Preliminary results from the STEPHI2009 campaign on the open cluster NGC 1817

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We present preliminary observational results of the multi-site STEPHI campaign on the cluster NGC 1817. The three observatories involved are San Pedro Mártir (Mexico), Xing Long (China) and the Observatorio del Teide (Spain) — giving an ideal combination to maximise the duty cycle. The cluster has 12 known δ Scuti stars and at least two detached eclipsing binary systems. This combination of characteristics is ideal for extracting information about global parameters of the targets, which will in turn impose strict constraints on the stellar models. From an initial comparison with stellar models using the known fundamental parameters, and just the observed pulsation frequencies and measured effective temperatures, it appears that a lower value of initial helium mass fraction will most likely explain the observations of these stars.

1 Introduction

δ Scuti stars are 1.5 – 2.5 M⊙ mostly MS stars, with few observed pulsation modes. Interpreting these pulsations is difficult, mainly because we do not know the fundamental parameters of the star. One possibility of overcoming this difficulty is studying pulsating stars in an open cluster where some fundamental parameters can be determined prior to using any pulsation frequencies. In this scenario all of the stars would be expected to have the same age and initial chemical composition — three of five main parameters needed to describe the stellar evolution and structure of the star (mass and convection parameter are unknown). Additionally their brightness would rank the objects in terms of masses.

NGC 1817 (α = 05h12m12s, δ = +16°41′00″, J2000) is an open cluster with 12 known pulsating δ Scuti stars [Arentoft et al. 2005]. It has also been studied by various authors and so the fundamental parameters are known with good precision. One of the most recent studies confirmed it as being a metal poor cluster with [Fe/H] = −0.33 ± 0.08 [Celeste-Parisi et al. 2005], consistent with [Fe/H] = −0.34 ± 0.26 from Balaguer-Nuñez et al. (2004). Balaguer-Nuñez et al. (2004) also determined an age of 1.12±0.14 Gyr and the distance modulus, which yields a distance of 1,513±580 pc [Harris & Harris (1977)] and Dutra & Bica (2000) determine E(B-V) = 0.23 and 0.33 respectively.

The international STEPHI (STEllar Photometry International) network has been operative since 1987. This network organizes ground-based photometric campaigns on pulsating stars, and has had many scientific successes (Michel & Baglin 1991; Michel et al. 2000; Li et al. 2004; Costa et al. 2007; Fox Machado et al. 2007; Fox Machado et al. 2008). Because some fundamental parameters of NGC 1817 have been well-determined, and some δ Scuti stars have been confirmed, the 2009 STEPHI campaign was dedicated to this open cluster. In this paper we discuss some preliminary results on the ground-based photometric campaign which took place in December 2009.

2 Observations and Analysis

We obtained a total of 46 nights of observations between three telescopes located around the globe; the 84cm at San
Table 1: Observing Log

| Station                  | Telescope | Nights Awarded | Useful Nights |
|--------------------------|-----------|----------------|---------------|
| San Pedro Mártir (Mexico)| 84cm      | 18             | 14            |
| Tenerife (Spain)         | IAC80     | 14             | 4             |
| Xinglong (China)         | 85cm      | 14             | 10.5          |

Fig. 1: The observed field of the open cluster NGC 1817 showing the monitored δ Scuti stars.

Pedro Mártir in Mexico, the IAC80 at the Observatorio del Teide, Spain, and the 85cm at the Xinglong Station in China. Table 1 summarizes the observing log, and Fig. 1 shows the cluster field and the monitored δ Scuti stars.

After reduction of the data, aperture photometry was performed on the candidate stars (which include some “constant” stars) for all of the images spanning the 46 nights. Light curves were then produced using differential photometry. Figure 2 shows 7 hours of V band light curves for the pulsating stars V1, V2 and V3 (denoted 1 – 3 in Fig. 1). The large amplitude pulsations of frequencies of 19.9, 18.6 and 18.5 cycles/day (c/d) can be clearly seen.

Molenda-Zakowicz et al. (2009) has performed an atmospheric analysis on these candidate stars, and they give $T_{\text{eff}} = 7991 \pm 434, 7298 \pm 317, \text{ and } 7962 \pm 707$ K for V1, V2 and V3 respectively using spectroscopy and $8118 \pm 61, 7970 \pm 50, \text{ and } 7982 \pm 26$ K using colour information. They also obtain $\log g = 3.96 \pm 0.06, 3.50 \pm 0.06 \text{ and } 4.49 \pm 0.02$ dex.

3 Initial Inference

Due to the tight constraints on the fundamental parameters of the stars, we can already construct some stellar models to compare the observations to. In Fig. 3, we show some theoretical pulsations frequencies of low-degree ($l$), low radial order ($n$) modes of a 1.12 Gyr star. We calculated these frequencies using the ASTEC and ADIPLS stellar structure, evolution and pulsation codes (Christensen-Dalsgaard 2008a,b) for various masses on the main sequence. We show the non-rotational counterparts ($n = 0$) for the modes of degree $l = 0$ (left) and 2 (right). The left panel shows the theoretical frequencies for the radial orders $n = 1$ and 2, while the right shows only the $n = 1$ mode, seen as any higher order modes would not correspond to any of the observed pulsation frequencies (horizontal dashed lines). The upper and lower panels show models for two values of initial helium mass fraction, $Y_i = 0.251$ (top) and 0.282 (bottom). $[Z_i/X_i] = -0.35$ (top) and -0.32 (bottom), where $Z_i$ and $X_i$ are the initial hydrogen and metal content and we do not include diffusion in the models so we assume $[Z_i/X_i] \sim [\text{Fe/Fe}]$. We show the frequencies also at the 1-$\sigma$ error bar on age and these are denoted by the dotted lines above and below each of the solid lines. We have also included the theoretical $T_{\text{eff}}$ of the models for 5 masses with an age of 1.12 Gyr, these are the 4-digit numbers on the solid lines.

By comparing these models with just the observed pulsation frequencies and measured $T_{\text{eff}}$, we can hypothesise the following:

- If any of the stars are post MS, then they have a minimum mass of 1.75 $M_\odot$.
- Comparing initially the measured effective temperatures (if any of the stars are MS), it is most likely that the models with lower $Y_i$ will best represent the observations.
- Given the constraints on the age and metallicity we can probably disregard the ($l = 0, n = 1$) mode for the main pulsation frequency of V1 (19.9 c/d). This would imply a minimum mass of 1.6 $M_\odot$ for V1.

Accurate apparent magnitudes and colours will constrain the masses of the star given that they are all at the same distance. This in turn will allow us to constrain the identification of many modes.

4 Conclusions

We described the recent observations of the open cluster NGC 1817, and summarized its known fundamental properties. We performed differential photometry of the monitored stars in the cluster field and analyzed three of the δ Scuti stars to determine their fundamental pulsation frequencies. The observed pulsations are consistent with those of Arentoft et al (2005). We then constructed some stellar evolution and pulsation models for a range of masses and two values of initial helium mass fraction, with the known fundamental properties of the cluster: Age $= 1.12^{+0.14}_{-0.12}$, and $[\text{Fe/Fe}] = -0.35, -0.32$, and we made some initial inferences of the three pulsating stars based on their observed pulsation frequencies. We showed that if any of the star’s are on the main sequence, then it is more likely that the cluster has...
Fig. 2  Differential magnitude light curves in $V$ for $\delta$ Scuti stars V1, V2, and V3, see Fig. [1] for reference.

Fig. 3  Theoretical frequencies of some oscillation modes ($l = 0, 2$ are left and right panels respectively) for stars of various masses. The thick line shows the frequencies for the 1.12 Gyr models and the dotted lines show the frequencies at the 1-$\sigma$ error bar on age. The numbers along the 1.12 Gyr frequency curves are the $T_{\text{eff}}$ for these models. The green horizontal lines show the dominant pulsation frequencies for the three stars shown in Fig. [2]. The upper and lower panels differ mainly by the initial He mass fraction ($Y_i = 0.251, 0.282$ for upper and lower respectively).
a lower initial helium mass fraction content, based on the observed pulsation frequencies and measured effective temperatures.

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References

Arentoft et al. 2005, PASP, 117, 601
Balaguer-Nuñez et al. 2004, A&A, 426, 827
Celeste-Parisi et al. 2005, BAAA, V.48
Christensen-Dalsgaard, J. 2008a, Ap&SS, 316, 113
Christensen-Dalsgaard, J. 2008b, Ap&SS, 316, 13
Costa et al. 2007 A&A, 468, 637
Dutra & Bica 2000, A&A, 359, 347
Fox Machado et al. 2007, AJ, 134, 860F
Fox Machado et al. 2008, CoAst, 157, 307F
Harris & Harris 1977, AJ, 82, 612
Li et al. 2004, A&A, 420, 283L
Michel & Baglin 1991, AdSpR, 11, 167
Michel et al. 2000, ASPC, 203, 483M
Molenda-Zakowicz et al. 2009, ActaAstronomica, 59, 00