I. INTRODUCTION

The conference took place in FaMAF, Córdoba, Argentina, during the week 6–10, November, 2006.

II. PROGRAM

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
9:00-10:00	**Registration**	Todd Oliynyk	Alan Rendall	Marcus Ansorg	Michel Grueneberg
10:00-10:30	Coffee				
10:30-11:30	Helmut Friedrich	Ricardo Troncoso	Sergio Dain	Burkhard Zink	Sascha Husa
11:40-12:20	Carlos Kozameh	Heinz Otto Kreiss	Reinaldo Gleiser	Florencia Parisi	Oscar Reula
12:30-14:00	Lunch				
14:00-14:40	Emanuel Gallo	Steven Willison	*enjoy*	Carlos Kozameh	Mark Hannam
14:45-15:25	Manuel Tiglio	Alex Giacomini	*your*	Mirta Iriondo	Anil Zenginoglu
15:30-16:00	Coffee				
16:00-16:40	Florian Beyer	Gustavo Dotti	*free*	Blaise Tchapnda	***Heinz Otto Kreiss***
16:45-17:25	M. Reisenberger	Julio Oliva	*afternoon*		***public lecture***

Participant Institutions

FaMAF: Facultad de Matemática Astronomía y Física, Universidad Nacional de Córdoba, Argentina.
CECS: Centro de Estudios Científicos, Chile
AEI: Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Germany
MPA: Max Planck Institute for Astrophysics, Germany
UJ: Institute of Theoretical Physics, Friedrich-Schiller University, Jena, Germany
LSU: Louisiana State University, USA
IAFE: Instituto de Astronomía y Física del Espacio, Argentina.
UNLP: Departamento de Física, Universidad Nacional de La Plata, Argentina.
UBA: Departamento de Física, Universidad Nacional de Buenos Aires, Argentina.
UR: Facultad de Ciencias, Universidad de la República, Uruguay.
KTH: Stockholm Royal Institute of Technology, Sweden.

Plenary talks (50' expositions + 10' questions)

MONDAY

1. **Helmut Friedrich, AEI: *Asymptotically flat space-times***
   We revisit some general existence results about asymptotically flat space-times. Considering then the main open question concerning the precise fall-off behaviour of asymptotically flat vacuum solutions at null infinity, we discuss results about the structure of the solutions near space-like infinity.

TUESDAY

2. **Todd Oliynyk , AEI: *Post-Newtonian expansions for perfect fluids***
   Post-Newtonian expansions are expansions of solutions to the Einstein field equations coupled to matter in a parameter v/c (near $v/c = 0$) where v is a characteristic velocity scale of the gravitating matter and c is the speed of light. This problem has been studied for many years by many people and there is an extremely large number of results available in the literature. However, the overwhelming majority of results are based on formal expansions in the parameter v/c which lack rigorous error estimates needed to ensure the validity of the expansions as an approximation. In this talk, I will describe recent rigorous results on post-Newtonian expansions for perfect fluids. I will discuss how energy estimates for symmetric hyperbolic PDEs can be used to analyze general relativistic solutions in the singular limit $v/c \to 0$ and also to derive error estimates for certain expansions in v/c near $v/c = 0$. Finally, I will discuss open problems and future research directions.

3. **Ricardo Troncoso, CECS: *Benchmarking higher dimensional theories of gravity***
   Theories of gravity constructed from the same basic principles as General Relativity are revisited in dimensions higher than four. They are characterized by the presence of terms with higher powers in the curvature appearing in the field equations, which nevertheless, are still of second order for the metric. Depending on the dimension as well as on the highest power of the curvature appearing in the action, the dynamics can be radically different from one theory to another. This fact is also reflected by the appearance of a different sort of sensible exact solutions in vacuum which cannot exist in General Relativity. Black holes and their thermodynamics can also be used to make a benchmark between different theories. Some interesting aspects of black holes, as the existence of solutions with nontrivial horizon geometries and with a slow asymptotic fall-off are also discussed. The benchmark indicates a very special class of theories possessing all of these new features. The supersymmetric extension of this class of theories can be performed, and an exact expression for the quasinormal modes of black holes can be found

WEDNESDAY

4. **Alan Rendall Alan, AEI: *Late-time oscillatory behaviour in cosmological spacetimes***
   One of the most frequently used matter models in the study of inflationary cosmological expansion is the linear massive scalar field. Although there is a picture of the dynamics of solutions of the Einstein equations coupled to this type of matter which has been around for twenty years there are few rigorous results available to confirm it. In this talk I will present this picture and describe which parts of it have been proved. In particular I will describe recent results on the late-time behaviour where oscillations play an important role. I will also describe cases where other models such as nonlinear scalar fields, k-essence and $f(R)$ gravity have similar late-time behaviour.

5. **Sergio Dain, FaMAF:** ***Angular momentum-mass inequality for axially symmetric black holes***
In this talk I will discuss the physical relevance of the inequality $\sqrt{J} \leq m$, where m and J are the total mass and angular momentum, for axially symmetric (non-stationary) black holes. In particular, I will prove that for vacuum, maximal, complete, asymptotically flat, axisymmetric initial data, this inequality is satisfied. The proof consists in showing that extreme Kerr is a global minimum of the mass. I will also comment on work in progress (in collaboration with Piotr Chrusciel) to generalize this inequality to include charge.

Thursday

6. **Marcus Ansorg, AEI:** ***Negative Komar masses in regular stationary spacetimes***
A highly accurate multi-domain spectral method is used to study axially symmetric and stationary spacetimes containing a black hole or disk of dust surrounded by a ring of matter. It is shown that the matter ring can affect the properties of the central object drastically. In particular, by virtue of the ring's frame dragging, the so-called Komar Mass of the black hole or disk can become negative. A continuous transition from such disks to such black holes can be found.

7. **Burkhard Zink, AEI:** ***Fragmentation and black hole formation in quasi-toroidal polytropes***
We investigate fragmentation instabilities and black hole formation in general relativistic, almost toroidal polytropes. From the set of models investigated in this study, many are unstable to non-axisymmetric perturbations, which lead to fission into one or several orbiting fragments. We discuss whether multiple orbiting black holes with a massive accretion disk can form by this fragmentation process.

Friday

8. **Michel Grueneberg, AEI:** ***Scalar Curvature, Mass and Black Holes: The Yamabe Problem as an Interaction between Geometry and General Relativity.***
The Yamabe Problem addresses the geometric question of constructing Riemannian metrics of constant scalar curvature. It was a deep discovery by Richard Schoen that this problem turns out to have an intimate connection with gravitational mass in Relativity, thus linking the fields of Geometry and General Relativity. We will discuss this connection and survey the recent activity on the Yamabe problem which has provided a much more thorough understanding of constant scalar curvature metrics both from a variational and heat equation point of view. Time permitting we provide further details how the latter point of view helps to precisely understand the role that gravitational mass plays in the problem.

9. **Sascha Husa, UJ:** ***Phase transitions in Numerical Relativity***
Recent months have seen a phase transition in the field of numerical relativity. After 30 years of struggle, the binary black hole problem appears solved: numerical simulations producing gravitational wave signals have become routine for several groups. This talk presents an overview of recent results obtained within the Jena group, and reviews the status of the field. I discuss the computational and mathematical basis of recent progress and highlights several open problems and questions, in particular concerning issues of potential interest to mathematical relativists.

Short talks (30' expositions + 10' questions)

MONDAY

1. **Carlos Kozameh, FaMAF:** ***Equations of Motion for Center of Mass in Type II Einstein Maxwell space-times***
using a recently developed approach we define the notion of center of mass for a class of sapce times known as, type II Einstein Maxwell The basic idea is that for each asymptotically flat vacuum solution there is a certain 'structure', a unique function on null infinity, that has been known in various contexts, but whose several unusual properties have largely been overlooked. This function, which we shall refer to as the Universal Cut Function (UCF), carries virtually all the asymptotic information, as well as much of the physical content of its associated solution. Using this function we are able to define the notion of center of mass on a holographic space and deduce its equations of motion.

2. **Emanuel Gallo, FaMAF:** ***Constructing a model for the two body problem in general relativity (with Osvaldo Moreschi)***
We present an approach to the two body problem in general relativity which makes use of the asymptotic structure and of a model for the dynamics of the interior of the spacetime.

3. **Manuel Tiglio, LSU:** ***A high order multiblock approach for solving hyperbolic equations on domains with non-trivial topologies and boundaries***
I will describe the main ingredients that allow us to solve symmetric hyperbolic equations on domains with non-trivial topologies and arbitrary boundaries with high accuracy. Schemes for arbitrary high order (we have explicitly constructed them up to tenth order) are derived by using discrete operators satisfying summation by parts and glueing the different subdomains through penalty terms. We additionally optimize the efficiency and accuracy of these operators by minimizing the boundary truncation error and maximizing their spectral radius (thus being able to take larger timesteps). I will present as an application accurate long term simulations of three-dimensional single distorted black holes with wave extraction, for which we use a first order reduction of an harmonic formulation of Einstein's equations with constraint damping, and new wave extraction techniques. If time allows, I might also discuss simulations studying quasinormal mode excitation amplitudes, interface with finite elements, some engineering-oriented projects, grid generation, and high performance computing issues like parallelization of our code, scalability, and speed.

4. **Florian Beyer, AEI:** ***A new code for simulating future asymptotically de-Sitter spacetimes with spherical topology***
To a large extent the global-in-time properties of cosmological solutions of Einstein's field equations are not understood. Recently, the fruitful interplay between rigorous analytical analysis and numerical simulations has shed some light on the properties of spacetimes with certain symmetries. Eventually, this has lead to proofs of fundamental conjectures like strong cosmic censorship and the so-called BKL-picture within special classes of spacetimes. However, the analysis is far from being complete both analytically and numerically even in cases with symmetry. From the numerical point of view reasons for this are that singular spacetimes are difficult to handle in general; moreover, the implementation of non-trivial topologies is subtle. In this talk, I will present a new code for simulating future asymptotically de-Sitter spacetimes with spherical topology. After having briefly introduced the general background I will discuss the current status of the code and its potential for future applications.

5. **M Reisenberger, UR:** ***Canonical General Relativity with free characteristic initial data***
Free initial data (not subject to constraints) for general relativity are known for Cauchy surfaces consisting of two intersecting null hypersurfaces. These provide independent coordinates on the phase

space of solutions in the domain of dependence of the Cauchy surface. The talk will be concerned with the Poisson bracket on this phase space, and in particular between the free initial data. The physical Poisson bracket can be defined easily on a class of sufficiently regular phase space functions (called "observables"). These brackets then define almost uniquely a pre-Poisson bracket (Poisson except that it doesn't satisfy the Jacobi relations) on the free data. The results presented may be of relevance to the quantization of general relativity and to a first principles understanding of the Beckenstein-Bousso bound and the holographic principle.

Tuesday

6. **Heinz Otto Kreiss, KTH:** ***Problems which are well-posed in a generalized sense with applications to the Einstein equations, (with Jeffrey Winicour)***
In the harmonic description of general relativity, the principle part of Einstein equations reduces to a constrained system of 10 curved space wave equations for the components of the space-time metric. We use the pseudo-differential theory of systems which are well-posed in the generalized sense to establish the well-posedness of constraint preserving boundary conditions for this system when treated in second order differential form. The boundary conditions are of a generalized Sommerfeld type that is benevolent for numerical calculation.

7. **Steven Willison, CECS:** ***Thin shells in Lovelock Gravity***
We study thin shells or membranes in classical lovelock Gravity, with special attention on the five dimensional theory. It is possible to have membrane-like solutions without a stress-tensor as a source but which in some ways mimic the behaviour of matter. Also collisions and intersections of membranes are shown to obey certain additional selection rules not found in Einsteins theory.

8. **Alex Giacomini, CECS:** ***Junction conditions in general relativity with spin sources***
The junction conditions for general relativity in the presence of domain walls with intrinsic spin are derived in three and higher dimensions. It will be shown that, in general, when torsion is localized on the domain wall it is necessary to relax the continuity of the tangential components of the vielbein. In fact it is found that the spin current is proportional to the jump in the vielbein and the stress tensor is proportional to the jump in the spin connection. The consistency of the junction consitions implies a constraint between the direction of the flow of energy and the orientation of spin.

9. **Gustavo Dotti, FaMAF:** ***Warped static spacetimes in Einstein-Gauss-Bonnet gravity (with Julio Oliva and Ricardo Troncoso).***
Satic solutions of the EGB vacuum equations in arbitrary dimensions are found for warped product spacetimes $ds^2 = -f(r)dt^2 + g(r)dr^2 + r^2 d\bar{s}^2$, $d\bar{s}^2$ the line element of an arbitrary "base manifold". Interesting particular cases arise in low dimensions and/or for non Einstein base manifolds.

10. **Julio Oliva, CECS:** ***Static wormholes of vacuum in higher dimensional gravity and their stability against scalar field perturbations.***
A static wormhole solution for gravity in vacuum is found for odd dimensions greater than four. In five dimensions the gravitational theory considered is described by the Einstein-Gauss-Bonnet action where the coupling of the quadratic term is fixed in terms of the cosmological constant. In higher dimensions $d = 2n + 1$, the theory corresponds to a particular case of the Lovelock action containing higher powers of the curvature, so that in general, it can be written as a Chern-Simons form for the AdS group. The wormhole connects two asymptotically locally AdS spacetimes each with a geometry at the boundary locally given by $\mathbb{R} \times S^1 \times H_{d-3}$. The causal structure shows that both asymptotic regions are connected by light signals in a finite time. The Euclidean continuation of the wormhole is smooth independently of the Euclidean time period, and it can be seen as instanton with vanishing Euclidean action. The mass

can also be obtained from a surface integral and it is shown to vanish. Some results on the stability against scalar field perturbations are presented.

Wednesday

11. **Reinaldo Gleiser, FaMAF:** ***Instability of charged and rotating naked singularities (with Gustavo Dotti and Jorge Pullin)***
We discuss evidence that "super-extremal" black hole space-times (either with charge larger than mass or angular momentum larger than mass), which contain naked singularities, are unstable under linearized perturbations. This evidence is provided by an infinite family of exact unstable solutions in the charged non rotating case, and by a set of (unstable) numerical solutions in the rotating case. These results may be relevant to the expectation that these space-times cannot be the endpoint of physical gravitational collapse.

Thursday

12. **Florencia Parisi, FaMAF:** ***Lorentz Invariance and backreaction effects in the semiclassical approximation of LQG.***
We study the electromagnetic field equations on an arbitrary quantum curved background in the semiclassical approximation of Loop Quantum Gravity. We obtain the effective interaction Hamiltonian for the Maxwell and gravitational fields and derive the corresponding field equations, which can be expressed as a modified wave equation for the Maxwell potential. We then analyze the case where backreaction effects on the geometry are taken into account and obtain propagation equations for the electromagnetic waves that are Lorentz Invariant.

13. **Carlos Kozameh, FaMAF:** ***On the stability of the Robinson Trautman Maxwell solutions***
We write down the RTM equations on an asymptotically flat space time and show that the linearized perturbation equations around the Reissner Nordstrom solution yield diverging solutions for future and past evolutions. Using the available theorems on PDF we conclude that the RTM equations are not well possed. Furthermore, since the RTM can be considered a perturbation of the RT equations we obtain as a corollary that the RT solutions are also unstable.

14. **Mirta Iriondo, FaMAF:** ***Cartan's normal connection in General Relativity***
Using Cartan's equivalence method for point transformation we obtain the conformal geometry associated with a special class of PDEs in two dimensions, and construct explicitly a so-called normal metric connection. The torsion of this connection depends on one relative invariant, the generalized Wnschmann invariant. This construction contains naturally the null surface formulation of general relativity.

15. **Sophonie Blaise Tchapnda, AEI:** ***On future completness for the surface-symmetric Einstein-Vlasov-Maxwell system.***
In the study of global dynamical properties of cosmological solutions of the Einstein equations, there are situations where it is expected that the evolution will be singularity-free in the future. Geometrically this is formulated in terms of the so-called future geodesic completeness. In this talk I will present a result related to this concept for the surface-symmetric Einstein-Vlasov-Maxwell system.

Friday

16. **Oscar Reula, FaMAF:** ***Einstein's equations as a constrained Yang Mills system: The subsidiary system***

Einstein's equations can be written as a constrained Yang Mills system whose curvature is associated with the standard frame bundle. This system is a constrained symmetric hyperbolic one and so it admits a well possed initial value problem. In this note we show that for this problem the constraints which renders it equivalent to Einstein's equations also propagate via symmetric hyperbolic equations, so that if they are initially satisfied they vanish in the whole domain of dependence.

17. **Mark Hannam, ITP:** ***New insights into puncture initial data and evolutions***
Recent breakthroughs in numerical relativity have motivated greater interest in understanding black-hole punctures. I will discuss two new results: (1) A Schwarzschild puncture, during evolution, loses contact with its second asymptotically flat end, and the final stationary slice ends at finite areal radius. In addition, it is possible to construct initial data that represent this stationary solution. (2) For spinning black holes, one can replace Bowen-York punctures with "Kerr punctures", for which the initial data can be demonstrated to contain less "junk" gravitational radiation.

18. **Anil Zenginoglu, AEI:** ***Numerical studies near spatial infinity***
Friedrich's work showed that the question of sufficient and necessary conditions for smoothness of null infinity is decided near spatial infinity. Numerical calculations might help to form expectations on this question. As a feasibility study, I will present 3D numerical calculations of an axially symmetric spacetime with non-vanishing radiation field in a neighbourhood of spatial infinity based on Friedrich's general conformal field equations and will point out some difficulties with this approach.

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