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A Conversation with John Maier

Mark Peplow

The spectroscopist discusses the search for buckyballs in deep space.


Courtesy of John Maier

This year marks the 30th anniversary of the discovery of C_{60}, the carbon cages affectionately known as buckyballs. Astronomers have long speculated that the molecules could be responsible for unusual features in the spectra of starlight, known as diffuse interstellar bands (DIBs). After two decades of research, John P. Maier, professor of chemistry at the University of Basel, in Switzerland, recently confirmed that hypothesis, proving that deep space is littered with buckyballs. Mark Peplow spoke with Maier to find out how he did it.

How did this astronomical quest begin?

About 90 years ago, a Ph.D. student at Berkeley named Mary Heger saw that there were absorption features in the spectra of starlight, with different intensities, widths and shapes. These are called diffuse interstellar bands and are caused when starlight passes through interstellar clouds that contain a higher density of hydrogen atoms, grains of material, and so on.

Today, there are something like 400 of these DIBs, and as the sensitivities of telescopes and detection systems improve you see more and more. Basically, it means there are very many types of molecules out there. But until now, there hasn't been a definite identification of which molecules cause these features.

When did C_{60} emerge as a candidate?

In 1985, Harry Kroto, Richard Smalley, and Robert Curl published the discovery of C_{60}, buckminsterfullerene. They also measured its electronic spectrum, and astronomers looked in the diffuse regions of space to see whether there was a signature of C_{60}. The answer was no.

Then Kroto realized in 1987 that any C_{60} out there would probably be ionized by starlight to C_{60}^+. So in 1993 my group measured the electronic spectrum of C_{60}^+ using matrix isolation spectroscopy, where we put these ions on a cold surface at 6 K. A year later, astronomers discovered two new DIBs that were so close to our results they proposed C_{60}^+ as the source.

The problem is that when you do a measurement in the solid phase, there is always a slight shift in the absorption compared to the gas phase. In astronomy, you've got to get the wavelengths bang on or else speculations go on forever. We needed to measure the spectrum of C_{60}^+ under interstellar conditions in the lab.

How did you re-create spacelike conditions in the lab?

We already knew how to produce C_{60}^+: You take C_{60}, vaporize it at 500 °C, and ionize it in a mass spectrometer. But then it's extremely hot, whereas in space it's 10–20 K. So we put the C_{60}^+ in an ion trap—which confines them with a radio frequency field—and cooled them down with a pulse of helium at 4 K. That forms very weakly bound complexes of C_{60}^+ with helium.

We saw that the absorption features were exactly at the infrared wavelengths of DIBs. This already implied that the effect of helium binding to C_{60}^+ is really small, but we proved it by complexing even more helium atoms. The shifts they caused were much less than the error of any astrophysical measurements.

So what we had was essentially the spectrum of bare C_{60}^+. The wavelengths match the DIBs exactly, the width of the bands match exactly, and the intensities are also reasonably close. We've been at it for 20 years, and we've achieved it!

How did you feel on the day when you got the results?

I was in the hospital—when you get to a certain age, one needs repairs—and after a few days I got bored and started sending emails to my co-workers, in particular Ewen Campbell, who is really responsible for getting this whole thing working. He replied, "We got signals!" I said, "Wonderful—Ewen, send it all to me; I have nothing to do in the hospital. I will start writing the draft of the paper."

One of the things we really have to follow up now is whether other fullerenes are out there and whether C_{60} is picking up elements like magnesium, aluminum, or iron. If metals do stick to C_{60}, they could be the source of many other DIBs.

What could C_{60}^+ tell us about interstellar chemistry?

Microwave spectroscopists have identified the simplest molecules required for building up DNA in places like interstellar clouds. Everything you need for life is out there in certain space environments. But where do these molecules come from?

Back in 2010, astronomers found C_{60} in planetary nebulae [clouds of material ejected from aging stars], and now you see C_{60}^+ in the interstellar clouds, so maybe this is the source of carbon. After all, there are cosmic rays and all sorts zapping it, so maybe this breaks up C_{60} to provide the simplest carbon molecules. I think people trying to explain the formation of these molecules will have a heyday now with C_{60}^+.

Mark Peplow is a freelance contributor to Chemical & Engineering News, the weekly news magazine of the American Chemical Society. Center Stage interviews are edited for length and clarity.

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