2020 Departmental Poster Competition

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Book of abstracts

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Cellular Automata Inspired Design of Autonomous Vehicle Behaviors in Heterogeneous Traffic Flow

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Properties of heterogeneous traffic flow are determined by behaviors of individual agents and how they interact. Unlike human drivers/vehicles (HVs), whose behaviors are mostly predetermined, the behaviors of autonomous vehicles (AVs) can be purposefully designed. This raises the question of how autonomous vehicle behaviors should be designed so that autonomous and human-driven vehicles utilize the roadway in an efficient and harmonized fashion. This paper aims to contribute to the understanding of this question, with a particular focus on developing design for autonomous vehicles to boost their spontaneous platooning in heterogeneous traffic flow. We present results of two aspects. We first propose stochastic urn models to approximate the dynamics of spontaneous platooning by considering agents' swapping of relative locations in heterogeneous traffic flow. Equilibrium distributions of platoon sizes are derived when agents are endowed with different behavioral characters. We also derive the Fokker-Planck equation that sheds light on the limit of such distributions when the system size is large. Then we conduct simulation experiments to verify our analytical insights, where two characters of AVs are considered: namly, neighbor awareness, and opportunisticity. We observe that, intriguingly, AVs could form into platoons spon- taneously without centralized control, as long as they are endowed with proper types of behavior. Our findings indicate the potential of regulating future mixed autonomous traffic flow through
agent behavior design and cooperations.

1

Challenges of Microsimulation Calibration with Traffic Waves using Aggregate Measurements

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This work explores the challenges associated with calibrating parameters of microscopic models with aggregate speed data, e.g., obtained from roadside sensors. Using the Intelligent Driver Model, we explore how reliably parameters that do not influence the equilibrium flow (i.e., the Fundamental Diagram), but do control the stability of those equilibria, can be determined from aggregate speed data. Using a carefully controlled computational setup, we show that standard loss functions used for calibrating microsimulation models can perform poorly when the true parameters result in an unstable traffic state. Precisely, it is found that all of the considered loss functions frequently return different and incorrect parameter sets that minimize the expected value of the loss function. These results highlight the need for improved loss functions, or even fundamental additions to the model calibration procedure.

2

A rubric for assessing thinking skills in free-response exam problems

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We designed a rubric to assess free-response exam problems in order to compare thinking skills evidenced in exams in classes taught by different pedagogies. The rubric was designed based on Bloom's taxonomy and then used to code exam problems. We have analyzed historical and recent exam problems in both algebra-based and calculus-based exams. In particular, we have examined cases where the same problem was administered on exams taught by different pedagogies. In one case, we were able to compare two different sections of the algebra-based physics course taught the same semester by the same instructor, one with inquiry-based instruction and the other in a more traditional lecture environment. We discuss the instrument and present results. The inquiry-based students demonstrated all of the thinking skills coded more often than the traditional students.

3

Extreme suppression of waveguide crosstalk with all-dielectric metamaterials

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We present and demonstrate an exceptional coupling that can extremely suppress the crosstalk between adjacent waveguides using highly anisotropic extreme skin-depth (eskid) waveguides. The anisotropic dielectric perturbations in eskid waveguides cancel the coupling from distinct field components, resulting in an extremely long coupling length.

4

Development of Classroom-Interaction Coding Schemes for PCK Assessment

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As part of a larger project to develop a written instrument to evaluate pedagogical content knowledge(PCK), we are observing classroom interactions between students and student assistants. When observing student assistants, two coding schemes emerged. The first coding scheme was developed to describe the student assistant's ability to guide students through a requested task. The second coding scheme was developed to describe the ability of the student assistant to help students work through their own thought development process. In my poster I will present the two coding schemes, go over the similarities/differences and discuss the future plans for the schemes. The two coding schemes will be used to help design the written PCK instrument.

5

Establishing a Cyber-Physical Network of Microcontrollers and Thermodynamic Sensors for Real-Time Environmental Monitoring

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At the Advanced Particle Detector Laboratory (APDL), we manufacture environmentally sensitive equipment that require careful monitoring. Since this is a specialized and individual task - it is expensive, and care should be taken such as to not damage the equipment. To alleviate this problem, we are creating a network of Raspberry Pi's embedded with BME280 sensors, to build a modular distributed weather station to monitor the environmental conditions in multiple areas around the lab. The 12 "worker" raspberry pi's record temperature, pressure, and humidity data and transmit the data to a localized "hub" pi through a broker-client system. The transmitted data is stored into a database with the intention of establishing a "Weather Stations Dashboard" that would host dynamic plots of such environmental data in real time to be readily accessible by all lab members.

6

Study of VO2 Coating Layer for Energy Savings Applications

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Optical coatings are key components in modern optoelectronic devices such as solar cells, optical filters and smart windows. One of the materials which have recently found some applications as a uniform or patterned layer in optical devices is vanadium dioxide (VO2). In this work, we have numerically and experimentally investigated the absorption spectrum of a single thin layer VO2 deposited over three metallic films including Nickel (Ni), Aluminum (Al), and Gold (Au) over a wide range of wavelengths at normal and oblique incident angles.

8

A search for variable stars and compact binaries in globular clusters with HST

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Globular clusters (GCs) are very old group of stars. Their age and very dense stellar environment lead to a higher formation rate, compared to the Galactic field, of compact binaries (harboring black holes, neutron stars, and white dwarfs) in tight orbits. Of special interest are the Cataclysmic Variables (CVs), which are accreting white dwarfs from Hydrogen-rich companions. CVs deserve special attention as they are predicted to account for a large fraction of the compact binary population in GCs and can be used to test whether GCs are in fact the efficient factories of compact binaries that we think. We present an ongoing survey which uses archival Hubble Space Telescope data to find and characterize the putative sizable population of CVs and compact binaries in 7 globular clusters, and preliminary findings for the globular cluster NGC 6397.

9

Rare-earth spin qubit selection using conventional spectroscopy methods

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Rare-earth spin qubits are a promising quantum system because of narrow energy level transition, long optical and spin coherence lifetimes at visible and near infrared. Here, we present our efforts to develop a quantum sensing device based on a rare-earth spin qubit. We choose a single erbium ion as a spin qubit candidate because its atomic level transition is in telecom wavelength (1550 nm) which will benefit an integration into on-chip silicon photonic devices. We prepare for an erbium (Er) doped oxychlorides (OCl) of the lanthanides (Yb) nanocrystals on silicon (Si) and silicon carbide (SiC) substrates. We use two conventional spectroscopy methods for spin qubit selection on the substrate. First, we take infrared spectrum and look for absorption spectrum from the erbium ion. Any cluster of ions with induce absorption spectrum broadening. Second, we take an infrared spectrum with a small magnetic field from a Helmholtz coil. Absorption band splitting due to the magnetic field, Zeeman splitting, creates the two-level systems that we will use for a single qubit operation. Resolution of two the absorption bands due to the two-level system depends on spectral band width and the strength of magnetic field. We take the infrared spectrum of small areas of the sample, using a Fourier Transform Infrared spectrometer with infrared microscope, to achieve the two-level system. Once the selection is done, we will use a home-built microscope imaging system for a single photon detection of telecommunication light at low temperature and immersed in external magnetic fields to communicate with a single erbium ion spin qubit.

10

Radiation-hardness Studies of Cerium-doped Fused-silica Optical Fibers

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We report on the radiation-hardness of cerium-doped scintillating fused-silica fibers for detector applications in particle and nuclear physics. Three types of fibers with the same coaxial 15-um-thick doped ring structure, but different cladding and buffer materials, were irradiated with varying dose rates up to 1,500 kGy at the gamma irradiation facilities at the Sandia National Laboratory, University of Maryland, and at the Department for Fusion and Nuclear Safety Technologies (ENEA) in Rome, Italy. Clear-fused silica fibers were also included in these irradiation campaigns as benchmark. We find that the radiation-induced attenuation grows with integrated dose obeying the well-established power law. This continued R project aims to achieve sufficiently robust and bright scintillating fibers that can survive the harsh radiation environments at the future high-intensity experiments.

11

Post-Merger Gravitational Wave Search of GRB200219A using a new technique COCOA

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Gamma-ray bursts (GRB), being highly energetic events, are believed to be associated with gravitational wave events and have recently been confirmed to be driven by binary neutron star mergers such as GW170817/GRB170817A. But this led us to another quest for finding their post-merger remnants. Their hints are embedded within the associated GRB afterglow curve; consisting of a central plateau region clubbed between two steep curves. It is long believed that such a plateau is seen because of a constant injection during that plateau period (Nousek et al 2005). One of the major reasons for such plateau could be that the central engine remains active for a long time and keeps feeding the GRB. With the same understanding, we focus on searching for gravitational wave emission from a secularly unstable magnetar, surviving for a few hundred seconds before collapsing to the final compact object (Corsi & Meszaros 2009). To probe for such GW signals, we have developed a state-of-the-art technique called Cross-Correlation Algorithm (COCOA) which we are using to search for remnant signals from a very recent GRB 200219A. This work on GRB 200219A has shown some potential detectability for Gravitational wave emission according to Lu et al 2020 wherein our technique would be able to better confirm it by finding upper limits on the distance for such an event.

12

Behavior of photons in a scintillator and how it affects light efficiency

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Scintillators are common devices used in radiation detectors. Radiation detectors are used for identifying and characterizing radioactive decay products and high energy particles from either showers of cosmic rays or particle collisions at accelerators. Scintillators have a property such that when these particles strike it, photons are emitted inside the scintillator which can be detected by a photodetector such as a silicon photomultiplier or a photomultiplier tube. A key aspect to designing effective scintillator-based detectors is optimizing the light collection efficiency. A number of factors affect light collection efficiency. Our work studies the nature of photons moving in a scintillator with a refractive index and is attempting to maximize the light efficiency given a set of variables to work with such as the dimensions of the scintillator, the refractive index of the scintillator, the dimensions of the photodetector, and whether or not there is an air-gap between the scintillator and the photodetector. This poster will present a python-based numerical simulation of light propagation in a scintillator which can be used to compute the light collection efficiency under various assumptions. We also present a first-principles calculation in two spatial dimensions which is used to validate the numerical simulation. We will present a flowchart of our numerical simulation and some comparison between the numerical simulation and our simplified 2D calculations under several operating conditions.

13

GW170817 - An overview

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GW170817 has been instrumental in providing important clues into the physics involved in collisions of neutron star mergers. Observations at different wavelengths on the electromagnetic spectrum have provided evidence for formation of heavier elements, insights into jet physics, circum-merger environment etc. and accompanied with gravitational wave measurements, it has changed the way we look at such transients. In particular, radio observations track the fastest moving ejecta and helped to zero in on possible models that could explain the observed radiation. Continued observations can constrain the parameter space, allowing for better modelling of the inherent physics. I will present a brief overview of all observations of GW170817 done till date and will also hint upon what we expect to observe from the source in near future.

14

The Prototype-I Portable Muon Telescope Data Acquisition System

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This presentation describes the advances made in the data acquisition (DAQ) system of the Prototype Portable Muon Telescope. The Prototype Portable Muon Telescope, created for High-Resolution Muography, was a collaborative effort between undergraduate physics students, Dr. Shuichi Kunori, and Dr. Nural Akchurin of the High Energy Physics Group at Texas Tech University. The DAQ system of the Prototype-1 Muon Telescope featured various methods and goals as it was developed. The setup of the system that remained constant consisted of four layers of eleven channels with each channel representing a scintillator bar with a Silicon Photomultiplier on the end. The DAQ system utilized Arduino Nanos (Workers) to store data and handle triggering at each layer and a single Arduino Mega (Master) to receive and process data into an event before sending that information to the DAQ computer via USB. Iterations of the DAQ system include the utilization of the wired I2C bus, a wireless network, using the nRF24L01 module, and wired serial communication to send data between each Worker, the Master, and DAQ Computer.

15

Optical spectroscopy of the Weyl semimetal RAlGe (R = Ce, Pr, La)

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We present mid/far-infrared frequency dependence of the optical response in the Weyl semimetal RAlGe (R = Ce, Pr, La). The RAlGe compounds are either type-I or type-II Weyl semimetals depending on the choices of R. Weyl semimetals harbor pairs of singular points, called Weyl nodes, in the momentum space, and the Berry curvature continuously changes between the Weyl nodes. The different band structures and magnetic properties will affect the formation of Weyl nodes, resulting in the different types of Weyl semimetal. While CeAlGe and LaAlGe are respectively magnetic and nonmagnetic type-II Weyl semimetals, PrAlGe is a magnetic type-I Weyl semimetal. Comparative studies of the optical spectroscopy on these three compounds would reveal distinct features of different types of Weyl semimetal. We perform measurements of mid/far-infrared reflection in a range of 20 cm-1 ~ 6000 cm-1 to get the optical conductivity that will show a Drude response (intraband) and interband transitions around the Weyl points. Our approach will shed light on the understanding of the optical properties of the newly discovered Weyl semimetal family RAlGe.

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Search for Dark Matter from Baryon Number Violation Process in Proton-Proton Collisions at □13 TeV

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The Standard Model (SM) of particle physics is a very successful model to explain matters and interactions of the matters in the universe with quarks, leptons, vector bosons and the Higgs particle. The SM predicted many experimental results in the particle physics for last 50 years and led to the discovery of the Higgs particle in 2012. But while it is incredible, it does not provides a complete picture of the Universe, for example it can not account for Gravity (G) and Dark Matter (DM). There are strong evidence of the existence of dark matter (DM) in the universe in astrophysical observations, such as rotational curves of galaxies, gravitational lensing and bullet cluster. Recent cosmological observations with the Hubble Space Telescope and Plank spacecraft indicate that DM and dark energy make up about 95% of the universe. Theoretical physicists have come up with a large number of theoretical models that include various types of DM. We explain methods used in search for DM productions in the early universe with the proton-proton collision experiments at the LHC.

17

Searching for narrow band thermal emission in mid-infrared from phonon polaritonic metasurfaces

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Metasurfaces, artificial optical devices, which consist of an array of two-dimensional optical antennas with subwavelength thickness and separation, can be tailored to produce gradient optical responses and shape the wave fronts of scattered light. The polaritonic metasurfaces used in this work, are comprised of polar dielectrics and metal-dielectric multilayers patterns. The excitation of surface phonon polariton modes in the mid-infrared are confined metal-dielectric nanostructures and shows a very strong resonance with low optical power loss. The purpose of the study is to investigate a well-defined and narrow-band thermal emission from surface phonon polaritonic metasurfaces in the optical phonon band of silicon carbide (SiC) in the mid-infrared wavelength of 10–12 microns. Recently, we obtained single, controllable, and strong localized polariton resonances of these optical devices. We expect to observe thermal emission according to Kirchhoff's law stating that a good absorber is a good emitter in thermal equilibrium. We built a home-made thermal emission measurement setup. A thermoelectric pad used to heat the metasurface device. To maximize the collection of thermal radiation from metasurface device, we used ZnSe objective lens and thermal emission data is taken by using a Fourier Transform Infrared Spectrometer. The thermal emission device will be used to construct novel thermal metasurfaces.

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Investigation of surface phonon polariton localization on hexagonal boron nitride

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Polar dielectrics have been chosen as a metasurfaces platform in recent years because the polar dielectrics have a low optical power loss and a high coupling efficiency to the light at the optical phonon band. We classified polar dielectrics into two groups, bulks and two-dimensional materials, depending on the evanescent field characters of surface waves of the light on polar dielectrics. We chose hexagonal boron nitride (hBN), one of the two-dimensional polar dielectric candidates. We made two-dimensional hBN flakes by mechanical exfoliation and transferred hBN flake on the nanostructures. We have searched for a localized surface phonon polaritons on metal or dielectric boundary underneath hBN. Two-dimensional platform of polaritons is useful to stack other exotic two-dimensional electron systems, for example, a coupling of Dirac or topological electrons to polaritons.

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Constraining the Properties of Kilonovae based on the Zwicky Transient Facility Searches for 13 Neutron Star Mergers

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In their third observing run (O3), LIGO and Virgo detected gravitational-wave (GW) candidates from several neutron star-black hole (NSBH) and binary neutron star (BNS) mergers. The Zwicky Transient Facility (ZTF), an optical time-domain survey telescope, followed-up thirteen of these GW events in search of kilonovae (KNe; electromagnetic counterparts to GW events). However, no KNe were found. To assess the implications on potential KN emission based on the upper limits, empirical limits on the KN peak magnitude and evolution rate were determined. One shortcoming of these analyses was the assumption that all peak magnitudes and evolution rates are equally likely. In this work, we present a method to improve upon this assumption by comparing to light curves generated using radiative-transport based KN models, parameterized by ejecta mass and inclination angle. Specifically, we construct priors informed by these KN models to identify regions of parameter space where particular luminosities and evolution rates are improbable. We factor color evolution into the decay rates, important as observations of GW170817 have shown that the photometric behavior of a KN differs in different bands. Using our new weighted and band-specific priors, more realistic constraints are placed on kilonova source properties. Finally, we close with an application of this methodology to derive constraints on KN ejecta masses.

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Machine-Learning Assisted Muon Tomography

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We report on a design of a computationally efficient parallelized framework to analyze the large data volume generated by our muon tomography detector system. The detector system consists of plastic scintillator counters with photomultiplier tubes and a CAMAC data acquisition system with analog-to-digital (ADC), time-to-digital (TDC), and scaler modules. We share our preliminary results that make use of reduced TDC information based on a novel "time - conservation" approach and introduce methods for generating tomograms through such schema. Plans of using Recurrent Neural Networks (RNN) in track reconstruction and other machine-learning inspired techniques for high fidelity images will also be presented.

21

Searching for X-ray Transients in Nearby Galaxies

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There has been debate about whether population sizes of Be X-ray binaries are a function of age or of the metallicity of a galaxy so using archival data of star forming galaxies I will be searching for correlations between the rate of Be X-ray binaries and the age of these galaxies. I began by looking for transient candidates in the star forming galaxy NGC 6744 by analyzing Chandra data using ds9 and topcat. The list of transient candidates I have found will be narrowed down by taking out sources with less than 30 counts and any sources that are off of the CCD chip in the observations. As of now the interpretation of the transient rate is still a work in progress.

22

Trends in magnetism and magnetic anisotropy of RCo5 materials

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The RCo5 family of materials (R = rare earth) are integral to many permanent magnet applications due to their high paramagnetic to ferromagnetic transition (Curie temperature) and potentially high magneto-crystalline anisotropy energy (MAE). These properties make them very attractive for sensitive industrial applications where other permanent magnets fail. We assess all the RCo5 systems within the advanced density function theory (that incorporates onsite electron correlation and spin orbit coupling models) framework by calculating their MAE, magnetic moments, and Curie temperatures. We review experimental anisotropy data and do simple machine learning modeling for first order anisotropy constants at low temperature. We find NdCo5 and SmCo5 with planar (non-useful) and uniaxial (useful) magnetic anisotropy respectively to deviate significantly within the light RCo5 MAE trend. Here we focus on the anomalous behavior of NdCo5 and SmCo5 and find the origin of the deviation stemming from the shape of the 4f charge density.

23

Using Radio Emissions to Detect Unknown Quiescent Black Holes and Pulsars

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Quiescent black holes produce large amounts of synchrotron radiation within the radio band due to the presence of the black hole's powerful relativistic jets. Here, we describe a method of locating unknown stellar mass black holes by using two radio sky surveys: VLASS and NVSS. Matching the two sky surveys allows for the spectral index of each source to be determined which can then be used to identify evidence of synchrotron radiation. In an effort to analyze the spectral indices, an interesting offshoot became evident. The steep spectrum point sources within the list may be indicative of unknown pulsars. Matching the list of sources to the ATNF Pulsar Catalogue yielded around 60 sources with a significant number of steep spectrum sources. Although this is very much a work in progress, it illustrates a possible method of discovering previously unknown black holes and pulsars.

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Introductions and competition hub

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