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Fundamental properties and seismological analysis of three *Kepler* stars

K. Liu and S. L. Bi

Deparment of Astronomy, Beijing Normal University, Beijing 100875, China
email: liukang@mail.bnu.edu

Abstract. The lithium abundance of KIC 11395018 and KIC 10920273 are not compatible with their age, which is deduced by asteroseismology. To explain this phenomenon, we investigate the possible evolutionary status and perform seismological analysis of the three stars KIC 11395018, KIC 10273246 and KIC 10920273. Using the Yale Rotating Stellar Evolution Code (YREC), we constructed a grid of evolutionary tracks with different input physics and rotation rates. In addition to the conventional observed properties, we added two observed constraints: lithium abundance and rotational period. As a result, the lithium abundance of our rotation models agrees well with the observation. Meanwhile, we obtained a set of more accurate stellar fundamental parameters than previous studies.

Keywords. stars: fundamental parameters, stars: rotation, stars: abundances.

1. Introduction and Observation

In this paper, we study three stars which have clear solar-like oscillation. Their identities in the *Kepler* Input Catalogue (KIC) are as follows: KIC 11395018, KIC 10273246 and KIC 10920273. We refer to them as C1, C2 and C3. Creevey *et al.* (2011) provided the fundamental properties of the stars, and they also found that the lithium abundance $\log N$ (Li)=2.6 ± 0.1 and $\log N$ (Li)=2.4 ± 0.1 for C1 and C3 is not compatible with their own age. These values suggest a lower age than asteroseismology. Mathur *et al.* (2011) and Campante et al. (2011) provided a period of $36^{+6.04}_{-4.53}$, 23 and 27 days for C1, C2 and C3, respectively. The errors of C2 and C3, which we estimated according to their PSD (Campante *et al.* 2011), are $^{+2.57}_{-2.10}$ days (0.05 μHz) and $^{+6.15}_{-4.22}$ days (0.08 μHz).

Furthermore, the solar-like oscillations of the three stars have been carefully studied by Mathur *et al.* (2011, see their Table 4) and Campante *et al.* (2011, see their Table 5 and Table 6). 25, 32 and 21 individual modes are identified. We adopted the large frequency separation $< \Delta\nu > = 47.76 \pm 0.99$ μHz, $< \Delta\nu > = 48.2 \pm 0.5$ μ and $< \Delta\nu > = 57.3 \pm 0.3$ μHz as a representative value for C1, C2 and C3, respectively.

2. Method and Results

We constructed a grid of stellar evolutionary models with the YREC7; (Guenther *et al.* 1992, Demarque *et al.* 2008), which include diffusion, angular momentum loss and mixing driven by rotation, for different input parameters. Because the rotation was considered in our stellar models, the characteristics of a model depend on six parameters: the mass M, the age t, the mixing length parameter $\alpha \equiv l/Hp$, the rotation period P_{rot} and two parameters ($X_{\rm ini}$, $Z_{\rm ini}$) describing the initial chemical composition of the star. The helium abundance $Y_{\rm ini}$ of 0.275 was regarded as a constant in all models of the stars. The remaining parameters will be given in Table 1 for each star.

Table 1. Input parameters for grid calculation.

Variable	Minimum	Maximum	δ^*	Minimum	Maximum	δ^*	Minimum	Maximum	δ^*
	C1			C2			C3		
$M(M_\odot)$	1.23	1.45	0.02	1.15	1.35	0.02	1.12	1.34	0.02
Z	0.022	0.028	0.002	0.010	0.014	0.002	0.014	0.018	0.002
α	1.75	2.15	0.20	1.75	2.15	0.20	1.75	2.15	0.20
V_{ZAMS}(km/s)	5	15	5	10	15	5	5	10	5

Notes:
$^{(*)}$ The value δ defines the increment between minimum and maximum parameter values used to construct the models.

Table 2. Stellar parameters determined by different methods and previous studies.

Observational constraints	M($M_\odot$)	τ(Gyr)	M($M_\odot$)	τ(Gyr)	M($M_\odot$)	τ(Gyr)
	C1		C2		C3	
Previous results	1.34 ± 0.11	4.50 ± 0.50	1.25 ± 0.10	3.70 ± 0.60	1.23 ± 0.11	5.00 ± 1.90
Classical features$^{(*)}$	1.33 ± 0.10	4.55 ± 1.33	1.22 ± 0.07	4.46 ± 0.95	1.18 ± 0.06	5.68 ± 1.09
Previous step + log N (Li)	1.32 ± 0.09	4.68 ± 1.19	1.21 ± 0.06	4.49 ± 0.92	1.17 ± 0.05	5.69 ± 1.08
Previous step + P_{rot}	1.28 ± 0.05	5.11 ± 0.76	1.22 ± 0.03	3.92 ± 0.23	1.15 ± 0.03	5.86 ± 0.91
Previous step + $< \Delta\nu >$	1.27 ± 0.02	4.98 ± 0.10	1.22 ± 0.01	3.88 ± 0.02	1.16 ± 0.02	5.45 ± 0.19

Notes:
$^{(*)}$ The differences in results between Creevey *et al.* (2011) and us were a result of rotation model.

Our study was based on conventional observations and four additional observed quantities (log N (Li), P_{rot}, $< \Delta\nu >$ and $\nu_{n,\ell}$). Four steps were performed to estimate the stellar parameters of the three stars. First, we estimated the mass and age of the stars using only the conventional observational constraints. The precision of the results is approximately 0.08 $M_\odot$ and 1.10 Gyr, and it is interesting that our results are not identical to the results in Creevey *et al.* (2011); these differences may be caused by the rotation model. As we added the lithium abundance, the rotational period and the average large frequency separation into our analysis, more accurate determinations were obtained. The lithium abundance helped us improve our precision of mass and age to 0.07 $M_\odot$ and 1.00 Gyr, respectively. Next, base on the above results, we brought the rotational period to constrain more accurate stellar parameters. Very precise estimations were obtained in this step, specifically $\Delta M \sim 0.04$ $M_\odot$ and $\Delta t \sim 0.60$ Gyr. Finally, the pulsation analysis was performed. By comparing the observation with the theoretical $< \Delta\nu >$ and the frequencies, we obtained the most accurate results in this work. Our best estimations of mass and age of the three stars were listed in Table 2.

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References

Campante *et al.* 2011, *A&A*, 534, 6
Creevey *et al.* 2012, *A&A*, 537, 111
Demarque, P., Guenther, D. B., Li, L. H., *et al.* 2008, *Ap&SS*, 316, 31
Guenther, D. B., Demarque, P., Kim, Y.-C., & Pinsonneault, M. H. 1992, *ApJ* 387
Mathur, S., Handberg, R., Campante, T. L., *et al.* 2011, *ApJ*, 733, 95