# A Principal Component Analysis of the Diffuse Interstellar Bands

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2017, ApJ, 836, 162

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# OUTLINE

- Diffuse Interstellar Bands (DIB)
- Principal Component Analysis (PCA)
- Observational Data
- PCA results
- Interpretation of Principal Components (PC)
- Conclusions

# Diffuse Interstellar Bands (DIB-s)

- DIB-s - absorption lines that arise from material in interstellar clouds
- There are known for more than 100 years - Mary L. Heger letter (1922)
- There are known about 500 bands
- The carriers of most DIB-s remain unidentified.
- Very difficult identification - it is usually assumed that responsible are big molecules containing carbon.
- The only known absorber related to DIB-s is *buckminsterfullarene* ($C_{60}^{+}$) responsible for several DIB-s in the infrared (Campbell et al. 2015).

# Diffuse Interstellar Bands (DIB-s) - correlation studies

- If two DIB-s arise from the same state in the same carrier, they should have the same strength ratio in all lines of sight and thus, their equivalent widths (EWs) should exhibit a perfect correlation.
- Mutual DIB-s correlations
- No perfect correlation - different carriers, but "one DIB - one carier" is rather exaggeration ( $C_{60}^{+}$ is responsible for 4 DIB-s at least)
- DIB-s families - strong correlations between EW (for $\lambda$ 6196 and $\lambda$ 6614 r = 0.986)
- Corelatons between DIB-s and line-of-sight properties (E(B-V), N(H), N(HI)).
- Dependence on environmental conditions (example W($\lambda$ 5797)/ W($\lambda$ 5780) ratios are smaller in clouds with stronger UV exposure - effects on dust properties $\sigma$ clouds and $\zeta$ clouds)

# Diffuse Interstellar Bands (DIB-s) - correlation studies

The main aim of a paper: determine parameters that drive the variations in DIB spectrum.

- Perform a principal component analysis (PCA) on the data to find out how many parameters are required to describe the observed variations among the DIB-s.
- Interpret new parameters.
- Use DIB-s to determine physical parameters of their environment

# Principal Components Analysis (PCA)

- Krystian Iłkiewicz introduction to PCA given at SJC 05.05.2022.
- PCA - statistical technique for reducing dimensionality of a dataset.
- We chose new parameters by linear combination of input data parameters
- New parameters form ortogonal set of vectors whereas old parameters are often strongly correlated.

# Principal Components Analysis (PCA) - main steps

- n variables for m lines of sight.
- Rescaling of a data (subtract mean, divide by standard deviation)

$$z_{i,j} = \frac{x_{i,j} - \bar{x}_i}{s_{x_i}}$$

- Calculate covariation matrix ($n$ x $n$ matrix)

$$C_{k,l} = \frac{1}{m-1} z_{k,i} z_{i,l}$$

- Find eigenvalues and eigenvctors of covariation matrix
- Sort eigenvalues from the largest
- Corresponding eigenvecteors give principal components
- Multiply transposed eigenvector matrix by rescaled data matrix to obtain a data in principal components base

$$y_i \hat{\mathrm{n}}' = \mathrm{a_{i,1} x_1 \hat{n}_1} + \mathrm{a_{i,2} x_2 \hat{n}_2} + .. + \mathrm{a_{i,n} x_n \hat{n}_n}$$

$\hat{\mathrm{n}}_\mathrm{n}$ - unit vectors in the original parameter space
$\hat{\mathrm{n}}'_\mathrm{n}$ - unit vectors in the new reference frame - principal components

$$a_{i,1}^2 + a_{i,2}^2 + .. + a_{i,n}^2 = 1$$

$$Y = AX$$

$X$ - $n$ x $m$ matrix containing original set of data
$A$ - $n$ x $n$ - transformation matrix
$Y$ - $n$ x $m$ matrix containing transformed data points in the new reference frame.

# Observational data - target selection

- Search for high quality, high resolution spectra in VLT/UVES and ELODIE archives for 243 stars from the study of Jenkins (2009) where are present fairly strong and narrow DIB-s possibly free of contaminantion from stellar lines (16 DIB-s)
- Selection of single cloud lines of sight based on examination of Na I (589.0 nm and 589.5 nm) and K I (766.5 and 769.9 nm) lines.
- Final set of 30 stars with observations characterized by 23 parameters

# Target stars.

**Table 1**
Basic Target Data

| Target | Alt. Name | R.A. (J2000) | Decl. (J2000) | $V$ | $E(B-V)$ | $N$(H I) ($10^{21}$ cm$^{-2}$) | $N(H_2)$ ($10^{20}$ cm$^{-2}$) | $f(H_2)$ | $F_\star$ | $\frac{W(\lambda5797)}{W(\lambda5780)}$ | $v_{ISM}$[a] (km s$^{-1}$) | References[a] | Data Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HD 15137 | ⋯ | 02 27 59.81 | +52 32 57.6 | 7.86 | 0.24 | $1.29^{+0.57}_{-0.40}$ | $1.86^{+0.26}_{-0.12}$ | $0.22^{+0.09}_{-0.06}$ | 0.37 ± 0.09 | 0.30 ± 0.02 | −9.58 | 1 | ELODIE |
| HD 22951 | 40 Per | 03 42 22.65 | +33 57 54.1 | 4.98 | 0.19 | $1.10^{+0.35}_{-0.32}$ | $2.88^{+1.48}_{-0.98}$ | $0.35^{+0.27}_{-0.18}$ | 0.73 ± 0.05 | 0.35 ± 0.02 | 12.47 | 1 | ELODIE |
| HD 23180 | o Per | 03 44 19.13 | +32 17 17.7 | 3.86 | 0.22 | $0.76^{+0.26}_{-0.23}$ | $3.98^{+1.64}_{-1.16}$ | $0.51^{+0.33}_{-0.24}$ | 0.84 ± 0.06 | 0.65 ± 0.04 | 13.45 | 2 | ELODIE |
| HD 23630 | $\eta$ Tau | 03 47 29.08 | +24 06 18.5 | 2.87 | 0.05 | $0.22^{+0.10}_{-0.07}$ | $0.35^{+0.18}_{-0.12}$ | $0.28^{+0.23}_{-0.15}$ | 0.89 ± 0.10 | 0.16 ± 0.04 | 16.76 | 2 | ELODIE |
| HD 24398 | $\zeta$ Per | 03 54 07.92 | +31 53 01.1 | 2.88 | 0.27 | $0.63^{+0.06}_{-0.07}$ | $4.68^{+2.40}_{-1.59}$ | $0.59^{+0.46}_{-0.31}$ | 0.88 ± 0.05 | 0.55 ± 0.02 | 14.54 | 2 | ELODIE |
| HD 24534 | X Per | 03 55 23.08 | +31 02 45.0 | 6.10 | 0.31 | $0.54^{+0.08}_{-0.07}$ | $8.32^{+0.80}_{-0.73}$ | $0.76^{+0.13}_{-0.11}$ | 0.90 ± 0.06 | 0.62 ± 0.04 | 14.5 | 5 | ELODIE |
| HD 24760 | $\epsilon$ Per | 03 57 51.23 | +40 00 36.8 | 2.90 | 0.07 | $0.25^{+0.05}_{-0.05}$ | $0.33^{+0.27}_{-0.15}$ | $0.21^{+0.25}_{-0.14}$ | 0.68 ± 0.04 | 0.18 ± 0.02 | 7.06 | 2 | ELODIE |
| HD 24912 | $\xi$ Per | 03 58 57.90 | +35 47 27.7 | 4.04 | 0.26 | $1.29^{+0.26}_{-0.24}$ | $3.39^{+1.40}_{-0.99}$ | $0.35^{+0.21}_{-0.15}$ | 0.83 ± 0.02 | 0.26 ± 0.01 | 11.2 | 1 | ELODIE |
| HD 27778 | 62 Tau | 04 23 59.76 | +24 18 03.6 | 6.33 | 0.34 | $0.22^{+0.55}_{-0.22}$ | $5.25^{+1.06}_{-0.88}$ | $0.82^{+0.45}_{-0.27}$ | 1.19 ± 0.07 | 0.43 ± 0.03 | 15.22 | 2 | ELODIE |
| HD 35149 | 23 Ori | 05 22 50.00 | +03 32 40.0 | 5.00 | 0.08 | $0.43^{+0.12}_{-0.13}$ | $0.03^{+0.00}_{-0.03}$ | $0.02^{+0.00}_{-0.02}$ | 0.54 ± 0.11 | 0.20 ± 0.04 | 24.09 | 2 | UVES |
| HD 35715 | $\Psi$ Ori | 05 26 50.23 | +03 05 44.4 | 4.60 | 0.03 | $0.31^{+0.13}_{-0.13}$ | $6 \pm 2 \times 10^{-6}$ | $4 \pm 2 \times 10^{-6}$ | 0.66 ± 0.11 | 0.10 ± 0.04 | 25.2 | 1 | ELODIE |
| HD 36822 | $\phi^1$ Ori | 05 34 49.24 | +09 29 22.5 | 4.40 | 0.07 | $0.65^{+0.13}_{-0.12}$ | $0.21^{+0.09}_{-0.06}$ | $0.06^{+0.04}_{-0.03}$ | 0.74 ± 0.08 | 0.19 ± 0.04 | 25.53 | 1 | ELODIE |
| HD 36861 | $\lambda$ Ori A | 05 35 08.28 | +09 56 03.0 | 3.30 | 0.10 | $0.60^{+0.16}_{-0.16}$ | $0.13^{+0.08}_{-0.05}$ | $0.04^{+0.04}_{-0.02}$ | 0.57 ± 0.04 | 0.48 ± 0.04 | 25.2 | 3 | ELODIE |
| HD 40111 | 139 Tau | 05 57 59.66 | +25 57 14.1 | 4.82 | 0.10 | $0.79^{+0.16}_{-0.15}$ | $0.54^{+0.31}_{-0.20}$ | $0.12^{+0.10}_{-0.07}$ | 0.49 ± 0.04 | 0.20 ± 0.04 | 15.29 | 2 | ELODIE |
| HD 110432 | BZ Cru | 12 42 50.27 | −63 03 31.0 | 5.32 | 0.39 | $0.71^{+0.29}_{-0.21}$ | $4.37^{+0.42}_{-0.38}$ | $0.55^{+0.13}_{-0.11}$ | 1.17 ± 0.11 | 0.25 ± 0.01 | 6.8 | 3 | UVES |
| HD 143275 | $\delta$ Sco | 16 00 20.01 | −22 37 18.1 | 2.29 | 0.00 | $1.41^{+0.29}_{-0.29}$ | $0.26^{+0.15}_{-0.09}$ | $0.03^{+0.03}_{-0.02}$ | 0.90 ± 0.03 | 0.19 ± 0.02 | −10.90 | 2 | UVES |
| HD 144217 | $\beta^1$ Sco | 16 05 26.23 | −19 48 19.6 | 2.62 | 0.18 | $1.23^{+0.12}_{-0.11}$ | $0.68^{+0.10}_{-0.09}$ | $0.10^{+0.02}_{-0.02}$ | 0.81 ± 0.02 | 0.11 ± 0.01 | −8.95 | 2 | UVES |
| HD 145502 | $\nu$ Sco | 16 11 59.74 | −19 27 38.5 | 4.13 | 0.20 | $1.17^{+0.56}_{-0.59}$ | $0.78^{+0.32}_{-0.23}$ | $0.12^{+0.08}_{-0.07}$ | 0.80 ± 0.11 | 0.18 ± 0.01 | −8.49 | 2 | ELODIE |
| HD 147165 | $\sigma$ Sco | 16 21 11.32 | −25 35 34.0 | 2.91 | 0.31 | $2.19^{+0.90}_{-0.87}$ | $0.62^{+0.25}_{-0.18}$ | $0.05^{+0.04}_{-0.03}$ | 0.76 ± 0.06 | 0.13 ± 0.01 | −6.26 | 2 | UVES |
| HD 147933 | $\rho$ Oph A | 16 25 35.10 | −23 26 48.7 | 5.02 | 0.37 | $4.27^{+0.98}_{-0.80}$ | $3.72^{+1.53}_{-1.09}$ | $0.15^{+0.09}_{-0.07}$ | 1.09 ± 0.08 | 0.27 ± 0.03 | −8.02 | 2 | UVES |
| HD 149757 | $\zeta$ Oph | 16 37 09.54 | −10 34 01.5 | 2.58 | 0.29 | $0.52^{+0.02}_{-0.04}$ | $4.47^{+0.90}_{-0.75}$ | $0.63^{+0.20}_{-0.17}$ | 1.05 ± 0.02 | 0.50 ± 0.04 | −14.98 | 2 | UVES |
| HD 164284 | 66 Oph | 18 00 15.80 | +04 22 07.0 | 4.78 | 0.11 | $0.42^{+0.23}_{-0.39}$ | $0.71^{+0.29}_{-0.21}$ | $0.25^{+0.18}_{-0.20}$ | 0.89 ± 0.18 | 0.15 ± 0.02 | −15.32 | 1 | ELODIE |
| HD 170740 | ⋯ | 18 31 25.69 | −10 47 45.0 | 5.76 | 0.38 | $1.07^{+0.59}_{-0.47}$ | $7.24^{+1.47}_{-1.22}$ | $0.58^{+0.22}_{-0.18}$ | 1.02 ± 0.11 | 0.26 ± 0.01 | −12.9 | 6 | UVES |
| HD 198478 | 55 Cyg | 20 48 56.29 | +46 06 50.9 | 4.86 | 0.43 | $2.04^{+0.84}_{-0.63}$ | $7.41^{+3.06}_{-2.17}$ | $0.42^{+0.27}_{-0.20}$ | 0.81 ± 0.05 | 0.24 ± 0.01 | −10.04 | 2 | ELODIE |
| HD 202904 | $\upsilon$ Cyg | 21 17 55.08 | +34 53 48.8 | 4.43 | 0.09 | $0.23^{+0.21}_{-0.23}$ | $0.14^{+0.07}_{-0.05}$ | $0.11^{+0.12}_{-0.10}$ | 0.39 ± 0.11 | 0.13 ± 0.05 | −12.90 | 4 | ELODIE |
| HD 207198 | ⋯ | 21 44 53.28 | +62 27 38.0 | 5.96 | 0.47 | $3.39^{+0.59}_{-0.50}$ | $6.76^{+0.65}_{-0.59}$ | $0.28^{+0.05}_{-0.05}$ | 0.90 ± 0.03 | 0.53 ± 0.01 | −15.28 | 2 | ELODIE |
| HD 209975 | 19 Cep | 22 05 08.79 | +62 16 47.3 | 5.11 | 0.27 | $1.29^{+0.41}_{-0.38}$ | $1.20^{+0.62}_{-0.41}$ | $0.16^{+0.12}_{-0.09}$ | 0.57 ± 0.26 | 0.31 ± 0.01 | −11.39 | 2 | ELODIE |
| HD 214680 | 10 Lac | 22 39 15.68 | +39 03 01.0 | 4.88 | 0.08 | $0.50^{+0.14}_{-0.15}$ | $0.17^{+0.05}_{-0.04}$ | $0.06^{+0.03}_{-0.03}$ | 0.50 ± 0.06 | 0.34 ± 0.02 | −9.2 | 1 | ELODIE |
| HD 214993 | 12 Lac | 22 41 28.65 | +40 13 31.6 | 5.23 | 0.06 | $0.58^{+0.20}_{-0.18}$ | $0.43^{+0.22}_{-0.14}$ | $0.13^{+0.10}_{-0.07}$ | 0.68 ± 0.10 | 0.17 ± 0.02 | −9.44 | 1 | ELODIE |
| HD 218376 | 1 Cas | 23 06 36.82 | +59 25 11.1 | 4.84 | 0.16 | $0.89^{+0.28}_{-0.26}$ | $1.41^{+0.73}_{-0.48}$ | $0.24^{+0.19}_{-0.13}$ | 0.60 ± 0.06 | 0.28 ± 0.01 | −12.65 | 1 | ELODIE |

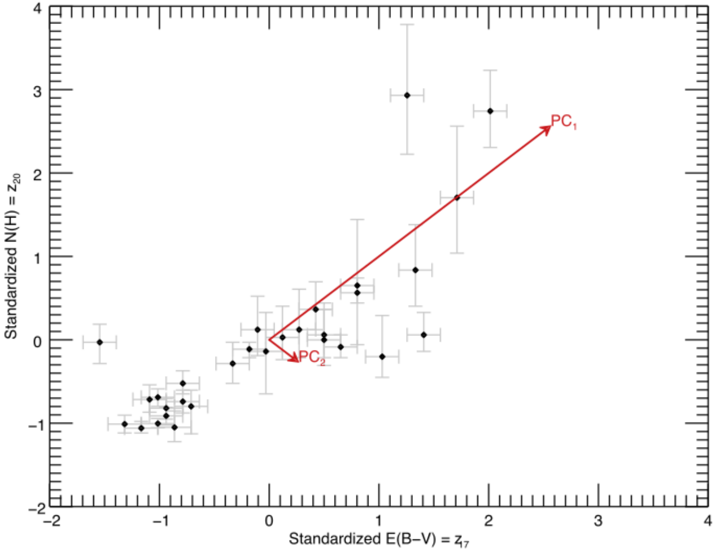
**Note.** R.A. and decl. are taken from SIMBAD. $V$, $E(B-V)$, $N$(H I), $N(H_2)$, and $F_\star$ values are from Jenkins (2009), where we assume an uncertainty of ±0.02 mag on the $E(B-V)$ values. $f(H_2) = 2N(H_2)/[N(H) + 2N(H_2)]$ is the fraction of molecular hydrogen.
[a] Value and reference refer to the velocity of the dominant interstellar component.

# Observational parameters.

**Table 2**
Input Variables Used in the PCA, and Their Mean Values and Standard Deviations

| Variable Name ($x_i$) | Mean ($\bar{x}_i$) | Standard Deviation ($s_{x_i}$) |
|---|---|---|
| $x_1 = \mathrm{W}(\lambda 4428)$ | 645.9 | 350.9 |
| $x_2 = \mathrm{W}(\lambda 4964)$ | 6.8 | 5.7 |
| $x_3 = \mathrm{W}(\lambda 5494)$ | 5.6 | 4.1 |
| $x_4 = \mathrm{W}(\lambda 5513)$ | 3.9 | 3.9 |
| $x_5 = \mathrm{W}(\lambda 5545)$ | 5.9 | 4.3 |
| $x_6 = \mathrm{W}(\lambda 5546)$ | 2.8 | 2.2 |
| $x_7 = \mathrm{W}(\lambda 5769)$ | 2.6 | 2.2 |
| $x_8 = \mathrm{W}(\lambda 5780)$ | 131.5 | 77.0 |
| $x_9 = \mathrm{W}(\lambda 5797)$ | 37.7 | 27.8 |
| $x_{10} = \mathrm{W}(\lambda 5850)$ | 15.6 | 13.6 |
| $x_{11} = \mathrm{W}(\lambda 6196)$ | 13.5 | 8.3 |
| $x_{12} = \mathrm{W}(\lambda 6270)$ | 20.7 | 13.9 |
| $x_{13} = \mathrm{W}(\lambda 6284)$ | 149.4 | 84.1 |
| $x_{14} = \mathrm{W}(\lambda 6376)$ | 9.3 | 7.4 |
| $x_{15} = \mathrm{W}(\lambda 6379)$ | 24.7 | 18.0 |
| $x_{16} = \mathrm{W}(\lambda 6614)$ | 52.5 | 35.2 |
| $x_{17} = E(B - V)$ | 0.20 | 0.13 |
| $x_{18} = N(\mathrm{H\ I})$ | $1.0 \times 10^{21}$ | $9.2 \times 10^{20}$ |
| $x_{19} = N(\mathrm{H_2})$ | $2.4 \times 10^{21}$ | $2.6 \times 10^{20}$ |
| $x_{20} = N(\mathrm{H})$ | $1.5 \times 10^{21}$ | $1.2 \times 10^{21}$ |
| $x_{21} = f(\mathrm{H_2})$ | 0.27 | 0.23 |
| $x_{22} = \mathrm{F}_\star$ | 0.75 | 0.21 |
| $x_{23} = \frac{\mathrm{W}(\lambda 5797)}{\mathrm{W}(\lambda 5780)}$ | 0.2907 | 0.1567 |

# PCA for two parameters: E(B-V), N(H)



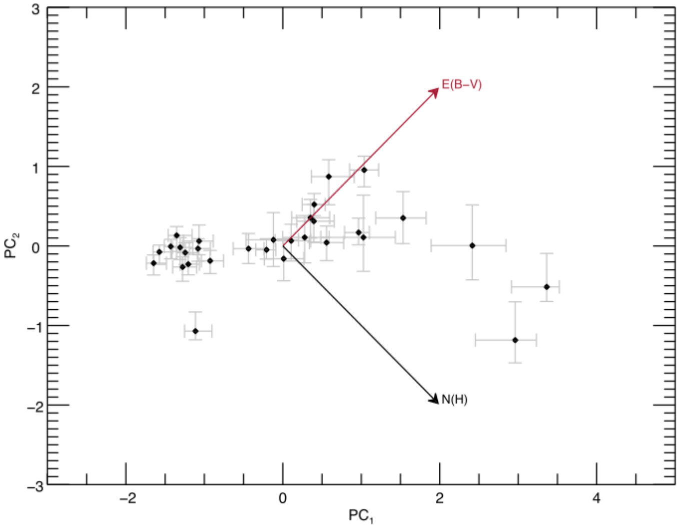
# PCA for two parameters: E(B-V), N(H)

**Table 3**

Principal Components, Eigenvalues, and Relative Importance of Each PC for a 2D Example Involving $E(B-V)$ and $N$(H)

| PC | Eigen-value | % Variation | Cumulative % | Eigenvector |
|---|---|---|---|---|
| 1 | 1.813 | 90.63 | 90.63 | (0.707, 0.707) |
| 2 | 0.187 | 9.37 | 100.00 | (0.707, −0.707) |

# PCA for two parameters: E(B-V), N(H)



# PCA for all components

**Table 4**
Principal Components, Eigenvalues, and Relative Importance of Each PC

| PC | Eigenvalue | % Variation | Cumulative % |
|---|---|---|---|
| 1 | 15.248 | 66.30 | 66.30 |
| 2 | 3.158 | 13.73 | 80.03 |
| 3 | 1.801 | 7.83 | 87.86 |
| 4 | 1.139 | 4.95 | 92.81 |
| 5 | 0.355 | 1.54 | 94.35 |
| 6 | 0.262 | 1.14 | 95.49 |
| 7 | 0.192 | 0.84 | 96.33 |
| 8 | 0.186 | 0.81 | 97.14 |
| 9 | 0.157 | 0.68 | 97.82 |
| 10 | 0.117 | 0.51 | 98.33 |
| 11 | 0.096 | 0.42 | 98.75 |
| 12 | 0.074 | 0.32 | 99.07 |
| 13 | 0.066 | 0.29 | 99.35 |
| 14 | 0.055 | 0.24 | 99.60 |
| 15 | 0.032 | 0.14 | 99.74 |
| 16 | 0.025 | 0.11 | 99.85 |
| 17 | 0.012 | 0.05 | 99.90 |
| 18 | 0.008 | 0.03 | 99.93 |
| 19 | 0.006 | 0.03 | 99.96 |

# Screeplot for principal components

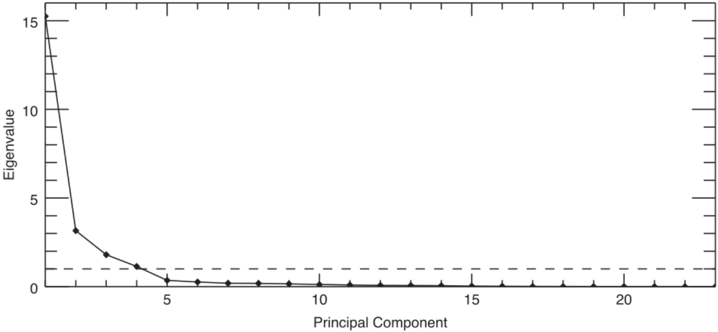
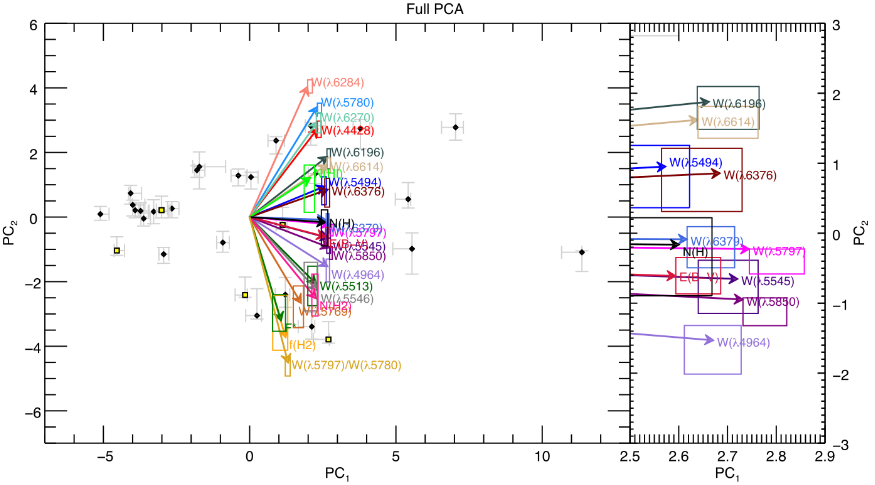



**Figure 6.** Screeplot illustrating the relative importance of each PC. The dashed line indicates an eigenvalue of one. The first four PCs lie above this limit.

# Biplot for principal components PC1 and PC2



# Biplots for principal components PC1 and PC2 for partial analysis $z_{17}$ - $z_{23}$ and $z_1$ - $z_{16}$

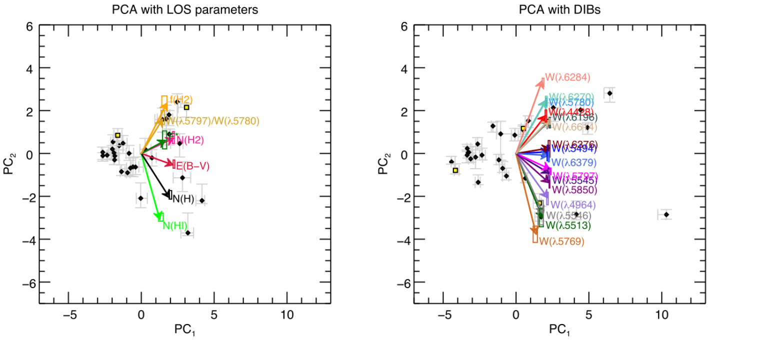



**Figure 7.** $PC_1$–$PC_2$ biplots for (top) all variables, (bottom left) line-of-sight parameters only (excluding DIBs), and (bottom right) DIBs only, excluding line-of-sight parameters. The 23-dimensional vectors corresponding to the original variables are projected onto the $PC_1$–$PC_2$ plane. The rectangular outlines surrounding the vectors indicate the uncertainty range for each projection, obtained through an MC simulation. Note that the vectors have been scaled by a constant factor for better visualization (as was done in Figure 4). Be stars are indicated by yellow squares. To help with clarity, a zoomed-in and rescaled portion of the full PCA results is presented next to the main figure. The same color scheme is used for all figures.

# Interpretation of PC1

- Largest projections on PC1 is related to equivalent widths of DIB-s
- PC1 - traces amount of DIB-s producing material in gas phase (W($\lambda$ 5797) has correlation 0.96 with PC1).

$$N_{DIB} = 0.136(PC1) + 0.90$$

$$N_{DIB} \approx 0.0185 W(\lambda 5797) + 0.19$$

# Correlation between $W(\lambda5797)$ and PC1

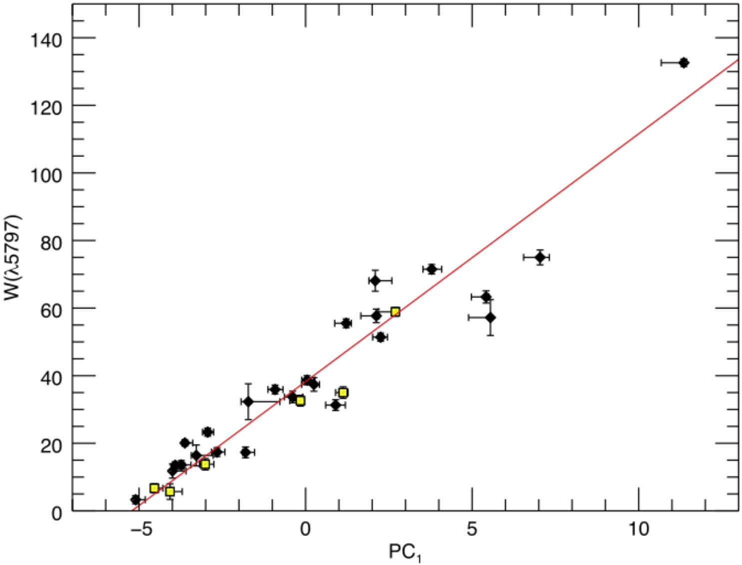



**Figure 8.** W($\lambda$5797) and $PC_1$ have a very strong correlation ($r = 0.957$). The equation of the best-fit line is $W(\lambda5797) = 7.31(PC_1) + 38.25$. Be stars are

# Interpretation of PC2

- Important negative contribution to PC2 comes from $W(\lambda 5797)/W(\lambda 5780)$ projection.
- $W(\lambda 5797$ has small projection on PC2 whereas $W(\lambda 5780$ corelates strongly
- PC2 - depend on radiation environment at place of DIB formation

$$G_{DIB} = PC2$$

$$G_{DIB} \approx -9.07[W(\lambda 5797)/W(\lambda 5780)] + 2.55$$

# PC2 ($G_{DIB}$) as a function of $W(\lambda5797)/W(\lambda5780)$

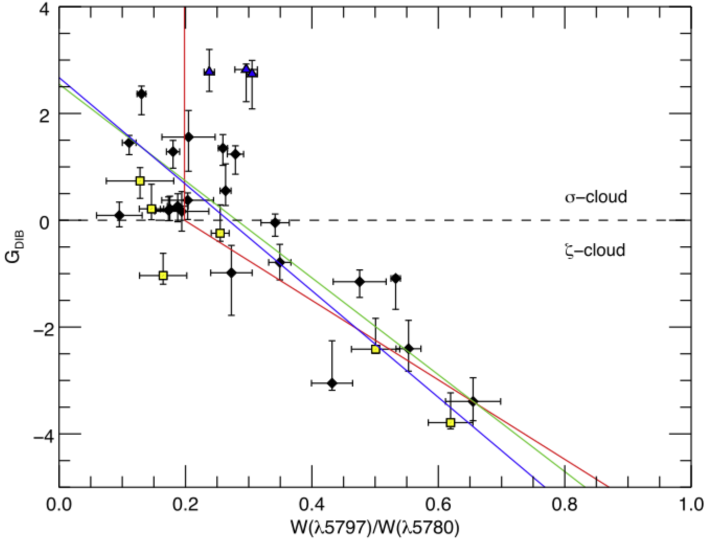
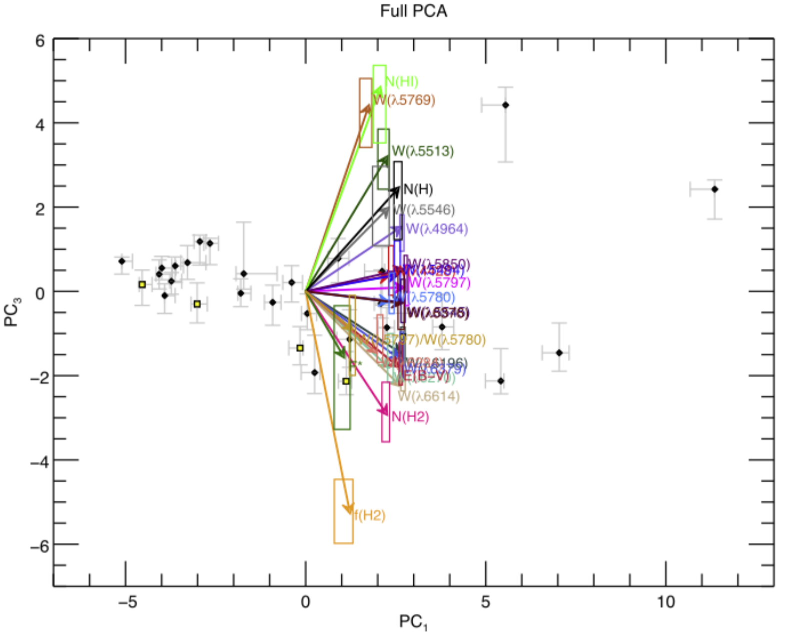



**Figure 9.** $G_{\rm DIB}$ as a function of W(λ5797)/W(λ5780). Be stars are indicated by yellow squares; three possible outliers (HD 15137, HD 198478, and HD 209975; located at $G_{\rm DIB} \approx 3$) are shown as blue triangles. We show the

# Interpretation of PC2

- There is a good corelation between PC2 and $W(\lambda5797)/W(\lambda5780)$ for $\zeta$ clouds, but there is unclear situation for $\sigma$ clouds.

# Biplot for PC1-PC3



# Biplot for PC2-PC3

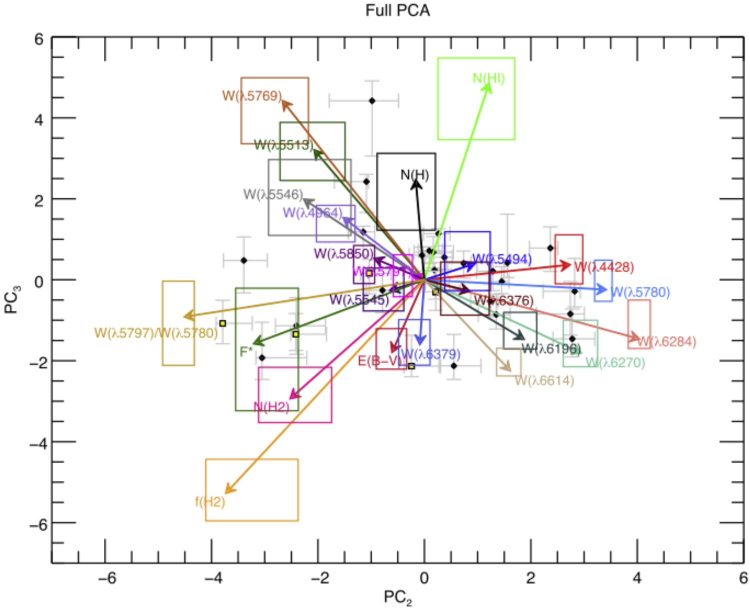



**Figure 10.** (Top) PC$_1$–PC$_3$ biplot. (Bottom) PC$_2$–PC$_3$ biplot. Be stars are

# Interpretation of PC3

Interpretation of PC3 is uncertain, but there are two good candidates

- Dust grains size, which should be inversely correlated to E(B-V) and $f(H_2)$ fraction
- Gas to dust ratio measured as $N(H)/E(B-V)$

# $N(H)/E(B-V)$ as function of PC3

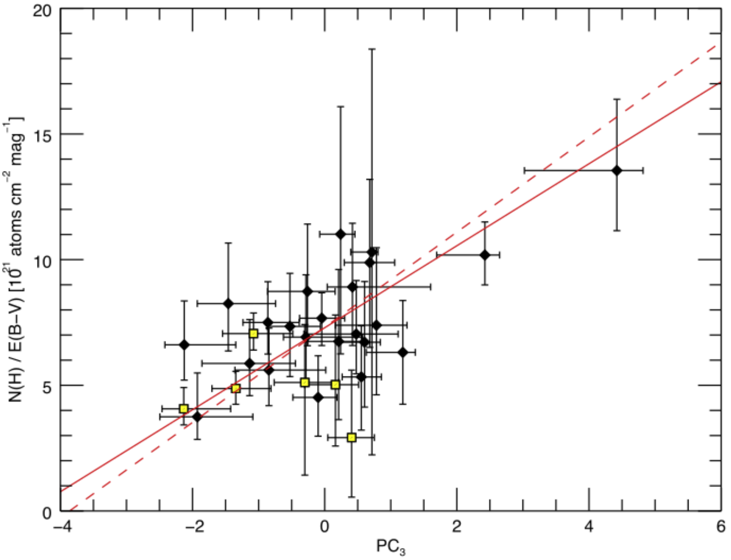



**Figure 12.** Total column of hydrogen per unit reddening as a function of $PC_3$. Yellow squares are used to indicate Be stars, which mostly fall below the trend line. The solid red line represents a straight line fit through all data points

# Interpretation of PC3

$$\frac{N(H) \times 10^{-21}}{E(B-V)} = 7.31 \pm 0.27 + PC3 \times (1.89 \pm 0.26)$$

When we assume that mean interstellar value of $N(H)/E(B-V)$ is $5.8 \times 10^{21}$ $atoms/cm^2/mag$ and GTD $= 1$ for this value one can obtain

$$GTD = 0.318 \times PC3 + 1.29$$

# Conclusions

- PCA analysis of DIB-s equivalent widths and line-on-sight properties for single cloud sightlines gives main parameters important for DIB-s formation and properties.
- PC1 - amount of DIB producing material
- PC2 - the level of UV radiation at place of DIB formation
- PC3 - related to dust properties or gas to dust ratio
- It is possible using DIB-s to determine physical parameters of their environment - even without identifying the carriers.