A Catalogue of Symbiotic Stars

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Abstract

More than 100 symbiotic stars are now known. A catalogue of them, complete to 1984 January 1, is presented. Finding charts are given for all examples, and optical spectra for the majority. A table summarises the observational material at X-ray, ultraviolet, infrared and radio wavelengths.

1. Symbiotic Stars

Over the last few years, symbiotic stars have once more become fashionable, and our understanding of these systems has greatly advanced. In part this is due to the application of X-ray, ultraviolet, infrared and radio techniques to what had previously been the domain solely of optical observers. In part, research into other types of interacting binaries has provided a clearer framework on which to build interpretations of the symbiotic stars.

It is now generally agreed that most, perhaps all, symbiotic stars are binaries, in which a cool giant sheds mass on to a more compact companion. It is also apparent that the class of objects we currently define to be symbiotic stars is heterogeneous, involving main sequence, white dwarf and neutron star accretors, and possibly even some non-accreting systems and some single stars. As a descriptor of the binaries, the term symbiotic star should more properly be replaced by symbiotic system or symbiotic binary.

For the present, however, we are not in a position to demonstrate the binary nature of all systems that have long borne the epithet symbiotic. Thus it is necessary to fall back on earlier definitions. An observationally convenient definition is:

> Late-type (G-K-M or carbon) giant providing red and infrared continuum;
> emission lines excited by a source of several 10^5 K.

It is not the purpose of this paper to present a full review of the observational data base or the wealth of theoretical discussion concerning the symbiotic stars. That task has been accomplished very successfully in three recent publications. The proceedings of IAU Colloquium 70 (Friedjung and Viotti 1982) gives an excellent overview of the subject; a compilation of references by Kenyon (1983) as a companion volume to his Ph.D. dissertation provides an unequalled bibliography; and my recent review (Allen 1983) gives a personal summary of the state of our knowledge together with suggestions for further work.

2. The Catalogue

The aim of this paper is to present a catalogue of symbiotic stars, complete to the end of 1983, which will serve to assist and stimulate further work on these complex systems. This is not the first catalogue of symbiotic stars, and a few words are needed to justify its publication.

Various catalogues listing up to about 20 symbiotic stars were in existence in the early 1970s. The number of known symbiotic stars grew dramatically during that decade, largely due to the discoveries on objective-prism plates made by Sanduleak and Stephenson (1973) and the follow-up work by the present author on both the Sanduleak and Stephenson discoveries and on planetary nebulae that had shown intense infrared continua. Five years ago I presented a paper (Allen 1979) describing the optical, infrared and radio work that I had undertaken on symbiotic stars, and in that paper I listed slightly more than 100 objects. That list has been adopted by most subsequent researchers as the definitive catalogue of symbiotic stars. It was not, however, complete. Moreover, it gave only brief summaries of the optical spectra, which remain one of the most important data bases in the study of symbiotic stars. Finally, no finding charts were given to assist subsequent observers. Charts of varying quality are scattered throughout the literature for only about half of the stars in that list, and some charts actually mark the wrong star.

The present work provides three sets of data for symbiotic stars. The catalogue itself, presented in Table 1, contains a concise summary of what I consider to be the most important numerical and codable data. In addition to such obvious entries as names and positions, the catalogue indicates the result of X-ray and radio (line and continuum) investigations, the existence of ultraviolet spectroscopy from IUE, the infrared properties, the type of variability exhibited, and for the few known cases, the orbital period. Since some underobserved systems invariably enter the grey area mapped out by any definition, the catalogue is supplemented by 15 stars which are considered likely to be closely related to, or genuine examples of, the symbiotic stars.

The second part of the present work, which is also complete, is a uniform set of finding charts. The third, of necessity incomplete, is a set of optical spectra, also to uniform format. These spectra are entirely my own data, and with a scant handful of exceptions have not previously been published, except in very brief summary (Allen 1979). They occupy 36 figures. To render this section more complete, notes and/or references to comparable spectroscopy are given for those objects (mostly in the northern hemisphere) lacking spectral plots.

3. Nomenclature

Because the nomenclature for symbiotic stars borrows from those of variable stars, Be stars and planetary nebulae, it is confusing and diverse. I have preferred stellar designations, since these objects involve stars. Where possible, variable star designations, HD, BD or CD numbers have been used. Table 2 gives references to the names and abbreviations. Therein, PK = Perek and Kohoutek (1967); W = Wackerling (1970). I have eschewed He3- in reference to Henize's (1976) catalogue of Be stars, preferring the former Hen: He3- is a designation more typical of planetary nebulae.

4. Notes on Table 1

References to existing data used to compile this table will be found in Kenyon (1983) or in Friedjung and Viotti (1982) with the exceptions listed below.

Table 1. Catalogue of Symbiotic Stars

Star	Position (1950) R.A. h m s	Dec ° ′ ″	Gal. Coords. l °	b °	HD/ other	X-ray	UV	Infrared K		Radio	Opt. Var.	Orbital period d	Spectrum Fig.
EG And	00 41 52.7	+40 24 22	121.5	-22.17	4174		u	2.6	S		m?	470??	
SMC N60	00 55 30.2	-74 29 30			Ln 323			13.0	D		n		
SMC Ln 358	00 57 42.3	-75 21 29						11.5	S		n		
SMC N73	01 03 18.9	-76 04 28			Ln 445a			11.5	S		n		
AX Per	01 33 05.7	+54 00 07	129.5	-8.04	MWC 411	x	u	5.5	S	co	re?	682	
V741 Per	01 55 32.9	+52 39 15	133.1	-8.64	M1-2		u	9.8	D′	c	n		
UV Aur	05 18 33.3	+32 27 50	174.2	-2.35	34842			2.2	D′	c	m?		33
Sanduleak's	05 46 02.7	-71 17 13			(LMC)		u	12.9	D	c	n		29
LMC S63	05 48 52.1	-67 37 02			HV 12671		u	11.3	S	c	*		1
BX Mon	07 22 52.9	-03 29 51	220.0	5.88	AS 150		u	5.7	S	co	m?		33
Wray 157	08 04 32.2	-28 23 18	246.6	1.95				9.4	D′	c	n		28
RX Pup	08 12 28.2	-41 33 18	258.5	-3.93	69190		u	2.0-3.5	D	C	m		
Hen 160	08 23 26.7	-51 18 46	267.7	-7.87				7.5	S		n		8
AS 201	08 29 36.8	-27 35 20	249.1	6.97	Hen 172	x		9.9	D′	c	n		27
He2-38	09 53 03.7	-57 04 39	280.8	-2.24		x		3.7-5.7	D	c	m		2
SS 29	11 06 27.3	-65 31 02	292.6	-5.00				10.7	S	c	n		3
SY Mus	11 29 55.0	-65 08 36	294.8	-3.81	100336		u	4.7	S	c	e?	622	15
BI Cru	12 20 40.3	-62 21 39	299.7	0.06	Hen 782			4.7-5.2	D		m?		32
He2-87	12 42 48.3	-62 44 09	302.3	-0.14				6.0	S	co	n		24
Hen 828	12 48 01.6	-57 34 28	302.9	5.03				7.1	S	c	n		8
SS 38	12 48 21.8	-64 43 40	302.9	-2.13				5.7-6.5	D	C	m?		4
Hen 863	13 04 49.0	-47 44 22	305.7	14.78				8.5	S	c	n		28
St2-22	13 11 22.4	-58 36 01	305.9	3.87				8.5	S		n		
Hen 905	13 27 23.2	-57 42 50	308.1	4.51				8.5	S	c	n		21
RW Hya	13 31 31.9	-25 07 29	315.0	36.49	117970		u	4.7	S	Co	m?	372?	20
Hen 916	13 31 59.1	-64 30 25	307.6	-2.29				7.8	S	c	r?		15
He2-106	14 10 22.7	-63 11 45	312.0	-2.03		x		4.3-5.7	D	C	m		4
BD -21.3873	14 13 45.8	-21 31 56	327.9	36.95		x		7.2	S	c	n		26
He2-127	15 21 10.4	-51 39 15	325.5	4.18		x		7.9-8.3	D	co	m?		5
Hen 1092	15 42 29.7	-66 19 58	319.2	-9.35	He2-134	x		7.8	S	c	n		19
Hen 1103	15 45 00.3	-44 09 50	333.2	7.90				8.4	S	c	n		20
He2-139	15 50 48.6	-55 20 48	326.9	-1.40				5.3-6.4	D	c	m?		22
T CrB	15 57 24.5	+26 03 39	42.4	48.16	143454	X	u	4.8	S	co	r	228	
AG Dra	16 01 23.2	+66 56 25	10.3	40.97		X	u	6.2	S	co	r	554	
W16-202	16 03 15.0	-49 18 40	332.8	1.95				6.8	S		n		
He2-147	16 09 55.6	-56 51 56	327.9	-4.30				5.0	S	co	n		32
UKS-Ce1	16 12 31.2	-22 04 50	353.0	20.25				11.3	S	c	n		34
Wray 1470	16 20 16.2	-27 33 16	350.1	15.24				7.8	S	c	n		17
He2-171	16 30 47.0	-34 59 12	346.0	8.55		x		6.2-7.2	D	C	m?		6
Hen 1213	16 31 23.0	-51 36 14	333.9	-2.81				6.7	S	c	n		22

He2-173	16 32 58.9	-39 45 40	342.8	5.01				6.8	S	C	n		13
He2-176	16 37 54.3	-45 07 22	339.4	0.74				5.7	D	Co	n		31
Hen 1242	16 40 00.3	-62 31 40	326.4	-10.94	Cn1-2	x		6.0	S	c	n		7
AS 210	16 48 15.6	-25 55 24	355.5	11.55	Hen 1265			6.7	D	C	n		26
HK Sco	16 51 29.8	-30 18 17	352.5	8.27	AS 212			7.9	S	c	r		14
CL Sco	16 51 40.3	-30 32 30	352.3	8.09	AS 213		u	7.9	S	c	r	625?	25
V455 Sco	17 04 04.1	-34 01 18	351.2	3.89	H2-1	x		5.9	S	C	r		5
Hen 1341	17 05 42.5	-17 22 41	5.0	13.39				7.6	S	c	n		26
Hen 1342	17 05 53.1	-23 19 48	0.1	9.92				8.5	S	c	n		28
AS 221	17 08 56.2	-32 34 12	353.0	3.93	H2-4			7.6	S	c	n		25
H2-5	17 12 04.7	-31 30 39	354.2	4.02				5.5	S	c	n		12
Th3-7	17 17 51.9	-29 19 55	356.7	4.26				8.1	S		n		12
Draco C-1	17 19 08.5	+57 53 01									n		
Th3-17	17 24 21.4	-29 00 28	357.8	3.28				8.2	S		n		8
Th3-18	17 25 17.1	-28 36 09	358.2	3.33				8.2	S		n		18
Hen 1410	17 25 54.9	-29 41 01	357.4	2.62	Th3-20			8.5	S	c	n		14
V2116 Oph	17 28 57.9	-24 42 35	1.9	4.79	GX 1+4	X		8.1	S	c	x		
Th3-30	17 30 34.2	-28 05 20	359.3	2.65				8.3	S		n		19
Th3-31	17 31 05.6	-29 27 12	358.2	1.80				7.6	S		n		16
M1-21	17 31 20.4	-19 07 23	7.0	7.36				7.2	S	c	n		21
Pt-1	17 35 46.5	-23 52 24	3.5	3.94				8.6	S		n		19
RT Ser	17 37 04.1	-11 55 04	13.9	9.97	MWC 265			7.0	S	Co	s		12
AE Ara	17 37 19.7	-47 01 50	344.0	-8.66	PC18	x		6.3	S	c	r		6
SS 96	17 38 04.9	-36 46 17	352.8	-3.38				6.4	S	C	n		10
UU Ser	17 39 46.5	-15 23 23	11.2	7.62	AS 237			9.1	S	c	r?		22
AS 239	17 40 31.6	-22 44 16	5.0	3.62	Hen 1465			7.5-8.2	D?	c	s		33
SSM 1	17 40 32.6	-36 02 07	353.7	-3.41				8.3	S		s?		
Hen 1481	17 44 41.6	-36 07 19	354.1	-4.17				8.0	S	co	r?		13
H1-36	17 46 24.1	-37 00 36	353.5	-4.92		x		6.8-8.1	D	C	m	35000??	30
RS Oph	17 47 31.6	-06 41 40	19.8	10.37	162214			6.5	S	co	r		33
AS 245	17 47 59.7	-22 18 49	6.3	2.37	H2-28			7.2	S	C	n		24
He2-294	17 48 28.5	-32 54 10	357.3	-3.18				8.4	S		n		18
B13-14	17 49 14.1	-29 45 19	0.1	-1.70				8.7	S		n		19
B13-6	17 49 42.1	-31 18 41	358.8	-2.58							n		
B1 L	17 50 00.7	-30 17 25	359.7	-2.12				7.8	S		n		24
AS 255	17 53 47.7	-35 15 18	355.8	-5.32	Hen 1525			8.4	S	c	n		28
V2416 Sgr	17 54 15.6	-21 41 10	7.6	1.44	M3-18			4.6	S	C	r		22
SS 117	17 59 07.5	-31 59 14	359.2	-4.66				7.7	S	c	n		23
Ap1-8	18 01 19.8	-28 21 48	2.6	-3.28				7.9	S	c	n		21
SS 122	18 01 33.2	-27 09 26	3.7	-2.73				6.6	S?	Co	n		7
AS 270	18 02 35.2	-20 20 52	9.7	0.42	Hen 1581			5.5	S		n		11
H2-38	18 02 51.5	-28 17 23	2.8	-3.54				6.7	D	Co	n		30
SS 129	18 03 54.0	-29 36 50	1.8	-4.39				8.0	S	c	n		27
V615 Sgr	18 04 17.5	-36 06 47	356.1	-7.60	He2-349			7.6	S	c	m		10
Hen 1591	18 04 25.8	-25 54 10	5.1	-2.68				9.0	D	c	n		29

Table 1. continued

Star	Position (1950) R.A. h m s	Dec ° ′ ″	Gal. Coords. l °	b °	HD/ other	X-ray	UV	Infrared K		Radio	Opt. Var.	Orbital period d	Spectrum Fig.
AS 276	18 05 37.3	-41 13 58	351.6	-10.24	Hen 1595			8.1	S	c	n		11
Ap1-9	18 07 19.5	-28 08 20	3.4	-4.33				8.8	S	c	n		23
AS 281	18 07 34.6	-27 58 31	3.6	-4.30	Ap1-10			7.0	S	c	n		14
V2506 Sgr	18 07 51.6	-28 33 21	3.1	-4.63	AP1-11			8.4	S	c	r?		25
SS 141	18 08 53.9	-33 11 29	359.1	-7.04				9.0	S	c	n		16
AS 289	18 09 34.7	-11 40 55	18.1	3.19	Hen 1627			5.0	S	C?	n		24
Y CrA	18 10 47.3	-42 51 27	350.6	-11.83	166813	x		6.6	S	c	r		1
V2756 Sgr	18 11 22.5	-29 50 19	2.4	-5.92	AS 293			7.8	S	c	m?e?		24
HD 319167	18 12 11.5	-30 32 56	1.8	-6.41	CnMy 17			7.5	S	c	n		12
YY Her	18 12 25.9	+20 58 20	48.1	17.25	AS 297		u	8.0	S	co	r		9
He2-374	18 12 30.9	-21 36 24	9.7	-2.21				6.5	S	c	n		15
AS 296	18 12 33.0	-00 19 53	28.5	7.93				4.5	S	C	n		16
AS 295B	18 12 51.9	-30 52 16	1.6	-6.69	Hen 1641	x					r		13
AR Pav	18 15 24.6	-66 06 07	328.5	-21.61	MWC 600		u	7.2	S	c	re		23
Hen 1674	18 17 12.4	-26 24 10	6.0	-5.43				7.7	S	c	n		29
He2-390	18 17 51.4	-26 49 50	5.7	-5.76				7.0-7.7	D	C	m		32
V443 Her	18 20 02.9	+23 25 47	51.2	16.60	MWC 603		u	5.4	S	co	r		9
V3811 Sgr	18 20 28.5	-21 54 45	10.3	-3.98	He2-396			8.5	S	c	m?		25
AS 304	18 22 16.7	-28 37 42	4.5	-7.46	Hen 1691			7.6	S	c	n		14
V2601 Sgr	18 35 00.7	-22 44 30	11.2	-7.35	AS 313			8.0	S	c	e?		17
AS 316	18 39 33.4	-21 20 46	12.9	-7.67	He2-417			7.8	S	c	n		18
MWC 960	18 44 58.1	-20 09 12	14.5	-8.27	Hen 1726			7.8	S	c	n		27
AS 327	18 50 13.3	-24 26 43	11.1	-11.23	Hen 1730			8.5	S	c	n		11
FN Sgr	18 50 58.5	-19 03 27	16.2	-9.06	AS 329			7.9	S	co	r		11
Pe2-16	18 51 30.9	-04 42 40	29.1	-2.72				8.1	S	c	n		23
V919 Sgr	19 00 51.6	-17 04 24	19.0	-10.31	AS 337			7.2	S	c	m		17
CM Aql	19 00 57.9	-03 07 44	31.6	-4.09				7.6	S	c	r		25
AS 338	19 01 32.0	+16 21 47	49.0	4.77	K4-12			7.5	S	c	n		2
Ap3-1	19 08 05.4	+02 44 33	37.6	-2.97				8.7	S		n		
BF Cyg	19 21 55.2	+29 34 34	62.9	6.70	MWC 315		u	6.3	S	C	e?	757?	
Hen 1761	19 37 20.8	-68 14 45	327.7	-29.76				5.6	S	c	n		13
HM Sge	19 39 41.4	+16 37 33	53.6	-3.15		X	u	3.6-4.9	D	Co	sm		31
AS 360	19 43 35.7	+18 29 23	55.6	-3.02	Hen 1771			7.1	S	c	n		10
CI Cyg	19 48 20.6	+35 33 23	70.9	4.74	MWC 415		u	4.5	S	co	re	855	
V1016 Cyg	19 55 19.8	+39 41 30	75.2	5.68	AS 373	X	u	4.6-6.0	D	Co	sm	>7000??	
RR Tel	20 00 20.1	-55 52 04	342.2	-32.24	Hen 1811	X	u	3.6-4.8	D	C	sm		31
He2-467	20 33 42.6	+20 01 02	63.4	-12.15				9.4	S	c	n		29
He2-468	20 39 20.5	+34 34 07	75.9	-4.44				8.0	S		n		
V1329 Cyg	20 49 02.6	+35 23 37	77.8	-5.48	HBV 475		u	6.9	S	C	se		
CD -43.14304	20 56 48.6	-42 50 34	358.6	-41.10	Hen 1924			7.6	S	c	n		20

V407 Cyg	21 00 24.1	+45 34 41	87.0	-0.48	AS 453					c	m?e?		
AG Peg	21 48 36.2	+12 23 27	69.3	-30.89	207757	x	u	3.9	S	Co	s	827	9
Z And	23 31 15.3	+48 32 31	110.0	-12.09	221650		u	5.0	S	Co	r		
R Aqr	23 41 14.3	-15 33 43	66.5	-70.33	222800		u	-0.5--1.2	D	CoS	m	16000??	
					Possible symbiotic stars								
Hen 461	10 37 03.9	-51 08 33	282.9	6.25				3.9	S		n		
Hen 653	11 23 16.5	-59 40 02	327.8	-8.14				5.4	S	c	n		35
CD -36.8436	13 13 12.0	-36 44 18	308.4	25.61	Hen 886			5.7	S		n		
V704 Cen	13 51 30.5	-58 12 42	311.2	3.40	He2-101			8.4	D	c	m?		35
He2-104	14 08 33.3	-51 12 18	315.5	9.46				6.9	D	c	n		3
HD 330036	15 47 38.0	-48 35 54	330.8	4.15	Cn1-1	x	u	7.6	D'		n		34
Sa3-43	17 14 44.0	-29 58 34	355.8	4.45				7.9	S		n		
Th3-29	17 29 17.3	-29 03 01	358.3	2.35				7.0	S		n		34
H2-19	17 41 47.9	-38 16 13	352.0	-4.79				7.8	S		n		34
W16-312	17 47 03.0	-30 56 45	358.8	-1.91				7.2-8.0	D		m?		36
Th4-4	17 47 25.9	-19 52 56	8.3	3.73				7.9	S		n		
Ve2-57	18 05 17.9	-24 34 13	6.3	-2.20	SS 134			7.1	S		n		36
V3804 Sgr	18 18 13.8	-31 33 31	1.5	-8.02	AS 302			7.3	S	c	r		35
CH Cyg	19 23 14.2	+50 08 31	81.9	15.58	182917	x	u	-0.7	S	c	rf	5750??	
PU Vul	20 19 01.1	+21 24 43	62.6	-8.52				6.0-6.4	S		s?e?		

Key:

X-ray: x = no detection, X = detection.

UV: u = published IUE spectrum.

IR: K magnitude, and type: S = star dominates at K, D = thermal radiation from dust prominent at K, except D' where dust is seen only at longer wavelengths.

Radio: c = continuum not detected, C = continuum detected, o = OH maser not detected, S = SiO maser detected.

Variability: e = eclipses or other modulation on orbital period, f = flickering on short time scales, m = Mira-like, n = no known variations, r = recurrent flares (classical symbiotic), s = slow nova (eruptive symbiotic), x = X-ray variable, * = R CrB type?

Table 2. Abbreviations and names for symbiotic stars.

Ap1- and Ap3-	Apriamashvili; see PK.
AS	Merrill and Burwell: additional stars with Hα emission; see W.
B1 and B13-	Blanco; see PK.
Cn1-	Cannon; see PK.
CnMy	Cannon and Mayall; see PK.
Draco-C	Draco dwarf spheroidal galaxy: Aaronson et al. (1982)
GX	Galactic-centre X-ray source: Lewin et al. (1971).
H1- and H2-	Haro; see PK.
HBV	Hamburg-Bergedorf variable.
He2-	Henize; see PK.
Hen	Henize (1976); first listed in W.
HV	Harvard variable (LMC).
K4-	Kohoutek; see PK.
Ln	Lindsay(1961) emission-line object in Small Magellanic Cloud.
M1- and M3-	Minkowski; see PK.
MWC	Merrill and Burwell: Mount Wilson Catalogue; see W.
N	Henize nebula in Magellanic Clouds: Henize (1956).
PC	Peimbert and Costero; see PK.
Pt-	Peterson (1977).
S	Henize star in Magellanic Clouds: Henize (1956)
Sa3-	Suspected planetary nebula, table 2 in Sanduleak (1976).
SS	Sanduleak and Stephenson (1973).
SSM	Sanduleak et al. (1978).
St2-	Stephenson: suspected planetary nebula from table 2 in Sanduleak (1976).
Th3- and Th4-	The; see PK.
UKS-Ce	Longmore and Allen (1977).
Ve2-	Velghe; see W.
W16-	Wray (1966) table 16.
Wray	Wray; see W.

-- compilations --

PK = Perek and Kohoutek (1967)

W = Wackerling (1970)

All other data are my own. The major contribution to the increased number of symbiotic stars over my 1979 list is through slit spectroscopy of stars selected by MacConnell (1983) as having Hα emission on an M-type continuum.

Some positions and many of the latest radio continuum data are from Seaquist *et al.* (1984). Some of the non-detections reported in the OH 1612 MHz line are from Michalitsianos (private communication) and from Allen and Caswell (unpublished).

Extragalactic systems can be recognised by the absence of galactic coordinates in the table: they lie in the Magellanic Clouds or the Draco dwarf spheroidal galaxy.

Optical magnitudes are not given because of the sparsity of good determinations, and because of the contamination by emission lines which is filter-dependent. Infrared magnitudes (at K, 2.2 μm) quantify the apparent brightness of the cool giant, and the charts serve as a rough guide to the optical brightness of all systems.

Although Sanduleak's star is included in the main body of the table, a late-type component is not definitely seen. A low-luminosity carbon star is suspected, and inclusion is justified by the presence of the unidentified 6830 Å band (Allen 1980) in emission. If indeed there is no late-type component in Sanduleak' star, it is the only known non-symbiotic star exhibiting the 6830 Å band.

The inclusion of V741 Per, which closely resembles HD 330036 (mentioned in the next paragraph), is justified by the supergiant classification of its G-type absorption; this is probably better interpreted as an accretion disk (Zipoy 1975).

Several stars in Table 1 currently exhibit low-excitation emission spectra, and are included on the strength of descriptions of their spectra taken from the literature. These are BI Cru (Henize and Carlson 1980), T CrB (e.g. Swings and Struve 1941; Herbig and Neubauer 1946), AS 239 (Merrill and Burwell 1950), and RS Oph (Joy and Swings 1945; Dufay *et al.* 1964).

The 'possible' symbiotic stars are now described briefly.

He2-104 and W16-312 are bipolar nebulae having very high excitiation, but possibly lacking late-type stars. They may instead resemble NGC 6302 (Oliver and Aller 1969; Aller and Walker 1970).

HD 330036 has been described as a conventional, young planetary nebula in a normal binary relationship with a G star (Lutz 1984).

PU Vul exhibits weird photometric and spectroscopic behaviour, and probably does not belong in the symbiotic bin, though it has been so classified by several authors. For a more complete description, see Yamashita *et al.* (1982).

All other entries are M stars exhibiting unusually strong HI and HeI emission. These are either lower-excitation cousins to the symbiotics, involving a cooler radiation field, or are faint, reddened symbiotics for which the data are not yet adequate for certain classification.

5. Notes on the Charts

Charts are given in all cases even though for some stars they are trivial. They occupy plates 1-8, and the order of presentation follows that in Table 1. Observers who wish to work on the brightest specimens are thus afforded a means of rapid selection of suitable stars. All charts have the same scale (shown on each plate) to the tolerance on focusing the copy camera, namely a few per cent.

North is at top and east to the left throughout. Care was taken to align the charts to within a few degrees of true celestial coordinates; this is of course not necessarily the same as the direction of the diffraction spikes. Guide marks are provided, and have been oriented so as to obliterate very few stars, and only those more than about one magnitude fainter than the symbiotic star itself.

In most cases a blue-sensitive plate was chosen. The choice generally renders the symbiotic star less prominent than on red-sensitive plates or at the eyepiece, but allows more certain identification on crowded charts, or for stars with a large range of variability when observed near minimum. Preference was given to UKSTU blue plates, but in very crowded fields or where UKSTU material was not readily available, the less deep ESO plates were used. In the northern hemisphere, Palomar O plates were used. The original material was from film copies for UKSTU and ESO fields, and copy plates for Palomar. Marks on the protective envelopes of UKSTU and ESO transparencies will therefore not reproduce on other users' versions.

Below each chart, a key describes the original material. The cipher is:

E – ESO quick blue survey, IIaO.
P – Palomar, IIaO.
U – UKSTU blue survey, IIIaJ.
Ur – UKSTU short red survey, IIIaF, companion to the infrared survey.

Many of these objects have finding charts in Perek and Kohoutek's (1967) catalogue of planetary nebulae. However, in several cases the Perek and Kohoutek chart indicates the wrong star. It is possible that further erroneous identifications have escaped notice and persist in the present catalogue. Should any discrepancy be noted, the 1950 coordinates should be preferred to the chart identification.

6. Notes on the Spectra

Figures 1-36 display the spectra. The order of presentation was selected, partly for efficient use of journal space, but also so as to group loosely together stars with similar spectra. Table 1 gives, for each star, the figure in which the spectrum is shown.

The wavelength range selected is 3400-7500 Å. At the blue end, this allows an indication of the Balmer continuum emission, and of the [Ne V] line λ3425. At the red end, some of the stronger TiO bands are seen. The wavelength range of the plots is the same for all stars even if data do not exist for some parts of that range.

The display scale causes some of the strongest emission lines to be truncated at the top of the plot. In practice, these strong lines were usually not accurately measured due to saturation effects.

For 14 objects, in Figures 1-7, spectrophotometry is given. This was achieved by opening the spectrograph slit to a width of 7-10 arcsec, depending on the seeing, and using a comparable spread of data along the slit. Observations of white dwarf standards from the list of Oke (1974) were used to calibrate the data, and standard procedures to compensate for atmospheric extinction were employed. The units of spectrophotometric diagrams are 10^{-14} erg s^{-1} cm^{-2} Å^{-1}. The wide-slit observations were accompanied by, and used to calibrate, conventional observations using a narrow slit. In this way spectral resolution was not sacrificed. For some stars, two sets of spectrophotometry were obtained. These were averaged, there in no case being evidence of significant differences between the two observations. In general, the spectrophotometry is thought reliable to about $\pm$ 15% in absolute flux, and considerably better for features little separated in wavelength.

The remaining spectra were secured through only a narrow slit. No attempt was made to calibrate them, in the belief that too much reliance is often placed on such data. Rather, these spectra have been deliberately modified so as to make the continuum approximately constant over the wavelength range displayed, thereby loosely removing instrumental influences. In this way, the emission lines are well seen. Inspection of Figures 1-7 demonstrates that this procedure yields a good first approximation to the average symbiotic star anyway. No ordinate scale is appropriate in these cases, and none is given; however, the display is linear. In some highly reddened stars the signal is barely detected in the blue; the continuum was allowed to retain a redward gradient in such cases.

Inset in each spectrum is the name of the object together with the date of the observation and a code to describe the detector. All observations were made with the 3.9-m Anglo-Australian Telescope (AAT). Two digital electronic detectors were used, according to availability. These are the Image Photon Counting System (IPCS) and Image Dissector Scanner (IDS). Their characteristics differ, and the most relevant differences are as follows:

IDS low spectral resolution; accepts high count rates on emission lines; gives high signal-to-noise on bright objects.

IPCS high spectral resolution; limited maximum count rate gives poor signal-to-noise on bright objects, whose light must be attenuated, and fails to reproduce intense emission lines faithfully.

The figure in brackets following the detector abbreviation is the spectral resolution (in Å) of the raw data. In Figures 1-36 this resolution is often somewhat degraded by the plotting and subsequent reproduction.

One of the striking features of symbiotic stars is the wealth of emission lines and other features in the optical spectra. In order to assist the reader in identifying some of them, a synthetic spectrum is presented as the last scan in Figure 36. This is on the same wavelength scale as the data.

For 24 symbiotic stars, and 5 possible symbiotic stars, no suitable spectra are available. Table 3 gives references to digital spectra of comparable quality and nature to those in the present paper. Where this is not possible, notes on the stars'

Table 3
Notes on the spectra of stars not included in Figs. 1–36.

EG And: Oliversen and Anderson (1982)
SMC N60, Ln 358 and N73: Like peas in a pod, in FORS observations these three objects all exhibit H, He I and 6830 emission superimposed on a carbon star continuum. The equivalent widths of these lines in the three stars are similar, but N60 is bluer than the other two. Walker's (1983) observations at shorter wavelengths appear to show greater differences between these stars, especially in their continua.
AX Per: Oliversen and Anderson (1983); Blair et al. (1983).
V741 Per: Blair et al. (1983).
RX Pup: The spectrum recently converted from low to high excitation. A description during this change, with photographic reproductions of the spectra, is in Klutz and Swings (1981).
St2-22: FORS shows a late M star with strong Hα, weak He I, O I and [Fe VII], and strong 6830 emission.
T CrB: Blair et al. (1983).
AG Dra: Smith and Bopp (1981); Blair et al. (1983).
W16-202: FORS shows a very late M star with strong Hα, weak He I, O I and [Fe VII], and moderate 6830 emission.
Draco C-1: Aaronson, Liebert and Stocke (1983).
V2116 Oph: Davidsen, Malina and Bowyer (1977). A recent FORS spectrum showed no spectral change from the observation of Davidsen et al., despite the cessation of X-ray emission discovered only a few days earlier (Hall 1983) and the subsequent fading of the emission lines (Whitelock, Menzies and Feast, 1983). Unusually for a symbiotic star, O I 8446 was very strong on the FORS spectrum.
SSM 1: The spectrum is briefly described in Sandulaek, Stephenson and MacConnell (1978).
B13-6: The spectrum is briefly described in Carrasco, Costero and Serrano (1983).
Ap3-1: FORS shows a late M star with strong Hα, [Fe VII] and 6830, and weak He I, He II, O I, [Ar III] and [Ca VII].
BF Cyg: Oliversen and Anderson (1983).
CH Cyg: Blair et al. (1983).
CI Cyg: Oliversen and Anderson (1983); Blair et al. (1983).
V1016 Cyg: Oliversen and Anderson (1983); Blair et al. (1983).
He2-468: FORS shows a late M star with strong Hα, He I, He II, and 6830, and weak [Fe VII].
V1329 Cyg: Blair et al. (1983).
V407 Cyg: Spectral information is scant: study of this star is encouraged.
Z And: Blair et al. (1983).
R Aqr: Wallerstein and Greenstein (1980) give a good description of the spectrum.
Hen 461: An IPCS observations of very restricted spectral range shows an M star with H, Fe II and [O I] emission.
Sa3-43: FORS shows an early M star with strong Hα, weak He I.
Th4-4: FORS shows a late M star with very strong Hα, He I emission. There is moderate forbidden-line emission from [Ar III] and the high-density lines of [S III], [N II] and [O II]. O I 8446 is strong. He II is not quite definite.
PU Vul: See section 4.

spectra are given. In Table 3, FORS refers to the newly-commissioned Faint Object Red Spectrograph on the AAT, which offers coverage from 5000 to 10000 Å at a resolution near 20 Å.

7. The Need for Further Work

This catalogue is in no way the last word on symbiotic stars. Rather, its publication is designed to stimulate further work. As noted above, suggested directions for future observations are given in Allen (1983). Here I reiterate what is surely the most important. In Table 1, the sparsest coverage is the column giving the orbital period. Yet this parameter relates to the separation of the component stars and hence to their ability to interact. Linked to it is the question of whether the late-type star fills its Roche lobe; if so, its luminosity and distance may be estimated. The accretion luminosity and other important parameters also follow. In parallel to the deficiency of orbital periods is the large proportion of stars to which 'no known variability' must be assigned. Many of these may have undergone several small outbursts or larger, slow nova eruptions unobserved but in historical times.

Optical photometry is the most important tool for determining the orbital period, but filters which avoid the strongest lines should preferably be employed. In most cases standard V and I filters are adequate. Variations on the optical period may be due to eclipses or to illumination of one side of the cool star by its hot companion. Eclipses should occur in one third of systems which fill their Roche lobes. Only the length of the orbital periods and the interference of outbursts and other forms of variability complicate the measurements. Many symbiotic stars have been monitored by amateur groups, or are recorded in sky patrol plates. These sources of information should be tapped, whilst observers with patience and access to continuing supplies of time for photometry should give full consideration to undertaking such observations. Spectroscopy of suitable lines (including radio maser lines) may also lead to orbital periods, as in AG Peg.

8. Appeal

The author would appreciate having brought to his attention any errors or omissions noted in this catalogue.

I thank the many staff of the AAO without whom this compilation would have been difficult indeed, but especially John Crawford, who helped so much.

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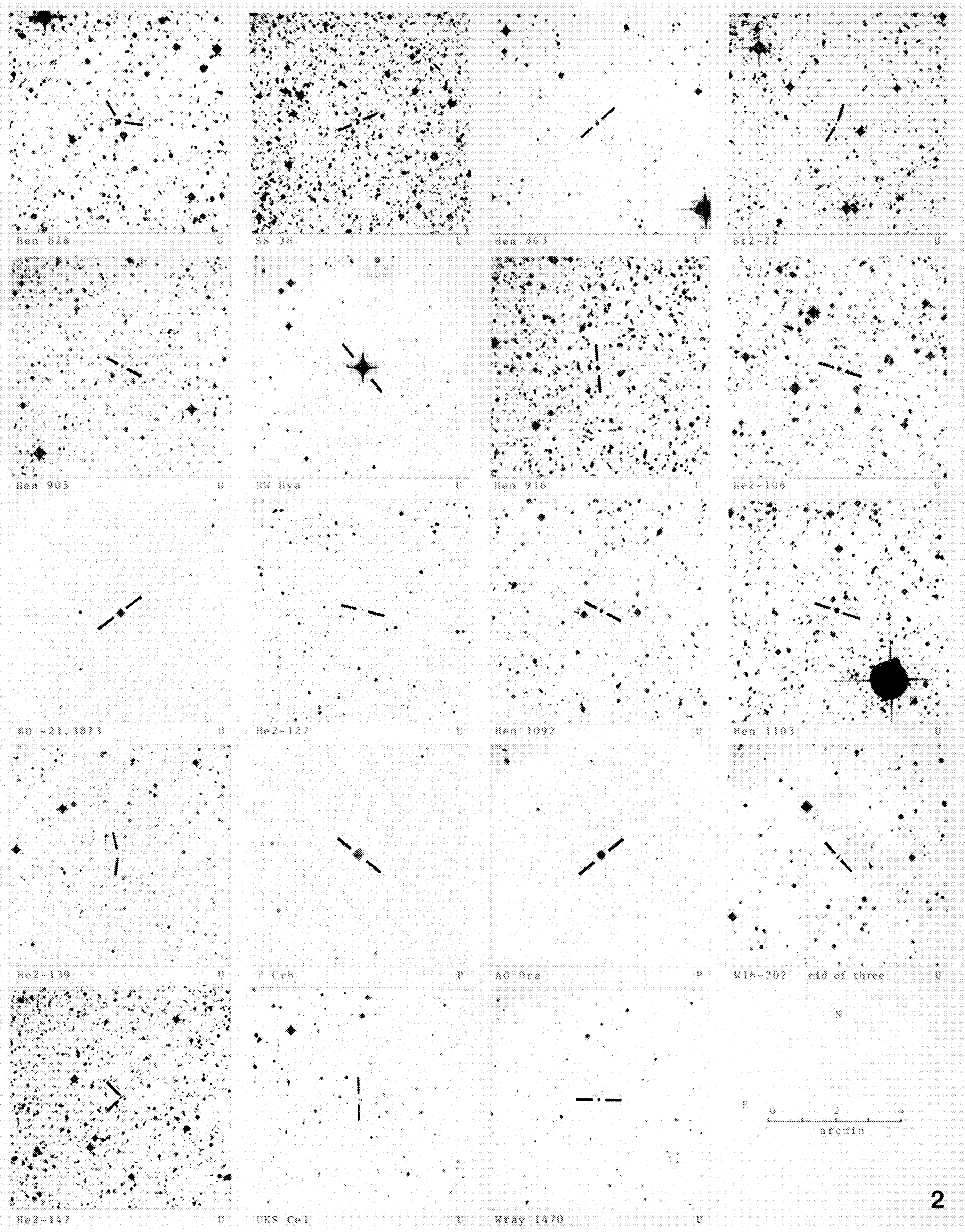
EG And P
SMC N60 U
SMC Ln 358 U
SMC N73 U
AX Per P
V741 Per P
UV Aur P
Sanduleak's star E
LMC S63 U
BX Mon U
Wray 157 U
RX Pup U
Hen 160 U
AS 201 U
He2-38 U
SS 29 U
SY Mus U
BI Cru U
He2-87 W of two U
N
E
0 2 4
arcmin

1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SS 38 U
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He2-127 U
Hen 1092 U
Hen 1103 U
He2-139 U
T CrB P
AG Dra P
W16-202 mid of three U
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Wray 1470 U
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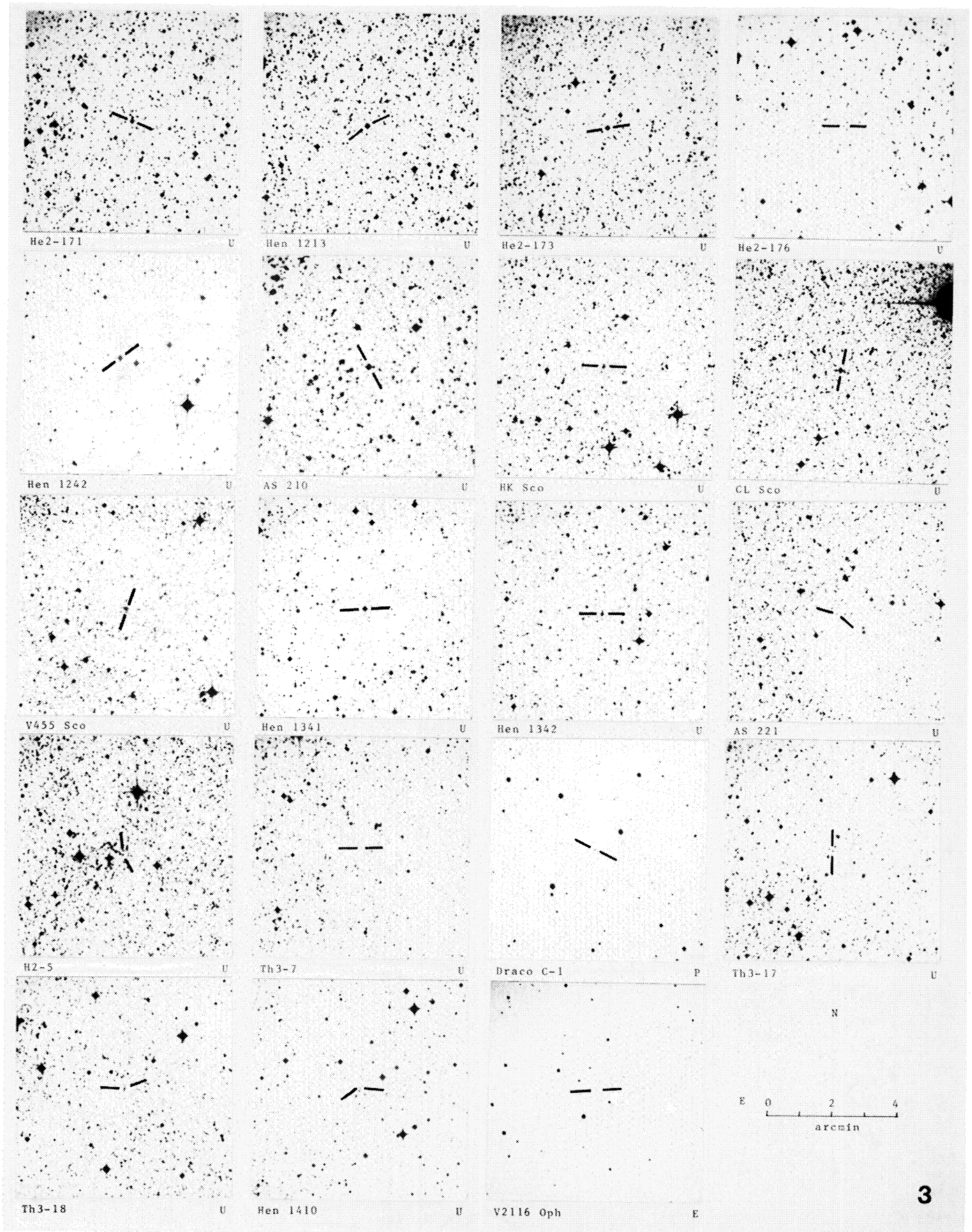
arcmin

2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CL Sco U
V455 Sco U
Hen 1341 U
Hen 1342 U
AS 221 U
H2-5 U
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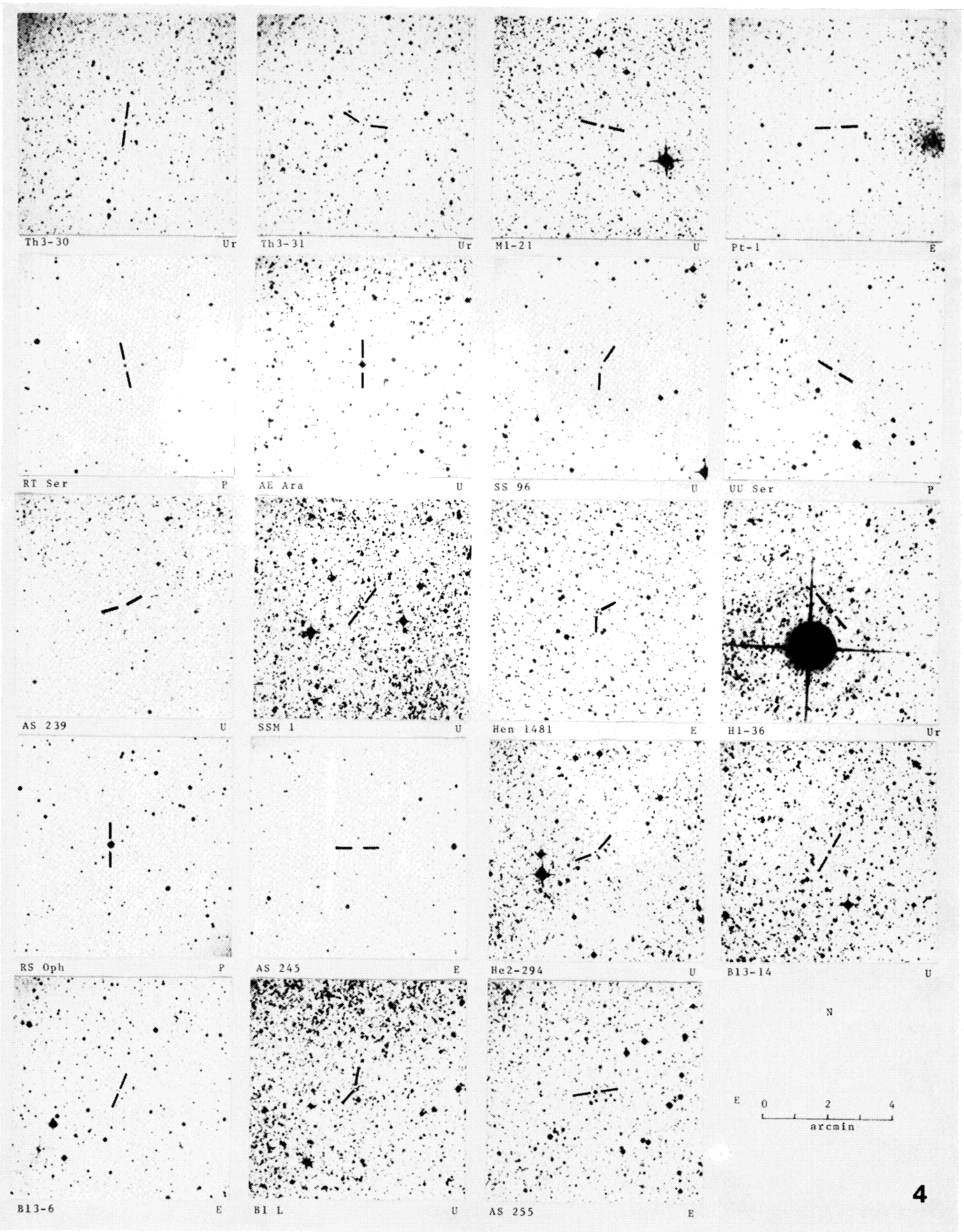
arcmin

3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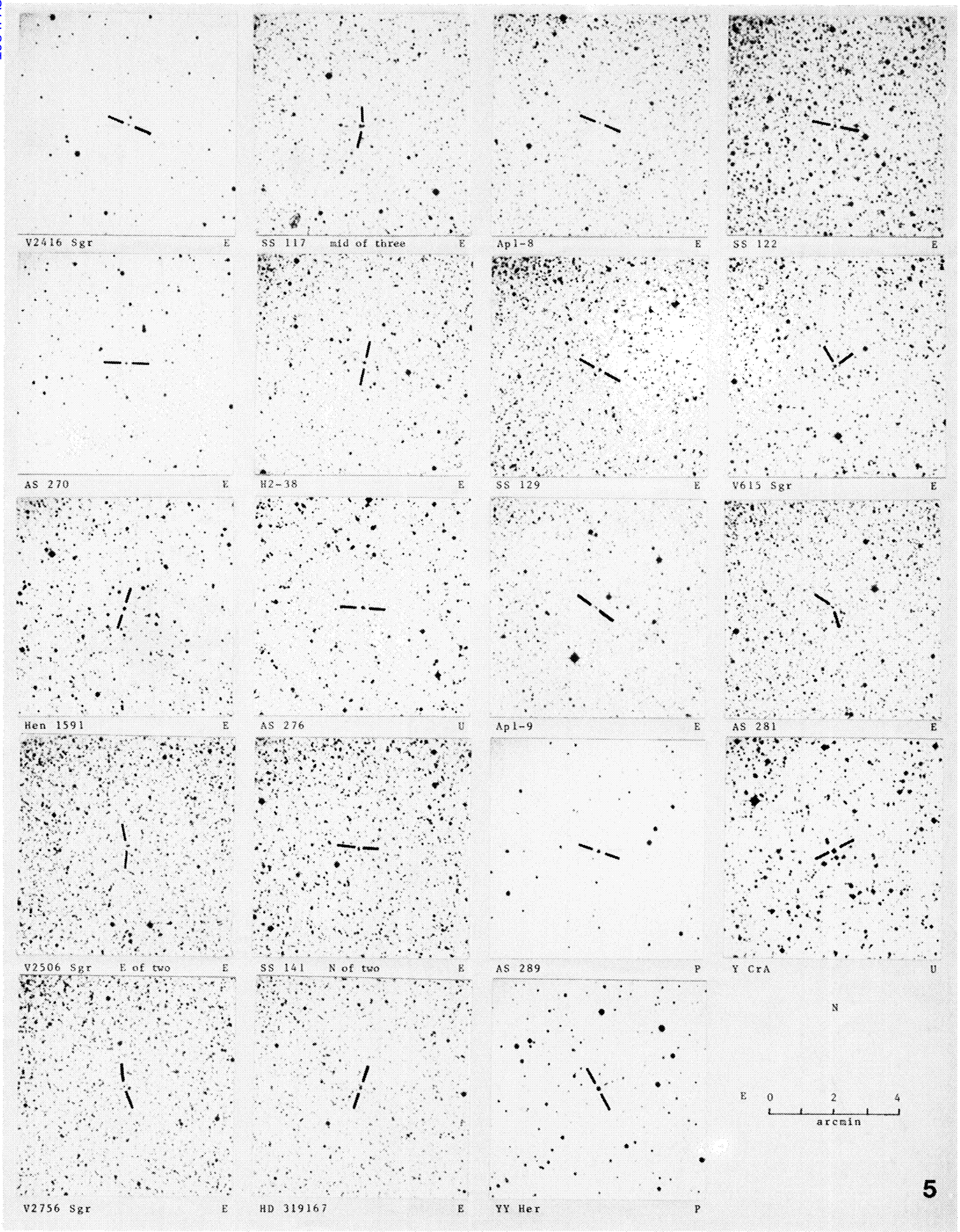
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Ap1-9 E
AS 281 E
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arcmin
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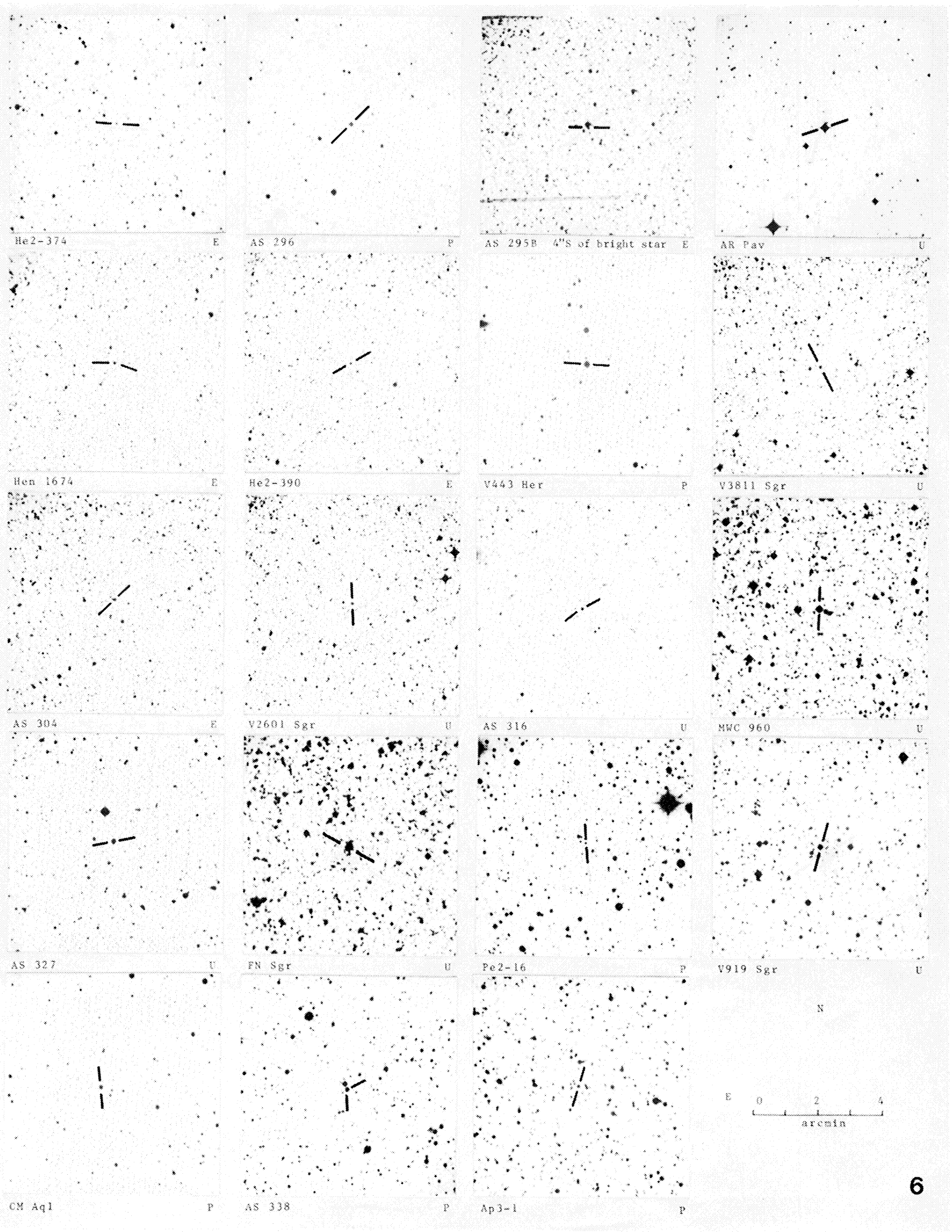
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AS 295B 4"S of bright star E
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AS 316 U
MWC 960 U
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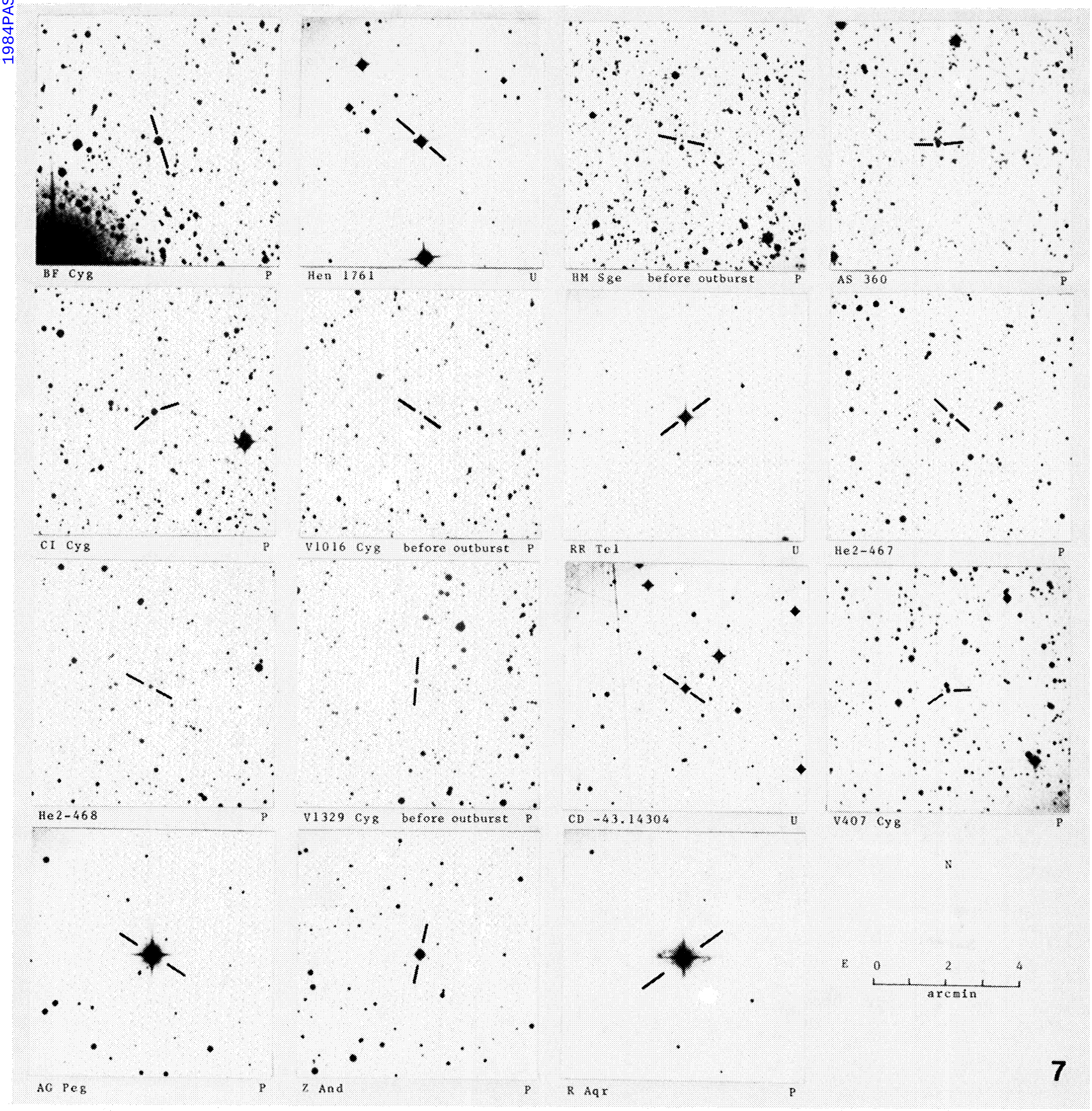
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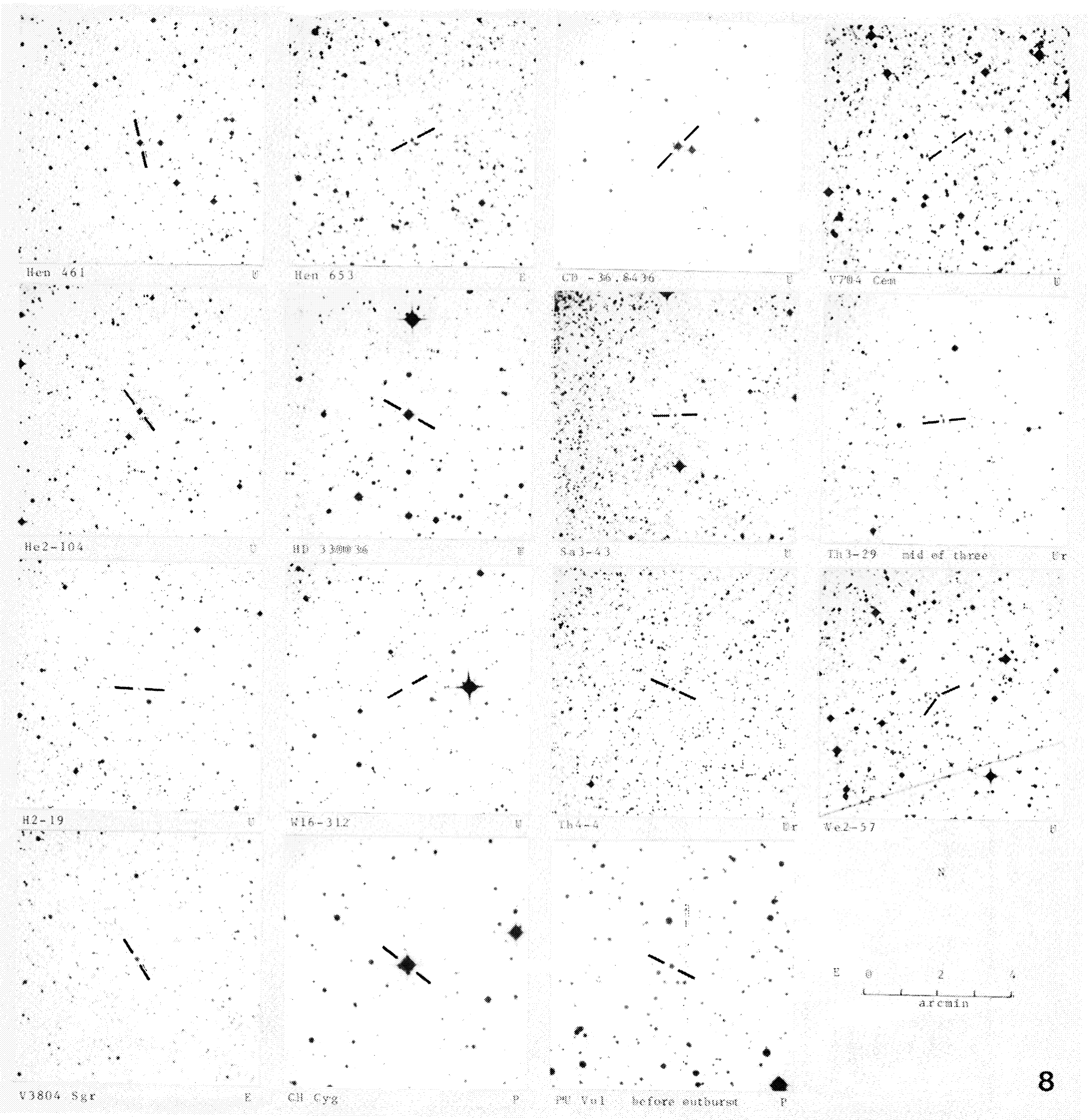
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E
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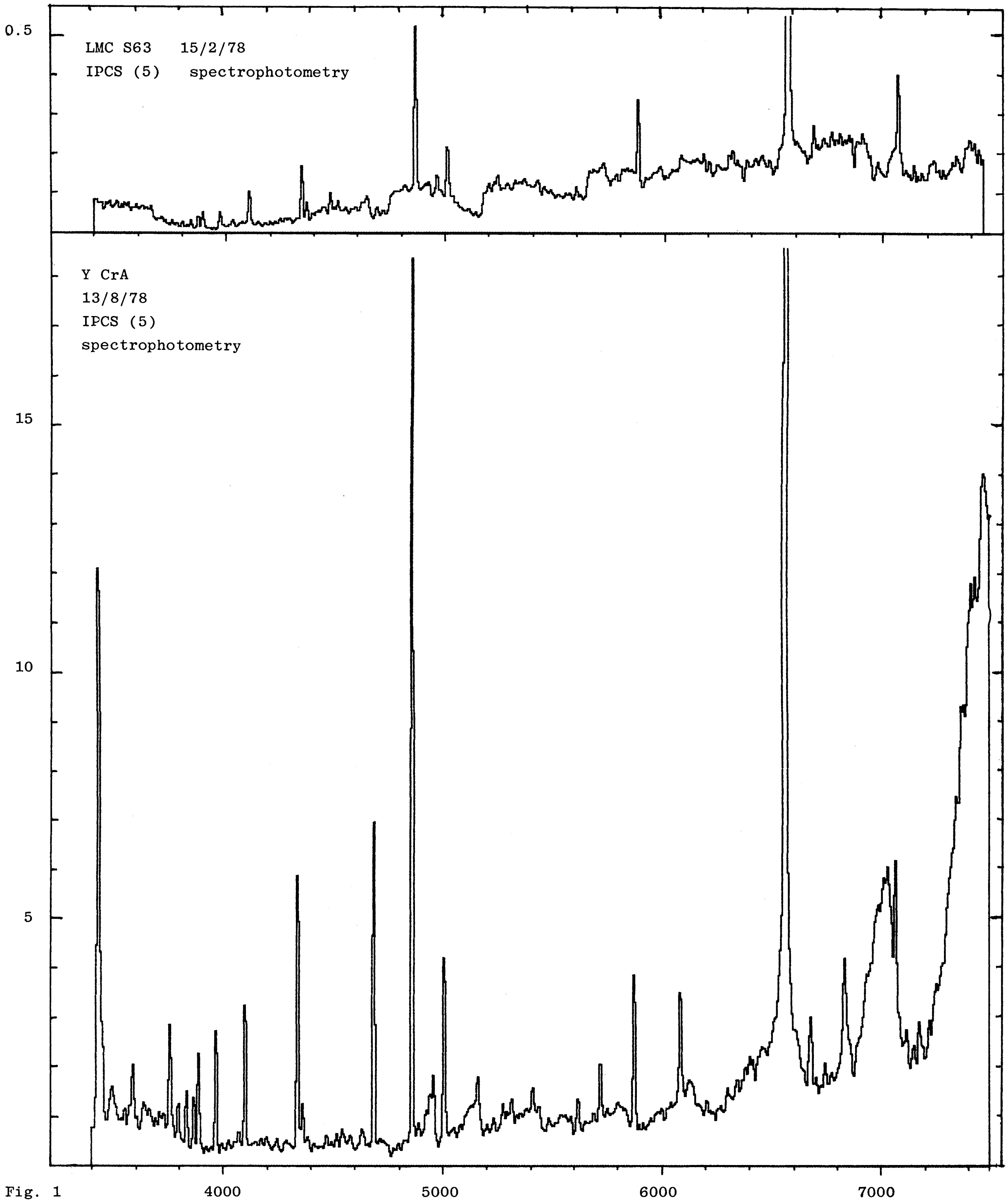
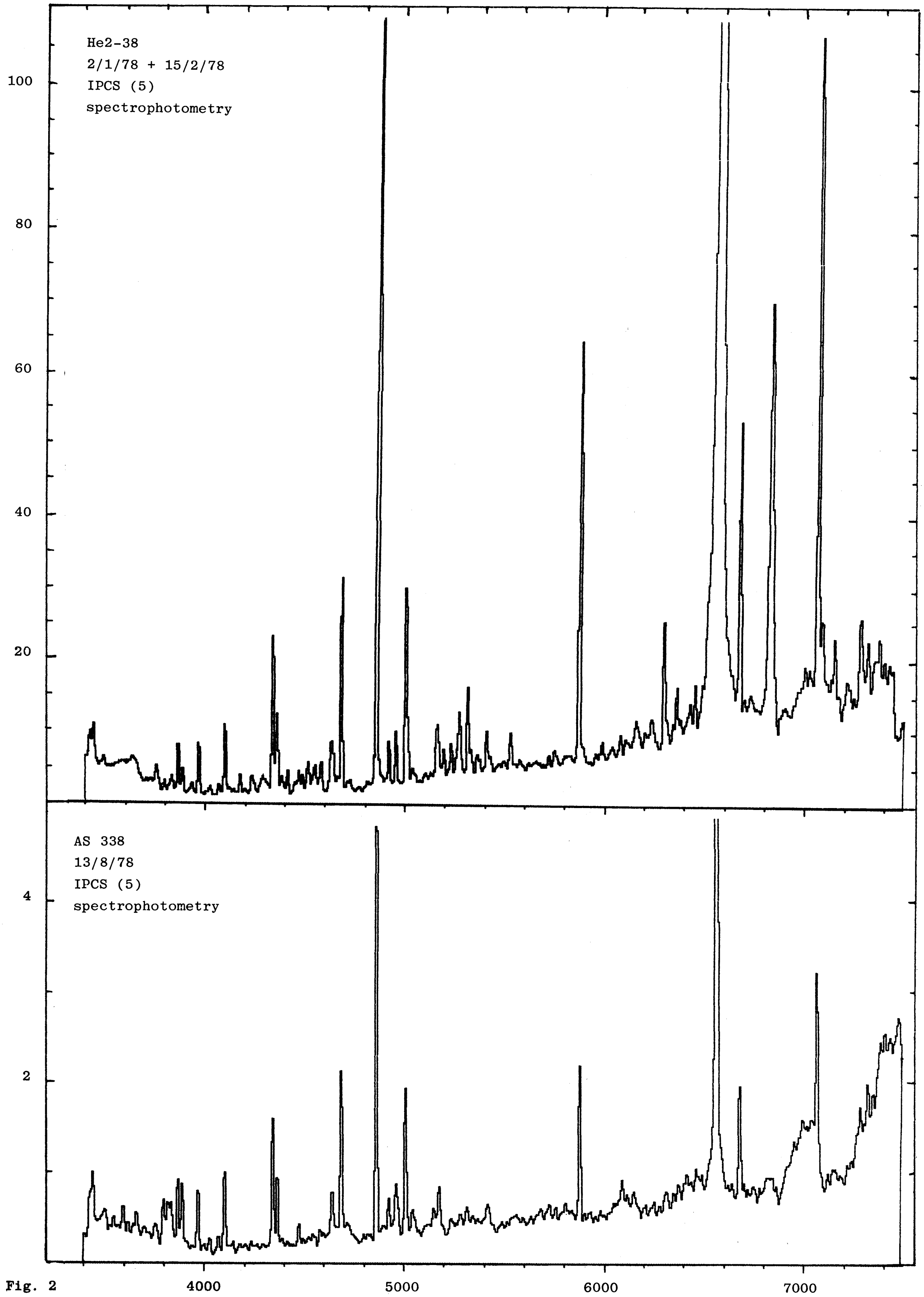


Fig. 1

Figures 1-36. Spectra of the symbiotic stars. In all cases the abscissa is wavelength in Angstroms. An ordinate axis is provided only for Figures 1-7, the spectrophotometry. The units here are 10^{-14} ergs s^{-1} cm^{-2} $Å^{-1}$. See text, section 6, for further details.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IPCS (5)
spectrophotometry
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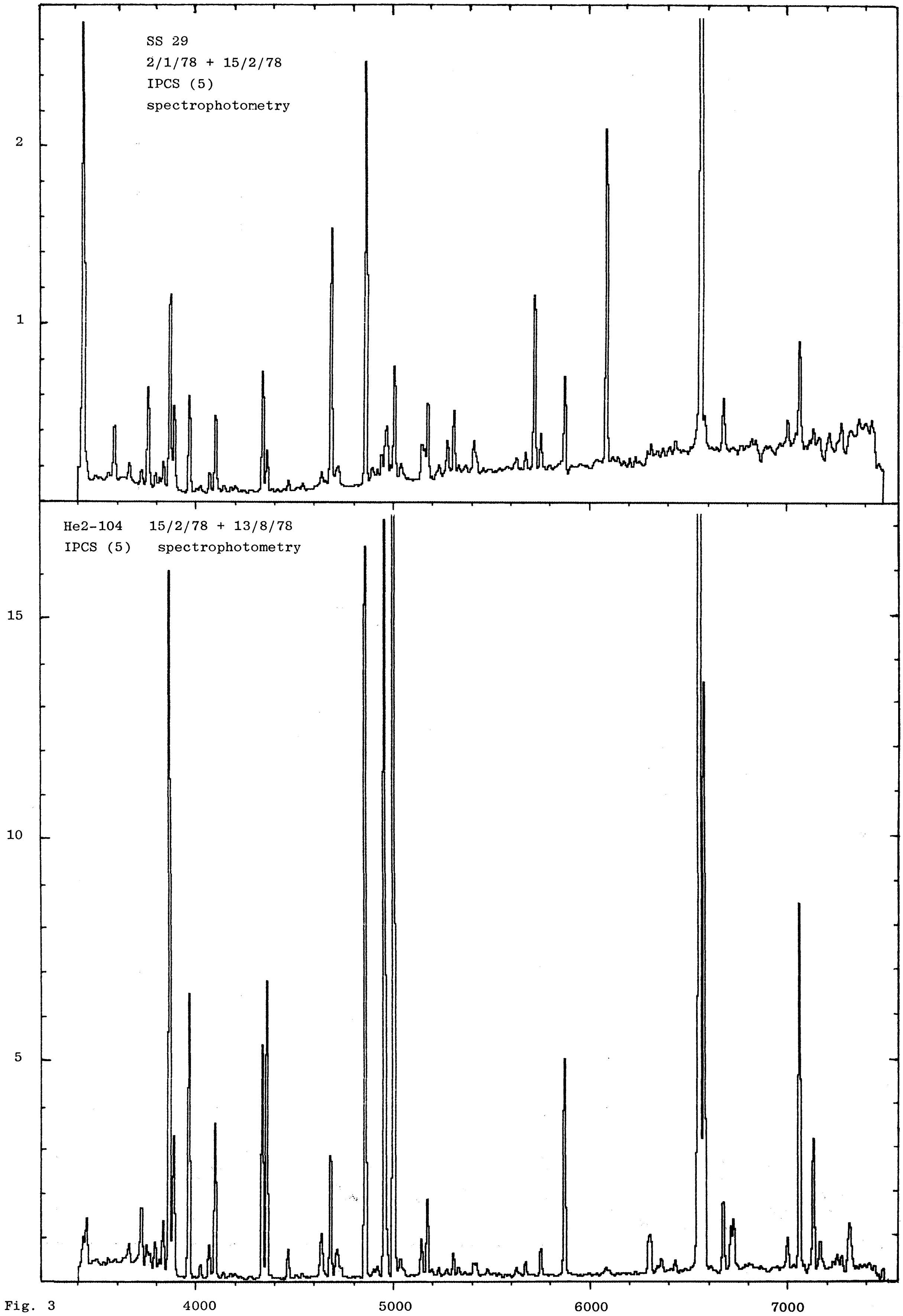
80
60
40
20
AS 338
13/8/78
IPCS (5)
spectrophotometry
4
2
4000
5000
6000
7000

Fig. 2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IPCS (5)
spectrophotometry
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He2-104 15/2/78 + 13/8/78
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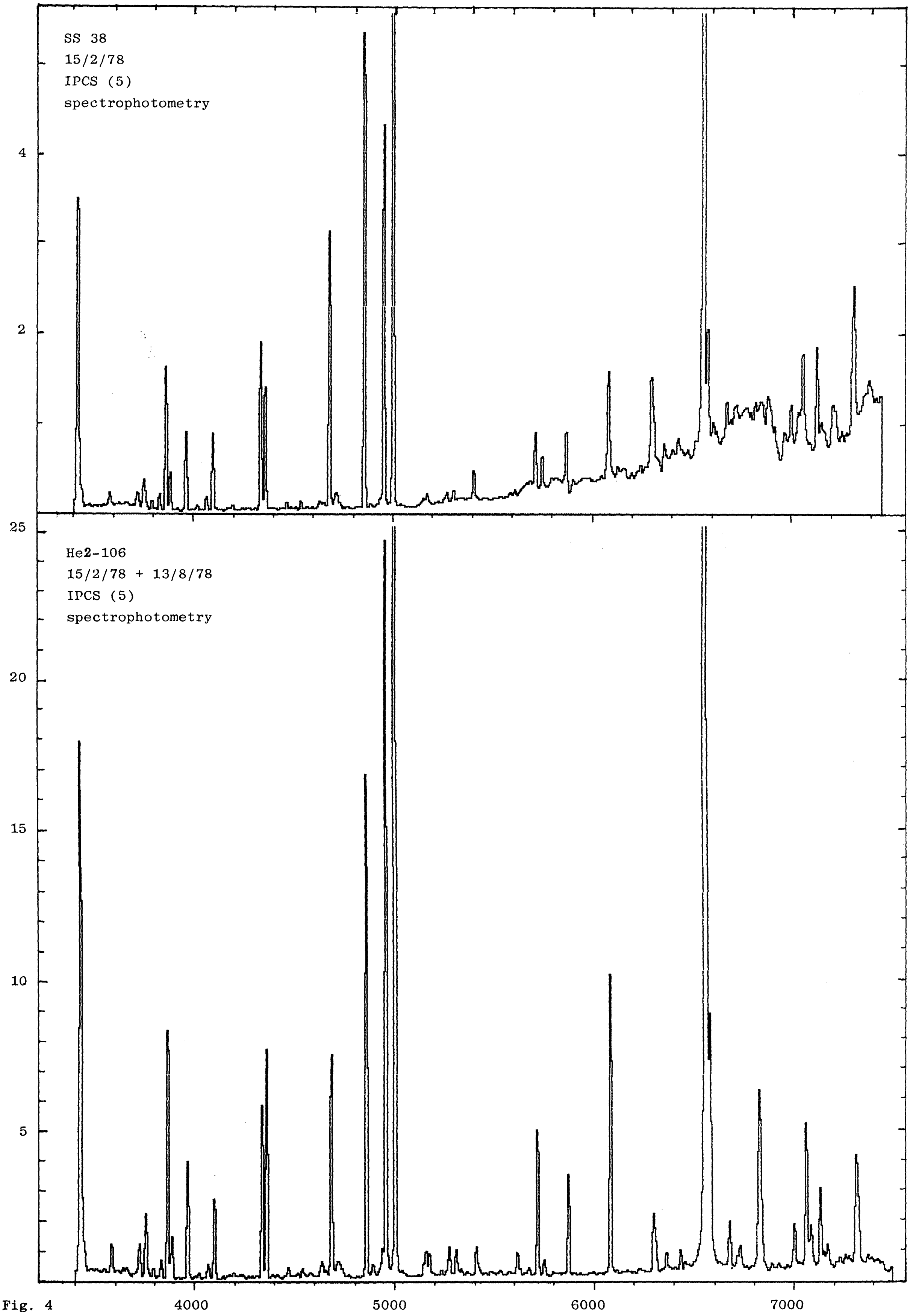
4000
5000
6000
7000

Fig. 3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15/2/78
IPCS (5)
spectrophotometry
He2-106
15/2/78 + 13/8/78
IPCS (5)
spectrophotometry
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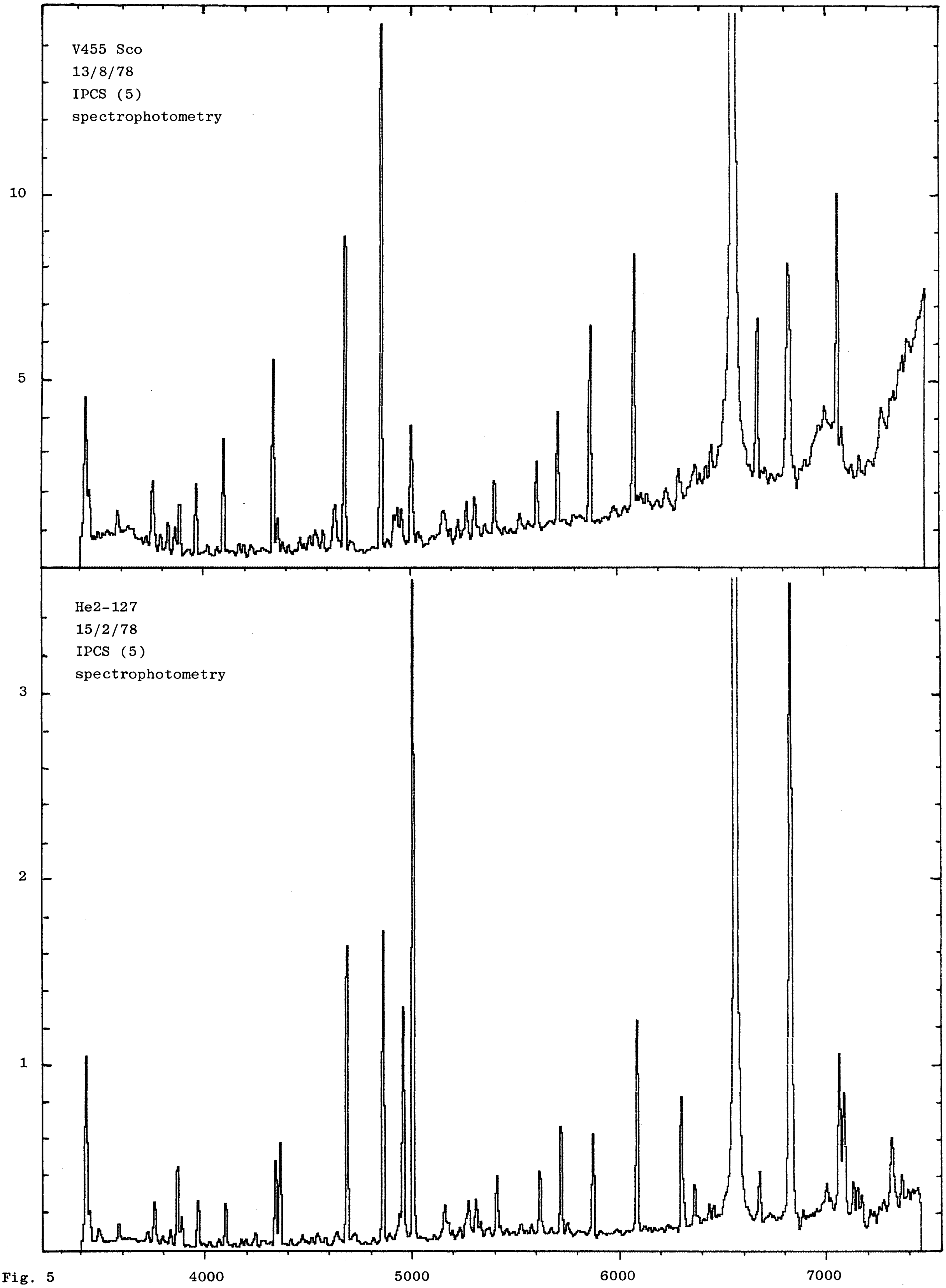
25
20
15
10
5
4000
5000
6000
7000

Fig. 4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13/8/78
IPCS (5)
spectrophotometry
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He2-127
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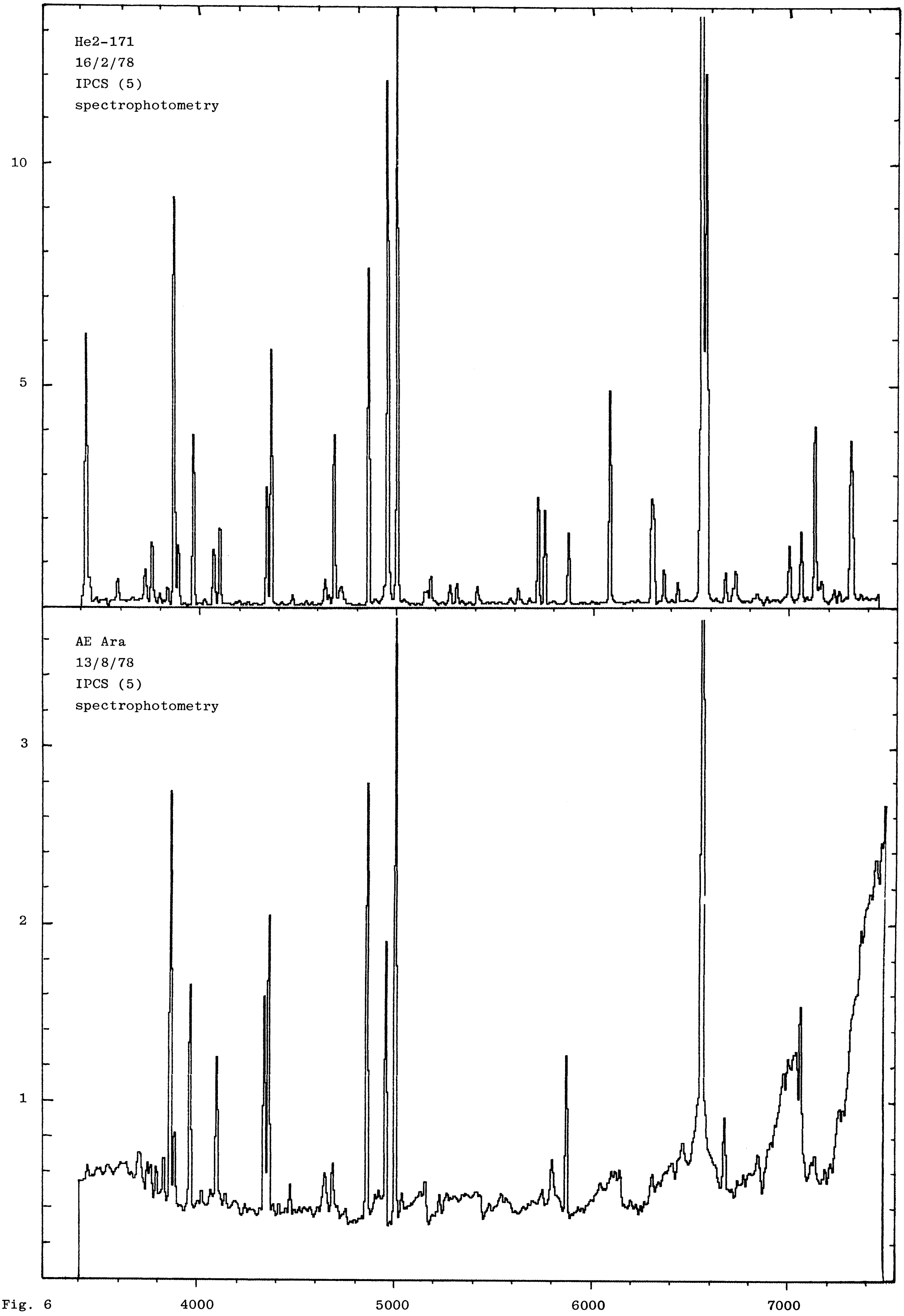
1
4000
5000
6000
7000

Fig. 5


He2-171
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AE Ara
13/8/78
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spectrophotometry
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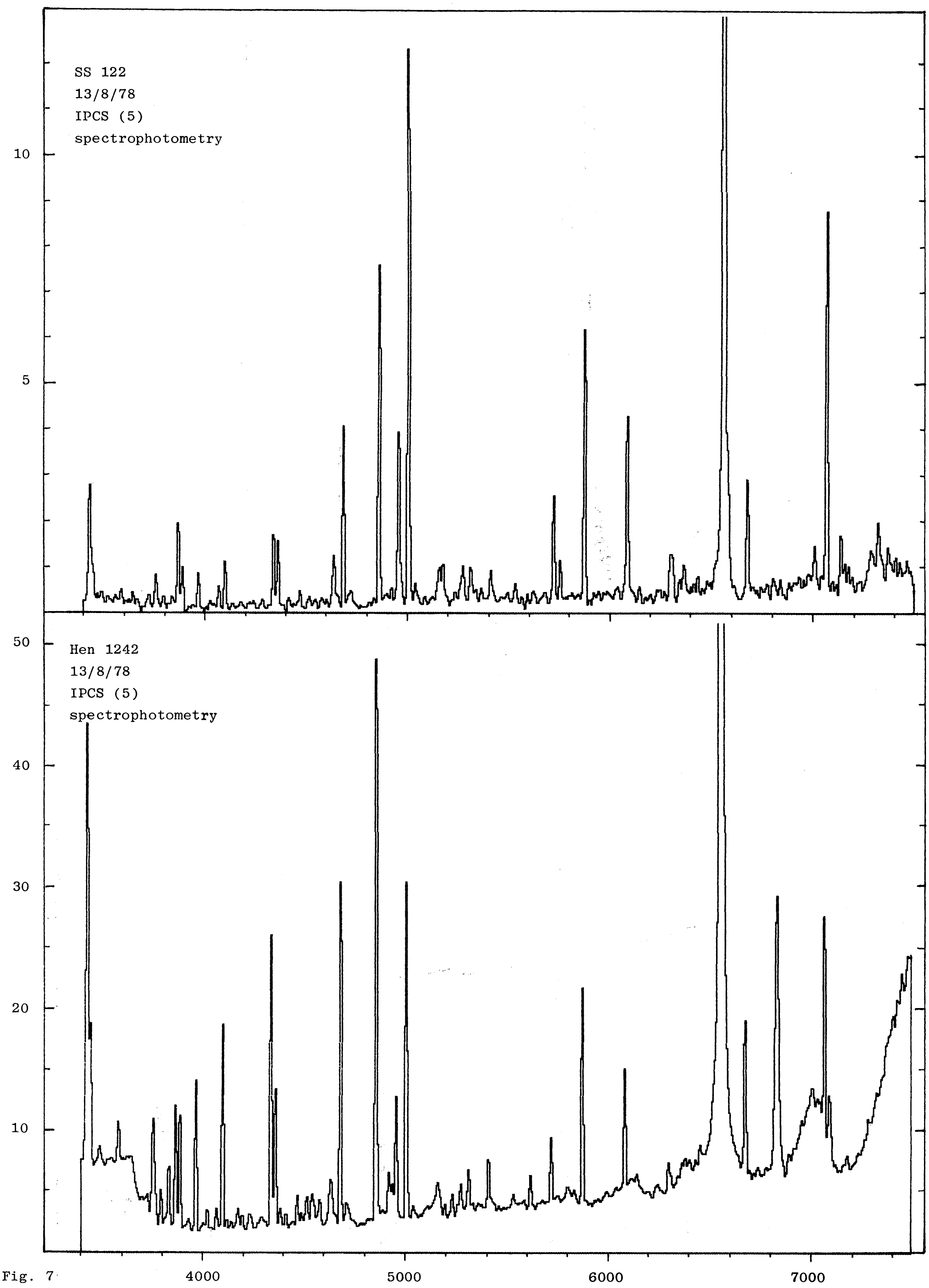
6000
7000

Fig. 6


SS 122
13/8/78
IPCS (5)
spectrophotometry
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Hen 1242
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IPCS (5)
spectrophotometry
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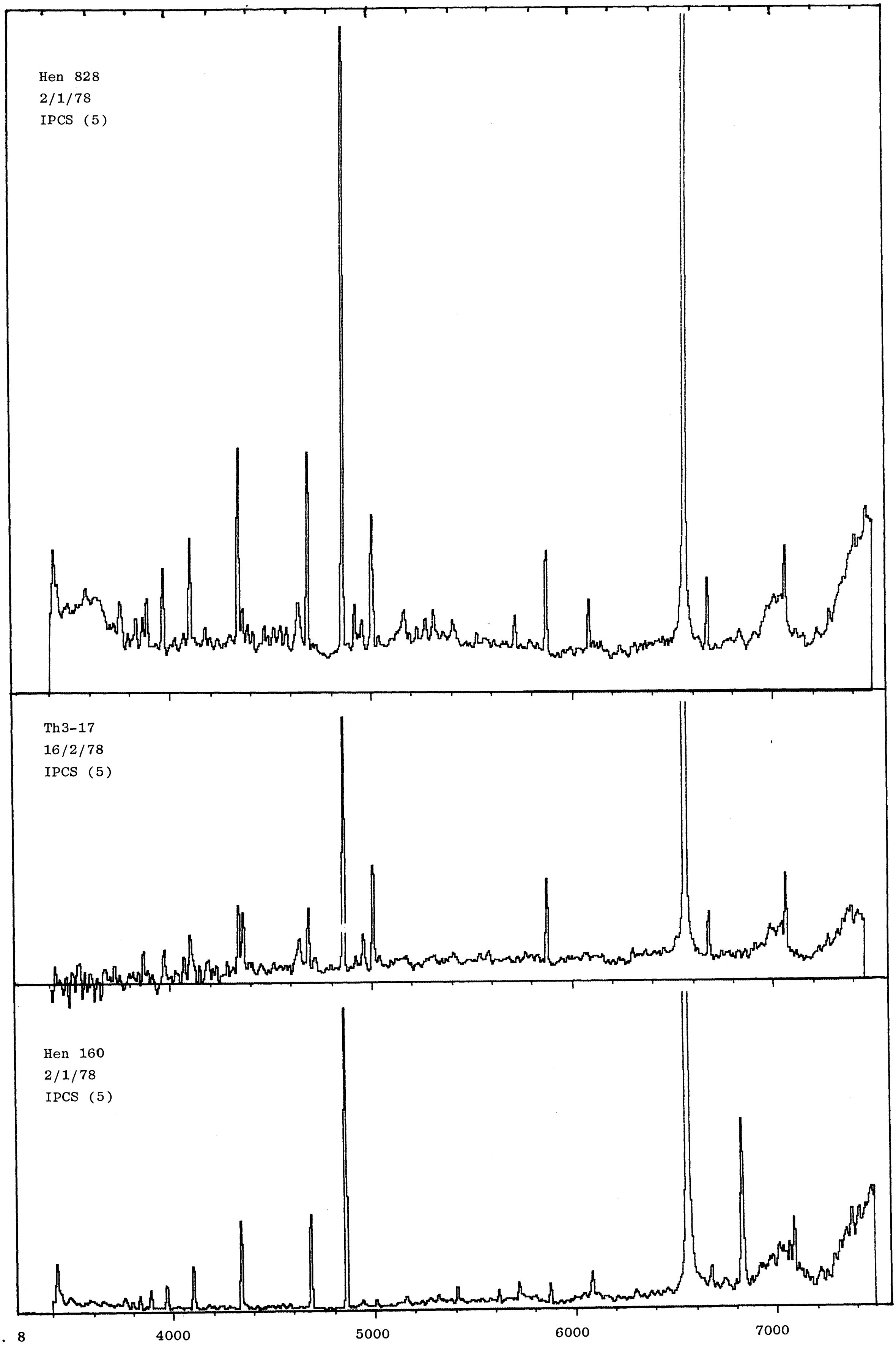
10
4000
5000
6000
7000

Fig. 7


Hen 828
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IPCS (5)
Th3-17
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IPCS (5)
Hen 160
2/1/78
IPCS (5)
4000
5000
6000
7000

Fig. 8

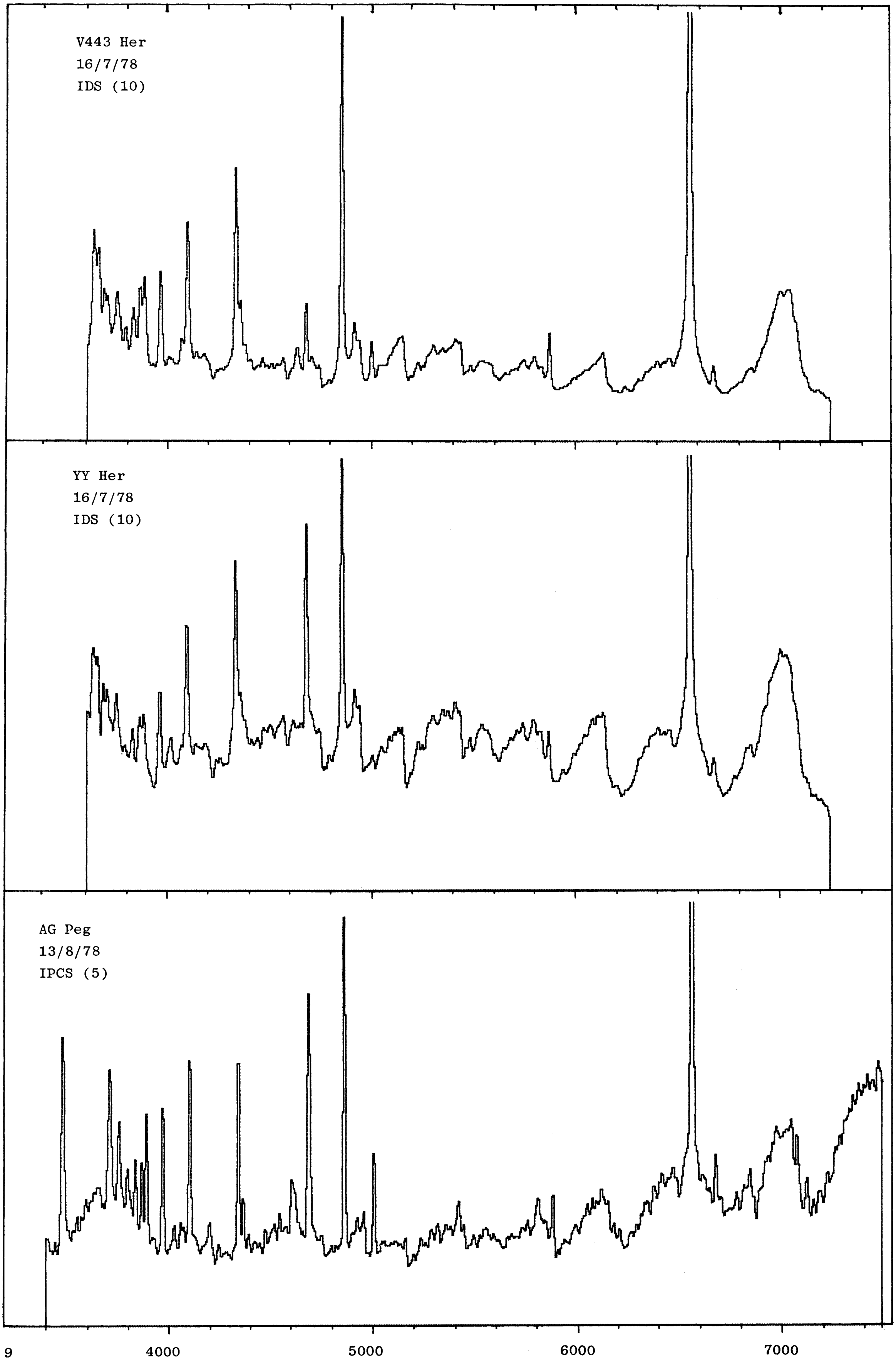

V443 Her
16/7/78
IDS (10)
YY Her
16/7/78
IDS (10)
AG Peg
13/8/78
IPCS (5)
4000
5000
6000
7000

Fig. 9

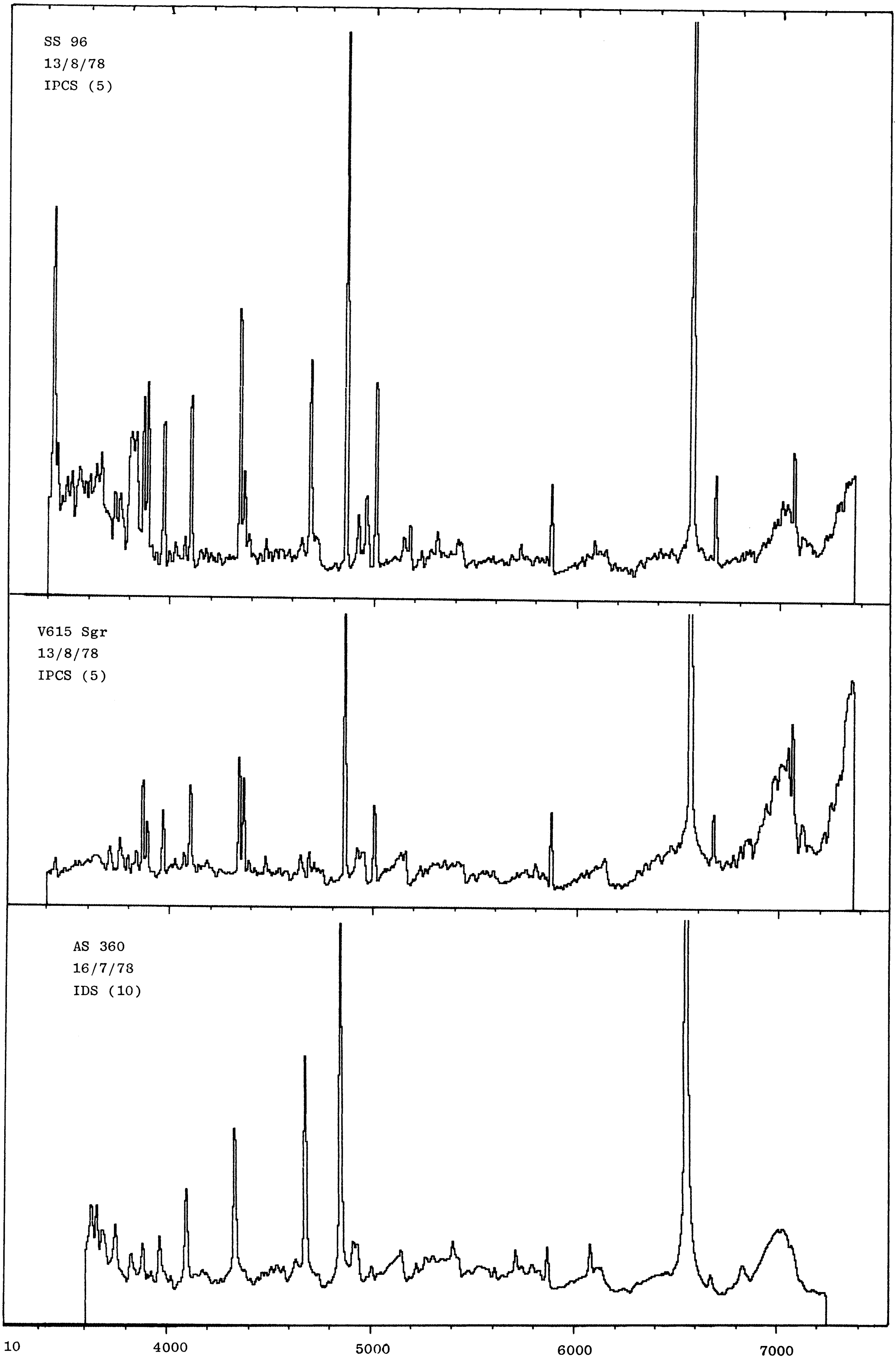

SS 96
13/8/78
IPCS (5)
V615 Sgr
13/8/78
IPCS (5)
AS 360
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 10

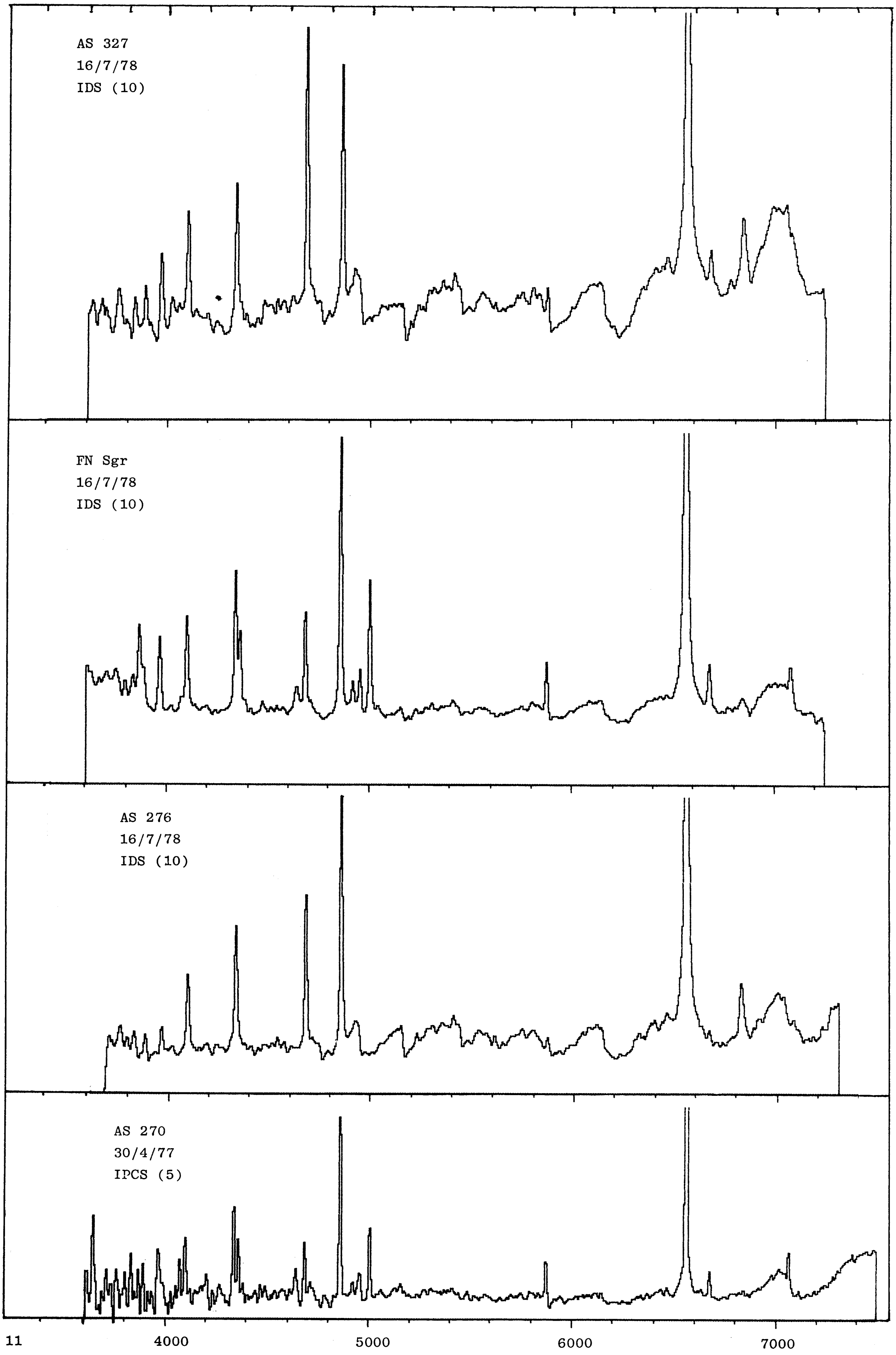
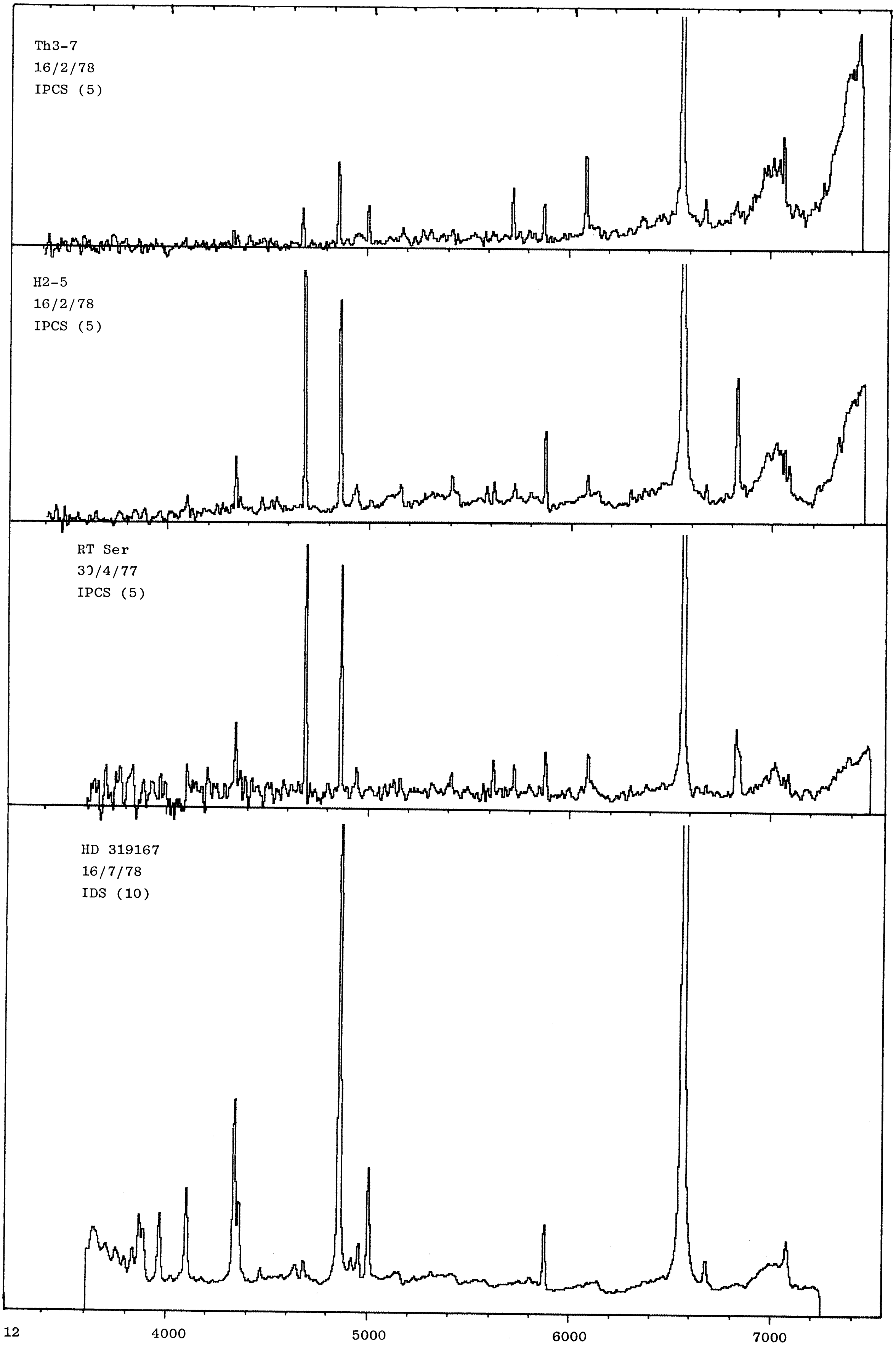

AS 327
16/7/78
IDS (10)
FN Sgr
16/7/78
IDS (10)
AS 276
16/7/78
IDS (10)
AS 270
30/4/77
IPCS (5)
4000
5000
6000
7000

Fig. 11



Th3-7
16/2/78
IPCS (5)
H2-5
16/2/78
IPCS (5)
RT Ser
30/4/77
IPCS (5)
HD 319167
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 12

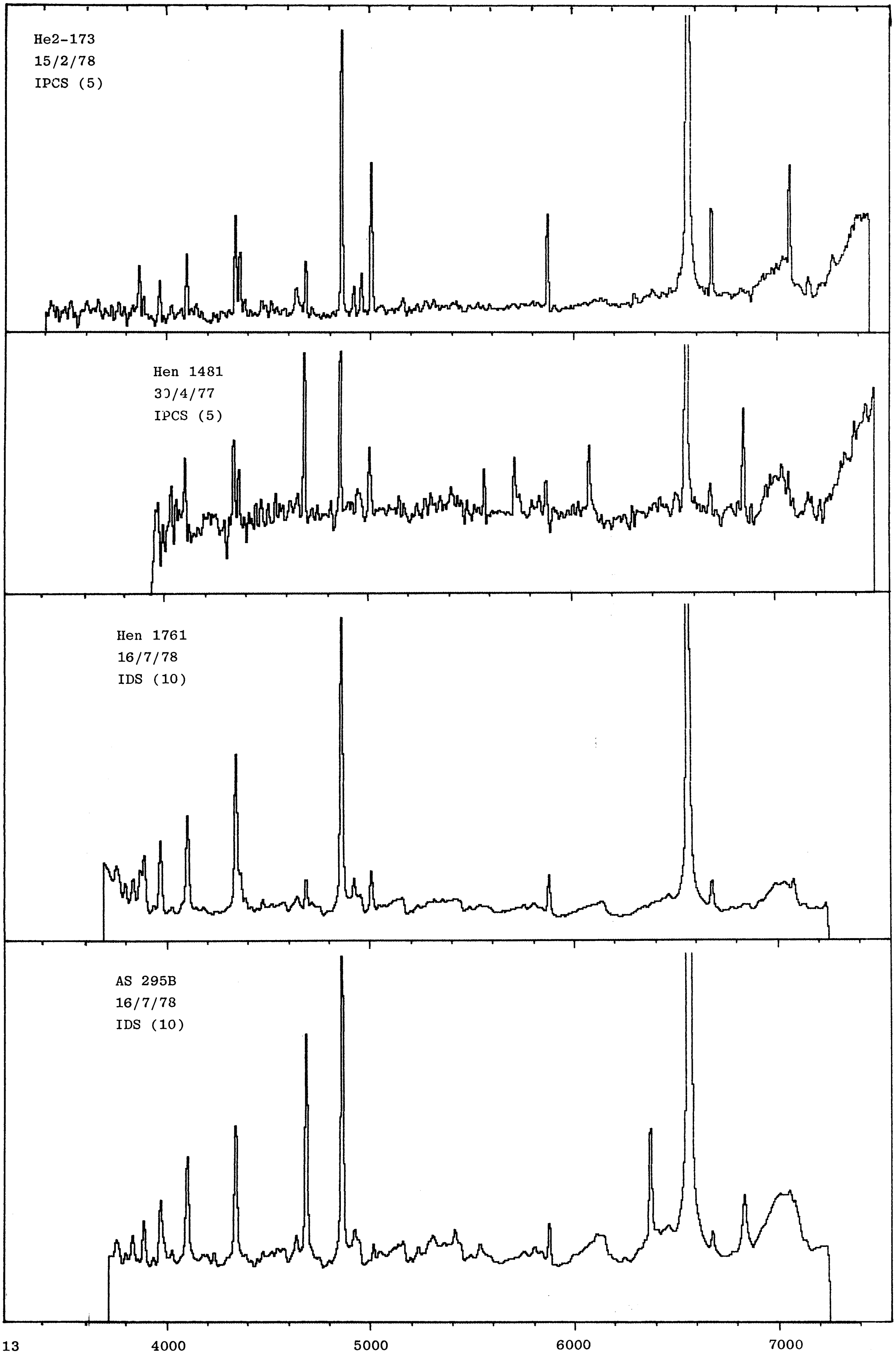
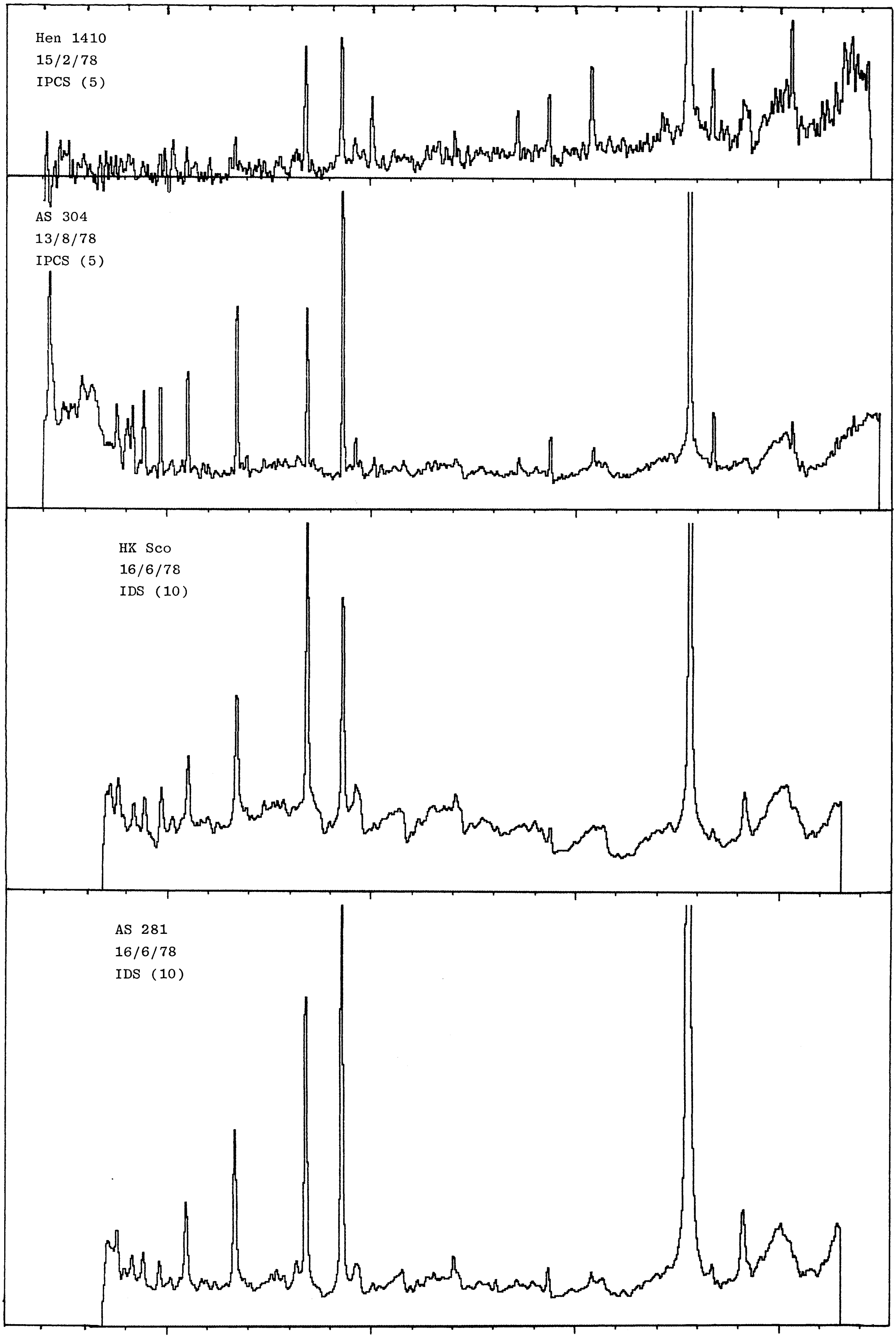

He2-173
15/2/78
IPCS (5)
Hen 1481
30/4/77
IPCS (5)
Hen 1761
16/7/78
IDS (10)
AS 295B
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 13



Hen 1410
15/2/78
IPCS (5)
AS 304
13/8/78
IPCS (5)
HK Sco
16/6/78
IDS (10)
AS 281
16/6/78
IDS (10)
4000
5000
6000
7000

Fig. 14

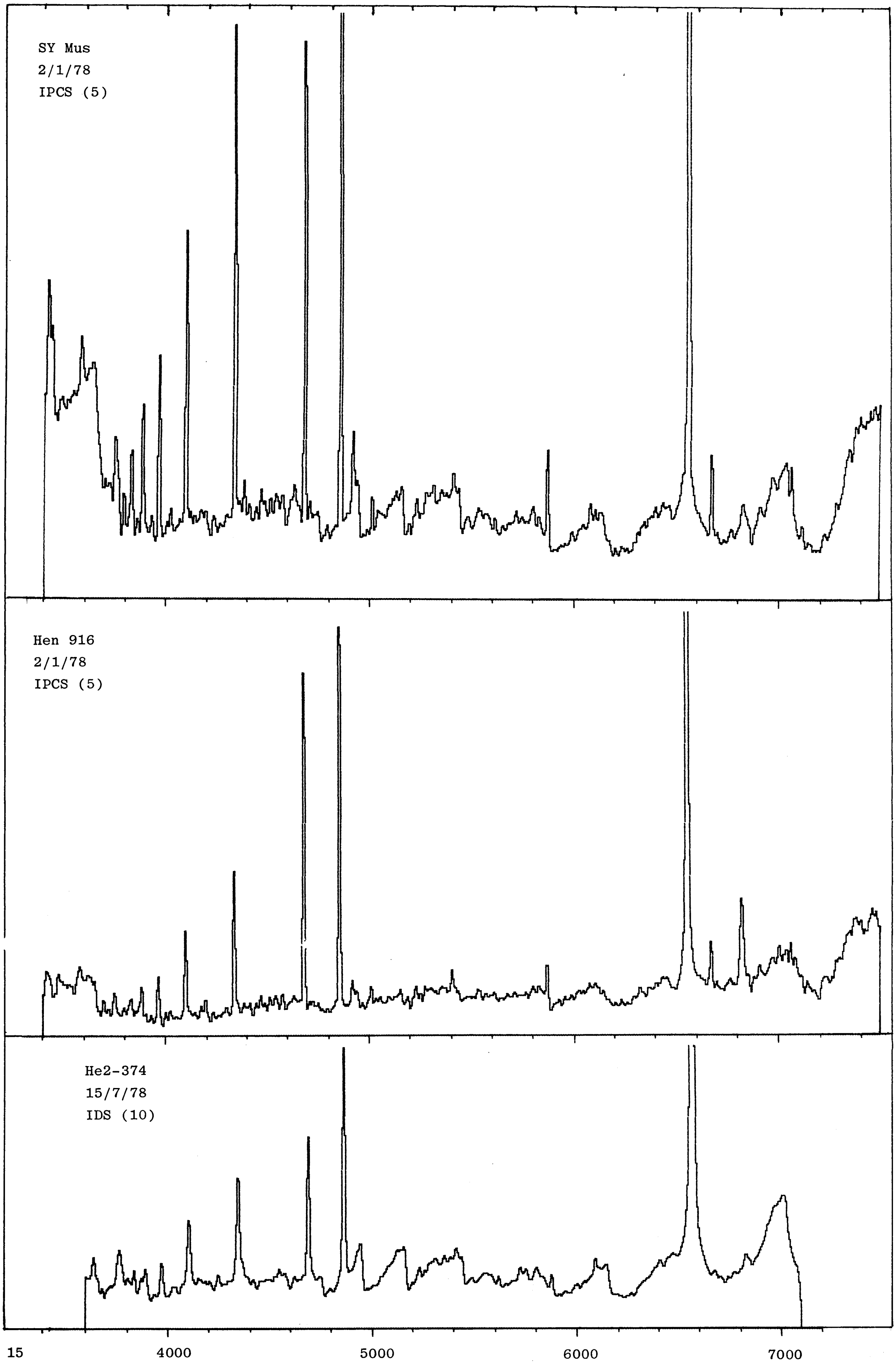

SY Mus
2/1/78
IPCS (5)
Hen 916
2/1/78
IPCS (5)
He2-374
15/7/78
IDS (10)
4000
5000
6000
7000

Fig. 15

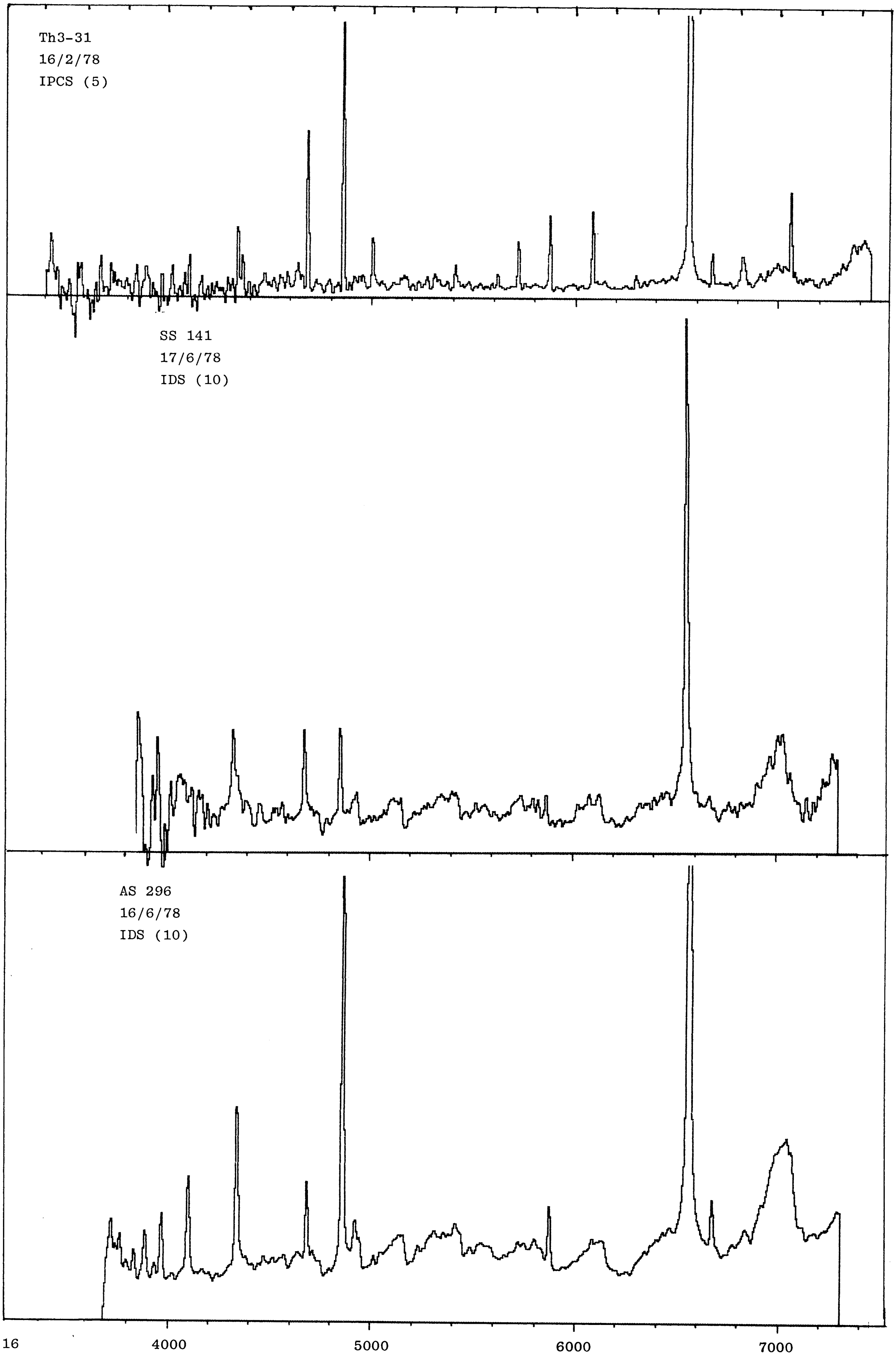

Th3-31
16/2/78
IPCS (5)
SS 141
17/6/78
IDS (10)
AS 296
16/6/78
IDS (10)
4000
5000
6000
7000

Fig. 16

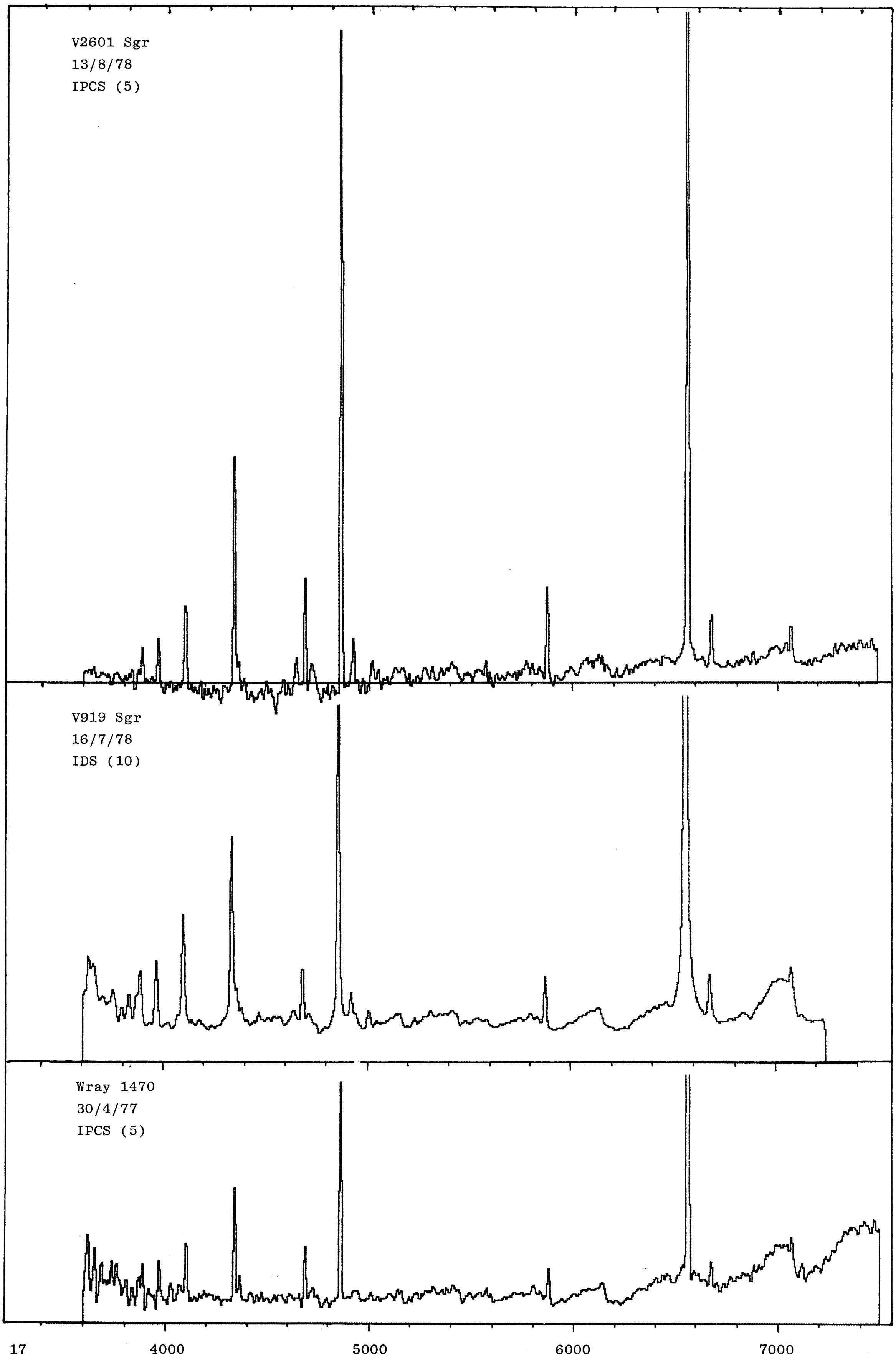

V2601 Sgr
13/8/78
IPCS (5)
V919 Sgr
16/7/78
IDS (10)
Wray 1470
30/4/77
IPCS (5)
4000
5000
6000
7000

Fig. 17

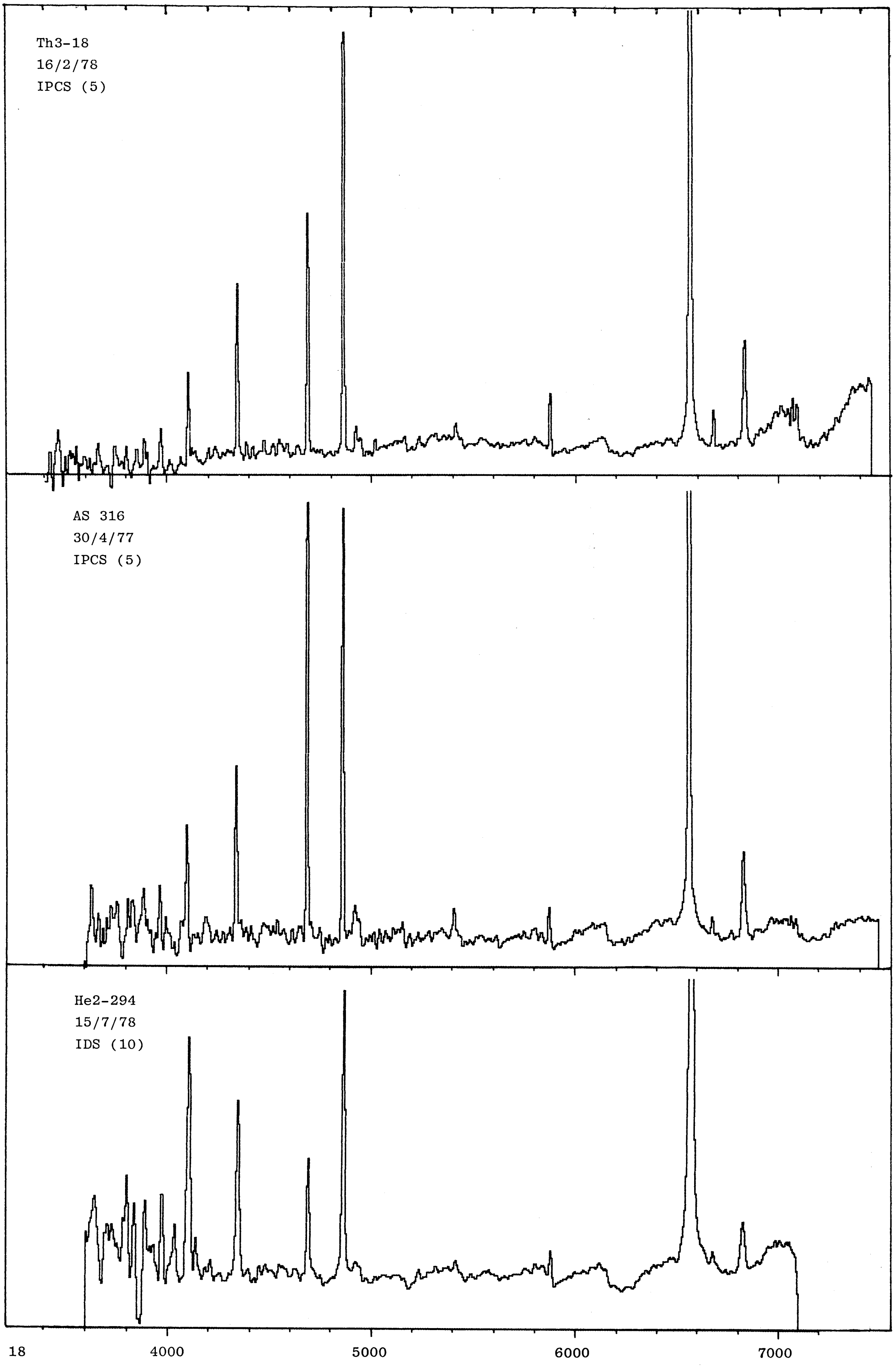
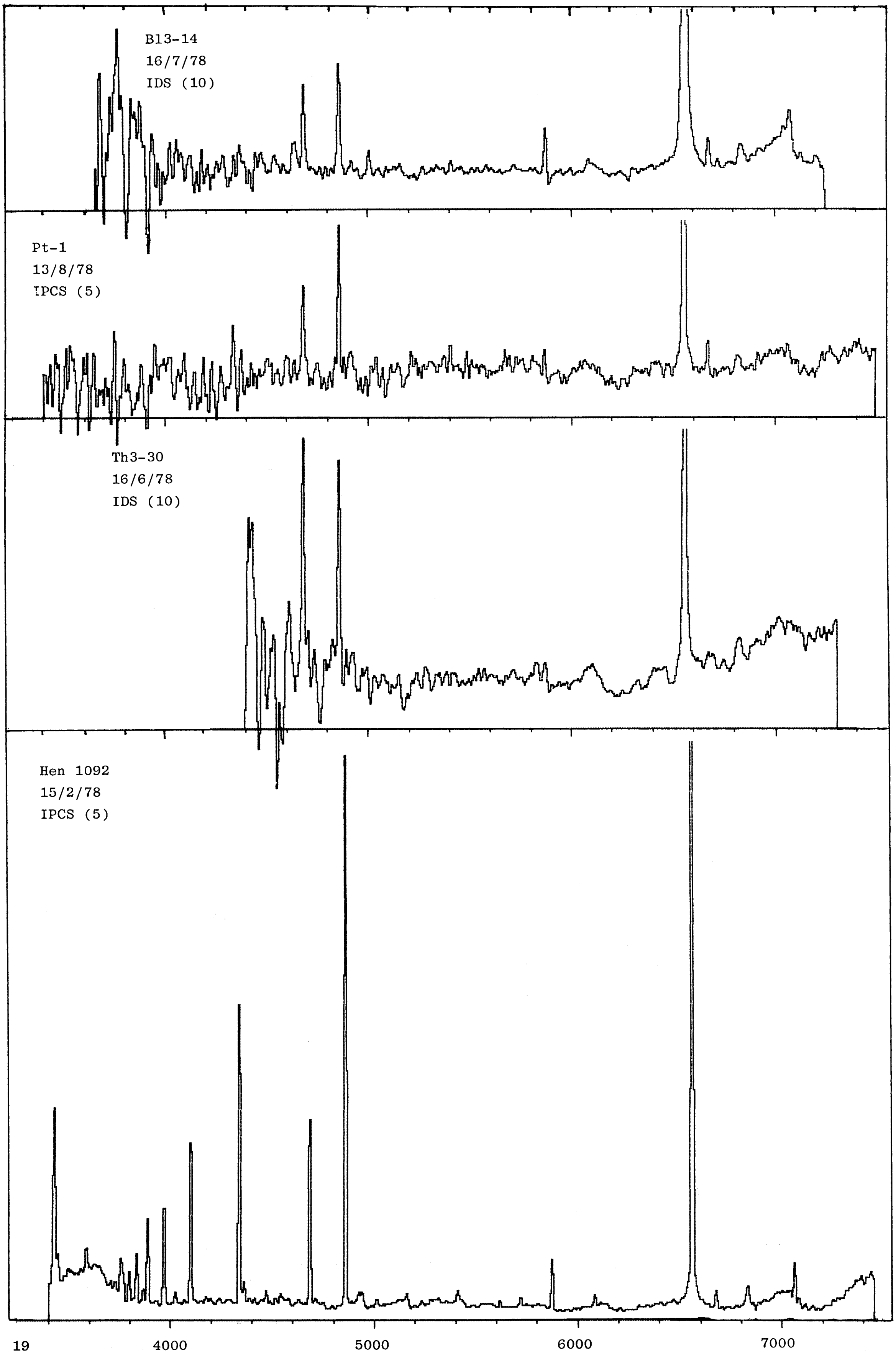

Th3-18
16/2/78
IPCS (5)
AS 316
30/4/77
IPCS (5)
He2-294
15/7/78
IDS (10)
4000
5000
6000
7000

Fig. 18



B13-14
16/7/78
IDS (10)
Pt-1
13/8/78
IPCS (5)
Th3-30
16/6/78
IDS (10)
Hen 1092
15/2/78
IPCS (5)
4000
5000
6000
7000

Fig. 19

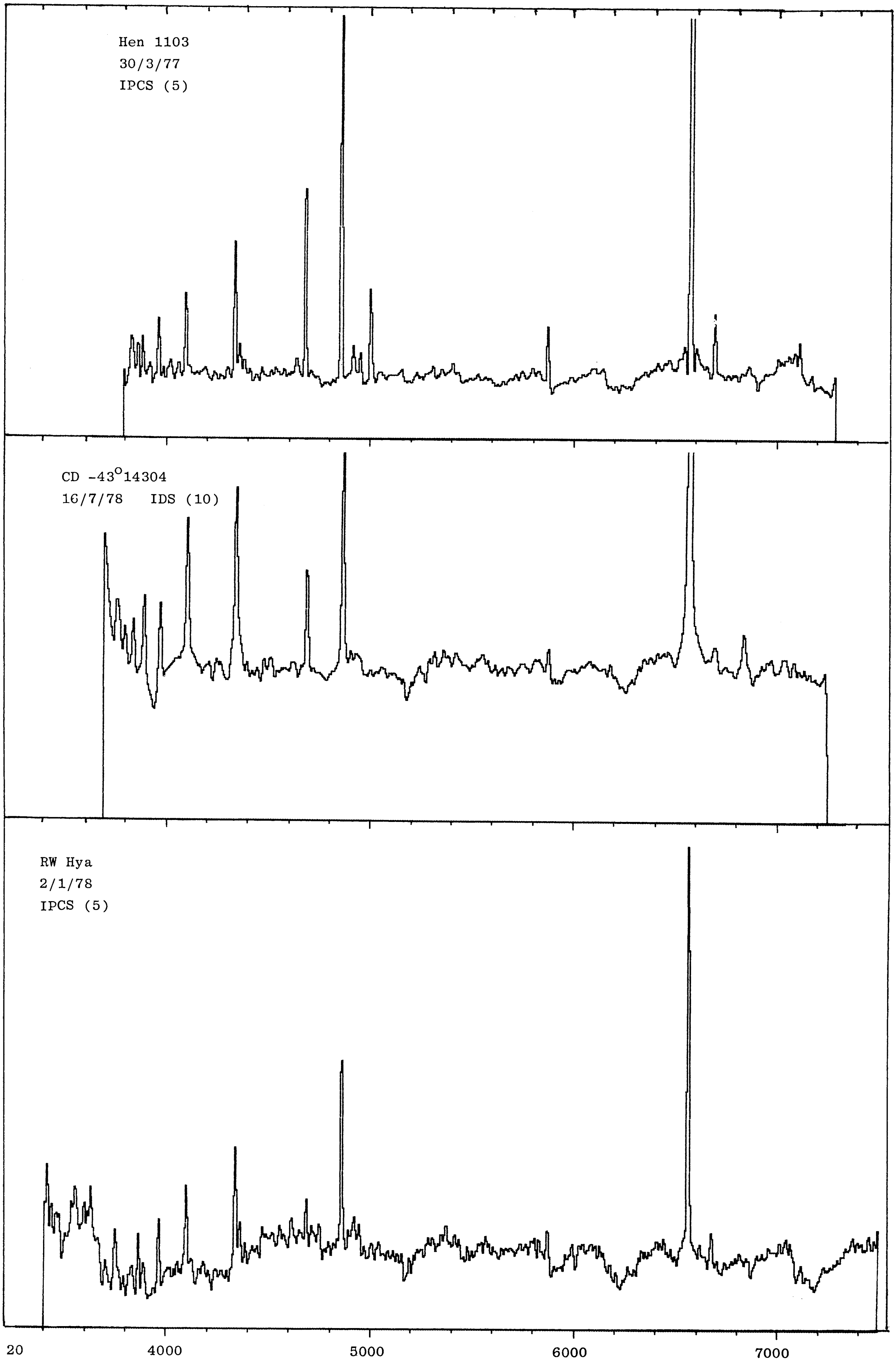

Hen 1103
30/3/77
IPCS (5)
CD -43°14304
16/7/78 IDS (10)
RW Hya
2/1/78
IPCS (5)
4000
5000
6000
7000

Fig. 20

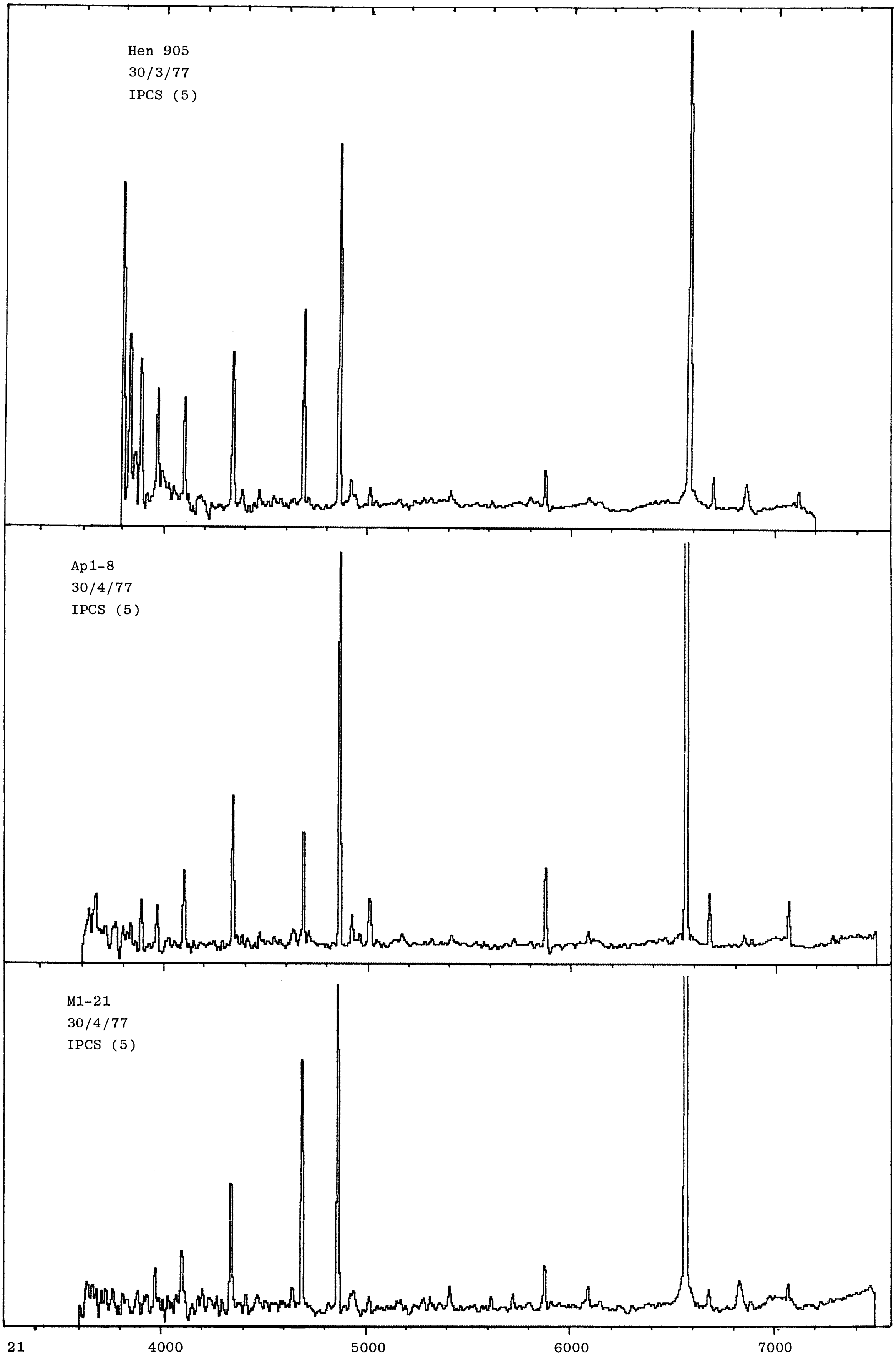

Hen 905
30/3/77
IPCS (5)
Ap1-8
30/4/77
IPCS (5)
M1-21
30/4/77
IPCS (5)
4000
5000
6000
7000

Fig. 21

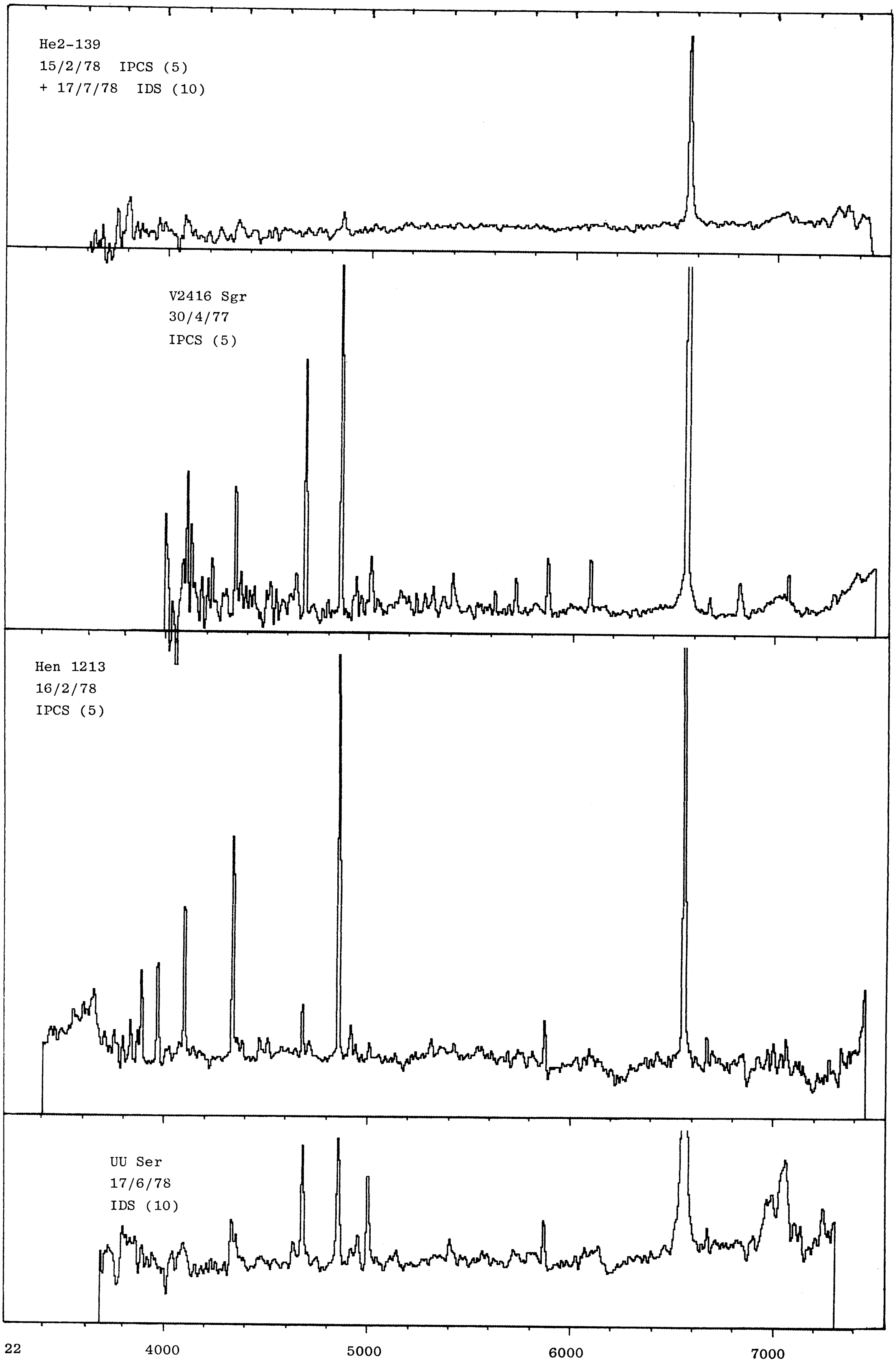

He2-139
15/2/78 IPCS (5)
+ 17/7/78 IDS (10)
V2416 Sgr
30/4/77
IPCS (5)
Hen 1213
16/2/78
IPCS (5)
UU Ser
17/6/78
IDS (10)
4000
5000
6000
7000

Fig. 22

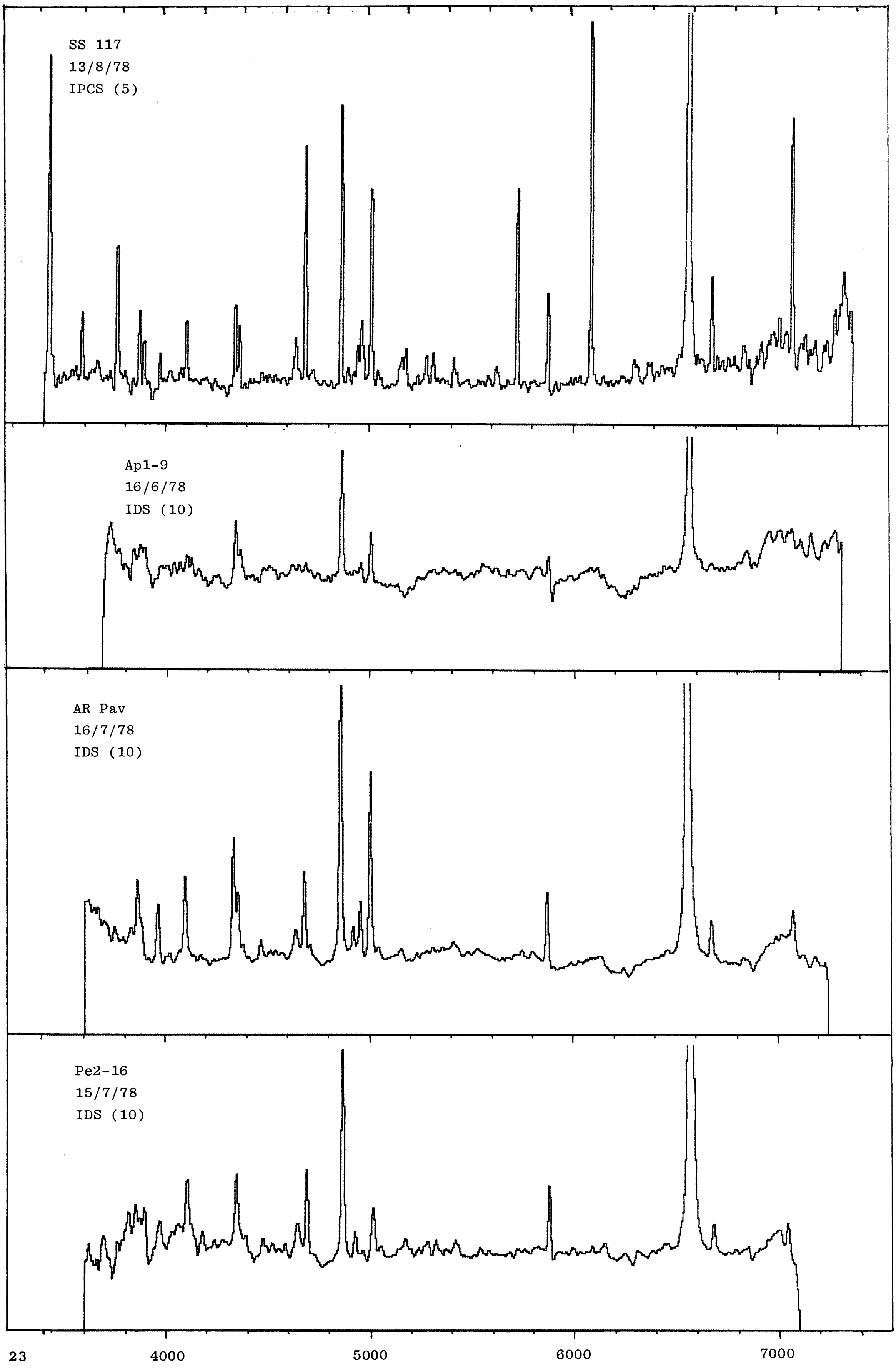

SS 117
13/8/78
IPCS (5)
Ap1-9
16/6/78
IDS (10)
AR Pav
16/7/78
IDS (10)
Pe2-16
15/7/78
IDS (10)
4000
5000
6000
7000

Fig. 23

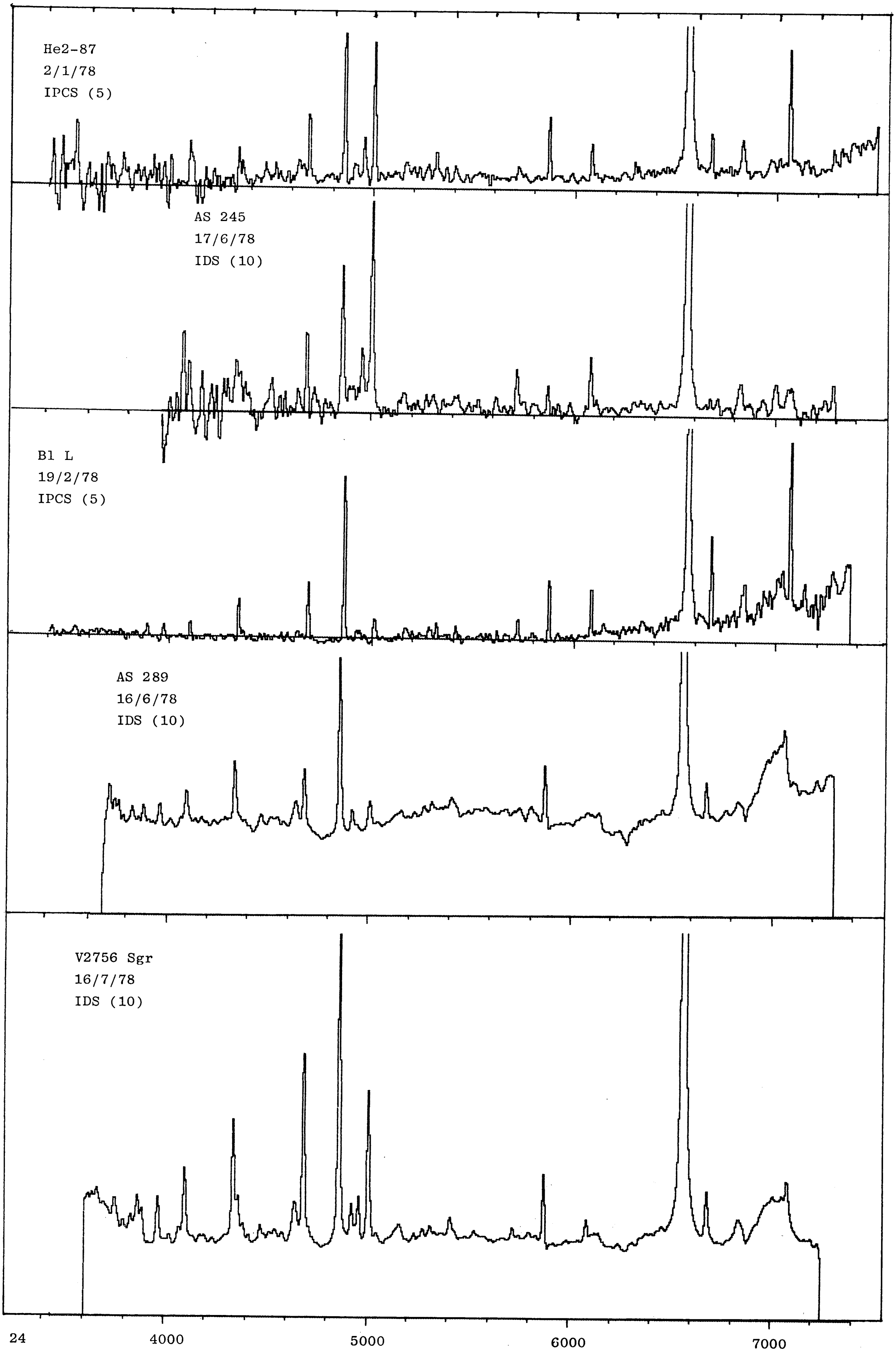

He2-87
2/1/78
IPCS (5)
AS 245
17/6/78
IDS (10)
Bl L
19/2/78
IPCS (5)
AS 289
16/6/78
IDS (10)
V2756 Sgr
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 24

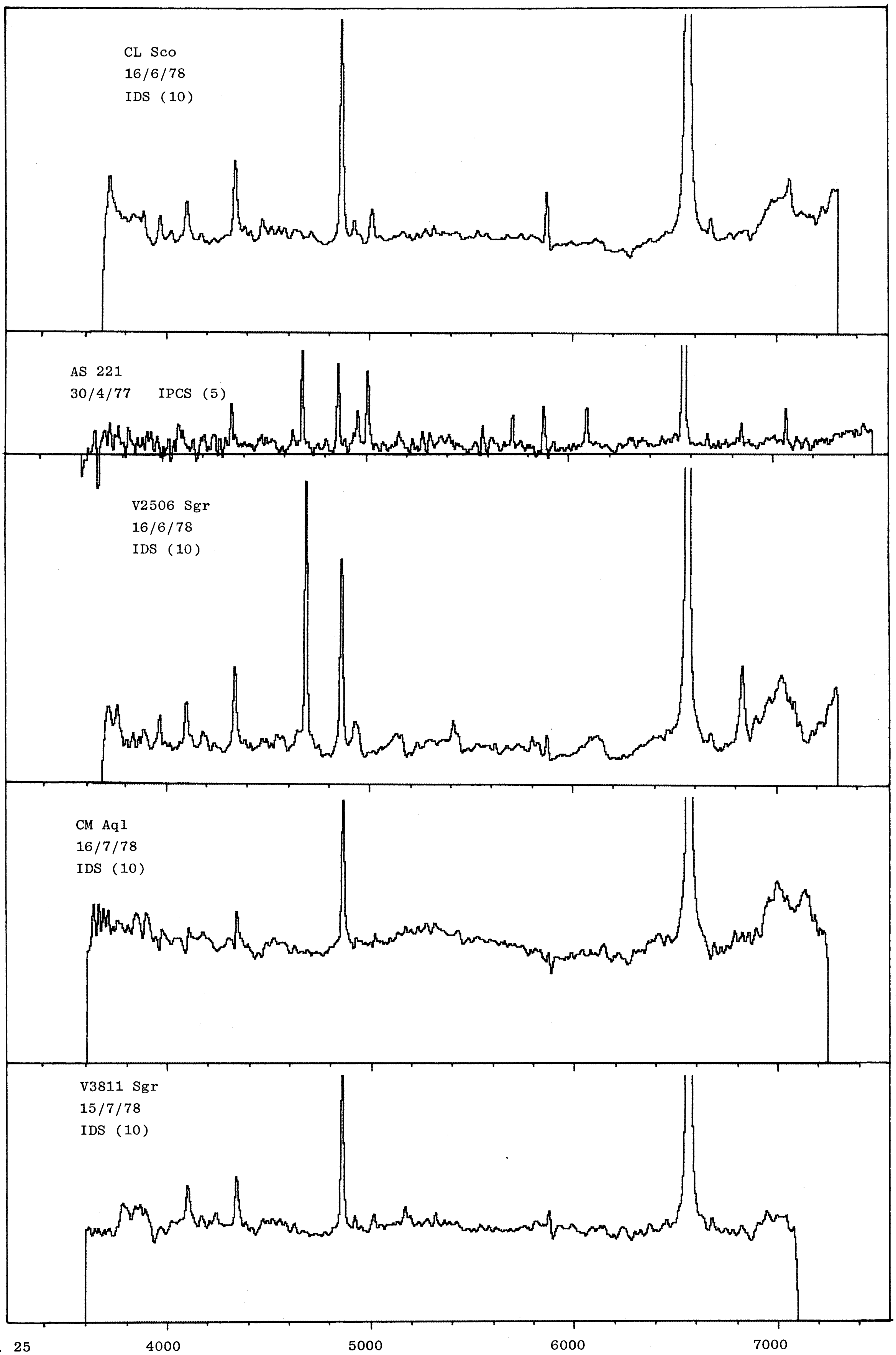

CL Sco
16/6/78
IDS (10)
AS 221
30/4/77 IPCS (5)
V2506 Sgr
16/6/78
IDS (10)
CM Aql
16/7/78
IDS (10)
V3811 Sgr
15/7/78
IDS (10)
4000
5000
6000
7000

Fig. 25

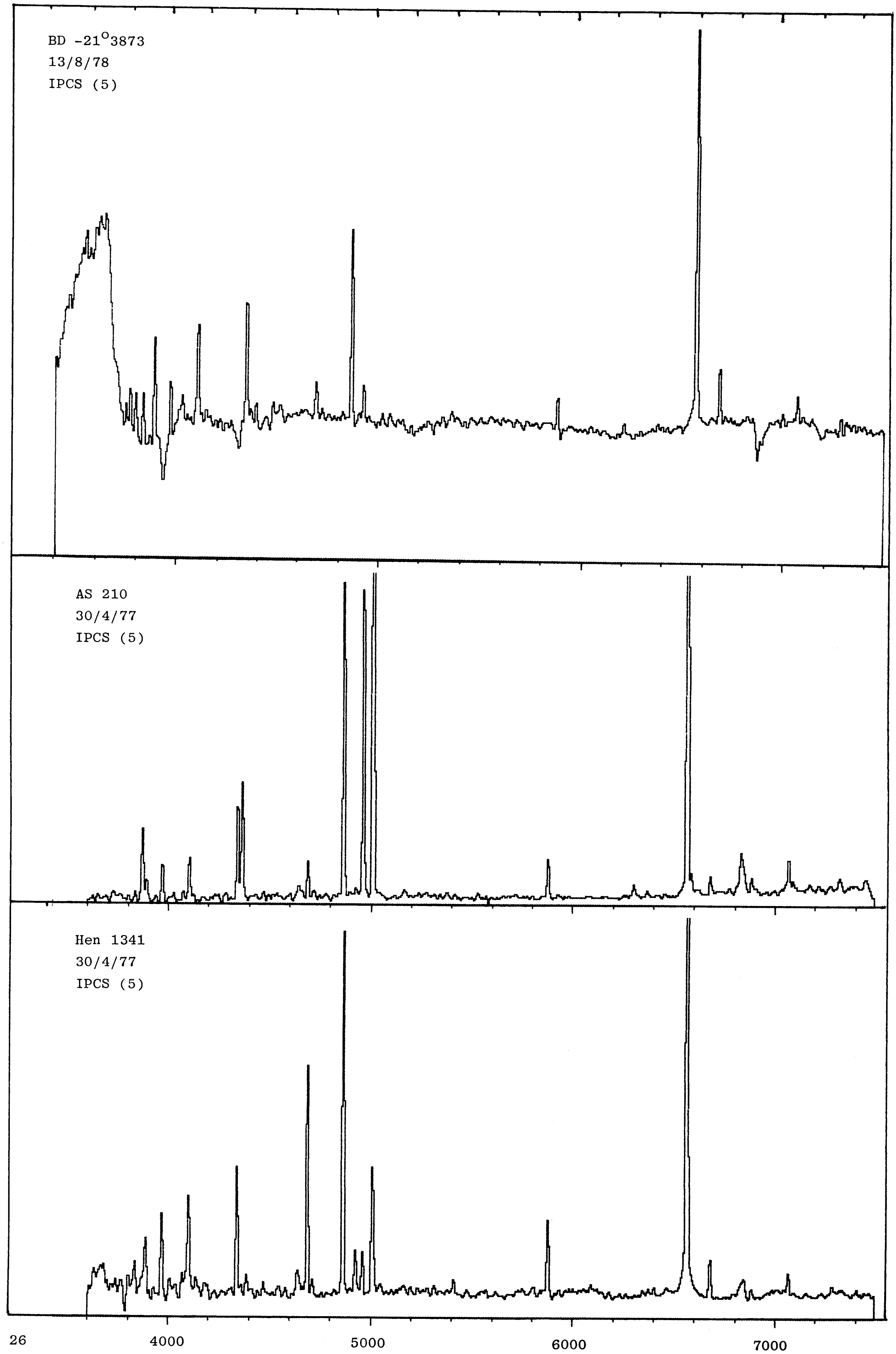

BD -21°3873
13/8/78
IPCS (5)
AS 210
30/4/77
IPCS (5)
Hen 1341
30/4/77
IPCS (5)
4000
5000
6000
7000

Fig. 26

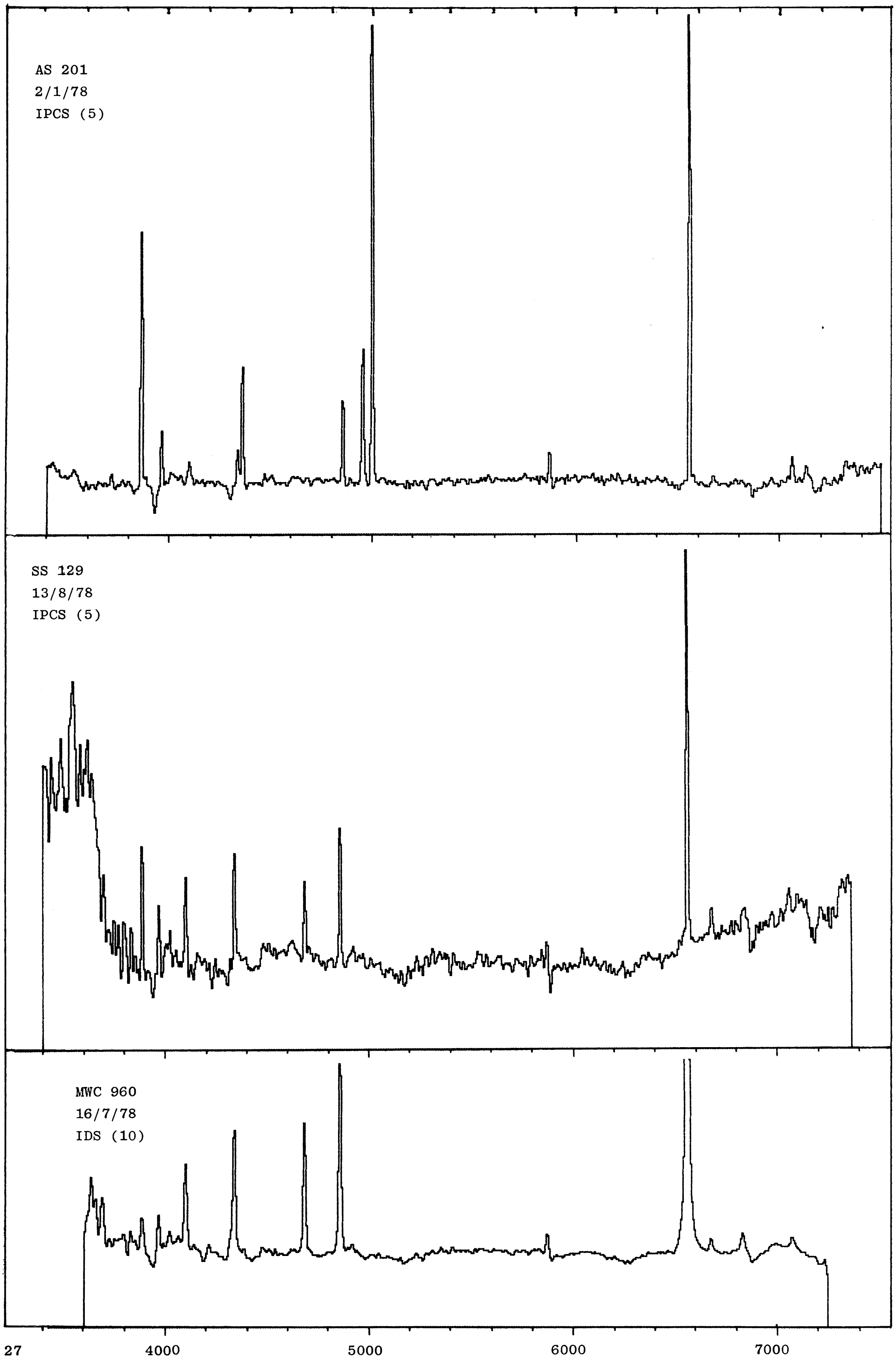

AS 201
2/1/78
IPCS (5)
SS 129
13/8/78
IPCS (5)
MWC 960
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 27

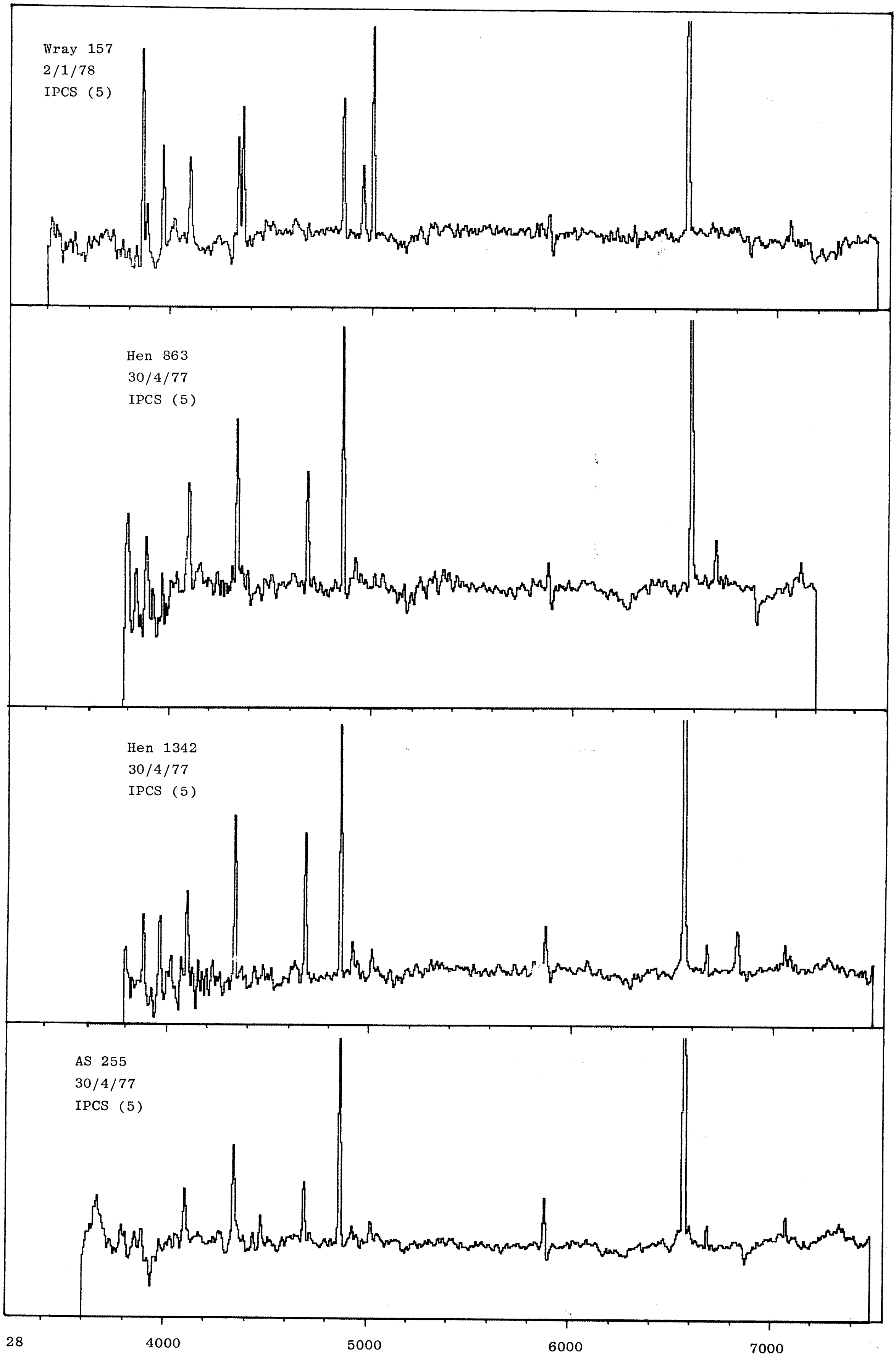

Wray 157
2/1/78
IPCS (5)
Hen 863
30/4/77
IPCS (5)
Hen 1342
30/4/77
IPCS (5)
AS 255
30/4/77
IPCS (5)
4000
5000
6000
7000

Fig. 28

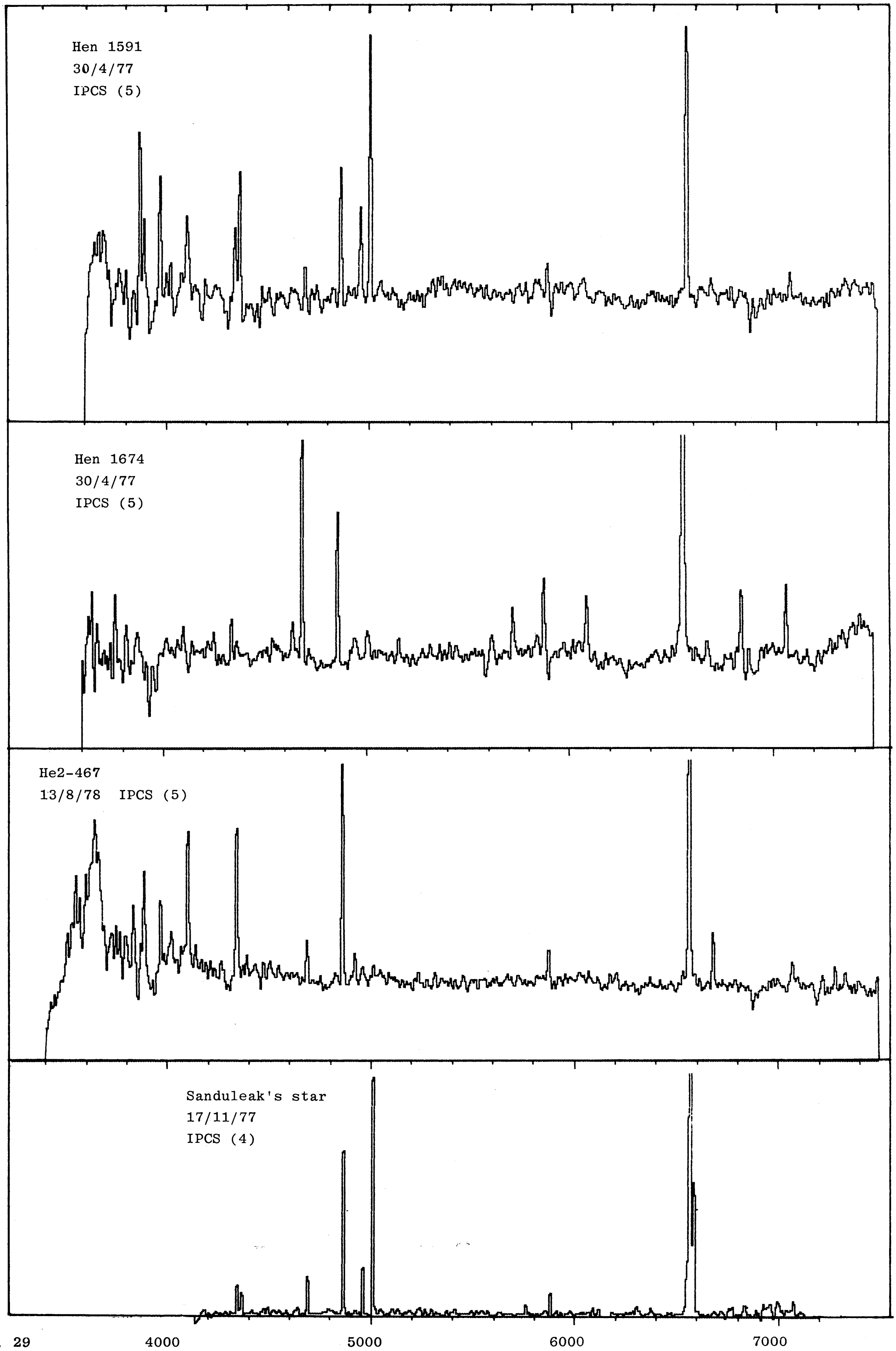

Hen 1591
30/4/77
IPCS (5)
Hen 1674
30/4/77
IPCS (5)
He2-467
13/8/78 IPCS (5)
Sanduleak's star
17/11/77
IPCS (4)
4000
5000
6000
7000

Fig. 29

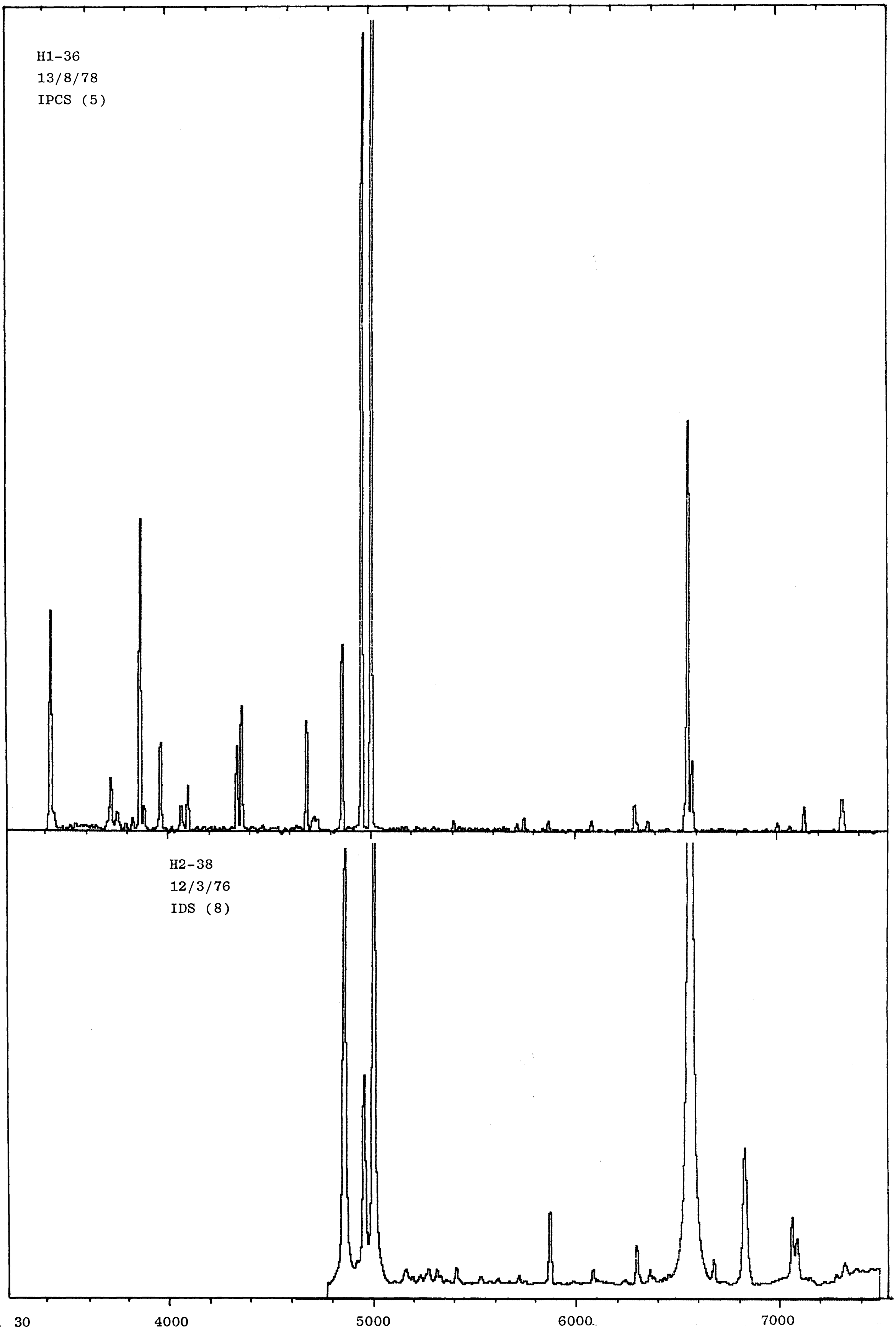


Fig. 30

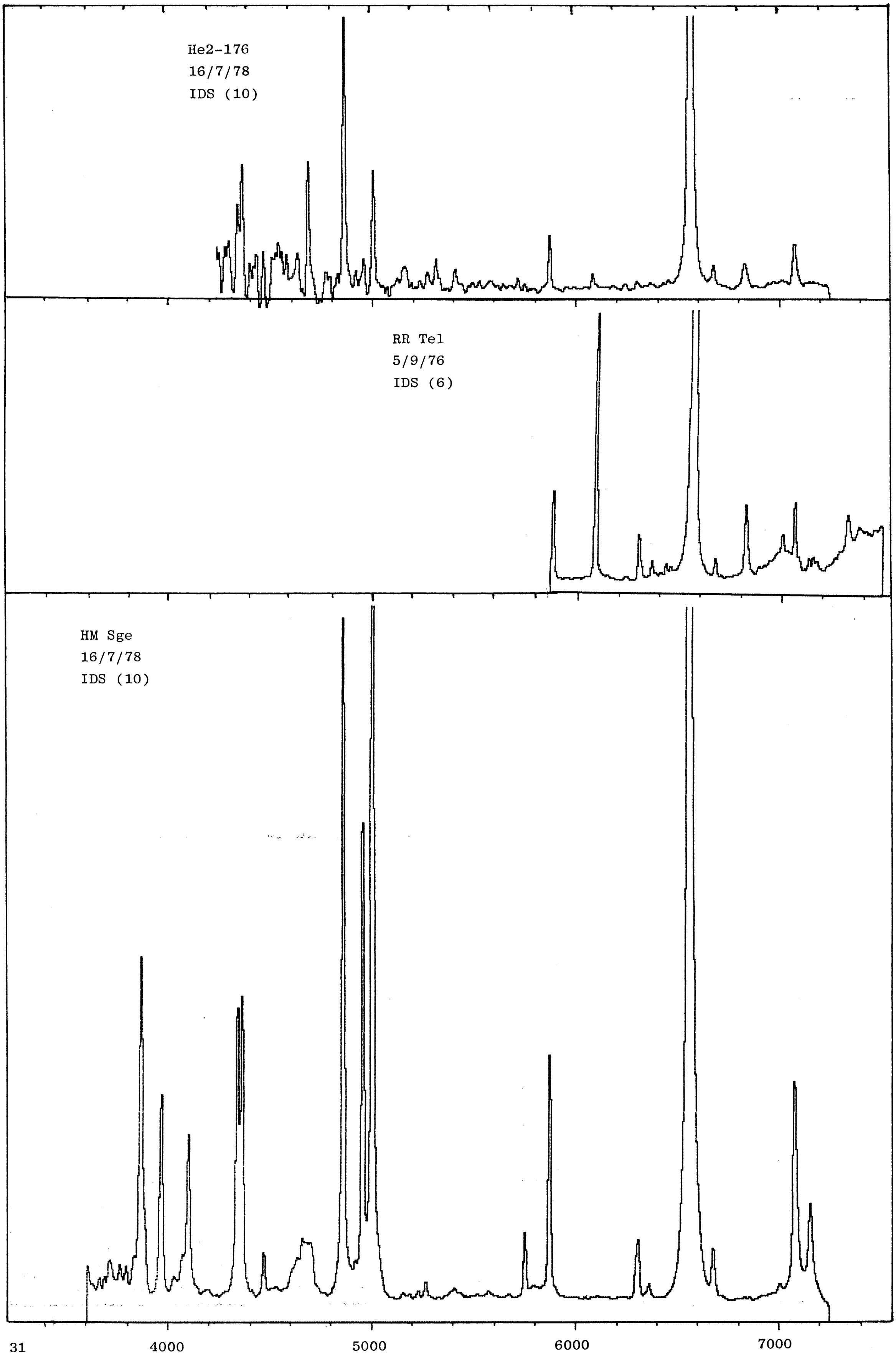

He2-176
16/7/78
IDS (10)
RR Tel
5/9/76
IDS (6)
HM Sge
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 31

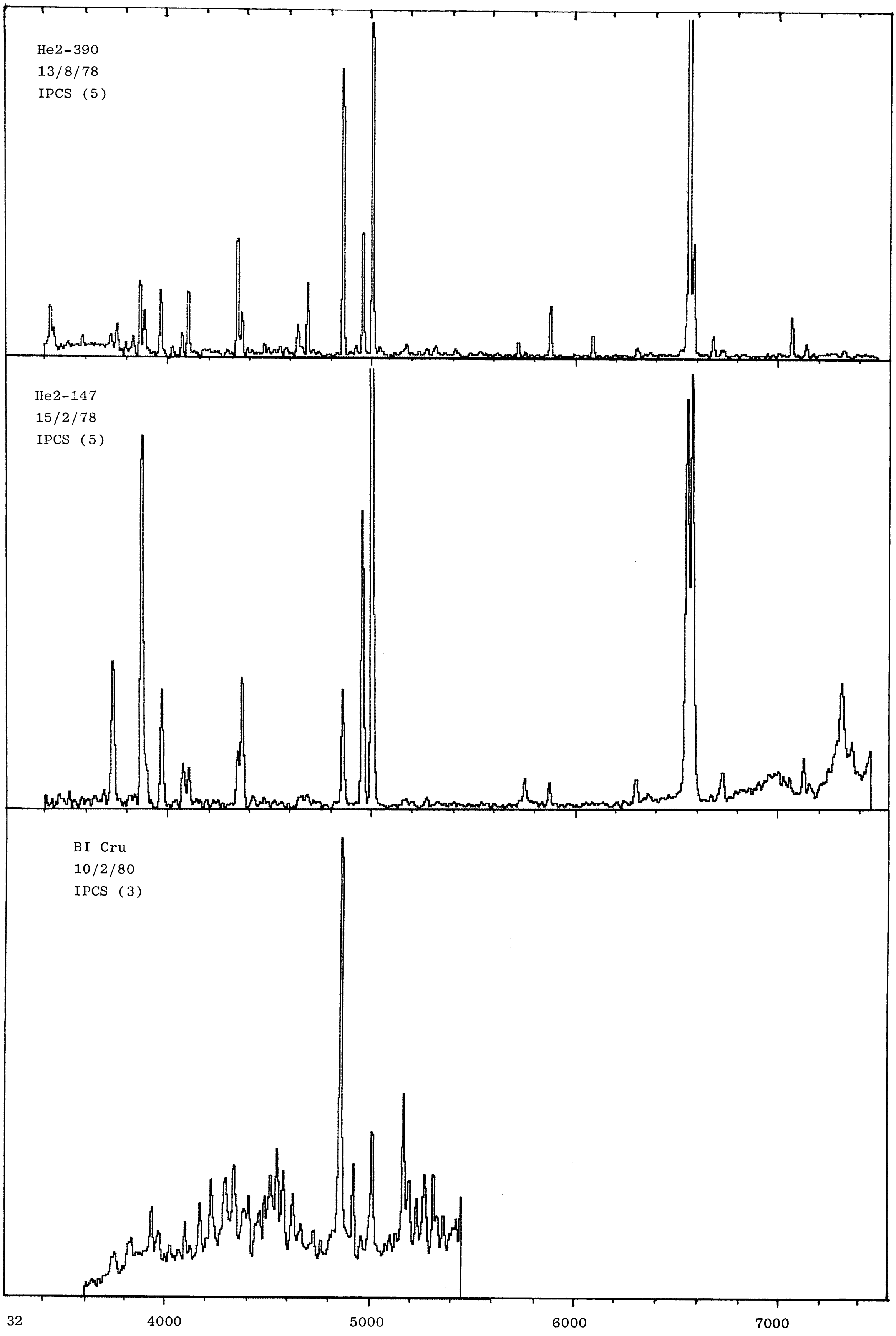

He2-390
13/8/78
IPCS (5)
He2-147
15/2/78
IPCS (5)
BI Cru
10/2/80
IPCS (3)
4000
5000
6000
7000

Fig. 32

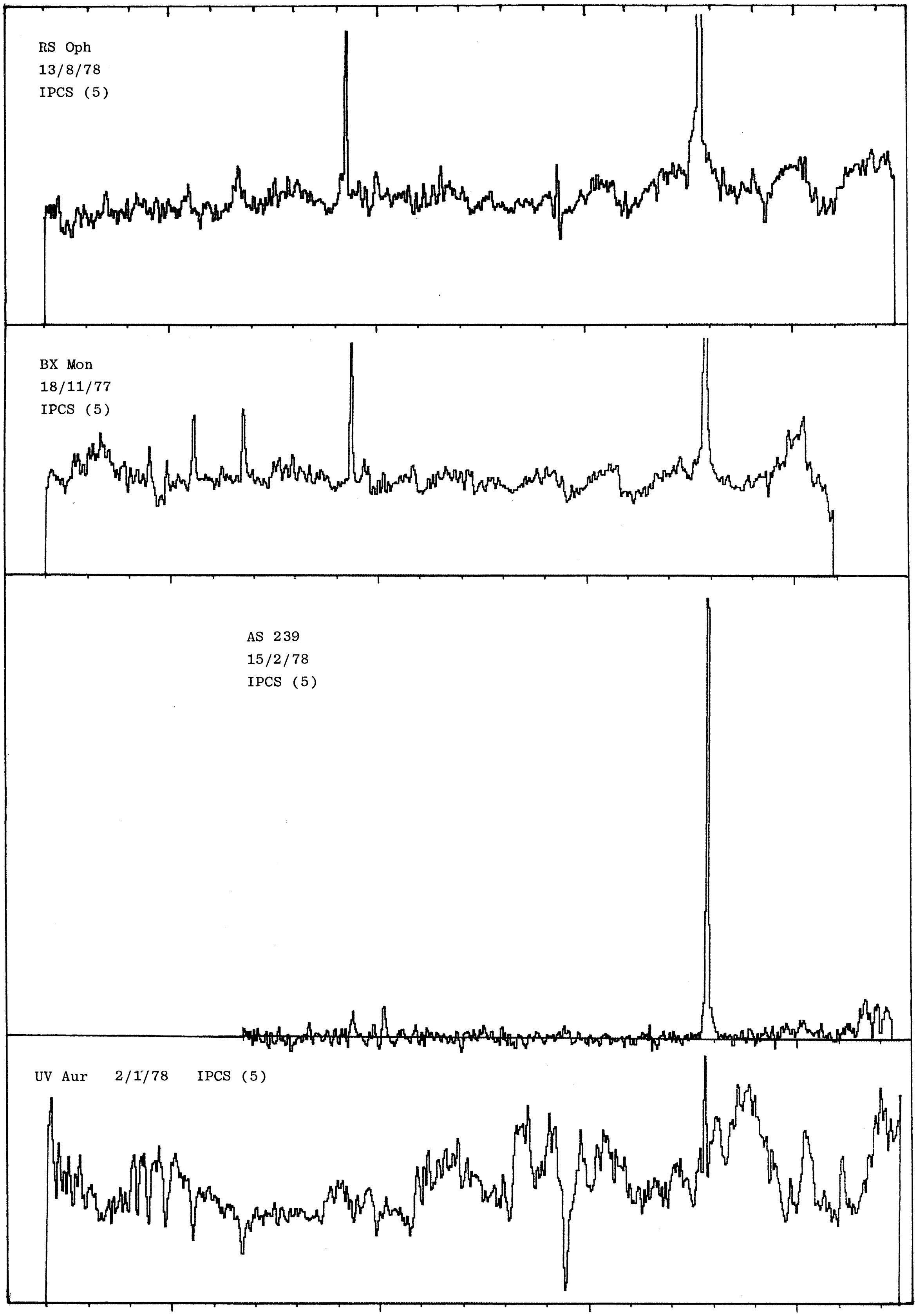
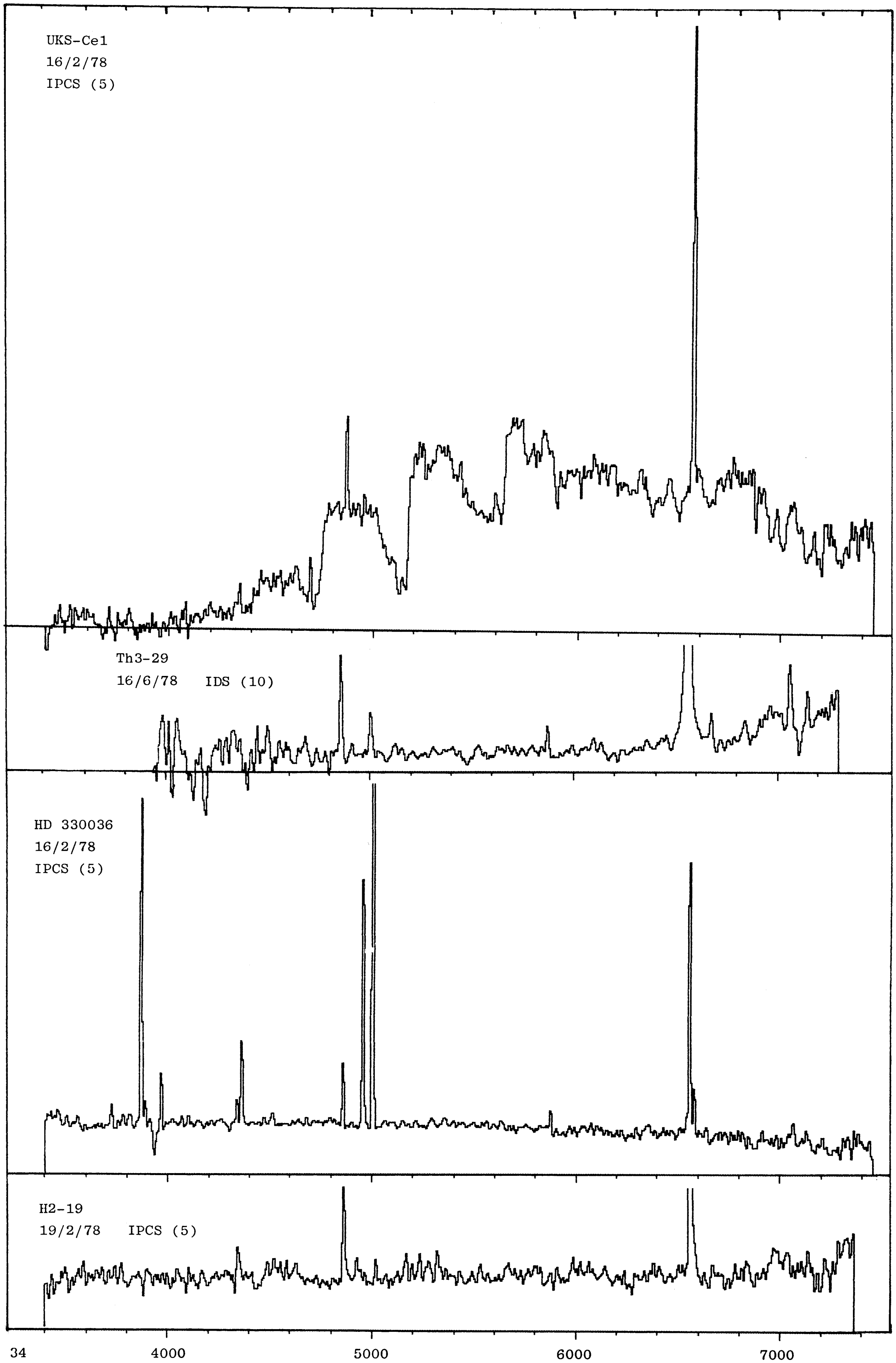

RS Oph
13/8/78
IPCS (5)
BX Mon
18/11/77
IPCS (5)
AS 239
15/2/78
IPCS (5)
UV Aur 2/1/78 IPCS (5)
4000
5000
6000
7000

Fig. 33



UKS-Ce1
16/2/78
IPCS (5)
Th3-29
16/6/78 IDS (10)
HD 330036
16/2/78
IPCS (5)
H2-19
19/2/78 IPCS (5)
4000
5000
6000
7000

Fig. 34

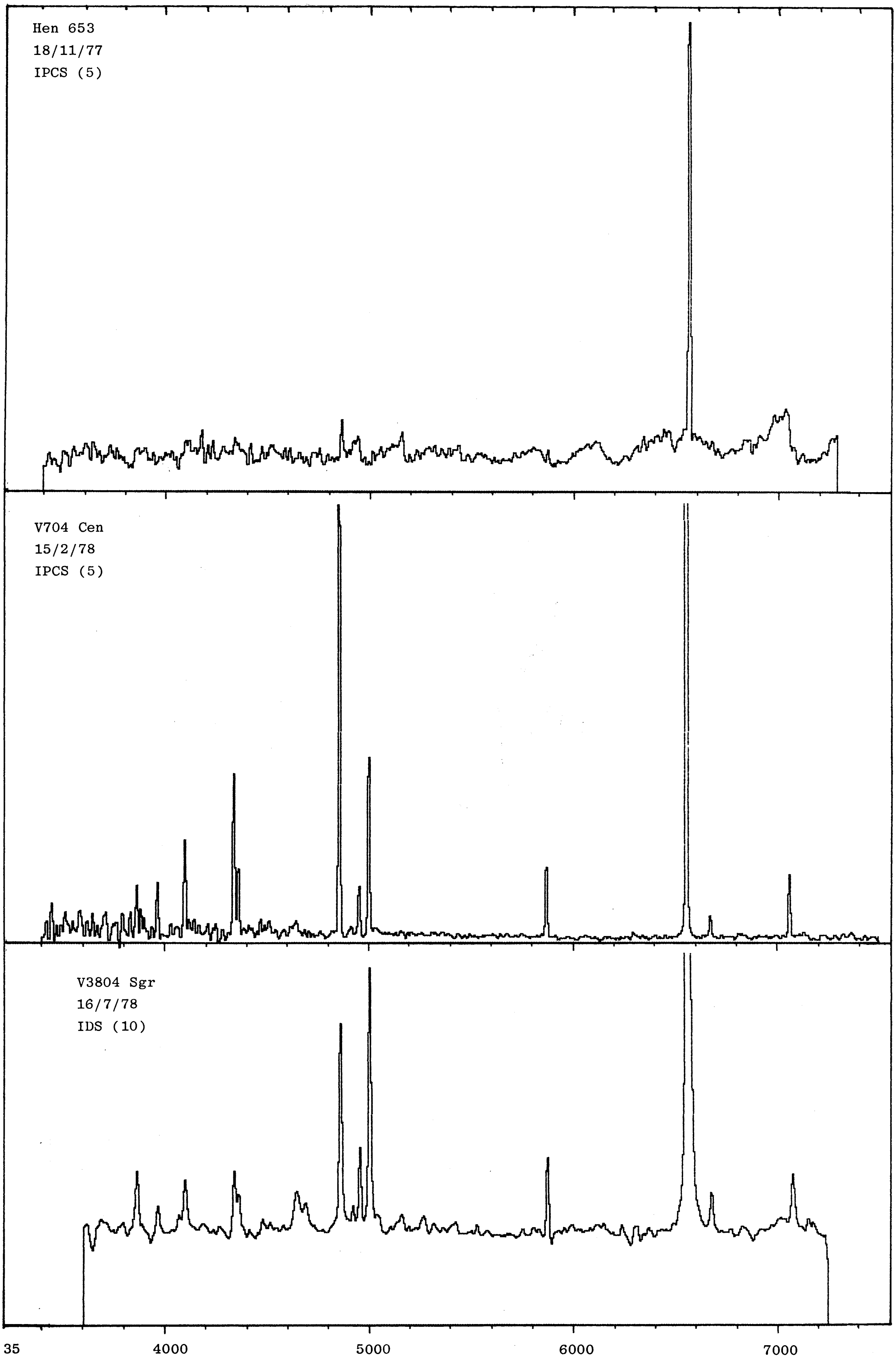
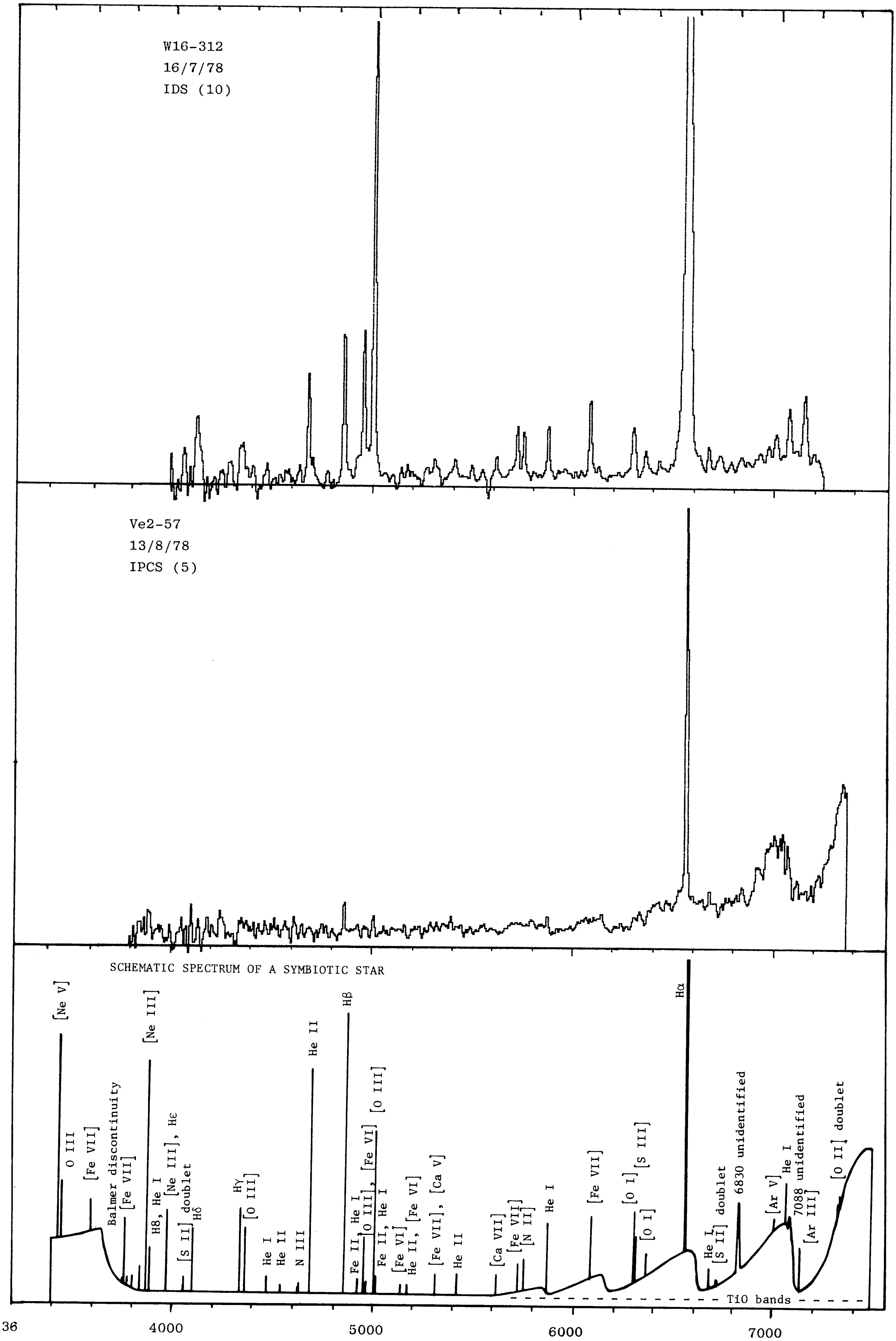

Hen 653
18/11/77
IPCS (5)
V704 Cen
15/2/78
IPCS (5)
V3804 Sgr
16/7/78
IDS (10)
4000
5000
6000
7000

Fig. 35



W16-312
16/7/78
IDS (10)
Ve2-57
13/8/78
IPCS (5)
SCHEMATIC SPECTRUM OF A SYMBIOTIC STAR
[Ne V]
O III
[Fe VII]
Balmer discontinuity
[Fe VII]
H8, He I
[Ne III]
[Ne III], Hε
[S II] doublet
Hδ
Hγ
[O III]
He I
He II
N III
He II
Hβ
Fe II
He I
[O III], He I
[Fe VI]
[O III]
Fe II, He I
[Fe VI]
He II, [Fe VI]
[Fe VII], [Ca V]
He II
[Ca VII]
[Fe VII]
[N II]
He I
[Fe VII]
[O I]
[S III]
[O I]
Hα
He I
[S II] doublet
6830 unidentified
[Ar V]
He I
7088 unidentified
[Ar III]
[O II] doublet
TiO bands
4000
5000
6000
7000

Fig. 36