Meteor science

December σ-Virginids

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We studied the December σ-Virginids from the TV meteor observation network database in Japan (the "SonotaCo Network"). The December σ-Virginids are a minor annual meteor shower that has a broad peak around December 20 and about 40 days active duration. The visual maximum zenithal hourly rate (ZHR) is estimated at 1.5.

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1 Introduction

Greaves (2012) identified four meteor showers from the SonotaCo Network database. In our study presented here we have also found a new meteor shower individually. This shower is the same as one of Greaves' showers named the December σ-Virginids, 428 DSV at the IAU Meteor Data Center (MDC). Additionally, this shower may be the same as the unnamed meteor shower in (Molau 2007, Table 2, no. 82). In fact the radiant position at the shower maximum that we derive is closer to the stellar position τ Virginis than to σ Virginis, especially using the radiant and velocity selection method (Section 4 below). However, we use the name DSV for this meteor shower in order to be consistent with the existing IAU MDC name.

2 Observation data

We researched the database of the Japanese TV meteor observation network, the SonotaCo Network (SonotaCo, 2009), over five seasons from 2007 November to 2012 January. Many reliable orbit data can be used for statistical research. The duration we studied is from November 20 to January 20 each year. Observers use high sensitivity CCD cameras, typically such as Watec 100N or Watec 902h, equipped with lenses having focal length from 3.8 mm to 12 mm. The locations of observers are shown in Figure 1. All observers analysed detected meteors with UFOAnalyser V2 and after the analysis uploaded `csv` data files to the network site. We downloaded these data and calculated all available orbits using UFOOrbit V2. Details of observations and the network are described in (SonotaCo, 2009; Uehara et al., 2006).

3 December σ-Virginid meteors

We found unclear concentrated radiants in Virgo from meteor radiant mapping in 2011 December. Thus we reviewed the recent five years of meteor radiant and orbit data from each November 20 to January 20. The total numbers of meteor orbit data available each year are shown in the second column ("All meteors") of Table 1. We used two methods to identify the meteor shower among these data of all meteors.

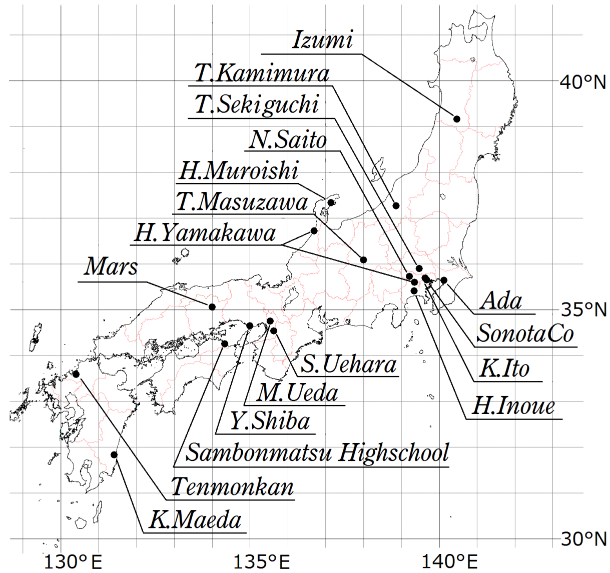

Figure 1 – Observers distribution

One is to use the D' criterion (Drummond, 1981). We selected meteor orbits with $D' < 0.105$ compared with estimated mean orbital elements. After this, we recalculated the mean radiant and geocentric velocity using the selected meteors only, thus obtaining corrected mean shower orbital elements. We continued by reselecting shower members related to the new corrected orbital elements, using the D' criterion. We repeated calculations until the results converged, leading to a selection of shower members with mean orbital elements. The second method is to use radiant position and meteor velocity. We selected meteors with radiants differing by less than 3° from the estimated mean radiant and velocity less than ±5% from the mean. From these

Table 1 – Meteor numbers in seasons investigated. December σ-Virginids selected by two methods (D' or radiant/velocity).

Season	All meteors	December σ-Virginids	
		D' criterion	radiant/ velocity
2007 Nov–2008 Jan	4093	19	26
2008 Nov–2009 Jan	4022	25	27
2009 Nov–2010 Jan	2883	12	27
2010 Nov–2011 Jan	7016	29	44
2011 Nov–2012 Jan	7377	49	46

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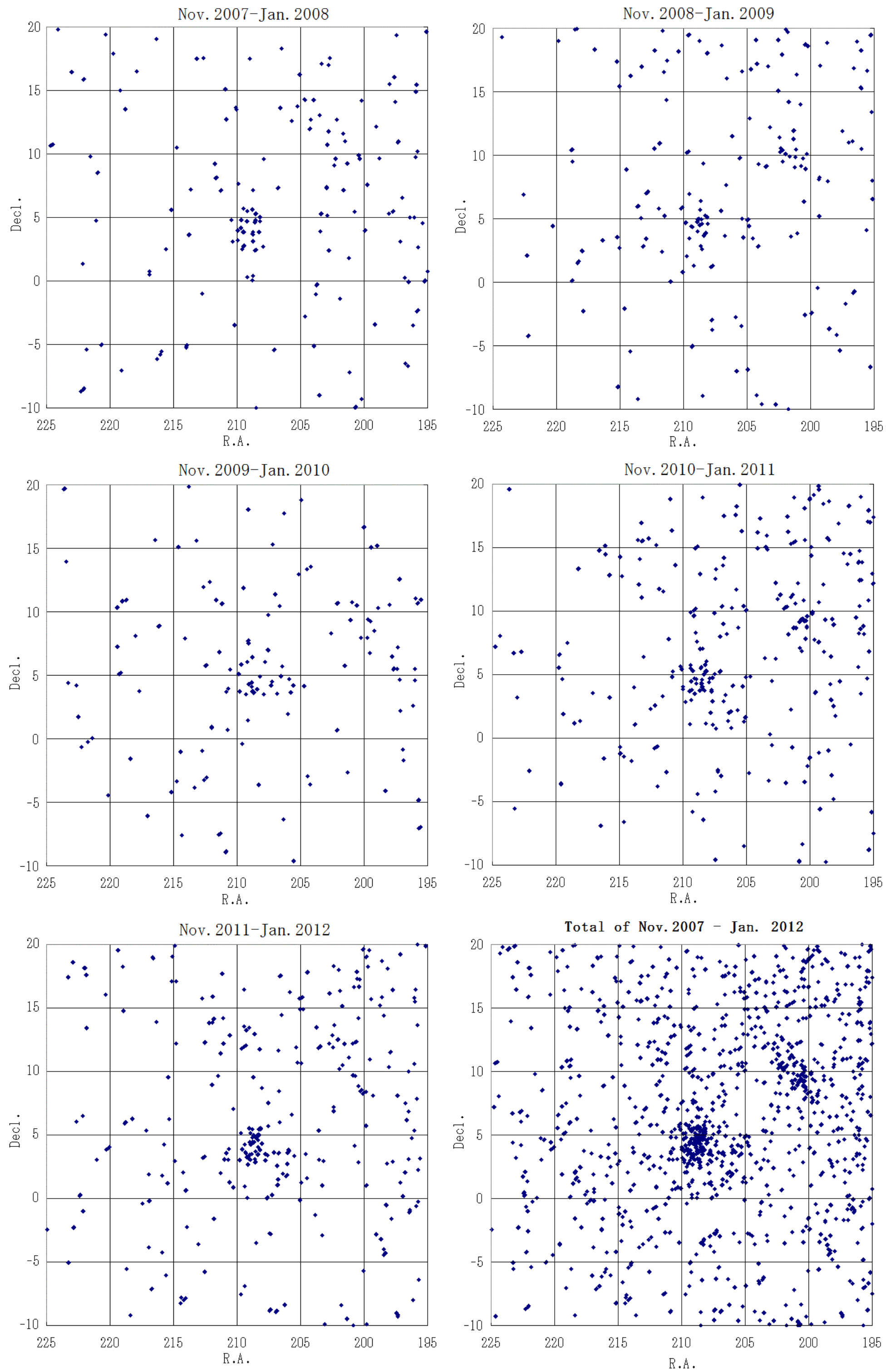

Figure 2 – Radiant distribution around December σ-Virginids in five seasons. Each radiant shifted to solar longitude $\lambda_\odot = 271\overset{\circ}{.}9$ by DSV radiant drift equation.

meteors a corrected mean radiant (with its drift) and velocity can be calculated. We repeated this until the results converged, yielding shower members and mean radiant, radiant drift and velocity. As a result, the numbers of DSV meteors are shown in the right two columns of Table 1.

4 December σ-Virginids properties

The mean radiant position obtained when meteors are selected by the D' criterion method is $\alpha = 206\overset{\circ}{.}30$, $\delta = +4\overset{\circ}{.}78$, $V_g = 66.63$ km s^{-1}, $\lambda_\odot = 269\overset{\circ}{.}307$ (J2000.0) where $\lambda_\odot$ is solar longitude. From this radiant, orbital elements are calculated and shown in Table 2.

Table 2 – December σ-Virginid orbital elements (J2000.0)

a [AU]	q [AU]	e	ω [°]	Ω [°]	i [°]	P [year]
23.54	0.619	0.974	104.42	269.31	149.89	114.2

Radiant position and radiant drift shown next are from the radiant and velocity selection method, while meteor velocity is constant with solar longitude.

$$\alpha = 208\overset{\circ}{.}73 + 0.819(\lambda_\odot - 271\overset{\circ}{.}90) \quad (1)$$

$$\delta = +4\overset{\circ}{.}36 - 0.198(\lambda_\odot - 271\overset{\circ}{.}90) \quad (2)$$

$$V_g = 66.40 \text{ km/s} \quad (3)$$

where $\lambda_\odot = 271\overset{\circ}{.}90$ is the mean solar longitude of selected meteors. Radiant plots are shown in Figure 2. The radiant positions are corrected for the radiant drift using equations (1) and (2) and are shown for the solar longitude $\lambda_\odot = 271\overset{\circ}{.}90$. Figure 2 clearly shows radiant concentrations at the common position every year.

The number of December σ-Virginids versus solar longitude is shown in Figure 3. Meteor numbers are binned in 1° intervals of $\lambda_\odot$. The left column of a pair is D' criterion results, right is radiant and velocity selection results. The active season begins on December 1 and ends on January 10. Maximum is several days around December 20. We compared with the number of σ-Hydrid (16 HYD) meteors recorded. The number ratios of recorded meteors (DSV to HYD) are about 1/7, for the peak value about 1/10.

The magnitude distribution is shown in Figure 4 in bins of 0.5 mag. In this Figure, left is also D' criterion results, right is radiant and velocity selection results. The population index γ was calculated from the magnitude distribution of meteors from −4.5 to −2 mag:

$$\gamma = 3.1 \quad (D' \text{ criterion}) \quad (4)$$

$$\gamma = 3.2 \quad (\text{radiant and velocity selection}) \quad (5)$$

The σ-Hydrid population index was $\gamma = 2.6$ (from −5 to −2.5 magnitude) for radiant and velocity selection.

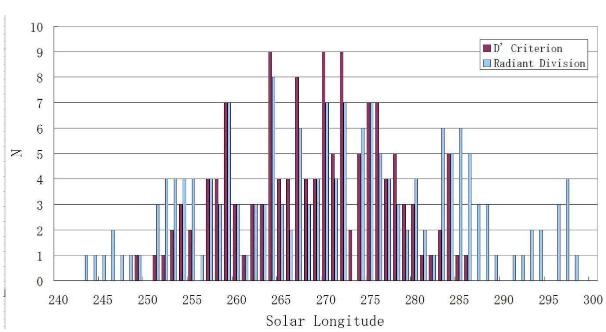

Figure 3 – Recorded numbers of December σ-Virginid meteors.

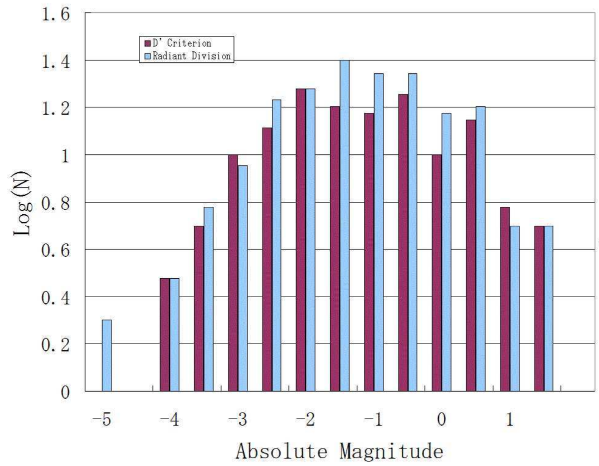

Figure 4 – Magnitude distribution.

5 Discussion

We estimate the visually observable number of December σ-Virginids as a ZHR (zenithal hourly rate), by comparison with σ-Hydrids. These two meteor showers are good for comparison because they have common features, namely a long and overlapped active duration, broad maximum and high velocity. Firstly, the observable time for DSV on one night is about half that for HYD and additionally the radiant elevation for DSV is low. As a result of this, DSV are 2.8 times as difficult to observe (in terms of number of meteors that can be seen) as HYD. Secondly, the effect of the difference in population index γ is considered: $\gamma = 3.1$ or 3.2 for DSV and $\gamma = 2.6$ for HYD. Visual observations generally allow meteors 3–4 mag fainter to be recorded than TV observations. This reason means that the number of December σ-Virginids relative to σ-Hydrids will be increased by a factor of 1.7 times when we extrapolate from TV observation to visual observation. Combining these two effects, and from the relative numbers (DSV to HYD) of *recorded* meteors (Section 4), the ratio of the ZHRs of the two showers is about $1/10 \times 2.8 \times 1.7 = 1/2$. IMO's "Handbook for Meteor Observers" (Rendtel & Arlt, 2011) gives a ZHR of 3 for σ-Hydrids. As a result, we estimate the December σ-Virginid ZHR for visual observation is about 1.5 at its maximum.

The DSV argument of perihelion is about 100 degrees. The shower's long observable duration suggests a dispersed meteor stream orbit. These two features suggest that the meteor stream orbit comes close to Earth's orbit not only at the descending node where it was identified as the December σ-Virginids but also at the ascending node. The "Q-adjustment method" of (Hasegawa, 1990) was applied and a twin-shower radiant was predicted: $\alpha = 319\overset{\circ}{.}0$, $\delta = -29\overset{\circ}{.}7$, $V_g = 65.4$ km/s, $\lambda_\odot = 66\overset{\circ}{.}6$. We analysed recorded meteor orbits in the same database from May 1 to July 15 to detect similar orbits as December σ-Virginids. We find three small D' criterion meteor orbits that have $D' < 0.105$. These were observed individually at 2009 June 25 ($D' = 0.064$), 2010 June 12 ($D' = 0.052$), 2010 June 21 ($D' = 0.0736$). Because these meteors were not concentrated together, we estimate that they are not shower members but instead are sporadic meteors. However, during the predicted season for this twin shower, the night-time is short and the rainy season occurs in Japan. Moreover, the radiant elevation is very low from the northern hemisphere. This negative result is therefore possible because of the unfavorable observing conditions. The research must be concluded by means of a large quantity of orbit data from southern hemisphere observations.

In Figure 2, you can find a concentrated radiant at $\alpha = 201°$, $\delta = +9°$ in some years. We find rather many radiants at December 6 and for a few days around then, at $\alpha = 185°$, $\delta = +13°$. Future accumulation of observational data will make sure whether a meteor shower exists or not. The SonotaCo Network database will be an outstanding data source for such new meteor shower detection. New features even in well known meteor showers will also be found with SonotaCo Network data.

Acknowledgments

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