# Meteor shower analysis using a Hausdorff metrization function

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**Introduction:** Since 2009 orbital data of about 120,000 meteors have been collected using a novel head-echo analysis algorithm for the lower VHF band [1]. The data was collected using the middle and upper atmosphere radar (MU radar) of Kyoto University at Shigaraki. We now perform a shower-association analysis of the database [2] using a new Hausdorff metrization function $d_H$ [5] and compare the results with an analysis using two D-criterion's $D_{SH}$ [3] and $D_N$ [4]. The D criterion is based on a sum of weighted differences between the orbits' dependent variables. There are, however, no indications that these satisfies the metric requirements and some of the weight functions have no direct physical explanation. Since the spaces representing elliptic orbits cannot carry a norm compatible with their standard topology [6] we choose to develop the new Hausdorff-based metrization that acts on the subsets in three-dimensional space representing the trajectories. These calculated distances are then used, together with statistical simulations, to perform a cluster analysis of the set of data. In all cases we use the same type of cluster analysis, using a critical threshold for association, but with a different distance function as a basis. The results are also compared to IAU Meteor Data Center's shower list to examine if some of the listed showers can be repeated and perhaps improved upon.

**Discussion:** The statistical analysis of the new Hausdorff metrization function exhibit interesting properties. A Monte Carlo simulation of false association, where we generate a pseudo-random set of orbits, calculate the distances with the three different distance functions and then perform a series of cluster analysis with different critical thresholds, shows that the Hausdorff based function is linear in its false association while the D-criterions generate a convex curve [4]. Another interesting feature of the Hausdorff distance function is that the metrization is the same regardless of the examined problem. All physical modeling is used only to create the corresponding subsets in three dimensions for the examined objects, which is often not a problem. In the case of phase-space functions, if one tries to introduce physics beyond a static Kepler trajectory, the phase-space becomes complicated and much harder to work with and some times one cannot even create an appropriate space in which the points are static. The downside is that the speed of the algorithm is very slow compared to a phase-space function. There is, however, a possibility that due to the different properties of the Hausdorff distance one can find a mathematical prediction for the critical thresholds. This would remove the need for Monte Carlo simulations, thereby greatly reducing computing time.

**References:** [1] Kero J., Szasz C., Nakamura T., Terasawa T., Miyamoto H., Nishimura K., A meteor head echo analysis algorithm for the lower VHF band, *Ann. Geophys., 30, 639. (2012)*; [2] Kero, J., Szasz, C., Nakamura, T., Meisel, D. D., Ueda, M., Fujiwara, Y., Terasawa, T., Nishimura, K. and Watanabe, J., The 2009–2010 MU radar head echo observation programme for sporadic and shower meteors: radiant densities and diurnal rates. *Monthly Notices of the Royal Astronomical Society, 425: 135–146. doi: 10.1111/j.1365-2966.2012.21407.x (2012)*; [3] Hawkins G. Southworth, R. Statistics of meteor streams. *Smithson. Contrib. Astrophys. 7, 261285, (1963)*; [4] Valsecchi, G.B., Jopek T.J., Froeschl Cl. Meteoroid stream identification: a new approach. I. Theory. *Mon. Notic. Roy. Astron. Soc. 304(4), 743750, (1999)*; [5] D. Kastinen. Metrization of trajectories. *(2014)*; [6] D. Todorov. Non-normability of spaces of Keplerian orbits. *ArXiv e-prints, October (2012).*