5.11

A TECHNIQUE FOR MEASURING THE INTERSTELLAR COMPONENT OF COSMIC DUST

Daniel A. Tomandl
Department of Astronomy
University of Washington
Seattle, Washington USA 98195

That there is an interstellar (IS) component in cosmic dust has been demonstrated by Pioneers 8 and 9 (Wolf, Rhee, and Berg, 1975). The Pioneer spacecrafts distinguished the IS from interplanetary (IP) dust by measuring particle velocity and direction. Unfortunately, detectors that are capable of measuring a particle's velocity and direction are so restricted in their sensitive area and/or solid angle that their event rate is very low. Pioneers 8 and 9, for example, detected 1-5 IS particles out of 20 events in 7 spacecraft-years of operation (Wolf, Rhee, and Berg, 1976). More events can be obtained, however, if one uses a detector that only measures the direction of travel. The direction alone can be sufficient to distinguish between IS and IP dust--at least on a statistical basis. For example, if most IP dust travels in directions near the ecliptic plane, then an IS flux from out of the plane should be detectable. This paper will examine the use of direction alone in detecting IS particles.

There are two basic types of space probes that are available to look for IS dust by its direction: 1) spacecraft with particle detectors (for example, Pioneers 8 and 9), and 2) the moon. The Pioneers have detected more than 800 particles which did not have enough energy to make a velocity measurement possible but for which there is approximate direction information (the front film data). Lunar samples can be used to look for particle travel directions by examining the microcraters formed upon impact. Only those samples whose lunar orientation was documented can be used. To determine the impact direction more accurately than to within 1 hemisphere, one can examine the bottoms of small cavities where the cavity wall defines a fairly narrow acceptance cone. The disadvantage of using lunar samples compared to man-made spacecraft is that, due to lunar rotation, information about one dimension of the direction of travel is lost. Fortunately, the moon's equator is very near

https://doi.org/10.1017/S0252921100052210 Published online by Cambridge University Press

the ecliptic plane (less than 2° difference) so the critical ecliptic latitude dimension is retained. The advantage of using lunar samples is their long integration times--exceeding 10^5 years.

As IS particles come into the solar system in hyperbolic orbits, some of their aspects will be considered. For a given set of conditions --position of the particle detector, sun, and initial velocity (far from the sun) of IS particles--there are two types of hyperbolic impact paths: "direct" and "around". These are illustrated in Fig. 1 wherein the detector is near the earth, on the moon for example. The around paths can be ignored only if their perihelion distances are so small that they are interfered with by the sun, but this is not usually the case. The importance of the around path particles is realized when one considers the example of limiting the problem to gravitational influences alone. In this case, the flux per unit solid angle (specific flux) is the same for both the around and the direct path particles! Furthermore, if the initial IS particle direction distribution is isotropic, then the detected distribution will be isotropic when the direct and around path particles are combined. These results are not changed by considering radiation pressure effects, but they are somewhat modified when the earth's orbital motion is taken into account.

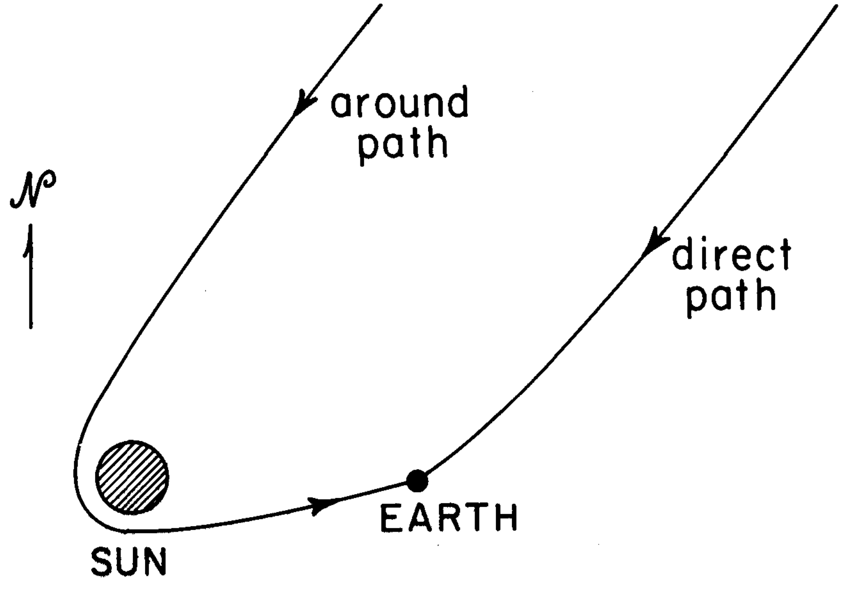

Figure 1. The two types of impact paths: "direct" and "around"

https://doi.org/10.1017/S0252921100052210 Published online by Cambridge University Press

A computer model was developed to calculate the distribution in impact directions from an initial direction of travel of IS particles. The initial direction was assumed to be that due to the sun's local motion in the galaxy as measured with respect to nearby O and B stars. Fortunately, this direction is well away from the ecliptic plane: toward 53° north ecliptic latitude at 20 km/s. Recent measurements of local hydrogen L_α and He I and II emission indicate that IS gas is coming toward the solar system from a direction near the ecliptic plane (Fahr 1974). However, if the solar wind and solar UV flux are asymmetric, the apparent direction of the L_α maximum would be altered. Also the dust particles may not be coupled to the gas. The particles approach the earth between 30 and 60 km/s; at such velocities the earth's and moon's gravitational effects can be neglected. The calculations then include the effects of the sun's gravity, the orbital motion of the earth about the sun, and solar radiation pressure as given by Mie scattering theory.

Typical results of the calculations are given in Fig. 2. Only the direct path impact directions are shown. As the earth changes its position with respect to the sun and IS initial direction, the impact direction changes along the curve of Fig. 2. As mentioned, if a lunar sample is used as a detector, lunar rotation will spread the line into a band. The around path particles have impact directions 10-25° below the ecliptic equator. Thus, the around path particles may be too close to the ecliptic to be distinguished from IP dust. The direct path particles, however, should be discernible on lunar samples and, if enough particles are detected, on spacecrafts.

References:

Wolf, H., Rhee, J.W., and Berg, O.E. (1976).
This Volume.

Fahr, H.J. (1974) Space Sci. Rev., 15, 483.

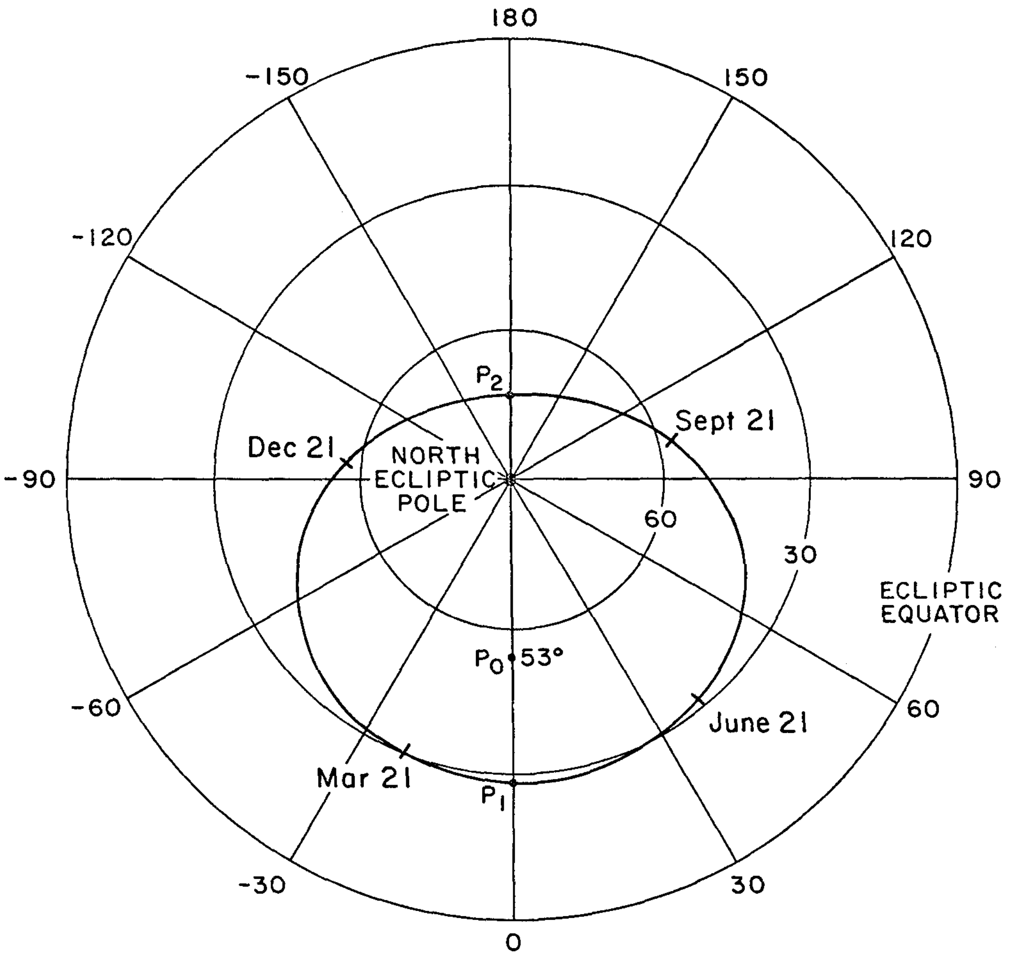

Figure 2. Polar plot of the annual change of the radiant (impact direction) of interstellar dust grains (direct path only). The coordinates, fixed with respect to the stars, are ecliptic longitude ($\lambda-\lambda_0$) and latitude (β). P_0 is the initial direction (λ_0 = -90°, β_0 = 53° N). The initial velocity (V_∞) is 20 km/sec. Points P_1 and P_2 are the approximate minimum and maximum latitude points. For no radiation force these are 28° and 73°. For the radiation force equal to one-half the gravitational force these are 26° and 68°.