2021 Departmental Poster Competition

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Book of abstracts

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Enhanced mid-infrared absorption by Fabry-Pérot cavity resonance of the coupled surface plasmon and phonon polaritons

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Resonant optical cavity has been utilized extensively in plasmonic nanostructure to enhance a coupling of light and the sub-wavelength scale resonator. The enhanced optical power absorption has been observed in various types of Fabry-Pérot resonant cavity constructed in metal-insulator-metal plasmonic waveguides. For long-wave infrared, surface phonon polaritons have been considered as an alternative to surface plasmon polaritons because of low optical power loss. However, Fabry-Pérot cavity has not been adapted yet because of the complexity to make polar dielectric waveguide which requires both strong field confinement and long propagation length. Here, we experimentally demonstrate the resonant cavity in asymmetric metal-insulator-polar dielectric waveguides presenting a strongly enhanced optical power absorption from the frequency tunable cavity mode of the coupled surface plasmon-phonon polaritons. Our resonant cavity will benefit to design devices for infrared control of fundamental optical processes at the sub-wavelength nanoscale.

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A Search for Kilonova Radio Flares in a Sample of Swift/Bat Short GRBs

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Following the remarkable binary neutron star merger known as GW170817, much research has been conducted to uncover its nature and investigate whether its nearby location presents an opportunity to unveil similar events. GW170817 was accompanied by a gamma-ray burst (GRB) and a kilonova, an optical transient, which is thought to be able to generate late-time radio emission. It has thus been suggested that such late-time emission can be used to find neutron star mergers years after they have occurred. In this context, I will present the results of an analysis aimed at determining whether previously detected GRBs, lacking accurate localization and an early afterglow detection, could have originated from events like GW170817. Specifically, I will discuss the progress of a late-time radio follow-up campaign of a subset of short GRBs in the Swift/BAT sample. The goal of this campaign, carried out with the Jansky Very Large Array (VLA), is to determine whether any of the GRB sites in our sample is associated with kilonova-like radio emission, which would suggest an neutron star merger progenitor.

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A Study On Machine Learning In Muon Tomography

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Machine learning (ML) has been used in almost all aspects of our lives, but Muon Tomography has been rather slow embracing the full capabilities offered by ML. In this paper, we report on the implementation of ML concepts to depth reconstruction by two neural networks (NN) models. The first NN is the image classification model which is used to classify the tomograms to in- and out-of-focus. The training dataset has around 20 thousand tomograms and is used to obtain the best in-focus image. The second model is the object detection model coupled with k-means clustering for shape extraction. The dataset used in this training is unique and has to be annotated. By using k-means clustering, the shape of the detected objects in the tomograms is extracted to generate the 3D reconstruction. The image classification showed an accuracy of 85% and the object detection model resulted in 80% accuracy.

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Muon Tomography for surveying Queen Maeve's Cairn

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This poster details the development of our muon tomography detector in attempt to survey Queen Maeve's Cairn, a burial structure in Ireland. Muon tomography is the process of receiving cosmic muons through detection devices in order to determine internal structure. Muons get absorbed less by materials than other particles, which allows them to probe deeper into materials. The structure of the detector is two layers consisting each of a pair of orthogonal scintillators at a distance away from each other. As a muon passes through both layers, we can determine the position and angle of the muon through the detector. The signal from the detector is processed through a DAQ system for data analysis and image reconstruction. The data is then further compared to our Monte Carlo simulations, and fed into a machine learning algorithm to improve its resolution and depth reconstruction.

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ZTFJ0522: A new compact hot HW Vir binary with a potential substellar companion found in the EREBOS data

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HW Vir systems are binary stars with orbital periods below a few hours, consisting of a hot subdwarf primary and a low-mass stellar or substellar companion. The EREBOS project aims to systematically study the population of HW VIr binaries. ZTFJ0522 was discovered as one of the most compact HW Vir binaries with a period of only 89 minutes as part of the EREBOS project. We obtained follow-up spectroscopy to study the object in more detail. In this poster we will present preliminary results from our analysis. We find a very hot sdO primary with a temperature of ~50,000K making it one of the hottest known hot subdwarfs discovered in an HW Vir. From the velocity semi-amplitude and the assumption of 0.5 Msun sdO star we can estimate a companion mass and find a mass of ~50 Jupiter masses which makes the system a candidate HW Vir hosting a substellar companion. The compact orbit combined with the high primary effective temperature makes ZTFJ0522 a prime target to search for reflection signatures of the cool companion in infrared spectra.

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QuEST: Quantum Erbium Sensor @ TTU

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Quantum sensing focuses on utilizing quantum effects to gain non-classical metrological capabilities. Recently, solid-state qubits (quantum bits) are a promising alternative to superconducting or trapped-ion qubits because of easy integration and scalability. Rare-earth spin qubits have gained attention due to their narrow energy level transitions and long optical spin coherence lifetimes at visible and near-infrared. However, the lifetime of spin coherencies suffers from interactions between the rare-earth qubits and noisy environments. Here, we demonstrate a rare-earth spin qubit sensor embedded on an active resonant cavity on-chip. A single erbium ion is chosen as a spin qubit. By placing the device in the vicinity of a resonant cavity structure, Purcell enhancement occurs, increasing spin coherence lifetimes. Our cavity utilizes a thin film of VO2 deposited onto a gold back-mirror on a sapphire substrate. Vanadium Oxide is an active material whose index of refraction is controllable by a metal-insulator phase transition. We drop cast Er ions onto the VO2 surface and tune the cavity by adjusting its temperature. NMR information of the ensemble is obtained by placing the device in an optical cryostat, applying an external magnetic field, and observing fluorescence lifetime and spin relaxation rate using a pulsed laser and Ramsey interferometer. By observing that external factors can control the lifetime of coherencies and that the signal can be enhanced (or erased) by a reconfigurable cavity, we will demonstrate that our device can be used as a quantum sensor, whose output depends on the coherence of an ensemble of spin states.

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Hydrodynamic Description of Transport Properties in Quantum Wires

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Recently, there has been intense interest in the application of hydrodynamics to quantum gases and liquids. In this talk, I will describe current theoretical work using hydrodynamics to describe the electrons in one-dimensional quantum wires. Often, in these systems, the electron liquid fails to fully equilibrate. In this regime, the system can be described by two-fluid hydrodynamics, the same theory used to characterize superfluid He-4. Our theoretical efforts are focused on connecting transport phenomena to this hydrodynamic description. Specifically, I will present the results of a preliminary calculation of the Peltier coefficient and the resistance in terms of the bulk viscosities of the electron liquid.

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A Search for Intermittent Gravitational Wave Backgrounds

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A stochastic gravitational wave background (SGWB) is composed of signals from many independent and overlapping sources. One source which contributes to this background is a population of unresolvable binary black hole (BBH) mergers throughout the universe. These mergers occur roughly every 5-10 minutes and the signals are about 1 second long in duration, making them "popcorn-like" (or intermittent). We propose a new search which models this "popcorn-like" nature by looking for bursts of cross-correlated power.

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A Pilot Radio Survey of the Galactic Bulge at 1-2GHz

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The Galactic Bulge is a very dense region of the galaxy, and has the observational advantage over the Galactic Center by being out of the plane of the galaxy, thus avoiding a portion of the issues that arise from the presence of dust and gas. This makes the Galactic Bulge an efficient region of the sky to observe and see a high number of many different classes of objects over a relatively small area. Sensitive radio observations of the Bulge region are lacking, though recent all-sky radio surveys have greatly contributed to observations over the area. A targeted survey of this region in the radio should dredge up thousands of radio sources, and, combined with other wavelength data for classification, allow for the various populations of sources in this region to be revealed and compared to theory. A pilot radio survey with the Very Large Array has been observed over part of the Galactic Bulge region as a complement to already-completed optical and X-ray wavelengths as part of the Galactic Bulge Survey project. There are ~1200 unique radio sources in the data. Most sources are point sources and the analysis of the data is ongoing, but so far there are over 100 morphological active galactic nuclei, 33 known planetary nebulae, and about 100 pulsars. It is clear that sensitive radio observations of this region have great potential to reveal the diverse populations present, particularly those where radio emission can be a defining feature for classification.

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Optical Vortex Efficiency for varying grating envelopes using high-phase modulation spatial light modulators

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Spatial light modulators used for diffraction and to induce angular momentum in laser beams has been studied extensively by various teams. Missing in the literature is a systematic analysis of how varying the envelope of the grating can affect the diffraction efficiency of SLMs, both for grating diffraction and for optical vortex generation. The work of Bowman shed light on how one can analyze the potential distortion of an SLM by viewing its phase unwrapping scheme, doing ones best to ensure this line is as linear as possible. Analysis of efficiency through phase unwrapped lines for each hologram has been applied to different grating envelopes. In specific, we have analyzed sinusoidal, sawtooth, triangle, and square envelopes and compared with experimental results. The results show that the sawtooth grating achieves the highest efficiency at a specific diffraction order.

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How to run a poster competition

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