CONTENTS

ABOUT THE AUTHORS

Bob Argyle

I have been observing double stars ever since I acquired a telescope in 1966. To this day I do not know what prompted me to give them special attention but I do know that using a copy of *Norton's Star Atlas* which was given to me by an early mentor, Frank Acfield of Newcastle-on-Tyne, had an effect. I suspect it was the lack of up-to-date information about the separation and position angles included in the lists which accompanied each of the star maps that prompted me to start making observations, by eye at first. In my copy (the 15th edition of 1964), for example, the date of the given position angle and separation for the bright binaries was no later than 1938 and many of the wider pairs were 20 or 30 years older than that. This gave me the distinct impression that here was something useful that could be done, and I remember thinking that I must get a micrometer in order to do some of this work properly. At that time, however, micrometers were rare and expensive objects and I never did come across one to use on my 10-inch reflector.

Around this time I bought a copy of Webb's *Celestial Objects for Common Telescopes*, Volume 2, which was available then in the paperback reproduction issued by Dover. It is a little treasure chest of double stars and considerably expanded the number available to a small telescope compared to the lists in *Norton*. As a subscriber to *The Astronomer* magazine I followed the columns of 'From the Night Sky' written by John Larard, which described his observations of double stars made at Mill Hill using an 8-inch Cooke refractor.

John spent much, perhaps too much, of his energy bringing the Webb Society into being as he felt there was a distinct lack of direction in deep-sky and double star observation amongst the amateur community.

I joined the Webb Society in 1968 and was soon sending in observations of double stars to John, who was then Director of the Double Star Section. After a reorganisation in 1970 John became Director of the Nebulae and Clusters Section, and I was asked to direct the Double Star Section. I'm still doing it.

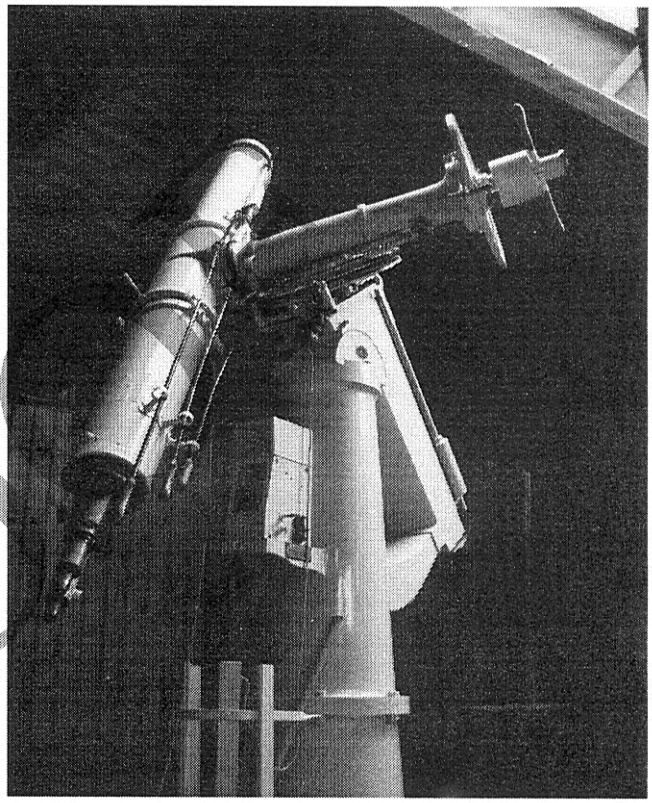

Figure 0.1 The 8-inch (20-cm) Thorrowgood Cooke refractor at the Observatories, Cambridge. It was delivered to Dawes in 1865 and was left to the Royal Astronomical Society in 1927. It has been at the Institute of Astronomy, Cambridge since 1929 (R. W. Argyle)

The 8-inch refractor at Cambridge Observatories is an historic instrument. Measurements started in 1990 and the programme continues to this day – 28 years on. This volume contains some results of these observations.

Mike Swan

Having now retired from a job with the Ordnance Survey in England, I have extensive experience in computer graphics and uranography and was solely responsible for the *Webb Society Star Atlas*. I am currently completing a two part *Atlas*

REPLACE WITH NEW PROFILE

of Galactic Clusters, the first part of which is now available. In the present volume I have produced the field diagrams, the all-sky charts, and the orbital plots.

REPLACE WITH NEW PROFILE

Andrew James

I have been interested in double stars since the late 1970s. I am a long-term member, and past President, of the Astronomical Society of New South Wales (ASNSW) and formed its Double Star Section in 1979. I presented many papers on double stars to the National Australian Convention of Amateur Astronomy (NACAA) between 1980 and 2014. In recent times I have focussed on southern double stars and the historical backgrounds and works of various discoverers in Australia, including James Dunlop and Charles Rümker, who made the first southern double star catalogues.

Another associated interest is Henry Chamberlain Russell, and the various observational assistants, who found and measured many new doubles within the Sydney Observatory Double Star Programme between 1870 and 1900.

Further current investigations have recently extended to a new examination of Sir Thomas Brisbane's Paramatta Star Catalogue, created during the 1820s at Sydney, and its important connection to the discovery of double stars and deep-sky objects.

General southern historical accounts and information on double stars and some selected double stars also appear on my website, Southern Astronomical Delights `www.southastrodel.com`. I am still active in the local astronomical scene in Sydney, and between 2013 and 2015 I acted as a consultant to the design revamp of Sydney Observatory's new East Dome used by the public – especially aimed for access by the disabled and seniors. My astronomical experience also extends to lecturing on the subject to Evening Colleges, and I have presented many talks over a large range of subjects. I am presently the Planetary Nebulae and Deep-Sky Section Leader of the ASNSW.

CHAPTER

1 Introduction

Christian Mayer published the first proper double star catalogue in 1784. However, the study of visual double stars effectively started with William Herschel. He not only systematically searched for them, initially to try to determine stellar parallax, but ended up by proving that some pairs of stars that appeared close together really were attracted by a common gravitational pull. By 1830 we knew of more than 3000 double stars but this figure did not exceed 10,000 until the beginning of the last century. The current number is 145,000 and we stand on the brink of a revolution in terms of discovery which will come when the Gaia satellite ends its current mission. It is expected that millions of new pairs will be catalogued; however, Gaia will not only find new systems, but will also give us more detail on existing systems, in particular distances, proper motions, and multiplicity.

This volume aims to fill out the story on some of the brighter and more interesting visual double stars which can be seen in small and moderate apertures. Here we may define small as 20-cm or less, medium as 20 to 40-cm and large as 40 to 60-cm. Many double stars have contrasting colours; some are very unequal, some are at or beyond the resolving limit. To make a selection of pairs which can all be seen in a small aperture risks discouraging observers with larger telescopes who wish to push them optically. Its also fair to say that views of many pairs improve with aperture. Some systems have three or more components. None are the same.

It is, of course, impossible to definitively choose the finest visual double stars in the sky. Such a distinction depends too heavily on personal taste. The catalogue of objects that is discussed here does not necessarily contain the brightest, the most spectacularly coloured, the closest or the most-difficult-to-see pairs that exist in the heavens. Rather it is a summary of all these properties: visual pairs are presented that have something which attracts the observer to observe them. What can be said is that the vast majority have been observed (or attempted) by the authors, and hopefully this fact will recommend them to the reader.

Visual double stars come in two main forms. *Optical* pairs consist of two stars which appear to be angularly close on the sky but which are in reality totally unrelated because one star is much further away than the other. *Binary* stars appear close together on the sky because they are, in fact, physically connected and are rotating around a common centre of gravity. For the common telescope user the periods in which they do this range from about 25 years to tens of thousands of years. Binary stars are important to stellar astronomers. Measurements of the relative positions of the two components give good information on stellar masses and can also indicate how far way such stars are.

There has been a historical inbalance in the professional approach to research into visual double stars. This is clear from the numbers of observations made of southern binaries as opposed to those visible from the northern hemisphere. As an example, γ Virginis has had 1720 measures whereas its southern equivalent, γ Cen, has only 181, yet the latter has half the orbital period of the former.

The whole sky is covered in this volume. Not to do so would be to leave out some of the best objects in this class. In fact the very finest double star in the sky, α Centauri, is only practically visible to anyone south of about +25° – say, the latitude of Hawaii. Not every object in the catalogue will be resolvable, even with a significant aperture, but, because of the changing nature of binary stars, that will not always be the case. That well-known test object, the companion to the star

imbalance

γ And B, is now way beyond the resolution of most telescopes and will remain so for ten years or so; in the case of ζ Boo it might be 20 years before it can be seen again. As apertures and techniques used by amateurs are constantly getting larger, these bland statements of fact might be seen as challenges to the observer wishing to test his or her telescope optics. When it comes to deciding whether stars of a particular separation can be divided by a given aperture there are a number of formulae which can be used to check this possibility (see also p. xx). We have the Rayleigh limit and the Dawes limit; whilst other more complex predictors exist, in my experience the Dawes limit is as good (and as simple) as any. The atmosphere and state of the telescope are just as important in obtaining a resolution. Go and find out for yourself.

If you are new to double star observing, it will take a little time to get used to the look of the images but, eventually, even though you cannot see two separate images, the fact that a close pair is double will usually be apparent given enough time. Even on nights when the atmosphere is very unsteady there will be the odd moment of calm when the images sharpen. This is the basis of the lucky imaging technique, which some observers are using to good effect with CCD cameras. How far can you go visually? With careful collimation of telescope optics and some experience of examining images from close pairs of stars, it is possible to see duplicity in stars at the 0″.2 level with a 32-cm telescope whilst the Dawes limit is formally accepted as 0″.36.

Other bright binaries move sufficiently quickly that the angular motion can be seen in the course of a year. Eyepieces which contain a fine illuminated mesh of grid lines, called graticule eyepieces, can be used to make more precise measurements of the relative angle and separation between two stars but are not, in general, suitable for binary stars, which tend to be too close. Other instruments, such as micrometers for the visual observer or a CCD camera for those who prefer their stars served electronically, can be employed. It is outside the scope of this book to describe these techniques, but see the volume edited by Argyle [85].

Software

There are many software packages which contain lists of double stars and can be used to display star fields allowing each pair to be located. These are extremely useful when looking for fainter pairs beyond the range of the commonly available star atlas. For more information see the chapter by Owen Brazell in Argyle [85]. I found Cartes du Ciel by Patrick Chevalley particularly useful on a recent observing trip. This is freely available and can be downloaded from www.sourceforge.com.

The following notes describe those books and atlases which are most helpful to the observer, in the estimation of the present authors. In any case, not everyone has a laptop or other online terminal available at the eyepiece.

DELETE OR ADD LIST

CHAPTER

8 Catalogue Lists and Charts

ADD 'HIC', Hipparcos number

Table Headings

WDS, Washington Double Star Catalog Number
Disc., discoverer
Comps., components
Epoch, ~~year of discovery~~ latest measure
θ, position angle in degrees
ρ, separation of componenets in arcseconds
V_A, V_B, magnitudes of components A and B

I The Catalogue in Right Ascension Order

					Latest measure				
No.	*WDS*	Disc.	Comps.	HIC	Epoch	θ	ρ	V_A	V_B
1	00057+4549	STT 547	AB	473	2016	189	6.0	8.98	9.15
2	00063+5826	STF 3062		518	2017	1	1.7	6.42	7.32
3	00094−2759	BU 391	AB	761	2003	258	1.5	6.13	6.24
4	00184+4401	GRB 34	AB	1475	2015	64	34.3	8.31	11.36
5	00315−6257	LCL 119	AC	2484	2016	168	27.3	4.28	4.51
6	00373−2446	BU 395		2941	2015	113	0.8	6.60	6.20
7	00491+5749	STF 60	AB	3821	2018	327	13.5	3.52	7.36
8	00550+2338	STF 73	AB	4288	2018	335	1.3	6.12	6.54
9	01061−4643	SLR 1	AB	5165	2016	84	0.7	4.10	4.19
10	01084−5515	RMK 2	AB,C	5348	2016	239	6.8	4.00	8.23
11	01137+0735	STF 100	AB	5737	2016	63	22.9	5.22	6.26
12	01158−6853	HJ 3423	AB	5896	2016	316	4.8	5.00	7.74
	01158−6853	I 27	CD	5896	2016	345	1.2	7.84	8.44
13	01361−2954	HJ 3447		7463	2015	194	0.8	5.97	7.35
14	01398−5612	DUN 5		7751	2016	186	11.5	5.78	5.90

contd

No.	*WDS*	Disc.	Comps.	HIC	Latest measure			V_A	V_B
					Epoch	θ	ρ		
82	11363+2747	STF 1555	AB	56601	2016	148	0.8	6.41	6.78
83	11551+4629	STF 1579	AB	58112	2012	42	3.7	6.68	8.72
84	12140−4543	RMK 14		59654	2008	243	2.7	5.78	6.98
85	12244+2535	STF 1639	AB	60525	2017	326	1.7	6.74	7.83
86	12266−6306	DUN 252	AB	60718	2016	112	4.2	1.25	1.55
87	12312−5707	DUN 124	AB	61084	2010	26	128.9	1.83	6.45
88	12351+1823	STF 1657		61418/5	2016	272	20.4	5.11	6.33
89	12415−4858	HJ 4539	AB	61932	2014	199	0.2	2.82	2.88
90	12417−0127	STF 1670	AB	61941	2018	359	2.9	3.48	3.53
91	12463−6806	R 207	AB	62322	2016	53	1.1	3.52	3.98
92	12533+2115	STF 1687	AB	62886	2015	198	1.2	5.15	7.08
93	12546−5711	DUN 126	AB	63003/5	2016	17	34.9	3.94	4.95
94	12560+3819	STF 1692		63125/1	2016	229	20.0	2.85	5.52
95	13081−6518	RMK 16	AB	64094	2016	189	5.5	5.65	7.55
96	13100+1732	STF 1728	AB	64241	2015	193	0.0	4.85	5.53
97	13226−6059	DUN 133	AB,C	65271	2016	345	60.4	4.49	6.15
98	13239+5456	STF 1744	AB	65378	2016	152	14.4	2.23	3.88
99	13375+3618	STF 1768	AB	66458	2017	88	1.7	4.98	6.95
100	13491+2659	STF 1785		67422	2016	189	3.2	7.36	8.15
101	13518−3300	H 3 101		67669	2013	104	7.9	4.50	5.97
102	14135+5147	STF 1821	AB	69483/1	2017	235	13.7	4.53	6.62
103	14396−6050	RHD 1	AB	71683/1	2016	313	4.1	[-0.01] →	1.33 MOVE
104	14411+1344	STF 1865	AB	71795	2015	287	0.5	4.46	4.55
105	14450+2704	STF 1877	AB	72105	2016	344	2.8	2.58	4.81
106	14514+1906	STF 1888	AB	72659	2018	300	5.3	4.76	6.95
107	15038+4739	STF 1909		73695	2016	72	0.9	5.20	6.10
108	15051−4703	HJ 4728		73807	2016	65	1.8	4.56	4.60
109	15185−4753	HJ 4753	AB	74911	2016	299	0.8	4.93	4.99
110	15227−4441	DUN 182	AB,C	74376/38	2010	143	26.5	3.83	5.52
111	15232+3017	STF 1937	AB	75312	2017	231	0.6	5.64	5.95
112	15234−5919	HJ 4757		75323	2016	0	1.0	4.94	5.73
113	15245+3723	STF 1938	Ba,Bb	75415/1	2017	4	2.2	7.09	7.63
114	15351−4110	HJ 4786	AB	76297	2016	277	1.0	2.95	4.45
115	15360+3948	STT 298	AB	76382/75	2017	187	1.3	7.16	8.44
116	15394+3638	STF 1965		76669	2016	307	6.2	4.96	5.91

contd

II The Catalogue in Constellation Order

					Latest measure				
No.	*WDS*	Disc.	Comps.	HIC	Epoch	θ	ρ	V_A	V_B
Andromeda									
1	00057+4549	STT 547	AB	473	2016	189	6.0	8.98	9.15
4	00184+4401	GRB 34	AB	1475	2015	64	34.3	8.31	11.36
8	00550+2338	STF 73	AB	4288	2018	335	1.3	6.12	6.54
18	02039+4220	STF 205	A,BC	9640	2016	63	9.4	2.31	5.02
175	23595+3343	STF 3050	AB	118281	2018	343	2.5	6.46	6.72
Aquarius									
165	22266−1645	SHJ 345	AB	110778	2017	81	1.3	6.29	6.39
167	22280+5742	KR 60	AB	110893	2013	326	1.5	9.93	11.41
170	22478−0414	STF 2944	AB	112559	2016	307	1.8	7.30	7.68
174	23460−1841	H 2 24		117281	2016	135	7.1	5.65	6.46
Ara									
130	17191−4638	BSO 13	AB	84720	2016	258	10.8	5.61	8.88
132	17269−4551	DUN 216	AC	85389	2016	312	102.5	5.63	7.12
Aries									
15	01535+1918	STF 180	AB	8832	2018	1	7.5	4.52	4.58
17	02037+2556	STF 208	AB	9621	2018	348	1.3	5.82	7.87
24	02592+2120	STF 333	AB	13914	2016	211	1.4	5.17	5.57
Auriga									
40	05597+3713	STT 545	AB	28380	2017	305	4.1	2.60	7.2
Boötes									
100	13491+2659	STF 1785		67422	2016	189	3.2	7.36	8.15
102	14135+5147	STF 1821	AB	69483/1	2017	235	13.7	4.53	6.62
104	14411+1344	STF 1865	AB	71795	2015	287	0.5	4.46	4.55
105	14450+2704	STF 1877	AB	72105	2016	344	2.8	2.58	4.81
106	14514+1906	STF 1888	AB	72659	2016	302	5.5	4.76	6.95
107	15038+4739	STF 1909		73695	2016	72	0.9	5.20	6.10
113	15245+3723	STF 1938	Ba,Bb	75415/1	2017	4	2.2	7.09	7.63
115	15360+3948	STT 298	AB	76382/75	2017	187	1.3	7.16	8.44
~~Camelopardus~~ Camelopardalis									
32	04400+5328	STF 566	AB,C	21730	2016	170	0.8	5.56	7.49
35	05226+7914	STF 634	AB	25110	2016	142	31.1	5.14	9.14
Cancer									
58	08122+1739	STF 1196	AB	—	2017	16	1.2	5.30	6.25
61	08467+2846	STF 1268		43103	2016	308	31.3	4.13	5.99

contd

No.	*WDS*	Disc.	Comps.	HIC	Latest measure Epoch	θ	ρ	V_A	V_B
Lupus									
108	15051−4703	HJ 4728		73807	2016	65	1.8	4.56	4.60
109	15185−4753	HJ 4753	AB	74911	2016	299	0.8	4.93	4.99
110	15227−4441	DUN 182	AB,C	74376/38	2010	143	26.5	3.83	5.52
114	15351−4110	HJ 4786	AB	76297	2016	277	1.0	2.95	4.45
Lynx									
42	06221+5922	STF 881	AB	30272	2014	149	0.6	6.13	7.71
48	06462+5927	STF 948	AB	32438	2017	68	1.9	5.44	6.00
64	09188+3648	STF 1334	AB	45688	2017	224	2.6	3.92	6.09
65	09210+3811	STF 1338	AB	45858	2017	312	1.2	6.72	7.08
Lyra									
139	18369+3846	H 5 39	AB	91262	2015	184	82.3	0.09	9.5
141	18443+3940	STF 2382	AB	91919	2017	346	2.2	5.15	6.10
	18443+3940	STF 2383	CD	91926	2017	77	2.4	5.25	5.38
142	18501+3322	STFA 39	AB	92420	2016	148	45.6	3.63	6.69
Monoceros									
43	06238+0436	STF 900	AB	30422	2017	29	12.0	4.42	6.64
44	06288−0702	STF 919	AB	30867	2017	133	7.0	4.62	5.00
46	06410+0954	STF 950	AB	31978	2015	214	3.0	4.66	7.9
Musca									
91	12463−6806	R 207	AB	62322	2016	53	1.1	3.52	3.98
95	13081−6518	RMK 16	AB	64094	2016	189	5.5	5.65	7.55
Ophiuchus									
125	17104−1544	BU 1118	AB	84012	2016	231	0.6	3.05	3.27
128	17153−2636	SHJ 243	AB	84405	2016	143	5.4	5.12	5.12
135	18031−0811	STF 2262	AB	88404	2017	291	1.7	5.27	5.86
136	18055+0230	STF 2272	AB	88601	2017	124	6.4	4.22	6.17
138	18096+0400	STF 2281	AB	88964	2016	285	0.7	5.97	7.52
Orion									
33	05079+0830	STT 98		23879	2017	291	1.0	5.76	6.67
34	05145−0812	STF 668	A,BC	24436	2017	204	9.4	0.3	6.8
36	05245−0224	DA 5	AB	25281	2015	77	1.8	3.56	4.87
38	05320−0018	STFA 14	Aa-C	25930	2015	2	53.3	2.41	6.83
39	05407−0157	STF 774	AB	26727	2013	167	2.4	1.88	3.70

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No.	*WDS*	Disc.	Comps.	HIC	Latest measure Epoch	θ	ρ	V_A	V_B
~~Scorpio~~ Scorpius									
118	16044−1122	STF 1998	AB		2016	10	1.1	5.16	4.87
	16044−1122	STF 1998	AC		2016	45	7.6	5.16	4.87
119	16120−1928	H 5 6	AC	79374	2016	338	41.6	4.35	6.60
	16120−1928	BU 120	AB	79374	2016	2	1.6	4.35	5.31
	16120−1928	MTL 2	CD		2016	56	2.5	6.60	7.23
121	16294−2626	GNT 1		80763	2016	276	3.2	0.96	5.4
(122	16309+0159	STF 2055	AB	80883	2017	44	1.5	4.15	5.15)
129	17190−3459	MLO 4	AB	84709	2016	124	0.9	6.37	7.38
Taurus									
31	04301+1538	STF 554		20995	2014	14	1.5	5.70	8.12
Triangulum Australe									
117	15549−6045	DUN 194	AB	77927	2016	47	44.1	6.35	9.97
	15549−6045	SLR 11	AB		2016	97	1.1	6.35	8.09
Tucana									
5	00315−6257	LCL 119	AC	2484	2016	168	27.3	4.28	4.51
12	01158−6853	HJ 3423	AB	5896	2016	316	4.8	5.00	7.74
	01158−6853	I 27	CD	5896	2016	345	1.2	7.84	8.44
Ursa Major									
63	09144+5241	STF 1321	AB	120005	2016	97	17.2	7.79	7.88
78	11182+3132	STF 1523	AB	55203	2017	164	1.9	4.33	4.80
81	11323+6105	STT 235	AB	56290	2017	46	0.9	5.69	7.55
83	11551+4629	STF 1579	AB	58112	2012	42	3.7	6.68	8.72
98	13239+5456	STF 1744	AB	65378	2016	152	14.4	2.23	3.88
Ursa Minor									
21	02318+8916	STF 93	AB	11767	2013	233	18.1	2.1	9.1
Vela									
57	08095−4720	DUN 65	AB	39953	2009	221	40.3	1.79	4.14
60	08447−5443	I 10	AB	42913	2013	263	0.4	1.99	5.57
67	09307−4028	COP 1		46651	2016	122	1.0	3.91	5.12

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~~III Charts Legends~~ DELETE

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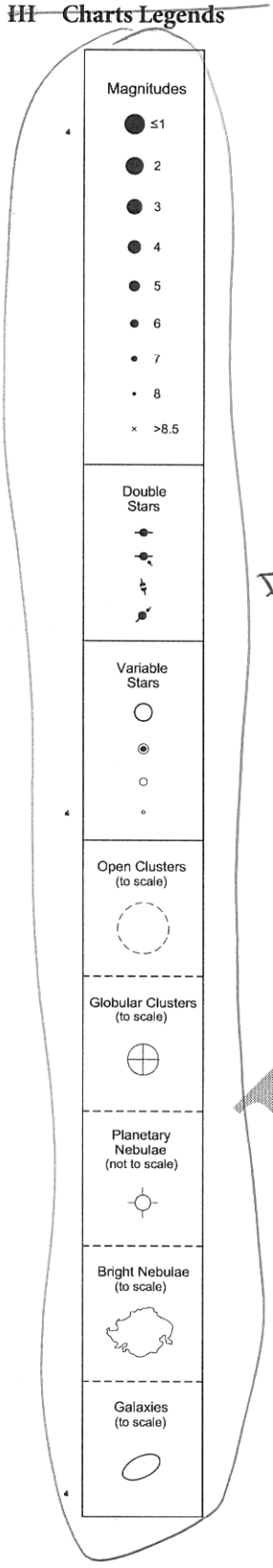

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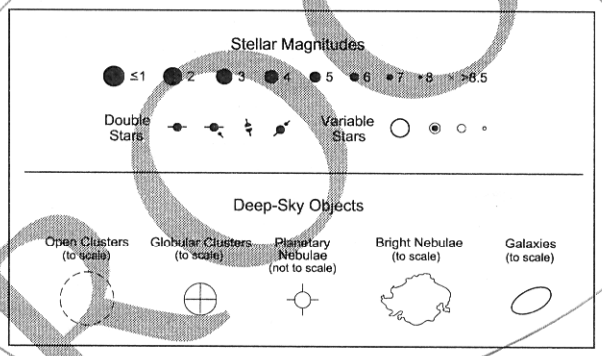

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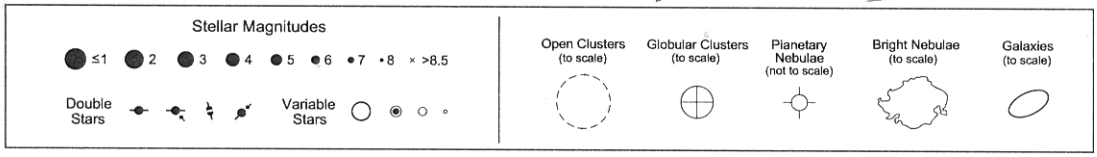
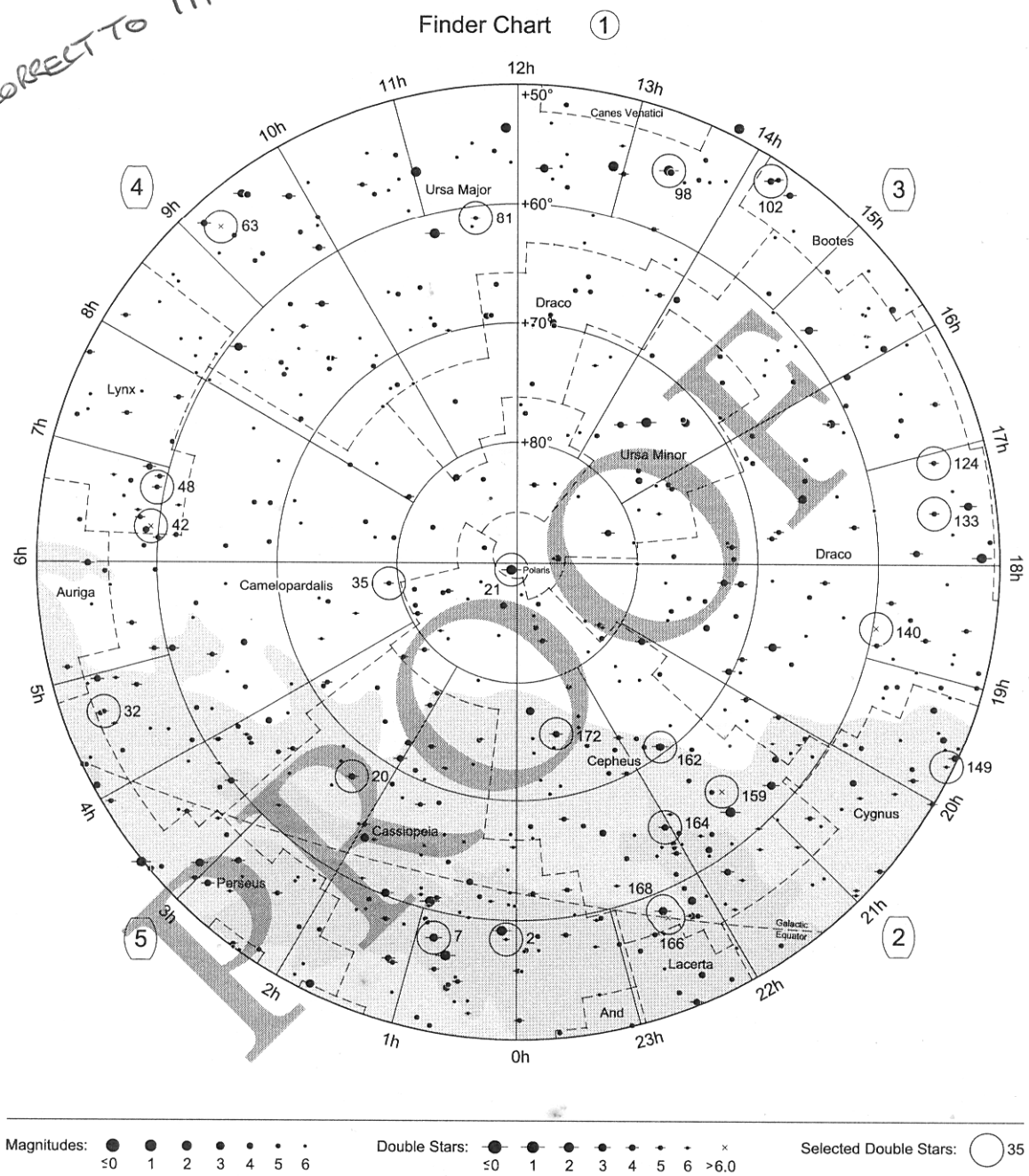


IV All-Sky Finder Charts

CORRECT TO '111'



Magnitudes: ≤0 1 2 3 4 5 6

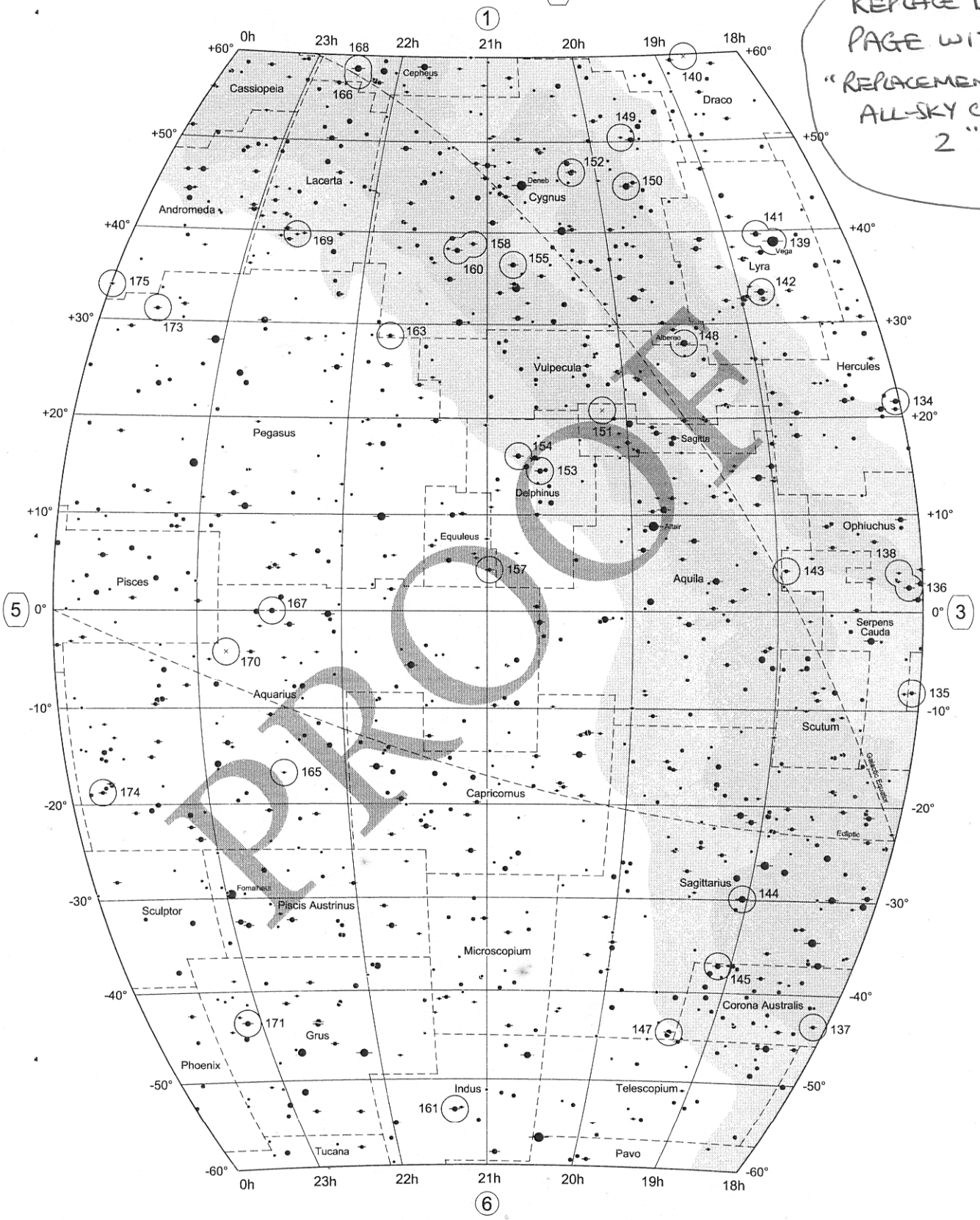
Double Stars: ≤0 1 2 3 4 5 6 >6.0

Selected Double Stars: 35

CORRECT TO III

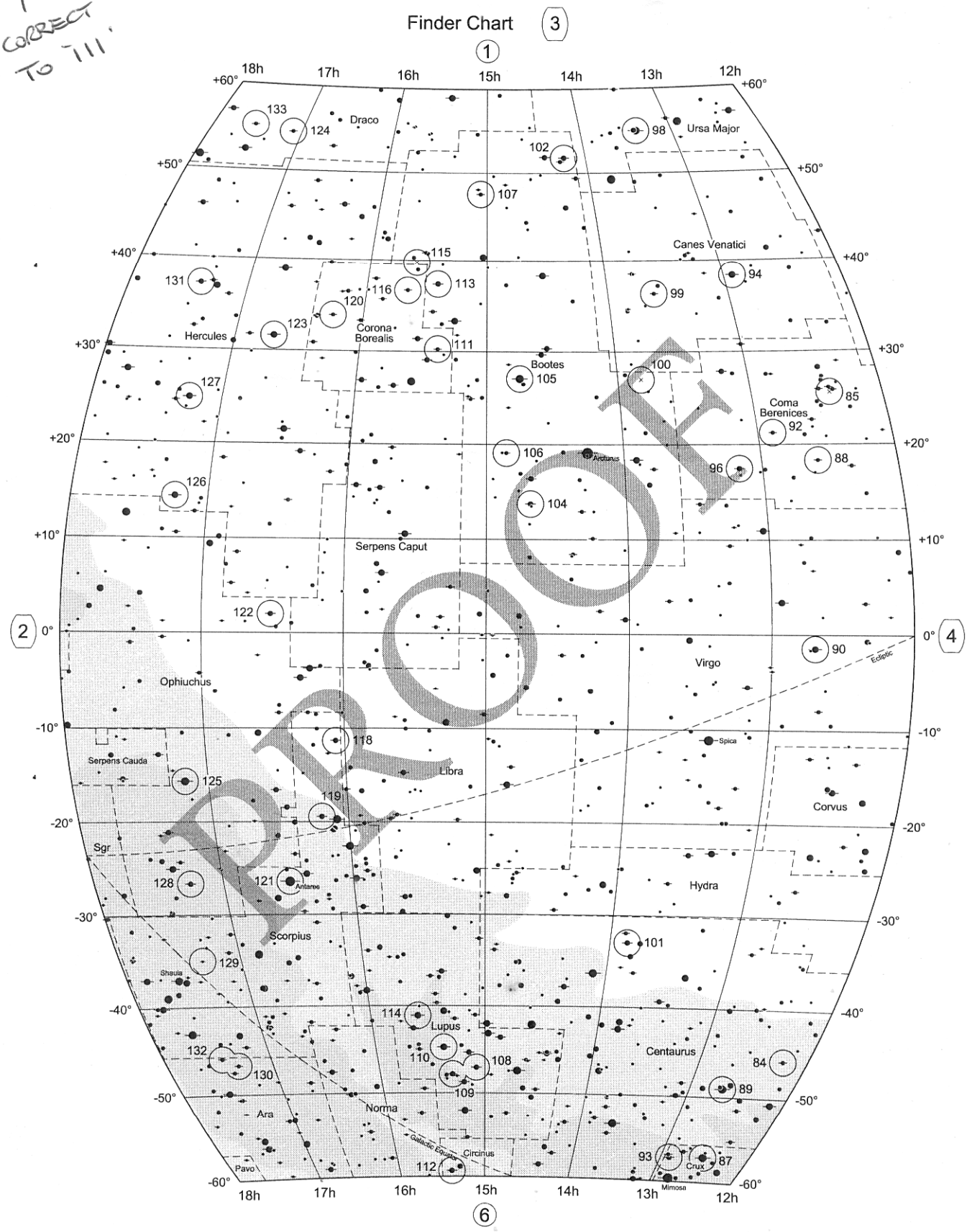
REPLACE WHOLE PAGE WITH "REPLACEMENT ALL-SKY CHART 2"

Finder Chart 2



Magnitudes: ≤0 1 2 3 4 5 6 Double Stars: ≤0 1 2 3 4 5 6 >6.0 Selected Double Stars: 35

CORRECT TO 'III'

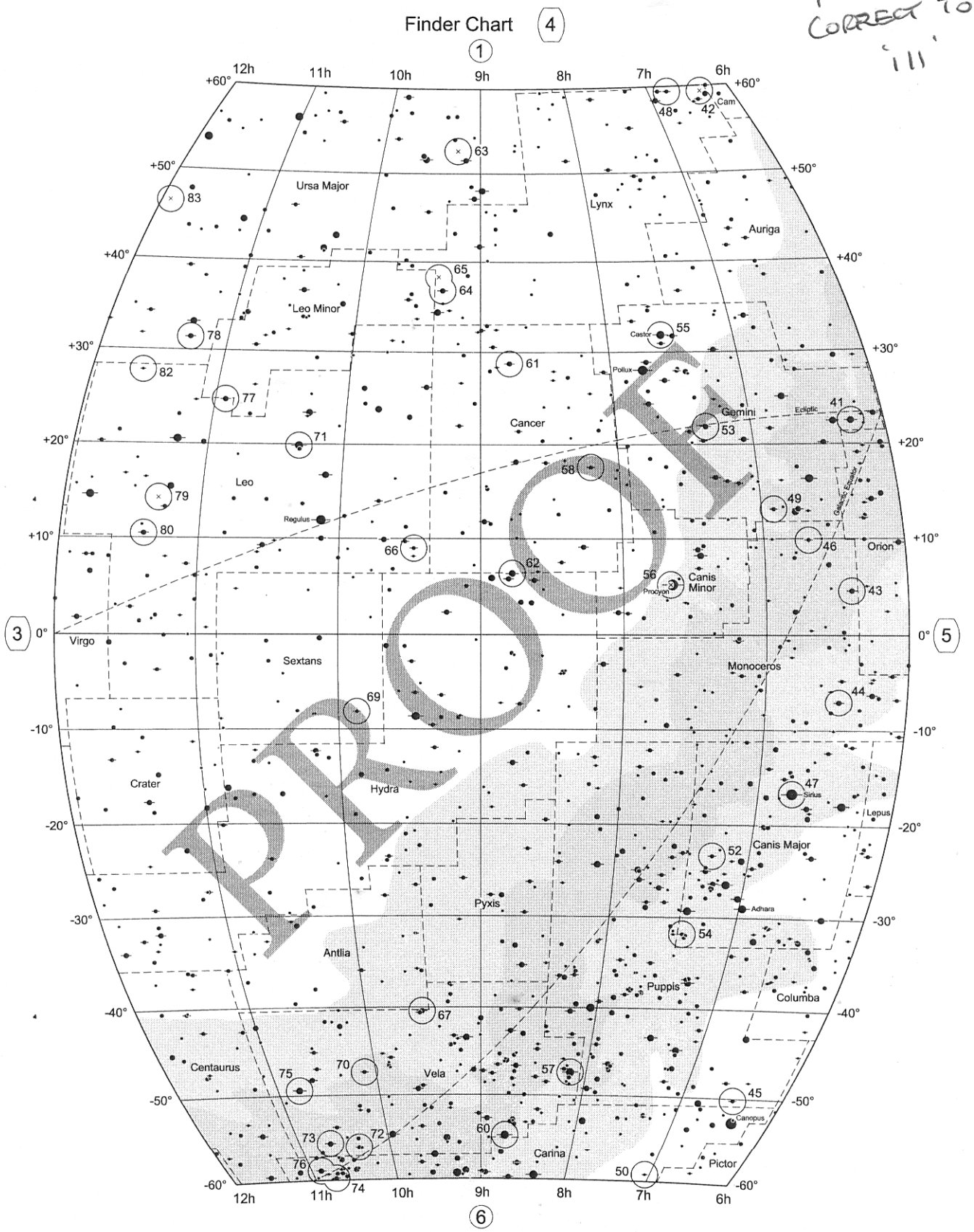


Magnitudes: ≤0 1 2 3 4 5 6

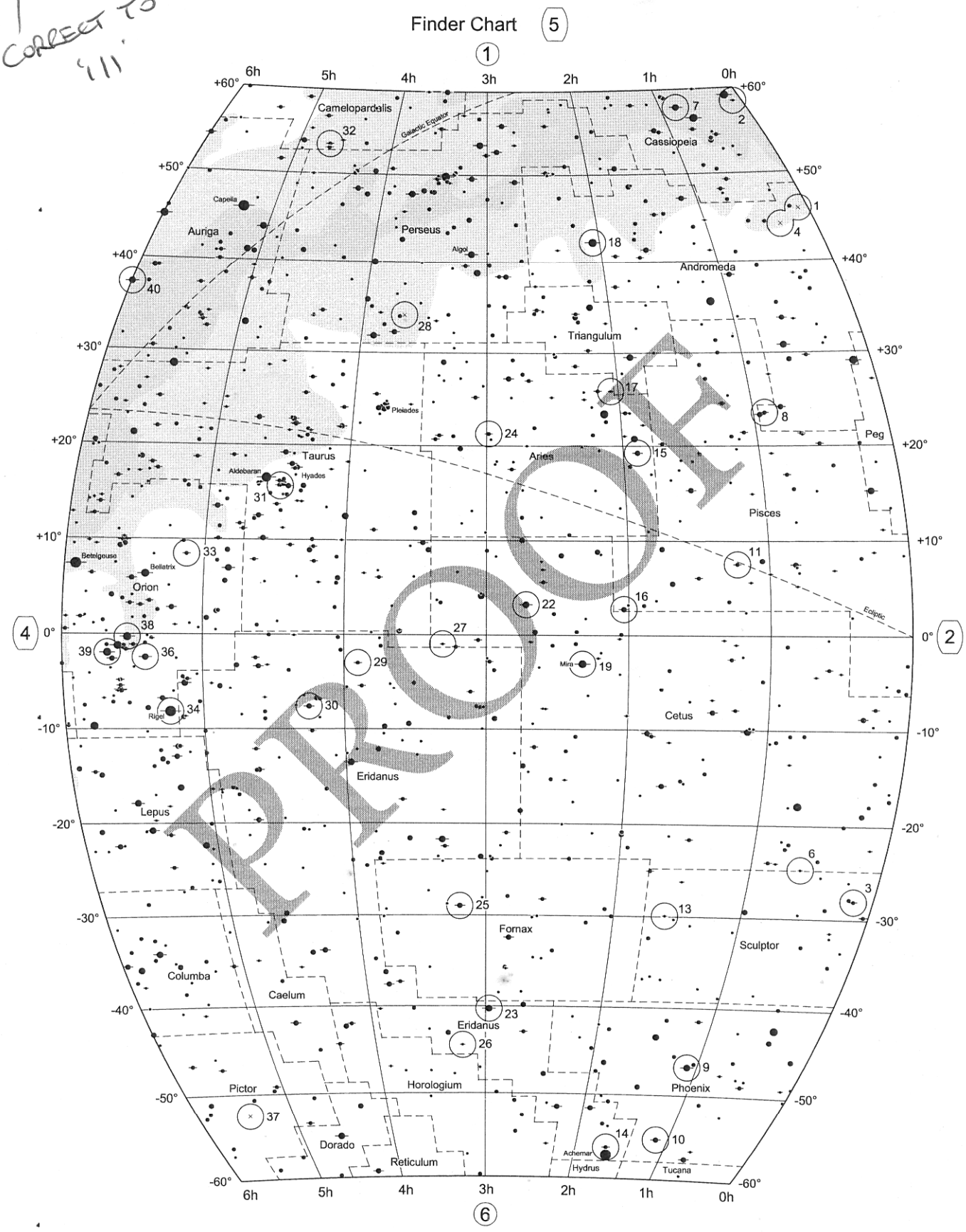
Double Stars: ≤0 1 2 3 4 5 6 >6.0

Selected Double Stars: 35

CORRECT TO 'III'



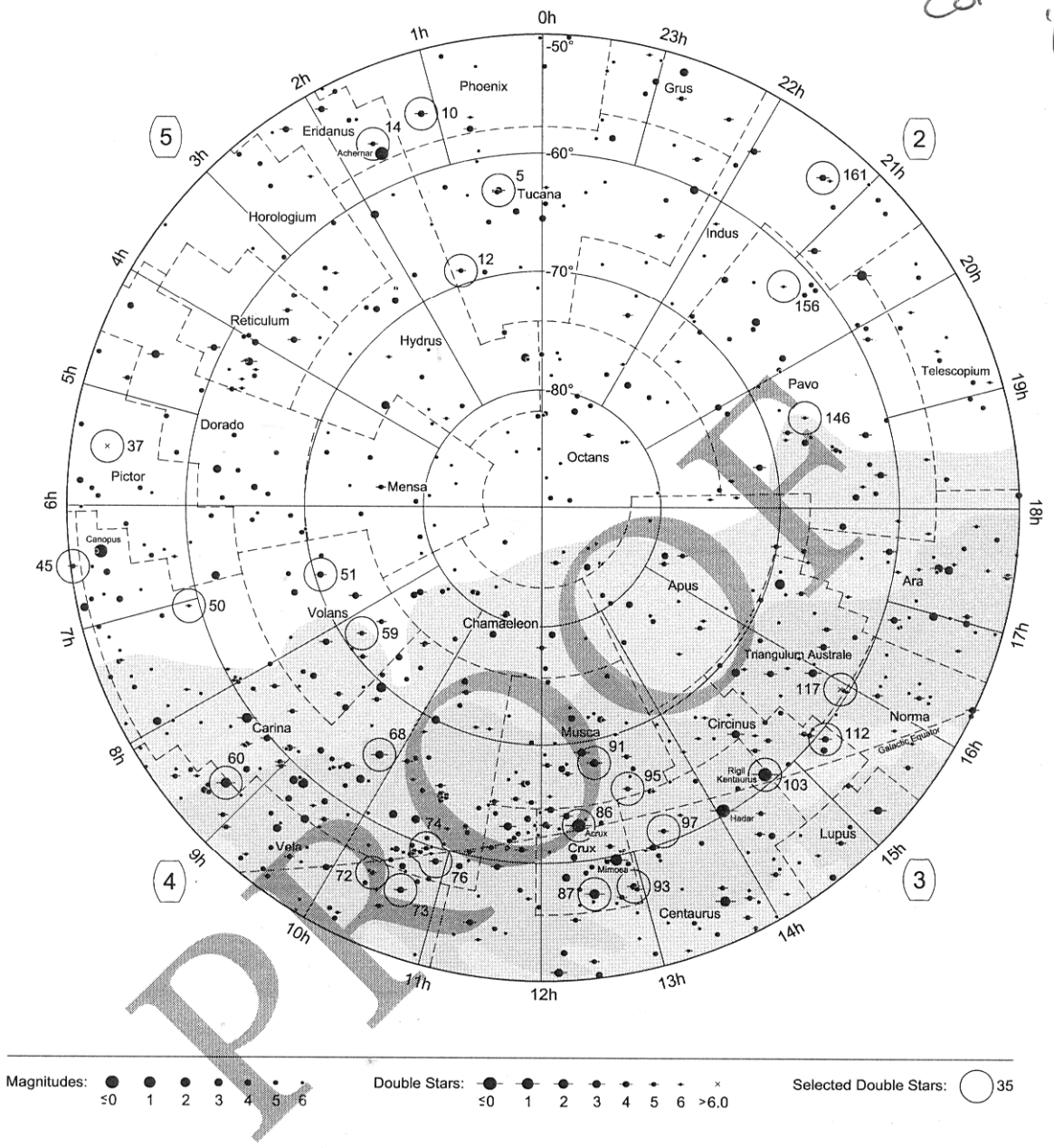
CORRECT TO 'III'



Magnitudes: ≤0 1 2 3 4 5 6 Double Stars: ≤0 1 2 3 4 5 6 >6.0 Selected Double Stars: 35

CORRECT TO III

Finder Chart 6



Magnitudes: ≤0 1 2 3 4 5 6

Double Stars: ≤0 1 2 3 4 5 6 >6.0

Selected Double Stars: 35

As is the case for the finder charts, the diagrams showing the apparent orbit of each binary have all been compiled by Mike Swan, whose description of them follows later in this section. The angular scale of the field of view is indicated in each case. The resolving limit for three separate apertures, 10-cm (1″.16), 20-cm (0″.56), and 40-cm (0″.30), in each case based on the Dawes limit, is represented on the diagram by three shaded gray circles (smallest, 40-cm limit; middle, 20-cm limit) and an outer dotted circle representing the limit of resolution of a 10-cm telescope. The ephemerides are calculated from the orbital elements given in the *Sixth Catalog of Elements of Visual Binary Orbits* [6], take from the USNO website at the time of going to press. In general the validity of an orbit calculation is more short-lived in the case of pairs of shorter period. The catalogue [6] is constantly being updated and added to, so, in critical cases where quickly moving binaries are being observed, it is advisable to check with the current version of the online catalogue at the USNO website.

The history of each system is traced back to the original observation, where possible, in order to give due credit to the discoverer. In many cases, stars with a Struve (STF) designation were actually found by Sir William Herschel, who, in turn, re-observed many of the pairs found by Christian Mayer. References to the original sources, which have been consulted, are given wherever possible.

The modern era section for each star system attempts to summarise what has been found out about the pair in the last few decades; in terms of membership, in particular. Current high-resolution observations with large telescopes are constantly adding new components, often, in the case of infrared work, at the faint end of the main sequence.

Exoplanets seem to be no respecters of stellar singularity. Multi-planetary systems are known to be present in binary star systems and examples are even known where each component of a binary star is accompanied by exoplanets. Where exoplanets are known to exist, or have been looked for around the systems in this catalogue, details are given.

For the visual observer the most relevant section is 'Observing and neighbourhood'. Here there are more details on how to star hop in order to reach the system being described from bright stars, and, having made the effort to find a particular pair, it may be of interest to know what other pairs are in the immediate neighbourhood. Details are given of any such pairs to be found within a few degrees of the current target.

Some of the systems in this volume are bright stars and visible to the naked eye; nevertheless, finder charts are supplied for each system. The field sizes are given and the orientation is always with N to the top and E to the left ~~— i.e. the standard telescopic view.~~ Nearby double stars of interest are also marked on the finder charts.

The data tables start with the RA and Dec for J2000 taken from the WDS. Although more accurate positions are available, it was felt that RA to two decimal places (d.p.) and Dec to one d.p. was more than adequate for finding any of the stars in the catalogue using GOTO (computer controlled) telescopes. For those without this facility, ~~wide-field~~ finder charts are also given ~~at the end of the book.~~ Next to the position is the order in the WDS observations catalogue, in terms of the total number of observations made followed in brackets by the number of observations.

The V magnitudes and $(B - V)$ colours are taken where possible from the Tycho catalogue produced by the Hipparcos satellite.

Proper motions and parallaxes as determined by Hipparcos are presented except when Gaia (DR2) data is available. The definitive final catalogue of this mission is not due out until 2022 and, unfortunately from our point of view, many of the double and multiple systems in this catalogue will not be dealt with until DR3 is issued in 2020. Occasionally, dynamical parallaxes, which are derived from the orbits of the binary pairs, are available which in some case (Sirius, for example) rival the astrometric values. The precision of the astrometry is reproduced as given in the original source catalogues. How accurate these values are can be judged from the size of the accompanying error. Proper motions (μ, in milliarcseconds per year) and parallaxes (π, in milliarcseconds) from DR2 are marked thus. Unsourced astrometry can be assumed to come from Hipparcos and represents the centre of the light measures of the two components.

Spectra are taken from SIMBAD or WDS.

Occasionally, individual masses for components in binary systems are available. This is also true for radii, although directly observed radii are rather uncommon.

Luminosity is derived in each case from the absolute magnitude, which in turn is calculated from the distance as found by the trigonometrical parallax measured by Hipparcos or Gaia. No correction is made for reddening. The Gaia DR2 parallax is known to have a systematic error of 0.1 mas. This has not been applied, as it has a negligible effect even on the smallest measured parallaxes.

The 'official' name for a double star is taken to be its classification in the WDS catalogue (i.e. WDS J12345+1234). Although rather long, it does have the advantage of being both uniform and useful, containing as it does the J2000 coordinates within its structure. The double star catalogue

numbers are given in chronological order, starting with Mayer, then William Herschel, F. G. W. Struve (or O. Struve), and the Burnham and Aitken Double Star catalogues. Many books adopt the official WDS nomenclature and shorten the catalogue name to three letters, representing the discoverer, followed by a running number, e.g. STF 1523. (A short list of the common three-letter codes used is given in the Appendix.) These are followed by the relevant star catalogue numbers, again listed chronologically – Flamsteed/Bayer, HR, HD, SAO, and Hipparcos numbers. Some wider and brighter pairs have catalogue numbers for both components.

Radial velocities, derived largely from SIMBAD, are quoted for the combined system in most part or, in the case of wider pairs, where each star can be observed separately, the velocities are those of the individual stars. Radial velocities derived by the Gaia DR2 project are marked '(DR2)'. Radial velocities which are negative indicate a motion away from the Solar System, and positive velocities represents motion towards the Sun.

Description of the Charts

All-Sky Finder Charts

These six charts (see ~~the end of~~ the previous chapter) cover the entire night sky. The polar charts use a zenithal equidistant projection, whilst the equatorial charts use a pseudoazimuthal Aitoff projection. These seemed the most suitable projections considering the large areas involved. The scale at the centre of each chart is 18 mm to 10° of arc but will vary away from the centre point owing to the projections used. There are no overlapping areas between the four equatorial charts but there is a 10° overlap between the polar and equatorial charts.

The stars are plotted in AutoCad™ from the Hipparcos catalogue. The limiting visual magnitude of the charts is 6.00. Stars are allocated in one-magnitude bins, e.g. the magnitude-3 bin contains stars in the 2.50 to 3.49 range but the magnitude-6 bin just contains the stars from 5.50 to 6.00.

Constellation names have been added and constellation boundaries plotted with dashed lines. No other information, apart from the galactic equator, the ecliptic, and the names of some of the brightest or most popular stars, has been included.

To make it easier to find the positions of the double stars listed in this book, each one is centred in a circle and numbered 1 to 175, according to their listing in the catalogue.

Double stars are plotted using information from WDS catalogue. All doubles are shown by the conventional symbol. Those doubles that feature in this book, and are fainter than magnitude 6.00, are shown by a cross.

All variable stars are plotted at their maximum magnitude with an ordinary star symbol, but are not annotated as a variable.

Individual Finder Charts

Every double star is accompanied by its own finder chart. Each chart covers 8° square, has a scale of 8.35 mm to 1° of arc and has North to the top; as it covers such a small area, and could be at any latitude (declination, Dec), a gnomic projection was deemed the most suitable.

The RA and Dec for the double star centred on each chart is given these are the same as the WDS code. The 1°, 3°, and 5° 'field of view' circles may assist in locating the double star in the night sky.

The stars are plotted in AutoCad™ using data from the Hipparcos and Tycho catalogues. Stars are allocated in one-magnitude bins; e.g. magnitude-3 contains stars in the 2.50 to 3.49 range and magnitude-8 contains stars from 7.50 to 8.49.

All stars with Greek letters and Flamsteed numbers are annotated. Constellation names have been added and constellation boundaries plotted with dashed lines.

Double stars are plotted using information from the WDS catalogue. Most doubles are shown by the conventional symbol, but where the separations of the individual components are large enough, and they can be plotted separately, then a unique symbol is used. Double stars are only labelled if they are mentioned in the observing and neighbourhood paragraph for each double in the main section of this book.

Variable stars are only shown and labelled if their magnitude range is greater than 2. These consist mostly of Mira-type variables. They are annotated with a circle symbol indicating the maximum magnitude and sometimes (if the minimum is 8 or brighter) with a dot at the center that shows the minimum magnitude.

The most prominent deep-sky objects are plotted and annotated, but, in the case of open star clusters, they are only shown when a number of the stars in the chaster are brighter than magnitude 8.5.

Orbital Diagrams

Orbital diagrams for those double stars that are also binary stars have been plotted in AutoCad™ using data extracted from the USNO Sixth Catalog of Orbits of Visual Binary Stars.

The full references can all be found in the WDS Reference Notes Catalogue.

The orbit has been plotted through one complete revolution. Each diagram has North (0°) to the bottom with the position angle (PA) increasing in an anticlockwise direction. The scale (in arcseconds) is shown beneath each diagram. Close binaries are shown with three levels of grey shading, which indicate the Dawes limit when one is splitting pairs of equal magnitude, using respectively 10-cm, 20-cm, and 40-cm aperture telescopes.

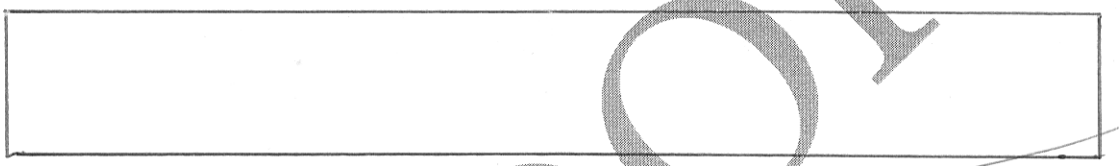
The orbital ephemeris, computed using the orbital elements from the Sixth Catalog, is included with each diagram, showing the PAs and separations (Sep) of the binary in future years. Also listed is the abbreviation for the name of the author who computed the orbital elements, the period of the binary in years, and the grade (1 to 5) of the elements, "1" being the most accurate and usually a binary that has been observed through at least one complete revolution of its orbit.

Orbital Measures

The diagrams of seven binaries that are regularly measured by author RWA have been included in the individual sections on those stars. They are STF 1196, 1523, 1670, 1937, 2084, and 2272 and SHJ 345. They are copies of the orbital diagrams but with the addition of his own observations made with the 8-inch refractor at Cambridge.

ADD

Legend for Individual Finder Charts



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