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Biocomplexity Faculty Search Committee
c/o Prof. Rob de Ruyter van Steveninck
Biocomplexity Institute
Indiana University
Swain Hall West 117
Bloomington IN 47405-7105

Re: Dezhe Jin

It is a pleasure to write a strong letter of recommendation for Dezhe Jin's application for an assistant professor position at Indiana University.

Dezhe completed a PhD. with me in 1999 and subsequently worked with me as a postdoc for one year before heading to MIT to work in computational neuroscience. His research with me fell in the general areas of theoretical/computational fluid dynamics and plasma physics. He focused on the 2D dynamics of inviscid Euler fluid flow in a bounded domain, which is isomorphic to the dynamics of a 2D plasma in the ExB drift limit. His work therefore supported the non-neutral plasma experimental effort here.

I cannot comment in any detail on Dezhe's recent work in biophysics, as this research is beyond my area of expertise. I do think that it is impressive that he was able to move into this new area with such apparent ease. I am told that his recent PRL describing a new dynamical model for neural networks is important and imaginative work (D. Jin, Phys. Rev. Lett. **89**, 208102 (2002)). This new work exhibits many of the same strengths shown by Dezhe during our collaborations - facility with computer simulations, impressive analytic ability, and strong intuition and model-building skills. I am not really surprised by his recent success given his strengths as a physicist.

Below, I briefly summarize the work he did for me in the area of theoretical and computational plasma physics/fluid dynamics.

Dezhe's work in these areas was well received, resulting in several papers in high-profile journals, invited talks at the American Physical Society, and coverage in the popular press.

Dezhe focused on the equilibrium and dynamics of vortex crystals. Vortex crystals are stable, geometrically regular arrays of strong self-trapped vortices immersed in a lower vorticity background; the ratio of the background vorticity level to that in the strong vortices is typically on the order of 1/10. The crystals are found experimentally to form from turbulent flows consisting of many randomly located strong vortices. These crystals had never previously been observed to form from the inviscid relaxation of a turbulent initial condition, and Dezhe's work constitutes the best current understanding of the formation process and the final equilibrium state.

Dezhe's thesis work comes in three parts, attacking three different aspects of this phenomenon. In the first part, we developed a theory based on a variation of maximum entropy analysis in order to explain the final state of the crystal- the positions of the strong vortices and the vorticity distribution in the background. The theory supposes that the background vorticity is ergodically mixed by the strong vortices, driving the background to a maximum entropy state subject to the constraints that the robust integrals of the motion are conserved, and that the flow is inviscid (i.e. the microscopic vorticity elements making up the background flow are incompressible). However, the vorticity in the strong vortices themselves is self-trapped and is therefore assumed not to contribute to the entropy of the system – i.e. the strong vortices are treated as pointlike without internal degrees of freedom. The theory matches the experiments quite well, without adjustable parameters except that the number of strong vortices in the final state must be specified in the theory. This work was published in physical review letters (Jin and Dubin, Phys. Rev. Lett. **80**, 4434 (1998)), and has also been the subject of some attention in the popular scientific press ('From a Turbulent Maelstrom, Order', by J. Glanz in Science **280**, 519 (1998)).

There was a considerable amount of computational as well as analytic work required in this problem. Dezhe is an accomplished programmer both in C and in Fortran, and was able to solve the required 2D nonlinear Poisson equation using a multigrid relaxation method that he wrote himself.

The second part of Dezhe's thesis considers the motion of several strong vortices in a Top-Hat background vorticity distribution, in order to understand the early-time dynamical interaction between the vortices and the background. This work involved a quite complex analytic two-timescale analysis involving the relatively slow motion of the vortices through the background and the relatively fast motion of Kelvin waves on the surface, keeping nonlinear effects. Wave-breaking of the background was observed to be enhanced by the presence of the strong vortices, and a nonlinear contour dynamics simulation of the fluid flow (again, which Dezhe wrote himself) was shown to match the analytics quite well. (Phys. Fluids **13**, 677 (2001).) The predictions of this theory were recently verified in experiments at UC Berkeley (Durkin and Fajans, Phys. Rev. Lett. **85**, 4055 (2000).)

The final part of Dezhe's thesis is an attack on the missing ingredient in the theory of the vortex crystal state: a way to predict for given initial conditions the number of strong vortices in the final state. Based on Dezhe's work in the first two chapters, the formation of the crystal can be seen as a competition between 2 processes: mergers of the strong vortices which reduce the number of vortices toward a final state consisting of a single strong vortex; and cooling of the chaotic motions of the strong vortices caused by the vortices mixing the background, which eventually impedes the merger process since the vortices no-longer have sufficient energy to approach one-another closely enough to merge. The average time between mergers can be estimated on the basis of punctuated Hamiltonian dynamics, but the time required for cooling is not well-understood. Dezhe's inspiration was to estimate this cooling time as the time required to mix the background (i.e. the cooling time is approximately the inverse of the Lyapunov exponent of the background flow in the field created by the strong vortices. Both the time between mergers and the cooling time depends on the number and intensity of the strong vortices, and when the cooling time becomes shorter than the time between mergers, mergers cease, determining the number of vortices in the final crystal state. On the basis of comparison to the experiments as well as to particle in cell simulations carried out by Dezhe it appears that Dezhe's theory can predict within a factor of 2 or so the number of final vortices in the crystal. This work appeared in physical review letters (Jin and Dubin, Phys Rev. Lett. **84**, 1443 (2000).

Dezhe is extremely bright, and very creative. For example, the idea put forward in the third chapter of his thesis, that the cooling rate of the strong vortices can be estimated as the Lyapunov exponent of the background flow, was entirely his. At our group meetings he constantly bubbled with new ideas. It is often the case that graduate students have a hard time focussing on the important physics and require constant supervision to keep them on track. This was far from the case with Dezhe. He is a self-starter, quite aggressive in following the physics, and has excellent physical intuition. Dezhe is also quite broad, with excellent analytic capabilities as well as broad computational experience.

Although Dezhe's teaching experience has been confined to the usual teaching assistantships and grading positions, I have seen Dezhe give several lectures on his research, and they were always well-organized and very clear. Dezhe is an exceptional public speaker, able to present even quite complicated physics ideas quite clearly. We used to have a departmental oral topic exam, and when Dezhe presented his topic, one faculty member on the exam committee approached me afterwards (I was not on this committee) and told me that Dezhe's performance was the best he had ever seen.

In my career I have been lucky to attract several good students, but Dezhe ranks as the very best so far. I would be happy to have him as a faculty member in our physics department.

Sincerely yours,

Daniel H.E. Dubin
Professor of Physics
UC San Diego