Every day, billions of meteoroids enter the Earth’s atmosphere, where they ablate and form plasma between approximately 140 and 70 km altitude. Radar systems, such as the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR), can detect the plasma head echoes (the radar return from the plasma immediately surrounding and moving with the meteoroid). ALTAIR can give the meteoroid’s 3-D position and velocity, which allows for the calculation of the meteoroid’s orbital parameters. Analysis of the orbital parameters provides information about the sources of meteoroids, which may lead to better estimates of the meteoroid’s composition and density, used to estimate mass and size. Understanding the meteoroid’s properties will lead to better risk assessment and mitigation techniques of catastrophic meteoroid impacts on spacecraft.

The data presented here consists of 659 plasma head echoes, detected by the ALTAIR radar on 1 January 2008. ALTAIR is a 46-m diameter, high-power, two-frequency radar operating at 158 MHz (VHF) and 422 MHz (UHF). It is located on the island of Roi-Namur in the Kwajalein Atoll, Republic of the Marshall Islands, in the central Pacific (9°N, 167°E). ALTAIR transmits a peak power of 6 MW simultaneously at the two frequencies, with RHCP polarized signal energy in a half-power beam width of 2.8° (VHF) and 1.1° (UHF). ALTAIR receives both RHCP and LHCP polarized energy and has four additional receiving horns for angle measurements, giving 3-D position and velocity measurements.

The ALTAIR radar measures the range to the meteoroids. By using several range measurements for a given meteoroid, range rates can be calculated by using the change in phase measurements and a rough approximation from differencing the range. ALTAIR has four additional receiving horns, which gives a measurement of the meteoroid’s azimuth and elevation, allowing for the meteoroid position and velocity (relative to the radar) to be specified in 3-D. With the radar location known, the position and velocity can be expressed in an Earth-centered frame, and assuming that the gravitational force from the Earth is dominant, the meteoroid’s orbit about the Earth is approximated. For meteoroids, the orbit is hyperbolic, and the asymptotic position and velocity is found for entry into the Earth’s gravitational sphere of influence. Knowing the time of the measurements, the Earth’s position and velocity in a Sun-centered frame is specified, allowing the meteoroid’s position and velocity in the Sun-centered frame to be determined just before entry into Earth’s sphere of influence. Assuming that at this point, the gravitational force from the Sun is dominant, the meteoroid’s orbit about the Sun is approximated. An elliptical orbit suggests that the meteoroid originated within the solar system, and a hyperbolic orbit may indicate that the meteoroid is interstellar, although additional analysis is necessary to ensure that the large orbital energy (required for a hyperbolic orbit) is not due to a fly-by of one or more planets. The preliminary analysis indicates two distinct sources for the detected meteoroids. The clusters appear to coincide with the Helion and Anti-Helion apparent meteoroid sources. However, the calculated velocities of the meteoroids relative to the Sun, and by extension the orbital parameters for the heliocentric orbit indicate that the meteoroids are in hyperbolic orbits about the Sun. Further analysis is needed to determine whether the detected meteoroids are actually interstellar in origin (a very unlikely outcome) or have had their orbits altered by other bodies in the solar system.

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References

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