Carbon in Nano and Outer Space

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The age-old awe that man has had for the heavens has driven almost all aspects of human culture and knowledge and resulted in technologies with generally positive, though occasionally negative effect. Arguably the most positive have taken place since Galileo recognized that the phases of Venus provided the evidence that confirmed the Copernican heliocentric system and cemented his position firmly as the "Father of Science". From this moment on we had, at long last, a straightforward philosophical construct and language which enabled mankind to determine what is and is not "True". Particularly important truths have resulted from the curiosity that humans have had for a detailed understanding of the way Universe works. This led to the development of astrophysics and the associated technologies that have been spun-off. Not least of these has been the telescope – from Galileo's beautiful original design to the fantastic satellite-born devices put up by NASA. These have not only enabled us to observe the planets and stars more clearly but we have been able to see to the very edge of the Universe and make a plethora of discoveries about all aspects of the Universe from the occupants of the space between stars to the processes occurring deep inside stars. Perhaps the most fundamental advance based on space observations led to the development of Classical Mechanics in order to understand the motions of the planets and comets and concommitantly the development Calculus, one of the greatest of Mathematical achievements. As Quantum Mechanics developed along with Spectroscopy it was inevitable that we should start to study the atomic and molecular composition of heavenly bodies - first hot stars as well as cool comets. With the development of radiotelescopes, the very cold interstellar medium was found to be a veritable Pandora's Box, full to the brim with fascinating and exotic molecules, dust particles and also some highly puzzling material responsible for some as yet unidentified spectroscopic features. These latter are known as the Diffuse Interstellar Bands (DIBs) first observed in the 1920s.

Particularly fascinating, curious and crucial has been the role that the element carbon has played in almost every aspect of the development of our understanding of both the physical and natural sciences. The fact that the element is at all abundant is due to a curious set of coincidences involving its nucleosynthesis from helium in stars. If one furthermore adds into the overall carbon equation its uniquely profuse chemistry, *ie* Organic Chemistry, it is hard to conceive that life could be based on any other element. The most recent big surprise that the element had up its sleeve was the existence of C_{60}, Buckminsterfullerene, the third well-defined form of carbon. The discovery was made serendipitously in 1985 during laboratory experiments which attempted to explain the chemical synthesis of some unusually long linear carbon chain molecules detected in the interstellar medium in the 1970's. A second aim of these experiments involved curiosity as to whether the carriers of the DIBs might be long linear carbon chains. Interestingly the extraction of C_{60} in 1990 by Kraetschmer and Huffman resulted from experiments aimed at understanding another mysterious feature known as the 217nm hump and conjectured to also involve carbon – perhaps carbonaceous dust particles. The fact that this third, well-defined, form of carbon had been hiding in the shadows since time immemorial brings to mind the mysterious character lurking in the dark streets of Vienna, made famous by Orson Welles in the classic movie "The Third Man". In fact we now know that the molecule forms fleetingly within sooting flames but is immediately destroyed as it passes through the flame barrier into an oxygen atmosphere. On the basis of such revelations the suggestion that C_{60} might exist in space and be responsible for the DIBs (Kroto & Jura) seemed an as good, if not a better, possibility than most other ideas that had heretofore been proposed. Especially compelling support for the idea that C_{60} existed in space lay in the fact that the original discovery was made serendipitously during laboratory experiments designed to simulate the atmospheric conditions in cool red giant carbon stars. This conjecture has just been confirmed by Cami et al who have found infra red bands in the spectra obtained by NASA's Spitzer satellite telescope. The discovery also makes some recent work here at FSU on endohedral fullerenes, in which atoms are trapped inside the carbon cage, extremely relevant to certain anomalous isotope ratios observed in meteorites, in particular carbonaceous chondrites. This is yet another example of the remarkably synergistic relationship between terrestrial and space science. In these difficult times it lends useful support for the fundamental value of "Blue Skies" or perhaps more accurately "Black Skies" cross-disciplinary research. All these results taken together suggest that the 90 year-old mystery of the carrier of the DIBs might be close to being resolved at long last.