Book Reviews

Particulate Matter in Space

The Dusty Universe. Proceedings of a symposium, Cambridge, Mass., Oct. 1973. GEORGE B. FIELD and A. G. W. CAMERON, Eds. Published for the Smithsonian Astrophysical Observatory by Neale Watson Academic Publications, New York, 1975. x, 324 pp., illus. $15.

Interstellar dust grains constitute only about 1 percent (by mass) of the matter in space, but their light scattering and absorbing properties, their interaction with the ambient rarefied gas, and their role in the formation of stars and planetary systems combine to make them a subject of intense interest to astrophysicists. Interplanetary dust and debris represent the material from which the solar system formed; scientists studying the early history of the planets must therefore examine the nature of this material as well.

Traditionally astronomers have treated interplanetary and interstellar grains in quite different manners, and indeed very few researchers have attempted to study both. This division of effort arose for a combination of reasons, based largely on the separate historical development of and the differing techniques used in research on the solar system and on the interstellar medium. In a modern view of the universe it is clear that a neat dichotomy between interplanetary and interstellar dust is not realistic. Stars and planetary systems form out of condensations in the interstellar medium, and the supply of interstellar gas and dust is replenished by the ejection of matter from stars.

The Dusty Universe, which contains papers from a symposium honoring Fred Whipple, a pioneer in research on interplanetary material, is partly intended to bridge the gap between the two disciplines. Although it does succeed in collecting papers from both under one cover, the dichotomy persists except in the opening paper by A. G. W. Cameron and a discussion of grain condensation processes by Lawrence Grossman. The remaining 11 papers are devoted to research within one discipline or the other. It may be surmised that the greatest benefit of the symposium was the informal interaction among the astronomers present; perhaps research efforts begun in the hallways there will eventually fulfill the hopes of the conference organizers.

The book contains several outstanding papers, however, and may be recommended on that basis. A particularly good example is Grossman's paper, which describes thermodynamical model calculations of the condensation of solids during the cooling of the presolar nebula. Even though the quantitative details are omitted, the discussion of the results makes it clear that this is a promising line of research for understanding the composition of meteoritic material, and hence the condensation process itself. Furthermore, Grossman's models have special relevance to the purpose of this volume in light of the evidence, discussed in the chapter by George Field, that interstellar grains may have formed under similar conditions by similar processes. As Grossman points out, these similarities may indicate that his type of theoretical approach can be extended into the interstellar realm.

Among the remaining contributions, the papers by E. E. Salpeter on grain formation in stellar atmospheres and by Peter Millman summarizing the distribution and properties of interplanetary dust stand out, the former for its concise depiction of a very complex process, and the latter for its broad perspective and unifying overview. Finally, the short chapter by E. M. Purcell on interstellar grains as pinwheels, which describes a marvelously simple mechanism for inducing suprathermal rotation in grains as a result of collisions with gas atoms, not only makes good reading but in addition outlines a process that may be of far-reaching importance for understanding the alignment of grains in space, a long-standing problem.

Some of the remaining articles are too brief or are reiterations of material already summarized in many places. Despite such flaws and despite its general failure to stress sufficiently the relationship of interstellar and interplanetary grains, *The Dusty Universe* is a useful compendium for advanced students in astronomy or specialists in related fields.

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Celestial Mechanics

Interplanetary Encounters. Close-Range Gravitational Interactions. ERNST J. ÖPIK. Elsevier, New York, 1976. viii, 156 pp., illus. $26.95. Developments in Solar System- and Space Science, 2.

Understanding the dynamical history of the solar system requires discovery of the principles governing its behavior on a time scale of $\sim 10^{10}$ years, far beyond the 10^4 to 10^5 years accessible to direct numerical integration. On this long time scale the orbital evolution of "stray" bodies, such as comets, meteorites, planet-crossing asteroids, and primordial planetesimals, is essentially stochastic. This situation arises because the orbital perturbations associated with close planetary encounters are extremely sensitive to the minute details of previous encounters. Öpik's major contribution to this field has been to turn this difficulty into an asset by developing probabilistic methods for dealing with the orbital evolution of a swarm of small bodies with similar initial orbits. This development has played a major role in recent progress toward understanding the history and origin of these important interplanetary bodies.

Until the appearance of this book, most of this work by Öpik had been scattered through several journals and relatively obscure observatory reports, and although many have made use of his conclusions, few have worked through the theory that led to them. The theory is presented here in a systematic manner and may now receive the attention it deserves. The book is by no means a collection of reprints, but rather represents an original unification of the previous work, in some cases involving quite different derivations of the same results.

This is very much Öpik's book, in that little space is given to discussing the contributions of those who have extended the work during the past decade. To some extent this limitation seems to arise from Öpik's strong preference for analytical results over numerical simulation by means of computers. There is merit in this view, but the limitations of the analytical approach show forth in the difficulty of dealing in a straightforward way with some of the more complex problems of the real solar system, such as the common situation of a "stray" body simultaneously crossing the orbits of several planets. In contrast, this problem is readily amenable to the numerical Monte Carlo extension of Öpik's theory developed by Arnold. There is value in both the analytical and the numerical ap-