A scale-independent observable for turbulent pair-dispersion

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The Richardson-Obukhov law of pair dispersion was introduced nearly a century ago, predicting that the mean squared distance between pairs of Lagrangian particles in turbulence grows algebraically with time with an exponent of 3. However, this hallmark of turbulence theory has evaded unequivocal experimental confirmation ever since. Among the issues that make its verification difficult are having too small Reynolds numbers or observation volumes[1,2], which limit the available separation of scales, an intrinsic intermittency of the process[3], and an innate dependence on initial conditions[4,5]. To overcome these issues, we present a new way of identifying and verifying Richardson's law in empirical work using a new observable - the angle formed between the separation and the relative velocity vectors[6] (Fig. 1). Our theory predicts that the average value of this angle is a constant in the inertial range, as we confirm in an experiment and DNS. Moreover, this is a unique feature which enables identifying the super-diffusive regime in empirical work. Thus, our work allows to identify whether the super-diffusive regime exists in future experiments and at which scales, independently of the flow parameters. This presents a breakthrough in turbulent dispersion studies.

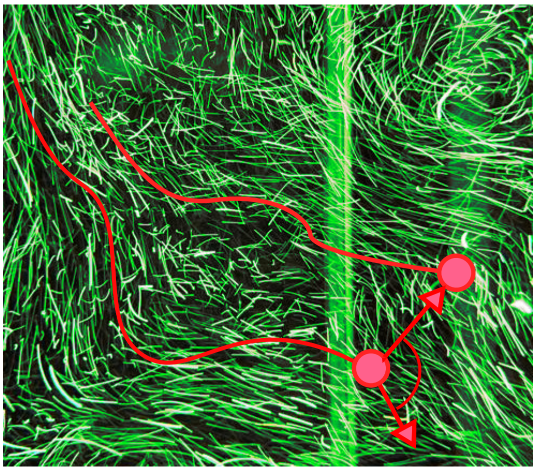

Figure 1: A sketch of two particles dispersing in a turbulent background flow, showing the relative position vector, the relative velocity vector and the angle between them.

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[1] Ott and Mann, *J. Fluid Mech.* **422** (2000).
[2] Ouellette, Xu, Bourgoin, and Bodenschatz, *New J. Phys.* **109**, 8(6) (2006).
[3] Scatamacchia, Biferale, and Toschi, *Phys. Rev. Lett.* **109**(14), 144501 (2012).
[4] Shnapp, and Liberzon, *Phys. Rev. Lett.* **120**(24), 244502 (2018).
[5] Tan, and Ni, *Phys. Rev. Lett.* **128**(11), 114502 (2022).
[6] Shnapp, Brizzolara, Neamtu Halic, Gambino, and Holzner, *arXiv*:2208.00320 (2022).