

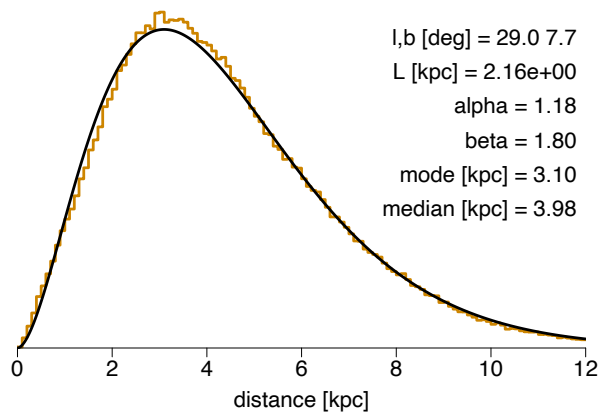
Distances for 1.47 billion stars in Gaia DR3

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Overview

We provide photometric and photogeometric distances for all sources in Gaia DR3 that have parallaxes. Our distance estimates are posterior probability density functions (PDFs) that incorporate a prior constructed from a three-dimensional model of the Galaxy. This model includes both interstellar extinction and Gaia's variable magnitude limit. Geometric distances are computed from the parallaxes together with a direction-dependent prior on distance. Photogeometric distances additionally use the colours and apparent magnitudes of the stars, by exploiting the fact that stars of a given colour have a restricted range of probable absolute magnitude (plus extinction), as shown on the right.



The geometric prior is obtained by fitting a generalized gamma distribution to the stars' distances in each HEALpixel of the Galaxy model.

Method

The PDF for the geometric distance is the product of the likelihood - a function of the parallax and its uncertainty - and the geometric prior:

$$P_p(r | \varpi, \sigma_\varpi, p) = P(\varpi | r, \sigma_\varpi) P(r | p)$$

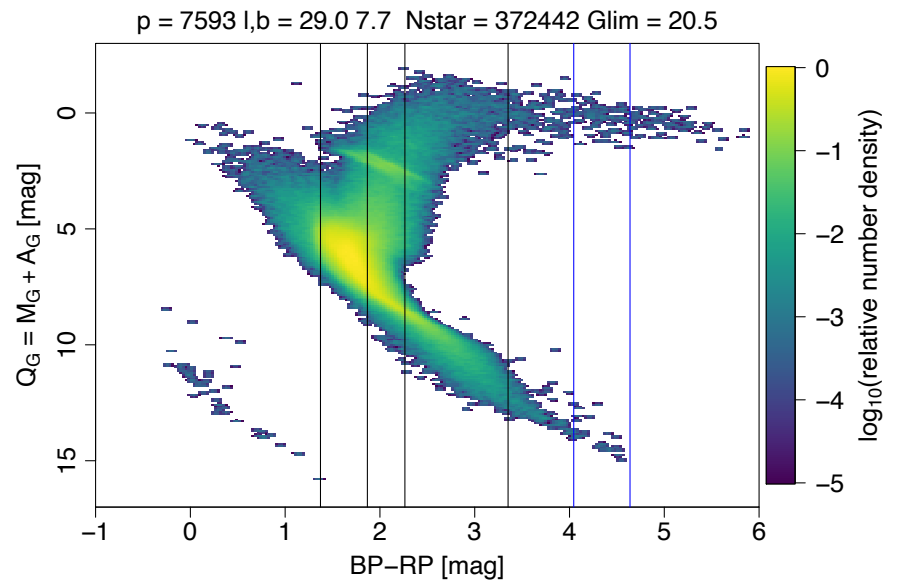
Defining

$$Q_G \equiv M_G + A_G = G - 5 \log r + 5$$

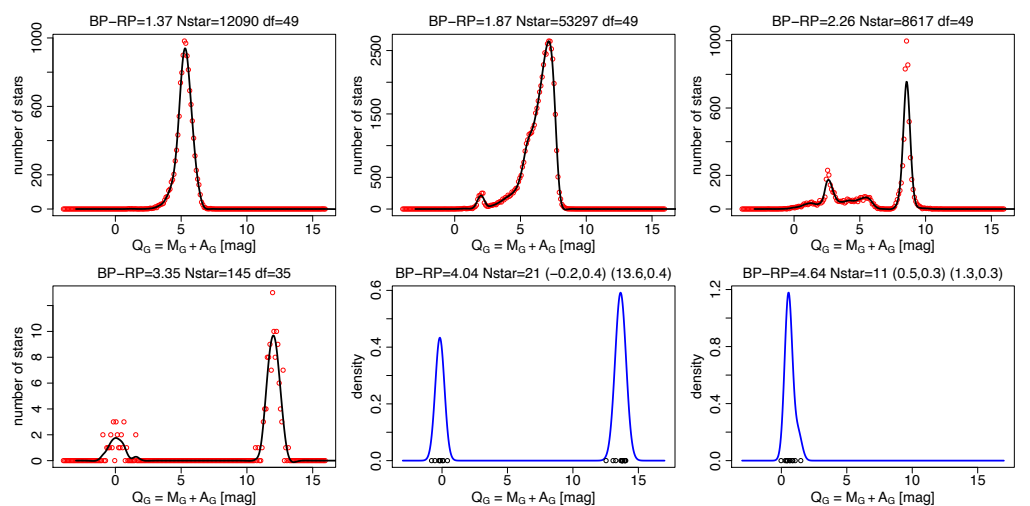
we use a photometric prior in which this quantity is a function of the star's distance (r), colour (BP-RP), and sky position (p). After marginalizing over the unknown value Q_G , and assuming negligible uncertainty in the measured colour, the posterior PDF for the photogeometric distance is

$$P_{pg}(r | \varpi, \sigma_\varpi, G, BP-RP, p) = P(\varpi | r, \sigma_\varpi) P(r | p) P(Q_G | BP-RP, p)$$

We sample both PDFs for every source in Gaia DR3 using MCMC. We summarize each PDF with the median, and with the 16th and 84th percentiles (which together give the central 1-sigma-like confidence interval). The logarithm of these quantiles correspond to the same quantiles on the log distance, and thus on the distance modulus and absolute magnitude of a star.



The photometric prior is produced from a Galaxy model. Above is the colour-absolute magnitude diagram for one small region of the sky (level 5 HEALpixel). Vertical stripes through this give the prior probability distribution on Q_G for stars of a given colour, some examples of which are shown below.



Below: Distribution of Gaia DR3 stars found using our inferred geometric distances (left) and photogeometric distances (right), in Galactic Cartesian coordinates with the Sun at the origin. The Galactic centre is at around (+8,0,0) kpc. The top plots are the view from the Galactic north pole, the bottom plots are a side view.

