THE PLANETARY HABITABILITY LABORATORY (PHL). A. Méndez, Planetary Habitability Laboratory, University of Puerto Rico at Arecibo (abel.mendez@upr.edu).

Introduction: The PHL is a research and education laboratory dedicated to studies of the habitability of Earth, the Solar System, and exoplanets. The main scientific goal of the PHL is to characterize the habitable universe via the theoretical development and application of methods to measure the potential for life of planetary bodies. The PHL provides a unique combination of scientific tools for scientists, educators, and students interested in the astrobiology field and the potential for life in the universe.

The PHL was founded by Prof. Abel Méndez on April 26, 2010, during the NASA Astrobiology Science Conference 2010 (AbSciCon 2010) in League City, Texas. The PHL was motivated by the need for quantitative habitability studies in the astrobiology community. Since its inception, many international scientists studying planetary habitability have joined as collaborators of the PHL.

The two most notable projects of the PHL are the Visible Paleo-Earth (VPE), a unique photorealistic visual reconstruction of Earth's past in the last 750 million years, and the Habitable Exoplanets Catalog (HEC), a listing and comparison of potentially habitable extrasolar planets. The research focus of the PHL is on habitability metrics and the characterization of habitable worlds [1, 2, 3].

The PHL collaborates with many scientists from national and international institutions. The most active collaborations are with scientists from NASA Ames, the Lunar and Planetary Laboratory (LPI), and the Arecibo Observatory. For example, the PHL's Planet-Hab Collaboration consists of an international group of scientists interested in developing and applying habitability models in the astrobiology field. The collaboration combines novel modeling approaches to understand and compare the suitability for life of terrestrial, planetary, and exoplanetary environments.

The PHL provides a wide range of research topics (Figure 1) and mentoring experiences to students, especially undergraduates. These experiences give students essential skills in scientific computing using the Python and R programming languages. Students present their work at local and international conferences, are encouraged to participate in summer internships, and co-author scientific papers. All these experiences contribute to the preparation of students for graduate school.

The PHL also organizes astrobiology conference sessions and workshops with an emphasis on the participation of students. For example, the *2nd Earth-like Worlds Workshops* connected local scientists and students with other international Spanish-speaking scientists studying habitable worlds. The annual conference *AstroChat* connects our local students with other Puerto Rican students and scientists working in different institutions outside Puerto Rico in fields related to planetary science, astronomy, and astrobiology.

Scientists, educators, students, and the general public have extensively used the PHL research and

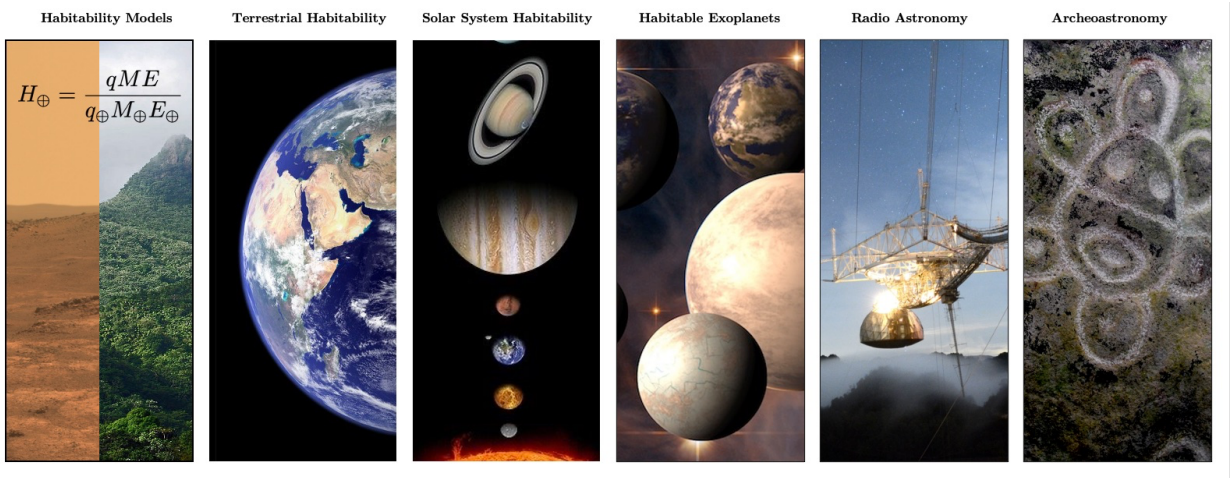

Figure 1. Research topics at the PHL are divided into Habitability Models (*e.g.,* habitability metrics), Terrestrial Habitability (*e.g.,* paleo-Earth), Solar System Habitability (*e.g.,* Mars), Habitable Exoplanets (*e.g.,* potential biospheres), Radio Astronomy (e.g., stellar activity), or Archeoastronomy (e.g., astronomy of the Taino Indians). Most of the research experiences for the students are theoretical/computational in nature, except the observational work at the Arecibo Observatory.

educational resources since its founding. The work of the PHL has been cited by hundreds of peer-review scientific papers, educational resources, textbooks, and news media articles, including CNN, BBC, Scientific American, and National Geographic. The PHL also creates multimedia content for scientists and educators.

The research of the PHL has been consulted for documentaries such as National Geographic's *Cosmos: A Spacetime Odyssey* (2014) and BBC's *Human Universe* (2014). The science behind the PHL was also featured in National Geographic's *One Strange Rock* (2018) and UAGM's *The Biggest Dream* (2021), together with the Arecibo Observatory.

Goals and Strategies: The primary purpose of the PHL is to map the habitable universe. The specific objectives of the PHL are to (1) Develop quantitative habitability assessments and classifications. (2) Trace the evolution of terrestrial habitability from paleo-climates to global warming. (3) Assess the habitability potential of solar and extrasolar planets. (4) Devise tools and methods for ground, orbital, and remote habitability assessments. (5) Create, provide, and facilitate astrobiology science tools for scientists, educators, and the general public. (6) Increase the participation of more students and scientists from minority-serving institutions in astrobiology-related research and educational opportunities.

The scientific research strategy of the PHL includes the development of habitability models and the evolution of terrestrial habitability as a baseline for comparisons with other planets. The habitability models are based on adapting the habitat suitability models used in the ecology field [3]. The education and outreach strategy includes visualizations, social media, and the participation of underrepresented scientists and students.

Impact and Accomplishments: The PHL website receives an average of over 15k visits per month and has had over 1.4 million visitors since its foundation. The research and products of the PHL have appeared in hundreds of news outlets around the world. Some of the most notable research and education accomplishments, in chronological order, of the PHL since its foundation are:

1. The PHL was launched at the NASA Astrobiology Science Conference 2010 in League City, Texas (April 2010).
2. Creation of the first scientific photorealistic visualizations of Earth in the last 750 million years, the Visible Paleo-Earth (VPE) (April 2011).
3. Creation of a new software tool to visualize exoplanets, the Scientific Exoplanet Renderer (SER) (September 2011).
4. Creation of the first measure of Earth-likeness for exoplanets, the Earth Similarity Index (ESI) (November 2011). [1]
5. Creation of the first database of potentially habitable exoplanets, the Habitable Exoplanets Catalog (HEC) (December 2011).
6. The PHL is selected as one of the Best of the Web resources on space and search for alien life by the Teacher Network of *The Guardian* (August 2012).
7. *1st Workshop of Earth-like Planets* (April 2015).
8. NSF proposal collaboration with Rice University and the Arecibo Observatory (October 2015).
9. Book *Searching for Habitable Worlds* is published (April 2016). [2]
10. A study of the average temperature of planetary bodies is published (February 2017). [4]
11. *2nd Workshop of Earth-like Planets* (February 2017).
12. A study on habitability models is published (October 2021). [3]

Facilities: The PHL is located in room AC-331A at the University of Puerto Rico in Arecibo (UPRA). This space provides a conference and research area for scientists and students, and storage for scientific and educational materials. Radio astronomy research is done at the facilities of the Arecibo Observatory. High-performance computing resources are available at the UPR High-Performance Computer Facility (HPCf) or the Arecibo Observatory.

The PHL has a research account in the main scientific computation cluster of the HPCf. This cluster provides over 2240 computational cores, and 200 terabytes of high-performance storage served over a QDR InfiniBand and 10G Ethernet backbone. The HPCf also hosts the web server and domain name of the PHL (phl.upr.edu).

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