Can we use the nearby velocity distribution to constrain the properties of the bar and the spiral arms of the MW? Gaia capabilities

M. Teresa Antoja Castelltort

DAM and IEEC-UB,
Institut de Ciencies del Cosmos de la Universitat de Barcelona

GAIA: At the Frontiers of Astrometry, ELSA conference
Sevres, 7th-11th June 2010

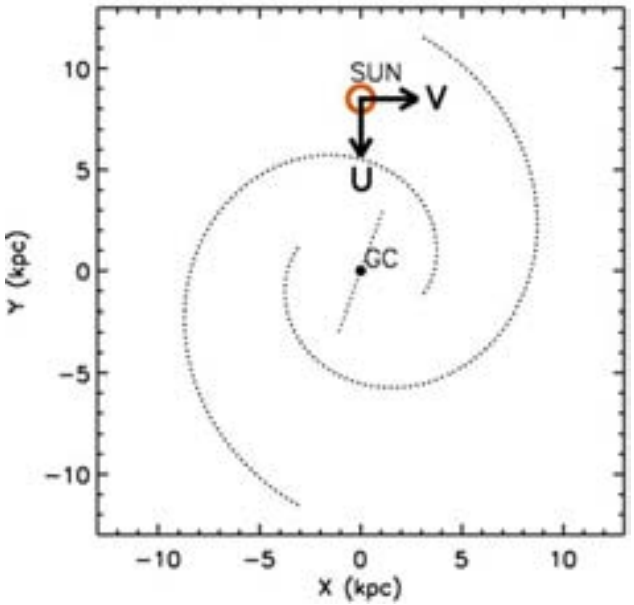
Dra. Francesca Figueras
Dra. Mercè Romero-Gomez
Maria Monguió
Santi Roca

Dr. Octavio Valenzuela
Dra. Barbara Pichardo

Outline

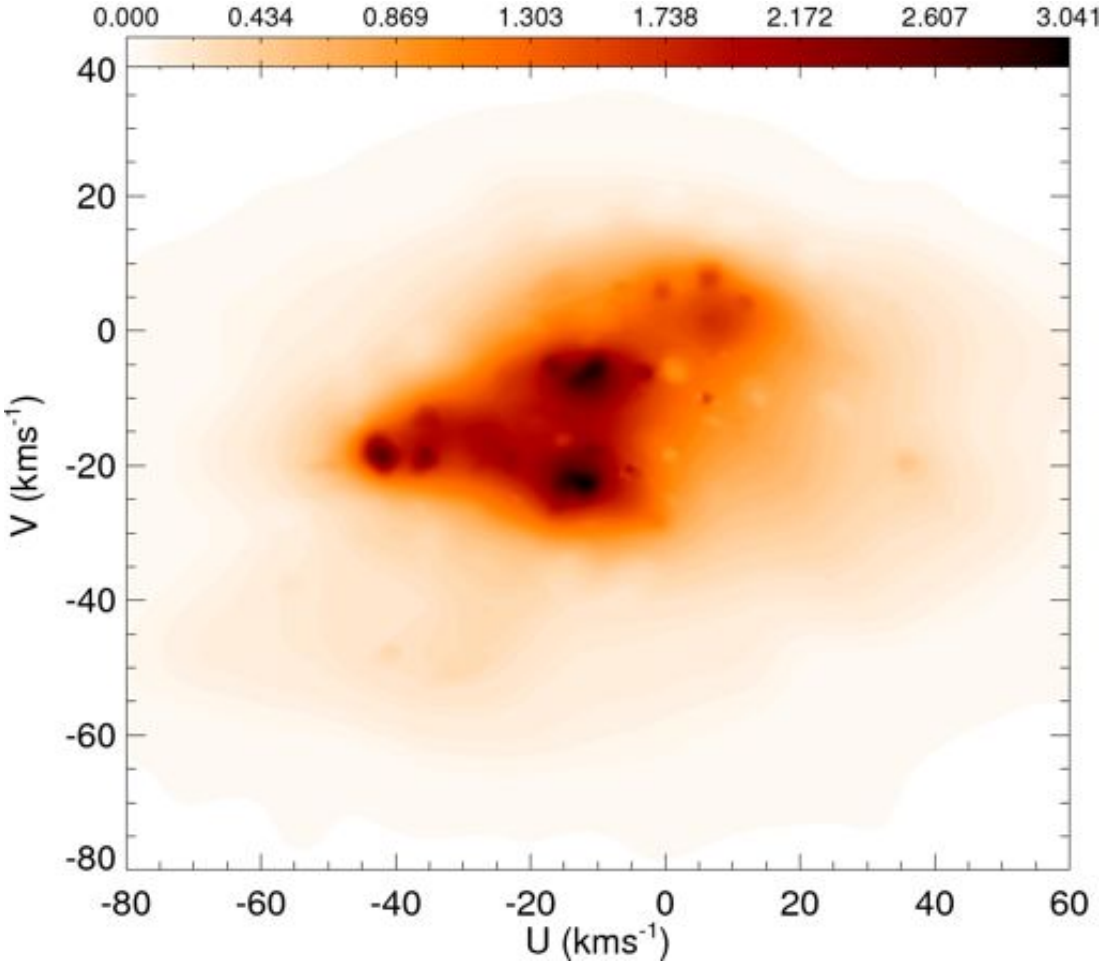
What are moving groups?

- U V W for 24000 stars: Nordström et al. (2004); Asiain et al. (1999a); Torra et al. (2000); Reid et al. (2002); Bochanski et al. (2005); Famaey et al. (2005)



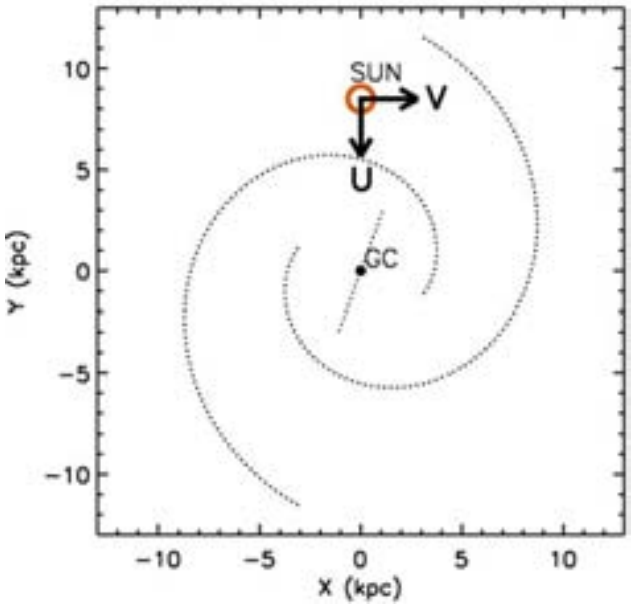
- Wavelet denoising

Antoja et al. 2008



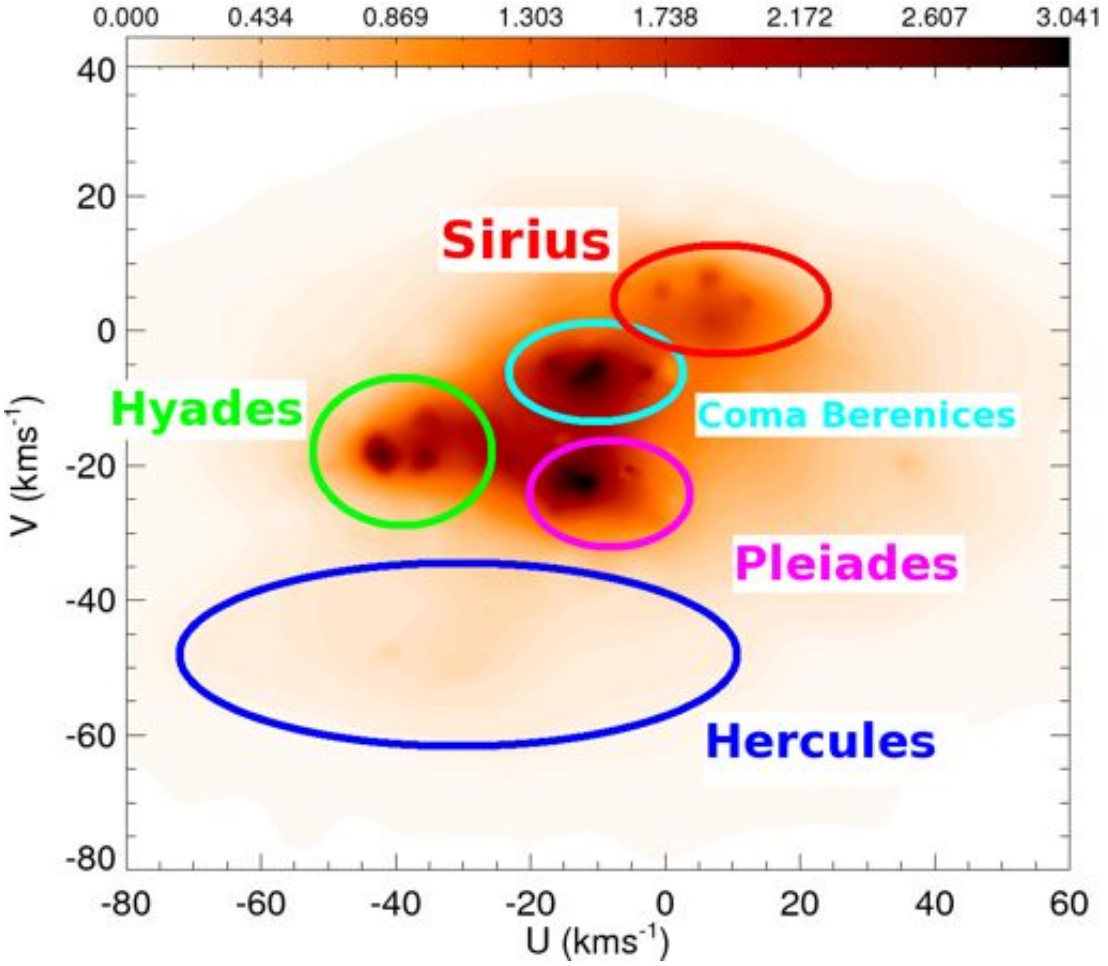
What are moving groups?

- U V W for 24000 stars: Nordström et al. (2004); Asiain et al. (1999a); Torra et al. (2000); Reid et al. (2002); Bochanski et al. (2005); Famaey et al. (2005)



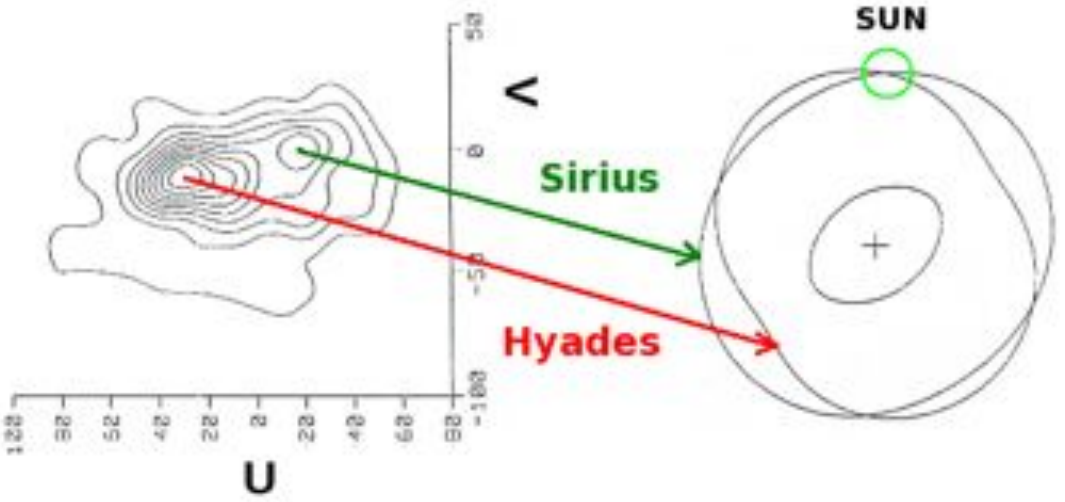
- Wavelet denoising

Antoja et al. 2008



Interest of moving groups

Orbital and resonant effects of the MW spiral arms and bar



Kalnajs (1991)

Only for particular bar orientation and pattern speed!!

MOVING GROUPS:
tool to constrain the properties of the bar and the spiral arms!

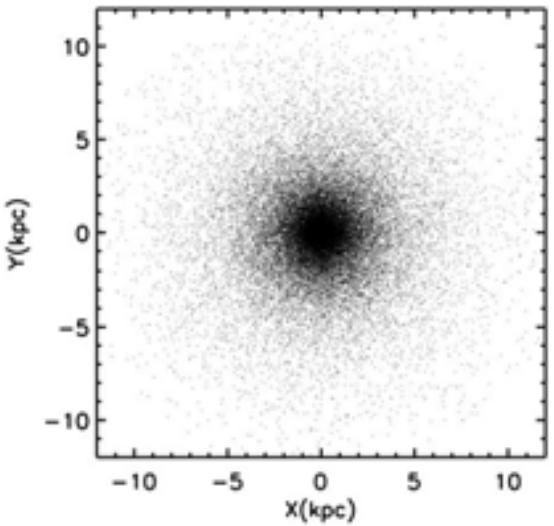
SPIRAL ARMS & BAR:

- Mass or strength?
- Pattern speed?
- Orientation?

Outline

Simulation method

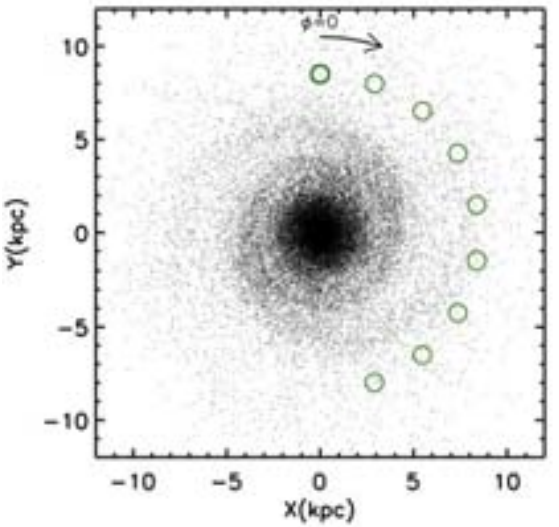
- **Initial Conditions:**
  - IC1 cold disk
  - IC2 warm disk
  - IC3 hot disk



Integration of test particle orbits

$\Longrightarrow$

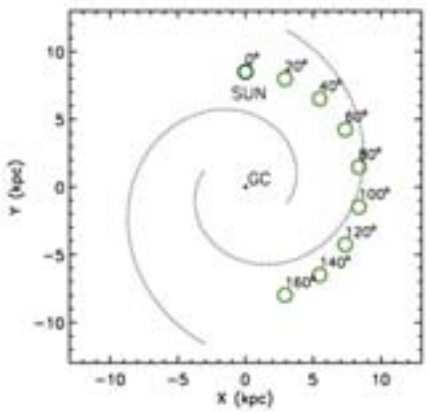
- **Analysis of the velocity distribution**



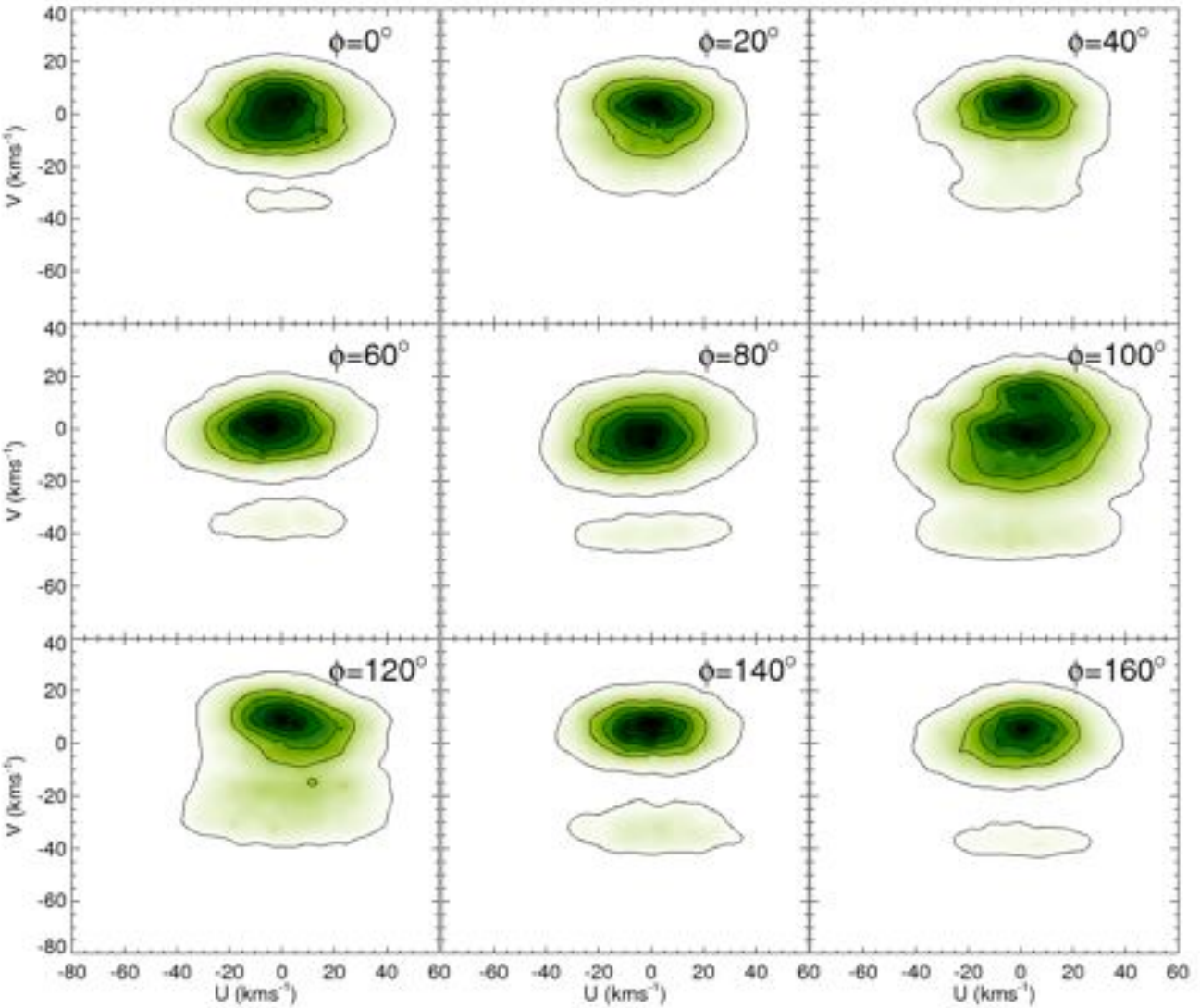
- **Potential Model for the MW:**

AXISYMMETRIC
SPIRAL ARMS (Pichardo et al. 2003b)
BAR (Pichardo et al. 2004)

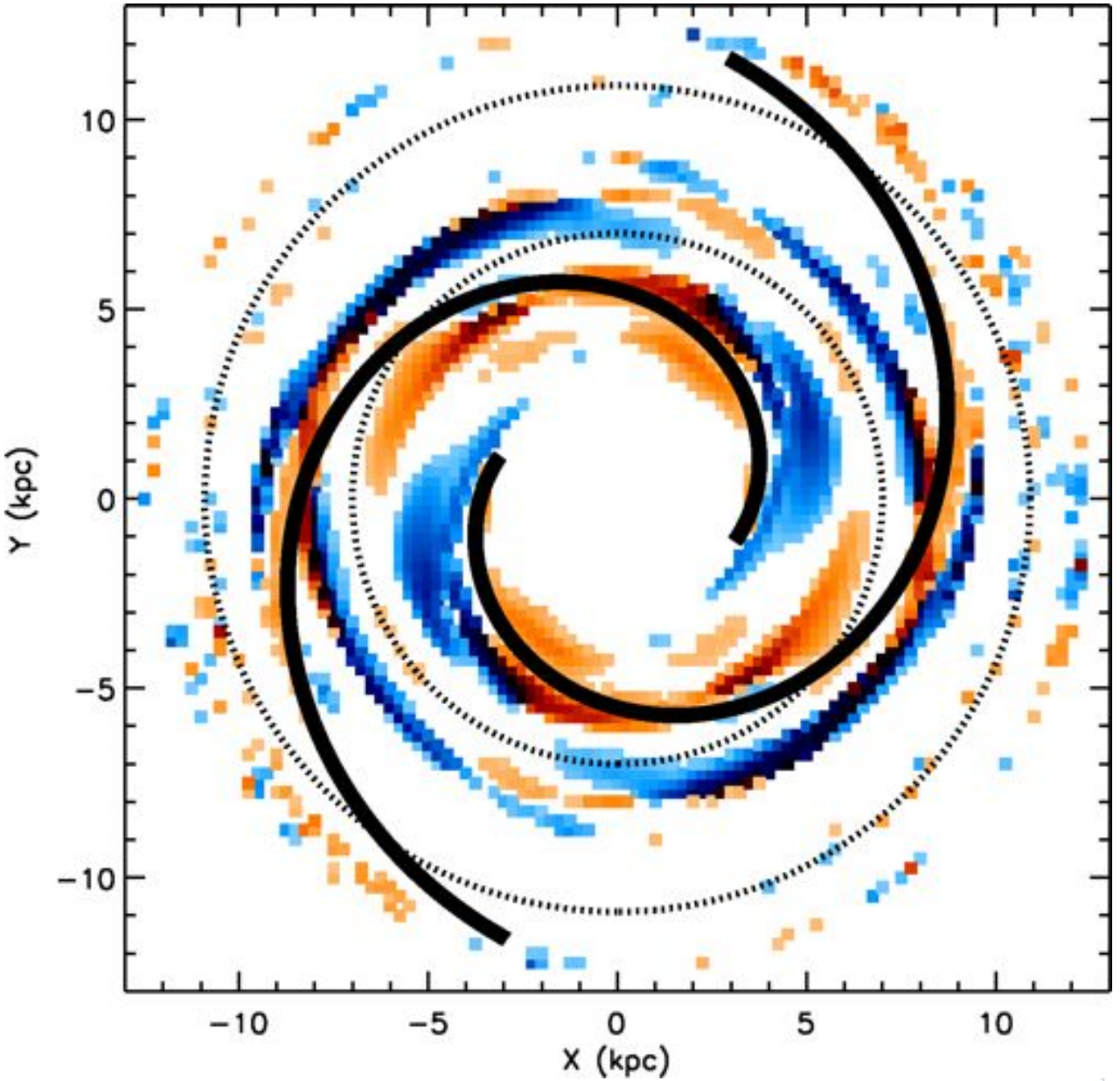
Imprints of the spiral arms IC1

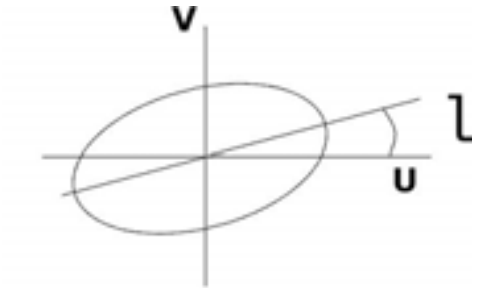


- Strong imprints on the velocity plane, specially near the arms
- Branches resembling the observed ones
- Crowding at $V \sim -40\,\mathrm{km\,s^{-1}}$, not only the bar!



Imprints of the spiral arm: vertex deviation

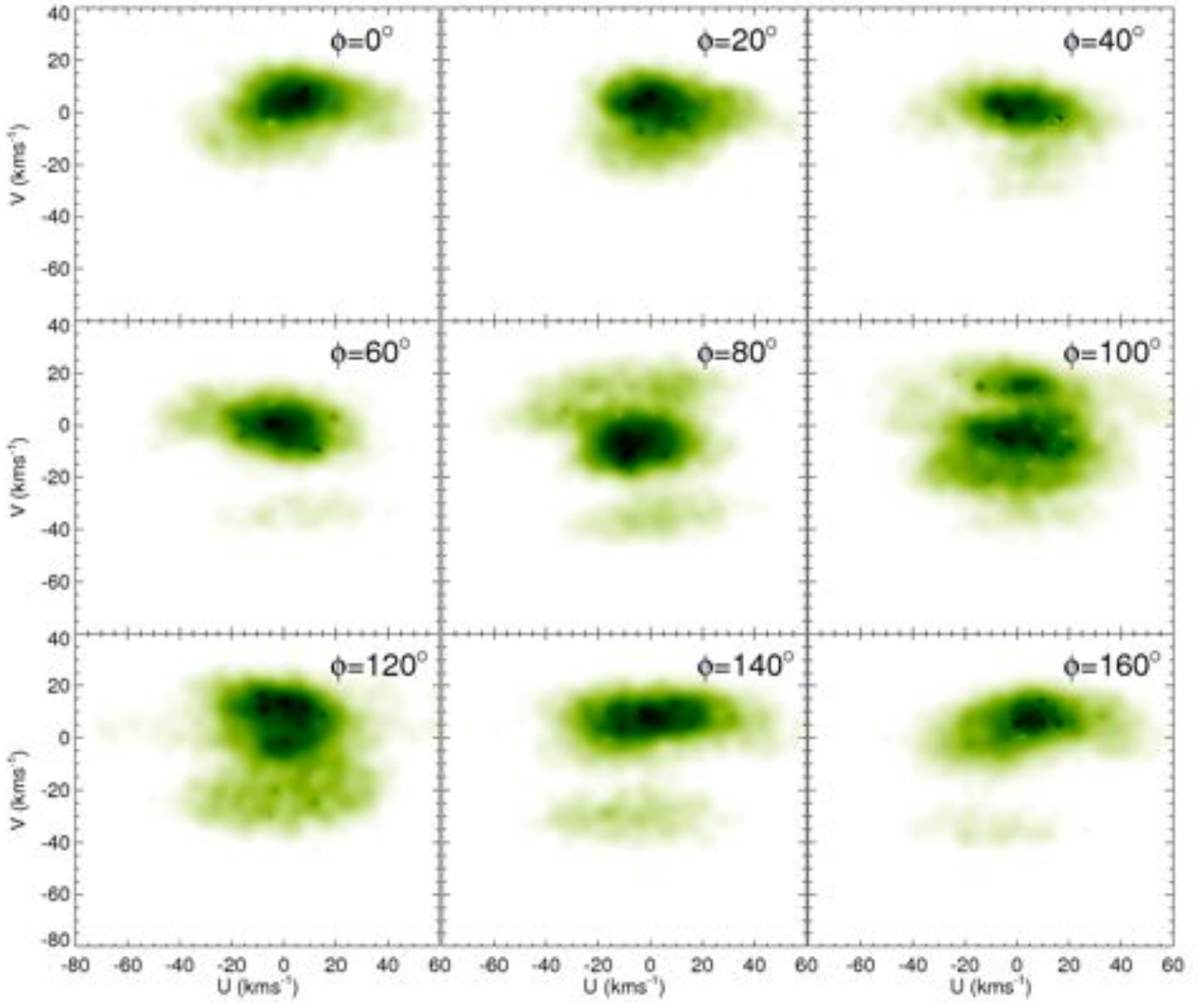




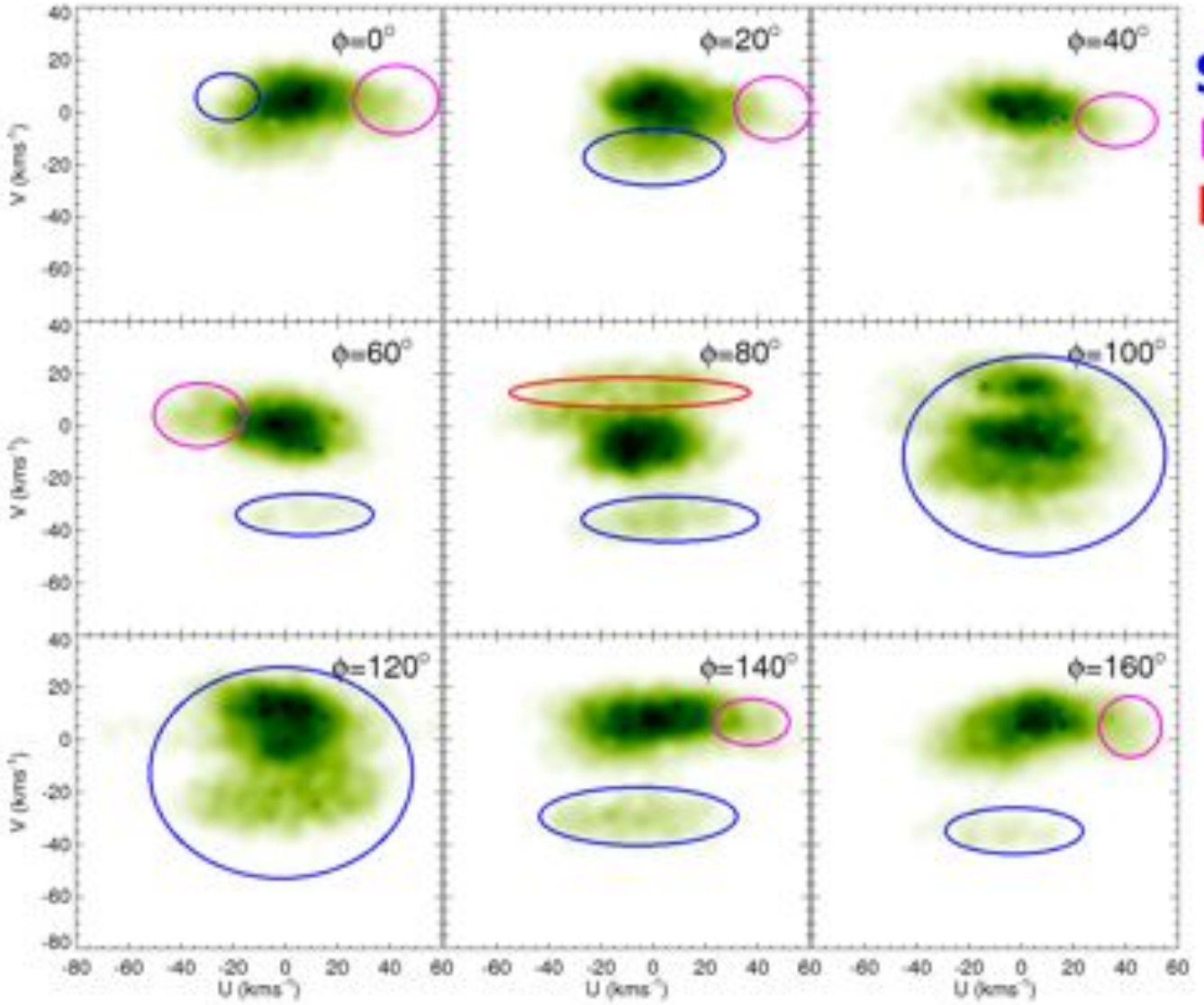
$l<0$

$l>0$

Imprints of the spiral-bar model IC1



Imprints of the spiral-bar model IC1



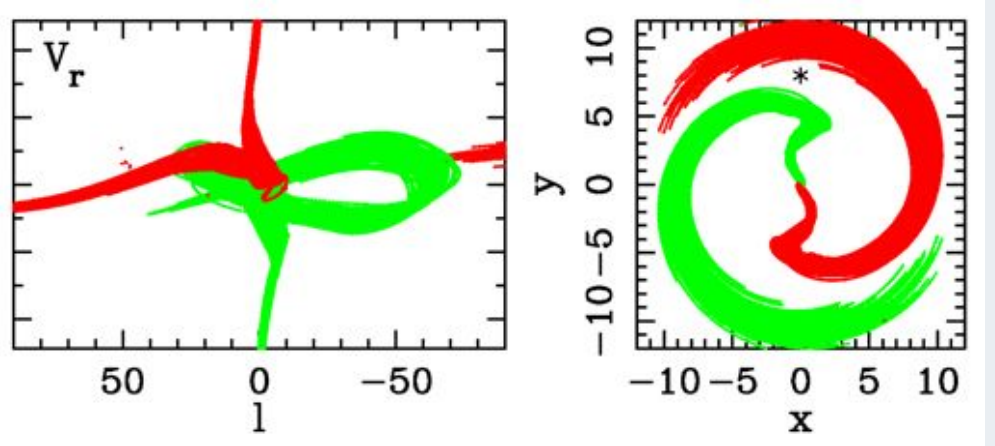
SPIRAL ARMS
BAR
NEW

Direct spiral arm kinematic perturbation

Observationally:
Monguio et al. 2010, in prep.

Theoretically:
Romero-Gomez et al. 2010, in prep.
Testing kinematic perturbation
of different models:

- Lin&Shu perturbation?
- Invariant manifolds of the bar potential?



Outline

Particular cases:

1) Scutum-Centaurus tangency

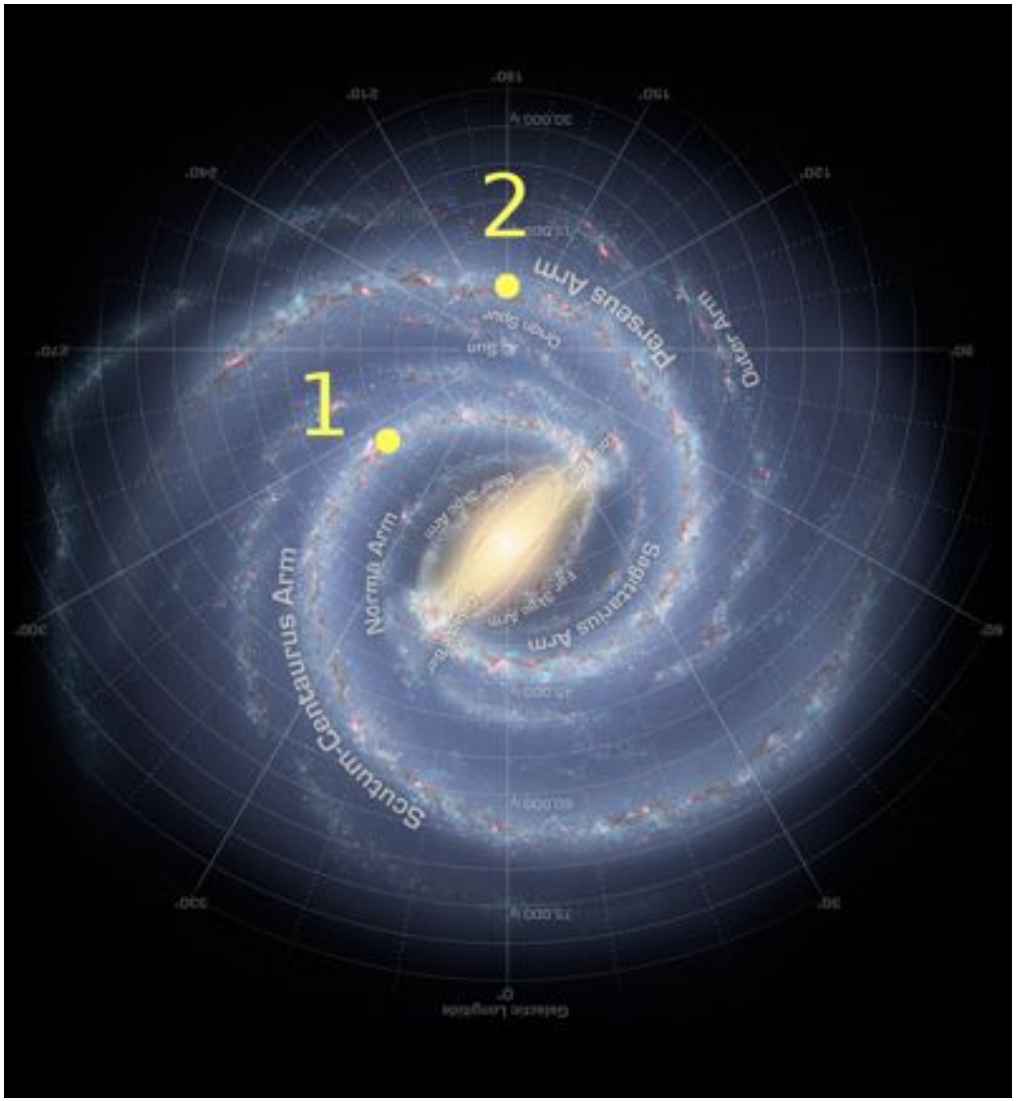
2) Perseus arm in the anti-center

Why these positions?

- Particularly rich in resonant substructure
- Regions that experience the spiral arm perturbation

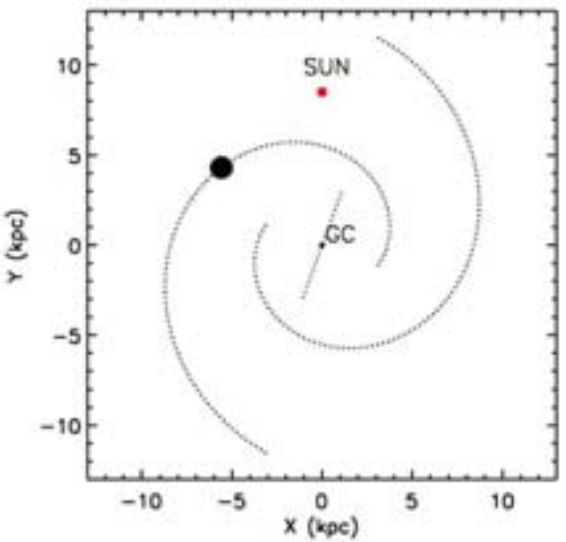
SIMULATIONS
WITH SPIRAL ARMS
+
GAIA EXPECTED ACCURACIES

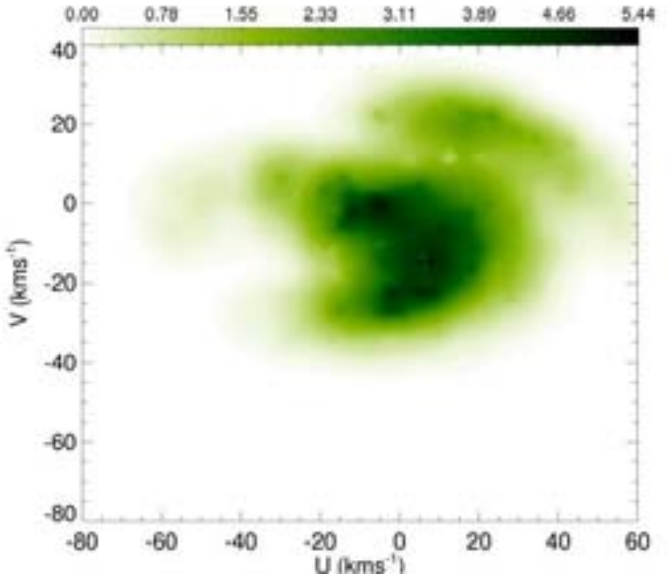
Spitzer/GLIMPSE (Benjamin et al. 2005)

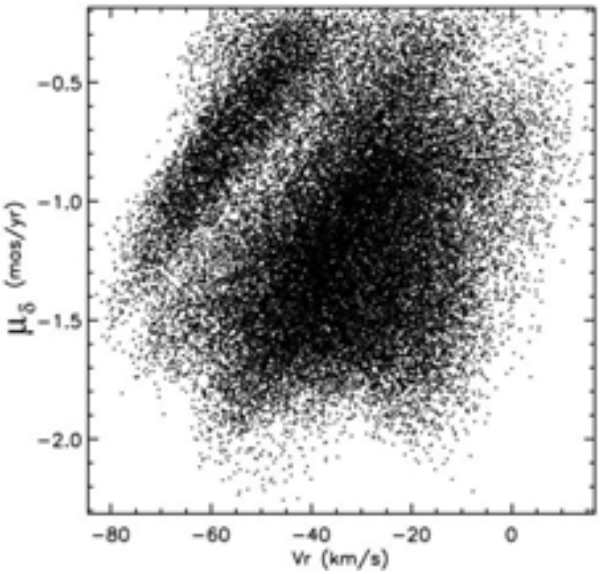


Scutum-Centaurus tangency

$l = 305^\circ, \beta = 0^\circ,$
$dist = 6.9\,\mathrm{kpc}$







K4-5 III
M_V, (V-I)$_i$, A_V, A_I

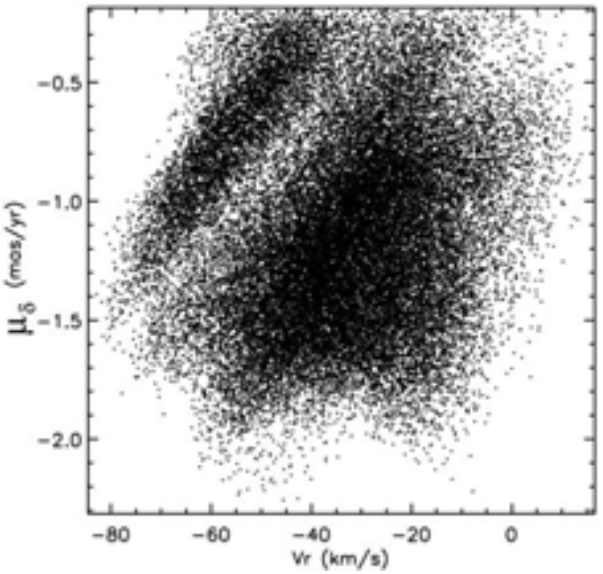
$\Longrightarrow$

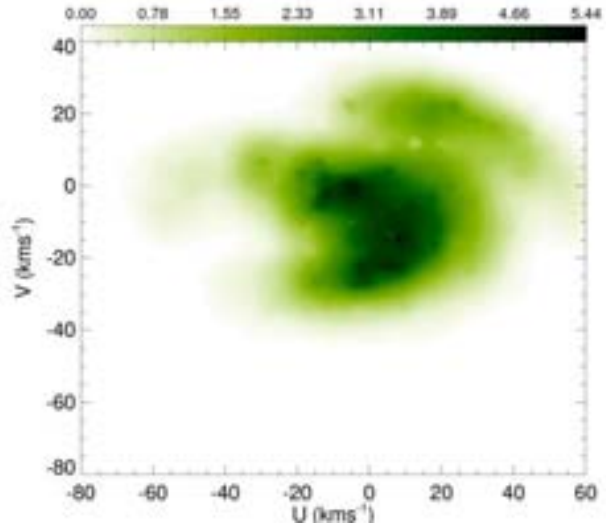
$G \sim 18$
$e_\pi \sim 90\ \mu as$ (62% !!)
$e_\mu \sim 50\ \mu as/yr$
No radial velocities!!

- Radial velocities needed
- Better distances

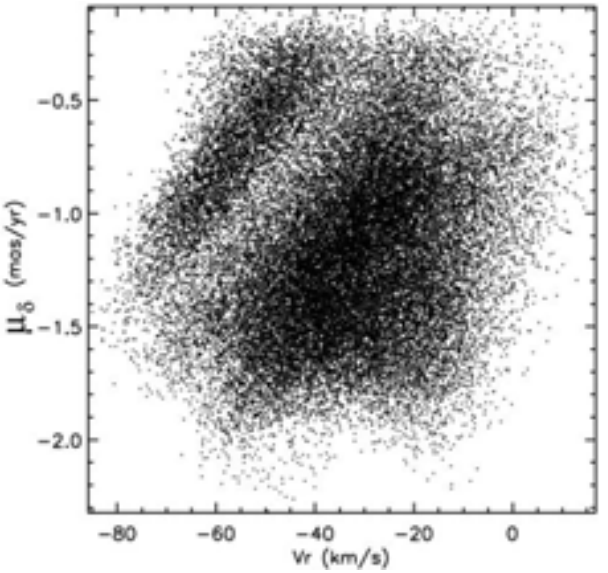
Scutum-Centaurus tangency

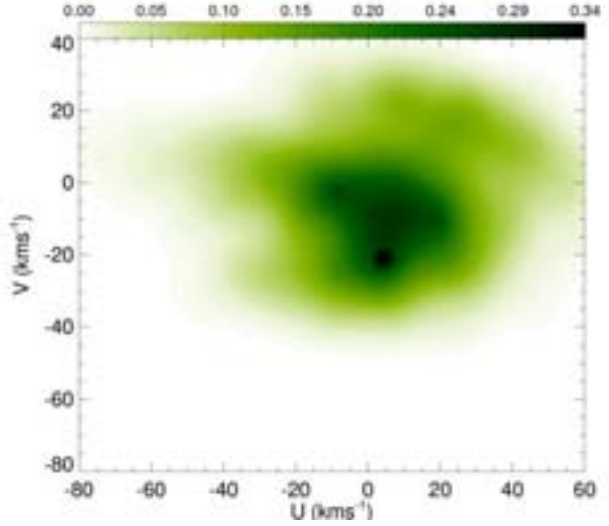
Model



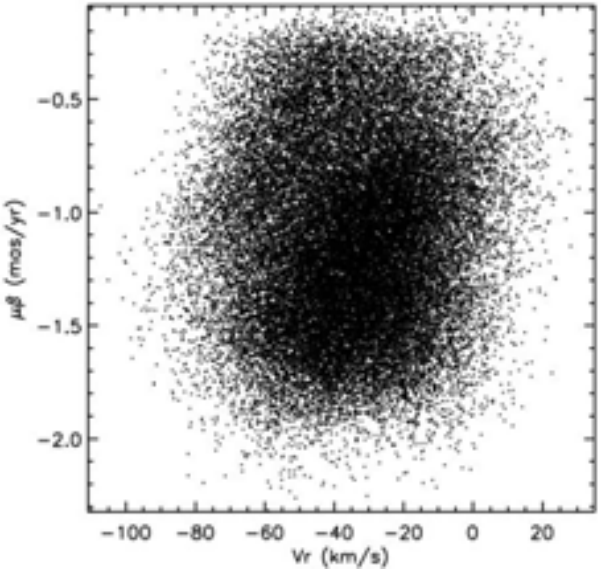


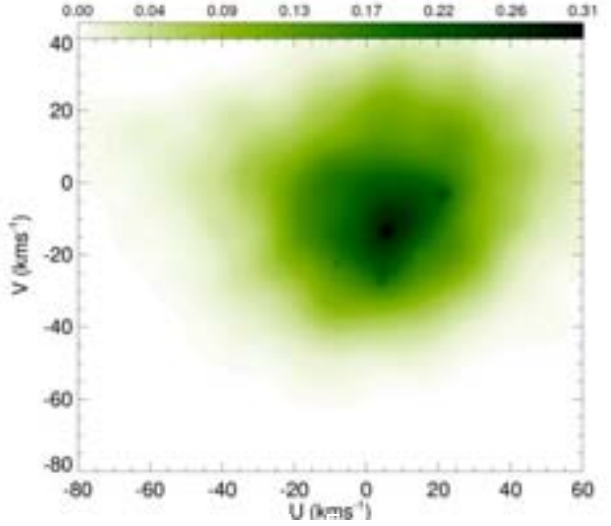
+ GAIA errors
+ survey $e_{VR} = 2\,\mathrm{km\,s^{-1}}$





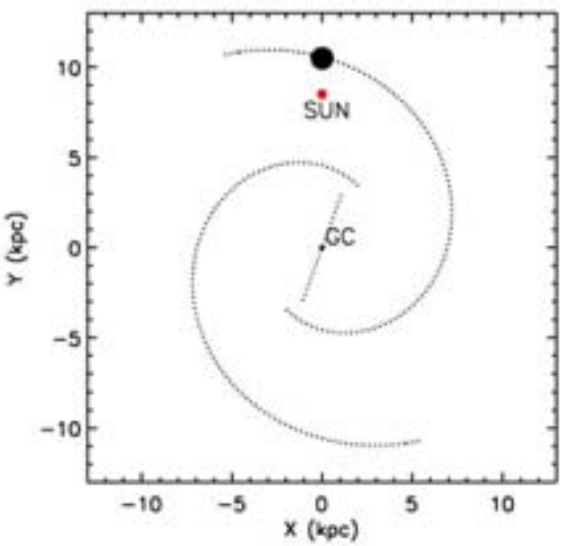
+ GAIA errors
+ survey $e_{VR} = 10\,\mathrm{km\,s^{-1}}$

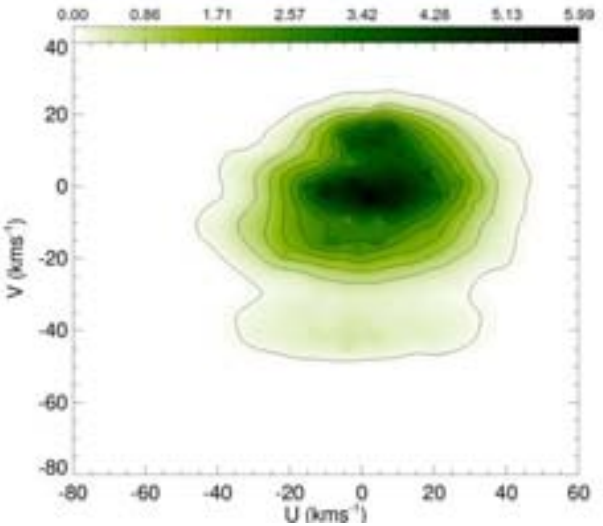


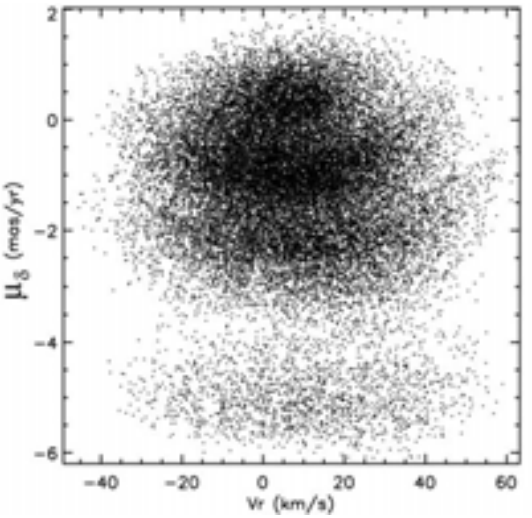


Perseus arm in the anti-centre

$l = 180°, \beta = 0°,$
$dist = 2.0\,\mathrm{kpc}$





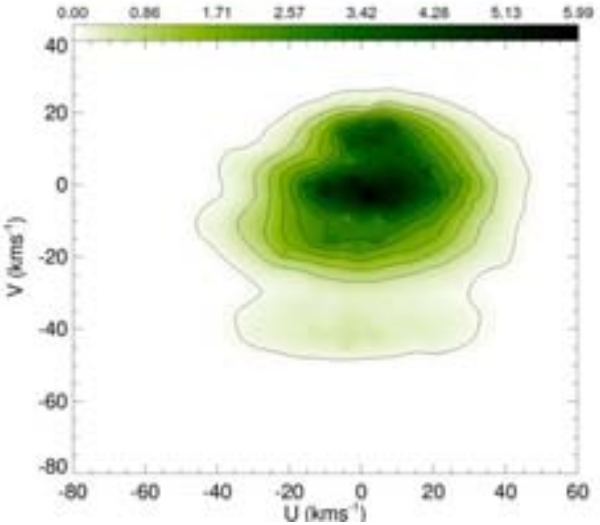


M_V, (V-I)$_i$,
A_V, A_I $\Longrightarrow$

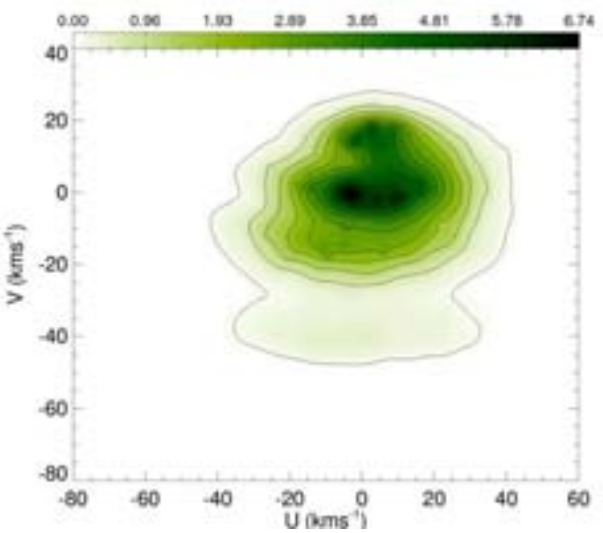
ST	G	$e_\pi(\mu as)$	$e_\mu(\mu as)$	$e_{VR}(\mathrm{km\,s^{-1}})$
B5 V	13	8 (2%)	4	10
K5 III	13	8 (2%)	4	1
A5 V	15	23(5%)	12	20

Perseus arm in the anti-centre

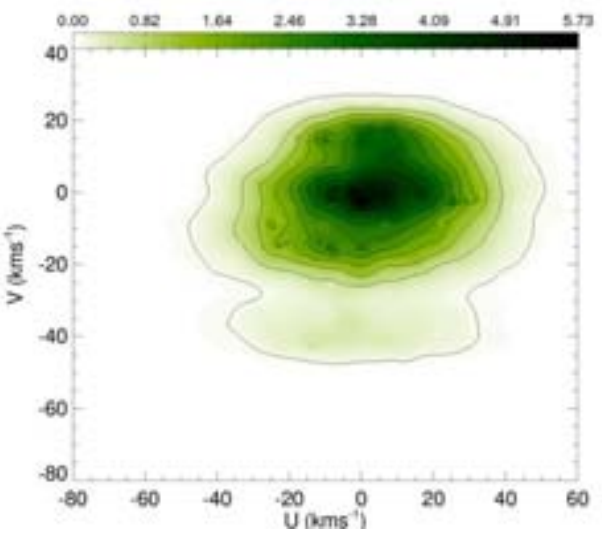
Model



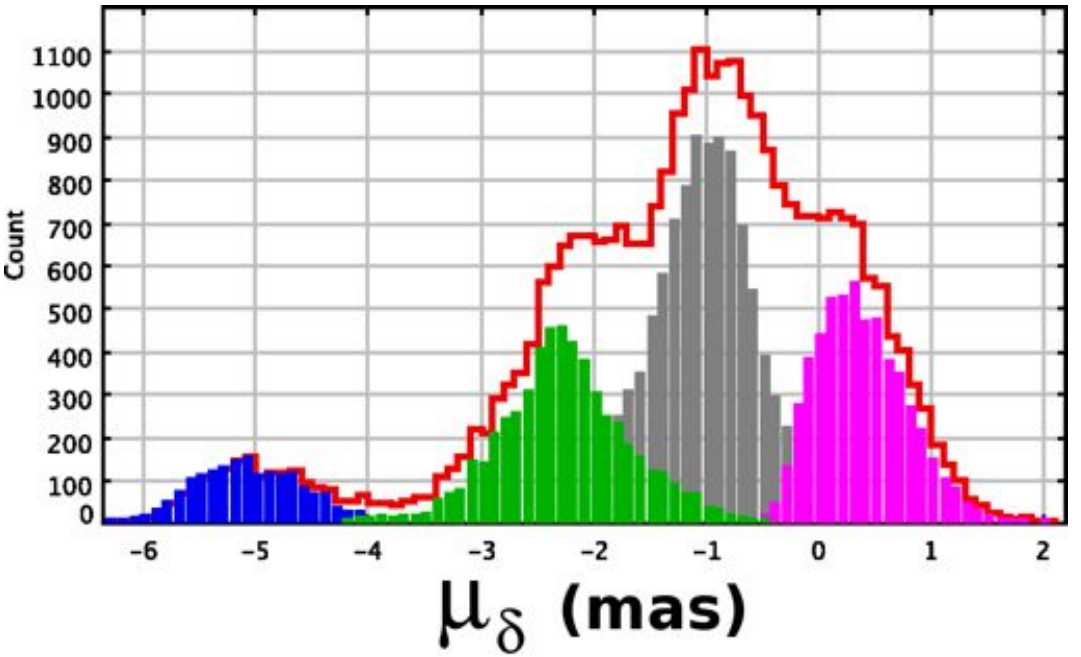
+ GAIA errors (K5 III)



+ GAIA errors (B5 V)



Very good job
in the Perseus arm!



References

Abadi, M.G., Navarro, J.F., Steinmetz, M., et al. 2003, AJ, 597, 21
Aguilar, L., Hoogerwerf, R. 2001, RMxAC, 11, 99
Allen, C., Santillán, A. 1991, Rev. Mexicana Astron. Astrofis., 22, 255
Anscombe, F.J. 1948, *Biometrika*, 15, 245
Arenou, F., Luri, X. et al. 1999, ASPC 167, 13
Arifyanto, M.I., Fuchs, B. 2006, A&A, 449, 533
Asiain, R., Figueras, F., Torra, J. et al. 1999, A&A, 341, 427
Asiain, R., Figueras, F., Torra, J. 1999, A&A, 350, 434
Athanassoula, E., Bienaymé, O., Martinet, & L., et al. 1983, A& A, 127, 349
Athanassoula, E. 2002, ApJ, 569, 83
Athanassoula, E. 2003, MNRAS, 341, 1179
Athanassoula, E. 2005, New York Academy Sciences Annals, 1045, 168
Aumer, M., Binney, J.J. 2009, MNRAS, 397, 1286
Baba, J., Asaki, Y., Makino, J., et al. 2009, ApJ, 706, 471
Baiesi Pillastrini, G.C., 2009, MNRAS, 397, 1990
Barbanis, B. 1976, A&A, 46, 269
Benjamin, R.A., Churchwell, E., Babler, B.L., et al. 2005, ApJ, 630, 149
Bensby, T., Feltzing, S., Lunström, I. 2007a, A&A, 410, 527
Bensby, T., Oey, M.S., Feltzing, S., et al. 2007b, ApJ, 655, 89
Binney, J.J., Dehnen, W., Houk, N. et al. 1997, ESA SP-402, 473
Binney, J. and Tremaine, S., 2008, *Galactic Dynamics*, Princeton University Press Princeton, New Jersey
Binney, J.J. 2010, MNRAS, 401, 2318
Bissantz, N., Gerhard, O. 2002, MNRAS, 330, 591
Bissantz, N., Englmaier, P., Gerhard, O. 2003, MNRAS, 340, 949
Block, D.L., Puerari, I., Elmegreen, B.G. et al. 2009, AJ, 694, 115
Block, D.L., Buta, R., Knapen, J.H, et al. 2004, AJ, 128, 183
Bobylev, V.V., Bajkova, A.T. 2007, ARep, 51, 372
Bochanski, J.J., Hawley, S.L., Reid, I.N. et al. 2005, AJ, 130, 1871
Bochanski, J.J., Munn, J.A., Hawley, S.L. et al. 2007, AJ, 134, 2418
Bok, B.J. 1934, HarCi, 384, 1
Bovy, J., Hogg, D.W., Roweis, S.T. 2009, ApJ, 700, 1794
Buta, R. 1986, ApJS, 61, 631
Buta, R., Block, D.L. 2001, ApJ, 550, 243
Brown, A. G. A., Arenou, F., van Leeuwen, F. et al. 1997, ESA SP-402, 63
Bruch, T., Read, J., Baudis, L., & Lake, G. 2008, 804, arXiv:0804.2896
Ceverino, D. & Klypin, A. 2007, MNRAS, 379, 1155
Chakrabarty, D. 2004, MNRAS, 352, 427
Chakrabarty, D. 2007, A&A, 467, 145
Chakrabarty, D., Sideris, I.V. 2008, A&A, 488, 161
Chen, B., Asiain, R., Figueras, F., et al 1997, A&A, 318, 29