Boletim da Sociedade Astronômica Brasileira, **37**, no. 1, 153-154

Automation and optimization of SP30T and AR30T telescope data

Ian Grinkraut, Guillermo Guiménez de Castro, & Amauri S. Kudaka

[1] Universidade Presbiteriana Mackenzie e-mail: iangrinkraut@gmail.com, guigue@craam.mackenzie.br, amauri.kudaka@mackenzie.br

Abstract. Solar observation in the mid-infrared (MIR, between 10 and 30 THz) region of the electromagnetic spectrum began very recently and has already made significant contributions to solar flare diagnostics. However, all MIR telescopes are ground-based, and therefore attenuated by atmospheric opacity. For this reason, only a few spectral windows can be used, requiring the use of "tuned" sensors (e.g., QWIP) or bolometers with band-pass filters. CRAAM has been successfully using commercial cameras with germanium filters that allow observation at a wavelength of 10 μm ± 2.5 μm. These cameras use proprietary software to generate videos in proprietary formats. The motivation for this research is to obtain a framework that leads to cost reduction in software usage and greater practicality for researchers during use. The proposed software will eliminate dependence on restricted software licenses, allowing the conversion of proprietary files to FITS files in an accessible, collaborative way adapted to CRAAM's needs. The methodology focuses on using the "FLIR Science File SDK" and conducting tests in collaboration with researchers. File readings have already been performed using the library and conversion to FITS files. Expected results include the complete automation of the telescope data capture and conversion process, allowing greater flexibility in thermal camera usage.

Resumo. A observação solar na região do infravermelho médio (IVM, entre 10 e 30 THz) do espectro eletromagnético começou muito recentemente e já realizou aportes significativos no diagnóstico de explosões solares. No entanto todos os telescópios para o IVM estão instalados em terra, e, portanto, atenuados pela opacidade atmosférica. Por esse motivo somente algumas janelas espectrais podem ser usadas e se faz necessário o uso de sensores "sintonizados" (e.g. QWIP) ou de bolômetros com filtros passa-banda. O CRAAM vem utilizando com grande sucesso câmeras comerciais com filtros de germânio que permitem a observação no comprimento de onda de 10 μm ± 2.5 μm. Estas câmeras utilizam software proprietário para gerar vídeos em formatos também proprietários. A motivação dessa pesquisa constitui-se na obtenção de um framework que leve a uma redução de custos na utilização do software e uma maior praticidade durante o uso dos pesquisadores. O software proposto eliminará a dependência de licenças de software restritas, permitindo a conversão de arquivos proprietários em arquivos FITS de forma acessível, colaborativa e adaptada às necessidades do CRAAM. A metodologia se centra no uso do "FLIR Science File SDK" e testes em colaboração com os pesquisadores. Já foram feitas leituras de arquivos utilizando-se a biblioteca e a conversão para arquivos FITS. Os resultados esperados incluem a automação completa do processo de captura e conversão dos dados do telescópio, permitindo maior flexibilidade no uso da câmera térmica.

Keywords. Infrared: general, Sun: flares, Methods: data analysis

1. Introduction

Historically, the MIR range has been little explored for investigating solar flares. However, in 2013, the detection of an intense impulsive pulse at 30 THz (10 μm) by the AR30T telescope demonstrated the relevance of terrestrial observations in this spectral window. To advance observation in this frequency range, the SP30T and AR30T telescopes were developed in 2012. These instruments aim to understand energy transport mechanisms and investigate emission mechanisms in the MIR/THz range (Kaufmann et al. 2013).

However, a significant barrier to the advancement of this research is the reliance on proprietary instrumentation and software. Both telescopes utilize FLIR (Forward Looking Infrared) technology cameras. The operation of these commercial systems relies on the proprietary software *FLIR ResearchIR Max*. This software, essential for recording and converting .SEQ files, imposes a financial barrier with a license cost exceeding US$ 10,000.00, restricted to a single machine. This prohibits broad access for researchers and limits scientific collaboration.

This work proposes the development of an open-source framework using Python to eliminate these costs. By automating the conversion of proprietary files to FITS (Flexible Image Transport System) and implementing robust calibration pipelines, we aim to democratize access to MIR solar data.

2. Methodology and Tools

The methodology is divided into two distinct phases: Phase 1 focuses on data acquisition and format conversion, while Phase 2 addresses calibration and standardization. A particular emphasis is placed here on the specific instrumentation characteristics that dictate the software requirements.

2.1. Instrumentation Characteristics

The project processes data from two ground-based instruments operating at a central frequency of 30 THz (10 μm). Both utilize uncooled microbolometer technology, but their optical and sensor configurations differ significantly, requiring adaptable software solutions (Lopez Araujo 2024; Lopez et al. 2022).

2.1.1. AR30T (Argentina)

Located at the Félix Aguilar Astronomical Observatory (OAFA) in the Argentine Andes at 2500 m altitude, the AR30T utilizes a Newtonian telescope with a 20 cm aperture diameter. This aperture results in a diffraction limit of 12.6 arcseconds. The instrument is mounted "piggy-back" on the HASTA telescope.

The sensor is a FLIR SC645 uncooled microbolometer. Due to the optical arrangement, the AR30T cannot record the full solar disk, necessitating precise pointing and jitter correction in software.

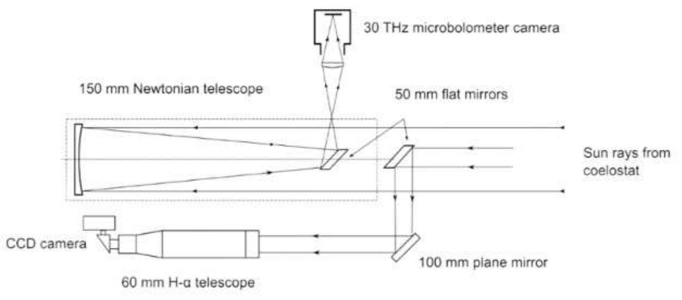

Figure 1. Illustration of how light enters the telescope and interacts with the acquisition methods: 30 THz frequency detection and CCD (Charge-Coupled Device) imaging.
Source: (Kudaka et al. 2015)

2.1.2. SP30T (Brazil)

Located at the Mackenzie Solar Observatory in São Paulo, the SP30T has a smaller aperture of 15 cm, implying a diffraction limit of approximately 17 arcseconds. It utilizes a Hale-type coelostat with two 20 cm flat mirrors to direct light to the telescope. Figure 1 shows the setup.

The camera is a FLIR ThermoVision A20 M (Giménez de Castro et al. 2018).

2.2. Software Development

To bypass the proprietary software, we utilized the FLIR Science File SDK to interface with the .SEQ files generated by these cameras. The conversion logic was implemented in Python. The workflow involves initializing the SDK, setting unit parameters to Kelvin, and iterating through frames to extract data into CSV format, which is subsequently converted to FITS using the ‘astropy.io.fits‘ library.

3. Expected Results

3.1. Automation and Accessibility

The primary expected result is the complete automation of the telescope data capture and conversion process. By replacing the proprietary *ResearchIR Max* with a Python-based tool, we eliminate the licensing cost barrier and allow data processing on any machine supporting Python.

3.2. First observation of this work

Initial investigations have already been conducted. An initial test for the software was performed on July 5, 2024 (Figure 2).

A recording of 60 frames of the Sun was successfully acquired using the proprietary software to generate initial test data, which was then processed by the new Python pipeline.

3.3. Calibration Deliverables

The software is expected to deliver "Level 1" scientific data by applying the following corrections to the raw "Level 0" data:

1. **Irregularity Removal:** Application of the Kuhn-Lin-Loranz (KLL) technique to remove fixed patterns (flat-field) and subtraction of dark currents (thermal noise) introduced by the uncooled microbolometers (Lopez et al. 2022; Lopez Araujo 2024).

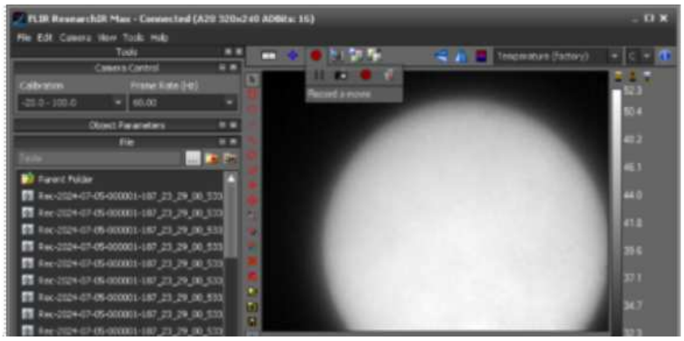

Figure 2. First observation registered by Amauri S. Kudaka of this work from the 60-frame test sequence acquired in July 2024.

2. **Physical Unit Conversion:** Conversion of camera temperatures (I) to Excess Brightness Temperature (T_b) using the Quiet Sun (T_{QS} = 5000 K) as a reference standard (Lopez et al. 2022; Lopez Araujo 2024).

4. Discussion and Future Work

The development of this tool is strategic for CRAAM. The MIR range is a new frontier in solar physics, but the instrumentation is subject to specific noise sources and geometric instabilities that must be rigorously corrected.

4.1. Future Work

The development timeline extends through early 2026. Immediate next steps involve refining the post-acquisition calibration modules in Python:

- **Geometric Correction (Feb 2026):** Implementation of cross-correlation algorithms to correct for jitter and image rotation. This includes resizing the Field of View (FOV) to 800 × 800 pixels to prevent data loss during rotation.
- **Astrometry (Feb-Mar 2026):** Integration of World Coordinate System (WCS) headers into the FITS files. This is crucial for multi-wavelength studies, allowing the overlay of 30 THz data with EUV images from SDO/AIA.

Acknowledgements. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Prosuc I

References

Giménez de Castro, C. G. et al. 2018, Space Weather, 1261
Kaufmann, P. et al. 2013, ApJ, 768, 134
Kudaka, A. S. et al. 2015, Sol. Phys., 290, 2373
Lopez Araujo, K. F. 2024, Evolution of a weak solar flare observed at 30 THz by the AR30T telescope, Master’s thesis, Univ. Presbiteriana Mackenzie
Lopez, F. M. et al. 2022, A&A, 663, A1
Silveira, E. 2014, Revista Pesquisa FAPESP, 219, https://revistapesquisa.fapesp.br/em-nova-frequencia/