6

Overall Conclusion

At the begining of the universe the only abundant elements present were mainly hydrogen (H) and some amount of helium (He). Uneven distribution of these elements was confirmed by Cosmic Background Radiation (CMB) by the COBE satellite in the early 90's which under the influence of gravity they began to "clump" to form more concentrated volumes. These clumps would eventually form galaxies and stars, and through the internal processes by which a star "shines" higher mass elements were formed inside the stars. Upon the death of a star (in a nova or a supernova) these high mass elements, along with even more massive nuclei created during the nova or supernova, were thrown out into space to eventually become incorporated into another star or celestial body. Studies on metal-poor stars have progressed significantly over the past three decades. Detailed studies of a number of metal-poor stars have revealed a large fraction of them to possess a wide variety of elemental abundance patterns. Inspite of several efforts to understand their formation mechanisms numerous questions still remain as to the nucleosynthetic histories and astrophysical sites associated with the production of these classes of objects. In this work we studied the distribution and production mechanisms of light and heavy elements in star some of which are peculier stars or metal poor. Metal poor stars are mostly found in Globular clusters. Although these stars have several sub classes all of them have major impacts on the Galactic chemical evolution. An important aspect of this work is to study the production mechanisms that leads to the observed elemental abundances and also a detailed spectroscopic studies of some stars which are in general enhanced with heavy elements. Following are the summary of the important results,

• Elemental abundances are presented for four peculiar stars (HD 49641, HD 58368, HD 119650 & HD 191010) listed in the Barium star catalogue of Lü (1991)[146]. All the objects are found to be low-velocity objects ($V_r < 45$ km/s). Metallicity estimates indicate that they are mostly solar or near-solar objects, with metallicity [Fe/H] ranging from -0.03 to $+0.1$ dex. Barium is enhanced in HD 49641 and HD 58368 with [Ba/Fe] > 1.0; the other two objects, HD 119650 and HD 191010 are found to be mild barium stars with [Ba/Fe] ~ 0.52 and 0.4 respectively.

• The estimated masses are $2.5M_\odot$, $2.3M_\odot$, $2.5M_\odot$ and $3.0M_\odot$ for HD 49641, HD 58368, HD 119650 and HD 191010 respectively. The mass of HD 58368 is within the average mass of typical mild Ba stars, i.e., 1.9 or $2.3M_\odot$ with the 0.60 or 0.67 $M_\odot$ companion white dwarfs (Jorissen et al.(1998)[298]).

• Our sample of Ba stars are found to have masses less than 3 solar mass which is suggested by Han et al. (1995)[169], in which they assigned masses less than $3M_\odot$ for all Ba stars.

• HD 58368 (M = 2.3$M_{\odot}$) is found to have larger heavy-element overabundances which is consistent with the fact that a lower mass for the barium star results in a smaller dilution of the accreting materials in envelope of the Ba star (Jorissen et al.(1998)[298]).

• One of our sample, HD 191010 has a mass more than the average mass of mild Ba star ie 2.3 $M_{\odot}$. In such type of high mass mild Ba stars the binary accretion method can't only explain the heavy element overabundance. Hence an intrinsic nucleosynthesic event within itself associated with mixing processes can also be an alternative origin of the elements in Ba star (Malaney & Lambert (1988)[299]).

• Our sample HD 49641 is found to have [Eu/Fe]= 0.90. Such an enhancement of Eu cannot be explained based on only binary pictures. Further investigation of its formation scenario is necessary to understand its abundance patterns.

• It has been argued that a metallicity lower than solar is required to form a barium star. Kovacs (1985)[162] also noticed that there is a correlation between [Ba/Fe] and metallicity [Fe/H]: strong barium stars generally have a metallicity lower than mild barium stars. However our sample of four stars do not exactly show this trend.

• Anomalies in abundance ratios of α-elements are noticed in a few objects. Sc, V and Mn in the program stars show similar values as seen in other barium stars. In two objects HD 58368 and HD 119650, Zn shows clearly higher values than what is generally noticed in barium stars as well as in normal giants. Na, Mg, Si, Sc, V, Cr, and Co show large scatter with respect to metalllicity. It is to be noted that the Galactic Chemical Evolution (GCE) model predicts that such trends of evolution of these elements are likely originating from massive stars. The behavior of Sc abundance is found to be decreasing with increasing metallicity.

• Enhancement of heavy elements, a well known characteristic of Ba stars is evident from our analysis in case of the four objects which is likely to be because of radial velocity variations or binarity nature. Light s-process elements Sr, Y and Zr show large enhancement points towards a mass-transfer scenario is likely to hold for these objects. This s-process enhancement in Ba stars are similar to subgiant-CH stars.

• In our sample, the abundances of the heavy elements appear scattered with respect to metallicity, suggesting that the enrichment may not be a function of only metallicity. Zacs (1994)[192] concluded that a correlation exists between s-process abundance anomalies and orbital periods for Barium star binaries as most of the Ba stars possess long orbital periods.

• Ba stars also show enhanced spectral features of carbon, the bands of the molecules CH, CN and C_2 like CH stars. Moreover subgiant CH and dwarf Ba stars occupy the same region of the HR Diagram. Most of the Ba stars are in general long-period, spectroscopic binary systems (McClure (1989)[300]). Through binary interactions one star evolves into Ba stars and the other evolve as metal-poor stars (Vanture (1992 a,b)[301][302]). It is believable that nucleosynthesis of metal-poor stars are more efficient than the metal-rich one and the nucleosynthetic pattern observed can be attributed to now unseen companions, which at earlier epoch were low-mass AGB stars. Thus Ba stars can give more clues on AGB stars' nucleosynthesis.

• The abundance of light s-process elements' (Sr, Y, Zr etc.) enhancements in our sample stars with low masses can be used to probe the mass function, binary mass ratios and structure of low metallicity stars. Work on both observational (such as binary distribution) and theoretical (such as mass dependence of s-process) fronts will help us figure out the final answers.

• Investigation of the proton-capture nuclear reaction cycles (CNOF, NeNa, and MgAl) with updated reaction rates (Iliadis et al.(2010)[133]) in fast rotating massive star at high temperature and low density condition have resulted a good agreement between the observed and estimated abundance ratios of [O/Fe], [Na/Fe] and [Al/Fe] in a sample of stars of GCs M3, M4, M13 and NGC6752. The same CNOF cycle, however with an upadated rate constant from La Cognata *et al.* (2011) for ^{19}F$(p,\alpha)^{16}$O has been used to ascertain the abundance of

^{19}F in metal poor stars belonging to GC M4, M22, 47 Tuc and NGC 6397 which is found to be in again in good agreement with the observed abundance of $\varepsilon(F^{19})$.

• Another consequence is the production of an important amount of primary N^{14}. Our calculation yields the highest production of this element with mass fraction 0.001 (Chapter 4, Fig.4.3) which is in the same order of magnitude in a stellar model with mass $60M_{\odot}$, Z= 5×10^{-4} and initial rotational vel. 800 kms^{-1} (Decressin et al. (2007b)[130]). We also find that the Na^{23} has the same order of magnitude, when compared with Table 5 of (Decressin et al. (2007b)[130]) but these orders are closer to the mass fraction obtained if one uses the high reaction rate constants in the reaction networks (Iliadis et al.(2010)[133]). Mg^{24} mass fraction abundance is in same order of magnitude as the values reported in Table 3 of (Decressin et al. (2007b)[130]) which falls well within the considered temperature range. Al^{27} has been found almost 10 times greater than those estimated by Decressin et al. (2007b)[130] at temperatures greater than $T_9 = 0.05$.

• GC stars are known to show Na-O anti-correlation. This anti-correlation is a common feature for globular clusters in the range of metallicity ($-2.5 \leq [Fe/H] \leq -1$). We also have produced the Na-O anti-correlation trend range $-0.80 \leq [Na/O] \leq 0.40$ collectively for all the four clusters. However we didn't look for any (anti-)correlation between Mg and Al in the four clusters. As far as $\varepsilon(F^{19})$ is concerned the trends have been found to be similar with the ^{23}Na abundance observed, from literature used here.

• The simultaneous determinations for the very same stars of Na, O and Ba abundances offer the possibility to unveil possible differences (or analogies) between binary fraction in First and Second Generation stars. These binary fractions in different stellar generations allow to infer key information on density conditions of their formation environment which is a basic constraint for hydrodynamical simulations of GC formation and early evolution (Lada & Lada (2003)[303]).

• The computed abundances of the elements do not deviate much from the observed values of [O/Fe],[Na/Fe] and [Al/Fe], and hence, supports the possibility of occurrence of these nuclear cycles in rotating massive star. The synthesized elements due to proton-capture reactions are brought to the surface by some internal physical mechanisms. Then a mass loss will result if the rotational speed reaches a critical value and thus enriching the space with these materials, from which the second generation stars are formed which supports the primordial scenario. However, for fluorine it seems that the evolutionary scenario fits well as the estimated $\varepsilon(F^{19})$ abundance has not been found much deviating from the observed values of the same.

6.1 Future plans

Detailed chemical analysis of a large number of Ba stars are required to draw a robust conclusion on their roles in the Galactic chemical evolution. We would like to extend this study to more number of Ba stars. The data used for the present analysis cover a wavelength range 3800 - 6800 Å. We would like to extend the analysis along the higher wavelength region and derive the nitrogen and oxygen abundances which would help to understand better the evolutionary stages. We also plan to extend our study based on theoretical models in order to get better ideas about the nature of binary companions and hence to understand the origin of the observed abundances. The present analysis is based on optical spectroscopy, it would be worthwhile to carry out the investigation using IR spectroscopy to understand the nature and extent of the circumstellar envelop; this is expected to provide insight into the mass transfer mechanisms. Not only that a more detailed nucleosynthetic calculation in these kind of stars (peculiar as well as massive) at low metallicity is highly in our focus that could give us hopefully more elaborate idea about the evolutionary phases which might have these stars passed through.