CALCULATING SPACE VELOCITIES (U,V,AND W) FOR STARS IN THE HALO OF OUR GALAXY

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Abstract
Space velocities (U,V,and W)for many stars in the halo of our galaxy were calculated by choosing A,G and K spectral type stars at a distance nearly 10 pc. It was found that some of these stars represent a Local Association group (kinematic stream), the stars of this group are sharing in similar 3-D kinematic motion in the galaxy, in the solar neighborhood. The results displayed that these velocities are in a good correlation with each other .

Keywords: Space velocity,Local association,Kinematic stream,Solar neighborhood, Galaxy

حساب السرع الفضائية (U,V, and W) لعدد من النجوم في هالة مجرتنا

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الخلاصة
السرع الفضائية (U,V,and W) لعدد من النجوم في هالة مجرتنا قد تم حسابها باختيار نجوم ذات اطياف(A,G,and K) على مسافة تقرب من عشرة فراسخ من الشمس. لقد وجدنا ان بعض هذه النجوم تمثل مجموعة مترابطة. نجوم هذه المجموعة متشابهة في الحركة الثلاثية الابعاد ، وانها في المجموعة الشمسية المجاورة.لقد بينت النتائج ان سرع هذه النجوم مترابطة فيما بينها.

INTRODUCTION

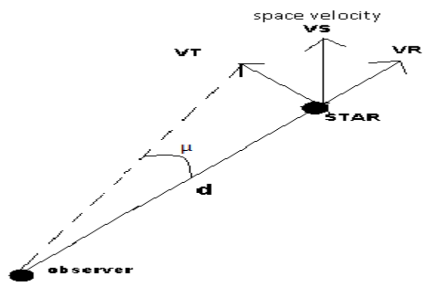
Our galaxy (milky way) and its constituents revolve around a central point in a flat orbital plane (resemble a disc). In other words, the milky way is rotating in a rotational axis perpendicular to the galactic plane. Although the stars in our galaxy take part in the general rotational movement, they also have their own peculiar velocity, random or non random.

The frequency function f(x,y,z,U,V,W ,M,S)contains eight descriptive variables and describes the distribution of stars in terms of spatial coordinate (x,y,z) that centered on sun ,in terms of peculiar velocity in the direction of axes (U,V,W) where each of the axis`s are respectively parallel to the direction of x,y,z , in terms of absolute magnitude M ,and in terms of spectral type S. The solar neighborhood can be considered as an area where its stars are isotropically distributed and centered on the sun coordinates. i.e. (x=0, y=0, z=0). Then the coordinates of the solar neighborhood is given by the frequency function: f(U,V,W,M,S).

During the years (1950 – 1967) several studies showed a systematic dependence of stellar kinematics on spectral type: younger groups of stars have lower velocity dispersion and higher galactic rotational velocity than older groups[1].

THEORY

The motion of a star can be determined by observing the radial velocity V_R and tangential (transverse) velocity V_T of the star as illustrated in **(Figure-1)**. Radial velocity is the velocity parallel to the observer`s line of sight, which can be determined by observing Doppler shift in a spectrogram of the star, while the tangential velocity is the velocity perpendicular to the line of sight. In order to determine tangential velocity, one needs information on its proper motion (μ) and distance (d) of the star.



(Figure-1): stellar motion relative to the observer can be discerned into two perpendicular components , the radial velocity and the tangential velocity , the distance to the star , the proper motion , and V_S is the space velocity .

Distance (in parsec, pc) can be determined from the measurements of the parallax angle (π) of the star (in arc second) by the following relation [1]

$$d = 1/\pi \text{ ----------------(1)}$$

the proper motion is the changes in stars coordinates over a certain lapse of time measured in miliarcsecond per year (mas yr^{-1}) and given by the relation:

$$\mu = V_T/d \text{ --------------------- (2)}$$

The proper motion is divided into proper motion in the direction of right ascension (α) and in the direction of declination (δ). (μα) is measured along the great circle of the celestial equator, while (μδ) is measured along the declination line [1].

Stellar kinematic groups (SKGs) are kinematically coherent groups of stars that could share a common region [2], such as the remains of a star forming region or collections of overlapping star formation bursts at different time periods in adjacent regions. The (SKGs) are defined by three components of motion in the galaxy[1]. These components of space velocity in the milky way`s Galactic coordinate system are usually designated by U, V, and W, given in km/s with U positive in the direction of the galactic centre, V positive in the direction of galactic rotation , and W positive in the direction of the north galactic pole.

The peculiar velocity of Sun with respect to the Local Association Rest (LSR) is:(U, V,W)= (10.00±0.36, 5.23±0.62, 7.17±0.38) km/s [3].

In order for the stars to be considered members of the kinematic stream (Local Association or cluster), their space motion must be extremely close to one another. If a star`s space motion lies outside of these conditions, the star will eventually drift outside of the cluster, and thus, would not be a member of the Local Association. The Local Association also known as kinematic stream is a moving cluster of stars sharing in similar 3-D kinematic motion in the galaxy, which are in the solar neighborhood. Furthermore the stars that make up the local association are young, typically 300 million years old [1].

In order to calculate the space motions, certain parameters are needed. The first is stellar position in terms of Right Ascension / Declination [RA/Dec] (which are analogues to longitude and latitude on earth). The second is distance (d) which can be determined from parallax measurements by the Hipparcos satellite. Proper motion is the third parameter needed to define the space motion, in terms of RA/Dec.

The only unknown parameter is the radial velocity of the star. Once all four parameters are determined, they are used to populate a very complex matrix, whose solution provides the (U, V, W) space motions of the stars. [4][5]The matrices were tabulated in the following equations:

$$T=\begin{bmatrix} +\cos\theta & \sin\theta & 0 \\ +\sin\theta & -\cos\theta & 0 \\ 0 & 0 & +1 \end{bmatrix} \begin{bmatrix} -\sin\delta_{NGP} & 0 & +\cos\delta_{NGP} \\ 0 & -1 & 0 \\ +\cos\delta_{NGP} & 0 & +\sin\delta_{NGP} \end{bmatrix} \begin{bmatrix} +\cos\alpha_{NGP} & +\sin\alpha_{NGP} & 0 \\ +\sin\alpha_{NGP} & -\cos\alpha_{NGP} & 0 \\ 0 & 0 & +1 \end{bmatrix} --- (3)$$

Where

α_{NGP} , δ_{NGP} are the equatorial position of the North Galactic Pole

θ is the position angle of the north Celestial Pole

$\alpha_{NGP}=12^h\ 49^m = 192^\circ.25$

$\delta_{NGP}=27^\circ.4$

$\theta = 123^\circ$

α_{NGP} , δ_{NGP} , θ are called Galactic coordinate system [2]. After substituting these values in equation (2), the following matrix can be obtained:

$$T=\begin{bmatrix} -0.06699 & -0.87276 & -0.48354 \\ +0.49273 & -0.45035 & +0.74458 \\ -0.86760 & -0.18837 & +0.46020 \end{bmatrix} \text{------ (4)}$$

We also define a coordinate matrix:

$$A=\begin{bmatrix} +\cos\alpha\cos\delta & -\sin\alpha & -\cos\alpha\sin\delta \\ +\sin\alpha\cos\delta & +\cos\delta & -\sin\alpha\sin\delta \\ +\sin\delta & 0 & +\cos\delta \end{bmatrix} \text{----- (5)}$$

By substituting the values of α,δ we get the matrix A with numbers. Then the galactic space velocity components could be obtained from the equation:

$$\begin{bmatrix} U \\ V \\ W \end{bmatrix} = B.\begin{bmatrix} \rho \\ k\mu\alpha/\pi \\ k\mu\delta/\pi \end{bmatrix} \text{-------------------- (6)}$$

Where B=T.A and K=4.74057, and ρ is the radial velocity of the star.

μα is the proper motion in terms of Right Ascension (RA).

$\mu\delta$ is the proper motion in terms of Declination (Dec).

π is the parallax

DATA COLECTIONS

The following stars were chosen to calculate the space velocity (U, V, and W) from HIPARCOS CATALOGUE database [6]. These stars were selected since they have a distance nearly 10 pc. And the spectral types were chosen A, G

(Table-1): selected stars and their parameters

star name	Radial velocity (ρ) (ρ)	RA α	Dec δ	Parallax (mas) (π)	PM(ra) (mas/yr) (μα)	PM(de) (mas/yr) ($\mu\delta$)	Spectral type (S)	Distance (d)
AB Doradus	28.0	$05^h28^m44.82\ 8^s$	-65° 26′ 4.85″	66.92	32.14	150.97	K1	14.9
Arcturus	+5	$14^h\ 15^m\ 40.347^s$	+19° 11′ 14.172″	88.85	-1093.4	-1999.4	K1	11.0
Delta eridani	-6	$3^h43^m14.90^s$	-09° 45′ 48.2″	110.61	-93.16	743.64	K0	9.04
HR 4458	-22.6	$11^h34^m29.48$	-32° 49′ 52.82″	104.8	-670.99	823.89	K0V	9.54
Pollux	+3.3	07 45 19.364	+28 01 34.717	96.74	-625.69	-45.95	K0III	9.97
Tw piscis Austrini	+6	22 56 24.0529	-31 33 56	130.94	-330.53	-159.85	K5V	7.64
41 G.Arae	25.3	17 19 03.8337	-46 38 10.44	113.81	1035.2	109.26	G8V	8.8
Beta aquilae	-40.3	19 55 18.8	+06 24 24	72.95	46.35	-481.32	G8IV	13.7
Capella	29.19	05 1641.296	+45 59 56.505	77.29	75.52	-427.13	G8III	9.8
Eta bootis	1.0	13 54 41.1	18 23 55	88.17	-60.95	-358	G0IV	11.34
HD 10307	+3.1	01 41 47.1	+42 36 48	79.09	791.35	-180.16	G1.5V	12.6
Lamda aurigae	66.4	05 19 08.47	+40 05 56.6	79.17	518.99	-665.06	G	12.63
Eta bootis muphrid	1.0	13 54 41.1	+18 23 55	88.17	-60.95	-358.1	G0IV	11.34
Delta capricorni	-.2	21 47 03	-16 07 38	84.58	263.26	-296.23	A7III	11
Denebola	-0.2	11 49 03.5776	14 34 19.417	901	-499.02	-113.78	A3V	11.1
Fomalhaut	+6.5	22 57 38.826	-29 37 18.613	130	329.22	-164.22	A3V	6.51
R coronae australis	-36	19 01 53.65 03	-29 37 18.613	121	-34	50.57	A5II	8.21
vega	-13.9	18 36 56.186	+38 46 58.77	128.9	201	287	A0V	7.72

CALCULATIONS AND RESULTS:

The calculations of (U, V, and W) for these stars have been done by using eqns. (3-6). The calculated results are shown in (Table-2):

(Table-2): the (U, V, and W) coordinates for stars with spectral type (A, G, and K)

star name	spectral type (S)	U ($km.s^{-1}$)	V ($km.s^{-1}$)	W ($km.s^{-1}$)
delta capricorni	A7III	21.1292	-4.0463	4.01551
denebola	A3V	-0.2	-26.23	-5.98
fomalhaut picis	A3V	13.7885	-0.0489	5.275
R coronae australis	A5II	12.6	28.8367	-17.0739
vega	A0V	15.55	9.83	1.4481
41 G.Arae	G8V	-27.37	15.7	38.7
beta aquilae	G8 IV	46.008	-15.5	-14
Capella	G8III	29.19	4.6	-26.19
eta bootis	G0III	1	-3.277	-19.25
HD 10307	G1.5V	3.1	47.43	-10.79
Lambda Aurigae	G	31.53	29.9	-26.3
Muphrid	G0IV	8.8554	-16.9	-4.44
AB doradus	K1	-16.25	20.29	15.074
Arcturus	K1	71.28	-82.66	-51.4
TW piscis austrini	K0	6	-11.96	-5.78
delta eridani	K0V	6.3285	-31.4	4.02
HR 4458	K0III	6.064	51.8448	2.99
pollux Geminorum	K5V	15.8967	14.3122	22.38

The calculated results in (Table-2) were then subtracted by the (U, V, and W) for the Sun, these values are:$U_{\odot}$=10.0 km/sec, $V_{\odot}$ =15.0 km/sec, and $W_{\odot}$ =7.2 ($km.s^{-1}$).

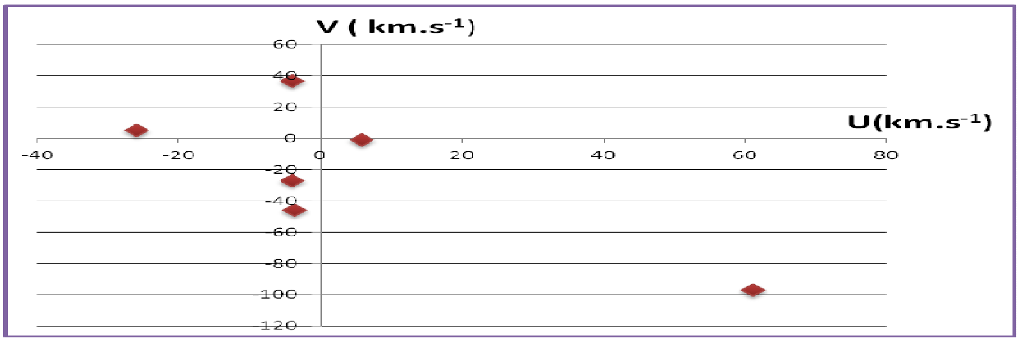
The final result after subtraction is shown in (Table-3):

(Table-3): (U, V, and W) of the stars with spectral type (A, G, and K) after the subtraction from the sun coordinates ($U_{\odot}$, $V_{\odot}$, and $W_{\odot}$).

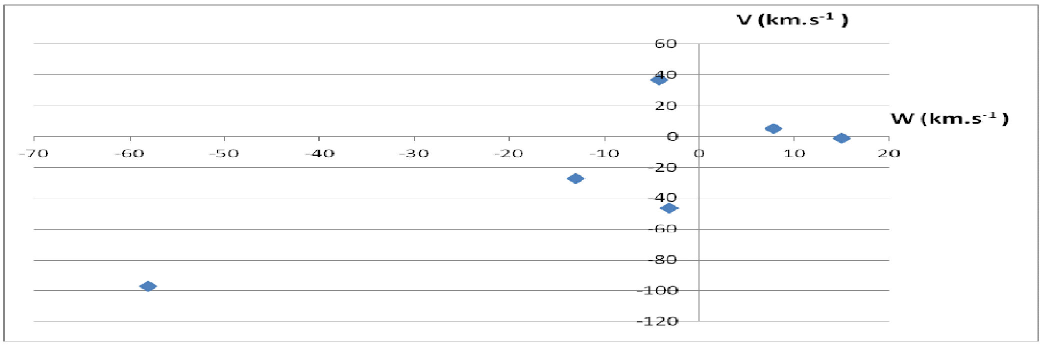
Star name	Spectral type (S)	U ($km.s^{-1}$)	V ($km.s^{-1}$)	W ($km.s^{-1}$)
delta capricorni	A7III	11.12	-19.66	-3.0449
Denebola	A3V	+9.8	-41.43	-13.18
fomalhaut picis	A3V	3.78	-15.2	-1.9249
R coronae australis	A5II	2.6	13.6	-24.2739
vega	A0V	5.55	-5.36	-5.7519
41 G.Arae	G8V	-37.3	0.54	31.54
beta aquilae	G8 IV	36.	-30.7	6.8
Capella	G8III	19.19	-10.56	-33.39
eta bootis	G0IV	-9.00	-10.47	-26.45
HD 10307	G1.5V	-6.9	32.28	-17.99
Lambda Aurigae	G	21.5	14.7	-33.5
Muphrid	G0IV	-1.14	-32.1	-11.6
AB doradus	K1	-26.2	5.1	7.87
Arcturus	K1	61.2	-97.86	-58.6

TW piscis austrini	K0	-4	-27.1	-12.98
delta eridani	K0V	-3.7	-46.6	-3.1717
1879HR 4458	K0III	-4	36.6	-4.2
pollux Geminorum	K5V	5.89	-0.88	15.1879

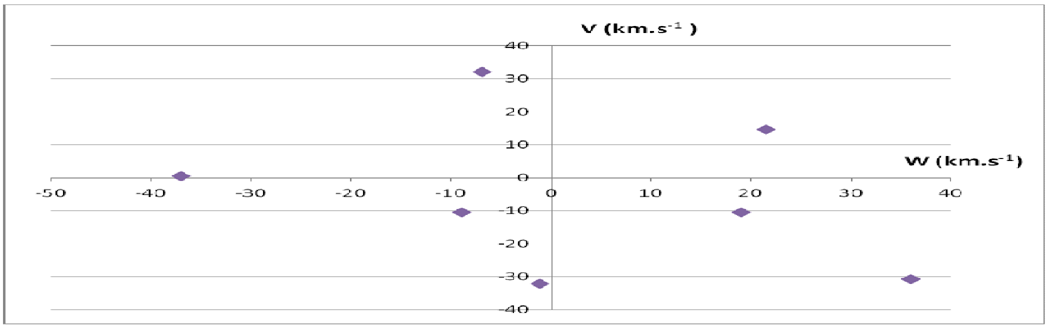
The above results were plotted in order to make decisions' for judgment whether the group of stars represent a Local Association or not for each spectral type, and shown in (Figures2-7) with (V) as a function of (U) and of (W).



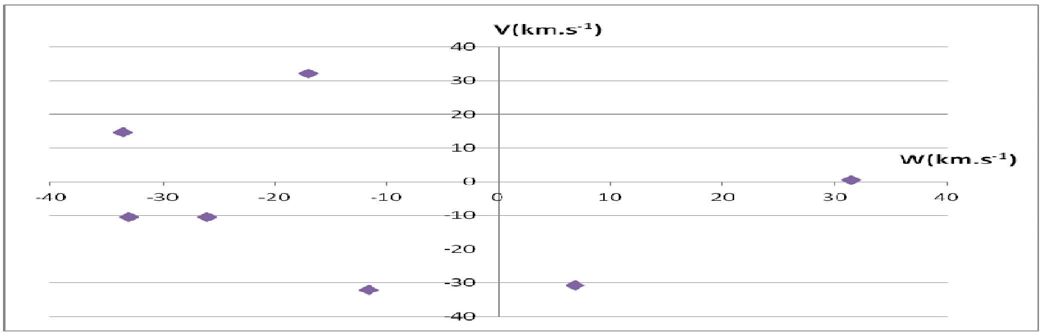
(Figure-2): Relation between (V) as a function of (U) for stars of spectral type (k) in (Table-3)



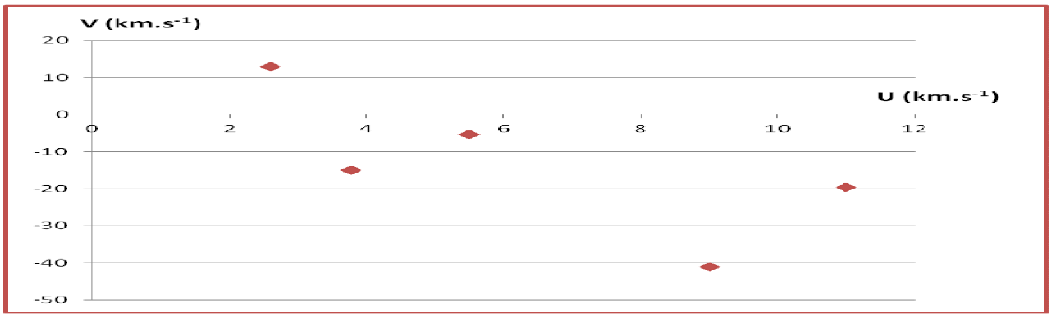
(Figure-3): Relation between (v) as a function of (w) for stars of spectral type (k) in (Table-3)



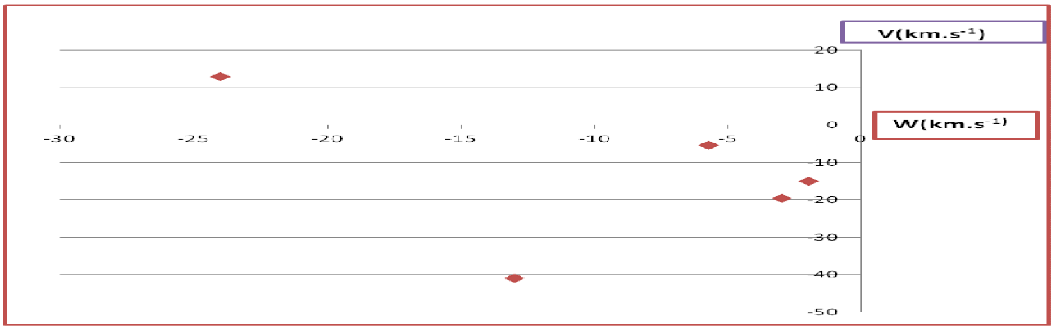
(Figure-4): Relation between (V) as a function of (U) for stars of spectral type (G)



(Figure-5) :Relation between (v) as a of (w) for stars of spectral type (G)



(Figure-6) :Relation between (V) as a function of (U) for stars of spectral type (A)



(Figure-7): Relation between (v) as a function of (w) for stars of spectral type (A)

From the above results & figures it`s obvious that some stars have positive and negative values for (U, V, and W).

Each group (Local Association) must have a positive or negative direction of the velocity. That means the stars in order to be represent members in a Local Association and move together must have positive or negative direction of velocity. Hence **(Table-3)** was refined and became as follows:

(Table-4) (U, V, and W) of the refined stars taken from (Table-3) with spectral types (A, G, and K) after subtraction them from the sun coordinates.

Stars name	Spectral type (S)	U ($km.s^{-1}$)	V ($km.s^{-1}$)	W ($km.s^{-1}$)
Delta capricorni	A7 III	11.12	-19.66	-3.0
Denebola	A3 V	9.8	-41.43	-13.18
Fomalhaut	A3V	3.78	-15.	-1.9
Vega	A0V	5.55	-5.36	-5.75
Capella	G8 III	19.19	-10.56	-33.4
Arcturus	K1	61.28	-97.8	-58.6

From the (Table-4) we have noticed that the selected stars of (A, G, and k) spectral types have the same direction sign of motion, then these stars represent a Local Association. These are well illustrated when they are plotted in (Figures 8-11)
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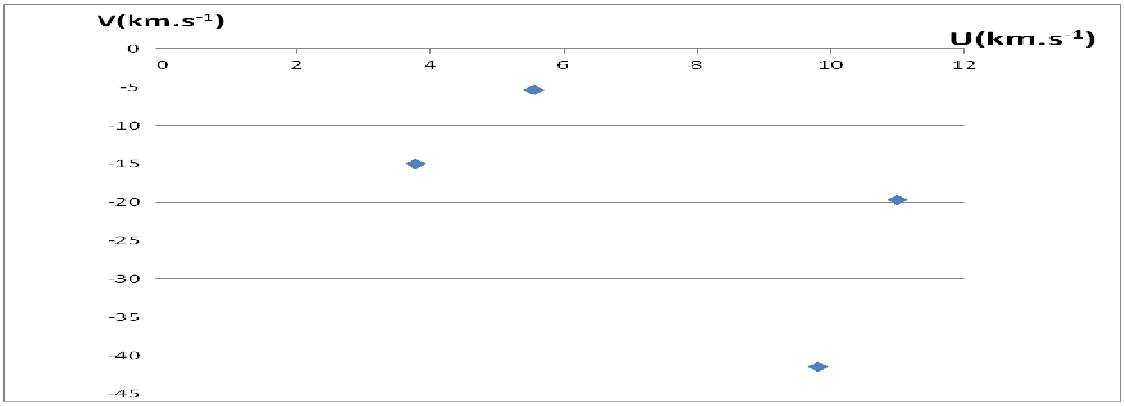
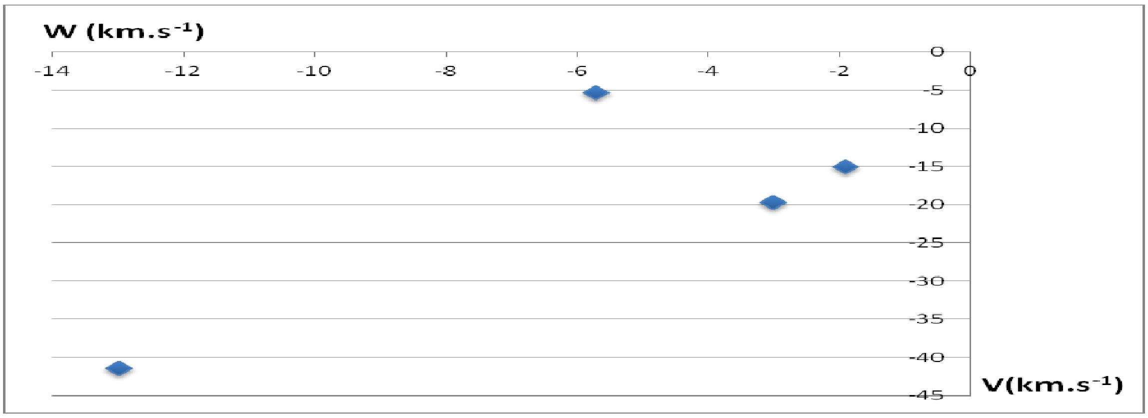
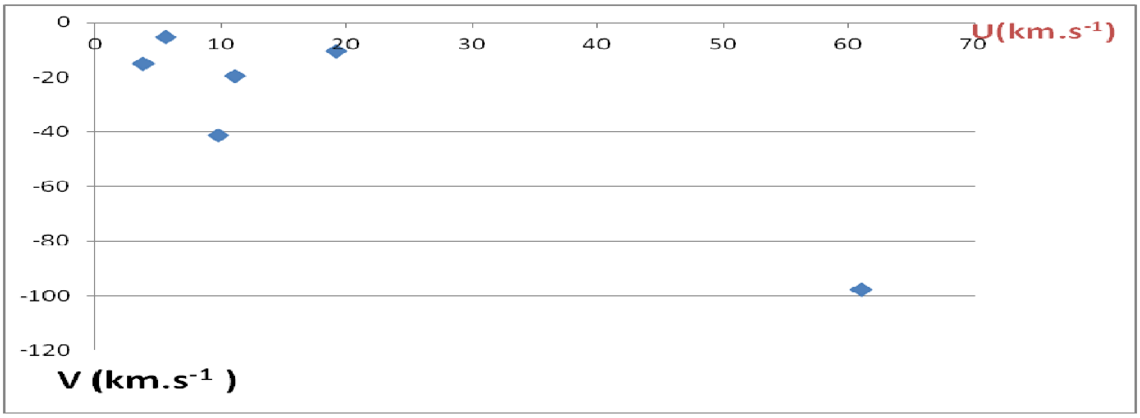


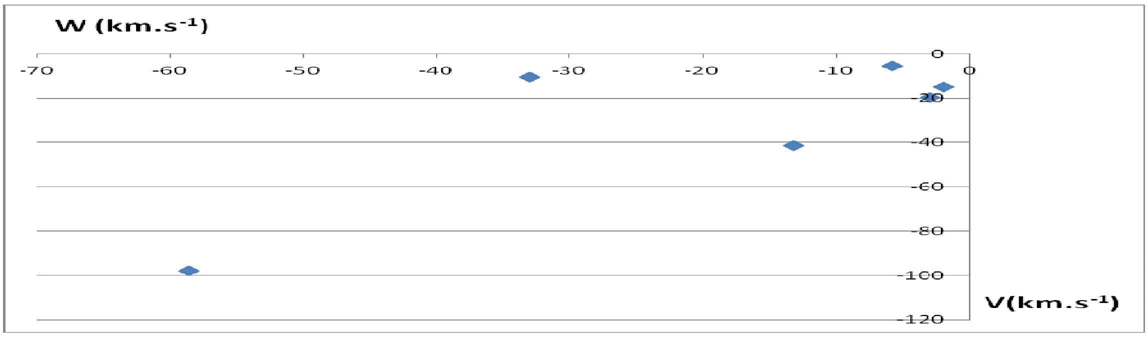
(Figure-8): Relation between (V) as a function of (U) for stars of spectral type (A) showing a Local Association



(Figure-9): Relation between (v) as a function of (w) for stars showing a Local Association for spectral type (A)



(Figure-10): Relation between (V) as a function of (U) for the stars of three spectral type (A, G, and K) in (Table-4) that show the Local Association



(Figure-11): Relation between (v) as a function of (w) for the stars of spectral types (A, G, and K) in (Table -4) that show the Local Association

CONCLUSIONS:

From this investigation it had been found that the contribution of the Local Association for spectral type (A) is better than the other two (K&G) spectral types. This is because group (A) consists of stars closed to each other as shown in the (Table-3) and (Figures -8 and 9).

From (Figures-10 and 11) we concluded that the stars {Delta capricorni, Denebola, fomalhaut, Vega, Capaella, and Arcturus} with spectral types{A7 III ,A3V ,A3V ,G8 III, K1, and A0V} respectively, make up a Local Association, because its stars satisfy the conditions of the Local Association Group .

The direction of motion of this group is away from us, anticlockwise and against the galactic rotation, and downward the galactic plane.

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