Pergamon

Planet. Space Sci., Vol. 42, No. 2, pp. 123–126, 1994

0032–0633/94 $7.00+0.00

The radiant distribution of sporadic meteors

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Received 7 September 1993; revised 21 September 1993; accepted 21 September 1993

Abstract. The radiant distribution of sporadic radiometeors has been studied using six surveys catalogued by the IAU Meteor Data Center. In addition to the previously known Apex, Helion, Anithelion and Northern Toroidal sources, we have discovered a Southern Toroidal source and have confirmed that the Apex source may be split into Northern and Southern components.

Introduction

Although showers have been the focus of meteor studies, meteors belonging to recognized showers constitute only a small fraction of all visible and radar meteors. For the purpose of meteor-burst communications, sporadic meteors are much more important than shower meteors since they are the dominant factor determining the rate of information flow.

The study of the distribution of the orbits of sporadic meteors is beginning to attract renewed interest, since they form the major part of the interplanetary dust complex. Even now it is not clear if the origin of sporadic meteoroids is predominantly cometary or asteroidal. The complex mechanisms that act on the particles to change their size and orbital distributions are not understood to the point where we have a comprehensive set of predictions to compare with observations.

For over a century there has been disagreement between the theoretical (Schiaparelli, 1866) and observational (Denning, 1886) studies of the radiant distribution of sporadic meteors. According to Schiaparelli, the radiants which are isotropically distributed in the heliocentric frame appear to be concentrated about the Apex of the Earth's way because of the Earth's orbital motion. Denning, on the other hand, felt that the observations suggested a very nonuniform distribution of radiants in the stationary heliocentric frame and this view has been born out by both photographic and radiometeor studies.

In the mid-1950s, Hawkins (1956), using radar meteor data obtained at Jodrell Bank, showed that the sporadic meteor radiant distribution does indeed have considerable structure. In addition to the Apex source he also found concentrations at $\pm 75^\circ$ to the Apex in the plane of the ecliptic that have become to be known as the "Helion" and "Antihelion" sources. Davies (1957) presented radiant distributions corrected for systems biases. Weiss and Smith (1960) found that radar observations made in Australia were in good agreement with Hawkins' three-source model. It is interesting to note that even as recently as 1993, Davies' version of the three-source model is still being used to predict the likely performance of meteor-burst systems (Mawrey and Broadhurst, 1993).

One of the most ambitious radiometeor projects, The Harvard Radio-meteor Project, which measured (among many other quantities) meteor radiants, revealed the presence of a strong concentration of radiants at an ecliptic latitude of 60° at the same longitude as the Apex, that Hawkins (1963) was not able to attribute to instrumental effects at that time and which he called the "Toroidal" source. A more careful analysis (Elford and Hawkins, 1964—see Thomas *et al.*, 1988) indicated that the toroidal source was probably an artifact of the system, but Stohl (1968) after analysing the echo rate data from the Springhill (Ottawa) meteor radar found a significant toroidal radiant component. Elford (1967) has given a good description of the sources as they were understood in the mid-1960s; since that time until very recently little progress has been made in this area.

It is clear that there is still some uncertainty as to what the radiant distribution of sporadic meteors really is and, in particular, whether the toroidal source is genuine.

Present work

Over the past several decades, numerous surveys of the orbits of radar meteors have been made. Before we can make a useful comparison between theory and observation, we must recognize that the data in the surveys

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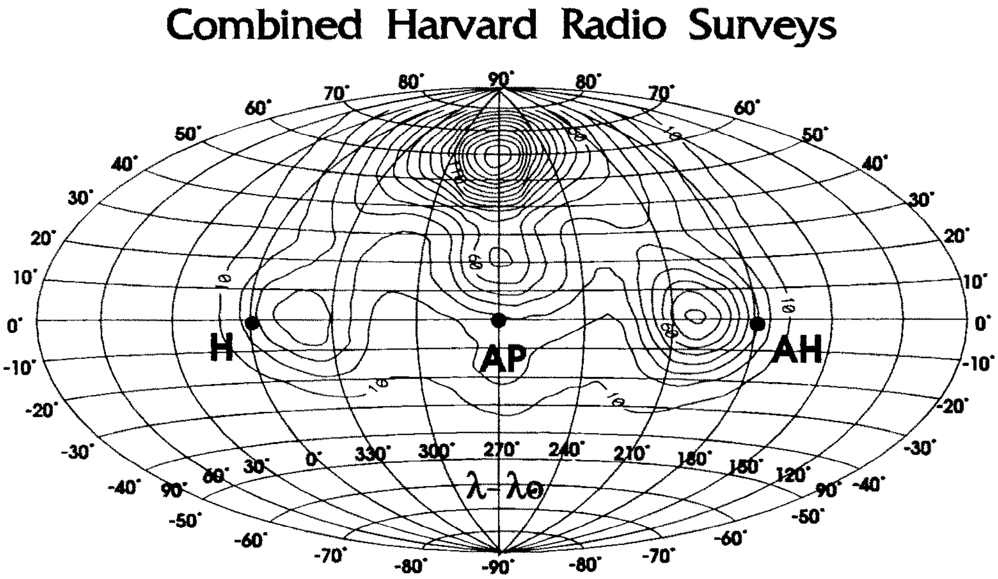

Fig. 1. Contours of apparent density of meteor radiants observed by the 1961–1965 and 1968–1969 Harvard radiometeor orbital surveys. H denotes the position of the Sun, AP the Apex and AH the Antihelion point

are strongly influenced by many factors peculiar to each particlar system, such as location, antenna system, radar parameters and especially the fraction of any one day that the radiant of a given declination is within the collecting area of the meteor radar. To get a good idea of the true distribution of sporadic meteor orbits, these observational biases have to be removed. This is a major undertaking, and in this paper we have tried to identify the features that emerge from an analysis of the major surveys. In the present paper we limit ourselves to the discussion of radar-meteors, since these can be observed on a 24 h basis.

Table 1. Orbital surveys of radar-meteors

Survey	No. of orbits	Year
Harvard I	19,327	1961–1965
Harvard II	19,698	1968–1969
Adelaide I	2092	1960–1961
Adelaide II	1667	1968–1969
Obninsk	9354	1967–1968
Kharkov	5327	1975

To bring the Hawkins model up to date, we have analysed the orbital data that is now available from the IAU Meteor Data Centre (IAUMDC) in Lund, Sweden (Lindblad, 1987, 1991). We use the data from six major surveys of the orbits of radar meteoroids. We realize from the outset that observational bias precludes any reliable esti-

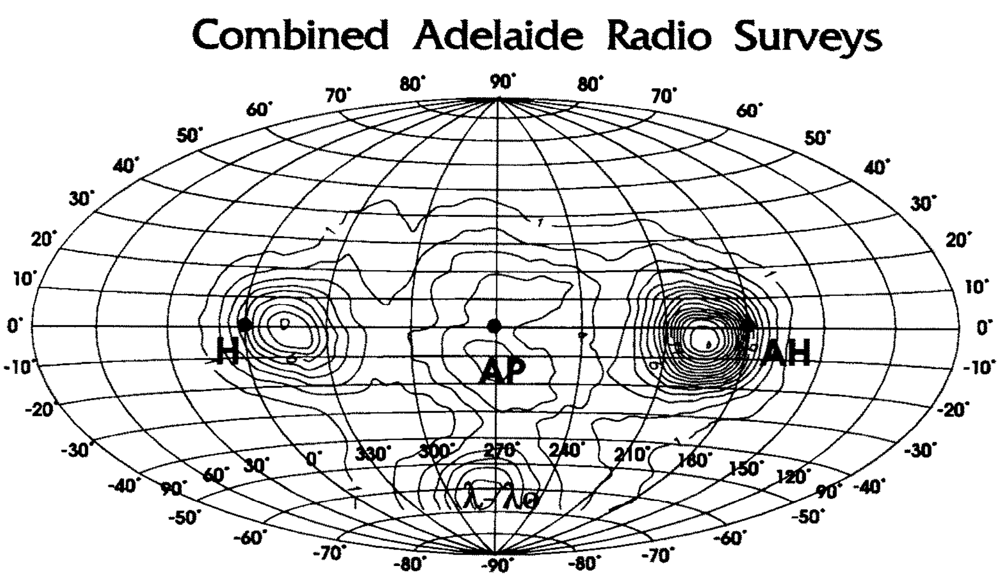

Fig. 2. Contours of apparent density of meteor radiants observed by the 1960–1961 and 1968–1969 Adelaide radiometeor orbital surveys

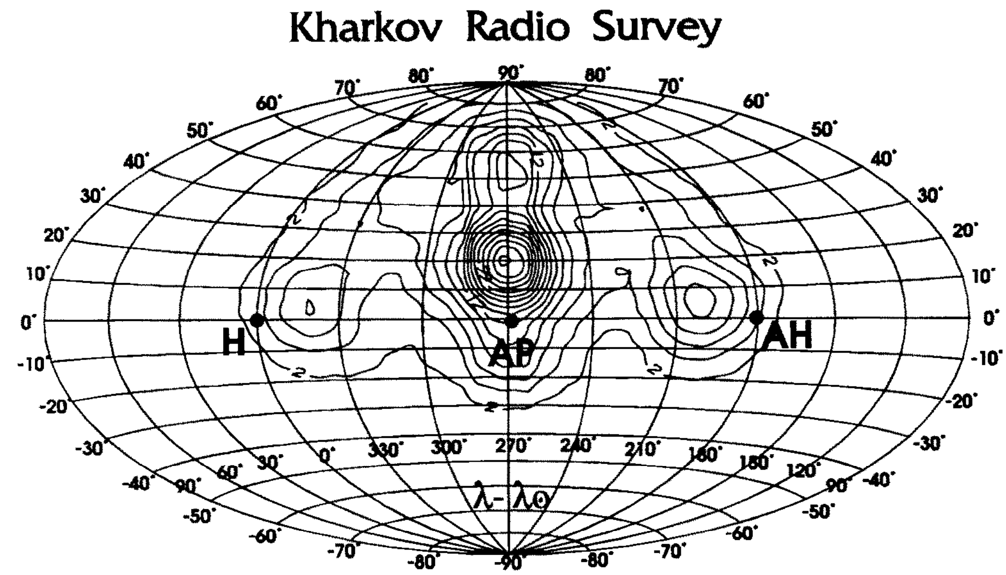

Fig. 3. Contours of apparent density of meteor radiants observed by the 1975 Kharkov radiometeor orbital survey

mate of source strengths at this stage, but we anticipate that our estimates of source location and size will not be grossly in error.

The data

The details of surveys used in the present analysis are listed in Table 1. The Harvard data are given by Sekanina (1973, 1976); the Adelaide data by Nilsson (1964) and Gartrell and Elford (1975); the Kharkov data by Kascheev and Tkachuk (1980) and the Obninsk data by Lebedinets *et al.* (1981, 1982).

Since the raw data contained in the above surveys includes meteors from all the major meteor streams, we tried to remove these as far as possible. To identify the stream members, we used Southworth and Hawkins' (1963) D-criterion which is a measure of the similarity of two orbits. A zero value for D corresponds to identical orbits. For each meteor shower we started by removing all orbits which had a value of less than 0.1 for D relative to the mean stream orbit and progressively increased the upper limit of D until the showers were no longer discernible from the sporadic background on the resulting radiant density contour plot. Typically this occurred for $D = 0.5$ and is comparable with, though slightly greater than, the value of 0.4 which is Porubcan's (1968) criterion for shower membership.

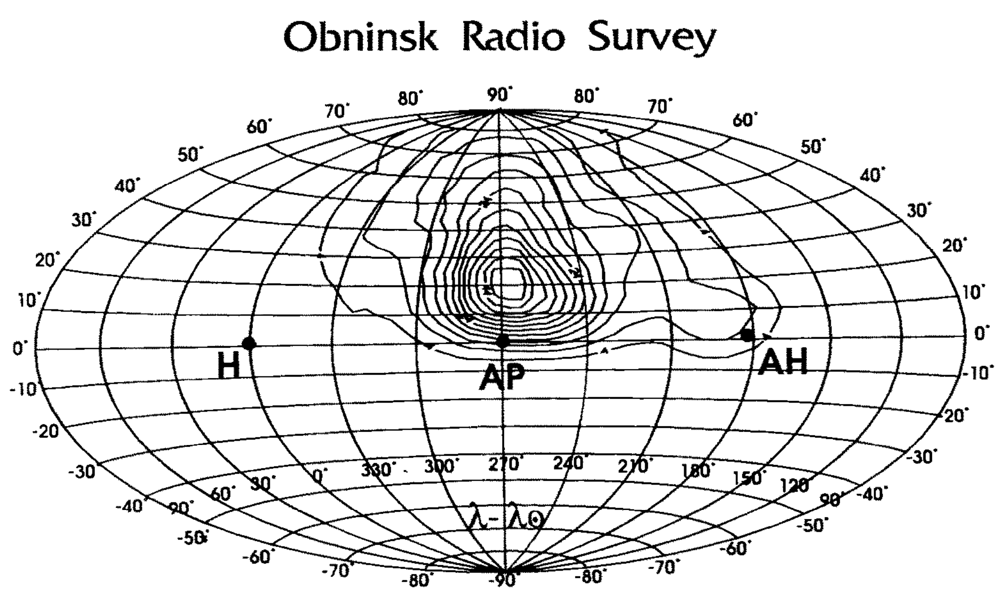

Fig. 4. Contours of apparent density of meteor radiants observed by the 1967 Obninsk radiometeor orbital survey

Table 2. Mean locations and widths of sporadic sources

Source	Long. (°)	Lat. (°)	Radius (°)
Antihelion	198	0	18
Helion	342	1	16
N. Toroidal	271	58	19
S. Toroidal	274	−60	16
N. Apex	271	19	21
S. Apex	273	−11	?

Results

Figures 1–4 show the results of our analysis as contour plots of radiant density on a Hammer–Aitoff equal-area projection in a system of coordinates in which the Apex of the Earth's way is at the centre. The axes are ecliptic latitude and longitude in the ecliptic plane reckoned from that of the Sun.

The radiant density contours were calculated by dividing the celestial sphere into $5° \times 5°$ squares and counting the number of meteor radiants in each of these squares. A two-dimensional running average was then calculated using adjacent matrix elements.

Several sources are immediately apparent from inspection of the radiant density plots—the familiar Helion, Antihelion, Apex and Northern Toroidal sources are easily recognized. However, the Apex source appears to be split into northern and southern components, and a Southern Toroidal source is clearly visible. The splitting of the Apex source has been previously reported by Elford and Hawkins (1964), but has not been widely acknowledged. The relative strengths of the sources differ widely, but this is only to be expected since the observational biases are strongly system dependent and the sheer volume of data precluded the acquisition of continuous observations. In spite of this there is a fair degree of consistency as to the location and width of the sources. The mean values of these are given in Table 2.

Acknowledgements. This work was funded by a grant from the Natural Sciences and Engineering Council of Canada. The authors gratefully acknowledge the thoughtful comments of Dr B. A. Lindblad and Dr W. G. Elford.

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