemanship. A whole series of riding maneuvers were developed for horses in battle, and modern Dressage incorporates these movements into tests, with increasing levels of difficulty. Dressage, at its top level, Grand Prix, is an Olympic sport.

I, of course, started at the lowest level, but over the years moved up and earned Bronze, Silver, and Gold medals with the United States Dressage Federation. With my amazing Dutch Warmblood, Sylvano, I was able to master the sport sufficiently well to ride at the Grand Prix level. This achievement, however, took me over a decade of training with Sylvano, plus the other 40 years of riding.

Dressage is a tough sport because it requires intense mental focus, precise physical control, and cardiovascular fitness. That’s for the human; then there is the horse. It’s amazing how humans and horses can communicate, though. Horses are extremely smart and intuitive animals. And they are good friends and forgiving partners.

Sylvano retired from the show ring at age 20, and I am now training with my new horse, Oficial. He is an Andalusian or P.R.E. breed (Pura Raza Española) stallion. I never thought I would own a Spanish horse, but Oficial and I just get along. Funny how the right horse finds you!