CIERA

CENTER FOR INTERDISCIPLINARY EXPLORATION AND RESEARCH IN ASTROPHYSICS

2015 Midwest Relativity Meeting

Thursday, October 1 — Afternoon

Welcoming Remarks 1:00 p.m. – 1:10 p.m.
Vicky Kalogera, Center for Interdisciplinary Exploration and Research in Astrophysics

Special General Relativity Invited Talks 1:10 p.m. – 5:10 p.m.
Chair: Vicky Kalogera

1:10 2:00 Stu Shapiro, University of Illinois
Compact Binary Mergers as Multimessenger Sources of Gravitational Waves

2:00 2:50 Lydia Bieri, University of Michigan
Mathematical Relativity

Chair: Shane Larson

3:30 4:20 Eva Silverstein, Stanford University
Quantum gravity in the early universe and at horizons

4:20 5:10 Rainer Weiss, MIT
A brief history of gravitational waves: theoretical insight to measurement

Public lecture 7:30 p.m. – 9:00 p.m.
7:30 9:00 John D. Norton, University of Pittsburgh
Einstein's Discovery of the General Theory of Relativity

Friday, October 2 — Morning, Session One

Gravitational Wave Sources 9:00 a.m. – 10:30 a.m.
Chair: Vicky Kalogera

9:00 9:12 Carl Rodriguez*, Northwestern University
Binary Black Hole Mergers from Globular Clusters: Implications for Advanced LIGO

9:12 9:24 Thomas Osburn*, UNC Chapel Hill
Computing extreme mass ratio inspirals at high accuracy and large eccentricity using a hybrid method

9:24 9:36 Eliu Huerta, NCSA, University of Illinois at Urbana-Champaign
Detection of eccentric supermassive black hole binaries with pulsar timing arrays: Signal-to-noise ratio calculations

9:36 9:48 Katelyn Breivik*, Northwestern University
Exploring galactic binary population variance with population synthesis

9:48 10:00 Eric Poisson, University of Guelph
Fluid resonances and self-force

10:00 10:12 John Poirier, University of Notre Dame
Gravitomagnetic acceleration of accretion disk matter to polar jets John Poirier and Grant Mathews

10:12 10:24 Philippe Landry*, University of Guelph
Tidal Deformation of a Slowly Rotating Material Body

Friday, October 2 — Morning, Session Two

Gravitational Wave/Electromagnetic Detections

11:00 a.m. – 12:30 p.m.
Chair: Daniel Holz

11:00 11:12 Luis Lehner, Perimeter Institute
Electromagnetic counterparts from non-vacuum gravitational binaries
11:12 11:24 Hsin-Yu Chen*, University of Chicago
Optimizing gravitational wave sources followup strategies

11:24 11:36 Huan Yang, Perimeter Institute for Theoretical Physics
Plasma wave generation in a dynamic spacetime

11:36 11:48 Archisman Ghosh, ICTS-TIFR
Prospects of estimating cosmological parameters from gravitational-wave observations of coalescing binary black holes

11:48 12:00 Zoheyr Doctor*, University of Chicago
Search for Kilonovae in DES Supernova Fields

12:00 12:12 Nestor Ortiz, Perimeter Institute for Theoretical Physics
The shadow of a naked singularity.

12:12 12:24 Milton Ruiz, UIUC
Relativistic simulations of black hole-neutron star coalescence: the jet emerges

Friday, October 2 — Afternoon, Session One

Numerical Relativity/Mathematical Relativity-Gravity

2:00 p.m. – 3:30 p.m.
Chair: Luis Lehner

2:00 2:12 John Ryan Westernacher-Schneider*, University of Guelph
Forced Turbulence in Relativistic Fluids

2:12 2:24 David Garfinkle, Oakland University
Universal spike behavior in spacetime singularities

2:24 2:36 Carlos Lousto, Rochester Institute of Technology
Spin flips in generic black hole binaries

2:36 2:48 Stephen Green, Perimeter Institute for Theoretical Physics
Islands of stability and recurrence times in AdS

2:48 3:00 Eric Van Oeveren*, University of Wisconsin-Milwaukee
Accelerated Scalar Self-Force on a Schwarzschild Background

3:00 3:12 Alexander Tolish*, The University of Chicago
Preliminary Work Regarding Gravitational Wave Memory In An Expanding Universe

3:12 3:24 Marco Hernandez*, Indiana University
Gravitational field equations and long range repulsive effect

***Student**

Friday, October 2 — Afternoon, Session Two

Mathematical Relativity- Mathematical Methods

4:00 p.m. – 5:30 p.m.
Chair: Robert Wald

4:00 4:12 Jim Wheeler, Utah State University
Time in conformal general relativity

4:12 4:24 Jeffrey Hazboun, Hendrix College
A Cartan geometry approach to the AdS/CFT correspondence

4:24 4:36 Benjamin Lovelady*, Utah State University
Dynamical internal symmetry: a Yang-Mills field on biconformal space

4:36 4:48 Tevian Dray, Oregon State University
The Geometry of Relativity

4:48 5:00 Morgan Lynch*, University of Wisconsin-Milwaukee
Aspects of accelerated quantum dynamics

5:00 5:12 Weishun Zhong*, University of Michigan-Ann Arbor
Holographic c-Theorem in Schrodinger Spacetime

5:12 5:24 Mohammad Akbar, University of Texas at Dallas
Lie point symmetries of static axisymmetric vacuum Einstein equations

Saturday, October 3 — Morning, Session One

Mathematical Relativity-Gravity

8:30 a.m. – 10:30 a.m.
Chair: David Garfinkle

8:30 8:42 Richard Kriske, University of Minnesota
Revisiting the Horizon

8:42 8:54 Vic Dannon, Gauge Institute
The Sun's Orbit Radius and Period

8:54 9:06 Greg Proper, Proper Eng.
An Alternative to the Robertson-Walker Metric and the Accelerated Expansion of Space-Time

9:06 9:18 Paul O’Brien
Black Hole Enthalpy and the Bekenstein Bound

9:18 9:30 Kartik Prabhu*, University of Chicago
First law and entropy for charged fields

9:30 9:42 Sam Gralla, University of Arizona
Physics near Rapidly Spinning Black Holes

9:42 9:54 Soichiro Isoyama, University of Guelph
Hamiltonian Dynamics of Self-Forced Motion in Kerr Spacetime: Inspiral-Dynamics

9:54 10:06 Robert Wald, University of Chicago
Instability of AdS Black Holes with Ergoregions

10:06 10:18 Shouhong Wang, Indiana University
A new blackhole theorem and its applications to cosmology and astrophysics

10:18 10:30 Shuang-Yong Zhou, Case Western
The strong coupling scale of massive gravity

***Student**

Saturday, October 3 — Morning, Session Two

Gravitational Wave Experiments & Alternative Tests

11:00 a.m. – 12:30 p.m.
Chair: Patrick Brady

11:00 11:12 Frank Barrett*, Grand Valley State University
Spurious Noise Acceleration of LISA Spacecraft Due to Solar Wind

11:12 11:24 Brandon Piotrzkowski*, Grand Valley State University
Spurious Acceleration Noise on the LISA Configuration Due to Solar Irradiance

11:24 11:36 Brittany Kamai*, Vanderbilt University
The Fermilab Holometer as a gravitational wave antenna

11:36 11:48 Michael Zevin*, Northwestern University
LIGO Glitch Classification using Machine Learning Algorithms

11:48 12:00 Peter Zimmerman, University of Arizona
Gravitational self-force in scalar-tensor theories

12:00 12:12 Rui Xu*, Indiana University, Bloomington
Searching for Lorentz violation using gravitational effective field theory

12:12 12:24 Jonah Miller*, Perimeter Institute for Theoretical Physics
Testing Gravitational Aether Theory Through the Astrophysics of Compact Objects

Saturday, October 3 — Afternoon

Blue-Apple Award

2:00 p.m. – 2:10 p.m.

Alternative Tests, Gravitational Wave Data, Mathematical Relativity-Mathematical Methods

2:00 p.m. – 3:45 p.m.
Chair: Shane Larson

2:10 2:22 Raissa Mendes, University of Guelph
Possibility of setting a new constraint to scalar-tensor theories

2:22 2:34 Tigran Kalaydzhyan, UIC
Testing gravity on accelerators

2:34 2:46 Chris Pankow, Northwestern University
A Rapid Bayesian Parameter Estimation Scheme for Binary Neutron Stars in the Advanced LIGO Era

2:46 2:58 Laura Sampson, Northwestern University
Astrophysical Inference with Pulsar Timing Arrays

2:58 3:10 Scotty Coughlin, Northwestern University
Distinguishing Neutron Stars from Black Holes with LIGO/Virgo

3:10 3:22 Roberto Salgado, UWisconsin-La Crosse
Relativity on Rotated Graph Paper: Lorentz-Invariant Calculations with Causal Diamonds

3:22 3:34 George Hrabovsky, Madison Area Science and Technolgy (MAST)
Solving the Field Equations of General Relativity in Mathematica

***Student**

Thursday, October 1 — Afternoon

Special General Relativity Invited Talks 1:10 p.m. – 5:10 p.m.

1:10 2:00 Stu Shapiro, University of Illinois

Compact Binary Mergers as Multimessenger Sources of Gravitational Waves

On the centennial anniversary of Einstein's theory of general relativity, we are on the verge of directly detecting one of its most remarkable predictions -- gravitational waves (GWs). The inspiral and merger of compact binaries -- binaries with black hole, neutron star or white dwarf companions -- are among the most promising sources of GWs. Many of these sources are likely to generate observable electromagnetic (EM) counterparts to the GWs, constituting a major advance in multimessenger astronomy. By way of illustration, we describe recent magnetohydrodynamic simulations in general relativity (GRMHD) that show how black hole-neutron star mergers can launch jets, lending support to the idea that such mergers could be the engines that power short-hard gamma-ray bursts. We also discuss other recent GRMHD simulations that show how an inspiraling, supermassive binary black hole in a galaxy core stirs and accretes magnetized plasma that orbits the holes in a circumbinary disk. This process can generate ``precursor'' and ``aftermath'' EM radiation with respect to the peak GW emission at merger. Computer-generated movies highlighting some of these simulations will be shown.

2:00 2:50 Lydia Bieri, University of Michigan

Mathematical Relativity

In this talk, I will highlight some of the milestones in mathematical general relativity (GR), including but not restricted to the following topics. Mathematical GR describes and solves physical problems by various mathematical means. Even though Einstein's theory of general relativity generated big successes in the early years such as the 1919 expedition that confirmed the bending of light, the mathematical challenges yet had to be overcome. Mathematicians worked towards a formulation of the initial value problem in GR. It wasn't until the 1950s and 1960s, with the works by Yvonne Choquet-Bruhat and Robert Geroch, that the Cauchy problem in GR was rigorously formulated. Based on these results, mathematical GR took off to solve burning problems. Among the most spectacular solutions we find the global nonlinear stability of Minkowski spacetime in the 1990s, the result that black holes form through the concentration of gravitational radiation 2008, the positive mass theorem 1979 and 1981 as well as the incompleteness (singularity) theorems. A highly active branch of research in mathematical GR has been working towards a broad understanding of gravitational energy and radiation in physically important systems. On the verge of detection of gravitational waves, experiments, numerical relativity and mathematical relativity have been in fruitful interaction. A still open question and a hot topic of research in mathematical GR is the stability of the Kerr solution. We will follow the road of mathematical GR from its beginnings in 1915 until today.

3:30 4:20 Eva Silverstein, Stanford University

Quantum gravity in the early universe and at horizons

After a brief survey of current work in the string-theoretic approach to quantum gravity, I will explain its role in two timely applications: (1) Cosmic microwave background and other cosmological measurements are sensitive to quantum gravity effects within the context of early universe inflation, and (2) the leading cause of beyond-GR physics at black hole horizons may be intrinsic non-localities arising concretely in string theory.

4:20 5:10 Rainer Weiss, MIT

A brief history of gravitational waves: theoretical insight to measurement

The talk will describe the evolution of ideas about gravitational waves from the original Einstein papers in 1916 and 1918 through the various epochs of confusion, doubt and skepticism to our time where a considerable effort has been made to detect them. The astrophysical discoveries and technological advances made in the past century are responsible for the transition from a mathematical notion to a new field of physics and astronomy.

Thursday, October 1 — Evening

Public lecture — 7:30 p.m. – 9:00 p.m.

7:30 9:00 John D. Norton, University of Pittsburgh

Einstein's Discovery of the General Theory of Relativity

It took Albert Einstein eight years, from 1907 to 1915, to complete his general theory of relativity. His work in these years was driven by ingenious thought experiments, forays into new mathematics, tedious calculations, painful missteps, dogged persistence and moments of great exhilaration. This talk will review some of the highlights of Einstein's achievement and take a peek into his research notes, written at the crucial moment.

Friday, October 2 — Morning, Session One

Gravitational Wave Sources — 9:00 a.m. – 10:30 a.m.

9:00 9:12 Carl Rodriguez*, Northwestern University

Binary Black Hole Mergers from Globular Clusters: Implications for Advanced LIGO

The predicted rate of binary black hole mergers from galactic fields can vary over several orders of magnitude and is extremely sensitive to the assumptions of stellar evolution. But in dense stellar environments such as globular clusters, binary black holes form by well-understood gravitational interactions. In this letter, we study the formation of black hole binaries in an extensive collection of realistic globular cluster models. By comparing these models to observed Milky Way and extragalactic globular clusters, we find that the mergers of dynamically-formed binaries could be detected at a rate of ~100 per year, potentially dominating the binary black hole merger rate. We also find that a majority of cluster-formed binaries are more massive than their field-formed counterparts, suggesting that Advanced LIGO could identify certain binaries as originating from dense stellar environments.

9:12 9:24 Thomas Osburn*, UNC Chapel Hill

Computing extreme mass ratio inspirals at high accuracy and large eccentricity using a hybrid method

We use the gravitational self-force in Lorenz gauge to drive the evolution of small mass-ratio ($m/M<<1$) binary systems. Computing the self-force at high accuracy is challenging when the eccentricity is large ($e\sim=0.8$). To improve the accuracy we utilize a hybrid method where the adiabatic part of the self-force is calculated using high accuracy flux data, while the oscillatory, post-1-adiabatic correction is provided from Lorenz gauge self-force data. We demonstrate that, ignoring averaged second-order effects, we can compute the accumulated orbital phase to within ~0.1 radians. This is sufficient for determination of source parameters from eLISA data. We also give intermediate mass-ratio results of possible relevance to LIGO observations.

9:24 9:36 Eliu Huerta, NCSA, University of Illinois at Urbana-Champaign

Detection of eccentric supermassive black hole binaries with pulsar timing arrays: Signal-to-noise ratio calculations

We present a detailed analysis of the expected signal-to-noise ratios of supermassive black hole binaries on eccentric orbits observed by pulsar timing arrays. We derive several analytical relations that extend the results of Peters and Mathews [Phys. Rev. D 131, 435 (1963)] to quantify the impact of eccentricity in the detection of single resolvable binaries in the pulsar timing array band. Building upon the work of Phinney (arXiv:astro-ph/0108028) and Enoki and Nagashima [Prog. Theor. Phys. 117, 241 (2007)], we present a model-independent analytical framework that enables the construction of rapid spectra for a stochastic gravitational-wave background generated by a cosmological population of eccentric sources.

9:36 9:48 Katelyn Breivik*, Northwestern University

Exploring galactic binary population variance with population synthesis

In the years preceding eLISA, Milky Way compact binary population simulations can be used to inform the science capabilities of the mission. Galactic population simulation efforts generally focus on high fidelity models that require extensive computational power to produce a single simulated population. Each simulated population represents an incomplete sample of the functions governing compact binary evolution, thus introducing variance from one simulation to another. We present a rapid Monte Carlo population simulation technique that can simulate hundreds of populations in less than a week, thus allowing a full exploration of possible Milky Way compact binary populations.

9:48 10:00 Eric Poisson, University of Guelph

Fluid resonances and self-force

The gravitational self-force acting on a small particle moving around a massive body has so far been formulated and evaluated in vacuum spacetimes. This is perfectly adequate for the study of motion around black holes, but it is of interest to also formulate and evaluate the self-force when the central body is a material body instead of a blackhole. We do this in this work, and explore the consequences of the fluidynamics on the self-force. In particular, we observe that the particle can excite a number of fluid quasinormal modes as it inspirals toward the central body, and that these produce sharp resonant features in both the conservative and dissipative pieces of the self-force. We exhibit these features in a simple Newtonian model in which the self-force is the result of a tidal interaction with the central body, and in a special-relativistic generalization of Newtonian gravity, which captures some of the general-relativistic aspects of the problem. Our results motivate a fuller investigation of the fluid resonances in general relativity. This work was carried out with Raissa Mendes and Soichiro Isoyama.

10:00 10:12 John Poirier, University of Notre Dame

Gravitomagnetic acceleration of accretion disk matter to polar jets John Poirier and Grant Mathews

The motion of the neutral masses of an accretion disk around a black hole creates a gravitomagnetic (GEM) field which accelerates nearby neutral masses [with rotational velocities similar to the accretion disk but located slightly above (or below) the disk], vertically away from the disk and then inward toward the axis. As the accelerated material nears the axis with near vertical angles, a frame-dragging effect twists the trajectories around the axis. These two effects contribute to the formation of narrow polar jets emanating from the poles. The GEM effect is numerically evaluated.

10:12 10:24 Philippe Landry*, University of Guelph

Tidal Deformation of a Slowly Rotating Material Body

The deformation of an astronomical body subject to weak, slowly varying tidal forces is characterized by a set of dimensionless, equation-of-state-dependent constants known as tidal Love numbers. If the body in question is non-rotating, its gravitational response to a generic quadrupolar tidal field is encoded in two of these quantities: the gravitoelectric Love number k_2^{el} and the gravitomagnetic Love number k_2^{mag}. If, however, the body is rotating -- as is typically the case for astrophysical compact objects -- coupling between its angular momentum vector and the tidal field complicates its response, which can no longer be captured by the gravitational Love numbers alone. In the slow-rotation limit, four additional quantities, designated rotational-tidal Love numbers, are required to complete the description. Like the gravitational Love numbers, the new rotational-tidal Love numbers are found to vanish when the body is a black hole. Together, the two types of Love numbers specify the external metric of a slowly rotating, tidally deformed material body in general relativity.

Friday, October 2 — Morning, Session One

Gravitational Wave/Electromagnetic Detections — 11:00 a.m. – 12:30 p.m.

11:00 11:12 Luis Lehner, Perimeter Institute

Electromagnetic counterparts from non-vacuum gravitational binaries

This talk will discuss several possible electromagnetic counterparts from non-vacuum binaries and their importance for providing both complementary and supplementary information about the sources and gravity itself.

11:12 11:24 Hsin-Yu Chen*, University of Chicago

Optimizing gravitational wave sources followup strategies

The successful follow-up of gravitational wave (GW) sources would open up a new era of multi-messenger astronomy. The distribution of GW detections follows a universal distribution, allowing for the development of an optimal follow-up plan based on localization area, event rate, and available telescope time. For first few years of Advanced LIGO operation the typical source sky error box is a few hundred square degrees. Given limited telescope resources, the best strategy for follow up will consist of neither full coverage of the error box nor follow-up of each and every event. We use analytic distributions of GW events to develop a strategy which maximizes the probability of successful followup.

This optimal strategy can be tailored to a range of follow-up facilities with different available resources and capabilities.

11:24 11:36 Huan Yang, Perimeter Institute for Theoretical Physics

Plasma wave generation in a dynamic spacetime

I will discuss a new electromagnetic-emission mechanism in magnetized, force-free plasma, which is driven by the evolution of the underlying dynamical spacetime. With this radiation-generation process, gravitational energy is converted into electromagnetic energy, which is then carried away by both fast-magnetosonic and Alfven waves of the plasma. As an immediate demonstration, I will consider compact binary mergers occurring within magnetized plasma, which have been shown by previous numerical studies to produce copious amounts of electromagnetic radiation. The emission power and angular distribution of the two classes of waves are separately determined. Combining this mechanism with previously understood mechanisms such as the Blandford-Znajek process and kinetic-motion-driven radiation, I shall classify different components of electromagnetic emissions seen in the inspiral stage of compact-binary coalescence.

11:36 11:48 Archisman Ghosh, ICTS-TIFR

Prospects of estimating cosmological parameters from gravitational-wave observations of coalescing binary black holes

The measurement of cosmological expansion parameters relies crucially on the complex physics of electromagnetic sources like supernovae and it is significantly affected by the systematics of their calibration and detection. An independent measurement of these parameters will be of prime significance in testing the current cosmological paradigm. The expected observation of gravitational waves (GWs) with the second generation detectors opens up such a possibility. For GW signals from compact binary coalescences, one can estimate directly the luminosity distance to the source. If it is possible to associate the host galaxy of the merger event, one can use the redshift-distance relation to obtain the cosmological parameters. Recent work [arXiv:1108.1317 [astro-ph]] has shown that with few tens of observations of inspiral GW signals with a worldwide network of detectors, one can constrain the Hubble constant to an accuracy of a few percents. In this work, we estimate the expected constraints using future GW observations of the inspiral, merger and ringdown of binary black holes and try to lay constraints on the Hubble constant and the matter fraction of the universe.

11:48 12:00 Zoheyr Doctor*, University of Chicago

Search for Kilonovae in DES Supernova Fields

A promising electromagnetic counterpart to gravitational waves from compact binary mergers is the kilonova. A kilonova occurs when a compact merger produces r-process ejecta resulting in isotropic thermal emission. Through simulations of DES observations, we determine the efficiency and efficacy of a search for kilonovae using DES data. We make light curve color and shape cuts on the simulated observations to reject background events such as supernovae. Applying these cuts to real DES Y1 data, we set limits on the kilonova rate and compare to rates set by LIGO.

12:00 12:12 Nestor Ortiz, Perimeter Institute for Theoretical Physics

The shadow of a naked singularity.

A study of nonradial light rays traversing a spherical dust cloud in gravitational collapse, reveals the formation process of a shadow masking the image of the collapsing object as seen by a distant observer. The nature and dynamics of the shadow, as well as the redshift of the light rays measured by the observer, depend crucially on whether the collapse leads to the formation of a black hole or a naked singularity. Implications of this result for a potential method to test the weak cosmic censorship hypothesis will be discussed. Based on Phys.Rev.D 92, 044035 (2015).

12:12 12:24 Milton Ruiz, UIUC

Relativistic simulations of black hole-neutron star coalescence: the jet emerges

Black hole-Neutron star (BHNS) systems have been suggested as viable central engines that power short-hard gamma ray bursts. We will present ideal magnetohydrodynamic simulations of BHNS systems in full general relativity that for the first time demonstrate that jets can be launched after NS tidal disruption if the NS is endowed with a dipolar B-field extending into the exterior. The exterior is initially characterized by a low density atmosphere with constant plasma parameter β□Pgas/Pmag. Varying β in the exterior from 0.1 to 0.01, we find that at □100(MNS/1.4M□)ms following the onset of accretion of tidally disrupted debris, magnetic field winding above the remnant black hole poles builds up the magnetic field sufficiently to launch a mildly relativistic, collimated outflow - an incipient jet. The duration of the accretion and the lifetime of the jet is Δt0.5(MNS/1.4M)s.

Friday, October 2 — Afternoon, Session One

Numerical Relativity/Mathematical Relativity-Gravity 2:00 p.m. – 3:30 p.m.

2:00 2:12 John Ryan Westernacher-Schneider*, University of Guelph

Forced Turbulence in Relativistic Fluids

Given the renewed interest arising both from AdS/CFT and astrophysics, we revisit the phenomenon of relativistic turbulence. We build on some recent work which extends known non-relativistic results in turbulence to the case of relativistic (and thus compressible) fluids. In particular, we derive the scaling behaviour of classical two-point correlation functions in 2+1 dimensions---holographically dual to 3+1 dimensional gravity. Turbulence in 2+1 dimensions also approximates several astrophysical situations, such as thin accretion disks. We perform numerical simulations of forced steady-state turbulence in an effort to measure the scaling relations we have derived.

2:12 2:24 David Garfinkle, Oakland University

Universal spike behavior in spacetime singularities

The formation of singularities in gravitational collapse is accompanied by the formation of structures on very small spatial scales called spikes. This talk presents a combination of analytical and numerical work that makes clear the exact properties of these spikes.

2:24 2:36 Carlos Lousto, Rochester Institute of Technology

Spin flips in generic black hole binaries

We study the spin dynamics of individual black holes in a binary system. In particular we focus on the polar precession of spins and the possibility of a complete flip of spins with respect to the orbital plane. We perform a full numerical simulation that displays these characteristics. We evolve equal mass binary spinning black holes for t=20,000M from an initial proper separation of d=25M down to merger after 48.5 orbits. We compute the gravitational radiation from this system and compare it to3.5 post-Newtonian generated waveforms finding close agreement. We then further use 3.5 post-Newtonian evolutions to show the extension of this spin {flip-flop} phenomenon to unequal mass binaries. We also provide analytic expressions to approximate the maximum {flip-flop} angle and frequency in terms of the binary spins and mass ratio parameters at a given orbital radius. Finally we discuss the effect this spin {flip-flop} would have on accreting matter and other potential observational effects.

2:36 2:48 Stephen Green, Perimeter Institute for Theoretical Physics

Islands of stability and recurrence times in AdS

We study the stability of anti−de Sitter (AdS) spacetime to spherically symmetric perturbations of a real scalar field in general relativity. Further, we work within the context of the "two time framework" (TTF) approximation, which describes the leading nonlinear effects for small amplitude perturbations, and is therefore suitable for studying the weakly turbulent instability of AdS— including both collapsing and non-collapsing solutions. We have previously identified a class of quasi-periodic (QP) solutions to the TTF equations, and in this work we analyze their stability. We show that there exist several families of QP solutions that are stable to linear order, and we argue that these solutions represent islands of stability in TTF. We extract the eigenmodes of small oscillations about QP solutions, and we use them to predict approximate recurrence times for generic non-collapsing initial data in the full (non-TTF) system. Alternatively, when sufficient energy is driven to high-frequency modes, as occurs for initial data far from a QP solution, the TTF description breaks down as an approximation to the full system. Depending on the higher order dynamics of the full system, this often signals an imminent collapse to a black hole.

2:48 3:00 Eric Van Oeveren*, University of Wisconsin-Milwaukee

Accelerated Scalar Self-Force on a Schwarzschild Background

In 2004, Hikida et al. introduced a new way to decompose the (scalar, electromagnetic or gravitational) retarded field sourced by a particle orbiting a black hole. This new decomposition made it easier to renormalize the the field and express the self-force of the particle as a post-Newtonian expansion. Hikida et al. then applied their work to find the self-force on a scalar charge moving on a circular geodesic on a Schwarzschild background. We extend the results of Hikida to the case of an accelerated charge, with the goal of applying the method to the gravitational case.

3:00 3:12 Alexander Tolish*, The University of Chicago

Preliminary Work Regarding Gravitational Wave Memory In An Expanding Universe

We investigate issues related to the memory effect for linearized perturbations on a FLRW background--in particular, the effects that a cosmic fluid might have on memory. It is well known that tensor perturbation modes (i.e., gravitational waves, the most obvious mechanism of memory) do not depend on scalar quantities such as fluid density and pressure, but it is not immediately clear that memory cannot also be associated with scalar modes, which are coupled to the fluid. Using a simple decay process as a sample gravitational wave source, we argue that this is not so--there is no scalar or vector memory, only tensor memory. Ultimately, we hope to present a concrete example of the memory effect in an expanding universe; towards this end, we are also exploring wave equation Green's functions and retarded fields for decaying particles in FLRW spacetimes.

3:12 3:24 Marco Hernandez*, Indiana University

Gravitational field equations and long range repulsive effect

Taking the variation of the Einstein-Hilbert action under an energy-momentum conservation constraint gives rise to a new set of gravitational field equations. In this talk, we show that these equations allow for a long-range repulsive gravitational effect. More precisely, we consider a spherically symmetric, static and vacuum space time, for which an ad-hoc change of variables brings the equations to a simple form. Under the additional assumption of asymtotic flatness we are able to show the existence of solutions for which the gravitational force is attractive for the most part, and becomes repulsive at very long distances. This is joint with Tian Ma and Shouhong Wang.

Friday, October 2 — Afternoon, Session Two

Mathematical Relativity-Mathematical Methods — 4:00 p.m. – 5:30 p.m.

4:00 4:12 Jim Wheeler, Utah State University

Time in conformal general relativity

Gravity theories based on the conformal group or its subgroups frequently give a form of general relativity augmented by local dilatational covariance (CGR). In one of these theories, biconformal gravity, the dimension of the original space is doubled, giving a symplectic manifold with CGR on a lagrangian submanifold. The full symplectic space has a solution which includes a signature changing bilinear form as the restriction of the Killing form to the biconformal space. This opens several possibilities, from time emerging within solutions to a Euclidean gravity theory to the natural emergence of an SO(n) Yang-Mills field on gravitating spacetime. We briefly discuss some of our investigations into these options.

4:12 4:24 Jeffrey Hazboun, Hendrix College

A Cartan geometry approach to the AdS/CFT correspondence

An explicit AdS/CFT correspondence is shown for the Lie group SO(4,2). The Lie symmetry structures allow for the construction of two physical theo- ries through the tools of Cartan geometry. One is a gravitational theory that has anti-de Sitter symmetry. The other is also a gravitational theory but is conformally symmetric. The conformal theory lives on an 8-dimensional biconformal space, where one of the 4-dimensional subspaces possesses a Euclidean metric. The presence of this metric allows for the construction of an SU(2) × SU(2) Yang-Mills theory from the gravitational degrees of freedom. These theories have a natural correspondence that comes directly from their Lie algebra without the use of either SUSY or holography.

4:24 4:36 Benjamin Lovelady*, Utah State University

Dynamical internal symmetry: a Yang-Mills field on biconformal space

According to the Coleman-Mandula theorem, the symmetry of any gauge theory of gravity with an internal symmetry must take the form of a direct product in order to be consistent with basic assumptions of quantum field theory. However, we show that an alternative gauging of a simple group can lead dynamically to a compact internal symmetry, within Lorentzian gravity. The biconformal gauging of the conformal symmetry of N-dim Minkowski space doubles the dimension to give a symplectic manifold, naturally developing an SO(N) curvature on the extra N-dimensions. When the space is projected back to spacetime, this SO(N) curvature appears as a Yang Mills field on the resulting configuration space. We consider both the flat case, and cases perturbative in the curvature.

4:36 4:48 Tevian Dray, Oregon State University

The Geometry of Relativity

The geometry of special relativity can be neatly described using hyperbolic trigonometry. The geometry of general relativity can be similarly described using differentials and differential forms. This talk presents an excursion through both special and general relativity, emphasizing geometric structure using elementary concepts from trigonometry, linear algebra, and vector calculus.

4:48 5:00 Morgan Lynch*, University of Wisconsin-Milwaukee

Aspects of accelerated quantum dynamics

We present a formalism for the computation of observables due to acceleration-induced particle physics processes. Of particular importance in characterizing these systems are the transition rate, power, spectra, and displacement law. Expressions for these observables will be presented for particles undergoing time-dependent acceleration and transitioning into a final state of arbitrary multiplicity.

5:00 5:12 Weishun Zhong*, University of Michigan-Ann Arbor

Holographic c-Theorem in Schrodinger Spacetime

We study the constraint from null energy condition on flows between asymptotically Schrodinger spacetime, and found that the result agrees with the relativistic holographic c-theorem, in which the effective radius L monotonically decreases from UV to IR, regardless of the value of critical component z. We also construct several numerical examples to demonstrate this theorem. In particular, we found that a constant $z = 2$ flow is possible, suggesting when the full Schrodinger symmetry group is admitted in the dual conformal field theory, the solution to Einstein equation takes a special form. At the end, we propose an energy condition for Lifshitz background such that a holographic c-theorem will be recovered.

5:12 5:24 Mohammad Akbar, University of Texas at Dallas

Lie point symmetries of static axisymmetric vacuum Einstein equations

An explicit one-parameter Lie point symmetry of the four-dimensional vacuum Einstein equations with two commuting hypersurface-orthogonal Killing vector fields will be presented. The parameter takes values over all of the real line and the action of the group can be effected algebraically on any solution of the system. This enables one to construct particular one-parameter extended families of axisymmetric static solutions and cylindrical gravitational wave solutions from old ones, in a simpler way than most solution-generation techniques, including the prescription given by Ernst for this system. As examples, we obtain the families that generalize the Schwarzschild solution and the C-metric. These in effect superpose a Levi-Civita cylindrical solution on the seeds. Exploiting a correspondence between static solutions of Einstein's equations and Ricci solitons (self-similar solutions of the Ricci flow), this also enables one to construct new steady Ricci solitons.

Saturday, October 3 — Morning, Session One

Mathematical Relativity-Gravity — 8:30 a.m. – 10:30 a.m.

8:30 8:42 Richard Kriske, University of Minnesota

Revisiting the Horizon

This author put forward a controversial theory about a decade ago, wherein he claimed that the Universe was probably a three space with one dimension of time perpendicular to each point of space. He also compared it to the Earth and proved that if you substitute time for height, then the time dimension diminishes with distance, not only because of perspective but also because of curvature of the surface, and this can be seen with height on the globe. So any length of time tends to zero at the limit, as it does with height. A tree infinitely tall will still disappear if it is on the other side of the Earth. This author also put forward an idea explaining why measurement of the positively curved universe always show a flat Universe. This is because the nature of measurement, each measurement has been tried is always a product of the inner surface of the Curved space-time surface, times the outer surface of the space-time surface, so the curvature simply cancels out, since you are using the metric from the same surface. There is a way around this problem, in that one could use a piece of that surface that has a high torsion, and measure the drag of that surface, since the inner and outer portion can't cancel in the vortices instantaneously. There should be a remainder that would give the correct curvature and size of the Universe.

8:42 8:54 Vic Dannon, Gauge Institute

The Sun's Orbit Radius and Period

We assume that the Gravitational Power Radiation is proportional to the acceleration squared. Then, at Radiation Power Equilibrium between the Sun and its nine Planets, the Sun's Orbit Radius is approximately (20.67)X10^8, about 3 times the Sun's Radius of (6.96)X10^8. And the Sun's year is approximately 0.937188048 earth years.

8:54 9:06 Greg Proper, Proper Eng.

An Alternative to the Robertson-Walker Metric and the Accelerated Expansion of Space-Time

It is demonstrated that if a metric slightly dissimilar to the Robertson-Walker were allowed, then the Einstein equation would give an analog to the Friedmann 2 (acceleration) equation with a positive rho.

9:06 9:18 Paul O'Brien

Black Hole Enthalpy and the Bekenstein Bound

Black hole thermodynamics tells us that BH temperature times the mass is a constant; M□T□ = ħc3/8kπG = Mp2c2/8πk = MuKu = MpKi/2. If the mass times temperature is a constant, and temperature is a measure of internal energy, then the enthalpy (internal energy) of BH's must be a constant. The internal energy (H□), which is the available energy to do work is a property of all BH's. The equation for BH enthalpy is thus H□ = c2 M□T□/Ki = 2πkKi = ½c2Mp. This equation has never been seen before and using the Bekenstein Bound I will prove this to be true. Ki = initial temperature of universe in Kelvins, which is the temperature of a ½Mp BH. Mu = rest mass of universe; Mp = plank mass; Ku = BH temperature of universe in Kelvin. IMO this discovery is as big as BH Entropy. This equation is just one small part of the HSI theory which I am the sole author of. I would not have the time to present the HSI theory in 15 minutes but more information can be found @ osubb.com. I can send a PDF upon request.

9:18 9:30 Kartik Prabhu*, University of Chicago

First law and entropy for charged fields

We extend the analysis of Iyer and Wald to derive the First Law of blackhole mechanics in the presence of fields charged under an 'internal gauge group'. We treat diffeomorphisms and gauge transformations in a unified way by formulating the theory on a principal bundle. The first law then relates the energy and angular momentum at infinity to a potential times charge term at the horizon. The gravitational potential and charge give a notion of temperature and entropy respectively. We also analyse ambiguities in the definition of entropy and identify them as topological charges.

9:30 9:42 Sam Gralla, University of Arizona

Physics near Rapidly Spinning Black Holes

The near-horizon region of a near-extreme Kerr black hole has two extra Killing fields beyond those of Kerr. I will discuss some recent efforts to find astrophysical consequences of these enhanced symmetries.

9:42 9:54 Soichiro Isoyama, University of Guelph

Hamiltonian Dynamics of Self-Forced Motion in Kerr Spacetime: Inspiral-Dynamics

We discuss our ongoing work to formulate a motion of a self-gravitating particle on a generic orbit in Kerr spacetime as a geodesic Hamiltonian dynamics in a certainly defined effective spacetime. In this talk, we focus on the inspiral sector of the dynamics, and sketch our strategy to compute it in practice beyond the adiabatic approximation.

9:54 10:06 Robert Wald, University of Chicago

Instability of AdS Black Holes with Ergoregions

For a black hole in an asymptotically AdS spacetime, an ergoregion is defined as a region of the spacetime outside the black hole where the horizon Killing field becomes spacelike; typically, such a region would occur near infinity. We prove that for any asymptotically AdS black hole with an ergoregion, one can find perturbations that have negative canonical energy. It follows that such black holes are dynamically unstable. Unlike the asymptotically flat case, there is no need to assume that the black hole or the perturbation is axisymmetric. This work was done in collaboration with S. Green, S. Hollands, and A. Ishibashi.

10:06 10:18 Shouhong Wang, Indiana University

A new blackhole theorem and its applications to cosmology and astrophysics

We shall present a blackhole theorem and a theorem on the structure of our Universe, proved in a recently published paper, assuming the validity of 1) the Einstein general theory of relativity, and 2) the cosmological principle. These two theorems are rigorously proved using astrophysical dynamical models coupling fluid dynamics and general relativity based on a symmetry-breaking principle. With the new blackhole theorem, we further demonstrate that both supernovae explosion and AGN jets are due to combined relativistic, magnetic and thermal effects. The radial temperature gradient causes vertical Benard type convection cells, and the relativistic viscous force (via electromagnetic, the weak and the strong interactions) gives rise to a huge explosive radial force near the Schwarzschild radius, leading e.g. to supernovae explosion and AGN jets. This is joint with Tian Ma.

10:18 10:30 Shuang-Yong Zhou, Case Western

The strong coupling scale of massive gravity

I would like to present some new development regarding the strong coupling scale and decoupling limit of dRGT massive gravity. The relevant paper, in collaboration with Claudia de Rham and Andrew Tolley, is being finalized.

Saturday, October 3 — Morning, Session Two

Gravitational Wave Experiments & Alternative Tests 11:00 a.m. – 12:30 p.m.

11:00 11:12 Frank Barrett*, Grand Valley State University

Spurious Noise Acceleration of LISA Spacecraft Due to Solar Wind

Measurements from the Laser Interferometer Space Antenna (LISA) are dependent upon the isolation of the proof mass within each sciencecraft. One possible source of noise that must be accounted for is the force due to the solar wind. Current LISA proposals use cesium ion thrusters to counteract forces on the order of μN in order to correct for deviations from the natural geodesics of the sciencecraft. The Advanced Composition Explorer (ACE) is a space borne craft that has measured solar wind data since 1998. Using this data we calculated the forces on an individual LISA sciencecraft over the duration of a solar cycle. This will tell us the frequency of forces that the thrusters must correct in order to provide isolation of the test masses.

11:12 11:24 Brandon Piotrzkowski*, Grand Valley State University

Spurious Acceleration Noise on the LISA Configuration Due to Solar Irradiance

The stability of the Laser Interferometer Space Antenna (LISA) satellite configuration will be crucial to its ability to measure gravitational waves. Although solar irradiance is the largest contributor to this disruption, while also introducing noise in the desired frequency band, previous research has only considered zeroth order calculations in static systems. To remedy this we used a geometric approach to calculate the force on the satellites' solar arrays, based on the materials. Running our simulation of LISA based on irradiance data from VIRGO, we then examined the Fourier transform of force to find the associated spurious noise. This research will help engineers in the construction of the solar array as well as help isolate the gravitational wave signal when LISA is flown.

11:24 11:36 Brittany Kamai*, Vanderbilt University

The Fermilab Holometer as a gravitational wave antenna

The spectrum of gravitational waves remains poorly constrained at the high frequency end. The Fermilab Holometer has the length sensitivity to probe this region using two nested 40 meter Michelson interferometers. The experiment is optimized to achieve strain sensitivity better than 10^-20 /rt.Hz within the 1-10 MHz frequency band. Potential candidates could be nearby exotic sources such as cosmic strings and primordial black holes that would show up as narrow-lined sources. The Holometer team has finished construction and begun scientific operations. I will discuss the current status of the instrument, first results in the gravitational wave search along with plans for extended analysis.

11:36 11:48 Michael Zevin*, Northwestern University

LIGO Glitch Classification using Machine Learning Algorithms

Advanced LIGO has begun observing runs, and by the end of the decade is expected to make the first detections of gravitational wave signals and open up a new window to the Universe. As the most complicated and sensitive gravitational physics experiment ever constructed, LIGO is susceptible to non-cosmic artifacts and noise from a variety of sources. Some of these 'glitches' can also mimic true gravitational wave signals. The proper characterization and extraction of these artifacts from the data are crucial tasks in optimally identifying gravitational wave signals from the Universe. I present preliminary results in using machine learning algorithms as a means to identify and classify glitch morphologies from the LIGO data, as improved characterization of glitch morphologies will lead to better techniques of removing glitches from the data and finding their cause. Additionally, machine learning classification of glitch morphologies such as this will be used to compliment GlitchZoo, an upcoming citizen science glitch classification project run by Zooniverse.

11:48 12:00 Peter Zimmerman, University of Arizona

Gravitational self-force in scalar-tensor theories

I shall discuss a derivation of the leading-order gravitational self-force experienced by compact bodies in scalar-tensor gravity. I'll then compare the equation of motion in a general background with a black hole solution having a constant scalar field configuration. The effects of the self-force on floating orbits will also be mentioned.

12:00 12:12 Rui Xu*, Indiana University, Bloomington

Searching for Lorentz violation using gravitational effective field theory

Lorentz symmetry is an essential property of modern physics, so it is important to test it precisely by experimentation. General violations of Lorentz symmetry can be described by an effective field theory for gravity and matter known as the gravitational standard-model extension (SME). The SME predicts modifications of gravitational physics that can be tested in high-precision experiments. Recent experimental and theoretical studies of Lorentz violation in the pure-gravity sector of the SME have improved existing sensitivities and have yielded many dozens of measurements of previously unexplored effects. This talk will discuss some SME predictions for Lorentz violation in weak-field gravity and will present recent measurements of the corresponding effects.

12:12 12:24 Jonah Miller*, Perimeter Institute for Theoretical Physics

Testing Gravitational Aether Theory Through the Astrophysics of Compact Objects

The cosmological constant problem asks why a naive application of quantum field theory predicts an enormous amount of vacuum energy, but empirical observations indicate a tiny amount. Gravitational aether theory solves part of this problem by proposing the vacuum does not gravitate. To effect this, aether theory modifies general relativity so that it is decoupled from the vacuum. The price of this modification is a breaking of Lorentz symmetry and the emergence of a preferred frame. Therefore, even if aether theory proves incorrect, it serves as a useful probe of Lorentz symmetry breaking in gravity. In our study, we use a toy model of a neutron star as a testing ground for gravitational aether theory. We seek numerical predictions of deviations from general relativity and numerical evidence for whether or not gravitational aether theory is a well-posed initial-value problem.

Alternative Tests, Gravitational Wave Data, Mathematical Relativity-Mathematical Methods 2:00 p.m. – 3:45 p.m.

2:10 2:22 Raissa Mendes, University of Guelph

Possibility of setting a new constraint to scalar-tensor theories

Scalar-tensor theories are a widely studied alternative to general relativity in which gravity is endowed with an additional scalar degree of freedom. Although severely constrained by solar system and pulsar timing experiments, there remains a large set of scalar-tensor theories which are consistent with all present day observations. In this talk, I review the current constraints on these theories and discuss the possibility of probing a yet unconstrained region of their parameter space based on the fact that stability properties of highly compact neutron stars in these theories may radically differ from those in GR. This is based on the paper PRD 91, 064024 (2015) and ongoing research.

2:22 2:34 Tigran Kalaydzhyan, UIC

Testing gravity on accelerators

In this talk I will introduce several methods of testing the weak equivalence principle with the use of modern particle accelerators. Predictions of the general relativity (GR) for the high-energy particles and/or the antimatter were never confirmed experimentally, which is the main motivation for my work. I will show that the absence of the vacuum Cherenkov radiation at LEP and photon stability for the Tevatron experiments confirm validity of GR for high-energy electrons and positrons at 4% level. High precision measurements of the synchrotron losses at LEP reduce this figure to0.1%. I will also comment on a possibility of improving the limits in the Compton scattering experiments at the future ILC and CLIC colliders.

2:34 2:46 Chris Pankow, Northwestern University

A Rapid Bayesian Parameter Estimation Scheme for Binary Neutron Stars in the Advanced LIGO Era

With the first observation runs with second generation gravitational-wave interferometers imminent, the benefit of prompt estimation of the physical parameters and orientation of binary coalescences is obvious not only in confident detection and event population studies, but also in its coupling to electromagnetic astrophysics and observations. Conventional parameter estimation schemes are primarily Bayesian as well as Markovian. In some cases, however, convergence can complete well after the electromagnetic fluence has subsided. We have developed a scheme which is also Bayesian but simply parallelizable across all available computing resources, drastically decreasing convergence time to few tens of minutes. In this talk, I will demonstrate the capabilities of our parameter estimation framework in the context of binary neutron star coalescence. I will also review recent developments in regards to computational efficiency and efforts to expand the framework to other quantities such as tidal parameters and component spins.

2:46 2:58 Laura Sampson, Northwestern University

Astrophysical Inference with Pulsar Timing Arrays

Pulsar timing arrays are sensitive to gravitational waves from the merger of supermassive black holes throughout our universe. These waves are thought to form a signal that takes the form of a stochastic background which can be characterized by the form of its power spectrum. By measuring the shape of this spectrum, we can constrain the mechanisms that lead to the merger of these black holes. I will discuss the techniques that allow us to access this information, and show that we can already constrain astrophysical models with current PTA data.

2:58 3:10 Scotty Coughlin, Northwestern University

Distinguishing Neutron Stars from Black Holes with LIGO/Virgo

As the LIGO and Virgo detectors reach their advanced design sensitivities gravitational wave observations will become an indispensable tool for learning about the universe. The mergers of binary systems comprised of compact stellar remnants (black holes and neutron stars) are expected to be the most abundant sources detectable by ground-based interferometric detectors.Advancing our understanding of binary astrophysics has long been recognized as a primary science objective for LIGO and Virgo.The potential for using GW observations as laboratories to study the nature of binary systems, and the underlying population of compact binaries, has been explored for several decades building the signal processing framework needed for the coming rush of data. We assess LIGO/Virgo's capabilities by taking advantage of modern data analysis methods and waveform models which include spin-precession effects to study a large ensemble of plausible GW sources. From this large-scale parameter estimation investigation we make quantitative predictions for how well LIGO and Virgo will be able to distinguish between black holes and neutron stars; we appraise the prospect of using LIGO/Virgo observations to definitively confirm, or reject, the existence of a ``mass gap'' between high-mass neutron stars and low-mass black holes; and we demonstrate the importance of including spin precession effects in our model for the gravitational wave signal.

3:10 3:22 Roberto Salgado, UWisconsin-La Crosse

Relativity on Rotated Graph Paper: Lorentz-Invariant Calculations with Causal Diamonds

We extend our earlier work (Relativity on Rotated Graph Paper, arXiv:1111.7254) by visualizing Lorentz-invariant calculations associated with the Causal Diamonds between pairs of events, rather than observer-dependent calculations with light-clock diamonds associated with a given inertial observer. In our approach, we use spacetime diagrams drawn on graph paper that has been rotated by 45 degrees. Quantitative results can be read off the diagram by counting boxes, using a minimal amount of algebra.

3:22 3:34 George Hrabovsky, Madison Area Science and Technolgy (MAST)

Solving the Field Equations of General Relativity in Mathematica

This talk presents methods for solving the Einstein Field Equations using Mathematica. If time permits we will begin with more traditional numerical/symbolic solution methods. Then we will turn to development of the field equations in specific coordinate bases. Then we will explore the mesh generation system in Mathematica, both fixed and adaptive. Then we will explore finite element methods.