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NEUTRAL COMA MODELS

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This presentation is supposed to be about Neutral Coma Models. Since ions are not mentioned specifically in the Agenda, I will also include them in the region inside the contact surface. Outside the contact surface they will be included in the next paper on Comet - Solar Wind Interaction Models.

Before I start on the main topic, I would like to digress and cover some points that were made earlier in this meeting and have not been fully answered. A point was made that the Halley Multicolour Camera (HMC) images were not sharp, possibly because they lacked resolution and were taken through the dust. They were compared to the sharp features seen on images of planets and satellites. Then a comment was made in their defense that the movie, made from a sequence of HMC images as the spacecraft approached the nucleus, shows the consistency of the observed features. I do not have the movie with me, but I can show you some individual pictures in the sequence. The resolution on the last picture was less than 50 m per pixel. That is of the order of 0.5% of the minor diameter of the nucleus and is better than the resolution requested earlier in this meeting. We can clearly identify features of the order of a few hundred meters on several consecutive images. I believe the reason that they are not as sharp as the ones on rocky planets is that the features on a comet nucleus are produced by very lightly compacted ice and dust. Lack of gravity and cohesion prevent formation of sharp features. In addition erosion from at least 30 perihelion passages would have destroyed any sharp features that might have existed on the nascent nucleus.

The nucleus is bigger than was anticipated, it is very black with an albedo of about 3%, and it is highly irregular in shape and in dust production. The visible dust comes from isolated source areas in the form of jets and on the sunlit side only. I conclude from this that the gas is also produced primarily in these isolated source areas. This means that the composition of the nucleus is heterogeneous.

Although we have only seen one comet nucleus in such detail, I believe that the irregular and heterogeneous features that we have seen on Halley's nucleus are typical. Comets have many features in common, but we can also expect that each comet will show different characteristic properties. It is therefore necessary that we investigate as many different comets as possible and bring samples back to earth to be examined and analyzed in the laboratory. The only other planned sample return missions are the CAESAR and the CNSR missions. Although they are extremely important, and CNSR is the only mission to return a core sample from a nucleus, they go to only one comet each.

Finally, all missions go to short period comets. If our goal is not only to learn more about comets but also about the solar nubula or presolar nebula, then a "new" comet would be closer to our objectives. But even "new" comets are not pristine in the sense that they represent a sample of the cloud in which they originated. Figure 1 illustrates why they are not pristine. During their formation only condensable materials became part of comet nuclei. While they were in "storage" in the Oort cloud, ultraviolet radiation and cosmic rays changed the composition on their surface. Internal low-level radioactivity may have changed amorphous ice to the crystalline form and "warming" will have liberated and diffused some of the more volatile components. Even with very slow reactions chemical changes will have occurred. That chemical changes occur in the coma has been well established. Modeling all of these processes will be essential to determine the original composition of the region of the nebula in which comets formed. Additional complications are introduced by repeated passages through the inner solar system. If we could go to a "new" comet, some of the uncertainties associated with physical and chemical changes related to these passages would be eliminated, leaving only the ones shown in figure 1. Going to a new comet would greatly enhance the Multi-Comet mission. It would require having an instrumented probe in earth orbit ready to go once the trajectory for a new comet is determined. Perhaps this can be considered.

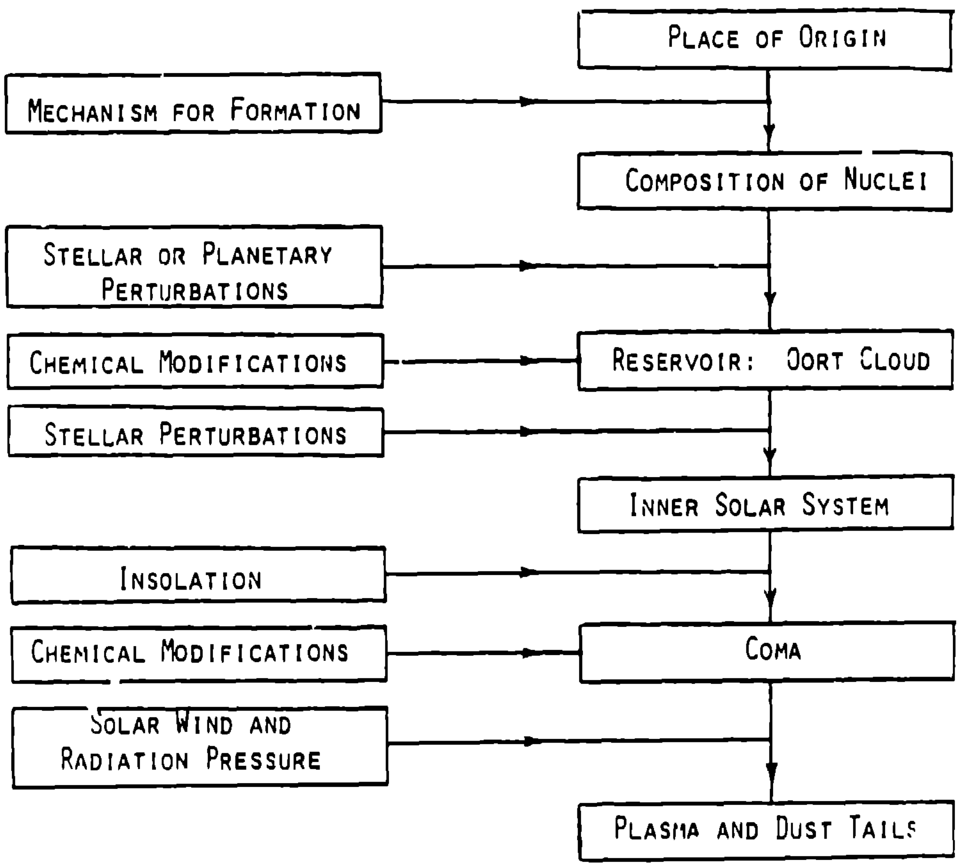

Fig. 1. Modifications of "new" comets from the time of their birth until they reach the inner solar system.

As far as coma modeling is concerned, the following processes are taken into account: Sublimation (vaporization) of the icy component of a cometary nucleus determines the initial composition of the coma gas as it streams outward and escapes. Photolytic reactions in the inner coma, escape of light species such as atomic and molecular hydrogen, and solar wind interaction in the outer coma alter the chemical composition and the physical nature of the coma gas. Models that describe these interactions must include chemical kinetics, coma energy balance, multi-fluid flow for rapidly escaping light components and heavier bulk fluid, separate temperatures for electrons and the rest of the gas, transition from a collision dominated inner region to free molecular flow in the outer region, mass pick-up of solar wind ions, counter and cross streaming of cometary particles and solar wind ions, magnetic fields carried with the solar wind, and gas - dust interaction.

All of the present coma models assume spherical symmetry. This is a reasonable approximation for larger distances in the coma. The following processes are as yet not included in coma models:

I believe that the highly asymmetric and irregular dust and gas production that has been observed in comet Halley is not unique to that comet. Pressure equalization in a jet just above the surface of the nucleus will cause a tangential wind across the surface. The number of gas - dust collisions in that direction within the jet is not sufficient to entrain much of the visible dust, although some of the smallest dust grains may be carried with this wind.

A one - temperature representation of the electron energies is not sufficient. A detailed energy distribution of the electrons or at least a two - temperature representation is needed.

Although ions and electrons are treated as separate fluids from the neutral gas outside the contact surface, ions and neutrals are not treated as separate fluids inside the contact surface. Inward directed flux of ions and electrons has been modeled, but outward directed flux has not been included in coma models.

It is not clear whether heterogeneous chemical reactions are important in coma models. This must be investigated.