RPHOT

AUTOMATED DATA ACQUISITION
AND REDUCTION SOFTWARE PACKAGE
FOR APERTURE PHOTOMETRY

USER'S MANUAL

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

SECTION 1.0

INTRODUCTION

RPHOT is a data acquisition and reduction package for aperture photometry written by Dr. Richard Nolthenius at Cabrillo College and Nolten Software. The package consists of a real-time data acquisition program, data reduction programs, and supporting utilities. The data-taking program DTAK will allow computer controlled filter positioning and data acquisition with the SSP-3A and SSP-5A photometers, computer controlled data acquisition for SSP-3 and SSP-5 photometers connected to the SSP3CARD. With any photometer, RPHOT allows computer controlled manual data logging and reductions with optional automated UT time logging.

The package is written in Lahey F77L version 4.01 Fortran and designed to run on an IBM compatible 8086 / 8088 / 80286 / 80386 / 80486 computer operating under MS-DOS or PC-DOS, either with or without an INTEL 80x87 mathchip (user's with Weitek mathchips can request a Weitek version). With this package, the user can efficiently log aperture photometry data and, within a few minutes, produce easy to read files containing reduced, standardized UBVRI or instrumental u,b,v,r,i,c magnitudes, as well as light curves, occultation plots, extinction / transformation regression plots, and periodograms. The operating interface is through the command line and keyboard (RPHOT release 2.0 does not use a graphical interface with menus, multiple windows, etc.). It is hoped that a menu and window environment can be incorporated into a future release.

As both an astronomer and teacher, I've found that talking in first person usually makes for a more readable and easily understandable presentation, and you'll see this style sprinkled throughout the manual. I recommend that you read this entire manual once, then re-read it again while at the computer. Running the programs while reading the descriptions is the fastest way to master RPHOT. To paraphrase a cliche, a screen-full is worth a thousand words! Also, be patient; some points need to be mentioned before they are more fully explained later.

In addition to the hardware requirements listed below, I assume that you have a basic familiarity with a PC and with DOS, and that you have some sort of editor which will permit you to examine and edit ASCII files. If you don't yet have an editor, I've found QEDIT to be excellent (using DOS's "edlin" is much too painful to consider); it's cheap ($60 or so), can be configured to look like your favorite (and much slower) word processor (Wordstar, WordPerfect, etc.), and has many nifty features. Call SemWare at (404) 641-9002 (in Georgia). Finally, I expect that you are familiar with the more basic ideas, methods, and terms of aperture photometry. This manual is not meant to be an introduction to the subject. Excellent texts such as Henden and Kaitchuck's "Astronomical Photometry" and Hall and Genet's "Photoelectric Photometry" are more appropriate starting points. They and several newer books are

available from Willman-Bell Publishing Co.

Upon first reading, RPHOT may seem intimidating to the novice photometrist, with all its options and terminology. RPHOT, however, is designed to be easy to USE, which unavoidably means it takes a bit more effort to LEARN. With the observing list and command line options now available, the new RPHOT is even easier to use. Data can be logged quickly, and an entire night can be converted into final output files and screen plot light curves in just a couple of minutes. This is compared with some less comprehensive and less versatile packages which may be easier to master, but require tedious reductions in a rigid format which soon proves limiting and tiresome. RPHOT is designed for photometrists of all levels.

Finally, some notes on terminology in this manual;

* "Program object" refers to any object whose light variations are being studied. This will often be a variable star, but could also be an asteroid, comet, quasar, etc. This is to be contrasted with comparison stars, check stars, and standard stars, which are NOT program objects.

* You will see the phrase "hit ENTER..." often in the manual. This refers to the carriage return or "ENTER" key on the keyboard. Do not type in the word "enter"!

* SOE is an abbreviation for "second order extinction", and FOE is an abbreviation for "first order extinction".

* Entries you will type in at the keyboard are generally presented in the manual in UPPERCASE, sometimes with double quotes. For example, program names, file names, sky and object names. The different modes in which the programs can be operated are generally given in lower case, e.g. "slowmode" or "logmode". Unlike some aspects of version 1.0, version 2.0 is entirely case insensitive. File names, star names, paths..., all entries can be entered in upper or lower case or a mixture. In some cases they will be converted to upper case before being logged into your files. If you edit your data files or catalogs by hand, you may change to lower case without fear.

1.1 VERSION 2.0 IMPROVEMENTS

Version 2.0 has been upgraded substantially. Check the READ.ME text file included on the ENVIRONMENT Distribution Disk for the latest improvements to your particular release. Here is a summary of the more important revisions...

--- PARMS now allows the user to customize the optimum delay loop length to be used during DTAK's calls to the SSP3CARD. This will enable more finely spaced sampling in time during "fastmode" events than was possible for version 1.0 users.

--- PARMS will now allow the user to explicitly specify the parameters of his graphics card for graphics cards which are not 100% compat-

ible with the CGA, EGA, VGA and Hercules standards. It also allows non-graphics card owners a graceful sidestep around the unpredictable results of trying to run graphics on such cards.

--- A new program OLIST will make a list of observing targets which can optionally be read by DTAK, automating object name entry at the keyboard when observing.

--- In addition to the standard 80 column screen format, DTAK can now be operated in 40 column format. For some observatories, it may be easier to read the output and instructions in this larger format.

--- DTAK will optionally do all filters on an object and/or sky without pausing until the filter set is done.

--- DTAK will now do up to 100 lines (400 integrations) at a time for single filter observations on any object, or for any filter set combination on non-program objects. (The limit is still 4 integrations per filter on multi-filter observations of program objects).

--- DTAK will output to the screen each integration as it comes in, rather than waiting for a full line of data to finish.

--- DTAK will now output one "fastmode" count per second to the screen, allowing the user to monitor occultation events entirely from the computer.

--- IREX will now process up to 1000 lines of raw data, instead of version 1.0's 700. TRANS will now process up to 120 extinction and transformation filtersets, up from 50 available in version 1.0. RPLOT will now plot up to 2000 points for all plot options.

--- Single filter photometry in all filters can now be reduced; RPHOT will now compute, store, and plot these as instrumental differential magnitudes in u,b,v,r,i, and "clear".

--- Multi-filter photometry in release 1.0 was automatically reduced to the Johnson system. You may now specify that such data, for any given star on a given night, be reduced to the instrumental system instead.

--- The following programs will now take command line specification of the input file names: DTAK, IREX, FREX, TRANS, RPLOT, TRIM, XJD, PSEARCH, ECBIN.

--- The following programs will now take command line arguments to answer most or all of the questions usually encountered during execution, permitting batch file processing; IREX, FREX, TRANS, RPLOT, ECBIN. These programs will also ask at the end if another file is to be processed, permitting "assembly line" processing of multiple sets of data.

--- IREX will supply a default output filename formed by appending a ".R" to the input filename.

--- IREX will now automatically search through your comparison star catalog COMP.CAT and, if possible, pair up variable / comparison / check combinations.

--- New extinction and transformation coefficients have been defined to solve for V using the V-I color index (as well as the traditional B-V and the version 1.0 option of V-R). This allows two-color Johnson photometry in I, and makes possible the definition of extinction coefficients for each color individually. This in turn allows the solution of instrumental differential magnitudes in all filters. Users can now do Johnson two-color photometry in UB, BV, VR, and VI.

--- The version 1.0 plot programs KPLOT, VPLOT, and OPLOT have been consolidated into a single program RPLOT.

--- RPLOT will now allow axis labels to be done in either text or graphics mode. A (now fully descriptive) y axis is given vertically.

--- The plot programs now have the option of using direct writes to video memory, which is faster than BIOS calls. Those machines requiring BIOS calls remain supported.

--- Users can now get high quality hardcopy output of their plots. This can be done either from within RPLOT and PSEARCH, or by first writing the hardcopy to a file and printing with the new utility HCOPY. Output can be directed to laser, PostScript, and most other popular printers, as well as .PCX files for importing to PC Paintbrush compatible software.

--- After viewing your RPLOT or PSEARCH plot, a small "clear screen" .COM routine is called to return to text mode and should preserve any color background in the user's set-up. In version 1.0, background color upon return defaulted to black.

--- Three new utility programs have been added;

* TRIM will take a final output file and make a new version which has had columns for unobserved filters and color indices removed; making a data file more suitable for submittal to publications.

* PSEARCH will perform a Jurkevich period search on data files in any color between any selected periods, and plot a periodogram to the screen.

* HCOPY takes printing files generated from your screen plots and, using AnSoft Inc.'s GrafPrint, will produce printed hardcopy or .PCX files, with customized margins, orientation, and resolution.

--- ADDSTAR will now add stars to VPERIOD.DAT as well as to the star catalogs, saving the user from having to use an editor for this task.

--- In version 1.0, users who modified any of the star catalogs or VPERIOD.DAT with an editor (rather than using ADDSTAR) had to be

sure to enter star names in capital letters. This is now no longer necessary. The entire package is insensitive to case.

--- Many minor cosmetic improvements have been made.

--- All observational files produced by version 1.0 can be processed by version 2.0 programs.

1.2 VERSION 1.0 CORRECTIONS

In the course of upgrading RPHOT, I have discovered a number of bugs in version 1.0. Most of these are minor and more an annoyance than anything else. However, bugs found in the TRANS's calculation of the V-R and V-I zero points on MODE=F or MODE=S nights actually affect the numerical magnitudes derived and are therefore more serious (These errors do not affect reductions on nights when the full extinction and transformation coefficients are calculated). The serious bugs are described first...

--- In TRANS, when solving for new zero points by backsubstitution (which is done on nights when transformation coefficients are not solved for, but instead only first and/or second order extinction is calculated; i.e. MODE='F' and MODE='S', not MODE='T'), the backsubstitution equation for the zero point for V using the V-R color index erroneously used the second order extinction coefficient for V using B-V, instead of the correct V-R. The resulting errors in V should be only on the order of .01 mag.

--- A similar error occurred in the solution of the V-I zero point. Also in the V-I zero point calculation; the UT used to evaluate the airmass was incorrectly calculated. The resulting error in the zero point, in most cases, will be a few hundredths of a magnitude. However, if an attempt is made to evaluate the airmass for a star erroneously thought to be below the horizon, a compiler generated error or widely erroneous V-I zero point could result.

--- In the V-R calculation, a term requiring the first order extinction coefficient in V-R inadvertently used the second order extinction coefficient. This could cause an error of up to .1 magnitude in the V-R zero point.

These bugs come into play unless one runs TRANS in mode 'F' or 'S'. Mode 'T' reductions were and are done correctly.

The less serious bugs are now described...

--- IREX is now more robust in it's handling of interpolating SKY's. In version 1.0, if even one filter did not have a valid SKY, the whole filterset was rejected. Now the test is done on each filter separately. This should make it easier to rearrange data taken out of order and still get reductions.

--- TRANS will now create COEFF.DAT if it has accidentally been deleted. In version 1.0 TRANS would fail to execute if COEFF.DAT was empty or had only one night of prior data.

--- VPLOT's plots in V-I were erroneously labeled with "V-R".

--- Some "slowmode" observations were tagged in DTAK with UT's which corresponded to the end of the observation interval, rather than the midpoint. This typically means a maximum error of 20 seconds, which does not significantly affect the calculation of airmass in the reductions. However, the error is systematic and so would slightly affect the derived times of minimum for eclipsing binaries.

--- FREX was intended to reduce single filter differential U, V and "clear" observations to produce instrumental magnitudes. In fact, it only did so for "clear". Version 2.0 produces differential instrumental u,b,v,r,i, and c magnitudes, and flags them as such on final reduced files. The user can now plot either Johnson, or instrumental magnitudes exclusively.

--- Version 1.0 TRANS would not do first order extinction in V unless B-V was available. Now this is not necessary; Either B-V, V-R, or V-I may be used as the color index in Johnson magnitude reductions.

--- XJD sometimes failed to add a dot "." before appending the "JD" extension to the transformed filename, if the input filename did not contain an extension.

Some of these bugs were found while working with a new, more extensive testing program. Version 2.0 was tested with the help of program ART, which takes assumed extinction/transformation coefficients and generates artificial data for cataloged stars. Using such assumed coefficients, Version 2.0 IREX, TRANS, and FREX reproduce Johnson magnitudes which agree with input values to better than .001 magnitudes (the limiting precision of stored values). Linear regression plots show zero scatter about the regression line.

1.3 PLANNED UPGRADES FOR THE FUTURE

1. AnSoft Inc. will be releasing a package designed to let users select a variety of fonts for their hardcopy plots. I hope to incorporate this in a later release of RPHOT.

2. AnSoft will also be releasing an upgrade to their GrafPrint (used in RPHOT) which will preserve hardcopy line thickness. In the current version, resolution of, for example, 300 dots per inch result in line thicknesses of 1/300 inch. This means that higher resolution must be traded off with heavy line thickness.

3. I also plan to modify many of the RPHOT executables so that the user interface includes menus and windows. The two plot programs cannot be so modified, however, since the Lahey Windows library is incompatible with their plot libraries. This project involves a lot of rewriting and will probably come out one program at a time, beginning with OLIST and DTAK.

SECTION 2.0

SYSTEM REQUIREMENTS

Math Co-Processor Support

Your computer need not have a math chip, but processing will be faster if you have one. The compiled code includes 8087/80287/80387/80487 emulation, so if you have one of these mathchips, your execution will be faster.

DOS 2.1 or later

Your computer must have DOS 2.1 or later.

500K RAM

Your computer must have at least 500K memory, and 640K is recommended. The largest memory requirement occurs when the RPHOT shell is running the largest single program, RPLOT, which in turn runs HCOPY and GP when plots are printed. DOS plus RPHOT plus RPLOT plus HCOPY plus GP plus the printer drivers and associated data files require about 500K of memory, for a typical large data file, and exclusive of any TSR's (like Sidekick, PRTSC, etc.) you may have. However, the RPHOT shell is not required for making full use of the package; it is included as a convenience for beginning users. Not using the RPHOT shell will save about 57K of memory.

Hard Disk Recommended

Your computer must have either a) a hard disk, or b) a hard disk plus 1 or more floppy drives, or c) two floppy drives. If you do not have a hard disk the floppy drives must be 720K or larger. Version 2.0 has grown, and RPHOT can no longer be run from dual 360K drive systems. Only hard disk owners will be able to run the package from the RPHOT shell. The package is easier to run from a harddisk.

SSP-3A/5A for Automatic Filter Selection

To use the automated filter positioning feature of DTAK you must have the SSP3CARD installed and the SSP-3A or SSP-5A photometer.

Any Standard Graphics Card

To use the screen plotting programs, you must have a graphics card running your monitor (e.g. CGA, EGA, Hercules, etc.). RPHOT will produce screen plots with virtually all standard graphics modes and graphics cards through the computer's BIOS calls. For Hercules Graphics Card systems, writes must always be done directly to video memory. Non-Hercules user's may also specify that all screen output be done through video memory writes. There's a chance it may not work on your machine, but it is significantly faster than BIOS calls.

Wide Range of Printer Support

To obtain hardcopy output, you will need a printer. It may be connected to either a serial or parallel port. RPHOT supports a wide range of popular printers, including dot matrix, laser, ink jet, and any printer running the Post-Script language. Quick, low resolution hardcopy is also possible with a screen dump, either through DOS 4.0's

PRTSC.COM Shareware

GRAPHICS.COM (not included), or through the included shareware utility PRTSC.COM. PRTSC.COM will produce screen dumps for all IBM compatible printers, as well as the EPSON series and HP Laserjet series printers. It is included free of charge. If you find it useful, please read the included PRTSC.DOC for information on how to register your copy with User Friendly Software for the very reasonable price of $10, which will include information on tailoring to your system. PRTSC works just like the DOS GRAPHICS.COM; it is a TSR which you execute before running RPHOT plot programs (or, better yet, put it in your AUTOEXEC.BAT file). Then, when viewing a plot you'd like to print, just hit the "print screen" key.

Incompatibilities

Users should note that the RPHOT graphics modes are not compatible with the Hummingboard adapter card.

SECTION 3.0

INSTALLATION

3.1 SETTING THE DOS ENVIRONMENT

AnSoft's program GP (see Appendix B.2) produces the printed versions of your plots. It is called from within the RPHOT plot programs, or may be run separately by HCOPY (as will be described in Appendix B.2). The parameters controlling the appearance of your plots are transmitted to GP in two ways; on the command line from within the RPHOT plot programs (for the parameters expected to change often), and by setting a DOS environment variable GRAFPRINT (for those parameters not expected to change often). RPHOT will ask you for the command line parameters in the normal course of operations, and you needn't worry about them right now.

Using the SET Command in AUTOEXEC.BAT

The DOS environment variable GRAFPRINT, however, must be explicitly typed by you, the user, into your AUTOEXEC.BAT file before you can get printed plots. Use your favorite editor to add the following line to your AUTOEXEC.BAT file...

```
SET GRAFPRINT=/T:C:\RPHOT /Q /P:1 /E:1
```

(See your DOS manual about the meaning of the SET command). This line sets four parameters needed by GP. The first parameter begins with "/T:" and is the directory on which you choose to store the printer and .PCX drivers included with the RPHOT package. In the example above, you will be storing them on drive C: in directory RPHOT. Choose whatever drive and directory you wish. The second and third parameters will never change and need not be discussed. The fourth parameter, /E:1, tells GP that you want it to use EMM extended memory, if it is available. If EMM extended memory is not available on your machine, that's ok; /E:1 is still appropriate. However, it is possible that using /E:1 will, in some network environments, cause your machine to lock up when attempting to get hardcopy. If this happens to you, you will want to tell GP to explicitly not use extended memory in its operations. You do this by instead substituting the parameter /E:0 above.

Use of Extended Memory

CONFIG.SYS Files Command

There is one other system change to make; the number of allowable files open at one time should be increased to 20. You do this by adding the following line in your CONFIG.SYS file...

```
FILES=20
```

(If you already have a FILES=XX specification where XX is greater than 20, then you need make no change).

"Out of Environment Space" error

After adding this SET command, you will need to re-boot your machine before it will take effect. If you are already using a lot of SET commands it is possible that this addition will cause an overflow of the DOS environment space (you'll see an error "out of environment space" during your re-boot). If this happens, see if you can eliminate some of your SET commands, or use the DOS "SHELL" command to increase your environment limits.

3.2 SOFTWARE INSTALLATION

Hard Disk Recommended

Installation of the RPHOT software package is fairly straight-forward. Simply copy the program files to your hard disk or working floppy disks and transfer the copy protection to the new media (see Appendix D). A hard disk is strongly recommended and installation can be accomplished using the INSTALL.BAT batch file provided on the ENVIRONMENT Distribution Disk .

The observed data files you produce can be written to either the hard disk (in the same or a different directory as the RPHOT files) or to the floppy disk. You make this choice later, when running PARMS. Note that you do not need all of the printer drivers (the .DRV files), only those corresponding to your printer and .PCX format.

3.2.1 Hard Disk Systems

Hard Disk Installation

If you are installing RPHOT onto a hard disk, create a directory on the hard disk using whatever naming convention you are comfortable with. (We will use C:\FOT for this example.) You may refer to your DOS manual if you are unsure about creating subdirectories or simply log on to drive C:\ and type:

```
>MD FOT
```

Next you will insert the ENVIRONMENT Distribution Disk into drive A: and type the following (note the last space between the destination drive and the path name)

```
>INSTALL FROM A: TO C: \FOT
```

Using the INSTALL Batch File

INSTALL.BAT will then copy all the files on the ENVIRONMENT disk to the hard disk, change directory to C:\FOT (in this example), and call a second batch file INSTALL2.BAT from the hard drive.

INSTALL2.BAT will prompt you to insert each Distribution Disk in succession and will copy all files and transfer copy protection to the hard disk. You may perform the installation manually by simply copying all files from the Distribution Disks to the hard disk and then running the

Using the TRANSFER Program

TRANSFER.COM program (from the hard disk) with the following command:

```
>TRANSFER FROM A: TO C:
```

This step must be repeated for each Distribution Disk containing copy protected programs. Refer to Appendix D for a listing of the copy protected programs and additional information regarding the copy protection.

3.2.2 Dual Floppy Systems

720 or High Density Floppies Required

It was possible, though tedious, to run RPHOT version 1.0 from dual 360K drive systems. Version 2.0 (due, in particular, the new hardcopy capability) is larger, and RPHOT now requires that both drives be either 720K, 1.2M, or 1.44M. Copy the files to diskettes as shown below.

*** Important note: Note that your disks are not "write-locked", since your parameter files are on these disks and must be update-able. Don't put a write-protect tab on your working disks!

Data Taking Disk

Label your first diskette "#1 DATA TAKING" and copy onto it the following ...

```
DTAK.EXE    DPARMS.DAT  OLIST.EXE
```

Reduction Disk

Label a second diskette "#2 REDUCTION" and copy onto it the following...

```
IREX.EXE    I.BAT       RPARMS.DAT  TRANS.EXE
T.BAT       FREX.EXE    F.BAT       COEFF.DAT
ASTAR.CAT   SOE.CAT     FOE.CAT     COMP.CAT
VAR.CAT
```

Plot Disk

Label a third diskette "#3 PLOT" and copy onto it the following...

```
RPLOT.EXE   PPARMS.DAT  VPERIOD.DAT PSEARCH.EXE
PRTSC.COM   PRTSC.DOC   HCOPY.EXE   GP.EXE
GPRINT.BIN  P.BAT       ppp.DRV     PCXxxx.DRV
EPS.BIN (PostScript printer owners only)
```

If you have a printer equipped with PostScript, then you should also include the encapsulated postscript driver file EPS.BIN. The file "ppp.DRV" is the printer driver corresponding to your printer, and "PCXxxx.DRV" is the .PCX file driver corresponding to your graphics card/monitor. Section 5.3.1 on PARMS describes the supported printers and PCX formats.

Utilities Disk

Label a fourth diskette "#4 UTILITIES" and copy onto it the following...

PARMS.EXE	F77L.EER	XJD.EXE	E.BAT
JDAY.EXE	AIR.EXE	TRIM.EXE	ADDSTAR.EXE
ECBIN.EXE	EC1.DAT	EC2.DAT	EC3.DAT
EC4.DAT			

Sample Data Disk

Finally, copy the following files onto a fifth diskette and label it "#5 SAMPLE DATA"....

RAW1	RAW2	RAW3	OCC1
RED1	RED2	RED3	BS-6469.DAT
BS-6902.DAT	YY-ERI.DAT	KBVPP1.DAT	KVPP1.DAT
KRRPP1.DAT	KVRPP1.DAT	KBVP.DAT	KVP.DAT
KVRP.DAT	EPS.DAT	MU.DAT	TAU.DAT

High Density Disks

These assignments assume 720K drives (the smallest acceptable drive). If you have one or two higher density floppy drives, you will probably want to move ADDSTAR.EXE onto the #2 REDUCTIONS diskette, since ADDSTAR operates on the star catalogs. Note that the shell environment program RPHOT.EXE does not appear in your working diskettes. This is because dual floppy owners without harddrives cannot use the RPHOT shell; You MUST have all files loaded onto a single directory or subdirectory of a harddisk to use the RPHOT shell.

Special Note

If the installation to working floppy disks seems somewhat intimidating, feel free to call Optec for technical support.

3.3 SSP3CARD INSTALLATION

Refer to SSP3CARD Technical Manual

Installation of the software is now complete. Read the relevant sections in the SSP3CARD manual for installing the SSP3CARD into an open slot of your computer. You can set the divide jumper to any value you want, but "4" is a good value which will allow negligible round-off error for integration times larger than .01 second. The interrupt level jumper on the SSP3CARD should be set to the "X" position. RPHOT does not use the keyboard interrupt method of control. Once these two jumpers are set, you are ready to insert the SSP3CARD into your computer and connect the appropriate cable. You must determine which I/O ports are available to your computer for communicating with the SSP3CARD. Independent vendors have software which will do a check-out of your system and give you this information (e.g. "System Sleuth"), or you can check your IBM technical reference manual. Typically, a 7 address block of memory beginning at address= 768 (=300 HEX) is available on PC's for "prototype boards". However, YOU MUST be sure this memory space is available and not being used by other peripherals. Otherwise, there is a small but theoretical chance you may damage your hardware! This address starting point will be input into RPHOT's data taking parameter file later (see Section 5.0 below).

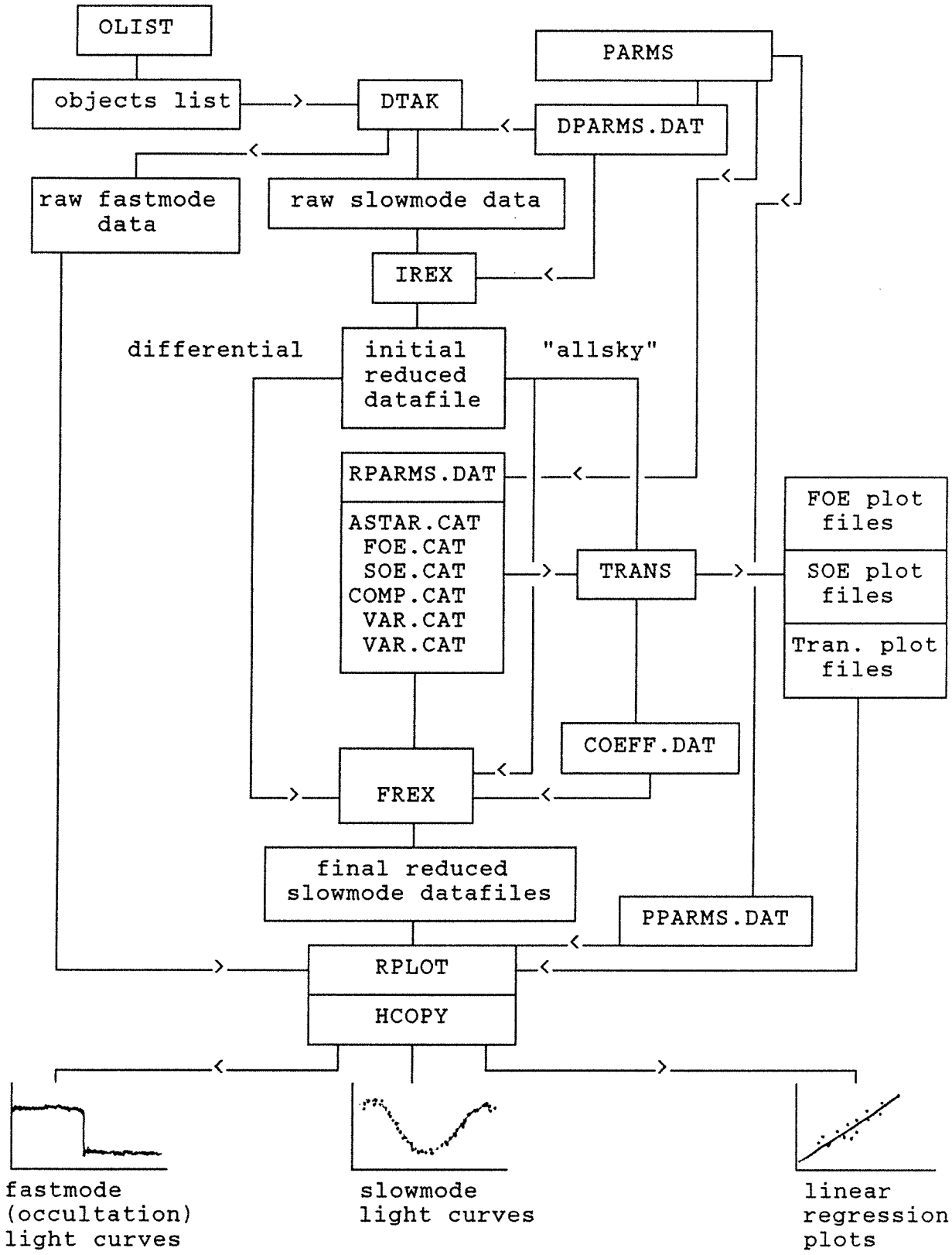

Figure 4-1. RPHOT Flowchart.

SECTION 4.0

OVERVIEW OF RPHOT PROGRAMS

4.1 THE RPHOT SHELL

RPHOT.EXE Shell Program

Within the RPHOT package there is an executable program called RPHOT.EXE. This is a rudimentary shell from which all of the principle data taking and reduction programs can be run. It is meant more as a learning device, since it adds time and overhead, and will only execute the other programs once and only in the normal order in which they are used. Also, it is only possible for the RPHOT shell to access all of the RPHOT programs from a hard disk. After becoming familiar with the package, you will probably want to run each program directly from the DOS prompt. To run from the RPHOT shell, type

>RPHOT

at the DOS prompt and RPHOT will help you run each data acquisition and reduction program in the normal order they will be executed.

4.2 PROGRAM FLOWCHART

PARMS.EXE

Refer to Figure 4-1 during this description. You begin by running PARMS, which queries you for relevant parameters of your observatory and photometer. These are stored into files DPARMS.DAT, RPARMS.DAT, and PPARMS.DAT, which are read by the data taking and reduction programs. Many of these parameters you will set once and never change, and you will rarely need to run PARMS after this first time.

OLIST.EXE

Next, if you desire to take data from a pre-determined schedule of observing targets, you run OLIST, which produces a list of names of objects and the catalogs they will be found. This can then be read by the data-taking program DTAK.

DTAK.EXE

Next run DTAK while at the telescope. This produces a data file of your objects, counts, filters, UT's, gain scales, comments, etc.

IREX.EXE

Next run IREX, which does initial reductions on this data and puts it into a form easily digestible to the final reduction programs. Each and every object you observe must first be entered into one of 5 catalogs (included with the package) before they can be reduced. You need not catalog them before running IREX, but things will go faster if you do. The exception is for moving objects such as asteroids or comets. Moving objects need not be cataloged.

TRANS.EXE

Next you have a decision; if you want to calculate transformation and/or first and/or second order extinction coefficients from your data, run TRANS. This produces new extinction/transformation coefficients which are appended to the file COEFF.DAT. TRANS also produces a set of files which are input for RPLOT, which will plot to the screen the points and linear regression lines for any of your extinction/transformation coefficients and zero points. If you are only doing differential photometry, and prefer not to calculate new first order extinction coefficients, then skip TRANS.

FREX.EXE

Next run FREX. FREX reads the file output by IREX, as well as the new extinction/transformation coefficients, and produces final magnitudes and colors. These are output to separate files; one for each object you observed that night.

RPLOT.EXE

Next, you may want to run RPLOT and ask for the "slowmode" option. This produces a light curve to the screen for any chosen object, in any color, for any chosen interval of time. You may also ask for the "fastmode" option, which will plot either of two different versions of counts vs. time for a "fastmode" (e.g. an occultation) event logged by DTAK.

HCOPY.EXE

After viewing your plot, you will be asked if you want a printed version. RPLOT can run the utility HCOPY to accomplish this. A quick, low resolution screen dump can also be done by simply hitting the "print screen" key (if you've installed the included PRTSC.COM, or similar screen dump TSR.

4.3 THE STAR CATALOGS

ADDSTAR to update catalogs

Before reductions can be done, all observed stars must first be logged into one of the catalogs below by running ADDSTAR (easiest), or by using your favorite editor. You needn't include magnitudes which don't involve filters which you will never use; just leave those columns blank. (There is one exception; if you do UB photometry, you must enter U, B, and V for all standard or comparison stars, since U is calculated by adding (U-B)+(B-V)+V). You need not enter any standard magnitudes when adding variable stars to the variable star catalog.

4.3.1 ASTAR.CAT

UBVRI Standards (B-V ≈ V-R)

The ASTAR.CAT catalog contains UBVRI standard stars with B-V = V-R < .06 magnitude. These are typically stars of spectral type early A or late B, hence the catalog name. These stars are needed for determining first order extinction coefficients when your transformation coefficients are unknown (see Henden and Kaitchuck p. 314 for an explanation why). Note that ASTAR.CAT is an extracted subset of

FOE.CAT; no stars are in both catalogs. If you add new standard stars, put B-V = V-R < .06 stars into ASTAR.CAT. ASTAR.CAT stars will be used for first order extinction even if transformation coefficients are known. They are also used for finding transformation coefficients. Most of these stars were taken from the "Astronomical Almanac", but in regions of the sky not well sampled, some stars from the Arizona-Tonanzintla Catalog have been added.

4.3.2 FOE.CAT

First Order Ext. Stars

The FOE.CAT catalog contains UBVRI standard stars of all colors (except those with B-V = V-R < .06). These are used for finding first order extinction coefficients, transformation coefficients and zero points. Virtually all of these stars are true standards taken from the "Astronomical Almanac".

4.3.3 SOE.CAT

Second Order Ext. Stars (Red-Blue Stds.)

The SOE.CAT catalog contains red-blue pairs of stars from various sources. These are used for finding second order extinction coefficients. Close, bright, nonvariable red-blue pairs are hard to find and two sources have been used for this compilation; the Arizona-Tonanzintla Catalog for bright pairs (V brighter than 6, labeled with Yale Bright Star Catalog (BS) numbers, and Barnes and Moffatt's red-blue standards (V = 6 to 9, labeled with Henry Draper Catalog (HD) numbers; see Publ. Astr. Soc. Pacific 91,290 [1979]). These latter probably have more reliable magnitudes and are more certain of being non-variable, but may be too faint for small telescopes. If you are only planning on observing in UBV, you may want to add the standards given in table B.1 in Henden and Kaitchuck. Some of these are bright and easy in all telescopes. Feel free to delete stars or add stars from other sources.

4.3.4 COMP.CAT

Comparison and Check Stars

The COMP.CAT catalog contains comparison stars and check stars used for differential photometry of your program objects. This is a file you will actively update as you add stars to your observing program. You need not enter standard magnitudes if you are only interested in magnitudes differences between variable and comparison.

Change for Version 2.0

*** IMPORTANT NOTE TO VERSION 1.0 USERS: Version 2.0's COMP.CAT differs slightly from version 1.0's; there is now an additional column after the spectral type; containing either a "C", "K" or blank. This is to indicate that this star is being used as a comparison star, check star, or neither (or sometimes both), respectively. This new feature allows automated pairing of variables and comparison/checks in

differential photometry. If you want to make use of this new feature, you must modify your version 1.0 COMP.CAT to include this new column, and be sure the next column (specifying the associated variable star) has exactly the same name as is shown in VAR.CAT. If you don't modify COMP.CAT, IREX will still work, but it will ask you to do the pairings explicitly, as in version 1.0.

4.3.5 VAR.CAT

Program Variable Stars

The VAR.CAT catalog contains your program variable stars. This, too, is a file you will actively update as you add new stars to your program. You need not enter standard magnitudes for these stars.

Some of the standard stars could be found in more than one source. The following priorities for adopting data have been followed; The Astronomical Almanac, if possible, then Moffatt and Barnes PASP 91, 180 (1979) if possible, then Arizona Tonanzintla Catalog (Sky and Telescope July 1965). Stars with only one observation, those flagged as possibly variable or uncertain, and some close doubles have been weeded out. Still, most of the Arizona Tonanzintla stars are not bonafide primary standards. Also, some may have companions close and bright enough to be unusable for some photometers; most have not been field checked. So, user beware!

Catalog Contents

Each of these catalogs contains the star's name, RA and DEC and associated epoch, and the standard V magnitude and colors (except for VAR.CAT, where magnitudes are not needed). The columns at far right (spectral type, source of data, notes) are purely for your information and are not read by the programs. COMP.CAT has an additional two columns at right; whether it is used as a comparison star or as a check star, and the name of its associated variable star. IREX will search for each of your objects and make sure it is in the catalog you said it would be in. If not, it will tell you so and stop execution.

SECTION 5.0

SYSTEM PARAMETERS

If this is your second reading of this manual, this is where you'll want to begin "learning by doing" at the computer. Take out the diskettes and get them installed (see the "Installation" section), and prepare to run program PARMS.

Parameter Data Files

RPHOT needs to know some items about your observatory, computer, and photometer in order to reduce your data. These parameters are put into the three ascii files DPARMS.DAT, RPARMS.DAT, and PPARMS.DAT. Why not just one parameter file? Those without hard disks must keep their data taking, reduction, and plotting programs on separate diskettes.

Hard disk owners who have put all RPHOT programs into one directory can either run PARMS directly, or set these parameters by running from the command shell. If you prefer the latter, type

```
>RPHOT
```

at the DOS prompt. The RPHOT shell will then ask if you need to modify your parameter files, to which you answer (Y)es. It will then execute program PARMS. You may instead choose to run PARMS directly, as described below. PARMS updates each of the three parameter files.

5.1 DATA TAKING PARAMETERS

For dual floppy systems, put the disk containing PARMS.EXE into drive a:, put your DATA TAKING diskette into drive b: and you are ready to modify DPARMS.DAT. When finished with DPARMS.DAT, swap out the DATA TAKING diskette and insert the REDUCTIONS diskette and update RPARMS.DAT. Finally, swap out the REDUCTIONS diskette and insert the PLOT diskette in order to update PPARMS.DAT. To begin, from the a: drive, type at the DOS prompt...

```
>PARMS
```

and answer (Y)es at the query "Modify DPARMS.DAT?". Note that the version 2.0 DPARMS.DAT has a new, additional line of information (the first question; the screen format for DTAK), so those upgrading from version 1.0 will have to run PARMS to upgrade their DPARMS.DAT.

Notes about Defaults

As in all RPHOT programs, most queries include a default in angle brackets < >. If you want to stick with the default, just hit the ENTER key (If you don't see angle brackets,

```
******* DPARMS.DAT - CONTAINS YOUR PHOTOMETER'S DATA-TAKING PARAMETERS *******
 DTAK screen width, in columns        80
 Photometer/computer/cabling set-up   A
 I/O Port Address (e.g. 768)          768
 SSP3CARD divide jumper setting       4
 Computer bus speed, in Mhz           12
 Optimum SSP3CARD delay loop length   201
 Optimum SSPFLTR delay loop length    2905
 DOS path to raw data output files    C:\FOT\DAT
 DOS path to intermediate data files C:\FOT\DAT
 dead-time coefficient (in seconds)   0
 U filter is in slot number.....0
 B filter is in slot number.....1
 V filter is in slot number.....2
 R filter is in slot number.....3
 I filter is in slot number.....4
 C filter is in slot number.....5
 No. of gain settings (DC photometers)= 3
 for gain scale=1      GAIN CALIBRATION=100.
 for gain scale=10     GAIN CALIBRATION=10.
 for gain scale=100    GAIN CALIBRATION=1.
```

Figure 5-1. Listing of DPARMS.DAT Data Taking Parameter File.

then hitting the ENTER key may do nothing; the program may wait patiently until you enter a value).

MODE 40 Screen Format

First, you'll be asked which screen format you prefer while running DTAK. The screen can be set to show either 40 "fat" characters across your screen, or the more standard 80 characters. In a dark observatory with the operator shuttling between telescope and computer, it may be easier to read the screen in the 40 column mode.

SSP3CARD Settings

Next, PARMS will ask you 3 questions related to your computer and SSP3CARD. The first question is the address (expressed in base 10) of the I/O port used by the SSP3CARD. You must answer this correctly, or you may (very slight chance) cause damage to your machine! See the SSP3CARD manual. Next, PARMS asks for the position of the divide jumper on the SSP3CARD (1,2,4,8, or 16) and the speed of your computer's bus, in megahertz (this is NOT necessarily the same as the clock speed of the CPU on the motherboard. See your technical manual for this number. For standard IBM PC's, it is 4.77273). This frequency is used in setting the integration times, so if this number is entered incorrectly, your integration times will not be correct. For example, if you have a 10 Mhz bus speed but enter 20 instead, your integration times will end up being twice as long as you expected. If you don't know your PC's bus speed, you can get a reasonable approximation by going backwards; try assuming the bus speed is the same as the clock speed, then hook up your photometer and take data

Set for computer bus speed

requires that a delay be inserted in the code which toggles the stepper motor, and the length of the delay depends on the speed of your computer. Be sure the SSP3CARD is installed and connected to the photometer before you proceed. PARMS will then drive the filter slider back and forth twice and time how long this takes, then calculate the corresponding delay length needed to achieve 2.25 filter positions per second with your system. Unlike the procedure for determining CDELAY, this procedure is automatic. Just sit back and watch it happen!

Dead-Time Coefficient

Next you'll be asked for your dead-time coefficient. For SSP users and other DC photometer systems which have no dead time correction, enter "0" (which is also the default value).

Filter Order

Next, you'll be asked for the positions of each of your filters. (This is relevant only for SSP-3A or SSP-5A users, who will be using DTAK for data taking. For others, it doesn't matter what you enter here, so skip thru it.) The SSP-3A and 5A filter sliders have 6 or 10 positions. These are positions 1 thru 10 going from left to right as seen by someone standing in back of the photometer (i.e. with the round aperture facing away from you). So, if your U filter is in the far left end, you answer that it is in slot "1", etc. In version 2.0, this is now a 2 digit number, to accommodate the new 10 position filter slider now available from Optec.

Gain Settings

Next you'll be asked for the number of gain calibration settings on your photometer. The SSP has 3; the "1", "10", and "100" scales. For each of your scales, you'll be asked for the name of the scale (i.e. "1","10","100" for SSP users) and for the calibration of that scale. The name of the scale must be the same as what you'll enter when asked for "scale?" inside DTAK. The gain calibration is defined as follows: Let x be the gain calibration for a given scale, C be counts taken on that scale. Then the goal is for xC to be on the same relative scale (Ideally, the scale with the most digits) for all data. For example, SSP users would enter "100.0" for the gain calibration of the "1" scale, since this is what "1" scale counts need to be multiplied by to make them equivalent to data taken on the "100" scale (the most sensitive scale). Similarly, the gain for the "10" scale should be 10.0, and the gain for the "100" scale should be 1.0. If you have some way of calibrating the different scales on your particular photometer (e.g. with an accurately nonvarying light source), then these entries allow you to use your actual calibrations instead of the preset values. Note that in the real world, these calibrations will never be perfect and unvarying. It is therefore good photometric practice to observe all objects which will be inter-compared on the same gain scale. Then the exact value of these calibrations in unimportant; if you plan to do your observing this way, SSP owners can stay with the standard 1, 10, 100 calibrations already entered.

```
**** RPARMS.DAT - CONTAINS DATA REDUCTION PARAMETERS FOR YOUR OBSERVATORY ***
 DOS PATH TO INTERMEDIATE DATA FILES;   C:\FOT\DAT
 PATH TO FINAL REDUCED DATA FILES;      C:\FOT\DAT
 VAR FILE HEADER=CABRILLO OBSERVATORY  SSP-3A
 PREFERRED INDEX FOR V CALCULATIONS;    VR
 LONGITUDE (+WEST, -EAST, IN DEGREES)=  121.92
 LATITUDE (+NORTH, -SOUTH, IN DEGREES)= 36.98
 FIRST ORDER EXT. IN U     ; KUP=        .24
 FIRST ORDER EXT. IN VISUAL; KVP=        .196
 FIRST ORDER EXT. IN U-B; KUBP=          .25
 FIRST ORDER EXT. IN B-V; KBVP=          .225
 FIRST ORDER EXT. IN V-R; KVRP=          .066
 FIRST ORDER EXT. IN V-I; KVIP=          .102
 SECOND ORDER EXT. IN U     ; KUPP=     .001
 SECOND ORDER EXT. IN V (on b-v); KVPP= .028
 SECOND ORDER EXT. IN V (on v-r); KRRPP=.000
 SECOND ORDER EXT. IN V (on v-i); KIIPP=.000
 SECOND ORDER EXT. IN U-B; KUBPP=       -.03
 SECOND ORDER EXT. IN B-V; KBVPP=       -.037
 SECOND ORDER EXT. IN V-R; KVRPP=        .007
 SECOND ORDER EXT. IN V-I; KVIPP=        .007
 TRANSFORMATION COEFF. FOR U; EPSILONU= -.05
 TRANS. COEFF. FOR V (on b-v); EPSILON=  .000
 TRANS. COEFF. FOR V (on v-r); EPSILONR=-.070
 TRANS. COEFF. FOR V (on v-i); EPSILONI=-.038
 TRANSFORMATION COEFF. FOR U-B; PSI=    1.0
 MOFFATT/VOGT TRAN. COEFF. FOR U-B; RHO=.02
 TRANSFORMATION COEFF. FOR B-V; MU=     1.036
 TRANSFORMATION COEFF. FOR V-R; TAU=    1.082
 TRANSFORMATION COEFF. FOR V-I; ETA=    1.050
```

Figure 5-2. Listing of RPARMS.DAT Data Reduction Parameter File.

5.2 DATA REDUCTION PARAMETERS

RPARMS.DAT Reduction Parameters

When DPARMS.DAT has been written, you'll be asked if you want to modify your data reduction parameters file RPARMS.DAT. (Dual floppy disk owners should now swap out the DATA TAKING diskette and insert the REDUCTIONS diskette. Then...). Answer (Y)es. You will then be queried for the following items;

Header Info

A. A header to appear at the top of your data sheets (for example; observatory name, photometer name, or whatever you like).

B-V or V-R Color Index

B. Your preferred color index to use in V calculations. V magnitudes are traditionally calculated using extinction and transformation coefficients based on the B-V color index (see appendix A or any good book on photometry). However, one can just as well define analogous relations using the V-R or V-I color indices. For SSP-3 users, V-R may be

preferred, since the photometer is more sensitive to R light than B light, and hence the signal to noise may be expected to be better. The reduction programs will use whichever is available, but for stars which have B, V, and R or I observations, you have the option of specifying whichever you prefer. In general, SSP-3 or other photodiode photometer users should specify the "VR" index, SSP-5 or other PMT photometer users will probably prefer the "BV" index.

Observatory Location

C. Your longitude and latitude. (Enter east longitudes and south latitudes with a minus sign, in degrees and decimals)

Default Ext/Trans Coefficients

D. Default or long term average values of your extinction and transformation coefficients (if you don't have any idea what these should be yet, just use the ones already given until you've determined your own. They were determined on an SSP-3A with a Meade 10" Schmidt-Cassegrain). You may not have all of the filters requested. That's ok...if you don't have them, then it doesn't matter what you enter for default coefficients. These coefficients can be used to improve your differential photometry. When doing final reductions (described later), you can also treat these as long term average coefficients and use them in place of your most recently determined coefficients.

5.3 PLOTTING PARAMETERS

PPARMS.DAT Plot Parameters

When RPARMS.DAT has been written, PARMS will ask if you want to modify your plotting parameters file PPARMS.DAT, which contains information needed for doing light curves, extinction plots, occultation traces, and hardcopy.

Video Graphics Card

PARMS will first ask you to specify your video graphics card adapter. You enter a mode number (shown on your screen on the left). The Lahey graphics software can automatically detect standard CGA, EGA, VGA (and 100% compatible) card parameters. In this case, you may specify mode=0. Many non-standard cards are "compatable enough" (in Lahey's words) with one of the standard cards that graphics is still possible. In this case, you need to explicitly specify which card you are most compatible with. The allowable possibilities follow under "non-standard". Lahey graphics will also work with Hercules monochrome cards; in this case, writes are always done directly to video memory and require a mode=99 reply here. No graphics is possible (for ANY software!) with "monochrome" (non-graphics) cards. In this case, specify a mode of "98" and you will skip over the later graphics questions in PARMS; and don't plan on running RPLOT or PSEARCH!. You should note that Lahey's technical staff has had trouble achieving compatability with SuperVGA, and their manual gives the following recipe for operating with extended resolution VGA graphics cards: Specify mode = 0 here. Then, after leaving PARMS, add a line to your AUTOEXEC.BAT file which looks like this...

Monochrome Cards

```
*************** PPARMS.DAT - CONTAINS PLOTTING PARAMETERS ************
Monitor/graphics card=                  0
DOS path to raw data files =            C:\FOT
DOS path to intermediate data files =
DOS path to final, reduced data files= C:\FOT
Graphics mode (video mem. or BIOS);     V
Screen plots will be in pen color =     14
Printed plots will be in pen color =     8
Transform x to column no.:   scale=        7.2701  zero pt=   -0.4155
Transform y to row no.:      scale=       -2.9453  zero pt=   24.6213
Printer port device name=               PRN
Page format (landscape/portrait)=       LANDSCAPE
Printer no. and type=                    1 EPFX
.PCX file format no. and screen type=    2 PCXCOLOR
Print resolution: 0,1,2,3               0
Use extended memory if available (y,n) Y
Page top margin (hundredths of inches) 150
Page bottom margin (hundredths inches) 150
Page left margin (hundredths inches)   100
Page right margin (hundredths inches)  100
```

Figure 5-3. Listing of PPARMS.DAT Plotting Parameter File.

LPLOT Environment Variable

```
SET LPLOT=HH,XXXX,YYYY,CCC
```

where,

HH= the value of the hexidecimal number required by your card to initialize the BIOS mode (study the documentation on your video card to find this number!).

XXXX= the number of pixels on your monitor in the horizontal direction,

YYYY= the number of pixels in the vertical direction,

For example, standard SuperVGA has XXXX=800 by YYYY=600 pixels.

Path to Raw Data Files

You'll then be asked to enter the DOS path names to your raw data (in particular, the "fastmode" output produced by DTAK), your extinction/transformation plot data (produced by TRANS), and your "slowmode" plot data (produced by FREX), respectively. For example, if you are logged into drive A: and your data disk will reside in drive B: in the directory DATA, then you would answer the PATH? queries with

```
B:\DATA
```

In this example, if the data is instead in the root directory, you just answer with "B:". (Version 1.0 users should note that RPHOT's non-standard convention of asking for a trailing backslash to terminate the path has been abandoned in version 2.0).

Direct Video Writes vs. BIOS Calls

Next is a new feature added with version 2.0; Users may now ask that all graphics screen output be done as direct writes to video memory. This is much faster than using BIOS calls. The trade-off is this: some machines may not work properly since paging conventions differ. My advice is, try specifying the faster (V)ideo writes. If it doesn't work, go back and run PARMS again and specify (B)IOS calls.

Next, the screen goes into graphics mode. (If it doesn't, you may not have a "compatible" enough monitor/graphics card and graphics plots may not be possible with your current card. Get a 100% compatible CGA, EGA, VGA, or Hercules card). You will see a column of text; "PEN COLOR= 1", etc., for all colors 1-16. You are then asked for the number corresponding to the color in which you want to see your plots drawn (always on a black background). After anwering, you'll see an identical question for printed plots. If you have a black and white printer, any color value other than zero will work. If you have a color printer, to get black ink you must specify your color value for black. Drawing with the color white, while looking fine on screen, will give you a blank printed page! If you find your printer working busily producing a page and there is no error message anywhere, yet the page is blank, this may be the problem... try using different pen colors.

Graphics Transformation Procedure Explained

The next procedure requires a bit of explanation. Lahey 4.0 FORTRAN graphics has the option of using text mode to label plots. The advantage is that it looks cleaner and nicer. The disadvantage is that text positioning is coarser and consecutive numbers along an axis may "jump" (you'll know what we mean after looking at a few plots). Coordinates for inserting text are in row and column numbers, rather than the x,y inches used in specifying graphics. What is needed inside the plot programs is a way of transforming back and forth from row, line coordinates to x,y inches. The goal is for RPHOT to run on the widest possible range of graphics card/monitor/computer combinations, all of which require different transformations. The safest solution to this dilemma is to allow the user to spend 30 seconds and determine this transformation for his system. Here's how this is accomplished; After you've read a similar intro to this on the screen, hit "ENTER". PARMS will produce a grid of x coordinate lines, each line separated by .1 screen coordinate units (approximately inches). Round number coordinates (i.e. 1,2,3,4...10) are shown as slightly extended and in different shade or color. In addition, 1,2,3,8, and 9 are labeled explicitly. On this same grid, across the center of the screen, is text-mode column numbers, running from

column 0 up to 63. Only the last digit of these column numbers is plotted, and every 10th column is labeled "-". Some monitors (e.g. CGA) only allow 40 characters across, so that columns 40-63 are wrapped down to the next line. Ignore this wrapped down line; it is not usable for our purposes. Your goal is simple; use the x grid to estimate as carefully as you can (i.e. to .02 inch precision) the center of two arbitrary but widely separated text mode column numbers. For example, on most CGA screens column number 3 is centered on x coordinate 0.91, and column number 36 is at x=9.98. Write down the corresponding two pair of coordinates for your screen, and hit return. When requested, enter the column and corresponding x coordinate for your first point, then for your second point, as instructed. Then follows an exactly analogous procedure for the y direction. Note that row numbers run from the top down, while y screen graphics coordinates run from the bottom up. Again for CGA monitors, row 22 is centered on y=0.90, row 1 on y=8.02. Hit "return" and enter your numbers. PPARMS then calculates the scale and zero points for transforming the coordinates, in the form

Coordinate Transformation Calculation

column no. = xscale * x + xzero

row no. = yscale * y + yzero

These are automatically entered onto PPARMS.DAT, and you are now set up for doing screen plots with the text mode option for labeling. If, when you do your plots, you notice that axis labels are appearing in some strange location, you probably did this little exercise incorrectly, and you should re-run PARMS. Notice that row / column positioning is coarser than the monitor's resolution. As a consequence, tick labels are not always perfectly centered on the ticks. This cosmetic defect can be remedied within the plot programs by asking for graphics mode labeling.

5.3.1 Setting Parameters for Hardcopy

Hardcopy Plot Parameters

The last set of questions set the parameters needed to obtain printed hardcopy of your plots. First you are asked for the DOS reserved name for the printer port your printer is connected to. If you have only one printer, this is probably PRN or LPT1 for a parallel printer. It may be COM1 or COM2 if using a serial printer.

Landscape or Portrait mode

Next you are asked whether you want your hardcopy printed in (L)andscape or (P)ortrait orientation. Answer with "L" or "P".

Next you specify your printer. RPHOT comes with a list of printer drivers which are used to tell the printer how to print your plot. Each printer has it's own conventions and a different driver is needed for each. Like most modern soft-

Select Printer Driver

ware, RPHOT uses drivers which are installed at run time (rather than in CONFIG.SYS), to save memory and file size. The list below certainly does not include every printer ever made, but it does include the standard printers; nearly all printers will emulate one of those below. The "low resolution" Epson LQ drivers EPLQLO.DRV AND EPLQLOWC.DRV may be puzzling. They can be used if (for some strange reason) one wants his Epson LQ printer to produce output which looks like the lower quality output from the FX/MX series. The list of supported printers (also shown on screen when running PARMS) is shown in Figure 5-4.

```
PRINTER DRIVER                    PRINTER

CITGSX14.DRV.....................Citizen GSX 140
CITMSP10.DRV.....................Citizen MSP 10
CITMSP15.DRV.....................Citizen MSP 15
EPFX.DRV.........................Epson FX/MX
EPFXWC.DRV.......................Epson FX/MX wide carriage
EPLQ.DRV.........................Epson LQ
EPLQLO.DRV.......................Epson LQ low res 60 x 60dpi
EPLQWC.DRV.......................Epson LQ wide carriage
EPLQLOWC.DRV.....................Epson LQ wide carriage 60 x 60
HPDJET.DRV.......................HP DeskJet / DeskJet Plus
HPLJET.DRV.......................HP LaserJet II/II D
HPLJET2P.........................HP LaserJet II P
HPLJET3..........................HP LaserJet III
HPPJET.DRV.......................HP PaintJet /XL color
HPTJET.DRV.......................HP ThinkJet
```

Figure 5-4. Printers Drivers Supported by RPLOT.

5.3.2 Setting Parameters for .PCX Output

PC Paintbrush .PCX format

In addition to sending plots to the printer, you may also have them sent to a file in .PCX format. This is useful for later processing with PC Paintbrush and PC Paintbrush compatible software, or for importing to word processors like WordPerfect which can then improve the fonts, merge your plot into a document, etc.. If you have high end software like PC Paintbrush which can handle full page high resolution format .PCX files, then specify one of the full page drivers; PCX.DRV for monochrome systems, or PCXCOLOR.DRV for color. Many low end applications (like those which are often bundled with mice) cannot handle these large .PCX files. In this case, you will want to specify one of the more specialized drivers corresponding to your monitor/card combination. However, if you choose a driver not identical to your system, you should still be able to work with them on screen. They may under- or overflow your screen, though, requiring you to pan around to access the entire

PCX FILE DRIVERS	GRAPHICS CARD / MONITOR
PCX.DRV	Full page monochrome
PCXCOLOR.DRV	Full page color
PCXEGA.DRV	EGA 640x350 monochrome
PCXEGAC.DRV	EGA 640x350 16 color
PCXVGA.DRV	VGA 640x480 monochrome
PCXVGAC.DRV	VGA 640x480 16 color
PCXSVGA.DRV	SuperVGA 800x600 monochrome
PCXSVGAC.DRV	SuperVGA 800x600 color
PCX8514.DRV	IBM 8514 monochrome
PCX8514C.DRV	IBM 8514 color
PCXHERC.DRV	Hercules

Figure 5-5. PCX Drivers for Graphics Card/Monitor Combinations.

plot.

Print Resolutions

Next you are asked for your preferred print resolution. 0 is the lowest and 3 is the highest. Each printer has it's own range of possible resolutions, but in most cases 0 will correspond to 75 dots per inch and 3 with 300 dots per inch. If you always want the highest resolution achievable by your printer, specify "3". The trade-off is that higher resolution plots require more time and disk space. A typical RPHOT plot may require around 30-50K at resolution=0, but 250K to 300K at resolution=3. Producing such a large file will also take time. Sending a resolution=3 plot on my 12 Mhz AT with math chip (and a very slow harddisk) to a binary file suitable for copying to the printer took nearly 3 minutes!

Specify Margins

The last questions ask you to specify the top, bottom, left, and right margins on your printed page. Specify them in units of .01 inch. So, for example, a half inch margin would be specified with a "50". Note that each printer has it's own convention on where the margin begins (not necessarily at the edge of the paper!), so you will have to play with different values before settling on margins you like. Note that the newly modified PPARMS.DAT which scrolls to the screen also contains the extended memory parameter EMM, described in the "Installation" section. However, currently EMM must be set with the DOS SET command in AUTOEXEC.BAT, as described earlier; it is not read or modified in PPARMS.DAT.

Now that you are finished setting up your parameter files, you can practice taking data with DTAK.

SECTION 6.0

DATA ACQUISITION

6.1 USING OLIST

Using OLIST to Automate Data Acquisition

A new feature of version 2.0 is the ability to run DTAK with a pre-defined list of observing targets. Entering data in the data-taking loop now involves (mostly) just hitting the "ENTER" key to take defaults. This is an initial step towards solving one inconvenience with version 1.0; it required observers to hunt and peck keys during what might be very cold, dark nights (difficult to do in gloves!). The addition of OLIST should go a fair ways towards making DTAK possible to operate with "gloved hands".

Generating the Observation List Data File

The new program OLIST will produce your observing list. You name the file to contain this list. You can thus make a set of standard observing lists for your program stars. These output files will show up in the same directory as is OLIST. OLIST can be run from the RPHOT shell, or from the DOS prompt. From DOS, type...

```
>OLIST
```

and you will first be asked for the file name to give to the observing list output. Don't put a path on this file name. This file must remain on the same directory as both OLIST and DTAK. You'll then be asked for the filter sequence desired. For example, if you want to observe your objects in U, then B, then V, you enter "UBV". OLIST will then ask you if this will be a differential photometry block. Let's explain the concept of a block...

Differential Photometry Block

A differential photometry observing block consists of your program object, it's comparison star, and (optionally) its check star, together with any SKY observations (this may be a good point for you to read ahead about the distinction between "SKYNEXT", "SKY" and "SKYLAST" in DTAK). A "non-differential photometry block" would be used for all other types of observing. Non-differential photometry blocks would be used, for example, to do "allsky" photometry. Why does OLIST make this distinction? For differential photometry, you will typically take many readings on the same two or three objects. In this case, OLIST can simplify entering these names by providing one-letter abbreviations.

If you are doing a differential photometry block, OLIST will now ask whether you plan to put comparison and check stars into COMP.CAT (Usually this is what you'll choose). If yes, OLIST needn't bother you with inputting the star catalog each time. Next you'll be asked for the names of your program object, your comparison star, and your check star

(if no check star, just hit "ENTER" to leave it blank). These names must be the same names you will enter into the catalogs. You then enter the loop which writes out your objects to the observing list file. Each time OLIST asks for "object?", you type in "V" for your variable, "C" for your comparison, "K" for your check, and either "N", "S", or "L" for the three kinds of "sky"'s. If you instead type "OP" (for "options"), you'll see a list of other possible responses; "FIX" to change the previous entry (you can enter "FIX" repeatedly to position yourself at successively earlier records), or "STOP" to end this block and begin a new block, or "END" to exit from OLIST. If you want to change the filter sequence, type "STOP" and begin a new block.

OLIST Shortcuts

"Allsky" Photometry

For non-differential photometry blocks, you will be asked for the full name and catalog of each object. If you enter one of the "SKY"'s, you will be asked for the catalog with the default entry being blank. Just hit "ENTER" here, since "SKY"'s are not cataloged objects. Again, "OP" gives you all the options available at the "Object?" query. Note that "FILT" will allow you to change the filter sequence for succeeding objects.

These possibilities are explained again during OLIST execution. Try producing a few files to see how it works.

6.2 RUNNING DTAK

6.2.1 Initial Set-Up and Modes

You are now ready to take data using program DTAK. DTAK may be run in any of three modes; SLOWMODE, FASTMODE, LOGMODE.

FASTMODE for Occultations

Use FASTMODE for observing any event which requires a long series of integrations without user interaction and without needing comparison and sky readings. It was designed with lunar or asteroid occultations in mind, but could be useful for other events as well. It allows you to take up to 32000 consecutive integrations one immediately after the other. No user changes of filters, scales, integration times, or objects are possible once the integrations begin.

SLOWMODE for Differential and "AllSky"

SLOWMODE is used for doing any real-time (i.e. at the telescope) observations of variable stars, asteroids, comets, etc.; any object which may require changes to the filter, object observed, integration time, or gain scale, and for any observations requiring comparison and sky readings. Filter changes can be computer automated (SSP-3A/5A only), counts can be automatically input (SSP-3/5 or 3A/5A only), and UT time can be automatically read from the computer system clock (any photometer).

LOGMODE for Previous Data

Use LOGMODE for logging observations which were made at some previous time, or at the telescope for photometers without the SSP3CARD. In "logmode", the user is explicitly prompted for keyboard entry of filter, counts, and UT time.

After choosing your mode, DTAK then asks for the file name to contain the output. As with most filename queries in the RPHOT package, do not include the DOS path. The path will be appended automatically.

Synch System Clock to WWV

If not in LOGMODE, DTAK then asks if the system clock needs to be synchronized to WWV Universal Time. You must be sure your system clock is on WWV Universal Time. For accuracy at the millisecond level, you can install a WWV CARD which will receive radio broadcast WWV and keep your clock synched (call Optec for more information). For SLOW-MODE or LOGMODE purposes this is not necessary, and the procedure DTAK takes you through is adequate. For SSP users, DTAK takes counts directly from the photometer/SSP3CARD. It will use the system clock to automatically determine and log the UT of the centerpoint of your integrations. Non-SSP users may still use the automatic time logging feature as long as DTAK is in SLOWMODE. In this case, DTAK assumes each of the integrations on a given line is done consecutively, and that it takes 4 seconds to enter the last count at the keyboard. The few seconds error which may be made in this procedure is not significant for later reductions.

Reading OLIST File

Next, DTAK will ask if you prefer DTAK to read your objects and their catalogs from your observing list prepared by OLIST. If so, you then enter the file name (without path) of your list. In this mode, the "Object?", "Catalog?", and "Filter?" queries (described below) will be automatically filled with default values from your list. You can accept this default by just hitting the "ENTER" key, or enter something else. When a new integration is ready to be done, DTAK moves to the next line on your list. Your list may be up to 500 lines long. When DTAK reaches the end of your observing list, it will automatically recycle to the beginning. This way, you can program a short sequence and use it over and over. You may instead prefer to begin your OLIST observing list sometime midway during the night. You may enter and leave OLIST mode as often as you prefer, as part of the "options" described below.

AUTOOBJECT Mode

Next, DTAK will ask if you prefer that all filters on a given object be observed automatically without pausing. Normal mode is for DTAK to pause after each line of data, ask for comments, then ask for a new object and number of integrations desired. For those with telescopes that track well, specifying (Y)es to AUTOOBJECT mode will tell DTAK to do all filters on this object before pausing and asking for comments. This will make life at the telescope much easier! If your tracking is more suspect and you answer

AUTOSKY Mode

(N)o, then DTAK will ask if you want AUTOSKY mode, which will automate only the SKY filter sets (this normally won't get you into trouble even with mediocre telescope tracking, unless you are in a very crowded star field. Of course, if you are REALLY worried, you can answer (N)o to both options.

Header Info

Next DTAK asks for header information to appear at the top of the raw data output file. The name of your telescope (15 characters), the name of the observer(s) (<27 characters), sky conditions (<60 characters), and the dark current from the photometer. The dark current reading is optional. It is not read or needed by the reduction programs. It is solely for your records.

Set Integration Time

Next, DTAK asks for the integration time. In all modes DTAK assumes the integration time does not change unless you explicitly change it with the INT command (see below). If, for example, you always use 10 seconds, you need only enter it this once. Gain scale is treated the same way. After entering your gain scale, DTAK will search DPARMS.DAT to verify that this is indeed a valid scale.

Gain Scale

6.2.2 The Data Taking Loop

This completes the preliminaries. You now enter the data taking loop. In order to produce compact output, simplify data entry, allow you to monitor possible changes in counts due to clouds, poor tracking, etc., and provide flexibility in how much integration time to share between objects, each line of data contains up to 4 separate integrations. Each line is tagged with the UT time corresponding to the center of these integrations, filter used, integration time, gain scale, object name, and which catalog it is to be found in. For SSP users not in LOGMODE, these 1 to 4 integrations are done consecutively without user interaction. If, for example, you have a bright star and the sky contributes little, then you may want to do only, say, 2 integrations (20 seconds) on the sky, and then 4 on the star (40 seconds). For each set of integrations, the first question asked is the name of the object. Your choices are:

Catalog Objects

(a.) The name of an object, exactly as typed in col. 1 of the catalogs.

SKYNEXT, SKY and SKYLAST Readings

(b.) The sky; the reduction programs need to know which sky readings are to be sky-subtracted from which object readings. This is accomplished by having three different names for the sky readings: Type "N" for "SKYNEXT", which means this sky reading is only to be applied to later object(s) (i.e. objects appearing after this sky), not to previous object(s); type "S" for "SKY", which means this sky will be applied to both preceding and following objects; type "L" for "SKYLAST", which means this sky applies only

to preceding objects (see sample data for examples). For example, a typical series of integrations on a star would begin with a "SKYNEXT", be interspersed with occasional SKY's, and finish with a "SKYLAST". The programs understand this nomenclature and will prevent sky readings taken in one part of the sky from being used on stars in other parts of the sky. If you're in a daring mood, you can skip the "SKYLAST" as long as you begin your next object with a "SKYNEXT". You may also skip "SKYNEXT" as long as you finished your previous object with a "SKYLAST". The correct "sky"'s will still be subtracted from the correct objects, and the only cost of these omissions is that your first or last set of object integrations will only have either a preceding or a following sky to work with, and no interpolation between sky's will be possible. If you want, you can explicitly type out "SKYNEXT" rather than the abbreviation "N"; the same goes for "SKY" and "SKYLAST".

Optional Responses

(c.) Type "OP" to see optional responses: Since "Object?" is the first query for a new observation, it is used as the branch point for a number of options which will now be described.

6.2.2.1 "OP"tions; Changing Operations and Editing Data

Typing "OP" at the "Object?" query will produce a box of optional responses for changing the operations of DTAK or for editing the most recent data. Entering the responses below at the "Object" query will have the described effect...

```
In addition to entering the name of your object,
you may choose among the options below:

"FAST".....to log a "FASTMODE" event
"FILTER"...to change filters or filtering mode
"INT"......to change integration times
"OLIST"....resume reading objects from OLIST
"ENDLIST"..stop reading objects from OLIST
"AUTOOBJ"..do all filters in a set w/o pausing
"AUTOSKY"..do all filters in a SKY set w/o pausing
"PAUSE"....to kill AUTOOBJ and AUTOSKY; pause from
           now on after each filter
"SCALE"....to change gain scale
"TRIAL"....to try out different integration times
           before doing an observation
"FIX"......to edit the previous data record
"BAD"......to delete the previous data record
"END"......to end data taking and return to DOS
```

Figure 6-1. Optional responses to the "Object?" query (SSP-3A/5A users).

```
In addition to entering the name of your object,
you may choose among the options below:

"FAST".....to log a "FASTMODE" event
"INT".....to change integration times
"OLIST"....resume reading objects from OLIST
"ENDLIST"..stop reading objects from OLIST
"SCALE"....to change gain scale
"TRIAL"....to try out different integration times
           before doing an observation
"FIX"......to edit the previous data record
"BAD"......to delete the previous data record
"END"......to end data taking and return to DOS
```

Figure 6-2. Optional Responses to the "Object?" query (SSP-3/5 users).

Change Integration Time — INT: change the integration time, in seconds, for later observations.

Scale Change — SCALE: change the gain scale logged (note that the SSP3CARD does not at present allow you to physically change the SSP's gain scale from the computer, so you must make sure the gain scale logged is the one you set by the by hand using the manual toggle switch on the photometer. This blunder has happened more than once in the process of taking the enclosed sample data!).

Filter Change — FILTER: change the filter (SSP-3A/5A users only). In manual filter mode, the filter stays put until you explicitly ask to change it. You change it by typing "FILTER" at the OBJECT? query. You will then first be asked if you want to change the filtering mode. You may choose to have the filters automatically cycled through any of a number of multi-color modes; UB, BV, VR, VI, UBV, BVR, BVI, VRI, and BVRI, (any of these may be ended with the C filter as well). Type FILTER, then "F" to change filtering mode, then e.g. "BVRI" for BVRI automated filter cycling. The photometer will advance to the next filter after completing your integrations. The software will move the filter directly to filters which are later in the UBVRIC sequence. In moving to an earlier filter, the slider will first be re-registered against the filter cover and you'll hear a few faint (and harmless) knocks. Note that FILTER is not a valid option if objects are being read from the OLIST file. This is because OLIST file already has it's own filter sequence. If you want to use your OLIST objects but with a different filter sequence, you'll have to first re-run OLIST.

AUTOOBJECT Mode AUTOOBJ: (SSP 3A/5A users only) Switch into AUTOOBJECT mode; now all filters in a filterset will be automatically observed before DTAK pauses and asks for comments and the next object.

AUTOSKY Mode AUTOSKY: (SSP 3A/5A users only) Switch into AUTOSKY mode; now all filters in a set will be automatically observed, but only while observing a SKY.

Normal Mode PAUSE: (SSP 3A/5A users only) Switch out of AUTOOBJECT and/or AUTOSKY mode into normal mode; DTAK will pause and ask for comments after each filter.

Read OLIST File OLIST: Begin or resume reading objects from the observing list set up by OLIST.

Stop Using OLIST ENDLIST: Stop taking objects from the observing list. From now on, the default object will be the last object done, rather than one from your list.

Fix Errors FIX: fix mistakes in the previous line of data (if you select this option, you will be queried for each item you want to change. Hitting "ENTER" will leave the item unchanged). Although I've added this feature for completeness, in my own photometry I almost never use it. Night time is too precious to spend editing data! Instead, I either enter "0" for the number of integrations to take (if I catch the mistake soon enough), or at the "comments?" query after the integrations I make some brief note, like "4th bad" if the last count is ruined by the star drifting out of the aperture, for example. Then I can review the data file at my leisure and edit mistakes or delete bad data. You will note when examining the sample data that any of the 1-4 counts on a line may be zeroed or deleted without problems. The reduction programs interpret a zero or missing count as no integration.

Delete Bad Data Line BAD: delete the entire previous line of data (which also resets the filter to that previous filter, i.e. setting you up to retake that line of data). Typing BAD repeatedly will delete more and more lines of data. Note that BAD only deletes the previous line; if there is more than one line of data on your last filter and you want to delete the entire filter's worth of data, you'll need to type BAD more than once.

Take Test Data TRIAL (SSP users only): take test data (trying out different integration times or scales in order to get a reasonable count rate). This trial data is not logged. Saves you from having to inspect counts at the LED on the photometer.

Change to FASTMODE FAST: (SSP-3A/5A users only) open a FASTMODE data file to e.g. log an occultation (see below).

Quit END: end data taking and return to DOS.

6.2.2.2 Logging the Star Catalog and Taking Counts

Specify Catalog

After asking for the name of your object, DTAK will ask for the catalog it is in (unless it is a "sky"). You respond with either A, F, S, C, V, or M, for ASTAR.CAT, FOE.CAT, SOE.CAT, COMP.CAT, VAR.CAT, or "moving object" respectively. Although your objects do not have to be logged into these catalogs in order to run DTAK, they must be logged in before you reduce the data. If your object is an asteroid or comet or other moving object, then answer with "M". "M" objects do not need to be cataloged at all. Instead, the final reduction program FREX will explicitly ask you to either enter this object's coordinates on this evening, or let the comparison star's coordinates serve as the moving object's coordinates.

Use 0 Integrations to Correct Object Query Errors

Next, SSP users will be asked for the desired number of integrations. You respond either with a number between 0 and 4, inclusive, for multi-filter observations of program objects; or 0 to 400 otherwise. Note that answering with a number larger than 4 will produce more than one line of data. Using "0" is a handy way to deal with errors in answering the above questions about your object. Your request for 0 integrations will tell DTAK that it should return to the OBJECT? query. If you request 1-400 integrations, the integrations will begin at the moment you hit "ENTER". You may terminate this set of integrations early by hitting the "ESC" key. This will cause the current integration to be the last in this integration set. The data will be written, and program flow will continue. If you hit another key before hitting the "ESC" key, the integrations will not be terminated; they will continue until normal completion.

Why are you allowed up to 400 non-stop integrations for non-program objects or single filter observations of program objects, but only 4 for multi-filter observations of program objects? The reduction programs can combine consecutive lines of data on a given filter together to get a more accurate, averaged reading. This is desirable for "SKY" or comparison/check stars. However, for program objects this could cause trouble. Suppose you really wanted to see the point-to-point variation on a single filter in a rapidly varying star? IREX has no convenient way of knowing when and by how much to smooth program object data, so it takes the conservative approach and doesn't smooth at all. (Any data can, however, be smoothed at plot time (see RPLOT below)). This restricts you to only one line per filter when doing multi-filter observations on a program object (single filter observations, as will be seen, are reduced differently; the limit here is again 400). There IS one way around this limitation; to get more photons per point on a program object simply specify a longer integration time.

FASTMODE Output

When you're done, it'll give you the actual interval between counts. Notice that this is typically slightly larger than your requested integration time, due to the overhead associated with the software execution time. DTAK will then take you back to SLOWMODE, telling you your present status and allow you to reset the UT again if you need to. It will then continue where you left off, appending to your original SLOWMODE data file.

6.4 SEQUENCING FILTERS AND OBJECTS

Rules for Structuring Observations

The RPHOT package's greatest feature (and the biggest reason for its programming complexity) is the great flexibility it gives to the observer in how to structure his observations. However, there are some (mostly common sense) rules which must be followed;

Do All Colors on Each Star Before Changing Objects

1. If you want to do multi-color observations, all desired colors must be observed consecutively on one object before doing the next object. For example, you cannot do "b" filter observations on sky-comparison-variable-comparison-sky, followed by "v" on sky-comparison-variable-comparison-sky, and expect to get reduced B-V colors. In this example, the reduced magnitudes will instead remain instrumental "b", then "v", with no calculation of B-V. Also, while you can observe in 1, 2, 3, 4, 5, or 6 filters per set, the filters cannot be arbitrarily mixed in any order. They must follow

Follow Standard UBVRI Order

in the order UBVRIC. For example, you may observe in the order UB, or UBV, or BVR, or VR or VRI, or VI, etc., but the reverse orders RV or VB or IRB, etc. are forbidden. When the programs encounter a filter which is earlier in sequence than the previous filter, they assume this is the beginning of a new filter set. Doing things this way allows an arbitrary number of filter sets to be done consecutively on one object without bothering the user for which filters go with which set. (Finally, note that while the PHYSICAL position of your filters in the slider is arbitrary, computer controlled filter changes will be faster if they are in the order UBVRIC).

SOE Pair Observation Requirements

2. Second order extinction observations are done on a red and blue pair of stars. A single point on the linear regression plot requires that a set of filters be done on both stars. You may get such a point by either doing the red star followed by the blue star, or the blue star followed by the red star. However, TRANS requires that, for a given point, between the red and the blue there can be no other stars ("sky" observations between the red and blue are ok). Of course, after doing a red-blue pair, you may then do as many other stars or other kinds of data as you want before you return to that red-blue pair. (Look at the sample data in RAW3.DAT if this isn't clear). If you do embed an extra-

No Intervening Stars

neous star between your red and blue, that SOE point will not be reduced. (The programs will not abort, however, and

the red and the blue stars in that point will still be used for transformation and/or first order extinction). So for example, if you observed one red-blue pair, with 10 observations of the pair, but one observation included an intervening star between the red and the blue, your final SOE plot would only have 9 points.

SOE Star as Comparison

Suppose you wanted to use an SOE star as a comparison star for a nearby variable. This is fine and their will be no confusion, since the programs will not reduce it as an SOE star unless, as just described, its mate is also observed immediately before or after. This star will, however, still be used in any FOE or transformation calculations desired. If you don't want to use this star for FOE/transformation calculations when running TRANS, you should copy it from the SOE catalog into the comparison star catalog COMP.CAT. This is probably a good rule in general; any standard stars you also want to use as comparison stars should be copied to COMP.CAT. This will help you keep straight in your own mind which stars are serving what purposes during your observing.

More Notes on SKY Measurements

As noted previously, each star integration must have at least one sky done sometime before or sometime after. This means that if you have a "SKYLAST" followed by star integrations, followed by a "SKYNEXT", your intervening star integrations will not be reduced, since IREX will see a "SKYLAST" as only applying to earlier stars, and the "SKYNEXT" as only applying to later stars. It is not necessary that a sky be done IMMEDIATELY before or after a star integration (although this is usually good photometric practice). Table 6-1 provides examples of valid and invalid ways of positioning your "SKY"'s.

(1)	(2)	(3)	(4)	(5)	(6)
SKYNEXT	SKYNEXT	VAR1	SKYLAST	SKYNEXT	SKY
COMP1	VAR1	COMP1	COMP1	VAR1	COMP1
VAR1	COMP1	SKYLAST	VAR1	SKY	VAR1
SKY	SKYNEXT	SKYNEXT	COMP1	VAR1	VAR2
VAR1	COMP2	COMP2	SKYNEXT	COMP1	COMP2
COMP1	VAR2	VAR2	COMP2	SKYNEXT	SKYLAST
SKYLAST			VAR2		
VALID	VALID	VALID	INVALID	VALID	VALID

Table 6-3. Examples of Valid and Invalid Observing Sequences.

Example (1) is a "classic" well constructed block. (2) is valid and is more suited to stars which are so bright the sky is a minor part of the total light. (3) is similar; the "SKYLAST" will be applied to VAR1 and COMP1, and the "SKYNEXT" will be applied to COMP2 and VAR2. (4) is in-

valid. The "SKYLAST" will not be applied to VAR1 or COMP1, and the "SKYNEXT" will only be applied to COMP2 and VAR2. The VAR1 in this block will not be reduced. (5) shows a valid intervening "SKY", applied to both VAR1's. Only the first "SKYNEXT" will be used on VAR1 here. (6) is valid as long as VAR1 and VAR2 are close together in the sky, since the "SKY" and "SKYLAST" will be applied to both. Note that the first "SKY" will also be applied to the previous block.

Obeying these guidelines, when doing either single filter photometry or multi-color photometry, you may take sky readings whenever you want and comparison star readings whenever you want. You can follow good photometric practice, or quick and dirty, as you prefer....RPHOT will do it's best either way. You may precede your star set with a sky set, or follow it with a sky set, or both. Study also the arrangement of "SKY"'s in the sample data enclosed. All will be properly reduced by RPHOT. Also, Appendix E gives example data taken on Sept. 21, 1989 which shows the appearance of the files at each stage in the reductions, as well as final light curve plots.

Aside from these rules, you may arrange your data in any order that suits you.

SECTION 7.0

DATA REDUCTION

7.1 REDUCING OCCULTATIONS

Occultation Timings

Reducing occultation timings is short and simple, so it will be covered first. To begin with, let's note that the SSP photometer is not ideally designed to do a good job on lunar occultations. The smallest available detector aperture size (.5mm) coupled to an 8" f/10 corresponds to 50 arcsec; wide enough so that the integrated sky brightness near the dark limb of a half moon is about first magnitude! Stars fainter than magnitude 6 or 7 will simply be lost in the noise. Even bright stars will be difficult on large moons. For the SSP-5 the signal to noise (S/N) is better, but the large aperture is still a problem. For asteroid occultations, there is typically little background light and timings are much easier to identify. In either case, the best way to identify the moment of occultation is to visually inspect the counts vs. time tracing.

Use RPLOT to View FASTMODE Data File

Program RPLOT will produce a plot of the raw counts or integrated counts vs. time for any fastmode data file. RPLOT will take extensive command line arguments which will save you from answering most or all of the questions below. See the more complete section on RPLOT later in this manual for a complete description of the available command line arguments.

At the DOS prompt type

```
>RPLOT filename   (filename optional here)
```

and ask for option 2; FASTMODE reductions. If you didn't specify it on the command line, you will first be asked for the data filename; this is the filename you gave when running DTAK. Next it will ask whether you want your axis numbering annotation in text or graphics mode (try it each way to see which you like). The plot will be in terms of seconds measured from the minute of the first observation. If this spans more than 60 seconds, you can ask that the annotation reset to 0 at the minute marks, or not. Next you will be asked whether you want to inspect raw counts vs. time, or integrated counts vs. time. Answer "R" or "I". The raw counts vs. time will give a more intuitive feel for how the light varied, but it may be easier to spot the moment of occultation by plotting the integrated counts. The idea is taken from Dunham, et. al (Astron. J. 78, 482 [1973]). The quantity plotted is;

Raw Counts vs. Integrated Counts

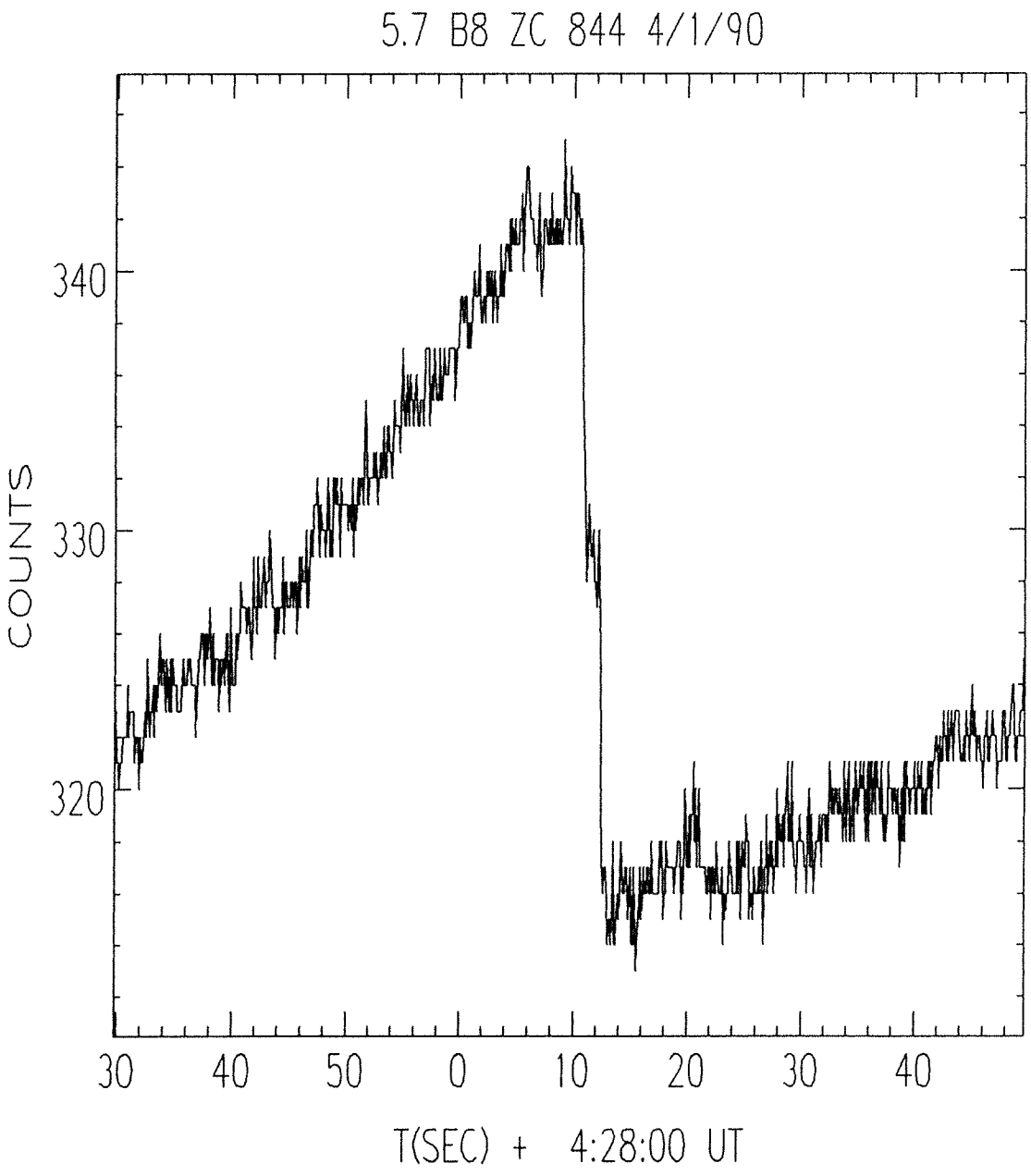

Figure 7-1. Occultation Plot Showing Raw Counts vs. Time.

$$I_n = \frac{\sum_{i=1}^{n} [C_i - \langle C \rangle]}{\langle C \rangle}$$

where i=1 is the first count in the desired time window, and <C> is the average of all counts in the time window. Point-to-point noise is essentially eliminated in the integrated plot. Occultations show up as a change in slope. Typically, aperture photometry counts will ramp up during the data taking interval, as more and more of the eartlit moon enters the aperture. The integral of a sloping straight line is a parabola. If the line takes a dip (change of zero point due to the occultation), the resulting integral will be a new parabola offset in time from the before-occultation parabola; this will be the typical appearance of your integrated plots of lunar occultations. If you see no offset in your parabola, the occultation is lost in the noise. For asteroid occultations, there will typically be no overall trend up or down with the counts, and the integral will then be a straight line. The occultation is identified on the integrated plot as the point where the slope changes from positive to negative. See "Solar System Photometry" by Genet, p. 9-15 for more information on integrated plots.

Plot Zoom Feature

After selecting "R" or "I", RPLOT will then ask whether you want to plot all the data, or only a subset time window. Answer "A" or "S", respectively. If you type "S", it will ask for the UT hour, minute and second for the beginning and ending of your plot. The default is "A". Next you'll see the screen go into graphics mode and your plot will appear. Hit "ENTER" when you're finished looking at it, and OPLOT will ask if you want this plot sent to the printer immediately (answer "Y"), saved to a file for storage (answer "S"), or skip doing hardcopy (answer "N"). The hardcopy options are common to all types of RPHOT plots; See Appendix B.2 for a complete description. Finally, you'll be asked if you want to do another plot. It will prompt you with the default file you just plotted, but you can enter any FASTMODE file name.

Large FASTMODE File Limitations

Version 2.00 can plot a maximum of 2000 points. This can be rather limiting for some events. A new version capable of plotting 32000 points is written and will be available when a Fortran compiler bug is resolved by Lahey. For now, this limit is dealt with in the following way: RPLOT will read through your data and if your chosen window contains K (more than 2000) points, only every Nth point is plotted. N is the lowest number such than K/2000 is less than N. N is printed to the screen, alerting you to this issue. With this solution, your entire selected range can be plotted. This allows you to locate the important moments, select a smaller time window, and get every observed point plotted.

Note that absolute time is taken from the DOS system clock.

DOS Timing Considerations

This clock is only updated by DOS every 55 milliseconds. Also, unless you are using a WWV CARD, system time can drift by as much as 2 or 3 seconds per day. Finally, your absolute time will be limited by the accuracy with which you know your reaction time. All these factors mean that your absolute times probably will be no more accurate than +- 0.1 seconds in most cases. In general, for integration times less than 20 - 30 minutes, DOS clock drift should be less than the discretization error of 55 ms.

At the end, RPLOT will ask if you want to do another plot. If you answer (Y)es, you'll notice your previous datafile is the default. If you do plot again, and this time using the "Subinterval" time window option, RPLOT will show you the previous time window you used when it asks for a new subinterval to plot (saving you from having to remember it!).

Play with the sample data file OCC1.DAT included with the package. Note how the counts ramp up as more of the earth-lit moon enters the diaphragm. Note too that this star was a double star, with two distinct disappearances.

7.2 INITIAL REDUCTIONS (IREX)

IREX Goals

The first step in reducing SLOWMODE files is to run IREX, which stands for "Initial REduXtion" program. IREX will do the following;

Consolidate Data

1. Consolidate consecutive lines of data done with the same filter on a non-program object (i.e. an object not cataloged with "M" or "V"). For example, if you want more than 4 consecutive integrations on a star or sky, you will be logging more than one line of input data. All of these integrations will be reduced to one data point. IREX will not consolidate consecutive lines of program object counts.

Check Dispersion

2. Warn you if the dispersion in counts among your 1-4 integrations on a line exceeds 3% (this may indicate the object was drifting out of the aperture, or clouds, or other problems). This warning will not stop reductions, however.

Standardize Data

3. Standardize counts to look as if they were taken with a uniform integration time of 10 seconds on the most sensitive scale available (for SSP: the 100 scale. This maximizes the number of output digits).

Subtract Sky Readings

4. Perform sky subtractions. If you have both preceding and following "sky" sets for that star, IREX will interpolate between the "sky"'s before doing sky subtraction. You may take as many consecutive lines of data on the sky with a given filter as you want. IREX will make a weighted average of the readings and the times before using them. If you have only sky sets on one side of your star set, there will

be no interpolation. If you are missing a needed filter on an adjacent sky, IREX will continue to look forwards and backwards from your star observation and try and find a sky reading in that filter. If it first encounters a set of "SKYNEXT"'s downstream, it stops looking. And, if it first encounters a set of "SKYLAST"'s upstream, it stops looking. If there are no legitimate "sky"'s for a given star observation (perhaps because they were bad and had to be exorcised), IREX will simply not reduce that star in that filter; it will be skipped in the output file. In this way, IREX will permit you the maximum flexibility in data taking and in weeding out bad points. You will not have to throw out a whole filter set just because you later find an airplane went thru your field on the R filter!

Prompt for "Allsky"

5. For each program object it encounters, IREX will first look through COMP.CAT, find your variable star and it's associated comparison and check stars, and see if those are indeed the comparison/checks you used on this particular night. If it was, they will be automatically grouped without bothering the user. If not, it means you may be either using a different comparison, or doing "allsky" photometry; IREX then will ask if you want to do "allsky" photometry on that star. If you answer no, it'll list through all the designated comparison stars found (i.e. all those whose source catalog you designated as COMP.CAT when running DTAK) and ask you if that is the comparison or check star which goes with that program object. You answer "C" if it is the comparison, "K" if it is the check star, and "N" if neither. If you are lucky enough to be able to use a UBVRI standard in either FOE.CAT, SOE.CAT or ASTAR.CAT as a comparison or check star, this star need not be included in COMP.CAT and then would not be one of the "designated comparison stars" listed. In this case, you will have answered "N" to all listed comparison stars, and IREX will then ask you to enter the name of this star explicitly. (Later, FREX is smart enough to go looking in the other catalogs if it can't find what it wants in COMP.CAT). Again, it will probably prove easiest in the long run to simply be sure that ALL stars used as comparisons or checks be included in COMP.CAT, so that the automatic search feature can spare you the above interactions. At the bottom of the initial reduced file output by IREX you'll see a tabulation of each program object and its companion comparison/check stars.

Dead Time

6. For photon-counting photometers, corrects for dead time.

7.2.1 Automating IREX - Command Line Arguments

There are two ways of running IREX. If you simply type

```
>IREX filename          ("filename" is optional)
```

(where "filename" is the raw data filename to be reduced)

at the DOS prompt, you will be queried for the appropriate answers to the options described above. This is a good way to learn how the program works. Later, you will probably want to use a new feature in version 2.0; the batch file I.BAT contains a listing of command line arguments you can specify which will automate the reductions. You can even build a batch file with many command lines and automate the reduction of a whole list of raw data files. In either method, the output file is then the input file for your next two reduction programs, TRANS and FREX. The command line arguments available are listed below, with their function. These arguments may be entered in either upper or lower case, in any order, and some or all may be missing.

I.BAT Batch File

ARGUMENT	FUNCTION
OUT=xxxx	filename xxxx will receive the output
OUT=DEF	default filename (formed by appending a ".R" to the input filename) will receive the output
ALLSKY	at least some stars are reduced by allsky method. the user will be queried explicitly during execution for comparison star, check star, or "allsky" photometry match-ups. If ALLSKY is missing, then COMP.CAT will be read in an attempt to match up comparison and check stars with variables.
COMPATH=xxxx	path to comparison star catalog COMP.CAT. If not specified, it is assumed to be on the default directory (i.e. the same directory as IREX.EXE). Only used if ALLSKY not present
END	End execution after file is processed; do not ask for another file

Figure 7-2. IREX Command Line Parameters.

As an example, executing the batchfile consisting of the single line below...

```
IREX %1,COMPATH=C:\CATS\,OUT=DEF,END
```

by typing at the DOS prompt

```
>I RAW1.DAT
```

will tell IREX to reduce raw data file RAW1.DAT. It will search for catalog COMP.CAT in directory C:\CATS\, quit after doing one input file (file specified by the first DOS replacement parameter %1), and store the output on a file named by the default ".R" added to the input filename. Since ALLSKY is not specified, it assumes all stars are reduced by differential photometry and will therefore search through COMP.CAT to try and do the variable / comparison / check star match-ups.

Default IREX Output File

One can automate a whole series of initial reductions from a simple batch file. For example, the batch file consisting of the following lines

```
CALL I RAW1.DAT
CALL I RAW2.DAT
CALL I RAW3.DAT
```

will, (in conjunction with the above described I.BAT), reduce all three raw data files without pausing. The DOS "CALL" (DOS 3.30 and later) is required for invoking multiple batch files from within a batch file. See your DOS manual.

7.3 EXTINCTION/TRANSFORMATION COEFFICIENTS (TRANS)

Use TRANS for "Allsky" Photometry

"Allsky" photometry requires you to first solve for the extinction and transformation coefficients and zero points for that night. Even simple differential photometry needs pre-determined extinction / transformation coefficients for accurate calculations. This is done by program TRANS.

The reduction procedures and formulae were generalized from Henden and Kaitchuck (1982) and from Moffatt and Vogt (1977), and are summarized in Appendix A. TRANS assumes your transformation coefficients and second order extinction coefficients are stable enough that you won't necessarily want to redetermine them each night. There are therefore three possible modes to choose from, and nearly every conceivable combination of SOE, FOE and transformation calculations vs. manual input can be accommodated from one of these three modes:

7.3.1 Full Extinction / Transformation Calculation

"T" Mode

Answering "T" to the MODE? query will give a full calculation of first and second order extinction coefficients, transformation coefficients, and zero points for all observed filters and color indices (U, U-B, B-V, V, V-R, and/or V-I). In this mode, it is assumed that transformation coefficients are initially unknown, and therefore first order extinction must be done with B-V = V-R = 0 stars to minimize the uncertainties due to the use of estimated, default transformation coefficients (see Henden and Kaitchuck). These spectral type B7-A3 stars are all contained in ASTAR.CAT. After choosing this mode, TRANS will search the catalogs for all observed stars and list them to the screen, sorted by purpose (first order extinction (FOE), transformation, and second order extinction (SOE) red-blue pairs, respectively). Next it'll ask if, rather than calculate them, you want to simply input your own SOE coefficients. If yes, TRANS will prompt you for each and then skip to the first order extinction calculation. If you don't want to input your own (this is the default) it'll identify the first red-blue pair found in

```
                    MODE

(F):  First order extinction coefficients
      calculation only.

(S):  First order extinction and second order
      extinction calculations only.

(T):  Full first order/second order extinction
      and transformation coefficients calculation.
      Use this also if you want only FOE and
      transformation calculations done
```

Figure 7-3. TRANS Extinction/Transformation Calculation Modes.

Correlation Coefficient

your data, process all observations of this pair, and calculate the SOE coefficients in the colors you observed. It'll then output each SOE coefficient, together with its correlation coefficient COR (a rough measure of how well the points fall on a line; COR=1 for perfectly linear data. Note, though, that COR is meaningless if the slope is near zero. A better way to get a feel for the quality of your data is to plot it using RPLOT, described later), and the names of the files which received the RPLOT plot data. It will then do this for succeeding red-blue pairs and give a number-weighted average over all pairs of the SOE coefficients. You may observe up to 3 different red-blue pairs with up to 50 observations of each pair, in a given night. SOE coefficients can be hard to measure and should be small (typically absolute value less than .06 or so); so it'll then ask you if you want to set them to zero for later reductions. (If you don't trust them, this may be best!). Next it'll ask again if you want to ignore these calculated values and give you a second chance to instead input your own SOE coefficients now from the keyboard. If you answer "Y", it'll ask for each coefficient and these will be used for the later calculations of first order extinction and transformation coefficients.

Three Kv" Coefficients

You may be puzzled by the coefficient Kv"; there are three of them. The traditional formulae for Kv" uses the b-v color index as a measure of the color of the star. For VR, VI, or VRI photometry, this index is not measured. In order to get V magnitudes, TRANS therefore defines analogous coefficients which use v-r or v-i. If you have B, V, and R or I data on stars, TRANS will determine all versions possible. Note that for virtually all stars bluer than B-V of 1.5, the relations V-R = .79(B-V) and V-I = 1.54(B-V) hold fairly closely. Therefore, the SOE coefficients for v should obey the following ratios; K"v{b-v} : K"v{v-r} : K"v{v-i} = 1.00 :

1.26 : 0.65, approximately. And, more important, they should all be quite small (less than .02). If your data differs substantially from this, you may have to try again on a better quality night with more points.

FOE Plot Values

Next, TRANS will solve for and print to the screen the first order extinction coefficients, correlation coefficients, and names of the files receiving the plot data (Later, you can use RPLOT and these files to look at how well the best fit linear regression line follows your data). Note that there is no need for a v-r or v-i version of the first order extinction coefficient in "v", since this coefficient is not a mulitplier of a color index.

Transformation Coefficients

Finally, TRANS will calculate the transformation coefficients. Since transformation can be done with stars of any color, it'll use all standard stars; (i.e. any star cataloged "F", "S", or "A"), in deriving slopes and zero points. However, you may want to limit which stars to use. Some first and second order extinction observations are necessarily at low altitude, and you may not want to use these in finding transformation coefficients. If so, when it asks; "Do you want to use all transformation stars regardless of their airmass?", answer "N"o. You may then input the highest acceptable airmass. For example, to use only stars observed at higher than 45 degrees altitude, set your maximum acceptable airmass to 1.41. The default is to use all stars. Raw instrumental magnitudes are defined by simply -2.5 log (counts), so the zero point for V is typically around 15 for SSP users on 8" or 10" telescopes. The transformation coefficients for U, U-B, B-V, V-R and V-I are called EPU, PSI, MU, TAU, and ETA, respectively. The transformation coefficients for V are EPS (when using the traditional B-V color index), EPR (when using the V-R color index), and EPI (when using the V-I color index).

RMS Error

TRANS will then give the rms error in each color. This is an important number and tells you how good your data is. It is calculated by taking each standard star in turn and treating it like a variable star; calculating its magnitudes and colors by the "allsky" formulae (see Appendix A). The sum of the squares of the deviations of these calculated magnitudes from the tabulated standard magnitudes is the given rms error. For acceptable photometry, these should be less than .05 magnitude or so. Note that the standard stars themselves have catalog magnitudes and colors with errors of about .02 magnitude, so don't expect your results to be any better than this, even under ideal circumstances. Next, you can see the deviations contributed by each star, so if you have one or two discrepant points contributing most of the error, you can spot them here. Finally it'll ask you if you want to write these SOE, FOE and transformation coefficients to COEFF.DAT. Normally you'll say yes. If you want to fix up blunders in the data and re-reduce, you can say "no". COEFF.DAT contains one line of data for each night of

COEFF.DAT File

allsky photometry. It is continually appended, and contains all the extinction and transformation coefficients you have measured and recorded.

SOE and Trans. Coefficients are Carried Forward

COEFF.DAT is meant to contain your latest estimates of all extinction/transformation coefficients. Therefore, if you have SOE or transformation coefficients in some colors which were not determined on this most recent night, but they are available from the previous COEFF.DAT record, they will be re-written to the record for tonight. For example, suppose you did BVRI photometry on Jan 12, but only BV photometry on your next transformation night (say, on Mar 22). The SOE and transformation coefficients for V-R and V-I will be copied to the record for Mar 22. This transfer is NOT done for first order extinction coefficients or zero points, since these vary widely from night to night. Instead, undetermined FOE coefficients and zero points are set to zero.

7.3.2 FOE Calculation Only

"F" Mode Use Previous SOE/Trans.

You can use this mode if you trust previously determined SOE and transformation coefficients. TRANS will use those on the latest entry in COEFF.DAT. You run TRANS as before and answer "F" to the mode query, it'll then grind for a while and finally output the FOE coefficients and derived correlation coefficients, assuming the SOE and transformation coefficients read from COEFF.DAT. It'll list these assumed transformation coefficients and give you the new zero points for this night, and the rms error and deviations for each star, as described earlier.

7.3.3 SOE and FOE Extinction Calculation

"S" Mode Use Previous Trans. Coeff.

Suppose you want to just re-do second order extinction and not re-determine tranformation coefficients? For example, it can be quite time consuming getting a good long set of red-blue pair observations. This may not leave you with enough time (or wakeful attention) to do additional transformation stars of other colors. If you answer the mode query with "S", you will determine new second order and first order extinction values and zero points while using previous transformation coefficients from the last line in COEFF.DAT. It will process SOE first, as described above, and then do FOE and zero points as described under mode "F" above.

The sample data file RAW3.DAT contains observations of first and second order extinction and transformation standards in VRI taken at Cabrillo College Observatory Nov. 28, 1990. Practice reducing the sample raw data RAW3.DAT in each of the ways described here.

perfect straight line. However, the color-color relations is fairly linear for virtually all stars with B-V color index less than 1.5, and for most stars redder than this, and calculated V's should agree to within .01 or .02 for high quality data. The calculated V transformation coefficients should obey the same ratios as the second order V extinction coefficients; EPS : EPR : EPI = 1.00 : 1.26 : 0.65 , to within the scatter around your data. If your results are widely different from this, you do not have well determined V coefficients and need to try again on a better night.

EPS, EPR, and EPI Ratios

7.3.7 Determining Filter Requirements

RPHOT defines the extinction and transformation coefficients for the single filters U and V and for the color indices U-B, B-V, V-R, and V-I. However, differential instrumental magnitudes can still be calculated for single filter observations in any color; u, b, v, r, i, or c. The way RPHOT accomplishes this is to use the relations defining extinction in color index...

Single Filter Instrumental Magnitudes

$$K_y = K_x - K_{xy}$$

where "x" and "y" stand for any two valid colors; e.g. ub, bv, vr, or vi, and the K's can stand for either first or second order extinction (see Appendix A for these relations written in full for all color indices). What this means for the user is that even if, for example, only instrumental r magnitudes are desired, RPHOT must have available to it extinction coefficients in v(v-r) and in v-r, which means that the user must have done an extinction night in two color VR on his standard stars. Table 7-3 shows the minimum required filter set done on extinction / transformation nights in order to do single filter instrumental magnitude reductions.

Instrumental Color Desired	Required TRANS night data
u	UB
b	BV
v	BV or VR or VI
r	VR
i	VI

Table 7-4. Required Filter Sets for Instrumental Magnitudes.

Of course, if you do more colors on trans nights, you'll have more options. Doing UBV will enable reductions to u, b, or v; doing BVR will enable reductions to b, v or r; BVI will enable reductions to b, v, or i; VRI will enable reductions

Clear Filter Reduction

to v, r, or i; BVRI will enable reductions to b, v, r, or i, and UBVRI will enable reductions to u, b, v, r, or i. Instrumental reductions to "Clear" require only observations in C, and TRANS need never be run at all.

Note, though, that differential photometry is rather insensitive to extinction coefficients (completely insensitive if comparison and variable are extremely close in position and color), so that if only differential photometry is desired, the rough values already given in RPARMS.DAT (for an SSP-3A on a Schmidt-Cassegrain near sea level) may be sufficient for many purposes.

7.3.8 Automating TRANS - Command Line Arguments

T.BAT Batch File

A new feature of version 2.0 is the ability to specify answers to any or all of the options described above. The most convenient way to do this is by running the included batch file T.BAT, which also contains the descriptions below of each of the command line arguments you may specify. They can be in any order and all, some, or none, can be included. If you do not include a response and it is relevant for TRANS to ask, you will be asked during execution, as described in the normal mode above. Using this feature, it is possible to reduce a file by simply typing

```
>T filename
```

where "filename" is the input filename (the output of IREX). If all relevant command line arguments are specified in T.BAT, the program will go to completion without further user interaction. You can even reduce several files automatically by creating a batchfile with several command lines, as described previously with I.BAT. The command line arguments available and their functions are described in Table 7-4.

As an example, the batch file consisting of the single line below...

```
TRANS %1,NOSKIPSOE,TMODE,NOINPUTSOE,NOZEROSOE,
NOSUBSOE,NOINPUTTRAN,NOALLAIR,AIRMAX=1.5,COFWRIT
```

when executed with the command

```
>T RAW1.R
```

at the DOS prompt, will perform full SOE/FOE/transformation reductions on data in RAW1.R with no keyboard input substitutions, limit transformation calculations to stars with an airmass less than 1.5, and write the derived coefficients to COEFF.DAT.

Note that if the name T.BAT is inconvenient, you may

ARGUMENT	FUNCTION
TMODE	mode='T'; do full extinction/transformation calculation
SMODE	mode='S'; do first and second order extinction only
FMODE	mode='F'; do first order extinction only
MV	use Moffatt-Vogt term in calculations
NOMV	do not use Moffatt-Vogt term in calculations, assume it is zero
SKIPSOE	skip doing SOE calculations; use latest SOE coefficients in COEFF.DAT
NOSKIPSOE	do not skip SOE calculations
INPUTSOE	rather than calculate them, input SOE coefficients at the keyboard
NOINPUTSOE	do not input SOE coefficients at the keyboard
ZEROSOE	set SOE coefficients to zero for later calculations
NOZEROSOE	do not set SOE coefficients to zero, use the coefficients calculated in all later calculations of FOE and TRANS
SUBSOE	substitute in your own SOE coefficients after viewing those calculated
NOSUBSOE	do not ask to substitute in your own SOE coefficients
INPUTTRAN	rather than calculate them, input transformation coefficients at the keyboard
NOINPUTTRAN	do not ask for transformation coefficients to be input at the keyboard
ALLAIR	use all standard stars in transformation coefficient calculations, regardless of airmass
NOALLAIR	use only stars with airmasses less than AIRMAX (which will be asked for during execution if not supplied on the command line)
AIRMAX=xxxx	use only stars with airmasses less than xxxx in the transformation coefficients calculation
COFWRIT	write final calculated coefficients to the file COEFF.DAT
NOCOFWRIT	do not write calculated coefficients to COEFF.DAT

Table 7-5. TRANS Command Line Arguments.

change it. This is true also of the other command line argument batch files (I.BAT, F.BAT, and E.BAT) of RPHOT.

7.4 DIFFERENTIAL PHOTOMETRY

This is photometry done with a comparison and, optionally, a check star. It is capable of giving accurate magnitudes even from default, average values of the extinction coefficients. If you're doing differential photometry and don't want to determine new FOE coefficients for tonight, you

don't need to run TRANS at all. You can skip on to the final reduction program FREX.

7.5 PLOTTING EXTINCTION/TRANSFORMATIONS

Visual Check on Quality of Data

You can look at an x,y plot of any extinction or transformation regression fit and visually check the quality of your data by using RPLOT. After running TRANS, the appropriate data files needed by RPLOT are produced and ready for use. Again, see the descriptions of the SLOWMODE light curve plotting capabilities of RPLOT for an explanation of the command line arguments available in RPLOT.

At the DOS prompt you type

>RPLOT

Using RPLOT Option 3

and ask for option 3; Extinction/transformation regression plots. RPLOT will first ask whether you want your plot to be labeled in text or graphics style annotation, then ask you first whether you want to do a plot of first order extinction, second order extinction, or transformation. Next it will ask which color or filter you want to do. If you are interested in second order extinction or transformation in "V", you then select whether to look at the coefficient defined by the {b-v}, {v-r} or {v-i} color indices. If you are interested in transformation to the U-B color, there is also a choice; the Moffatt/Vogt regression which solves for the slope "rho", or the transformation coefficient "psi". (Note that the definition of rho forces the least squares line to go through (0,0).) RPLOT will then produce your linear regression plot, with the best fitting line, as well as the slope and the intercept of this line. For SOE plots, the names of the red/blue pair of stars is also included on the plot. When you've finished examining the plot, hit "ENTER" to return from graphics mode. You will then be asked if you want a hardcopy of this plot. Answering "Y"es will send your plot immediately to the printer, "N"o will skip hardcopy, and "S" allows you to save it to a file for later processing. The processing of hardcopy is described in Appendix B.2. Finally, RPLOT will ask if you want to do another plot.

Producing Hardcopy

The Y axis label on the plot for first order extinction in V includes a second order extinction term. The color index used in this label is the color index used in the calculation of the x and y coordinates of the first relevant observation in your data file. Note that FOE in V can be calculated from different color indices for different filtersets, since either B-V, V-R, and V-I can be used in the calculation of V.

If there is a bad point or two in your data, you can determine which observation is the culprit by browsing the

KUP.DAT	for first order extinction in U
KVP.DAT	for first order extinction in V
KUBP.DAT	for first order extinction in U-B
KBVP.DAT	for first order extinction in B-V
KVRP.DAT	for first order extinction in V-R
KVIP.DAT	for first order extinction in V-I
KUPPx.DAT	for second order extinction in U
KVPPx.DAT	for second order extinction in V, using the traditional b-v color index
KRRPPx.DAT	for second order extinction in V, using the v-r color index
KIIPPx.DAT	for second order extinction in V, using the v-i color index
KUBPPx.DAT	for second order extinction in U-B
KBVPPx.DAT	for second order extinction in B-V
KVRPPx.DAT	for second order extinction in V-R
KVIPPx.DAT	for second order extinction in V-I
	(where "x" is 1,2,3...for the 1st, 2nd, or 3rd red/blue pair observed)
EPU.DAT	for transformation to U
PSI.DAT	for transformation to U-B
RHO.DAT	for the Moffatt/Vogt transformation in U-B
EPS.DAT	for transformation to V, using B-V
EPR.DAT	for transformation to V, using V-R
EPI.DAT	for transformation to V, using V-I
MU.DAT	for transformation in B-V
TAU.DAT	for transformation in V-R
ETA.DAT	for transformation in V-I

Figure 7-6. Extinction/Transformation Data Files and Usage.

appropriate file listed in Table 7-5.

Suspicious Data

In these files, you'll see X and Y as the last two columns, just as plotted. The first column gives the name of the object producing this point, and the second column the heliocentric UT (in decimal form) of the observation. Use these to identify which observation is suspicious in your raw data. If you're lucky, you'll see some good explanation logged into your "comments" column, like "dew on mirror", or "police helicopter shined searchlight down telescope tube". If you don't see a good explanation, maybe you've discovered something new and interesting!

7.6 UBVRI AND INSTRUMENTAL MAGNITUDES (FREX)

Final Reductions

FREX ("Final REduXion program") will read the initial reduced data file output by IREX, and the extinction/ transformation coefficients stored either on COEFF.DAT or long term averages stored in RPARMS.DAT, as well as the reduc-

tion parameters on RPARMS.DAT, and calculate standard, Johnson / Kron-Cousins UBVRI or instrumental magnitudes of your program objects.

You can execute FREX in the normal way (i.e. without the command line argument options described later) at the DOS prompt...

```
>FREX filename              (filename optional)
```

where "filename" is the input file name produced by IREX. If you don't specify "filename" on the command line, FREX will ask for the it. FREX first reads through your data and looks up each object's coordinates and any available magnitudes from the star catalogs.

Asteriod and Comet Data Reductions

Moving objects such as asteroids and comets which you designated with CAT=M during data taking are treated a little differently. FREX will ask if you want to input the coordinates of these objects explicitly. If yes, it will prompt you for tonight's RA hours, minutes, seconds, and declination degrees, minutes, and seconds, and the epoch of your coordinates. If you don't know the coordinates, or feel safe in ignoring differential atmospheric corrections between comparison and program object, FREX will instead look up the comparison star's coordinates and use them for the program object as well. If you choose to do "allsky" photometry on a moving object, there is no comparison star and you will have to enter tonight's coordinates explicitly.

Separate Files for Each Program Object

FREX will produce a separate file for each program object you observed, forming the filename made from the object's name. For example, if you observed RZ CASS it'll produce a default file name for that star of RZ_CASS.DAT. It'll then ask if this is the file name you want to use. If not, enter a different name. It will do this for each program object, then list the comparison/check stars found and the program objects found on your input file. It will then cycle through and process each program object sequentially.

Check COEFF.DAT for "Allsky"

If you're doing "allsky" photometry on that object, FREX will automatically go to COEFF.DAT and pull off the correct coefficients corresponding to that night. You'd better have run TRANS first to produce this data or the program will bomb! Remember, transformation coefficients may not change much, but zero points change every night. You MUST run TRANS on each night on which you want to do "allsky" photometry!

You may reduce your data to produce either Johnson UBVRI magnitudes, or instrumental magnitudes. In version 1.0, all data was automatically reduced to Johnson magnitudes. However, since calculating Johnson magnitudes requires observations in at least two colors, if those colors weren't observed, magnitudes were not calculated. Now, in version

Reduce to the Instrumental or Johnson Systems

2.0, you may choose to reduce to the instrumental system no matter which filters were used, or to the Johnson system if the necessary color indices were observed. Your first question will be to chose the desired magnitude system to reduce to. Answer "J" to do Johnson reductions for all possible stars. If you want instrumental reductions for all stars, answer "I". If some stars are to be reduced to Johnson and some to instrumental, answer "M", for "mixed". If you answer "J", FREX will attempt to reduce all stars to the Johnson system. If there are filter sets which do not have the necessary color indices observed, FREX will automatically produce instrumental magnitudes instead. The necessary color indices for reductions to the Johnson system are given in Table 7-6.

If you answer "M", you will be asked for the desired magnitude system for each star individually.

If you are doing differential photometry on that object, FREX will then ask you to choose which extinction/transformation coefficients you want to use. Traditionally, differential photometry often ignores first order extinction corrections. However, including them improves accuracy, especially if your comparison stars are more than a degree or so from your program object, and FREX therefore uses them. Your choices are; input your own values explicitly at the keyboard, use the latest values given in COEFF.DAT, or to use the long term average values you chose when running PARMS earlier. The default is to use the long term average values. When running PARMS, if you have no idea what these numbers should be, just leave in the ones already included on RPARMS.DAT. Using these will be better than using none at all, until you've determined your own.

REDUCTIONS TO JOHNSON BAND	REQUIRED INDEX
U	U-B
B	B-V
V	B-V or V-R or V-I
R	V-R
I	V-I

Table 7-7. Required Index for Reductions to Johnson Bands.

Clear Filter Considerations

Note that when you ran TRANS you did not produce first or second order extinction coefficients for the non-standard "CLEAR" filter. Since "CLEAR" is only used for differential photometry, such calculations were not necessary. However, differential "CLEAR" photometry between a comparison and program object more than a degree or so apart can be

improved with a first order extinction coefficient included and airmass determined separately for comparison and variable. FREX does this, but uses an unchanging value of 0.20 for the first order extinction coefficient in "CLEAR". This value was found from experience with the SSP-3A. If this value is off by a worst-case factor of 2, the resulting error in differential magnitudes is less than .007 magnitude for a comparison and variable 3 degrees different in altitude, at altitude 45 degrees. Leaving this extinction coefficient constant saves the user the hassle of using TRANS on differential photometry nights.

FREX Output

FREX will then output to the screen and to your program object output files the reduced, standardized UBVRI magnitudes and their heliocentric dates and UT times. If these magnitudes are on the instrumental system, then the tabulated magnitude is followed by a lower case u,b,v,r, or i. "Clear" is always instrumental and is therefore not specially tagged. Instrumental "b" magnitudes are written in the B-V column, instrumental "r" and "i" magnitudes are written in the V-R and V-I columns, respectively.

Reduced Magnitude Considerations

Suppose your observations or comparison star standard magnitudes are incomplete; how will this affect reduced magnitudes?

CASE I. You do multi-color observations and enter standard UBVRI magnitudes in COMP.CAT for your comparison star. Your reduced magnitudes are then Johnson / Cousins UBVRI magnitudes.

Incomplete Comparison Magnitudes

CASE II. You do multi-color observations but don't know the standard magnitudes of your comparison star. Then leave those columns blank in COMP.CAT. FREX will essentially be reading zeros and your reduced magnitudes and colors will then be standard UBVRI magnitude DIFFERENCES between program object and comparison, in the sense program object minus comparison.

Single Filter Observations

CASE III. You do single filter observations. (With version 2.0, this is now possible on all filters; u,b,v,r,i,c). Your reduced magnitudes will be differences (program object minus comparison) on the instrumental system. This will be true whether or not your comparison star has magnitudes entered in COMP.CAT.

"Clear" Magnitudes

CASE IV. Reduced "Clear" magnitudes are always on the instrumental system. There is a column in COMP.CAT to enter the C magnitude. This can be useful if you have some observations done with one comparison and some with another. You can determine the C magnitude of one with respect to the other and enter it in COMP.CAT. Reductions will then put all the observations on one system.

In producing standard Johnson magnitudes you must of

B-V, V-R, or V-I Measurements Required for V Calculation

course observe in at least two colors in order to form a color index and do the transformation. For each set of filter observations, FREX will use the transformation coefficient for V corresponding to the color index you chose when running PARMS (either B-V, V-R, or V-I), if that color index was observed. If not, it will use one of the other indices according to the following priorities; B-V is preferred over V-R, which is preferred over V-I. If none of these color indices was measured, V will remain on the instrumental system for that filter set. Note that since these decisions are made for each separate filter set, you can do a BV set, then a VR set later, or any combination thereof, and still get V magnitudes calculated for all. This is useful when later reductions force you to throw out an occasional filter because of unsuspected problems.

Check Stars

When it has finished reducing the program objects, FREX will go back and do the same for your check stars. It'll treat them as variable stars and compute standardized magnitudes using the same comparison star as before, and store the results to a filename selected as before. You can then look at these magnitudes over time and see if your check is varying with respect to your comparison, and, if it is, puzzle over which is actually varying. If some or all your differential program objects have no check stars, that's OK; it'll skip this last stage for those stars.

7.6.1 Automating FREX - Command Line Arguments

All of the questions described above can be answered on the command line using the command line arguments given in Table 7-6.

F.BAT Batch File

Any of these may be incorporated in a one-line batch file, like F.BAT included with the RPHOT package, so that all reductions can be accomplished without user interaction. Any questions not answered with command line switches will be explicitly asked for during execution. As an example, the one-line batch file F.BAT below...

```
FREX %1,PAUSE,NOASKFOE,LCOFS,DEFNAM
```

can be invoked at the DOS prompt with the command

```
F RAW1.R
```

which will cause the initial reduced file RAW1.R to be FREX'ed, using long term average extinction / transformation coefficients from RPARMS.DAT, naming the output files with the default naming convention, and pausing between reductions of each star. One can run a whole set of final reductions from a batch file. For example, a batch file F2.BAT might look like this

```
CALL F RAW1.R
CALL F RAW2.R
CALL F RAW3.R
CALL F RAW4.R
```

where the DOS "CALL" is required, and available only on DOS 3.30 and later. For earlier DOS versions, see your DOS manual for how to run multiple batch files.

ARGUMENT	FUNCTION
PAUSE	pause after each program object is reduced
NOPAUSE	don't pause, continue with the next object
MOFFVOGT	use the Moffatt-Vogt term to improve U-B values
NOMOFFVOGT	do not use Moffatt-Vogt term; assume k"(u-b)=0
ASKFOE	ask explicitly for first order extinction coefficients to be input at the keyboard
NOASKFOE	do not ask for FOE coefficients from the keyboard
LCOFS	use long term averages of coefficients, stored on RPARMS.DAT
JSYS	reduce all stars to the Johnson magnitude system, if possible
ISYS	reduce all stars to the instrumental system
MSYS	some stars will be reduce to the Johnson, some to the instrumental system. Users will be queried for the desired system for each star
CCOFS	use the latest coefficients, found on COEFF.DAT
DEFNAM	use the default filename for storing output (the program object name with a ".DAT" appended)
NODEFNAM	do not assume the default filename, ask for it
OUT=xxxxx	use the filename xxxxx to receive all output. Useful for sending all output to a temporary file while doing trial reductions
END	bypass "Reduce another file?" query at end of FREX to allow batch processing of multiple files

Table 7-8. FREX Command Line Arguments.

SECTION 8.0

PLOTTING LIGHT CURVES

To produce a light curve for any object run RPLOT

>RPLOT

RPLOT Option 1

and specify option (1); SLOWMODE light curve plots. RPLOT will first ask for the name of the file containing the reduced magnitudes (i.e. YY-ERI.DAT). You are then asked whether the plot axis annotation should be in text (cleaner looking, but not as finely positioned) or graphics (better positioned, but a bit jaggy on low resolution monitors) mode. Then you're asked for which color index or filter you want to plot. You can only plot one color index or filter at a time.

Parabolic Fit

Next you'll be asked if you want a parabolic fit to the data. If you answer "Y"es, RPLOT will solve for the best fitting parabola through your data. It will plot this on your light curve and drop a perpendicular from the curve to the time axis. It will also output the minimum (or maximum) of the fit to the screen. This is useful for e.g. finding the times of minima of eclipsing binaries.

Smoothing Interval

Next, you select the smoothing interval (in days); a new feature with version 2.0. If you enter, for example, the value 0.3 at this query, RPLOT will do the following... It will read the first data point which is within your selected time window, and then look forward and combine all succeeding points for the next 0.3 days into one averaged point. It then reads the next point and then combines all succeeding points within 0.3 days of that point, and so on until the end of the time window is reached. In this way, you will get a plot showing smoothed data as data points whose size is proportional to the expected root mean square error in the resulting average, which depends on the number of points used in making the average. One common use for this feature is on slowly varying variables on which you hope to improve accuracy by taking several points per night. The value entered is always interpreted in days, even if you are asking for a phase plot (see below). If asking for a phase plot, RPLOT converts your requested smoothing interval from days into appropriate phase units. The default smoothing interval is 0 days, i.e. no smoothing.

Select Time Window

You next select your time window. RPLOT will let you plot almost any time window desired. Some common choices have been simplified; if you want to plot all the data on the most recent night, answer "L"; if you want to plot all the data on file, answer "A" (with this option, the x axis will be Julian Date). If you want to plot a given single night

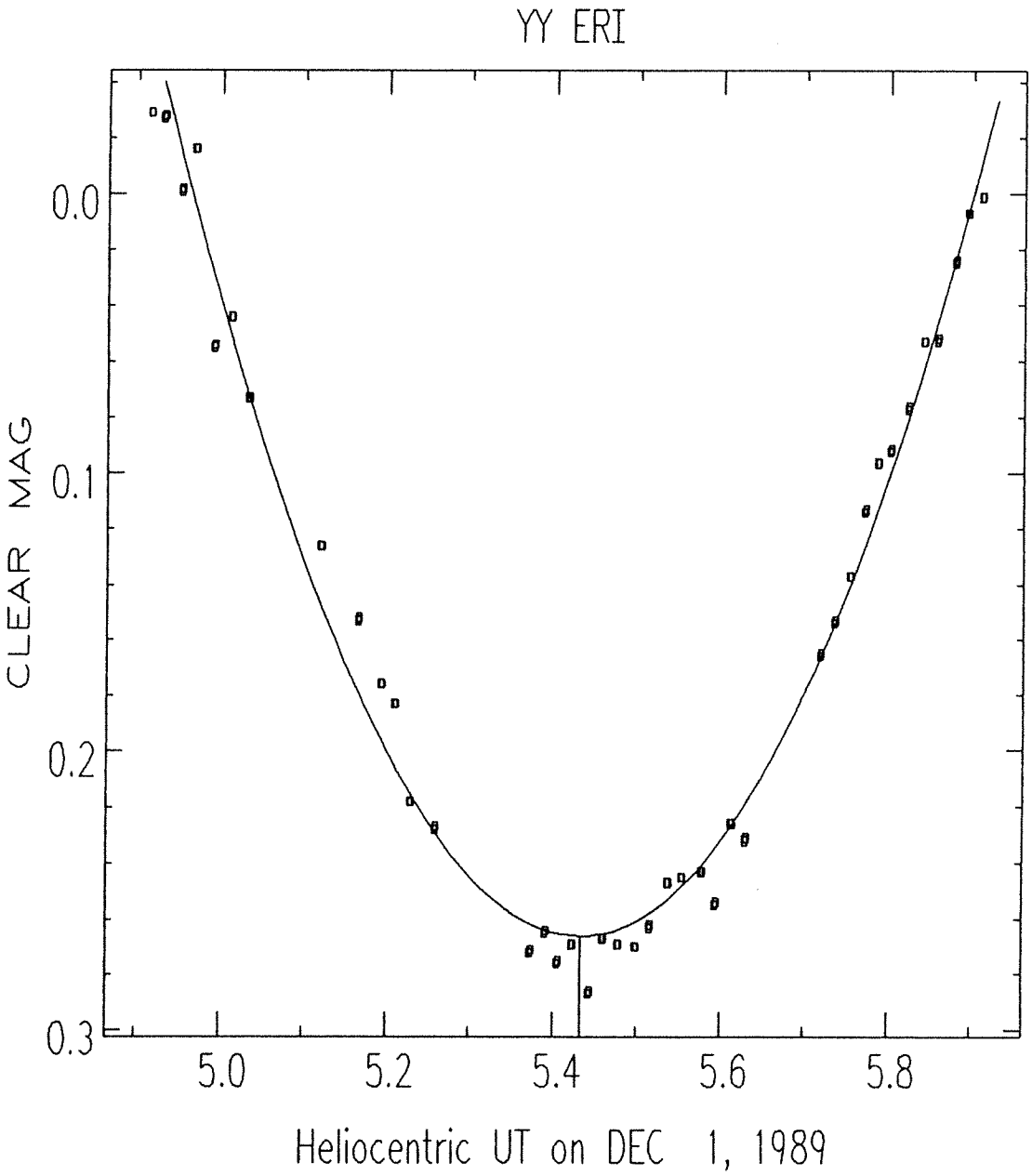

Figure 8-1. RPLOT Display With Parabolic Fit.

skip the parabolic fit.

Obtaining Hardcopy

After viewing your light curve on screen, you will be asked if you want hardcopy. Answering "Y"es sends it to the printer directly, "S" saves it to a file, and "N" skips hardcopy. See Appendix B.2 for a complete description of how hardcopy is produced and the available options.

Unknown Periods

Now, suppose you have a suspected periodic variable whose period is unknown. RPLOT allows you to look at folded light curves with successive trial periods in a convenient way: If you specified WINDOW=F and yet RPLOT cannot find your variable star filename on VPERIOD.DAT, it will put you in "manual mode" (this is the ONLY way to get into "manual mode") and ask for the period to be input at the keyboard. Enter the first trial period and examine the light curve; when finished, hit "ENTER" several times (taking the next several defaults). You will remain in "manual mode" and again be asked for a (new) period. The epoch is always set to be the time of the first plotted observation. Using this feature, you can zero in on a best fitting period fairly quickly. When you're done with manual mode, enter "0" at the period query.

8.1 AUTOMATING RPLOT WITH COMMAND LINE ARGUMENTS

RPLOT's extensive list of questions can be circumvented by using the command line arguments listed below. The file P.BAT also contains these descriptions.

P.BAT Batch File

For example, a batch file P.BAT consisting of the single line shown below...

```
rplot %1,slow,NPAR,FOLDED,ALLPHAZ,NOFFSET,
SMOOTH=0.,JMAG,HC=Y
```

would produce a slowmode folded light curve, in Johnson magnitudes, plotting all phases, with no phase offset, and no smoothing, and with no parabolic fit. After viewing the screen plot it will be sent to your printer. Executing this batch file on the data file for YY Eridanii as follows...

```
P yy-eri.dat
```

would result in only one remaining question being asked of the user; the color to plot.

ARGUMENT	FUNCTION
GRAF	plot axis labeling in graphics style
TEXT	plot axis labeling in text style
SLOW	do a SLOWMODE (e.g. variable star, etc.) plot
FAST	do a FASTMODE (e.g. occultation) plot
EXTRAN	do an extinction/transformation regression plot
HC=Y	send plot to printer for immediate printing
HC=N	do not generate hardcopy output
HC=S	save plot data to a file; options will follow on screen
**********	OPTIONS RELEVANT FOR "SLOWMODE" PLOTS **********
USLO	plot U filter magnitudes
BSLO	plot B filter magnitudes
VSLO	plot V filter magnitudes
RSLO	plot R filter magnitudes
ISLO	plot I filter magnitudes
UBSLO	plot U-B filter magnitudes
BVSLO	plot B-V filter magnitudes
VRSLO	plot V-R filter magnitudes
VISLO	plot V-I filter magnitudes
PAR	do parabolic fit for minimum/maximum light
NPAR	do not do parabolic fit for minimum/maximum light
1NITE	do "one night only" plot time window
LASTJD	do "last night only" plot time window
SELJD	do "selected date range" plot time window
ALLJD	do "all data on file" plot time window
FOLDED	do "folded periodic light curve" plot time window
SMOOTH=xxxx	smooth data over interval xxxx; a real number selected by user
JMAG	plot only Johnson magnitudes (relevant for U or V only)
IMAG	plot only instrumental magnitudes (relevant for U or V only)
SELPHAZ	zoom in on a restricted range of phases
ALLPHAZ	plot all phases
PMIN=xxxx	restrict phases to those greater than xxxx; selected by user
PMAX=xxxx	.....and less than phase xxxx; selected by user
OFFSET	plot phase values after first offsetting
NOFFSET	don't offset phase values
OFFSET=xxxx	offset phase values by amount xxxx; selected by user
ALLSLOWUT	plot all UT's (used when only one date is plotted)
SELSLOWUT	do only a selected range of UT's (range will be queried during execution)
*********	OPTIONS RELEVANT FOR "FASTMODE" PLOTS **********
RAW	plot raw counts in fastmode plot
INTEG	plot integrated counts in fastmode plot
60MAX	re-normalize x-axis seconds to be within range 0-60
N60MAX	do not re-normalize seconds
ALLFASTUT	plot all data in fastmode plot
SELFASTUT	plot only selected range of times in fastmode plot (range will be queried during execution)

***** OPTIONS RELEVANT FOR EXTINCTION/TRANSFORMATION PLOTS ********	
FOE	do a first order extinction plot
SOE	do a second order extinction plot
TRAN	do a transformation plot
ETU	plot U magnitude data
ETV	plot V magnitude data
ETUB	plot U-B magnitude data
ETBV	plot B-V magnitude data
ETVR	plot V-R magnitude data
ETVI	plot V-I magnitude data
BVINDX	plot V data obtained using B-V as the color index
VRINDX	plot V data obtained using V-R as the color index
1SOE	for SOE plots; plot red-blue pair #1
2SOE	for SOE plots; plot red-blue pair #2
3SOE	for SOE plots; plot red-blue pair #3
PHI	plot U-B transformation coefficient phi
RHO	plot U-B Moffatt-Vogt transformation coefficient rho

Table 8-2. RPLOT Command Line Arguments.

SECTION 9.0

COMMON ERRORS

Most common errors have been trapped and should not result in a compiler-generated error message. Some known exceptions to this are...

Common Error Sources

1. If you modify one of the parameter files by hand (i.e. not using program PARMS) and you goof, then unpredictable results may happen within programs which need those parameters. The solution is to always use PARMS to modify your parameters, and depend on its error checking to keep you out of trouble.

2. Running a program with the wrong input file(!). For example, running FREX or RPLOT on raw data.

3. Telling PARMS you have a PostScript printer when you don't! When it comes time to print out a hardcopy plot, you may lock up your machine.

Compiler Errors

Hopefully, you will not get run-time compiler generated errors, but it will help Optec and Nolten Software if, upon getting such an error, you place the included file F77L.EER on the directory with the program giving you trouble and try again (F77L.EER contains the text of the run-time errors from Lahey). You should then get a more informative error message. Please report it to Optec or Nolten Software.

SECTION 10.0

REDUCING THE SAMPLE DATA

Practice Reductions

The data disk contains some representative real data taken with this system. You can practice reducing any of these files. The files are named RAW1, RAW2, etc., and the corresponding IREX reduced files RED1, RED2, etc.

File Naming Conventions

For your own data, if you haven't decided on a file naming convention, you might consider the following idea. For raw SSP data, use the first letter of the observer's last name followed by the UT date (yr,mo,day); e.g. N881202 is data taken by observer "N" on the night of Dec. 1/2, 1988. The corresponding IREX reduced files have an ".R" as the extension. This way, you stay inside the DOS limitation of 8 characters for a filename, DOS can easily sort by date, and files can be easily listed chronologically. The final, reduced magnitudes are on files with obvious names, like YY-ERI.DAT for YY Eridanii, etc.

10.1 SLOWMODE DIFFERENTIAL PHOTOMETRY

Sample File RAW1.DAT

The raw data file RAW1.DAT contains BV differential photometry of the RS CVn binary LX Per, an eclipse of the W UMa star YY Eridanii, and a few points on the eclipsing binary EE Pegasi, both of the latter on the "clear" filter. Let's step through the reduction of this data. After running PARMS to set up your parameter files, enter at the DOS prompt

```
>IREX RAW1.DAT
```

IREX Matches Comparison and Variable Stars

IREX will spend a few seconds matching up the comparison stars (abbreviated CLX and CYY) to the variable stars, then you'll see the question...

```
Output file name <RAW1.R                    >;
```

Enter Output File Name

IREX has formed a default filename to receive the intermediate reduced output named RAW1.R. If you like this choice, simply hit the "ENTER" key. If you don't, you are positioned to enter your choice for a filename. Either way, after hitting "ENTER" IREX will say "...now processing...". You should see one warning...

```
*** WARNING: YY ERI AT 4:52:34 HAS DISPERSION IN COUNTS OF 3.0%
```

Large Std. Deviation Warning

meaning that the standard deviation of the 4 counts on this line just misses the maximum acceptable limit of 3%. If you think this means your data needs to be "massaged" (as we scientists like to say), then you can hit CTRL C to return

Use CTRL-C to Abort

DOS and inspect the offending counts. If you do not abort processing, you should answer <N>o to the allsky photometry prompt. Then answer "C" for the comparison star CLX to LX Per, and "N" (default) for CYY and CEE. The file contains no check stars so simply hit "ENTER" to bypass the next question and then specify CYY as the comparison for YY Eri and CEE as the comparison for EE Peg. RAW1.R will be written, and you'll get the question

```
Reduce another file?.... <Y>;
```

Hitting "ENTER" will take IREX back to the "Input file name?" question. Instead, enter N and "ENTER" to terminate IREX

END "IREX"

New Data File RAW1.R

You now will see in your data directory a new file RAW1.R. Since this data contains no "allsky" photometry, we do not need to run TRANS to determine extinction/transformation coefficients. We can go directly to FREX for the calculation of reduced magnitudes. Enter at the DOS prompt

```
>FREX RAW1.R
```

FREX Screen Output

FREX will read through your data, look up the relevant comparison stars in COMP.CAT, and output to the screen the list of comparison / check stars, followed by the program objects, and a question...

```
COMPARISON STAR LIST
   CLX
   CYY
   CEE

PROGRAM OBJECT LIST
   LX PER
   YY ERI
   EE PEG

Magnitude system (J,M,I)?.....<J>;
```

Johnson System Default

Answer by taking the default (J)ohnson system. This way, LX Per will get Johnson reductions, and the two stars with only clear magnitudes will automatically get instrumental reductions, without troubling you with this same question for each individual star. Next you'll see...

```
Rather than use first order extinction coefficients
stored in COEFF.DAT or RPARMS.DAT, would you like to
explicitly enter your own? (Y or N).....<N>;
```

Accept <N>o as Default

Typically, you will not want to explicitly enter your own extinction coefficients, so you take the default answer of <N>o by simply hitting the "ENTER" key. Next you are asked whether you want to use the long-term averages of your extinction/transformation coefficients stored on RPARMS.DAT, or use your most recent coefficients, stored on COEFF.DAT. It's usually a good idea to put your best guess average coefficients on RPARMS.DAT and take the default answer to this question; "L"ong term averages on RPARMS.DAT.

Use "L"ong Term Averages

The Reductions Loop

You now enter the reductions loop; one pass for each variable or check star. A reminder is given to dual floppy machine users that the time to swap output floppies is at the "File name?" query. Stars are processed in the order encountered; LX Per first. At the "File name?" query,

```
File name? (no more than 12 char) Default=<LX-PER.DAT    >;
```

FREX File Output

you'll notice that FREX took the variable star name LX Per and formed from it a reasonable output file name LX-PER.DAT. To accept this name, hit "ENTER". FREX will then inform you whether it found that this file already exists and therefore data will be appended to the end of it, or the file is now newly created. It also informs you that this will be reduced by differential photometry, and you'll see the "clear" and "V" UT's and magnitudes of each filterset are output to the screen at the same time that all observed filters are output to LX-PER.DAT. Follow the same procedure with YY Eri and EE Peg, and answer "N"o to

```
Reduce another file?.....<Y>;N
```

to quit

END "FREX"

New Data Files
LX-PER.DAT
YY-ERI.DAT
EE-PEG.DAT

Check your directory and you will see that you now have the new files LX-PER.DAT, YY-ERI.DAT, and EE-PEG.DAT. If these files already existed, then RAW1.R's data will have been appended to the end.

Now let's plot a light curve of YY Eri on this night. At the DOS prompt type

```
>RPLOT YY-ERI.DAT
```

RPLOT Slowmode Light Curves

At the first question, answer (1) for "slowmode light curves", and you'll then see...

```
Axis numbering in (T)ext or (G)raphics? <T>;
```

Choose Clear Filter Color

Answer with "ENTER" to take the default text mode, then choose to plot the data in the "clear" filter by answering C to the question...

```
Which  color to  plot?  (U,B,V,R,I,C,UB,BV,VR,VI)    <V >;C
```

Then answer Y to the next question...

```
Do parabolic fit for time of minimum/maximum? (Y,N)  <N >;Y
```

in order to get a parabolic fit to the eclipse. To the following question...

```
Smoothing interval? (in days)..... <0    >;
```

Do Not Smooth

take the default of zero 0, i.e. do not smooth the data. The next question asks which data to plot...

```
Which time window?  <L >;
```

Use "O" to Plot One Night of Data

The default is "L" for plotting the last night of data. You instead will want to answer with "O" (the letter, not zero!) to get one night of data which isn't the last night. It will then ask for the date to plot. Fill in the date shown below...

```
The UT date of the first data point to plot:
...month (1-12)? 12
...day? 1
...year (e.g. 1989)? 1989
```

Then, to the question...

```
Plot all UT's on this date?  <Y>;
```

take the default and plot it all. RPLOT will then process the data for a moment and you will then see your light curve. Note that the numbering is in the same style as the axis labels; normal text mode. The precision with which text can be positioned is limited to the size of a character, and this may not "look pretty" in some cases. Notice also that the parabolic fit is not particularly good. The problem is that the data is not symmetric and starts to level out at the tail end. We can fix these problems on the next pass. Hit "ENTER" and the screen will return to text mode. You'll see a message that the parabolic fit gave a time of minimum light of 5.475 hours heliocentric UT (a poor estimate). Try sending this plot to your printer by answering "Y"es to the query

Poor Parabolic Fit

```
Hardcopy? (Y,N,S).....<N>; Y
```

Printing Hardcopy

Specify "1" copy and your printer should start printing. When finished, you'll see...

```
.....Do another "slowmode" plot? <Y>;
```

Hit "ENTER" to take the default <Y>es and you'll be back at

Try Graphics Axis Numbering

the question "name of your data file?". Hit "ENTER" to again take the default YY-ERI.DAT, then at the next question answer with "G" to get graphics style axis numbering (we'll try it this way just for comparison with text style), then C filter again, etc., taking all the defaults until it asks for the date to plot. Answer with Dec 1, 1989, as before. Now, this time, to the question...

```
plot all UT's on this date?     <Y>;N
```

you answer "N"o. RPLOT will then ask for the beginning UT (answer 4.9) and the ending UT (answer 5.9). You have thus narrowed your time window to a 1 hour period roughly centered on minimum light, which is well fit to a parabola. Notice that the axis numbering is more accurately placed, but not as polished looking.

Use the "F"olded Option

Next try looping through again and this time taking the "F" time window to get a folded light curve. You'll see the x axis labeled in terms of phase.

Next try looping through again and at the question...

```
Smoothing interval? (in days)..... <0    >; .01
```

Now Try Smoothing

answer with .01. You'll see fewer (and bigger) points on your light curve, which now has data combined into .01 day averages.

To exit RPLOT, answer "N"o to the "...another "slowmode" plot?" question and again "N" to the "...another plot option" question.

10.2 EXTINCTION/TRANSFORMATION EXAMPLE

Sample File RAW3.DAT

RAW3.DAT contains data on standard stars taken on Nov 28, 1990, as well as a few points on the RS CVn star HD 12545. As above, do initial reductions with

```
>IREX RAW3.DAT
```

Use IREX First

and take the default output filename of RAW3.R. Then run TRANS...

```
>TRANS RAW3.R
```

Choose Mode "T"

This data was taken with the purpose in mind of solving for all extinction and transformation coefficients in V, R, and I. Therefore, choose mode "T" (the default) by hitting the "ENTER" key at the question...

```
Enter mode here: <T>;
```

TRANS will read through the file and give a (very fast!)

listing to the screen of each star observation set; ASTAR.CAT stars, followed by FOE.CAT, followed by SOE.CAT star pairs. Take the default <N>o answer to the next two questions. TRANS will then compute and output the SOE coefficients for V (using both v-r and v-i) and V-R and V-I. based on the observations of the red-blue pair BS 1373 / BS 1380. It will then ask you to hit "ENTER" to process the next red-blue pair. Since there is only one pair, it will then give the final SOE coefficients...

SOE Coefficients From Red-Blue Pair

```
Kv" (on v-r) = 0.004
Kv" (on v-i) = 0.002
K(v-r)"      = 0.006
K(v-i)"      = 0.004
```

(NOTE: If you have already run PARMS and changed DPARMS.DAT to your local coordinates, the SOE coefficients calculation will not produce the same results as shown above.) These coefficients are close to zero, as they should be, so they should be accepted as valid. Take the default <N>o answer to the next two questions

SOE Coefficients Close to Zero

```
....Want to zero out these SOE coefficients? (Y,N).......<N>;

....Want to substitute your own SOE coefficients? (Y,N)....<N>;
```

TRANS will then do first order extinction, with resulting coefficients Kv' = 0.266, K(v-r)'=0.059, K(v-i)=0.087. Valid results would be a positive Kv' of a few tenths, and coefficients for the color indices of less than +-0.1. These coefficients thus look OK. Hit "ENTER" to continue with transformation calculations. Answer <N>o to...

Valid FOE Results

```
Would you rather input your own transformation coefficients
and only determine new zero points? (Y,N).....<N>;
```

and answer <N>o to the question...

```
Do you want to use all transformation stars, no matter
what their airmass? (Y,N).......<Y>;N
```

We want to exclude low altitude observations from the transformation calculation. Let's try excluding all stars with airmass greater than 1.5 (i.e. stars lower than 42 degrees altitdude) by answering as follows...

Exclude Low Altitude Observations

```
Specify the maximum allowable airmass..... 1.5
```

You will then see a table of the calculated transformation coefficients in V (both V-R and V-I versions) and V-R and V-I. Note that the root mean square error in V is a disturbingly large 0.184 magnitudes...

Note Large RMS Error

```
RMS error in  V  = 0.184 magnitudes (using V-R)
RMS error in  V  = 0.185 magnitudes (using V-I)
```

```
RMS error in V-R = 0.028 magnitudes
RMS error in V-I = 0.052 magnitudes
```

This is a hint that there may be one or more bad stars. To see if this is the case, hit "ENTER" to see how well the derived coefficients predict the magnitudes of each star (you'll need to hit "ENTER" twice to see the two page's worth of stars). You will see that all observations produce deviations comfortably less than 0.1 magnitude, except those for BS 664, whose V error is almost 1 magnitude! So, to the last question

Note Problems With BS-664

```
Write these coefficients to "COEFF.DAT"?  (Y,N).....<Y>; N
```

answer "N"o. To sniff out the bad data, try running RPLOT with option (3) and looking at the (T)ransformation coefficient in (V) using either the (R) or (I) options and the bad point will be very obvious. It can also be spotted on the file EPR.DAT or EPI.DAT as the one with the deviant Y value.

Use RPLOT to Discover Bad Data

Now go back and edit RAW3.R to delete the three filters done on BS 664. When you re-run it through TRANS you will see much smaller RMS deviations in the transformation coefficients.

Delete BS-664 Data

In Appendix E you will find an example of multicolor photometry on the stars BS 6902 and BS 6469, showing the raw data file, the initial reduced file output by IREX, and the final data files BS-6469.DAT and BS-6902.DAT output by FREX, as well as example plots.

APPENDIX A

THE REDUCTION FORMULAE USED BY RPHOT

The formula for airmass was taken from Henden and Kaitchuck p. 87 from a paper by Hardie (1962). It takes into account the spherical shape of the earth by a polynomial expansion;

$$X = \sec z - .0018167(\sec z - 1) - .002875(\sec z - 1)^2 - .0008083(\sec z - 1)^3$$

where X is the airmass and z is 90 degrees minus the apparent (refraction corrected) altitude of the star. z is found from Z (the zenith angle uncorrected for refraction) by

$$z = Z - (60.4 \text{ arcsec}) \tan Z$$

Z is found by simple spherical trigonometry from the hour angle of the star, which is found from your longitude and Greenwich Mean Sidereal Time. (Actually, Greenwich Apparent Sidereal Time. However, the difference between GMST and GAST is always less than half a second and is negligible for our purposes). The formula for GMST was taken from the Astronomical Almanac page L2;

$$\text{GMST at 0 hr UT1} = 24110.54841 + 8640184.812866T + .093T^2 - .0000062T^3 \text{ in seconds}$$

where T is in Julian centuries of 36525 days of UT1 from January 1, 2000, at 12 hr UT1. Sidereal intervals are obtained from solar time intervals by multiplying by 1.00273. This is also the procedure used in the utility program AIR described in Appendix B.

The Extinction / Transformation Equations

TRANS makes use of your estimated values of first and second order extinction and transformation coefficients to improve the accuracy of the determinations of the x and y values used in the linear regression calculation. These estimates are stored in RPARMS.DAT when the user runs PARMS and should be based on past experience with your equipment and observing site.

In all the formulae below, raw instrumental magnitudes are defined as -2.5 log(count), where "count" is the counts after IREX converts the reading to look as if it were taken on the most sensitive scale available on your photometer, with a 10 second integration.

The first calculation done is for the second order extinction coefficients. They are determined by regressing "y" on "x" from the equations...

$$u_1 - u_2 - k'_u(X_1 - X_2) = k''_u [(u-b)_1 X_1 - (u-b)_2 X_2] + \text{const}$$

$$(u-b)_1 - (u-b)_2 - k'_{ub}(X_1 - X_2) = k''_{ub} [(u-b)_1 X_1 - (u-b)_2 X_2] + \text{const}$$

$$(b-v)_1 - (b-v)_2 - k'_{bv}(X_1 - X_2) = k''_{bv}[(b-v)_1X_1 - (b-v)_2X_2] + \text{const}$$

$$v_1 - v_2 - k'_v(X_1 - X_2) = k''_v[(b-v)_1X_1 - (b-v)_2 X_2] + \text{const}$$

$$= k''_{rr}[(v-r)_1X_1 - (v-r)_2 X_2] + \text{const}$$

$$= k''_{ii}[(v-i)_1X_1 - (v-i)_2 X_2] + \text{const}$$

$$(v-r)_1 - (v-r)_2 - k'_{vr}(X_1 - X_2) = k''_{vr}[(v-r)_1 X_1 - (v-r)_2X_2] + \text{const}$$

$$(v-i)_1 - (v-i)_2 - k'_{vi}(X_1 - X_2) = k''_{vi}[(v-i)_1X_1 - (v-i)_2 X_2] + \text{const}$$

where "1" and "2" refer to the red and blue star of the pair, respectively. The known "y" in the regression calculation is the left hand side, and "x" is in brackets [ ]. The k' terms are long term averages from RPARMS.DAT. The term k''_{ub} is preset to zero if the user does not want to use the Moffatt/Vogt $U-B$ correction procedure.

The single color coefficients for b, r, and i are found from the relations...

$$k''_b = k''_{bv} + k''_v$$

$$k''_r = k''_v - k''_{vr}$$

$$k''_i = k''_v - k''_{vi}$$

Next, first order extinction coefficients are determined from standard stars (only $B-V = V-R = 0$ stars in ASTAR.CAT if transformation coefficients are assumed unknown; otherwise all stars used which are in either ASTAR.CAT or FOE.CAT) using the formulae (with the k'' now known)...

$$U - u + k''_u(u-b)X - \varepsilon_u(U-B) = -k'_uX + \zeta_u$$

$$(U-B) - (u-b) + k''_{ub}(u-b)X - (1 - 1/\psi^*)(U-B) = -k'_{ub}X + \zeta_{ub}/\psi$$

$$(B-V) - (b-v) + k''_{bv}(u-b)X - (1 - 1/\mu^*)(B-V) = -k'_{bv}X + \zeta_{bv}/\mu$$

$$V - v + k''_v(b-v)X - \varepsilon(B-V) = -k'_vX + \zeta_v$$

or $$V - v + k''_{rr}(v-r)X - \varepsilon_{rr}(V-R) = -k'_vX + \zeta_v$$

or $$V - v + k''_{ii}(v-i)X - \varepsilon_{ii}(V-I) = -k'_vX + \zeta_v$$

$$(V-R) - (v-r) + k''_{vr}(v-r)X - (1 - 1/\tau^*)(V-R) = -k'_{vr}X + \zeta_{vr}/\tau$$

$$(V-I) - (v-i) + k''_{vi}(v-i)X - (1 - 1/\eta^*)(V-I) = -k'_{vi}X + \zeta_{vi}/\eta$$

Which V equation is used depends on which is preferred, as described in the text. The linear regression "y" are on the left hand side, and the "x" are just the airmasses X on the right which multiply the desired first order extinction coefficients k'. The "starred" (*) transformation coefficient terms are either long term averages or the values taken from the last record on COEFF.DAT, whichever the user prefers. The effect of this term is minimized for ASTAR.CAT stars with near zero color indices.

The linear regression "y" are on the left hand side and "x" are in brackets [ ] on the right. Zero points are the intercepts (the ζ's), also output by the least squares regression calculation. In the U-B transformation equation, ϱ is set to zero if the Moffatt/Vogt correction procedure is not desired. If the user does want to use the Moffatt/Vogt correction (recommended!) then ϱ is determined from regressing γ on q, where...

$$\gamma = \frac{(U-B) - (u-b)}{(1 - 0.27X)}$$

$$q = (U-B) - 1.05(B-V)$$

and X is airmass, as before. The intercept is forced to pass through (0,0).

If one is only solving for first order extinction for that night, and transformation coefficients and second order extinction coefficients are assumed known, then the first order extinction coefficients are again solved by linear regression, as shown previously, but zero points for the transformation calculation are found by averaging the zero points inferred by each standard star by solving for the ζ's in the transformation equations above (now with known, previously determined transformation coefficients; see Henden and Kaitchuck for a discussion).

After the extinction and transformation coefficients have been determined, the standard magnitudes for program objects are found by formula set #1 below if "allsky" photometry, and formula set #2 if differential photometry.

1. "Allsky" Photometry

$$U-B = \psi[(u-b) - k'_u X - k''_u (u-b)X] + \zeta_{vb} + \varrho q(1-.27X)$$

$$U = u - k'_u X - k''_u (u-b)X + \varepsilon_u(U-B) + \zeta_u$$

$$B-V = \mu[(b-v) - k'_{bv} X - k''_{bv} (b-v)X] + \zeta_{bv}$$

$$V = v - k'_v X - k''_v (b-v)X + \varepsilon(B-V) + \zeta_v$$

$$V = v - k'_v X - k''_{rr} (v-r)X + \varepsilon_{rr}(V-R) + \zeta_{rr}$$

$$V = v - k'_v X - k''_{ii} (v-i)X + \varepsilon_{ii}(V-I) + \zeta_{ii}$$

$$V-R = \tau[(v-r) - k'_{vr} X - k''_{vr} (v-r)X] + \zeta_{vr}$$

$$V-I = \eta[(v-i) - k'_{vi} X - k''_{vi} (v-i)X] + \zeta_{vi}$$

2. Differential Photometry

First, the comparison star magnitude is interpolated between front end and back

end readings using the UT of the program object's observation, for each filter. Then, the raw differential magnitude between variable and comparison is defined as

$$b = -2.5 \log [Cb(var)/Cb(comp)]$$

for the blue filter, and similarly for the other filters. "Cb" is raw counts in the blue filter here. Then, the extra-atmospheric magnitudes and colors are calculated from

$$\Delta u_0 = \Delta u - k'_u (X_{var,u} - X_{comp,u}) - k''_u(u-b)(X_{var,u}+X_{comp,u})/2$$

$$\Delta v_0 = \Delta v - k'_v (X_{var,v} - X_{comp,v}) - k''_v(b-v)(X_{var,v}+X_{comp,v})/2$$

$$\Delta v_0 = \Delta v - k'_{rr} (X_{var,v} - X_{comp,v}) - k''_{rr}(v-r)(X_{var,v}+X_{comp,v})/2$$

$$\Delta v_0 = \Delta v - k'_{ii} (X_{var,v} - X_{comp,v}) - k''_{ii}(v-i)(X_{var,v}+X_{comp,v})/2$$

$$\Delta (u-b)_0 = \Delta (u-b) - k'_{ub}(X_{var,ub} - X_{comp,ub}) - k''_{ub}(u-b)(X_{var,ub}+X_{comp,ub})/2$$

$$\Delta (b-v)_0 = \Delta (b-v) - k'_{bv}(X_{var,bv} - X_{comp,bv}) - k''_{bv}(b-v)(X_{var,bv}+X_{comp,bv})/2$$

$$\Delta (v-r)_0 = \Delta (v-r) - k'_{vr}(X_{var,vr} - X_{comp,vr}) - k''_{vr}(v-r)(X_{var,vr}+X_{comp,vr})/2$$

$$\Delta (v-i)_0 = \Delta (v-i) - k'_{vi}(X_{var,vi} - X_{comp,vi}) - k''_{vi}(v-i)(X_{var,vi}+X_{comp,vi})/2$$

where the airmass X for the comparison is interpolated between front and back end values. Then the transformed differential magnitudes are calculated from...

$$\Delta U = \Delta u_0 + \varepsilon_u \Delta (U-B)$$

$$\Delta (U-B) = \psi \Delta (u-b)_0$$

$$\Delta (B-V) = \mu \Delta (b-v)_0$$

$$\Delta V = \Delta v_0 + \varepsilon \Delta (B-V)$$

$$\Delta V = \Delta v_0 + \varepsilon_{rr} \Delta (V-R)$$

$$\Delta V = \Delta v_0 + \varepsilon_{ii} \Delta (V-I)$$

$$\Delta (V-R) = \tau \Delta (v-r)_0$$

$$\Delta (V-I) = \eta \Delta (v-i)_0$$

Finally, the program object's standard magnitudes are found from

$$U_{var} = U_{comp} + \Delta U$$

$$(U-B)_{var} = (U-B)_{comp} + \Delta (U-B)$$

$$V_{var} = V_{comp} + \Delta V$$

$$(B-V)_{var} = (B-V)_{comp} + \Delta(B-V)$$

$$(V-R)_{var} = (V-R)_{comp} + \Delta(V-R)$$

$$(V-I)_{var} = (V-I)_{comp} + \Delta(V-I)$$

For the clear filter, the procedure is simpler, since there are no standard magnitudes in that filter. The output magnitude C is simply the program object minus comparison magnitude difference corrected for differential first order extinction, using a constant representative value for the extinction coefficient of $k'_c = 0.20$

$$\Delta C = -2.5 \log[c(var)/c(comp)] - k'_c (X_{var} - X_{comp})$$

where the airmass X for the comparison star is interpolated between values before and after the program object observation.

APPENDIX B

ADDITIONAL UTILITY PROGRAMS

Also included in the package are several programs which are useful for maintaining the software, planning observations, doing certain reductions, and for generating hardcopy files or printouts.

B.1 PRTSC – A Quick Way to Send Screen Plots to your Printer

The DOS command GRAPHICS.COM is supposed to allow the user to hit the "print screen" key to get a hardcopy of what's on the screen. In practice, it often doesn't work. The DOS 4.0 version is better, and should work with the RPHOT package screen plots. If not, or if you have an earlier version of DOS and an IBM compatible printer, or one of the EPSON series or HP Laser jet series printers, the shareware utility PRTSC is included and will do the job that GRAPHICS.COM was meant to do. It is a TSR program which is installed by simply executing the command PRTSC. Thereafter, (until to shut off your machine) to get a screen dumped to the printer, just hit the "print screen" key. To read more about PRTSC, read the file PRTSC.DOC included on the environment disk. If you find this utility useful, for a modest $10 fee you can register with User Friendly Software and get extra help in tailoring PRTSC to your system. See the instructions in the file PRTSC.DOC on the ENVIRONMENT disk.

B.2 HCOPY – A Better Way to Generate Hardcopy

Rather than using PRTSC, a better way to get printed versions of plots is to use software which invokes printer drivers specialized to each printer. RPHOT version 2.0 can now accomplish this. Within the plotting programs RPLOT and PSEARCH is a "call" to install the necessary driver.

The driver EPS.BIN is supplied by Lahey and will generate printer commands or store them on a binary file for any printer equipped with the PostScript language. For all other printers, there is an intermediate step: AnSoft Inc. has a product called GrafPrint, which uses a generic driver GPRINT.BIN and a utility program GP to either send plots to the desired printer format, send them to a binary file for later printing, or generate a .PCX file suitable for later processing by your own PC Paintbrush or other compatible software. GP takes various command line arguments which set the orientation, margins, resolution, and output format. These arguments were set by you when you ran PARMS. It is the purpose of Nolten Software's HCOPY to take the user's preferences (some from PPARMS.DAT, some from the keyboard), form the appropriate command line, and run GP with this command line. Lahey Fortran's routine for performing DOS calls from within programs will take a maximum of 77 characters in the command line string. Unfortunately, the length of the command line argument string for GP runs longer than this. After trying several approaches, the solution I settled on is to divide the arguments into those which can change often, and those which will (probably) be set only once and not again. The latter are entered in a DOS Environment variable GRAFPRINT which you loaded with the SET command in AUTOEXEC.BAT (described in this manual in the "Installation" section). The more frequently adjusted parameters are placed automatically on the command line within HCOPY.

B.2.1 Running HCOPY from RPLOT or PSEARCH

From within RPLOT and PSEARCH, you'll see the question "Make Hardcopy?". Your options will do the following...

* "N"o skips hardcopy.

* "Y"es tells the software to send the plot to the printer immediately. If you have a PostScript Printer, Lahey's own driver EPS.BIN will produce binary printer commands which go directly to your printer, causing it to print your plot. HCOPY and GP are never called. If you do not have a PostScript Printer, HCOPY is called, the GP command line is formed, and GP invoked (all invisible to the user) and the printer will output plot.

* "S"ave tells the software to save the hardcopy to a file for later printing. You will then see two or three options for how to save the hardcopy (Don't worry; the instructions on screen are a lot simpler than this description, and will guide you through this array of possibilities!)...

  (F) will send the hardcopy to a "drawing file". This is a (relatively) small file of typically 20-40K. RPLOT (or PSEARCH) will then exit. You may now run HCOPY as a stand-alone (see below). This option is not available for PostScript printer owners, since Lahey's driver installer automatically produces binary output for PostScript printers. This file is always stored on the default directory. For dual floppy owners, there is enough space left on the "PLOT" diskette to accomodate these files.

  (B) will send the hardcopy to a .BIN binary file. This file may range in size from 20K for some small resolution=0 plots to 300K or larger for full page resolution=3 plots. PostScript printer owners will have this binary file produced from within RPLOT or PSEARCH. Non-PostScript owners have it produced by GP from within HCOPY, called automatically by the plot programs. These binary files contain the full printer commands needed for hardcopy. You may then get a printed version by simply doing a DOS "COPY" command to your printer device; e.g.

  ```
  >COPY HPLOT.BIN PRN /B
  ```

  If you choose to do the COPY yourself (instead of letting HCOPY do it for you) be sure to include the /B in the command! This is necessary for properly sending binary to the printer. You can instead run HCOPY and it will do this for you.

  (X) is for producing a file in .PCX format, suitable for later processing by your own PC Paintbrush or compatible software. This file must be created by GP, so HCOPY will be called. You will be asked for the file name; A ".PCX" will be automatically appended to your chosen name, so you do not include a .xxx filename extension. The file will be created and you will exit.

For both (B) and (X) options, you are asked for the name of the file to store the output. Unlike most such requests in RPHOT, here you may explicitly give the path, as long as the total file plus path is less than 10 characters. The reason for including the path option is that for high resolution plots, dual

floppy owners may not have enough space on the default diskette for holding the file. They may then put a path of, for example, "B:\output.bin" and store the file on a fresh diskette in drive B:. These same considerations apply in running HCOPY as a stand-alone. The command line string length limit of 77 characters described above requires that the input and output filenames be no longer than 10 characters, including any path and the three character extension. If you enter a longer filename, it will be truncated to 10 characters. You will see the command line string when GP is called. It will look something like this...

```
GP HPLOT.PRT /R=0 /F=P /t=100 /b=100 /r=100 /l=100 /O=HPLOT.BIN /D=EPFX
```

If your choices result in a length greater than 77 characters then an error message will result and you will be asked for new filename(s).

B.2.2 Running HCOPY as a Stand-Alone

There may be times when you want to run HCOPY separately; i.e. not have it automatically called from the plotting programs RPLOT and PSEARCH. Why? RPLOT is a large program; about 230K; and HCOPY and GP are both another 60-70K. If you are trying to produce a high resolution, full screen .BIN or .PCX file of size 300K or more, some machines may run out of memory (you should see some kind of "out of memory" error). To deal with this, run RPLOT or PSEARCH again and this time ask for hardcopy to be (S)aved. Save it to a drawing (F)ile (default filename is HPLOT.PRT). Then you can leave RPLOT or PSEARCH and run HCOPY alone. This will free up a lot of memory and enable you to produce larger hardcopy files.

Running HCOPY as stand-alone, you will first be asked for the destination of the output...

(B) sends it to a .BIN binary file suitable for direct printing at your later convenience. This option is not seen by owners of PostScript printers, since the file output by RPLOT or PSEARCH is already a .BIN file.

(P) sends the plot to the printer.

(X) sends the plot to a .PCX file.

Next you are asked for the file name. If it has a .BIN extension, it is assumed that it can be sent to the printer with a simple DOS "COPY /B" command. If it does not have a .BIN extension, it is assumed to require processing by GP.

For output going to the printer, you are lastly asked how many copies you want. Copies will be done without pause, one after the other.

B.3 JDAY - For Calculating Julian Date

FREX outputs dates as day, month, year, since this is the easiest form in which to review your data. For some purposes, you may want to know the corresponding Julian Date. JDAY is a simple routine for finding Julian Date for any month, day, year in the Gregorian calendar. It will ask you for the month (1-12), day, and year (including century), separated by commas. Then it will

ask for the UT time as hours, minutes, and seconds. It will then output the Julian Date, to .0001 day, to the screen.

B.4 XJD – Transforms Output Files into Julian Date Format

The output files produced by FREX give date in Month / Day / Year plus heliocentric UT format. This is easiest for spotting which data goes with which observing session, and is also convenient for plotting data on a single evening. However, standard format for reporting reduced data usually uses the Julian Date plus fraction. XJD will read any output file and produce a new file with the extension ".JD" which gives the integer Julian Date (the complete Julian date; e.g. 2447949), with the individual filter and color index columns containing the fractional date. The integer date chosen is that of the first color observed in that set. If later colors straddle the next Julian date, these fractional dates will be greater than 1.0.

At the DOS prompt, type

>XJD

XJD will ask for the path to your desired data file. Enter just the path, not the filename. As usual, all paths must end with a backslash. XJD will then ask for the name of the file to be transformed. A few seconds later, you will have your transformed file, written to the same path as the original data. XJD will then return and ask for a new file to transform, if desired.

Try XJD'ing some of the test data files (e.g. BS-6469.DAT) and see what is output.

B.5 ECBIN – For Producing Ephemerides of Periodic Variables

ECBIN will produce a set of predicted times of minima (or maxima) of periodic variable stars in a compact, easy to read form, modeled on the similar predictions available to AAVSO members (but better!). The name and much of the nomenclature found below assumes you are producing eclipsing binary star ephemerides, but in fact any strictly periodic variable star's ephemeris can be calculated. The output is an ASCII text file which can be printed by DOS or any standard editor. ECBIN reads data files which contain the initial epoch and exact period of your stars, as well as informative notes in a header. The enclosed example files (EC1, EC2, EC3, EC4) all contain eclipsing binary stars conveniently visible in the U.S. You may substitute your own program stars, or make new files with your stars. The example files all contain 16 stars; the maximum number which can fit across the long dimension of an 8 1/2 x 11 sheet of paper from a standard printer. If you would rather print your predictions in portrait mode, then simply abbreviate the files to include only 8 stars (or 7 or 9....play with it!). You may also need to shorten the informative notes on each star at the
top of each file.

The output will give the predicted UT times to .01 hour precision, precede these times with a "p" or "s" according to whether it is a primary minimum (maximum) or secondary minimum (maximum), and capitalize these "p"'s and "s"'s if the observability is sufficiently favorable according to the user's criteria (so that

there is a reasonable chance of getting enough data before and after the predicted time for a good timing.

B.5.1 Data File Format

Each star gets one line of informative data. If you have N stars in your file (N less than 17), then you have N lines of header information. These headers can include anything you wish. Follow these with a blank line. This tells the program that you've finished reading in header data.

The main data is found in 8 columns....

Col 1:	The variable star letter designation; no more than 6 characters
Col 2:	The constellation name abbreviation (usually 3 letters)
Col 3:	The magnitude range, written without decimal points
Col 4:	The duration of the primary eclipse (if known or applicable), in hours
Col 5:	An initial epoch. Primary minimum for eclipsers; whatever you want for other periodic variables
Col 6:	The period of the variation, in days
Col 7:	The phase at which secondary minimum occurs, if an eclipsing binary (or perhaps minimum for a cepheid). If empty, the program assumes secondary is exactly halfway between primaries; i.e. phase=.5
Col 8:	The type of variable star.

B.5.2 The Output

The output begins with the descriptive information on each star, then follows with the header: star letters, constellation, magnitude range, eclipse duration, and variable type, on successive lines. Then there follows the month and day, in (AAVSO recommended!) double date format, and the UT times, to .01 hour, of predicted primary and secondary events. Primary events are preceded by a "p" or "P", secondary events are preceded with an "s" or "S". A time is printed only if the sun and star altitudes falls inside your specified time and altitude windows (see below). It can be useful to know there is an event for your star sometime that day, even if you can't observe all of it. It's also useful to flag those events which occur high enough in the sky and with the sun far enough down that there is a good prospect of getting good data both well before and well after predicted minimum (maximum). Therefore, ECBIN will ask you to specify two altitude criteria for both the star and the sun; if the more generous criteria is satisfied, a lower case "p"/"s" is printed with the time; if the stricter criteria is met, a capital "P"/"S" is printed with the time. If there are multiple eclipses in one night , ECBIN prints the most favorable in order of "P"/"p"/"S"/"s". (primary before secondary.)

After a page of data has been filled, it will add another header, and continue with more predictions, until finished. Before printing, some printers may want you to insert page breaks before the headers. Any word processor can do this.

B.5.3 Running ECBIN

With version 2.0, you may now run ECBIN either in the normal, interactive way, or from a batch file (included here as E.BAT) which contains command line arguments corresponding to the questions asked during interactive execution. First we describe normal interactive execution...

Type ECBIN at the DOS prompt. It will first ask for the month and year to begin the predictions. Answer with the month (1-12) and full 4 digit year, separated by a comma.

Next it will ask for the number of months of predictions you want. For example, if you answer with "12", you will get one year of predictions, beginning with your first month.

Next it will ask for your longitude and latitude, in degrees, so it can do the altitude calculations. Next it will briefly describe the altitude criteria and ask for the more generous criteria. For example, you could enter an altitude criteria here of 0 degrees for the star and -12 degrees for the sun. If the predicted time meets this, you should be able to get at least a few points during the eclipse, though not the minimum. Next it will ask for the more stringent criteria. Here I usually specify 35 degrees altitude for the star, and -25 degrees for the sun. This usually insures getting at least an hour on both sides of the eclipse minimum.

Next, it will ask for how many lines make up a full page for your printer. It will use this to decide when to insert the header, so that you can see the header info on your stars at the top of each page. You can experiment with this number so that it corresponds with pagination on your printer. ECBIN will then produce your predictions.

The output dates are in "double date" form, which western hemisphere observers interpret as happening on the evening of the first of the two dates, and eastern hemisphere observers interpret as happening on the evening of the second date.

To run ECBIN from a batch file, you may use as an example the file E.BAT included with the package, as follows...

```
>E filename                                ("filename" optional)
```

where filename is the data file (e.g. E1.DAT). Use your favorite editor to change the command line arguments. By stacking together several lines you can run several sets of predictions all automatically. The command line list in E.DAT is reproduced below:

ARGUMENT	PURPOSE
LONG=xxxx	longitude of site, in degrees (+west, -east)
LAT=xxxx	latitude of site, in degrees (+north, -south)
STARCAP=xxxx	minimum star altitude for "high quality" observable event, degrees

SUNCAP=xxxx	minimum sun altitude for "high quality" observable event, degrees
STARMIN=xxxx	minimum star altitude for event to be printed, in degrees
SUNMIN=xxxx	minimum sun altitude for event to be printed, in degrees
PLINES=xx	no. of lines per page for your printer
OUT=xxxx	file to receive output predictions
OUT=DEF	send output predictions to default filename formed by appending ".OUT" to the name of the input file
MONTH=xx	predictions will begin with this month (1-12)
YR=xxxx	predictions will begin with this (4 digit) year (e.g. 1991)
NMO=xx	no. of months of predictions desired
END	tells ECBIN to end after first set of predictions finished

For example an E.BAT consisting of the single line below...

```
ecbin %1,long=121.92,lat=36.98,starcap=35,suncap=-25,starmin=0,
sunmin=0,plines=54,MONTH=12,YR=1990,NMON=1,OUT=def,END
```

and executed with the command

```
>E E1.DAT
```

will produce one month of predictions, for December 1990, for a site at longitude 121.92 degrees west, latitude 36.98 degrees north, with primary and secondary minima printed and labeled with "P" and "S" if the star is at least 35 degrees up and the sun at least 25 degrees below the horizon, minima printed with "p" and "s" if the star is at altitude 0 to 34 degrees up and the sun at 0 to -24 degrees down. The headers will be spaced 54 lines apart, the output file will be called E1.OUT, and the program will exit to DOS after completion of this one set. Note that these arguments can be entered in either upper or lower case.

One can automate the production of a whole series of ephemerides with batch file processing. For example, running a batch file which looks like...

```
CALL E E1.DAT
CALL E E2.DAT
CALL E E3.DAT
```

(where the DOS "CALL" is required for invoking multiple batch files, in DOS versions 3.30 and later. See your DOS manual) will, in conjunction with the E.BAT described earlier, produce ephemerides sets E1.OUT, E2.OUT, and E3.OUT, without user intervention.

B.6 AIR - Calculates Altitude and Airmass

AIR will calculate the altitude and the airmass of a given star with specified RA and DEC and date and time. Put the utilities disk in the default drive and, at the DOS prompt type

>AIR

AIR will first ask for the DOS path to the catalogs and to RPARMS.DAT (they should be one and the same). AIR pulls your longitude and latitude off of RPARMS.DAT, so even if your desired object is not cataloged, you must still give the path to RPARMS.DAT. If RPARMS.DAT is already on the default directory, just hit the carriage return. Next it will ask for the catalog containing the object. If it is already in one of the RPHOT catalogs, AIR will find it and read off the coordinates automatically. If it is not in your catalogs, answer the catalog query with "N". It will then ask for the coordinates explicitly, then the UT. It then outputs the altitude of the object, in degrees, and the airmass.

B.7 ADDSTAR – Adds Stars to the Catalogs

New stars may be added to the RPHOT catalogs either by using your favorite editor, or by running ADDSTAR. If you prefer to use an editor to add them by hand, note that it is not necessary for the stars in the ASTAR.CAT, FOE.CAT, COMP.CAT, or VAR.CAT catalogs to be in any particular order. It is, however, necessary that each SOE.CAT red-blue pair be entered in the following order; a blank line, followed by the blue star, followed by the red star. Simply follow the format of the data already in the catalogs.

It is probably easier, at least at first, to use ADDSTAR to do this automatically. With the Utilities disk loaded into the default drive and the catalogs loaded into another drive (or all on a hard disk), at the DOS prompt type

>ADDSTAR

ADDSTAR will first ask for the path to your catalogs (For those without hard disks, they may be on a drive other than the drive running ADDSTAR). Be sure to follow the example given and include a backslash both before and after the appropriate directory. If ADDSTAR and the catalogs are both on the default drive, as they should for hard drive owners, you can simply hit "ENTER" at the path query.

You will then be prompted for data on your star. Some of the information in the catalogs is essential; the star name, the coordinates, and the epoch of the coordinates must be entered for all stars. In addition, magnitudes in the colors you plan to observe are needed for all stars in the ASTAR.CAT, FOE.CAT, and SOE.CAT catalogs. Magnitudes are not needed in VAR.CAT, and, if only differential photometry on a relative scale is planned, are not needed for your comparison stars in COMP.CAT.

A new feature of version 2.0 is the inclusion of a column in COMP.CAT after the spectral type for specifying whether this star is used as a comparison or a check star. Using this feature, along with the following column specifying which variable star this comparison/check is used with, will allow IREX to pair up your variable/comparison/check sets automatically. Version 1.0 users will have to modify their COMP.CAT's to include this feature if they want to take advantage of this streamlining in IREX.

Other items are optional in all the catalogs, and are written to the files only for your convenience. These are; the common name (i.e. some other name which

may help you to find it in another catalog), the spectral type, the source of your data, and additional notes.

The cataloged stars come in order of ascending right ascension. ADDSTAR will insert stars in their proper right ascension order. If you make a mistake in entering data, you will have to use an editor after exiting in order to fix it.

B.8 TRIM - Trims Unobserved Columns from Final Data Files

A new addition with version 2.0. TRIM will read your final reduced data file output by FREX and make a clone which has had the filter and color index columns which contain no data removed. This is useful for reporting data, since the full width of the data files is 131 columns and must be printed in landscape mode on conventional printers. Typically, one or more filters are never observed, and in these cases, using TRIM may save enough space to permit you to print it in normal portrait mode on your printer. TRIM takes the file to be TRIMmed as a command line argument (or will query you if you don't enter a command line argument)

```
>TRIM filename
```

TRIM will make a new version with the same name as the original, but with the extension .TRM. It leaves your old version intact. FREX must always output it's data to your original version, so DON'T DELETE YOUR ORIGINAL VERSION! Use TRIM only to produce trimmed copies.

B.9 PSEARCH - Plots a Periodogram from Final Data Files

Another addition with version 2.0, PSEARCH uses the Jurkevich period search method to plot a periodogram to the screen from "slowmode" data on FREX output files. It was written around a kernel kindly supplied by David DuPuy. This is a powerful program for use in searching data for periodicities. You may specify any continuous time interval of your data to search, the range of periods to plot, which filter or color index data to use, and how many frequencies within your period range to plot. For those unfamiliar with periodograms, a periodogram in general is a plot of amplitude versus frequency (frequency equals 1/period). Amplitude is in arbitrary units, and the meaning of the plot is that the higher the amplitude at a given frequency, the better that corresponding period fits the data. Since frequency is not especially meaningful, PSEARCH instead plots amplitude versus period, in days.

B.8.1 Running PSEARCH

PSEARCH optionally takes the name of the data file on the command line (this is the only command line argument available):

```
>PSEARCH filename                          "filename" optional
```

PSEARCH will first ask whether you prefer axis numbering in text or graphics style, then asks the data range. If you ask for selected data range, it will ask for the beginning and ending dates (be sure to use 4 digit year, not 2 digit year; e.g. 1990, not simply 90). Then you'll be asked which color index or filter

to use. Any of the columns produced in FREX'ed data are valid possibilities; U, U-B, B-V, V, V-R, V-I, or instrumental u,b,v,r,i,c. You will then be asked for the range of periods to analyze, from shortest to longest, in days. Lastly, you'll be asked for how finely to divide up this range of periods. The maximum possible is 400. In other words, you can calculate the amplitude at a maximum of 400 evenly spaced frequencies between your chosen maximum and minimum frequency (calculated from your input shortest and longest periods). If you have a slow machine, calculating 400 points will require some patience. On a 12 Mhz AT with mathchip it takes about 30 seconds to do 400 frequencies.

After viewing you plot, you are asked if you want it sent to hardcopy. The questions and options on screen are exactly the same as described previously in Section B.2.

Please realize that periodograms are only the first step in deciding which periods are present. It is best to use PSEARCH to identify likely approximate periods and then go back and see how well you can refine these by examining RPLOT light curves in manual period mode. More important, sub-harmonics will be present which may require more data in order to eliminate. Day / night aliases, yearly aliases, beating with low order harmonics of other aliases, etc., can all complicate period analysis. Read the excellent introductions to this subject by David DuPuy and collaborators in *IAPPP Comm. 20* and *IAPPP Comm. 24*.

APPENDIX C

PROGRAM LIMITATIONS

These limitations were formulated to allow a full night (10 hours) of data to be done in nearly all conceivable circumstances. A second goal was to keep the executable files as small as possible to conserve disk space and speed loading.

C.1 DTAK Data-taking Limitations

Number of objects in OLIST observing list file.....500
Number of lines of slowmode data.....32000
Number of lines of fastmode data.....32000

C.2 IREX Limitations

In any given raw data file output from DTAK or DLOG, there is a limit on the number of various kinds of objects which can be reduced at one time (i.e. are all on one file). If these limits are exceeded, you must first subdivide your file into 2 or more files before they can be reduced;

Number of different program objects which can be reduced at one time.....35
Total number of different comparison or check stars which can be reduced at one time.....70
Total number of sky measurements which can be reduced at one time is.....500
Total number of comparison stars which are cataloged as standard stars (i.e. they are not in the COMP.CAT catalog).....40
Total number of lines of raw data of any kind, per file.....1000

C.3 Extinction/Transformation Reduction Limitations in TRANS

The initial reduced data file output by IREX must obey the following limitations if it is to be reduced by TRANS. If exceeded, you must first subdivide the file. A "set" is a set of filters, all done on one object. For example, three lines of data, done in B, V, and R, respectively, on YY Ori, is considered one set.

Total observations of any kind.....1000
Total ASTAR.CAT star filtersets.....50
Total FOE.CAT star filtersets.....120
Total no. of different red/blue SOE pairs.....3
Total filtersets on any given SOE red/blue pair.....40
Total filtersets used in transformation calculations.....120

(Since ASTAR.CAT, SOE.CAT, and FOE.CAT stars can all be used in transformation calculations, this last limit of 120 will probablybe the limit exceeded first)

C.4 FREX limits

The IREX reduced data file which is input to FREX must also obey the following limits if it is to be reduced without first being subdivided.

Total number of lines of data in IREX output file.....800
Total number of different comparison stars plus check stars....70
Total number of different program objects.....35

C.5 RPLOT Plotting Program limitations

Total number of lines in a "fastmode" files which can be read by RPLOT option(2).....32000

Total number of "fastmode" points which can be plotted by RPLOT option(2).....2000

Total number of lines of data in a "slowmode" data file which can be read by RPLOT option(1).....10000

Total number of points per RPLOT option(1) plot.....2000

APPENDIX E

LISTINGS OF SAMPLE DATA

On the following pages is shown sample data taken with the RPHOT software and an SSP-3A connected to a Meade 10" Schmidt Cassegrain. Data from the night of Sept. 20/21 1989 is shown at all stages of the data acquisition and reduction process. Notice how missing filters are handled, how consecutive data on a given filter on non-program objects is consolidated into a single line, and how missing or "0" count integrations are ignored.

RAW1 and RAW2 both use differential photometry. The comparison stars for LX Persei, EE Pegasi, YY Eridanii, BS 6469, BS 6902, CQ Cephei are called CLX, CEE, CYY, C64, C69, and CCQ, respectively in the comparison star catalog (These were convenient abbreviations I formed to speed entry at the telescope). When running IREX, tell it these variables are to be reduced with differential photometry.

VAR.CAT - VARIABLE STAR CATALOG

NAME	COMMON	EPOCH	RA------ DEC-----|	V	U-B	B-V	V-R	V-I	CLEAR	Sp.	SOURCE	Comments
TV CASS	SAO 21296	1950.0	1636.0 58 51 42	7.7						B9		
IZ PER	SAO 22365	1950.0	12856.5 53 45 43	7.9						A5		
BX AND	SAO 037805	1950.0	2 559.3 40 33 28	8.9						G0		
S23229	SAO 23229	1950.0	21745.6 54 16 54							F5	SAO	new var; see Feb '90 S&T
DM PER	SAO 23321	1950.0	22225.9 55 52 40							B9	SAO	
LX PER	SAO 038651	1950.0	30952. 47 55 05	8.4						G5		
V711 TAU	BS 1099	2000.0	33647. 0 36	6.1						dG9		v=8.2 companion 6.5" separation, leave in
EI ERI	HD 26337	1950.0	40715. -8-01-27	6.9						G5IV		
48 PER	BS 1273	2000.0	40840. 47 43	4.02	-0.03					B3Vpe		member alpha Per assoc. ref. iauc4877
YY ERI		1950.0	40946.5-10-35-44							G5		
EK ERI	BS 1362	2000.0	42039. -6-15	6.33						G5		
AO CAM		1950.0	42418.0 52 56 6								GCVS	
HU TAU	SAO 76680	1950.0	43518.6 20 35 9	5.7						B9		
RZ ERI	SAO 149847	1950.0	44124. -10-46-29	8.1						A5		
BM CAM	BS 1623	1950.0	50151. 58 57 15	6.4						K0		
SX AUR	SAO 40094	1950.0	5 810.2 42 6 19							A3	SAO	SP. B ON ATLAS BOR.
CD TAU	SAO 77084	1950.0	51433.5 20 04 48	6.8						F5		
AR AUR	SAO 57858	1950.0	515 1.2 33 42 55							B9	SAO	
IU AUR	SAO 58059	1950.0	52433.0 34 44 30							B1	GCVS	
ZETA TAU	BS 1910	2000.0	53739.0 21 9 0							B2IVp	BS	B-V=-.13 IN BS
BS 2024	HD 39118	1900.0	54518.0 1 59 44							G+A	BS	
BS 2047		1987.5	55338.5 20 16 29	4.41		0.59	0.51					
LT GEM		1950.0	61523.0 23 35 30							B1	GCVS	
WW AUR	SAO 59194	1950.0	62911.4 32 29 33	5.6						A0		
BS 2484		1980.0	64407.5 12 54 44	3.34		0.42	0.40					
R CMA	SAO 152724	1950.0	71712.3-16-17-59							F0	SAO	
AK CMI		1950.0	73737.0 4 0 0							A-F	GCVS	
BS 3569		1987.5	85821.3 48 05 29	3.14		0.19	0.22					
W UMA		1950.0	94015.4 56 10 56	7.9						G0		
NU VIR		2000.0	114551.0 6 31 00	4.02		1.54						
AG VIR		1950.0	115829.8 13 17 13							A0	SAO	
S139174	SAO 139174	1950.0	13 555.3 -2-24-46							F2	IBVS	New possible eclipser
ALF COM	ALF COM	2000.0	130959.2 17 31 46	5.22						F5V		
DELTA LIB		1950.0	145817.8-08-19-18	5.4						A0		
delta lib	bs 5586	1950.0	145817.8 -8-19-18							A0V	SAO	from Smith's Finder Chart
I BOO		1950.0	150208.0 47 50 51			-.14						
R CBR		2000.0	154834.0 28 10 00	5.8								
S121803	SAO 121803	1950.0	1640 7.0 0 37 11							A3	IBVS	New 2 hr .04mag var
V1010 OPH		2000.0	164928.0-15-40-00	6.11						A3		
AI DRA		1950.0	165508.8 52 46 31	7.1						A0		
AK HER	SAO 102668	1950.0	171143.2 16 24 28	8.8						F8		
U OPH	SAO 122226	1950.0	171359.0 1 15 9							B8	GCVS	
TX HER	SAO 46626	1950.0	1717 2.0 41 56 21							A5	GCVS	
BS 6469		2000.0	172144.0 39 58 00	5.60						dF8		
SZ HER		1950.0	173731.2 32 58 15	9								
V566 OPH	SAO 122946	1950.0	175424.3 4 59 31	7.5						F		
Z HER	SAO 103254	1950.0	175551.4 15 08 31							F5p		
V839 OPH	SAO 123183	1950.0	180658.4 9 08 28	8.8						G0		
BS 6902		2000.0	182539.0 8 2 00	5.56						gG2		
Z VUL		1950.0	191935.0 25 28 7							B4	GCVS	
V1143 CYG	SAO 031850	1950.0	193733.7 54 51 22	5.8						F5		
22 VUL		1985.0	201451.2 23 27 44	5.20						G2		
V444 CYG	HD 193576	1950.0	201742.9 38 34 24	8.3						WN5+O6		
Y CYG	SAO 70599	1950.0	205003.6 34 28 08	7.3						B		
RY AQR		1950.0	211733. -11-00-54	8.8						A3		
BE PEG	SAO 126971	1950.0	213734.2 8 57 26	6.8						A0		
AR LAC	SAO 51684	1950.0	220639.5 45 29 45	6.5						G5		
CQ CEP	SAO 34622	1950.0	223456.8 56 38 46	8.6						W5		

FILENAME=N890921 . RAW OUTPUT DATA FILE FROM "DTAK"
UT DATE= SEP 21 1989 TELESCOPE= MEADE 10 OBSERVER= NOLTHENIUS
CONDITIONS=DRY, NO MOON, SOME SMOG, LIGHT CIRRUS NEAR HORI. DARK CNTS=

MO-DY-YEAR	UT	CAT	OBJECT	F	COUNTS				INT	SCLE	COMMENTS
9-21-1989	3:37:25		SKYNEXT	B	469	466	469	0	10	10	
9-21-1989	3:38: 7		SKYNEXT	V	480	479	479	0	10	10	
9-21-1989	3:39:50	C	C69	B	711	712	711	712	10	10	
9-21-1989	3:41:10	C	C69	V	1359	1356	1344	1348	10	10	
9-21-1989	3:44: 2	V	BS 6902	B	631	632	630	628	10	10	
9-21-1989	3:45:33	V	BS 6902	V	1100	1101	1098	1096	10	10	
9-21-1989	3:46:53	V	BS 6902	B	631	632	630	630	10	10	
9-21-1989	3:48: 5	V	BS 6902	V	1099	1093	1095	1096	10	10	
9-21-1989	3:49:22		SKY	B	474	473	469	472	10	10	
9-21-1989	3:50:12		SKY	V	484	485	483	486	10	10	
9-21-1989	3:52:48	C	C69	B	713	712	710	707	10	10	
9-21-1989	3:54:15	C	C69	V	1345	1354	1339	1356	10	10	
9-21-1989	3:56:19	C	CK69	B	1018	1017	1019	1023	10	10	
9-21-1989	3:57:26	C	CK69	V	2269	2244	2252	2273	10	10	
9-21-1989	3:58:33		SKYLAST	B	472	474	469	0	10	10	
9-21-1989	3:59:14		SKYLAST	V	484	484	485	484	10	10	
9-21-1989	4:14: 0		SKYNEXT	B	474	472	477	473	10	10	
9-21-1989	4:14:50		SKYNEXT	V	483	483	482	481	10	10	
9-21-1989	4:15:38		SKYNEXT	R	485	486	487	486	10	10	
9-21-1989	4:17: 5	C	C64	B	634	633	631	634	10	10	
9-21-1989	4:18:18	C	C64	V	1015	1014	1012	1015	10	10	
9-21-1989	4:19:22	C	C64	R	1147	1144	1148	1146	10	10	
9-21-1989	4:21:33	V	BS 6469	B	777	779	778	772	10	10	
9-21-1989	4:22:51	V	BS 6469	V	1249	1244	1246	1251	10	10	
9-21-1989	4:24: 1	V	BS 6469	R	1311	1317	1325	1320	10	10	
9-21-1989	4:25:10	V	BS 6469	B	771	773	770	771	10	10	
9-21-1989	4:26:14	V	BS 6469	V	1241	1245	1241	1247	10	10	
9-21-1989	4:27:34	V	BS 6469	R	1319	1316	1318	1319	10	10	
9-21-1989	4:29:12	V	BS 6469	B	771	775	773	776	10	10	
9-21-1989	4:30:18	V	BS 6469	V	1240	1240	1249	1236	10	10	
9-21-1989	4:31:24	V	BS 6469	R	1304	1310	1309	1307	10	10	
9-21-1989	4:33:25	C	C64	B	627	629	629	629	10	10	
9-21-1989	4:34:59	C	C64	V	1003	1004	1003	1004	10	10	
9-21-1989	4:36: 1	C	C64	R	1135	1138	1129	1136	10	10	
9-21-1989	4:37:22		SKY	B	476	477	475	474	10	10	
9-21-1989	4:38: 8		SKY	V	484	486	484	486	10	10	
9-21-1989	4:39: 0		SKY	R	488	490	491	488	10	10	
9-21-1989	4:40:48	V	BS 6469	B	761	758	761	759	10	10	
9-21-1989	4:41:51	V	BS 6469	V	1221	1218	1220	1226	10	10	
9-21-1989	4:42:55	V	BS 6469	R	1298	1291	1300	1305	10	10	
9-21-1989	4:43:59	V	BS 6469	B	758	762	763	757	10	10	
9-21-1989	4:44:58	V	BS 6469	V	1225	1223	1225	1222	10	10	
9-21-1989	4:46: 3	V	BS 6469	R	1303	1294	1301	1293	10	10	
9-21-1989	4:47:14	V	BS 6469	B	762	761	763	766	10	10	
9-21-1989	4:48:30	V	BS 6469	V	1230	1220	1223	1225	10	10	
9-21-1989	4:49:34	V	BS 6469	R	1290	1302	1292	1297	10	10	
9-21-1989	4:50:45	V	BS 6469	B	761	758	759	763	10	10	
9-21-1989	4:51:43	V	BS 6469	V	1221	1223	1222	1228	10	10	
9-21-1989	4:52:44	V	BS 6469	R	1297	1306	1306	1297	10	10	
9-21-1989	4:54:36	C	C64	B	634	630	634	634	10	10	
9-21-1989	4:55:44	C	C64	V	1009	1004	1009	0	10	10	4TH BAD
9-21-1989	4:56:55	C	C64	R	1135	1136	1135	1142	10	10	
9-21-1989	4:59: 2	C	C64	B	631	627	628	626	10	10	
9-21-1989	5: 0: 8	C	C64	V	1002	1002	1001	996	10	10	
9-21-1989	5: 1:11	C	C64	R	1132	1141	1141	1145	10	10	STILL NO DEW
9-21-1989	5: 2:41		SKY	B	476	477	477	476	10	10	
9-21-1989	5: 3:28		SKY	V	485	487	486	484	10	10	
9-21-1989	5: 4:15		SKY	R	489	488	491	490	10	10	
9-21-1989	5: 6: 0	V	BS 6469	B	760	758	756	754	10	10	
9-21-1989	5: 7: 0	V	BS 6469	V	1203	1209	1225	1215	10	10	
9-21-1989	5: 8:19	V	BS 6469	R	1290	1288	1278	1286	10	10	
9-21-1989	5: 9:24	V	BS 6469	B	749	754	752	749	10	10	
9-21-1989	5:10:29	V	BS 6469	V	1221	1205	1211	1206	10	10	
9-21-1989	5:11:34	V	BS 6469	R	1286	1289	1287	1288	10	10	
9-21-1989	5:12:42	V	BS 6469	B	752	754	748	747	10	10	
9-21-1989	5:13:43	V	BS 6469	V	1208	1208	1207	1204	10	10	
9-21-1989	5:14:43	V	BS 6469	R	1290	1288	1285	1298	10	10	
9-21-1989	5:15:55	V	BS 6469	B	753	753	755	749	10	10	
9-21-1989	5:16:51	V	BS 6469	V	1204	1193	1215	1212	10	10	
9-21-1989	5:17:57	V	BS 6469	R	1299	1280	1286	1289	10	10	
9-21-1989	5:19:46	C	C64	B	625	624	625	625	10	10	
9-21-1989	5:20:54	C	C64	V	998	999	995	996	10	10	
9-21-1989	5:21:59	C	C64	R	1139	1134	1130	1134	10	10	
9-21-1989	5:23:21		SKYLAST	B	481	479	481	481	10	10	

9-21-1989	5:24:56		SKYLAST	K	492	491	492	491	10	10	
9-21-1989	5:29:55		SKYNEXT	B	478	478	482	483	10	10	
9-21-1989	5:30:39		SKYNEXT	V	499	499	500	494	10	10	
9-21-1989	5:31:28		SKYNEXT	R	500	499	499	501	10	10	
9-21-1989	5:34: 9	C	C69	B	698	697	701	700	10	10	
9-21-1989	5:35:58	C	C69	V	1312	1307	1320	1305	10	10	
9-21-1989	5:37:37	V	BS 6902	B	628	639	631	631	10	10	
9-21-1989	5:38:52	V	BS 6902	V	1081	1087	1079	1084	10	10	
9-21-1989	5:40: 4	V	BS 6902	B	631	634	630	627	10	10	
9-21-1989	5:41: 8	V	BS 6902	V	1084	1082	1082	1085	10	10	
9-21-1989	5:43:53	C	C69	B	693	694	689	695	10	10	
9-21-1989	5:45: 6	C	C69	V	1315	1308	1302	1309	10	10	
9-21-1989	5:46:26		SKYLAST	B	483	485	485	485	10	10	
9-21-1989	5:47:12		SKYLAST	V	503	500	503	505	10	10	
9-21-1989	5:49:37		SKYNEXT	B	482	482	480	480	10	10	
9-21-1989	5:50:28		SKYNEXT	V	491	491	491	494	10	10	
9-21-1989	5:51:18		SKYNEXT	R	496	495	496	495	10	10	
9-21-1989	5:53:27	C	C64	B	616	615	615	616	10	10	
9-21-1989	5:54:38	C	C64	V	974	983	977	982	10	10	
9-21-1989	5:55:35	C	C64	R	1128	1119	1123	1121	10	10	
9-21-1989	5:57:38	V	BS 6469	B	728	724	723	726	10	10	
9-21-1989	5:59: 6	V	BS 6469	V	1154	1163	1151	1149	10	10	
9-21-1989	6: 0:18	V	BS 6469	R	1235	1239	1244	1253	10	10	
9-21-1989	6: 1:22	V	BS 6469	B	724	721	725	720	10	10	
9-21-1989	6: 2:34	V	BS 6469	V	1160	1156	1160	1155	10	10	
9-21-1989	6: 3:31	V	BS 6469	R	1242	1254	1256	1261	10	10	
9-21-1989	6: 4:36	V	BS 6469	B	724	722	722	725	10	10	
9-21-1989	6: 5:48	V	BS 6469	V	1162	1163	1162	1151	10	10	
9-21-1989	6: 6:58	V	BS 6469	R	1254	1256	1246	1246	10	10	
9-21-1989	6: 8: 8	V	BS 6469	B	721	723	716	0	10	10	4TH BAD
9-21-1989	6: 9:31	V	BS 6469	V	1144	1149	1151	1156	10	10	
9-21-1989	6:10:52	V	BS 6469	R	1252	1243	1249	1250	10	10	
9-21-1989	6:12: 3	V	BS 6469	B	721	717	720	715	10	10	
9-21-1989	6:13:19	V	BS 6469	V	1149	1157	1148	1148	10	10	
9-21-1989	6:14:28	V	BS 6469	R	1243	1238	1244	1235	10	10	
9-21-1989	6:19: 0	C	C64	B	609	610	604	607	10	10	
9-21-1989	6:20: 6	C	C64	V	962	955	957	959	10	10	
9-21-1989	6:21:11	C	C64	R	1108	1102	1103	1105	10	10	66% MN 4 DEG UP RISING
9-21-1989	6:22:50		SKY	B	487	486	484	485	10	10	STILL NO DEW
9-21-1989	6:24: 3		SKY	V	499	497	497	500	10	10	
9-21-1989	6:24:52		SKY	R	500	504	500	499	10	10	
9-21-1989	6:27:28	V	BS 6469	B	718	706	710	707	10	10	
9-21-1989	6:28:43	V	BS 6469	V	1134	1146	1153	1151	10	10	
9-21-1989	6:29:46	V	BS 6469	R	1234	1243	1251	1240	10	10	
9-21-1989	6:30:59	V	BS 6469	B	715	714	716	712	10	10	
9-21-1989	6:32: 6	V	BS 6469	V	1150	1135	1133	1141	10	10	
9-21-1989	6:33:17	V	BS 6469	R	1233	1235	1236	1242	10	10	
9-21-1989	6:34:20	V	BS 6469	B	710	716	718	715	10	10	
9-21-1989	6:35:32	V	BS 6469	V	1139	1144	1126	1147	10	10	
9-21-1989	6:36:38	V	BS 6469	R	1244	1253	1237	1250	10	10	
9-21-1989	6:37:59		SKY	B	490	490	490	0	10	10	
9-21-1989	6:38:36		SKY	V	502	500	501	0	10	10	
9-21-1989	6:39:15		SKY	R	503	500	502	0	10	10	
9-21-1989	6:41:58	C	C64	B	604	611	600	601	10	10	
9-21-1989	6:42:47	C	C64	V	936	937	936	937	10	10	
9-21-1989	6:43:57	C	C64	R	1080	1082	1082	1091	10	10	
9-21-1989	6:45:36	V	BS 6469	B	709	705	709	706	10	10	
9-21-1989	6:46:45	V	BS 6469	V	1123	1120	1139	1127	10	10	
9-21-1989	6:47:54	V	BS 6469	R	1238	1238	1232	1227	10	10	
9-21-1989	6:49: 0	V	BS 6469	B	707	701	706	703	10	10	
9-21-1989	6:50:10	V	BS 6469	V	1118	1132	1120	1132	10	10	
9-21-1989	6:51:18	V	BS 6469	R	1236	1219	1229	1243	10	10	
9-21-1989	6:54:32	C	C64	B	602	600	597	596	10	10	
9-21-1989	6:55:46	C	C64	V	925	933	932	921	10	10	
9-21-1989	6:56:50	C	C64	R	1076	1073	1068	1064	10	10	
9-21-1989	6:58:17		SKYLAST	B	495	489	490	492	10	10	
9-21-1989	6:59: 2		SKYLAST	V	503	506	504	504	10	10	
9-21-1989	6:59:50		SKYLAST	R	509	509	508	509	10	10	STILL NO DEW

FILENAME=NR890921 . OUTPUT FILE FROM "IREX"
UT DATE= SEP 21 1989 TELESCOPE= MEADE 10 OBSERVER= NOLTHENIUS
CONDITIONS=DRY, NO MOON, SOME SMOG, LIGHT CIRRUS NEAR HORI. DARK CNTS=

MO-DY-YEAR	UT	CT	USBS	OBJECT	FLT	COUNTS	INT
9-21-1989	3:39:50	C	C	C69	B	2427	
9-21-1989	3:41:10	C	C	C69	V	8711	
9-21-1989	3:44: 2	V	V	BS 6902	B	1600	
9-21-1989	3:45:33	V	V	BS 6902	V	6162	
9-21-1989	3:46:53	V	V	BS 6902	B	1596	
9-21-1989	3:48: 5	V	V	BS 6902	V	6122	
9-21-1989	3:52:48	C	C	C69	B	2386	
9-21-1989	3:54:15	C	C	C69	V	8641	
9-21-1989	3:56:19	C	C	CK69	B	5475	
9-21-1989	3:57:26	C	C	CK69	V	17752	
9-21-1989	4:17: 5	C	C	C64	B	1588	
9-21-1989	4:18:18	C	C	C64	V	5313	
9-21-1989	4:19:22	C	C	C64	R	6597	
9-21-1989	4:21:33	V	V	BS 6469	B	3020	
9-21-1989	4:22:51	V	V	BS 6469	V	7643	
9-21-1989	4:24: 1	V	V	BS 6469	R	8311	
9-21-1989	4:25:10	V	V	BS 6469	B	2965	
9-21-1989	4:26:14	V	V	BS 6469	V	7599	
9-21-1989	4:27:34	V	V	BS 6469	R	8303	
9-21-1989	4:29:12	V	V	BS 6469	B	2988	
9-21-1989	4:30:18	V	V	BS 6469	V	7572	
9-21-1989	4:31:24	V	V	BS 6469	R	8193	
9-21-1989	4:33:25	C	C	C64	B	1533	
9-21-1989	4:34:59	C	C	C64	V	5189	
9-21-1989	4:36: 1	C	C	C64	R	6457	
9-21-1989	4:40:48	V	V	BS 6469	B	2841	
9-21-1989	4:41:51	V	V	BS 6469	V	7362	
9-21-1989	4:42:55	V	V	BS 6469	R	8092	
9-21-1989	4:43:59	V	V	BS 6469	B	2842	
9-21-1989	4:44:58	V	V	BS 6469	V	7386	
9-21-1989	4:46: 3	V	V	BS 6469	R	8084	
9-21-1989	4:47:14	V	V	BS 6469	B	2871	
9-21-1989	4:48:30	V	V	BS 6469	V	7393	
9-21-1989	4:49:34	V	V	BS 6469	R	8059	
9-21-1989	4:50:45	V	V	BS 6469	B	2842	
9-21-1989	4:51:43	V	V	BS 6469	V	7382	
9-21-1989	4:52:44	V	V	BS 6469	R	8121	
9-21-1989	4:54:36	C	C	C64	B	1568	
9-21-1989	4:55:44	C	C	C64	V	5220	
9-21-1989	4:56:55	C	C	C64	R	6476	
9-21-1989	4:59: 2	C	C	C64	B	1516	
9-21-1989	5: 0: 8	C	C	C64	V	5148	
9-21-1989	5: 1:11	C	C	C64	R	6503	
9-21-1989	5: 6: 0	V	V	BS 6469	B	2799	
9-21-1989	5: 7: 0	V	V	BS 6469	V	7269	
9-21-1989	5: 8:19	V	V	BS 6469	R	7956	
9-21-1989	5: 9:24	V	V	BS 6469	B	2732	
9-21-1989	5:10:29	V	V	BS 6469	V	7241	
9-21-1989	5:11:34	V	V	BS 6469	R	7973	
9-21-1989	5:12:42	V	V	BS 6469	B	2718	
9-21-1989	5:13:43	V	V	BS 6469	V	7195	
9-21-1989	5:14:43	V	V	BS 6469	R	7997	
9-21-1989	5:15:55	V	V	BS 6469	B	2734	
9-21-1989	5:16:51	V	V	BS 6469	V	7182	
9-21-1989	5:17:57	V	V	BS 6469	R	7977	
9-21-1989	5:19:46	C	C	C64	B	1449	
9-21-1989	5:20:54	C	C	C64	V	5085	
9-21-1989	5:21:59	C	C	C64	R	6430	
9-21-1989	5:34: 9	C	C	C69	B	2177	
9-21-1989	5:35:58	C	C	C69	V	8115	
9-21-1989	5:37:37	V	V	BS 6902	B	1500	
9-21-1989	5:38:52	V	V	BS 6902	V	5824	
9-21-1989	5:40: 4	V	V	BS 6902	B	1476	
9-21-1989	5:41: 8	V	V	BS 6902	V	5822	
9-21-1989	5:43:53	C	C	C69	B	2089	
9-21-1989	5:45: 6	C	C	C69	V	8064	
9-21-1989	5:53:27	C	C	C64	B	1340	
9-21-1989	5:54:38	C	C	C64	V	4864	
9-21-1989	5:55:35	C	C	C64	R	6266	
9-21-1989	5:57:38	V	V	BS 6469	B	2432	
9-21-1989	5:59: 6	V	V	BS 6469	V	6608	
9-21-1989	6: 0:18	V	V	BS 6469	R	7458	
9-21-1989	6: 1:22	V	V	BS 6469	B	2399	

9-21-1989	6: 4:36	V	V	BS 6469	B	2402
9-21-1989	6: 5:48	V	V	BS 6469	V	6648
9-21-1989	6: 6:58	V	V	BS 6469	R	7525
9-21-1989	6: 8: 8	V	V	BS 6469	B	2365
9-21-1989	6: 9:31	V	V	BS 6469	V	6546
9-21-1989	6:10:52	V	V	BS 6469	R	7499
9-21-1989	6:12: 3	V	V	BS 6469	B	2342
9-21-1989	6:13:19	V	V	BS 6469	V	6543
9-21-1989	6:14:28	V	V	BS 6469	R	7409
9-21-1989	6:19: 0	C	C	C64	B	1225
9-21-1989	6:20: 6	C	C	C64	V	4608
9-21-1989	6:21:11	C	C	C64	R	6043
9-21-1989	6:27:28	V	V	BS 6469	B	2234
9-21-1989	6:28:43	V	V	BS 6469	V	6469
9-21-1989	6:29:46	V	V	BS 6469	R	7409
9-21-1989	6:30:59	V	V	BS 6469	B	2263
9-21-1989	6:32: 6	V	V	BS 6469	V	6400
9-21-1989	6:33:17	V	V	BS 6469	R	7352
9-21-1989	6:34:20	V	V	BS 6469	B	2258
9-21-1989	6:35:32	V	V	BS 6469	V	6386
9-21-1989	6:36:38	V	V	BS 6469	R	7445
9-21-1989	6:41:58	C	C	C64	B	1137
9-21-1989	6:42:47	C	C	C64	V	4348
9-21-1989	6:43:57	C	C	C64	R	5805
9-21-1989	6:45:36	V	V	BS 6469	B	2167
9-21-1989	6:46:45	V	V	BS 6469	V	6250
9-21-1989	6:47:54	V	V	BS 6469	R	7291
9-21-1989	6:49: 0	V	V	BS 6469	B	2134
9-21-1989	6:50:10	V	V	BS 6469	V	6227
9-21-1989	6:51:18	V	V	BS 6469	R	7259
9-21-1989	6:54:32	C	C	C64	B	1075
9-21-1989	6:55:46	C	C	C64	V	4240
9-21-1989	6:56:50	C	C	C64	R	5625

...VARIABLE	COMPARISON	CHECK...
BS 6902	C69	CK69
BS 6469	C64	

BS-6902.DAT ; CABRILLO OBSERVATORY SSP-3A

UT DATE	UT(CLR)	CLEAR	UT(V)	V	UT(U)	U	UT(U-B)	U-B	UT(B-V)	B-V	UT(V-R)	V-R	UT(V-I)	V-I
9-21-1989			3:46:41	0.374					3:45:55	0.080				
9-21-1989			3:49:13	0.380					3:48:37	0.073				
9-21-1989			5:40: 0	0.371					5:39:22	0.042				
9-21-1989			5:42:16	0.370					5:41:44	0.050				
9-26-1989			3:23:38	0.234					3:22:54	-0.153				
9-26-1989			3:26: 4	0.239					3:25:33	-0.173				
9-28-1989			3:43:37	0.224					3:43: 6	-0.144				
9-28-1989			3:45:28	0.228					3:44:59	-0.148				
10- 4-1989			4:30:24	0.333					4:29:53	-0.235				
10- 4-1989			4:32:28	0.311					4:31:59	-0.208				
10- 4-1989			4:35:20	0.217					4:34:52	-0.150				
10- 6-1989			3:55:25	0.248					3:54:55	-0.144				
10- 6-1989			3:57:32	0.248					3:57: 1	-0.141				
10- 6-1989			3:59:46	0.256					3:59:14	-0.138				
10- 9-1989			3:37:29	0.230					3:36:57	-0.150				
10- 9-1989			3:39:23	0.223					3:38:57	-0.148				
10- 9-1989			3:41:44	0.226					3:41: 8	-0.146				

BS-6469.DAT ; CABRILLO OBSERVATORY SSP-3A

UT DATE	UT(CLR)	CLEAR	UT(V)	V	UT(U)	U	UT(U-B)	U-B	UT(B-V)	B-V	UT(V-R)	V-R	UT(V-I)	V-I
9-21-1989			4:21:54	-0.383					4:21:15	-0.317	4:22:29	-0.149		
9-21-1989			4:25:17	-0.382					4:24:45	-0.306	4:25:57	-0.143		
9-21-1989			4:29:21	-0.384					4:28:48	-0.322	4:29:54	-0.155		
9-21-1989			4:40:54	-0.359					4:40:23	-0.292	4:41:26	-0.137		
9-21-1989			4:44: 1	-0.362					4:43:32	-0.286	4:44:34	-0.141		
9-21-1989			4:47:33	-0.361					4:46:55	-0.294	4:48: 5	-0.145		
9-21-1989			4:50:46	-0.359					4:50:17	-0.281	4:51:17	-0.134		
9-21-1989			5: 6: 3	-0.358					5: 5:33	-0.312	5: 6:43	-0.159		
9-21-1989			5: 9:32	-0.357					5: 9: 0	-0.294	5:10: 5	-0.152		
9-21-1989			5:12:46	-0.351					5:12:16	-0.302	5:13:16	-0.142		
9-21-1989			5:15:54	-0.351					5:15:26	-0.316	5:16:27	-0.142		
9-21-1989			5:58: 9	-0.317					5:57:25	-0.326	5:58:45	-0.146		
9-21-1989			6: 1:37	-0.329					6: 1: 1	-0.311	6: 2: 6	-0.139		
9-21-1989			6: 4:51	-0.338					6: 4:15	-0.315	6: 5:26	-0.147		
9-21-1989			6: 8:34	-0.329					6: 7:53	-0.320	6: 9:15	-0.136		
9-21-1989			6:12:22	-0.337					6:11:44	-0.316	6:12:57	-0.152		
9-21-1989			6:27:46	-0.363					6:27: 9	-0.291	6:28:18	-0.151		
9-21-1989			6:31: 9	-0.358					6:30:36	-0.321	6:31:45	-0.150		
9-21-1989			6:34:35	-0.365					6:33:59	-0.323	6:35: 8	-0.136		
9-21-1989			6:45:48	-0.369					6:45:14	-0.316	6:46:23	-0.139		
9-21-1989			6:49:13	-0.372					6:48:38	-0.312	6:49:47	-0.137		
9-28-1989			4:18:53	-0.434					4:18:27	-0.317	4:19:21	-0.172		
9-28-1989			4:21:51	-0.431					4:21:19	-0.323	4:22:19	-0.171		
10-29-1989			2:29:49	-0.356					2:29:19	-0.306	2:30:26	-0.153		
10-29-1989			2:33:38	-0.357					2:32:58	-0.300	2:34: 8	-0.159		
10-29-1989			2:39: 3	-0.357					2:38:35	-0.281	2:39:38	-0.152		
10-29-1989			2:49:40	-0.344					2:49: 0	-0.275	2:50:23	-0.148		
10-29-1989			2:54:49	-0.352					2:54:15	-0.284	2:55:22	-0.169		
10-29-1989			3: 6: 1	-0.318					3: 3:39	-0.309	3: 6:37	-0.134		
10-29-1989			3:17:25	-0.332					3:16:56	-0.277	3:18:20	-0.145		
10-29-1989			4:16:59	-0.346					4:16:18	-0.173	4:17:31	-0.128		
10-29-1989			4:20: 9	-0.358					4:19:39	-0.301	4:20:38	-0.144		
10-29-1989			4:23:57	-0.362					4:23:15	-0.292	4:25: 6	-0.143		
11- 2-1989			3:37:25	-0.415					3:37: 2	-0.325	3:37:58	-0.146		
11- 2-1989			3:40:11	-0.415					3:39:45	-0.339	3:40:34	-0.148		
11- 8-1989			2:46:10	-0.389					2:45:31	-0.315	2:46:33	-0.161		
11- 8-1989			2:48:45	-0.395					2:48:22	-0.318	2:49:12	-0.151		
11- 8-1989			2:51:38	-0.393					2:51:10	-0.316	2:52: 8	-0.159		
11- 8-1989			2:54:33	-0.401					2:53:59	-0.311	2:55: 0	-0.153		
11- 8-1989			3: 3:39	-0.384					3: 3:15	-0.304	3: 4:13	-0.162		
11- 8-1989			3: 6:37	-0.371					3: 6: 5	-0.304	3: 7: 4	-0.152		
11- 8-1989			3: 9:21	-0.370					3: 9: 0	-0.310	3: 9:55	-0.141		
11- 8-1989			3:12:14	-0.375					3:11:51	-0.309	3:12:42	-0.151		
11- 8-1989			4:14:37	-0.331					4:14: 3	-0.315	4:15: 2	-0.102		
11- 8-1989			4:17:43	-0.345					4:17:14	-0.289	4:18:16	-0.126		
11- 9-1989			3:57:55	-0.405					3:57:32	-0.304	3:58:29	-0.142		
11- 9-1989			4: 1: 2	-0.398					4: 0:26	-0.315	4: 1:27	-0.143		
11- 9-1989			4: 3:52	-0.388					4: 3:24	-0.336	4: 4:17	-0.126		