Contribution ID: **25** Type: **not specified**

The critical role of cooling in shaping circumbinary disk cavities: hydrodynamics and observational comparisons

Wednesday 27 August 2025 16:10 (20 minutes)

Multiwavelength and time-variable observations of circumbinary disks and their inner cavities have been made possible thanks to recent advancements in interferometry with ALMA and the VLTI instruments. These disks show large, eccentric cavities whose properties depend on the disk's aspect ratio, viscosity, binary eccentricity and mass ratio. Recent studies show that radiative cooling significantly affects the shape and size of gaps/cavities created by planets. We study the role of different thermodynamical models—locally isothermal, radiatively cooled, and parameterized β-cooling—on the cavity properties of circumbinary disks using 2D hydrodynamical simulations for varying binary eccentricities, and over very long timescales. While radiative and locally isothermal models yield comparable cavity shapes, the inner disk structure and precession rates differ. With β-cooled models, the shape and size of the cavity changes dramatically towards values of $\beta = 1$. We propose a parameterized β model that captures the shorter cooling timescales within the cavity, closely reproducing radiative model results, emphasizing the importance of accurate thermodynamic treatment. Additionally, new GRAVITY and PIONIER reductions for HD 45677, combined with Brγ imaging, reveal orbital motion of a dusty feature and high-velocity deviations indicative of a potential secondary companion. Our hydrodynamical models and mock observations constrain the cavity temperature and place an upper limit on the binary mass ratio, offering insights into the system's dynamics.

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Session Classification: Planet formation and stability in multiple systems