FINE STRUCTURE IN RADIO METEOR SHOWERS

By

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Abstract

This thesis is concerned with the observation and study of meteors with a narrow beam VHF radar operated by the University of Adelaide at the Buckland Park research station, in particular the study of the structure and characteristics of meteor showers and the geocentric speeds of meteors. There have been several observations of meteors with the radar previously (Steel & Elford 1991, Cervera 1996, Taylor et al. 1996), but this is the first with an automated data analysis directed to a systematic study of the properties of meteor showers.

The Buckland Park VHF radar offers significant advantages over the wide beam radars traditionally used for meteor observation. The narrow beam, while reducing the collecting area of the radar, allows observations of much lower electron line densities than a wide beam radar of similar power. It also allows the determination of meteor shower radiants by the use of the radar response function. Pulse repetition frequencies of up to 2000 Hz allow excellent time resolution, and the ability to record in-phase and quadrature data allows the phase information to be used. This phase information is important as it allows the use of the phase information to accurately determine radial wind drifts, and the atmospheric speeds of meteoroids.

During 1998, 1999 and 2000, observations were made of a number of meteor showers and the sporadic background. These showed that the η-Aquarid meteor shower was active in these years, and the Orionid and the Leonid showers were detected in 1999. Analysis of the η-Aquarid activity revealed multiple peaks which show that the shower is produced by at least four distinct "filaments", subsets of the meteoroid stream which produces the shower. Not only does the stream have spatial structure, containing groups of particles in different orbits, but also the presence or absence of the peaks in a random fashion from day to day shows that the filaments are themselves made up of clumps of particles. The radar response function is developed and used to determine radiants for the four η-Aquarid filaments.

Evidence is given of a significant number of meteors detected at heights which are above the "radar ceiling", a height at which the theoretical initial radius attenuation factor is near zero for radars operating at the frequency of the Buckland Park VHF Radar, and underdense echoes should be impossible to detect. Investigation showed that over 60 % of meteor trails at heights above the ceiling (105 km) were underdense. Not only does the expected meteor height distribution extend up to 130 km, but also another distribution, peaking at 145 km is uncovered.

Diffusion coefficients estimated from the decay of echoes are compared to theoretical calculations. There is a general agreement, but a number of meteor trails show slower diffusion than expected. This is attributed to the effect of the Earth's magnetic field.

Three methods are used to determine meteoroid speeds using the phase data, each applying to a different type of meteor echo, and in combination, speeds could be determined for over 90 % of all meteor echoes. The first, the pre-t_0 method can be applied to transverse meteor echoes with great success, although it may underestimate the speed of weak echoes with speeds under 15 km s^{-1}. Using the Cauchy approximations to the Fresnel integrals allows speed determination from head echoes which were aliased near the t_0-point. Meteor trails which form at a small angle to the boresight of the radar beam are called "down-the-beam" echoes, and a new method is developed to determine the meteoroid speed and deceleration from these.

The speed measurements of meteors detected during the η-Aquarids show a strong peak in the distribution at 66 km s^{-1}, as well as a smaller peak at 50 km s^{-1}, which may due to a minor shower. The sporadic background shows a broad peak at 25 km s^{-1}, with a smaller peak at 58 km s^{-1}.

Distributions of the speed of meteors in the sporadic background show good agreement with previous observations (McCrosky & Posen 1961, Nilsson 1962, Elford et al. 1995, Cervera 1996), with the exception of meteoroid speeds smaller than 15 km s^{-1}, which can be underestimated by the pre-t_0 technique.

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It is hard to believe that it is finally finished. The production of this work has been a great struggle, worthy of an epic poem. Not only did I produce a thesis, but at the same time, a wife, two beautiful children, and a rally-car. Of course had I been working on my own, this would have been impossible, but fortunately I had the support of a great number of people and managed to submit, even if it was months after I had expected to (but then isn't that always the way?)

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