Space Science Seminar Presentations
Agenda, 1:00-5:00PM
Tuesday, October 9, 2018

Reinhard Friedel, CSES 5min 1:00-1:05pm
Introduction to CSES Space Focus Area Presentations

Yue Chen, ISR-1 20min 1:05-1:30pm (5min Q&A)
CSES Internal project
Title: Listen to the Canary: Understanding and Utilizing a Storm Precursor in Low-Earth-Orbits for MeV Electrons in the Earth's Radiation Belt

Kateryna Yakymenko, T-5 20min 1:30-1:50pm (5min Q&A)
CSES Post doc project
Title: Beam-plasma interaction physics in support of active space experiments

Katherine Mesick, ISR-1 15 min 1:50-2:15pm (5min Q&A)
CSES Emerging Ideas R&D
Title: Engagement in LunaH-Map Mini-NS Detector Calibration

Daniel Coupland, ISR-1 20min 2:15-2:40pm (5min Q&A)
CSES Emerging Ideas R&D project
Title: Analysis of Lunar Prospector Data to Constrain the Neutron lifetime

Hot Rocks Café- BREAK 15min 2:40-2:55pm

Andrew Walker, ISR-3 20min 2:55-3:20pm (5min Q&A)
CSES Emerging Ideas R&D
Title: DREAM utilizing real-time Van Allen Probe data

Kimberley Nichols, AOT-AE 20min 3:20-3:45pm (5 min Q&A)
CSES Emerging Ideas R&D project
Title: Plasma Waves Generated by Energetic Electrons Injected into Magnetized Plasma at the Large Area Plasma Device at UCLA

Grant Miars, T-5 20min 3:45-4:10pm (5 min Q&A)
CSES Student Project
Title: Laboratory validation of electron beam emission mediated by a plasma contactor

Rollin Lakis, NEN-1, 20min 4:10-4:35pm (5 min Q&A)
CSES Emerging Ideas R&D project
Title: A drone-based gamma ray imaging system for application

Suzanne Nowicki, ISR-1 20min 4:35-5:00pm (5 min Q&A)
CSES Emerging Ideas R&D project
Title: Thermal neutron flux characterization at aircraft altitudes with the TinMan Detector **(PENDING ABSTRACT)**

Listen to the Canary: Understanding and Utilizing a Storm Precursor in Low-Earth-Orbits for MeV Electrons in the Earth's Radiation Belt

Yue Chen, ISR-1, LANL

Relativistic electrons trapped in Earth's outer radiation belt present a highly hazardous radiation environment for spaceborne electronics. These electrons, with kinetic energies up to multiple megaelectron-volt (MeV), manifest a highly dynamic and event-specific nature due to the delicate interplay of competing transport, acceleration and loss processes. Thus, developing the capability of forecasting outer belt MeV electrons has long been a critical and challenging task for space weather community. Recent studies have demonstrated the vital roles of electron resonance with waves (including such as chorus and electromagnetic ion cyclotron); however, it remains difficult for current diffusion radiation belt models to reproduce behaviors of MeV electrons during individual geomagnetic storms, mainly because of the large uncertainties existing in input parameters. This work designs a new model called PreMevE that is able to predict storm-time changes of MeV electrons within the outer belt. This model, taking advantage of the cross-energy, L-shell, and pitch-angle coherence caused by wave-electron resonant interactions, ingests observations from belt boundaries—mainly NOAA POES from low-Earth-orbits (LEOs)—to provide high-fidelity nowcast (multiple hour prediction) and forecast (> ~1 day) of MeV electron fluxes over L-shells between 2.8-7 through linear filters. As a first of its kind, PreMevE can not only accurately predict incoming enhancements of MeV electrons during storms with 1-day forewarning time, but also reliably specify the evolving electron spatial distributions afterwards. The high performance of PreMevE is assessed against long-term in situ data from one Van Allen Probe and a LANL geosynchronous satellite. This new model enhances our preparedness for severe MeV electron events during post-RBSP era, and further adds new science significance to existing and future LEO space infrastructure.

Beam-plasma interaction physics in support of active space experiments

Kateryna Yakymenko, T-5, LANL

Electron beams are ubiquitous in space and astrophysical plasmas. Such beams present a free energy source and are known to excite various electrostatic and electromagnetic waves. This can potentially be used to artificially generate waves that are very efficient in scattering energetic electrons present in natural environment. Active space experiments where beam parameters can be controlled are crucial to study beam-generated radiation and its ability to scatter background electrons. A NASA Beam-PIE ("The Beam-Plasma Interactions Experiment") project will fly an advanced electron beam on an ionospheric rocket in order to generate plasma waves capable to induce measurable precipitation of electrons. Our work supports the design of the Beam-PIE experiment through theoretical studies and numerical simulations.

In this presentation we will first revisit basic physics of the coupling between an electron beam and a magnetized plasma in the framework of cold-plasma theory. Next, using highly-accurate 3D Vlasov code called the Spectral Plasma Solver (SPS), we will demonstrate that pulsed electron beams radiate through Landau resonance for field-aligned beam propagation and through higher-harmonics cyclotron resonances for oblique beam propagation. We further show that the beam mainly radiates through high-frequency Z-mode and the radiated power does not depend on the pitch angle of the beam. The beam pulse self-charge can deform the pulse thus affecting the radiation. We explore the effect of the self-charge on the pulse spreading. A simple physics-based model to account for the beam spreading is developed and tested against Particle-In-Cell (PIC) simulations. We demonstrate that the model describes well pulse spreading for the case of field-aligned beam propagation. We couple the model with SPS to simulate the radiation from a finite-width pulsed beam. Using the pulse spreading model we also show that a lower background density and a larger transverse size can increase the longitudinal extend of the radiated field. Finally, using PIC simulations we discuss the possibility to increase the transverse size of the beam by adding a pitch angle spread to the electron beam distribution.

Engagement in LunaH-Map Mini-NS Detector Calibration

Katherine Mesick, ISR-1, LANL

The miniature neutron spectrometer (Mini-NS) is a CLYC based neutron detector flying as the primary payload on the Lunar Polar Hydrogen Mapper Cube-Sat mission, lead by Arizona State University. LunaH-Map will detect epithermal neutrons over the South pole of the Moon at low altitudes, leading to a map of water-ice in permanently shadowed craters with excellent spatial resolution. The Mini-NS detector will be calibrated at LANL which will be described in this short presentation.

Analysis of Lunar Prospector Data to Constrain the Neutron lifetime

Daniel Coupland, ISR-1, LANL

The neutron decay lifetime is of considerable interest right now. At the moment, there are two major techniques to measure the lifetime, and the difference between the results from the two are an order of magnitude larger than the uncertainty quoted by the most precise individual measurements. One of the techniques, or both, have missed a systematic correction to their measurements. Constraints on beyond-the-standard model physics are possible with the precision that should be achievable by future experiments, but these future measurements cannot be believed if the discrepancy between measurement techniques remains. A robust third technique with completely different systematic corrections is needed to resolve the controversy.

This project is a proof-of-principle evaluation of a technique to measure the neutron lifetime using a satellite-based neutron detector in an elliptical orbit. Cosmic ray spallation on planetary bodies or atmospheres creates a source of neutrons, which have been observed in the past to measure the elemental composition, particularly the hydrogen abundance, of the top tens of centimeters of the Moon, Mars, Mercury, Vesta, and Ceres. Thermal neutrons move slowly enough that the flux at an orbiting satellite depends on the neutron decay lifetime. Using data collected during several highly elliptical orbits by the Lunar Prospector Neutron Spectrometer during orbital insertion, we evaluate the utility of the orbital technique to measure the neutron lifetime.

DREAM utilizing real-time Van Allen Probe data

Andrew Walker, ISR-3, LANL

Satellites whose orbits pass through the Earth's radiation belts are subject to anomalies and hazards due to energetic charged particles trapped in the belts. In order to better predict and diagnose the conditions that cause spacecraft anomalies, some satellites have been equipped with instruments designed to monitor the space environment. The Van Allen Probes were built specifically for this purpose and are considered the gold standard for radiation belt measurements. The Van Allen Probes three primary space environment instruments include HOPE (low energy), MagEIS (medium energy), and REPT (high energy). One major advantage of the Van Allen Probe data over other space environment monitoring satellite data such as GOES or the LANL-GEO satellites is that the Van Allen Probes are in highly elliptical orbits and therefore measure the radiation belts under a much larger range of radial and magnetic field conditions than geosynchronous satellites.

Van Allen Probe data is available in two forms: science and beacon data. Science data is available at a lag of approximately a week compared to when the measurements were taken whereas beacon data is available in near real-time. The beacon data undergoes less processing/filtering, is available only in a spin-averaged form, and has significantly less temporal coverage than the science data. While the Van Allen Probe science data is critical for historical studies and physical analysis of the radiation belts, it cannot be used to forecast the state of the radiation belts due to the lag time in data processing. But the beacon data alone are localized data that cannot be easily extended to other locations in the radiation belts without the use of a data assimilative model. The Dynamic Radiation Environment Assimilation Model (DREAM) is such a model that allows using localized measurements as input into a one-dimensional radial diffusion model of the radiation belts in order to obtain a global estimate of the energetic particle populations.

In this study, a data processing pipeline was developed to download and pre-process Van Allen Probe beacon data for the MagEIS instrument for ingestion into DREAM. Because the Van Allen Probe data only includes spin-averaged fluxes but DREAM requires the pitch angle distribution of fluxes, the Relativistic Electron Pitch Angle Distribution (REPAD) code was applied to convert the spin-averaged beacon data fluxes to the required DREAM format. Comparisons were made between the pitch angle distribution of the Van Allen Probe science data and beacon data after REPAD was applied to determine the errors associated with applying the REPAD model. For the time period compared, the Van Allen Probe science and beacon data with REPAD applied show excellent agreement. The preprocessed Van Allen Probe beacon data and GOES energetic particle flux data were ingested into DREAM in order to obtain near real-time estimates of the global radiation belts. Historical comparison were also made to determine the effect on the output DREAM phase space density (PSD) of using Van Allen Probe beacon data as opposed to higher fidelity Van Allen Probe science data. The primary improvement of using Van Allen Probe science data over beacon data is the reduction in discontinuities in the DREAM PSD. Beacon data generally has multiple large time gaps which results in discontinuities in the DREAM PSD. The science data has nearly continual temporal coverage and the DREAM PSD does not suffer from these discontinuities. The final product of the study is an automated chain that produces global DREAM PSD in near-real time based on GOES and Van Allen Probe beacon data.

Plasma Waves Generated by Energetic Electrons Injected into Magnetized Plasma at the Large Area Plasma Device at UCLA

<u>Kim Nichols, AOT-AE, LANL</u>

We were able to successfully couple an 18.3 kV electron beam from a LANL designed electron gun into the LAPD Plasma and observe interesting waves further down in the plasma. The first set experiments demonstrated out ability to inject beam into the LAPD device and propagate it along the device. We observed waves of high frequency (~fpe), and lower-frequency waves (fci< f< fce) modes excited by the injected beam and the edge of the beam profile. These results are highly encouraging, there are plans to do another experiment at 18.3 kV with beamline improvements before adding a linac to increase the beam energy to 1 MeV. I present results of the first laboratory experiments here and a plan for the next set of experiments.

Laboratory validation of electron beam emission mediated by a plasma contactor

Grant Miars, Omar Leon, and Brian Gilchrist
The University of Michigan, 1301 Beal Avenue
Ann Arbor, MI 48109 USA

Gian Luca Delzanno
Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Spacecraft charge mitigation in tenuous space plasmas is especially difficult and essential during experiments that feature ion or electron beams. This is primarily because current collection from a tenuous space plasma is often insufficient to balance the beam emission. The imbalance between collected and emitted currents leads to significant spacecraft charging such that the beam is pulled back to the spacecraft. In the last few years, LANL has attempted to find a solution using Curvilinear Particle-In-Cell (CPIC) simulations. These CPIC simulations predict that a plasma contactor (which emits an ionized gas) should act as a self-regulating source of ions and represents the only practical option to mitigate spacecraft charging for electron beam experiments in tenuous space plasmas.

A series of vacuum chamber experiments were performed at the University of Michigan in order to validate this critical spacecraft charge mitigation scheme. The key results are presented in brief during this presentation. Preliminary experiments demonstrated that (simulated) spacecraft neutralization could be achieved in the laboratory. Next, large-scale experiments in the 6 x 9 meter Large Vacuum Test Facility determined the contactor plasma's response to spacecraft charging and where ion emission actually occurs. A smaller scale study of localized ion emission currents roughly matched analytical predictions and revealed additional considerations for modeling a real world system. More recent work has examined how spacecraft charging scales with electron beam current and contactor ion mass in comparison to CPIC predictions. Follow-on projects, collaborations, science community engagement, and plans moving forward are also summarized.

A drone-based gamma ray imaging system for application to Mars

Rollin Lakis, NEN-1, LANL

The goal of this project was to demonstrate the feasibility of using a CnZnTe (CZT) gamma ray imager on a drone platform to obtain information about the geochemistry of Mars-analog field sites. Our preliminary results will support a proposal by this team to the NASA Planetary Science and Technology through Analog Research (PSTAR) program. To simulate measurement of water-bearing martian materials, we acquired a set of neutron-induced gamma ray spectra in the laboratory using a DT Neutron generator (14.1 MeV neutrons) to act as a surrogate for cosmic ray interactions to induce characteristic gamma rays. The signatures of martian surface materials were created by the combination of water and one of three materials: Two compositions of commercially available Mars soil simulant, and gypsum drywall to act as a surrogate for observed martian gypsum deposits. Both a conventional high purity germanium detector (HPGe) and a CZT detector were used to collect data.