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ASTROSAT/UVIT Photometry of PHAT Stars in M31

Megan Buick[1], Denis Leahy[1], Joe Postma[1], Cole Morgan[1], Luciana Bianchi[2], John Hutchings[3]
1. Dept. Physics and Astronomy, University of Calgary; 2. Dept. of Physics and Astronomy, JHU; 3. HIA, Victoria

Introduction

M31 is our closest neighbouring galaxy. Like our own, it is a spiral galaxy; however, since we are not inside it, we can use it to understand the structure of our own galaxy.

Many surveys have been performed on M31. The highest resolution survey is the Panchromatic Hubble Andromeda Treasury (PHAT), which can distinguish objects in the optical 5 to 10 milliarcseconds in size (Williams et al., 2014). PHAT used 6 filters from NUV to IR; the IR data is crowding-limited. The previous NUV/FUV survey of M31 was performed by Galex at a spatial resolution of 4 to 5 arcseconds (Kang et al., 2009).

The Ultraviolet Imaging Telescope (UVIT) has a spatial resolution of 1 arcsecond and field of view of 28 arcminutes. From 2017 to 2019, it surveyed M31 in 19 fields. All UVIT fields have data in the FUV CaF2 filter and more than half have data in NUV filters. The FUV filters cover the wavelength range 1200 to 1900 Angstroms and the NUV filters cover the range 2000 to 3000 Angstroms.

Previous work with UVIT on M31 carried out SED fits for 30 hot stars with PHAT data in the bulge (Leahy et al. 2018), created a UVIT catalog (Leahy et al. 2020a), and matched UVIT with Chandra sources for SED fitting (Leahy et al. 2020b).

For this analysis, UVIT fields 1, 2, 7, and 13 are considered as these are the regions overlapping PHAT that have NUV observations. The areas for PHAT and UVIT is shown in Figure 1.

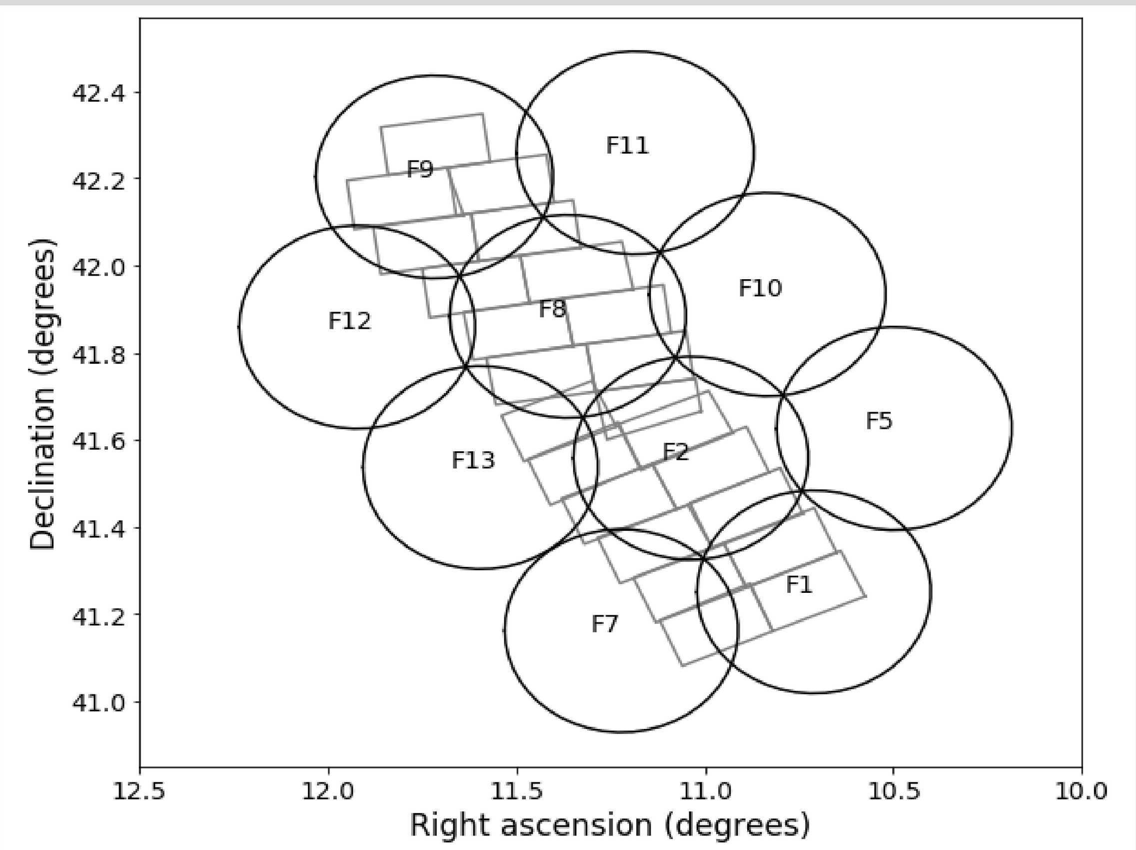

Figure 1. Comparison of the UVIT and PHAT areas.

References

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Acknowledgement

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Data Analysis

UVIT data are processed using the software package CCDLAB (Postma & Leahy, 2017). Since the previous version of this catalog, the data processing has been improved so that:

- CCDLAB calibrates the image to the sky using an auto-solving WCS algorithm (Postma & Leahy, 2020). This compares to the previous method of selecting ~ten sources by hand to calibrate the sky position.
- The UVIT detector distortion maps use a bilinear interpolation that acts on a scale of 1/32 pixels instead of a unit pixel scale.
- Separate flat field maps were used for each filter instead of an overall flat field map (Tandon et al., 2020).

This has led to an improvement in the astrometric errors and a reduction in the size of the Point Spread Function (PSF).

After calibration, star positions from PHAT with f275w Vega mag. brighter than 21.5 were inserted into CCDLAB and the corresponding magnitudes were measured in the CaF2, Silica, NUVB15, and NUVN2 filters for Regions 1, 2, 7, and 13. The sources were fit using a constrained, elliptical Gaussian on images that had undergone a 1.5 pixel convolution. For UVIT, one pixel is equal to 0.4168 arcseconds. Sources were only fit if they were at least 9 pixels from another source. Those closer were kept in a separate list for further analysis. A comparison between the PHAT and UVIT sources is shown in Figure 2.

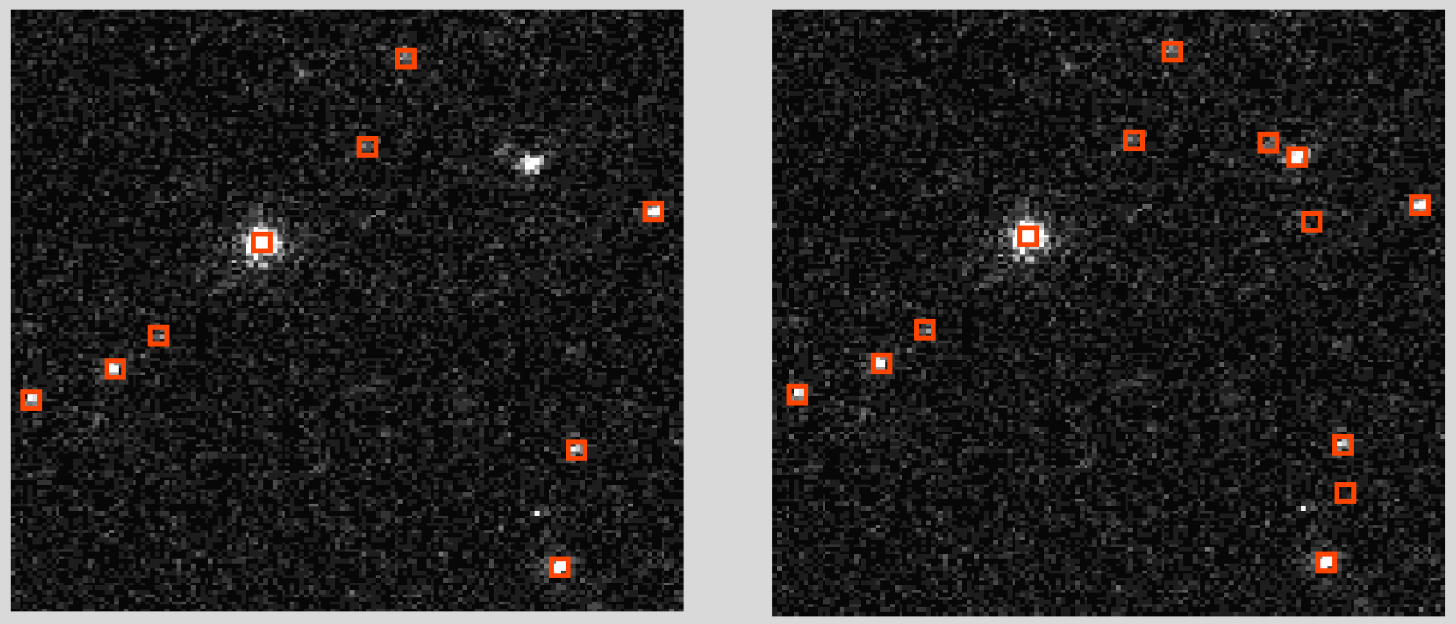

Figure 2. A small section from Field 2 NUVN2 filter, 63 arcseconds across, centred at coordinates are RA 00h44m24s and DEC 41d31'03". Sources fit in UVIT (left) and all sources in PHAT with Vega magnitude < 20.5 (right).

NUVN2 and PHAT F275w filters are both 275 nm band. Due to uncertainty in calibration of UVIT, a single offset was added to the NUVN2 magnitudes for all sources in Fields 1, 2, 7 and 13 to obtain good agreement with PHAT F275w magnitudes.

PHAT Stellar clusters (Johnson et al, 2015) are also detected with UVIT –some resolved by UVIT, others not. These will be studied separately by fitting UVIT and PHAT photometry with the appropriate analysis: stellar SED (resolved stars) or cluster SED models (unresolved stars), in order to study cluster properties in M31.

Discussion

Matching the obtained UVIT positions with Gaia, the mean difference in position is now 0.18±0.13 arcseconds. This is an improvement compared to the previous method of UVIT data processing, which gave 0.23±0.17 arcseconds (Leahy et al. 2020a).

A colour magnitude diagram (CMD) for the sources in Regions 1, 2, 7, and 13 is shown in Figure 3. The detection limit of UVIT is shown by a red dashed line and corresponds to approximately a B3V star with A_V=0.5. A fit for one source is shown in Figure 4.

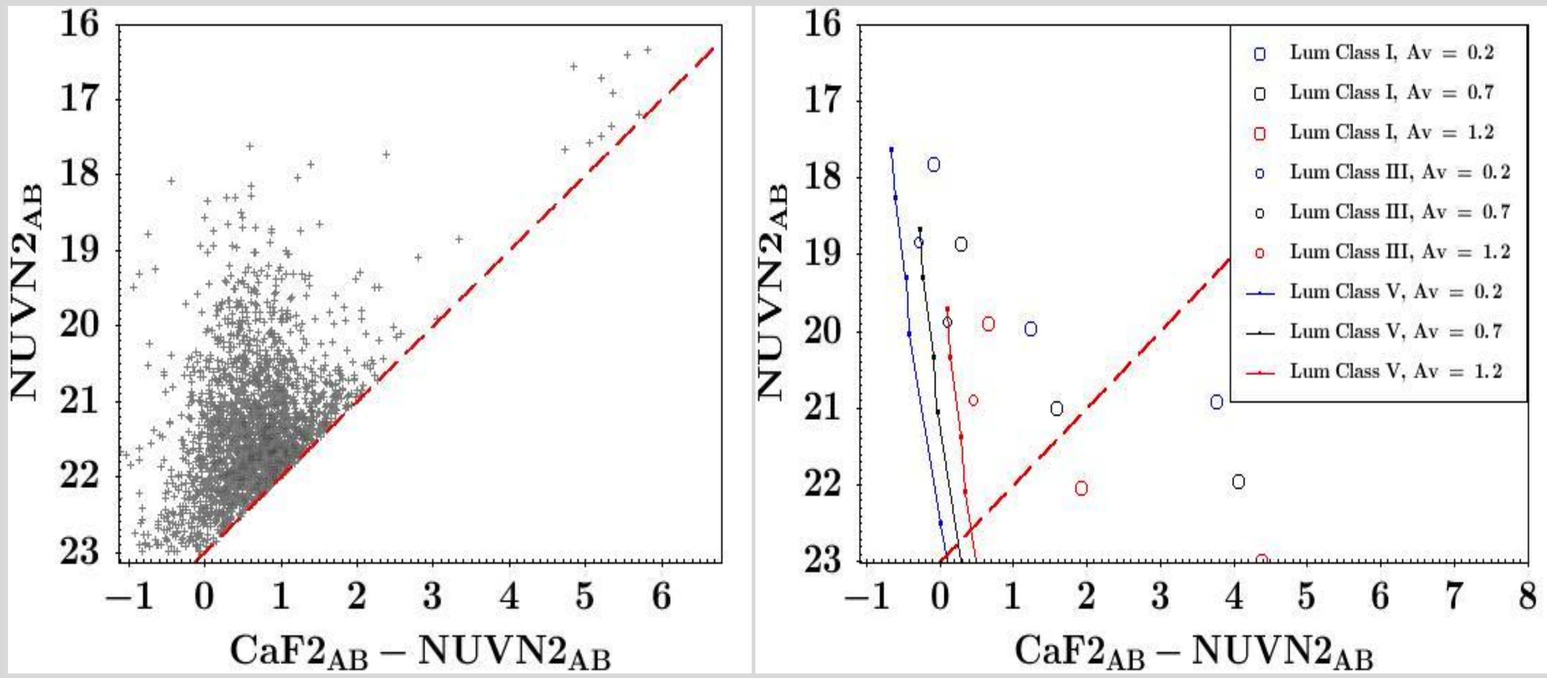

Figure 3. Colour magnitude diagram for the UVIT sources with the measured magnitudes (left) and theoretical magnitudes (right). Luminosity class V includes O3V, O5V, O8V, B0V, B3V (others are too faint and off the diagram); I includes B0I, A0I, F0I (others too faint); III includes B0III (others too faint). The red dashed line shows the approximate detection limit for the UVIT telescope.

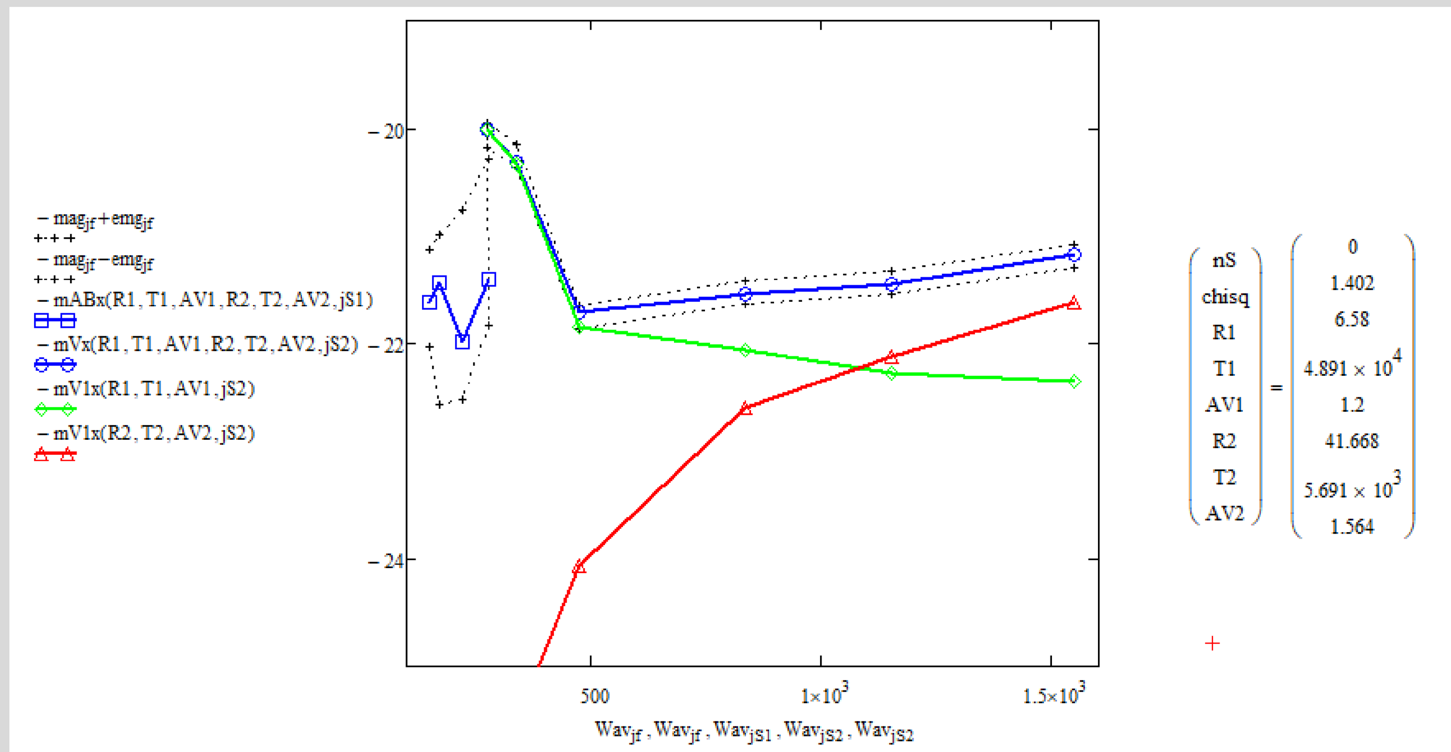

Figure 4: Fit of 2 component stellar spectrum (CK models) to the combined UVIT (4 data, AB magnitudes) plus PHAT (6 data, Vega magnitudes): best-fit is a hot star with T= 49 000K, radius 6.6 R_{sun} plus cool star with T=5700 K, radius 42 R_{sun}.

Conclusion: The UVIT data have been reprocessed with improved position and photometry, allowing identification of a large number of sources (~3000) with HST PHAT survey sources. The combined FUV-NUV- optical photometry (10 bands) is adequate to model the photometry of different sets of stars in M31 (work in preparation) and significantly improve our knowledge of the stellar populations.