ROTATIONAL VELOCITY OF THE METAL-POOR K-GIANT STARS IN THE MILKY WAY

A Project Work

Submitted to the Department of Physics,
Tri−Chandra Multiple Campus,in the Partial Fulfillment for the Requirement of Bachelor's Degree of Science in Physics

By

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TU Reg no.: 5 - 2 - 37 - 840 - 2016

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February, 2021

Declaration

Project report entitled **Rotational Velocity of the Metal-Poor K-giant Stars in the Milky Way** which is being submitted to the Department of Physics Tri-Chandra Multiple Campus, is a project work carried out by me under the supervision of Asst. Prof. Madhu Sudan Paudel and Mr. Raj K Pradhan.

I hereby declare that this written submission represents my ideas in my own words and where other's ideas or words have been included and I have cited the references of the original sources that I have used.

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Recommendation

It is certified that **Mr. Ukesh Karki** has carried out the project work entitled **Rotational Velocity of the Metal-Poor K-giant Stars in the Milky Way** under my supervision.

I recommend the project work in the Partial fulfillment for the requirement of Bachelor's Degree of Science in Physics.

Asst. Prof. Madhu Sudan Paudel	Raj Kumar Pradhan
Supervisor	Co-supervisor
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Tri-Chandra Campus	Amrit Campus
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	Pokhara Astronomical Society

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Letter of Approval

We certify that we have read this project work and in our opinion it is good in the scope and quality as project work in the partial fulfillment for the requirement of Bachelor's Degree of Science in Physics.

External Examiner

Internal Examiner

Asst. Prof. Madhu Sudan Paudel
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Asst. Prof. Iswar Prasad Koirala
Head
Department of Physics
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Raj Kumar Pradhan
Co-supervisor

Date:..........................

Certificate

This is to certify that the project report **Rotational Velocity of the Metal-Poor K-giant Stars in the Milky Way** carried out by Mr. Ukesh Karki, of final year B.Sc. in physics during the year $2020 - 2021$ is an excellent work submitted to the Department of Physics, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu, in partial fulfillment of requirement for the award of degree of Bachelor of Science in Physics.

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where p is parallax and d is distance of star, further for small p we can write :
$\tan p \approx p$

$$d = \frac{1}{p} \tag{2.2}$$

We get distance of star in parsec when parallax is in arcseconds. This method is popularly used in determining the distance of distant celestial body.

To explain the working mechanism of parallax, we consider a pencil shifting method as parallax. In this method, we extend our arm and observe the position of pencil by the right eye while the left eye is closed. By doing so, we can observe the shift in its position.

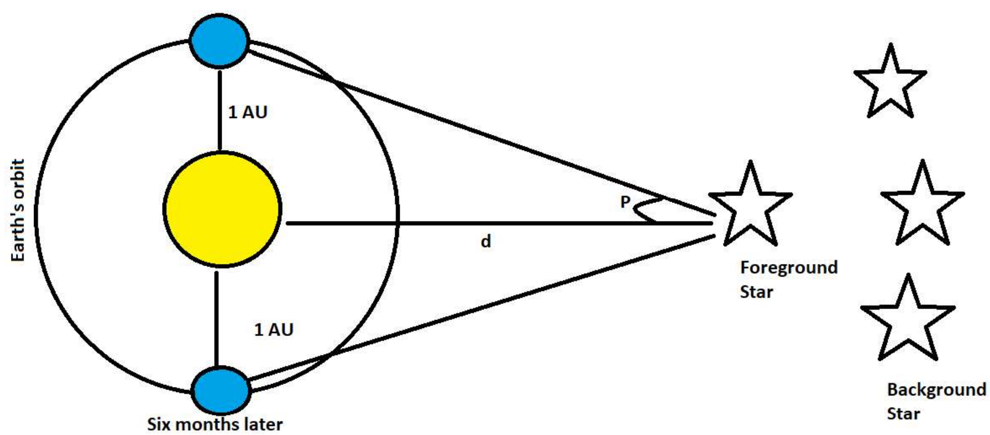

Figure 2.1: Stellar parallax of star with parallax (p) situated at distance (d) from the Sun, where 1 AU (Astronomical Unit) is distance between the Sun and Earth.

2.2 Proper Motion

Stars appear to maintain a fixed position relative its neighbor stars, so we see fix the shape of the constellation. But in reality over a long period of time, this constellation changes its shape which means stars are in independent motion. This motion is caused by the movement of the star relative to the Sun and solar system.

So, we can define the proper motion as astrometric measure of the observed changes in the position of the stars and celestial bodies as observed form the Sun. It is generally measured in arcseconds (as/yr) per year or milliarcsecond per year (mas/yr) [8]. It is a 2-dimensional vector that can be defined by two quantities - position angle and its magnitude. The first quantity gives the direction of motion in the celestial sphere and the second quantity gives motion's magnitude.

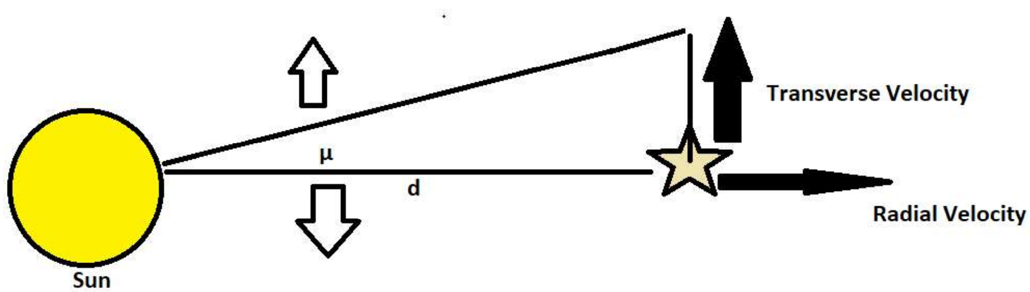

Figure 2.2: Proper motion of the star.

2.3 Velocity Anisotropy

Velocity anisotropy characterizes the extent to which orbits in the stellar system are predominantly tangential, isotropic, or radial. It is denoted by the symbol β. If σ_r(r) be velocity dispersion along the radial vector and σ_t(r) be velocity dispersion along perpendicular direction then velocity anisotropy is given as: [10]

$$\beta = 1 - \frac{\sigma_t^2}{\sigma_r^2} \tag{2.3}$$

In case of variate z has a mean μ=0 and variance σ=1. So, now, we have characteristics function of z as:

$$\phi(t) = \exp\left(-\frac{1}{2}\sigma^2 t^2\right) \tag{2.21}$$

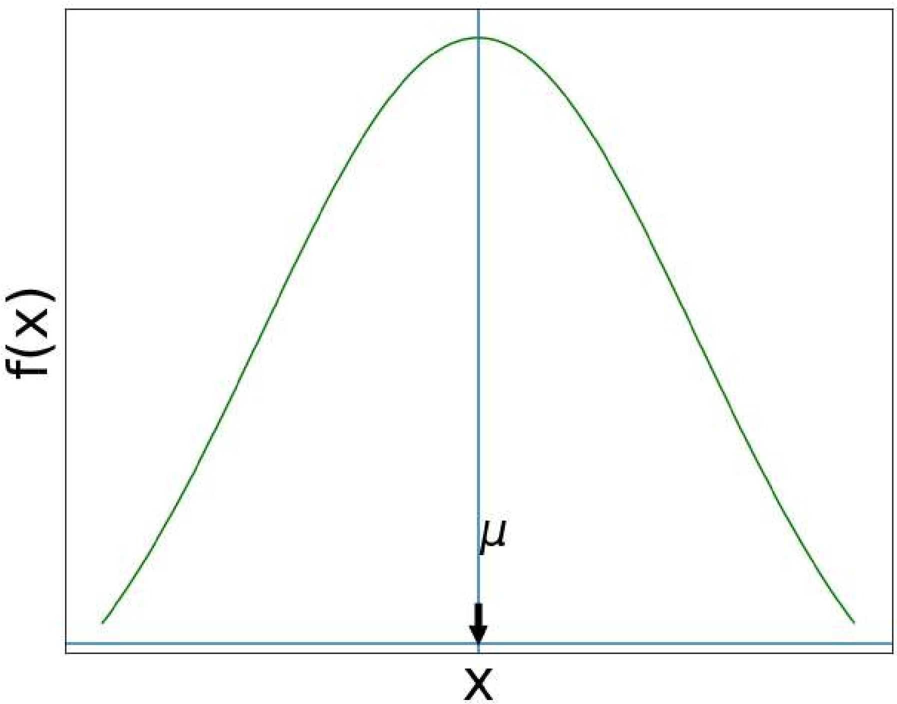

Figure 2.4: Probability density function of the Gaussian distribution with mean μ and variance σ^2.

2.7 Bayes' Theorem

Bayes' theorem was given by the Thomas Bayes in 1763, it is foundation of Bayesian inference. Bayes' theorem is used to determine the conditional probability distribution. Suppose A and B are two events

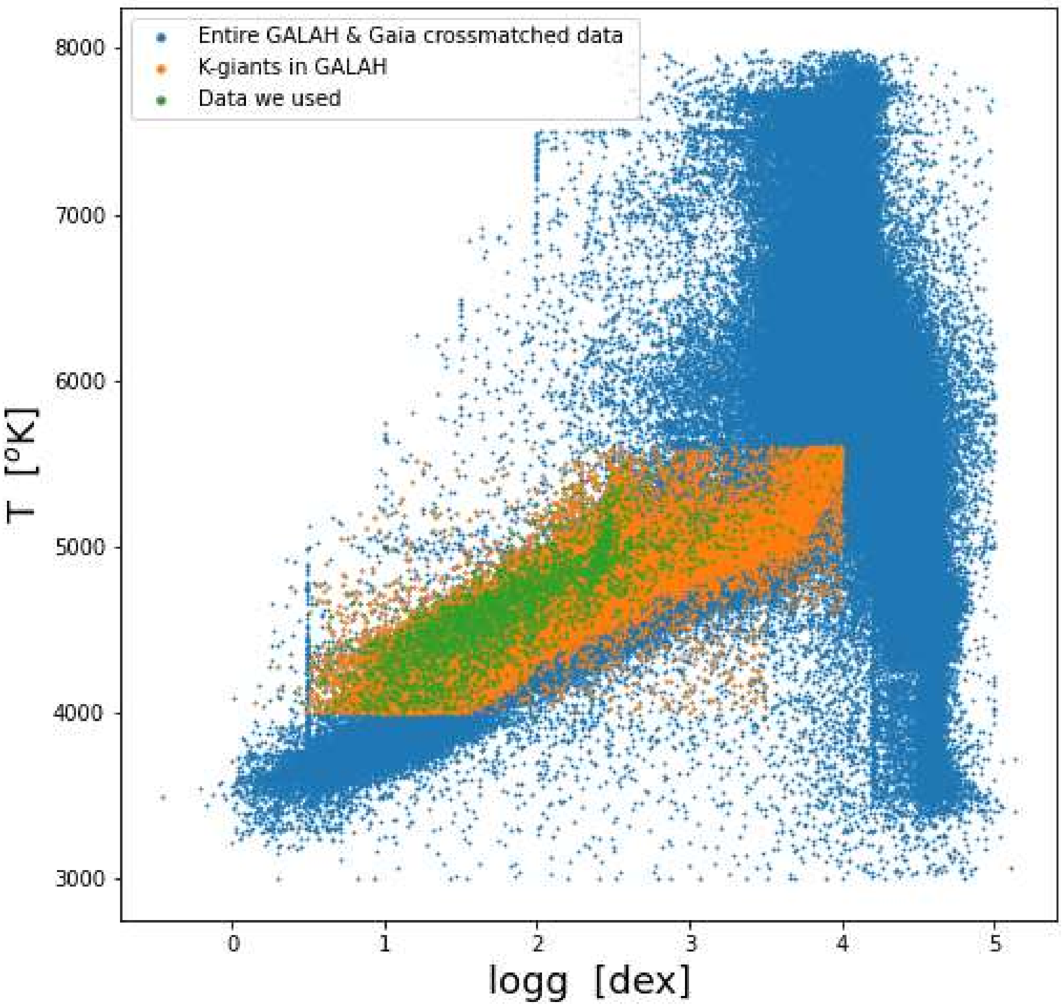

Figure 3.1: Temperature versus logg plot for entire dataset of GALAH cross-matched with Gaia (represented by blue dot), K-giant stars in GALAH (represented by orange dot) and K-giant stars selected for our research (represented by green dot).

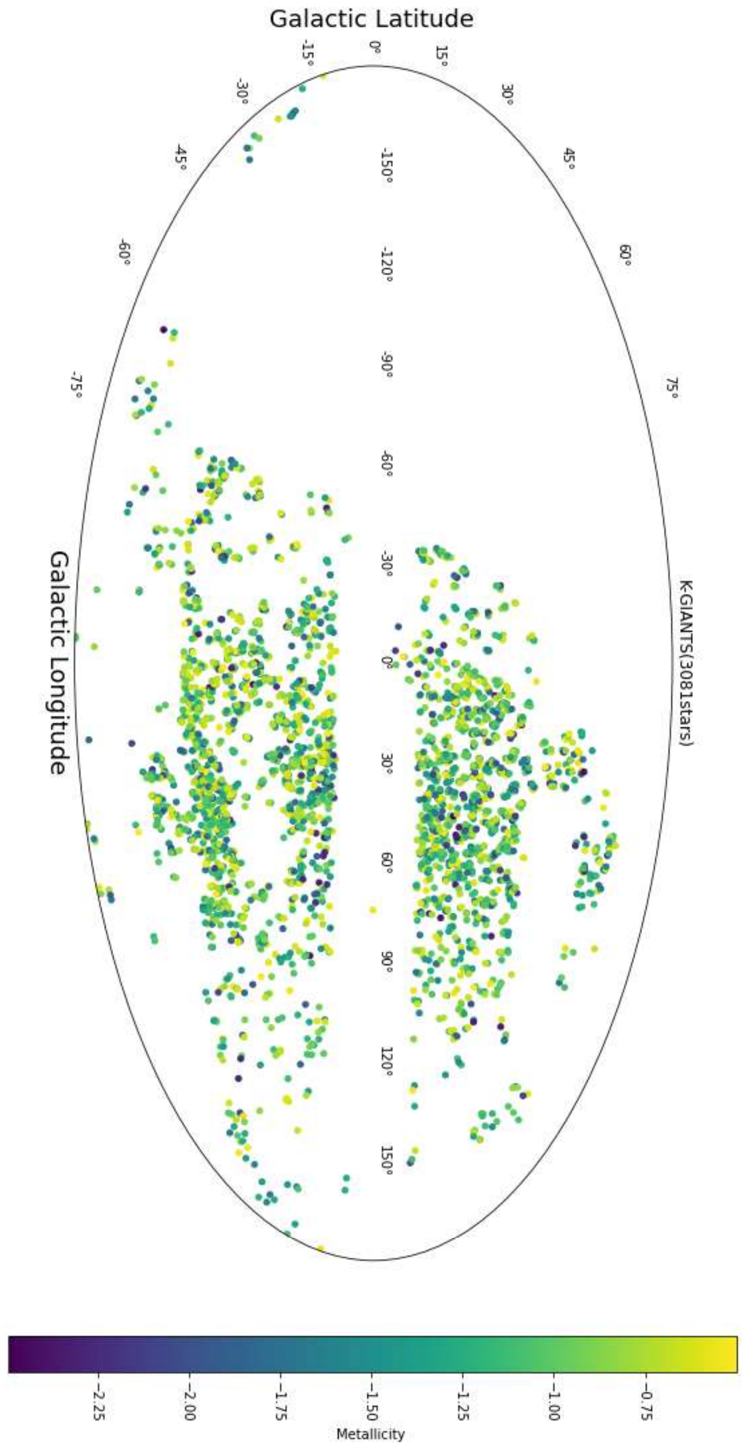

Figure 3.2: Molliweide projection of selected K-giant stars with the color bar representing there metallicity [Fe/H]

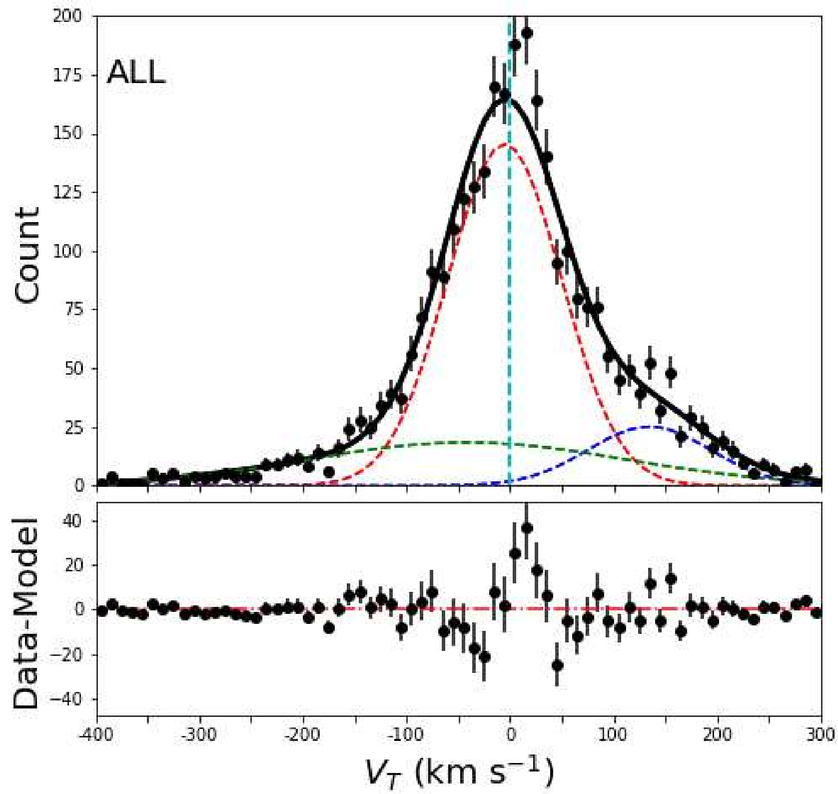

Figure 4.1: The plot of distribution of azimuthal velocity (V_T) with an error bar generated using Poisson distribution. The dark black line represents the entire sample, the red dash line represents the first component, the blue dash line represents the second component and the green dash line represents the third component.

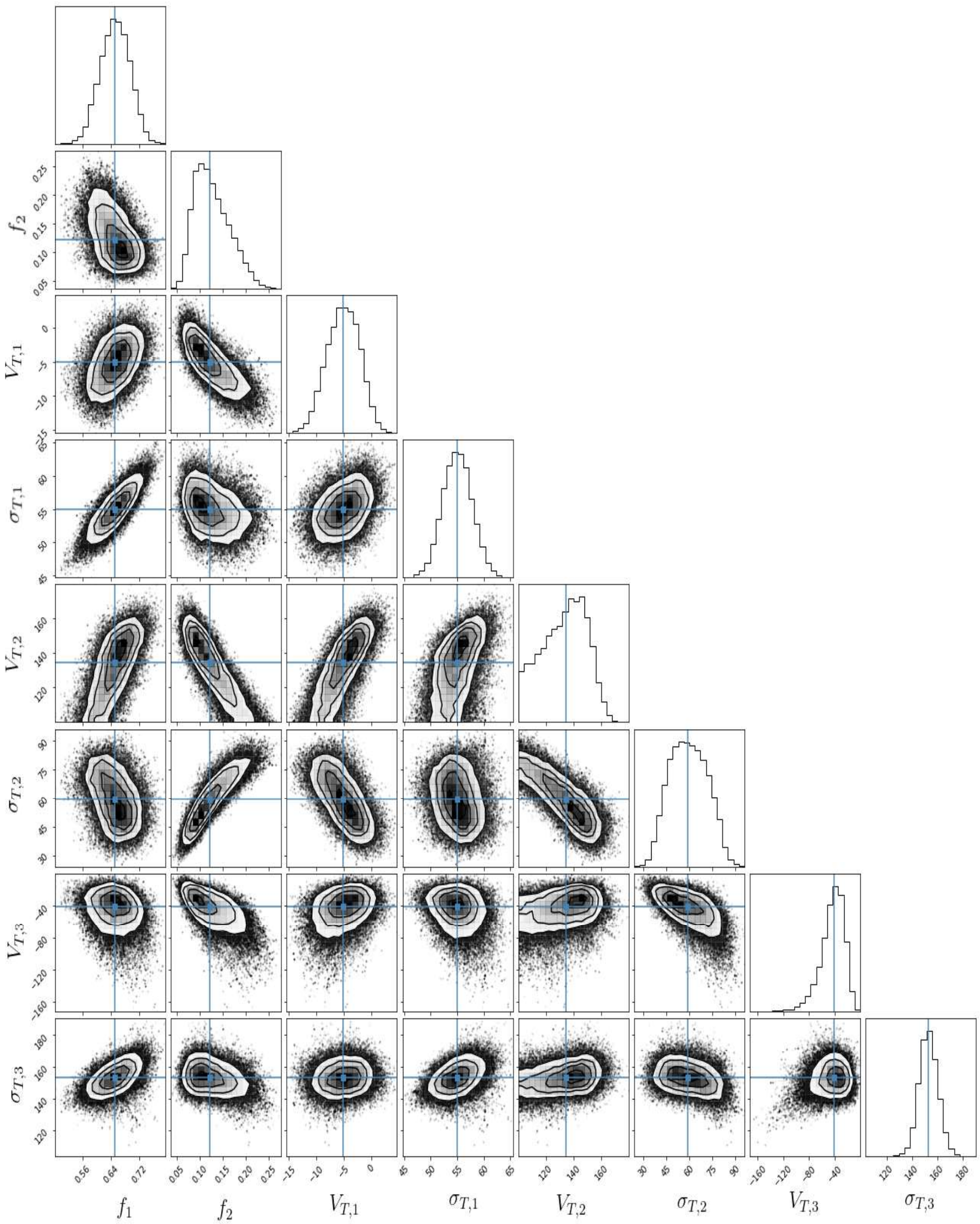

Figure 4.2: The result of MCMC is shown in the corner plot. The corner plot shows the correlation between any two parameters. The blue line indicates the median value of samples which we have taken as the best fit. 1σ, 2σ and 3σ counters shows the joint posterior probability distribution of our parameters (θ_i's) for K-giant stars. The histogram represents one-dimensional marginalized posterior distribution.

4.1.2 Velocity Anisotropy

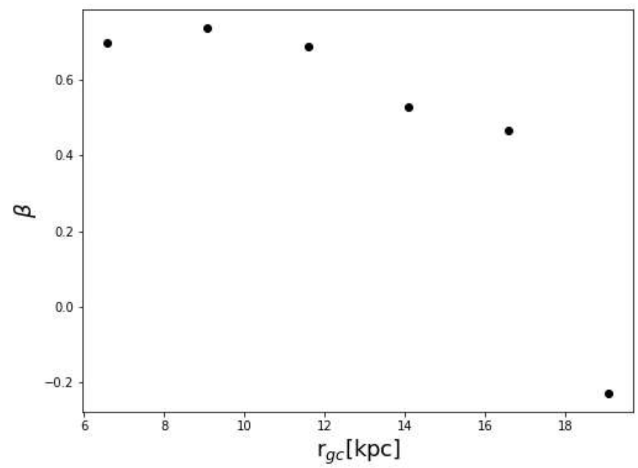

Figure 4.4: The plot of velocity anisotropy(β) as a function of the galactocentric radius, here we have binned star at 2.5 kpc galactocentric radius.

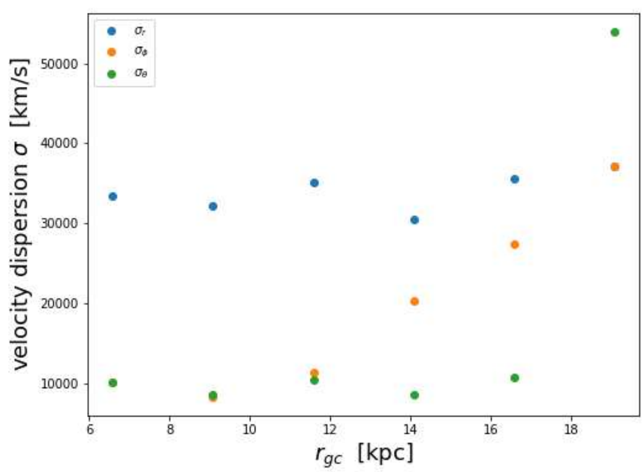

Figure 4.5: Plot of the velocity dispersions $(\sigma_r, \sigma_\theta, \sigma_\phi)$ with the galactocentric radius binned at 2.5 kpc.

By analyzing the Fig. 4.4 we find beta decreases as distance increases which is similar to that observed by kafle *et al*. (2013) [31] and also by

4.2 Discussion

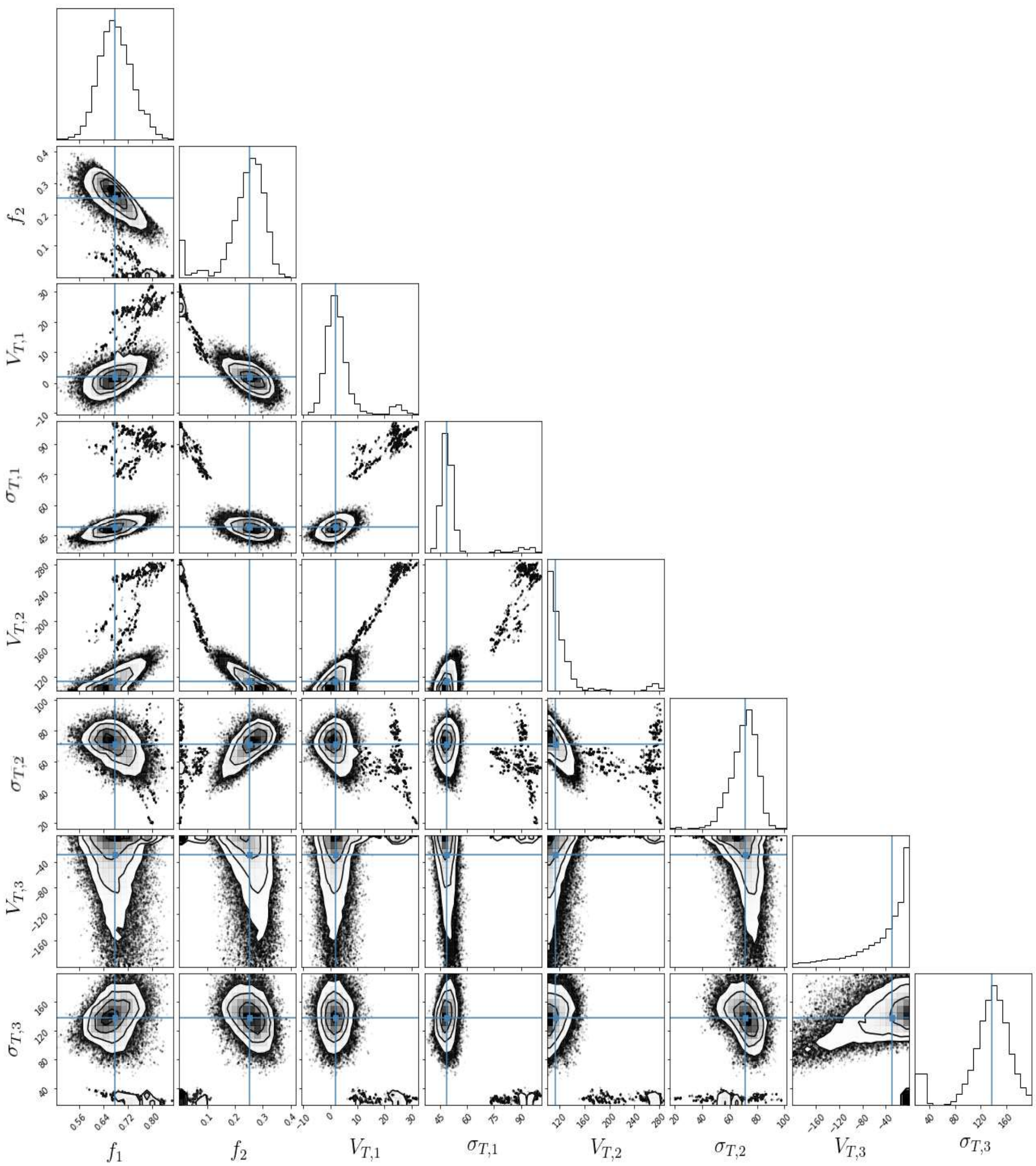

Figure 4.9: The result of MCMC for K-giant stars with metllicity -0.9 dex $<$ [Fe/H] < -0.5 dex is shown in the corner plot. Corner plot shows the correlation between any two parameters. The blue line indicate the median value of samples which we have taken as a best fit. 1σ, 2σ and 3σ counters shows the joint posterior probability distribution of our parameters (θ_i's) for K-giant stars. The histogram represent one dimensional marginalize posterior distribution.

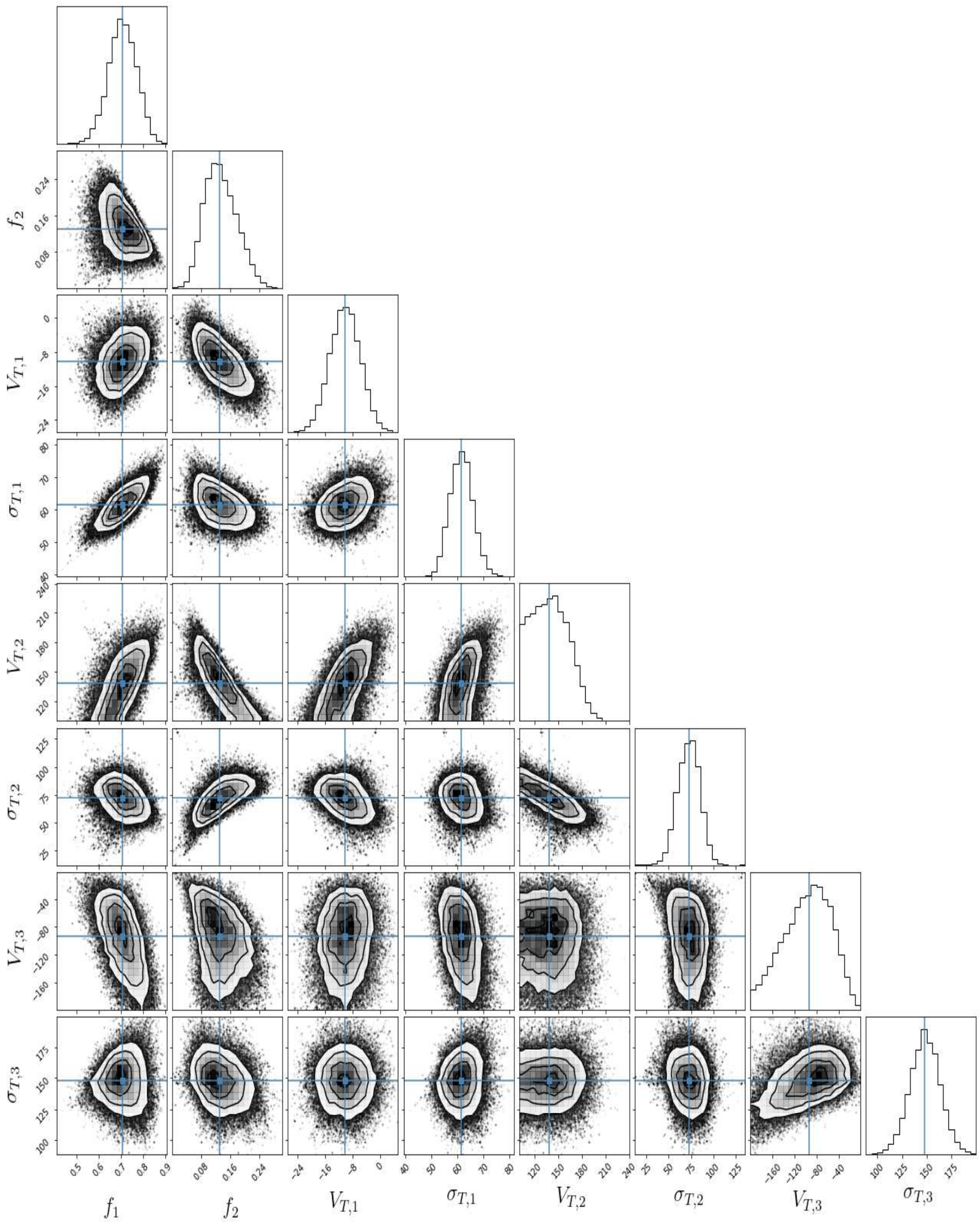

Figure 4.11: The result of MCMC for K-giant stars with metllicity $-$ 1.3 dex < [Fe/H] < $-$ 0.9 dex is shown in the corner plot. Corner plot shows the correlation between any two parameters. The blue line indicate the median value of samples which we have taken as a best fit. 1σ, 2σ and 3σ counters shows the joint posterior probability distribution of our parameters (θ_i's) for K-giant stars. The histogram represent one dimensional marginalized posterior distribution.

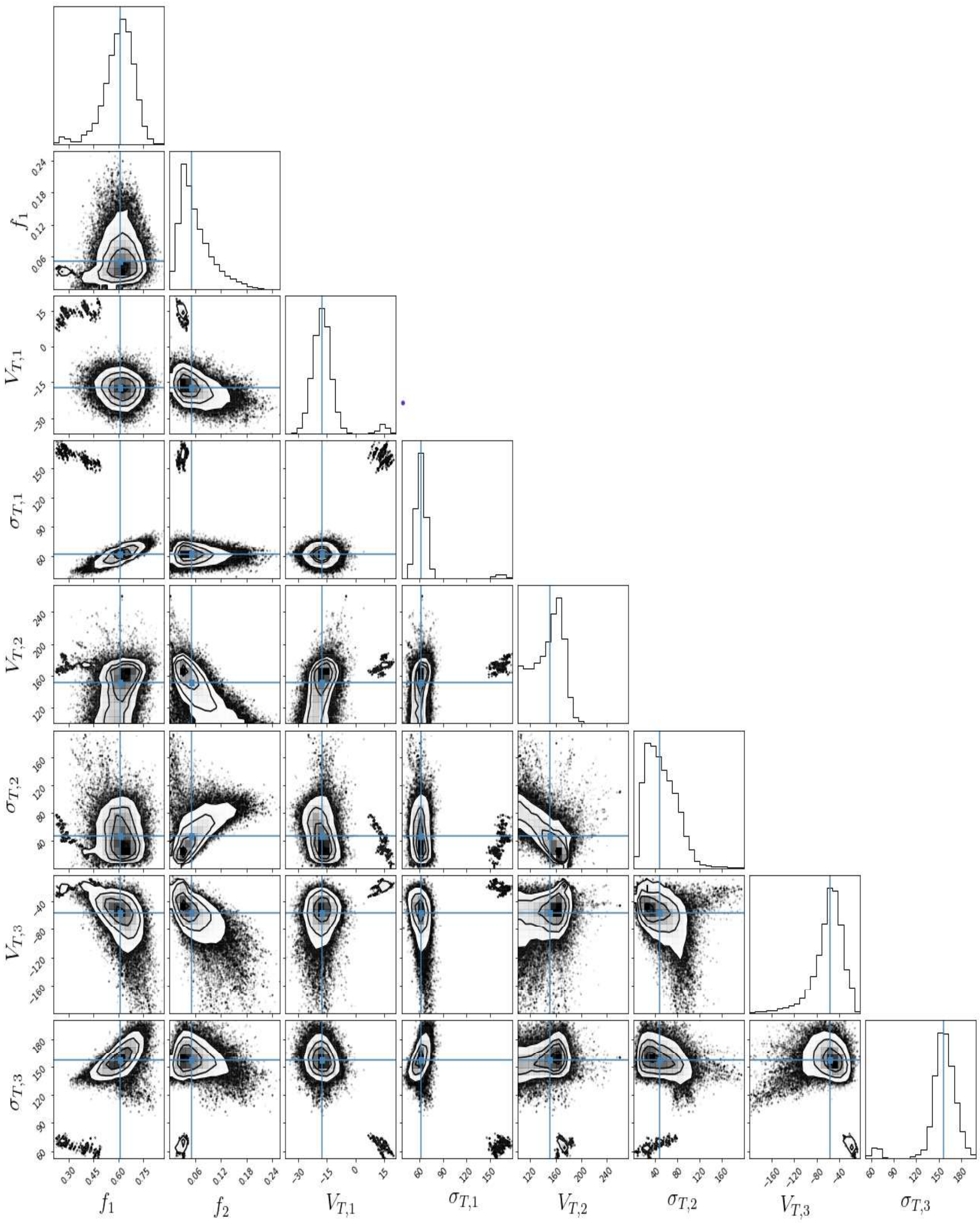

Figure 4.13: The result of MCMC for K-giant stars with metllicity $-$ 2.5 dex < [Fe/H] < $-$ 1.3 dex is shown in the corner plot. Corner plot shows the correlation between any two parameters. The blue line indicate the median value of samples which we have taken as a best fit. 1σ, 2σ and 3σ counters shows the joint posterior probability distribution of our parameters (θ_i's) for K-giant stars. The histogram represent one dimensional marginalize posterior distribution.

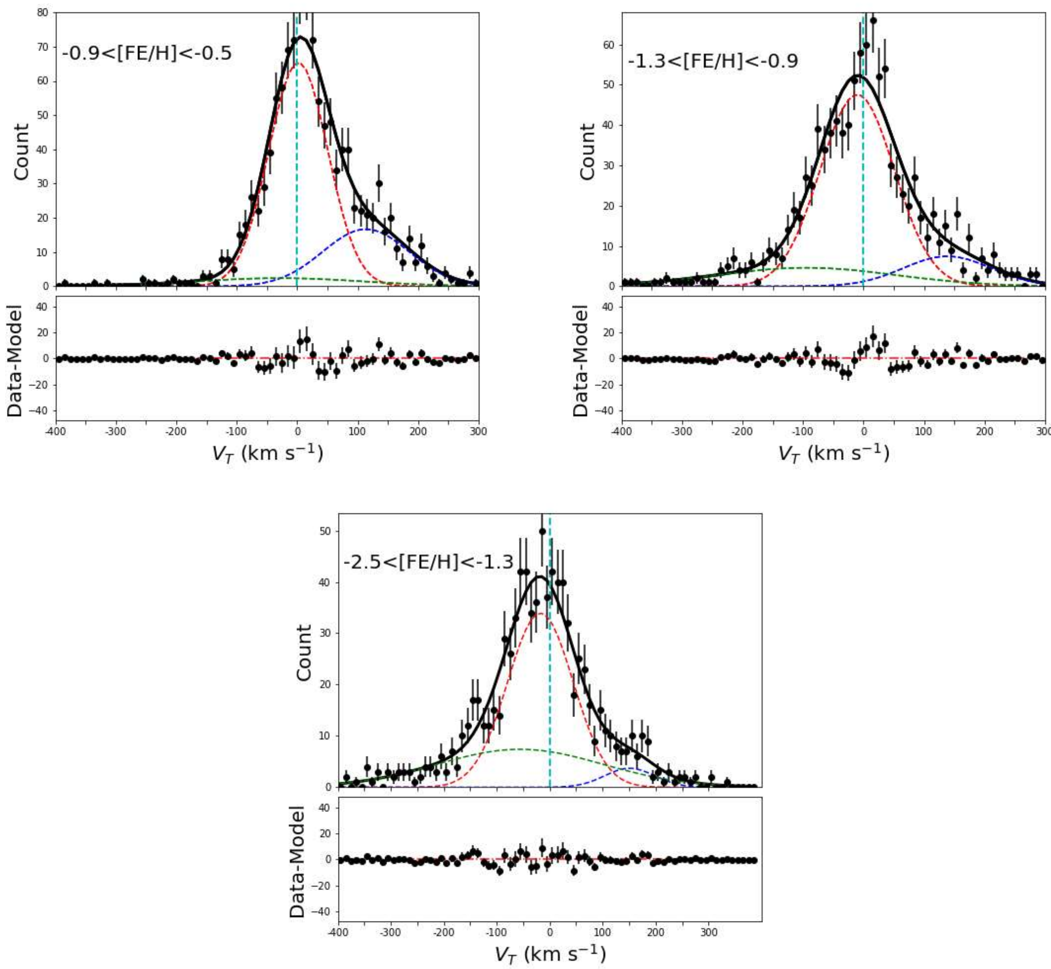

Figure 4.15: Distribution of the azimuthal velocity V_T of 3081 K-giant stars divided according to metallicity, first being the metal richest and third being the metal poorest K-giant stars in our sample. Here error is generated using the Poisson distribution.

To determine the effect of metallicity on the rotational velocity, we have divide the entire sample of K-giant stars into 3 groups depending upon their metallicity. After dividing them into three groups, we have determined the rotational velocity for each group independently by fitting three Gaussian components. The result obtained for different groups are as follow:

we find there is no any systematic variation of rotational velocity with metallicity. That indicates the independence of rotational velocity with metallicity.

Metallicity [Fe/H]	All	$-0.9 <$ [Fe/H] < -0.5	$-1.3 <$ [Fe/H] < -0.9	$-2.5 <$ [Fe/H] < -1.3
f_1	$0.650^{+0.042}_{-0.041}$	$0.678^{+0.056}_{-0.049}$	$0.706^{+0.06}_{-0.06}$	$0.611^{+0.073}_{-0.091}$
f_2	$0.121^{+0.05}_{-0.03}$	$0.253^{+0.046}_{-0.063}$	$0.130^{+0.049}_{-0.040}$	$0.094^{+0.045}_{-0.023}$
f_3	0.229	0.069	0.164	0.295
$V_{T,1}$	-5^{+3}_{-3}	2^{+4}_{-1}	-10^{+4}_{-4}	-17^{+5}_{-5}
$\sigma_{T,1}$	55^{+3}_{-3}	49^{+4}_{-3}	61^{+4}_{-4}	62^{+6}_{-6}
$V_{T,2}$	135^{+14}_{-20}	114^{+20}_{-10}	138^{+25}_{-25}	151^{+8}_{-32}
$\sigma_{T,2}$	59^{+13}_{-12}	71^{+8}_{-10}	72^{+11}_{-12}	47^{+31}_{-23}
$V_{T,3}$	-41^{+15}_{-19}	-29^{+24}_{-64}	-94^{+40}_{-49}	-56^{+18}_{-26}
$\sigma_{T,3}$	153^{+7}_{-7}	138^{+23}_{-30}	148^{+15}_{-15}	157^{+13}_{-12}
Number	3081	1181	1039	861

Table 4.2: Table shows the results of MCMC simulation for different K-giant stars grouping that we made.

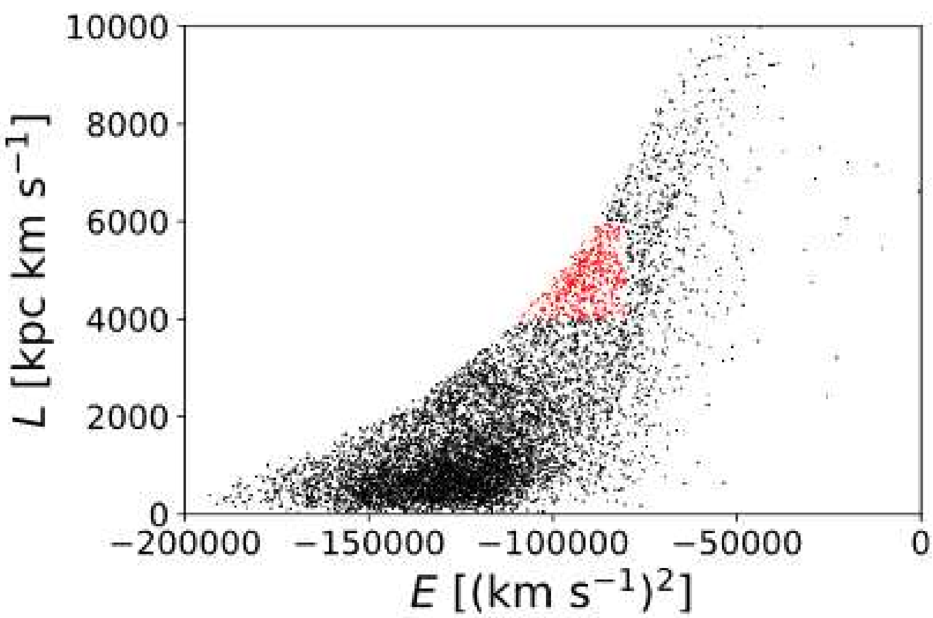

Figure 4.16: Energy versus angular momentum plot obtained by Bird *et al*. (2018) [8]