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X-raying the Sub-lightyear Environment of Supermassive Black Holes

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The innermost environment of supermassive black holes (SMBH) are often hidden from our view by the gas and dust surrounding it on larger spatial scales. They are too small in terms of angular size on the sky to resolve with nearly any modern telescope. However, the X-ray radiation produced in the immediate vicinity of the SMBH allows us to probe the larger-scale components shaped by the tenuous balance between inflows and outflows of matter. Recent studies of active galactic nuclei (AGN) in the nearby universe placed interesting constraints on the geometry of these systems using X-ray data. The percentage of sightlines to the SMBH covered by significant amounts of gas was found to non-monotonically depend on luminosity. We are further probing this relationship using self-consistent multi-epoch spectral analyses, which we will demonstrate using new X-ray data on a high-luminosity quasar and a low luminosity AGN. In the latter case we find a uniform, nearly spherical, low-density distribution of gas on sub-lightyear scales, similar to recent results for other low-luminosity AGN. We will also show how very long baseline interferometry measurements can inform building of new X-ray spectral models for angularly unresolved signatures of the SMBH environment geometry in the X-ray band.

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Diurnal Variation in Cosmic Rays

Lindsay Yatsuhashi, Fiona Willette, Tomohiko Narita; College of the Holy Cross

A diurnal variation is the change in the amount of cosmic rays that reach Earth throughout the day. Due to the Sun's rotation and magnetic field, we expect to see more muons during the daytime and less muons, and therefore less cosmic rays, during the nighttime. Observing muons over many days allows us to look for these diurnal variations in cosmic rays. Cosmic rays are high energy particles that move at the speed of light and create a shower of muons and electrons when colliding with atoms in Earth's atmosphere. The muons that reach Earth's surface can be detected with a telescope composed of a scintillator and a photomultiplier tube. These telescopes record the number of muons that pass through, as well as the time each muon came through, and we can observe cosmic rays by observing the muons. By observing the muons for many days, we can look for diurnal variations in cosmic rays. From our experiments, we did not find evidence of a diurnal variation in cosmic rays.

NEF21-2021-000011

Analysis of ``Non-Prompt" Backgrounds in Four-Lepton Events at the LHC

Iria Wang, Gabriella Sciolla; Brandeis University

In the search for new physics beyond the Standard Model (SM), the ATLAS detector at the Large Hadron Collider (LHC) is collecting an ever-growing collision dataset requiring a precise understanding of background sources. An ideal candidate for high-precision studies of the SM are four-lepton events, which have final states of two same-flavor opposite-charge lepton pairs. These events have contributions from interesting SM processes including single Z boson production, Higgs boson production, and on-shell ZZ production, as well as sensitivity to new physics beyond the SM. However, non-prompt leptons produced by secondary hadron decays or as artifacts of mis-reconstructions contaminate the dataset and must be suppressed. These backgrounds are subject to rare detector effects and are therefore preferentially studied using data driven methods. Through comparisons with Monte Carlo simulated data, I studied a sample of collision data in which the final states include a pair of leptons, and any additional third lepton is likely to be non-prompt. I investigated the non-prompt lepton suppression methods and refined the non-prompt lepton region to reduce systematic uncertainties on background measurements.

NEF21-2021-000017

Semiclassical Trans-Series from the Perturbative Hopf-Algebraic Dyson-Schwinger Equations

Max Meynig, Gerald Dunne; University of Connecticut

The seminal work of Dirk Kreimer and Alaine Connes uncovered the structure underlying Renormalization in quantum field theory. This work has enabled perturbative calculations to incredibly high orders, notably the through the Hopf-approximation of the Dyson-Schwinger equations. We study the Hopf approximation to the Dyson-Schwinger equations for a ϕ^3 theory in six dimensions. Our main new result is to decode the perturbative Hopf formulation to find a rich nonperturbative structure. Our results have the characteristics of semi-classical series involving instanton and anti-instanton interactions but arise from a purely perturbative formalism.

NEF21-2021-000013

Resurgence and the Schwinger Effect

Zachary Harris, Gerald Dunne; University of Connecticut

Describing quantum systems in the presence of extreme electromagnetic fields is a very hard problem, one which defines the frontiers of many areas of research from astrophysics to non-linear optics. In this talk, I will explore the strong magnetic field regime and the complementary strong electric field regime for the Schwinger effect: the creation of particle-antiparticle pairs from vacuum. One of our best tools for solving hard problems is perturbation theory, but many

of the phenomena of interest in systems with strong fields or interactions are non-perturbative. Moreover, even in systems of weak fields, perturbative expansions are generically divergent. Though it seems perturbation theory is completely inapplicable to these problems, it turns out that the divergence of the weak field expansions is deeply connected to the appearance of non-perturbative phenomena. These ideas can be used to construct remarkably accurate new extrapolations from the weak field to the strong field regime.

NEF21-2021-000009

A New Frontier for the Quantum Measurement Problem: The Humble Cloud Chamber

Jonathan Schonfeld; Harvard-Smithsonian Center for Astrophysics

We are taught that quantum wavefunctions evolve smoothly until measurements, when they collapse. Making microscopic sense of this contrast is the measurement problem. Analysis of the microphysics underlying cloud chamber track initiation from radioactive decays shows that apparent collapse can be an idealization of a more complex but smooth process. We test this analysis with opportunistic data found in pedagogical video available on the internet. The results suggest a modification to the standard Born probability rule.

NEF21-2021-000018

Temperature-dependent Characterization of Ge2Sb2Te5 using Multi-wavelength Ellipsometry

Derek Lefcort, Hasan Talukder, Helena Silva; University of Connecticut

With extensive developments over the past few decades, chalcogenide materials have developed from optical disk storage materials to leading candidates for electronic phase change memory (PCM), bridging the gap between the much slower flash memory, and the faster but volatile DRAM. PCM is based on the fast (1-100 ns) and reversible transitions between crystalline and amorphous states of chalcogenide compounds, with high contrast in electrical resistivity that is utilized for data storage. Switching between the stable crystalline state and the metastable amorphous state is done through suitable electrical pulses for crystallization or melt-quench amorphization. Ge2Sb2Te5 (GST) has been the most common PCM material due to its suitable properties but repeated cycling between states (>10^{10} cycles) tends to result in voids within the active region of a device, due to the mass density change between its amorphous and crystalline phases. Voids can leave a device in an irreversible high resistance state and are a main failure mechanism in PCM. We aim to study the amorphous-crystalline mass density change of GST films deposited by sputtering under different conditions, using *in situ* ellipsometry, to identify deposition conditions that can minimize void formation in the material.

NEF21-2021-000015

Electrical Properties of Liquid Crystal Cells

David Webb, Yuriy Garbovskiy; Central Connecticut State University

Liquid crystals are ubiquitous electro-optical materials. Their applications include liquid crystal displays, tunable optical components such as filters, lenses, waveplates, and shutters, to name a few. As a rule, the tunability of liquid crystal devices is achieved by applying electric fields across mesogenic materials resulting in a reorientation of liquid crystals. Ions present in liquid crystals in small quantities can alter this reorientation and compromise the overall performance of liquid crystal devices. Therefore, research into the electrical properties of liquid crystals is very important because it allows the identification of materials suitable for particular applications. Electrical properties of liquid crystals are studied using liquid crystal cells. In this talk, we discuss how interactions between ions and substrates of a liquid crystal cell can affect the measured values of DC conductivity. Because of these interactions, the measured DC conductivity of liquid crystals can depend on the cell thickness. Important information about ions in liquid crystals can be deduced by analyzing this dependence.

NEF21-2021-000002

Neonatal diabetes mellitus and a review of a specific mechanism for mutation in the INS gene for human insulin on the genome using a computer model. Evidence in support of further research and study of this variant.

Robert Goshen, Harriet Papernick; Goshen & Papernick Incorporated, Pittsburgh, PA

A variety of gene mutations are known to play a role in the development of diabetes mellitus in patients from the neonatal to the older adult. This study focuses on a DNA triplet involved in the translation of the preproinsulin precursor peptide (messenger) mRNA into the mature bioactive insulin protein. A successful translation of the mRNA creates a peptide chain with a length of 110 amino acids, but the failure of this triplet called the AUG start codon to properly initiate the translation could potentially yield a mutant chain that damages the pancreatic beta cells, leading to permanent neonatal diabetes disease. Our computer (MS C sharp) simulation model allows both novel and well reported genetic mutation patterns to be tested and evaluated. The results for the case of this AUG start codon are shown to merit further investigation by means of both in vitro processing and expanded collection and analysis of patient genetic information along with the data from medical records.