AST 300B – Spring 2019

In-class/take-home Problems Due: Friday April 12th

34. The Orion KL object is a region behind the Orion Nebula with what appears to be an "explosion" of outflowing gas that can be traced by H_2 in shocks. Observations of shocked H_2 in the infrared toward Orion KL indicate the following integrated intensities for the ro-vibrational lines:

$$I=6.9\times10^{-3} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ ster}^{-1} \text{ for v=1-0 S(1)}$$

$$I=5.7\times10^{-4} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ ster}^{-1} \text{ for v=2-1 S(1)}$$

Assuming the emission is isotropic, optically thin, and thermalized (T_{ex} = T_k), calculate the gas kinetic temperature (T_k) in the shocked gas. Hints: Take the ratio of the observed integrated intensities of the two lines. Check out the references Turner et al. 1977, ApJS, 35, 281 for Einstein As and Table 3 of Black & van Dishoeck 1987, ApJ, 322, 412 (on back) for wavelengths of transitions. The statistical weights are $g_{v,J}$ = 3(2J + 1) when J is odd and $g_{v,J}$ = (2J + 1) when J is even (there is no dependence on v because it is not an angular momentum).

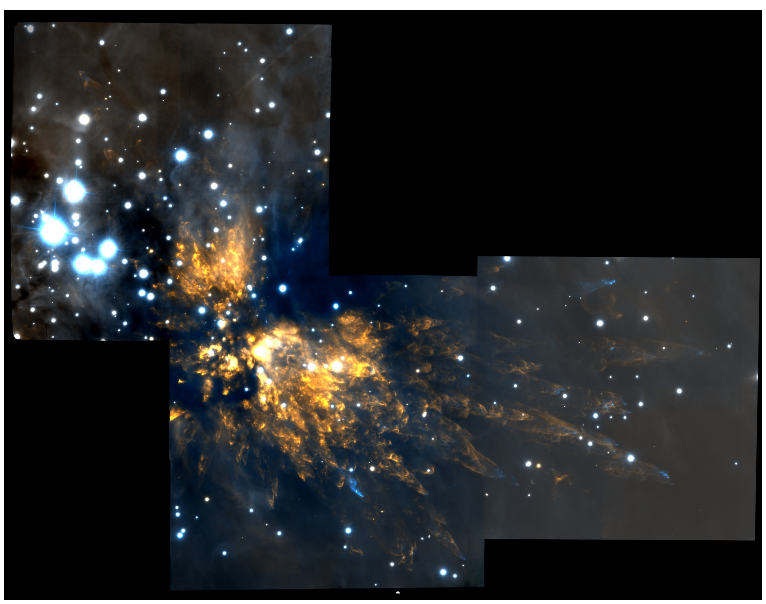

Figure 1: Near-IR H_2 emission (orange) toward Orion KL.

TABLE 3

STRONGEST FLUORESCENT LINES OF H_2 IN MODEL 14

$\tilde{\nu}$[a] (cm^{-1})	λ[b] μm	Transition	$100I/I_{total}$ per cent
354.37350[c]	28.21112	(0, 0) S(0)	2.35
587.03211[c]	17.03020	(0, 0) S(1)	1.48
814.42473[c]	12.275259	(0, 0) S(2)	.21
1034.67024[c]	9.6622810	(0, 0) S(3)	.43
1246.09811[c]	8.0228631	(0, 0) S(4)	.13
1447.27882[c]	6.907635	(0, 0) S(5)	.31
1637.046	6.1069	(0, 0) S(6)	.10
1720.899	5.8093	(1, 1) S(7)	.05
1814.496	5.5097	(0, 0) S(7)	.27
1978.984	5.0517	(0, 0) S(8)	.08
2018.494	4.9528	(1, 1) S(9)	.09
2130.102[d]	4.69333	(0, 0) S(9)	.22
2264.147	4.4155	(1, 1) S(11)	.09
2267.648	4.4087	(0, 0) S(10)	.06
2376.602	4.2065	(5, 4) O(5)	.06
2391.612	4.1801	(0, 0) S(11)	.15
2458.414	4.0666	(1, 1) S(13)	.05
2466.679	4.0529	(2, 1) O(7)	.08
2517.633	3.9709	(3, 2) O(6)	.06
2552.812	3.9162	(4, 3) O(5)	.12
2563.921	3.8992	(6, 5) O(3)	.07
2569.762	3.8904	(5, 4) O(4)	.06
2600.0[e]	3.8451	(0, 0) S(13)	.07
2626.460	3.8064	(1, 0) O(7)	.14
2685.504	3.7227	(2, 1) O(6)	.10
2729.822	3.6622	(3, 2) O(5)	.21
2756.803	3.6264	(4, 3) O(4)	.12
2763.565	3.6175	(5, 4) O(3)	.14
2856.483	3.4999	(1, 0) O(6)	.18
2908.775	3.4369	(2, 1) O(5)	.37
2944.738	3.3950	(3, 2) O(4)	.21
2956.311	3.3817	(5, 4) O(2)	.07
2961.679	3.3755	(4, 3) O(3)	.26
3008.130	3.3234	(6, 5) Q(1)	.07
3091.200	3.2341	(1, 0) O(5)	.63
3134.981	3.1889	(2, 1) O(4)	.37
3160.729	3.1630	(3, 2) O(3)	.46
3165.664	3.1580	(4, 3) O(2)	.14
3207.774	3.1166	(5, 4) Q(3)	.09
3224.653	3.1003	(5, 4) Q(2)	.07
3235.949	3.0894	(5, 4) Q(1)	.15
3329.040	3.0030	(1, 0) O(4)	.62
3362.408	2.9732	(2, 1) O(3)	.81
3375.974	2.9613	(3, 2) O(2)	.25
3383.984	2.9543	(4, 3) Q(5)	.08
3411.695	2.9303	(4, 3) Q(4)	.07
3434.063	2.9112	(4, 3) Q(3)	.19
3450.963	2.8970	(4, 3) Q(2)	.14
3462.292	2.8875	(4, 3) Q(1)	.29
3509.952	2.8483	(5, 4) S(0)	.06
3539.850	2.8242	(3, 2) Q(7)	.07
3568.225	2.8017	(1, 0) O(3)	1.34
3578.004	2.7941	(3, 2) Q(6)	.05
3589.170	2.7854	(2, 1) O(2)	.43
3611.073	2.7685	(3, 2) Q(5)	.16
3638.898	2.7473	(3, 2) Q(4)	.14
3661.342	2.7305	(3, 2) Q(3)	.36
3676.336	2.7194	(2, 1) Q(9)	.07
3678.285	2.7179	(3, 2) Q(2)	.27
3680.158	2.7165	(5, 4) S(1)	.11
3689.635	2.7096	(3, 2) Q(1)	.53
3753.274	2.6636	(4, 3) S(0)	.12
3768.134	2.6531	(2, 1) Q(7)	.13
3794.871	2.6344	(1, 0) Q(11)	.07
3806.770	2.6262	(2, 1) Q(6)	.10
3806.800	2.6262	(1, 0) O(2)	.71
3840.294	2.6033	(2, 1) Q(5)	.29
3868.528	2.5843	(2, 1) Q(4)	.26
3891.314	2.5691	(2, 1) Q(3)	.65
3906.478	2.5592	(1, 0) Q(9)	.14
3908.523	2.5578	(2, 1) Q(2)	.48
3920.053	2.5503	(2, 1) Q(1)	.94
3934.676	2.5408	(4, 3) S(1)	.24
3950.060	2.5309	(10, 8) O(3)	.08
3955.655	2.5273	(1, 0) Q(8)	.07
3988.761	2.5064	(5, 4) S(3)	.06
3997.637	2.5008	(3, 2) S(0)	.23
4000.075	2.4993	(1, 0) Q(7)	.23
4039.507	2.4749	(1, 0) Q(6)	.17
4073.739	2.4541	(1, 0) Q(5)	.51
4082.876	2.4486	(9, 7) O(5)	.08
4102.582[f]	2.436824	(1, 0) Q(4)	.45
4105.855	2.4349	(4, 3) S(2)	.11
4125.8739[f]	2.4230678	(1, 0) Q(3)	1.12
4143.4660[f]	2.4127801	(1, 0) Q(2)	.81
4155.25469[f]	2.4059349	(1, 0) Q(1)	1.59
4190.247	2.3858	(3, 2) S(1)	.47
4245.187	2.3550	(2, 1) S(0)	.42
4263.450	2.3449	(9, 7) O(4)	.08
4265.235	2.3439	(4, 3) S(3)	.13
4305.777	2.3218	(10, 8) Q(1)	.07
4372.445	2.2864	(3, 2) S(2)	.23
4437.230	2.2530	(9, 7) O(3)	.16
4448.958	2.2471	(2, 1) S(1)	.89
4497.8391[f]	2.2226833	(1, 0) S(0)	.73
4523.365	2.2101	(8, 6) O(5)	.13
4542.592	2.2008	(3, 2) S(3)	.28
4602.652	2.1721	(9, 7) O(2)	.08
4642.069	2.1536	(2, 1) S(2)	.44
4699.270	2.1274	(3, 2) S(4)	.09
4712.9054[f]	2.1212544	(1, 0) S(1)	1.60
4713.535	2.1210	(8, 6) O(4)	.12
4741.551	2.1084	(7, 5) O(6)	.05
4760.474	2.1001	(9, 7) Q(3)	.09
4798.307	2.0835	(9, 7) Q(2)	.07
4822.834	2.0729	(2, 1) S(3)	.56
4823.551	2.0726	(9, 7) Q(1)	.15
4831.006	2.0694	(12, 9) O(3)	.07
4841.305	2.0650	(3, 2) S(5)	.11
4897.691	2.0412	(8, 6) O(3)	.26
4917.0069[f]	2.0332026	(1, 0) S(2)	.80
4926.890	2.0291	(6, 4) O(7)	.06
4945.497	2.0215	(7, 5) O(5)	.18
4989.794	2.0035	(2, 1) S(4)	.19
5031.836	1.9868	(9, 7) S(0)	.06
5074.206	1.9702	(8, 6) O(2)	.13
5108.4040[f]	1.9570243	(1, 0) S(3)	1.07
5141.750	1.9443	(2, 1) S(5)	.25
5142.519	1.9440	(6, 4) O(6)	.07
5145.551	1.9429	(7, 5) O(4)	.18
5146.110	1.9427	(8, 6) Q(5)	.07
5146.794	1.9424	(9, 7) S(1)	.11
5154.249	1.9396	(12, 9) Q(1)	.06
5205.628	1.9205	(8, 6) Q(4)	.06
5253.408	1.9030	(8, 6) Q(3)	.16
5277.779	1.8942	(2, 1) S(6)	.08
5285.605	1.8914	(1, 0) S(4)	.37
5289.346	1.8901	(8, 6) Q(2)	.12
5311.340	1.8822	(5, 3) O(7)	.07
5313.358	1.8815	(8, 6) Q(1)	.25
5324.762	1.8775	(9, 7) S(3)	.05
5340.162	1.8721	(7, 5) O(3)	.37
5356.190	1.8665	(6, 4) O(5)	.24
5397.235	1.8523	(2, 1) S(7)	.12
5447.354	1.8353	(1, 0) S(5)	.53
5527.648	1.8086	(7, 5) O(2)	.20
5536.710	1.8056	(5, 3) O(6)	.08
5540.521	1.8044	(8, 6) S(0)	.10
5566.454	1.7960	(6, 4) O(4)	.23
5592.701	1.7876	(1, 0) S(6)	.16