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**FINAL TECHNICAL REPORT FOR F49620-93-1-0457**

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## AASERT FINAL REPORT

### “Topics in Astrophysical Fluid Dynamics”

Edward A. Spiegel, Principal Investigator

Award number: F49620-93-1-0457

### Personnel

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#### Alex R. Casti

Casti worked for a time on a project in nonlinear stability theory, described in a previous report, but received a setback in the form of the appearance of a related work in the literature. He then attended the summer program in geophysical fluid dynamics in Woods Hole, where he began work on thermohaline convection in collaboration with N.J. Balmforth, a former participant in the parent grant. Thermohaline convection is a form of doubly diffusive convection and is thus a simple version of magnetoconvection. Both dissolved salt and magnetic fields can affect the local bouancy of a fluid, but dissolved salt, being represented by a scalar field, is somewhat easier to deal with mathematically and some interesting progress is possible. This form of convection will also occur in the cores of certain stars, including the sun, in the course of their evolution, the role of dissolved salt being taken by helium in the stellar case. In that case, it is called semiconvection. Two papers have been written with Balmforth on this project and submitted for publication.

To round out his dissertation, Casti has been working on the gravitational instability of two interpenetrating, barotropic fluids interacting only through gravity. If there is an initial relative velocity between the two fluids, small perturbations are unstable at all wavenumbers in some range of Mach numbers. By exploiting the analogy between this problem and the two-stream instability of plasma physics, it has been possible to demonstrate the existence of negative energy modes from the indefiniteness of the energy functional. This allows for explosive nonlinear growth even in situations for which the linear theory predicts absolute stability. Casti will present a poster on this work, in collaboration with P.J. Morrison of Fusion Institute of the University of Texas, at the next meeting of the AAS. It is expected that Casti will defend his dissertation in the present academic year.

## Orkan M. Umurhan

Umurhan has extended his earlier calculations of acoustic instability in stellar atmospheres to the nonlinear regime. He now has a complete discussion of such instability with extensive analytical and numerical results. In his study he has examined the instabilities of nonadiabatic acoustic modes in plane parallel atmospheres where the source of nonadiabaticity is thermal conduction. Since he has adopted a constant coefficient of thermal conduction, this instability is not the conventional  $\kappa$ -mechanism.

Umurhan has adopted a polytropic static state in which the density is related to the pressure by a polytropic index  $m$ . He has solved the resulting fourth order eigenvalue problem describing perturbations by a variety of asymptotic and numerical methods. He finds that disturbances are unstable under a variety of parameter regimes including conditions where the background polytrope is either super- or subadiabatic. Two main instabilities emerge and one of them resembles the thermoacoustic engine familiar in industrial applications. He has also gone on to develop a weakly nonlinear theory of the unstable acoustic modes. Umurhan will present a poster on this work at the forthcoming AAS meeting.

In the course of coupling the acoustic modes to the convective modes, Umurhan has made an interesting contribution to convective pattern theory in the low Prandtl number limit. (The Prandtl number is the ratio of viscosity to conductivity and, though it is of order unity in most laboratory experiments, it is quite small in stars.) In particular, he has derived a new nonlinear pattern equation for fixed-flux convection, which generalizes the one used for laboratory convection. Two papers on this work are in preparation. This work will complete Umurhan's dissertation research and he is engaged in the process of preparing his thesis for the final defense.