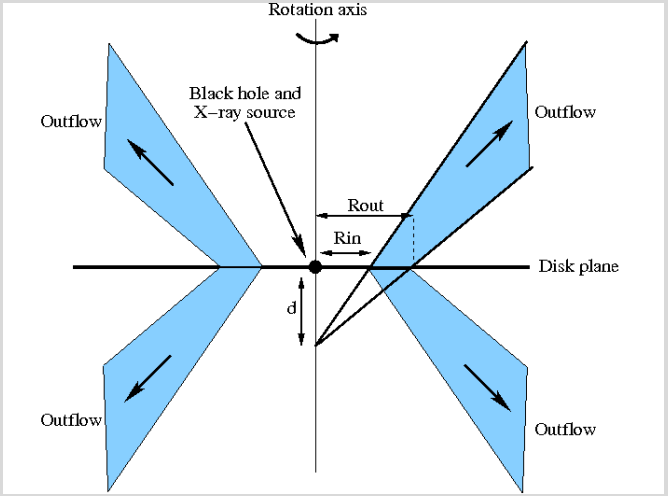
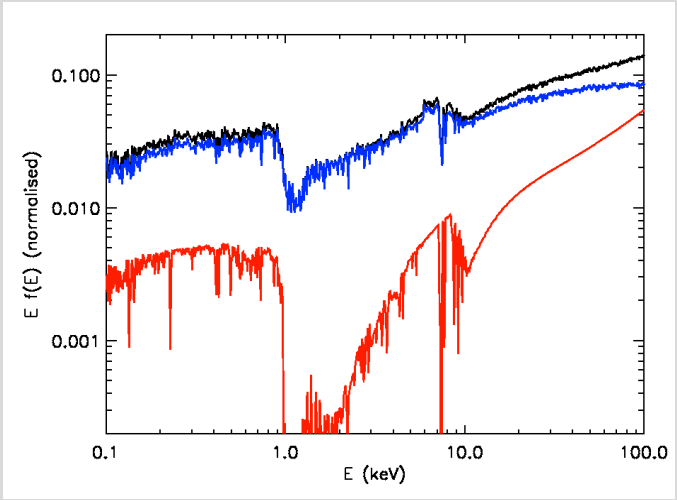
Modelling X-ray spectra for AGN outflows





Stuart Sim

Lance Miller (Oxford), Knox Long (STScI), Jane Turner (NASA/GSFC)

Max Planck Institute
for Astrophysics

Overview

- Motivation
- Method
- Example calculation
- Range of properties in a grid of models
- Conclusions and prospects

Motivation

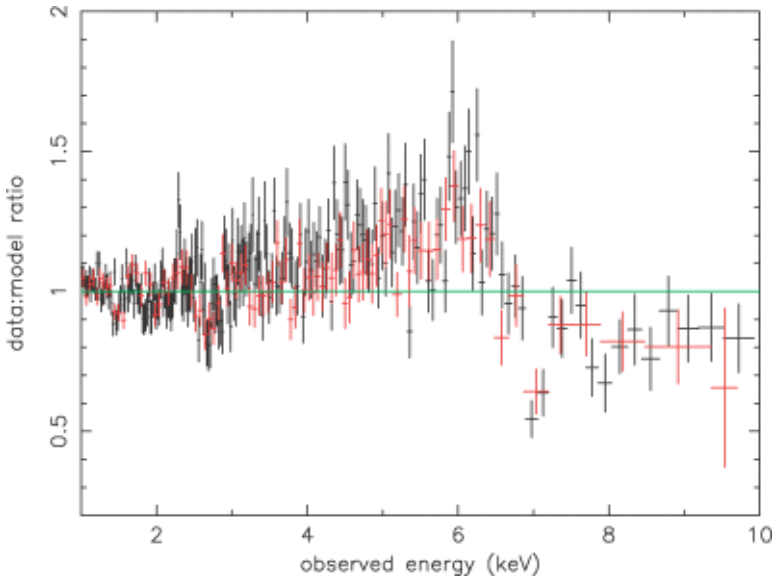
- **Very compelling observational evidence that some AGN host outflows**

Motivation

- **Very compelling observational evidence that some AGN host outflows**
- **Disk winds have been invoked to explain features in X-ray spectra**

Motivation

- **Very compelling observational evidence that some AGN host outflows**
- **Disk winds have been invoked to explain features in X-ray spectra E.g.**
  - **PG1211+143**



Pounds et al. (2003)

Motivation

- Very compelling observational evidence that some AGN host outflows
- Disk winds have been invoked to explain features in X-ray spectra E.g.
  - PG1211+143
  - Mrk 766 (Turner et al. 2007)
  - MCG 5-23-16 (Braito et al. 2007)
  - MCG 6-30-15 (e.g. Miller et al. 2007)
  - ....

Motivation

- Very compelling observational evidence that some AGN host outflows
- Disk winds have been invoked to explain features in X-ray spectra
- Hydrodynamical models (e.g. Proga & Kallman 04)
  - Leave signatures in X-ray spectra (Schurch et al. 09)

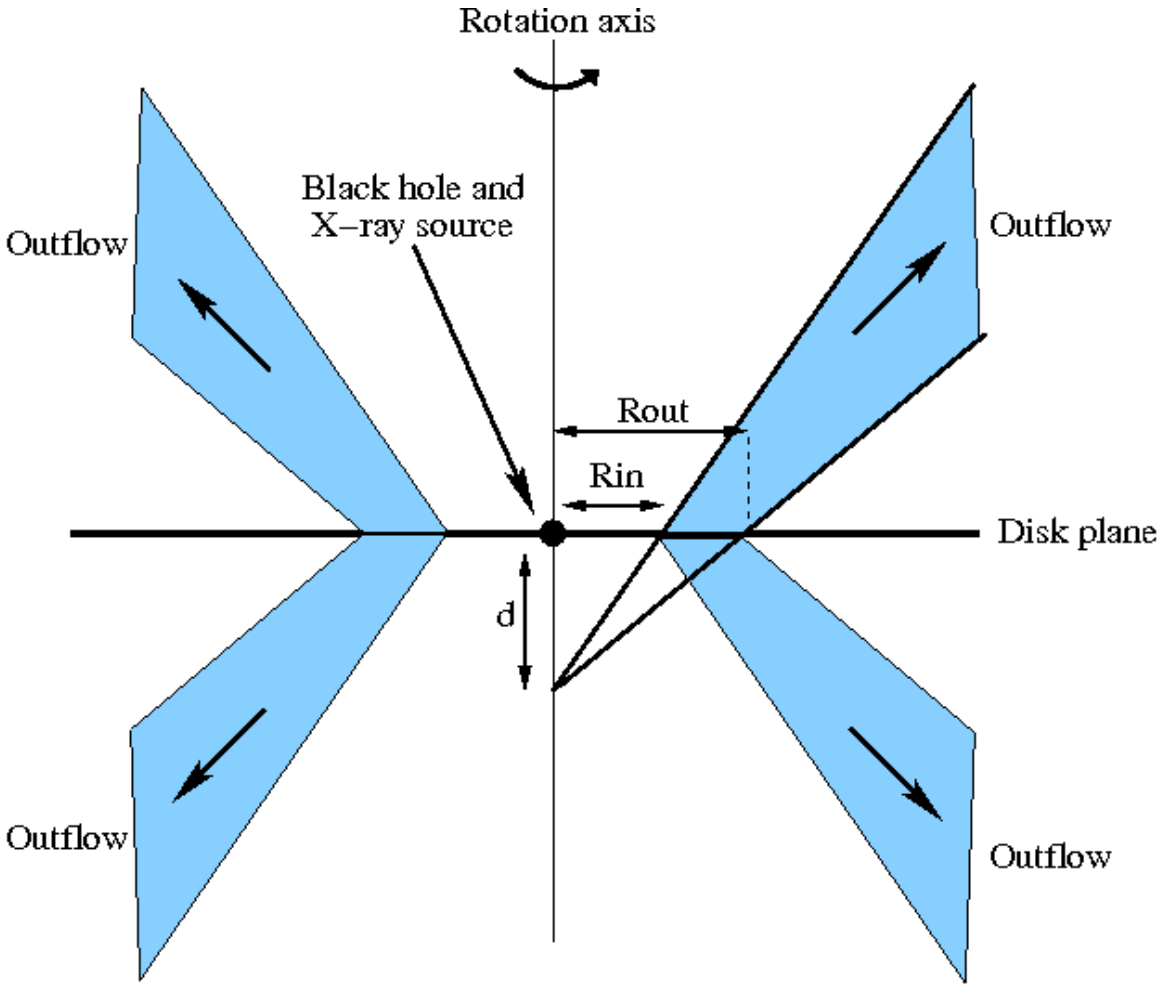
Motivation

- Very compelling observational evidence that some AGN host outflows
- Disk winds have been invoked to explain features in X-ray spectra
- Hydrodynamical models (e.g. Proga & Kallman 04)
  - Leave signatures in X-ray spectra (Schurch et al. 09)
- For proper comparison with data want theoretical disk wind spectra to test model

Method: parameterised model

- **Perform radiative transfer simulations for parameterised models**
  - **Realistic disk wind scenario requires non-spherical geometry**

Method: adopted geometry



Standard KWD disk wind (Knigge et al. 95)

Method: parameterised model

- **Perform radiative transfer simulations for parameterised models**
  - **Realistic disk wind scenario requires non-spherical geometry**
  - **Centrally concentrated power-law X-ray source**
  - **Include velocity law (outflow + rotation)**
  - **Smooth, stationary flow (described by $\dot{M}_{wind}$)**

Method: the code

- Monte Carlo method (Lucy 2002, 2003)
  - + Good for complex geometry/Compton scattering
  - + Parallelizable
  - – MC noise
- Solves for ionization balance
  - + Use MC estimators on computational grid
  - + Coupled to approximate thermal balance
- Obtain l.o.s. spectra
  - + Both transmitted and scattered/reprocessed
  - - Sobolev approximation for lines

Method: atomic processes

- **Atomic Physics**
  - + Bound-bound line
  - + Bound-free continua (and inner shell photo. abs)
  - + Compton scattering (cold electrons)
  - + Free-free
  - + Auger effect
  - + Electron collisions (ionization/excitation)
- **Data for K- and L-shell ions**
  - – C, N, O, Ne, Mg, Si, S, Ar, Ca, Fe, Ni
  - – High M-shell ions of Fe and Ni

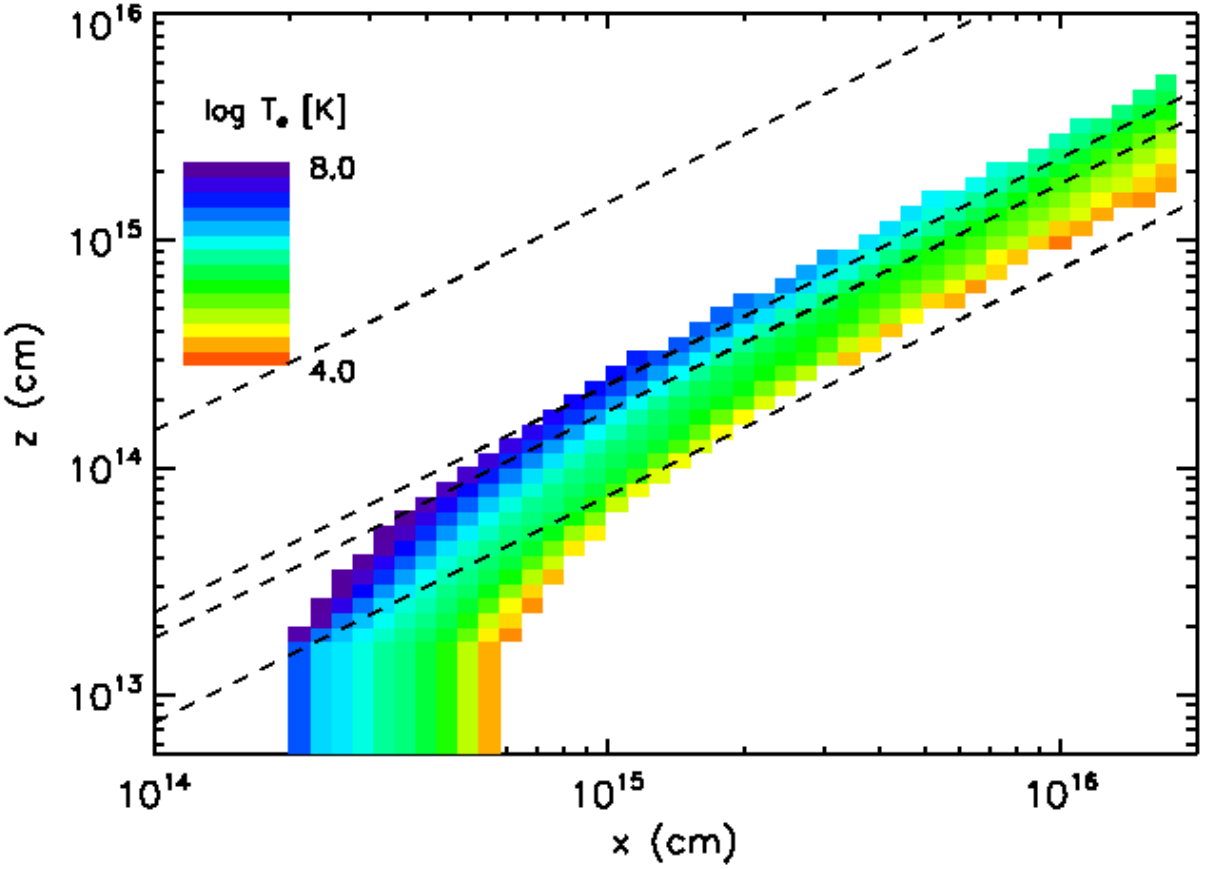
Example calculation

Example calculation

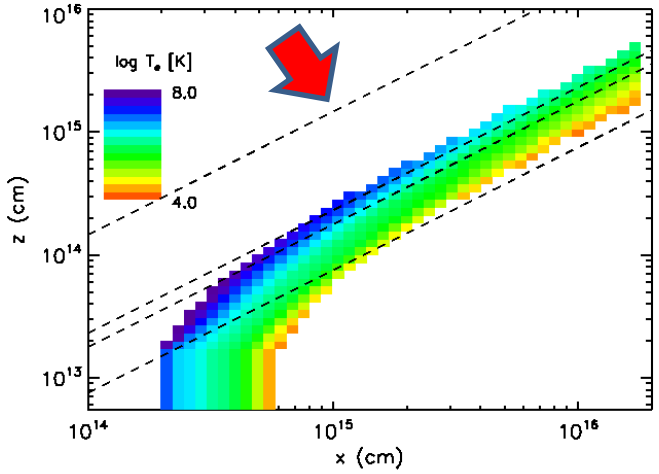
- KWD geometry
  - Launch between 100 and 300 R_g
  - Swept-back geometry (d=0.3)
  - Standard velocity-law parameters ($v_\infty = v_{esc}$)
- L_X (2-10keV) = 2.5×10^{43} ergs / s
- Photon index, $\Gamma = 1.8$
- $M_{BH} = 10^7\ M_\odot$
- $\dot{M}_{wind} = 1.2\ M_\odot$ / yr

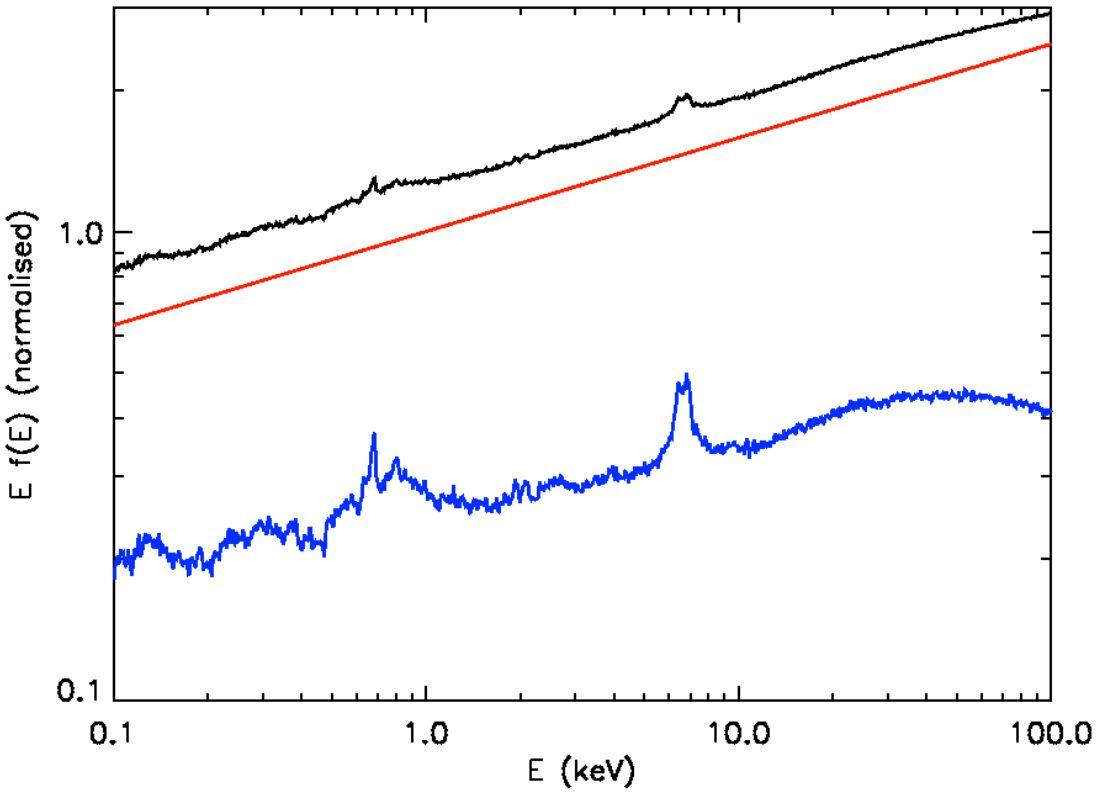
Example calculation

Kinetic Temperature Distribution

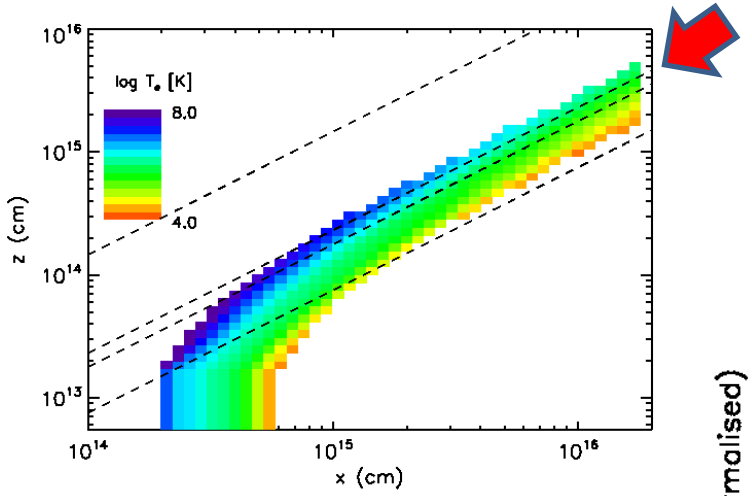


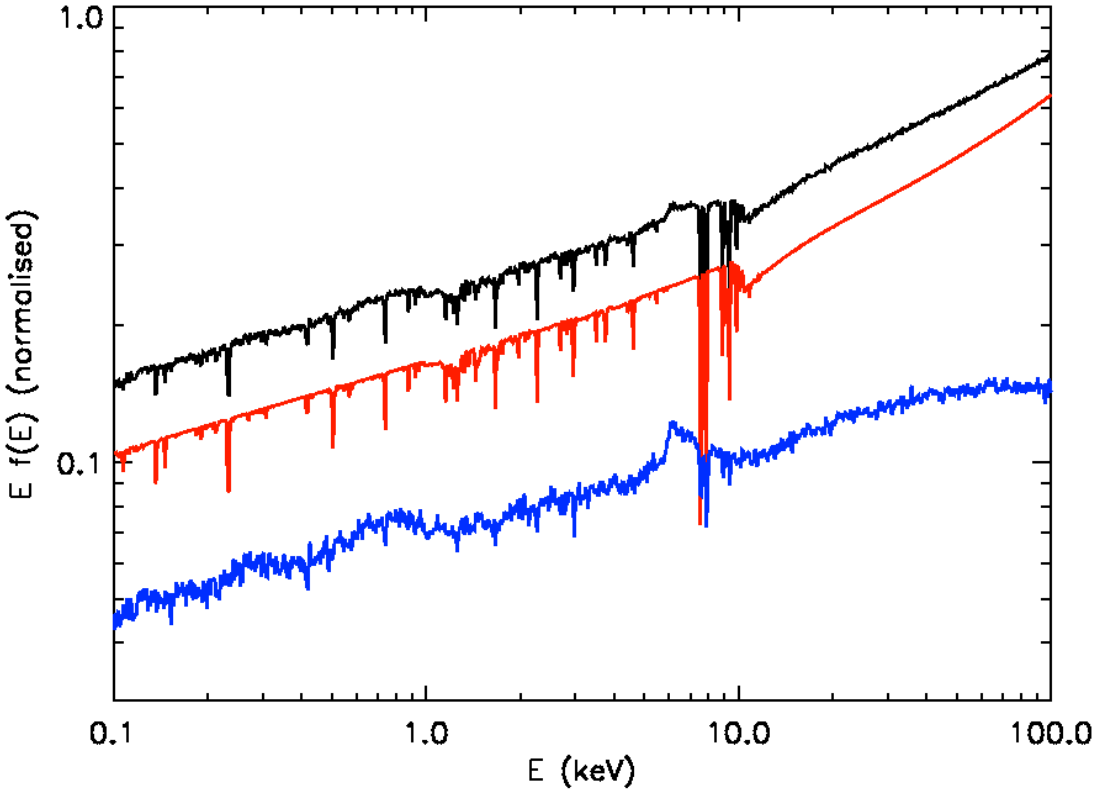
Example calculation



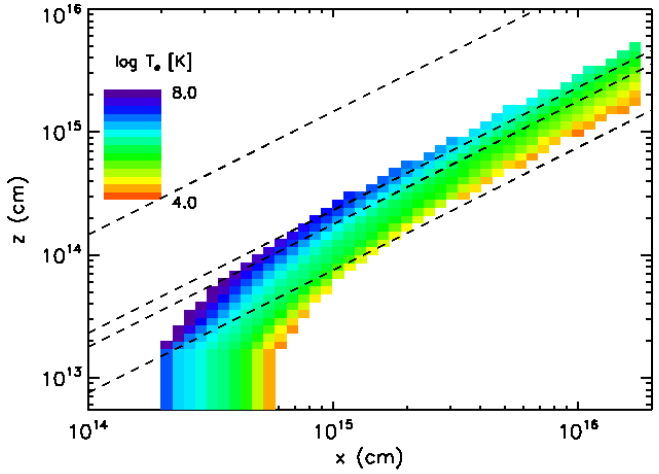


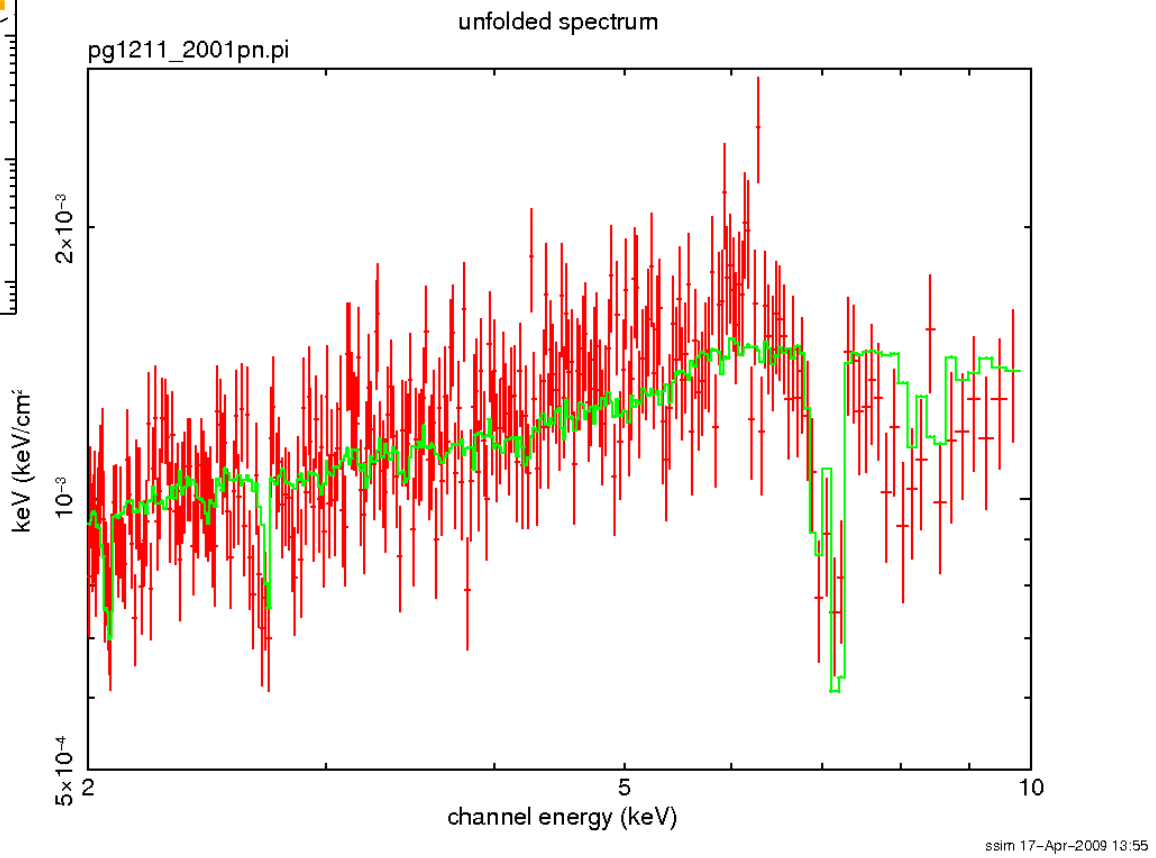
Example calculation



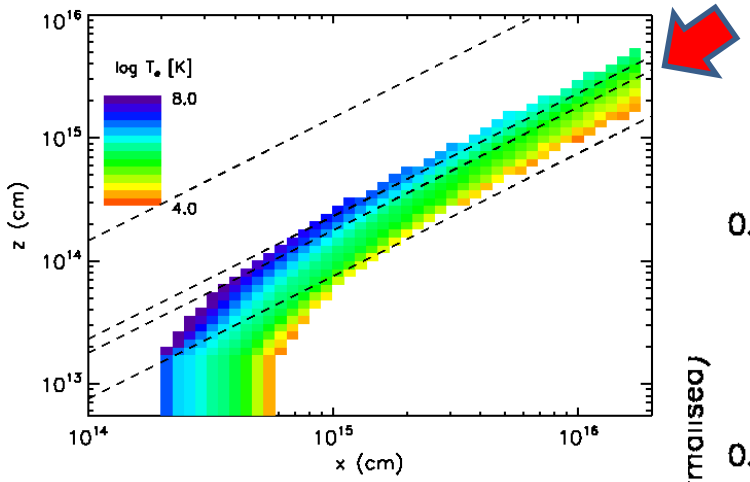


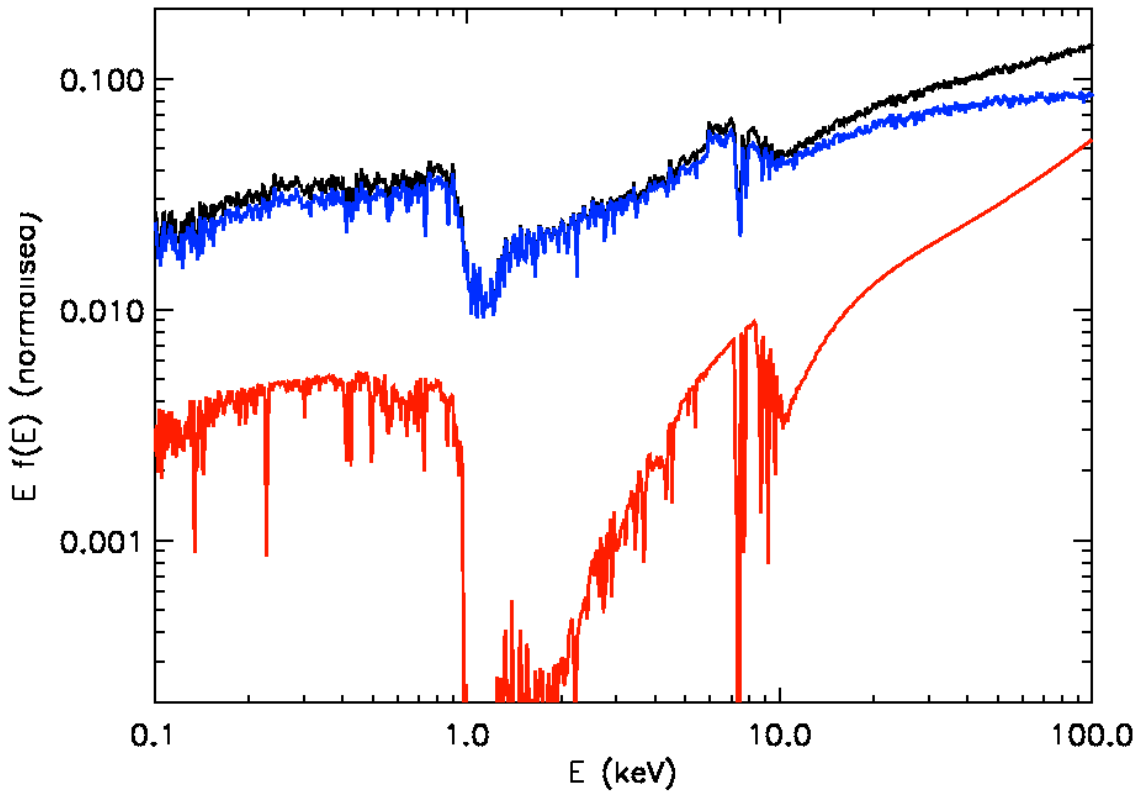
Example calculation



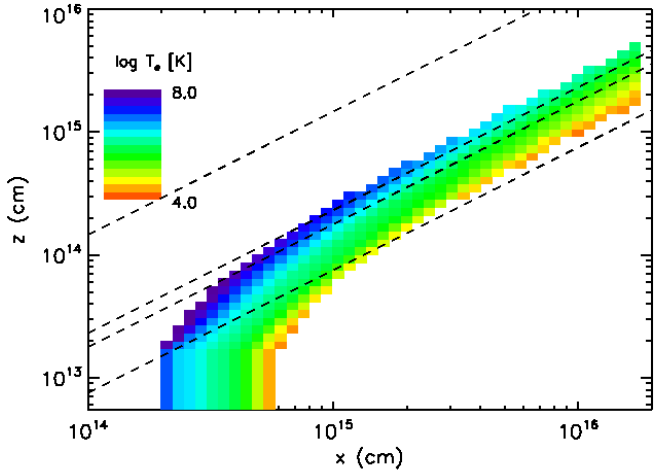


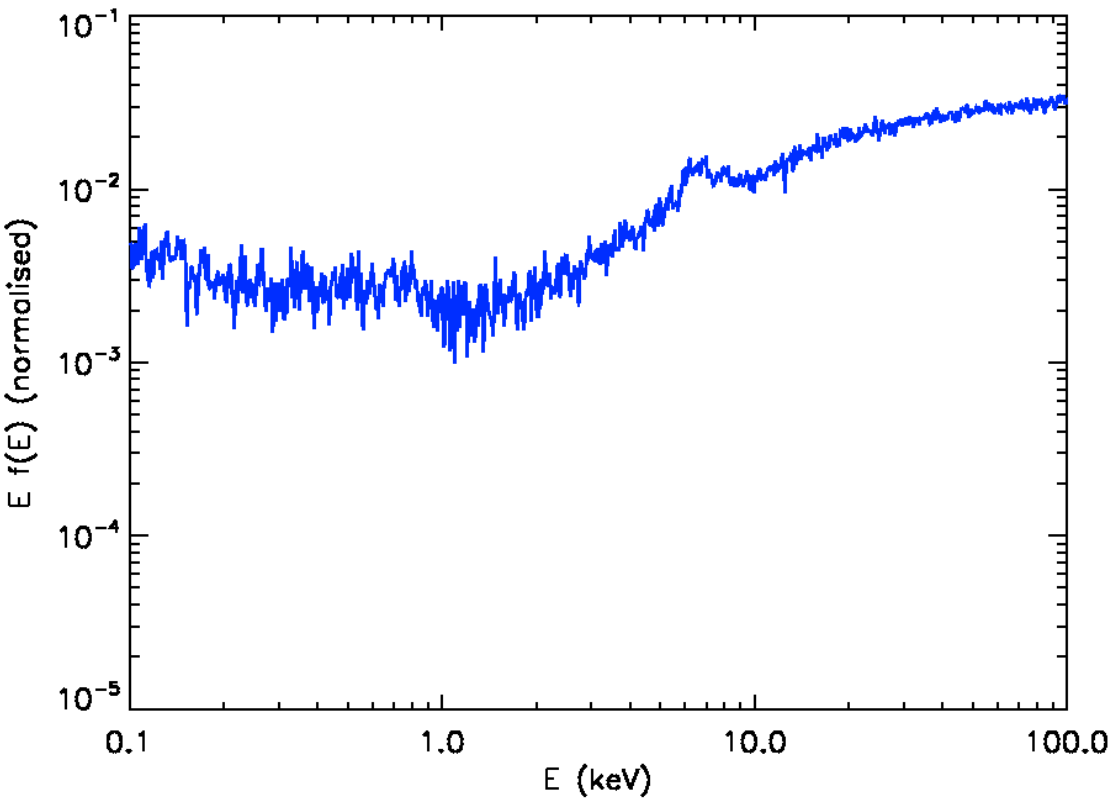
Example calculation





Example calculation



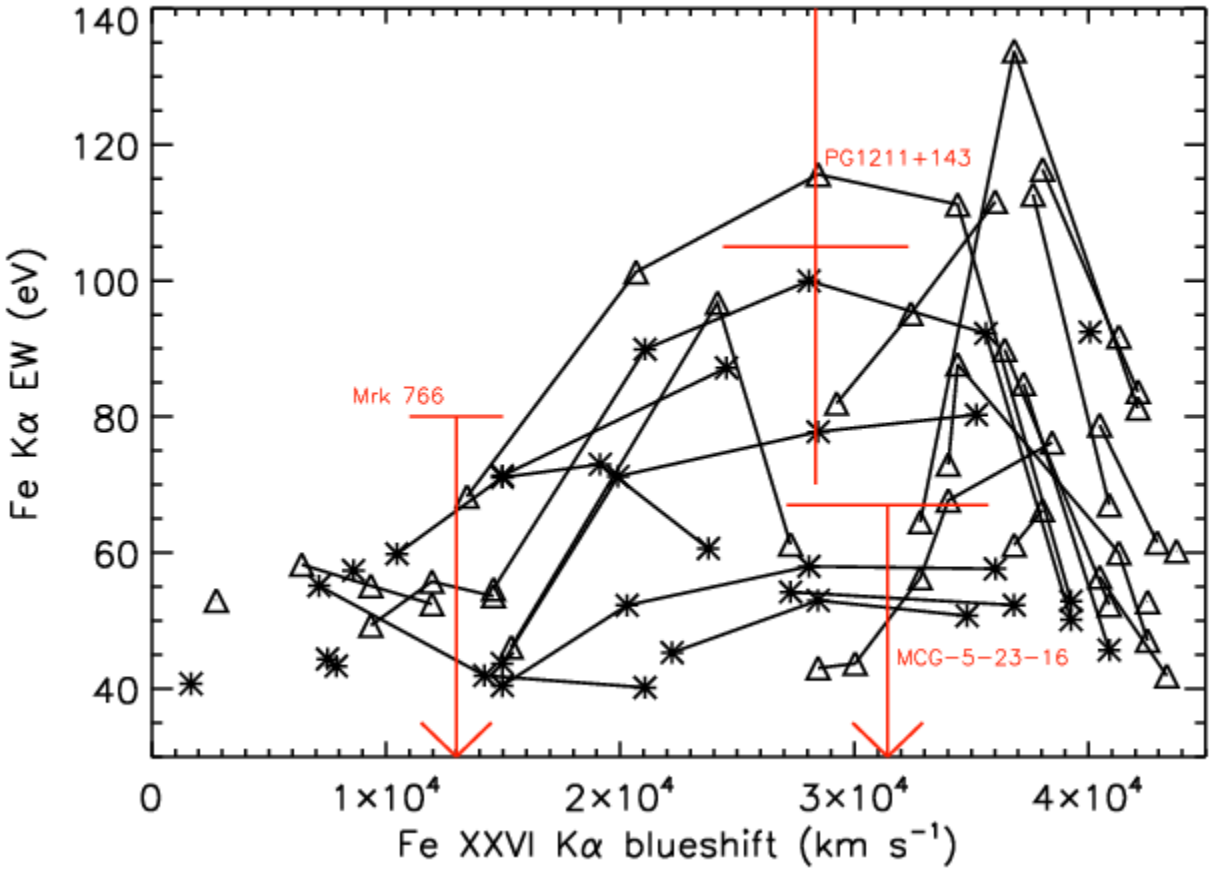


Grid of models

- **Preliminary grid of models (Sim et al. 2008)**
  - **Explored $\dot{M}_{wind}$, d, r_{in}, Γ**
  - **Limited to highest ionization states**
  - **No thermal balance calculation**

- **Focused on Fe K region**
  - **Primarily concerned with narrow absorption lines**

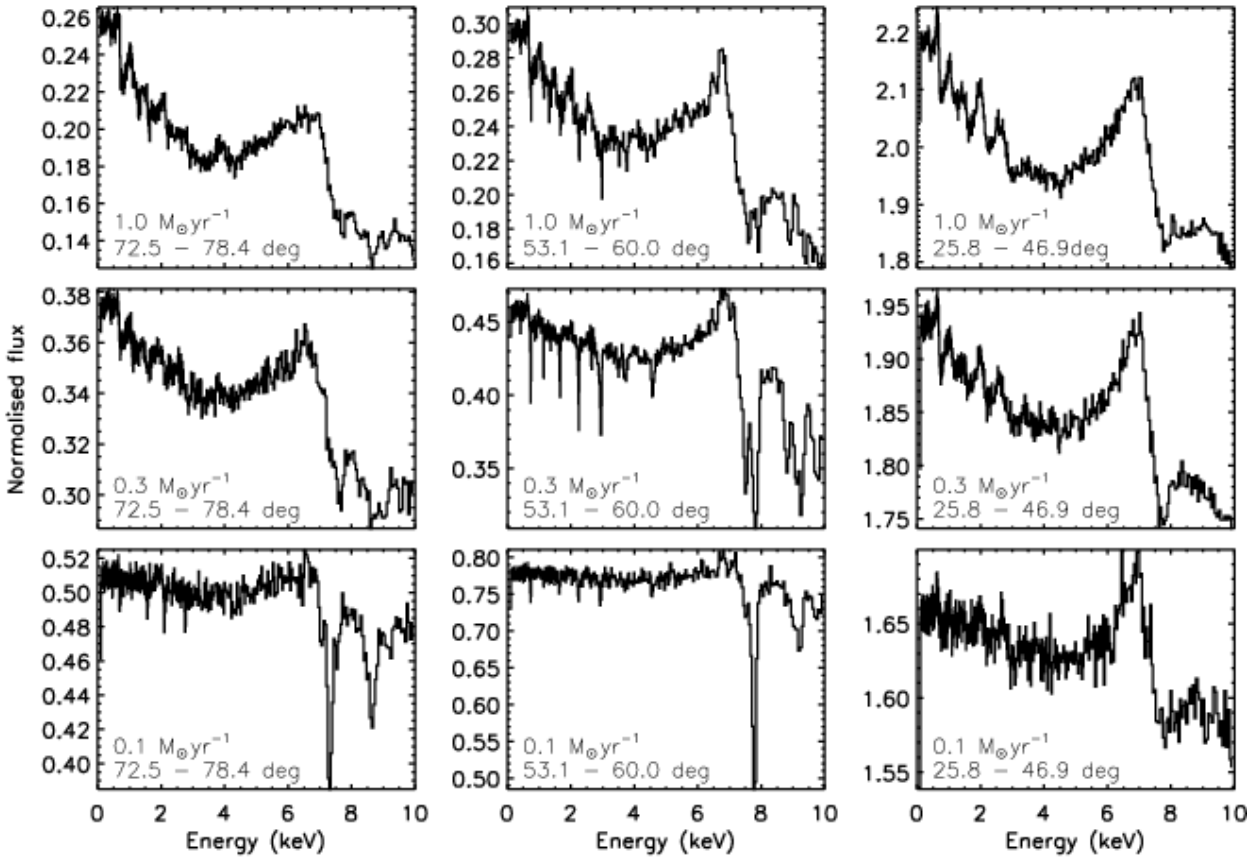
Grid of models



Models showed wide range of EWs and blueshifts

Pounds et al. 2003
Turner et al. 2007
Braito et al. 2007

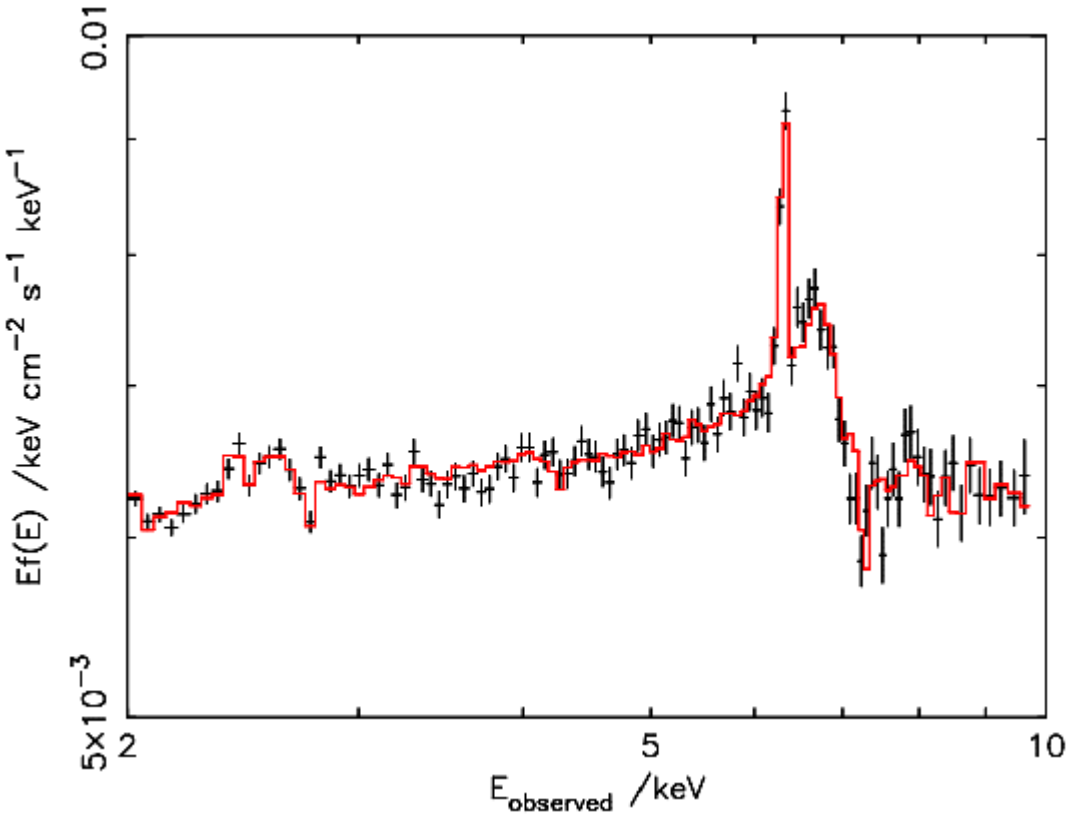
Grid of models



Also show a wide range of emission line shapes:

- **P Cygni profiles**
- **extended red wings**

Grid of models



Fit to Mrk 766

- **Mean XMM data**

Conclusions and Prospects

- Performing MC radiative transfer calculations to obtain X-ray spectra for AGN outflows
  - Both transmitted/reprocessed radiation
- Wide range of features possible
  - Narrow blue-shifted absorption lines
  - Emission features with red wings
- Plan to explore larger grids
  - Implement for XSPEC fitting