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The size distribution of Jupiter Family comets

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Abstract

We present an updated size distribution for the nuclei of Jupiter Family comets (JFCs), based on observation of nuclei at large heliocentric distance. The data set used includes our own recently published work and that of others published since the comprehensive review by Lamy et al. [1], in addition to older measurements from the literature that were included in that compilation.

We apply a new approach to make a rigourous assessment of the uncertainty on the size distribution gradient, taking into account all unknown factors and sources of uncertainty. We include:

- The uncertainty on the original photometry.
- The difference between the measured effective radius from snap-shots and the mean effective radius, for observations at unknown rotational phase of a nucleus with unknown pole orientation and axial ratio.
- The unknown Solar phase function.
- The unknown albedo.

To do this we briefly review the current knowledge of the distribution of JFC shapes, albedos and phase functions. We use a Monte Carlo technique to look at how the size distribution changes when allowing individual size measurements to vary due to these uncertainties.

First, we produce a catalogue with the magnitude and uncertainty from the 'best' observation of each comet. From this we generate a size for each by generating a shape, phase function and albedo from within suitable distributions, and fit a cumulative size distribution (CSD) to the resulting sizes. We repeat this many times to allow the size of each comet to vary within all the possible values that match the photometry, and measure the average CSD slope and the uncertainty on this average. This gives us a rigourous assessment of the uncertainty on the CSD slope including all measurement and assumption uncertainties.

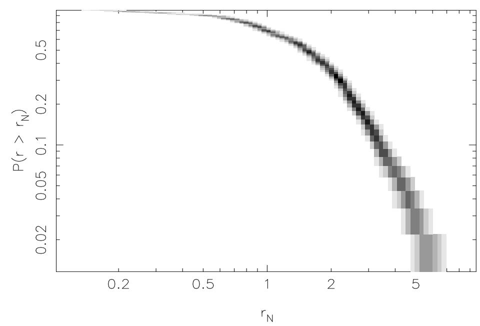

Figure 1: Probability map for the M-C run that gives our final result by allowing all parameters to vary. The shading shows the average shape of the 10,000 CSDs: darker areas are the bins where the majority of CSDs passed through, lighter areas show the outlying areas explored at the ends of the distributions.

We test the contribution to the CSD slope uncertainty from each source by varying each parameter separately and holding others fixed at assumed values. The largest variation is found by letting the albedo vary. This is mostly due to the very shallow slope that results from any albedo distribution that includes exceptionally dark ($A_R \approx 0$) nuclei, which are unlikely to be realistic. In any case, this demonstrates the importance of better constraining the albedo distribution of comets, an important result that the SEPPCoN survey will provide [2]. The only other M-C runs with a large difference from the reference CSD are the extreme shape distributions, which are also unlikely to represent reality. We can conclude from this that the uncertainty on the input parameter distributions actually has only a small effect, as the variation in slopes always falls within the typical uncertainty found when varying a single parameter at a time. We also find the optimum cut-off radius for each CSD: All comet CSDs have a 'knee' below which the slope changes due to observational incompleteness or a genuine lack of small comets. We fit slopes on either side of the knee and use a χ^2 minimisation procedure to find the best value for the cut-off between these slopes.

Finally, we obtain our best estimate of the CSD slope, and a rigourous assessment of the uncertainty on this slope, by allowing all parameters to vary at once. We use the latest observed distributions of shape, albedo and phase function to define the ranges for these parameters, so we ensure that we explore all realistic values. This gives an average CSD gradient $q = 1.92 \pm 0.20$ for nuclei with a radius ≥ 1.25 km.

References

[1] Lamy P. L., Toth I., Fernandez Y. R., Weaver H. A., 2004, in Comets II, Festou M. C., Keller H. U., Weaver H. A., eds., University of Arizona Press, pp. 223–264

[2] Lowry S. C., Fernandez, Y., et al, 2010, This conference.