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Correlations between abundances and magnetic activity in FGK dwarfs

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Abstract. It is known that the magnetic activity in Solar-type stars decay as the star ages. Therefore, it is possible to use the level of chromospheric activity, measured by the $\log R'_{\rm HK}$ index, as an age indicator. Also, the elemental abundances must be related to the stars age due to the chemical evolution of the galaxy. However, both chronological scales appear to be non-linear, specially by mixing stars born at different galactocentric radius, or by our incomplete understanding of the stars' magnetic field evolution. In this work, we use a sample of 2503 stars with $\log R'_{\rm HK}$ and O, Fe, C, Mg and Si abundances to study how the scale relations of chromospheric, abundancy and age of stars compare. The sampling was made by joining magnetic activity Boro-Saikia et al. catalog and Hypatia, chemical abundances catalog. We show that there are tenuos correlations between chromospheric and chemical age scales, once we exclude the stars with regard to the mean radius of their stellar orbit.

Resumo. Sabe-se que a atividade magnética em estrelas de tipo solar decai à medida que a estrela envelhece. Desta forma, é possível usar o nível de atividade cromosférica, medido pelo índice $\log R'_{\rm HK}$, como um indicador de idade. Também as abundâncias elementais devem se relacionar com a idade das estrelas devido à evolução química da Galáxia. Todavia, ambas as escalas cronológicas parecem ser não-lineares, especialmente por misturarem estrelas nascidas em diferentes raios galactocêntricos ou pela nossa compreensão incompleta acerca da evolução do campo magnético nas estrelas. Nesse trabalho, usamos uma amostra de 2503 estrelas com $\log R'_{\rm HK}$ e abundâncias de O, Fe, C, Mg e Si, para estudar como se comparam as escalas das relações entre atividade cromosférica, abundâncias e idade. A amostra foi formada pela junção dos catálogos de atividade magnética de Boro-Saikia et al. com o catálogo de abundâncias químicas Hipatia. Mostramos que há relações tênues entre as escalas de idade cromosférica e química, que ficam mais bem marcadas uma vez que isolamos as estrelas em função do raio médio de sua órbita estelar.

Keywords. Stars: abundances – Stars: magnetic Activity – Stars: solar-type

1. Introduction

Stellar age can be inferred from certain properties that vary throughout stellar evolution. The traditional method for measuring it, is to compare the star's position with theoretical isochrones in the HR diagram. Among Solar-type stars — spectral class F, G and K — the possibility of using the chromospheric activity level as an age index is very explored in literature (Soderblom et al. 1991; Rocha Pinto & Macial 1998). If the most active stars are also younger, it is expected that the chemical abundances distribution favors richer stars, in the context of the chemical evolution on the galaxy. Our work aims to explore how the distribution of chemical abundances varies according to the level of chromospheric activity.

2. Methods

We built a sample of stars that simultaneously have data related to chromospheric activity and to chemical abundances. For this, we made a crossover between the Hypatia catalogues (Hinkel et al. 2014) and the compilation of chromospheric activity made by Boro-Saikia et al. 2018. The initial crossover yielded a sample of 2504 stars. By applying the color cut 0.3 < B-V < 0.8, to limit the sample to FGK stars only, we reached our final sample of 1819 stars. We investigated the behavior of the abundances of the following elements: O, C, Ca, Fe, S, Si, Mg and Ti, in order to understand how the abundances vary according to the activity. Traditionally, the chromospheric activity is divided into 4 regimes, giving rise to very active stars ($\log R'_{\rm HK} > -4.2$; VAS), active stars ($-4.2 < \log R'_{\rm HK} < -4.75$; AS), inactive stars ($-4.75 < \log R'_{\rm HK} < -5.1$; IS) and very inactive stars ($\log R'_{\rm HK} < -5.1$; VIS). In this study, we maintained this distinction.

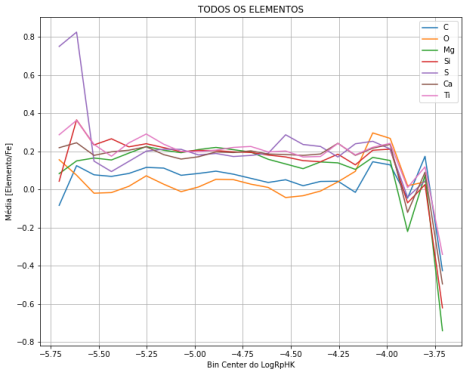

Figure 1. Average abundances of FGK dwarfs as a function of the stellar chromospheric activity. It is remarkable that very active stars (those having $\log R'_{\rm HK} > -4.2$) have substantially lower average abundances in all elements compared to stars with other activity levels. This puts into question whether the chromospheric activity index for these stars can be used to estimate the stellar age.

3. Results

The initial results show not very intuitive behaviors in the context of the chemical evolution of the Galaxy. Our graphs point to all the elements investigated:

1. an anticorrelation between abundance and chromospheric activity in the case of inactive stars (region marked AS IS).

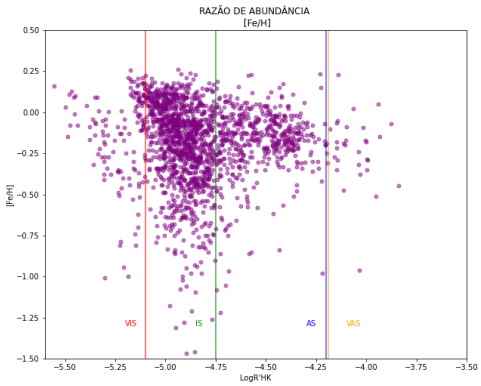

Figure 2. Abundance Ratio of Fe as a function of $\log R'_{\rm HK}$

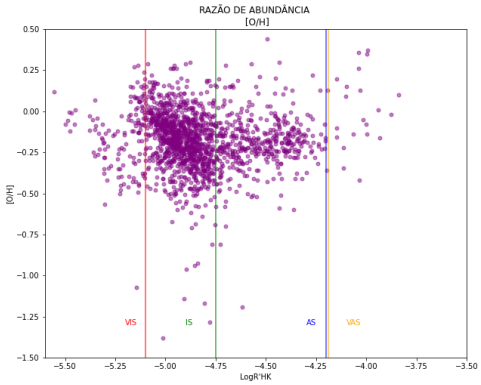

Figure 3. Abundance Ratio of O as a function of $\log R'_{\rm HK}$

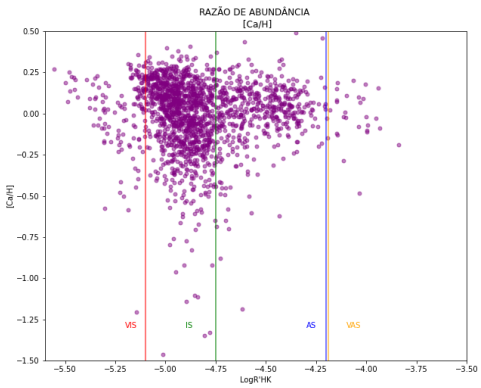

Figure 4. Abundance Ratio of Ca as a function of $\log R'_{\rm HK}$

2. Active stars (marked as AS on figures 2, 3, 4 and 5) usually possess an average abundance smaller than the maximum abundance of inactive stars.

This behaviour had already been found by Rocha-Pinto & Maciel (1998), but when abundance was measured by photometric indexes and was interpreted according to the proposal of Giampapa et al. (1979), according to which chromospheric activity fills the background of photopherical lines and affects the measurement of metalicity via photometric indexes. Our case confirms this behavior in an unprecedented way, through abundances measured by spectroscopy. It's not very clear why abundances present this behaviour when stars are separated by chromosferic activity. Possibly, there is a statistical bias not clearly treated during the selection process. For instance, we could be sampling unequally the stellar mass and the birth place in distinct part of our plots; stars born in inner galactocentric rays tend to be richer and older than those born in the solar neighbour(among which we will find the most active). We intend to further investigate such question, taking into consideration that other parameters might be biasing our sample.

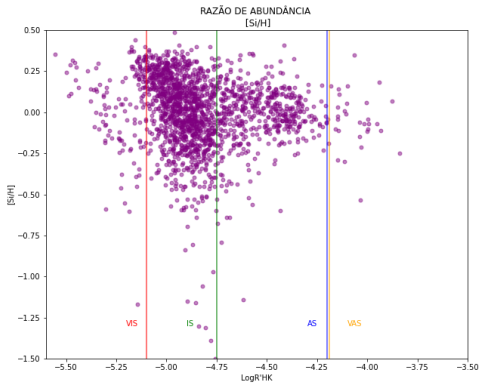

Figure 5. Abundance Ratio of Si as a function of $\log R'_{\rm HK}$

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