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Introduction

1.1 Distribution of Elemental Abundances

There has been a considerable effort made toward understanding the relative distribution of abundance of the elements. Principles of nuclear physics give a generic relationship between different nuclear species with a significant correlation between their properties and abundances. On the other hand principles of astrophysics tell us that the universe had a beginning, hence whatever the present abundance that we observe, the condition for that must be present in the early universe as well as in the stars. Thus the principles of nuclear astrophysics give us clues not only to elemental synthesis, but also about the elemental distribution at various locations of the universe. The material in the universe is composed of about 100 elements, which have been created through different nuclear reactions since the time of the Big Bang. The cosmic distribution of elements, thus reflects these processes, and also the relative nuclear stability of different nuclides. However, the distribution of elements in different parts of the universe is significantly different.

1.2 Elemental abundance distribution in galaxy: A brief review

1.2.1 α-elements in Galactic disk

The galactic disk is the flattened component of a galaxy, and the way the stars are distributed there demands the necessity of the presence of two disk components (Gilmore & Reid (1983)[1]) which was subsequently confirmed by Edvardsson et al. (1993)[2] in their detailed abundance survey. Their report that a thin disk with a scale height of 300 pc and a thick disk (forms due to massive galactic collision (Minchev et al. 2015[3]) with a scale height of about 1300 pc have put an end to the long-standing puzzle regarding the nature of the thin and thick disk of galaxies. However, the overlap in metallicity between thin and thick disks in the range $-0.8 < [Fe/H] < -0.4$ is still not understood well. The striking evidence reported in Edvardsson et al.(1993)[2] is that the variation of α-capture elements (O, Mg, Si, Ca, Ti etc.) as [α/Fe] ratios amongst the F and G main sequence stars with the same [Fe/H]. Three years later the work of Gratton et al. (1996)[4] in their sample found that the thin disk stars are with [Fe/O]> -0.25 and thick disk stars are with [Fe/O]< -0.25 for [O/H]> -0.5. This was then justified by (McWilliam & Rauch 2004[5]) using the fact that Type Ia SNe contributes, not only more with iron at a high [Fe/H] in the inner parts of the Galaxy as compared to the outer parts but also enriches the interstellar gas with Fe without any increase in O and Mg. Then the work of Reddy et al. (2003)[6] also got attention because they found that the

α-elements, O, Mg, Si, Ca, and Ti, show [α/Fe] increment slightly with decreasing [Fe/H] in the range $-0.7 <$[Fe/H]< 0.0. A similar type of result was also obtained by Bensby and Feltzing (2005)[8]) for C, where they have found enrichment in C in a sample of 51 nearby F and G dwarf disk stars. Feltzing et al. (2003b)[7], on the other hand, provides evidence of declination of [α/Fe] at a metallicity [Fe/H]≥ -0.4 in thick disk stars. Thus a general inference is very difficult to put forward about the trend of the distribution of α-elements in the disk stars. However, more data will definitely help.

1.2.2 α-elements in Galactic halo

The galactic halo which is the dust free region surrounding a galaxy, nearly spherical in shape and the host of collection of some of ancient star clusters known as globular clusters has been backed up by two profound theories as far as its formation is concerned. Eggen et al. (1962)[9], states that the Galactic halo formed during a rapid, monolithic collapse of the proto-Galactic gas cloud whereas according to Searle & Zinn (1978)[10], it's rather chaotic as it's a kind of accretion of small galaxies over several Gyr. The turn-offs as a function of metallicity and spectroscopic studies of this site are very much important to get to the ages of these stars and to know about the presence of elements respectively. However, the information of several of the α-elements (Ne, Ar, S) at low metallicity is very difficult to obtain because of spectroscopic inaccessibility. A few of them (C, O, Mg) take part in proton capture burning modes and Ti seats in both α-capture and Fe-peak element groups leaving only Si and Ca as easily observed "pure" α elements. Thus the [α/Fe] values are considered to be the average of Mg, Si, Ca, and Ti abundances, produced mainly during Type II supernovae (SNe) explosions on a short timescale ($\approx 10^7$ years), whereas iron is also produced by Type Ia SNe on a much longer timescale ($\approx 10^9$ years) (Nissen et al. 2010[11]). Previous studies performed by (Fulbright 2002)[12], Stephens & Boesgaard (2002)[13], and Gratton et al. (2003)[14] focussing on the possible differences in [α/Fe] for stars in the solar neighborhood confirmed that the stars associated with the outer halo have lower [α/Fe], not larger than 0.1 dex, (the unit often used for metallicity which is a (now-deprecated) contraction of *'decimal exponent'*. One can read this in a comparsion form as % Difference of a star from the sun = $10^{dex\,of\,the\,star}$), than the stars connected to the inner halo. The work of Nissen et al.(2008)[15] have reported that the halo stars consist of two distinct populations, the 'high-α' stars with a nearly constant [α/Fe] and the 'low-α' stars with a declining [α/Fe] as a function of increasing metallicity. One more important result was disclosed by de Jong (2010)[16] is that [α/Fe] values in the Galactic halo stars with that of those with the same metallicity in the Dwarf spheroidal galaxies shows very little in common. Later on the work of Vargas et al.(2013)[17] on Ultra Faint Dwarfs (UFDs) have found an increase of [α/Fe] towards lower [Fe/H], and low [α/Fe] ratios for their highest [Fe/H] stars. Thus the average of α-elements show overabundance in halo field stars.

1.2.3 α-elements in Galactic bulge

A bulge is a tightly packed group of stars, which is believed to form in the dynamical violence of galaxy mergers (Shen & Li 2015)[18] and hence bear a complex formation history. The stars in the bulge have a range of metallicities ($-1 <$[Fe/H]< 0.5) with an average metallicity of, a little under solar ([Fe/H]$= -0.2$). To establish the abundance efforts have been made with low resolution by Whitford & Rich (1983)[19] and Rich (1988)[20] and reported that the bulge giants were in general metal rich, with a wide range in metal abundances. Then the works of Tuan Do et al.(2015)[21] have found that the stars belonging to this site exhibit a wide range of metallicities, from a tenth of solar metallicity all the way to super-solar metallicities. They have also found that the abundances of the low-metallicity stars are consistent with globular cluster metallicities and the super-solar metallicity stars were likely formed closer to the galactic center or from the disk. As far as the α-elements are concerned different groups of people like Rich & Origlia (2005)[24], Zoccali et al.(2006)[23], Alves-

Brito et al.(2010)[22] and Barbuy et al.(2013)[25] found that, irrespective of the [Fe/H] ratio in the bulge stars, their [α/Fe] ratios are uniformly enhanced at low metallicity relative to the thin disk. Johnson et al.(2014)[26] have found that the bulge [α/Fe] ratios may remain enhanced slightly at higher [Fe/H] value but for stars with [Fe/H]$\geq +0.3$ there is mostly a monotonic decline in [α/Fe] with increasing [Fe/H]. However no significant variations in the [α/Fe] trends was detected between different bulge sight lines by Jönsson et al.(2014)[27]. Further it was reported by Johnson et al.(2014)[26] that the [O/Fe] ratios compared to other α-elements are reported to be higher by ~ 0.2 dex in stars with negative [Fe/H]. However for stars with [Fe/H]≤ -0.5 the [O/Fe] and [Mg/Fe] ratios that are slightly enhanced by ~ 0.03 dex whereas [Si/Fe] and [Ca/Fe] ratios are enhanced by 0.05 dex. But this trend reverses for stars with [Fe/H] ≥ 0, where [O/Fe] is, on average, lower by ~ 0.2 dex. Then [Mg/Fe],[Si/Fe] and [Ca/Fe] trend exhibits small dip with increasing [Fe/H] as compared to [O/Fe]. As far as Ti is concerned the nucleosynthesis calculations yield a low value than the observed ones in the stars of galactic bulge, still remains a problem (Woosley & Weaver(1995)[28]).

1.2.4 Fe-peak elements in Galactic disk

Still today no Galactic chemical evolution models have been able to explain the observed abundance distributions of different iron peak elements (22 $<$Z$<$ 28, ie Ti, V, Cr, Mn, Fe, Co, Ni) in Galactic metal-poor disk stars completely. Reports from various spectroscopic studies have shown a decreasing [Cr/Fe] and an increasing [Ti/Fe] ratios with decreasing metallicity, while the [Co/Fe] ratio remains solar down to the lowest metallicities (Goswami & Prantzos 2000 [56], Bergemann et al. 2010[57]). [Ni/Fe] is usually found to show a solar value irrespective of [Fe/H] (eg. Feltzing & Gustafsson 1998[58]; Chen et al. 2000[59]) but the work of Bensby et al.(2003)[60] has shown a slight overabundance at the lowest metallicities but the overall scatter in the [Ni/Fe] trend is found to be low. The work of Mishenina et al.

(2013)[61], also have shown the [Ni/Fe] ratio following a similar type of pattern with value close to the solar one for the whole metallicity range $-1 < [Fe/H] < +0.3$.

1.2.5 Fe-peak elements in Galactic halo

In the galactic halo too, Fe-peak elements' abundance distribution suffer from having a complete description either due to inadequate models of galactic chemical evolution (GCE) or due to inadequacy in spectroscopic determination processes (Bergemann & Gehren 2007)[62]. Using Non-LTE, the trend of [Mn/Fe] with [Fe/H] is only slightly subsolar, whereas [Co/Fe] ratios steadily increase with decreasing Fe abundances in the halo stars. In the recent work of Ishagaki et al. (2013)[63], they have reported for their subsamples in the inner halo and outer halo the [Sc/Fe] and [Mn/Fe] ratios are enhanced in the metallicity range [Fe/H]> -1.5 with a modest decreasing trend toward lower [Fe/H] with small scatter (< 0.10 dex) but [V/Fe] is found to have a flat response. Then [CrI/Fe] ratios are found to be slightly decreasing toward lower metallicity for the whole [Fe/H] range, while the [CrII/Fe] ratios are supersolar without any trends with [Fe/H]. However the [Ni/Fe] ratios in the inner halo and outer halo stars have shown ≈ 0.10 dex lower [Ni/Fe] ratios in [Fe/H]> -2.5. As far as Zn is concerned Ishigaki et al. (2013)[63] have found that both the inner and the outer halo stars show a modest scatter and slightly lower [Zn/Fe] values for [Fe/H]> -1.0. The [Co/Fe] values in general found to be enhanced inner and outer halo stars Cayrel et al. (2004)[64], Lai et al. (2008)[65] which is in agreement with Ishigaki et al. (2013)[63].

1.2.6 Fe-peak elements of Galactic bulge

This part of abundance distribution in galactic bulge has been explored to a large extent. The initial work of McWilliam & Rich (1994)[66] have found that [V/Fe], [Cr/Fe], and [Ni/Fe] ratios are near solar and a posibility of enhancement in [Co/Fe] and [Sc/Fe]. The work of Johnson et al. (2014)[26] have found that the average [Cr/Fe] ratio is almost solar with no variation for their entire choice of [Fe/H] range. Then [Co/Fe] and [Ni/Fe] are found to be enhanced at all [Fe/H] values. However [Cu/Fe] exhibits a large increase towards metal rich distribution showing correlation with [Fe/H] and indicating towards a different source of Cu. Then various groups of people working on microlensed dwarfs have come to the conclusion that all Fe-peak elements have the same trend as that of the local disk except [Mn/O] ratios Johnson et al. (2014)[26] and ref. therein).

1.2.7 Neutron-capture elements in Galactic disk

Elements heavier than iron (more precisely Z$>$ 30) are primarily synthesized by neutron capture processes: the slow neutron capture (or the s-process) which occurs principally in the He-burning zones of low and intermediate mass AGB stars and the rapid neutron capture process (or the r-process) can occur in several situations during supernova deaths of high-mass stars (Burbidge et al. (1957)[83], Cameron (1957))[84]). The solar-system abundances of these isotopes have been built in roughly equal measure of products of the r- and s-process. The work performed by Mishenina et al.(2013)[61] for a sample of 276 FGK dwarfs in the galactic disk with metallicity $-1 < [Fe/H] < +0.3$, the s-process element Ba, La, and Ce in that sample have shown a decreasing trend for [Fe/H] $\gtrsim 0.1$ particularly for La it's more prominent. The r-process element Eu had shown a decreasing trend with metallicity but [Zr/Fe] ratio is found to be slightly higher in the thick disk compared to the thin disk whereas [Y/Fe] has a flat response. In case of [Sm/Fe] and [Nd/Fe], a larger r-process contribution has shown a higher ratio than the solar one but they have shown a decreasing trend with metallicity [Fe/H]$\gtrsim$ 0. More data will definitely give a better interpretation about the distribution of these elements in this locality.

1.2.8 Neutron-capture elements in Galactic halo

In order to determine not only the differnt phases of evolution that a galaxy has passed through but also the age of the Galactic halo, the abundance analyses of n-capture elements in old, metal-poor stars is very important since the abundance ratios are distinctly non-solar which has been confirmed by the works Spite & Spites (1978)[85]. The works of Gilroy et al. (1988)[86], McWilliam et al. (1995)[46], Ryan et al. (1996)[81], Burris et al. (2000)[105] have given proper justification to the fact that the abundance of n-capture elements significantly vary in comparison to Fe-peak elements by several order of magnitudes which is more prominent in the lowest metallicity regimes by an amount $\approx\pm1.5$ dex in stars with [Fe/H]< -2. The work of Ishagaki et al. (2013)[63] have found that in the inner and outer halo subsamples the [Sr/Fe] abundances are near-solar with scatter 0.06 to 0.24 dex. On the other hand the trend of the [Y/Fe] ratios in the lower metallicity is found to be having a large scatter of $\gtrsim 0.20$ dex, the inner halo and the outer halo subsamples both seem to have correlation with [Fe/H]. The large star-to-star scatter can probably have only one interpretation: the influence of individual and localized nucleosynthesis events in short-lived stars in a poorly-mixed early Galactic halo (Sneden et al.(2008)[88]). Moreover in the subsamples picked up by Ishagaki et al. (2013)[63], it has also been found that the [Ba/Fe] decreases toward lower [Fe/H] with [Ba/Fe] is near solar in the range [Fe/H]> -1.5. However the trend of [Zr/Fe] ratios in the halo stars is in agreement with that reported by Gratton & Sneden (1994)[87] which is more enhanced in the range [Fe/H]> -1.5. Then Cowan & Sneden (2005)[89] have found that Ge, Zr and Pt in a group of 11 halo stars, are in correlation with Eu abundance. As far as the heavier s-process elements are concerned in low metallicity stars, a downward trend in [Ba/Eu] is observed with decreasing metallicity (Aoki et al.(2002)[90]). As far as [La/Fe], [Nd/Fe], and [Sm/Fe] ratios are concerned in the inner/outer halo seem to increase with increasing [Fe/H]. Sivarani et al. (2004)[91], have shown that about 30 halo stars have found to show high Pb abundances. Finally it has been concluded that a larger sample is desirable to have a precise interpetation on the heavy neutron-capture elemental abundances in the halo stars.

1.2.9 Neutron-capture elements in Galactic bulge

Amongst the works performed by various groups viz. Fulbright et al. (2007)[92] clearly found out that the bulge [La/Eu] ratios are halo-like even for the most metal-rich bulge stars. Then McWilliam et al. (2009)[93] found that the [Eu/Fe] trend is similar to that of the solar neighborhood disk. A very recent work by Koch et al. (2016)[94] and references therein, have found in their sample that (s-) and (r-) neutron-capture processes are fully compatible with the halo distributions except in two, which shows strong enhancement in s-process. The Zr abundance were well within the error estimation and Sr was coinciding with 0.7 dex. Then the Ba abundances we found to be following the trend of metal-poor halo stars apart from two of their samples. Finally the [Eu/Fe] ratios are almost found to be solar throughout the sample. Thus apart from the two stars which are exceptional, are believed to be CEMP and CH star towards the Galactic bulge, the rest samples imply that the central regions of a Galaxy is chemically similar with the inner halo.

1.3 Elemental abundance distribution in Globular clusters: A brief review

1.3.1 α-elements in Globular cluster

Globular clusters (hereafter GCs) are densely packed collections of ancient stars. Roughly spherical in shape, they contain hundreds of thousands, and sometimes millions, of stars. For uncountable reasons GCs are the tools of our knowledge of the Universe. Therefore GCs have been subjected to intensive investigations in the past decades, leading to large progress in our understanding of stellar and Galactic evolution. Different groups of people (Sneden (2003)[30], Gratton et al.(2004)[31]) have studied the abundance variations in α-elements which are known to be overabundant in all the analysed GCs. The works of Lee & Carney (2002)[32], have showed that Si is overabundant in globular cluster. Due to Sneden (2004)[67] Ca has been found to be overabundant ($0.2-0.4$ dex) in GC stars. Then one of most complete studies performed by Yong et al. (2005)[33] on 20 different elements of 38 bright giants of the globular cluster NGC 6752 have reported that the α-elements [Si/Fe],[Ca/Fe] and [Ti/Fe] are overabundant with respect to Fe. Again Marino et al.(2011b)[34] have observed that Si, Ca, and Ti are overabundant in the whole 35-star sample of M22 with an average of $<[\alpha/Fe]>=+0.33\pm0.01$ which square measures with those reported in Marino et al. (2009)[35]. Recently Barbuy et al. (2016)[36] have found enhancements in O, Mg, and Si in stars of GC HP1 but only a slight enhancement is shown by Ca and Ti with the values being [Ca/Fe]= $+0.13$ and [Ti/Fe]= $+0.18$. Villanova et al.(2016)[37] working on NGC 4147 found that Si, Ca, and Ti are overabundant compared to the Sun with average value [α/Fe]= $+0.39\pm0.04$. Then Hanke et al.(2017)[38] found [Mg/Fe]= 0.44 ± 0.05 dex, [Ca/Fe] and [Ti/Fe] mean abundances 0.25 ± 0.03 dex and

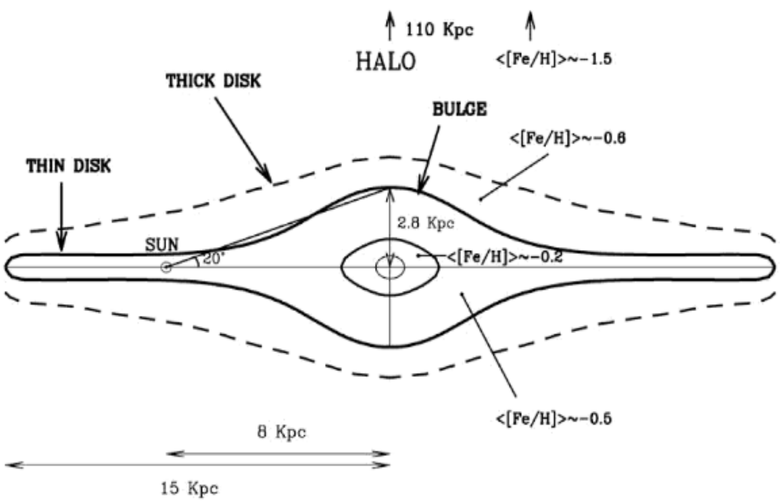

Fig. 1.1 Picture of E. Zoccali and S. Ortolani adopted from Matteucci (2012)[29] showing various parts of a galaxy and the metallicity distribution

0.20 ± 0.04 dex in NGC 6426 indicating that the cluster falls in the same line. All these studies have found overabundance of α-elements in GC stars.

1.3.2 Fe-peak elements in Globular cluster

Amongst the Fe-peak elements, the study of abundance of Ni in GCs, stands out because of the fact that spectroscopically there are lots of accessible Ni I lines and the stellar atmospheric parameter uncertainties don't have much influence on [Ni/Fe] abundance (Sneden (2004)[67]. The GC and open cluster [Ni/Fe] abundance ratios is in agreement with their field-star counterparts (Sneden (2004)[67]). However, Gonzalez & Wallerstein (2000)[68] have found that for M11 open cluster this [Ni/Fe] abundance is anomalously low and Sneden (2004)[67] have found a significant deviations from solar ratios in low-metallicity regimes. Cu is also found to behave in the similar way as well (Sneden (2004)[67]). The V abundance has been also studied by various authors in various clusters like M92 (Sneden et al. (1991)[69]), M5 (Sneden et al. (1992)[70]), M3 and M10 (Kraft et al. (1995)[71]), M13 (Kraft et al. (1997)[72]), M15 (Sneden et al. (1997)[73]) and NGC 7006 (Kraft et al. (1998)[74]) is found to be -0.01. Then $<$[Ti/Fe]$>= +0.26$ and $<$[Ni/Fe]$>= -0.01$ in all except for M15 and M92 where no value is reported, which is found to be consistent with the field metal-poor stars of GC M4 (Ivans et al. (1999)[75]). A more detailed discussion can be found in Gratton et al. (2004)[31] about the abundance of Mn, Ni, and Cu. The abundances shown by Gratton et al. (2004)[31] clearly indicate that $<$[Ni/Fe]$>\sim 0$ over the entire Galactic metallicity range and hence no significant differences are found in field stars, GCs and open clusters. However the star-to-star scatter in [Ni/Fe] is found to increase with decreasing [Fe/H]. Then among metal-poor stars of GCs, Cu and Mn exhibit significant departures from solar abundance ratios. However for precise abundance computation for these two elements the hyperfine structure must be taken into careful account. The work of Villanova et al. (2016)[37] found that the abundance of Cr is sub-solar while Ni is basically solar-scaled which are, at the cluster metallicity, in agreement with halo and dwarf galaxies environment. NGC 6426 is found to show a regular behavior i.e. little scatter among the sample stars in connection with Fe-peak elements (Hanke et al. (2017)[38]) with its metallicity. Then at comparable [Fe/H], the cluster mean abundances for Sc, V, Cr, Mn, Co and Ni are found to coincide well with other GCs.

1.3.3 Neutron-capture elements in Globular cluster

The work of Shetrone (1996a)[95] amongst the giants in GC M5, M71, M13 and M92, the average abundance value of [Eu/Fe] found to be lying from $+0.3$ to $+0.5$ with little scatter which is found to be consistent with the value obtained by Ivans et al. (1999)[75] as $+0.35 \pm 0.02$ for GC M4. But for the same cluster $<$[Ba/Fe]$>$ and $<$[La/Fe]$>$ has been reported as $+0.60 \pm 0.02$ and 0.45 ± 0.02 respectively. Yong et al.(2005)[33] found that in the stars of NGC6752 the mean [Eu/Fe] value is similar to that of field stars whereas [Y/Fe] and [Ba/Fe] in the field stars do not show any significant behavior. The same authors also have found that the [Ba/Eu]$= -0.37 \pm 0.16$ was lower than the value obtained by James et al. (2004a)[96] as -0.18 ± 0.11. Then La abundance is found to be -0.23 ± 0.10 in bright giants of NGC6752. Another work of Yong et al. (2008a[97],b[98]) have published the abundance of few neutron capture elements in GC M4 as [Y/Fe]$= 0.69 \pm 0.02$, [Sr/Fe]$=$ 0.73 ± 0.04, [Zr/Fe]$= 0.48 \pm 0.03$, [La/Fe]$= 0.48 \pm 0.03$ and [Eu/Fe]$= 0.40 \pm 0.03$. However the abundance of Ba for GC M4 have reported to be overabundant by many authors (Marino et al. (2008)[230], D'Orazi et al. (2010)[100], Villanova & Geisler (2011)[101]) from time time. The work on M62 performed by Yong el al. (2014)[102] have revealed s-process elements, Zr, Ba, La, Rb and Y are overabundant except Sr.

1.4 Elemental abundance distribution in peculiar stars: A brief review

1.4.1 α-elements in CEMP-, CH- and Ba-stars

There are lots of of metal-poor stars which show large over-abundances of carbon, and hence are called Carbon-Enhanced Metal-Poor (CEMP) stars. These are also known as CH stars because compared to stars at same temperature, they show strong CH absorption bands (Keenan(1942)[39]). But two discoveries, HE $0107-5240$ (Christlieb et al.(2002)[40]) and HE $1327-2326$ (Frebel et al.(2005)[41]) as Hyper Metal-Poor (HMP) star really have boosted that importance of CEMP stars because the large overabundance of carbon in these objects and the peculiar abundance pattern of other elements. Beers & Christlieb (2005)[42] argued that the nucleosynthesis of first generations of stars is important to understand the nucleosynthesis in the early Galaxy. The work by Goswami et al. (2006)[43] on three CEMP stars namely HE $1305+0007$, HE $1152-0355$ and HD 5223, Mg is found to exhibit the usual halo-star overabundance, with [Mg/Fe]$\sim +0.25$ in HE $1305+0007$, -0.01, which is almost solar value for HE $1152-0355$ then for HD 5223 it's found to be $+0.58$. Calcium also exhibits a normal halo overabundance and Ti has shown a significant overabundance. Suda et al. (2011)[44] performed a more elaborate study on α-elements from oxygen through calcium and titanium as a function of [Fe/H] and have found that apart from O, the other α-elements show almost constant trends with decreasing metallicity for [Fe/H]< -1 with three stars CS $22949-037$, CS $29498-043$ and CS $22949-037$ showing large enhancement of Mg, Ca which was later confirmed by (McWilliam et al. 1995[46]). Then Si and S are also found to behave in the same way was established by Norris et al. 2001[45] and Depagne et al. 2002[47] respectively. HE $1012-1540$ also show large excesses of Mg and Si (Aoki et al. 2002b[48]) and is confirmed by Suda et al. (2011)[44]. In a recent work by Bonifacio et al. (2015)[49] on six of their sample stars, all of which are found to be CEMP stars with Ca surprisingly lying in the range $-5.0 \leq$[Ca/H]< -2.1. Thus an enhancement of α-elements is found in CEMP stars. Barium stars were recognized as a group of peculiar stars by Bidelman & Keenan(1951)[50]. The study of their chemical peculiarities is important for understanding not only the accretion phenomena but also the evolution of a binary systems and hence people over the years have devoted lots of hard work to determine the chemical abundances and kinematics of these stars. The seminal work of Allen & Burbuy (2006a,b)[51, 52] in their sample of 26 Ba stars, the α-elements tend to be overabundant at low metallicities, with [α/Fe] reaching ≈ 0.5 at $-4 <$[Fe/H]< -1. At [Fe/H]≈ -1, the overabundance starts to decrease toward higher metallicities, and [X/Fe] can be subsolar at [Fe/H]≈ 0. The O, Mg and Si abundance have been reported to be in agreement with the values obtained by François et al. (2004)[53] but Ti is found to be having lower abundance compared to those of Ca, Si and Mg. But François et al. (2004)[53] in their work have found that Ti and Mg behaving in the same way showing their dispersive behaviour. The work of Pereira et al. (2011)[54], in their sample of Ba-stars disclosed that the trend of the [Mg/Fe] ratio is similar to that of dwarfs in metallicities higher than [Fe/H]> 0.0, the mean [Si/Fe]≈ 0.1 flattens out for the Ba-giants for [Fe/H]$= 0.0 - 0.3$ and the mean [Ca/Fe] ratio is found to be ≈ 0.0 in their sample of Ba stars. However the [Ti/Fe] ratios are lower than the [Mg, Si, Ca/Fe] ratios, and flattens around ≈ 0.1 behaving in the similar way as local-disk giants. Then work of de Castro et al. (2016)[55] have shown a slight increase of [α/Fe] ratio with decrease in metallicity for the barium stars just like the field giants. Thus they have concluded that their sample of barium stars are probably the stars of the transition of the thin and thick disk, or of the thick disk.

1.4.2 Fe-peak elements in CEMP-, CH- and Ba-stars

The general behaviour of the ratios of [Mn/Fe] and [Cr/Fe] in CEMP stars is found to be decreasing (McWilliam et al. (1995)[46] and Ryan et al. (1996)[81]) which was confirmed by Ivans et al. (2003)[82]. The abundance of Sc and Ni relative to Fe is found to be solar even at very low metallicity ([Fe/H]= -4). As far as the Cr and Co are concerned their abundances are found to be dependent on effective temperature, especially at metallicity below -2.5 (Lai et al. (2008)[65], Suda et al (2011)[44]). Sneden et al. (1991)[69] found that the abundance of Cu show an increasing trend with increase in metallicity which was later on confirmed by Mishenina et al. (2002)[76] whereas and Zn abundance also shows an increasing trend but with decreasing metallicity at [Fe/H]< -2 (Suda et al (2011)[44]). The work of Goswami et al. (2006)[43] on three CEMP stars the [Mn/Fe] and [Ni/Fe] abundance for HE $1305+0007$ is found to be $+0.14$ and mildly underabundant with a value -0.25 respectively and in HD5223 with a value [Ni/Fe]= -0.47. A work by Karinkuzhi et al. (2016)[77] reporting for first time on the abundance of CD-27 14351 found only one Fe-peak element Cr with a value -0.18. Sc is found to be overabundant ≈ 0.25 dex and ≈ 0.20 dex in Ba stars by Zhao & Magain (1990)[78], Prochaska et al. (2000)[79] respectively with a decreasing trend for lower metallicities which is also confirmed by François et al. (2004)[53]. Allen & Burbuy (2006a[51],b[52]) working on 26 Ba stars found [Sc/Fe] are above solar, reaching 0.7 for the star HD 147609 and the V abundance lies in the range $-0.40 <$[V/Fe]< 0.2. Gratton & Sneden (1991)[80] in their sample of 20 stars found [V/Fe]~ 0 whereas Prochaska et al. (2000)[79], in their work obtained $0.1 <$[V/Fe]< 0.4 for the same. The Cr abundance by Allen & Burbuy (2006a[51],b[52]) found to be lying between $-0.2 \leq$[Cr/Fe]≤ 0.2. However Co has shown some opposite behaviour, Prochaska et al. (2000)[79] found an overabundance ~ 0.2 dex, whereas Gratton & Sneden (1991)[80] found a deficiency of 0.1 dex in the same range of metallicity. However the work of Allen & Burbuy (2006a[51],b[52]) reported $-0.15 <$[Co/Fe]< 0.4 in their sample. Then Gratton & Sneden (1991)[80], Edvardsson et al. (1993)[2], Ryan et al. (1996)[81] find that the Ni abundance lying between -0.1 to 0.1 in the range $-4 \leq$ [Fe/H]≤ 0 which is not in agreement with the work François et al. (2004)[53]. However $-0.13 \leq$[Ni/Fe]≤ 0.12 was found by

Allen & Burbuy (2006a[51],b[52]) in their sample of 26 Ba-stars. As far as Cu is concerned Allen & Burbuy (2006a[51],b[52]) found, except for a few stars, its abundance is below solar in their sample. As far as Cu is concerned Sneden et al. (1991)[69] pointed out a linear decrease of [Cu/Fe] with decreasing metallicities. A slight dispersion of Zn abundance is found as $-0.25 \leq$[Zn/Fe]≤ 0.3 by Allen & Burbuy (2006a[51],b[52]).

1.4.3 Neutron-capture elements in CEMP-, CH- and Ba-stars

In two of the three sample stars namely in HE $1305+0007$ and HD 5223, taken by Goswami et al. (2006)[43], the light s-process elements Sr, Y and Zr are found to be overabundant. On the other hand the other star of their sample ie HE $1152-0355$ Y and Zr are found to be almost solar. The same author has also reported on heavy s-process elements Ba, La, Sm, Eu, Ce, Pr and Pb in their three sample stars which show large overabundant. However Nd has reported showing variation. The behaviour of the neutron-capture-element abundances is remarkably different and the scatter is much higher (Goswami et al. (2006)[43]) which has been found by Allen el al. (2012)[103] in their sample. They have found three stars CS $22949-037$, CS $29498-043$, and HE $1012-1540$ have [Ba/Fe]< 0, whereas three other stars namely CS $29528-028$, HE $1447+0102$ and HE $1327-2326$ are found to have very high Ba abundances, with [Ba/Fe]$= +3.27$, $+2.70$, and $+1.40$, respectively. However for Eu, the same authors have given the upper limits for CS $22949-037$, HE $1012-1540$, and HE $1327-2326$ as [Eu/Fe]$< +0.57$, $< +1.62$, $< +4.64$, respectively. A recent work by Karunkuzhi et al.(2016)[77] on a CEMP star CD-27 14351 found that Ce abundance is exceptinally high [Ce/Fe]~ 2.63 however other n-capture elements Sr, Ba, La, Nd and Eu are found to be slightly overabundant. In Ba stars there have been many published works reporting on the abundances of these elements. Gratton & Sneden (1994)[87] found that Sr abundances in their sample belonging to these types of stars lies between $-0.2 \leq$[Sr/Fe]≤ 0.2. Allen & Burbuy (2006a[51],b[52]) updates this as $0.6 \leq$[SrII/Fe]≤ 1.40

and 0.3 $\leq$[SrI/Fe] $\leq$ 1.2. Gratton & Sneden (1994)[87] obtained $-0.3 \leq$ [Y/Fe]$\leq$ 0.1 at [Fe/H]≈ -1, and [Y/Fe]$\approx$ 0 at [Fe/H]≈ -0.3 found an increasing trend of [Y/Fe] toward higher metallicities in Ba stars which was confirmed by Edvardsson et al. (1993)[2]. However the work of Allen & Burbuy (2006a[51],b[52]) estimated the values much higher lying in the range 0.50 $\leq$[Y/Fe]$\leq$ 1.60. Thus Y have been found to show some metallicity dependence. However, Zr is found to show some dispersion which are much higher than as compared to normal stars (Allen & Burbuy (2006a[51],b[52])). As far as Mo is concerned the work of Allen & Burbuy (2006a[51],b[52]) obtained a range for the stars as $-0.20 \leq$[Mo/Fe]$\leq$ 1.0. Gratton & Sneden (1994)[87] have found a trend of Ba increment with metallicity and dependance on metallicity. Then Allen & Burbuy (2006a[51],b[52]), in their work have shown high Ba overabundance in their sample with all values of [Ba/Fe] are in the range of 0.8 $\leq$[Ba/Fe]$\leq$ 1.80. Then a correlation between [C/Fe] and [Ba/Fe] is seen for these Ba-enhanced stars (Beers & Christlieb(2005)[42]). Like [Ba/Fe], a range of $-0.4 \leq$[La/Fe]$\leq$ 0.05 at $-2 \leq$[Fe/H]$\leq$ 0 was found by Gratton & Sneden (1994)[87] in their sample stars thus a similar behaviour for [La/Fe] as well. Similarly the works of Allen & Burbuy 2006a[51],b[52] also have obtained a range as 0.6 $\leq$[La/Fe]$\leq$ 1.70. Gratton & Sneden (1994)[87] and Jehin et al.(1999)[104] showed for [Ce/Fe] a behaviour similar to [Ba/Fe] and [La/Fe]. Their results are in the range$-0.4 \leq$[Ce/Fe]$\leq$ 0.15 for $-2 \leq$[Fe/H]$\leq$ 0. With large dispersion among the stars, Allen & Burbuy (2006a[51],b[52]) also have reported abundance excess of Ce relative to Fe which is lying in the range 0.4 $\leq$ [Ce/Fe]$\leq$ 1.80. Nd was also reported by various authors (Gratton & Sneden (1994)[87], Burris et al. (2000)[105]) and references therein of showing dispersion and behaving in a similar way to that of Ba, La and Ce. Burris et al. (2000)[105] found a high dispersion in the metallicity range $-3 \leq$[Fe/H]≤ -1.5, with a value close to [Nd/Fe]≈ -0.6. However Allen & Burbuy (2006a[51],b[52]) have obtained 0.3 $\leq$[Nd/Fe]$\leq$ 1.70 an abundance excess relative to Fe for their sample of 26 Ba stars. As far as Pb is concerned there are a few stars for which its abundance is determined. The work by Van Eck et al. (2003)[106] show that some CH stars are also found to show high Pb abundances. And the work of Allen & Burbuy (2006a[51],b[52]) Pb is found to show a large dispersion with the results lying in the range $-0.2 \leq$[Pb/Fe]≤ 1.6.

1.5 Nucleosynthesis: Origin of these elements

Astronomers are very keen to explain the composition of the universe via a theory of how the elements formed. Though they have developed an elaborate, physically robust evolutionary theory to explain the abundances throughout the universe but it has no predictive power. A creationary theory of the chemical abundances is more desirable and subsequently they have recognized two distinct episodes of elements' synthesis: primordial nucleosynthesis and stellar nucleosynthesis (Faulkner (2014)[107]). Primordial nucleosynthesis is the production of certain elements like hydrogen, helium, and a small amount of lithium from the big bang model. However, stellar nucleosynthesis also involves nucleosynthesis in supernovae. Other elements (some amount of helium too) are thought to have been produced in stars either by normal stellar nucleosynthesis or in supernovae nucleosynthesis.

1.5.1 Primordial Nucleosynthesis

Astronomers began to take the universe seriously once it was discovered that it is expanding (Friedmann(1922)[108]) and because it is expanding it's getting cool too, and then cool enough for protons and electrons to recombine into neutral hydrogen atoms. The Big Bang nucleosynthesis (hereafter BBN) is still required to explain the abundances of several other light nuclides. Thus the importance of the primordial nucleosynthesis lies in the fact that it not only prevented elements heavier than beryllium from forming, but also, at the same time, allowing unburned light elements, such as deuterium, to exist. According to Alpher &

Herman(1950)[109], the temperatures in the early universe were suitable enough for fusion reactions which resulted in the formation of light elements like Deuterium, Helium and Lithium, and trace amounts of Beryllium along the radioactive isotopes like H^3, Be^7, Be^8 which were also produced during the primordial nucleosynthesis, either decayed or fused to make other stable isotopes.

The primordial H^2 abundance:

Deuterium is the most weakly bound of the light nuclides and it gets fused in stars to produce He^3 during pre-main sequence evolutionary stage where convective zones are fully mixed (Epstein et al.(1976)[110]). The fusion processes can only destroy, but never produce deuterium. Any deuterium that astronomers can detect anywhere, anytime, must have been produced in the early universe, and any deuterium abundance measured can only serve as a lower limit of the primordial value. Thus its post-BBN evolution is simple and its BBN-predicted abundance depends on the baryon abundance. And its abundance can be estimated investigating some of the oldest objects like distant quasars. At present, the best estimate indicates that, in the early universe the ratio of deuterium to hydrogen nuclei was in exponential notation, $3 \pm 0.4 \times 10^{-5}$ (Weiss(2006)[111]).

The primordial He^3 abundance:

Observations of He^3 have been carried out in the solar system and in the galaxy to get an abundance of the element. As in the galaxy there is a clear gradient of metallicity with location, the He^3 abundance is also expected to follow a same trend. However the work of Bania et al.(2002)[112] have revealed that there is no statistically significant correlation between the abundance of He^3 and metallicity. This indicates that there is a very delicate balance between net production and net destruction of He^3. Thus the evolution of He^3 is considerably more complex as far as its production, destruction, and survival is concerned. In low-mass stars, it is produced in substantial amounts, preserved in the cooler, outer layers. While in massive stars, in the hotter interiors, equally substantial amounts of this element are transformed into He^4 and other heavier nuclei (Steigman(2006)[113]). From the surveys of HII-clouds people have deduced an average value for the ration of galactic He^3 to H nuclei as $1.1 \pm 0.2 \times 10^{-5}$ (Weiss(2006)[111]). However, astronomers have found that an overall increase of He^3 due to stellar nuclear fusion which indicates that current models of stellar evolutions are incomplete and hence some new effects will have to be included in those models (Weiss(2006)[111]).

The primordial He^4 abundance:

He^4 which is one of the major products of BBN however, has a quite simple post-BBN evolution. To get an idea about its primordial abundance astronomers looked into the emission lines of interstellar helium, both in our galaxy and in certain other dwarf galaxies which are especially poor in oxygen (Steigman(2006)[113]). Oxygen is produced by short-lived, massive stars and He^4 is synthesized in various amounts by all stars. Thus, through generations of stars, hydrogen is burned to He^4 (and beyond), increasing the He^4 abundance. Peimbert (1975)[114] has found evidence for a small increase in helium abundance with increasing abundance of heavy elements. Thus more oxygen a dwarf galaxy contains, the higher its He^4 abundance will be. This indicates a correlation between oxygen and helium. So the primordial abundance of He^4 will be when no oxygen at all. Peimbert (1975)[114] has concluded that its primordial abundance probably lies in the range $0.20 \leq X(He^4) \leq 0.25$.

The primordial Li^7 abundance:

Though Li^7 has a reputation of getting destroyed still in the post-BBN universe it has a production scheme too and it's by cosmic ray spallation. When the high-energetic protons in the cosmic rays collide with interstellar gas this element is produced. Ryan et. al(1990)[115] have also reported the primordial abundance of $Li^7 \approx 2.0 - 2.1$. The work of Thorburn(1994)[116] has found the same as $\approx 2.25 \pm 0.10$. Recently Melendez & Ramirez(2004)[117] have published their work on 62 halo dwarfs and found the lithium abundance as $[Li] = 2.37 \pm 0.05$. But the discovery of the super-lithium rich red giants have indicated lithium increment above the primordial value. Almost two decades ago Ryan et. al(1990)[115] claim evidence for a 0.3 dex increase in the lithium abundance. Studies of halo and galactic globular cluster stars can provide lithium abundance (Steigman(2006)[113]). Thus the overall trend is that its abundance has increased with time. However the amount of Li^7 produced in stars is very much sensitive to the star's mass, temperature and initial composition. Evidence has been found about the presence of a constant amount Li^7 in the outermost layers of some oldest stars. Their constant lithium content has, in fact, given these stars their name as lithium-plateau stars. On average, the stars contain one Li^7 nucleus for every 8 billion hydrogen nuclei, the ratio of Li^7 to hydrogen nuclei is somewhere between 1.3×10^{-10} and 2.0×10^{-10} (Weiss(2006)[111]). These stars have been around for around 95% of the age of the universe.

The primordial Be^9 abundance:

Researchers thought that beryllium could not have been produced during rather generic circumstances in BBN but thanks to the work of Pospelov & Pradler(2011)[118] where they have shown that the decay of a unknown particle during BBN, it can release a large amount of energy that can influence the production of Be^9 at the end of a chain of transformation with an the efficiency of beryllium/hydrogen abundance ratio of 10^{-14}. However Be^9 still can be observed in metal-deficient stars, which were formed from the nearly pristine interstellar gas. But unlike Li^7 it has no plateau. In fact the abundance of beryllium seems to be decreasing to smaller and smaller values as stellar metallicity decreases (Pospelov & Pradler(2011)[118]). In these stars it is hardly affected by stellar dynamics and hence beryllium could be more useful for constraining nonstandard BBN models. The abundance pattern of these elements reported in Burles et. al(1999)[119] has been shown in the Fig. 1.2. Then in the standard picture of BBN the ordinary matter (baryons) relative to radiation (photons) is important in determining elemental abundances as it leads towards the conditions under which nuclear fusion occurs. Though the homogeneity of the universe indicates a unique value of the

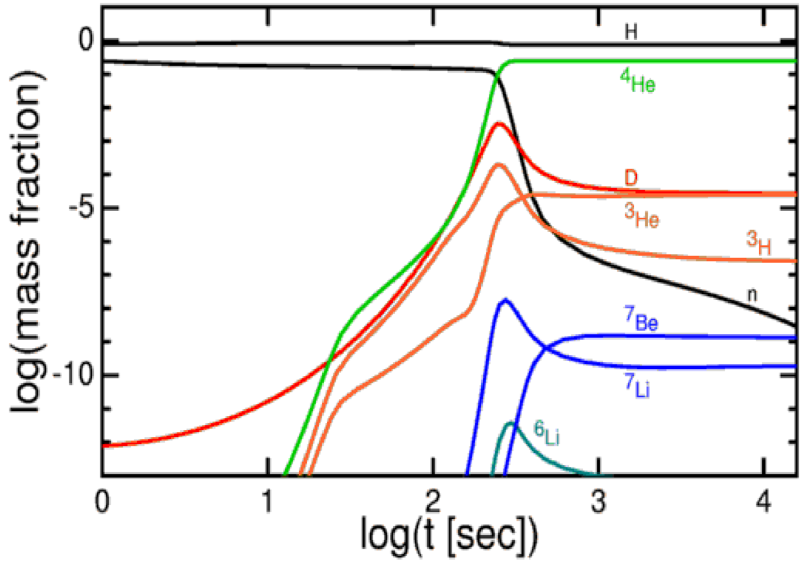

Fig. 1.2 Figure from Burles et. al(1999)[119] showing the time evolution of the primordial elements.

baryon-to-photon ratio but the value given by the discovery of cosmic microwave background radiation doesn't fit Li^7 which demanded to investigate the intensities of reactions like Be^7(n,p)Li^7 versus Be^7(d,p)Be^8. Thus the primordial models have to be modified so that they bring consistency in the light elements' abundance. The work of Applegate & Hogan(1985)[120] have reported that the abundance He^4 is suppressed and Deuterium along with Be^9 is more abundantly synthesized. Then Malaney & Fowler(1989)[121] had reported that many other heavy elements were found to get synthesized abundantly in low density neutron rich region. This overabundance in Be^9 gives clue to inhomogeneous nucleosynthesis (Terasawa, & Sato(1990)[122] and ref. therein) which paved the way for searching metal poor Pop-II stars with low Be^9 (Ryan et. al(1990)[115]). BBFH[83] worked out the nucleosynthesis processes which are going in stars, where carbon formation can take place from the Triple-α reaction at a suitable temperature density condition and then to proceed to make further heavier elements.

1.5.2 Stellar nucleosynthesis

Though the BBN is responsible for producing some lighter elements, but its the stellar nucleosynthesis which is the most dominant factor for the observed the chemical composition of a galaxy. Nuclear burning reactions occurring in many generations of stars result in production of elements essential for harbouring life. Low mass stars have long lifetimes and they are important as they contain information about the history of the evolution of chemical abundance in a galaxy. On the other hand massive stars have short lifetimes and hence they have immediate influence on their environment. Though these stars are less common, but not only they dominate the visible spectrum of galaxies but also inevitably linked to galactic formation through their winds and SNe. Thus, they influence the ISM and contribute heavily to the chemical enrichment of the universe (Hoyle(1954)[123]). One can try to understand these processes and chemical evolution from theoretical models, but the best way to learn about the history of the elements in the Galaxy is to look at the fossils. The work of Pagel& Patchett(1975)[124] have shown in their model of evolution in a closed system, that interstellar gas (ISM) is responsible for making generations of stars. Then a part of the synthesized elements are recycled to the ISM and thereby enrich the ISM by each generation of stars; which are then locked up as stellar remnants and they no longer take part in further chemical evolution. This recycled material is commonly called as the yield. Mathematically, it is the ratio of mass ejected to mass locked up. This yield thus, depends on the mass of metals ejected by stars (usually a function of mass) and the relative frequency of different mass stars born in a stellar generation (this is the initial mass function, or IMF). The star formation rate (SFR) is also one of the strong candidates for chemical evolution, which affects the time evolution of the metallicity but does not affect the final metallicity function of the system after the gas has been exhausted. Thus, in simple model the yield (y) and the metallicity (Z) can be connected as following (McWilliam(1997)[125])

$$f(Z) = y^{-1}e^{-Z/y}$$

Tinsley(1979)[126] had proposed that SN Ia are the key producers of iron in the galaxy whereas according to Woosley & Weaver(1995)[28] SN II are the major producers of elements like O, Mg, Si, S, Ca, and Ti together called as α-capture elements where [α/Fe] ratio is sensitive to the SFR. Thus abundance ratios can be used to probe the IMF and SFR parameters for chemically evolving systems. Tinsley(1979)[126] also argued that the time delay between SN II and SN Ia could be a key factor in the observed abundance of elements not only in halo stars but also in the Galactic bulge. Elements like C, O, and those in the Fe-peak, thought to be produced in stars from the original hydrogen. And there are some elements which are produced from some other preexisting seed nuclei, such as s-process heavy elements. The abundance of both these categories of elements is expected to increase linearly with [Fe/H] as they have dependence on the abundance of their source. But these elements do not show the expected dependence on metallicity (McWilliam (1997)[125]).

p-capture nucleosynthesis beyond Carbon:

The fusion of hydrogen to helium is the longest phase in stellar evolution, which is associated with a release of 26.7 MeV amount of energy. The CNO-cycles become more efficient than the pp-chains at temperatures $T_9 \approx 0.017$ which are nothing but the transformation processes of (^1H) into ^4He; this corresponds to H-burning temperatures in a 1.2 $M_\odot$ star. When CNO-elements are available, the CNO-cycles dominate in massive stars. The most efficient cycle in H burning of massive stars is CNO denoting the following reaction sequence:

$$^{12}C(p,\gamma)^{13}N(e^+,\nu_e)^{13}C(p,\gamma)^{14}N(p,\gamma)^{15}O(e^+,\nu_e)^{15}N(p,\alpha)^{12}C$$

$^{14}N(p,\gamma)^{15}O$ is the slowest reaction in this cycle and thus determines the lifetime of the H burning cycle. A steady flow equilibrium can be assumed and most of the C, N and O nuclei of the initial gas is converted to ^{14}N. Thus elemental and isotopic CNO equilibrium ratios like N/C and $^{12}C/^{13}C$ will now be different from the ratios generally found in the ISM and thus can be used as indicators for H burning in massive stars as they will indicate mixing in the envelopes of massive stars (Przybilla et. al(2010)[127]). With increasing stellar mass and burning temperatures further CNO-cycles branching from ^{15}N and ^{17}O will occur. A detailed discussion is followed in the forthcoming sections. During hydrogen burning in the mass region, A$\geq$20 the nucleosynthesis processes likely to produce the isotope ^{23}Na. One possibility is the reaction $^{23}Na(p,\alpha)^{20}Ne$ which ^{23}Na to a lighter isotope (^{20}Ne) and thereby gives rise to the so-called NeNa cycle (Rolfs & Rodney(1988)[128]). The other possibility is $^{23}Na(p,\gamma)^{24}Mg$ which leads to MgAl cycle activates at a slightly higher temperature to that of NeNa cycle. This MgAl cycle is crucial because it produces the two isotope $^{26}Al^{g}$ and $^{26}Al^{m}$ from pre-existing ^{25}Mg via $^{25}Mg(p,\gamma)$. NeNa and MgAl each lead to an anti-correlation (Na vs. O and Al vs. Mg) in an ISM enriched with H-burning ashes, ejected by the mass loss of massive stars. These anti-correlations are observed in globular cluster stars (Decressin et. al(2007)[129]). In this work we have considered the nuclear burning cycles Carbon-Nitrogen-Oxygen-Fluorine (CNOF), Neon-Sodium (NeNa), and Magnesium-Aluminium (MgAl) in rotating massive star at high temperature and low density conditions and have estimated the abundances of the product elements O, Na and Al in a temperature range of 2×10^{7} to 10×10^{7} K since CNO, NeNa and MgAl cycles activated above temperature 0.02×10^{9} K, 0.035×10^{9} K and 0.05×10^{9} K respectively (Decressin et. al(2007*b*)[130]). Although nucleosynthesis during NeNa and MgAl cycles are discussed at length in Arnould et. al(1999)[131], Jose et. al(1999)[132],the availability of new estimates of the cross-sections for many of the reactions involved in these cycles, from recent experimental determination Iliadis et. al(2010)[133], prompted us to investigate the synthesis of elements due to these cycles. Our aim is to compute the abundances of the key elements, O, Na, and Al which are important diagnostics for understanding the chemical evolution, and thereby examine the impact of proton-capture reactions on the observed abundances of GC stars. A comparison between the computed and observed data suggests contributions coming from other sources, yet to be identified, that might have possibly influenced the observed abundances.

Nucleosynthesis in massive stars:

Helium burning:

The reaction converting three ^{4}He nuclei to a ^{12}C starts at temperatures $T_9 \geq 0.15$. Moreover, $^{12}C(\alpha,\gamma)^{16}O$ also contributes to the energy generation and has a big impact on the subsequent stellar structure and evolution. Because $^{12}C/^{13}C$ determines whether the subsequent C burning is convective or not. But the most significant nuclear reaction chain is perhaps the following $^{14}N(\alpha,\gamma)^{18}F(e^{+},\nu_e)^{18}O(\alpha,\gamma)^{22}Ne$ because ^{22}Ne is the main neutron source of the s-process in massive stars (Arnett & Thielemann(1985)[134]).

Carbon burning:

The main reaction during C burning is the fusion of two ^{12}C nuclei. It has three different major decay channels, of which neutron emission channel is endothermic and thus weaker given by $^{12}C\,(^{12}C,\alpha)\,^{20}Ne$, $^{12}C\,(^{12}C,p)\,^{23}Na$ and $^{12}C\,(^{12}C,n)\,^{23}Mg$. The $^{12}C(\alpha,\gamma)^{16}O$ reaction is also active, leaving the main products ^{16}O, ^{20}Ne and ^{24}Mg in the burning ashes along with many other reactions to produce minor abundances of isotopes like ^{26}Mg and ^{27}Al (Arnett & Thielemann(1985)[134]).

Neon burning:

Neon burning takes place after carbon burning has consumed all carbon in the core. If temperature reaches a value $T_9 \approx 1.2$ K, ^{20}Ne starts to photodisintegrate via $^{20}Ne(\gamma,\alpha)^{16}O$. These liberated α particles are captured on ^{20}Ne and ^{24}Mg producing ^{24}Mg and ^{28}Si via $^{20}Ne(\alpha,\gamma)^{24}Mg(\alpha,\gamma)^{28}Si$. There is also an alternate way of ^{20}Ne if neutron are available via $^{20}Ne(n,\gamma)^{21}Ne(\alpha,n)^{24}Mg$ where the neutron consumed in the first step is regenerated in the second. Neutrons are released via different reaction chains and lead to the production of heavier elements (Arnett & Thielemann(1985)[134]), but it does not produce a typical s-process signature since it acts on a shorter time scale.

Oxygen burning:

Though it seems that ^{16}O burning should come before ^{20}Ne burning, but it does not happen because ^{16}O is very stable since it is at proton and neutron magic number N = Z = 8. $T_9 \approx 1.9$ K is the value of temperature at which oxygen starts fusing with itself and produces compound nucleus of $^{32}S^*$ which then decays to ^{31}P and ^{28}Si via $^{16}O\,(^{16}O,\alpha)\,^{28}Si$, $^{16}O\,(^{16}O,p)\,^{31}P$ and $^{16}O\,(^{16}O,n)\,^{31}S(e^+,\nu_e)\,^{31}P$. These liberated protons, neutrons and α-particles will then engage themselves in further fusion reactions where the main burning products are, mainly ^{28}Si, ^{30}Si, ^{34}S, ^{38}Ar, ^{42}Ca and ^{46}Ti (Arnett & Thielemann(1985)[134]).

Silicon burning:

Si burning (^{28}Si+^{28}Si), final burning phase of stars, is unlikely because of its high Coulomb barrier at temperature achieved by massive stars which is on the other hand is sufficient to have photodisintegrations of the nuclei. Thus the possibility of getting new nuclei is very much on the cards via the capture of the liberated protons, neutrons or α-particles. Thus the increase of temperature will further link up several groups of nuclei via quasi-statistical equilibrium (QSE). The two main QSE-clusters are around ^{28}Si ($12 \leq Z \leq 20$) and ^{56}Ni ($22 \leq Z \leq 28$)(Arnett & Thielemann(1985)[134]). With even higher temperature $T_9 \gtrsim 4$K nuclear-statistical equilibrium (NSE) is achieved via strong and electromagnetic interactions and the production of the isotopes with the highest binding energy are favoured which are the iron group nuclei and in particular ^{56}Ni.

1.5.3 Neutron capture nucleosynthesis

With very high proton numbers, heavy elements with atomic numbers $\geq$ 56 inhibits the charged particle reactions (proton and -capture) because of the electrostatic repulsion. Hence, the elements heavier than the iron peak are made through the neutron addition on to the abundant Fe peak elements via two principal processes: the rapid neutron-capture process (r-process) and the slow neutron-capture process (s-process). The fundamental studies on these processes started with the works of BBFH[83]. Production mechanisms of s- and r-process require not only two widely different astrophysical sites but also very different time scales and neutron flux. The s-process occurs at relatively low neutron densities (N_n= 10^7 neutrons/cm^3) and the time scale for neutron-capture by iron-seed elements for s-process is much longer than the time required for their β-decay. Hence the s-process, produces elements along the valley of β-stability which include Sr, Y, Zr, Nb, Ba and La. Identification of an explicit stellar site for s-process nucleosynthesis started with the works of Weigert(1966)[135], Schwarzschild & Härm[136] on the thermal pulse calculations. The free neutrons for the slow neutron-capture elements are produced mainly by two reactions,

$$^{12}C\,(p,\gamma)\,^{13}N(\beta,\nu_e)\,^{13}C\,(\alpha,n)\,^{16}O$$
$$^{14}N\,(\alpha,n)\,^{18}F(\beta,\nu_e)\,^{18}O\,(\alpha,\gamma)\,^{22}Ne\,(\alpha,n)\,^{25}Mg$$

Since very high temperature is required for the operation of ^{22}Ne(α, n)^{25}Mg reaction to occur, it is an efficient neutron source in massive AGB stars with initial masses$\geq$4 $M_\odot$. The main source of neutrons in the low-mass AGB stars is $^{13}C(\alpha,n)^{16}O$. The $^{13}C(\alpha,n)^{16}O$ reaction requires the operation of both proton and α-capture to occur in He shell, a region free of protons. During CNO cycle, there is some ^{13}C left over in the He intershell, which is not enough for the occurrence of s-process in AGB stars (Gallino et. al(1988)[137]). Hence some mixing of protons from the convective envelop into the top layers of the He-intershell is required. The $^{13}C(\alpha,n)^{16}O$ reactions occur at low temperature $T_9 \geq 0.09$ K, hence the ^{13}C burns under radiative conditions (Straniero et. al(1995)[138]). The s-process occurs in the same layers where the ^{13}C was produced. The time scale for the neutron production during the interpulse are very long ($\geq 10^3$ years). This results in a much lower neutron densities than the $^{22}Ne(\alpha,n)^{25}Mg$ reaction. Clayton & Ward(1974)[139] explained three components of s-process namely, weak, main and strong responsible for the production of heavy elements (see Figure 2.1 for different s-process peaks). The weak component of s-process is responsible for the production of elements with mass number up to 88. The main component is responsible for the production of elements with 88$\leq$A$\leq$208. The strong component of s-process is responsible for the production of 50% of ^{208}Pb. Busso et. al(1999)[140] explained the various sites for the occurrence of these three components. The double shell burning phase of the AGB star is the preferred site for the main component of the s-process. While strong s-process occurs in very low metallicity AGB stars, the weak component occurs during He and C burning in massive stars with M$\geq$12 $M_{\odot}$. Prantzos et. al(1990)[141] show that massive stars produce Zn to Zr. For r-process a very high neutron density of the order of 10^{25} neutrons/cm^3 is required and the time scale is much shorter than the β-decay time scale. Due to the extreme conditions required for the r-process, it is expected to occur during supernova explosions. The elements Eu, Er, Hf, Th etc. are mainly produced by r-process. Insight into the astrophysical sites and the production mechanisms of neutron-capture processes can be obtained by studying the chemical composition of stars that exhibit large enhancement of neutron-capture elements. In the Fig. 1.3 a local galactic abundance of elements relative to Si as shown by Cameron(1982)[142] has been given.

1.6 Information towards Galactic Chemical Evolution

Galactic chemical evolution is that the proportional buildup of not only the H or He but also and a serious part or metals, among a galaxy over time as a result of the continual manufacture and the expulsion of those parts by resident stars. There square measure precise physical and chemical processes that govern the evolution of planets, stars, and galaxies.

By analyzing the structure and chemical content of astronomical objects, scientists have gathered valuable info not solely concerning the stars, however additionally concerning what the universe's conditions must have been like long back in order to account for currently ascertained elemental abundance ratios. Astronomers refer to all the chemical elements heavier than hydrogen and helium as metals, even though this includes elements such as carbon and oxygen which are not considered metals in the traditional sense. Generally the metallicity of a star is therefore specified as the fraction of the star's mass composed of these 'metals'. However, this definition fails to completely outline the chemical composition of a star because the same metallicity can be achieved in an almost infinite variety of how. For instance, a star with any given metallicity could have all of its metals as a particular element, whereas another with an equivalent overall metallicity, could have all of its metals as a different one. In fact, the whole elements of the periodic table are present in each star, but the relative amounts of each element vary from star to star. In order to quantify the relative amounts of individual elements present in a star, astronomers define an 'abundance

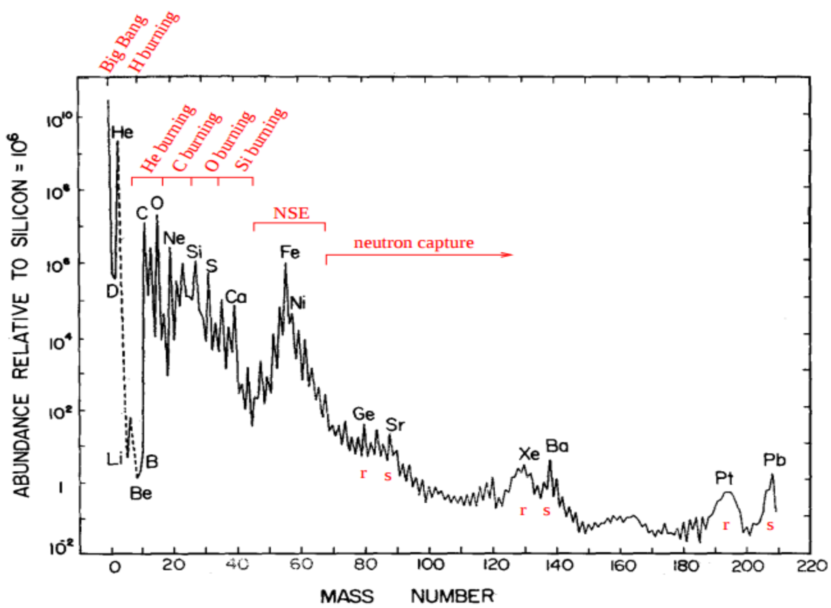

Fig. 1.3 The abundance distribution of nuclear species, as a function of mass number A adopted from Cameron(1982)[142].

ratio' as the logarithm of the ratio of two metallic elements in a star relative to their ratio in the Sun. For example, the abundance ratio of any element X to iron (written as [X/Fe]) is defined as the logarithm of the element X to iron ratio in a star compared to the ratio of X to iron in the Sun. Mathematically

$$\left[\frac{X}{Fe}\right] = log\left[\frac{X}{Fe}\right]_{star} - log\left[\frac{X}{Fe}\right]_{\odot}$$

Studies of galactic chemical evolution involve estimation of elemental abundance using some models based upon a set of input parameters determined by the stellar conditions. Observed abundances can provide us lots of basic information. First, expressions like [C/H], [O/H] or [Fe/H](<0 metal poor, >0 metal rich by definition) i.e. ratios of heavy elements relative to hydrogen, serve as gauges of how far the star has progressed as far as the chemical evolution is concerned. This is because they measure the extent to which hydrogen has been converted into heavier elements. Secondly, these ratios are particularly very much sensitive to the rate at which gas is cycled through not only in stars but also in a star forming clouds, i.e., it has also some linkage with the star formation rate, and how that rate may have changed with time. Thus the chemical elements are produced through a variety of processes, meaning that abundance ratios contain useful information regarding the source of the gases making up the star. In the third place, ratios of two heavy elements, such as [N/O] or [O/Fe], provide information about elemental production rate by stars. That is, at what rate, is nitrogen produced relative to oxygen, or oxygen relative to iron. Then in the fourth place one can also draw some conclusion about the chronological aspects of the system based upon the elemental ratio. For example the element Mg is produced in Type II supernovae (SNII; the explosions of massive stars), while 'Fe-peak' elements (Fe, Ni, Zn, Co, Mn, Cr) are produced in Type Ia supernovae. For any given population of stars, the different types of supernova will explode, of course, at different times. This is because the massive stars that explode as SNII have short lives, while the SNIa are the end product of the stellar evolution of long-lived, low to intermediate mass stars. The elements produced in the different explosions are therefore incorporated into stars at different epochs during the star formation history of the galaxy, and the abundance ratios of individual stars can also give us strong clues about their ages as well. In short, chemical evolution can be traced indirectly by associating abundance patterns within a galaxy or within a cluster or in a star with local conditions, where the latter ultimately depend on time, and directly by observing abundances in stars of different ages or in galaxies of different look-back times.

1.7 Outline of this thesis

The rest of the thesis includes the following chapters

In CHAPTER 2 the **Spectroscopic analysis of Ba stars I: Data and Methodology** describes the source of data and the methodology used for this study. The observation and data reduction techniques are described. The specifications and the properties of the instruments used are also explained.

CHAPTER 3 entitled as **Spectroscopic analysis of Ba stars II: Atmospheric parameters and elemental abundances** deals with the derivation of the atmospheric parameters and chemical abundances of the objects in our study. Then abundance patterns and abundance ratios observed are also critically analysed for the characteristic abundance patterns of Ba stars.

CHAPTER 4, **Abundance of O, Na and Al in stars of GC M**3**, M**4**, M**13 **and M**6752 consists of proton capture reactions (CNOF, NeNa and MgAl cycles) in rotating massive stars which can explain the observed abundances in the metal poor stars of Globular cluster M3, M4, M13 and NGC 6752.

CHAPTER 5, **Abundance of F in stars of GC M**4**, M**22**,** 47 **Tuc and NGC** 6397 consists of proton capture reactions (CNOF cycles) in metal poor stars belonging to Globular cluster M4, M22, 47 Tuc and NGC 6397 which can explain the observed abundance of fluorine in those stars.

In CHAPTER 6, **Overall Conclusion** gives the summary of the work highlighting the important results. A brief description of the direction for the future work is also proposed.