PHOTOELECTRIC PHOTOMETRY OF THE PLEIADES

SOFTWARE USERS' GUIDE

A Manual to Accompany Software for
Introductory Astronomy Lab Exercise
Document SUG 2: Version 1

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I. INTRODUCTION

I-1. Purpose

This document provides specific technical information for users of the CLEA software module "Photoelectric Photometry of the Pleiades". It includes discussions of hardware and operating system requirements (Section II); software installation and operation (Section III); files associated with the exercise (Section IV); user options and file formats for possible user modifications (Section V); and astronomical data, models and algorithms employed in the exercise (Section VI). The material in this guide is intended for use by the instructor and by other personnel involved in installing and configuring the exercise software and PC hardware. It is not intended for distribution to the students. (The word "user" when it appears herein should be interpreted as "instructor", and not "student".)

Readers of this document are assumed to have available the **General Users' Guide To CLEA Windows Software** which contains technical information that applies to all CLEA Windows software. Information contained therein is not repeated here.

I-2. Acknowledgements

Development of CLEA exercises and materials, including this guide, is supported in part by National Science Foundation Grant USE 9155927 and by Gettysburg College.

II. SYSTEM REQUIREMENTS

This software runs on IBM and compatible PCs under Microsoft Windows 3.0/3.1. It requires a hard disk with at least 1.5 MByte of available storage, and a color VGA monitor. For additional information on systems requirements, including a discussion of color modes and video drivers, see the **General Users' Guide To CLEA Windows Software**.

III. INSTALLATION AND OPERATION

All files for this exercise are compacted into the distribution file CLEA_PHO.ZIP. They must be extracted using the PKUNZIP program (also included on the distribution diskette), and placed together in a single directory, such as C:\PHO_LAB. Details of unpacking, running, and installing this software under Windows are given in the **General Users' Guide To CLEA Winodws Software**.

IV. FILES INCLUDED WITH EXERCISE

The software module for each CLEA exercise includes a (largely) unique set of files that are vital to its operation. In addition to the executable code for the program (.EXE), these files hold the bitmaps for the screen displays (.BMP), data and parameters for the astronomical objects in the exercise (.DAT), text for the Help screens (.HLP), startup parameters (.INI), and documentation (.PHO, .UPD). Many of these files can be modified or replaced to tailor the exercise to specific classroom requirements (see Section V). The following files comprise this exercise, and should be present in your working directory after unpacking the distribution (.ZIP) file (**General Users' Guide To CLEA Windows Software**):

README.PHO - Notes on the current version, including any incompatibilities with previous versions, old files that should be deleted, etc.

PHO_0P7.UPD - A list of updates (by version) since version 0.50.

USRGUIDE.PHO - This document, in text form.

CLEA_PHO.EXE - The executable code for the exercise.

CLEALOGO.BMP - 256-color bitmap data for the CLEA Logo screen.

CLEALG16.BMP - 16-color bitmap data for the CLEA Logo screen.

PLEIALAB.BMP - 256-color bitmap data for the Title screen.

PLEIAL16.BMP - A 16-color version of the Title screen.

PHOFILES.DAT - A list of files containing star fields, and the field coordinates (see Section V-2.1).

PLEIADES.DAT - Positional and photometric data for the Pleiades stars (see Section V-2.2).

CLEAHELP.HLP - Text for "Help" ...."On Help".

PHOSTART.HLP - Text for "Help"...."Getting Started".

PHODATA.HLP - Text for "Help"...."Taking Data".

REMINDER.PHO - Text to display when "Quit" is selected (**General Users' Guide To CLEA Windows Software**).

(PHOTOPTS.INI) - This file is not included in the distribution, but is created the first time the exercise is run. It contains default settings for options (see **General Users' Guide To CLEA Windows Software**). This file can be deleted if desired, it will then be re-created.

V. USER OPTIONS

See the **General Users' Guide To CLEA Windows Software** for a general discussion of user options, including password access to the options dialog and the options file (PHOTOPTS.INI).

V-1 Parameters and Selectable Options

The following switches on the options dialog enable features that simplify the exercise by providing information not normally available at the telescope:

Show Magnitudes: When this switch is on, the measured magnitude is computed and displayed on the screen when a reading is taken. If this switch is off, the student must compute the magnitude from the raw counts and measurements of standard stars. The default is ON.

Show ID, Comments: When this switch is on, the contents of the ID and comments fields from the star data record (see Section V-4.2) are displayed on the screen when the star is measured. This can be used to determine whether the correct stars are being measured, and to provide information such as spectral type, binary nature, etc. to the students. The default is OFF.

Show Field Size: When this switch is on, the size of the field in the viewscreen is displayed. If this switch is off, the students can determine the field size by turning off the drive and timing the diurnal drift through the field. The default is ON.

NOTE: The size of the "Finder" field is currently fixed at 2.5 degrees (see discussion in Section V 4.3). The "Instrument" field is one tenth the "Finder" field (0.25 deg = 15').

The following parameters are set via the options dialog:

UT-Local Time (Hrs): The value (in integer hours) of Universal Time minus local (zone) time for the presumed location of the "observatory" for this exercise. This number is used to convert the time obtained from the system clock on the individual PC to Universal Time. The table below gives the standard time values for North American time zones. (For daylight time, subtract one from the table value.) The default is 5 hours (Eastern Standard Time).

Zone	UT-ST (Hrs)
Atlantic	4
Eastern	5
Central	6
Mountain	7
Pacific	8
Alaska	9
Hawaii	10

Image Bias (Mag): The value (integer) of the magnitude bias to be used when mapping the magnitudes from the star data (Section V-2.2) onto the available star images for display. (For details, see Section VI-1.) This parameter must be equal to or less than (numerically) the magnitude of the brightest star in the field (rounded to a whole number). The default is 1.

Options Password: This is the password for access to the options dialog (see **General Users' Guide To CLEA Windows Software**). Allowable passwords have a maximum length of four characters, and are case sensitive. The default password is "CLEA".

V-2. Data (.DAT) Files

Data for the star fields and individual stars used in this exercise is read from files typically identified by the qualifier .DAT. These files, like the .HLP files, are in text format, and can be created and maintained with a text editor. (See **General Users' Guide To CLEA Windows Software** for comments concerning the Help files and word processors) The specific record formats for the star fields list file and the stellar data files are given in Sections V-2.1 and V-2.2, respectively. The following general rules apply:

1) Data should be entered one record per line.

2) Fields within records are separated by at least one space. Do not use commas or other separators, and do not embed spaces in numeric fields.

3) String fields are enclosed in single quotes ('), and the number of characters + spaces between the quotes must be <= the maximum length of the field.

4) Real fields may carry a sign, and may be in decimal (1.0, -2.345) or exponential (0.1234E-06, -8.549E+18) form. Real fields will also accept integer (0, 1, -99) values.

5) Integer fields may carry a sign, and cannot include a decimal point or exponent.

6) The maximum allowed values for all numeric fields (in terms of both absolute value and number of digits) are much larger than required for any reasonable values for the quantities they represent.

7) Values must be provided for all fields in a record, in the proper order. For null strings enter two single quotes (' '), for null numeric fields enter 0 or 0.0.

8) There is no specific limit on the number of records in a file. However, these files are read into and maintained in memory when they are used, so there is some risk of running out of heap space with a large file.

To add a new star field to the exercise, you must create a stellar data file (Section V-2.2), place it in the exercise directory (Section III), and add a record to PHOFILES.DAT (Section V-2.1) naming the file and specifying its coordinates. Before creating new fields or adding data to existing fields you should read Section V-2.3, which presents some restrictions and guidelines on star field coordinates and sizes.

V-2.1. Star Fields List File

This file provides a list of the files that contain the stellar data for each star field, along with the coordinates of the field centers. It is identified in the field labeled "Star Field List" on the options dialog (Section V-1); the default is PHOFILES.DAT. Records in this file have the following format (see general rules under V-4):

Field	**Data Type**	**Contents**
File Name	String[12]	Name of stellar data file (name + qualifier, no path).
Right Ascension	Real	RA of field center in decimal hours (0.0..24.0, but see Section V-4.3).
Declination	Real	Dec of field center in decimal degrees(-90.0..+90.0, but see Section V-4.3)

When the telescope is moved via the "Set Coordinates" button, the program searches the star fields list to find the field center closest to the target coordinates, and loads the corresponding star data file.

> **NOTE:** The star fields list is not searched during a slew (using the N-S-E-W buttons). It is therefore possible to slew off a star field into empty space, even though a neighboring field may be available. Always use the "Set Coordinates" button to change fields. (Of course, if the nearest field center is too far away or the field is small you may still get an empty screen.)

V-2.2. Stellar Data Files

These files contain the data (magnitude, color, etc.) for each star in a star field. Each entry in the star fields list (Section V-2.1) identifies a stellar data file, which must be present in the working directory when the exercise is run. (Note that these files are not identified on the options dialog (**General Users' Guide To CLEA Windows Software**).) Only one of these files (PLEIADES.DAT) is supplied with the exercise, but the user may add as many as desired (supplying corresponding entries in PHOFILES.DAT), and may also add/delete/modify data in PLEIADES.DAT. Stellar data file records have the following format (see general rules under V-2):

Field	**Data Type**	**Contents**
Star ID (Note 1)	String 15	Optional (Note 2) Star name, HD/BD Number, id # in cluster, or other identification
Right Ascension	Real	RA of star in decimal hours (0.0..24.0)
Declination	Real	Dec of star in decimal degrees (-90.0..+90.0)
V Magnitude	Real	Photometric magnitude in UBV system
B-V Color	Real	Photoelectric color index in UBV system.
U-B Color	Real	Photoelectric color index in UBV system.
Comment (Note 1)	String[23]	Optional (Note 2) additional information (spectral type,binary, etc.).

Notes:

(1) If the "Show ID, Comments" switch (Section V-1) is set, the contents of this field will appear on the screen when the star is measured.

(2) Enter two single quotes (' ') to blank out this field.

V-2.3. Field Coordinates and Angular Size

When creating new star fields for this exercise, or modifying existing fields, give consideration to the following:

1) The "finder" (wide) field of the simulated telescope is 2.5 degrees square. Users may want to provide a larger field to avoid having part of the visible field go blank when slewing to stars of interest.

2) The object of interest (probably a cluster) should be centered in the field. The coordinates of the field center should be entered in the star field list file (Section V-2.1).

3) Avoid high declinations (stay within -60 < dec < +60). The display algorithm is relatively simple, similar to a Mercator projection.

4) Similarly, avoid fields that straddle the 24Hr/0Hr dichotomy in right ascension. (The program will not identify a coordinate of, for example, 23Hr 50Min RA as being "near" one at 0Hr 5Min, etc.)

We have developed a separate program, GENSTARS, which can be used to generate random star fields, primarily for backgrounds. The GENSTARS program and documentation is included with the CLEA exercise "The Hubble Redshift - Distance Relation". GENSTARS output requires some text editor modification, including deletion of some record fields and the possible addition of color data, for use with this exercise.

VI. ASTRONOMICAL DATA, MODELS AND ALGORITHMS

VI-1. Star Images

A frequent problem with much astronomical software we have seen, even some that is otherwise quite sophisticated, is that the plotted star fields do not look realistic. The most common techniques are to either plot all stars as a single pixel of the same intensity, or to use filled circles of varying sizes to represent the magnitudes. The problem with the first method is that while the images look somewhat like stars, the field does not look like the sky (picking out constellations or other patterns is difficult), and attempting to vary the intensity of a single pixel yields a useful range of only two or three "magnitudes". On the other hand, the second method yields images that look nothing at all like stars, with the brighter "stars" being large sharp-edged circles, some as large as dimes. As we feel that it is important for the students to appreciate the true appearance of the sky, both to the naked eye and through various astronomical instruments, we devoted some time to the creation of more realistic looking star images, for this and for other CLEA exercises.

Clearly, the ideal way to display a realistic star image is to use a real star image, which will not be smooth and perfectly round, but will have natural irregularities caused by seeing, optics, etc. A CCD image is the obvious choice, since it is already in digital form.

We began by selecting a single fairly bright CCD star image. We then developed a series of successively fainter images by reducing the intensities, pixel by pixel, in equal stages. The factor used to decrease the intensity at each stage was experimentally adjusted, balancing the desire for a reasonably wide magnitude range against the need for each image to be "clearly fainter" in appearance than its successor. (The faint end of this process was reached when the resulting image was barely visible on the screen against a black background.) This eventually resulted in a series of 11 images.

The brightest image was (more or less arbitrarily) assigned magnitude 0, and each succeeding image increased by 1 magnitude to give a base magnitude range of 0 through 10. To provide for zero point adjustment for fainter clusters, we added an image bias parameter that can be set by the user (Section V-1). This number is used as the actual magnitude which corresponds to the magnitude 0 image. When stars are plotted, their magnitude is rounded to a whole number and the corresponding image is assigned. Stars fainter than the (adjusted) end of the image range are all plotted using the faintest image.

Users who add new star fields to this exercise may want to experiment with various values of the bias parameter to yield a realistic and pleasing display. We have found that the brightest images are perhaps a bit too "bright" and have set the bias parameter at 1 rather than 3, which is the magnitude of the brightest star in the Pleiades. Do not set the bias parameter to a value that is larger (numerically) than the magnitude of the brightest star you are plotting.

We have not attempted to add color to the star images. The images are displayed on the screen by setting all three color values (RGB) to the same level. Intensities in the image data that exceed 256 (in the original (Mag 0) image the values go as high as 17,000) are set to 256, the highest available. This yields a burned-out center, which is realistic for TV monitors. When the images are displayed in a 16-color video mode (**General Users' Guide To CLEA Windows Software**), the edges of the brighter images show some step contouring, due to the limited number of grayscale values available.

VI-2. Pleiades Photometric Data

The photometric data for the Pleiades supplied with this exercise (in PLEIADES.DAT) is taken from Hendon and Kaitchuck (1990), with additional data from Blanco, et al (1968). Some non-cluster members are included.

VI-3. Observational Calculations

The following Pascal functions compute the observed quantities, NoisyCount and Magnitude. We present this material in this format, rather than as mathematical formulae, so that this document can be distributed as ASCII text. The underlying mathematics should be readily apparent. In this code:

Mag = the star's magnitude from the stellar data file. (Mag(V)=V, Mag(B)=(B-V)+V, Mag(U)=(U-B)+Mag(B))

Seconds = Integration time of the observation.

MeanSky = Measured mean sky count, in the appropriate color.

The values used for CountBase and MagBase are more or less arbitrary.

The code follows:

```
type
    FilterType = (U, B, V);
const
    SkyMag: array[FilterType] of Float = (17.33,17.0,16.0);
    CountBase = 10;
    MagBase = 18.0;
function BaseCount(Mag: Float): Float;
var
    Exp:  Float;
begin
    Exp:  = (Mag - MagBase) / -2.5;
    BaseCount := CountBase * raise(10.0,Exp);
end;  {BaseCount}

function NoisyCount(Mag,Seconds: Float): Float;
var
    Count: Float;
     SNR: Float;
     LoLimit: Float;
     Range: Float;
begin
    Count := BaseCount(Mag) * Seconds;
    SNR := sqrt(Count);
    LoLimit := Count - SNR;
    Range := 2*SNR;
    NoisyCount := LoLimit + Random*Range;
end;  {NoisyCount}
```

```
function Magnitude(Count: LongInt; Interval: Float; MeanSky: Float): Float;
var
    Base: Float;
begin
    Base := Count/Interval - MeanSky;
    Magnitude := -2.5*log(Base/CountBase) + MagBase;
end;  {Magnitude}
```

REFERENCES

Blanco, V.M., Demers, S., Douglass, G.G., and Fitzgerald, M.P.: Photoelectric Catalogue. Publications of the United States Naval Observatory, Second Series, Vol XXI 1968.

Hendon, A.A., and Kaitchuck, R.H.: *Astronomical Photometry* . Richmond: Willman-Bell 1990.