Reconstruction of the past activity of the centre of our Galaxy through X-Ray reflection spectra simulations.

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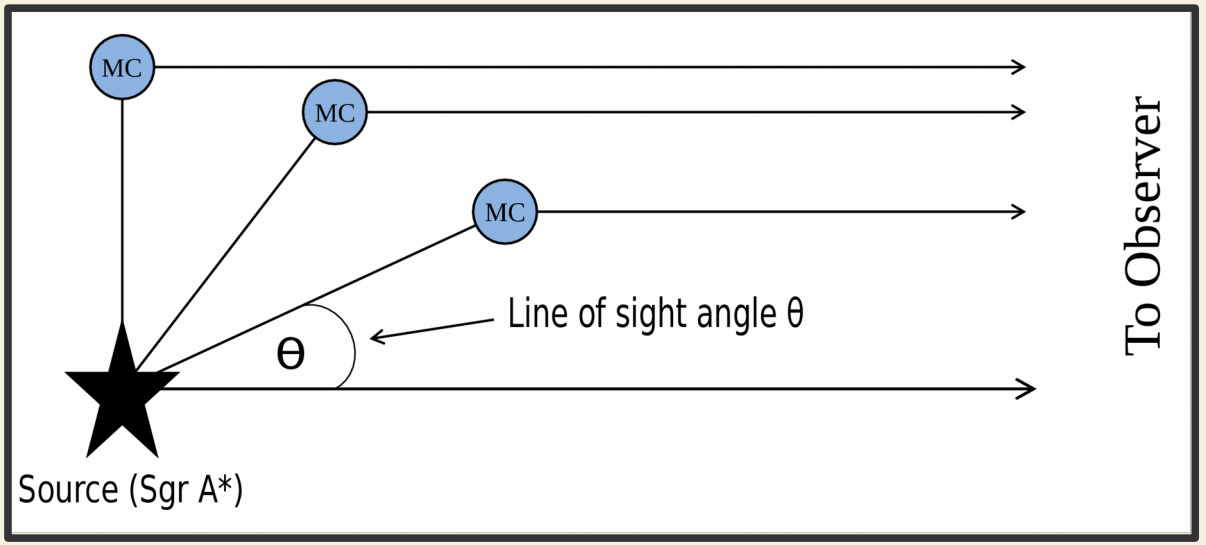
Introduction

- We wish to investigate the past behaviour of Sgr A*.
- Its current luminosity is on the order of 10^{33}-10^{34} erg/s, however it is generally accepted that it was more active in the recent past ~100-300 years.
- The largest molecular cloud nearby Sgr A*, Sgr B2 is a reflection nebula.
- To understand the timings, durations and intensities of any past Sgr A* activity, we need to know the position of the reflecting cloud relative to Sgr A*.
- We create a Monte Carlo code to simulate X-ray reflection from Molecular Clouds in order to answer this question.

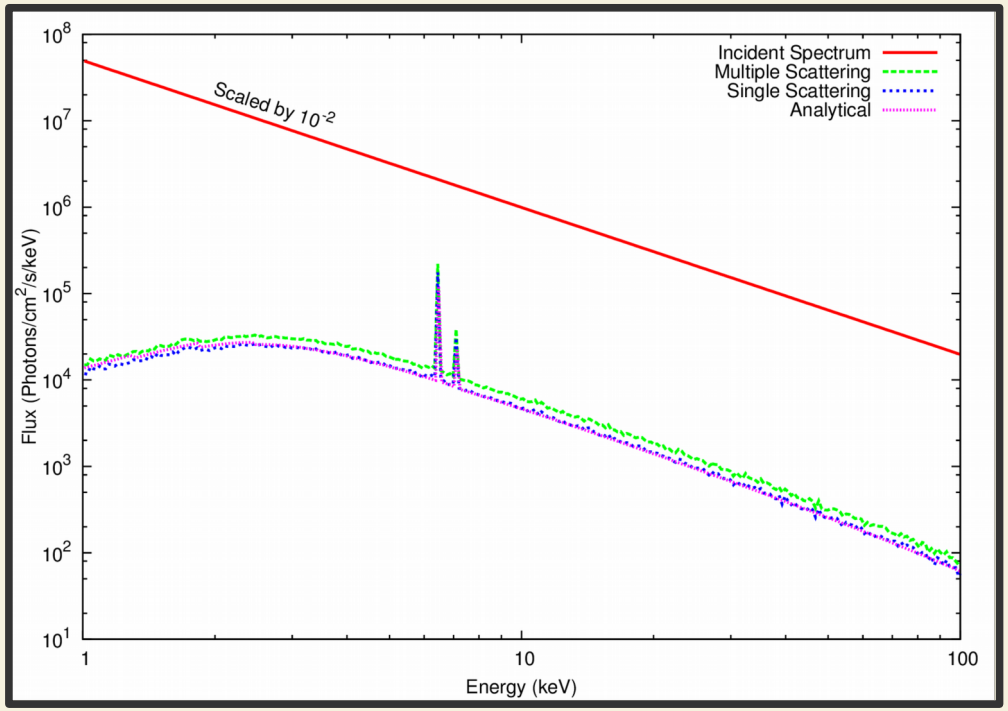
The Code

- The code takes several input parameters, importantly the N_H of the molecular cloud, the position of the cloud and the index of the input power law.
- Cloud is taken to be spherical, although other geometries are possible.
- Constant and non-constant densities.
- Inside the cloud, we model absorption and scattering with an artificial limit of 5 scatters per photon.
- Photons can re-emit at 6.4 keV k-alpha or 7.05 keV k-beta.



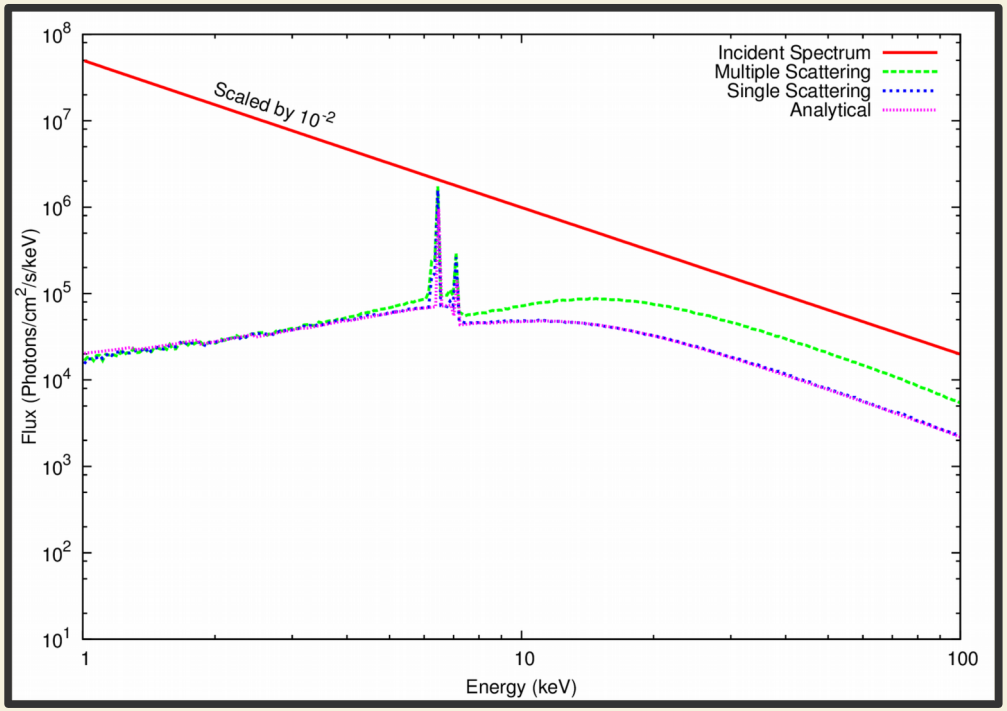
Analytical Comparison

- Spectra calculated analytically by colleagues in Paris, for spherical, single scattering, free electron case.
- Used to verify code output.
- Increasing N_H shows increasing effect of multiple scattering on iron line and continuum (Compton hump).



$N_H = 5\,x\,10^{22}\,cm^{-2}$

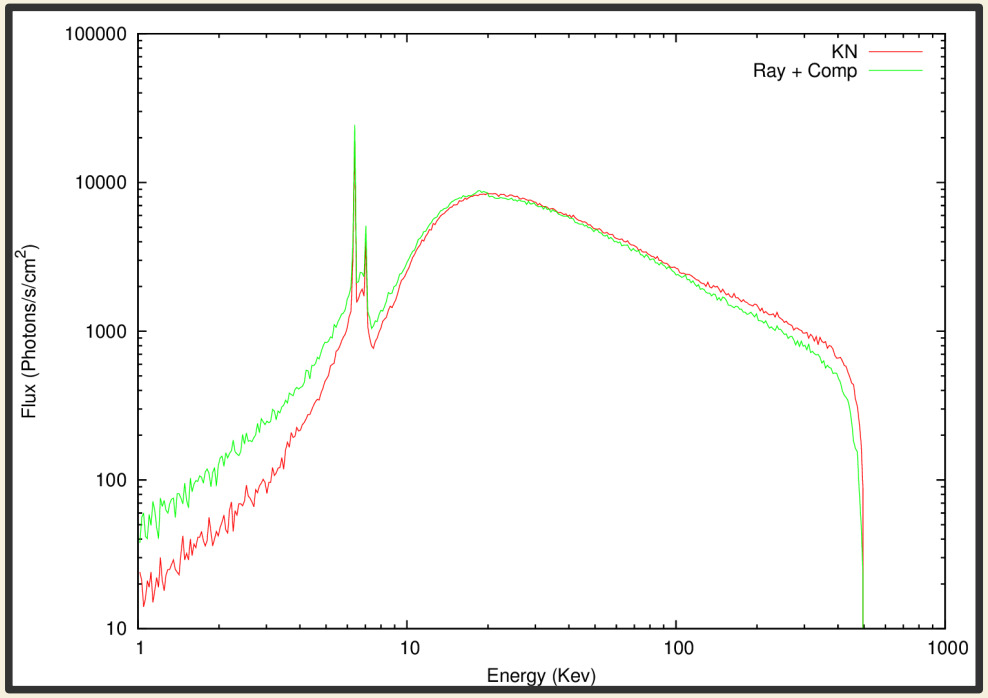
$\theta = 120$



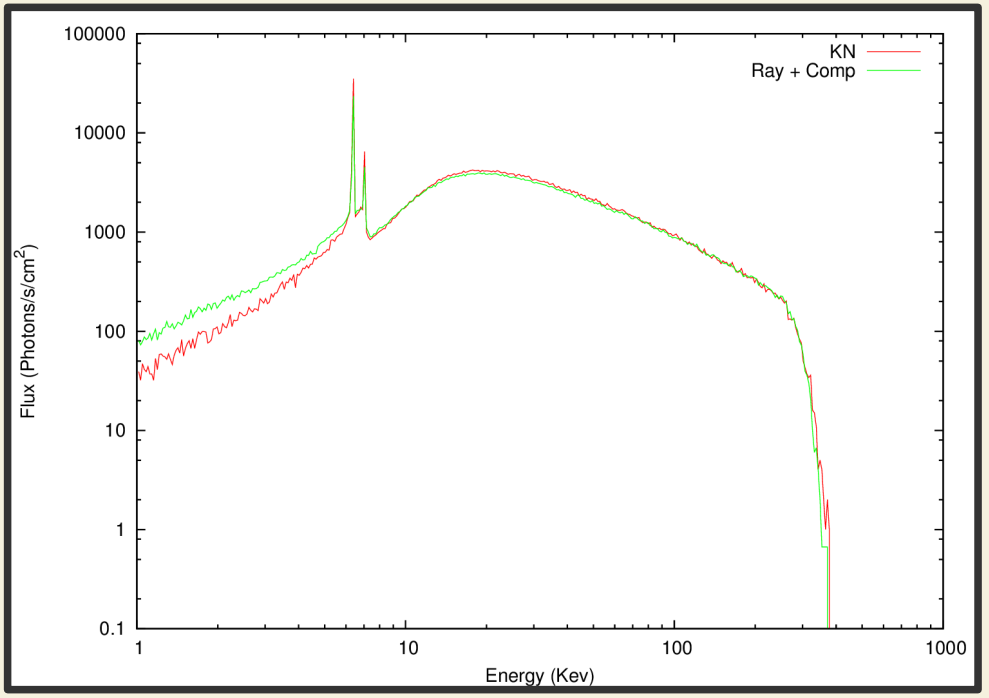
$N_H = 5\,x\,10^{24}\,cm^{-2}$

Binding effects

- Binding effects are not insignificant and cannot be ignored. We cannot use free electron approximation.
- Moleculer hydrogen, so cross section is factor of 2 larger *(Sunyaev et al, 1999)*.
- Rayleigh scattering is dominant over Compton scattering up to ~ 2 keV.
- Produces large flux increases in low energy regime through increased Rayleigh scattering.



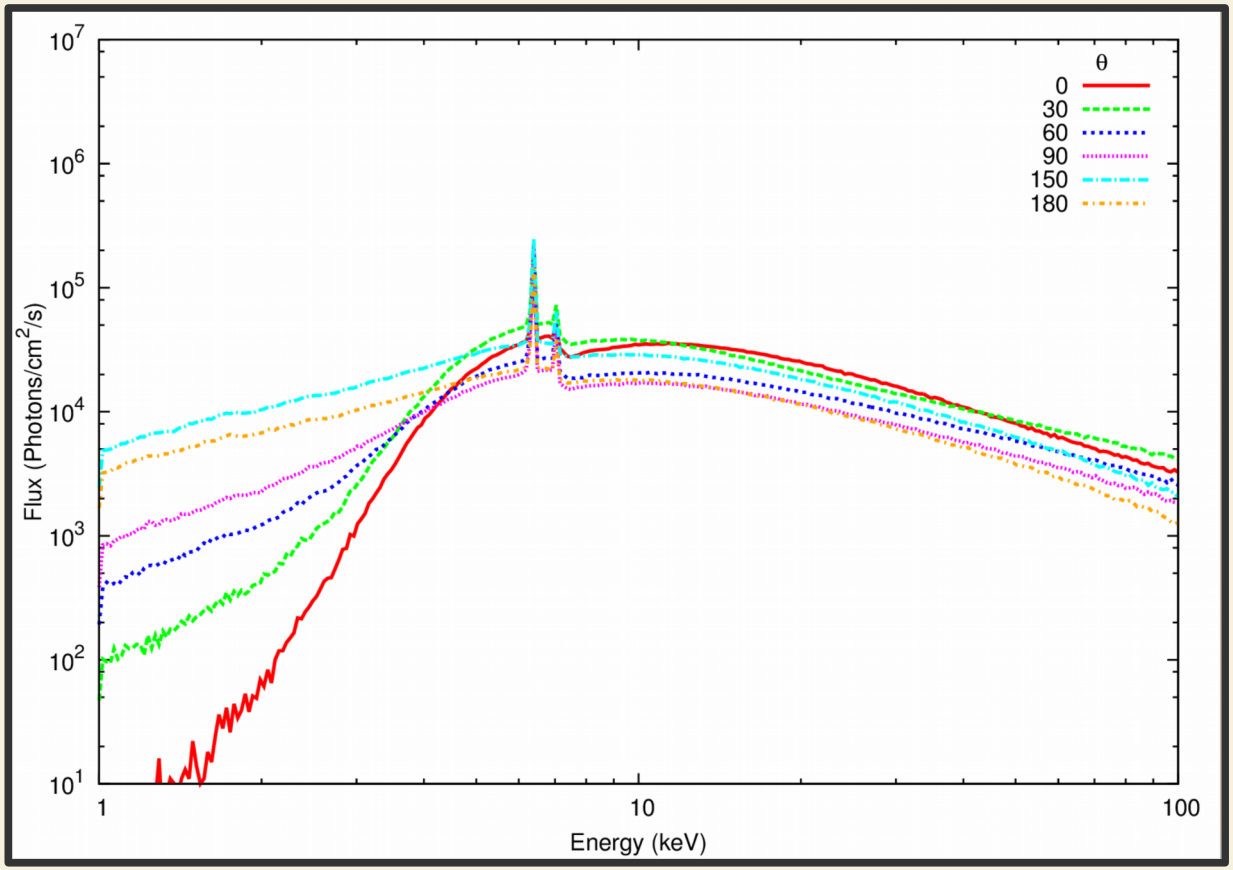
$\theta = 30$



$\theta = 150$

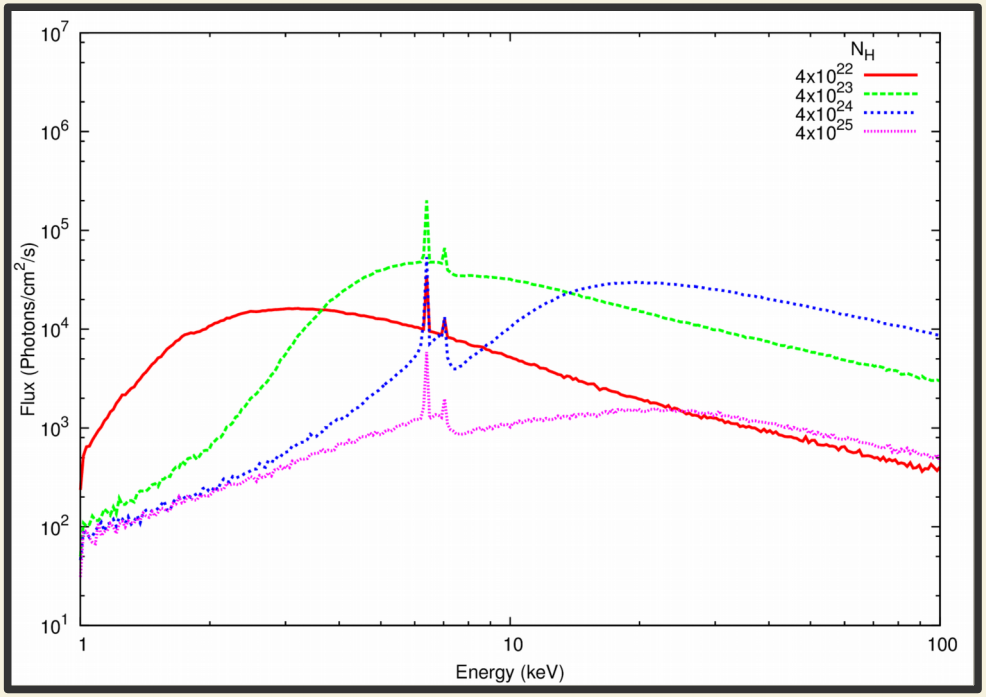
Angular Comparison

- Continuum shape converges as angle increases.
- Caused by the fact that most photons scatter off the surface of the cloud. At higher angles this mean a smaller chance to absorb after scatter.
- Continuum shape remains viable in differentiating angular position up to ~120 degrees.

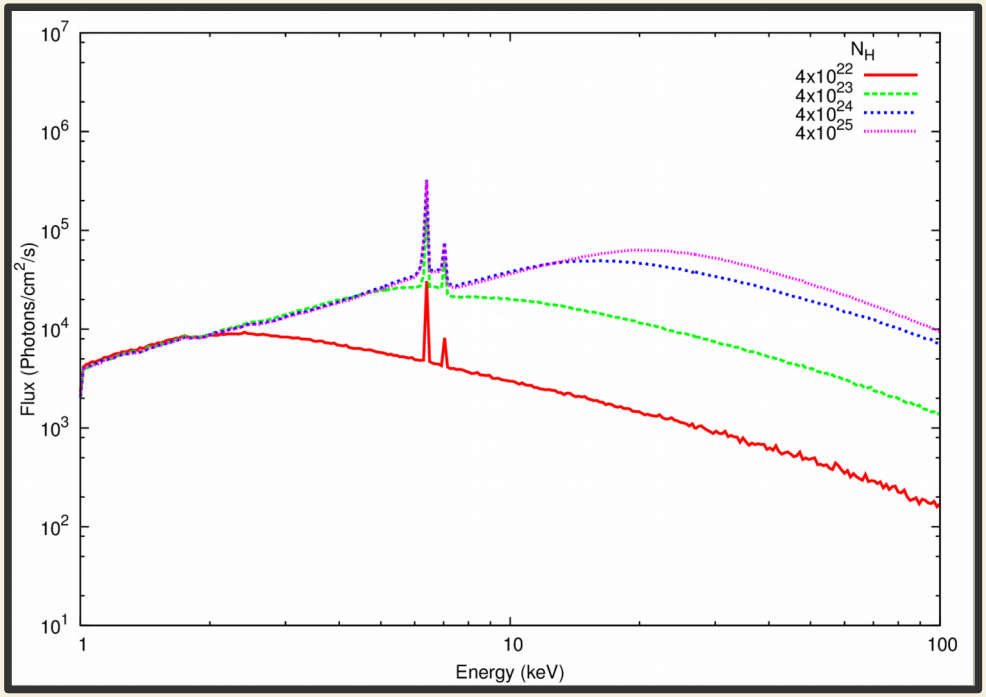


N_H Comparison

- Differences caused by increasing N_H.
- In low angle case N_H increase has large effect.
- Again the high angle converges due to surface scattering.



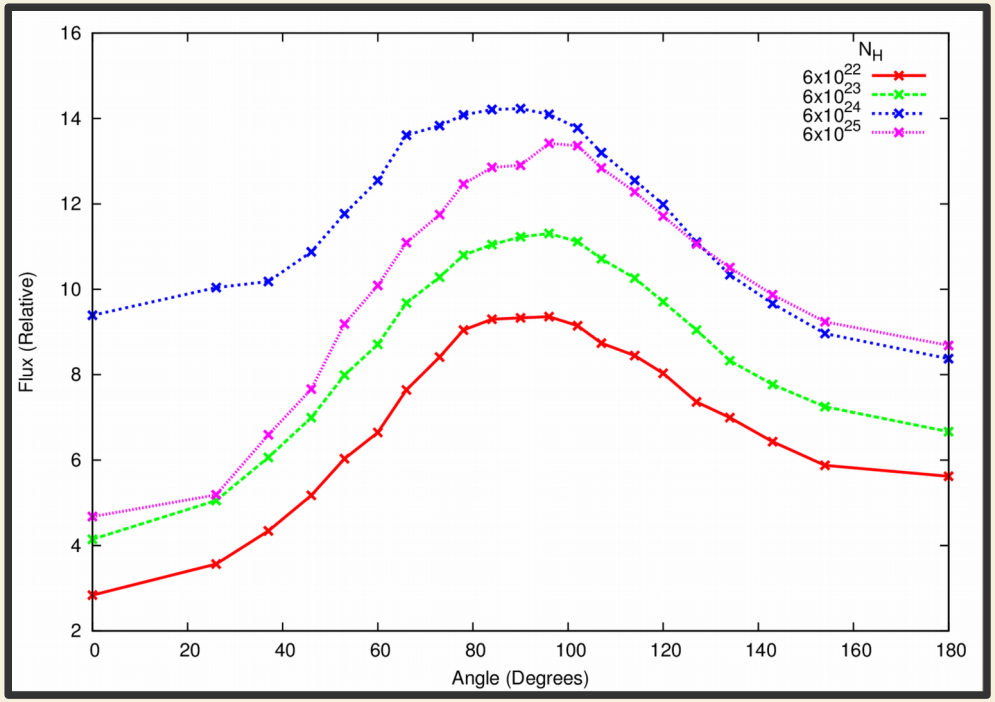
$\theta = 30$



$\theta = 140$

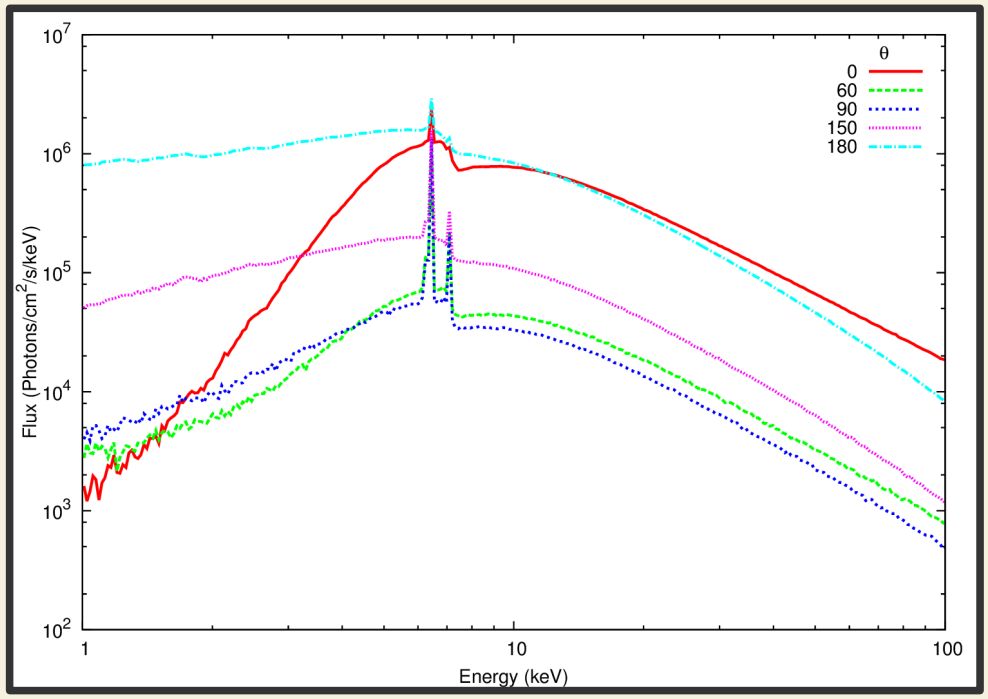
Iron Line

- Iron line can be used to determine angular position of cloud.
- Relative flux peaks at 90 degrees.
- Follows same general distribution regardless of N_H.

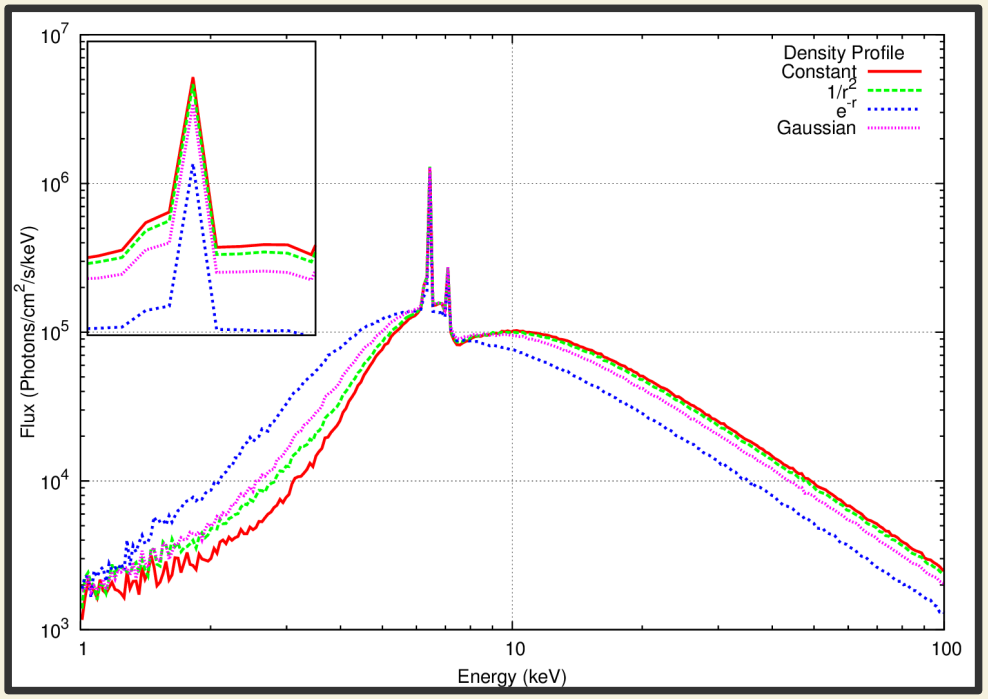


Relative flux -V- Angle

Non-Uniform Density



Gaussian density Profile



Density Profile Comparison

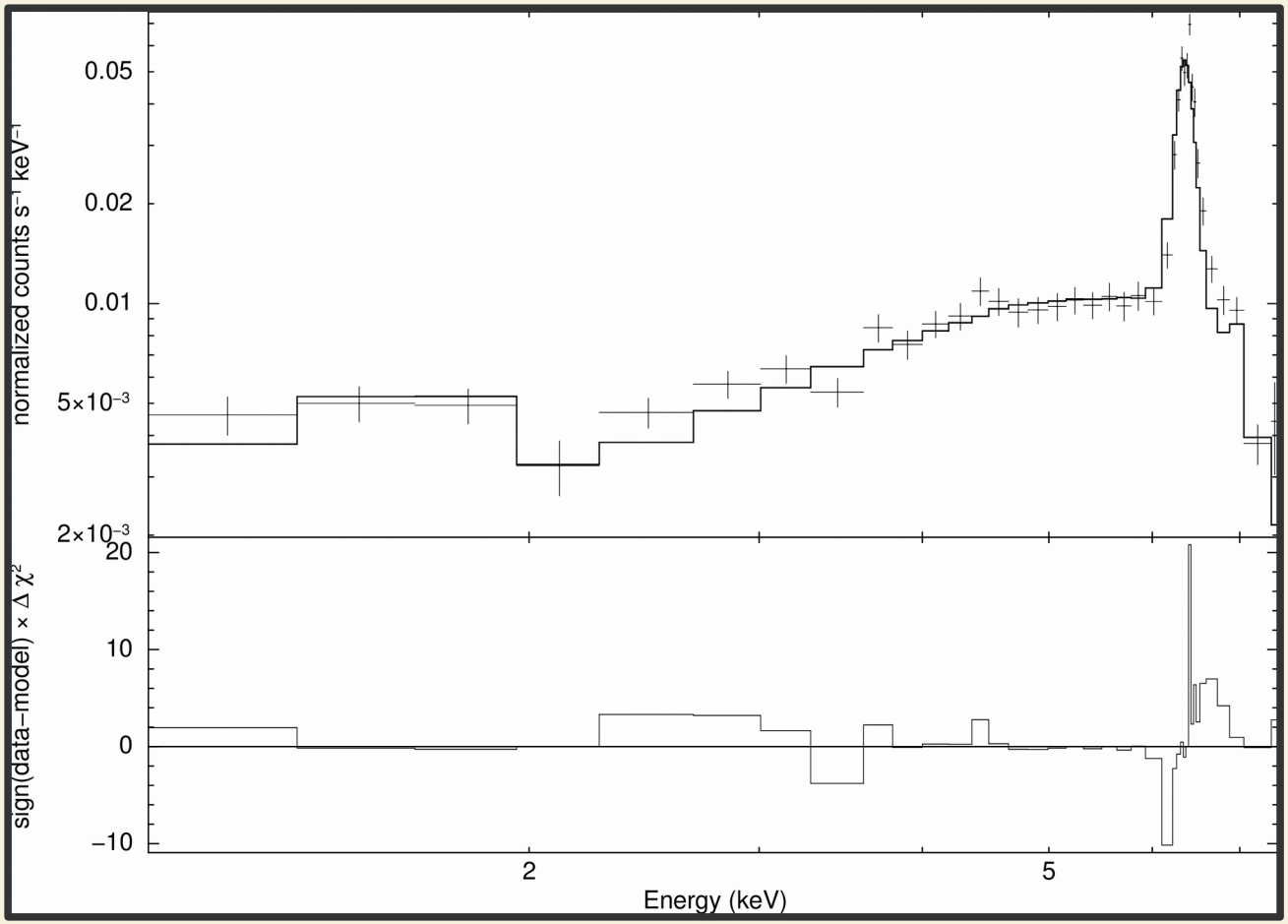
- Gaussian Profile angle changes follows pattern similar to that of constant density but with greater flux variability.
- When compared directly the various density profiles are broadly similar. With e^{-r} being the most different from constant density.

Table Model & Observations

- Created Xspec Table models for easy fitting to observations. Can be shared with community at large.
- We constrain the parameters of Sgr B2 using observations from Chandra and XMM-Newton, Integral, 2000 & 2004 respectively.
- We find that the uniform density model fits all observations well.
- Gaussian profile also gives a good fit, while other density profiles give poor fits.
- The XMM and Integral data was fit simultaneously.
- The 2004 observations are dimmer than the 2000 Chandra observations, as a result the warm plasma contribution is more prominent, thus we also fit the data with a double apec mode.

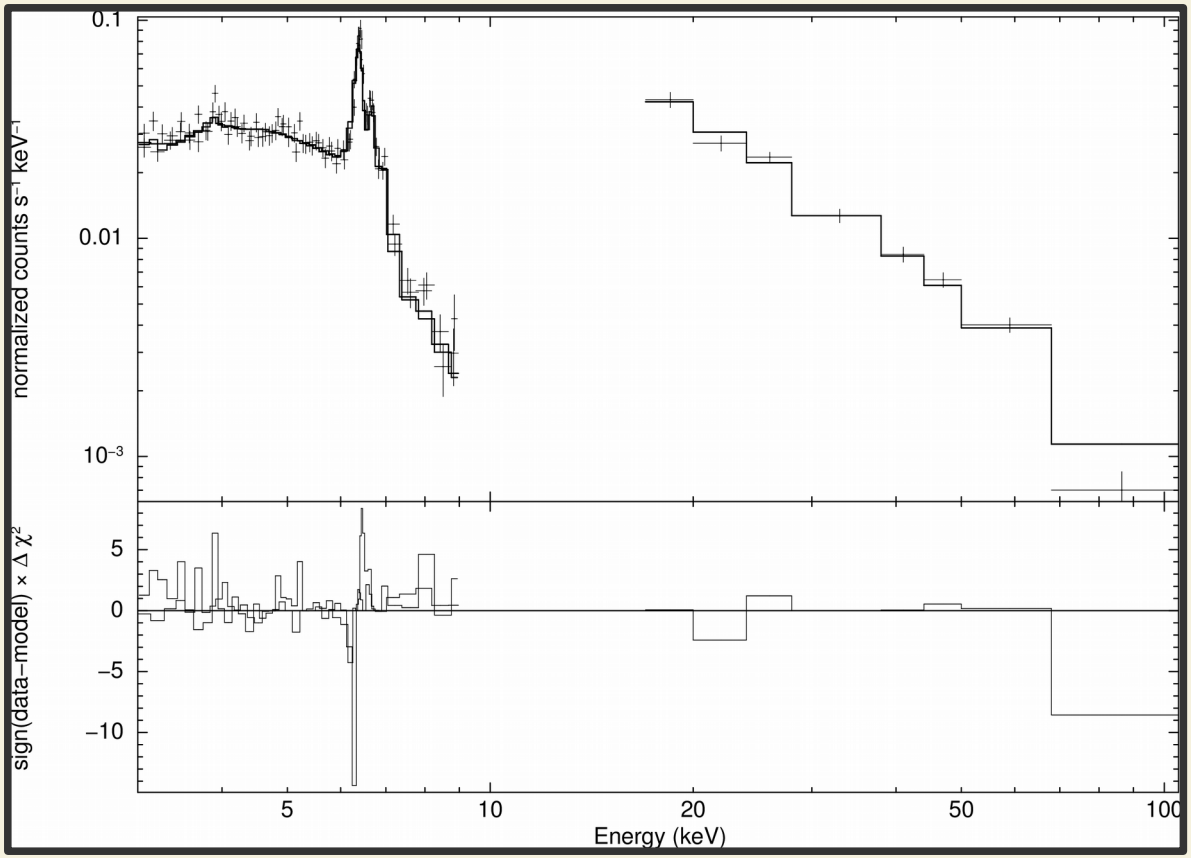
Results

Observation	θ	$N_H(10^{24} cm^{-2})$	α	$\chi^2(dof)$
Chandra	60^{+11}_{-8}	$2.6^{+0.9}_{-0.5}$	$1.8^{+0.1}_{-0.2}$	255(221)



Results

Observation	θ	α	N_H $(10^{24}\,cm^{-2})$	$wabs\,N_H$ $(10^{22}\,cm^{-2})$	kT 1 & 2	$\chi^2(dof)$
XMM+Integral	70^{+9}_{-10}	$2.3^{+0.1}_{-0.3}$	$1.9^{+0.4}_{-0.4}$	14^{+3}_{-3}	1 & 6.5	588(571)



Results

Observation	$Flux_{2-10}$ $\left(10^{-12} erg/cm^2/s\right)$	L_{2-10} $10^{39}\left(erg/s\right)$
Chandra	$3.9372^{+0.4}_{-2.3}$	$9.01^{+0.8}_{-4.22}$
XMM+Integral	$9.0236^{+0.6}_{-1.9}$	$6.8^{+1.5}_{-1.3}$

- Current Sgr A* luminosity on order of 10^{34} erg/s.
- Luminosity of incident light to Sgr B2 found to be on order of 10^{39} erg/s.
- Angle found to be 66^{+13}_{-15}
- Sgr B2 is positioned ~66 degrees off the line of sight between Earth and Sgr A*.

Conclusions

- Monte Carlo code to simulate X-ray reflection spectra.
- Angular position has noticeable effect on reflected spectra. Relative position of molecular clouds is important.
- Created Xspec table models for fitting to molecular clouds.
- Fit to observations of Sgr B2.
- Relative angular position of Sgr B2 is 66^{+13}_{-15} degrees.
- Angle of 66 degrees, puts Sgr B2 at a distance of 115 pc from Sgr A* assuming a projected distance of 100 pc.

Thank you.