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Cautionary Remarks on Using SPH to Model the ISM in Galaxies

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Abstract. In many SPH simulations of galaxy formation a lower limit is imposed on the kernel radius h equal to the gravitational softening length ϵ. It has been found that such a constraint can in some circumstances compromise the spatial resolution to which hydrodynamical quantities are evaluated to the extent that the evolution of the gross features of a numerical galaxies are affected. Such effects can be avoided by allowing h to evolve freely to maintain a roughly constant number of neighbours in SPH summations. Here we focus on how imposing a constraint on h may affect the velocity field.

Figure 1 shows the gas mass fraction with $\nabla \cdot \mathbf{v} < 0$, and the mean $\nabla \cdot \mathbf{v}$ for this mass versus time t in a number of simulations using the constrained and unconstrained h approaches. The initial conditions used were a sphere of uniform density given a Poisson spectrum of noise, in solid body rotation with a spin parameter of 0.06. Initially 100% of the gas has negative $\nabla \cdot \mathbf{v}$ due to the collapse of the protogalaxy, but after the formation of the galactic disc both expansion and compression are present. For the unconstrained h simulations roughly half the gas is in convergent flows; while there is a trend for increased mass of gas to be in convergent flows with increasing constraint on h. The frames on the left show that a large fraction of this gas resides in the central regions of the constrained h galaxy simulations. Secondly, these data show how velocity gradients are systematically diminished with increases in the constraint on h; while the mean values are broadly consistent between the four unconstrained h simulations shown.

These trends occur because when h is not allowed to decrease naturally in high density regions, the SPH summations sample over a large range in velocities, especially in the central regions of the numerical galaxy disks. As a consequence, all quantities evaluated with SPH summations are smoothed. Due to the large values of h, shear viscosity becomes effective in transporting angular momentum radially outwards and gas mass inwards. Thus it is preferable that no constraint is applied to h; rather that h is allowed to evolve freely such that SPH summations contain a roughly constant number of neighbours.

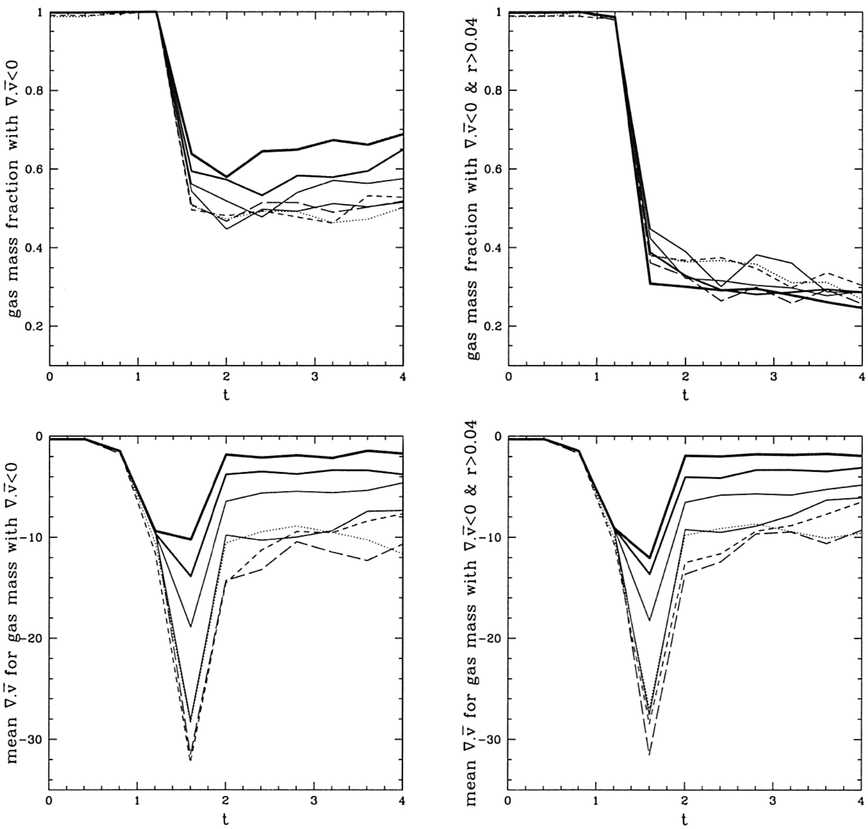

Figure 1. The gas mass fraction with $\nabla \cdot \mathbf{v} < 0$, and the mean $\nabla \cdot \mathbf{v}$ for this mass versus time t. The right hand frames show these data excluding the central 4 kpc of the numerical galaxies. Simulations which used constraints on h of $h \geq \epsilon/2$, $h \geq \epsilon$, and $h \geq 2\epsilon$ respectively are shown with increasing line thickness. Simulations which use the unconstrained h method with gravitational softening lengths of 1.5 kpc and 1.0 kpc are shown with a thin–solid and thin–dotted lines respectively (using 12000 particles in total). Simulations in which the total number of particles used is 12000, 24000, and 48000, with a gravitational softening length of 1.0 kpc are shown with thin–solid, dashed, and long–dashed lines respectively.

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