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A path to planets: youngest known ringed structures in a protostellar disk

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Abstract:
Circumstellar disks are fundamental to the low-mass star and planet formation processes, yet their properties are only beginning to be unveiled in detail during the earliest Class 0 and I phases due to the dense gas and dust envelopes present at early times. ALMA observations of the older Class II protostar HL Tau exposed dark gaps and dust rings in the disk, sparking the question: can ringed substructures already be found in younger Class I disks? To determine how early ringed structures occur, we targeted the disk of the Class I protostar IRS 63 with ALMA. Since only ~14 confirmed rotationally supported disks in the young Class 0/I phases are known, previous observations with the SMA were vital in the selection of IRS 63 as a target source. Not only is it a relatively bright Class I protostar, SMA molecular line data showed rotational signatures consistent with a moderately-inclined, rotationally-supported disk with a relatively large (~160 au) radius making it an ide al target for disk substructure studies. We have used ALMA 1.3 mm long-baseline dust continuum observations to study the Class I disk IRS 63 with 7 au resolution and expose the detailed physical structure of a Class I disk. The ALMA data indicate that concentric dust rings are present in the disk, revealing IRS 63 is the youngest-known protostellar disk with ringed dust substructures and demonstrating that these features are already present in the Class I phase. The dust ring structures could arise via several mechanisms including rapid pebble growth near snowlines, magnetorotational instabilities, or planet-disk interactions carving gaps in the disk. Even if planets have not yet formed, dust rings in disks at such an early evolutionary stage could provide a stable environment for long enough time scales to grow planets, and the ringed disk of the Class I protostar IRS 63 is the earliest evidence for these planetary cradles.

Presenter: Dr SEGURA-COX, Dominique

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