# THE CIS METHOD: A PROPOSED STANDARDISED PROTOCOL FOR MEASURING AND REPORTING SIZES OF CHONDRULES AND OTHER CHONDRITIC OBJECTS

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Introduction: The methodologies used to report the sizes of chondrules and other objects in chondritic meteorites vary between studies [1-5], and in many cases methods are not fully descibed. The variation and the lack of detail in some studies makes comparison of object sizes between samples, both inter- and intra- meteorite class difficult. Here we propose a simple, standardized method for measuring and reporting the sizes of chondrules and other objects (e.g. CAIs) in 2D, in an attempt to facilitate improved comparison of object sizes between chondritic samples. Whilst 2D measurements provide only an apparent size, the current lack of sufficiently high resolution 3D data sets (for example from X-ray computed tomography), and the complexity of 2D-3D true size corrections justifies the use of a uncomplicated, standardised 2D approach for straightforward chondrite descriptions and comparisons.

2D Measurement Method: The methodology set out here, and hereafter referred to as CIS (**C**hondrule **I**mage **S**egmentation), can be carried out on image mosaics collected via scanning electron microscopy and conventional transmitted/reflected light microscopy. The steps are outlined in Figure 1 and involve chondrules (or other objects) being identified based on clearly defined criteria. Objects truncated by fractures or the edge of the sample should be excluded as their whole shape/size is unknown. Identified objects should be segmented using an image processing package, our preference is the free software: GNU Image Manipulation Program - GIMP. Segmented chondrules should then be fitted with best-fit ellipses to smooth perimeter irregualrities and produce clearly defineable long and short axes, which can subsequently be measured based off the resolution of the image (μm/pixel). Ellipse fitting and axes measurement can be undertaken in image analysis software, such as ImageJ, under the 'Analyse Particles' function.
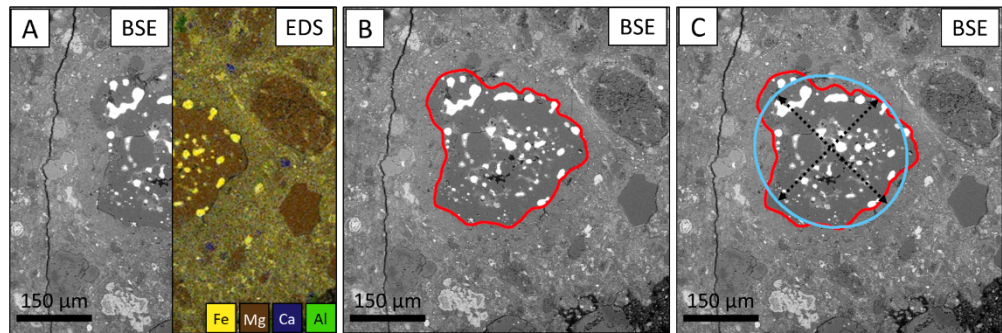
Figure 1. Schematic of steps involved in CIS method (831 pixels/μm). A) Chondrule identification B) Chondrule segmentation in GIMP software C) Ellipse fitting and axes measurement in ImageJ software.

Analysis and Reporting: Object sizes should be described by long and short axes measurements and as already suggested by [6] reporting of raw size data for all measured objects within chondrites should encouraged to allow greater comparison between samples and allow other object dimensions (e.g. aspect ratio) to be taken into account. Additionally, as the resolution of a given image mosaic impacts on the identification of objects, a statement regarding the image resolution is required. With regards to reporting chondrule size statistics, data should not be considered normally distributed [6], and is typically positively skewed. Reporting statistics (e.g. averages, medians and standard deviations) based on the assumption of a normal distribution can lead to mis-interpretation. The precise size-frequency distribution of chondrules is the subject of significant scientific debate [7]. However, for simplicity the sedimentological function Phi (φ), described by the equation: $\varphi = -\log_2 d$, can be used to approximately describe the data prior to statistics being calculated. Statistics and values reported should be given in both Phi units and a metric equivalent (e.g. 1.723 φ; 303 μm) for ease of comparison and understanding within the community. Phi (φ) has been used previously in studiess of chondrule size by [8-9].

Conclusion: It is hoped that the CIS method described here provides a simple approach to chondrule and chondritic object size measurements which can lead to improved consistency in reporting and better facilitate size comparisons between chondritic samples.

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