RNAAS RESEARCH NOTES OF THE AAS

Extinction along Sightlines Sampled by the APO Catalog of DIBs

To cite this article: Helena Xing *et al* 2024 *Res. Notes AAS* **8** 90

Research Notes of the AAS

Draft version March 24, 2024
Typeset using LaTeX **RNAAS** style in AASTeX631

Extinction Along Sightlines Sampled by the APO Catalog of DIBs

Helena Xing (邢妍),[1] Ailish Sullivan,[1] Halis Seuret,[1, 2] Cercis Morera-Boado,[2] Tina A. Harriott,[1, 3] Daniel Majaess,[1] Lou Massa,[4] and Chérif F. Matta[1, 5, 6, 7]

[1] *Department of Chemistry and Physics, Mount Saint Vincent University, Halifax, Nova Scotia, B3M2J6 Canada*
[2] *Department of Chemistry, Autonomous University of Morelos States, Cuernavaca, Mexico*
[3] *Department of Mathematics and Statistics, Mount Saint Vincent University, Halifax, Nova Scotia, B3M2J6 Canada*
[4] *Hunter College & the PhD Program of the Graduate Center, City University of New York, New York, USA*
[5] *Department of Chemistry, Saint Mary's University, Halifax, Nova Scotia, B3H3C3 Canada*
[6] *Département de Chimie, Université Laval, Québec, G1V0A6 Canada*
[7] *Department of Chemistry, Dalhousie University, Halifax, Nova Scotia, B3H4J3 Canada*

ABSTRACT

Identification of molecular carriers for diffuse interstellar bands (DIBs) may stem in part from the determination of interrelated lines using the Apache Point Observatory Catalog of DIBs. However, Pearson correlations may be impacted by the number of interstellar clouds along the sightlines. The trend of extinction with distance was constrained using Bayestar19 and Gaia DR3, and clouds were identified via step-functions and extended increasing linear progressions may be indicative of traversal through dense spiral arms. Thirteen sightlines are likely observed through more than one cloud. The hypergiants HD168625 and VI Cyg 12 are contaminated by local nebulosity and circumstellar disks. New findings presented here support the reddenings cited within the APO catalog of DIBs.

Keywords: Astrochemistry(75) — Diffuse interstellar bands(379) — Interstellar reddening(853)

INTRODUCTION

A century after Mary Lea Heger's seminal discovery of diffuse interstellar bands (DIBs), there are more than 550 known DIBs (Fan et al. 2019). However, only a sole carrier, C_{60}^{+}, has been identified for a small family of several DIBs, and yet even that assertion is debated (e.g., Galazutdinov et al. 2020; Schlarmann et al. 2021).

Previous work by the authors relied on the Apache Point Observatory (APO) catalog of optical DIBs. Several DIB families that likely each arise from a single carrier were proposed (Smith et al. 2021). This was achieved by examining the equivalent width (EW) measurements of 154,846 pairs of DIBs. Highly correlated DIBs ($r > 0.95$) with sufficient sightlines ($n \geq 15$) were used to identify potential families. In particular, two separate families linked to the first two DIBs identified by Heger were investigated further (5780 and 5797 Å). The legitimacy of each family was bolstered by examining correlations between the EWs of each DIB in the family with optical reddening (Smith et al. 2022). The reddening values used were those reported by Fan et al. (2019). We are seeking additional near-infrared (NIR) reddening data to provide independent support for the existence of each family (Smith et al. 2023), and on a separate front aiming to examine whether the spectral line morphologies are partially consistent.

To identify the separate molecular candidates for the 5780 and 5797 Å families, potential vibrational energies linked to offsets between pairs of DIBs within each family were evaluated following Bondar (2020). Thereafter, wavelengths associated with those vibrational energies were compared to spectra for approximately 16,000 molecules in the RASCALL database (Rapid Approximate Spectral Calculations for All, Sousa-Silva et al. 2019). Candidate molecules that could be responsible for each DIB family were identified by Sullivan et al. (2023).

Corresponding author: Tina A. Harriott, Daniel Majaess, Chérif F. Matta
Tina.Harriott@msvu.ca, Daniel.Majaess@msvu.ca, Cherif.Matta@msvu.ca

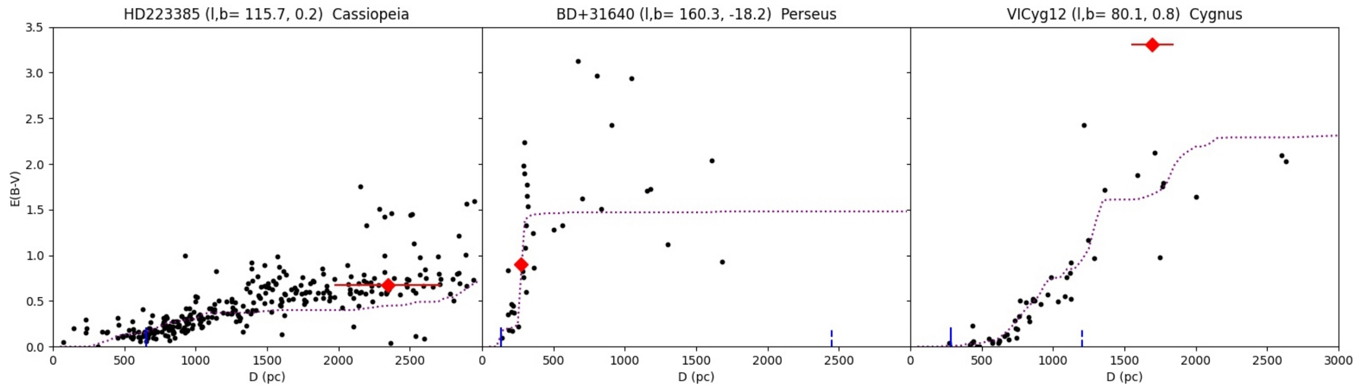

Figure 1. Sample reddening plots.

To further test the validity of these candidate molecules, synthetic optical spectra for each candidate are being calculated using a high level of quantum chemical theory. The results will be compared to the observed spectral lines for each proposed family of DIBs.

DIBs arising from passage through a single cloud may, for example, offer an opportunity to relate spectral profiles to specific cloud characteristics (e.g., radiation field). However, viewing a DIB through multiple clouds along the sightline is preferred when establishing broad correlations, thereby mitigating individual anomalies endemic to a single cloud.

This work characterizes the number of clouds along each of the 25 sightlines featured in the APO catalog. The results will foster subsequent evaluations regarding the veracity of the proposed families.

METHODS

The 3D extinction map Bayestar19 (Green et al. 2019) was employed to help constrain the trend of extinction with distance for each of the 25 sightlines. Three stars (HD147084, HD147889 and HD148579) were not included in the subsequent analysis because they are close to the Sun ($d < 0.2$ kpc), and beyond the range of reliable Bayestar data. The reddening along the sightline for a subsample of the remaining targets are conveyed in Fig. 1. The median Bayestar solution is the dotted magenta line. The red diamond is the location of the star from the Gaia DR3 parallax (Gaia Collaboration et al. 2023), in tandem with the optical reddenings $E(B-V)$ cited by Fan et al. (2019). The black dots represent advantageous spectroscopic data from Gaia DR3. Bayestar19 relies partly on an earlier version of Gaia data, and thus deviations are expected.

Interstellar clouds were identified in part by the appearance of step-functions (see Fig. 6 in Neckel & Klare 1980). Moreover, a positive linear trend over a sufficient baseline may be conducive to the traversing of spiral arms.

RESULTS

The following 9 sightlines are likely seen through a single cloud: HD23512, HD24534, HD24912, HD28482, HD37903, HD168625, HD175156, HD204827 and HD206267. The remaining 13 sightlines seemingly feature more than one cloud: HD20041, BD+31640, HD23180, HD281159, HD37061, HD43384, HD166734, HD183143, HD190603, HD194279, VI Cyg 5, VI Cyg 12, HD223385. Five stars appear to be embedded within a cloud (HD23512, HD37061, HD37903, HD281159, BD+31640). Furthermore, 4 sightlines with more than one cloud may be viewed traversing or through a spiral arm (HD43384, HD166734, HD190603, HD223385), however, confirmation awaits a separate analysis currently being planned.

The Fan et al. (2019) reddenings are consistent with independent field data (i.e., Gaia DR3 parallaxes and spectroscopic results), except for HD168625 and VI Cyg 12 (Fig. 1), where the Fan et al. (2019) reddening exceeds the field. Hutsemekers et al. (1994) detected that HD168625 is encompassed by a complex dusty nebula, whose presence explains the excess reddening for HD168625 when compared to the field. Previous studies examining DIB EWs relative to optical/NIR reddening indicated that the hypergiant VI Cyg 12 was often an outlier (Herbig 1975; Smith et al. 2022). VI Cyg 12 may be encompassed by circumstellar material (e.g., Maryeva et al. 2016), and Cygnus could be along a sightline exhibiting anomalous dust (Herbig 1975).

CONCLUSIONS

Approximately one-third of the sightlines examined are likely being viewed through a single cloud. Sightlines with numerous clouds may mitigate anomalies and yield a more robust correlation (i.e., average out real scatter). Peculiarities endemic to single clouds could be reflected in the EWs and line profiles of DIBs, and may contribute to the scatter exhibited in correlation plots. Work is underway to re-evaluate correlations owing to these findings, and benchmark proposed DIB families that are suspected to arise from a common molecular source. The reddenings cited by Fan et al. (2019) are consistent with the new field data presented here, and confirm that excess reddening is endemic to HD168625 and VI Cyg 12.

Acknowledgements: NSERC, CFI, MSVU, and thanks to Gregory Green and Clara Sousa-Silva for their broader input.

REFERENCES

Bondar, A. 2020, MNRAS, 496, 2231, doi: 10.1093/mnras/staa1610

Fan, H., Hobbs, L. M., Dahlstrom, J. A., et al. 2019, ApJ, 878, 151, doi: 10.3847/1538-4357/ab1b74

Gaia Collaboration, Vallenari, A., Brown, A. G. A., et al. 2023, A&A, 674, A1, doi: 10.1051/0004-6361/202243940

Galazutdinov, G., Bondar, A., Lee, B.-C., et al. 2020, AJ, 159, 113, doi: 10.3847/1538-3881/ab6d01

Green, G. M., Schlafly, E., Zucker, C., Speagle, J. S., & Finkbeiner, D. 2019, ApJ, 887, 93, doi: 10.3847/1538-4357/ab5362

Herbig, G. H. 1975, ApJ, 196, 129, doi: 10.1086/153400

Hutsemekers, D., van Drom, E., Gosset, E., & Melnick, J. 1994, A&A, 290, 906

Maryeva, O. V., Chentsov, E. L., Goranskij, V. P., et al. 2016, MNRAS, 458, 491, doi: 10.1093/mnras/stw385

Neckel, T., & Klare, G. 1980, A&AS, 42, 251

Schlarmann, L., Foing, B., Cami, J., & Fan, H. 2021, A&A, 656, L17, doi: 10.1051/0004-6361/202142669

Smith, E., Sullivan, A., Smith, F., et al. 2023, in American Astronomical Society Meeting Abstracts, Vol. 55, American Astronomical Society Meeting Abstracts, 213.04

Smith, E. R., Smith, F. M., Harriott, T. A., et al. 2022, Research Notes of the American Astronomical Society, 6, 82, doi: 10.3847/2515-5172/ac680f

Smith, F. M., Harriott, T. A., Majaess, D., Massa, L., & Matta, C. F. 2021, MNRAS, 507, 5236, doi: 10.1093/mnras/stab2444

Sousa-Silva, C., Petkowski, J. J., & Seager, S. 2019, Phys. Chem. Chem. Phys., 21, 18970, doi: 10.1039/C8CP07057A

Sullivan, A., Smith, E., Smith, F., et al. 2023, in American Astronomical Society Meeting Abstracts, Vol. 55, American Astronomical Society Meeting Abstracts, 213.05