



# Statistical distances of the northern sky bright K and M dwarfs with apparent magnitude $J < 9$

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## ABSTRACT

In this paper, we estimate distances and generate the mean absolute magnitudes and dispersions for K and M bright dwarfs using two different approaches. The methods are based on the assumption that the absolute and apparent magnitude follows the exponential and Gaussian distributions functions. The effect of Malmquist bias has been studied to show how effective bias is in comparison. We found that the range between the calculated distances for the spectral subtypes K is small (2.6 pcs), while the range in the distance of the spectral subtypes M is a little big (21.6 pcs), and this may be due to the different chemical compositions and evolution scenarios for each spectral subtype. This means that these dwarfs are situated in the same cloud as near and far sides. We spread the dwarfs above and below the galactic plane to gain certain physical properties based on the statistical study and also on the spectral subtypes. The estimated distances from the two approaches are approximately the same but there are noticeable differences between the generated mean absolute magnitudes and dispersions.

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## 1. Introduction

The main sequence M dwarfs have a cool atmosphere with effective temperatures in the range

2400 K–3700 K (Allard and Hauschildt 1995), and masses of about  $\approx 0.5 M_{\odot}$  (Delfosse et al. 1999). M dwarfs have become of particular interest in their applications to exoplanet research. Their low masses and small radii lead to greater sensitivity to the discovery of orbiting low mass planets via radial velocity and transit techniques. Furthermore, planets lying in the habitable zone around M dwarfs have short orbital periods as well as relatively favourable contrast ratios between the planet and the host star (Frith et al. 2013).

Using applied modern technologies in telescopes, satellites, and sensors offered us a huge amount of data in a wide variety of heavenly objects. When astronomers discovered a new object, they want to study the astrophysical aspects of the object so they can classify its kind carefully. The most important key is the distance to the object; this has been considered as one of the most crucial points of needed information in astronomy.

For example, calibration approximated distance  $d$  (in parsecs) as well as the proper motion of a star  $\mu$  (in second of arc per year), have the ability to calculating the tangential velocity  $V_t$ , the velocity perpendicular to the line of sight (in km per second). The distributed stars in the globular clusters and in its galaxy can be studied if the accurate distance is obtained (Cassisi et al. (2001), Duncan et al. (2001)). Moreover, distance determination is an important issue for astronomers to understand the

philosophy of our universe such as its expansion, size, and age (Willick and Batra (2001) and Mazumdar and Narasimha (1999)). For this reason, there is considerable attention has been paid to using the statistical distribution functions to obtain accurate distance.

Several publications have been appeared in the last years documenting the statistical distance determination. Sharaf et al. (2003) approximated the distance to the stellar group due to the Gaussian distribution function. Abdel-Rahman et al. (2009) suggested three different methods under the Gaussian distribution function used to derive the distance to the stellar groups. Sharaf and Sendi (2010) introduced computational developments for the distance determination of stellar groups. Abdel-Rahman et al. (2012) have also demonstrated that the flexibility of the exponential distribution function for the cosmological distance determinations of the stellar groups. Abdel-Rahman and EL-Essawy (2019) determined the distance to the Camelopardalis area for spectral types and subtypes.

Thévenin, F. et. al. (2017) applied different techniques of geometrical astrometry to various stellar and cosmic objects (Megamaser) that have been introduced to demonstrate the ability of these techniques to measure distances with high accuracy. The ultimate goal was to estimate the  $H_0$  parameter. Arnett, W. D. (1982) developed a dynamic method that uses newly discovered analytical solutions for supernovae of the first type and used a model in this study capable of reproducing both fast and

slow light curves indicating a dispersion of intrinsic brightness, which is approximately the size observed in the Virgo and Coma clusters. Hodgson et al. (2020) proposed a new approach for determining cosmological distances to the active galactic nuclei (AGNs) via light travel time arguments, which can be expanded from near-to-far sources of very high redshift. The main assumption is that the apparent variability in AGNs is limited by the speed of light and thus provides an estimation of the linear size of the emission area.

In this paper, we estimate the distances below and above the galactic plane of M and some K types bright dwarfs of different spectral subtypes. We describe some statistical parameters to get physical properties for M and some K types bright dwarfs, depending on a self-generation of the mean absolute magnitude and optimum dispersions by using the Malmquist relation.

## 2. Observational data and method of analysis

### 2.1. Methods of analysis

To determine the distances, we used the Exponential approach as suggested by Abdel-Rahman et al. (2012) and the Gaussian approach (hereafter  $G_B$ ) as suggested by Abdel-Rahman et al. (2009) to model the distribution of the apparent and absolute magnitude in the following subsections we shall describe the two approaches briefly.

#### 2.1.1. The Exponential approach

The distance  $d_E$  could be determined from the following relation (Abdel-Rahman et al. 2012)

$$d_E = 10^{1 + \frac{(m_1 - \theta y_e)}{5}} \quad (1)$$

where  $y_e$  is the distance parameter, obtained by the solution of the following transcendental equation

$$G(y_e) = \frac{-\frac{1}{2}y_e \frac{m_1}{\theta} + \frac{1}{2} \frac{m_1}{\theta} + \frac{1}{3} \left(\frac{m_1}{\theta}\right)^2}{1 - y_e + \frac{1}{2} \frac{m_1}{\theta}} - \alpha_e = 0 \quad (2)$$

where

$$\alpha_e = \frac{m_1 - \bar{m}_{Exp}}{\theta} \quad (3)$$

$m_1$  is the faintest magnitude limit reached by the Hubble space telescope  $m_1 = 26$  and the mean apparent magnitude  $\bar{m}_E$ .

Where  $\bar{m}_E$  could be given by,

$$\bar{m}_E = \frac{\int_0^{m_1} m(m) dm}{\int_0^{m_1} (m) dm} = \frac{\int_0^{m_1} m e^{\frac{-(m+5-5\log d_{Exp})}{\theta}} dm}{\int_0^{m_1} e^{\frac{-(m+5-5\log d_{Exp})}{\theta}} dm} \quad (4)$$

$$\psi(m) = e^{\frac{-(m+5-5\log d_{Exp})}{\theta}} \quad (5)$$

The distance modulus implies that

$$(m - M)_e = m_1 - \theta y_e \quad (6)$$

To determine the value of  $\theta$ , we take the logarithm of the likelihood function  $l(\theta/M_i)$

$$l(\theta/M_i) = \ln L(\theta/M_i) = -n \ln \theta - \sum_{i=1}^n \frac{M_i}{\theta} \quad (7)$$

Differentiating Eq. (7) with respect  $\theta$  and equating the result to zero

$$-\frac{n}{\hat{\theta}} - \sum_{i=1}^n \frac{M_i}{\hat{\theta}^2} = 0, \quad (8)$$

From (8), we obtain the estimator of  $\theta$  as

$$\hat{\theta} = \sum_{i=1}^n \frac{M_i}{n} = M_0, \quad (9)$$

Posteriorly,  $\hat{\theta}$  is replaced by  $M_0$ .

#### 2.1.2. The Gaussian approach

The distance  $d_G$  could be determined from the following relation (Abdel-Rahman et al. 2009)

$$d_G = 10^{1 + \frac{(m_1 - M_0 - \sigma y_B)}{5}} \quad (10)$$

where  $y_B$  is a solution of the following transcendental equation

$$G(y_B) = y_B - \left\{ e^{-\frac{z_1^2}{2}} + e^{-z_1 y_B} \right\} \left\{ \sqrt{\frac{\pi}{2}} \times \left[ \text{Erf} \left( \frac{y_B}{\sqrt{2}} \right) + \text{Erf} \left( \frac{z_B}{\sqrt{2}} \right) \right] \right\} - \alpha_B = 0 \quad (11)$$

$$\alpha_B = \frac{m_1 - \bar{m}_{GB}}{\sigma}, \quad z_B = z_1 + y_B \text{ and } z_1 = \frac{m_1 - m_g}{\sigma} \quad (8)$$

where  $m_1$  is the faintest apparent magnitude,  $m_g$  is the brightest apparent magnitude,  $\sigma$  is the dispersion, and  $\bar{m}_{GB}$  is the mean apparent magnitude given by:

$$\bar{m}_{GB} = \frac{\int_{m_g}^{m_1} m \psi(m) dm}{\int_{m_g}^{m_1} \psi(m) dm} = \frac{\int_{m_g}^{m_1} m e^{\frac{-(m+5-5\log d - M_0)^2}{2\sigma^2}} dm}{\int_{m_g}^{m_1} e^{\frac{-(m+5-5\log d - M_0)^2}{2\sigma^2}} dm} \quad (12)$$

The error function is given by

$$\text{Erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-\frac{x^2}{2}} dx \quad (13)$$

Malmquist (1924) derived a formula for the absolute magnitude of the form

$$M_0 = \bar{M} + 1.382 \sigma^2 \quad (14)$$

where  $\bar{M}$  is the average of the absolute magnitude of the sample and  $\sigma^2$  is the variance of the population.

We used the percentage errors for the mean ( $F_m(\sigma) = \left| \frac{r_s(\sigma) - \bar{r}}{\bar{r}} \right| * 100$ ) to get the optimum dispersion, where  $r_s(\sigma)$  and  $\bar{r}$  are the statistical distances corresponding to dispersion values and the average distance of the individual stars respectively. The optimum dispersion occurs at a minimum value of percentage errors (Sharaf and Abdel-Rahman (2005)).

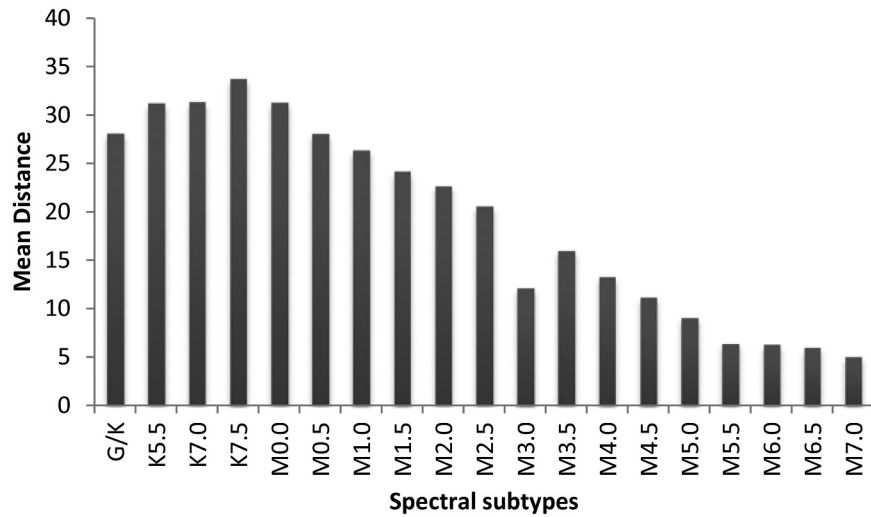
## 2.2. The observation

We used the spectroscopic data of a nearly complete list of M dwarfs in the northern sky with apparent magnitudes  $J < 9$  gathered by L'epine et al. (2013). Their survey identified a total of 1403 very bright M dwarfs. The data contains  $\alpha$ ,  $\delta$ , apparent magnitude, galactic longitude, galactic latitude, parallax, spectral subtypes,

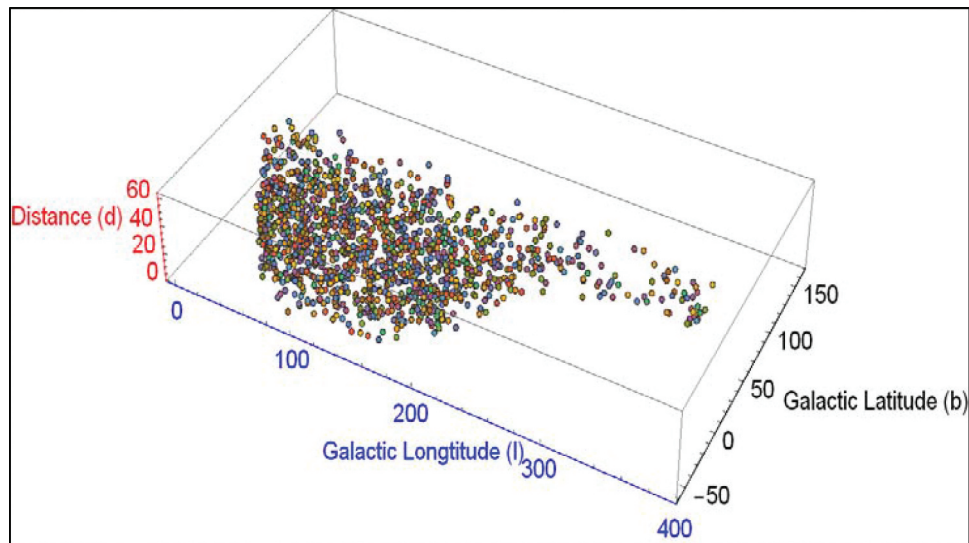
and other parameters. We computed some parameters from the data such as the individual distances and absolute magnitudes for each spectral subtype. The frequency distribution of spectral subtypes is shown in Table 1. The distribution of the bright dwarfs by their mean individual distances and spectral subtypes is shown in Figure 1. The distribution of bright M dwarfs in the northern sky according to their galactic coordinates and mean distances is shown in Figure 2.

**Table 1.** The frequency distribution of spectral subtypes.

Spectral subtypes	G/K	K5.5	K7	K7.5	M0	M0.5	M1	M1.5	M2	M2.5
Frequency	50	1	27	101	177	160	152	147	141	119
Spectral subtypes	M3	M3.5	M4	M4.5	M5	M5.5	M6	M6.5	M7	Total
Frequency	125	125	72	36	13	4	2	2	1	1455



**Figure 1.** The distribution of the spectral subtypes for M bright dwarfs according to mean distance (pc).



**Figure 2.** The distribution of bright M dwarfs in the northern sky according to their galactic coordinates and distances (pc).

### 3. Results and discussions

#### 3.1. Exponential distances

The statistical approach described in subsection 2.1.1 is applied to the sample of stars to determine the distances of the bright M and K dwarfs in the northern sky. The practical applications show that the optimum values of  $\sigma$  can be obtained when  $m_1 = \frac{\bar{m}}{2} - 1$ . The results are given in Tables 2 and 3.

In Table 2: the headings of the columns are: column 1 denote the Spectral subtypes of the bright M dwarfs from K to M, column 2 for the frequencies, column 3 for the mean apparent magnitude  $\bar{m}$ , column 4 the unbiased dispersion  $\sigma$ , column 5 gives the unbiased mean absolute magnitude  $M_0$ , column 6 contains the parameter  $\alpha$ , column 7 gives the solution of equation (2) ( $y$ ) and column 8 for the statistical distance  $d_E$  computed by Equation (1).

Table 2 shows the results for the distances of spectral subtypes of M dwarfs situated between 28 pcs for G/K subtype to 31.4, 34 pcs for K5.5- K7 and K7.5. The distances of M0 and M7 are 31.3 and 10 pcs respectively.

We noted that the statistical distances have direct proportional to the subtypes of the K-type (from K 5.5 to K7.5) and the distances have inverse proportional to the subtypes of the M-type (from M0 to M7). The difference in the distance in K-subtypes (K5.5 to K7.5) is about 2.6 pcs and in M-subtypes is about 21 pcs approximately. Although both belong to the same spectral type M, a 21

**Table 2.** The Exponential parameters and distances  $d_E$  of a bright M dwarfs for spectral subtypes from K to M.

Spectral subtypes	Frequency	$\bar{m}$	$\sigma$	$M_0$	$\alpha$	$y$	$d_E$ (Pc)
G/K	50	10.91	6.50	8.78	0.209	0.354	$28 \pm 1.27$
K5.5- K7	28	10.99	6.49	8.73	0.209	0.352	$31.4 \pm 2.12$
K7.5	101	1.22	6.48	8.69	0.210	0.350	$34 \pm 0.86$
M0	177	11.20	6.48	8.81	0.209	0.352	$31.3 \pm 0.62$
M0.5	160	11.34	6.47	9.20	0.209	0.354	$28.09 \pm 0.69$
M1	152	11.39	6.47	9.41	0.208	0.355	$26.37 \pm 0.66$
M1.5	147	11.59	6.46	9.81	0.208	0.357	$24.07 \pm 0.61$
M2	141	11.80	6.46	10.16	0.207	0.359	$22.62 \pm 0.63$
M2.5	119	12.01	6.44	10.55	0.207	0.361	$20.52 \pm 0.53$
M3	125	12.15	6.43	11.04	0.206	0.364	$17.57 \pm 0.47$
M3.5	125	12.52	6.41	11.61	0.205	0.366	$16.08 \pm 0.41$
M4	72	12.68	6.40	12.21	0.204	0.369	$13.34 \pm 0.59$
M4.5- M7	58	13.36	6.36	13.54	0.202	0.375	$10 \pm 0.51$

pcs difference is quite big. This is an indicator of some kind of differences in the chemical constituents of the original cloud, then this is evolutionary and can be attributed to the differences in the chemical and physical constitution of the K and M subtypes. The width of the clouds is 24 pcs ( $34 - 10 = 24$  pcs), this means K's and M0 to M2.5 spectral subtypes are situated on the far side, while M3 to M7 is located at the near side of the cloud. The distribution for the M bright dwarfs in the Milky Way according to the spectral subtypes with their distances is shown in Figure 3.

Table 3 shows the results for galactic latitude classes above and below (positive – minus) of the galactic plane for the brightest M dwarfs in the northern sky. The headings of the columns are the same as in Table 2 except for column 1 which is the classes of the galactic latitude. To construct the frequency distribution, we followed the steps described by Abdel-Rahman et al. (2017).

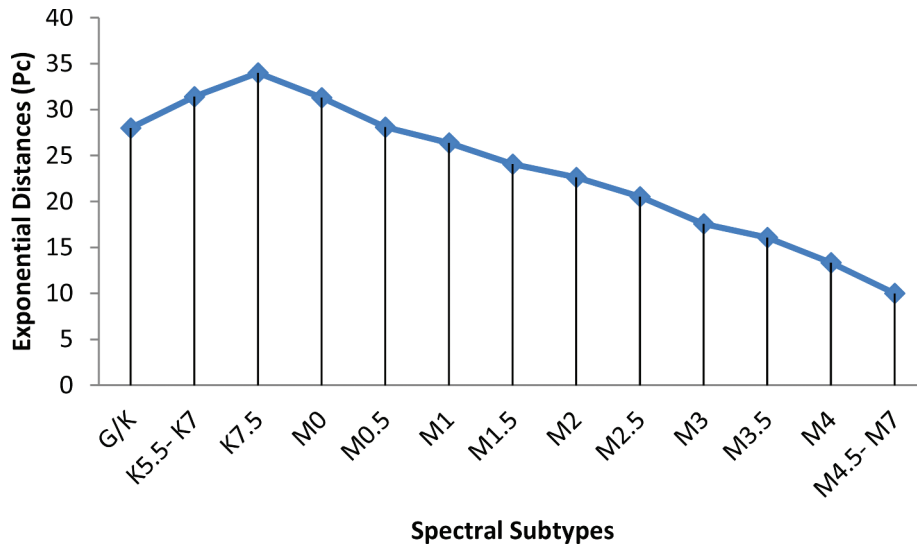
The total number of the data is 1455 bright dwarfs and the number of the classes for the range  $-10.88^\circ$  to  $60^\circ$  is 400 dwarfs by approximate percentage frequency 27.5% while for the range  $-10.88^\circ$  to  $13.68^\circ$  is 297 dwarfs from above and below the galactic plane by approximate percentage 20.4%. In the range  $13.68^\circ$  to  $87.36^\circ$  above the galactic plane the number of stars is 758 dwarfs by 52%. The total number above the galactic plane beginning from class 1.4 to  $87.36^\circ$  is 919 dwarfs with percentage frequencies 63%, i.e. the largest number of brightest dwarfs are situated above the galactic plane.

The estimated distances of classes with galactic latitudes  $[(-47.72^\circ - -35.44^\circ), (-23.16^\circ - -10.88^\circ)]$  and  $(-10.88 - 1.4^\circ)$  have the same distance  $\sim 24$  pcs and are situated below the galactic plane while the classes  $(1.4^\circ - 13.68^\circ, 25.96^\circ - 38.24^\circ$  and  $62.8^\circ - 75.08^\circ)$  have the same distance  $\sim 22$  pcs and up the galactic plane. The two classes  $(-47.72^\circ - -35.44^\circ$  and  $38.24^\circ - 62.8^\circ)$  have the same distance 24 pcs and  $[(-35.44^\circ - -23.16^\circ)$  and  $(75.08 - 87.36^\circ)] \sim 25$  pcs above and below the galactic plane and the class  $(-60 - -47.72)$  have the distance  $\sim 27$  pcs.

The difference in distances of the classes situated above and below the galactic plane is very small. Since our estimated distances are statistically, we can infer that the original clouds that are formed the brightest M dwarfs in the northern sky are at a distance of 24

**Table 3** The distances  $d_E$  of a bright M dwarfs for the galactic latitudes above and below the galactic plane.

Classes	Frequency	$\bar{m}$	$\sigma$	$M_0$	$\alpha$	$y$	$d_E$ (Pc)
$-60 - -47.72$	45	11.71	6.45	9.71	0.208	0.355	$27 \pm 1.5$
$-47.72 - -35.44$	87	11.70	6.44	10.05	0.208	0.357	$24 \pm 1.1$
$-35.44 - -23.16$	98	11.65	6.45	9.83	0.208	0.357	$25 \pm 0.96$
$-23.16 - -10.88$	170	11.73	6.44	10.06	0.208	0.358	$23.9 \pm 0.74$
$-10.88^\circ - 1.4^\circ$	136	11.66	6.45	9.99	0.208	0.358	$23.7 \pm 0.78$
$1.4^\circ - 13.68^\circ$	161	11.80	6.44	10.28	0.207	0.359	$22.4 \pm 0.75$
$13.68^\circ - 25.96^\circ$	173	11.64	6.45	9.93	0.208	0.357	$24.3 \pm 0.72$
$25.96^\circ - 38.24^\circ$	160	11.93	6.43	10.36	0.207	0.358	$22.9 \pm 0.76$
$38.24^\circ - 62.8^\circ$	257	11.79	6.44	10.05	0.208	0.357	$24.57 \pm 0.6$
$62.8^\circ - 75.08^\circ$	118	11.65	6.45	10.19	0.207	0.359	$22 \pm 0.9$
$75.08 - 87.36^\circ$	50	11.67	6.45	9.78	0.208	0.356	$25.64 \pm 1.3$



**Figure 3.** The distribution for the M bright dwarfs in the Milky Way according to the spectral subtypes and with distances computed using the exponential approach.

pcs above and below the galactic plane. The average distance for M-dwarf stars according to the galactic latitude classes is about  $24 \pm 0.92$  pcs.

Figure 4 shows the frequency distribution of the statistical distances  $d_E$  for bright M dwarfs above and below the galactic plane.

### 3.1.1. Statistics of some parameters: the distances $d$ , $\sigma$ , and $M_0$

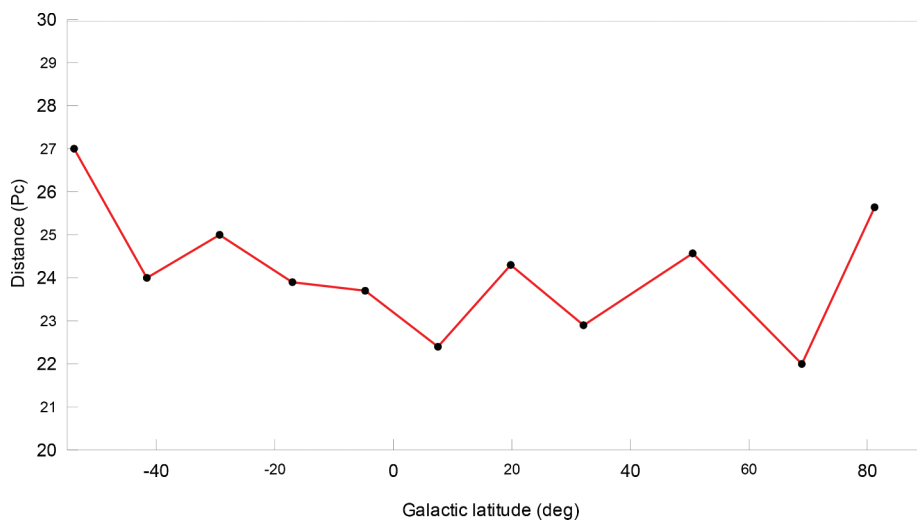
For K spectral subtypes in Table 2: we found that the minimum value of spectral subtypes is 31.4 pcs for K5.5- K7 and the maximum is 34 for K7.5 with range 2.6 pcs and the mean distance is  $32.7 \text{ pcs} \pm 1.5 \text{ pcs}$ , while the mean dispersion of spectral subtypes K has the mean  $6.485 \pm 0.005$ . The average mean absolute magnitude for the K spectral subtypes is  $8.71 \pm 0.02$  for K. We note that the range of these distances is small; it may an indicator that the dwarfs are situated in the same cloud.

For M spectral subtypes, we note that the minimum value is 10 pcs for (M4.5 – M7) and the maximum is 31.4 pcs for M0 with range 21.4 pcs and the mean distance is  $21 \pm 2.14$  pcs, while the average dispersion is  $6.44 \pm 0.12$  and the average mean absolute magnitude is  $10.6 \pm 0.47$  pcs.

According to the galactic latitude in Table 3, we found that: the distances of all classes are comparable with a difference  $\sim 5$  pcs, this means that the bright dwarfs are situated in the same cloud. The average dispersion is  $6.44 \pm 0.002$  and the average mean absolute magnitude is  $10.02 \pm 0.06$ .

### 3.2. Gaussian distances

We estimate the Gaussian distances and generate the mean absolute magnitudes and dispersions for the spectral subtypes whenever the number of stars is sufficient statistically. All dwarfs of spectral subtypes



**Figure 4.** The frequency distribution for the M bright dwarfs in the Milky Way according to the galactic latitude with its exponential distances.



K and M were used to derive the statistical distances for each spectral subtype whenever the number is sufficient. The statistical approach described in section 2.1.2 is applied and the results are given in Tables 4 and 5.

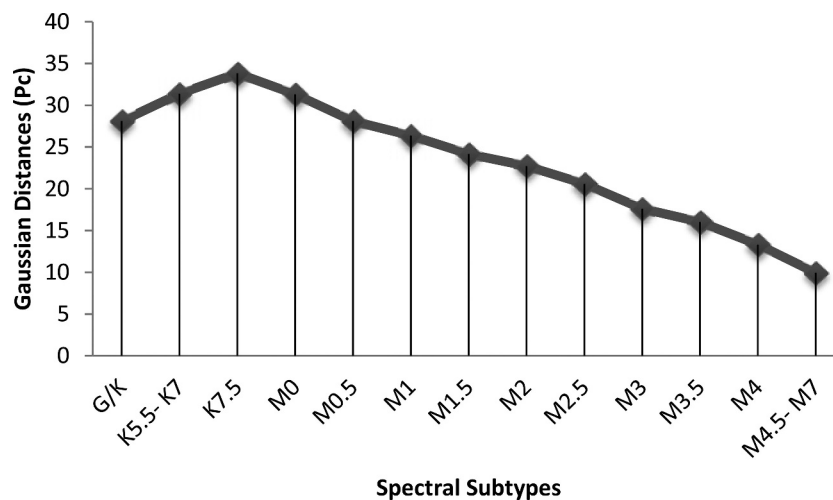
In Table 4: the headings of the columns are self-explained but columns 3 and 4 are the limiting magnitude  $m_L$  (the faintest dwarf in the sample) and  $m_g$  (the brightest dwarf in the sample). We found that the distances of G/K are about 28 pcs and the distances for K5.5- K7 and K7.5 are 31.4 and 33.8 pcs respectively, the difference in the distance is about 2.6 pcs. This means that both intervals belong to the same association and spectral type, a 2.6 pcs difference is small. While the distances of M0, M0.5, and M1 are 31.3, 28, and 26.4, the difference about 3.3, 1.6 and 5 pcs between them respectively and for M1.5, M2, and M2.5 have nearly the same distances (the difference from 1.5 to 4 pcs), while the distance of M3 and M3.5 are 17.6 and 16 pcs, the difference is about 1.6 pcs, and the differences between M3.5, M4, and M4.5- M7 are about 3 pcs. Also, we find that the difference in distance between M0 to M4.5- M7 is 21.3 pcs, this mean that K5.5- K7, K7.5, and M0 to M2.5 are situated on

the far side of the cloud while the other spectral subtypes are situated in the middle and near side of the association. This could be an indication that the chemical compositions of the original cloud are identical. The distribution for the M bright dwarfs in the Milky Way according to the spectral subtypes with their distances is shown in Figure 5.

Table 5 shows the distribution of M bright dwarfs, mixed between the spectral subtypes K and M, according to the galactic latitude regardless of the spectral subtype and we note that: the total number below the galactic plane to 1.4 is 536 dwarfs by percentage frequency 36.84% and from 1.4 to 87.36 is 919 dwarfs by percentage 63.16%, this means that the large ratio of dwarfs is situated above the galactic plane. The estimated largest distance is 27 pc at the class  $(-47.72 - -60)$  below the galactic plane and the smallest is approximately 24 pc at the class  $(-10.88-1.4)$  while above the galactic plane, the largest is 25.7 pc at  $+75.08-87.36$  and the smallest is 22.1 at the class  $(+62.8-75.08)$ . The differences in distance between all classes of galactic latitude below and above galactic plane are about 1 to 3 pcs, it is a small difference. We think that all dwarfs are formed in this cloud and the

**Table 4.** The Gaussian parameters and distances  $d_G$  of a bright M dwarfs in the northern sky according to spectral subtypes from K to M.

Spectral subtypes	Freq.	$m_l$	$m_g$	$\bar{m}$	$\sigma$	$M_0$	A	y	$d_G$ "Pc"
G/K	50	12.99	8.73	10.91	1.136	8.78	1.83	0.161	$28.11 \pm 1.27$
K5.5- K7	28	11.99	8.86	10.99	0.716	8.73	1.40	0.094	$31.39 \pm 2.12$
K7.5	101	12.34	6.60	11.22	0.83	8.69	1.35	0.062	$33.83 \pm 0.86$
M0	177	12.61	8.61	11.20	0.939	8.81	1.50	0.113	$31.32 \pm 0.62$
M0.5	160	13.77	8.99	11.32	1.236	9.20	1.98	0.173	$28.11 \pm 0.69$
M1	152	12.50	8.55	11.38	0.814	9.41	1.38	0.085	$26.37 \pm 0.66$
M1.5	147	12.99	7.49	11.59	0.926	9.81	1.51	0.086	$24.16 \pm 0.61$
M2	141	14.31	9.65	11.80	1.245	10.16	2.02	0.181	$22.73 \pm 0.63$
M2.5	119	13.23	9.12	12.01	0.869	10.55	1.40	0.09	$20.59 \pm 0.53$
M3	125	13.72	8.94	12.15	0.986	11.04	1.59	0.109	$17.61 \pm 0.47$
M3.5	125	13.91	9.64	12.52	0.924	11.61	1.50	0.103	$16.03 \pm 0.41$
M4	72	14.32	9.54	12.68	1.0	12.21	1.65	0.116	$13.33 \pm 0.59$
M4.5- M7	58	15.33	10.05	13.36	1.096	13.54	1.80	0.13	$9.94 \pm 0.51$



**Figure 5.** The frequency distribution of the Gaussian distances for the M bright dwarfs in the Milky Way.

**Table 5.** The Gaussian parameters and distances  $d_G$  of a bright M dwarfs in the- northern sky according to the Galactic Latitude.

Classes (degrees)	Freq.	$m_l$	$m_g$	$\bar{m}$	$\sigma$	$M_0$	$\alpha$	$\gamma$	$d_G$ "Pc"
-60°: -47.72°	45	13.48	8.98	11.71	1.03	9.71	1.72	0.13	$27.10 \pm 1.50$
-47.72°: -35.44°	87	15.13	8.68	11.70	1.45	10.05	2.36	0.19	$23.90 \pm 1.08$
-35.44°: -23.16°	98	14.34	9.61	11.65	1.28	9.83	2.10	0.19	$24.96 \pm 0.96$
-23.16°: -10.88°	170	14.31	9.02	11.73	1.258	10.06	2.07	0.17	$23.83 \pm 0.74$
-10.88°: 1.4°	136	15.22	8.73	11.66	1.49	9.99	2.39	0.19	$23.69 \pm 0.78$
1.4°: +13.68°	161	15.33	8.55	11.80	1.48	10.28	2.39	0.19	$22.40 \pm 0.75$
+13.68°: +25.96°	173	14.09	8.94	11.64	1.21	9.93	2.02	0.17	$24.24 \pm 0.72$
+25.96°: +38.24°	160	14.74	8.81	11.93	1.32	10.36	2.15	0.17	$22.93 \pm 0.76$
+38.24°: +62.8°	257	14.06	6.60	11.79	1.18	10.05	1.93	0.11	$24.59 \pm 0.62$
+62.8°: +75.08°	118	15.02	7.49	11.65	1.44	10.19	2.34	0.16	$22.11 \pm 0.93$
+75.08°: +87.36°	50	13.22	9.06	11.67	0.96	9.78	1.61	0.12	$25.67 \pm 1.28$

evolution process occurred at the same time for these dwarfs in its regions. Figure 6 shows the frequency distribution of the statistical distances  $d_G$  for bright M dwarfs above and below the galactic plane.

### 3.2.1. Statistics of some parameters: the distances $d$ , $\sigma$ , and $M_0$

For K spectral subtypes in Table 4: we found that the minimum distance is 31.4 pcs for K5.5- K7 and the maximum is 34 for K7.5 with range 2.6 pcs and the mean distance is  $32.6 \text{ pcs} \pm 1.22 \text{ pcs}$ , while the dispersion of spectral subtypes K has the mean 0.77 and the standard error  $\pm 0.057$ . The average mean absolute magnitude is  $8.71 \pm 0.02$  for K. We note that the range of these distances is small. This may indicate that the sample of stars is situated in the same cloud.

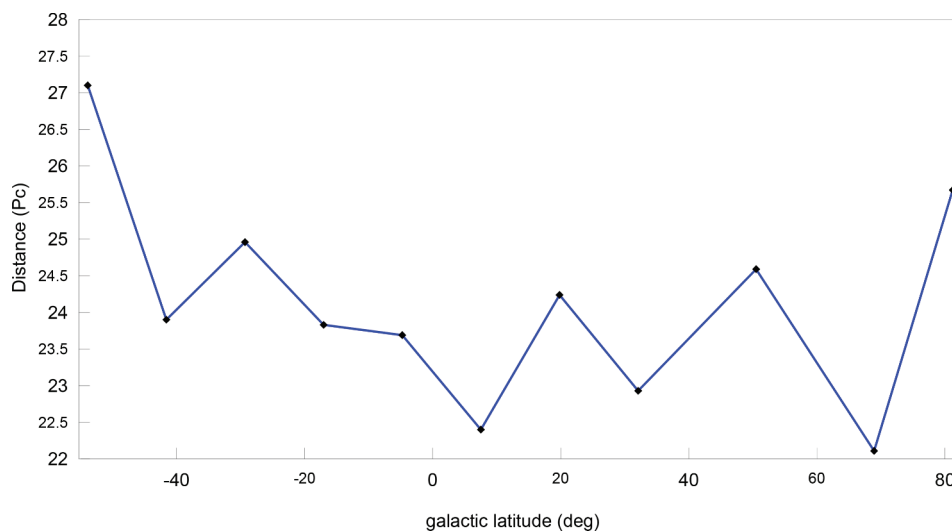
For M spectral subtypes, we note that the minimum distance value of M spectral subtypes is 10 pcs for (M4.5 – M7) and the maximum is 31.3 pcs for M0 with range 21.3 pcs and the mean distances is  $21 \text{ pcs} \pm 2.15 \text{ pcs}$ , while the average of dispersion is  $1.004 \pm 0.046$  and the average mean absolute magnitude for spectral subtypes is  $10.63 \text{ pcs} \pm 0.47 \text{ pcs}$ .

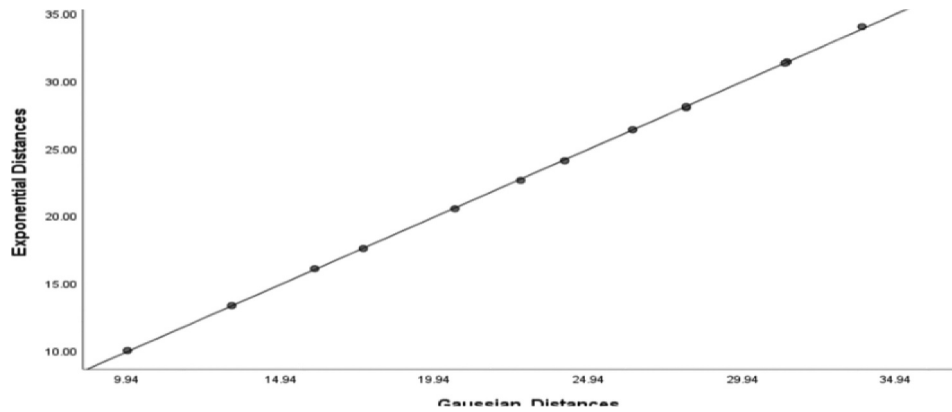
According to the galactic latitude in Table 5, we found that: the distances in all classes are near each other's and the minimum distance is 22 pcs and the maximum distance is 27 pcs and the range is 5 pcs, this means that the bright dwarfs are situated in the same cloud. The average dispersion is  $1.28 \pm 0.054$  and the average mean absolute magnitude is  $10.02 \pm 0.06$ .

By comparing the results of the distances obtained from the two methods (Table 2 with Tables 4 and 3 with Table 5), Figures 7 and 8 plot this comparison. We found that the correlation coefficient in the case of a perfectly linear spectral sculpting type is equal to one and also in the case of galactic length is approximately equal to one (99.9 %).

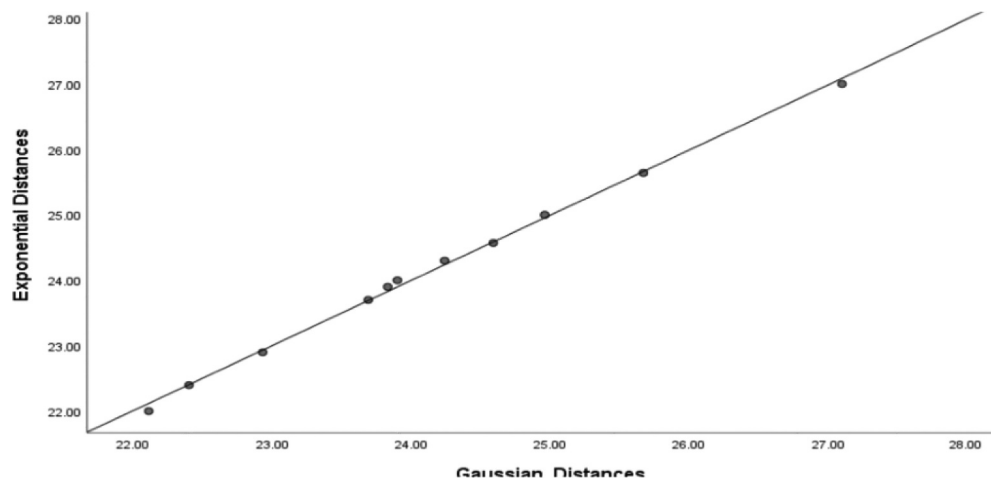
## 4. Conclusion

In the present paper, the distances of the M dwarfs are calculated for each spectral subtype from K to M and the galactic latitude from  $-60^\circ$  to  $87.36^\circ$ . Moreover; we generate the mean absolute magnitude and dispersion for each spectral subtype and each class of galactic latitude.

**Figure 6.** The distribution for the M bright dwarfs in the Milky Way according to the galactic latitude with its Gaussian distances.



**Figure 7.** Comparison of the statistical distances between Gaussian and Exponential of a bright M dwarfs for spectral subtypes from K to M.



**Figure 8.** Comparison of the statistical distances between Gaussian and Exponential of a bright M dwarfs for galactic latitudes.

- The distances estimated from the two approaches are approximately the same but the generation of the mean absolute magnitudes and dispersions are different.
  - The differences between the exponential and Gaussian distances are nonsystematic for the M dwarfs, which may be attributed to their chemical constituents and locations in the northern sky.
- In Table 2, there are small differences between distances for K and M dwarfs, which means that these dwarfs are situated near and far sides in the same cloud.
- Tables 3 and 5 shows that the original clouds that form the brightest M dwarfs in the northern sky are at a distance of 24 pcs above and below the galactic plane.
- If we are looking at the results of the two approaches in Tables 2, 3, 4, 5, we find that the distances are very close to each other but the dispersions and the mean absolute magnitudes are different.

- The exponential and Gaussian statistical distributions functions demonstrated their feasibility to estimate the cosmological distance to the bright M dwarfs in the northern sky.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

### References

- Abdel-Rahman HI, EL-Essawy SH. 2019. Statistical distance determination of the Camelopardalis area. *NRIAG Journal of Astronomy and Geophysics*. 8(1):112–116. doi:10.1080/20909977.2019.1626561.
- Abdel-Rahman HI, Issa IA, Sharaf MA, Nough MI, Bakry A, Osman AI, Saad AS, Kamal, Essam FY. 2009. Statistical Gaussian Distribution Function as a Distance Indicator to Stellar Groups. *Journal of the Korean Astronomical Society*. 42(4):71–79. doi:10.5303/JKAS.2009.42.4.071.
- Abdel-Rahman HI, Nough MI, Elsanhoury WH. 2017. Statistical Study of Visual Binaries. *Astrophysical Bulletin* 72(2):199–205.



- Abdel-Rahman HI, Sabry MA, Issa IA. 2012. Statistical exponential distribution function as a distance indicator to stellar groups. *NRIAG Journal of Astronomy and Geophysics*. 1(1):77–80. doi:[10.1016/j.nrjag.2012.12.001](https://doi.org/10.1016/j.nrjag.2012.12.001).
- Abdel-Rahman HI, Sharaf MA, Nouh MI, Saad AS, Osman AI, Ahmed AB, Mohanna M, Issa I. A ND. 2005. Distance determination for some stellar groups. *Journal of astronomical society Egypt*. Vol. 2, JASE. p. 22–33.
- Allard F, Hauschildt PH. 1995. Model Atmospheres for M (Sub)Dwarf Stars. I. The Base Model Grid. *Astrophysical Journal*. 445:433. doi:[10.1086/175708](https://doi.org/10.1086/175708).
- Arnett WD. 1982. The cosmic distance scale: Methods for determining the distance to supernovae. *Astrophysical Journal*. Part 1. 254 1982 Mar 1. 1–7. doi:[10.1086/159698](https://doi.org/10.1086/159698).
- Cassisi S, de Santis R, Piersimoni AM. 2001. The distance to Galactic globular clusters through RR Lyrae pulsational properties. *Monthly Notices of the Royal Astronomical Society*. 326(1):342–348. doi:[10.1046/j.1365-8711.2001.04613.x](https://doi.org/10.1046/j.1365-8711.2001.04613.x).
- Delfosse X, Forveille T, Udry S, Beuzit J-L, Mayor M, Perrier C. 1999. Accurate masses of very low mass stars. II. The Very Low Mass Triple System GL 866. *Astronomy and Astrophysics*. 351:619–626.
- Duncan D, Chaboyer B, Carney B, Girard T, Latham D, Layden A, McWilliam A, Sarajedini A, Shao M. 2001. Anchoring the Population II Distance Scale: accurate Ages for Globular Clusters and Field Halo Stars. *American Astronomical Society, 198th AAS Meeting*, id.63.09; *Bulletin of the American Astronomical Society*. Vol. 33. p. 881.
- Frith J, Pinfield DJ, Jones HRA, Barnes JR, Pavlenko Y, Martin EL, Brown C, Kuznetsov MK, Marocco F, Tata R, et al. 2013. A catalogue of bright (K<9) M dwarfs. *MNRAS*. 435:2161–2170.
- Hodgson JA, Benjamin L, Liodakis I, Lee S-S, Shafieloo A. 2020. Using variability and VLBI to measure cosmological distances. *Monthly Notices of the Royal Astronomical Society: Letters*. 495(1):L27–L31. doi:[10.1093/mnras/laa051](https://doi.org/10.1093/mnras/laa051).
- L'epine S, Hilton JE, Mann WA, Matthew Wilde M, Rojas-Ayala B, Cruz LK, Gaidos E. 2013. A Spectroscopic Catalog of The Brightest (J<9) M Dwarfs in The Northern Sky. *The Astronomical Journal*. 145(102):3–16.
- Malmquist KG. 1924. Researches on the Distribution of the Absolute Magnitudes of the Stars. *MNRAS*. 32:64.
- Mazumdar A, Narasimha D. 1999. Cepheid distance estimation for Virgo cluster. *Current Science*. 80(3):361–368.
- Sharaf MA, Issa IA, Saad AS. 2003. A method for the determination of cosmic distances. *New Astronomy*. 8 (1):15–21. doi:[10.1016/S1384-1076\(02\)00198-7](https://doi.org/10.1016/S1384-1076(02)00198-7).
- Sharaf MA, Sendi AM. 2010. Computational developments for distance determination of stellar groups. *Journal of Astrophysics and Astronomy*. 31(1):3–16. doi:[10.1007/s12036-010-0002-0](https://doi.org/10.1007/s12036-010-0002-0).
- Thévenin F, Falanga M, Kuo CY, Pietrzyński G, Yamaguchi M. 2017. Modern Geometric Methods of Distance Determination. *Space Science Reviews*. 212(3–4):1787–1815. doi:[10.1007/s11214-017-0418-9](https://doi.org/10.1007/s11214-017-0418-9).
- Willick JA, Batra P. 2001. A Determination of the Hubble Constant from Cepheid Distances and a Model of the Local Peculiar Velocity Field. *The Astrophysical Journal*. 548(2):564–584. doi:[10.1086/319005](https://doi.org/10.1086/319005).