# Numerical modelling of the flame front dynamics

*V. Karlin and J. Mai*
*University of Central Lancashire, Preston, UK*

It was observed in experiments that expanding flame fronts do not remain smooth given enough time. Instead, a structure of cells is formed on their surface, and the flame fronts can even experience substantial acceleration. This phenomenon was linked with the intrinsic long wave instability of flame fronts which is also known as the Darrieus-Landau or the hydrodynamic flame instability. Huge variety of time and space scales involved makes it inefficient to study this phenomenon on the base of the general Navier-Stokes system. A hierarchy of asymptotic mathematical models of cellularization of hydrodynamically unstable flames was obtained as an alternative approach to the problem. For example, the Sivashinsky equation

$$\frac{\partial \Phi}{\partial t} - \frac{1}{2}\left|\nabla \Phi\right|^2 = \Delta\Phi + \frac{\gamma}{2}(-\Delta)^{1/2}\,\Phi, \quad \chi \in R^2, \quad t > 0, \qquad (1)$$

which governs evolution of the perturbation of the propagating plane flame front, was derived in [1]. A more sophisticated asymptotic model of expanding spherical flames was suggested in [2].

In spite of the fact that the asymptotic models of cellular flame dynamics are much simpler than the original Navier-Stokes system, they are still very difficult to solve. Accurate numerical resolution of the surface patterns requires substantial computing resources and the situation is worsened by the very high sensitivity of these patterns to noise [3]. The formation of a cell on the surface of a plane flame front and of a cellular structure on the surface of an expanding flame is illustrated in Figures 1 and 2 respectively. The calculations were carried out on the Cray T3E 1200 computer (Turing) in the Manchester Computing Centre. Details of the algorithm and its parallel implementation are given in [4].

So far, our investigations have demonstrated that the formation of the cellular structures is triggered by noise, which is always present both in numerical and physical experiments in one or another form. These essentially nonlinear cellular structures are generated through the huge linear transient nonmodal amplification of perturbations of noisy origins. Their final appearance and dynamics on the flame surface is governed by essentially nonlinear mechanisms intrinsic to the physics of the flame front dynamics. As the size of the flame increases, the nonmodal amplification of noise grows. Hence, the number of cells on the flame surface grows as well, contributing into its total area and, eventually, in the acceleration.

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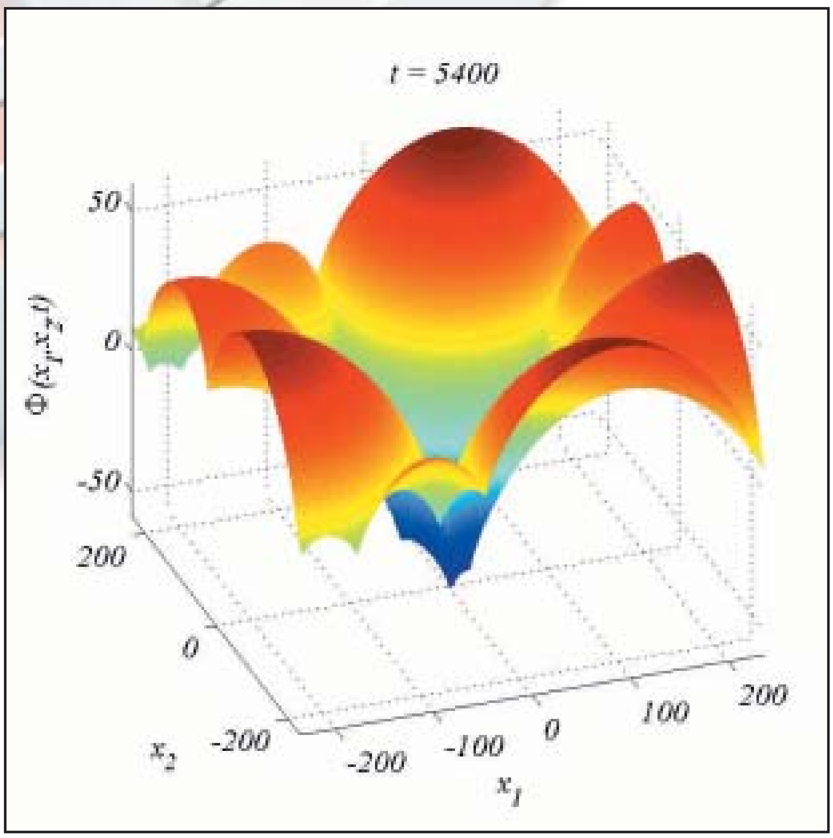


Figure 1: Formation of a cell on the surface of a plane flame front.

### References

[1] G.I. Sivashinsky. *Acta Astronautica*, 4:1177–1206, 1977.
[2] Y. D'Angelo, G. Joulin, and G. Boury. *Combustion Theory Modeling*, 4:1–22, 2000.
[3] V. Karlin. *Proc. Combustion Institute*, 29(2):1537–1542, 2002.
[4] V. Karlin, V. Maz'ya, and G. Schmidt. *J. Computational Physics*, 188(1):209–231, 2003.

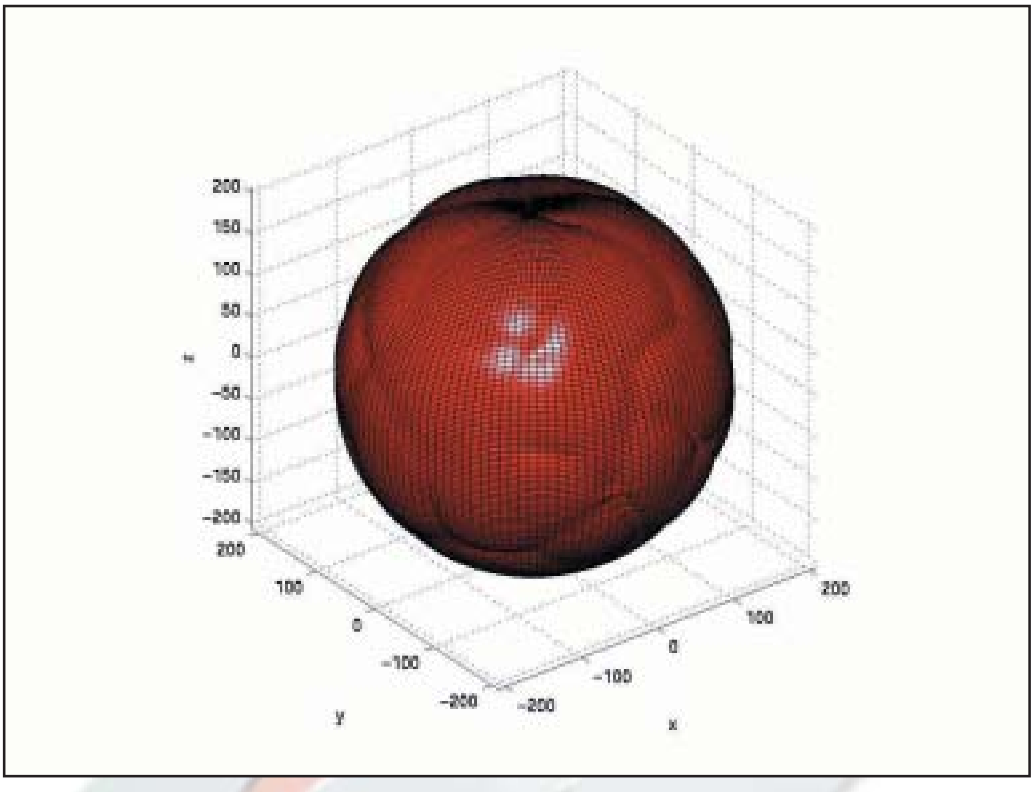


Figure 2: Formation of a cellular structure on the surface of a spherical flame front as a result of a stochastic perturbation.