letters

Placing Chandra's work in historical context

In the December 2010 issue of PHYSICS TODAY, Freeman Dyson gave an interesting account (page 44) of Subrahmanyan Chandrasekhar's role in 20th-century science. I enjoyed reading it, but the section concerning Chandra's work on the limiting mass of white dwarfs and its early reception by Ralph Fowler, Edward Arthur Milne, and Arthur Eddington has several statements, some often repeated in the past, that contradict what publications and correspondence at the time reveal.[1,2]

Dyson states that "Fowler had calculated that for a given chemical composition, the density of a white dwarf would be proportional to the square of its mass." Actually, in his 1926 seminal paper Fowler did not present such a calculation; he only discussed the pressure-density relation of a degenerate gas of electrons in the nonrelativistic limit.[2] In that limit, the first physicist who calculated the density of a white dwarf model of uniform density with a solar mass was the Russian physicist Yakov Frenkel,[3] who apparently was unaware of Fowler's paper. A year later Edmund Stoner, a former student of Ernest Rutherford's at Cambridge University, independently carried out the same calculation showing explicitly the dependence of the density on the square of the mass.[2] The mean momentum of a degenerate gas of electrons is proportional to the cube root of the density, and Wilhelm Anderson, a physicist at the University of Tartu, Estonia, pointed out that for white dwarfs with a solar mass, Stoner's result was inconsistent because the mean electron momentum is of the order of its rest mass.[2]

Anderson attempted to calculate the relativistic pressure density relation, but his result was incorrect, although it indicated, fortuitously, the occurrence of a limiting mass for white dwarfs. Then Stoner, following Anderson's observation, obtained the exact relativistic equation of state for degenerate electrons and evaluated the complete density–mass relation in the approximation of uniform density, finding an upper limit for the mass.[2] A year earlier Frenkel also obtained the fully relativistic equation for a degenerate electron gas and applied it to account for the extremely high density of white dwarfs. Like Anderson, he found that for a white dwarf with a solar mass, the electrons would become relativistic, and he also found that in this case a solution does not exist. Interestingly, for larger masses, Frenkel showed that the degeneracy pressure of ions could lead to a solution with much higher density, of order 1016 g/cm^3, that now is known to correspond to a neutron star. In February 1931, about the same time that Chandra wrote his paper, Lev Landau also obtained the relativistic mass limit for white dwarfs[2] but concluded that since stars with higher masses are observed, the laws of quantum mechanics must break down in such cases.

Dyson states that during Chandra's first voyage to England, "to his amazement, Chandra found that the change from Newton to Einstein has a drastic effect on the behavior of white dwarf stars." But a letter to his father[2] reveals that Chandra already was aware of Anderson's paper that had been published a year earlier. Moreover, Dyson states that "Chandra finished his calculation before he reached England and never had any doubt that his conclusion was correct." But in a 1977 interview with Spencer Weart,[2] Chandra admitted that "at first I didn't understand what this limit meant and I didn't know how it would end." Afterwards, Chandra wrote several papers with Milne that introduced an ad hoc incompressible finite density at the core of the white dwarf to allow the existence of such stars for arbitrary large masses. Dyson states that "when he arrived in Cambridge and showed his results to Fowler, Fowler was friendly but . . . unwilling to sponsor Chandra's paper for publication." In a biographical portrait of Chandra, in the same issue of PHYSICS TODAY (page 38), Kamesh Wali adds that Fowler "offered to send it to Edward Arthur Milne, who Fowler thought was more familiar with the subject. After getting no response from Fowler or Milne for months and seeing no possibility of its publication in *Monthly Notices of the Royal Astronomical Society*, Chandra sent it to the *Astrophysical Journal* on 12 November 1930; it was published the following July."

Wali further writes that "neither Fowler nor Milne appreciated the startling discovery he [Chandra] had made." Actually, when Fowler first met Chandra, he told him that his "startling discovery" had already been published by Stoner.[2] Moreover, Milne promptly responded to Chandra by saying, "I have been interested in your paper, it seems very useful. . . . As regards publication, I think that your paper might well be accepted by R.A.S. for M. N."[4]

Finally, contrary to Dyson's assertion that Chandra "received so little recognition and acclaim at the time" for his work, within four months after Chandra presented his solution to the white dwarf problem, Henry Russell gave it a positive evaluation; soon afterwards Gerard Kuiper analyzed a recently found white dwarf to show that it strongly favored Chandra's result over Eddington's faulty analysis, and not much later other prominent astronomers came out in support of Chandra's work.[5]

References

1. W. Israel, *Found. Phys.* **26**, 595 (1996).
2. M. Nauenberg, *J. Hist. Astron.* **39**, 297 (2008), and references therein.
3. J. Frenkel, *Z. Phys.* **47**, 819 (1928).
4. E. A. Milne to S. Chandrasekhar (2 November 1930), in Subrahmanyan Chandrasekhar Papers, Special Collections Research Center, University of Chicago Regenstein Library.
5. F. Wesemael, *Ann. Sci.* **67**, 205 (2010).

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In their engaging recollections of Subrahmanyan Chandrasekhar's extraordinary career, neither Freeman Dyson nor Kamesh Wali mention that Chandra was the third person, not the first, to publish a white dwarf mass limit that involved a relativistic treatment of degenerate electrons. Chandra

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