Study of Galactic Structure Using UVIT/AstroSat Star Counts

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Introduction

The structure of Milky Way can be studied by analyzing star counts obtained from the large sky survey observations. The observations from the GALEX survey was first used to analyze the photometric data in UV region. UV star counts also help in identifying the white dwarfs (WDs) and blue horizontal branch (BHBs) which are evasive at other wavelengths due to their high temperature and low luminosities.

Data Reduction and Analysis

- We have observed five fields towards Galactic center (GC), Galactic anti-center (GAC), and South Galactic Pole (SGP) in NUVB4 and BaF2 filters of the UVIT telescope. The details of the observed fields are given in Table-1.
- We have used CCDLAB software (Postma & Leahy, 2017) and DAOPHOT package in IRAF software to reduce the data and to perform photometry. The obtained magnitudes were corrected for extinction using the extinction law of Cardelli et al. (1989).
- We have crossmatched the observed UVIT data using WISE + 2MASS survey within a match radius of 3” using CDS X-match and applied the IR color cut method (J-W1 > 1.2 mag, where J is 2MASS band at 1.24 µm and W1 is a WISE band at 3.4 µm) to separate out the extra-galactic sources.

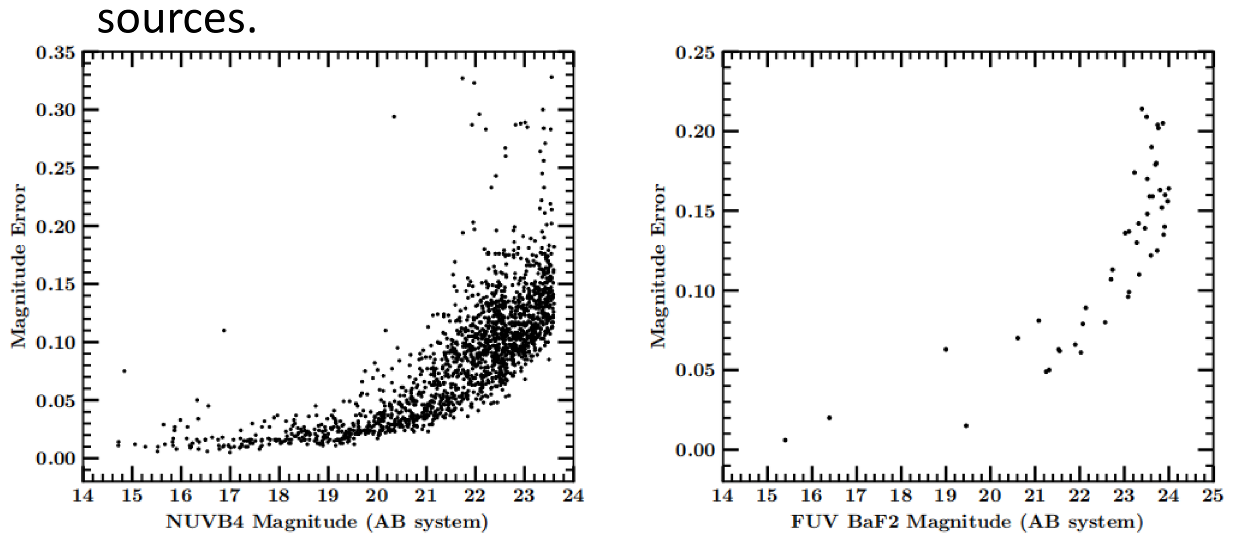

Figure.1: UVIT observed magnitudes plotted against their respective errors for the NUVB4 and BaF2 filters. Sources with errors less than 0.2 ABmag are retained.

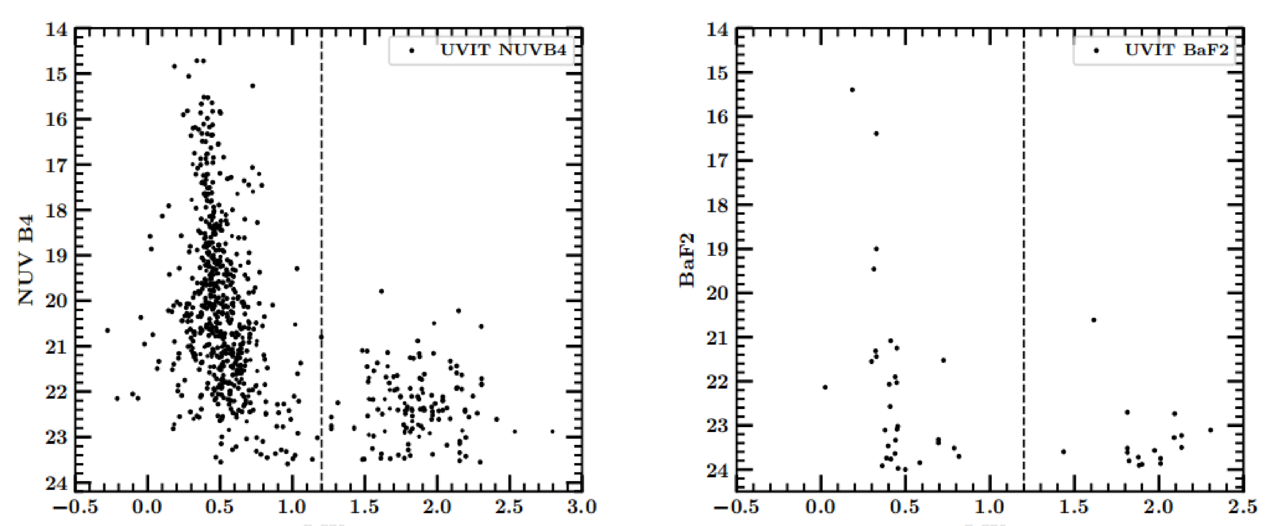

Figure.2: CMD, J-W1 vs NUVB4 (left) and J-W1 vs BaF2 (right). A vertical dashed line at J-W1 = 1.2 mag, separate the extra-galactic sources with J-W1 < 1.2 mag.

Table-1: The details of the UVIT observations of various Galactic fields.

Fields	Galactic positions		Filters	Exposure Time (s)
	RA (J2000)	DEC (J2000)		
GAC146-46	29.4583°	13.0000°	NUVB4	4,665
GC47-42	326.6767°	-8.6110°	BaF2	4,989
GC47-42	326.6767°	-8.6110°	NUVB4	5,521
SGP30-90	12.8583°	-27.1283°	NUVB4	4,638
GC15+60	222.3558°	14.9447°	NUVB4	5,718
GAC175+60	160.8379°	41.9471°	NUVB4	5,694

Besancon Model

- Besancon Model is a population synthesis model that takes various parameters as input such as star formation rate, initial mass function, and a set of evolutionary tracks to produce the star counts of different population.
- The main components of the Milky Way are thin disc, thick disc, bulge and halo (Robin et al, 2003, 2012). This model was extended to UV passbands by including GALEX and UVIT filters (Pradhan et al.,2014)

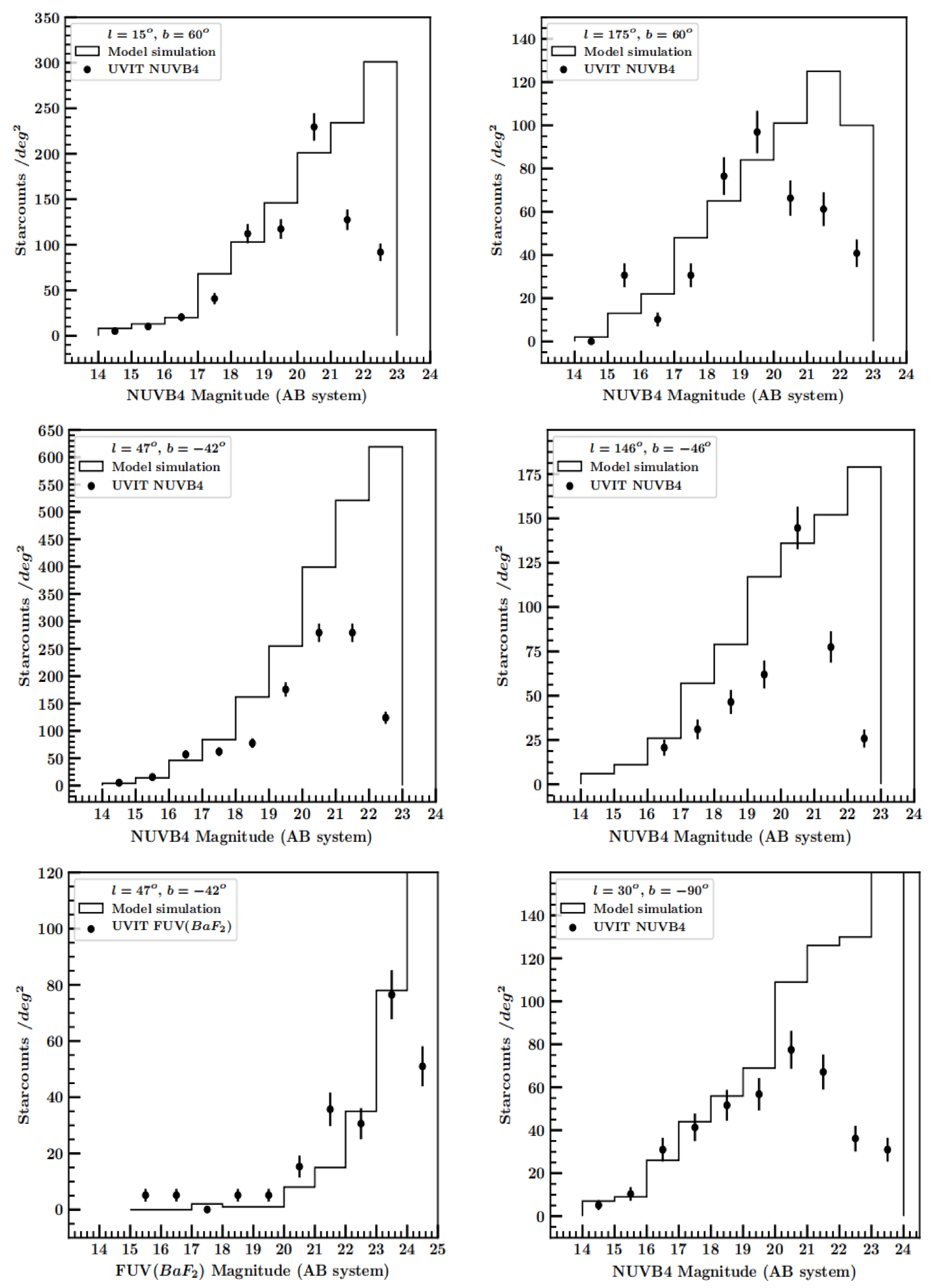

Figure.3: Model predicted star counts (solid line) compared with the UVIT star counts (solid circles). The star counts are binned in a magnitude interval of 1.0 ABmag.

Scale length and scale height of thick disc

- To derive the structural parameters of the galaxy using the star count method, we use the density law approximated by a double exponential:

$$\rho(R,z) = \rho(R_o) exp(-\frac{R-R_o}{h_R}) exp(-\frac{|z|}{h_z}),$$

where $\rho(R_o)$ is normalized stellar density at solar neighborhood, R_o = 8.33 ± 0.35 kpc, is the distance of the Sun from Galactic center, z = d sin(b), is height above Galactic plane, b is the Galactic latitude, R is Galectocentric distance projected on the Galactic plane, h_R, h_z are the scale length and scale height of the disc respectively.

- Star counts ratio between fields at the same Galactic latitude towards GC and GAC directions,

$$\frac{A_{GC}}{A_{GAC}} = exp(\frac{+2\,|R-R_o|}{h_R})$$

where $|R-R_o|$ = d cos (b), is the distance of stars from the sun on the Galactic plane. Scale length of the disc is obtained by,

$$h_R = \frac{2d\,cos(b)}{log(A_{GC}/A_{GAC})}$$

Table 2: Scale length and scale height of of think and thick disc using UVIT star counts.

Galactic positions		Thick disc		Thin disc
b	l	scale length (h_R, in kpc)	scale height (h_z, in pc)	scale height (h_z, in pc)
60°	15°	3.11	570 ± 54	320 ± 17
	175°	3.11	650 ± 49	280 ± 05
-42°	47°	5.40	530 ± 32	330 ± 11
	146°	5.40	630 ± 32	230 ± 20

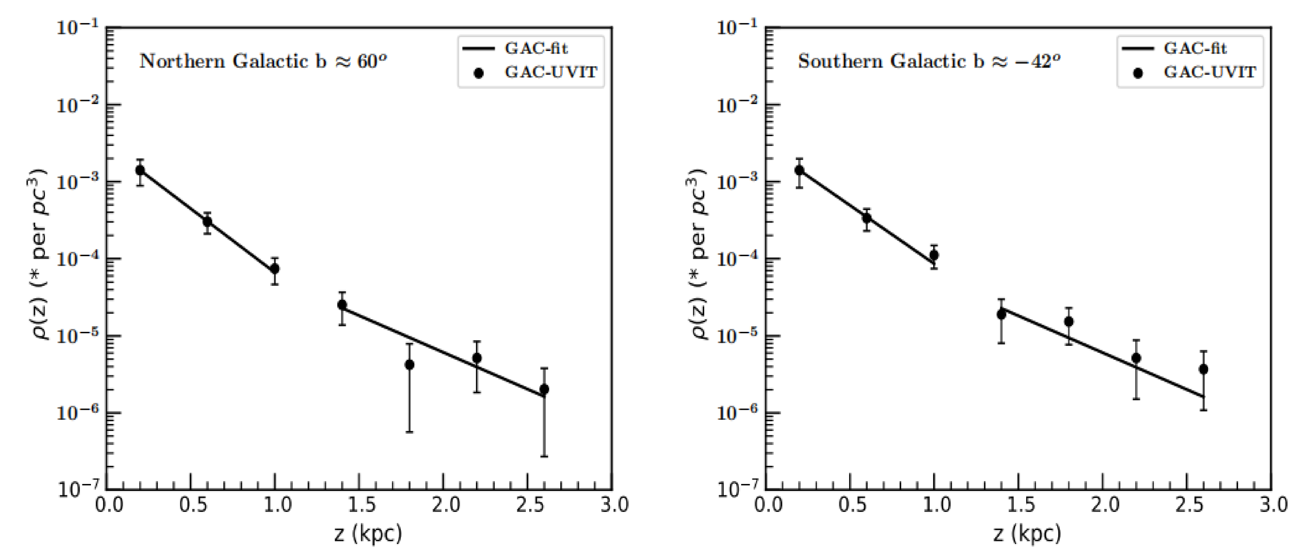

Figure.4: Space desity (counts per cubic parsec) vs. height above the Galactic plane (z, in kpc) for GAC fieldsat intermediate latitudes the northern (left panel) and southern (right panel) Galatic directions.

Results and Conclusion

- We found a turnover at z ∼ 1.2 kpc in space density of stars. This indicates the presence of two physically distinct components: a thin disc with z < 1.2 kpc and a thick disc with z > 1.2 kpc.
- We have fitted the exponential density laws for thin disc stars for z < 1.2 kpc and for thick disc stars from z ∼ 1.2 to 2.8 kpc.
- We have studied the UVIT star counts in different Galactic directions.
- The scale height ranges of thick disc and thin disc obtained from UV star count analysis are from 530 ± 32 pc to 630 ± 29 pc and 230 ± 20 pc to 330 ± 11 pc, respectively.
- Scale length of thick disc varies from 3.11 to 5.40 kpc.

Future Work

Here, we have only considered the analysis in one FUV and one NUV filter. In future, we will present our analysis by comparing model predictions in other filters of UVIT.

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