Solar Radio Burst Tracker: A citizen science initiative to identify Type III solar radio bursts

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1. Introduction

Type III Solar radio bursts are rapid frequency-drifting emissions originating from energetic solar events known as **solar flares**. During these flares, energetic particles are accelerated and travel into the **interplanetary medium**, where they interact with the surrounding plasma[Reid & Ratcliffe, 2014].

This interaction generates **radio waves** at the local **plasma frequency** (f_p), which is proportional to the **local plasma density** (n_e). As the particles move away from the Sun, they encounter decreasing plasma densities, resulting in a **decreasing emission frequency**. This leads to the characteristic **fast frequency drift** observed in **Type III solar radio bursts**[Benz, 2009].

The **Solar Radio Burst Tracker** is a **citizen science project** hosted on Zooniverse.org, inviting the public to help identify **Type III bursts** in radio spectrograms collected by the **RPW instrument onboard the Solar Orbiter** [Maksimovic et al., 2020].

By combining **human classifications** with **expert validation**, the project aims to build a **high-quality, large-scale catalog** of interplanetary Type III bursts. This catalog will be used for:
- Statistical studies of solar activity
- Cross-matching with solar flares and other events
- Improving and training **automated Type III detection tools** for future missions

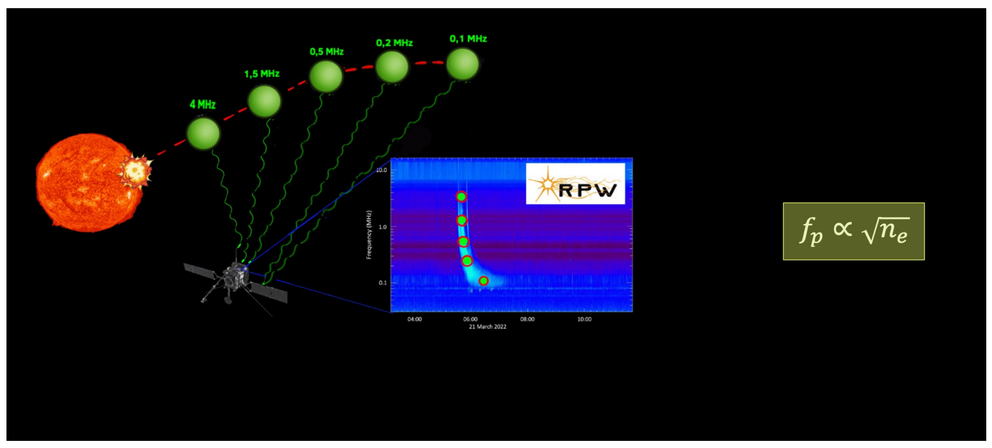

Figure 1: Type III solar radio burst generation

2. Methodology

Data Selection
The first step was to create all the spectrograms to provide to the volunteers.
Radio spectrograms are generated from data recorded by the RPW instrument onboard the Solar Orbiter, spanning frequencies from approximately 4 kHz to 16 MHz.
Spectrograms are segmented into daily plots, cropped, and pre-processed to enhance burst visibility (e.g., scaling and filtering). These images are uploaded to the Zooniverse platform.

Citizen Science Design
In addition to the spectrograms, training material was prepared for the volunteers.
This material includes a detailed description of the science, an introduction to the team, tutorials, example cases, explanatory videos, and forum discussions. All content was designed to be accessible to a general public.

Citizen Classification
Volunteers are asked to identify and outline Type III bursts by contouring the shape of the observed Type III solar radio bursts.
Each image is reviewed and classified by multiple users to ensure accuracy.
In total, the project engaged 865 volunteers who scanned all the provided spectrograms, covering the RPW dataset from 2020 to 2025.

Post Processing Analysis
User classifications are combined using a clustering algorithm to identify regions with consistent user agreement.
These regions are tagged as candidate Type III bursts. The clustering algorithm is based on the number of users who identified a specific area (density-based clustering). From the resulting clusters, the frequency and time range of each identified burst is calculated.

Uncertainty measures
Along with the user identifications, it is necessary to provide a measure of how reliable the detections are.
The first measure of uncertainty is based on the number of users who selected the same area.
The second measure of uncertainty is based on the frequency drift rate of the selected region.

Catalog Creation
Validated detections are compiled into a catalog that includes the Type III burst duration, frequency range, corresponding flux values, peak flux values, frequency drift rate, and the two uncertainty measures.

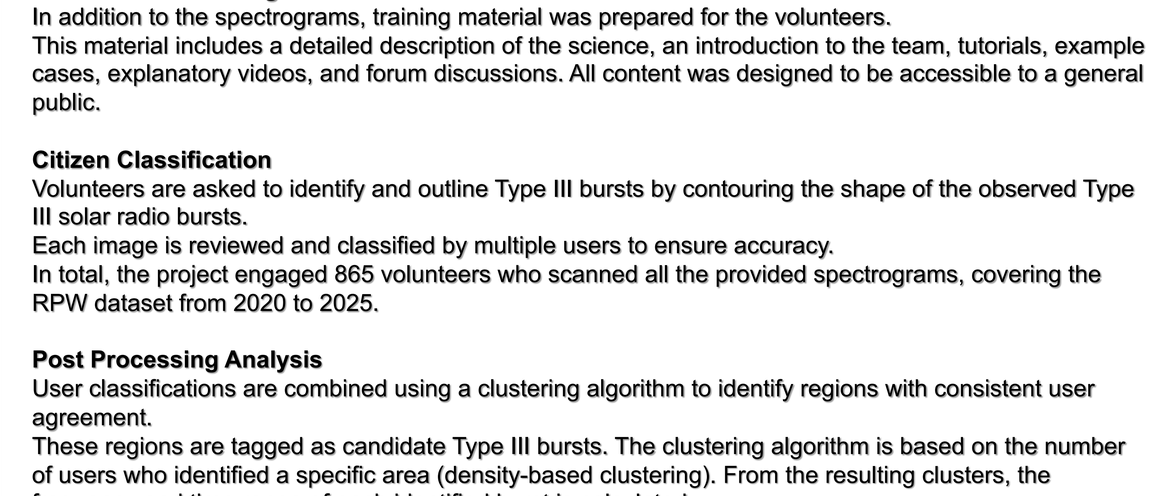

Figure 3: Post processing – Density Based Clustering algorithm example

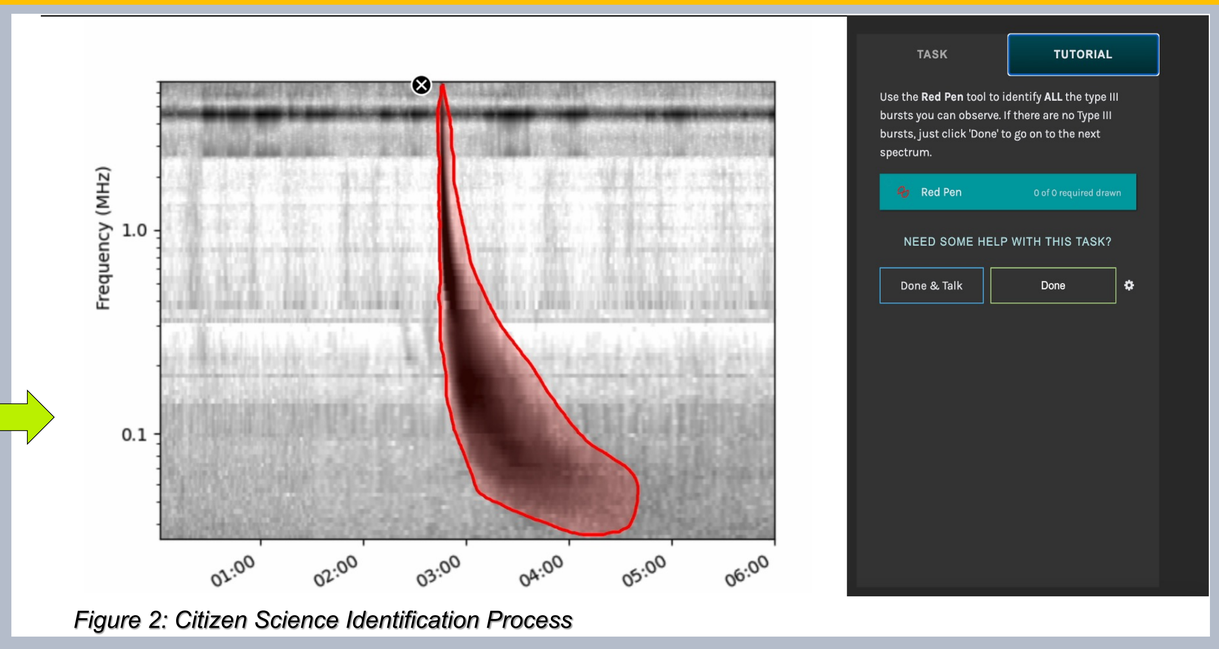

Figure 2: Citizen Science Identification Process

3. Results

After the post-processing analysis, volunteers identified 18,445 Type III bursts. All of these detections will be included in the first extensive catalog of Type III bursts observed in space.
The following graph demonstrates the evolution of the daily number of selected Type III regions alongside the daily sunspot number from 2020 to 2025.
Both trends show a well-aligned increasing pattern, consistent with expectations as solar activity rises toward the solar maximum.

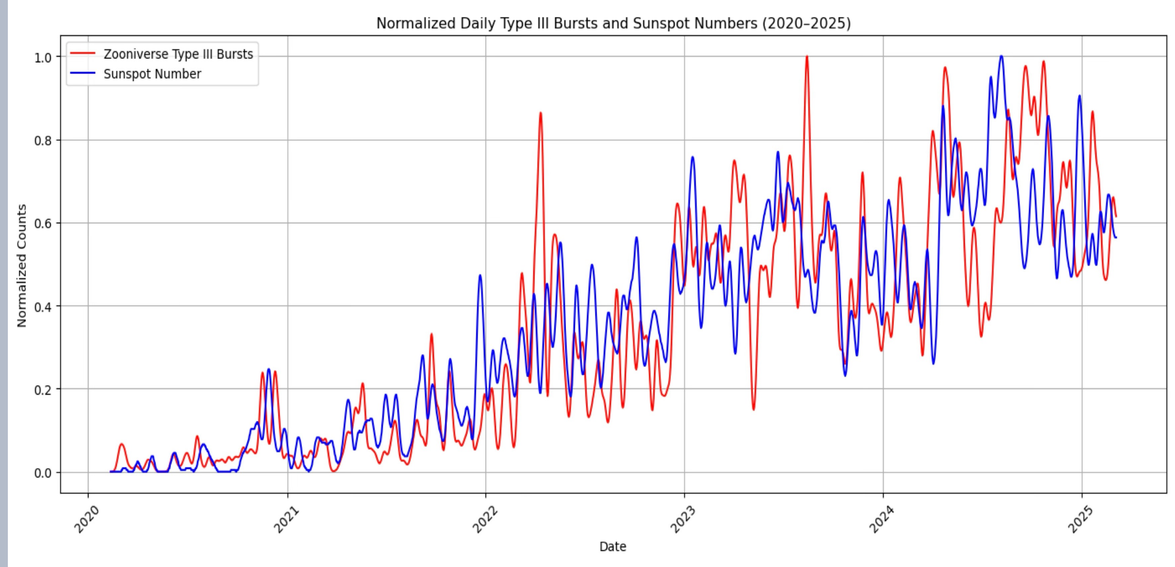

Figure 4: Type III bursts vs Sunspots

4. Future Applications

The resulting catalog offers a wide range of opportunities for further research and development, including:

- **Multi-wavelength observations study from the same spacecraft**

Using data from multiple instruments onboard the same spacecraft, the catalog enables comparative studies of Type III bursts with solar flares observed in EUV and X-rays. This supports deeper investigation into the energy release from the Sun to the solar corona.
The inclusion of faint Type III signals also opens the possibility to compare them with microflares and nanoflares. This will help quantify the energy contribution of weaker solar flares to coronal energy transfer and provide further insight into the long-standing coronal heating problem.

- **Type III periodicity study along the Solar cycle**

The campaign is planned to extend to STEREO data, allowing the creation of a Type III catalog covering two full solar cycles. This long-term dataset enables the investigation of periodic patterns in Type III activity and the comparison of kilometric bursts with sunspot trends.
Type III bursts observed in the kilometric range provide the opportunity to monitor solar activity not only from the Earth-facing side of the Sun but also from regions beyond the line of sight. This offers a more complete picture of solar activity throughout the solar cycle.

- **Automatic Type III burst detection**

The human-validated catalog can serve as a training set for machine learning algorithms designed to automatically detect Type III solar radio bursts. This tool will support continuous updates to the catalog and enhance future large-scale data processing efforts.

5. Participate In the Solar Radio Burst Tracker

If you want to be part of this citizens science campaign scan the following QR code to help us identify Type III bursts.

Link: https://www.zooniverse.org/projects/xbonnin/solar-radio-burst-tracker