EPSC Abstracts
Vol. 8, EPSC2013-161, 2013
European Planetary Science Congress 2013

The true stellar parameters of the Kepler target list

R. Farmer,U. Kolb, A.J. Norton
Department of Physical Sciences, The Open University, United Kingdom (rob.farmer@open.ac.uk)

Abstract

We present results of a population synthesis study of the Kepler field. We adapted BiSEPS, a code that includes a fully self-consistent treatment of single and binary star evolution, to generate a sample of synthetic stars that represents the Kepler Input Catalogue (KIC). By subjecting this synthetic sample to the same target selection criteria that defined the actual Kepler target list we obtain a synthetic target list. We analysed the synthetic target list in turn with the methods of the Kepler Stellar Classification Project (SCP), to obtain SCP-derived stellar parameters. From this we find significant differences between the actual physical stellar parameters and those derived by the SCP of the stars in the synthetic sample. For a main sequence (MS) star, we find on average a $\sim 3\%$ increase in stellar radius and a consequent $\sim 3\%$ overestimate of the radius for any transiting exoplanet, when considered over the whole target list.

1. Introduction

Kepler's Stellar Classification Program (SCP) derived basic physical parameters of all KIC stars, chiefly the effective temperature T_{eff}, surface gravity g, and metallicity Z, and, by comparison with suitable stellar models, the stellar mass, radius and age, using only the observed broad-band magnitudes and colours of these stars as an input. The target selection in turn is based on these SCP-derived stellar parameters.

These SCP-derived parameters may suffer from random and systematic uncertainties introduced because the measured magnitudes of a star may differ from its true, intrinsic magnitudes, and because colours alone will not always unambiguously deliver appropriate estimates of the physical parameters. This will in turn translate into a bias of the statistical properties of samples drawn from Kepler data, including the exoplanet candidate sample itself.

It is therefore important to critically examine the performance of the SCP approach, and the consequences of any inherent systematic bias for the actual Kepler target list, and for subsamples created from Kepler data. To this end we aim to create a synthetic version of the KIC, obtained by population synthesis calculations that include self-consistently evolved binary systems. We validate the population model against the actual KIC in colour-magnitude space, and employ the SCP technique to derive "apparent" stellar parameters for all stars in the synthetic sample, i.e. exclusively from their magnitudes in different colour bands. We then investigate the difference between the actual, physical parameters of our synthetic stars, and their SCP-derived parameters.

2. Method

To calculate a model for the stellar and binary star population in the Kepler field-of-view we use the BInary and Stellar Evolution Population Synthesis (BiSEPS) code described in [3] and references therein. At the core of the population synthesis scheme is a large library of single star and binary system evolutionary tracks from the ZAMS up to a maximum age of 13 Gyrs. These evolutionary tracks are then combined with a model of the Galaxy, taking into account a thin and thick disc, Galactic extinction and a set of suitable initial distribution functions. This gives us a probability distribution function Γ, that is then randomly sampled from, to form a synthetic sample of stars in the field of view.

This synthetic sample is then subjected to the same target selection criteria that defined the original Kepler target list Briefly, we use the SCP to determine a set of physical parameters (T_{eff},g,Z) [2] from the stars' colours. We then obtain a synthetic full frame image (FFI) of each of Kepler's CCD channels by stacking the predicted pixel response function (PRF) for each system in each channel. The PRFs are subjected to the predicted CCD noise to derive a S/N ratio for each system. The S/N ratio is combined with the SCP parameters to select objects that are predicted to have the highest chance of detecting an Earth-like transit around a Sun-like star [1].

3. Results

We can compare the real parameters, as determined by our evolutionary model, with those of the SCP to determine the bias introduced by using the SCP parameters. Figure 1 shows the distribution of $\Delta \log g = \log g_{real} - \log g_{SCP}$ over the $\log T_{eff,SCP}$ - $\log g_{SCP}$ plane. We can clearly see a population of giants that have been misclassified as dwarfs in Figure 1, as well as the general underestimation of the $\log g$ value by the SCP for the dwarf star systems.

The SCP will therefore return a larger radius than the real radius, and consequently any derived planet radius will be larger as well. If $\log g$ for a main-sequence star is underestimated by the average value of 0.23 dex the implied stellar radius is too large by $\sim 3\%$. For a measured transit depth $\Delta F/F = (R_p/R_*)^2$ the planet radiusR_p will also be overestimated by $\sim$ 3%, and its bulk density underestimated by nearly 10% if the stellar mass is assumed known. While confirmed Kepler planets will have stellar radii determined by other means, usually by spectroscopy, most systems are too faint, and they are too numerous, for affordable, individual follow up, thus their radii will be uncorrected in the first instance and any derived planetary distributions skewed.

Comparing the distribution of systems in our synthetic sample pre and post target selection we find that the relative fraction of main-sequence (MS) and MS+MS objects increases by $\sim 10\%$, while the fraction of systems containing a giant decreases by $\sim 40\%$. The original aim of the Kepler target selection was to prioritize Sun-like stars, while also removing giant stars where Earth-sized transits are harder to detect. Our analysis shows that the target selection largely succeeded in this goal, and our simulations allow one to quantify the bias this procedure introduces to the stellar sample.

4. Summary and Conclusions

In this work we present a comprehensive population synthesis model of the Kepler field, taking into account single and binary star evolution. We have also modelled the selection effects inherent in the Kepler objects of interest, i.e. the SCP parameter estimation, Kepler's instrumental noise, and the targeted selection of systems with the highest chance of detecting an Earth-like planet orbiting a Sun-like star in the HZ. The main output of this procedure is a synthetic catalogue of systems in the Kepler field. This catalogue was the basis for a comparison between the real physical parameters of the catalogue stars, as indicated by the population model, and the corresponding SCP-derived parameters. Such a comparison over the bulk of the Kepler field is only possible with a full theoretical population model; purely observational tests of the SCP performance will always be limited to a small sample of stars on the basis of bespoke spectral fitting.

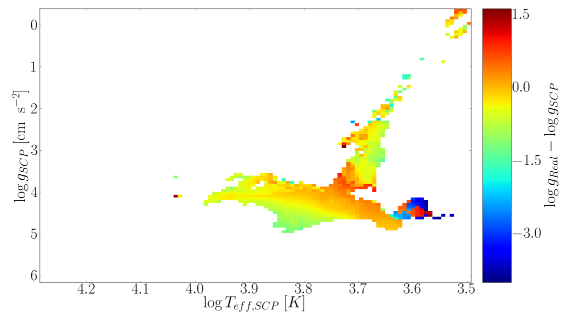

Figure 1: Distribution of the median of the difference between real and SCP-derived surface gravity, $\Delta \log g = \log g_{real} - \log g_{SCP}$, per bin of $\log T_{eff}$-$\log g$.

References

[1] Batalha, N. M. et al,, ApJ, 713, L109, 2010

[2] Brown, T. M., Latham, D. W., Everett, M. E., Esquerdo, G. A., AJ, 142, 112, 2011

[3] Farmer, R., Kolb, U., and Norton, A.: ArXiv:1302.2867, 2013