Scientists study the problem of hydrodynamic stability of Keplerian flow

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Researches from Sternberg Astronomical Institute, Lomonosov Moscow State University, have focused their efforts on one of the major theoretical issues of modern astrophysical fluid dynamics, which is the stability of Keplerian shear flow of liquid or gas. The results are available in the *Monthly Notices of the Royal Astronomical Society* journal.

Keplerian flow is ubiquitous in space. It appears in accretion and protoplanetary discs, where fluid rotates differentially so that its angular velocity decreases inversely to the distance from the rotation axis to the three-halves power.

Dr. Viacheslav Zhuravlev of Lomonosov Moscow State University and the author of the paper says, "Numerous observations reveal that both accretion and protoplanetary discs are in a turbulent state. Nevertheless, no one has managed so far to model or simulate in laboratory conditions turbulent Keplerian flow of non-ionized matter. In other words, unlike the other known shear flows, Keplerian flow manifests amazing nonlinear dynamical stability. To date, this stability has been checked up to the Reynolds number of several millions. However, in real astrophysical discs, the Reynolds number can be as high as tens of billions."

In the project, the authors suppose that Keplerian flow breaks into a turbulent state at the Reynolds number not yet attained in the research. As turbulence cannot exist in the absence of growing perturbations of velocity and pressure, they consider in detail how large the growth factor of transiently growing perturbations can be. Generally, those perturbations arise in the form of spirals being unwound by the differential rotation of the bulk flow.

Viacheslav Zhuravlev says, "We've managed to show for the first time that such perturbations are able to sustain turbulence also at scales significantly exceeding the disc thickness. Additionally, we predict a value of the Reynolds number corresponding to transition to turbulence both in Keplerian and super-Keplerian flows."

The researchers have been solving the linearised Navier-Stokes equations both numerically and analytically. Moreover, for the first time in astrophysical scientific literature, they have employed a so-called variational approach in order to determine the optimal perturbations that demonstrate the highest possible growth of amplitude.

The scientist sums up: "We are going to carry out a set of special computer simulations, which will help to reveal an exact mechanism of the shear flow stabilization in the model situation, when the angular velocity profile evolves from a so-called cyclonic type to the Keplerian type. In turn, this will contribute to better understanding of the behavior of Keplerian flow and the evolution of finite amplitude perturbations in it . We believe that the discovery of the nonlinear hydrodynamical instability of Keplerian flow is nearly at hand. In fact, it is directly related to the explanation of the very existence of accretion and protoplanetary discs and, consequently, to the emergence of many other objects in the universe."

More information: D. N. Razdoburdin et al, Transient growth of perturbations on scales beyond the accretion disc thickness, *Monthly Notices of the Royal Astronomical Society* (2017). DOI: 10.1093/mnras/stx050

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