A SPATIAL HEAT MAP FOR THE 7 NOVEMBER 2020 IRON METEORITE FALL

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Introduction: The dark flight Monte Carlo model (DFMC) can be used to test if a fireball produces meteorites [1]. The output of DFMC is a map of the area where the meteorite strewn field is most probably located [1]. By applying Bayesian propabilities for different variables the model simulates trajectories of all individual fragments. Morever, by adopting at the start point a value of maximum possible mass implied by the fireball deceleration, the simulation produces a realistic number and total cumulative mass of meteorites landed on the ground.

Methods: In some cases only a few simulated fragments survive down to the ground. Usually this occurs when incoming body is small yet conditions for meteorite productions are favorable [2, 3]. A default DFMC output and/or parameters can also be adjusted, e.g. in the cases where practical search suggests not many meteorites are 'recoverable'on the ground. In these cases a single simulation does not necessarily show the full extent of the strewn field. This problem can be avoided by running multiple simulations into one 'burn' result instead of one DFMC simulation program. Such burn simulation usually reflects well the actual strewn field. If the simulation has hundreds of data points also spatial heat maps can be produced. Heat maps show mass or density distribution per surface area inside the predicted strewn field. That makes heat maps very informative and greatly aid meteorite recovery efforts.

Swedish iron meteorite fall: A bright fireball over Sweden was observed from Finland, Norway and Denmark on 7 November 2020 at 21:17 UTC. The fireball was seen as far as 720 km away. Fireball cameras in Sweden were under clouds. The closest fireball camera capturing the event was situated over 300 km away in Norway. Private surveillance cameras near the fall site registered the light and following sonic booms. Sonic booms were also registered by several seismic stations. Within short time multiple searches for meteorites begun in the Ådalen area. To the best of our knowledge, despite considerable search in the area, only one 13.8 kg meteorite fragment was found in the beginning of December 2020. The 30 cm long quite flat iron piece sculptured by regmaglyps is on loan to the Swedish Museum of Natural History and is not yet listed in the Meteoritical Bulletin Database due to ownership issues.

Results: Known strewn fields show that productive iron meteorite falls form narrower strewn field compared to more common stony meteorites [1]. However, lack of meteorites found from the Swedish fall does not suggest that it was a productive fall. According to sonic recordings of the nearby private surveillance camera there were at least 3 strong (out of 8 distinct) sonic booms suggesting at least 3 good sized individual fragments. To provide insight where those fragments may have landed we produce two DFMC heat maps. For DFMC input we use trajectory parameters obtained by Esko Lyytinen [4]. Result of burn DFMC simulation can be seen in Figure 1. We do not fix this simulation in geographical coordinates similar to [1] since the aim of this presentation is to exemplify the difference between density and mass distribution per surface area heat maps made from DFMC simulations. This is a benchmark case showing how irons behave in the atmosphere since this is the first instrumentally documented fall of an iron meteorite and first iron meteorite with known heliocentric orbit. With the terminal altitude of ~11.4 km this is the deepest recorded atmospheric penetration of a fireball so far.

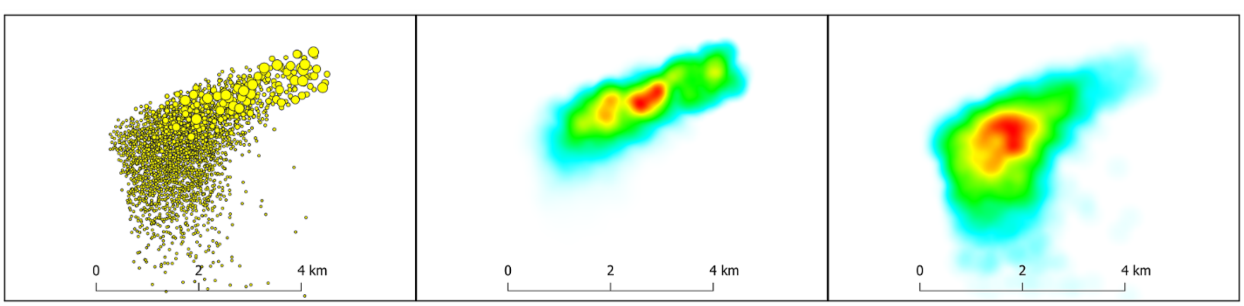

Figure 1. Three different visualization of the same DFMC simulation. On the left a full fragment cloud (10x more fragments). In the middle is a heat map of mass and on the right density of fragments.

References: [1] Moilanen J. et al. (2021) *Monthly Notices of the Royal Astronomical Society*, 503:3, 3337-3350. [2] Gritsevich M. I. et al. (2012) *Cosmic Research* 50(1):56–64. [3] Sansom E. et al. (2019) *The Astrophysical Journal* 885:115-121. [4] Esko Lyytinen (November 2020), personal communications.