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This Week's Citation Classic®

Hoyle F & Wickramasinghe N C. On graphite particles as interstellar grains. *Mon. Notic. Roy. Astron. Soc.* **124**:417-33, 1962.

It is argued that interstellar dust grains are graphite particles that have condensed in the atmospheres of cool carbon stars and were subsequently expelled into interstellar space. This model is offered as a replacement of the generally accepted theory that interstellar dust is comprised of ices that have condensed from gaseous molecules in space. [The *SCI*® indicates that this paper has been cited in over 150 publications.]

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In October 1960 I went up to Cambridge as a graduate student seeking to work with Fred Hoyle for a PhD degree. After an abortive attempt to set me onto a problem concerning the reversal of the Sun's polar magnetic field, Fred quickly directed my interest to the interstellar dust grains. Over toast and tea at the university combination room, he convinced me that the question of the composition and origin of dust grains was one that urgently needed to be reopened. I promptly got started by assessing all the available facts, and I learned to my amazement how dogma-ridden this field of astronomy had been at the time. The postwar work of the Dutch astronomer H.C. van de Hulst[1] had led to a firm belief that the interstellar dust grains were virtually certain to be composed largely of H_2O ice and that such icy particles must perforce condense from gas in the tenuous interstellar medium. Our researches showed that neither of these assertions were on a sound footing. The supposition that the composition might be ice was far from proven, and as for condensation of grains from gas, there seemed to be insuperable obstacles for the nucleation of particles in a low-density interstellar medium. Our attention was therefore turned away from ice condensation in the interstellar medium to the alternative possibility that more refractory particles could condense in the atmospheres or environs of cool stars.

In this paper, we considered the possible formation of graphite particles in the atmospheres of N-type carbon stars, which are irregular variable stars whose effective temperatures vary from ~ 1,500 K to 2,500 K over a typical time scale of about a year. Thermochemical calculations including considerations of nucleation led to the conclusion that during the pulsation phase of such a star when the temperature fell below 1,800 K, graphite-particle formation was virtually certain. We also showed that such particles are expelled to the interstellar medium by radiation pressure from the parent star, and that aspects of the known optical properties of the grains are elegantly explained by the graphite-particle model.

This paper was vigorously attacked by several astronomers, notably J.M. Greenberg, who felt unable to depart even one iota from the concept of ice grains in space. The graphite thesis gained rapid acceptance after the discovery from infrared studies[2] that not much ice existed in the interstellar medium, and, more importantly perhaps, after a prediction of an ultraviolet absorption feature in graphite spheres[3] was later borne out in the ultraviolet spectra of stars.[4] The work on graphite grains was first reviewed in a comprehensive manner in a book I wrote in 1967.[5] A more recent review of this subject was published by Martin,[6] and most recent of all Hoyle and I[7] have traced the development of ideas that began with this paper leading up to the present day.

1. **van de Hulst H C.** The solid particles in interstellar space. *Rech. Astr. Obs. Utrecht* **11** (Part 2), 1949.
2. **Danielson R E, Woolf N J & Gaustad J E.** A search for interstellar ice absorption in the infrared spectrum of Mu Cephei. *Astrophysical J.* **141**:116-25, 1965.
3. **Wickramasinghe N C & Guillaume C.** Interstellar extinction by graphite grains. *Nature* **207**:366-8, 1965. (Cited 50 times.)
4. **Stecher T P.** Interstellar extinction in the ultraviolet. *Astrophysical J.* **142**:1683-4, 1965. (Cited 80 times.)
5. **Wickramasinghe N C.** *Interstellar grains.* London: Chapman and Hall, 1967. 154 p. (Cited 180 times.)
6. **Martin P G.** *Cosmic dust. its impact on astronomy.* Oxford: Clarendon Press, 1978. 266 p.
7. **Hoyle F & Wickramasinghe N C.** *From grains to bacteria.* Cardiff: University College Cardiff Press, 1984. 210 p.

