Correlations Among the Diffuse Interstellar Bands

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The APO DIB Survey

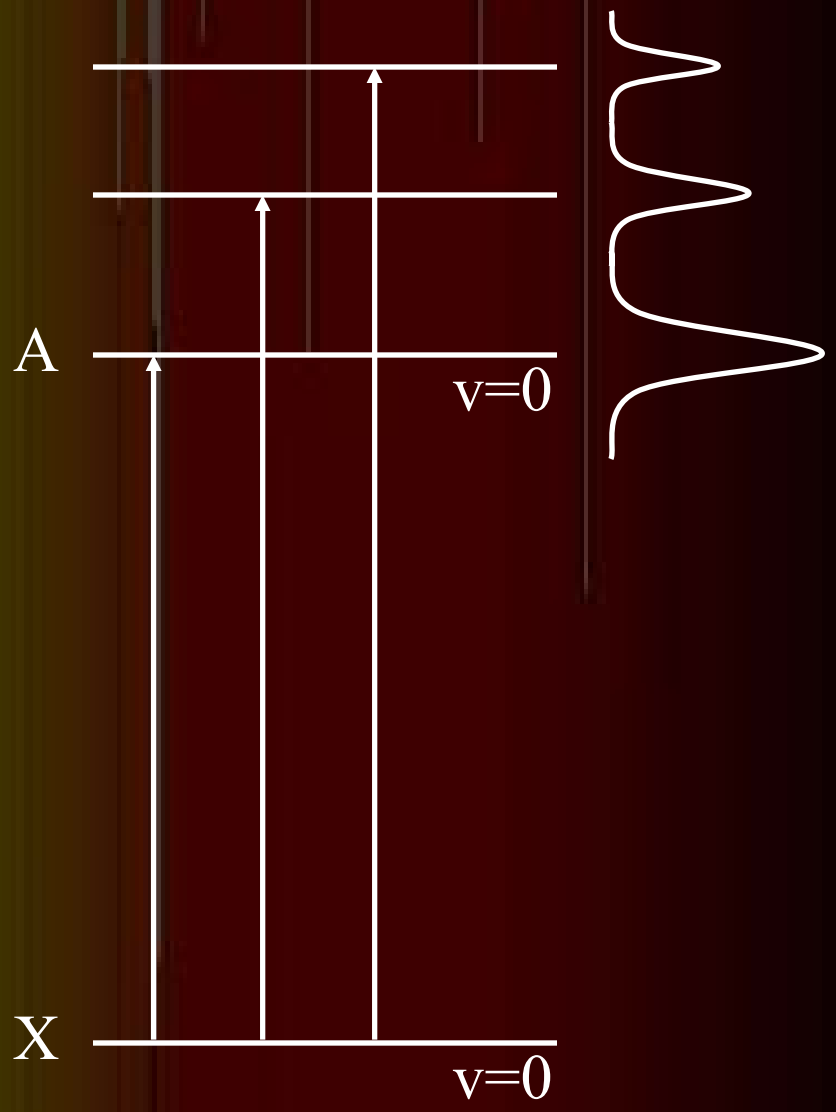
- Apache Point Observatory 3.5-meter
- 3,500–10,200 Å ; $\lambda/\Delta\lambda \sim 37{,}500$ (8 km/s)
- S/N (@ 5780Å) > 500 for 160 stars
- 119 nights, from Jan 1999 to Jan 2003

Understanding the DIBs

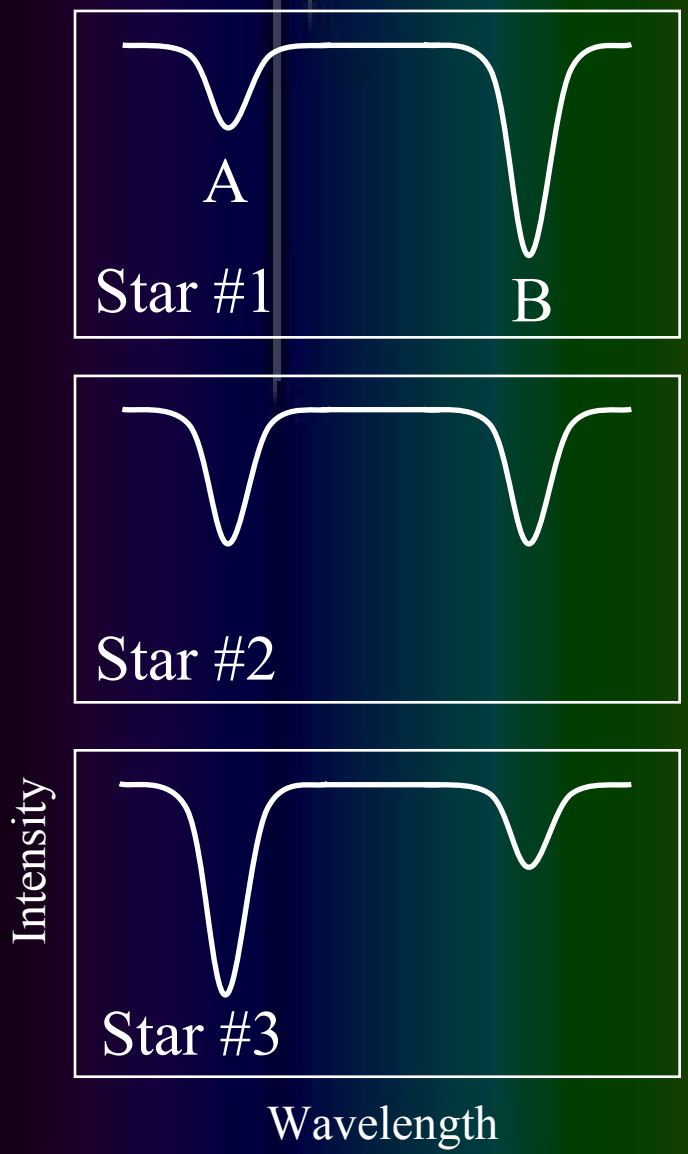
- Ideal: match with laboratory spectrum
  - after 70+ years, no luck yet
- Correlations with other species
  - C_2, C_3 (Oka, next talk)
    - insights into chemistry
  - H, H_2 (Snow, following talk)
    - insights into environment
- Correlations among the DIBs
  - identify chemically related DIBs?
  - identify DIBs caused by common carrier?
  - pick out spectrum of a single carrier?

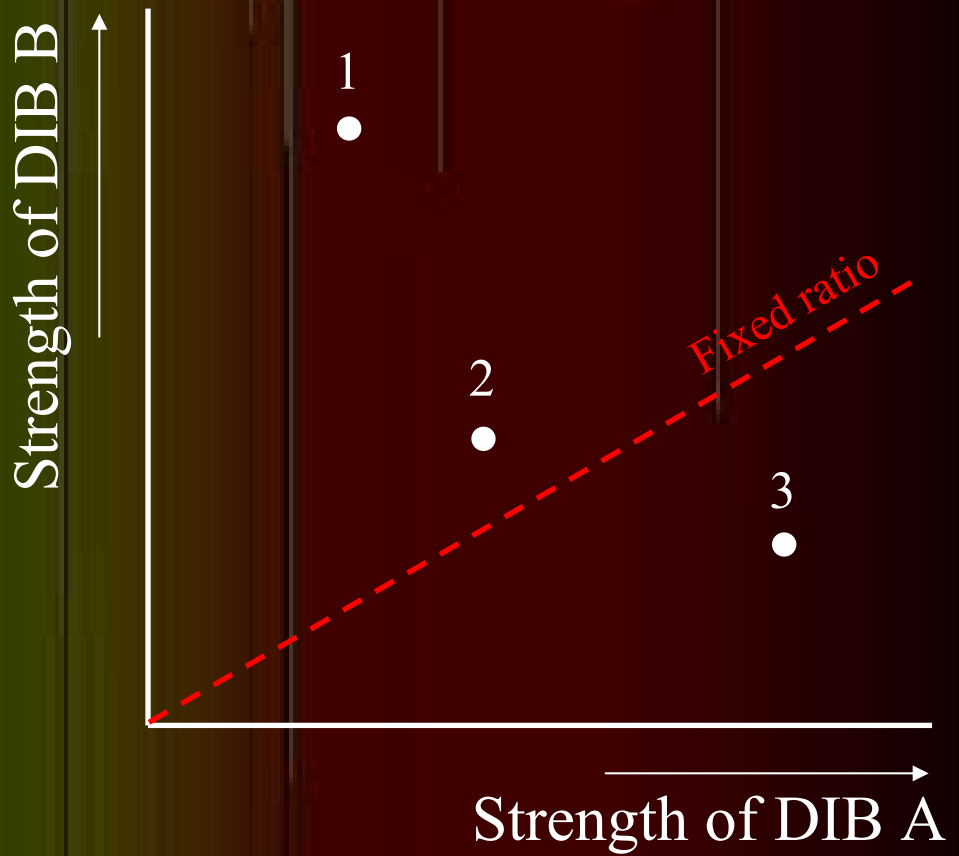
Search for a Common Carrier

- Assumptions:
  - gas phase molecules
  - DIBs are vibronic bands
  - low temperature
    - carriers all in ground vibrational state
  - relative intensities fixed
    - Franck-Condon factors
    - independent of temperature and density
  - rotational structure may vary with temperature
  - low-lying splittings (e.g. spin-orbit) will foil this

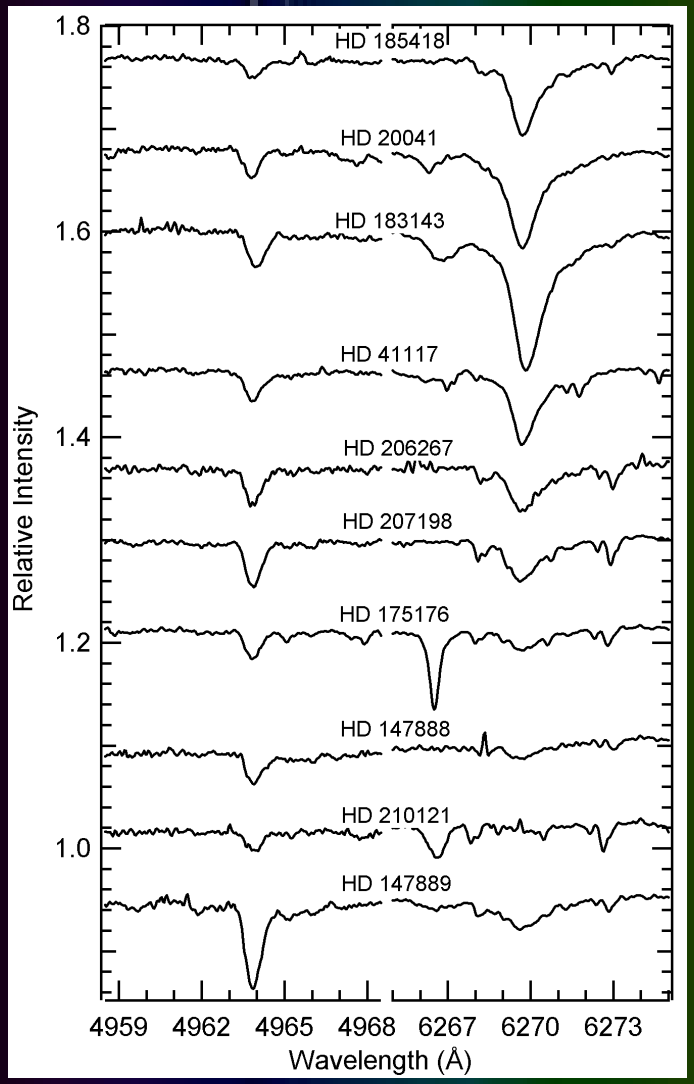


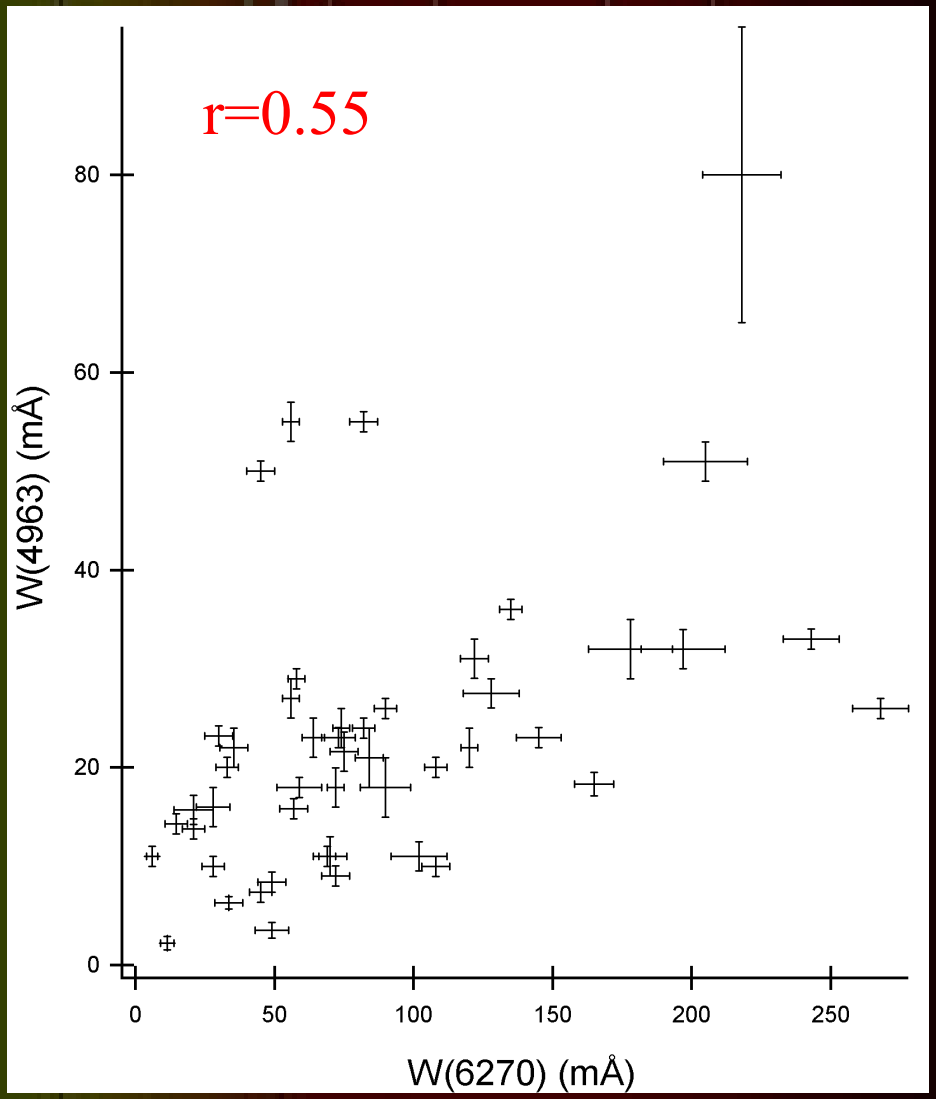
DIB Correlations



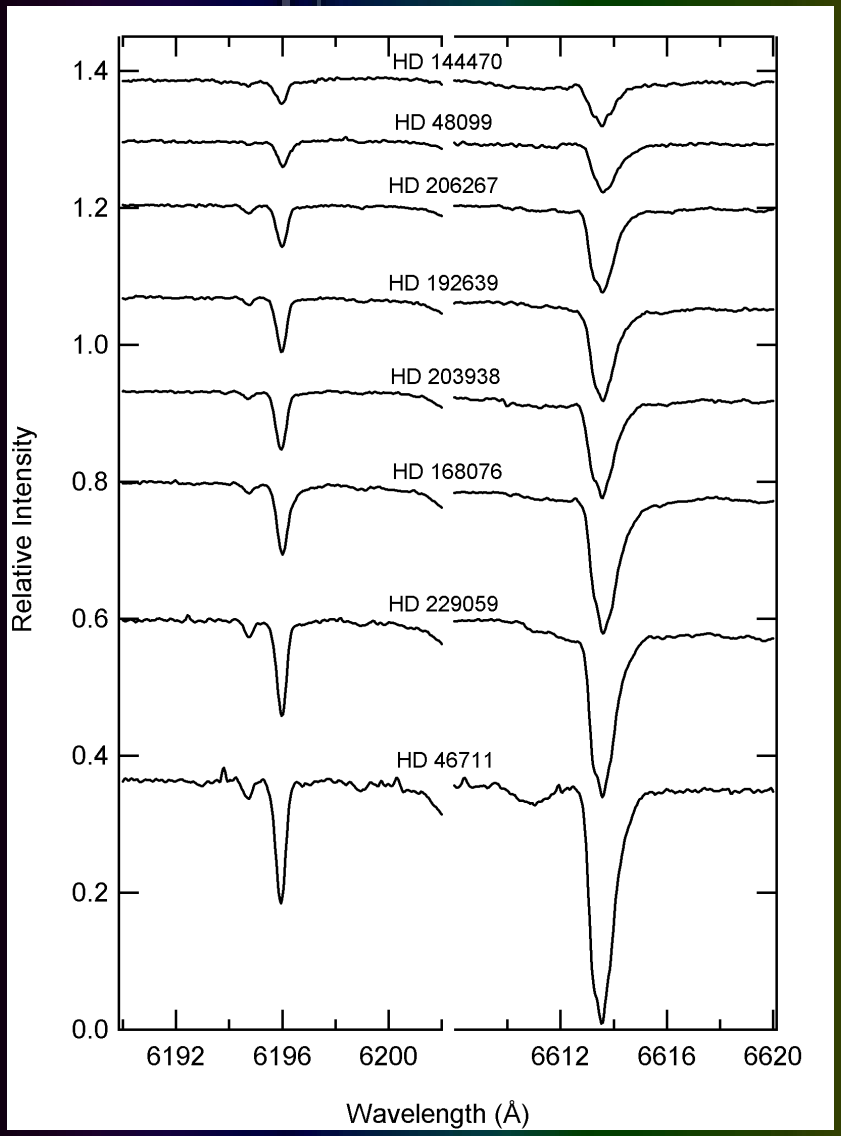


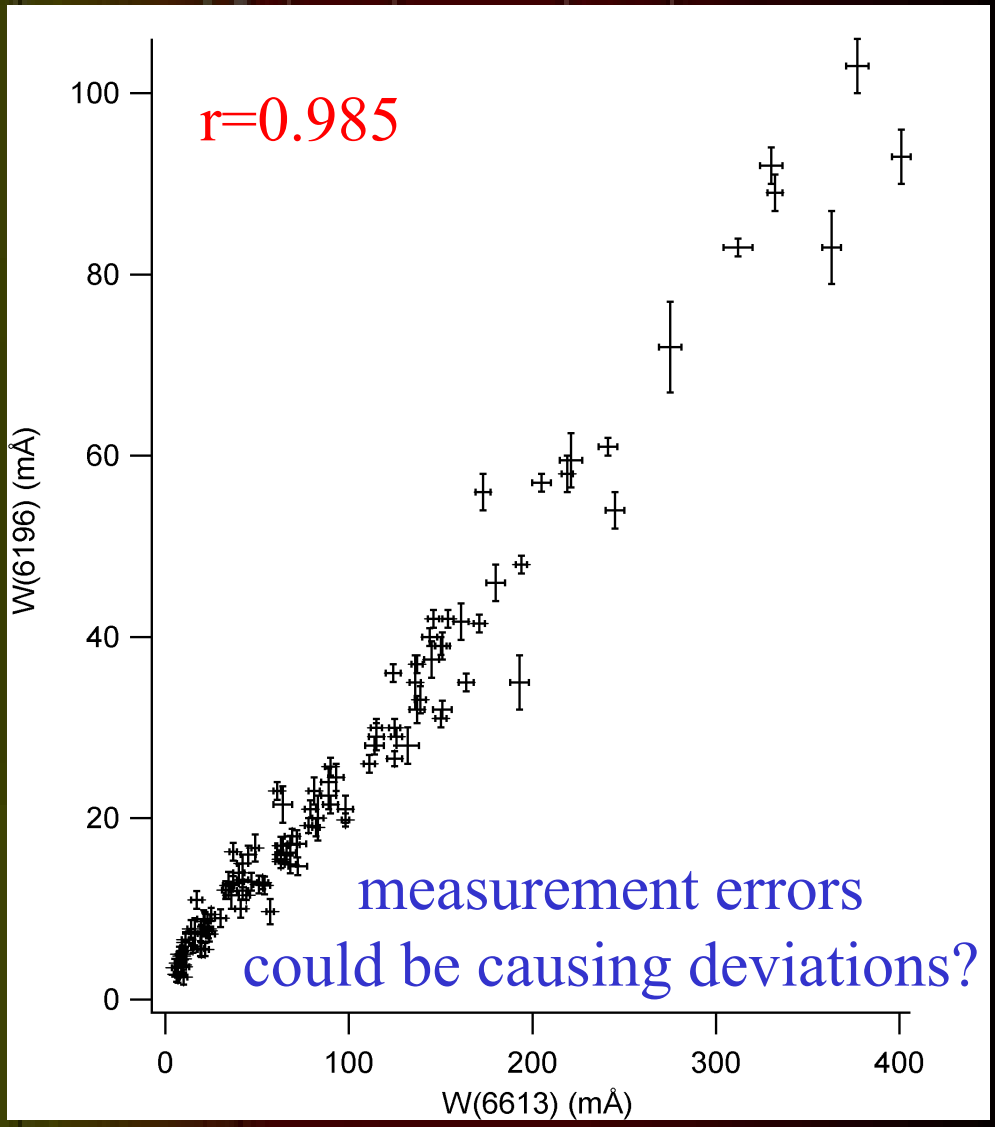
Example: Bad Correlation





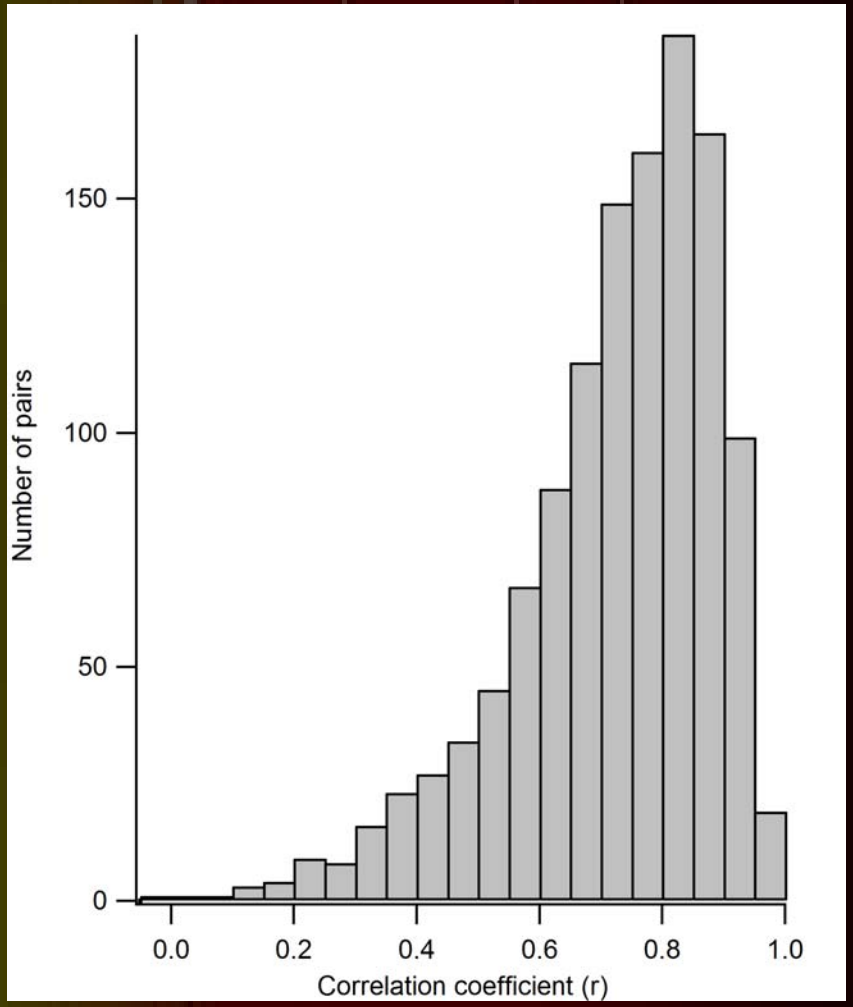
Example: Good Correlation





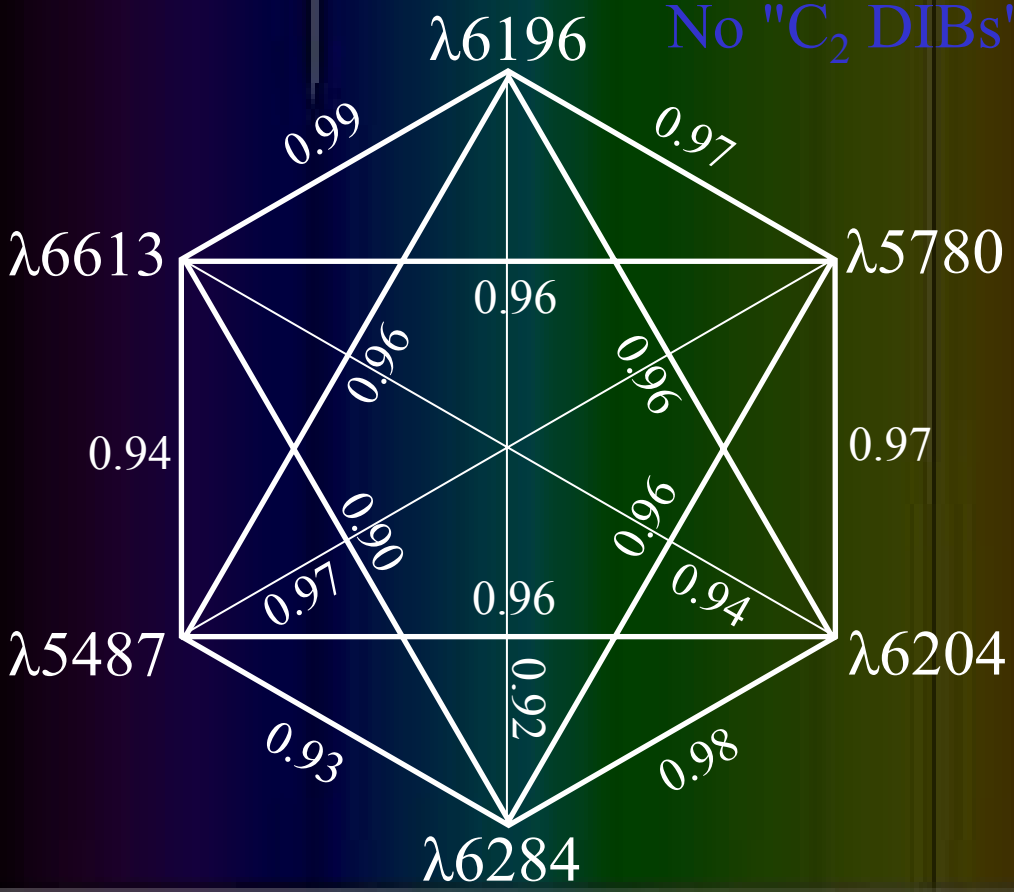
Statistics of Correlations

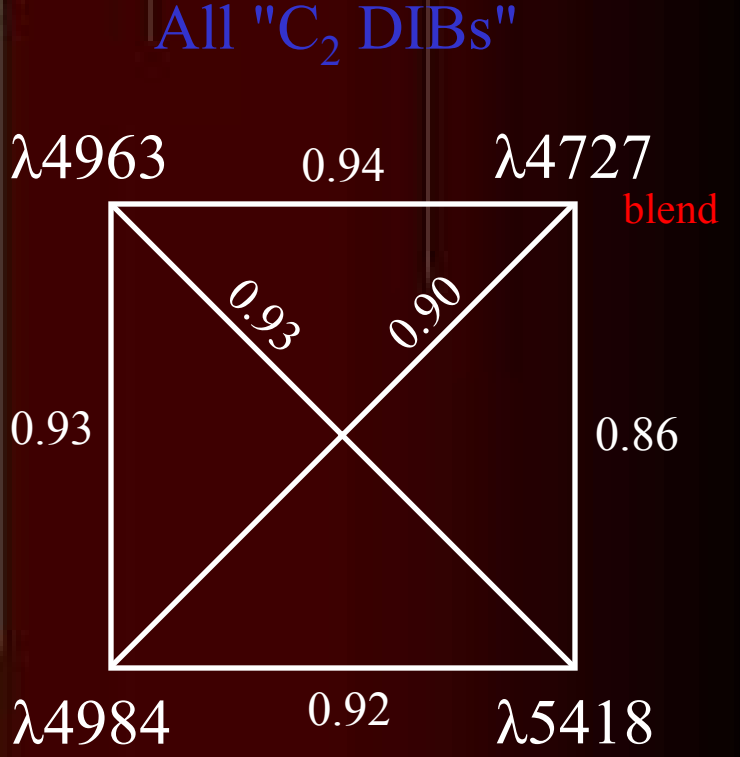
- Pairs of DIBs observed in >40 stars
- 1218 pairs
- 58 DIBs included
- Histogram of r
- Generally well correlated
- Few very good correlations
  - 19 with r > 0.95
  - 118 with r > 0.90



DIB "Families"

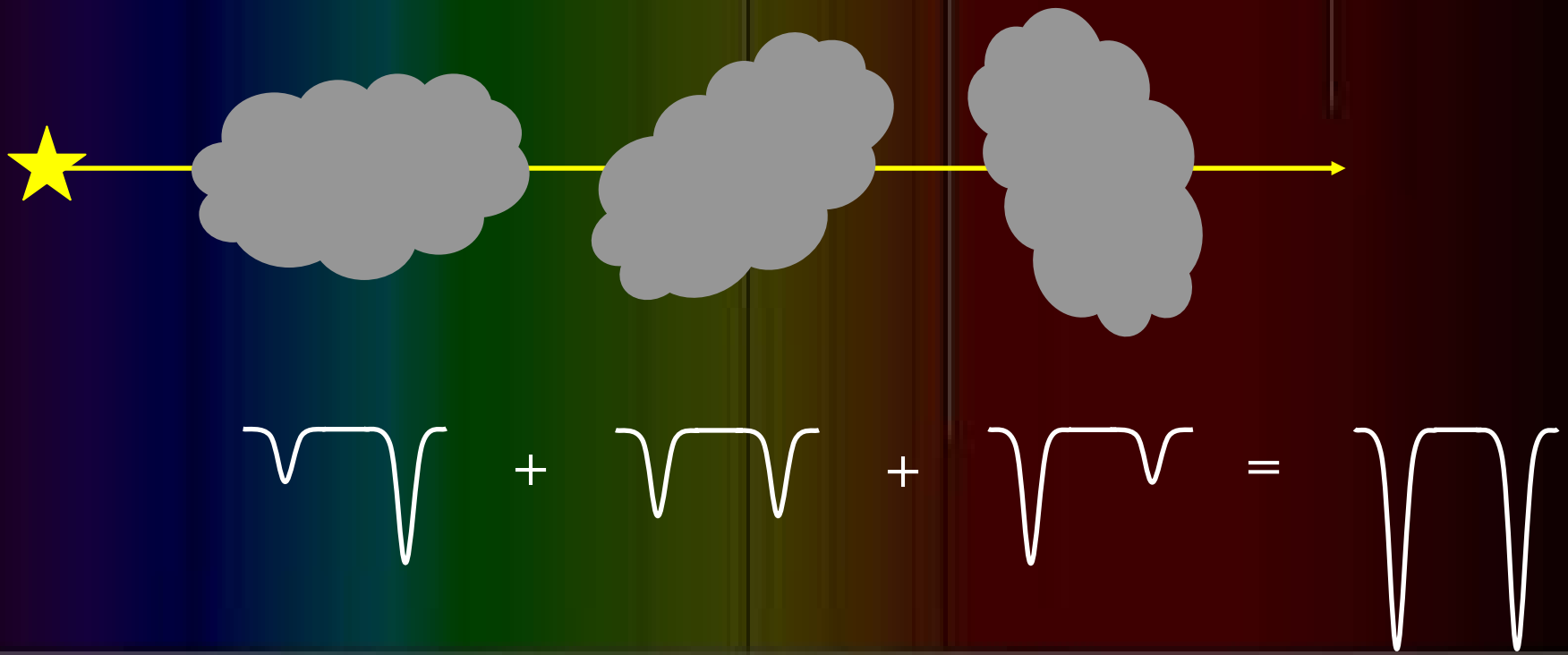
- Look for sets of DIBs in which all correlation coefficients are high



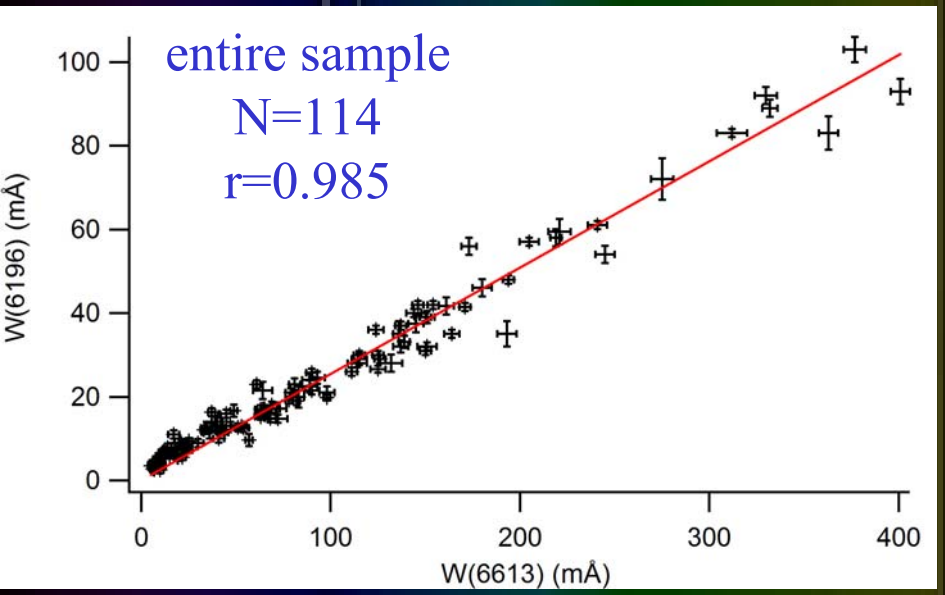


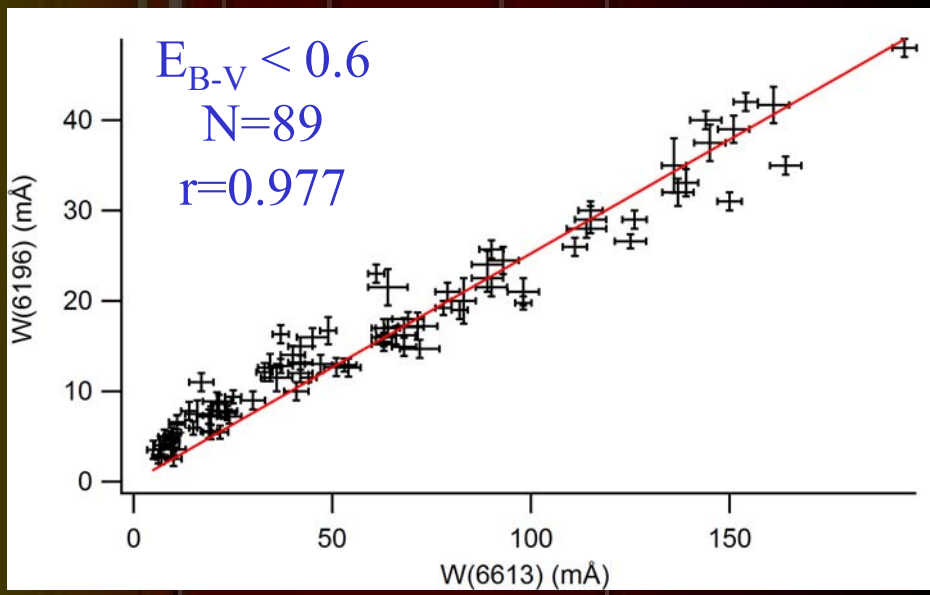
False Positives?

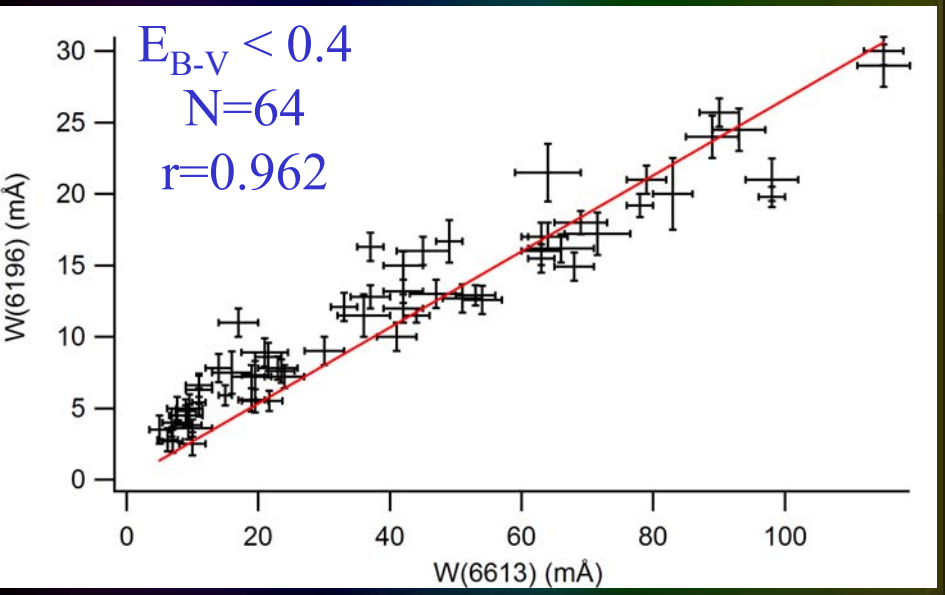
- Most sightlines sample multiple clouds
- DIBs broader than velocity differences
- Conditions may be different in each cloud
- Uncorrelated DIBs may "wash" into correlation?

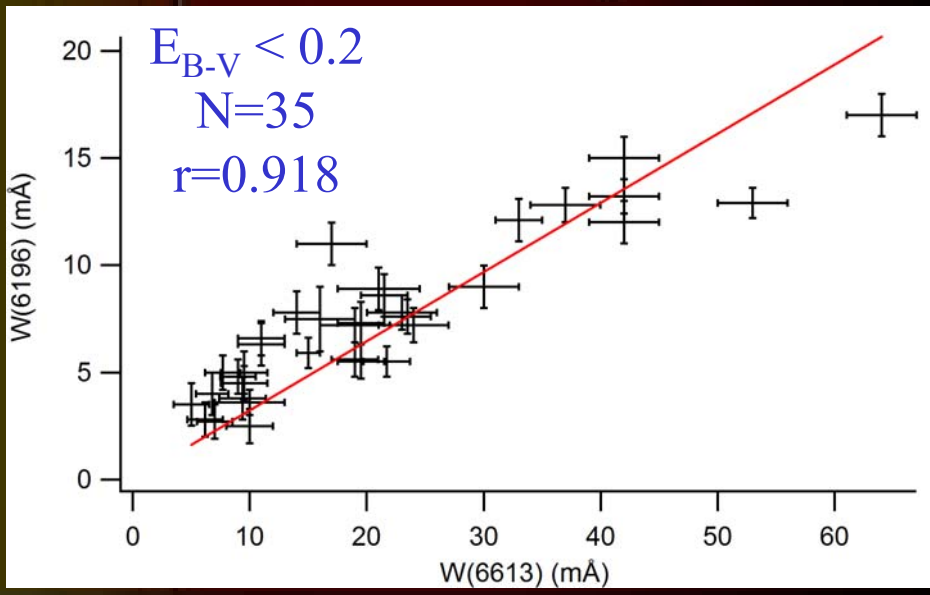


6196 vs. 6613 in Detail









Trends with $E_{B-V,\ max}$

$E_{B-V,\ max}$	r(6196,6613)	r(6204,6284)	r(5797,6284)	r(4963,5780)
0.2	0.918	0.847	0.818	0.200
0.3	0.945	0.896	0.738	0.238
0.4	0.962	0.903	0.649	0.375
0.5	0.976	0.939	0.779	0.409
0.6	0.977	0.944	0.798	0.333
1.0	0.977	0.959	0.806	0.432
all	0.985	0.976	0.860	0.623

"correlated DIBs"

"uncorrelated DIBs"

Conclusions

- Two families of chemically related DIBs
  - λλ6196, 6613, 5487, 5780, 6204, 6284 ["normal" DIBs]
  - λλ4963, 4727, 4984, 5418 ["C_2 DIBs"]
- Few, if any, strong DIBs share a common carrier
  - many many different DIB carriers!
- Constraint on carriers of most strong DIBs
  - Must have strong (origin) band, other bands weaker
- As we measure weaker DIBs, we hope to find some "perfect" correlations
  - vibronic progressions
  - one strong DIB, many weak DIBs