EUROMECH Colloquium 599

"Rotating convection: from the lab to the stars"

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Thermal buoyancy is arguably the largest dynamic force in the universe, driving many planetary and stellar flows. These flows are almost invariably further shaped by the influence of axial rotation of their celestial bodies. Convective systems are generally too complex and too vast for a full direct simulation and too large and too remote for direct measurements. The recent development of asymptotically reduced mathematical models and upcoming experiments studying these flows in a simplified form have opened up new perspectives to get a better grip on such flows that shape our universe. Our aim for the workshop was to bring geo- and astrophysicists in contact with researchers studying fundamental fluid dynamics, to bridge the gap from the lab to the stars.

During the workshop the twelve keynote lectures set the stage by giving broader introductions to relevant subfields: from simplified but well-controlled, readily-accessible laboratory experiments, to accompanying direct numerical simulations of various levels of complexity in terms of geometry and involved physical processes, from rigorous mathematical analysis to observational work. Next to these keynote lectures there were 24 shorter oral contributions by senior participants and poster contributions from junior participants. We were pleasantly surprised to see that, despite the breadth of the studied topics, the "language" of each field was easily understood by the other participants. This became also readily apparent in the lively discussion sessions, with ample input from the various fields represented in the workshop.

In the discussion sessions many new perspectives for laboratory experiments were sketched. The experiments are moving beyond integral measurements (overall heat transfer) to more localized diagnostics, like in situ temperature measurements and optical flow measurements using techniques such as particle image velocimetry or Lagrangian particle tracking. There is a great need for these more advanced flow statistics. Additionally, many suggestions for experiments move on from canonical simple geometries toward more complex situations involving geometrical effects (e.g. spherical shells with rapid centrifugation for gravity) and/or extra physics such as multiphase and double-diffusive media, or magnetic fields in liquid metals.

For numerical simulation the development of the asymptotically reduced equations has brought a means to connect smaller-scale laboratory experiments and full direct simulations to actual geo- and astrophysical flows. The connection of asymptotics and direct simulations/experiments is now being made, with favorable comparisons on display during the workshop. Now the challenge is to add other physical effects (change geometry from a plane layer, involve a magnetic field, etc.) to these equations. Comparisons with cutting-edge direct simulations of the full equations will be required here for proper validation and to delineate the range of validity of the asymptotic equations.

It is unfortunate that traditional subgrid-scale approaches (typically assuming isotropy and exploiting the notion of a downscale cascade of energy) cannot be applied to these systems given that rotation leads to strong anisotropy and scale separation. Small-scale features are active and cannot be filtered out. There may also be an inverse energy cascade, further complicating the picture. Mathematical analysis (e.g. upper bound analysis of heat transfer) is also facing problems in that rotation does not contribute directly to the traditional energy-based approaches. However, for both these approaches some out-of-the-box ideas came up that may still lead to progress.

The meeting has fostered new collaborations and many new research ideas have sprouted over the course of the week. The community plans to organize a follow-up meeting in about two years time to assess the progress, then in the United States.

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