Mathematisches Forschungsinstitut Oberwolfach

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Asymptotic and Numerical Methods for Kinetic Equations

April 15th – April 21st, 2001

The present meeting was organized by Pierre Degond (Toulouse), Reinhard Illner (Victoria) and Axel Klar (Darmstadt). 41 researchers from Austria(2), France(14), Germany(10), Italy(2), Japan(3), Sweden(3) and USA(7) participated. During the five days of the conference, 37 talks were given. The following key words sketch the main topics:

- Kinetic and macroscopic models for vehicular traffic
- Kinetic schemes for fluid dynamics equations
- Numerical methods for Boltzmann and Vlasov equations
- Numerical methods for radiative heat transfer and transport equations
- Numerical schemes for diffusion equations
- Kinetic equations for multiphase flows, and evaporation and condensation
- Modeling and numerical simulation of semiconductor devices

The organizers and participants thank the '*Mathematisches Forschungsinstitut Oberwolfach*' for making this conference possible.

The abstracts below are listed in alphabetical order.

Abstracts

Numerical Simulations and Asymptotic Models for Quantum Nano–Structures

Naoufel Ben Abdallah

A 2D Schrödinger–Poisson model with open boundary conditions is presented and simulated. A hierarchy of approximate models is presented and the results are compared to the full model.

Modelling Gunn Oscillations

Angelo Marcello Anile

In order to accurately describe non–stationary transport in GaAs devices it is necessary to use Monte Carlo methods or hydrodynamical models which incorporate transfer between valleys. In this talk, we present simulations of Gunn oscillations in a GaAs diode based on two–valley hydrodynamical models. Scattering parameters within the models are obtained from homogeneous Monte Carlo simulations. The simulation results for the hydrodynamical models are compared with those obtained by direct Monte Carlo simulation.

Wigner–Fokker–Planck Models: Kinetic versus Density Matrix Aproaches

Anton Arnold

Wigner–Fokker–Planck (–Poisson) models describe diffusive processes in quantum mechanics and are applied, for instance, in semiconductor modeling. In this talk we shall compare a kinetic approach — like for the Vlasov-FP equation — on the Wigner function level to the density matrix approach for the operator evolution equation. The topics include existence, uniqueness, rescaling and large–time behaviour.

Continuum Limit for Vapor Flows with Evaporation and Condensation: Effect of Infinitesimal Concentration of a Noncondensable Gas

Kazuo Aoki
(joint work with S. Takata, S. Taguchi and K. Suzuki)

The behavior of steady flows of a vapor with evaporation and condensation on the boundary is investigated on the basis of kinetic theory. The special attention is focused on the behavior in the continuum limit, the limit where the mean free path of the vapor molecules goes to zero, when an infinitesimal amount of a noncondensable gas (another gas that neither evaporates nor condenses on the boundary) is contained in the domain (more precisely, the average concentration of the noncondensable gas is infinitesimally small). With the aid of asymptotic analysis and supplementary numerical analysis of the Boltzmann equation and its boundary condition, it is shown that, in the continuum limit, the infinitesimal amount of the noncondensable gas accumulates inside the infinitely thin Knudsen layer on the condensing surface of the boundary and gives a finite effect on the vapor flows.

A Half–space Problem for Finite Dimensional Kinetic Equations

Alexander Bobylev

As a typical example we consider the half–space problem (evaporation/condensation) for discrete velocity models

$$\begin{aligned} v_{ix}\frac{df_i}{dx} &= Q_i(f_1,\dots,f_n), \quad \text{for} \quad x>0,\ i=1,\dots,N \\ f_i^+|_{x=0} &= F_i. \end{aligned}$$

Similar problems can be considered for other finite dimensional approximations of the Boltzmann–type equations with respect to the velocity space e.g. equations for moments under a certain closure. We study, from a very general point of view, the phase portraits of such dynamical systems.

Electrodynamics and extremal surfaces

Yann Brenier

It is shown how extremal surfaces in the 5d Minkowski space (1 time variable, 3 space variable, 1 "interpolation" variable) can be related to classical Electromagnetism and Electrodynamics. Negative and positive particles respectively correspond to the edges of such surfaces, the interpolation variable linking the + and the -. The starting point is the introduction of an Action given by the area of 2d surfaces embedded in 5d Minkowski space. Next, generalized surfaces ("cartesian currents" in the geometric measure theory vocabulary) are substituted for classical surfaces and the Action is redefined accordingly. Then, from the standard least action principle, evolution PDEs are obtained. In the simplest cases, these equations can be shown to be hyperbolic and linearly degenerate in all fields. Formal asymptotics can be performed.

1) As the macroscopic density and current are nearly uniform, and the edges of the generalized surfaces are prescribed, the Maxwell equations can be formally recovered, the right hand side of the inhomogeneous part corresponding to the edge data.

2) By prescribing only free surface conditions at the edges, a richer, selfconsistent, model for charged particles is obtained. The equations restricted at the edges provide (monokinetic) Vlasov equations for positive and negative particles,with the expected Lorentz forces. However the coupling equations for the electromagnetic field differ from the classical Maxwell equations and unavoidably involve the interpolation variable. The standard Maxwell coupling can also be recovered by a suitable 3 point finite differencing of the least action calculation.

Relaxation time operator: asymptotic limits and simulation

José Antonio Carrillo

One of the main goals of this study was to validate numerically the various asymptotic limits proposed in the literature for the relaxation time operator, namely: drift-diffusion (diffusive limit), corrected drift-diffusion (high field limit) and ballistic approximation (Child-Langmuir asymptotics). The kinetic equation is solved by WENO finite difference method which is demonstrated to be very robust and efficient in its solution.

The second part of the talk was devoted to showing a new numerical procedure to solve the Boltzmann-Poisson equation for semiconductors in the non-parabolic band approximation. By a spherical coordinate change of variables we remove one dimension and we solve by finite difference (WENO) methods. The different results were compared and discussed.

About the entropic average applied to a non-linear Fokker-Planck operator and kinetic fluid coupling in the field of the Inertial Confinement Fusion

Stéphane Dellacherie

To obtain a good description of the first thermonuclear reactions in the field of the Ineal Confinement Fusion, we have to use a kinetic description of coulombian interactions between the ions (deuterium and tritium) and the electrons. The kinetic model for one species is the following :

$$(1)\quad \begin{cases} \partial_t f + \overrightarrow{v} \cdot \nabla_x f - \frac{\nabla_x P_e}{\rho} \cdot \nabla_v f = B(f) + S(f), \\ \partial_t(\rho\varepsilon_e) + \nabla_x \cdot \left(\rho\varepsilon_e \overrightarrow{U}\right) + P_e \nabla_x \cdot \overrightarrow{U} = -3\Omega N(T_e - T), \\ P_e = ZNT_e, \qquad \varepsilon_e = \frac{3}{2} ZNT_e, \\ \rho = mN \equiv m \int f d\overrightarrow{v}, \qquad N\overrightarrow{U} \equiv \int \overrightarrow{v} f d\overrightarrow{v}, \qquad 3NT \equiv m \int (\overrightarrow{v} - \overrightarrow{U})^2 f d\overrightarrow{v}. \end{cases}$$

$f(t,x,v)$ is the ionic distribution, m is the ionic mass, T_e is the electronic temperature (the electron are supposed to be always at the thermodynamical equilibrium) and Ω is the ion/ion collision frequency. B and S are Fokker-Planck operators which describes respectively the ion/ion and the ion/electron collisions. To solve (1), we use a splitting technic which treates separately each operator.
In the first part of the talk, we introduce a new numerical scheme designed for the resolution of the homogeneous in space ion/electron interactions described with

$$\partial_t f = S(f) \equiv \Omega \nabla_v \cdot \left[(\overrightarrow{v} - \overrightarrow{U}) f + \frac{T_e}{m} \nabla_v f \right]$$

by introducing the notion of the *entropic average* to define the distribution f at the interfaces of the mesh $\{v_j\}$. Then, we prove that our scheme is positiv, entropic and that, in the semi-discret case, it converges to a unique thermodynamical equilibrium.
In the second part of the talk, we show how to couple a kinetic area described with the system (1) with a fluid area described with the formal fluid limit of (1) obtained when $\Omega \to +\infty$. To obtain natural boundary limits at the kinetic/fluid interface, we use the kinetic schemes (see Perthame '92) in the fluid domain.

Low Vicosity Limit for a One-Dimensional Kinetic Model of Two-Phase Flows.

Komla Domelevo
(joint work with Marie-Hélène Vignal)

In this talk, after a brief presentation of the general methodology for deriving kinetic models of dispersed two-phase flows, we concentrate on the solutions to a simple kinetic

modelling of one-dimensionnal two-phase flows:

$$(\mathcal{P}^{\epsilon,\eta}) \quad \begin{cases} \partial_t u^{\epsilon,\eta} + u^{\epsilon,\eta}\partial_x u^{\epsilon,\eta} - \epsilon\partial_{xx} u^{\epsilon,\eta} = \partial_s \int_v f^{\epsilon,\eta}(v - u^{\epsilon,\eta})dv \\ u^{\epsilon,\eta}(x,0) = u_0(x) \end{cases}$$

$$\begin{cases} \partial_t f^{\epsilon,\eta} + v\partial_x f^{\epsilon,\eta} + \partial_v(f^{\epsilon,\eta}(u^{\epsilon,\eta} - v)) - \eta\partial_{vv} f^{\epsilon,\eta} = 0 \\ f^{\epsilon,\eta}(x,v,0) = f_0(x,v), \quad f_0 \geq 0, \end{cases}$$

where $\epsilon > 0$ and $\eta > 0$. Here, the gas obeys a conservation law with smooth $\mathcal{C}^1$ flux and diffusion term. The dispersed phase obeys a linear transport-diffusion kinetic equation of Fokker-Planck type. The problem, therefore, involves the kinematic viscosity of the disperse phase accounting for the turbulent dispersion of the particles and the usual one of the gas flow. We present the estimates and techniques allowing to prove the well-posedness of the system. In particular, we present the case where the spray is described by bounded measures. Finally, vanishing viscosity limits for the problem when either one or the two viscosity coefficients tend to zero are studied. We prove existence of limiting solutions and uniqueness in the case where at least one of the two viscosities is positive.

Moment closure for radiative transfer equation and combustion applications

Bruno Dubroca

(joint work with J.L. Feugeas, G. Duffa, T. Nguyen-Bui and J.-F. Ripoll)

We here present the numerical treatment of the coupling of Navier-Stoke equations with the M_1 hyperbolic radiative model with non-constant mean absorption coefficients. Two simple splitting methods are developed in order to be able to include easily the radiative equations in an existing hydrodynamics code. We discuss about the splitting method and show three cases: methane flame, radiative shocks (subcritical and superrcritical) and a buoyant flow in a square box with lateral hot walls.

On a Discrete Velocity Model for the Wigner Equation

Thierry Goudon

We introduce a semi-discretized version of the Wigner equation, discretization concerning the velocity variable. We show that the corresponding discrete velocity problem:

- is well-posed,
- permits to recover the solution of the continuous problem when the mesh size of the discretization vanishes. The approximation presents spectral accuracy since the rate of convergence corresponds to the (Sobolev) regularity of the continuous solution.
- preserves the behaviour of the continuous problem with respect to the behaviour of the Planck constant.

Analytical Approaches to Charge Transport in a Moving Medium

Joseph W. Jerome

We consider electrodiffusion in an incompressible electrolyte medium which is in motion. The Cauchy problem is governed by a coupled Navier-Stokes/Poisson-Nernst-Planck system. We prove the existence of a unique smooth local solution for smooth initial data, with nonnegativity preserved for the ion concentrations. We make use of semigroup ideas,

originally introduced by T. Kato in the 1970s for quasi-linear hyperbolic systems. The time interval is invariant under the inviscid limit.

High–frequency behavior of the focusing nonlinear Schrödinger equation with random inhomogeneities

Shi Jin
(joint work with G. Papanicolaou and A. Fannjiang)

We consider the effect of random inhomogeneities on the focusing singularity of the nonlinear Schrödinger equation in three dimensions, in the high–frequency limit. After giving a phase space formulation of the high–frequency limit using the Wigner distribution, we derive a nonlinear diffusion equation for the evolution of the wave energy density when random inhomogeneities are present. We show that this equation is linearly stable even in the case of a focusing nonlinearity provided that it is not too strong. The linear stability condition is related to the variance identity for the nonlinear Schrödinger equation in an unexpected way. We carry out extensive numerical computations to get a better understanding of the interaction between the focusing nonlinearity and the randomness.

Kinetic theory based numerical methods for the Navier-Stokes equation

Michael Junk
(joint work with Mapundi Banda and Axel Klar)

The relation between the Boltzmann equation and the Navier-Stokes equation is used to derive a new numerical method. First, the simple kinetic transport operator is discretized with a slope limiter approach. Then, the discretized kinetic equation gives rise to a discretization of the incompressible Navier-Stokes system by carrying out the usual diffusive limit. As a result, a new slope limiter for the nonlinear convective term is obtained. The slope limiter is tested in several examples.

Turbulence models for incompressible fluids derived from kinetic theory

Mohamed Lemou
(joint work with Pierre Degond)

Turbulence models for incompressible fluids are derived from kinetic theory. The kinetic model involves a relaxation time type collision operator which describes the relaxation of the probability distribution function (pdf) towards an isotropic pdf on a time scale τ. The dependence of τ upon the kinetic turbulent energy can be tuned in such a way that both the so called "viscous subrange" (dominated by molecular viscosity) and the "inertial range" (obeying the Kolmogorov law) can be described. Starting from this kinetic model and focusing on the "inertial range" regime, we derive turbulence models of $K - \epsilon$ type and compare the form an the properties of this model with the standard $K - \epsilon$ models for incompressible flows. Finally, macroscopic system of equations including the mean velocity, the turbulent energy, and an arbitrary higher order velocity-moment of the 'pdf', is derived by means of a minimisation entropy principle.

The Diffusion Velocity Method: a Deterministic Way of Moving the Nodes for Solving Diffusion Equations

Sylvie Mas–Gallic

We shall present some applications of the diffusion velocity method, which was intoduced several years ago but not widely used in the context of kinetic problems. This method is primarily based on an approximation of the equation to be solved (mainly a diffusion equation) by another equation (mainly a a convection equation) thanks to the introduction of a small parameter. The new equation introduced is chosen in such a way that a Langrangian method can be easily applied to solve it. We shall present some results in the framework of the porous medium equation, the heat equation, the 3D Navier–Stokes equations for an incompressible fluid, and various kinetic models.

Discrete Velocity Models of BGK–type Equations and Numerical Methods for the Fast Computation of Rarefied Flows

Luc Mieussens

We present a numerical resolution of the BGK equation based on a rigorous velocity discretisation coupled to an implicit scheme. This gives a fast method for computing steady flows. Despite its simplicity, the BGK model of the Boltzmann equation can give very good results in many cases, particularly in aerodynamics. Moreover, this approach can be generalized to other relaxation models e.g. the BGK–ES equation, the BGK equation in axisymmetric geometries or a BGK model of polyatomic gases. The main mathematical properties of our method are discussed and some important numerical results are presented.

The Chapman–Enskog solution of the Prigogine–Herman kinetic equation for Vehicular Traffic Flow: Theory and Applications

Paul Nelson

The equilibrium solution of the Prigogine–Herman kinetic equation is shown to comprise a one–parameter familiy below some critical density, but a two–parameter family above this critical density. The corresponding traffic stream model (analog to the equation of state) is discussed and compared to observational data for traffic flow. For subcritical densitites the corresponding zero–(Lighthill–Whitham), first–(diffusively corrected Lighthill–Whitham) and second–order Chapman–Enskog solutions are described. Acceleration waves are discussed for the zero– and first–order approximations, particularly in regard to the *synchronized flow* and *wide traffic jams* that have recently been reported observationally.

Kinetic Methods for Ginzburg–Landau Equations

Benoit Perthame

We consider a Ginzburg–Landau energy for two dimensional divergence free fields appearing, for instance, in the gradient theory of phase transition. We prove that, as the relaxation parameter vanishes, families of such fields with finite energy are compact in $L^p(\Omega)$. Our proof is based on a kinetic interpretation of the entropies which were introduced by Desimone, Kohn, Müller and Otto. The so–called *kinetic averaging lemmas* allow to generalize their compactness results. Also, the method yields a kinetic equation for the limit where the right hand side is an unknown *kinetic defect-bounded measure* from which we deduce some Sobolev regularity. This measure also satisfies some cancellation properties which

seem to indicate several level of singularities in the limit. The method also allows to characterize entirely the domains where zero energy solutions exist. These solutions are either constant or vortices.

Macroscopic Quantum Models and their Numerical Approximation

René Pinnau

During the last decade, macroscopic quantum models gained considerable attention due to their ability to simulate quantum dominated device behaviour at low computational costs. In this talk, we present two discretization schemes for the transient quantum drift diffusion model (QDD), which consists of a nonlinear fourth order parabolic system for the electron density and the electrostatic potential. The first relies on an exponential transformation of variables followed by a semidiscretization in time, while the second one introduces some nonlinear potential. Both methods are positivity preserving on the discrete level and prove to be convergent. Furthermore, we generalize the classical Scharfetter-Gummel discretization to the stationary QDD and present numerical simulations of the isothermal quantum hydrodynamic model, which exhibit a zero-bias anomaly in the current voltage characteristics.

Mixed Spectral-Difference methods for the Boltzmann Equation in Non-Equilibrium Regimes

Christian Ringhofer

The approximate solution of the Boltzmann transport equation via Galerkin-type series expansion methods leads to a system of first order differential equations in space and time for the expansion coefficients. In this paper we derive discretization methods for these equations which are based on the entropy principles of the underlying Boltzmann equation and discuss the performance of these discretizations and the series expansion approach in non - equilibrium regimes .

Fourier transform for the approximation of the Boltzmann collision integral

Sergej Rjasanow

The Galerkin-Petrov method for the approximation of the Boltzmann collision integral leads to the necessity to study its properties. We discuss the mapping properties of the nonlinear Boltzmann collision operator on a scale of weighted Bessel potential spaces. We prove the following boundedness property of the operator $Q_+(f)$

$$Q_+ \;:\; \left(\mathbb{H}_1^{\theta,\langle\nu+\lambda\rangle} \bigcap \mathbb{H}_p^{\theta}\right) \times \mathbb{H}^{s,\langle\nu+\lambda\rangle} \to \mathbb{H}^{s+1,\langle\nu\rangle}$$

under the following restrictions on the collision kernel

$$B(|u|,\mu) = |u|^{\lambda} g(\mu)\,,$$

$$0 \le \lambda \le 1\,, \quad p > \frac{3}{2+\lambda}\,, \quad \theta \ge 0\,, \quad |s| \le \theta\,,\ \nu\, s \ge 0$$

and $\nu \ge 0$ if $s = 0$. A similar result for the operator $Q_-(f)$ reads:

$$Q_- \;:\; \mathbb{H}_p^{s,\langle\nu\rangle} \times \mathbb{H}_q^{\theta,\langle\mu\rangle} \to \mathbb{H}_p^{s,\langle\nu-\lambda\rangle}$$

under the following restrictions

$$0 < |\lambda| + 3 - \frac{3}{q} < \mu\,, \quad 1 \le p,\ q \le \infty\,, \quad \theta \ge 0\,, \quad s \le \theta\,,\ \nu \in \mathbb{R}\,.$$

Convergence to equilibrium for a cometary flow model

Christian Schmeiser

(joint work with K. Fellner and F. Poupaud)

A nonlinear kinetic model for wave-particle collisions in cometary flows on a bounded domain subject to specular reflection boundary conditions is considered. Similarly to the work of Desvillettes (1990) for the Boltzmann equation, convergence to an equilibrium distribution for large times is proven. The set of equilibrium distributions is infinite dimensional. A special feature of the model is that all the corresponding collision invariants except 5 (mass, momentum, energy) depend on the mean velocity of the distribution function and, thus, do not produce macroscopic conservation laws. As a consequence, the correct equilibrium distribution corresponding to given initial data is not known at present. This is also the main reason why the extension of recent work by Desvillettes and Villani on the rate of convergence remains an open problem.

Bifurcation Studies of Flows of a Gas between Rotating Coaxial Circular Cylinders with Evaporation and Condensation on the Boltzmann System

Yoshio Sone

(joint work with Hiroshi Sugimoto and Masato Handa)

Bifurcation of flows of a gas between rotating coaxial circular cylinders made of the condensed phase of the gas, where evaporation or condensation takes place, is studied on the basis of the Boltzmann equation. First, the studies for the case where the flow field is axially symmetric and uniform are reviewed. Then, the stability and bifurcation of the solution when the restriction of axial uniformity is removed are studied by the direct-simulation Monte-Carlo method. Three types of solution occur: two axially uniform solutions and a roll-type solution are shown to exist stably. Finally, the difficulty of this method in studying stability and bifurcation problems is discussed and a false solution of oscillating behavior is presented.

Numerical methods for the Vlasov equation

Eric Sonnendrücker

In the Vlasov equation, the unknown $f(t, x, v)$, depending on the time t, the position x, and the velocity v, represents the distribution of particles in phase space for each species. Most of the time the numerical resolution of the Vlasov equation is performed by particle methods (PIC) which consist in approximating the distribution by a finite number of particles. The trajectories of these particles are computed from the characteristic curves given by the Vlasov equation, whereas self-consistent fields are computed on a mesh of the physical space. This method allows to obtain satisfying results with a small number of particles. However, the numerical noise inherent to the particle method becomes, in some cases, too important to have an accurate description of the distribution function in phase space. Moreover, the numerical noise only decreases in $1/\sqrt{N}$, when the number of particles N is increased. To remedy to this problem, methods discretizing the Vlasov equation on a mesh

of phase space have been proposed: The semi-lagrangian method, consisting in computing the distribution function at each grid point by following the characteristic curves. To compute the origin of the characteristic a high order interpolation method is needed. And also finite volume type methods based on the computation of the average of the Vlasov equation solution on each cell of phase space grid by a conservative method. Another option is to use spectral methods (Fourier-Fourier or Fourier- Hermite).

One of the flaws common to all Vlasov solvers is their smearing of small structures and the associated non physical increase of entropy. However, this feature is necessary for the stability of eulerian Vlasov solvers as a finite difference scheme based on a method introduced by Arakawa which conserves $\int f^2 dxdv$ numerically becomes unstable when filamentation phenomena occur

On fully discrete schemes for the Fermi pencil–beam equation

Alexandros Sopasakis

We consider a Fermi pencil–beam model in two space dimensions (x, y), where x is aligned with the penetration direction of the beam and y, together with the angular variable z, corresponds to a bounded, symmetric transversal cross section. We study some fully discrete numerical schemes using the standard Galerkin and streamline diffusion finite element methods for the discretization of the transversal domain combined with backward Euler, Crank–Nicolson and discontinuous Galerkin methods for the discretization in the penetration variable. We derive stability estimates for the semi–discrete problems and, assuming a sufficiently regular exact solution, we show optimal a priori error estimates. Numerical examples presented in some typical cases confirm the expected performance of the combined schemes.

Coupling kinetic equations and their hydrodynamic limits

Moulay Tidriri

In this paper, we give a survey of the mathematical theory of the coupling of kinetic equations and their hydrodynamic limits. A particular focus will be on the existence theory for a coupled system of kinetic equations and their hydrodynamic conservation laws limit. This mathematical theory is made possible by the introduction of various new methods.

Numerical Methods for Higher Order Diffusions

Giuseppe Toscani
(joint work with J.A. Carrillo)

In this talk, I illustrate recent results concerning the large–time behavior of strong solutions to the one–dimensional fourth order degenerate parabolic equation $u_t = -(uu_{xxx})_x$, modeling the evolution of the interface of a spreading droplet. For non-negative initial values $u_0(x) \in H^1(\mathbb{R})$, both compactly supported or of finite second moment, we proved explicit and universal algebraic decay in L^1–norm of the strong solution $u(x, t)$ towards the unique strong source-type solution of the equation with the same mass. The method is based on the study of the time decay of the entropy introduced by the same authors for the porous medium equation and uses analogies between the thin-film equation and the porous-medium equation.

Uniform Stability of a Finite Difference Scheme for Transport Equations in Diffusive Regimes

Andreas Unterreiter

An asymptotic preserving numerical scheme (with respect to diffusion scalings) for a linear transport equation is investigated. The scheme is adopted from a class of schemes developped by Jin, Pareschi, Toscani (1999) and Klar (1998). Stability is proved uniformly in the mean free path under a CFL–type condition turning into a parabolic CFL condition in the diffusion limit.

On the Convergence of Particle Methods for Relativistic Vlasov–Maxwell Systems

Harold Dean Victory

For Vlasov-Maxwell (VM) systems, particle methods are numerical techniques that simulate the behavior of a plasma by a large set of superparticles which obey Maxwell's equations. The trajectories of these charged particles are then followed. Estimates for the errors incurred for a semidiscrete approximation to the underlying Vlasov-Maxwell system are given by first superimposing a rectangular grid or mesh on all of phase space and then replacing the initial continuous distribution of charges by discrete charges located at the centroid of each grid cell. Our analysis for establishing convergence with rates uses the representation of the Lorentz fields in terms of tangential and convective derivatives along the backward light cone for the three dimensional d'Alembertian, obtained by R. Glassey and W. Strauss [Arch. Rational Mech. Anal., 92(1986), 56-90]. Such a representation for both the exact and approximate systems ties the Vlasov characteristics with the d'Alembertian characteristics. The global convergence rates for the approximate Hamiltonian trajectories and Lorentz fields are fundamentally due to the strict hyperbolicity of the approximate VM systems and are effected by exploiting the improved estimates, reflecting Huygens Principle, which occur when convolving with spherical means of the Friedrichs mollifier. The convergence theory of particle or simulation methods is also developed for lower-dimensional relativistic Vlasov-Maxwell systems. The controlling estimates make use of the improved representation of the Lorentz fields, obtained recently by R. Glassey and J. Schaeffer [Commun. Math. Phys., 185(1997), 257-284; Arch. Rational Mech. Anal., 141(1998), 331-374] by means of a clever Hadamard descent calculation which fundamentally displays the absence of Huygens Principle.

A new kinetic equation for dense gases

Wolfgang Wagner
(joint work with A.L. Garcia)

A theoretical foundation for the Consistent Boltzmann Algorithm is established by deriving the limiting kinetic equation. Besides its relation to the algorithm, this new equation serves as an alternative to the Enskog equation in the kinetic theory of dense gases. For a simplified model, the limiting equation is solved numerically, and very good agreement with the predictions of the theory is found.

Discretization of a dissipative Boltzmann equation

Bernt Wennberg
(joint work with A. Palczewski)

We modify discrete schemes developed for the usual Boltzmann equation, in particular the method of Heintz and Pankeson, which is very suitable for dissipative equations.

Edited by Guido Thömmes

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