2022 Departmental Poster Competition

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Book of abstracts
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How to run a poster competition

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Maximum Solubilities of Ergosterol and Stigmasterol in Various Lipid Membranes

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The chemical structure of cholesterol is very similar to that of other sterols, such as bacteria sterol ergosterol and plant sterol stigmasterol. However, mammalian cells universally utilize cholesterol. Scientists have been wondering what makes cholesterol so unique that animal cells prefer cholesterol, not other sterols. We recently measured the maximum solubilities of ergosterol and stigmasterol in various types of lipid membranes (DPPC, DOPC, POPC) using an anti-correlation light scattering technique. We found that cholesterol has the highest solubility in lipid membranes (~67 mole %) regardless the saturation of lipids, while other sterols have much lower solubilities. Furthermore, ergosterol and stigmasterol have lower solubilities (15% - 22%) in unsaturated (DOPC) lipid bilayers and higher solubilities (40% - 55%) in saturated (DPPC) lipid bilayers. Our result shows that a small difference in sterol structure can result in a major difference in the behavior of sterols. The uniquely high solubility of cholesterol is essential for cholesterol to perform its biological functions in mammalian cells.

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Discovery of Millisecond Pulsar and Transient Emission in Glimpse-C01

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We present evidence for a strong pulsar candidate and the detection of radio transients in the stellar cluster Glimpse C01. Using images from the VLA Low-band Ionosphere and Transient Experiment (VLITE) centered at a frequency of 340 MHz, we searched 94 globular clusters for steep spectrum radio sources. We cross-correlated with several radio sky surveys including VLASS to further analyze the sources and to calculate spectral indices. We identified a strong pulsar candidate with a steep spectral index (alpha ~ -2.7), which is well within the expected range for pulsars. There is ongoing debate about the classification of Glimpse C01, and confirming that a pulsar is present in the cluster is especially important because it will provide insight on the age of the cluster. In addition, it demonstrates that searches for steep spectrum sources as pulsar candidates are effective in areas of high dispersion. We also observed transient radio emission following the X-ray outburst MAXI J1848-015. This has been identified with a black hole in the center of the cluster; if associated, then the radio emission may be caused by jets from the black hole that appeared within a year of the X-ray outburst.
Detection of Faint Donors in Ultracompact Accreting White Dwarf Binaries

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AM CVn systems are mass transferring compact binaries consisting of a helium-rich white dwarf accretor and a degenerate/semi-degenerate donor having an orbital period of approximately 5-65 min (Solheim 2010). They allow us to study phenomena including stellar evolution and accretion disk physics and they are strong gravitational wave sources (Kupfer et al. 2020). Observationally, the optical data of these sources is dominated by the accreting white dwarf or the accretion disc (e.g., Carter et al. 2013). The donor star has never been observed directly. Due to the expected cool temperatures of the donor star most of the emission is expected in the far-infrared bands. In this project, we combined, for the first time, multi-wavelength data from different resources covering the ultraviolet to far infrared searching for an infrared excess from the donor star. Using the photometric data, distance, and reddening, we measured the temperature and radius of the accretor and the donor. To achieve this, a double blackbody was fitted with the first containing wavelengths below 20,000 angstroms to model the accreting white dwarf and the second containing wavelengths above 20,000 angstroms to model the donor star. We discovered a confident infrared excess for 10 systems marking the first detections of the donor star in AM CVn systems. We find a stable temperature and radius for the donor star but a decrease in temperature and radius for an increase in period for the accreting white dwarf. We compare our results with theoretical models as well.

Assessing Thinking Skills in Free-response Exam Problems: Pandemic Online and In-person

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We present an analysis of students' thinking skills as evidenced in free-response exam problems. We compare two sections, one taught online and the other in-person during the pandemic. The rubric was originally designed based on Bloom’s taxonomy (revised version) to compare thinking skills of students in classes taught by different pedagogies. We discuss the instrument, present results and interpretations.
Palladium Nanoparticles towards Highly Efficient Electrochemical Nitrogen Fixation

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Ammonia is playing a vital role in the sustainability of human development as artificial fertilizer, and an energy carrier to store and transport renewable energy. There are different ways to synthesize ammonia i.e., the Haber-Bosch process, the electrochemical process, homogenous catalysis, etc. Each year, around 150 million tons of NH3 are produced globally through the Haber–Bosch process, which consumes 3–5% of the annual natural gas production worldwide, approximating to 1–2% of the global annual energy supply. Due to the limited supply of fossil fuels, there is a critical demand to use renewable energy to drive the chemical processes that have heavily relied on the consumption of fossil fuels. And also, it is highly desirable to develop an alternative, efficient process for NH3 synthesis, which can simultaneously reduce the CO2 emissions. The electrochemical nitrogen fixation under mild conditions is a promising alternative to the current nitrogen industry. We have observed nitrogen fixation by electrochemical approach due to its simplicity, low cost and speed. We used palladium (Pd) as a cathode, platinum (Pt) as an anode and Pd nanoparticles in LiOH solution. In addition, we are developing measurement techniques to quantitatively measure the production of ammonia.
Magnetic measurements by utilizing the self-oscillating LC-tank circuit

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The techniques utilizing the inductor-capacitor (LC) self-oscillators are versatile experimental tools for the investigation of magnetic properties. Consequently, numerous scientific measurements have employed this type of technique. An LC self-oscillator generically offers high sensitivity because of the intrinsic elimination of the large background due to a long coax cable. The self-oscillator has been successful with frequency ranges from radiofrequency to microwave. However, the applications lack long-wavelength signals although this frequency range can bridge phenomena between the direct current (DC) and alternating current (AC) techniques. We propose and design a brand-new measurement technique based on the Colpitts oscillator (CO).

To characterize the magnetic properties at low temperatures, a commercial superconducting quantum interface device (SQUID) magnetometer is usually used, which provides excellent accuracy. However, the SQUID magnetometer always requires applying a minimum DC external magnetic field of ~1 Oe, and the material with a high magnetic moment is the first choice for the best sensitivity. Whereas the application of CO requires neither a large moment nor a DC applied field to obtain the best sensitivity. Due to the non-perturbative measurement using a long-wave AC and a negligible driving magnetic field, CO technology would allow the investigation of intrinsic magnetic properties. This technique is particularly useful for studying ferromagnetic materials that exhibit decentralized susceptibility near the Curie temperature. CO technique requires a relatively low power to operate, which makes the application of the CO technique at low temperatures possible. CO can also be used as an ultra-stable frequency source and can be used as a reference signal for heterodyne techniques.

The CO circuit is composed of a parallel inductor-capacitor (LC) resonator circuit, and its feedback is realized through a capacitive voltage divider. Measurements with the LC oscillators are typically performed in the frequency domain by using multiple AC amplifiers, mixers, and frequency counters to record the frequency shift of the sample's susceptibility changes. The oscillation frequency is a relatively pure sine wave voltage, which is determined by the resonant frequency of the oscillation circuit. The operating frequency can be varied from 20 kHz to 300 MHz, and the frequency can be fine-tuned by selecting L and C. Although both inductance and capacitance can be used as probes, we use the inductive probe for magnetic materials.

Development of a Likert-style instrument to assess LA’s PCK-Q

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As part of a project to develop a written instrument for assessing learning assistants’ (LAs’) pedagogical content knowledge (PCK) in the context of questioning (PCK-Q), we are experimenting with questions in a Likert-style format. Previously, we have developed and validated questions in free-response format. We are now using those questions as the basis for Likert-style questions. Likert-style questions are different because they require the LAs’ to evaluate possible LA responses to students in classroom scenarios. They are also beneficial because scoring can be automated. The instrument will examine a LA’s ability to identify appropriate responses that provide evidence of the application of PCK-Q in the classroom. We will discuss problem development, present sample problems, and future plans.
A Search for Kilonova Radio Flares in a Sample of Swift/BAT Short GRBs

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Following the discovery of the remarkable binary neutron star merger GW170817, much research has been conducted to uncover the nature of its post-merger remnant. GW170817 was accompanied by a gamma-ray burst (GRB), an optical kilonova, and a radio-to-X-ray emitting structured jet. Several theoretical scenarios predict that, once the jet emission fades sufficiently, the kilonova ejecta itself may power a late-time radio flare associated with the fastest ejecta tail visible years after the merger. This late-time radio emission can reveal important information on the nature of the post-merger remnant, such as whether a neutron star or black hole formed, and can be used as a tool to find nearby, GW170817-like neutron star mergers years after they have occurred. In this context, I will present the results of an observing campaign carried out with the Jansky VLA aimed at determining whether short GRBs in the Swift/BAT sample lacking accurate localization could have originated from events like GW170817.

The LDMX Trigger Scintillator system

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New theoretical developments have motivated “hidden sector” dark matter with mass below the proton mass. The Light Dark Matter Experiment (LDMX) will use an electron beam to produce dark matter in fixed-target collisions. A low current, high repetition rate (37.2MHz) electron beam extracted from SLAC’s LCLS-II will provide LDMX with sufficient luminosity to explore many dark matter candidates. Using a novel detector design, LDMX is expected to definitively search for thermal relic dark matter with masses between 1 MeV and several hundred MeV. The LDMX trigger system will reduce the high repetition rate of 37.2MHz down to about 5 kHz. In order to identify signal events, a missing energy trigger will be used that will rely on knowledge of the number of incoming electrons. To determine the electron multiplicity, arrays of fast scintillators will be used. A strategy for the missing energy trigger will be described. An overview of the LDMX trigger scintillators, the current status of simulation and the preliminary results of the LDMX prototype tests will be presented.
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Quark energy loss measurement with the CLAS detector

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In this analysis, we studied quark energy loss for positive pions produced in DIS events. Measurements of quark energy loss can hopefully help our understanding of hadronization processes. The analysis used data from experiments carried out during the run period EG2 in Hall B of Jefferson Lab, Virginia. The experiments used a 5.014 GeV electron beam and studied the nuclear targets deuterium, carbon, iron and lead.

By looking at the production of pi+ from two different targets we can obtain information about quark energy loss by comparing the curves of the energy spectra. Assuming that the energy distributions from the different targets have approximately the same behavior, the goal of the study is to measure the size of the horizontal shift between the distributions that would correspond to a shift in quark energy. To compare the curves the Kolmogorov-Smirnov statistical test was used, that gives the probability that both curves follow the same distribution.

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Electronic Link Testing for the Inner Tracker Pixel Detector Upgrade at the Compact Muon Solenoid Experiment

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The electrical signal transmission characteristics of electronic links (E-links) are measured for the Compact Muon Solenoid's (CMS) Inner Tracker Detector upgrade. In the KU CMS Electronics Lab, E-links are produced and tested. Data derived from the collisions inside CMS, recorded by a custom readout chip, must be transmitted to low-power gigabit optical transceivers which will send the data outside CMS to be analyzed and stored. This requires a wired connection that can transmit data at speeds of 1.28 gbps over lengths of up to two meters. Electrical transmission characteristics must be measured, including DC resistance, impedance, and bit error rate. The results illustrate how E-link quality varies from cable to cable. Statistical analysis is used to construct a grading system, making it easier to determine whether future E-links need to be repaired or if they are ready to be installed at the CMS detector. The results document how the performance of cables varies as a function of length.
OGLE-BLAP-009 - A Case Study for the Properties and Evolution of Blue Large Amplitude Pulsators

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Blue Large Amplitude Pulsators are a rare class of hot sub-dwarf variable star. These stars periodically change brightness by 0.2 - 0.4 [mag] through the expansion and contraction of their outer layers, on the timescale of 20 to 40 minutes. Today, there are only 24 confirmed BLAPs and observations of these objects are still scarce. There are few measurements of the fundamental properties of these stars, such as masses and radii, and minimal descriptions of their pulsation characteristics though time series spectroscopy. Consequently, their evolutionary history is still debated. Here we present a case study of one of these objects, OGLE-BLAP-009. Using time series photometry and phase resolved spectroscopy, a precise pulsation period of 31.936 ± 0.002 minutes was obtained with radial velocity (RV) variations of ~100 [km/s] and effective temperature (Teff) fluctuations of ~10,000 [K]. These spectroscopic measurements resulted in an average Teff and surface gravity (log(g)) of 28,000 [K] and 4.4, respectively. Using these parameters, we performed a spectral energy distribution (SED) fitting in order to measure the stars radius and mass. This method revealed a radius of 0.54 ± 0.07 solar radii and mass of 0.26 (+0.18,-0.11) solar masses. Evolutionary models of helium-core pre-white dwarfs which include adiabatic pulsation calculations of fundamental and first-overtone radial pulsation periods were constructed with the stellar evolution codes MESA and GYRE. Comparing the observed Teff, log(g) and pulsation period to these models shows agreement with a helium-core pre-white dwarf pulsating in the first-overtone mode. Using the stellar dynamical frequency and the observed frequency, a dimensions frequency factor was calculated for each model. Combining this value for the first-overtone mode with the surface gravity measurement resulted in a radius of 0.63 +/- 0.11 solar radii and mass of 0.36 +/- 0.14 solar masses. These values are consistent with both the spectral energy distribution fitting as well as predicted properties of BLAPs.

Looking for the Largest Bound Atoms in Space

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The largest bound atoms in space have extremely short lives, emitting radio recombination lines (RRLs) that enable the study of the physical conditions of the gas they are emitted from. This project studies hydrogen RRLs from the diffuse ionized gas in the W43 region using the high frequency GBT Diffuse Ionized Gas Survey (GDIGS) and the first results from the GDIGS at Low frequencies (GDIGS-Low). We focus on the brightest emission in the data at around 100 km/s, and using a peak ratio model, compute density estimates of about tens of electrons per cubic centimeter. Carbon RRLs have also been detected, providing further avenues into studying cold atomic gas and the formation of molecular clouds.
Limiting the accretion disk light in two mass transferring hot subdwarf binaries

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Hot subdwarf (sdB) stars are Helium core burning stripped stars predominantly found in binary systems. When the binary companion is a sufficiently massive white dwarf (WD) and the binary period is less than 2 hours, the sdB can start transferring mass to the WD while it is still burning Helium. This mass transfer can potentially detonate and blow up the WD as a double detonation supernova. Although theoretical models support the feasibility of this phenomenon, little is known observationally about the characteristics of mass transfer.

Two mass transferring sdB-WD binary systems ZTFJ2130 and ZTFJ2055 having periods of 39 min and 56 min respectively were discovered recently. Light curve analyses indicated the presence of accretion disks but no clear signs of the same were observed in their spectra. High resolution spectra with Keck/ESI were obtained to perform a detailed analysis and look for accretion features. I present the methods of this high resolution spectral analysis and place constraints on the accretion disk contribution for both objects.

Protocols to Reduce Resource Expenditure of Communication within Networks of Quantum Computers

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It is evident that a network of quantum computers, a quantum internet, will inevitably come into fruition as quantum computing (QC) concludes its nascence. The utility of sharing resources between computational systems is apparent, and it would be imprudent to assume that QC would not follow the same rule. However, there are significant barriers to networking on quantum computers, such as high rates of error, the inherently probabilistic nature of QC, and the copious qubits necessitated by quantum state tomography. Moreover, since qubits possess multiple degrees of freedom and quantum networks must account for variability in measurement results, many conventional approaches of optimizing database accession via sorting algorithms are inapplicable. This raises the question: Is there a way to handle requests for data within a network of quantum computers that universally reduces the computational resources utilized in transmitting the desired information? The author presents two possible solutions to this problem.
One Dimensional Electron System Coupled to Light

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Light-matter coupling is fundamental to many quantum informational platforms.

While the study of coupling to two-state systems is extensive, work on many-body systems coupled to light is select. Given the potential relevance to quantum transduction, for example, we examine radiation from a finite-sized one-dimensional electron system. Considering a variety of physically motivated excited states, we study the many-body state of the system as photons are emitted. We find that the electronic states exhibit entanglement and superradiance, similar to the celebrated Dicke model. In general, we find that the decay processes involve a competition between superradiance and Pauli blocking. This work made extensive use of the bosonization and representation theory.