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TT1 time-series observations of the star forming region Sh 2-284

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Abstract. Sh 2-284 is a metal poor star forming complex at a distance of ∼ 4 kpc hosting several open clusters. The low and high mass young stellar population of Sh 2-284 was investigated and characterized by us, in a previous work, using spectroscopic and photometric proprietary data complemented with various catalogs. Based on our analysis we found 23 new Pre-Main Sequence (PMS) stars, 8 of which are good PMS δ Scuti candidates. In the present work, we report Toppo Telescope 1 (TT1) time-series observations of 4 of these objects. δ-Scuti pulsation frequencies were detected in two stars. New variable stars of various types (eclipsing binary systems, magnetically active stars, pulsating stars etc.) were also serendipitously discovered.

Key words. Stars: variables: delta Scuti – Stars: variables: T Tauri, Herbig Ae/Be– Stars: variables: general

1. Introduction

Sh 2-284 is an HII region (Fig.1, Sharpless et al. 1959) at a distance of ∼ 4 kpc (Cusano et al. 2010) characterized by a low metallicity content (Z∼0.004, Lennon et al. 1990), which harbors several open clusters. Triggered star formations is in act in this region (Puga et al. 2009) with an age spread of ∼ 10 Myr among the young stellar population (Cusano et al. 2010). Using VIMOS@VLT and complementary multi-band photometry, the stellar population of Sh 2-284 was investigated discovering 23 low and intermediate mass PMS stars (Cusano et al. 2010). Among these objects, 8 stars are good δ Scuti PMS star candidates. In order to assess their δ Scuti nature and detect the photometric signatures of stellar pulsation, we performed time-series observations of a part of the Sh 2-284 region by using the Toppo di Castelgrande Telescope. An asterosismological study of PMS δ Scuti stars allows us to derive their mass and radius (Ripepi et al. 2006; Ruoppo et al. 2007), using models which depend weakly on the physics of the star. The identification of the fundamental mode or/and the first overtone of oscillations in a PMS δ Scuti star, can be also used to determine the distance of the object with an accuracy up to ∼ 5% (McNamara et al. 2007). Time-series observations of PMS stars are also

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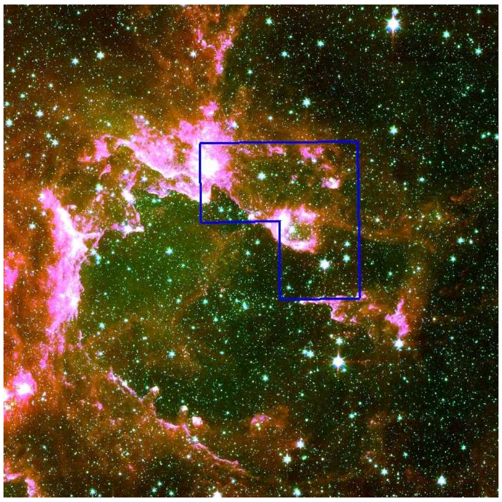

Fig. 1. Infrared image of the Sh 2-284 region obtained by combining Spitzer-Irac images (Puga et al. 2009) in the [3.6], [4.5] and [5.6] μm bands. The region indicates the field of view of the TT1 observations.

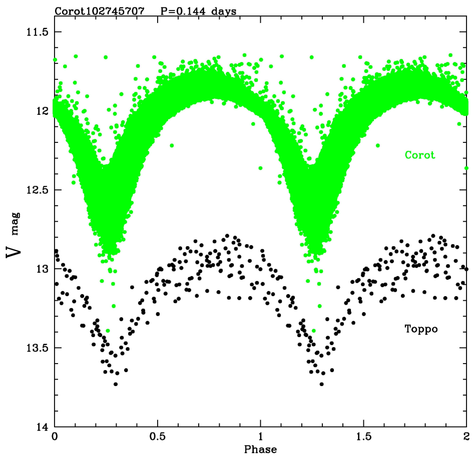

Fig. 2. Comparison between CoRoT and TT1 observations of the eclipsing binary CoRoT 102745707. The CoRoT data were arbitrarily shifted in magnitude for the sake of clarity. Note that the high scatter in both light curves is caused by intrinsic variability of one or both components of the binary system.

important tools to study the variability of these active objects associated to accretion processes or rapid rotation.

The present work is complementary to part of the CoRoT space telescope (Baglin et al. 2007) observations of young stellar objects in the same field (Ripepi et al. 2010). Indeed the targets imaged by CoRoT are usually brighter than $\sim$ 16 mag in the V-band. Given the distance of Sh 2-284, deeper ground-based observations are crucial to recover the faintest objects (V > 16 mag) and fully characterize the stellar population of the region.

2. Observations and data reduction

Time-series observations were performed in the V band with the 1.54 m telescope at the Osservatorio Astronomico di Castelgrande using the Toppo Telescope Scientific Camera (TTSC). The total field of view of the observations is about $13'X13'$ (see Fig. 1). The coordinates of the center of the observed field (α=06^{h}44^{m}50.5^s, δ=+00^{o}20'25") were chosen to observe simultaniously in one frame 4 of the δ Scuti candidates selected in Cusano et al. (2010). This field of view also included other 5 PMS stars reported in Cusano et al. (2010), but only 2 of them were bright enough to collect reliable signal. The observed 6 PMS stars are listed in Table 1. The observations were spread over 8 nights (November 2009) for a total of $\sim$ 32 hours. An exposure time of 600 seconds was used for each frame. In order to perform the photometric calibration of the V magnitude zero-point, the standard star field Landolt 98 (Landolt et al. 1992) was also observed. Bias subtraction and flat field correction were performed on the scientific and calibration images using standard procedures with *IRAF*. Aperture photometry was performed on the images by using *Daophot* and *Daomaster* packages (Stetson et al. 1987, 1992).

In total the light curves of 2651 objects were obtained in the region marked in Fig. 1. An example is shown in Fig. 2, where the TT1-light curve of a known eclisping binary is compared with the CoRoT observations. The frequency analysis of the resulting light curves was performed using the *Period*04 (Lenz & Breger 2005) and *SigSpec* (Reegen et al. 2007) packages.

Table 1. Physical parameters of the PMS stars observed in the present work, as reported in Cusano et al. (2010).

Star (2MASS)	Sp.Type	$\log T_{\rm eff}$	$\log L_{\rm BC}/L_{\odot}$	Mass ($M_{\odot}$)
J06443291+0023546[a]	F0V	3.860	1.27	1.8
J06443541+0019093[a]	F2V	3.831	1.00	1.6
J06443682+0016186[a]	A8V	3.880	0.98	1.4
J06443788+0021509[a]	F0V	3.857	1.27	1.8
J06443827+0019229[b]	F2V	3.831	0.66	1.2
J06444496+0019335	F8V	3.781	0.88	1.6

[a] Candidate δ Scuti star (Cusano et al. 2010).
[b] Suspected δ Scuti star (Cusano et al. 2010).

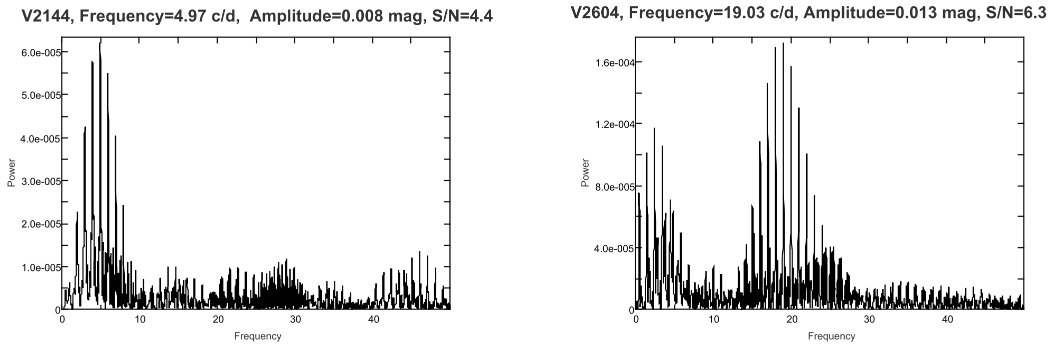

Fig. 3. Periodograms of the two PMS stars J06443827+0019229 (*left*) and J06443291+0023546 (*right*) in which δ Scuti type pulsations were detected.

3. Results and Conclusions

Our observations allowed us to detect δ Scuti type pulsations in two PMS stars (see Fig. 3) in the star forming region Sh 2-284. These stars are 2MASS J06443827+0019229 and 2MASS J06443291+0023546 (see Table 1). Their pulsation frequencies were compared with the period-luminosity ($P - L$) relations given by McNamara et al. (2007) and Santolamazza et al. (2001), taking into account the metallicity of the region. The continuum blue line in the upper panel of Fig. 4 shows the observed $P - L$ relation of δ Scuti stars for the fundamental mode (McNamara et al. 2007). The dashed, dotted, and continuum black lines represent the theoretical $P - L$ relations, derived by Santolamazza et al. (2001), for the second, the first overtone, and the fundamental mode of pulsation, respectively. Finally, the red line is the observed $P - L$ relation in the fundamental mode for low-metallicity δ Scuti stars found by Pych et al. (2001). The position of the two PMS stars 2MASS J06443827+0019229 and 2MASS J06443291+0023546 in the $P - L$ diagram (see Fig. 4) is consistent with a distance to the stars of 4 kpc and an $A_{\rm v} = 2.6$ mag. These values are in agreement with the ones found by Cusano et al. (2010) for the Sh 2-284 region. The red points in Fig. 4 are candidate δ

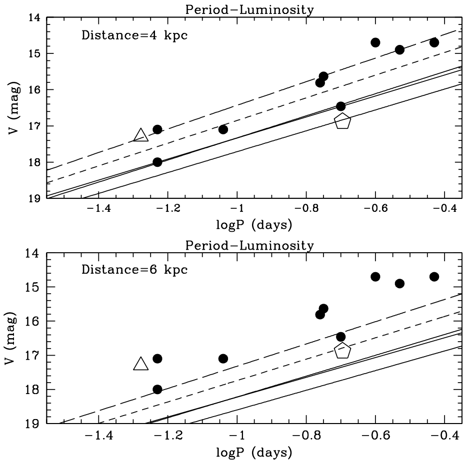

Fig. 4. *Upperpanel*: The Period-luminosity relations of δ Scuti stars are shown (see text for details). The magnitude of the relations were corrected for the distance modulus of the Sh 2-284 region and its average A_v (13 and 2.6 mag, respectively, Cusano et al. 2010). The open triangle is the pulsation frequency detected in the star J06443682+0016186, while the open pentagon the one in J06443827+0019229. The red points are candidate δ Scuti stars. *Lowerpanel*: The same as the upper panel, but for a distance modulus of 13.9 mag (d∼6kpc, Lennon et al. 1990)

Scuti stars, which might belong to the Sh 2-284 star forming region. Indeed the V-magnitude and the oscillations frequencies of these stars, can be compared with the $P-L$ relations corrected for distance and interstellar absorption of the region. For comparison, the lower panel in Fig. 4 shows the $P-L$ relations corrected for the distance modulus of 13.9 mag, corresponding to the distance estimate of $\sim$ 6 kpc previously reported in the literature for the Sh 2-284 region (Lennon et al. 1990; Turbide & Moffat 1993). The 4 kpc distance seems to be favoured by our analysis.

Moreover, given the high number of light curves analyzed in the present work, a remarkable number of new variable stars was serendipitously discovered, including eclipsing binaries, magnetically active and spotted stars, and evolved post-main sequence δ Scuti stars. The detailed analysis of the light curves and the spectroscopic follow up of the most interesting objects is still on going, and it will be the subject of a forthcoming paper.

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References

Baglin, A., Auvergne, M., Barge, P. et al. 2007, AIPC, 895, 201
Cusano, F., Ripepi, V., Alcala, J. M. et al. 2010, MNRAS.tmp.1480
Landolt, A. U. 1992, AJ, 104, 340
Lennon, D. J., Kudritzki, R.P., Becker, S. R., Eber, F., Butler, K. 1990, A&A, 240, 349
Lenz, P., Breger, M. 2005, CoAst, 146, 53
McNamara, D. H., Clementini, G., Marconi, M. 2007, AJ, 133, 2752
Puga, E., Hony, S., Neiner, C. et al. 2009, A&A, 503, 107
Pych, W., Kaluzny, J., Krzeminski, W., Schwarzenberg-Czerny, A., Thompson, I. B. 2001, A&A, 367, 148
Reegen, P. 2007, A&A, 467, 1353
Ripepi, V., Bernabei, S., Marconi, M. et al. 2006, A&A, 449, 335R
Ripepi, V., Leccia, S., Baglin, A. et al. 2010, Ap&SS, 328, 119
Ruoppo, A., Marconi, M., Marques, J. P. et al. 2007, A&A, 466, 261
Santolamazza, P., Marconi, M., Bono, G. et al. 2001, ApJ, 554, 1124
Sharpless, S. 1959, ApJS, 4, 257
Stetson P. B. 1987, PASP, 99, 191
Stetson P. B. 1992, ASPC, 25, 297
Turbide, L. & Moffat, A. F. J. 1993, AJ, 105, 1831