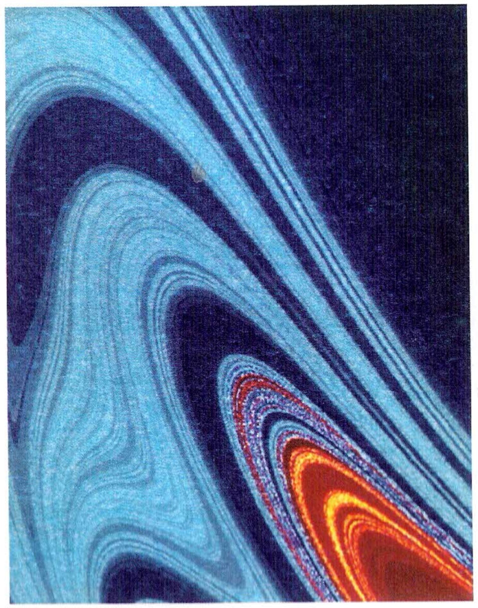
Dynamics Days 2012

Poster Abstracts



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16. **Flights in a pseudochaotic system**

John Lowenstein, *New York University*

We consider the problem of transport in a one-parameter family of piecewise rotations of the torus, for rotation number approaching 1/4. This is a zero-entropy system which in this limit exhibits a divided phase space, with island chains immersed in a pseudochaotic region. We identify a novel mechanism for long-range transport, namely the adiabatic destruction of accelerator-mode islands. This process originates from the approximate translational invariance of the phase space, and leads to long flights of linear motion, for a significant measure of initial conditions. We find an interesting consequence of time-reversal invariance in the model: most long flights are followed by equally long flights in the opposite direction, a phenomenon which greatly enhances the production of periodic orbits and their associated islands of stability.

17. **Topological Reversibility Dense Granular Flows Under Oscillatory Shear**

Mitchell Mailman, *University of Maryland*

Recent experiments[1] have demonstrated that tools borrowed from complex network analysis can be used to characterize novel mesoscale features of dense granular flows. In particular, a characteristic strain can be associated with a topological transition in the broken link (BL) network, which is attributed to the emergence of a giant component of the network. We present experimental and numerical results that extend the BL network analysis to cyclic shear. We find that while such granular flows are clearly not spatially reversible, a characteristic reversal amplitude leads to a similar topological transition. This transition is reminiscent of a reversible/irriversible transition in that the largest network component disappears after shear reversal, unless the reversal amplitude is large enough for a giant component to emerge, which persists through all shear cycles.

References:

[1]Herrera et al, "Path to fracture in granular flows: Dynamics of contact networks," PRL 83, 061303 (2011)

18. **Linear stability of time-dependent fluid flows**

Shreyas Mandre, *Brown University*

We present a mathematical framework for performing the linear stability analysis of time-dependent background flows. Instabilities of unsteady flows are ubiquitous in nature, and a rigorous framework for analyzing and understanding them has not been available. We identify two physical examples to highlight the significance of such methods. The first example is from droplet splashing and the second from carbon dioxide sequestration. The existing methods for linear stability of time-dependent flows are either approximate or their results depend sensitively upon the details of the implementation. The approximate methods simply freeze the unsteady background flow at one instance, ignore the time-dependence of the background flow, and apply traditional modal theories of hydrodynamic stability. Modern methods analyze the amplification of a norm of the linear perturbations, but this analysis results in different amplification factors depending on the norm used. Moreover, even for steady background flow, these methods could result in qualitatively different conclusions. In this

research, we resolve the drawbacks of each method by unifying them in a common framework.

The physical systems identified as model problems are significant in their own right. They also serve as ideal model problems to highlight the differences between traditional hydrodynamic stability and our method. The rational mathematical framework for analyzing stability of unsteady flows that we develop is applicable to any unsteady flow. Since most flows in nature are unsteady, such a framework will be widely used in the scientific community to understand unsteady dynamics. Along with the mathematical framework we also derive and develop numerical algorithms to efficiently compute the stability properties of the unsteady flow. An ecology of mathematical and physical problems result from our mathematical framework. The framework lends itself to classification and organization of the linear instabilities, analogous to the classification of bifurcations in the field of dynamical systems. The framework also begs the question whether a weakly nonlinear analysis can be carried out for unstable unsteady flows.

19. **How to organize your biochemical reactions: Lessons learned from cyanobacteria**

Niall Mangan, *Harvard University Systems Biology PhD Program*

Cyanobacteria are model organisms for photosynthesis and are of interest for bio-fuel production and carbon dioxide sequestration. I mathematically model the carbon concentrating mechanism (CCM) in cyanobacteria. The CCM is a combination of transporters and enzymes distinctively organized in the cell, which increase the internal concentration of carbon dioxide, and thereby improve the efficiency of converting carbon dioxide to sugar within the cell. I model the carbon concentration in the cell using reaction-diffusion equations, which I solve using a finite-difference method and analytic techniques. Understanding the CCM in cyanobacteria will give us insight into design principles for the cellular organization of biological reactions.

20. **Scale invariance of textural and spectral patterns of Brazilian Cerrado physiognomies**

Sergio H.V.L. Mattos, *Dept.Geography-Inst.Geosciences-State University of Campinas (Unicamp)*

Landscape patterns are strictly related to geoecological process. So, analysis of these patterns may reveal the dynamic of a landscape. Patternsí studies are specially important when system dynamic is not well understood, as is the case of Brazilian Cerrado. Composed for several phytophysiognomies, Cerrado varies since a totally open to forest formations. A still open question is what dynamic governs Cerrado organization. In present study, we had evaluated complexity of textural and spectral patterns of remote sensing images of Cerrado physiognomies with the objective to verify if they could show some hints about Cerrado dynamics. For this purpose, three conservation reserves with different Cerrado physiognomies were selected and, for each physiognomy/area chosen, textural and spectral patterns of three sample-areas were obtained from images of Aster multispectral sensor. Complexity of textural and spectral patterns were calculated using methods derivate of fractal mathematics (fractal dimension) and informational entropy (LMC measure and H/Hmax). Results had pointed out that measures based on informational entropy were more efficient than fractal dimension to attributed higher values of complexity to Cerrado physiognomies with textural and spectral patterns more heterogeneous. There was also a strong tendency

that each physiognomy presents the same values at different localities, attributing a typical range of values for each one, independent of its localization. For different extents of a same physiognomy/area, it was very frequent that no statically differences between patterns values had been found, both in spectral as in textural analysis (in this last case, only for fractal measures). This self-similarity of physiognomies patterns at different scales suggests that scalar invariance is a relevant characteristic of Cerrado organization and dynamic, which could be associated to multiscalar phenomena responsible for these patterns. Scalar invariance is also indicative that Cerrado would present self-organized criticality, with some of their physiognomies representatives of states near to critical points. Results suggest that intermediary physiognomies would present this type of organization, while more extreme physiognomies would represent more stable states.
Key-words: criticality, complexity, entropy, fractal, self-similarity

21. Chaos and the Quantum: How Nonlinear Dynamics Can Produce Classical Correlations Analogous to Quantum Entanglement

Wm. C. McHarris, *Michigan State University*

In recent years I have suggested that many of the so-called paradoxes resulting from the Copenhagen interpretation of quantum mechanics might well have more logically satisfying parallels based in nonlinear dynamics and chaos theory [WCM, Complexity 12(4), 12 (2007); 'Proceedings of the 5th International Workshop DICE2010: Space-Time-Matter Current Issues in Quantum Mechanics and Beyond,' J. Phys.: Conf. Ser. 306, 012050 (2011)]. From such arguments one can infer that quantum mechanics might not be the strictly linear science that orthodoxy postulates. Indeed, quite recently experimentalists reported definite signatures of chaotic behavior in an unquestionably quantum system [S. Chadhury et al., Nature 461, 768 (8 Oct 2009)]. As an example of what can go amiss when quantum behavior is forced into a linear interpretation, I examine Bell-type inequalities. In conventional derivations of such inequalities, a classical system imposes an upper limit on statistically correlated properties of a pair of entangled particles as measured by observers separated by an effectively infinite, incommunicado distance. (Most often these are correlations in spin orientation for particles in a Bell singlet state.) Quantum mechanics, conversely, allows greater statistical correlations and numerous sophisticated experiments have upheld the quantum mechanical predictions! The inference is that a measurement made on particle 1 instantaneously collapses the wave function of particle 2, i.e., superluminal signals are transmitted between the particles, violating the tenets of relativity. Upon closer examination, I argue that the fault lies not with the quantum mechanical side of such derivations (the usual point of attack by those seeking to debunk Bell- type arguments), but that implicit in the derivations for the so-called classical side (such as for the ubiquitous CHSH inequality [J. Clauser, M. A. Horne, A. Shimony, and R. Holt, Phys. Rev. Lett. 23, 880 (1969)]) is the assumption of independent, uncorrelated particles. Thus, one winds up comparing independent probabilities against conditional probabilities rather than comparing classical mechanics versus quantum mechanics. Now, if one examines nonlinear dynamics and chaotic systems, including emergent classical systems, one finds that many such systems exhibit correlations that can easily be as great as those found in quantum systems. Various explanations have been proposed, including the fact that nonergodic behavior of nonuniform or preferential visitation of various regions in phase space by nonlinear trajectories can easily ape action-at-a-distance. Nonextensive thermodynamics has verified this with numerous examples

[Nonextensive Entropy: Interdisciplinary Applications, M. Gell-Mann and C. Tsallis, eds., Oxford: Oxford Univ. Press (2004)]. In short, classical nonlinear dynamics involves many of the same sort of superficially counterintuitive, imponderable paradoxes as does quantum mechanics; when examined in depth, however, the classical ìparadoxesî dissolve into relatively logical explanations. This encourages one to raise the question as to whether or not quantum mechanics might contain nonlinear elements. When quantum mechanics was being developed, nonlinear dynamics, and especially chaos theory, were for all practical purposes terra incognita. Thus, quantum mechanics was necessarily shaped according to a linear template. If, however, one were to allow the possibility that nonlinear dynamics and chaos theory could lead toward an emergent quantum mechanics, then they could well provide a bridge between the determinism so dear to Einstein and the statistical interpretation essential to the Copenhagen interpretation. Perhaps both Einstein and Bohr were correct in their debates over the fundamental meaning and completeness of quantum mechanics.

22. How the Dynamics of Host-Parasite Interactions in Malaria Can Affect Disease Transmission

Philip G McQueen, *National Institutes of Health*

Analysis of host-parasite systems can benefit immensely from John Maynard Smith's prescription that mathematical modeling (1) 'provides a rapid way of discovering the kind of effect various features may have on the behavior of a population,' and (2) 'suggests what needs to be measured before the behavior of any particular species can be understood.' Vertebrate host immune responses are complex, self- amplifying and self-limiting: knowledge of relevant parameters and even the actual immune mechanism are difficult to obtain. The parasite, too, may evolve elaborate biochemical mechanisms to evade or modulate host immune response. But the logical outcome of the presence of a specific interaction in this system can be accessed by building mathematical models incorporating the suspected interaction.

Here I focus on human malarias, diseases caused by single-cell eukaryotes of phylum Apicomplexa, genus Plasmodium. These organisms have a complex life cycle, with asexually dividing forms attacking red blood cells, but with specialized sexual forms (gametocytes) taken up by the mosquito vectors and mating in the insect. Field studies indicate that gametocytes trigger host antibodies, yet patients can transmit malaria for weeks after they clear the asexual forms. I present results of simulated malaria infection using models incorporating various possible host immune mechanisms against the gametocytes. A major result is that the immune evasion strategy needed by the parasite to ensure its transmission to the vector depends crucially on the developmental stage of gametocytes targeted by host antibodies. Antibodies attacking the immature gametocytes (which cannot mate) would reduce gametocyte density in the blood overall, limiting the number taken in a mosquito bite, assuming that gametocyte density is uniform in the blood volume. Such an attack by the host could be overcome if mature gametocytes could concentrate themselves in skin capillaries. However, antibodies to the mature forms would still reduce the window of time for transmission. Then the mature gametocyte would need some other evasion mechanism to ensure transmission.