Peculiar abundances of the cool carbon star HE 1104-0957

Meenakshi Purandardas[1], Aruna Goswami[1], Sridharan Rengaswamy[1]

[1]Indian Institute of Astrophysics, Koramangala, Bangalore 560034, India

Introduction

- **Carbon stars**
  - Strong features due to carbon molecular bands such as C_2 , CH and CN.
  - CH, C-R, CN, C-J stars
  - Fraction of carbon enhanced objects increases with decrease in the metallicity (Beers & Christlieb 2005, and references therein)

Carbon star

CH
1. Warmer stars
2. Prominence of the secondary P-branch head near 4342 Å
3. Ca I at 4226 Å is marginally noticeable
4. Strong CH band
5. Hα , Hβ, Ba II at 6496 Å and 4554 Å are clearly noticeable
6. Enhanced s-process elements
7. CIR ~ 20-100

C-R
1. Warmer stars
2. Secondary P-branch head is not prominent
3. Strong Ca I at 4226 Å
4. Weak Hβ, Hα, Ba ii at 4554 Å, and 6496 Å
5. Dip in Na I D1 and Na I D2 lines in low-resolution spectra
6. Near solar s-process elements
7. CIR ~ 4-9

CN
1. Cooler stars
2. No flux at λ < 4000 Å
3. Weak Hα and isotopic C bands
4. Enhanced s-process elements
5. CIR > 30

C-J
1. Cooler stars
2. Strong silicate bands
3. CIR < 15

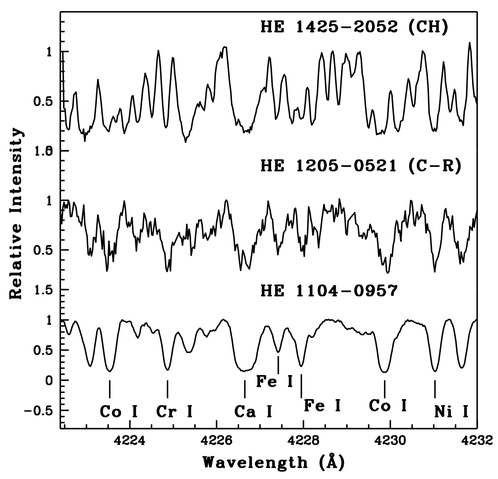
Objective

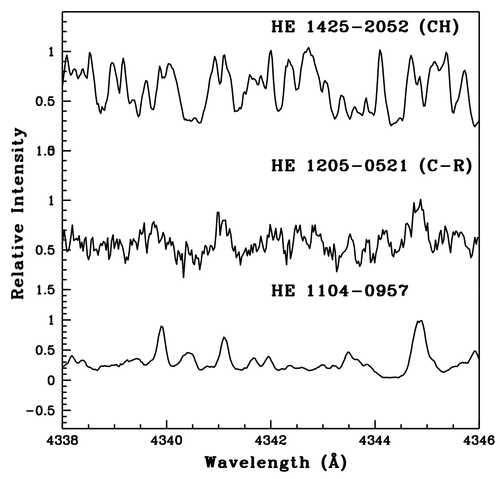
Detailed studies on C-R stars based on high-resolution spectroscopic analysis are quite scanty in literature. Goswami (2005) identified the object HE 1104−0957 as a C-R star based on low-resolution spectroscopic analysis. This work is a high-resolution spectroscopic follow-up of the object with a primary goal to understand the surface chemical composition and hence to probe its possible progenitor.

Methodology

- Source of spectra → SUBARU/HDS (Archive data), R ∼ 50 000
- Abundance → Local Thermodynamic Equilibrium (LTE) analysis using MOOG, and Kurucz grid of model atmospheres

Comparison of the spectral features of HE 1104−0957 with C-R and CH stars

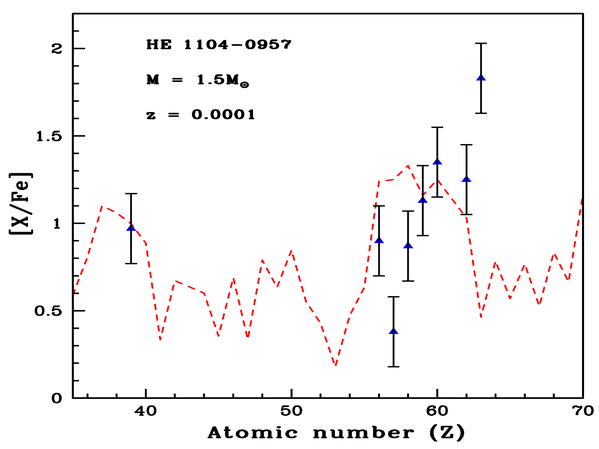




Results

Atm parameters

- T_{eff} = 3900K
- logg = 0.60
- $\zeta = 2.75 kms^{-1}$
- [FeI/H] = −2.95, [FeII/H] = −2.98
- $R_v = 105.3 kms^{-1}$

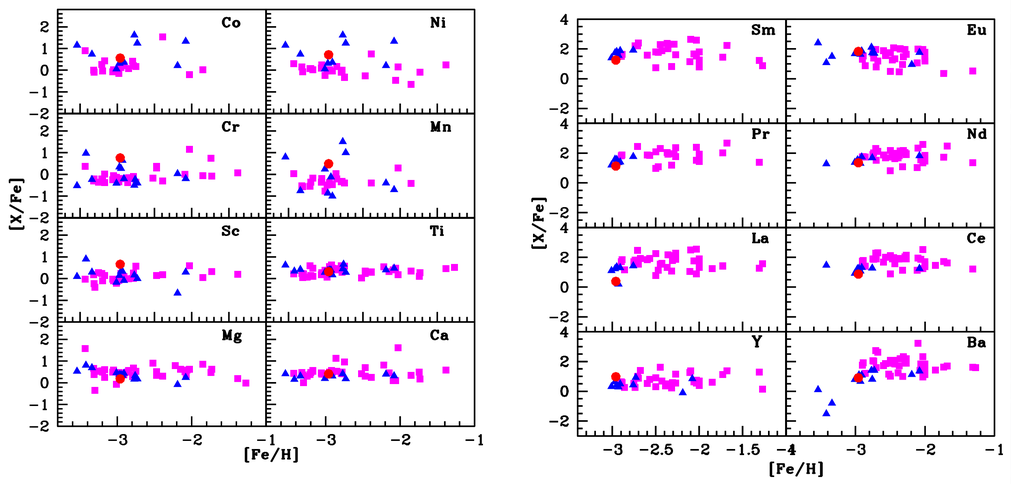


Is HE 1104−0957 a binary star?

- The observed elemental abundances in HE 1104−0941 could not be fully reproduced by AGB model yields (Cristallo et al. 2015).
- Another mechanism is required to interpret the observed abundance patterns
- Binary status - unknown

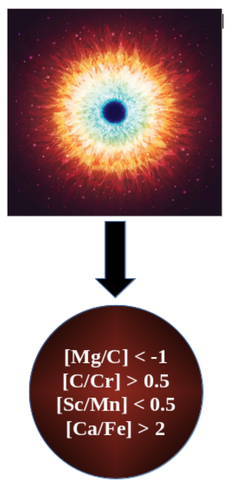
Abundances of key elelments wrt Iron

[C/Fe] = 1.82; [N/Fe] = 2.54;
[O/Fe] = 1.54; [Mg/Fe] = 0.18;
[Sc/Fe] = 0.66; [Cr/Fe] = 0.76;
[Mn/Fe] = 0.49; [Ba/Fe] < 0.90;
[La/Fe] = 0.38; [Eu/Fe] < 1.83



Comparison of the light and heavy elements abundance ratios observed in HE 1104 - 0957 with their counter parts observed in Reticulum II dwarf galaxy stars and the halo stars. Blue and magenta symbols represent Reticulum II stars (data taken from Ji et al. (2016), Roederer et al. (2016)) and the halo stars (data taken from Purandardas et al. (2021), and Ji et al. (2016) and references therein) respectively. The red symbol represents HE 1104−0957.

Is there any supernovae contribution?



HE 1104−0957

- [C/Cr] = 1.09, [Sc/Mn] = 0.14
  [Mg/C] = -1.64 ⇒ **Polluted by core collapse Supernova**
- [Ca/Fe] = 0.41⇒ **Multiple pollution events**

Hartwig et al. (2018)
⇒ HE 1104−0957 is formed from a medium polluted by supernova, however the surface chemical composition of this object may also be influenced by some other sources as indicated by [Ca/Fe].

Conclusion

- Our analysis shows that HE 1104−0957 does not exhibit characteristic properties of a typical C-R star.
- The observed abundance patterns in HE 1104−0957 matches quite closely with the abundance patterns of Reticulum II stars.
- High values for [Eu/Fe] ($\geq$ 1.7) are noticed in many Reticulum II stars. Metal-poor stars with such a level of r-process enhancement are only rarely found in the halo (Ji et al. 2016). The measured [Eu/Fe] ratio in HE 1104−0957 is found to be enhanced with an upper limit of 1.83. With such a high value of [Eu/Fe], it is unlikely to be a halo star in origin. Whether its origin may be traced in neighbouring dwarf galaxies needs to be further investigated.
- Previous studies have shown that the supernovae are one of the important pollutants of Reticulum II dwarf galaxy. Various diagnostic elemental abundance ratios estimated in the program star also indicate a supernova progenitor for this object. However, a detailed comprehensive study is required to draw a robust conclusion in this regard.

References

[1] Asplund M. et al., P. 2009, ARA&A, 47, 481
[2] Beers T. C., Christlieb N. 2005, ARA&A, 43, 531
[3] Cristallo S. et al., 2015, ApJS, 219, 40
[4] Goswami A. 2005, MNRAS, 359, 531
[5] Hartwig T. et al., 2018, MNRAS, 478, 1795
[6] Ji et al., 2016, ApJ, 830, 93
[7] Purandardas & Goswami, 2021, ApJ, 922, 28
[8] Roederer et al., 2016, ApJ, 151, 82

meenakshi.p@iiap.res.in