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DOCUMENT

Estimating the astrophysical point source contamination in the EChO field of view

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1. INTRODUCTION

The goal of this document is the estimate of the contamination due to astrophysical point sources falling in the EChO field of view. In order to evaluate the contamination as a function of the radius of EChO field of view (FoV), we may adopt two different approaches:

- A detailed target-based approach by counting the objects around each target. This can be done only after the definition of the "true" final target list.
- A statistical approach based on galactic models or source counts, able to predict the average number of sources at a given magnitude expected in a given sky direction

In this phase of the mission we adopt the latter method, that will be useful to estimate the contribution of very faint sources merging in a "diffuse" background. In a more advanced phase will be important to adopt the first approach.
In the following we will adopt a stellar count model to estimate the star contribution, while we will use observed star counts to evaluate the extragalactic source contribution.
In both cases, we find that, on average, contaminating sources may be very few, especially at the bright end of logN-logS and for small FoVs, therefore we run a large number of simulations to evaluate the effects of fluctuations. In the following we report the results for different sizes of FoV: circles with radius of 0.1', 0.5', 1', and 2'.

2. STELLAR CONTRIBUTION

We use a Milky Way model that describes the stellar populations in the entire Galaxy. Since most of the contaminants may be far away, they will be distributed following the galactic population spatial distribution, therefore with a strong dependence on galactic latitude. For this reason we will analyze two directions at different latitudes: 15° and 59°. For our analysis we use the Besançon model, available at http://model.obs-besancon.fr/. This is a model for stellar population synthesis in our Galaxy and may include dynamical and evolutionary aspects. The description of the model may be found in Robin et al. (2003, A&A, 409, 523). It derives from the original paper of Robin & Creze, (1986 A&A 157, 71).
The model takes into account the populations of the thin disc, thick disc, spheroid, and bulge. Each component has its own spatial distribution (different scale height and density), Initial Mass Function, evolutionary tracks and metallicity. The spatial distribution of the thin disc is self-consistent with the potential of the Galaxy. The extinction is modelled by a diffuse thin disc, following an Einasto ellipsoid of eccentricity 0.014, and its value may be modified by the user. The model is quite complete and may adequately predict the average properties of the Galaxy, while cannot account for local fluctuations and it is not well suited for specific predictions on the Galactic Plane direction.

We ran the Besancon Milky Way model in two different directions (lat=59^o, long=200^o) and (lat=15^o, long=200^o)[1], with the default parameters, predicting the stars with K < 25 expected in one square degree (then scaled to the required area). The output is a Monte Carlo simulation of a catalog of stars expected in the chosen direction, including several parameters for each star, in particular distance, magnitudes and colors. From these values we built the expected cumulative distributions (number of stars brighter than a given magnitude) for B, V, I, K magnitude (Johnson – Cousins system - the available photometric bands in the output of the model). The results for both directions are reported in Figures 1. The most evident result is the strong dependence – a factor of about seven - on latitude (a total of 8093 stars per square degree predicted at lat=59^o vs. 55003 stars at lat = 15^o - with K < 25) and the deviation from the spherical distribution due to the scale heights of the stellar populations, clearly present at any latitude. The plots show also that, since the cumulative distributions flattens at the adopted limiting magnitude (K < 25), the contribution of fainter stars is negligible.
From such distributions it is possible to determine what is the density of stars with magnitude comparable with that of a given target, the density of stars one order of magnitude fainter (Δ(magn)=2.5) in a given band, or the integrated flux due to the stars fainter than a given magnitude and so on.
The plots in Figure 1 show the number of expected stars per arcmin^2, therefore, in principle, the average number of expected stars as a function of the radius of the FoV could be obtained simply scaling by the area of the aperture. However since there are only a handful of stars in the FoVs we are considering, we expect that fluctuations will dominate in real cases. This aspect is further enhanced since, because of the deviation from the spherical distribution, the major contribution to the integrated flux is due to the brightest stars, that are very few.

[1] The predicted numbers are very weakly dependent on galactic longitude.

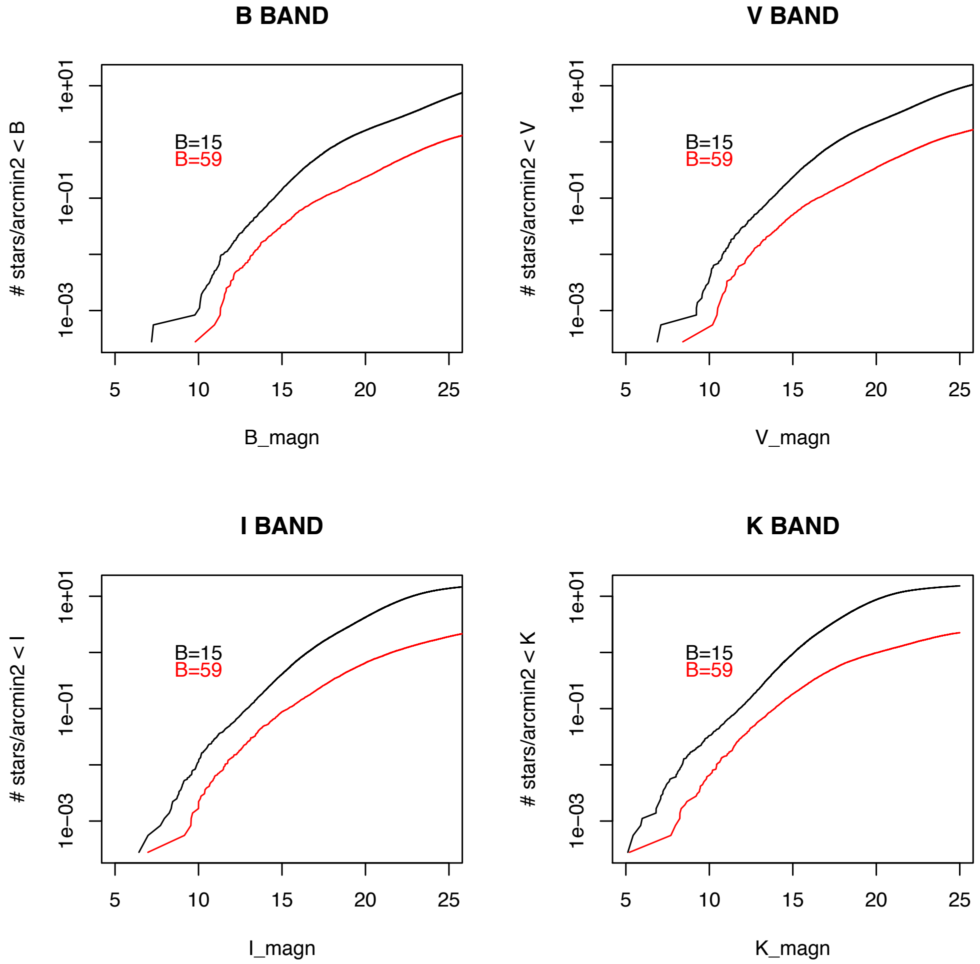

Figure 1: *Cumulative distribution of expected star density (number per square arcmin) brighter than a given magnitude as computed by the Besancon model in two sky directions (lat=15°, lat=59° , long=200o) .*

Figures 2 show the cumulative distributions of star density as a function of flux expressed in mJy. To derive flux from magnitude, we used the zero-points reported in Lada et al (2006 , AJ, 131, 1574).

In order to estimate the average surface brightness in K and bluer bands, we have summed up the model-computed flux of simulated stars. For redder bands, since the public version of the Besancon Model does not predict infrared magnitudes M(Spitzer), we have assumed for all the stars that:

$$K - M(Spitzer)=0.$$

This is a reasonable assumption for all “normal” stars , since the vast majority of stars in the Galaxy do not have any excess above photospheric flux. Finally using the zero points reported by Lada et al. (2006) also for these bands we obtain the average surface brightness in eight bands from B to 8μ, as reported in table 1.

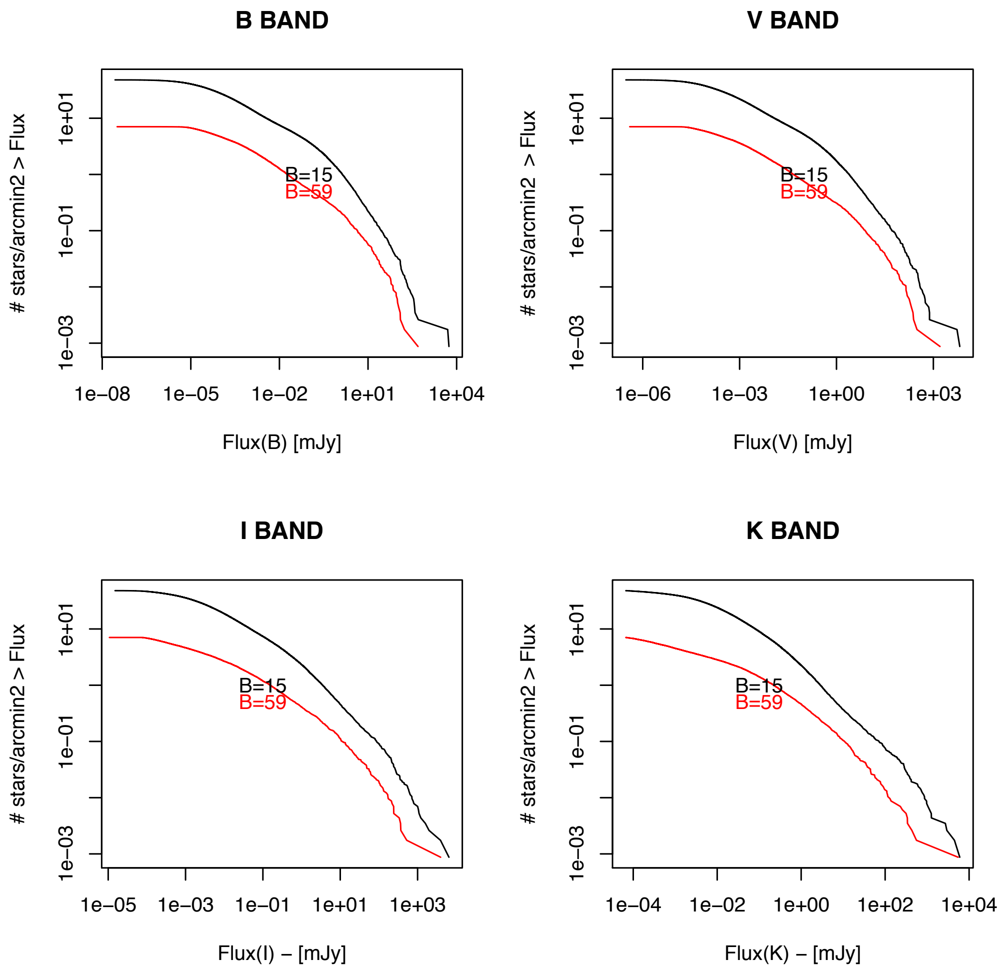

Figure 2: *Cumulative distributions of star density as function of observed flux [mJy] in B, V, I, and K bands.*

Table 1: *Average stellar contribution to the surface brightness [mJy/arcmin²]*

Band ------- Latitude	B	V	I	K	3.6μ	4.5μ	5.8μ	8.0μ
15°	7.831	12.370	17.537	17.910	7.533	4.814	3.084	1.720
59°	1.027	2.094	3.559	3.757	1.580	1.010	0.647	0.361

Since the number of sources per arcmin is small – in particular at the bright end of logN-logS - we expect significant spatial fluctuations of the stellar contribution. In order to evaluate the typical amplitude of the fluctuations we simulated 100,000 possible realizations, drawing from the catalogue generated by the Besancon model a random number of sources following a Poisson distribution centred on the resulting expected average number of sources scaled to the chosen FoV (a circle of 1 arcmin of radius). For each of such simulations we compute the integrated surface brightness. The 10%, 50%, 90% quantiles of the derived distributions for each band are reported in Tables 2a and 2b, for latitude 15° e 59°, respectively.

Table 2a: *Quantiles of distributions of the stellar contribution to surface brightness for several bands at lat=15° in a field of view of 1 arcmin of radius (flux in mJy)*

Quantile	B	V	I	K	3.6	4.5	5.8	8.0
10%	0.671	1.438	2.888	3.364	1.415	0.904	0.579	0.323
50%	3.998	7.364	11.408	10.261	4.316	2.758	1.767	0.985
90%	32.051	61.267	95.359	76.718	32.270	20.621	13.211	7.367

Table 2b: *Quantiles of distributions of the stellar contribution to surface brightness for several bands at lat=59° in a field of view of 1 arcmin of radius (flux in mJy)*

Quantile	B	V	I	K	3.6	4.5	5.8	8.0
10%	0.003	0.008	0.028	0.037	0.016	0.010	0.006	0.004
50%	0.067	0.163	0.474	0.657	0.277	0.177	0.113	0.063
90%	4.371	7.923	12.133	11.448	4.815	3.077	1.971	1.100

The comparison between the values in tables 2 with the average values reported in table 1 shows that average values are much higher than the typical values obtained by simulation of relatively small fields (note that the table 2 refers to an area=π sq. arcmin, while table 1 reports the brightness per sq. arcmin). This occurs because of the spatial fluctuations are very significant, since the average contributing flux is dominated by a small number of very bright sources that only rarely fall in the (small) EChO field of view, giving origin to very broad and asymmetric distributions. This circumstance makes of limited use a simple scaling of surface brightness with the area of the field of view, while it is essential to simulate distributions for specific FoVs. We report in tables 3a and 3b the results of simulations corresponding to FoVs ranging from 0.1 to 2 arcmin of radius. The largest field corresponds to an area for which fluctuations are only moderately relevant, while the smallest fields are subject to large fluctuations and correspond to realistic EChO FoV.

Table 3a: *Quantiles of distributions of the stellar contribution to surface brightness for several bands at lat=15° for several field of view sizes (flux in mJy).*

FoV	Quantile	B	V	I	K	3.6	4.5	5.8	8.0
	10%	10.474	19.718	31.601	29.637	12.467	7.966	5.104	2.846
2’	50%	31.602	59.563	89.010	74.352	31.275	19.985	12.804	7.140
	90%	155.109	277.066	427.034	441.031	185.513	118.546	75.949	42.353
	10%	0.671	1.438	2.888	3.364	1.415	0.904	0.579	0.323
1.’	50%	3.998	7.364	11.408	10.261	4.316	2.758	1.767	0.985
	90%	32.051	61.267	95.359	76.718	32.270	20.621	13.211	7.367
	10%	0.009	0.030	0.126	0.219	0.092	0.059	0.038	0.021
0.5’	50%	0.286	0.600	1.166	1.308	0.550	0.352	0.225	0.126
	90%	5.084	9.093	13.073	10.254	4.313	2.756	1.766	0.985
	10%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1’	50%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	90%	0.003	0.011	0.045	0.077	0.032	0.021	0.013	0.007

Table 3b: *Quantiles of distributions of the stellar contribution to surface brightness for several bands at lat=59° for several field of view sizes (flux in mJy).*

FoV	Quantile	B	V	I	K	3.6	4.5	5.8	8.0
	10%	0.177	0.423	1.197	1.628	0.685	0.438	0.280	0.156
2’	50%	2.467	4.773	8.426	8.527	3.587	2.292	1.468	0.819
	90%	29.143	54.386	78.816	63.511	26.715	17.0712	10.937	6.099
	10%	0.003	0.008	0.028	0.037	0.016	0.010	0.006	0.004
1’	50%	0.067	0.163	0.474	0.657	0.277	0.177	0.113	0.063
	90%	4.371	7.923	12.133	11.448	4.815	3.077	1.971	1.100
	10%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.5’	50%	0.001	0.003	0.010	0.013	0.005	0.003	0.002	0.001
	90%	0.213	0.472	1.025	1.254	0.527	0.337	0.216	0.120
	10%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1’	50%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	90%	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000

The results reported in the previous tables may be visualized in Figures 3, where we report the 10%, 50%, and 90% quantiles vs. the radius of the field of view for the analyzed bands. The plots show clearly that fluctuations dominate the distributions, that are very broad (large differences between 10% and 90% percentiles), in particular for very small fields of view, and that the dependence of the quantiles curves vs. FoV radius deviate from the behavior expected in the case of high spatial density source distribution (simple scaling with area of the FoV as indicated by the slope of solid-line segment). In particular, for small FoVs the median value of the flux falls well below the extrapolation based on homogenously spatially distributed sources (corresponding to large FoVs). This is especially relevant for high latitude fields, where the main contribution come from brightest tail, because stellar distribution reaches the scale height at high flux.

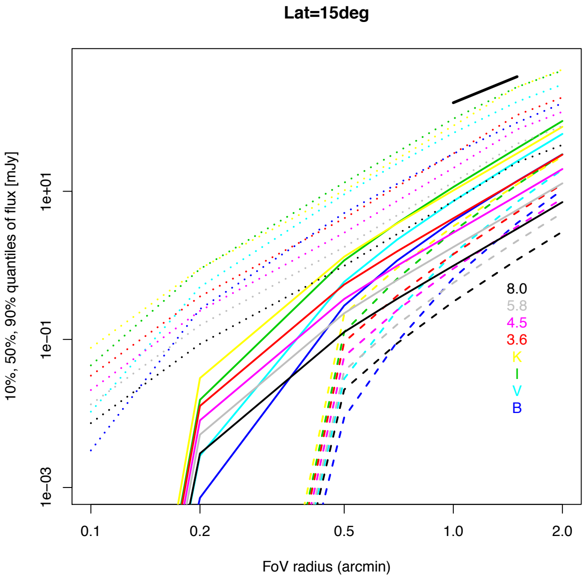

Figure 3a): *10% (dashed line), 50% (solid line), and 90% (dotted line) percentiles of the simulated distributions of stellar flux integrated in a given FoV. Bands are coded with different colors as in legend. Short solid segment (arbitrary offset) indicates the expected shape for high stellar density (flux proportional to FoV area)*

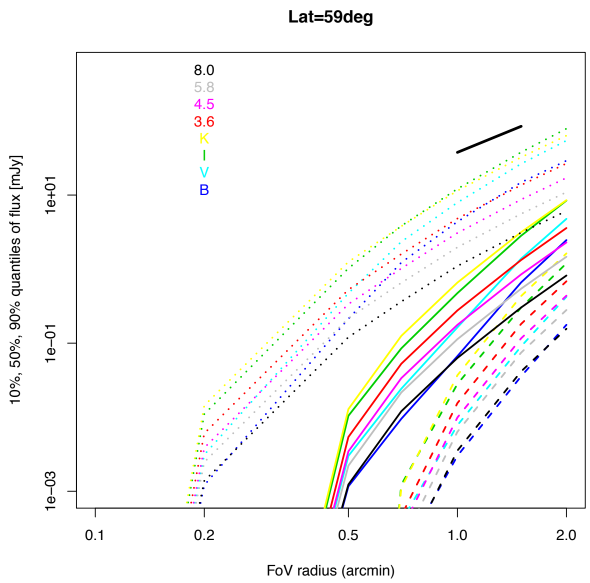

Figure 3b) *as Figure 3a) for the high latitude field.*

3. EXTRAGALACTIC CONTRIBUTION

On first approximation, the extragalactic contribution is independent from galactic latitude. In order to estimate the surface density in Spitzer IRAC bands we have used the differential counts derived from Fazio et al. (2004, ApJS 154, 39) that analyse three surveys with different depth and size in order to estimate the source counts in a large range of magnitudes. In the following, we consider the extragalactic source counts reported in Table 1 of Fazio et al. paper, adopting counts from Bootes survey for the brightest magnitudes and the average of the EGS and QSO 1700 surveys for the faintest range.
By integrating the flux in the entire magnitude range, corrected for incompleteness as evaluated in Fazio et al. (2004), we obtain the following surface brightness:

Table 4: ***Average extragalactic contribution to the surface brightness [mJy/arcmin²]***

3.6μ	4.5μ	5.8μ	8.0μ
0.507	0.428	0.413	0.441

The average contribution of extragalactic sources reported in table 4 represents quite well the expected contribution except for very small FoV. In fact the typical density of extragalactic sources originating the surface brightness is higher than in the stellar case, producing moderate size distributions. Our simulations show that the ratio between the 90% and 10% percentiles is in the 1.5 - 5 range, with the largest value (a factor of five) for the FoV down to 0.2 arcmin and band 8μ, as shown in Figure 4. For smaller fields of view the extragalactic contribution in the reddest bands is also subject to large fluctuations, with most of the fields with negligible contaminating flux.

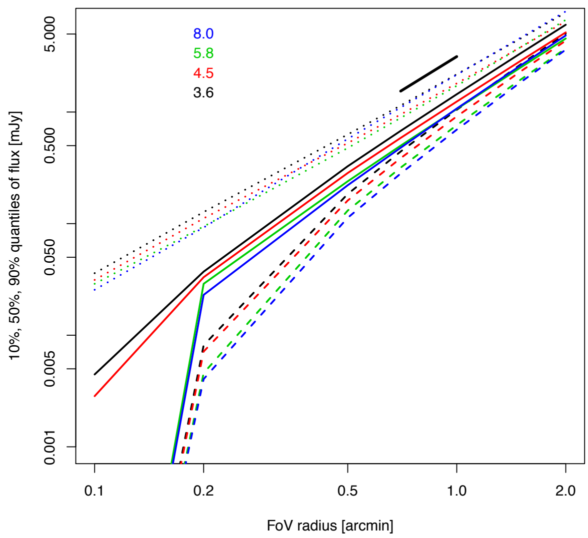

Figure 4: *10% (dashed line), 50% (solid line), and 90% (dotted line) percentiles of the simulated distributions of extragalactic flux integrated in a given FoV. Bands are coded with different colors as in legend. Short solid segment indicates the expected shape of a contribution proportional to area of FoV.*

4. CONCLUSIONS

The analysis reported above shows that at high latitude, in most of cases (more than 50%) the extragalactic contribution dominates from a large factor (up to 180) for small FoVs, to few units for the largest FoV. On the contrary at low latitude the stellar contribution dominates the extragalactic one, by a factor between two and five, except than for the reddest bands where the two contributions are comparable. The situation is more complex considering the extreme values of the distributions, in which mainly of the stellar contribution may become very high.

The flux at low latitude scales quite linearly with the area of the FoV except that for very small FoV, while at high latitude is dominated by stellar density spatial fluctuations with a small fraction of the cases with high flux and many more with low flux, specially for small FoV. The extragalactic flux shows an analogous behaviour for very small FoV. Such behaviour make more convenient the adoption of a small FoV, for which the integrated flux is in the large majority of cases smaller than the average value.

Acknowledgements
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