Status of the Diffuse Interstellar Band Problem

Ben McCall

Department of Chemistry and Department of Astronomy

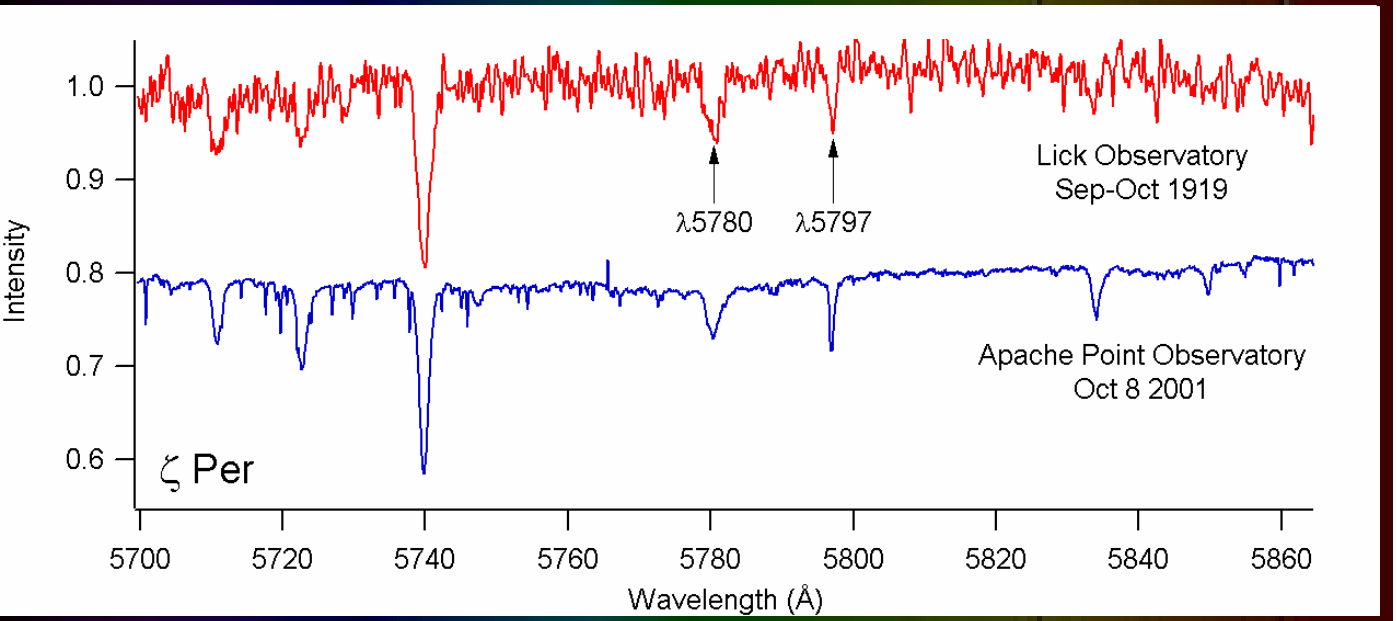
University of Illinois at Urbana-Champaign

APO DIB Collaboration:

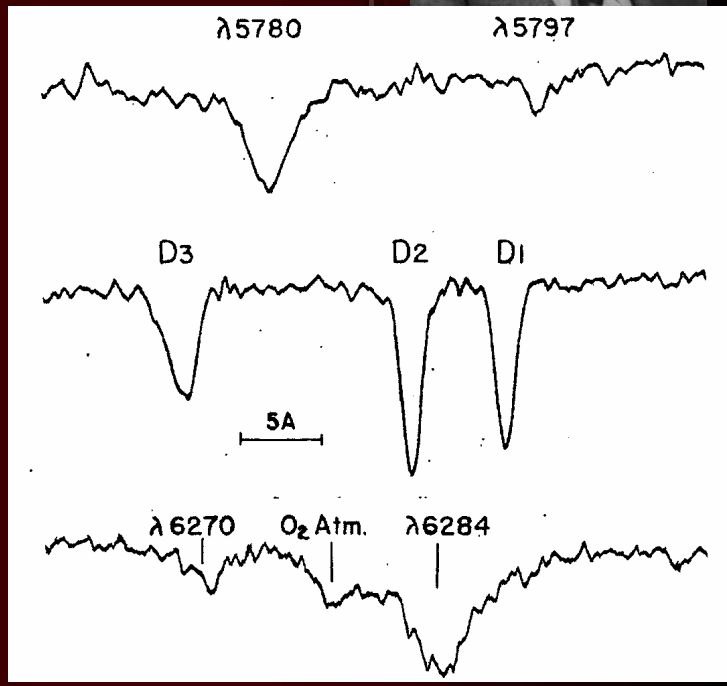
Tom Fishman (Chicago), Scott Friedman (STScI), Lew Hobbs (Yerkes), Ben McCall (UIUC), Takeshi Oka (Chicago), Brian Rachford (Carleton), Ted Snow (Colorado), Paule Sonnentrucker (JHU), Julie Thorburn (Yerkes), Dan Welty (Chicago), Don York (Chicago)

Discovery of the DIBs

- λλ5780, 5797 seen as unidentified lines
  - ζ Per, ρ Leo (Mary Lea Heger, Lick, 1919)
- Six bands confirmed as "detached" lines
  - Merrill & Wilson, Mt. Wilson, 1938
- Broad ("diffuse")



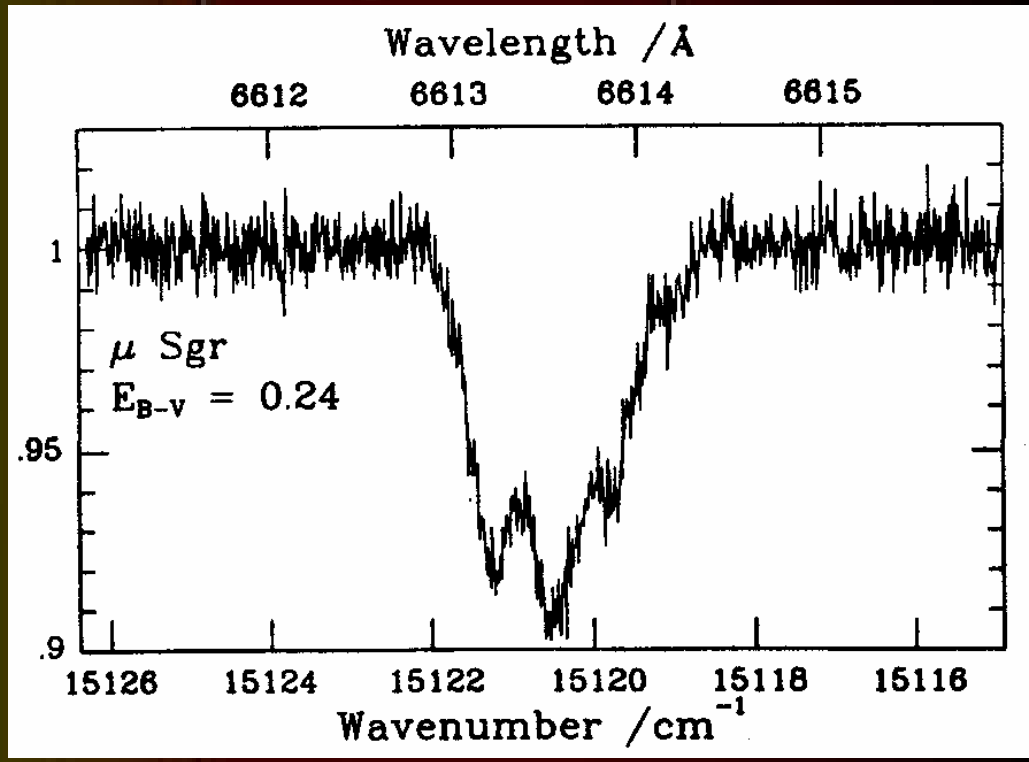
B. J. McCall, in preparation



Merrill & Wilson, ApJ 87, 9 (1938)

What are the DIBs?

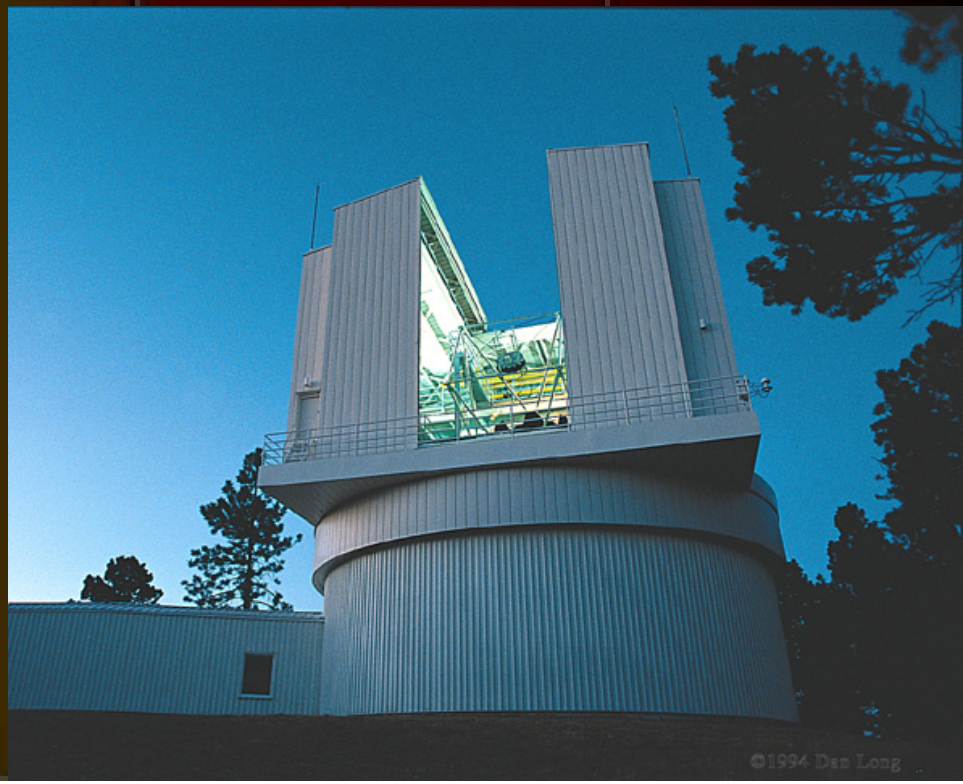
- Reasonable correlation with dust extinction
  - but "level off" at high $A_V \rightarrow$ diffuse clouds only?
  - for a long time, solid state carriers favored
- Several characteristics argue against dust:
  - constancy of λ
  - lack of emission
  - fine structure!
- Present consensus:
  - gas-phase molecules
  - probably large
  - likely carbon-based
  - reservoir of organic material
- Greatest unsolved mystery in spectroscopy!



Sarre et al., MNRAS 277, L41 (1995)

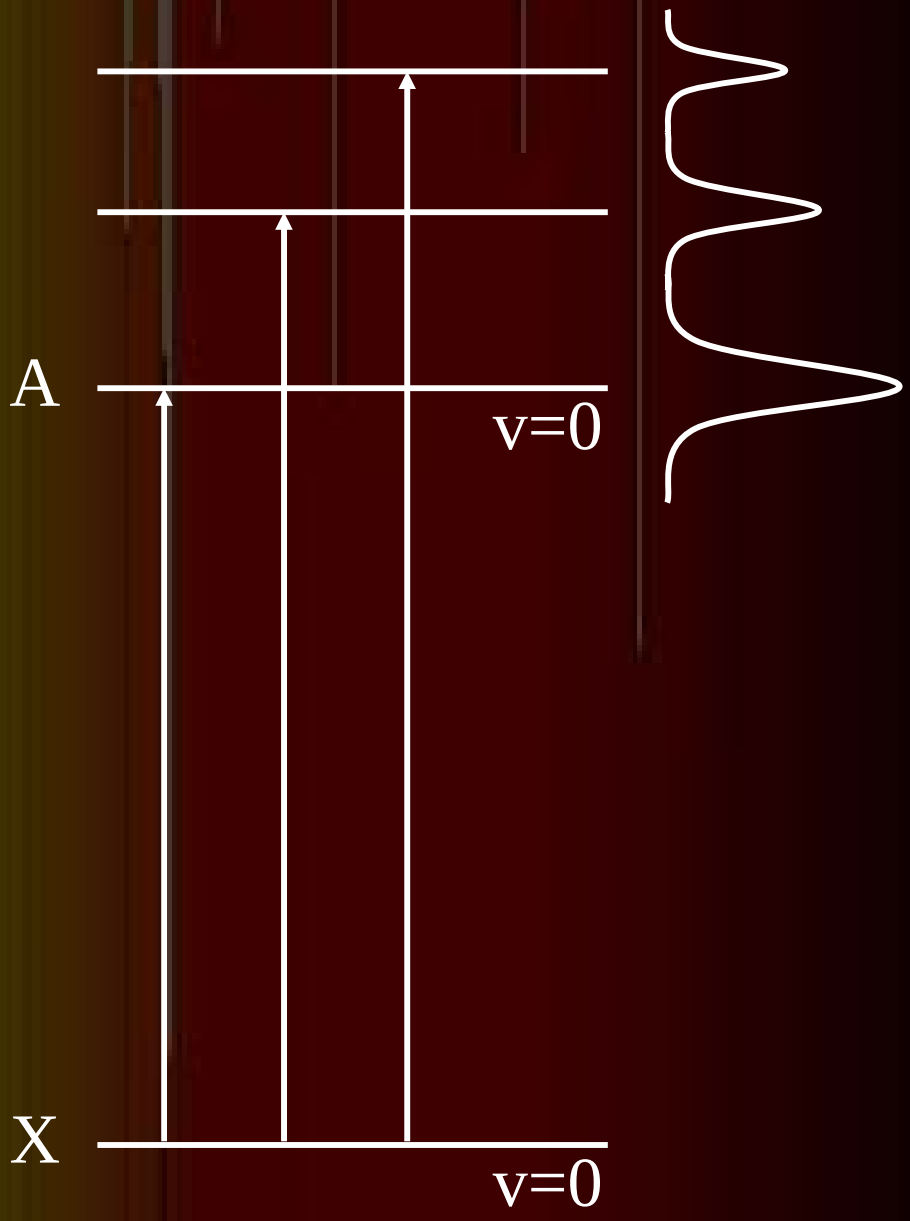
The APO DIB Survey

- Apache Point Observatory 3.5-meter
- 3,600–10,200 Å ; $\lambda/\Delta\lambda$ ~ 37,500 (8 km/s)
- 119 nights, from Jan 1999 to Jan 2003
- S/N (@ 5780Å) > 500 for **160** stars (115 reddened)
- Measurements & analysis still very much underway

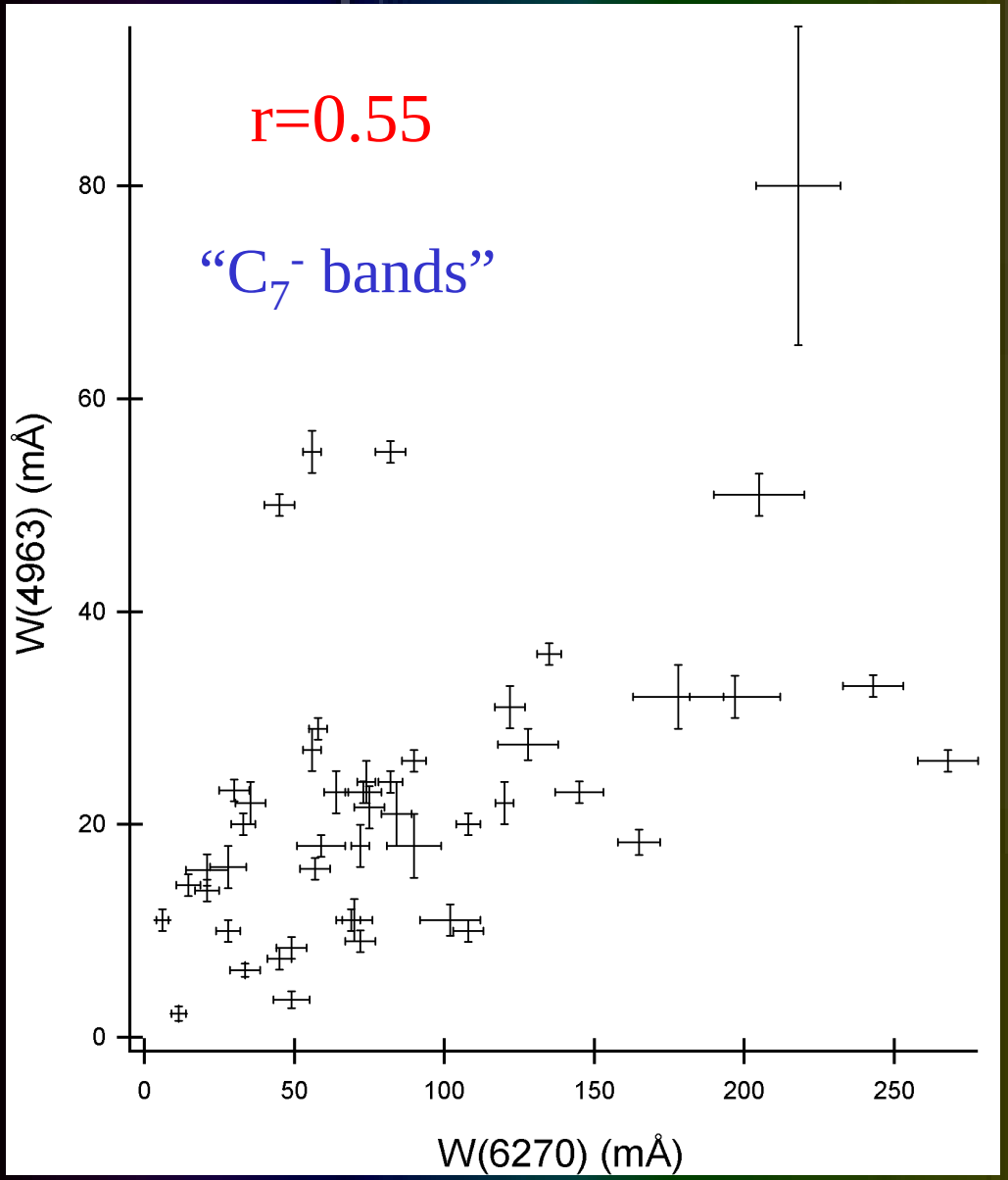


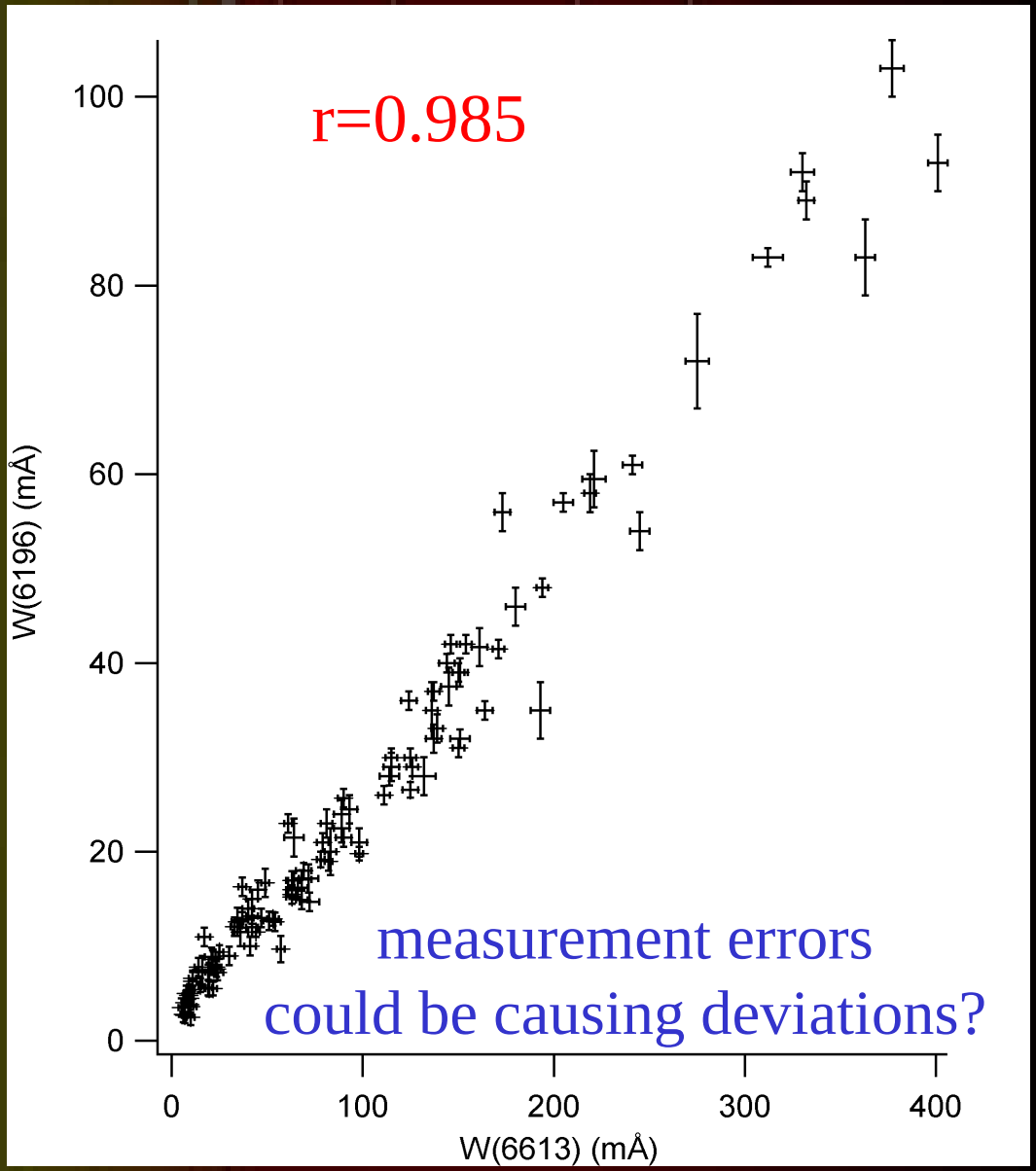
Search for a Common Carrier

- Assumptions:
  - gas phase molecules
  - DIBs are vibronic bands
  - low temperature
    - carriers all in v=0
  - relative intensities fixed
    - Franck-Condon factors
    - independent of T, n
- Method:
  - look for DIBs with tight correlations in intensity
- Prospect:
  - identify vibronic spectrum of single carrier
  - spacings may suggest ID



DIB Correlations

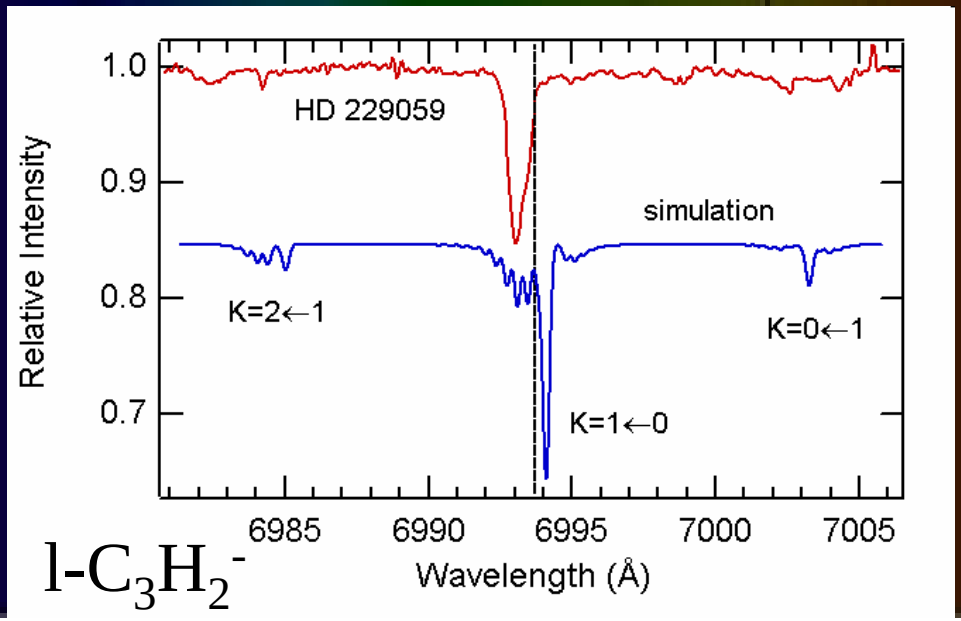




Still much work to do, especially on weaker bands!

Evaluation of Proposed DIB Carriers

- Need a laboratory spectrum
  - gas phase (avoid matrix shifts)
  - rotationally resolved (or profile resolved)
- Need to be able to simulate spectrum
  - interstellar temperatures, excitation conditions
- DIB, simulated spectra must match exactly
  - central wavelength & profile
  - relative intensities & correlation
  - all laboratory bands present

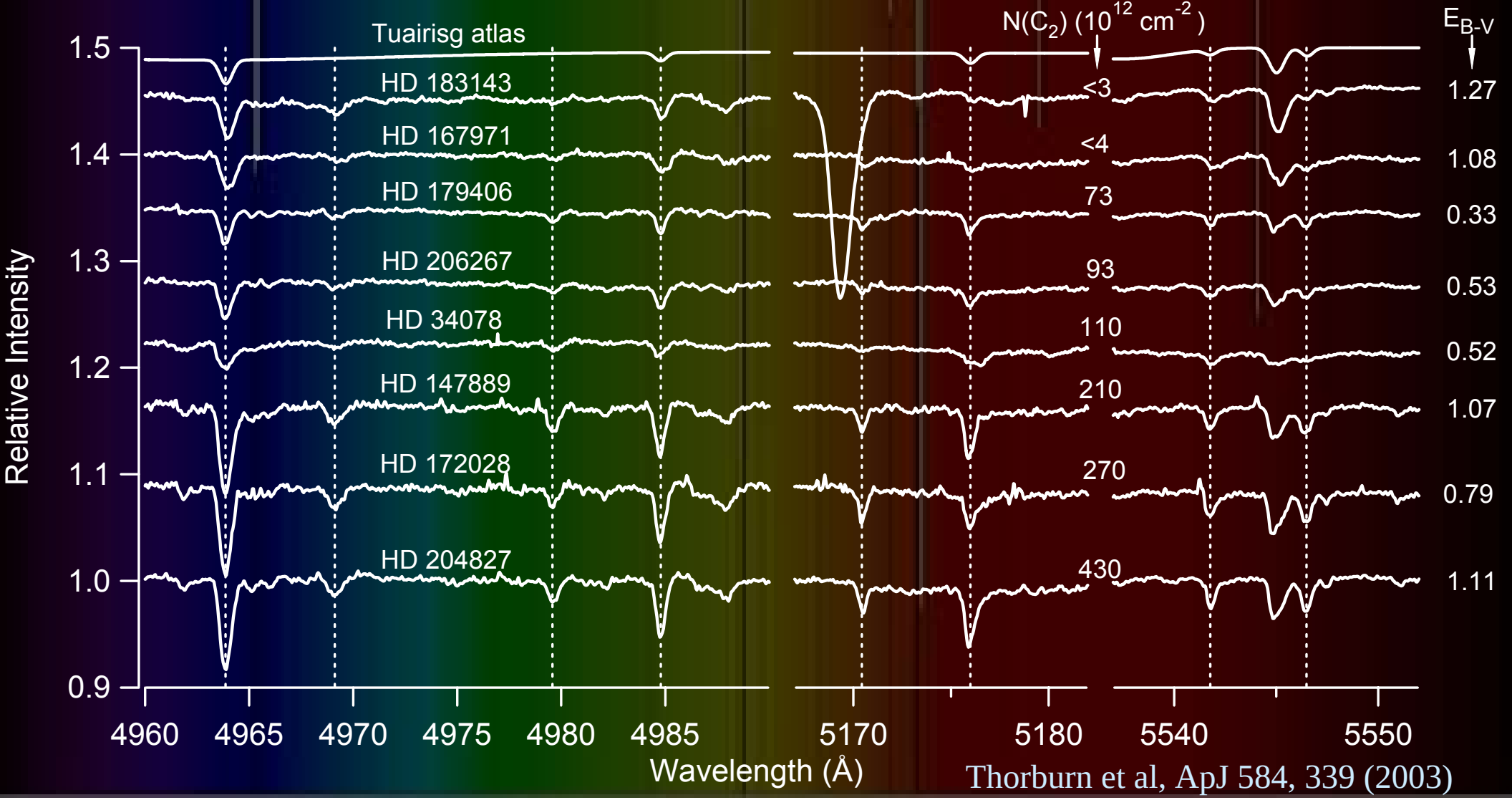


McCall et al., ApJ 559, L49 (2001)

McCall et al., ApJ 567, L145 (2002)

The "C_2 DIBs"

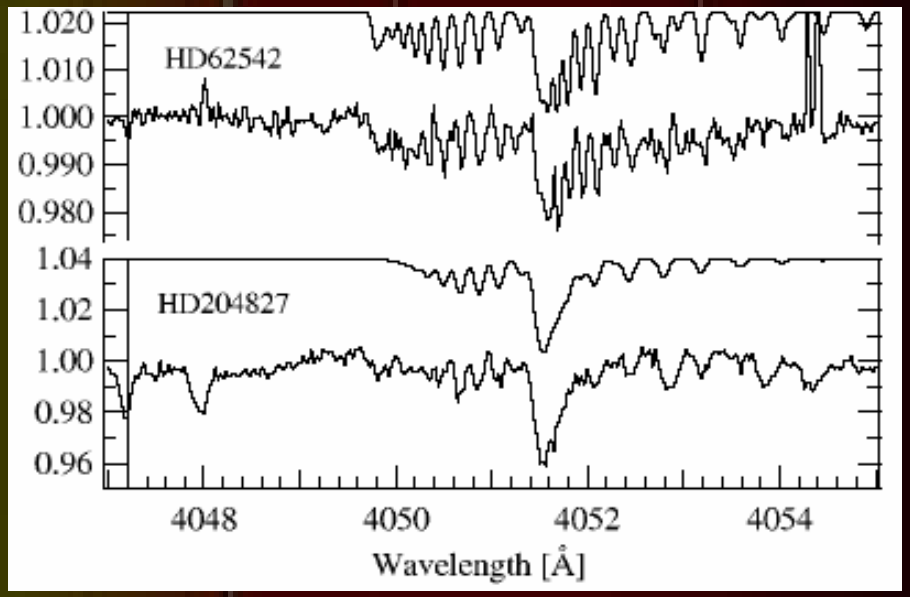
- First set of DIBs known to be correlated with a known species!



Thorburn et al, ApJ 584, 339 (2003)

Carbon Chains as DIB Carriers?

- Some DIBs correlated with C_2
- C_3 widely observed in diffuse clouds
  - J. P. Maier 2001
- But, search for C_4, C_5 unsuccessful so far
- Conclusions:
  - Need high abundance, or
  - Large oscillator strength
  - Maier, Walker, & Bohlender [ApJ 602, 286 (2004)]:
    - Potential carbon chain DIB carriers must have >15 carbon atoms
    - C_{2n+1} (n=7-15); HC_nH (n>40); C_{2n} (n>10); C_nH; HC_nH^+; C_n^-
  - No lab spectra of long chains; very little of cations



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

PAHs as DIB Carriers?

- Polycyclic Aromatic Hydrocarbons
  - proposed by Leger & d'Hendecourt and by van der Zwet & Allamandola in 1985
- Would expect complex mixture
  - ionization stages (cation, neutral, anion?)
  - hydrogenation states
- So far, no spectroscopic match with DIBs
- Cation transitions observed so far in gas-phase are too broad!
- Still no convincing evidence

See poster 32.09, Salama et al.

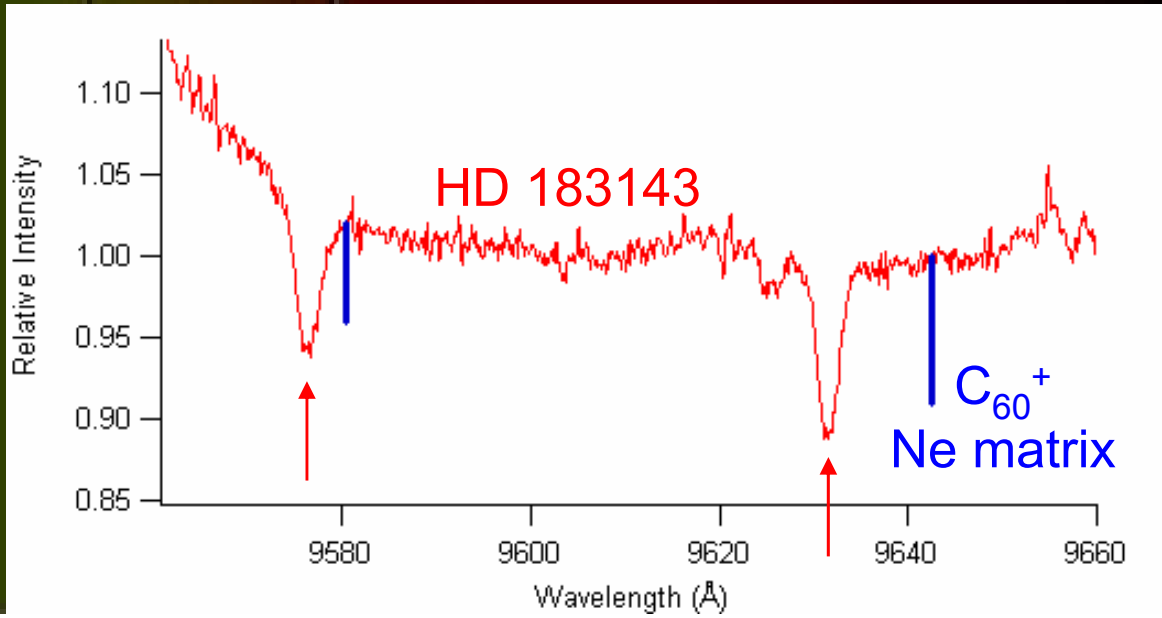
Fullerenes as DIB Carriers?

- IP(C_{60}) = 7.6 eV
  - Ionized in diffuse clouds
- C_{60}^{+} in Ne matrix
  - two bands near 9600 Å
- Detection claimed in HD 183143
- Need gas-phase spectrum!
  - Experiment in preparation

Fulara, Jakobi, & Maier
Chem. Phys. Lett. 211, 227 (1993)

Foing & Ehrenfreund
A&A 319, L59 (1997)

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
TM

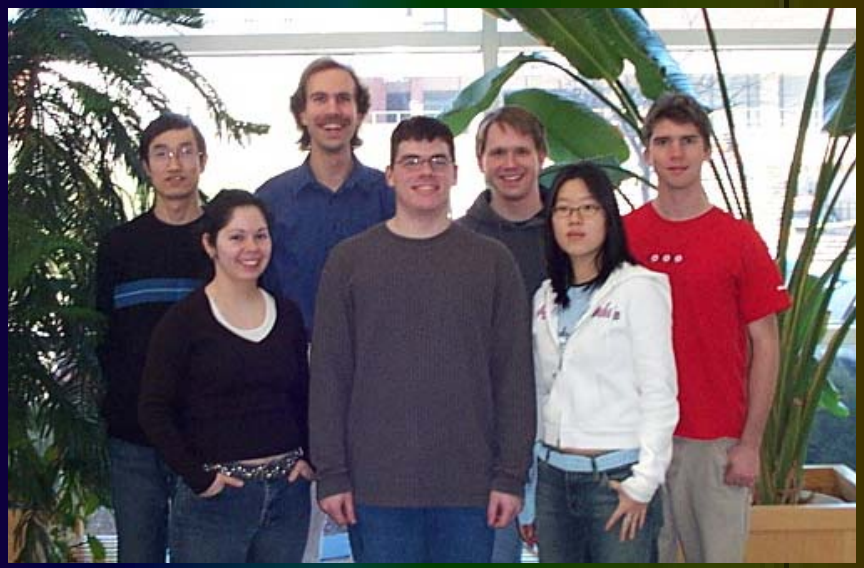


The Road to a Solution

- Laboratory spectroscopy is essential
- Blind laboratory searches unlikely to work
  - ~10^7 organic molecules known on Earth
  - ~10^{200} stable molecules of weight < 750 containing only C, H, N, O, S
- Observational constraints & progress are also essential!
- Computational chemistry will play an important role
- Close collaborations needed!

Acknowledgments

- NASA Laboratory Astrophysics
- NSF CAREER Award
- Dreyfus New Faculty Award
- University of Illinois
- McCall Group



THE CAMILLE & HENRY DREYFUS FOUNDATION, INC.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN