Variability of Sgr A*, Monte Carlo code for X-Ray Emission

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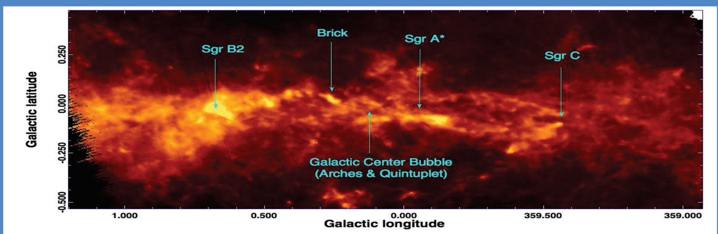
Introduction

In the centre of our galaxy lies a super-massive black hole, identified with the bright radio source Sagittarius A* (Sgr A*). This black hole has an estimated mass of around 4 million solar masses, however excluding the radio, Sgr A* is quite dim. The aim of this project is to investigate the past behaviour of Sgr A*, investigating whether the current dim state is normal or as is suspected Sgr A* undergoes periods of far higher activity. We begin this investigation with the development of a Monte Carlo simulation code to interpret the X-ray emission from the Molecular Clouds in the galactic Centre region, believed to be associated with a previous high activity period(flare) of the black hole.

One such cloud, Sgr B2, is thought to be located ~130 pc in front of Sgr A* relative to us (Reid et al 2009). Any flaring must have ended ~100 years ago, and the Fe Ka emission from another nearby cloud, G0.11- 0.11, suggests it is being irradiated by the same flare or phase of the same flare as that which is illuminating Sgr B2 (Ponti et al 2012). Knowledge of line of sight position of both clouds and further observations will allow this hypothesis to be tested.



The Galactic Centre, showing the source Sgr A*, the cloud Sgr B2 and other Molecular Clouds.

Methodology

It now becomes important to test this model of the X-ray emission with recently acquired data and theoretical modelling. In 2001 the Chandra satellite along with XMM-Newton performed a long exposure observation of the entire region of about 700 kilo-seconds. This data is available now for interpretation. The primary aim is to determine the column densities and line of sight positions of the various molecular clouds in the Galactic Centre.

The code follows the life of the photon from beginning to end all in a fully realised 3d environment. The photon begins at the source and heads toward the cloud with an isotropic distribution, then taken into account is the absorption, iron line emission and scattering on electrons.

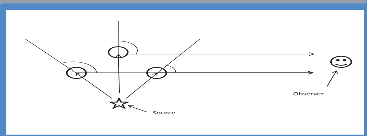
In order to find out the angular position of the molecular cloud, the code will simulate a molecular cloud at a given distance from the X-ray generating source. The position of the cloud in the simulation can be rotated around the source relative to the observer.

The scattering cross section is sourced directly from the Klein-Nishina formula. While the absorption cross section is taken from the NIST XCOM database allowing for the direct setting & altering of elemental abundances. The geometry of the cloud can also be modified.

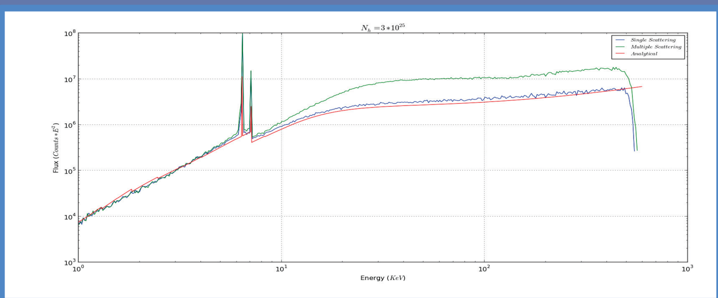
The code then takes the following input parameters:

- Shape of the cloud
- Position of the cloud
- Density Profile of the cloud
- Metallicity
- Photon Index

And produces an output reflected spectrum.



Output spectra



In this graph we see the output of the code, in both single & multiple scattering modes. This is compared to an analytically calculated spectra using similar input parameters. The analytical calculation is only valid for a spherical cloud of constant density, and will only consider single scattering. When the Monte Carlo code follows similar parameters in single scatter mode it follows the analytical case quite nicely. However, when multiple scattering is turned on, there is a noticeable increase in iron line and higher energy flux.

References

Ponti et al (2012). arXiv:1210.3034v1
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Terrier et al.(2010). Terrier, R., Ponti, G., B´elanger, G., et al. 2010, ApJ, 719, 143
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Hi-GAL Project.

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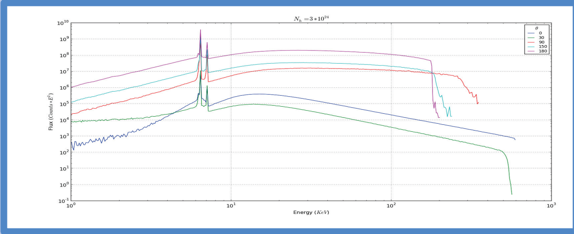
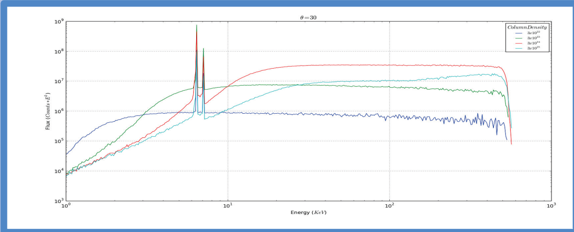
Changing the Parameters



Changing Angle:

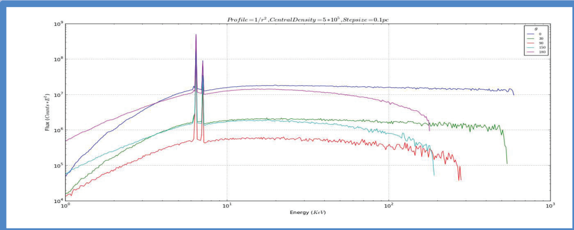
- Marked Flux changes
- Changing high energy cut off
- Increased low energy absorption with smaller angles



Changing Column Density:

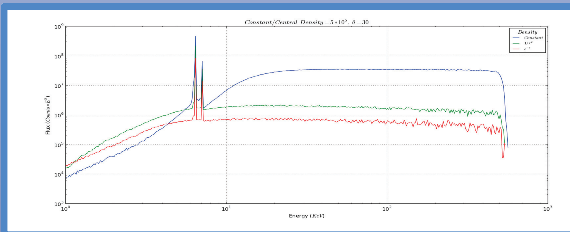
- Marked Flux changes
- Fe Line flux increases up to an nH ~6e23, then begins decreasing.
- Increased low energy absorption with higher densities

Variable density profiles



Changing angle with variable density profile:

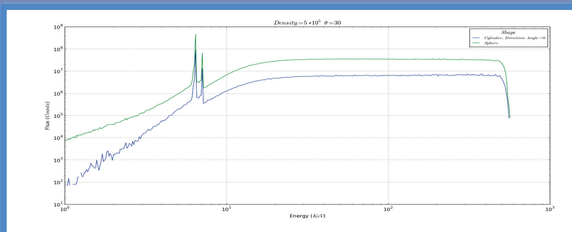
- Marked Flux changes
- Larger low energy absorption than constant density
- Lowering of cut off point when compared to constant density



Comparing Density profiles:

- Lower overall flux
- Similar cut off points
- Slightly different absorption profiles in low energy

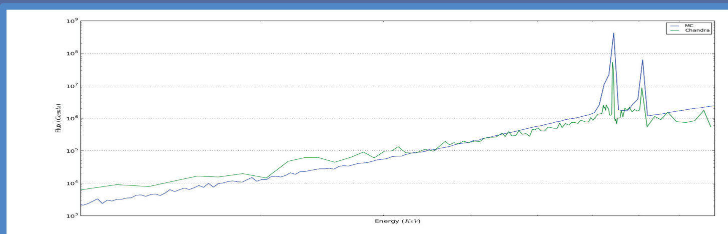
Changing Cloud shape



Comparing spherical and cylindrical clouds of constant density:

- Marked Flux changes
- Increased low energy absorption in cylindrical case (Dependant on cylinder orientation)

Real Data



The Green Line represents a real spectra of the Molecular Cloud Sgr B2 taken by Chandra in 2000, the blue line is an output spectra from the Monte Carlo code with the following input parameters. Alpha= 1.59, Cloud Radius = 2 pc, Density = 2e5(nh = 1.2e24), Line of sight angle = 78 degrees from the Source – Observer line. They agree reasonably well.

Conclusions

Created a Monte Carlo code to simulate X-Ray reflection spectra from Molecular clouds.
Can change many input parameters of the code.
Code fits real data from Sgr B2.
Can be used to determine line of sight positions of Galactic Centre Molecular Clouds, as well as other useful properties of the clouds.