Analysis of Rotationally Resolved C_3 Using Updated Oscillator Strengths

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Introduction

Temperature profiles of diffuse interstellar clouds can often be determined from the number densities of carbon chain molecules. In 2003, Adamkovics et al. observed C_3 towards ten sightlines and used available C_3 rotational data (oscillator strengths and transition wavelengths) to determine the number densities and estimate the temperature profiles of these clouds.[1] Recently, new oscillator strengths and transition wavelengths have been determined based on the borrowing effects of nearby states which create perturber transitions.[2] To fit the spectra, a different approach has been taken rather than determining the number densities from the equivalent widths of the individual peaks. Instead, the population of each rotational level has been adjusted such that the intensities of the P, Q, and R branch lines were fit.

Calculations

Initial estimates for each level are calculated based on the preliminary thermal excitation results from Adamkovics et al.[1] The additional perturber transitions used are listed below.[2] In addition, some of the previous non-perturbed transitions have adjusted oscillator strengths based on these additional transitions. Since most of the fits defaulted to large negative number densities, most were constrained to be greater than 10^{10} cm^{-2}.

Perturber Line	Wavelength (Å)	f_{JJ} (x 10^3)
R(6)	4050.401	0.58
R(4)	4050.567	0.49
R(2)	4050.746	0.45
R(2)	4051.19	2.08
R(0)	4051.396	10.58
P(6)	4052.122	0.28
P(4)	4052.18	0.86
P(8)	4052.521	0.39

Data

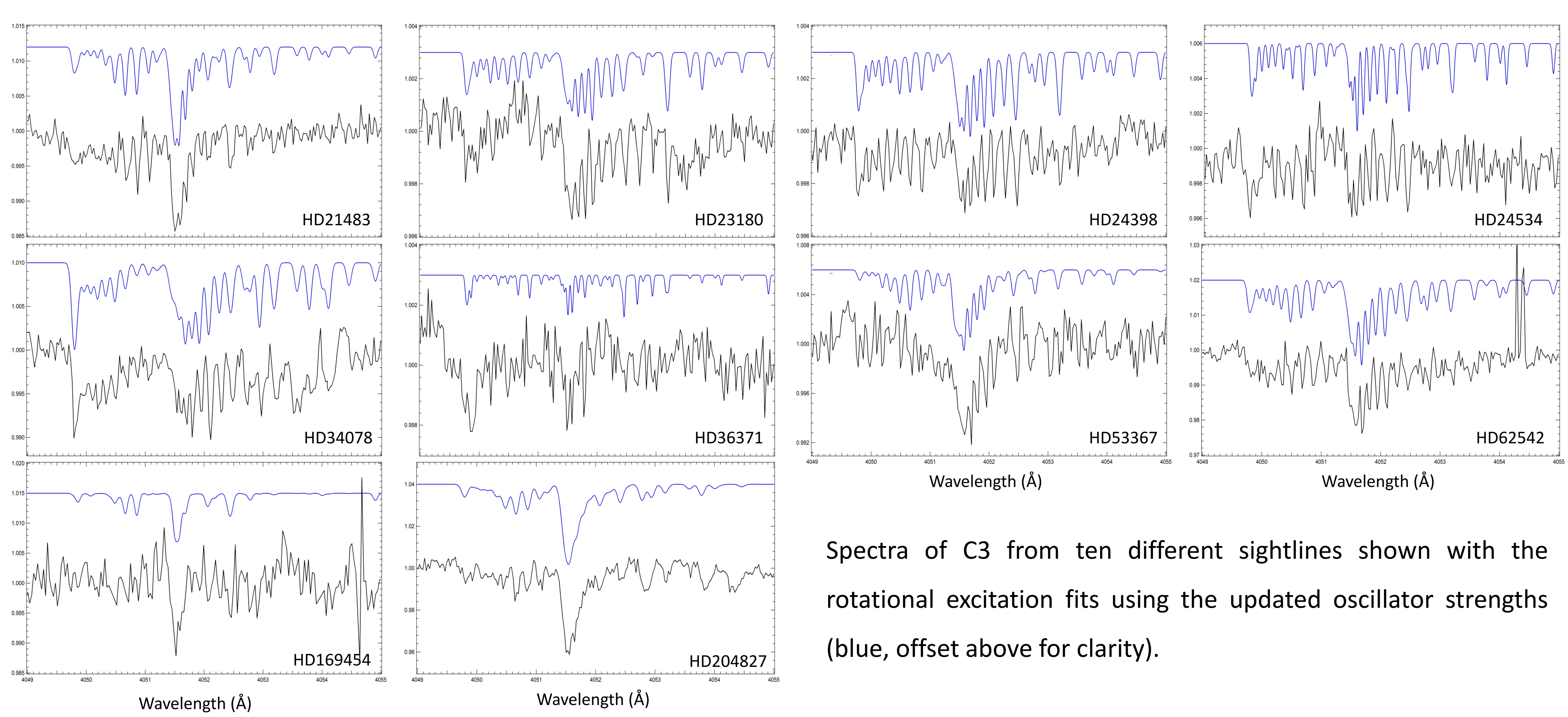
The rotational level populations determined from fitting with the updated oscillator strengths are shown in the table below. Unless noted otherwise, all fittings include a constraint of greater than 10^{10} cm^{-2} for each rotational level. Uncertainties are calculated based on the signal-to-noise ratio, the equivalent widths, and the dispersion of the instrument. The largest unperturbed oscillator strength (Q-branch, except for R(0)) was used for the conversion to number density.

	N_J (x 10^{11} cm^{-1})									
J	**HD21483**	**HD23180**	**HD24398**	**HD24534***	**HD34078**	**HD36371**	**HD53367**	**HD62542**	**HD169454****	**HD204827**
0	1.06	0.10	0.24	0.16	0.54	0.10	1.46	1.06	0.10	1.13
2	5.43	0.73	0.98	1.28	2.65	0.25	2.65	5.56	0.39	14.16
4	8.48	1.18	1.65	1.55	2.43	0.52	2.97	10.51	5.52	23.55
6	8.90	1.40	1.81	2.32	4.98	0.50	4.39	14.22	5.15	27.88
8	7.10	1.56	2.01	1.87	7.91	0.23	3.72	16.61	2.64	22.76
10	3.77	1.42	1.55	1.44	7.17	0.28	2.52	12.07	0.10	11.72
12	2.37	1.66	1.79	1.34	8.10	0.12	2.22	10.81	0.10	6.58
14	1.95	0.95	1.33	1.46	6.86	0.10	0.76	9.53	0.84	5.88
16	1.38	1.07	1.27	1.34	4.91	0.15	0.59	6.51	0.10	2.74
18	2.07	0.73	1.33	1.52	3.32	0.44	0.11	5.47	2.20	0.10
20	1.11	0.10	0.47	0.67	2.19	0.36	0.46	4.44	0.10	0.10
22	0.90	0.10	0.79	0.55	6.41	0.27	0.10	4.19	0.10	6.59
24	1.79	1.11	1.17	1.08	2.50	0.20	0.12	2.88	--	0.10
26	0.10	0.10	0.10	0.32	0.10	0.10	0.10	0.10	--	0.10
28	1.16	0.89	0.43	0.93	4.30	0.10	0.28	0.86	--	5.67
30	1.58	0.22	0.57	1.06	4.47	0.45	0.49	2.36	--	0.48
δN_J[a]	0.40	0.21	0.17	0.27	0.38	0.15	0.31	0.57	0.96	0.76

* No constraints were needed for HD24534

** Populations for J = 24 through J = 30 could not be determined for HD169454

[a] The uncertainty value for R(0) is half the listed value



Spectra of C3 from ten different sightlines shown with the rotational excitation fits using the updated oscillator strengths (blue, offset above for clarity).

Conclusion

Overall, the fitting procedure used for these sightlines takes into account the intensities from all the P, Q, and R branch lines in order to determine accurate number densities for each of the rotational levels. The spectra are the same as fit by Adamkovics et al. in 2003[1] and it is found that the new oscillator strengths used adjusted the number densities of the rotational populations for each sightline slightly.

Future Work

The next step is to determine the temperature profiles of these sightlines. This will be accomplished by using a modeling system similar to the one used by Roeuff et al.[3] and the C_3 collisional excitations from Smith et al.[4] Additionally, many of these sightlines seem to have two temperature regimes, which are difficult to distinguish. This will be more easily accomplished through modeling. The final results will give a more accurate description of the clouds, which can be used in astrochemical modeling to determine other properties of interest. Eventually, the fitting procedure and temperature determination used for these spectra could be applied to spectra of other molecules of astronomical interest.

References

[1] Adamkovics et al. *Ap. J.*, **595**, 235 (2003)

[2] Schmidt et al. *MNRAS*, **441**, 1134, (2014)

[3] Roueff et al. *A&A*, **384**, 629 (2002)

[4] Smith et al. *J. Phys. Chem. A*, **118**, 6351 (2014)