使用網路視訊 CCD 進行雙星散斑干涉觀測

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摘要

本論文使用網路視訊Philip 840K CCD，裝置在中大鹿林天文台一公尺望遠鏡上，針對14個雙星進行散斑干涉技術觀測，分辨出其中比6.5星等亮的13個雙星系統，角距範圍爲0.3"至5.3"。使用雙子座主星北河二作爲比例尺與方位角的校準，比例尺爲0.043"/pixel。本觀測顯示商業等級之CCD可以用來進行散斑觀測，達到小型或中型望遠鏡的干涉極限。

Speckle interferometry of selected binaries using webcam CCD

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Abstract

There were 14 binaries chosen for speckle interferometry technique with a modified Philip 840K webcam CCD equipped on LOT, and 13 of them with component brighter than magnitude 6.5 are resolved in the range of angular separation 0.3" to 5.3". The scale, 0.043"/pixel, and position angle are calibrated in term of the bright binaries, Castor. According to this work, the commercial webcam CCD is suitable for speckle interferometry observation of binary to reach the diffraction limit of the small or moderate sized telescopes.

關鍵字（Keywords）：雙星（binary）、散斑（speckle）、北河二（Castor）。

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1. Introduction

The angular resolution of optical observation is limited to about 1"~2" because the wavefront of the light emitted from the star is distorted by the turbulence of atmosphere. However, Texereau (1963) first described that the image of a single star on a very short exposure time is composed of numerous short-lived speckles. When the angular separation of binary is less than 1"~2", the speckle interferometry method (Labeyrie 1970) is typically used to reach the diffraction limit of the telescope, because the original information of the binary can be read with the extreme short

Table 1. Data of the selected binaries.

binary	ADS	RA	Dec	V1	V2	*a*(")	period(yrs)
Castor	ADS 6175	$07^h\,34^m\,36^s$	+31° 53'19"	1.58	2.62	6.593	444.95
STT208	ADS 7545	$09^h\,52^m\,06^s$	+54° 03' 51"	4.55	4.67	0.349	105.4
STF1669AB	HR 4821-2	$12^h\,41^m\,16^s$	-13° 00' 50"	5.88	5.89		
STF1670AB	ADS 8630	$12^h\,41^m\,40^s$	-01° 26' 58"	2.74	2.79	3.68	168.9
WRH 12	HR 4789						
STF1728AB	ADS 8804	$13^h\,10^m\,00^s$	+17° 31' 45"	5.1	5.1	0.6684	25.804
BU 341	ADS 8757	$13^h\,03^m\,46^s$	-20° 35' 00"	6.51	6.25		
McA38Aa	ADS 8801	$13^h\,09^m\,57^s$	-05° 32' 20"	4.49	6.83		
BU 612AB	ADS8987	$13^h\,39^m\,35^s$	+10° 44' 47"	5.57	5.69	0.19983	22.46
STF1865AB	ADS 9343	$14^h\,41^m\,09^s$	+13° 43' 42"	4.46	4.55	0.595	123.44
STF1877	ADS 9372	$14^h\,44^m\,59^s$	+27° 04' 27"	2.58	4.81		
STF1937AB	ADS 9617	$15^h\,3^m\,12^s$	+30° 17' 18"	4.98	5.28	0.8676	41.585
CHR259	HR 5881	$15^h\,49^m\,37^s$	-03° 25' 49"	3.75	5.39	0.37	36
STF1998AB	ADS 9909	$16^h\,04^m\,21^s$	-11° 22' 25"	4.8	5.1	0.663	45.68

exposure time, about 15 ms, to freeze the pattern distorted by the atmosphere. There are many programs of binary observation with speckle interferometry technology (e.g. Mason *et al.* 2004, Prieur *et al.* 2003, Scardia *et al.* 2005, Rutkowski & Waniak 2005).

The typical cooled CCD cameras of NTNU and that of LOT are not suitable for speckle observation because the shutter cannot work at such high speed, less than 0.03 seconds. A CCD chip taken from Phillip 840K webcam is used to satisfy the requirement of speckle observations.

The 14 binaries listed on Table 1 are chosen for the speckle observations, and 10 binaries with the angular separation between 0.2" and 0.8", 3 binaries between 2" and 6". The V1 and V2 are magnitude of primary and secondary, respectively. The semi-major axis and period of 9 binaries listed are taken from Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf & Mason 2003). Castor, a wide binary with good observed speckle data, was chosen for the calibration of scale and angular separation.

2. Equipments

The Philip 840k webcam without the lens is used for the speckle observation, because it can be work at extreme short time, such as 15 milliseconds, suitable for speckle interferometry. Philip 840k webcam is a common commercial camera, and it can download images with B/W raw format with the ability to adjust the contrast, brightness, gain, gamma, high-pass filter, and shutter speed on the control interface.

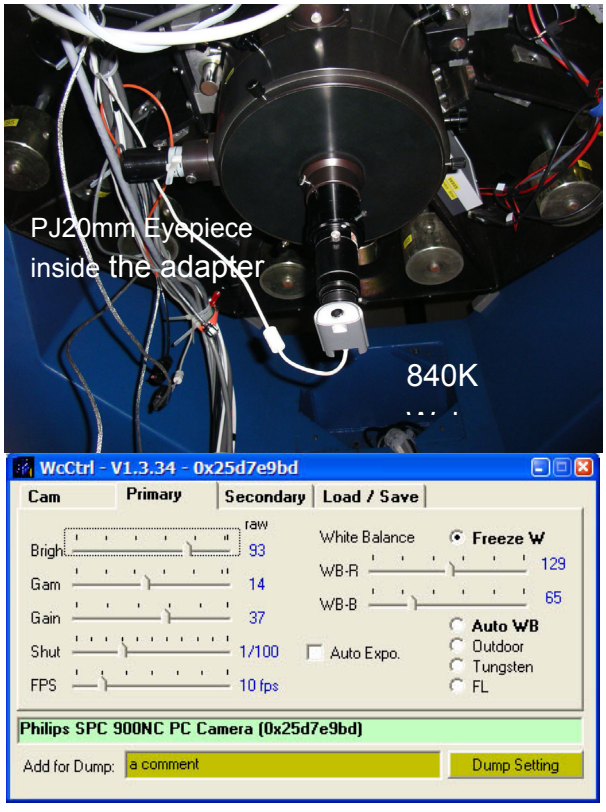
For enhancing the sensitivity and providing the better image resolution, the original CCD chip of the Phillip 840K webcam Sony ICX098BQ is replaced by a B/W CCD chip Sony ICX098BL in 650×570 square pixels of side 5.6 μm and an 8 bit A/D converter. Because the Sony ICX098BQ is a color type CCD arrayed in the order of pixel of red color and green, or the order green and blue, and with spatial interpolation for each color will decrease the image resolution about 2 times. The ICX098BL is a monochrome type CCD chip without that problem.

The firmware of ToUCam 840K is upgraded from the firmware of SPC900NC in order to disable internal high pass filter and to adjust the

download image to B/W raw mode. For 840K, the image enhancing is built internally without adjustable function, however, Philips company provides a new type webcam SPC900NC in that image enhancing function can be turned off, i.e., the signals of CCD are original. The hardware design of SPC900NC is very similar to 840K, and the firmware can fully fit with 840K chip. Furthermore, a free software tool called WcRmac released in Mr. Martin Burry's website is used to upgrade the firmware.

The control parameters of webcam are not shown in the tuning interface, so it is hard to know and to compare observational parameters with different observations. A free software tool called WcCtrl can display the parameters in the soft control panel, i.e., WcCtrl can record clearly the data of gain, shut… for each observational run. Furthermore, the interface of control panel -WcCtrl (figure 1) is updated from a personal website of Martin Burri[a].

Fig. 1: The picture of control panel



3. Observations

The observations of speckle interferometry with a Johnson R filter for selected 14 binaries were performed with the modified CCD chip taken from Phillip 840k, and the webcam was equipped on the LOT on April 2-3, 2006. An eyepiece of PJ 20 mm is used to produce a scale, 0.043″/pixel, on the CCD chip in R band. For comparing, the scale at the original focal length of 8000mm is about 0.14"/pixel.

A series of speckle images of a binary are recorded to a personal computer or notebook in avi format with five frames per second. Usually, the total 1500 frames for a binary are recorded, and the different gain adjusted depending on the rate of signal/noise of image of each binary.

There is no two-slits-mask on the aperture of the LOT for observing the interference pattern to calculate the scale. The astrometry of the wide binaries, α Gem (Castor, WDS07346+3153=ADS 6175) is chosen for the calibration of angular scale and orientation.

4. Data reduction and calibration

The speckle images stream in the file of avi format are transformed to a series of images of bmp format with AVI2BMP software. The raw

[a] http://www.burri-web.org/bm98/soft.wcctrl

image in bmp format is processed by a normalized 2-D auto-correlation image (figure 2) and the box-card process with Matlab. The relative positions to primary star of 13 binaries are determined with the commercial astronomical software, Astroart 3. However, the result of CHR 259 is failed (figure 3).

There is no mask of two slits for scale calibration on the aperture of LOT, and the star tracking is done in fast or slow tracking mode that is not suitable for the calibration of orientation. For the calibration of the angular scale and orienttation, a wide binary, Castor, with long period and good observational data in the Fourth Catalog of Interferometric Measurements of Binary Stars (Harkhopf & McAlister 1998) is used.

The angular separation and the position angle of Castor at the our observing time, 2006.253, calculated from the orbit elements taken from the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf & Mason 2003) are 4.36" and 59.62°, respectively. The distance between Castor A and B is 101.0 pixels and the angle responds to the y-axis of CCD chip is 57.20°, so that the angular scale is 0.043"/pixel, and the angle between the direction of north and the y-axis 2.42° (figure 4).

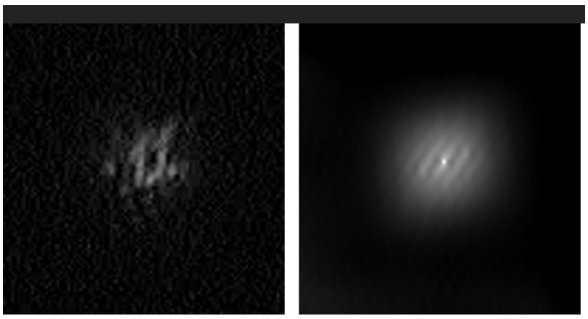


Fig. 2: An example of the raw image and the result after autocorrelation.

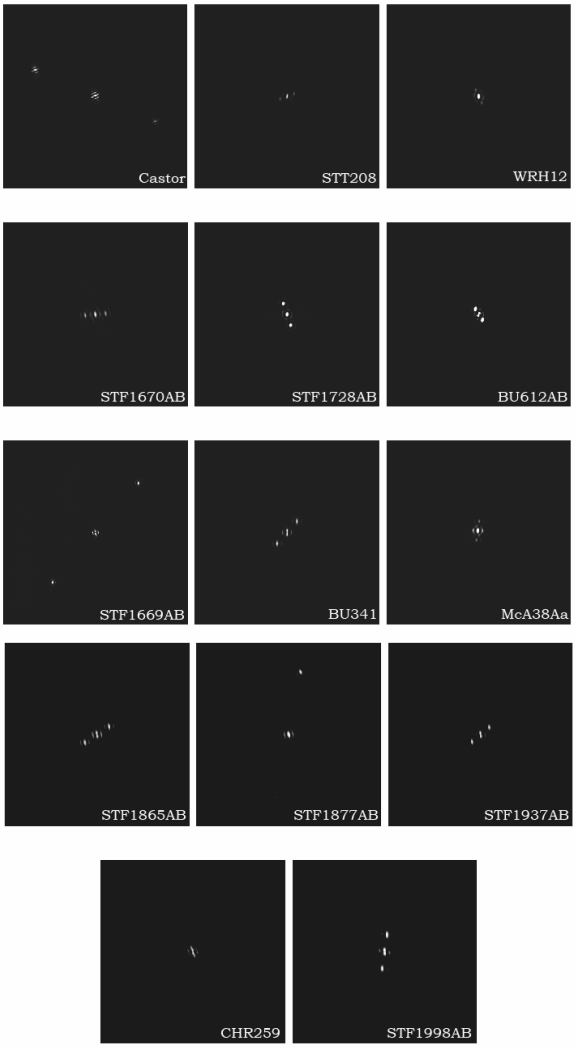


Fig. 3: The images after autocorrelation processed

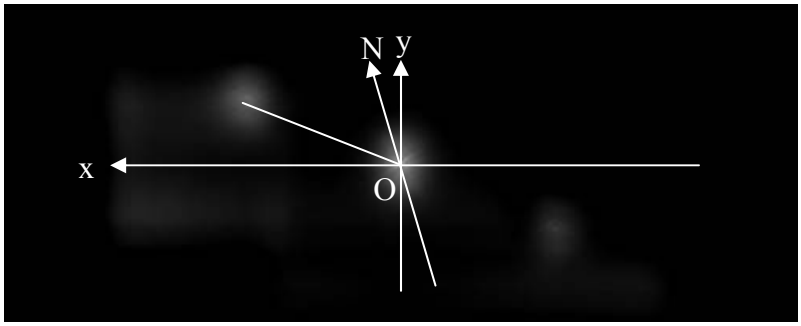


Fig. 4: The astrometry of Castor image of autocorrelation is used for the calibration of the angular separation and the orientation. The angle between N and y-axis is about 2.42°.

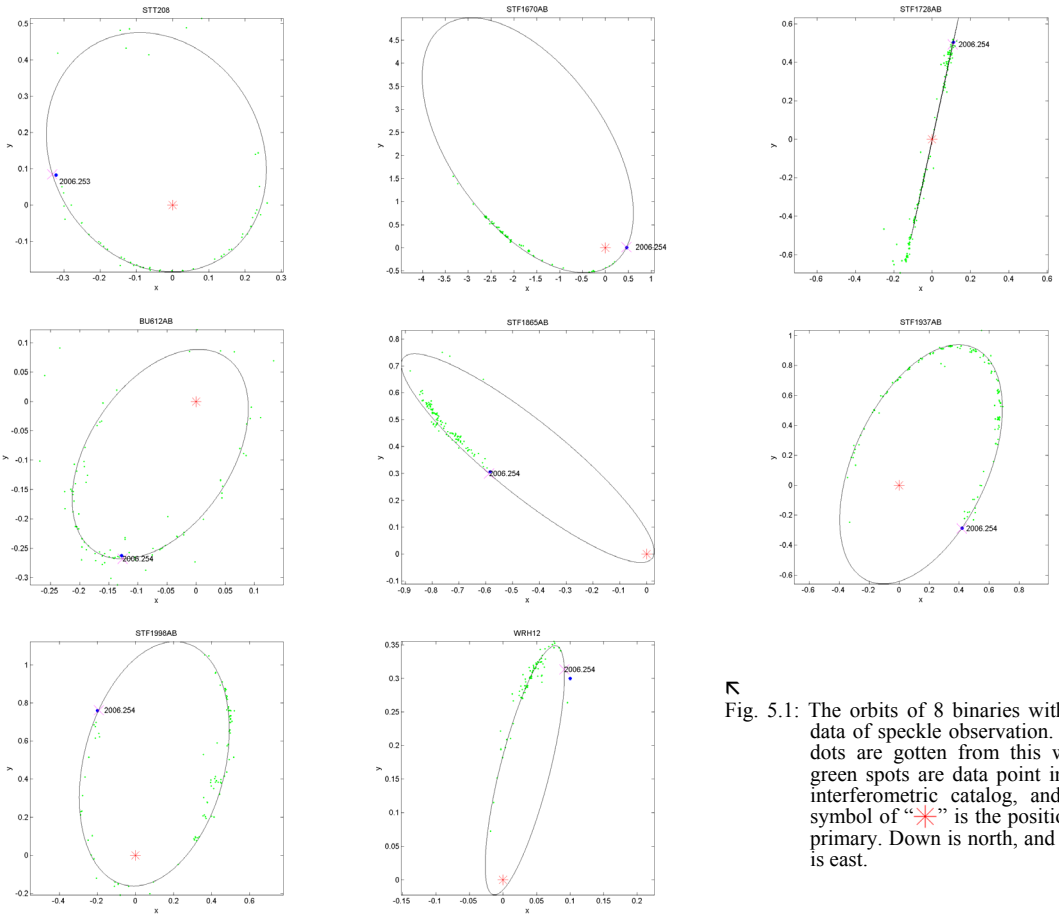


Fig. 5.1: The orbits of 8 binaries with the data of speckle observation. Blue dots are gotten from this work, green spots are data point in 4th interferometric catalog, and red symbol of "✳" is the position of primary. Down is north, and right is east.

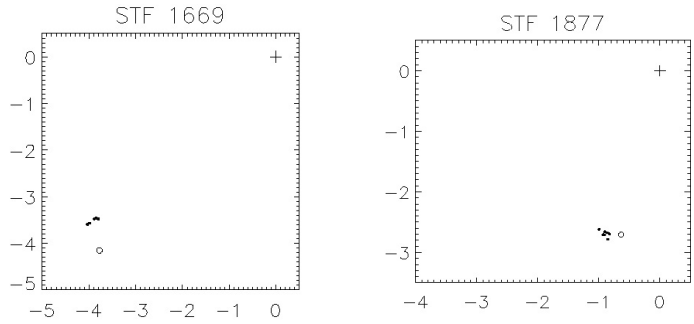


Fig. 5.2: The position of 2 binaries with the data of speckle observation. The circle mark is gotten from this work. Down is north, and right is east.

Table 2. Measurements of 14 binary stars on April 2-3, 2006.

WDS	Name	ADS	."	°	Notes
07346+3135	Castor	ADS 6175	4.36	59.62	*
09521+5404	STT208	ADS 7545	0.33	284.5	
12413-1301	STF1669AB	HR 4821-2	5.30	319.2	
12417-0127	STF1670AB	ADS 8630	0.46	84.7	
12348+2238	WRH 12	HR 4789	0.32	198.5	
13100+1732	STF1728AB	ADS 8804	0.52	161.2	
13038-2035	BU 341	ADS 8757	0.67	41.8	
13099-0532	McA38Aa	ADS 8801	0.42	189.0	
13396+1045	BU 612AB	ADS8987	0.29	147.6	
14411+1344	STF1865AB	ADS 9343	0.66	55.9	
14450+2704	STF1877	ADS 9372	2.90	349.3	
15232+3017	STF1937AB	ADS 9617	0.51	49.3	
	CHR259	HR 5881			fail
16044-1122	STF1998AB	ADS 9909	0.79	8.3	

* used for calibration of the angular separation and the position angle.

5. Results and discussion

The orbit of each binary system with the data in dots from literature and our results in open circle are shown on the figure 5.1 and 5.2. The orbits are plotted using the orbital elements on the Sixth Catalog of Orbits of Visual Binary Stars (Hartkopf & Mason 2003), and the data are taken from the Fourth Catalog of Interferometric Measurements of Binary Stars (Hartkopf et al. 2006.5 version) primary.

From our work, it is shown that a commercial webcam CCD is suitable for speckle interferometry observation of binary to reach the diffractional limit of the small or moderate sized telescopes. It is expected that the S/N will be increased if the raw image is corrected by dark current and flat field in the future speckle observations.

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In this work, we used the Fourth Catalog of Interferometric Measurements of Binary Stars[b], the Sixth Catalog of Orbits of Visual Binary Stars[c], and the Washington Double Star Catalog maintained at the US Navy Observatory[d].

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[b] http://ad.usno.navy.mil/wds/int4.html

[c] http://ad.usno.navy.mil/wds/orb6.html

[d] http://ad.usno.navy.mil/wds/wds.html