Longitudinally Averaged R-band Field Star Counts Across the Entire Sky

Doug Simons
August 1995

Overview

In June 1994 I acquired from John Bahcall a copy of his "export code", a FORTRAN IV program that is capable of predicting the field star density at V at any point in the sky $\geq$20 degrees from the Galactic equator. This program is based upon the well documented Bahcall-Soneira model (see Bahcall 1986, *ARAA*, **24**, 577). Subroutine provisions built into the program make it possible to alter the output field star surface densities to various bandpasses. Accordingly I modified the code so that output at RIJHK is also possible, based upon Johnson standard star data. The extinction subroutine was also modified for these bandpasses. While the reliability of the model is certainly questionable at infrared wavelengths, it is not in serious question at submicron wavelengths for magnitudes $\lesssim$20, which is roughly the point at which the Gilmore Galactic model containing a "thick disk" begins to depart significantly from the Bahcall-Soneira model.

Since the aforementioned modifications were made to the export code, the need for estimating mean field star densities, averaged across Galactic longitude, has arisen. Specifically an action was placed on me during the March 1995 A&G/AOSWG in Victoria to produce a grid of field star densities using Bahcall's modified code, in part as a check of the fit that Rene Racine presented at that meeting which was based on color transformed V data published Allen's Astrophysical Quantities. A generalized fit to the sky also makes it easier for the various people within the Gemini Community working on AO and A&G performance models to use a common field star model.

All Sky Bahcall-Soneira Field Star Grid

Shown in Figure 1 is a surface plot of longitudinally averaged R-band field star density ranging from 10° to 90° degrees. The structure in this plot is of course dominated by faint stars at low Galactic latitudes. The greatest uncertainty in the model predictions is for low latitudes (b $\lesssim$ 20°), where variable extinction and assumptions about the structure of the Galactic disk become important in the calculations. Adopting the same basic functional form that Rene used, a 2D fit to this surface is expressed by:

$$\log(N_{R,b}) = \log(N_{R,90}) + \left(\frac{b}{90} - 1\right)^2 \left(a_0 + a_1 R + a_2 R^2\right) \qquad \text{eq. 1}$$

where $N_{R,b}$ is the longitudinally averaged field star density, $N_{R,90}$ is the value at the Galactic pole, b is Galactic latitude, a_0 is -0.1, a_1 is 0.10, and a_2 is -0.0008. To be clear, $N_{R,b}$ is the cumulative number of stars per square degree, not the number per magnitude interval. Figure 2 is the ratio of this fit to the Bahcall-Soneira grid points and

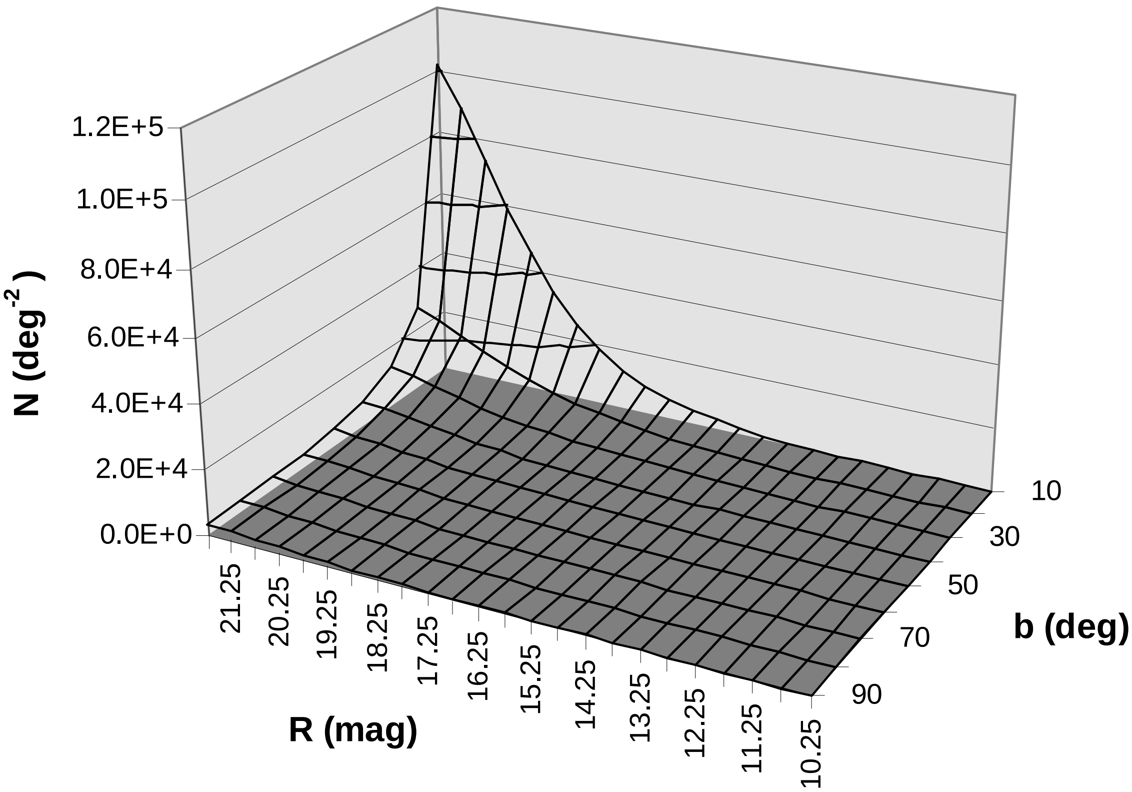

Figure 1 - The all-sky surface density grid derived from the Bahcall-Soneira export code is plotted for 10.25 < R < 21.25. All values are longitudinally averaged and range from the NGP to 10° latitude.

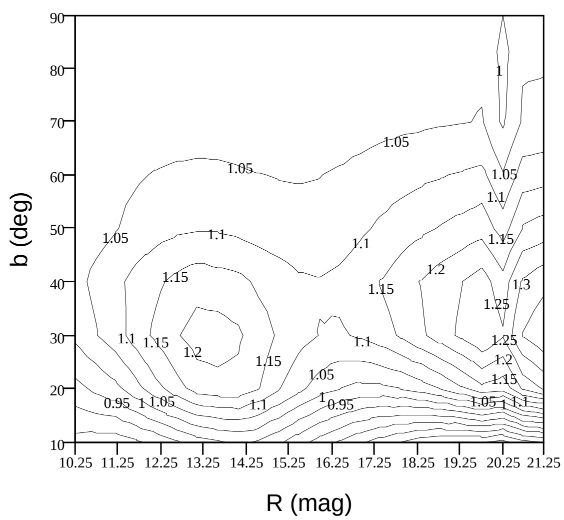

Figure 2 - The Bahcall-Soneira model shown in Figure 1 ratioed against the 2D fit expressed in equation 1. Worst case errors are ~25% for a small area between 20° < b < 40° and R > 19 mag.

illustrates the overall accuracy of the fit. For b ⓿ 50° the 2D fit is typically accurate to within ~5%. The worst errors are ~25% for R ⓿ 19 and 20° < b < 40°. Table 1 lists the actual Bahcall-Soneira grid point values.

Figure 3 shows the *all-sky* average density together with a quadratic fit. The all-sky averaged R-band quadratic fit derived here is:

$$\log\langle N_R \rangle = a_0 + a_1 R + a_2 R^2 \qquad \text{eq. 2}$$

where a_0 is -3.58673, a_1 is 0.554968, and a_2 is -0.00880835. The error in the polynomial fit expressed in equation 2 to the mean all-sky Bahcall-Soneira model is ~1%. The points

R (mag)	Galactic Latitude								
	10	20	30	40	50	60	70	80	90
10.25	41	25	17	13	11	9	8	7	7
10.75	65	38	25	19	16	13	12	11	11
11.25	101	57	37	28	23	19	17	15	16
11.75	156	84	54	40	33	28	25	23	23
12.25	236	123	79	59	48	40	36	33	33
12.75	355	180	116	86	70	59	52	47	47
13.25	527	262	168	124	101	84	75	67	68
13.75	773	382	244	179	144	119	105	94	95
14.25	1127	555	354	255	203	166	145	130	130
14.75	1632	804	504	358	278	225	194	173	174
15.25	2383	1156	707	488	373	298	256	227	228
15.75	3414	1620	962	651	487	386	329	291	291
16.25	4828	2229	1281	845	623	489	416	367	367
16.75	6730	3008	1669	1078	786	614	521	459	459
17.25	9399	4004	2139	1361	984	767	650	572	572
17.75	13098	5256	2720	1706	1232	959	812	715	715
18.25	18224	6823	3442	2146	1546	1203	1017	896	895
18.75	25292	8786	4340	2696	1942	1509	1276	1122	1122
19.25	34515	11144	5452	3380	2428	1885	1592	1399	1399
19.75	45883	13934	6783	4200	3010	2334	1969	1729	1728
20.25	58970	17154	8346	5159	3692	2860	2409	2114	2113
20.75	73437	20824	10136	6262	4468	3456	2908	2548	2399
21.25	89127	24889	12066	7415	5261	4055	3403	2978	2974
21.75	101814	27627	13314	8160	5777	4452	3736	3267	3264

Table 1 - Predicted longitudinally averaged field star values based upon the Bahcall-Soneira model are listed. All field star densities are per unit square degree and assume a Johnson R bandpass.

showing Rene's fit in Figure 3 corresponds to his expression at 30° latitude multiplied by the Bahcall-Soneira predicted density at the North Galactic pole. Figure 3 demonstrates good agreement between the *functional form* used by Rene to describe the all-sky mean stellar surface density and the more sophisticated Bahcall-Soneira prediction. For $12 < R < 20$ the difference between the fits is typically ≈5%. It is important to note that this only represents a verification of the relative distribution of stars in the sky. The Bahcall-Soneira model significantly differs from the model used by Rene (based upon Reid and Majewski 1993, *ApJ*, **409**, 635) in terms of absolute numbers of stars, presumably due to different R bandpass definitions between the Bahcall-Soneira model and the Reid and Majewski observations.

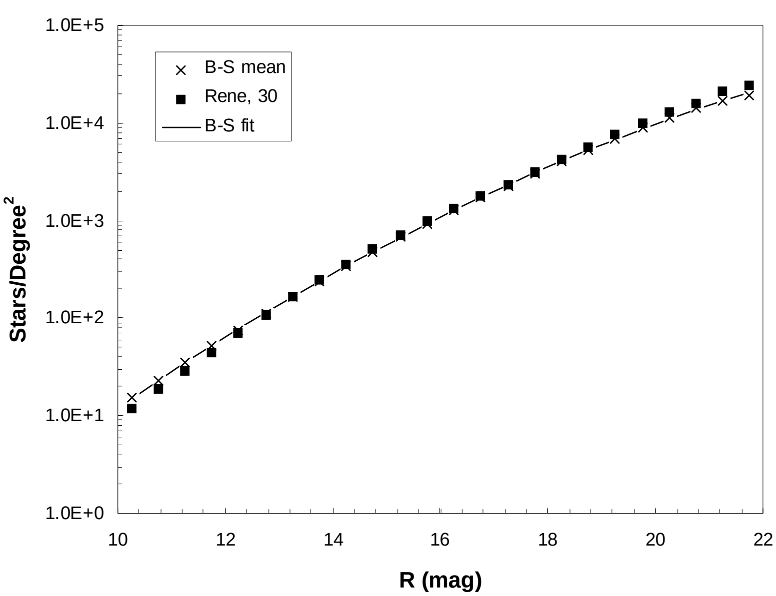

Figure 3 - The all-sky average is plotted (crosses) against a quadratic fit (line) explained in the text and the relation expressed by Rene Racine (solid boxes) at the March 1995 A&G/AOSWG. In the magnitude range of interest, the scaling relation used by Rene appears to be a good fit to the Bahcall-Soneira model all-sky average.