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Hyperbolic and interstellar meteors in the IAU MDC radar data

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Abstract. The radar meteor orbits of the most recent version of the IAU Meteor Data Center have been analysed and the hyperbolic orbits among them have been examined with the aim of to determining a real proportion of interstellar orbits in this database. It is shown from the tests that a large proportion of meteors with hyperbolic orbits is concentrated to the radiants of meteor showers and to the ecliptic plane. These belong to the orbits of typical interplanetary behaviour following annual and diurnal variation. In spite of this they highly increase a proportion of retrograde orbits. A vast majority of hyperbolic orbits, even for the highest measured velocities, may be considered as a consequence of measurement errors. We estimate that only a fraction of 10^{-3} of the total numbers of 39 145 Harvard radar data in the MDC could be ascribed to real interstellar meteors. It means that from the number of 970 hyperbolic orbits in the Harvard radar catalogues only about 5% can be recognized as interstellar.

Key words: meteors – meteoroids – hyperbolic – interstellar – radar meteor orbits

1. Introduction

The most recent version of the IAU Meteor Data Center (MDC) contains 4 581 photographic meteor orbits and 62 906 radar meteor orbits (Lindblad 2001, 2003; Lindblad et al. 2001, 2004). Among the photographic orbits there are 527 (11.5%) orbits hyperbolic. Radar orbits contain 1 875 (2.98%) hyperbolic orbits. The proportion of hyperbolic orbits (with excentricity $e > 1$) differs in different catalogues in MDC, but surprising is a much higher proportion of hyperbolic orbits in photographic data, generally qualified as much more precise than radar data. This contradiction should be explained by the comparison of results of the analysis of photographic and radar orbital data. Major surveys of both photographic and radar data have been compared by Steel (1996), where the distributions of orbital parameters, radiants and velocities can be found; however the hyperbolic orbits were out of scope of that analysis. The hyperbolic orbits of older photographic data have been analysed by Štohl (1971), showing the strong dependence of the proportion of hyperbolic orbits on the quality of

Table 1. IAU MDC radar meteor data (version 2003)

Project/Station	*No of orbits*	*No of hyperbolic orbits*	N_{hyp}/N_{all} *(%)*
Harvard 1961 - 1965 (Havana, USA)	19 327		
Harvard 1968 - 1969 (Havana, USA)	19 818	970	2.47
Obninsk 1967 - 1968 (Russia)	9 357	426	4.55
Kharkov 1975 (Russia)	5 317	145	2.73
Mogadisho 1969 - 1970 (Somali)	5 328	105	1.97
Adelaide 1960 - 1961 (Australia)	2 092		
Adelaide 1968 - 1969 (Australia)	1 667	229	6.09
All	62 906	1 875	2.98

observations. Also in the catalogue by Jacchia and Whipple (1961) (included in MDC) all the hyperbolic orbits belong to the lower quality data with a maximum error in velocity. More recently (Hajduková 1994), from a detailed analysis of hyperbolic orbits in IAU MDC photographic meteor data it was made clear that a vast majority of "hyperbolic orbits" in catalogues are a consequence of the dispersion of the determined geocentric velocities and radiant coordinates of meteors.

Many conclusions based on the highly hyperbolic orbits derived from radar observations are based mainly on the measured meteor velocities. These do not take into account the sensitivity of radar methods of the velocity determination (Hajduk 2001) and therefore they do not allow us to have much confidence to the derived results, especially those concerning interstellar sources of high velocity meteors.

The present paper analyses the radar meteor orbits in IAU MDC with a special emphasis on the 39 145 orbits of the Harvard Meteor Project, searching the characteristics of parameters of hyperbolic orbits and the reasons of their hyperbolicity.

2. IAU MDC radar meteor data and hyperbolic meteors

The data of the IAU MDC for radar meteors with the numbers of orbits in particular catalogues are shown in Tab.1.

We will undertake this rough material of meteor orbits to different astronomical approaches, which can either approve the true hyperbolicity of orbits, or show the sources of possible errors, causing the apparent hyperbolicity of them. These approaches are statistical; the individual cases, which remain outside the statistical approach, will be studied then separately. Our statistical approach will be concentrated on the generally different behaviour of samples of interplanetary orbits in comparison with the orbits of interstellar origin, following from the dynamics and orbital characteristics of particles entering the Earth.

2.1. The velocity distribution of data

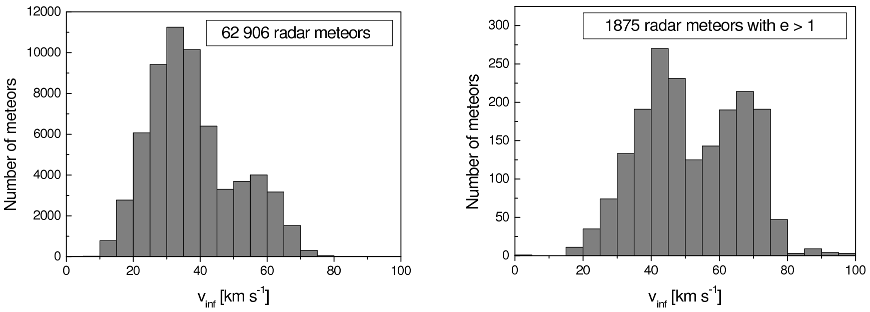

Figure 1. The velocity distribution of radar meteors from the MDC catalogues: all meteors and hyperbolic meteors ($e > 1$).

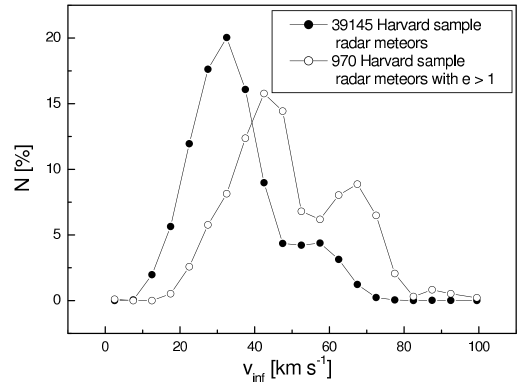

Figure 2. The velocity distribution (normalized to 100%) of all meteors and hyperbolic meteors ($e > 1$) for the Harvard sample of MDC.

The velocities of meteors given in the radar catalogues are no-atmosphere velocities v_{inf}, which are somewhat greater than the geocentric velocities, treated in photographic data. The heliocentric velocities v_H are not directly included in catalogues, as they can be calculated from the observational data. The velocity distribution of the whole material of 62 906 meteors and of the total of 1 875 hyperbolic meteors is shown in Fig. 1. The velocity distribution of meteors with the excentricity $e > 1$ in Fig. 1 follows exactly the distribution of all meteors, but they are shifted by about $10\,\mathrm{km\,s^{-1}}$ towards larger velocities along the whole scale.

It is very improbable that the interstellar component of the observed meteoroids moves through the solar system with the same distribution of velocities, but with the velocities of $10\,\mathrm{km\,s^{-1}}$ higher. We can also exclude the influence of different catalogues, as the same effect is shown in Fig. 2 for the Harvard 39 145 radar meteors and 970 hyperbolic meteors of the same sample, visualized here in the same proportion. The only logical explanation for the observed shift between both sets of data is that the hyperbolicity of the set of meteors with $e > 1$ is caused by a high spread in velocity determinations, shifting a part of the data through the parabolic limit. This is a very strong suggestion, as in calculations for meteor streams and associations from the Harvard catalogues (papers by Sekanina 1970, 1973 and 1976) the errors in v_{inf} are given within $1\,\mathrm{km.s^{-1}}$. However, the suggestion that the errors in the determination of v_{inf} from radar observations may be as large as $10\,\mathrm{km\,s^{-1}}$ should have some independent support. We have found it by the analysis of meteors belonging to the known meteor showers.

2.2. Annual variation of interplanetary and interstellar particles

It is generally known that the interplanetary meteors show an annual variation of the frequences of sporadic meteors, showing the maximum during July - September and minimum in March - May period for the Northern hemisphere sites. This was summarized also from the older radar observations by McKinley (1961) and recently by Schmude (1998). The Southern hemisphere observations, in contrary to some expectations, confirm the higher meteor rates in the second half of the year and the overhelming concentration of the interplanetary particles in the ecliptic plane (Poole 1995).

On the other side, there is no such reason for the variation of interstellar meteors, orbits of which are independent on the ecliptic plane and therefore they should not show annual variation similar to the interplanetary particles. If they will show it, it will mean that they behave as the interplanetary particles and, hence, they are subjects of errors, which shifted their parameters into the range of hyperbolic orbits. Fig. 3 shows the annual variation of radar meteor frequences in IAU MDC for the Northern hemisphere data with the observational site 90.02°W and 40.22°N for Havana. It is clear from Fig. 3 that statistically the orbits with $\mathrm{e} > 1$ follow the interplanetary distribution of all meteors with a negligible scatter in data. It means that a vast majority of orbits correspond to the orbital characteristics of the interplanetary particles and have been erroneously attributed to the hyperbolic orbits probably as a consequence of errors in the measured parameters.

From the comparison of monthly ratios for $N_{e>1}/N_{all}$ it is seen that they differ only slightly, not exceeding the normal scatter in the data (influenced also by the presence of meteor showers). Hence, from this test it follows that if

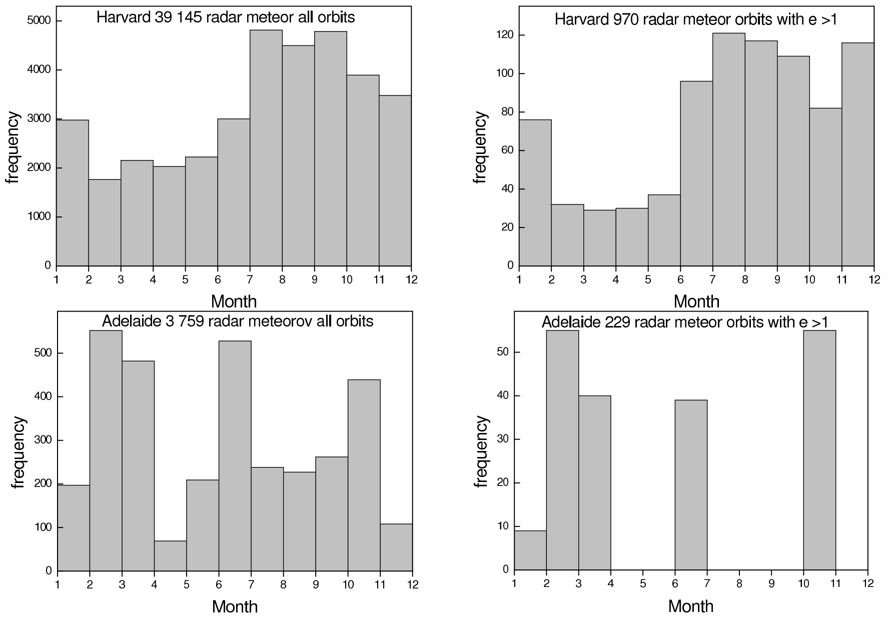

Figure 3. Annual variation of frequences for the Harvard and Adelaide radar meteors from IAU MDC shows that the orbits with $e > 1$ follow exactly the annual variation of all meteors. This means that statisticaly the orbits with $e > 1$ are not independent on the Earth's apex elevation.

there are some interstellar meteors among the orbits for which is a calculated $e > 1$, then the number of such cases is within the scatter of data. Also here it should be noted that the cases with the extreme values should be examined individually.

The Southern hemisphere data from Adelaide in the IAU MDC are, unfortunately, too scarce for the comparison (only 229 orbits with $e > 1$), however the annual variation of all meteors confirms the Grahamstown distribution of Poole (1995).

2.3. The diurnal variation of interplanetary and interstellar particles

The diurnal variation of frequences of all meteors and of meteors with $e > 1$ for the chosen samples as shown in Fig. 4, for Harvard and Adelaide material only, confirms the similarity of both variations. Samples with $e > 1$ follow the samples of all meteors belonging to the interplanetary matter. The ratios of $N_{e>1}/N_{all}$ in all four selected cases are within the scatter, corresponding to $\Delta N = N^{1/2}$. Scarcely it can be found a good reason why should the interstellar meteors follow

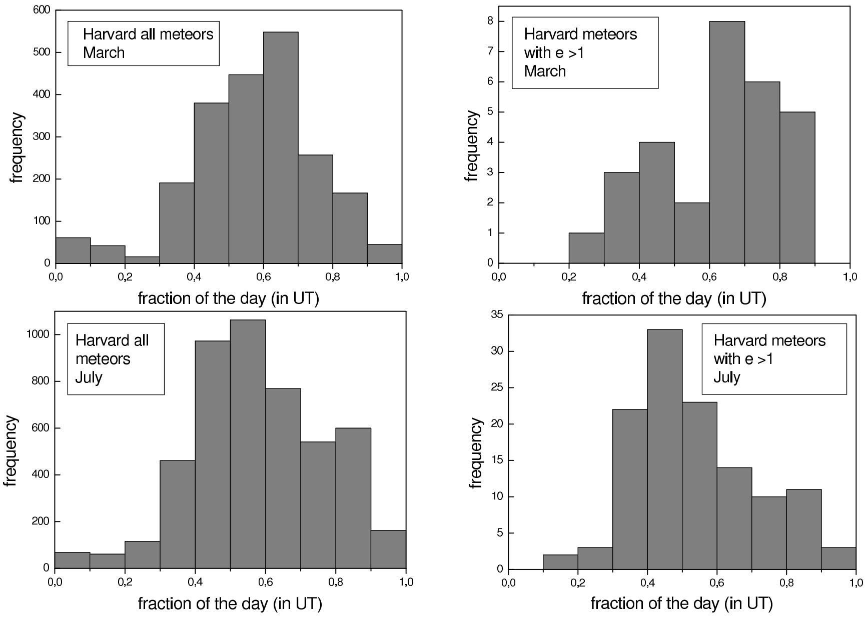

Figure 4. Diurnal variation of frequences for the Harvard radar meteors from IAU MDC shows a feature for the samples of all meteors as for meteors with e > 1.

the diurnal variations of the interplanetary ones. Hence, the conclusion of this test is the same as in the previous section.

2.4. Shower meteor data and hyperbolic orbits

In comparison with the photographic IAU MDC data containing many meteors belonging to the main meteor showers the radar programs of observations were chosen to avoid the main meteor shower periods. The stream search made by Sekanina (1970, 1973) for the Harvard radar program identified a great number of small streams and associations. Members of major showers are, because of elimination of central periods of showers, not so frequent, counted in tens of meteors, except for Geminids with about 300 members. The use of the parent comet orbit as a reference orbit for the associated meteor stream by Sekanina (1970) may cause serious problems for the identification of stream members by the D-criteria because of the evolution of orbits of particles released from the comet many revolutions ago and because of the evolution of the parent comet orbit itself. The orbital elements of stream members may differ considerably from the elements of the parent comet and may not meet the narrow limits of the D-criterion. This problem was analysed by Neslušan (2000) and led to

Table 2. Selected shower meteor data from IAU MDC Harvard radar program.

Shower	*No of meteors*	*No of hyp. meteors*	*Hyperbolic meteors (%)*	*geocentric velocity* v_G *(km s^{-1})*	$\Delta v = v_H - \sqrt{2}v_0$
Lyrids	17	1	5.9	47	-0.2
Perseids	26	6	23.1	59	-0.4
Orionids	39	6	15.4	67	-0.6
Leonids	17	1	5.9	71	-0.67
Eta Aquarids	26	2	7.7	66	-1.13

Table 3. Used values or intervals for the analysed shower data.

Shower	*Shower period*	$\alpha \pm \Delta\alpha$	$\delta \pm \Delta\delta$	$i \pm \Delta i$	$\Omega \pm \Delta\Omega$
Lyrids	17.4. - 26.4.	272 ± 10	33 ± 5	80 ± 10	32 ± 10
Perseids	23.7. - 27.8.	46 ± 15	58 ± 5	113 ± 10	139 ± 15
Orionids	2.10. - 31.10.	94 ± 10	16 ± 5	164 ± 10	208 ± 10
Leonids	14.11. - 17.11.	153 ± 10	22 ± 5	162 ± 10	235 ± 10
Eta Aquarids	29.4. - 15.5.	337 ± 10	−2 ± 5	164 ± 10	44 ± 10

the suggestion of a new, modified C-criterion taking into account the orbital evolution of bodies.

In the present analysis we will use the shower characteristics given by Ceplecha et al. (1998) in the same way, as they were applied to the search of IAU MDC photographic data for the same high velocity meteor showers (Hajduková 2002). A clear dependence of the contributions of hyperbolic meteor orbits on the mean heliocentric velocity of particular meteor showers has been found for photographic meteor data. Similar effect could be, therefore, expected also for the radar data.

Table 2 and Table 3 contain the selected shower meteor data from IAU MDC Harvard radar meteor program, found among 39 145 orbits. The other catalogues are even less represented by shower meteors, or some shower periods were entirely excluded from observations. A much smaller number of shower meteors in radar data has also another explanation. The shower meteors generally have a lower mass exponent, therefore they are more prominent in observations of larger particles, corresponding to the interval of visual and photographic magnitudes of meteors. Radar equipments used by observations included in the IAU MDC records much fainter meteors (up to 13^m) with a predominance of sporadic background over the shower meteors, the contribution of which, especially outside the shower maximum period (which is our case), remains much poorer in comparison with the sporadic background. But, if they are present, they are spread around the mean radiant and around the mean shower velocity, causing

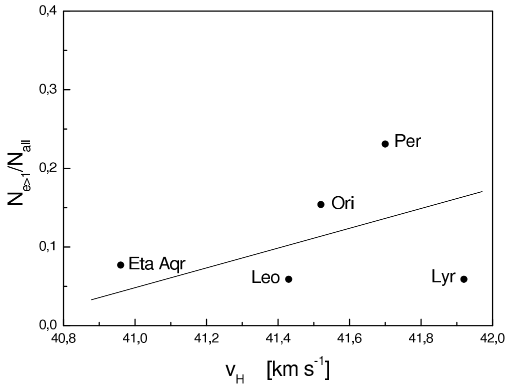

Figure 5. The dependence of the proportion of hyperbolic meteor orbits to all orbits ($N_{e>1}/N_{all}$) on the mean heliocentric velocity v_H of particular meteor showers in IAU MDC Harvard radar meteors.

errors in the determination of orbital elements and in some cases could cause an erroneous hyperbolic meteor. As it is seen from Tab. 2, there is a fairly large proportion of hyperbolic orbits among the meteor orbits fulfilling the criteria of belonging to meteor showers. A small number of cases of such orbits can be attributed to a chance; their occurence should be a consequence of errors in the measured parameters. The different precision of measurements, depending on the quality of observations, causes a natural spread in the velocity distribution or in the radiant position; the shape of this spread with a small number of members gives a scattered gaussian distribution, which in the vicinity of the parabolic limit of the velocity, as it is in cases of investigated showers, exceeds the difference Δv between the mean heliocentric velocity v_H of a particular shower and the parabolic limit $\sqrt{2}\, v_0$ (where v_0 is the mean orbital velocity of the Earth) resulting then as a "hyperbolic meteor". Fig. 5 shows the increasing number of such "hyperbolic" cases with the decreasing difference from the parabolic limit for a particular shower. The dependence for radar data in Fig. 5, due to much larger scatter, following from a much smaller number of cases, is less clear as it was obtained from much hugher photographic data (Hajduková 2002).

The conclusion of this test follows from the observation of "hyperbolic orbits" among the shower meteors and suggests that a similar effect of erroneously determined "hyperbolic orbits" should be ascribed also to the sporadic meteors, at least for those, the velocity of which are not too far from the hyperbolic limit. From the data in Tab. 2 and Fig. 5 we can estimate that about 20 percent of all radar orbits in the investigated MDC data excced the limits of $0.5\, km\, s^{-1}$ in the heliocentric velocity determination, causing erroneous hyperbolic orbits. Moreover, about 10 percent (or 15 percent, respectively) of cases exceed the

$1.0\,km\,s^{-1}$ error limit in Δv_H.

2.5. Interstellar meteors and the retrograde orbits

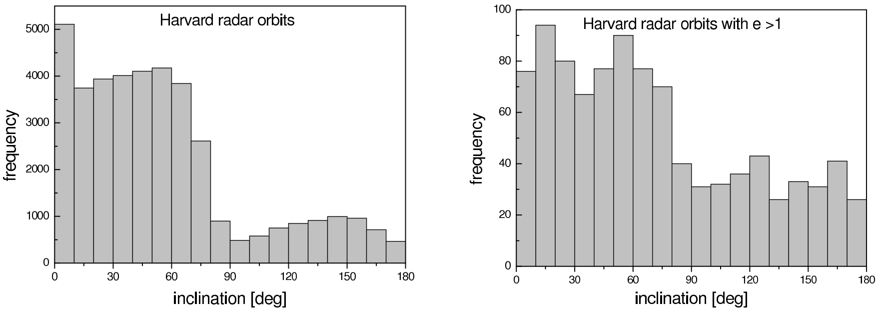

Figure 6. a, b, Inclination distribution of the IAU MDC Harvard samples of 39 145 radar meteor orbits and of 970 hyperbolic orbits. Orbits with $e > 1$ prefer 2.5 times the inclination $i > 90°$.

The study of the inclination distribution of radar meteor orbits in IAU MDC supports the arguments of the previous sections in favour of quasihyperbolic orbits present among the samples of meteors with $e > 1$.

Figures 6a, and 6b, show the inclination distribution of the Harvard sample of 39 145 meteors and of 970 hyperbolic orbits. From the comparison of both distributions it is obvious that the proportion of hyperbolic orbits is approximately 2.5 times higher for the retrograde orbits (with $i > 90°$) than for the prograde orbits. If the hyperbolic orbits would be of interstellar origin, the natural question is why should the interstellar particles so much prefer the retrograde orbits in comparison with the prograde ones. There is no logical answer to this question. Hence, the only explanation is that the errors in the measured velocities increase towards higher velocities, belonging to retrograde orbits, and so they increase the proportion of orbits with $e > 1$. It means that the number of hyperbolic orbits is at least 2.5 times less than it occurs from the data, apart from other errors.

2.6. Radiant positions of hyperbolic meteors

An argument supporting the presence of "hyperbolic orbits" within the shower meteor data is seen from the radiant positions of meteors with $e > 1$. Figure 7 depicts the radiant position of 970 hyperbolic orbits from the IAU MDC Harvard radar data in equatoreal coordinates α and δ. All concentrations of radiants, seen in Fig. 7, can be easily identified with the radiant positions of main meteor showers, (see Ceplecha et al. 1998 or our Tab. 3) in spite of the fact that the

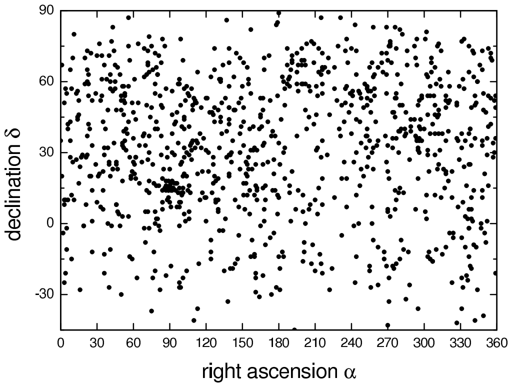

Figure 7. Radiant position of the IAU MDC Harvard sample of 970 meteors with $e > 1$ in equatoreal coordinates (α, δ). Concentrations to radiants of main meteor showers are clearly seen.

central periods of main meteor showers were excluded from the observations. (Much higher radiant concentration to the meteor shower positions was found in photographic IAU MDC hyperbolic orbits, where the shower periods were not excluded from the observational program (Hajduková 1994, 2002).)

The presence of orbits with $e > 1$ in radiant areas of meteor showers indicate also the overestimation of calculated velocities, leading then to the increase of the number of "hyperbolic" meteors and supports the conclusion from section 2.4.

2.7. Extreme hyperbolic velocities and interstellar meteors

As it was shown in previous sections, many hyperbolic orbits from radar observations can be a consequence of erroneous measurements mainly near the parabolic velocity limit of meteor velocity. The spread of errors leads to parameters crossing the parabolic limit. It could be expected that the gaussian distribution of errors should cut this production of pseudohyperbolic orbits at some reasonable value of meteor velocity.

In our analysis of the radar data we consider all meteors with heliocentric velocity $v_H > 46.6\, km\, s^{-1}$ as meteors on extremely hyperbolic orbits. Interstellar dust particles should have a velocity equal or higher than this value, which was calculated from the radial velocity distribution of the stars in the vicinity of the Sun (Hajduková 1994). Altogether there are 258 orbits in the catalogues with $v_H > 46.6\, km\, s^{-1}$. On the other hand, Lindblad et al. (2004) have shown (considering photographic orbits and calculating the deviations of the velocities according to the standard gauss distribution) that velocities exceeding $48\, km\, s^{-1}$ are not real and should be considered as incorrect. That is why we have restricted the interval of heliocentric velocities for searching pos-

Table 4. Abundance of the hyperbolic meteors in radar observations of the Harvard program IAU MDC.

Total number of radar meteors	$N=$ 39 145
Number of hyperbolic meteors	$N_{e>1}=$ 970
Number of extremely hyperbolic meteors with $v_H > 46.6\,km\,s^{-1}$	$N_{v_H>46}=$ 258
Abundance of hyperbolic meteors	$N_{e>1}/N$=2.5x10^{-2}
Extremely hyperbolic to hyperbolic meteors ratio	$N_{e>1,v_H>46}/N_{e>1}$=2.6x10^{-1}
Abundance of extremely hyperbolic meteors	$N_{e>1,v_H>46}/N$=6.5x10^{-3}
Abundance of possible ISM	N_{ISM}/N=1.4x10^{-3}

sible interstellar meteoroids to $(46.6 - 48)\,km\,s^{-1}$, though hypothetically every meteor having a non-zero hyperbolic excess could be treated as of interstellar origin. Table 4 gives an overview of possible interstellar meteors in the Harvard database. 58 extremely hyperbolic meteors in this database have the heliocentric velocity in the considered interval. In table 5 we summarize their orbital characteristics and hyperbolic excesses. The symbols denote: $\Delta v_H = v_H - v_p$ - the hyperbolic excess, q - perihelion distance, e - excentricity, i - inclination, ω - argument of perihelion, Ω - ascending node, α and δ equatoreal coordinates right ascension and declination of the radiant point of a meteoroid, v_{inf} and v_H velocities (non atmospheric and heliocentric), ε - elongation of the radiant point from the Earth's apex; The angular elements are referred to the 2000.0 equinox (Lindblad et al. 2001); *Date* - date in order day, month, year (two digits for each, year expressed by (19)xx).

From a statistical point of view we can conclude that the upper limit for the number of possible interstellar meteors does not exceed 6.5 x 10^{-3} (1.4 x 10^{-3} respectively) from a total of 39 145 meteors in the Harvard catalogues of IAU MDC. According to the tests described in this paper, it is clear that the number of interstellar meteors definitely does not reach 2.5% of all hyperbolic meteors ($e > 1$) in the database.

3. Conclusions

The analysis of the IAU MDC radar meteor data from the point of view of the occurence of interstellar meteors among the data shows that the orbits in catalogues recorded as hyperbolic, with $e > 1$, are subjects of the number of factors, as shown in sections 2.1 - 2.7, which may cause their hyperbolicity as a consequence of measurement errors. A large proportion of hyperbolic orbits among the known meteor showers, among the orbits of typical interplanetary behaviour, following the annual and diurnal variation, the highly increased rate of hyperbolic orbits among the retrograde orbits and among the orbits near the ecliptical plane suggest that statistically a vast majority of hyperbolic orbits in radar data are conequences of measurement errors. Even the extreme cases with velocities $v_H > 46.6\,km\,s^{-1}$ show only few cases to which the above mentioned

Table 5. Hyperbolic excess, orbital and geophysical parameters of meteors of possibly interstellar origin from radar Harvard catalogues of MDC.

N	Δv_H	q	e	i	ω	Ω	α	δ	v_{inf}	v_H	ε	*Date*
1	4.6	0.24	1.11	30.8	116.2	73.9	90	9	45.6	46.7	285.7	061261
2	5.4	0.83	1.45	169.6	223.3	255.0	153	17	76.4	47.5	344.0	071261
3	5.5	0.98	1.55	63.3	175.0	297.0	253	57	45.0	47.6	15.2	170162
4	4.7	0.94	1.44	51.7	155.1	339.6	298	54	38.9	46.8	80.6	280262
5	4.9	0.65	1.32	0.7	111.9	114.4	130	19	32.7	47.0	102.7	170762
6	4.5	0.77	1.35	40.0	126.0	156.8	185	50	37.1	46.7	91.9	300862
7	4.8	0.99	1.47	67.3	183.1	225.9	229	75	46.3	46.9	354.5	081162
8	4.7	0.66	1.31	43.0	64.9	85.8	91	-18	39.6	46.8	275.6	181262
9	3.6	0.96	1.44	63.9	197.8	325.4	236	58	44.8	46.7	317.8	150263
10	5.5	0.64	1.35	49.7	110.4	126.4	131	31	43.5	47.6	78.7	300763
11	4.6	0.89	1.41	35.6	146.2	236.7	261	33	32.7	46.7	109.3	191163
12	5.3	0.12	1.07	24.8	134.0	70.3	90	16	49.3	47.4	289.8	031263
13	4.6	0.63	1.29	67.7	108.6	84.2	34	61	48.5	46.7	61.8	150664
14	5.0	0.85	1.43	147.1	43.9	278.5	359	-21	72.3	47.1	342.2	300664
15	4.8	1.01	1.48	31.5	176.5	125.3	235	51	28.8	46.9	169.5	280764
16	5.1	0.65	1.33	94.6	112.8	169.0	139	58	58.2	47.2	42.6	110964
17	5.0	0.55	1.28	163.7	259.0	179.2	57	28	71.1	47.1	331.6	220964
18	5.5	0.96	1.53	2.2	196.2	233.7	347	0	21.4	47.6	204.4	161164
19	4.7	0.48	1.22	166.2	86.4	96.5	156	4	71.2	46.8	329.6	281264
20	4.6	0.96	1.44	147.5	203.7	126.0	17	28	73.0	46.7	350.5	290765
21	5.7	1.01	1.59	51.8	177.5	133.7	265	68	38.9	47.8	92.3	060865
22	4.6	1.00	1.46	106.1	10.7	313.7	50	-30	62.1	46.7	353.2	060865
23	4.8	0.31	1.15	34.5	287.3	139.2	328	7	44.3	47.0	283.4	120865
24	5.7	0.21	1.12	2.4	119.5	46.6	58	19	45.4	47.8	282.9	091165
25	4.6	0.89	1.41	128.1	33.4	54.8	124	-12	69.4	46.7	344.8	171165
26	4.7	0.68	1.32	47.7	242.5	251.2	72	68	40.9	46.8	279.2	031268
27	5.3	0.91	1.49	25.7	209.8	254.8	9	57	28.8	47.4	233.2	071268
28	5.2	0.96	1.51	154.2	165.6	293.0	212	4	76.6	47.4	5.3	130169
29	5.2	0.74	1.40	115.4	54.4	113.9	161	-29	65.8	47.4	331.6	140169
30	4.9	0.98	1.49	18.3	166.8	351.6	38	61	24.3	47.1	157.0	120369
31	5.0	0.84	1.42	38.9	223.0	3.3	202	48	35.6	47.1	260.7	240369
32	5.1	0.55	1.28	7.1	78.4	210.8	200	-16	35.6	47.2	263.9	210469
33	5.6	0.91	1.51	169.2	213.7	45.6	303	-14	76.2	47.7	346.7	060569
34	4.7	0.66	1.31	38.4	247.1	59.9	247	16	38.5	46.8	271.5	210569
35	4.5	1.00	1.45	47.0	192.6	76.0	259	57	36.0	46.6	251.7	070669
36	5.4	0.71	1.39	14.0	119.2	87.1	106	41	31.9	47.5	105.6	180669
37	5.0	0.41	1.21	16.8	275.2	99.0	283	-11	39.9	47.1	273.7	010769
38	4.8	1.01	1.48	107.2	190.4	112.5	351	47	62.8	46.9	353.1	150769
39	5.2	0.98	1.51	128.5	200.5	112.6	357	34	69.5	47.3	349.9	150769
40	4.6	0.40	1.19	58.5	96.5	304.8	342	-41	47.7	46.7	291.6	280769
41	4.7	0.40	1.18	116.3	97.0	304.9	3	-25	61.9	46.8	317.7	280769
42	4.6	1.01	1.46	103.5	190.4	124.9	359	54	61.3	46.7	352.9	280769
43	5.2	0.79	1.41	46.3	128.6	124.9	151	68	39.6	47.3	86.6	280769
44	4.8	1.01	1.48	123.6	187.1	125.9	14	45	68.1	46.9	356.3	290769
45	5.5	0.44	1.25	18.1	89.0	127.1	131	32	40.1	47.6	87.4	300769
46	5.1	0.93	1.48	6.1	210.1	128.5	262	-10	23.8	47.2	223.2	010869
47	5.9	1.01	1.60	170.4	182.7	138.4	43	23	77.5	48.0	358.9	110869
48	5.7	0.47	1.27	162.0	88.1	319.2	19	-1	70.0	47.8	327.7	120869
49	5.7	0.93	1.53	146.0	210.7	139.3	26	33	73.6	47.8	347.1	120869
50	5.7	0.75	1.43	22.6	124.4	155.1	184	30	33.2	47.8	105.2	280869
51	5.0	0.19	1.09	126.6	303.9	180.0	36	29	61.6	47.1	313.4	230969
52	4.7	0.91	1.43	90.3	212.7	192.8	56	75	56.5	46.8	333.1	061069
53	4.5	0.97	1.44	121.7	197.6	193.8	98	59	67.8	46.6	351.4	071069
54	5.1	0.95	1.49	47.1	158.0	196.1	239	55	37.1	47.2	97.2	091069
55	4.7	0.32	1.15	4.7	286.2	201.6	26	14	40.9	46.8	277.5	151069
56	5.5	0.94	1.52	98.2	24.6	28.8	98	-27	60.3	47.6	341.9	221069
57	5.2	0.80	1.42	141.5	228.7	208.7	102	44	71.8	47.3	340.0	221069
58	4.8	0.86	1.41	9.2	218.3	225.3	1	20	25.3	46.9	233.7	081169

factors could not be applied. However, they represent from the whole number of 39 145 Harvard radar catalogue a fraction of about 10^{-3} meteors as a proportion of possible interstellar meteors to the interplanetary ones. If it was accepted the value of 1 or 2 percent of interstellar meteors in radar observations, as proposed by the authors of catalogues, we should increase our estimate in this paper of more than $10 - 10^2$ times. This appears very improbable.

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