Binary Origin of CH and Ba stars: Observational perspectives

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Introduction

Metal-poor stars : HK survey and HES survey

$$[Fe/H] = \log (N_{Fe}/N_H)_* - \log (N_{Fe}/N_H)_{sun}$$

- Carbon-Enhanced Metal-Poor (CEMP) Stars
  - a. Intrinsic : Deep mixing process in AGB stars
  - b. Extrinsic : Mass transfer of carbon rich materials
- Different groups of CEMP stars: CH, C-R, C-N, C-J

Different groups of CEMP stars: CH, C-R, C-N and C-J

- CH : high radial velocity, strong G band of CH, enhancement of heavy neutron-capture elements, binary system.
- C-R : warmest carbon stars, strong G band, solar abundance for heavy neutron-capture elements.
- C-N : Coolest carbon stars with strong molecular bands and high isotopic ratios, Intrinsic carbon stars
- C-J : Strong merril-sanford band around 4900 Å, low isotopic ratios, no indication of binarity

Classification Of CEMP stars : Identification of CH stars

- Analysed 111 metal-poor stars (HES survey) using spectra obtained from 2m HCT, Hanle, India, with resolution 1330, WL 3800 - 6800 Å
- Results: Identified 38 potential CH star candidates along with 13 C-N stars and 9 C-R stars

Ref: Goswami , Karinkuzhi and Shantikumar, MNRAS (2010a)
Goswami, Karinkuzhi and Shantikumar, MNRAS (2010b)

High Resolution spectroscopic analysis of CH star candidates

- Aim : Determination of atmospheric parameters and chemical abundances

- Data: Elodie archive, WL :4000 - 6800 Å,
  : HDS attached to the 8m Subaru
  : FEROS, WL : 3800-9000 Å

Results

Analysed 30 objects

- T_{eff} 4000 – 6640 K
- Log g 0.5 – 4.65
- Metallicity -2.63 to 0.09
- Abundances of 22 elements
- Enhancement of C and heavy elements

IRAF, MOOG, IDL
Kurucz model atmospheres
LTE

Ref: Karinkuzhi and Goswami MNRAS (2014, 2015), Karinkuzhi and Goswami (2016a,b) – to be submitted

Origin of abundance patterns: Production mechanisms

Neutron-capture nucleosynthesis processes

a. slow neutron-capture - s-process

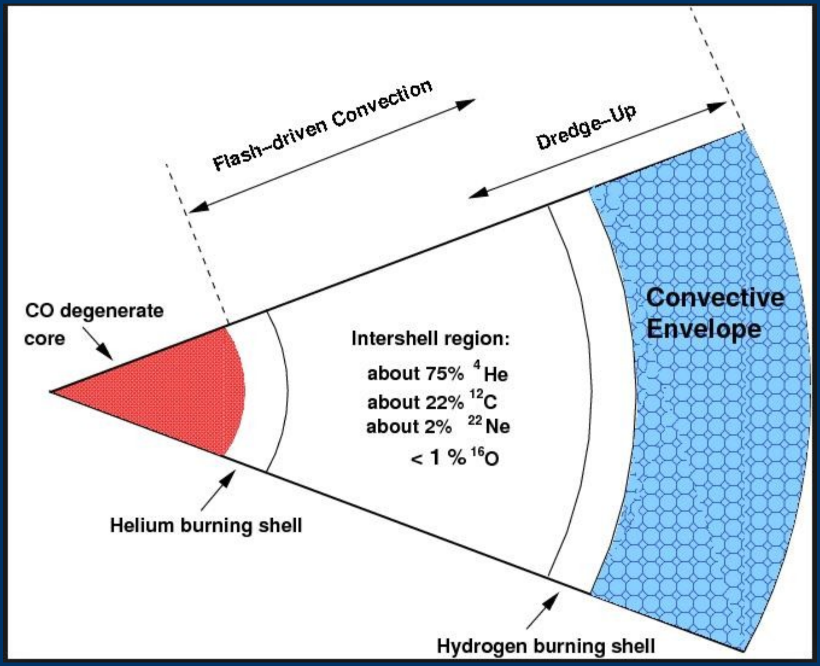
b. rapid neutron-capture - r-process

- Neutron fluxes and time scales ➞ Astrophysical sites

- **Production of s-process elements: Occur in low and intermediate mass AGB stars**

- **Neutron sources**
  $^{12}C(p,\gamma)^{13}N(\beta)^{13}C(\alpha,n)^{16}O$

  $^{22}Ne(\alpha,n)^{25}Mg$ for mass > 2.5 M_{sun}
- r-process : During supernova explosions



Classification based on abundance ratios *(Beers and Christlieb 2005)*

CEMP-s
[Ba/Fe] >1, [Ba/Eu]>0.5
↓
12 objects

CEMP-r/s
0.0<[Ba/Eu]<0.5
↓
2 objects

CEMP-r
[Eu/Fe] >1, [Ba/Eu]<0.0
↓
NIL

CEMP-no
[Ba/Fe]<0.0
↓
NIL

Parametric model based study

$$N_i(Z) = (A_s N_{is} + A_r N_{ir})\ 10^{[Fe/H]}$$

Z - metallicity of the star ;

N_{is} - abun by s-proces;

N_{ir} - abun by r-process;

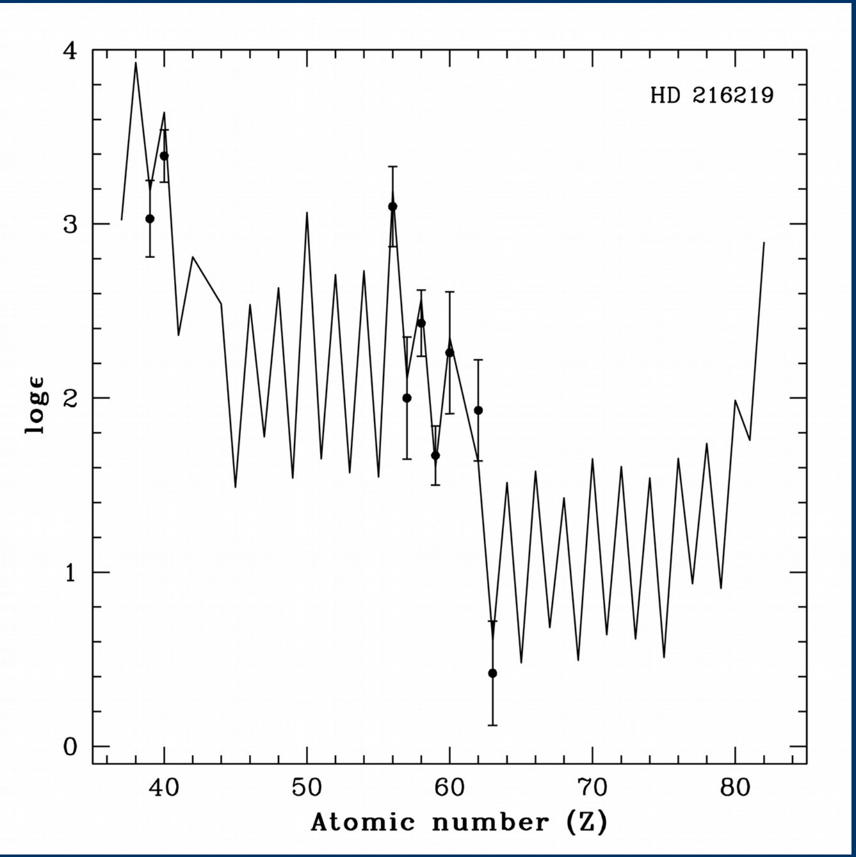
A_s , A_r - the component coefficient that correspond to contributions from the s-process and r-process respectively

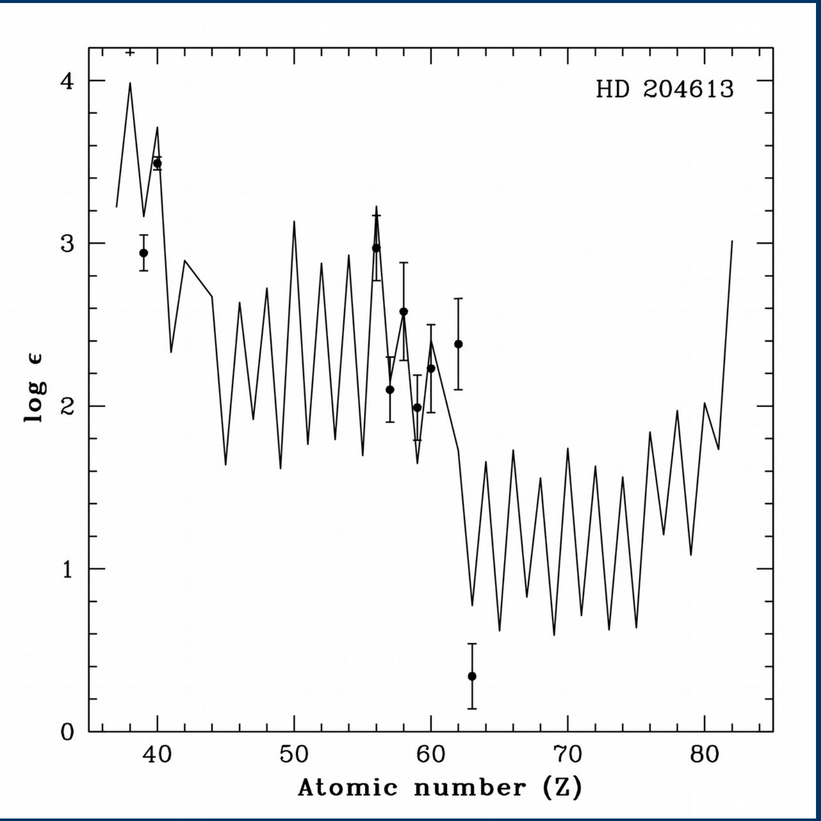
- Scale the solar system `s-’ and `r-’ process elemental abundances (Arlandini et al. 1999 - stellar Model) to the metallicity of the corresponding star.
- Normalize scaled abundances (`s-’ and `r-’ process) to the observed Barium (Ba) abundance
- Fit the observed abundances of heavy neutron-capture elements using the parametric model functions
- Look for the minimum chi-square

Results

Star name	A_s	A_r	χ^2
HD 16458	0.49±0.09	0.60±0.09	1.6
HD 48565	0.84±0.09	0.11±0.08	1.15
HD 92545	0.56±0.33	0.50±0.33	2.15
HD 104979	0.51±0.16	0.49±0.15	0.5
HD 107574	0.82±0.01	0.17±0.09	1.22
HD 125079	0.83±0.16	0.18±0.15	0.5
HD 204613	0.74±0.08	0.29±0.01	1.65
HD 216219	0.86±0.14	0.17±0.13	1.22

Theory *Vs* Observation



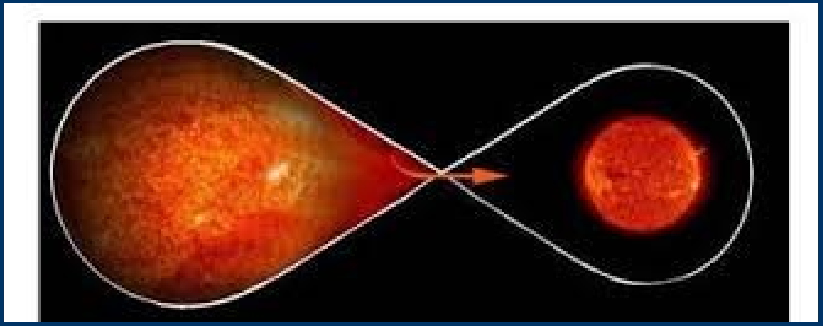


Luminosity and Mass

- Luminosity
- Mass: Evolutionary tracks (Girardi et al. 2000) using spectroscopic temperature and log g
- low mass objects but luminosities are not comparable to **AGBs**

Binarity

Mass transfer from an AGB companion which underwent s-process nucleosynthesis during its lifetime and now evolved to a white dwarf.



CH binaries

- 7 objects - Confirmed binaries

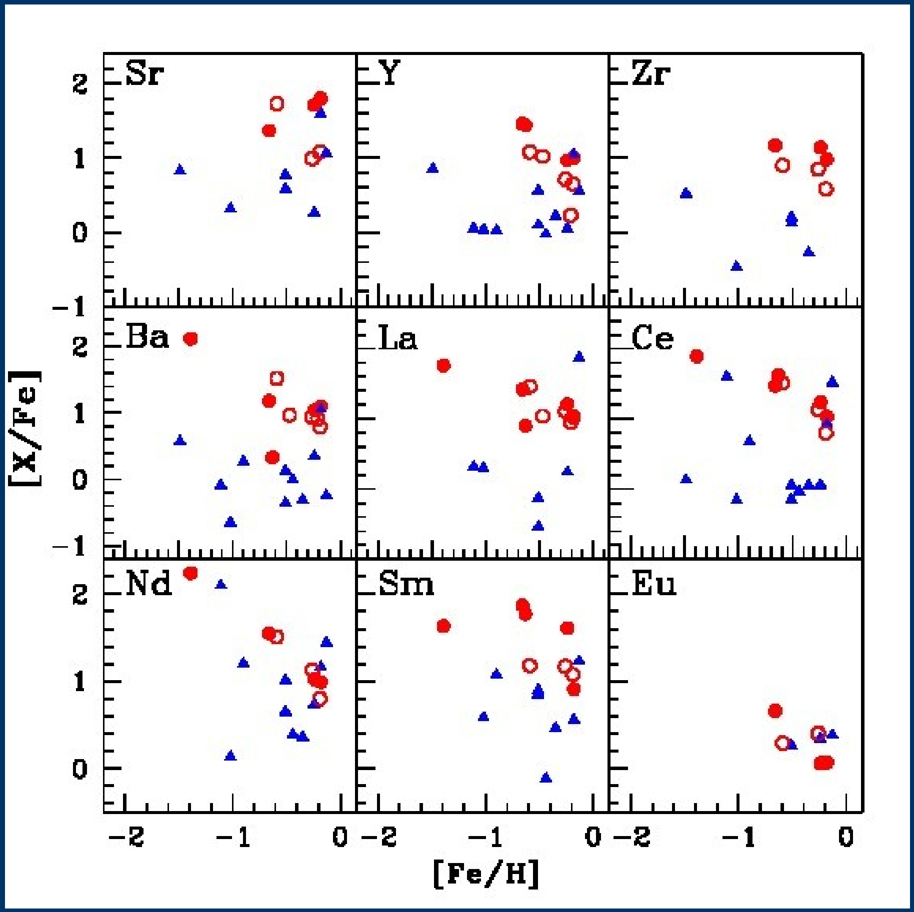
  HD 5223 - 700 days

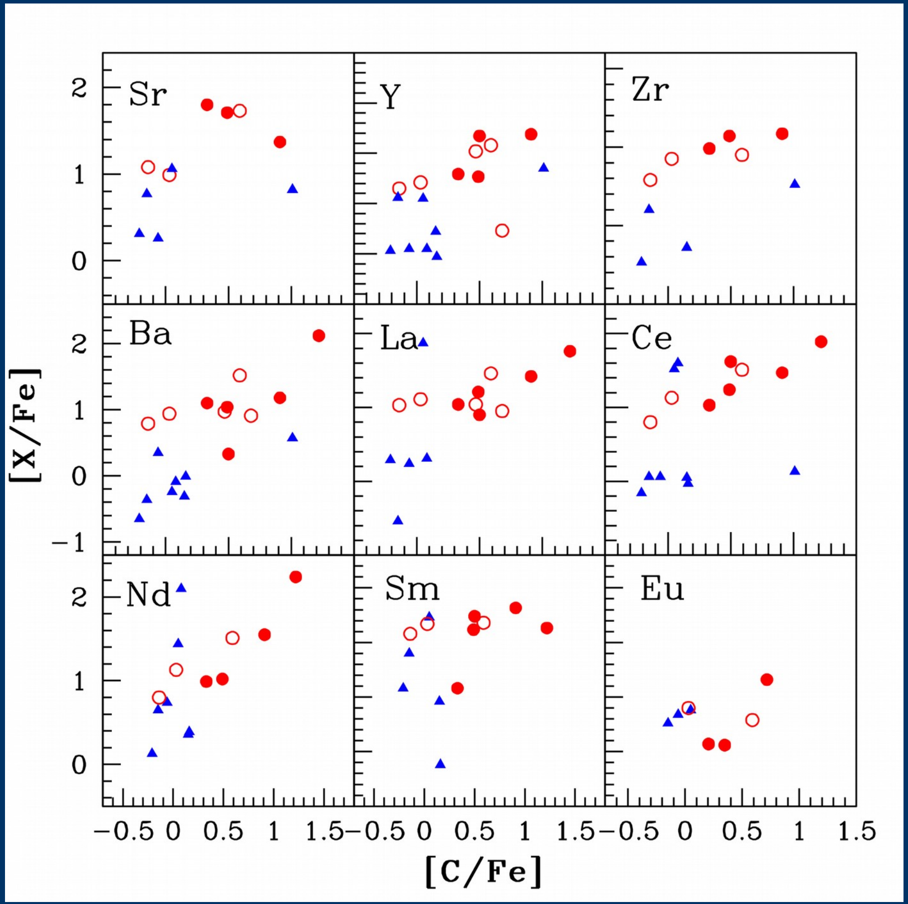
  HD 16458 - 2018 days
  HD 122202 - 1290 days
  HD 201626 - 1465 days
  HD 204613 - 890 days

  HD 209621 - 477 days
  HD 216219 - 3871 days (McClure 1983, 1987,1990)

- 7 objects, radial velocity variations have been noticed. But not yet confirmed – may be due to long period nature

Comparison





Understanding the AGB companion

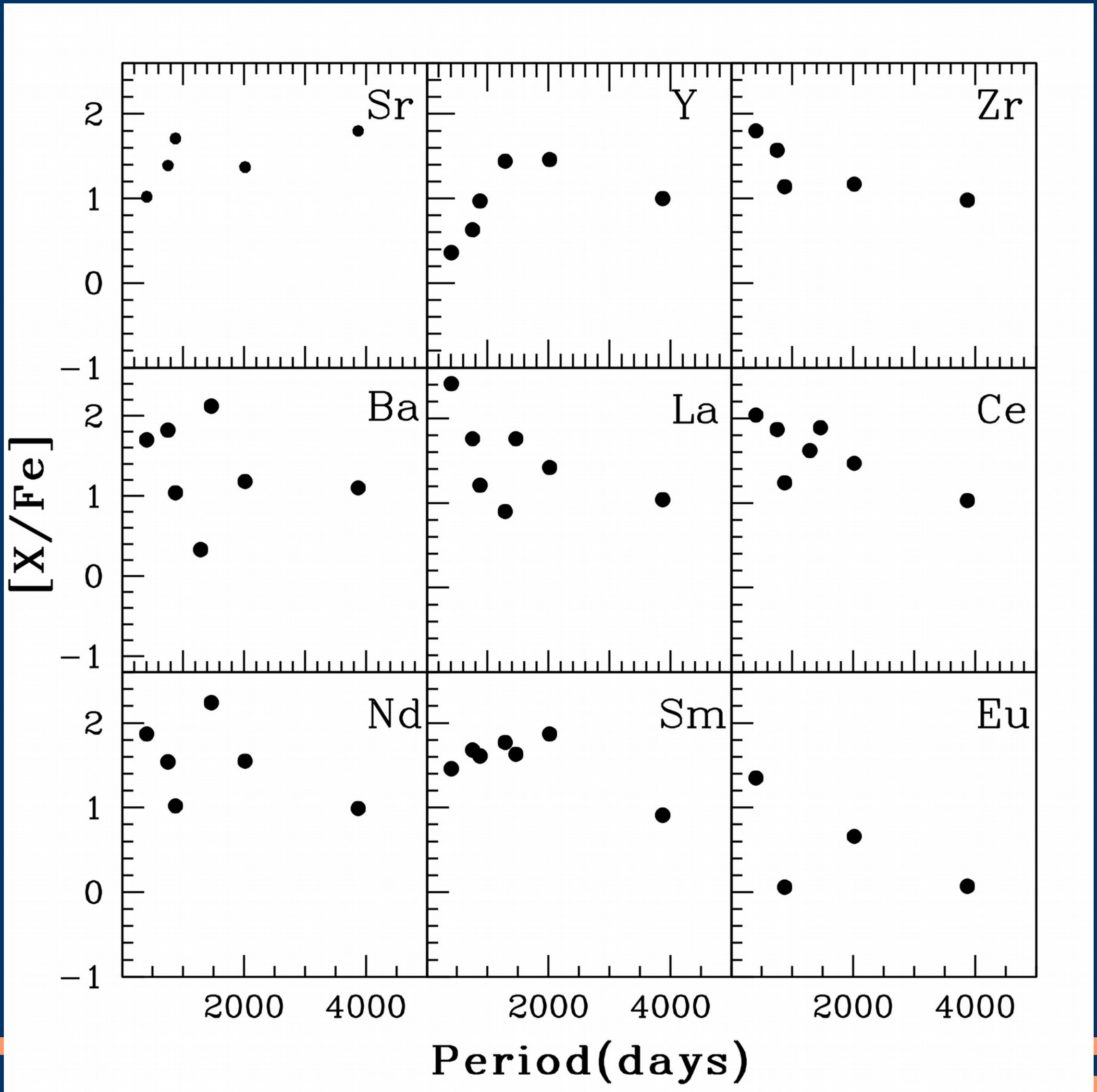
1. Orbital separations: possible correlation/non correlation of elemental enhancement will help us to understand the possible mass transfer mechanisms

2. mass accretion efficiency

3. Internal mixing : Programme stars are in first ascent of the giant branch, no possibilities for internal nucleosynthesis of heavy elements.

4. Mass ratios of the binary members

s-process abundances versus period



Mass transfer mechanisms

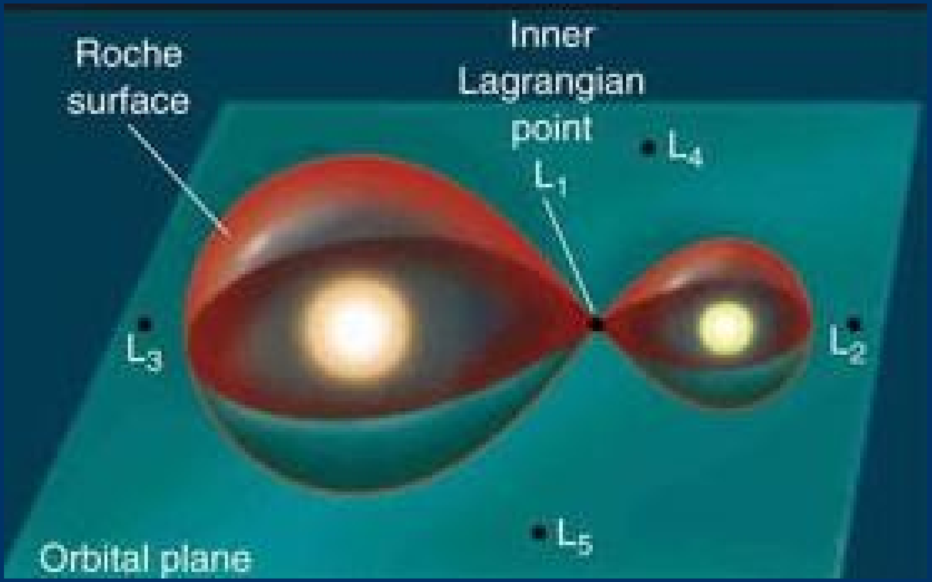
Depends on the orbital separation and mass ratio

- Roche-lobe overflow (RLOF)
- Wind mass transfer (WMT)
- Wind Roche-lobe overflow (WRLOF)

(mohamed and Podsiadlowski 2007, mohamed 2010, Abate et al 2013, 2015)

RLOF:

- In the case of CH stars and Ba stars with AGB companion, it may lead to Common evolution rather than mass transfer.



WMT

- Wind velocity >> orbital velocity of accreting star
- Binary stars with long period have orbital velocity ~10 km/s but wind outflow is found with 5-30 km/s

WRLOF

- Gravitational focussing of the wind of the primary towards the orbital plane of the secondary.

Polarimetric study of CH and CEMP stars

To detect the presence of circumstellar dust from the polarization of light scattering by the dust

Data : 2m telescope at IUCAA Girawali, Pune, India

Methodology and Results (Goswami and Karinkuzhi, A&A 2013):

No significant polarization is detected

Summary and Ongoing works...

- Radial velocity monitorings of the objects
- Analysis of an extented sample of CH, CEMP and Ba stars

  1. High resolution optical spectroscopic analysis
  2. UV (proposals submitted to recently launched UVIT in the astrosat).
- Preliminary results based on the observational results indicate wind mass transfer is the possible reason for the enhancements. But a detailed theoretical model based study is required for the confirmation.

Thank you

Comparison with well known spectrum