THE NEUTRAL ATMOSPHERES OF COMETS*

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Abstract. In this paper we have endeavored to critically evaluate our present understanding of cometary atmospheres. Following a brief introduction of the significance of the study of cometary atmospheres (Section 1), the relevant photometric and spectroscopic observations are summarized in Section 2.

The interaction with the solar radiation, with regard to both the excitation of the observed species as well as the dissociation of stable molecules evaporating from the nucleus, is considered in Sections 3 and 4. The gas phase chemistry likely to take place in the dense inner coma is next considered in Section 5.

The exospheric and hydrodynamic models of the expanding cometary atmosphere are considered in detail in Section 6, and both their limitations as well as possible improvements are discussed.

The observed chemical composition of the neutral atmosphere and the inferred chemical composition of the volatile component of the nucleus, together with possible variations between different classes of comets is next considered in Section 7, and their possible cosmogonic significance is discussed.

In conclusion, some of the important directions in which future research should progress, in order to provide more complete and secure knowledge of cometary atmospheres, are stressed (Section 8).

1. Introduction

There has been a strong upsurge in the scientific interest in comets in recent times. Their cosmogonic significance is clearly understood. Due to their small sizes they have undergone little metamorphic change due to the effects of gravity, internal heat, weathering and high velocity meteoritic impact, unlike the larger bodies: planets and satellites. Particularly those so-called 'new' long period comets which may be coming into the inner solar system for the first time since their formation may very well represent the most primitive material in the solar system and consequently their proper understanding could shed light on the chemical composition and physical state of the primeval solar environment.

The important role of comets as natural probes of the interplanetary plasma has been realized since the pioneering work of Biermann (1951). Indeed it was the behavior of the plasma tails of comets which provided us the earliest information regarding the continuous outflow of corpuscular radiation from the Sun, which we now call the solar wind. In this role comets have not been entirely superseded by the advent of artificial space probes, because while these latter are confined to regions close to the ecliptic plane, long period comets approach the Sun at all inclinations and a few of them get

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closer to the Sun than any artificial probe has or will in the foreseeable future. Furthermore, comets are the most distant voyagers of the solar system, sampling regions that are essentially 'interstellar'.

Finally, comets act as cosmic laboratories, providing us with an opportunity of studying matter under unusual physical conditions, not easily reproducible in the laboratory. The free radicals observed in their comas and tails can exist there despite their extreme chemical instability only in virtue of the extremely small densities that prevail.

Basic to the understanding of cometary phenomena is the physical structure and chemical composition of the 'nucleus'. However, by the time a comet is visible even with the most powerful telescopes its nucleus (or center of activity) is already shrouded by a thick atmosphere of gas and dust, and one of the main objectives of studying cometary atmospheres is to infer the nature of the nuclei which are responsible for them. In this paper we propose to make a comprehensive review of our present knowledge of the neutral gas atmospheres of comets and proceed to discuss very briefly a tentative picture of the nucleus that seems to be indicated.

2. Observations

For the sake of completeness the general morphology of a bright comet when sufficiently close to the Sun (i.e. $R \lesssim 1$ AU) is shown schematically in Figure 1. All the chemical species identified spectroscopically in the head and tails to date are given in Table I. The contribution of Comet Kohoutek (1973f) (which, due to its early detection, produced an extensive observational program) is worth noting. It consists of CH$_3$CN (Urlich and Conklin, 1973) and HCN (Snyder et al., 1974) in the radio, H$_2$O$^+$