The 8 Best Contributions of Leon van Dommelen

Leon van Dommelen

For my official retirement from the FAMU-FSU College of Engineering, my department chair asked me to give him a few key pictures with legends illustrating my most important contributions. I ended up with 8 pictures that I felt I could not leave out.

My chair used only three, for a plaque. But in the following pages you find the entire set.

Enjoy.

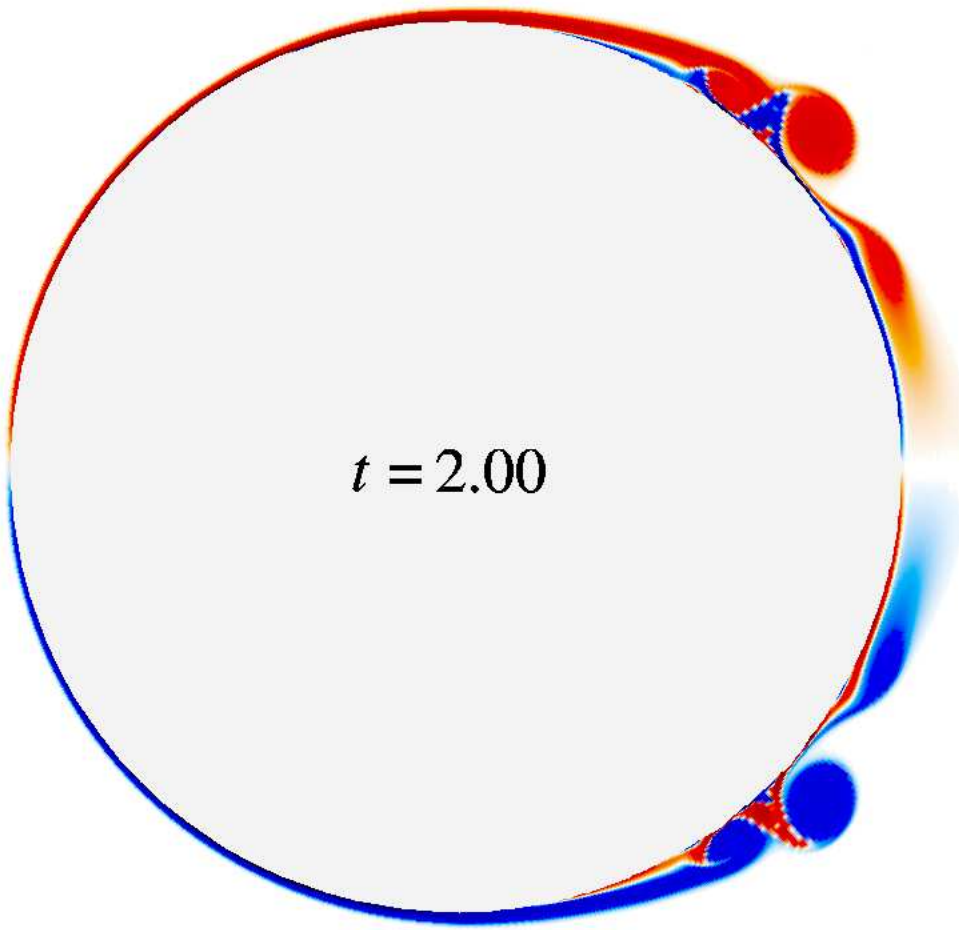

Figure 1: Flow around a circular cylinder started from rest. The break-up of initially thin and smooth boundary layers around solid bodies into discrete vortices, as in the picture, is due to a process now generally known as the "Van Dommelen & Shen" singularity. After the fluid mechanics community had come to the consensus that no such break up occurred, Van Dommelen and Shen showed numerically that, actually, it does. They did this by developing a new "Lagrangian" numerical scheme that allowed the flow to be computed accurately for a time longer than previously possible. Van Dommelen and Shen then proceeded to study the structure of the process theoretically. They showed that its nature was dramatically different from the break-up hypothesized by earlier authors. [With PhD advisor Shan-Fu Shen at Cornell University.]

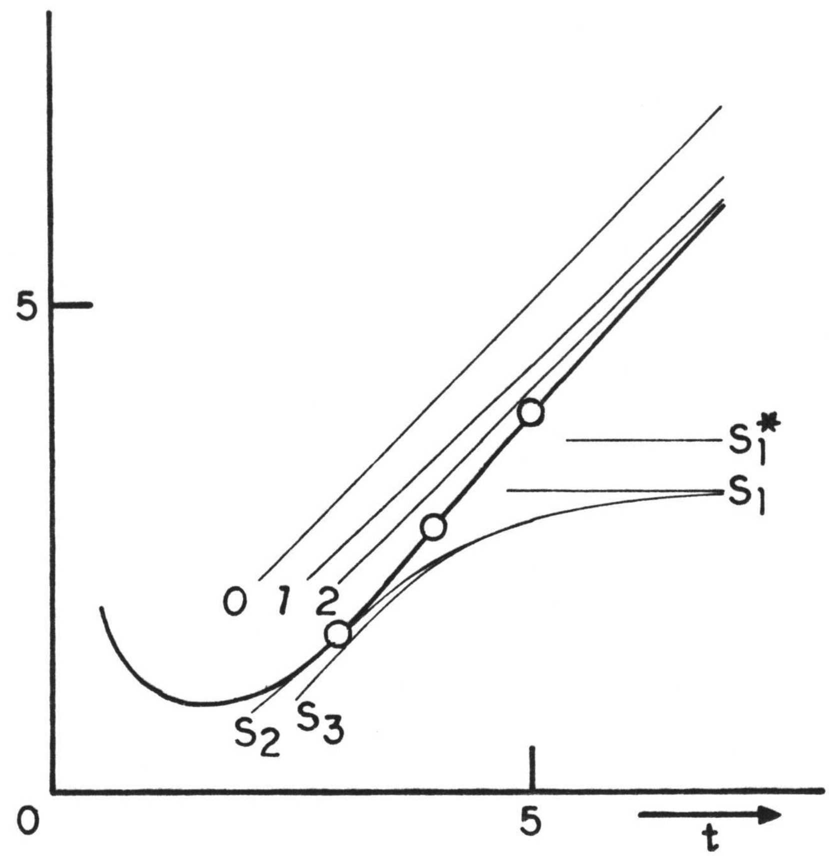

Figure 2: The plot shows the scaled unsteady boundary layer thickness near the rear stagnation of a bluff body like a circular cylinder. There was a recognized problem with this flow as numerical data for the thickness, (thick line and circles), disagreed somewhat from the existing theory, (S_1, S_2, S_3). Van Dommelen and Shen explained why. While only theoretical fluid dynamicists may care how thick the boundary layer really is, there is a catch. Van Dommelen and Shen showed that effects that are initially very small grow to dominate the flow. They warned that this may produce produce numerical problems in the numerical solution of flows around bluff bodies. This was confirmed many years later by PhD student Shankar Subramaniam, to his embarrassment. Van Dommelen writes "The rear stagnation point was the most satisfying investigation in my life. While the Van Dommelen & Shen singularity may be more important for fluid dynamics, there I just moved from one blunder to the next. With the stagnation point, I had my initial suspicions of what was going on, and once I got the mathematics worked out, they were nicely confirmed. There is also a rare beauty in how the successive approximations 0, 1, and 2 nicely fold into the exact curve with absolutely no help from me." [With Shan-Fu Shen at Cornell University.]

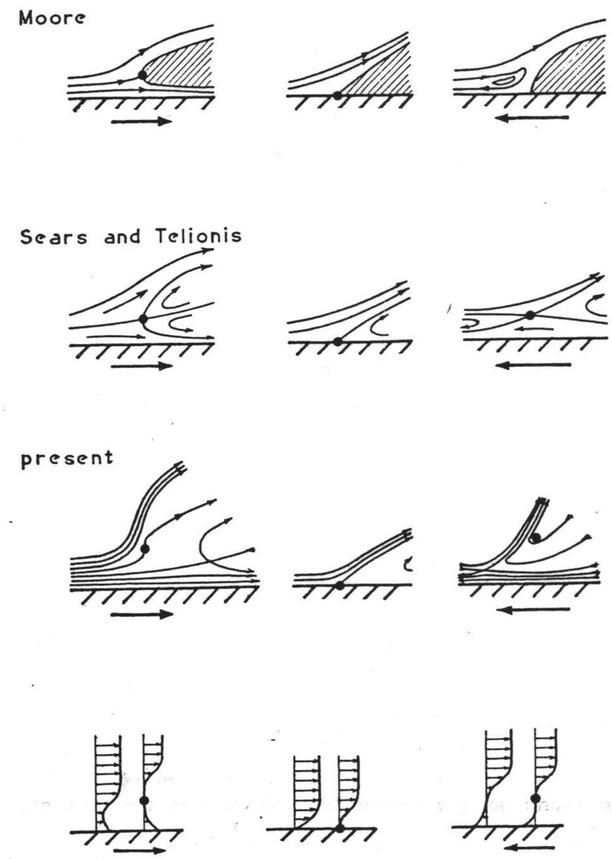

Figure 3: Sketches of how in flows around smooth bodies, fully developed boundary layers will separate from the surface of the bodies. This phenomenon is of great practical importance, as it dramatically increases the flow resistance of the bodies and inversely affects stability. The structure of the detachment process depends on whether the point of separation moves upstream, downstream, or not, compared to the local surface of the body. The structure when the separation point is not moving compared to the surface was settled by V.V. Sychev and F.T. Smith well before Van Dommelen started working in boundary layers. There was also a proposal for the case that the separation moves upstream compared to the wall by Vic.V. Sychev. However, Van Dommelen and Shen showed that this proposal was not possible. They formulated a modified proposal that was. The corrected flow field was worked out to higher degree of approximation by J. Elliot, S. Cowley, and F.T. Smith and is presumably settled. The case that the separation moves downstream however is quite different. Here very little is solidly established, analytically, numerically, or experimentally. Van Dommelen and Shen developed a solution showing how the process may occur, the only one available at present that may qualitative explain the measurements of G. Ludwig. However, it is incomplete and limited to restricted circumstances. [With Shan-Fu Shen at Cornell University.]

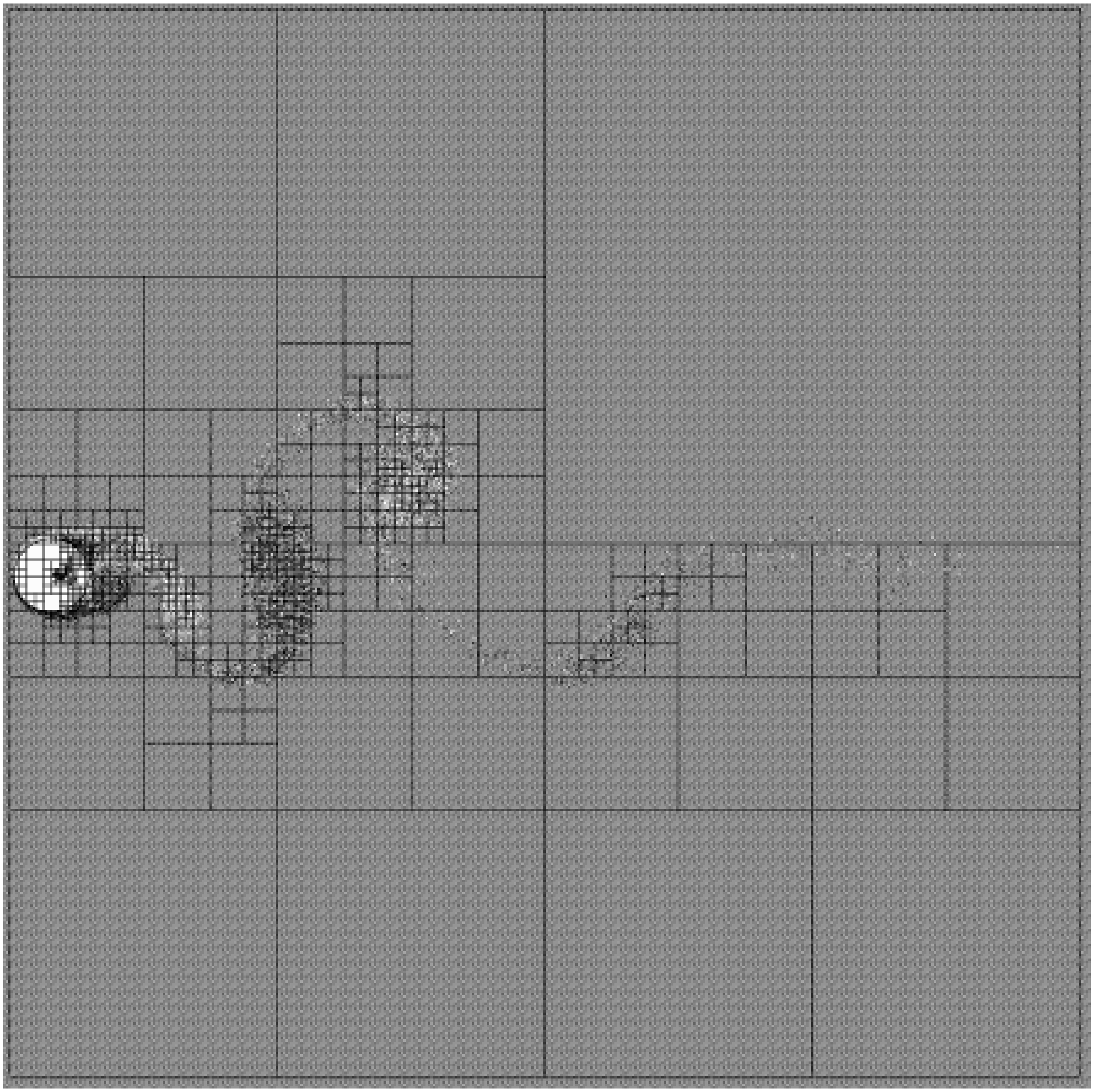

Figure 4: Adaptive fast velocity summation, also known as adaptive fast multipole method. This addresses such questions as how to find the motion of stars and planets, the forces exerted by sparsely distributed electrical charges, and many other problems. In principle these tasks are straightforward, but unfortunately, they take excessive computational time. Fast methods cut down on the time needed by identifying acceptable approximations that can be made. To do so, the region is subdivided into squares as shown in the picture, such that the amount of bodies / charges / etcetera in each smallest square is limited. L. Greengard received recognition as “One of the Best Numerical Algorithms of the [twentieth] Century” for his scheme. However, Van Dommelen and Ründensteiner presented an adaptive version of essentially the same algorithm well before Greengard. In addition, Van Dommelen and Ründensteiner managed to do this efficiently on, at that time, an advanced Supercomputer, the CYBER 205 (later the ETA 10). That was quite an achievement, as the original algorithm was already very fast on a computer like that. [With Elke Ründensteiner, a computer science graduate student at the Florida State University.]

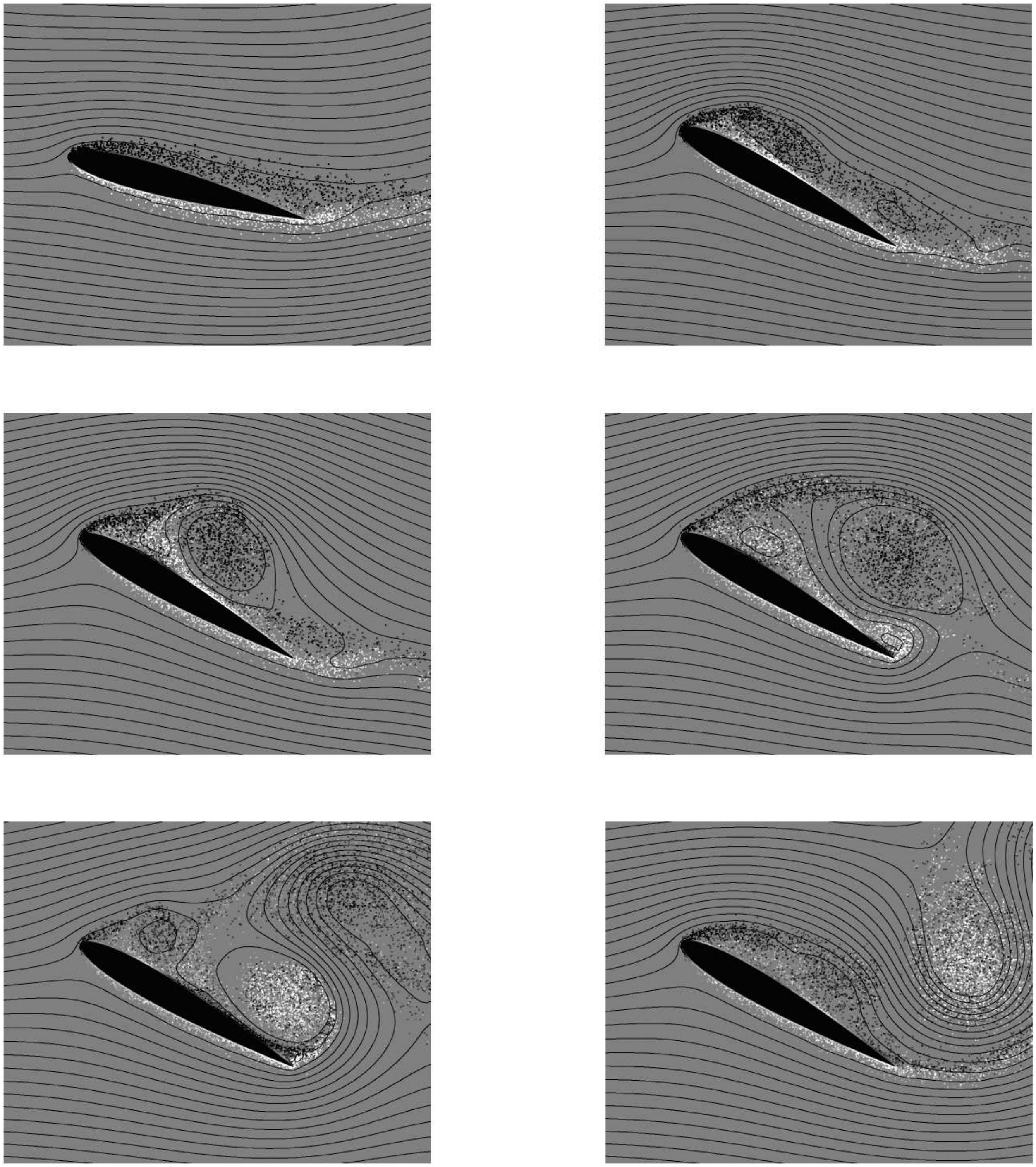

Figure 5: Most people who know Leon van Dommelen but are not fluid dynamicists probably do so because of the pictures above, made by Szu-Chuan Wang. The pictures show the process of separation from an airplane wing (in cross-section). Van Dommelen put them in a web page, with a description of how they relate to airplane stalls and spins, when the web was young. This page proved to be very popular, creating large amounts of hits. It has been translated in many languages. [With PhD student Szu-Chuan Wang at the FAMU-FSU College of Engineering.]

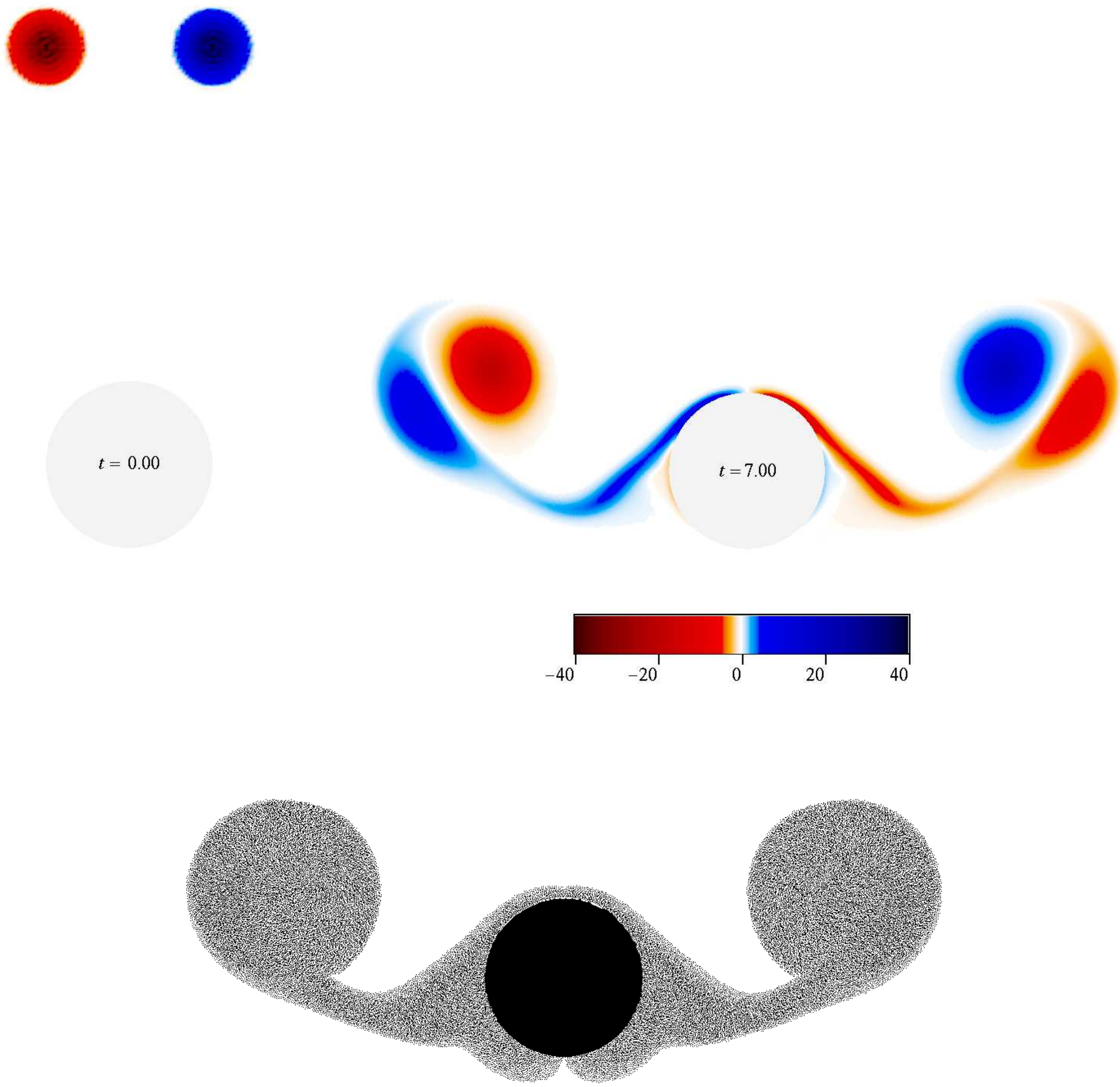

Figure 6: A pair of diffusing vortices bounces off a circular cylinder, by inducing a separating boundary layer on the cylinder surface. Even more interesting than the flow is the way it has been computed. It was done by a new numerical method, the "Redistribution Method" developed by Shankar Subramaniam and Van Dommelen. The computation is initiated by representing the initial two vortices at the desired location by patches of computational points. The new method then automatically adds more computational points to simulate both the thickening of the vortices and the generation and evolution of the induced boundary layer on the cylinder surface. As the final picture shows, the method *only* adds vortices where there is vorticity to be represented. For the classical problem of an impulsively started circular cylinder at Reynolds number 9,500, the new scheme further proved to be of astonishing accuracy, with results matched only by the spectral element method of Kruse and Fisher using on the order of ten thousand spectral elements. A modified distribution method (that loses many of the interesting features) was subsequently developed at the Massachusetts Institute of Technology. [With PhD student Shankar Subramaniam at the FAMU-FSU College of Engineering.]

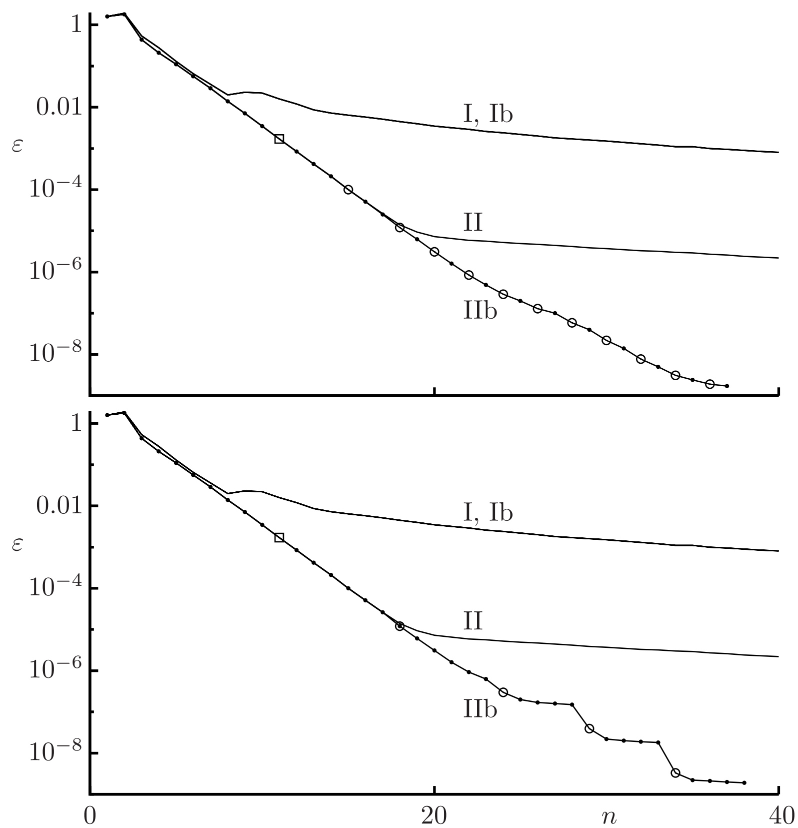

Figure 7: The picture shows how a new numerical procedure (IIb) developed by Van Dommelen quickly reduces the errors in a numerical computation to an acceptable level. The fact that the error keeps going down at a constant rate makes it what is technically called a "fast" method. It is a reformulation of a widely used numerical procedure called the SIMPLE method. Despite its acronym, the SIMPLE method is *not* simple, *not* reliable, and *not* fast. The new algorithm is all of the above.

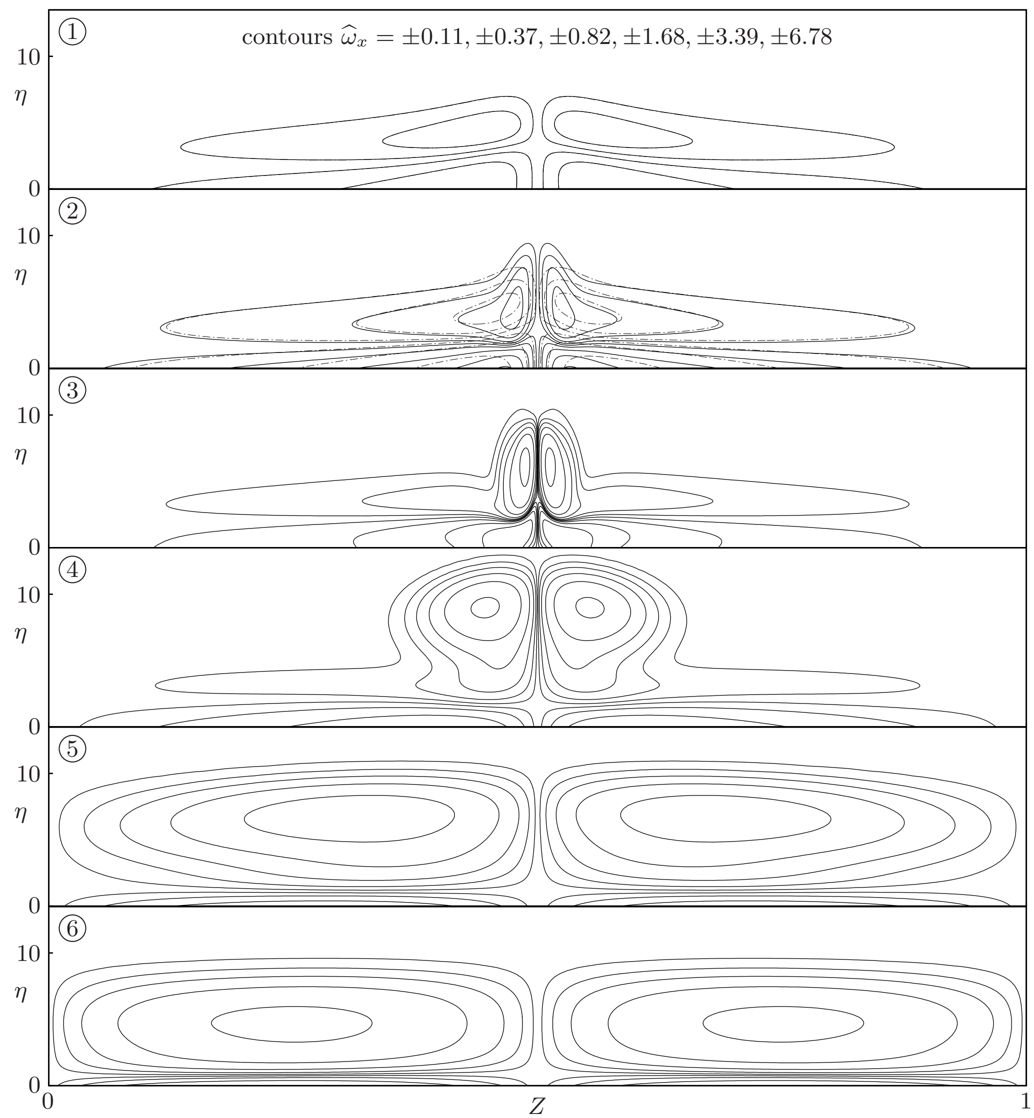

Figure 8: An iconic picture showing the complex three dimensional inner structure of an example boundary layer in which blowing through the surface is used to eliminate separation. Cross-plane vorticity contours are shown at successive streamwise locations. Experimentally, blowing through the surface to prevent separation using microjets was pioneered by A. Krothapalli of the FAMU-FSU College of Engineering and his many collaborators. However, theoretically the method was not at all understood. Van Dommelen and Yapalparvi pioneered consideration of short-scale three-dimensional effects in understanding what happens. In particular, they proved that two-dimensional blowing (like through a long spanwise slot) does not work; it cannot eliminate separation. But they also showed, through the solution above, that in the presence of three-dimensionality, blowing can indeed eliminate separation. [With Ramesh Yapalparvi, then at the FAMU-FSU College of Engineering.]