Principles of X-ray spectroscopy

Spectral resolution

- Gas counters: typically $E/\Delta E \sim 10$
- CCDs: typically 100
- Gratings/calorimeters: several thousand
- Gamma-ray spectroscopy uses still different instrumentation

The response matrix

- Combination of effective area and spectral resolution
- Determines, when a photon arrives at the detector, whether it will be detected, and in which channel
- Produced from calibration data, sometimes varies with time, depending on the satellite/detector type

How XSPEC works

- Input a data set and its associated response matrix
- Choose a spectral model
- XSPEC then folds the model through the response matrix to compute how many photons should be detected in each channel
- Fitting is then done by chi-squared minimization

Models

- Several classes of model components
  - Additive – e.g. power law or blackbody
  - Multiplicative – e.g. foreground absorption
  - Convolution – e.g. reflection
  - Pile-up – deals with pile-up in CCDs

Things you can plot

- Raw data
- Unfolded spectra
  - Attempt to infer, from model and response matrix, number of photons that came from each energy rather than number that came from each bin

Key pitfalls

- Local minima
  - Must compute error bars before fit meaningful
- Believing model fits
  - Remember that fitting can only falsify, not verify
- Believing parameter values
  - Be sure to consider systematic effects
  - Be sure not to trust extrapolations outside the fit range very much

XSPEC walkthrough

- We will fit a few spectra using XSPEC
- examples:
  - stellar mass black hole in high/soft state
  - Mkn 421 in a bright state