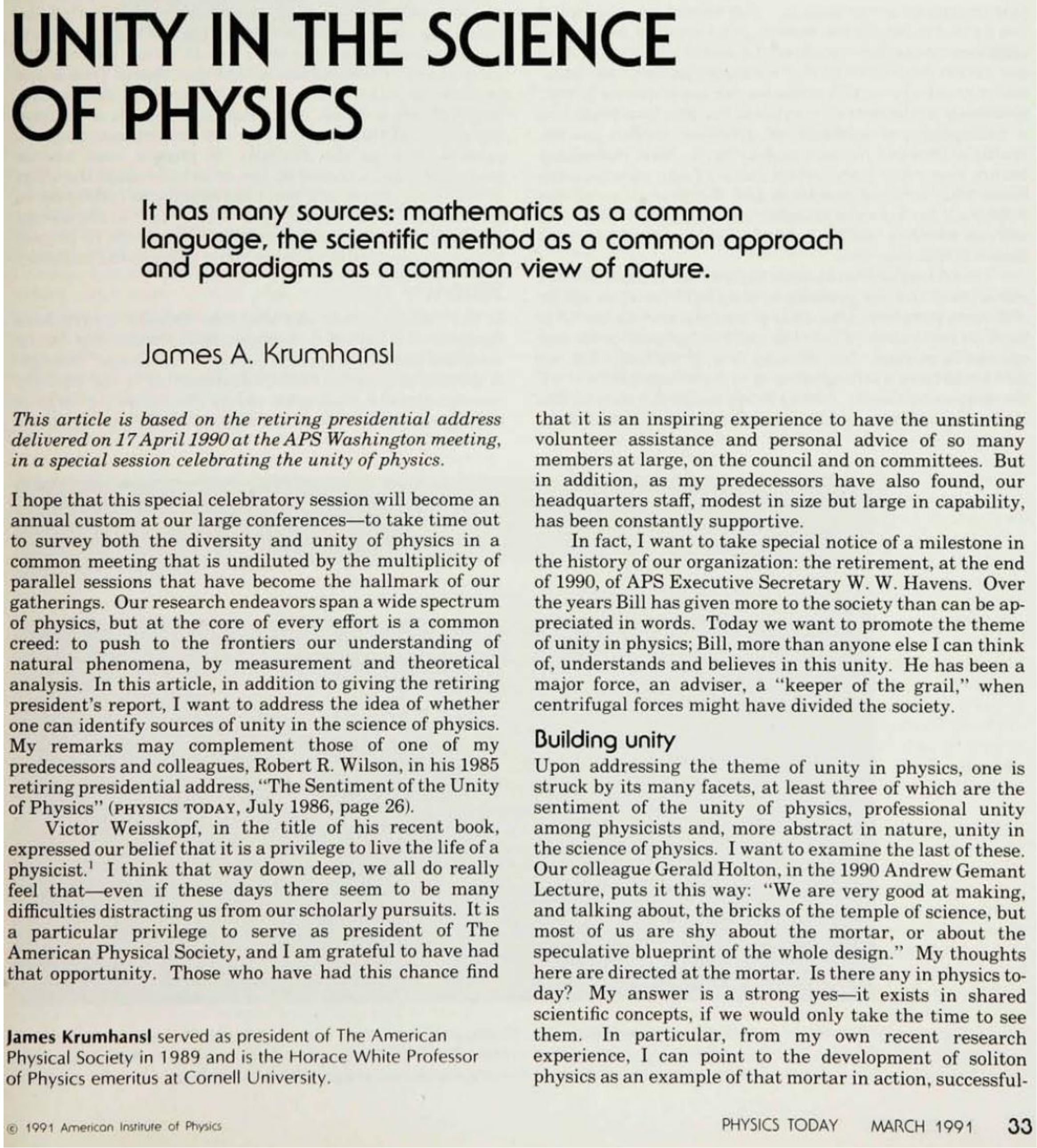
LA-UR-12-00551

UNIFYING CONCEPTS IN PHYSICS, BIOPHYSICS & MATERIALS SCIENCE

Avadh Saxena (Los Alamos National Lab)

1. Prof. Jim Krumhansl (1919-2004): Science, vision & policy.
2. Functional materials.
3. Glassy/Driven materials.
4. Granular materials.
5. Biological/Soft materials.
6. Unity in approach: lateral thinking.

Physics Today
March 1991



UNITY IN THE SCIENCE OF PHYSICS

It has many sources: mathematics as a common language, the scientific method as a common approach and paradigms as a common view of nature.

James A. Krumhansl

This article is based on the retiring presidential address delivered on 17 April 1990 at the APS Washington meeting, in a special session celebrating the unity of physics.

I hope that this special celebratory session will become an annual custom at our large conferences—to take time out to survey both the diversity and unity of physics in a common meeting that is undiluted by the multiplicity of parallel sessions that have become the hallmark of our gatherings. Our research endeavors span a wide spectrum of physics, but at the core of every effort is a common creed: to push to the frontiers our understanding of natural phenomena, by measurement and theoretical analysis. In this article, in addition to giving the retiring president's report, I want to address the idea of whether one can identify sources of unity in the science of physics. My remarks may complement those of one of my predecessors and colleagues, Robert R. Wilson, in his 1985 retiring presidential address, "The Sentiment of the Unity of Physics" (PHYSICS TODAY, July 1986, page 26).

Victor Weisskopf, in the title of his recent book, expressed our belief that it is a privilege to live the life of a physicist.[1] I think that way down deep, we all do really feel that—even if these days there seem to be many difficulties distracting us from our scholarly pursuits. It is a particular privilege to serve as president of The American Physical Society, and I am grateful to have had that opportunity. Those who have had this chance find that it is an inspiring experience to have the unstinting volunteer assistance and personal advice of so many members at large, on the council and on committees. But in addition, as my predecessors have also found, our headquarters staff, modest in size but large in capability, has been constantly supportive.

In fact, I want to take special notice of a milestone in the history of our organization: the retirement, at the end of 1990, of APS Executive Secretary W. W. Havens. Over the years Bill has given more to the society than can be appreciated in words. Today we want to promote the theme of unity in physics; Bill, more than anyone else I can think of, understands and believes in this unity. He has been a major force, an adviser, a "keeper of the grail," when centrifugal forces might have divided the society.

Building unity

Upon addressing the theme of unity in physics, one is struck by its many facets, at least three of which are the sentiment of the unity of physics, professional unity among physicists and, more abstract in nature, unity in the science of physics. I want to examine the last of these. Our colleague Gerald Holton, in the 1990 Andrew Gemant Lecture, puts it this way: "We are very good at making, and talking about, the bricks of the temple of science, but most of us are shy about the mortar, or about the speculative blueprint of the whole design." My thoughts here are directed at the mortar. Is there any in physics today? My answer is a strong yes—it exists in shared scientific concepts, if we would only take the time to see them. In particular, from my own recent research experience, I can point to the development of soliton physics as an example of that mortar in action, successful-

James Krumhansl served as president of The American Physical Society in 1989 and is the Horace White Professor of Physics emeritus at Cornell University.

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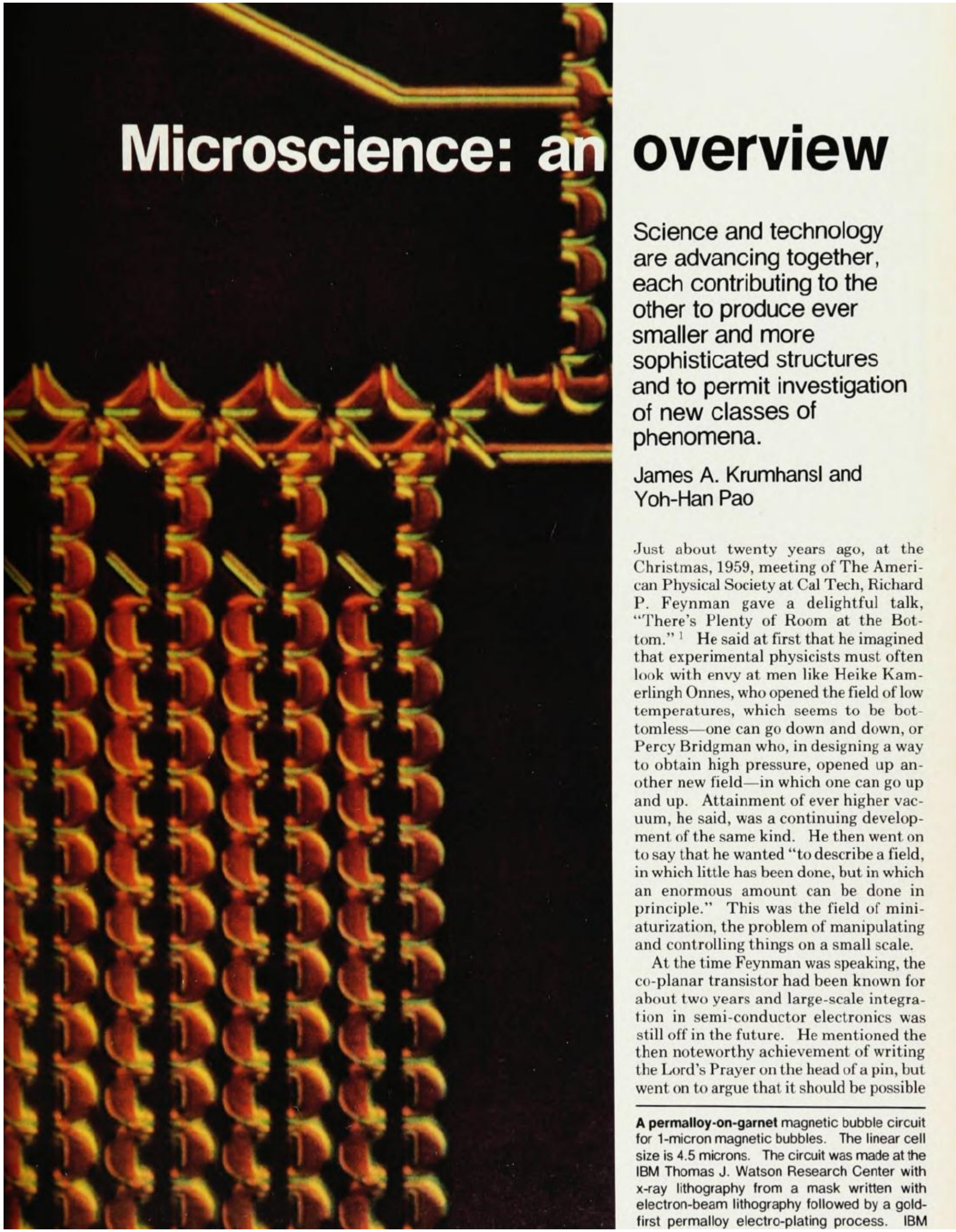
Physics Today
November 1979



Microscience: an overview

Science and technology are advancing together, each contributing to the other to produce ever smaller and more sophisticated structures and to permit investigation of new classes of phenomena.

James A. Krumhansl and
Yoh-Han Pao

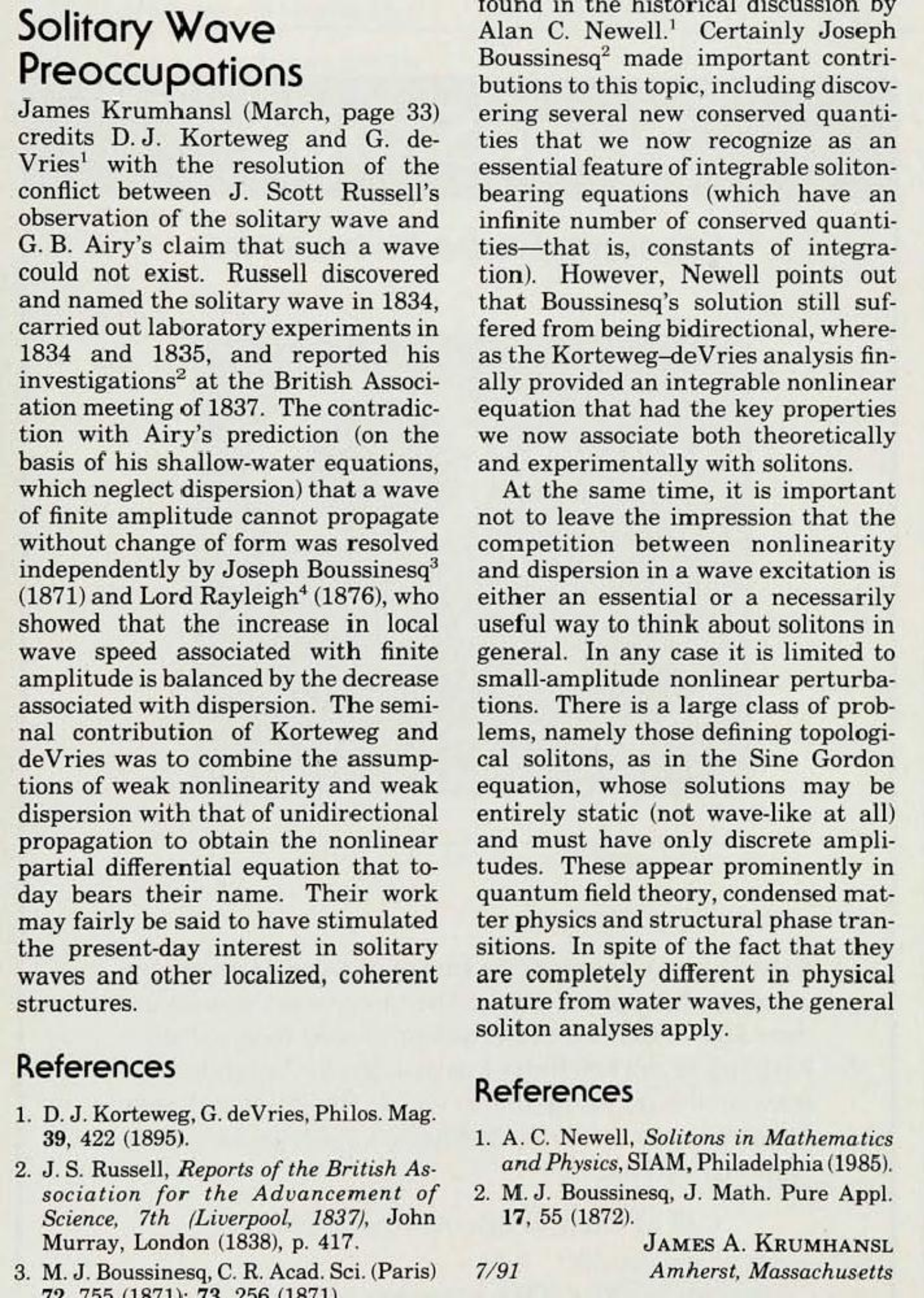
Just about twenty years ago, at the Christmas, 1959, meeting of The American Physical Society at Cal Tech, Richard P. Feynman gave a delightful talk, "There's Plenty of Room at the Bottom."[1] He said at first that he imagined that experimental physicists must often look with envy at men like Heike Kamerlingh Onnes, who opened the field of low temperatures, which seems to be bottomless—one can go down and down, or Percy Bridgman who, in designing a way to obtain high pressure, opened up another new field—in which one can go up and up. Attainment of ever higher vacuum, he said, was a continuing development of the same kind. He then went on to say that he wanted "to describe a field, in which little has been done, but in which an enormous amount can be done in principle." This was the field of miniaturization, the problem of manipulating and controlling things on a small scale.

At the time Feynman was speaking, the co-planar transistor had been known for about two years and large-scale integration in semi-conductor electronics was still off in the future. He mentioned the then noteworthy achievement of writing the Lord's Prayer on the head of a pin, but went on to argue that it should be possible

A permalloy-on-garnet magnetic bubble circuit for 1-micron magnetic bubbles. The linear cell size is 4.5 microns. The circuit was made at the IBM Thomas J. Watson Research Center with x-ray lithography from a mask written with electron-beam lithography followed by a gold-first permalloy electro-plating process. IBM

Nanoscience &
Nanotechnology
~ 2000

Physics Today
August, 1991



Solitary Wave Preoccupations

James Krumhansl (March, page 33) credits D. J. Korteweg and G. de-Vries[1] with the resolution of the conflict between J. Scott Russell's observation of the solitary wave and G. B. Airy's claim that such a wave could not exist. Russell discovered and named the solitary wave in 1834, carried out laboratory experiments in 1834 and 1835, and reported his investigations[2] at the British Association meeting of 1837. The contradiction with Airy's prediction (on the basis of his shallow-water equations, which neglect dispersion) that a wave of finite amplitude cannot propagate without change of form was resolved independently by Joseph Boussinesq[3] (1871) and Lord Rayleigh[4] (1876), who showed that the increase in local wave speed associated with finite amplitude is balanced by the decrease associated with dispersion. The seminal contribution of Korteweg and deVries was to combine the assumptions of weak nonlinearity and weak dispersion with that of unidirectional propagation to obtain the nonlinear partial differential equation that today bears their name. Their work may fairly be said to have stimulated the present-day interest in solitary waves and other localized, coherent structures.

References

1. D. J. Korteweg, G. deVries, Philos. Mag. **39**, 422 (1895).
2. J. S. Russell, *Reports of the British Association for the Advancement of Science, 7th (Liverpool, 1837)*, John Murray, London (1838), p. 417.
3. M. J. Boussinesq, C. R. Acad. Sci. (Paris) **72**, 755 (1871); **73**, 256 (1871).

found in the historical discussion by Alan C. Newell.[1] Certainly Joseph Boussinesq[2] made important contributions to this topic, including discovering several new conserved quantities that we now recognize as an essential feature of integrable soliton-bearing equations (which have an infinite number of conserved quantities—that is, constants of integration). However, Newell points out that Boussinesq's solution still suffered from being bidirectional, whereas the Korteweg–deVries analysis finally provided an integrable nonlinear equation that had the key properties we now associate both theoretically and experimentally with solitons.

At the same time, it is important not to leave the impression that the competition between nonlinearity and dispersion in a wave excitation is either an essential or a necessarily useful way to think about solitons in general. In any case it is limited to small-amplitude nonlinear perturbations. There is a large class of problems, namely those defining topological solitons, as in the Sine Gordon equation, whose solutions may be entirely static (not wave-like at all) and must have only discrete amplitudes. These appear prominently in quantum field theory, condensed matter physics and structural phase transitions. In spite of the fact that they are completely different in physical nature from water waves, the general soliton analyses apply.

References

1. A. C. Newell, *Solitons in Mathematics and Physics*, SIAM, Philadelphia (1985).
2. M. J. Boussinesq, J. Math. Pure Appl. **17**, 55 (1872).

JAMES A. KRUMHANSL
Amherst, Massachusetts

7/91

AIP ESVA

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James A. KRUMHANSL Gerhard R. BARSCH

Aug. 2, 1919 – May 6, 2004 Jun. 22, 1927 – Jul. 10, 2011

Cornell University Penn State University

NONLINEAR PHYSICS of MARTENSITE

Barsch-Krumhansl (twins: “strain solitons”)

1. Cubic-Tetragonal transition (1984 PRL).
2. Landau theory: strain as order parameter (FePd).
3. Strain as secondary order parameter (LaInTl) .
4. Proper vs. Improper ferroelastics (shuffle, 1994).
5. Elastic fringing fields in austenite (1987 PRB).
6. Elastic compatibility, long-range interaction (1994 PRB).
7. Consequences: Microstrucure, dynamics, scaling.

- Example: Cubic to Tetragonal

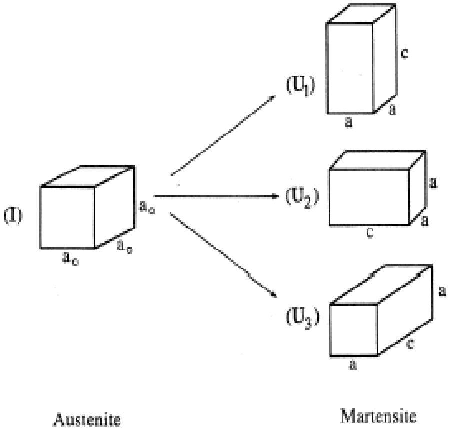
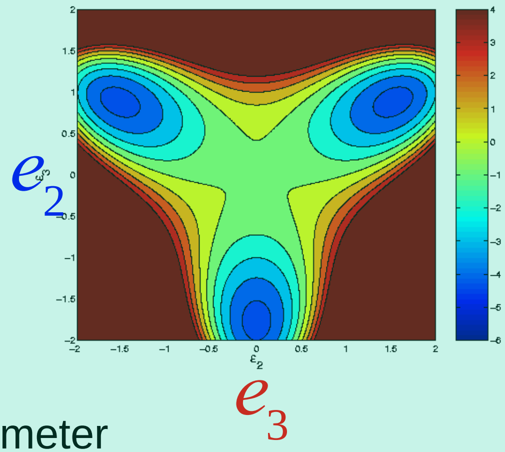


Figure 4.4: The three variants of martensite in a cubic to tetragonal transformation.

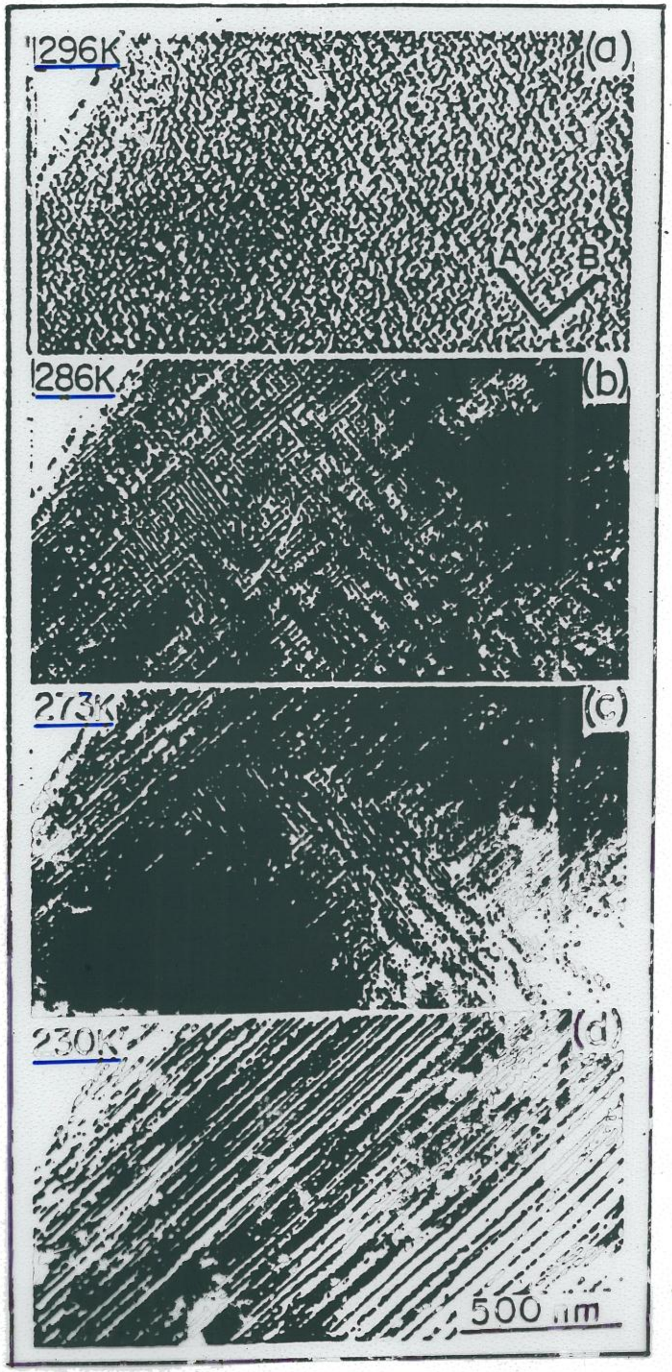
$$F\left(e_2, e_3\right)$$



Order parameter

$$\left(e_2 = \frac{e_{xx} - e_{yy}}{\sqrt{2}}, e_3 = \frac{e_{xx} + e_{yy} - 2e_{zz}}{\sqrt{6}}\right)$$

Barsch &Krumhansl, 84, Falk, 83



$Fe_{0.7}Pd_{0.3}$

AUSTENITE

TWEED

$T_0 = 268$ K

(TWINNED)
MARTENSITE

Sugiyama
(1985)

ICOMAT-08
Edited by: G. B. Olson, D. S. Lieberman, and A. Saxena
TMS (The Minerals, Metals & Materials Society), 2009

JAMES ARTHUR KRUMHANSL: NONLINEAR PHYSICS OF MARTENSITIC TRANSFORMATIONS

Gerhard R. Barsch[1] and Avadh Saxena[2]
[1]Department of Physics and Materials Research Lab, The Pennsylvania State University, State College, PA 16802, USA.
[2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Keywords: Nonlinear elasticity, Ginzburg-Landau theory, first order phase transformation, historical development

Abstract

We provide a tribute to Prof. James Arthur Krumhansl, Professor Emeritus of Cornell University, USA and put in a historical perspective his contributions to the field of martensitic phase transformations using concepts from physics such as Landau theory as well as nonlinear and nonlocal elasticity. We also emphasize his role as an effective mentor, visionary science policy maker, thoughtful administrator and someone who sparked world-wide collaboration among scientists with very different backgrounds.

Introduction

Professor James Arthur Krumhansl (Fig. 1), a distinguished materials physicist, passed away at the age of 84 on May 6, 2004 at Dartmouth-Hitchcock Medical Center in Lebanon, New Hampshire, USA of a massive stroke. Prof. Krumhansl made countless contributions to materials physics not only as a researcher but also as an advisor and policy maker for numerous educational, government, industrial, and professional institutions around the world[1]. For the last 25 years of his life he was deeply involved in the research on martensitic phase transformations[2-4] and the accompanying microstructure. He will be remembered not only by the martensite community but also by all his students, postdoctoral associates, colleagues, and collaborators for his quick mind, impromptu humor, naturally inspiring style, unlimited energy as well as unflinching enthusiasm.

Prof. Krumhansl was born on August 2, 1919 in Cleveland, Ohio, USA. He received his BS degree from the University of Dayton, Ohio in 1939 in Electrical Engineering, his MS degree from Case Institute of Technology (now Case Western Reserve University) in Cleveland, Ohio in 1940 in Physics, and his Ph.D. degree from Cornell University, Ithaca, New York state in 1943 also in Physics. His educational career[1] as a physics instructor began at Cornell (1943-1944) and during 1946-1948 he was an Assistant and Associate Professor of Physics and Applied Mathematics at

his retirement, he held adjunct professorships at the University of Massachusetts, Amherst, and Dartmouth College, New Hampshire, USA.

In his teenage years he was a baseball pitcher with Dayton, Ohio and won a game against Ohio State (1937). He had great interest in sailing (e.g. he was once a crew member of Miami-Bermuda sailing), skiing, fly fishing, traveling and music. Specifically, he played classical violin and Jazz saxophone. He also enjoyed and sampled wines. He was particularly fascinated by the American southwest and its Indian culture. In fact, every time he visited Los Alamos, he got a chance to indulge in one of his non-science passions --collecting Kachina dolls (Fig. 2). He is survived by his two sons (James L. at Sandia National Laboratory, Albuquerque, New Mexico and Peter A. at Amherst, New Hampshire, geophysics/seismology) and a daughter (Carol L.; professor of psychology at Cornell University). He was twice married and divorced. He has a grandson Robert and a granddaughter, Kira.

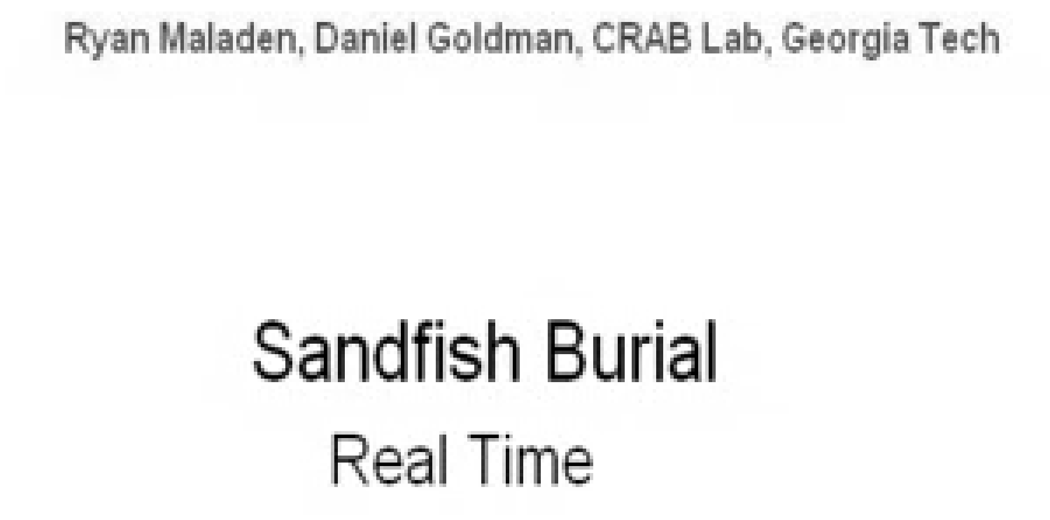
COMPLEX systems/materials:

- "Composed of interconnected or interwoven parts"
- Multiscale aspects: … meso … is the key.
- Critical phenomena vs. phase diagram.
- Nonequilibrium and nonlinear phenomena.

- Landscape paradigms (rugged, dynamic).
- Notion of phonons → metallurgists.
- Concept of solitons → materials scientists.
- Idea of localization → biologists.

Scientists look at the camouflage technique employed by the cuttlefish (ABC news)

SWIMMING IN SAND

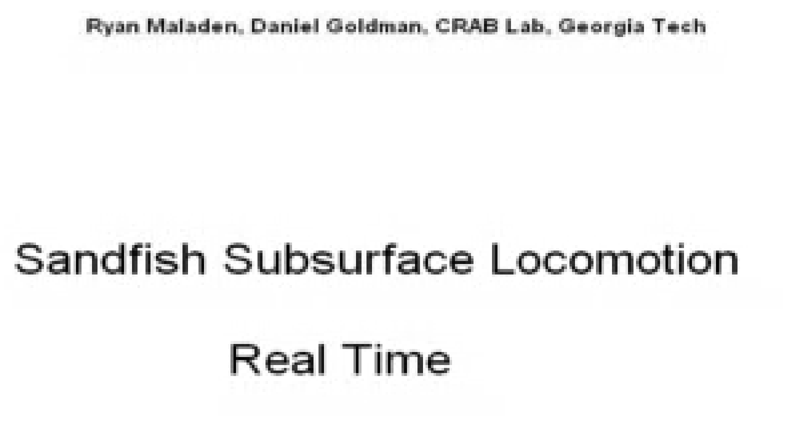


Ryan Maladen, Daniel Goldman, CRAB Lab, Georgia Tech

Sandfish Burial

Real Time

SWIMMING IN SAND



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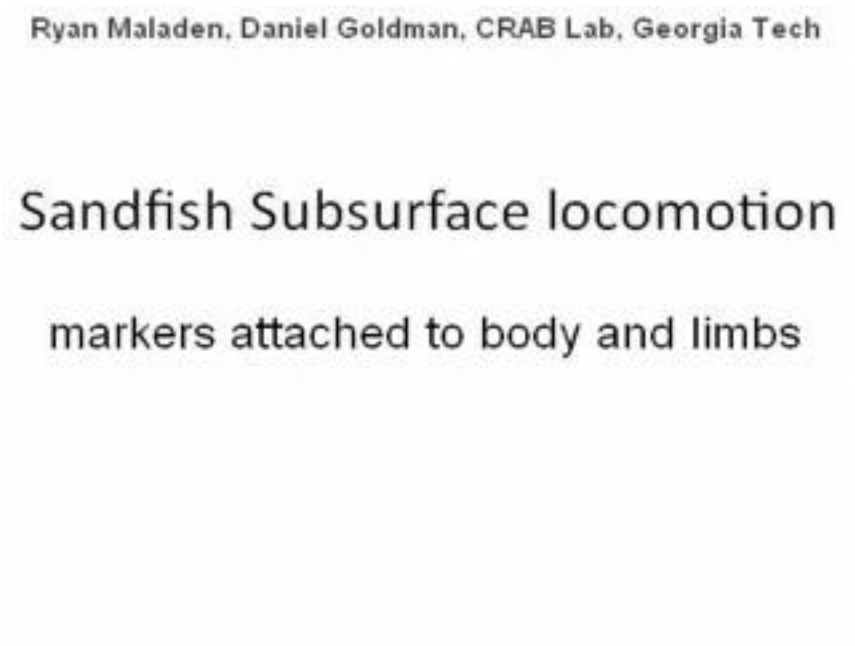
Sandfish Subsurface Locomotion

Real Time



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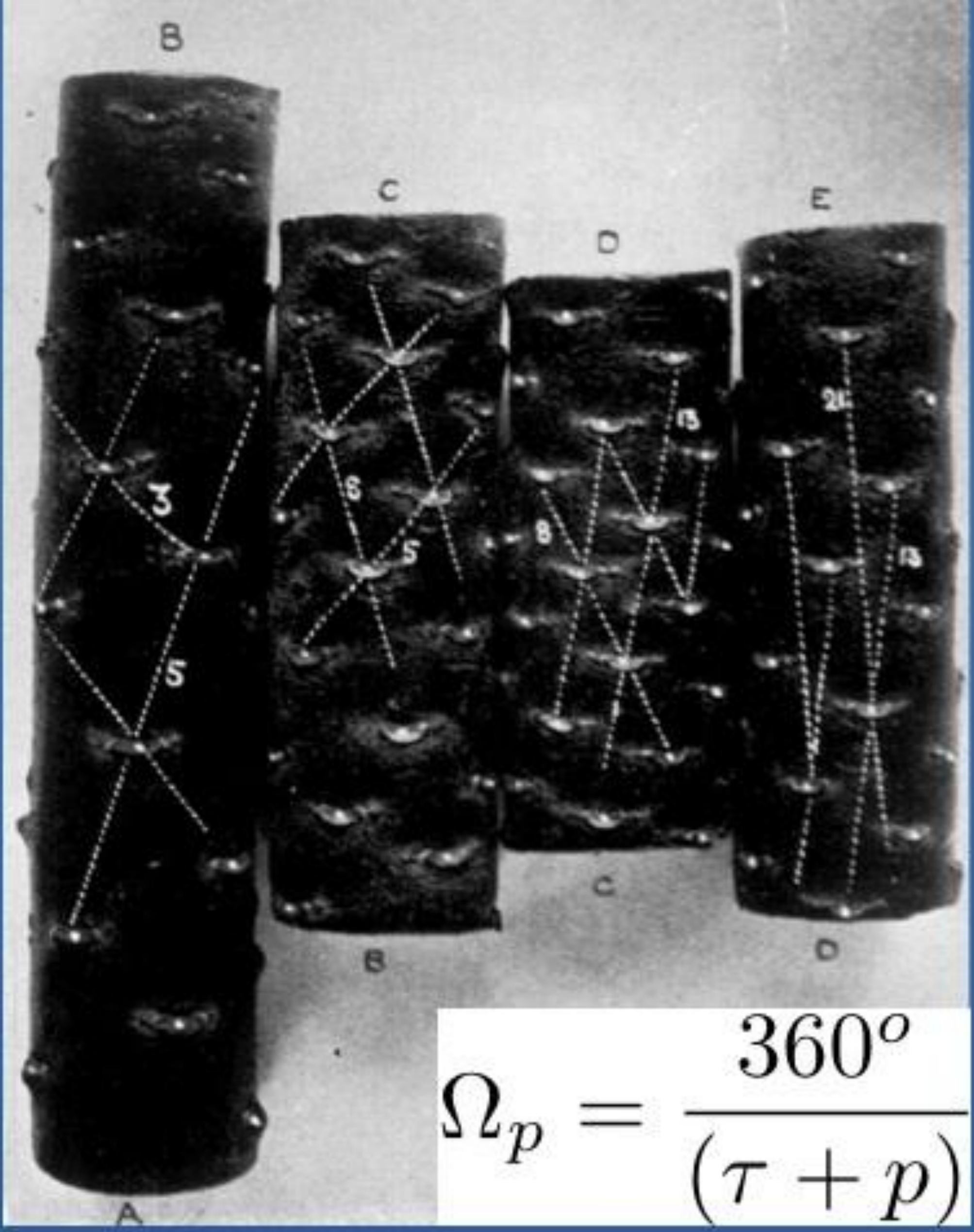
Sandfish Subsurface locomotion

markers attached to body and limbs

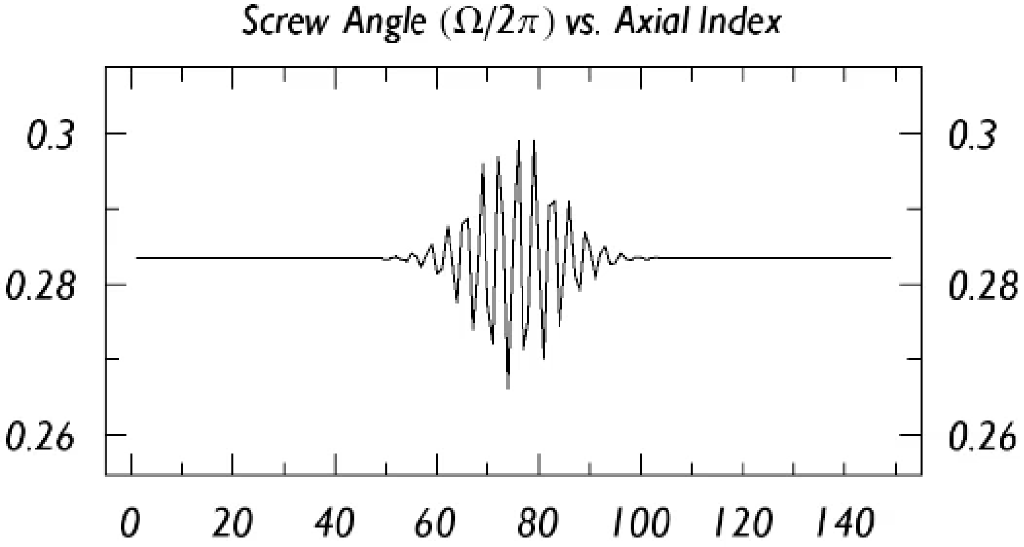
SWIMMING IN SAND

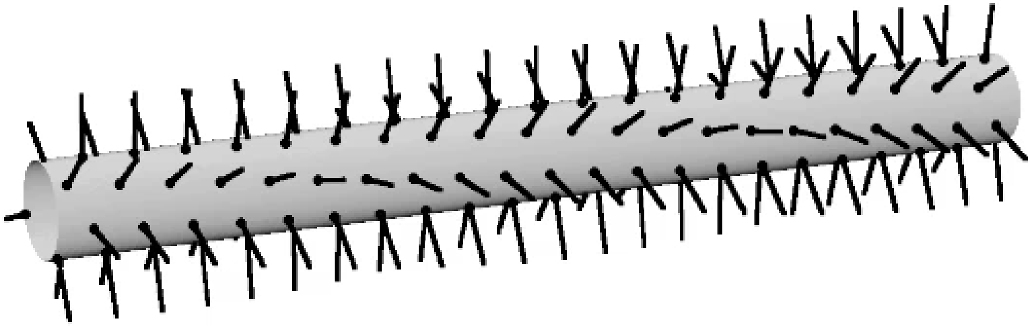


$$\Omega_p = \frac{360^o}{(\tau + p)}$$

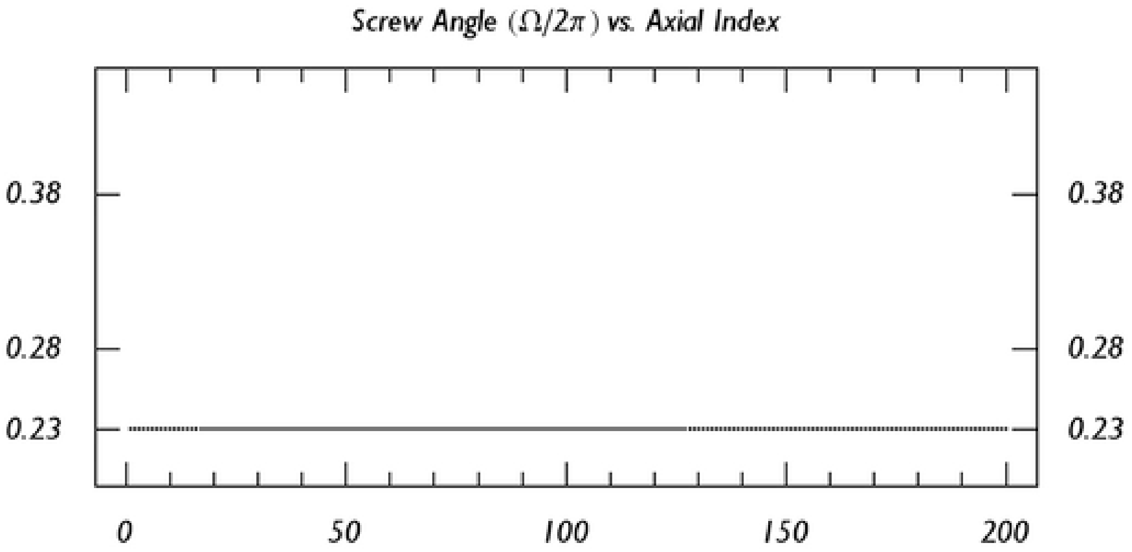
C. Nisoli et Al. PRL 102, 186103 (2009)

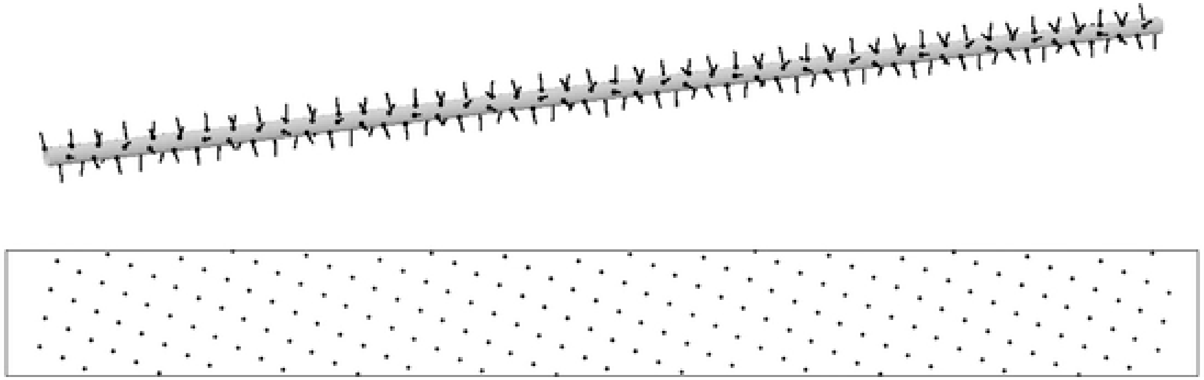
Dynamical Phyllotaxis: Phonons



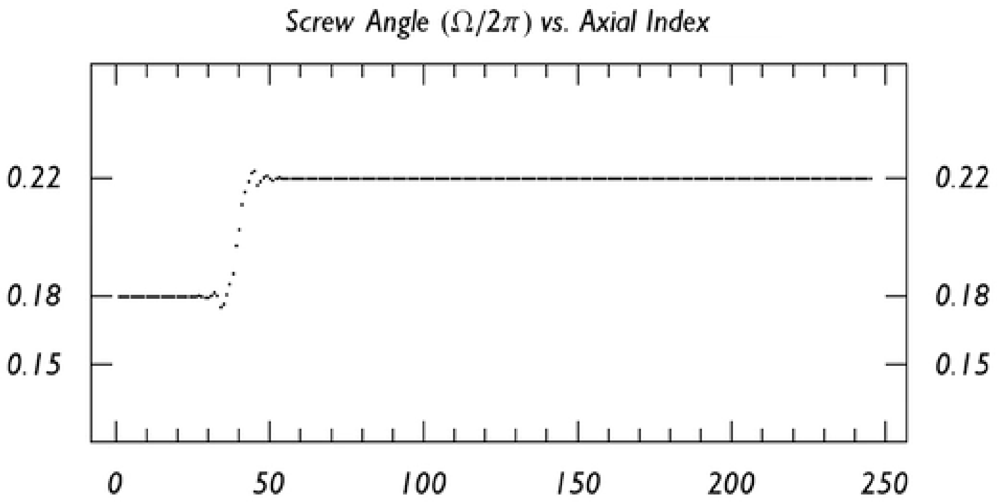


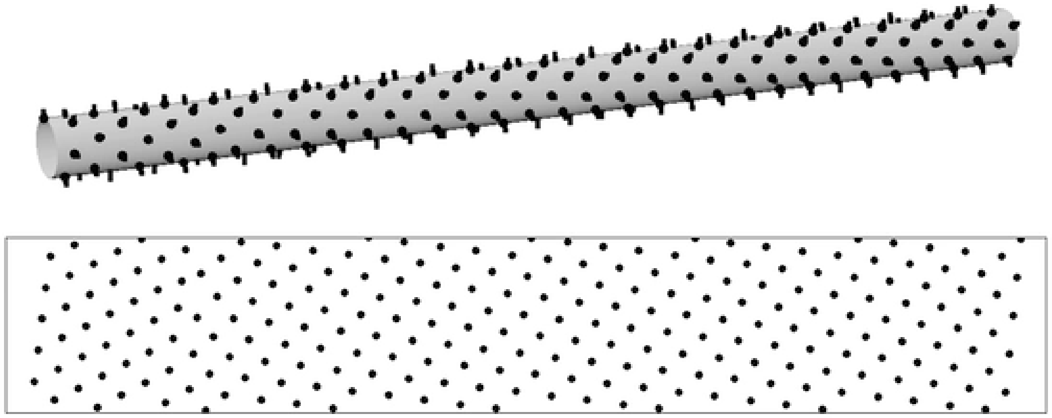
Dynamical Phyllotaxis: Solitons



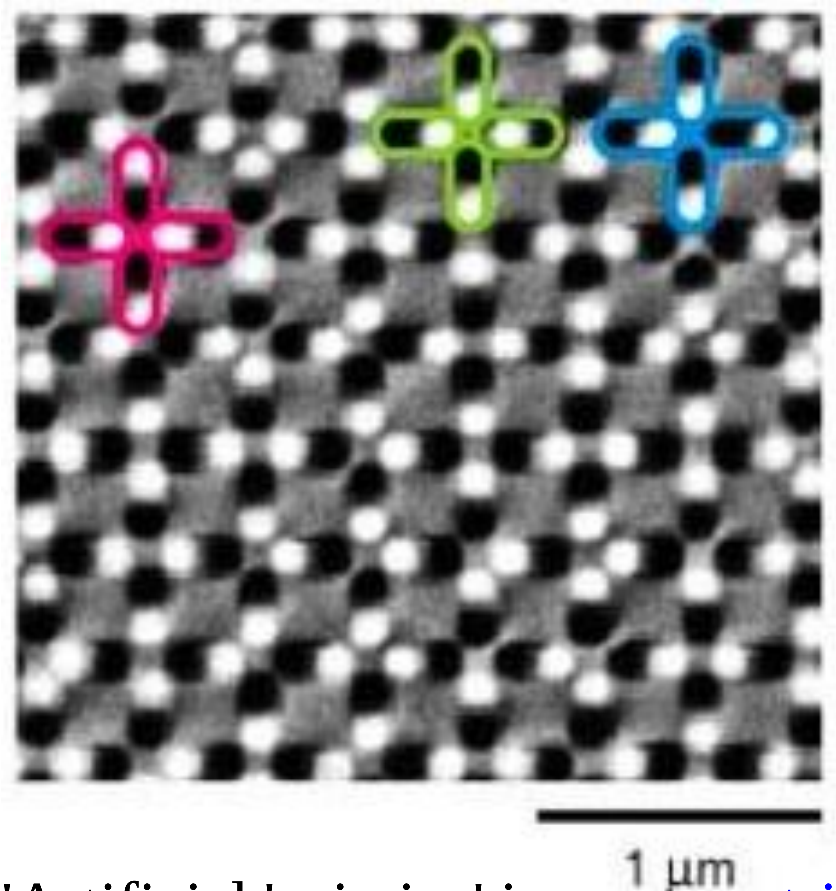


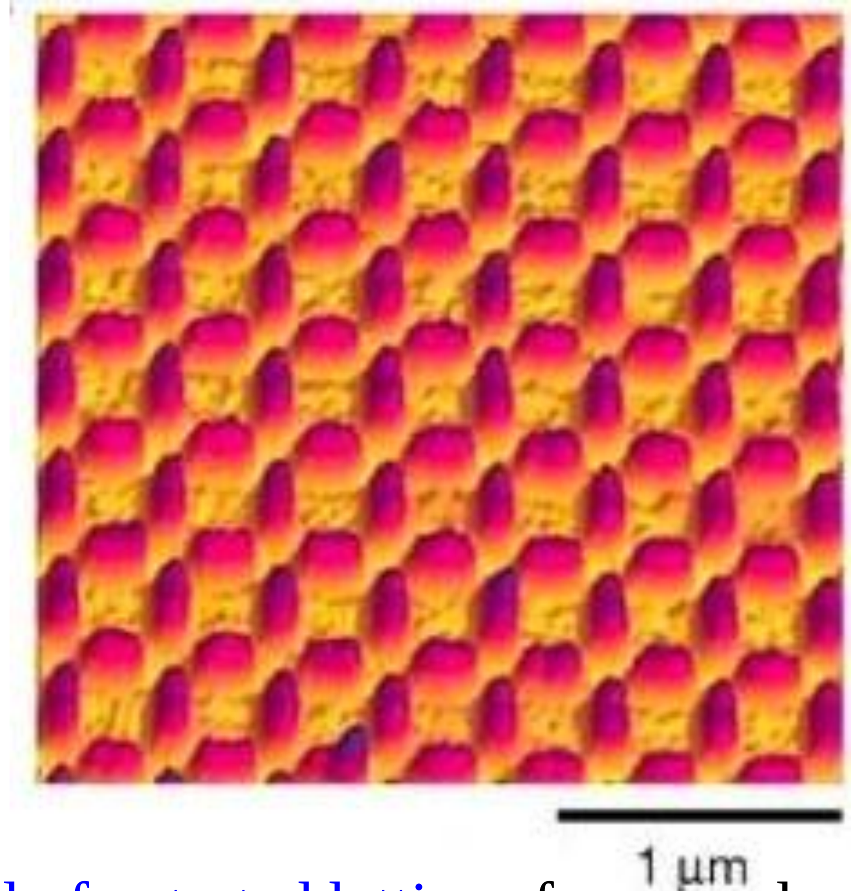
Dynamical Phyllotaxis: Solitons



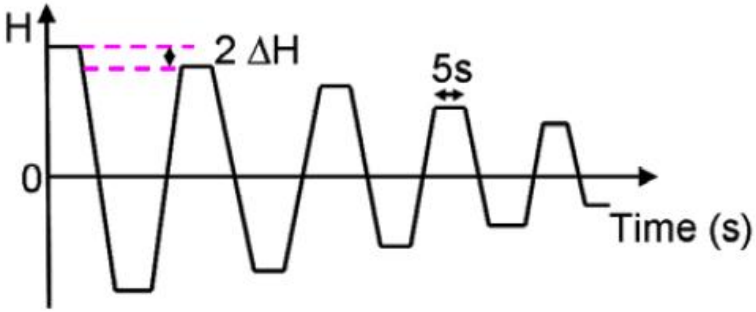


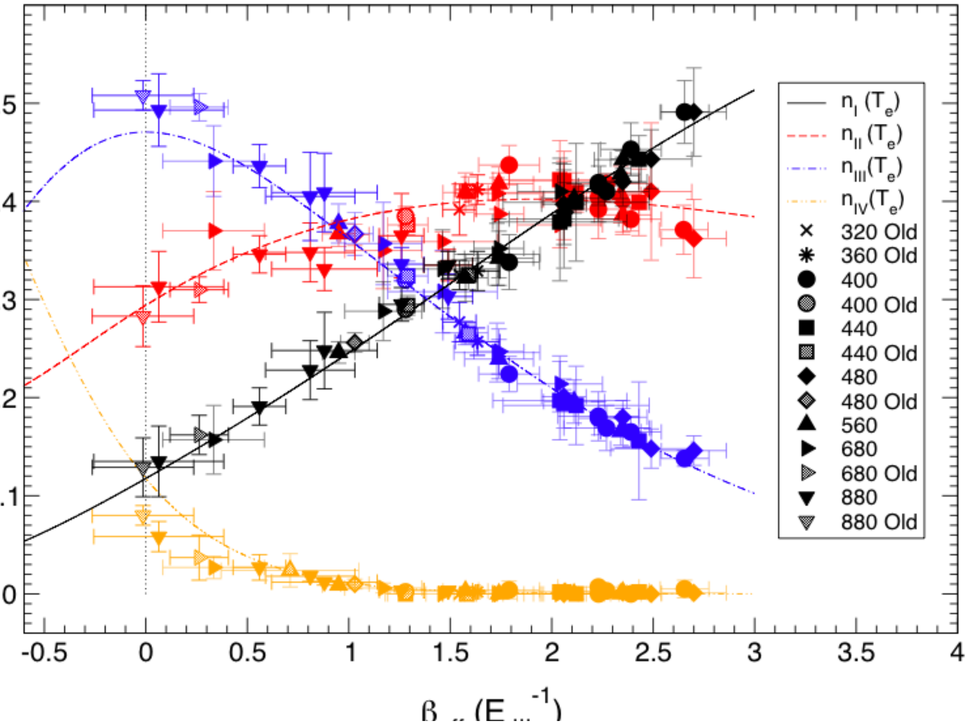
Can We Image Spin Ice Directly?

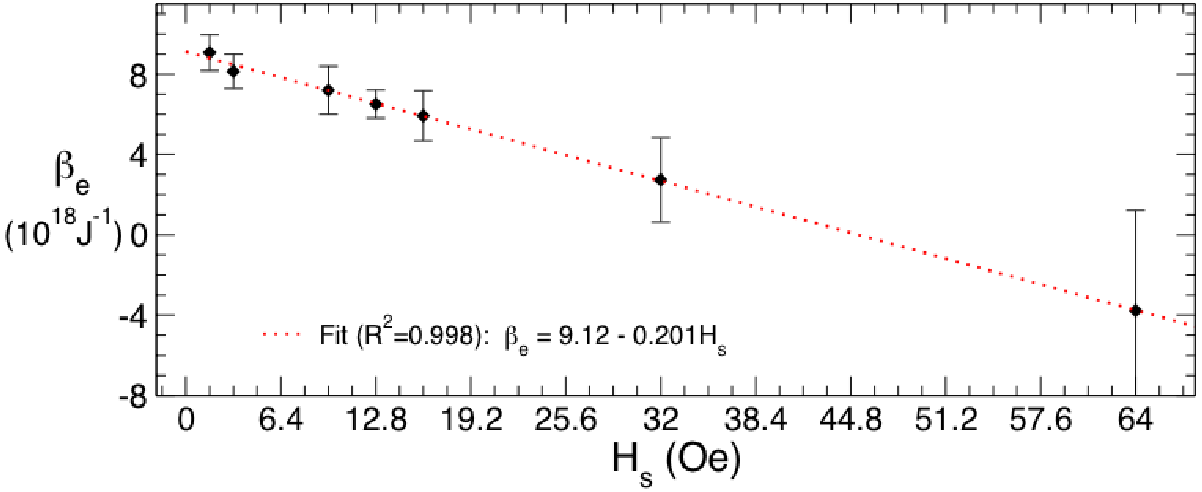




"Artificial 'spin ice' in a geometrically frustrated lattice of nanoscale ferromagnetic islands" Nature 439, 303 - 306 (2006).







Effective temperature can be controlled by the external magnetic drive by changing the magnetic step in the magneto-fluidization process.

C. Nisoli et al. Phys. Rev. Lett. 105, 047205 (2010) .

CONNECTION BETWEEN:

- Glassy and bio: Neural networks, brain

- Functional and glassy: strain glass

- Granular and glassy: Nonequilibrium, effective temperature

- Functional and granular: Novel emergent properties

CURIOUS MIND

BOUNDLESS ENERGY

JAKS-2016: Santa Fe, New Mexico, USA