Round Table III:
Numerical simulations

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State of the Field

In your opinion, what are the most exciting ISM-related questions that numerical experiments are tackling today?

And what are the key scientific questions where we can expect progress in the next 5-10 years?

What are the advantages and disadvantages of the different numerical methods (e.g. grid-based methods, smoothed particle hydrodynamics, moving mesh) for studying the ISM (at different scales)? Is one method likely to become dominant in the future?

Science Spotlights

What are the most important bottlenecks to interpreting observations of distant galaxies where we should be investing effort ?

The efficiency of various feedback processes depends on the spatial scale under consideration. How do you properly take into account the small-scale feedback at the galactic scale and the galactic-scale feedback at molecular cloud scale?

How can we study the effect of metallicity, enrichment and chemical mixing on galaxy evolution?

We start to be able to simulate galactic eco-systems. What about simulating the formation of a galaxy from the primordial gas?

Are there attempts to couple (magneto-)hydrodynamical simulations with dark matter ?

Comparing observations and simulations

What do you find to be the main obstacles to comparing your simulation results with observations?

In practice, how do you identify the observations that are most pertinent and reliable to benchmark your simulation results?

Is the production of synthetic observables from the results of numerical simulations sufficient to compare them to observations, or does it simply add more potential sources of uncertainty?

Is it possible that interesting processes present in numerical simulations remain hidden, simply because we are not looking for them?

Comparing observations and simulations II

An observation or a simulation of the ISM is necessarily particular, and hence subject to contingencies. How do you take this into account when making comparisons from which you draw general conclusions?

Simulations evolve through time while observations are only ever a snapshot at a given moment in time. How do you take this into account when making comparisons from which you draw general conclusions?

Should there be more effort to identify statistical quantities that can be determined from both simulations and observations (e.g. the power spectrum)?

Simulations and observations are both highly specialized areas of expertise. How can we improve dialogue between observers and people doing simulations?

Theory and simulations

How do you see the relationship between (semi-)analytical theory and numerical simulations? Do they each provide insight for the other, or does one depend more on the other?

How do we strike the right balance between capturing the full complexity of the ISM and making progress in physical understanding via simplified models/simulations? How can we productively test and improve simulations using "human-scale" models ?

Among the different ISM processes, which critically require full 3D simulations (vs 1D approximations)? Likewise, which processes critically require out-of-equilibrium calculations (vs stationary models)?

Laboratory astrophysics and simulations

Grain physics is central for MHD in dusty plasma, but there is little work on this aspect of the grains by laboratory astrophysicists. Do you have any suggestions for how to improve this situation?

Is laboratory astrophysics able to measure key quantities and provide useful constraints for current simulations? Among the possible effects we could think of:

- grain physics (depletion factors, shattering, coagulation,...)
- gas physics (cooling functions, transition probabilities, collisional cross-sections for multi-ionized metals…)
- shock physics (bomb test, wind tunnel, shock simulations, dust ambipolar diffusion, dusty plasma MHD…)
- feedback in the ISM (laboratory dusty plasma MHD and self-organization, ITER for magnetized plasma…)

Analysis of simulations

How do you ensure that what you see is not a numerical artefact?

What are the main processes for which subgrid recipes are necessary? Which processes have subgrid recipes that are lacking, or that need significant improvement?

What are the main risks of subgrid recipes?

The ISM is shaped by processes occurring over a wide range of scales (in space and time). When analysing simulations, how important (or not?) is it that the simulations only conform to reality over a restricted subset of scales? Is there a general rule, or does it depend on the science question being posed?

How do you handle transitions between a dominant physical mechanism at one scale to another mechanism that becomes dominant at another scale?

Analysis of simulations II

With the increasing complexity of simulations, is there a risk that it will become more and more difficult to make sense out of what has been computed?

Is it possible that interesting processes present in the simulation remain hidden, simply because we are not looking for them?

Looking to the Future

What are the main limitations to solving key ISM questions with numerical simulations of the ISM today? Are we limited by CPU, by algorithmic development, or by our understanding of the key processes?

Are all scales from intergalactic to planet formation coupled? Is there hope for a “DeepThought” simulation that encompasses the full hierarchy?

What are the numerical techniques or types of physical processes that could be lead to big improvements in numerical simulations of the ISM in the next years, and that you think young people starting out in the field should invest time in mastering?

What could be the impact of quantum computers on ISM simulations, as they do not only represent a quantitative improvement, but will also be efficient to solve particular problems?

Looking to the Future II

Which upcoming observational capabilities are you most excited about? What important gaps in our current knowledge do you think will be answered by instruments and observatories coming online in the next 5-10 years?

Will upcoming facilities significantly improve our knowledge of magnetic fields?

What are the key observations that are still not covered by existing or upcoming facilities?