Relaxation Stages in a Nonequilibrium Closed Quantum System: Decaying Turbulence in a Trapped Superfluid

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The dynamics of nonequilibrium closed quantum systems and their route to thermalization are of fundamental interest to several fields, from cosmology to particle physics. However, a comprehensive description of nonequilibrium phenomena still presents a significant challenge. In this work, we report the observation of distinct stages during the relaxation of the decaying turbulence in trapped Bose-Einstein condensates. Our findings show a direct particle cascade from low to high momenta, a consequence of the energy injection in the system, exhibiting a characteristic universal scaling. This stage is followed by an inverse particle cascade responsible for repopulating the previously depleted condensate. Both cascades can be explained through self-similar solutions provided by wave turbulence theory. Many different situations are explored.