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Detectability of resonant planets migrating outwards

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Abstract

The outward migration of two planets in resonance embedded in a circumstellar disk affects the local dust distribution. We focus on the 3:2 and 2:1 resonance, where the trapping may be caused by the convergent migration of a Jupiter- and Saturn-mass planet, preceding the common gap formation and ensuing outward (or inward) migration. Peculiar features arise from the interplay among the gravitational perturbations of the planets in resonance, the evolution of the gas, and its influence on the dust grains' dynamics [3]. We exploit the RADMC-3D code package [2] to test if these features may be detected by high resolution observations of dust continuum emission in disks (ALMA or SPHERE).

1. Introduction

Planets embedded in a circumstellar disk can produce pressure variations in the gas that act like dust traps and may lead to the formation of gaps and rings. The interpretation of these morphological features that appear in observations (see ad example [1]) may be complex since traits may be produced by single or multiple planet systems with a large variety of masses. We explore the peculiar signatures that two giant planets in a low-order mean motion resonance, like the 2:1 or 3:2, may produce on the dust. In this dynamical configuration, inward or outward migration may result, which is determined by the values of viscosity in the disk, the density and temperature profiles of the gas, and the masses of the two planets. In some cases, the formation of a common gap in the gas leads to a reversal of the torque sign, causing the interior planet to migrate outward, carrying the outer planet with it (via resonant forcing). An example of this behaviour is described by the "grand tack" scenario [4].

2. Decoupling of the dust gap from the gas gap

The gas gap evolves outwards following the pair of planets in resonance since at the inner border the gas streaming through the gap from the outer disk refills the region left empty by the outward movement of the edge. On the other side, the dust, unable to efficiently filter through the planets' orbits, does not replenish the portion of the disk left devoid of dust by the outward shift of the inner gap edge. As a result, the inner border of the dust gap is left behind while the planets and the gas gap move outward. This different behavior of the dust and the gas is outlined in Figure 1 where the spatial distribution of the dust is compared to that of the gas after 30 Kyr of outward migration.

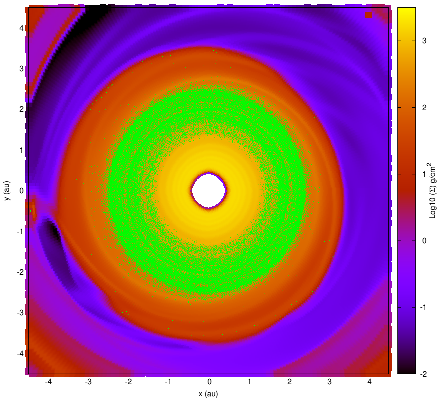

Figure 1: Gas density distribution (color coding) and 10 um size dust particles (green dots) in the inner region of the disk after 30 Kyr of outward migration of the planets locked in a 2:1 resonance.

3. Dust overdensity at the outer border

An additional effect of the outward migration of the common gas gap is the accumulation of dust particles at its outer border where a dust trap develops. As the planets move outward, the exterior edge pushes the dust outward, locally collecting solids and generating an over-dense dust region around the exterior border of the gas gap. Over time, this region of enhanced density moves outward, carried by the expanding gas gap edge. This overdensity is illustrated in Figure 2 for the 2:1 resonance which is more efficient, compared to the 3:2, in blocking the inward motion of the dust.

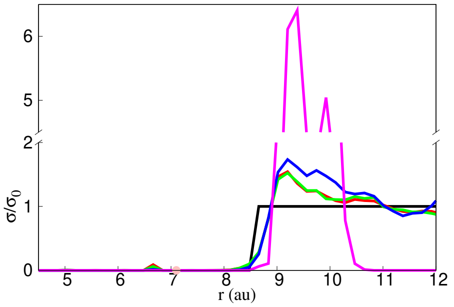

Figure 2: Histogram of the dust radial distribution after 30 kyr of evolution. Along the y-axis, we plot the ratio between the initial dust density and the final dust density as a function of the radial distance. The black line marks the initial distribution of dust while the red, green, blue and magenta lines indicate the distribution after 20 kyr of 10 µm, 100 µm, 1 mm, and 1 cm size particles, respectively. As the gas gap moves outward, the dust develops an increasing density peak at the exterior border.

4. Summary and Conclusions

We have shown that two planets in resonance migrating outwards alter the dust distribution in specific ways. The decoupling between the dust and gas distribution may be detectable by the difference in the CO and dust spatial distributions, while the overdensity at the outer border of the common gap may be visible as a bright ring, enhanced with respect to the single planet case. This hypothesis is verified by creating synthetic images of dust continuum emission produced using RADMC-3D. The goal is to test the level of detectability of these features, and whether they might allow to distinguish among cases with a single massive planet, two planets in resonance and, possibly, in which resonance the planets are trapped (either the 2:1 or the 3:2).

References

[1] Andrews, S. M., Wilner, D. J., Zhu, Z., Birnstiel, T., Carpenter, J. M., Perez, L. M., Bai, X.-N., Oberg, K. I., Hughes, A. M., Isella, A. and Ricci, L., Ringed Substructure and a Gap at 1 au in the Nearest Protoplanetary Disk, ApJL 820, L40, 2016.

[2] Dullemond, C.: RADMC-3D: A multi-purpose radiative transfer tool, Astrophysics Source Code Library. 02015-, 2012.

[3] Marzari, F., D'Angelo, G., Picogna, G.: Circumstellar Dust Distribution in Systems with Two Planets in Resonance, AJ, 157, article id. 45, 12 pp., 2019.

[4] Walsh, K. J., Morbidelli, A., Raymond, S. N., O'Brien, D. P. and Mandell, A. M., A low mass for Mars from Jupiter's early gas-driven migration, Nature, 475, 206, 2011.