X-ray spectroscopy - a walk through XSPEC

- Download data:
  - go to http://galaxy.asu.cas.cz/~svoboda/pub/AGN_workshop/data/ and download folders spectrum_1 and spectrum_2
- Load data in the Xspec
  - go to the folder Spectrum_1 and load EPIC/PN data:
    - **data** mcg6_10_r.pi
  - check what data you have:
    - **show data**
  - ignore bad data and data out of valid energy range:
    - **ignore** bad
    - ignore **-1. 10.-** (opposite command is **notice**)
      - **- means everything up to.., -** means everything from
      - be aware that if you put integers behind ingore/notice, it will not ignore energies but channels!
    - **notice** 0.5-1. (XMM-Newton is good also below 1 keV)
      - if you have more data and you want to apply notice/ignore to all of them, just type "**:": e.g., ignore **:**-0.5 10.-**
- Plot your data
  - **plot ldata** (plot data, plot counts)
- Define a model
  - **model phabs*powerlaw**
    - enter model parameters
  - change a parameter of the model, freeze known parameters
    - **newpar** 1 0.036
    - **freeze** 1 (opposite command is **thaw**)
  - you can also define delta of a parameter, which is a first step of the value for the fitting procedure (if negative the parameter is frozen), you can also define allowed intervals for the parameter: newpar #param_number #param_value, #delta, #min, #min, #max, #max
    - e.g. newpar 2 2.,0.1,1.5,1.5,3.,3.
  - show free/all parameters
    - e.g., **show free**
    - **show all**
- Fit the data
  - **fit**
  - if you want to define number of steps in fitting and the depth (critical delta), you can type e.g.:
    - fit 1000 1e-2
  - plot the data and model residuals, they are different ways of plotting residuals:
    - **plot ldata ratio**
    - **plot ldata residuals**
    - plot ldata chisq, ...
- Add a component to your model
  - **addc** 2 zxipcf
  - addc 3 zgau
  - fit with the new model, has the fit improved?
- Save your model/all
  - **save model** my_model.mdl
  - **save all** my_session.xcm
- Load model/all:

        - **@**my_model.mdl
        - **@**my_session.xcm
- Check your model if it makes sense:
    - what is the energy and sigma for the gaussian line, any physical interpretation?
        - plot model
- Replace a Gaussian line by a relativistic iron line:
    - delete a model component:
        - **delc** 3
    - add a new component, you can also use "editmod" instead of "addc"
        - e.g., **editmod** phabs*zxipcf*(po+kyrline)
- Try to fit, change parameters if needed. Try to get the least residuals as possible and achieve the reduced chi-2 less than two (reduced chi-2 is chi-2 divided by degrees of freedom).
- Calculate the error of a parameter (must be a free parameter):
    - **error** 6
    - error 8
    - error command works only if your reduced chi-2 is less than 2; if it is higher and you want to run this command, you can do it by typing, e.g., error max 10 8
- Calculate the dependence of chi-2 on the parameter value:
    - **steppar** 8 0 1 100
    - **plot contour**
- Calculate a 2D contour between two parameters:
        - if you want Xspec to start calculation in each grid from the best fit type "steppar best ..."
    - steppar best 8 0 1 20 9 20 45 20
    - plot contour
- Write your results in a file
    - **setplot command we** myfit
    - plot ldata ratio (or what you want to write in your file)
    - **setplot delete 1** (otherwise your file will be rewritten again by new commands)
- Save all and exit:
    - save all bestfit.xcm
    - exit

- **Good luck with fitting!**

Additional Exercise:

1) Investigate two unknown X-ray spectra and find out which is Type-1 and which is Type-2 AGN:

   Spectrum 1: z = 0.008, Galactic column density nH = 3.6e20 cm^{-2}
   Spectrum 2: z = 0.015, Galactic column density nH = 5.7e20 cm^{-2}

   Cross the line between the corresponding AGN spectrum and type:

AGN spectrum 1	Seyfert-1 AGN
AGN spectrum 2	Seyfert-2 AGN

2) Fit the spectra with a simple absorbed power-law model and measure the power-law slope and the level of absorption. Add a reflection model (line "gauss" and/or reflection continuum "pexrav") to your spectral fit and check for the presence of reflection features. If present measure the reflection fraction or the equivalent width of the iron line.

3) Calculate uncertainty of the interesting parameters and plot a statistical contour (in 1 or 2-D parameter space).

4) Advanced exercise: in Spectrum 1 load a spectrum from a different time interval (in folder "Additional") and compare the two spectra from different time intervals. Which spectrum was caught in high/low state and what changed in the spectrum?