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Elemental abundances in star-forming regions: results in Lupus and future analysis in Orion

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Abstract. We present a recent study in press on lithium, iron, and barium abundance measurements obtained for low-mass ($\sim 0.025 - 1.8\,M_{\odot}$) stars in four Lupus clouds and future investigations on chemical content to be performed in the Orion A cloud.

1. Lupus: Introduction

This work, dedicated to the memory of Francesco, was aimed to derive the lithium abundance for the almost complete sample (~90%) of known class II stars in the Lupus I, II, III, IV clouds, and to perform a chemical tagging. In this region, few iron abundance measurements have been obtained in the past and no determination of the barium content has been done so far (Biazzo et al. 2017).

Lithium is a fragile element, which is burnt at temperatures of $\sim 3\times10^6$ K (Bildsten et al. 1997). Low-mass stars can reach these temperatures when they contract towards the main sequence (Bodenheimer 1965), with a depletion timescale that depends on stellar mass. Lithium can be therefore used as a reliable diagnostic tool to estimate the ages of low-mass members of star-forming regions (SFRs).

Iron, together with other Fe-peak and α-elements, is important in the field of star formation. Several studies have provided hints that regions where star formation has ceased share a metallicity close to the solar value, while SFRs where the molecular gas is still present are characterized by slightly lower Fe content (e.g. Biazzo et al. 2011a,b; Spina et al. 2014). It was hypothesized that the metal-poor nature of these young environments could be the result of a common widespread star formation episode involving the Gould Belt (Spina et al. 2014; Meléndez et al. 2017).

Barium is synthesized by neutron capture reactions mostly through the s-process occurring in asymptotic giant branch (AGB) stars and represents a tracer of chemical enrichment mechanisms in the Galaxy. A trend of increasing Ba abundance with decreasing age from solar values up to ~0.3 dex was detected in the

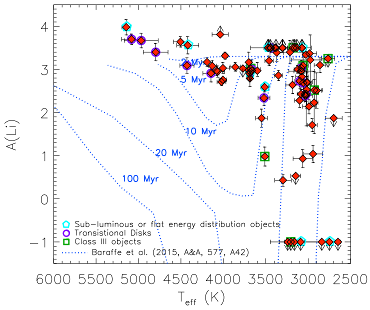

Fig. 1. A(Li) vs. $T_{\rm eff}$ (credits: Biazzo et al. 2017).

age range ~0.5-4.5 Gyr. It was reproduced by assuming high Ba yields from low-mass AGB stars in Galactic chemical evolution models (D'Orazi et al. 2009). Such models were not able to reproduce the further increase (up to ~0.6-0.7 dex) found for younger clusters (~30-50 Myr; D'Orazi et al. 2012).

2. Lupus: dataset and results

2.1. Sample

We analyzed 89 spectra acquired with the X-shooter@VLT spectrograph (Chile) at a resolution R ~8800-17400. The sample comprises 82 class II and 7 class III sources (see details in Alcalá et al. 2014, 2017; Frasca et al. 2017).

2.2. Lithium, Iron, and Barium abundance

Lithium abundance A(Li) was estimated from Li equivalent width corrected for veiling, atmospheric parameters derived by Frasca et al. (2017), and using curves-of-growth by Pavlenko & Magazzu (1996) and Palla et al. (2007). In Fig. 1 we show A(Li) as a function of effective temperature. Most of the stars have A(Li) between 2 and 4 dex, with a peak at ~3.1 dex, independently of their classification as class II/III, transitional disks, or sub-luminous objects. A spread of A(Li) appears for stars cooler than about 3500 K, regardless of uncertainties or upper limits. Therefore, for the sub-sample of stars with $0.2 < M_\star < 0.5 M_\odot$, we applied the so-called Li-test (Palla et al. 2005) and considered the possibility that some of these stars underwent Li depletion.

Iron and barium abundances were derived by employing the code MOOG (Sneden 1973) and model atmospheres (Kurucz 1993). We found: *i*) [Fe/H] consistent, within the errors, with the chemical pattern of the Galactic thin disk in the solar vicinity; *ii*) [Ba/H] enhanced up to ~0.7 dex level. Our results extend the trend observed by D'Orazi et al. (2009, 2012) to younger ages. We investigated several explanations for this puzzling behavior (chromospheric and accretion effects, uncertainties in stellar parameters, NLTE effects), but none of these is able to completely justify the Ba overabundance. The Ba problem is an open issue and deserves further work, both observational and theoretical, at ages <50 Myr.

3. Orion: future perspectives

In 2011 we reported with Francesco a surprising result about the slightly metal-poor nature of the Orion Nebula Cluster when compared to other older Orion sub-groups. Afterwards, we obtained observations at the TNG of young stars in L1641, a cloud within the Orion A complex, which also houses ONC, but located away from it. Our goal is to investigate whether the low ONC metallicity is the rule or the exception across Orion A, and to put further constraints on the star formation process within the different subgroups. This project unfortunately will continue without Francesco, but his contribution was and will be fundamental.

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