Report on the Use of SAOPLOT

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CENTER FOR SPACE RESEARCH
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SAOPLOT

A Utility Program for Plotting
Overlay Maps of Designated Celestial Positions
and Field Stars Selected from
the Smithsonian Star Catalog Tapes*

by

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[1] The appendices are contained in a separate book which belongs to Prof. George Clark, 37-611.

I. Introduction

This FORTRAN program produces Calcomp plots of selected portions of the celestial sphere. One example is shown in Figure 1. The brightest stars in the regions are selected out of two magnetic tapes which are rewritten versions of the SAO Star Catalog tapes. The stars are plotted in their correct positions relative to the center for a flat plate photograph, and are indexed in a table with further information on both plot and line printer. Positions of x-ray sources can be input and will be plotted and listed, and any nearby stars, irrespective of magnitude, can be found. Also, a variable mesh grid of constant α and δ lines and a title can be specified. Stars may be selected by spectral type.

II. Directions for Using the Program

To use the program, preface the deck* with the standard JCL cards, and follow it with the following:

```
//G.FT01F001  DD  UNIT=(TAPE9,,DEFER),LABEL=(,NL),      +
//               VOLUME=SER=XR4026,DISP=(OLD,PASS),      +
//               DCB=(RECFM=V,LRECL=7188,BLKSIZE=7200)
//G.FT02F001   DD   UNIT=(TAPE9,,DEFER),LABEL=(,NL),    +
//               VOLUME=SER=XR4027,DISP=(OLD,PASS),      +
//               DCB=(RECFM=V,LRECL=8988,BLKSIZE=9000)
//G.PLOTTAPE   DD   UNIT=(TAPE7,,DEFER),LABEL=(,BLP),   *
//               VOLUME=SER=XR2084
//G.FT05F002 DD DUMMY
//G.SYSIN    DD   *
```

where the underlined are the names of the north, south, and plot tapes, in that order. (XR4144 is a copy of XR4026,

* See appendix 1.

XR4145 of XR4027. If the tape names are changed, change them here too.) These are followed by the data cards, specifying what plots are to be made.

Each plot is specified by a plot packet, consisting of one parameter card, as many coordinate cards as necessary, and ending with a delimiter card, in that order. As many packets as desired can be put at the end, and the program will read one at a time, complete it, and read the next. [A time estimate for the job is based primarily on how much magnetic tape must be read. If the plot regions are not in order in the data cards according to the ordering of the tapes (see TAPE FORMAT) north to south, then backspacing will occur, but the job will take longer].

Contents of the parameter card are specified on that list and the card format (Figure 3). The coordinate cards in excess of the number required to specify the plot (either 1 or 2) are treated as x-ray source positions, and those not on the plot region are ignored. (If a star is found within EPSLON of the source it is not plotted, but an x-ray symbol put next to it in the Table. Each coordinate can be in decimal degrees (DD), radians (RD), hours, minutes, and seconds (HM), or degrees, minutes, seconds (DM) as specified by the letters preceeding it (DD is default). If it is HM, or DM, and negative, the minus sign must go with the seconds field only (to prevent trying to read a -0 hours).

The delimiter card must contain asterisks in the first two columns. If the next column is blank, there will be no title. If it contains an asterisk, a default title is used (date and plot number in this job sequence). If it contains anything else, col 3-80 are printed as a title.

The program will compute the center of a limit specified plot on the basis that the geometric center of the specified region in the plot (which will, in general, look like ) will be the projection center, so a true picture is obtained.

The form of the printer table is the same as that in the SAO Star Catalog, with the exception that the codes are printed as numbers according to the SAO tape code, which is appended. (Code 52 is printed explicitly after the index number on the left. VV stands for variable in the visual, D for double, DV double and variable, etc.)

The orientation of the plot is always such that vertically upwards from the center is NORTH. Right ascension can increase from right to left through the center, or vice versa, depending on the INVERT parameter.

SAOPLOT uses the REREAD routine for data input, and also makes use of the PLOT routines available at LNS. The routine HACK, which returns the date in a form suitable for printing is used, but it can easily be removed. The use of these routines has unfortunately made SAOPLOT installation dependent and it should not be run on other 360's (including the Computation Center, which does not presently have REREAD) without

first checking the availability and names of the CALCOMP routines and REREAD feature.

The coordinate card input data have an original input format of DD, since this is the form used in the program. Once a specification other than DD has been found on a card, this new specification becomes the default (i.e., is used until new key letters are found). This default setting is done independently for right ascension and declination; changing the default for one has no effect on the other.

The setting of defaults holds between plots, but is always DD for the first plot of a run. The defaults can be easily changed by altering 2 cards in the FORTRAN deck of the program as explained in comment cards in the deck.

The following example may clarify the operation of the default system:

```
          Parameter Card
1)         5.6634          DM  34  26 31.7134
2)  HM     6 12  -3.8          35  20 14.86
3)         7 14  -5.1       RD   1.6394
    ***

          Parameter Card
4)         18 23 6.85       DD  14.861
5)  DM    220 48 6.231          14.256
    ***
```

1) declination is in DD by default, right ascension is DM.
2) declination in HM, right ascension in DM since default changed
3) declination in HM by default, right ascension in RD.
4) declination in HM since default continues over plot packet boundaries, right ascension in DD.
5) declination in DM, right ascension DD by default.

Note that negative values under HM and DM must have the minus sign on the seconds value.

III. The Program INTRP*

INTRP is a Fortran-callable subroutine designed to translate the packed 7094 format of the original SAO tapes to a format compatible with the 360. Data is passed to it by reading a record of the 7094 tapes into a COMMON area labeled INREC. The original tapes can be read using the LNS routines in the FBSRI system (see the LNS 360 Users Manual). They should be read with TRTCH=C. The record length is 2476 and recording format is U.

The program returns the translated data in the order and form shown in Table 1 in a common area named OUTPAC.

The form of one record of the old tapes is 50 stars, each of which has 11 7094 words of packed data, which comes to 49 1/2 bytes in the 360. The form of the data for one star in the INTRP WORKAREA is shown in Figure 2. The format of the old tapes is completely described in the manual for the SAO

*This is background information and is not used by SAOPLOT.

Table I

	Base above OUTPAC (bytes)	Type	Quantity	Bytes (total)
Delta	0	real*8	δ_{1950}	400
Alpha	400	real*8	α_{1950}	400
Delta O	800	real*8	δ_0	400
Alpha O	1200	real*8	α_0	400
A	1600	real*4	annual μ'(rad)	200
B	1800	real*4	annual $\sigma_{\mu'}$(rad)	200
C	2000	real*4	annual μ(rad)	200
D	2200	real*4	annual σ_μ (rad)	200
E	2400	real*4	photomag	200
F	2600	real*4	epoch of δ_o in years-1850	200
G	2800	real*4	σ_{δ_o} (rad)	200
H	3000	real*4	v is mag	200
V	3200	real*4	epoch of α_o in years-1850	200
J	3400	real*4	σ_{α_o} (rad)	200
K	3600	real*4	σ_{1950} (rad)	200
P	3800	integer#4	Spectype (EBCDIC)	200
L	4000	integer#2	codes 10&20	100
M	4100	integer#2	codes 30,40,51&52	100
N	4200	integer#2	DM zone & codes 60,70	100
O	4300	integer#2	DM no.	100
Q	4400	integer*4	Smithsonian book # & Source cat. star #	200
	4600		total bytes	

Output common=OUTPAC

Input common=INREC

catalog binary tapes by K. L. Haramundanus.

A complete listing of INTRP, as well as listings of the programs NTAPE and STAPE which contain examples of the use of FBSRI and INTRP in the MAIN programs, are in appendices 3,4, and 5, respectively.

IV. Tape Format

One tape contains the northern hemisphere stars; the other, the southern. Each tape contains 3600 records, each holding stars in the area $10n°$ to $10(n+1)°$ declination, $0.9K°$ to $0.9(K+1)°$ right ascension, n and K integers. The position of a given record r, $1 \leq r \leq 3600$, tells its field: $r=400(8-n) + K$ since the tapes are ordered similar to the SAO catalog tapes: all the 400 records in a 10° band of declination are in order of increasing α, and these blocks are in order of declination north to south. Data on the tapes are at epoch 1950.0.

The original tapes for the 7094 contain the catalog in a packed format that is convenient for the 7094 but rather hard for the 360 to handle. The particular information that we require has thus been converted from the old representation to the standard 360 internal floating point format (single or double precision as required). In addition, codes that were packed as close as possible in the original tapes have been expanded for easier handling in FORTRAN. The converted and streamlined version of the catalog was then written on two 360 9-track tapes (one each for northern and southern hemispheres).

The programs that perform the translation are called NTAPE and STAPE (two programs are required because of the varying number of records per file on the original tapes). They consist of a FORTRAN main program and 4 FORTRAN subroutines to sort the data, switch files on the old tapes, write the new tapes, and print a record map of each new tape.

There is also an assembly language program called INTRP, which performs the actual translation operations at a bit level. INTRP translates all the data, including those parts (such as information on right ascension and declination at epoch of original observation) which are not needed by SAOPLOT and are therefore not written on the new tapes. Anyone having need of this information should see Table 1 of the output COMMON area of INTRP. Any information that is already on the new tapes should be taken from them, since they are in a format compatible with the 360.

V. Parameter Card Quantities

The quantities on the parameter card (see Figure 3) act as follows:

KEYLETTERS (col. 1-2) tell how the location of the plot region is specified: CN, or center, means the next card must be a coordinate card containing a legal α and δ which will be used as the center of the plot. LM, or limits, means the next two cards must be coordinate cards giving the coordinates of the lower left and upper right hand corners

of the plot, in that order.

Any further coordinate cards beyond these required, in the same packet, will be interpreted as x-ray sources, and the first 30 or less will be plotted. (Default CN).

SCALE (col. 5-10) scale of the plot, in great circle degrees per inch at the center, a real number. Mandatory for CN plots, calculated from SIZE parameter if blanks on LM plot.

SIZE (col. 15-20) vertical height of the plot, less than or equal to the 10" maximum, a real number. (Default 10.0)

MAXMAG (col. 25-30) a real number. Any star from the region will be excluded from the plot if its visual magnitude is unlisted or greater in numerical value (i.e. less bright) than MAXMAG. (Default 20, i.e. no stars excluded on this basis)

MAXNO (col. 35-40) an integer. If the number of stars that pass the magnitude test reaches this number, a further star is accepted only if it is brighter than the dullest star already listed, and it then replaces that star in the list. MAXNO can be no larger than 30. (Default 30) [note: if MAXNO is -1, the star section is skipped, and just the grid is drawn]

EPOCH (col. 70-75) a real number, equal to the year at which the celestial sphere is to be displayed.

This plot will be correct for both equinox and epoch (i.e., both relative motion of stars, and the movement of the vernal equinox will be considered). (Default=1950.0)

EPSLON (col. 55-65) a real number, expressing a radius in degrees. Any stars in the circle of radius EPSLON centered on the x-ray source will be entered in the list of MAXNO stars as dead entries (i.e., are not plotted, but are listed with a source symbol and are not subject to elimination if brighter stars are found). (Default 10^{-3}). (See page 2).

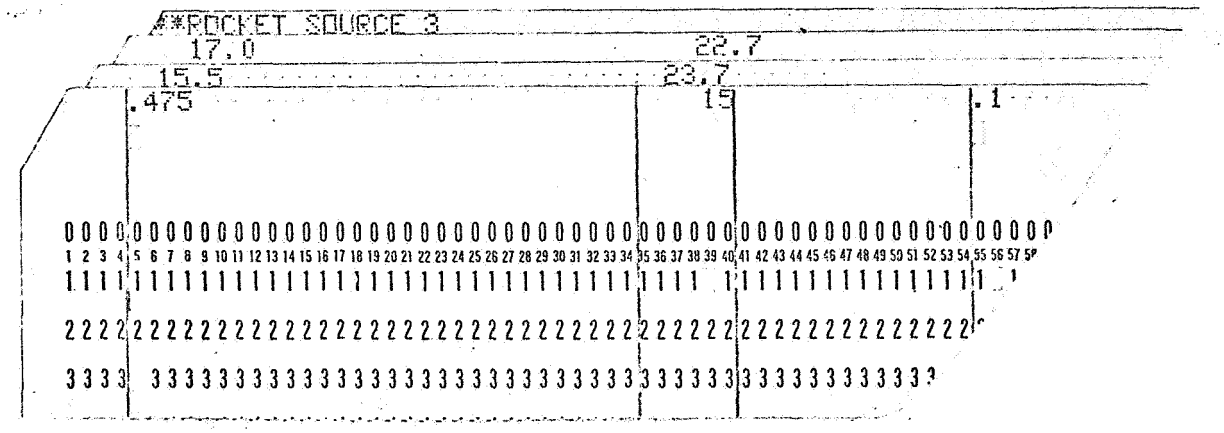
INVERT (col. 79) letter I or blank: presence of I means α increases from left to right through the plot center on the plot. Blank means right to left.

GRID (col. 45-50) real number, in degrees. A constant δ grid line will be drawn on the plot every multiple of GRID in declination that falls in the plot region. Lines of constant α are also drawn every multiple of some "nice" number that makes the grid boxes approximately square in the middle. (Default=1.0) [For example, if center α=3.5°, δ=0.7°, GRID=1.0, we would have lines at δ=-1, 0, +1, +2, etc., α=2,3,4]

TRACE (col. 80) a "T" in this column gives a record of which records on the tape were read for this plot.

SPEC (col. 78) A letter in this column means only stars of that spectral type will be included in the list.

Example of Plot Packet



This packet will produce a plot with center at δ=15.5°, α=23.7°, and a scale of .475°/inch [the scale on the Palomar plates]. All stars above magnitude 20 (the default) are selected, up to 15, after which only the brightest are kept. An X-Ray source is plotted at δ=17.0°, α=22.7°, and all stars in a .1° box around it are kept in the list, irrespective of magnitude. The Plot is titled "ROCKET SOURCE 3". A grid of mesh 1° (default) is drawn, and the plot will be 10" (default) in height.

VI. Definitions of Codes in the Smithsonian Catalog

(From the Smithsonian Tape Description)

Code 10: Visual Magnitude

Code Visual	Photo-visual	Magnitude Source
0		Does not appear in source catalog
1	21	Determined by source catalog
2		Determined by source catalog or by authority in footnote
3	23	Source cited in source catalog introduction
	24	Source unspecified
5		Taken from BD
8		Based on Durchmusterung magnitudes and visual estimates
9		Taken from AGK 1
10		Taken from Cordoba Zones (Resultados)
12		Taken from CGA or Cordoba Zones
13		Taken from Harvard Publications
14		Taken from Harvard or San Luis Photometry
15		Taken from Henry Draper
16		Combined magnitude of component stars
17		Arithmetic mean of maximum and minimum magnitudes of a variable star

Where no figures were reported for magnitudes of a variable star, 0.00 was stored on the tapes (i.e., always check code 52 when using magnitudes). When blank, code=0, and field =zeros.

Code 20: Star Number and Footnotes

Footnote without	Footnote with	Star Number
0	16	Source catalog only
1	17	Source catalog and BD
2	18	Source catalog and CD
3	19	Source catalog and CPD
4	20	Cordoba B (Resultados) and CD
5	21	Cordoba A (Resultados) and CD
6	22	AGKI and BD
7		GC and BD
8	24	Cordoba B (Resultados) and CPD
9		Cordoba A (Resultados) and CPD

When blank, code of DM is 0 or 16, footnote is 0 through 9, and field is zeros. Footnotes and star numbers are those appearing in the source catalogs.

Code 30: Photographic Magnitude

Code	Source
0	Does not appear in source catalog
1	Determined by source catalog
4	Taken from magnitudes of the CPD and diameters of the Cape Astrographic Catalog
8	Source cited in source catalog introduction
9	Columbia Contributions Nos. 30 and 31 (Schilt)

When blank, code is 0, field is zeros.

Code 40: Proper Motion

Code	Source
1	Determined in source catalog
3	Determined by comparison of catalog and Greenwich AC
5	Determined by comparison of catalog and AGK 1
6	Determined by comparison of catalog and Greenwich AC on the basis of the smallest difference in positions
8	Determined by comparison of catalog with AGK 1 on the basis of the smallest difference in positions

When blank, code is 0, field is zeros.

Code 51: Spectral Type

Code	Source
0	Taken from the Henry Draper or no spectrum in source catalog
1	Taken from the HD with M stars reclassified by Miss Cannon
2	Classified by G. G. Cillie
3	Classified by Goedicke
4	Classified by D. Hoffleit
5	Classified by M. V. Mayall
6	Classified by McCormick Observatory
7	Classified by Nassau and Seyfert

When no spectra were recorded, the code is 0 and the field is BCD blanks. If the spectrum is composite, +++ is stored in the field, and the code is 0.

Code 52: Miscellaneous

Code	Meaning
0	No additional information
1	Double star, see source catalog for source
2	Double star in Aitken's Double Star Catalog
3	Double star in Burnham's Double Star Catalog
4	Variable star in visual magnitude in source catalog
5	Variable star in photographic magnitude in source catalog
6	Variable star in both magnitudes
7	Both double and variable, in either visual or photographic magnitudes

When blank, code is 0, no field involved.

Code 60: Accuracy of Visual Magnitude

Listed on tape as 0 or 1; 0 indicates the magnitude was reported in source catalog to $0^{m}.00$; 1, to $0^{m}.0$

Code 70: Accuracy of Photographic Magnitude

Listed on tape as 0 or 1; 0 indicates the magnitude was reported in source catalog to $0^{m}.00$; 1, to $0^{m}.0$.

VII. Book Numbers for Source Catalogs

No.	Abbreviated Title
01	AGK 2, vol. 1
02	AGK 2, vol. 2
03	AGK 2, vol. 5
04	AGK 2, vol. 6
05	AGK 2, vol. 7
06	AGK 2, vol. 8
20	Yale Transactions, vol. 11
21	Yale Transactions, vol. 12 I
22	Yale Transactions, vol. 12 II
23	Yale Transactions, vol. 13 I
24	Yale Transactions, vol. 13 II
25	Yale Transactions, vol. 14
26	Yale Transactions, vol. 16
27	Yale Transactions, vol. 17
28	Yale Transactions, vol. 18
29	Yale Transactions, vol. 19
30	Yale Transactions, vol. 20
31	Yale Transactions, vol. 21
32	Yale Transactions, vol. 22 I
33	Yale Transactions, vol. 22 II
34	Yale Transactions, vol. 24
35	Yale Transactions, vol. 25
36	Yale Transactions, vol. 26 I
37	Yale Transactions, vol. 26 II
38	Yale Transactions, vol. 27
40	Cape Annals, vol. 17
41	Cape Annals, vol. 18
42	Cape Annals, vol. 19
48	Cape Zone

No.	Abbreviated Title
60	Melbourne 3
61	Melbourne 4
70	General Catalog
71	FK3
74	FK4

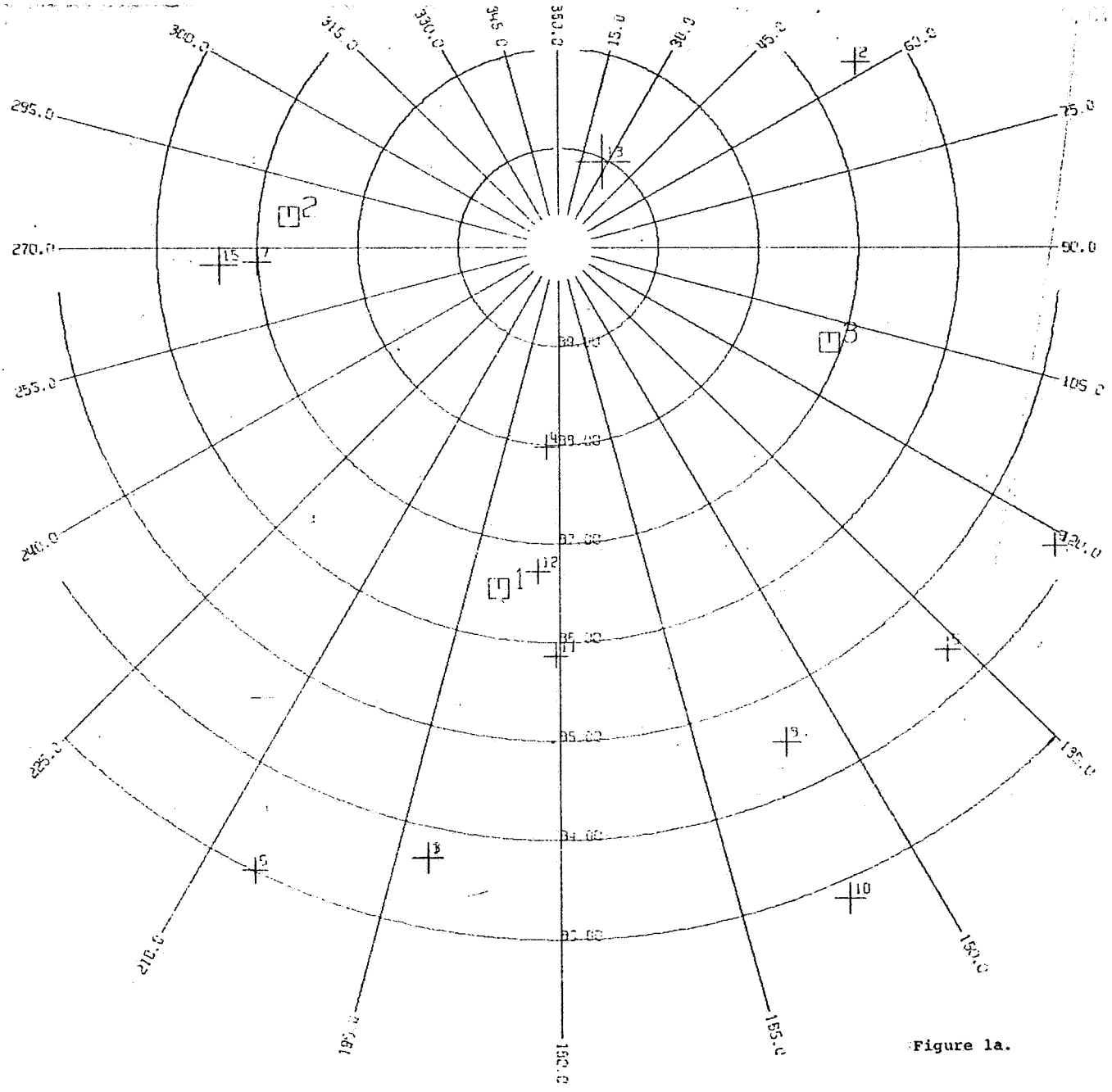

0.0
15.0
30.0
45.0
60.0
75.0
90.0
105.0
120.0
135.0
150.0
165.0
180.0
195.0
210.0
225.0
240.0
255.0
270.0
285.0
300.0
315.0
330.0
345.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure 1a.

SAMPLE SAØPLØT ØUTPUT

STAR NØ.	ALPHA	DELTA	MAG	SPECTYPE
1	192.191680	83.684496	5.3	A2
2	57.818816	86.488608	5.8	F5
3	192.161440	83.689552	5.8	A0
4	183.687200	87.977056	6.3	F0
5	136.318288	84.386240	6.3	F0
6	205.919520	83.003552	6.2	G5
7	267.300960	86.992176	5.9	A3
8	155.674992	84.507856	5.6	A3
9	121.307200	84.208496	6.4	A0
10	156.291200	82.614416	5.3	F2
11	180.540960	85.864048	6.4	F5
12	183.852000	86.713616	6.3	F2
13	27.203232	89.028736	2.1	F8 V
□ 14	109.460800	87.126176	5.3	M0
15	267.076000	86.609552	4.4	A0

Figure 1b. Plotted Star Data

SOURCE	ALPHA	DELTA
1	189.9998	86.4999
2	276.7997	87.2999
3	109.4598	87.1259

Figure 1c. Plotted Source Data.

SAMPLE SAOPLOT OUTPUT

PLOT NUMBER 1 INPUT DATA --

CENTER OF PLOT --

DECLINATION	87.0000000
RIGHT ASCENSION	180.0000000
EPOCH	1950.0
SCALE	1.000
SIZE	10.0
MINIMUM MAGNITUDE	20.0
MAXIMUM NO. OF STARS	15
NO. X-RAY SOURCES	3
GRID	1.00
EPSILON	5.00E-03

X-RAY SOURCES --

NO.	DECLINATION	RIGHT ASCENSION
1	86.4999745	189.9999620
2	87.2999809	276.7999731
3	87.1259477	109.4599559

Figure 1d. Printed output.

NO.	RT ASCENSION H M S	MOTION SIGMOT S ''	DECLINATION ° ' ''	MOTION SIGMOT '' ''	SIGPOS ''	MAGNITUDES PHOT VIS	SPEC	CATNO	DMNO	CODES 10-52
1 D	12 48 46.034	-0.0182 0.002	83 41 4.450	0.0151 0.002	0.08	5.28	A2	70*17443	84* 290	14 1 0 1 0 2
2	3 51 16.524	0.1674 0.002	86 29 19.337	-0.0771 0.002	0.10	5.84	F5	70* 4693	86* 51	14 17 0 1 0 0
3 D	12 48 38.786	-0.0163 0.002	83 41 22.588	0.0171 0.002	0.10	5.81	A0	70*17440	84* 289	14 1 0 1 0 2
4	12 14 44.983	-0.0590 0.001	87 58 37.567	0.0519 0.002	0.08	6.28	F0	70*16763	86* 71	14 17 0 1 0 0
5	9 5 16.422	0.0193 0.001	84 23 10.569	0.0093 0.001	0.04	6.26	F0	74* 1640	84* 196	15 1 0 1 0 0
6	13 43 40.746	0.0175 0.001	83 0 13.021	-0.0470 0.001	0.04	6.16	G5	74* 1643	83* 397	15 1 0 1 0 0
7	17 49 12.247	0.0694 0.002	86 59 31.937	0.0028 0.002	0.13	5.86	A3	70*24266	86* 272	14 1 0 1 0 0
8	10 22 42.003	-0.0885 0.002	84 30 28.742	-0.0403 0.002	0.10	5.64	A3	70*14305	84* 234	14 17 0 1 0 0
9	8 5 13.751	-0.0069 0.001	84 12 30.910	-0.0216 0.001	0.04	6.39	A0	74* 1639	84* 169	15 1 0 1 0 0
10	10 25 9.905	-0.0445 0.001	82 48 52.050	0.0256 0.001	0.03	5.34	F2	74* 911	83* 297	15 1 0 1 0 0
11	12 2 9.876	-0.0514 0.001	85 51 50.917	0.0885 0.001	0.04	6.38	F5	74* 1642	86* 176	15 1 0 1 0 0
12	12 15 24.528	0.2459 0.002	86 42 49.260	-0.0092 0.002	0.16	6.33	F2	70*16778	87* 107	14 17 0 1 0 0
13 VV	1 48 48.785	0.1811 0.001	89 1 43.738	-0.0043 0.001	0.03	2.12	F8 V	74* 907	88* 8	17 1 0 1 0 4
14	7 17 50.619	-0.0479 0.001	87 7 34.518	-0.0340 0.001	0.03	5.26	M0	74* 909	87* 51	15 1 0 1 0 0
15	17 48 18.337	0.0107 0.001	86 36 34.777	0.0539 0.001	0.03	4.44	A0	74* 913	86* 269	15 1 0 1 0 0

Figure 1d continued.

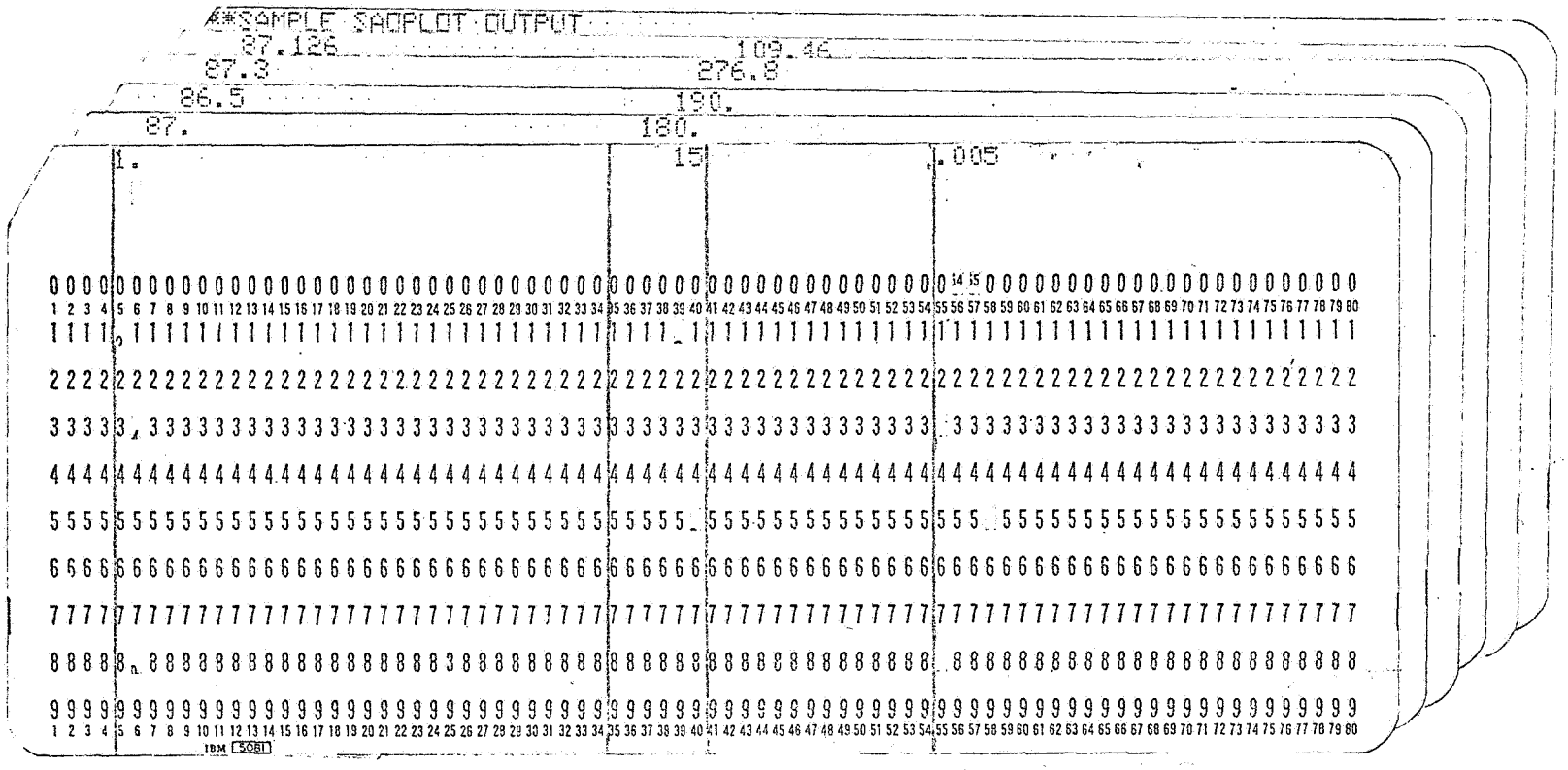
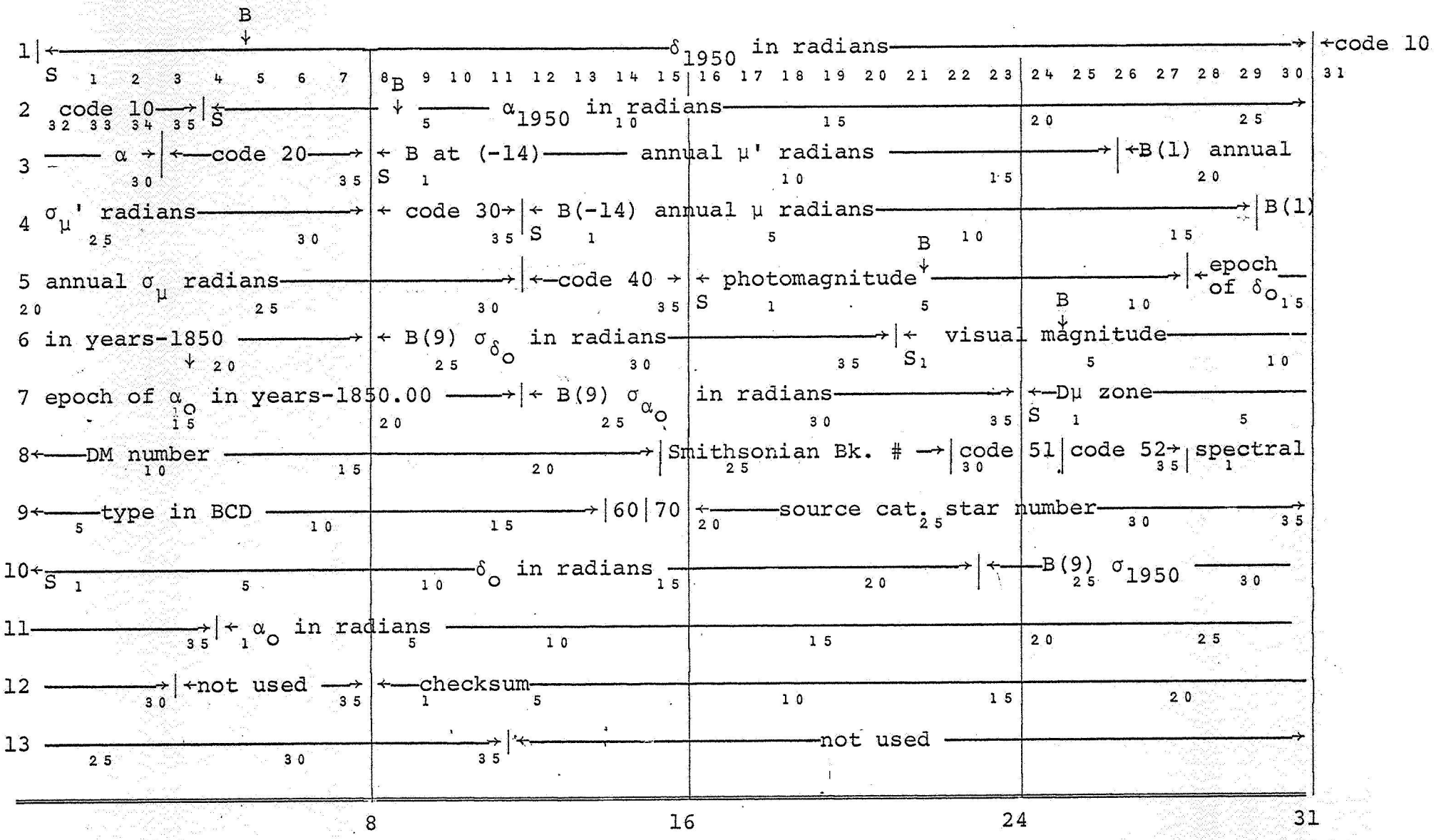


Figure 1e - Input Plot Packet



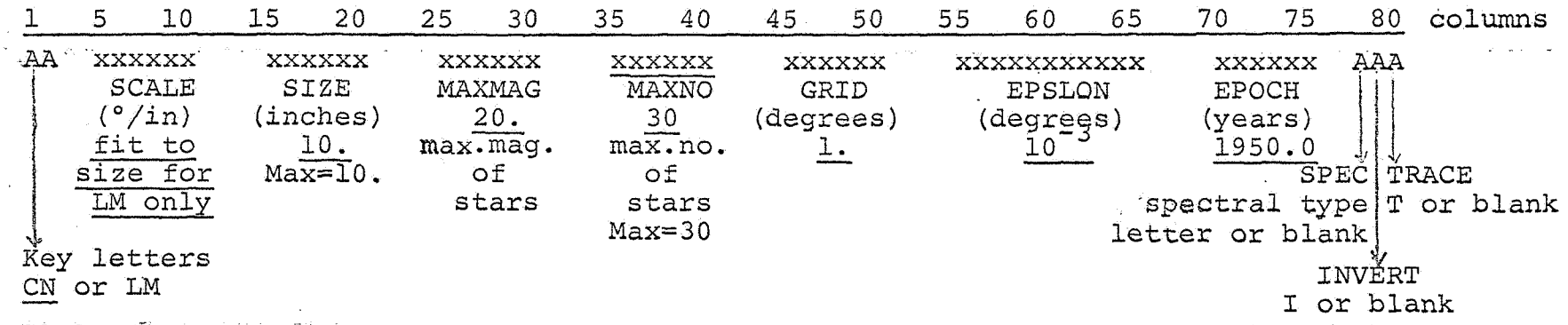
Codes: 10 - visual magnitude; 20 - star numbers and footnotes; 30 - photo magnitude; 40 - proper motion; 51 - spectral type; 52 - double and variable stars; 60 - accuracy of visual magnitude; 70 - accuracy of photo magnitude.

Figure 2. Form of data for one star in INTRP WORKAREA.

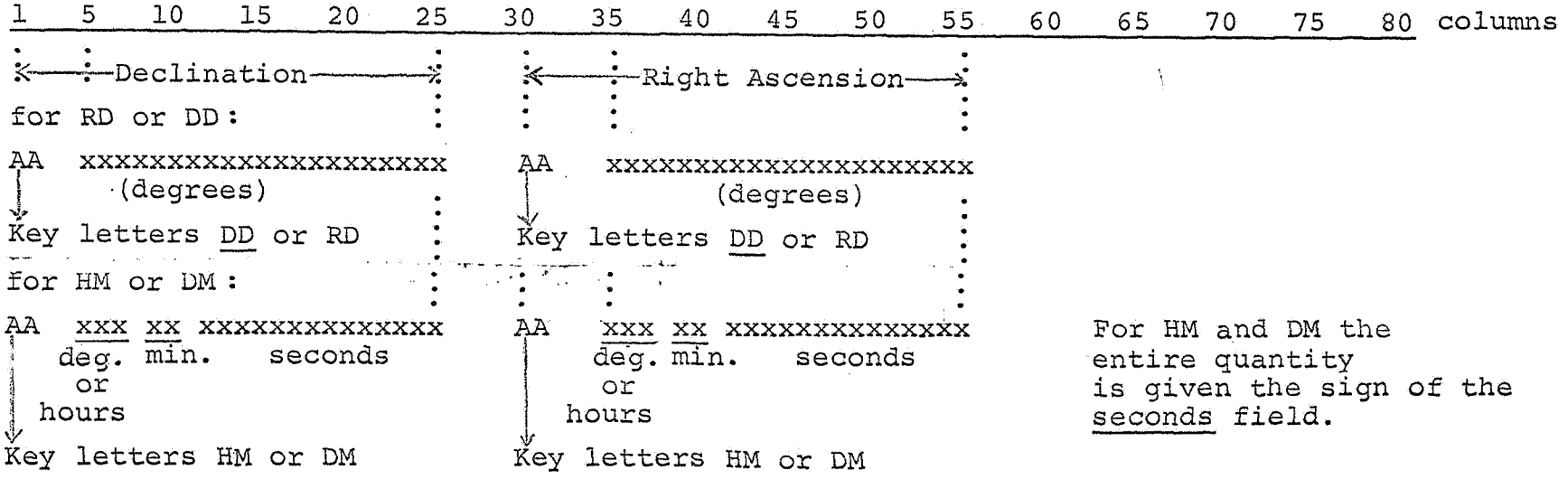
Figure 3 - Input Card Formats

Field definitions are indicated by x's. An underlined x denotes an integer which must be right justified in the field. A's indicate alphabetic information. All other fields are real numbers. Underlined data values denote the default options, e.g., a value of 1.0 is used for GRID when the field is blank. Maximum values are indicated when appropriate.

PARAMETER CARD:



CO-ORDINATE CARDS:



DELIMITER CARD: (First two asterisks are required.)

**AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

col 3: * denotes default plot label; blank denotes no plot label; otherwise, the 78 characters after the initial double asterisk appear on the printed and plotted output as a label.