A unified tool to estimate distances, masses and ages from spectrophotometric data

Alexey Mints and Saskia Hekker

Max Planck Institute for Solar System Research, Göttingen, Germany
Stellar Astrophysics Centre, Aarhus University, Denmark

Abstract

For detailed studies of Galactic structure and evolution it is essential to obtain accurate stellar parameters and distances. We developed an efficient tool to obtain stellar masses, ages and distances from spectral parameters ($T_{\rm eff}$, $\log g$ and $[\rm Fe/H]$) and infrared photometry. We apply this tool to data from large publicly available spectroscopic surveys such as APOGEE, SEGUE, RAVE, Gaia-ESO and LAMOST, combined with 2MASS and AllWISE photometry.

Aims

We provide estimates of stellar masses, ages and distances, for a large set of stars (see Table below) taking into account non-gaussianity and possible multi-modality of the Probability Distribution Functions (PDFs).

Survey	Number of stars	Reference
RAVE	450,000	[1]
LAMOST-GAC	225,000	[2]
LAMOST-CANNON	450,000	[3]
APOGEE	88,000	[4]
GCS	13,800	[5]
SEGUE	277,500	[6]
Gaia-ESO	7,000	[7]
AMBRE	3,400	[8]

Method

In the current version of our tool, we use $T_{\rm eff}$, $\log g$ and $[\rm Fe/H]$ as well as photometry from 2MASS and AllWISE combined with PARSEC isochrones [9] to derive mass, age and distance for each star. Other inputs, like Gaia parallaxes and asteroseismic masses can be used to increase the precision of the results.

We select for each star all models within four sigmas from the observed $T_{\rm eff}$, $\log g$ and $[\rm Fe/H]$. We build a PDF for each parameter using weighted model values. Weights are assigned using the model likelihood (i.e. how close is the model to the observed spectral parameters and photometric magnitudes).

Transition from $T_{\rm eff}$, $\log g$ and $[\rm Fe/H]$ to mass, age and distance is in many cases degenerate. We therefore split models into subsets (named Unimodal sub-PDFs, or USPDFs), such that each subset contains models with the same evolutionary stage and has a unimodal PDF. Evolutionary stages are main-sequence and giants (pre-core-helium burning, stage I), core-helium burning stars (stage II) and asymptotic giant branch (post-core-helium burning, stage III).

For each USPDF we report mean, median, mode and variance values for mass, log-age, distance modulus, distance and parallax.

We also fit a normal, a skewed-normal and a truncated-normal distribution to each USPDF and select a best fit. See figure below for an example of USPDFs and fits. For the best fit for each USPDF we report fit parameters and two- and three-sigma confidence intervals.

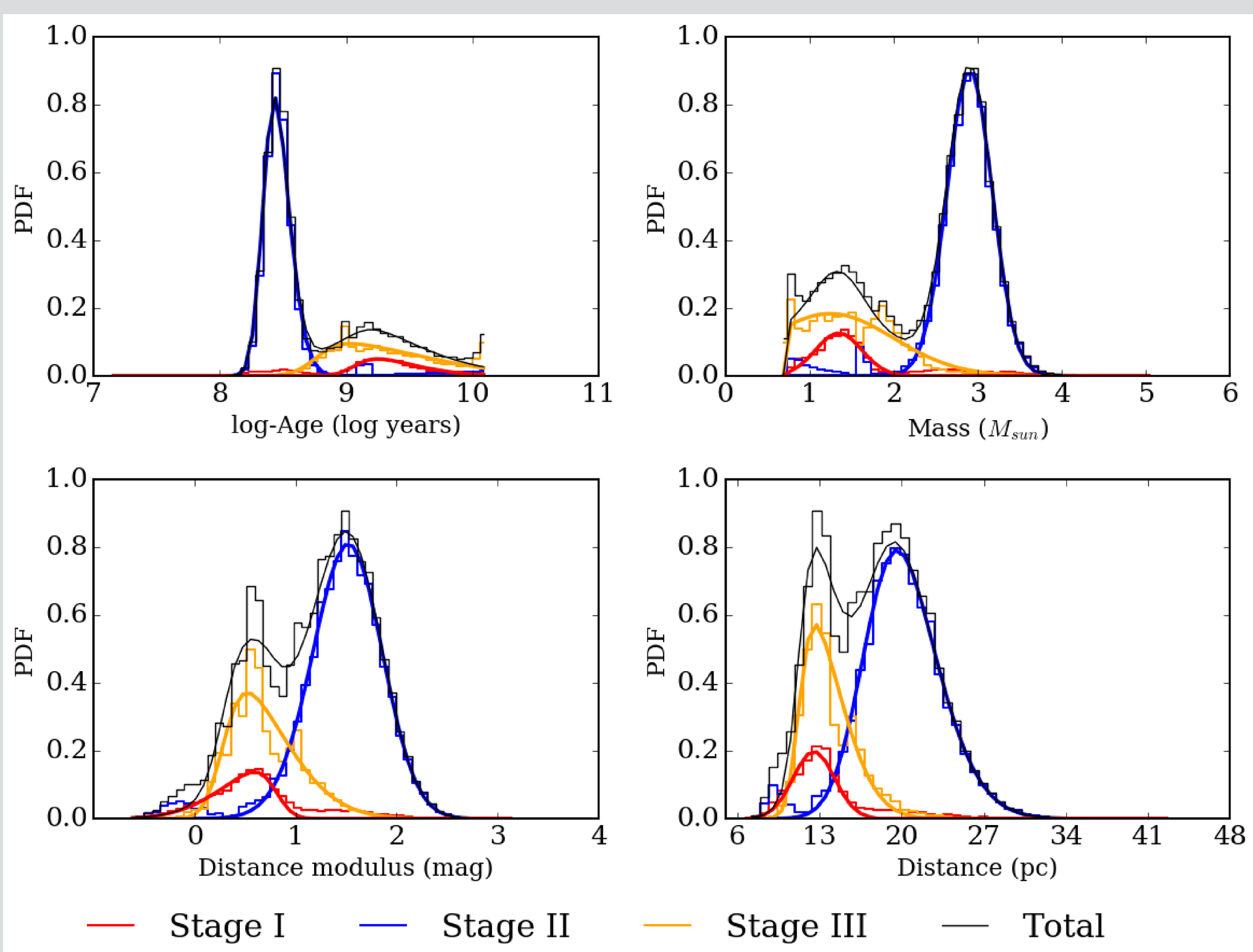

Figure: An example of PDFs for log-age, mass, distance modulus and distance and USPDF fits.

Results

We run a series of tests with mock data to ensure that our tool is working as expected. We measured a relative uncertainties of 0.17 for masses, 0.13 for distances and 0.03 for logarithmic ages. Additionally, we compared our results with measurements of distances, masses and ages available in the literature. Our results are consistent with published results in the vast majority of cases.

We provide a catalog of distances, ages and masses for about 1.4 million stars. The Figure below shows distributions of fractional uncertainties in parameters for all stars in our catalog.

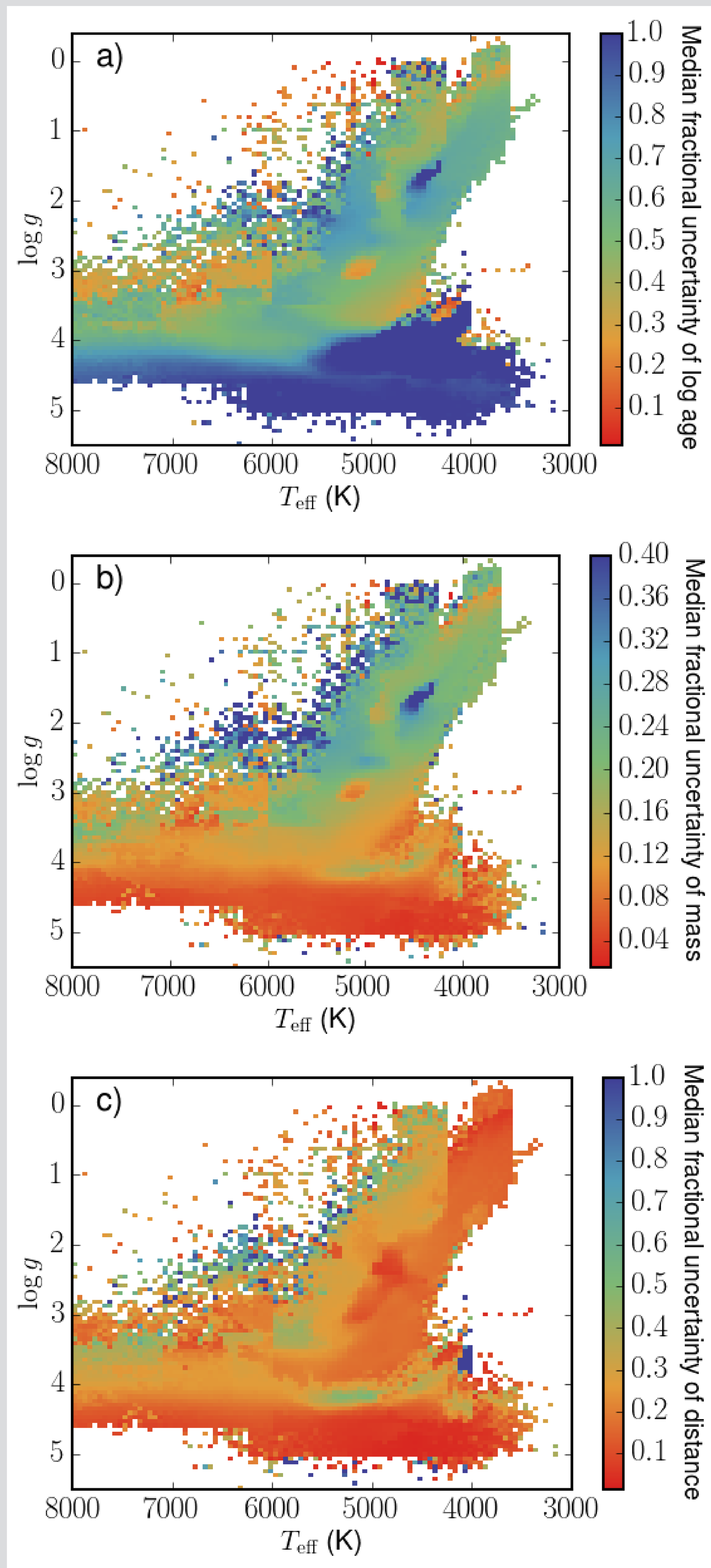

Figure: Hertzsprung-Russel diagrams with color maps for: a) median fractional uncertainty in log-age (fractional uncertainties greater or equal than 1 are shown in blue color), b) median fractional uncertainty in mass, c) median fractional uncertainty in distance.

Acknowledgments

The research leading to the presented results has received funding from the European Research Council under the European Communitys Seventh Framework Programme (FP7/2007- 2013)/ERC grant agreement (No 338251, StellarAges).

References

[1] Kordopatis, G., Gilmore, G., Steinmetz, M., et al. 2013, AJ, 146, 134
[2] Luo, A.-L., Zhao, Y.-H., Zhao, G., et al. 2015, Research in Astronomy and Astrophysics, 15, 1095
[3] Ness, M., Hogg, D. W., Rix, H.-W., Ho, A. Y. Q., & Zasowski, G. 2015, ApJ, 808, 16
[4] Ahn, C. P., Alexandroff, R., Allende Prieto, C., et al. 2014, ApJS, 211, 17
[5] Casagrande, L., Schönrich, R., Asplund, M., et al. 2011, A&A, 530, A138
[6] Yanny, B., Rockosi, C., Newberg, H. J., et al. 2009, AJ, 137, 4377
[7] Gilmore, G. 2015, ESO Phase 3 Data Release Description, ,
[8] Worley, C. C., de Laverny, P., Recio-Blanco, A., Hill, V., & Bijaoui, A. 2016, A&A, 591, A81
[9] Bressan, A., Marigo, P., Girardi, L., et al. 2012, MNRAS, 427, 127

http://www.mps.mpg.de/sage
mints@mps.mpg.de