
248. Exoplanet host stars

IN THE EARLY DAYS of the development of Gaia, almost 30 years ago, I made the first estimate of the number of exoplanet discoveries that we can expect from their observed astrometric ‘wobble’. My more quantitative estimates (Perryman et al., 2014) put the final number in the range 10–30 000 or more, sensitively dependent on the final instrument calibration (essay 19).

This number stands in stark contrast to the five Gaia discoveries to date, listed in the [NASA Exoplanet Archive](#): Gaia–1 and 2 from transit photometry (Panahi et al., 2022), the microlensing system Gaia22dkvL from the Science Alerts pipeline (Wu et al., 2024), and Gaia–4 and 5 from DR3 astrometry (Stefánsson et al., 2025).

With detection of the photocentric wobble requiring accurate (astrometric, photometric, and chromaticity) calibration, we can expect many more with Gaia DR4 (perhaps a few hundred?), with the final haul only expected with DR5 around 2030 or beyond. I have covered these, and several other aspects of Gaia’s contribution to exoplanet science, in various previous essays, and summarised in my recent review (Perryman, 2026).

AN IMPORTANT contribution to the characterisation of known exoplanetary systems lies in Gaia’s accurate measurement of the distances, and to some extent the space motions, of their host stars. Gaia’s photometry, low-resolution (BP/RP) photometry, and high-resolution (RVS) spectroscopy, also contribute significantly to establishing their host star properties, notably their effective temperature and metallicity, and their derived masses and radii. Accurate and homogeneous determination of host star radii in turn leads to accurate and homogeneous estimates of the planet radii as an important by-product of transit measurements.

I described the early results on star and planet radii based on Gaia DR1 in May 2021 (essay 21), and an updated summary based on Gaia DR3 in February 2025 (essay 216). The latter included the homogeneous catalogue of 7993 planet-hosting stars (3248 from Kepler, 565 from K2, 4180 from TESS), and their total of 9324 transiting planets by Berger et al. (2023).

THE MORE RECENT study by de Laverny et al. (2025), also based on DR3, prompted this further update, not because the radii of the individual planets and their host stars have changed dramatically, but because the resulting homogeneity of treatment can better identify subtle trends in the occurrence of exoplanets as a function of host star mass, metallicity, and Galactic location.

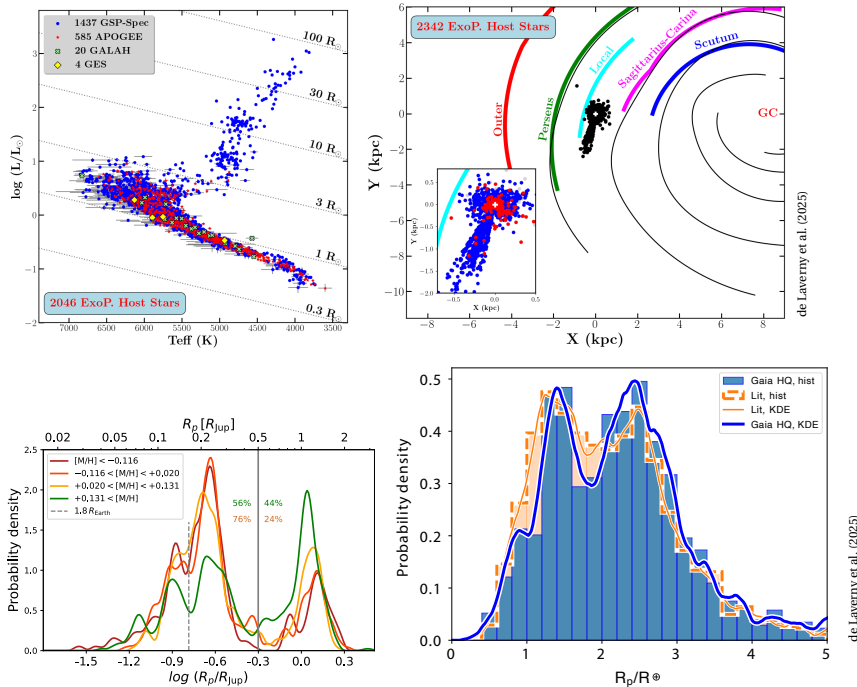
For example, the ‘radius valley’ (aka ‘evaporation valley’) at about $1.5 - 2R_{\oplus}$, first identified in the Kepler data of 2025 planets by Fulton et al. (2017), appears to separate rocky super-Earths ($1 - 1.5R_{\oplus}$) and sub-Neptunes with gas envelopes ($2 - 3R_{\oplus}$). It was characterised across different stellar types by Cloutier & Menou (2020), although Berger et al. (2023) found it less prominent in the K2 and TESS samples.

This ‘valley’ has generally been attributed to photoevaporation by the host star’s X-ray/UV radiation, with sub-Neptunes losing their H/He envelopes and shrinking into super-Earths. Core-powered mass loss (Ginzburg et al., 2018) leads to a similar valley, with a slightly different dependence of the period–radius relation (e.g. Owen & Schlichting, 2024). Any improvement in the accuracy of exoplanet radii is likely to place this phenomenon on a more secure observational footing.

LET ME outline what de Laverny et al. (2025) have done, and then focus on their main results.

Along the same lines as Berger et al. (2023), they used improved Gaia DR3 estimates of T_{eff} , $\log(g)$, and $[M/H]$ provided by the RVS spectral modelling module GSP-Spec where possible (Recio-Blanco et al., 2023), or from ground-based spectroscopy otherwise. Along with Gaia distances and G -band absorption, A_G , they determined stellar radii for 2573 exoplanet host stars from the Stefan–Boltzmann relation, and masses from the resulting radii and surface gravities.

They estimated typical uncertainties of 3% on stellar radii, broadly aligned with previous values, but with some more substantial discrepancies in the derived stellar masses. The masses and radii of their 3556 exoplanets were then derived from the various transit data.



THE DISTRIBUTION of effective temperature versus luminosity (top left) shows that the uncertainties on T_{eff} are larger for dwarfs than for giants, as a result of their parameterisation being from lower S/N spectra, while hot dwarfs have larger temperature uncertainties as a result of their fewer spectral lines.

With respect to their Galactic distribution and metallicity dependence, de Laverny et al. (2025) found that most host stars (56%) belong to the thin disk, and are located in the solar vicinity near the local spiral arm (top right). The inset (zoom) distinguishes giants (red) and dwarfs (blue), according to their radius.

Some older members are found in the thick disk (31%), as well as in the Galactic halo (3%). The presence of exoplanets around these older, metal-poor stars suggests that planet formation already occurred at the earliest Galactic epochs; targeted studies of these systems will probe planet formation in environments with more extreme chemistry and dynamics. For less massive planets, the average planetary radius increases continuously with host star metallicity, while the occurrence of giant planets increases with higher metallicity.

ONE OF THEIR findings relates to the properties of giant planets based on their density and host star metallicity. Dense giant planets, $R_p \lesssim 1.1R_J$, tend to be more massive as the host star's metallicity increases (lower left). Inflated giant planets are typically more massive around lower metallicity hosts. This in turn suggests that their diversity is associated with their Galactic

origin, with dense giant planets appearing to be more numerous in super-metal-rich environments like the central regions of the Milky Way.

THE HIGHER ACCURACY of their stellar radii, and the resulting improved accuracy for their 3556 exoplanets, allowed for a finer analysis of the radius valley, and their sample confirmed the presence of a gap at $R_p \approx 0.5R_J \approx 5R_\oplus$ (lower right). It is even more prominent in their high-quality sub-sample of 1826 host stars (being 71% of their whole sample, and with 84% derived from the Gaia GSP-Spec data set), and also when restricted to host stars with T_{eff} in the range 4700–6500 K.

They characterised the gap in terms of a parameter C , dependent on planet radius and incident luminosity, essentially a measure of the effectiveness of thermal evaporation of an H_2 –He atmosphere. This provides further evidence that the ‘radius valley’ is at least partly attributable to evaporation.

INFERRED EXOPLANET DENSITIES drive conclusions on their internal composition, and the revised masses derived from these revised exoplanet radii clearly result in revised densities, albeit generally marginally so. Amongst several examples, de Laverny et al. (2025) detail the case of GJ 9827. Compared with a literature value of $R_\star = 0.58 \pm 0.03R_\odot$, the Gaia-derived $R_\star = 0.67 \pm 0.03R_\odot$ results in densities changing from 8.5, 7.5, and 2.6 Mg m^{-3} to 7.0, 6.2, and 2.1 Mg m^{-3} , for planets b, c, and d respectively.