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MEASUREMENT OF DOUBLE STARS WITH A CCD CAMERA: TWO METHODS

J. Smolinski[1] and W. Osborn[1]

RESUMEN

El propósito de este trabajo es determinar ρ y θ en estrellas dobles usando coordenadas ecuatoriales. Esta aproximación ofrece varias ventajas. Una comparación de los valores derivados con aquellos obtenidos tras el empleo de métodos tradicionales de coordenadas rectangulares, sobre las mismas imágenes, muestra una equivalencia de resultados. Se determinaron las medidas correspondientes a 62 estrellas dobles.

ABSTRACT

This research aims to determine ρ and θ for double stars using equatorial coordinates. This approach offers several advantages. A comparison of the derived values with those from traditional measures of rectangular coordinates for the same images shows the results are equivalent. Measures for 62 double stars have been determined.

Key Words: **BINARIES: VISUAL**

1. INTRODUCTION

The systematic observation of double stars to detect orbital motion, and hence, to determine stellar masses, is perhaps the oldest branch of stellar astrophysics. Work has been traditionally concentrated on the systems with small separations since they have the most probability of both being physical binaries and showing rapid motion. In contrast, wide pairs generally need measures over many years - or even centuries - to determine if a system is gravitationally bound or an optical double.

The Washington Double Star catalog (WDS; Mason et al. 2001) contains measures of over 85,000 visual pairs. Many of the wider ones have not been observed regularly or very recently. Most of these neglected doubles are relatively bright, therefore, obtaining new observations is an ideal project for a small telescope equipped with a CCD camera. In fact, a number of programs of CCD observations of neglected pairs using 50 cm or smaller telescopes have been carried out in the past decade (for example, Salaman, Morlet & Gili 1999; Ryan 2003; Wilson 2003).

This paper presents measurements for 62 wide double stars. There were two objectives: (1) to obtain recent epoch measures for neglected pairs and (2) to investigate the technique of determining separations and position angles from the stars' equatorial coordinates rather than differential rectangular ones.

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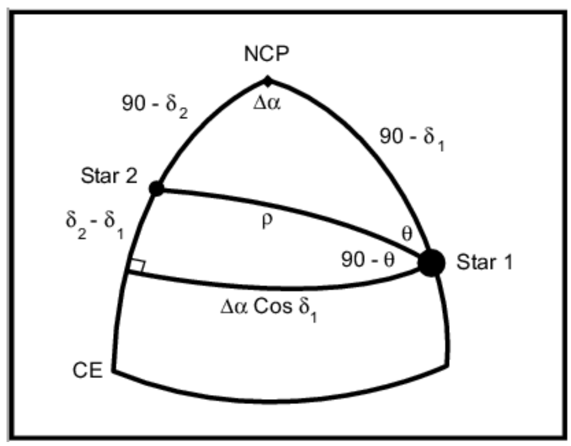

Fig. 1. The relation between (ρ,θ) and (α,δ) coordinates.

TABLE 1

AVERAGE VALUES OF Φ^a

Tel.	1999	2001	2002	2003
CMU	−1.32	−1.64	−1.21	−1.80
NURO	−3.89	−0.33	...	...

[a]In degrees, with errors less than 0.1°.

2. MEASUREMENT METHODS

For observations with a CCD camera, the separation (ρ) and position angle (θ) of a given pair are typically determined from the rectangular pixel

TABLE 2

MEASURES OF 62 DOUBLE STARS

WDS No.	Name	α_{2000}	δ_{2000}	Epoch	ρ	θ	N	Tel.
02282+5423	HJ 5535 CD	02 28 22.1	+54 25 20	2003.082	19.34	145.4	4	CMU
03178+5457	SCA 12	03 17 43.8	+54 57 18	2003.082	19.50	350.8	3	CMU
03393+6513	STI 471	03 39 13.6	+65 12 05	2003.082	10.65	95.2	2	CMU
03404+3022	HJ 335	03 40 23.4	+30 22 06	2003.082	15.41	250.3	3	CMU
03547+5200	PAN 2	03 54 37.8	+51 58 21	2003.082	7.07	313.4	3	CMU
04276+3204	SEI 47	04 27 37.3	+32 03 41	2003.082	19.86	186.2	3	CMU
05032+2921	HJ 354	05 03 16.1	+29 20 51	2003.082	11.89	296.2	3	CMU
05044+3743	SEI 59	05 04 23.6	+37 41 53	2003.082	16.65	322.6	3	CMU
05083+3716	SEI 74	05 08 15.5	+37 16 21	2003.115	11.47	208.9	3	CMU
05104+3742	SEI 85	05 10 27.0	+37 41 58	2003.115	15.30	312.8	3	CMU
05119+3757	SEI 91	05 11 59.1	+37 57 17	2003.115	14.76	247.3	3	CMU
05121+3650	SEI 94	05 12 08.1	+36 50 39	2003.143	17.19	177.4	3	CMU
05136+3749	SEI 110	05 13 38.3	+37 48 34	2003.143	10.99	350.0	3	CMU
05138+3520	SEI 112	05 13 46.8	+35 19 37	2003.143	17.39	242.6	3	CMU
05151+3623	SEI 118	05 15 06.2	+36 23 15	2003.156	18.45	343.9	3	CMU
05154+3635	SEI 119	05 15 24.7	+36 34 14	2003.156	10.57	353.7	3	CMU
05155+3804	SEI 120	05 15 32.3	+38 02 59	2003.156	12.41	84.2	2	CMU
05156+3731	SEI 122	05 15 33.1	+37 30 42	2003.156	14.24	120.8	3	CMU
05168+3709	SEI 143	05 16 48.7	+37 08 09	2003.156	9.49	204.7	2	CMU
06321+3253	SEI 460	06 32 04.2	+32 52 52	2003.115	8.96	187.4	4	CMU
06462+4962	ES 2619	06 46 18.8	+49 56 49	2003.121	9.65	279.8	1	CMU
07159+3131	SEI 476	07 15 57.3	+31 31 41	2003.121	15.23	230.9	3	CMU
07554+3818	MLB 834	07 55 21.9	+38 18 49	2003.121	7.82	293.9	3	CMU
11022+0954	STF 1503	11 02 10.9	+09 53 44	2002.275	11.45	270.6	2	CMU
12033+5924	STI 738	12 03 17.8	+59 24 05	1999.395	6.52	38.6	2	NURO
12085−0259	BAL 219[a]	12 08 29.0	−02 59 04	1999.395	7.57	16.7	2	NURO
12151+0959	STF 1618[a]	12 15 03.5	+09 59 27	1999.395	25.95	245.0	2	NURO
12272+5519	MLB 1076	12 27 07.2	+54 10 21	1999.395	10.91	225.4	2	NURO
12279+6105	STI 746[a]	12 27 51.5	+61 04 55	1999.395	4.98	335.5	1	NURO
12511+0152	BAL 1887	12 51 05.4	+01 52 04	1999.395	8.33	51.0	2	NURO
14165+4633	ES 1085[a]	14 16 30.2	+46 33 09	1999.398	5.72	175.0	2	NURO
14485+1203	HJ 241	14 48 30.9	+12 03 28	1999.392	17.29	140.9	2	NURO
14514+4436	HJ 2752	14 51 25.1	+44 36 34	1999.398	6.11	120.8	2	NURO
15094+1437	HEI 165	15 09 22.1	+14 37 41	1999.398	3.54	15.3	2	NURO
15141+2545	STF 1924	15 14 06.6	+25 45 26	1999.398	15.37	306.0	2	NURO
17594+2929	STF 2247 Aa-B	17 59 24.5	+29 29 30	2001.491	11.53	188.5	2	NURO
18029+5626	STF 2278 AB	18 02 53.1	+56 25 41	2001.852	36.25	28.1	2	NURO
18029+5626	STF 2278 AC	18 02 53.1	+56 25 41	2001.852	33.90	37.2	2	NURO
18029+5626	STF 2278 BC	18 02 55.1	+56 26 13	2001.852	6.06	145.4	2	NURO
18048+2353	STF 2274	18 04 45.2	+23 53 14	1999.726	18.08	292.0	1	CMU
18057+1200	STF 2276 AB	18 05 43.4	+12 00 14	1999.622	7.11	256.3	2	CMU

[a]Only rectangular coordinate measures.

coordinates of the image centers of the two stars: (x_1, y_1) and (x_2, y_2). Formally,

$$\rho = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\ (\mathrm{S})$$
$$\theta = \tan^{-1}[(x_2 - x_1) / (y_2 - y_1)] + \Phi$$

where S is the plate scale in arcsec per pixel and Φ is the rotation angle of the pixel array coordinates relative to the equatorial coordinates on the sky. Both S and Φ may vary and must be determined. Calibration can be time consuming and may pose problems if the field of view is small.

An alternate approach is to determine ρ and θ from the equatorial coordinates (α, δ) of the two stars. These values can be obtained by standard astrometry techniques using catalogued reference stars that appear on the image. By spherical trigonometry (see Fig. 1), ρ and θ are given by

$$\rho = \cos^{-1}[cos(\Delta\alpha\ cos\ \delta_1)\ cos(\delta_2 - \delta_1)]$$
$$\theta = 90^\circ - \tan^{-1}\left[\frac{sin(\delta_2 - \delta_1)}{cos(\delta_2 - \delta_1)\ sin(\Delta\alpha\ cos\ \delta_1)}\right].$$

The astrometric solution provides the scale and the orientation, and determines both ρ and θ. Obviously, this method can also be applied to catalogued positions as well as measurements of images.

3. THE OBSERVATIONS

Images for 62 systems were obtained during the period 1999-2003 using the Central Michigan University (CMU) 40 cm and National Undergraduate Research Observatory (NURO) 70 cm reflectors. Even though the observations were not done in any systematic manner, short periods of time were devoted while other observation programs had place. Two or three images of each system were usually obtained.

Standard zero point and flat field corrections were applied and after that the double stars were measured by the two methods independently. MIRA[2] was used to derive the equatorial coordinates from reference star positions, which were taken from the USNO-A2.0 catalog. The rectangular pixel coordinates were determined by using IRAF[3] with the adopted scale and orientation, which are mean values from the astrometric solutions. In a few cases, results could only be obtained from rectangular coordinates because suitable reference stars were not in the field.

[2]Axiom Research (http://www.axres.com).

[3]IRAF is distributed by the National Optical Astronomy Observatory. which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

4. COMPARISON OF THE TWO METHODS

Comparison of the results from the two techniques with Hipparcos or other measures for well-observed unchanging systems showed:

- The two methods provide equivalent results when there are no difficulties (such as blended images or a poor reference frame). The differences averaged $0.04''$ in ρ and 0.16° in θ.
- At least, 5 well-distributed reference stars are needed to adequately determine the relative equatorial positions.
- Φ can vary over several degrees due to the remounting of a camera on a telescope, as shown in Table 1.
- Our measures have errors in ρ and θ that are typically $0.1''$ and 0.3°, respectively, but somewhat larger for close systems.

5. RESULTS

Table 2 shows results for a sample of the whole set.[4] Two new pairs are found on the images of targeted doubles. The columns show the WDS identifier, star name, equatorial coordinates of the primary, epoch of the observation, the average ρ and θ from the separate images, the number of images, and the telescope used. Eleven stars have not been observed for over 50 years and six stars have not been measured since their discovery, over 100 years ago. Several systems show significant motion.

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[4]The full table can be requested to the authors.

Homage to Jürgen Stock, in the background the telescope with his name.