MATHEMATISCHES FORSCHUNGSINSTITUT OBERWOLFACH

T a g u n g s b e r i c h t 32/1992

Lower–dimensional theories and domain decomposition methods in mechanics

July 19 – July 25, 1992

The conference was organized by Prof. Dr. P.G. Ciarlet (Paris) and Prof. Dr. K. Kirchgässner (Stuttgart). The conference' theme comprises all theories for mechanical systems which lead in a rational way to simplified descriptions of the underlying mechanical phenomenon. In this sense, the derivation of equilibrium equations for one– and two–dimensional elastic structures (rods, plates and shells) from three–dimensional elasticity should be and was a central problem of the conference. Of similar interest – and partly related to the dimensional reduction – is the formulation of modulation equations for the long time asymptotics in unbounded domains, such as the Ginzburg–Landau equations. The mathematical justification of these equations were a main topic as well as the description of attractors of dissipative systems when the underlying domain is thin in one direction. Finally, domain decomposition methods were discussed from a theoretical and practical point of view. Here, the space domain, where a solution of a partial differential equation is sought, is divided into subregions with artificial interfaces. The analytical and algorithmic aspects were dicussed in connection with elastic structures, even of mixed type.

Plates versus shells
Philippe G. Ciarlet

We consider a shell with middle surface S and thickness 2ϵ. We show that when the surface S "converges" in a specific sense to a plane domain, i.e., when "the shell becomes a plate" with the same thickness 2ϵ, the solution of the three–dimensional shell equations converges towards that of the three–dimensional plate equations. We also recall that, when the thickness 2ϵ approaches zero, the appropriately "scaled" solution of the three–dimensional plate equations converges towards the solution of a two–dimensional plate model where "bending" and "membrane" effects simultaneously appear.

We next consider the same shell with middle surface S and thickness 2ϵ, but we now interchange the order of the limits: This time, the thickness goes to zero first and secondly, "the shell becomes a plate". Using recent results of E. Sanchez–Palencia, we then show that, according to the geometry of S and to the boundary conditions, it is no longer possible to simultaneously obtain the "bending" and "membrane" effects, but only one of them. In this sense, the two "double limits" are not the same.

A Global Attracting Set for the Kuramoto–Sivashinsky Equation
Pierre Collet

We consider the Kuramoto–Sivashinsky equation

$$\partial_t U(x,t) = -(\partial_x^4 + \partial_x^2)U(x,t) - U(x,t)\partial_x U(x,t)$$

for real initial data $U(0,x) = U_0(x)$ which are periodic with period L, and show that, if $\int_{-L/2}^{L/2} U(x,t)\, dx = 0$ then

$$\limsup_{t\to\infty} \left(\int_{-L/2}^{L/2} U^2(x,t)\, dx \right) \leq \text{const}\, L^{16/5}.$$

The proof, which extends the paper by Nicolaenko, Scheurer and Temam [Phys.D16,221 (1986)], uses a set of comparison functions $\phi_b(x) = \phi(x+b)$ with

$$\phi(x) = i \sum_{\substack{n\in\mathbb{Z}\\ n\neq 0}} \frac{L\psi_n}{2\pi n} e^{\frac{2\pi i n}{L}x}$$

with $\psi_n = -\psi_n = f(\frac{n}{M})$ and $M = \mathcal{O}(L^{7/5})$.

We show then that

$$\int_{-L/2}^{L/2} \left(U(x,t) - \phi_{b(t)}(x)\right)^2 \, dx$$

stays bounded, where

$$\partial_t b(t) = \frac{4}{L} \int_{-L/2}^{L/2} U(x,t) \partial_x \phi_{b(t)}(x) \, dx.$$

Pierre Collet (Jean-Pierre Eckmann, Henri Epstein, Joachim Stubbe)
Ecole Polytechnique, Palaiseau
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Die Ginzburg-Landau Approximation bei hydrodynamischen Problemen

Guido Schneider

We consider parabolic equations on infinite domains, like $\mathbb{R}$ or cylinders. The theory will be applied to Bénard's problem which consists of Navier-Stokes equation and a heat equation. We consider solutions near a zerosolution. By increasing a parameter the zerosolution gets unstable. We want to describe the bifurcating solutions locally by a reduced problem. If linear increased spatial periodic patterns appear in the analysis of stability a two scaling ansatz formally gives the Ginzburg–Landau equation for the amplitude $A \in \mathbb{C}$. We get so approximative solutions, which are modulations of the periodic pattern. We show that these solutions are good approximations for solutions of the original problem for a natural long time-scale. Former works are restricted to scalar equations. Furthermore only analytic initial conditions or cubic nonlinearities were allowed. These assumptions are no longer necessary.

Exact controllability in thin domains

Jeanine Saint Jean Paulin

We consider a thin domain $\Omega^e = \omega \times]-\frac{e}{2}, \frac{e}{2}[$ of thickness e and the system

$$\begin{cases} y'' - \Delta y = 0 \text{ in } \Omega^e \times]0,T[\\ y = \begin{cases} v^e & \text{on part of the lateral boundary} \\ 0 & \text{on the rest of the lateral boundary} \end{cases} \\ \dfrac{\partial y}{\partial n} = W^e_{\pm} \text{ on top/bottom boundaries} \\ + \text{ initial conditions.} \end{cases}$$

It is already known (Lions) that it is possible, if T is large enough, to stabilize the vibrations at time T, that is, to find controls v^e. $w^e_\pm$ (and to choose correctly the part of the lateral boundary) so that $y(T) = y'(T) = 0$.

In the present work (with M. Vanninathan, Bangalore, India) we study the limit behaviour of these controls, of this minimal time for exact controllability and of the system when the thickness $e \to 0$. The extension to the case of linearized elasticity is under progress.

Some finite elements for Mindlin–Reissner plates

Dietrich Braess

The MITC elements of Brezzi et al. are appropriate for the numerical treatment of Mindlin–Reissner plates since locking is avoided. The mathematical analysis can be done by a reformulation as a mixed method with penalty terms. The Helmholtz decomposition $L_2(\Omega)^2 = \nabla H_0^1(\Omega) \oplus \mathrm{curl}\,(H^1(\Omega)/\mathbb{R})$ helps when the penalty term is part of a singular perturbation. In this context, some folklore on mixed methods is put into the right terms. The main step is the introduction of a discrete version of the curl–operator with which a Helmholtz decomposition of the finite element spaces $T_h = \nabla W_h \oplus \mathrm{curl}_h\, Q_h$ can be achieved.

Pattern Formation and Repair: A Case Study

P. Collet and J.–P. Eckmann

We consider the Ginzburg–Landau and Swift–Hohenberg equation in 1 space dimension in the infinite domain.

$$\begin{aligned} &\text{GL:} \quad \dot{u} = u'' + u - u|u|^2 \\ &\text{SH:} \quad \dot{U} = (\alpha - (1 + \partial_x^2)^2)U - U^3, \quad \alpha > 0 \end{aligned}$$

We establish relations between the two equations and study in detail the convergence of the initial value problem (GL) with $u(x,0) \sim \sqrt{1 - q_\pm^2}\exp(iq_\pm x)$ as $x \to \pm\infty$. The solution will "converge" to $\sqrt{1 - q_*^2}\exp(iq_* x + \vartheta_* + \mu_* \sqrt{t})$.
(Bricmont and Kupiainen)

On the derivation of geometrically exact rod and plate equations

Alexander Mielke

Rods and plates can be considered as limits of three-dimensional elasticity when thickness goes to zero. We propose a different limit by letting the length going to infinity, i.e. we consider an infinitely long cylinder and an infinite layer, respectively. This has the advantage that variables don't have to be scaled, and hence nonlinearities (geometric exactness!) can be retained through all the analysis.

Using center manifold theory the rod equations of Kirchhoff–Antman type can be derived rigorously. A generalized Lyapunov–Schmidt reduction enables us to find a geometrically exact "thick" plate equation which contains a non–local constitutive law. It consists of nine directors. Using the standard scaling to lowest order the van Karman plate model is found as a "thin" plate limit.

Membrane locking in thin elastic shells

E. Sanchez Palencia

Starting from the Koiter model of thin elastic shells, the solution of the problem after some scaling is

$$\text{Inf} \quad \frac{1}{2}\left[\frac{1}{\epsilon}a^m(u,v) + a^f(u,v)\right] - \langle f, v\rangle \quad \text{in } V$$

in the configuration space of the displacement vector u satisfying the kinematic boundary conditions. Here a^m and a^f are the membrane and flexion terms of the stored energy bilinear form. a^m containes the strain of the medium surface and the variation of the curvatures produced by the displacement u. $\epsilon = h^2$ is a small parameter, and h is the thickness of the shell.

We study the limit process $\epsilon \downarrow 0$. $\epsilon^{-1}a^m$ appears as a penalty term and the solution u^ϵ converges to u^0, where u^0 is the solution of

$$\text{Inf} \quad \frac{1}{2}a^f(u,v) - \langle f, v\rangle \quad \text{in } G$$

with $G = \{v \in V,\ a^m(v,v) = 0\}$. This is the subspace of the pure bendings, i.e. displacements keeping constant the first fundamental form of the surface.

When approximating the solution by finite elements, we consider a finite dimensional subspace V_n of V. It is chosen at random, $V_k \cap G = \{0\}$, and the approximate solution $u_n^\epsilon \to 0$ as $\epsilon \downarrow 0$ with constant n. The proof is the same as for the continuous problem, as u_n^ϵ tends to an element of G and is contained in V_n. This is the locking phenomenon. To avoid it, V_n must be chosen such that $V_n \subset G$.

Eigenvalues of clamped plates and related questions

B. Kawohl

A clamped plate embedded in an elastic medium with elasticity constant a is laterally compressed. Buckling occurs for compressions of magnitude $\gamma_i(a)$. The buckled deformation is described by

$$\Delta\Delta u + \gamma(a)\Delta u + au = 0 \text{ in } \Omega, \quad u = \partial u/\partial n = 0 \text{ on } \partial\Omega.$$

The dependence of the first eigenvalues $\gamma_i(a)$ on a is investigated. In particular I study the behaviour as $a \to \infty$ (stiffening of the ambient medium).

The mathematical tools are then applied to other eigenvalue problems such as vibrating plates under tension, transition from plate to membrane, linear elasticity systems and variational problems of type

$$\text{minimize } \epsilon J_2 + J_1$$

over a set of admissible functions. There are examples for which the limiting problem ($\epsilon = 0$) has many, one or no solutions. The latter ones are most interesting, because for small ϵ the solutions exhibit rapid oscillations.

The results were obtained jointly with Howard Levine (Ames) and Waldemar Velte (Würzburg) and will appear in SIAM J. Math. Anal.

Attractors and transients for a periodic perturbed KdV equation

Heinz Roitner

The initial–boundary value problem

$$\left.\begin{aligned} u_t + uu_x + \delta^2 u_{xxx} + u_{xx} + \beta^2 u_{xxxx} = 0 \\ u(x+1) = u(x) \quad u(x,0) = f(x) \end{aligned}\right\} (*)$$

has applications in fluid dynamics (viscous fluid flowing down an inclined plane, unstable drift waves in plasma, ...) and is a hybrid between two important and well–known equations of mathematical physics: the Korteweg–de Vries (KdV) equation and the Kuramoto–Sivashinsky (KS) equation. For strong dispersion $\delta^2 \gg 1$ numerical studies show that the solution is attracted to a travelling wave close to a KdV cnoidal wave with a primitive period $1/N$ which may also depend on the initial condition. We have $N \leq [(2\pi\beta)^{-1}]$.

We show existence and smoothness in $\epsilon := \delta^{-2}$ of travelling wave solutions for $(*)$ and carry out a linear stability theory of these TW's using a 'squared eigenfunction basis' related to KdV spectral theory and perturbation theory. Periodic KdV equation is a completely integrable Hamiltonian system whose action and angle variables are obtained from the spectral data of

$$-y'' + \frac{u(x,t)}{6\delta^2} y = \frac{\lambda}{6\delta^2} y \qquad \text{(Hill's equation)}.$$

The equations of motion of the spectral coordinates under the flow of $(*)$ are written down and studied analytically and numerically (diagnostic tool).

Finally, the boundedness of solutions to $(*)$ is discussed in the light of the method of Collet and Eckmann. This method, originally devised for the KS–equation gives for one equation as a first estimate:

$$\limsup_{t\to\infty} \|u(x,t)\|_{L^2} \leq \max\left(\beta^{-8/5}, \delta^2\beta^{-11/5}\right).$$

Junctions between thin shells

M. Bernadou

In this talk we present some results on the numerical analyses of junctions between thin shells. Successively, we consider:

i) the general thin shell equations (Koiter theory);

ii) the modelization of their junction for an elastic or a rigid hinge;

iii) the corresponding variational formulations and the associate existence results;

iv) the approximation by various conforming or nonconforming finite element methods;

v) the results of convergence and a priori asymptotic error estimates which can be expected;

and we conclude by listing some open problems.

Inertial forms for the Navier Stokes equations on thin 3D domains

George R. Sell

In this lecture we show that the Navier–Stokes equations (NSE) (with periodic boundary conditions) on a thin 3D domain of the form

$$\Omega_\epsilon = (0,2\pi) \times (0,2\pi) \times (0,2\pi\epsilon)$$

have an inertial form for every choice of viscosity ν and for ϵ sufficiently small. The existence of an inertial form implies that all the long time dynamics of NSE is completely described by the dynamics of a finite dimensional system of ODEs, with *no error*. The proof is based on two recent developments:

1. The theorem of Raugel and Sell where it is shown that there exists a global attractor for the weak solutions of NSE, provided ϵ is sufficiently small.

2. The Kwak transformation, which is a nonlinear imbedding of the NSE into a system of reaction–diffusion equations (RDE), where the nonlinearities are algebraic and do not involve spatial derivatives.

It happens that the RDE has an inertial manifold, and the dynamics on this inertial manifold is described by a finite dimensional system of ODEs.

On dimension reduction in plate and shell problems
Jahani Pitkaeranta

In this talk we demonstrate how one can do dimension reduction in plate and shell problems with very straightforward energy methods. Moreover, one can analyze the error of the resulting reduced models with the same method. Further, the same approach is natural in the derivation of numerical models based on finite elements and in the analysis of numerical discretization error. In the talk we concentrate, however, on dimension reduction rather than on numerics. The main focus is on recent results on cylindrical shells. Here we have shown in certain model problems the convergence results

$$[\![U^{3D} - U^{K}]\!] = \mathcal{O}(t^{\frac{1}{2}})$$

$$[\![U^{K} - U^{0}]\!] = \mathcal{O}(t^{\frac{1}{4}}),$$

where $[\![\cdot]\!]$ stands for the relative energy norm, U^{3D} is the 3D–displacement field, U^{K} the displacement field according to the Koiter model, and U^{0} the asymptotic limit of U^{K} as t (the thickness of the shell) tends to zero. The error bounds are proved in both membrane – and bending–dominated situations.

Nonlinear invariant membrane and plate models through asymptotics
Annie Rauolt

Asymptotic procedures have been extensively studied during the last fifteen years that lead to the derivation of bi–dimensional models (plate models) from three–dimensional elasticity. Well–known models such as the Kirchhoff model or the van Kármán model have been shown to be limiting problems.

Those models are basic theories in plate modelling. Nevertheless they suffer from two drawbacks: they are not frame–indifferent, and they are valid for small displacements only.

We present here a new approach of the asymptotic procedure on the fully nonlinear three–dimensional system of elasticity. In this deformation approach, we do not perform any scaling on the unknowns (deformations and stress–tensors). We show that for large loads, the limiting problem is a nonlinear membrane problem. The energy only depends on the first fundamental form of the deformed middle surface. Therefore the problem is frame–indifferent.

When the order of magnitude of the loads, every surface isometry φ solves the membrane problem. To determine a solution one has to investigate further terms in the expansion. Compatibility conditions for the higher order problems to be solvable show that φ should be a solution of a bending problem. The bending energy only depends on the second fundamental form. Therefore, the bending problem is frame–indifferent. The van Kármán model is found next in the hierarchy.

Domain Decompositon methods for asymptotic models.

F. Bourquin

This talk aims to illustrate a possible interplay between domain decomposition and asymptotic analysis in the case of elastic structures that exhibit somewhere a small geometrical parameter. We consider a structure mode of a three–dimensional elastic body in which a three–dimensional thin plate is inserted and glued. The eigenvalue problem is treated. It is known that the asymptotic problem is posed over a "composite" domain, called a multistructure, mode of a three–dimensional domain with a slit and a two–dimensional domain. A general method that converges with error estimates for standard domains is given and does not seem to be suitable for the asymptotic problem. On the contrary, a quite natural method for the latter is presented, with error estimates. However, the key ideas of this method do not apply for standard domains.

Discretization of autonomous differential equations and rapid forcing

J. Scheurle

We say that an autonomous equation with periodic forcing is rapidly forced, if the forcing frequency tends to infinity as the forcing amplitude tends to zero. Recently the investigation of such equations has become quite popular in connection with the phenomenon of exponentially small splitting of separatrices and "invisible" chaos. There are various contexts where such systems come up naturally, e.g. averaging or singular perturbations. In this talk another one will be discussed, namely the discretization of autonomous differential equations by finite difference schemes.

Perturbation of noncompact operators. Numerical pollution

J. Sanchez–Hubert

Perturbations of noncompact, or with noncompact resolvent, modify deeply the structure of the spectrum. Because the finite elements introduce a perturbation, the numerical computation of the spectrum of such operators is very difficult. In particular, polluant eigenvalues, or eigenvalues with polluant multiplicity, appear. For some cases rules exist to avoid the pollution but general rules are not known.

In this lecture we gave, by simple examples, a first analysis of the phenomenon of pollution. The first example is issued from the theory of elastic shells in the membrane approximation. We exhibit, by a convenient choice of the discretization, the possibility to pollute the multiplicity of an eigenvalue. We note that, with an adapted discretization, this pollution disappears, according to a rule given by Rappaz (78). The second example is a model to show what it may happen for problems depending on a parameter, which are anticompact for each fixed value of the parameter. In spite of the rules given by Rappaz we show the possibility to exhibit an alternant pollution or even a random pollution. At last, we give a method to eliminate the pollution in example 1.

Partial differential equations on thin domains

Geneviève Raugel, Orsay (Paris 11)

Let $Q_\epsilon \subset \mathbb{R}^{n+k}$ be a thin domain "around" a domain Ω in $\mathbb{R}^n$. One considers an evolutionary equation (P) on Q_ϵ or, after a change of variables, an equation $(P)_\epsilon$ on the reference domain Q. Can we define a *formal limit* problem $(P)_0$ on Ω? In general, the answer is yes. When you have determined the formal limit problem $(P)_0$, the second question to be answered is: In which sense is $(P)_0$ really the limit of $(P)_\epsilon$. Can we compare the dynamics of $(P)_0$ and $(P)_\epsilon$? The purpose of the talk is to compare the asymptotic behaviour in time of the problems $(P)_0$ and $(P)_\epsilon$. For instance, if $(P)_0$ and $(P)_\epsilon$ have a global attractor A_0 and A_ϵ, one can estimate the distance of A_0 and A_ϵ. In the case of Morse–Smale systems, one can compare the flows of $(P)_\epsilon$ and $(P)_0$ on A_ϵ and A_0. In the general case, one can still compare same connecting orbits of A_ϵ with same connecting orbits of A_ϵ with same connecting orbits of A_0, by using tools like, for instance, the Conley index.

Optimal shear correction factors in hierarchical plate modelling

C. Schwab

For the problem of bending of a linearly elastic, homogeneous plate of thickness $2d$, we present a family of two–dimensional, hierarchical models of increasing accuracy (and complexity). The well known Reissner–Mindlin model is contained in the hierarchy as a special case. All models are obtained via energy projection of the 3d solution (with possibly modified material parameters) and can be directly implemented via existing FE–codes.

We present an analysis of the consistency of the models as $d \to 0$ which uses as a tool the modelling error for the elastic layer $\mathbb{R}^2 \times (-d, d)$ and explicit Fourier–solutions of 3d–elasticity and the plate models. Rates of convergence as $d \to 0$ can be read off the Laurent–expansion of the transformed Green's functions at $|\xi| = 0$. We show:

1) for smooth data, all models of order greater than 3 do not allow for skew correction factors.

2) The bending models of order 1 (Reissner–Mindlin) and 2 do allow for a skew correction factor.

3) For properly scaled loads, the relative error in energy is $\mathcal{O}(d^2)$ if $\kappa = \kappa_{\text{opt}} = 5/6(1-\nu)$ and $\mathcal{O}(d)$ if $\kappa \neq \kappa_{\text{opt}}$ for the Reissner–Mindlin model, and

4) for the bending model of order 2, this error is $\mathcal{O}(d^2)$ iff

$$\kappa_{\text{opt}} = \frac{12-2\nu}{\nu^2}\left\{-1+\sqrt{1+\frac{20\nu^2}{(12-2\nu)^2}}\right\}, \quad \nu \neq 0$$

and $\mathcal{O}(d)$ else.

Here $\nu \in (0, 1/2)$ is the Poisson ratio (~ 0.3 for steel). For $\nu \to 0^+$, all values of κ tend to 5/6.

Domain Decomposition Methods in 3D Elasticity

P. Le Talec

Domain decompostion methods are useful from the point of geometric flexibility, one uses unstructured decompositions and nonmatching grids.

The talk presents and analyzes different strategies for the coupling of incompatible grids. It is proved that continuity at the corners is sufficient to ensure an optimal order of convergence of the discretization strategy. Iterative substructuring techniques are then proposed, which are proved to converge almost independently of the discretization step. These techniques can be accelerated by the use of a coarse grid preconditioner as introduced by J. Mandel.

Global solutions to the dynamical van Kármán equations

Herbert Koch

Energy conservation of the van Kármán equations

$$u_t + \Delta^2 u = [u, B([u,u])] \text{ in } \Omega \subset I\!R^2$$

$$u|_{\partial\Omega} = \partial_\nu u|_{\partial\Omega} = 0$$

implies the existence of global weak solutions. The main step in constructing global classical solutions consists in obtaining similar a priori estimates of higher norms of the solution. These estimates are delicate because the nonlinearity has a critical exponent. They can be obtained by differentiating the equations by t, interpolating with respect to $\Omega \times [t_0, t_1]$ and using the symmetries of the right hand side.

Effect of domain shape in thin domains on dynamics

Jack K. Hale

For a PDE on a thin domain $Q_\epsilon = \Omega \times (0, \epsilon)$, $\Omega \in \mathbb{R}^n$, smooth boundary, bounded, it is natural to compare the dynamics of the PDE on Q_ϵ with the same PDE on Ω. On the other hand, if Q_ϵ, for example, is $Q_\epsilon = \{(x, y) : y = \epsilon g(x), x \in \Omega\}$ the limit PDE as $\epsilon \to 0$ will not be the original PDE restricted to Ω. Therefore, it is natural to see how $g(x)$ affects the dynamics in the limit equation. For a model parabolic equation, we give several illustrations of how variations in g can lead to many bifurcations and, as a result, give more complicated dynamics. Examples of this type are instructive for beginning to understand how the shape of the domain in general problems affects dynamics.

Some Schwarz type domain decomposition Algorithms

Olof Widlund

The classical Schwarz alternating method can be described in terms of subspaces, directly related to to the subdomains into which the given region has been divided, and projections onto these subspaces. Many other domain decomposition algorithms for elliptic problems can be placed in a framework which is closely related to this point of view. This framework has also recently been quite useful in the systematic study of other iterative methods for partial differential equations, in particular multigrid methods.

As an introduction, the classical block Jacobi–conjugate gradient preconditioner is considered. An analysis of its rates of convergence points to two strategies to improve its performance; a second, coarse level should be introduced and the performance is also improved by increasing the overlap between the subregions.

The main focus of the talk is a powerful algorithm introduced by Barry Smith in 1989. It can be characterized as a Schwarz method on the interface that is formed by the boundaries of the substructure into which the given region has been decomposed. A new result is given which shows that the number of iterations of Smith's algorithm grows only logarithmically as a function of the relative overlap size.

Comments are also made on the actual performance of these algorithms for difficult finite element problems arising in elasticity.

The work has been carried out jointly with Maksymilian Dryja of Warsaw.

Dynamics of some nonlinear waves

Klaus Kirchgässner

The lecture treats the long time dynamics of nonlinear fluid waves under the influence of gravity. Up to now this dynamics are not understood since it requires the analysis of the Euler–equations in an unbounded space–time domain. First the KPP (Kolmogorov et al.) equation is treated as a model. For sufficiently large speed there exists a one parameter family of fronts. Local perturbations of these fronts are defined. Their long time asymptotics are shown to consist of a modulated package of diffusive waves which is convected along the front with a speed corresponding to the space asymptotics at $x = +\infty$. Then the 2D Euler–equations are analysed and it is shown that the long time behaviour of local perturbations of a solitary wave is determined by a modified KdV equation and nonlocal corrections of this. The latter part of the talk reports on work in progress together with M. Haragus.

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