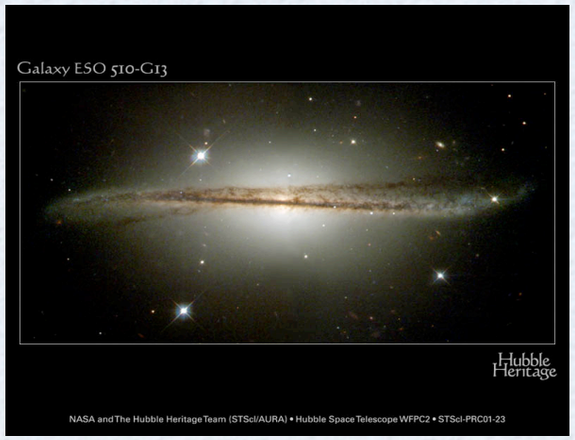


# *New Results on the Galactic Warp from a Stellar Population Synthesis Model*

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**Abstract :** The Besancon Galaxy model is used to interpret 2MASS star counts in external regions of the Galaxy. We adjust a warp model and describe the global shape of this large scale structure. It is found that the stellar warp is asymmetric and less pronounced that the HI warp. The result is also compared with the warp as seen in the dust by Marshall et al (2006) and discussed with regards to other warp studies.

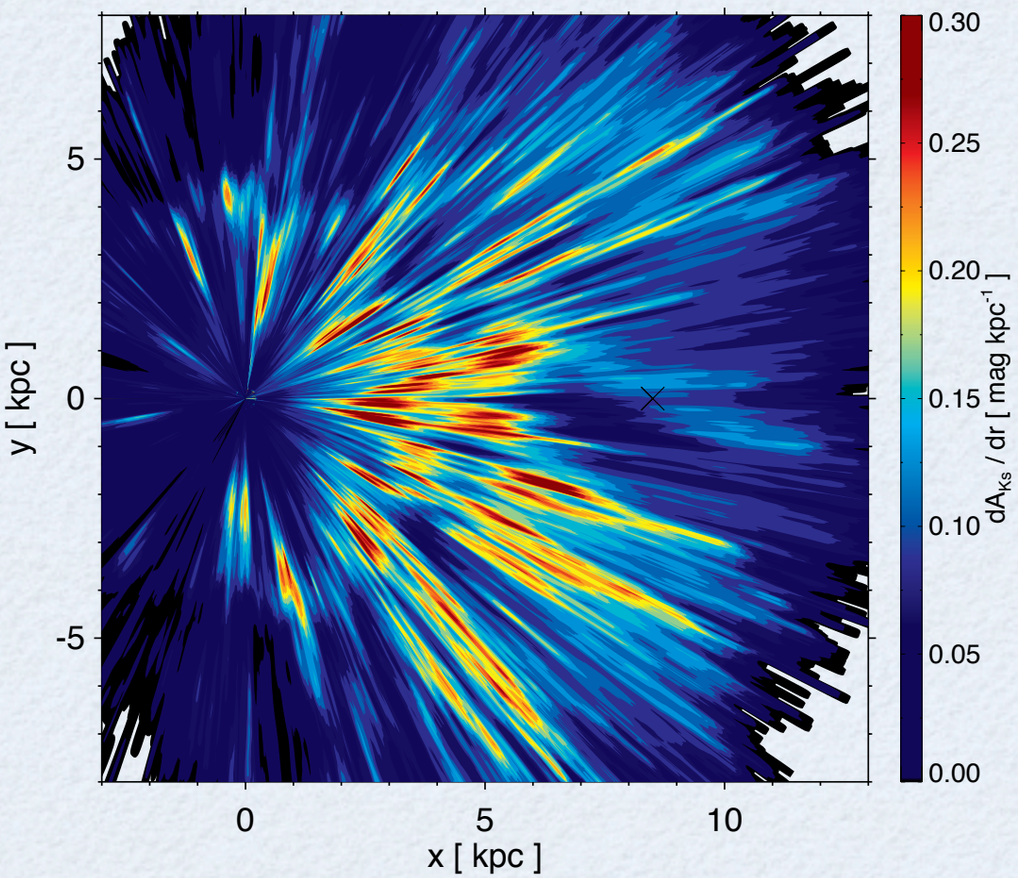
**Objective :** Constrain warp origin
**Method :** Study warp structure from stellar populations by comparing 2MASS star counts with population synthesis model simulations. Compare the stellar warp with HI and dust warps.

Model simulations : Besançon galaxy model (Robin et al, 2003)
Use Marshall et al (2006) 3D extinction map

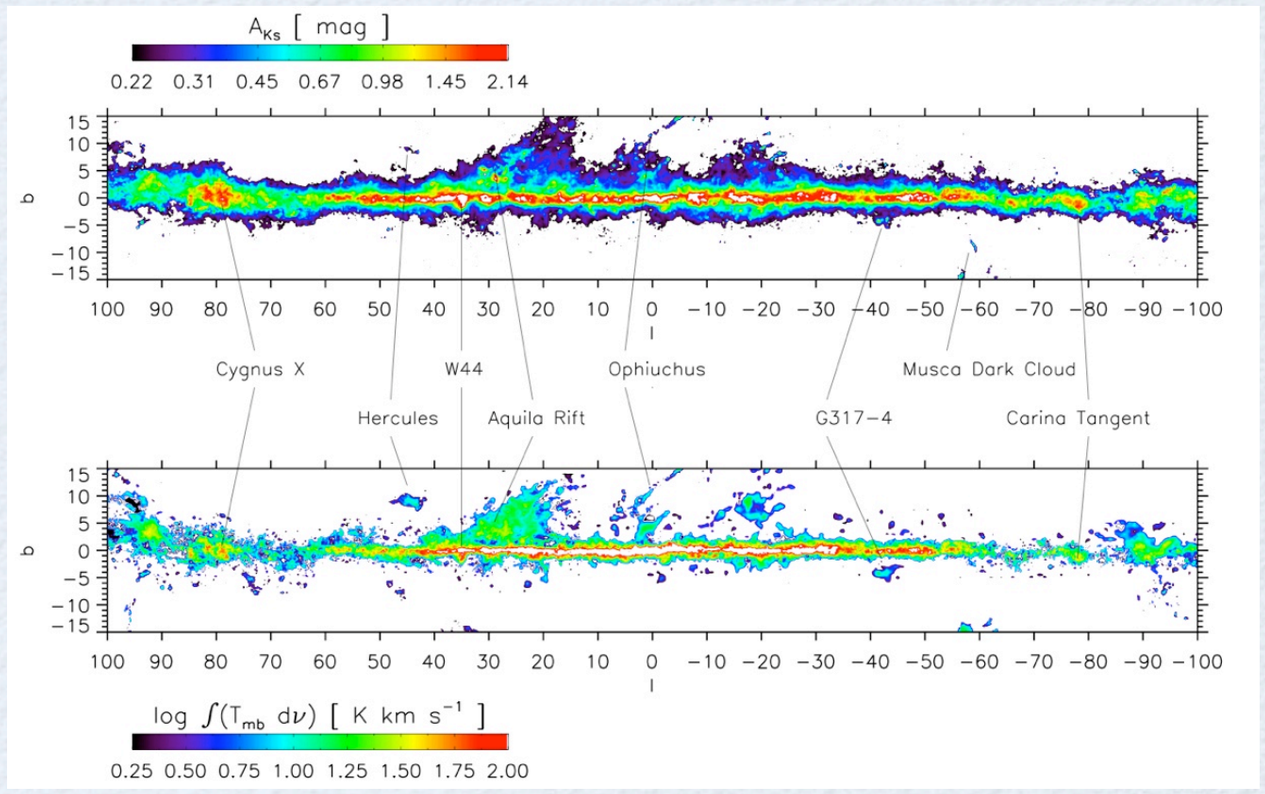
## *References*


Dame, T. M., Hartmann, Dap & Thaddeus, P. 2001, ApJ, 547, 792
Drimmel, R., & Spergel, D. N. 2001, ApJ, 556, 181
Levine, E. S., Blitz, L., & Heiles, C. 2006, ApJ, 643, 881
Lopez-Corredoira, M. et al, 2002, A&A 394, 883
Marshall, D.J., Robin, A.C., Reylé, C., Schultheis, M., Picaud, S. 2006, A&A 453, 635
Marshall, D.J. 2006, PhD Thesis, Université de Franche-Comté
Reylé, C., Marshall, D.J., Robin, A.C., Schultheis, M., 2008, in prep.
Robin, A.C., Reylé, C., Derrière, S., & Picaud S. 2003, A&A, 409, 523. Erratum 2004, A&A, 416, 157
Skrutskie, M. F., et al. 2006, AJ, 131, 1163

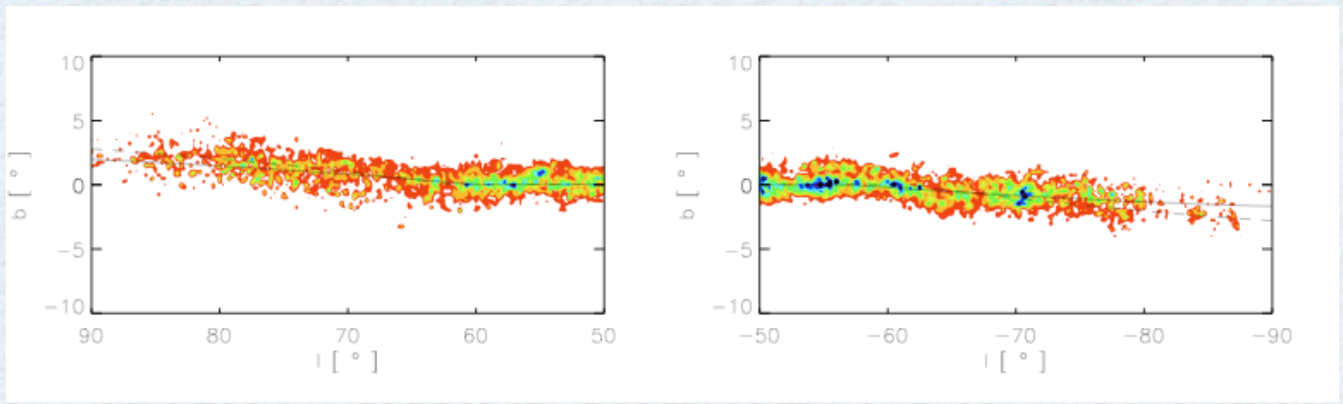
# 3D extinction map




*3D map : Extinction distribution in the plane of the Galaxy as seen from the North Galactic Pole. The Sun is at the origin, the G.C. is marked by an X.*



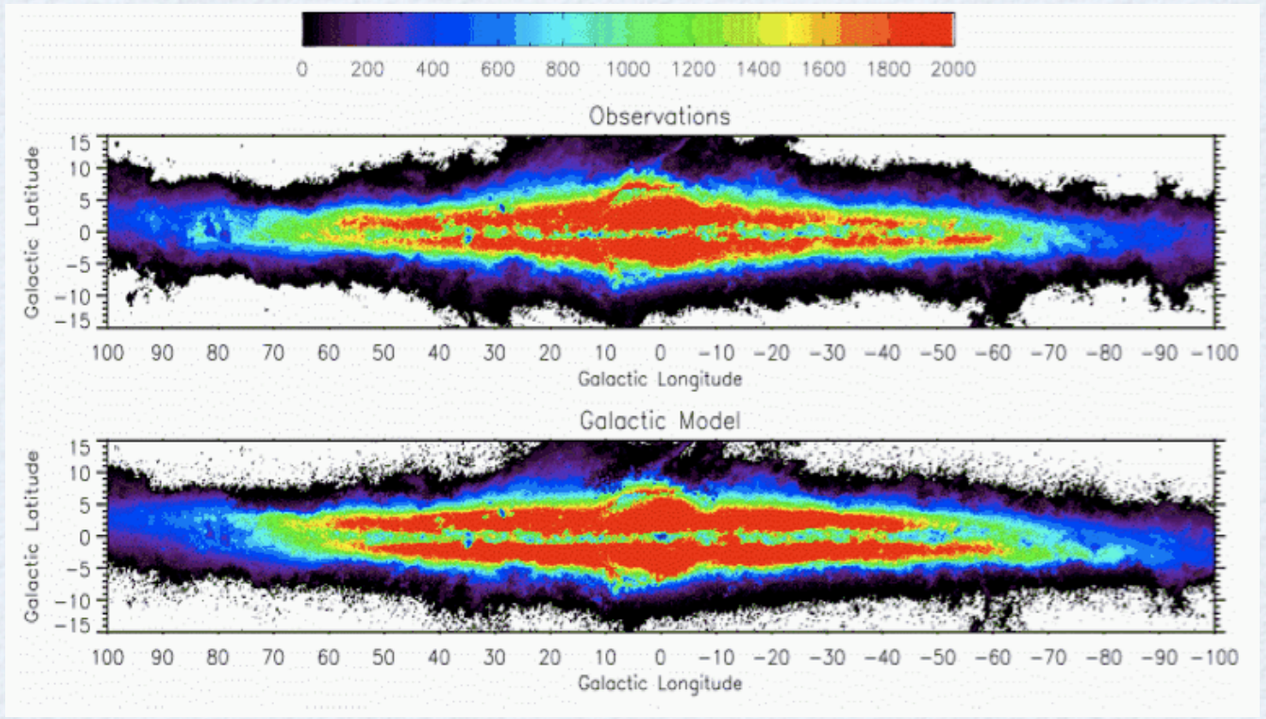

*Comparison of the projected 3D extinction map with the velocity integrated CO emission from Dame et al. (2001)*



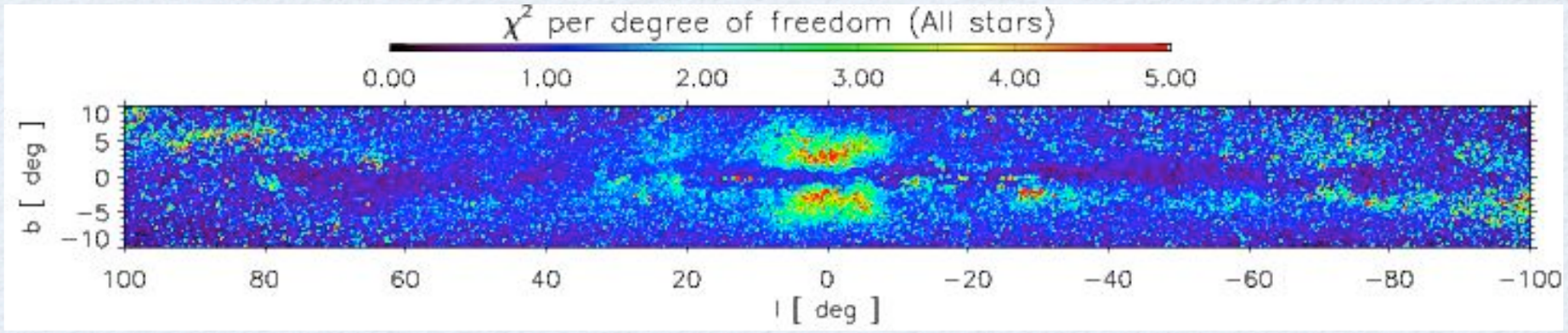
← Warp in the dust

*Extinction distribution at 8 kpc from the sun (Marshall et al, 2006)*

# *Comparison 2Mass / Standard Model*




*Comparison between 2MASS (Skrutskie et al, 2006) star counts per square degree at K<12 and model predictions.*




*$X^2$ difference between 2MASS and extinction adjusted model : significant differences exist in the external bulge and in the* ***warp*** *(Besançon model 2003)*

# *Stellar warp fitting*

## Warp parameters :

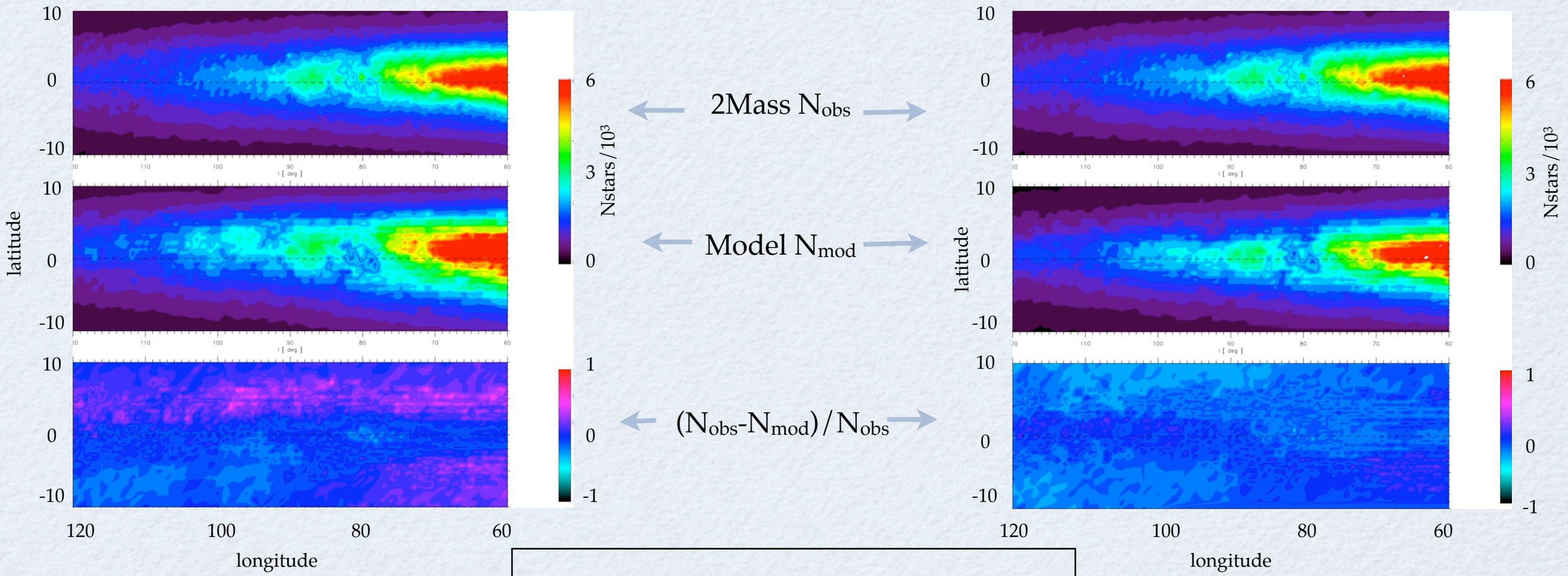
symmetrical S shape, slope γ, scale length $h_R$, Disc Cutoff $R_c$ :

$$zwarp = \gamma \times (R - Rwarp) \times \cos(\theta - \theta warp)$$

γ =0.18, $h_R$=2530 pc, $R_c$=14 kpc

θwarp= 90° ±10°
Rwarp≈8 kpc

γ =0.09, $h_R$=2200 pc, $R_c$=14 kpc

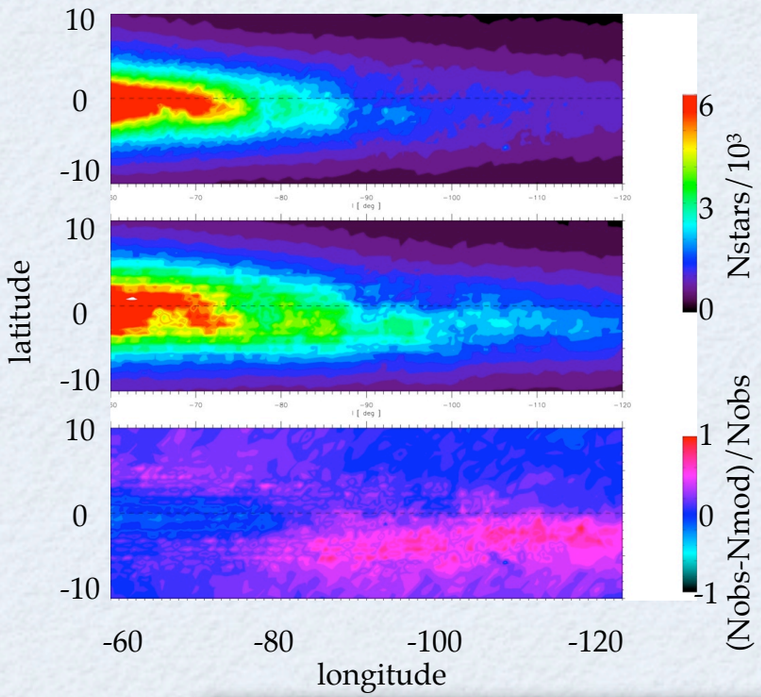



*at positive longitudes*

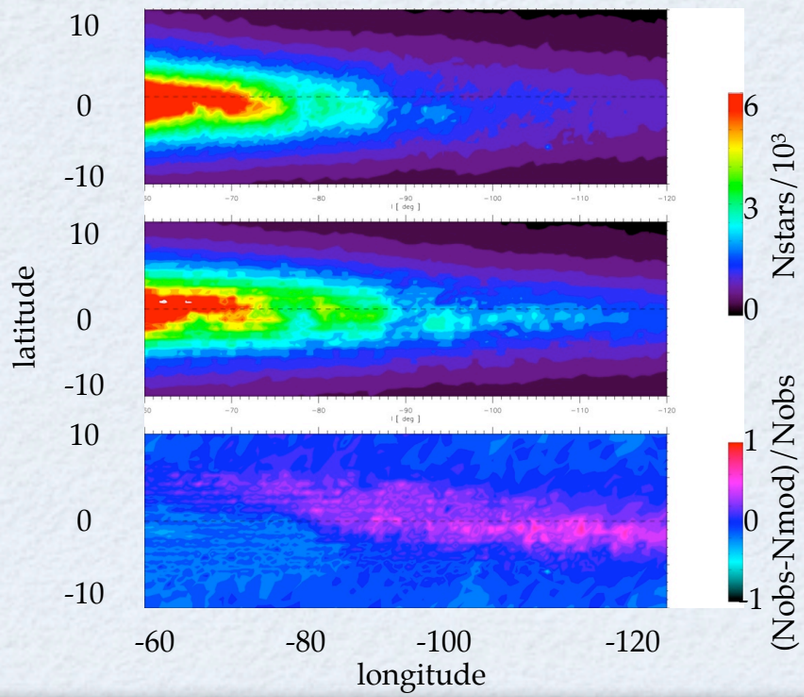
*The S warp fits the data at positive longitudes with a slope of 0.09 a scale length of 2.2 kpc*

# *at negative longitudes*

γ =0.18, $h_R$=2530 pc, $R_c$=14 kpc




γ =**0.09**, $h_R$=**2200** pc, $R_c$=14 kpc




*The S warp does not fit at negative longitudes with the best fit values from positive longitudes*

# *Non axisymmetric warp in HI : Levine et al (2006)*

$$W(\phi) = W_0 + W_1 \sin(\phi - \phi_1) + W_2 \sin(2\phi - \phi_2);$$

Warp model fitted to HI data
3 Fourier modes m=0, 1, 2

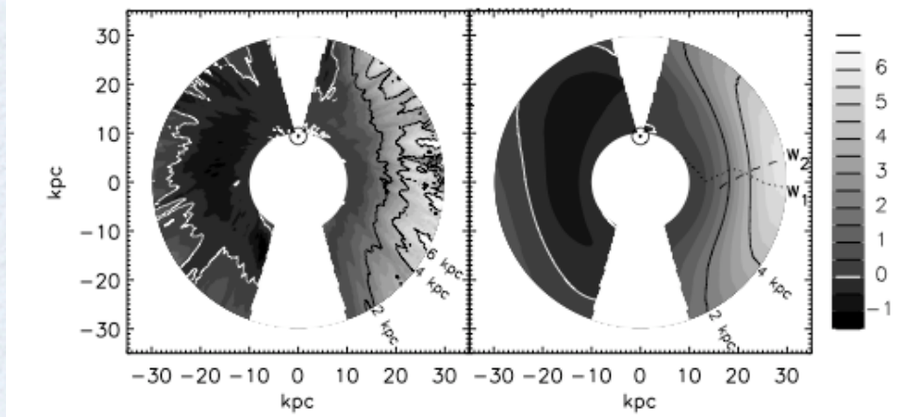
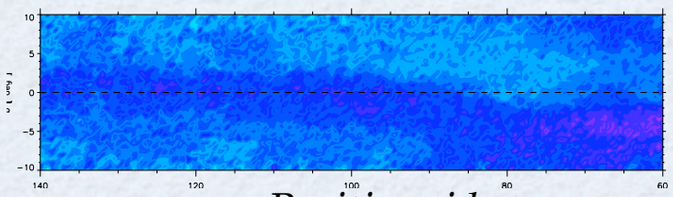
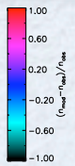


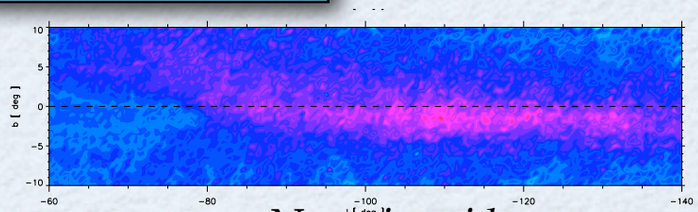

**Fig. 1.** Left panel: $h(R, \phi)$. Right panel: The fit to the warp is plotted, along with the lines of maximum amplitude for the m=1 (dotted) and m=2 (dashed) modes. These lines are marked $W_1$ and $W_2$ respectively. The white contour line denotes a height of 0 kpc; black lines mark the 2, 4, and 6 kpc elevations. The colorbar is marked in kpc.

# Test Levine warp :

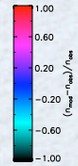


Positive side



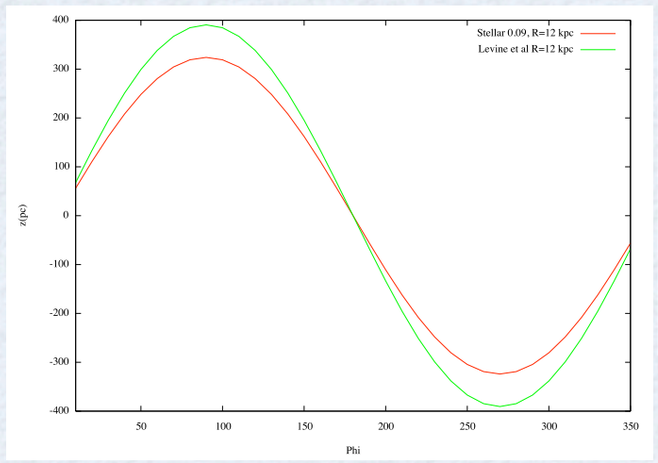


Negative side

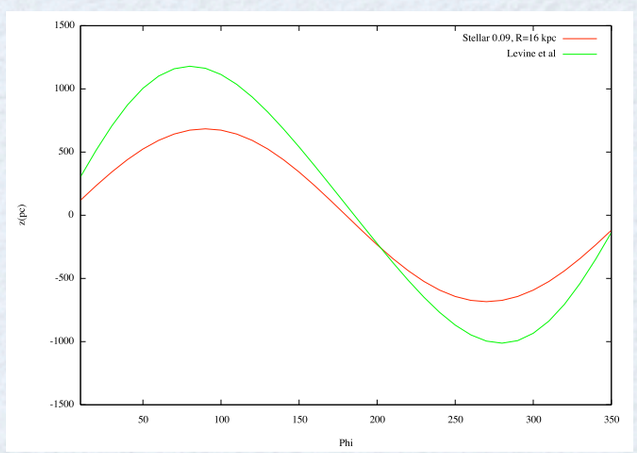


*Levine warp : with m=1 starts at 8.5 kpc, and m=2 at 12. kpc : not a good fit at negative side !*
*The m=2 mode does not solve*

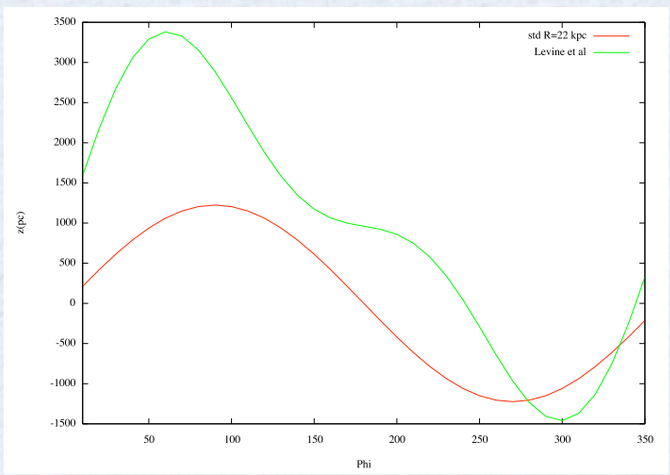
*Other possibilities: a cutoff at a shorter distance at negative longitudes, or a stronger flare => the disc would have an ellipsoidal shape*




*Warp amplitude as a fct of azimuth*
*- For symmetric S warp*
*- For Levine 3 Fourier modes*
*at R=12 kpc*




at R=16 kpc




at R=22 kpc

*But the stellar disc cuts at about 15 kpc (may be less)*

# *Comparison Stars/dust/HI*

| | Slope (pc per kpc) | Height (pc) at R=14 kpc | Rs (kpc) |
|---|---|---|---|
| Stars | 0.09x(R-Rs) at l>0 | 500 at l>0 | 8.5 at l>0 |
| Dust | ≈0.12x(R-Rs) | 700 | 8.9 - 7.8 |
| HI | 9.+197.E-3x(R-Rs)-3.1E-6*(R-Rs)**2 | 750 | 10 (m=1)<br>15 (m=0, m=2) |

# *Conclusions*

- The stellar warp is found asymmetric, as is the warp in dust and gas components
- All models agree that the node angle direction close to sun-center (<10°), "S" model fits at positive longitudes, slope smaller than in Drimmel & Spergel (2001) and Lopez-Corredoira et al (2002)
- The warp slope seems to be less steep for the stars than for the HI gas (and maybe the dust as well)
- The Fourier mode m=2 appears in gas and probably stars and dust, but seen at negative longitudes only
- Possible shifts in the position of the beginning of the warp (m=1 mode : ~8 kpc for stars, 10 kpc for the gas, m=2 mode : >15 kpc in gas, <14 kpc for stars)
- *Different components react differently to the forces at the origin of the warp*