Professor Willy Fowler (1911–1995) – An obituary

William Alfred Fowler, Nobel Laureate (1983), passed away on 14 March 1995 in Pasadena, California, the place where he had worked for about six decades. He was better known to all his friends as 'Willy'.

Born on 9 August 1911 in Pittsburgh, Willy Fowler did his first degree at the Ohio State University and then in 1933 went to the California Institute of Technology as a graduate student of Charles Lauritsen at the newly established Kellogg Radiation Laboratory. With so much nuclear astrophysics that has come out of Kellogg, it is interesting to know that the lab had been established to study the physics of 1 MeV X-rays and their application to the treatment of cancer. As Willy recalled in his Nobel Lecture, the change of direction came right at the beginning with the discovery in 1932 by Walton and Cockroft that nuclei could be disintegrated by protons accelerated to energies below 1 MeV. This led Lauritsen to convert one of his X-ray tubes to a positive-ion accelerator and to initiate work in nuclear physics.

The shift towards astrophysics took place in Willy's postdoctoral career at Caltech, where, in fact, he remained throughout his life. His early work with his colleagues at Kellogg included the study of the proton–proton chain and the carbon–nitrogen cycle for making helium from fusion of hydrogen. Kellogg provided data on the many experimental cross-sections for the intermediate reactions in these processes. The fusion process from light to heavier nuclei, however, encounters a stumbling block beyond helium (atomic mass 4).

There is a mass gap from 5 to 8 showing a lack of stable nuclei in this mass range and this was the subject of Willy's study for several years. In the end it became clear that because of this gap the grand scheme proposed by George Gamow of synthesizing all nuclei in the early hot era of the big bang universe would not work. How then were heavier nuclei like carbon and oxygen, or iron, made? Astrophysicists building on the pioneering work of Eddington in the 1920s and Bethe in the late 1930s expected the answer to come from stars. But here also, how was the mass gap to be bridged?

The clue to this question came from a highly imaginative solution proposed by Fred Hoyle in 1953, which was to bring Hoyle and Fowler together in a very fruitful collaboration in nuclear astrophysics, a collaboration that lasted nearly 30 years. It was Hoyle's conjecture that the element-building process would more naturally take place inside stars whose cores were known to be hot enough to sustain nuclear fusion reactions. And to bridge the mass gap after helium, Hoyle proposed that the process would jump over the unstable gap. Thus, three nuclei of helium (atomic mass 4) would fuse to make carbon (atomic mass 12) in a resonant reaction. Resonance would make the triple fusion go fast, to compensate for the rarity of three nuclei coming together.

Willy used to recall how Fred walked into Kellogg with this idea which led to the verifiable result that there ought to exist an excited level of the carbon nucleus to which the three helium nuclei get converted. Look for it, he urged the nuclear physicists. After an initial scepticism, Ward Whaling and others at Kellogg got going and did indeed succeed in confirming Hoyle's conjecture. As the helium nucleus is called the alpha particle, this process came to be known as the *triple alpha process*.

This episode led Willy firmly and irrevocably into astrophysics, where plenty of challenges existed for nuclear physicists, especially in the area of stellar evolution. Eddington's work had shown the way of constructing stellar models essentially for the main sequence stars, whose energy is generated from the fusion of hydrogen to helium. What next? Hoyle's triple alpha process had opened the way for the synthesis of even heavier nuclei. But information on the various reaction rates was lacking. Willy turned his attention to this problem.

While Hoyle provided the theory on stellar structure, Fowler brought the nuclear physics inputs. Still lacking were the theoretical and observational details on how radiation interacts with matter as it escapes from the stars. The husband and wife team of Geoffrey and Margaret Burbidge provided this help in a fourfold collaboration that came to be known as the B^2FH, which culminated in 1957 in a mammoth paper entitled 'The synthesis of elements in stars' in the *Reviews of Modern Physics* (**29**, p. 547). This B^2FH was to set the tone for all future work in stellar nucleosynthesis, for it covered the synthesis of different nuclei in stars in all their different stages of evolution.

From the late fifties to the mid-sixties the Hoyle–Fowler combination turned from stellar setting to the larger extragalactic one. Radio astronomy was beginning to provide glimpses of the highly energetic extragalactic world. Geoffrey Burbidge had been the first one to draw attention to the fact that taken at face value the powerful radio sources demanded huge energy reservoirs that far exceeded the dynamical energies of colliding galaxies. Some new source was needed. Would the stellar option, say, of a supermassive star work? Fowler and Hoyle considered the models of such objects and came to the conclusion that these objects will have a far more dominating force to contend with, namely, the force of gravity. Under such a force these objects would tend to shrink faster and faster. In a paper in *Nature* in early 1963 (**197**, p. 533) they conjectured such highly collapsed supermassive objects as likely sources of the observed energy.

Parallelly, the observational front was also progressing and, thanks to a rare collaboration between the optical and radio astronomers in 1962–63, the first discovery of the quasistellar objects (QSOs) was made. Almost star-like in appearance the QSOs showed large redshifts in their spectra and theoretical estimates led to the conclusion that energy comparable to that of an entire galaxy might well be coming out of a source no greater than a light year across. Here then was the very example of the kind of objects conjectured by Hoyle and Fowler.

This discovery opened up a new field in astrophysics, called *relativistic astrophysics*, which dealt with the astrophysical phenomena in strong gravitational fields, in situations where Newtonian gravity must be replaced by Einstein's general theory of relativity. So great was the excitement amongst the astronomical community that an international symposium was held in December 1963 in Dallas to discuss the implications of theories and observations in this emerging field. Both Hoyle and Fowler were the lead speakers in this meeting on the theoretical side. These meetings now continue to be held biennially under the title 'Texas Symposia'. Much of the present black hole bandwagon in astrophysics has its origin in the Hoyle–Fowler work of 1963

Another of Willy's seminal contributions came in the big bang cosmology when in 1967 he along with Fred Hoyle and Robert V. Wagoner carried out a revised and updated version of Gamow's primordial nucleosynthesis The Wagoner–Fowler–Hoyle paper in the *Astrophysical Journal* (**148**, p. 3) again turned out to be a trendsetter for future work in big bang nucleosynthesis. It is interesting to recall that this work was carried out in a shed in the Cambridge Observatories while Hoyle's new institute building was under construction.

It was during the first six years of the Institute of Theoretical Astronomy at Cambridge that Willy was a frequent visitor during the summer months. He and Fred would sometimes take off to the Scottish Highlands for hiking, a practice that Willy continued till late in his life.

For his work in nuclear astrophysics Willy Fowler shared the 1983 Nobel Prize with S. Chandrasekar. It was the second time that a Nobel award was given for theoretical astrophysics, the previous occasion being in 1967 when Hans Bethe was honoured for his work on stellar structure models with nuclear energy generation. The 1983 award, however, brought both surprise and disappointment at the omission of Fred Hoyle from the list.

Willy was known for his thoroughness in all the work he did, a fact which was belied by his informality and jolly demeanour. He would be the life and soul of a party discussing (over a martini) either the world series, or the Scottish terrain, or one of his long train journeys (he was a train buff), or nuclear cross-sections all with equal ease. Amongst his many honours, his Indian connection was with IUCAA as one of its Honorary Fellows, and several of us recall his jokes and anecdotes as he talked about his latest work in cosmology in March 1990. As a personality he will be greatly missed but his work will continue to guide the succeeding generations of astrophysicists.

Willy Fowler is survived by his wife Mary Dutcher Fowler and two daughters by his first wife Ardienne (deceased).

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Who should look at stars*

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In January 1994, I met Jayant Narlikar on a flight from Calcutta to Bombay. He then reminded me of an earlier occasion when (in a weak moment), I had agreed to deliver a Foundation Day lecture at his Institute in Pune. I tried to wriggle myself out of the commitment, firstly, by reminding Jayant that I would have nothing meaningful to say to what was likely to be a distinguished gathering of scholars, and secondly, because my daughters were discouraging me from being typecast as a Foundation Day fixture. Both attempts failed, as you will notice from my presence here today.

Having made the commitment to speak, I spent many agonizing evenings trying to focus on a suitable topic. Finally, I drew inspiration from my association with Narlikar as a member of the Science Advisory Council to the Prime Minister (1986–89) and settled on a 'blue sky' approach. More of that shortly.

A few recent events spurred me to put down some initial thoughts on paper before I lost track of them. A very close friend and his wife were visiting us in London. While we were driving to Glyndebourne to attend a performance of the Opera, Don Giovani, I shared with them my dilemma about the Foundation Day lecture. My friend's wife, a well-known physician from Bombay in her own right, asked me, 'Why should a poor country like India, with its impoverished millions, fund research to watch stars?' For the best part of the two-hour car ride, we had a series of disagreements on the subject. These disagreements ranged from the concept of curiosity, through the nature of the Indian mind and the need to be part of the international community in leading-edge science, to the origins of the universe and life on Earth. I could not convince her that curiosity-driven exploration was at the heart of human civilization, starving or otherwise. Finally, the arguments ended inconclusively when I raised a rhetorical question, 'What was the level of poverty and deprivation in Italy in the days of Galileo Galilei?', I asked, feeling that would end the debate amicably. Neither

*This was the subject of the Foundation Day Lecture delivered at Inter-University Centre for Astronomy and Astrophysics, Pune, India, on 29 December 1994