Chapter 5

Summary and Conclusions

5.1 Summary of AGN Study

Understanding the physical conditions of the emitting region and surrounding environments of AGNs is a challenging task. In AGN, emission takes place through mass accretion on to the central engine i.e., the supermassive black hole. The rapid, high amplitude variability is often observed in the X-ray band indicates that this flux must be emitted by a very compact region. This definitely suggests that X-ray band is an important tool to probe the innermost region of AGNs, close to the central engine. The study of AGNs in this band also provides important insights about the evolution of the AGN luminosity function. AGNs show variability in all wavelength but extreme variability is seen in the X-ray band. Variability study of long observations of the most extreme and highly variable sources provide opportunity to understand the physical conditions of AGNs.

I have carried out a systematic study of two highly variable AGNs observed by *XMM-Newton* satellite. This observatory with its broad X-ray bandpass, large effective area and high spatial resolution provides a better understanding of the Physics of X-ray sources. In order to understand the underlying AGN phenomenon, I have considered two NLS1 galaxies- Mrk 335 and Ark 564 in the X-ray regime. I have used *XMM-Newton* archival data (16 observations) of these two AGNs.

The light curves for each observation of the two AGNs reveal that for nearly all the observations there is a significant flux variation in timescales of $\sim 10^4$ s. I found Mrk 335 at low flux state during the 2007 observation (ID0510010701). I have done a comprehensive flux resolved spectral analysis of the two sources to investigate the variation of the photon index. The mean and the flux resolved spectra is fitted by an empirical model consisting of two Comptonization components, one for the low energy soft excess and the other for the high energy power-law. A broad Iron line and a couple of low energy edges are required to explain the spectra.

For Mrk 335, the 0.3–10.0 keV luminosity relative to the Eddington value, L_X/L_{Edd}, varied from 0.002 to 0.06. The index variation can be empirically described as $\Gamma = 0.6 \log_{10} L_X/L_{Edd} + 3.0$ for $0.005 < L_X/L_{Edd} < 0.04$. At $L_X/L_{Edd} \sim 0.04$ the spectral index changes and then continues to follow $\Gamma = 0.6 \log_{10} L_X/L_{Edd} + 2.7$, i.e. on a parallel track.

This result indicates that for Mrk 335, there may be accretion disk geometry changes which lead to parallel tracks. These changes could be related to structural changes in the corona or enhanced reflection at high flux levels. Changes in the accretion disc geometry at the same X-ray luminosity seem to indicate that the accretion flow is not determined only by the local accretion rate but rather it may also depend on the previous history of the accretion rate variation. A brief analysis including a blurred reflection component suggests that this indeed may be the case.

The results for Ark 564 are significantly different than that for Mrk 335. For Ark 564, the 0.3–10 keV luminosity relative to the Eddington value, L_X/L_{Edd}, varied from 0.02 to 0.07. The correlation between X-ray Eddington ratio and photon index is flatter and more scatter. Thus no homogeneous or universal relationship exists for the X-ray index and luminosity for different AGNs or even for the same AGN.

5.2 Summary of O VI Study

The phase structure of the ISM of galaxies is mainly determined by kinetic and radiative energy input from stars. ISM is studied via the absorption and emission processes that are closely related with the radiation emitted by background or nearby stars. The ISM of galaxies show up in different electromagnetic bands with each of them giving information about different physical properties. While the X-ray is emitted by hot gas, UV bands directly tell us about several atomic species present in the ISM. Highly ionized gases spanning the temperature range from 10^5 to 10^7 K are important constituents of the ISM. The hot phase of the ISM can be studied observationally using resonant absorption lines from lithium-like ions C IV, N V, Si IV and O VI, which are produced in collisionally-ionized gas. These ions have a range of ionization energies, corresponding to a range of temperature in equilibrium. O VI absorption at 1032 and 1037 Å is the most important diagnostic to understand gas in this temperature regime since it is unlikely to arise from photoioization in the ISM as 113.9 eV is required for the conversion of O V to O VI.

I have studied the properties of O VI in the MW along the lines of sight to 70 stars in the LMC using high resolution absorption spectra taken by *FUSE*. The observed absorption lines are studied using apparent optical depth method which reveal significant variation in O VI column densities over very small angular scale. The main conclusions of this work are as follows:

For all 70 sight lines, strong O VI absorptions at 1031.926 Å in the MW have been found. The highest column density measured for the MW is log N(O VI) = 14.73 atoms cm $^{-2}$ and the minimum value is log N(O VI) = 13.68 atoms cm $^{-2}$. The mean MW O VI column density is found to be 14.29 atoms cm^{-2}. The median value of the sample is 14.21 atoms cm^{-2}. The logarithm of the column densities perpendicular to the Galactic plane varies between 13.42 and 14.50 with average value of 14.03 atoms cm^{-2}. The measured O VI column densities can be described by a patchy exponential distribution in the MW which is in accordance with earlier measurements of O VI absorption for the Galaxy.

The column density variation with respect to the angular scale may provide us informations on physical properties of the regions in which O VI is produced. There is a significant variation of O VI column densities on all scales studied by this observation ($0'.024$ - $5^{\circ}.779$). The smallest scale for which O VI column density variation has been found is $\sim 1''.44$ ($\sim$ 0.28 pc). Interestingly as report of O VI column density variation which is smaller than this is not found, definitely this result is the smallest scale variation in the MW.

The velocity dispersion (b-values) of the O VI absorption profiles range from 16.99 to 80.69 kms^{-1}. The median, average and standard deviation of equivalent width are 45.23, 45.32 and 13.29 kms^{-1} respectively. The average value of equivalent width represents a temperature of $\approx 7 \times 10^5$ K. The b-values are larger than expected from thermal broadening in gas at $2.8{\times}10^5$ K. This may be due to different environments dominated by inflow, outflow and turbulent motions.

The broad ($\geq$16.99 km s^{-1}) O VI absorption profiles suggest collisional ionization at the interface of warm-hot ISM be the mechanism that produces this ion. These much higher values of velocity dispersions reveal effect of turbulence, multiple velocity components and collision on broader O VI profiles.

O VI column density and the Doppler parameter, b, are found to be correlated for the 70 sight lines. This definitely confirms earlier results.

It is observed that the kinematics of the observed O VI absorption of the MW varies from LMC profiles. Comparisons of Fe II and O VI line profiles reveal the presence of HVC and/or IVC components in the O VI absorption along all sight lines. But in Fe II profiles I have not observed either of these components. The distribution of O VI is significantly different than that of Fe II. The broad absorption profiles of O VI traces more extended layers than that of the Fe II-bearing layer.

The scale height for all the sight lines has been measured. For a midplane density $n_0=1.64\times10^{-8}$ cm^{-3}, the mean O VI scale height is found to be 2.85±0.7 kpc. The value ranges from 2.73 to 2.95 kpc.

Future Plans

I have studied the relation between X-ray power-law spectral index and Eddington ratio for two highly variable NLS1 galaxies. It is found that for Mrk 335, there may be changes in the accretion disk geometry which is indeed crucial and interesting. Since *XMM-Newton* covers 10 keV range only so broad band data covering energies > 10 keV may be crucial to confirm such behaviour. In this context, I plan to undertake a systematic study of a set of highly variable NLS1s, specially Mrk 335 using broad band data covering energies > 10 keV. It will also be interesting to study such AGNs in other wavelengths specially in the UV. I have also planned to study correlated X-ray/UV variability in AGNs.

I have also studied O VI absorption in the MW which tells us about the properties of hot gas in the interstellar medium. Studies of the hot gaseous content of the Milky Way and the Magellanic Clouds are important for understanding the energy input into the ISM from the stars. I found a patchiness of O VI distribution even in small angular scale. I plan to use FUSE data for doing a survey of O VI absorption measurements for the nearby intergalactic medium. I do have plan to study the interstellar absorptions from all highly ionised ions i.e. C IV, N V, Si IV and O VI towards stars in the Magellanic Clouds. As these high ions often trace matter in the interfaces between hot and warm ionized gas in the ISM, these are used as probes of energetic processes of interface environments of galaxies. All the above mentioned studies will help in providing a better understanding of the ISM of the MW.

These interesting results motivate us to extend this work in future. A lot of work is possible to explore the hot ionizing gas using both UV and X-Ray data. Both *XMM-Newton* and *Chandra* can observe the hot phases of the ISM with significant spectral resolution. So using data from these observatories, the study of the hot phases of the ISM can be extended.

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