Turbulence in interstellar gas clouds reveals multi-fractal structures

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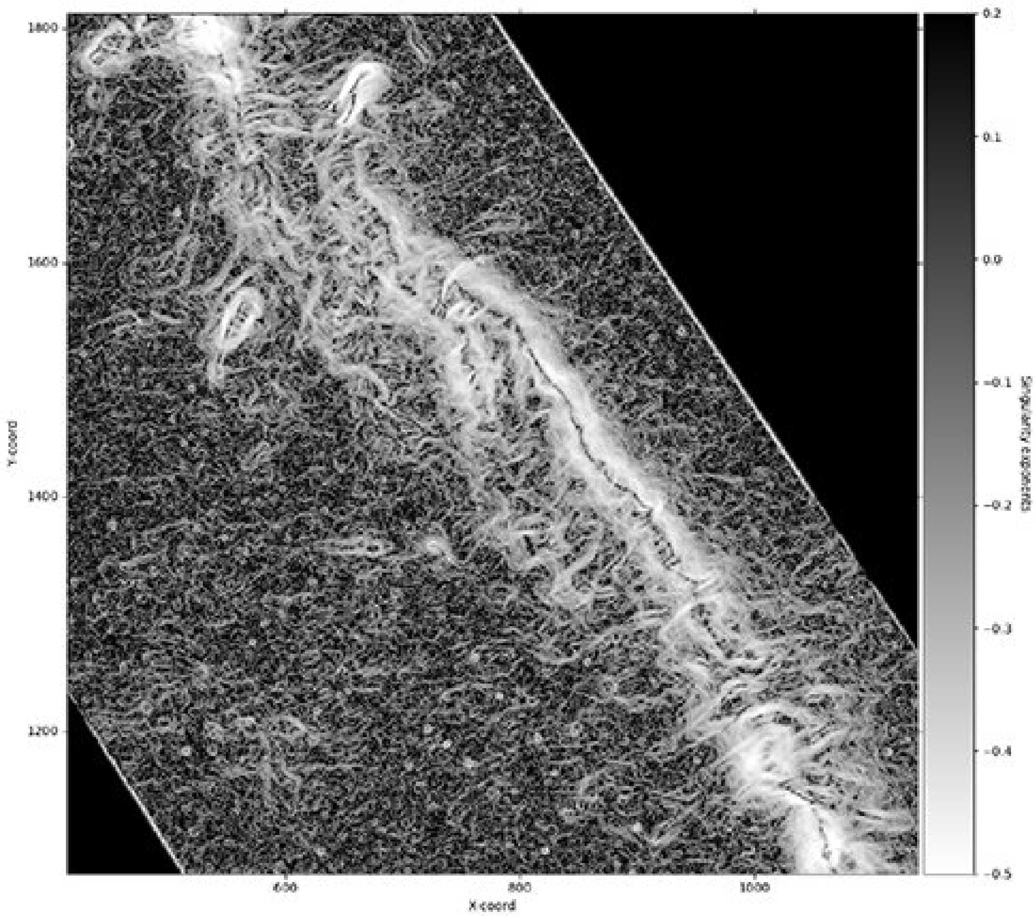

Credit: University of Cologne

In interstellar dust clouds, turbulence must first dissipate before a star can form through gravity. A German-French research team has now discovered that the kinetic energy of the turbulence comes to rest in a space that is very small on cosmic scales, ranging from one to several light-years in extent. The group also arrived at new results in the mathematical method: Previously, the turbulent structure of the interstellar medium was described as self-similar—or fractal. The researchers found that it is not enough to describe the structure mathematically as a single fractal, a self-similar structure as known from the Mandelbrot set. Instead, they added several different fractals, so-called multifractals. The new methods can thus be used to resolve and represent structural changes in astronomical images in detail. Applications in other scientific fields such as atmospheric research is also possible.

The German-French program GENESIS (Generation of Structures in the Interstellar Medium) is a cooperation between the University of Cologne's Institute for Astrophysics, LAB at the University of Bordeaux and Geostat/INRIA Institute Bordeaux. In a highlight publication of the journal *Astronomy & Astrophysics*, the research team presents the new mathematical methods to characterize turbulence using the example of the Musca molecular cloud in the constellation of Musca.

Stars form in huge interstellar clouds composed mainly of molecular hydrogen—the energy reservoir of all stars. This material has a low density, only a few thousand to several tens of thousands of particles per cubic centimeter, but a very complex structure with condensations in the form of 'clumps' and 'filaments', and eventually 'cores' from which stars form by gravitational collapse of the matter.

The spatial structure of the gas in and around clouds is determined by many physical processes, one of the most important of which is interstellar turbulence. This arises when energy is transferred from large scales, such as galactic density waves or supernova explosions, to smaller scales. Turbulence is known from flows in which a liquid or gas is 'stirred', but can also form vortices and exhibit brief periods of chaotic behavior, called intermittency. However, for a star to form, the gas must come to rest, i.e., the kinetic energy must dissipate. After that, gravity can exert enough force to pull the hydrogen clouds together and form a star. Thus, it is important to understand and mathematically describe the energy cascade and the associated structural change.

More information: H. Yahia et al, Description of turbulent dynamics in the interstellar medium: multifractal-microcanonical analysis, *Astronomy & Astrophysics* (2021). DOI: 10.1051/0004-6361/202039874

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