Modelling Circumstellar Discs with 3D Radiation Hydrodynamics

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The Torus Monte-Carlo radiative transfer code (Harries, 2000) has been coupled with a Smoothed Particle Hydrodynamics (SPH) code (Bate 2009) to give a flexible system for modelling radiation hydrodynamics in arbitrary geometries. The combined code has been applied to modelling a circumstellar disc.

Using sufficient SPH particles to accurately represent the disc density is vital to ensure that the radiative transfer code can give an accurate representation of the temperature within the disc. To test how many particles are required, the benchmark disc of Pascucci et al (2004) was constructed using different numbers of particles and the temperature errors relative to the benchmark result were calculated. Fractional temperature errors for discs represented by different numbers of SPH particles are plotted in Fig. 1. The number of particles used also has a significant impact on the SED from the disc. Figure 2 shows SEDs for discs with different numbers of particles viewed at a 13 degree inclination angle, also plotted is the benchmark result.

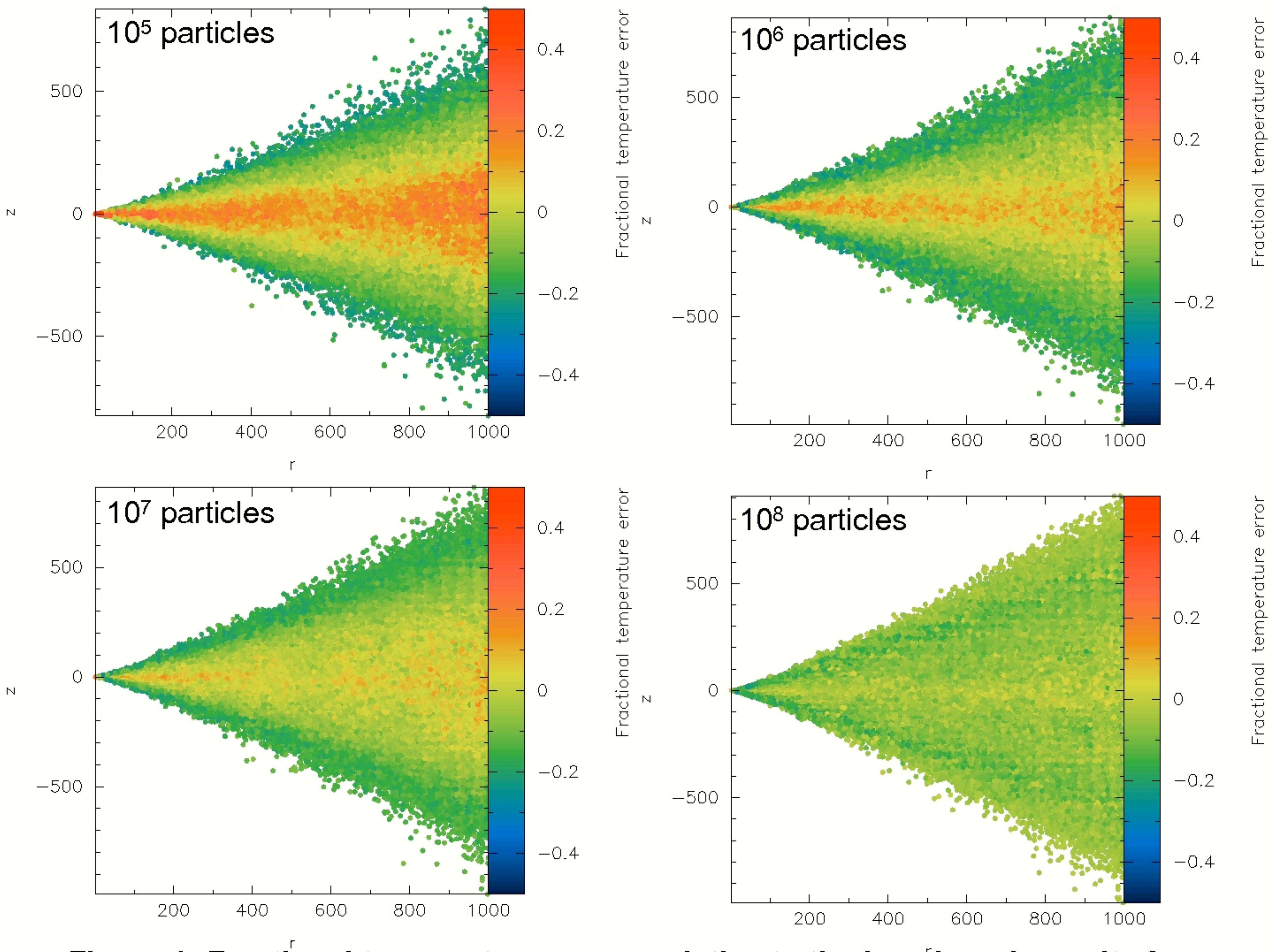

Figure 1: Fractional temperature errors, relative to the benchmark results from Pascucci et al (2004), for discs represented with different numbers of SPH particles. The temperature is calculated using the Torus Monte-Carlo radiative transfer code. The axes are cylindrical polar r,z co-ordinates in units of AU.

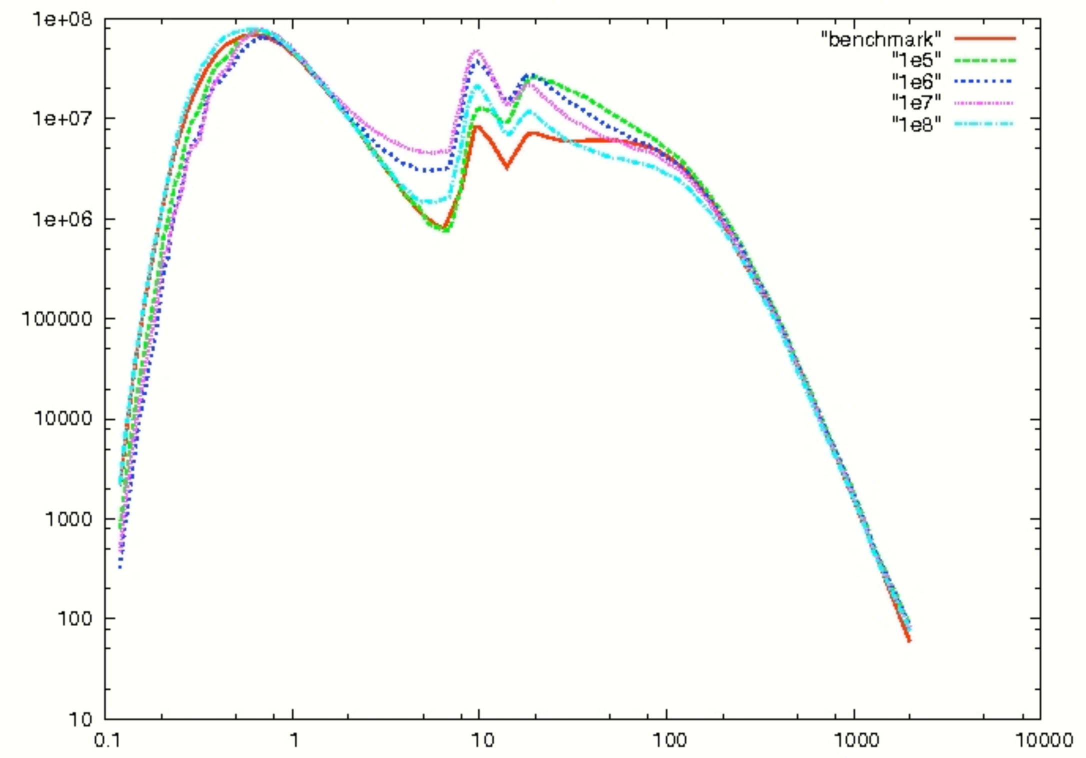

Figure 2: SEDs from discs represented by different numbers of SPH particles. Also plotted is the benchmark SED (solid red line).

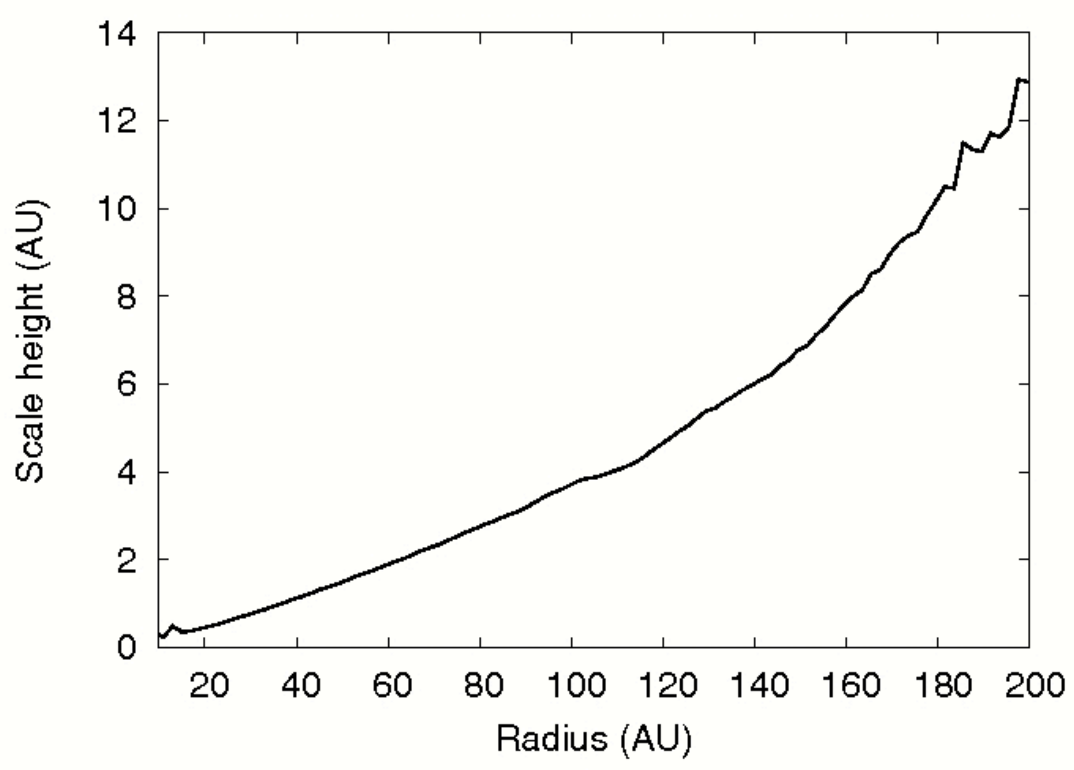

Figure 3: Scale height as a function of radius for a disc in hydrostatic and radiative equilibrium.

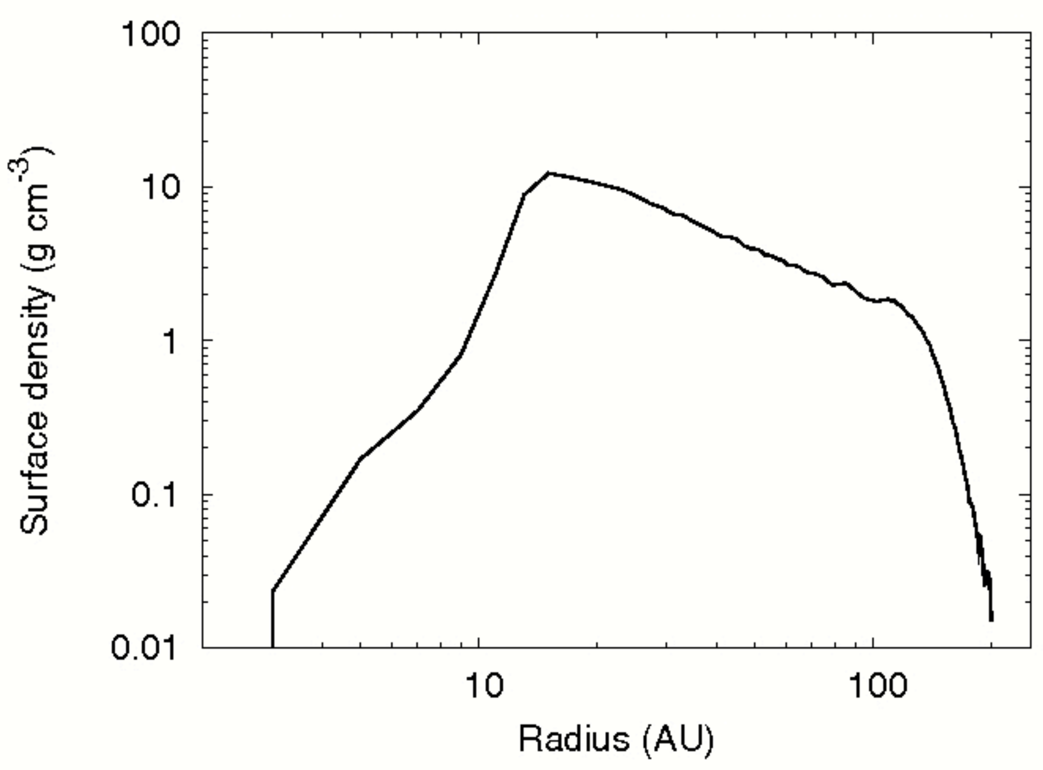

Figure 4: Surface density as a function of radius for a disc in hydrostatic and radiative equilibrium.

The combined radiation hydrodynamics code was used to model a disc around a classical T Tauri star. The disc was initially set up using the SPH code only, then evolved using the combined radiation hydrodynamics code into a state of hydrostatic and radiative balance. Scale height fluctuations are seen in the disc as it evolves towards equilibrium but they dissipate over time and the disc reaches a steady state. The resulting scale height as a function of cylindrical polar radius is shown in Fig. 3 and surface density is plotted in Fig. 4.

In future we will apply the code to modelling a circumstellar disc with the inclusion of self-gravity, in order to study the impact of radiative feedback on disc fragmentation.

References:

Bate M. R., 2009, MNRAS, 392, 590
Harries T. J., 2000, MNRAS, 315, 722
Pascucci et al, 2004, A&A, 417, 793