DUST MIGRATION IN TRUNCATED DISCS: TRIGGERING THE GRAVITATIONAL INSTABILITY.

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1 introduction

One of the proposed mechanisms for planet formation is the gravitational instability (Toomre, 1964). When a certain density and temperature is reached in the protoplanetary accretion disc, the stabilising effects of thermal pressure and differential rotation are overcome and the disc may collapse locally to form planets.

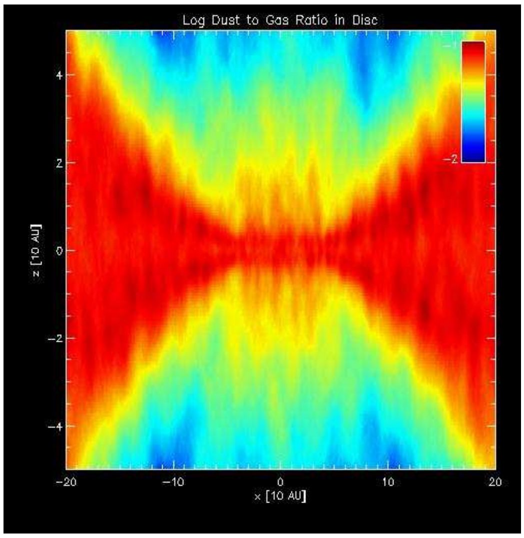
Dust in protoplanetary discs generally moves with a purely Keplerian speed, in contrast to gas, whose orbital speed is moderated by the effect of the gradient in pressure. Drag forces between the two fluids drive dust to the high density parts of the disc. Dust should therefore settle to the midplane and migrate inwards, and be swallowed by the star.

If the inner disc is truncated, the dust will accumulate at the truncation radius. This could trigger a gravitational collapse. Our poster presented preliminary numerical results from an exploration of this effect (Section 2). We also present two other projects for the simulation of outbursts (Section 3) and turbulence (Section 4), either of which may disrupt this mechanism.

2 Dust triggering mechanism

We are performing three-dimensional smoothed particle hydrodynamics (SPH) simulations of dusty discs. Simulations are performed with 10^5 gas particles and an equal number of dust particles. The initial condition is a steady state gas accretion disc of mass 10^{-2} solar masses and radius 300 AU, with a central hole maintained by a simulated magnetic propeller. Gas is dropped onto the disc at a constant rate. The disc is marginally gravitationally stable. Once steady state is reached, dust is added with the same dust to mass ratio (0.02) throughout the disc. The dust-gas drag (due to the wake of the dust particles or to thermal agitation) is modelled following the approach of Barrière-Fouchet et al. (2005) and viscosity is modelled with a simple Shakura-Sunyaev (1973) prescription.

Initial results (Figure 1) are promising, showing vertical settling and radial migration of dust. The dust to gas ratio reaches a maximum near the truncation radius. Extended simulations should show the triggering of the gravitational instability at this radius.



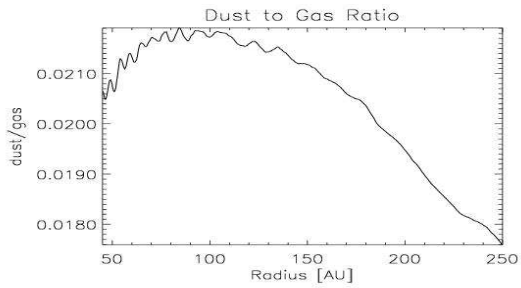


Figure 1: SPH simulation showing dust migration and settling in an accretion disc.

3 Realistic opacity driven outbursts

The thermal-viscous disc instability model (DIM) relies on the sudden change in opacity around the ionisation of hydrogen (e.g. Osaki 1989). This leads to a limit cycle between a high accretion state and a low accretion state. Previous 3D models (e.g. Truss 2002) have usually altered α by hand to mimic this effect. In our new smoothed particle hydrododynamic (SPH) model internal energy is evolved using an ideal gas equation of state, opacity is set according to an analytic model (Bell & Lin, 1994) and cooling is applied using simplified radiation transport

The opacity function used stretches from the ice-crystal regime to electron scattering, as shown in Figure 2. Outbursts should arise naturally in this model and the effect of radiation from the accreting star or other sources can easily be accommodated. During outburst we would expect to see heating, and the closure of the central hole in a truncated disc. Either of these things could disrupt our planet formation mechanism.

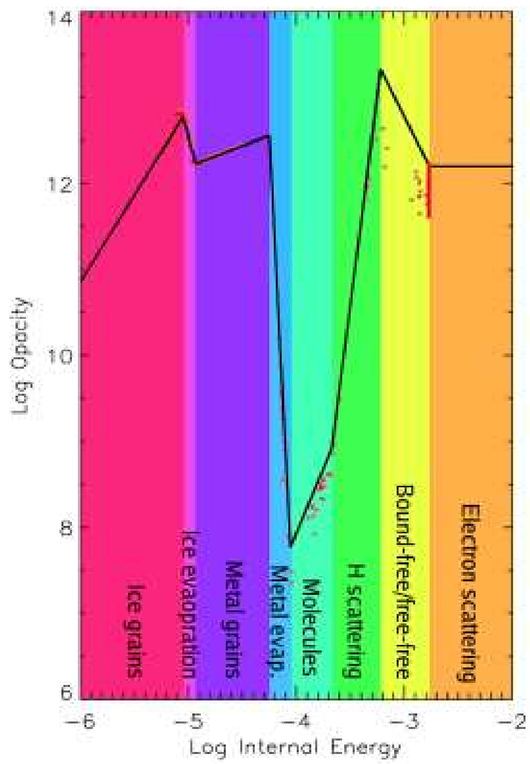


Figure 2: Opacity as a function of specific internal energy in arbitrary units. The functional relation at a given density is plotted in black, and SPH particles are plotted in red.

4 Sub-grid modelling of MHD turbulence

It is useful to be able to reproduce turbulent effects at lower, and computationally cheaper, resolutions. This can done using the large eddy simulation technique (LES), which has now been extended to MHD (e.g. Verma, 2001). The code used here uses renormalised values for resistivity and viscosity and accounts for turbulent behaviour at unresolved scales. It is based on the University of Chicago's grid-based FLASH code, which incorporates MHD and adaptive mesh refinement. Viscosity and resistivity are renormalised using resolution, the alfven ratio, and strain as inputs. Results from an initial test calculation are shown in Figure 3.

At present, pre-tabulated values for the viscosity and resistivity are used. We aim to move to a dynamic model. This will use FLASH's AMR to evaluate MHD variables on two scales so that the effective viscosity and resistivity become independent of resolution. A good model of turbulence is important to asses the robustness of our planet formation model in a realistic disc.

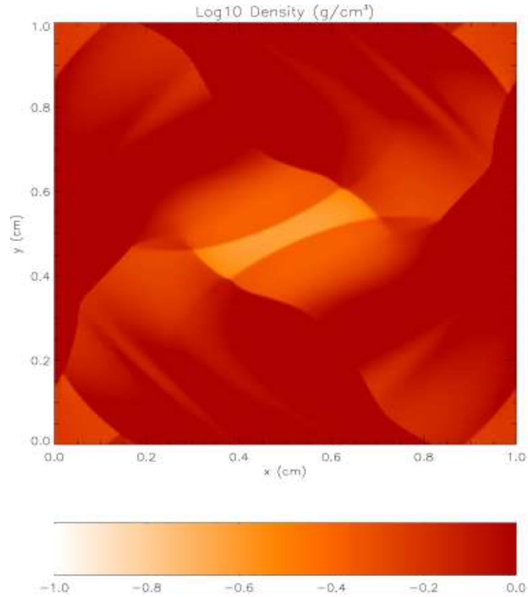


Figure 3: The Orszag-Tang vortex test problem using the FLASH code, and incorporating renormalised resistivity and viscosity.

References

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