Astronomy A305 - Modern Observational Techniques
Lab Assignment 10

Determining the Velocity Dispersion of Messier 13

Goal: Continue to improve your IRAF and analysis skills. Become familiar with the identification of spectral lines and the measurement of radial velocity. Determine the velocity dispersion of giant stars in the globular cluster M13.

What to hand in - Hand in a complete lab report of your work, including:
• An introduction describing the measurement you are trying to make
• A description of your procedure and results, including a list of the lines you measured and their laboratory wavelengths
• A sample spectrum with the lines you measured identified
• A brief summary of what problems you encountered in trying to identify lines and measure the wavelengths.
• A description of your analysis procedures and plots, including any error analysis
• A table of velocities of the individual stars

An appropriate length is 3-5 typed pages, single spaced, 12-point font, with 1" margins, plus figures and tables. You may work with partners to obtain the data for the lab, but your analysis and writeup should be entirely your own. Be sure to review the general lab instructions on the "lab options" sheet.

M13 Observations
In the M13 subdirectory of the A305 directory, you will find a moderate resolution spectrum of giant stars in the globular cluster M 13 taken with the Hydra fiber spectrograph on WIYN. This is a multi-fiber spectrum, in which each line of the image is the spectrum of a different star in M 13. Copy that spectrum into a new subdirectory of your own home directory and examine it using the IRAF task splot.

In Rm 246 are copies of the solar spectrum, and of a line list of solar lines prepared by F. Thevenin (Astronomy and Astrophysics Supplement Series, Vol. 82, pp. 179-188, 1990). Use the solar spectrum and the line list to identify 10 relatively unblended spectral lines in one of the M13 stars. Measure the wavelengths of these 10 lines in the spectrum of each star in which they appear. It will be useful to enter your data into a spreadsheet program to keep track of it all.

Information extracted from the image header for the M13 spectra is attached. The specific apertures/stars to be measured for radial velocity are listed (8, 9, 17, 24…). The aperture number refers to the specific fiber position on the slit of the spectrograph, and the L, K, CM and Roman designations are the assigned names of stars in M13.

Compute the radial velocity of each star from the difference between the measured wavelength and the laboratory wavelength for each line measured given in one of the
standard references (e.g. the Thevinin reference available in Rm 246, the Multiplet Table, or the solar equivalent width tables. Compute the standard deviation of the measured radial velocity of each star.

Compute the standard deviation of the all the stars to determine the velocity dispersion of the cluster. Identify possible sources of systematic error. Also convert your measurements to heliocentric velocities, and compare to the published velocity of M 13.

For advanced students, also determine velocities using a cross-correlation technique. You can use the solar spectrum from Lab 6 as a velocity template.

**Splot hotkeys:**

- ? - This display
- / - Cycle thru short help on stat line
- a - Autoexpand between cursors
- b - Toggle base plot level to 0.0
- c - Clear and redraw full spectrum
- d - Deblend lines using profile models
- e - Equiv. width, integ flux, center
- f - Arithmetic functions: log, sqrt...
- g - Get new image and plot
- h - Equivalent widths(*)
- i - Write current image as new image
- j - Fudge a point to Y-cursor value
- k - Profile fit to single line(*)
- l - Convert to F-lambda
- m - Mean, RMS, snr in marked region
- n - Convert to F-nu
- o - Toggle overplot of following plot
- p - Convert to wavelength scale
- q - Quit and exit
- r - Redraw the current window
- s - Smooth (boxcar)
- t - Fit continuum(*)
- u - Adjust coordinate scale(*)
- v - Velocity scale (toggle)
- w - Window the graph
- x - Connects 2 cursor positions
- y - Plot std star flux from calib file
- z - Expand x range by factor of 2
- ) - Go to next spectrum in image
- ( - Go to previous spectrum in image
- # - Select new line/aperture
- % - Select new band
- $ - Toggle wavelength/pixel scale
- - - Subtract deblended fit
- , - Down slide spectrum
- . - Up slide spectrum
- I - Interrupt task immediately
- <space> - Cursor position and flux
M13.fits[2069,46][real]: H0441-013.1 M13
OBSERVAT= 'KPNO' / Origin of data
TELESCOP= 'WIYN3.5m' / Specific system
DETECTOR= 't2kc' / Detector (CCD type, photon counter, etc.)
DATE-OBS= '24/05/99' / Date (dd/mm/yy) of observation
UTSHUT  = '06:28:01.0' / UT of shutter open
EXPTIME = 1800.000 / Exposure time in secs
GAIN_12 = '1.7' / gain, electrons per ADU
NOISE_12= '4.3' / read noise, electrons
UT      = ' 6:27:59.36' / universal time
ST      = '15:07:15.74' / sidereal time
EL      = '70:01:43.46' / elevation
AZ      = '70:31:32.53' / azimuth
COORDS  = 'Helio. mean FK5' / coordinate system
RA      = '16:41:39.77' / Telescope RA
DEC     = '36:26:43.25' / Telescope DEC
TARGRA  = '16:39:54.10' / right ascension
TARGDEC = '36:39:54.10' / declination
EQUINOX = 1999.4 / equinox of position
EPOCH   = 1999.4 / same as EQUINOX (for back compat.)
ZD      = 19.974 / zenith distance
AIRMASS = 1.046077 / airmass at start of exposure
JD      = 2451322.7798537
Aperture 8 = L 414 III-56
Aperture 9 = L 250
Aperture 17 = L 465
Aperture 24 = L 745 I-13
Aperture 27 = K 699 X24
Aperture 29 = L 72 III-73
Aperture 31 = L 353 II-40
Aperture 33 = L 26 J38
Aperture 38 = L1048 I-60
Aperture 40 = L 512 IV-13
Aperture 43 = L 877 I-50
Aperture 46 = L1097
Aperture 48 = L 262
Aperture 49 = L 436
Aperture 53 = L 687 IV-15
Aperture 54 = L 240 II-34
Aperture 55 = L 261
Aperture 61 = L 169 III-37
Aperture 63 = L 940
Aperture 64 = L1023 IV-61
Aperture 65 = L 830
Aperture 67 = L 919 IV-28
Aperture 72 = L 677 IV-4
Aperture 73 = CM 2
Aperture 76 = L 43 J49
Aperture 82 = L 800 IV-18
Aperture 84 = L 768 IV-49
Aperture 85 = L 853
Aperture 94 = L1073
Aperture 97 = L1032 I-76
VHELIO = 6.45