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The DR14 APOGEE-TGAS catalogue: Precise chemo-kinematics in the extended solar vicinity

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Abstract. We describe the DR14 APOGEE-TGAS catalogue, a new SDSS value-added catalogue that provides precise astrophysical parameters, chemical abundances, astro-spectro-photometric distances and extinctions, as well as orbital parameters for $\sim 30,000$ APOGEE-TGAS stars, among them $\sim 5,000$ high-quality giant stars within 1 kpc.

Keywords. catalogs, solar neighborhood, astrometry, stars: late-type, stars: abundances, stars: distances, stars: kinematics, Galaxy: stellar content

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1. Catalogue overview

The first data release of the *Gaia* mission (Gaia Collaboration *et al.* 2016) contains improved parallaxes and proper motions for more than 2 million stars contained in the Tycho-2 catalogue (Høg *et al.* 2000), among them 40,250 stars contained in the APOGEE DR14 catalogue. The combined dataset (see Table 1) presents an ideal testbench for chemo-kinematical tagging studies beyond the *Hipparcos* volume.

The Apache Point Observatory Galactic Evolution Experiment (APOGEE; Majewski *et al.* 2017) delivers high-resolution ($R \sim 22,500$) high signal-to-noise ($S/N \sim 100$ pixel^{-1}) spectra of primarily red giant stars in the H band ($\lambda = 1.51 - 1.69 \mu$m), enabling the determination of precise (~ 100 m/s) radial velocities as well as stellar parameters and chemical abundances of more than 15 elements. For this paper, we use the results from the APOGEE Stellar Parameters and Chemical Abundances Pipeline (ASPCAP; García Pérez *et al.* 2016) contained in the Sloan Digital Sky Survey's Fourteenth data release (DR14; Abolfathi *et al.* 2017), together with the recommended stellar parameter cuts and post-calibrations for effective temperature and surface gravity†.

The DR14 APOGEE-TGAS catalogue is available as an SDSS-IV DR14 value-added catalogue (VAC). The data can be downloaded as a FITS table from `https://data.sdss.org/sas/dr14/apogee/vac/apogee-tgas/apogee_tgas-DR14.fits`.

† `http://www.sdss.org/dr14/irspec/parameters/`

Table 1. Sizes of various useful subsamples of the APOGEE-TGAS sample.

Name	Requirements	Objects
DR14 APOGEE-TGAS sample	Best 5" match between allStar.l31-c2.fits and TGAS	46,033
Unique DR14 APOGEE-TGAS stars	Internal APOGEE_ID match	40,250
with measured $T_{\rm eff}$, [Fe/H], [α/Fe]	ASPCAP converged	30,076
with ages, distances, and orbits	`StarHorse` (Santiago *et al.* 2016; Queiroz *et al.* 2018) converged	29,661
with most reliable abundances	SNREV> 100, 4000 K< $T_{\rm eff}$ < 5000 K, 1 < $\log g$ < 3.8, $\chi^2_{\rm ASPCAP}$ < 10 no cluster or commissioning stars, no suspect broad lines or RV combination	10,499
Extended solar-neighbourhood sample	d < 1 kpc & most reliable abundances	4,844
blurring-cleaned	7 kpc < $R_{\rm mean}$ < 9 kpc, $Z_{\rm max}$ < 1 kpc	2,988

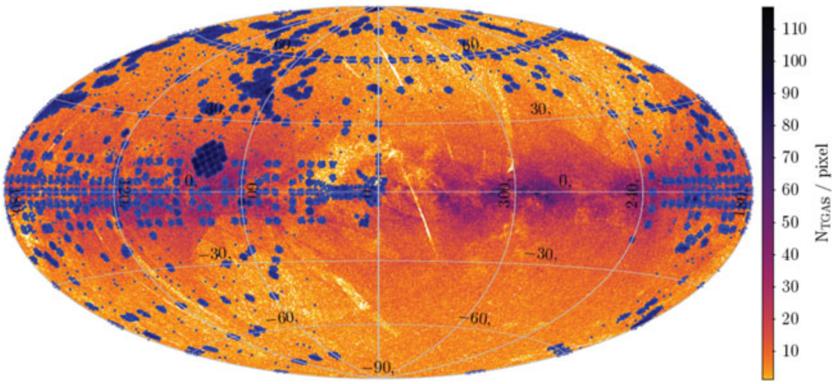

Figure 1. Footprint of the DR14 APOGEE-TGAS sample, superimposed on the TGAS source density sky map. The tile size of the HealPix map is 0.21 $\rm deg^2$.

2. Cross-match, distances and extinctions

We cross-matched the APOGEE DR14 ASPCAP summary file with the *Gaia* DR1/TGAS catalogue (Lindegren *et al.* 2016, see Table 1 for details). For the stars with measured ASPCAP atmospheric parameters we computed ages, masses, distances, and extinctions using the combined astro-spectro-photometric information and the new Bayesian isochrone-fitting code `StarHorse` (Santiago *et al.* 2016; Queiroz *et al.* 2018). The code computes the posterior probability over the PARSEC 1.2S grid of stellar models (Bressan *et al.* 2012; Tang *et al.* 2014; Chen *et al.* 2014), taking into account spectroscopic measurements of effective temperature, surface gravity, and global metallicity, as well as multi-band photometry and the parallax measurements from TGAS. All uncertainties were modelled to be Gaussian, and the TGAS parallaxes were corrected for systematics as suggested by Arenou *et al.* (2017). Our priors are an overall Galactic stellar density prior taking into account thin and thick disc, halo and bulge, and a Chabrier (2003) initial-mass function. Tests on a APOGEE-TGAS mock sample of simulated stars showed that our code delivers accurate distance and extinction estimates. The median precision of the reported distances and extinctions for giants amounts to $\sim 10\%$ and ~ 0.09 mag, respectively. For details we refer to Queiroz *et al.* (2018).

3. Orbital parameters

From the full phase-space information $(\alpha, \delta, d, \mu_\alpha, \mu_\delta, v_{\rm los})$, the stellar orbits for our sample were calculated in a non-axisymmetric Galactic potential that includes a 3D

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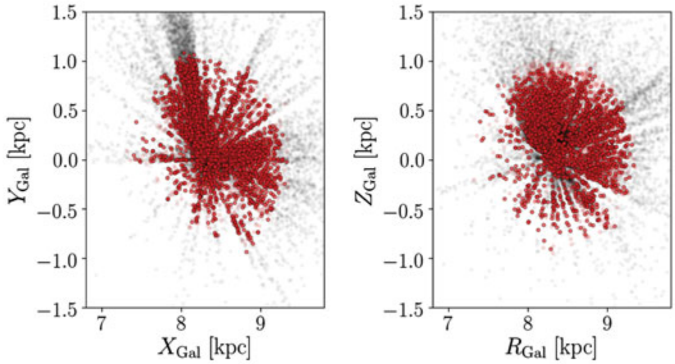

Figure 2. Location of the full DR14 APOGEE-TGAS sample (grey) and the extended solar-vicinity sample (red) in Galactocentric coordinates.

model for the bar (Model 4 in Fernández-Trincado *et al.* 2016) using the `GravPot16` code†. For $R_{\rm Gal} > 4.5$ kpc, the model was scaled to the observed rotation curve given by Sofue (2015) and $v_{\phi,\rm LSR} = 239$ km/s at the solar position ($R_{\rm Gal,\odot} = 8.3$ kpc; e.g. Bland-Hawthorn & Gerhard 2016). From the integrated Galactic orbits, we computed characterizing orbital quantities such as $e, R_{\rm mean}$, and $Z_{\rm max}$, along with their uncertainties, using a Monte-Carlo technique (e.g. Anders *et al.* 2014).

4. First application: t-SNE dissection of the solar-vicinity chemical-abundance space

As a first scientific application, we tested for the first time a new non-linear projection method, t-SNE (van der Maaten & Hinton 2008), to dissect the local chemical-abundance space. In an accompanying paper (Anders *et al.* 2018), we show that this method is extremely efficient for finding groups and outliers in multi-dimensional chemical-abundance space, using local high-resolution optical spectroscopic survey data. A subsequent analysis by Kos *et al.* (2018), using GALAH data, has shown that it is also possible to reconcile physical star clusters with this method.

Fig. 3 summarises the results of our preliminary t-SNE analysis of the ASPCAP chemical-abundance space for the blurring cleaned APOGEE-TGAS solar-vicinity sample. The t-SNE map clearly reveals three distinct groups that correspond to the well-known chemical thin and thick discs (blue and red), and the high-[α/Fe] metal-rich population (hαmr, green; e.g. Adibekyan *et al.* 2011). The two [α/Fe]-enhanced groups seem to have very similar age distributions, which suggests that the thick disc and the hαmr stars were formed on similar time scales, but in different places. A comprehensive analysis will be presented in a forthcoming paper.

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† `https://fernandez-trincado.github.io/GravPot16/index.html`

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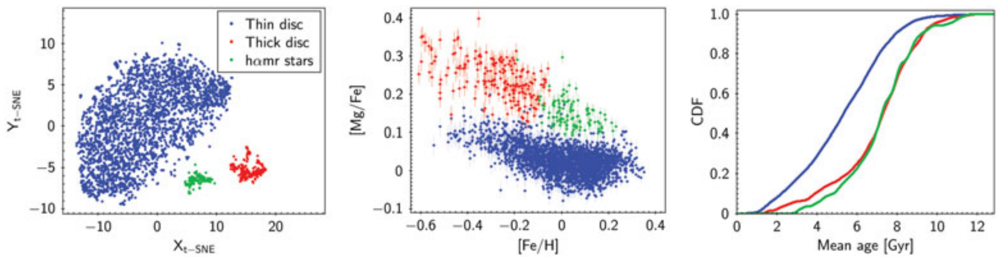

Figure 3. Broad t-SNE classification of the blurring-cleaned APOGEE-TGAS extended solar-vicinity sample. Left: Resulting t-SNE projection in 2D, using a perplexity of $p = 75$ and the t-SNE hyper-parameters recommended by van der Maaten & Hinton (2008). Middle: [Mg/Fe] vs. [Fe/H] digram, colour-coded by t-SNE population. Right: Cumulative mean age distributions (from `StarHorse`) for the three populations.

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