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Chemical abundances of four red supergiants star clusters (RSGCs) in Scutum-Crux arm

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Abstract. We investigate the spectral properties of red supergiant stars in the four RSGCs (RSGC2, RSGC3, RSGC4, RSGC5, and Alicante 10) in the Scutum-Crux arm of the Milky Way. The high-resolution ($R \sim 45,000$) near-infrared (H and K bands) spectra for 41 red supergiants were obtained using IGRINS at Gemini South telescope. The calibration of effective temperatures and gravities are derived based on the EW_{Ti} and EW_{CO} using supergiants in IGIRNS library. The resulted temperatures and gravities are consistent with previous results. Model spectra were synthesized using derived stellar parameters from which we estimate metallicities and chemical abundances like α-elements. In our preliminary result, we find that overall four RSGCs indeed have sub-solar metallicities as already known in previous studies. The metallicity properties of RSGCs are far off the nominal metallicity trend in this region, and this suggests recent low-metallicity gas fueling into the inner disk and bulge.

Keywords. stars: abundances, stars: late-type, (stars:) supergiants, Galaxy: disk

1. Introduction

Massive stars are important to investigate the structures and chemical evolution of galaxies because of their luminous brightness and chemical enrichment as supernova. Young massive star clusters ($>10^4 M_{\odot}$) where we can find a coeval sample of massive stars at uniform metallicity are excellent laboratories to study massive stellar evolution, star formation process and abundance patterns in galaxies. Recently, several RSGCs (RSGC1, RSGC2, RSGC3, RSGC4, RSGC5, and Alicante 10) are found near Scutum-Crux arm in the Milky Way (Figer *et al.* 2006; Davies *et al.* 2007; Clark *et al.* 2009; Negueruela *et al.* 2010, 2011; Gonzalez-Fernandez & Negueruela 2012), and they are showing very interesting chemical abundance patterns regarding to the Galactic metallicity gradients. The high-resolution spectroscopic studies for the limited samples of RSGs in RSGC1, RSGC2, and RSGC3 (Davies *et al.* 2009; Origlia *et al.* 2016) report that the average metal abundances of the clusters are about subsolar, which is conflict with increasing metal abundance trend at lower R_{GC}. Subsolar metallicity of RSGs is also definitely contradictory to the recent starburst predicted from the interaction between Galactic bar and spiral arms. This indicates that the chemical information and star formation history in this area seem to be much more complicated, and simple bar and spiral arm interaction can not explain the subsolar metallicity of RSGs. In this study, we investigate the spectral properties of RSGs in the four RSGCs (RSGC2, RSGC3, RSGC4, RSGC5, and Alicante 10) using the high-resolution ($R, \sim 45,000$) near-infrared (H and K bands) spectra for 41 red supergiants obtained using IGRINS at Gemini South telescope.

2. Stellar parameters

Previous spectroscopic studies for RSGs have derived the effective temperatures (T_{eff}) of RSG empirically from the relation between equivalent width of the CO band-head

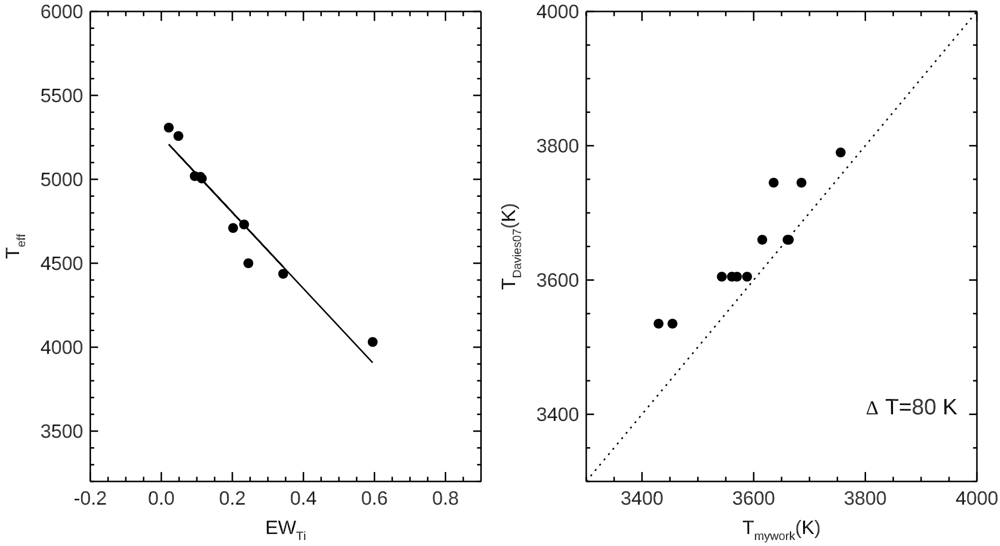

Figure 1. Left: The effective temperatures as a function of calculated EW_{Ti} for the supergiants in IGRINS spectral library. Solid line indicates empirical relation between EW_{Ti} and effective temperatures. Right: Comparison of effective temperatures between this work and Davies *et al.* (2007) for the RSGs in RSGC2.

feature (EW_{co}) and spectral types (Davies *et al.* 2007; Davies *et al.* 2009; Negueruela *et al.* 2010). In IGRINS spectral library study (Park *et al.* 2018), however, they find that EW_{co} correlates with both log g and T_{eff}, while EW_{Ti} is the most sensitive indicator of T_{eff}. Thus, we adopt the method of Park *et al.* (2018), and reaclibrate EW_{co} and EW_{Ti} with template spectra of supergiants in IGRINS spectral library. The left panel of Figure 1 shows the effective temperatures as a function of calculated EW_{Ti} for the supergiants in IGRINS spectral library. The solid line in the left panel of Figure 1 indicates empirical relation between effective temperature and EW_{Ti}. Using calibrated T_{eff} and EW_{CO}, we also recalibrate and derive empirical relation of gravities. The derived equations for effective temperatures and log g from EW_{Ti} and EW_{CO} are indicated as below.

$$T_{eff} = -2265.57 \times EW_{Ti} + 5255.62 \tag{2.1}$$

$$log\ g = -13.806 - 0.228 \times EW_{CO} + 4.347 \times log\ T_{eff} \tag{2.2}$$

In order to test our equations, we compared our results with already known T_{eff} and gravities derived by Davies *et al.* (2007) for the commonly observed RSGs in RSGC2. The right panel of Figure 1 shows the comparison of T_{eff} between ours and Davies *et al.* (2007). We find that the difference in effective temperature between our results and those of Davies *et al.* (2007) is only about $80K$, and also gravities are consistent. Therefore, using these equations, we derived all T_{eff} and log g for the observed 41 RSGs in four RSGCs.

3. Metallicities and Chemical abundances

In this work, we investigate the metallicities and α-elements for seven RSGs among 41 RSGs of RSGCs. Stellar model atmospheres were calculated from the grids of MARCS models (Gustafsson *et al.* 2008) with the determined atmospheric parameters. Using synth task in MOOG with atmosphere models, we then synthesized model spectra

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Table 1. The stellar parameters and preliminary results of metallicities and α-elements for seven RSGs

RSG	T_{eff}	log g	[Fe/H]	V_{mic}	A(Mg)	A(Al)	A(Si)	A(Ca)	A(Ti)
RSGC2-9	3429.60	−0.05	−0.31	4.0	7.45	5.93	7.25	5.78	4.43
RSGC2-12	3561.00	0.07	−0.37	4.0	7.38	5.69	7.42	5.83	4.51
RSGC2-19	3542.88	0.10	−0.36	4.0	7.58	6.05	7.33	5.95	4.52
RGCC3-1	3477.18	0.02	−0.43	4.0	7.46	5.92	7.13	6.13	4.52
RSGC4-3	3504.36	0.08	−0.85	4.0	6.22	5.45	6.38	5.82	4.09
RSGC5-9	3538.35	0.13	−0.66	4.0	7.22	5.85	7.25	5.72	4.17
Alicante10-1	3683.34	0.38	−0.87	4.0	6.06	5.53	6.40	5.80	4.15

Notes: Abundances are expressed in the form A(X)=log (X/H)+12.

to estimate the metallicity and chemical abundances. We fixed microturbulence as 4 km s^{-1} and used atomic and molecular line list of Kurucz (2011) for model spectra calculation. Metallicities are calculated based on several Fe I lines in H and K bands, and abundances of α-elements are also estimated to all available lines. Table 1 shows the preliminary stellar parameters, metallicities, and α-elements results for severn RSGs in four RSGCs. In our study, investigated RSGs in four RSGCs still have sub-solar metallicities, which is conflict with the radial Galactic metallicity trend traced by Cepheids and other young stellar populations at lower R_{GC} (Luck *et al.* 2006; Magrini *et al.* 2009; Genovali *et al.* 2013). Our results suggest the recent low-metallicity gas fueling into the inner disk and bulge, and indicate that the Galactic bulge and bar region have inhomogeneous chemical composition and complex star fromation history. The chemical properties for more complete samples of 41 RSGs will provide more realistic statistical interpretation for the inhomogeneous chemical properties of Scutum-Crux arm reagion.

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