Bridging the gap between large-scale simulations and observations of star forming cores

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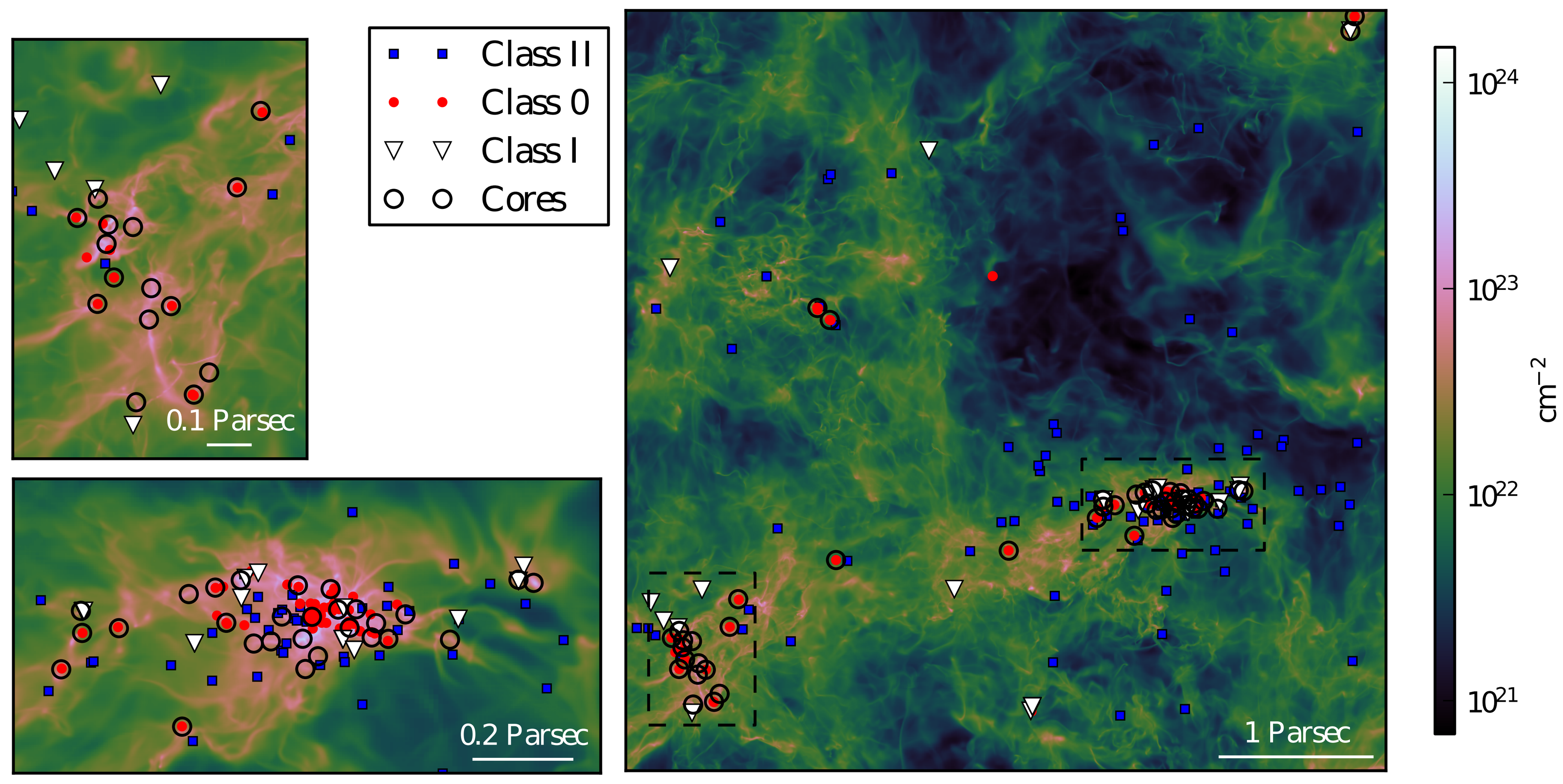
Introduction

Numerical simulations and observations of star forming cores are topics which both see a lot of progress these years. MHD simulations of molecular clouds have reached a level, where it is possible to evolve the cloud on parsec scale, while simultaneously resolving the neighbourhood around the individual protostars on AU scale. At the same time interferometers such as ALMA, with its increased sensitivity and resolving capabilities, are making it possible to zoom in on the protostellar cores in their earliest stages and map their gas and dust content.

Here we present synthetic observations of star forming cores created from the high resolution numerical simulations of Padoan, Haugbølle & NordLund (2014) and Haugbølle et al. (in prep). This approach allows for the direct comparison of observations with numerical simulations.

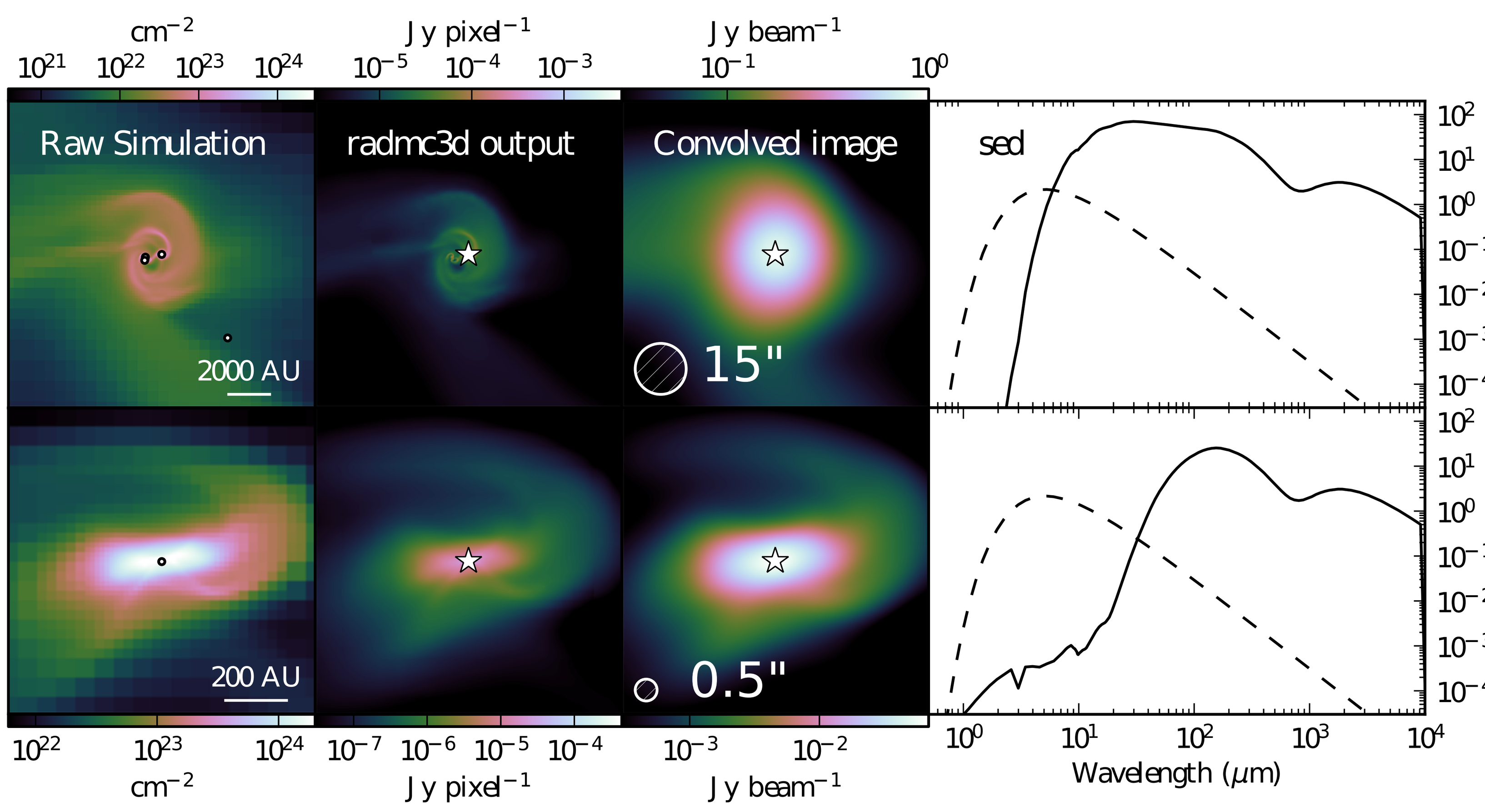


Top: Projected column density of the entire numerical simulation, plotted along with protostars and cores. The protostellar classes are calculated from the SEDs, and the cores from the continuum images.

Left: From simulations to synthetic observations. The continuum images and SEDs are created using the dust radiative transfer code RADMC-3D[1], with dust opacities from Ossenkopf & Henning (1994). A distance of 125 pc is assumed for both examples.

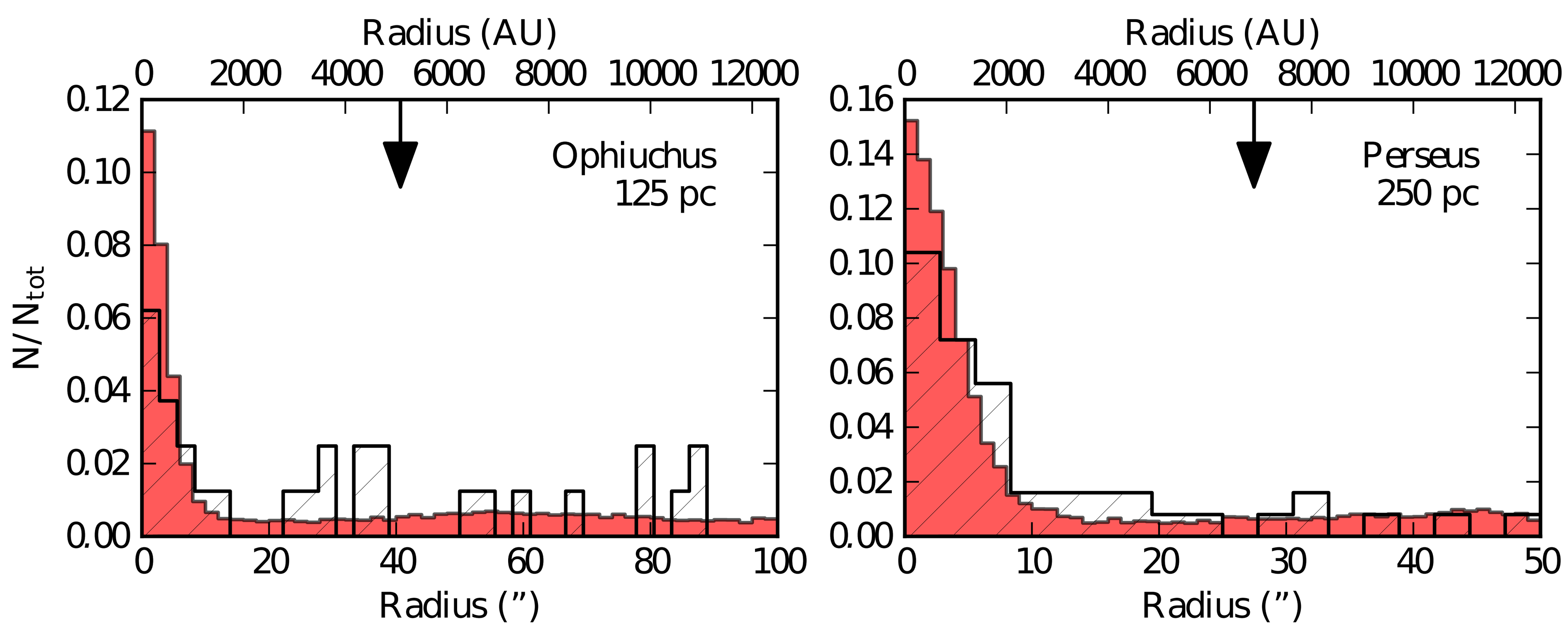
Bottom: Distance distribution between cores and protostars in the simulation (shaded histogram) and the observations of Jørgensen et al. (2007,2008) (hatched histogram). Both distributions are peaked at small distances showing that cores and protostars remain closely associated over the embedded phase. The arrows indicate the average radius of the cores in the simulation.

[1] *http://www.ita.uni-heidelberg.de/~dullemond/software/radmc-3d/*

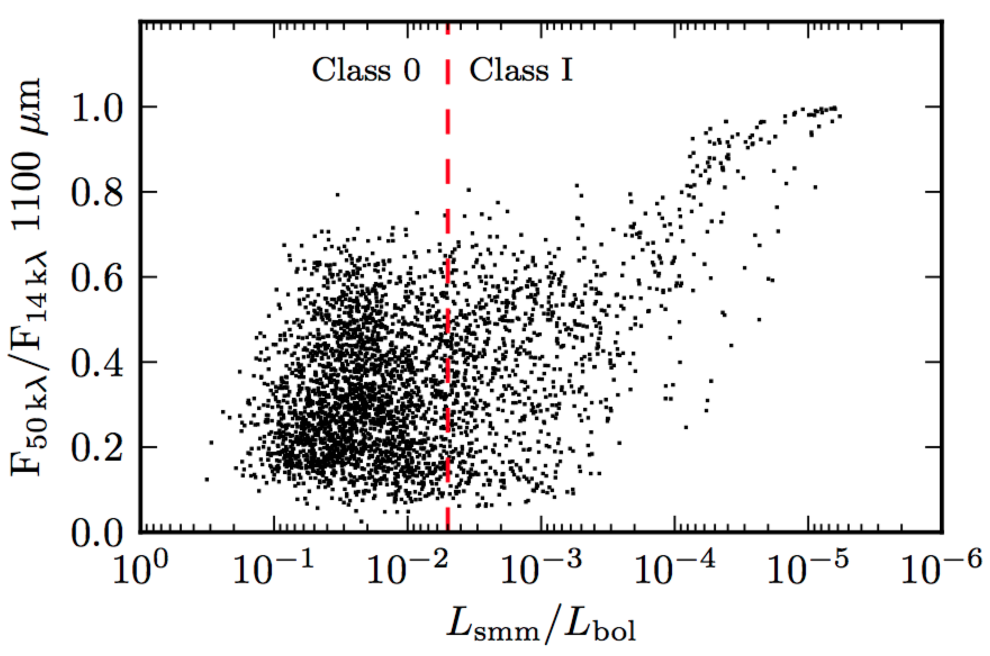


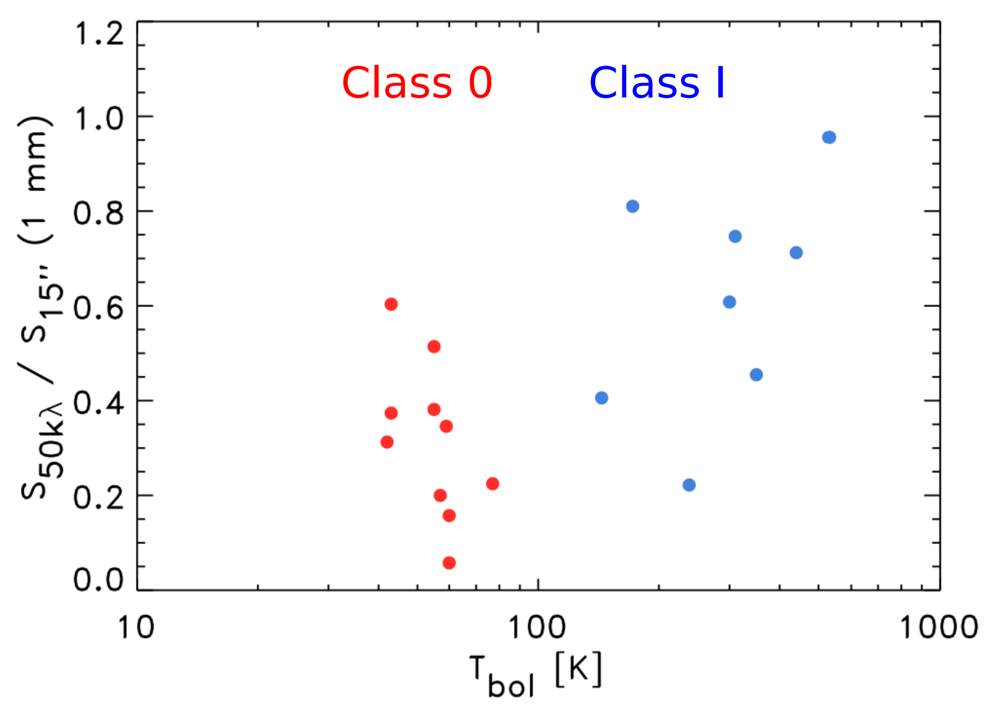
Core to protostar distance distribution

Jørgensen et al. (2007,2008) studied the cores and embedded protostars in Ophiuchus and Perseus, and found that the two remain closely associated throughout the embedded protostellar phase (see histograms to the right). This indicates that protostars remain closely associated to their parental core throughout their main accretion phase. The agreement between the distributions produced from synthetic observations, and the distributions produced by real ones is excellent.



Flux ratios measured in the simulation (top) and in the observations of Jørgensen et al. (2009) (bottom).





Flux ratios

One of the outstanding questions in star formation is the timing of formation of rotationally supported disks. Using a combination of interferometric and single dish continuum observations, Jørgensen et al. (2009) surveyed a sample of 20 deeply embedded protostars. For this sample they calculated the ratio between compact and extended fluxes. By using semi emperical methods Jørgensen et al. (2009) found that flux ratios $\gtrsim 0.1$ indicate the presence of an unresolved compact component (i.e. a disk). The synthetic observations reproduce the distribution of observed flux ratios well. A study of the simulation reveal that virtually all objects with a flux ratio $\gtrsim 0.3$ contain a disk, while ratios below this value is a mix, thus the limiting ratio appears to be somewhat above that proposed by Jørgensen et al. (2009).

References

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