Researchers at the Weizmann Institute of Science, the University of Rome, CNRS and the University of Helsinki have recently carried out a study investigating the difference between 3-D anisotropic turbulence in classical fluids and that in superfluids, such as helium. Their findings, published in *Physical Review Letters* (PRL), are supported by both theory and experimental evidence.

"The present research was initiated by our group at the Weizmann Institute, Israel, comprised by Victor L'vov, Itamar Procaccia and Anna Pomyalov, who were trying to understand novel experimental observations by the groups of Prof. Wei Guo from Florida State University, Tallahassee and Prof. Ladislav Skrbek from Charles University, in Prague," Itamar Procaccia, one of the researchers who carried out the study, told Phys.org. "Our main objective was to understand an apparent surprising difference in how energy distributes between turbulent eddies of different scales in classical viscous fluids like air and water and superfluids like helium at low temperatures."

All turbulent flows, both in nature and laboratory settings, are anisotropic on energy injection scales, meaning that energy distributes differently between their turbulent eddies. Past studies have shown that the model of homogeneous and isotropic turbulence (HIT) is particularly effective for predicting the statistical properties of turbulence on scales much smaller than stirring scales, yet larger than dissipative scales. In classical fluids, 3-D anisotropic turbulence tends towards isotropy and homogeneity with decreasing scales, hence it is eventually possible to apply the HIT model to them. In their study, however, Procaccia and his colleagues demonstrated that the opposite is true for superfluid $^4$He turbulence in 3-D counter-flow channel geometry, which becomes less isotropic as scales decrease, to the point of becoming almost two-dimensional.

The approach used by them involves a so-called 'two-fluid model' of superfluid helium. This model is based on the early work of Laszlo Tisza and Lev Landau back in 1940-1941, which was later improved by H. Hall, W.F. Vinen, I.M. Khalatnikov, and I.L Bekarevich.

"The model describes superfluid helium as an interpenetrating mixture of two fluids: a superfluid that moves without friction, and a normal viscous fluid that are coupled by a mutual friction," Procaccia explained.

Past studies carried out by two teams of researchers in Tallahassee, Florida and Prague examined superfluid helium under a temperature gradient, creating what is referred to as 'counter-flow'. As suggested by its name, in counter-flow
different components of a fluid flow in opposite
directions; the superfluid flows from the cold to the
hot side and the normal fluid from the hot to the
cold side.

"Our model rationalized some of these
experimental observations and predicted new
features that were later confirmed experimentally,"
Procaccia explained. "The main result of our study
is that contrary to classical turbulent flows which
become more and more isotropic at smaller scales,
the flow we examined becomes less and less
isotropic as the scales reduce."

Before they carried out their study, Procaccia and
his colleagues had theoretically predicted that their
experiments would lead to the observations that
they subsequently collected. However, the strength
of the effect they observed only became clear after
they carried out direct numerical simulations on a
EU supercomputer, in collaboration with a team of
researchers led by Luca Biferale. According to
Procaccia, their theoretical and numerical findings
have already motivated other experimental groups
to pursue further research into counter-flow
turbulence.

"At the Weizmann Institute, we are now developing
our theory further, being attentive to the new
experimental techniques that enable elaborate
studies of turbulence in superfluid helium,"
Procaccia said. "Our group continues to participate
in the analysis of new experimental data, hoping to
contribute to deeper understanding of superfluid
flows from laboratory experiments to cosmological
realization, such as neutron stars."

More information: L. Biferale et al. Superfluid
Helium in Three-Dimensional Counterflow Differs
Strongly from Classical Flows: Anisotropy on Small
Scales, Physical Review Letters (2019). DOI:
10.1103/PhysRevLett.122.144501

© 2019 Science X Network
APA citation: Study shows the difference between classical flows and superfluid helium in 3-D counter-
flow (2019, April 22) retrieved 11 April 2020 from https://phys.org/news/2019-04-difference-classical-
superfluid-helium-d.html