The Determination and Classification of Low Mass Brown Dwarf Stars Using Metallicity Technique

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Abstract

Low mass brown dwarf stars in the northern hemisphere were investigated; their population and metallicity have been determined using the spectroscopic technique. The classification of these stars was pointed out as belongs to population I, varies in metallicity range between $-0.417 \leq z \leq 0.143$.

Keyword: Stellar properties, low mass stars, metallicity

تحديد وتصنيف نجوم الاقزام البنية ذات الكتل الواطئة بأستخدام تقنية نسبة عامل المعدنية

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الخلاصة

تم التحقق من نجوم الاقزام البنية ذات الكتل الواطئة التي يمكن رؤيتها في النصف الشمالي من الكرة الارضية وكذلك ايجاد نوع التجمهر لهذه النجوم. تم تصنيف هذه النجوم بأستخدام التقنيات الطيفية. اظهرت النتائج ان هكذا نوع من النجوم تنتمي الى التجمهر من نوع (I) وان مدى التغير في نسبة عامل المعدنية لهايقع بين $-0.417 \leq z \leq 0.143$.

Introduction

The variation of metallicity in stars is a major problem in the knowledge of chemical evolution of our galaxy and of other galaxies [1].

Low–mass dwarfs are the most numerous stellar constituents of the Milky Way and have main sequence lifetimes that exceed the current age of the Universe. They form an important tool for probing the structure and evolution of the galaxy's disks. Because of their existence, cool dwarfs may represent the largest population of stars with exoplanets which are considerably closer for cool dwarf systems. In addition, the sizes of these stars make the detection of transiting planets easier than for higher mass stars [2].

Many authors worked on the metallicity of low-mass stars. Aoki *et al* (2005**)** worked on Extremely Metal-Poor stars (EMP) with metallicity [Fe/H] ≤ -3. Results provided new data on the abundance of EMP stars (-5.5 < [Fe/H] < -3). It is already evident that EMP stars exhibit significant variations in their metallicities [3]. Another D'Orazi *et al* (2009) worked on Orion nebula cluster (ONC), found that the average metallicity for the candidate stars of ONC [Fe/H] = -0.01 ± 0.04. No metal-rich stars were

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found. The metallicity of the λOri member is also solar like, while the OB1b star has an [Fe/H] significantly below the ONC average [4].

Andrew et al (2011) reviewed spectroscopic and photometric techniques for estimated metallicity in low–mass dwarfs and discuss the importance of measuring accurate metallicities using dwarf stars, obtaining metallicity for brown dwarfs. They identified the possibility of searching for exoplanets host and chemical evolution [2]. Santos *et al*, (2012) investigated stellar parameters and iron abundances of 18 giant stars in 6 open clusters, The results showed that these clusters cover a metallicity range between -0.63 and +0.63 [5].

It is useful to investigate spectra for low mass stars of solar like (G), down (K) and above (F) spectral types, in the northern hemisphere, located in different constellation, in order to classify them as population I or II stars. By finding their metallicities, it would be possible comparing the nature of the stellar formation of these types of stars.

Stellar metallicity

The ratio of Iron (Fe) to hydrogen (H) has become almost universally adopted by researcher because iron lines are generally readily identifiable in stellar spectra.

During a supernova detonation (type Ia), iron is ejected, enriching the interstellar medium. New stars can then be formed with a greater abundance of iron in their atmospheres than in their predecessors.

As a result, iron content should correlate with stellar age; the youngest, most recently formed stars having the highest relative abundance of iron [6].

The iron-to-hydrogen ratio in the atmosphere of a star is compared with the Sun`s value through a quantity often referred to as the "Metallicity", according to the formula:

$[Fe/H]= \text{Log10} [(N_{Fe}/N_H)\text{star}/(N_{Fe}/N_H)\text{sun}]$ ……………..(1)

Where:

N_{Fe} and N_H represent the number of iron and hydrogen atoms respectively.

Stars with abundances identical to the Sun's have [Fe/H] =0. Stars with [Fe/H] < 0 are metal-poor relative to the Sun, and star with [Fe/H] > 0 are relatively metal-rich [6].

For comparison, extremely metal-poor (population II) stars in our galaxy have measured with values of [Fe/H] as low as -5.4, while the highest values for metal-rich stars in the galaxy are about 0.6. Metal-rich stars tend to be younger then metal-poor ones of similar spectral type.

In the thin disk (350 parsec above or below the galactic disk), typical values for the iron-hydrogen metallicity ratio are in the range: -0.5 < [Fe/H] < 0.3 namely population I, while for the majority of stars in the thick disk are in the range: -0.6 < [Fe/H] < -0.4, are called population II (> 350 up to 1000 parsec) [6].

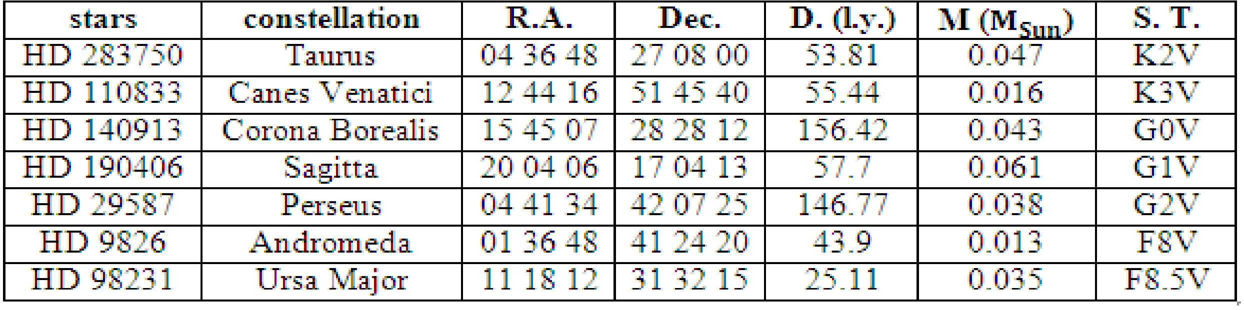
Knowing that some thick-disk member may have metallicities at least as low as [Fe/H] = -1.6. Star formation began in the thin disk about $8*10^9$ years ago and is ongoing today, while those for thick disk star formation spanned the time interval between (10 and 11)$*10^9$ years ago.

It is obvious that metallicity becomes important in order to classify stars as young or old, namely population I and II respectively [6].

Data collection

In order to investigate metallicity of low-mass stars of spectral type (FGK) in the northern hemisphere; Corona Borealis, Sagitta, Perseus, Ursa Major, Andromeda, Taurus and Canes Venatici Constellations were chosen, and their spectra are obtained from ELODIE archive web- site [7]. table-1 is a list of star's sample, including their physical parameters.

Table-1 Physical parameters of the candidate stars selected for this investigation [7]

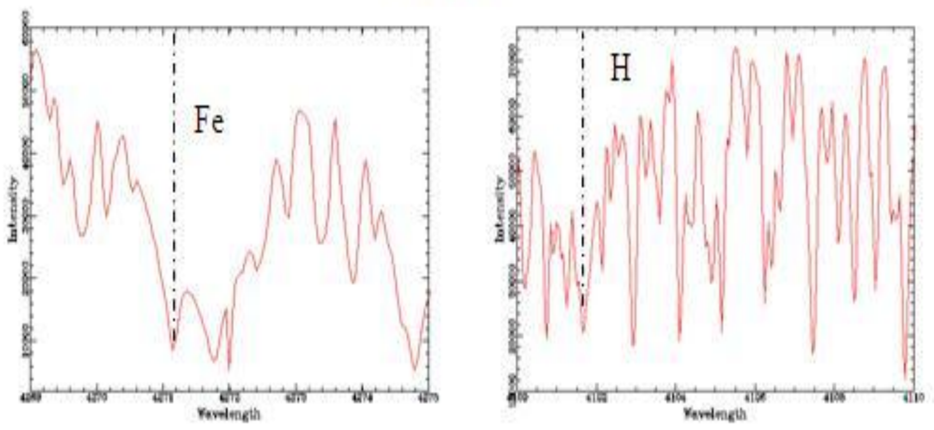


stars	constellation	R.A.	Dec.	D. (l.y.)	M (M_{Sun})	S. T.
HD 283750	Taurus	04 36 48	27 08 00	53.81	0.047	K2V
HD 110833	Canes Venatici	12 44 16	51 45 40	55.44	0.016	K3V
HD 140913	Corona Borealis	15 45 07	28 28 12	156.42	0.043	G0V
HD 190406	Sagitta	20 04 06	17 04 13	57.7	0.061	G1V
HD 29587	Perseus	04 41 34	42 07 25	146.77	0.038	G2V
HD 9826	Andromeda	01 36 48	41 24 20	43.9	0.013	F8V
HD 98231	Ursa Major	11 18 12	31 32 15	25.11	0.035	F8.5V

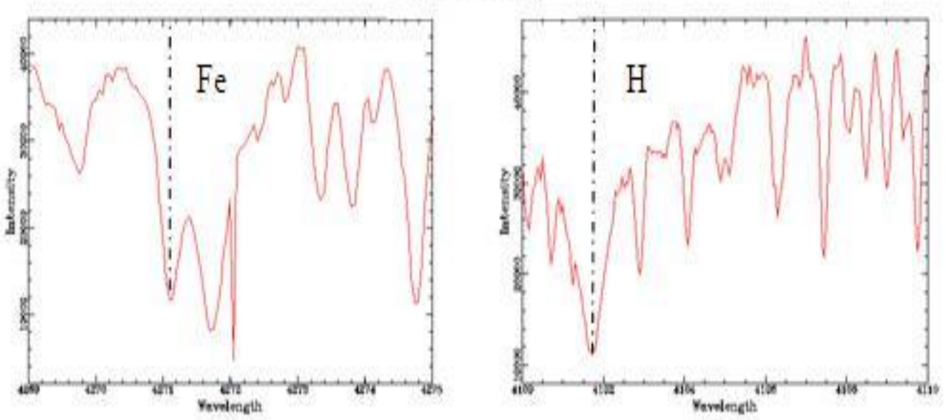
The third column of this table represents the Right Ascension, fourth column represents the Declination, fifth column represents Distance in the in light year, sixth column represents the ratio between star’s mass and sun’s mass and seventh column represents the Spectral Type.

Figure-1 Shows spectra of the above chosen stars, plotted as intensities (arbitrary number) Vs wavelength in angstrom, showing the absorption lines of hydrogen and iron.

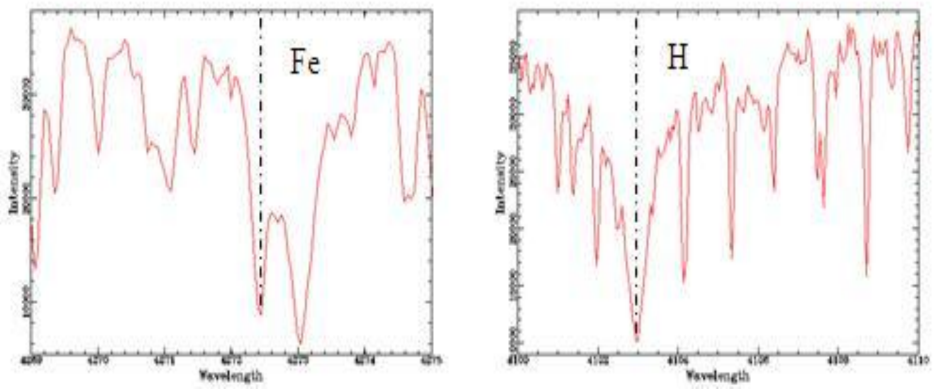
HD 110833



HD 140913



HD 29587



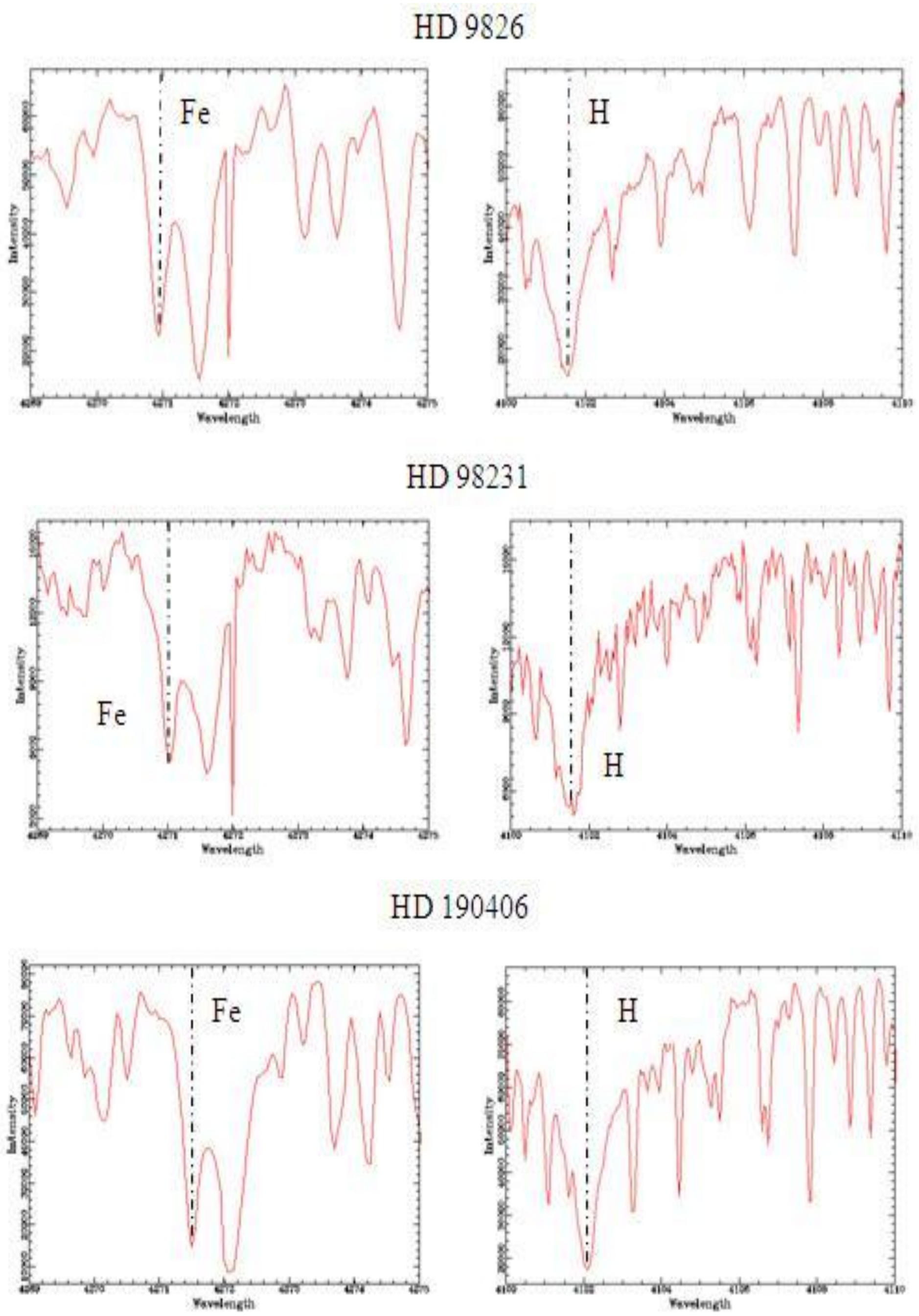


Figure-1 Stars spectra of the present sample

Calculations and results

The absorption lines for each spectrum are determined according to the relative wavelength for hydrogen and iron using Get Data computer program and the metallicity (z) of each star is calculated, using equation (1).

Also the position of each star deviated from the galactic plane are calculated for the justification of population type as: population I or II. This is done by converting the equatorial right ascension and declination into longitude and latitude (l", b”) respectively by using the equations [8]:.

$l'' = 303 - \tan^{-1}[(\sin(192.25 - \alpha)/(\cos(192.25 - \alpha)*\sin 27.4 - \tan\delta*\cos 27.4)]$……………(2)

$b'' = \sin^{-1}[\sin\delta*\sin 27.4 + \cos\delta*\cos 27.4*\cos(192.25 - \alpha)]$……………..(3)

Where:

α and δ are right ascension and declination. Results are as listed in table 2.

Table-2 Results for b’, l’, h and z for each star in the sample with their population type

stars	S. T.	ℓ''	b''	h	Z	Population type
HD 283750	K2V	-12.7	-7.08	14.4	-0.417	Population I
HD 110833	K3V	65.4	-55	-13	-0.356	Population I
HD 140913	G0V	51.2	45.1	35.9	-0.012	Population I
HD 190406	G1V	-7.8	56.9	-2.4	-0.086	Population I
HD 29587	G2V	-2.2	-17.8	5.4	-0.109	Population I
HD 9826	F8V	-20.2	-47.4	5.2	0.143	Population I
HD 98231	F8.5V	69.7	15.9	7.5	0.019	Population I

Figure-2 shows the distribution of stars around the galactic plane. The location of each star above or below the galactic plane are plotted, indicated the height appeared to be very closed to the galactic plane (±2.5 to ±35.9) parsec.

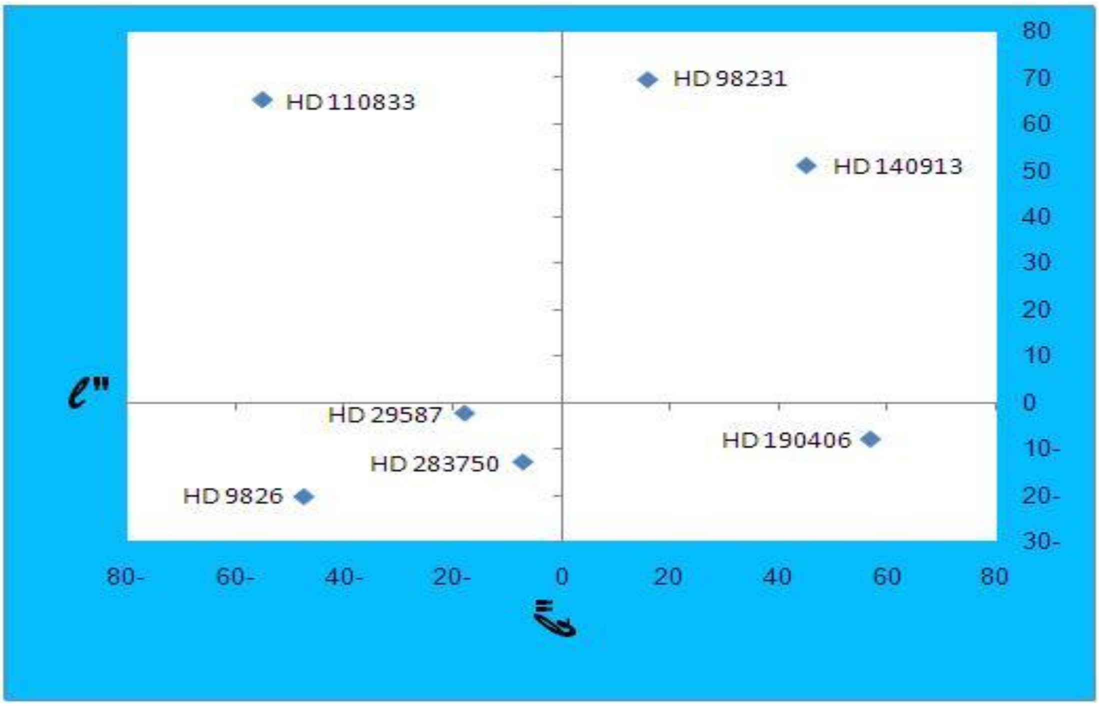


Figure-2: Galactic coordinates (l", b”) for the chosen sample of stars.

Discussion and conclusion

According to the results obtained by this work, it is found that the metallicity of low mass brown dwarf stars in the northern hemisphere for the same spectral type range increases as mass decreases. This is because of the presence of iron in the core of low mass stars where the heavier metal are accumulated in their core due to insufficient temperature and pressure for being a fuel participating for nuclear fusion processes. The classification of these stars according to the results obtained and shown in table 2 are belong to population I, varies in metallicity range between $-0.417 \leq z \leq 0.143$.

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