Indian Institute of Technology Bombay

EP219 Data analysis and interpretation
Assignment 3
Dated : 24 - 10 - 2016
Deadline: 4-11-2016 at 10 am

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Please rotate roles for group members for this assignment.

Problem 1 Error regions Use the likelihood maximization method to find the parameters m and c from problem 3 in the last assignment. Show a 1-sigma and 2-sigma error region in the plane of m and c. Fixing c to its maximum likelihood estimate, give an error interval for m and vice-versa.

Problem 2 Discover dark matter Consider a dark matter direct detection experiment that is designed to measure the recoil energy of nuclei being scattered by dark matter particles. The measured recoil energies (E_R) range from $0 - 40$ KeV and the total number of events are reported in 1 KeV bins. The published data is attached in the text file "recoilenergydata_EP219.csv" showing the number of events as a function of recoil energy (For the first bin 0.5 KeV is the central value of the bin, so the first bin corresponds to recoil energies between 0-1 KeV).

We want to analyze this data to look for a dark matter signal! Unfortunately, there are a large number of background processes that could also contribute to dark matter scattering.

The dark matter signal spectrum has the following triangular form as a function of the recoil energy of the nucleus (E_R).

$$\frac{dN}{dE_R} = \sigma * 20 * (E_R - 5 \text{ KeV}) \text{ for } 5 \text{ KeV} < E_R < 15 \text{ KeV} \quad (1)$$

$$= \sigma * 20 * (25 \text{ KeV} - E_R) \text{ for } 15 \text{ KeV} < E_R < 25 \text{ KeV} \quad (2)$$

$$= 0 \text{ otherwise} \quad (3)$$

Here the signal strength depends on a single parameter (σ) which is the dark matter-nucleus scattering cross-section measured in femto-barns (fb) (1 fb $= 10^{-39}$ cm^2).

The background rate is exponentially falling with energy and has the form,

$$\frac{dN}{dE_R} = 1000 * e^{-E_R/(10 \text{ KeV})} \quad (4)$$

a) Make a clearly labelled histogram of the data.

b) Assuming background only processes, calculate the mean number of events that you would expect to see in each bin. Make a histogram of this expected background.

c) Assuming cross-sections of 0.01 fb, 0.1 fb, 1 fb, 10 fb, 100 fb, calculate the mean number of events that you would expect to see in each bin assuming background *and* signal. Make histograms for each of these cases. In which cases do you expect to tell by eye whether or not you have a dark matter signal?

d) Find the log likelihood function of the cross-section $\log \mathcal{L}(\sigma)$ and plot it. Describe in detail the process used to arrive at this log likelihood function.

e) Use this log likelihood function to find the maximum likelihood estimate (MLE) of the cross-section. Also report a 1-σ interval of cross-sections that are consistent with the data.

f) Can you conclude whether or not the data favors the presence of a dark matter signal? Justify your conclusions.