

Group-theoretical model of developed turbulence and renormalization of the Navier-Stokes equation

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On the basis of the Euler equation and its symmetry properties, this paper proposes a model of stationary homogeneous developed turbulence. A regularized averaging formula for the product of two fields is obtained. An equation for the averaged turbulent velocity field is derived from the Navier-Stokes equation by renormalization-group transformation.

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I. INTRODUCTION

There is a long history of the use of renormalization-group ideas in describing turbulence. In the profound books of McComb [1,2] and Frisch [3], one can find an extensive review on this subject. Among fundamental papers in the field are papers by Martin, Siggia, and Rose [4]; Forster, Nelson, and Stephen [5]; and Yakhot and Orszag [6]. The Navier-Stokes equation with random stirring forces is used as a mathematical model of turbulence in these fruitful but very sophisticated approaches. In contrast to these approaches, we propose here a mathematical model of developed turbulence that is based on special self-similar solutions of the Euler equation—therefore we do not need to introduce the external stirring forces. In our approach, we do not use the Fourier transform, perturbation series, or the sophisticated diagrammatic technique. The term “renormalization group” is broadly used in a variety of scenarios. At times, this term is used in situations where the transformation groups are not even considered. In our paper, we apply the idea of a renormalization group in its initial sense [7–9]. In relation to turbulence, we can roughly express Kadanoff’s idea of “block picture” for the spin field in Ising’s model as follows: If, instead of turbulent field $\mathbf{v}(\mathbf{r})$, we consider a field $\langle \mathbf{v} \rangle_\sigma(\mathbf{r})$ that is averaged on the scale σ , then the last one will “resemble” the original turbulent field $\mathbf{v}(\mathbf{r})$. The exact sense of “resemble” must be defined by the group of transformations for both fields and equations for these fields. Classical approaches [8,9] do not initially present the explicit expression for transformations from a renormalization group; they are provided, accurate to some unknown functions. Therefore, classical renormalization-group methods on the first step only exploit the fact that the symmetry exists. The transformations are then obtained in approximate form while considering the problem in the required range of the transformation parameter.

In this paper, solely on the basis of the Navier-Stokes equation, we propose a simple model of homogeneous stationary developed turbulence. This model allows us to explicitly derive the group of renormalization transformations. We average the Navier-Stokes equation over some small length scale σ_0 with the help of our averaging formula. Then we transform this averaged equation by a renormalization-

group transformation to the equation for the average over any scale σ velocity field $\langle \mathbf{v} \rangle_\sigma(\mathbf{r}, t)$, making use of symmetry properties of the base solution. Note that Frisch in his profound book [3] writes about applying the symmetries of Euler and Navier-Stokes equations in turbulence but he does not associate turbulence with the specific self-similar solutions of the Euler equation.

II. RENORMALIZED AVERAGING FORMULA

In different areas of physics (turbulence, kinetic theory, radiophysics, nonlinear dynamics), the averaged equations include the mean value of nonlinear terms. The fundamental problem in developing tractable quantitative theories is the closure of these equations. Specifically, the problem is obtaining the explicit expression for the averaged product of two functions in terms of their mean values. This section addresses this problem.

We derive the renormalized averaging formula on the basis of group properties of the specially chosen averaging procedure (Gaussian filtering). The method by which this formula has been obtained is similar to the method [10] used to rewrite (exactly) the Boltzmann collision integral in the divergence form. For simplicity, the analysis is initially performed for one space dimension and then extended for the general case of three (or more) dimensions.

Consider two functions $v(x)$ and $u(x)$ depending on one-dimensional real coordinate x , $-\infty < x < \infty$. The average of $v(x)$ is

$$\langle v \rangle(x) = \int_{-\infty}^{\infty} v(x') \Psi(x - x') dx', \quad (1)$$

where $\Psi(x)$ is a weight function. When this function is Gaussian,

$$\Psi_\sigma(x) = \frac{1}{\sqrt{4\pi\sigma}} e^{-x^2/4\sigma}, \quad (2)$$

the average is defined by Gauss transform (filtering),

$$\langle v \rangle(x) = \int_{-\infty}^{\infty} v(x') \Psi_\sigma(x - x') dx' = \hat{G}_\sigma v, \quad (3)$$

The Gaussian distribution verifies the diffusion equation,

Field Theoretic Renormalization Group In Fully Developed Turbulence

Padhraic Smyth



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web guest speaker invitation letter use this letter when you are contacting a potential speaker to invite him or her to speak at an event customize this letter according to your specific needs be sure to include any pertinent details such as the amount of guest speaker compensation if applicable

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web feb 15 2022 here s how that part of a guest speaker invitation letter might look an invitation letter example for this section would look something like this we re expecting 3 000 attendees and another 5 000 people to join the event online with an edited version available on our youtube channel after our event speakers usually present for 30 45

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web jun 5 2023 guest speaker invitation letter to name of the recipient address date sub letter of invitation for a guest speaker dear sir madam we are delighted by having the opportunity to invite you as a guest speaker in our school seminar to enlighten our precious students regarding the subject mention details they will be

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web speaker job title speaker address date 6 th september 2022 sub invitation letter to speaker dear x on behalf of an international technology conference i am pleased to invite you to our inaugural technology conference that will be held on 20 september 2016 this conference is the get together of the best 5 it company in our country