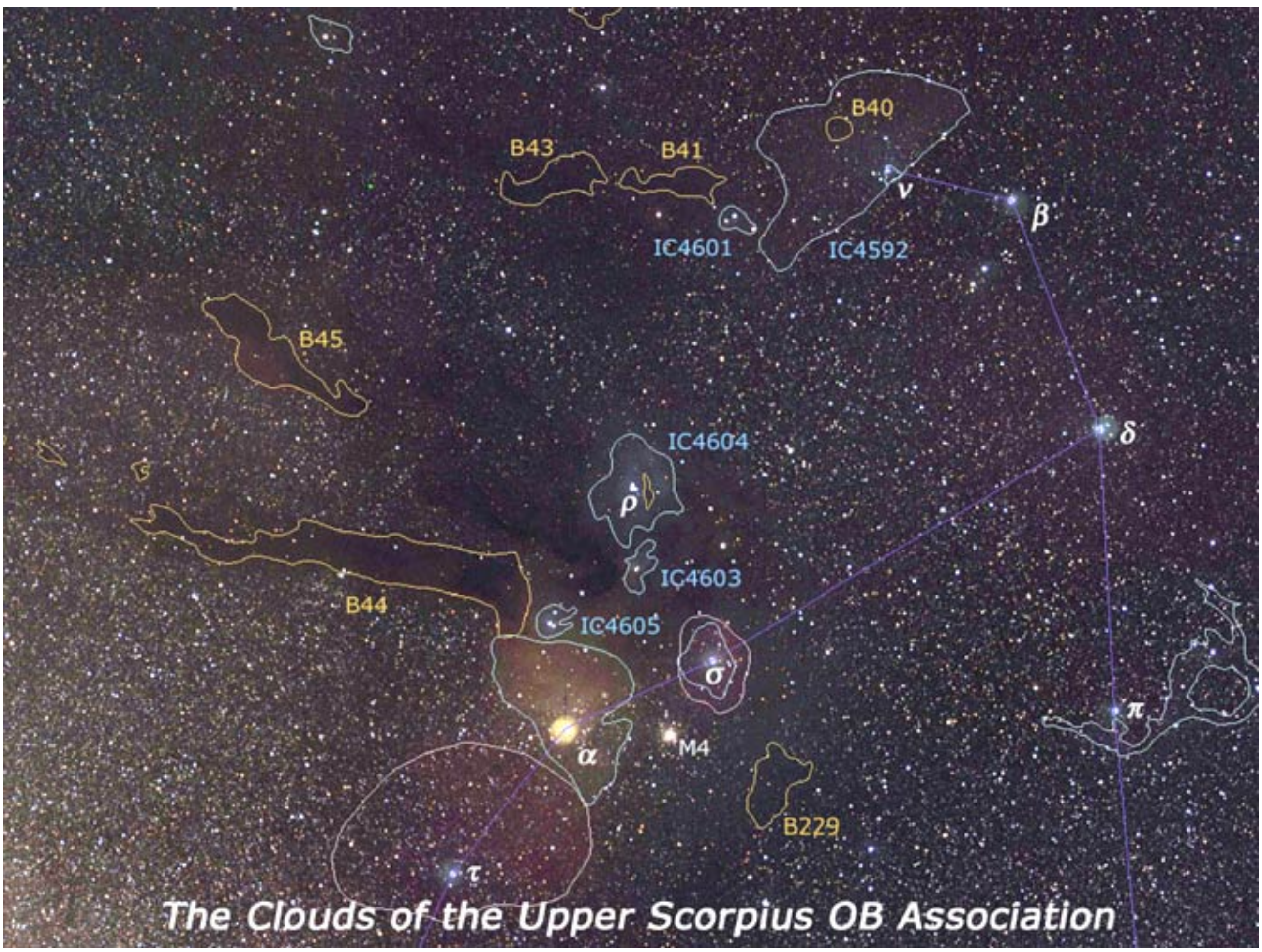
AST 300B – Spring 2019

In-class/take-home Problems Due: Wed. Feb. 6

12. Observations of a supergiant star in the Upper Sco OB Association indicate that it has a spectral type of A5II with magnitudes of B = 5.38 mag and V = 4.55 mag that have been modified by dust. Assuming a standard $R_V = 3.1$, calculate the hydrogen column density (cm^{-2}) along this line of sight. Table 1 from Fitzgerald 1970, A&A, 4, 234 ("The Intrinsic Colours of Stars and Two-Colour Reddening Lines") is attached.



13. In this problem, you will explore extinction/opacity laws at OIR and far-infrared/millimeter wavelengths.

(a) Consider a UV to near-IR dust extinction law that varies with wavelength as a power-law $A_\lambda \sim \lambda^{-\beta}$ [mag]. What power-law index β corresponds to $R_V = 3.1$ for standard ISM dust ?

(b) Dust grains can coagulate and grow in size in dense environments. Furthermore, in cold environments, ices (H_2O, CO, etc.) can form on the surface of the grains. These effects change the opacity of the grains. In a classic paper by Ossenkopf & Henning (1994 A&A, 291, 943), the dust opacities were calculated for dust grains that have coagulated at different densities and with different amounts of H_2O ice. Column 5 for grains coagulated at a density of 10^6 cm^{-3} with thin ice mantles (called "OH5" dust) is a very popular model used to approximate the opacities of dust in dense star forming regions at far-infared through millimeter wavelengths. Assume the dust opacity at λ >= 350 μm is well described by a single power law with $\kappa_\nu \sim \lambda^{-\beta}$ [cm^2/g]. Calculate β for OH5 dust. HINT: use a linear regression.

V. Ossenkopf & Th. Henning: Dust opacities for protostellar cores

Table 1. (continued)

Initial distribution:	MRN			MRN with thin ice mantles			MRN with thick ice mantles		
Gas density [cm^{-3}]	–	10^6	10^8	–	10^6	10^8	–	10^6	10^8
	Fig. 1a	Fig. 2a	Fig. 2b	Fig. 1b	Fig. 3a	Fig. 3b	Fig. 1c	Fig. 4a	Fig. 4b
λ [μm]	κ [cm^2/g]								
5.41e+1	9.05e+1	1.45e+2	2.19e+2	1.92e+2	2.80e+2	3.48e+2	9.79e+2	1.19e+3	1.34e+3
6.31e+1	7.16e+1	1.16e+2	1.76e+2	1.43e+2	2.11e+2	2.63e+2	6.59e+2	8.21e+2	9.37e+2
7.36e+1	5.60e+1	9.19e+1	1.41e+2	1.05e+2	1.58e+2	1.97e+2	4.25e+2	5.41e+2	6.22e+2
8.58e+1	4.37e+1	7.32e+1	1.14e+2	7.76e+1	1.18e+2	1.47e+2	2.62e+2	3.40e+2	3.90e+2
1.00e+2	3.44e+1	5.92e+1	9.38e+1	5.56e+1	8.65e+1	1.07e+2	1.27e+2	1.72e+2	1.95e+2
1.17e+2	2.70e+1	4.82e+1	7.86e+1	4.30e+1	6.75e+1	8.30e+1	8.30e+1	1.13e+2	1.28e+2
1.36e+2	2.07e+1	3.88e+1	6.57e+1	3.30e+1	5.25e+1	6.45e+1	5.73e+1	7.91e+1	8.85e+1
1.58e+2	1.59e+1	3.16e+1	5.61e+1	2.53e+1	4.09e+1	5.03e+1	3.98e+1	5.57e+1	6.19e+1
1.85e+2	1.17e+1	2.53e+1	4.74e+1	1.87e+1	3.07e+1	3.77e+1	2.71e+1	3.84e+1	4.23e+1
2.26e+2	8.16e+0	1.95e+1	3.89e+1	1.30e+1	2.17e+1	2.67e+1	1.75e+1	2.51e+1	2.74e+1
3.50e+2	3.64e+0	1.13e+1	2.58e+1	5.91e+0	1.01e+1	1.24e+1	7.79e+0	1.12e+1	1.20e+1
5.00e+2	1.77e+0	7.61e+0	1.98e+1	2.90e+0	5.04e+0	6.21e+0	3.79e+0	5.50e+0	5.72e+0
7.00e+2	9.09e−1	4.56e+0	1.25e+1	1.48e+0	2.57e+0	3.18e+0	1.93e+0	2.81e+0	2.93e+0
1.00e+3	4.77e−1	2.74e+0	7.85e+0	7.81e−1	1.37e+0	1.69e+0	1.01e+0	1.48e+0	1.54e+0
1.30e+3	3.09e−1	1.99e+0	5.86e+0	5.11e−1	8.99e−1	1.11e+0	6.48e−1	9.62e−1	1.00e+0

Portion of Table 1 from Ossenkopf & Henning 1994 (p. 949).

Table 1. *Adopted* $(B-V)_0$ *colours*

	V	IV-V	IV	III-IV	III	II-III	II	Ib	Iab	Ia
O5	−0.32									
O6	−0.32									
O7	−0.32									
O7.5	−0.31									
O8	−0.31				−0.31				−0.29	
O9	−0.31	−0.31	−0.31	−0.31	−0.31	−0.31	−0.31	−0.28	−0.28	−0.28
O9.5	−0.30	−0.30	−0.30	−0.30	−0.30	−0.30	−0.30	−0.27	−0.27	−0.27
B0	−0.30	−0.30	−0.30	−0.30	−0.30	−0.30	−0.29	−0.24	−0.24	−0.24
B0.5	−0.28	−0.28	−0.28	−0.28	−0.28	−0.30	−0.28	−0.22	−0.22	−0.22
B1	−0.26	−0.26	−0.26	−0.26	−0.26	−0.28	−0.24	−0.19	−0.19	−0.19
B1.5	−0.25	−0.25	−0.25	−0.25	−0.25	−0.27	−0.22	−0.17	−0.18	−0.18
B2	−0.24	−0.24	−0.24	−0.24	−0.24	−0.22	−0.21	−0.16	−0.17	−0.17
B2.5	−0.22	−0.22	−0.22	−0.22	−0.22	−0.20	−0.19	−0.15	−0.15	−0.15
B3	−0.20	−0.20	−0.20	−0.20	−0.20	−0.18	−0.17	−0.13	−0.13	−0.13
B4	−0.18	−0.18	−0.18	−0.18	−0.18					−0.11
B5	−0.16	−0.16	−0.16	−0.16	−0.16	−0.15	−0.14	−0.09	−0.09	−0.09
B6	−0.14	−0.14	−0.14	−0.14	−0.14	−0.13	−0.12	−0.07	−0.07	−0.07
B7	−0.13	−0.13	−0.13	−0.12	−0.12	−0.12	−0.12	−0.04	−0.04	−0.04
B8	−0.11	−0.10	−0.10	−0.10	−0.10	−0.10	−0.10	−0.02	−0.02	−0.01
B9	−0.07	−0.07	−0.07	−0.08	−0.08	−0.08	−0.06	−0.02	0.00	0.00
B9.5	−0.04	−0.04	−0.04	−0.05	−0.05	−0.04	−0.03	−0.01	0.00	0.01
A0	−0.01	−0.02	−0.02	−0.03	−0.03	−0.01	0.00	0.00	0.01	0.02
A1	0.02	0.01	0.00	0.01	0.01			0.02	0.03	0.03
A2	0.05	0.06	0.06	0.05	0.05			0.05	0.05	0.05
A3	0.08	0.09	0.09	0.09	0.09				0.06	0.06
A4	0.12	0.12	0.12	0.12	0.12				0.08	0.08
A5	0.15	0.15	0.15	0.15	0.15	0.13	0.10	0.10	0.10	0.10
A7	0.20	0.22	0.22	0.22	0.24		0.14	0.13	0.13	0.13
A8	0.27	0.27	0.26	0.26	0.26			0.14	0.14	0.14
A9	0.30	0.30	0.29	0.29	0.28		0.18	0.14	0.14	0.14
F0	0.32	0.30	0.30	0.30	0.32			0.15	0.15	0.15
F1	0.34	0.34	0.33	0.33	0.33			0.16	0.16	0.16
F2	0.35	0.38	0.37	0.37	0.36			0.18	0.18	0.18
F3	0.41	0.39	0.39	0.39	0.39					
F4	0.42	0.40	0.42	0.42	0.42					
F5	0.45	0.42	0.44	0.43	0.43		0.38	0.26	0.26	0.26
F6	0.48	0.48	0.46	0.46	0.46					
F7	0.50	0.49	0.50	0.49	0.48					
F8	0.53	0.51	0.53	0.52	0.52			0.55	0.55	0.55
F9	0.56	0.56	0.57							
G0	0.60	0.60	0.63	0.62	0.64		0.73	0.82	0.82	0.82
G1	0.62	0.60	0.63		0.69		0.80	0.85	0.85	0.85
G2	0.63	0.60	0.64		0.77		0.87	0.88	0.88	0.88
G3	0.65	0.60	0.66		0.85	0.86	0.87	0.92	0.92	0.92
G4	0.66	0.64	0.68		0.88	0.87	0.87			
G5	0.68	0.68	0.70	0.85	0.90	0.88	0.87	1.00	1.00	1.00
G6	0.72	0.73			0.92	0.92	0.91	1.04	1.04	1.04
G7	0.73	0.76			0.94	0.94	0.95	1.10	1.10	1.10
G8	0.74	0.80	0.82	0.89	0.95	0.96	0.99	1.14	1.14	1.14
G9	0.76	0.83	0.90	0.95	0.98	1.00	1.02	1.16	1.16	1.16