*From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution*
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# Old open clusters as key tracers of Galactic chemical evolution. First results: NGC 3960

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**Abstract.** In the context of a large observational project on old open clusters, we employed FLAMES + UVES on VLT UT2 to collect new high resolution spectra for giant stars in 7 clusters with the aim of investigating the radial abundance distributions in the Galactic disk. The gradients of Fe, $\alpha$ and Fe-peak elements and their evolution with Galactic age are indeed one of the most critical constraints to the star formation history in the Galactic disk and to Galactic chemical evolution models. We present here our preliminary results on the metallicity and abundance ratios for red clump stars in the ∼1 Gyr old cluster NGC 3960, located at a Galactocentric distance $R_{gc} \sim 8$ kpc.

**Keywords.** Stars: abundances, open clusters and associations: general

## 1. Introduction: the project

Open clusters (OCs) represent the best tool to investigate the distribution of chemical abundances in the Galactic disk (e.g., radial gradients) and their evolution with age. In spite of the theoretical and observational efforts carried out during the last decades, several questions on radial gradients remain elusive (e.g., Friel 1995; Twarog *et al.* 1997; Friel *et al.* 2002). Furthermore, the results obtained by different authors are affected by systematic errors depending on the method of analysis and/or on physical assumptions. Our project, based on observations of giant stars in a well defined sample of OCs with FLAMES+UVES@VLT UT2, has two main goals: (i) the investigation of the Fe abundance distribution in the disk and its evolution with time; (ii) the determination of $\alpha$ and Fe-peak elements in order to derive their (possible) evolution with age and/or position. The variation with time (or lack thereof) of the radial metallicity gradient slope and the abundances of other species and their ratios to Fe are indeed crucial to get insights on the disk formation and evolution processes, as well as on the heavy element enrichment of the interstellar medium.

We will carry out a homogeneous analysis of all the sample clusters and compare them on the same abundance scale.

## 2. Data and analysis

We observed red giant branch and clump stars in 7 old OCs: NGC 2324, NGC 2477, NGC 2660, NGC 3960, NGC 6253, Be 29, Be 32, spanning an age range between ∼0.9 and 7 Gyr, and with Galactocentric distances from ∼6 up to 21 kpc. The metallicities estimated in the literature are $-0.50 \leqslant$[Fe/H]$\leqslant +0.36$ (see Mermilliod's database at obswww.unige.ch/webda/).

**Table 1.** Element abundances for NGC 3960 and the Sun.

| | Sun $\log n(\mathrm{X})$ | NGC3960 [X/Fe] |
|---|---|---|
| Fe | 7.51±0.05 | −0.02±0.05 |
| Na | 6.27±0.02 | +0.21±0.04 |
| Mg | 7.63±0.13 | −0.03±0.04 |
| Si | 7.61±0.06 | +0.06±0.04 |
| Ca | 6.36±0.08 | +0.06±0.06 |
| Ti | 4.94±0.06 | −0.07±0.05 |
| Ni | 6.28±0.06 | −0.05±0.04 |

The analysis is carried out with MOOG (version 2002, Sneden 1973). Initial effective temperatures and surface gravities are derived from $(B-V)$ or $(V-K)$ colors, using the calibration and bolometric correction by Alonso *et al.* (1999); the microturbulent velocity is computed as $\xi = 1.5 - 0.13 \cdot \log g$ (Carretta *et al.* 2004). $T_{\rm eff}$ and $\log g$ are optimized during the spectroscopic analysis.

## 3. Results for NGC 3960

The metallicity of NGC 3960 was measured by Friel *et al.* (2002) using low-resolution spectroscopy ([Fe/H]=−0.34). Prisinzano *et al.* (2004), using this metallicity, determined from their photometric data an age of 0.9 to 1.4 Gyr and $(m-M)_0$=11.35. They also found a differential reddening, with a value of $E(B-V)$=0.29 for the central part of the cluster, where all our targets are located.

We observed 7 clump stars and 3 main sequence stars in NGC 3960, and we present here our preliminary results for chemical abundances in the clump ones. From radial velocities 5 objects are confirmed cluster members, 1 is a probable member (abundance analysis suggests that it should belong to the cluster), and 1 is a non-member. Average abundances for Fe, Na, Ni and the $\alpha$-elements Mg, Si, Ca, Ti are reported in Table 1, together with the corresponding solar values derived by us. The final stellar parameters are very similar for the 6 stars: $T_{\rm eff}$∼4800–5000 K, $\log g$∼2.0–2.5, $\xi$∼1.15–1.25 km s$^{-1}$.

We found that the cluster has a nearly solar iron content ([Fe/H]=−0.02±0.11), at variance with the findings of Friel *et al.* (2002). This applies also to Ni and the four $\alpha$-elements, while Na results enhanced. Note however that [Na/H] values in Table 1 were not corrected for non-LTE effects, which affect the spectral lines used to derive the abundance of this element (Mashonkina *et al.* 2000).

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