A Search for $\text{C}_4$ and $\text{C}_5$ in the (Molecular) Carbon-Rich Sightline toward HD 204827

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C$_2$: The Shortest Carbon Chain

  - Cygnus OB2 12, A-X 1-0 band near 10150 Å
- Modern spectra: usually 2-0 band near 8750 Å

- Rotational excitation
  - provides n, T estimates
Triatomic Carbon: $C_3$

- Detected toward $\zeta$ Oph, $\zeta$ Per, 20 Aql
  - $A \ ^1\Pi_u - X \ ^1\Sigma_g^+$ 0-0 band
  - first seen by Huggins in a comet in 1881

APO Survey Yields C$_3$

- Lower resolution survey for DIBs
- Detected unresolved C$_3$ profiles in 15 sightlines

Full Excitation Model of C$_3$

- Roueff et al. 2002
  - detected C$_3$ toward HD 210121
  - developed full excitation model → n, T

Keck/Lick Survey of C$_3$

- High signal/noise
- High resolution
- Fit each N(J) independently
- 10 sightlines

A Search for C$_4$ & C$_5$

- ζ Oph (V=2.56)
- CFHT, S/N~4000
- Comparison with Maier lab spectra
  - C$_4$ $^3\Sigma_u - ^3\Sigma_g$ - 3789Å
  - C$_5$ $^1\Pi_u ? - ^1\Sigma_g^+$ - 5109Å
- Non-detection

Keck Search for $\text{C}_4$ & $\text{C}_5$

- HD 204827 ($V=7.94$)
- Keck, 2 nights integration $\rightarrow$ S/N$\sim$1000

Ádámkovics, Blake, & McCall, in preparation
## Comparison of Results

<table>
<thead>
<tr>
<th></th>
<th>$\zeta$ Oph (Maier et al.)</th>
<th>HD 204827 (present work)</th>
</tr>
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<tbody>
<tr>
<td>$C_2$</td>
<td>$2.5 \times 10^{13}$ (250)</td>
<td>$4.4 \times 10^{14}$ (630)</td>
</tr>
<tr>
<td>$C_3$</td>
<td>$1.6 \times 10^{12}$ (16)</td>
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<tr>
<td>$C_4$</td>
<td>$&lt; 5 \times 10^{11}$ (&lt;5)</td>
<td>$&lt; 4 \times 10^{12}$ (&lt;6)</td>
</tr>
<tr>
<td>$C_5$</td>
<td>$&lt; 1 \times 10^{11}$ (&lt;1)</td>
<td>$&lt; 7 \times 10^{11}$ (&lt;1)</td>
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Column density in molec cm$^{-2}$ ratio to $C_5$
Comparison to Roueff Model

Model greatly overpredicts C4, C5

### Table: HD 204827

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\( n_H = 1500 \text{ cm}^{-3}, \chi = 0.5 \)
Carbon Chain Chemistry

Key to Reaction Types:
Photodissociation
Radiative association
Dissociative recombination
C+ ion-molecule
H2 ion-molecule

Key to Reaction Rates:

\[ \text{< 10}^{-12} \text{ s}^{-1} \]
\[ \sim 10^{-10} \text{ s}^{-1} \]
\[ \sim 10^{-8} \text{ s}^{-1} \]
\[ \sim 10^{-6} \text{ s}^{-1} \]

[assume: \( n_H \sim 500 \text{ cm}^{-3} \)]

\[ \text{C}^+ + \text{C}_n \rightarrow \text{C}_{n+1}^+ + \text{hv} \]

Freed, Oka, & Suzuki
Needs

• Photodissociation cross-sections
  – especially for $C_n$
• Rate coefficients
  – radiative association $C^+ + C_n$
  – ion-molecule, esp. $C_5H^+ + H_2$
• Oscillator strengths
• UV spectra of $C_4$ & $C_5$
  – would enable more sensitive search
• Chemical models of diffuse clouds
Conclusions

- $C_4$ & $C_5$ still not yet detected
- Longer chains seem not very abundant
  - still potential DIB carriers if $f > 1$
  - only demonstrated for $C_n$
- Need better chemical models
  - understand low $C_4$ & $C_5$ column densities
  - investigate abundance of other species
Acknowledgements

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