Podcast interview: Paul Dunk

**PNAS:** I’m your host, Paul Gabrielsen, and welcome to Science Sessions. We are all made of stardust. Most of the elements that make up our bodies, our planet, and our solar system were formed in the cores of ancient stars, and in the supernova explosions that scattered these elements throughout the universe. Researchers study this stardust to learn more about the origins of the solar system. But previous studies of carbon-bearing grains within meteorites, older than the solar system, uncovered something strange: these samples were unusually enriched in the stable isotope neon-22. Researchers hypothesized that this neon-22 formed from the radioactive decay of unstable sodium-22, but sodium-22 forms in supernova explosions and is extremely short-lived – how could it become trapped in a grain of stardust in the violent aftermath of a supernova? A recent paper in PNAS suggests that cage-like carbon molecules called fullerenes may be the culprits. I spoke with Paul Dunk, one of the paper’s co-authors, over the phone from his office at the National High Magnetic Field Laboratory in Tallahassee, Florida.

**PNAS:** What led you to suspect that fullerenes might be responsible for neon enrichment in stardust?

**Dunk:** It turns out that this exotic neon is the radioactive decay product of sodium-22, and that’s fascinating because sodium-22 is formed by explosive nucleosynthesis in a supernova explosion. Therefore, the condensing carbon gas that ultimately results in stardust must somehow selectively interact with sodium and physically trap it before it decays into inert neon, and it’s unknown how carbon can do that. So, fullerenes, since there are now, popping up everywhere in space, are a very attractive choice, but the question is, can sodium become selectively entrapped within a carbon cage under the conditions of stellar outflows.

**PNAS:** You obviously can’t travel to a supernova to answer that question. So how do you simulate the deep-space conditions of fullerene formation in the lab?

**Dunk:** So, we are trying to replicate the conditions of stellar outflows. Now, these are very high-temperature conditions, so carbon in that state is present as gaseous atoms and ions, and we take solid carbon, we vaporize it with a high-energy laser, and this actually creates carbon gas which is, just like in space, comprised of gaseous carbon atoms and ions.

**PNAS:** So, what did you find?

**Dunk:** So we found that condensing carbon gas in the presence of substantial quantities of oxygen and hydrogen, these conditions roughly approximate stellar outflows, we find that when sodium is present, the sodium is spontaneously entrapped within carbon cages that form, in other words, metallofullerenes. And, we find that when neon is present, it is never entrapped within a fullerene.

**PNAS:** You said earlier that you’re starting to see fullerenes everywhere in space. Did you expect to find them in space?
Dunk: Some people had predicted that fullerenes should be found in space, specifically Harry Kroto, who participated in this work. It was only in 2010 that the first unambiguous evidence for fullerenes in space were found. We have also studied in this work the interaction of fullerenes with another very important cosmic molecule, polycyclic aromatic hydrocarbons. And these are also very large carbon molecules, like fullerenes, that are found in space. Further, they are often found in environments with each other, so we have studied high-energy reactions that take place between them, and we have found that fullerenes actually react with them to form complex molecules that are quite stable and which can explain other astrophysical mysteries.

PNAS: Could fullerenes have played some astrochemical role in the origins of life on Earth?

Dunk: Well, carbon stardust that forms in stellar outflows eventually gets pushed out into interstellar space, forming a molecular cloud. That cloud collapses under gravity to form a solar system. This is how our solar system formed. So the formation of fullerenes or metallofullerenes could be quite important for concentrating carbon, which would obviously be very important for carbon-based life. It is now clear that fullerenes are a very important cosmic molecule, and understanding their astrochemistry will give insight into the distribution of carbon in the universe, and also, it could even give insight into the actual processes that go on in a supernova explosion.

PNAS: Thanks for listening. You can find more Science Sessions podcasts at PNAS.org.