

Studying the Flux Density of Bright Active Galaxies at Different Spectral Bands

Y. E. Rashed*

M. N. Al Najm

H.H. Al Dahlaki

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Abstract:

Statistical studies are reported in this article for an active galactic nuclei sample of different type of active galaxies Seyferts 1, Seyferts 2, and Quasars. These sources have been selected from a Catalogue for bright X-ray galaxies. The name of this index is ROSAT Bright Source Catalogue (RBSC) and the NRAO VLA Sky Survey (NVSS). In this research, multi-wavelength observational bands Radio at 1.4 GHz, Optical at 4400 Å, and X-ray at energy 0.1-2.4 KeV have been adopted in this study. The behavior of flux density ratios has been studied $\frac{f_{X-ray}}{f_B}$, $\frac{f_{1.4}}{f_B}$ with respect to the absolute magnitude M_B . Furthermore, the Seyfert 1 and Seyfert 2 objects are combined in one group and the QSOs are collected in another group. Also, it has been found that the ratios $\frac{f_{X-ray}(2KeV)}{f_B}$, $\frac{f_{1.4}}{f_B}$ are increasing towards fainter optical absolute magnitude especially in Quasars.

Key words: Active galaxies, Astronomical instrumentation, Nuclei – Radio continuum, Seyfert – Quasars, X-ray emission.

Introduction:

All what is known about the galaxies comes from the light that we observe. This light is considered to be a very important component to understand and solve the puzzle of the universe. This component (light) contains a huge amount of information about the source emitted from it (e.g. mass, distance, age, and type ...etc.). Among the information that can be extracted from the light is the galaxy's luminosity. This luminosity will lead us to know how much is the amount of flux density that radiate from the source, because the luminosity is directly proportional to flux.

As clarified before, there are many parameters that can be extracted from the light emitted from the galaxies. These parameters are correlated to each other in different ways. For instance, some researchers conclude there are correlation between absolute magnitude and redshift (M_{B-z}) where both absolute magnitudes and apparent magnitudes increase with respect to the redshift in the Friedman universes model in which both the cosmological constant and the pressure are vanishing (1).

A recent example for the articles that study the correlation between magnitude and redshift, concludes that there is series relation extension, as they clarify in their research (2). Other astronomical scientists try to find the correlation between the black hole mass (M_{BH}) and the dispersion velocity of the stars (σ_*) for active galactic nuclei of the host galaxies (3, 4). In this research, new correlations have been tried to be suggested like, the relationship between flux density ratio and luminosity distance, the relationship between flux density ratio and redshift and the relationship between flux density ratio and absolute magnitude.

In this article, the sections have been arranged as follow: Section Two: state the mathematical process that has been involved in this project to derive the form used in mathematical analysis as well as the derivation of the parameters that have been employed in this analysis. Section Three: Presentation of calculated results, as well as statistical analysis of samples approved in this work. In addition, in this section, the relationship between the ratio of flux density and absolute volume value will be addressed as well as the discussion of these correlations. Finally, in section Four, the conclusions of this work will be summarized.

Department of Astronomy and Space, Collage of Science, University of Baghdad, Baghdad, Iraq.

Corresponding author: yasir_ezz81@yahoo.com

The Bright Sources Sample and Parameters Estimation:

In this research, a statistical investigation has been presented of three different types of galaxies samples (Seyfert galaxies type 1 and 2 in addition to Quasars). These objects have been chosen from active galaxies catalogue for X-ray bright sources (5). The arrangement of these sources was as follows: we had 315 sample of Seyfert objects type (Sy1), and 32 sample of Seyfert objects type (Sy2), number 347 of (Sy1 + Sy2) together, in addition to 97 sample of Quasars (QSO).

The global emission characteristics comparison of different active galaxies type at different bands from X-ray to Radio, can give us a vision about the formation and evolution of this kind of active sources. For instance, the comparison between radio continuum and IRAS far-IR data led to the discovery of the eminent connection between the star formation and non-thermal radio emitting (6). Another example for such important comparison is the comparison between X-ray and radio continuum data, which will guide us to an important relationship between X-ray and Radio emission data (7). Furthermore, the global emission characteristics comparison in extensive range of different bands can show the relative importance of those parameters and the responsible processes for practical connections between the universal parameters of active galaxies.

Spectral flux density is denoted by f_λ or f_ν where these parameters represent the quantity that defines the spectral power “energy” incident per unit surface “region” and per unit time. The monochromatic soft X-ray flux density (f_{X-ray} (2keV)) at (2.0 keV) band in units $erg.cm^{-2}.s^{-1}.Hz^{-1}$ derived from (8) is given by:

$$f_{X-ray}(2KeV) = 4.14 \times 10^{-18} (1 + \alpha_{X-ray}) 2^{\alpha_{X-ray}} \frac{f_{X-ray}(0.1-2.4KeV)}{E_2^{1+\alpha_{X-ray}} - E_1^{1+\alpha_{X-ray}}}$$

.....1

Where: E_1, E_2 are X-ray energies in the 0.1 and 2.4 KeV bands respectively, $f_{X-ray}(0.1-2.4KeV)$ is often called the X-ray spectral flux density in units of $erg.cm^{-2}.s^{-1}$, and X-ray energy index ($\alpha_{X-ray} \neq -1$). The spectral index α is described by power law ($f_\nu \propto \nu^{-\alpha}$).

In this work, the observed optical flux in the blue optical region f_B has been used as well as the relative effective flux density equation to the AB-magnitude has been used at different wavelengths. The system monochromatic AB magnitude is defined by (9, 10):

$$m_{AB}(\lambda) = -2.5(\log \frac{f_\nu}{363} \text{ in units of Jy}) \dots \dots \dots 2$$

We have $Jansky(1Jy) = 10^{-23} erg.cm^{-2}.s^{-1}.Hz^{-1}$, yielding $-2.5 \log\{363 \times 10^{-23}\} = 48.6$ So eq. 2 becomes:

$$m_{AB}(\lambda) = -2.5 \log (f_\nu \text{ in units of } erg.cm^{-2}.s^{-1}.Hz^{-1}) - 48.6 \dots 3$$

Depending on eq. 3 and from the equations mentioned in (11,12), we calculate the monochromatic flux density f_B in units of $erg.cm^{-2}.s^{-1}.Hz^{-1}$ within the optical bands (B-band) at 4400Å, where (λ - wavelength in unit angstroms Å):

$$f_B = (3.63 \times 10^{-20} erg.cm^{-2}.s^{-1}.Hz^{-1}) 10^{-m_B/2.5} \dots 4$$

Here 3.631×10^{-20} is zero point flux for all frequency ν (a flat spectrum source) in the AB system.

The relation between optical absolute magnitude (M_B) and luminosity distance $d_L(z)$ has been derived accurately from the equation that mention in (13):

$$M_B = m_B - 5 \log d_L (\text{in unit pc}) + 2.5(1 + \alpha_B) \log(1 + z) + 5 \dots \dots 5$$

According to eq. 5, we have calculated (M_B) via:

$$M_B = m_B - 5 \log d_L (\text{in unit Mpc}) + 2.5(1 + \alpha_B) \log(1 + z) - 25 \dots \dots 6$$

where m_B is represent the blue magnitude at 0.44 μm blue-band, (α_B) is the blue spectral index and (z) is the redshift.

Futhermore, to calculate the $\frac{f_{X-ray}}{f_B}$ and $\frac{f_{1.4}}{f_B}$, we

use the soft X-ray flux density $f_{X-ray}(2KeV)$ at 2 KeV band, radio emission flux density $f_{1.4}$ at 1.4 GHz monochromatic band and the blue flux density f_B at 4400 Å measured in units of $erg cm^{-2} s^{-1} Hz^{-1}$, which corresponds to an apparent magnitude (m_B) (13).

We can define the luminosity distance $d_L(z)$ as a relation between the bolometric flux density which denoted by f_ν at the corresponding frequency ν (i.e. combined comprehensive all the frequencies) and the luminosity bolometric (L) (14, 15):

$$d_L = \sqrt{\frac{L}{4\pi(\nu f_\nu)}} \dots \dots \dots 7$$

It's found that the luminosity distance d_L is relevant to the tangential comoving distance d_M via(15,16):

$$d_L = (1 + z)d_M \dots \dots \dots 8$$

Where d_M is given by(15):

$$d_M = d_H \frac{2[2-\Omega_M(1-z)-(2-\Omega_M)\sqrt{1+\Omega_M z}]}{\Omega_M^2(1+z)} \quad [\text{in unitMpc}]... 9$$

The Hubble distance d_H defined as (15, 17):

$$d_H = \frac{c}{H_0} \dots\dots\dots 10$$

Where (c) is the speed of light and (H_0) represent the Hubble constant, and this constant can be defined as the ratio between stagnation speed (v) and the distance (d) in the extending universe.

Assuming that dimensionless density parameters $\Omega_M, \Omega_\Lambda = 1, 0$ for Einstein–de-Sitter cosmology, then the deceleration parameter is just half value Ω_M ($q_0=0.5$)

We assume energy index for the optical band $\alpha_B = -0.5$ for the Seyfert galaxies types 1, 2 and also Quasars type (6, 13). The value of Hubble constant H_0 can be variable of 70 ± 5 according to the cosmological models. Therefore, we adopted this value to be $70 \text{ Km s}^{-1} \text{ Mpc}^{-1}$ according to very recent publications (18-21). Consequently, we have used the current value of Hubble constant ($H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$) through this article to compute the blue absolute magnitudes.

The following information has been obtained from (5): First, the densities flux data of the X-ray at 0.1 – 2.4 KeV and radio at 1.4 GHz. Second, the apparent blue magnitudes. Third, the redshifts. Fourth, the spectral classification morphology of the Seyfert galaxies (Sy1 and Sy2) and Quasars. In the next section, we used parametres that derived in previous section and (statistic-win-program) for calculate the correlations between the parameters that used in this work as well as discuss the results statistically for the extragalactic soft X-ray at (2 KeV) to radio emission at 1.4 GHz flux densities for Bright Seyfert galaxies (Sy1 and Sy2) and Quasars samples. According to eqs. 6,8, 9 and 10, we have computed a blue absolute magnitude (M_B), and luminosity distance (d_L).

Results and Discussion:

Here we used a program named (statistic-win-program) deals statistically with the data to find either there is correlation between the parameters or not. The parameters statistically analyzed in this article to find if there is a correlation between them are as follow: (fluxes densities ratio – blue absolute magnitude) and (fluxes densities ratio – distance). Moreover, different regressions are used in this article to get the plot between these factors and determine the levels of the significance (P) (the chance of probable relationship, $P < 0.01$) as well as the degree of the partial correlation coefficient (R), which should be between ($1 \leq R \leq -1$). The goal of

the linear reduction approach is to appropriately fit a line through the points. Accurately, the software that used in the research will determine a line, where this line will be reduced due to the points that is deviational squared. In general, a linear regression equation will be determined via eq. 11 (6):

$$Y_1 = a_1 + \beta_1 X_1, Y_2 = a_2 + \beta_1 X_2 \text{ and } Y_n = a_n + \beta_n X_n \dots\dots\dots 11$$

Where: (Y_1, Y_2, \dots, Y_n) : defined as the dependent variables.

(X_1, X_2, \dots, X_n): defined as the independent variables(or predictors).

($\beta_1, \beta_2, \dots, \beta_n$): regarded the slopes that applied as the retraction coefficients.

(a_1, a_2, \dots, a_n): represent the intercept with Y-axis.

In this paper, the investigation of the observational flux density for radio, optical (blue), and soft X-ray bands of (Sy1, Sy2, and QSO) led us to some formulas as will exhibit later, according to the statistical program that we used in this research. Statistical data analysis are shown in Table 1, as well as the relationship between fluxes densities

$$\left(\frac{f_{1.4}}{f_B}\right), \left(\frac{f_{X-ray}}{f_B}\right) \text{ and blue absolute magnitude } M_B,$$

distance (d_L) for sample of number 347 (Seyfert1 + Seyfert2) together, in addition to sample of number 97 QSO galaxies is given by according to above eq. 11:

a- Fluxes densities and blue absolute magnitude, distance correlation for Brighth Sy1+Sy2 sources, the number of valid cases is (N=342):

$$\frac{f_{X-ray}}{f_B} = (0.73 \pm 0.07)M_B + (0.6 \pm 0.08) \log d_L + (0.18 \pm 0.07) \log(1+z) + (39.7 \pm 4.8) \dots\dots 12$$

$$\frac{f_{1.4}}{f_B} = (0.29 \pm 0.085)M_B + (0.28 \pm 0.09) \log d_L + (0.7 \pm 0.25) \dots\dots 13$$

b- Fluxes densities and blue absolute magnitude, distance correlation for Brighth QSO sources, (N=94):

$$\frac{f_{X-ray}}{f_B} = (1.10 \pm 0.11)M_B + (0.86 \pm 0.19) \log d_L + (128.6 \pm 18.5) \dots\dots 14$$

$$\frac{f_{1.4}}{f_B} = (0.66 \pm 0.14)M_B + (0.6 \pm 0.13) \log(1+z) + (2.6 \pm 0.5) \dots\dots 15$$

Table 1. Partial correlation coefficients (R) and probability of chance correlation (P) between Various Parameters of (Sy1+Sy2) together and QSO galaxies

Active Galaxy	Flux density Ratio	M_B	$\log d_L$	$\log(1+z)$
Sy1+Sy2	$\frac{f_{X-ray}}{f_B}$	R = 0.45	R=0.36	R=0.12
	f_B	$P < 10^{-7}$	$P < 10^{-7}$	P=0.03
	$\frac{f_{1.4}}{f_B}$	R=0.18	R=0.16	-
QSO	f_B	$P \sim 10^{-3}$	P=0.003	-
	$\frac{f_{X-ray}}{f_B}$	R=0.73	R=0.64	-
	f_B	$P < 10^{-7}$	$P < 10^{-7}$	-
	$\frac{f_{1.4}}{f_B}$	R=0.45	-	0.42
	f_B	$P = 5 \times 10^{-6}$	-	2×10^{-5}

In this research, we studied the relations between the ratio of flux densities of soft X-ray to blue ($\frac{f_{X-ray}}{f_B}$), radio continuum to blue band ($\frac{f_{1.4}}{f_B}$), and absolute blue magnitude M_B and distance d_L for a different samples Seyfert types 1,2 and Quasars galaxies.

The ratio of flux densities ($\frac{f_{1.4}}{f_B}$) and ($\frac{f_{X-ray}}{f_B}$) as a

function of absolute blue magnitude M_B and distance d_L , redshift $(1+z)$ as shown in Figs. (1 to 5) to describe qualitatively spectral behaviour for (Seyfert1 and Seyfert2) collected together and Quasars galaxies of RBSC-NVSS catalogue. The mean values of blue absolute magnitude and standard deviations values for (Seyfert1 and Seyfert2) and (QSO) galaxies are (-21.7 ± 0.09) , (-24.3 ± 0.18) respectively, and it has been found that $M_B > -26$ for (Seyfert1 and Seyfert2) and $M_B < -20$ for (QSO type) in our sample. From the linear regression eqs. 12 to 15, the results of statistical analysis of the relation between $\frac{f_{X-ray}}{f_B}$,

$\frac{f_{1.4}}{f_B}$ and absolute blue magnitude M_B , distances, redshift for (Seyfert1+ Seyfert2) and (QSO) galaxies sample, show that, there is a strong correlation coefficient ($R=0.73$) and a very high probability $P \approx 10^{-7}$, and a very high linear relation with a slope > 1 between $\frac{f_{X-ray}}{f_B}$ and M_B , and

slope ~ 1 between $\frac{f_{X-ray}}{f_B}$ and distance (d_L) for the

QSO galaxies (Figs. 3, 4), greater than the correlation relation between $\frac{f_{X-ray}}{f_B}$ and M_B for the Seyferts type 1 and 2 (Figs. 1, 2). Furthermore, there is a positive correlation ($R \sim 0.5$) between $\frac{f_{1.4}}{f_B}$ and M_B , redshift $(1+z)$ with a nearly linear slope with a high chance probability $P < 10^{-6}$ for QSO type sample (Fig. 3, 5), and weak of relationship or there is no significant correlation ($R \sim 0.2$) between $\frac{f_{1.4}}{f_B}$ and (M_B, d_L) respectively and weak correlation ($R=0.12$) of a relationship between $\frac{f_{X-ray}}{f_B}$ and

redshift $(1+z)$ for (Seyfert1 and Seyfert2) sample galaxies, which is due to the effect of the distance factor and also that these galaxies are classified as earlier types compared with the (QSO) galaxies.

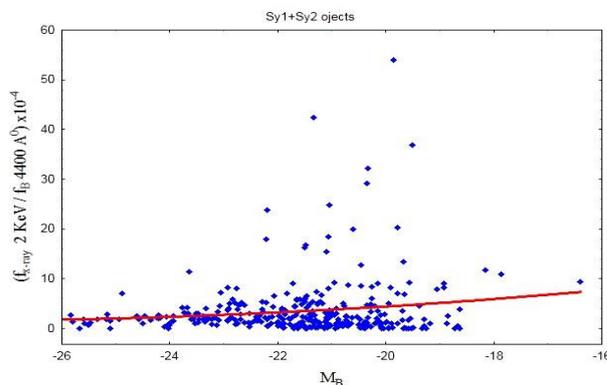


Figure 1. The ratio densities X-ray at 2 KeV and blue at 4400Å as a function of M_B for (Sy1+Sy2) galaxies sample.

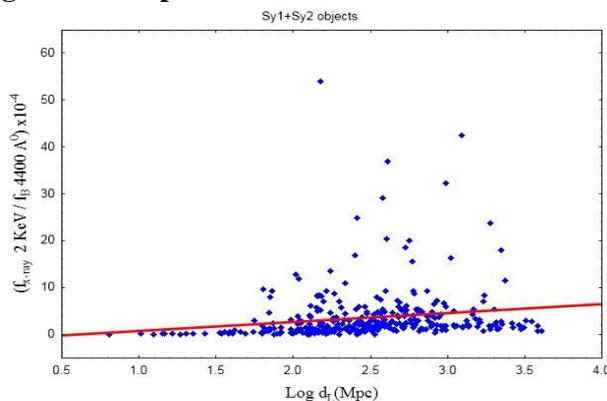


Figure 2. The ratio densities X-ray at 2 KeV and blue at 4400Å as a function of d_L for (Sy1+Sy2) galaxies sample.

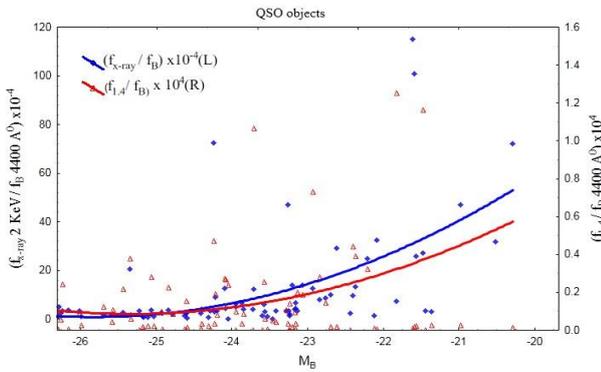


Figure 3. The ratio densities X-ray at 2 KeV and blue at 4400Å (right), radio at 1.4 GHz and blue at 4400Å (left) as a function of M_B for Quasars galaxies sample.

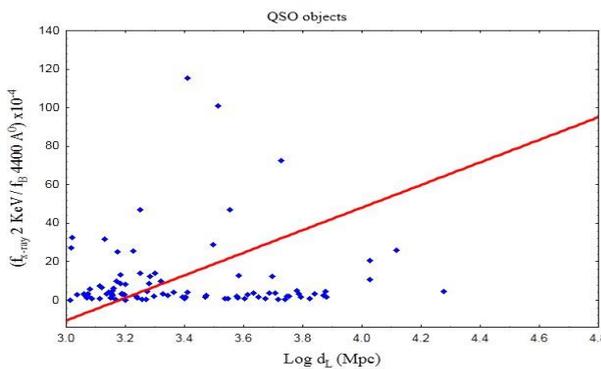


Figure 4. The ratio densities X-ray at 2 KeV and blue at 4400Å as a function of d_L for Quasars galaxies sample.

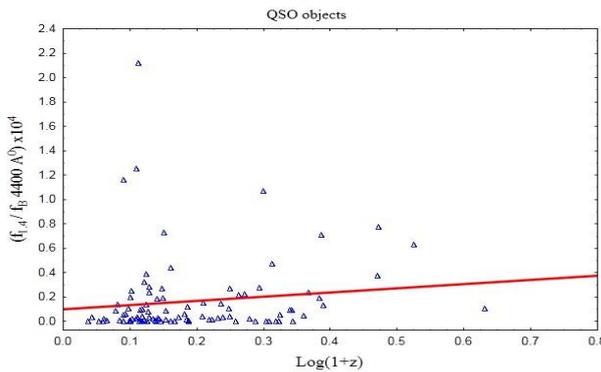


Figure 5. The ratio densities radio at 1.4 GHz and blue at 4400Å as a function of $(1+z)$ for Quasars galaxies sample.

The results of statistical analysis shows many main points as following:

- 1- It had been noted that there are different behaviors between ratio $\frac{f_{X-ray}}{f_B}$, $\frac{f_{1.4}}{f_B}$ and M_B for (Sy1 + Sy2) and QSO galaxies. The ratio $\frac{f_{X-ray}}{f_B}$ increasing forward the fainter blue

absolutemagnitude M_B for both groups (Sy1+Sy2) and QSOs from (-26 to -20) mag. So the ratio $\frac{f_{X-ray}}{f_B}$ depends on M_B and d_L . While, we found that

no significant correlation between ratio $\frac{f_{1.4}}{f_B}$ and

M_B , redshift $(1+z)$ or distance for Seyfert 1 and 2 types with a slope ($\beta \sim 0.3$) and a correlation coefficient ($R \sim 0.2$).

- 2- The results reveal that the X-ray emission and radio extended to blue flux densities ratio $\frac{f_{X-ray}}{f_B}$,

$\frac{f_{1.4}}{f_B}$ increasingly strong towards fainter absolute

blue magnitude with ($M_B < -20$) for QSO type

galaxies. So the ratios $\frac{f_{X-ray}}{f_B}$, $\frac{f_{1.4}}{f_B}$ depends on M_B ,

redshift $(1+z)$ or distance with a linear slope ($\beta \sim 1$). Where believed that Quasars are objects with strong X-ray- radio radiation more than Seyfert galaxies and it could be detectable at very large distances.

In comparison with previous results obtained by other authors (12, 8, 22), it has been found that these results are agreed with results of (12) for selected Schmidt BQX QSOs sample, while with results of (8, 22) they are different. These differences between our sample RBSC-NVSS of active galaxies (Sy1, Sy2 and QSO) and IRAS (Infrared Astronomical Satellite) Seyfert1 galaxies and Warm IRAS AGNs galaxies do not dominate

the distribution between ratio $\frac{f_{X-ray}}{f_B}$ and M_B , and

also has high flux Infrared sources, while the sample of active galaxies that involved in this work has brightest X-ray sources.

- 3- The statistical investigation of the result shows that the QSO objects are the most luminous sources that has host active galactic nuclei in their center, in which we compare with other galaxies (i.e. normal spiral galaxies) in the same redshift, it will be very difficult to be detectable in many case, as well as, it will looks like very faint sources with respect to QSO.

Conclusions:

From the results illustrated in the previous section including the statistical investigation of the flux density at different band (radio, blue-optical, and soft X-ray) for the tested galaxy samples that

have been selected in this work the following, the following points can be concluded:

1. There are very strong linear correlation relationships between $\frac{f_{X\text{-ray}}}{f_B}$ and M_B for QSO

sample galaxies with a very high level of significance $P < 10^{-7}$ more than for Sy1 + Sy2 type, and show different slopes in the relation between

$\frac{f_{X\text{-ray}}}{f_B}$, $\frac{f_{1.4}}{f_B}$ and M_B in our sample.

2. We believe that the energy indices α used for the radio, blue and X-ray spectra are of a similar value, and approximation proportional to frequency ν ($f_\nu \sim \nu^{-0.5}$) for QSO sample, based on a power law ($L_\nu = C\nu^{-\alpha}$) in the observed spectra radio to X-ray regions, while for Seyfert galaxies Sy1 + Sy2 the spectral indices are various values, and the ratio of flux densities monochromatic radio/blue, soft monochromatic X-ray (2 KeV)/ blue are independent of redshift (1+z) for QSO galaxies.

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Conflicts of Interest: None.

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دراسة كثافة الفيض للمجرات الفعالة اللامعة عند حزم طيفية مختلفة

حسنين حسن علي

محمد ناجي آل نجم

ياسر عز الدين رشيد

قسم الفلك والفضاء، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة:

دراسات احصائية ذكرت في هذه الورقة البحثية لدراسة عينة من النوى المجرية الفعالة لانواع مختلفة من المجرات الفعالة والتي شملت (مجرات سيفرت نوع 1، مجرات سيفرت نوع 2 والكوازرات). هذه المصادر تم اختيارها من كاتلوج المجرات السينية اللامعة المسماة بكتالوج RBSC- NVSS. في هذا البحث تم الاعتماد على الارصاد متعدد الاطوال الموجية والتي شملت الراديوية عند التردد 1.4 كيكاهرتز ، البصرية عند طول موجي 4400 انكستروم والاشعة السينية عند طاقة 0.1-2.4 كيلو الكترون فولت. سلوك نسبة كثافة الفيض f_{x-ray} f_B , $f_{1.4}/f_B$ درست بالنسبة الى القدر البصري المطلق (M_B). علاوة على ذلك تم دمج المجرات السيفرات من النوع الاول والثاني في مجموعة واحدة والكوازرات في مجموعة اخرى. كذلك، نحن وجدنا بان نسبة كثافة الفيض السيني عند طاقة (2 كيلو فولت) و كثافة الفيض الراديوي الى كثافة الفيض البصري الزرقاء تتزايد باتجاه القدر البصري المطلق الخافت وبالاخص في الكوازرات.

الكلمات المفتاحية: المجرات النشيطة، الاجهزة الفلكية، التواصل الراديوي – النوي، سيفرت – كويزرات، الانبعاثات السينية.