Exercise Sheet 4

Deadline: November 3, 2025 @ 07:00 am

Exercise 16: In Mooodle (Week 4) you find an IDL save file `q_data.sav`. The save file contains the variables `im0`, `dd0` and `ff0`, with `im0` the raw image of a small field of the Sun recorded by the German VTT (Vacuum Tower Telescope, D = 70 cm) in the red continuum, with a pixel scale $0.1''$/pixel. `dd0` is a dark current frame and `ff0` a flat field. The observing run was on 19-Jun-2004 ($1'' \approx 736$ km).

(a) Reconstruct the variables from the IDL save file und display all three images (original `im0`, flat field `ff0` and dark current `dd0`) side by side in one window. What do you see in these images?

(b) Inspect the range of values of the original image by making a histogram (select a proper binsize). What do you think was the dynamic range of the CCD camera: 8-bit, 10-bit, 12-bit, 14-bit?

(c) Also make a histogram of the dark current frame. Compare the value range of the dark current image to the original image. How large is it compared to the original image, in %?

(d) Apply the astronomical data reduction (see Lecture Notes #3). Correct the the image for flat field and dark current, and display the corrected image. How is it different from the raw (original) image?

(e) Multiply the corrected image with the mean value of (im_{flat}–im_{dark}), to arrive from the normalized image back to physical units. Calculate the histogram of the corrected image and compare it with that of the original (raw) image by plotting the histograms on-top of each other in the same panel.

(f) How large is the field-of-view that is observed (in arcseconds, in km, in units of the solar radius)?

(g) What is the diffraction limited resolution of the observations? How does this relate to the pixel scale of the CCD?

Exercise 17: In Moodle (Week 4) are the files `mdi_mf.dat` and `mdi_cont.dat`. They contain images saved in binary IDL data format (width: 355 pixel, height: 254 pixel, data type: Integer) of a subfield of the Sun, that were recorded by the MDI instrument onboard the SOHO spacecraft (magnetic field image, continuum image). The units of the magnetic field image are Gauss.

a) Display the magnetic field map using the function `image`.

b) 1 pixel of the MDI image corresponds to $2''$ on the Sun. Display the image together with an x- and y-axis, so that the spatial units are given in arcesconds ($''$). Also add proper x- and y-axis titles.

c) Display the continuum image and the magnetic field image side by side. This can be achieved using the keywords `layout` and `current` (analogously like in the `plot` function).

d) Display the MF image in color, and add left to it a color bar that shows the magnetic field strength. Use, e.g., the keyword `position` in the function `image` as well as the function `colorbar` (see IDL help or online resources).

e) Display the contours of the magnetic field image using the function `contour`. Display the contours filled and in color. Try further keywords and properties of the contour function (labels, filling, etc; check the IDL help).

f) Display the continuum image and overplot the contours of the image (keyword `overplot`).

g) Display the continuum image, but this time overplot the contours of the magnetic field map. Use the properties `xrange` and `yrange` in the image display to zoom to the regions of the sunspots.

h) Check the range of values in the magnetic field image, and choose the contour levels so that they reflect the sunspot umbra and penumbra. Display the contour lines of the different magnetic polarities in different colors/color tables (e.g., positive: red, negative: blue).

i) Use the function `text` to write a title into the image.

Exercise 18: Create separate maps from the following fits files and display them: `kso_ha.fts.gz`, `fd_Ic.fits`, `fd_M.fits`

a) Check the meta-data in the map structure (time, image center, pixel scale, orientation, . . .)

b) Create a new map, in which the Kanzelhöhe image is oriented to North up, and visualize this map. Also, draw a grid on it and compare it with the visualization of the original map.

c) Display a zoom of the continuum image of the big active region in the southern hemisphere (use the `xrange`, `yrange` keywords in plotting the map). Overplot on this image the contours of the corresponding magnetic field map. Display positive and negative polarities in different colors (keywords `level`, `c_color`). Choose the contour levels so that they emphasize sunspot regions (strong fields).

d) Display the magnetic field map of the active region, and overplot the contours of the flare region observed in the Hα filtergram.

Exercise 19: Download the EIT observations in the 195 Å filter for the 3rd November 2003 09:00-11:00 UT from VSO.

a) Read the data and apply the EIT data reduction.

b) Convert the images/headers to an array of map structures.

c) Create an array of submaps in the quadrant, in which the flare occurs.

d) Create difference maps from this new map array (either running diffs or running ratios) and animate a sequence of these difference maps. Choose different scalings (e.g. using the keywords `dmin`, `dmax`), to emphasize a) the flare and b) the large-scale (but much weaker) changes due to the propagating EIT wave.

e) Make an eps file which contains a representative sequence of maps to show the event evolution, e.g. 3×4 panels.

Exercise 20: In Moodle (Week 4) the directory `aia_11-Apr-13` there are SDO/AIA data recorded at different EUV wavelengths during a flare event.

(a) Read the FITS header of all the AIA data in the directory, and select the data recorded in the 171 Å filter (use `read_sdo`).

(b) Read each third image of the available sequence into a map array. When reading the data, reduce their size to a quarter of the full resolution.

(c) Load the color table defined for the AIA 171 Å filter and play the map sequence as a movie. Use a logarithmic intensity scaling in the image visualisation.

(d) Plot the first map of the series. Overlay a heliospheric coordinate grid (in 10° levels).

(e) From this image, roughly read by eye the position of the flare, in cartesian (arcsec) as well as in heliospheric coordinates. What is the solar NS an EW position of the flare?

(f) In a second step, use the procedure `cursor` or `rdpix` to interactively click to the flare position and returning the (x,y) position in arcseconds into a variable.

(g) Check the SSWIDL routine `arcmintohel` (by using, e.g., `xdoc`), and use it to calculate from the (x,y) flare coordinates in arcsec, the heliographic coordinates.