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Dust and gas surface density distribution in protoplanetary disks with ALMA

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Abstract

ALMA is revolutionising our view of planet formation. The high angular resolution campaigns are revealing that disks are highly sub-structured with the dust particles concentrated often in concentric rings, suggesting the presence of (proto-)planets on very short time scale (Andrews *et al.* 2018). On the other hand, ALMA unprecedented sensitivity offers a unique possibility to detect the weak signal of various molecular species, allowing us to determine the chemical composition of the disk interior. I will review some recent highlights regarding the surface density profile of dust and gas obtained with ALMA.

1 Introduction

Despite the remarkable number of exoplanet discoveries, we still know very little about the exoplanet population at large radii (a few tens of au). Direct imaging has revealed the existence of giant planets ($>$ a few $M_{\rm Jupiter}$) on wide orbits ($>50\,$au) around several stars. The technique has been particularly successful around A-type stars, with several high-profile discoveries (e.g., HR 8799: Marois 2008; beta Pictoris: Lagrange 2010; Fomalhaut, Kalas 2010, HD 95086, Rameau 2013); in fact, almost all the directly imaged companions in the planetary mass regime are around A stars (Bowler 2016). The statistic is currently biased towards the more massive planets as these are easier to detect and the occurrence of planets on wide orbits is likely underestimated. This planet population is of particular relevance because it challenges our planet formation models: at such large distances from the star, the standard *core-accretion* model (e.g., Pollack et al. 1996) fails to form the rocky core ($\gtrsim 5-10\,M_{\rm Earth}$) needed to initialise the runaway growth that leads to the formation of a giant planet, mostly because of the long timescales involved. Observations of the dust and gas distribution in protoplanetary with ALMA give us precious insights on the physical conditions and chemical composition during the early stages of planet formation and evolution.

2 ALMA observations of protoplanetary disks

ALMA has recently shown the existence of wide dust gaps at large radii ($r \gtrsim 50\,$au) in several disks: e.g., HD 100546 (Walsh *et al.* 2014), HD 163296 (Isella *et al.* 2016), HD 97048 (van der Plas *et al.* 2017), HD 169142 (Fedele *et al.* 2017, Figure 1), AS 209 (Fedele et al. 2018). These might be the evidence of giant planets carving out one or multiple dust gaps via dynamical clearing (e.g., Papaloizou & Lin 1984). The way to discern the gap opening mechanism is to look at the distribution of the gas. This can be done with sensitive high angular resolution observations of the low-J lines of multiple CO isotopologues and the comparison to hydro-dynamical simulations.
I will review some recent ALMA highlights on this topic and will outline some still open questions.

References

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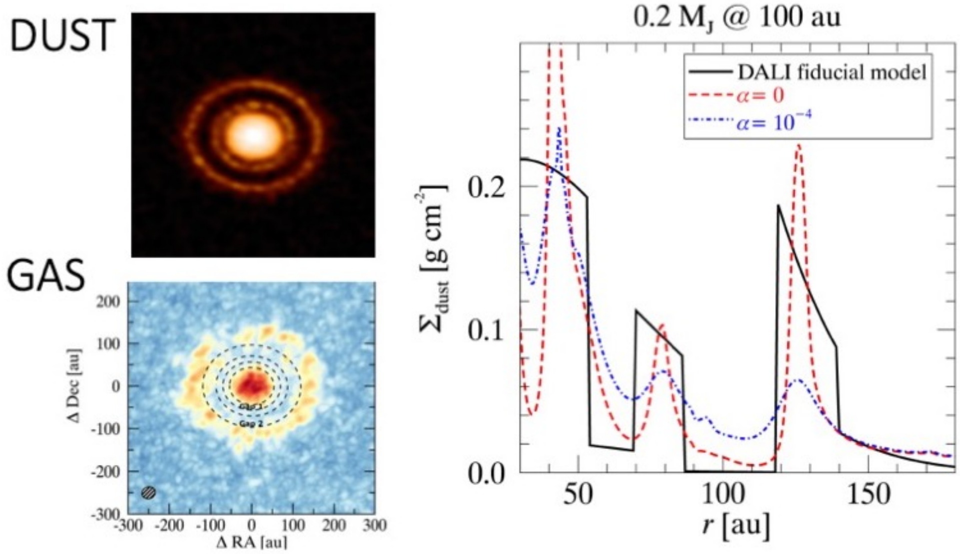

Figure 1: ALMA observations of the dust (traced by the millimeter continuum, top left) and gas (traced by C^{18}O $J = 2 - 1$), bottom left toward the protoplanetary disk AS 209 (Fedele et al. 2018, Favre et al. 2019). The derived surface density profiles are compared to hydro-dynamical simulations of disk-planet interaction (right)

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