ANNUAL TECHNICAL REPORT
NONLINEAR WAVE PROPAGATION
AFOSR GRANT AFOSR-84-0005

by

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The essential point of view involved in this work is the continued study of certain fundamental features associated with the nonlinear wave propagation arising in and motivated by physical problems. The usefulness of the work is attested to by the varied applications, and wide areas of interest in physics, engineering and mathematics. The work accomplished involves wave propagation in a number of areas including fluid mechanics, plasma physics, nonlinear optics, multidimensional solitons, multidimensional inverse problems, Painleve equations, direct linearizations of certain nonlinear wave equations, DBAR problems, Riemann-Hilbert boundary value problems, etc.
A. Abstract

The essential point of view involved in this work is the continued study of certain fundamental features associated with the nonlinear wave propagation arising in and motivated by physical problems. The usefulness of the work is attested to by the varied applications, and wide areas of interest in physics, engineering and mathematics. The work accomplished involves wave propagation in a number of areas including fluid mechanics, plasma physics, nonlinear optics, multidimensional solitons, multidimensional inverse problems, Painleve equations, direct linearizations of certain nonlinear wave equations, DBAR problems, Riemann-Hilbert boundary value problems etc.

(1) Research Objectives

The continuing theme of the work performed under this grant has been the study of nonlinear wave propagation associated with physically significant systems. The work has significant applications in fluid dynamics (e.g. long waves in stratified fluids), nonlinear optics (e.g. self-induced transparency, and self-focussing of light), and mathematical physics as well as important consequences in mathematics. Individuals working with me and hence partially associated with this grant include: Dr. Thanassios Fokas, Associate Professor of Mathematics and Computer Science, Dr. Adrian Nachman, Visiting Assistant Professor of Mathematics, Dr. Chris Cosgrove, Assistant Professor of Mathematics and Computer Science, Dr. Daniel Bar Yaacov, post-doctoral fellow in Mathematics and Computer Science and Mr. Ugurhan Mugan, graduate student in Mathematics and Computer Science. Attached please find the technical section of our recent proposal to A.F.O.S.R. In this proposal many of the main directions and results are outlined. Also attached please find the vitae of Ablowitz, Fokas, Nachman, Cosgrove and Bar Yaacov.
Areas of Study Include:

- Solutions of nonlinear multidimensional systems
- Inverse problems, especially in multidimensions
- DBAR methodology
- Riemann-Hilbert boundary value problems
- Solitons in multidimensional systems
- IST for nonlinear singular integro-differential equations; e.g. the Benjamin-Ono equation and the Intermediate Long Wave Equation
- Discrete IST and numerical simulations
- Painlevé equations
- Focussing singularities in nonlinear wave propagation
- Applications to surface waves, internal waves, shear flows, nonlinear optics, S.I.T., relativity etc.
- Direct linearizing methods for nonlinear evolution equations

Recent publications of M.J. Ablowitz supported by this research grant include the following:


Linear Operator and Conservation Laws for a Class of Nonlinear Integro-Differential Equations, I.N.S. #34, A. Degasperis and P. Santini.


Continuation of Research Funding
Submitted to
Air Force Office of Scientific Research
Nonlinear Wave Propagation

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0. Forward

The main purpose for the continuation of this research funding is to support the work presently being carried out by Professor Mark J. Ablowitz, and his associates, in the Mathematics and Computer Science Department at Clarkson College of Technology. The principal investigator has been working in the general area of nonlinear wave propagation for over ten years. The scope of the work is broad, although it has as its principal focus the understanding of nonlinear phenomena connected with the wave propagation which arise in physical problems. In recent years significant breakthroughs have been made and this area of research is of current interest to mathematicians, physicists, and engineers alike. During past years the active research funds allowed us to support Dr. Adrian Nachman, Dr. P. Santini, Dr. Athanassios Fokas, Dr. Chris Cosgrove, Dr. J. Satsuma, Dr. A. Nakamura and Dr. D. Bar Yaacov as collaborative faculty and postdoctoral Research Associates at Clarkson. All of these people have expertise in this field of research and have been valuable assets to our research program.

The proposal is divided as follows. In the first section an abstract of the research is given. In the second section we give a report of current and proposed research. The third section gives references; the fourth section contains curriculum vitaes of the principal investigator and his close associates, and the fifth section contains a proposed budget for two years.
1. Abstract

In recent years important advances in the study of nonlinear wave phenomena have occurred. These advances have allowed researchers to begin to understand some of the fundamental building blocks associated with nonlinear waves as well as being able to obtain solutions to a number of nonlinear evolution equations. We feel that it is important to recognize that these studies are generic in nature and apply to numerous physical problems. Examples are the propagation of long waves in stratified fluids, self-focussing in nonlinear optics, self-induced transparency, water waves, plasma physics, relativity, particle physics, etc.

In the period of time mentioned above, both approximate and exact methods of solution to problems of physical significance have emerged. Especially significant amongst the exact methods of analysis is what we shall refer to as the Inverse Scattering Transform and the associated concept of the soliton. This method has found applications in many areas of physics, engineering and mathematics. The results already obtained, and the wide ranging interest in these problems have motivated our work. In this proposal we discuss some of the research problems which we are particularly interested in.
with \( \sigma \in \mathbb{C}, (s, x) \in \mathbb{R} \times \mathbb{R}^n \), \( \Delta = \sum_{i=1}^{n} \frac{\partial^2}{\partial x_i^2} \), \( \nu \) scalar

(b) First Order Systems

\[
\frac{d\psi}{ds} + \sigma J \cdot \nu \psi - Q(s, x)\psi = 0
\]  

(5)

with \( \sigma, (s, x) \) as above, \( J \cdot \nu = \sum_{i=1}^{n} J_i \frac{\partial}{\partial x_i}, J_i = \text{diag} (J_1, \ldots, J_n) \) and \( Q, \psi, J_i \) all \( \mathbb{N} \times \mathbb{N} \) matrices with \( Q_{ii} = 0 \).

Even though there is great interest in the cases for (a): \( \sigma = i \) for (b): \( \sigma = -1 \) nevertheless we carry out the analysis for \( \sigma \) an arbitrary complex number and obtain via limits these important values. In this way we are always able to obtain Green's functions with suitable symmetry properties - a crucial requirement of the method. This approach also gives a unified treatment to the K-PI (eq. (1) with \( \sigma = 1 \)) and K-PII (eq. (1) with \( \sigma = -1 \)) equations.

It must also be remarked that our procedure gives results for the \( n \) dimensional "time"-independent case i.e. \( v(s, x) = v(x) \). This allows us to compare many of our formulae with well known formulae for the three dimensional case. Specifically the important works of Faddeev [13] and Newton [14].

This is only the beginning of what we anticipate will be a fruitful line of research.

(c) A Class of Physically Significant Singular Nonlinear Integro-Differential Equations.

We have applied the I.S.T. to a class of nonlinear singular integro-differential equations. One particular physical application is long internal gravity waves in a stratified fluid. In fact there have been a number of recent discoveries of soliton type phenomena for internal waves in the ocean. These studies have been reported in Scientific American [15], Physics Today [16] and the New York Times [17]. However both the way in which it arises, and the relevant mathematics strongly suggest that many other applications will be found as well. In fact it has been shown that there are applications to shear flow
problems [18].

The specific equation we have considered is:

\[ u_t + 2uu_x + T(u_{xx}) + \frac{1}{\delta}u_x = 0 \]  \tag{6}

where

\[ T(u) = \int_{-\infty}^{\infty} \left( -\frac{1}{2\delta} \right) \coth \left( \frac{x - \xi}{2\delta} \right) u(\xi) d\xi. \]

\( \int_{-\infty}^{\infty} \) represents the principal value integral and \( \delta \) is a parameter. References [19,20] discuss the derivation of (6) in the context of internal waves. As \( \delta \to 0 \), we have the KdV equation

\[ u_t + 2uu_x + \frac{\delta}{3} u_{xxx} = 0, \]  \tag{7}

whereas if \( \delta \to \infty \) we have the so-called Benjamin-Ono equation

\[ u_t + 2uu_x + H(u_{xx}) = 0, \]  \tag{8}

where \( H(u) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{u(\xi)}{\xi - x} d\xi \) is the Hilbert transform of \( u \).

Thus equation (6) contains as limiting forms both the KdV and Benjamin-Ono equations. The fact that (6) has multisoliton solutions ([21,22]) suggested to us that indeed (6) may be solvable by the Inverse Scattering Transform (I.S.T.). In fact we have found [23], [24] a Bäcklund Transformation, a generalized Miura Transformation, soliton and rational solutions, interesting dynamical systems and a new type of scattering problem. This scattering problem is given by the equation

\[ i\psi_x^+ + (u-\lambda)\psi^+ = \mu\psi^- \]  \tag{9}
where $u$ satisfies equation (6), and $\psi^\pm$ are the boundary values of a function analytic in the strips $0<\Im x<2\delta$ for $\psi^+$, $-2\delta<\Im x<0$ for $\psi^-$, and periodically extended. Specifically, equation (6) is a differential Riemann-Hilbert problem. When $\lambda,\mu$ are given by

$$\lambda = -\text{coth}2k\delta, \quad \mu = \text{cosech}2k\delta,$$

and $\psi^-(x) = \psi^+(x+2i\delta)$ (by periodicity) we find that in the limit we have the Schrödinger scattering problem

$$\psi_{xx} + (k^2 + \mu/\delta)\psi = 0$$

(10)

which is the linear scattering problem associated with the KdV equation (7).

Despite the fact that (9) is a totally new type of scattering problem we were nevertheless able to develop [25] the necessary I.S.T. Viewed as a Riemann-Hilbert boundary problem (9) bears many similarities to the I.S.T. associated with the classical Korteweg-deVries equation, i.e. the I.S.T. reduces to solving a Riemann Hilbert problem with a "shift". A certain discrete symmetry relation yields this shift. On the other hand when $\delta \to \infty$ we have just shown [26] that the Riemann-Hilbert problem becomes nonlocal. Specifically the discrete symmetry relation becomes continuous, and this gives rise to the nonlocality of the Riemann problem. Moreover we have been able to demonstrate how one can find the solution of the Benjamin-Ono equation ($\delta \to \infty$) by taking the suitable limit of the intermediate equation ($\delta$ finite) [27]. It is significant to note that the Benjamin-Ono equation bears many similarities to the multidimensional problem, especially the Kadomtsev-Petviashvili equation. We discuss many of these ideas in recent review papers [28].

Finally, it should be pointed out that it has been found that there are significant nonlinear singular integro-differential evolution equations which should fall into similar categories such as those discussed above. One such example is the so-called Modified Intermediate Long Wave equation. This equation is related to
via a Miura Transformation [29]. We are investigating such equations and their relevant inverse problems. Some interesting results have already been obtained.

(d) Transverse Instability of One Dimensional Transparent Optical Pulses in Resonant Media.

It is well known that ultrashort optical pulses may propagate coherently, without attenuation in certain resonant media [30,31]. This phenomena is commonly referred to as Self-Induced Tranparency (S.I.T.) and has been intensively studied experimentally, numerically, and analytically by numerous researchers, motivated at least in part, by significant potential applications. From a mathematical point of view the one dimensional equations of S.I.T are very special. Namely, it has been shown that these equations can be fully integrated by the use of the Inverse Scattering Transform [32,33]. Specifically, the above analysis has shown that arbitrary initial values break up into a sequence of coherent pulses, which do not decay as they propagate, plus radiation which rapidly attenuates. These coherent pulses are referred to as solitons.

There are various types of solitons [30,31]; e.g. "\(2\pi\) pulses" ("hyperbolic secant pulses"), "\(\omega_m\) pulses" ("breathers") etc." In our paper, "Transverse Instability of One-Dimensional Transparent Optical Pulses in Resonant Media", [34] we have shown analytically, that the \(2\pi\) pulse is, in fact, unstable to certain transverse variations (i.e. multidimensional perturbations). These results are consistent with numerical and experimental studies on the transverse effects in S.I.T.[35,36]. The latter work has shown that transverse variations can lead to frequency-amplitude modulations and in some cases self-focussing filaments. Similarly in [37] we have recently been able to show that the breather solution (\(\omega_m\) pulse) is also unstable to long transverse perturbations. Mathematically speaking, this work was difficult because the earlier analysis had to be much further developed. We point out that this analytical stability calculation is on
a mode which is much more complicated than a permanent travelling wave (i.e. a simple soliton $2\pi$ pulse). In the future we wish to examine the stability of a double pole solution (i.e. a limiting form of a breather solution just before it breaks up into a two soliton state) as well as attempting to more fully understand both the properties of the two dimensional model, as well as looking for multi-dimensional soliton solutions in analogy with the lump solutions discussed in (a) above.

(e) Perturbations of Solitons and Solitary Waves.

The above work on transverse stability of solitons in S.I.T. led us naturally to the problem of adding general weak perturbations to equations which admit solitons or solitary waves as special solutions (both in one and more than one dimension). Some of the mathematical machinery was already in place due to the work done in part (b) described above. We have found [38] that, generally speaking, such perturbation problems can be successfully handled by more or less well known perturbation methods. We have compared our results to some of those in the literature which employ the Inverse Scattering Transform (see for example [39-41]). One advantage of our technique is that it also applies to problems which are not necessarily integrable and hence I.S.T. will not apply.

Our analysis, shows in some detail, that there is quite different phenomena occurring in different regions of space. Namely near the peak of the soliton we have adiabatic motion of the soliton (or solitary wave). Away from the soliton a linear W.K.B. theory applies. The results are asymptotically matched in order to obtain a uniformly valid theory. To our knowledge this theory is the first such uniformly valid calculation of a perturbation of a soliton or solitary wave. Previous theories were valid in limited regions of space only.
By examining other equations admitting solitary wave solutions (i.e. ones which are not solvable by I.S.T.) we believe that we have discovered a new class of equations which have focussing singularities, (namely, equations which have certain solutions which are "nice" initially, but blow up in a finite time).

For example, we have discovered evidence that strongly indicates that the following equation is in this class:

$$u_t + u^p u_x + u_{xxx} = 0$$

for $p>4$. We hope to continue to investigate such questions in the future. These questions are of both mathematical and physical interest.

(f) On a linearization of the Korteweg-deVries (KdV) and Painlevé II ($P_{II}$) Equations

Recently we have discovered an alternative linear integral equation which, in principle, allows one to capture a far larger class of solutions to KdV than does the Gel'fand-Levitan equation. Specifically we have shown by direct calculation that if $\phi(k;x,t)$ solves

$$\int \frac{d\lambda(k)}{2\pi i} \frac{e^{i(kx+k^3t)}}{L} \frac{\phi(k;x,t)}{L} = e^{i(kx+k^3t)}$$

where $d\lambda(k)$, $L$ are an appropriate measure and contour respectively then

$$u(x,t) = -\frac{3}{3\pi} \int \phi(k,x,t) d\lambda(k)$$

satisfies KdV:

$$u_t + 6uu_x + u_{xxx} = 0$$
In our paper [42] we (a) give a direct proof of the above facts; (b) for a special contour and measure we show how the Gel'fand-Levitan equation may be recovered as a special case; For this contour/measure such an integral equation had been recently discovered in the context of pure scattering - inverse scattering theory (see for example [43]). (c) Characterize a three parameter family of solutions to the self-similar o.d.e. associated with KdV which may be directly related to the second Painlevé Transcendent (P_{II}): (We note that the Gel'fand-Levitan-Marchenko equation associated with P_{II} only characterizes a one parameter family of solutions). In order to carry out (c) we had to investigate a concrete singular integral equation in which the contour L consists of 5 rays all passing thru the origin. The analysis requires the full power (and some extensions) of the classical theory of singular integral equations [44-46].

It should be remarked that (i) the integral equation (12) applies to potentials of the Schrödinger equation, even without the application to KdV or P_{II}; (ii) the motivation for developing such an integral equation originates from the concept of summing perturbation series [47,48]. (iii) Recently Flaschka and Newell [49] considered P_{II} via monodromy theory. In their work they derive a formal system of linear singular integral equations for the general solution of P_{II}. However the highly nontrivial question of existence of solutions was left open. How their work and ours relate is a question which we have been investigating. (iv) The linear version of KdV: $u_t + u_{xxx} = 0$ is solved in full generality as a special case. Some future directions are: (a) Investigation of the full generality of the solutions of KdV via this new formulation. (b) Development of similar types integral equations for other nonlinear evolution equations, as well as ones which relate to natural "equilibrium" states for KdV, other than the zero (or vacuum) state.
(c) Compare this direct linearization to the direct Riemann-Hilbert method of Zakharov and Shabat

(g) A Connection Between Nonlinear Evolution Equations and Certain Nonlinear O.D.E.'s of Painlevé type.

The development of the inverse scattering transform (I.S.T.) has shown that certain nonlinear evolution equations possess a number of remarkable properties, including the existence of solitons, an infinite set of conservation laws, an explicit set of action angle variables, etc. We have noted in [52] that there is a connection between these nonlinear partial differential equations (PDE's) solvable by I.S.T. and nonlinear ordinary differential equations (ODE's) without movable critical points. (Some definitions: a critical point is a branch point or an essential singularity in the solution of the ODE. It is movable if its location in the complex plane depends on the constants of integration of the ODE. A family of solutions of the ODE without movable critical points has the P-property; here P stands for Painlevé.) In [53-55] we have announced and developed a number of results which indicate that this connection to ODE's of P-type is yet another remarkable property of these special nonlinear PDE's. We have conjectured that:

Every nonlinear ODE obtained by a similarity reduction of a nonlinear PDE of I.S.T. class is, perhaps after a transformation of variables, of P-type.

Here we refer to a nonlinear PDE as being in the I.S.T. class if nontrivial solutions of the PDE can be found by solving a linear integral equation of the Gel'fand-Levitan-Marchenko form. No general proof of this conjecture is available yet, but we have proven a more restricted result in this direction. It is known that under scaling transformations certain nonlinear PDE's of I.S.T. class reduce to ODE's. Moreover, the solutions of these ODE's may be obtained by solving linear integral equations. We have shown that every such family of solutions has the P-property.
We note that the conjecture in its strongest form relates to ODE's obtained from equations solved directly by I.S.T. There are many examples of equations solved only indirectly by I.S.T.; the sine-Gordon equation is one of the best known examples. An ODE obtained from an equation solved indirectly by I.S.T. need not be of P-type, but it may be related through a transformation to an ODE that is.

One consequence of this conjecture is an explicit test of whether or not a given PDE may be of I.S.T. class; namely, reduce it to an ODE, and determine whether the ODE is of P-type. To this end, we identify certain necessary conditions that an ODE must satisfy to be of P-type and describe an explicit algorithm to determine whether an ODE meets these necessary conditions.

We have exploited this connection in order to develop both solutions and asymptotic connection formulae to some of the classical transcendents of Painlevé [56] as well as others. The method which we have given in order to determine if an ODE is of P type is a useful device for determining the integrability of an ODE. For example in [57] using this method we have derived a new explicit solution for the traveling waves of Fisher's equation. Indeed this method, which was also used successfully in classical problems [58] has seen a recent revival of interest (for example see [59-61]).

In the future we intend to consider the following problems:

(1) The complete connection formulae (i.e. the global connection of asymptotic states) for the interesting Painlevé equations associated with linear Gel'fand-Levitan'Marchenko equations. It should also be mentioned that some other important work has already been accomplished in this direction (see for example [62], [63]).
(2) To prove that the ODE's which we have derived, in fact satisfy the property; i.e. that they have no movable essential singularities, regardless of initial conditions.

(3) To develop solutions to these ODE's which correspond to general initial conditions. In this regard we shall reconsider the recent work of Flaschka and Newell [49] especially in relation to the work discussed earlier in this proposal [see ref. [42]].

(4) Study the connection between the Bäcklund transformations developed in the Russian literature (the reader may wish to see the review [64] as well as the articles by Fokas [65] and Fokas and Ablowitz [66] and their connection to I.S.T. and monodromy preserving deformations. We have very recently made progress in this direction.

(g) Discrete I.S.T. and Numerical Schemes.

It is significant that many of the concepts related to the inverse scattering theory apply to suitably discretized nonlinear evolutions equations; for example the Toda lattice, and discrete nonlinear Schrödinger equation (see for example [67], [68]). It is of interest to ask whether one can solve partial difference equations (i.e. numerical schemes) by inverse scattering. An obvious application is to numerical simulations. We have succeeded in analytically developing such schemes [68]. These schemes can be shown to converge to a given nonlinear P.D.E. (which itself is solvable by inverse scattering) in the continuous limit. Moreover they have the nice property that they are neutrally stable, have exact soliton solutions and possess an infinite number of conserved quantities. Recently we have compared the practical numerical simulation of a given nonlinear P.D.E. (e.g. cubic nonlinear Schrödinger or KdV) using traditional methods, with our newly developed schemes. Our schemes have proven to be extremely strong.
The results are compiled in a sequence of recent papers [69-71]. In the future, we hope to continue to assess the usefulness of various numerical schemes on important model nonlinear problems.
3. Bibliography


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Professor of Mathematics, Clarkson College of Technology, 1976-79
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74. Linear Operator and Conservation Laws for a Class of Nonlinear Integro-Differential Equations, I.N.S. #34, A. Degasperis and P. Santini.


NONTECHNICAL ARTICLES:


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National Science Foundation, Mathematics Section
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McGill University, Mathematics Department, November, 1975.

Princeton University, Applied Mathematics Department, January, 1976.

University of Pittsburgh, Mathematics Department, March, 1976.

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Nihon University, Physics Department, Tokyo, Japan, July, 1976.

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Princeton University, Applied Mathematics Department, April, 1978.


Syracuse University, A.M.S. Meeting, invited speaker, October, 1978.

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International Conference on Solitons, Jadwisin, Poland, August, 1979.


New York University, Courant Institute of Mathematical Sciences, December, 1979.


Brown University, Providence, Rhode Island, October, 1980.

University of Montreal, November, 1980.

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Georgia Institute of Technology, December, 1980.


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Workshop on Nonlinear Evolution Equations, Solitons and Spectral Methods, August 24-29, 1981, Trieste, Italy.

Workshop on Mathematical Methods in Hydrodynamics and Integrability in Related Dynamical Systems, La Jolla Institute, La Jolla, California, December 7-9, 1981.

York University, Physics Department, March, 1982.

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Princeton University, Applied Mathematics Program, April, 1982.

Columbia University, Program in Applied Mathematics, April, 1982.

Solitons '82, Scott Russell Centenary Conference and Workshop, Edinburgh, Scotland, August, 1982.


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S.U.N.Y. at Stony Brook, Department of Theoretical Physics, April 22-25, 1983.

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Elementary Calculus
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Ph.D. STUDENTS:


Y.C. Ma, Studies of the Cubic Schrodinger Equations, Princeton University, 1977. I was an informal advisor and reader of the thesis.

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Conference Board on Mathematical Sciences, Regional Conferences Panel, 1979, 1980.


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TEACHING EXPERIENCE: I have taught most of the courses in the calculus sequence at Yale during the past three years.

HONORS: Dean's List, The Hebrew University, 1975-77
University Fellow, Yale, 1977-81

REFERENCES: Professors: R. Beals, R.R. Coifman, and

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CURRICULUM VITAE

Christopher M. Cosgrove

1967: Higher School Certificate. Gained first place in Mathematics in N.S.W.

1967: First place in N.S.W. School Mathematics Competition (a 3-hour exam consisting of six challenging problems accessible to high school students).

1968: Awarded Barker Scholarship no. III, Horner Exhibition, and T.G. Room Medal for gaining first place in Mathematics in H.S.C.


1971: Gained first place and four individual question prizes in the Sydney University Mathematical Society (SUMS) Annual Problem Competition. (This is a nationwide competition open to undergraduate students; it consists of ten very difficult problems bordering on original research in some cases).


1973: Fourth-year honours course in Applied Mathematics (non-degree). Gained High Distinction (equivalent to good 1st Class Honours in B.Sc. degree course).


July 1980-June 1982: Richard Chace Tolman Fellow in Theoretical Astrophysics at California Institute of Technology (awarded on the basis of an international competition).

July 1982-present: Assistant Professor of Mathematics at Clarkson College of Technology.

LIST OF PUBLICATIONS


ATHANASSIOS S. FOKAS

1971: Graduated from high school, Athens, Greece

"General Certificate of Education"

1972-75: Department of Aeronautics, Imperial College, University of London, London, England
Degree: B.Sc. 1975, with first class honors, also awarded the "Governors" Prize in Aeronautics: for 1975, for being the best student in the final year of the Aeronautics.

1975-79: Department of Applied Mathematics, California Institute of Technology, Pasadena
Degree: Ph.D. June 1979 (supervisor: P.A. Lagerstrom)

1979-80: Saul Kaplun Research Fellow in Applied Mathematics, Caltech

1980-82: Assistant Professor, Clarkson College

June - August, 1981: Visiting Professor, Universitat Paderborn, West Germany

1983: Associate Professor, Clarkson College
PUBLICATIONS:


\[ S_t = (\beta S + \gamma)^{-2} S_x + \alpha (\beta S + \gamma)^{-2} S_{xx} \]


Participation in National and International Conferences

The author has been invited and has given lectures in the following conferences:

5. Workshop on Mathematical Methods in Hydrodynamics and Integrability in Related Dynamical Systems, La Jolla, CA, December 7-9, 1981.
9. 2nd Workshop on Nonlinear Evolution Equations and Dynamical Systems, Chania, Crete, Greece, August 9-25th, 1983.

Colloquia and Seminars Given
5. "One-Parameter Families of Solutions of the Sixth Painlevé Equation", University of Georgia, June 1980.
7. "Linearization of the Korteweg-deVries and Painlevé II Equations, University of Georgia, October 1981."


Contract Awards:

1982- : National Science Foundation, Mathematics Section.

1982- : Office of Naval Research, Mathematics Division.
CURRICULUM VITAE

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EDUCATION:
1971-1974 McGill University - B.Sc. (Honors Math.) 1974
- Ph.D. (P.D.E.) 1980

Doctoral Thesis Advisor: Charles Fefferman

SCHOLARSHIPS & HONORS:
1972-1974 J.W. McConnel Scholarship - McGill University
1973-1974 Anne Molson Scholarship - McGill University
1974 First Class Honors in Math. - McGill University
1974 Anne Molson Gold Medal - McGill University
1974-1979 Research & Teaching Asst. - Princeton University
1979-1981 J.W. Gibbs Instructor - Yale University
1982-1983 Lilly Fellow - University of Rochester

PRESENT POSITION:
Visiting Assistant Professor - Department of Mathematics and Computer Science,
Clarkson University, Potsdam, NY 13676

TEACHING EXPERIENCE:
- 11 semesters Calculus at Princeton U., Yale U. and U. of Rochester
- undergraduate courses in Linear Algebra, Ordinary Differential Equations and Partial Differential Equations.
- a graduate course on Hyperbolic Differential Equations at Yale U.
- a graduate course on Pseudodifferential Operators at U. of Rochester
- a one year seminar on Solitons and Inverse Scattering at U. of Rochester

PUBLICATIONS:


### INVITED LECTURES:

**1983**
- Cornell University - Analysis Seminar
- Clarkson University - Mathematics Colloquium

**1984**
- Clarkson University - Mathematics Colloquium
- University of Montreal - Mathematical Physics Seminar
- Princeton University - Applied Mathematics Colloquium

### REFERENCES:

- Professor Richard Beals
  - Dept. of Math., Yale University
- Professor Charles Fefferman
  - Dept. of Math., Princeton University
- Professor Elias Stein
  - Dept. of Math., Princeton University

### LANGUAGES:

- English, French, German, Roumanian