Search for Exoplanets and Variables in the Open Cluster, NGC 381

Juei-Hwa Hu, and Wing-Huen Ip
Institute of Astronomy, National Central University, Chung-Li, Taiwan
email: d939003@astro.ncu.edu.tw

Abstract

A program to search for exoplanets and variable stars in the open cluster star fields has been established using the Lulin One-meter Telescope (LOT) in Taiwan. The main scientific goal is to use time series CCD photometry measurements to detect exoplanets via transit effects. Observations of open clusters would give us important information on the formation of planets in different stellar environments. The secondary scientific goal is to discover and study variable stars with the similar data analysis process. Several program stellar clusters have been observed. Four variable candidates were discovered in the NGC 381 star field. One of them was previously identified as the suspected cluster members, CT 123, by Crinklaw & Talbert, 1988. However, no transiting extrasolar planet has been found in this observation.

INTRODUCTION

To date, about two hundred extrasolar planets have been detected orbiting solar-type stars (ref. http://exoplanet.eu). Most of them were discovered by high-precision spectroscopic measurements employing Doppler and timing techniques (Mayor & Queloz 1995 & Marcy & Butler 1998). Nine exoplanets have been detected via the transit effect during which the stellar brightness drops as the planet passes by the light-of-sight. They are HD209458b (Charbonneau et al. 2000 ;Henry et al. 2000), OGLE-TR-56 (Udalski et al. 2000a,2000b; Konacki et al. 2003a), OGLE-TR-113 (Bouchy et al. 2004), OGLE-TR-132 (Bouchy et al. 2004), OGLE-TR-111 (Pont et al. 2004), TrES-1 (Alonso et al. 2004), OGLE-TR-10, HD 149026b (Sato et al. 2005), and HD 189733b (Bouchy et al. 2005). As demonstrated by Charbonneau et al. (2000) and Henry et al. (2000) in the case of HD 209458b, the transit effect of an exoplanet across the disk of its host star could provide additional information on the size and hence average density of the exoplanet. Using both radial-velocity and the transit observation methods, the exoplanets radius and mass can be obtained to study the formation, evolution, and migration of planetary system (e.g. Burrows et al. 2000; Guillot & Showman 2002; Baraffe et al. 2003). Accurate measurements of the transit phenomena are challenging tasks because the small intensity variation during the transit is only around 1% for a Jupiter sized planet, and the probability of the detectable events is less than 0.035% (Mallén-Ornelas et al. 2003). To improve the probability of transit searches, we select several open clusters including NGC 2324, NGC 2374, NGC 2420, NGC 381, & NGC 7245, etc. as our observation targets. Open clusters contain stars more than normal star fields do. The similarities in the physical parameters of the member stars (i.e. the age and metallicity) in a open cluster give us more information on the formation and evolution of planetary systems. In addition, with the time series observations, variable stars can be identified and studied.

THE TARGET : NGC 381

NGC 381 is an intermediate-age open cluster in Cassiopeia with $l = 127.94$, $b = -1.22$ and about 6 arcsec of angular diameter. The distance modulus and reddening are $(m-M)_0 = 10.3 \pm 0.3$ (Ann 2002) and $E(B-V) = 0.40 \pm 0.10$ (Ann 2002), respectively. NGC 381 is not a well-studied open cluster. Crinklaw & Etzel (1989) provided the star catalogue and the membership from the positions in the color-magnitude diagram. NGC 381 is one of 23 open clusters in the CCD photometry studies by Phelps & Janes (1994) and one of the 12 open clusters in Ann's (2002) studies. Their age estimates of NGC 381 vary from 0.3 Gy (Ann 2002) to 1.1 Gy (Phelps & Janes 1994). The metallicity of $[Fe/H] = 0.07$ (Ann 2002) is an important consideration of target chosen. Observations and studies have showed that stars with extrasolar planets tend to have a higher metallicity than stars without detected extrasolar planets (e.g. Fischer 2005). Planets could be born in the higher metallicity environment.

OBSERVATIONS

The observations were carried out with Luin One-Meter Telescope on Septerber 21, 22, & 23, 2004 with PI1300B (Princeton Instrument, Inc.) 1340×1340 (Kinoshita et al. 2004) at Lulin Observatory in Taiwan. The FOV for PI1300B is about 12 arcmin by 12 arcmin and the pixel scale is 0.52 arcsec. The exposure times were 30 & 60 seconds with R filter. We have obtained around 360 frames in total. While the cadence (~ 3 min) was small enough, the search for transit events was handicapped by the short time interval ($\sim$ 2 hours) available at each night. We present here the result of the observation campaigns.

DATA ANALYSIS

The pre-processing of the CCD frames and data reduction were performed with the standard rourines in the IRAF CCDRED and DAOPHOT II (Stetson 1987) packages. The WCSTools were used to obtain the world coordinates system in the header of fit files. Positions of stars in different images were then aligned by matching the relative distances from their neighboring stars. This procedure would permit the determination of light curves of the target stars. To search for exoplanets, we have opted for visual inspection in the preliminary study. It's about one thousand stars in the NGC 381 star field. For variable star candidates, we selected stars with the peak-to-peak amplitudes of the magnitude variations $> 3\sigma$ in their light curves for further analysis. we determined the possible periods with the Phase Dispersion Minimization (PDM) method (Stellingwerg 1978) and the Lomb Normalization Periodogram (LNP) (Lomb 1976 & Scargle 1982).

RESULTS

We have found four variable candidates in the NGC 381 star field. V1 has been identified as a suspected cluster member, CT 123, by Crinklaw & Talbert (1988). Figure 1 shows their locations in the frame taken by LOT. Figure 2 is four phase diagrams with estimated periods. The photometric errors are about 0.02 for V1 & V3 and about 0.04 for V2 & V4. We present the parameters of variable candidates in Table 1. No extrasolar planets were found in this observation.

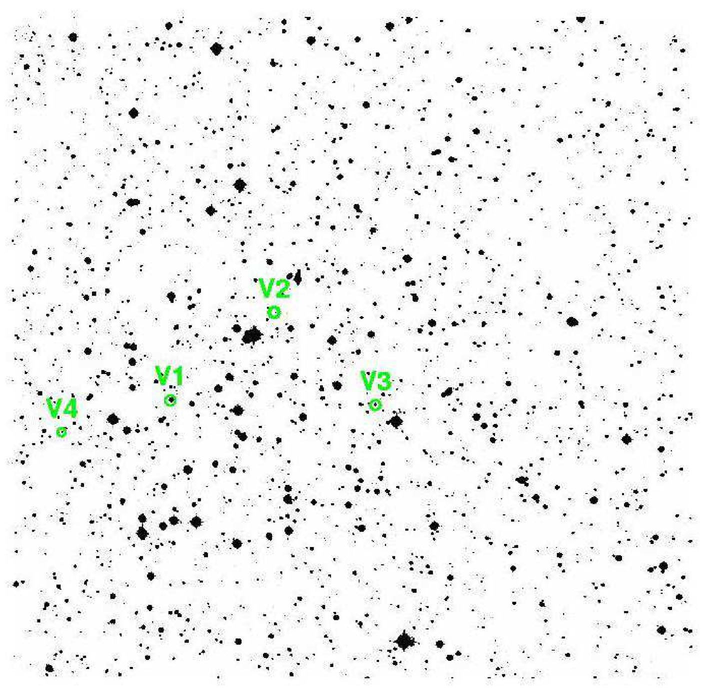

Figure 1. The NGC 381 star field obtained by LOT. The circles are positions of variable candidates.

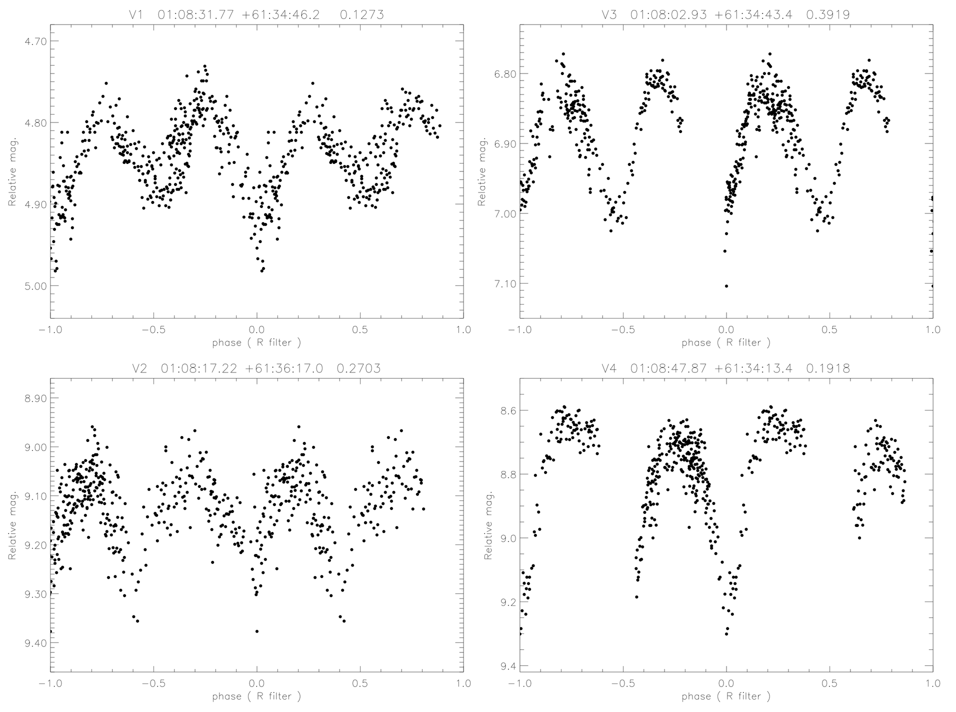

Figure 2. The phase diagrams of the four variable candidates in the NGC 381 field.

Star	RA(J2000)	Dec	Possible Period (day)	Amplitude (mag)
V1	01:08:31.77	+61:34:46.2	0.1273	~ 0.25
V2	01:08:17.22	+61:36:17.0	0.2703	~ 0.45
V3	01:08:02.93	+61:34:43.4	0.3919	~ 0.3
V4	01:08:47.87	+61:34:13.4	0.1918	~ 0.7

Table 1. Parameters of variable star candidates

DISCUSSION

Von Braun et al. (2005) estimated that for exoplanets with orbital periods between 1 day and 5 days, an observing run of 18 nights are most efficient for the two-transit requirement. The 3-day observations is difficult to detect transit events. Only 4 short period variables are presented here. V1 could be EB type eclipsing binaries with amplitude smaller than 0.25 mag. V2 is W UMa tpye eclipsing variables. Though the incompletely light curves, V3 could be W UMa tpye eclipsing variables and V4 could either be W UMa or δ scuti with 0.38 days period.

REFERENCES

Alonso, R., et al. 2004, ApJ, 613, L153
Ann, H.B., Lee, S.H., Sung, H., Lee, M.G., Kim, S.-L., Chunm,-Y., Jeon, Y.-B., Park, B.-G., & Yuk, I.-S. 2002, AJ, 123, 905
Baraffe, I., Chabrier, G., Barman, T. S., Allard, F., & Hauschildt, P.H. 2003, A&A, 402, 701
Bouchy, F., Pont, F., Santos, N. C., Melo, C., Mayor, M., Queloz, D., & Udry, S. 2004, A&A,421, L13
Bouchy, F., Udry, S., Mayor, M., et al. 2005, A&A, 444, L15
Burrows, A., Guillot, T., Hubbard, W.B., Marley, M.S., Saumon, D., Lunine, J. I., & Sudarsky, D. 2000, ApJ, 534, L97
Charbonneau, D., Brown, T.M., Latham, D.W., Mayor, M., 2000, ApJ, 529, L45
Guillot, T., & Showman, A.P. 2002, A&A, 385,156
Crinhlaw, G. & Etzel, P.B., 1989, AJ, 98, 1418
Crinhlaw, G. & Talbert, F.D., 1988, PASP, 100: 693
Henry, G.W., Marcy, G.W., Butler, R.P., Vogt, S.S., 2000, ApJ, 529, L41
Fischer, D. & Valenti, J., 2005, APJ, 622, 1102
Kinoshita, D., Chen, Chin-Wei, Lin, Hung-Chin, Lin Zhong-Yi & Chen, Wen-Ping, 2005, Chin. Y. Astron. Astrophys., 5:315
Konacki, M., Torres, G., Jha, S., & Sasselov, D. D. 2003a, Nature, 421, 507
Lomb, N.R. 1976, Ap. Sp. Sci., 39, 447
Marcy, G. W., & Butler, R. P. 1998, ARA&A, 36, 57
Mayor, M., & Queloz, D. 1995, Nature, 378, 355
Mallén-Ornelas G., Seager, S., Yee, H.K.C., Minniti, D., Gladders, M.D., Mallén-Fullerton G.M., & Brown, T.M. 2003, ApJ, 582, 1123
Phelps, R.L., & Janes, K.A. 1994, ApJS, 90, 31
Pont, F.,Bouchy, F., Queloz, D., Santos, N. C., Melo, C., Mayor, M., & Udry, S. 2004, A&A,426, L15
Sato, B., Fischer, D. A., Henry, G. W. et al. 2005, ApJ, 133, 465
Scargle, J.D. 1982, ApJ, 263, 835
Stellingwerf, R.F. 1978, ApJ, 224, 953
Stetsonm P.B. 1987, PASP, 99, 191
Udalski, A., Paczynski, B., Zebrun, K., Szymaski, M., Kubiak, M., Soszynski, I., Szewczyk, O., Wyrzykowski, L. and Pietrzynski, G., 2002, Acta Astron., 52, 1, 2002a
Udalski, A., Paczynski, B., Zebrun, K., Szymaski, M., Kubiak, M., Soszynski, I., Szewczyk, O., Wyrzykowski, L. and Pietrzynski, G., 2002, Acta Astron., 52, 115, 2002b
von Braun, K.,Lee, B.L.,Seager, S., Yee, H. K. C., Mallen-Ornelas, G.,Gladders, M. D. 2005, PASP, 117, 141

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