NITheCS Workshop on Gravitational Waves, 22 January 2026
Town Lodge, Port Elizabeth

8:15 Welcome

8:20 Nigel Bishop and Denis Pollney: GW detectors review: current and planned ground, space and pulsar timing

8:45 Denis Pollney

9:25 Nigel Bishop

10:05 Melusi Khumalo

10:45 Tea / Coffee

11:15 Peet van der Walt (online)

11:55 Ulrich Beckering Vinckers

12:35 Monos Naidoo

13:15 Lunch

14:15 Vishnu Kakkat (online)

14:55 Bishop Mongwane

15:35 Amos Kubeka

16:15 Tea / Coffee

16:45 Anslyn John

17:25 Riyaadh Jamodien

17:45 End

Zoom link, morning session: https://zoom.us/j/91381694773
Zoom link, afternoon session: https://zoom.us/j/96097984628

Abstracts

Ulrich Beckering Vinckers (RU)

Black-hole initial data in the Einstein-Maxwell-Dilaton theory and prospects for numerical evolution

The Einstein-Maxwell-Dilaton (EMD) theory is a modification of General Relativity involving a scalar dilaton field that is non-minimally coupled to the electromagnetic field. In the context of this theory, we consider initial data solutions that are obtained at the moment of time-symmetry, and correspond to multiple black-holes. The notion of self-interaction energy is considered, and we discuss its relationship to the presence of primary scalar hair. We conclude by discussing the numerical evolution of Schwarzschild initial data and how similar techniques could potentially be applied to evolve EMD black-hole initial data which have non-zero self-interaction energy.

Nigel Bishop (RU)

Gravitational waves linearized about a spherically symmetric background

The theory of linearized perturbations in the Bondi-Sachs formalism is reviewed. The simplest case is when the background is Minkowskian and everything reduces to elementary functions. The perturbations on a de Sitter background remain elementary functions, albeit rather more complicated. However for a Schwarzschild background, and all other known cases, the problem has to be solved numerically in a non-standard way. Computer code to do so has been developed and tested.

Riyaadh Jamodien (US)

Relativistic Wave Equations for the Photon and Graviton

Maxwell's equations may be rewritten in the form of a spin-1 relativistic wave equation akin to the Dirac equation. We introduce the generalised, covariant form hereof, expand on its relation to the geometric phase, then elaborate on how this procedure may be applicable and adapted to deriving a spin-2 relativistic wave equation from the gravitational analogue of Maxwell's equations in the form of the Weyl tensor Bianchi identities.

Anslyn John (US)

Transformation Optics and Gravitational Waves

Maxwell's equations in a curved vacuum spacetime can be recast in an equivalent form describing electromagnetic fields in a flat, non-empty spacetime. Transformation optics exploits this equivalence when designing meta-materials such as cloaking devices. Curved spacetime may be viewed as a dielectric medium with an effective permittivity and permeability that are metric-dependent. We will expand and utilize this formalism to investigate how electromagnetic waves propagate in the presence of gravitational waves.

Vishnu Kakkat (Unisa)

Interaction of Gravitational Waves with Matter

The interaction of gravitational waves (GWs) passing through matter is normally treated as being very weak. In a series of papers, we have re-investigated this issue using linearized perturbations within the Bondi–Sachs formalism. As expected, the effect is very weak when the matter is far from the GW source; however, close to the source, the interaction can be very significant. We consider a GW source surrounded by a spherical shell of matter. It is shown that the shell modifies the GWs both in magnitude and phase, and that if the shell is viscous, the induced shear in the velocity field leads to an energy transfer, damping the GW amplitude. This presentation focuses on the effect of GW damping on the matter shell, namely the heating of the matter, and applies this to astrophysical scenarios.

Melusi Khumalo (Unisa)
A Mathematical Research Programme on Gravitational Waves Advanced Numerical, Dynamical, and Fractional Models for Einstein Systems
Gravitational-wave observations have opened an unprecedented window into the strong-field regime of General Relativity, placing significant demands on the mathematical and numerical frameworks used to model relativistic systems. This project proposes a mathematically driven research programme focused on the development, analysis, and application of advanced numerical, dynamical, and fractional methods for gravitational-wave modelling. The research treats the Einstein field equations as nonlinear evolutionary systems and investigates their numerical stability, bifurcation structure, and long-time dynamics under high-order discretization schemes.
The programme will develop structure-preserving spectral, compact finite difference, and implicit time-integration methods for Einstein evolution equations, with particular emphasis on waveform fidelity and robustness. A novel component of the project introduces fractional and nonlocal operators to model memory effects, long-range correlations, and perturbative dynamics in relativistic wave propagation. These approaches will be applied to the computation of quasi-normal modes and the analysis of inspiral–merger–ringdown phases of compact-object systems.
The project integrates rigorous mathematical analysis with computational experimentation and will deliver new numerical schemes, theoretical insights into relativistic dynamics, and open-source prototype solvers. It will also support postgraduate training and capacity building in mathematical gravitational-wave science, positioning the research group as a leading contributor to gravitational-wave modelling from a pure and applied mathematics perspective.

Amos Kubeka (Unisa)
The very early universe and GWs
We are currently doing some research with on the physics of the very early cosmology that is now leading us to astroparticle physics to investigate the well known shortcomings of the standard model in context of early cosmology within the irreversible thermodynamics framework.
For future work, once this work is done then we will be able to look at early epoch galaxy and GWs simulations including GWs.
So we are yet fully understanding the implication of our results in relation to very early GWs physics from irreversible cosmological thermodynamics in the context a white hole framework

Bishop Mongwane (UCT)
Quasi-normal and Quasi-resonant modes in metric f(R) gravity
Short abstract: The talk will focus on the computation of tensor and (massive) scalar quasi-normal modes in metric f(R) gravity. This is done within the characteristic formulation of numerical relativity, where the master equations are treated both in the frequency domain and time domain. The master equations take a convenient form, resulting in one evolution equation and one hypersurface equation. As a byproduct of this, we explore whether stiff solvers (implemented cheaply within the characteristic framework) may help address stiffness that is typical with modified gravity theories, e.g. from stiff source terms. Lastly, we explore the associated late-time tails and why the characteristic formulation is best suited to compute these.

Monos Naidoo (RU)
Core-collapse supernovae
Core-collapse supernovae (CCSNe) represent one of the most violent astrophysical processes in the universe. As the iron core of a massive star exceeds the Chandrasekhar mass ($\sim 1.4\ M_{Sun}$), electron degeneracy pressure fails, triggering gravitational collapse. The collapse halts when nuclear densities ($\rho \sim 2 - 3 \times 10^{17}$ kg m^{-3}) are reached, leading to the formation of a proto-neutron star

(PNS) and an outgoing shock wave. The post-bounce hydrodynamics and anisotropic mass motions produce gravitational waves expected to be detectable by current observatories. For now, all detection of supernovae have been confined to electromagnetic detection. The GW signal from a supernova event would be different (but not altogether so) from the characteristic signal of a BBH merger or BNS merger, Photons originate at the outer edge of a star and hence provide only limited information on the interior regions. The detection of GWs which are the result of the aspherical motion of the inner regions will provide a wealth of information on these regions and the mechanism leading to the supernova explosion, where all the four fundamental forces of nature are involved. The PNS consists of a dense core surrounded by a less dense, hot mantle (or thin shell). Using a thin shell analysis, the effects of the outer core on GWs produced in the inner core are considered and we discuss the implications for GW detection from CCSNe.

Denis Pollney (RU)
Gravity at Scri
We are working on tools and methods for evaluating the transfer of gravitational information from an isolated source out to scri+, including gravitational waves and other curvature-associated quantities. Among the topics we've been looking at:
- Modifications of the Bondi formulation for well-posed numerical integration
- Evaluating "new" observables at scri+, including the Newman-Penrose constants.
- Adapting numerical methods to alternate gravitational theories, such as Starobinksy gravity

Peet van der Walt (RU)
Primordial gravitational waves : A cursory introduction
Primordial gravitational waves (PGWs) are GWs that were emitted during the very early epochs of the Universe. The nature of these waves are fundamentally different to those emitted from discrete sources for two main reasons. First, they are fundamentally stochastic and second, theoretical properties of the Universe at the time of emission are still rather speculative. In this talk, a brief overview of PGWs are given from the point of view of providing a stepping stone for researchers that are well versed in studying GWs propagating from discrete sources.