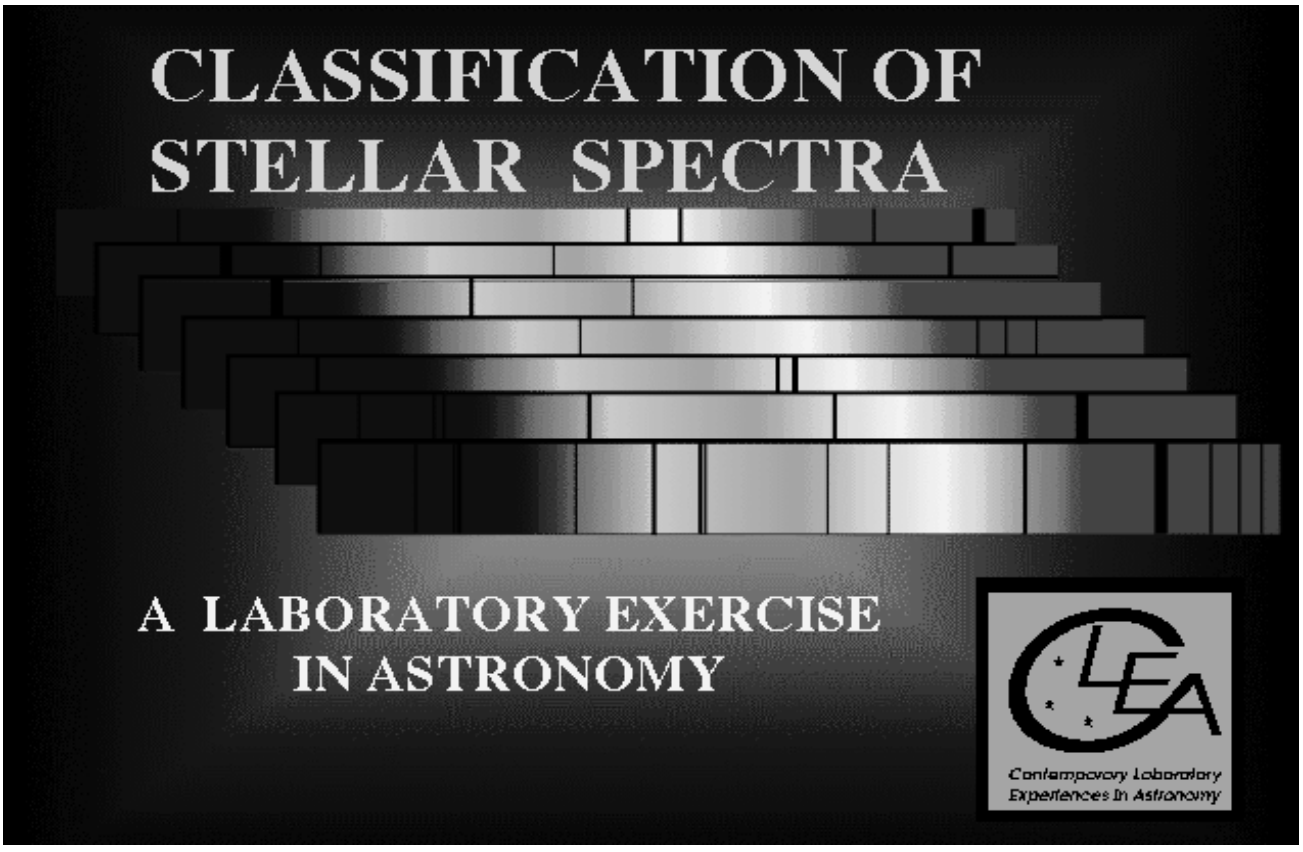
THE CLASSIFICATION OF STELLAR SPECTRA

SOFTWARE USERS' GUIDE

A Manual to Accompany Software for
Introductory Astronomy Lab Exercise
Document SUG 6: Version 1



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I. INTRODUCTION

I-1. Purpose

This document provides specific technical information for users of the CLEA software module **"The Classification of Stellar Spectra"**. Included are 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 (SUG)**, which contains technical information that applies to all CLEA Windows software. Information contained therein is generally not repeated here.

I-2. Acknowledgements

Development of CLEA exercises and materials, including this guide, is supported in part by the National Science Foundation (Grants USE 9155927 and 9354514) 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 approximately 4 MByte of available storage (significantly more than the 1-2 MByte required by most of the other CLEA modules), and a color VGA monitor. The "Photo" spectrum display mode is not available on systems operating in a 16-color display mode (see Section VI-3). For additional information on systems requirements, including a discussion of color modes and video drivers, see the **General Users' Guide to CLEA Windows Software**.

II-1. Recommendation

This exercise includes a number of displays designed to assist the student in the classification of stars. In particular, it is especially advantageous if the atlas spectra selection display and the spectral line list, as well as the Classification Window, are visible in their entirety throughout the classification process. To permit this, we recommend that, if possible, this exercise be run in a 1024 x 768 pixel display mode. In this mode, the main window is sufficiently reduced in size that the aforementioned displays can be moved off to the side and bottom areas of the screen and remain visible. This eliminates the annoyance of constant repositioning and/or minimizing/maximizing of the windows. If your video card and monitor support a 1024 x 768 mode, you can switch to it by following the instructions in the **General Users' Guide to CLEA Windows Software** for changing the video driver.

III. INSTALLATION AND OPERATION

Files for this exercise are compacted into two distribution files, CLEA_SPE.ZIP and JSPECTRA.ZIP. The working files must be extracted using the PKUNZIP program (also included on the distribution diskette), and placed together in a single directory, such as C:\SPEC_LAB. (Be sure that you unzip both files). Details of unpacking, running, and installing CLEA software under Windows are given in the **General Users' Guide to CLEA Windows Software**.

IV. FILES INCLUDED WITH EXERCISE

This exercise requires a large number of files for its operation. Most of these are compressed into the distribution files CLEA_SPE.ZIP and JSPECTRA.ZIP, and should be present in your working directory after unpacking with PKUNZIP. These files are described in Sections IV-1 and IV-2 below. Section IV-3 identifies additional files that are not included in the distribution, but will appear in the working directory during/after execution of the exercise software.

IV-1. Files in CLEA_SPE.ZIP

The following files are compressed into the distribution file CLEA_SPE.ZIP. The list is grouped by function, with references to related discussions in this document.

Software and Documentation

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

UPDATE.SPC - A list of updates (by version) since version 0.86 (the first version to be widely circulated).

USRGUIDE.SPC - This document, in text form.

CLEA_SPE.EXE - The executable code for the exercise.

CLASSIFY.KEY - A text file containing the names and spectral types of the stars in the version of CLASSIFY.LST provided with the exercise.

JACOBY.DOC - A brief description of the Jacoby spectral data provided with the exercise (see Section VI-1).

JACOBY2.INX - An Index File to the Jacoby spectra, giving star IDs, spectral types, and other information (see Section VI-1 and JACOBY.DOC above).

Bitmap Files for Displays

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

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

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

SPECL16.BMP - A 16-color version of the Title screen.

Atlases of Standard Spectra (Section V-2.1)

ATLAS2.LST - A list of the available atlases of standard stars.

MS.ATL - An Atlas Index File for the Main Sequence.

O8_LUM.ATL - An Atlas Index File for luminosity near O8.

B2_LUM.ATL - An Atlas Index File for luminosity near B2.

A3_LUM.ATL - An Atlas Index File for luminosity at A3.

F5_LUM.ATL - An Atlas Index File for luminosity at F5.

G2_LUM.ATL - An Atlas Index File for luminosity at G2.

K0_LUM.ATL - An Atlas Index File for luminosity at K0.

M2_LUM.ATL - An Atlas Index File for luminosity near M2.

Data for Star Fields (Section V-2.2)

SPECFILS.DAT - A list of available star fields.

SPECFLD1.DAT - Data for a synthetic star field.

PLEIADES.DAT - Data for the Pleiades star field.

JSPEC.SPI - An Index File linking CLEA spectral type codes (Section V-2.2.4) with the available spectra.

Unknowns for Classification (Section V-2.3)

CLASSIFY.LST - A list of "unknowns" for classification by the students.

Help and Related Files (Section V-4)

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

SPECHLP.LST - Topic Index List for Help on taking spectra.

SPECLAB.HLP - Text for Help topics on taking spectra.

CLASSHLP.LST - Topic Index List for Help on classifying spectra.

CLASSIFY.HLP - Text for Help topics on classifying spectra.

SPECLNS.LNL - List of spectral lines giving wavelength in Ångstroms, line identification, and associated Help file.

SPECLNS.HLP - Text for Help on spectral lines.

REMINDER.SPC - Text to display when "Quit" selected.

IV-2. Files in JSPECTRA.ZIP

The Jacoby spectra provided with this exercise (files J001.SP through J161.SP) are compacted into distribution file JSPECTRA.ZIP. In their expanded form the files require approximately 2 MBytes of disk storage. The format of these files is given in Section V-2.4, the Jacoby spectral material is described in Section VI-1. (See also JACOBY.DOC, JACOBY2.INX, & JSPEC.SPI above.)

IV-3. Files Generated During Execution

The following files are generated during execution of this exercise, and will appear in the working directory. (CLEALOG.LOG and SPECOPTS.INI are automatically created. Files with extensions .CSP and .CTX are created on option, as noted.)

CLEALOG.LOG - A record that includes the program name (CLEA_Spe), the date and time, and the names and table number from the Login dialog is appended to this file whenever the exercise is started, and when it is terminated. This file is in text format and can be read and/or printed at any time. Since this file can grow without limit it should be deleted from time to time (via DOS or the Windows File Manager). A new file will then be started at the next login. This file can optionally be given a different name (see Section V-1.2).

NOTE: A logout record will be written to this file only if the students exit correctly from the program (select "Quit" from the main menu). They should be instructed to do this, rather than simply abandoning the computer or turning it off.

SPECOPTS.INI - Current settings for file names and options. This file can be deleted if desired, it will then be re-created from internal defaults when the program is run. If the options are updated (see Section V-1), the previous version is saved as SPECOPTS.BAK.

***.CSP** - Files with the extension .CSP are created when a spectrum is saved via selection "Save" on the spectrometer menu. Spectra taken with the simulated telescopes must be saved in this manner before they can be classified. Names for these files are generated from the first login name ("Student #1") and a three character ID provided by the student, as described below (Section IV-3.1). These files are in the spectrum file format described in Section V-2.4.

***.CTX** - A file with extension .CTX is written to the working directory when "Results"..."Save to File" is selected from the classification menu. (The file name is generated from the first login name - see Section IV-3.1 below.) This file is written in a format (tab delineated text) that can be used as input to most commercial spreadsheet programs. See Section V-3 for information about using a spreadsheet program with this exercise, and the contents of the .CTX file.

NOTE: Files *.CSP and *.CTX should be periodically deleted from the working directory when they are no longer needed. This can be done under DOS or via the Windows File Manager.

IV-3.1. Naming .CSP and .CTX Files

Names for the student-generated .CSP and .CTX files are created from the first login name ("Student #1"). If the login entry includes both a first and last name, the first letter of the name is combined with the first seven (if present) letters of the last name. If only one name is entered, the first eight (if present) letters are used. Since only one .CTX file may be generated (new classifications may be appended to an existing file), the .CTX extension is simply concatenated to the generated file name. For .CSP files, the name is truncated (if necessary) to five characters. A three character (max) id is then solicited from the student and added, along with the .CSP extension. Examples:

Login Name	File Names
Annie Jump Cannon	ACANNON.CTX
	ACANOxxx.CSP
Martin Schwarzschild	MSCHWARZ.CTX
	MSCHWxxx.CSP
Galileo	GALILEO.CTX
	GALILxxx.CSP

If the first login name is blank, the files are named NOLOG.CTX and NOLOGxxx.CSP.

V. USER OPTIONS

This software has been designed to provide the user with a great deal of flexibility in configuring the facility for specific needs. Users may provide their own spectra (both standards and unknowns), configure atlases of standards and lists of unknown spectra, adjust the wavelength range, modify the Help facility (including the wavelength table), add or modify star fields, modify telescope and star image parameters, attach a spreadsheet program, and select from a list of optional features. Details of the facilities providing this adaptability are given in Sections V-1 through V-4 below.

V-1. Parameters and Selectable Options

In all CLEA software, modification of control parameters and options is accomplished through an options dialog that is accessed through the login dialog, via a password. Details of this feature, including the password access, are provided in the **General Users' Guide to CLEA Windows Software**. Due to the number of modifiable features associated with this exercise, the options facility comprises three dialog windows, as detailed in the Sections that follow (V-1.1 through V-1.3).

V-1.1. Switches and Parameters

The following switches and parameters appear on the window titled "Startup Parameters/Options", which appears as the main dialog when the options facility is accessed.

UT-Local Time: Enter 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

Base Magnitude: The base magnitude for spectrum integration and other computations (see Section VI-2). The default value is 9.00.

Sky Magnitude: The sky brightness for spectrum integration and other computations, expressed as a magnitude (see Section VI-2). The default value is 19.00.

Base Photon Count: The photon count associated with the base magnitude (see Section VI-2). The default value is 50.

Timer Wait: The time (in milliseconds) between successive counting steps during spectrum integration. The default value of 1 means that the speed of integration is normally limited by the speed (CPU and display) of the computer. This parameter is provided so that in the future, extremely fast processors may be slowed down to realistic rates of spectrum integration.

Wavelength Range: The wavelength range in Ångstroms (Å) for the spectral displays. For best results in labeling and appearance these values should be multiples of 100 Å. If the available data (Sections V-2.4, VI-1) does not cover the range specified, the spectra will appear truncated. The default range is 3900 to 4500 Å, which is the range of the spectral data supplied with the exercise.

"Difference" Option: When this switch is set, the control panel in the Classification Window includes a button labeled "Difference". When this button is pressed the lower spectral standard is replaced by a point by point plot of the intensity of the upper standard minus the unknown (in display mode "Intensity Trace" only). If this switch is not set, the option is not available and the button does not appear. The default is "On".

Spectral Line Table: When this switch is set, the spectral line table and associated Help facility (see Section V-4.2) is available under "Load" on the Classification Window menu. The default is "On".

Use Small Help Font: When this switch is set, a small type face is used for the Help windows to improve their appearance and use less space on the screen. This font may be too small to be read easily in some screen modes. The default is "On".

Restrict Telescope Access: When this switch is set, the student must apply for access to the larger (1 and 4 meter) telescopes, and receives a limited number of uses if access is granted (see Section V-1.3 for associated parameters). The default is "On".

Restrict File Access: When this switch is set, the student has access to only those .CSP and .CTX files whose names correspond to the current 1st login name (see Section IV-3.1). The default is "ON".

Table Number: This field allows the instructor to preset the table number for each machine in the lab. This number then appears as the default on the Login dialog. The table number has a maximum length of 4 characters, but need not be numeric.

Password: This is the password for access to the Options dialog. Allowable passwords have a maximum length of 16 characters, and are case sensitive. The default password is "**CLEA**".

Login Required: This switch is provided for those who may wish to avoid the login process when using this software as a demonstration. When this switch is off, the "Run" selection on the main menu, as well as "Login", is enabled when the program starts. If "Run" is then selected before "Login", the program proceeds as if the login process had actually occurred. (In this case the 1st login name is set to "Demonstration", the file name base becomes "DEMO", and the "Login" menu selection is disabled.) The default is "On".

V-1.2. File Name Options

The following file and path name parameters appear on the window titled "File Name Options". To access this dialog press the button labeled "Files..." on the "Startup Parameters/Options" window. See the **General Users' Guide to CLEA Windows Software** for discussions of Windows bitmap (.BMP) files, including logo and title screens and color issues.

Directory Path: See the **General Users' Guide to CLEA Windows Software** for a discussion of this parameter. This field is normally left blank. The default is "" (no entry).

256-Color Logo: A 256-color bitmap for the CLEA logo screen. The default is "CLEALOGO.BMP".

16-Color Logo: A 16-color bitmap for the CLEA logo screen. The default is "CLEALG16.BMP".

256-Color Title: A 256-color bitmap for the exercise title screen. The default is "SPECLAB.BMP".

16-Color Title: A 16-color bitmap for the exercise title screen. The default is "SPECL16.BMP".

Star Fields List: A list of star fields for the exercise (see Section V-2.2.1). The default is "SPECFILS.DAT".

Atlas Files List: A list of atlas files for the exercise (see Section V-2.1.1). The default is "ATLAS2.LST".

Spectra Index List: An index file linking CLEA spectral type codes (Section V-2.2.4) with the available spectra. See Section V-2.2.3 for details. The default is "JSPEC.SPI".

Spectral Line List: A list of spectral lines that are important in the classification of stellar spectra (see Section V-4.2). The default is "SPECLNS.LNL".

Unknowns List:	A list of unknowns for classification by the students (see Section V-2.3). The default is "CLASSIFY.LST".
Main Help List:	An index list of Help topics for the Main Window (telescope controls for taking spectra) (see Section V-4.1). The default is "SPECHLP.LST".
Classify Help List:	An index list of Help topics for the Classification Window (see Section V-4.1). The default is "CLASSHLP.LST".
User Help File:	Site-specific Help information available under "Help"..."User" (see Section V-4.1). The default is "" (no entry).
Reminder File:	Text to be displayed when the students want to terminate the exercise (see Section V-4.1). The default is "REMINDER.SPC".
Spreadsheet Program File:	The full file name (including path) of a spreadsheet program to be accessed during the exercise for data manipulation and analysis (see Section V-3 for details). The file must be of type .EXE or .PIF, and must be accessible from the student's computer in the drive and file specified (example: C:\EXCEL\EXCEL.EXE). This parameter is completely optional. There is no default.
Log File:	A file (text) where log information is written during login and at termination of the exercise (see Section IV-3). The default is "CLEALOG.LOG".

V-1.3. Telescope Parameters

This exercise provides the students access to three telescopes, a 0.4 meter (16 inch) default telescope that is always available to them, and 1 meter and 4 meter (40 and 160 inch) instruments whose use may (optionally) be restricted. If the "Restrict Telescope Access" switch is set (Section V-1.1), the students must apply for time on the larger instruments, and are given a limited number of uses if time is awarded. The rate of integration of spectra is accurately scaled to the size of the telescope in use. The following parameters, which appear on the window titled "Telescope Parameters", allow the user to modify various aspects of this facility. To access this dialog, press the button labelled "Scopes..." on the "Startup Parameters/Options" window.

Name	The name or identification of the telescope. (38 characters)
Site	The site of the telescope. (35 characters)
Availability	The fraction of applications for telescope time that will be approved. (0.0 to 1.0)
Reapply Wait	The amount of time the student must wait to reapply if an application is not approved. The software automatically informs the student when reapplication can be made. (1 to 255 minutes)
Minimum Allocation	The minimum number of uses that are granted if time is awarded.

Maximum Allocation	The maximum number of uses that are granted if time is awarded.
Scope Factor	The "gain" in light gathering power of the telescope, expressed in magnitudes (see Section VI-2 for details, including calculation of this parameter). The zero point is determined by the "Base Magnitude" parameter on the Startup Parameters/Options dialog (Section V-1.1). The scope factor determines the relative speed at which the spectra are collected, and is also used to scale the appearance of star images on the "Spectrometer" display.
Finder Factor	The relative "gain" in light gathering power of the telescope finder. This parameter is used to scale the appearance of star images on the "Finder" display. It is not used in calculations or for any other purpose.

Allocation of observing time is random, based on the "Availability", "Minimum Allocation" and "Maximum Allocation" parameters. (These parameters, along with "Reapply Wait", do not apply to the default (0.4m) telescope.) The student is kept informed of uses remaining as spectra are taken with the restricted telescopes.

V-2. Data Files

In order to provide maximum adaptability, data for this exercise is read from files that can be created and modified with a text editor. The various file formats used to identify and define spectral atlases, star fields, unknowns for classification, and stellar spectra are described in Sections V-2.1 through V-2.4 below. In addition to conforming to the appropriate format, all data files should adhere to the general rules listed below. Bad data will almost always result in program failure!

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) Boolean fields may be assigned only the values 0 (false) and 1 (true).

7) 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.

8) Values must be provided for all fields in a record, in the proper order. (Exception: all remaining empty fields on the end of records may be omitted.) For null strings enter two single quotes (‘’), for null numeric fields enter 0 or 0.0.

9) 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.

10) Do not include blank records in a file. Take special care to insure that there are no blank records at the beginning or end of a file.

11) Records should not contain carriage return, line feed, or other non-alphanumeric characters. Such characters may sometimes be inserted during file transfers by "Text Mode" protocols.

V-2.1. Spectral Atlases

Atlases of spectral standards can be created to include any of the available spectra. Each available spectral atlas must be identified in the Atlas List File (Section V-2.1.1) and defined in an Atlas Index File (Section V-2.1.2).

V-2.1.1. The Atlas List

The Atlas List File (default ATLAS2.LST) contains records that identify each available atlas and supply the name of its associated Atlas Index File. This information is carried in two string fields, as follows:

Field	Data Type	Contents
Atlas ID	String[65]	Name/ID of the atlas to appear on the "Select Spectral Atlas" list.
File Name	String[12]	Name of the associated Atlas Index File (name + qualifier, no path).

There is no fixed limit to the number of entries in this file, and thus to the number of atlases that may be defined. The Atlas List File ATLAS2.LST is supplied with the exercise, and is identified in the field labeled "Atlas Files List" on the File Name Options dialog (Section V-1.2).

V-2.1.2. Atlas Index Files

The Atlas Index File contains records that identify each spectral type in the atlas and supply the name of the file containing the spectrum. The format of the records carrying this information is as follows:

Field	Data Type	Contents
Spectral Type	String[12]	The spectral type for the atlas entry.
(Unused)	Longint	This field is designed to hold a spectral type code (Section V-2.2.4). The field is currently unused and should be set to 0.
File Name	String[12]	Name of the file containing the spectrum (name + qualifier, no path). (See Section V-2.4 for the format of this file.)

An Atlas Index File must be supplied for every atlas identified in the Atlas List File (Section V-2.1.1). An Atlas Index File may contain a maximum of 20 entries. The following Atlas Index Files, identified in ATLAS2.LST, are supplied with the exercise:

MS.ATL	Main Sequence
O8_LUM.ATL	Luminosity near O8
B2_LUM.ATL	Luminosity near B2
A3_LUM.ATL	Luminosity at A3
F5_LUM.ATL	Luminosity at F5
G2_LUM.ATL	Luminosity at G2
K0_LUM.ATL	Luminosity at K0
M2_LUM.ATL	Luminosity near M2

V-2.2. Star Fields

The star fields for this exercise are identified in the Star Field List File (Section V-2.2.1). Data for each star field is carried in a Star Field Data File (Section V-2.2.2). The format and purpose of these files is the same as those used to define the star fields in the CLEA exercises **"Photoelectric Photometry of the Pleiades"** and **"The Hubble Redshift-Distance Relation"**, with the exception that various specific fields are important to some exercises and not used in others.

Two star fields are supplied with the exercise. The file PLEIADES.DAT contains data for stars in the region of the Pleiades. This file is identical to that supplied with the Pleiades photometry exercise, except that spectral type codes have been added. (This version of PLEIADES.DAT can be used with the Pleiades photometry exercise, and should replace the one supplied therein if the exercises are kept in the same directory.) The file SPECFLD1.DAT contains an artificial star field that was generated with the parameters listed on the following page:

Right Ascension:	6 Hr 0 Min to 6 Hr 24 Min
Declination:	30.0 Deg to 35.0 Deg
Number of Stars:	500
Magnitude Range:	3.5 to 15.0
Percent Type O:	1%
" " B:	4%
" " A:	10%
" " F:	15%
" " G:	30%
" " K:	30%
" " M:	10%
Percent Lum. I:	5%
" " III:	25%
" " V:	70%

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 should, in general, provide fields that are at least 5 degrees square to allow slewing from edge to edge of the field that first appears. Fields should not be larger than 7.5 degrees square.

2) This software does not currently provide for displaying galaxies. If fields from the Hubble redshift exercise are used, the galaxy records should be removed, and spectral type codes (Section V-2.2.4) should be added to the records for the stars.

3) Avoid high declinations (stay within -60 < dec < +60). The display algorithm is relatively simple, basically a "square" 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..)

V-2.2.1. The Star Field List

This file provides a list of the files that contain the star data for each star field, along with the coordinates of the field centers. It is identified in the field labeled "Star Fields List" on the File Name Options dialog (Section V-1.2); the default is SPECFILS.DAT. Records in this file have the following format (see general rules under V-2):

Field	Data Type	Contents
File Name	String[12]	Name of Star Field Data File (name + qualifier, no path).
Right Ascension	Real	RA of field center in decimal hours (0.0..24.0, but see Section V-2).
Declination	Real	Dec of field center in decimal degrees (-90.0..+90.0, but see Section V-2).
Field Name	String[20]	Field identification for selection lists.
Default	Boolean	One record in the file may carry a 1 (True) in this field to identify the default star field. All other records should carry a 0 (False) in this field.

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 Field 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 or the "Change Field" menu selection 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 when using the "Set Coordinates" button.)

V-2.2.2. Star Field Data Files

These files contain positional and other data for each star in a field. Each entry in the star fields list (Section V-2.2.1) identifies a field 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 (Section V-1).) Two of these files are supplied with the exercise (Section V-2.2). The user may add as many as desired (supplying corresponding entries in SPECFILS.DAT), and may also add/delete/modify data in the files provided. Star Field Data File records have the following format (see general rules under V-2):

Field	Data Type	Contents
Star ID	String[15]	Optional name, HD/BD number, or other identification. ***Note 1***
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	Apparent magnitude of star.
B-V Color	Real	Not used in this exercise.
U-B Color	Real	Not used in this exercise.
(Unused)	Real	For future use.
(Unused)	Real	For future use.
(Unused)	Byte	For future use.
(Unused)	Byte	For future use.
(Unused)	Byte	For future use.
(Unused)	Byte	For future use.
Spectrum	Longint	Spectral type code (see Section V-2.2.4).
Comment	String[23]	Optional additional information. (The supplied files carry the spectral type in this field.) ***Note 1***.

Notes:

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

V-2.2.3. The Spectrum Index File

The Spectrum Index File contains records that link spectral types to the files containing the spectra. The default Spectrum Index File supplied with the exercise (JSPEC.SPI) associates spectral types with the supplied Jacoby spectral library (Section VI-1). Records in the Spectrum Index File have the following format:

Field	Data Type	Contents
Spectrum	Longint	Spectral type code (see Section V-2.2.4).
File Name	String[12]	Name of the file containing the spectrum (name + qualifier, no path). (See Section V-2.4 for the format of this file.)

When used, the records in this file are read into memory and sorted by spectral type code. The file itself need not be sorted.

V-2.2.4. The CLEA Spectral Type Code

In order to provide indexing of spectral types to expedite table searches, etc., we have developed a spectral type code. The coded spectral type consists of 8 decimal digits and is stored in a long integer (4 byte) field. The digits are set in pairs as follows:

Spectral Type Code: "aabbccdd"

Field "aa" (Temperature Class)

O:	10
WR:	11
B:	20
Be:	21
A:	30
Am:	31
Ap:	32
F:	40
G:	50
K:	60
M:	70
R:	71
N:	72
S:	73

Field "bb" (Temp. Subclass)

0:	00
0.5:	05
.	
.	
.	
9:	90
9.5:	95

Field "cc" (Luminosity Class)

I:	10
Ia:	11
Ib:	12
I-II:	15
II:	20
II-III:	25
III:	30
III-IV:	35
IV:	40
IV-V:	45
V:	50
VI/SD	60
WD	70

Field "dd" (Other)

(For future enhancements)

Examples:

G2V	= 50205000
B9.5IV-V	= 20954500
M2III	= 70203000

To match a spectral type to an available spectrum, the software searches the spectrum index (Section V-2.2.3) for a match on the spectral type code. If an exact match is not found, a search is made for the closest earlier type of the correct luminosity class. If none is found, the closest earlier spectral type in the Index File, regardless of luminosity class, is returned. Thus, the spectrum obtained for a star may not exactly correspond to the spectral type code given in the Star Field Data File (Section V-2.2.2), but the algorithm attempts to minimize the error in absolute magnitude resulting from an inexact match.

V-2.3. List of Unknowns for Classification

The file identified in the "Unknowns List" field on the File Name Options dialog (Section V-1.2) provides a list of unknown spectra to be classified by the students, and identifies the corresponding files containing the spectra. (These spectra do not have to be "taken" by the students to be classified.) The file CLASSIFY.LST is provided with the exercise as the default unknowns list. (The correct spectral classifications for the stars in CLASSIFY.LST are provided in the file CLASSIFY.KEY.) Records in the unknowns list file have the following format:

Field	Data Type	Contents
Unknown ID	String[65]	Name/ID of the star to appear on the program stars selection list.
File Name	String[12]	Name of the file containing the spectrum (name + qualifier, no path). (See Section V-2.4 for the format of this file.)

V-2.4. Data Format for Spectra

Stellar spectra used in this exercise are stored individually in text files as lists of wavelengths and associated normalized intensities. This format is used both for spectra supplied with the exercise (*.SP, Section VI-1) and spectra "taken" by the students and saved for classification (*.CSP, Section IV-3). The format of an individual record in a spectrum file is as follows:

Field	Data Type	Contents
Wavelength	Real	Wavelength in Ångstroms.
Intensity	Real	Normalized intensity (see below) at the given wavelength. (0.0 to 1.0)

The following rules should be followed when preparing additional spectra for use in this exercise:

1) The file should be in ascending order by wavelength.

2) The range in wavelengths should include the display range specified in "Wavelength Range" on the Startup Parameters/Options dialog (Section V-1.1).

3) The wavelength interval between data points is not fixed, but must be uniform. (The software makes internal use of a fast interpolator that requires uniform spacing.) The nominal value of the interval is 1 Å.

4) Intensities should be normalized to the highest value in the range of data provided. All intensity values should be in the range 0.0 to 1.0.

V-3. Using a Spreadsheet Program

This software provides the following features to expedite students' use of a spreadsheet program for data reduction and analysis:

1) Classification results may be saved in a file (*.CTX) that is formatted for import into most commercial spreadsheet programs.

2) If an available spreadsheet program is identified in the "Spreadsheet Program File" field on the File Name Options dialog (see Section V-1.2), the spreadsheet may be accessed directly from the exercise.

Selecting "Results"..."Save to File" from the main menu on the Classification Window causes recorded classifications to be written to a file (qualifier .CTX) that is suitable for import into a spreadsheet program. Included in this file are the date, time, table number and students name(s) from the login data; and the object identification, magnitude, spectral classification, and remarks for each star classified and recorded, arranged in tab-delineated columns. This file may also be used to save classifications between sessions if the exercise must be interrupted for any reason. If the software locates an existing .CTX file with the appropriate name (see Section IV-3), the student is given the chance to reload it the first time the Classification Window is accessed.

> **NOTE:** Do not use a text editor on a .CTX file if you intend to import it into a spreadsheet. Many text editors convert tab characters to spaces when the file is re-written, which will cause the columnization to be lost. Do all editing within the spreadsheet program itself, or make a copy of the file for the text editor.

If the software finds an entry in the "Spreadsheet Program File" field on the File Name Options dialog (Section V-1.2), the "Spreadsheet" item on the "Results" sub-menu is enabled. Selecting "Results"..."Spreadsheet" will then start the spreadsheet software. The exact technique for loading the .CTX file will depend on the spreadsheet - consult your documentation. (As examples, the file can be opened directly into Microsoft Excel Version 4.0, while Lotus 123 Version 2.2 requires "File"..."Import"..."Numbers".) To return to the exercise, either minimize the spreadsheet program or exit from it. (Remember to save the results again If you make additional classifications and wish to return to the spreadsheet. In this case you must also re-load the file into the spreadsheet to get the new data.)

V-4. Revised CLEA Help Facility

This exercise utilizes an extension of the Help facility described in the **General Users' Guide to CLEA Windows Software**. The main features of the revised facility are a Help topic selection list, with related topics indented under group headings, and the ability to place the text for multiple Help topics in a single file. Both the selection list and the individual Help windows now include a string search capability to assist the user. As has been the case, all files related to the Help facility are in text format to facilitate modification or replacement by the instructor. The revised general Help facility is described in Section 4.1. (This facility will eventually be used in all CLEA exercises, and the material in Section 4.1 will appear in the **General Users' Guide to CLEA Windows Software**.)

This exercise also employs a specialized extension of the Help facility that provides a list of spectral features by wavelength, including cursor tracking and line marking on the spectrum displays, and related individual Help windows for each line in the list. This facility is described in Section 4.2.

V-4.1. General Help Facility

The revised general Help facility includes several components. The Help Index File (Section V-4.1.1) identifies the available Help topics and provides for indentation under group headings when the list is displayed for selection. The text for each Help topic is placed in a Help Text File (Section V-4.1.2), under a topic heading that duplicates the Index File entry. A string search capability speeds topic searches in both the selection list and the individual Help windows. Its use is self-evident.

The "User Help" and logout "Reminder" features are retained as described in the **General Users' Guide to CLEA Windows Software**.

V-4.1.1. The Help Index File

The Help Index File identifies available Help topics for selection and points to the file containing the text for each topic. Entries in the Help Index File also provide topic grouping for indentation under group headings on the selection list.

Records in the Help Index File have the following format:

Field	Data Type	Contents
Topic/Group Hdr	String[65]	Topic or group header (see V-4.1.1.1 below) to appear on the Help selection list.
File Name	String[12]	Name of the file containing the text for the Help topic (name + qualifier, no path). (See Section V-4.1.2 for the format of this file.) If the record's topic field contains a group header, this field must contain either 'begin' or 'end' (see V-4.1.1.1 below).

Two Help Index Files are used in this exercise. They are identified on the File Name Options dialog (Section V-1.2) as "Main Help List" and "Classify Help List". The default file names are "SPECHLP.LST" and "CLASSHLP.LST".

V-4.1.1.1 Topic Grouping and Indentation

Topics on the Help selection list may be grouped and indented under group headings. To identify a group, place a record in the Help Index File with the group header in the first field and 'begin' in the second. All topics below this header will be indented two spaces on the selection list until a record with the same group header in the first field and 'end' in the second is encountered. Groupings may be nested, each will indent an additional two spaces. Be sure that 'end' records for all groups are provided, in the opposite order of the 'begin' records. For examples, see the default Help Index File SPECHLP.LST provided with the exercise.

Group headings appear on the selection list with a "-" at each end. If the user selects a group heading from the dialog list, he/she is instructed to select a specific subtopic under the heading.

V-4.1.2. Help Text Files

Text for the Help screens is maintained in Help Text Files (usually identified with the qualifier .HLP). If there is only one topic in the file, it may simply contain the text for that topic (as described in the **General Users' Guide to CLEA Windows Software**).

If one file contains multiple topics, the text for each is entered under a topic header. Each topic header appears on a single line and must be identical to the entry in the first field of the Help Index File record (Section V-4.1.1), except that the Help Text File entry is enclosed in asterisks ("*"), rather than single quotes (" ' "). There are no special rules for the text entered under the headers, except that a maximum of 72 characters per line is recommended. Users who create new Help text should check its actual appearance in a Help window. Variable width fonts can cause unanticipated changes in appearance.

Group headers do not have associated text, and therefore should not have related entries in a Help Text File. For examples of Help Text Files, see SPECLAB.HLP and CLASSIFY.HLP provided with the exercise.

V-4.2. The Spectral Line List/Help Facility

A modified version of the general Help facility described above is used for the spectral line identification list and associated Help facility. The Line List File described in Section V-4.2.1 is a modification of the general Help Index File (Section V-4.1.1), and serves in its place. The Line Help File (Section V-4.2.2 is essentially the same as the general Help Text File (Section V-4.1.2), except for a slight change to the headers.

V-4.2.1. The Line List File

The Line List File is much like the general Help Index File described in Section V-4.1.1, with an added real field to hold the wavelength. In addition, topic grouping and the associated records are not used in this file. Records in the Line List File have the following format:

Field	Data Type	Contents
Wavelength	Real	Wavelength of the spectral line/feature in Ångstroms.
Line ID	String[65]	Identification of line/feature to appear on the Line ID list.
File Name	String[12]	Name of the file containing the Help text for the line (name + qualifier, no path). (See Section V-4.2.2 for the format of this file.)

One Line List File is used in this exercise. It is identified on the File Name Options dialog (Section V-1.2) as "Spectral Line List". The default file name is "SPECLNS.LNL".

V-4.2.2. The Line Help File

A special format is required for the topic (line) headers in this file, which is otherwise similar to the general Help Text File described in Section V-4.1.2. Each header begins with an asterisk ("*") in column 1, as before. This is immediately followed by the wavelength of the line (Å), rounded to two decimal places. This is followed by three spaces, then the Line ID as it appears in the Line List File (Section V-4.2.1), then a final asterisk. Help text for each line is entered following the header, as before. For an example, see SPECLNS.HLP included with the exercise.

VI. ASTRONOMICAL DATA, MODELS AND ALGORITHMS

VI-1. The Jacoby Spectral Library

One hundred sixty-one stellar spectra (files J001.SP through J161.SP) are included with this exercise. This material was prepared for CLEA by Dr. Gordon Spear of Sonoma State University from the spectral library originally published by Jacoby, Hunter, and Christian in 1984. Additional information is given in the file JACOBY.DOC, the format of the .SP files is described in Section V-2.4. The file JACOBY2.INX identifies the stars and gives spectral types and dereddened colors. Associations between the spectra and the CLEA spectral type codes (Section V-2.2.4) are assigned in the file JSPEC.SPI (Section V-2.2.3). These spectra are used both as standards and as unknowns in this exercise.

VI-2. Integration of Spectra (Magnitudes, Telescopes and Noise)

Integration of ("taking") stellar spectra involves the following user-modifiable parameters:

Base Magnitude	(Section V-1.1)
Sky Magnitude	"
Base Photon Count	"
Wavelength Range	"
Timer Wait	"
Scope Factor	(Section V-1.3, also see VI-2.1 below)

In addition, we have:

Sp(Wvl)	= the spectrum assigned to the star (normalized intensity as a function of wavelength (Wvl)). The value of Sp(Wvl) lies in the range (0.0..1.0). (See Sections V-2.4, V-2.2.4, VI-1)
m	= the apparent magnitude of the star

To integrate a spectrum, we begin by computing

mBase = Base Magnitude + Scope Factor(Current Scope)

We also determine the Slit Factor, which is a fraction (0.0..1.0) reflecting the accuracy with which the star is centered in the slit. (If the Slit Factor is less than 0.05, we assume we are reading only the sky (B=0).) We compute a brightness (B) from the magnitude equation and the Slit Factor:

B = Slit Factor * 10**((m - mBase) / -2.5)

Similarly, a sky brightness (BSky) is computed from the Sky Magnitude parameter (mSky):

BSky = 10**((mSky - mBase) / -2.5)

We now compute an array of intensities (Int(i)) at 500 discrete points ("spectrometer channels") covering the specified wavelength range:

Int(i) = B * Sp(Wvl(i))

(The values of Sp(Wvl) at points intermediate to the original tabulated values are determined by 3-point interpolation (Meeus, Ch.3).) A related array of photon counts (Count(i)) is initialized to zero, as are accumulators for the total signal counts, total sky counts, and elapsed time.

The software now initiates a timer, using the Timer Wait parameter. At each timer interrupt we perform the following calculations for all points in the array Count(i):

XM = Base Photon Count * Int(i)
New = PoiDev(XM)
add New to Total Signal
SM = Base Photon Count * BSky
Sky = PoiDev(SM)
add Sky to Total Sky
add New + Sky to Count(i)

where PoiDev(XM) is an integer value that is a random deviate drawn from a Poisson distribution of mean XM (Press, *et al*, Ch. 7). We then calculate the signal to noise ratio (SNR) from:

Total Count = Total Signal + Total Sky
SNR = (Average Signal) / √(Average Count)

where the averages are computed by dividing the Total Signal and Total Count by the number of points (500). The values in array Count(i) are normalized for plotting by dividing by MaxCount, where MaxCount is the largest current value in Count(i).

This process continues until stopped by the user, at which time the plot display changes to connect the individual points, and the normalized values may be saved in a .CSP file (Section V-2.4) for classification.

The effects of varying the parameters can be summarized as follows:

1) To speed up the overall rate at which the spectra integrate, lower the Base Magnitude (increase the numeric value), increase the Base Photon Count, or both.

2) To lower the overall integration rate, raise the Base Magnitude (decrease the numeric value), decrease the Base Photon Count, increase the Timer Wait, or any combination of the above.

3) To increase the effect of the sky on the spectra, raise the Sky Magnitude (decrease the numeric value), and vice versa.

4) To vary the relative integration rates for the various telescopes, change the Scope Factors (see IV-2.1 below).

Some "tuning" of the parameters may be required to achieve satisfactory results. The effective overall integration rates vary significantly with processor speed and video display performance.

VI-2.1 Calculating the Scope Factors

The scope factors (Section V-1.3) set the relative "gain" in light gathering power for telescopes of various sizes. Scope factors (SF) are calculated from the magnitude equation as follows:

Let A = aperture (diameter) of telescope
B = aperture of "base" telescope

then SF = 2.5 * log((A/B)**2)
= 5 * log(A/B)

For example, in this exercise the base telescope has an aperture of 0.4 meters. Therefore, for a 1 meter telescope:

$$SF = 5 * \log(1.0/0.4)$$
$$= 5 * \log(2.5)$$
$$= 2$$

And for a 4 meter telescope:

$$SF = 5 * \log(4.0/0.4)$$
$$= 5 * \log(10.0)$$
$$= 5$$

The scope factor for the base telescope should be set to 0.0. (In this exercise we could, for example, make the 1 meter telescope the base. Then the scope factor for the 0.4 meter would be -2, and for the 4 meter, SF = 3.) Note that the Base Magnitude and Base Photon Count parameters (Section V-1.1) apply to the base telescope, and establish the reference point for spectral integration rates and other calculations (see VI-2 above for details).

VI-3 "Photo" Displays

The following technique is employed to create the spectrum displays in the "Photo" mode. To make the display more authentically "photographic", the value of the intensity (range 0.0 to 1.0) from the spectrum data (Section V-2.4) is replaced by its square root. Then, to prevent the brightest areas of the display from merging into the white background, this value is multiplied by 0.9. The resulting value, in the range 0.0 to 0.9, is mapped to the nearest color in a palette consisting of 64 levels of gray scale between black (0) and white (255). The resulting color (gray shade) is displayed across the breadth of the spectrum at the corresponding wavelength position.

16-color video modes provide insufficient levels of gray scale and yield a display that is distinctly non-photographic and generally unsatisfactory. For this reason the "Photo" mode is disabled when the software detects 16-color video. If your system is operating in a 16-color mode, it may be possible to change it. See the **General Users' Guide to CLEA Windows Software** for details.

VI-4. Measuring Equivalent Widths

The equivalent width of a spectral line represents the total energy absorbed in the line, divided by the energy per unit wavelength emitted by the star in its continuum spectrum around the wavelength of the line. The equivalent width may be thought of as the width of a completely black strip in the spectrum whose area is the same as the area within the line profile, and is generally expressed in Ångstroms or milliångstroms. (For further information, see Harwit, Ch.7, or other references on astrophysics and stellar atmospheres.) In this exercise we provide a facility for measuring equivalent widths as a method of quantifying line strengths for comparison. To determine equivalent widths, the software calculates the area between the intensity levels within the line and the continuum level, using a Simpson's rule integrator (Press, *et al*, Ch.4).

Equivalent width measurement is available on the Classification Window. Follow the instructions provided on the Help screen (select "Help"..."Measure Equivalent Widths"). Take care in marking the "shoulders" of the line for measurement, you must accurately indicate both the continuum level and the wavelength limit of the line on each side. Equivalent width measurement is not available in the "Photo" spectrum display mode (Section VI-3).

REFERENCES

The following are excellent (fairly technical) references for spectral classification of stars:

Jaschek, C. and Jaschek, M.: *The Classification of Stars*, Cambridge University Press, Cambridge, 1990

Kaler, J.B.: *Stars and Their Spectra*, Cambridge University Press, Cambridge, 1989

The following are referenced in the text:

Harwit, M.: *Astrophysical Concepts*, 2nd ed., Springer-Verlag, New York, 1988

Meeus, J.: *Astronomical Algorithms*, Willmann-Bell, Richmond, 1991

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T.: *Numerical Recipes*, Cambridge University Press, Cambridge, 1986

The Jacoby spectral library was originally published by Jacoby, Hunter, and Christian in 1984. The reference is Astrophys. J. Suppl. 56, 256.