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Abstract

A sample of 40 Spitzer/IRAS (3.6μm) spiral galaxies were selected. This sample consisted of ranging of Hubble types from Sa to Sc to discover new correlations.

The total mass (M⋆) of the stellar associated with the subhalo were used, which it find directly from the simulation outputs.

We used a large sample of accurate estimates of host galaxy velocity dispersions (σ*) coupled with libraries of the total mass of the stellar (M*), total mass of halo (M_{halo}), and mass of dark matter (M_{DM}), of the host galaxies.

We explored correlations between the spheroid velocity dispersion (σ*) and mass of the total stellar (M∗) (σ*-M∗), mass of dark matter (M_{DM}) (σ*-M_{DM}) and, mass of total halo (M_{halo}) (σ*-M_{halo}) of host galaxies.

Keywords: spiral galaxies, dark matter, dispersion velocity, halo mass.

Introduction

The researches of galaxies have led to the found out many new correlations between the SMBHs masses or SMBH growth and the characteristics of host galaxies (Davis 2012, Al-Baeidhany et al. 20017 & 2019). At this time, astrophysicists consider that the released energy from SMBHs have a great function in the structure characteristics of host galaxies (Benson 2010; Ferrarese et al. 2000).

The bulges of spiral galaxies contain SMBH whose strongly correlates with dispersion velocity (σ*) (r_e, M_{BH}-σ*); (Ferrarese et al. 2000; Gebhardt et al. 2000a) with luminosity of bulge's galaxy (L_{bul}, M-L_{bul}; Kormendy et al.1995; Maigorrian et al. 1998; Marconii at al. 2003 Härinng at al. 2004; Gültekkin et al. 2009) , with mass of the bulge (M_{bul}) (Magorriann et al. 1998, Haäring et al. 2004), rotation velocity (Fearrarese 2002), and with the dark matter (Ferrarese 2002). In addition, Seiagar et al. (2008) found out a new correlation between pitch angle and dispersion velocity.

In this work, we used the mass of total stellar (M⋆) of particles bound for subhalo, which it find usig the simulation results as the mass of total stellar of the particles of bound for subhalo.

The present study examined the correlations between the spheroid dispersion of velocity (σ*) and the total stellar mass (M_*) (σ*-M_*), mass of dark matter (M_{DM}) (σ*-M_{DM}) and mass of total halo (M_{halo}) (σ*-M_{halo}) of the host galaxies.

This work is consistent of : Section 2, we briefly characterize of sample of 40 Spitzer/IRAS (3.6μm) spiral galaxies. Section 3 is an analyse and study of the results. Section 4 is the conclusions.

Sample

A sample of 40 Spitzer/IRAS (3.6μm) spiral galaxies were selected (see Table 1). The sample consisted of 40 galaxies, which it is possible to find these correlations.

In this study, we obtained the bulge of velocity dispersion for spiral galaxies from the literature (Seigar et al. 2006, Davis et al. 2012, Davis et al. 2014, Al-Baidhany et al. 2019b, Treuthardt et al. 2012).

We take on halo mass as the mass enclosed within a sphere, centered on the potential minimum of the halo that has a mean internal density of 200 times the critical density of the Universe.

We use total stellar using the simulation as total mass of stellar of the particless bound for subhalo. In this study, This sample consists of 40 spiral galaxies, 5 are classical bulges, 28 are pseudo-bulges, 7 have both pseudobulges and classical bulges.

Table 1: Linear correlation coefficient and linear regression coefficients of the bulge stellar velocity dispersion as a function of host galaxies: [(σ*) = α – βM]:

correlation coefficient	β	α	Types of correlation
0.71	61.62 ± 1.5	500.45 ± 8.1	σ*-M_{total}
0.73	69.41 ± 1.8	677.48 ± 4.6	σ*-M_{DM}
0.74	72.49 ± 1.3	717.26 ± 3.5	σ*-M_{halo}
0.0087	0.354 ± 0.02	151.79 ± 3.5	σ*-P
0.0613	0.226 ± 0.03	143.52 ± 3.1	σ*-P (Classical bulges)
0.0012	0.354 ± 0.02	143.98 ± 2.3	σ*-P (psudobulges)

Results and Discussion

By using our sample of 40 galaxies and drawing the σ* − M_{tot}, σ* − M_{DM}, and σ* − M_{halo} correlations, we conclude that there is a new correlation between (σ*) and M_{total}, M_{DM}, and M_{halo}. In Table 2, we record the of the best-fitting lines parameters.

Figures (1) illustrate the relation for σ*–M_{tot}, M_{DM}, M_{halo} , where (σ*) is the stellar velocity dispersion of spiral galaxies. In Fig. (1) we note that spiral galaxies are existing between the fitting line. The best-fitting line is:

$$(\sigma^*) = 61.62\pm1.5M_{total}–500.45\pm8.1$$

Linear correlation of Pearson's coefficient for a relation for the bulge of velocity dispersion of spiral galaxies (σ*) and M_{total} is 0.71. This means a good relation exists between the bulge velocity dispersion and total stellar in spiral galaxies.

Fig. (1) shows a new correlation of the bulge stellar velocity dispersion distribution for 40 galaxies described in Table 2.

The σ_*-M_{tot} relation backing the idea of regulated formation mechanisms and co-evolution for the galaxy's bulge stellar velocity dispersion(the smallest structures in a galaxy) and total stellar of spiral galaxies (the largest structures in a galaxy).

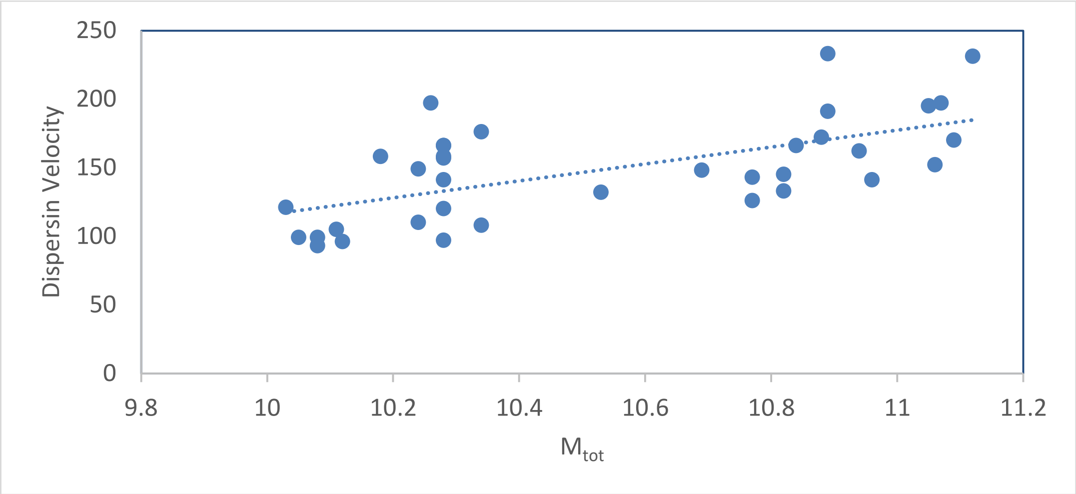

Figure (1): bulge stellar velocity dispersion as a function of total stellar for 40 spiral galaxies.

The essential $\sigma^* - M_{DM}$ scaling relation of spiral galaxies was examined. Figure 2 illustrates the relations in $\sigma^* - M_{DM}$, where the spiral galaxies have correlation. The best-fitting line is:

$(\sigma^*) = 69.41 \pm 1.8 M_{DM} - 677.48 \pm 4.6$

linear correlation of Pearson's coefficient for the relation between (σ*) and M_{DM} is 0.73, for all galaxies. We note that linear correlation of Pearson's coefficient value for spiral galaxies have a good correlation.

Fig. 2 also demonstrates that there is a statistically important relation for the stellar velocity dispersion and the dark matter mass: galaxies with high bulge dispersion of velocity have high mass of the dark matter.

The bulge of dispersion velocity–halo mass correction (Fig.3) shows the same behavior. There is a important realtion between bulge dispersion of velocity and the mass of halo for all of them.

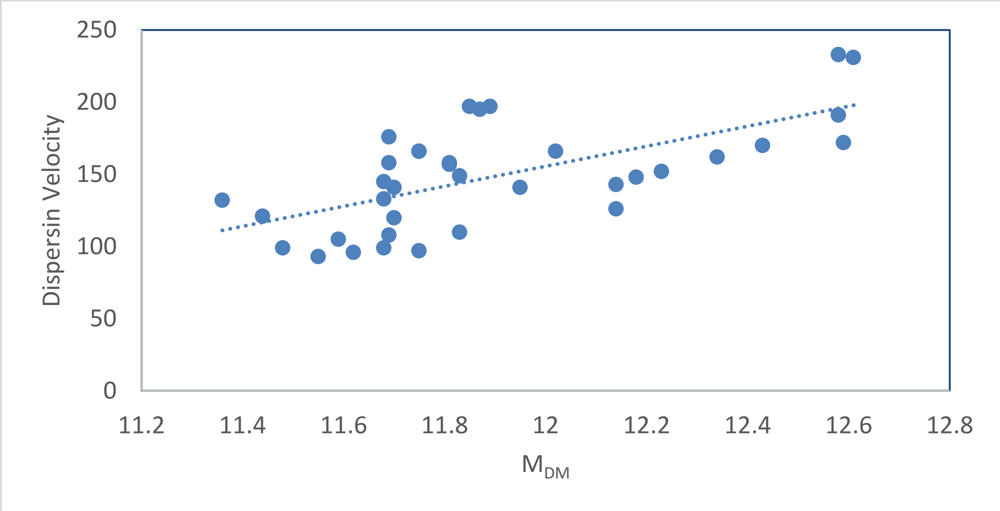

Figure (2): bulge dispersion of velocity as a function of dark matter mass in galaxies.

Fig. (3) shows a plot of halo masses calculated for (σ*-M_{halo}) correlation, for spiral galaxies. linear correlation of Pearson's coefficient for a relation for σ*- and M_{halo} was found to be 0.74.

linear correlation of Pearson's coefficient value for all of galaxies are noted to have the significance level.

The best-fitting line is:.

$(\sigma^*) = 72.49 \pm 1.3 M_{halo} - 717.65 \pm 3.5$

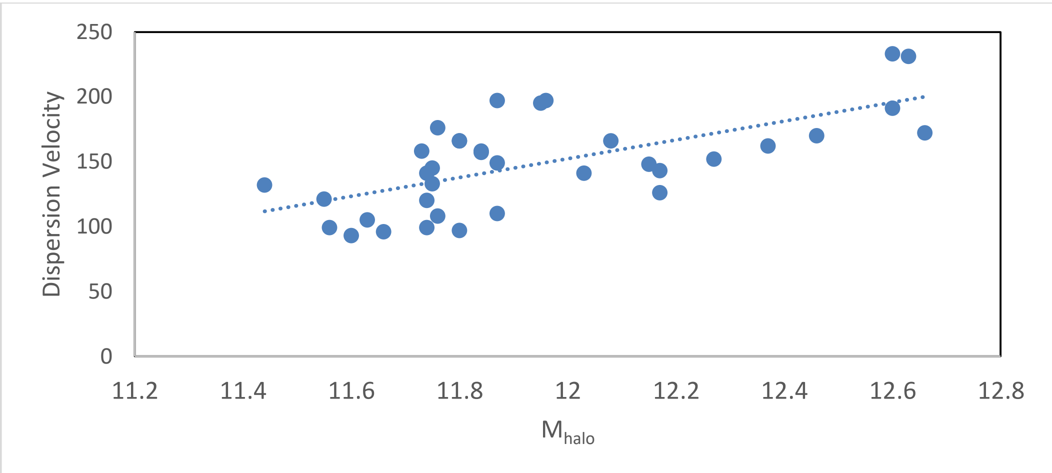

Figure (3): bulge dispersion of velocity as a function of halo mass for 40 galaxies.

The galaxies are classified into those which harbor classical bulges and those which harbor pseudobulges according to Sérsic indices (n_b) and the ratio of bulge (B) – to -total (T) (B/T) luminosities. Two ways were adopted for this classification: first, pseudobulges (P) have (Sersic index (n)) $n_b \leq 2$ and classical bulges have $n_b > 2$ (Fisheer & Driory 2008). our sample galaxies are classified into those which harbor classical bulges and those which harbor pseudobulges according to Sérsic indices (n_b) and the ratio of bulge-to-total (B/T) luminosities. Two ways were adopted for this classification: first, pseudobulges have $n_b \leq 2$ and classical bulges have $n_b > 2$ (Fisiher & Dirory 2008). Second, the average (B/T)of pseudobulges is (0.16) whereas, the B/T of classical bulges (C) is (0.4) (Fisher & Drory 2008; Kormendy & Kennicutt 2004). The basic morphological Hubble type has been taken from HYPERLEDA[1] and NED[2].

Figure (4) shows the dispersion velocity versus the pitch angle. In Table (2) we list the best fits to the σ* versus P relation for a sample of 40 Spitzer/IRAS (3.6µm) spiral galaxies.

The fits for the σ*– P relation, along with the corresponding correlation measures - are detailed in Table (2). Pearson's linear correlation coefficient is found, which is 0.0087 for the a sample of 40 spiral galaxies

$$\sigma * = (151.79 \pm 3.52) - (0.354 \pm 0.02)P$$

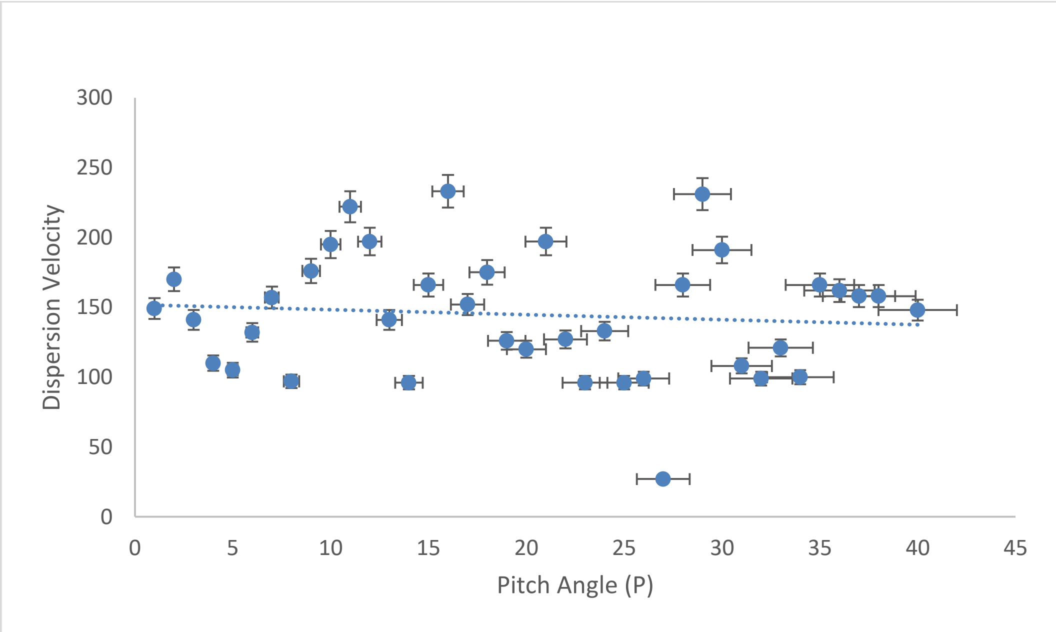

Figure (4): Dispersion velocity (σ*) versus pitch angle (P).

[1]http://leda.univ-lyon1.fr/
[2]http://nedwww.ipac.caltech.edu/

Table 2. Columns: (1) galaxy name. (2) Hubble type taken from the Hyper-Leda catalogue. (3) Bar morphology: Y for barred, N for non-barred. (4) Bulge morphology (C=classical bulge, P=pseudobulge and N=bulge-less. (4)(5) Spiral arm pitch angle (P). Most of (P) taken from Berrier et al. (2013), and Davis et al. (2012, 2017). The spiral arm pitch angle given for MW, and NGC 4945 are taken from Braun (1991), Levine et al. (2006) and Burg et al. (1986) respectively. (6) Dispersion velocity (Davis et al. (2017)). (7) $M_{*,total}$is total stellar mass. (8) M_{DM} is the mass of dark matter. (9) M_{halo} is halo mass.

Galaxy name (1)	Type (2)	Bar (3)	Bulge (4)	Pitch Angle (P) (5)	Dispersion Velocity (σ*)Km/s (6)	$Log(M_{*,total}/M_\odot)$ (7)	$Log(M_{DM}/M_\odot)$ (8)	$Log(M_{halo}/M_\odot)$ (9)
Circinus	SABb	N	P	17.0± 3.9	149 ± 18	10.24	11.83	11.87
ESO558G009	Sbc	N	P	16.5± 1.3	170± 21	11.09	12.43	12.46
IC 2560	SBb	Y	P,C	22.4±1.7	141 ± 10	10.28	11.70	11.74
J0437+2456	SB	Y	P	16.9±4.1	110±13	10.24	11.83	11.87
Milky Way	SBbc	Y	P,C	13.1 ± 0.6	105 ± 20	10.11	11.59	11.63
Mrk 1029	S	N	P	17.9 ± 2.1	132±16	10.53	11.36	11.44
NGC 0224	SBb	Y	C	8.5 ± 1.3	157 ± 4	10.28	11.81	11.84
NGC 0253	SABc	Y	P	13.8 ± 2.3	97 ± 18	10.28	11.75	11.80
NGC 1068	Sb	N	P,C	17.3 ± 1.9	176 ± 9	10.34	11.69	11.76
NGC 1097	SBb	Y	P	9.5 ± 1.3	195±5	11.05	11.87	11.95
NGC 1300	SBbc	Y	P	12.7 ± 2.0	222 ± 30	10.96	11.95	12.03
NGC 1398	SBab	Y	C	9.7 ± 0.7	197 ± 18	11.07	11.89	11.96
NGC 2273	SBa	Y	P	15.2 ± 3.9	141 ± 8	10.96	11.95	12.03
NGC 2748	Sbc	N	P	6.8 ± 2.2	96 ± 10	10.82	11.68	11.75
NGC 2960	Sa	N	P	14.9 ± 1.9	166±17	10.28	11.75	11.80
NGC 2974	SB	Y	C	10.5 ± 2.9	233 ± 4	10.89	12.58	12.60
NGC 3031	SBab	Y	C	13.4 ± 2.3	152 ± 2	11.06	12.23	12.27
NGC 3079	SBcd	Y	P	20.6 ± 3.8	175 ± 12	10.53	11.36	11.44
NGC 3227	SABa	Y	P	7.7 ± 1.4	126 ± 6	10.77	12.14	12.17
NGC 3368	SABa	Y	P,C	14.0 ± 1.4	120 ± 4	10.28	11.70	11.74
NGC 3393	SBa	Y	P	13.1 ± 2.5	197 ± 28	10.26	11.85	11.87
NGC 3627	SBb	Y	P	18.6 ± 2.9	127 ± 6	11.09	12.43	12.46
NGC 4151	SABa	Y	C	11.8 ± 1.8	96 ± 10	11.06	12.23	12.23
NGC 4258	SABb	Y	P,C	13.2 ± 2.5	133 ± 7	10.82	11.68	11.75
NGC 4303	SBbc	Y	P	14.7 ± 0.9	96 ± 8	10.12	11.62	11.66
NGC 4388	SBcd	Y	P	18.6 ± 2.6	99 ± 9	10.08	11.68	11.74
NGC 4395	SBm	Y	P	22.7 ± 3.6	27 ± 5	10.08	11.55	11.60
NGC 4501	Sb	N	P	12.2 ± 3.4	166 ± 7	10.84	12.02	12.08
NGC 4594	Sa	N	P,C	1 5.2 ± 0.4	231 ± 3	11.12	12.61	12.63
NGC 4699	SABb	Y	P,C	5.1 ± 0.4	191 ± 9	10.89	12.58	12.60
NGC 4736	SBab	Y	P	15±2.3	108 ± 4	10.34	11.69	11.76
NGC 4826	Sab	N	P	24.3± 1.5	99 ± 5	10.05	11.48	11.56
NGC 4945	SBc	Y	P	22.2 ± 3.0	121 ± 18	10.03	11.44	11.55
NGC 5055	Sbc	N	P	4.1 ± 0.4	100 ± 3	10.88	12.59	12.66

NGC 5495	SBc	Y	P	13.3 ± 1.4	166±20	10.28	11.75	11.80
NGC 5765	SABb	N	P	13.5 ± 3.9	162±20	10.94	12.34	12.37
NGC 6264	SBb	Y	P	7.5 ± 2.7	158 ± 15	10.28	11.81	11.84
NGC 6323	SBab	Y	P	11.2 ± 1.3	158 ± 26	10.18	11.69	11.73
NGC 6926	SBc	Y	P	9.1 ± 0.7	122 ± 13	10.77	12.14	12.17
NGC 7582	SBab	Y	P	10.9 ± 1.6	148 ± 19	10.69	12.18	12.15

Figure (5 and 6) show the correaltions in σ* - P. linear correlation of Pearson's coefficients are found, which are 0.0012 and 0.0613 for the pseudobulges and classical bulges respectively. Most spiral galaxies are concluded, including pseudobulges or classical bulges have a good correlation between σ* and P. The best-fitting lines are:

$$\sigma *= (143.52 \pm 3.13) - (0.226 \pm 0.03)P \quad \text{(Classical bulges)}$$

$$\sigma *= (143.98 \pm 2.31) - (0.128 \pm 0.02)P \quad \text{(Pseudobulges)}$$

The classical bulges have a linear fit very different to that of pseudobulges galaxies and to the combined sample of spiral galaxies.

Surprisingly, there are not correlations between dispersion velocity and spiral arm pitch angle.

These results are contradictory with Sigar's results (Seigar 2008).

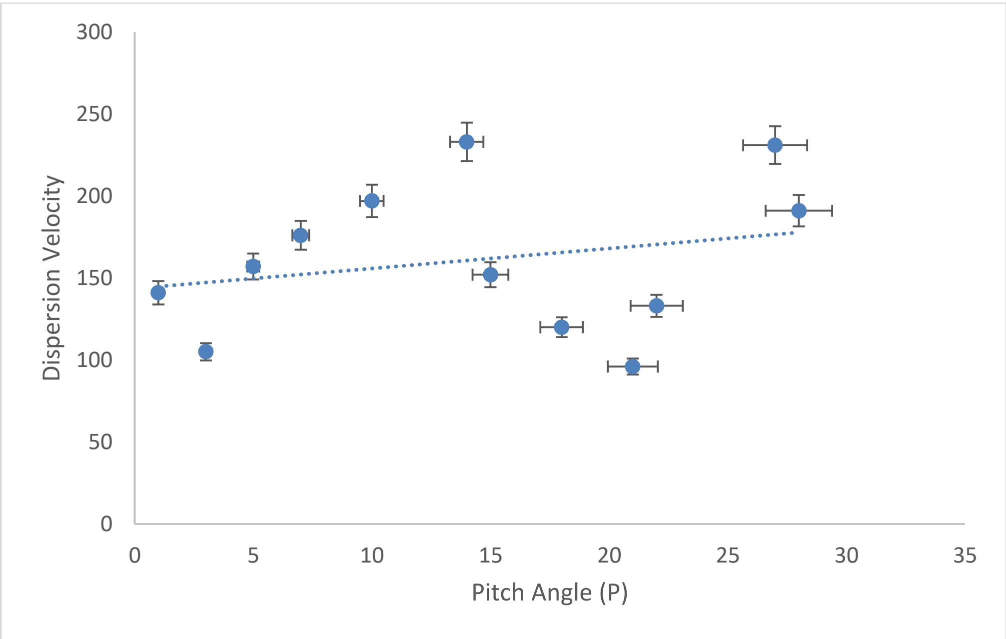

Figure (5): Dispersion velocity (σ*) versus pitch angle (P) for classical galaxies.

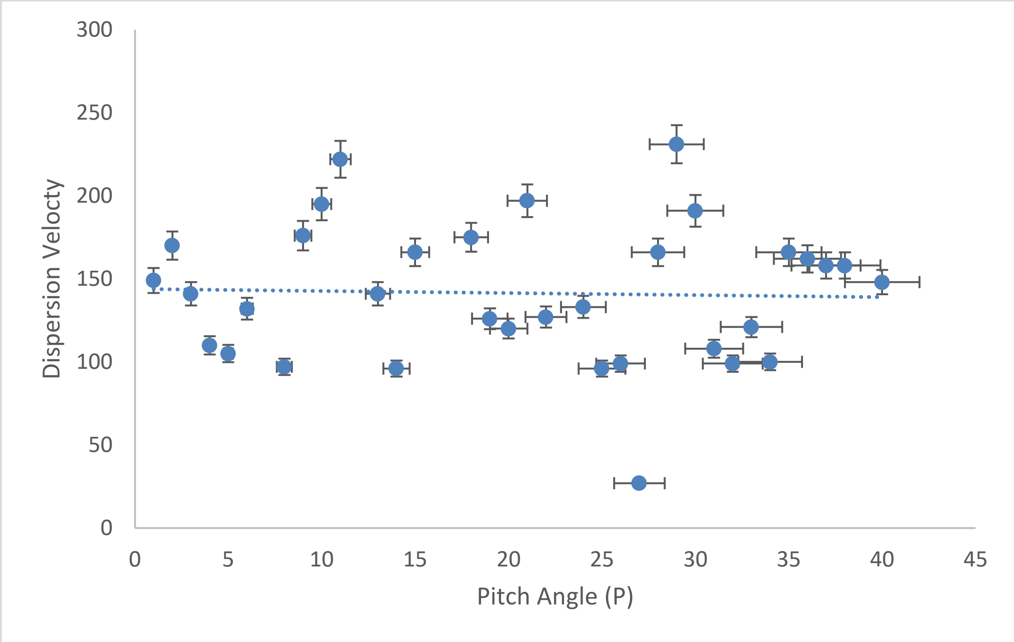

Figure (6): Dispersion velocity (σ*) versus pitch angle (P) for pseudobulges galaxies.

Conclusions

Based on this work, the following conclusions can be made:

1- The scaling relations were studied for the bulge stellar velocity dispersion (σ*), and M_{*tot}, M_{DM}, M_{halo}. The best-fitting linear regressions are:

$(\sigma^*) = 61.62 \pm 1.5 M_{total} - 500.45 \pm 8.1$

$(\sigma^*) = 69.41 \pm 1.8 M_{DM} - 677.48 \pm 4.6$

$(\sigma^*) = 72.49 \pm 1.3 M_{halo} - 717.65 \pm 3.5$

$$(\sigma *) = (151.79 \pm 3.52) - (0.354 \pm 0.02)P$$

$$(\sigma *) = (143.52 \pm 3.13) - (0.226 \pm 0.03)P \quad \text{(Classical bulges)}$$

$$(\sigma *) = (143.98 \pm 2.31) - (0.128 \pm 0.02)P \quad \text{(Pseudobulges)}$$

2- The results of this study indicate that bulge stellar velocity dispersion of spiral galaxies played an important role in growing supermassive black hole masses in center of galaxies.

3- New relations were found to exist between the bulge velocity dispersion and large-scale properties of host galaxy.

4- There are not correlations between dispersion velocity and spiral arm pitch angle.

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