Mid-term Exam: Physics 642, Spring 2019.

A) Abel Inversion.

1. The Abel transform pair $f(r) = r^2 \exp\left\{-r^2/2\sigma^2\right\}$ and $f_A(x) = \sqrt{2\pi}\sigma(x^2 + \sigma^2)\exp\left\{-x^2/2\sigma^2\right\}$ describes a possible outcome for a spherically symmetric radiator. Generate separate graphs for the two functions. Numerically compute the integrals $f_A(0) = 2\int_0^{+\infty} f(r)dr$ and $\int_{-\infty}^{+\infty} f_A(x)dx = 2\pi\int_0^{+\infty} f(r)rdr$, and check whether these values agree with the graphs. ($+\infty$ means: a distance $R/r >> 1$, i.e., for values much larger than the characteristic size of the radiator.)
2. Now consider that there is a constant background that was measured, viz $\tilde{f}_A(x) = f_A(x) + \mathrm{C}$. Compute the finite Abel transform and show graphs with a background of the order of 10 per cent of the $f_A(x)$ maximum. Also check whether your results agree with $f_A(0) = 2\int_0^{+\infty} f(r)dr$ and $\int_{-\infty}^{+\infty} f_A(x)dx = 2\pi\int_0^{+\infty} f(r)rdr$.

B) Wavelength and sensitivity calibrations.

1. A set of measured hydrogen beta spectra "500-setting.png," "490-setting.png," and "480-setting.png" correspond to actual settings of 500.14 nm, 490.14 nm, and 480.14 nm on the spectrometer. Use linear fitting to determine the wavelength scale at the 500-vertical pixel scale. Subsequently, determine the wavelength calibration at the 200- and 800- vertical scale. What is the difference for a nominal 0.1 nm spectral resolution. (Here, you would utilize a 3-point linear fitting routine with error bars associated with the errors in reading wavelengths from the png files.)
2. From the measured calibration data "calibdata512.dat" for line at the vertical pixel 512 and for the setting of 490.14 [see B) 1. above], use the "lamp.dat' file to determine the sensitivity factors versus wavelength. Please consider smoothing of the values in "calibdata512.dat" and interpolation of the "lamp.dat" points.

C) Fitting of atomic spectra.

1. Determine the electron density from the FWHM of the measured Balmer series hydrogen-alpha line-of-sight data "!!!9average.dat" and from the hydrogen-beta data "!!!hbeta.dat" using 0.1-nm spectral resolution.
2. Fit the recorded hydrogen-alpha line to a Lorentzian with background and determine the 10-nm line-to-continuum ratio. Do the same for hydrogen-beta using a Lorentzian for the purpose of determining the FWHM, subsequently the 10-nm line-to-contiuum ratio.

D) Fitting of molecular spectra.

1. The wavelength-calibrated and sensitivity-corrected line-of-sight CN spectrum "CNdata04icorrline90.dat" shows a measured spectrum containing CN and an atomic line in second order. Prior to analyzing this data set, compute CN spectra for spectral resolutions corresponding to the recorded data, and for T = 4 kK, 5 kK, 6 kK, and 7 kK (using the BESP program). Further, the 193.09-nm CI line appears to be measured in 2-nd order, infer the FWHM of this line.
2. Determine the best-fit 0.1-nm spectral resolution, background, and temperature of the CN emission spectrum using the NMT program communicated in the course.

Due March 5, 2019.