

Statistical analysis of the new catalogue of CP stars

S. Ghazaryan^{1*}, G. Alecian², A. A. Hakobyan¹

¹NAS RA V. Ambartsumian Byurakan Astrophysical Observatory (BAO), Armenia

²LUTH, CNRS, Observatoire de Paris, PSL University, Université Paris Diderot, 5 Place Jules Janssen, 92190 Meudon, France

*E-mail: satenikghazarjan@yahoo.de

Abstract

This talk is devoted to the statistical analysis of the new catalogue of Chemically Peculiar stars compiled from papers, where chemical abundances of those stars were given. The catalogue contains chemical abundances and physical parameters of 428 stars based on high-resolution spectroscopy data. Spearman's rank correlation test was applied for 416 CP (108 HgMn, 188 ApBp and 120 AmFm) stars and the correlation between chemical abundances and different physical parameters (effective temperature, surface gravity and rotational velocity) was checked. From dozens interesting cases we secluded four cases: the Mn peculiarities in HgMn stars, the Ca correlation with respect to effective temperature in AmFm stars, the case of helium and iron in ApBp stars. We applied also Anderson-Darling (AD) test on ApBp stars to check if multiplicity is a determinant parameter for abundance peculiarities.

Keywords: *Chemically Peculiar stars - abundances - catalogues - individual stars: HgMn, ApBp and AmFm.*

1. Introduction

Historically, main sequence Chemically Peculiar (CP) stars were divided in 4 groups by Preston (1974) – AmFm, ApBp, HgMn and λ Boo stars. Later, two groups of CP stars were added to the known ones - He-weak and He-rich stars. All CP stars have different physical properties. The effective temperatures of all CP stars are in the range of 7000-30000K, some of them are non-magnetic, some- magnetic. More than 50 percent of CP stars are binaries or belongs to the multiple systems. But all those stars have one generality – in the atmospheres of those stars we see peculiarities of different chemical element' abundances. AmFm stars are non-magnetic and they are characterized by underabundances of calcium and scandium, and high overabundances of iron and nickel (see Kunzli & North 1998; Gebran,

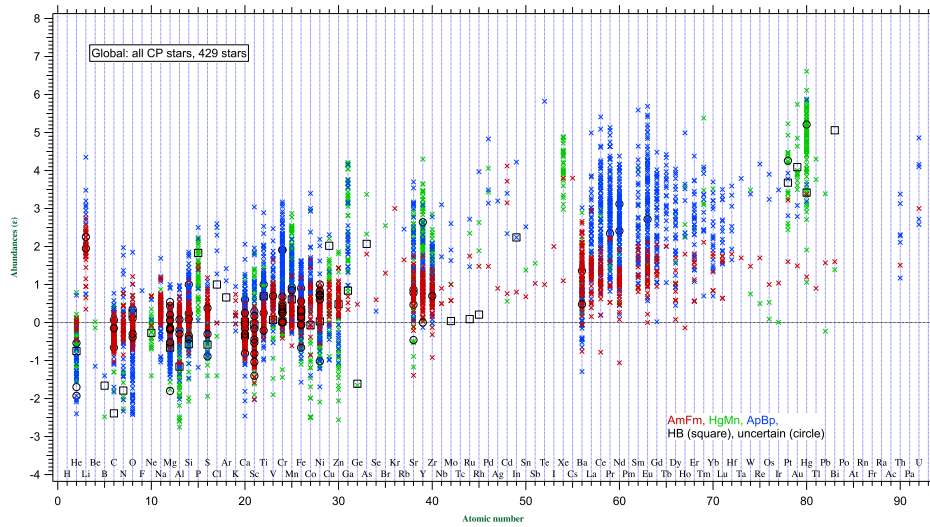


Figure 1. Abundances for the three CP Types in the present compilation versus atomic number. Abundances are the logarithm of the abundances divided by the solar Asplund et al. (2009) ones, the zero line corresponds to solar abundances. In the HgMn panel, the squares are abundances of the horizontal-branch star Feige 86.

Monier & Richard 2008, for example). HgMn stars are non-magnetic as well; they are characterized by strong overabundances of mercury and manganese (Hg overabundance reaches up to 107) (see Catanzaro, Leone & Leto 2003; Dolk, Wahlgren & Hubrig 2003, Alecian et al. 2009, etc.). In contrary, ApBp stars are magnetic and characterized by silicon, chromium, europium and strontium overabundances (see Leckrone 1981; Ryabchikova et al. 1999; Kochukhov et al. 2006, etc.). In this research we studied 3 groups of CP stars – AmFm, ApBp and HgMn stars.

2. The new catalogue of CP stars

Our new catalogue of CP stars consists in 428 stars, for which all chemical abundances were determined through high resolution spectroscopy techniques. 108 stars are identified as HgMn stars (see Ghazaryan & Alecian 2016), 128 stars as AmFm and 188 as ApBp stars. The types of 11 stars are uncertain and one star is a known horizontal-branch star (Feige 86). The catalogue contains physical parameters such as effective temperature, gravity, rotational velocity, and chemical abundances with their error measurements. If for a given element the abundances of different ions were given, we took the mean of them for the abundance value, and the error bars were recalculated by the mean square of the errors as in Ghazaryan & Alecian (2016). Compiled abundances with their errors are shown in Fig. 1. The

detailed information on our catalogue is given in Ghazaryan et al. (2018).

Table 1. Spearman’s rank test results for HgMn stars. Statistically significant correlations are shown in boldface (p -value ≤ 0.05), marginal ones are underlined ($0.05 < p$ -value < 0.06).

<i>Elements</i>	$\epsilon(T_{\text{eff}})$			$\epsilon(\log g)$			$\epsilon(v \sin i)$		
	ρ	p	N	ρ	p	N	ρ	p	N
He	-0.40	0.001	65	-0.10	0.450	65	0.12	0.355	64
C	-0.23	0.105	51	0.00	0.982	51	0.03	0.841	50
O	0.23	0.156	38	-0.28	0.091	38	0.15	0.391	37
Mg	-0.39	0.001	69	-0.07	0.580	69	0.09	0.489	68
Al	-0.42	0.005	44	0.24	0.112	44	0.32	0.037	44
Si	0.01	0.929	74	-0.15	0.192	74	-0.01	0.913	73
S	-0.61	0.000	52	0.05	0.743	52	-0.03	0.813	51
Ti	0.24	0.064	62	0.11	0.403	62	0.10	0.448	61
Cr	-0.28	0.010	86	-0.02	0.828	86	0.22	0.041	85
Mn	0.48	0.000	70	0.06	0.650	70	0.26	0.032	69
Fe	0.07	0.488	90	0.06	0.561	90	-0.11	0.313	89
Ni	-0.05	0.730	48	-0.01	0.945	48	0.11	0.473	47
Cu	0.32	0.106	26	<u>-0.38</u>	<u>0.053</u>	<u>26</u>	0.22	0.289	26
Zn	-0.18	0.339	29	<u>0.00</u>	<u>0.999</u>	<u>29</u>	0.12	0.533	29
Ga	0.30	0.083	34	0.23	0.184	34	0.00	0.997	33
Sr	-0.49	0.001	45	0.33	0.027	45	0.11	0.492	44
Y	-0.17	0.220	55	0.20	0.134	55	0.19	0.161	54
Zr	0.25	0.133	37	0.25	0.136	37	0.38	0.021	36
Xe	0.41	0.032	28	-0.04	0.823	28	0.11	0.568	28
Hg	-0.22	0.045	86	0.27	0.011	86	-0.01	0.944	85

3. Statistical analysis

The abundance anomalies may be explained by theoretical models, including atomic diffusion, and for that reason it is interesting to know the correlation between abundances and physical parameters, such as effective temperature, surface gravity and rotational velocity. To check that correlation we applied Spearman’s rank test (see Spearman 1904) between abundances and mentioned physical parameters. The statistical analysis was done for each element measured in more than 11 stars. In Table 1 as an example we show statistical results for HgMn stars. As you see, we found significant correlation with respect to effective temperature for Mg, Al, S, Cr, Mn, Sr, Xe, Hg. Possible correlations suggested by Ghazaryan & Alecian (2016) for Ni, Ti, and Si are not confirmed in this study. We found also significant correlation with respect to gravity for strontium and confirmed

it for mercury suggested in our previous paper. Considering rotation velocity as parameter, correlations have been found for aluminum, chromium, manganese, and zirconium.

Such types of tables were created for ApBp and AmFm stars as well. Dozens correlations between abundances and fundamental parameters were found for those type of stars too. Four noteworthy cases are secluded and explained in detail in our paper (see Ghazaryan et al. 2018).

We have applied AD test on single CP stars and those being in binary systems and do not find any relation between abundance anomalies and multiplicity in all three CP type stars, possibly because of the lack of data.

4. Conclusions

We present a unique catalogue of 428 Chemically Peculiar stars observed by spectroscopy during the last decades. Our new compilation of the main physical parameters and the abundances of elements from helium to uranium for 108 HgMn, 188 ApBp, 120 AmFm stars, plus 12 other peculiar stars (including 1 horizontal-branch star) confirms the increase of overabundances for heavy elements with atomic number (see Smith 1996) and the large scatter of the abundances anomalies. This scatter is not only due to the heterogeneity of the data, or abundance determination errors, but it is real. The applied statistical tests proofs that there is no any correlation between abundance anomalies and multiplicity of HgMn, ApBp and AmFm stars. We have found a significant number of correlations with the effective temperatures, but also some (fewer) with gravity and rotational velocity. We discuss also four noteworthy cases, but this does not mean that there are only four cases that deserve discussion. We are convinced that considering as a whole, the abundance measurements in CP stars will lead to interesting understanding of the physical processes in play in the atmospheres of those stars. In the near future we plan to extend our database to other categories of CP stars (such as stars with helium anomalies), and we have no doubt that a major extension of such a database will be achieved from the final GAIA catalogue.

Acknowledgements

This work was supported by the RA MES State Committee of Science, in the frames of the research project N^o 16YR-1C034.

References

- Alecian G., Gebran M., Auvergne M., et al. 2009, *A&A*, 506, 69
- Asplund M., Grevesse N., Sauval A. J., Scott P. 2009, *ARA&A*, 47, 481
- Catanzaro G., Leone F., Leto P. 2003, *A&A*, 407, 669
- Dolk L., Wahlgren G. M., Hubrig S. 2003, *A&A*, 402, 299

- Gebran M., Monier R., Richard O. 2008, *A&A*, 479, 189
Ghazaryan S., Alecian G. 2016, *MNRAS*, 460, 1912
Ghazaryan S., Alecian G., Hakobyan A. A. 2018, *MNRAS*, 480, 2953
Kochukhov O., Tsymbal V., Ryabchikova T., et al. 2006, *A&A*, 460, 831
Kunzli M., North P. 1998, *A&A*, 330, 651
Leckrone D. S. 1981, *ApJ*, 250, 687
Preston G. W. 1974, *ARA&A*, 12, 257
Ryabchikova T., Piskunov N., Savanov I., et al. 1999, *A&A*, 343, 229
Smith K. C. 1996, *Ap&SS*, 237, 77
Spearman C. 1904, *Am. J. Psychol.*, 15, 72