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Solar Virtual Observatory for millimeter wavelength survey

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Abstract. The study of the Sun is a very important area of astronomy due to its effects on the Earth. The objective of this work is to develop a Virtual Observatory to store data observed by the POEMAS polarimeters and the automatic detection of flares at 45 and 90 GHz.

Resumo. O estudo do Sol é uma área da astronomia muito importante, devido aos seus efeitos na Terra. O objetivo desse trabalho é desenvolver um Observatório Virtual para disponibilizar aos especialistas, dados de explosões solares observadas pelos polarímetros POEMAS (POlarização de Emissão Milimétrica da Atividade Solar) e a detecção automática de explosões observadas em 45 e 90 GHz.

Keywords. Virtual observatory tools – Sun: flares – Telescopes

1. Introduction

Currently, with the evolution of technology such as the development of space and ground observatories great amount of data can be collected. To process the data quickly for analysis is a challenge for experts.

The study of solar activity is very important due to its effects on Earth. The importance of analyzing the radio spectrum and polarization of solar flares at millimetric wavelengths to understand:

- Particle Acceleration Mechanisms.
- Magnetic field configuration.
- Population of energetic particles.

The Center for Radio Astronomy and Astrophysics at Mackenzie (CRAAM) monitors solar activity by collecting data from different telescopes in the Southern Hemisphere and is responsible for the operation of several experimental resources. For the CRAAM-SVO project, we highlight the Solar Submilimetric Telescope (SST) and the telescopes for POlarization Emission of Millimeter Activity at the Sun (POEMAS).

The POEMAS (Fig. 1) is a system of two telescopes that monitors the Sun, operating in two bands of millimeter wavelengths (45 and 90 GHz). This unique circular polarization Telescopes were installed at the observatory El Leoncito Astronomical Complex (CASLEO) – in Argentina and operated from 11/2011 to 12/2013. Currently it is being repaired in Germany and should be back in operation by the end of 2018.

A Virtual Observatory (VO) consists of a set of data and information with tools for access and research that allow the comparison of data with other facilities of the astronomical community. The CRAAM-SVO (Solar Virtual Observatory) allows the astronomer to make global electronic access to data files and analysis results. The CRAAM-SVO makes available the data as FITS (Flexible Image Transport System) files. The project is being developed in Python and using Django as a framework. We hope this data will disseminate to the community interested in studying millimetric emission of the Sun.

Figure 1. POEMAS (POlarization Emission of Millimeter Activity at the Sun). Valio (2013)

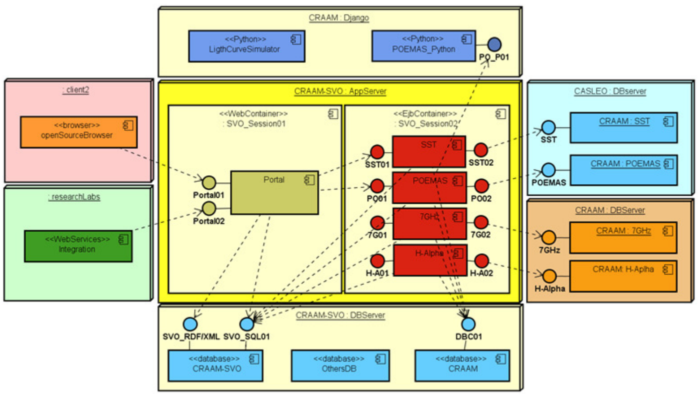

Figure 2. Architecture of the CRAAM-SVO.

2. Methodology

The architecture of the CRAAM-SVO (Fig. 2) is composed of an application server that supports requests from users and partner research centers. This component is developed in the Java architecture using the JPA and Jena frameworks for integration to the Virtuoso database through SQL and RDF / XML, respectively, in addition to the API for generating FITS files for data sharing.

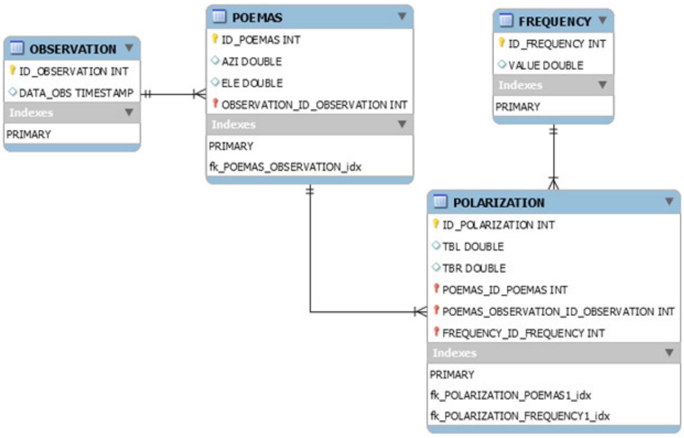

FIGURE 3. CASLEO: DBServer.

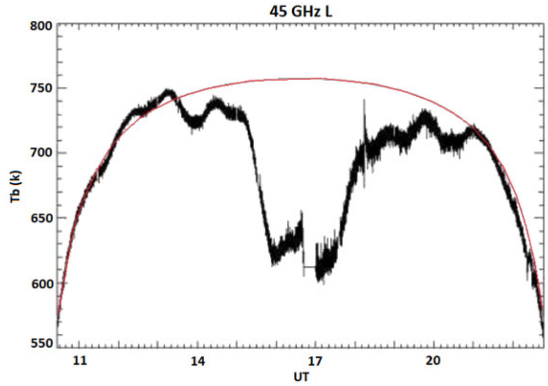

FIGURE 4. Diurnal Variation (Silva 2016).

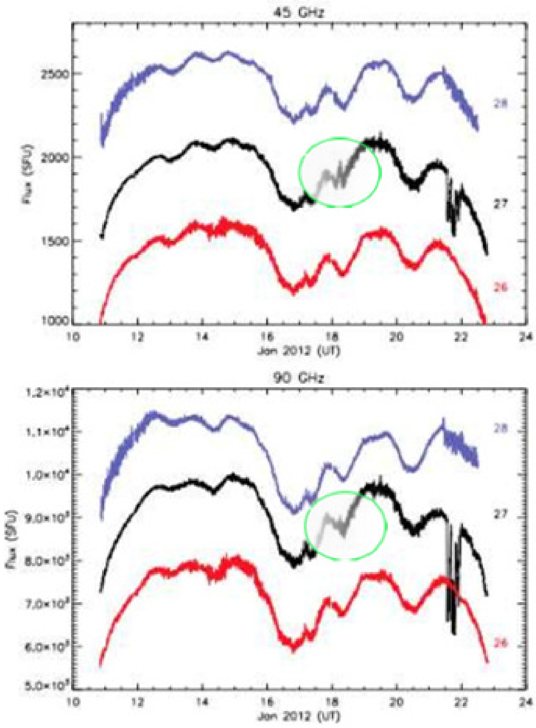

FIGURE 5. Subtraction of the previous and/or the next day emission (Silva 2016).

After the solar observation performed by POEMAS, the data are stored in binary files and forwarded for analysis to the Radio Astronomy and Astrophysics Center (CRAAM). The binary files used in this work have TRK (* .TRK) extension, Sun Tracking Brightness Temperatures.

The TRK file has the number of frequencies (always 2 - 45 GHz and 90 GHz), the maximum and minimum brightness of the file, the date (YYYY - MM - DD) and the time (HH - MM - SS) and the elevation and azimuth angles (the position of the sun on the sky), the Right - R and Left - L polarization brightness temperatures of the two frequencies (TBR45, TBL45, TBR90 and TBL90). The Telescope stores 100 records per second. In 1 day of observation, we have approximately 320 MBytes.

After reading the binary file a FITS file is generated. FITS is a widely used file format in the astronomy community for storing images and tables. A FITS file contains a sequence of header units, and in each of them there are records describing the following dataset. For each Extension Header of the FITS file we have the Subheader data from the FITS file (date, time, elevation angles and azimuth). In the dataset we have TBL45, TBR45, TBL90 and TBR90 records.

The data will be stored in a CASLEO: DBServer database. In Fig. 3 we have the relationship entity diagram where we show a flow diagram of the relationship between entities (POEMAS, Polarization, Frequency and Observation). This diagram was used to design the project database with the POEMAS data.

3. Solar Data

The data recorded by the telescopes present a great challenge of processing, analyzing, storing and understanding the large volume of data generated. For the data on the web we will use Big Data Analytic techniques to be discussed in future works.

As sun from tipycal observation day is shown in Fig 4 there is a diurnal variation in flux due to the misalignment of the telescope. The expected variation of the millimeter emission during the day is shown by the red curve. However what is observed by POEMAS is the black curve, where it is evident the variation close to noon due to instrumental problems.

To solve this problem, we carry out a subtraction of the previous and/or the next day observation (when available) of the same polarization brightness temperature. An example of this proceedure is shown in Fig 5, on 27 Jan 2012. On this day, a flare occurred, shown by the Greenwich. The background used for subtraction is a combination of the previous day (red curve) and the next day (blue curve), also shown before subtraction.

We apply a running mean on the reference curve. With the overlap of the observations in the three days, the coincidence between the reference curves (blue and red) and the day of the observed event (black), shows that there is little change from one day to another. Due to this small variation, we can use the data from the days before or after to correct the diurnal variation, thus obtaining the excess flux due to the solar flare.

The light curve of the flare after the background subtraction is depicted in Fig. 6. The gradual component of the flare is clearly at 45 GHz, which was not evident before the subtraction process.(Fig. 6)

4. Conclusions

This work is part of a larger project developed by CRAAM researchers and students. To reach our goal a great deal of programming, researching, and testing is needed, such as:

- Big Data Analytics for CRAAM-SVO.

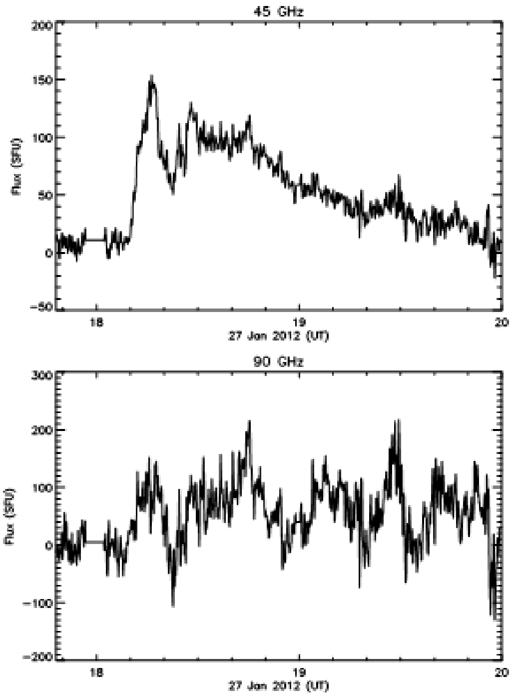

FIGURE 6. Light curve of the flare after the background subtraction (Silva 2016).

- Online pipeline calibration for background subtraction;
- Artificial Intelligence process to automatically detect solar flares.

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