NUVA eMeeting 2024

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Detection of a new sample of Galactic White Dwarfs in the direction of the Small Magellanic Cloud

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with

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Motivation: UV Surveys to Identify White Dwarfs

- Using various optical and IR surveys, the census and characterization of cool white dwarfs has significantly improved in recent years. (eg: Gentile Fusillo et al. (2021), Gentile Fusillo et al. (2019), Kepler et al. (2016, 2019), Eisenstein et al. (2006) etc.)
- But, UV photometry combined with optical measurements significantly increases the sensitivity to the hottest temperatures.
- For example, the colour difference between a $T_{eff} =$ 50,000 K and 20,000 K star is about 1.5 mag in FUV-g, but <0.4 mag in U −B, and <0.15 mag in g − r which are comparable to photometric errors when large surveys are considered. (Bianchi et al. 2007a; Bianchi 2009)
- Bianchi et al. (2011) catalogued hot WDs in the milky way using GALEX.

AstroSat/UVIT - UltraViolet Imaging Telescope

- AstroSat is India's space observatory dedicated for multiwavelength astronomy. One of the five instruments onboard the AstroSat is the UltraViolet Imaging Telescope (UVIT).
- UVIT - two 38cm telescopes with three detection channels: FUV, NUV and Visible, with FOV of 28' with spatial resolution of about 1.5". Predecessor, GALEX has an FOV of 1.2° and spatial resolution of 5".
    - Far-UltraViolet (FUV) - 130 to 180 nm
    - Near-UltraViolet (NUV) - 200 to 300 nm.
    - Visible (VIS) - 320 to 550 nm.
- The UVIT data is publicly available from ISSDC AstroSat Archive.

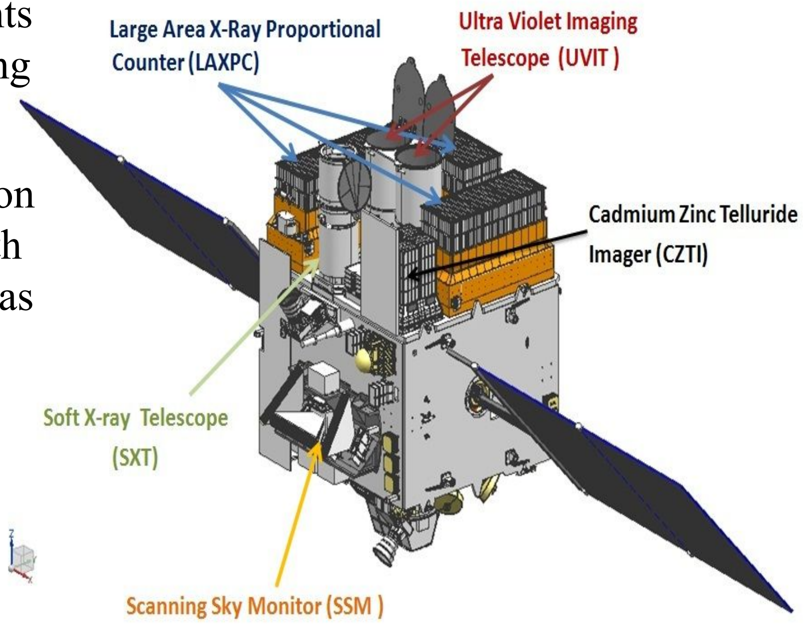
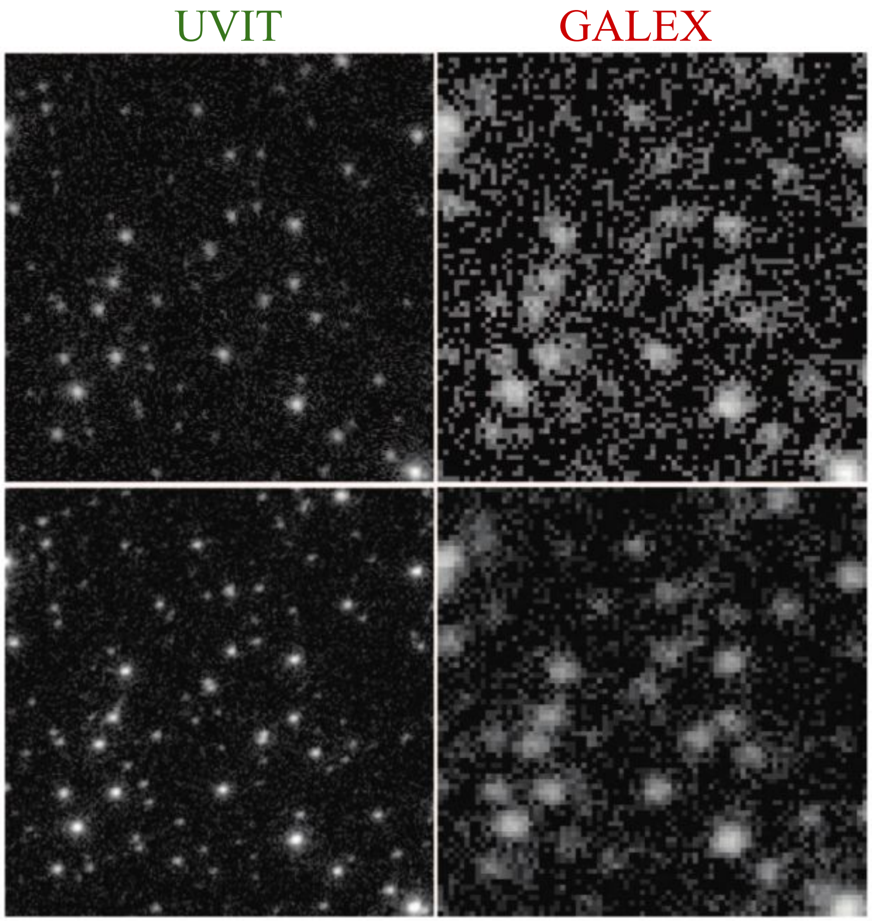


Figure 1: Illustration of AstroSat. Credits: *isro.gov.in/astrosat-0*



Advantages of UVIT over other UV missions

- Spatial resolution of Hubble Space Telescope (HST), the ultraviolet imaging telescope (UIT): 3”
- Spatial resolution of GALEX: 5”
- **Spatial resolution of UVIT: 1.5”**
- Data across **7 UV filters**

Figure 2: A 2′ × 2′ region of SMC-1 centered at α = 01:09:46.0, δ = −71:20:30.0. The top left panel shows the UVIT FUV image in F154W filter, while the top right panel is the GALEX FUV image. The bottom panels show the image of the same region in UVIT NUV in the N245M filter (left panel) and in GALEX NUV (right panel). Credits: Devaraj et al. (2023)

DATA

UVIT point source catalogue

- Devaraj et al. (2023)
- 3 fields towards the SMC (~ 40' FoV)
- 7 filters (F154W, F169M, F172M, N245M, N263M, N279N and N219M)
- Total no. of sources: 11,241

Gaia DR3

- UVIT catalogue was cross-matched with GAIA DR3 and with GAIA EDR3 distances (Bailer-Jones et al. 2021)
- Match radius: 1.5'' (Spatial resolution of UVIT)
- No. of sources: 10,847

Photometric & Astrometric Quality cut

- Flux in BP / Error of flux in BP ≥ 10
- Flux in RP / Error of flux in RP ≥ 10
- Flux in G / Error of flux in G ≥ 10
- Parallax / Error in Parallax ≥ 3
- Parallax ≥ 0
- $M_X / \sigma_{MX} \geq 10$

No. of sources after: 273

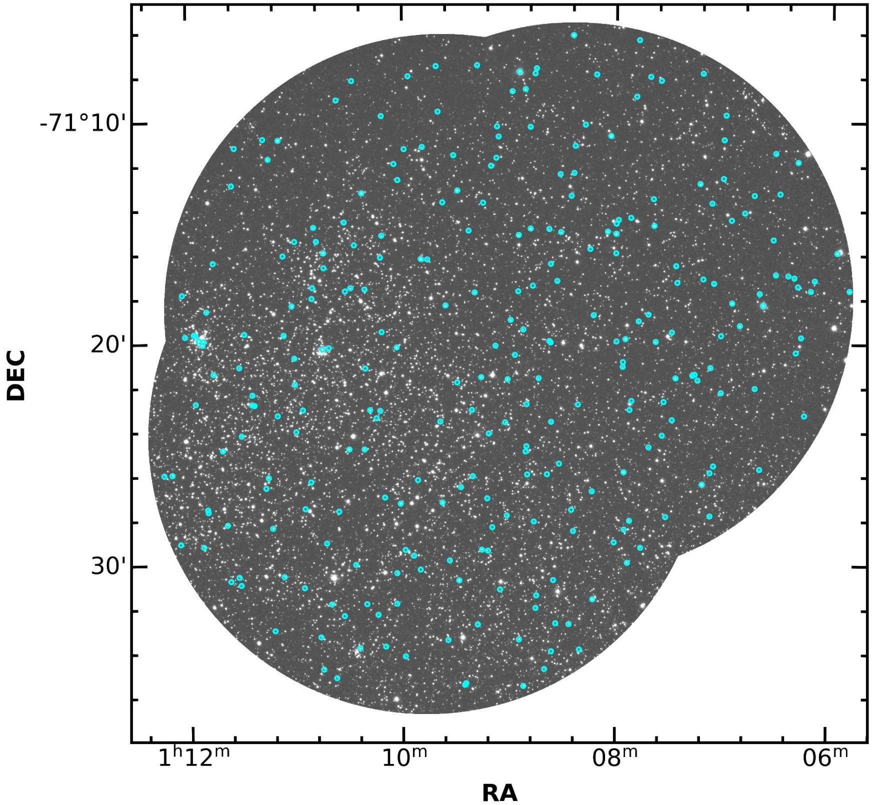


Figure 3: The greyscale mosaic of the three SMC fields observed by UVIT in the N245M filter. The sample of 273 sources in this study is given in cyan open circles.

Disentangling MS Sources and WD Sources

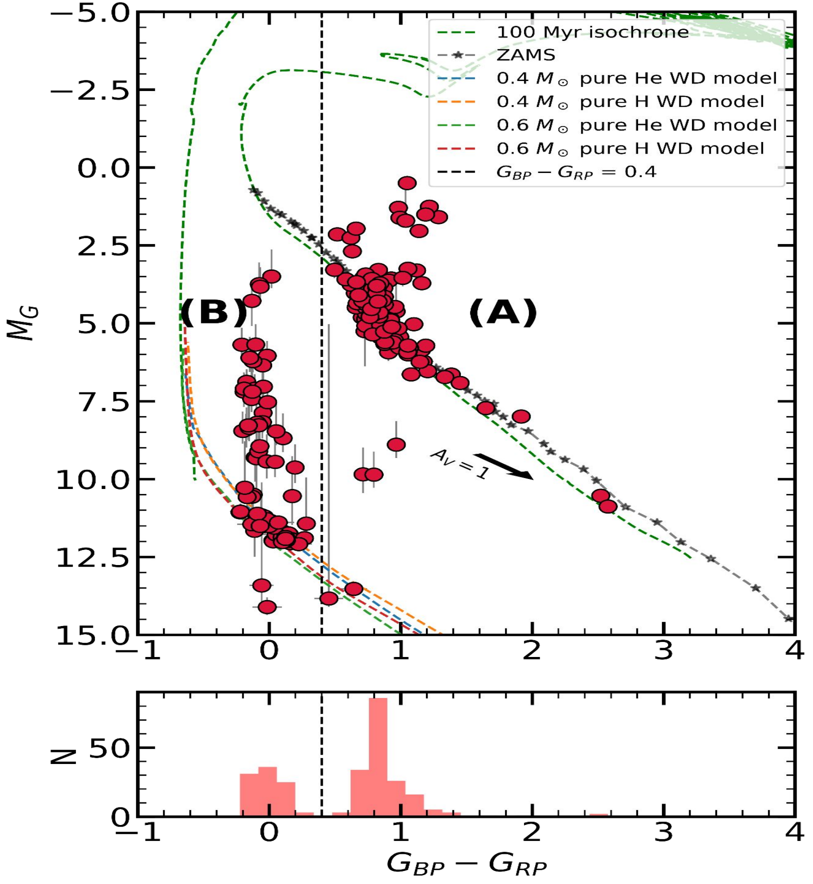


Figure 4: Extinction corrected Gaia CMD of the 273 sources

Spectral Energy Distribution (SED)

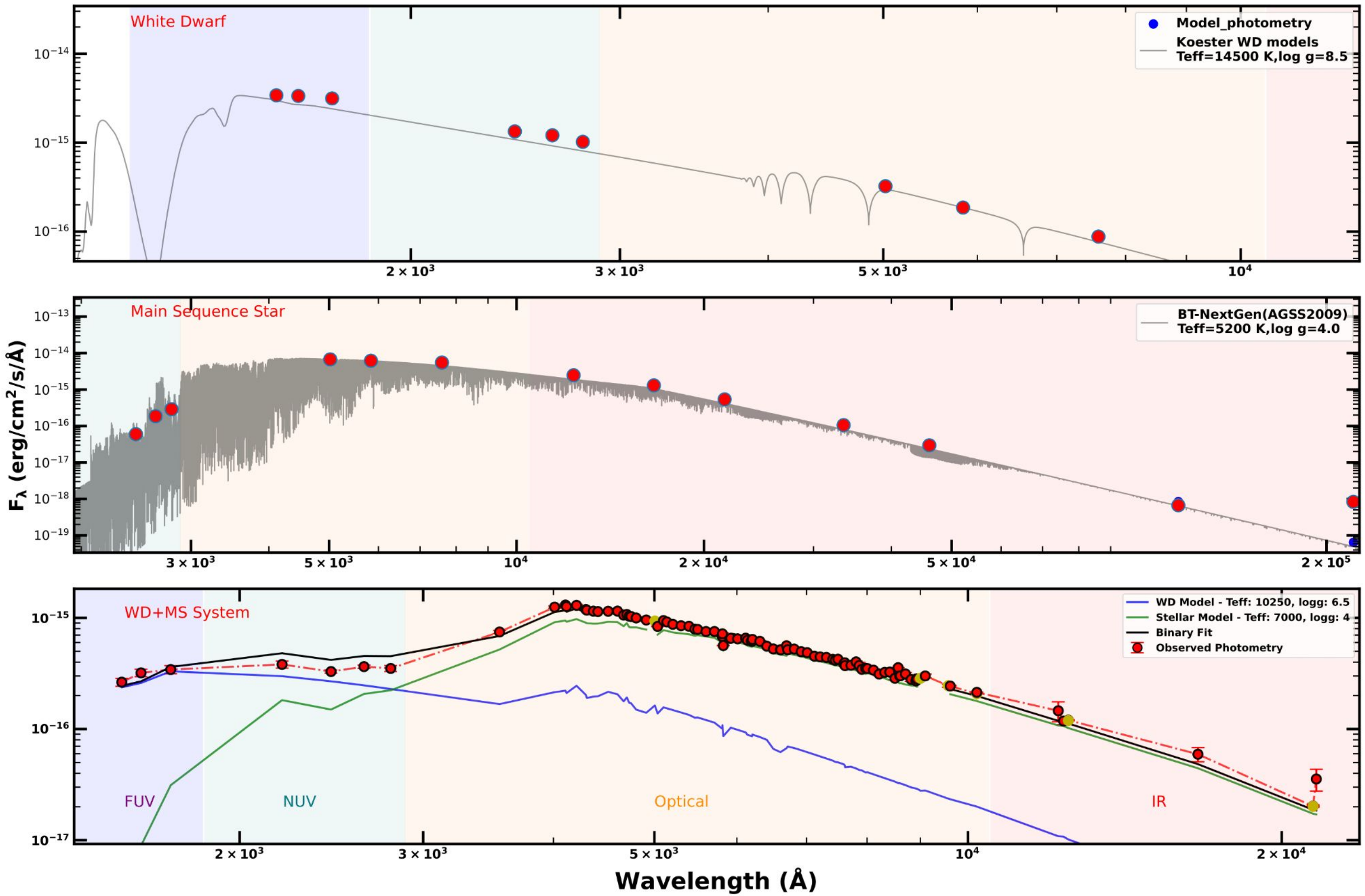


Figure 5: representative sample of SEDs of WD (Gaia DR3 4690625700572457088), MS star (Gaia DR3 4690614052626726016), WD+MS (Gaia DR3 4690657483318685312) over-plotted by their respective best-fitted models.

Disentangling MS Sources and WD Sources

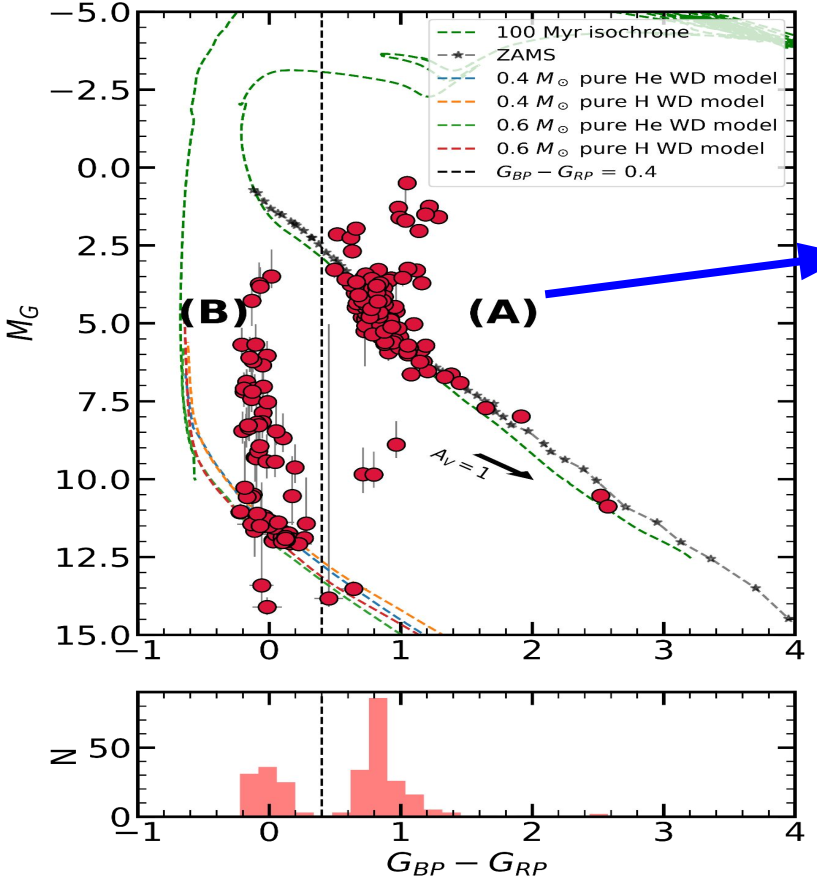


Figure 6: Extinction corrected Gaia CMD of the 273 sources

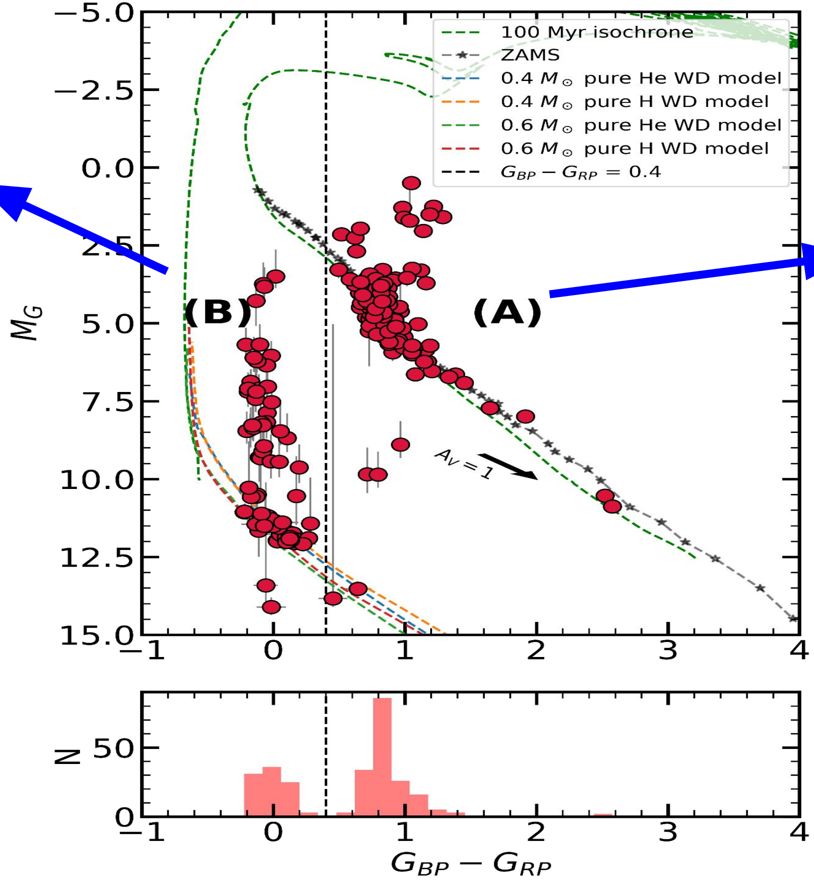
UV Bright MS Stars

- SED fit is done for the 177 potential MS stars using a python routine.
- Model used:
  Bt nextgen 2009
- 161 UV bright MS stars.

Disentangling MS Sources and WD Sources

White Dwarfs

- SED fit for the 96 potential WD systems using the same python routine.
- Koester WD models for pure H atmosphere.
- **43 Single WDs**
- **37 New detections!**



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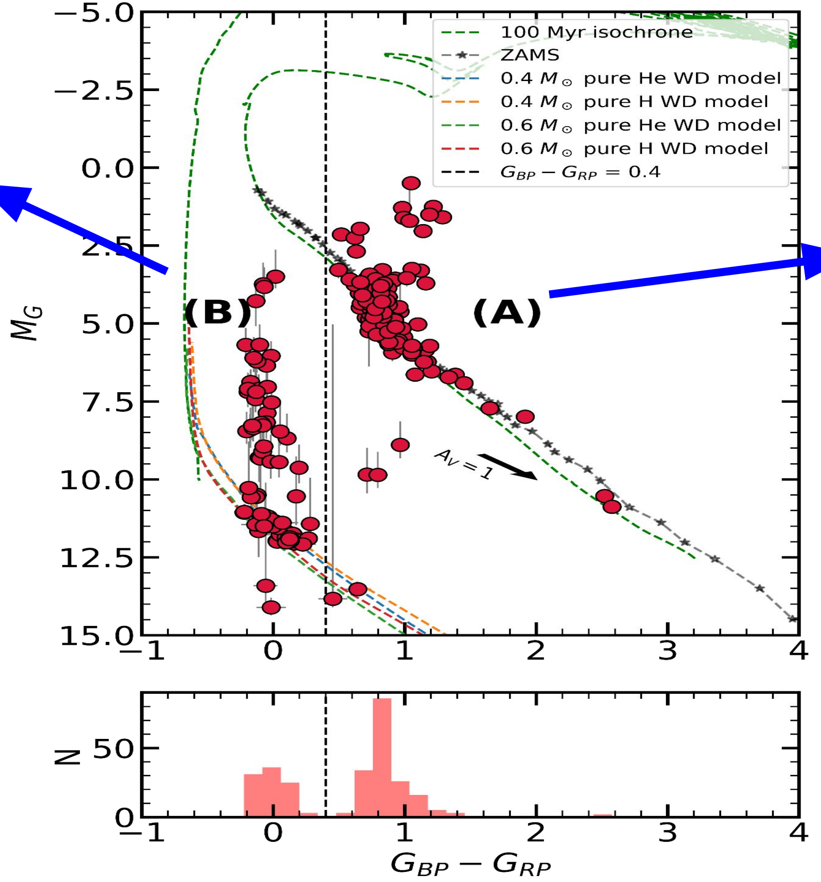
Single WD model didn't fit

WD+MS Binary

- Binary fitting for the sources showing IR excess
- MS: BT-Settl-CIFIST models (Baraffe et al. 2015)
- WD: Koester WD models
- 13 WD+MS candidates



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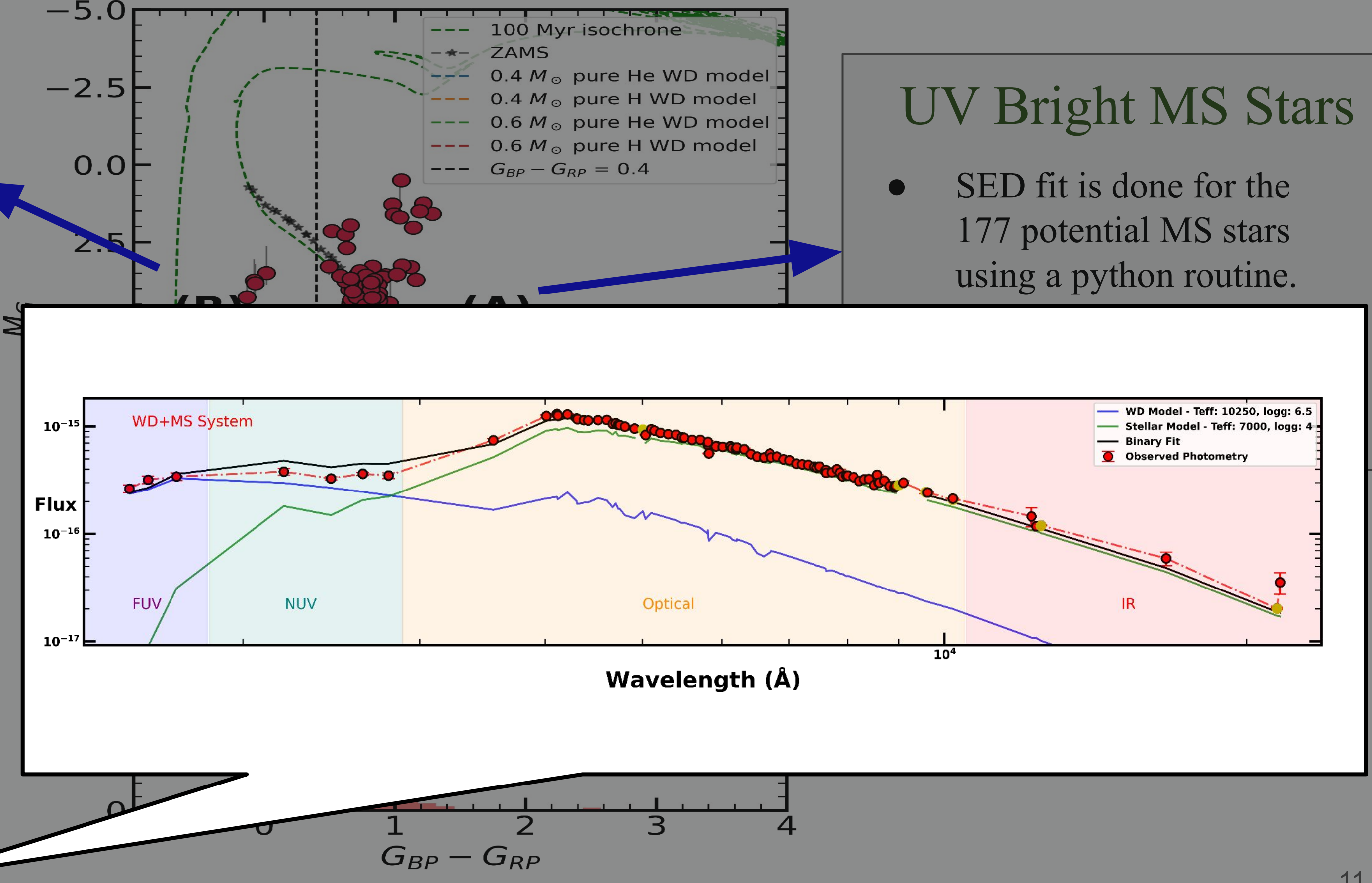

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20 ELM Candidates!

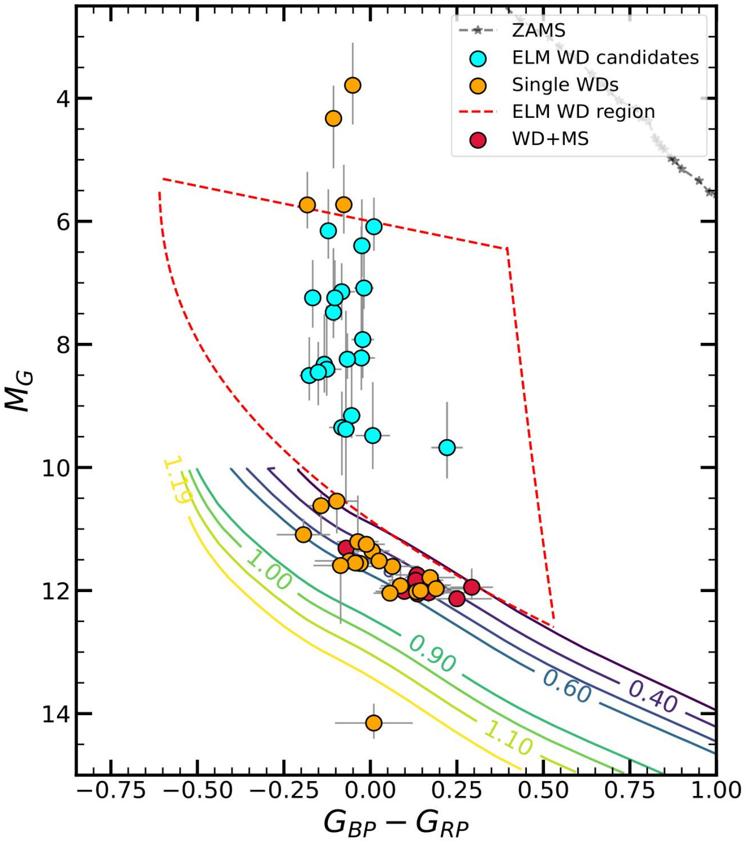


Figure 7: Extinction corrected Gaia CMD of single WDs and WD+MS candidates from our classification. The ELM region is marked with red dotted lines. The WD cooling models for different masses from Bédard et al. (2020) are also overlaid.

Estimation of Mass and the cooling age of WDs and WD+MS candidates

- WD mass and cooling age was estimated using theoretical cooling curves of WDs by Bédard et al. (2020)
- 20 out of 43 of our identified single White Dwarfs fall within the defined ELM region by Pelisoli & Vos (2019).

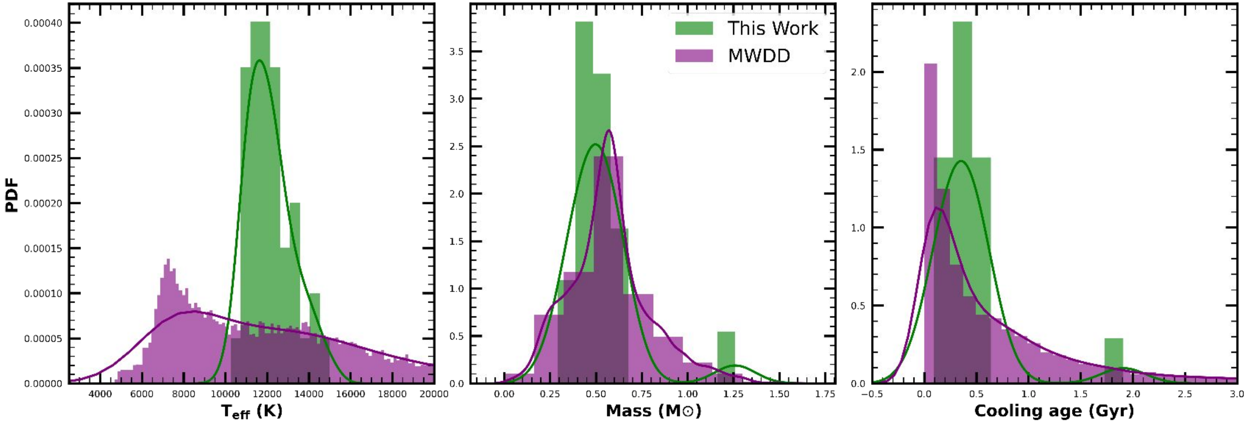
$$Mg < 5.25 + 6.94\ (BPmag - RPmag + 0.61)^{1/2.32}$$

$$Mg > 1.15\ (BPmag - RPmag)\ + 6.00$$

$$Mg > -42.2\ (BPmag - RPmag)^2 + 83.8(BPmag - RPmag) - 20.1$$

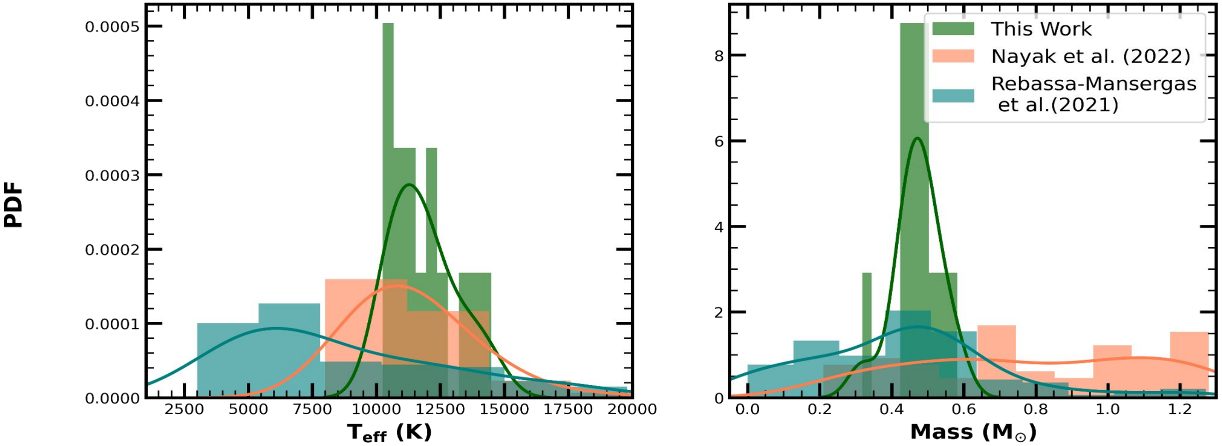
Comparison with existing WD and WD+MS catalogues

Single WDs



Hotter WDs!

WD+MS



Conclusion

- Using colour cuts and SED analysis, we identified 43 single WDs, out of which 37 are new detections.We also identified 13 WD+MS and 161 UV bright MS stars candidates.
- We estimated the mass and cooling age of the white dwarfs using model WD cooling curves and effective temperature from SED.
- We find that the masses of WDs identified in this study range from 0.2 $M_\odot$ to 1.3 $M_\odot$ and the T_{eff} from 10000 K to 15000 K. Cooling ages of these WDs range from 0.1 Gyr to 2 Gyr.
- We detect hotter WDs compared to literature values, which is attributed to the sensitivity of UVIT
- We report the detection of 20 ELM candidates.
- We provide an estimate of the WD space density within 1 kpc as 1.3×10^{-3} pc^{-3} , which is higher than previous estimates in the literature.
- Our results underscore the instrumental capabilities of UVIT and anticipate the forthcoming UV missions for systematic WD discovery.

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Astronomy & Astrophysics

Detection of a new sample of Galactic white dwarfs in the direction of the Small Magellanic Cloud

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ABSTRACT

Aims. In this study, we demonstrate the efficacy of the Ultraviolet Imaging Telescope (UVIT) in identifying and characterizing white dwarfs (WDs) within the Milky Way Galaxy.
Methods. Leveraging the UVIT point-source catalogue towards the Small Magellanic Cloud and cross-matching it with *Gaia* DR3 data, we identified 43 single WDs (37 new detections), 13 new WD+main-sequence candidates, and 161 UV bright main-sequence stars by analysing their spectral energy distributions. Using the WD evolutionary models, we determined the masses, effective temperatures, and cooling ages of these identified WDs.
Results. The masses of these WDs range from 0.2 to 1.3 $M_\odot$ and the effective temperatures (T_{eff}) lie between 10 000 K to 15 000 K, with cooling ages spanning 0.1–2 Gyr. Notably, we detect WDs that are hotter than reported in the literature, which we attribute to the sensitivity of UVIT. Furthermore, we report the detection of 20 new extremely low-mass candidates from our analysis. Future spectroscopic studies of the extremely low-mass candidates will help us understand the formation scenarios of these exotic objects. Despite limitations in *Gaia* DR3 distance measurements for optically faint WDs, we provide a crude estimate of the WD space density within 1kpc of 1.3×10^{-3} pc^{-3}, which is higher than previous estimates in the literature.
Conclusions. Our results underscore the instrumental capabilities of UVIT and anticipate forthcoming UV missions such as INSIST for systematic WD discovery. Our method sets a precedent for future analyses in other UVIT fields to find more WDs and perform spectroscopic studies to verify their candidacy.

Key words. techniques: photometric – binaries: general – Hertzsprung–Russell and C–M diagrams – white dwarfs – ultraviolet: stars

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I thank the organizing committee for giving this opportunity to present my work at this conference. All questions and comments are welcome!

Thank You!

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