Abstract Booklet:
Oral Contributions

Abstract number: **1**
Author: Thomas J Maccarone
Title: **Millimeter transients and variables**

Abstract:
Ultra-widefield, high cadence surveys of the sky have been done for almost the whole history of X-ray and gamma-ray astronomy, and have had a recent Renaissance in optical astronomy. In the longer wavelengths, they have been impractical in the past, except at meter wavelengths where they detect few transients due to slow timescales of variability at low frequency. The recent generation of CMB surveys has sufficient angular resolution to detect foreground sources including transients and strong variables, already showing a greater rate of transient discovery than meter-wave surveys. Source classes for transients include flare stars, symbiotic stars, classical novae and active galactic nuclei in current data, which has mostly avoided the Galactic Plane. Next generation CMB surveys from space can allow higher cadence, more bands, better sensitivity, and truly all-sky coverage of transient and variable sources relative to what is possible from the ground. I will highlight current capabilities, and discuss the prospectus for opening up studies to new classes of transients like gamma-ray bursts, X-ray binaries, magnetars, and merging supermassive black holes.

Abstract number: **2**
Author: Joseph Lazio
Title: **Imaging Supermassive Black Hole Binaries**

Abstract:
Compelling evidence has been presented by the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) and other international pulsar timing array (PTA) consortia for a stochastic gravitational wave (GW) background at nanohertz GW frequencies. The existence of such a stochastic GW background has been expected based on projections from mergers of galaxies and the occupation fraction of supermassive black holes (SMBHs) in galaxies—as galaxies merge, the SMBHs in their centers should spiral together to form GW-emitting binaries. However, the amplitude of the stochastic GW background is higher than initial expectations. Possibilities to explain this higher amplitude include that galaxy scaling relations underpredict the population of the most massive SMBHs or physics beyond the Standard Model or extensions of the Hot Big Bang model. If SMBH binaries are the dominant contribution to the stochastic GW background, there should be a “local”' population of SMBH binaries. With in-spiral lifetimes of millennia or longer, these local SMBH binaries could be powerful multi-messenger laboratories, enabling GW and electromagnetic studies of the inner regions of massive galaxies. The expected angular separation between the SMBHs in such a “local” binary would be a few to several hundred microarcseconds. While a fraction of these may be accessible to ground-based very long baseline interferometric (VLBI) observations, the likelihood is that most or all SMBH binaries will require space-based VLBI observations. This presentation will review the likely landscape of SMBH binaries, the potential yields from being able to image them, and outline the requirements for space-based VLBI.

Abstract number: **3**
Author: Javier Garcia
Title: **The Growth and Spin of Supermassive Black Holes with a Broad-Band X-ray Observatory**

Abstract:
Understanding supermassive black holes grow, and how that growth couples to the evolution of their host galaxies, remains one of the defining questions for astrophysics in the 2030s. The upcoming galaxy surveys from JWST, Roman, Rubin/LSST, Euclid, and future far-infrared and radio facilities, will map the environments, stellar populations, and assembly histories of galaxies across cosmic time. Yet, these data will trace the consequences of accretion rather than the accretion physics itself. Black hole growth is encoded most directly in the X-ray band, and accessing it requires broad spectral coverage. Relativistic reflection probes black hole spin, while the high-energy continuum and its curvature separate intrinsic coronal emission from line-of-sight obscuration. Spin is an almost permanent fossil of accretion history: coherent accretion, chaotic accretion, and mergers imprint distinct signatures on the population spin distribution. Today's census is a few dozen heterogeneous measurements; the transformative step is a homogeneous sample of ~100 AGN, uniformly analyzed, that turns individual spins into a population-inference problem discriminating between growth channels. We discuss how a sensitive broad-band X-ray observatory delivers these measurements through the modeling of the reflexion spectrum, the soft excess, continuum curvature beyond 10 keV, and variable absorption; while simultaneously resolving the obscured accretion that produces the bulk of the cosmic X-ray background near its ~30 keV peak. Such an observatory would connect galaxy demographics to the physics of accretion, resolve a larger fraction of obscured black-hole growth, and provide the X-ray capability required to turn multiwavelength galaxy surveys into a physical census of supermassive black-hole assembly.

Abstract number: **4**
Author: Daniel Stern
Title: **Compact Objects and Energetic Phenomena with a Broad-Band X-ray Observatory**

Abstract:
Astrophysics in 2026–2035 is being driven by wide-field, time-domain, and multi-messenger discovery engines, including but not limited to Rubin/LSST, Roman, UVEX, ULTRASAT, the upgraded LIGO–Virgo–KAGRA network, Simons Observatory, IceCube/IceCube-Gen2, wide-field gamma-ray monitors, and LISA. These survey facilities reveal that an event has occurred, but it is in the X-ray band, particularly the broad-band X-ray band reaching beyond 10 keV, that the driving physics can be measured — shocks, outflows, accretion-state transitions, reprocessing, and absorption all leave direct signatures in X-ray spectra and timing. The X-ray sky is also inherently highly dynamic, with key X-ray sources such as Galactic binaries and active galaxies producing time-variable high-energy spectra that reveal their inner physics. I will describe key science questions and the power of a broad-band X-ray observatory to address them.

Abstract number: **7**
Author: Steven Edward Boggs
Title: **Origin of the Isotopes: The Case for a Next-Generation Nuclear Line Spectrometer**

Abstract:
Nuclear gamma rays and positron annihilation radiation are among the most powerful diagnostics in astrophysics. Tied to specific radioactive isotopes and carrying their decay lifetimes as intrinsic chronometers, nuclear lines enable studies of nucleosynthesis, explosion physics, and matter transport that are inaccessible by other means. Yet these gamma rays are exceptionally hard to detect. The number of known sources is quite small, including only a few supernova in the prompt or remnant phase, with the origin of the Galactic positron flux unexplained. NASA's forthcoming COSI mission delivers an order-of-magnitude sensitivity gain for such signals; we ask what could be next. We make the science case for a mission optimized for nuclear line sensitivity to point sources, with at least an order of magnitude sensitivity advance over COSI and sufficient spectral resolution, possibly with imaging ability. Such a spectrometer would enable population studies of supernovae and novae, which will allow for understanding the unique physics involved in these cosmic explosions, as well as refining our use of type Ia as standard candles. It may be able to find the first kilonova remnants; with the mapping of numerous lines from a signal event being a foundational advancement in nuclear astrophysics. Such a mission could also uncover a population of supernova remnants and refine the sources of Galactic diffuse emission.

Abstract number: **8**
Author: Eric Burns
Title: **The Future of Gamma-Ray Burst Science**

Abstract:
Gamma-ray bursts sit at the center of several enduring grand questions in astrophysics. In cosmology, as the brightest electromagnetic counterparts of compact-object mergers, they enable standard-siren measurements of cosmic expansion and the nature of dark energy, and high redshift events allow mapping of reionization and insight into star formation at cosmic dawn. In fundamental physics, observations have enabled the most precise limits on Lorentz invariance violation and unique tests of gravity, and they constrain the neutron-star equation of state and the states of matter at extreme density. Gamma-ray bursts are the fastest jets in the universe, offering a unique window into the most powerful cosmic accelerators. The only two known sources of heavy (r-process) elements are gamma-ray bursts, and observations of these events over cosmic time probe the chemical enrichment history of the universe from the first stars onward. We will map this science, and how to unlock it with future high-energy monitors, in the broader astrophysical context. As informed by the Gamma-ray Transient Network SAG, requirements include true, continuous all-sky monitoring of the keV-MeV sky, with precise localization, and, ideally, rapid alerts. Sensitivity needs will also be highlighted. Such a capability is a foundational need for time-domain astrophysics, and we will close with a brief discussion on possible implementation architecture.

Abstract number: **9**
Author: Erin K. S. Hicks
Title: **From Accretion to Feedback: AGN Science Priorities for Future NASA Missions**

Abstract:
Supermassive black holes (SMBHs) are fundamental drivers of galaxy evolution, yet the physical processes linking black hole growth to the evolution of their host galaxies remain poorly understood. A central challenge for the coming decades is to understand how SMBHs grow, interact with their environments, and ultimately shape galaxies across cosmic time. These processes span the full electromagnetic spectrum and a vast range of physical scales, making AGN science uniquely dependent on coordinated observations across nearly every wavelength regime and positioning it to both benefit from and contribute to the science cases for future NASA astrophysics missions. This presentation will outline key AGN science questions and how they can help motivate future NASA mission capabilities. These questions follow the physical processes that connect black hole growth to galaxy evolution: How is gas transported from galactic scales to fuel SMBH accretion? What are the structure and dynamics of the multiphase circumnuclear environment that regulates inflow and AGN feedback? What physical mechanisms launch AGN winds and outflows, and how do they transfer energy and momentum into the surrounding interstellar and circumgalactic media? Under what conditions does AGN feedback regulate star formation and the baryon cycle? Finally, how do these processes collectively drive the coevolution of black holes and galaxies over cosmic time? Addressing these questions will require transformative advances in high angular resolution and high throughput imaging and spectroscopy, long-term time-domain monitoring, and coordinated multiwavelength observations. Together, these capabilities will enable a comprehensive picture of black hole growth and feedback, highlighting how advances across future NASA observatories can address fundamental questions in AGN science.

Abstract number: **11**
Author: Krista Lynne Smith
Title: **The X-ray Timing Science Analysis Group: Extreme and Fundamental TDAMM Science with DEUS-X**

Abstract:
X-ray timing offers the most direct path to the detailed physics of dynamic phenomena involving accretion, extreme matter and fields, explosive stellar events, and the structure and fate of the most luminous objects in the universe. The fastest variability from compact objects reveals geometry on nano-arcsecond spatial scales, inaccessible by any other means. X-rays are essential for multi-messenger data reliant upon electromagnetic information for physical interpretation; indeed, a “notable absence of sensitive, wide-field X-ray” coverage has been explicitly identified as a concern for characterizing binary supermassive black holes detectable in gravitational waves. I will explain how time-resolved X-ray imaging, spectroscopy, and perhaps polarimetry can address major questions in key decadal initiatives, including how to measure the spins of black holes, the nature of supranuclear matter, the launching and collimation of relativistic jets, and the signatures of electromagnetic counterparts to multimessenger neutrino and gravitational wave sources. In addition to summarizing the science priorities of the X-ray timing Science Analysis Group I will present the proposed mission concept developed by the SAG to meet this urgent need: Dynamic Extreme Universe in X-rays (DEUS-X), a fleet concept with both transient detection and detailed follow-up capabilities that has strong synergy with the nuclear and gravitational astrophysics community.

Abstract number: **13**
Author: Laura Brenneman
Title: **Finding and Characterizing High-Redshift Black Holes with Next-Generation X-ray Missions**

Abstract:
The origin and evolution of structure at high redshifts remains a core question in astrophysics. Efforts are underway to address this question by finding and characterizing the first black hole seeds and understanding the demographics of obscured AGN. Though JWST has made important progress – e.g., the discovery of 'Little Red Dots' – definitive identification and characterization of these sources requires X-ray observations in order to distinguish between AGN and star-forming galaxies. Achieving these science goals requires arcsecond-class imaging and square-meter-class effective area to enable source characterization at $z > 6$ without running into the confusion limit. Maximizing survey efficiency also requires mirrors in which the PSF remains within requirements over the field of view. The next generation of X-ray telescopes must take advantage of readily available substrates that can be ground and polished using commercial, programmable tools in order to fabricate the optics that facilitate this science at reasonable cost. SAO is currently leading such an effort, enabling the development of X-ray mirrors beyond the standard Wolter I or Wolter-Schwarzschild configurations, making it possible to optimize resolution to arcsecond-class performance across a broad (> ±10 arcmin) field of view. Because the fabrication process leverages industrial polishing and alignment techniques, mirror modules can be produced in parallel, reducing cost and schedule risks. These optics are suitable for a broad class of mission architectures to address a wide range of science questions from Astro2020. The new SAO optics could satisfy all of the above instrument requirements within the next decade. This would enable the launch of one or more next-generation X-ray missions temporally overlapping with JWST, Roman and LISA, preventing the critical loss of X-ray coverage in the panchromatic mission portfolio of the 2030s.

Abstract number: **14**
Author: Varoujan Gorjian
Title: **PanChromia: The EM Machine for TDAMM Science**

Abstract:
As noted in the Astro 2020 Decadal Survey, the Neil Gehrels Swift Observatory, launched in 2004, has shown the great advantages of a space-based observatory doing Gamma-Ray, X-ray, and UV/optical localization and photometric monitoring of transient and variable sources. Hence, an expanded follow-up of such an observatory, either as a single space facility, or a set of coordinated space facilities acting as one observatory, will allow for incredible follow-up opportunities for time-domain and multimessenger (TDAMM) science. Since the launch of Swift, NASA has flown not only more advanced Gamma-ray, X-ray, and UV/optical telescopes, but also advanced passively cooled and cryocooled infrared telescopes, opening the possibility for a follow-up observatory that has capabilities from the Gamma-rays all the way out to the Mid-infrared. The technologies exist now to go beyond localization and photometry of targets, to providing spectroscopy covering a vast wavelength range that can quickly follow-up transient events like Gamma-Ray bursts and electromagnetic (EM) counterparts to Gravitational Waves, as well as regular monitoring of variable sources like protoplanetary disks and active galactic nuclei. So we discuss the potential science resulting from a proposed Gamma-Ray to Mid-infrared space observatory dubbed PanChromia: a powerful EM machine for TDAMM science.

Abstract number: **15**
Author: Fabio Pacucci
Title: **What Lit Up the Universe? Completing the Picture of Cosmic Dawn with a Next-Generation X-ray Flagship**

Abstract:
JWST has revolutionized our view of the first billion years of cosmic history, revealing an unexpectedly rich population of luminous sources during Cosmic Dawn. These discoveries include candidate black hole seeds, the enigmatic Little Red Dots (LRDs), galaxies extending to redshifts beyond 14, and the earliest proto-clusters. These findings have transformed our understanding of how the young Universe emerged from primordial darkness. However, the physical engines powering these systems remain largely hidden. Many of the key processes that shaped the early Universe—black hole accretion, high-energy feedback, compact-object formation, and the heating of the first large-scale structures—are most directly revealed through X-ray observations. While JWST identifies where these phenomena occur, it cannot directly probe the energetic mechanisms driving them. As a result, our current picture of Cosmic Dawn remains fundamentally incomplete. We present a science case, developed through a broad community effort, for a next-generation X-ray flagship observatory to complement JWST and future multi-wavelength facilities. Such an observatory would enable direct detections of accreting black hole seeds, distinguish between competing seed formation pathways through high-redshift population studies, uncover the nature of the LRDs, reveal compact-object populations and feedback processes in the first galaxies, and trace the emergence of hot gas within the earliest proto-clusters. These science goals require transformational advances in sensitivity, angular resolution, and survey capability that motivate a next-generation X-ray flagship mission. By providing the missing high-energy view of Cosmic Dawn, a next-generation X-ray observatory would address one of the most fundamental questions in astrophysics: what powered Cosmic Dawn and ultimately lit up the Universe?

Abstract number: **16**
Author: Tiffany Lewis
Title: **Blazar Jets - Connecting Gamma-ray Polarization to Galactic Evolution**

Abstract:
Galaxies and supermassive black holes co-evolve through cosmic time, but the precise mechanisms are not well understood. We know that the active phase is significant to both elements, as well as the distribution of energy in the universe when these systems produce jets. The jet launching mechanism for active galaxies is not directly observed, but it is possible to constrain through the composition of the jet itself. Blazars emit at all wavelengths, but their high-energy emission process is uncertain and points to their composition. While spectra alone are insufficient to differentiate between models, polarization measurements from 100 keV to 100 MeV would be instrumental. This discovery space contributes important insights for the broader galaxy and cosmic evolution communities because it reveals a key phase of SMBH co-evolution. As some of the most sustained astrophysical jets, blazars are also a touchstone source class for observationally elucidating astrophysical jet physics.

Abstract number: **17**
Author: Joaquin Vieira
Title: **The Extragalactic Millimeter Sky with CMB Probe+: A Census of Cosmic Structure and Obscured Star Formation**

Abstract:
A Cosmic Microwave Background (CMB) Probe, surveying the millimeter and sub-millimeter full sky with one arc-minute resolution and the equivalent sensitivity of more than 6,000 Planck missions, would be transformative for extragalactic science. With 21 frequency bands between 20 and 800 GHz it would produce un-precedented measurements of the Cosmic Infrared Background (CIB), dusty star-forming galaxies, active galactic nuclei (AGN), and other compact sources. The CIB traces the integrated history of obscured star formation and its connection to dark matter halos, while also serving as a key tracer for CMB lensing, delensing, baryonic feedback, and primordial non-Gaussianity studies. This presentation will outline the CIB and point-source science enabled by a CMB Probe, including reconstruction of the cosmic star-formation history, constraints on the halo mass scale of peak star-formation efficiency, full-sky catalogs of AGN, dusty galaxies, clusters of galaxies, and protoclusters. I will also emphasize complementarity with current and upcoming ground-based facilities connecting high-resolution small-area maps with stable, multi-frequency, all-sky measurements.

Abstract number: **18**
Author: Chien-Ting Chen
Title: **Resolving the Cosmic X-ray Background for Cosmic Accretion History with a Broad-band X-ray Observatory**

Abstract:
The cosmic X-ray background (CXB) is the integrated emission of accreting supermassive black holes across cosmic time, and resolving it into discrete sources has been a cornerstone of modern galaxy evolution — establishing the cosmic accretion history, black hole–galaxy coevolution, and the role of AGN feedback. Yet this accounting is most incomplete where it matters most. Deep Chandra and XMM-Newton surveys resolve ~80–90% of the CXB below 10 keV, but at the peak of the CXB near ~ 30 keV, the resolved fraction collapses to a few tens of percent at best, leaving the spectral peak largely unaccounted for at the source level. This gap conceals the heavily obscured and Compton-thick AGN that population-synthesis models require to reproduce the peak, yet their abundance remains unconstrained. The knowledge of the obscured AGN population is crucial for the accretion energy budget, black hole fueling, and feedback. I will describe how a broad-band X-ray observatory can resolve the CXB and address key science questions in galaxy evolution.

Abstract number: **19**
Author: Alan Kogut
Title: **CMB Spectral Distortions -- The New Frontier**

Abstract:
Spectral distortions -- small deviations from a perfect blackbody spectrum -- in the cosmic microwave background represent one of the last remaining unexplored frontiers for cosmology. Current upper limits, from more than 3 decades ago, limit such spectral distortions to 50 parts per million and provide a foundation for the Hot Big Bang model of the early universe. Modern upgrades to the 1980's-era technology behind these limits enable 3--4 orders of magnitude improvement in sensitivity. The standard cosmological model provides compelling targets at this sensitivity, while the broad discovery space enables stringent tests for new physics. I will discuss the science returns from a next-generation spectral distortion mission and the ancillary science from the resulting absolutely-calibrated data set.

Abstract number: **20**
Author: Srinivasan Raghunathan
Title: **A Next-Generation Full-Sky CMB Survey for Probing Fundamental Physics and Structure Formation with Secondary CMB Anisotropies**

Abstract:
Secondary anisotropies of the cosmic microwave background (CMB) provide a powerful window onto the late-time Universe, linking fundamental cosmology, structure formation, and baryonic physics. A next-generation, full-sky CMB survey with broad frequency coverage will deliver transformative advances across a wide range of observables. The survey will measure CMB lensing with signal-to-noise approaching ~1000, particularly through foreground-robust polarization-only reconstruction, thereby enabling sensitive searches for primordial gravitational waves via delensing of lensing-induced B-modes. The measurements will support high-fidelity cross-correlations with complementary probes, including galaxy clustering, shear, and Sunyaev–Zeldovich (SZ) signals. In combination, these multi-tracer analyses will probe the growth of structure and baryonic feedback, break degeneracies between cosmology/astrophysics, and tightly constrain primordial non-Gaussianities. The survey will further exploit the thermal SZ (tSZ) effect as a probe of baryons, enabling detection of galaxy clusters and protoclusters to high redshifts beyond the epoch of cosmic noon. Combined with CMB-lensing-based mass calibration, these measurements will tighten constraints on dark energy and neutrino mass. High signal-to-noise (~200) measurements of the small-scale tSZ power spectrum, together with cross-correlations, will constrain baryonic feedback and the thermal history of gas. Beyond the standard tSZ signal, the survey's broad frequency coverage will enable clean separation of relativistic and non-thermal SZ components, providing new insight into intracluster gas temperatures, high-energy electron populations, and spectral distortion anisotropies sensitive to primordial physics. Finally, the kinetic SZ (kSZ) effect will probe the velocity field and distribution of ionized gas through cross-correlations with galaxy surveys, while its two- and four-point statistics will further constrain the ionization history of the Universe, offering an independent and complementary determination of the optical depth to that inferred from large-scale polarization. In combination with galaxy surveys, the full-sky CMB survey enables a multi-mission, multi-probe framework that delivers a unified, high-precision view of baryons and cosmic evolution.

Abstract number: **21**
Author: Jack O. Burns
Title: **A Vision for Low Radio Frequency Astrophysics and Cosmology from the Far Side of the Moon: The Cosmic Dark Ages**

Abstract:
The radio-quiet lunar far side offers a unique opportunity to address one of the most profound questions in modern astrophysics and cosmology: How does the Universe work? At ultra-long wavelengths inaccessible from Earth, a far-side interferometric array operating at 1–50 MHz would enable transformational science spanning the Dark Ages, fundamental physics, and stellar space weather. The Astro2020 Decadal Survey identified the Cosmic Dark Ages as the sole Discovery Area for cosmology. By measuring the redshifted 21-cm signal from neutral hydrogen at z≈30-100, a lunar far-side array can produce 3D tomographic maps and precision power spectra of the early Universe in a largely linear regime, before the formation of the first stars and galaxies. These observations provide a matchless probe of physics beyond the standard model, including inflationary initial conditions, primordial non-Gaussianity, dark matter physics, and early dark energy - beyond the reach of CMB and galaxy surveys. Lunar radio astronomy began with the NASA ROLSES-1 mission in 2024, which demonstrated low frequency observations using Earth as a technosignature prototype and detected galactic radio emissions from the lunar surface for the first time. This will be followed by ROLSES-2 in 2028 that will conduct observations of space weather from the Sun to the Earth. LuSEE-Night, launched to the lunar far side in early 2027, will undertake the first search for the global 21-cm Dark Ages signal. Building on these pathfinders, the FARSIDE Probe-class 256-element interferometric array concept is responsive to the Astrophysics Roadmap Enduring Quests, Daring Visions. Future telescope concepts, including MoonRISE, FIORE, FarView, and the Lunar Crater Radio Telescope (LCRT), provide a scalable pathway toward permanent lunar far side radio observatories enabling flagship-class science in the 2030s.

Abstract number: **22**
Author: John Callas
Title: **Fundamental Physics and Precision Measurements in Space**

Abstract:
Einstein's General Relativity and the Standard Model of particle physics are the two central pillars of modern fundamental physics. Both have been extraordinarily successful, yet together they leave several basic questions unresolved: What is the particle nature of dark matter? What drives the accelerated expansion of the universe? Why is the observable universe dominated by matter rather than antimatter? And how can gravity be reconciled with quantum theory? Extensive accelerator, direct-detection, indirect-detection, and astronomical searches have placed stringent constraints, but no confirmed dark-sector particle or definitive deviation from known physics has yet been identified. Space-based precision measurement offers a complementary discovery strategy. Instead of producing new particles directly, it tests the principles underlying General Relativity and the Standard Model by searching for extremely small departures from their predicted observables. Space provides key advantages for such tests: microgravity, long baselines, large variations in gravitational potential and velocity, and access to cold, high-vacuum environments. Atomic clocks, atom interferometers, optical time and frequency transfer, quantum optical links, gravity gradiometers, and lunar laser ranging can probe gravitational redshift, Local Position Invariance, Local Lorentz Invariance, the Universality of Free Fall, the Strong Equivalence Principle, PPN gravity parameters, possible time variation of Newton's gravitational constant, and inverse-square-law deviations. Relevant observables include fractional clock-frequency shifts, differential accelerations parameterized by the Eötvös parameter η, anomalous gravity-gradient tensor components, Bell-test or entanglement metrics over long baselines, and lunar range residuals at the millimeter to tens-of-micrometers level. Many models of dark matter, dark energy, modified gravity, fifth forces, and ultralight scalar fields predict small signals in precisely these channels. This presentation describes how space-based precision measurements and JPL instrumentation capabilities can open a quantitatively testable search space for new fundamental physics beyond the reach of traditional high-energy and direct-detection approaches, with clear connections to measurable mission-level performance and physics return.

Abstract number: **23**
Author: Yun Wang
Title: **CHROMOS Cosmology: Transforming Our Understanding of the Universe**

Abstract:
We propose the Cosmic Higher Resolution Origins Multi-Object Spectroscopy (CHROMOS) mission concept for ASTRA. CHROMOS will fill major science gaps by definitively addressing fundamental questions identified by Astro2020, and remain critical in the coming decade. CHROMOS features a 2m aperture space telescope with 0.7 sq deg field-of-view (FoV) and multi-object slit spectroscopy for up to 16,000 objects simultaneously at R = 1000, over the wavelength range of 1.25 to 5 microns. It will answer key questions in cosmology, as well as exoplanets, galaxy evolution, and Milky Way science. This talk will discuss CHROMOS cosmology science in the context of Astro2020 and the current and future landscape of synergistic projects, including DESI, SPHEREx, Euclid, and Roman. CHROMOS will transform our understanding of the Universe. By leveraging Euclid photometry over 14,000 sq deg to H = 24.5, CHROMOS will obtain slit spectra for 1 billion Hα and [OIII] emission line galaxies at $1 < z < 9$ over 14,000 sq deg in 2 years, providing the ultimate 3D map of the Universe that will revolutionize cosmology. CHROMOS is designed to answer these fundamental questions in cosmology: (1) What is the physics of cosmic inflation? (2) What is the nature of the observed cosmic acceleration? (3) What is the total mass of neutrinos? CHROMOS is the modest scaling up of ATLAS Probe from 1.5m to 2m telescope aperture, and expected to meet the cost cap of an ASTRA mission. It will be a powerful spectroscopic observatory for general physics investigations, filling the capability gap of current and planned space and ground-based projects. CHROMOS uses proven technologies and is ready to enter the ASTRA incubator now, to fill critical science and spectroscopic capability gaps, and will drive discoveries in astrophysics for decades once launched.

Abstract number: **24**
Author: Daniel Green
Title: **Transformative Cosmology with a CMB Probe**

Abstract:
Measurements of the cosmic microwave background provide our clearest view of the Universe, its contents, and history. Key targets that could transform our understanding of the Universe, past, present, and future, are only accessible from space. The CMB Probe mission would have the raw sensitivity of 10,000 Planck satellites and would be capable of reaching these targets through ultraprecise, high-resolution measurements of the CMB temperature and polarization. Critically, it would probe the amplitude of primordial gravitational waves at the $\sigma(r)=10^{-4}$ level. A measurement at this sensitivity is essential for distinguishing broad classes of inflationary models. In addition, a CMB Probe mission would provide the definitive measurement of the optical depth to reionization and the neutrino mass, and offer unparalleled insights into the particle content and forces that shape the Universe. In this talk, I will review scientific questions in cosmology that motivate the CMB Probe and explain how such a next-generation satellite can reach these ambitious goals. In particular, I will detail how detector sensitivity, sky fraction, and resolution translate into scientific impact.

Abstract number: **25**
Author: Nicholas Kern / Steve Furlanetto
Title: **Cosmology in the Cosmic Dark Ages**

Abstract:
The cosmic Dark Ages, the era preceding the formation of the first stars and black holes at redshifts $z \gtrsim 30$, was identified by the two most recent Decadal Surveys as a key discovery area. Observations of primordial hydrogen gas backlit by the Cosmic Microwave Background (CMB) are a unique probe of this uncharted era. In the standard cosmological model, after recombination, the CMB and H i gas cool at different rates, leading to a characteristic absorption signal at frequencies $f \sim 15$ MHz. This prediction, unlike signals sourced at later times during the era of star formation, is simple to model from first principles and serves as a robust test of ΛCDM cosmology. The brightest observational signature from this era is the sky-averaged "global" signal, the shape of which acts as a cosmic thermometer: unexpected energy injection creates distinct deviations from ΛCDM predictions, enabling tests of fundamental physics, from decaying or annihilating dark matter, baryon-dark matter interactions, primordial magnetic fields, accretion of gas onto primordial black holes, or other exotic physics. The Dark Ages H i signal enables probing small spatial scales in 3-D, combining the best aspects of previous CMB missions (WMAP, Planck) and SPHEREx, while reaching beyond the CMB's ability to map only a 2-D slice of the Universe. For example, a number of works have illustrated the potential of the Dark Ages H i spatial fluctuation signal to set precise constraints on the inflationary potential, the neutrino mass, and the nature of dark matter. This presentation will review the predicted evolution of the Universe during the Dark Ages, the potential yield for cosmology and fundamental physics in being able to probe the Dark Ages, and outline the requirements for a future space-based radio telescope.

Abstract number: **26**
Author: W.L. Kimmy Wu
Title: **CMB lensing and cosmology: current status and future outlook**

Abstract:
CMB lensing is now a precision cosmology probe. The latest CMB lensing measurement from SPT-3G, ACT, and Planck produces constraints on sigma8*Omega_m^0.25, a measure of matter clustering, that have comparable constraining power to that from the primary CMB while anchoring on a low-redshift range that peaks around z = 1–2, probing different scales and redshifts of the universe. In this talk, I will present new results on CMB lensing using data from SPT-3G, the third-generation mm-wave receiver installed on the South Pole Telescope. This measurement provides state-of-the-art constraints on matter clustering. When combined with the primary CMB, we find Omega_m to be more consistent with that from the DESI DR2 BAO measurement, leading to shifts in LCDM extension models---such as a less artificially tight upper limit on the sum of neutrino mass and lower preference for non-zero spatial curvature---compared to recent results. I will then give a preview of upcoming CMB measurements and discuss the possible science reach of future CMB probes.

Abstract number: **27**
Author: Philip von Doetinchem
Title: **Low-energy Antinuclei Measurements**

Abstract:
Light low-energy cosmic ray antinuclei constitute powerful probes for detecting dark matter or other sources of new physics in our Galaxy. This contribution reviews the theoretical motivation, highlighting the transformative potential and current experimental status. Motivated by exciting tentative results, it makes a clear case for the need for the next flagship mission to confirm or refute claims of cosmic antinuclei as signs of new physics.

Abstract number: **28**
Author: Zorawar Wadiasingh
Title: **A future γ-ray pulsar timing array and other revolutionary science with neutron stars**

Abstract:
I will highlight two deep science cases for a sensitive broadband continuum mission in the MeV-GeV: characterizing low-frequency gravitational waves (GWs) and understanding strong-field quantum electrodynamics not accessible terrestrially. Pulsar timing arrays with ground-based radio telescopes are opening a new window on the nanohertz GW universe, but their ultimate reach depends on discovering and timing far more Galactic pulsar "clocks". Millisecond pulsars (MSPs) are luminous GeV sources. Unlike radio observations, γ-ray timing is unaffected by interstellar plasma, offers nearly continuous and unbiased sky coverage of both hemispheres, and benefits from homogeneous instrumentation. Next-generation GeV missions operating over an optimal band of approximately 0.1–5 GeV could detect and time ~5000 MSPs to the edge our galaxy and enabling a γ-ray pulsar timing array with sensitivity beyond current radio PTAs. Such a population would provide an unprecedented probe of the GW background, its anisotropy, sources and its astrophysical or cosmological origins while clarifying the origin of the Galactic-center GeV excess often attributed to dark matter, detect numerous pulsar planets, and serve as a treasure map for radio PTAs. The same mission transform our understanding on how pulsar magnetospheres work and create electrons and positrons from the vacuum. The resulting measurements would establish a Galaxy-scale GW observatory for precision cosmology and fundamental physics. Turning to the MeV, photon splitting is a third-order QED process that splits one photon into two, forbidden in a vacuum for allowed in the strong fields of magnetars but whose rules are not calculable due to strong-field non-linear effects. This QED process can only be tested and understood with energy-dependent polarization measurements of magnetars in our galaxy in the at and below ~1 MeV. Detection of photon splitting and its rules would constrain foundational aspects of QED and give insights into how magnetars work across the cosmos.

Abstract number: **30**
Author: Tsuguo Aramaki
Title: **The GRAMS Project: MeV gamma-ray observations and antinuclei-based background-free dark matter searches with a LArTPC**

Abstract:
Gamma-Ray and AntiMatter Survey (GRAMS) is a next-generation balloon-borne and satellite-based mission utilizing Liquid Argon Time Projection Chamber (LArTPC) technology. Towards the 2040s and beyond, GRAMS aims to operate at the Sun-Earth Lagrange Point 2 (L2) as a dual observatory, capable of providing unprecedented sensitivities for MeV gamma-ray observations of cosmic sources and antinuclei-based, background-free dark matter searches, while minimizing the geomagnetic cut-off effect and atmospheric attenuation with several years of exposure.

Abstract number: **31**
Author: Kevin Stevenson
Title: **Characterizing Nearby Non-Transiting Rocky Worlds in the Mid-Infrared**

Abstract:
The nearest potentially habitable rocky exoplanets are among the most important targets for comparative terrestrial planetology, yet the vast majority do not transit their host stars. This leaves a scientifically compelling population of nearby M-dwarf planets, many in or near the habitable zone, largely inaccessible to current atmospheric characterization methods. The Planetary Infrared Excess (PIE) technique addresses this gap by using simultaneous, broad-wavelength observations to measure planetary thermal emission from unresolved star-planet systems. PIE observations could address three central questions: How common are atmospheres on rocky planets orbiting M dwarfs? What climate states exist among the nearest temperate terrestrial planets? Which nearby rocky planets are most likely to be habitable? Answering these questions requires measurements of planetary thermal emission, phase variations, and molecular absorption features. By identifying planets with atmospheric and climate properties consistent with stable, temperate surface conditions, PIE observations could establish a comparative sample of nearby rocky worlds ranked by their likelihood of supporting life as we know it. With a sufficiently large aperture, a cryogenic observatory with ultra-stable pointing and spectrophotometry could further search for atmospheric biosignatures, providing a direct path from climate characterization to the search for life on nearby worlds. This science directly extends the Astro2020 theme of pathways to habitable worlds by moving beyond the small sample of transiting terrestrial planets toward a broader census of nearby rocky worlds.

Abstract number: **32**
Author: Brenda Matthews/Lee Mundy
Title: **Resolving Architectures of Planetary Systems: the case for a sub-arcsecond far-infrared interferometer in space**

Abstract:
Understanding the formation and evolution of planetary systems is a challenging area of study; high spatial resolution and special techniques are required to observe planets in formation and the resulting disk/planet systems that are created. These systems provide a point of comparison to our own Solar System, in which the architecture of the asteroid and comet belts provide strong constraints on how the planets, particularly the outer gas and ice giants, formed and evolved. The signatures of that evolution are imprinted in these planetesimal belts, which are detectable and therefore provide constraints to planetary populations beyond the Solar System. The ALMA telescope has provided a powerful new window into the formation phase of protoplanets, thereby probing planetary architectures at the earliest times. Webb has provided another perspective, with the highest resolution to date in the mid-IR, and sufficient sensitivity to image warm and cold dust components in the nearest members of the much fainter debris disk (2-3 orders of magnitude) population associated with mature planetary systems. What we have been missing is a means to observe the diversity of substructure in a significant number of debris disks. Achieving this requires unprecedented spatial resolution in the far-infrared, where these disks emit most strongly. SPICE (SPace Interferometer for Cosmic Evolution) will throw open the window on planetary architectures to these later epochs; the differences we observe will reveal how planetary systems evolve. The proposed SPICE probe would enable a disk legacy survey of > 100 known disks around well-characterized nearby stars (out to 125 pc) through the evolutionary phases of terrestrial planet formation, through the migration phase, to stable, mature planetary systems. The data from such a facility will provide the best picture of the planetary populations of outer planetary systems, which cannot be probed by any other planet-finding method.

Abstract number: **33**
Author: Tom Greene
Title: **CHROMOS for Transiting Exoplanet Spectroscopy**

Abstract:
We propose the Cosmic Higher Resolution Origins Multi-Object Spectroscopy (CHROMOS) mission concept for ASTRA. CHROMOS will fill major science gaps by definitively addressing fundamental questions identified by Astro2020, and remain critical in the coming decade. CHROMOS features a 2-m space telescope with 0.7 deg2 field-of-view (FoV) and multi-object (MOS) slit spectroscopy for up to 16,000 objects simultaneously at R = 1000. It will answer several fundamental questions in cosmology, along with key questions in exoplanets, galaxy evolution, and Milky Way science. CHROMOS will provide exceptional capabilities for characterizing the atmospheres of transiting planets. It will observe hundreds of transiting ice and gas giant planets to address several fundamental questions: (1) What are the compositions of exoplanets to sub-Saturn masses, and how did they form? (2) What causes departures from equilibrium chemistry? CHROMOS will complement and surpass JWST, Aerial, and HWO by leveraging multi-object spectroscopy of many stars in the MOS field of view to mitigate effects of stellar heterogeneity that plague the spectra from these single-object missions (especially for late-type host stars). It will also observe the 1.25 - 5 micron spectral region simultaneously, capturing strong features of H2O, CH4, CO, CO2, as well as SO2 and CS2 photochemical products at R ~ 1000, something that is impossible with JWST or planned future exoplanet missions. CHROMOS is the modest scaling up of ATLAS Probe from 1.5-m to 2-m telescope aperture, and expected to meet the cost cap of an ASTRA mission. It will be a powerful spectroscopic observatory for general physics investigations, filling the capability gap of current and planned space and ground-based projects. CHROMOS should enter the ASTRA incubator now, since it fills critical science and spectroscopic capability gaps, and will drive discoveries in astrophysics for decades once launched.

Abstract number: **34**
Author: Meredith Ann MacGregor
Title: **Connecting Planet Formation from the Solar System to Exoplanet Systems**

Abstract:
Planets form from disks of dust and gas surrounding newly formed stars. The Atacama Large Millimeter/submillimeter Array (ALMA) has revolutionized our understanding of the structure and chemistry of these circumstellar disks over the last decade. As we look towards the next decade, however, many open questions that ALMA cannot answer: How much material is available to form planets and how quickly does this process proceed? How does a planet's nascent environment determine its ultimate habitability and potential to host life? Observations of disks is not the only way to probe planet formation, however. We have now detected some of the large 'exocomets' in these systems directly through transits opening a new window into their composition and dynamics. With the advent of large surveys, the population of interstellar objects (ISOs) - exocomets that have been ejected from their home systems - will continue to grow. To truly understand the formation of habitable planets, we need to put all of these puzzle pieces together and design observatories that can study all clues to the planet formation process.

Abstract number: **36**
Author: Jake Turner
Title: **The ongoing hunt to detect the radio emissions of exoplanets using the LOFAR and NenuFAR low-frequency telescopes**

Abstract:
Exoplanets with and without a magnetic field are predicted to form, behave, and evolve very differently. Therefore, there is great need to directly constrain these fields to holistically understand the properties of exoplanets. Observing planetary auroral radio emission is one of the most promising methods to detect exoplanetary magnetic fields. Despite decades of searching, there is still no conclusive detection of an exoplanet's magnetic field. Although promising hints are starting to emerge. In this talk, I will discuss our extensive, ongoing survey using multiple low-frequency radio telescopes to detect auroral radio signals from exoplanets. First, I will present our study of the hot Jupiter tau Boo b using the low-frequency telescope LOFAR, highlighting the first potential detection of an exoplanet observed in the radio. The observed planetary magnetic field strength, flux density, active orbital phases, polarization, and handedness of the emission are all consistent with theoretical predictions. I will also share preliminary results from our comprehensive follow-up campaign of tau Boo b. Next, I'll introduce our NenuFAR large-scale survey and highlight a second hot Jupiter candidate that shows promising signs of radio emission. Looking ahead, I'll briefly touch upon the exciting future of radio exoplanet studies, highlighting the potential of upcoming space- and Lunar-based radio telescopes in the coming decades.

Abstract number: **37**
Author: Klaus Pontoppidan
Title: **Building on JWST observations of exoplanets and planet-forming disks with future infrared high-resolution spectroscopy**

Abstract:
Measuring the carbon-to-oxygen (C/O) ratio in protoplanetary disks and exoplanetary atmospheres provides a direct link between planetary bulk compositions and the chemical environments in which they form. This elemental abundance ratio dictates atmospheric chemistry, sets the initial conditions for chemical habitability, and serves as a key diagnostic for the origins of planetary systems. JWST is currently yielding transformative new understanding of protoplanetary and exoplanetary chemistries with its powerful mid-infrared spectroscopic capabilities in the 3-28 micron region. Specifically, protostars and planet-forming disks are showing ubiquitous and rich molecular spectra, revealing the ingredients for planet formation, and tracing water and organic materials on the path to enabling habitable worlds. However, the low maximal resolving power (R~3000) of JWST's instrument does not kinematically resolve the molecular lines and bands in disks, which leads to degeneracies and uncertainties in retrieving abundances and other physical properties of molecular gas. Thus, a major need for high-resolution spectroscopic instruments is emerging. A future instrument should be capable of broadly following up on JWST's discoveries to retrieve precise chemistries of a wide range of astrophysical objects, including exoplanet and protoplanetary disks. This presentation will discuss why high-resolution infrared spectroscopy from space is essential for next decades.

Abstract number: **38**
Author: Gregg Hallinan
Title: **The Magnetospheres of Terrestrial Exoplanets from the Lunar Farside**

Abstract:
Planetary magnetic fields may play a decisive role in the retention and evolution of terrestrial planet atmospheres, and the National Academies' Exoplanet Science Strategy identified the detection of exoplanet magnetospheres as critical to assessing planetary habitability. Auroral radio emission provides a direct measurement of a planetary magnetic field: generated by the electron cyclotron maser instability at the electron gyrofrequency, its emission frequency scales directly with field strength, with additional insight into field topology, rotation, and planetary interior structure. Among the solar system planets, only Jupiter's radio emission extends above the terrestrial ionospheric cutoff; Earth, Saturn, Uranus, and Neptune emit predominantly below 2 MHz. Earth-like exoplanets are expected to peak below ~1 MHz, placing their detection firmly beyond the reach of any ground-based telescope. The lunar farside is the unique location in the inner solar system where this is possible. A lunar farside array of 128 dual-polarization dipoles, distributed across a 10 km diameter area, will conduct night-time observations in the critical 200–500 kHz frequency range optimal for terrestrial exoplanet detection. Shielded from solar-wind quasi-thermal noise within the plasma cavity of the lunar wake, the array will be an order of magnitude more sensitive than any ground-based array operating below 100 MHz. Continuous all-sky imaging via full cross-correlation will enable monitoring of thousands of known and unknown exoplanets, accumulating thousands of hours on each to measure quiescent emission while capturing transient enhancements driven by extreme space weather events. Detecting the magnetic fields of candidate habitable exoplanets will ultimately provide essential context for comparative planetology while offering insight into the evolution of our own solar system.

Abstract number: **39**
Author: Paul Felix Goldsmith
Title: **Key science questions in star formation astrophysics addressed by the LunAr Submillimeter Survey Observatory (LASSO)**

Abstract:
The LunAr Submillimeter Survey Observatory (LASSO) combines high angular and spectral resolution observations to provide an unprecedented view of the relatively unexplored far–infrared/submillimeter wavelength range. It will address fundamental questions about how galaxies form and grow in our Universe, the origins of planetary systems, and how terrestrial planets in habitable zones obtain the water that is essential to life as we know it. Key science questions include 1. What controls the rate of star formation in galaxies and what role does feedback from newly formed massive stars play? 2. How does the process of star formation work in galaxies of different types and metallicity? 3. What is the structure of protoplanetary disks in regions of star formation and how is composition of disks related to that of their surroundings? LASSO will operate in the bottom of a permanently shadowed lunar crater, employing Blue Origin's New Glenn launch vehicle to deliver 1000s of kg with the Blue Moon Lander to the lunar surface. LASSO's 7m aperture (twice that of the ESA/Herschel mission) and 64-100 pixel heterodyne camera operating over the 50 - 250 μm range will enable R=106 spectral resolution maps of hundreds of nearby galaxies, galactic star forming regions, and observations of protoplanetary disks, in key atomic, ionic, and molecular lines, enabling the characterization of physical and chemical conditions in a large variety of astrophysical environments. There will be enormous synergy between PRIMA's superb sensitivity to polarized dust emission in the diffuse interstellar medium (ISM) and LASSO's ability to measure the linewidths in these regions, for which [CII] 158 μm is the best probe, but only with high spatial and spectral imaging. Together, these two quantities yield the magnitude and direction on the sky of the B-field, essential for modeling the evolution of the ISM and star formation.

Abstract number: **40**
Author: Brandon Hensley
Title: **Galactic Astrophysics with a Full-Sky CMB Polarization Survey**

Abstract:
The Milky Way Galaxy is threaded with magnetic fields that align interstellar dust grains, polarizing their submm emission. Encoded in this signal is the multi-scale structure of the Galactic interstellar medium (ISM), the coupling of Galactic structure and magnetic fields, and the physics of interstellar grains. Full-sky observations of polarized dust emission with the Planck satellite proved revolutionary for understanding the magnetized ISM. In this talk, I will discuss the science opportunities in Galactic astrophysics provided by a survey of the full sky with a mission more than 6000 times deeper than Planck, having angular resolution more than 5 times better, and measuring polarization at frequencies at least 2 times higher, as has been envisaged for a future CMB Probe. I will also highlight science opportunities opened by measurement of low-frequency (≤30 GHz) polarized synchrotron emission over the full sky from this platform.

Abstract number: **41**
Author: John ZuHone
Title: **Elucidating the Nature of Feedback Mechanisms in Galaxies via Emission-Line Studies of the Warm and Hot Circumgalactic Medium**

Abstract:
One of the three priority science areas recommended for future investment by the 2020 Decadal Survey was identifying the drivers of galaxy growth and evolution. The circumgalactic medium is the multiphase gas filling the dark matter halos surrounding galaxies, serving as both the reservoir for gas accretion from the cosmic web that provides the fuel for star formation, as well as the place where mass, momentum, energy, and metals are driven from the galaxy by feedback from stars and supermassive black holes. Large-volume cosmological simulations designed to study galaxy formation have their feedback models tuned to reproduce key features of the galaxy population, but make widely different predictions for the extent and morphology of the warm and hot phases of the circumgalactic medium, observable in the UV and X-ray bands, respectively. These phases are also the least-studied, due to the fact that they are faint and diffuse, and the instruments required to study them in detail—detectors which can resolve their faint emission lines with both high spatial and spectral resolution against the bright Milky Way foreground—have not yet flown. In this talk, I will present recent results on studies of the circumgalactic medium of galaxies from a range of cosmological simulations implementing very different forms of feedback from AGN and stars, showing that mapping the surface brightness, temperature, and warm and hot phases in emission can distinguish between these mechanisms, and help constrain the modes of feedback that decisively shape the formation and evolution of galaxies. I will close by highlighting the instrument capabilities that are needed to perform these measurements.

Abstract number: **42**
Author: Kathryn Plant
Title: **Probing the Galactic ISM Tomographically at Low Frequencies**

Abstract:
Dense regions of the warm, ionized phase of the Galaxy's interstellar medium become optically thick due to free-free absorption at radio frequencies below ~70 MHz. This absorption poses both an obstacle, by confining dark ages cosmology to low-column-density windows where we can see of out of our Galaxy, and an opportunity, as sightlines that contain a fully optically thick HII region at a known distance create 3D tomographic probes of the distribution of synchrotron emitting cosmic ray electrons along that line of sight. Understanding the distribution of Galactic cosmic ray electrons is essential to mapping their role in the cosmic ecosystem in the context of the Astro2020 key question “How do star-forming structures arise from, and interact with, the diffuse interstellar medium?” I will present preliminary results from a study of free-free-absorption regions as tomographic probes conducted at 30-80 MHz with the Owens Valley Radio Observatory Long Wavelength array, discussing how these results inform science planning for future space-based radio telescopes operating at even lower frequencies where the technique will be applicable along many more lines of sight.

Abstract number: **43**
Author: Carlos J. Vargas
Title: **Ardua: Unveiling the Baryon Cycle from Stars to the Cosmic Web**

Abstract:
Every galaxy is governed by the baryon cycle — the continuous exchange of gas, metals, and energy between the galaxy and its halo — and understanding this cycle is essential to understanding how galaxies form and evolve. Yet the baryon cycle remains among the least observationally constrained processes in galaxy formation, because most of it occurs in the circumgalactic medium (CGM), which has never been comprehensively mapped. The Astro2020 Decadal Survey recognizes this explicitly, calling for "Mapping the CGM and IGM in emission" as a Discovery Area within the priority theme "Unveiling the Drivers of Galaxy Growth." Progress requires comprehensive, spatially resolved emission mapping of each CGM phase in both the ultraviolet and X-ray. The UV bandpass traces CGM gas from cool neutral and photoionized gas at T<10^4 K through warm and warm-hot phases at T~10^5–10^6 K, with well-established spectral diagnostics across this range accessible with existing technology. The X-ray bandpass picks up where the UV leaves off, tracing the volume-filling coronal phase at T~10^6-10^7 K predicted to dominate the mass budget in Milky Way-mass halos, yet essentially undetected in emission around individual galaxies. Answering key open questions about the spatial distribution of multiphase CGM gas, baryon cycle dynamics, and feedback-driven outflows requires co-spatial UV and X-ray emission mapping that no existing or planned mission provides. We present the science case for Ardua, a joint UV and X-ray ASTRA mission concept combining a wide-field far-UV spectrograph with a soft X-ray microcalorimeter based on LEM heritage. This capability uniquely fits ASTRA's mandate for large strategic missions and positions Ardua as the observational leap needed to address CGM science priorities recognized by Astro2020.

Abstract number: **44**
Author: Vivian U
Title: **Bridging the Gaps in Black Hole Demographics for the 2030s and Beyond**

Abstract:
Characterizing the full history of black hole growth requires next-generation strategic missions to address critical gaps in both AGN demographics and host obscuration. The upcoming decade will be redefined by the multi-messenger era, where gravitational wave detections from merging black holes by LISA and pulsar timing arrays must be matched with electromagnetic counterparts to map the full evolutionary sequence from intermediate-mass black hole (IMBH) seeds to supermassive binaries. Uncovering the local demographics and dynamics of IMBH seeds requires high-cadence, high-throughput time-domain monitoring and spectroscopy stretching from the UV through the optical. Concurrently, tracking the gas dynamics, merger histories, and multi-phase feedback of heavily obscured systems at cosmic noon demands a major leap in far-infrared spatial resolution and cryogenic detector sensitivity. Aligning space-based electromagnetic capabilities with the timeline of gravitational wave discoveries ensures that future probe- and flagship-class concepts are optimized to trace the complete co-evolutionary lifecycle of AGN and their host galaxies.

Abstract number: **45**
Author: Priyarshini Ghosh
Title: **From Iron to the Actinides and Isotopes in-Between: Ushering in the Next Era of Precision Ultra-Heavy Galactic Cosmic Ray Measurements**

Abstract:
Ultra-heavy galactic cosmic rays (UHGCRs; Z > 30) are powerful tracers of nucleosynthesis, stellar evolution, and the origin and transport of matter in the Galaxy, yet they remain among the least-measured particles in the cosmos. They can probe r-process and s-process nucleosynthesis channels by providing direct, macroscopic samples of material from core-collapse supernovae, neutron star mergers, and other candidate r-process sites now debated in the multi-messenger astronomy era. By yielding isotopic and elemental abundances inaccessible to astronomical spectroscopy, these ratios constrain the relative contributions of their sources, while their propagation histories encode diffusion, halo geometry, and spallation at the high-charge frontier. Extending measurements to trans-actinide species would open an entirely new nucleosynthetic discovery window. Decades of increasingly capable instruments—from HEAO and ACE-CRIS to SuperTIGER—have built a foundational picture at the elemental level. SuperTIGER's landmark measurements revealed a 3σ enhancement in the second r-process peak region (Z = 50–56) that breaks the OB association model, pointing to a secondary nucleosynthetic source. However, elemental abundances cannot disentangle the r-process from the s-process, cannot extract propagation timescales from radioactive-to-stable ratios, and cannot test isotope-level predictions of galactic chemical evolution models. ACE-CRIS demonstrated the capabilities of isotopic measurements for Z < 30 yet the most compelling science remains unexplored, at the second or third r-process peaks, the actinides, and beyond. Meanwhile, spallation cross-sections for Z > 30 species — essential for interpreting any cosmic-ray propagation model, remain unmeasured. The next frontier of nucleosynthesis discoveries will be enabled by higher precision of measurements of UHGCRs.

Abstract number: **46**
Author: Martijn Oei
Title: **Galactic cosmic ray physics with the Ultra-long Wavelength Lunar Farside Observatory**

Abstract:
Cosmic ray (CR) feedback is thought to shape galaxies from the scales of forming planets to those of their cosmic environs, but major open questions remain. Indeed, the Astro2020 Decadal Survey highlights that ‘The impact of cosmic rays is one of the largest uncertainties in understanding feedback in galaxy formation’. Addressing the Astro2020 key science area ‘Unveiling the Hidden Drivers of Galaxy Growth’ and key question ‘How do star-forming structures arise from, and interact with, the diffuse interstellar medium?’ thus requires close scrutiny of CR physics. Synchrotron emission from CR electrons (CRe) is a key diagnostic of star formation activity, magnetic fields, and the still-uncertain physics of cosmic ray propagation. Even so, a decade of CRe energies near peak ISM CRe energy density remains unexplored: Lorentz factors 10^2 to 10^3, corresponding to 0.1–10 MHz synchrotron radiation. The Ultra-long Wavelength Lunar Farside Observatory proposed by the AMMB SIG would constrain the Milky Way's low-energy CRe origins, abundance, transport and energy spectrum, mixing, and the ISM's magnetic field strength with multi-frequency maps yielding details of ~10 pc at 1 kpc distance. In this talk, we present an overview of the Galactic CR science that such an observatory would unlock, and its synergy with the detection and physical characterization of HII regions. This detailed Galactic effort is uniquely important, because free–free absorption and interstellar scattering prohibit such studies in any other galaxy.

Abstract number: **47**
Author: Michael Koss
Title: **A Chandra Successor in the 2030s**

Abstract:
Chandra established that soft X-ray spectral imaging with ~1" angular resolution is an essential tool for almost every area of astrophysics, from the early Universe to ice chemistry in protoplanetary disks. While Chandra continues to deliver groundbreaking science, it lacks the sensitivity to be the counterpart to JWST, Roman, Rubin, LISA, ngVLA, ALMA, IceCube, NewAthena, ELT, and other upcoming large facilities. In this presentation, we describe the scientific potential of a Chandra successor with >10x higher sensitivity and >50x survey speed. While the scientific reach of such a mission is very broad, we showcase four high-priority science questions that require these capabilities – How did supermassive black holes form? How does stellar and AGN feedback work in galaxies? How does high-energy stellar activity affect exoplanet atmospheres? And, how do black holes merge? A Chandra successor in the 2030s would also demonstrate the X-ray mirror technology for a future flagship and sustain the US high-energy astrophysics workforce until that flagship launches. We outline the science–instrument trade space by sketching three missions based on the NASA Probe concept study report for the Advanced X-ray Imaging Satellite (AXIS): AXIS-Deep, AXIS-Classic, and AXIS-Fast, highlighting a breakthrough science case for each and listing others that drive the design.

Abstract number: **48**
Author: Michelle Park
Title: **Non-Thermal Physics Drives Compact, Self-Regulated Galaxy Morphologies at Cosmic Dawn**

Abstract:
JWST has revealed high redshift galaxy sizes that are remarkably larger than predicted by traditional galaxy formation models. To explain their rapid emergence, we analyze the Azahar cosmological simulation suite, which produces synthetic JWST observations of thousands of highly resolved galaxies including instrumental effects and dust absorption. We compare three physical models with recent JWST data: one with standard hydrodynamics and feedback, one with enhanced supernova feedback calibrated to match the galaxy stellar mass function at $z = 3$, and a full-physics model that comprehensively includes the physics of radiative transfer, cosmic rays, and magnetism. We find that different physical models strongly shape galaxy appearances and morphologies. The artificially calibrated HD-Boost model is disfavored by recent observations because it results in unphysically puffed-up galaxy sizes at early and late times. In contrast, the full-physics model regulates the stellar mass while reproducing the galaxy mass growth predicted by JWST observations. While the standard hydrodynamical model appears to align well with the observed galaxy size evolution, we show that their smaller sizes are most susceptible to size overestimation from instrumental effects. Therefore, observational biases from the telescope's point-spread function can mask differences between galaxy formation models and systematically alter inferred galaxy sizes and shapes. Overall, we show that explaining JWST's discovery of large high-redshift galaxies requires more realistic physics in cosmological simulations and forward modelling to enable direct comparison between simulation outputs and observable data.

Abstract number: **49**
Author: Andreas Faisst
Title: **CHROMOS to Explore the Drivers of Large Scale Structure, Galaxy, and Black Hole Evolution**

Abstract:
We propose the Cosmic Higher Resolution Origins Multi-Object Spectroscopy (CHROMOS) mission concept for ASTRA. CHROMOS will fill major science gaps by definitively addressing fundamental questions identified by Astro2020, and remain critical in the coming decade. CHROMOS is a 2m space telescope with 0.7 deg2 field-of-view (FoV), and multi-object (MOS) slit spectroscopy at 1.25 to 5μm for up to 16,000 objects simultaneously at R=1000. It will answer fundamental key questions in various fields including cosmology, galaxy evolution, exoplanets, and Milky Way science. In this presentation, we showcase CHROMOS' exceptional capabilities for answering several fundamental questions in the field of large scale structure (LSS), galaxy, and black hole evolution: (1) What are the physical drivers of the LSS evolution and how does it affect galaxies within it? (2) How was the early universe reionized? (3) How do supermassive black holes form and how is their growth coupled to the evolution of their host galaxies? In addition to this, CHROMOS' stability, large area coverage, and time cadence will open up a new window to characterize transient phenomena and to contribute to the quantification of gravitational wave detections. CHROMOS will go beyond Roman and planned future missions in answering the above questions. Importantly, CHROMOS will bridge the gap between current and planned small-area deep and wide-area shallow spectroscopic surveys, enabling complementary science investigations for decades after its launch. CHROMOS is the modest scaling up of ATLAS Probe from 1.5m to 2m telescope aperture, and expected to meet the cost cap of an ASTRA mission. It will be a powerful spectroscopic observatory for general physics investigations, filling the capability gap of current and planned space and ground-based projects. CHROMOS should enter the ASTRA incubator now, since it fills critical science and spectroscopic capability gaps, and will drive discoveries in astrophysics for decades once launched.

Abstract number: **50**
Author: Hans Moritz Günther
Title: **Dust in the Milky Way from the ISM to star formation**

Abstract:
Dust is a curious state of matter. Dust is responsible for most of the opacity in the ISM. Dust also comes in much wider range of physical properties than gas. Dust grains can be amorphous or crystalline, and they can be made of silicates, carbon, ices, or all of them combined. They can be solid or fluffy, and they can align with magnetic field lines. Dust is formed in the atmospheres of evolved stars and in supernovae, is distributed throughout the Milky Way and it is destroyed by shocks and sputtering in the ISM. Dust grains are also responsible for the formation of planets, as they coagulate to form planetesimals, which then grow to form planets. Without dust grains, we could never make habitable, earth-like planets, so understanding the dust in protoplanetary disks is crucial to the "Pathways to Habitable Worlds". So, how do we learn what the dust it made of and how it looks? While ALMA and JWST are great at finding dust, they only see the whole grain or the surface. On the other hand, X-rays from a bright background source can literally X-ray the dust grains. A full accounting of their elemental content can be made from measuring absorption edges. The energy of the edge differs between single atoms and atoms bound in molecules and the structure of the chemical bond leads to structure near the absorption edge (XANES), which is routinely used in synchrotron facilities on Earth to determine concentrations and chemical bonds of trace elements. So far, the spectral resolution and S/N of current X-ray telescopes is too limited to use this diagnostic in astronomy except for a handful of the brightest sources. I will show what instrumental capabilities are needed to make this a routine diagnostic for the ISM and protoplanetary disks.

Abstract number: **51**
Author: Margaret Meixner
Title: **Far-infrared Space Astronomy Science Gaps beyond 2030**

Abstract:
The ASTRA far-infrared landscape will be shaped in part by the mission concept PRIMA (the PRobe far-Infrared Mission for Astrophysics), which, if selected, will push the boundaries of science in planetary system formation, supermassive black hole and galaxy co-evolution and the building of dust and metals in galaxies in the 2030s. As such, it is important to consider what far-infrared science areas will be out of PRIMA's grasp and what capabilities are needed to address them by mission concepts considered by ASTRA. In this talk, I will outline the differences between PRIMA's objectives for studies of galaxies, star and planet formation and the interstellar medium and the science objectives and requirements of the Origins Space Telescope Study, a large mid- to far-IR concept studied as part of Astro2020. In doing so, we aim to provide the landscape upon which a far-IR flagship concept would be developed for ASTRA.

Abstract number: **52**
Author: Scott Wolk
Title: **High Spatial Resolution X-ray Studies of Star formation, stellar evolution, and planets studies**

Abstract:
Stars set the conditions for planet formation, for planet evolution, and for habitability – all critical topics in modern astronomy. Stars are also important in their own right as the most visible component of galaxies. In cool stars, X-ray emission is powered by magnetic fields. To date, our Sun is the only star whose fields have been spatially resolved. High-resolution X-ray imaging can track the origin and evolution of those fields, see how they connect young stars to their disks and outflows, and track the energy, mass, and momentum that radiation and coronal mass ejections (CMEs) carry into the circumstellar environment. This is crucial for understanding whether planets can form and survive in young stellar systems, whether life can develop on those planets, and how the star evolves over time. Intermediate-mass and high-mass stars blow winds and eventually evolve into degenerate objects such as white dwarfs, neutron stars, and black holes. Their evolution and death drive the chemical evolution of galaxies. High-resolution X-ray imaging can study the hottest components in those systems, such as the colliding winds of massive stars, accretion and nova explosions in CVs, and the shocks in outflows that form planetary nebulae. All these cases have in common that the X-ray emission is tracing the hottest, fastest, and most energetic components of the shocks. High spatial resolution observations can reveal the temperature, spatial structures, and elemental abundances of different system components that no other wavelength can. While stars are physically small compared to more powerful objects such as accreting black holes and AGN, they are also much closer to us; this allows high spatial resolution to resolve a variety of physical phenomena fundamental to our understanding of how stellar systems form, evolve, and interact with their environment.

Abstract number: **53**
Author: Paolo Coppi
Title: **MeV-GeV Gamma-Ray Observations: Constraining Cosmic Ray-Mediated Feedback and Star Formation Activity**

Abstract:
In the interstellar medium of our Galaxy, the (non-thermal) pressure due to cosmic rays is comparable to the pressure due to thermal gas motions and the magnetic field. This is probably not a coincidence and suggests that cosmic rays and magnetic fields play an important role in the dynamical evolution of our Galaxy. Indeed, recent cosmological simulations that include magnetic fields and recipes for non-thermal (cosmic ray) particle acceleration and transport show that the presence of cosmic rays can have a dramatic effect on the development of a galaxy. Star formation and AGN activity leads to the production of cosmic rays which "feed back" on the gas driving the activity, enhancing or suppressing it. Understanding the origin and propagation of cosmic rays in galaxies is thus key for understanding how the Universe we see today was built. I will explain how space-based, MeV-GeV gamma-ray observations have a critical role to play here if we can develop an instrument suite with sufficient sensitivity. Gamma-rays are produced when cosmic rays interact with ambient matter, and MeV-GeV gamma-rays turn out to constrain the portion of the cosmic ray population directly relevant to the feedback problem. A recent and dramatic example of how gamma-rays can do this is the discovery of the ``Fermi bubbles'' extending out of the plane our galaxy and pointing back towards the nucleus of our galaxy, indicating the presence of intense star formation and/or AGN activity there in the relatively recent past. In addition, the stellar explosions that accompany star formation not only produce cosmic rays, but they also leave behind radioactive isotopes. Their associated nuclear line emission probes the explosion process and the origin of the elements in our galaxy as well as providing an independent and complementary tracer of recent star formation activity.

Abstract number: **54**
Author: Ivey Davis
Title: **Space Weather of Other Stars Below 15 MHz with the MegaWave Radio Surveyor**

Abstract:
Solar System planets are immersed in space weather—a steady solar wind punctuated by impulsive, transient events. Similarly, stellar space weather alters atmospheric and surface chemistry, drives atmospheric escape, and influences long-term habitability of exoplanets, and it represents a fundamental aspect of stellar evolution through which stars lose mass, angular momentum, and magnetic energy. The Decadal Survey identified the Science Question “How do the Sun and other stars create space weather?” Stellar electromagnetic emissions are the subject of regular study, but a reliable measure of stellar particle fluxes is lacking, especially for high-energy particles that can transform planetary atmospheres. Plasma emission is a highly-luminous process that explicitly depends on the properties of the ambient medium and which traces both shock wave-accelerated electrons and relativistic electron beams escaping to interplanetary space. Below 15 MHz, it is thus a diagnostic of both transient mass motions and corona and wind properties for distances $r \gtrsim 5\,R_\odot$. Observing stellar plasma emissions below 15 MHz (frequencies inaccessible from the ground) would provide insight to steady stellar mass loss at distances inaccessible to other methods and conclusive evidence of energetic, transient mass escape into their interplanetary media. Confidence in this latter point is missing from observations at other wavelengths/frequencies, which probe only low in stellar atmospheres. Within 25 pc are more than 5000 stars of various spectral types. A space-based radio interferometer to monitor their plasma emissions would enable us to constrain their space weather characteristics, the environment of their planets, and place the Sun and its planets in Galactic context.

Abstract number: **55**
Author: Roberta Paladini
Title: **Star Formation: a Long-Standing Riddle that Asked to be Solved**

Abstract:
Star formation (SF) results from the complicated interplay between gravity, turbulence and magnetic fields. The key of the SF riddle likely lies in analyzing this process across many physical scales, from the diffuse ISM, to parsecs-long filaments, to sub-parsec molecular cores. This is how we can understand the scale on which a given force, e.g., gravity, becomes sub-dominant with respect to another, e.g., turbulence and/or magnetic fields, thus leading to molecular core collapse. Furthermore, SF takes place in cold, dense environments, which can only be probed by far-IR wavelengths, but this wavelengths regime has historically been characterized by poor angular resolution, therefore hindering our ability to connect the post-collapse and collapse phases probed by sub-arsec JWST and ALMA observations, with the very early stages traced by filamentary structures and the diffuse ISM, for which only low-resolution (e.g., Spitzer Herschel) data are available. A high-resolution far-IR space facility is therefore highly needed in the future to finally shed light on one of the most important questions of Astrophysics.

Abstract number: **56**
Author: Abigail T Crites
Title: **Line Intensity Mapping Capabilities of an All-sky mm/sub-mm Polarimetric Space Mission**

Abstract:
Line intensity mapping (LIM) is a technique that will allow us to map the cosmic structure and to probe cosmology over a wide range of redshifts and spatial scales. In the millimeter and sub-millimeter range a LIM survey targeting the CO rotational lines and the [CII] line would constrain star-formation across cosmic time, reionization, and properties of neutrinos and light relics, science highly prioritized by the Astro2020 decadal survey. LIM surveys probe large comoving volumes, significantly lowering statistical uncertainty on model parameters, probe higher redshifts (z ~ 5 - 10), accessing a larger number of modes in the linear regime, and efficiently breaking parameter degeneracies present in the CMB and lower-redshift probes of large scale structure. By adding modest spectroscopic capabilities to an all-sky mm/sub-mm polarimetric space mission (CMB Probe+), we would improve on the sensitivity of current LIM instruments in this wavelength range. With ~10 spectroscopic pixels (numbers comparable to current ground-based LIM experiments), the instrument would be 25x faster in the 200-400 GHz 100x faster in the 400GHz-1THz range.

Abstract number: **57**
Author: Saptarshi Bandyopadhyay
Title: **Lunar Crater Radio Telescope (LCRT) on the Farside of the Moon**

Abstract:
The Cosmic Dark Ages, spanning the period between CMB decoupling and the formation of the first stars, holds vital clues to the standard cosmological model, dark matter, and inflation. The neutral hydrogen signal is the sole probe of this era, but cosmological redshift has shifted it to the 4.7–47 MHz band—frequencies blocked by Earth's ionosphere. To overcome this, we propose a radio telescope on the far side of the Moon. This location bypasses ionospheric distortion and leverages lunar shielding to provide a pristine, radio-quiet environment free from terrestrial interference. We present the design of the Lunar Crater Radio Telescope (LCRT) mission concept that intends to carry out unprecedented measurements of this signal by deploying a 350m-diameter parabolic reflector mesh inside a lunar crater on the far side of the Moon and suspending a receiver at its focus. Our concept of operations employs a single lander which launches a sequence of projectile anchors onto the rim of the crater, establishing ‘lift wires’ that are then used to hoist the feed antenna followed by the deployment of the folded mesh reflector. We also describe the rationale for crater selection and technological solutions for achieving desired shape accuracy and thermal performance with our design. The LCRT mission concept is has been funded by the NIAC and APRA programs. We have developed a 1/200-scale model of LCRT and performed detailed RF-characterization of this LCRT model at NASA Glenn Research Center. In the future, we will performing astronomical observations with this LCRT model at Owens Valley Radio Observatory.

Abstract number: **59**
Author: Lin Yi
Title: **Far-Infrared Heterodyne Interferometry as a Hosted Science Capability on Orbital Computing Swarms**

Abstract:
Emerging orbital computing spacecraft combine high-capacity power, thermal management, optical crosslinks, onboard processing, and autonomous operations. We propose using this infrastructure as a dual-use platform for a distributed far-infrared/submillimeter heterodyne interferometer. Small cryogenic collector modules hosted on multiple computing-enabled spacecraft would locally mix incoming far-IR/THz radiation with stable local oscillators, digitize intermediate-frequency signals, and use the swarm's optical crosslinks and onboard processors for timing transfer, electronic delay tracking, calibration, and distributed correlation. This heterodyne-first architecture is well matched to orbital swarms because astronomical beam combination is performed electronically rather than by physically transporting far-IR beams across the formation. It therefore supports longer and more natural spacecraft separations than direct-detection beam-combining concepts. Baselines from 0.1–10 km would provide angular resolution from approximately 0.2 arcsec to 2 milliarcsec at 100 μm, addressing the source-confusion and resolution limits that have long motivated far-IR interferometry studies such as SPIRIT, SPECS, FIRI, Origins, and ESPRIT. The key payload challenge is thermal and electromagnetic separation: cryogenic mixers, detectors, and optics must remain isolated from warm compute buses while retaining access to platform power, pointing, communication, and processing resources. Rather than treating far-IR interferometry as a standalone flagship architecture, this concept reframes it as a hosted science layer on emerging orbital computing infrastructure. A near-term demonstration would validate cryogenic heterodyne receiver hosting, optical-link-assisted timing and baseline knowledge, and onboard distributed correlation of digitized IF signals. Once demonstrated, the same architecture could scale from engineering baselines to kilometer-class separations, producing high-angular-resolution far-IR spectral-line maps of planet-forming disks, cold dust structures, water-bearing gas, and obscured star formation.

Abstract number: **60**
Author: Kimberly Ann Weaver
Title: **The Accretion Explorer Interferometer**

Abstract:
I will present the Accretion Explorer Interferometer (AEI), an X-ray mission concept that could achieve a transformative increase in observational capabilities by enabling images up to six orders of magnitude better than Chandra's 0.5 arcseconds. AEI will resolve the X-ray corona and black hole accretion, reveal the process by which dual and binary AGN ultimately merge, and show how stellar flares affect exoplanet habitability. I will present a design for a multiple spacecraft system that aligns mirror pair baseline groupings provided by individual "collector mirror" spacecraft, with the pointing precision to achieve micro-arcsecond angular resolution. A recently completed NIAC study has addressed well-known technical challenges from prior X-ray interferometry designs, including formation flying, pointing accuracy and stability, and observation feasibility, with innovations that demonstrate a practical architecture for a future large mission in the 2040s.

Abstract number: **61**
Author: Rita Sambruna
Title: **AstroDOME: Standardized, Mass-produceable, Small Astrophysics missions**

Abstract:
We investigated the use of small, commercial off the shelf spacecraft to enable breakthrough astrophysics research. Low-cost COTS spacecraft have proliferated in the last ~5 years and represent an order of magnitude reduction in the cost of spacecraft bus development and acquisition. Our study was tasked with developing a standardized, mass-produceable, astrophysics payload which is reconfigurable to different wavelength bands while maintaining a single optics bench design, and a standardized mechanical, electrical, data, and thermal interface to the spacecraft bus, and which may be reconfigured to multiple COTS spacecraft offerings. In this contribution we will discuss lessons learned from our case study. We will also present identified keys to mission success for performing cutting edge astrophysics observations while taking advantage of economies of scale with a disaggregated, standardized architecture.

Abstract number: **63**
Author: Matthew Marcus
Title: **AstroDOME Engineering**

Abstract:
Low-cost spacecraft have proliferated in the last ~5 years. They represent an order of magnitude reduction in the cost of spacecraft bus development and acquisition. They are enabled by low cost smallsat launch options in the immediately preceding years, and are seeded by recent disaggregated missions in other sectors such as telecommunications megaconstellations (e.g. Starlink, OneWeb, Amazon Leo) and ongoing Space Development Agency (SDA) disaggregated architecture developments. Last year NASA's Goddard Space Flight Center investigated the use of small, commercial off the shelf (COTS) spacecraft to enable critical astrophysics research at radically reduced cost over previous generations of missions. Our study was tasked with developing a standardized, mass-produceable, astrophysics payload which is reconfigurable to different wavelength bands while maintaining a single optics bench design, and a standardized mechanical, electrical, data, and thermal interface to the spacecraft bus, and which may be reconfigured to multiple COTS spacecraft offerings. This talk will cover the engineering side of AstroDOME, as a companion to the AstroDOME highlights talk. It will cover the spacecraft to instrument interface, and lessons learned in early concept payload development. We will discuss lessons learned from our case study. We will also present identified keys to mission success for performing cutting edge astrophysics observations while taking advantage of economies of scale with a disaggregated, standardized architecture.

Abstract number: **64**
Author: David Leibrandt
Title: **Asteroids for μHz gravitational wave detection**

Abstract:
The detection of gravitational waves has revolutionized our understanding of the universe around us. However, we have only begun to scratch the surface of the discoveries this spectrum will enable. There are presently no well-established, sufficiently sensitive techniques to search for gravitational waves in the 0.1 μHz to 100 μHz frequency band, between LISA and NANOGrav. This gap is critical; this band is expected to be rich with a number of astrophysical and cosmological sources exhibiting characteristic strains around 10^{-18}. To close this gap, we propose a novel mission concept: utilizing km-scale stony asteroids as proof masses. By measuring the distance between carefully selected asteroids separated by of order 1 AU using optical atomic clocks and time-transfer links, we can detect μHz gravitational waves with 10^{-18} strain sensitivity, opening a new window into the physics of the cosmos.

Abstract number: **65**
Author: Ralph Kraft
Title: **Wide-Field Soft X-ray Imaging Spectroscopy**

Abstract:
We present a brief overview of the scientific goals, the technology development requirements, and the relevance to the astrophysics landscape of the 2030s and 2040s of a wide-field of view soft X-ray microcalorimeter mission. Imaging spectroscopy (i.e. integral field units) is the primary scientific tool used by modern astrophysicists across the electromagnetic spectrum. This is most clear in X-ray astrophysics where the ACIS instrument on Chandra and the MOS and PN cameras on XMM-Newton have dominated our field over the past ~25 years and transformed all of astrophysics by providing sharp images with modest spectral resolution. The Japanese/US XRISM mission has given our community a taste of imaging spectroscopy using an instrument that has the spectral resolving power capable of measuring subsonic velocities and multiple ionization states of hot gas at X-ray temperatures. Coupled with a much larger mirror, NewAthena's X-IFU (4 eV, R =1600 at 6.4 keV, 4' FOV, launch date ~2039) will be far more sensitive than XRISM, but with a similar spectral resolution and FOV. Rather than refining incremental approaches, a truly transformative step would be to couple a large-pixel count microcalorimeter array (1-2 eV resolution) with a large-area, large FOV (20'-40' diameter) X-ray optic that would chart most of the gas around Milky Way-like galaxies, assay the contents of the cosmic web, measure the lifetime of stellar nurseries, conduct wide-field time-domain surveys, map AGN outflows, and much more. In this presentation we outline in general terms a range of instrumentation options that could comfortably fit within several mission cost ranges including a Probe (~$1B), a Flaglet (~$1-2B), and a Flagship (~$2.5B+). We provide a summary of the scientific discoveries such an instrument would enable, the synergies with the astrophysics landscape of the 2030s and beyond, and the technological advances required to reach them.

Abstract number: **66**
Author: Regina Caputo
Title: **Next-Generation Wide-field Gamma-Ray Observatories**

Abstract:
The Astro2020 decadal survey highlighted the critical need for advanced, high-energy astrophysics capabilities. To meet this scientific imperative, our team developed the All-sky Medium Energy Gamma-ray Observatory (AMEGO), a probe-scale mission concept. To mature the required subsystems, we built and successfully flew the ComPair balloon mission in 2023, systematically raising the Technology Readiness Level (TRL) of our core components in a relevant space-like environment. In parallel we developed AstroPix, a pixelated silicon detector technology to improve the performance of a critical detector subsystem on AMEGO. AstroPix revolutionized our architectural approach, enabling the design of AMEGO-X—a smaller MIDEX version of the AMEGO mission concept. Due to the incorporation of the AstroPix detectors into the telescope, the significantly smaller and more cost-effective AMEGO-X concept achieved almost the same sensitivity as the original AMEGO design. We are currently taking the next steps to raise the TRL of this newly designed system. We are building ComPair-2, a prototype telescope that fully implements AstroPix, and we are preparing orbital demonstrations to definitively raise the TRL of these detectors for spaceflight. Through this comprehensive technology maturation program which spans balloon campaigns, detector development, and orbital prototyping, we have demonstrated that a large-scale gamma-ray mission is highly feasible in the near term and more sensitive than ever before. These adaptable, flight-proven concepts directly support the ASTRA initiative’s strategic goals, ensuring the community is poised to execute the next generation of high-energy observations without waiting on fundamental technology development.

Abstract number: **67**
Author: Slava G Turyshev
Title: **TETRA: A Tetrahedral Heliocentric Field-Equations Observatory**

Abstract:
TETRA is a late-2030s mission concept for a four-spacecraft heliocentric observatory that would test a local field-equation prediction not addressed by cosmological surveys: in source-free Solar-System vacuum, the gravity-gradient tensor trace must vanish, $\tau = \mathrm{tr}(T) = \nabla^2 U = 0$, after modeled solar, relativistic, spacecraft, and non-gravitational terms are removed. Roman, Rubin, Euclid, DESI, CMB-S4, clocks, atom interferometers, and ephemerides will constrain expansion, growth, lensing, and conventional Solar-System parameters; TETRA adds a direct heliocentric null measurement of non-harmonic residual gravity. The observable is reconstructed with internal closure from six coherent inter-spacecraft optical links, generalized Sagnac angular-rate observables, absolute arm knowledge, and one precision inertial reference per node. This tetrahedral architecture is forced by the measurement: four non-coplanar nodes provide independent vertex trace solutions, geometry-aware null channels, and repeated radial sweeps that distinguish physical $\tau(r,t)$ templates from thermal, attitude, clock, force-model, and estimator leakage. The reference science point uses $q = 0.60$ AU, $Q = 1.80$ AU, and $L_0 = 2000$ km, giving a factor-27 modulation of the Newtonian solar tidal scale and $L_{\mathrm{eff}} \simeq 3518$ km during science-quality arcs. A nonzero residual would test Yukawa-like fifth forces, Galileon/Vainshtein-screened scalars, weakly screened scalar-tensor sectors, or gravitationally coupled dark-sector phenomena that can evade standard PPN, equivalence-principle, $\dot{G}/G$, clock, and ephemeris guardrails. A null result would still define a new local bound on AU-scale vacuum trace residuals. The ASTRA study would determine whether the required $\delta\tau \simeq 10^{-24}\ \mathrm{s}^{-2}$ mission floor is achievable by closing the trace estimator, range-plus-Sagnac metrology, time-delay calibration, inertial-reference implementation, thermal/self-gravity budget, and orbit/mass trades to CML-3/MRL-3. The same six-link phase and inertial archive would support conditional dark-sector time-domain searches and a secondary 0.1–5 Hz gravitational-wave phase archive, but the primary value is a decisive, prediction-driven Solar-System field-equation test.

Abstract number: **69**
Author: Ahmed Soliman
Title: **Hybrid space-ground Observatory for Earth-Like Exoplanets (HOEE)**

Abstract:
We present the Hybrid Observatory for Earth-like Exoplanets (HOEE), our mission concept featured on the cover of Nature Astronomy in March 2026. HOEE combines a 100-m orbiting starshade with large ground-based telescopes, including the ELT, TMT, and GMT, to suppress starlight while preserving exoplanetary signals. Our studies show that HOEE paired with the ELT and advanced adaptive optics can achieve contrasts of 10^{-11}, enabling detection of Earth-like exoplanets at 5 pc within one minute and acquisition of biosignature spectra, including water and oxygen, in about one hour. The concept leverages the ELT Planetary Camera and Spectrograph (ELT-PCS) and a laser beacon integrated at the center of the starshade to overcome Earth's atmospheric effects. Compared with a 6-m HWO-class space telescope, HOEE delivers approximately 1000× faster observations and 6× higher angular resolution, enabling exoplanet measurements that would otherwise remain beyond reach, even through exozodiacal dust and cloud obscuration. How can the HOEE concept be implemented? A wonderful 30-person interdisciplinary team, spanning engineering, exoplanet science, adaptive optics, orbital dynamics and representatives from ELT, Keck and GMT, met together at Caltech Keck-Institute for Space Studies from March 9-13, 2026, to discuss the challenges and outline a road map toward implementing this concept. In this talk, we present on behalf of the KISS team our important key findings from our final "in-progress" KISS report, including the science cases, mission architecture and workflow. We also present the ELT first-light timeline, end-to-end optical performance, the mechanical engineering design to meet the required tolerances, and the role of integrating a coronagraph to further relax starshade tolerance and shape-accuracy requirements, along with the remaining work, technology demo flow chart and planned actions. These all contribute to the possibility of flying and observing Earth 2.0 and entire planetary systems with HOEE in the near future.

Abstract number: **70**
Author: Joseph Lazio
Title: **The MegaWave Radio Surveyor**

Abstract:
Fundamental questions spanning astrophysics, exoplanetary science and astrobiology, and cosmology require observations at radio frequencies blocked by Earth's ionosphere. The MegaWave Radio Surveyor, a space-based interferometer of un- precedented scale composed of mass-produced smallsats, would address those goals. Primary science objectives include detecting space weather generated by other stars; probing the interiors of exoplanets and assessing the magnetic shielding of their atmospheres through the detection of their magnetic fields; conducting unique observations of the Universe's evolution during the Dark Ages to test models of cosmological and fundamental physics; and assessing the role of cosmic rays in galactic halos-circumgalactic media and intracluster media. These science goals directly respond to priorities identified in the Pathways to Discovery Decadal Survey and half-a-dozen other National Academies' studies, and it would serve as a Formative Era concept in the Enduring Quests, Daring Visions roadmap. A distributed spacecraft constellation forming a radio interferometer, the MegaWave Radio Surveyor concept offers a versatile and scalable architecture capable of sensitive observations, multiple simultaneous science investigations, and enhanced resilience. Beyond its scientific impact, the MegaWave Radio Surveyor would enable NASA to develop and mature a new paradigm for space observatories. The MegaWave Radio Surveyor is enabled by developments in the U.S. space industry including the standardization of small spacecraft buses, advances in onboard processing and communications, commercial spacecraft mass production, and increasing heritage in distributed smallsat missions. The available trade space allows for leveraging elements of Artemis/Moon-to-Mars, including access to cislunar space and communications/navigation capabilities. The MegaWave Radio Surveyor leverages experience from NASA's Sun Radio Interferometer Space Experiment (SunRISE), Star-Planet Activity Research CubeSat (SPARCS), and LuSEE-Night. Beyond its specific science objectives, by opening one of the last unexplored windows in the electromagnetic spectrum and pioneering space interferometry at unprecedented scales, MegaWave would establish a transformational new capability.

Abstract number: **71**
Author: Volker Quetschke
Title: **LILA Observatory: A Lunar-Surface Mid-Band Gravitational-Wave Observatory**

Abstract:
The moon offers unique opportunities and challenges to realize interferometric gravitational wave detectors that are sensitive over a range of frequencies that are currently not covered. Compared with Earth-based detectors, the moon's reduced gravity and lower seismic activity allow us to shift the sensitivity of interferometric GW detectors to lower frequencies. The Laser Interferometer Lunar Antenna (LILA) project—a next generation gravitational-wave detector on the surface of the Moon— will be presented. The LILA detector will have unique access to the mid-band, approximately 0.1–10 Hz, range for detecting gravitational waves. This frequency range of waves cannot be measured by any ongoing or upcoming experiment on the Earth or in space. LILA will fundamentally change the landscape of multi-messenger astrophysics by opening up this mid-band. LILA will provide early warnings prior to mergers of black holes and neutron stars. Measurements in the deci-Hertz regime can vastly improve measurements of the Hubble constant, the equation of state of neutron stars, and tests of General Relativity. Furthermore, LILA will uniquely observe phenomena like white dwarf mergers as Type Ia supernovae progenitors, tidal disruption around intermediate mass black holes, and novel dark matter probes. A preliminary design for the LILA project and the planned future development stages will be shown: the LILA Autonomous Interferometry Technology Demonstration (LILA-AITD), the Initial LILA (iLILA) strainmeter and the full, operational LILA Observatory.

Abstract number: **73**
Author: Richard Scott Miller
Title: **Time-domain All-Sky Nuclear Gamma-ray Observatory (TANGO)**

Abstract:
The Time-domain All-Sky Nuclear Gamma-ray Observatory (TANGO) is a novel mission concept for MeV astrophysics. TANGO will fill the “MeV gap” (0.1-20 MeV), one of the last electromagnetic regimes without a sensitive sky survey. Motivated by the promise of discovery, TANGO maximizes flux sensitivity, sky coverage, and source localization performance. TANGO is uniquely enabled by the Moon with a pioneering implementation approach built on strong foundations, including in-situ validation in lunar orbit. TANGO challenges the status quo by making observations from lunar orbit. Our observing strategy is based on lunar occultation, an extension of classic on-off measurement techniques. Repeated eclipses of astrophysical sources by the Moon generate all information necessary to detect, localize, and characterize candidate sources; spacecraft and lunar ephemerides are all that is necessary to decode this information. Multiple sources can be imaged and characterized simultaneously. TANGO will continuously survey the entire sky across the time domain. Detected sources will be localized with an energy-independent precision of <0.2 deg to facilitate contemporaneous multi-messenger investigations; the temporal and spectral variability of sources will be monitored over time scales from seconds to months with modest energy resolution. TANGO’s observing strategy is made possible by the cis-lunar environment. Here the dominant background is the well-understood, easily-monitored cosmic ray-induced lunar gamma-ray albedo. Absence of a lunar atmosphere and magnetosphere mitigate the albedo’s intensity and variability relative to backgrounds in Earth orbit. Kinematic event reconstruction is not required, eliminating the need for complex position-sensitive instruments. TANGO’s lone instrument is a large-area non-imaging sensor array, i.e., a mosaic of modest gamma-ray spectrometers; its performance is tightly coupled to mission-level design rather than technology development. Achievable sensitivity is limited only by size, weight, and power (SWaP) resources. Ultimately, TANGO leverages a stable background environment and a well-established statistical framework to enable transformational MeV gamma-ray astrophysics.

Abstract number: **74**
Author: Walter Peter Maksym
Title: **An X-ray Extremely wide-field Spectroscopic Surveyor (XESS, or “chess”)**

Abstract:
XRISM has shown the transformative power of sensitive, high resolution X-ray spectroscopy for studying the formation of cosmic structure, black hole accretion, the fates of stars and more. And we look forward to a future with NewAthena and potentially a Lynx-like mission that combines high angular resolution, large effective area and exquisite angular resolution. But pointed NASA and ESA flagship missions leave critical strategic gaps in an era that will be profoundly influenced by time domain astrophysics and synoptic surveys. Surveyors and wide-field monitoring are essential for statistical population studies and for understanding both the nearest phenomena in our own Galaxy and the large-scale structure of the universe. We propose the X-ray Extremely wide-field Spectroscopic Surveyor (XESS, or “chess”), which will map the entire sky with greater depth, sensitivity, angular resolution and spectral resolution than has ever been possible for an X-ray surveyor. Thanks to multiple optimizations for this task, XESS is a mission ideally matched to the wide-ranging needs of the era of wide-field surveys and time domain astrophysics.

Abstract number: **75**
Author: Avi Mandell
Title: **The MIRECLE Concept: Revealing the Properties of Non-Transiting Temperate Rocky Planets Orbiting the Nearest M-Stars**

Abstract:
We present an introduction to the a new observatory+instrument concept called MIRECLE (Mid-Infrared Exoplanet CLimate Explorer), a concept that pairs a MIR-optimized cryogenic telescope with broad wavelength coverage (3 - 17 μm minimum) low-resolution spectrograph designed for extreme flux measurement precision. With its unique simultaneous NIR/MIR wavelength coverage and high photometric stability, MIRECLE would be capable of measuring the atmospheric and surface characteristics of a statistically significant sample of temperate rocky planets around the nearest M-stars. MIRECLE would utilize a new technique called Variable Planetary Infrared Excess (Stevenson 2020, Mandell et al. 2022, Johnson & Mandell 2026) to extract a planet's phase-dependent thermal emission spectrum without requiring the planet to transit – thereby enabling phase curves of non-transiting rocky planets around the nearest stars with a relatively modest telescope aperture. Spectroscopic characterization of terrestrial atmospheres around a sample of 30 – 50 nearby rocky planets on the inner and outer edges of the habitable zone would provide constraints for the distribution of planets with tenuous vs. substantial atmospheres, determine the composition and climate state, and search for signatures of habitability and life. Currently available or planned missions such as JWST and ARIEL are limited in their spectroscopic characterization of HZ planets to wavelengths below 12 μm due to the design of their instruments, telescope operating temperature, and/or wavelength coverage – thereby requiring a future VPIE-optimized MIR mission. We will present the overall mission concept and the key enabling technologies, as well as exploratory simulations of the potential science yield for several known nearby planets. We will also describe our progress on demonstrating the VPIE technique using archival JWST data, and we will present the overall expected science yields for several mission architecture and performance metrics.

Abstract number: **76**
Author: Lee G Mundy
Title: **Far-Infrared Interferometer Mission Concept**

Abstract:
Far infrared (Far IR) space interferometry with sub-arcsecond spatial resolution is essential for addressing major astrophysical questions about the origins of galaxies, stars, planets, and habitable environments. The key capabilities are spatial resolution to spatially resolve relevant size scales, and spectral coverage and resolution to study spectral energy distributions as well as line emissions. Achieving these capability demands interferometry in baselines from 10-100 meters and advanced technologies such as double Fourier techniques, cryogenic optics, new spectral dispersion techniques, and highly sensitive detectors. A structurally connected interferometer operating from 25-400 microns with spectral resolving power of 100,000 or more uniquely complements JWST and ALMA in spatial and spectral coverage, resolving circumstellar disks, probing the inner regions of AGN, and beating the confusion limit to measure complete far-IR spectra of individual high-z galaxies. Building from earlier mission concepts, a mission study to utilize new and emerging technologies to optimize the spatial and spectral capabilities and the sensitivity of a Far-IR interferometer mission is the path to enabling transformative studies of galaxy evolution, black hole growth, and the chemical and physical processes shaping planetary systems, while providing a community resource through both legacy and guest observer programs. Such an interferometer could be equipped with a technology demonstration instrument to reduce risk for a mid-infrared starlight nulling mission to search for signatures of life in exoplanet atmospheres. The mission we envision addresses all three of NASA's astrophysics themes: How did we get here? How does the universe work? Are we alone?

Abstract number: **77**
Author: Nicholas Cannady
Title: **LCRO: A Modular Cosmic-Ray and Gamma-Ray Observatory on the Lunar Surface**

Abstract:
Understanding the origin of Galactic cosmic rays approaching and exceeding the PeV “knee” remains a major outstanding challenge in high-energy astrophysics. High-energy particles, extreme phenomena, and the chemical evolution of the galaxy are central to NASA’s roadmap goal of understanding “How does the Universe work?” and the Astro2020 decadal question of how “injection of energy, momentum, and metals from stars” circulates matter. Space-based instruments for detecting cosmic rays currently lack the exposure necessary to reach PeV energies directly. While large, ground-based observatories can indirectly measure PeV-energy cosmic rays, their composition resolution is coarse and subject to large modeling uncertainties, hiding differences in the spectra of individual species. The Lunar Cosmic Ray Observatory (LCRO) is a concept for a large-scale instrument exploiting the lunar surface and Artemis-era infrastructure. It is a modular design for an observatory comprising many detector towers that can be launched and installed on successive missions rather than depending on launch vehicle support of a massive, monolithic calorimeter. Together, the towers are sensitive to cosmic rays and gamma rays with an unprecedented acceptance and energy range for direct detection. LCRO would measure the fluxes of individual galactic cosmic ray species from GeV energies to beyond the “knee,” study the gamma-ray emission of energetic sites of particle acceleration, and contribute to multi-messenger campaigns with gravitational wave and neutrino observatories. These capabilities push the frontiers of astrophysics and enable searches for signatures of new physics, including indirect probes of dark matter. The convergence of these high-priority questions, mature detector technologies, and Artemis Program investment in lunar infrastructure creates a timely opportunity for a new paradigm for high-energy astrophysics. LCRO is uniquely positioned to fill a critical observational gap with direct measurements beyond current space-based capabilities, representing a potential long-term facility architecture capable of transforming observations of the high-energy Universe.

Abstract number: **78**
Author: Simon Richard Bandler
Title: **De-risking the Next X-ray Flagship: A Dedicated Technology Development and Proto-Flight Strategy**

Abstract:
Future large, strategic X-ray missions face significant programmatic hurdles, primarily driven by the massive "marching army" costs and extended schedules of traditional flagship implementation. While the Astro2020 Decadal Survey recognized this risk by recommending a mission and technology maturation program, we propose taking this concept a step further. A key advantage for the X-ray community is that the Lynx 2020 concept was exhaustively studied, leaving us with a highly mature foundational design. In our view, the basic architectural assumptions—specifically focal length, angular resolution, and effective area—are relatively stable. Because these fundamental requirements are already sufficiently well-evolved for the optics and key instruments, we argue it is possible to bypass some of the traditional mission lifecycle components and focus on critical hardware development. Leveraging this stability, this presentation advocates for a dedicated, heavily funded (e.g., ~$0.5B) technology program. Crucially, provided that TRL-5 has been successfully achieved, this program would advance beyond standard TRL-6 demonstrations to fund the construction of complete Engineering Development Units (EDUs) for the detectors and allow for the serious industrialization of X-ray optics development prior to full mission formulation. Delaying mission-level implementation until these EDUs are successfully proven dramatically alters the risk posture. Validated EMs would allow the mission to transition straight to a proto-flight model, enabling fixed-price industry contracts for major elements like the spacecraft and optics. This front-loaded investment creates a sharper pre-adoption S-curve, targeting a streamlined mission cost of ~$3B rather than the $6.5B+ estimates of previous flagship studies. Finally, we propose the upcoming Science and Technology Definition Team (STDT) formally investigate this alternative pathway. We suggest a framework for the STDT to rigorously evaluate this approach’s tradeoffs, examining whether stable requirements enable early EDU development to definitively de-risk the observatory, and provide a detailed cost estimate for this dedicated technology funding phase.

Abstract number: **79**
Author: Gregory D Wirth
Title: **CHROMOS (Cosmic Higher Resolution Origins Multi-Object Spectroscopy): Mission Implementation**

Abstract:
We propose the Cosmic Higher Resolution Origins Multi-Object Spectroscopy (CHROMOS) mission concept for ASTRA. CHROMOS fills major science gaps by definitively addressing fundamental questions identified by Astro2020 which will persist into the 2030s. CHROMOS probes three critical cosmological issues: (1) What is the physics of cosmic inflation? (2) What drives cosmic acceleration? (3) What is the total mass of neutrinos? It also addresses key questions in exoplanets, galaxy evolution, and Milky Way science. CHROMOS couples a wide-field telescope (2-m aperture, 0.7 sq deg FoV) with a powerful near-to-mid-infrared multi-object spectrometer capturing <=16,000 spectra simultaneously over the full 1.25–5 micron spectral range. Each of the four identical, separable spectrometer arms uses a Digital Micromirror Device (DMD) capturing <=4,000 spectra with resolving power R=1000. CHROMOS executes a 5-year program addressing four primary science pillars: a massive 1-billion-galaxy redshift survey mapping large-scale structure in exquisite detail over the full $1 < z < 9$ redshift range, an exoplanet characterization survey for high-precision transit spectroscopy, a deep Galactic survey of the dust-obscured inner Milky Way, and community surveys. The mission emphasizes technical efficiency, cost containment, and high reliability through modular instrument design, a purely passive cooling system enabled by its thermally stable L2 halo orbit, and a versatile pointing system leveraging direct imaging for precise target acquisition. CHROMOS represents a modest upscaling of the original ATLAS Probe concept from 1.5-m to 2-m telescope aperture, and expects to meet the ASTRA cost cap. It constitutes an extraordinarily powerful spectroscopic observatory addressing multiple outstanding fundamental problems in cosmology highlighted in Astro2020. CHROMOS fills the capability gap in current and planned space- and ground-based projects and will drive discoveries in astrophysics for decades, and thus should enter the ASTRA incubator immediately.

Abstract number: **80**
Author: John F Krizmanic
Title: **The Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) Observatory**

Abstract:
Ultra-high energy cosmic rays (UHECRs) are the most energetic particles ever detected, with measured energies exceeding 10^20 eV, yet their sources and acceleration mechanisms to remain unidentified. Likewise, the detection of a larger sample of very-high-energy (VHE) cosmic neutrinos (E> 1 PeV) has so far eluded measurement. During both the Astro2020 Decadal Survey and the Snowmass community planning process, the UHECR community and the high-energy neutrino community detailed the high exposure offered by space-based observations for both of these messengers. The Probe Of Extreme Multi-Messenger Astrophysics (POEMMA), a probe-class mission for observing UHECRs and VHE neutrinos, is designed to observe both messengers from space with full-sky sensitivity and the high exposure. POEMMA comprises two identical satellites flying in loose formation at 525 km altitude with each satellite hosting a wide field-of-view Schmidt telescope with 6 m^2 light collecting area and a hybrid focal surface optimized for the air fluorescence measurements of extensive air showers (EAS) produced by UHECRs above 20 EeV and a smaller section that detects Cherenkov radiation from upward-going EASs from decaying tau-leptons produced by > 20 PeV tau neutrinos that interact in the Earth. In a five-year mission, POEMMA will substantially increase the statistics of the highest-energy UHECRs and provide unparalleled sensitivity to transient neutrino sources, as well as rapidly re-orient to follow up alerts. New discoveries, like the detection of KM3-230213A (most energetic neutrino event recorded) and the dawn of neutrino astronomy initiated by IceCube along with the technological advances achieved by the JEM-EUSO and POEMMA collaborations through missions such as Mini-EUSO, EUSO-SPB2, and the forthcoming POEMMA-Balloon with Radio (PBR), offer potential improvements to the POEMMA design to optimize science return. In this contribution, we summarize the POEMMA instrument design, UHECR and VHE neutrino measurement capabilities, and discuss potential instrument and mission implementation improvements.

Abstract number: **81**
Author: Michael R. Meyer
Title: **Charactering Exoplanets with Nulling: Surveying Unseen Systems (CENSUS)**

Abstract:
We will provide an overview the mission concept CENSUS, a near-term 3-8 micron nulling interferometer that can detect warm planets inferred from radial velocity (RV) observations. While RV provides period, eccentricity, phases, and minimum masses (modulo the inclination), we lack luminosities, radii, and atmospheric characterization including compositional information, not to mention accurate masses. These data are vital in order to confront theories of planet formation for planets with orbital radii from 0.02-2.5 AU and masses super-Earth and above. This unique sample of > 100 planets will allow us to connect, for the first time, close-in planets characterized through transmission and secondary eclipse spectroscopy with wide-orbit planets studied through direct imaging. It also provides a bridge between currently accessible systems and potentially habitable planets in their liquid water zones, as well as surveying global planetary system architectures. CENSUS relies on proven technologies such as passively-cooled telescopes and mature low-background detectors, as well as medium TRL tech, such as infrared nulling combiners and formation flying.

Abstract number: **83**
Author: Gary Melnick
Title: **Beyond Zodi Mid-Infrared Wide-Field Surveyor**

Abstract:
We describe the scientific potential of a 2 m-class wide-field IR imaging survey telescope deployed beyond 3 AU, equipped with near- and mid-IR (2-10 μm) detector arrays, broadband filters, and slitless spectrometers. Four investigations illustrate its transformative impact: (1) a wide-area (~100 deg²) census of z ≥ 10 galaxies at JWST sensitivity; (2) direct measurement of 5–10 μm cosmic infrared background (CIB) fluctuations, currently inaccessible near Earth, where the zodiacal foreground is 100–1000x brighter than the expected CIB signal; (3) ultra-low surface-brightness imaging of nearby galaxy halos to trace faint stellar envelopes and tidal debris, thereby constraining stellar masses and merger histories; and (4) multi-latitude mapping at 10 AU, where zodiacal emission is suppressed by >200x, directly constraining the Epoch of Reionization component of the extragalactic background light while simultaneously constraining diffuse Galactic emission. Infrared observations conducted near 1 AU from the Sun are inescapably limited by foreground emission from interplanetary (zodiacal) dust, whose scattered sunlight dominates at short wavelengths ($\lesssim$ 3 μm) and whose thermal emission dominates from a few to tens of microns. Extrapolating the COBE/DIRBE zodiacal model of Kelsall et al. (1998), with dust temperature scaling as $r^{-0.467}$ and dust density as r^{-1}, we show that relocating a passively cooled IR telescope beyond the Asteroid Belt (~3 AU) reduces the effective background by a factor of 10^2–10^4, depending on heliocentric distance and optics temperature. Gains approaching 10^4 are achievable near 10 AU with optics cooled to ~40 K. Additional opportunities include mapping the radial and vertical structure of interplanetary dust, detecting Kuiper Belt dust in scattered light, time-domain monitoring (e.g., of Sgr A*), microlensing with parallax, and targets of opportunity when inner-Solar-System observatories are unavailable. Key mission drivers include passive thermal design, onboard data storage and downlink, and electrical power.

Abstract number: **84**
Author: C. Megan Urry
Title: **Extragalactic Science with SPICE, the Space Interferometer for Cosmic Exploration**

Abstract:
Far-infrared observations are critical for understanding the universe because dust obscures most star formation and accretion onto supermassive black holes, such that most of the detectable energy emitted from these systems comes out in the FIR (25-400 um). Single-dish FIR telescopes with resolution of tens of arcseconds cannot resolve individual sources in the legacy multiwavelength fields (e.g., COSMOS or CANDELS) and reach the confusion limit well above flux levels of interest; the lack of positional accuracy also precludes accurate association between FIR emission and optical/near-IR or X-ray counterparts (the latter localized with subarcsecond precision). Here we describe the science possible with a FIR interferometer that achieves subarcsecond spatial resolution and spectral resolution of ~3000-5000. In particular, we describe a ~1000 hour survey of a COSMOS-like area, which would detect thousands of AGN and tens of thousands of galaxies, yielding unprecedented information about the cosmic history of star formation, black hole accretion, and how each affects the other.

Abstract number: **85**
Author: Naceur Gaaloul
Title: **AEDGE: Atomic Experiment for Dark Matter and Gravity Exploration in Space**

Abstract:
Cold-atom interferometry has emerged as a powerful approach to precision measurement, with the potential to open new windows on fundamental physics from space. This talk presents the science case and mission concept of AEDGE — the Atomic Experiment for Dark Matter and Gravity Exploration — a proposed space-based cold-atom observatory designed to search for ultra-light dark matter and detect gravitational waves in the mid-frequency band between the optimal ranges of LISA and terrestrial detectors such as LIGO, Virgo, KAGRA and Einstein Telescope [1]. The central idea is to use long-baseline atom interferometry with cold atomic clouds as inertial references. Variations in atomic transition frequencies could reveal oscillating ultra-light dark-matter fields, while gravitational waves would imprint differential phase shifts through changes in the light-propagation baseline. Operating in space provides a quiet environment and long interrogation times that are difficult to realize on Earth, enabling sensitivity to dark-matter couplings and gravitational-wave sources inaccessible to existing instruments [1]. I will discuss how AEDGE could probe scalar ultra-light dark matter, including couplings to electrons, photons, and Higgs-portal scenarios, extending searches into new regions of parameter space. I will also outline its gravitational-wave reach, with emphasis on intermediate-mass black-hole mergers, the formation history of supermassive black holes, first-order phase transitions in the early universe, and cosmic strings. Beyond these primary goals, AEDGE illustrates how cold-atom technology can contribute to tests of fundamental constants, Lorentz invariance, quantum mechanics, and other precision probes of new physics. The talk will place AEDGE in the broader landscape of quantum sensors, terrestrial atom-interferometer pathfinders, microgravity experiments, and space missions. It will argue that space-based atom interferometry is not merely an incremental extension of existing technologies, but a genuinely interdisciplinary platform connecting quantum optics, particle physics, cosmology, and gravitational-wave astronomy. [1] Y. Abou El-Neaj et al, EPJ QT 7, 6 (2020)

Abstract number: **86**
Author: Curtis McCully
Title: **CIELO: LCO in Space**

Abstract:
As the next era of Time Domain and Multi-Messenger Astrophysics (TDAMM) begins, with new surveys like the Nancy Grace Roman Telescope, the Legacy Survey of Space and Time (LSST) on the Vera C. Rubin Observatory, and the Argus Array coming online, we have a mismatch between TDAMM discoveries and TDAMM follow-up. These surveys will provide a plethora of new targets, but the characterization of any of these targets will be limited by the survey cadence and to a few photometric colors (often only in the optical for ground-based surveys) without additional follow-up resources. High-cadence monitoring, expanded wavelength coverage beyond the optical, and spectra are essential to realize the full potential of these new surveys. Our current suite of instruments in space is not up to the task, with most facilities (e.g., Hubble) taking days to weeks to observe a newly discovered target. Here we present a mission concept for the Constellation of Interwavelength Explorers in Low-earth Orbit (CIELO) to fill this need. Our proposed constellation of smallsats that operate as an integrated network will build on the legacies of both Swift's rapid response and Las Cumbres Observatory (LCO), which operates a network of telescopes for TDAMM. I will give an overview of some of the science cases that could be achieved with this kind of mission and discuss the economies of scale we achieve with this concept, which provide redundancy, expandability, and longevity of the constellation and open novel observational possibilities, e.g., continuous monitoring.

Abstract number: **87**
Author: Brandon Chalifoux
Title: **A Diffraction-Limited Milli-arcsecond X-ray Imager**

Abstract:
We present a concept for X-ray imaging at milli-arcsecond angular scales. Using our design, X-ray astronomy can catch up and eventually achieve an imaging resolution of micro-arcseconds, needed to resolve the event horizons of supermassive black holes. For now, we focus on the 1-5 mas scale, where we can identify many potential science investigations. Nine science cases are presented in the Science table, taken from the summary report of the Hi-ReX SAG (Marshall, et al. 2026), which also details studies requiring imaging at finer scales, achievable with the suggested architecture. This innovative telescope design (Chalifoux et al. 2020) combines X-rays from grazing incidence surfaces to form diffraction-limited images at the focal plane. This configuration will provide milli-arcsecond scale images as a stepping stone toward micro-arcsecond imaging of a similar design. While designed using interferometric techniques, true images would be produced without resorting to post-processing of fringe data, practically eliminating background. The method uses a delay line approach with curved mirror segments that are diffraction limited at the 1" level for a subtended entrance aperture of 1 mm used at grazing incidence. A mirror module is formed as a P-S set of 9 pairs of segments each. The diffraction limit at 2 keV is 5 mas for this strawman design; the module images are not coherently combined, so we set 160 such modules in concentric rings to accumulate an effective area of 600 sq. cm. at 2 keV, depending on the coating. The focal length of the system was constrained to 100 m, assuming 2.9 micron detector resolution.

Abstract number: **88**
Author: Elizabeth Hays
Title: **Future Large Gamma-ray Mission Concepts**

Abstract:
The Future Large Gamma-ray Mission Concept Science Analysis Group was established to collect and synthesize community input on potential Probe-class and Flagship-class gamma-ray mission concepts that the community wishes to explore in the coming decade. The group, which is organized under the Gamma-ray Science Interest Group with open membership, has compiled technical capabilities that reflect the current state of development for supporting gamma-ray mission concepts. The report to be delivered from this group summarizes capabilities available for large missions in the next decade with a focus on those motivated by compelling science questions from Astro 2020 and gaps in the current program, as well as more recent reports and community white papers. The report also points to promising development paths that push beyond the current state of the art. In this talk, we will present the summary and highlights from the FLAG SAG report.

Abstract number: **89**
Author: Haeun Chung
Title: **Ardua: UV Instrument Technology and Design Trades for Wide-Field, Ultra-Low-Surface-Brightness Circumgalactic Medium Mapping**

Abstract:
Ardua is a joint far-ultraviolet (FUV) and X-ray mission concept that maps the baryon cycle by imaging every phase of the circumgalactic medium (CGM) in emission: FUV for cool, warm, and warm-hot phases and X-ray for the hot phase. This presentation covers Ardua's UV instrument. The driving requirement for the UV instrument is to detect far-ultraviolet emission lines (e.g., O VI 1032/1038 Å, C IV 1550 Å) at surface brightnesses of ~10^-20 erg/s/cm^2/arcsec^2, over arcminute-scale fields, and at spectral resolution (R~50,000) sufficient to resolve CGM kinematics. This regime exposes a defining property of diffuse-source spectroscopy: survey speed scales with detector area and the inverse of the focal ratio, not with aperture size. A large, slow single-mirror observatory is therefore prohibitive (mapping even a single galaxy halo could take >10 years), and a fundamentally different, fast-optics architecture is required. The central design question is how best to partition the required étendue: a single fast telescope feeding a large-format spectrograph or IFU, an intermediate number of medium telescopes, or many small telescopes each with a compact spectrograph. We frame this trade space and the metrics that drive it - survey speed, spectral resolution, spatial sampling, and cost - noting that back-end spectrograph fabrication and qualification are likely the dominant cost driver. We then review the enabling FUV technologies across coatings (eLiF/XeLiF), photon-counting detectors (Skipper CCDs, MCPs), and gratings (e-beam lithography vs. holographically ruled), with their current readiness. Key maturation needs include fast-readout Skipper CCDs, coating scale-up and space qualification, and system-level control of stray light and diffuse foregrounds, which set the sensitivity floor independent of detector performance. We present the state of the art, the design trade space, and where investment is most needed.

Abstract number: **90**
Author: Anish Roshi
Title: **PHOENIX: A Photonics-Enabled Heterodyne Submillimeter/Far-Infrared Interferometer for Planet Formation, Star Formation, and Galaxy Evolution**

Abstract:
Over the past several decades, observations in the submillimeter (submm) and far-infrared (FIR) regimes have transformed our understanding of planet formation, star formation, and galaxy evolution by providing unique access to key spectral diagnostics and cold dust emission. The next generation of breakthroughs requires resolving protoplanetary disks and star-forming regions at AU scales and tracing the buildup of galaxies across cosmic time on spatial scales below ~150 pc, capabilities that demand a milliarcsecond-resolution heterodyne submm/FIR interferometer with km s-1 level spectral resolution and exceptional continuum sensitivity. We propose PHOENIX, a photonics-enabled heterodyne submm/FIR interferometer that leverages optical frequency combs and integrated photonic technologies as a unified architecture for array synchronization, precision metrology, local-oscillator generation and distribution, delay compensation, wideband signal transport, and low-power correlation. The baseline concept consists of an array of approximately 25 free-flying spacecraft distributed in a quasi-spherical configuration of diameter 1-2 km to provide dense and uniform uv coverage for high-fidelity imaging over a large fraction of the sky. Each spacecraft is equipped with a 4–8 m deployable antenna and a heterodyne receiver operating from 0.9 to 5 THz, and operates in concert with a dedicated communications and signal-processing spacecraft at the Earth–Sun L2 Lagrange point. An alternative implementation would deploy the interferometer within a lunar Permanently Shadowed Region (PSR). Realizing PHOENIX will require advances in photonic architecture, the mission's primary enabling technology, along with the maturation of ultra-wideband low-noise heterodyne receivers, high-efficiency cryogenic systems, and lightweight deployable apertures with micron-level surface accuracy. The need to mature these technologies and establish a pathway toward a future flagship-class submm/FIR observatory makes PHOENIX an ideal candidate for incubation within NASA's ASTRA Initiative.

Abstract number: **91**
Author: Garreth Ruane
Title: **Servicing Mission to Bring Second-Generation Coronagraph Instrumentation to the Habitable Worlds Observatory**

Abstract:
The Habitable Worlds Observatory (HWO) aims to be the first space telescope capable of directly imaging and characterizing a robust sample of at least 25 potentially habitable exoplanets. While HWO's first-generation coronagraphs will pioneer the unprecedented 1e-10 raw contrast needed to achieve this, there may be practical limitations regarding inner working angles, wavelength ranges, and spectral resolution due to current technological readiness, schedule, and risk postures. We advocate for a dedicated robotic servicing mission to install a highly capable, second-generation coronagraph suite on HWO at the Sun-Earth L2 point. This strategic upgrade would transition HWO into an extended mission phase, mitigating the initial technical risk of the first-generation instruments while realizing the observatory's ultimate scientific objectives. A second-generation instrument suite could introduce drastic leaps in capability. Anticipated upgrades may include expanded wavelength ranges (e.g., dedicated parallel near-ultraviolet to near-infrared spectroscopy channels), polarimetric observations (e.g., for surface ocean glint detection), expanded high-contrast fields of view for exozodiacal dust and outer planet characterization, advanced backend instrumentation (e.g., higher-resolution spectrometers), enhanced overall performance (throughput, instantaneous bandwidth, and inner working angles), multi-star capabilities, and improved wavefront and contrast stabilization. Crucially, because HWO is currently in its formative architectural phase, we emphasize the urgent need to establish the physical and operational bounding boxes for the telescope's base infrastructure today. Prioritizing modularity, standard interfaces, thermal management, and volume requirements is essential to ensure true forward-compatibility. By designing the observatory, first-generation instrumentation, and interfaces with the second-generation instruments and servicing mission in mind, we can enable HWO to seamlessly evolve and deploy the robust toolkit required to unambiguously identify biosignatures. Initiating a formal servicing mission concept through the ASTRA initiative today may therefore be essential to ensure HWO is built from day one to accommodate the future of direct imaging exoplanet and circumstellar disk science in space.

Abstract number: **92**
Author: Asantha Cooray
Title: **CDIM-ASTRA: A Strategic Wide-Field Spectro-Imaging Mission for Cosmic Dawn and Reionization**

Abstract:
DIM-ASTRA is a strategic near- and mid-infrared spectro-imaging mission concept designed to address the formation of the first galaxies and black holes and the history of cosmic reionization. The concept combines wide-area, moderate-resolution spectral mapping over the 0.75–7.5 μm wavelength range with a large instantaneous field of view to produce three-dimensional spectral data cubes spanning the critical redshift range from the end of reionization through cosmic dawn. The mission is designed to complement, rather than duplicate, the capabilities of JWST, Roman, SPHEREx, and forthcoming 21-cm experiments. While JWST provides detailed observations of individual sources and Roman and SPHEREx deliver wide-area imaging and low-resolution spectroscopy, CDIM-ASTRA provides the large-area spectral mapping needed to connect individual galaxies with the evolving intergalactic medium. The science program combines spectroscopy of galaxies and active galactic nuclei, Lyα and Hα intensity mapping, cross-correlation with 21-cm surveys, and searches for signatures of Population III stellar populations and high-redshift transients. The reference mission concept employs a passively cooled telescope at Sun-Earth L2 together with large-format HgCdTe detector arrays and linear variable filters to obtain spectral imaging without moving optical components. This architecture builds on existing infrared mission heritage while focusing technology maturation on long-wavelength detector performance and large-format linear variable filters. The presentation will summarize the scientific motivation, mission architecture, survey strategy, enabling technologies, and opportunities for coordination with current and planned international facilities. The discussion will also consider how a CDIM-class mission could contribute to a balanced NASA astrophysics portfolio as a candidate strategic mission for the Astro2030 era.

Abstract number: **93**
Author: Thomas Marshall Eubanks
Title: **Fundamental Physics, Astrophysics and Cosmology with the Interplanetary Laser Trilateration Network (ILTN)**

Abstract:
The interplanetary laser trilateration network (ILTN) will enable orders of magnitude improvement in the metrology of the inner solar system by providing laser range and phase measurements over interplanetary distances. The ILTN will form a ring laser gyroscope ~ten orders of magnitude larger than currently-existing systems, will provide substantial improvements in tests of gravity and general relativity in the solar system, and will enable, between micro Hertz and nano Hertz frequencies (periods of a few days to years) the observation of both the stochastic gravitational wave background and also of nearly monochromatic gravitational waves produced by relatively nearby supermassive black hole binaries close to merger, inspiral and ringdown. The ILTN will complement measurements from pulsar timing arrays (PTAs), as the ILTN and PTA data will have different spectral sensitivity to gravitational waves, and it will observe the observational spectral “gap” (roughly, periods of a few days to a few months) poorly observed by either the PTA data or data from Laser Interferometer Space Antenna (LISA). The combination of ILTN, LISA and PTA data will help in the localization of relatively near SMBH binary sources, thus addressing the "Discovery Area" B-DA in the 2020 Astrophysical Decadal Survey, “Transforming our view of the universe by combining new information from light, particles and gravitational waves.” The ILTN was the subject of a W. M. Keck Institute for Space Studies (KISS) workshop on September 22 - 26, 2025, which helped to identify the challenges associated with the design, development, and implementation of the ILTN. The proposed ASTRA study should retire three major challenges: 1) whether the ILTN should use laser pulse or laser phase measurements ; 2) what are the optimum ILTN orbits; and 3) how should the ILTN best address the asteroid gravitational noise problem.

Abstract number: **94**
Author: Ahmad Sohani
Title: **LUSTER-net: LUnar-based Survey for Time-domain Exploration and Research network**

Abstract:
As time-domain astrophysics enters a new era of heavily condensed data sets driven by the upcoming Rubin Observatory, Roman Space Telescope, and other transient facilities with high discovery alerts stream, real determination of the physical nature of the discovered events requires long-term monitoring and multiwavelength light curves and spectra. LUSTER-net (LUnar-based Survey for Time-domain Exploration and Research network) addresses this gap with a coordinated network of 6–12 lunar-surface UVOIR telescope nodes distributed across the lunar surface, each in the ~0.5 to 1 meter aperture class to achieve a suitable balance between angular resolution, collecting area, and feasibility with commercially available telescopes, providing ultraviolet-to-near-infrared imaging and/or spectroscopy. By exploiting long, uninterrupted observing windows of lunar platforms, LUSTER-net can increase sky access, redundancy, cadence, and provide faster response capabilities compared to single-telescope systems. To maximize science return while leveraging lunar infrastructure and designed operations, an ASTRA study would support optimization of the number of nodes and their placement, appropriate aperture scale, instrument complement, and deployment cadence. Network-level coordination would enable adaptive observing strategies across transient alerts and continuously evolving priorities. The science drivers of this mission include repeated exoplanet transit spectroscopy for atmospheric characterization, microlensing parallax to break events degeneracies and constrain lens properties, to continuous monitoring of near-Earth asteroids and small-body activity, early characterization of supernovae and fast transients, and rapid electromagnetic follow-up of gravitational-wave, neutrino, and high-energy events. LUSTER-net would provide a persistent UVOIR time-domain layer that converts incoming multi-messenger and survey discoveries into physical understanding of these events.

Abstract number: **95**
Author: Eduardo Bendek
Title: **ASPECT: Astrometry Space Probe for Exoplanet Characterization and True Masses**

Abstract:
ASPECT is a mission concept for a moderate-cost space observatory that would extend precision astrometry into the sub-microarcsecond regime to enable the detection and characterization of Earth-mass exoplanets around nearby Sun-like stars. By measuring the reflex motion of host stars, ASPECT directly determines planetary true masses and complete three-dimensional orbits, overcoming the inclination ambiguities inherent to radial velocity measurements and complementing transit and direct-imaging observations. The mission targets approximately 100–200 nearby FGK stars with a per-epoch astrometric precision goal of ~0.2 μas, sufficient to detect Earth analogs within the habitable zones of the nearest stellar systems. The concept is enabled by the diffractive-pupil astrometric calibration technique, which suppresses time-variable optical distortion—the dominant systematic limiting ultra-precise astrometry—by generating diffraction spikes that share the optical path with background reference stars. Combined with a wide-field 2-m telescope operating from the Sun–Earth L2 point, this approach offers a scalable path toward sub-μas performance while leveraging heritage from Gaia, Roman, Theia, and previous NASA technology investments. ASPECT is being developed within the ASTRA framework as a Concept Maturity Level (CML) 3 mission with ongoing architecture and technology trades. Current studies examine aperture size, detector technologies, distortion calibration strategies, and alternative architectures, including distributed aperture concepts and interferometric implementations, to quantify cost, performance, and technical risk. In addition to addressing fundamental questions on planetary system architectures and the demographics of cold terrestrial planets, ASPECT could substantially enhance the science return of the Habitable Worlds Observatory by providing pre-launch or contemporaneous measurements of planetary masses, orbital elements, and observing ephemerides, enabling more efficient target selection and atmospheric characterization.

Abstract number: **96**
Author: Edward Balaban
Title: **Fluidic Telescope (FLUTE): Transformative Science with Ultra-Large, Single-Aperture Space Observatories**

Abstract:
The Fluidic Telescope (FLUTE) project, led by NASA Ames Research Center, aims to develop extremely large, cost-effective space observatories with apertures measuring tens or even hundreds of meters, achievable with current or near-term technologies. The monolithic, self-healing, molecularly smooth primary mirror of such an observatory is formed in situ using a thin liquid film, thus decoupling aperture from the mass, segmentation, and cost-scaling of figured-glass mirrors. These observatories promise a transformational effect on astronomy, astrophysics, and cosmology by greatly increasing angular resolution and light-collecting power compared to the current generation of space telescopes. At this workshop, we present a mission concept for FLUTE-50: an ultraviolet/optical/near-infrared FLUTE observatory with a 50-m primary mirror. Compared to the 15-m LUVOIR-A concept, a 50-m filled aperture offers 3x finer angular resolution, up to 11x the collecting area, and up to 37x the surveyable volume. It advances the full LUVOIR general astrophysics portfolio and, for exoplanets, approaches the regime in which survey overheads — rather than photon collection — set the limit, making a statistical census of a few hundred potentially habitable worlds plausible. We envision a staged development roadmap toward FLUTE-50 and beyond. The first major milestone is FLUTE-1, a 1-meter low-Earth-orbit demonstration mission designed to retire key fluidic-optics risks. This will be followed by an intermediate (LUVOIR-A class), 15-m aperture FLUTE-15 to validate our subsystem scaling approaches. The feasibility of the fundamental FLUTE approach has been demonstrated through extensive laboratory experiments, as well as experiments aboard the International Space Station and during three parabolic microgravity flight campaigns. The FLUTE project is a collaborative effort between NASA (Ames Research Center and Goddard Space Flight Center), Technion - Israel Institute of Technology, Boston University, Rice University, University of Maryland (College Park), Stanford University, and the University of Arizona.

Abstract number: **97**
Author: Nivedita Mahesh
Title: **An Ultra-Long-Wavelength Observatory on the Lunar Farside**

Abstract:
The low-frequency radio sky below 30 MHz remains one of the last unexplored frontiers in astrophysics. Earth's ionosphere and pervasive radio-frequency interference (RFI) render these wavelengths, especially the sub-MHz regime, inaccessible from the ground. The lunar farside is the most radio-quiet location in the inner Solar System: the Moon shields an array from terrestrial RFI, auroral kilometric radiation, and, during the lunar night, solar-wind plasma effects, enabling an exquisitely low noise floor. We present a mission concept for a low-frequency interferometric array on the farside surface, comprising 100–500 electrically-short dipole antennas deployed by rovers across 1-10 km of terrain, tethered to a central lander for power-and-RF-over-fiber and onboard correlation. Operating from ~100 kHz to 50 MHz, the observatory delivers transformational science across multiple communities: Dark Ages 21-cm cosmology (probing dark matter microphysics, deviations from ΛCDM, and inflationary signatures), the first detection of exoplanet magnetospheres and stellar space weather around nearby M-dwarfs, and resolved maps of Galactic cosmic-ray electrons; with bonus Solar System and lunar-ionosphere returns. The concept builds on more than a decade of technical development for lunar radio astronomy, from surface precursors (ROLSES, LuSEE-Night) to NASA-funded radio telescope studies (FARSIDE, FarView, LCRT), inheriting flight-qualified hardware heritage (SunRISE electronics, TYMPO tethers) and mature ground heritage (OVRO-LWA full cross-correlation, all-sky imaging, and calibration pipelines) at high technology readiness. at high technology readiness. Placing the telescope on the surface raises the dipoles radiation resistance through dielectric loading, keeping the array sky-noise-limited and boosting sensitivity in the sub-MHz regime. We outline the concept of operations, mission architecture, and the trade studies needed to mature this concept toward a future strategic mission, leveraging Artemis and Commercial Lunar Payload Services infrastructure.

Abstract number: **98**
Author: Ref Bari
Title: **T-REX: Time-Resolving Explorer**

Abstract:
We present T-REX: The Time-Resolving Explorer Satellite, a mission concept for a low-Earth-orbit (LEO) small satellite (M~85kg, P~1kW, >$50M) designed to explore the feasibility of millimeter-wave very long baseline interferometry (VLBI) from space. T-REX will operate at 86 GHz and seeks to achieve a temporal resolution of 22.5 minutes, enabling minute-scale sampling of the light curves of Sgr A* and M87. By co-observing with ground radio telescopes, T-REX also seeks to time-resolve the accretion flow of Sgr A*, which varies on the timescale of minutes. By advancing the technology readiness of mm-wave receivers and compact antenna systems, T-REX will serve as a pathfinder for future space VLBI missions. We invite collaborators, particularly researchers with VLBI/radio instrumentation experience, to contribute to the maturation of this concept.

Abstract number: **99**
Author: Michael Johnson
Title: **Space-VLBI Frontier Observatory**

Abstract:
The Space-VLBI Frontier Observatory (SFO) is a mission concept for a space-enabled millimeter/submillimeter very-long-baseline interferometry (VLBI) observatory that would open the microarcsecond radio sky. By deploying three or more cryogenic antennas in high-Earth to cislunar orbits and combining them with the world's most sensitive ground facilities, SFO would extend VLBI baselines far beyond Earth's diameter and access observing bands that are inaccessible to ground arrays. SFO would be a community observatory for precision studies of supermassive black holes, magnetized accretion flows, relativistic jet launching and feedback, supermassive black-hole binaries, and explosive transients. The Event Horizon Telescope demonstrated the power of horizon-scale imaging with the first images of M87* and Sgr A* at 230 GHz. However, current Earth-sized VLBI arrays can resolve these two black hole targets and cannot yet deliver precision measurements of their black hole spacetime parameters. Astro2020 identified high-angular-resolution radio/millimeter imaging, polarimetry, sensitivity, and time-domain observations as key capabilities needed to understand jet launching, acceleration, and the coupling between black-hole growth and galaxy evolution. SFO directly addresses these gaps by combining longer baselines, higher frequencies, improved sensitivity, polarization, and repeated multi-epoch observations. Combined, these would allow studies of hundreds to thousands of new targets. This talk will present the motivation for SFO as an ASTRA study, building on a series of space-VLBI pathfinder studies over the past decade. The proposed ASTRA study would address four central design questions: how much collecting area is required; where the antennas should be placed; what frequency range should be supported; and what balance of onboard recording, processing, optical communications, and ground-based correlation best enables the science.

Abstract number: **100**
Author: Christopher K Walker
Title: **SALTUS: Single Aperture Large Telescope for Universe Studies**

Abstract:
SALTUS (Single Aperture Large Telescope for Universe Studies) is a ~40-meter, 10 K space observatory for exoplanet biosignature detection. It utilizes a gold-coated inflatable primary corrected by a custom Offner relay and deformable mirror, achieving ~2 ppm photometric sensitivity across 1–25 μm — the only mission concept capable of detecting the full biosignature disequilibrium ensemble in single-transit observations of nearby M-dwarf habitable-zone planets. The ~40 meter aperture size emerges from a specific crossing point where photon noise falls below the stellar contamination floor for the quietest M-dwarf targets. Projected SALTUS performance been recently validated through metrology of a scaled aperture in TVAC together with subsequent optical design/analysis. Beyond our own solar system, the best chance for finding evidence of life elsewhere will be in the search for unambiguous chemical biosignatures in the atmospheres of a statistically significant number of exoplanets. This will require simultaneously identifying a thermodynamic disequilibrium ensemble of gases — O_2, O_3, CH_4, N_2O, and H_2O coexisting at abundances that cannot be sustained without continuous biological replenishment. The large SALTUS aperture reduces required transit stacks from 50–100 (JWST) to ~1-3, bringing the full biosignature ensemble within reach of a 5–10 year mission program to survey nearby M-dwarf habitable-zone planets. No current or approved mission accesses this full spectral range from space with sufficient sensitivity. The f#2 telescope consists of two independent spacecraft; the PSC which carries only the inflatable primary and the ISC which carries all precision optics and cryogenic instruments. The separation between the two is maintained using proven laser metrology and ion propulsion techniques. The ISC contains a dual-arm high resolution cross correlation spectrograph (HRCCS;1–5 μm NIR; 5–25 μm mid-IR) to differentiate between planetary and stellar spectra, plus a stellar activity monitor, all cooled to 7–40 K.

Abstract number: **102**
Author: Eiichi Egami
Title: **Mid-Infrared Wide-Field Surveyor: Toward the Next Redshift Frontier**

Abstract:
To probe galaxies at z>13, we need a Roman-like survey telescope but covering >2 μm. Here, we present a concept for such a mission, Mid-Infrared Wide-Field Surveyor. In addition to the wide-field imaging capability at 2-5 μm, it will also have a grism-based wide-field slitless spectroscopy (WFSS) mode at 2-5 μm (R~1000), which has proven to be extremely powerful with JWST as the success of large NIRCam WFSS programs clearly demonstrates (e.g., ASPIRE, EIGER, FRESCO, MAGNIF, COSMO-3D, SAPPHIRES). By ensuring overlapping coverages with Roman, the proposed mission will produce a massive legacy data with wide-field imaging and spectroscopy covering 1-5 μm continuously, which will enable a variety of scientific programs not limited to high-redshift sciences (e.g., a Galactic-plane survey, brown dwarfs).

Abstract number: **103**
Author: Daniel Apai
Title: **Nautilus Space Observatory: Flagship Science with a Scalable, Modular, Rapidly Deployable Architecture**

Abstract:
The Nautilus Space Observatory is a constellation-based observatory optimized for sensitive near-UV to near-infrared spectroscopic and imaging surveys. It will provide transformative statistical datasets on exoplanets, the Solar System, the Milky Way Galaxy, and the high redshift Universe. Nautilus is a non-conventional architecture that provides a scalable, modular, long-lived observatory composed of high-quality but simple and lower-cost 4m space telescopes. Nautilus will enable cross-cutting science and address the following questions – and beyond: 1) What Processes Shape the Small Exoplanet Population? 2) What is the nature of stellar activity and how does it impact planetary habitability? 3) How did the Universe expand? What is dark energy? 4) What are the nature of explosive stars and black holes? At the Probe class, Nautilus Space Observatory would consist of four identical 4m-diameter Nautilus Quattro Telescopes (NQT) paired with one of two instruments: the Near-Infrared Nautilus Quattro Imager (NQI-NIR) or the Quattro SWIR Spectrograph (NQS-SWIR). Small Flagship and Flagship-class realization would allow larger telescopes (D~8m) and cryogenically cooled imagers working up to 2.9μm and a higher-resolution SWIR spectrograph. These units would be more capable but not require new technology beyond that developed for the initial units. The Nautilus architecture is conducive to novel funding mechanisms including public-private partnerships. Nautilus ensures rapid science return (<6 years from project start), with precisely controlled costs and distributed risks while providing Flagship-class science return. In short, Nautilus provides a modern, innovative approach to ensure a bright, sustainable future for NUV/VIS/NIR astrophysics – from cosmology through time-domain astrophysics to exoplanets and planetary science.

Abstract number: **104**
Author: Kristin Madsen
Title: **Next Generation X-ray Optics**

Abstract:
The Next Generation X-ray Optics (NGXO) team is working hard to develop and mature an X-ray mirror technology that is capable of building a mirror assembly for an X-ray flagship. The NGXO team combines the stress-free nature of single crystal silicon with advanced polishing techniques to make mirror segments that are of figure quality comparable to or better than Chandra mirror shells, but are ten times thinner and therefore lighter. The NGXO work encompasses all elements that make a complete process to design, build, test, and deliver a complete mirror assembly, including optical design, mirror segment fabrication, coating, alignment and bonding to make mirror modules. In addition, the NGXO team also investigates the latest mass-production techniques to ensure that building such a mirror assembly can also meet the programmatic requirements of future missions.

Abstract number: **105**
Author: Johannes Hubmayr
Title: **Superconducting Focal Plane Technology for a CMB Probe of Inflation**

Abstract:
Measurements of the cosmic microwave background (CMB) support rich and compelling science cases, from constraining the physical processes near the big bang to time domain astrophysics. This science is accessible via the analysis of high sensitivity millimeter-wave maps with coarse spectral resolution (broad bands observing between 20-800 GHz). A CMB Probe is an ideal platform for these observations. Here we present the detector and readout requirements that would enable a CMB Probe and show a set of technologies that either meet these needs today or can be quickly matured to readiness. We discuss arrays of transition edge sensor bolometers with multiplexed SQUID readout, microwave kinetic inductance detectors, as well as coherent detectors utilizing near-quantum limited amplifiers. We highlight advances since Astro2020 and point out opportunities for technology advancements, which would enhance the science return of a CMB Probe.

Abstract number: **106**
Author: Tom Shutt
Title: **GammaTPC: a transformative 0.1 MeV - 10 GeV gamma ray instrument concept**

Abstract:
I will talk about GammaTPC, a new MeV-GeV gamma-ray instrument based on liquid argon time projection chamber (TPC) technology. This technology has achieved five order of magnitude increase in sensitivity for dark matter searches in just under two decades, largely due its ability to economically achieve fine-grained position readout of a large detector mass. Those attributes are highly advantageous for measuring gamma rays. Core to GammaTPC is GAMPix, a new fine grained charge readout architecture that achieves low noise readout at very low power. Operation in space will also require maintaining a single phase if sub-cooled liquid argon. Such an instrument appears ideally suited to take advantage of current large mass launch capabilities.

Abstract number: **108**
Author: Peter Shirron
Title: **Continuous Adiabatic Demagnetization Refrigerator Systems for Future CMB Missions**

Abstract:
Future Cosmic Microwave Background and other Probe missions will likely use detectors cooled to deep subkelvin temperatures. The basis for cooling the instruments is the use of space-qualified cryocoolers operating at approximately 4.5 K. A common set of requirements emerging from mission studies is the need for additional lower temperatures for cooling optics and detectors/focal planes, in the range of 0.3-1.0 K and 0.04-0.12 K, respectively. At NASA/GSFC, we have developed an architecture for Continuous Adiabatic Demagnetization Refrigerators (CADRs) that can produce continuous cooling at these temperatures, and have demonstrated continuous cooling at temperatures as low as 35 mK and at an intermediate temperature of 1 K. The cooling powers achieved exceed the fully (100%) margined loads for candidate CMB probes. The talk will describe the range of cooling capabilities available and options for expansion as additional requirements are identified.

Abstract number: **110**
Author: Weibo Chen
Title: **Low-Temperature Cryocooler Status Review**

Abstract:
Since the Astrophysics Decadal Survey 2020, significant progress has been made in the development of low-temperature cryocoolers to support advanced astronomical detectors. This paper reviews the design, testing, and current TRL of 4.5 K cryocoolers specifically developed for the PRIMA and New Athena missions. It explores the transition toward higher-efficiency cooling cycles and the mitigation of parasitic heat loads in complex system integrations. Additionally, the review catalogues the progress of low-temperature cooling technologies developed by international partners (non-US), providing a global baseline of available cooling capacities. This technical synthesis serves as a foundation for the Astrophysics Decadal Survey 2030, outlining the capabilities and limitations of current cryocooler technology in meeting future mission specifications.

Abstract number: **111**
Author: Brendan Crill
Title: **Telescope Architectures for a CMB Probe+**

Abstract:
Future Cosmic Microwave Background and other Probe missions will likely use detectors cooled to deep subkelvin temperatures. The basis for cooling the instruments is the use of space-qualified cryocoolers operating at approximately 4.5 K. A common set of requirements emerging from mission studies is the need for additional lower temperatures for cooling optics and detectors/focal planes, in the range of 0.3-1.0 K and 0.04-0.12 K, respectively. At NASA/GSFC, we have developed an architecture for Continuous Adiabatic Demagnetization Refrigerators (CADRs) that can produce continuous cooling at these temperatures, and have demonstrated continuous cooling at temperatures as low as 35 mK and at an intermediate temperature of 1 K. The cooling powers achieved exceed the fully (100%) margined loads for candidate CMB probes. The talk will describe the range of cooling capabilities available and options for expansion as additional requirements are identified.

Abstract number: **112**
Author: Johannes G Staguhn
Title: **Detector Technologies and Performance Requirements for Future Mid-Infrared Space Missions**

Abstract:
As demonstrated by JWST, the mid-infrared (mid-IR) spectral region provides access to a broad range of astrophysical and exoplanetary science objectives and is highly relevant for future space missions. High-angular-resolution observations from future space-based interferometric facilities will enable the detection of potential biosignatures in the atmospheres of rocky exoplanets in the habitable zones of stars across a wide range of spectral types. In addition, such facilities will support high-spectral-resolution studies of protoplanetary disks, high-resolution imaging of active galactic nuclei (AGN) and their host galaxies, and mid-IR power-spectrum measurements capable of probing baryonic acoustic oscillations on small angular scales, among other applications. The detector performance requirements for future mid-IR missions are highly demanding and are not necessarily met by currently deployed detector technologies. In particular, doped-silicon detectors used in this wavelength regime are significantly limited in performance and may not even be available for future missions. Consequently, a range of competing technologies—including superconducting sub-Kelvin detectors and long-wavelength HgCdTe detectors—must be evaluated for use in next-generation instruments. I will discuss these detector technologies, as well as the associated observatory infrastructure requirements, which depend on the scientific objectives.

Abstract number: **113**
Author: Michael Hoenk
Title: **Delta-doped sensors for X-ray to ultraviolet imaging and spectroscopy**

Abstract:
NASA's goals in precision astrometry and time domain astrophysics require stable, precisely calibrated sensors, and yet UV and X-ray CCDs and CMOS image sensors are susceptible to damage and instabilities caused by the very photons they're supposed to detect. UV astronomers have been advocating an expansion of the spectral range of the Habitable Worlds Observatory into the far and extreme UV range, where the rates and severity of UV-induced surface damage are severe. Additionally, there are x ray Probe mission concepts are currently in the competition for step 1. Depending on the outcome of the competition, development of x ray detectors will remain critical in the near to mid future. We've previously reported that delta-doped detectors are uniquely hardened against the effects of this type of radiation-induced surface damage. In this paper, we will explore the physics and performance of delta-doped detectors based on new data, and we will report our progress on developing and deploying large format delta-doped CCDs and CMOS image sensors for NASA missions.

Abstract number: **114**
Author: Peter Cheimets
Title: **Novel scaleable high resolution X-ray mirror system**

Abstract:
We describe a new X-ray mirror initiative led by SAO. The mirror system is developed from the start to use existing optical fabrication technology and proven mounting and alignment techniques, scaled to the requirements of the currently conceivable X-ray missions. Every step of the development effort leverages increased substrate thickness, enabled by lower launch costs and greater lift capability, to achieve high imaging resolution, reduce fabrication cost and schedule, and simplify the processes of coating, mounting and alignment. In addition, the baseline approach places the primary and the secondary on a single substrate, thus offloading the most critical and challenging part of the alignment to the high precision grinding and polishing machines. The mirrors are < 30o segments of a complete shell and are mounted and aligned in modules that each hold 10 substrates. Each substrate is a combination of a single primary and a secondary. The mirror mounting system is based on a TRL-6 system developed and tested for Arcus. As the substrate stiffness increases as a cube of the mirror thickness (baselined at 3 mm compared to 0.5 mm baselined for the proposed Lynx mirrors), many aspects of the fabrication, metrology, coating, and alignment of the optics are simplified. The materials (mirrors and structure) are selected to have near zero coefficient of thermal expansion (CTE), greatly reducing the thermal control requirements on every phase of the mirror system, from fabrication through operation. Both the primary and the secondary mirror segments are 200 mm long (in the photon travel direction) and range from 100 mm to 200 mm wide depending on the shell position. Preliminary test mirror surfaces are based on Wolter I designs; however, we are examining Wolter-Schwarzschild and polynomial-based designs as well. The overall system design is compatible with arbitrary grazing-incidence surface shapes.

Abstract number: **115**
Author: Drew Miles
Title: **Developments in X-ray reflection gratings**

Abstract:
"High-efficiency X-ray grating arrays for high-resolution spectroscopy" are a Tier 1 NASA Astrophysics Strategic Technology Gap. Here we provide an overview of an active development program to manufacture arrays of aligned X-ray reflection gratings to address this technology gap and help enable the next generation of high-performance X-ray spectroscopy. This effort includes the nanofabrication of X-ray grating masters, high-volume replication of grating masters to produce identical grating copies, and the processing and alignment of replica gratings into stacked modules that comprise co-aligned arrays. We discuss the latest developments in each of these manufacturing efforts, and provide an overview for future work.

Abstract number: **116**
Author: Kathryn Plant
Title: **The Digital Signal Processing Trade Space for Space-based Radio Telescopes**

Abstract:
Modern radio telescopes directly sample the electric fields of light propagating from celestial sources, and this sampling must be faster than the frequency of the electromagnetic waves themselves. The resulting large (e.g. Tb/s) data rates that terrestrial radio telescopes enjoy highlight a design challenge for space-based missions, where data rate and volume constraints (in addition to size, weight, and power) necessitate careful choices among tradeoffs in the digital signal processing (DSP) subsystem. I will review the DSP trade space that future space-based radio astrophysics missions must navigate. Key design decisions include correlator architecture, spectral response and resolution, time resolution, bandwidth, and bit depths. I will also highlight how choices in this trade space couple to top-level mission requirements such as the number of antennas in an array and the knowledge and control of those antennas' positions.

Abstract number: **117**
Author: Alessandra Buonanno
Title: **Beyond LISA: A Space-Based Gravitational-Wave Program for the micro-Hz to deci-Hz Frontier**

Abstract:
Gravitational-wave (GW) astronomy has transformed our view of the Universe, yet existing and planned detectors cover only a fraction of the GW spectrum: ground-based detectors probe ~1–1000 Hz, pulsar timing arrays the nano-Hz band, and LISA will open the milli-Hz band in the late 2030s. The richest discovery space for the birth and growth of cosmic structure lies across the still-unobserved micro-Hz, milli-Hz, and deci-Hz bands. The Gravitational-Wave Space 2050 (GW-Space 2050) Working Group has developed the science cases and assessed the technological feasibility of three candidate space-based GW missions — one in each band — built on a common beyond-LISA laser-interferometric payload. Those missions would trace the assembly of the first massive black holes (MBHs) and their seeds from $z \sim 20$, distinguishing light- from heavy-seed formation and explaining the quasars seen at $z \geq 7$; characterize intermediate-mass black holes and stellar-origin compact binaries across cosmic time; enable multi-messenger studies of accreting MBHs, tidal disruptions, and quasi-periodic eruptors; detect or constrain primordial stochastic backgrounds from inflation, phase transitions, and cosmic strings; measure the cosmic expansion at $z > 8$ to address the Hubble tension; and test general relativity while probing dark matter. We summarize the science objectives, the required micro-Hz/milli-Hz/deci-Hz sensitivities, and the enabling technology and implementation roadmap. Organized worldwide to provide quantitative scientific and technological input to ESA's upcoming Expert Committee for the third Large-mission theme of Voyage 2050 and NASA's ASTRA program, GW-Space 2050 is positioned to advance these open questions.

Abstract number: **118**
Author: Drew Miles
Title: **Developments in blazed UV diffraction gratings**

Abstract:
Planned and future ultraviolet (UV) astrophysics missions require advances in spectroscopic capabilities, a need highlighted by a Tier 1 NASA Astrophysics Strategic Technology Gap for high-performance UV diffraction gratings. Active research programs seek to address this technology gap with the development of next-generation UV diffraction gratings with electron-beam lithography (EBL) and complementary nanofabrication techniques. The first UV EBL gratings have shown improved diffraction efficiency and scatter performance relative to the previous state of the art and have helped enable new, aberration-correcting grating designs for a variety of UV instrument applications. Here we provide an overview of recent UV results from EBL gratings and outline the development plans for the coming years to demonstrate applicability to future missions such as the Habitable Worlds Observatory, Ardua, and other probe- and explorer-class missions.

Abstract number: **119**
Author: Ruby Byrne
Title: **Capabilities Needed for the Next Generation of 21 cm Cosmology Measurements**

Abstract:
Measurement of 21 cm line emission from neutral hydrogen represents a promising probe of the universe's large-scale structure across cosmic time. At high redshift, the 21 cm signal is the only direct observable of the Dark Ages, where it serves as a cosmic thermometer: unexpected energy injection will cause distinct deviations from ΛCDM predictions, enabling tests of fundamental physics, from decaying or annihilating dark matter, baryon-dark matter interactions, primordial magnetic fields, accretion or other exotic physics. We discuss capabilities needed to overcome the challenges of these measurements, providing a pathway to next-generation, space-based 21 cm experiments. Due to the ionospheric cutoff below ~15 MHz, high redshift 21 cm observations require space-based radio observatories. The measured signal combines several quantities: the 21 cm signal itself, intervening foreground emission, contaminating radio-frequency interference (RFI), and the inherent instrument response. Proper recovery of the cosmological signal requires careful instrument design, high-fidelity characterization of the astrophysical foregrounds, and novel statistical techniques for calibration and data analysis. We discuss recent progress and next steps towards achieving precise, contamination-free measurements of the 21 cm signal from the Dark Ages, drawing upon experience with ground-based Cosmic Dawn and Epoch of Reionization experiments.

Abstract number: **120**
Author: Daniel Jacobs
Title: **Roadmap to readiness of space-based Dark Ages 21cm receivers**

Abstract:
A primary science goal of a space-based low frequency radio telescope is measuring the high-redshift (z>50) 21cm signal from the dark ages, a spectral feature centered near 18 MHz. Its spectral shape probes fundamental physics in the early universe—after recombination and before the first stars—using the universe as a sensitive calorimeter to constrain physics beyond the standard model. The brightest signal is the global mean 21cm absorption. Spatial fluctuations are smaller but carry additional information. The driving requirement for the global signal is flux accuracy across roughly 1–40 MHz. The mean sky spectrum here has a brightness temperature of 10,000 K from Galactic foreground emission, and must be measured to within 10 mK (one part per million). Previous space-based instruments achieved only 20% accuracy, so a five-order-of-magnitude improvement is needed. Performance approaching the PPM level has, however, been demonstrated for ground-based instruments—including EDGES and SARAS—targeting the global 21cm signal from cosmic dawn and reionization (50–200 MHz). Calibration error arises from uncontrolled variations in instrument bandpass and antenna beam, which couple bright sky foregrounds into the spectral measurement. Antenna pattern stability is driven by deployment errors, vibrations, thermal variations, and other environmental effects—well-studied for ground-based experiments, less so for space missions. Ground-based work shows that receiver design can absorb much of the error budget, using internal first-principle calibration references, low-noise power supplies, tuned RF design, and in-situ antenna impedance characterization. The EDGES receiver has recently been miniaturized for space use. Some components have flown on a cubesat, and a full prototype is ready for further testing. Finally, sky measurements that significantly improve on historical data are needed to reduce uncertainty in instrument and beam modeling, informing performance forecasts for future missions.

Abstract number: **121**
Author: Sven Herrmann
Title: **Fast, low noise SiSeRO detectors for NUV-VIS-NIR and X-ray applications**

Abstract:
Future flagship space observatories at near-UV/visible/near-IR and X-ray wavelengths, including the Habitable Worlds Observatory, will require extremely low-noise, high-speed, megapixel imagers with single-electron sensitivity to address their science goals, as defined by the Astro2020 Decadal Survey. The Single-Electron-Sensitive-ReadOut (SiSeRO) CCD technology, developed at MIT Lincoln Laboratory (MIT-LL), in collaboration with Stanford University and the MIT Kavli Institute for Astrophysics and Space Research (MKI), is designed to address this gap. Leveraging mature process technology, SiSeROs utilize a p-type metal oxide semiconductor field effect transistor (p-MOSFET) with an underlying internal gate to measure charge with higher sensitivity and lower noise than traditional CCD output stages (Chattopadhyay et al. 2022, 2023, 2024). A key feature of the design is that it preserves the original charge packet during measurement, enabling repetitive non-destructive readout (RNDR). First generation 512x512 pixel SiSeRO CCD devices employing just a single readout node have demonstrated substantially subelectron noise performance (<0.5e- RMS) at 10 kpix/s serial readout speeds, an order of magnitude faster than earlier “skipper” technology. Critically, the reduction in read noise over RNDR cycles has also been shown to follow a simple Poisson distribution, reducing as the square root of the number of cycles, out to the limits of first generation tests (200 RNDR cycles), opening a realistic path towards the development of extremely low read noise (≪ 0.1e- RMS) devices (Pan et al. 2026). This performance is supported by SiSeRO-optimized readout ASICs also developed by our team (Herrmann et al. 2020, 2022, 2025; Orel et al. 2022, 2024; Chattopadhyay et al. 2025). For applications requiring low noise but faster speeds than are achievable with SiSeRO CCDs, SiSeRO active pixel sensor (APS) devices offer a candidate technology, with the first proof-of-principle matrices currently undergoing commissioning and initial tests. We will review the current status of these developments.

Abstract number: **122**
Author: Mary Knapp
Title: **Electromagnetic vector sensors: better antennas for space-based low frequency radio interferometry**

Abstract:
Electromagnetic vector sensors are composed of mutually orthogonal electrically small dipole and loop antenna triads (6 antennas total), typically with a common phase center. While vector sensors can be designed for a range of frequencies, we focus on HF (3-30 MHz) and lower frequencies. These sensors have multiple advantages compared to dipoles or tripoles alone. They can provide an omni-directional beam pattern with no nulls or they can perform coarse beamforming for forward gain and selective nulling of RFI sources. An interferometer composed of vector sensors, with 6 channels per sensor instead of 2 or 3, produces 4x the information of an array composed of the same number of tripoles (Kononov & Knapp 2025), leading to faster sky mapping with fewer sensors. Finally, the addition of loop antennas to dipoles may provide an advantage in mitigating quasi-thermal noise when compared to dipoles/tripoles alone. We present simulation results demonstrating the above advantages as well as a deployable design that packs into a ~1U (10 x 10 x 10 cm) volume; through the use of a mode former, the same conductors can be used for both loop and dipole modes. Vector sensor technology is relevant to the goals of the MegaWave Radio Surveyor concept.

Abstract number: **123**
Author: John ZuHone
Title: **From Simulations to Observations: the Necessity of End-to-End Simulations for Linking Science Objectives to Mission Requirements**

Abstract:
As the quality of the technology of astronomical observations has continued to improve, probing deeper into the Universe with higher angular, spectral, and time resolution, at the same time theoretical predictions have also become more detailed. In particular, numerical simulations have achieved higher spatial and time resolutions, as well as including more relevant physical processes and exploring wider parameter spaces. Discerning the precise observational predictions that will be made from these simulations is challenging, not least because the simulations operate in three dimensions with local thermodynamic, kinematic, and chemical quantities, whereas (most) observations operate with derived electromagnetic spectrum-based quantities projected onto the sky. Making the best possible comparison between the theoretical simulation domain and the corresponding observational predictions increasingly requires the development of "end-to-end" simulations where one starts with the three-dimensional properties of the system, and processes these through emission and absorption models in combination with models for the instrumental responses. In this talk, I will argue for the importance of integrating such end-to-end simulations deeply into the process of designing new missions, highlighting recent examples from proposed X-ray missions that I have been involved in. I will show detailed examples of the design choices that needed to be made at every step, as well as the trade-offs that need to be considered.

Abstract number: **124**
Author: Dhruva Ganapathy
Title: **Gravitational-wave astronomy with a space-based optical clock network**

Abstract:
Gravitational-wave astronomy has become an indispensable astrophysical tool since the landmark detection of a binary black hole merger in 2015. While ground-based detectors are fundamentally limited by terrestrial noise, upcoming space-based missions like the Laser Interferometer Space Antenna (LISA) will soon open the entirely new millihertz (mHz) observation band. Concurrently, atomic sensors such as atom interferometers and optical clocks, bring unique, complementary strengths to traditional interferometry. Thanks to their highly adaptable architectures, these sensors can achieve exceptional sensitivity across a wide frequency range, spanning from the mHz regime up into the Hz band. In this work, we explore the potential of space-based atomic clock networks utilizing one-way Doppler tracking to operate in tandem with LISA-like observatories. We design specialized measurement schemes, rigorously assess the primary noise contributions, and execute preliminary parameter estimations on simulated gravitational-wave events. Ultimately, our findings highlight how these observational strategies can successfully extract vital astrophysical data from binary systems.
This work was supported by a Packard Fellowship for Science and Engineering, the Sloan Foundation, the Simons Foundation, the Templeton Foundation, the Gordon and Betty Moore Foundation under Grant No. DOI 10.37807/gbmf12966, NASA under Grant No. 80NSSC24K1561, and the National Science Foundation under Grants No. 2143870 and No. 2326810 and PHY-2020275 [Network for Neutrinos, Nuclear Astrophysics, and Symmetries (N3AS)].

Abstract number: **132**
Author: Hans Moritz Günther
Title: **X-ray grating spectroscopy as a mission enhancement**

Abstract:
We present a concept to enhance an X-ray observatory chosen in the ASTRA process with a high-resolution (R> 3000) soft X-ray (0.2-3 keV) grating spectrometer, plus optional UV imaging and/or UV spectroscopy. Instead of flying a stand-alone mission, gratings can be added to imaging, timing, polarimetry, or low-res spectroscopy missions, substantially expanding science return for a comparatively small increase in cost and complexity. The core instrument uses critical-angle transmission (CAT) gratings in a Rowland-torus geometry. Gratings are placed behind the telescope mirrors and disperse soft X-rays onto a dedicated detector strip offset from the prime focal plane. The grating assembly can be deployable or permanently inserted; in the latter case, high-energy photons can still reach the main instrument because transmission gratings are largely transparent at harder energies. CAT gratings available today reach 20-40% efficiency with R > 10000, so spectrometer resolution is limited only by the optics of the host mission. Either commercial CCD or CMOS detectors match the requirements for the grating detectors. Our ray-tracing shows that R>3000 can be achieved with from sub-arsec to Athena-like optics, using sub-aperturing (covering only a fraction of the mirror area with gratings). The technology is already mature: Commercial CCDs are available and grating fabrication uses established semiconductor/MEMS processes. Gratings developed for Arcus have reached TRL 5/6. Additional developments (bar coatings, bent gratings, chirped periods) could further improve efficiency and reduce system cost. Mission implementation follows Chandra and XMM-Newton heritage: Some fraction of the available observing time is used for grating spectroscopy. The add-on instruments have modest resource needs (e.g. pointing stability better than ~1.5 arcsec/s, data rate ~600 kb/s, power <200 W, mass <200 kg for the grating spectrometer). UV options span a lightweight imager to a larger spectrograph. Estimated incremental cost is roughly $100-200M.

Abstract number: **135**
Author: Stuart B Shaklan
Title: **Starshade: A Broad-Band, High-Throughput Architecture for ExoEarth Discovery and Characterization**

Abstract:
Characterizing Earth-like exoplanets demands broadband spectroscopy spanning ultraviolet (UV), visible, and near-infrared (near-IR) wavelengths to comprehensively characterize their atmospheres. Combining these spectral ranges is key to sorting Earth-like planets from the cosmic crowd. Consider a planet showing water vapor in the visible, CO_2 and CH_4 in the near-IR, and ozone in the UV, with water clouds reflecting across the spectrum. This paints a compelling picture: a rocky world with oceans, geological activity, and possibly life—akin to Earth. Contrast that with a planet rich in water vapor but lacking CO_2 and showing hydrogenated molecules (e.g., in the near-IR): likely a variety of sub-Neptune with no solid surface. Or take a CO_2-heavy atmosphere with little water and no ozone: a Venus analog, rocky but hostile. These distinctions hinge on broadband data—single-range observations risk misclassification, especially as exoplanet diversity challenges our assumptions. A starshade is a spacecraft with a carefully shaped screen flown in formation with a telescope. The starshade size and shape and the starshade-telescope separation are designed so that the starshade casts a very dark and highly controlled shadow, suppressing the light from the star while leaving the planet's reflected light unaffected. By removing the starlight before it is contaminated by the telescope optics, starshades achieve deep contrast, large bandwidth, high throughput, and small working angle. They work exceptionally well in the UV and can tune the bandpass by adjusting the telescope-starshade separation. This performance is achieved with standard machining and standard thermal design. In this paper we show a range of starshade-based missions. The starshades discussed here range in size from 16 to 99 m in diameter, they work with telescope from 1 m to 39 m on the ground or in space, and with single or multiple telescopes such as the Nautilus constellation.

Abstract number: **141**
Author: Jacob Slutsky
Title: **The Decihertz Interferometer Space Antenna**

Abstract:
The origins and fate of massive compact objects such as black holes, neutron stars, and white dwarfs can only be fully answered by measuring deci-Hertz (dHz) gravitational wave emission. A plethora of innovative mission concepts have been proposed motivated by this need, promising incredible potential sensitivity and development cost. Like COBE rather than Plank, we prioritize time to first knowledge over ultimate sensitivity. We describe the highest priority science goals contained in and motivating a dHz observatory, the minimum sensitivity required to make these observations, and the fastest, least-costly mission that meets these minimum requirements. We dub this mission the Deci-hertz Interferometer Space Antenna (DISA).

Abstract number: **142**
Author: Kenneth G Carpenter
Title: **The Artemis-enabled Stellar Imager (AeSI)**

Abstract:
The Artemis-enabled Stellar Imager (AeSI) mission concept is a lunar-based, long-baseline (1 km+) UV/Optical Interferometer (UVOI) with over 200x the resolution of HST. It is implemented as a lunar-surface-based observatory that can be efficiently deployed, operated and maintained in collaboration with the human Artemis Program. AeSI will enable 0.1 milli-arcsec (@2000 Å) spectral imaging of stellar surfaces and the Universe in general and open an enormous new "discovery space" for Astrophysics with its combination of high angular resolution, dynamic imaging, and spectral energy resolution. AeSI's science goal is to study the role of magnetism in the Universe and revolutionize our understanding of: • Solar/stellar dynamos and magnetic activity and their roles in the formation and evolution of stars and in the habitability of planets • Mass transport processes and their roles in the formation, structure, and evolution of stars and stellar systems • Active Galactic Nuclei (AGN), Black Hole environments, and accretion flows and jets At this resolution, sequences of images will reveal the dynamics of astrophysical processes and allow us to directly see, for the first time, the evolution of active-region-scale magnetic fields of Sun-like stars, planetary nebulae, early supernovae phases, mass exchange in binaries, (proto-) stellar jets, and accretion systems. The UV capability of AeSI allows imaging of high temperature plasmas not visible from the ground. The primary science driver of this mission is to accelerate the development and validation of a predictive dynamo model for the Sun and other magnetically active stars. This will improve our understanding of the origins of variability in the Sun-Earth system and provide the foundation for more accurate long-term forecasting of solar/stellar magnetic activity and its impact on space weather, planetary climates, and life.

Abstract number: **147**
Author: David Leibrandt
Title: **CHRONOS: Chronometric High-precision Relativistic Observatory of Networked Optical-clocks in Space**

Abstract:
CHRONOS is a quantum-clock telescope to detect gravitational waves in the unexplored mid-frequency regime (deci-Hz, 0.1 – 10 Hz). Mid-frequency gravitational waves are emitted by merging compact-object binaries, that include pairs of black holes, white dwarfs, and neutron stars in the months leading up to their merger and subsequent explosion. Observing them will provide an early warning for explosive transients such as kilonovas and gamma-ray bursts. Knowing where they will happen in advance, we can watch them from beginning to end. This brings to fruition the full potential of multi-messenger astronomy. This science was included within one of the Astro2020 decadal survey highest priority areas. Studying neutron star mergers addresses NASA's Cosmic Origins theme because these events are key sites of heavy element formation. By enabling precise localization of compact object mergers, CHRONOS will dramatically enhance the probability of detecting kilonovas and allow deeper insight into the astrophysical processes driving heavy element formation. This mission concept addresses key science themes of Physics of the Cosmos. Beyond kilonova progenitors, the mid-frequency band is predicted to be populated by compact binaries across the mass spectrum—including intermediate-mass black holes and white dwarf binaries—making it rich for astrophysical discovery. Additional objectives include placing limits on ultralight dark matter, predicting white dwarf mergers, for Type 1a SNe cosmology and testing general relativity with high precision. CHRONOS will measure minuscule changes in time, as measured by frequency shifts between two widely separated, spaceborne clocks. Recent advances in optical atomic clocks establish a plausible implementation path. There is potential for broad advocacy of this mission within NASA and the federal government because this technology is essential for US competitiveness and national security.

Abstract number: **152**
Author: Andreas Zoglauer
Title: **Closing the MeV Gap with ARCTIS and Hybrid Germanium Pixel Detectors**

Abstract:
The MeV gamma-ray band (0.2–10 MeV) remains the least-explored window in astrophysics due to a sensitivity gap of two to three orders of magnitude between hard X-ray and GeV instruments. Closing it requires a Compton telescope that simultaneously achieves germanium-grade spectral resolution, close to Doppler-broadening-limited angular resolution, and Compton recoil-electron tracking. No existing or planned detector provides all three. We propose to develop the enabling technology, the Hybrid Germanium Pixel Detector (HGePD), for ARCTIS, a future all-sky MeV Compton telescope that would resolve the diffuse Galactic line emission into individual sources, constrain nucleosynthesis, positron, and r-process physics, detect the prompt MeV counterparts of multi-messenger transients, and characterize magnetar fields through high-energy polarization. A germanium crystal produces two charge signals as electrons and holes drift to opposite faces. The HGePD instruments these faces asymmetrically. A fine-pixel face (~0.2 mm pitch) collects the electron signal for position determination and recoil-electron tracking. A coarse face (~2.0 mm pitch), pixelated or strip-segmented, collects the hole signal optimized for ~3 keV per-interaction energy resolution. Limited waveform sampling adds interaction depth and flags multiple hits within a coarse element. Consequently, this dual-face geometry is expected to deliver, in one detector, the required Ge-class spectral resolution, near-Doppler angular resolution, and recoil-electron tracking. Currently, the technology is at TRL 2 to 3. Different groups have demonstrated fine-pixel germanium imagers, but the required dual-face HGePD has not yet been built. The principal challenges are the asymmetric electrode geometry on a single crystal without charge trapping, a custom 80 K low-noise readout ASIC across the ~100,000 fine-face channels, per-channel power extraction from the cold mass, Ge/Si bond survival through thermal cycling, and minimizing passive material. We are currently working on a first optimized HGePD design, with the goal of being ready for a flight proposal within a decade.

Abstract number: **155**
Author: Jake Turner
Title: **The Lunar Farside Technosignature and Transient Telescope (LFT3) Mission**

Abstract:
We present here an overview of the Lunar Farside Technosignature Transient Telescope (LFT3) mission to take advantage of the extremely clear radio frequency environment on the lunar farside. Radio observations performed from the lunar farside effectively and fully mitigate two unavoidable limitations of terrestrial-based radio telescopes: (i) the prevalence of interfering radio transmitters from human activity; and (ii) the impact of the Earth's ionosphere. However, in the era of cost-effective access to the Moon, there are many scheduled lunar missions over the next few years, and the window of opportunity to perform radio interference-free observations from the lunar farside is closing fast. LFT3 is the only mission proposed to go to the lunar farside and exploit this unique opportunity in human history. LFT3 will observe in an uncluttered radio environment to conduct unambiguous technosignature searches, transient surveys, solar physics and planetary emissions studies, spectral line observations, and cosmological science observations.

Abstract number: **162**
Author: Jack O. Burns
Title: **The FarView Low Frequency Radio Array on the Moon's Far Side**

Abstract:
FarView is a transformative low-frequency radio observatory proposed for the lunar far side, exploiting its radio-quiet environment and emerging in-situ resource utilization (ISRU) capabilities to open the last unexplored electromagnetic window: 1–50 MHz. This band is mostly inaccessible from Earth and delivers breakthrough science across cosmology, heliophysics, Galactic astronomy, and exoplanet habitability. The primary driver is the Cosmic Dark Ages, the pristine epoch between recombination and first-star formation, identified by the Astro2020 Decadal Survey as the Discovery Area for Cosmology and unreachable by any existing or planned observatory. By measuring the redshifted 21-cm signal at $z \approx 30–100$, FarView will produce 3D tomographic maps and precision power spectra of the early Universe, enabling tests of inflation, primordial non-Gaussianity, dark matter (including ultra-light axions and dark matter–baryon interactions), neutrino mass, and early dark energy. The reference architecture uses ~100,000 crossed-dipole antennas in a hierarchical, beamformed core–halo layout spanning ~200 km²: a compact ~4 km core (~83,000 dipoles) for sensitivity to large-scale modes, and a ~14 km halo (~20,000 dipoles) for angular resolution and foreground calibration. This achieves a 10σ detection of the Dark Ages power spectrum at $z \approx 30$ over five years of half-duty-cycle lunar-night operation. An FFT-based EPIC beamformer emerges as the optimal signal-processing approach, minimizing compute and data volume without sacrificing performance. Beyond cosmology, FarView will image low-frequency solar radio bursts to advance space-weather forecasting (Heliophysics Decadal, NASA Moon-to-Mars), detect stellar radio bursts and coronal mass ejections, map Galactic cosmic-ray propagation via free-free absorption tomography, and detect auroral emission from exoplanet magnetospheres as a habitability diagnostic. As lunar activity accelerates, far-side radio quiet is a finite, vulnerable resource—making early pathfinder deployment and phased construction time-critical for this flagship-class opportunity.

Abstract number: **165**
Author: Kevin Karlyle Hardegree-Ullman
Title: **Near-Infrared Transit Explorer (NITE)**

Abstract:
The Near-Infrared Transit Explorer (NITE) is a 5+ year transiting exoplanet survey mission using a 0.5-meter telescope with a near-infrared bandpass (0.9-1.8 μm) optimized to detect >100 Earth-sized planets in the habitable zones of M dwarfs. The abundance (~70%), greater planet-to-star radius ratio, higher frequency of smaller planets, and closer-in habitable zones make M dwarfs ideal targets to search for planets. However, no current or previous mission or survey has been sensitive enough or been dedicated to finding nearby transiting planets with orbital periods beyond a few days around all M dwarfs. By finding thousands of small planets orbiting M dwarfs, NITE will address several questions and discovery areas posed in Astro2020 and the NASA Exoplanet Exploration Program Science Gap List, such as: How common are habitable zone Earths ("eta-Earth")? What are the occurrence rates of Mars to Jupiter-sized planets around the most common stars in the Milky Way? Do rocky planets orbiting M dwarfs have atmospheres? We propose three different configurations at this stage: NITE-Lite to achieve the primary science goals, and NITE-Vision and NITE-Owl with added capabilities to broaden the mission's scientific impact. NITE-Lite has a 500 square degree field-of-view and will survey at least 5 separate fields for one year each during the primary mission. NITE-Vision adds a second narrow bandpass (0.7-0.9 μm) to aid planet validation, enhance studies of planets around more massive stars, probe stellar variability and activity, and mitigate saturation in the primary bandpass for the nearest targets. NITE-Owl adds a second telescope with a 2000 square degree field-of-view, but changes position every 90 days to survey the entire night sky in 5 years. This complements NITE-Lite's deeper survey and will give a complete census of nearby transiting M dwarf planets out to at least 30 day orbital periods.

Abstract number: **172**
Author: Zaven Arzoumanian
Title: **The Dynamic Extreme Universe in X-rays (DEUS-X) TDAMM Machine**

Abstract:
We present the DEUS-X mission concept, put forward for consideration as part of the ASTRA initiative. DEUS-X aims to ensure the availability, during the coming decade(s), of X-ray capabilities vital to the full fruition of the TDAMM (time-domain and multi-messenger) astrophysics enterprise, while also providing synergistic multiwavelength resources. The two major functional components of DEUS-X are: 1) an X-ray transient-search and monitoring system consisting of a small fleet of spacecraft that together provide uniform and uninterrupted coverage of the full sky outside of a ~45º Sun-avoidance cone; and 2) a suite of prompt follow-up instrumentation distributed across a separate fleet of agile spacecraft, ensuring good coverage of the sky and maximum scheduling flexibility to carry out multiple scientific investigations simultaneously. The follow-up system is envisioned to include soft- and hard-X-ray timing-spectroscopy instruments (perhaps with polarimetry in hard X-rays), an X-ray imager with improved collecting area and angular resolution over the Swift XRT, and UV+IR imagers. We describe these key elements of DEUS-X, the rationale behind the two-fleet approach, and the anticipated performance that will enable fundamental and forefront TDAMM science.

Abstract number: **178**
Author: Leo Singer
Title: **Ad Astra Per Lunam: A Flagship TDAMM Observatory on the Lunar Surface**

Abstract:
The Astro2020 Decadal Survey established Time Domain and Multi-Messenger (TDAMM) astrophysics as a defining priority. Capturing rare transients—including kilonovae, tidal disruption events, and ultra-long gamma-ray bursts—and conducting continuous microlensing surveys for exoplanets requires uninterrupted, wide-field monitoring. However, free-flying space telescopes remain severely constrained by narrow fields of view, slow slew times, and failure-prone reaction wheels. We present MITHRA, a multi-wavelength (gamma-ray, UV, IR) flagship observatory concept located in a lunar South Pole Permanently Shadowed Region. Anchored to the lunar surface, MITHRA operates as a ground-based telescope, but completely free from the blurring and absorption of an atmosphere. It exploits the Moon's perpetually dark, cryogenic, and slowly rotating environment to achieve a 100% observing duty cycle, establishing the lunar South Pole as the ideal site for a generational TDAMM observatory.

We are entering an exciting new era where human presence and permanent deep-space infrastructure will directly enable flagship science. The Artemis program provides a commercial and operational foundation that astrophysics can powerfully leverage. As a dual-use facility, MITHRA peers into the deep universe while simultaneously protecting our explorers through critical space weather monitoring and precision Space Situational Awareness (SSA). This talk presents MITHRA’s scientific capabilities alongside architectural trades, exploring how next-generation astronomy can thrive alongside a permanent Moon base.

Abstract number: **179**
Author: Dan Kocevski
Title: **The Hydra Constellation: A Proliferated Space Architecture for Time-Domain and Multi-Messenger Astrophysics**

Abstract:
Time-Domain and Multi-Messenger Astrophysics is entering a discovery-rich but follow-up-limited era, creating an urgent need for responsive, multiwavelength space-based capabilities. Hydra is a concept for a strategic distributed observatory composed of coordinated, relatively low-cost spacecraft that collectively provide capabilities traditionally concentrated within a single large mission. The architecture would combine persistent wide-field gamma-ray monitoring, wide-field and focused X-ray observations, and rapid-response ultraviolet, optical, and infrared imaging and spectroscopy. Hydra would both discover high-energy transients and respond to external alerts from gravitational-wave detectors, neutrino observatories, and ground- and space-based surveys, using low-latency communications, automated event prioritization, and community coordination frameworks to rapidly assign observing resources. A proliferated architecture would offer operational advantages over a single larger mission, including simultaneous observations of multiple targets, graceful degradation following individual spacecraft failures, recurring technology refresh, and opportunities for commercial, international, and contributed elements to join the network. The constellation would address fundamental questions concerning cosmic accelerators, the origin and evolution of the elements, the behavior of matter at extreme density, and the nature of dark energy through gravitational-wave standard sirens.