XSPEC Analysis

Valentina Fioretti

INAF/IASF Bologna

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Setup commands

> xspec
> data file

```
[eleonora@MacBook]pn>xspec

                XSPEC version: V.12.8.1
        Build Date/Time: Thu Dec 22 11:10:41 2011

XSPEC12>data pn_25.grp

1 spectrum  in use

Spectral Data File: pn_25.grp  Spectrum 1
Net count rate (cts/s) for Spectrum:1  3.924e+00 +/- 1.948e-02 (98.6 % total)
 Assigned to Data Group 1 and Plot Group 1
  Noticed Channels:  1-2312
  Telescope: XMM Instrument: EPN  Channel Type: PI
  Exposure Time: 1.06e+04 sec
 Using fit statistic: chi
 Using Background File                 back_spectrum.fits
  Background Exposure Time: 1.06e+04 sec
 Using Response (RMF) File             pn.rmf for Source 1
 Using Auxiliary Response (ARF) File   pn.arf

XSPEC12>
```

Setup commands

> ignore bad
> setplot energy
> ignore **-0.5,10.-**
> plot ldata

```
XSPEC12>ign bad

ignore:  1685 channels ignored from  source number 1
XSPEC12>setplot energy
XSPEC12>ign **-0.5,10.-**
    64 channels (1-64) ignored in spectrum #     1
  1689 channels (624-2312) ignored in spectrum #     1

XSPEC12>plot ldata
```

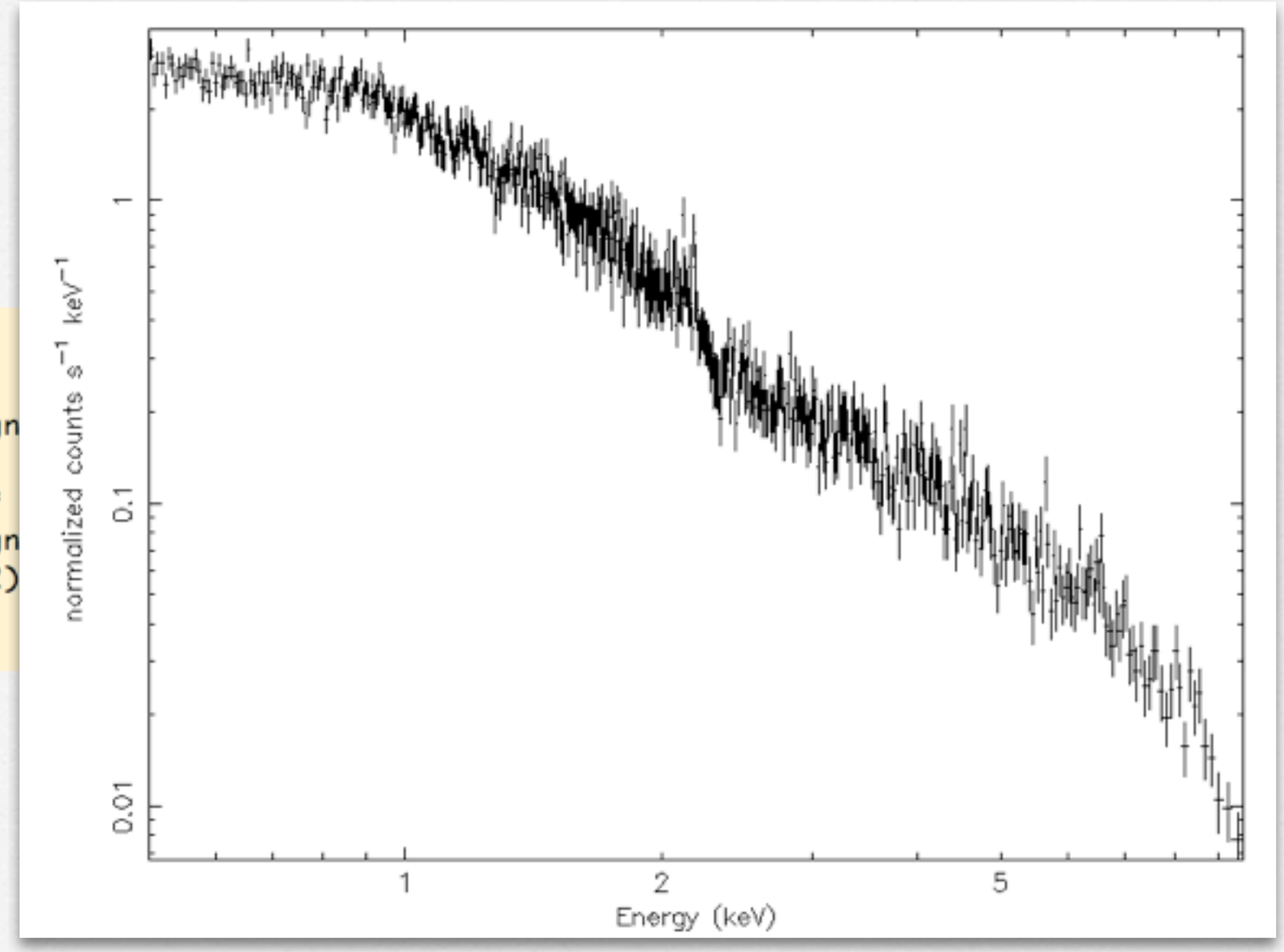
Setup commands

> ignore bad
> setplot energy
> ignore **-0.5,10.-**
> plot ldata

```
XSPEC12>ign bad

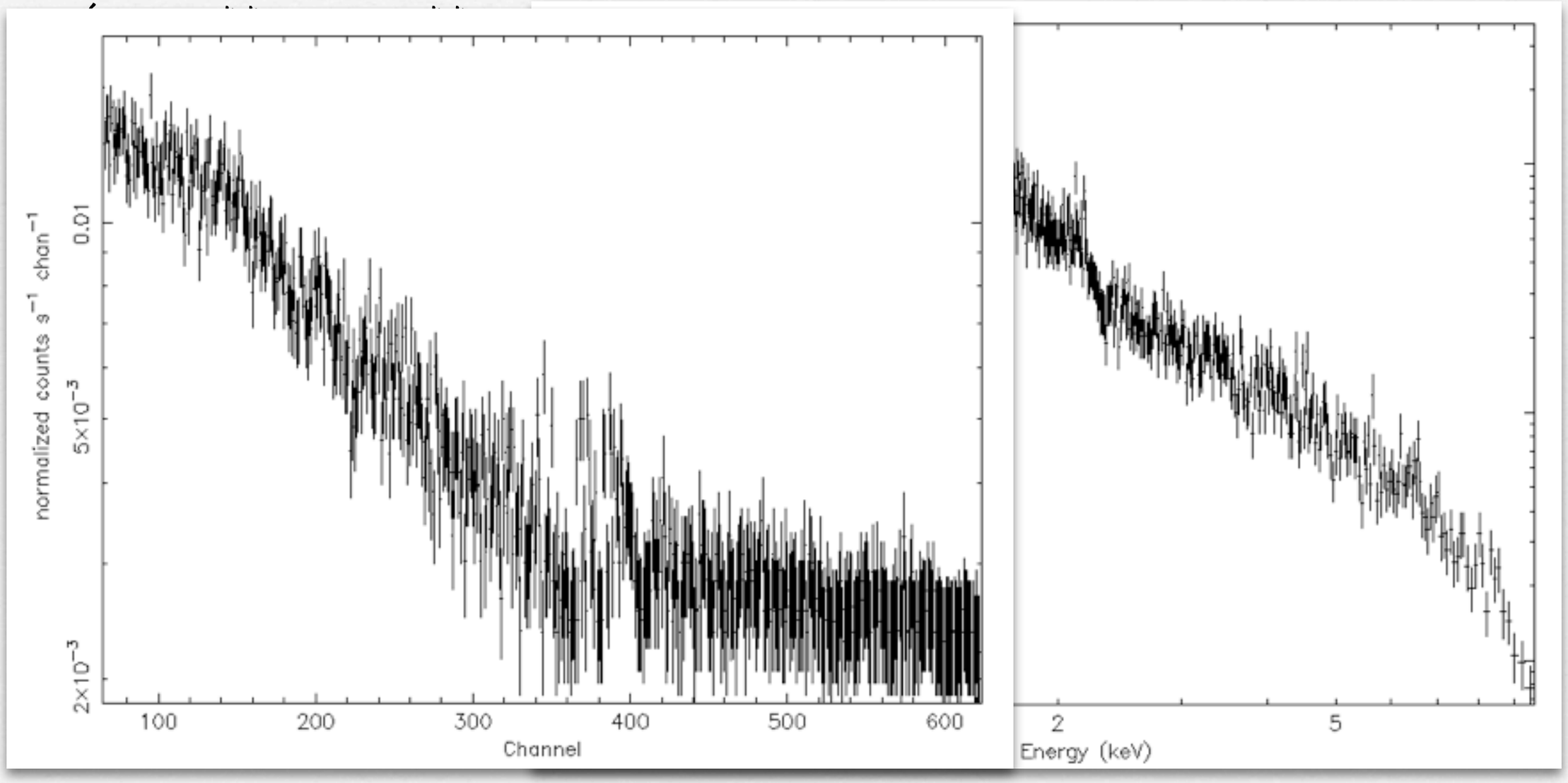
ignore:  1685 channels ign
XSPEC12>setplot energy
XSPEC12>ign **-0.5,10.-**
    64 channels (1-64) ign
  1689 channels (624-2312)

XSPEC12>plot ldata
```



Setup commands

> ignore bad
> setplot energy



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XSPEC12>ign bad

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XSPEC12>ign **-0.5,10.-**
    64 channels (1-64) ign
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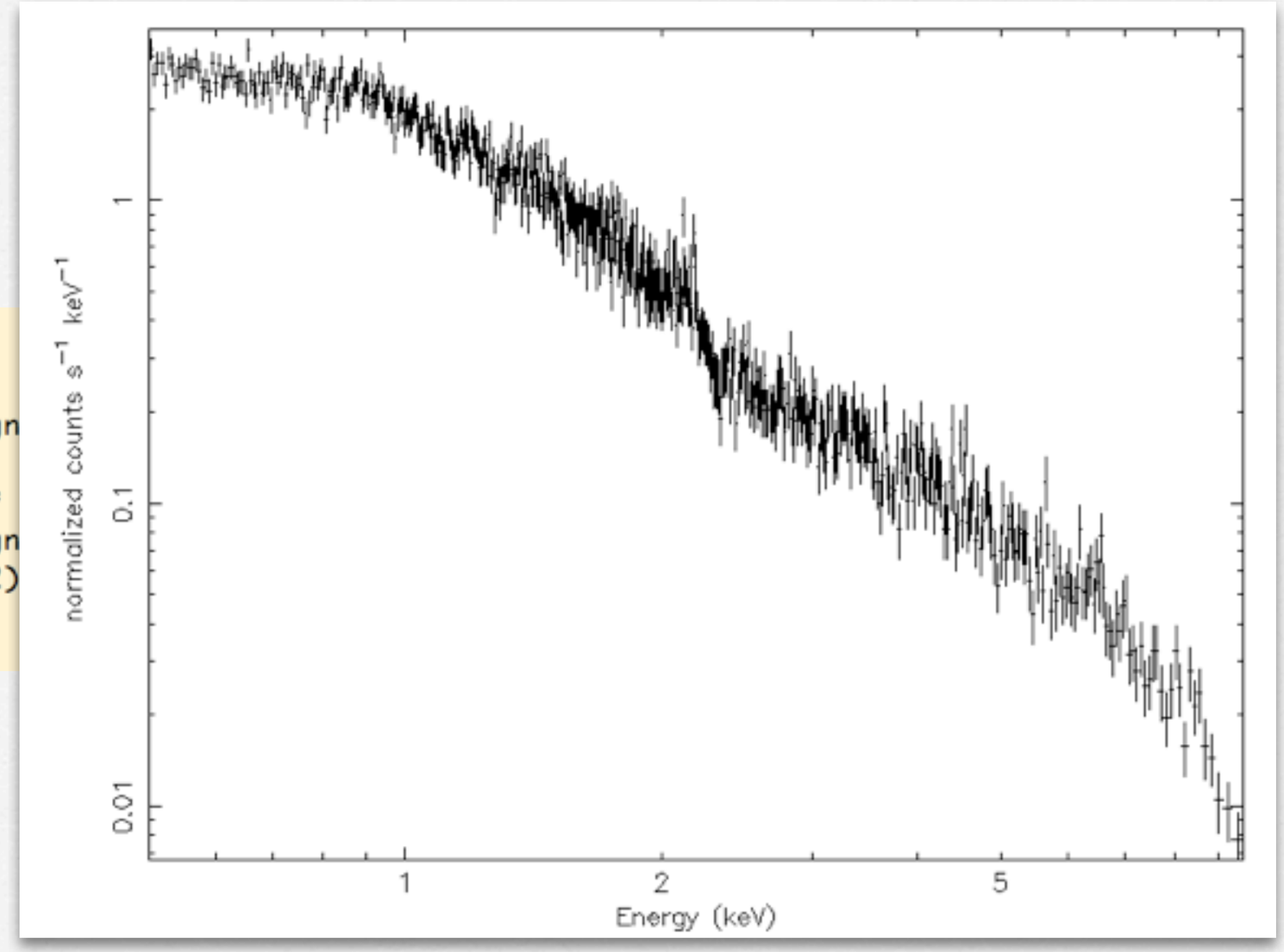
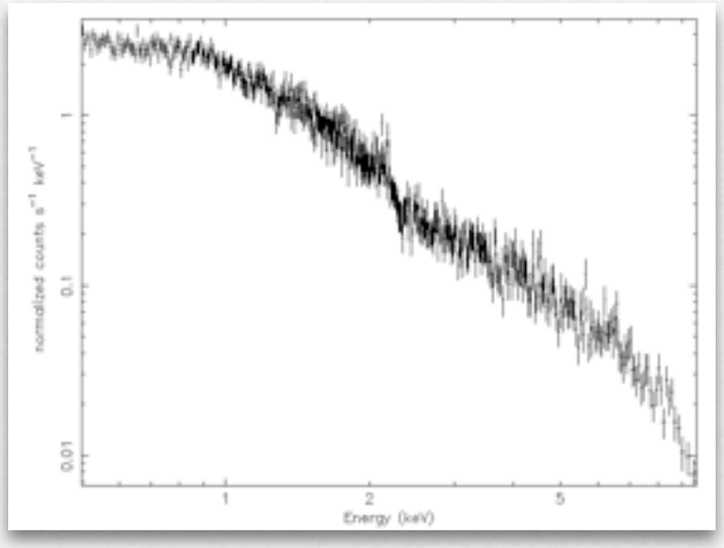
XSPEC12>plot ldata
```



Model Fit

Aim: find the best fit model that better describes the source emitted radiation (and therefore the physical process at work)



You can try different models:

MULTIPLICATIVE MODELS

```
Multiplicative Models:
     SSS_ice        TBabs      TBgrain     TBvarabs        absori      acisabs
        cabs     constant     cyclabs         dust          edge       expabs
      expfac        gabs     highecut        hrefl         notch       pcfabs
       phabs       plabs         pwab       recorn        redden       smedge
    spexpcut      spline      swind1         uvred        varabs       vphabs
        wabs       wndabs        xion       zTBabs         zdust        zedge
     zhighect     zpcfabs      zphabs      zredden       zsmdust      zvarabs
     zvfeabs      zvphabs       zwabs      zwndabs        zxipcf

Convolution Models:
       cflux      gsmooth       kdblur      kdblur2      kerrconv      ls
     partcov       rdblur      reflect        simpl

Mixing Models:
       ascac       projct       suzpsf       xmmpsf

Pile-up Models:
      pileup
```

ADDITIVE MODELS

```
XSPEC12>model ?
 Additive Models:
        apec        bapec        bbody      bbodyrad       bexrav       bexriv
      bkn2pow      bknpower          bmc       bremss        bvapec       c6mekl
     c6pmekl      c6pvmkl      c6vmekl       cemekl        cevmkl        cflow
       compLS       compPS       compST       compTT       compbb     cutoffpl
        disk       diskbb       diskir      diskline       diskm        disko
     diskpbb       diskpn        equil        expdec     ezdiskbb      gaussian
        gnei         grad         grbm        kerrbb       kerrd      kerrdisk
        laor        laor2      lorentz          meka        mekal       mkcflow
         nei      npshock          nsa        nsagrav      nsatmos       nsmax
       nteea      nthComp     pegpwrlw        pexrav       pexriv       plcabs
        posm      powerlaw       pshock       raymond        redge       refsch
       sedov        smaug        srcut         sresc         step        vapec
     vbremss       vequil        vgnei        vmcflow       vmeka       vmekal
        vnei      vnpshock       vpshock      vraymond      vsedov       zbbody
     zbremss       zgauss      zpowerlw
```

Syntax:

M1*M2*(A1+A2+M3*A3)

M=multiplicative model -> i.e. modifies incident flux

A=additive model -> i.e. source of emission

Example:
model wabs*(powerlaw+gaussian)

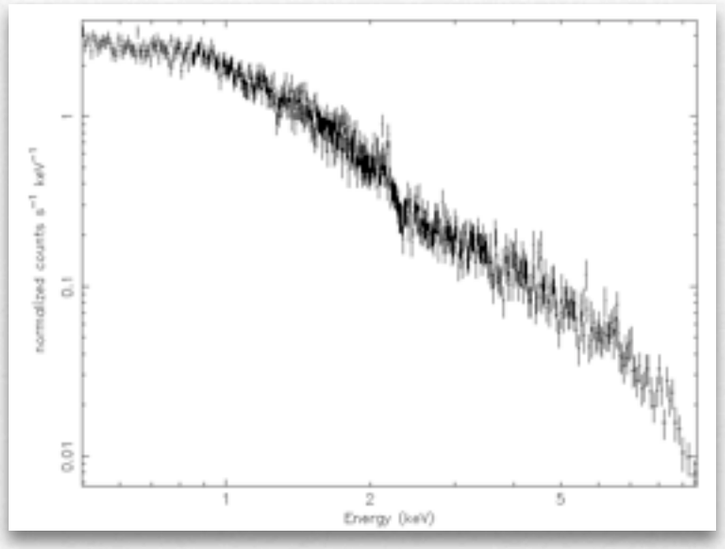
$$M(E) = \exp\left[-n_H \sigma(E)\right]$$

$$A(E) = KE^{-\alpha}$$

$$A(E) = K\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(E-E_l)^2}{2\sigma^2}\right)$$

Model Fit

Aim: find the best fit model that better describes the source emitted radiation (and therefore the physical process at work)



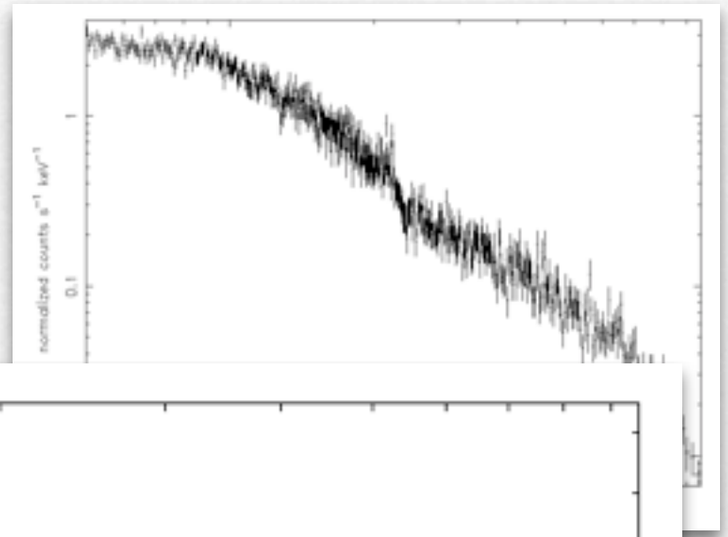
For plotting purposes only:

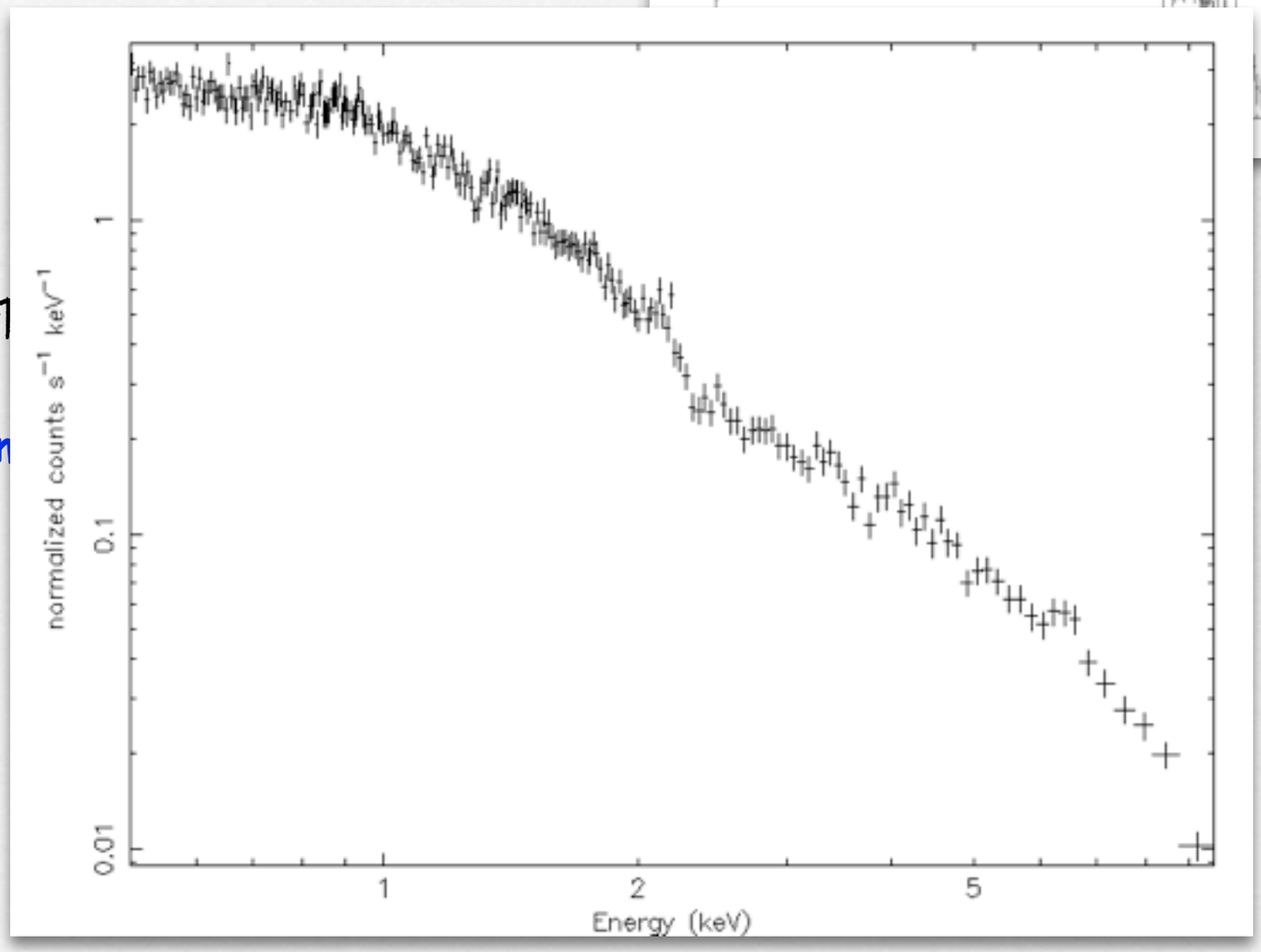
> setplot rebin 10 20 (for example)

adjacent bins are combined (not more than 20) until they have a significant detection at least as large as 10 sigma.

Model Fit

Aim: find the best fit model that better describes the source emitted radiation (and therefore the physical process at work)





For plotting purposes only:

> setplot rebin 10 20 (for exam

adjacent bins are combined (not r
they have a significant detection
as 10 sigma.

Model Fit

```
XSPEC12>mo wa*po

Input parameter value, delta, min, bot, top, and max values for ...
               1      0.001(      0.01)           0           0      100000       1e+06
1:wabs:nH>2.6e-2 -0.1
               1       0.01(      0.01)          -3          -2           9          10
2:powerlaw:PhoIndex>
               1       0.01(      0.01)           0           0       1e+24       1e+24
3:powerlaw:norm>

========================================================================
Model wabs<1>*powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs        nH          10^22    2.60000E-02  frozen
   2    2   powerlaw    PhoIndex             1.00000      +/-  0.0
   3    2   powerlaw    norm                 1.00000      +/-  0.0
------------------------------------------------------------------------


 Chi-Squared =   2.887901e+10 using 559 PHA bins.
 Reduced chi-squared =   5.184741e+07 for    557 degrees of freedom
 Null hypothesis probability =   0.000000e+00
 Current data and model not fit yet.
```

freeze this parameter (otherwise free #parameter). To unfreeze use thaw #parameter

> query yes
> fit

Model Fit

```
========================================================================
Model wabs<1>*powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs        nH          10^22    2.60000E-02  frozen
   2    2   powerlaw    PhoIndex             1.81758      +/-  8.76494E-03
   3    2   powerlaw    norm                 1.84712E-03  +/-  1.16040E-05
------------------------------------------------------------------------

 Chi-Squared =          598.53 using 559 PHA bins.
 Reduced chi-squared =          1.0746 for    557 degrees of freedom
 Null hypothesis probability =  1.084892e-01
```

Reduced chi2 (chi2÷degrees of freedom) ≈1 -> good fit

Model Fit

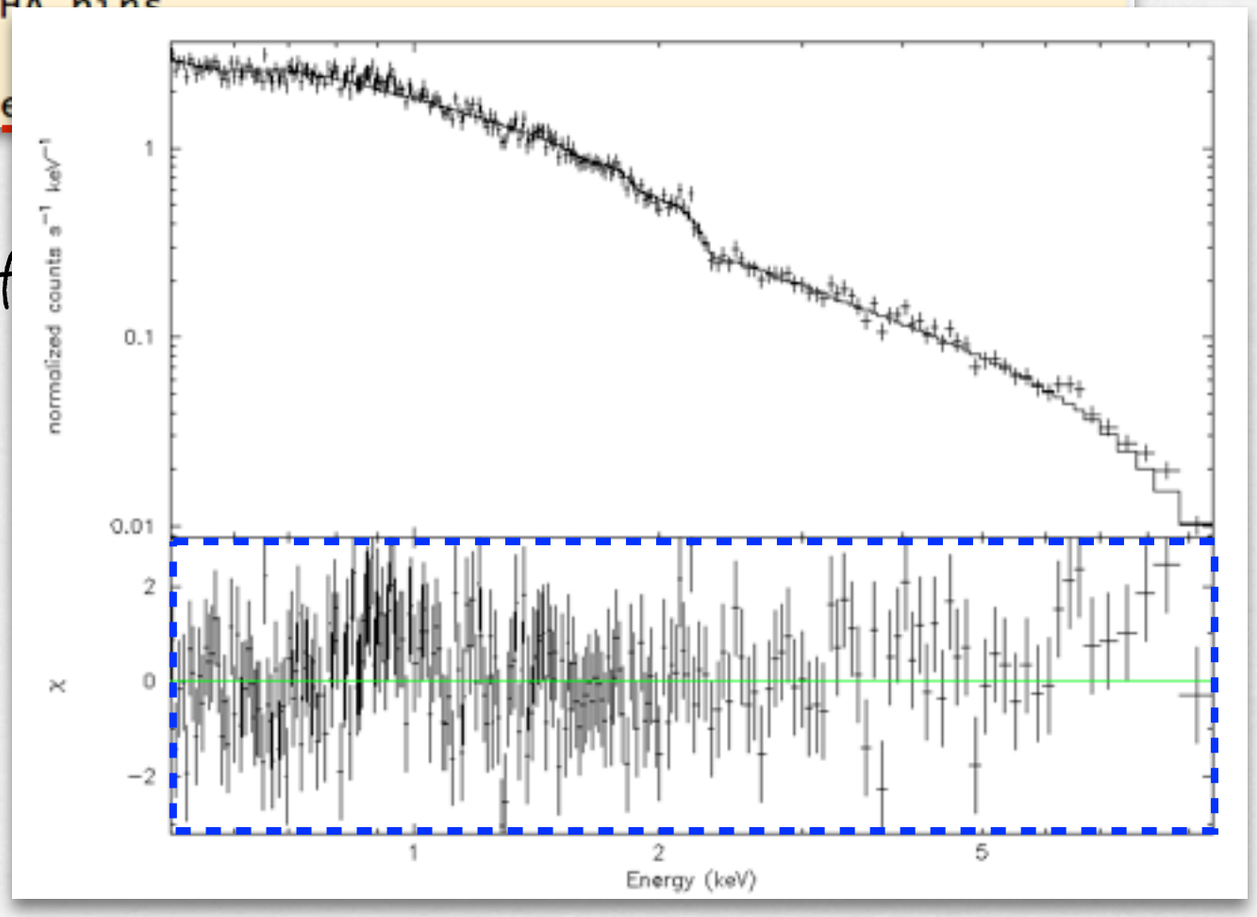
```
========================================================================
Model wabs<1>*powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs        nH          10^22    2.60000E-02  frozen
   2    2   powerlaw    PhoIndex             1.81758      +/-  8.76494E-03
   3    2   powerlaw    norm                 1.84712E-03  +/-  1.16040E-05
------------------------------------------------------------------------

 Chi-Squared =          598.53 using 559 PHA bins
 Reduced chi-squared =          1.0746 for
 Null hypothesis probability =  1.084892e
```

Reduced chi2 (chi2÷degrees of f

> plot ldata delchi

plot the chi2 residuals



```
XSPEC12>add 2 zga

Input parameter value, delta, min, bot, top, and max values for ...
             6.5       0.05(     0.065)           0           0       1e+06       1e+06
2:zgauss:LineE>6.4 -0.1
             0.1       0.05(     0.001)           0           0          10          20
3:zgauss:Sigma>0.1 -0.1
               0      -0.01(      0.01)      -0.999      -0.999          10          10
4:zgauss:Redshift>0.028
               1       0.01(      0.01)           0           0       1e+24       1e+24
5:zgauss:norm>

 Chi-Squared =   2.178332e+11 using 559 PHA bins.
 Reduced chi-squared =   3.917863e+08 for    556 degrees of freedom
 Null hypothesis probability =   0.000000e+00
 Current data and model not fit yet.

========================================================================
Model wabs<1>(zgauss<2> + powerlaw<3>) Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs       nH         10^22    2.60000E-02  frozen
   2    2   zgauss     LineE      keV      6.40000      frozen
   3    2   zgauss     Sigma      keV      0.100000     frozen
   4    2   zgauss     Redshift              2.80000E-02  frozen
   5    2   zgauss     norm                  1.00000      +/-  0.0
   6    3   powerlaw   PhoIndex              1.81758      +/-  8.76494E-03
   7    3   powerlaw   norm                  1.84712E-03  +/-  1.16040E-05


------------------------------------------------------------------------
XSPEC12>fit
```

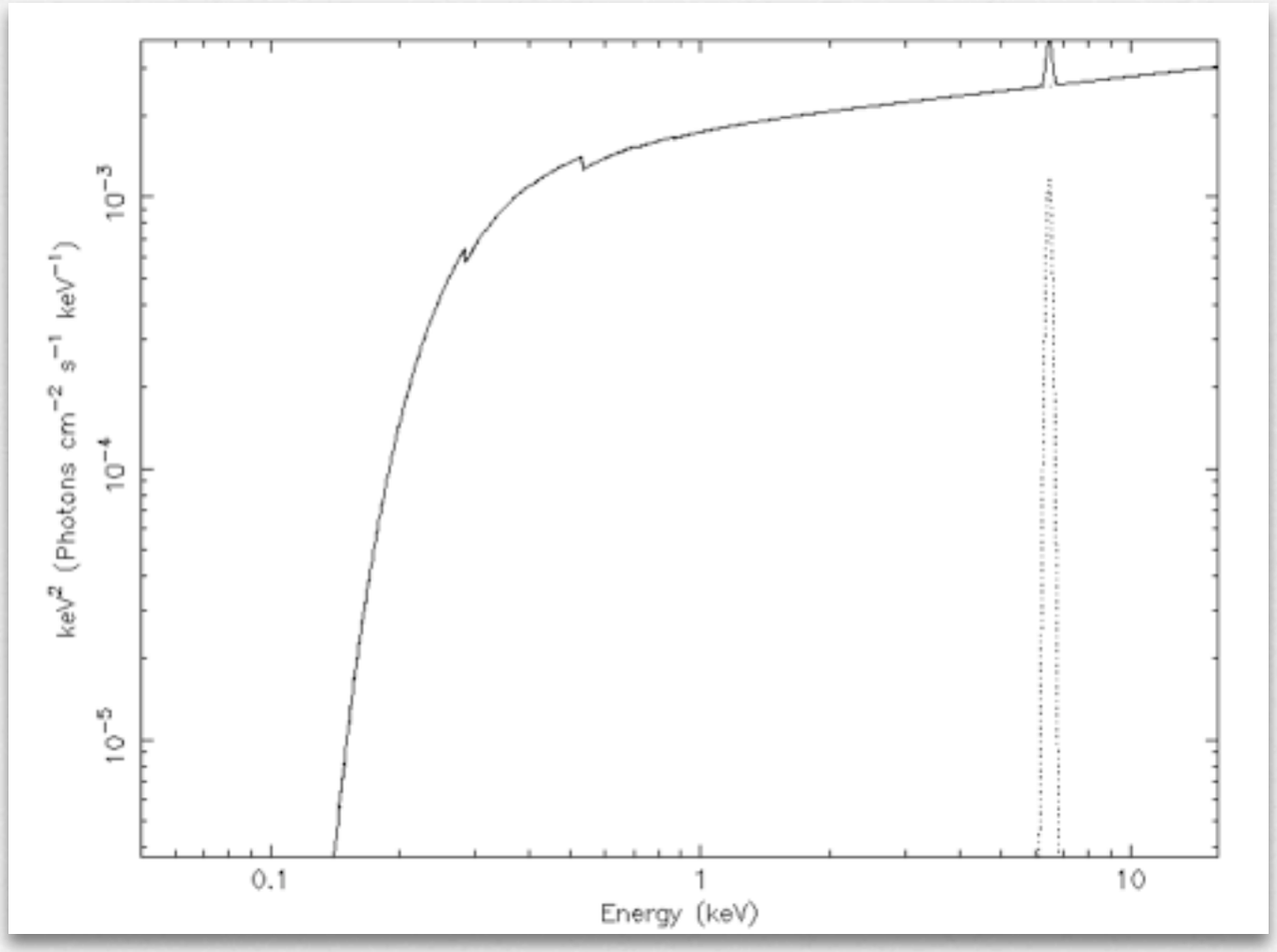
To change the value of a certain parameter

> newpar (number of parameter) (new value)

Model Fit

> pl eemodel

(plot the current incident model spectrum in $E^2f(E)$)



Model Fit

Error estimate:

```
========================================================================
Model wabs<1>*powerlaw<2>  Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs        nH         10^22    2.60000E-02  frozen
   2    2   powerlaw    PhoIndex            1.81759      +/-  8.76533E-03
   3    2   powerlaw    norm                1.84712E-03  +/-  1.16038E-05
------------------------------------------------------------------------


 Chi-Squared =         598.53 using 559 PHA bins.
 Reduced chi-squared =         1.0746 for    557 degrees of freedom
 Null hypothesis probability =   1.084892e-01
XSPEC12>err 2
 Parameter   Confidence Range (2.706)
     2      1.80315      1.83212     (-0.014432,0.0145352)
```

errore al 90%
per un parametro interessante

Model Fit

Error estimate:

```
========================================================================
Model wabs<1>*powerlaw<2>  Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   wabs        nH         10^22    2.60000E-02  frozen
   2    2   powerlaw    PhoIndex            1.81759      +/-  8.76533E-03
   3    2   powerlaw    norm                1.84712E-03  +/-  1.16038E-05
------------------------------------------------------------------------

 Ch
 Re                                                    ees of freedom
 Nu
XSP
 Po                                                    352)
```

$\Delta\chi^2$ as a Function of Confidence Level and Degrees of Freedom						
	ν					
P	1	2	3	4	5	6
68.3%	1.00	2.30	3.53	4.72	5.89	7.04
90%	2.71	4.61	6.25	7.78	9.24	10.6
95.4%	4.00	6.17	8.02	9.70	11.3	12.8
99%	6.63	9.21	11.3	13.3	15.1	16.8
99.73%	9.00	11.8	14.2	16.3	18.2	20.1
99.99%	15.1	18.4	21.1	23.5	25.7	27.8

interessante

Contour plots

> steppar par1 min value max value #steps par2 min value max value #steps

Perform a fit while stepping the value of a parameter through a given range.

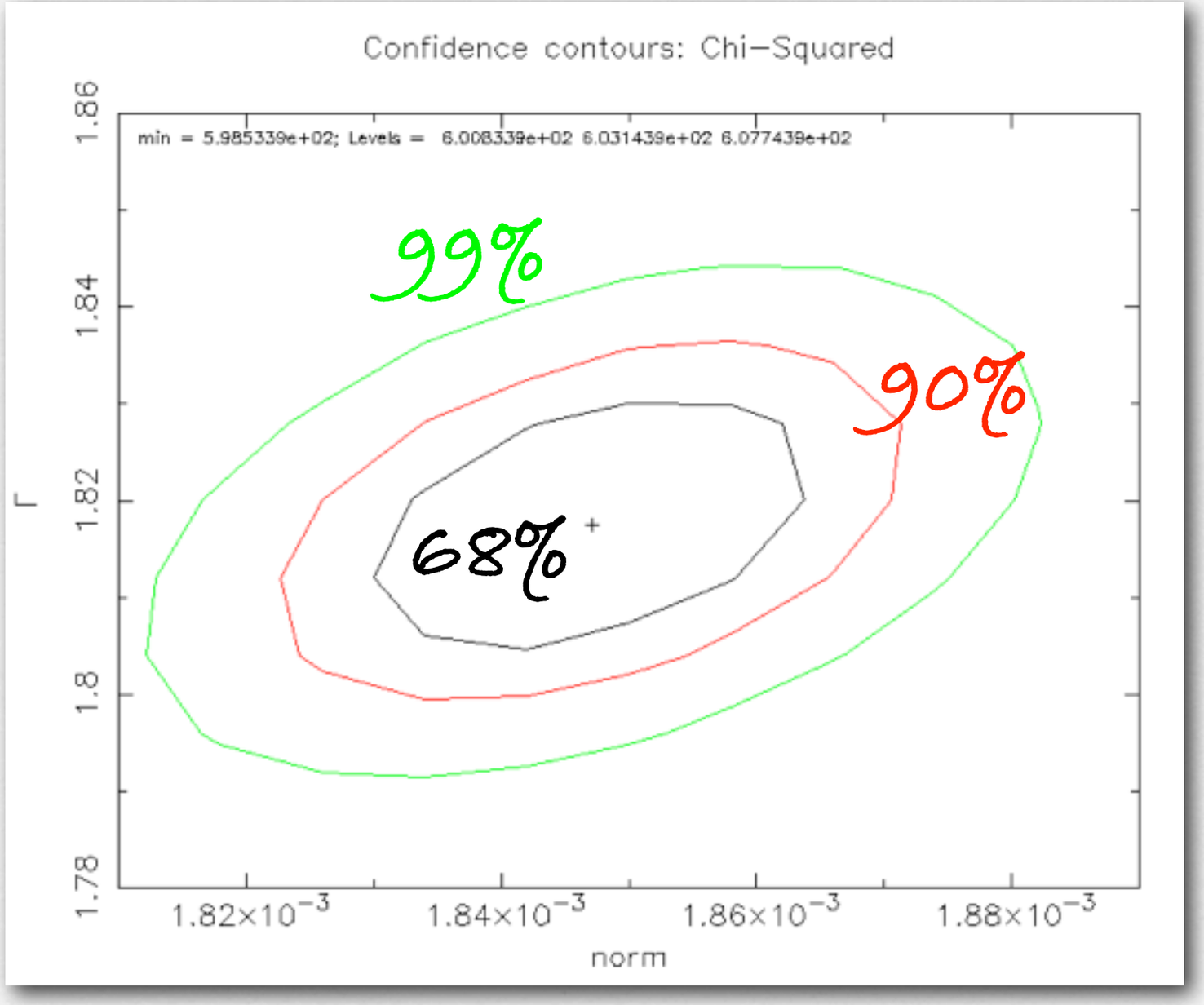
```
XSPEC12>steppar 3 1.81e-3 1.89e-3 10 2 1.78 1.86 10

     Chi-Squared    Delta                 norm       PhoIndex
                 Chi-Squared                 3              2

          619.12      20.584    0     0.00181    0         1.78
          617.52      18.983    1    0.001818    0         1.78
          617.09      18.559    2    0.001826    0         1.78
          617.84      19.311    3    0.001834    0         1.78
          619.77      21.239    4    0.001842    0         1.78
          622.88      24.344    5     0.00185    0         1.78
          627.16      28.626    6    0.001858    0         1.78
          632.62      34.083    7    0.001866    0         1.78
          639.25      40.717    8    0.001874    0         1.78
          647.06      48.528    9    0.001882    0         1.78
          656.05      57.515   10     0.00189    0         1.78
          643.03      44.498   10     0.00189    1        1.788
          634.82      36.288    9    0.001882    1        1.788
          627.78      29.249    8    0.001874    1        1.788
          621.91       23.38    7    0.001866    1        1.788
          617.21      18.681    6    0.001858    1        1.788
          613.69      15.152    5     0.00185    1        1.788
          611.33      12.794    4    0.001842    1        1.788
          610.14      11.606    3    0.001834    1        1.788
          610.12      11.588    2    0.001826    1        1.788
          611.27      12.741    1    0.001818    1        1.788
           613.6      15.064    0     0.00181    1        1.788
          610.17      11.636    0     0.00181    2        1.796
          607.15       8.619    1    0.001818    2        1.796
           605.3      6.7663    2    0.001826    2        1.796
          604.61      6.0778    3    0.001834    2        1.796
          605.09      6.5537    4    0.001842    2        1.796
```

Contour plots

> plot contours



Other useful commands

in XSPEC

> show all
> show files
> show notice

> save all bestfit.xcm (save the best fit model with the data)
> save model bestmodel.xcm (save only the best fit model, without the data)

in PLOT

> time off
> csize 2 (character size)
> msize (marker size)
> label top (title of the plot)
> label filename (title of the file)
> hardcopy nomefile.ps/cps (save a figure)
> plot

Flux and Luminosity

> flux 2 10

```
XSPEC12>flux 2 10
 Model Flux 0.00093467 photons (6.2672e-12 ergs)/cm^2/s range (2.0000 - 10.000 keV)
```

> lumin 2 10 redshift of the source

```
XSPEC12>lumin 2 10 0.028
Model Luminosity 1.1306e+43 ergs/s  (2.0000 - 10.000 keV rest frame)
     (z = 0.0280 H0 =  70.0 q0 =  0.00 Lambda0 = 0.730)
```

APPENDIX

How to estimate the value of the Galactic column density

1. LAB survey (Kalberla et al. 2005)

The Leiden/Argentine/Bonn Galactic H I Survey

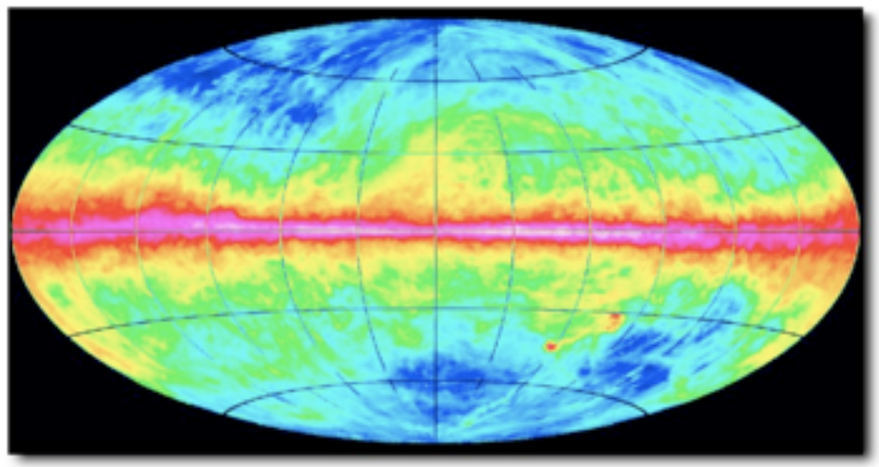


Fig. 1: H I emission integrated over the velocity range $-400 < v < +400$ km s^{-1} in the LAB dataset, shown in Aitoff projection. The Galactic centre is in the middle. The integrated emission ($0 < N_H < 2 \cdot 10^{22}$ cm^{-2}, logarithmic scale) yields column densities under the assumption of optical transparency; this assumption may be violated at latitudes within about 10° of the Galactic equator.

Introduction

The LAB survey contains the final data release of observations of λ21-cm emission from Galactic neutral hydrogen over the entire sky, merging the Leiden/Dwingeloo Survey (LDS: Hartmann & Burton 1997) of the sky north of $\delta = -30°$ with the Instituto Argentino de Radioastronomia Survey (IAR: Arnal et al. 2000 and Bajaja et al. 2005) of the sky south of $\delta = -25°$. The angular resolution of the combined material is HPBW ~ 0.6°. The LSR velocity coverage spans the interval −450 km/s to +400 km/s, at a resolution of 1.3 km/s. The data were corrected for stray radiation at the Institute for Radioastronomy of the University of Bonn, refining the original correction applied to the LDS. The rms brightness-temperature noise of the merged database is 0.07 – 0.09 K. Residual errors in the profile wings due to defects in the correction for stray radiation are for most of the data below a level of 20 – 40 mK. It would be necessary to construct a telescope with a main beam efficiency of $\eta_{MB} > 99\%$ to achieve the same accuracy. The merged and refined material entering the LAB Survey of Galactic H I is intended to be a general resource useful to a wide range of studies of the physical and structural characteristices of the Galactic interstellar environment. The LAB Survey is the most sensitive Milky Way H I survey to date, with the most extensive coverage both spatially and kinematically.

Additional information about the LAB Survey can be found in the corresponding = press release (in German only).

Search the LAB Survey

With the form on this page you can extract the H I column density and the complete spectrum for any position on the sky from the LAB Survey. Please specify below the desired position in either equatorial or Galactic coordinates. For additional help please click on the corresponding labels next to the fields.

Sky position

RA / l:

Dec / b:

http://www.astro.uni-bonn.de/~webaiub/english/tools_labsurvey.php

APPENDIX

How to estimate the value of the Galactic column density

2. Heasarc WebTools -> nh column density

http://heasarc.nasa.gov/cgi-bin/Tools/w3nh/w3nh.pl

HELP

N_H

Calculate the Total Galactic H I Column Density
(Powered by HEAsoft)

Object Name or Coordinates:
(e.g., Cyg X-1 or 101.295, -16.699 or 6 45 10.8, -16 41 58)

Name Resolver: GRB, SIMBAD, then NED

Coordinate System: Equatorial FK5

Equinox: 2000 (Only applies to Equatorial coordinates.)

Cone Radius: 1.00 degrees

Map: Both

Calculate nH Reset

R.A. and Dec. can be entered in ddd.ddd/[s]dd.ddd or hh mm ss.s/[s]dd mm ss.s .

APPENDIX

How to estimate the value of the Galactic column density

3. XSPEC -> enter the command nh and put the coordinates of the object