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Simulated Analogues: connecting observations with simulations using Deep Learning

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Recent advances in observations and theory show increasing evidence that star formation is a multi-scale problem. Global simulations that properly account for the connection from the large-scale gas flow to the accreting protostar can be used to understand protostellar systems in such a context. Given the turbulent nature of the initial conditions, it is challenging to compare models directly to specific observations. Both because a perfect match between unknown initial and boundary conditions are hard to establish, and also because observations are two dimensional projections, at one point in time. To overcome this challenge, we have used Deep Convolutional Neural Networks (DCNN) to make unbiased matching between a specific observation and large catalogues of synthetic observations using image similarity. A set of simulated analogues, with metadata such as age, mass, disk size, and other parameters, matching visually the observations may then be used as an aid in understanding and interpreting the physical and chemical structure in the observations. Using global models and statistical matching is of particular relevance for multiple protostellar systems. Only global models can provide the mass flux from the large environment, the correct anchoring of magnetic fields, and the torques and tidal forces that generate the resulting binary system. Statistical matching help us tremendously in understating the complicated kinematic structure of multiple inflows, outflows, and spiral bridges present in a protostellar binary. We will present ab initio MHD zoom-in models of three binary protostellar systems forming due to core-collapse in a large 4 pc box where we use deep adaptive meshes refinement to reach down to 0.8 to 3.2 AU resolution while following the binary stars for up to 150 kyr. This unprecedented data set allow us to better investigate the formation process of binaries in a realistic environment, provide us with a large catalogue of synthetic observations, and allow us to perform a down-selection from large datasets of synthetic images to a handful of matching candidates using Deep Convolutional Neural Networks (DCNN). The networks are used to infer several system parameters for the observed system IRAS-2A.

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