On the Extend of Eddington Ratio and Accretion Rate in Seyfert 1 and Hidden Broad Line Region Seyfert 2 Galaxies

Nwankwo Ifeanyi Francis, Ogwo Jemima Ngozi

Department of Physics, Abia State University, Uturu, Nigeria

Email address:
ifeanyichy@gmail.com (N. I. Francis), jimogwo@yahoo.com (O. J. Ngozi)

Abstract: We present our result on the Eddington ratios and accretion rates of 13,516 Seyfert galaxies consisting of 6,758 Seyfert 1s and 6,758 Seyfert 2s. These objects under study are a sub-sample of 91,006 Seyfert galaxies from SDSS-DR14. Using the separation criterion > 3 for Seyfert 2 galaxies, the 91,006 objects are separated into Seyferts 1s and 2s and we further select Hidden broadline region (HBLR) Seyfert 2s. Our results show that Seyfert 1 galaxies have higher Eddington ratio that Seyfert 2s an indication that Seyfert 1 galaxies may be more AGN-dominated than Seyfert 2 galaxies. We find the mean luminosity of the doubly ionized oxygen line () to be higher in Seyfert 2 galaxies a pointer that narrow line regions (NLRs) in Seyfert 2s may contain higher density of cloud of particles than Seyfert 1s. In addition, () is found to increase with increasing Eddington ratio which shows that the NLR is likely to be illuminated by the central region; a precursor that the central region and the NRL should be few parsecs apart. The observation we make that Seyferts 1 and 2 of equal black hole mass (=) have diametrically unequal Eddington ratio of log=8.9638 for Seyfert 2s and log=5.801 for Seyfert 1s suggests that each of the Seyfert classes may have been associated with different AGN activities. On accretion rate, Seyfert 2 galaxies have higher accretion rate which implies that they are probably in the gravitational force era dominated by absorption by matter while Seyfert 1s are probably in the radiation force dominated era and as such not associated with absorption by matter.

Keywords: Galaxies, Eddington Ratio, Accretion, Narrow Line Region, Brood Line Region

1. Introduction

Seyfert galaxies are active galactic nuclei (AGN), radio quiet galaxies powered by super massive black holes (SMBHs). They are called radio quiet because they emit more energy in the optical waveband than in the radio waveband with the ratio of radio to optical power (in the blue) greater than ten (10). They exist as Seyferts 1and 2 galaxies. Seyfert 1gaalxies have both broad optical lines and narrow lines while Seyfert 2s do not have broad optical lines but narrow lines. However, the unified model states that the two classes are intrinsically the same that what is seen is as a result of the direction of observation such that face-on observation reveals the optical broadline while edge-on observation hides it [1, 18, 7, 22, 11, 19, 24]. Observation in the infrared reveals the existence of broad emission lines in many Seyfert 2 galaxies [21]. Other observations that support the unification scheme are X-ray observations. In addition, Seyfert 2 galaxies have been observed to be Compton thick having neutral column density [13, 2, 17]. Pertinent to note is that some Seyfert 2 galaxies do not show hidden broad line regions in the spectropolarimetric observations having column densities less than [16] in the X-ray observation and this poses a challenge to the orientation based unified model. This is the reason it is believed that orientation, neutral column density size and star-burst activities may not be the only candidates responsible for hidden broad line and non-hidden broad line phenomena among Seyfert galaxies.

In our work, we use the Eddington ratio and accretion rate to study the relationship between Seyfert 1 and HBLR Seyfert 2 galaxies.

2. The Sample

The data used in this paper are from Sloan Digital Sky

Survey Data Release (SDSS) DR-14 having 91,006 Seyfert galaxies which we separate into Seyferts 1 and 2 using the separation criterion 3 for Seyfert 2s and 3 for Seyfert1s. We further select Hidden broadline region (HBLR) Seyfert 2s using (> for HBLR Seyfert 2s) to ensure that only true Seyfert 2s are used

3. Analyses and Results

We have explained in the proceeding sub-sessions the methods we use to arrive at our results and conclusions.

Accretion Rate

The accretion rate () of each of the objects is estimated from

$$\text{Log}\dot{m}=-36.977 + \text{log}L_{\text{bol}} - 4.02\,\text{log}\sigma \text{ (Laor 2003)} \quad (1)$$

Eddington Ratio

The Eddington ratio which is the ratio of bolometric luminosity to Eddington luminosity is calculated as follows [8]:

$$L\text{bol}=3500L_{[\text{OIII}]} \quad (2)$$

Because the [OIII] is affected by reddening, is it extinction corrected as follows:

$$L_{[\text{OIII}]}=4F^{\text{Cor}}_{[\text{OIII}]} \quad (3)$$

Where $\dot{m}$ is accretion rate, L_{bol} is bolometric luminosity and σ(rho) is velocity dispersion.

$$\text{But } F^{\text{cor}}_{[\text{OIII}]}=F^{\text{obs}}_{[\text{OIII}]}{}^{2.94} \quad (4)$$

Figures 1 and 2 are the logarithmic distribution of the accretion rates of Seyferts 1 and 2 respectively with Seyfert 1s having an average accretion rate of 0.2030 solar mass units and Seyfert 2 having an average accretion rate of 0.3319 solar mass units suggesting that accretion is higher in Seyfert 2 galaxies. Seyfert 2 galaxies used in this study have an average black hole mass of $7.66\,m_\odot$ while Seyfert1 galaxies have an average black hole mass of $7.61m_\odot$. This may imply that accretion rates increases with increasing black hole mass or that accretion disk efficiency plays an important role in accretion rates.

Where Fcor is the extinction corrected flux density,

Fobs is the observed flux density is Balmer decrement with zero reddening usually 2.86.

Using eqns (3) and (4) in (1) gives:

$$L_{\text{bol}=14,000}\pi_{\text{d}}{}^2F^{\text{obs}}{}_{[\text{OIII}]}\left[\frac{\left(\frac{H\alpha}{H\beta}\right)^{obs}}{\left(\frac{H\alpha}{H\beta}\right)^{0}}\right]^{2.94} \quad (5)$$

Eddington luminosity () is calculated from is estimated from

$$L_{\text{Edd}}=1.3 \times 10^{31} \text{ watts} \quad (6)$$

$$\text{Eddington luminosity}=\frac{L_{\text{bol}}}{L_{\text{Edd}}} \quad (7)$$

We show the distribution of the logarithm of the Eddington ratios of Seyferts 1 and 2 respectively in figures 3 and 4 as normal distributions. Seyfert 1 has a mean Eddington ratio of 6.277 while Seyfert 2 galaxies have a mean Eddington ratio of 3.183 implying that Eddington ratio is higher in Seyfert 1 galaxies than Seyfert 2 galaxies. This means in both classes of Seyfert galaxies, bolometric luminosity is greater than Eddington luminosity suggesting that the black holes of both classes are in the radiation force dominated era as at the time of observation.

The Luminosity of the Doubly Ionized Oxygen Line [OIII].

The doubly ionized oxygen is called forbidden line because it is produced from transitions that do not obey the laws of quantum mechanics. In such transitions, the electrons in their excited states are scattered before de-excitation occurs and this prevents the radiations that would have being emitted had they undergone de-excitation from being emitted as a result they are never detected and this is the reason they are called forbidden lines. To calculate the luminosity of doubly ionized oxygen [OIII], we use equation (3), the extinction corrected formula to eliminate reddening because of the susceptibility of the [OIII] line to reddening.

4. Discussion of Results

Investigating accretion rates in Seyfert 1 and HBLR Seyfert 2 galaxies, we plot the histograms of the logarithm of accretion rates in figures 1 and 2 as normal distributions. Seyfert 1s have a mean accretion rate of $\text{log}\dot{m}=-0.6924$ with a standard deviation of $\text{log}\dot{m}=1.066$ while Seyfert 2s have a mean accretion rate of $\text{log}\dot{m}=-0.4790$ units with a standard deviation of$=\text{log}\dot{m}=1.124$. Close observation shows that the standard deviation of each of the quantities discussed above is greater than their respective mean value. The reason is that in each case there is a preponderance of low values in the distribution meaning that accretion rate is low in both objects under study. Since [14, 15, 3, 12, 6] agree that there exists a threshold of accretion rate below which broad line does not exist because of low luminosity, it is expected that HBLR Seyfert 2s should be associated with the lowest accretion rates possible. However, in our result, Seyfert 2s have higher accretion rates meaning that Seyfert 2s maybe Seyfert 1s whose broad lines are hidden as predicted by the orientation based unification scheme.[10], gives a minimum accretion rate below which broad line doesn't exist as=and that the condition for HBLR is > while < is for non-HBLR. When we investigate this, we discover that among the 6,758 Seyfert 2s, 19 (0.28%) objects satisfy the condition for non-HBLR Seyfert 2s while 6739 (99.7%) satisfy the condition for HBLR Seyfert 2 galaxies. But, surprisingly, among the Seyfert 1s, only 40 (0.59%) objects qualify as Seyfet1s by the [10] condition meaning that accretion rate might not be responsible for the presence and/or absence of BL since Seyfert 1s have BL. This suggests that it is either Seyfert 1s just lack torus or that they harbor thin or small torus that cannot obscure their which agrees with [23], 2004; [5, 20]

We represent our analysis on the Eddington ratios of Seyfert1s and true Seyfert 2s (HBLR) in figures 2 and 3 as

histograms of normal distribution (figures 1 and 2) in which Seyfert1s have a mean Eddington ratio of log=3.183 and HBLR Seyfert 2s a mean Eddington ratio of log=6.277. According to [4, 9], majority of both Seyferts 1s and 2s undergo supper- Eddington accretion. We use 'majority' because 27 and 19 objects respectively among Seyfert 1s and HBLR Seyfert 2s undergo sub-Eddington accretion having < 1. We propose that a possibility about the presence and/absence of BL in an AGN is whether the AGN activity is dominated by gravitational force or radiation force. If it is dominated by radiation force beams of photons are largely emitted which is likely to favor BL production. If the AGN activity is dominated by gravitational force, the production of BL is not favored since the gravitational force era is associated with either absorption of radiations by matter or scattering by charged particles like electrons. Succinctly, what determines what is seen is whether the radiation force dominated era is further dominated by absorption or scattering. If it is dominated by absorption, unionized matter is the object of interaction with the energy carrying photons from the event horizon of the black hole in which case radiation detected will be determined by the extent of absorption. If it is dominated by scattering, radiation from the central region is interacting with such ionized particles as electrons and the extent of scattering also determines what is detected. Further, the type of scattering will also affect the detected radiation. That is whether it is Compton scattering in which radiations interacting with electrons lose energy to the electrons becoming weak as a result or inverse Compton in which electrons lose energy to the radiations making them stronger as a result.

Having calculated L [OIII], we check the logarithmic distribution of L [OIII] for both classes of Seyferts in figures 5 and 4 as histograms of normal distribution. Seyfert1 has a mean doubly ionized oxygen luminosity of watts and a standard deviation of watts while Seyfert 2 galaxy has a mean doubly ionized oxygen luminosity of watts and a standard deviation of. The difference in their luminosity

shows that the narrow line region (NLR) which is the region of production of doubly ionized oxygen [OIII] for Seyfert 2 galaxies are likely to be associated with higher density cloud of particles than Seyfert 1 galaxies.

We investigate the extent of the effect of the activities of the central region on the NLR since it is the region of production of L [OIII] by plotting log L [OIII] against log in figures 7 and 8. This investigation reveals that L [OIII] increases with increasing Eddington luminosity meaning that there is a chance that the NLR is located close to the central region which strongly suggests that the high density clouds of particles of the NLR are directly illuminated by the central region. The regression fit for the distribution of L [OIII] against log for Seyfert1 is log L [OIII=37.20 + 0.4297 log while that of Seyfert 2 is log L [OIII=37.73+ 0.7388 log from which it is clear that HBLR Seyfert 2s have a stronger correlation coefficient of R=0.733 as opposed to Seyfert 1s having a correlation coefficient, R=0.504. Figures 5 and 6 show that Seyfert 2 galaxies have higher L [OIII] luminosity than Seyfert 1s (seyfert1, log L [OIII]=39.896 with a standard deviation of 1.074 and this is in agreement with [9]. HBLR Seyfert 2s having a mean log L [OIII]=40.0798 with a standard deviation of 1.096) is an indication that the NLR of HBLR Seyfert 2 galaxies may contain denser cloud of particles than Seyfert1s.

We further examine the effect of the size of black hole on Eddington ratio by plotting the log of black hole mass against the log of Eddington ratio in figures 9 and 10 for Seyferts 1 and 2 respectively and see that black hole size decreases with increasing Eddington ratio such that Seyfert 2 galaxy of black hole mass (smallest black hole mass) has the highest Eddington ratio log=8.9638. For Seyfert 1 galaxy of approximately the same mass (smallest black hole mass), Eddington ratio is log=5.8010. This result implies different nuclear activities for the two classes of Seyfert galaxies otherwise they would have had relatively the same Eddington ratio since they have approximately the same black hole mass.
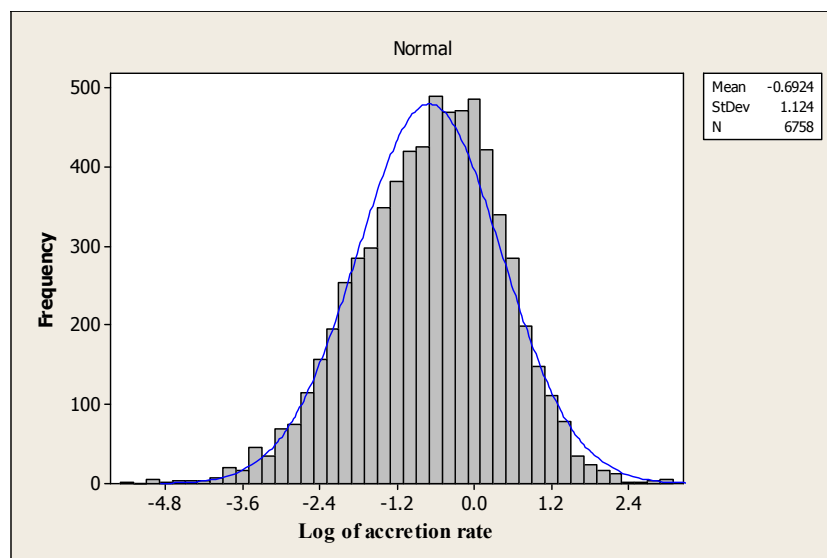

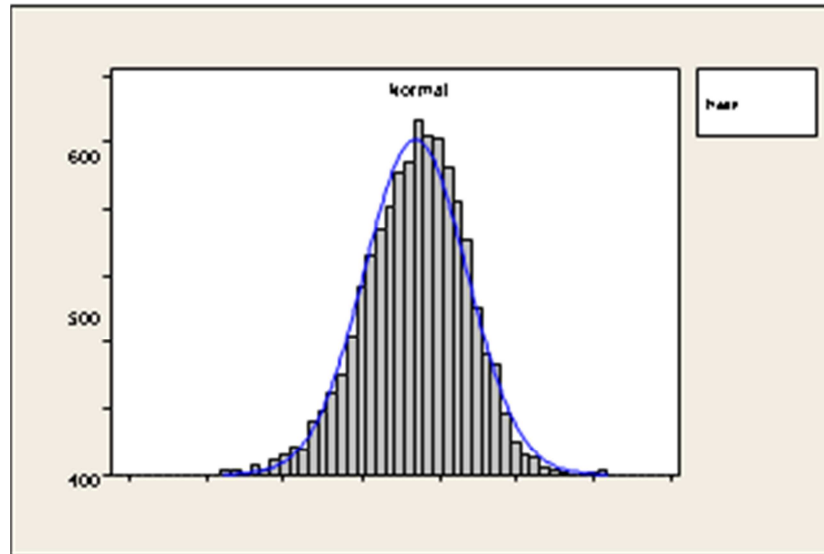*Figure 1.* Logarithmic distribution of log for Seyfert 1s.

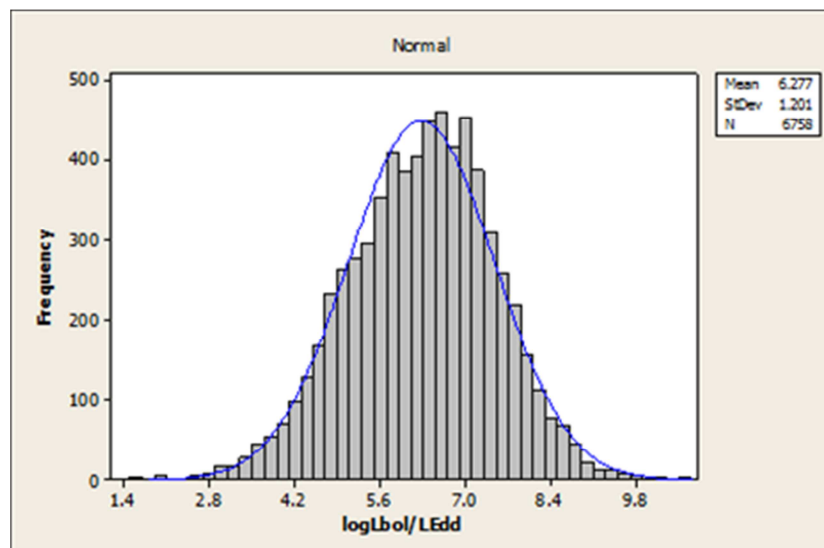**Figure 2.** *Logarithmic distribution of log for Seyfert 2s.*

Figure 3. *Logarithmic distribution of log Eddington ratio for Seyfert 1s.*
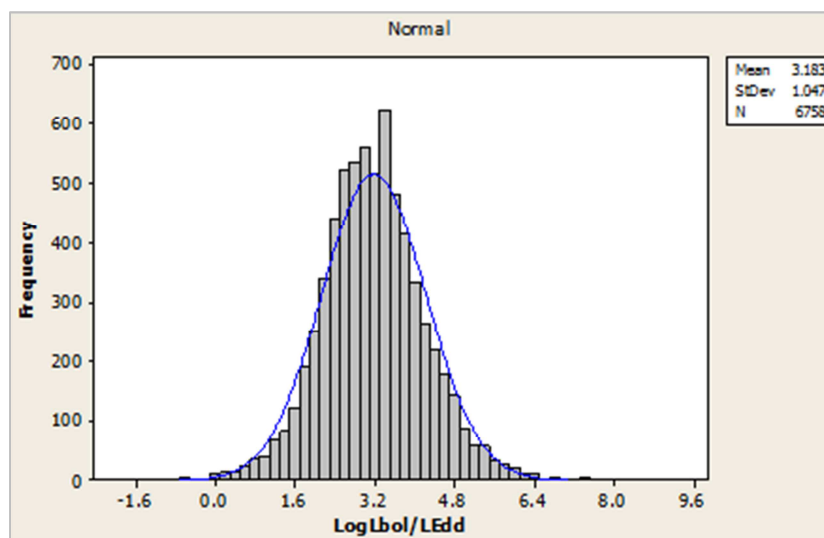

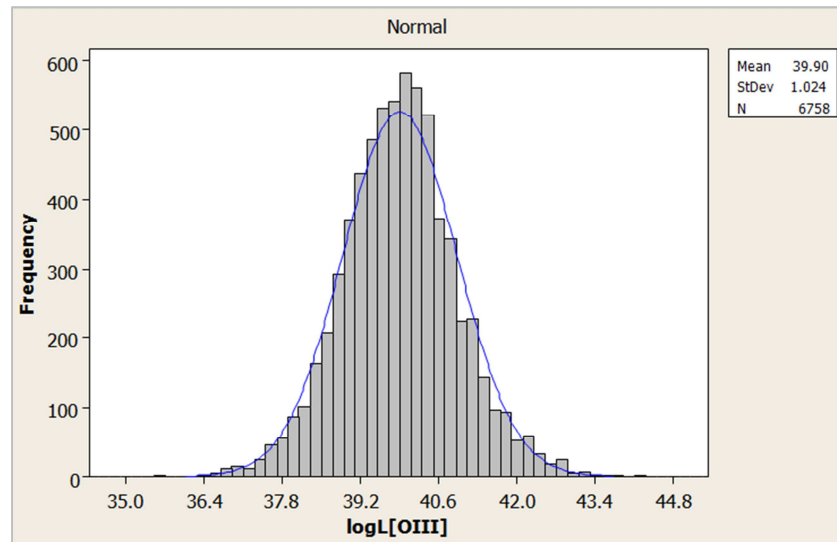**Figure 4.** *Logarithmic distribution of log Eddington ratio for Seyfert 2s.*

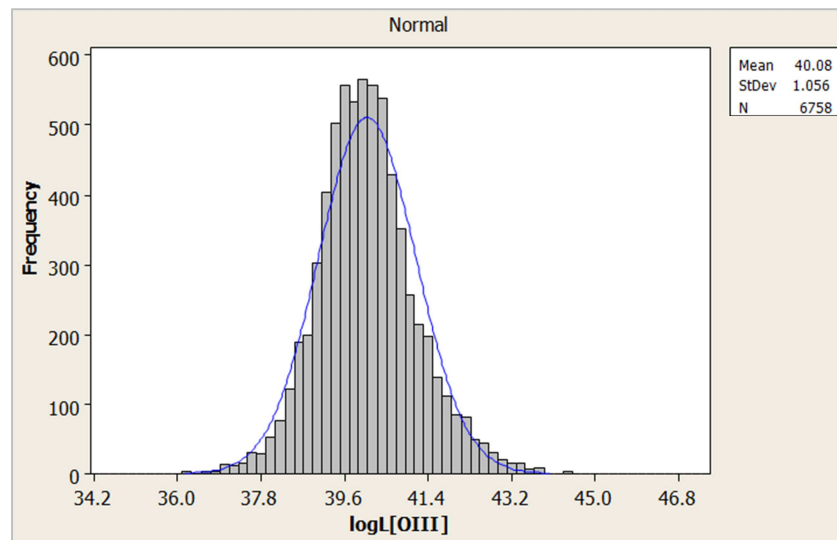***Figure 5.*** *Logarithmic distribution of log L [OIII] for Seyfert 1s.*

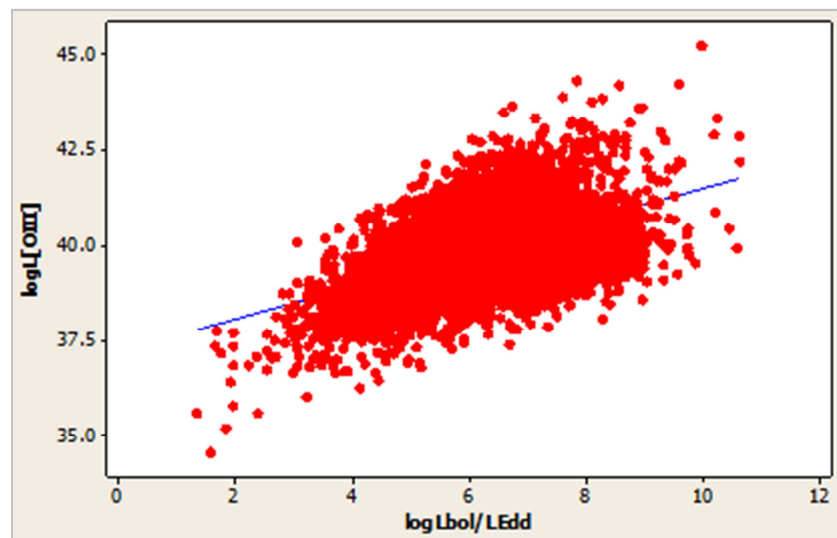***Figure 6.*** *Logarithmic distribution of log L [OIII] for Seyfert 2s.*

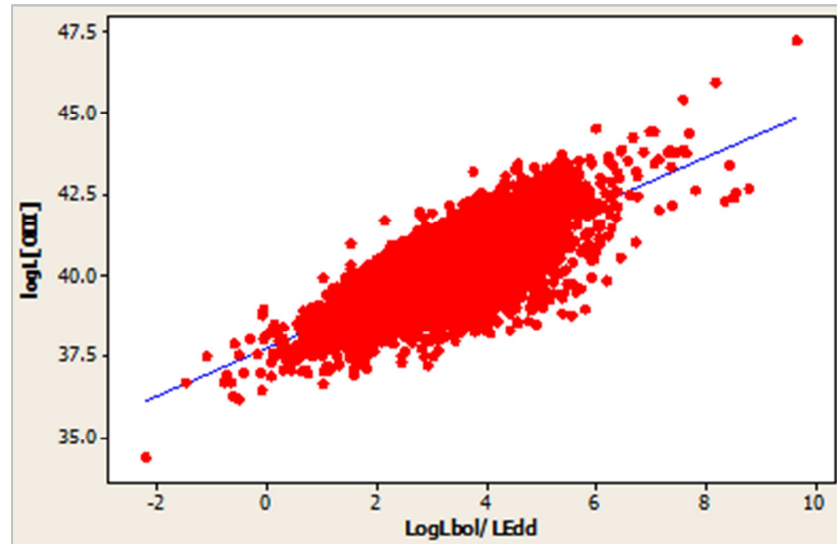***Figure 7.*** *The graph of log st log for Seyfert 1s.*

Figure 8. *The graph of log st log for Seyfert 2s.*
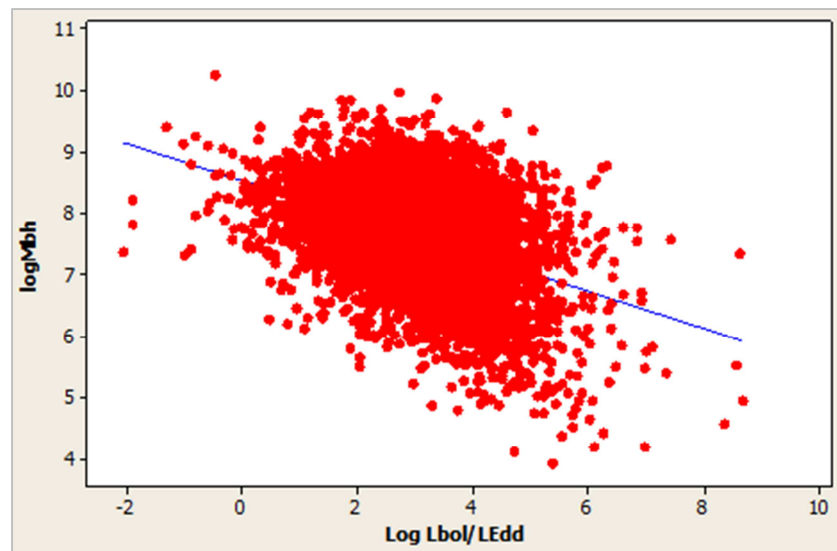

Figure 9. *The graph of log of blackhole mass versus Eddington ratiofor Seyfert 1s.*
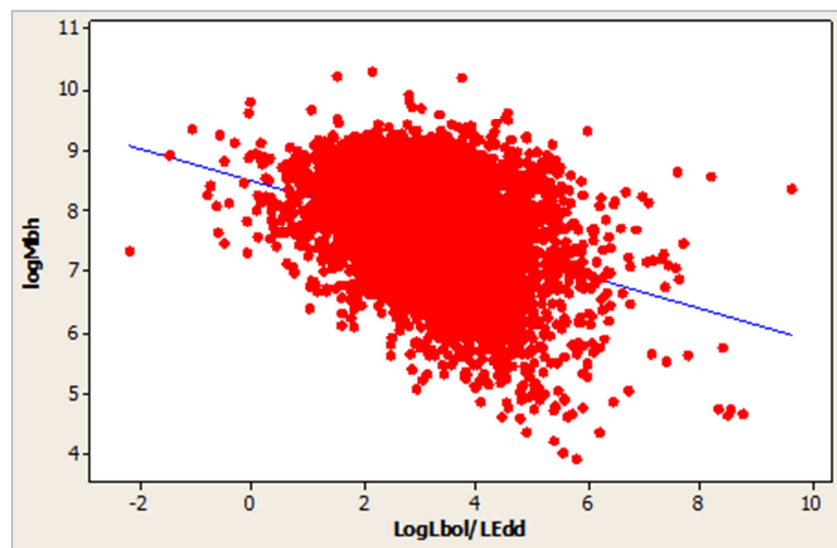

Figure 10. *The graph of log of blackhole mass versus Eddington ratiofor Seyfert 2s.*

5. Conclusion

This study highlights the behavior and properties of Seyfert 1 and HBLR Seyfert 2 galaxies and compares with recent studies and explains the reason for some of our observations. With emphasis on accretion rates and Eddington ratios, it became evident that accretions rate is not the only candidate responsible for the availability and/or unavailability of broad lines in HBLR Seyfert 2 galaxies. There is a strong indication that the reason broad lines are not detected in HBLR Seyfert 2s is because of obscuration by torus. Another possibility is that broad lines may be absorbed by unionized matter if the AGN activity is gravitational force dominated or that such lines may be scattered by ionized particles in directions that will make their detection impossible. However, if AGN activity changes from gravitational force dominated era to radiation force dominated era, these broad lines can be detected as has been noticed from spectropolarimetric observations in which certain HBLR Seyfert 2s later were seen to harbor broad lines in the X-ray and other wavelengths.

References

[1] Antonucci, R. R. J., &, J. S 1985, Spectropolarimetry and the Nature of NGC 1068 APJ, 297, 621.

[2] Bassani. L., Dadina, M., Maiolino, R., Salvati, M., Risaliti, G., Della Ceca, R., Matt, G., & Zamorani, G. 1999. A Three-Dimensional Diagnostic Diagram for Seyfert 2 galaxies: Probing X-ray Absorption and Compton Thickness, APJS, 121, 473.

[3] Bian, W., Gu, Q., Zhao, Y., Chao, L., & Cui, Q. 2006, Stellar and Gaseous Velocity Dispersions MNRAS, 372, 876 in Type II AGN at $0.3 < z < 0.83$ from the Sloan Digital Sky Survey.

[4] Bian, W., 2004, The Black hole- Bulge Relation in Active Galactic Nuclei, MNRAS, 347, 607.

[5] Elitzur, M., & Shlosman, I. 2006, The AGN-obscuring Torus: the end of the Doughnut Paradigm. ApJ, 648, L101.

[6] Elitzur, M., Ho, L. C., &Trump, J. R. 2014, Evolution of Broad line Emission from Active Galactic Nuclei. MNRAS, 438, 3340.

[7] Heisler, C. A., Lumsden, S. L., & Bailey, J. A. 1997, Visibility of Scattered Broad-line Emission in Seyfert 2 galaxies, Nature, 385, 700.

[8] Heckman, T. M., Kauffmann, G., Brinchmann, J., Charlot, S. Tremonti, C., & White, S. D. M. 2004, The Growth of Present-day Black hole and Bulges: The Sloan Digital Sky Survey Perspective APJ, 613, 109.

[9] Koulouridis, E., Plionis, M., Chavushyan, V et al. 2013, Activities of the Seyfert galaxy Neighbors A & A, 552, A135.

[10] Laor, A. 2003. On the Nature of Low-luminosity Narrow-line Active Galactic Nuclei APJ, 590, 86.

[11] Lumsden, S. L., & Alexander, D. M. 2001, The Infrared Luminosity of the Torus and the Visibility of the Scatted Broad Line in Seyfert 2 Galaxies, MNRAS, 328, L32.

[12] Marinucci, A., Bianchi, S., Nicastro, F., Matt, G., & Goulding, A. D. 2012, The Link between the Hidden Line Region and the Accretion Rate in Seyfert 2 Galaxies. APJ, 748, 130.

[13] Maiolino, R., Salvati, M., Bassani, L., Dadina, M., Della Cecca, R., Matt, G., Risaliti, G., & Zamorani, G. 1998, Heavy Obscuration in X-ray Weak AGNs A&A, 338, 781.

[14] Nicastro, F. 2000, Broad Emission Line Regions in Active Galactic Nuclei: The Link with the Accretion Power APJ, 530, L65.

[15] Nicastro, F., Martocchia, A., & Matt, G. 2003, The Lack of Broad line Regions in Low Accretion Rate Active Galactic Nuclei as evidence of their Origing in the Accretion Disk, APJ, 589, L13.

[16] Panessa, F., & Bassani, L. 2002, Unabsorbed Seyfert 2 Galaxies A&A, 394, 435.

[17] Risaliti, G., Maiolino, R., & Salvati, M. 1999. The Distribution of Absorbing Column Densities among Seyfert 2 Galaxies APJ, 622, 157.

[18] Trans, H. D. 1995, The Nature of Seyfert 2 Galaxies with Obscured Broad Line Region. I. Observation APJ. 440, 565.

[19] Trans, H. D, 2001, Dusty Nuclear Disks and Filaments in early-type Galaxies APJ, 554, L19.

[20] Vander Wolk, G., Barthel, P. D., Peletier, R. F., & Pel, J. W 2010, A&A 552, A135.

[21] Veilleux, S., Goodrich, R. W., & Hill, G. J. 1997, Infrared Spectroscopy of Seyfert 2 Galaxies: A look through the Obscuring Torus. II. APJ, 477, 631.

[22] Moran, E. C., Barth, A. J., Kay, L. E., & Filippenko, A. V. 2000, The Frequency of Polarized Broad Emission Lines in Seyfert Galaxies APJ, 540, L73.

[23] Whysong, D., & Antonucci, R. 2004, Thermal Emission as a Test for Hidden Nuclei in Near-by Seyfert Galaxies APJ, 602, 116.

[24] Zakamska, N. L., 2005, Candidate Type II Quasars from the Sloan Digital Sky Survey III Spectropolametry Reveals Hidden Type I Nuclei APJ, 129, 1212.