A Search for C_4 and C_5 in the (Molecular) Carbon-Rich Sightline toward HD 204827

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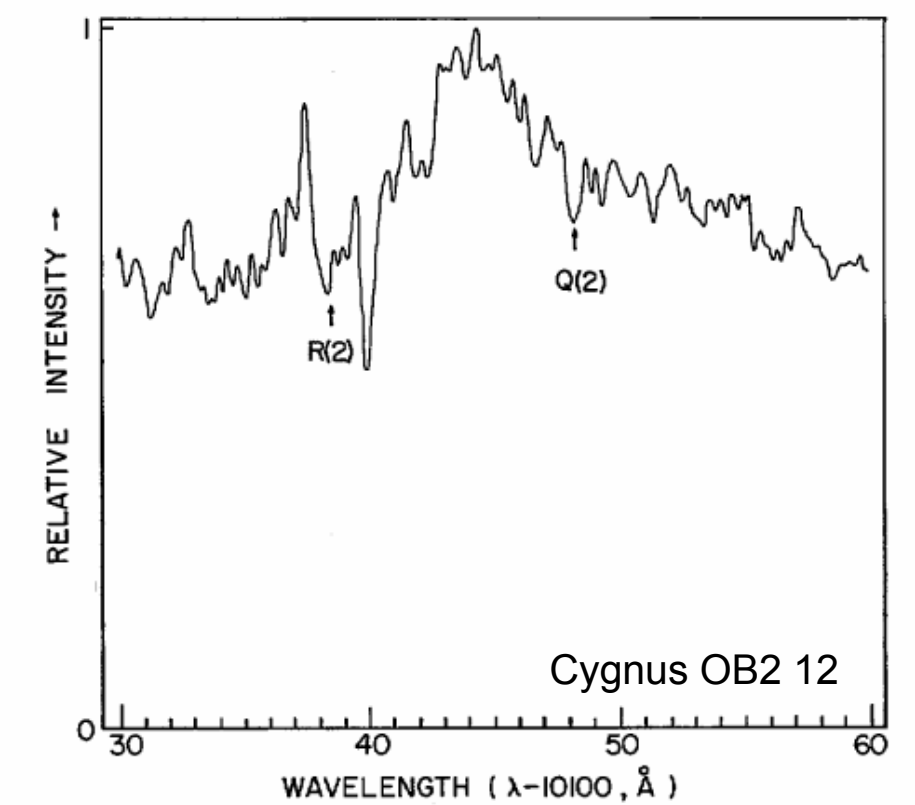
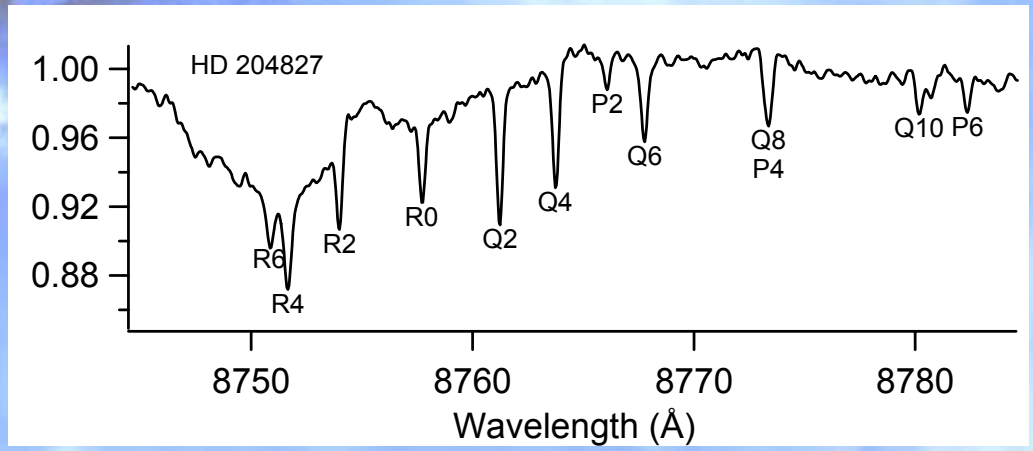
C_2: The Shortest Carbon Chain

- Discovery: Souza & Lutz 1977 [ApJ 216, L49]
  - Cygnus OB2 12, A-X 1-0 band near 10150 Å
- Modern spectra: usually 2-0 band near 8750 Å

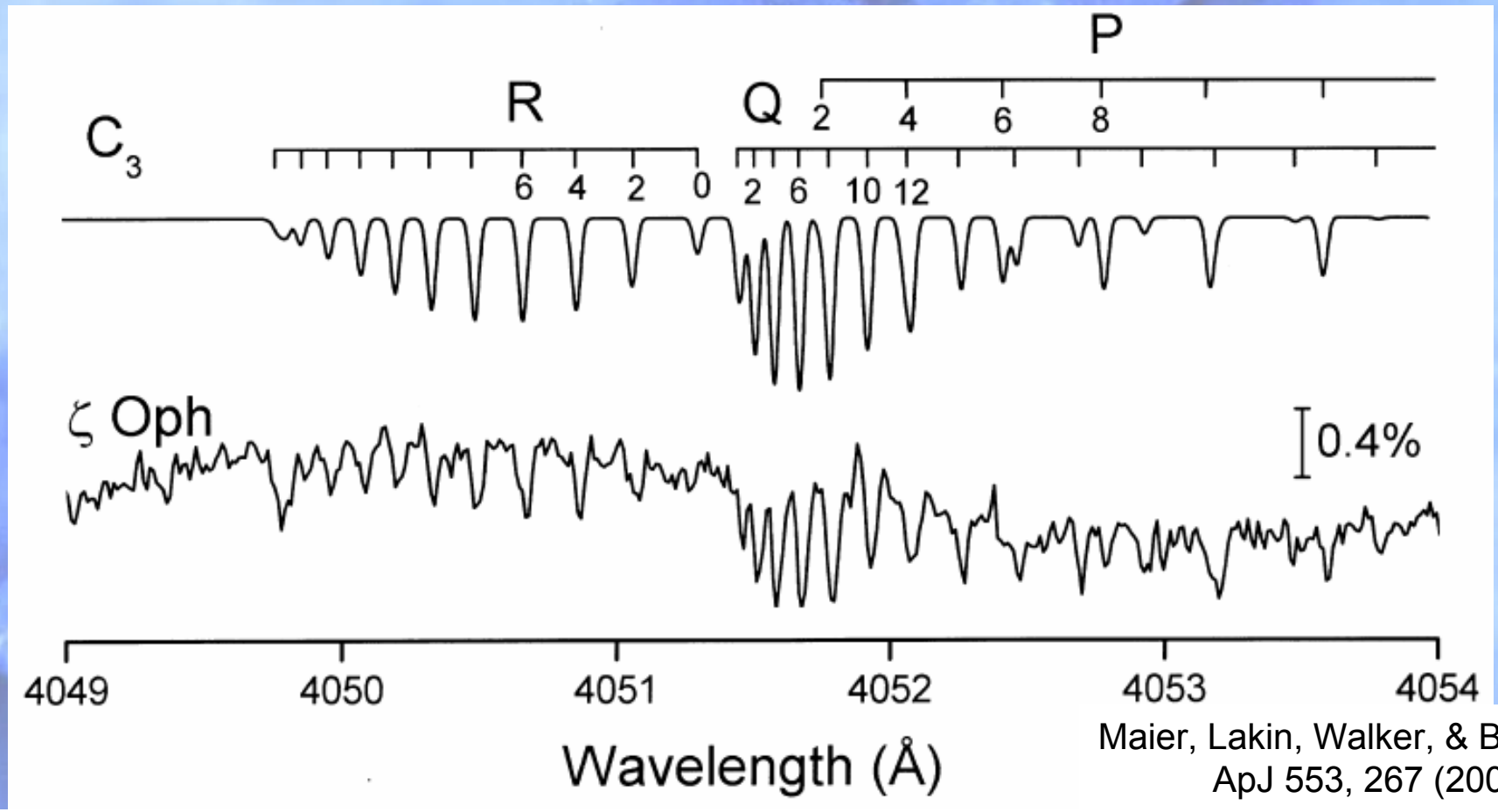


- Rotational excitation
  - provides n, T estimates



Triatomic Carbon: C_3

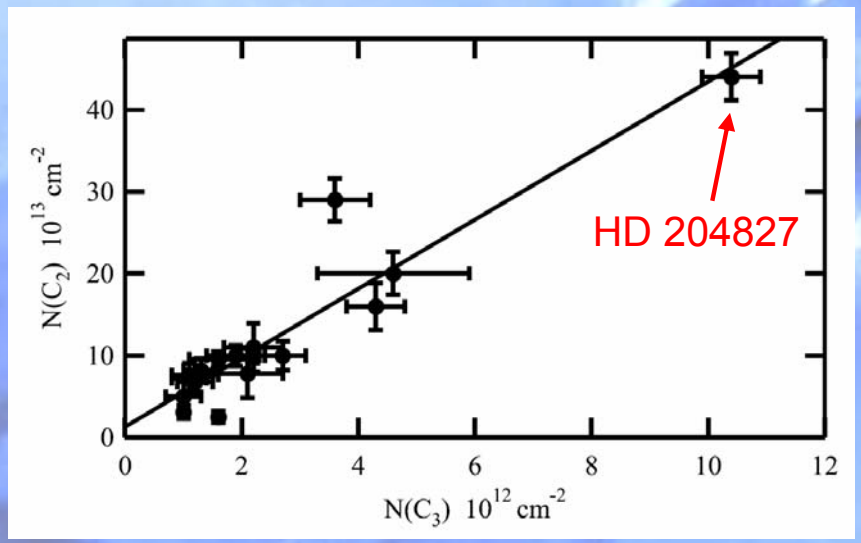
- Detected toward ζ Oph, ζ Per, 20 Aql
  - $A\ ^1\Pi_u - X\ ^1\Sigma_g^+$ 0-0 band
  - first seen by Huggins in a comet in 1881

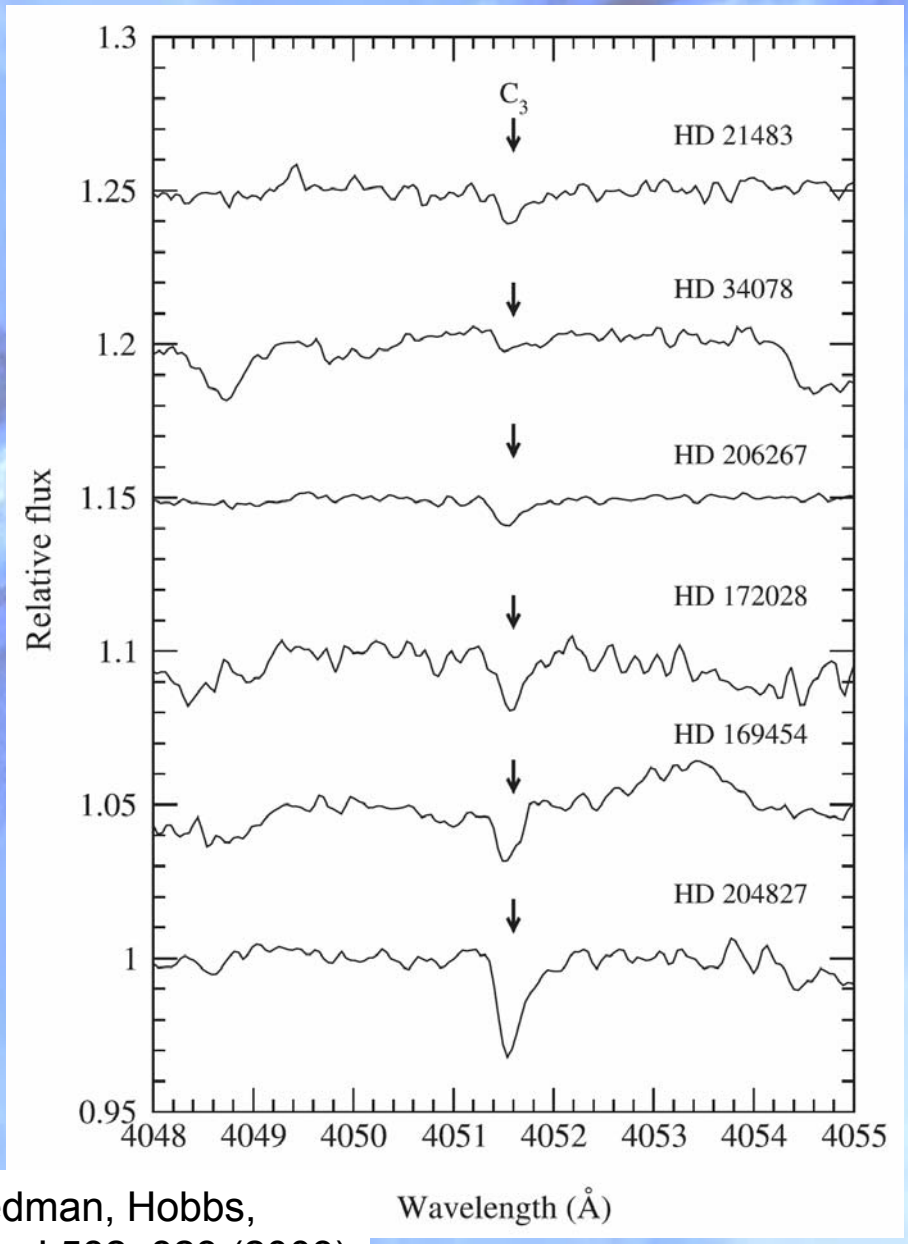


Maier, Lakin, Walker, & Bohlender, ApJ 553, 267 (2001)

APO Survey Yields C_3

- Lower resolution survey for DIBs
- Detected unresolved C_3 profiles in 15 sightlines

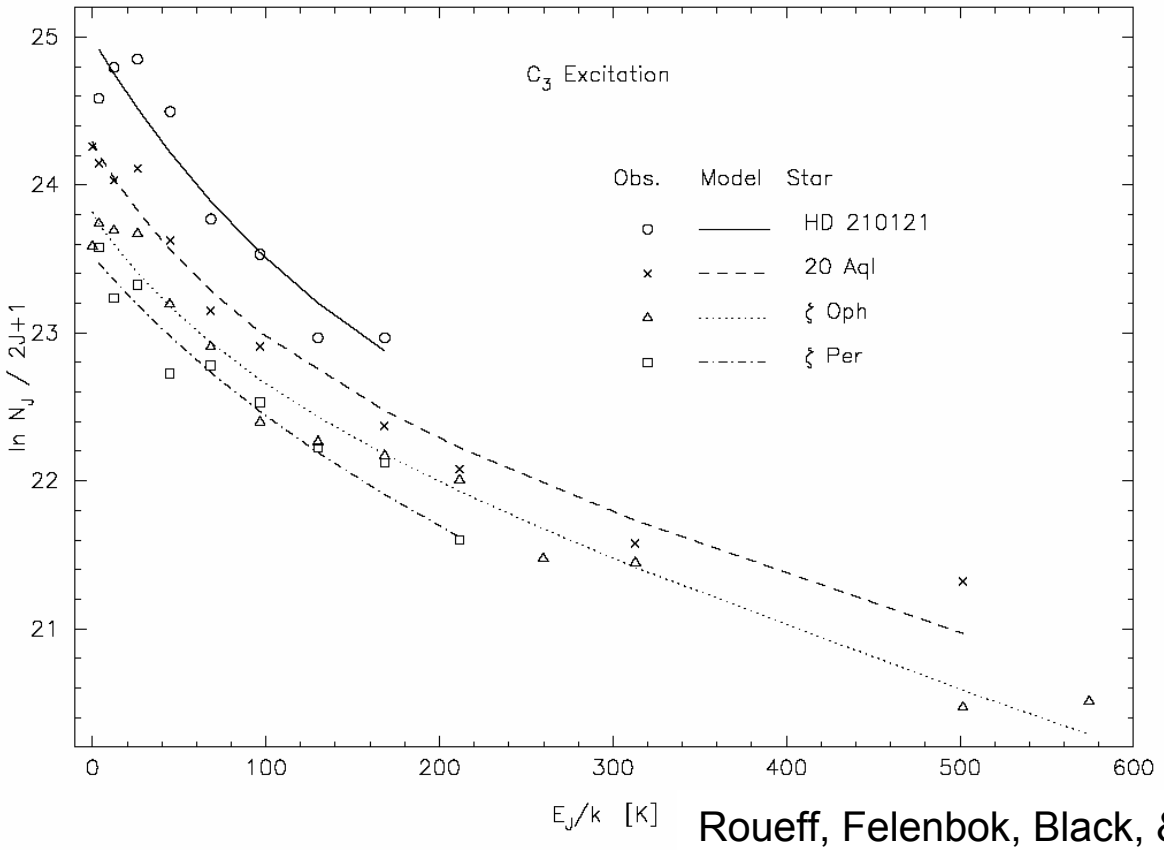


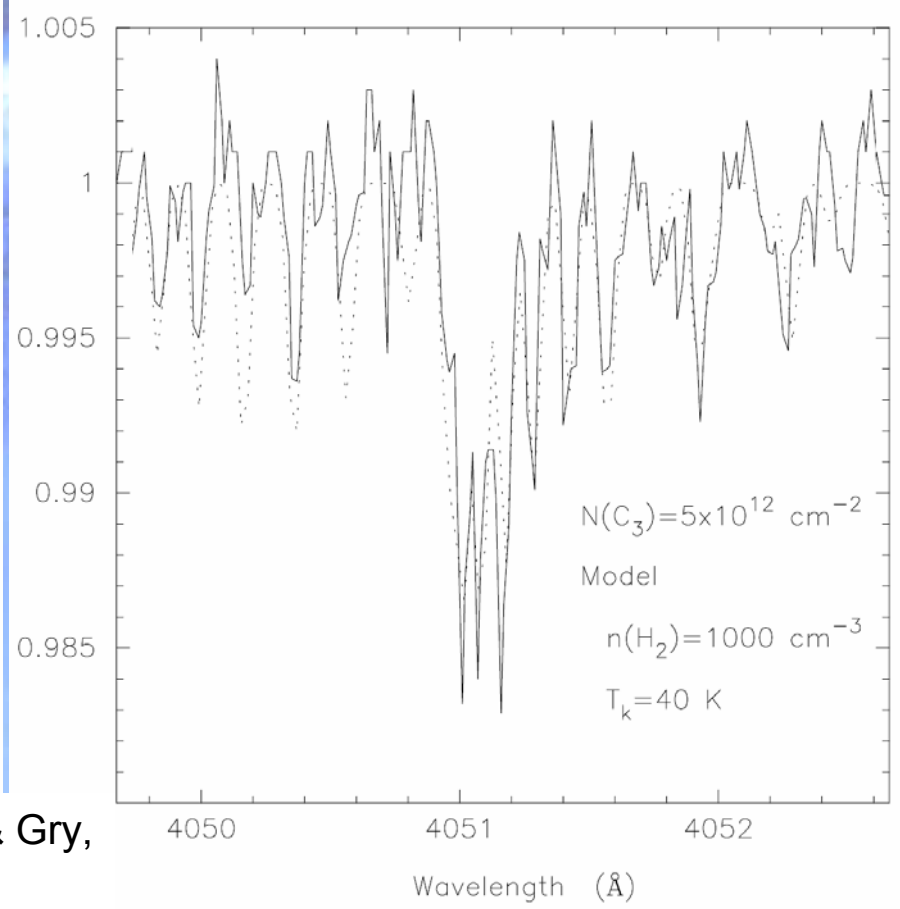


Oka, Thorburn, McCall, Friedman, Hobbs, Sonnentrucker, Welty, & York, ApJ 582, 823 (2003)

Full Excitation Model of C_3

- Roueff et al. 2002
  - detected C_3 toward HD 210121
  - developed full excitation model → n, T

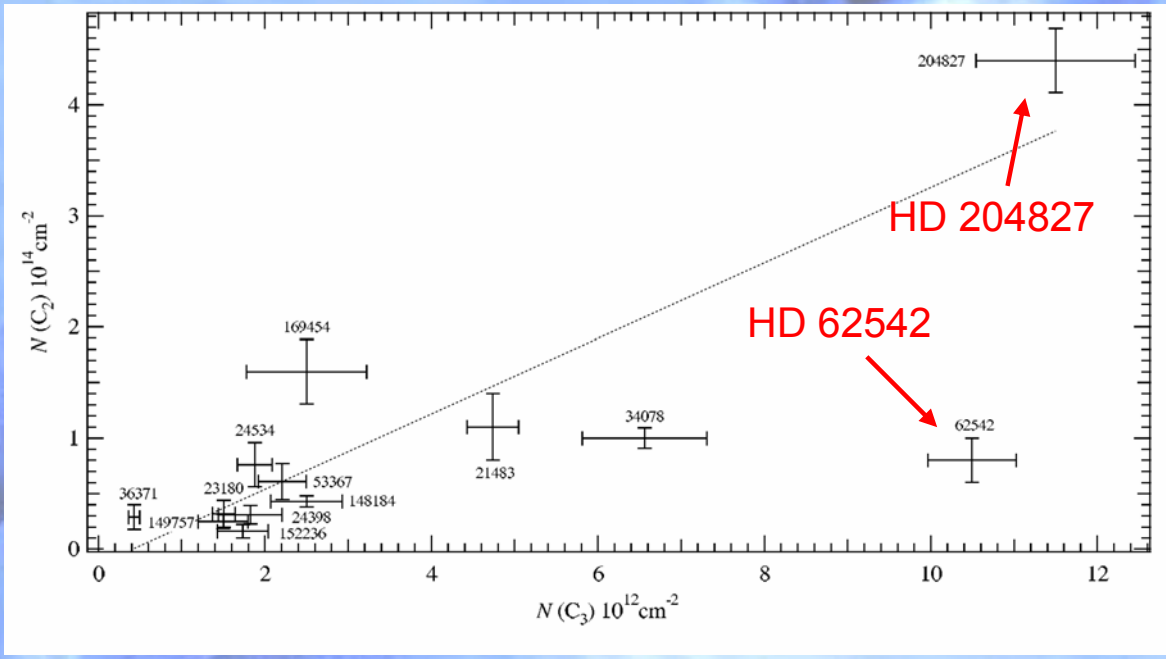


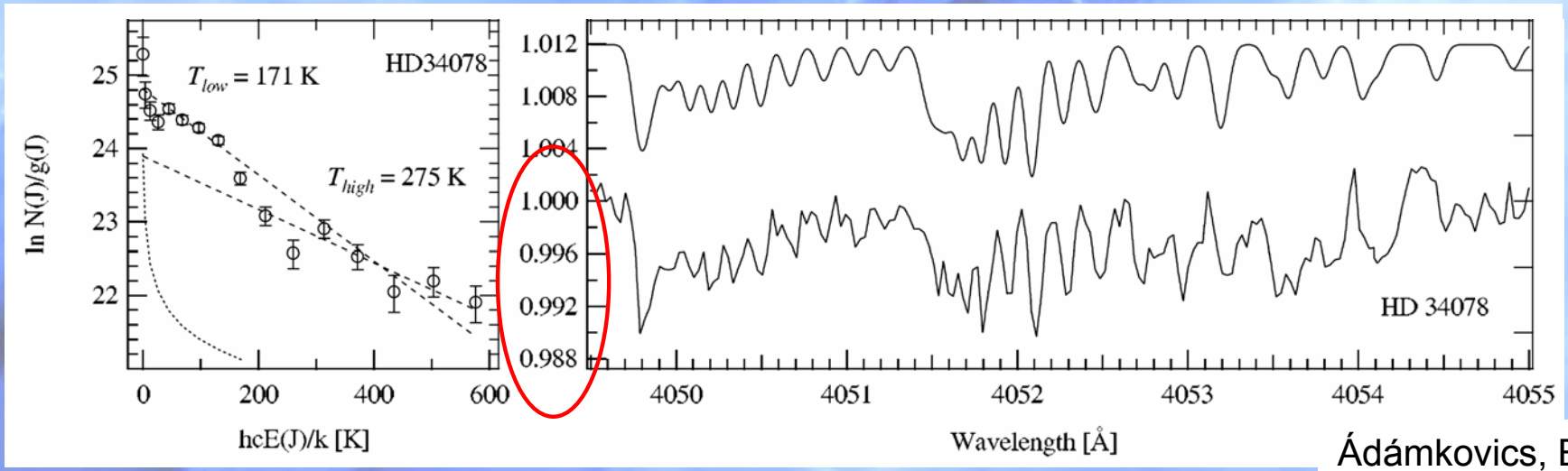


Roueff, Felenbok, Black, & Gry, A&A 384, 629 (2002)

Keck/Lick Survey of C_3

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

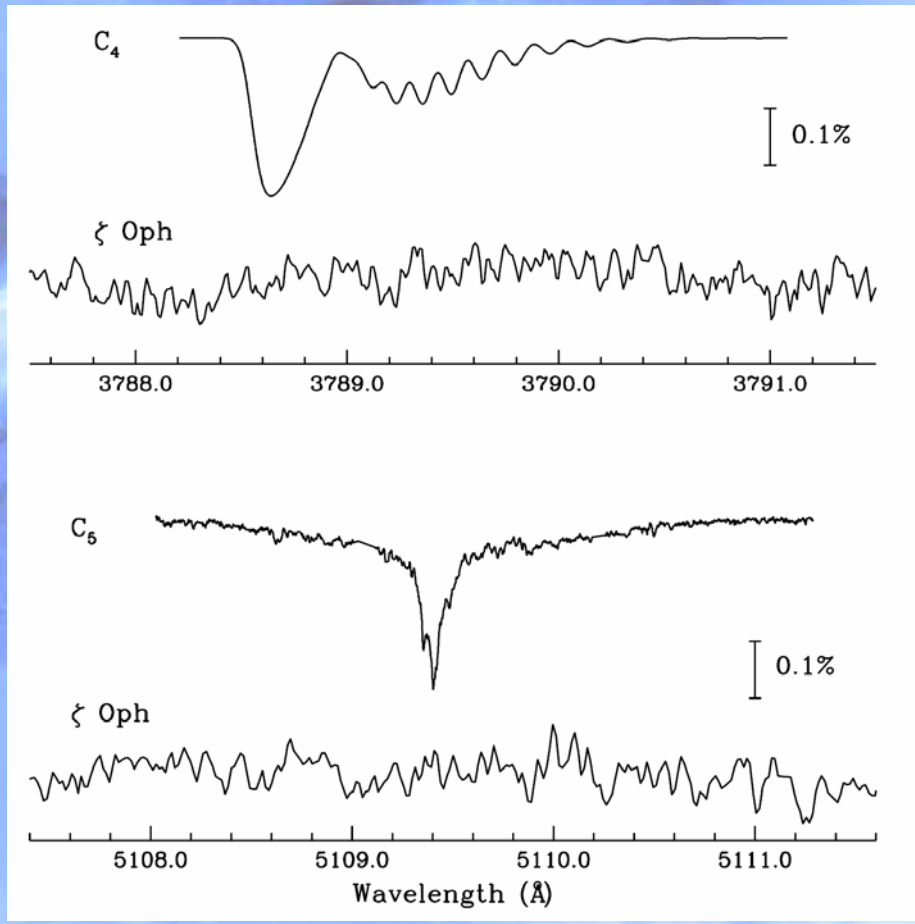




Ádámkovics, Blake, & McCall, ApJ 595, 235 (2003)

A Search for C_4 & C_5

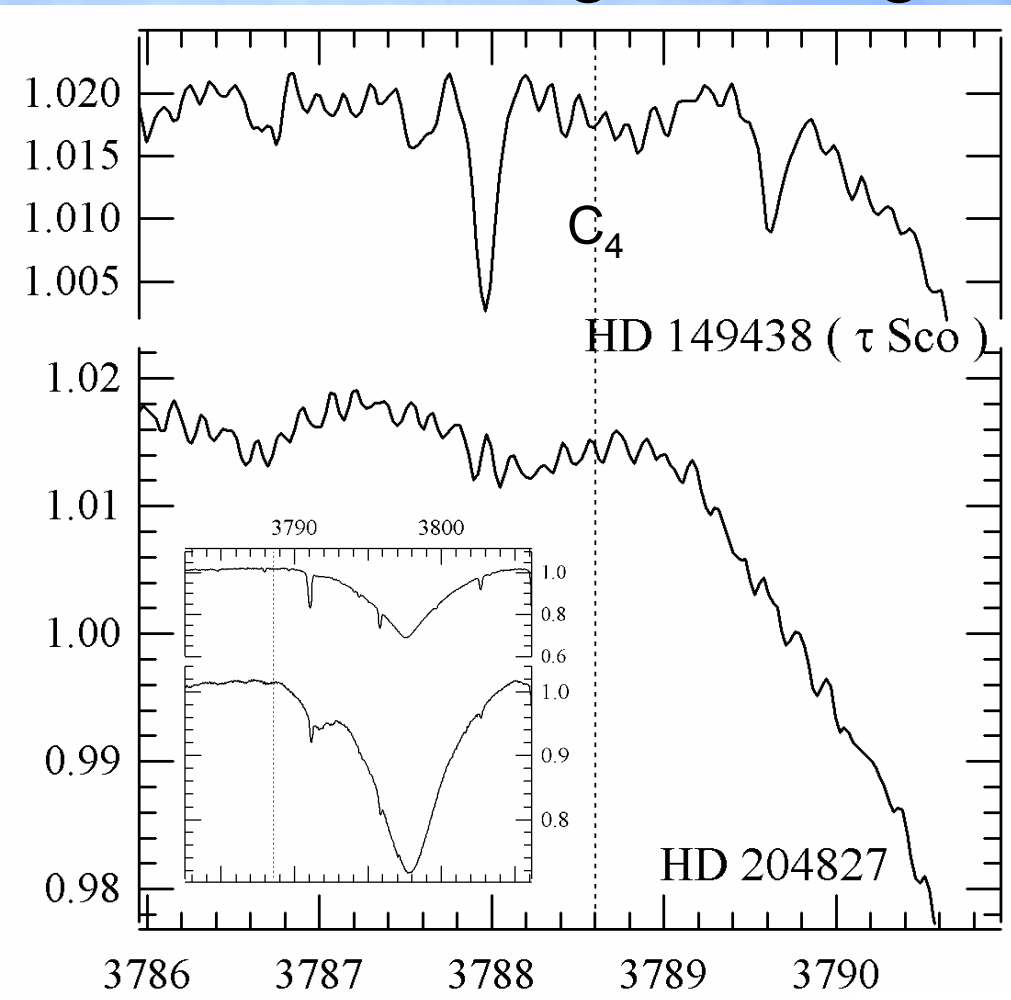
- ζ Oph (V=2.56)
- CFHT, S/N~4000
- Comparison with Maier lab spectra
  - C_4 $^3\Sigma_u^-$–$^3\Sigma_g^-$ 3789Å
  - C_5 $^1\Pi_u$?–$^1\Sigma_g^+$ 5109Å
- Non-detection

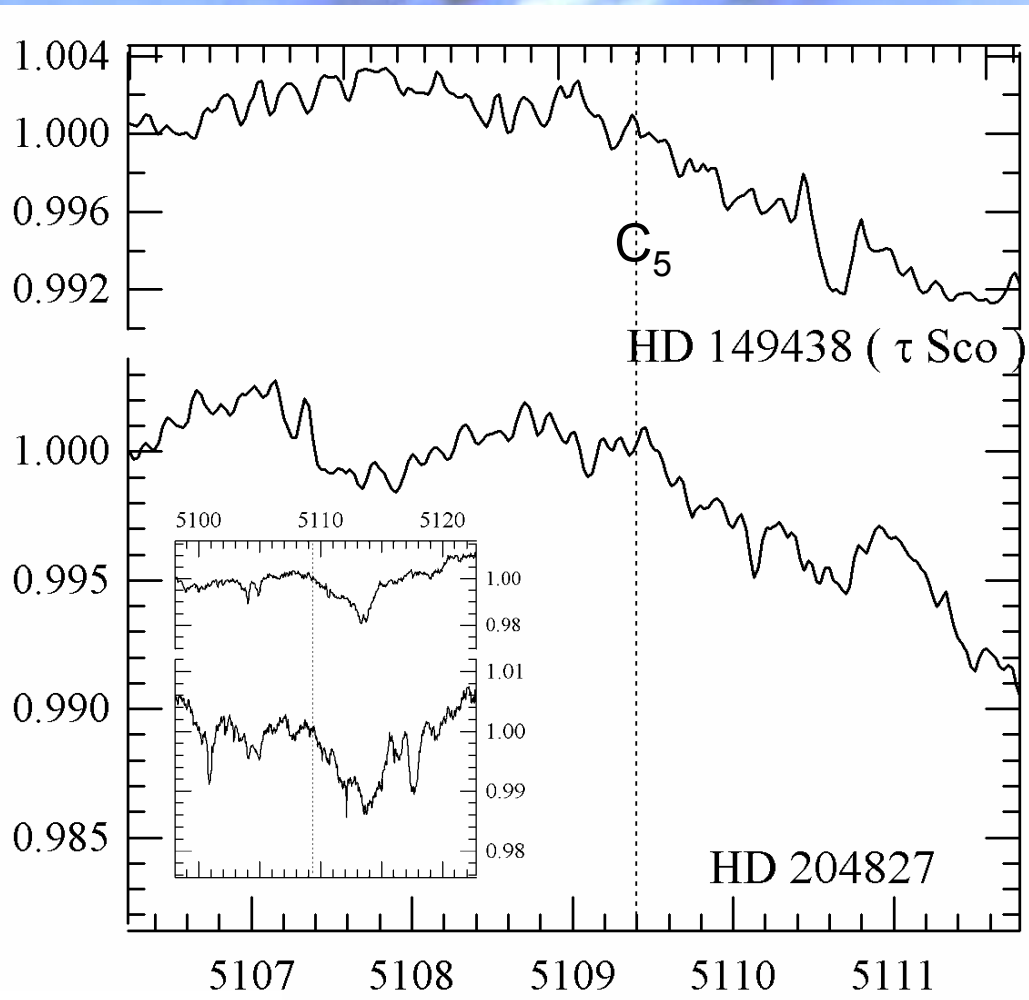


Maier, Walker, & Bohlender, ApJ 602, 286 (2004)

Keck Search for C_4 & C_5

- HD 204827 (V=7.94)
- Keck, 2 nights integration → S/N~1000



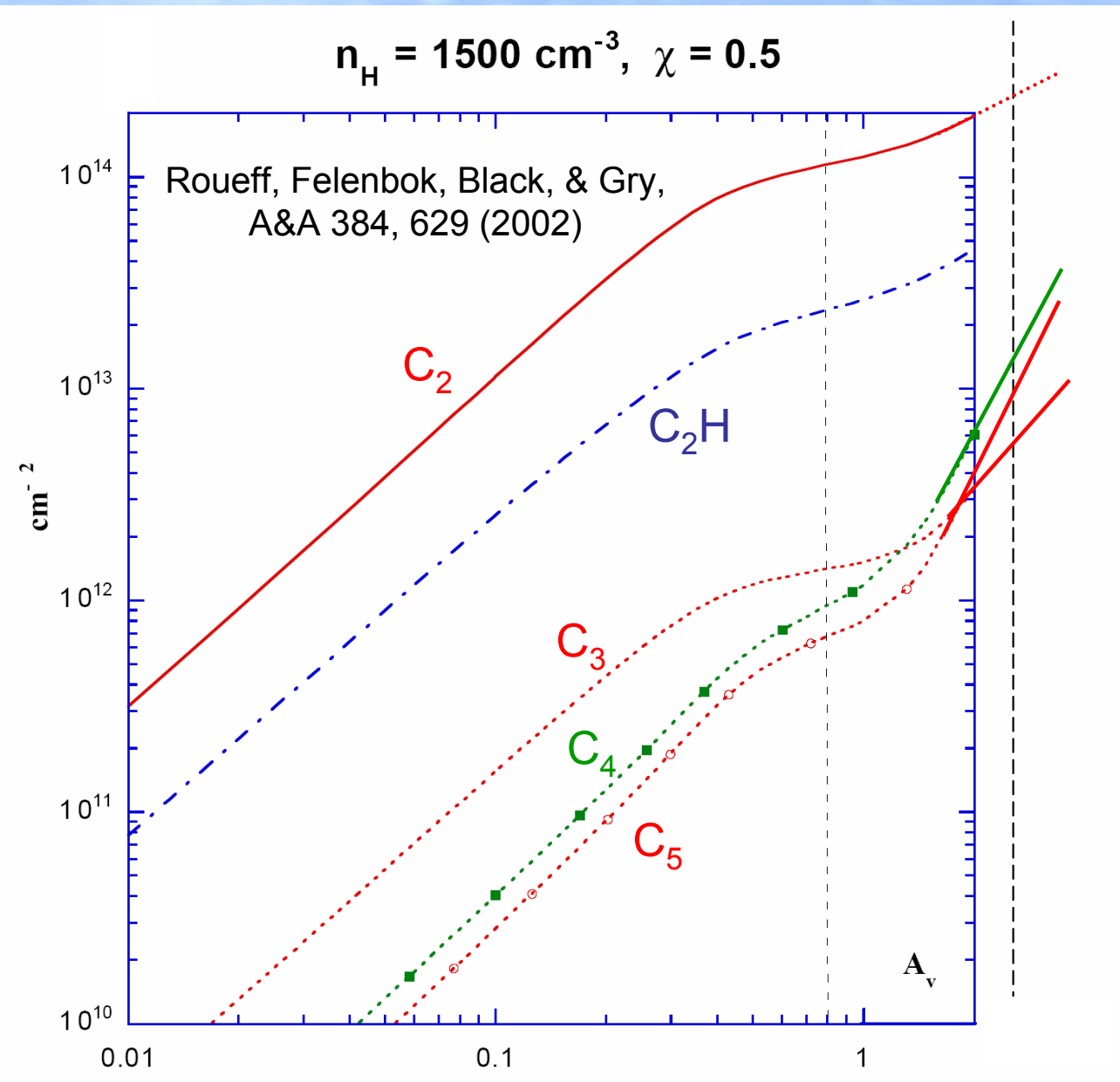


Ádámkovics, Blake, & McCall, in preparation

Comparison of Results

	ζ Oph (Maier et al.)		HD 204827 (present work)	
C_2	2.5×10^{13}	(250)	4.4×10^{14}	(630)
C_3	1.6×10^{12}	(16)	1.1×10^{13}	(16)
C_4	$< 5 \times 10^{11}$	(<5)	$< 4 \times 10^{12}$	(<6)
C_5	$< 1 \times 10^{11}$	(<1)	$< 7 \times 10^{11}$	(<1)
	column density in molec cm^{-2}	ratio to C_5		

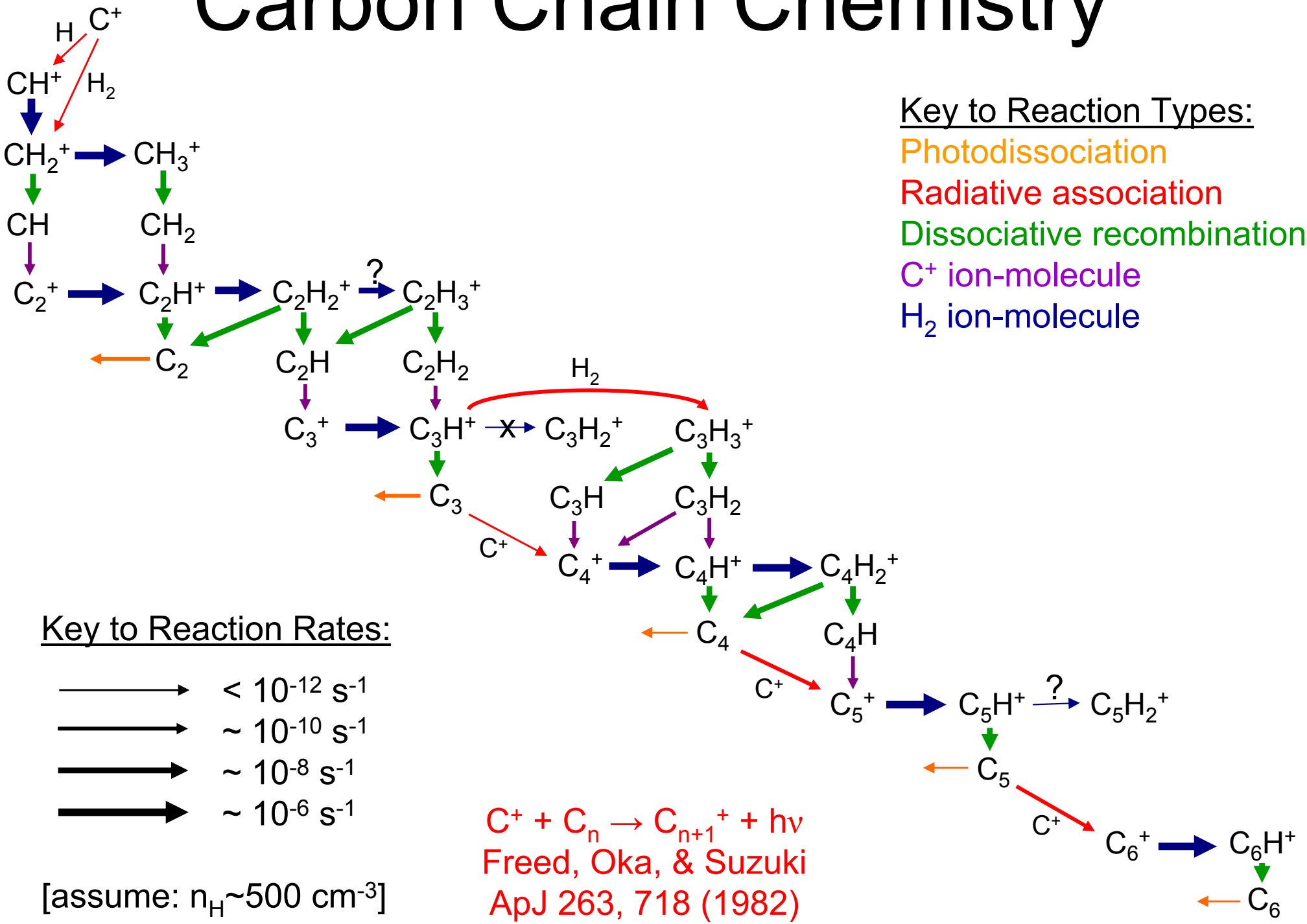
Comparison to Roueff Model



	HD 204827 (A_V=2.6)	
C_2	4.4 ×10^{14}	(630)
C_3	1.1 ×10^{13}	(16)
C_4	< 4 ×10^{12}	(<6)
C_5	< 7 ×10^{11}	(<1)

Model greatly overpredicts C_4, C_5

Carbon Chain Chemistry



Key to Reaction Types:

- Photodissociation
- Radiative association
- Dissociative recombination
- C^+ ion-molecule
- H_2 ion-molecule

Key to Reaction Rates:

- ⟶ $< 10^{-12}$ s^{-1}
- ⟶ $\sim 10^{-10}$ s^{-1}
- ⟶ $\sim 10^{-8}$ s^{-1}
- ⟶ $\sim 10^{-6}$ s^{-1}

[assume: $n_H \sim 500$ cm^{-3}]

$C^+ + C_n \rightarrow C_{n+1}^+ + h\nu$

Freed, Oka, & Suzuki

ApJ 263, 718 (1982)

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

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