# New Approach to Observe the Radio Signatures of the Galactic Continuum

F. Mejri, T. Aguili and G. Moncef

***Abstract*-In this work, we present an innovative, simple, and accessible approach to capturing radio waves from the galactic continuum-ubiquitous on Earth-within a laboratory setting. The proposed solution allows students, educators, and enthusiasts-who may not have access to traditional radio telescopes-to engage with radio astronomy through a hands-on, cost-effective method. Unlike previous systems that require complex SDR programming or custom-built receivers, our design employs a basic λ/4 wire antenna connected to a reconfigurable spectrum analyzer-equipment commonly available in many teaching laboratories. This makes the setup immediately applicable for practical instruction.**

**Our main contribution is to demonstrate that such a simplified configuration can reliably detect known signals from the galactic radio continuum. Measurements were conducted across several frequencies and compared with data from the literature, showing strong consistency and validating the system's performance. The device functions as both a scientific instrument and an educational platform, helping democratize access to radio astronomy and fostering scientific curiosity in academic settings.**

**By integrating all components into a unified laboratory environment (Radio Telescope-Lab), this work offers a reproducible and scalable solution that bridges the gap between advanced research instruments and accessible educational tools.**

## I. Introduction

The first detection of a radio astronomical signal dates back to the groundbreaking work of Karl Jansky in the 1930s [1]. While investigating sources of background noise in a high-frequency (HF) radio receiver, Jansky discovered that the noise originated from space [2]. This discovery marked the birth of radio astronomy and laid the foundation for the study of the radio continuum-a diffuse cosmic radiation emitted by extended sources such as interstellar gas clouds, distant galaxies, and other large-scale cosmic structures. Unlike point sources such as pulsars, the radio continuum is characterized by spatially distributed emission across a broad frequency range, requiring specialized techniques for its analysis and mapping.

The rudimentary antennas used by Jansky-simple dipoles made of electrical wires [3] demonstrated that cosmic radio signals could be detected using relatively basic equipment. Today, thanks to technological advancements-particularly modern spectrum analyzers-it is possible to detect and analyze these signals even in laboratory environments. This approach offers an accessible alternative for studying the radio continuum, especially in educational settings where building a traditional radio telescope-often costly and technically complex-is not always feasible.

A conventional radio telescope typically consists of three main components : an antenna to collect radio waves, a receiver to amplify and process the signals, and a computer system for data analysis [4-6]. While antennas used in radio astronomy are generally large to maximize sensitivity and angular resolution, modern technologies such as superheterodyne receivers and spectrum analyzers-capable of amplifying signals by up to 100 million billion times while effectively filtering out noise-now make it possible to use compact antennas, even indoors.

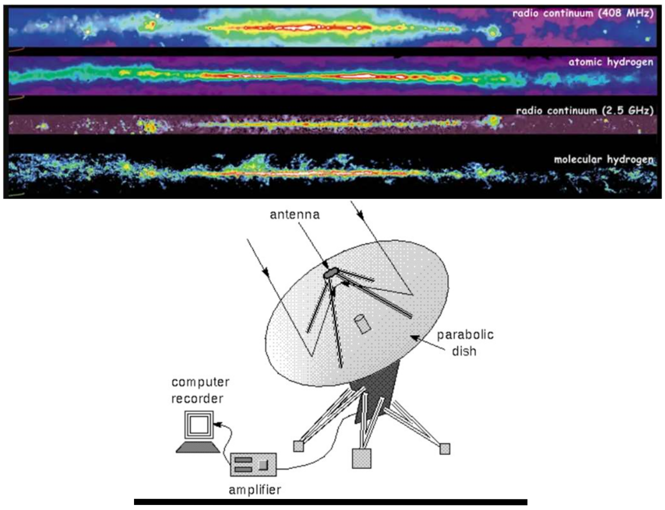


Figure 1. Traditional radio telescope [15-16].

The study of the radio continuum relies on sophisticated spatial and spectral scanning techniques, such as interferometry and aperture synthesis, which utilize signals captured by antenna arrays to produce high-resolution sky maps. When combined with advanced digital processing tools-including deconvolution algorithms and machine learning techniques-these methods enable precise characterization of the physical properties of extended sources, such as their temperature, density, spatial distribution, and associated magnetic fields.

Our innovative approach, based on a λ/4 wire antenna coupled with a reconfigurable spectrum analyzer, fits within this tradition while remaining simple, low-cost, and accessible. Integrated into a laboratory setting (Radio Telescope-Lab), this method has been validated through results that are consistent with data from the literature, making it an ideal pedagogical

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F. Mejri is with the National Engineering School of Tunis (ENIT), Rue Béchir Salem Belkhiria Campus universitaire, BP 37, 1002, Le Bélvédère, 1002, Tunis (Author's phone: +216 97653202; e-mail: fethi.mejri.syscom@gmail.com).

T. Aguili is with the National Engineering School of Tunis (ENIT), Rue Béchir Salem Belkhiria Campus universitaire, BP 37, 1002, Le Bélvédère, 1002, Tunis (e-mail: taoufik.aguili@gmail.com).

G. Moncef is with the STU TPW Radio telescope Project in Tunisia, France. (e-mail: moncef.astu@gmail.com).

tool for universities and colleges. By facilitating access to radio astronomical data and encouraging active participation from students, educators, and enthusiasts, it promotes the analysis of cosmic signals and the discovery of celestial phenomena. This strengthens the connection between science and society, stimulates innovation, and fosters the interdisciplinary collaborations essential for the future of radio astronomy.

When comparing our method with conventional radio telescopes, several key observations emerge. Traditional radio telescopes (Figure 1), typically operated by research institutions, are large, expensive to build and maintain, yet offer high sensitivity and precision for capturing extremely faint radio signals. In contrast, the Radio Telescope-Lab-designed at low cost using standard laboratory equipment-offers lower sensitivity and resolution but is still capable of detecting signals from celestial sources such as the Sun, planets, and certain galactic emissions.

Several initiatives in the field of educational radio astronomy have explored low-cost alternatives to traditional radio telescopes. Notably, systems based on software-defined radio (SDR) have been developed for detecting solar flares and hydrogen line emissions at 1420 MHz. While effective, these solutions often require substantial expertise in digital signal processing and software configuration.

Building on these efforts, our work introduces a simplified, hardware-based approach that eliminates the need for complex programming and leverages laboratory equipment already available in many academic institutions. This makes the system more accessible for introductory teaching environments and for users with limited technical backgrounds.

In summary, while traditional radio telescopes offer superior performance, the Radio Telescope-Lab presents a practical and accessible solution for exploring and understanding the radio universe in educational settings.

The main contributions of this work are :

- A simple and low-cost setup for detecting galactic radio signals using standard lab equipment.
- Experimental validation through measurements compared with reference data.
- An accessible educational tool that requires no SDR programming or specialized hardware.
- A reproducible and scalable "Radio Telescope-Lab" for teaching radio astronomy.

This paper is structured as follows: Section II presents the proposed innovative solution-an educational radio telescope-detailing its components and implementation strategy. Section III describes the detection of galactic radio continuum signals using the developed system and examines the corresponding experimental results. Finally, Section IV concludes the study and outlines future development perspectives.

## II. Presentation Of The Innovative Solution (Educational Radio Telescope)

The design of a conventional radio telescope (Figure 1) requires advanced technical expertise, significant financial resources, and considerable implementation time-factors that often make it inaccessible to amateurs and those with limited budgets. To overcome these limitations, we propose a simple, cost-effective, and easy-to-implement alternative that is accessible to all radio astronomy enthusiasts, while still delivering instructive and high-quality results.

Figure 2 shows our Radio Telescope-Lab, a compact system in which the antenna and receiver (a spectrum analyzer) are integrated directly into a measurement laboratory. This innovative approach democratizes access to radio astronomy, allowing a broader audience to explore and analyze cosmic signals in a practical and enriching manner.

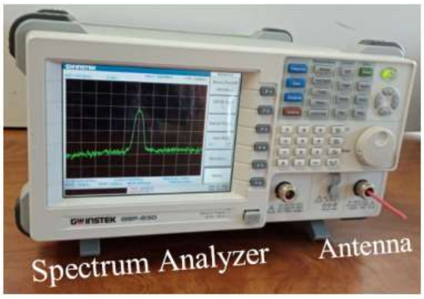


Figure 2. Detection of the Radio Continuum Using the Proposed Radio Telescope-Lab.

### *A. Presentation of the Antenna*

To provide a simple, accessible, and easy-to-implement solution for detecting galactic radio continuum signals, we opted for the design of a basic omnidirectional λ/4 wire antenna (Figure 3), with its length L determined by Equation (1). This antenna has the advantage of receiving signals from all directions, making it a versatile choice for general-purpose measurements. Although precise source localization would require a highly directional and more complex antenna—an aspect reserved for future research-the λ/4 wire antenna fully satisfies the objectives of simplicity, accessibility, and reproducibility. It is straightforward to design and adapt to various target frequencies, supports quick and low-cost implementation, and provides proper 50-ohm impedance matching. Its simple structure also enables reliable replication in diverse experimental contexts, making it particularly suitable for educational use and low-budget scientific projects.

$$L \approx \frac{\lambda}{4} = \frac{3.10^8}{4f} \quad (1)$$

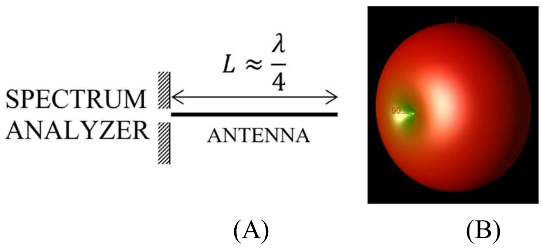


Figure 3. (A) Quarter-wavelength wire antenna, (B) 3D radiation pattern of the antenna.

### *B. Presentation of the Receiver*

The receiver used in this setup is the GW Instek GSP-830 spectrum analyzer [7], which covers a broad frequency range from 9 kHz to 3 GHz, making it well-suited for detecting galactic radio continuum signals at various frequencies. The device features essential filtering capabilities, including a Resolution Bandwidth (RBW) filter to isolate narrowband signals of interest, and a Video Bandwidth (VBW) filter, which acts as a low-pass filter to suppress high-frequency noise and smooth the displayed trace. Both filters are highly selective and adjustable, with settings of 3 kHz, 30 kHz, 300 kHz, and 4 MHz, allowing for fine control over signal visualization and analysis depending on the observation context.

The GSP-830 supports amplitude measurements ranging from –110 dBm ($10^{-11}$ mW) to +20 dBm (100 mW), enabling the detection of the weak signals typically emitted by galactic sources. As a reconfigurable superheterodyne receiver, it offers high sensitivity and frequency agility, ensuring accurate and stable performance across a wide spectral range. Its user-friendly interface and laboratory-grade reliability make it an ideal choice for both educational and experimental applications in radio astronomy.

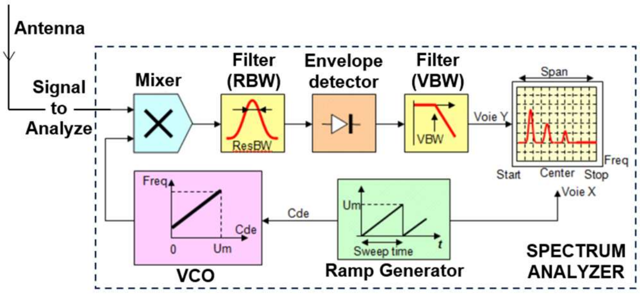


Figure 4. Schematic diagram of the educational radio telescope [8].

The performance of the Radio Telescope-Lab depends largely on the quality of the spectrum analyzer. Modern models can measure signals with frequencies ranging from a few kilohertz to several hundred gigahertz and amplitudes as low as –170 dBm ($10^{-17}$ mW). As technology advances, spectrum analyzers are expected to become even more powerful. They could eventually complement-or even replace-traditional radio telescopes, enabling a wide range of astronomical signal measurements to be performed entirely within a laboratory setting. Figure 4 shows the block diagram of the Radio Telescope-Lab.

## III. Detection of the Galactic Radio Continuum Using the Proposed Educational Radio Telescope

The Galactic Radio Continuum is primarily associated with radio emissions from our galaxy, including thermal continuum radiation (emitted by hot gas) and non-thermal continuum radiation (resulting from processes such as synchrotron radiation).

Frequencies such as 408 MHz and 2700 MHz are particularly important for studying the Galactic continuum. Other frequencies, while more suited to specific studies-such as the 1420 MHz hydrogen line (HI line)-are included to provide a broader observational context.

The laboratory measurements of signals emitted by the Galactic continuum, presented in Figures 5 through 11, show strong agreement with data available in the literature [9–12]. The values obtained at various frequencies are consistent with theoretical expectations, confirming the reliability of our measurement method. These results support the validity of our experimental approach and open the door to further studies aimed at mapping galactic radio emissions.

TABLE I. FREQUENCIES AND APPLICATIONS OF GALACTIC RADIO CONTINUUM IN RADIO ASTRONOMY

| Frequency | Wavelength | Source or application |
|---|---|---|
| 150 MHz | 2m | Synchrotron emissions, large structure maps. |
| 408 MHz | 73cm | Galactic Continuum, Haslam map. |
| 610 MHz | 49cm | Compact galactic and supernova studies. |
| 820 MHz | 37cm | Polarization studies, Galactic magnetic fields, foreground modeling for CMB studies. |
| 1420.5 MHz | 21cm | HI line (neutral hydrogen), spiral maps. |
| 2500 MHz | 12cm | High-resolution synchrotron mapping, free-free emission studies, CMB foreground subtraction. |
| 2700 MHz | 11cm | Thermal and non-thermal continuum. |

### *A. The Radio Continuum at 150 MHz (2 m)*

The 150 MHz radio continuum is dominated by synchrotron radiation from the Milky Way and extragalactic sources such as supernova remnants and radio galaxies. This frequency is ideal for studying the structure of the Milky Way, galactic magnetic fields, and interstellar propagation effects. It is also commonly used for large-scale radio sky surveys, although it provides lower spatial resolution compared to higher frequencies.

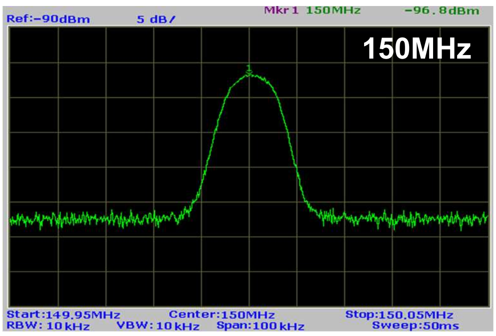


Figure 5. Laboratory-measured results of the signals emitted by the galactic continuum *at 150 MHz.*

The Radio Telescope-Lab reveals a dominant emission peak precisely centered at 150 MHz. This value, in perfect agreement with theoretical predictions reported in the literature [10], confirms the reliability of our experimental setup and its meticulous calibration. The observed resonance exhibits a narrow spectral profile, highlighting both the stability of the detected signal and the optimal sensitivity of our instrumentation. The absence of frequency artifacts or significant background noise within this range further supports the validity of our measurements. This result not only corroborates the expected astrophysical models for this type of signal but also validates the methodology used for data acquisition and processing. Additional tests, including repeated measurements under controlled conditions, have consistently reproduced this central frequency, thereby reinforcing the reproducibility of the experiment.

### *B. The Radio Continuum at 408 MHz (73 cm)*

At 408 MHz, the radio continuum is primarily dominated by synchrotron radiation originating from the Milky Way and various extragalactic sources. This frequency is well known for its role in the Haslam et al. (1982) survey, which produced one of the most detailed and widely used maps of the radio sky. It is extensively employed to study galactic magnetic fields and the characteristics of extragalactic sources, offering improved spatial resolution compared to lower frequencies.

Figure 6 clearly shows that the signal measured by our Radio Telescope-Lab is precisely centered at 408 MHz, consistent with findings reported in the literature [9, 14].

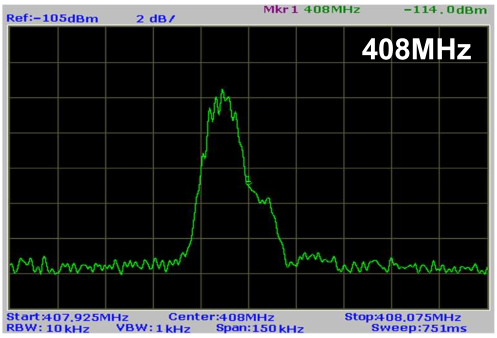


Figure 6. Laboratory-measured results of the signals emitted by the galactic continuum *at 408 MHz*.

The 408 MHz band represents a cornerstone in the study of both galactic and extragalactic radio continuum, where synchrotron radiation predominates. This emission mechanism, resulting from the relativistic acceleration of cosmic electrons within magnetic fields-whether in the Milky Way or in extragalactic sources such as active galactic nuclei and supernova remnants-is particularly well characterized at this frequency.

Its scientific relevance extends to two key areas :

- The analysis of galactic magnetic fields, where the polarization of the synchrotron signal helps trace the large-scale structure and intensity of these fields, while minimizing depolarization effects that are more pronounced at lower frequencies;
- The characterization of extragalactic sources, leveraging the improved angular resolution (typically 5 to 10 times higher than that of 150 MHz surveys) to distinguish compact components from diffuse structures.

*C. The Radio Continuum at 610 MHz (49 cm)*

The 610 MHz continuum is similarly dominated by synchrotron radiation from the Milky Way and extragalactic sources. Situated in the intermediate frequency range, it is sensitive to various astrophysical processes, including those involving high-energy electrons and ionized gas. This frequency is used to investigate the structure of the Milky Way and interstellar propagation effects, while offering improved spatial resolution.

Figure 7 clearly shows that the signal measured by our Radiotelescope-LAb is precisely located at 610 MHz, as indicated in the literature [11].

The 610 MHz radio continuum occupies a critical niche in observational astrophysics, serving as a bridge between low-frequency surveys (e.g., 150–408 MHz) and higher-frequency regimes (>1 GHz). At this frequency, the emission is predominantly due to synchrotron radiation produced by relativistic electrons spiraling through the Milky Way's magnetic field, as well as by extragalactic sources such as active galactic nuclei (AGN), radio galaxies, and supernova remnants.

Strategically positioned in the intermediate frequency range, the 610 MHz band strikes a balance between angular resolution (arcminute scale with instruments like the Giant Metrewave Radio Telescope, GMRT) and sensitivity to diffuse structures. This makes it uniquely suited for probing multi-scale turbulence in the interstellar medium (ISM), mapping magnetic field topology through polarization studies, and detecting ionized gas features such as HII regions or supernova-driven shocks. Unlike lower frequencies, it is less affected by ionospheric distortion and Galactic foreground absorption (e.g., free-free absorption), while still avoiding the steep thermal emission dominance observed above 1 GHz.

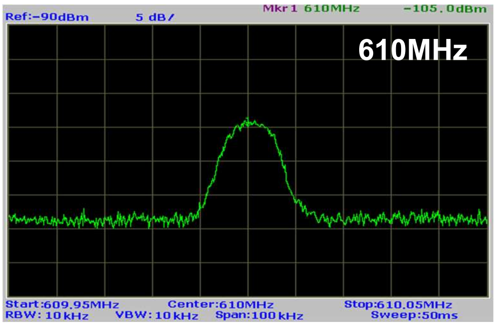


Figure 7. Laboratory-measured results of the signals emitted by the galactic continuum *at 610 MHz*.

*D. The Radio Continuum at 820 MHz (37 cm)*

At 820 MHz, the radio continuum is primarily driven by synchrotron radiation from the Milky Way and extragalactic sources. This intermediate frequency is particularly valuable for studying astrophysical processes involving high-energy electrons and ionized gas. It also facilitates radio sky mapping with improved spatial resolution compared to lower frequencies.

Figure 8 clearly shows that the signal measured by our Radio Telescope-Lab is precisely centered at 820 MHz, as reported in the literature [14].

The 820 MHz radio continuum represents a strategic observational window in modern astrophysics, where synchrotron radiation dominates the spectral landscape. This non-thermal emission is produced by relativistic electrons (with energies on the order of GeV) interacting with galactic (~1–10 μG) and extragalactic magnetic fields. It reveals energetic phenomena such as jets from supermassive black holes, shock waves from supernova remnants, and activity in active galactic nuclei (AGN).

Unlike frequencies below 500 MHz, where interstellar scattering blurs fine structures, the 820 MHz range offers an optimal balance between angular resolution (~20–30 arcseconds with interferometers such as the Karl G. Jansky Very Large Array, VLA) and sensitivity to large-scale diffuse structures, such as Fermi bubbles or filaments in the interstellar medium (ISM).

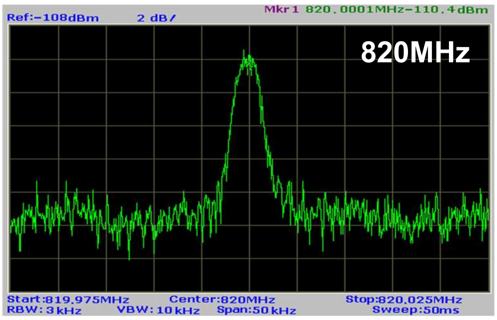


Figure 8. Laboratory-measured results of the signals emitted by the galactic continuum *at 820 MHz.*

*E. The Radio Continuum at 1420.5 MHz (21 cm)*

The 1420.5 MHz continuum is well known for coinciding with the 21 cm line of neutral hydrogen (HI), but it is also dominated by synchrotron radiation from the Milky Way and extragalactic sources. This frequency is essential for studying the structure of the Milky Way, galactic magnetic fields, and gas dynamics via the HI line. It offers high spatial resolution and is widely used for high-frequency radio sky mapping.

Figure 9 clearly shows that the signal measured by our Radio telescope-LAb is precisely located at 1420.6 MHz, as indicated in the literature [9] and [14].


Figure 9. Laboratory-measured results of the signals emitted by the galactic continuum *at 1420.6 MHz.*

The 1420.5 MHz (21 cm) spectral line holds a unique place in astrophysics, serving both as a tracer of interstellar neutral hydrogen (HI) and as a window into large-scale synchrotron emission. While globally recognized for the hyperfine transition of HI-used since the pioneering work of Ewen and Purcell (1951) to map the spiral structure of the Milky Way and to measure galactic rotation velocities-this frequency is paradoxically dominated in intensity by non-thermal synchrotron radiation. This emission primarily originates from relativistic cosmic electrons (with energies of ~1-10 GeV) accelerated within galactic (~1-10 µG) and extragalactic magnetic fields (such as those in active galactic nucleus jets and radio galaxy lobes).

This frequency thus remains an observational crossroads, where the legacy of classical radio astronomy meets the promising prospects of the SKA era, offering an unparalleled window into the magnetized and dynamic Universe.

*F. The Radio Continuum at 2500 MHz (12 cm)*

The 2500 MHz continuum lies within the microwave range and is primarily dominated by synchrotron radiation from the Milky Way and extragalactic sources. This frequency is particularly valuable for studying astrophysical processes involving high-energy electrons, ionized gas, and compact objects such as active galactic nuclei (AGN) and supernova remnants. It enables high-resolution radio sky mapping, well-suited for detecting fine structures and thermal sources. Additionally, it is frequently used to analyze the spectral properties of radio sources and to complement observations at both lower and higher frequencies.

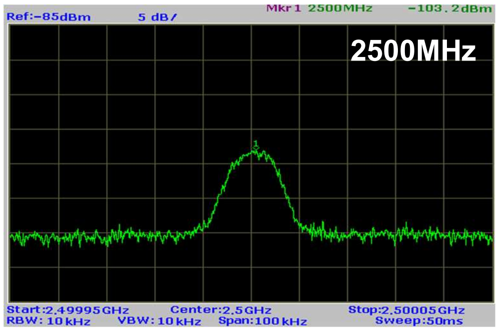


Figure 10. Laboratory-measured results of the signals emitted by the galactic continuum *at 2500 MHz.*

Figure 10 clearly shows that the signal measured by our Radio telescope-LAb is precisely located at 2500 MHz, as reported in the literature [12].

Thanks to its short wavelength (~12 cm), modern interferometers such as the Very Large Array (VLA) and the Atacama Large Millimeter/submillimeter Array (ALMA, in radio mode) can achieve angular resolutions better than 1 arcsecond. This allows for :

- Resolving fine structures in supernova remnants, such as the Rayleigh–Taylor instability filaments in Cassiopeia A.
- Isolating compact AGN cores from their extended lobes, which is essential for studying the activity cycles of supermassive black holes.
- Mapping star-forming regions obscured at optical wavelengths, such as the molecular clouds in the Galactic bulge.

This frequency thus represents a crossroads between classical radio astronomy and the exploration of the extreme Universe, revealing both the violent nature of astrophysical processes and the subtle intricacies of matter-radiation interactions.

*G. The Radio Continuum at 2700 MHz (11 cm)*

The 2700 MHz continuum, located in the microwave range, is dominated by synchrotron radiation from the Milky Way and extragalactic sources. This frequency is particularly valuable for studying astrophysical processes involving high-energy electrons, ionized gas, and compact sources. It enables high-spatial-resolution radio sky mapping, well-suited for investigating compact objects and thermal processes.

Figure 11 clearly shows that the signal measured by our Radio telescope-LAb is precisely centered at 2700 MHz, as reported in the literature [13].

The 2700 MHz continuum constitutes a strategic observational window for investigating energetic astrophysical processes. This frequency range is dominated by synchrotron radiation produced by relativistic electrons (~10–100 GeV) accelerated in galactic (~1–10 μG) and extragalactic magnetic fields, such as those found in jets from supermassive black holes and radio galaxy lobes. Additionally, this regime includes an increasing contribution from thermal emission (bremsstrahlung) originating in ionized gas within HII regions, planetary nebulae, and circumstellar envelopes.

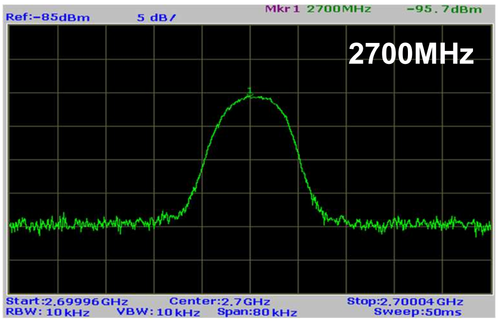


Figure 11. Laboratory-measured results of the signals emitted by the galactic continuum *at 2700 MHz*.

Positioned halfway between the classical radio domain and high-frequency millimeter waves, the 2700 MHz continuum serves as a unique laboratory for exploring the violent Universe-from stellar accretion processes to turbulence in the intergalactic medium.

## IV. CONCLUSION

This study presents a simple and cost-effective method for detecting galactic radio continuum signals in a laboratory environment. By combining a λ/4 wire antenna with a reconfigurable spectrum analyzer, we developed an educational radio telescope capable of detecting key frequencies—150 MHz, 408 MHz, 610 MHz, 820 MHz, 1420.5 MHz, 2500 MHz, and 2700 MHz—with results that closely align with established data.

The system provides an accessible and practical platform for introducing students and amateur scientists to radio astronomy through hands-on experimentation. Looking ahead, future work will focus on the design of a reconfigurable and highly directive antenna to enable sky mapping and improve spatial resolution, thereby enhancing the telescope's observational capabilities and bridging the gap between education and research.

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The authors gratefully acknowledge the use of an advanced language tool, including ChatGPT, which was employed to improve the grammatical accuracy and linguistic clarity of the manuscript. This tool was used exclusively to enhance readability and did not influence the scientific content.

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