Know thy star, know thy planet: Chemo-kinematically characterizing TESS targets

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ABSTRACT
The Transiting Exoplanet Survey Satellite (TESS) has already begun to discover what will ultimately be thousands of exoplanets around nearby cool bright stars. These potential host stars must be well-understood to accurately characterize exoplanets at the individual and population levels. We present a catalogue of the chemo-kinematic properties of 2,218,434 stars in the TESS Candidate Target List using survey data from Gaia DR2, APOGEE, GALAH, RAVE, LAMOST, and photometrically-derived stellar properties from SkyMapper. We compute kinematic thin disc, thick disc, and halo membership probabilities for these stars and find that though the majority of TESS targets are in the thin disc, 4% of them reside in the thick disc and <1% of them are in the halo. The TESS Objects of Interest in our sample also display similar contributions from the thin disc, thick disc, and halo with a majority of them being in the thin disc. We also explore metallicity and [$\alpha$/Fe] distributions for each Galactic component and show that each cross-matched survey exhibits metallicity and [$\alpha$/Fe] distribution functions that peak from higher to lower metallicity and lower to higher [$\alpha$/Fe] from the thin disc to the halo. This catalogue will be useful to explore planet occurrence rates, among other things, with respect to kinematics, component-membership, metallicity, or [$\alpha$/Fe].

Key words: (stars:) planetary systems – stars: solar-type – catalogues

1 INTRODUCTION
The search for exoplanets necessitates the detailed characterization of planet-hosting stars to map the diversity of exoplanets and ultimately understand the Galactic context of planet formation. Stars and their planets are formed from the same material, so determining the ages, compositions, and kinematics of planet-hosting stars is necessary to establish how, when, and under what conditions rocky planets and gas giants are created.

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this relationship inverts for gas giants which are twice as common around FGK stars than M dwarfs (Howard et al. 2012; Mulders et al. 2015). Decreasing host star $T_{\text{eff}}$ also correlates with higher planet occurrence (Howard et al. 2012). With these studies, it has become clearer that in order to find more Earth-like planets, we have to search for them around cooler and smaller stars.

These statistics have helped motivate the new generation planet finder satellite and successor to Kepler, TESS. TESS is actively obtaining light curves for $\sim 200,000$ main-sequence dwarf stars at 2-minute cadence as well as full frame images (FFI) for most of the sky every 30 minutes. It is targeting stars 30-100 times brighter than Kepler host stars to allow for easier follow-up and will cover 85% of the sky by the end of its primary mission. Simulations by Barclay et al. (2018) predict that TESS will find over 14,000 exoplanets, 2,100 of which would be smaller than Neptune and 280 of those would have radii less than 2 $\oplus$. The TESS 2-minute cadence and FFI observations will include a broad range of host stars in the different Galactic components, the thin disc, thick disc, and halo. This will help improve the link between the types of planets that exist around host stars with different properties and environments.

Characterization of the Galactic components has been carried out in both kinematic space and chemical space, for a multitude of stars in the solar neighborhood and to larger galactocentric radii, to study the thin disc, thick disc, and halo of the Milky Way (Freeman & Bland-Hawthorn 2002; Rix & Bovy 2013; Hayden et al. 2015). The thin disc is vertically thin (Bovy et al. 2012; Haywood et al. 2013), rotation dominated (Edvardsson et al. 1993; Rix & Bovy 2013), has a metallicity range of $-0.7 < [\text{Fe/H}] < +0.5$ dex (Bensby et al. 2014), and has ongoing star formation. The thick disc (Yoshii 1982; Gilmore & Reid 1983) has larger vertical scale-heights but smaller radial scale-lengths than the thin disc (Bovy et al. 2012; Haywood et al. 2013; Hayden et al. 2015), and has rotation but also higher velocity dispersion (Haywood et al. 2013; Kordopatis et al. 2013b). It is also chemically different than the thin disc, having lower metallicities and higher $[\alpha/\text{Fe}]$ (Edvardsson et al. 1993; Bensby et al. 2003; Kordopatis et al. 2013b; Nidever et al. 2014), pointing to a scenario where it is older than the thin disc. Alpha elements (O, Mg, Si, S, Ca) are dispersed into the interstellar medium due to core-collapse supernova (SN II). However, $[\alpha/\text{Fe}]$ goes down with time as supernova Type Ia (SNe Ia) events start to happen that contribute more Fe. Stars with enhanced $[\alpha/\text{Fe}]$ are formed from gas that was enriched primarily by core-collapse supernovae. Therefore, $[\alpha/\text{Fe}]$ is indicative of a stellar populations' star formation history, with stars having high $[\alpha/\text{Fe}]$ being older, on average.

Lastly, the halo is comprised of stars accreted from satellites and stars formed from rapid gas collapse during the Galaxy’s infancy (Eggen et al. 1962; Searle & Zinn 1978; Ibata et al. 1994; Belokurov et al. 2006). These stars are found to be very old and metal-poor (McWilliam 1997; Jofré & Weiss 2011; Hawkins et al. 2014). It could be further subdivided into an inner halo and outer halo that separate in space, kinematics, and metallicity (Carollo et al. 2010). Compared to the thin and thick discs, the halo has lower metallicities, higher $[\alpha/\text{Fe}]$, and is more pressure-supported (McWilliam et al. 1995; Carollo et al. 2010; Ishigaki et al. 2012).

Multiple astrometric, spectroscopic, and photometric surveys have improved our understanding of the Galaxy and its different components. We have positional and photometric information for 1.38 billion stars as well as radial velocities for 7 million stars brought by the Gaia mission (Gaia Collaboration et al. 2016), allowing us to make the most precise 3D map of the Milky Way to date. Large spectroscopic surveys have also been utilized to study the chemical make-up and cartography of the Milky Way. These surveys include the high-resolution infrared Apache Point Observatory (APO) Galactic Evolution Experiment (APOGEE; Majewski et al. 2017), which samples hundreds of thousands of evolved stars in the bulge, disc, and halo, and the optical Galactic Archaeology with Hermes (GALAH; De Silva et al. 2015) survey, which provides chemical abundances for 23 elements of very local dwarfs and giant stars. Other large spectroscopic surveys at lower resolution provide information for even more stars. These include the optical Radial Velocity Experiment (RAVE; Kunder et al. 2017), which aims to measure precise radial velocities for hundreds of thousands of dwarf and giant stars in the southern hemisphere and the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST; Cui et al. 2012), which provides stellar parameters for 5 million stars in the northern hemisphere. Each survey is important because they bring forth stellar parameters and metallicity (for some, also chemical abundances) for a statistically large sample of stars in various parts of the Galaxy, derived from the optical to the infrared.

Providing stellar parameters for even more stars are photometric surveys such as SkyMapper (Wolf et al. 2018), which has observations for 285 million stars in the Southern hemisphere. This has been utilized by Casagrande et al. (2019) and Deacon et al. (2019) to derive stellar parameters such as $T_{\text{eff}}$ and [Fe/H]. These surveys enable studies of the properties ($T_{\text{eff}}$ and [Fe/H]) of orders of magnitude more stars across the Galaxy than spectroscopic surveys.

We are now capable of studying the chemical and kinematic structure of the Milky Way in great detail, and with TESS discovering thousands of exoplanets in the coming years, it is imperative that we study these populations in their Galactic context and understand their host stars which is the goal of this study. Therefore, this paper is organized as follows: In Section 2 we outline the details of the surveys we have used to perform the chemical and kinematic analysis, in Section 3 we discuss the kinematic and chemical properties of 2,218,434 TESS host stars using the various photometric, astrometric, and spectroscopic surveys. We then tie together the chemistry and kinematics of TESS targets from the Candidate Target List (CTL) and TESS Objects of Interest (TOI) in Section 4. The results of this work are summarized in Section 5. We also provide the column names for the catalogue produced from this study (Table B1).

2 DATA

2.1 TESS

We use the TESS CTL v8.01, a refined list of targets made from the TESS Input Catalog (TIC) version

1 https://filtergraph.com/4701718
8 (Stassun et al. 2019). This version of TIC uses Gaia DR2 as base for better positions and parallaxes and as a result contains a total of ~1.7 billion point sources (See Appendix A1 for a comparison and discussion of TICv7). The expected TESS magnitude was calculated using relations with the Gaia G, G_{BP}, and G_{RP} photometry. The spectroscopically-determined $T_{\text{eff}}$ values (from catalogues listed in their Table 1) were provided if available, but otherwise, the photometrically-determined $T_{\text{eff}}$ values were given. The $T_{\text{eff}}$ is used to calculate radii, mass, and log g for the sources in TIC. The metallicity for an object is provided in the TIC if the star is cross-matched with the spectroscopic catalogues in their Table 1; for cases where there is more than one metallicity, the values are combined using a weighted-mean. Although the metallicity is included in the TIC, we independently cross-match the TESS targets with the individual spectroscopic and photometric surveys in order to avoid combining data (e.g., metallicity) with different selection effects.

The CTL was generated from a subset of the TIC as well as several curated lists including cool dwarfs (Muirhead et al. 2018, Muirhead et al., in prep.), hot subdwarfs (Geier et al. 2018, Marchetti et al. 2018a) includes radial velocities for 7.2 million stars which was used in Marchetti et al. (2018) to derive full 6D phase-space information in search of unbound stars in the Galaxy.

We use their kinematic catalogue for this study, specifically their derived UVW velocities. Since CTL v8 uses Gaia DR2 as base, it was straightforward to cross-match with the Marchetti et al. (2018) catalogue. We made quality cuts in the Gaia BP and RP photometry by removing the sources without these values, and applied the cut \( \text{Gaia}_{\text{astrometric, excess noise, sig}} \leq 2 \) following Marchetti et al. (2018), to ensure that we only select sources that are astrometrically well-behaved. We note that this cut preferentially deselects close or unresolved binaries (Evans 2018). We also applied a relative error cut to the total velocity, \( \nu \), such that \( \sigma_{\nu}/\nu < 0.3 \). This final sample, which we refer to as “TG” (for TESS cross-matched with Gaia), contains 2,218,434 sources. The decrease in the number of sources from 9.5 million to 2.2 million is due to the requirement of a Gaia radial velocity measurement. The net effect of this selection biases the TG sample to only include stars brighter than \( G \sim 14 \text{ mag} \) (Gaia Collaboration et al. 2018a).

The location of stars in the TG sample in the Milky Way is shown in Figure 1, where the Galactocentric radii and heights are derived using the distances from Bailer-Jones et al. (2018), which are computed in a Bayesian framework using a weak distance prior that varies as a function of Galactic position from Gaia DR2. Other distance catalogues also exist (e.g., Queiroz et al. 2018; Schönrich et al. 2019; Leung & Bovy 2019) but we choose Bailer-Jones et al. (2018) to be consistent with the analysis of Marchetti et al. (2018). Figure 2 shows a 2D histogram of the TG colour magnitude with the Marchetti et al. (2018) catalogue. We made quality cuts in the Gaia BP and RP photometry by removing the sources without these values, and applied the cut \( \text{Gaia}_{\text{astrometric, excess noise, sig}} \leq 2 \) following Marchetti et al. (2018), to ensure that we only select sources that are astrometrically well-behaved. We note that this cut preferentially deselects close or unresolved binaries (Evans 2018). We also applied a relative error cut to the total velocity, \( \nu \), such that \( \sigma_{\nu}/\nu < 0.3 \). This final sample, which we refer to as “TG” (for TESS cross-matched with Gaia), contains 2,218,434 sources. The decrease in the number of sources from 9.5 million to 2.2 million is due to the requirement of a Gaia radial velocity measurement. The net effect of this selection biases the TG sample to only include stars brighter than \( G \sim 14 \text{ mag} \) (Gaia Collaboration et al. 2018a).
diagram (CMD) showing that most of the targets are main sequence stars.

2.3 APOGEE

In addition to the astrometric and inferred kinematic data, we also take advantage of spectroscopic data from The Apache Point Observatory (APO) Galactic Evolution Experiment (APOGEE; Holtzman et al. 2018) DR14 that has 258,475 red giants stars and evolved stars. APOGEE has moderate spectral resolution (R ∼ 22,500) data taken in the H-band (1.5-1.7 μm), using the Sloan Foundation 2.5-m Telescope at APO. It uses fiber-plugged plates with a maximum simultaneous observation of 300 fibers for an area of 1.0 deg², enabling the acquisition of many stellar spectra at the same time. Since APOGEE is in the near-infrared, it is less sensitive to the effects of dust.

The spectra have been used to derive stellar parameters (log g, T eff, microturbulence, [Fe/H]) and abundances through the APOGEE Stellar Parameters and Chemical Abundances Pipeline (ASPCAP; García Pérez et al. 2016). ASPCAP determines the best-matching synthetic spectra (Zamora et al. 2015) with known stellar parameters to the observed spectra. We cross-match APOGEE with the TG sample using the 2MASS ID and applying the following quality control cuts: (1) STARFLAG = 0 to ensure no warnings on the observation, (2) ASPCAPFLAG = 0 to only select stars whose parameters have converged and have no warning flags, (3) [Fe/H] error <−9999, (4) signal-to-noise (SNR) > 80 to ensure high SNR, and (5) 4000 < T eff < 5500 K because estimates of ASPCAP outside this range are less reliable. This yields a final APOGEE-TG sample of 658 sources. We use the [Fe/H] and [α/Fe] in this study.

2.4 GALAH

In addition to APOGEE, we also use the Galactic Archaeology with Hermes (GALAH; Martell et al. 2017; Buder et al. 2018) survey. GALAH derives stellar parameters and chemical abundances for 342,682 stars in the Milky Way. It is a rich, high resolution (R ∼ 28,000) data set that enables us to understand the evolution of the Galaxy through a comprehensive list of abundances that range from light to neutron capture elements. It has four discrete wavelength channels within the range 4710-7890 Å taken with the HERMES Spectrograph at the 3.9-m Anglo-Australian Telescope. GALAH focuses primarily on stars in the disc, where most of the Milky Way’s stellar mass resides. Stellar parameters were determined in a two-stage process. First, ∼10,000 stars are used as training set, with stellar properties (e.g., log g, T eff, microturbulence, vsini, [Fe/H], and chemical abundances) determined through Spectroscopy Made Easy v3.60 (SME, Valenti & Piskunov 1996; Piskunov & Valenti 2017). Then these derived properties are used as labels to determine the stellar parameters and abundances for the rest of the GALAH sample using The Cannon (Ness et al. 2015).

For this study, we utilize GALAH DR2 released in April 2018 and the Gaia source ID to cross-match with the TG sample. We apply the following quality cuts: (1) flag_cannon = 0, (2) flag_x_fe = 0 for α elements to ensure no warnings and make sure we have reliable derived parameters, (3) SNR > 20, and (4) 4000 < T eff < 7000 K as the GALAH pipeline is not optimized for stars outside this range. Our meta-catalogue incorporates the [Fe/H], [α/Fe], log g, and T eff from the final GALAH-TG sample containing 32,517 sources.

2.5 RAVE

The fifth data release of the Radial Velocity Experiment (RAVE; Kunder et al. 2017) is a magnitude-limited (9 mag < I < 12 mag) spectroscopic survey with the goal of measuring precise radial velocities of stars with an accuracy of 1.5 kms⁻¹ as well as deriving T eff, log g, [Fe/H], and [X/Fe] (for X = Mg, Al, Si, Ti, Ni) for 457,588 randomly-selected stars in the southern hemisphere. It has a medium resolution of R ∼ 7,500 with a wavelength range spanning 8410-8795 Å which includes the Calcium triplet. Observations were taken at the 1.2m UK-Schmidt Telescope by the Australian Astronomical Observatory.

RAVE DR5, made available in November 2016, has improved surface gravities for giants and distances for metal-poor stars compared to RAVE DR4 (Kordopatis et al. 2013a) because of calibrations with asteroseismic data. The stellar parameters in RAVE DR5 were derived with the same pipeline as RAVE DR4: DEGAS (DEcision tree alogRithm for ASTronomy, Bijaoui et al. 2010) for the low SNR spectra and MATISSE (MATrix Inversion for Spectral Synthesis, Recio-Blanco et al. 2006) for the high SNR spectra. The RAVE data has also been re-analyzed with The Cannon (RAVE-on, Casey et al. 2016) trained on the APOGEE data set which does not include many dwarfs. We therefore chose to use the stellar parameters derived from RAVE DR5 to encompass the main TESS targets.

We use the 2MASS ID in the RAVE catalogue to cross-match with the TG sample. In doing so, the following quality cuts are applied: 1) Algo_Conv_K = 0 to ensure that the stellar parameter pipeline has converge, 2) SNR > 20, 3) c1, c2, c3 (spectra morphological flags) are n as prescribed in Kunder et al. (2017), 4) and Alpha_acc > −9.99. This yields 59,984 sources for the final cross-matched sample. We use [Fe/H], [α/Fe], log g, and T eff from this catalogue.

2.6 LAMOST

The Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST; Cui et al. 2012) is a 4.0-m reflecting Schmidt telescope at the Xinglong Observatory, northeast of Beijing, China. LAMOST has a 5 deg² field-of-view and aims to observe spectra for 10 million stars, galaxies and quasi-stellar objects (QSOs) in the span of 5 years. At a resolution of R=1800 spanning 3900-9000 Å, it is able to take spectra for 4000 objects in one exposure to a limiting magnitude of r=19. LAMOST DR5 (released June 2019) has obtained spectra for 5,348,712 stars in the northern hemisphere and produced a catalogue of heliocentric radial velocities, T eff, log g and [Fe/H] for these stars. LAMOST is targeting three main regions: the Galactic anti-center, the disc, and the halo.

Stellar parameters are derived using the LAMOST Stellr Parameter Pipeline (LASP, Wu et al. 2011; Luo et al. 2015) which implements the Correlation Function Initial
Deacon et al. (2019) derived stellar parameters for 939,457 sources, yielding a total of 500,007 stars. We include the TG sample with the Casagrande et al. (2019) using the InfraRed Flux Method (IRFM, Casagrande et al. 2010), which relates the ratio between bolometric and infrared flux to metallicities in GALAH, APOGEE, and RAVE. Since Casagrande et al. (2019) derived metallicities for 9 million stars using Equation 12 in their paper which relates the metallicity to these colour indices, and two others that trace [Fe/H] and log $\varepsilon$. This method requires multiple photometric bands in the optical and the infrared in order to get a bolometric flux.

Once the photometric zero points are determined, Casagrande et al. (2019) used the colours and $T_{\text{eff}}$ from IRMF to get stellar parameters for their whole sample, adopting and calibrating against the [Fe/H] and log $g$ for stars in common between SkyMapper and GALAH. Of particular importance to this study is their derivation of photometric metallicities which is aided by the SkyMapper $u$ and $v$ bands. They applied Principal Component Analysis (PCA) on different colour index relations and found that there are typically three components: a primary one due to temperature, and two others that trace [Fe/H] and log $g$. They derive the metallicities for 9 million stars using Equation 12 in their paper which relates the metallicity to these colour index relations. To validate their method, they compared these metallicities to GALAH, APOGEE, and RAVE. Since Casagrande et al. (2019) used GALAH [Fe/H] for calibration, there is no offset between the two surveys, with residuals having a standard deviation of 0.22 dex. Compared to APOGEE, there is a 0.01 dex offset (APOGEE metallicities being larger) with a 0.25 dex scatter and compared to RAVE, there is a 0.09 dex offset (SkyMapper metallicities being larger) with a scatter of 0.28 dex. Cross-matching the TG sample with the Casagrande et al. (2019) using the Gaia source ID, yields a total of 500,007 stars. We include the $T_{\text{eff}}$ and [Fe/H] from this survey.

2.7 Casagrande 2019

Casagrande et al. (2019) derived $T_{\text{eff}}$ and [Fe/H] for 9,033,662 stars in the Southern sky with the SkyMapper photometric survey (Wolf et al. 2018). SkyMapper has photometry for 285 million objects, taken on a 1.35m wide field survey telescope with 32 CCDs in Siding Spring Observatory, Australia. They use the $griz$ Sloan Digital Sky Survey filters (Fukugita et al. 1996), and SkyMapper filters $u$ and $v$ that are sensitive to hot stars and metallicity. Casagrande et al. (2019) determined the photometric zero point for SkyMapper using the InfraRed Flux Method (IRFM, Casagrande et al. 2010), which relates the ratio between bolometric and infrared flux to $T_{\text{eff}}$. This method requires multiple photometric bands in the optical and the infrared in order to get a bolometric flux.

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3 RESULTS

3.1 Kinematics

We adopt the kinematics from Marchetti et al. (2018) that use Gaia DR2 radial velocities, parallaxes, and proper motions. We refer the reader to their paper for details on deriving full 6D phase space information but we briefly discuss it here. One needs the distance to the source, derived from the parallax, $\pi$, in order to convert an apparent motion in the sky to an actual velocity with respect to the Galactic center. This total velocity is calculated using two approaches based on the relative parallax error, $f = \sigma_\pi / \pi$. For the first approach, the sample with the low parallax errors i.e. $0 < f < 0.1$, has distances derived from simply inverting the parallax. For the second approach, the sample with higher parallax errors i.e. $f > 0.1$ has distances derived from a Bayesian analysis following Bailer-Jones (2015), where they use a weak distance prior (i.e. exponentially decreasing space density prior) that changes with Galactic latitude and longitude.

The final data products include Galactic Cartesian velocities ($U,V,W$) which we convert to Local Standard of Rest (LSR) by subtracting $V = 238$ kms$^{-1}$, the adopted rotation velocity at the position of the Sun from Marchetti et al. (2018). Figure 3 shows the velocities in the UV, VW, and UW reference planes. We follow the convention where U is positive towards the direction of the Galactic center (GC),
V is positive for a star with the same rotational direction as the Sun going around the galaxy, with 0 at the same rotation as sources at the Sun’s distance, and W positive towards the north Galactic pole. Particularly in the UV plane, one can see substructures because of the presence of moving groups that have similar kinematics, possibly due to resonances with the bar and spiral arms (Skuljan et al. 1999; Quillen & Minchev 2005; Antoja et al. 2008; Bovy et al. 2009; Gaia Collaboration et al. 2018b; Trick et al. 2019).

We provide a quantitative metric for the thin disc, thick disc, and halo membership of TESS targets, following the membership determination from Appendix A of Bensby et al. 2014. There are other, more robust ways of determining the Galactic component membership of stars through using ages or [α/Fe] abundance; however, kinematics provide the simplest criteria that could be applied to the majority of the TESS targets. We therefore adopt this method, but caution the reader about the contamination between each Galactic components as would be discussed in Section 4.

This method assumes that the space velocities have Gaussian distributions,

\[ f = k \cdot \exp \left( \frac{(U_{\text{LSR}} - U_{\text{asym}})^2}{2\sigma_U^2} - \frac{(V_{\text{LSR}} - V_{\text{asym}})^2}{2\sigma_V^2} - \frac{W_{\text{LSR}}^2}{2\sigma_W^2} \right) \]

with \( k \) defined as \( (2\pi)^{3/2}\sigma_U\sigma_V\sigma_W)^{-1} \) for normalization, \( \sigma_U, \sigma_V, \) and \( \sigma_W \) are the velocity dispersions for each Galactic component, and \( V_{\text{asym}} \) and \( U_{\text{asym}} \) are the asymmetric drifts i.e. the mean tangential speed deviations from a circular velocity. We use the values listed in Table 1 to establish the relative probability for thick disc (TD) to thin disc (D) membership:

\[ \frac{TD}{D} = \frac{X_{TD}}{X_D} \frac{f_{TD}}{f_D} \]

where \( X \) is defined as the observed fraction of the stellar population in the Solar neighborhood. Thick disc to halo membership is calculated the same way. The majority of the TG sample as well as the majority of the sample from Bensby et al. (2014) are at distances well within the scale length of the thin disc. It is therefore adequate to assume the Solar neighborhood stellar population fractions for the rest of our sample.

We estimate the errors in the membership by performing a series of 500 Monte Carlo simulations, perturbing the observed Cartesian space velocities U, V, and W, by the errors reported in Marchetti et al. (2018) and adopting a Gaussian distribution for these errors. This leads to a distribution in \( f \) for the thin disc, thick disc, and halo, and consequently, a distribution in their relative probabilities. We quote the median values for \( \frac{TD}{D} \) and \( \frac{TD}{H} \) and the 16th and 84th
percentile for the lower and upper bounds, respectively, as not all the $f$ distributions are Gaussian in shape.

We show Toomre diagrams in Figure 4, with the vertical axis calculated as $\sqrt{U^2 + W^2}$. The diagrams are colour-coded by relative membership to the thin disc, thick disc, and halo. The Toomre diagram is helpful in determining the structure-membership because of the different contributions of rotation and velocity dispersion to each stellar population. In general, the disc shows evidence of rotation seen in the symmetry in the range of velocities around $V_{LSR} = 238 \text{ km s}^{-1}$, while the halo shows evidence of pressure support from high velocity dispersion. Using the relative probabilities, we assign the component memberships accordingly:

- thin disc: $TD/D < 0.5$ and $TD/H > 2$
- thick disc: $TD/D > 2$ and $TD/H > 2$
- halo: $TD/H < 0.5$ and $TD/D > 2$
- thick disc/thin disc: $0.5 < TD/D < 2$ and $TD/H > 2$
- thick disc/halo: $0.5 < TD/H < 2$ and $TD/D > 2$.

We find that 91.77% of the stars in the TG sample are in the thin disc; 3.64% in the thick disc, 0.16% in the halo, 3.00% in the thick disc - thin disc transition region, and 0.03% in the thick disc - halo transition region. The majority of the stars in the TG sample are from the kinematically defined thin disc. This is expected because TESS is targeting the nearest and brightest stars which would naturally originate from the thin disc. Further, the adopted values for the fraction of stellar population gives $X_D/X_{TD} = 9.4$, that is, we are 9 times more likely to find thin disc stars than thick disc stars. For comparison, we have applied other stellar population fractions in the literature (e.g. Reddy et al. 2006 with 0.93, 0.7, and 0.006 for the thin disc, thick disc, and halo, respectively) to get the kinematic membership of stars. This yielded similar contributions from each Galactic component at 94.16% for the thin disc, 3.14% for the thick disc, and 0.20% for the halo.

### 3.2 Atmospheric Parameters and Chemistry

We construct metallicity distribution functions (MDF) of the cross-matched TG sources with APOGEE, RAVE, GALAH, LAMOST, Casagrande et al. (2019), and Deacon et al. (2019) as shown in Figure 5 with the histogram normalized due to the varying number of targets available from each survey. We also show the CMD for these surveys in Figure 6 colour-coded by the metallicity. It is apparent in each survey CMD that the cross-matched TESS targets are indeed dwarfs and for the most part are the stars with lower absolute magnitudes (i.e. brighter than $M_G \sim 7.5$ mag) in the bigger TG sample (see Fig. 2), barring RAVE and LAMOST. The survey that shows the most difference is the APOGEE-crossmatched sample which covers a smaller parameter space than the other surveys, and contains stars with lower intrinsic brightness.

We obtained the difference in metallicities between each survey and find typical offsets of 0.00 to 0.50 dex with a median of 0.04 dex and scatters in the differences between 0.08 dex and 0.31 dex, with a median of 0.22 dex. Here we highlight the comparison between 249,152 stars in com-
From left to right: Gaia G-band magnitude vs \(G_{BP} - G_{RP}\) colours for stars in common between the TG sample and APOGEE, GALAH, RAVE, LAMOST, Casagrande et al. (2019), and Deacon et al. (2019), colour-coded by [Fe/H]. These color magnitude diagrams show that the majority of the TG-crossmatched samples are dwarfs.

The horizontal line shows where there is no difference between the two photometric metallicity catalogues. In general, the [Fe/H] from Casagrande et al. (2019) is lower than those from Deacon et al. (2019). This makes sense as both surveys use SkyMapper photometry, but the methods to derive [Fe/H] are different for both studies as discussed in Sections 2.7 and 2.8, respectively. Though the offset between Casagrande et al. (2019) and Deacon et al. (2019) is higher compared to the thin disc, which shows solar [\(\alpha/Fe\)] and higher metallicities. APOGEE, GALAH, and LAMOST show these trends with the two tracks, although the low metallicity, high-\(\alpha\) track is less populated, especially for APOGEE. The TG sample cross-matched with GALAH has an [\(\alpha/Fe\)] vs [Fe/H] trend that agrees with the larger GALAH sample (Buder et al. 2019). This makes sense as both the TESS CTL and GALAH overlap in their target sample i.e. nearby stars. On the other hand, the TG sample crossmatched with APOGEE has no giants by design, therefore the [\(\alpha/Fe\)] vs [Fe/H] trend in our study does not reflect that of the larger APOGEE sample (Holtzman et al. 2018). The RAVE [\(\alpha/Fe\)] vs [Fe/H] track does not show the same dichotomy as the other surveys. This is due to RAVE having lower resolution (R~7500) as well as a significantly shorter wavelength range (8410-8795 Å) compared to APOGEE and GALAH. The uncertainty in the [Fe/H] and [\(\alpha/Fe\)] in RAVE are both 0.2 dex, which also affects the distinction between the thin disc and thick disc trends (see Section 8 in Kunder et al. 2017). Nonetheless, we decide to report the [\(\alpha/Fe\)] from RAVE as we have applied the necessary flags suggested by Kunder et al. (2017).

3.3 The Catalogue

The chemo-kinematic properties of TESS host stars from the CTL cross-matched with Gaia DR2, APOGEE, GALAH, LAMOST, RAVE, Casagrande et al. (2019), and Deacon et al. (2019) are provided as a table with the columns listed in Table B1. The catalogue consists of the TG sample and includes information from the TESS CTL, astrometry and photometry from Gaia DR2, 6D phase space information from Marchetti et al. (2018), distances from Bailer-Jones et al. (2018), \(T_{\text{eff}}\), log \(g\), spectroscopic and photometric [Fe/H], and [\(\alpha/Fe\)] from APOGEE, GALAH, RAVE, LAMOST, Casagrande et al. (2019) and Deacon et al. (2019) where available, and kinematic membership probabilities to the thin disc, thick disc, and halo (as discussed is Sec-
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4 DISCUSSION

4.1 Tying Chemistry and Kinematics

We explore the kinematics of TESS host stars and investigate their chemistry using the spectroscopic and photometric surveys. In Figure 9, we use the spectroscopic and photometric metallicity to colour-code the cross-matched stars in the Toomre diagrams. Note that the range of the colour bars i.e., [Fe/H] is different for each survey. The Toomre diagrams of each survey show that stars belonging to the thin disc, thick disc, and halo have different characteristic metallicities. We also use the [$\alpha$/Fe] from APOGEE, GALAH, RAVE, and LAMOST to represent a third quantity in the Toomre diagrams shown in Figure 10. Similar to Figure 9, the different Galactic components show varying characteristic [$\alpha$/Fe] except for RAVE, as discussed in Section 3.2.

We analyze the chemistry of TESS host stars for different kinematic memberships. In Figure 5, we demonstrated that in general, the MDFs peak just slightly above or below solar metallicity for all the surveys. The MDFs also show a long tail towards lower metallicities. These results confirm that the majority of TESS CTL stars are nearby and mostly part of the thin disc, but that there are also stars from the thick disc and halo at lower metallicities. Using the same membership criteria from Section 3.1, we plot the MDFs and [$\alpha$/Fe] distribution functions (\(\alpha\)DF) for each kinematically-defined Galactic component – thin disc, thick disc, and halo – in Figure 11 using metallicities and [$\alpha$/Fe] (where available) from APOGEE, GALAH, RAVE, LAMOST, Casagrande et al. (2019), and Deacon et al. (2019).

4.1.1 Thin Disc

The fraction of the TG cross-matched thin disc stars in each survey is ~90%, which is similar to that of the complete TG except for APOGEE (98%, see Figure 11). The metallicities for the thin disc stars in Figure 9, shown as diamonds concentrated around (0,0), are higher compared to the rest of the TG cross-matched sample. This is also seen in the thin disc MDF in Figure 11 where all the surveys peak at
Figure 9. Toomre diagram (in LSR) colour-coded by metallicity for the TG sample cross-matched with APOGEE, GALAH, RAVE, LAMOST, Casagrande et al. 2019 and Deacon et al. 2019. We also show different symbols for the kinematic thin disc (diamond), thick disc (plus), and halo (triangle) stars as discussed in Section 3.1.

Around $[\text{Fe/H}] = 0 \pm 0.2$ dex, APOGEE shows the lowest dispersion in MDF (though highly negatively skewed), followed by LAMOST and GALAH, and then by RAVE, Casagrande et al. (2019), and Deacon et al. (2019).

We also show $[\alpha/\text{Fe}]$ when available (APOGEE, GALAH, RAVE, and LAMOST). The $[\alpha/\text{Fe}]$ values for the thin disc stars are the lowest of all the Galactic components as shown in Figure 10. This is confirmed by the $\alpha$DF in Figure 11 which shows that both APOGEE and GALAH peak at $[\alpha/\text{Fe}] = 0$ dex and are positively skewed. RAVE, on the other hand, is more Gaussian-shaped, peaks at $[\alpha/\text{Fe}] = 0.20$ dex, and extends to both higher and lower $[\alpha/\text{Fe}]$ values compared to APOGEE and GALAH. LAMOST is somewhere in the middle, peaking at $[\alpha/\text{Fe}] = 0.07$ dex.

We use the $[\alpha/\text{Fe}]$ vs $[\text{Fe/H}]$ diagram to distinguish the estimated contamination fraction of chemical thick disc stars to the kinematic thin disc following the works of Weinberg et al. (2018) and Buder et al. (2019) for APOGEE and GALAH, respectively. We also estimated this dividing line by eye for the LAMOST data. We show in Figure 8 the di-
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Figure 10. Left to right from top to bottom: Toomre diagram (in LSR) colour-coded by $\alpha$/Fe abundance ratio for the TG sample cross-matched with APOGEE, GALAH, RAVE, and LAMOST with different symbols for the kinematic thin disc (diamond), thick disc (plus), and halo (triangle) stars.

vinding lines for the thin disc and thick disc that we use for this analysis. Only 1% of the kinematic thin disc seem to be chemical thick disc stars for APOGEE, while it is 12% for GALAH and 13% for LAMOST. We caution that disentangling the two populations is not fool proof as they overlap at higher metallicities. We also did not do this for the TG cross-matched with RAVE because of its uncertainties that blur the distinction between the two populations.

We now compare the TG kinematic thin disc’s chemistry to abundances in the literature. Hayden et al. (2015) shows the MDF and $\alpha$DF for APOGEE DR12 stars in different Galactic locations that have varying contributions from the chemically-defined thin disc and thick disc stars. Their MDF and $\alpha$DF that best match what we see for our kinematic thin disc stars are those within the solar neighborhood i.e. $7 < R < 9$ kpc and in the plane of the disc. Buder et al. (2019) used GALAH to make $\alpha$DFs for stars in different metallicity bins (see their Figure 13) and show that for the higher metallicity bins with the greater contribution from thin disc stars (i.e. $[\text{Fe/H}] > -0.45$ dex), $[\alpha/\text{Fe}]$ has a primary peak at $0 < [\alpha/\text{Fe}] < 0.13$ dex and a secondary peak at $0.13 < [\alpha/\text{Fe}] < 0.2$ dex, which we do not see in our GALAH $\alpha$DF but is hinted at by the estimated contamination fraction.

Other authors have defined the thin disc with alternative ways. For example, Boeche et al. (2013) used RAVE and assigned component-membership based on a $Z_{\text{max}}$ vs $e$ diagram, where $Z_{\text{max}}$ is a star’s maximum distance from the Galactic plane and $e$ is its orbital eccentricity, with thin disc stars having low values for both quantities. Their thin disc MDF peaks at a lower metallicity ($[\text{Fe/H}] = -0.20$ dex) compared to stars from APOGEE, GALAH, LAMOST, and Deacon et al. (2019). They also show a $\alpha$DF where the thin disc component peaks at $\sim 0.20$ dex, similar to what we find for the TG sample cross-matched with RAVE, but not to the TG sample cross-matched with APOGEE, GALAH, and LAMOST. Wang et al. (2019) added an important quantity in Galactic component separation, age, and used LAMOST to examine the MDF and $\alpha$DF for similarly-aged populations in different Galactic locations. Comparing their thin disc MDFs to ours, their stars younger than 8 Gyr and between $6 < R < 9$ kpc at heights $> 0.3$ kpc and younger than 8 Gyr at the same Galactocentric radii show the same trends as our $\alpha$DF.

In addition to observations, it is also important to contrast our results with simulations. Comparison with models from Minchev et al. 2014 (see their Figure 9), who tested whether migration of stars explains why we see the changing skewness in the MDF, show that our thin disc chemistry
Figure 11. MDF and $\alpha$DF for the kinematically-defined thin disc (top left), thick disc (top right), and halo (bottom) as defined in Section 3.1. The MDF peaks at lower values while the $\alpha$DF peaks at higher values for all surveys as one goes from the thin disc and to the halo.

is consistent with their sample within $7 < R < 11$ kpc and are confined to the smallest scale height.

From these comparisons, it is evident that the TG kinematic thin disc sample mainly probes stars in the Solar neighborhood i.e. closer to the plane of the disc and at similar Galactocentric radii as the Sun. Since the thin disc in all TG cross-matched surveys peak at higher metallicity than the thick disc and halo, we would expect to discover more gas giants around stars that belong to this component (Fischer & Valenti 2005).
4.1.2 Thick Disc

The TG cross-matched thick disc stars from each survey again show similar percentages compared to the whole TG sample (4%) except for APOGEE which has a lower percentage of thick disc stars at 0.61%. The thick disc stars (plus) in Figure 9 show a lower range of metallicities compared to thin disc stars (diamond) as is expected. This is also evident in the thick disc MDF in Figure 11 where all the surveys peak between -0.9 < [Fe/H] < -0.3 dex.

We also explore the [α/Fe] of the thick disc stars in Figure 10 that show qualitatively higher [α/Fe] values than the thin disc stars. From Figure 10, the αDF for APOGEE has two peaks at [α/Fe] = 0.23, and 0.35 dex, with the lower peak having the higher amplitude. For GALAH, there are two peaks in the αDF, one at 0.1 dex and another at 0.25 dex with the peak at 0.25 dex being slightly higher. This is similar to LAMOST’s that show two peaks at [α/Fe] = 0.1 and 0.25 dex. RAVE’s αDF peaks at [α/Fe] = 0.25 dex, quite similar to the αDF for the thin disc stars in TG cross-matched with RAVE. The multiple peaks in the αDF’s suggest the presence of multiple stellar populations. Following the contamination determination in Section 4.1.1, the chemical thin disc contamination to the kinematic thick disc is 50% for APOGEE, 37% for GALAH, and 30% for LAMOST. We caution that the kinematic thick disc for the TG crossmatched with APOGEE sample contains only four stars and therefore suffers from small number statistics. In addition, the GALAH and LAMOST thick disc contamination fractions are overestimated because of how we have distinguished a chemical thick disc star from a chemical thin disc star, i.e., they becomes less distinct at higher metallicities.

Our thick disc MDFs are consistent with the MDFs of stars at the largest scale height from Hayden et al. (2015) which largely probe the thick disc. The MDF and αDF of simulated thick disc stars from Minchev et al. (2014) are consistent with kinematic thick disc stars in this study, except for the fact that they only see the higher peak in [α/Fe] compared to the multiple peaks that we see in APOGEE, GALAH, and LAMOST. Other studies have sampled stars at higher scale heights that better probe the thick disc and halo regions. Liu et al. (2018) used LAMOST to study a sample of stars with |z| > 5 kpc and constructed MDFs to see the contributions from the thick disc, inner halo, and outer halo. Their thick disc MDFs at all heights are consistent with what we see for our MDFs and peak at [Fe/H] = -0.5 dex.

We have shown that the TG cross-matched kinematic thick disc is lower in metallicity but higher in [α/Fe] than the thin disc, similar to comparisons with thick disc in the literature. Planets around low-metallicity, thick disc stars have indeed been found (e.g. Mayor et al. 2004; Cochran et al. 2007). These thick disc stars’ elevated [α/Fe] abundances may have repercussions for planet-formation, as it is typically the α-elements, especially Silicon, that contribute the most to the cores of gas giants (Brugamyer et al. 2011).

4.1.3 Halo

Lastly, we investigate the halo stars that make up <1% of the TG sample. All of the cross-matched spectroscopic and photometric surveys show similar (<1%) contribution from halo stars. There is only one cross-matched halo star from APOGEE which we decided not to include in the MDF and αDF. The halo stars (triangle) in Figure 9 show the lowest range of metallicities among the Galactic components as well as the largest spread in $\sqrt{V_{\phi}^2 + V_z^2}$ with no ordered rotation.

This range in metallicity is further supported by the halo MDF in Figure 11 where all the surveys peak between -1.5 < [Fe/H] < -0.8 dex. The MDF peaks for all six surveys also vary from one another. LAMOST shows two metallicity peaks ([Fe/H] = -1.4 and -0.7 dex) while RAVE, GALAH, Deacon et al. (2019), and Casagrande et al. (2019) show one peak at around [Fe/H] = -0.8 dex. The multiple peaks for LAMOST may be attributed to halo sub-populations with different origins (Carollo et al. 2010; Nissen & Schuster 2010; Bensby et al. 2014; Belokurov et al. 2018; Helmi et al. 2018).

We also examine the [α/Fe] of the halo stars using the TG sample cross-matched with APOGEE, GALAH, RAVE, and LAMOST. The Toumou diagram from Figure 10 show that the lone halo star in TG cross-matched with APOGEE has high [α/Fe] compared to the thin disc and thick disc. The TG cross-matched with GALAH and LAMOST halo stars also show the highest [α/Fe] compared to the thin disc and thick disc. RAVE on the other hand shows stars with both high and low [α/Fe] abundances. The range in [α/Fe] values is shown better in the halo αDFs in Figure 10. GALAH, RAVE, and LAMOST all peak at [α/Fe] = 0.25 dex with RAVE showing a second peak at around [α/Fe] = 0.9 dex. We are not able to determine the contamination fraction of chemically thick disc stars to the halo as the switch from the thick disc to the halo in the [α/Fe] vs [Fe/H] diagram is quite smooth.

We again compare our results to previous work. From Boeche et al. (2013), for stars that have the highest $Z_{\text{max}}$ and $e$ — i.e. have halo kinematics (panel i in their Figures 4 and 11) — the MDF and αDF in their Figure 12 are similar to what we find for the TG sample cross-matched with GALAH, Casagrande et al. (2019), and Deacon et al. (2019). That is, Boeche et al. (2013) have halo stars peaking at [Fe/H] ≈ -1.0 dex and at [α/Fe] ≈ 0.25 dex. An et al. (2015) used ugriz photometry from SDSS Strip 82 to investigate the Milky Way halo. They constructed MDFs that show two peaks at [Fe/H] = -1.4 dex and -1.9 dex that they attribute to an inner halo and an outer halo with prograde and retrograde motions, respectively. This is similar to what we see for LAMOST, though shifted to higher metallicities. Liu et al. (2018) also find an inner halo and outer halo MDF peak at [Fe/H] = -1.2 dex and -1.9 dex, respectively, using LAMOST.

4.2 The Chemo-kinematics of the TESS Objects of Interest

The TESS Objects of Interest (TOI) are sources that TESS has found to be possible planet-hosting stars, and are therefore good targets for follow-up observations. We obtained the TOI from https://exofop.ipac.caltech.edu/tess/view_toi.php that has 1,183 planet candidates. We crossmatched their host stars with the sources in TGV8 to determine their chemo-kinematics and end up with 563 sources.
As of 08 October 2019, there were 29 confirmed exoplanets discovered with TESS. As expected, most of these confirmed exoplanet-hosting stars are in the thin disc (e.g. Jones et al. 2018; Wang et al. 2018; Dragonmire et al. 2019; Huber et al. 2019). Esposito et al. (2018) reported the existence of a hot Neptune orbiting an inactive G7 dwarf star, TOI 118, which we classify as a kinematic thick disc star. TOI 118 is also cross-matched with Casagrande et al. (2019) and Deacon et al. (2019), where the reported metallicities are $0.341 \pm 0.171$ dex and $0.359^{+0.177}_{-0.185}$ dex, respectively, different from the spectroscopic metallicity from Esposito et al. (2018) i.e. $0.04 \pm 0.04$ dex. None of the confirmed exoplanet-hosting stars reside in the halo, to date.

We expect this catalogue to be more applicable for statistical studies as more exoplanets candidates discovered with TESS are confirmed. Recent work on the Galactic context of exoplanet populations has been made available utilizing Kepler data. For example, McTier & Kipping (2019) examined 1647 stars with confirmed planets from Kepler and measured lower velocities for these host stars than the average for the field sample, which may be an evidence of the planet-metallicity correlation or thick/thin disc membership. However, comparisons to non-Kepler host stars with identical properties reveal that planets are just as likely to form around fast stars as they do around slow stars, and that the observed velocity difference is an effect of Kepler’s selection function in that Kepler selects younger, brighter, hotter, and therefore slower stars. This would be interesting to further explore using the TESS catalogue outlined in this work, as TESS has a different selection function and is expected to discover more exoplanets.

5 SUMMARY

TESS is going to revolutionize exoplanet studies by discovering thousands of planets around the nearest and brightest stars. Yet the chemo-kinematic properties of these stars have yet to be explored. We have constructed a catalogue of 2,218,434 TESS CTL targets with chemo-kinematic properties from Gaia DR2, APOGEE, GALAH, RAVE, LAMOST, and photometrically-derived stellar parameters from Casagrande et al. (2019) and Deacon et al. (2019). We compute thin disc, thick disc, and halo membership probabilities for the stars in our catalogue based on their kinematics inferred from Gaia, following Bensby et al. (2014). While the majority of TESS CTL targets are in the thin disc, we find that 4% of them (∼89,000 stars) reside in the thick disc and <1% of them (∼22,000 stars) are in the halo. We find similar percentage for the different Galactic components using other cross-matched surveys with the exception of APOGEE which primarily targets more distant red giants that are preferentially removed for TIC/CTL v8. The TOIs in common with the TG sample are also comprised of similar fractions of the thin disc, thick disc, and halo with a majority of them being in the thin disc.

We explore the kinematics of the thin disc, thick disc, and halo stars and show that for all cross-matched surveys, there is decreasing metallicity and increasing $[\alpha/Fe]$ from the thin disc to the halo as seen in the Toomre diagrams. We also explore the metallicity and $[\alpha/Fe]$ distributions of each Galactic component and confirm that the MDF peak moves to lower values and the $\alpha$DF peak moves to higher values as one goes from the thin disc to the halo.

The catalogue we have generated will be advantageous to use for and valuable in curating samples based on kinematics, kinematic component-membership, metallicity, or $[\alpha/Fe]$. In the era of big data, especially relating to the search for exoplanets, it is now possible and in fact imperative to look at all these dimensions and properties; on how kinematics of host stars relate to their component-membership, how these component memberships relate to the host star metallicity and chemical abundance, how the metallicity and chemical abundance relate to the available materials for planet formation, and ultimately, how all of these tie together to produce the trends in the planet populations that we observe and that we expect to see.
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The cross-matched TGv7 with other surveys yielded

• TGV7 has 1,405,352 sources while TGV8 has 2,218,434 sources.
• The CMD of TGV7 has more contamination from subgiant and giant red giant branch stars which was improved upon by TGV8 because of the addition of Gaia DR2 information.
• The breakdown for kinematic component-membership is slightly different and has changed as follows: thin disc: from 91.77% in TGv7 to 93.17% in TGv8; thick disc: from 0.50% to 0.16%; thin-thick disc is slightly different and has changed as follows: thin disc: from 45.42% to 43.64%; halo: from 0.50% to 0.16%; other: from 8.83% in TGv7 to 6.81% in TGv8.
• We did the same analysis to TIC/CTL v7 as in Section 2 and call the TESS cross-matched with Gaia table TGV7. Below we list the main differences between TGV7 and TGV8:

1. The cross-matched TGV7 with other surveys yielded different number of sources compared to TGV8 (APOGEE: from 2,174 to 658; GALAH: from 19,030 to 32,517; RAVE:

APPENDIX A: TESS INPUT CATALOGUE V7

Although this study was done using TIC v8, we also explore TIC v7 (Stassun et al. 2018). The main difference between v8 and v7 is that v8 uses Gaia DR2 as base, compared to TIC v7 that uses 2MASS. Going from the v7 to v8 changes the estimated \( T \) mag, \( T_{\text{eff}} \), stellar mass, and stellar radius, as well as increasing the number of sources with these estimated properties. For more details on TIC/CTL v7, we refer the reader to Stassun et al. (2018).

We did the same analysis to TIC/CTL v7 as in Section 2 and call the TESS cross-matched with Gaia table TGV7. Below we list the main differences between TGV7 and TGV8:

- TGV7 has 1,405,352 sources while TGV8 has 2,218,434 sources.
- The CMD of TGV7 has more contamination from subgiant and giant red giant branch stars which was improved upon by TGV8 because of the addition of Gaia DR2 information.
- The breakdown for kinematic component-membership is slightly different and has changed as follows: thin disc: from 91.77% in TGV7 to 93.17% in TGV8; thick disc: from 4.42% to 3.64%; halo: from 0.50% to 0.16%; thin-thick disc transition: from 3.25% to 3.00%; thick disc-halo transition: from 0.06% to 0.03%.
- The cross-matched TGV7 with other surveys yielded different number of sources compared to TGV8 (APOGEE: from 2,174 to 658; GALAH: from 19,030 to 32,517; RAVE:

APPENDIX A: TESS INPUT CATALOGUE V7

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- TGV7 has 1,405,352 sources while TGV8 has 2,218,434 sources.
- The CMD of TGV7 has more contamination from subgiant and giant red giant branch stars which was improved upon by TGV8 because of the addition of Gaia DR2 information.
- The breakdown for kinematic component-membership is slightly different and has changed as follows: thin disc: from 91.77% in TGV7 to 93.17% in TGV8; thick disc: from 4.42% to 3.64%; halo: from 0.50% to 0.16%; thin-thick disc transition: from 3.25% to 3.00%; thick disc-halo transition: from 0.06% to 0.03%.
- The cross-matched TGV7 with other surveys yielded different number of sources compared to TGV8 (APOGEE: from 2,174 to 658; GALAH: from 19,030 to 32,517; RAVE:
There is a larger fraction of thick disc and halo stars in TGv7 compared to TGv8, though these stars may be too dim for follow-up observations.
## APPENDIX B: ONLINE TABLE

Table B1: Catalogue of TESS stellar properties from this work

| Column | Label | Format | Units | Notes |
|--------|-------|--------|-------|-------|
| 1      | Gaia source id | Long   |       |       |
| 2      | Gaia RA         | Double | deg   |       |
| 3      | Gaia Dec        | Double | deg   |       |
| 4      | Gaia parallax   | Double | mas   |       |
| 5      | Gaia e_parallax | Double | mas   |       |
| 6      | Gaia pmra       | Double | mas yr\(^{-1}\) |       |
| 7      | Gaia e_pmra     | Double | mas yr\(^{-1}\) |       |
| 8      | Gaia pmdec      | Double | mas yr\(^{-1}\) |       |
| 9      | Gaia e_pmdec    | Double | mas yr\(^{-1}\) |       |
| 10     | Gaia vrad       | Double | km s\(^{-1}\) |       |
| 11     | Gaia e_vrad     | Double | km s\(^{-1}\) |       |
| 12     | Gaia G mag      | Double | mag   | Gaia G band apparent magnitude |
| 13     | Gaia G mag error| Double | mag   |       |
| 14     | Gaia BP mag     | Double | mag   | Gaia blue pass band apparent magnitude |
| 15     | Gaia BP mag error| Double | mag  |       |
| 16     | Gaia RP mag     | Double | mag   | Gaia red pass band apparent magnitude |
| 17     | Gaia RP mag error| Double | mag  |       |
| 18     | Marchetti U     | Double | km s\(^{-1}\) | Cartesian Galactocentric x velocity |
| 19     | Marchetti el\text{U} | Double | km s\(^{-1}\) | Lower uncertainty on Cartesian Galactocentric x velocity |
| 20     | Marchetti eu\text{U} | Double | km s\(^{-1}\) | Upper uncertainty on Cartesian Galactocentric x velocity |
| 21     | Marchetti V     | Double | km s\(^{-1}\) | Cartesian Galactocentric y velocity |
| 22     | Marchetti el\text{V} | Double | km s\(^{-1}\) | Lower uncertainty on Cartesian Galactocentric y velocity |
| 23     | Marchetti eu\text{V} | Double | km s\(^{-1}\) | Upper uncertainty on Cartesian Galactocentric y velocity |
| 24     | Marchetti W     | Double | km s\(^{-1}\) | Cartesian Galactocentric z velocity |
| 25     | Marchetti el\text{W} | Double | km s\(^{-1}\) | Lower uncertainty on Cartesian Galactocentric z velocity |
| 26     | Marchetti eu\text{W} | Double | km s\(^{-1}\) | Upper uncertainty on Cartesian Galactocentric z velocity |
| 27     | Marchetti vtot  | Double | km s\(^{-1}\) | Total velocity in Galactic rest frame |
| 28     | Marchetti el\text{vtot} | Double | km s\(^{-1}\) | Lower uncertainty on Total velocity in Galactic rest frame |
| 29     | Marchetti eu\text{vtot} | Double | km s\(^{-1}\) | Upper uncertainty on Total velocity in Galactic rest frame |
| 30     | Bailer-Jones r\_est | Double | pc  | Estimated distance from Bailer-Jones et al. (2018) |
| 31     | Bailer-Jones r\_lo | Double | pc  | Lower bound on estimated distance from Bailer-Jones et al. (2018) |
| 32     | Bailer-Jones r\_hi | Double | pc  | Upper bound on estimated distance from Bailer-Jones et al. (2018) |
| 33     | 2MASS ID        | String |      |       |
| 34     | TICID           | Integer |      |       |
| 35     | TESS RA         | Double | deg   |       |
| 36     | TESS DEC        | Double | deg   |       |
| 37     | GLONG           | Double | deg   |       |
| 38     | GLAT            | Double | deg   |       |
| 39     | TESSMAG         | Float  | mag   |       |
| 40     | PRIORITY        | Double |       | Target priority, 1 is highest |
| 41     | HIP             | Float  |       | Hipparcos ID |
| 42     | TYCHO2          | Float  |       | Tycho – 2 ID |
| 43     | TD\text{D}     | Double |       | thick disc to thin disc membership probability based on Bensby et al. (2014) |
| 44     | TD\text{D}\_le | Double |       | 16th percentile on the thick disc to thin disc membership probability based on Bensby et al. (2014) |
| 45     | TD\text{D}\_ue | Double |       | 84th percentile on the thick disc to thin disc membership probability based on Bensby et al. (2014) |
| 46     | TD\text{H}     | Double |       | thick disc to halo membership probability based on Bensby et al. (2014) |
| 47     | TD\text{H}\_le | Double |       | 16th percentile on the thick disc to halo membership probability based on Bensby et al. (2014) |
|   | Description | Type | Source |
|---|-------------|------|--------|
| 48 | TD\(_H_{ue}\) | Double | 84th percentile on the thick disc to halo membership probability based on Bensby et al. (2014) |
| 49 | D | Double | \((1 + \frac{TD}{D} + \left(\frac{TD}{D}\right)/\left(\frac{TD}{H}\right))^{-1}\) |
| 50 | TD | Double | \((1 + \frac{TD}{H} + \left(\frac{TD}{H}\right)/\left(\frac{TD}{D}\right))^{-1}\) |
| 51 | H | Double | \(1 - D - TD\) |
| 52 | APOGEE \(Fe_H\) | Double dex | APOGEE cross-matched with TG sample (see Section 2.3) |
| 53 | APOGEE \(Teff\) | Float K | |
| 54 | APOGEE \(logg\) | Float dex | |
| 55 | APOGEE \(alpha\) | Float dex | |
| 56 | GALAH \(Fe_H\) | Double dex | GALAH cross-matched with TG sample (see Section 2.4) |
| 57 | GALAH \(Teff\) | Double K | |
| 58 | GALAH \(logg\) | Double dex | |
| 59 | GALAH \(alpha\) | Double dex | |
| 60 | RAVE \(Fe_H\) | Double dex | RAVE cross-matched with TG sample (see Section 2.5) |
| 61 | RAVE \(Teff\) | Double K | |
| 62 | RAVE \(logg\) | Double dex | |
| 63 | RAVE \(alpha\) | Double dex | |
| 64 | LAMOST \(Fe_H\) | Float dex | LAMOST cross-matched with TG sample (see Section 2.6) |
| 65 | LAMOST \(Teff\) | Float K | |
| 66 | LAMOST \(logg\) | Float dex | |
| 67 | LAMOST \(alpha\) | Float dex | |
| 68 | Casagrande \(Fe_H\) | Double dex | Casagrande et al. (2019) cross-matched with TG sample (see Section 2.7) |
| 69 | Casagrande \(Teff\) | Short K | |
| 70 | Deacon \(Fe_H\) | Float dex | Deacon et al. (2019) cross-matched with TG sample (see Section 2.8) |
| 71 | Deacon \(Teff\) | Double K | |
| 72 | Deacon \(logg\) | Double dex | |

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