Forty Years of Math Memories

Blake Temple
UC-Davis

John Hong's Conference on Shock waves and GR

Taiwan, April 7, 2026

(Dedicated to Joel Smoller, Eli Isaacson and Craig Tracy)

A Better Title:

A Better Title:

"I get by with a little help from my friends…"

I am fortunate now…

Four projects that we've been working on for decades have now come to fruition…

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…all with ingenious talented collaborators…

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…all with ingenious talented collaborators…

Robin Young, Moritz Rientjes, Christopher Alexander, Zeke Vogler, and Heinrich Freistuehler

"I get by with a little help from my friends…"

"I get by with a little help from my friends…"

-John Lennon 1967

"I get by with a little help from my friends…"

-John Lennon 1967

(For the young people in the room…

"I get by with a little help from my friends…"

-John Lennon 1967

(For the young people in the room…

…John Lennon was a member of a 60's band named "The Beatles")

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-John Lennon 1967

(For the young people in the room…

…John Lennon was a member of a 60's band named "The Beatles")

This is the quote by which Joel Smoller began his influential book…

"I get by with a little help from my friends…"

-John Lennon 1967

(For the young people in the room…

…John Lennon was a member of a 60's band named "The Beatles")

This is the quote by which Joel Smoller began his influential book…

Joel Smoller, University of Michigan, was first my teacher, and became my friend and collaborator…

Grundlehren der mathematischen Wissenschaften 258
A Series of Comprehensive Studies in Mathematics

Joel Smoller

Shock Waves and Reaction–Diffusion Equations



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(John Lennon and Paul McCartney)
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Joel Smoller and Students, University of Michigan…



David Wagner, Me, Joel Smoller, Tai-Ping Liu, David Hoff

F. Garaizar

At the time, you had to justify that Applied Math deserved the respect of Pure Mathematics…

At the time, you had to justify that Applied Math deserved the respect of Pure Mathematics…

So Joel began his book with a quote from John Von Neumann…

It is important to avoid a misunderstanding at this point. One may be tempted to qualify these (shock wave and turbulence) problems as problems in physics, rather than in applied mathematics, or even pure mathematics. We wish to emphasize that it is our conviction that such an interpretation is wholly erroneous.

JOHN VON NEUMANN, 1946

The rivalry between Applied Math and Pure Math is exemplified in the two best jokes of the era…

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The two competing math jokes of that time…

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Applications of Number Theory"

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(Paul Fedderbush?)

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(Paul Fedderbush?)

- "The only Mathematics that has no applications is…

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Applications of Number Theory"

(Paul Fedderbush?)

- "The only Mathematics that has no applications is…

Applied Mathematics"

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Each of these results is beyond anything I dreamed of when I started out studying math…

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Each was motivated by Shock Wave Theory…

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Each was motivated by Shock Wave Theory…

Here they are…

First a comment: Mathematics is as close to absolute certainty as is possible in life…

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I like the idea that mathematics at its best can anchor new, surprising and controversial possibilities…

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I like the idea that mathematics at its best can anchor new, surprising and controversial possibilities…

…and this is arguably more important than providing uncontroversial substantiation for well accepted theories.

(1) Discovery of a RT-equations:

—with Moritz Reintjes



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Solutions provide the coordinate transformations which lift the regularity of a connection to one derivative above its Riemann curvature.

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We recently used this to establish a geometric level of regularity for metrics and connections in General Relativity and Geometry.

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Solutions provide the coordinate transformations which lift the regularity of a connection to one derivative above its Riemann curvature.

We recently used this to establish a geometric level of regularity for metrics and connections in General Relativity and Geometry.

For his contribution, Reintjes won this year's Hong Kong Math Society Young Scholar Award.

arXiv > gr-qc > arXiv:2412.08928

Search...

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General Relativity and Quantum Cosmology

[Submitted on 12 Dec 2024]

The essential regularity of singular connections in Geometry

Moritz Reintjes, Blake Temple

We introduce a natural, mathematically consistent definition of the essential (highest possible) regularity of an affine connection -- a geometric property independent of atlas -- together with a checkable necessary and sufficient condition for determining whether connections are at their essential regularity. This condition is based on the relative regularity between the connection and its Riemann curvature. Based on this, we prove that authors' theory of the RT-equations provides a computable procedure for constructing coordinate transformations which simultaneously lift connection and curvature components to essential regularity, and lift the atlas of coordinate charts to the regularity required to preserve the essential regularity of the connection. This provides a definitive theory for determining whether or not singularities in a geometry are essential or removable by coordinate transformation, together with an explicit procedure for lifting removable singularities to their essential regularity, both locally and globally. The theory applies to general affine connections with components in L^p, $p > n$, which naturally includes shock wave singularities in General Relativity as well as continuous metrics with infinite gradients, (both obstacles to numerical simulation), but not yet singularities at the lower regularity $p \leq n$ associated with discontinuous metric components, for example, the event horizon of a black hole.

Subjects: **General Relativity and Quantum Cosmology (gr-qc)**; Mathematical Physics (math-ph); Differential Geometry (math.DG)
MSC classes: 58K30, 83C75
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1994



Craig Evans helped us with the Elliptic Regularity Theory!

(2) Shock-free time periodic solutions of the compressible Euler equations

—with Robin Young

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—with Robin Young

We discover a new wave mechanism for the propagation of nonlinear oscillatory signals.

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By this we establish consistency between the linear and nonlinear theories of sound…

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We discover a new wave mechanism for the propagation of nonlinear oscillatory signals.

By this we establish consistency between the linear and nonlinear theories of sound…

…proving that oscillatory signals need not decay by shock wave dissipation when entropy and temperature variations are accounted for.

(2) Shock-free time periodic solutions of the compressible Euler equations

—with Robin Young

The final breakthrough came when Robin got the idea that the nonlinear periodic solutions might lie within a smaller more symmetric class of solutions…

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—with Robin Young

The final breakthrough came when Robin got the idea that the nonlinear periodic solutions might lie within a smaller more symmetric class of solutions…

Casting the problem within this smaller class led to the discovery of a functional $\mathcal{F}$ which imposes periodicity using uniform small divisors…thereby overcoming the small divisor technicalities of Nash-Moser iteration…

arXiv > math > arXiv:2406.00200

Search...

Help | Adv

Mathematics > Analysis of PDEs

[Submitted on 31 May 2024 (v1), last revised 18 Aug 2024 (this version, v2)]

Time-periodic solutions of the compressible Euler equations and the Nonlinear Theory of Sound

Blake Temple, Robin Young

We prove the existence of ``pure tone'' nonlinear sound waves of all frequencies. These are smooth, time periodic, oscillatory solutions of the 3×3 compressible Euler equations satisfying periodic or acoustic boundary conditions in one space dimension. This resolves a centuries old problem in the theory of Acoustics, by establishing that the pure modes of the linearized equations are the small amplitude limits of solutions of the nonlinear equations. Riemann's celebrated 1860 proof that compressions always form shocks is known to hold for isentropic and barotropic flows, but our proof shows that for generic entropy profiles, shock-free periodic solutions containing nontrivial compressions and rarefactions exist for every wavenumber k.

Comments: 70 pages, 2 figures. arXiv admin note: text overlap with arXiv:2305.15623
Subjects: **Analysis of PDEs (math.AP)**; Functional Analysis (math.FA)
MSC classes: 35L65
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This resolves an historical inconsistency in the physical theory of how sound waves propagate…

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1848-Stokes and Challis identify shock formation as a problem with the theory of sound…

THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

CONDUCTED BY

SIR DAVID BREWSTER, K.H. LL.D. F.R.S.L.&E. &c.
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RICHARD PHILLIPS, F.R.S.L.&E. F.G.S. &c.
SIR ROBERT KANE, M.D. M.R.I.A.

"Nec aranearum sane textus ideo melior quia ex se fila gignunt, nec noster vilior quia ex alienis libamus ut apes." Just. Lips. *Polit.* lib. i. cap. 1. Not.

VOL. XXXIII.

NEW AND UNITED SERIES OF THE PHILOSOPHICAL MAGAZINE, ANNALS OF PHILOSOPHY, AND JOURNAL OF SCIENCE.

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laws which the actual motion tends indefinitely to obey when the magnitude of the velocity is indefinitely diminished. And if, moreover, we have every reason to believe that the first order of small quantities contains all that are sensible in practical cases, we have arrived, not merely at abstract mathematical results, but at important physical laws. Nevertheless it will be admitted on all hands, that any apparent contradiction arrived at by employing exact equations is deserving of serious consideration.

The difficulty already alluded to is to be found at page 496 of the preceding volume of this Magazine. In what follows I shall use Professor Challis's notation.

Without entering into the consideration of the mode in which Poisson obtained the particular integral

$$w = f\{z-(a+w)t\}, \quad . \quad . \quad . \quad . \quad . \quad (1.)$$

it may be easily shown, by actual differentiation and substitution, that the integral does satisfy our equations. The function f being arbitrary, we may assign to it any form we please, as representing a particular possible motion, and may employ the result, *so long as no step tacitly assumed in the course of our*

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…suggesting even that shock waves placed a fundamental limit on the propagation of acoustic signals.

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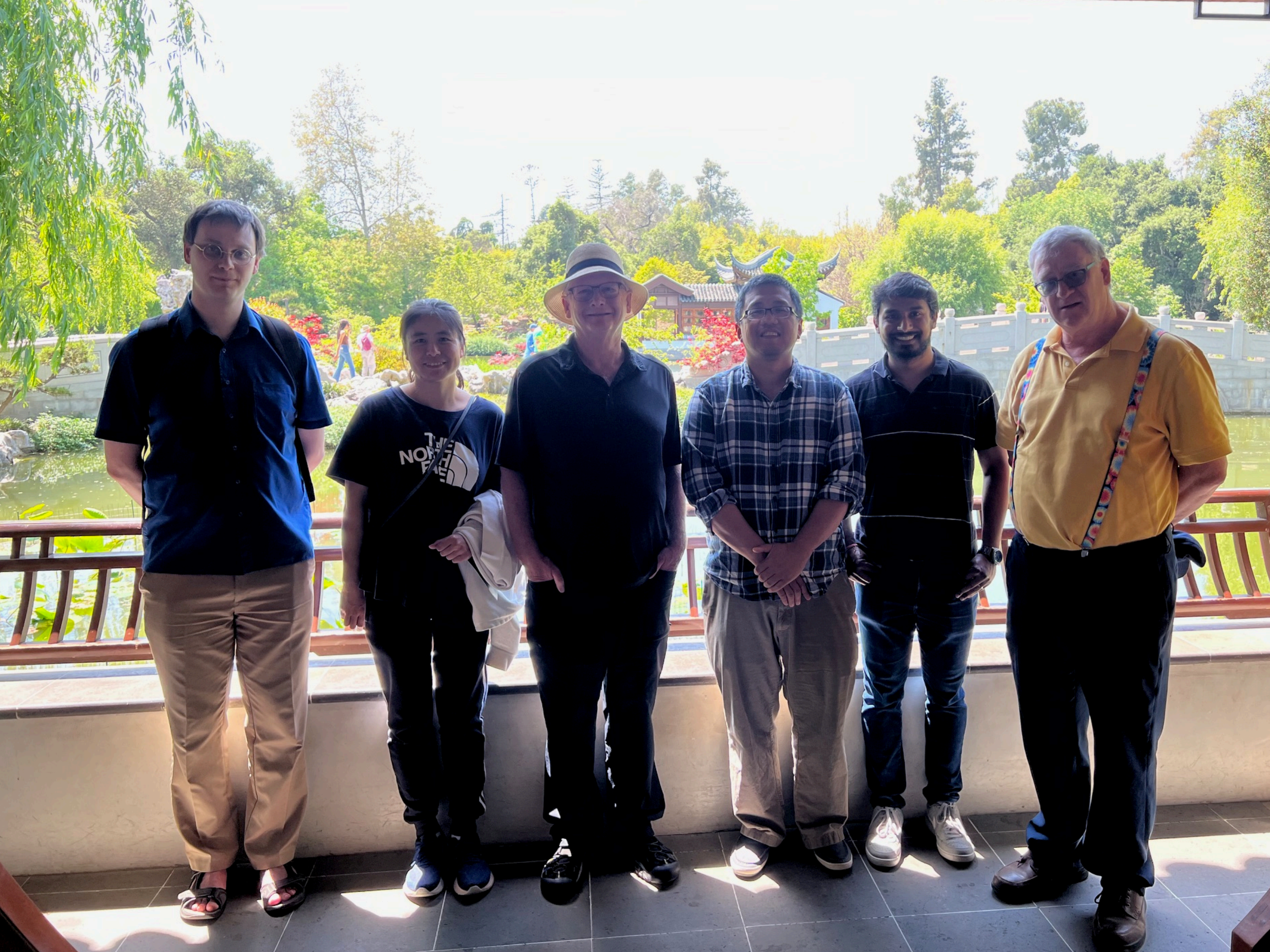
…suggesting even that shock waves placed a fundamental limit on the propagation of acoustic signals.

Our result says “not so” when temperature and entropy gradients are present.

Robin Young's research group at AIM Institute Cal Tech discovered the method extends to a rather large class of 3x3 systems of equations containing an entropy-like field…



(3) Characterization of the radial instability of Friedmann spacetimes at the Big Bang

—with Christopher Alexander and Zeke Vogler



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(Framework set out in 2017 paper in RSPA with Joel Smoller.)

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(Sounds like Dark Energy?)

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Proof based on a self-similar formulation of the Einstein equations which represents the critical Friedmann spacetime as a rest point, allowing for eigenvalue analysis of the stability.

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—Paper just accepted RSPA!

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Research

Article submitted to journal

Subject Areas:
Mathematical Physics, Differential Equations, Relativity

Keywords:
General Relativity, Instability, Cosmology, Big Bang, Dark Energy

Author for correspondence:
Blake Temple
e-mail: temple@math.ucdavis.edu

The Instability of the Critical Friedmann Spacetime at the Big Bang as an Alternative to Dark Energy

C. Alexander[1], B. Temple[2] and Z. Vogler[3]

[1]Department of Mathematics, University College London, London, WC1H 0AY, United Kingdom
[2]Department of Mathematics, University of California, Davis, CA 95616, United States
[3]Department of Mathematics, University of California, Davis, CA 95616, United States

We characterize the local instability of pressureless Friedmann spacetimes to radial perturbation at the Big Bang. The analysis is based on a formulation of the Einstein–Euler equations in self-similar variables (t, ξ), with $\xi = r/t$, conceived to realize the critical $(k = 0)$ Friedmann spacetime as a stationary solution whose character as an unstable saddle rest point SM is determined via an expansion of smooth solutions in

Referee: 1

Comments to the Author(s)
Report on the paper
"The Instability of the Critical Friedmann Spacetime at the Big Bang as an Alternative to Dark Energy"
by C. Alexander, B. Temple and Z. Vogler

The paper is concerned with a careful analysis of perturbations of the Friedmann-Lemaitre-Robertson-Walker (FLRW) spacetime of cosmology. The authors find an instability which provides an alternative explanation of the anomalous expansion of the universe. More precisely, the authors start from the homogeneous and isotropic FLRW spacetime in the flat case (k=0) for a pressureless gas. They reformulate the corresponding Einstein-Euler equations in self-similar variables, in which the metric resembles the Schwarzschild metric, and perturb in powers of the variable r/t. Expanding up to order n, they obtain a system of $2n$ coupled ODEs. The authors perform a careful stability analysis of these systems. They find an unstability to every order n, having the effect that the solutions generically accelerate away from the FLRW spacetime for intermediate times, but decay back to FLRW for large times. A quantitative analysis of the deviation from FLRW for intermediate times reveals that this effect could indeed account for the anomalous expansion of our universe which is usually explained by dark energy. This finding is very interesting and extremely important, because it indicates that dark energy might not needed to explain the anomalous expansion of the universe. Another finding which I find interesting is that, solving the Einstein-Euler system backward in time beyond the radiation-dominated epoch, there is an instabiility which could break the self-similarity of the big bang.

The paper is very well written. The main points are first described clearly in words. Then detailed formulas and theorems make the statements and conclusions mathematically precise. I should note that the paper is a continuation of an earlier paper by Smoller, Temple and Vogler (reference [29] of the present paper), where the equations were derived and analyzed numerically. The analysis in the present paper goes much deeper and comes to extremely important physical implications. To my opinion, this clearly justifies publication. I strongly recommend the paper for publication in Proceedings of the Royal Society A.

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RSPA: 100 Word Summary

In the early 1930's Einstein rejected the static universe as unstable. Instead he embraced Eddington, Lemaitre and Hubble's theory of the Big Bang based on uniformly expanding Friedmann spacetimes. Here we prove that zero pressure Friedmann spacetimes are unstable at the Big Bang on large length scales, generic spacetimes accelerate away from Friedmann spacetimes, and the critical Friedmann spacetime of ΛCDM is most unstable of all. Aside from the fact that unstable solutions are unphysical, the analysis suggests that the cosmic acceleration might be the manifestation of an instability at the Big Bang, not a mysterious anti-gravitating Dark Energy.

In 2025 Marcello Disconzi invitation to talk at Black Hole Institute Vanderbilt University…



(4) A causal relativistic version of the classical Navier-Stokes equations

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"phenomenologically correct at shock waves

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"phenomenologically correct at shock waves in the small dissipation limit."

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—with Heinrich Freistuehler

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"phenomenologically correct at shock waves in the small dissipation limit."

—with Heinrich Freistuehler

(…based on Freistuehler's recent deep and definitive investigations…)



(4) A causal relativistic version of the classical Navier-Stokes equations which is

"phenomenologically correct at shock waves in the small dissipation limit."

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Starting point: Navier-Stokes is fundamentally only a first order theory of dissipation…

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We took this seriously and formulated a set of first order equivalence transformations…

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Starting point: Navier-Stokes is fundamentally only a first order theory of dissipation…

We took this seriously and formulated a set of first order equivalence transformations…

**And proved the following theorem:

(4) A causal relativistic version of the classical Navier-Stokes equations which is

"phenomenologically correct at shock waves in the small dissipation limit."

—with Heinrich Freistuehler

Starting point: Navier-Stokes is fundamentally only a first order theory of dissipation…

Theorem: There is a unique causal hyperbolic system of equations which is first order equivalent to both the Eckart and Landau equations, such that all weak and strong shocks admit shock profiles.

arXiv:2303.11829v1 [math.AP] 21 Mar 2023

On Shock Profiles in Four-Field Formulations of Dissipative Relativistic Fluid Dynamics

Heinrich Freistühler[1,a] and *Blake Temple*[2,b]

March 17, 2023

Affiliations:
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2) Department of Mathematics, University of California at Davis, Davis CA 95616, USA

a) E-mail: heinrich.freistuehler@uni-konstanz.de
b) E-mail: temple@math.ucdavis.edu

Abstract

This paper shows that in second-order hyperbolic systems of partial differential equations proposed in authors' earlier paper (J. Math. Phys. 59 (2018)) for modelling the relativistic dynamics of barotropic fluids in the presence of viscosity and heat conduction, shock waves of arbitrary strength have smooth, monotone dissipation profiles. The results and arguments extend classical considerations of Weyl (Comm. Pure Appl. Math. **2** (1949)) and Gilbarg (Amer. J. Math. **73** (1951)) to the relativistic setting.

Forty Years of Math Memories

Forty Years of Math Memories

Starting at the Beginning…

Forty Years of Math Memories

My parents moved from Toronto Canada to Cleveland Ohio in 1948…

Forty Years of Math Memories

My parents moved from Toronto Canada to Cleveland Ohio in 1948…

…where I was born in 1951.



Cleveland…1954



a time when old men cut your hair…

I grew up and went to High School in Solon Ohio…near Cleveland…

More than anything else I hated wrestling

More than anything else I hated wrestling…



Solov High School

Athletic Award

S

This certifies that

John Temple

has been awarded this certificate for participation in

J. V. Wrestling

19 66-67

L. G. Cornelius
Principal

Arch Tunnell
Athletic Director

Walt Porowski
Coach

I experienced my first great sense of intellectual freedom in life when I realized I didn’t have to wrestle…

In 1967, my junior year of High School, my family moved to Ann Arbor, Michigan…

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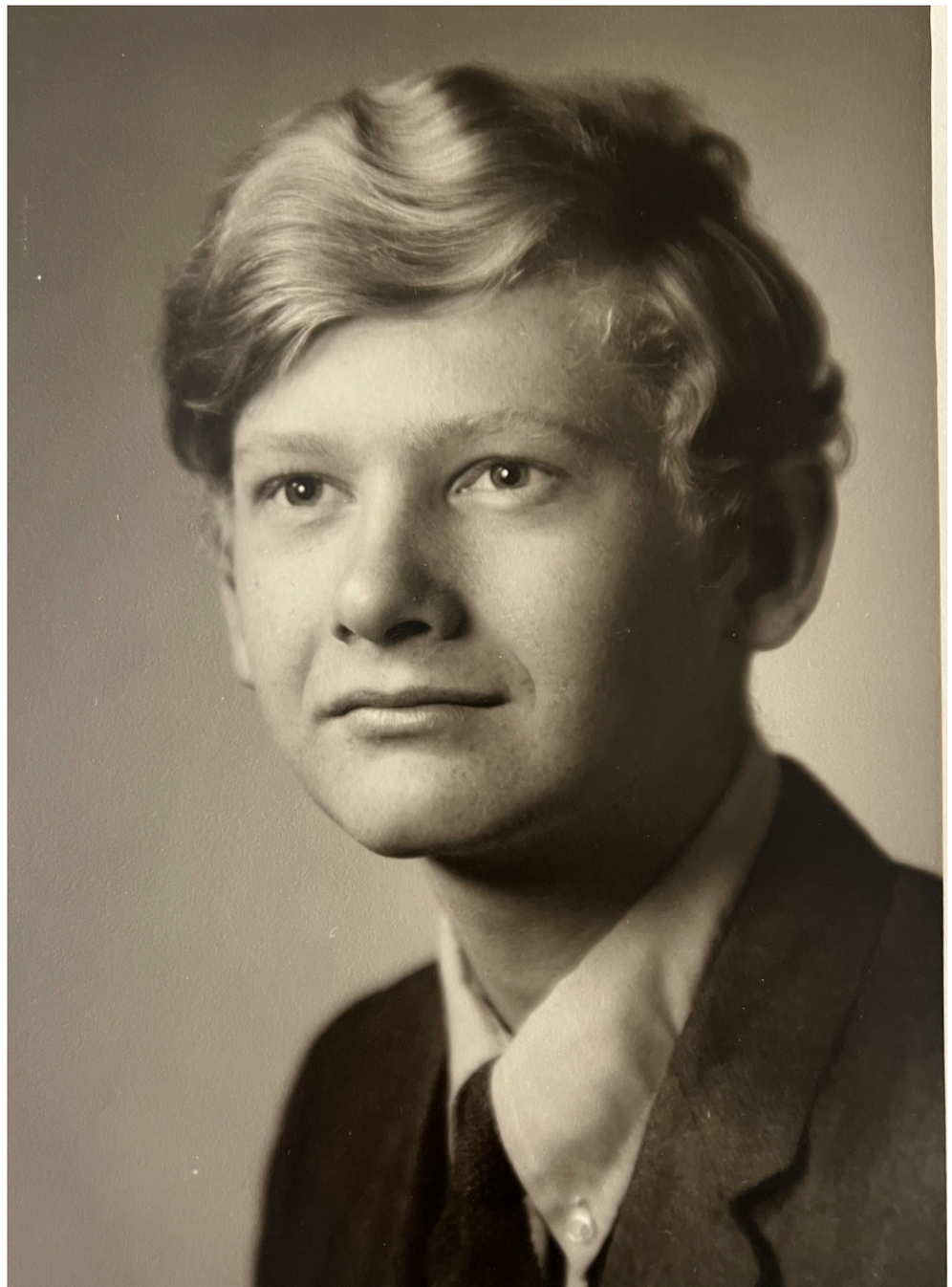

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I did well on a couple of exams…

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I did well on a couple of exams…



Certificate of Recognition

STATE OF MICHIGAN

COMPETITIVE SCHOLARSHIP PROGRAM

1969

THE MICHIGAN DEPARTMENT OF EDUCATION

Awards To

JOHN B TEMPLE

A CERTIFICATE OF RECOGNITION FOR OUTSTANDING PERFORMANCE IN THE STATE SCHOLARSHIP COMPETITION.

Ira Polley

Ira Polley
State Superintendent of Public Instruction

In 1969 I entered the University of Michigan at Ann Arbor MI…

In 1969 I entered the University of Michigan at Ann Arbor MI…

This was the height of the post WWII Baby Boomers entering College…

1969 was the height of the Vietnam War…

1969 was the height of the Vietnam War…

The University of Michigan was at the heart of the anti-war protests…

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It was a time of…

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It was a time of…

…the birth control pill

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The University of Michigan was at the heart of the anti-war protests…

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…the birth control pill

…the sexual revolution

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The University of Michigan was at the heart of the anti-war protests…

It was a time of…

…the birth control pill

…the sexual revolution

…Great Music—Beatles, Rock and Roll, Motown, Bob Dylan, Rolling Stones, Led Zeppelin, Simon and Garfunkel…

We went to school to learn the deep truths of life…not to make money, or make a career…

We went to school to learn the deep truths of life…not to make money, or make a career…

Going to school to get a job to make money was selling out to the establishment…

We went to school to learn the deep truths of life…not to make money, or make a career…

Going to school to get a job to make money was selling out to the establishment…

So…

I entered U of M as a Philosophy Major
(thinking I would become a Psychiatrist…)

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(thinking I would become a Psychiatrist…)

My advisor in Philosophy told me that my exams showed I should take Mathematics…

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(I hadn't even taken math my senior year HS!)

I entered U of M as a Philosophy Major
(thinking I would become a Psychiatrist…)

My advisor in Philosophy told me that my exams showed I should take Mathematics…

(I hadn't even taken math my senior year HS!)

So he convinced me to try one class, and signed me up for Calculus I…

I loved learning the proofs in Calculus!

I loved learning the proofs in Calculus!

It was the only class I wanted to study.

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I graduated with a Philosophy Major in 1973.

I loved learning the proofs in Calculus!

It was the only class I wanted to study.

I graduated with a Philosophy Major in 1973.

My goals were to learn Godel's Incompleteness Theorem…. and Einstein's theory of Relativity.

My junior year I met my wife Nancy through her brother Peter who was a friend of my brother…

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We all took an Asian Studies Class together,

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We all took an Asian Studies Class together, Nancy and I started arguing, and we've been arguing ever since!

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Nancy's father James Wendel was a Probabilist in the Department of Mathematics at Michigan…

My junior year I met my wife Nancy through her brother Peter who was a friend of my brother…

We all took an Asian Studies Class together, Nancy and I started arguing, and we've been arguing ever since!

Nancy's father James Wendel was a Probabilist in the Department of Mathematics at Michigan…

I was a Philosophy Major studying Math "in the patent office"…

At that time, everyone had long hair, grew beards, donned aviator glasses, wore blue jeans…

At that time, everyone had long hair, grew beards, donned aviator glasses, wore blue jeans…

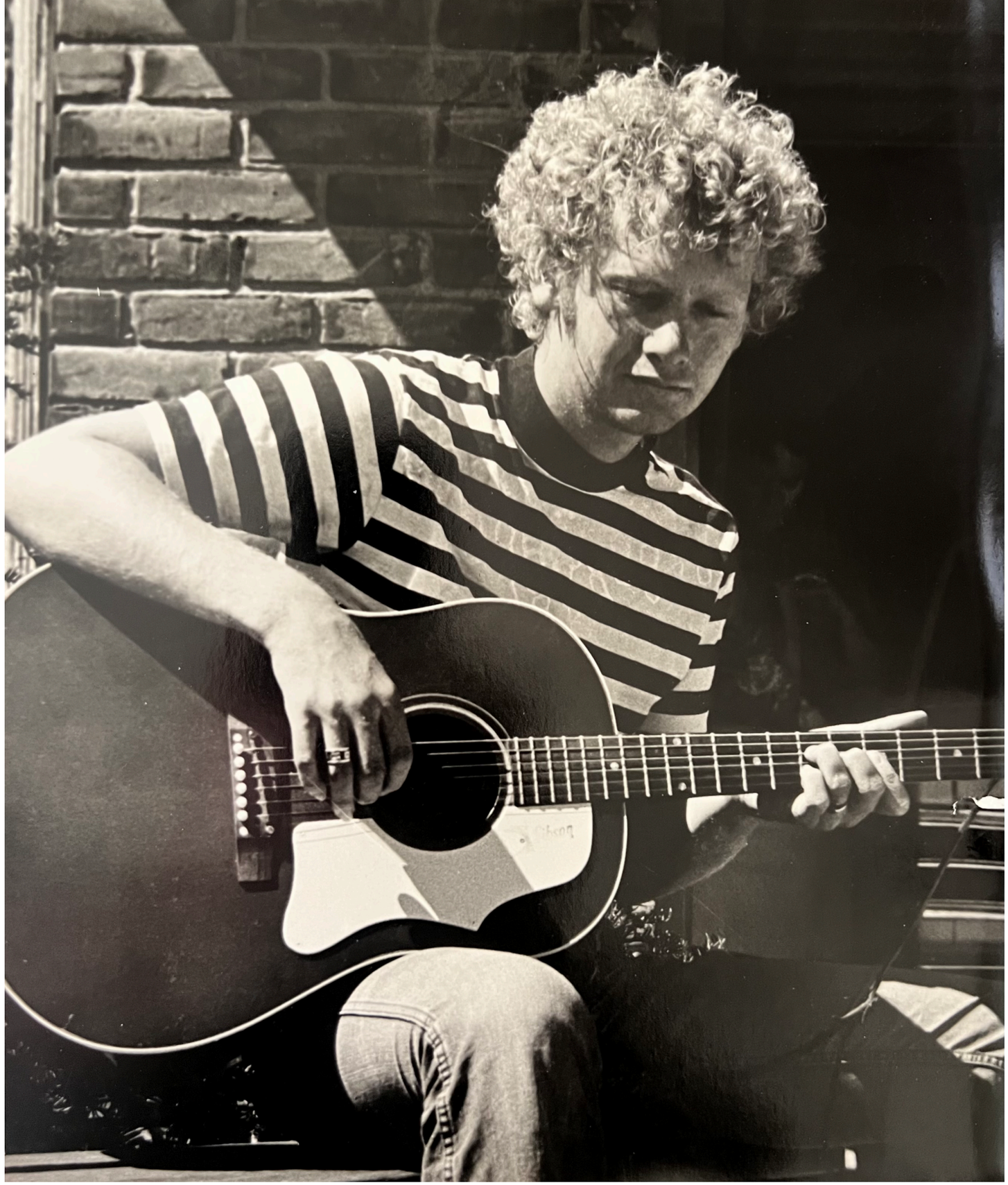
…and one in three people played the guitar…



Blake



Nancy



Blake



Nancy



Blake



Nancy



Blake and Nancy



Blake and Nancy



Blake and Nancy



Blake



and Nancy

In 1973 I entered Graduate Mathematics at Michigan in a new program to teach in Community Colleges.

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We were way over trained for the job…

In 1973 I entered Graduate Mathematics at Michigan in a new program to teach in Community Colleges.

We were way over trained for the job…

Later, when I began teaching at Davis, I realized that I was the only faculty member qualified to teach at the lower division level…

Credential No. 5 6 TEM 001

№ 105466

The California Community Colleges

J. BLAKE TEMPLE

The Board of Governors of the California Community Colleges, acting in accordance with the authority vested in it, awards to the person named above a

COMMUNITY COLLEGE INSTRUCTOR CREDENTIAL

This document, earned by meeting the provisions established by law and the requirements established by the Board of Governors of the California Community Colleges, authorizes the holder to perform all services permitted by these provisions and requirements.

Subject Matter Area: Mathematics

Issued: May 14, 1976

Valid for life

Chairman, Board of Governors
California Community Colleges

Chancellor, SIDNEY W. BROSSMAN
California Community Colleges

I aced Joel Smoller's class on Real Analysis

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Joel got me a full TA-ship to work with him…

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I told Joel I wanted to work in General Relativity,
but he told me that was a dead subject…

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I told Joel I wanted to work in General Relativity, but he told me that was a dead subject…

…told me I should learn shock wave theory

At that time, I knew I could do research…

…I wasn't sure I could do the teaching!

In teaching, Joel put in every detail…

In teaching, Joel put in every detail…

…he hated jargon…

In teaching, Joel put in every detail…

…he hated jargon…

…he always motivated proofs…

In teaching, Joel put in every detail…

…he hated jargon…

…he always motivated proofs…

…he loved theorems and proofs with surprises…

In teaching, Joel put in every detail…

…he hated jargon…

…he always motivated proofs…

…he loved theorems and proofs with surprises…

…he didn't respect numerical math w/o proofs…

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…but he loved confidence.

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…he hated jargon…

…he always motivated proofs…

…he loved theorems and proofs with surprises…

…he didn't respect numerical math w/o proofs…

…Joel hated arrogance and pretense…

…but he loved confidence.

…the first time I saw Joel lecture, I knew I could do math the way Joel did it!

In teaching, Joel put in every detail…

…he hated jargon…

…he always motivated proofs…

…he loved theorems and proofs with surprises…

…he didn't respect numerical math w/o proofs…

…Joel hated arrogance and pretense…

…but he loved confidence.

…as a student I met Tai-Ping Liu, Takaaki Nishida, Peter Lax and Ron Diperna…

Nancy’s father and I became friends…

Nancy's father and I became friends…



Nancy came from a Big Family…



Nancy and I got to know each other…

Nancy and I got to know each other…



Nancy and I got to know each other…



In 1977 Nancy and I got married…

We had a large wedding…

We had a large wedding…

John Blake Temple — Nancy June Wendel

SALINE — After a wedding trip to the Caribbean, newlywed Mr. and Mrs. John Blake Temple will reside in Ann Arbor.

They were married Friday in Weller's Carriage House in Saline by the Rev. Erwin Gaede. The reception was also held there.

The bride is the former Nancy June Wendel, daughter of Mr. and Mrs. James Wendel of Hillridge Boulevard in Ann Arbor.

The bridegroom is the son of Mr. and Mrs. Paul B. Temple of Day Street in Ann Arbor.

Honor attendants were Marian McGarrigle of Ann Arbor and Alan Clark of Ypsilanti.

Bridesmaids included Margaret and Laura Wendel, sisters of the bride; and Anne Temple, sister of the bridegroom.

Ushers were David Temple, brother of the bridegroom; and John, Robert and Peter Wendel, brothers of the bride.



John Temple
. . . Nancy Wendel

We danced…

We danced…



We fed each other cake…

We fed each other cake…



I played soulful blues guitar with the band…

I played soulful blues guitar with the band…



I played soulful blues guitar with the band…



In 1980 I completed PhD with Joel Smoller…

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I wrote a deeply technical thesis on the Glimm Scheme which pushed me to my limits…

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Glimm's idea was that solutions could be evolved by nonlinear wave interactions…

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Joel told me the Glimm scheme (1965) was the most original and difficult piece of analysis in PDE at that time…

Glimm's idea was that solutions could be evolved by nonlinear wave interactions…

…and the growth in TV could be controlled by a global Potential Interaction Functional Q

Glimm's method gave existence and bounds for all time for shock wave solutions of the compressible Euler Equations…

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Glimm's Q did better than Energy Methods…

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Energy methods give Gronwall estimates with exponential growth, and didn't handle shocks.

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Glimm's method applies to solutions which decay to non-interacting wave patterns: $Q \to 0$

Glimm's method gave existence and bounds for all time for shock wave solutions of the compressible Euler Equations…

Glimm's Q did better than Energy Methods…

Energy methods give Gronwall estimates with exponential growth, and didn't handle shocks.

Glimm's method applies to solutions which decay to non-interacting wave patterns: $Q \to 0$

The periodic solutions proved by Young and I are the first bounded solutions with sustained nonlinear interactions, which do not decay to non-interacting wave patterns: $Q \not\to 0$

Glimm's method only worked in 1-dimension…

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Glimm's proof (1965) worked for small TV…

Glimm's method only worked in 1-dimension…

Glimm's proof (1965) worked for small TV…

In my thesis I found a modified Q that worked for large TV by perturbing off of a special but interesting case…

JOURNAL OF DIFFERENTIAL EQUATIONS 41, 96–161 (1981)

Solutions in the Large for the Nonlinear Hyperbolic Conservation Laws of Gas Dynamics*

J. BLAKE TEMPLE

Department of Mathematics, University of Michigan, Ann Arbor, Michigan 48104

Received August 13, 1980

The constraints under which a gas at a certain state will evolve can be given by three partial differential equations which express the conservation of momentum, mass, and energy. In these equations, a particular gas is defined by specifying the constitutive relation $e = e(v, S)$, where $e =$ specific internal energy, $v =$ specific volume, and $S =$ specific entropy. The energy function $e = -\ln v + (S/R)$ describes a polytropic gas for the exponent $\gamma = 1$, and for this choice of $e(V, S)$, global weak solutions for bounded measurable data having finite total variation were given by Nishida in [10]. Here the following general existence theorem is obtained: let $e_\varepsilon(v, S)$ be any smooth one parameter family of energy functions such that at $\varepsilon = 0$ the energy is given by $e_0(v, S) = -\ln v + (S/R)$. It is proven that there exists a constant C independent of ε, such that, if $\varepsilon \cdot$ (total variation of the initial data) $< C$, then there exists a global weak solution to the equations. Since any energy function can be connected to $e_0(V, S)$ by a smooth parameterization, our results give an existence theorem for all the conservation laws of gas dynamics. As a corollary we obtain an existence theorem of Liu, *Indiana Univ. Math. J.* **26**, No. 1 (1977) for polytropic gases. The main point in this argument is that the nonlinear functional used to make the Glimm Scheme converge, depends only on properties of the equations at $\varepsilon = 0$. For general $n \times n$ systems of conservation laws, this technique provides an alternate proof for the interaction estimates in Glimm's 1965 paper. The new result here is that certain interaction differences are bounded by ε as well as by the approaching waves.

Contents. Introduction. 1. Preliminaries. 2. Interaction Estimates. 3. Gas Dynamic Equations. 4. Existence Theorem Using Glimm Difference Scheme. 5. An Existence Theorem for Polytropic Gases. Appendix I. Proof of Lemma 1.2. Appendix II. Proof of Proposition 3.1. Diagrams. References.

INTRODUCTION

The existence of a solution to the initial value problem for a one-dimensional system of nonlinear hyperbolic conservation laws was solved by

* This paper is part of a doctoral thesis written under Professor Joel Smoller of the University of Michigan, August 1980.

0022-0396/81/070096–66$02.00/0

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Nishida found a way to extend Glimm's method to large TV in the special case $p = \sigma\rho$



Takaaki Nishida



Me, TP Liu, G. Chen, Marshall Slemrod, Takaaki Nishida, D. Hoff



Nishida found a way to extend Glimm's method to large TV in the special case $p = \sigma\rho$

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In my thesis I found a Q which perturbed Nishida's solutions the way Glimm perturbed the constant state…

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Joel told me I was the first graduate student to write a thesis on Glimm's Method…

I won an NSF Postdoc and went to Rockefeller University NYC to work with Glimm…

Nishida found a way to extend Glimm's method to large TV in the special case $p = \sigma\rho$

In my thesis I found a Q which perturbed Nishida's solutions the way Glimm perturbed the constant state…

Joel told me I was the first graduate student to write a thesis on Glimm's Method…

My brother and sister were already living in NYC!



Anne: Actor

David: Photographer/writer/set builder

Ten years later Joel and I began our work in Relativity proving Nishida's idea extended to the relativistic Euler Equations.

Ten years later Joel and I began our work in Relativity proving Nishida's idea extended to the relativistic Euler Equations.

But in this case, $p = \sigma \rho$ wasn't just a model problem, it was the equation of state of pure radiation!

$$\sigma = \frac{c^2}{3}$$

Commun. Math. Phys. 156, 67–99 (1993)

Communications in Mathematical Physics

© Springer-Verlag 1993

Global Solutions of the Relativistic Euler Equations

Joel Smoller[1], **Blake Temple**[2]

[1] Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, USA; Supported in part by NSF Applied Mathematics Grant Number DMS-89-05205

[2] Department of Mathematics, University of California, Davis, Davis CA 95616, USA; Supported in part by NSF Applied Mathematics Grant Number DMS-86-13450

Received April 24, 1992

Abstract. We demonstrate the existence of solutions with shocks for the equations describing a perfect fluid in special relativity, namely, $\operatorname{div} T = 0$, where $T^{ij} = (p + \rho c^2)u^i u^j + p\eta^{ij}$ is the stress energy tensor for the fluid. Here, p denotes the pressure, u the 4-velocity, ρ the mass-energy density of the fluid, η^{ij} the flat Minkowski metric, and c the speed of light. We assume that the equation of state is given by $p = \sigma^2\rho$, where σ^2, the sound speed, is constant. For these equations, we construct bounded weak solutions of the initial value problem in two dimensional Minkowski spacetime, for any initial data of finite total variation. The analysis is based on showing that the total variation of the variable $\ln(\rho)$ is non-increasing on approximate weak solutions generated by Glimm's method, and so this quantity, unique to equations of this type, plays a role similar to an energy function. We also show that the weak solutions $(\rho(x^0, x^1), v(x^0, x^1))$ themselves satisfy the Lorentz invariant estimates $\operatorname{Var}\{\ln(\rho(x^0, \cdot)\} < V_0$ and $\operatorname{Var}\left\{\ln\frac{c + v(x^0, \cdot)}{c - v(x^0, \cdot)}\right\} < V_1$ for all $x^0 \geqq 0$, where V_0 and V_1 are Lorentz invariant constants that depend only on the total variation of the initial data, and v is the classical velocity. The equation of state $p = (c^2/3)\rho$ describes a gas of highly relativistic particles in several important general relativistic models which describe the evolution of stars.

1. Introduction

We consider the relativistic equations for a perfect fluid in Minkowski spacetime,

$$\operatorname{div} T = 0\,, \tag{1}$$

where

$$T^{ij} = (p + \rho c^2)u^i u^j + p\eta^{ij} \tag{2}$$

denotes the stress-energy tensor for the fluid. Recall that in Minkowski spacetime,

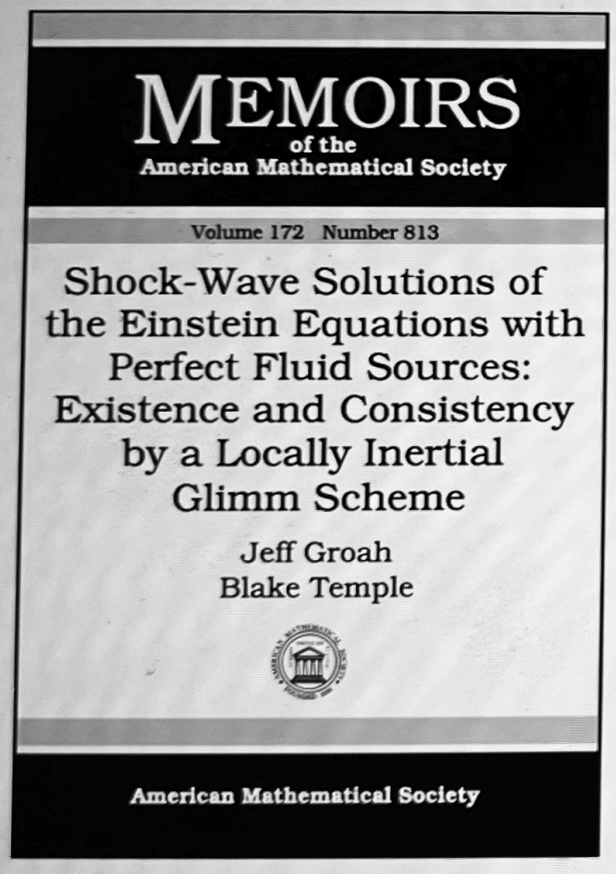
$$\operatorname{div} T \equiv T^i_{j,i}\,, \tag{3}$$

Later my student Jeff Groah and I extended this to General Relativity…

Later my student Jeff Groah and I extended this to General Relativity…

We gave the first general existence theory for shock wave solutions of the Einstein equations via Glimm's method.

Mathematical Physics



Shock-Wave Solutions of the Einstein Equations with Perfect Fluid Sources: Existence and Consistency by a Locally Inertial Glimm Scheme

Jeff Groah, *California State University at Monterey Bay, Seaside,* and **Blake Temple**, *University of California, Davis*


Jeff Groah
Jeff Groah

Most interesting: the existence theory was given in a coordinate system where the metric and connection appeared “Singular”.

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Both the connection and the the curvature were in L^∞, a regularity too low to define geodesic curves.

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For many years, experts questioned whether these shock solutions made physical sense!

Most interesting: the existence theory was given in a coordinate system where the metric and connection appeared “Singular”.

Both the connection and the the curvature were in L^∞, a regularity too low to define geodesic curves.

For many years, experts questioned whether these shock solutions made physical sense!

This was the original motivation for Reintjes and I to search for the RT-equations!

Joel Hass was first to recognize the significance of our new ideas!

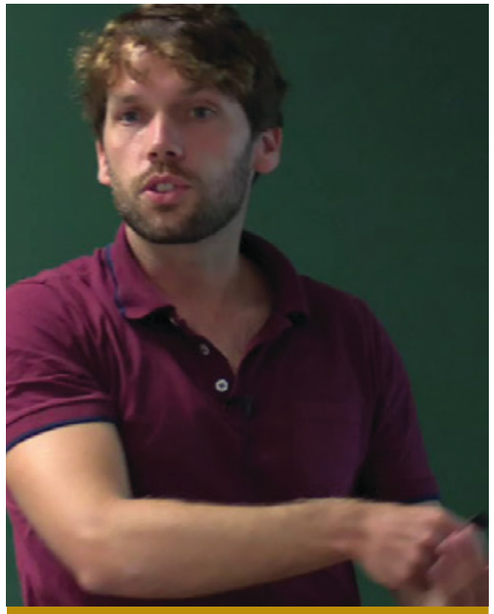


Crinkled Spacetime



by Blake Temple

Blake Temple is a Distinguished Professor of Mathematics at UC Davis.



Moritz Reintjes completed his Ph.D. with Professor Temple at UC Davis. Afterwards he was a postdoc at the University

In the early 20th century, Einstein proposed a set of equations that related the gravitational force to the curvature of space time. Understanding the mathematical theory of these questions is a central challenge that is far from complete. Recent work in this area by Professor Blake Temple with coauthor Moritz Reintjes has attracted attention in the Math and Physics communities. They have developed a new theory of "metric smoothing" in General Relativity, based on what they call *Regularity Transformation Equations*, or RT-equations.

Their studies began by investigating whether the interaction of shock waves in General Relativity (GR) could create a new kind of *regularity singularity* where spacetime itself is not smooth. Earlier work on shock waves was only able to prove existence of shock wave solutions for metrics that are Lipschitz continuous. A more regular spacetime, one order smoother, is required to make the correspondence between Einstein's theory of General Relativity and the physics of Special Relativity, the case when there is no gravitational curvature. What was unclear was whether the lack of smoothness was inherent in the spacetime itself, or in contrast, whether it was a feature of the way that space was being modeled, or *parametrized*. That is, was the lack of smoothness due only to a bad choice of map, or coordinate map from the original, it is necessary and sufficient to solve the RT-equations. In their final paper, they establish the general theory by proving solutions of the RT-equations always exist for wrinkled maps at least one order smoother than the shock wave case. In other words, for wrinkled maps above a threshold smoothness, the lack of smoothness is *never* caused by the nature of spacetime, but always by the way it is being modeled. As they put it, "a crinkled map of spacetime can always be smoothed out by a coordinate transformation." The theory still leaves open the problem of regularity singularities at GR shock waves, but reduces it to the problem of finding solutions of the RT-equations at the lowest level of smoothness.

In fact, their methods apply beyond Einstein's theory of relativity, to the general problem of smoothing the spaces that arise in analysis and differential geometry. A rather surprising aspect of their argument is that it relies on the theory of *elliptic* partial differential equations to find coordinate systems which smooth out solutions to the equations of General Relativity, which are *hyperbolic*. This is unexpected because hyperbolic PDE's, which govern sound waves and give rise to shocks, behave very differently than elliptic PDE's, which typically apply to more regular settings

So…in 1980 I won an NSF Postdoc to go work with Glimm at Rockefeller University.

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James Glimm and Peter Lax were the superstars.

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The Courant Institute was the intellectual center of Applied Mathematics.

James Glimm and Peter Lax were the superstars.

When I arrived at Rockefeller University and met James Glimm, I couldn't believe someone that famous could still be alive!

So…in 1980 I won an NSF Postdoc to go work with Glimm at Rockefeller University.

The Courant Institute was the intellectual center of Applied Mathematics.

James Glimm and Peter Lax were the superstars.

When I arrived at Rockefeller University and met James Glimm, I couldn't believe someone that famous could still be alive!

Peter Lax and James Glimm were our heroes for decades to come!

Rockefeller Univ, Upper East Side, & Queensboro Bridge

2021

A cold December night, just before Christmas. Pictures from Roosevelt Island, NYC, after 9pm, Dec 20, 2021.



↑ Manhattan's Upper East Side, north of the Queensboro Bridge. Parts of Roosevelt Island at lower right, red streaks of lights from passing vehicle. HDR photo.

↑ Manhattan's Upper East Side, north of the Queensboro Bridge. Parts of Roosevelt Island at lower right, red streaks of lights from passing vehicle. HDR photo.

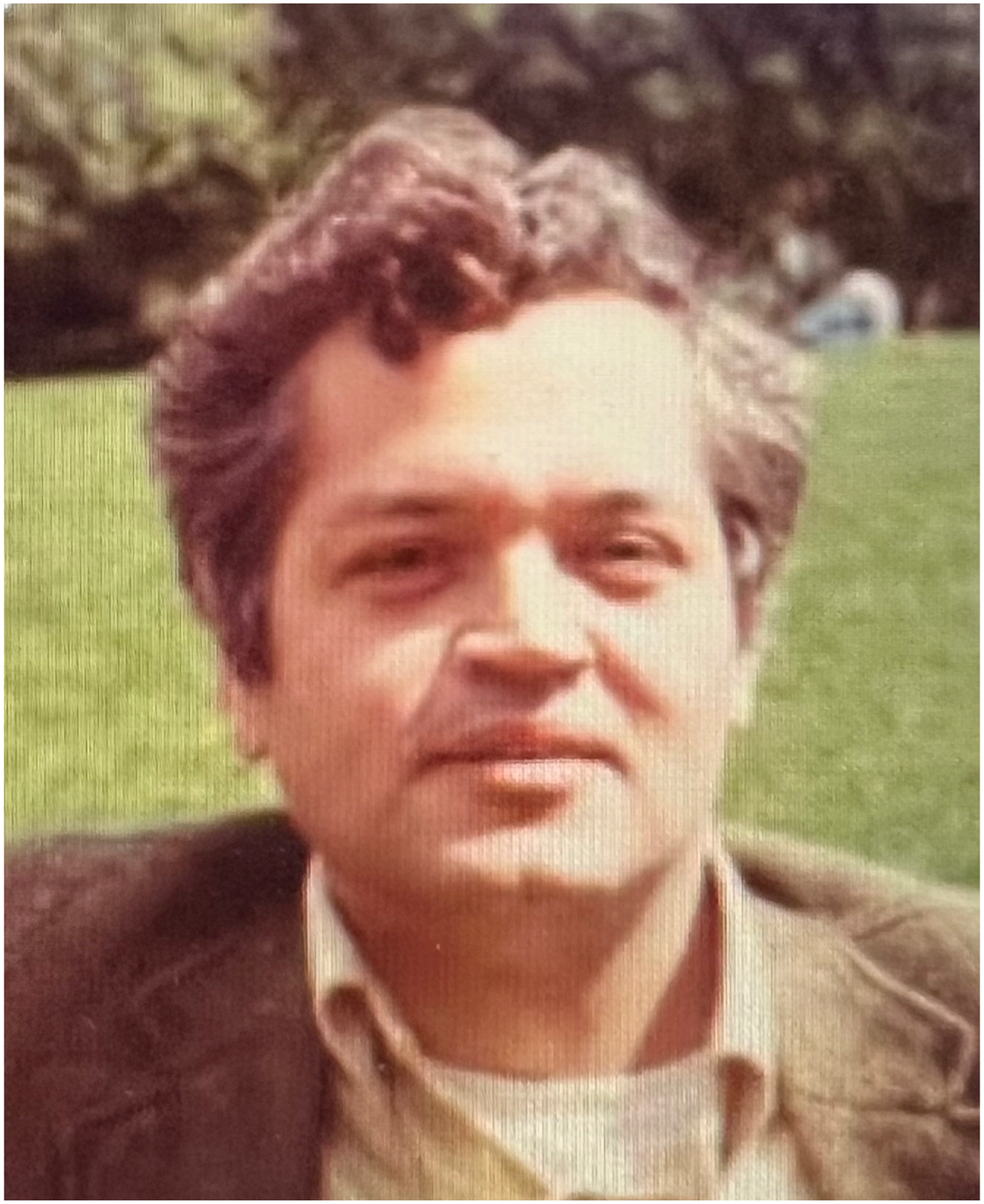


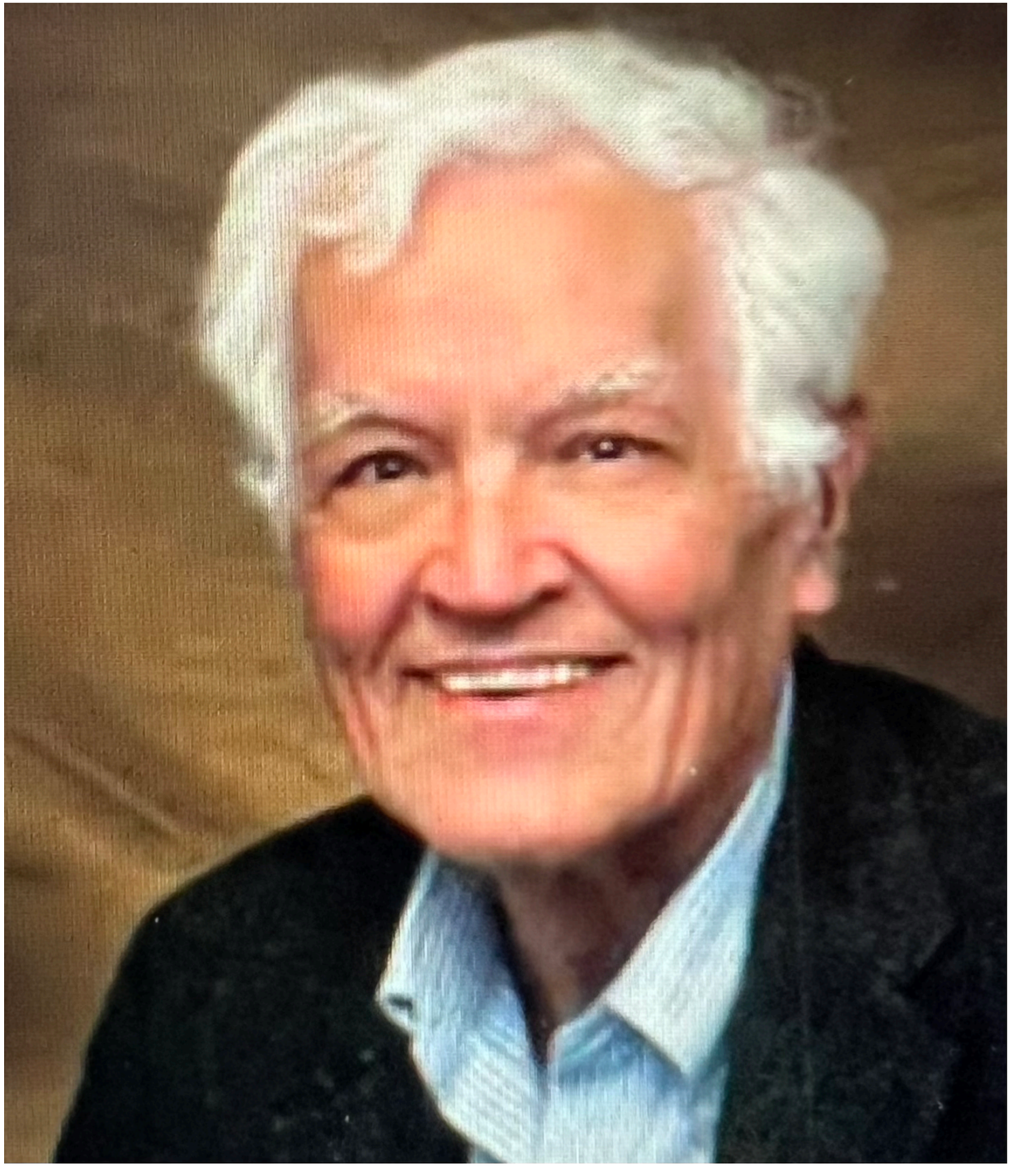


↑ Queensboro Bridge on a cold clear night. Streaks in the sky from aircraft and the movement of stars in the sky due to the long exposures. Sunstars atop the bridge. HDR photo.

James Glimm, Rockefeller University/Courant

James Glimm, Rockefeller University/Courant

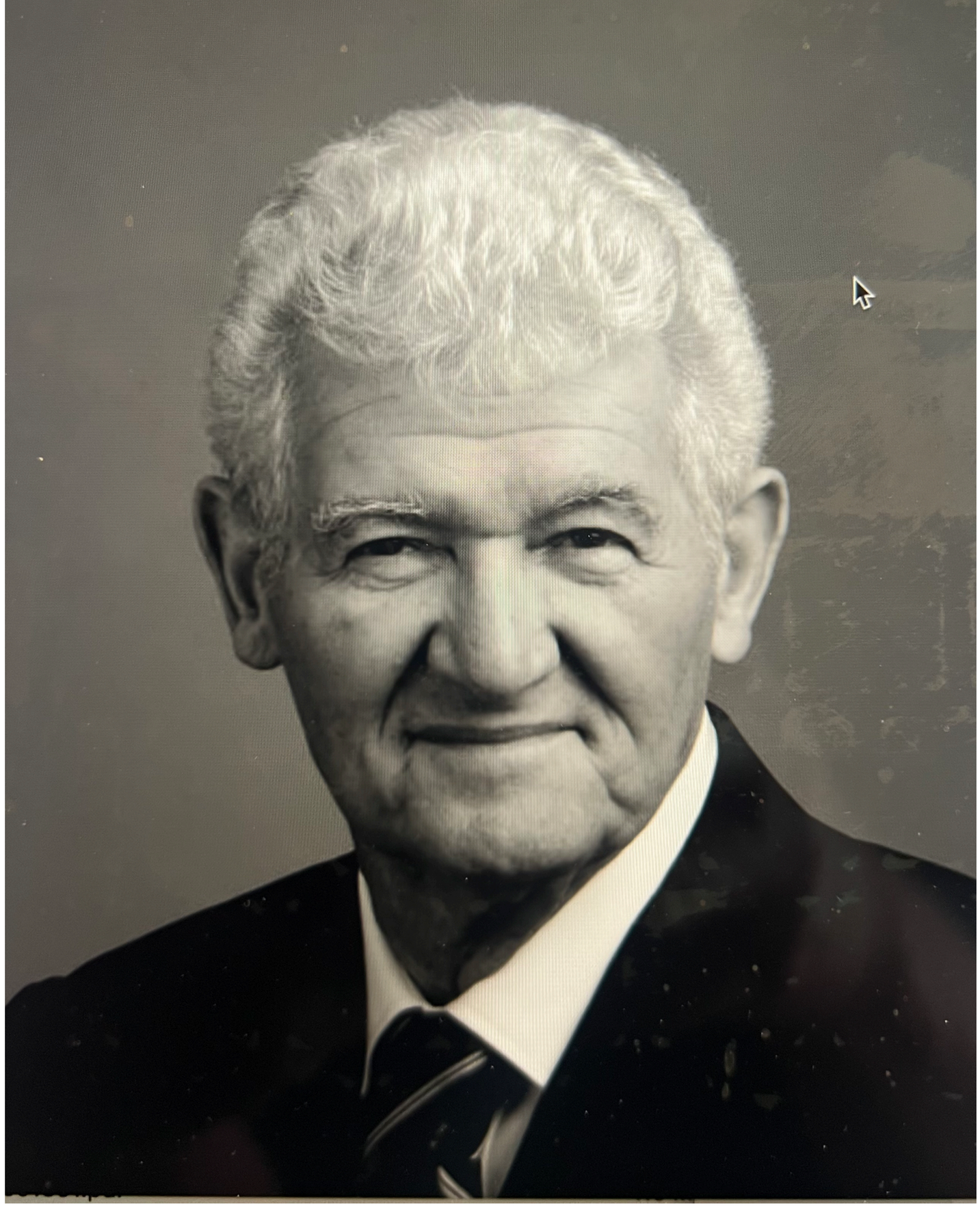




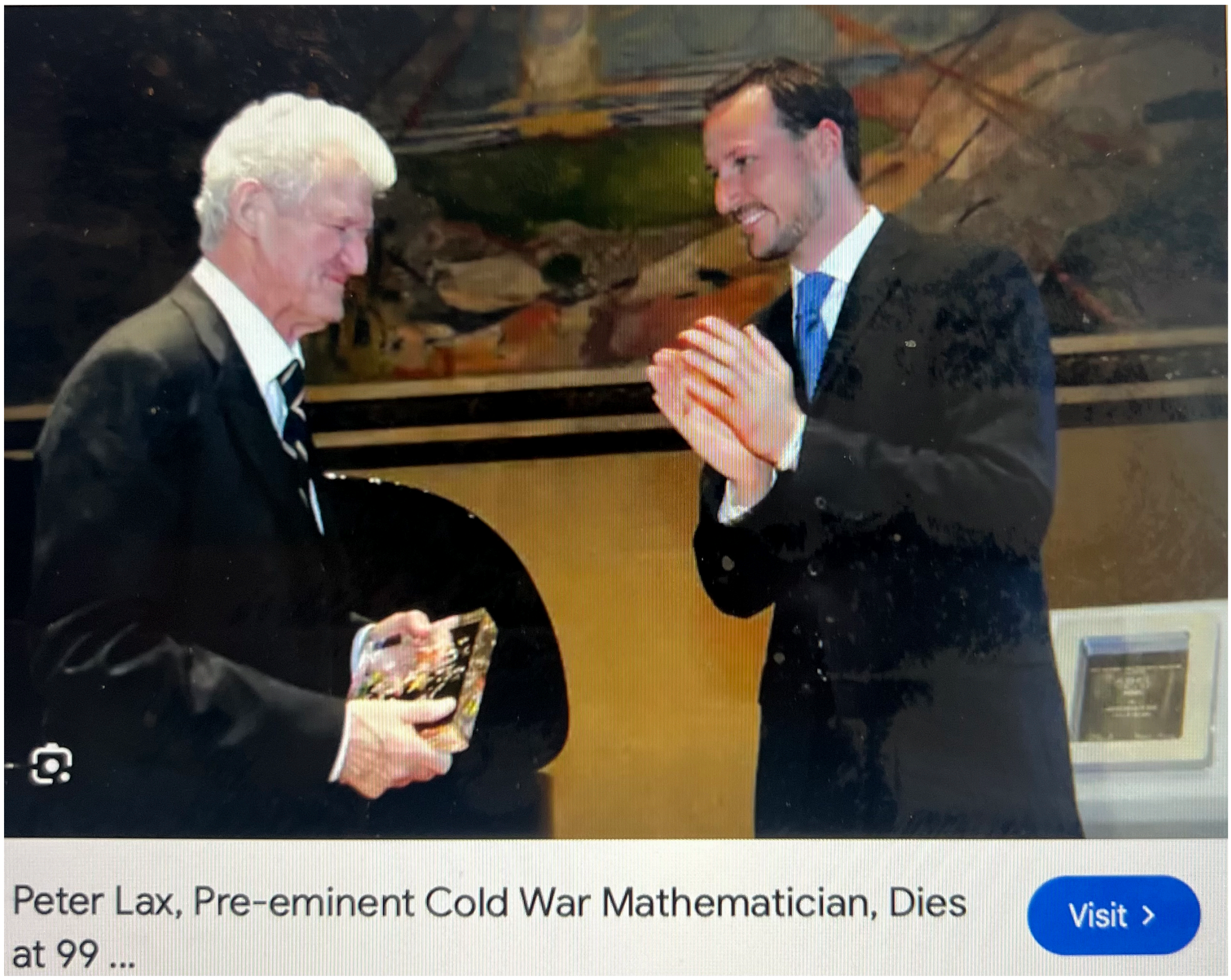
James Glimm



James Glimm wins Medal of Science



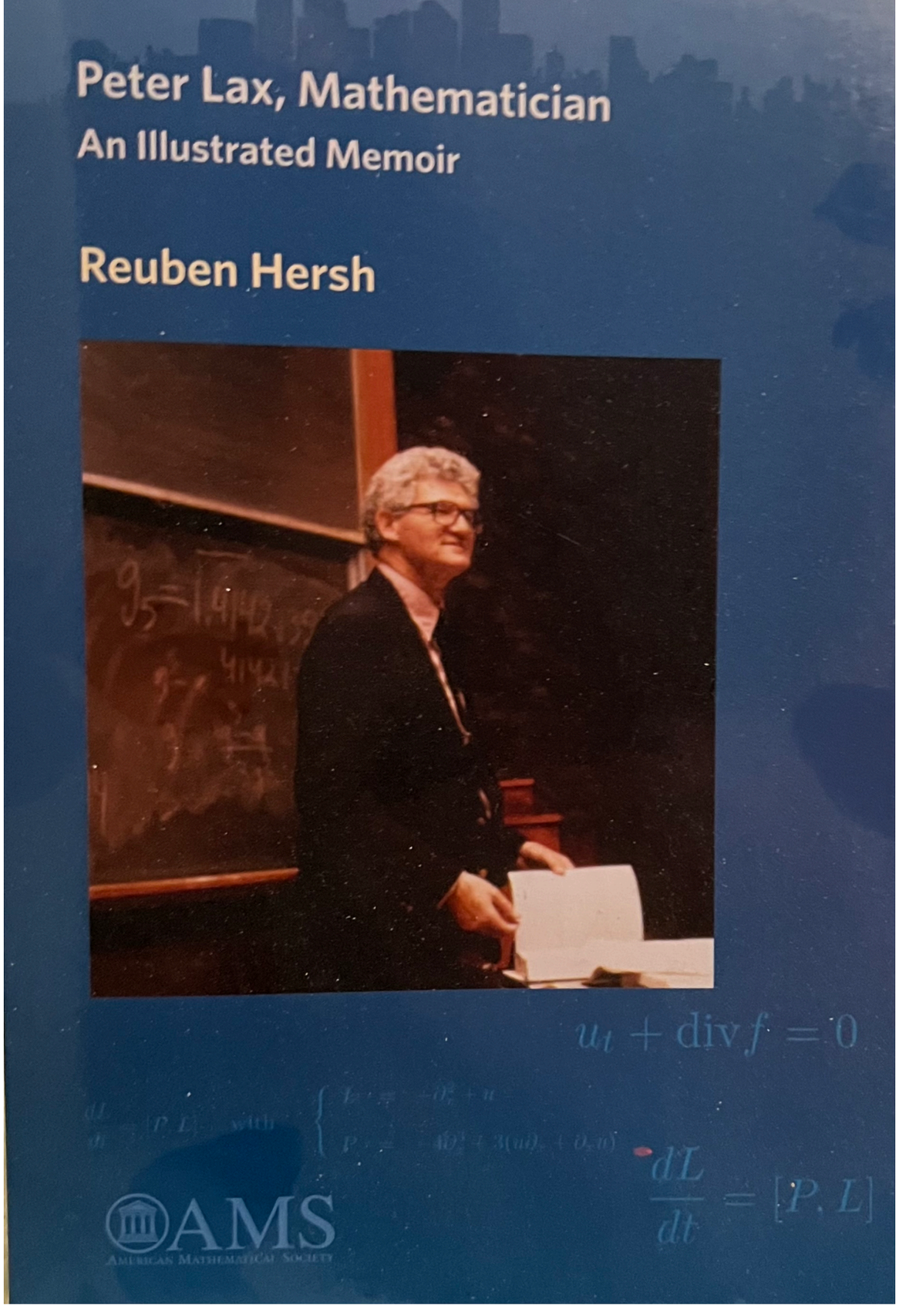
Peter Lax



Peter Lax, Pre-eminent Cold War Mathematician, Dies at 99 ...

Visit >

NYTimes: Peter Lax Receiving 2005 Abel Prize


Peter Lax, Mathematician
An Illustrated Memoir
Reuben Hersh
$u_t + \operatorname{div} f = 0$
$\frac{dL}{dt} = [P, L]$
AMS
American Mathematical Society

Peter Lax

Peter invited Lynne Ipena and myself to stay a weekend with him at his apartment in NYC after meetings in Beijing and Wyoming…

Peter invited Lynne Ipena and myself to stay a weekend with him at his apartment in NYC after meetings in Beijing and Wyoming…

…we went to museums, discussed mathematics, and attended a celebration in recognition of Gene Isaacson at Courant.

Dear Blake,
the estimate I mentioned is Lemma 3.5
on page 303; it is much sharper than the estimate in Lemma 3.3, which is Glimm's.

SIAM J. NUMER. ANAL.
Vol. 18, No. 2, April 1981
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0036-1429/81/1802-0008 $01.00/0

A RANDOM CHOICE FINITE DIFFERENCE SCHEME FOR HYPERBOLIC CONSERVATION LAWS*

AMIRAM HARTEN† AND PETER D. LAX‡

Dedicated to Robert D. Richtmyer on the occasion of his seventieth birthday

Abstract. In this paper, we show how to modify the random choice method of Glimm by replacing the exact solution of the Riemann problem with an appropriate finite difference approximation. Our modification resolves discontinuities as well as Glimm's scheme, but is computationally more efficient and is easier to extend to more general situations.

I enjoyed spending some time with you in Chicago, and I found your results with Joel on nonlinear shocks very interesting. Warmest regards,
Peter

Introduction. Glimm's random choice method is a semianalytical technique for calculating discontinuous solutions of hyperbolic systems of conservation laws. Approximate solutions are represented as piecewise constant at any time; they are advanced in time by solving exactly the Riemann initial value problem formed by the constant states between two neighboring cells. The value of the approximation in each cell at the new time is taken to be the value of the exact solution at a randomly chosen point in the cell. Glimm has proved the convergence of the method in one space dimension and for initial data which differ little from a constant state.

The original version of Glimm's method had an overall accuracy of order half; this was later improved by Glimm to accuracy of first order. The main advantages of the method for numerical calculations are the sharp resolution of discontinuities and absence of over and undershoots. Chorin has pointed out that these features were decisive for calculations of combustion problems, and has made significant use of the method for these problems [1], [2].

A drawback of the method is the need to solve many Riemann problems exactly. This is a time consuming procedure and, furthermore, stands in the way of extending the method to situations where exact solutions are not available. The goal of this paper is to show how to replace the exact solution of the Riemann problem by an approximate one while retaining the advantages of Glimm's method.

In the course of analyzing our method, we estimate the probability of gross error by the random choice method; this estimate is a great improvement on the (alarmingly) high previous estimates.

The organization of the paper is as follows:

1. Review of theory of weak solutions.
2. Glimm's scheme and its modifications.
3. Convergence of the random choice method.
4. A finite difference approximation of the Riemann problem.
5. Scalar conservation laws.

In a sequel, we shall apply these ideas to the equations of compressible flow.

1. Introduction. Review of theory of weak solutions. In this paper, we consider numerical solutions of the initial value problem for hyperbolic systems of conservation

* Received by the editors May 13, 1980, and in revised form August 13, 1980.

† Courant Mathematics and Computing Laboratory, New York University, New York, New York 10012. The work of this author was supported in part by Ames under contract NCA 2-OR 525-901 with the National Aeronautics and Space Administration, by the U.S. Department of Energy under contract DE-AC02-76ER03077, and by ICASE under contract NASA1-14101 with the National Aeronautics and Space Administration.

‡ Courant Mathematics and Computing Laboratory, New York University, New York, New York 10012. The work of this author was supported in part by the U.S. Department of Energy under contract DE-AC02-76ER03077.

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When I arrived at Rockefeller, Glimm asked me to work on his Front Tracking Code.

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I told him I was on my own money, and wanted to work on problems I chose.

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When I arrived at Rockefeller, Glimm asked me to work on his Front Tracking Code.

I told him I was on my own money, and wanted to work on problems I chose.

Without pause, Glimm said “Okay”.

Glimm's "Front Tracking Code" was the center of a controversy regarding how to best take advantage of the exponentially increasing power of available computers.

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Glimm's view was that one should build as much detailed knowledge of solutions into the codes as possible to help focus the numerics…

Alexander Chorin and Peter Lax held the view that this was too awkward, and it was best to design the numerics to do all the work for you.

The development of AI supported the latter point of view…a good example being when an AI chess program created by playing millions games with itself, beat IBM's deep blue, which incorporated all human knowledge of chess…

The development of AI supported the latter point of view…a good example being when an AI chess program created by playing millions games with itself, beat IBM's deep blue, which incorporated all human knowledge of chess…

A payoff of Glimm's approach was the discovery of new conservations laws very different from what mathematicians had addressed before…

Within two months with Glimm I solved two problems…

Within two months with Glimm I solved two problems…

One was the Glimm Scheme for a Resonant Nonlinear System he and Eli Isaacson had discovered from Oil Reservoir Simulation.

ADVANCES IN APPLIED MATHEMATICS 3, 335–375 (1982)

Global Solution of the Cauchy Problem for a Class of 2×2 Nonstrictly Hyperbolic Conservation Laws*

BLAKE TEMPLE

Department of Mathematical Physics,
The Rockefeller University,
New York, New York 10021

We prove the existence of a global weak solution to the Cauchy problem for a class of 2×2 equations which model one-dimensional multiphase flow, and which represent a natural generalization of the scalar Buckley–Leverett equation. Loss of strict hyperbolicity (coinciding wave speeds with a $\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix}$ normal form) occurs on a curve in state space, and waves in a neighborhood of this curve contribute unbounded variation to the approximate Glimm scheme solutions. The unbounded variation is handled by means of a singular transformation; in the transformed variables, the variation is bounded. Glimm's argument must be modified to handle the unbounded variation that appears in the statement of the weak conditions, and this requires that the random choice variable be random in space as well as time.

1. INTRODUCTION

We consider the Cauchy problem for the 2×2 system of nonlinear conservation laws

The other was the Solution of the Waterhammer Problem with Mitch Luskin.

The Existence of a Global Weak Solution to the Non-Linear Waterhammer Problem

MITCHELL LUSKIN
University of Minnesota

AND

BLAKE TEMPLE
The Rockefeller University

1. Introduction

Fluid flow in pipelines is usually modeled by the quasilinear hyperbolic system

$$\rho_t + G_x = 0, \qquad (x,t) \in (0,1) \times (0,\infty),$$

$$G_t + (G^2/\rho)_x + p(\rho)_x = -f|G|G/2D\rho, \tag{1.1}$$

where ρ is mass density, G is momentum density, $p = p(\rho)$ is pressure, $f = f(|G|)$ is the Moody friction factor, and D is pipe diameter, cf. [12]. In this paper, we construct global weak solutions to (1.1) satisfying given initial conditions

$$\rho(x,0) = \rho_0(x), \qquad G(x,0) = G_0(x), \qquad x \in [0,1], \tag{1.2}$$

Soon after my brother David asked me how we could have solved the water hammer problem when his pipes in Chelsea were still always pounding!

Soon after my brother David asked me how we could have solved the water hammer problem when his pipes in Chelsea were still always pounding!

I realized that his idea of solving a problem was completely different from mine!

The paper on non-linear resonance was…

The paper on non-linear resonance was…

…the first Glimm Scheme convergence proof in presence of coinciding wave speeds.

The paper on non-linear resonance was…

…the first Glimm Scheme convergence proof in presence of coinciding wave speeds.

The linearized system blew up, but the nonlinear system stayed bounded!

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The idea was to bound the TV under a singular transformation of the conserved quantities!

The paper on non-linear resonance was…

…the first Glimm Scheme convergence proof in presence of coinciding wave speeds.

The linearized system blew up, but the nonlinear system stayed bounded!

The idea was to bound the TV under a singular transformation of the conserved quantities!

Eli Isaacson and I wrote many papers on resonant systems starting with this idea.

Most interesting…published after Eli became disabled and could not do mathematics any more… before his time…

SIAM J. APPL. MATH.
Vol. 55, No. 3, pp. 625–640, June 1995
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003

CONVERGENCE OF THE 2×2 GODUNOV METHOD FOR A GENERAL RESONANT NONLINEAR BALANCE LAW*

ELI ISAACSON† AND BLAKE TEMPLE‡

Abstract. We introduce a generalized solution of the Riemann problem for a general resonant nonlinear balance law, and we prove the convergence of the 2×2 Godunov numerical method based on these solutions. In particular, we obtain generic conditions that guarantee a canonical structure for the elementary waves in the solution of the Riemann problem, and an interesting multiplicity of time-asymptotic wave patterns is observed and characterized.

Key words. Godunov method, resonance, shock waves, balance law, Reimann problem

AMS subject classification. 35L65

1. Introduction.

We study the initial value problem

$$\begin{aligned} U_t + \mathcal{F}(U)_x &= G, \\ U(x,0) &= U_0(x), \end{aligned} \tag{1}$$

for the system

$$\begin{aligned} a_t &= 0, \\ u_t + f(a,u)_x &= a' g(a,u), \end{aligned} \tag{2}$$

(where $a' \equiv a_x \equiv \frac{da}{dx}$) in a neighborhood of a state $U_* = (a_*, u_*)$ where the nonlinear wave speed $\lambda = f_u$ vanishes. Here, $U = (a,u), \mathcal{F} = (0,f), G = (0,a'g)$, and $a = a(x)$ is an inhomogeneous term that is treated as a variable (so that (2) is a system of two balance laws) to express the dependence of the time-asymptotic wave patterns on the inhomogeneity, and as a first attempt to model systems of this form.

In this paper we define a generalized solution of the Riemann problem for system (2), we isolate generic conditions on the functions f and g that guarantee a unique canonical structure to the elementary waves that appear in the solutions near U_*, and we construct the solution of the Riemann problem in a neighborhood of a state U_* under these generic conditions. Because of the inhomogeneous term in (2), there exists a multiplicity of solutions to the Riemann problem, (cf. [18], [19]), and here we introduce a new admissibilty criterion for Riemann problem solutions of (2). In the final section we prove the convergence of the 2×2 Godunov numerical method [3] based on these admissible solutions of the Riemann problem, and time-independent bounds on solutions as well as convergence (after extraction of a subsequence) is proved when $a(x)$ is an arbitrary function of bounded variation. Because of the appearance of a delta function in (2) when a is discontinuous, there is no classical weak formulation of (2) when a is discontinuous, but in the final section we prove that the limits of the converging approximate solutions generated by the 2×2 Godunov method do converge to weak solutions of (2) when a is Lipschitz continuous.

* Received by the editors November 25, 1992; accepted for publication (in revised form) August 27, 1993.

† Department of Mathematics, University of Wyoming, Laramie, Wyoming 82071.

‡ Department of Mathematics, University of California-Davis, Davis, California 95616. This research was supported in part by National Science Foundation Applied Mathematics grant DMS-92-06631 and the Institute of Theoretical Dynamics, University of California-Davis.

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(where $a' \equiv a_x \equiv \frac{da}{dx}$) in a neighborhood of a state $U_* = (a_*, u_*)$ where the nonlinear

Eli Isaacson and I spent more than a decade working with diagrams that looked like this…

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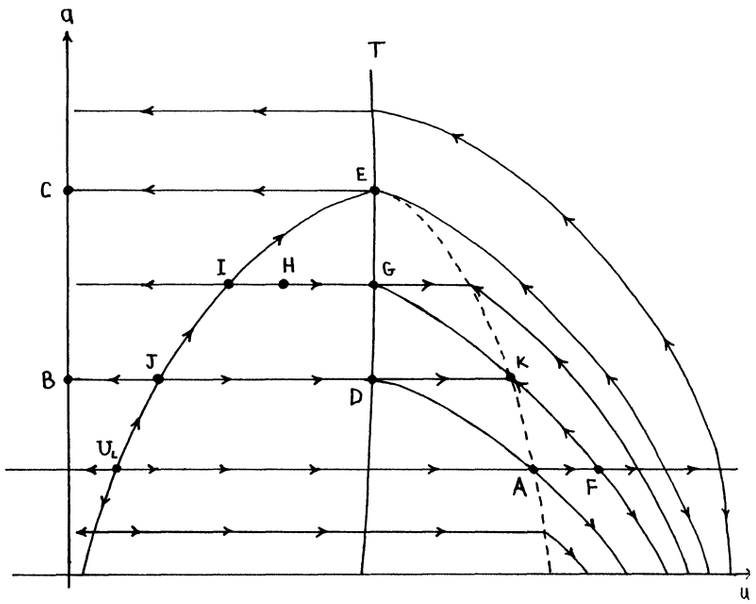


FIG. 5. $g_u > 0, u_L < u_T(a_L)$.

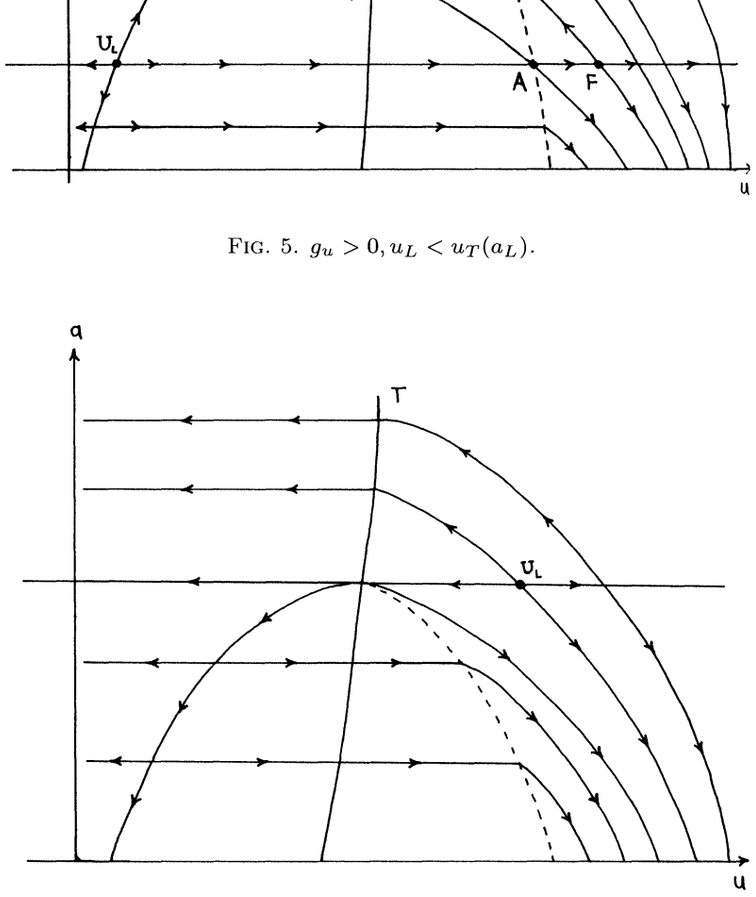


FIG. 6. $g_u > 0, u_L > u_T(a_L)$.

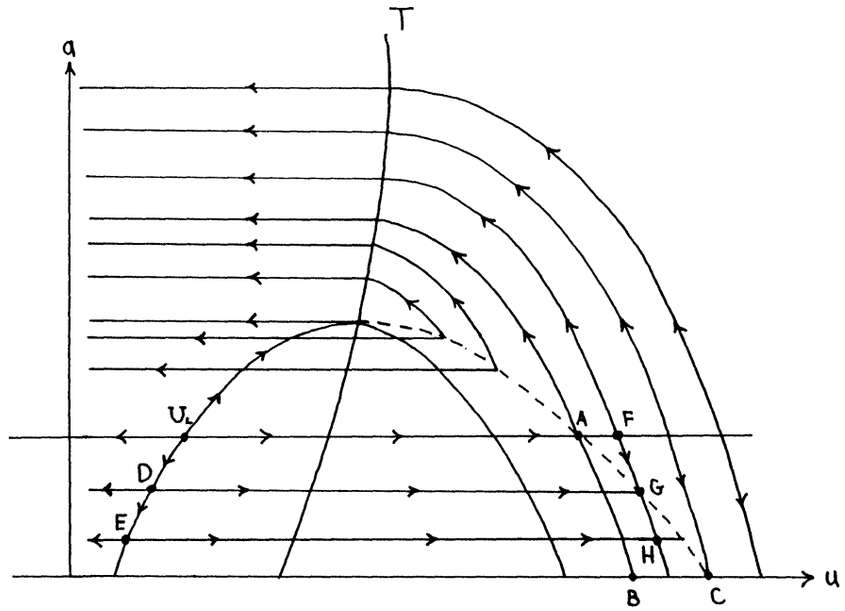


FIG. 3. $g_u < 0, u_L < u_T(a_L)$.

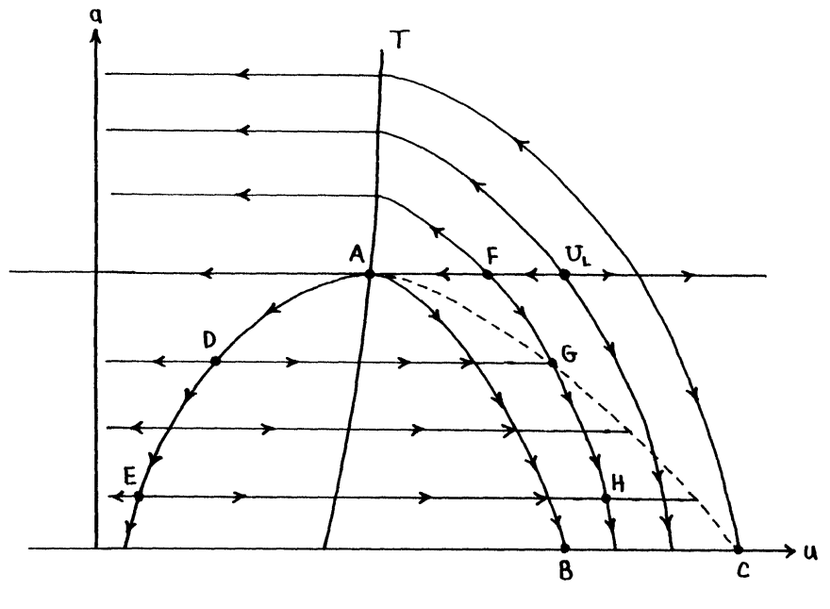
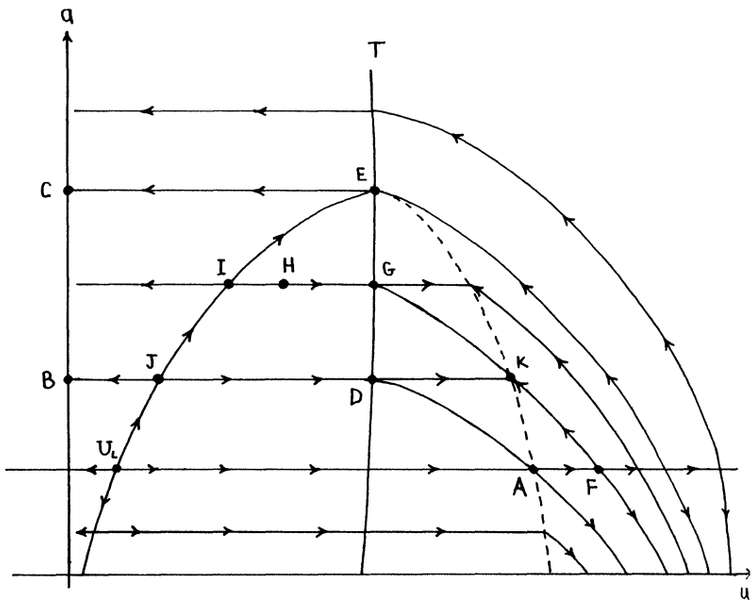


FIG. 4. $g_u < 0, u_L > u_T(a_L)$.

For some reason there were always four of them…



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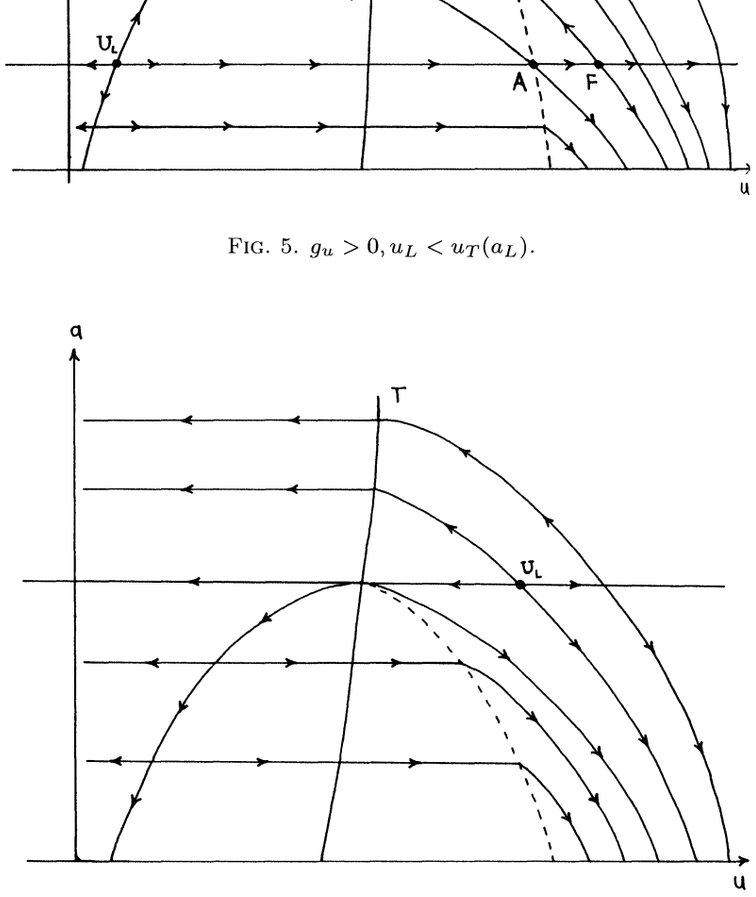

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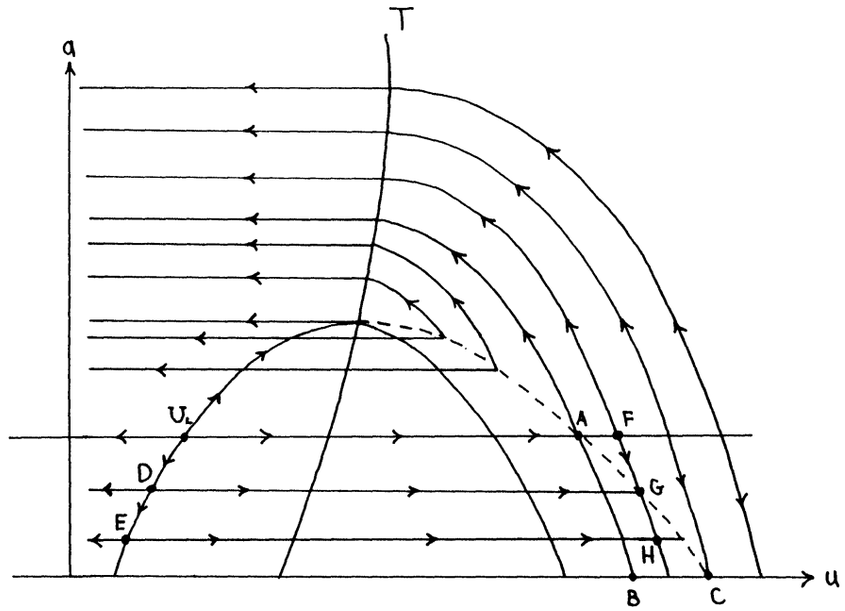

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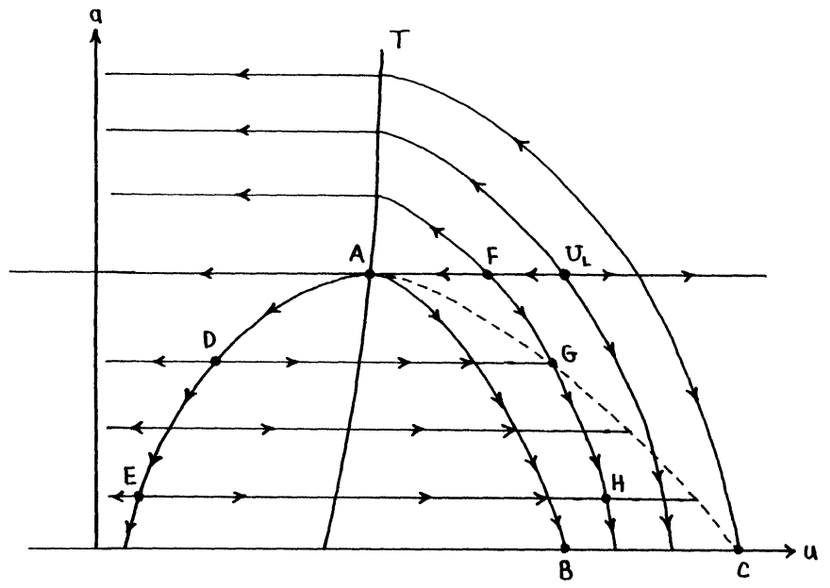

FIG. 4. $g_u < 0, u_L > u_T(a_L)$.

2000 Ph.D. Meng-kai (John) Hong extended these ideas to systems of equations…

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"An extension of Glimm's method to inhomogeneous systems of conservation laws", Hong, Postdoc UCLA



(2016-2019) Hong was Department Chair National Central University, Taiwan



Chairman

Chairman

Service Year	Name	Biographical Notes
2022 ~	Prof. Rung-Tzung Huang	Northeastern University, Ph. D. Global analysis, analysis on manifolds
2019-2022	Prof. Suh-Yuh Yang	Ph.D., National Chiao Tung University Computational and Applied Mathematics
2016-2019	Prof. Meng-Kai Hong	Ph.D., University of California at Davis Partial differential equations, Fluid mechanics
2015-2016	Prof. Hong-Gwa Yeh	Ph.D., National Chiao Tung University Combinatorial optimization, Algorithm, Applied probability
2012-2015	Prof. Jann-Long Chern	Ph.D., National Tsing Hua University Partial Differential Equations, Ordinary Differential Equations, Mathematical Physics
2010-2012	Prof. Yen-Mei J. Chen	Ph.D., Brown University Algebraic Number theory
2009-2010	Prof. Cheng-Hsiung Hsu	Ph.D., National Chiao Tung University Ordinary differential equations, Partial differential equations



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2012-2015	Prof. Jann-Long Chern	Ph.D., National Tsing Hua University Partial Differential Equations, Ordinary Differential Equations, Mathematical Physics
2010-2012	Prof. Yen-Mei J. Chen	Ph.D., Brown University Algebraic Number theory
2009-2010	Prof. Cheng-Hsiung Hsu	Ph.D., National Chiao Tung University Ordinary differential equations, Partial differential equations
2006-2009	Prof. Ming-Guang Leu	Ph.D., The Johns Hopkins University Number theory
2005-2006	Prof. Chiang Lin	Ph.D., University of South Carolina Discrete Mathematics
2003-2005	Asso. Prof. I-Feng Chao	Ph.D., University of North Carolina at Chapel Hill Information Theory

Three other former students later served as Department Chairs…

Three other former students later served as Department Chairs…

…Robin Young, Tong Yang and Brian Wissman

Brian Wissman

INTERIM ASSOCIATE VICE CHANCELLOR FOR ACADEMIC AFFAIRS

PROFESSOR, MATHEMATICS

COLLEGE OF NATURAL AND HEALTH SCIENCES

Dr. Brian Wissman grew up in the San Francisco bay area and earned his Ph.D. from the University of California, Davis in 2007. After receiving his degree, Dr. Wissman joined the faculty at the University of Hawai'i at Hilo where he is currently Interim Associate Vice Chancellor for Academic Affairs and Professor of Mathematics. His research interests include topics from nonlinear dynamics such as Gas Dynamics and Shockwaves, and analysis of nonlinear systems using Information Theory. With his applied mathematics background, Dr. Wissman regularly teaches classes on Ordinary and Partial Differential Equations, Chaos, and Mathematical Physics. Moreover, he has supervised directed study classes on advanced topics such as Nonlinear Conservation Laws and General Relativity. Dr. Wissman was Co-PI for the Pacific Undergrauate Research Experience (PURE) Mathematics REU and a Project NExT Fellow (Sun Dot, 2007). Beginning in 2011, Dr. Wissman established and co-organizes the UH Hilo Putnam team. Outside of academics, Dr. Wissman enjoys playing Ultimate Frisbee at the Hilo Bayfront Fields and coaches youth cross country.



Contact

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College of Natural and Health Sciences
Hilo, HI 96720
Phone (808) 932-7534
wissman@hawaii.edu
www2.hawaii.edu/~wissman

I lived three years in NYC

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1980 Rockefeller University with Glimm

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1982 Courant Institute NYC with Glimm

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“More people live by cancer than die by it”

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“More people live by cancer than die by it”

“In 1982, Rockefeller University paid their world renowned academic faculty 3 years pay to leave, making it a purely biological institution.”

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“More people live by cancer than die by it”

At Rockefeller I Met Dan Marchesin and Eli Isaacson…

I lived three years in NYC

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“More people live by cancer than die by it”

At Rockefeller I Met Dan Marchesin and Eli Isaacson…

Dan was a professor at IMPA in Rio DeJaneiro, Brazil, but often visited Glimm in NYC…

1980-1990: Many summers we spent working with Eli Isaacson and Dan Marchesin at IMPA, Rio DeJaneiro, Brazil…







My son Nathan was born in NYC…



My son Nathan was born in NYC…





One project with Dan was the classification of Hyperbolic Singularities.

SIAM J. APPL. MATH.
Vol. 48, No. 5, October 1988

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003

THE RIEMANN PROBLEM NEAR A HYPERBOLIC SINGULARITY: THE CLASSIFICATION OF SOLUTIONS OF QUADRATIC RIEMANN PROBLEMS I*

E. ISAACSON†, D. MARCHESIN‡, B. PLOHR§, AND B. TEMPLE¶

Abstract. The purpose of this paper is to classify the solutions of Riemann problems near a hyperbolic singularity in a nonlinear system of conservation laws. Hyperbolic singularities play the role in the theory of Riemann problems that rest points play in the theory of ordinary differential equations: Indeed, generically, only a finite number of structures can appear in a neighborhood of such a singularity. In this, the first of three papers, the program of classification is discussed in general and the simplest structure that occurs is characterized.

Key words. nonlinear hyperbolic conservation laws, Riemann problems, hyperbolic singularities

AMS(MOS) subject classifications. 35L65, 35L67, 35L80

Introduction. We study the Riemann problem for nonlinear 2×2 systems of conservation laws:

$$U_t + f(U)_x = 0, \tag{A}$$

$$U(x,0) = U_0(x) = \begin{cases} U_L, & x \leqq 0, \\ U_R, & x > 0. \end{cases} \tag{B}$$

Many of the solvable models Glimm's group worked on fell into a general class of equations with coinciding shock and rarefaction curves…

Many of the solvable models Glimm's group worked on fell into a general class of equations with coinciding shock and rarefaction curves…

I guessed that you could characterize these…

TRANSACTIONS OF THE
AMERICAN MATHEMATICAL SOCIETY
Volume 280, Number 2, December 1983

SYSTEMS OF CONSERVATION LAWS WITH INVARIANT SUBMANIFOLDS

BY

BLAKE TEMPLE[1]

ABSTRACT. Systems of conservation laws with coinciding shock and rarefaction curves arise in the study of oil reservoir simulation, multicomponent chromatography, as well as in the study of nonlinear motion in elastic strings. Here we characterize this phenomenon by deriving necessary and sufficient conditions on the geometry of a wave curve in order that the shock wave curve coincide with its associated rarefaction wave curve for a system of conservation laws. This coincidence is the one dimensional case of a submanifold of the state variables being invariant for the system of equations, and the necessary and sufficient conditions are derived for invariant submanifolds of arbitrary dimension. In the case of 2×2 systems we derive explicit formulas for the class of flux functions that give rise to the coupled nonlinear conservation laws for which the shock and rarefaction wave curves coincide.

Introduction. Systems of conservation laws which have coinciding shock and rarefaction curves arise in the study of oil reservoir simulation, nonlinear wave motion in elastic strings, as well as in multicomponent chromatography

Dennis Serre named these equations the The Temple's Class.

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Through the years I saw many systems came up in this class, including one in QFT by Ed Witten.

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Through the years I saw many systems came up in this class, including one in QFT by Ed Witten.

Such systems appeared in Chromatography, Oil Reservoir Simulations, limiting cases of gas dynamics…

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Through the years I saw many systems came up in this class, including one in QFT by Ed Witten.

Such systems appeared in Chromatography, Oil Reservoir Simulations, limiting cases of gas dynamics…

A lot of people worked on equations in the Temple's class.

1983-1986 I was a visitor in the Math Research Center at Madison Wisconsin…

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There I committed to learning General Relativity…

1983-1986 I was a visitor in the Math Research Center at Madison Wisconsin…

There I committed to learning General Relativity…

…and I renovated an old house…


2510

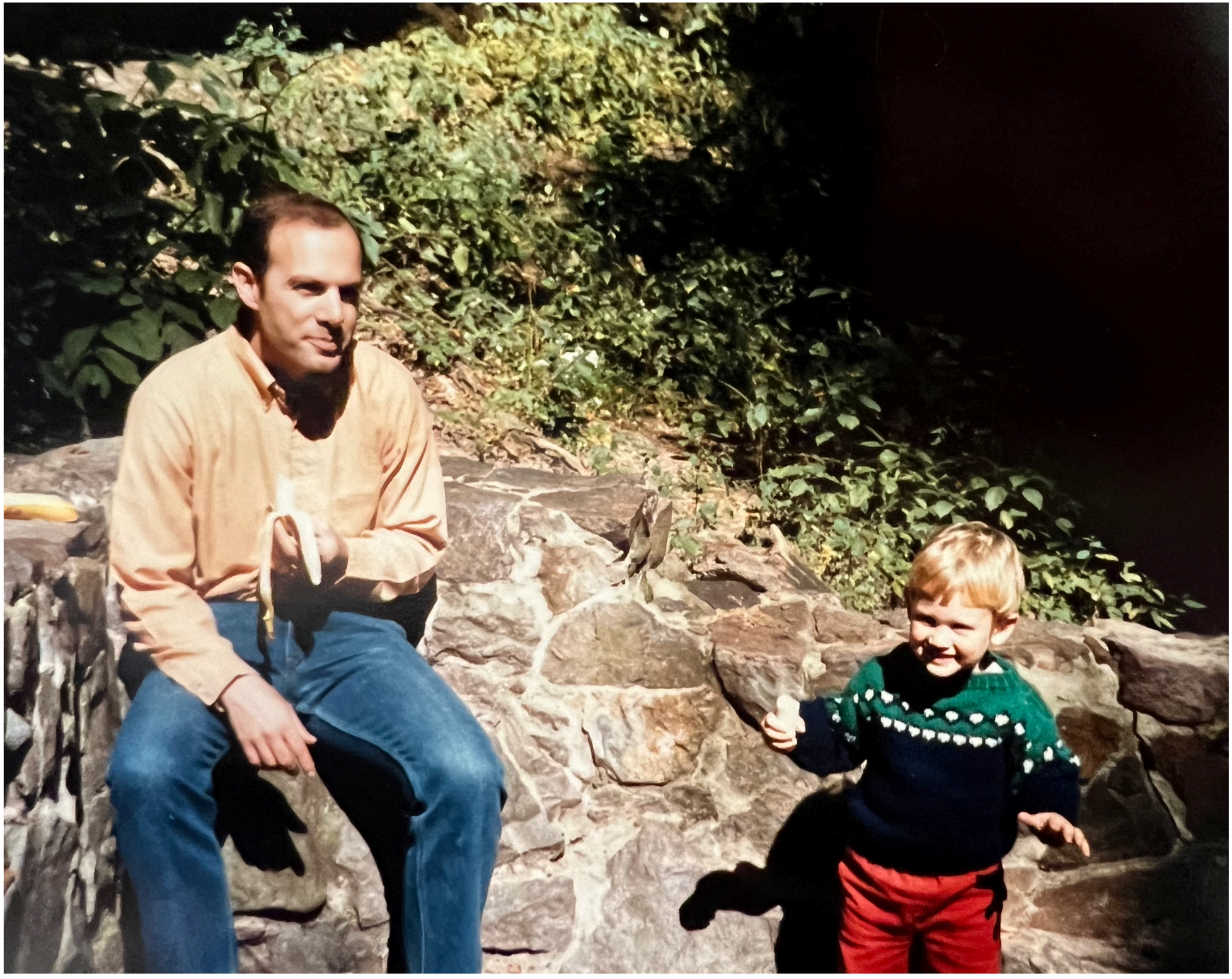



2510





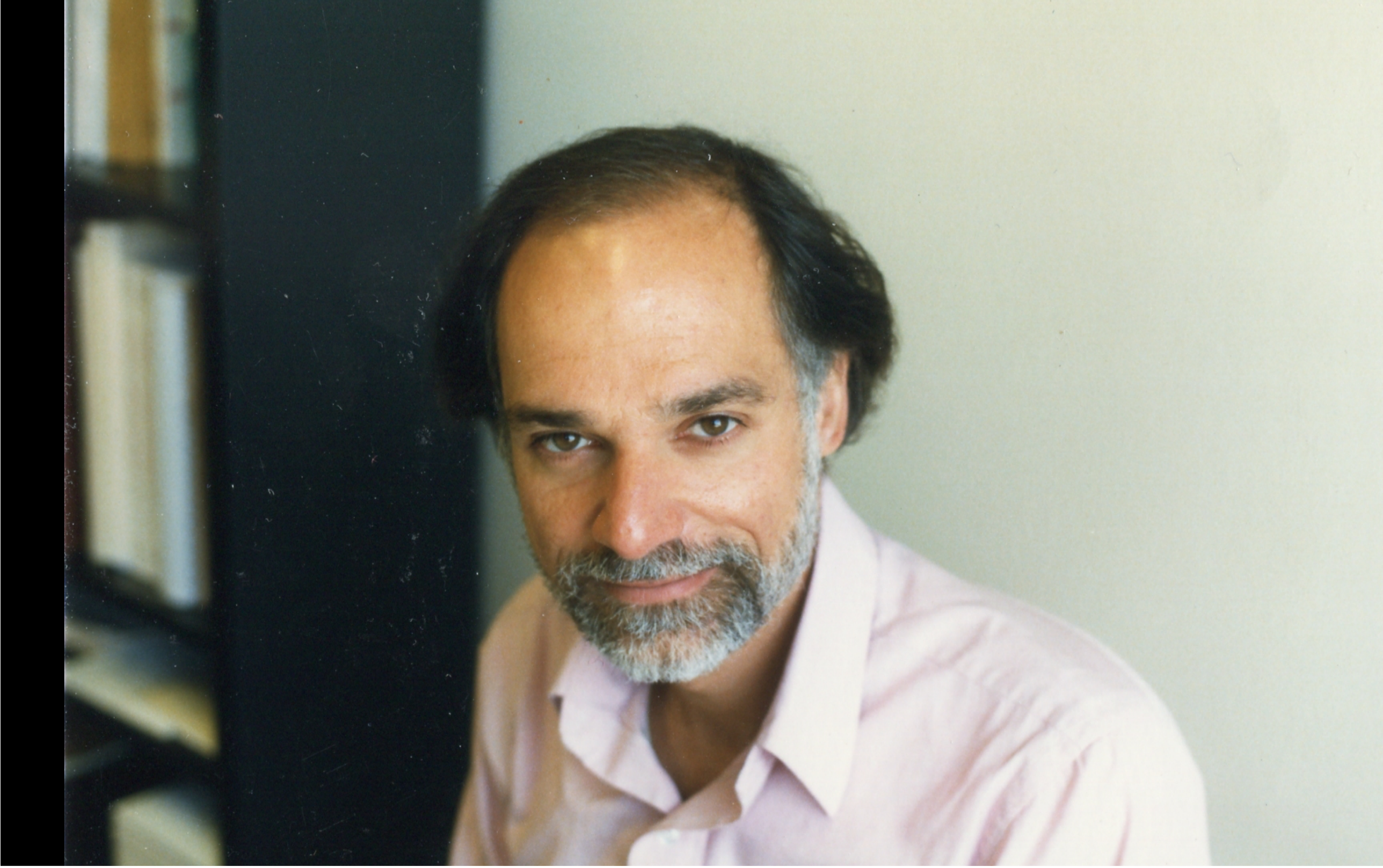
…Eli became a close friend who visited often



Madison Wisconsin was too cold for us…

Madison Wisconsin was too cold for us…

An inspiring dinner discussion with Ron DiPerna counseled me on what to do next…



Ronald DiPerna, Berkeley 1985

George M. Bergman

Ronald DiPerna, Berkeley 1985

CC

File: D

Uplo

Permission details

UNIVERSITY OF CALIFORNIA, BERKELEY

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SANTA BARBARA • SANTA CRUZ

DEPARTMENT OF MATHEMATICS

BERKELEY, CALIFORNIA 94720

August 13, 1986

Dear Blake,

Thanks for the letter + preprints. I'd enjoy hearing more about your stuff. I will move to San Jose at the end of the month + between now and then will be very busy. If it's O.K. with you, perhaps we could get together sometime in early september. I teach on Tues and Thursday from 12:30 to 2. Mostly likely I will come in only three times a week, perhaps just two times.

I'll call you soon.

Best regards,

Ron

I applied to the West Coast for a job…

I applied to the West Coast for a job…

I got lots of interviews…

I applied to the West Coast for a job…

I got lots of interviews…

Art Krener offered me a job…

I applied to the West Coast for a job…

I got lots of interviews…

Art Krener offered me a job…

I turned down a tenure offer at U of Arizona
to take Assistant Professorship at UC-Davis

During my interview at Davis, I was very impressed with the Applied Math Group…

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…Joel Keizer, Art Krener, Craig Tracy, Alan Hastings, Marc Mangel, Steve Whitaker…

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…Joel Keizer, Art Krener, Craig Tracy, Alan Hastings, Marc Mangel, Steve Whitaker…

I recall discussions with Don Chakerian, David Barnett, Washek Pfeffer, Dallas Banks, Tom Sallee, Angela Cheer, and Evelyn Silvia…

During my interview at Davis, I was very impressed with the Applied Math Group…

…Joel Keizer, Art Krener, Craig Tracy, Alan Hastings, Marc Mangel, Steve Whitaker…

I recall discussions with Don Chakerian, David Barnett, Washek Pfeffer, Dallas Banks, Tom Sallee, Angela Cheer, and Evelyn Silvia…

…and I loved Davis!

After my interview talk, Craig Tracy told me the 1-d solutions I talked about were unstable to 2-d perturbation, so they were unphysical, but it was interesting math anyway.

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Craig was my friend before he discovered the Tracy-Widom Distribution Function…


the Essential Air Fryer Cookbook

In Davis I bought an old Mercedes…

In Davis I bought an old Mercedes…



…and I built a Gallows…

…and I built a Gallows…



…and my daughter Annie was born…

…and my daughter Annie was born…



Annie has two kids I adore living in Davis…

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1988- Just two years after I arrived they made me Chair of GGAM…

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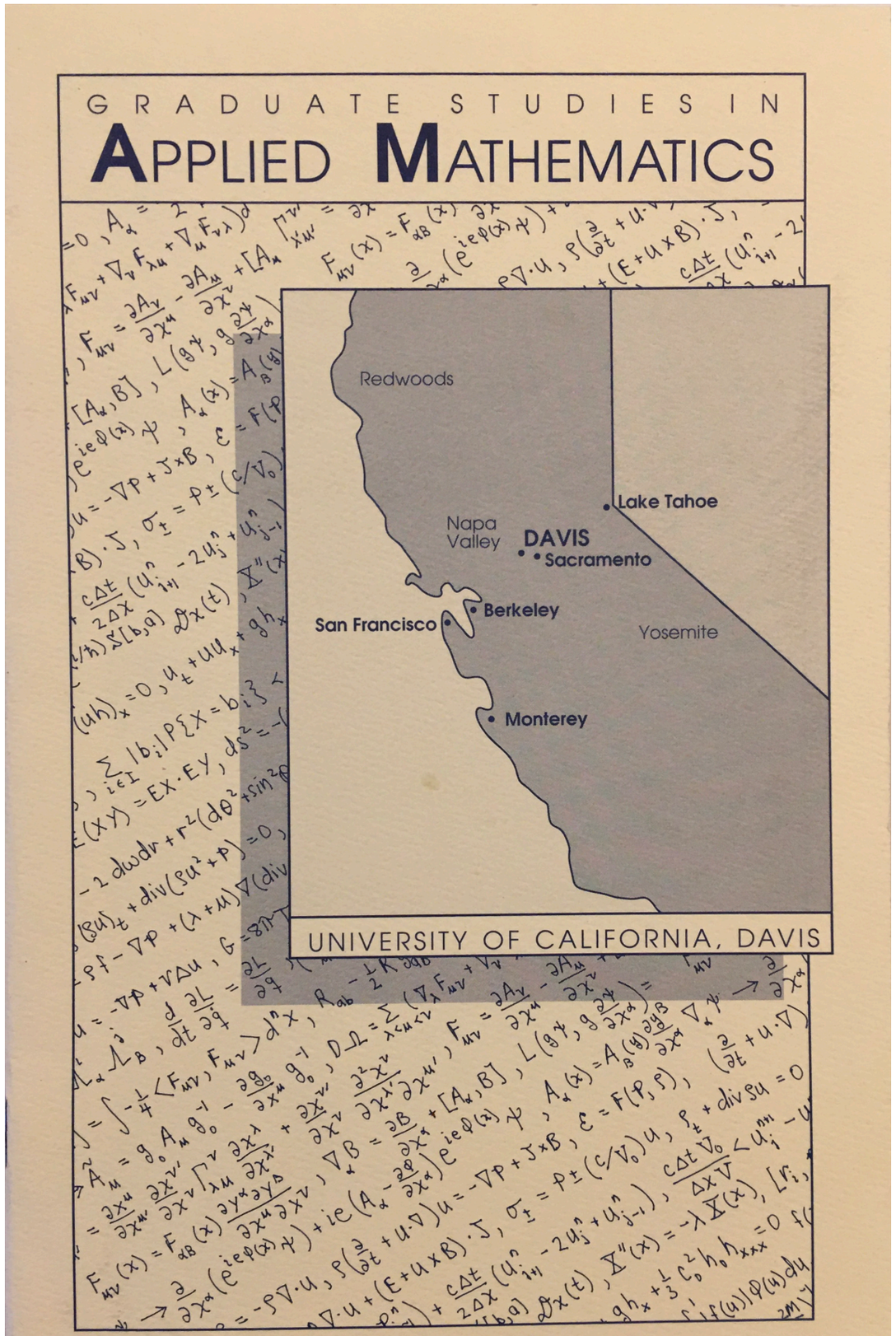
I made the first Brochure…

1988- Just two years after I arrived they made me Chair of GGAM…

I made the first Brochure…

The design was motivated by the fact that no one I knew in NYC knew about Davis Math..

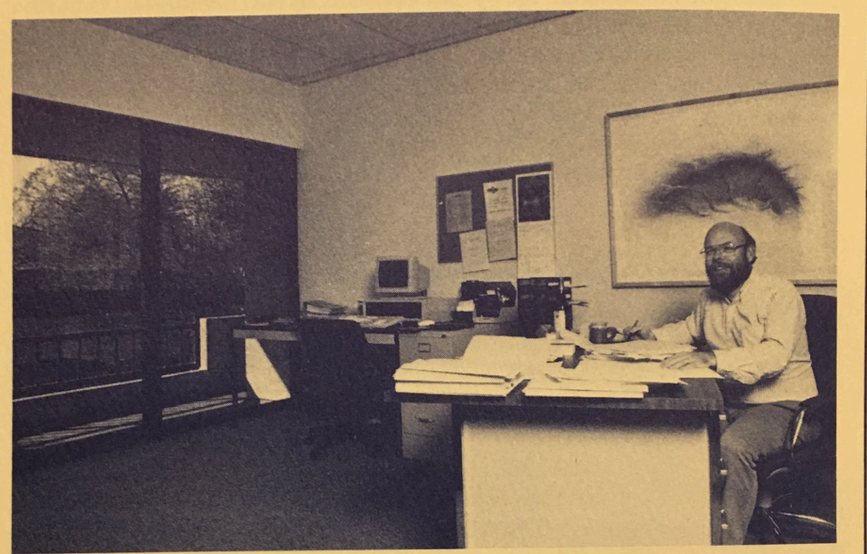
Location, location and location…



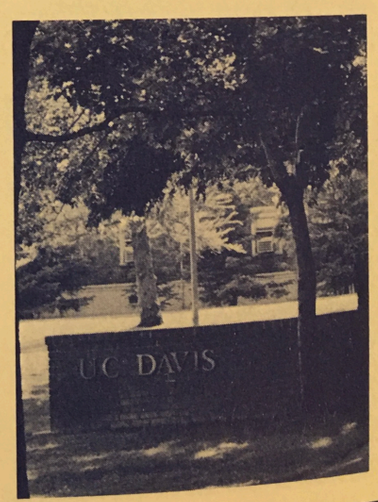
Joel Keizer's ITD was featured…

INTRODUCTION

THE GGAM IS HOUSED in the Department of Mathematics and in the Institute of Theoretical Dynamics. The Department of Mathematics is centrally located on the University's main campus adjacent to the town of Davis, and the Institute of Theoretical Dynamics is situated in downtown Davis near the edge of campus. The Institute serves as the research arm of the GGAM, and provides a colloquium room, office space, computer equipment, and support staff. It is funded primarily by the University of California, and sponsors visitors, meetings, and other forms of interaction among scientists and mathematicians, including a weekly applied math colloquium series. Overall, the University of California and the town of Davis provide a comfortable small town environment within an easy drive of the rich recreational and cultural facilities of Northern California.





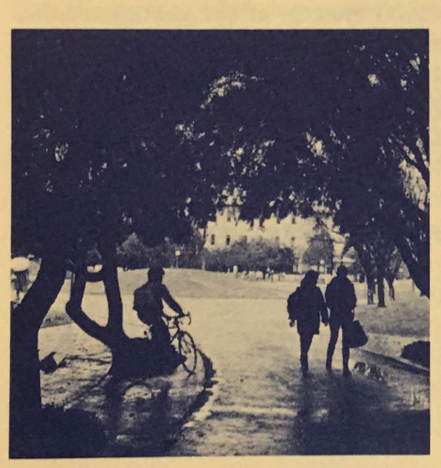




…research discussions in a beautiful place…

INTRODUCTION

THE DAVIS CAMPUS is both the third oldest and the third largest of the University of California's nine campuses with 21,838 students. The City of Davis is an interesting and forward looking city of 42,600 located in California's central valley just fifteen miles west of the state's capital in Sacramento, and 75 miles northeast of San Francisco. Travel is convenient with the Sacramento airport just a twenty-minute drive away. This central location puts Davis within a two hour drive of Lake Tahoe, forty-five minutes from the Napa Valley, and an hour and a half from the beaches of Northern California. Yosemite park lies 150 miles to the southeast. The city of Davis has established a tradition of controlled development and urban planning. This has led to the development of parks and greenbelts, and to the protection of the downtown area as the commercial center of the city. Since the campus is contiguous to the town, the University community can take advantage of the many restaurants and specialty shops that downtown Davis offers. The winters in Davis are mild, and the summers are sunny and clear, with a cooling ocean breeze each evening.










FOOD
SHOPS &
SERVICES



FINANCIAL INFORMATION

RESEARCH ASSISTANTSHIPS

Often a student doing M.S. or Ph.D. research can be supported by the adviser, if the research is sponsored through a grant or contract.

OUT-OF-STATE-FEE FELLOWSHIPS

If you are not a California resident, you may apply for Nonresident Tuition Fee Fellowship. (Consult the Graduate Announcement for details.) However, if you become eligible but do not apply for California residency, you are not entitled to the award.



FACULTY MEMBERS

FACULTY MEMBERS OF THE GRADUATE GROUP are listed together with a brief statement of their research interests. Students who are interested in a more complete description of a particular faculty member's research interests are encouraged to write directly to the faculty member in care of his or her department.

DALLAS O. BANKS, Mathematics. Mathematical modeling of physical and engineering processes, including fine particle collection processes.

LOUIS W. BOTSFORD, Wildlife and Fisheries Biology. Stability and control of populations that reflect age, size, or stage structure; population dynamics and management of fisheries and aquatic populations.

JOHN W. BREWER, Mechanical Engineering. Analysis and simulation of dynamic systems; the growth of populations in age, space, and time; computer-aided simulation of economic and demographic systems; the bond graph method; automatic control.

MICHAEL BUONOCORE, Radiology (UCD Medical Center). Medical imaging, specifically research in image reconstruction algorithms, numerical simulation of x-ray, ultrasonic, and nuclear magnetic resonance processes, numerical simulation of blood flow, NMR and ultrasound inverse scattering theory.

TIM E. CARPENTER, Epidemiology and Preventive Medicine. Epidemiologic and economic impact of diseases in livestock, including optimization and simulation modeling; microeconomic decision analysis and project evaluations.

TSU-SHUAN CHANG, Electrical and Computer Engineering. Dynamic optimization problems and applications, flow control and routing in computer network, path planning and obstacle advoidance, and robotics.

LING-LIE CHAU, Physics. Weak interactions, Yang-Mills and gauge field theory; supersymmetry and supergravity.

ANGELA CHEER, Mathematics. Numerical analysis, compulational fluid mechanics, mathematical biofluid dynamics, mathematical models in biology.

WILLIAM A. GARDNER, Electrical Engineering and Computer Science. Statistical theory of signal processing.

JOHN GILLESPIE, Genetics. Population genetics; evolution.

ROBERT GLAUZ, Mathematics. Numerical analysis.

RICHARD GROTJAHN, Land, Air and Water Resources. Numerical modeling of geophysical flows, especially atmospheric circulation modeling; linear instability analysis and nonlinear evolution of flows; applications of new numerical techniques to geophysical problems; advanced graphical display of data including computer animation; evaluation of finite difference scheme errors.

FACULTY MEMBERS

MOHAMED HAFEZ, Mechanical Engineering. Transonic aerodynamics, computational fluid dynamics; numerical solutions of partial differential equations.

ALAN M. HASTINGS, Division of Envinonmental Studies and Mathematics. Theoretical population biology including mathematical ecology and mathematical genetics; qualitative theory of differential equations, differential-delay equations, bifurcation theory.

LEONARD HERRMANN, Civil Engineering. Theory and application of finite element methods, modeling of structural composites and properties of engineering material.

BRIAN G. HIGGINS, Chemical Engineering. Theoretical fluid mechanics, hydrodynamic stability theory, and computational fluid mechanics.

FREDERICK A. HOWES, Mathematics. Singularly perturbed differential equations, mathematical fluid dynamics, quantum field theory.

RICHARD HOWITT, Agricultural Economics. Optimization and control of economic systems; estimation theory; bioeconomics.

T. C. HSIA, Electrical Enginering & Computer Science. Least squares parameter estimation, system identification and control, adaptive systems theory, signal processing, and robotics.

MONT HUBBARD, Mechanical Engineering. Applications of system theory, control, parameter identification and estimation to dynamical systems including internal combustion engines, vehicle suspensions, vibration control, biomechanics, flywheel energy storage, passive solar heating systems.

ANIL K. JAIN, Electrical and Computer Engineering. Image processing techniques, including fast algorithms for image analysis and stochastic models for images.

DAVID F. KATZ, Obstetrics and Gynecology. Sperm transport to the egg and fertilization; biofluid dynamics; fertility, infertility, and contraception.

JOEL KEIZER, Institute of Theoretical Dynamics. Nonequilibrium thermodynamics; molecular fluctuations in chemistry, physics, and biophysics; electrochemical oscillations; nonequilibrium statistical mechanics; theory of diffusion controlled chemical reactions.

JOSEPH E. KISKIS, JR., Physics. Quantum field theory and non-Abelian gauge fields as they relate to theoretical elementary particle physics.

ARTHUR J. KRENER, Mathematics. Systems and control theory; applied geometry; stochastics, particularly stochastic differential equations of the second order.

FACULTY MEMBERS

GARY KUROWSKI, Mathematics. Differential equations.

BRUCE LAROCK, Civil Engineering. Finite element method applied to fluid mechanics problems, including turbulence modeling, stratified flow, mass transport, and free surface flows.

BERNARD C. LEVY, Electrical Engineering & Computer Science. Multidimensional signal processing, statistical signal processing, inverse problems, estimation and stochastic processes, linear systems theory, scientific computation.

HEINER LIETH, Department of Environmental Horticulture. Mathematical models of crops at the plant and crop level. Ecological modeling, biomathematics, crop ecology, application of modeling techniques to horticulture.

PETER LINZ, Computer Science. Numerical analysis, including integral equations and ill-posed problems; programming languages, including vector- programming languages and their use in computational mathematics, and functional languages.

MARC MANGEL, Zoology. Behavioral and Evolutionary Ecology, Conservation Biology and Resource Management; stochastic differential equations.

MIGUEL A. MARINO, Land, Air, and Water Resources and Civil Engineering. Subsurface hydrology and pollution; optimization and simulation of water resource systems; irrigation planning, design, and operation models; hydrologic forecasting.

NORMAN MATLOFF, Statistics and Electrical and Computer Engineering. Regression analysis, stochastic processes, probabilistic modeling of computer systems, computer simulation.

DONALD McQUARRIE, Chemistry. Application of statistical mechanics and stochastic processes to chemical and biophysical systems.

KIM MISH, Civil Engineering. Theory and application of finite elements models in applied mechanics.

RICHARD E. PLANT, Agronomy. Applications of operations research in agricultural and resource management; mathematical population biology.

ROBERT POWELL, Chemical Engineering. Continuum mechanics, rheology, mechanics of viscoelastic fluids and solids.

CARLOS E. PUENTE, Land Air and Water Resources. General surface hydrology; rainfall-runoff modeling; forecasting of river flows; quantification of spatial variation; sampling of hydrologic processes; applications of stochastic processes, operations research and nonlinear science techniques to hydrologic problems.

DAVID M. ROCKE, Graduate School of Administration. Statistics, including time series analysis and forecasts, design and analysis of experiments, robust statistical methods.

FACULTY MEMBERS

JOHN E. ROEMER, Economics. Economic theory, Marxian economics.

ROBERT SHUMWAY, Statistics. Pattern recognition problems; signal detection and estimation for time series with stationary errors.

WENDY K. SILK, Land, Air and Water Resources. Plant growth and development; mathematical models for morphogenesis.

BLAKE TEMPLE, Mathematics. Nonlinear hyperbolic conservation laws and the mathematical theory of shock waves; partial differential equations; general relativity.

CRAIG A. TRACY, Mathematics. Statistical mechanics; the theory of exactly solvable models, completely integrable systems.

MICHAEL TURELLI, Genetics. Deterministic and stochastic models in population genetics, quantitative genetics, and ecology.

ROGER J-B. WETS, Mathematics. Deterministic and stochastic optimization, numerical procedures, modeling and theory; approximation schemes for variational problems.

STEPHEN WHITAKER, Chemical Engineering. Theoretical fluid dynamics, multiphase systems, applications of perturbation methods in fluid mechanics.

WILLIAM A. WILLIAMS, Agronomy and Range Science. Dynamic simulation of range and crop plant behavior; multivariate analysis in agricultural research; linear programming applications.

JOHN HUNTER, Mathematics. Asymptotic methods in applied mathematics (joining us in Fall 1989).

MOTOHICO MULASE, Mathematics. Geometry, physics and partial differential equations (joining us in Fall 1989).

Provost Barbara Horwitz was not impressed…

Provost Barbara Horwitz was not impressed…

About a decade later she called several of us into her office, sat us down in front of her, and lifted up my brochure, and lectured us that this was the kind of non-sense that was holding us back from becoming a world renowned institution!

My first years at Davis I met two exceptional students who wrote terrific theses…

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Robin and I started working on periodic solutions
12 years later…





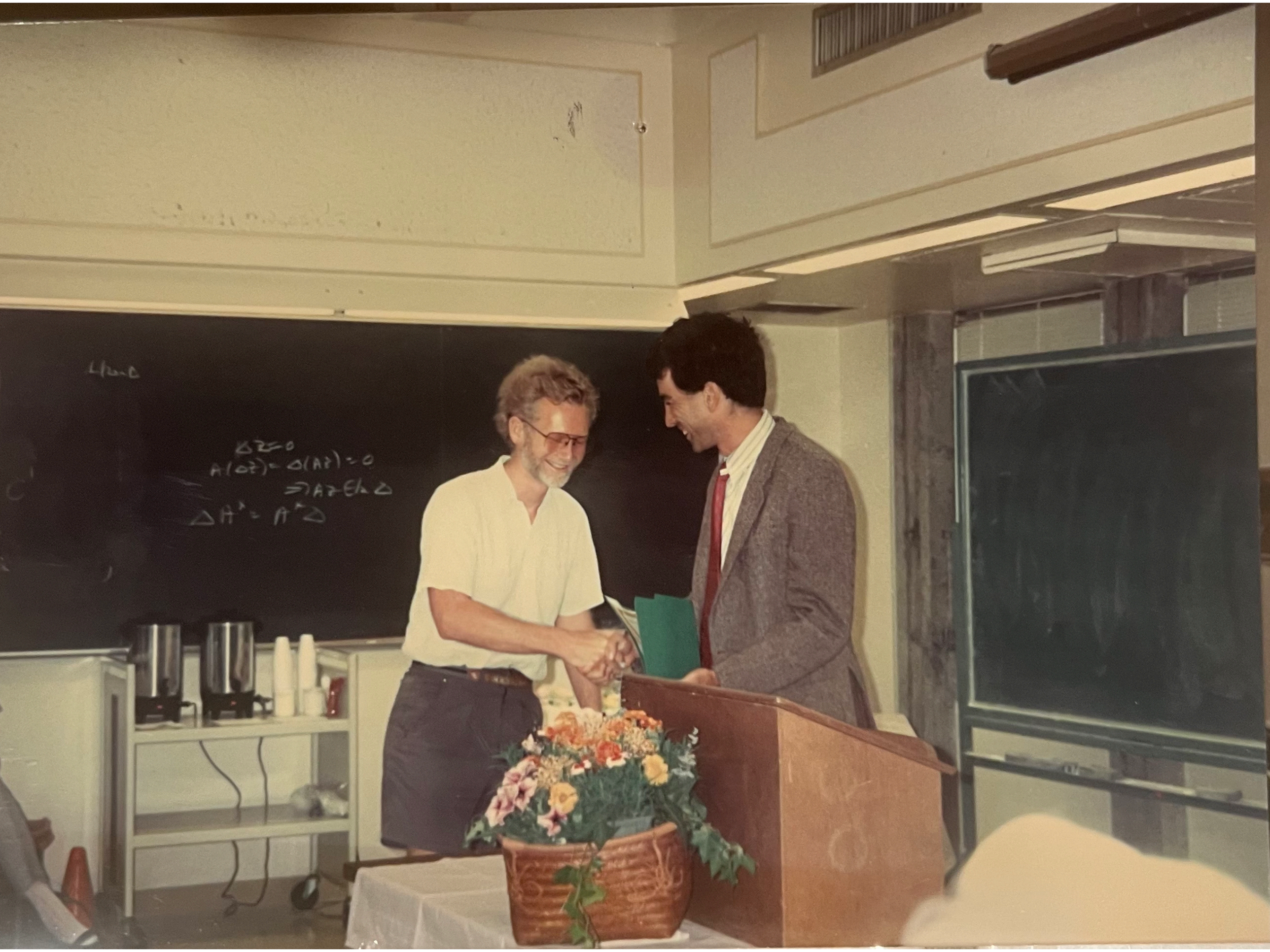
Tong Yang introduced a functional integral approach to bounding waves in spherical symmetry…

Tong Yang introduced a functional integral approach to bounding waves in spherical symmetry…

He won a fellowship at Institute for Advanced Study… and became a big shot in Hong Kong.



Based on this, Joel Hass found a way for me to win a Graduate Teaching Award…



Department of Mathematics, UC Davis

Award for Outstanding Achievement
in
Graduate Education in Mathematics

For his extraordinary successes in supervising Ph.D. students in mathematics, the Department of Mathematics, upon recommendation of the Graduate Program Committee, confers upon

JOHN BLAKE TEMPLE

its first award for outstanding achievement in graduate education in mathematics.

June 3, 1993 — ***Dated at Davis***

Joel Hass — ***Vice Chair Graduate Affairs***

Henry L. Alder — ***Chair***

Graduate Program Committee Award
(To be read at Award Ceremony)

Joel Hass: It is my great pleasure to be able to announce that this award is given to Professor John Blake Temple. The following is the resolution approved by the Graduate Program Committee:

"The Graduate Program Committee by this resolution confers special recognition to Professor John Blake Temple for his outstanding achievements in recent years in the supervision of graduate students in the Mathematics and Applied Mathematics programs. In particular, he has:

1. Supervised the 1991 dissertation of Robin Young, which resulted in the award to Young of the Richard C. DiPrima prize for the outstanding thesis in applied mathematics in the years 1989-90 and 1990-91.
2. Supervised the 1993 dissertation of Tong Yang, which resulted in a job offer to Yang from the Institute for Advanced Study in Princeton,. New Jersey, for the 1993-94 academic year.

By this action, the Graduate Program Committee applauds these extraordinary accomplishments."

Motohico Mulase was very nice…



In 1994 I won a Guggenheim Fellowship…

JOHN SIMON GUGGENHEIM MEMORIAL FOUNDATION

90 PARK AVENUE, NEW YORK, NY 10016 (212) 687-4470

Chancellor's Office
REFERRED TO:

Dean Crummey	Info
Dis Stratton	"
CT-K	"

April 13, 1994

Mr. Theodore L. Hullar, Chancellor
University of California, Davis
Davis, CA 95616

Dear Mr. Hullar:

It gives me a great deal of pleasure to send you word that Guggenheim Fellowships for 1994 have been granted to the following members of your faculty:

Squeak Carnwath, Professor of Art
Blake Temple, Professor of Mathematics

You may also be interested to know that altogether the Foundation is appointing 147 United States and Canadian Fellows this year from among 3,157 applicants. The enclosed story covering these awards is being released for publication today.

With all good wishes.

Most cordially yours,

Joel Conarroe

Joel Conarroe
President

JC:eg

Congratulations, Professor Temple!!
Larry N. Vanderhoef

RECEIVED
CHANCELLOR'S OFFICE
UCD
18 APR 94 11 02

In 1994 I won a Guggenheim Fellowship…

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I went to Ann Arbor and started working full time with Joel Smoller on General Relativity…

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We wrote a lot of papers…

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O-S demonstrated that black holes could form from the collapse of an ordinary ball of matter.

O-S employed an interface between matter and empty space that followed a geodesic of the metric.

To extend this to non-zero pressure, we needed to model the interface as a non-geodesic shock surface across which matter was transported.

Arch. Rational Mech. Anal. 138 (1997) 239–277. © Springer-Verlag 1997

General Relativistic Shock Waves that Extend the Oppenheimer-Snyder Model

Joel Smoller & Blake Temple

Communicated by T.-P. Liu

Abstract

In earlier work we constructed a class of spherically symmetric, fluid dynamical shock waves that satisfy the Einstein equations of general relativity. These shock waves extend the celebrated Oppenheimer-Snyder result to the case of non-zero pressure. Our shock waves are determined by a system of ordinary differential equations that describe the matching of a Friedmann-Robertson-Walker metric (a cosmological model for the expanding universe)

Matching a TOV metric outside an expanding Friedmann spacetime across a shock interface led to a family of exact GR shock wave solutions when

$$p = \sigma \rho$$

PHYSICAL REVIEW D VOLUME 51, NUMBER 6 15 MARCH 1995

Astrophysical shock-wave solutions of the Einstein equations

Joel Smoller
Department of Mathematics, University of Michigan, Ann Arbor, Michigan 48109

Blake Temple
Department of Mathematics, University of California, Davis, Davis, California 95616
(Received 22 July 1994)

We construct exact, spherically symmetric, shock-wave solutions of the Einstein equations for a perfect fluid. The solutions are obtained by matching a Friedmann-Robertson-Walker metric (a cosmological model for the Universe) to a static Oppenheimer-Tolman metric (a model for the interior of a star) across a shock-wave interface. This is in the spirit of Oppenheimer and Snyder, except, in contrast with the Oppenheimer-Snyder model, the pressure p is nonzero. Our shock-wave solutions model the general relativistic version of an explosion into a *static, singular, isothermal sphere.* Shock waves introduce time irreversibility, loss of information, decay, dissipation, and increase of entropy into the dynamics of a perfect fluid in general relativity. As a corollary, we also obtain a different Oppenheimer-Snyder model for the case $p \equiv 0$.

PACS number(s): 04.20.Jb, 04.40.Nr

I. INTRODUCTION

In a recent paper [1], the authors constructed a class of exact, shock-wave solutions of the Einstein equations of general relativity. The paper [1] concluded with the derivation of a set of ordinary differential equations (ODE's) that describe the matching of a Friedmann-Robertson-Walker (FRW) of [2] and [13] to a static

the outer layers of a star, or the outer regions of the Universe. In the exact solution constructed here, the shock wave emerges from $\bar{r} = 0$ at the initial *(big bang)* singularity in the FRW metric, and thus, our model provides a scenario by which the *big bang begins with a shock-wave explosion.*

The outer static solution is called a *static isothermal sphere* because the metric entries are time independent

Dimitri Christodoulou explained to us that our examples represented the GR version of an explosion into a static, singular, isothermal sphere…

Dimitri Christodoulou explained to us that our examples represented the GR version of an explosion into a static, singular, isothermal sphere…

…the singularity at the center already identified as a mechanism for ignition in simple models of star formation in Newtonian gravity…




Joel Smoller, Dimitri Christodoulou, Me

Decades later Christopher Alexander's thesis got the expanding wave behind the shock exactly right… replacing Friedmann with a self-similar wave…

Decades later Christopher Alexander's thesis got the expanding wave behind the shock exactly right… replacing Friedmann with a self-similar wave…

A definitive general theory of matching metrics across shock interfaces appeared in Handbook…

Solving the Einstein Equations by Lipschitz Continuous Metrics: Shock Waves in General Relativity

Jeff Groah

Department of Mathematics, University of California, Davis, CA 95616, USA
E-mail: jmgroah@saclink.csus.edu

Joel Smoller[1]

Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, USA
E-mail: smoller@math.lsa.umich.edu

Blake Temple[2]

Department of Mathematics, University of California, Davis, CA 95616, USA
E-mail: temple@math.ucdavis.edu

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[1]Supported in part by NSF Applied Mathematics Grant Number DMS-89-05205 and by the Institute of Theoretical Fynamics, UC-Davis.

[2]Supported in part by NSF Applied Mathematics Grant Number DMS-86-13450, by the Institute of Theoretical Dynamics, UC-Davis, and IHES.

HANDBOOK OF MATHEMATICAL FLUID DYNAMICS, VOLUME II
Edited by S.J. Friedlander and D. Serre
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In PNAS we proposed the universe was evolving inside a time-reversed Black Hole from which we would eventually emerge…

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PNAS

Shock-wave cosmology inside a black hole

Joel Smoller[†] and Blake Temple[‡§]

[†]Department of Mathematics, University of Michigan, Ann Arbor, MI 48109; and [‡]Department of Mathematics, University of California, Davis, CA 95616

Communicated by S.-T. Yau, Harvard University, Cambridge, MA, June 23, 2003 (received for review October 17, 2002)

We construct a class of global exact solutions of the Einstein equations that extend the Oppeheimer–Snyder model to the case of nonzero pressure, inside the black hole, by incorporating a shock wave at the leading edge of the expansion of the galaxies, arbitrarily far beyond the Hubble length in the Friedmann–Robertson–Walker (FRW) spacetime. Here the expanding FRW universe emerges be-hind a subluminous blast wave that explodes outward from the FRW center at the instant of the big bang. The total mass behind the shock decreases as the shock wave expands, and the entropy condition implies that the shock wave must weaken to the point where it settles down to an Oppenheimer–Snyder interface, (bounding a finite total mass), that eventually emerges from the white hole event horizon of an ambient Schwarzschild spacetime. The entropy condition breaks the time symmetry of the Einstein equations, selecting the explosion over the implosion. These shock-wave solutions indicate a cosmological model in which the big bang arises from a localized explosion occurring inside the black hole of an asymptotically flat Schwarzschild spacetime.

We describe a cosmological model based on matching a critically expanding Friedmann–Robertson–Walker (FRW) metric to a metric that we call the Tolman–Oppenheimer–Volkoff (TOV) metric inside the black hole across a shock wave that lies beyond one Hubble length from the center of the FRW spacetime. This implies that the spacetime beyond the shock wave must lie inside a black hole, thus

the total mass $M(\bar{r}, t)$ inside radius $\bar{r}$ in the FRW metric at fixed time t increases like $\bar{r}$,[¶] and so at each fixed time t we must have $\bar{r} > 2M(\bar{r}, t)$ for small enough $\bar{r}$, while the reverse inequality holds for large $\bar{r}$. We let $\bar{r} = \bar{r}_{crit}$ denote the smallest radius at which $\bar{r}_{crit} = 2M(\bar{r}_{crit}, t)$.] We show that when $k = 0$, $\bar{r}_{crit}$ equals the Hubble length. Thus, we cannot match a critically expanding FRW metric to a classical TOV metric beyond one Hubble length without continuing the TOV solution into a black hole, and we showed in ref. 4 that the standard TOV metric cannot be continued into a black hole. Thus to do shock matching with a $k = 0$ FRW metric beyond one Hubble length, we introduce the TOV metric inside the black hole.

2. The TOV Metric Inside the Black Hole

When the metric anzatz is taken to be of the TOV form

$$ds^2 = -B(\bar{r})d\bar{t}^2 + A^{-1}(\bar{r})d\bar{r}^2 + \bar{r}^2 d\Omega^2, \qquad [2.1]$$

and the stress tensor T is taken to be that of a perfect fluid comoving with the metric, the Einstein equations $G = \kappa T$, inside the black hole, take the form

$$\bar{p}' = \frac{\bar{p} + \bar{\rho}}{2}\frac{N'}{N - 1}, \qquad [2.2]$$

In our final RSPA with Joel Smoller in 2017…

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…we proposed the anomalous acceleration had emerged from a self-similar wave that formed during the radiation epoch of the Big Bang…

In our final RSPA with Joel Smoller in 2017…

…we proposed the anomalous acceleration had emerged from a self-similar wave that formed during the radiation epoch of the Big Bang…

…this implied a predicted correction from Dark Energy…

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An instability of the standard model of cosmology creates the anomalous acceleration without dark energy

Joel Smoller, Blake Temple, Zeke Vogler

Published 22 November 2017. DOI: 10.1098/rspa.2016.0887

Article Figures & Data Info & Metrics eLetters

PDF

Abstract

We identify the condition for smoothness at the centre of spherically symmetric solutions of Einstein's original equations without the cosmological constant or dark energy. We use this to derive a universal phase portrait which describes general, smooth, spherically symmetric solutions near the centre of symmetry when the pressure p=0. In this phase portrait, the critical k=0 Friedmann space–time appears as a saddle rest point which is unstable to spherical perturbations. This raises the question as to whether the Friedmann space–time

Andy Fell at UC-Davis put out a press release that got a lot of media attention…

Doing Without Dark Energy

Mathematicians Propose Alternative Explanation for Cosmic Acceleration

by Andy Fell | December 13, 2017



“Dark energy,” a mysterious force that counters gravity, has been proposed to explain why the universe is expanding at an accelerating rate. Mathematicians at UC Davis and the University of Michigan, Ann Arbor, argue for an alternative. Galaxy cluster image from the Hubble Space Telescope.

For the 2017 RSPA we re-discovered a family of GR self-similar waves which were just what we needed…

MEMOIRS
of the
American Mathematical Society

General Relativistic Self-similar Waves that Induce an Anomalous Acceleration into the Standard Model of Cosmology

Joel Smoller
Blake Temple

American Mathematical Society
Providence, Rhode Island

We proposed these self-similar waves as natural candidates for time asymptotic wave patterns during the radiation epoch of BB which naturally would create anomalous accelerations in present universe.

Expanding wave solutions of the Einstein equations that induce an anomalous acceleration into the Standard Model of Cosmology

Blake Temple[a,1,2] **and Joel Smoller**[b,1,2]

[a]Department of Mathematics, University of California, Davis, CA 95616; and [b]Department of Mathematics, University of Michigan, Ann Arbor, MI 48109

Edited by S.-T. Yau, Harvard University, Cambridge, MA, and approved June 30, 2009 (received for review January 2, 2009)

We derive a system of three coupled equations that implicitly defines a continuous one-parameter family of expanding wave solutions of the Einstein equations, such that the Friedmann universe associated with the pure radiation phase of the Standard Model of Cosmology is embedded as a single point in this family. By approximating solutions near the center to leading order in the Hubble length, the family reduces to an explicit one-parameter family of expanding spacetimes, given in closed form, that represents a perturbation of the Standard Model. By introducing a comoving coordinate system, we calculate the correction to the Hubble constant as well as the exact leading order quadratic correction to the redshift vs. luminosity relation for an observer at the center. The correction to redshift vs. luminosity entails an adjustable free parameter that introduces an anomalous acceleration. We conclude (by continuity) that corrections to the redshift vs. luminosity relation observed after the radiation phase of the Big Bang can be accounted for, at the leading order quadratic level, by adjustment of this free parameter. The next order correction is then a prediction. Since nonlinearities alone could actuate dissipation and decay in the conservation laws associated with the highly nonlinear radiation phase and since noninteracting expanding waves represent possible time-asymptotic wave patterns that could result, we propose to further investigate the possibility that these corrections to the Standard Model might be the source of the anomalous acceleration of the galaxies, an explanation not requiring the cosmological constant or dark energy.

Expansion waves and shock waves are fundamental to conservation laws because, even when dissipative terms are neglected, nonlinearities alone can cause noninteracting wave patterns to emerge from interactive solutions via the mechanism of shockwave dissipation. In this article, we construct a one-parameter family of noninteracting expanding wave solutions of the Einstein equations in which the Standard Model of Cosmology (during the pure radiation epoch) is embedded as a single point.

Our initial insight was the discovery of a set of coordinates in which the critical ($k = 0$) Fiedmann–Robertson–Walker spacetime with pure radiation sources ($p = \rho c^2/3$), referred to here simply as FRW, goes over to a standard Schwarzchild metric form (barred coordinates) in such a way that the metric components depend only on the single self-similar variable $\bar{r}/\bar{t}$ (cf. ref. 1). From this we set out to find the general equations for such self-similar solutions. In this paper we show that the partial differential equations (PDEs) for a spherically symmetric spacetime in Standard Schwarzchild coordinates (SSC) reduce, under the assumption $p = \rho c^2/3$, to a new system of three ordinary differential equations* in the same self-similar variable $\bar{r}/\bar{t}$. After removing one scaling parameter and imposing regularity at the center, we prove that there exists implicitly within the three-parameter family, a continuous one parameter family of self-similar solutions of the Einstein equations that extends the FRW metric.

Because different solutions in the family expand at different rates, our expanding wave equations introduce a acceleration parameter a, and suitable adjustment of parameter a will speed up or slow down the expansion rate. By normalization, $a = 1$ corresponds to the neutral FRW spacetime, $a < 1$ slows it down, and $a > 1$ speeds it up. Using special properties of the spacetime metrics near $a = 1$, we find an exact expression for the leading order (quadratic) correction to the redshift vs. luminosity relation of the standard model that can occur during the radiation phase of the expansion. By the continuity of the subsequent evolution with respect to the acceleration parameter, it follows that the leading order correction implied by an arbitrary anomalous acceleration observed at any time after the radiation phase of the Big Bang can be accounted for by suitable adjustment of the acceleration parameter.

Our proposal for further investigation, then, is to obtain the correction to redshift vs. luminosity induced by the expanding waves at present time by evolving forward, up through the $p = 0$ stage of the Standard Model, the correction induced by the expanding wave perturbations at the end of the radiation phase. Matching the leading order correction to the data will fix the choice of acceleration parameter, and the higher order corrections at that choice of acceleration parameter are then a verifiable prediction of the theory. The point to be made here is that decay to a noninteracting expansion wave would most likely occur during the radiation phase of the expansion because this is when the sound speed and modulus of genuine nonlinearity (GN) [in the sense of Lax (3)] are maximal (4). That is, by standard theory of hyperbolic conservation laws, GN is a measure of the magnitude of nonlinear compression that drives decay via shockwave dissipation, even when dissipative terms are neglected in the equations (cf. refs. 3, 5, and 6). That is why we focus on expanding wave solutions during the radiation phase. After this phase, the pressure drops to $p \approx 0$, and the resulting equations (for dust) have a zero modulus of GN. Thus significant decay should not occur after the uncoupling of radiation from matter. However, even though a self-similar expanding wave created when $p = \rho c^2/3$ should evolve into a noninteracting expansion wave during the $p \approx 0$ phase, there is no reason to believe that the solution would remain self-similar after the radiation phase. Moreover, we see no reason at this stage to assume that these noninteracting expansion waves should describe all of spacetime. As a consequence, the global analysis of solutions, while interesting, is of secondary interest to the purpose of this article, which is to explore the possibility that we might lie near the center of such an expansion

Author contributions: B.T. and J.S. designed research, performed research, analyzed data, and wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

[1]We have departed from our usual convention of listing authors alphabetically in order to recognize B.T.'s extraordinary contribution to this particular article.

[2]To whom correspondence may be addressed. E-mail: smoller@umich.edu or temple@math.ucdavis.edu.

*As far as we are aware the only other known way the PDEs for metrics in SSC with perfect fluid sources reduce to ordinary differential equations (ODEs), is the time independent case when they reduce to the Oppenheimer–Volkoff equations (2).

In Joel's final 2017 RSPA with Zeke Vogler we rigorously carried out the problem of bringing these self-similar waves up to present time to compare the induced accelerations with Dark Energy.

In Joel's final 2017 RSPA with Zeke Vogler we rigorously carried out the problem of bringing these self-similar waves up to present time to compare the induced accelerations with Dark Energy.

The analysis was a tour-de-force based on a new self-similar formulation of the Einstein equations in which the critical Friedmann spacetime appeared as an unstable saddle rest point.

In his recent thesis, Christopher Alexander proved these self-similar waves were precisely the expanding waves created by a GR shock wave explosion…

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…and the self-similar formulation of Einstein's eqns is the basis for our current characterization of the instability of Friedmann spacetimes.

In his recent thesis, Christopher Alexander proved these self-similar waves were precisely the expanding waves created by a GR shock wave explosion…

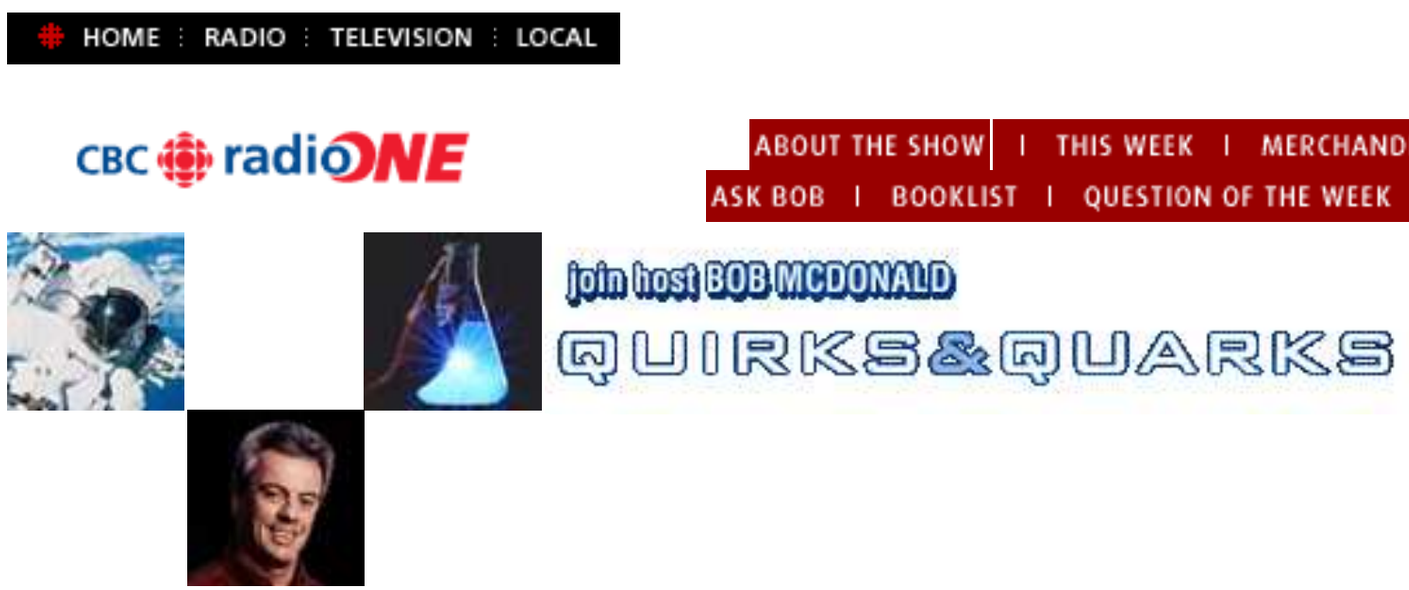
…and the self-similar formulation of Einstein's eqns is the basis for our current characterization of the instability of Friedmann spacetimes.

Most interestingly, the non-critical $k \neq 0$ Friedmann spacetimes are shown to be unstable solutions within the unstable manifold of critical $k = 0$ Friedmann.

Anything with potential Cosmological implications got a lot of interest in the press, and a lot of push back from cosmologists…

There was a particularly interesting interview on Quirks and Quirks…

CBC Radio | Quirks & Quarks | September 13, 2003 http://radio.cbc.ca/programs/quirks/archives/03-04/sep13.html



At that time, Joel and I did not see controversy as a bad thing…

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Surprisingly, it was Mohammed Hafez in Engineering who enjoyed the controversy the most!

I gave two talks in Hafez's seminar…

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Applied Mathematics

vs

Dark Energy

Blake Temple, UC-Davis

Collaborators: Joel Smoller and Zeke Vogler

I gave two talks in Hafez's seminar…

GR Simple-Waves
Trigger
An Instability in SM
which creates the
Anomalous Acceleration
without
Dark Energy

Blake Temple, UC-Davis

Collaborators: *Joel Smoller and Zeke Vogler*

In 2011 Joel Smoller honored me in a Sixtieth Birthday Conference which was really wonderful…

New Perspectives in Nonlinear Partial Differential Equations



May 2 – 6, 2011

University of Michigan, Ann Arbor, MI



In celebration
of Blake Temple's
60th birthday.

Invited Participants

A. Bressan – Penn State
G.-Q. Chen – Oxford
D. Christodonlou – ETH
V. Elling – Michigan
C. Evans – Berkeley
F. Finster – Regensburg
H. Freisthüler - Konstanz
J. Glimm – Stony Brook
D. Hoff – Indiana
T. Hou – Caltech
S. Jin – Wisconsin
B. Keyfitz – Ohio State
P. Lax – NYU
R. LeVeque – Washington
T-P Liu – Stanford
T. Luo – Georgetown
D. Marchesin - IMPA
S. Osher – UCLA
G. Papanicolaou – Stanford
R. Schoen – Stanford
S. Shkoller – Davis
M. Slemrod – Wisconsin
A. Strominger – Harvard
E. Tadmor – Maryland
D. Tataru – Berkeley
C. Tracy – UC Davis
S-T Yau – Harvard
R. Young – Massachusetts
S. Wu – Michigan
Z. Xin – Hong Kong
K. Zumbrun – Indiana

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Joel Smoller – Univ of Michigan, Chair, Craig Evans – Univ of California, Berkeley,
Tai-Ping Liu – Stanford, Craig Tracy – Univ of California, Davis, Tom Hou – Caltech
George Papanicolaou – Stanford

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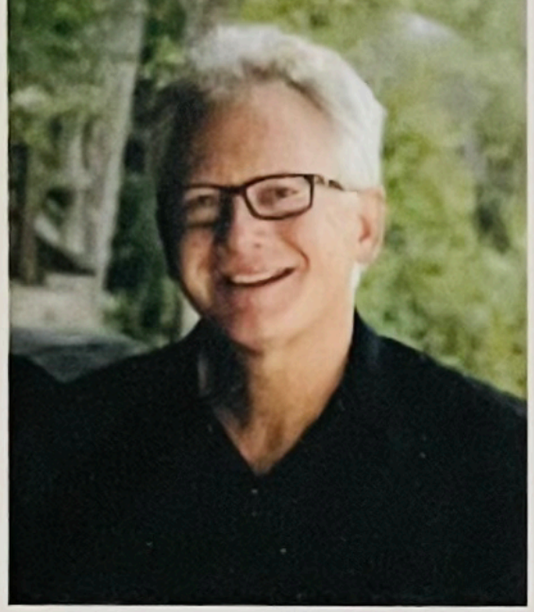
math.lsa.umich.edu/conferences/pde/

Registration and Hotel Accomodations: contact Molly Long, mollyl@umich.edu



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George Papanicolaou – Stanford

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E. Tadmor – Maryland

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R. Young – Massachusetts
S. Wu – Michigan
Z. Xin – Hong Kong
K. Zumbrun – Indiana

ST Yau and Zhouping Xin became supporters…

Since then…

Since then…

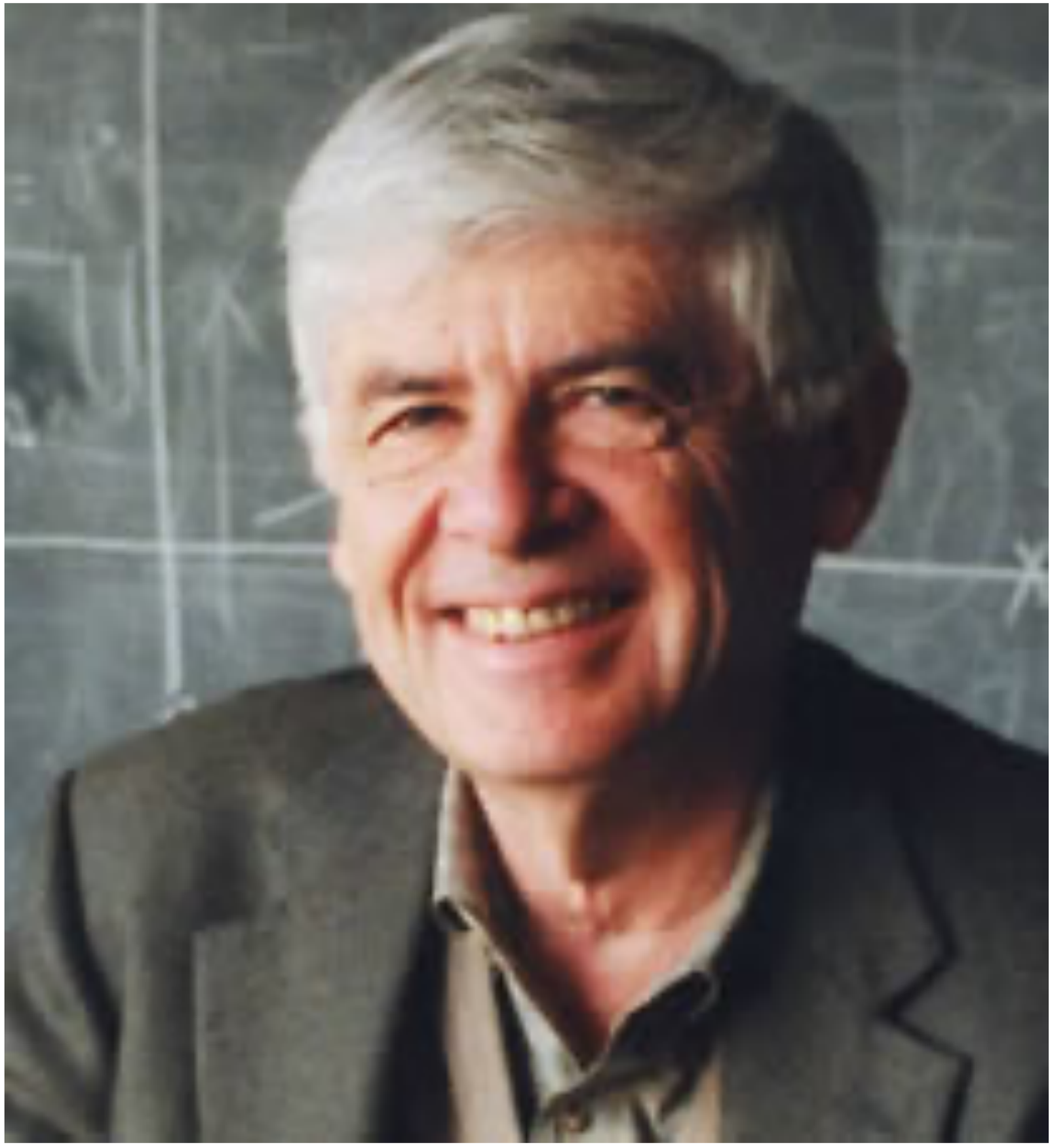
ST Yau, Zhouping Xin, Lars Anderson, Felix Finster, Joel Hass and the Proceedings of the Royal Society have been loyal supporters of our work!

At that time, Joel and I did not see controversy as a bad thing…

Surprisingly, it was Mohammed Hafez in Engineering who enjoyed the controversy the most!

Alexander Chorin and Craig Evans invited us to give several talks along the way in the Applied Math Seminar at UC-Berkeley…

I was honored when Alexander Chorin invited me to attend several seminars with him at Berkeley, and we had many interesting discussions.



Pictures from Margaret Smoller…





Oct 10, 2008

Margaret Smoller Joel Smoller Tau Luo


Margaret Smoller
Table #1
Tilapia

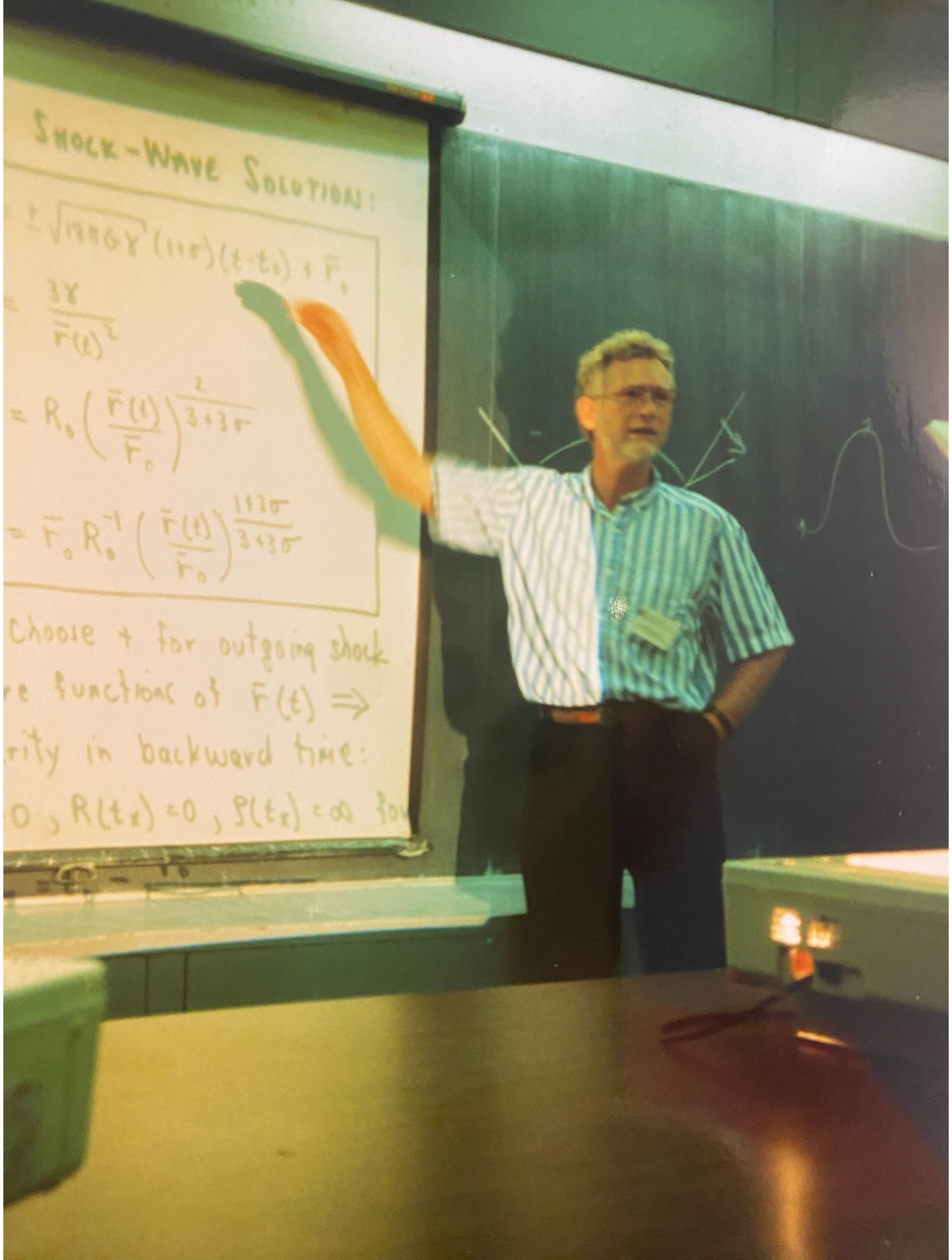


May 2, 2011

Joel Smoller Me Zhouping Xin Shing-tung Yau






SHOCK-WAVE SOLUTION:
Choose + for outgoing shock
functions of $\bar{r}(t) \Rightarrow$
in backward time:









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ENDS







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ON NONLINEAR EVOLUTION
PARTIAL DIFFERENTIAL EQUATIONS
⟨ICNEPDE⟩




迎友團餐館


中华人民共和国万岁
世界人民大团结万


WELCOME
欢迎惠顾
WELCOM




吃鸡只需
步行八分钟
用胎請用珠江胎
北京蓝图设计用品
服务公司
经营
绘图机械
测绘仪器
文具纸张
德国红环绘
进此门 在














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SEA ME
SAGRES
BEER
EXPERIENCE
MIGUEL CASTRO E SILVA
MIGUEL LAFFAN
NEXO


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FESTIVAL
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Cance z, divide x

$$-2\sqrt{AB}\,W^2 + W_t + \sqrt{AB}\,W(xW)_x = -\frac{1}{2}\sqrt{AB}\left\{4W^2 + \frac{1-A}{Ax^2}(1-x^2W^2)\right\}$$

$$\sqrt{AB}\,W^2 + x\sqrt{AB}\,WW_x$$

$$\boxed{W_t + x\sqrt{AB}\,WW_x = -\sqrt{AB}\left\{W^2 + \frac{1-A}{2Ax^2}(1-x^2W^2)\right\}}$$

$W = \frac{x}{t}$ $\quad \bar{W}(\xi,t) = W(x,t)$ $\quad Z(\xi,t) = Z(x,t)$

$W(\xi,t) = t\,\bar{W}(\xi,t)$

$W_t = \bar{W}_\xi\left(-\frac{x}{t^2}\right) + \bar{W}_t$

$W_x = \bar{W}_\xi\left(\frac{1}{t}\right)$

$t^2\bar{W}_t - x\bar{W}_\xi + x t^2\sqrt{AB}\,\bar{W}\bar{W}_\xi\frac{1}{t} = -\sqrt{AB}\left\{\bar{W}^2 + \frac{1-A}{2A\xi^2}(1-\xi^2\bar{W}^2\right.$

$t^2\bar{W}_t = t(t\bar{W})_t - t\bar{W}$ $\quad \xi W_\xi$ $\quad \xi\sqrt{AB}\,WW_\xi$

$tW_t - W$

$tW_t + \xi\{-1 + \sqrt{AB}\,W\}W_\xi = W - \sqrt{AB}\left\{W^2 + \frac{1-A}{2A\xi^2}(1-\xi^2\right.$

RHS

$$F(\xi) = D(\bar{t}(\xi)) - D(\tilde{t}(\xi))$$

$$F(\xi) = F(0) + O(\xi)$$

$$= 1 - a\xi + (b - a^2)\xi^2 + O(\xi^3)$$

$$= -J(\xi, t)$$

$$= 1 - \xi + (a^2 - b)\xi^2 + \left(\frac{11}{9} - 2D_2\right)\xi^3$$

$$\left(+\frac{b}{t} - D_2(t)\right)$$

$$= -J(\xi, t_0)\frac{t_0}{t_e}$$

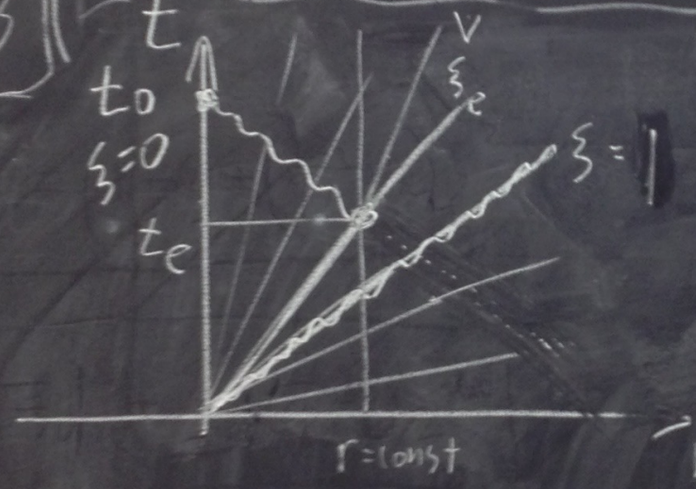
$$-\frac{1}{3}\xi^3$$

$$-\frac{1}{2}\xi^3 + \frac{1}{6}\xi^3 + O(\xi^4)$$

$$F(0) = D_2(\tilde{t}(0)) - D_2(\bar{t}(0)) = D_2'(t^*)\underbrace{[\tilde{t}(0) - \bar{t}(0)]}_{\Delta t_0}$$

$$\tilde{t}(0) \le t_* \le \bar{t}(0)$$

$$D_2'(t^*) = D_2'(t_0) + O(\Delta t_0)$$



$$\xi = \frac{r}{t} = \xi_*$$

$$r = \xi_* t$$

$$\frac{dr}{Ddt} = \frac{dr}{ds} = v$$

$$ds = D\,dt\,v$$

$$\frac{dr}{dt} = D\frac{dr}{ds}$$

$$\xi = \text{const} = \xi_e$$

$$r = \xi_e t$$

$$\frac{1}{D}\frac{dr}{dt} = \xi_e \frac{1}{D} = \bar{V} = \frac{\xi_e}{D}$$

$$\xi_e/(D/\sqrt{A}) = \bar{V}$$

V = speed of fluid wrt r = const

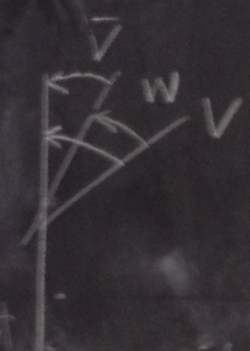
$$V + V\bar{V}W = \bar{V} + W$$

$$V - \bar{V} = W(1 - V\bar{V})$$

$$\frac{V - \bar{V}}{1 - V\bar{V}} = W$$

$$V = \frac{\bar{V} + W}{1 + \bar{V}W}$$

$$W = \frac{V - \bar{V}}{1 + V\bar{V}} = \frac{V - \xi_e/D}{1 + V\xi_e/D} = a\xi + b\xi^3 + \text{hot}$$



$$tD'(t) = -\frac{1}{4}\frac{1}{12}3w_0\left(\frac{4}{3} + z_0\right)$$

$$= -w_0\left(\frac{1}{3} + \frac{z_0}{4}\right)$$

$$\sqrt{\frac{AB}{A}}$$

$$\boxed{\frac{dr}{\left(\frac{D}{\sqrt{A}}\right)dt} = V}$$

motion of fluid




MONTEREY
Jazz


Università degli Studi



HAPPY VALENTINE'S DAY MOM!
XOXOXO BLAKE

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Zurich Colloquium in Mathematics

A Panorama

24.02.2015
Bo'az Klartag (Tel Aviv)
Needle decompositions and Ricci curvature

24.03.2015
Blake Temple (Davis)
An instability creates the anomalous acceleration without dark energy

14.04.2015
Angelika Steger (Zurich)
The determinism of randomness and its use in combinatorics

05.05.2015
Ben Green (Oxford)
Approximate algebraic structure

Dienstag: 17.15 Uhr bis 18.15 Uhr

Ort: Universität Zentrum, Karl-Schmid-Strasse 4, 8006 Zürich,
Kollegiengebäude 2, Hörsaal 150, 1. Stock (Eingang Zoologisches Museum)

Im Anschluss an das Kolloquium findet ein Apéro statt.

Transverse part:

$$M(\lambda,\xi)\begin{pmatrix}0\\ \xi^\perp\\ 0\end{pmatrix}=\begin{pmatrix}0\\ \{(\rho+p)\lambda+(\sigma\lambda^2+\eta|\xi|^2)\}\xi^\perp\\ 0\end{pmatrix}$$

$$\lambda=\frac{1}{2\sigma}\left(-(\rho+p)\pm\sqrt{(\rho+p)^2-4\sigma\eta\xi^2}\right);\quad \Pi^T(\lambda,\xi)=0$$

$$M(\lambda,\xi)\cong\begin{pmatrix}M^L(\lambda,\xi) & 0\\ 0 & M^T(\lambda,\xi)\end{pmatrix}$$

$$\Pi(\lambda,\xi)=\Pi^L(\lambda,\xi)\,\Pi^T(\lambda,\xi)$$

$$\Pi^L(\lambda,\xi)\overset{?}{=}\lambda\{c_v n\lambda+\chi(\lambda^2+\xi^2)\}\{(\rho+p)\lambda+\sigma(\lambda^2+\xi^2)\}+\lambda\chi c_v n p\xi^2+\chi p(\lambda^2+\xi^2)\xi^2$$

Lin'd eqs., restframe ($u^\beta=(0,\vec{u})$)

(1) $\left\{\frac{\partial\rho}{\partial t}+(\rho+p)\nabla\cdot\vec{u}\right\}_{\parallel}+\left\{\chi\left(\frac{\partial^2\theta}{\partial t^2}-\Delta\theta\right)\right\}_{\parallel}=0$

(2) $\left\{(\rho+p)\frac{\partial\vec{u}}{\partial t}+(\gamma-1)c_v n\nabla\theta+(\gamma-1)c_v\theta\nabla n\right\}_{\parallel}+\left\{\sigma\frac{\partial^2\vec{u}}{\partial t^2}-(\eta\nabla\cdot\nabla\vec{u}+\xi\nabla(\nabla\cdot\vec{u}))\right\}_{\perp}=0$

(3) $\left\{\frac{\partial n}{\partial t}+n\nabla\cdot\vec{u}\right\}_{\parallel}=0$

$\partial_t\to\lambda$

$\partial_x\to i\xi$

Dispersion relation:

let $M(\lambda,\xi)=0$

$\Pi(\lambda,\xi)=\Pi^L(\lambda,\xi)\,\Pi^T(\lambda,\xi)$

$$N(\lambda,\xi)=\begin{pmatrix}(\sigma\lambda^2+\eta|\xi|^2)\mathbb{I}+\left(\rho+\frac{\eta}{3}\right)\xi\xi^T\end{pmatrix}$$

proposition:

$N(\lambda,\xi)\xi=\sigma(\lambda^2+|\xi|^2)\xi$, long.

$N(\lambda,\xi)\xi^\perp=(\sigma\lambda^2+\eta|\xi|^2)\xi^\perp$ tr.

$$T^{\alpha\beta}_{,\beta}=\left((\rho+p)u^\alpha u^\beta+p\delta^{\alpha\beta}\right)_{,\beta}$$
$$=((\rho+p)u^\beta)_{,\beta}u^\alpha+p_{,0}$$
$$=\underbrace{((\rho+p)u^i)_{,i}}+\underbrace{(\rho+p)_{,0}-p_{,0}}$$

$$T^{i\beta}_{,\beta}=\left((\rho+p)u^i u^\beta+p\delta^{i\beta}\right)_{,\beta}$$
$$=\underbrace{(\rho+p)u^\beta u^i_{,\beta}}+p^{,i}$$
$$\approx(\rho+p)\dot{\vec{u}}+\nabla p$$

$$\left.\begin{array}{l}\partial_\beta(T^{\alpha\beta}+\Delta T^{\alpha\beta})=0\\ \partial_\beta(nu^\beta)=0\end{array}\right\}$$

$p=(\gamma-1)n\epsilon$
$=(\gamma-1)c_v n\theta$

$\nabla p=c_s^2(\gamma-1)n\nabla\theta$
$+c_v(\gamma-1)\theta\nabla n$

$\rho=n(m+c_v\theta)$

Replace first of these three eqn. by:

$$(1)\left\{c_v n\frac{\partial\theta}{\partial t}+(m+c_v\theta)\frac{\partial n}{\partial t}+(\rho+p)\nabla\cdot\vec{u}\right\}+\{\dots\}=0$$

$$M(\lambda,\xi)=\begin{pmatrix}c_v n\lambda & i(\rho+p)\xi^T & (m+c_v\theta)\lambda\\ i(\gamma-1)c_v n\xi & (\rho+p)\lambda\mathbb{I}_3 & i(\gamma-1)c_v\theta\xi\\ 0 & in\xi^T & \lambda\end{pmatrix}+\begin{pmatrix}\chi(\lambda^2+\xi^2) & 0 & 0\\ 0 & N(\lambda,\xi) & 0\\ 0 & 0 & 0\end{pmatrix}$$






ONE WAY
KITCHEN OPEN LATE

$$D_\varepsilon u = \frac{u(x+\varepsilon) - u(x)}{\varepsilon}$$

$$Du = \lim_{\varepsilon \to 0} D_\varepsilon u$$

① $\exists C$ s.t.

$$\|Du\|_s \leq C \|D_\varepsilon u\|_s$$

---

② away from consts,

$$\|u\|_s \leq C \|D_\varepsilon u\|_s$$

if ② fails,

$\exists u^j$ s.t. $\|u^j\|_s = 1$

and $1 \leq C(j) \|D_\varepsilon u^j\|_s$

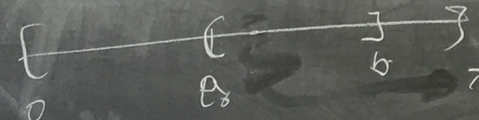
$\Rightarrow \|Du^j\|_{H^s} \to 0$

by ① $\|Du^j\|_{H^s} \to 0$

$\|u^j\|_{H^{s-1}} \to 0$

$\Rightarrow u^j \to 0$ pointwise

contr.



$\varphi > 0$ on $[\theta, \pi]$

t_0 with $\varphi(t_0) \neq 0$.

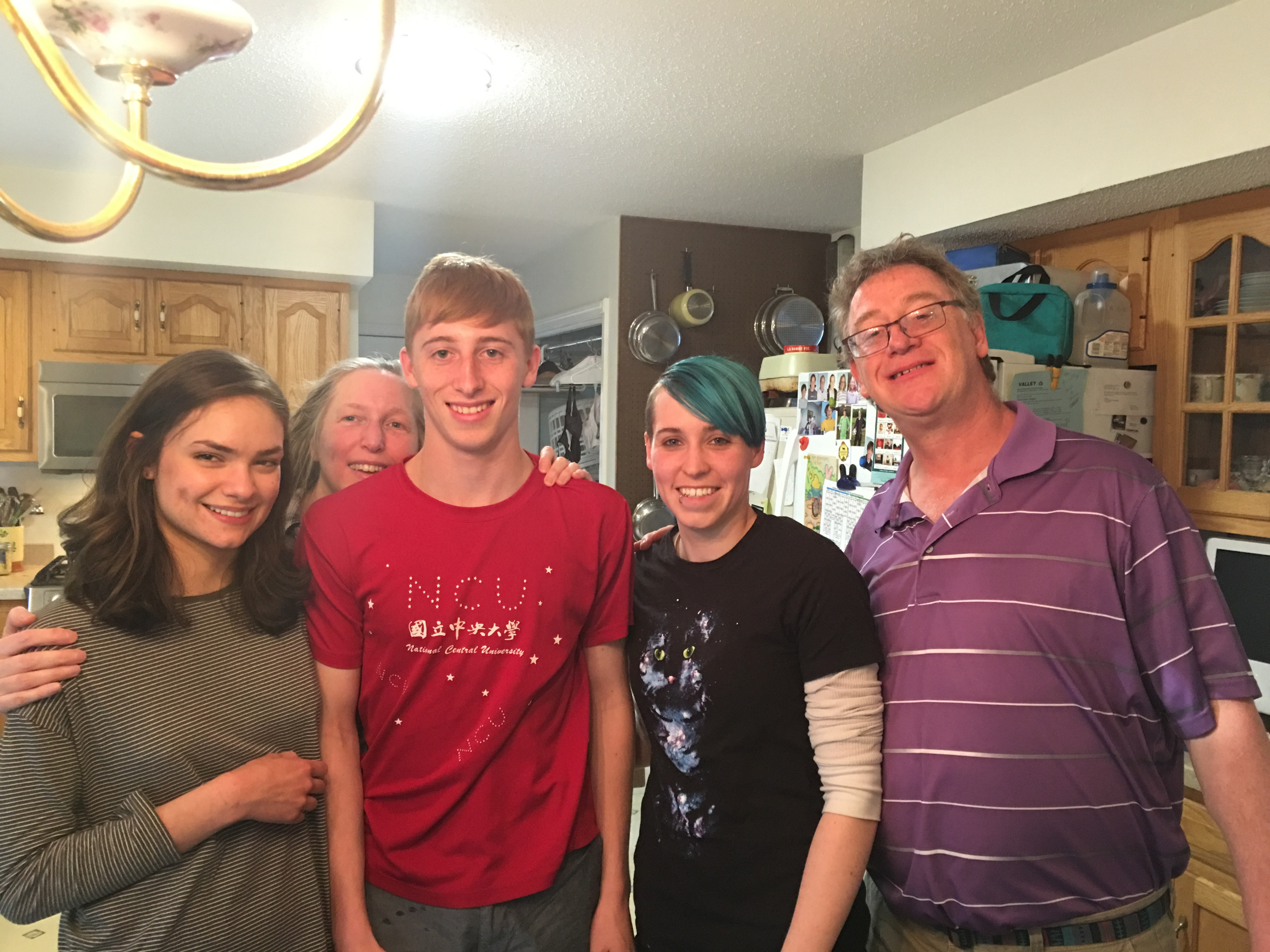
$t_1 = t_0 + \alpha \varphi(t_0)$ $\quad \underline{\alpha}$: $t + \alpha \varphi(t) \in [0, \pi]$

$t_{k+1} = t_k + \alpha \varphi(t_k)$

$u([t_k, t_{k+1}]) = u([t_{k-1}, t_k])$

$V(u([t_k, t_{k+1}])) = V(u([t_{k-1}, t_k]))$

$\Rightarrow V([0, \pi]) = \ell V = \infty$ unless $u =$ const


NCU
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OMEGA STAFF



Row 1: Joe Compton (Editor), Walter Hill (Editor). **Row 2:** Bob Itami, Betsy Robertson, Valoree Haag, Hester Pulling, Anne Bokram, Greg Barnsdale, Bill Kehoe. **Row 3:** Mr. Tabler, Robin Rossland, Marcia Watson, Edith Bowler, Chris Hughes, Sue Wenk. **Row 4:** Kathy Brinkman, Jackie Elzay, Blake Temple, Craig Robinson, Bob Jones, Nancy Dorow, Pam Brinkman.


EXIT
ROUTE
EXIT





$k=+1$

$$t = \frac{\Delta_0}{2}(2\theta - \sin 2\theta)$$

$$R = \frac{\Delta_0}{2}(1-\cos 2\theta) = \Delta_0 \sin^2\theta$$

$$\lim_{t\to 0} \frac{\Delta_0 t^2}{R^3} = \lim_{\theta\to 0} \frac{\Delta_0^2/2^2 (2\theta-\sin 2\theta)^2}{\Delta_0^3/2^3 (1-\cos 2\theta)^3}$$

$$= \lim_{\theta\to 0} \frac{2(2\theta-\sin 2\theta)^2}{(1-\cos 2\theta)^3} \overset{0/0}{\underset{\text{L'H}}{=}} 2 \lim_{\theta\to 0} \frac{2(2\theta-\sin 2\theta)(2-2\cos 2\theta)}{3(1-\cos 2\theta)^2 \sin 2\theta}$$

$$= \frac{4}{3} \lim_{\theta\to 0} \frac{2\theta-\sin 2\theta}{(1-\cos 2\theta)\sin 2\theta} \overset{0/0}{\underset{\text{L'H}}{=}} \frac{4}{3} \lim_{\theta\to 0} \frac{2-2\cos 2\theta}{\frac{2\sin 2\theta \sin 2\theta}{1-\cos 2\theta} + (1-\cos 2\theta)\cos 2\theta}$$

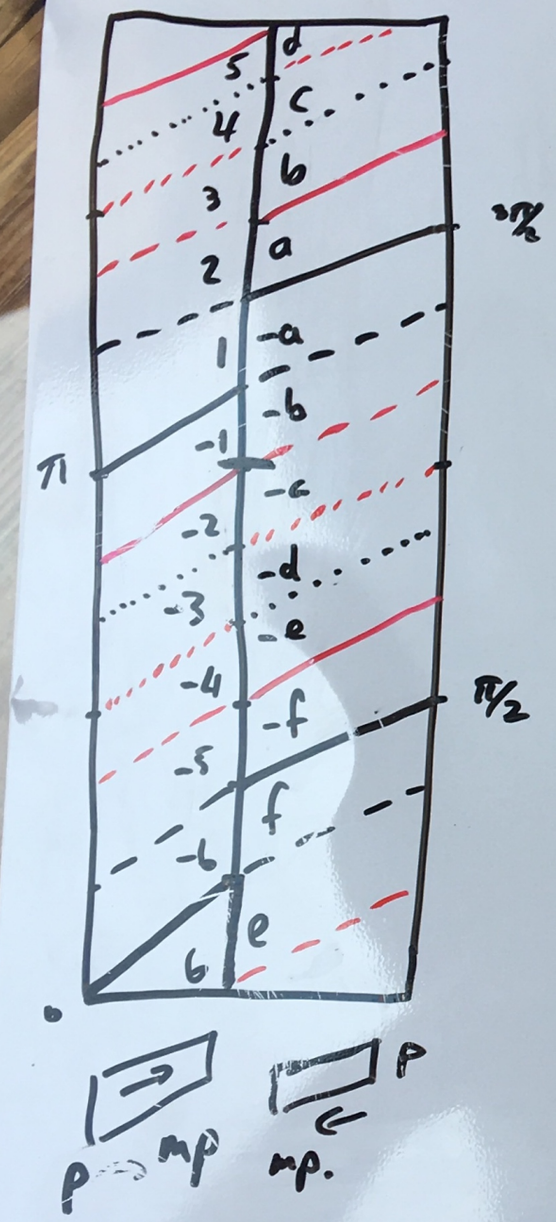
$$= \frac{4}{3} \lim_{\theta\to 0} \frac{1}{\frac{\sin^2 2\theta}{1-\cos 2\theta} + \cos 2\theta} = \boxed{\frac{4}{9}}$$

(3)

$$\lim_{\theta\to 0} \frac{\sin^2 2\theta}{1-\cos 2\theta} \overset{\text{L'H}}{=} \lim_{\theta\to 0} \frac{2\cdot 2\sin 2\theta \cos 2\theta}{2\sin 2\theta} = 2\lim_{\theta\to 0} \cos 2\theta = \boxed{2}$$









symmetry:

$$\frac{1}{m_i} p_i = \frac{1}{m_{-i}} p_{-i}$$

$i = 1, \ldots 6, -1 \ldots -6$
$a \ldots f, -a \ldots -f.$

$$\Rightarrow \boxed{p_{-i} = \frac{m_{-i}}{m_i} p_i}$$

Te Yo
SM 6/6/19
1

jumps: even part same.
odd part scales by J.

even parts:

$p_{-1} + p_{-2} = p_{-b} + p_{-c}$

$p_1 + p_{-3} = p_{-a} + p_{-d}$

$p_2 + p_{-4} = p_a + p_{-e}$

$p_3 + p_{-5} = p_b + p_{-f}$

$p_4 + p_{-6} = p_c + p_f$

$p_5 + p_6 = p_d + p_e$

odd parts:

$Jp_1 - Jp_{-2} = p_{-b} - p_{-c}$

$Jp_1 - Jp_{-3} = p_{-a} - p_{-d}$

$Jp_2 - Jp_{-4} = p_a - p_{-e}$

$Jp_3 - Jp_{-5} = p_b - p_{-f}.$

$Jp_4 - Jp_{-6} = p_c - p_f.$

$Jp_5 - Jp_6 = p_d - p_e.$

params:

$\underbrace{\bar{\theta}, \underline{\theta}}_{\approx \pi/6}, \alpha.$

$M \sim \underbrace{\frac{1}{1-\text{hit}}}_{1\text{-mode}}$

$\boxed{\sim \sin(t)}$

12 eqs, 12 unknowns!

TeYo 6/9 SM

1



$$\bar{t} = -t = \mathcal{R}\, t$$

$$\underline{t} = \underline{\mathcal{R}}\, t = \mathcal{S}_{\underline{\varphi}}\, \mathcal{S}^{-\pi/2}\, \mathcal{R}\, \mathcal{S}^{\pi/2}\, \mathcal{S}_{\underline{\varphi}}^{-1}\, t$$

$$\bar{t} = \bar{\mathcal{R}}\, t = \mathcal{S}_{\bar{\varphi}}\, \mathcal{R}\, \mathcal{S}_{\bar{\varphi}}^{-1}\, t.$$

pick t – generates: $\bar{t}\ \bar{t}\ \underline{t}$;
each of those generates same... etc.

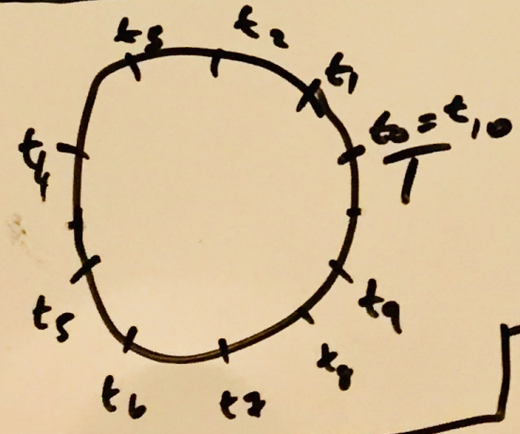
Resonance: $T = \{t_0, t_1, \dots t_N = t_0\}$,
st. $\forall j$, $t_j, \bar{t}_j, \bar{t}_j, \underline{t}_j \in T$.

Then: any (t_{j-1}, t_j) is a fund. interval.

Eqs for t are:

$$\left.\begin{aligned} \bar{p}(\bar{t}) &= \bar{m}(t)\, \bar{p}(t) \\ \underline{p}(\underline{t}) &= \underline{m}(t)\, \underline{p}(t) \end{aligned}\right\} \text{– symm}$$

$$\left.\begin{aligned} \bar{p}(t) + \bar{p}(\bar{t}) &= \underline{p}(t) + \underline{p}(\bar{t}) \\ J\bar{p}(t) - J\bar{p}(\bar{t}) &= \underline{p}(t) - \underline{p}(\bar{t}) \end{aligned}\right\} \text{jump.}$$



Multi-component shift, working at jump to understand as shifts/circle maps.










ALWAYS
IN
CONTROL

31/12/92

GRAFICAS 7 REVUELTAS

Dear Blake:

Feliz Nuevo Año!

Spain is really nice. See ya soon.

Joel

GRAFICAS SIETE REVUELTAS
SEVILLA. ESPAÑA - 954 - 215267

CONSIGNE EN SUS ENVIOS EL CODIGO POSTAL



Prof. Blake Temple
Mathematics Dept.
Univ. of California @ Davis
Davis, California
U.S.A.






'88



INTERLEAGUE

SF falls short in Long's debut

Giants lose ninth-inning lead, can't capitalize on reliever's first outing

By Kerry Crowley
Bay Area News Group

On a bullpen day that began with the Giants using a set-up man as an "opener" and a rookie making his major league debut as a "bulk innings" pitcher, Gabe Kapler's club had the Texas Rangers exactly where they wanted them.

The Giants hoped to be able to turn Wednesday's matinee over to closer Tyler Rogers with a ninth-inning lead, and that's exactly what they did. Rogers, however, was unable to keep the Rangers off the scoreboard as a leadoff single and a pop-up that fell in between a drawn-in infield and a deep outfield defense allowed Texas to tie the game at 2-2 in the bottom of the ninth.

After trading runs in the 10th, the Giants lost 4-3 on a walk-off single in the 11th after Rangers infielder Brock Holt hit an 0-2 fastball from Jake McGee into center field to bring home the automatic runner, Nate Lowe, from second base.

The Giants failed to bring automatic runner LaMonte Wade Jr. home from second in the 11th after Wade was thrown out between second and third in a rundown following a groundball hit by Wilmer Flores. The late collapse cost the Giants a chance to match the Tampa Bay Rays with a major league-best 39 wins and took some of the spotlight away from an otherwise impressive performance from their bullpen.

Rookie Sammy Long became

GIANTS » PAGE 2

THE SCORE
RANGERS 4, GIANTS 3 (11 INN.)
Up next: Giants at Washington
When: Thursday, 4:05 p.m.
TV/Radio: NBCS-BA/680 AM



TONY GUTIERREZ — THE ASSOCIATED PRESS

Giants shortstop Brandon Crawford, left, is unable to tag the Rangers' Isiah Kiner-Falefa (9) at second in the ninth inning on Wednesday in Arlington, Texas.

COMMUNITY SPORTS

FELLOWSHIP AND FUN

Pickleball community hopes to expand the fast-growing sport in Woodland



PHOTOS BY CARLOS GUERRERO — DAILY DEMOCRAT

A pickleball player attempts to hit the ball back to the other team while playing at Beamer Park.

By Carlos Guerrero
cguerrero@dailydemocrat.com

Pickleball has somehow turned into one of the fastest-growing sports in America and has been experiencing exponential growth for years now. If you haven't played or even heard about it, don't feel too bad because it has done so with a relatively low profile.

On certain days around Woodland, groups of players will meet up at Beamer and, now recently, Crawford Park to enjoy some fresh air, sun, and healthy competition by playing pickleball.

Pickleball is almost identical to tennis but is played on smaller courts with wooden or plastic paddles and lowered nets. The sport involves less physical exertion, so it is a good fit for seniors and youth who want to play.

"The range of motion is minimal," said community player Meg Murrieta. "You're not running as much as you are on a tennis court. You are hitting in small spaces taking two or three steps and hitting the ball."

While the game has been experiencing exponential growth nationwide for years now, Henry Murrieta hopes to grow it even more here in Woodland.

Murrieta, who serves as the unofficial pickleball ambassador in Woodland, takes on most of the scheduling and other logistical responsibilities.

Most of the playing takes place at Beamer Park. Murrieta mentions that the first group

PICKLEBALL » PAGE 2



Community members playing pickleball at Beamer Park. Pickleball has turned into one of the fastest-growing sports in America and has been experiencing exponential growth for years now.

SOCCER

Top players in MLS, Liga MX to square off

All-Star Game will be held Aug. 25 in LA

By Joe Reedy
The Associated Press

LOS ANGELES » It will take place more than a year later than originally scheduled, but a match between the top players in Major League Soccer and Mexico's Liga MX is on.

The two leagues announced Wednesday that the MLS All-Star Game will be played Aug. 25 at Banc of California Stadium, home of Los Angeles FC of the MLS.

The game was originally scheduled to take place last July 29 and coincide with MLS's 25th season until the coronavirus pandemic curtailed those plans.

MLS Commissioner Don Garber said planning for the game did not intensify until the past month after both leagues were able to make sure the top players could participate, along with ensuring the game could be played in a full stadium. California stadiums and arenas are cleared to go to full capacity beginning Tuesday.

"There is a rivalry that exists between the United States and Mexico as it relates to soccer. The game the other night in Denver (the CONCACAF Nations League final) just adds to this rivalry," Garber said.

The upcoming game represents a departure from the format for the past 15 MLS All-Star games that had the best players in the league facing European clubs. Los Angeles is a fitting location for the game — not only does it have one of the largest Latino populations in the world but it is a battleground for both leagues.

Garber noted the cooperation between both leagues is vital when it comes to improving the stature of CONCACAF on the world stage.

"To have our region become more important and influential in the football world, the two big leagues need to collaborate together," he said. "The connection between our leagues and countries goes back to the start of MLS. For many years, we have been looking at ways to bring our leagues together to grow our fan bases and learn from each other."

Mikel Arriola, who took over as Liga MX's executive president at the start of the year, said the game represents a good showcase

SOCCER » PAGE 2



TED S. WARREN — AP, FILE

Los Angeles FC head coach Bob Bradley watches from the sideline during the second half against the Sounders on May 16 in Seattle.

INTERLEAGUE

Manaea extends streak, A's top Diamondbacks

By Curtis Pashelka
Bay Area News Group

OAKLAND » Oakland A's starter Sean Manaea was about to throw his 100th pitch of Wednesday's game with the Arizona Diamondbacks when he faced Eduardo Escobar with two runners on no outs in the top of the sixth inning.

After a mound visit from A's pitching coach Scott Emerson, Manaea then threw four straight sinkers to strike out Escobar, then got both Christian Walker and Asdrúbal Cabrera to fly out to end the threat with no damage done.



Manaea

Manaea finished his day with a season-high 111 pitches over six scoreless innings, leading the A's a 4-0 win over the Diamondbacks before an announced crowd of 4,090 at the Coliseum.

Mark Canha's bizarre two-RBI triple in the second inning was all of the offense the A's needed as Manaea has now thrown 15 consecutive scoreless innings. Manaea threw a four-hit shutout on June 2 in a 6-0 A's win over the Seattle Mariners.

Over his last four starts, Manaea now has a 0.69 ERA with just two earned runs allowed in 26 2/3 innings.

The last time Manaea threw

A'S » PAGE 2

THE SCORE
A'S 4, DIAMONDBACKS 0
Up next: Kansas City at A's
When: Thursday, 6:40 p.m.
TV/Radio: NBCS-CA/960 AM


Congratulations
on Your
Permanent
Sabbatical!

Thanks to John Hunter, Bruno Nachtergaele and Steve Skhollar for a Retirement Celebration at Davis!

Craig Tracy's 50'th Birthday Toast




Me
Estelle Baser
Craig Tracy

Craig Tracy's 50'th Birthday Toast

Craig Tracy's 50'th Birthday Toast

I gave a toast at Craig Tracy's 50'th birthday party…

Craig Tracy's 50'th Birthday Toast

I gave a toast at Craig Tracy's 50'th birthday party…

My comments on the future of teaching were like Nostradamas in predicting the future…

Craig Tracy's 50'th Birthday Toast

I gave a toast at Craig Tracy's 50'th birthday party…

My comments on the future of teaching were like Nostradamas in predicting the future…

In my toast I predicted (joke!) that each of us would soon be teaching just one class of ten thousand students or more, just once every ten years.

Craig Tracy's 50'th Birthday Toast

I gave a toast at Craig Tracy's 50'th birthday party…

My comments on the future of teaching were like Nostradamas in predicting the future…

In my toast I predicted (joke!) that each of us would soon be teaching just one class of ten thousand students or more, just once every ten years.

By this I predicted online teaching a decade before it happened!

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I'll skip the rest of the inappropriate jokes in the toast!

Thank you!

John Hong

Craig Tracy's 50'th Birthday Toast




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Estelle Baser
Craig Tracy

Craig Tracy's 50'th Birthday Toast

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Thank you!

John Hong

…for you kindness, and

all your efforts…

Thank you!

John Hong

…for you kindness, and all your efforts…

…for organizing this today!

Thank you!

To students, collaborators and math friends…

Thank you!

To students, collaborators and math friends…

…for showing up!

Thank you!

Department of Mathematics,

University of California

and

Colleagues

for supporting my research

38 years!

End

Thank you!!