Archived Colloquia 2025-2026

Next Generation Seismicity Catalogs with Machine Learning

Gregory Beroza
Stanford University
Friday 27 March 2026

Machine learning is having an immense impact in earthquake monitoring. There are good reasons for this. There is a well-established sequence of tasks: phase detection, phase association, event location, and event characterization, used to develop seismicity catalogs around the world and across scales. Because the number of earthquakes increases rapidly as magnitude decreases, cataloging somewhat smaller earthquakes dramatically increases the information available. The large existing earthquake catalogs and their corresponding waveforms make seismic monitoring an ideal use case for supervised machine learning. Through a series of examples, I will demonstrate how AI-based earthquake monitoring is being applied to archived data, how it is beginning to be deployed for real-time applications, and how it results in earthquakes catalogs that are far more comprehensive and information-rich.

These developments and artificial intelligence in general have rekindled interest in earthquake forecasting. AI-based catalogs more clearly illuminate the failure process as expressed by seismicity. The extra information they contain has led to improvements in statistical forecasting methods, but not yet a breakthrough; however, we are still in the exploratory stages of applying AI methods. No one would deny that physics is important to the earthquake process, yet purely statistical models currently compete with physics-based models in forecasting accuracy. That suggests there are unrealized improvements in earthquake forecasting, and machine learning methods could have a role to play in extracting features that express the physics of fault failure. Such advances would lay the foundation for improved earthquake forecasting.

Unveiling Cosmic Messengers: From Plasma Scales to Galactic Observables

Luca Orusa
Columbia University
Friday 20 March 2026

Over the past decade, space-based experiments such as AMS-02, DAMPE, CALET, and Fermi-LAT, together with ground-based observatories including HAWC, H.E.S.S., and LHAASO, have transformed the study of Galactic cosmic rays and gamma rays into a

precision science. This new observational era raises fundamental questions about the plasma processes responsible for particle acceleration, magnetic-field amplification, and cosmic-ray transport in astrophysical environments.
In this talk, I will show how kinetic plasma simulations provide a first-principles description of particle acceleration at shocks. I will then discuss how cosmic rays modify the surrounding plasma close to their sources, driving instabilities and modifying the local magnetic and transport properties. Taken together, these plasma processes establish a direct connection between microscopic kinetic physics and the large-scale cosmic-ray and gamma-ray observables measured across the Galaxy.

Dense Spectroscopy as a Probe of Galaxy Clusters: Velocity Dispersion Functions and Spectroscopic Weak Lensing

Jubee Sohn
Seoul National University
Friday 13 March 2026

We are entering an era of extremely large spectroscopic surveys that enable dense sampling of galaxies across a wide range of environments. Dense spectroscopy provides a powerful framework for investigating the physical properties of statistically significant galaxy populations and for constraining the connection between galaxies and their dark matter halos. In this presentation, I discuss two applications of dense spectroscopy to the study of galaxy clusters and their member galaxies. The first application focuses on the stellar velocity dispersion function (VDF) of cluster galaxies, which serves as a direct probe of the underlying dark matter subhalo mass distribution. Using densely sampled spectroscopic data, we measure the VDF in galaxy clusters and derive corresponding theoretical predictions from cosmological simulations. A comparison between the observational measurements and simulation results provides insight into the galaxy–halo connection and the efficiency of subhalo assembly in dense environments. The second application is weak-lensing spectroscopic tomography (“spectrotomography”), a technique that combines weak gravitational lensing with dense spectroscopy. This approach reconstructs cluster lensing signals using exclusively spectroscopically confirmed background galaxies, thereby eliminating systematic uncertainties associated with photometric redshifts. I will present the methodology and early results from a sample of ten galaxy clusters. Spectrotomography offers an independent and precise avenue for cluster mass measurements and represents a promising cosmological probe in the era of large spectroscopic surveys.

When Neptune met Triton

Douglas P Hamilton
University of Maryland
Friday 6 March 2026

Triton, seventh largest satellite in the Solar System, orbits Neptune in a direction opposite the planet's spin. This peculiarity, unique amongst large satellites, points to a capture origin. Two plausible theories were advanced around the time of the Voyager flybys to explain how Neptune might have snared Triton, but both require some fine tuning. In 2006, Craig Agnor and I proposed a new scenario in which Neptune captured Triton from a binary Kuiper belt object that once freely orbited the Sun like Pluto and Charon do today. In the aftermath of this event, the original satellites of Neptune were destroyed, and most of the debris was absorbed by Triton. Over the next 100 million years, Triton's orbit was circularized by tides raised on it by the planet, and a stunted group of new moonlets grew from the remaining rubble. Periodically during the subsequent history of the system, Triton has exerted considerable influence on these small inner satellites via three-body resonances that have elongated and tilted the moonlet orbits. In this talk I will trace the orbital history of Neptune's satellite system from Triton's dramatic capture to the present day.

Neutron stars and extreme matter

Cole Miller
University of Maryland
Friday 27 February 2026

Precise and reliable measurements of neutron star radii and other properties are essential to our understanding of cold, catalyzed matter beyond nuclear saturation density. Over the last fifteen years, measurements of high-mass neutron stars, gravitational waves from the double neutron star merger GW170817, and X-ray observations have dramatically improved our understanding of neutron star structure. In particular, NASA's Neutron star Interior Composition Explorer (NICER) satellite has provided high-quality data sets that have yielded published measurements of the mass and radius of several neutron stars. I will discuss our group's analyses of these pulsars and will in particular discuss our assumptions and potential systematic errors, to help in the assessment of our work. I will also discuss the implications of our results, combined with other observations, for the properties of the dense matter in the cores of neutron stars.

Metastable helium in the thermosphere

Shri Kulkarni
CalTech
Friday 13 February 2026

SPHEREx, a recently launched astronomy mission, detected a bright 1.083 micron emission feature in the commissioning data. The PI group attributed this feature to the He I 1.0833 micron triplet line. In this seminar I review the physics and aeronomy of this well-known line of atmospheric origin. SPHEREx is in a dawn-dusk sun-synchronous polar orbit, circling the earth nearly 15 times a day and observing close to the terminator plane. With a height of 650 km, SPHEREx is located in the upper thermosphere that is dominated by atomic oxygen and helium. The He I line is a result of resonance scattering of solar photons by metastable helium atoms. It appears that SPHEREx has the capacity to provide a rich dataset (global, daily, and 2-minute cadence) of the column density of metastable helium in the upper thermosphere. As an example of this assertion, with data from just one orbit, the winter helium bulge was readily seen. Metastable helium should be of interest to astronomers since it provides a handle on studying the exosphere of earth. Helium in the thermosphere is of considerable interest to operators of low-earth orbiting (LEO) satellites, since drag in the thermosphere is the primary cause of the decay of these satellites. SPHEREx, along with on-going ground-based studies (passive NIR spectroscopy, lidar, incoherent scatter radar), is poised to contribute to this topic.

Time-Delay Cosmography in the era of LSST: Estimating Precise Time Delays from Lensed Supernovae

Erin Hayes
Cambridge
Friday 6 February 2026

Gravitationally lensed supernovae (glSNe) are powerful local probes of the Hubble parameter (H0), as they are independent of the distance ladder and insensitive to the assumed cosmological model. Despite their rarity, the Rubin Observatory's Legacy Survey of Space and Time (LSST) will increase the discovery rate of glSNe by an order of magnitude. In this talk, we present a comprehensive analysis of follow-up strategies for glSNe discovered by LSST based on how well time delays are estimated from the Glimpse model for time-delay estimation (Hayes+25b), built upon the GausSN framework (Hayes+24). Glimpse simultaneously models data in which the multiple images of the glSN are resolved and in which they are unresolved for the first time to achieve robust time-delay estimates. The model also accounts for chromatic microlensing, host galaxy dust extinction, and differential dust extinction in the lens galaxy in the statistical error budget. We apply this model to simulated glSN Ia systems with realistic LSST data and varying amounts of space-and ground-based follow-up. Whereas without follow-up, the time delay of an unresolved system on the dimmest end of detectability by LSST, having peak i-band magnitudes of 22-24 mag, can only be constrained to of order a week, the time delays are measured to as low as 0.7 day uncertainty with 6-8 epochs of resolved space-based observations. For systems of similar brightness that are resolved by ground-based facilities, time delays are consistently constrained to 0.5-0.8 day precision with 6 epochs of space-based observations or 8 epochs of deep ground-based observations. This work improves on previous time-delay estimation methods and demonstrates that glSNe time delays of ~10-20 days can be measured to sufficient precision for competitive H0 estimates in the Rubin-LSST era.

Science at the edge of the atmosphere

Alejandro Borlaff
NASA-Ames
Friday 30 January 2026

Humanity has launched more satellites to Low Earth Orbit (LEO) in the last four years (2021 – 2025) than in the previous seven decades of space flight combined. From 750 active satellites in 2000 to 15,000 satellites in January 2026, the exponential growth rate of LEO is driven by the rise of the space telecommunication industry, currently promising a total of 750,000 satellites by 2040. Contrary to the popular belief, satellites can affect the observations of space telescopes as well as every single ground-based telescope, all across the electromagnetic spectrum from radio to visible range as well as our planet´s atmosphere. Astronomers are not strangers to threats to the Dark and Quiet Sky, and in this talk we will review what steps the community is following to face this challenge, quantifying, mitigating, and combating the impact of the unregulated use of Low Earth Orbit.

SPT-selected protoclusters and the early emergence of hot cluster atmospheres

Scott Chapman
Dalhousie University
Friday 16 January 2026

The South Pole Telescope (SPT) has discovered a large sample of millimetre point sources in the 2500 deg^2 SPT-SZ survey. Follow-up observations with ALMA show that about 90% of these sources are strongly lensed dusty star-forming galaxies, while the remaining ~10% are compact groups of galaxies at z~3-7, representing protocluster cores caught during their most intense phase of star formation. These systems are ideal laboratories for studying how intracluster gas first emerges and interacts with extreme star formation and AGN activity.

In this talk, I will introduce the SPT-selected protocluster sample and highlight our recent ALMA detection of hot intracluster gas at z=4.3 via the thermal Sunyaev–Zeldovich effect. I will discuss the implications and briefly outline future prospects for high-redshift ICM studies, including opportunities with the upcoming facilities such as ALMA Wideband Sensitivity Upgrade (WSU), AXIS, and Athena.

Resolving dusty structures in AGN circumnuclear environments with near-infrared spectroscopy

Gaia Gaspar
Saint Mary's University
Friday 28 November 2025

Understanding how supermassive black holes interact with their host galaxies requires resolving the complex environments within the central tens of parsecs of active galactic nuclei.
In this colloquium, I will present results from ground-based near-infrared longslit spectroscopy obtained at the Gemini South telescope. Our observations reveal extended hot dust emission (T> 1000 K) on scales of tens of parsecs in nearby Seyfert galaxies. In NGC 6300, spatially-resolved spectroscopy shows K-band excess extending to ~50 pc, coincident with coronal line emission in an AGN-driven outflow. These observations support emerging models of dynamic, outflowing dusty structures rather than static tori, and provide constraints on dust survival and heating in AGN outflows. In NGC 4945, a Seyfert 2 with a strong nuclear starburst, the extended red excess is better explained by the presence of young stellar super-clusters.
I will also present my current work on GIRMOS (Gemini Infrared Multi-Object Spectrograph), a next-generation AO-assisted instrument for Gemini North. As part of the GIRMOS team, I am developing the data reduction pipeline and contributing to data simulations, working to enable the high-resolution multi-object spectroscopy that will address the current observational challenges for larger samples of AGNs.

Beyond the dripline: neutron-unbound systems, MoNA-LISA, and Virginia State University

Thomas Redpath
Virginia State University
Friday 21 November 2025

Modern efforts to study the atomic nucleus have reached an exciting juncture with the construction of the Facility for Rare Isotope Beams (FRIB). At the heart of this facility is a linear accelerator that will boost long-lived nuclei to high speeds after which they will be directed onto a target where nuclear collisions inside the target atoms will fragment the

beam nuclei into lighter, short-lived, exotic nuclei. These reaction products are still moving fast enough to be directed via magnets to any of several different experimental setups in less than a millionth of a second.
The Modular Neutron Array (MoNA) has been incorporated into one of the experimental stations. In the current setup, the array consists of 144 bar-shaped plastic scintillator detectors, each measuring 200 centimeters long, 10 centimeters wide, and 10 centimeters high. These detectors are used in experiments to measure neutron-unbound systems which are a special type of exotic nuclei. These systems are produced in nuclear reactions between high-speed exotic nuclei produced from the accelerator and nuclei in a second target positioned a few meters from the MoNA setup. They decay as soon as they're produced by emitting one or more neutrons, and MoNA is designed to detect these neutrons. Careful measurements of the neutrons and residual nucleus help scientists reconstruct information about the original, quickly decaying neutron-unbound system. Measuring the properties of various neutron-unbound systems is important for understanding how nuclear properties change and evolve from stable to exotic nuclear systems. This understanding is crucial to building a coherent picture of the dynamic system that is the atomic nucleus. This talk will discuss some of the ongoing projects that involve undergraduate students at Virginia State University in collaborative research between the VSU Nuclear Science Laboratory, the MoNA Collaboration, and FRIB.

Neutrinos and the Dark Universe: Peering into the Unknown with Liquid Argon detectors

Michela Lai
Queen's U/UCR
Friday 7 November 2025

Since the 1930s, astrophysical and cosmological observations have indicated that the majority of the Universe's mass is non-luminous, dominated by a dark component that has influenced its structure since the earliest epochs. Despite nearly a century of investigation, the direct detection of dark matter particles remains an open challenge.
Liquid argon has emerged as a highly sensitive medium for detecting GeV-scale dark matter candidates, particularly Weakly Interacting Massive Particles (WIMPs). This has been demonstrated by the DEAP-3600 and DarkSide-50 experiments, which utilize a 3.3-tonne single-phase and a 50 kg dual-phase Time Projection Chamber, respectively.
Building on these developments, we are constructing DarkSide-20k at the Gran Sasso National Laboratory (LNGS), the first experiment within the Global Argon Dark Matter Collaboration. Featuring a 50-tonne ultra-pure argon target and exceptionally low background levels, DarkSide-20k will enable exploration of dark matter-nucleon cross-sections down to for a WIMP mass of over a 200 tonne-year exposure.
DarkSide-20k, followed by ARGO, is designed to provide a definitive test of the WIMP hypothesis for masses above a few GeV/. To extend sensitivity to sub-GeV dark matter candidates, we are investigating the use of molecular dopants—introduced at part-per-

million concentrations into the argon—to enhance signal response. When scaled to tonne-scale detectors, this technique offers a novel pathway for probing previously inaccessible regions of dark matter parameter space, potentially opening a new observational window into the fundamental composition of the Universe.

Reaching and Teaching Neurodivergent Learners in STEM: Strategies for Embracing Uniquely Talented Problem Solvers

Jodi Asbell-Clarke
Saint Mary's University
Friday 31 October 2025

Our society is facing enormous STEM challenges, and we need problem solvers who are creative and systematic, who pay close attention to details, and who remain persistent until a problem is solved. We have these talented thinkers among us. They often identify as neurodivergent, be it autistic, dyslexic, and/or ADHD. Neurodivergent learners all too often they are treated as “broken” and needing to be “fixed” in our educational systems, rather than seen for their unique brilliance and potential. My book, *Reaching and Teaching Neurodivergent Learners in STEM: Strategies for Embracing Uniquely Talented Problem Solvers (*Routledge/Taylor & Francis, 2023) considers how neurodiversity—the different ways people learn and think—may present an exciting opportunity to build an innovative STEM workforce. Drawing from thirty years of collaboration with educators, learners, and STEM professionals; I have integrated a rich set of stories and strategies regarding neurodiversity in STEM, illustrating theories from research from psychology, education, and neuroscience. My talk will summarize this work and foster a discussion about how neurodiversity overlaps with many of the problem-solving skills needed in STEM.

Gravitational wave analysis with machine learning

Maximilian Dax
University of Tuebingen
Friday 24 October 2025

Gravitational-wave (GW) astronomy promises groundbreaking discoveries in the coming decades, but its progress is bottlenecked by the computational challenges of large-scale and real-time data analysis. I will present a machine learning (ML) approach for fast and accurate GW inference that addresses these challenges. This work combines simulation-based inference, generative modeling, equivariant ML, and classical sampling techniques. I will demonstrate how ML enables new scientific capabilities in GW astronomy and, conversely, how the demands of this domain drive fundamental innovations in ML, with applications beyond astrophysics.

A Local View of Stellar Astrophysics in the Early Universe

Grace Telford
Princeton
Friday 17 October 2025

Energetic feedback from massive stars with low abundances of heavy elements ("metals") regulates the evolution of low-mass galaxies, both nearby and in the early Universe. To understand those processes requires robust models of massive star formation, evolution, and ionizing photon production at low metallicity. Yet, these models remain largely theoretical and uncertain due to a lack of observational constraints in metal-poor galaxies close enough that individual stars and star-forming gas can be spatially resolved.
I will present new insights into the astrophysics of individual metal-poor stars in the nearby Universe from large observational surveys with the Hubble Space Telescope and some of the world's largest ground-based observatories. I will then describe the recent discovery of molecular gas in a very low-metallicity, star-forming galaxy with James Webb Space Telescope, which provides a novel constraint on the nature of the metal-poor gas from which stars formed in the early Universe. These detailed observations that can only be made in very nearby galaxies are essential to guide the massive-star models that astronomers rely on to interpret observations of distant, metal-poor galaxies and their impact on the evolution of the early Universe.

New insights into early galaxy formation with JWST and ALMA

Joris Witstok
Niels Bohr Institute
Friday 3 October 2025

Cosmic reionization began when ultraviolet (UV) radiation produced in the first galaxies began illuminating the cold, neutral gas that filled the primordial Universe. Recent JWST observations have shown that surprisingly UV-bright galaxies were in place beyond redshift $z = 14$, when the Universe was less than 300 Myr old, sparking a debate on the nature of these early systems. I will present spectroscopy from the JWST Advanced Deep Extragalactic Survey (JADES) of a galaxy at redshift $z = 13.0$ that reveals a singular, bright emission line unambiguously identified as Lyman-α (Lyα), the principal hydrogen transition. Together with an extremely blue UV continuum, the unexpected Lyα emission indicates that the galaxy is a prolific producer and leaker of ionising photons, suggesting that massive, hot stars or an active galactic nucleus have commenced reionisation early on. I will further present new observations from the Atacama Large Millimeter/submillimeter Array (ALMA), which have begun to provide vital insights on the gas, metal and dust content of $z > 10$ galaxies. Comparing the accurate ALMA redshifts to those measured purely from the Lyα break, even spectroscopically, we find damped Lyα (DLA) absorption can cause systematic overestimates of up to $\Delta z \sim 0.5$, suggesting the presence of large neutral gas reservoirs. While the [C II] 158 μm line remains undetected at $z > 10$, several detections of bright [O III] 88 μm emission agree well with local SFR scaling relations, indicating early galaxies rapidly enrich in oxygen (>10% solar) within a few hundred million years after the Big Bang.

Magnetic star-planet interaction

Ekatarina Ilin
ASTRON
Friday 26 September 2025

The past decade has revealed that exoplanets are abundant. The evolution of their atmospheres over cosmic timescales is the next great frontier in our understanding of those planets. Star-planet interactions can determine the long-term stability and survival of planetary atmospheres. This interaction occurs in one direction, where stellar high-energy radiation and particles gradually erode the planetary atmosphere. However, recent evidence shows that the reverse is also possible: A planet in a sufficiently close orbit can influence its host star through magnetic interactions. In this talk, I will review what we know and don't know about the magnetic ways in which planets perturb their host stars, and explore the potentially destructive repercussions for these planetary troublemakers.

Properties of nuclear star clusters in 41 dwarf galaxies from the MATLAS survey and implications on their formation

Melina Poulain
University of Oulu
Friday 12 September 2025

Debated for decades, the formation of nuclear star clusters (NSCs) --the densest stellar objects in the Universe-- currently opposes two main scenarios: the migration and merging of globular clusters (GCs) due to dynamical friction, and the in-situ star-formation from gas infall. Studies of NSC stellar populations suggest that the former prevails in dwarf galaxies, with a possible contribution of the latter. However, timescales are such that up to now, no ongoing GC mergers were caught in the act. I will present a follow-up study of 41 nucleated dwarfs from the MATLAS survey observed with the high resolution ACS camera of the Hubble Space Telescope. About 12% of the galaxies show a complex nuclear region containing multiple star clusters and stellar tails which, I will show, establish a first direct evidence of ongoing star cluster mergers in the center of dwarf galaxies. Structural properties and photometry of the full NSC sample have been derived and compared to NSCs from galaxies in a range of mass and environment. I will showcase the results and discuss them in terms of NSC formation process. I will conclude on the future of NSC studies in the context of upcoming large surveys with deep and high spatial resolution observations, such as the Euclid Wide Survey.

Direct imaging spectroscopy of exoplanets with JWST

Kielan Hoch
STSci
Friday 19 September 2025

JWST has opened the door to spectroscopy of directly imaged exoplanets beyond 3 microns, offering a new landscape for measuring their fundamental and atmospheric properties. Directly imaged planets are in a stage of early evolution and are undergoing atmospheric processes that are critical for understanding planetary atmospheric evolution and formation. These planets, with masses of ~2-14MJup and temperatures of ~500-2000 K, remain a mystery for planet formation models—core accretion and gravitational instability. Observations that probe elemental abundances in their atmospheres can shed light on their formation. Here I present JWST Cycle 1 programs that have pioneered the use of JWST's NIRSpec IFU to obtain spectra of substellar companions close to sunlike stars. For HD 19467 B, NIRSpec spectra show detections of CO, CO_2, CH_4, and H_2O. We forward model the R~2,700 spectra using custom PHOENIX atmospheric model grids to constrain the abundances of these molecules, the C/O ratio, and non-equilibrium chemistry. These results highlight a need for revisions of disequilibrium chemistry models to vary the CO_2 abundance with the new spectral information provided by NIRSpec. For the multi planet system YSES-1, my team obtained one of the most comprehensive datasets of a multi-planet system with spectral coverage from 1-12 microns using NIRSpec and MIRI. The spectra allow direct spectral comparison of sibling planets in unprecedented detail with spectra that show the first direct detection of silicate clouds in an exoplanet YSES-1 c and the detection of a circumplanetary disk around YSES-1 b with olivine emission that could be caused by formation of larger bodies such as moons.