The Second Annual PHAS Symposium

SB 146 and SB 148

February 22, 2017

Program

09:30 am - 10:00 am: Registration and coffee (SB 146)

10:00 am - 10:15 am: Opening of the Symposium (SB 146)

10:15 am - 11:45 am: Session 1 (SB 146)

Chair: Anna Ordog

- Jordi Baró Urbea
- Parisa Zarkeshian
- Taylor Cameron
- Kianoosh Tahani
- Nafiseh Sang-Nourpour

11:45 am - 1:15 pm: Poster session and lunch (SB 148)

- Aaron Barclay
- Grayson Owen
- Marcel.lì Grimau Puigibert

1:15 pm - 2:45 pm: Session 2 (SB 146)

Chair: Abdullah Khalid

- Russell Shanahan
- Isaura Oliver i Alabau
- Neda Amiri
- Andres Zambrano Moreno
- Mahmood Noweir

2:45 pm - 3:15 pm: Coffee break (SB 148)

3:15 pm - 4:45 pm: Session 2 (SB 146)

Chair: Mehrnoosh Tahani

- Alexander Anscombe
- Masoud Habibi Davijani
- Mohammad Hassan Yaghoubi
- Sarah Weppler
- Yadong Wu

4:45 pm - 5:00 pm: Closing remarks (SB 146)

5:00 pm - 7:00 pm: Social event (LDL)

The organizing committee would like to thank the Department of Physics & Astronomy, the PHAS DGA and PASA for their financial support for this symposium.

The organizing committee

- Abdullah Khalid
- Anna Ordog
- Mehrnoosh Tahani
- Elizabeth Watt

Presentation Abstracts

Critical and non-critical failure in mean field models of avalanche dynamics exhibiting triggering

J. B. Urbea and J. Davidsen

The mechanical failure of materials under external forces is a paradigmatic example of a non-linear phenomenon exhibiting avalanche dynamics. Instead of a smooth response, the micromechanical evolution of the system can be simplified as sequence of quiescent intervals and sudden stress releases that we call 'avalanches'. Part of the energy is radiated as mechanical waves that can be detected far from the source. At the geological scale, we identify them as earthquakes. In lab experiments, we call them 'labquakes' and are detected by means of ultrasonic piezoelectric transducers.

The energy of the recorded events is power-law distributed, implying that earthquakes and labquakes are both scale-free phenomena, usually associated to criticality. Several models reach the critical state after a smooth evolution towards a 'critical failure' stress. However, the hypothesis of critical failure is not consistent with some experimental results exhibiting a stationary distribution of energies during the whole failure process. We use a simple mean field model with generalized viscoelasticity to show how the same mechanisms giving rise to temporal correlations (triggering) explain also the stationary scale invariance observed in those experiments. Instead of changing the universality class, transient effects (such as viscoelasticity) disassociate the failure point and the critical point. Throughout the derivation of this model, we propose a new way to define such universality class, that does not rely on critical failure, but rather on the scaling of the energy distribution and the old concept of accelerated Benioff strain release.

Entanglement between many large atomic ensembles in a solid

P. Zarkeshian, C. Deshmukh, N. Sinclair, S. K. Goyal, G. H. Aguilar,
P. Lefebvre, M. Grimau Puigibert, K. Heshami,
D. Oblak, W. Tittel and C. Simon

The fundamental question whether quantum features such as superposition and entanglement can exist in macroscopic systems has spurred many experiments. One important type of entangled states corresponds to a single excitation that is delocalized over many quantum systems. Such "Dicke states" have been created for photons and cold atoms in free space. In the solid state, superradiance associated with a Dicke state was recently demonstrated for two superconducting qubits. In this project, we create Dicke states of many atomic ensembles in a solid by storing a single photon in a crystal that contains atomic ensembles with different resonance frequencies (atomic frequency comb system). The photon is re-emitted at a well-defined time due to an interference effect. We derive a lower bound for the number of entangled atomic ensembles based on the visibility of the interference and the single-photon character of the input state. We experimentally demonstrate entanglement between more than two hundred ensembles. Our results are the first demonstration of entanglement between macroscopic subsystems in a solid.

Using Mutual Information to Probe Geomagnetic Response to Solar Wind Orientation

T. Cameron and B. Jackel

The Earth's magnetic field is strongly influenced by the solar wind. Strong solar wind 'pushes' on the front of the magnetosphere, strengthening the magnetic field inside. Rapid variations in the solar wind, known as 'shocks', can have an especially dramatic effect on the magnetosphere. In particular, the orientation of the shock can have a large effect on how geoeffective (how strongly it affects the Earth's magnetosphere) a shock is, with shocks impacting the magnetosphere dead on being more geoeffective. In this presentation I present some early research investigating if this relationship can be extended to the solar wind all the time, even when the solar wind is not shocked. This is done using a mutual information analysis of a decade of solar wind and ground magnetometer data.

Characteristics of Pre-Protostellar Clumps from the Combined HiGal & JPS Galactic Surveys

K. Tahani, R. Plume, T. Moore, D. Eden et al.

Stars are constantly being formed in galaxies via fragmentation and gravitational condensation of the Interstellar Medium; notably in Giant Molecular Clouds (GMC). The GMCs, at some point, become unstable and forms higher density clumps. These clumps are sites of star formations. Despite the importance of massive stars (¿8Mo) to the energy budget of galaxies and production of heavy elements, their formation remains a major open question in astronomy. Therefore, extracting properties (physical, velocity structure, density, temperature, etc.) of star forming regions is essential. However, since the high mass stars are rare, they are typically at large distances. Therefore, more resolving power is needed for their identification. Higher resolving power can distinguish one massive clump from an an ensemble of clumps. Thus, angular resolution in observation is a paramount importance.

Data presented here are collected from two different telescopes, Herschel Space Observatory and James Clerk Maxwell Telescopes (JCMT). Herschel has a lower resolution than JCMT telescope. Therefore, it might be possible that a single clump detected by Herschel may actually be multiple unresolved clumps. This can be addressed by the higher resolution JCMT data. Therefore, can be defined as the probability that a clump may break down into multiple clumps. In the case of clump breaking, the flux change/break will cause the extracted properties of the clump to be altered. It is important to note that, since the high resolution 450 m data are only available in our two pilot regions, all current and future

statistical studies of the properties of star forming clumps in the Galaxy will incorporate only the low resolution Herschel data. Thus, they will have no independent information about clump breakup in their specific regions of study. My work will provide an important statistical correction factor () that can be used for the rest of the HiGal dataset.

Existence Criteria for Surface Plasmon Polaritons at Interface of Lossy, Linear, Isotropic, Homogeneous Materials

N. Sang-Nourpour, B. R. Lavoie and B. C. Sanders

We derive rigorous criteria for existence of surface plasmon polaritons (SPPs) at planar lossy interfaces by determining bounds for the square of the complex propagation coefficient for fields at the interfaces. Determining existence or nonexistence of SPPs is important to check the viability of a given study or application. Our existence criteria verify that the existence of SPPs does not just depend on the signs of permittivity and permeability at the interface, but additionally depends on the relative values of their real and imaginary parts. We show that SPPs cannot exist for double-negative refractive index regions with arbitrary values of permittivity and permeability and we employ our existence criteria to show that certain prior predictions of SPPs are not correct. Metamaterials are gaining interest for a variety of applications and having a clear understanding of SPPs at the interfaces of metamaterials with dielectrics is important. However, metamaterials are lossy and thus a careful treatment of lossy interfaces is essential to evaluate whether SPPs exist under given condition. We also explore the propagation coefficient and the wavenumber of the modes at the interface, as the characteristics of SPPs at the interface depend on these parameters.

Broadband Radio Polarimetry of the THOR Pilot Region

R. Shanahan

This thesis presents the first results of broadband polarimetry of the HI, OH, Recombination Line Survey of the Milky Way (THOR) pilot region. The THOR pilot survey covers $l =$ 29.2 degrees to 31.5 degrees, $|b| < 1$ degrees at frequencies from 988.433 MHz to 2012.433 MHz with an angular resolution that ranges from 24.4" x 15.1" at 988.433 MHz to 9.0" x 8.3" at 2012.433 MHz. After calibrating the visibility data for total intensity as well as polarization two mini-mosaics image cubes were made for the targets of this thesis. The two targets studied within the THOR pilot region presented in this thesis are the supernova remnant (SNR) Kes 75 and the star formation region W43-Main. At the frequencies of the THOR survey are thermal and synchrotron emission. By the use of Rotation Measure (RM) synthesis, it is found that the pulsar wind nebula (PWN) in Kes 75 and some diffuse emission in W43-Main display complex Faraday rotation.

Inferring networks from maximum entropy method

I. O. i Alabau and J. Davidsen

The maximum entropy give us the most stable configuration of a system. When the system has many interacting elements we can infer its structural network using the information shared by its elements. Our group has introduced a new method to compute the maximum entropy. This method consists in the conditioning of the univariate entropies and bivariate mutual information, and allow us to use information diagrams to compute the maximum entropy. We applied this method on synthetic data generated from the Kuramoto model of coupled oscillators. The method was able to capture well the information of the system when signals are discretized down to two states. We have applied the same method on fMRI data and we found the structure for two different models to represent the brain as a network: the default mode network and the fronto-parietal network.

The Role of Hydrocarbons in SO2 Oxidation in Oil Sand Regions of Alberta

N. Amiri, R. Ghahremani, O. Rempilo and A. Norman

Aerosols are tiny solid or liquid particles suspended in the atmosphere. They can cause adverse health impacts, degrade visibility, and change the climate by direct and indirect effects. Sulfate is an important component of atmospheric aerosols. A large portion (more than 50%) of atmospheric sulfate aerosols are formed within the atmosphere through SO2 oxidation. SO2 can be oxidized in gas phase mainly by OH radical and in the aqueous phase by H2O2, O3, and O2. Recently the role of hydrocarbons in the atmospheric SO2 oxidation has been investigated largely. Its been found that ozonolysis of alkenes forms Criegee intermediates which can be stabilized and oxidize SO2 in the atmosphere. Various field works and modeling studies have been conducted to determine the role of Criegee intermediates in SO2 oxidation but there are still disagreements between the measurements and modeling results. This can be because of unknown important SO2 oxidation pathways or wrong reaction rates of SO2 and Criegee intermediates. Oil sand regions are SO2 and hydrocarbon rich environments, so they are of great interest to investigate the role of hydrocarbons in SO2 oxidation. My study focuses on the oxidation pathways of SO2 and the role of hydrocarbons in SO2 oxidation in Oil sand regions of Alberta Canada.

Features of the self-similar model of aftershocks rates

A. Z. Moreno, J. Davidsen and M. Baiesi

Self-similarity is ubiquitous in many aspects of nature and can be seen anywhere from the head of a romanesco broccoli to the distribution of galaxies in the universe. In seismicity, one particular form in which self-similarity manifests itself is through the relation between

magnitude and the overall number of earthquakes (known as the Gutenberg-Richter relation). The Omori-Utsu relation which is often used to describe the temporal evolution of aftershocks or triggering is generally not self-similar. It has recently been shown through the analysis of data from Southern California along with comparison of self-similar and nonselfsimilar models, that seismic models which contain temporal decay of aftershocks with a specific form of self-similarity give a more accurate description of real world data and thus provides a strong motivation to develop and study these type of models further.

In this talk we will discuss various features of the self-similar model as well as our ongoing work where we establish the effective statistical properties that arise due to the presence of self-similarity in the triggering rates.

Radio over fiber for 5G wireless communication

M. Noweir, Q. Zhou, V. R. R. Valivarthi, A. Kwan, F. Ghannouchi, W. Tittel and M. Helaoui

The Radio-Over-Fiber (ROF) technology is bringing promising advancement to telecommunication world. Utilizing the speed of light as a carrier will offer high data rates, and huge number of subscribers. In addition, it will lead to saving in Capital Expenditure and Operational Expenditure compared to traditional electrical networks. Many applications based on ROF motivates telecommunication companies to design and commercialize an efficient ROF link. Proposal for efficient future fronthaul Radio Over Fiber (ROF) downlink and its applications in 5G wireless communication is demonstrated here. Electro-Optic Modulation (EOM) technology is the interface between electrical and light signals, needs to be optimized for efficient and better quality transmissions system. MZMs are inevitably needed to serve as an external (EO) modulators, especially when carrying high data rates. The transfer characteristics of MZMs is a cosine function which is highly nonlinear when driven by strong signal that exceeds midway boundaries (between minimum and maximum transmission points) causing eventually degradation in its output quality Lookup table (LUT) model is a digital Predistortion (DPD) algorithm that is relatively low in complexity while able to provide acceptable performance to MZM nonlinearity.

Deep field radio galaxies and their polarized emission

A. Anscombe

Astronomers are masters of light. By exploiting the subtle phenomena present in electromagnetic radiation, we uncover deep truths about the objects we study. In radio astronomy, physical properties of cosmic environments can be revealed by measuring polarized radio emission from various sources in the universe.

Polarized electromagnetic waves have a preferred orientation rather than being randomly scattered like the light form a light bulb. This preferred orientation is altered by magnetic fields and magnetized plasma of which polarized emission may travel through from the emitting source and on towards our radio telescopes here on Earth.

My master's thesis is focused on galaxies who are host to an active galactic nuclei (AGN). The AGN generates a massive double-lobed structure that is very bright in the radio part of the electromagnetic spectrum. This emission is measurably polarized and is subject to Faraday rotation. I will speak about the methods I use to infer characteristics of the host galaxy and it's surrounding environment.

This field of astrophysics is very active and will receive a further boost of excitement with the construction of the Square Kilometre Array (SKA) located in South Africa and Australia. The SKA is a technological feat and will be the most sophisticated radio interferometer ever built. This international project is well underway, and first-light observations are already being collected and analysed. For more information go to skatelescope.org

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Continuous-variable quantum ramp secret sharing

M. H. Davijani

The security of continuous variable quantum secret sharing protocols is compromised because of finite squeezing and local oscillator strength. In a protocol with weakened security quantum information can leak to an adversary. My aim is to analyse the effect of the finite squeezing on the security of continuous variable quantum secret sharing protocols.

Non-trivial neuronal avalanche dynamics in developing neuronal cultures

M. H. Yaghoubi, T. de Graaf, F. Girotto, J. G. Orlandi1, M. Colicos, and J. Davidsen

Using optical imaging techniques, we study neuronal avalanches in cultured neuronal networks and compare cases in which they developed in the presence of a low concentration of folic acid metabolites to control cases. For the latter, we find that the neuronal avalanches follow approximately the behavior of a simple mean-field branching process if one excludes system-wide events, consistent with other experimental observations in the past. In the case of folic acid, however, the neuronal avalanches appear to be in a distinct universality class with vastly different critical exponents. This is consistent with the expectation that the increase in synaptic density due to folic acid metabolites is an indicator of significantly different structural connectivities in the two cases and that feedback loops play a much more important role in cultures developing in the presence of folic acid making the network more susceptible to seizure-like dynamics.

Adaptive Radiation Therapy: Adjusting Cancer Treatment Plans to Account for Changes in Patient Anatomy

S. Weppler, H. Quon, R. Banerjee, C. Schinkel and W. Smith

When clinicians design an external beam radiation treatment plan for cancer patients, it is assumed that a pre-treatment CT scan will accurately represent patient anatomy throughout the 6-7 week treatment course. In select cases, patient weight loss and tumor shrinkage may violate this assumption, potentially leading to underdosing of the target volumes and overdosing of surrounding healthy structures. Adaptive radiation therapy (ART) - the adaptive adjustment of treatment plans in response to anatomical changes has been proposed as a solution. However, open questions remain regarding how to best identify those patients in need of a treatment replan to balance improvements in patient treatment quality with efficient clinical resource allocation. In this presentation, I will briefly overview key features of existing ART literature, present results of an ART protocol assessment performed at the Tom Baker Cancer Centre, and outline proposed future research.

Spacetime replication of quantum information using (2,3) quantum secret sharing and teleportation

Y. Wu, A. Khalid, M. H. Davijani and B. C. Sanders

Our research focuses on a quantum task, called spacetime replication of quantum information, which is a generalization of quantum no-cloning in a relativistic setting. The aim of this work is to build a protocol to replicate quantum state in any valid set of causal diamonds and to show the resources required to replicate quantum information. We provide a set of codes to convert the spacetime configuration of request points and reveal points to optical circuits for state replication, and give the bounds of the resources, in the form of squeezing, required for replicating continuous-variable quantum information. This work gives the first general protocol for replication of quantum information and formulates spacetime replication of quantum information as an adversarial game.

Poster Abstracts

Spectroscopic observation of the O-bonded T-shaped isomer of the CO-CO2 dimer and intermolecular frequency measurements

A. Barclay, S. Sheybani-Deloui, K. H. Michaelian,
A. R. W. McKellar, and N. Moazzen-Ahmadi

Binary systems of molecules are often used for construction of accurate potential energy surfaces. Infrared spectra of the CO-CO2 dimer is presented where a new O-bonded isomer is discovered along with intermolecular frequency measurements for both C- and O-bonded isomers. From this experimental data, comparisons with previous theoretical studies are made which show a need for new high level ab initio calculations.

Active frequency multiplexing of heralded single photons

M. G. Puigibert, G. H. Aguilar, Q. Zhou, F. Marsili, M. D. Shaw, V. B. Verma, S. W. Nam, D. Oblak and W. Tittel

Single photon sources (SPS) are key ingredients in quantum information technologies such as quantum computation and quantum communication. However, current SPS are far from perfect, hence limiting the performance of these applications. In particular the commonly utilized heralded sources based on spontaneous parametric downconversion process (SPDC) intrinsically have a statistical nature because they are based on a spontaneous process. Fortunately, active multiplexing and feed-forward operations have been proposed to overcome this limitation. Here, we propose and demonstrate a novel multiplexing approach in the spectral degree of freedom (SMUX). We experimentally implement multiplexing of 3 distinct spectral modes in a correlated SPDC spectrum. This is achieved by narrow spectral filtering, a nearly 100% efficient spectral-shifting operations, and precise synchronization. As a proof-of-principle, we show that spectrally multiplexing three modes increases the heralded photon rate compared to that of the individual modes without compromising the quality of the single-photons emitted. Although the improved rate is cancelled by the added loss required to implement the multiplexing we stipulate that the loss is fixed and independent of the number of modes. We conjecture that, by combining SMUX with the already explored multiplexing in the different degrees of freedom, a deterministic SPS could be accomplished.

Creating Neonatal Ultrasound Simulations using 3D printing

G. Owen

Medical imaging techniques are an important tool for physicians and technicians to use when diagnosing and treating illness. CT, MRI and Ultrasound are commonplace in most medical facilities due to their ease of use and far reaching applications. Ultrasound, in particular, is the ideal modality for diagnosing disease in children and infants due to several factors. For example, Ultrasound does not introduce ionizing radiation into the patient in the way that CT does, which is extremely important for developing children. Due to the considerations associated with neonatal ultrasound, it is beneficial for physicians and students to have access to training simulations that familiarize them with up-to-date ultrasound techniques. Such a simulation would ideally be low cost to produce and operate, easily communicable within the medical community, adaptable in order to simulate various conditions, and would make use of the same tools that are used when performing a live ultrasound. Currently, there exists no neonatal ultrasound simulation. This project proposes using 3D printing manufacturing to create a cheap, accurate model of a neonate brain to be used as a simulation tool. 3D printing presents a novel opportunity to create a simulation that satisfies all of the previously listed ideal characteristics. This project discusses the practicality, approach and challenges associated with using 3D printing to create a neonatal ultrasound simulation.