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Tardigrades and astrobiology: where Astrophysics and Biology meet at the University of Vigo

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Abstract

Astrobiology is the interdisciplinary scientific field focused on exploring questions about the origin, evolution, and distribution of life in the Universe. Specifically, research on the possible existence of extraterrestrial life is closely linked to the study of aquatic environments. Celestial bodies such as Enceladus, Europa, and certain exoplanets with oceans are of special interest in this field. Extreme terrestrial habitats, such as intertidal zones, provide useful analogies for understanding how life could develop under these conditions. In this context, marine tardigrades emerge as important models of habitability. Tardigrades, or water bears, are bilateral invertebrates with excellent polyextremophilic behavior and stress resistance. Although they have been studied in a wide range of habitats, our knowledge remains limited when it comes to marine populations, with fewer than 300 identified species out of more than 1,484 total species. In our research to understand how these organisms respond to different stress conditions, we have found that tardigrades provide a way to introduce both University of Vigo students (interns, undergraduate thesis students) and the general public to the fields of astronomy and astrobiology. The specimens used in this study were collected during sampling at Portiño Beach (Galicia, northwestern Spain) with the participation of students. Among the isolated individuals, we identified six different genera: *Ramazzottius*, *Macrobiotus*, *Milnesium*, *Echiniscoides*, *Styraconyx*, and *Batillipes*. The genera *Echiniscoides* and *Ramazzottius* were selected to establish long-term laboratory cultures, with the goal of obtaining individuals for new experimental procedures. Our group is actively involved in giving talks and conducting outreach activities about this work, especially for primary, secondary, and vocational education centers.

1 Introduction

Astrobiology is a multidisciplinary science that includes, among others, biology, physics, astronomy, chemistry, geology, ecology, and astrophysics. Its areas of study include topics such as the origin of life, prebiotic organic chemistry on celestial bodies, like planets or moons, as well as in the interstellar medium, and the characterization of exoplanets. Our research specifically focuses on model organisms and extremophiles.

Tardigrades, also known as water bears, are microscopic animals (50-1200 microns) with a segmented body plan composed of a head followed by a trunk with four pairs of legs, which are visible when they are in an active state. They belong to the phylum Panarthropoda, a clade with which they share segmentation, clawed appendages in the form of hooks, the need to molt to grow, a cuticle containing chitin and protein, and panarthropod sensilla (Fig. 1). They are, therefore, related to insects, arachnids, or crustaceans. Currently, 1,488 species have been discovered, which can belong to two classes: Eutardigrada or Heterotardigrada [1].

These animals need to be surrounded by water to maintain their active stage in which they can feed and reproduce. Although, their origin is believed to be in the marine environment, currently many species live in terrestrial environments, where they are able to withstand periods of drought thanks to their ability to endure periods of desiccation [2]. The latter are known as semi-terrestrial or limnoterrestrial species. Freshwater species mostly belong to the class Eutardigrada, while marine species are almost exclusively Heterotardigrada. Limno-terrestrial tardigrades can belong to both classes [3]. There are morphological and anatomical differences between marine and terrestrial individuals.

Tardigrades have the ability to enter an inactive state known as cryptobiosis, in which the animal reduces its metabolism by over 99.9% . During this stage, the water content decreases to 1% of its normal value and is replaced by trehalose while maintaining its molecular structure intact.

The main objective is to bring the field of astrobiology closer to society. To achieve this, we (Prof. Ulla) have integrated both the scientific aspects of laboratory research in an academic setting and fostered public interest through outreach activities.

Prof. Ulla has integrated astrobiology into the physics course she teaches for undergraduate Biology students, offering the option to carry out final degree projects (TFG) in this field. The first TFG in the astrobiology branch, focusing on tardigrades, was defended in the 2018/19 academic year [4]. This was followed by two consecutive STEMBach programs (Excellence in Science and Technology Baccalaureate that brings students closer to research) during the years 2020-2022 and 2021-2023. The first promotion focused on terrestrial tardigrades, while the second worked with marine tardigrades, laying the groundwork for the current research line. In the experimental part, studies have included culturing tardigrades under laboratory conditions and analysing the survival capacity of various tardigrade species

under stress conditions that might simulate extraterrestrial environments, such as isolation from magnetic fields and exposure to gamma radiation [5][6].

Since the beginning of the project, and alongside laboratory work, outreach activities have been carried out in schools and high schools, aiming to introduce students to astrobiology and to inspire the general public's interest in this emerging scientific field.

2 Why focus on Tardigrades?

Tardigrades have gained significant popularity in society. A quick internet search reveals numerous headlines highlighting their versatility and importance, both in the field of health and in their resistance and survival in extraterrestrial conditions.

This fame arises from these animals' ability to enter cryptobiosis. This condition is typically associated with the acquisition of a shape known as the "tun" state. In this state, they can withstand adverse conditions that no other animal can (high radiation, extreme low and high temperatures, lack of oxygen, changes in environmental salinity, etc.) [7]. Thanks to this cryptobiotic ability, the animal can survive for years, "coming back to life" when environmental conditions improve. As a result, they have been identified as the most resilient living organisms on Earth and excellent astrobiological candidates as study models for extraterrestrial habitability.

Another advantage of these animals is that they are ubiquitous and can be found in beaches, seas, lichens, leaf litter, mosses, and any place where there is enough water at certain times to maintain their active metabolism.

Among the different habitats we could select to study these microorganisms, we have focused our attention on marine tardigrades, specifically those living in the intertidal zone. This decision is based on our ultimate goal of proposing a viable species of tardigrade as a model for habitability in oceanic extraterrestrial bodies (including both moons and exoplanets). So far, available information indicates that both Europa (a moon of Jupiter) and Enceladus (a moon of Saturn) potentially harbor a subsurface ocean of salty water (though not necessarily sodium chloride) [8]. Among marine and limno-terrestrial tardigrades, the former live in more similar conditions due to the osmotic pressure of their environment, making them a better biological model.

Therefore, in our line of research, we maintain cultures of marine tardigrades from the coastal zone, which allows us to showcase individuals from different species and present images obtained using various types of microscopies. So far, we have been able to display images of the genera *Echiniscoides*, *Batillipes*, *Styraconyx*, *Macrobiotus*, *Ramazzottius*, and *Milnesium* using stereoscopic, optical, confocal, and scanning electron microscopies (Fig 1.).

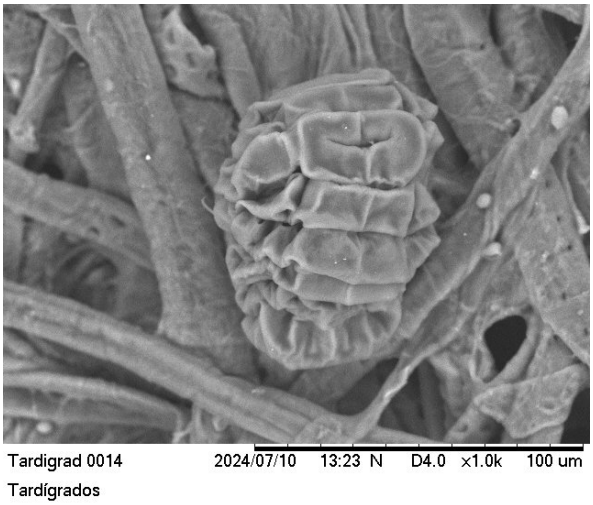

Figure 1: Image of a tardigrade from the species *Ramazzottius oberhaeuseri* obtained through scanning electron microscopy.

3 Outreach Activities

The first outreach activities on tardigrades and their application in astrobiology took place alongside the STEMBach initiative (uvigo.gal/es/ven-uvigo/centros-secundaria/steam/stembach). Educational talks were held in schools ranging from primary to vocational education, sometimes linked to initiatives such as the February 11th International Day of Women and Girls in Science (uvigo.gal/universidade/comunicacion/novas/dia-internacional-muller-nena-ciencia-2024) (Fig 2.). Additionally, there were open science activities in public spaces, such as Pontenciencia (in the municipality of Pontevedra - educacion.pontevedra.gal/pontenciencia/), and family-oriented events, both at the Forcarei Astronomical Observatory (OAF - observatorioforcarei.es/) and in collaboration with the Vigo Nature Environmental Park in the municipality of Vigo (vigonature.es/).

One of the goals of the outreach activities we conduct is to introduce and spark curiosity in the general public about astronomy and astrophysics. To discuss tardigrades in the context of astrobiology, it is necessary to first explain other concepts. For example:

- Bodies of the solar system: not only planets and their satellites but also other celestial bodies
- What stars are and their different types
- The existence of exoplanets and how planetary systems are formed
- Branches of astrobiology
- What the habitable zone is

Figure 2: Outreach activity as part of the February 11th initiative, the International Day of Women and Girls in Science, at the Integrated Higher Education Centre Politécnico de Santiago de Compostela institute.

Additionally, we have introduced practical activities directly related to astronomy, such as orientation exercises and the use of a planisphere.

4 Future steps

We are currently working on designing a new type of activity aimed at 6th-grade children that delves deeper into the concepts mentioned and allows them to relate Earth's biomes to different extraterrestrial environments. Additionally, these activities will include a practical component involving the search, handling, and observation of tardigrades, giving them firsthand experience in the world of research and an initial exposure to laboratory equipment.

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