

## ASTRO[SOUND]BITES: AN AUDIO RESOURCE FOR INFORMAL EDUCATION

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### ABSTRACT

Astro[sound]bites is a bi-weekly, freely-available podcast companion to the popular blog Astrobites.org. The graduate-student co-hosts of astro[sound]bites present Astrobites content, with an emphasis on synthesizing diverse subfields and pursuing topics peripheral to research. Each episode features a “space sound” segment in which we play and discuss an audio clip related to astronomy and astrophysics. Astro[sound]bites conveys recent astronomy research results in an engaging and accessible manner without visual media. As of April 2022, we have published 53 episodes across many streaming platforms, with approximately 200 downloads per episode in 70 countries, totalling over 12,000 downloads. While astronomy content is often conveyed visually, we provide a crucial resource for auditory learning and promote efforts for inclusionary practices in astronomy.

### RESUMEN

Astro[sound]bites es un podcast bisemanal disponible gratuitamente, que acompaña al popular blog Astrobites.org. Los coanfitriones son estudiantes graduados de astro[sound]bites que presentan contenido de Astrobites, con énfasis en sintetizar diversos subcampos y temas periféricos a la investigación. Cada episodio presenta un segmento de “sonido espacial” en el que reproducimos y discutimos un clip de audio relacionado con la astronomía y la astrofísica. Astro[sound]bites transmite resultados de investigaciones astronómicas recientes de una manera atractiva y accesible sin medios visuales. Hasta abril de 2022, hemos publicado 53 episodios en muchas plataformas de transmisión, con aproximadamente 200 descargas por episodio en 70 países, con un total de más de 12000 descargas. Si bien el contenido de astronomía a menudo se transmite visualmente, brindamos un recurso crucial para el aprendizaje auditivo y promovemos esfuerzos para prácticas inclusivas en astronomía.

*Key Words:* astronomy outreach — audio presentation

### 1. INTRODUCTION

Astro[sound]bites is a graduate-student-run science podcast that is freely available on Apple Podcasts, Spotify, Google Podcasts, SoundCloud, Audible, Amazon Music, and our website [astro-sound-bites.com](http://astro-sound-bites.com). Episodes are approximately 45 minutes in duration and center around a theme, with a typical focus on either a subfield or synthesis of subfields in astronomy. The authors, who are the co-hosts and founders of astro[sound]bites, take turns presenting papers that have been summarized on Astrobites.org, a graduate-student-run astronomy blog.

Astro[sound]bites was founded by the authors, all astronomy PhD students, in November 2019. It was conceived as a response to the following two issues:

(1) the need to “bridge the gap” between the latest scientific research presented in technical scientific papers and the popular science coverage of these same topics, and (2) the demand for multi-modal science communication – both to increase accessibility among non-visual learners and to provide an alternative approach to cement fundamental concepts for all listeners.

#### 1.1. *Bridging the Gap*

Much of the knowledge required for participating in astronomical research is obtained gradually by early-career scientists as they become familiar with technical jargon, domain-specific conventions, and active areas of research. The barriers to this knowledge and the learning curve associated with it are highly dependent on a student’s access to peers and mentors in the student’s intended specialization. By providing a free platform to learn about astronomy research, we aim to reduce existing resource inequities and provide undergraduates, graduate students, and interested members of the public with greater exposure to the latest findings in astronomy.

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The astro[sound]bites podcast was inspired by the blog Astrobites.org, whose goals align closely with our own. Since 2010, Astrobites has published daily research summaries written by graduate students for a STEM-oriented undergraduate audience. In addition, Astrobites publishes *Beyond* posts covering major conferences, relevant events such as #BlackInAstro week, personal experiences, and interviews. Astrobites has now begun to host professional development events and increase its participation as a media outlet. Astrobites regularly logs over 45,000 page views per month (Khullar et al. 2019).

The authors of Astrobites have been instrumental in helping us to design a complementary audio counterpart to their written articles. Author and astro[sound]bites co-host William Saunders serves in a leadership role in the Astrobites collaboration. Our logo was created by Joanna Ramasawmy, a graduate student member of Astrobites. We also maintain close ties with Astrobites to ensure mutual support in our outreach efforts. Some of these efforts are detailed in Section 3.2.1.

### 1.2. Multi-Modal Astronomy Outreach

Whereas Astrobites provides a critical resource for early-career scientists, we have found that the podcast allows us to explore outreach tactics not possible in written form. Through informal but engaging conversations, astro[sound]bites focuses on both individual research topics *and* the connections between them. We make intentional efforts to combine fields and research publications in atypical ways. We also regularly conduct interviews with early-career scientists, allowing them to provide firsthand accounts of their academic paths and their research findings. These interviews help our listeners identify the range of potential career paths based on the stories of scientists just one step ahead in their career stage. By amplifying diverse voices through the astro[sound]bites platform, we support representation within the field and present the human stories underlying cutting-edge research. Finally, an audio platform allows us to leverage sound to experience astronomy data in novel ways.

In the following sections, we outline in greater detail the format of the show, our current listener base, and our plans for improving the podcast in the coming months.

## 2. FORMAT

### 2.1. Traditional Episodes

The primary format taken by the majority of our episodes is that of a science discussion involving two

to three published results. In the currently adopted model, the role of “primary host” rotates among the authors and serves to direct conversation and elicit details about the work being presented. The other two co-hosts each discuss a paper corresponding to an associated Astrobite. The discussion between hosts revolves around the motivation, methods, and results of each paper. In this way, we orient the podcast toward listeners interested in the *process* of research, including the methods and thinking behind each result in addition to the findings themselves.

Some episodes in this category include interviews from guest speakers, who provide an overview of their own work or deliver insights into the presented Astrobites based on their expertise. Because we highlight the work carried out by early-career scientists, guest speakers are typically undergraduate/graduate students or postdoctoral researchers.

The conversational tone of our episodes naturally leaves room for discussion of the underlying threads across studies, which we highlight while drawing upon supplementary information. By synthesizing multiple results in each episode, we focus on not only the individual results themselves, but also the connections between results. Episode titles are selected to reflect these thematic connections; for example, past episodes have focused on dynamical instabilities and chaos (Episode 11: The Chaotic Universe), young astronomical objects at varying spatial scales (Episode 14: Baby Photos), recent discoveries about the solar wind (Episode 29: Walking on Sunshine), the fastest and slowest phenomena in astrophysics (Episode 44: Fast and Slow), and the astrophysical systems that can be studied with polarized light (Episode 51: A Picture of Polarization); among many others.

### 2.2. Beyond Episodes

As mentioned in Section 1.1, Astrobites publishes *Beyond* posts on relevant outside of the traditional paper summaries. These range from book reviews to historical paper overviews to discussions of discrimination in the sciences. In the same complementary vein, our team also produces *Beyond* episodes of astro[sound]bites. These include, for example, advice about applying to astronomy graduate programs, stories about individuals’ research paths, resilience in academia, and other topics that may be of interest to our target listenership of primarily undergraduate and early graduate students.

We have produced two *Beyond* episodes about personal experiences: one focusing on the authors’ experiences (Episode 12: Our First Research Experiences) and another exploring the paths of external

early-career researchers (Episode 35: The Road Less Traveled). We have also produced multiple *Beyond* episodes about graduate school and academia, as well (Episode 17: Success and Publishing in Astronomy, Great Advisors, Gap Years, and Getting into Grad School). Furthermore, we released a *Beyond* episode about sonification in astronomy (Episode 33: Scintillating Sounds of Science), which inspired our Sonification Competition 2021 discussed in greater detail in Section 2.3. We have focused additional *Beyond* episodes on careers outside academia, including our 50th episode about the many career paths that are opened up with a degree in physics or astronomy (Episode 43: Welcome to the World of Science Communication, Episode 50: 50 Careers in 50 Minutes).

These episodes typically include a discussion of, or reference to, at least one associated Astrobite; however, they are more flexible in format than our traditional episodes due to the varied nature of the topics covered.

### 2.3. Space Sounds & Sonification

Beginning in Episode 8, we have included in each episode a “Space Sound” segment in which we feature a short audio clip pertaining to space and/or astronomy and discuss it. Often these clips are audio representations of science data, or *sonifications*. Sonifications can be composed from telescope images, spacecraft data, or simulations. They can range dramatically in style and verisimilitude depending on the objective of the composer. Sonifications play an important role in astronomy: they allow visually-impaired individuals and auditory learners to interact with images and data at a high level. To leverage our unique mode of science communication, we incorporate sonification within each of our episodes through the Space Sound segment. This provides a venue for promoting the use of sound for inclusive practices and taking optimal advantage of the podcasting medium.

We devoted all of Episode 33: Scintillating Sounds of Science to sonification. This episode included an interview with Dr. Garry Foran, a blind astronomer based at the Swinburne University of Technology. Dr. Foran and audio engineer Jeffrey Hannam are leading figures in developing tools for visually-impaired astronomers to conduct research. In addition to carrying out research through sonification, Dr. Foran’s work helps to expand the use of sound for increasing inclusion in STEM fields. In this episode, we discussed and demonstrated how we each learned how to perform sonification using a suite of diverse and freely-available tools.

Episode 33 inspired us to heighten public awareness of and participation in sonification, a goal that was realized through our astro[sound]bites Sonification Competition. In 2021, we received a number of sonification submissions from our audience and selected a winner to interview on the show, as well as a runner-up. We are eager to continue this competition in 2022 and intend to showcase our efforts to hone our skills at sonifying data.

Beyond inclusion, sonification in astronomy is also used for inspiration and innovation. Museums, pop science astronomy websites, and NASA use sonification in the same way that they use observatory images and revolutionary discoveries: to inspire the general public’s interest in astronomy. The ear’s unique data processing capacities also make it possible to derive insights from data that are unique to what can be readily identified by sight, providing a complementary pathway toward innovation in astrophysics. One of the most meaningful undertakings of astro[sound]bites thus far has been encouraging and promoting sonification for its many uses.

### 3. LISTENER STATISTICS

As of early April 2022, astro[sound]bites episodes have been downloaded over 12,000 times in 71 countries spanning six continents. The majority of our listeners reside in the United States (63%), with others listening from the United Kingdom (7.7%), Germany (4.2%), India (3.3%), Canada (2.7%), and other countries. This relatively broad, international distribution for an English-only podcast is likely influenced by the increasingly international breadth of the Astrobites collaboration. Within the US, we have listeners from 47 states and the District of Columbia, with the plurality listening from California (17.7%), New York (8.2%), Massachusetts (8.1%), Texas (7.2%), and Illinois (4.1%).

Each episode is downloaded on average about 110 times in the first week after release, about 150 times in the first month after release, and about 200 times total, gradually increasing with time. These statistics are available from PodBean and SoundCloud. Figure 1 shows the number of downloads for Episodes 34 through 53 in the first week, first month, and to date after release. Figure 2 shows the number of downloads of all episodes by month from January 2020 through March 2022. Both of these figures suggest a growing listenership and a multitude of listeners regularly downloading our back catalog, even during times of hiatus (e.g., in the late summer).

The plurality of our downloads in the past year come from Apple Podcasts (39%), with a signifi-

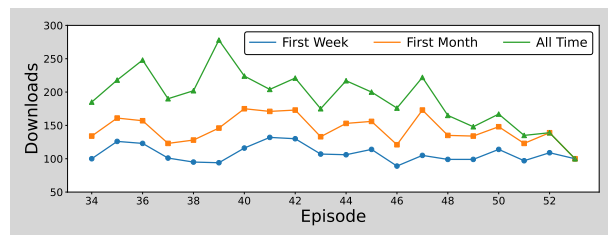


Fig. 1. Downloads of Episodes 34 through 53 in the first week, first month, and total since release. The general trends show a gradual increase in downloads in the first week and first month as new episodes came out. On the other hand, the total downloads increase with older episodes, showing that listeners are downloading episodes from the back catalog. (These statistics do not include downloads from SoundCloud.)

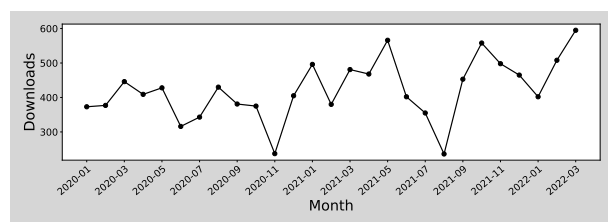


Fig. 2. Total downloads of all episodes by month from January 2020 through March 2022. We observe a gradual increase in downloads per month over time, with noticeable drops to about half the peak download rates during periods of hiatus. (These statistics do not include downloads from SoundCloud.)

cant number coming from Spotify (21%), SoundCloud (9.9%), Overcast (9.3%), and PodcastAddict (6.0%). Other applications comprise 37% of downloads. Though we do not directly publish to every app, many podcasting apps automatically ingest the latest episodes through our RSS feed at [astrosoundbites.podbean.com](https://astrosoundbites.podbean.com), where we host our audio.

### 3.1. Lessons Learned

#### 3.1.1. The Element of Surprise

In our initial podcast episodes, we constructed a single script to be shared between all co-hosts from each of the research papers that we presented. This was done to ensure consistency throughout the episode, but we found with this structure that the episodes sounded more “artificial” each time they had to be re-recorded (which might require as many as three takes to obtain a final, polished version). This is unsurprising: A joke is significantly less funny the third time you hear it.

To circumvent this issue, we have switched to having each co-host construct a script separately and “presenting” the paper for which we are responsible

to the other hosts of the episode. In this way, the off-script questions and reactions make for a more natural, conversational, and overall more exciting episode. In addition, as each presenter needs to be more familiar with the material to be able to discuss it without a verbatim script and field questions not known in advance, this format promotes richer and more technical discussions (and helps us hone our own presentation skills).

#### 3.1.2. How to Conduct an Interview

Conducting an informative and engaging interview with a pre-determined duration is a challenging undertaking. While there are many different styles that an interviewer can employ toward this goal, at minimum the interviewer must have enough of a foundation in the subject’s area of expertise to ask insightful follow-up questions and derive the broader context of the research.

If this is done well, these goals can be achieved while exploring interesting tangents in real time without shifting focus from the guest. As with any conversation, this is a continual interplay between participants: the interviewer must guide the interviewee toward the questions central to the episode (e.g. “What datasets were used to explore this problem?”) while affording the guest freedom to explain desired topics. Translating general questions (e.g., “Tell us a bit about your research.”) into more directed ones (e.g. “You’ve been studying Mars for 3 years; tell us what makes this planetary system so fascinating to you.”) helps us to achieve these goals while providing a framework upon which the interviewee can contribute their own subjective experiences.

This balance between the presence and absence of structure is encapsulated in our use of one-sentence summaries at the end of each episode. We summarize the results that we bring and challenge our interviewed guests to do the same. It severely limits the length of a summary but not its scope, which helps us to maintain structural balance.

#### 3.1.3. Embracing the Pros and Cons of Audio-Based Outreach

Because the majority of scientific research is disseminated through text and figures, an audio-only format appears to present significant obstacles. The most obvious of these challenges is that key findings are typically summarized in plots and schematic diagrams, neither of which can be shown to the listener. This challenge, however, also presents an opportunity. By improving our own ability to describe abstract concepts and images in words, we

improve our ability to make science more accessible to visually impaired and neuro-atypical learners in our other outreach endeavors. Further, we have found that audio representations of data allow us to “experience” it differently, and this often facilitates a more profound understanding of the results presented. Finally, the ongoing COVID-19 pandemic has forced the global astronomical community to rapidly provide virtual opportunities to train burgeoning scientists and highlight the work of early-career researchers; astro[sound]bites provides an approachable mechanism for accomplishing these goals.

### 3.2. Future Directions

We have outlined a number of specific objectives for astro[sound]bites in the coming year.

#### 3.2.1. Diversity, Equity, and Inclusion Efforts

During 2020, we, like many of our peers, became more deeply committed to directly addressing the injustices faced by people of color in the United States. It is imperative to recognize the discrimination faced by members of underrepresented groups—specifically women, people of color, and LGBTQ+ individuals in the physical sciences.

Astro[sound]bites engaged in diversity, equity, and inclusion (DEI) efforts in 2020 and 2021 by modifying the way that we select Astrobites to include in the show and guests to invite for interviews. We now consider the backgrounds of both the author of the Astrobite and the author of the paper summarized therein. In this way, we aim to elevate diverse voices and support scientists from underrepresented backgrounds. We take efforts to invite guests from a variety of backgrounds and have, in several cases, asked them to speak about their professional career track. In addition, we participated in #BlackInAstro week in 2020 and 2021 by developing episodes centered around papers authored by Black astronomers.

We intend to continue these efforts and broaden our reach in 2022. We will expand our use of *Beyond* episodes to feature the stories of members of underrepresented groups and discuss pivotal, historical figures from these groups. In particular, we are designing an episode around the interplay between indigenous culture and astronomy, with an emphasis on what the astronomy community can do to promote a culture of mutual respect. We will further use our platform to promote and endorse DEI work being undertaken by the Astrobites collaboration and its members, as well as our peers.

#### 3.2.2. Sonification

As detailed in Section 2.3, we are envisioning upcoming episodes that will discuss sonification in additional detail. These may include interviews from other visually-impaired astronomers who use sonification to conduct their work, as well as audio engineers and astronomers leading the way in promoting sonification as a valuable tool for data exploration of all kinds. We are also discussing how we might enhance the astronomy community’s awareness of and appreciation for sonification through a conference workshop.

#### 3.2.3. Conference Attendance

Conference venues offer an unparalleled opportunity to network with like-minded astronomy outreach practitioners and to learn from others with complementary experiences. In addition, conferences can provide the opportunity to spread awareness of astro[sound]bites and, in particular, to enhance the international appeal of our podcast.

We attended the Division for Planetary Sciences (DPS) of the American Astronomical Society Meeting in 2020, the American Astronomical Society Meeting in 2021, the Astronomy Society of the Pacific Meeting in 2021, the International Astronomical Union Communicating Astronomy with the Public (CAP) conference in 2021, and the Second Workshop in Astronomy Beyond the Common Senses in 2021. In 2022, we plan to attend the DPS Meeting as well as other outreach conferences such as CAP.

#### 3.2.4. Acknowledgements & Funding Sources

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## REFERENCES

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