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CNO Abundances in the Quintuplet Cluster M Supergiant 5-7

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We present and analyze infrared spectra of the supergiant VR 5–7, in the Quintuplet cluster 30 pc from the Galactic center. Within the uncertainties, the [C/H], [N/H], and [O/H] abundances in this star are equal to those of α Ori, a star which exhibits mixing of CNO processed elements, but distinct from the abundance patterns in IRS 7.

1 Introduction

We have previously published a differential analysis of the iron abundance [Fe/H] in ten cool, luminous stars within 30 pc of the Galactic Center, compared to 11 stars of similar temperature and luminosity in the solar neighborhood. We found that both samples of stars had a narrow distribution of [Fe/H] centered at the solar value (Ramírez et al. 2000). Carr et al. (2000) also studied [C/H], [N/H], and [O/H] in α Ori and in IRS 7, which lies at a projected distance of 0.25 pc from Sgr A*. They found that dredge-up of CNO-processed material was present in both M supergiants, as expected theoretically, but that the amount of internal mixing was much stronger in IRS 7, stronger than predicted by current evolutionary models. Our main goal is to investigate whether the strong internal mixing found in IRS 7 is due to the unusual conditions for star formation in the central 100 pc of the Galaxy (Morris 1993, Morris & Serabyn 1996), or is due to some tidal interaction between IRS 7 and the supermassive black hole (2.6×10^6 $M_\odot$: Schöedel et al. 2002, Ghez et al. 2000) at the Galactic Center. Here we present preliminary results on [C/H], [N/H], and [O/H] in the M supergiant VR 5–7, which lies in the Quintuplet cluster, 30 pc from the Galactic Center.

2 Observations and Analysis

High-resolution ($\lambda/\Delta\lambda \sim 25{,}000$) $K-$band and $H-$band spectra of VR 5–7 were obtained through Gemini sponsored access to the Keck Telescope using NIRSPEC in June 2001. The spectra were reduced using IRAF, involving flat fielding, sky subtraction, spectrum extraction, wavelength calibration, and removal of atmospheric absorption features. The observed spectra are of high quality, with a signal to noise ratio above 100, which is needed for detailed abundance analysis.

The abundance analysis was done using a current version of the LTE spectral synthesis program MOOG (Sneden 1973). The program requires a line list with atomic and molecular parameters and an input model atmosphere for the effective temperature and surface gravity appropriate for the star. The atomic and

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molecular parameters (wavelength, excitation potential, gf-value, damping constant, and dissociation constant) were obtained the same way as in Ramírez et al. (2000), and also included CO molecular parameters from Goorvitch (1994) and OH molecular parameters from Black (private communication). The solar abundance model atmospheres from Plez (1992) were used for our abundance analysis. The stellar parameters of VR 5–7 were taken from Ramírez et al. (2000): effective temperature $T_{\rm eff}$ = 3500 K, surface gravity $\log g = -0.2$, microturbulent velocity ξ = 2.9 km s^{-1}, and macroturbulent velocity ζ = 12.6 km s^{-1}.

3 Results and discussion

Synthetic spectra were computed in several regions of the $K-$ and $H-$ spectra, where CO, OH, and CN lines were selected. The resulting synthetic spectra (dotted lines) are plotted in Figures 1, 2 and 3 together with the observed NIRSPEC spectra (filled squares). We identified four relatively unblended CO lines in the $K-$band spectrum, four CO and four OH lines in the $H-$band spectrum, and ten CN lines in the $K-$band spectrum; those suspected of being blended with unidentified lines or lines with uncertain gf values were not considered in the analysis. Our results of VR 5–7 are listed in Table 1, together with the abundances of α Ori and IRS 7 from Carr et al. (2000).

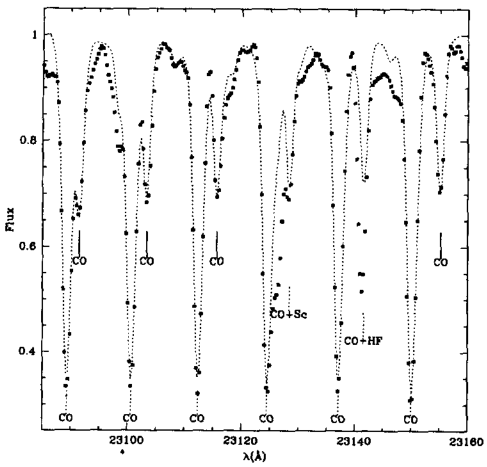

Fig. 1 $K-$band synthetic spectrum (dotted line) overplotted with the observed NIRSPEC spectrum (filled squares) for VR 5–7. In these and the following figures, the most prominent absorption features are shown; the ones used in the analysis were selected to be relatively unblended. The gf values for the Sc and HF features are not available.

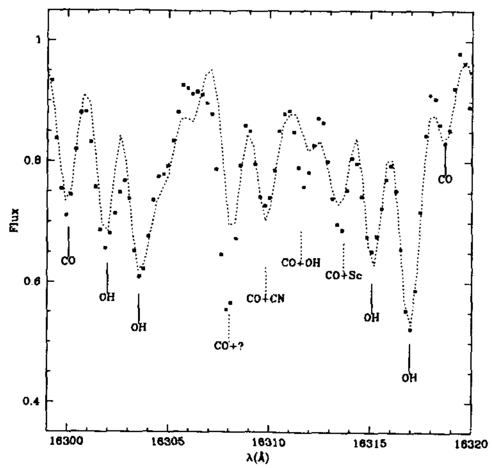

Fig. 2 $H-$band synthetic spectrum (dotted line) overplotted with the observed NIRSPEC spectrum (filled squares) for VR 5–7.

The statistical uncertainties arising from the scatter in abundance between individual lines of OH, CO, or CN, are less than 0.1 dex for 5-7. The systematic uncertainty in the abundances, however, from uncertain stellar parameters, is 0.2 dex.

Within the uncertainties, VR 5–7 is has comparable CNO composition to α Ori, and its CNO composition is distinct from that of IRS 7. The spectral differences between VR 5–7 and α Ori can be seen in Figure 4, and the differences between VR 5–7 and IRS 7 can be seen in Figure 5.

Current non-rotating evolutionary models predict that a 20 $M_\odot$ star would have [N/C]=+0.8 dex at the end of He burning, similar to that of α Ori and VR 5–7, whereas a rotating star with an initial main

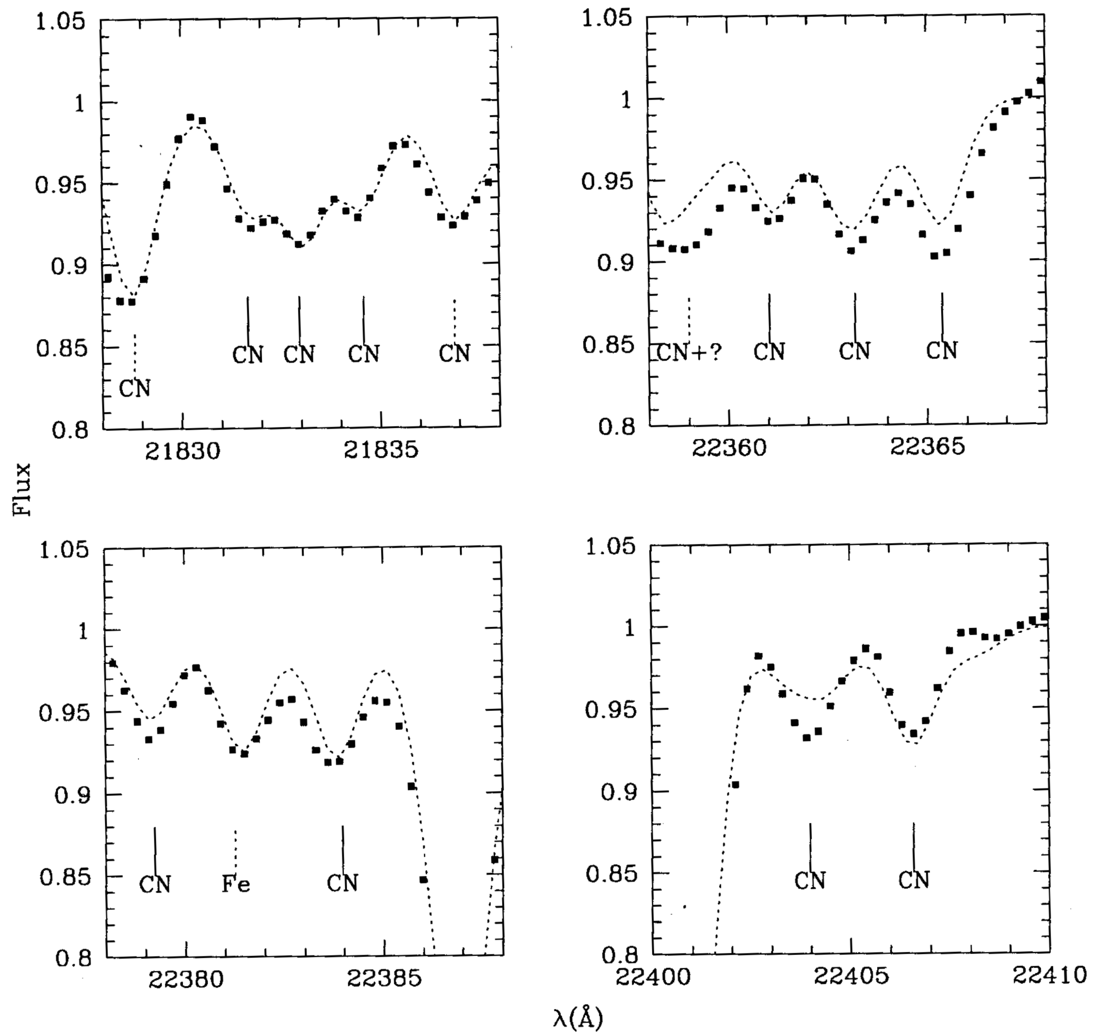

Fig. 3 $K-$band synthetic spectrum (dotted line) overplotted with the observed NIRSPEC spectrum (filled squares) for VR 5–7.

Table 1 Abundances of VR 5–7

Star	[C/H]	[N/H]	[O/H]	[(C+N+O)/H]	Reference
VR 5-7	–0.3	+0.6	+0.2	+0.16	this paper
α Ori	–0.3	+0.5	–0.2	–0.09	Carr et al. (2000)
IRS 7	–0.8	+0.9	–0.7	–0.11	Carr et al. (2000)

sequence equatorial velocity of 300 km s^{-1} would have $[N/C] = +1.3$ dex (Meynet and Maeder 2000). IRS 7 has $[N/C] = 1.7$ dex, which implies stronger mixing yet. It is possible that IRS 7 is experiencing tidal mixing due to its proximity to the super massive black hole (Alexander & Livio 2001, Alexander & Kumar 2000), given that its projected distance to Sgr A* is 0.25 pc.

To fully explore this possible interpretation we need to determine the CNO abundances of more stars in the Central Cluster. Right now, we have similar data taken with NIRSPEC at the Keck Telescope and PHOENIX at Gemini South, for four stars located within 2.5 pc of Sgr A*, and also several solar neighborhood stars, taken with CSHELL at the IRTF. If the black hole is key to mixing in the Galactic Center we might see an effect on the abundance patterns for the Galactic Center stars as their projected distance increases. If the extreme abundances in IRS 7 are related to the star formation process in the inner Galaxy (Morris 1993, Morris & Serabyn 1996), then we might expect to see similar patterns in the other Galactic Center stars and VR 5–7, but differences in the mean compared to the solar neighborhood stars.

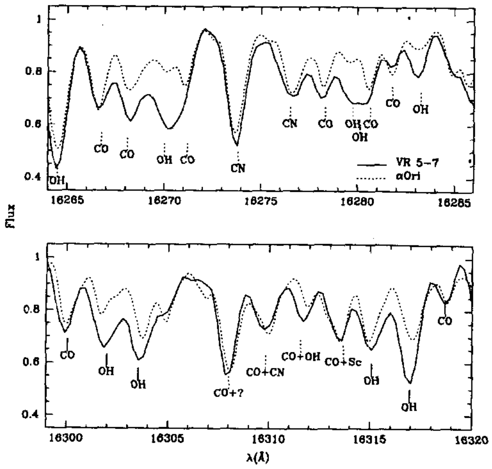

Fig. 4 Comparison between $H-$band spectra of VR 5–7 (solid line) and α Ori (dotted line).

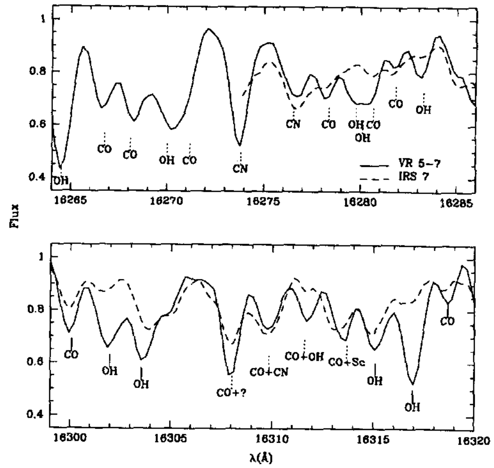

Fig. 5 Comparison between $H-$band spectra of VR 5–7 solid line) and α Ori (dotted line).

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