

Session V – Physics (Alphabetical)

An Optical Spectroscopic Database of Infrared Galaxies in the Bootes Field of the NOAO Deep Wide-Field Survey

Daniil Feldman

Mentor: Baruch Soifer

We are studying 24_μm galaxies in the Bootes field of the NOAO Deep Wide-Field Survey. Usually, emission at 24_μm means these galaxies have active galactic nuclei (AGN) and/or are in the process of star formation. We have 700 spectra of these sources in 3000-10000_Å range. We chose this range because that is where we expect certain emission lines, like H_α or [OIII], to appear. Large H_α/[NII] ratios point to the presence of AGN, while lines like [OIII] allow us to estimate star formation rates. Emission lines analysis of 24_μm sources will be contained in a publicly accessible database. This resource will help us understand how galaxies are formed. For instance, quantifying the fraction of the energy output that comes from star formation versus AGN activity can provide useful constraint for currently existing models of galaxy formation.

Fabrication of Bragg Gratings for Plasmonic Waveguides at Optical Wavelengths

Paul A. Fleiner

Mentor: Kristján Leósson

The boundary conditions present in a dielectric-metal-dielectric structure allow for a solution to Maxwell's equations, known as a long-range surface plasmon polariton (LR-SPP). By nanostructuring the metallic layer, the propagation of the LR-SPP can be efficiently controlled. This phenomenon is explored by using electron-beam lithography to create a Bragg grating within the waveguide, in which plasmons close to the Bragg wavelength are reflected within the waveguide. The wavelength is determined by characteristics of the waveguide, such as the period and the effective refractive index of the propagating plasmon polariton. The Bragg grating structure can be used, e.g., to realize a distributed-feedback plasmonic laser, where the dielectric cladding can either be a dye-doped or fluorescent conjugated polymer. This allows the LR-SPPs that are reflected to provide optical feedback, which can be combined with gain at the Bragg wavelength to create a plasmonic laser in the visible range, where the organic gain materials are most efficient.

Distribution of Star Formation in Intermediate Redshift Galaxies

John Forbes

Mentor: Tom Soifer

Luminous Infrared Galaxies (LIRGs) are dusty galaxies with high star formation rates. In the local universe, these are typically the result of major galaxy mergers which trigger star formation. At redshifts near $z=1$, however, there is little morphological evidence to indicate that the bulk of LIRGs have undergone a recent merger. Theoretical models suggest one solution; evidence for merging may disappear rather quickly as gas rich systems regrow a disk. Alternatively, high redshift LIRGs may just experience elevated star formation from elevated gas levels, unassociated with mergers. This study aims to determine whether star formation in LIRGs is distributed, or concentrated in the center. The former would indicate self-regulated star formation, while the latter would suggest star formation triggered by a merger. This determination is made by comparing five spatially resolved broadband flux measurements (four from the Hubble Space Telescope and one from the Keck observatory using laser guide star Adaptive Optics) to values predicted by theoretical models for a range of parameters. A least squares fit is used to estimate attenuation by dust and the age of stars in the centers, the disk, and the outer regions of each galaxy.

Electrorheological Fluid-Based Microfluidic Logic Gates

Casey Glick

Mentor: Weijia Wen

Applications of microfluidics, the study of flow in sub-millimeter channels, remains limited due to the unscalability of external controls to nanoliter-sized droplets. As a control method, we investigated the use of giant electrorheological (GER) fluid – a non-conducting suspension of nanoparticles in oil that reversibly transforms into an anisotropic solid under external electric fields – as the switching mechanism for microfluidic logic gates. We used photolithography to pattern a structure in polydimethylsiloxane (PDMS) consisting of parallel channels separated by AgPDMS (PDMS matrix with conducting silver microparticles), actuated by a pair of AgPDMS electrodes. Control channels of water droplets in carrier oil determined flow in a parallel GER-only channel. The different dielectric permittivities of oil and water transmitted a fluid-dependent voltage which directly controlled the rheology of the GER. With the addition of a capacitance-based inverter, we developed a reprogrammable universal microfluidic logic gate; by reconfiguring the voltages applied to four control electrodes, this device was capable of performing all sixteen binary logical

operations. This device is biologically compatible, and the central structure of this design supports the development of near limitless variety of computation-based microfluidic devices.

Deformation of a Black Hole Event Horizon by Radially Infalling Particles

Ryan Hamerly

Mentor: Yanbei Chen

We analyze the deformation of a Schwarzschild black hole event horizon using perturbation techniques. First, using the Regge-Wheeler formalism for black hole perturbation theory, we compute the perturbation to the background spacetime metric for a point particle falling radially into a Schwarzschild black hole. Second, by applying perturbation theory to geodesic propagation, we compute the future event horizon of the perturbed black hole and analyze its geometry. This study clarifies the existence of discontinuous kinks in the event horizon prior to merger, and supplements past event-horizon studies conducted with numerical simulations of comparable-mass black hole mergers.

Detection of B-Mode Polarization in the Cosmic Microwave Background using BICEP2: Vacuum Window Construction and Performance

Chao Liu

Mentors: Andrew E. Lange, John M. Kovac

Experiments in recent decades confirming the temperature and polarization anisotropies of the cosmic microwave background (CMB) provide increasing support for the inflation model of the early Universe. However, a discovery of a curl component ("B-mode") polarization in the CMB due to primordial gravity waves, which would rule out alternatives to inflation, has yet to be made. To this end, the BICEP2 polarimeter, scheduled for deployment to the South Pole this October as a powerful new upgrade to BICEP1, specifically searches for degree-scale B-mode polarization from inflationary gravity waves. Due to the faintness of the B-mode signature on the CMB, the BICEP2 cryostat requires a vacuum window that has both high microwave transparency and strength to withstand full atmospheric pressure. Using a multistage pre-stressing assembly process, we are able to construct a vacuum-holding 325mm aperture window made of four lamination-free sheets of Zotefoam PPA30 with a measured transmission loss of less than 0.5% at 150GHz. Additional windows will be made for the Keck Arrays, a suite of another five South Pole CMB polarimeters, following the same prototype. We have also found an alternative window material candidate in response to the very limited supply of Zotefoam PPA30.

Properties of Pseudocrystals, a Class of Self-Similar Structures without Long-Range Translational Order

Eric T Mintun

Mentors: Paul Steinhardt and Salvatore Torquato

This paper explores the properties of a new, hypothetical class of materials, dubbed pseudocrystals here, which are discrete, non-periodic, fully deterministic, generated by an iterative self-similar substitution rule, and possess Fourier transforms that cannot be expressed as a sum of Bragg peaks. Primarily studied here are one dimensional (1D) point patterns put forward by Bombieri and Godreche, though the pseudocrystal class includes other 1D and higher dimensional patterns. Numerical calculations are done of the number variance, which is the root-mean-square variation in the number of points within an interval of a given length averaged over all positions of the interval. For 1D pseudocrystals, it is found to scale with a power of interval length anywhere between zero and two, depending on the self-similar substitution rule for the pseudocrystal. This is significantly different from that of 1D crystals or quasicrystals (independent of interval length) and 1D random patterns (proportional to interval length). The pseudocrystals' diffraction patterns are also numerically calculated. Work is done towards analytically connecting the behavior of the number variance and diffraction pattern to the pseudocrystal's self-similar substitution rule. Further work involves determining the band gap and other photonic properties.

Automated Analysis Of Visual Field Defects

Cindy X. You

Mentor: Wolfgang Fink

Perimetry is the systematic analysis of the visual field and provides ophthalmologists with noninvasive access to the visual system (from retina to visual cortex). The 3D computer-automated threshold Amsler grid test (3D-CTAG, see http://autonomy.caltech.edu/biomedicine/3d_computer_automated.html; Fink & Sadun, JBO 2005) allows for an unprecedented characterization of the structure of visual field defects in three dimensions. The purpose of this SURF is to create an automated classification system for visual conditions based on 3D-CTAG data. The system, in the absence of clinical experts, will assess new visual field data, objectively characterize visual field defects, and probabilistically predict the ailment based on 3D-CTAG data. The classification system is currently capable of (1) identifying the number of visual field defects and (2) deriving the shape, extent (area and volume), perimeter, slope distribution, and

orientation for each identified defect. These objective parameters serve as the input for the subsequent automated classification of visual field defects using statistical methods and artificial neural networks. Equipped with the above analysis package, the online-based 3D-CTAG will be a significant step towards screening and examining people worldwide, and may assist physicians with an independent second opinion or provide expertise where otherwise not readily available.