Can we model all the substructures present in PDS70?

Planet-Disk Interactions in PDS 70: Characterizing Substructures in the Disk

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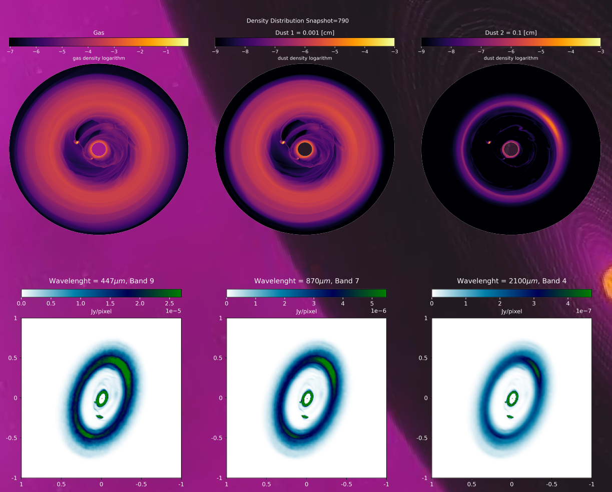
PDS70 is the only protoplanetary disc with confirmed directly imaged protoplanets. Therefore, it presents the ideal observational target to connect to models of planet-disc interaction. New high-resolution ALMA data in bands 4, 7 and 9 encouraged a deeper study of PDS70's substructures. We aim to recreate its protoplanetary disk, focusing on the vortex and shoulder, to identify key parameters for each feature. Using FARGO3D, we perform 2D hydrodynamical simulations of gas and dust, and with RADMC-3D, we carry out 3D radiative transfer simulations to obtain ALMA synthetic images in bands 4, 7, and 9. Our goal is to replicate both structures in a single simulation, with particular interest in the vortex, as only one previous study has examined it (Juillard+2022). We also employ a grid code for new insights into PDS70 disk modeling.

One Disk - Two Models: Modeling the PDS70 Disk Substructures

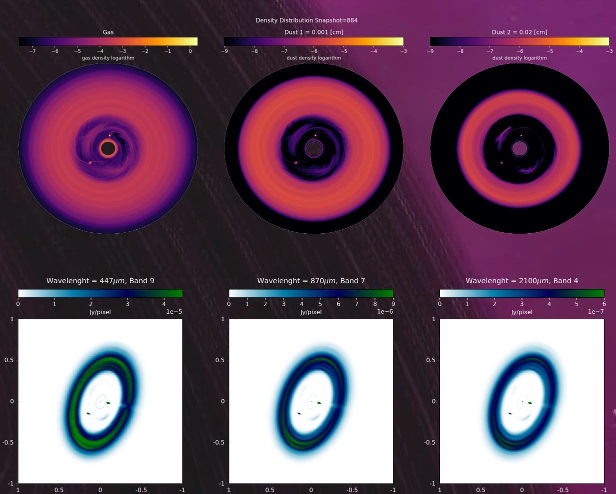
♣ Vortex Setup



FARGO3D
Benitez-Llambay & Masset+2016

RADMC3D
Dullemond+2012

♠ Shoulder Setup



Differences in Initial Conditions

We are mainly using the initial conditions from Bae+2019, the mass of the planets are 3 M_j and 7 M_j for planet B and C, respectively. Surface density normalization is 1×10^{-3}; α-viscosity is 10^{-4}; we have chosen two sizes of dust, 0.001 and 0.1 [cm], and their respective dust-to-gas ratio are of 3.6×10^{-3} and 4×10^{-4}.

We use 7.5M_j and 5M_j for planet B and C, respectively, and initial conditions from Rometsch+2024 (submitted). In this case, surface density normalization is 7.9×10^{-4}; α-viscosity is 10^{-3}. We took 2 sizes of dusts as well, 0.001 and 0.02 [cm]. Their dust-to-gas ratio are 7.5×10^{-3} and 2.5×10^{-3}, respectively.

Brief Comments on Preliminary Results

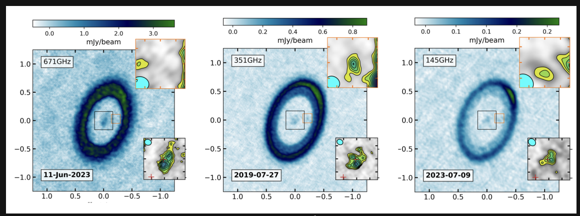
Vortex presents an emission excess and the structure appears after we activate the planet migration. Band 4 has the best correlation with the observations. In the other bands, we see a small dust excess.

The shoulder structure appears as a faint inner ring of large dust. Bands 4 and 7 show reasonable agreement, with excess in the upper and lower disk regions. Band 9 exhibits emission excess in all the disk.

Yes! we can model both substructures, but...

- We can obtain either vortex or shoulder with our best setups. However, we aim to include both in a single simulation. So? Find the correct values between 10^{-3} and 10^{-4} for viscosity and weights for dust-to-gas ratio, Add gas accretion to the simulations, extend to 3D simulations.
- The main mechanism for the vortex appears to be the planet migration, and for the shoulder formation is due to higher viscosity.
- Band 9 shows the lowest agreement, likely because it is new data with no established literature on its parameters.

observations



Casassus et al. in prep.

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