streams besides dustballs, or meteoroids. Since some streams are associated with comets it is expedient to begin with comets.

V. THE COMET—NATURE'S SOLAR PROBE

The solar system is surrounded by a vast spherically-shaped cloud of comets which must extend out to about 150,000 A.U. (astronomical units). The cloud is expected to contain 10^{11} objects of observable size.[12] At such great distances from the Sun the nuclei would have temperatures of a few degrees above absolute zero. Under these conditions the frozen nuclei would not suffer attrition from sublimation by solar heating.

The motivating forces which occasionally cause some of these entities to fall towards the Sun are supplied by passing stars which effectively reshuffle the velocity distributions every few million years.

A small number of these objects which are moving in long-period orbits, have a probability of being captured by the planet Jupiter. When this happens they are gradually brought down into short-period orbits. There are about 75 known comets with periods less than 100 years. Jupiter, more than any other planet, plays the leading role in capturing these objects and, indeed, they are known as Jupiter's family of comets. All of them have direct orbits, except for Halley's comet. The average absolute inclination to Jupiter's orbital plane is about 13°.

1. The Composition of Nuclei

The physical nature of comets has remained a mystery since the beginning of astronomy. Their origin, which appears to be relatively recent compared to the rest of the solar system, is also baffling. For example, their masses are not high enough to suggest a formation by gravitational accretion. Also the majority of nuclei, when visible, are in a peculiar state of disintegration and cannot be recognized by appearance alone. Furthermore, they have been observed to emit intense light, pass in and out of the Sun's corona, break into pieces, explode violently, speed up or slow down in their orbits, and occasionally vanish altogether or never return. Indeed, the comet is the "flying saucer" or UFO of astronomy.

It was believed quite generally, until the last decade, that comets were flying gravel banks, the gravel consisting of hard, solid, high-density materials called meteorites. In other words, they were composed of materials similar to the stony or iron-nickel objects sometimes found on the ground. The gravel bank hypothesis was useful for it seemed to explain several strange characteristics of comets: (1) the scarcity of phases in comets; (2) the absence of star occultations by any part of a comet; (3) the complete vanishing of the nuclei when the Sun was eclipsed; (4) the surprisingly large amounts of occluded gas liberated from the meteorite material (because of the large exposed surface in a gravel bank); and (5) the low masses of the nuclei.

However, the gravel bank hypothesis has several weak points. Many of the comets which have passed close to the Sun or Jupiter in the past, and remained intact, would have fallen apart or disrupted from the gravitational tidal forces. Also, the gases released during close passages to the Sun would tend to start the array diverging. According to Bobrovnikov,[13] every metallic object less than 1 ft. in diameter would have been vaporized during the perihelion passage of the great comet of 1882 II. This can be increased to about 4 ft. for an ice gravel. This not only would have created a significant amount of gas, but should have practically destroyed the gravel bank. No such effect was observed. Furthermore, not once during any meteor shower, known to be associated with a comet, has a meteorite been observed to fall which could be attributed to the shower.

Actually all five of the preceding observations can be explained if the nuclei are assumed to be small, single entities composed of *ices* (frozen gases). The *ices* referred to here are unknown compounds or radicals involving the elements hydrogen, oxygen, nitrogen, and carbon. Most of the more probable species would have melting points, under atmospheric pressure, of less than several hundred degrees absolute.[14]

A small amount of siliceous and metallic dust, in microscopic sizes, is also expected to be present. Meteorites, *per se*, are highly unlikely to be found in comets. It is not impossible, however, even if all meteorites originated from the asteroid belt. The reason is that the massive planet Jupiter is capable of ejecting asteroidal matter out to the cometary cloud region and beyond. Thus there could be ice bodies in the cloud of comets which contain imbedded meteorites.

2. Disintegration Products

In general, all comets having a coma and tail are in a state of disintegration. An outline of the immediate products of disintegration is given in Table I. Gases in the molecular, radical, atomic and ionized state are known to exist in the head (the head consists of the coma and nucleus taken together). Dust is believed to evolve from nuclei since light is scattered from solid particles in the heads and tails, and meteor showers have occurred after the passage of the Earth through a region previously occupied by a comet.

Table I.