Public Outreach and Engagement: From Space Sounds to Penguins

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2025 Joint CEDAR-GEM Workshop, Monday Plenary

Thank you to **James Harold, Kristina Collins, Emmanuel Masongsong, Jasper Laca, the HARP team** and many others who contributed to this talk, as well as NASA 80NSSC21K0796 and NSF AGS-2027210/AGS-2342095 for supporting the projects mentioned in the talk

My Journey Into Public Outreach

UCLA Instagram – From “Exploring Your Universe” Event

- Lesson plans/co-teaching high school: Partnered with teachers via the NSF GK12 program
- Events at libraries, museums, and universities
- Volunteer solar telescope operator
- Participatory science (citizen science) projects
- Radio/print/podcast interviews

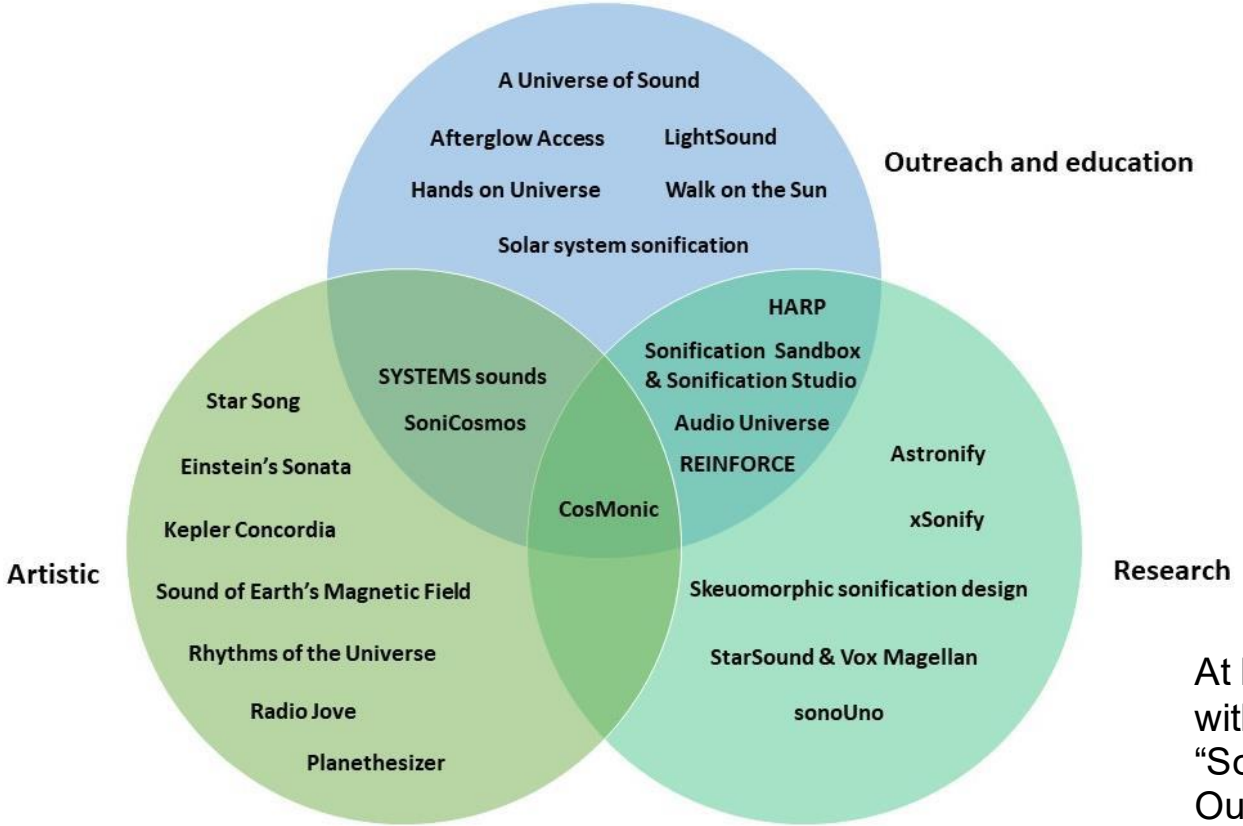
VIRGINIA Living museum

CULVER CITY HIGH SCHOOL
CULVER CITY CENTAURS

Lessons Learned

- Know your audience
- Connect the dots from science to impact on people’s lives
- Learn from other science communicators and leverage networks

Outreach and Engagement with Space Sounds



Public Outreach: Can include one-way interactions (e.g., public lectures, publishing space sounds in a press release)

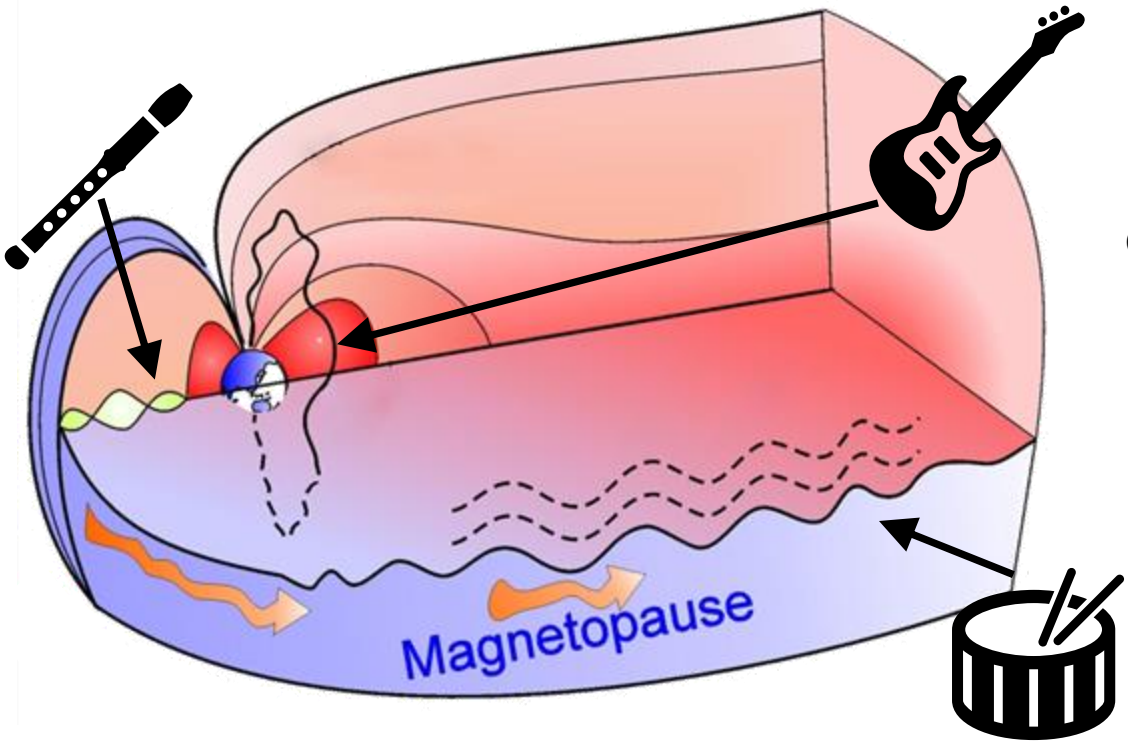
Public Engagement or Participation: Can include collaborative partnerships, two-way interactions

<u>There isn't a sharp divide between these definitions</u>

At left: UNOOSA Space for Persons with Disabilities Special Report, "Sonification: A Tool for Research, Outreach, and Inclusion in Space Sciences" Figure 1

Ultra Low Frequency waves in the Earth's magnetosphere

- "Ultra Low Frequency" plasma waves in near-Earth space form resonances like in musical instruments
- What we measure is a dynamic superposition, like a cacophony
- Possible to classify and identify different instruments, harder to classify/identify different cacophonies



Credit: Q. Zong

Outreach, Education, and Research with Space Sounds

- “Magnetospheric Undulations Sonified Incorporating Citizen Scientists (MUSICS)”: UK project led by Martin Archer
- London high school students conducted exploratory (not prescribed) projects

“It was truly amazing to hear how significant the event we found was and that it will be forming the basis of a proper scientific paper”

Space Weather

Volume 16, Issue 11
November 2018
Pages 1753-1769

Research Article | Full Access

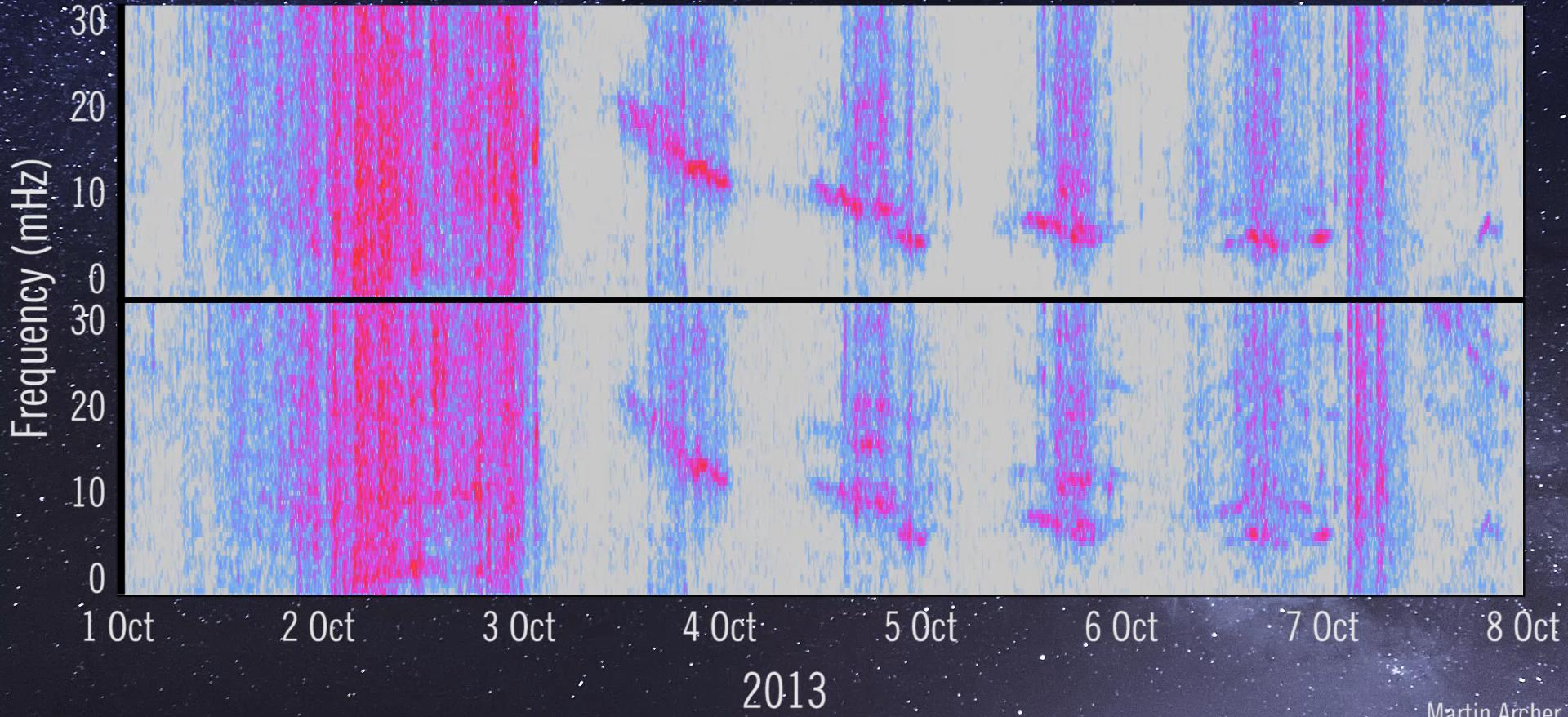
First Results From Sonification and Exploratory Citizen Science of Magnetospheric ULF Waves: Long-Lasting Decreasing-Frequency Poloidal Field Line Resonances Following Geomagnetic Storms

M. O. Archer, M. D. Hartinger, R. Redmon, V. Angelopoulos, B. M. Walsh, Eltham Hill School Year 12 Physics Students

Highlight

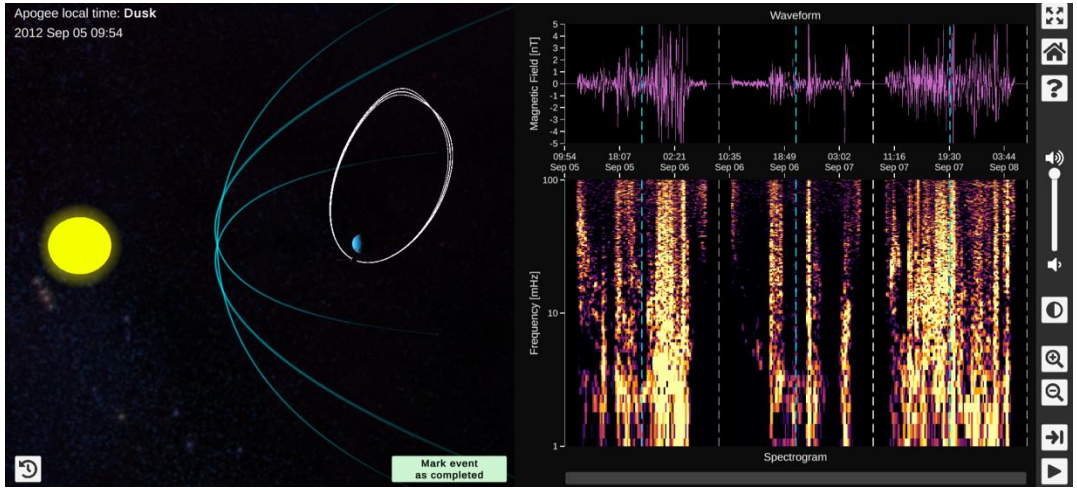
Blog—Sounds of a Solar System

School Students Identify Sounds of Earth's Magnetic Shield Recovering



Martin Archer

Heliophysics Audified: Resonances in Plasmas



- NASA CSSFP grant to develop open source audio software, audio processing protocol [Archer et al., 2022], and GUI to deploy with a large online audience. Project launched in April 2023.

Heliophysics Audified: Resonances in Plasmas

https://listen.spacescience.org

Heliophysics Audified: Resonances in Plasmas

Front. Astron. Space Sci., 08 June 2022
Sec. Space Physics
Volume 9 - 2022 | https://doi.org/10.3389/fspas.2022.877172

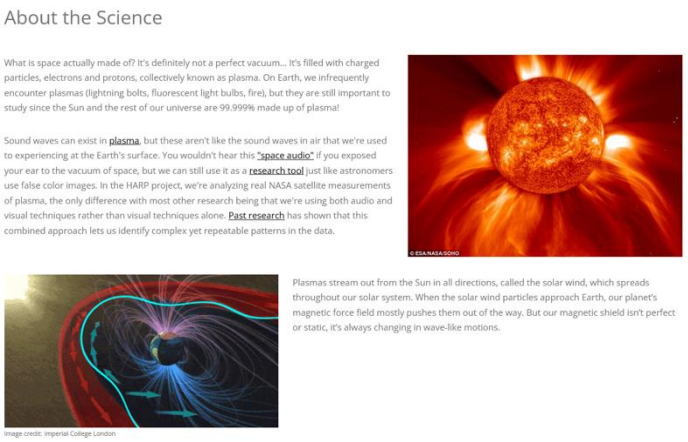
This article is part of the Research Topic
Sources and Propagation of Ultra-Low Frequency Waves in Planetary Magnetospheres
View all 9 Articles ›

Listening to the Magnetosphere: How Best to Make ULF Waves Audible

Martin O. Archer[1]* Marek Cottingham[1] Michael D. Hartinger[2] Xueling Shi[3,4] Shane Coyle[3]
Ethan "Duke" Hill[3] Michael F. J. Fox[1] Emmanuel V. Masongsong[5]

- **Know Your Audience:** Significant beta testing element, public survey to determine best audio processing,…
- Interface beta testing was performed by a cohort of high-school students in an SSI-affiliated Science Teen Library program, followed by students/researchers at UCLA
- Implemented several changes based on beta-testers: large spectrogram/smaller time series, more explanation in training mode, different way of serving events, ability to mark event completed, more metadata collected

Heliophysics Audified: Resonances in Plasmas



- **Connect the dots from science to impact on people's lives**: used online space weather resources from NOAA and NASA to develop website/FAQ, tutorial material, and intro videos; responsive to volunteer requests for audio processing tools for use in music/art; communicate how volunteer efforts on HARP contribute to the science in interviews on NPR, BBC Radio, NASA's Curious Universe Podcast,…

HARP team

Michael Hartinger

James Harold

Anne Holland

Emmanuel Masongsong

Xueling Shi

Robert Alexander

Martin Archer

Shane Coyle

Kristina Collins

Bobby Candey

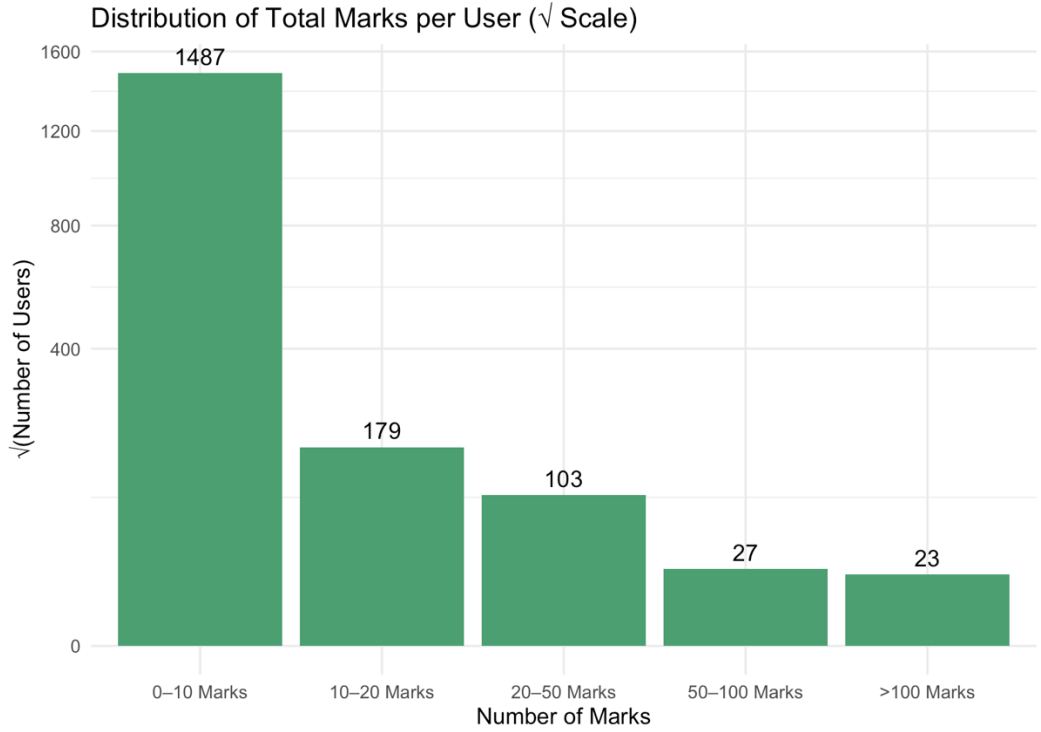
Evaldas Vidurigis

Alessandra Pacini

Not shown: Lauren Blum, Tiffiny Costello, and many others who contributed to HARP

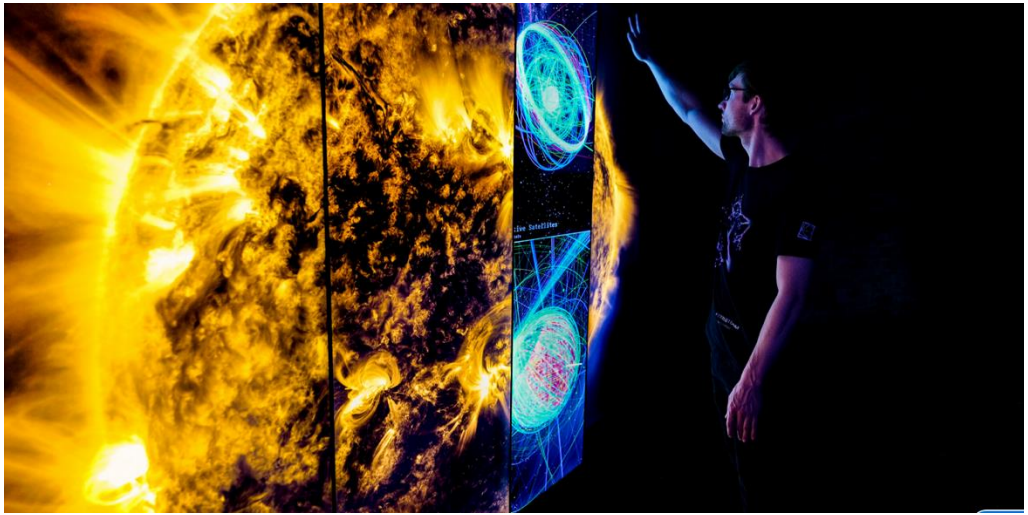
Heavily leveraged experience of HARP team and NASA Citizen Science Program at all stages of HARP project: library programs and online educational games, IRB, audio analysis, web development,…

HARP Project Results: Outreach and Engagement



- 1891 users on every continent except Antarctica
- 18817 Wave Event Marks
- Many users stop after <~3 marks, but ~600 users collect >3 marks with a slow drop off. 23 users made >100 marks, and a small number made thousands of marks – this equates to days of total effort!
- → labelled dataset of ULF wave activity

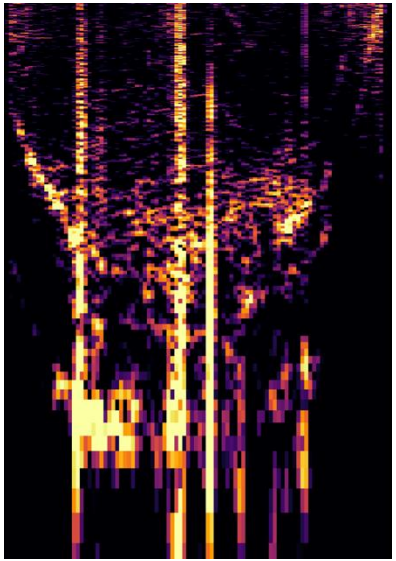
HARP Project Results: Outreach and Engagement

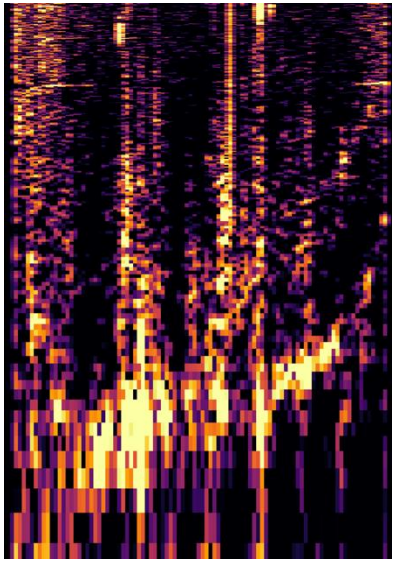


From ARTECHOUSE website, “Beyond the Light”

- Other collaborations with museums, musicians used HARP audio
- ARTECHOUSE museum exhibit (Robert Alexander)
- JVKE “Golden Hour” remix featured in Rolling Stone (Robert Alexander)
- Use of audio processing in follow-on projects led by Kristina Collins, Lauren Blum

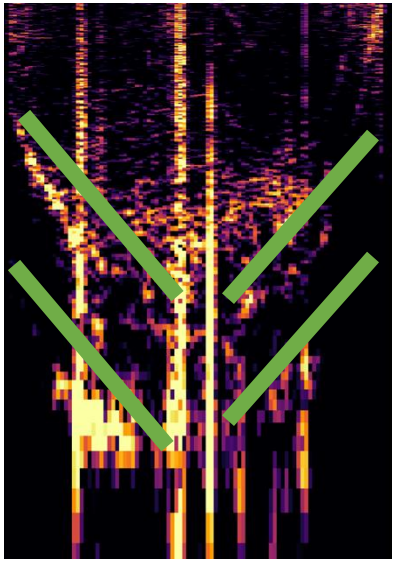
HARP Project Impacts: Science

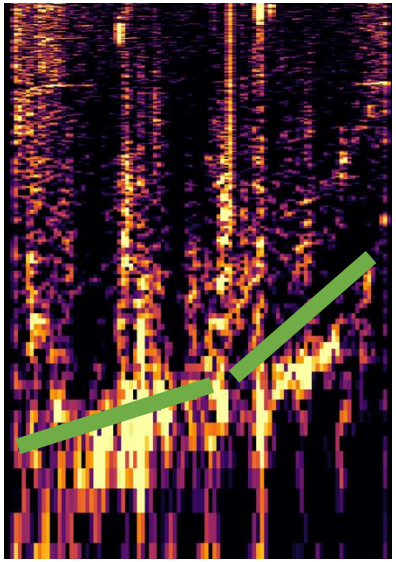




- One of the early users identified a trend in frequency that ran contrary to the standard expectation for wave frequencies in the magnetosphere, the “reverse” harp: the pitch doesn’t change like we expect suggesting unusual conditions occurring in near-Earth space

HARP Project Impacts: Science





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HARP Project Impacts: Science

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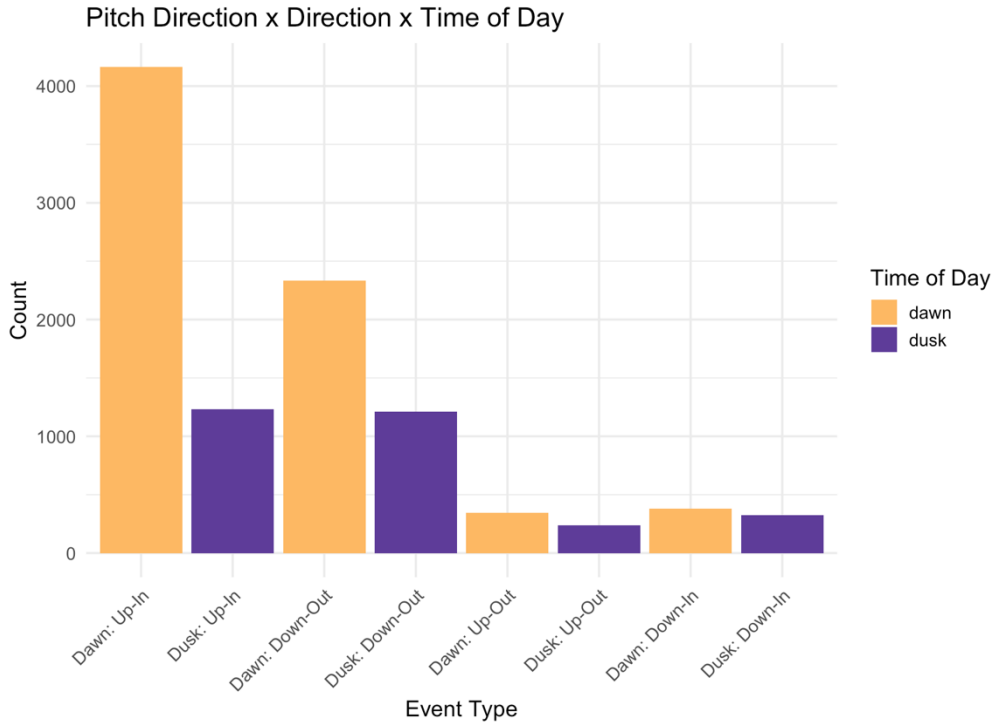
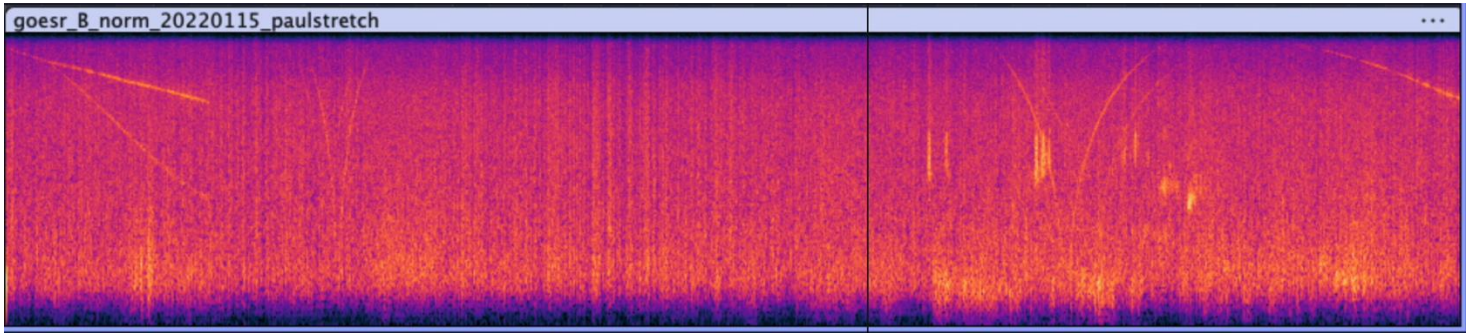
HARP Project Impacts: Science

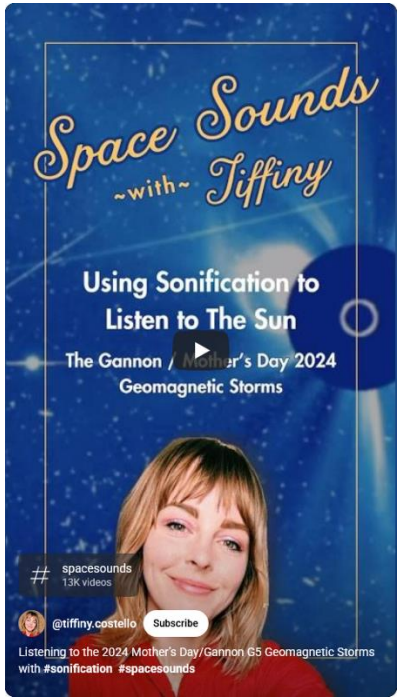


- “reverse” harps are rarer than “standard” harp events, but not exceptionally rare
- This dataset is providing new information since the “reverse” harp paradigm is almost never studied in the ULF wave literature

Related Projects Leveraging HARP resources



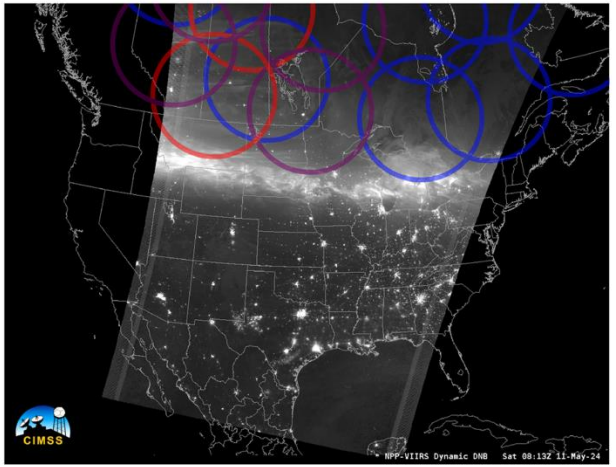
- NSF EAGER project (AGS-2342095) led by Lauren Blum using HARP-related audio analysis to identify elusive EMIC wave events in NOAA and NASA datasets.
- Tiffiny Costello leading production of YouTube videos and Instagram posts (@Tiffiny.Costello) on the audio processing and science related to the project



Avoiding burnout and over-commitment

"…while for academics such endeavours are part of their working time, for citizen scientists the corresponding hours are generally part of their leisure time…**academics also need to maintain their work–life balance and cannot always be reactive to solicitations and enquiries, especially outside of their working hours**" [Grandin et al., 2025, section 4.3]

This is just one example of the need to maintain work-life balance when doing public outreach and engagement activities. **Track your service hours and be mindful of over-volunteering and over-committing.**



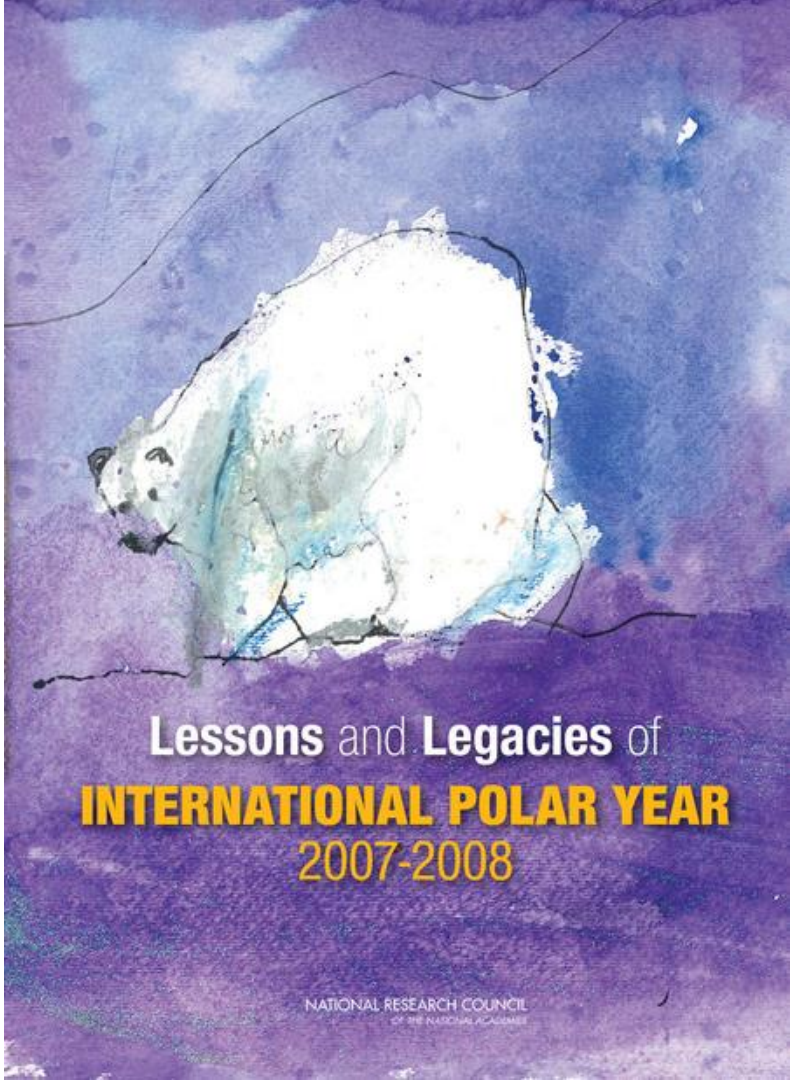
"Citizen Science in Space and Atmospheric Sciences: Opportunities and Challenges" review by Grandin et al. 2025

International Polar Years and Outreach

IPY's are international efforts to advance polar science, including geospace research. **An opportunity for bold new, interdisciplinary, international efforts that transcend individual satellite missions, instrument networks**.

Public outreach is a major part of IPYs:
"The critical '**what happens at the poles affects us all**' message was delivered to a wide audience during IPY through a broad spectrum of outreach and education activities"

More on IPY5 in GIC-GMAG session, Thursday 10AM
Rm 309-310



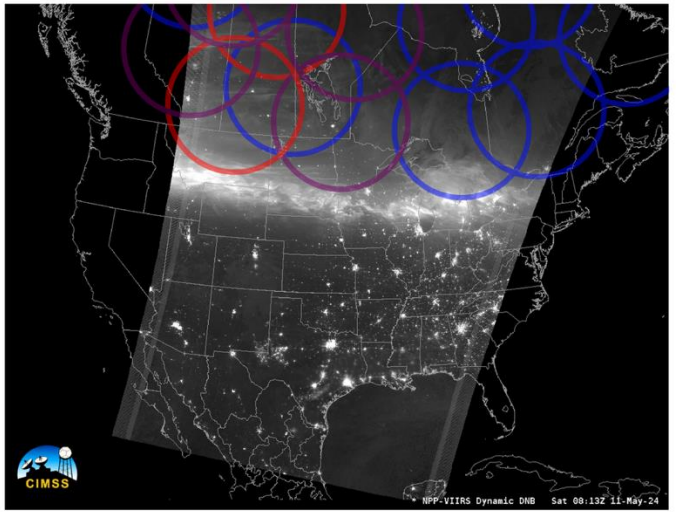
Coordinating Public Outreach for IPY5

IPY4 (2007-2008) happened during a solar minimum, and it ran in parallel with the International Heliophysical Year → less participation of geospace community in IPY4, less coordination of public outreach with the broader polar science community

IPY5 (2032-2033) will occur during solar maximum and will include a total solar eclipse in Alaska → a perfect opportunity to work across disciplines and connect the dots between polar/geospace research and impacts on people's lives

Credit: Annie Schmidt, taken during the 2021 Antarctic total solar eclipse

[From HamSCI 2021 Antarctic eclipse festival]



[Grandin et al., 2025]

Thoughts from a Recent IPY5 Planning Meeting

- We can learn outreach techniques from other science disciplines (and they can learn from us!)
- **Connecting the dots on the impact of scientific research**: $230 Billion to prepare for sea level rise in Houston, NYC, and San Francisco (Bay and port) alone; monitor ice sheets for a fraction of that cost to dramatically reduce uncertainty in sea leave rise predictions in all cities, and avoid under- or over-preparing

Richard Alley's keynote lecture

Other slides from meeting

Thoughts from a Recent IPY5 Planning Meeting

- We can learn outreach techniques from other science disciplines (and they can learn from us!)
- **Connecting the dots on the impact of scientific research isn't just about the science**: "One of our former students went from measuring sound velocity in Greenland ice cores to serving as an Air Force officer validating safety of jets because slower sound velocity reveals hidden cracks"

Richard Alley's keynote lecture

Other slides from meeting

Future of Public Outreach and Engagement?

- Budget cuts to NASA and NSF → many outreach and engagement programs will be cut or eliminated
- Please consider responding to requests from AGU, Heliophysics Coalition, and others
- This is another type of outreach/communications where knowing your audience and connecting the dots is critical. It's also an area where you can heavily leverage resources from networks/colleagues (AGU, Heliophysics Coalition)

Archived GEM Messenger post "Heliophysics Call to Action" on June 12, 2025

Summary of Lessons Learned

- Know your audience
- Connect the dots from science to impact on people's lives
- Learn from other science communicators and leverage networks

Thank you!

UCLA Instagram – From "Exploring Your Universe" Event

AGU Public Outreach Resources

AGU ADVANCING EARTH AND SPACE SCIENCE

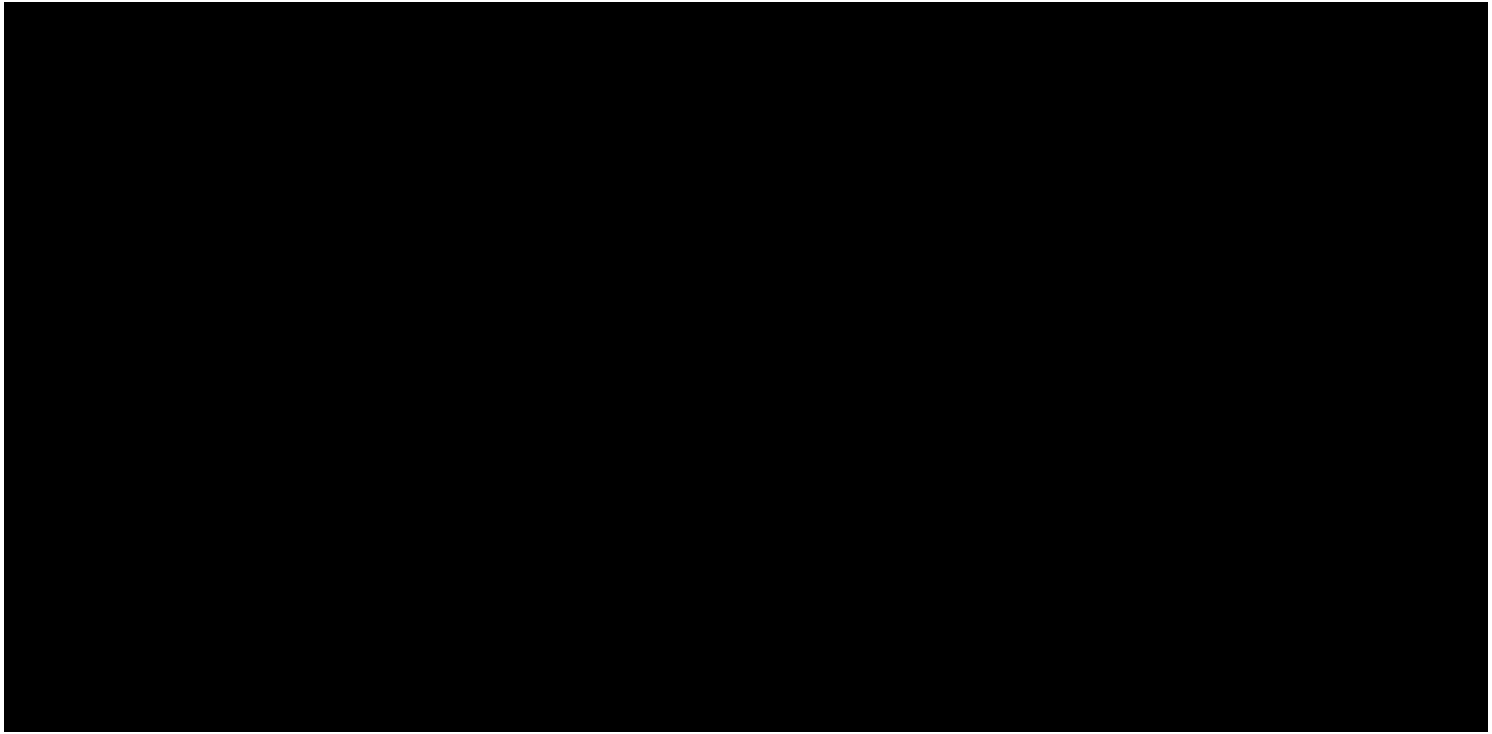
Decadal Survey: Expanding Public Outreach and Participation

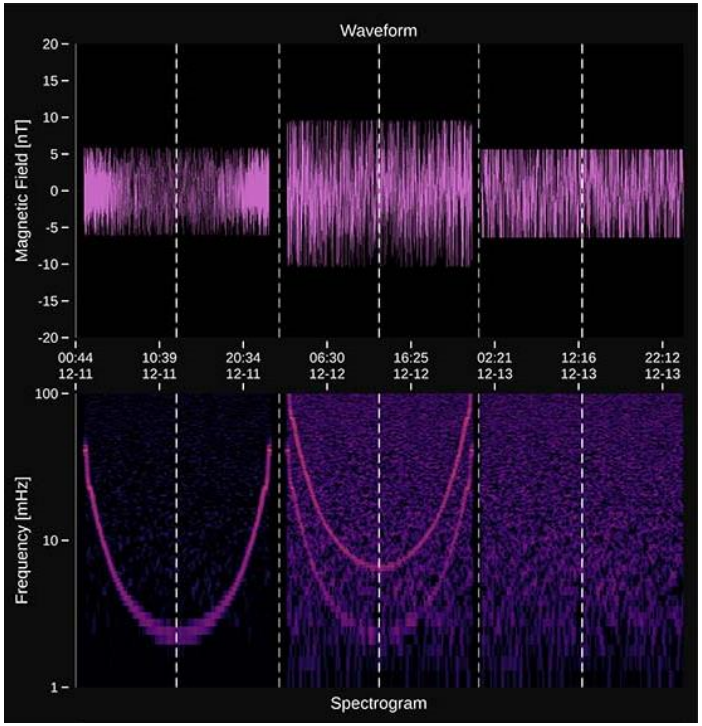
- *Conclusion: The space science community needs to have a data bank of resources and materials to draw from that communicate to the public what solar and space physics is and how it affects society.*
- ***Recommendation 4-6:*** *Funding agencies should increase the volume and dissemination of materials that communicate solar and space physics research results and their societal impacts to the general public. The National Science Foundation and the National Aeronautics and Space Administration should increase outreach programs related to active missions, ground-based facilities, and research and expand support of citizen science and participatory science.*

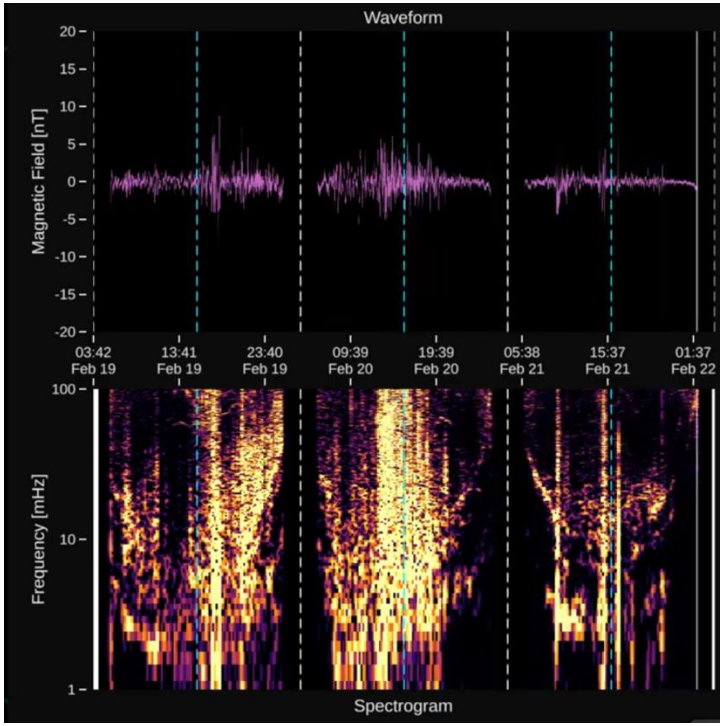
Heliophysics Audified: Resonances in Plasmas

https://listen.spacescience.org

Tutorial



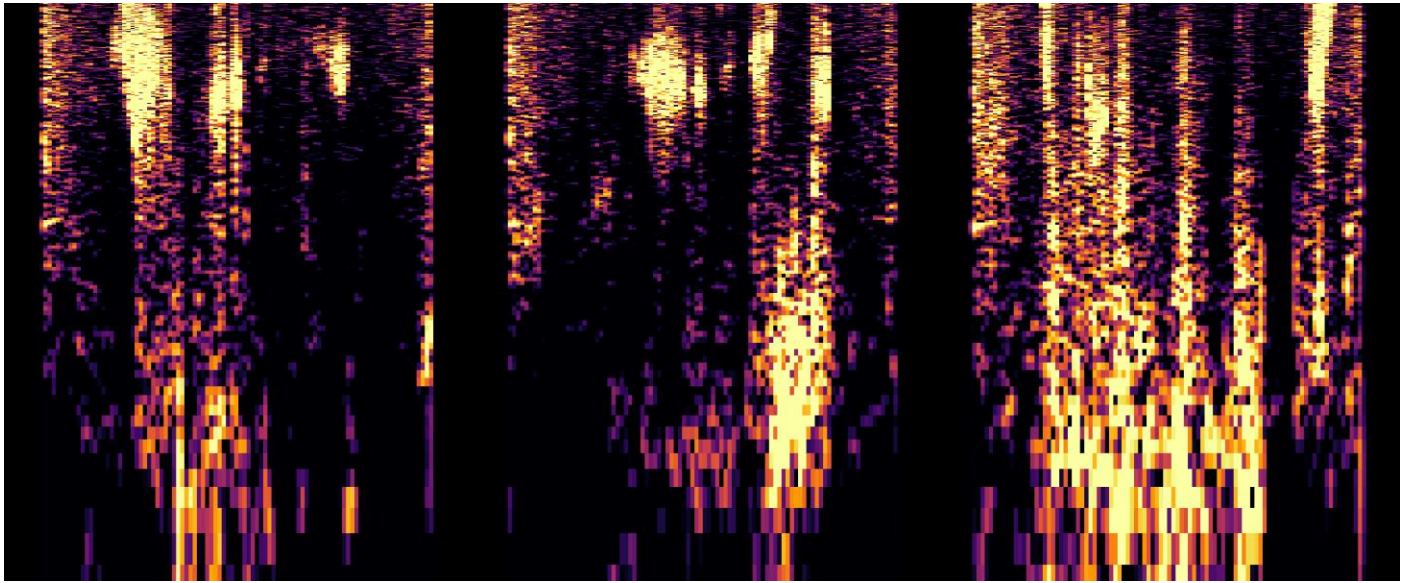




Idealized Model vs. Real Data

- Users first listen to the audio, then draw a box around any visible portions of waveforms within each apogee half-orbit, adding comments to describe notable features. Submissions are later confirmed by experts and characterized in detail to compare results across users.
- Interface beta testing was performed by a select cohort of high-school students in an SSI-affiliated Science Teen Library program. User login/password is encrypted, with no identifying data. Parental informed consent and student assent were obtained according to UCLA IRB#: 21-001709. Ages >18 can participate freely without consent/assent

EMIC wave in THEMIS data



Professor Lauren Blum leading an NSF EAGER project to use audio analysis to identify elusive EMIC wave events in NOAA and NASA datasets.
Tiffiny Costello leading audio processing and analysis…[can mention Instagram, etc.]