# Predicted deep NIR starcounts for the NGST GS system

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**Abstract**

The design of a Guide Star system must guarantee a sufficient probability of acquiring within its field of view a star brighter enough to provide a SNR adequate to the guiding in terms of position accuracy, under the constraints defined by the astrophysical properties of the targets.

In this regard, deep optical/NIR starcounts produced by means of Galactic models for low density fields at high galactic latitudes are presented here, in order to define the requirements of the NGST GS system.

NGST

# Galaxy models

Theoretical starcounts were produced by means of two independent Galaxy models:

- the model of stellar population synthesis of the Galaxy developed at the Observatory of Besançon (Robin & Crèzè 1986)
- the Galactic Structure and Kinematics model (Mendez & van Altena 1996)

These models describe the galactic stellar populations by a set of discrete components, each defined by a particular spatial and kinematical distribution, as well as by a specific Luminosity Function and HR diagram. Initially, the *default* parameters of both the models were adopted.

Figures 1, 2 and 3 show the resulting distribution toward the North Galactic Pole (NGP).

| Component | Parameter | Mendez | Besançon |
|---|---|---|---|
| **Thin disk** | Distribution | Exp(R,z) | Exp(R,z) |
| | $h_z$ (pc) | $M_V$ function | age-function |
| **Thick disk** | Distribution | Exp(R,z) | Exp(R,z) |
| | $h_z$ (pc) | 1400 | 760 |
| | $\rho/\rho_0$ | 2 % | 4.6 % |
| | Luminosity Function | 47 Tuc | 47 Tuc |
| | Color-Magnitude | 47 Tuc | 47 Tuc |
| **Halo** | Distribution | De Vaucouleurs | 3.1 Power Law |
| | $\rho/\rho_0$ | 0.2 % | 0.5% |
| | c/a | 0.8 | 0.6 |
| | Luminosity Function | M3 | Glob. Clusters |
| | Color-Magnitude | M3 | M3 |

Table 1: Parameters of the Galaxy models

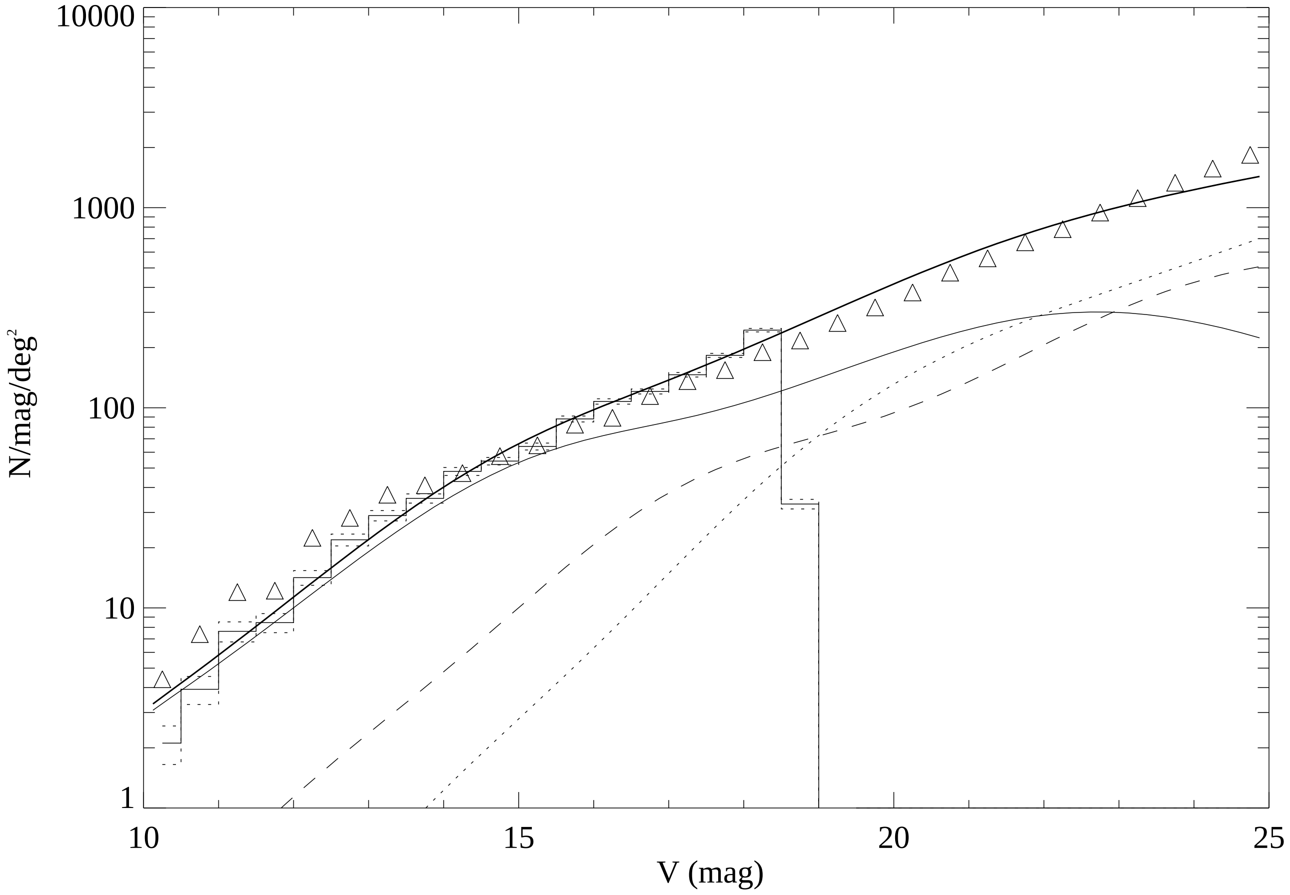


Figure 1: Starcounts at NGP. Observed GSC2 data from Spagna et al (1996) (histogram), Besancon model (triangles), Mendez model (thick solid line). The thin solid line, the dashed line and the dotted line show respectively the contribution from the thin disk, thick disk and halo stars for the latter model.

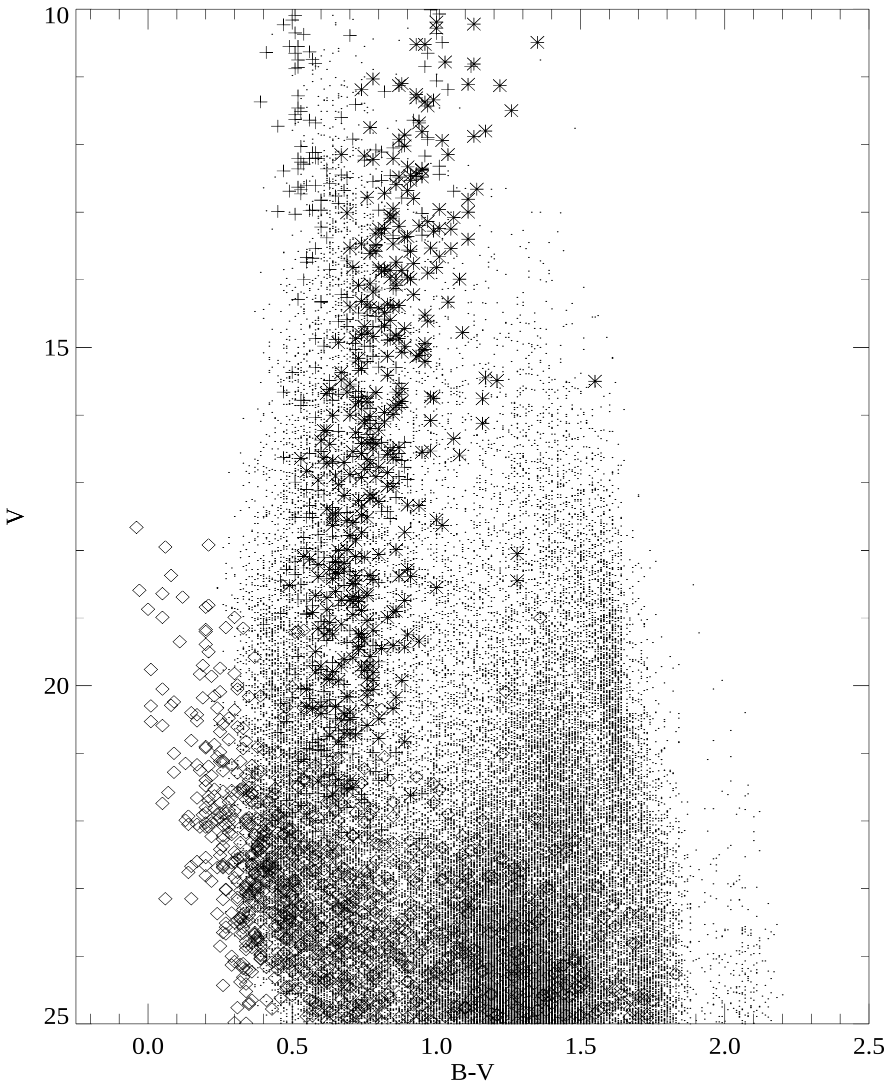


Figure 2: CM diagram of the synthetic catalog in a 10 square degrees field at the NGP from the Besançon model, including 56 201 dwarfs (dots), 359 giants (stars), 328 subgiants (crosses), and 1049 white dwarfs (diamonds) brighter than V=25 mag.

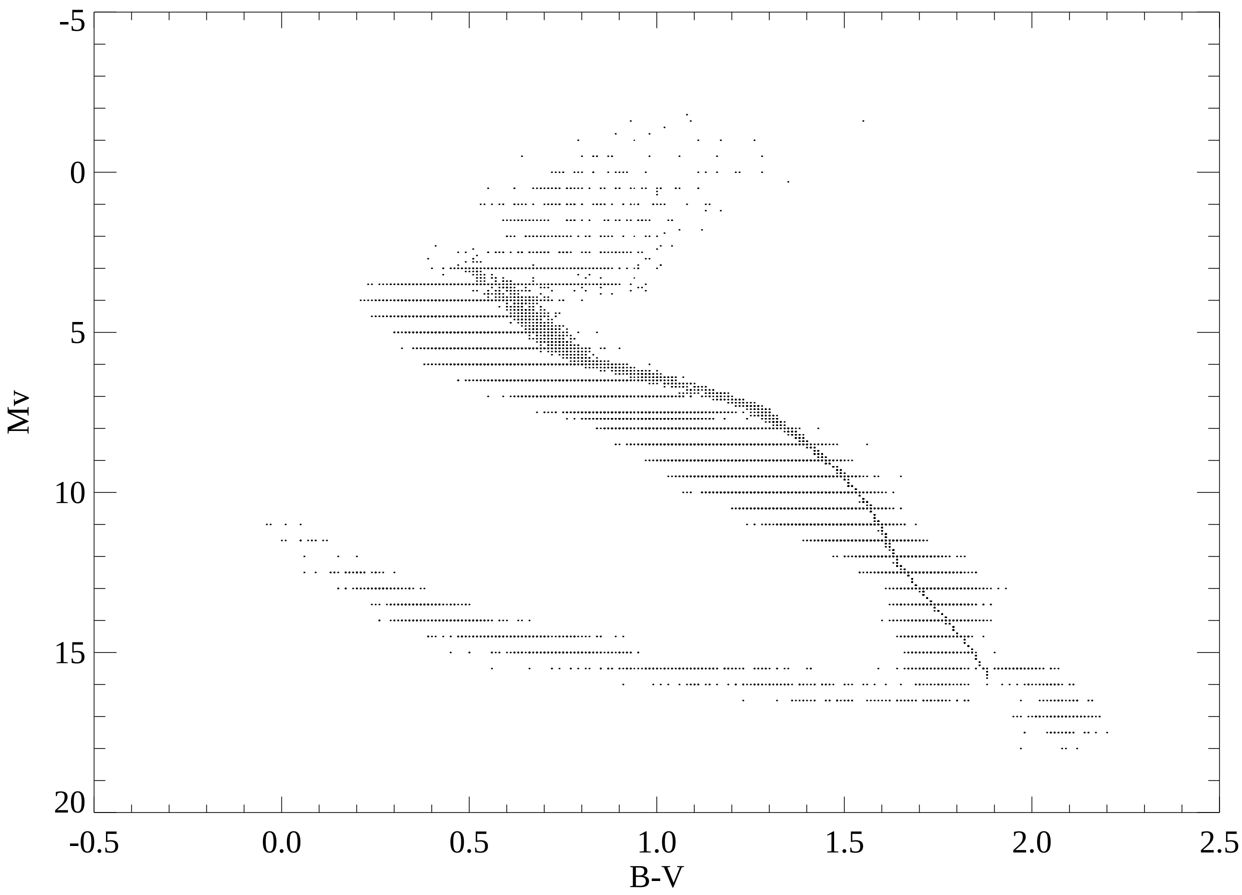


Figure 3: HR diagram of the synthetic catalog (the same as Fig. 2) at the NGP for stars brighter than V=25 mag.

# Model extension to the NIR filters

As both the models do not currently provide magnitudes for filters with effective wavelenghts greater than 1 $\mu$m, appropriate *color transformations* were applied in order to derive counts in the Johnson NIR filters:

- J ($\lambda_0 = 1.2$ $\mu$m, $\Delta\lambda = 0.3$ $\mu$m )
- K ($\lambda_0 = 2.2$ $\mu$m, $\Delta\lambda = 0.6$ $\mu$m )

$V - K$ and $V - J$ color tables as a function of spectral type for Luminosity Class V and III were adopted from Straizys (1992). Such colors were directly applied to the individual stars of the synthetic catalogs produced by the Besançon model, while in the case of the Mendez model the $B - V = f(V - K)$ function was directly included in the code. Moreover the presence of extinction $A(J) \simeq 0.86E(B - V)$ and $A(K) \simeq 0.35E(B - V)$ was taken into account by the color transformations, although the total absorption is negligible for the particular high galactic latitude fields presented here. The study and use of more sophisticated color tables, depending also on the stellar metallicity, is in progress.

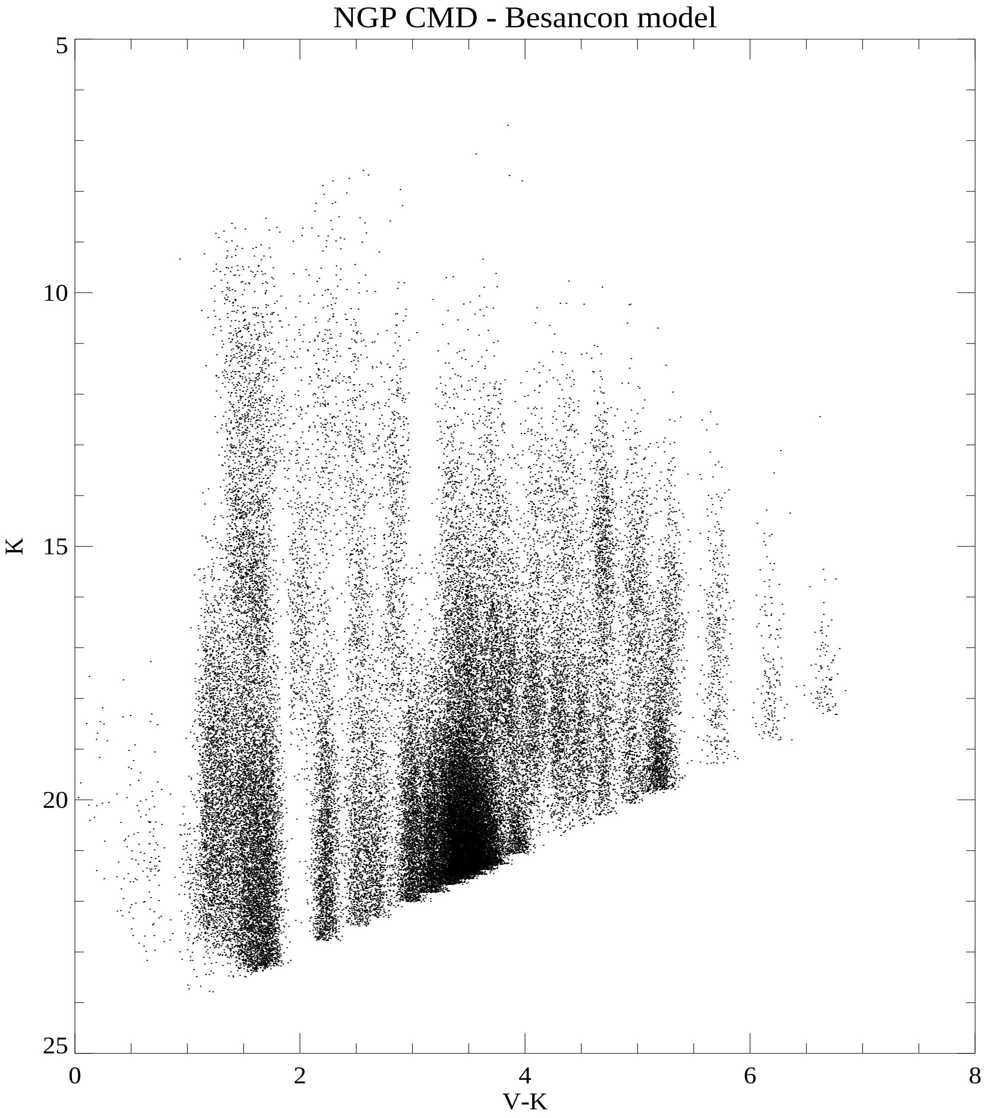


Figure 4: CM diagram of the synthetic catalog (the same as Fig. 2) extended to K mags at the NGP for stars brighter than V=25 mag.

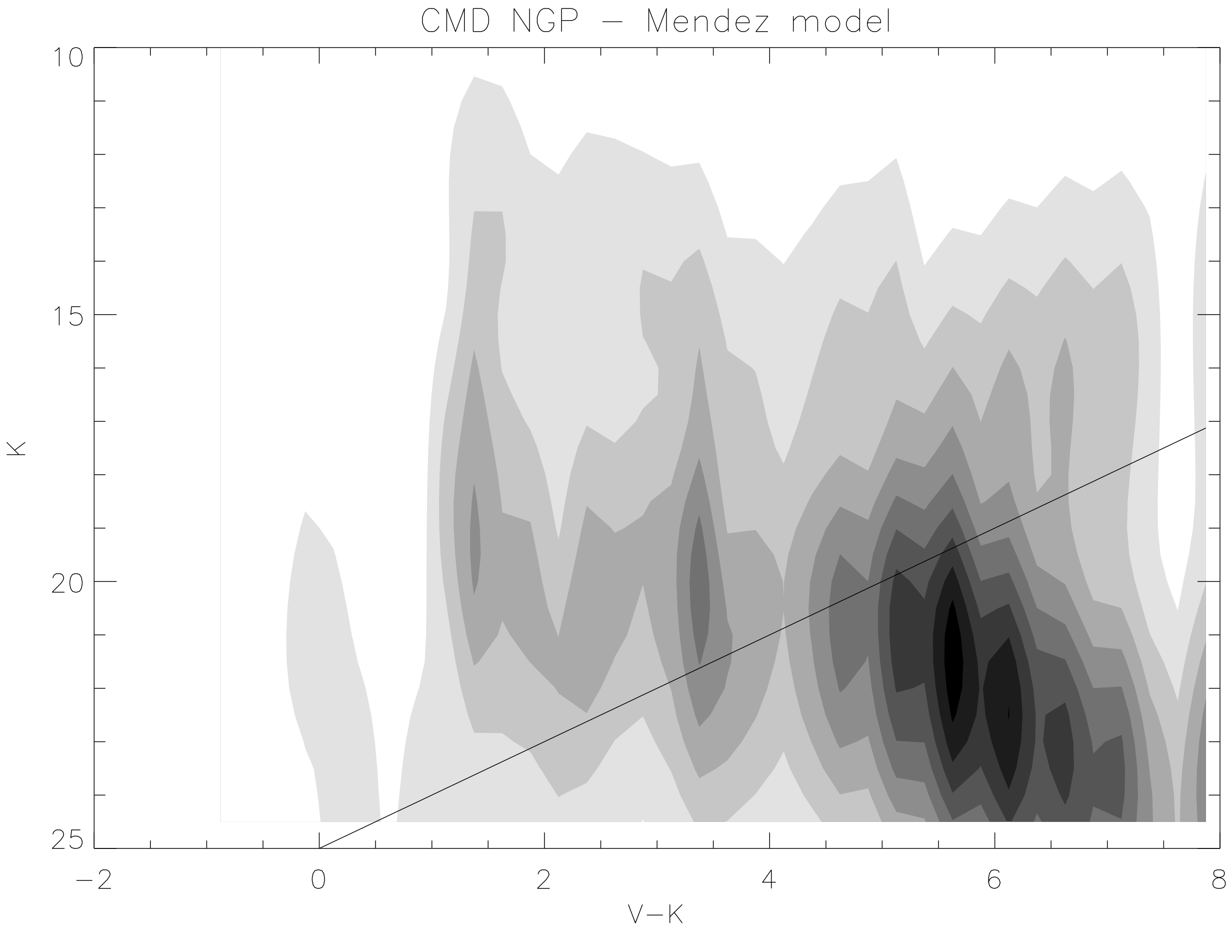


Figure 5: CM diagram at the NGP from the Mendez model extended to K mags. The straight line indicates the magnitude limit ($V \leq 25$) of the Besançon catalog shown in the previous figure.

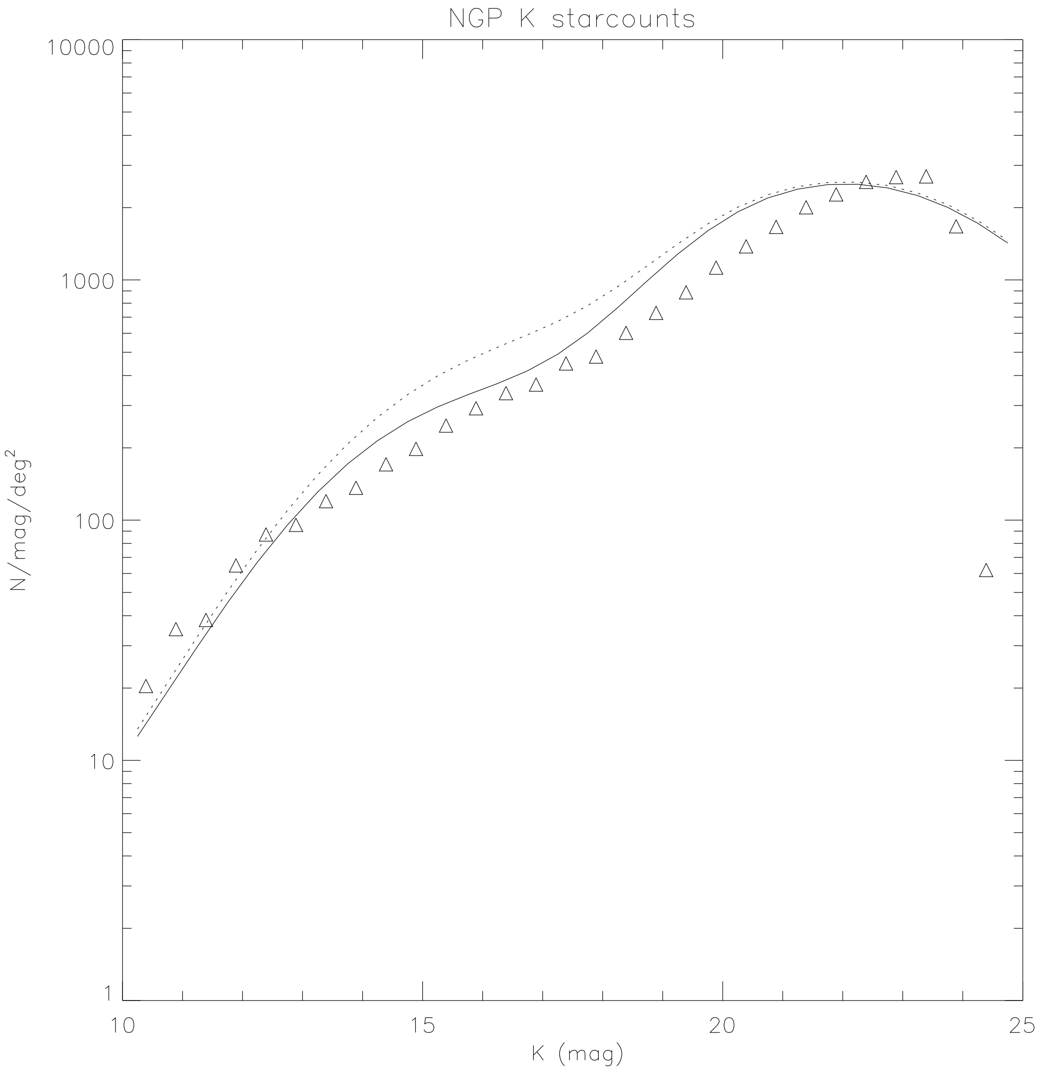


Figure 6: Differential $K$ starcounts at the NGP. Mendez model with original thin disk Luminosity Function (dotted line) and a new LF with less late type stars (solid line) compared with the Besançon model (triangles).

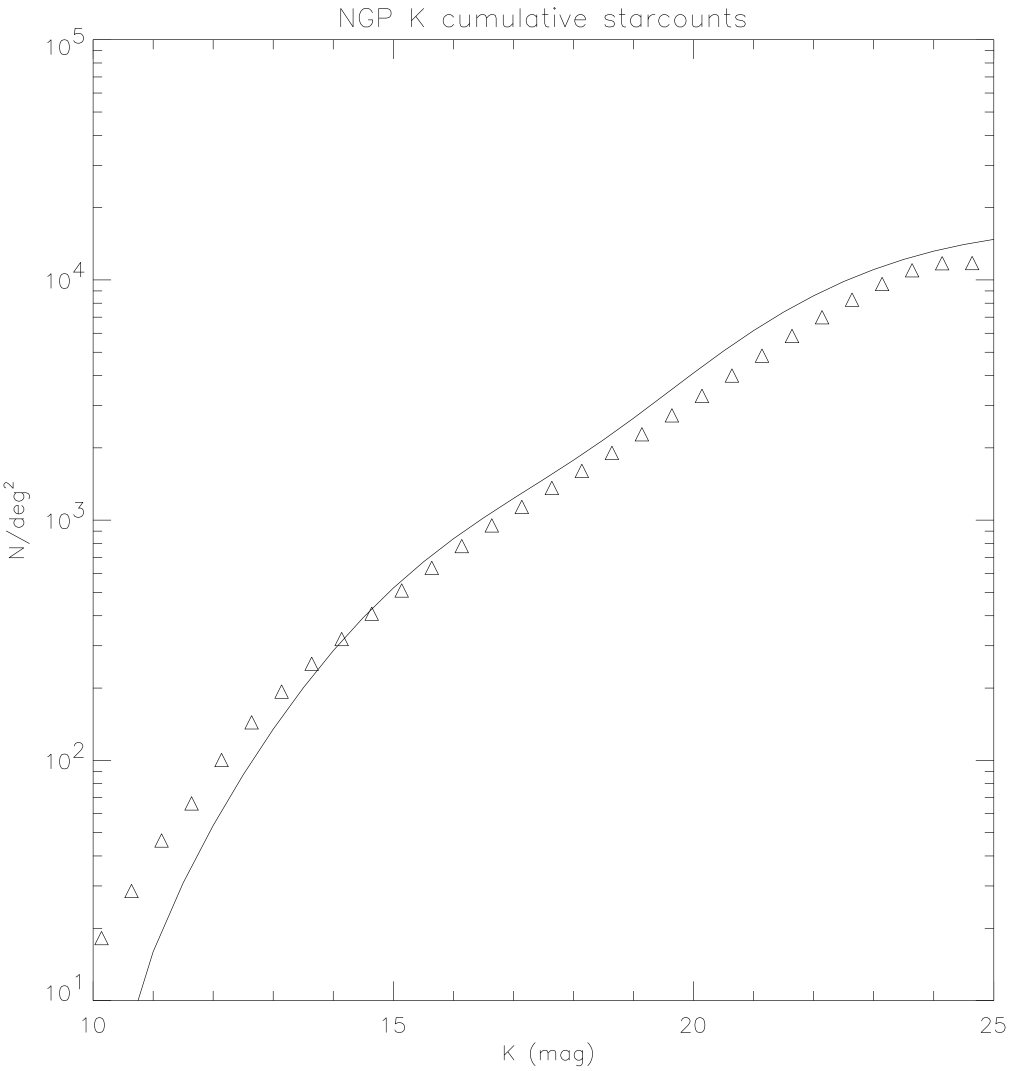


Figure 7: Cumulative $K$ starcounts at the NGP. Mendez model (solid lines), and Besançon model (triangles) extended to the NIR filters.

# Comparison with EIS data in the HDF South

Model predictions were also compared with deep optical and infrared data from ESO NTT. In particular, we used the catalogs containing JHK photometry down to $K \approx$24 mag at a $2\sigma$ level from the *Deep* EIS fields (da Costa 1999) located toward the Hubble Deep Field South ($b = -49^\circ$), and covering about 43 square arc-minutes (HDF1+HDF2).

$\Rightarrow$ The Mendez model shows a slightly better agreement to the EIS data down to $K \simeq 18$ with respect to the Besançon model, while the overestimation at $K \approx 20$ mag with respect to the observed data could suggest an excess of halo stars in this model.

$\Rightarrow$ The drop of Besançcon counts for $K > 20$ is not significant, as it depends on the brighter magnitude limit of this catalog (cfr. fig. 4).

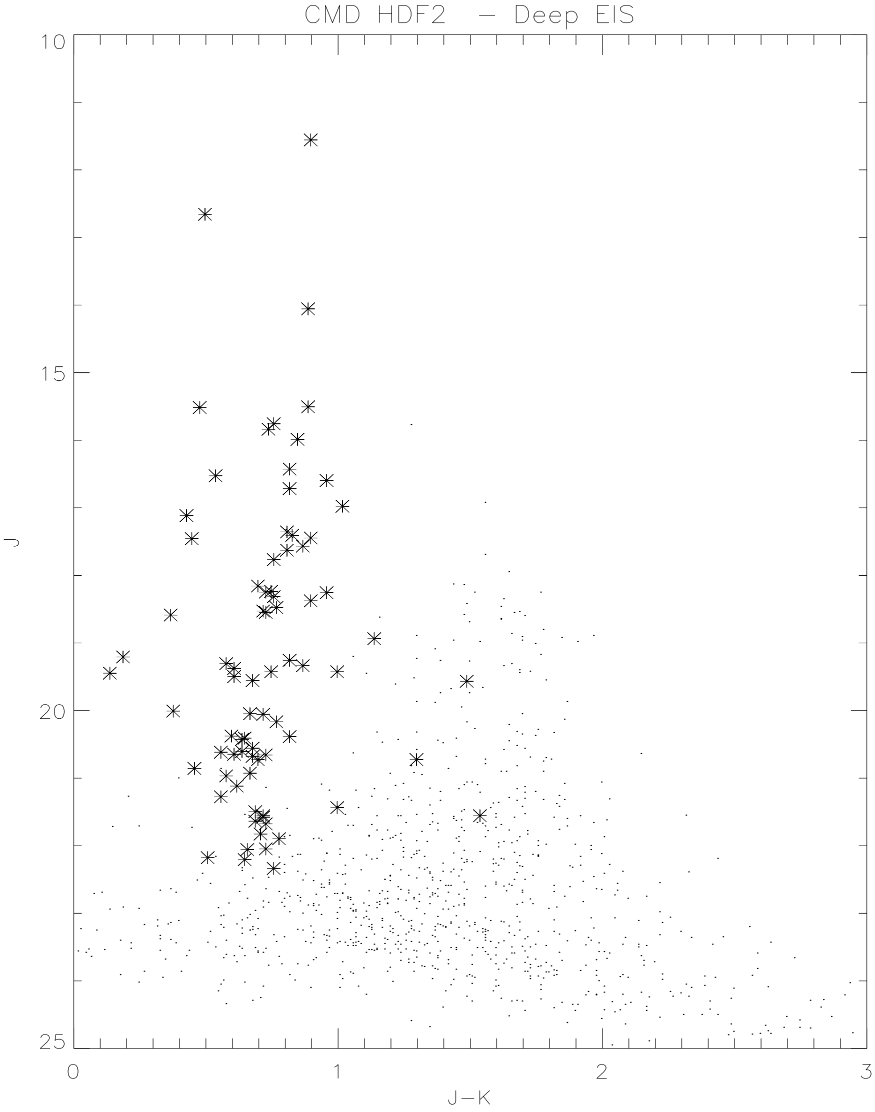


Figure 8: CM Diagram of EIS data (HDF2) in the HDF South. Dot and Star symbols represent objects classified as non-stellar and stellar sources respectively.

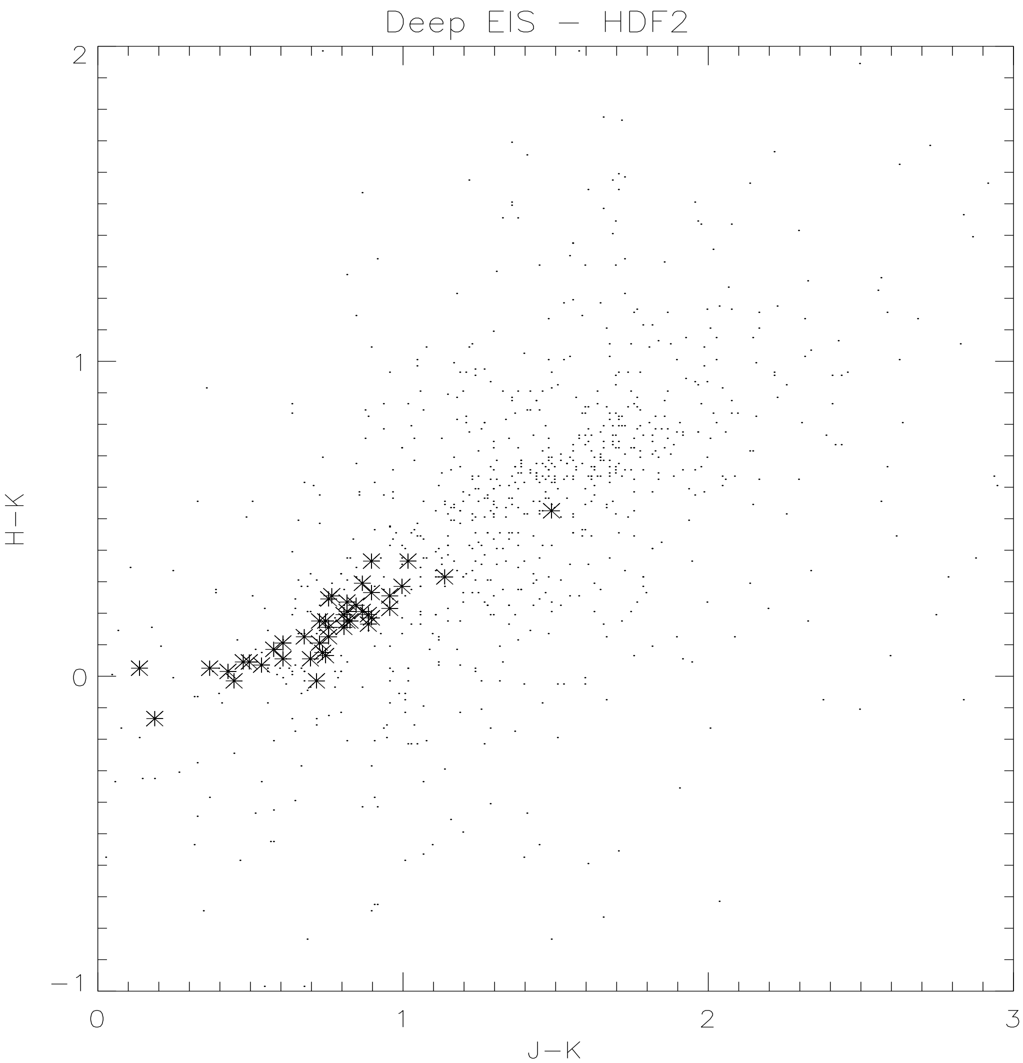


Figure 9: Color-Color Diagram of EIS data (HDF2) in the HDF South. Dot and Star symbols represent objects classified as non-stellar and stellar sources respectively.

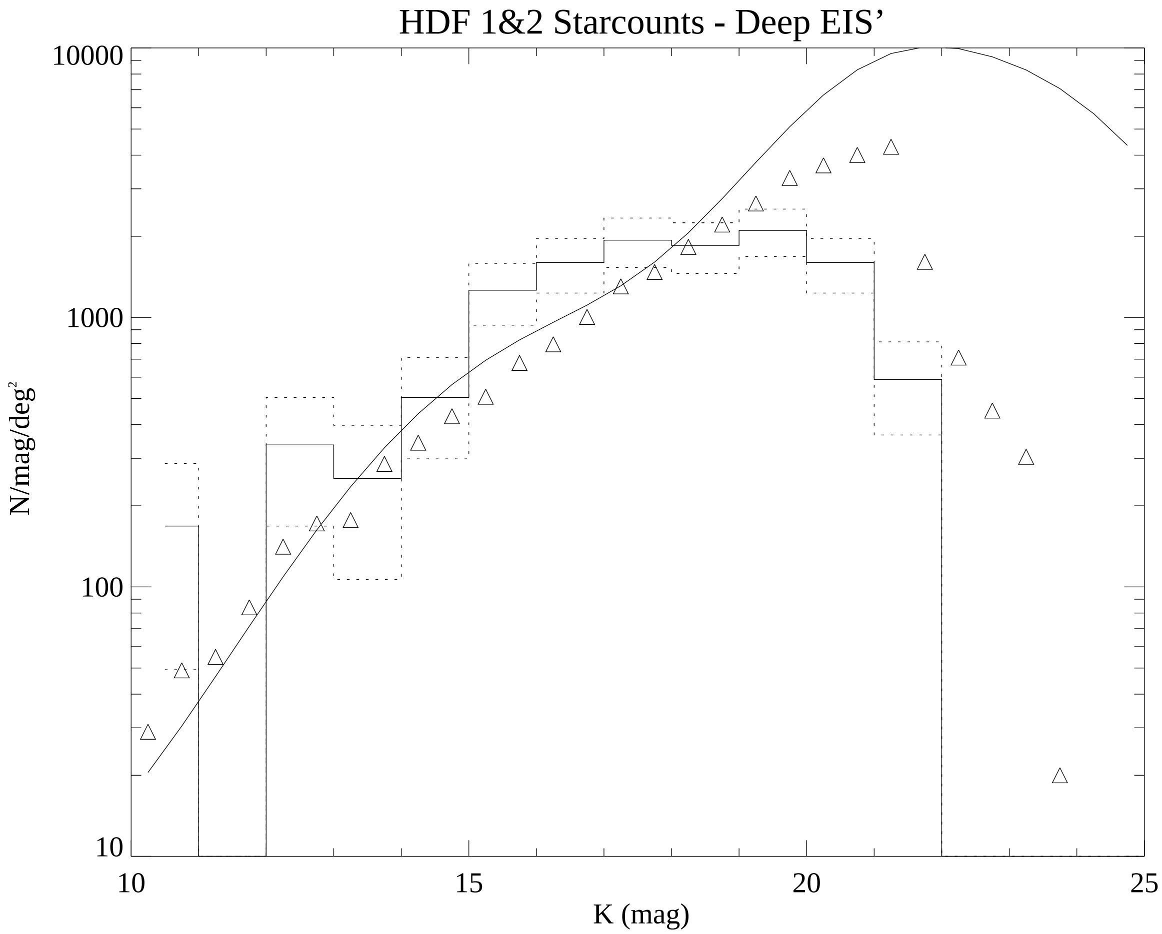


Figure 10: K starcounts in the HDF South. The histogram shows the observed counts from the Deep EIS fields (HDF1+HDF2), and the dotted lines indicate the $\pm 1\sigma$ poissonian thresholds. The solid line and the triangles represents respectively the distribution predicted by Mendez and Besançon models extended to the IR filters.

# Acquisition probability at the North Galactic Pole

Assuming a GS system area of $\Omega = 4' \times 4'$, corresponding to the whole area of the NIR science field designed for NGST, we evaluated the acquisition probability, i.e. the probability to find at least one GS brighter than a certain magnitude within the detector area $\Omega$.

$\Rightarrow$ A simple *poissonian* statistics was assumed on the basis of the unfavourable NGP counts, neglecting effects of stellar clustering and binarity.

In Figure 11 the cumulative starcounts are shown in the $V_{\rm AB} = V$, $I_{\rm AB} = I + 0.42$, $J_{\rm AB} = J + 0.89$ and $K_{\rm AB} = K + 1.86$. Figure 12 presents the corresponding acquisition probability as a function of the AB and Johnson magnitude.

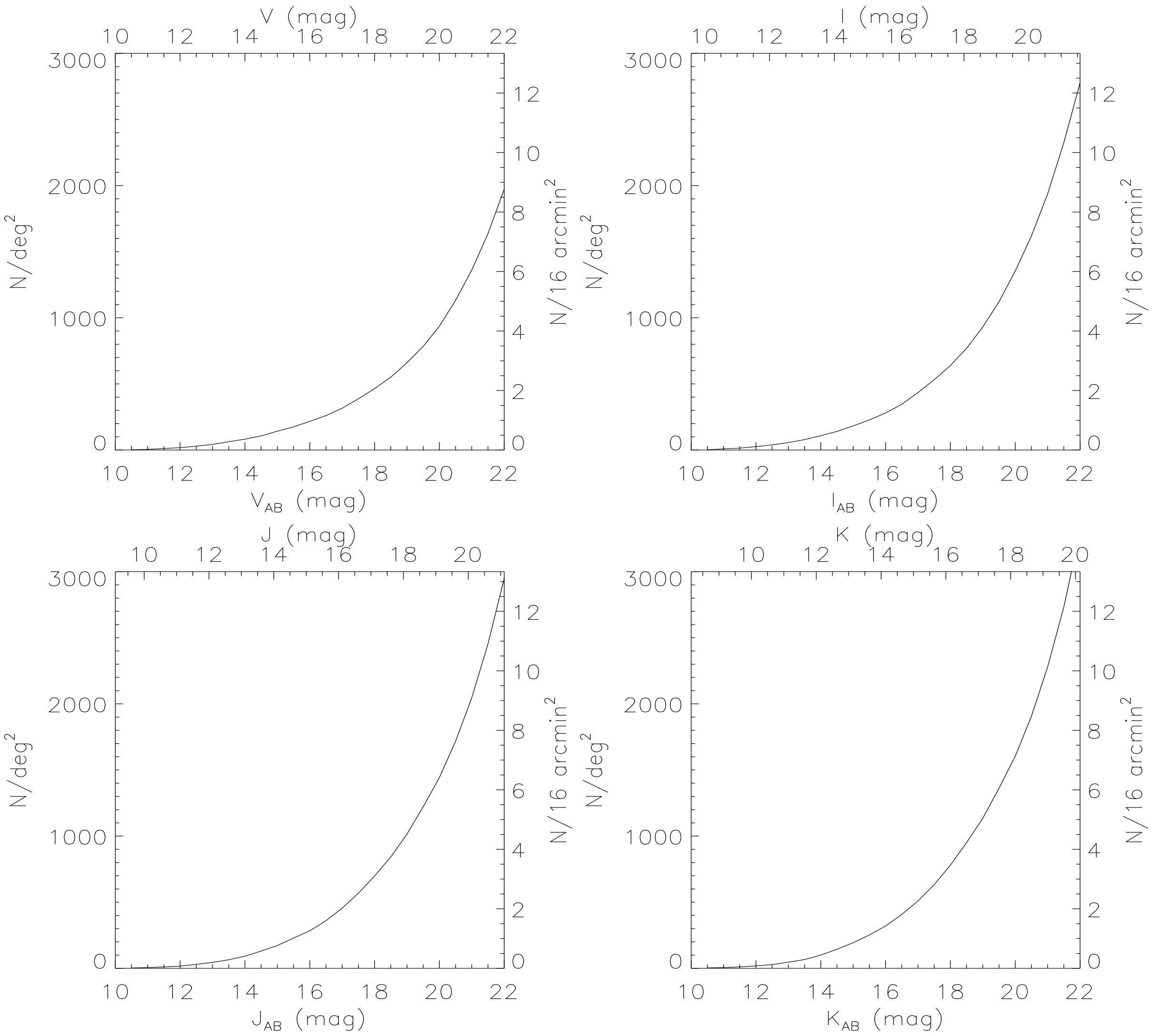


Figure 11: Integral starcounts at the NGP based on Besançon model in the Johnson+AB $VIJK$ filters.

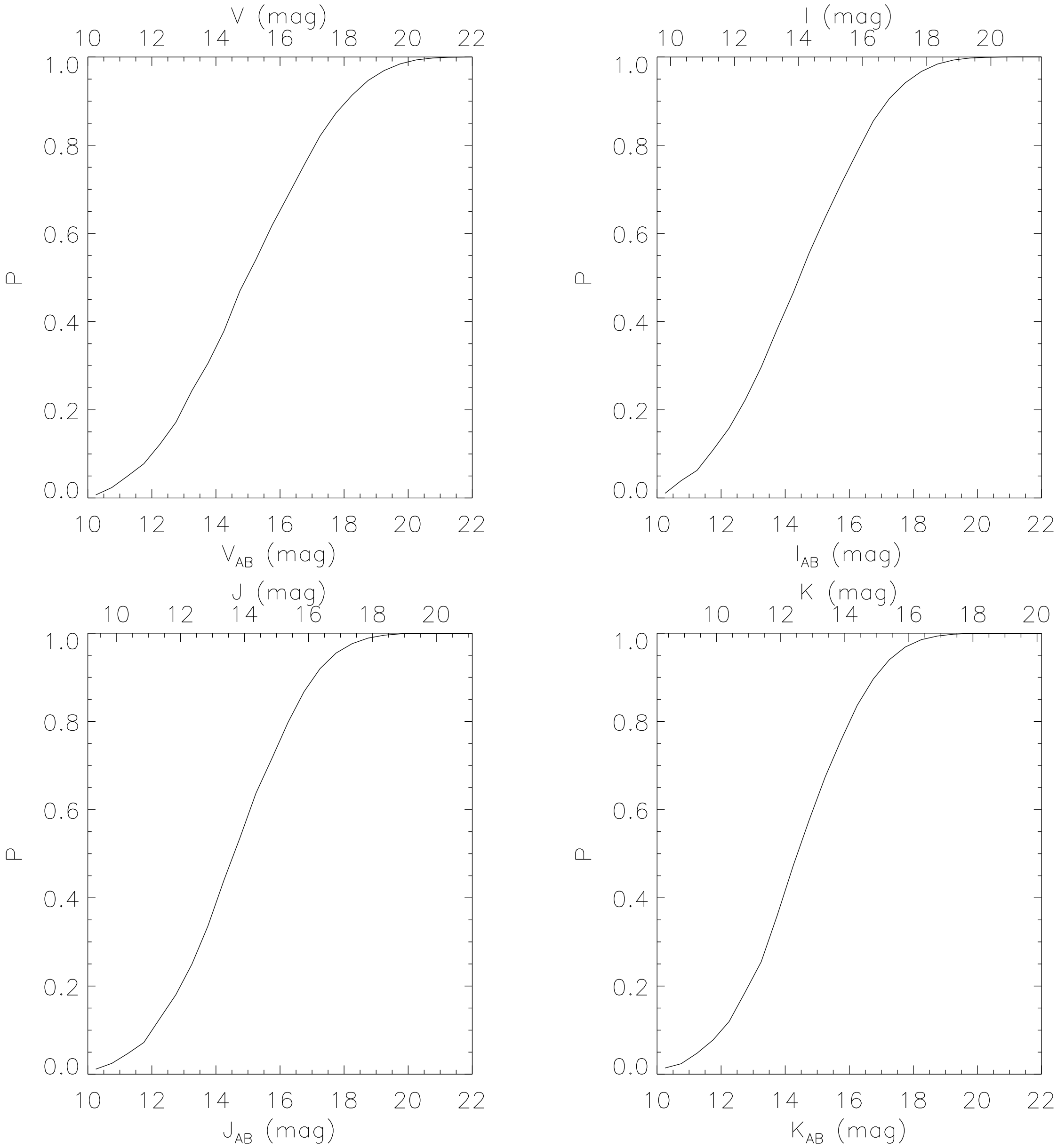


Figure 12: GS acquisition probability for a $4' \times 4'$ detector area in the Johnson+AB $VIJK$ filters.

# GS magnitude limit at NGP/SGP

The brighter magnitude limit for a Guide Star derives from the requirement of the availability of 3 stars on average within a FOV of $4' \times 4'$ which corresponds to 95% probability of observing 1 or more stars.

| | |
|---|---|
| B-S Model ? | $I < 16.5$ |
| Besançon model - NGP | $I < 17.5$ |
| Reid (1982) - SGP Survey | $I < 17.0$ |
| B-S model ? | $K < 15.5$ |
| Besançon model[1] - NGP | $K < 16.0$ |
| Mendez model[1] - NGP | $K < 15.5$ |

[1] Extended to the NIR filters.

# GS magnitude limit at NGP/SGP

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Results from the Besançon model[1]

| | |
|---|---|
| $V < 19$ | $V_{\mathrm{AB}} < 19$ |
| $R < 18.5$ | $R_{\mathrm{AB}} < 18.5\text{-}19$ |
| $I < 17.5$ | $I_{\mathrm{AB}} < 18\text{-}18.5$ |
| $J < 16.5$ | $J_{\mathrm{AB}} < 18$ |
| $K < 16$ | $K_{\mathrm{AB}} < 17.5\text{-}18$ |

[1] Extended to the NIR filters.

# Comparison with GSC2 data

The first release of the Second Guide Star Catalog (GSC2) (Lasker et al. 1995) will contain positions and magnitudes ($B_{\rm J}$ and $R_{\rm F}$) of about $2\ 10^9$ stars down to $R_{\rm F} \simeq 18$.

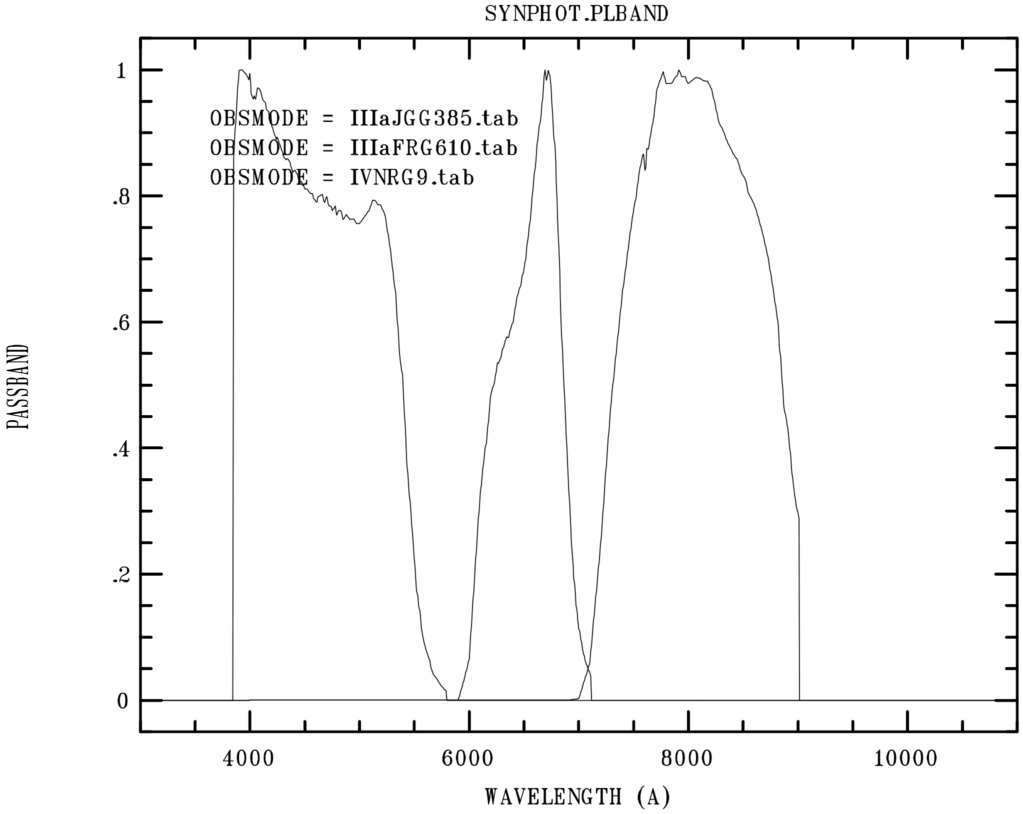


Figure 13: GSC2 photometric system. Transmission of $B_{\rm J}$, $R_{\rm F}$ and $I_{\rm N}$ for POSS-II plate material.

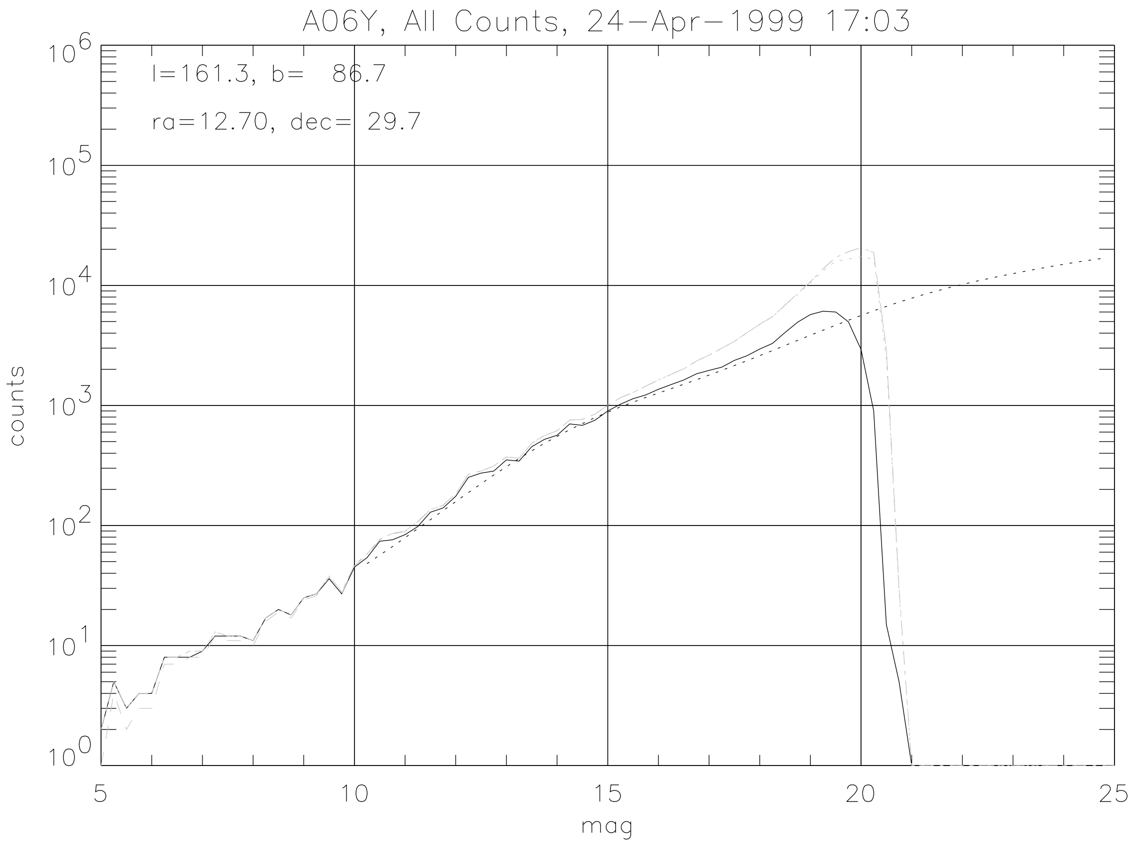


Figure 14: NGP starcounts. Comparison between the GSC2 data from the red XP442 plate (solid line and dotted lines for stars and stars+galaxies respectively) and the Mendez model extended to the $B_{\rm J}$ and $R_{\rm F}$ filters (dashed line). NGST GS requirements are satisfied for about $R_{\rm F} > 18$ mag.

# Conclusions

⇒ Final conclusions of this study are premature, because these first results need to be checked with more extended observative data and with galactic models revised for fainter magnitudes and lower galactic latitudes. However, at this level the stellar density does not appear to be a critical constraint for the NGST GS system, although other correlated factors, as

1. the detection system (pixel size, RON, DC, ...)
2. the acquisition method ($\lambda$, $\Delta\lambda/\lambda$, PSF size, Exp. time, ...)
3. location procedure (optimal or robust centroiding algorithms),

which affect significantly the required position accuracy, must be also taken into account.

⇒ Moreover, we can remark that an input catalog like the GSC2, i.e. complete and calibrated at least down to $R_{\mathrm{F}} \simeq 18$, satisfies at high galactic latitudes the needs of GSs for NGST.

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## References

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