Abstracts

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Topic 1: Current Status of Research & Forecasting

Ashwin Ashok

Ashok, Ashwin (1), Padgett, Tori (1), Sadykov, Viacheslav(1), He, Xiaochun(1), Martens, Petrus (1)

(1) Georgia State University

Monitoring Solar Effect with CubeSats on Cosmic Ray Flux Variation at Ground Level

A research team at Georgia State University is developing a global network of low-cost cosmic ray muon particle detectors for monitoring the dynamic changes of space and earth weather in real-time. The muon particles are mainly created in the region between the lower stratosphere and the upper troposphere by the interaction of the primary cosmic ray particles (mainly protons of galactic origin but modulated with solar activities) with molecules of the earth atmosphere. The muon flux variations recorded in the detector network are in close correlation with the changes in earth's weather condition and in solar-driven space weather events. By recording the muon flux at the ground level on earth in real-time and at a global scale, one could quantify and potentially forecast the changes both in the space and earth weather through AI-based model analysis. One of the challenges of this study is to disentangle the flux changes which are dominated either by the solar activities or the fluctuations of the weather system on earth. By launching cosmic ray detectors in a CubeSat we should be provided with a direct measurement of solar modulation of the global muon flux in the cosmic ray detector network. The team has assembled a 1U CubeSat prototype which consists of three 9cm x 9cm x 1cm scintillator sheets, GPS, an Inertial Measurement Unit (IMU), a LoRa communication module, lithium polymer battery, solar panels, and a custom-designed Raspberry Pi hat. All elements have been assembled into a custom designed chassis to support the scintillators. The three-layer cosmic ray sensor system provides coincidence counts between any two layers from passing galactic and solar cosmic ray particles. The details of the prototype design and development of the LoRa device to gateway and device to device communication system will be presented at this conference as well as the continuation of further research.

Charles Swenson

Utah State University, Logan, Utah

Science from an ad hoc ITM CubeSat constellation [invited scene-setting talk]

The increased number of ITM CubeSat and nanosat missions provides a new opportunity to answer long-standing ITM science questions by treating these individual missions as an ad hoc constellation. Multiple missions are planned to launch over the next few years funded through multiple agencies both domestically and internationally. When grouped together, these missions can provide new insight into the dynamic nature and control mechanisms in the thin layer of ionized plasma between Earth's atmosphere and space. The scientific value multiplies when analyzed alongside larger missions (such as ICON, GOLD, COSMIC-2) and ground networks (including imagers, GNSS, radar). This paper presents existing and future CubeSat and SmallSat missions, as well as science opportunities that will use the data from this ITM constellation to investigate the drivers of the variability of this region and coupling mechanisms.

Craig DeForest

DeForest, Craig (1), Gibson, Sarah (2), Seaton, Dan (1), Killough, Ronnie (1), Henry, Alan (1), Colaninno, Robin (3), Laurent, Glenn (1), and the PUNCH Team

(1) Southwest Research Institute, (2) University Corporation for Atmospheric Research, (3) Naval Research Laboratory

Tracking Space Weather Events with the Polarimeter to UNify the Corona and Heliosphere (PUNCH)

PUNCH is a constellation of four smallsats, under development for NASA's Explorers program and slated to launch to sun-synchronous low Earth orbit in 2025. The four satellites will work together to form a single "virtual instrument" that images the entire outer solar corona and inner heliosphere, in polarized light, once every four minutes throughout its mission. The PUNCH data analysis pipeline makes use of polarimetry to measure the 3-D location of bright features in the field of view. This permits, for the first time, direct tracking of space weather events in three dimensions as they propagate through the inner solar system. Space-weather-relevant observing targets include both solar ejecta up to and including coronal mass ejections, and also solar wind features that develop in transit, such as stream interaction regions or the "flocculae" observed by STEREO. PUNCH develops both scientific data products with multi-day latency determined by best practices for deep background subtraction, and prototype forecasting data products with shorter latency determined by the ground pass schedule of the mission. We describe current status and data products from the mission, and some of the potential space weather applications enabled by PUNCH.

David Tsiklauri

University of Georgia

Particle acceleration by dispersive Alfvén waves

Open research question that smallsats could address in this presentation is related to particle acceleration by dispersive Alfven waves both in the context of Auroral Zone density cavities in Earth Mangnetosphere and Solar coronal flaring loops. Tsiklauri, Sakai, & Saito, Astron. Astrophys. 435, 1105 (2005) have shown that if DAW propagates in plasma with transverse (with respect to external magnetic field) density inhomogeneity, the generated parallel electric field is orders of magnitude higher than (i) homogeneous plasma case and (ii) Dreicer electric field (one that triggers electron run-away acceleration). Subsequently Tsiklauri Phys. Plasmas 19, 082903 (2012) has revisited the problem with full 3D particle-in-cell approach. Ofman JGR 115, A04108 (2010) considered similar set up as in Tsiklauri, Sakai, Saito (2005) but instead of considering one DAW harmonic with 0.3 ω_{ci} he considered f^{-1} AW cascade and added He++ ions and used Hybrid simulation model. Note that our approach uses PIC code so it can resolve

electron-scale physics contrary to Ofman who used Hybrid code, which can resolve only ion-scale physics. Now in the present work we essentially revisit Ofman's set up run it for two cases:

1. when transverse density gradient is $\sim c/\omega_{ci}$ (as in Tsiklauri, Sakai, Saito (2005) and Tsiklauri (2012)), i.e. on "electron"-scale;
2. when the gradient is on ion scale circa 40 c/ω_{ci} (as in Ofman (2010)) i.e. on "ion"-scale.

In this presentation novel numerical simulation results will be presented. Including the scaling of the magnetic fluctuations power spectrum steepening in the higher-density regions, and the heating channelled to these regions from the surrounding lower-density plasma due to wave refraction. We also present runs where DAW collide multiple times in a situation similar to Daiffallah (2022) Journal of Plasma Physics, 88(1), 905880120.

Jaejin Lee

Jaejin Lee and SNIPE team

Korea Astronomy and Space Science Institute

Introduction to the SNIPE mission for studying micro-scale space weather phenomena

SNIPE (Small scale magNetospheric and Ionospheric Plasma Experiment) is a scientific mission consisting of four 6U CubeSats of ~10 kg developed by KASI (Korea Astronomy and Space Science Institute) for space weather research. The observation of particles and waves causing space storms with a single satellite inherently suffers from space-time ambiguity. Small-scale plasma phenomena on low altitude orbit have not been studied intensively. The goal of the SNIPE mission is to measure the spatial and temporal variations of the micro-scale plasma structures on the topside ionosphere. The spacecraft has two deployable solar panels and four body-mounted panels to produce electric power of more than 44W. SNIPE is a 3-axis stabilized spacecraft consisting of three reaction wheels, magnetorquers, sun sensors, star trackers, MEMS Gyros, and magnetometers to achieve the capability of attitude control with an accuracy of less than 1 arc degree. The onboard computer utilizes the core Flight Software (cFS) and handles the command and data in addition to the guidance, navigation, and control processing with a high-speed micro dual processor. The communication subsystem is a critical part of deciding CubeSat's success. For low-speed but effective communication, UHF, and for high-speed data download (~1Mbps), S-band uplink/downlink RF modules are installed on the bus system. In addition, the IRIDIUM communication module would make possible real-time housekeeping monitoring in addition to providing an opportunity to upload changes in operational modes when geomagnetic storms occur. In the SNIPE mission, the key technology is the demonstration of formation flying. For the orbit maneuver, each spacecraft has a cold gas thruster that produces the total thrust of del-v 50 m/sec, and GPS receivers determine the accurate position of less than 10 m.

Jesper Gjerloev

Jesper Gjerloev, EZIE Team

JHU-APL

EZIE: A Cubesat Mission to Study The Electrojets

The Electrojet Zeeman Imaging Explorer (EZIE) is an innovative multi-satellite mission that images the magnetic fingerprint of intense electrical currents flowing in the upper layers of Earth's atmosphere. EZIE's multi-point measurements of these electrojets will provide closure to decades-old, and much debated, mysteries of the interaction between the Earth and the surrounding space. In situ measurements of the electrojet region have proved elusive because the altitudes are too high for balloons and too low for satellites. EZIE's multi-point measurements will provide unprecedented 2D current maps allowing for a separation of spatial and temporal variations of the electrojets. EZIE will address two primary science questions:

[Q1] What is the structure and evolution of the auroral electrojet segment of the substorm current wedge?

[Q2] To what extent is the auroral electrojet modulated by localized (hundreds of kilometers) current segments?

The presentation will provide an overview of the mission science story with a focus on the how this relate to society.

Jonas Sousasantos

Sousasantos, Jonas (1), Abdu, Mangalathayil Ali (2), Fejer, Bela (3), Loures da Costa, Luís Eduardo Vergueiro (2)

(1) The University of Texas at Dallas, (2) Instituto Tecnológico de Aeronáutica, (3) Utah State University

ITASAT2, SPORT, and the contribution that small satellites provide to answer big scientific questions about the phenomenology over low-latitude regions

The space weather community is experiencing a breakthrough in terms of measurement capabilities. Successful missions, such as GOLD, may provide information over wide regions and have been revealing unprecedent macroscopic features over low and mid latitudes. The investigation of some aspects, however, require local or consecutive measurements. Very often this is not possible to achieve using these wide coverage approach. Miniaturized satellites, known as Cubesats, also belong to this boost of technological development and, despite the small size and cost, are able to carry valuable scientific instruments and provide very important measurements, being suitable for local and consecutive measurements. On this talk, some details about the scientific motivation leading to the development of two cubesat missions under progress, the ITASAT2 and the SPORT, will be presented, highlighting some unique features added to these missions. These small-satellite missions may collect data that is crucial to advance our comprehension about the formation of the equatorial plasma bubbles and the ensuing ionospheric scintillation on transionospheric signals, two of the most relevant space weather topics for low and mid latitudes. These cubesat missions were also planned to provide data that might be used to improve ionospheric models and to build forecasting strategies.

R.D. Bentley

Mullard Space Science Laboratory, University College London

A Space WeatherForecasting System for the Inner Heliosphere

Over the next two decades, there is a good possibility that humans will start to explore the inner heliosphere, away the protection of the Earth's environment. Although it will be time before various aspirations are realized, it will also take time to build and deploy a space weather monitoring system that is capable of supporting exploration activities.

Current space weather monitoring assets are very much oriented towards the Earth. We consider where new assets should be placed in order to both improve the ability to forecast space weather events that might affect the Earth and also facilitate the generation of forecasts for the entire inner heliosphere.

The aim would be to try to maximize the capability with the minimum number of spacecraft. Two constellations would be required but capabilities are significantly enhanced even when they are only partially deployed.

Rebecca Bishop

Rebecca L. Bishop (1), Aroh Barjatya (2), James H. Clemmons (3), Richard L. Walterscheid (2), Tad Gielow (1), and Diana Swanson (3)

(1) The Aerospace Corporation, USA, (2) Embry-Riddle Aeronautical University, USA, (3) University of New Hampshire, USA

The LLITED Mission: Part of the Growing Grass-Roots Ionosphere/Thermosphere Constellation

The LLITED mission will provide both ionosphere and thermosphere measurements with the goal of better understanding the coupling between the Equatorial Ionization Anomaly (EIA) and the Equatorial Temperature and Wind Anomaly (ETWA). While the EIA and ETWA are form and are maintained throughout the day, they also persist for a time post-sunset. LLITED will observe the phenomenon at this later time in order to better understand its coupling and dissipation. LLITED will, for the first time from a CubeSat, provide coincident high-resolution measurements of the dusk side ionosphere/thermosphere (IT) at lower altitudes that will characterize and improve our understanding of the ETWA, provide insight into the coupling physics between the ETWA and EIA, and increase our knowledge of the dusk side dynamics that may influence space weather.

The LLITED mission consists of two 1.5U CubeSats in a high-inclination circular orbit hosting three payloads each: an ionization gauge (IG), planar ion probe (PIP), and GPS radio occultation sensor (GPSRO). In addition to provide a focused study on the EIA/ETWA, LLITED will be one of over a dozen more IT CubeSat mission that will fly in the next few years resulting in a unique grass-roots IT constellation that will enable exploration of different parts of the IT system. This presentation will discuss the LLITED mission, the growing IT constellation of CubeSats, and how to better utilize and visualize the data from the constellation.

Tzu-Wei Fang

Tzu-Wei Fang (1), Terry Onsager (1), Nai-Yu Wang (2)

(1) NOAA/SWPC, (2) NOAA/NESDIS

Utilizing Small Satellites in Operational Space Weather Forecasting

The Space Weather Forecast Office (SWFO) at NOAA Space Weather Prediction Center (SWPC) monitors the space weather conditions 24/7 and issues space weather alerts and warnings. To make space weather forecasts possible, it is necessary to combine various observations from satellites and ground-based instruments to obtain specifications and nowcast. To provide forecasts of space environments near the Earth, typically these measurements need to be applied in the state-of-the-art models to provide simulation outputs for consideration. The increasing capability of the small satellite community and industry has largely enhanced the possibility of utilizing the smaller spacecraft in space weather monitoring. In this panel discussion, I will talk about SWPC's operations and models, discuss the possible space-based measurements in the small-satellite platforms based on NOAA NESDIS's space weather operational requirements that will benefit space weather operations, briefly describe several studies on Observing System Simulation Experiments (OSSEs) that were carried out, and share the ongoing NOAA projects that aim to utilize small satellites to improve space weather monitoring and forecasting.

Xiaojia Zhang

Zhang, Xiao-Jia (1,2), Angelopoulos, Vassilis (2), Artemyev, Anton (2), Mourenas, Didier (3), Tsai, Ethan (2), Wilkins, Colin (2)

(1) Department of Physics, University of Texas at Dallas, Richardson, TX, (2) Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, (3) CEA, DAM, DIF, Arpajon, France

New Insights on Energetic Electron Precipitation as Revealed by ELFIN

Energetic electron precipitation (loss to the atmosphere) due to wave-particle resonant interactions is one of the most important drivers for radiation belt dynamics. Due to the small equatorial loss-cone size, precipitation characteristics can be easily resolved only by spacecraft at low altitudes, where the local loss cone is large. In this presentation, we will review the main patterns of energetic electron precipitation as observed by UCLA's ELFIN CubeSats. ELFIN

provides the first low-altitude, high-resolution (in both pitch angle and energy) observations of energetic electrons, yielding new insights on: microburst precipitation of relativistic (>500keV) electrons as a result of resonance with field-aligned chorus waves, sub-relativistic (<200keV) electron precipitation bursts driven by electron resonances with very oblique whistler-mode waves, quasi-periodic sub-relativistic precipitation driven by ULF-modulated whistler-mode waves, and multi-MeV electron precipitation due to resonance with electromagnetic ion cyclotron waves. We will also discuss the main characteristics of waves responsible for each precipitation pattern and highlight remaining open questions for future SmallSat missions.

Young-Sil Kwak

Young-Sil Kwak (1), Jaejin Lee (1), Jongdae Sohn (1), Jaehung Park (1), Tae-Yong Yang (1), Ho Sub Song (1), Junga Hwang (1), Won-Kee Park (1)

(1) Korea Astronomy and Space Science Institute

SNIPE Mission for Space Weather Research

The small scale magnetospheric and Ionospheric plasma experiment (SNIPE)'s scientific goal is to observe spatial and temporal variations of the micro-scale plasma structures on the topside ionosphere. The four 6U CubeSats (~10 kg) will be launched into a polar orbit at ~500 km. The distances of each satellite will be controlled from 10 km to more than ~1,000 km by the formation flying algorithm. The SNIPE mission is equipped with identical scientific instruments, solid-state telescopes, magnetometers, and Langmuir probes. All the payloads have a high temporal resolution (sampling rates of about 10 Hz). Iridium communication modules provide an opportunity to upload emergency commands to change operational modes when geomagnetic storms occur. SNIPE's observations of the dimensions, occurrence rates, amplitudes, and spatiotemporal evolution of polar cap patches, field-aligned currents (FAC), radiation belt microbursts, and equatorial and mid-latitude plasma blobs and bubbles will determine their significance to the solar wind-magnetosphere-ionosphere interaction and quantify their impact on space weather. The formation flying CubeSat constellation, the SNIPE mission, will be launched in the first half of 2023.

Topic 2: Data Exploitation & Modeling Ideas

Brianna Maze

NextGen Federal Systems

Machine Learning Platform for Weather Applications at Scale

Data-driven machine learning (ML) approaches have been shown to outperform statistical approaches in most settings. However, results in the literature have historically been difficult to reproduce when the code or datasets are not available, and the runtime environment is not well documented. To combat this, the ML community is moving towards an ‘open-source’ approach, where code and data are encouraged to be made publicly available to ensure reproducibility.

There is not currently a single catalog of all datasets and models that are available for use, but rather one-off repositories scattered across various sites. Each of the repositories provides its own pipeline for transforming data, training a model, performing prediction, and evaluating a model. In essence, researchers are implementing their own ML pipeline, reinventing the wheel each time, even though most of the pipeline can be generalized to a variety of problem areas. This process of building out a pipeline for each problem is costly, time-consuming, and leads to results that are not reproducible and not easily comparable against like algorithms.

The Machine Learning Platform (MLP) addresses these issues by providing a “one-stop shop” for ML needs. The goal of MLP is to enable teams to develop ML applications at scale by providing tools and techniques that allows for rapid implementation and evaluation of new models. The ecosystem provides data pre-processing features such as normalization and outlier detection, data labeling capabilities, and data experimentation and visualization tools through JupyterHub. Users can use the platform to quickly kick-off model training, prediction, and evaluation tasks, monitoring the progress of each throughout its runtime.
NextGen has completed the first Research-to-Operation (R2O) transition of MLP to operations in a Cloud environment, deploying MLP to an operational DoD cloud environment. This transition was an important step to expand the platform, moving it forward from a research project to an operational ecosystem. Multiple teams are currently utilizing the operational platform for training and evaluating their own algorithms, including teams working on contrails detection, synthetic weather radar generation, and lightning forecasting.

MLP provides the ability to rapidly prototype state-of-the-art models, and in turn, helping to bridge the gap between DoD mission SMEs and ML SMEs. This reduces the duplication of work, allows for rapid experimentation and prototyping of ML techniques, and provides life-cycle management of ML artifacts. MLP trained models are easily extracted for use in an operational environment. This unified platform and pipeline will accelerate the advancement of AI and ML across a variety of domain areas in the DoD.

Christopher Pankratz

Christopher Pankratz (1,2), Jenny Knuth (1,2), Greg Lucas (1,2), Thomas E Berger (2), Dusan Odstrcil (3)

(1) Laboratory for Atmospheric and Space Physics (LASP) / Univ. of Colorado, (2) University of Colorado, Space Weather Technology, Research, and Education Center, (3) George Mason University

Two Tools to Enhance Access to Space Weather Data: One Tool to Access 100+ Data Sets and One Tool That Enables Interactive 3D Visualization of the Heliosphere

Two tools are presently available to the community that enable improved access and visualization of space weather phenomena. This talk will introduce these tools, provide a brief demonstration of each, and communicate recent advancements and enhancements to their capabilities. These tools have been developed by the Space Weather Technology, Research, and Education Center (SWx TREC, pronounced ""space weather TREK""), at the University of Colorado, Boulder, in collaboration with the Laboratory for Atmospheric and Space Physics (LASP).

The first tool presented here is The Space Weather Data Portal, which provides an easy way to access, organize, and visualize more than 170 data sets relevant to space weather events. Space weather data is diverse by nature and housed in disparate repositories, each with its own organizational system and formats. Accessing this diverse data typically requires a commitment of time and effort, and can come with a steep learning curve. To address this challenge, we developed the Space Weather Data Portal (https://lasp.colorado.edu/space-weather-portal). The Data Portal makes it easy to find, access, display and correlate a variety of space weather data all in one place. The aim of the website and its underlying API-driven data access service is to reduce the effort spent searching for and accessing space weather data and increase the time users spend on space weather research and education. Designed for researchers, educators, forecasters, and students, the Space Weather Data Portal is especially useful for illustrating the entire life cycle of a space weather event from the moment it occurs on the Sun to its impacts at the Earth. For example, you can look at SDO AIA imagery along with GOES X-ray flux and ACE solar wind measurements from NOAA, then add ground-based magnetometers from the USGS and see it all on one screen. You can easily save, share, download, and even later return to your selections. With practically no learning curve, the Data Portal does the work of accessing the data from many different sources while the user can more freely explore a space weather event as it propagates from the Sun to the Earth.

The second tool presented here is h3lioviz (https://swx-trec.com/h3lioviz/), an open source and publicly accessible visualization capability to take advantage of the full 3D data volumes produced by the Enlil solar wind model, which is a crucial tool used at forecasting centers around the globe for modeling (coronal mass ejection) CME propagation through the heliosphere. Solar wind models such as Enlil are critical to informing space weather forecasters of the direction, speed, and arrival times of CMEs and informing studies of CME evolution. Models like Enlil calculate the propagation of the solar wind throughout the 3D heliosphere, but large data volumes and traditional visualization capabilities have been restricted to 2D planes intersecting the Earth or other solar system satellites, thus limiting the utility of the model’s rich output data. Here, we present an update on this novel tool, which takes advantage of the full 3D

data volumes produced by the Enlil model. With this tool, a forecaster or other user can interactively visualize the expansion of a CME over time, including outside of the planes intersecting the Earth. We have developed this tool in close collaboration with the Met Office in the UK, the Space Weather Prediction Center (SWPC) in the USA, NASA's Community Coordinated Modeling Center (CCMC), and the Enlil developer to ensure that the tool is tailored to both researchers and forecasters. To enable this capability given the very large output data volumes produced by these models, the visualization interface is accessible via a standard web browser, with both the output data and visualization engine residing together within an Amazon Web Services (AWS) Cloud-based computing environment, which permits interactive visualization without the need for a user to transfer large data volumes to their local computer.

Space Weather Data Portal: https://lasp.colorado.edu/space-weather-portal
H3lioviz 3D Visualizer: https://swx-trec.com/h3lioviz/

Enrico Camporeale

University of Colorado, Boulder & NOAA Space Weather Prediction Center

How Machine Learning is reinventing Space Weather

Machine Learning is often described as a tool in the toolbox of the computational physicist. That is certainly true, but that definition is short-sighted, in my opinion. Machine Learning is crucially at the core of reinventing the way we approach and solve problems in physics. Space Weather offers a prime example.

Enrico Camporeale

University of Colorado, Boulder & NOAA Space Weather Prediction Center

An overview on the state of Uncertainty Quantification in SWx

Uncertainty Quantification (UQ) is still a relatively new concept in Space Weather. In this talk, I will present the state-of-the-art regarding some UQ application in SWx and a personal perspective on future research.

Irina N. Kitiashvili

Kitiashvili, Irina N. (1), Foy, Arthur (2), Sadykov, Viacheslav M. (3), Ranjan, Shubha S. (1), Spaulding, Ryan C. (1), Deardorff, Donald G. (1)

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Development of HelioPortal to Enable Reliable Forecasts of the Solar Activity Through Data Assimilation and Machine Learning Approaches

The crucial role of solar activity in influencing space weather requires monitoring and predicting solar activity and its manifestations (such as magnetic flux emergence, flares, global magnetic field variations, and others) to mitigate their impacts on human health (e.g., radiation hazards for astronauts and airplane crew), space technology, communication, and navigation systems. Because solar activity covers a variety of phenomena across a wide range of temporal and spatial scales, it is impossible to describe them in a single model. Also, the physical nature of many solar phenomena is not well understood. At the same time, the available observational data cannot provide complete information, and observing processes introduce uncertainties and bias in the interpretation. Thus, to enable robust forecasts of solar activity manifestations and their impact on Space Weather conditions, we need: 1) model the observed phenomena, 2) organize the available observations in databases, and 3) develop advanced techniques to analyze available data and assimilate them into models.

We develop the HelioPortal infrastructure, which includes multi-instrument databases for specific phenomena and supports building advanced physics-based models and data assimilation procedures to reconstruct past, current, and predict future solar activity states. The HelioPortal at NASA Ames (https://data.nas.nasa.gov/helio/) intends to include all these components. It currently consists of the Interactive Multi-Instrument Database of Solar Flares, Solar Radiation Data Portal, and numerical global and local radiative MHD models of the Sun. In addition, the ongoing development of the Global Solar Activity (GSA) data portal collects historical and modern data and intent to provide an observation-driven picture of the global solar activity from the deep interiors to the corona. This presentation discusses the status and challenges associated with the development of the HelioPortal and data assimilation and machine-learning approaches for predicting various aspects of solar activity.

Jack Ireland

Ireland, Jack (1), HDRL Consortium (2)

(1) Solar Data Analysis Center at NASA Goddard Space Flight Center, (2) Heliophysics Digital Resource Library

Readying data for research and space weather applications

There are an ever-increasing number of uses and users of data that are obtained from multiple sources. Combining data from multiple sources is often necessary to derive insight. There are an ever-increasing number of sources of relevant data for research questions, including documentation, software, and research papers. In addition, there are multiple computational platforms availble to users. Satisfying multiple users and multiple use cases running on multiple platforms places requirements on data and data systems. In addition, NASA open science requirements mean that science data must be available and usable. In this presentation I will describe some principles that can guide the development of data and data access systems. I also describe how the resources available via the Heliophysics Digital Resource Library (HDRL) allow users to provide data, and to analyze them.

James A. Bednar

Anaconda, Inc.

Open-Source Tools for Agile Big-Data Exploration, Visualization, and Analysis

Constellations of small satellites can quickly produce large quantities of space-weather data. Efficient workflows for exploring such data are essential so that researchers can easily examine the raw data, discover inconsistencies and gaps, and detect novel phenomena. However, typical analytics toolchains are localized on a single machine far from the source data), limited to a single machine's RAM or CPU power, limited to a predefined set of plots and analyses, require expensive proprietary licenses that make sharing analyses difficult, and/or require extensive coding even for common use cases. This talk will outline and demonstrate an open-source Python toolchain supporting easy exploration, visualization, and analysis of huge datasets on the cloud or on HPC systems. Components of this toolchain include Jupyter, for browser-based execution of code on remote cloud servers, Zarr and Parquet for efficient block-addressable distributed multidimensional and columnar file access, Intake for accessing groups of files through a high-level data catalog, Dask for distributed and out-of-core computation, Numba for compiling Python functions directly to machine code, Xarray and Pandas for multidimensional and columnar data structures, cuDF and CuPy for optional GPU acceleration, Datashader for server-side rendering of large and distributed datasets, and hvPlot and Panel for plotting and for building apps ranging from one-line ad hoc exploratory tools to full browser based data-exploration and analysis suites, bringing all of the other tools together into a convenient and extensible user interface inside or outside of a Jupyter notebook. Every component is open source and fully customizable, easily dropping down to lower-level tools where feasible, making it simple to get started even with large and complex data while supporting arbitrarily complex and ambitious apps and workflows when required. These tools let anyone with basic Python experience work with big space-weather datasets efficiently, focusing on your science and research goals rather than on coding or working around the limits of proprietary toolsets.

Matthew West

West, Matthew (1), Seaton, Daniel (1) DeForest, Craig (1), Hughes, Marcus (1), Lowder, Chris (1)

(1) Southwest Research Institute

The PUNCH mission and designing a science operations center for a constellation mission

The Polarimeter to UNify the Corona and Heliosphere (PUNCH) is a NASA Small Explorer to image the corona and heliosphere as parts of a single system. Imaging the corona and heliosphere together from a constellation of four synchronized smallsats, PUNCH will provide a unique window on global structure and cross-scale processes in the outer corona and young solar wind. In this presentation the challenges related to building the science reduction software, and the overarching Science Operations Centre (SOC), for such a mission are described, with emphasis on the techniques used to reconstruct observations obtained from four separate platforms, designed to observe co-temporally with partial co-spatiality. A brief overview to the PUNCH mission and the expected observations will be presented, followed by the layout of the SOC, the unique object orientated software reduction pipeline being built, and the challenges related to particular portions of the data reduction pipeline. A brief concluding discussion will focus on the PUNCH mission as a constellation amongst other satellites.

Piyush Mehta

Piyush Mehta (1), Richard Licata (1)

(1) West Virginia University

Uncertainty Quantification Techniques for Data-Driven Space Weather Modeling

Machine learning (ML) has been applied to space weather problems with increasing frequency in recent years, driven by an influx of in-situ measurements and a desire to improve modeling and forecasting capabilities throughout the field. Space weather originates from solar perturbations and is comprised of the resulting complex variations they cause within the numerous systems between the Sun and Earth. These systems are often tightly coupled and not well understood. This creates a need for skillful models with knowledge about the confidence of their predictions. This talk will discuss techniques for uncertainty quantification for operational space weather models.

Subhamoy Chatterjee

Subhamoy Chatterjee (1), Andrés Muñoz-Jaramillo (1), Maher Dayeh (1, 3), Kim Moreland (3, 1), Hazel M. Bain (2)

(1) Southwest Research Institute, USA, (2) CIRES CU Boulder / NOAA SWPC, USA, (3) University of Texas, San Antonio, Texas, USA

Forecasting the Probability of Solar Energetic Particle Event Occurrence using a Multivariate Ensemble of Convolutional Neural Networks

The Sun continuously affects the interplanetary (IP) environment through various interconnected and dynamic physical processes. Solar flares, Coronal Mass Ejections (CMEs), and Solar Energetic Particles (SEPs) are among the key drivers of space weather in the near-Earth environment and beyond. While some CMEs and flares are associated with intense SEPs, some show no or little SEP association. Furthermore, there is no clear and consistent connection between the properties of SEPs observed at 1 au and their progenitors at or near the Sun. The latter is due to the complex environment dominating SEP origin, acceleration, and transport in the IP space. To date, robust long-term (hours-days) forecasting of SEP occurrence does not effectively exist and the search for such development continues. In this work, we present an ensemble of Convolutional Neural Networks that ingest both remote, and in-situ pre-flare properties and are aimed toward the prediction of actual probabilities of Solar Energetic particle event occurrence. This provides flexibility for the users of our forecast to determine their own acceptable level of risk, rather than imposing a threshold of detection that optimizes an arbitrary binary classification metric. We also show how the model-ensemble performs on unseen data and how the uncertainty achieved from the ensemble approach adds value.

Topic 3: Instrumentation, Enabling Technologies & Mission Concepts

[WITHDRAWN] Aimee Merkel

Aimee Merkel (1), Katelynn Greer (1), Richard Eastes (1), Scott Evans (2), Greg Holsclaw (1), Rick Kohnert (1)

(1) Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO (2) Computational Physics Inc., Springfield, VA

The DYNamics Atmosphere GLObal-Connection (DYNAGLO) CubeSat mission

The DYNamics Atmosphere GLObal-Connection (DYNAGLO) cubeSat mission will help fill a crucial observational gap in the thermosphere –gravity wave characterization. DYNAGLO mission focus is to provide the community with global thermosphere gravity wave measurements and their characteristics to be correlated with known gravity wave sources (terrestrial and geomagnetic). Estimated to launch in 2025, DYNAGLO uses two 6U CubeSats in a string-of-pearls configuration, each with a miniaturized Far Ultraviolet Imager (FUVI) to provide common volume 2D nadir images (latitude, longitude) of neutral density variations at 150km. The two cubesat configuration will allow the extent, location, wavelength and phase speed of secondary and tertiary gravity waves to be characterized. DYNAGLO science goals are to determine: (1) What spectrum of gravity waves are present in the thermosphere and to what extent are they driven by lower atmospheric sources of gravity waves? (2) Is there a spectrum of thermosphere gravity waves that are correlated with magnetospheric activity? This talk will cover the concept behind this comprehensive mission, how it will help fill the thermosphere gap, and constrain models for improved space weather prediction.

Alex Hoffmann

Alex Hoffmann (1), Mark Moldwin (1)

(1) Department of Climate and Space Sciences and Engineering, University of Michigan

Boomless Magnetometry: Adaptive Noise Cancellation through Underdetermined Blind Source Separation

In situ measurements of magnetic fields in space are contaminated with stray magnetic field noise generated by spacecraft electrical systems. Spacecraft typically utilize a magnetometer mounted at the end of a mechanical boom in order to reduce the magnitude of stray magnetic fields. The use of booms greatly increases the design complexity, cost, and adds deployment risk. As a result, the use of a boom is not always tenable for low-cost spacecraft such as CubeSats. Spacecraft equipped with multiple magnetometers can take advantage of noise cancellation algorithms to separate spacecraft noise from the ambient magnetic field. We describe a bus-mounted, three magnetometer configuration and the use of Underdetermined Blind Source Separation (UBSS) in order to adaptively cancel spacecraft noise. The UBSS algorithm employs the DBSCAN clustering algorithm to identify noise signals, and compressive sensing to separate the ambient magnetic field signal. We demonstrate the efficacy of this algorithm through an experiment which separates four coil-generated noise signals from a simulated ambient magnetic

field signal using three PNI RM3100 magnetometers and a Mock CubeSat apparatus. The proposed algorithm reduced the RMSE of the magnetic field observations from 328 nT to 8 nT, which is the measurement uncertainty of the magnetometer when sampled at 50 Hz. This boomless magnetometer configuration and noise cancellation algorithm will be implemented on the NASA H-FORT CubeSat mission, ICOVEX.

Amir Caspi

Caspi, Amir (1), Shih, Albert Y. (2), Athiray, P. S. (3), Warren, Harry P. (4), Woods, Thomas N. (5), Barnes, Will (2,6), Cheung, Mark (7), DeForest, Craig E. (1), Klimchuk, James A. (2), Laurent, Glenn T. (1), Mason, James P. (8), Palo, Scott E. (5), Parker, Jake (2), Seaton, Dan B. (1), Stęślicki, Marek (9), Gburek, Szymon (9), Sylwester, Janusz (9), Mrozek, Tomasz (9), Kowaliński, Mirosław (9), Schattenburg, Mark (10), and the CubIXSS Team

(1) SwRI, (2) NASA GSFC, (3) UAH, (4) NRL, (5) CU, (6) AU, (7) CSIRO, (8) JHUAPL, (9) PAN CBK, (10) MITLL

CubIXSS: The CubeSat Imaging X-ray Solar Spectrometer

The CubeSat Imaging X-ray Solar Spectrometer (CubIXSS) is a 6U CubeSat funded under NASA H-FORT. CubIXSS is motivated by a compelling overarching science question: what are the origins of hot plasma in solar flares and active regions? Elemental abundances are a unique diagnostic of how mass and energy flow into and within the corona, and CubIXSS addresses its science question through sensitive, precise measurements of abundances of key trace ion species, whose spectral signatures reveal the chromospheric or coronal origins of heated plasma across the entire temperature range from ~1 to >30 MK. CubIXSS measurements of the coronal temperature distribution and elemental abundances directly address longstanding inconsistencies from prior studies using instruments with limited, differing temperature and composition sensitivities.

CubIXSS comprises two co-optimized and cross-calibrated instruments that fill a critical observational gap:
* MOXSI, a novel diffractive spectral imager using a pinhole camera and X-ray transmission diffraction grating for spectroscopy of flares and active regions from 1 to 55 Å, with spectral and spatial resolutions of 0.28–0.37 Å and 29–39 arcsec FWHM, respectively; and
* SASS, a suite of four spatially-integrated off-the-shelf spectrometers for high-cadence, high-sensitivity X-ray spectra from 0.5 to 50 keV, with spectral resolution of 0.06–0.5 keV FWHM across that range.

CubIXSS will launch in early 2025 to observe intense solar flares and active regions around the peak of the solar cycle. Its 1-year prime mission is well timed complementary missions such as SunCET and the PUNCH Small Explorer. CubIXSS is a pathfinder for the next generation of Explorer-class missions with improved capabilities for SXR imaging spectroscopy. We present the CubIXSS motivating science background, its suite of instruments and expected performances, and other highlights from the mission development, including novel analysis techniques to fully exploit the rich data set of CubIXSS spectral observations.

Angelos Vourlidas

Vourlidas, Angelos (1), Bernasconi, Pietro (1), Howard, Russ (1), Mason, James (1), Thernisien, Arnaud (2), Tun Beltran, Samuel (2), Vievering, Juliana (1)

(1) JHUAPL, (2) NRL

miniCOR: Miniature Coronagraph for Heliophysics Research & Operations

The primary goal of this project is to demonstrate that a low-cost miniaturized CubeSat coronagraph can return data with higher cadence and sensitivity (achieved through summing images) than that from the SOHO/LASCO. MiniCOR can be deployed in any standard CubeSat orbit: Low Earth (LEO), Geosynchronous (GEO) or Sun-synchronous (Sun-Sync). The successful operation of MiniCOR will demonstrate that a science-grade coronagraph can be assembled, tested and deployed relatively quickly, for a modest cost, thus ensuring the continuity of coronagraphic observations in support of the national Space Weather (SpWx) needs. Moreover, MiniCOR is a step towards placing low-resource coronagraphs at the Earth-Sun Lagrange points L4 and L5 for optimal viewing of Earth-directed CMEs.

[WITHDRAWN] Asal Naseri

Naseri, Asal (1), Martineau, Ryan (1), Neilsen, Tim (1)

(1) Utah State University Space Dynamics Laboratory

Understanding Small Satellite Mission Driving Requirements

With advancements in small satellite related technologies, current small satellite buses are now capable of supporting a variety of heliophysics missions. However, if payloads are too large, too heavy, or too power hungry, then they cannot be effectively integrated on small satellite platforms. Understanding the driving requirements for the bus not only helps to design a mission that can be achieved by small satellites, but intentionally designing the instrument to match the current state-of-the-art bus technology can also offer significant cost savings while meeting science objectives.

In this presentation, we give an overview of some of the driving requirements for small satellite buses, based on our experience and lessons learned working on small satellite missions. These include:

- Tight integration between payload and bus due to mass and volume limitations
- Capability driven payload/mission requirements: power, propulsion, data volume, etc.
- Canisterized vs. ESPA-class spacecraft platforms
- Telecom spectrum allocation

As an example, we discuss the design of the Sun Radio Interferometer Space Experiment (SunRISE) spacecraft and payload.

As a nonprofit University Affiliated Research Center (UARC), Utah State University Space Dynamics Laboratory (SDL) serves as a subject matter expert for government-specified core areas of expertise, including sensors and small satellites, as well as providing independent and objective advice. SDL has the experience and capability to design, develop, and build both payloads and spacecraft for small satellites ranging from 3U CubeSats to ESPA-class spacecraft.

Brady Strabel

Brady Strabel (1), Mark Moldwin (1), Lauro Ojeda (2), Leonardo Regoli (3)

(1) Climate and Space Sciences and Engineering, College of Engineering, University of Michigan (2) Mechanical Engineering, College of Engineering, University of Michigan (3) The Johns Hopkins Applied Physics Laboratory

Quad-Mag Board for CubeSat Applications

The design, characteristics, and performance of a CubeSat magnetometer board (Quad-Mag) equipped with four PNI RM3100 magnetometers and a Texas Instrument (TI) MSP430 microcontroller is presented. The low size, weight, power, and cost of the RM3100 enables the inclusion of four sensors on a single board, allowing a potential factor of two reduction in the noise floor and increase in the resolution established for an individual sensor via oversampling with multiple sensors. The instrument experimentally achieved a noise floor of 5.34 nT (individual axis), averaging across each axis of the four magnetometers, at a 65 Hz sampling rate. This approaches the previously theoretically established limit for the system of 4.37 nT at 40 Hz. A single on-board, TI MSP430 microcontroller handles synchronization of the magnetometers and facilitates data collection through a simple UART-based command interface to a host system. The Quad-Mag system has a mass of 59.05 g and total power consumption of 23 mW while sampling and 14 mW while idle. The Quad-Mag enables 1 nT magnetic field measurements at 1 Hz using commercial-off-the-shelf sensors for space applications. Combined with signal processing algorithms, the instrument additionally allows potential boomless CubeSat magnetic observations.

Bruce Fritz

Fritz, Bruce (1), Dymond, Kenneth (1), Nicholas, Andrew (1), Budzien, Scott (1), Stephan, Andrew (1)

(1) U.S. Naval Research Laboratory

Ionosphere-Thermosphere Miniaturized Sensor Development at the U.S. Naval Research Laboratory

The U.S. Naval Research Laboratory (NRL) has developed a wide range of miniaturized sensors for measuring various parameters the ionosphere-thermosphere (IT) system. The NRL Space Science Division has a long history of developing novel IT space flight hardware, both remote-sensing and in situ. The Triple-Tiny Ionospheric Photometer (Tri-TIP) measures ionospheric density on the nightside and Triple Magnesium Ion Photometer (Tri-MIP) measures Sporadic-E on the dayside. Both of these remote sensing instruments will soon launch on multiple spaceflight missions: the CIRCE CubeSat Mission, the Slingshot-1 CubeSat mission, and the ECLIPSE experiment on the International Space Station. In addition to the photometers, the

GNSS Orbital Situational Awareness Sensor (GOSAS) is a programmable, dual GPS receiver that is being developed for an upcoming CubeSat mission. The Wind Ion Neutral Composition Suite (WINCS) instrument recently flew on the NASA Green Propellant Infusion Mission (GPIM) collecting in situ neutral composition measurements in Earth's thermosphere. Finally, the Laser-sheet Anomaly Resolution and Debris Observation (LARADO) experiment has been developed as an on-orbit orbital debris tracking system. New developments are currently underway at NRL to extend the usability of these sensors for additional parameters, different environments and new mission concepts.

Bruce Fritz

Fritz, Bruce (1), Dymond, Kenneth (1), Nicholas, Andrew (1), Budzien, Scott (1), Stephan, Andrew (1)

(1) U.S. Naval Research Laboratory

Sporadic-E Detection from an Ultraviolet Remote-sensing Experiment

The Triple Magnesium Ionospheric Photometer (Tri-MIP) was developed as a 1U CubeSat compatible sensor to detect a mid-ultraviolet (MUV), Mg+ doublet emission near 280 nm. [1] The initial flight of Tri-MIP will be on the Slingshot-1 spacecraft that is anticipated to launch into a circular orbit at an altitude of 500 km and an inclination of 45º. Paired with a 1U scanning ultraviolet mirror (SUVM) on the Slingshot-1 spacecraft, Tri-MIP will provide altitude profiles of Mg+ airglow emissions through limb scans of Earth's ionosphere along the wake direction of the orbit. Tri-MIP is a highly sensitive, miniaturized alternative to larger spectrometers that have observed the same emission, for example the Ionospheric Spectroscopy And Atmospheric Chemistry (ISAAC) instrument on the DoD Space Test Program's Advanced Research and Global Observing Satellite (ARGOS) or the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) on the ESA ENVIronmental SATellite (ENVISAT). Furthermore, Tri-MIP is especially well-suited for Es detection and may allow for the observation of faint signatures Es that are otherwise not visible with other commonly used, remote plasma detection methods, such as ground-based ionosondes or GPS radio occultation experiments. This presentation will show background for the Tri-MIP measurement approach and the data reduction approach that will be applied to the observations.

Christopher A. Grasso

Vourlidas, Angelos (1), Grasso, Christopher (2)

(1) JHUAPL, (2) Blue Sun Enterprises, Inc., University of Colorado

Spitzer-Resurrector Space Weather Research

The Spitzer-Resurrector Mission (SRM, hereafter) is a space mission concept currently undergoing a Phase I study funded by the U.S. Space Force (USSF) under the Orbital Prime call. SRM is 'two missions in one', with goals of demonstrating spacecraft recovery and control in deep space, as well as demonstrating novel Space Weather (SWx) research and operations

capabilities. The spacecraft recovery is accomplished by launching a small ESPA-class satellite to rendezvous with the Spitzer Space Telescope (currently in hibernation) in 2028, station-keeping nearby and serving as a relay for recommissioning and science operations.

The SRM concept leverages an unusual funding opportunity, an interdisciplinary team from academia and industry, a novel mission design, and recent research and technical advances in Heliophysics to reach a cost-effective, yet innovative, solution to both research and operations gaps in SWx.

The presentation will cover the SWx science performed using Resurrector en route, recovery operations for the Spitzer Space Telescope, and ongoing science performed with both spacecraft once Resurrector is on station near Spitzer.

Ed Thiemann

Thiemann, Edward (1), Sewell, Robert (1), Woods, Thomas (1), Dominique, Marie (2), Greer, Katelynn (1), Sutton, Eric (3), Pilinksi, Marcin (1), Berger, Thomas (3)

(1) Laboratory for Atmospheric and Space Physics, U of Colorado, (2) Royal Observatory of Belgium, (3) Space Weather Technology, Research and Education Center, U of Colorado

Space Weather Monitoring of Thermospheric Density, Temperature, and Composition Using Compact Extreme Ultraviolet Photometers

Observations of thermospheric density, composition, and temperature provide direct indicators of space weather activity and serve as crucial constraints on models of the thermosphere-ionosphere (T/I) system. However, no such measurements are currently made in real-time for use in operational space weather forecasting and nowcasting, and few have been historically collected for research purposes. Solar ultraviolet (UV) occultations served as an early workhorse for characterizing upper atmospheric density and composition, where researchers exploited the fact that much of the UV spectrum is strongly absorbed by the major species of the upper atmosphere, and a large component of the current thermospheric measurement record has been filled by "bonus" measurements made by missions intended to study the Sun. More recently, the utility of modern solar extreme ultraviolet (EUV) instruments has been demonstrated for making thermospheric solar occultations using broadband solar measurements such as those made by the Large Yield Radiometer (LYRA) instrument onboard the European Space Agency (ESA) Project for OnBoard Autonomy 2 (PROBA2) satellite as well as the Extreme Ultraviolet Monitor onboard the NASA Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiter at Mars.
EUV photometers such as LYRA are well suited to fly on small satellites. NASA has funded the Occultation Wave Limb Sounder (OWLS) small-sat instrument suite, which includes the EUV Occultation Photometer (EUV-OP) instrument, the first EUV photometer designed for solar occultations of the thermosphere. Although EUV-OP's primary purpose is research related to gravity waves, its measurements of neutral density, composition, and temperature from 150 to 350 km are directly relevant to space weather research, and it will serve as a TRL 9 demonstration for potential future space weather forecasting and nowcasting missions.

In this presentation, we demonstrate the exciting potential of solar EUV occultations for space weather monitoring by presenting direct density measurements from PROBA2/LYRA made during the geomagnetic storm of early February 2022 that resulted in the loss of 38 Starlink satellites. We show how key LYRA technology is miniaturized into the OWLS/EUV-OP instrument and discuss possible space weather research applications of its measurements. Finally, we discuss how a network of small sensors making LYRA-like measurements could profoundly change our real-time knowledge of the thermospheric state, and we provide various options (and their requirements and costs) for establishing such a network.

Farzad Kamalabadi

Kamalabadi, Farzad (1), Lightsey, E. Glenn (2), Rabin, Douglas (3), Daw, Adrian (3), D'Amico, Simone (4), Chamberlin, Philip (5), Woods, Thomas (5), Gupta, Subhanshu (6), Ekici, Eylem (7), Sample, John (8), Park, Hyeongjun (9), Alexeenko, Alina (10), Hwang, John (11), Denis, Kevin (3), Klimchuk, James (3)

(1) University of Illinois at Urbana Champaign, (2) Georgia Institute of Technology, (3) NASA Goddard Space Flight Center, (4) Stanford University, (5) University of Colorado Boulder, (6) Washington State University, (7) Ohio State University, (8) Montana State University, (9) New Mexico State University, (10) Purdue University, (11) University of California San Diego

High-Resolution Imaging of the Solar Corona Enabled by Constellation of Small Satellites

High-resolution imaging enabled by small multi-spacecraft systems provides a novel approach to investigating space weather phenomena at unprecedented detail. Such pathfinder mission concepts have the potential to circumvent the limitations of conventional remote sensing/imaging systems by utilizing multiple baselines, synthesized apertures, and diffractive optics, combined with computational imaging via super-resolution. However, such small satellite constellation concepts require technological breakthroughs in precision formation flying and associated advances in guidance, navigation, and control; proximity operations and associated autonomy as well as robust orbit design with passive safety; innovations in sensor miniaturization; inter-satellite communication; and sophisticated computational sensing and reconstruction algorithms. We describe recent advances in such enabling technologies in the context of a scalable ultra-high-resolution spectral imaging mission called VISORS (VIrtual Super-resolution Optics with Reconfigurable Swarms) for investigating the solar corona, currently under development by a multi-university consortium in collaboration with NASA and under sponsorship by NSF.

Grant Berland

Berland, Grant D. (1), Marshall, Robert A. (1)

(1) University of Colorado Boulder

The AEPEX CubeSat Mission: Addressing Energetic Particle Precipitation through X-ray Imaging

Energetic particle precipitation (EPP) is a high energy charged particle phenomenon that couples the solar wind, magnetosphere, and atmosphere of magnetized planets. EPP constitutes a loss mechanism from the radiation belts, and a source of excess ionization in Earth’s atmosphere that

goes on to cause other direct and indirect effects, including radio communication interruption and ozone depletion. EPP is a vital component of the energy balance of the radiation belts and atmosphere, although the spatial and temporal scales, as well as the relative influence of the drivers behind this phenomenon, are poorly quantified.

The Atmospheric Effects of Precipitation through Energetic X-rays (AEPEX) CubeSat mission aims to address the questions of spatial and temporal scale through the deployment of a novel wide field-of-view X-ray imaging spectrometer that will observe bremsstrahlung X-ray emissions from the atmosphere, a proxy measurement for EPP. AEPEX will also have an onboard electron detector for in-situ measurements of electron spectra that are both trapped and within the loss cone in order to combine these measurements for a comprehensive evaluation of EPP. This presentation describes the engineering development of the Atmospheric X-ray Imaging Spectrometer (AXIS) instrument and the capabilities of the AEPEX mission in quantifying the spatial and temporal scales of EPP.

James Mason

Mason, James (1), The SunCET Team (2)

(1) JHU/APL, (2) CU/LASP, NASA/GSFC, HAO, SWRI, NWRA, NRL

Overview of the upcoming Sun Coronal Ejection Tracker (SunCET) NASA CubeSat

The Sun Coronal Ejection Tracker (SunCET) is a new CubeSat funded by NASA Heliophysics dedicated to figuring out how coronal mass ejections (CMEs) are accelerated. There are SO MANY theories and models about how stored up magnetic energy can be released to force massive amounts of plasma to escape its magnetic confinement. Perhaps the background magnetic field falls with height just steeply enough that even a small random expansion of a flux rope is enough to let it fly free (torus instability model). Or perhaps the boiling motion at the surface of the star twists the coronal magnetic field so much that the flux rope crosses a critical threshold (448º) and it's suddenly kicked out (helical kink model). Magnetic energy release can continue to happen even after this initial phase, continuing to power the acceleration (e.g., varying velocity perturbations model). CMEs can also be deflected by the surrounding magnetic field they are passing through (e.g., ForeCAT model). All of these models produce unique predicted acceleration versus time profiles. The problem is we haven't had the ideal observations to discriminate between them.

Enter SunCET, which solves the underlying technical hurdle that prevented prior observations from obtaining those complete acceleration profiles. The solar disk is 10 thousand to a billion times brighter than its surrounding corona, so prior observatories focused on only imaging one or the other, leaving a critical spatial gap between them… in exactly the place CMEs experience the bulk of their acceleration. SunCET observes the whole thing, from 0-4 solar radii with no gap. Our new simultaneous high dynamic range detector algorithm is SunCET's enabling technology, which has broader applications for imaging and spectroscopy in astrophysics as well. The understanding we gain from SunCET CME observations and modeling efforts will inform our estimates of stellar CMEs and their impacts on the stellar environment. SunCET is expected to launch in early 2025.

John McCormack

NASA Science Mission Directorate, Heliophysics Division

ENLoTIS: ESA/NASA Lower Thermosphere-Ionosphere Science Working Group

ENLoTIS is an agency cooperation on potential future lower thermosphere-ionosphere satellite mission concepts, targeting studies of neutral/ion interactions and related science topics with in-situ sampling of key geophysical parameters. The specific altitude region of interest targets the 100-200 km that includes the ionospheric E-region and sits at the interface between Earth and Space. This presentation will offer an update on ENLoTIS activities and invite feedback from the broader research community.

Juan Carlos Martínez Oliveros

Juan Carlos Martínez Oliveros (1), Steven Christe (2), Pascal Saint-Hilaire (1), Amir Caspi (3), Säm Krucker (1), Laura Hayes (4), Olivier Limousin (5), Aline Meuris (5)

(1) Space Sciences Laboratory, University of California Berkeley, Berkeley, CA, (2) NASA GSFC, Washington, DC, (3) Southwest Research Institute, Boulder, CO, (4) ESA-ESTEC, Noordwijk, Netherlands, (5) CEA, Gif Sur Yvette, France

The solar PolArization and Directivity X-Ray Experiment: PADRE

Solar flares are known to accelerate electrons to high energies efficiently. However, how the underlying acceleration mechanisms work remains poorly understood. The angular distribution of the accelerated electrons, the resultant hard X-ray emission, and its polarization and directional anisotropy are key to solving this mystery. The solar PolArization and Directivity X-Ray Experiment (PADRE) is a 12U Cubesat observatory developed to solve this mystery. PADRE will investigate the accelerated electron angular distribution in solar flares with two complementary approaches (1) by making spatially-integrated spectro-polarimetric X-ray measurements (~10-100 keV) and (2) by coordinating with Solar Orbiter/STIX to make the first two-point measurements of X-rays and determining their directivity. We present the PADRE observatory concept, its science objectives, design, and updates. We will discuss the observations its two instruments (SHARP and MeDDEA) will make.

L Alberto Canizares

L Alberto Canizares [1][2], Shane A Maloney [1], Peter T Gallagher [1], Eoin P Carley [1], Sophie Murray [1], Dale Weigt [1], Ciara McGrath [3], Nicholas Crisp [3], Alejandro Macario Rojas [3], Jack Cullen [1][4], Akhil Vinod Kumar [1][4]

[1] Dublin Institute of Advanced Studies, Ireland [2] Trinity College Dublin, Ireland [3] University of Manchester, UK [4] University College Dublin, Ireland

SURROUND, A constellation of CubeSats around the Sun

The Sun regularly produces flares and coronal mass ejections (CMEs) that can drive solar energetic particle events (SEPs). CMEs and SEPs can produce a variety of adverse space weather (SW) effects at Earth and in the near-Earth environment[1]. CMEs and SEPs produce radio emission in particular: (1) CME-driven shocks produce Type II solar radio bursts (SRBs)[2], and (2) energetic electrons escaping into the heliosphere produce Type III SRBs[3], which can be utilised to track these events.

At present, there is no operational means to monitor and track SRBs, the SURROUND mission aims to address this gap with a constellation of CubeSats, and is currently in a Phase-0 study supported by ESA. SURROUND will observe and track, in three dimensions (3D), Type-II and Type-III SRBs in order to fore-/now- cast CME and SEPs for space weather monitoring. Each SURROUND satellite will be equipped with a radio spectrometer capable to tracking radio bursts from the surface of the Sun to the Earth.

SURROUND is proposed to be composed of 6 CubeSats; one at each of the Lagrange (L) 1, 4, and 5 points, one orbiting ahead of the Earth, one orbiting behind the Earth, and one out of the ecliptic plane. This configuration would allow accurate 3D triangulation of SRBs and their associated space weather activity to achieve the mission aims to monitor and track solar radio bursts. These goals are complementary to those set out by other missions (such as ESA Solar Orbiter/RPW and NASA Parker Solar Probe/FIELDS). SURROUND will therefore provide Europe with more accurate monitoring and forecasting of space weather activity in near real-time.

Marcel Ayora

Marcel Ayora I Mexia, Teresa Nieves-Chinchilla

NASA Goddard Space Flight Center

Exploration of the Internal Flux Rope Current Density Using a Spacecraft Constellation

For many years the scientific community has been working on understanding the topology and the physical properties of flux ropes since they are one of the main ways solar activity structures plasma and electromagnetic fields. These flux ropes are, by definition, rotations of the magnetic field lines around an axis. Therefore, the main focus of its research has always been on magnetic field topology. However, according to Maxwell's laws, the current density distribution can be considered the genesis of the helical magnetic field structure.

This work introduces a new methodology to approach the flux rope investigation by studying its internal current density distribution. To this end, a constellation of spacecraft is employed to estimate the current density through the curlometer technique. The methodology has been validated and tested by simulating the trajectory of a 4-spacecraft constellation through a synthetic flux rope. Thereupon, the methodology's performance is evaluated under various circumstances and conditions. Finally, the methodology is applied to a flux rope observed by Cluster on the 13th of February 2001.

Matt Orvis

Matt Orvis (1), Hank Voss (2), Jeff Dailey (3)

(1) NearSpace Launch, Inc., (2) NearSpace Launch, Inc., (3) NearSpace Launch, Inc.

Flight Proven ThinSat Constellations with Persistent EyeStar Communications and Miniaturized Space Weather Sensors

Small satellites have continuously benefited from the miniaturization of technology, with space weather instrumentation and small satellite subsystems rapidly growing in capability. NearSpace Launch has been a part of contributing to this field, through the development of the CubeSat based ThinSat constellation, the EyeStar-S4 communication system, and small sensors such as particle detectors and plasma probes.

The ThinSat takes the already compact CubeSat form factor, and slices it into smaller, independent satellites forming a constellation. The 1st two STEM constellations of this were flown on 4/17/2019 and 2/20/2021 with ThinSat-1 and ThinSat-2. These took 3U CubeSats and sliced them into 21 ThinSats, each outfitted with particle detectors, plasma probes, and other experiments. The NASA SBIR Phase II Space-Weather CubeSat Array for 24/7 Prompt Global Coverage Experiment (SWAP-E) mission extends that concept to a 3x2U CubeSat, hosting several space weather payloads, such as the CU/LASP DART sensor payload and others.

The ThinSat uses the NSL/Iridium EyeStar radio, which provides the satellite 24/7 connectivity and global coverage for downlinking mission data, at a fraction of the cost, mass, and power that most radios require. The new EyeStar-S4 now includes uplink capability, and the developmental EyeStar-S4 Next will increase data rates by up to 1000 times.

Small sensors such as the NearSpace Launch Particle Detector and Plasma Probe have been utilized many times now on orbit to characterize the in-situ ion density, electron temperature, and energetic particle flux incident on the satellite electronics. The constellation application of these sensors allows multi-point data to be collected for a fixed point in time, synchronized into a single database.

Neal Hurlburt

N. Hurlburt, G. Vasudevan, Georgios Chintzoglou

Lockheed Martin Advanced Technology Center

IPSOS, the Imaging Photonic Spectropolarimeter for Observing the Sun

The Imaging Photonic Spectropolarimeter for Observing the Sun (IPSOS) collapses the optical elements of an Imaging Spectro-Polarimeter (ISP) into a single, multilayer wafer, thus reducing the size and weight by orders of magnitude. And instead of painstaking manual assembly, these wafers are printed using photolithographic methods – leading to a dramatic reduction in cost with improved reproducibility. These revolutionary properties expand hosting opportunities and enable the formation of novel constellations combining traditional and non-traditional platforms for monitoring solar oscillations and magnetic fields. The IPSOS demonstration mission develops and matures the technology developed MICRO, the Magnetograph using Interferometric and Computational imaging for Remote Observations - a disruptive imaging technology developed with NASA HTIDS and LM IRAD support. The future IPSOS Instrument addresses key science questions while fitting easily on cubesats or other hosts.

These questions revolve around the solar magnetic field generated by the solar dynamo which is the root of all major space weather in our solar system: from the 22-year magnetic cycle that modulates total solar irradiance, to global coronal magnetic fields that structure the solar wind, to magnetic eruptions from sunspot active regions that power coronal mass ejections triggering major geomagnetic storms. Yet we have only consistently measured the solar magnetic field from one vantage point at Earth, missing approximately 3/4 of the activity at any one time. Space weather researchers and forecasters need complete knowledge of the emerging fields over the entire solar surface and interior in a timely and uniform fashion.

We lack global measurements of the Sun, in part, due to the cost, which is driven by the expensive, high-mass ISPs needed to measure the Sun's magnetic field and surface velocity. IPSOS removes this impediment, enabling cost-effective global measurements. These measurements are best made in both the photosphere and chromosphere. IPSOS includes both with minimal additional impact to cost or mass.

The IPSOS demonstration mission focuses on on-orbit performance testing to raise IPSOS TRL to 7 with a prototype using Commercial-off-the-shelf (COTS) electronics. The IPSOS prototype is used to evaluate the sensitivity, accuracy, stability and survivability of the IPSOS technology to reduce risk and verify beneficial impacts. It demonstrates magnetic and Doppler imaging and accurate measurement of solar oscillations at cadences and resolutions achievable today. The IPSOS demonstration mission will observe large-scale flows, sunspots, active regions and filament eruptions during the 6-month mission and optimize observing strategies enabled by MICRO technology.

Rafael Mesquita

Rafael L.A. Mesquita (1), Jeng-Hwa Yee (1), Jesper W. Gjerloev (1), Nelli Mosavi (1), Viacheslav G. Merkin (1), Astrid Maute (2), Kareem A. Sorathia (1), Karl M. Laundal (3), and Michael Madelaire (3)

(1) The Johns Hopkins University Applied Physics Laboratory, Laurel, MD. (2) High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO. (3) University of Bergen, Bergen, Norway.

The Electrojet Zeeman Imaging Explorer mission design through OSSEs

The Electrojet Zeeman Imaging Explorer (EZIE) is a recently selected NASA Heliophysics mission of opportunity designed to provide measurements needed to study the mesoscale structure of the electrojets and its temporal evolution. EZIE employs four identical miniaturized radiometers on each of the three 6U CubeSat, flying in a pearls-on-a-string managed formation, to measure, for the first time, the two-dimensional structure the electrojets flowing at altitudes of ~100–130 km. It is currently in Phase C of its development and expected to launch in late 2024 and early 2025. A series of Observing System Simulation Experiments (OSSEs) specifically designed for EZIE has been used to optimize its mission design, establish the spacecraft and instrument performance requirements, ready the retrieval algorithms, and, most importantly, demonstrate measurement capabilities for science closure. In this paper, we will discuss the various observation modes and measurement capabilities of this mission from an OSSE standpoint. Specifically, we will discuss the EZIE OSSE and present simulation results that give confidence in the qualities of its primary data products (e.g., high-latitude electrojet-induced magnetic field vectors, 2D equivalent current maps). We will also discuss possible secondary data products (e.g., magnetic fields in the equatorial electrojet, neutral winds at 80 km, and temperature profiles).

Robert Robinson

Robert Robinson (1), Douglas Rowland (2), Katherine Garcia-Sage (2), Larry Kepko (2)

(1) The Catholic University of America, (2) NASA Goddard Space Flight Center

Small Satellite Constellations for Space Weather Research and Forecasting

Constellations of small satellites offer a number of benefits to space weather research and operational forecasting. Not only do constellations provide extended coverage to observe large scale phenomena, but they also sample the same regions of space at different times to help discriminate between spatial and temporal variations. Optimization of measurements from constellations requires careful planning and sophisticated numerical techniques for data analysis, data assimilation, and generation of higher-level data products. Observing system simulation experiments (OSSEs) play an important role in mission planning for satellite constellations. Numerical techniques are often needed to fill in gaps in sparsely filled regions or irregularly spaced data, ideally constrained by the physics of the processes being observed. Parallel development of numerical models and constellation observing strategies is essential to ensure direct traceability to the scientific questions being investigated. Constellations designed for research purposes represent valuable testbeds for future operational missions. Taking data from

constellations to higher technical readiness levels for space weather applications demands an integrated approach to designing mission architectures to make key data products available with high cadence and minimal latency. Observing System Experiments (OSEs) can be conducted with existing data to demonstrate the impact of data from constellations on future space weather operations. We describe the merits and challenges associated with satellite constellations, drawing on results from the Active Magnetosphere and Planetary Response Experiment (AMPERE) and mission planning activities for the Geospace Dynamics Constellation (GDC). Careful consideration of the challenges and successes of past and current missions provide valuable guidance for planning of future missions.

Romina Nikoukar

R. Nikoukar (1), M. Zettergren (2), L. Kistler (3), D. Hampton (4), E. Reynolds (1), K. Deshpande (2), R. Erlandson (1), H. Kil (1), H. Kucharek (3), K. Lynch (5), and M. Samara (6), C. Haskins (1), J. Bradfield (1), A. Sharma (1)

(1) Johns Hopkins University Applied Physics Laboratory, (2) Embry-Riddle Aeronautical University, (3) University of New Hampshire, (4) University of Alaska at Fairbanks, (5) Dartmouth College, (6) Goddard Space Flight Center

Enabling Scintillation Science with CubeSats

CubeSat technology advancements have created exciting, new, and enhanced opportunities for science that we must take advantage to continue to advance the state-of-the-art in our field. In this work, we make an argument for the applicability of low size, weight, and power instrumentation and small satellites for scintillation science. Scintillation, rapid fluctuations in the amplitude and phase of radio signals, is a major space weather hazard that hinders radio communication and global navigation satellite systems (GNSS). In the past decades, a large number of studies have covered various aspects of measurements and theories of ionospheric irregularities and radio wave scintillation caused by turbulent media. However, critical questions remain concerning where and when scintillation occurs in relation to larger-scale ionospheric phenomena, such as aurora and causative physical processes. The Auroral Network for Ionosphere imaging with CubeSats (ANTICS) mission concept, submitted to NASA Heliophysics Flight Opportunities for Research and Technology (HFORT), is a novel, two-cubesat investigation with ground-based observatories (GBO) dedicated to scintillation science. It will make high-resolution measurements of ionospheric scintillation, flows, temperature, density, total electron content (TEC), and ground-based auroral imagery to characterize different processes for ionospheric irregularities that result in scintillation. We present detailed information about ANTICS science and instrumentation.

Sam Yee

Yee, Jeng-Hwa (1), Gjerloev, Jesper (1), Mosavi, Nelli (1), Kelly, Rebecca (1), Mesquita, Rafael (1), Misra, Sidharth (2), Kangaslahti, Pekka (2), Baron, Dave (3), Science Team

(1) Johns Hopkins University, Applied Physics Laboratory (2) Jet Propulsion Laboratory (3) Blue Canyon Technologies

Overview of the EZIE (Electrojet Zeeman Imaging Explorer) SmallSat Mission

EZIE, the Electrojet Zeeman Imaging Explorer, is a NASA Heliophysics mission currently under development. It is designed to provide critically needed measurements of the mesoscale structure and temporal evolution of the electrojets. It utilizes four identical miniaturized polarimeters on each of the three 6U CubeSat flying in a pearls-on-a-string managed formation, to measure, for the first time, the two-dimensional structure and the temporal evolution of the electrojets that flow at altitudes of ~100–130 km. It employs a newly developed Zeeman sensing technique to remotely obtain the current-induced magnetic field vectors at ~80 km, an altitude region very close to the electrojet. The four cross-track downward-looking antennas on each satellite measure polarimetric radiances of the 118 GHz O2 thermal emission and obtain the magnetic signatures of the electrojet based on measured Zeeman splitting spectral properties. This novel measurement technique allows for the remote sensing of the electrojets at four different cross-track locations simultaneously at altitudes notoriously difficult to measure in situ. The combination of the sensing technique, compact instrument, CubeSat technologies, mission operations, allow EZIE to cost-effectively obtain never-before "mesoscale" measurements of the electrojets needed to understand how the solar wind energies stored in the magnetosphere are transferred to the thermosphere and ionosphere. In this paper we will present an overview of the EZIE mission, the Zeeman sensing technique employed, and the measurement products.

Sidharth Misra

Misra, Sidharth (1), Padmanabhan, Sharmila (1), Kangaslahti, Pekka (1), Montes, Oliver (1), Bosch-Luis, Javier (1), Cofield, Rick (1), Ramos, Isaac (1) and Yee, Sam (2)

(1) Jet Propulsion Laboratory, California Institute of Technology, (2) Applied Physics Lab LLC, The Johns Hopkins University

Microwave Electrojet Magnetogram (MEM) Instrument for the Electrojet Zeeman Imaging Explorer (EZIE) Mission

EZIE is a cost-effective three CubeSat mission that visualizes, for the first time with innovative instrumentation, the electrical currents (electrojets) flowing at altitudes of ~100–130 km, which are notoriously difficult to explore. EZIE resolves mysteries of these electrojets and paves the way for space-weather predictions. These measurements are provided by compact 4-beam O2 118.75 GHz spectropolarimeters (MEM) on three 6U CubeSat flying on a pearls-on-a-string configuration with varying temporal separation utilizing an innovative Zeeman magnetic field sensing technique. JPL is delivering three MEM instruments. Each JPL instrument includes four 118.75-GHz polarimetric radiometers. The MEM instrument is compact and proven, enabled by Indium Phosphide MMIC Low Noise Amplifier technology and digital spectrometer backends.

Topic 4: Programmatic Issues & Outlook

Angelos Vourlidas

JHUAPL

The LWS Architecture Study: the Role of SmallSats

I will present a brief overview of the recently completed LWS Architecture Study and discuss the prominent role that SmallSat concepts can play in the future of LWS research and consequently in improving Space Weather understanding and forecasting accuracy.

Jesse Woodroffe

Woodroffe, Jesse (1), Spann, James (1), Favors, James (1)

(1) NASA Headquarters, Heliophysics Division

The role of smallsats in NASA's Space Weather Program

The NASA Space Weather Program (NSWP) supports the development of new measurement strategies and platforms to augment and advance the nation's monitoring capabilities. A recent development within the NSWP is strategic use of small satellite missions to drive forward innovation in space weather observations. The first cohort of NSWP-supported missions – comprising CubIXSS (SWRI), SunCET (JHU/APL), WindCube (UCAR), and DynaGLO (CU/LASP) – is now being actively developed, serving as a demonstrator and pathfinder for future smallsat investments. In this talk, we will provide an overview of the NSWP and the important role smallsats play in its current and future strategy.

Jim Spann

NASA HQ

Leveraging commercial constellations in LEO and MEO for research and operations

(TBD)

Melanie Heil

Heil, Melanie (1), Luntama, Juha-Pekka (1), Kraft, Stefan (1)

(1) European Space Agency

ESA's Distributed Space weather Sensor System

ESA's Space Safety Programme aims at protecting space and ground assets against adverse effects from space. The Space Weather Segment is focussing on such effects due to the activity of our Sun.

Monitoring of the Earth's and Sun's environment is an essential task for the now- and forecasting of Space Weather and the modelling of interactions between the Sun and the Earth. Due to the asymmetry and complexity of Earth's magnetosphere, the involved particle environment and its dynamics, it is necessary to capture the state of the magnetic field and the particle distribution in a sufficiently large number of sampling points around the Earth, such that it allows state-monitoring and modelling of the involved processes with sufficient accuracy and timeliness.

ESA is implementing a space weather monitoring system, including the establishment of a Distributed Space Weather Sensor System (D3S) to observe the effects of solar activity within Earth's vicinity. Its current configuration and planned implementation using SmallSats and CubeSats will be presented.

Paul O'Brien

The Aerospace Corporation

Opportunities and value that small satellites offer for space weather research

(TBD)

Steven Christe

Christe, Steven (1), Kreisler, Stephen (1), Rager, Amy (1), Barrous-Dume, Damian (1)

(1) NASA Goddard Space Flight Center

The Space Weather Science Operations Center

The Space Weather Science Operations Center (SWSOC) is a new program to develop SOC capabilities for current and future space weather missions. The SWSOC architecture is uses Amazon Web Services (AWS) and is being designed to be general and easily expandable to new missions. HERMES is the first mission to use the Space Weather Science Operations Center. The design of the SWSOC is compliant with the new Heliophysics Division Science Data Management Policy (and the parent document NASA SPD-41 Scientific Information Policy for the Science Mission Directorate. The SWSOC Science Data Center (SDC) will generate Level-1 and Quicklook instrument and science products for HERMES and the entire pipeline architecture is controlled by repositories on GitHub. The purpose of this presentation is to describe the SWSOC and how you can use it to process data from future and current missions.

Posters:

Annsley Greathouse

Greathouse, Annsley (1), Kozic, Ty (1), Nightingale, Mel (1), Ley, Lukas (1), Savadogo, Mansour (1), Wieber, Meredith (1,5), Glesener, Lindsay (1), Gebre Egziabher, Demoz (1), Setterberg, William (1), Sample, John G. (2), Smith, David M. (3), Caspi, Amir (4)

(1) University of Minnesota, (2) Montana State University, (3) University of California, Santa Cruz, (4) Southwest Research Institute, (5) University of California, Berkeley

Methods of Managing the Student Led Impulsive Phase Rapid Energetic Solar Spectrometer (IMPRESS) CubeSat Mission

This poster discusses issues and best-practices associated with managing and executing a student-lead, CubeSat mission for conducting space weather research. Since the inception of the NASA CubeSat Launch Initiative (CSLI) in 2010, 148 CubeSats have been launched; 121 of which launched in the last 6 years. Due to the continuous turnover of undergraduate CubeSat researchers, managing student-led CubeSat missions has presented major challenges. The primary three being knowledge retention, documentation, and training. Many student-led programs have been successful, however there is not one universally accepted management method.

The Impulsive Phase Rapid Energetic Solar Spectrometer (IMPRESS) is an NSF-sponsored solar science mission that will fly a hard X-ray (>10 keV) spectrometer on a 3U CubeSat to investigate particle acceleration in solar flares during solar cycle 25. It is a student-led project under development at the University of Minnesota Small Satellite Research Lab (SSRL) in collaboration with Montana State University, the Southwest Research Institute, and University of California, Santa Cruz.

This poster will discuss the timeline and status of the IMPRESS mission, the organizational structure of SSRL, and methods of optimizing subsystem efficiency and researcher retention.

Savannah Perez-Piel

Savannah Perez-Piel (1), Juan Camilo Buitrago-Casas (1), Anton Tremsin (1), Juan Carlos Martínez Oliveros (1)

(1) Space Sciences Laboratory - University of California Berkeley

Quad-Timepix2 and 3 Detector Development and Applications

We report on the current status of the Timepix2 and Timepix3 - QuadPIX flight-ready hard X-ray (HXR) detector modules. Medipix Collaboration, including CERN, NIKHEF, and Bonn University, developed the ASICs as a part of the evolving Medipix family. The detector consists of a 2 x 2 array of TimePix ASICs with a substrate. The active area is 14 x 14 mm, made up of a total 512 by 512-pixel matrix, and comes in CdTe, Si, or both substrates, each taking half of the ASICs in the module. The Timepix3 ASIC provides 1.56ns time granularity with almost zero

dead time, and both detectors work within the range of 3- or 5- Kev to 100 Kev, dependent on substrate choice. The final developments will be flown on FOXSI-4, a sounding rocket launched in 2024, and PADRE, a 12U Cubesat observatory, to be in low earth orbit. Due to Timepix ASICs accessibility and resolution, it is an ideal candidate for application in space and solar astrophysics in the 3-100 keV range.

Suman Panda

Panda,Suman(1), Kankelborg, Charles(1)

(1) Montana State University

FUV Spectrum of the Sun-as-a-star from a CubeSat

The spectrum of stars are a great diagnostic tool that provides us information about composition, age, structure and activity of the stars. The Sun being closest to us provides us with a unique opportunity to study it in great detail. We have high-resolution far-ultraviolet (FUV) spectrum for many stars courtesy of Hubble. Ironically, we do not have FUV spectrum of the Sun-as-a-star in comparable resolution. Our team at MSU is developing a sounding rocket mission called the Full-sun Ultraviolet Rocket SpecTrometer (FURST), planned to launch in 2023, which aims to obtain full disk FUV spectrum of the Sun in high resolution. But FURST will not answer all of our questions. The Sun is an active star that is variable and dynamic on all timescales. We are preparing to propose a CubeSat mission as a sequel to FURST, which will enable us to get high-resolution FUV spectrum of the Sun-as-a-star daily over a period of years. This satellite and its successors will allow us to study the variability of the Sun through its activity cycle. With a satellite continuously taking data, we will also have the opportunity to obtain high resolution flare spectra. Flares are of increasing interest due to space weather implications, but little is known about their FUV spectra. Our proposed mission would fill this void, opening a new window on flare physics and (perhaps) flare prediction.
