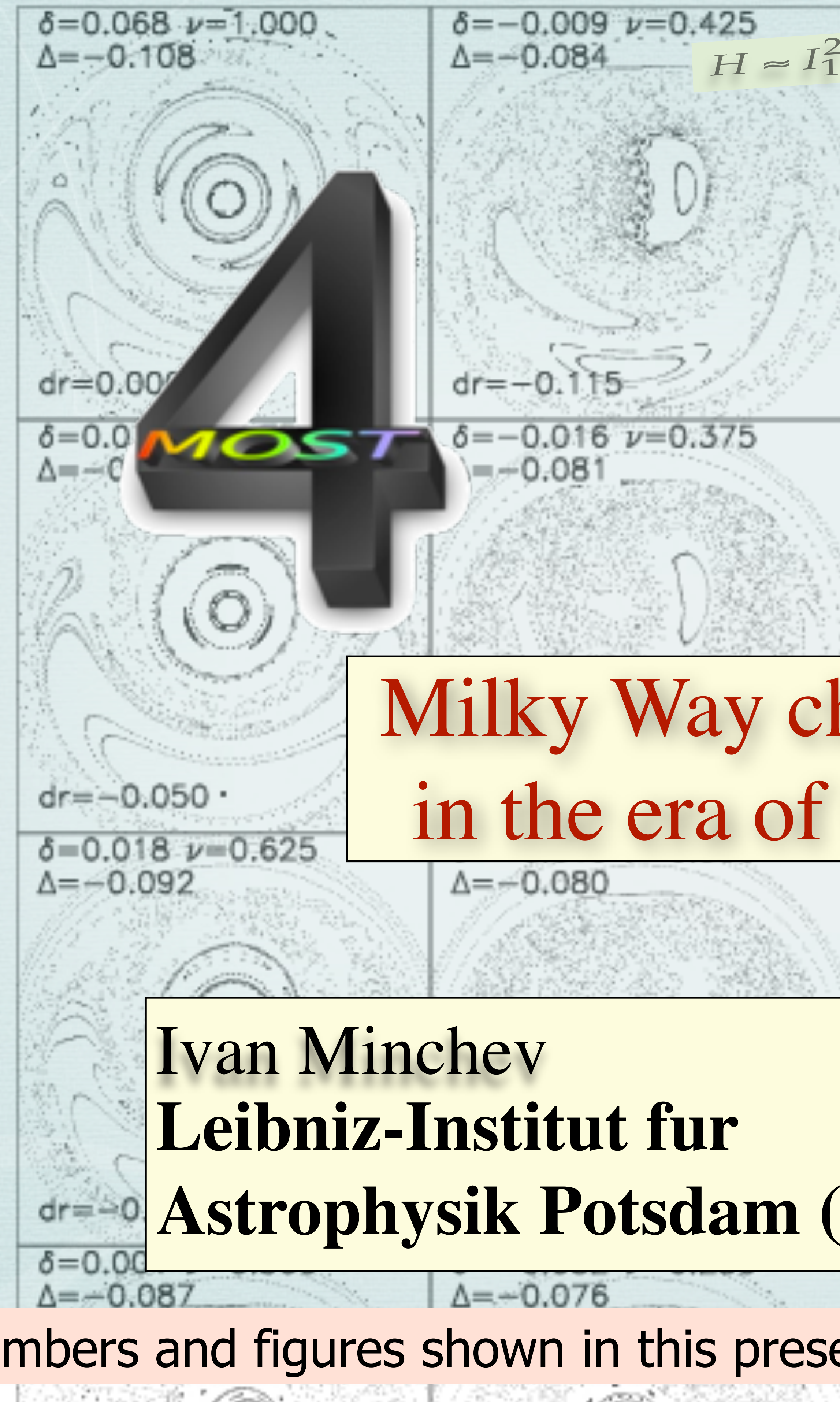

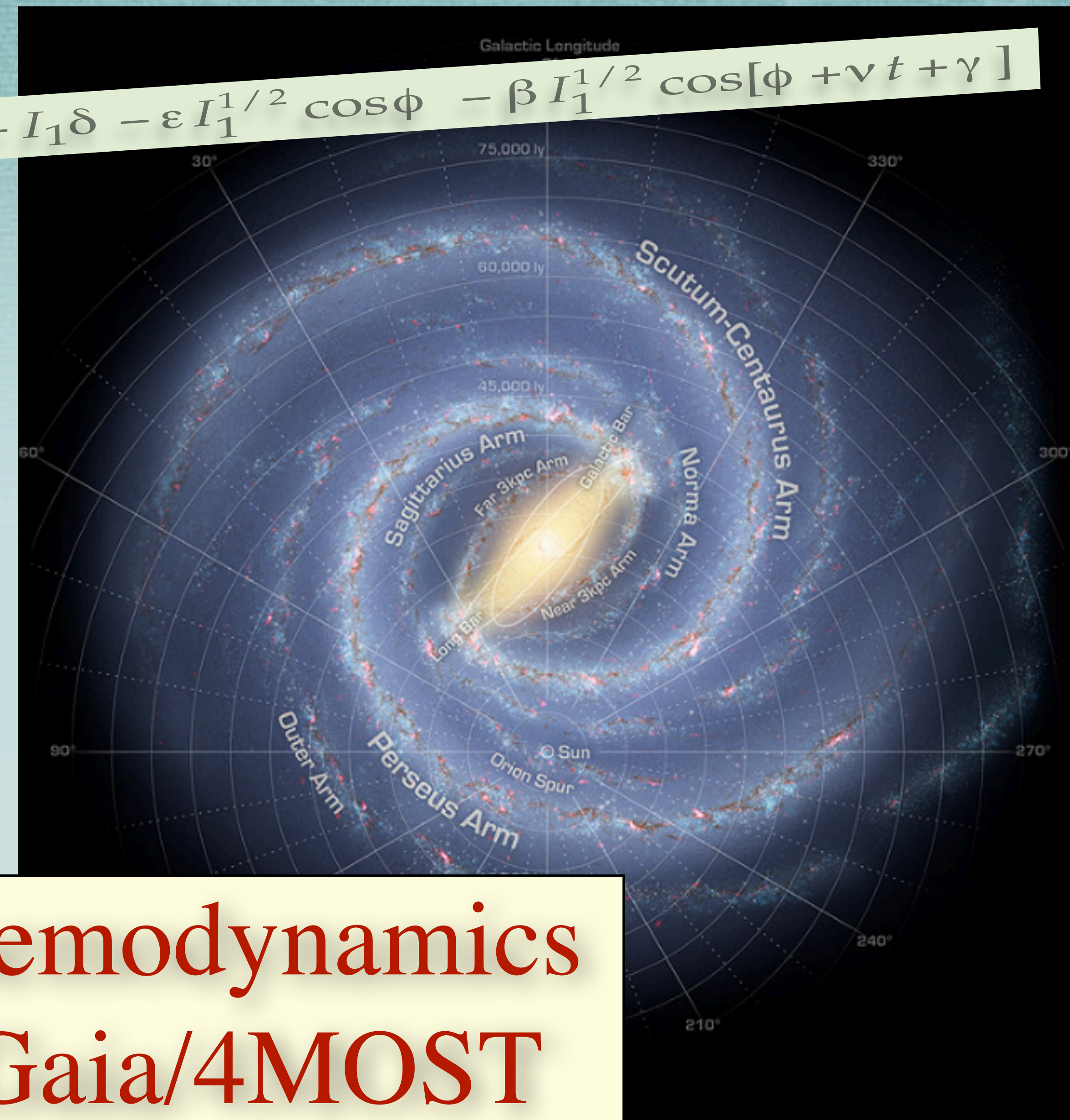

$$H \approx I_1^2 + I_1\delta - \varepsilon I_1^{1/2}\cos\phi \; - \beta I_1^{1/2}\cos[\phi + \nu t + \gamma]$$

Milky Way chemodynamics in the era of Gaia/4MOST

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Leibniz-Institut fur Astrophysik Potsdam (AIP)

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AIP

All numbers and figures shown in this presentation are preliminary

Galactic archeology done for the first time

- The first step toward understanding the MW disk past history is understanding its morphology and dynamics. We can use two approaches:

  (1) study a volume of d=2 kpc around the Sun (extended solar neighborhood), where a high level of precision in velocities and distances is achievable.

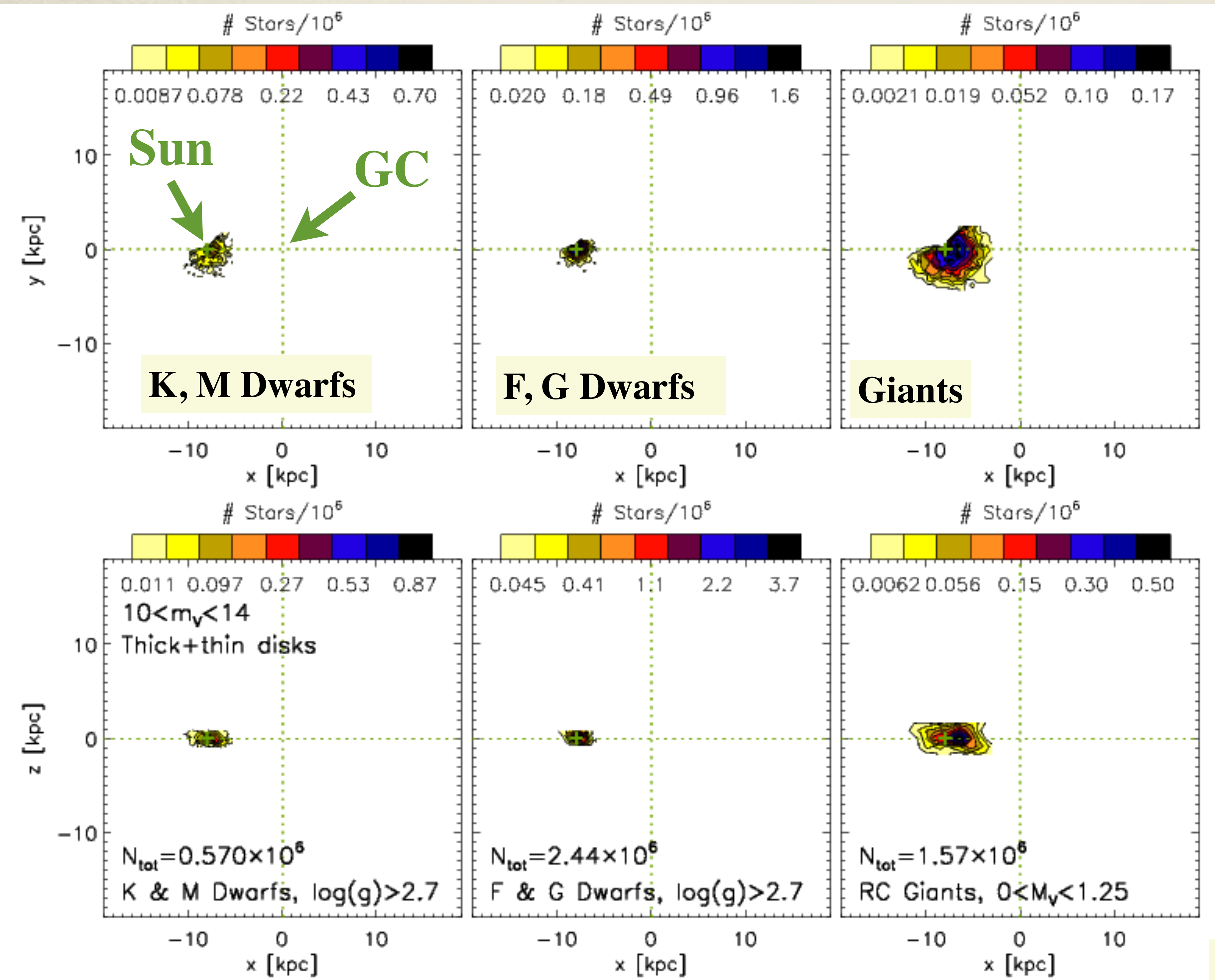
  (2) study the disk morphology and dynamics globally.

- Using constraints from (1) and (2), we can get, for the first time, an unambiguous picture of the MW disk dynamics.

- Combining with good chemistry, we can then go back in time and recover the disk past evolution.

What can we observe in the South for different magnitude ranges (Galaxia data)

What can we observe in the South for different magnitude ranges (Galaxia data)

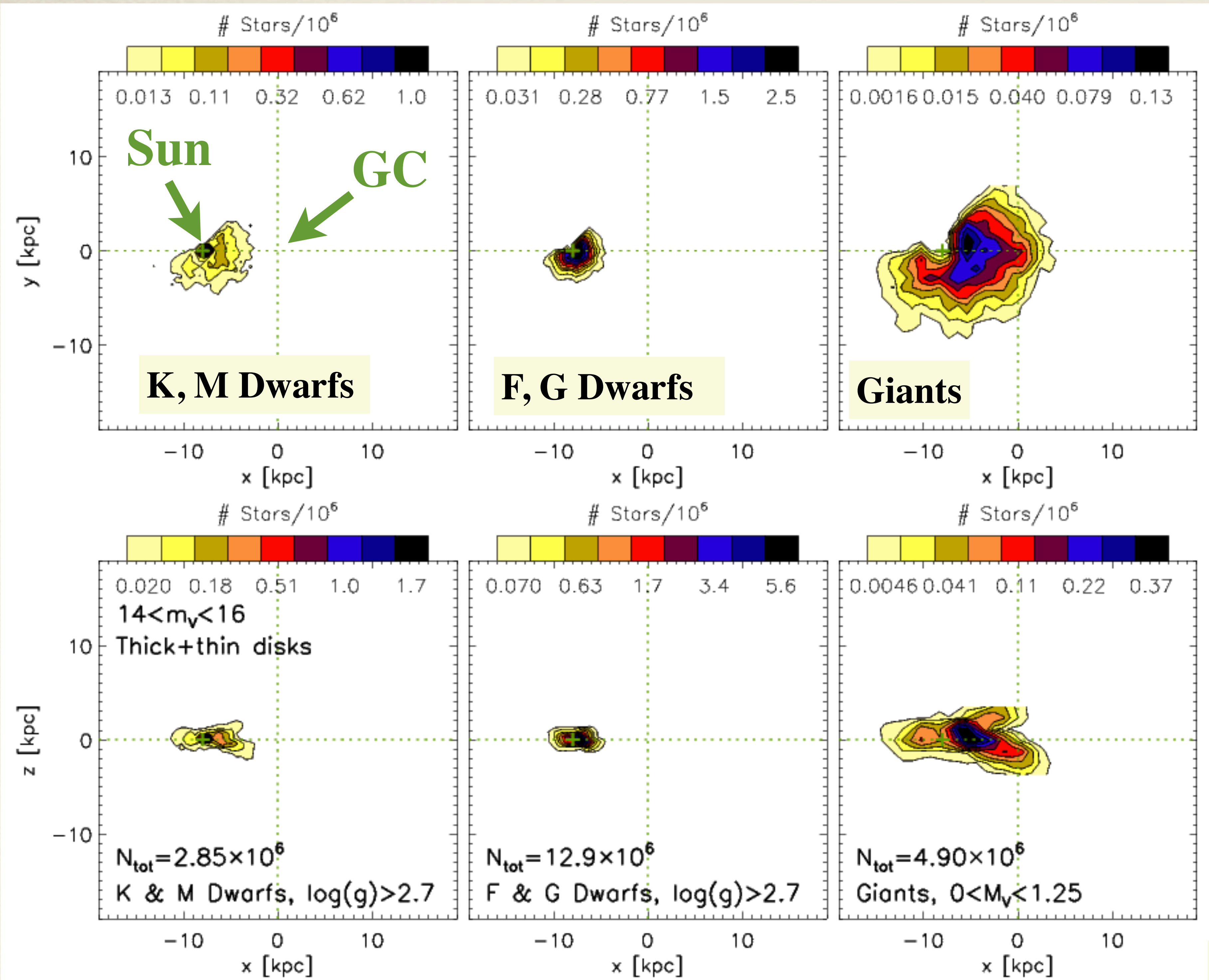


10<V<14

HERMES

Data provided by S. Sharma

What can we observe in the South for different magnitude ranges (Galaxia data)

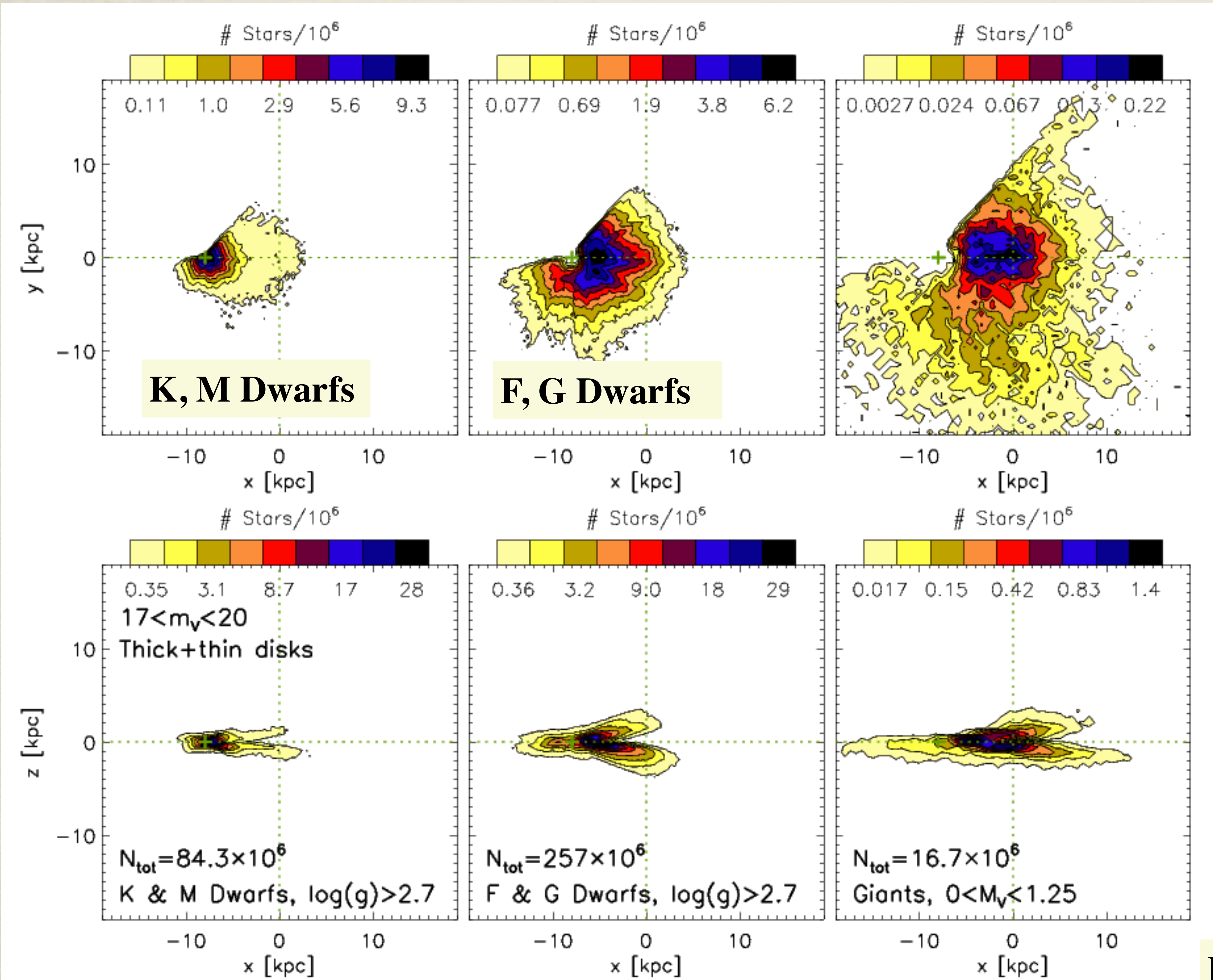


14<V<16

Expected RVs and Metallicities from GAIA

Data provided by S. Sharma

What can we observe in the South for different magnitude ranges (Galaxia data)



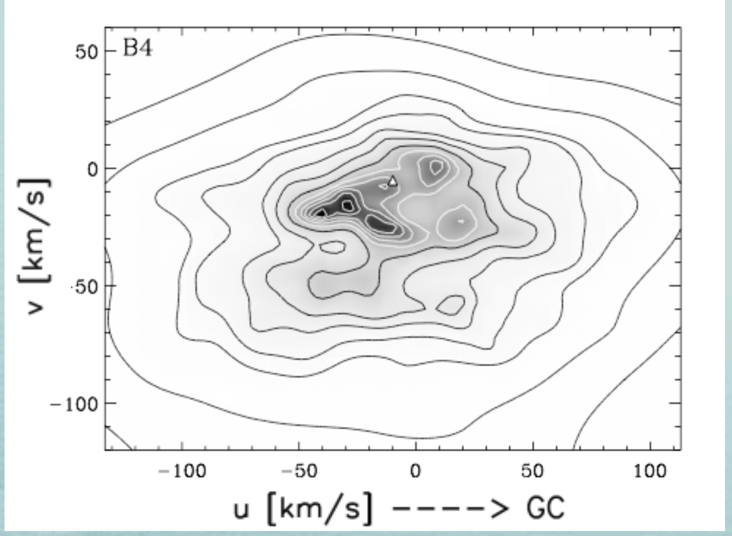
17<V<20

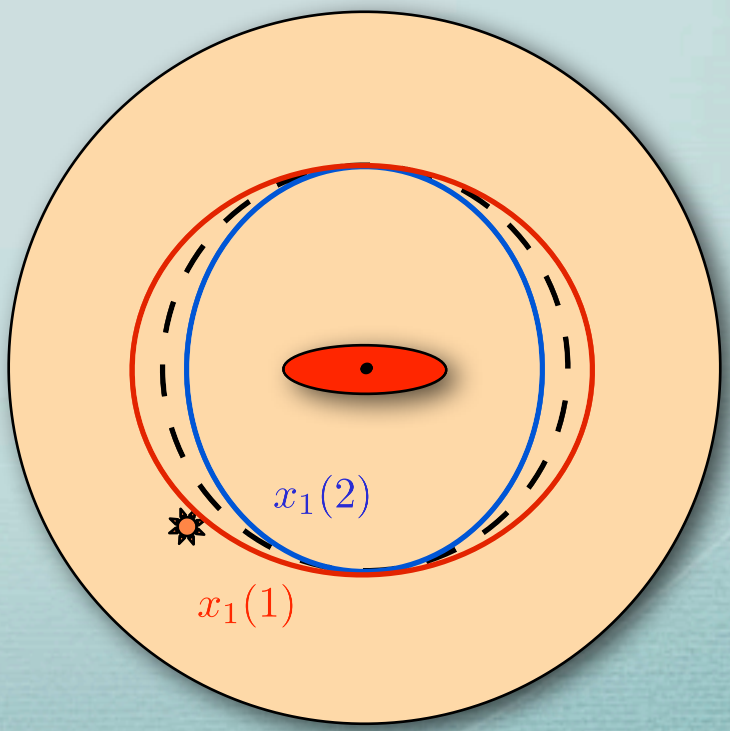
4MOST complements Gaia with RVs and Metallicities

See Chiappini's talk on 4MOST

Data provided by S. Sharma

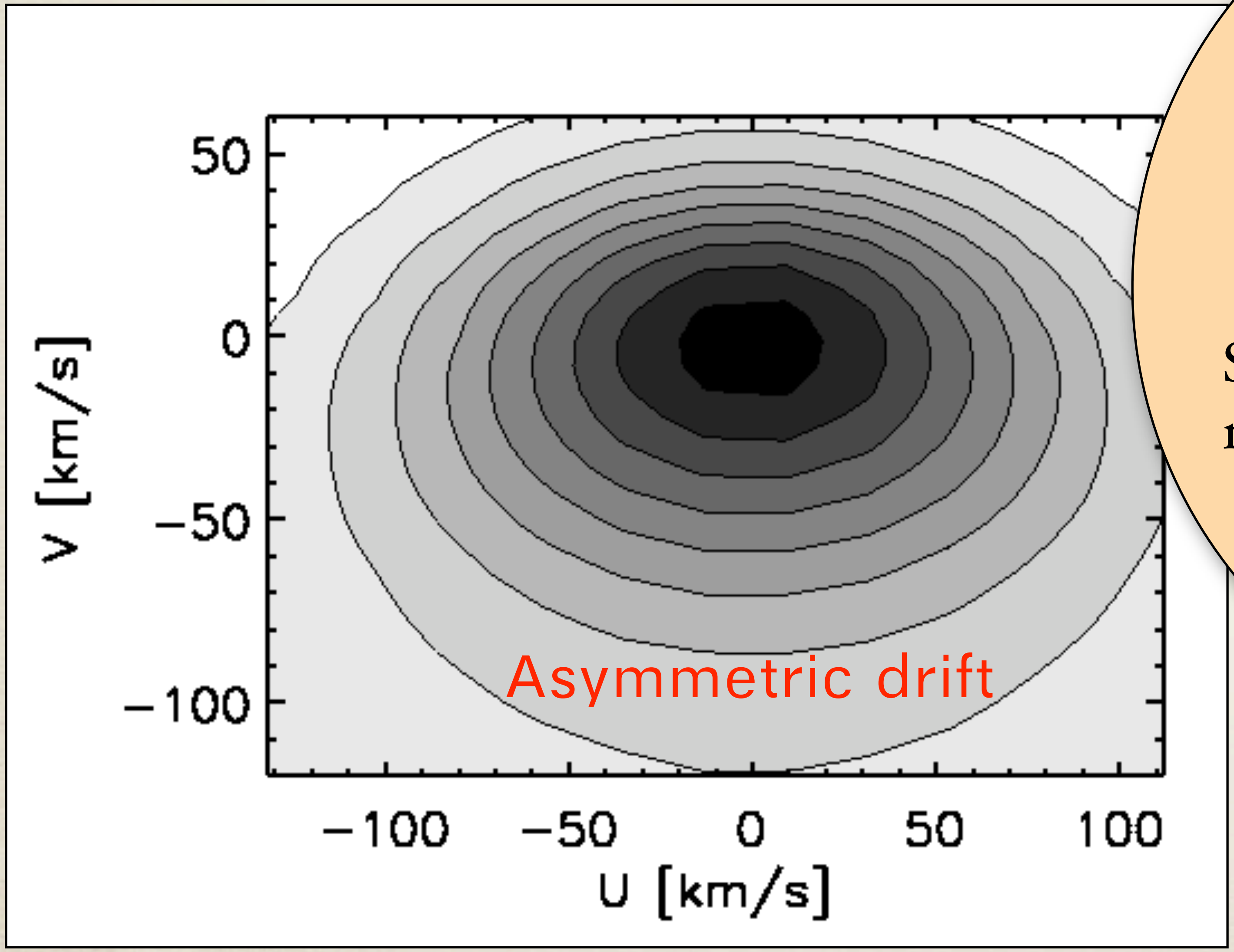
Resonant moving groups in the EXTENDED Solar neighborhood

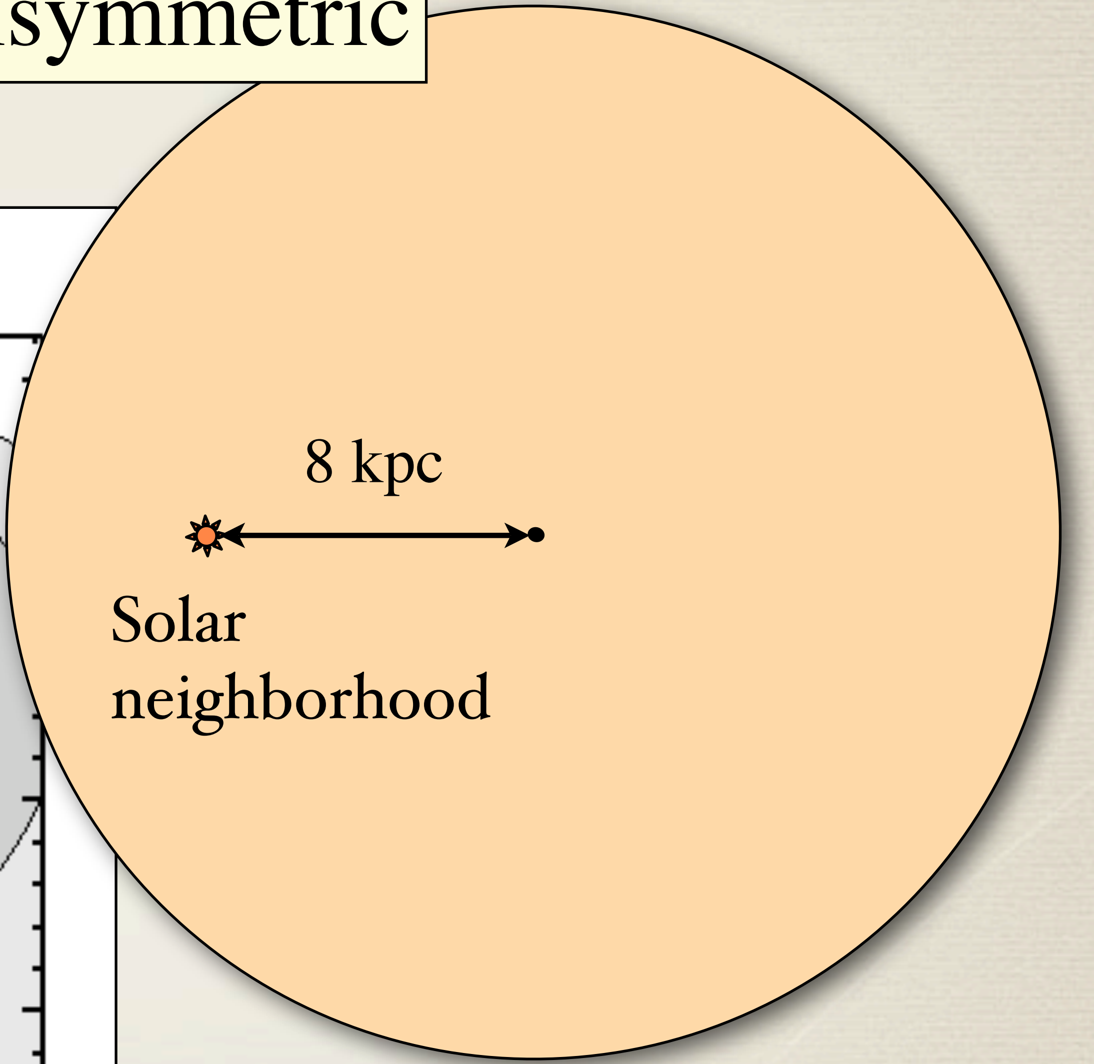




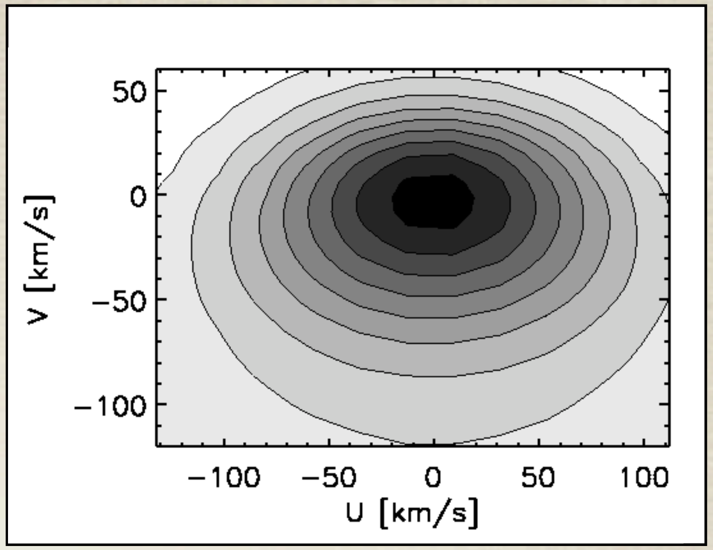
The u-v plane

If the Milky Way disk were axisymmetric





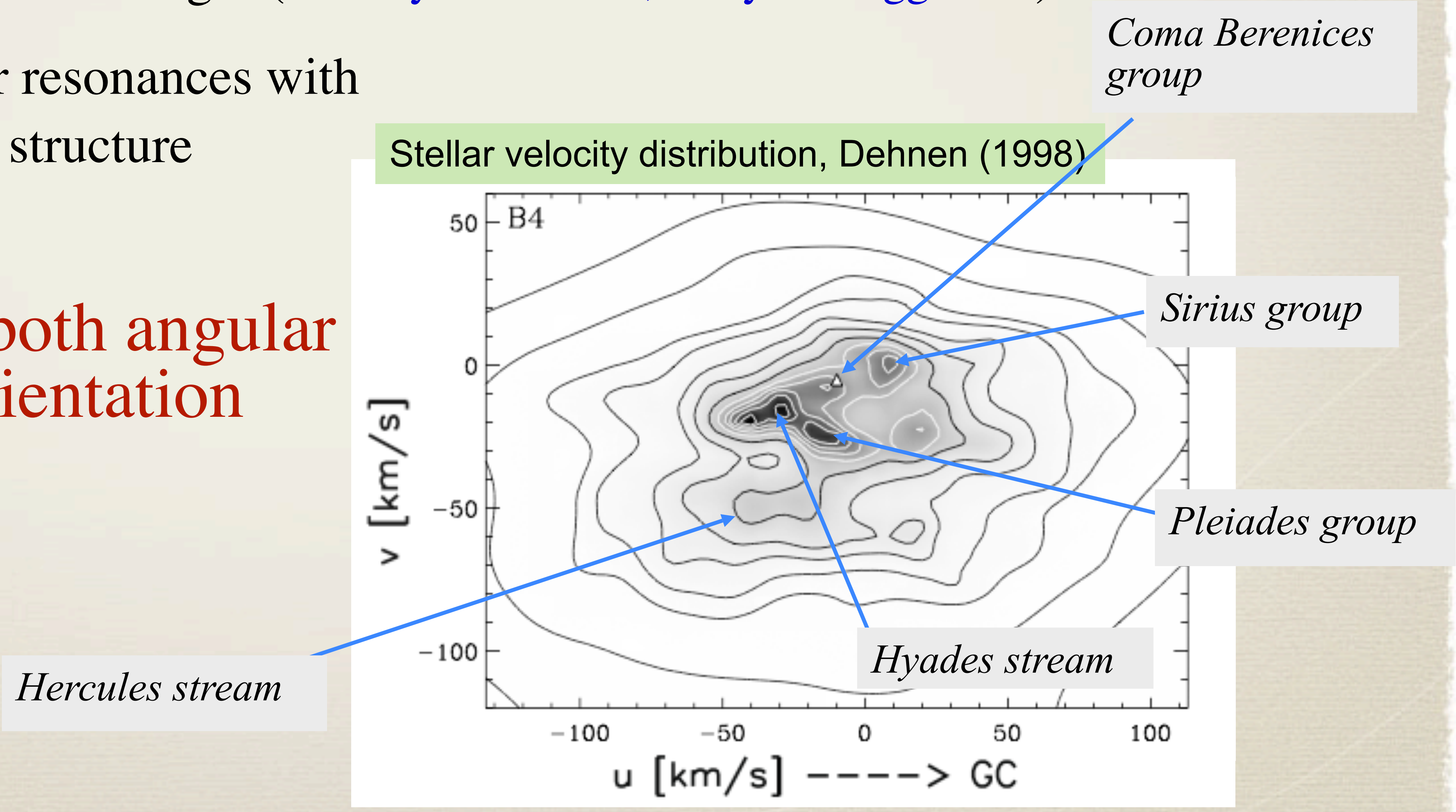
Hipparcos stellar velocity distribution



- Lots of structure in the u-v plane.
- The most prominent low-velocity moving groups in the solar neighborhood favor a dynamical origin (Famaey et al. 2008, Bovy & Hogg 2009).
- Created near resonances with bar or spiral structure

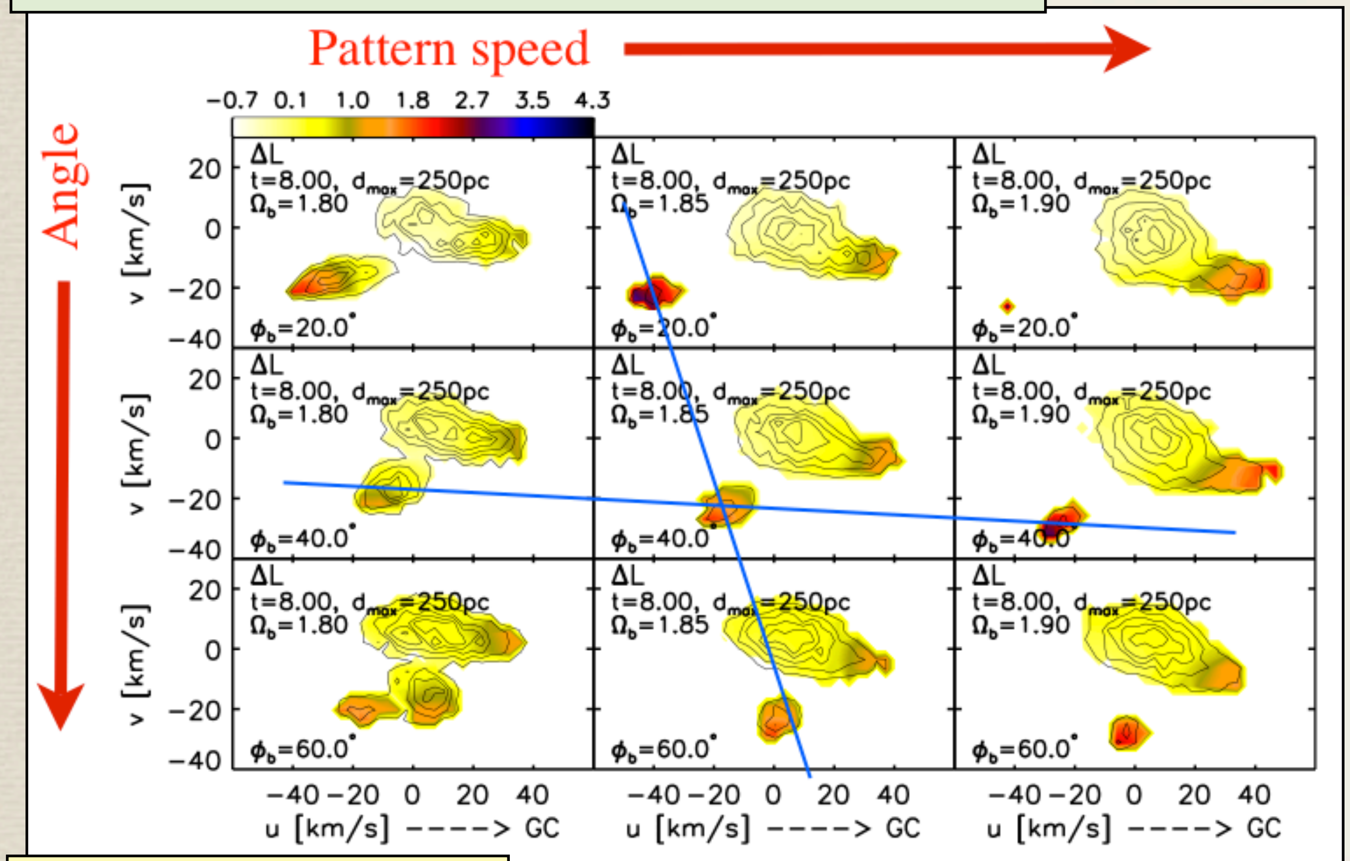
Can constrain both angular velocity and orientation

Dehnen (2000)
Quillen & Minchev (2005)
Minchev et al. (2010)
Antoja (2009, 2011)

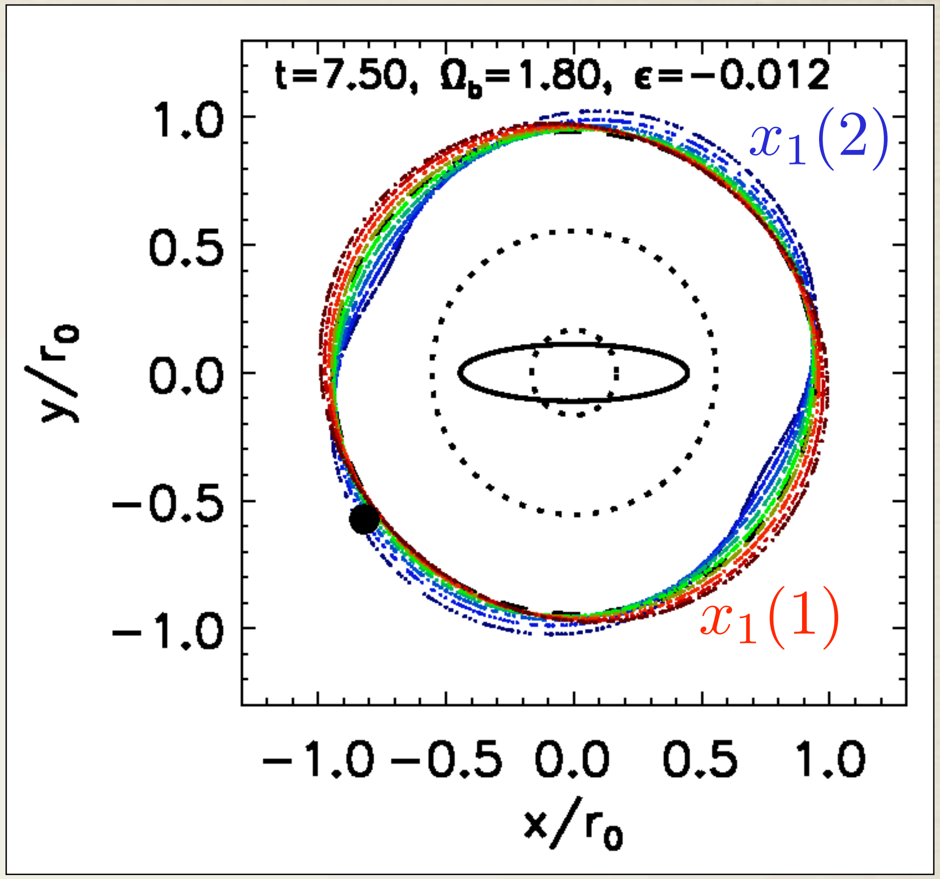


Modeling the u-v plane

The effect of the Galactic bar



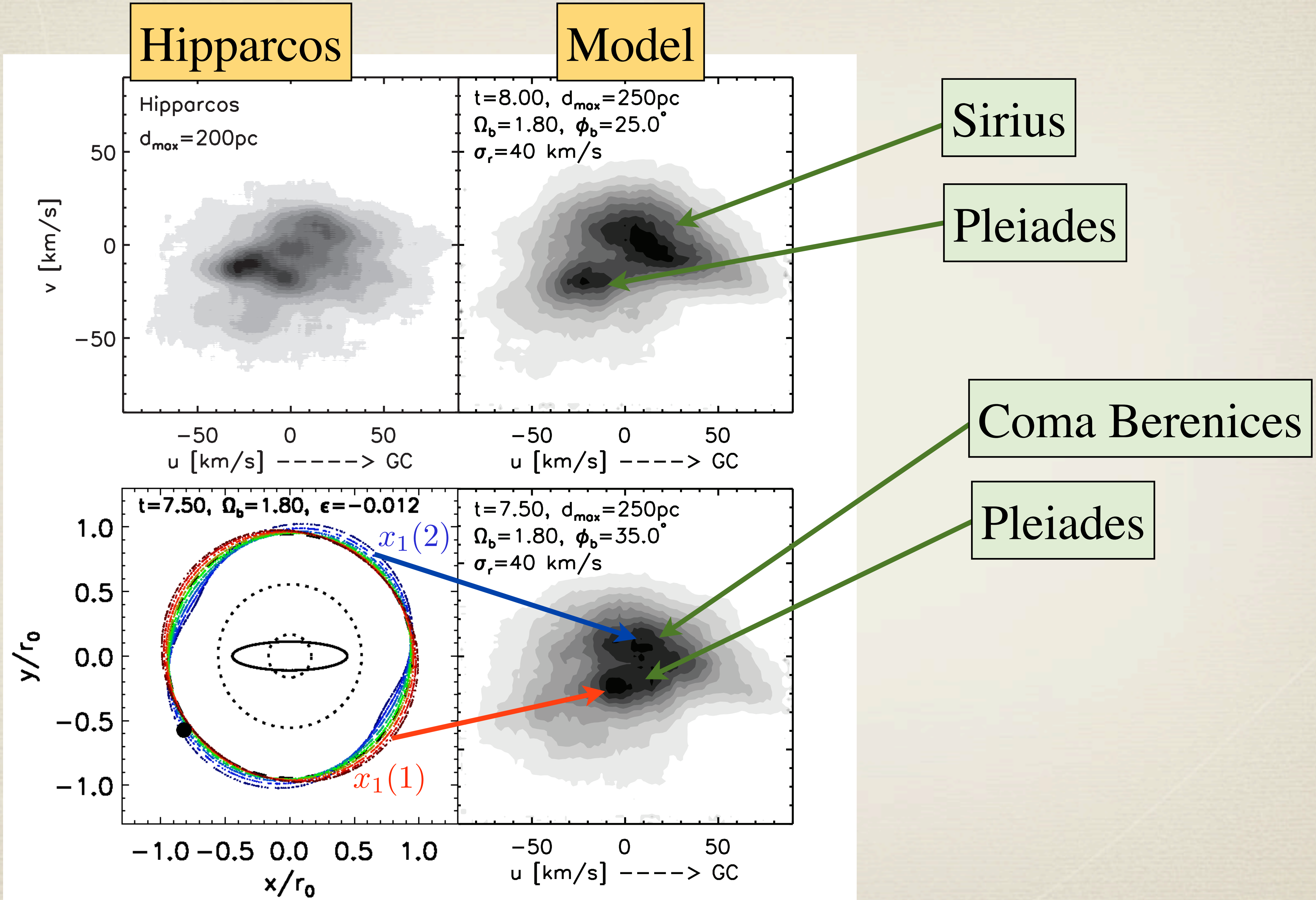
Minchev et al. (2010)



- Each region on the u-v plane corresponds to a different family of closed/periodic orbits

- Clumps shift with galactic radius and azimuth

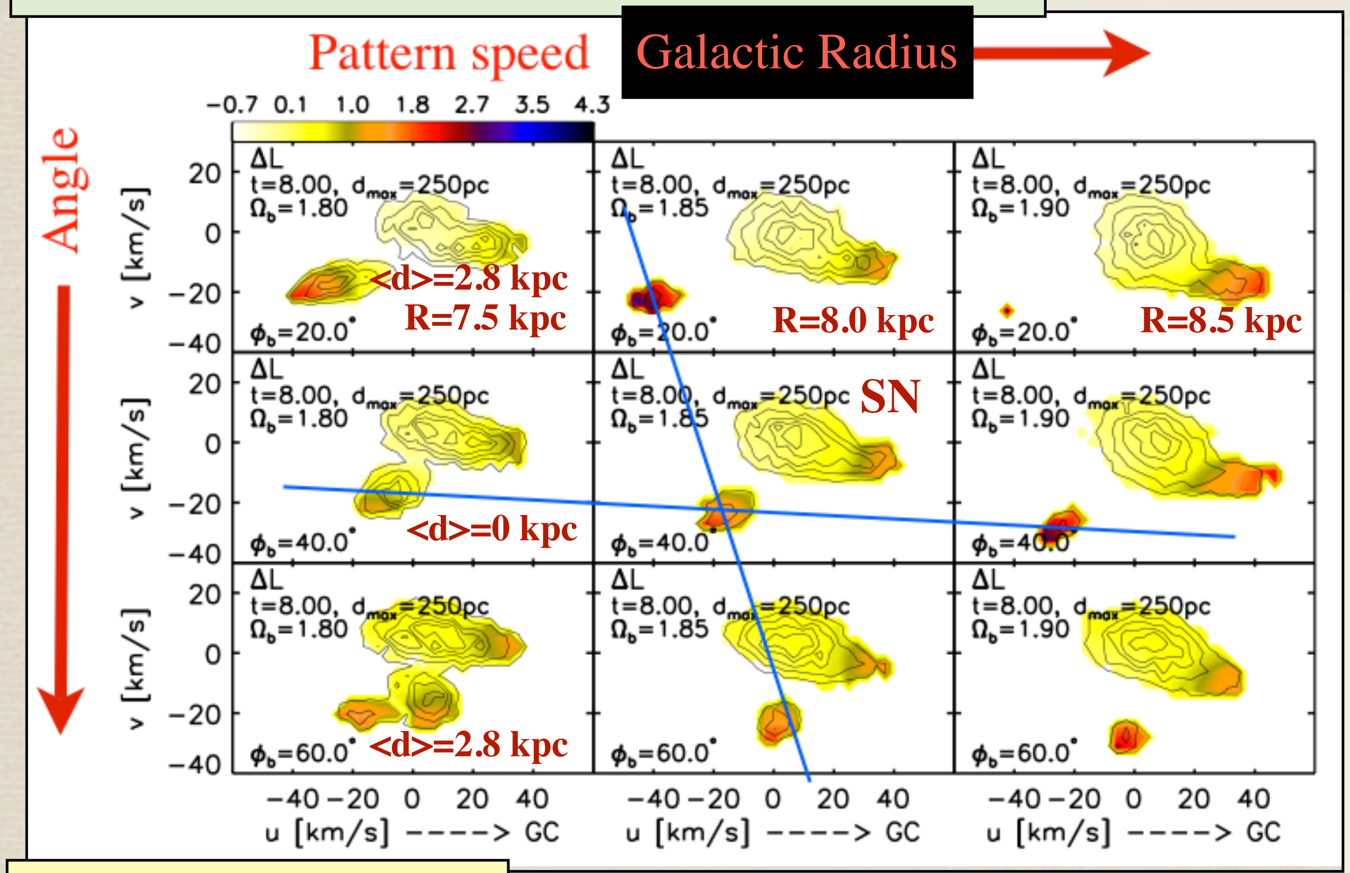
Matching to Hipparcos data



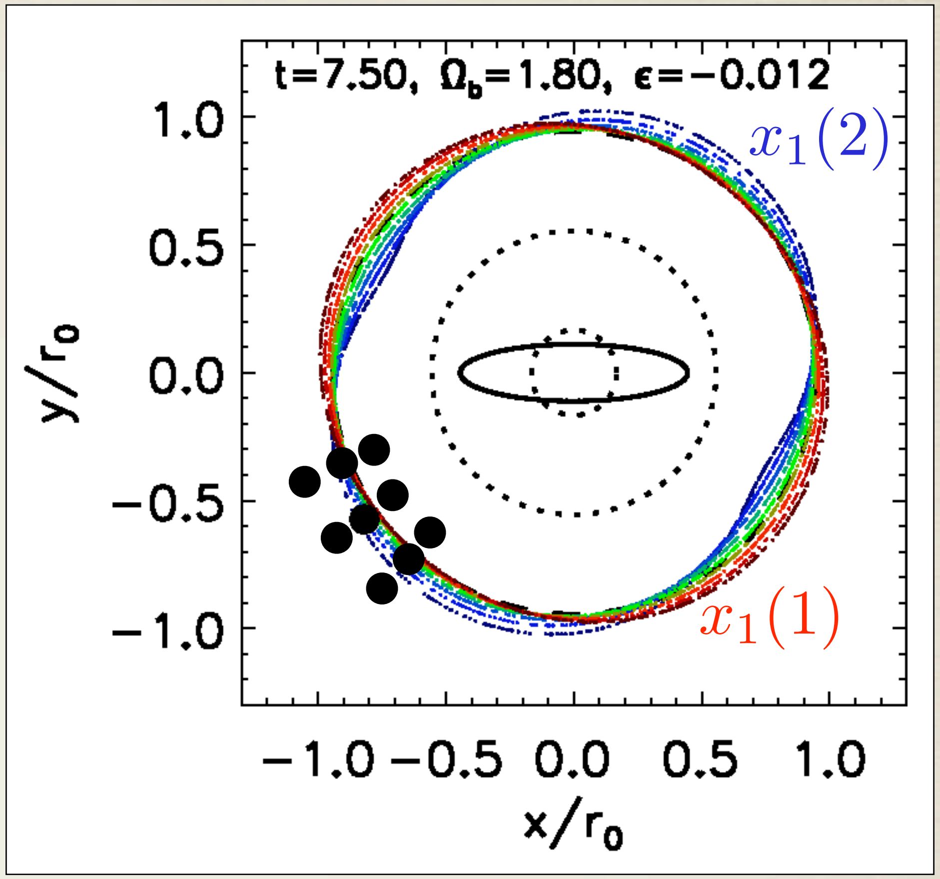
Minchev et al. (2010)

Modeling the u-v plane at different positions in the disk

The effect of the Galactic bar



Minchev et al. (2010)



- Clumps shift with galactic radius and azimuth (~5 km/s).

We need ~2 to 5 km/s error in U, V, W (depending on streams) to detect this shifting.

- Neighborhoods are spheres of radius 250 pc.

—> Needed distance precision to 200 pc

Gaia distances

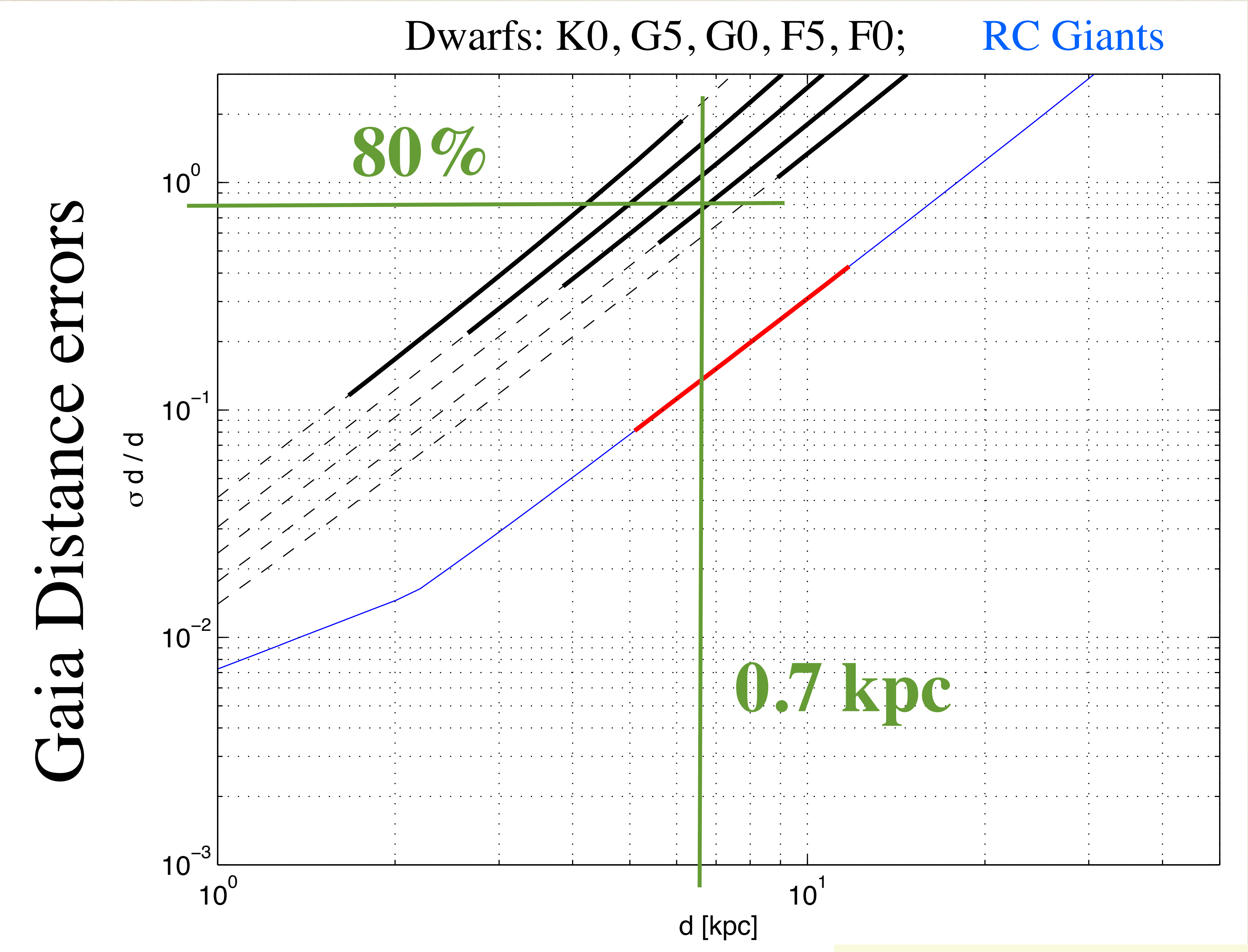


Fig. provided by A. Koch

solid lines: 17<V<20

- We need distance precision to 200 pc.

Gaia distances

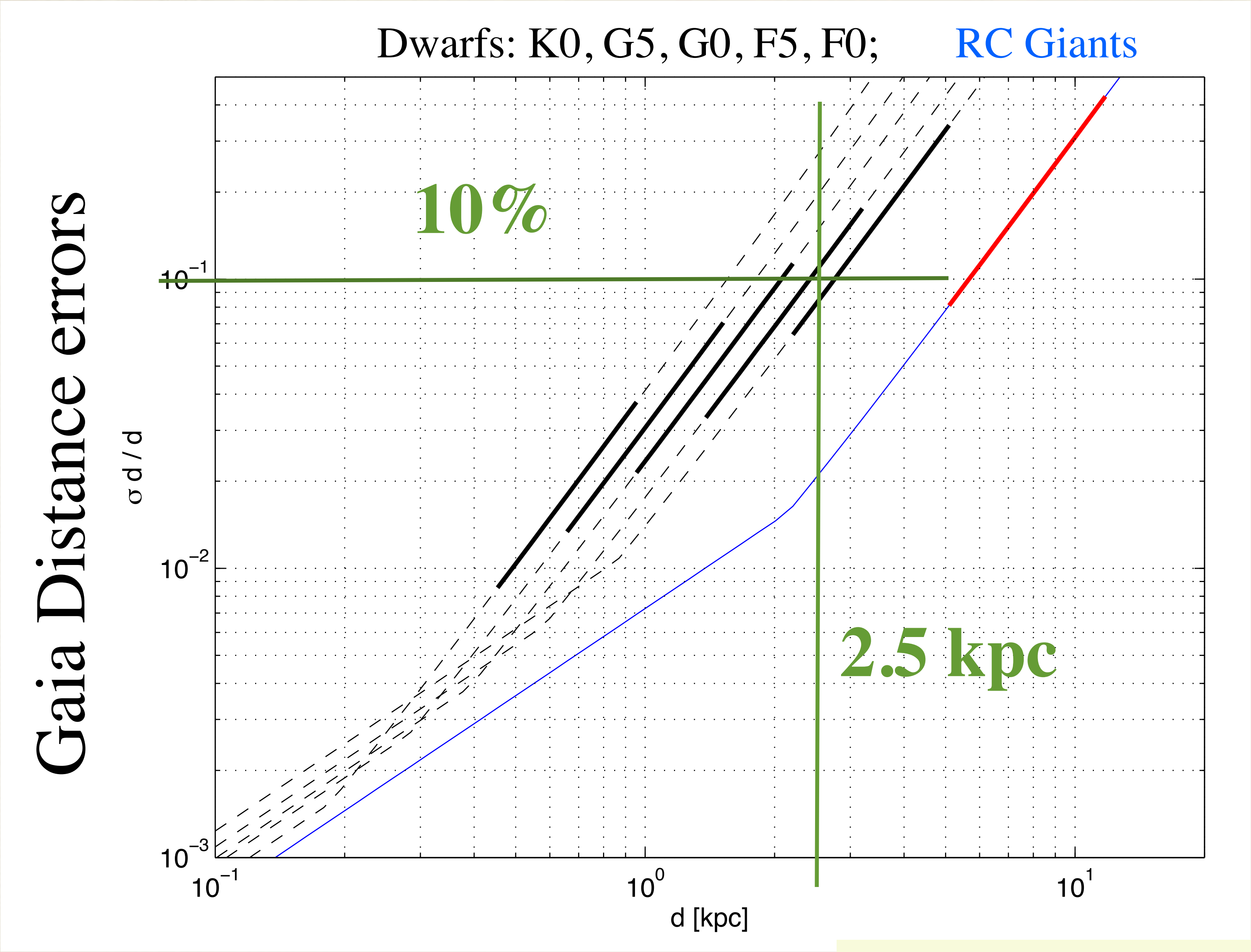


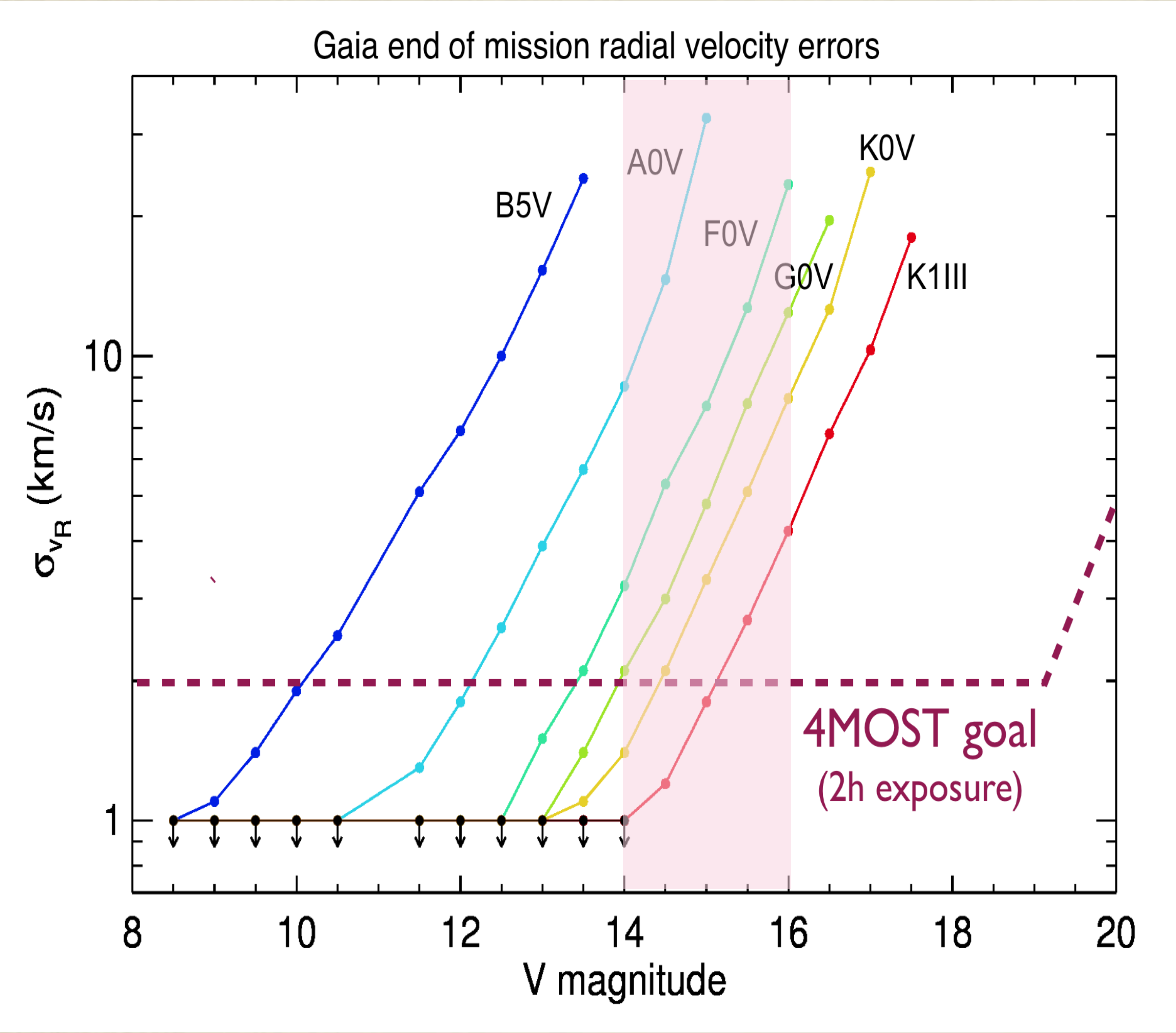
Fig provided by A. Koch

solid lines: 14<V<16

Using RCG, we can get out to ~7 kpc

- We need distance precision to 200 pc.
- Possible from Gaia for d<~2.5 kpc

Gaia RVs



Gaia will provide RVs in the range 14<V<16

This precision may not be sufficient for studying the U-V plane at the detail we want.

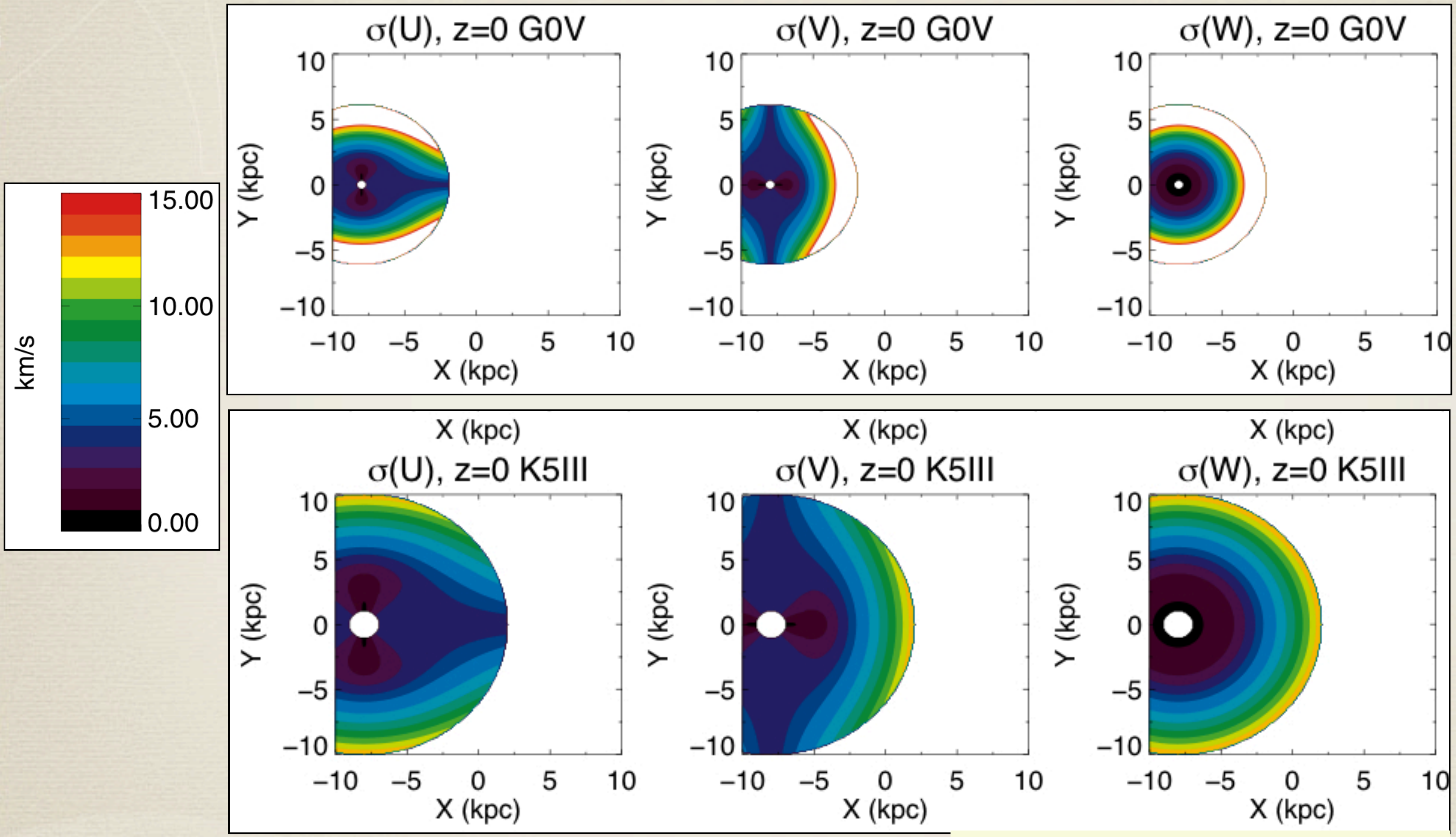
However, 4MOST will provide RV errors < 2 km/s.

We need ~2 km/s error.

(Gaia + 4MOST) UVWs

For Gaia distances in 14<V<16

For RVs error of 2 km/s from 4MOST



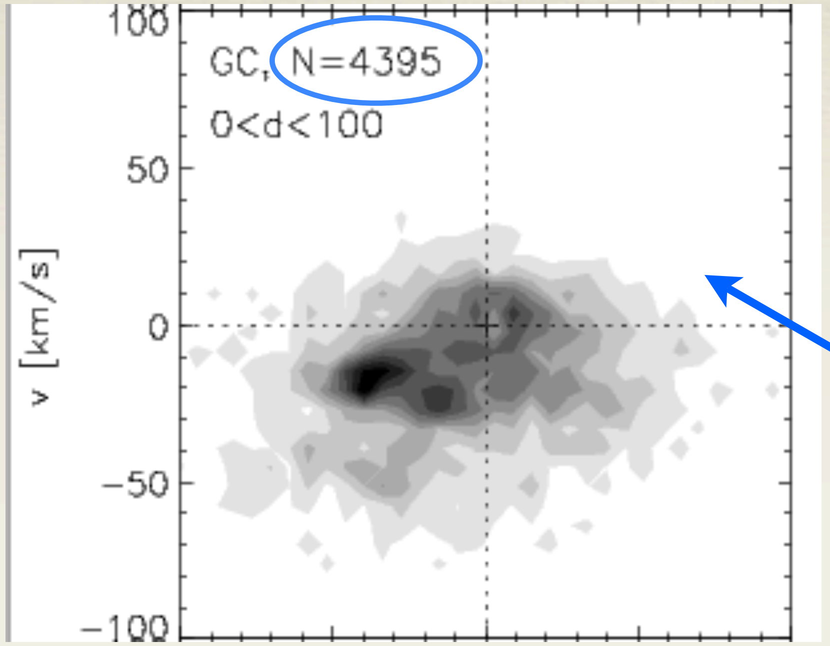
Dwarfs

Giants

Figure provided by M. Williams

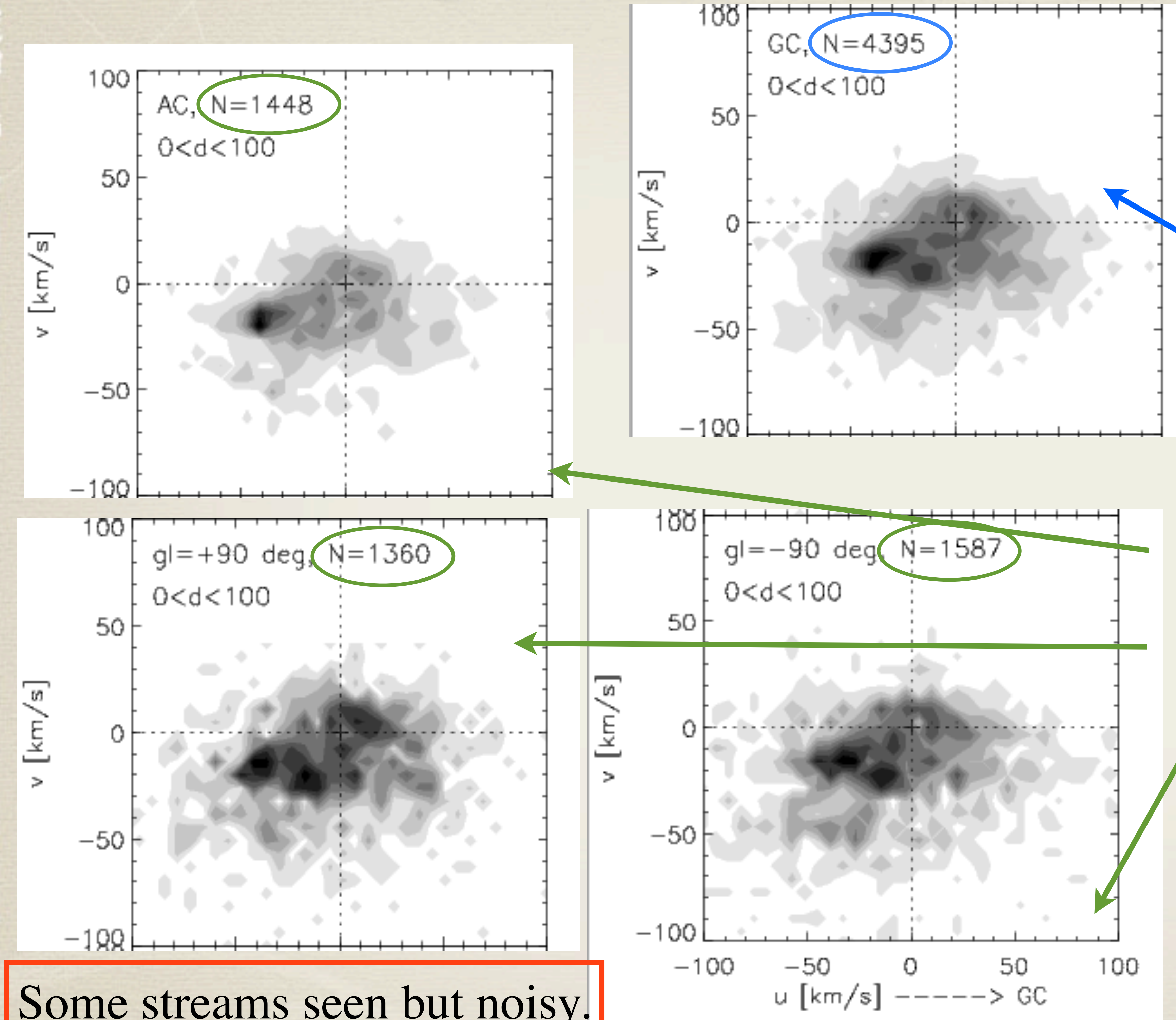
- We need ~2 km/s error in UVW.
- Possible for d < 2-3 kpc (Dwarfs) and d < 5 km/s (Giants)!

The u-v plane for the GCS, d < 100 pc



For the GCS resolution of 4400/(100 pc)^3 we need 18x10^6 stars at d<2 kpc!!

The u-v plane for the GCS, d < 100 pc



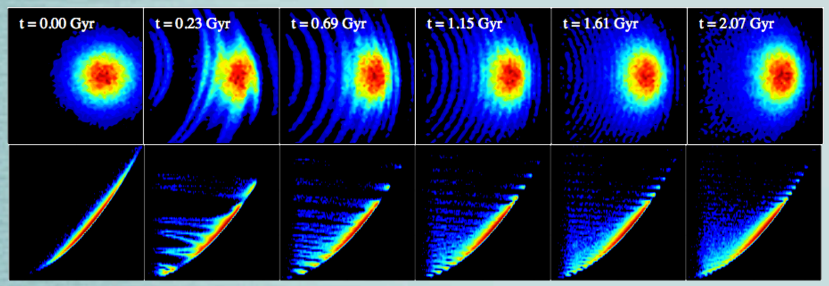
For the GCS resolution of 4400/(100 pc)^3 we need 18x10^6 stars at d<2 kpc!!

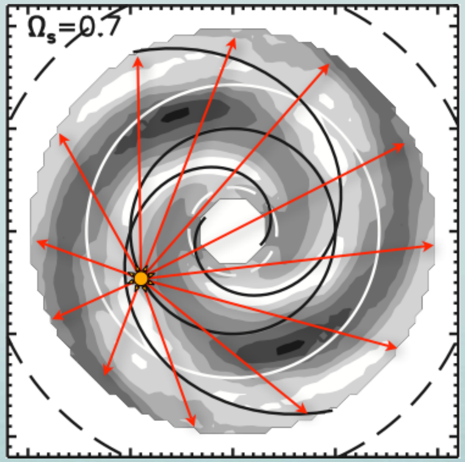
For density=1400/(100 pc)^3 we need 6.6x10^6 stars

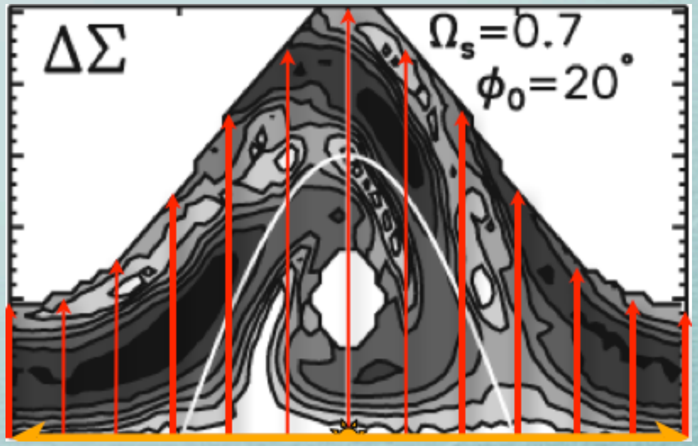
Some streams seen but noisy. 1400/(100 pc)^3 is the minimum density required.

Studying the extended solar neighborhood is NOT sufficient to constrain large–scale morphology, and thus the disk evolution

Studying the entire available disk







Why study the whole disk?

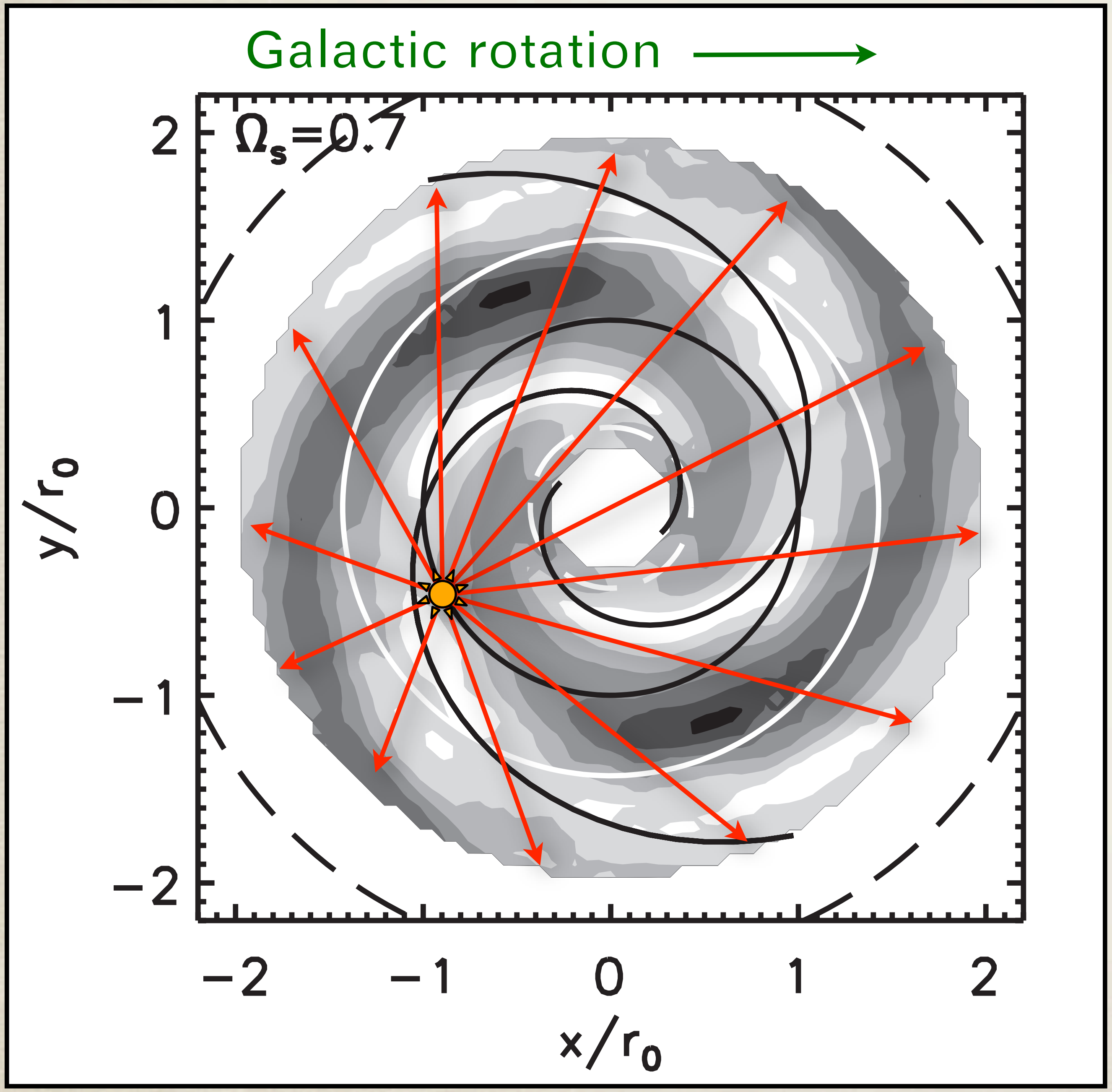
- To disentangle the importance of the internal processes (radial migration etc.) on the MW disk evolution from the effect of mergers, we *first need to know the MW disk morphology and dynamics*. Due to the complexity of asymmetries expected, we need to survey the entire disk.

- Strong variation in the migration efficiency expected with galactic radius and time.

- Given the number of asymmetric pattens and their characteristics, in combination with good metallicity distributions and gradients, we can put constraints on the amount of mixing which has taken place in the past.

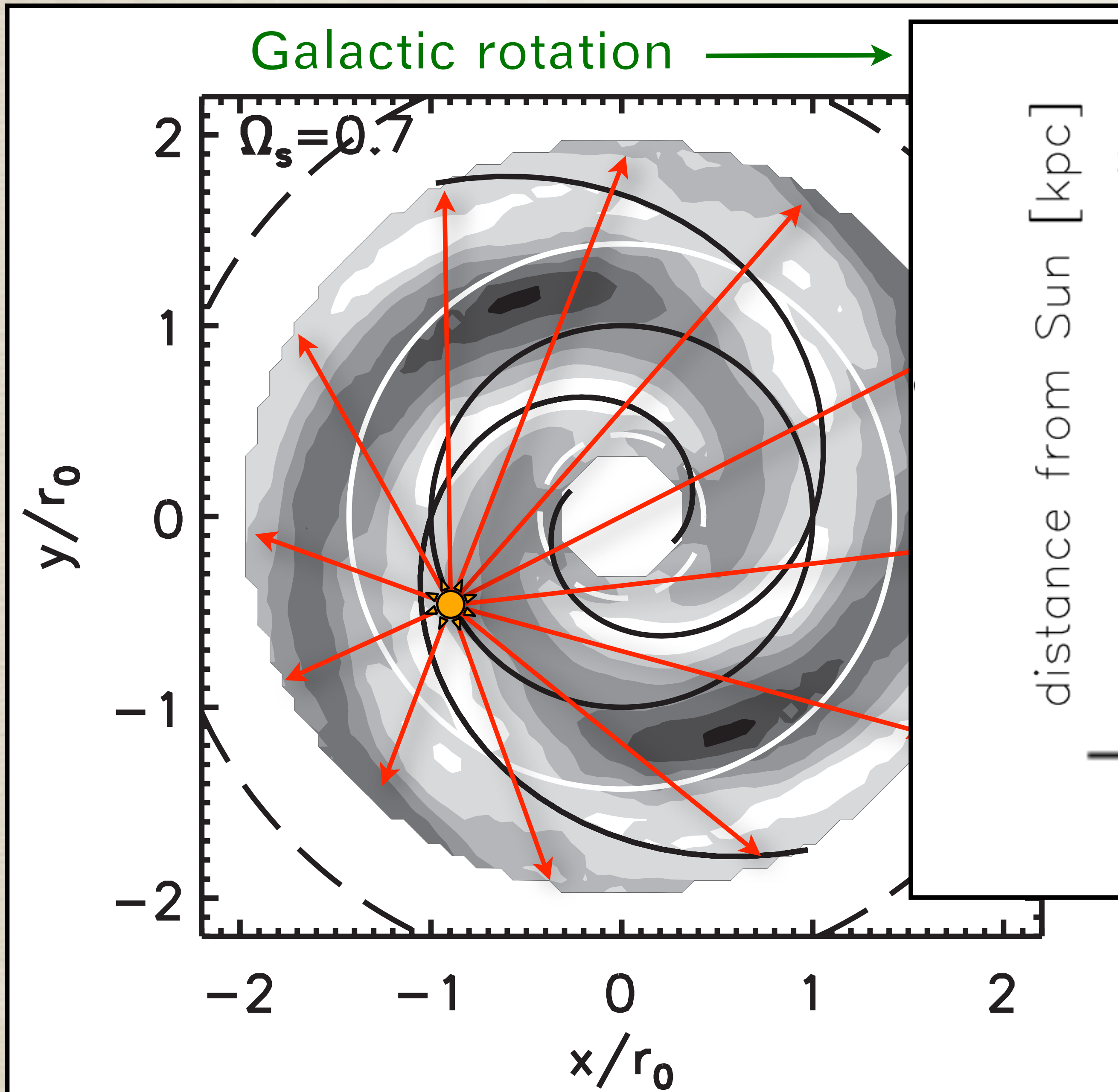
- Velocity dispersion gradients and distribution at different positions.

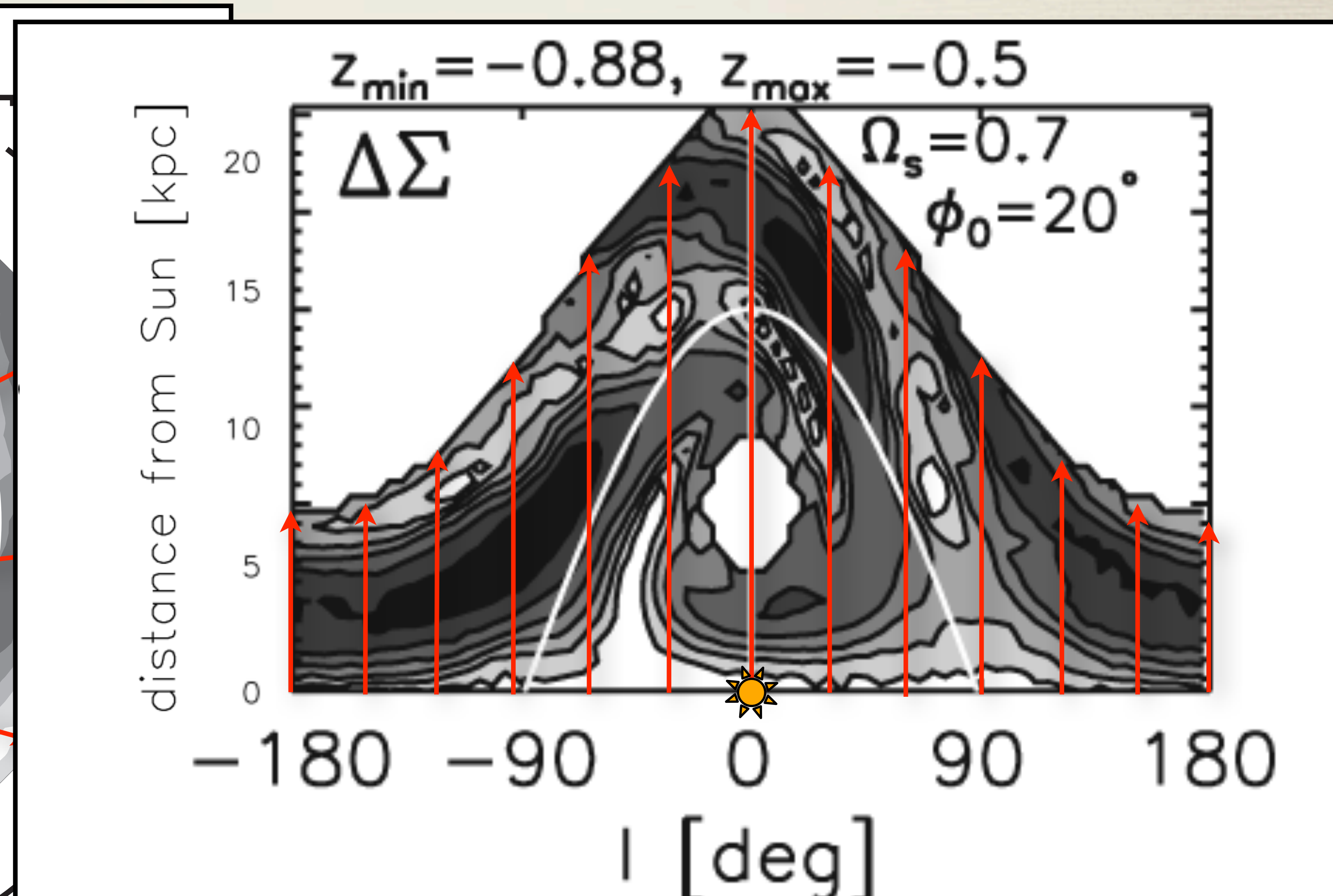
Large-scale surveys: Gaia and 4MOST



- Take spectroscopic and photometric measurements.
- Bin in Galactic longitude and Heliocentric distance.
- Create line of sight velocity and number density maps.

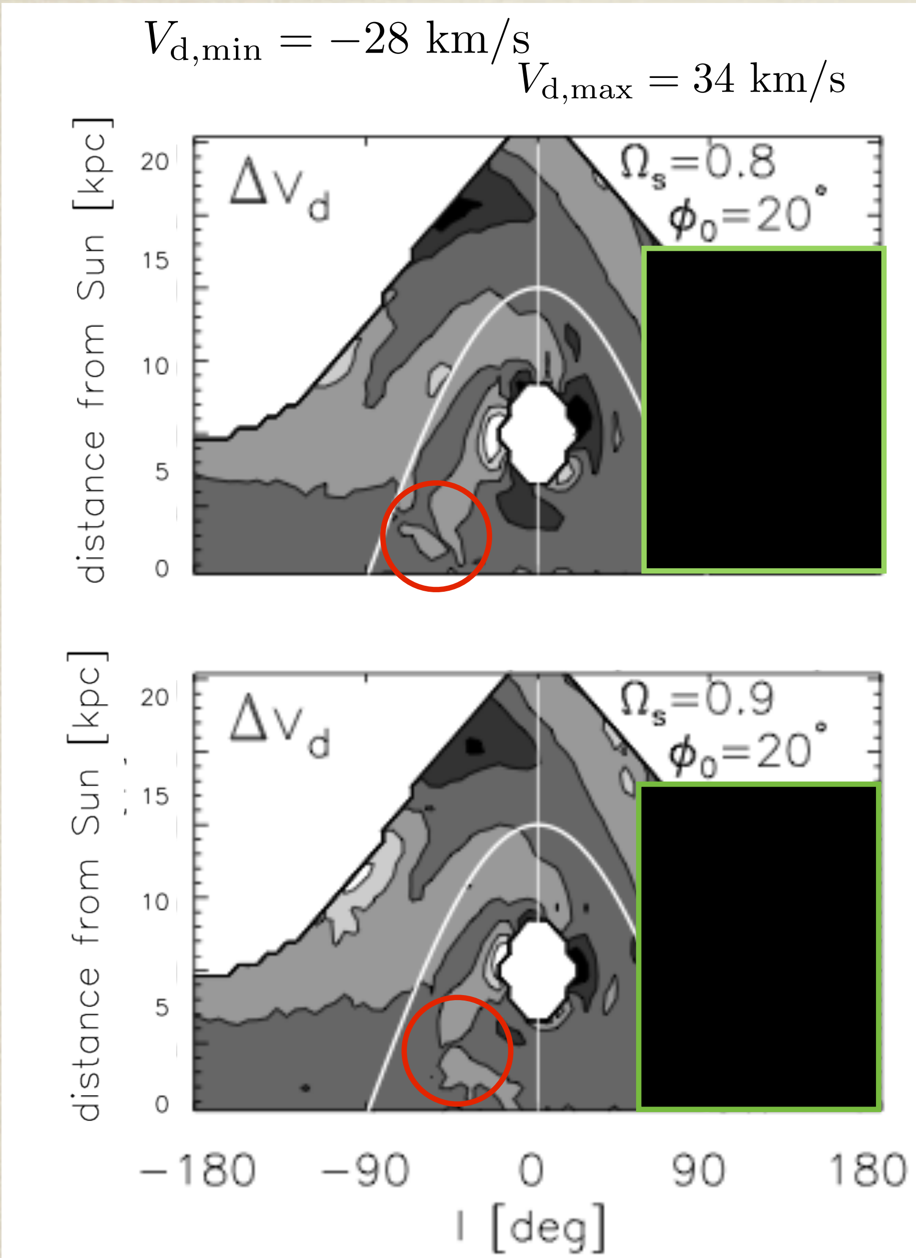
x-y to l-d plane



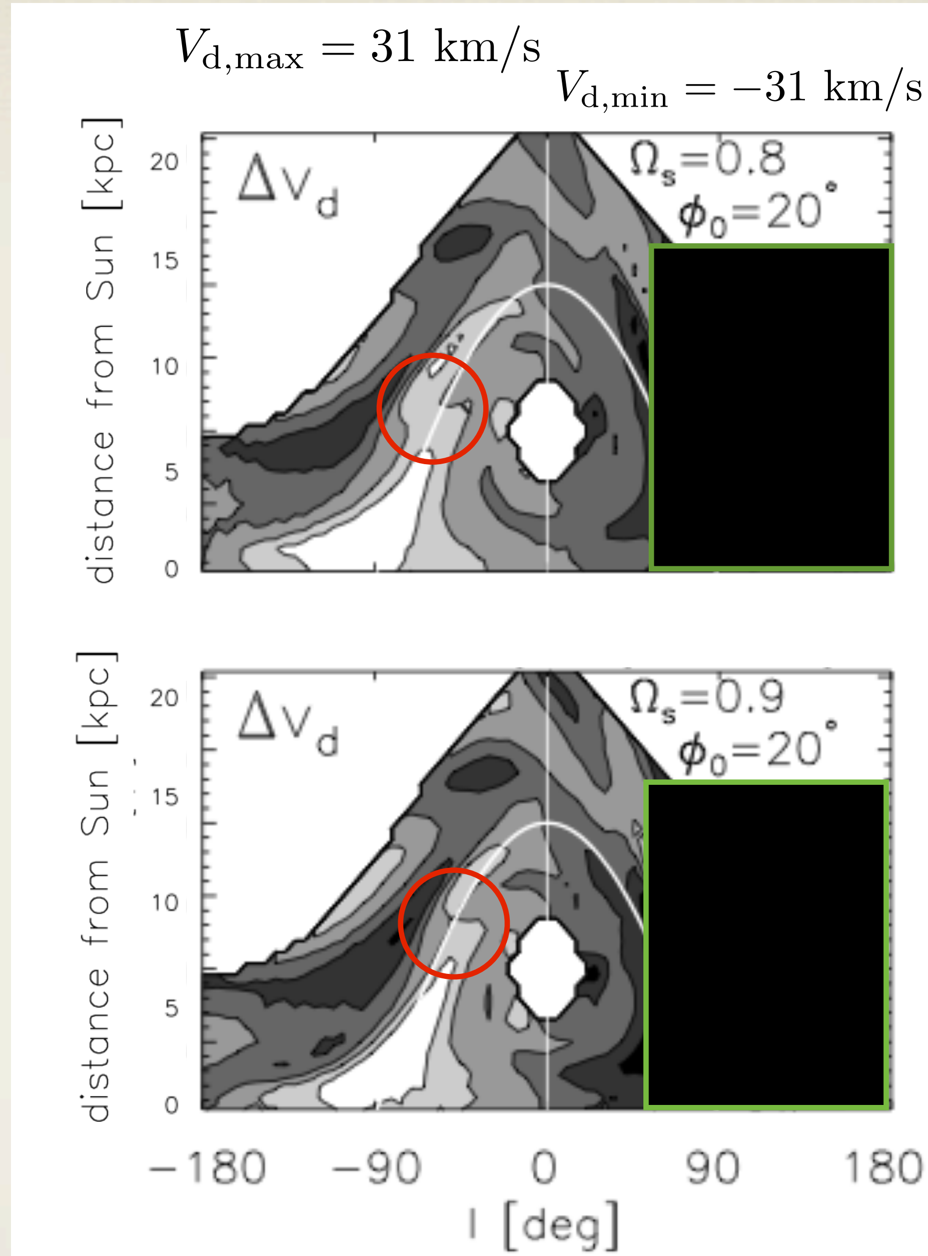


Learn about the disk morphology and dynamics

2-armed



4-armed



Same spiral orientation but different angular velocity, Ω

Ω=24 km/s/kpc

Resonant features

Ω=27 km/s/kpc

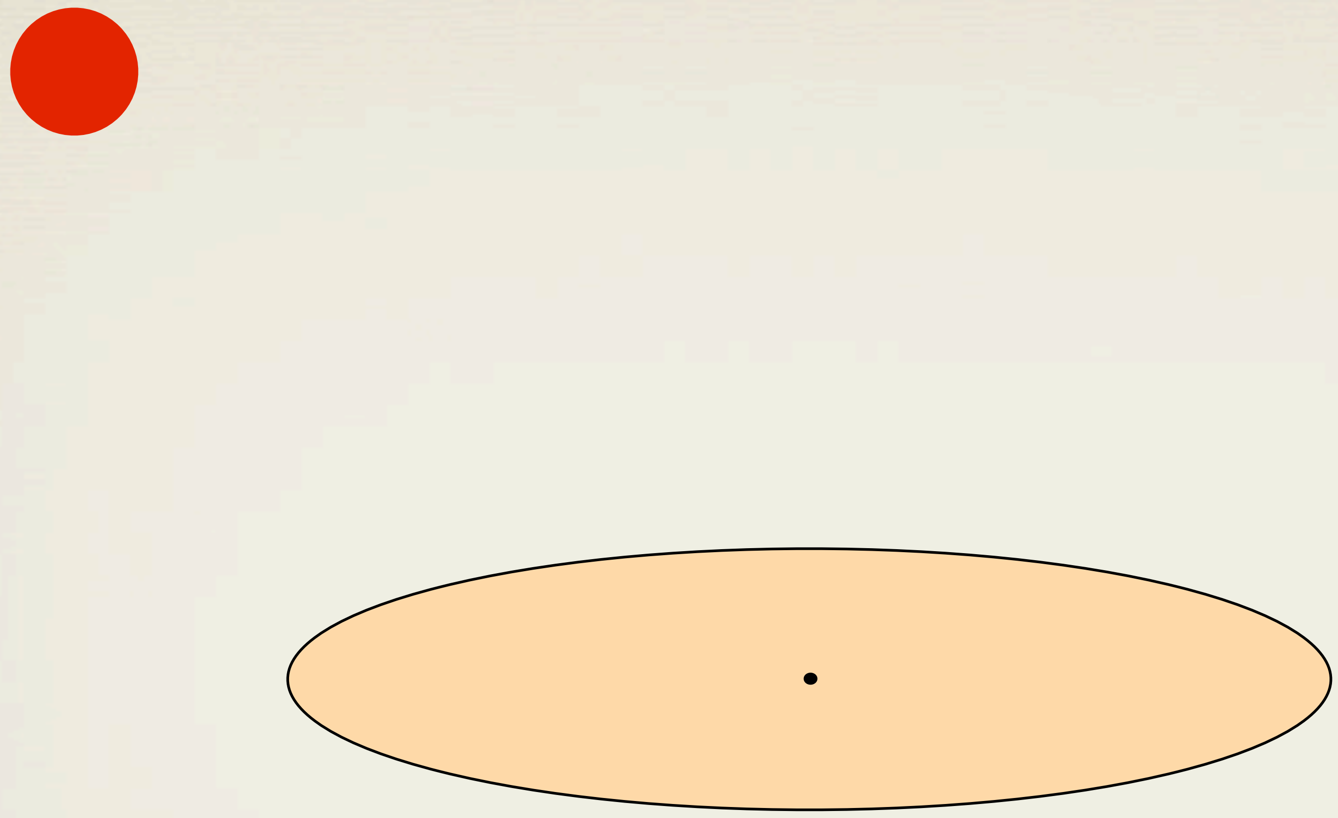
- We need to know:

distances better than ~15% (1.5 kpc error at 10 kpc)

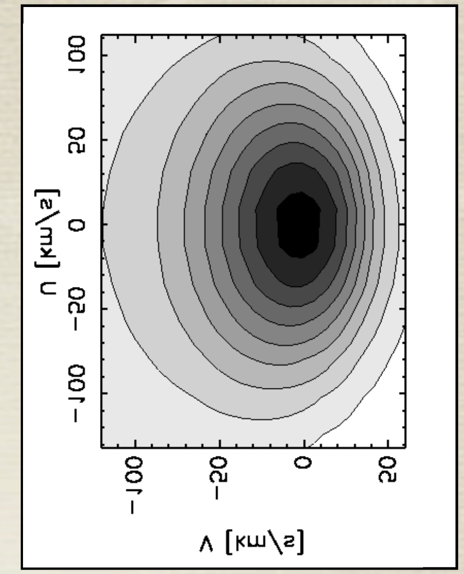
line of sight velocities to ~2-5 km/s

We can do good with 5, but much better with 2 kpc!

The effect of minor mergers on the Galactic disk

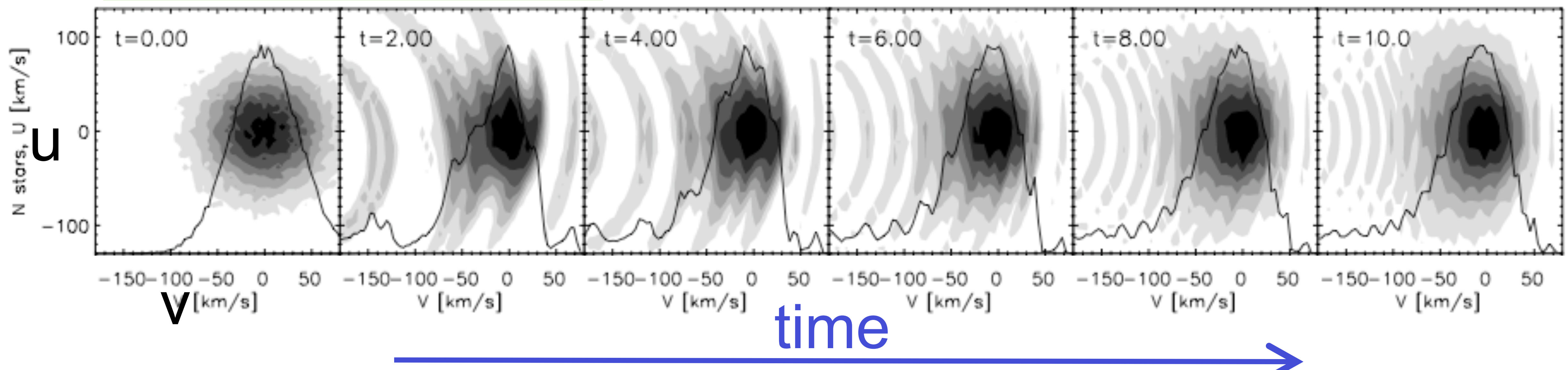


Phase wrapping in the disk

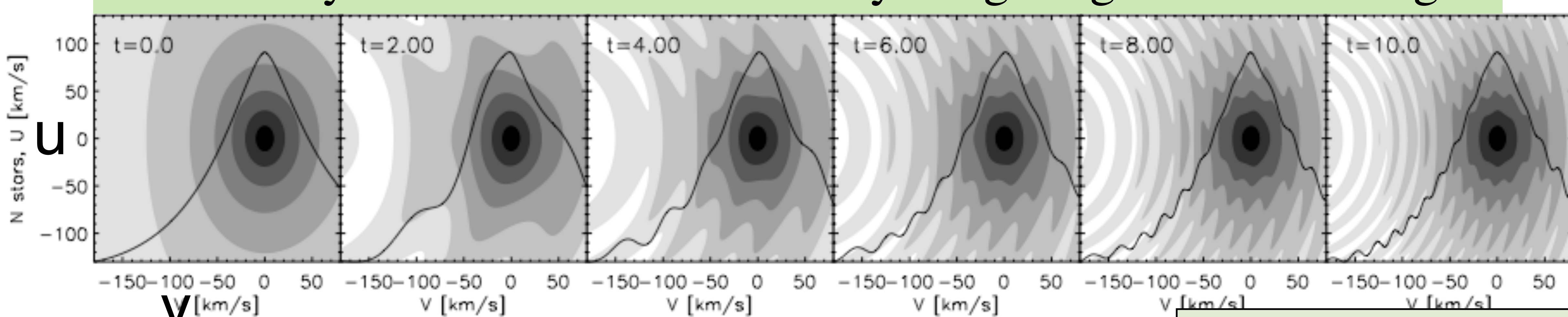


- Following an uneven distribution in epicyclic angle, the thick disk can exhibit streams

Stellar disk simulations

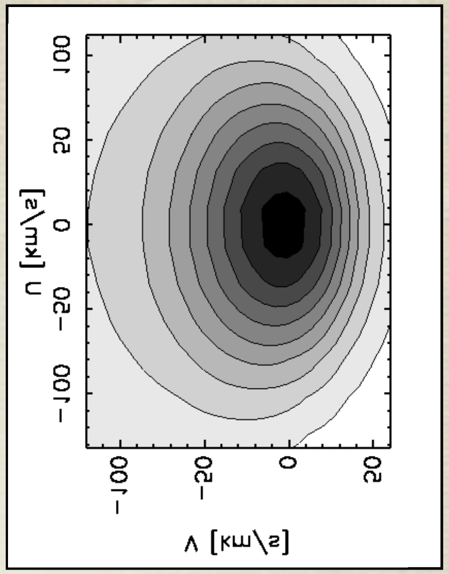


Semi-analytical model constructed by weighting with radial angle



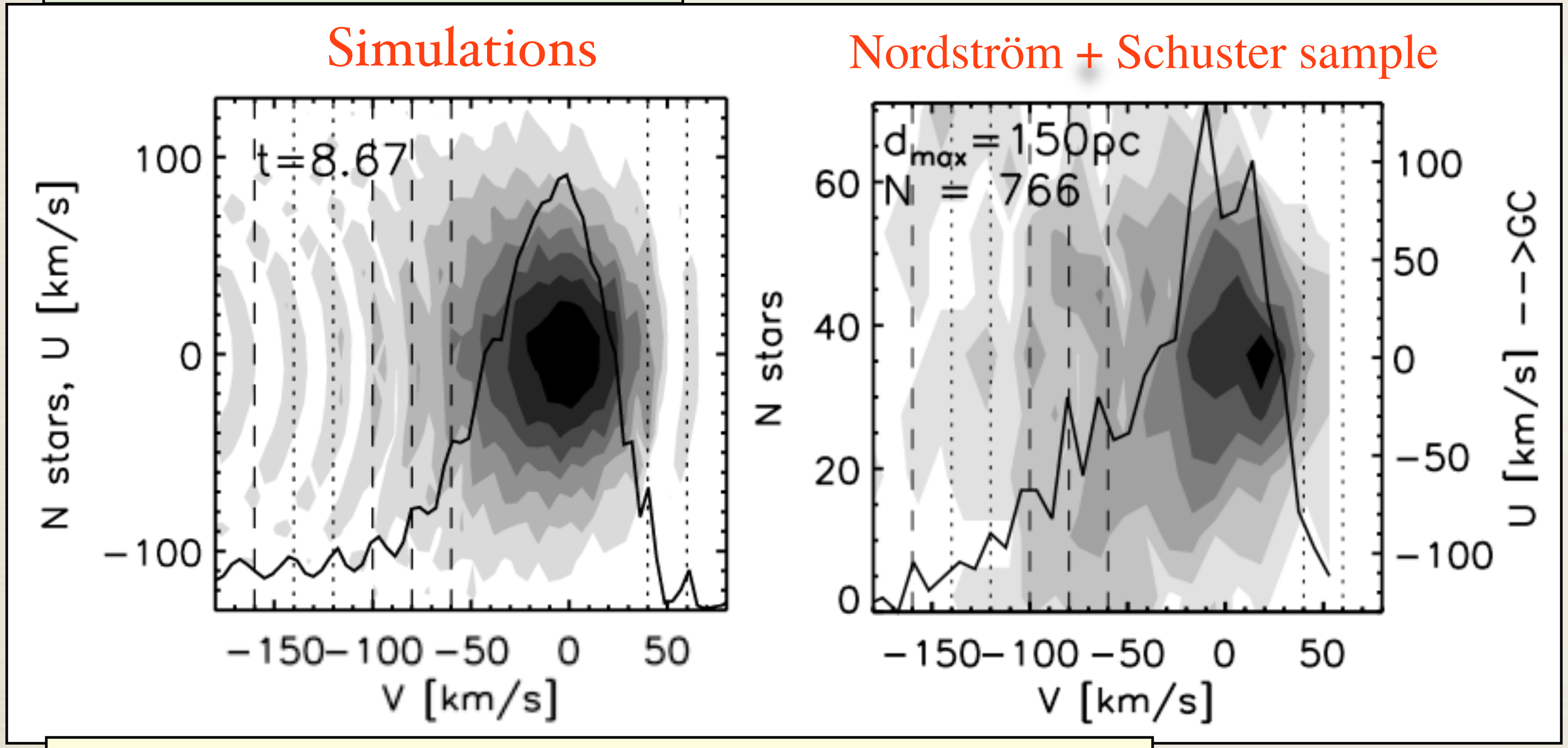
Minchev et al. (2009)

Is the Milky Way ringing?



- Match stream positions to known high-velocity streams in the solar neighborhood velocity distribution.

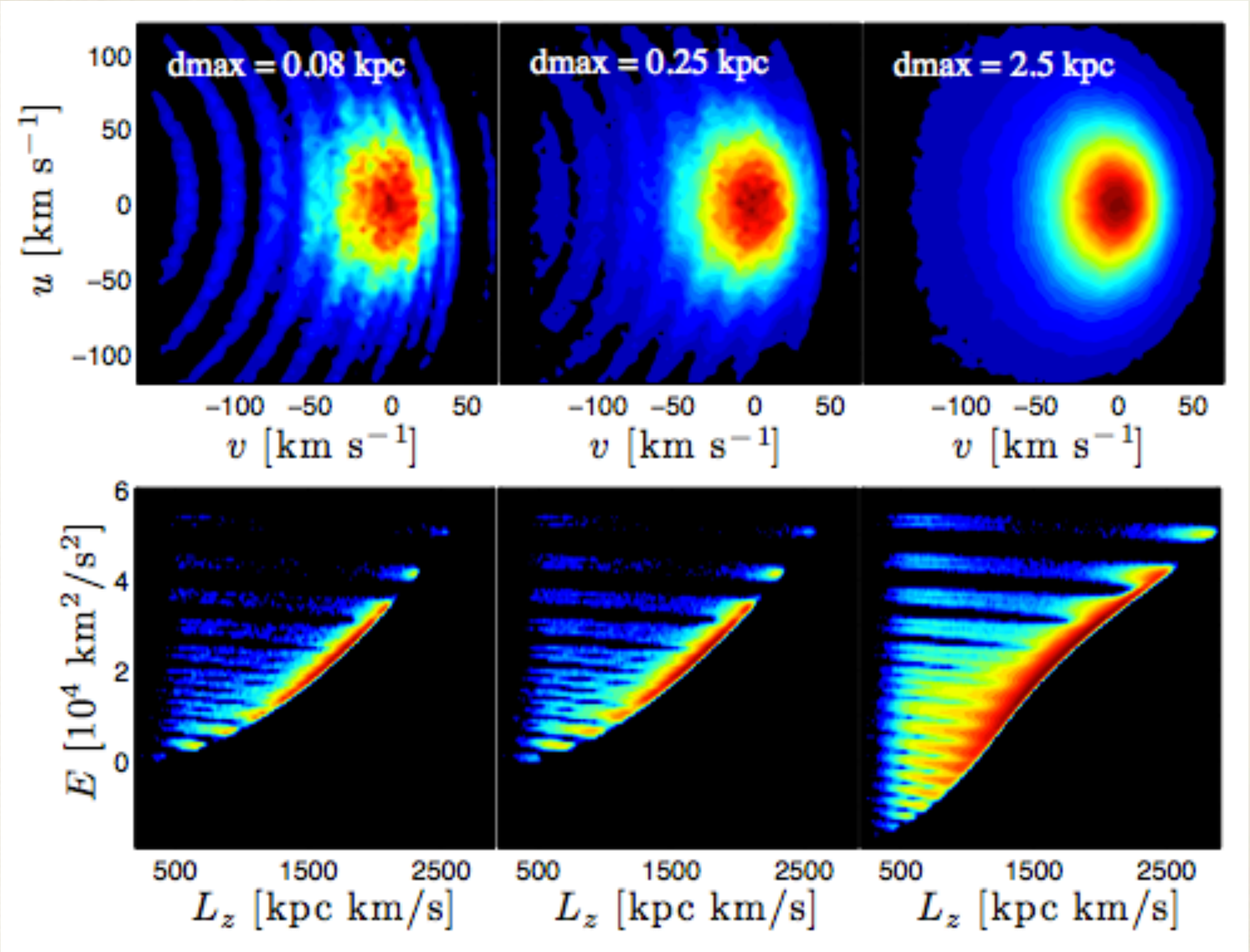
Minchev et al. (2009)



Thick disk: -1.1 < [Fe/H] < -0.55

- Minor merger ~2 Gyr ago.
- Could have triggered bar formation

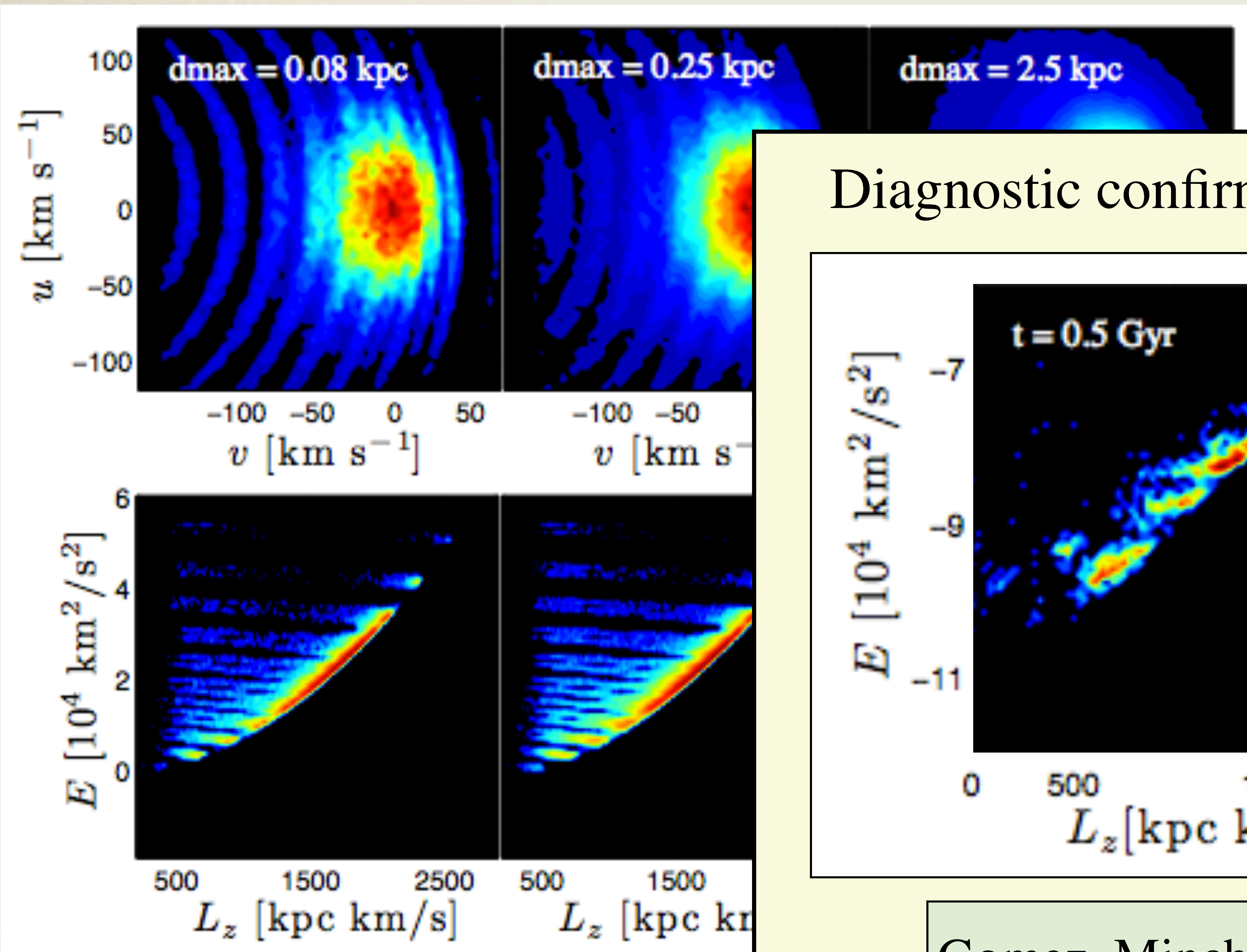
u-v versus L-E space



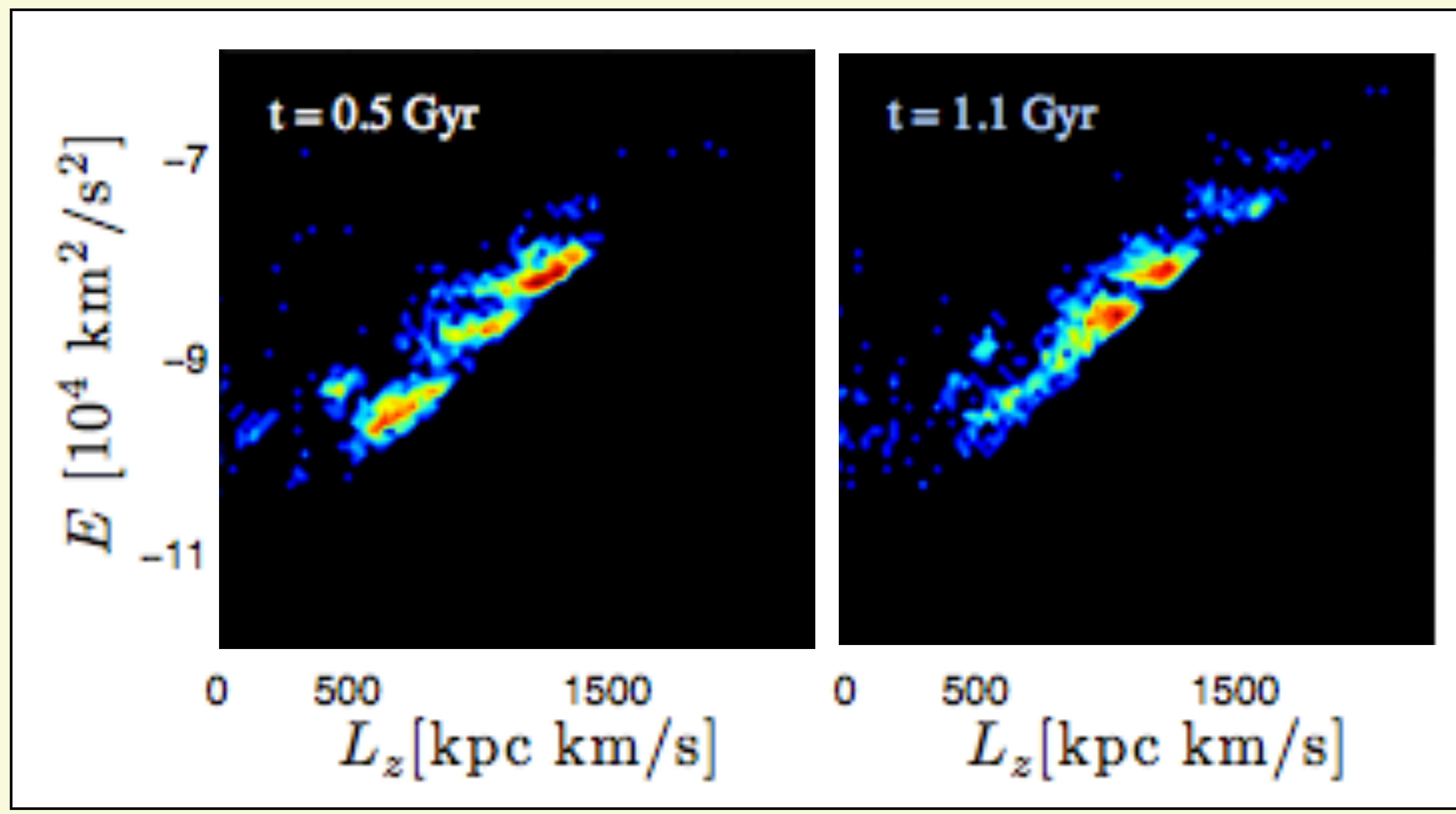
Structure saturates at large sample depth

Structure visible even at large distances from the Sun

u-v versus L-E space

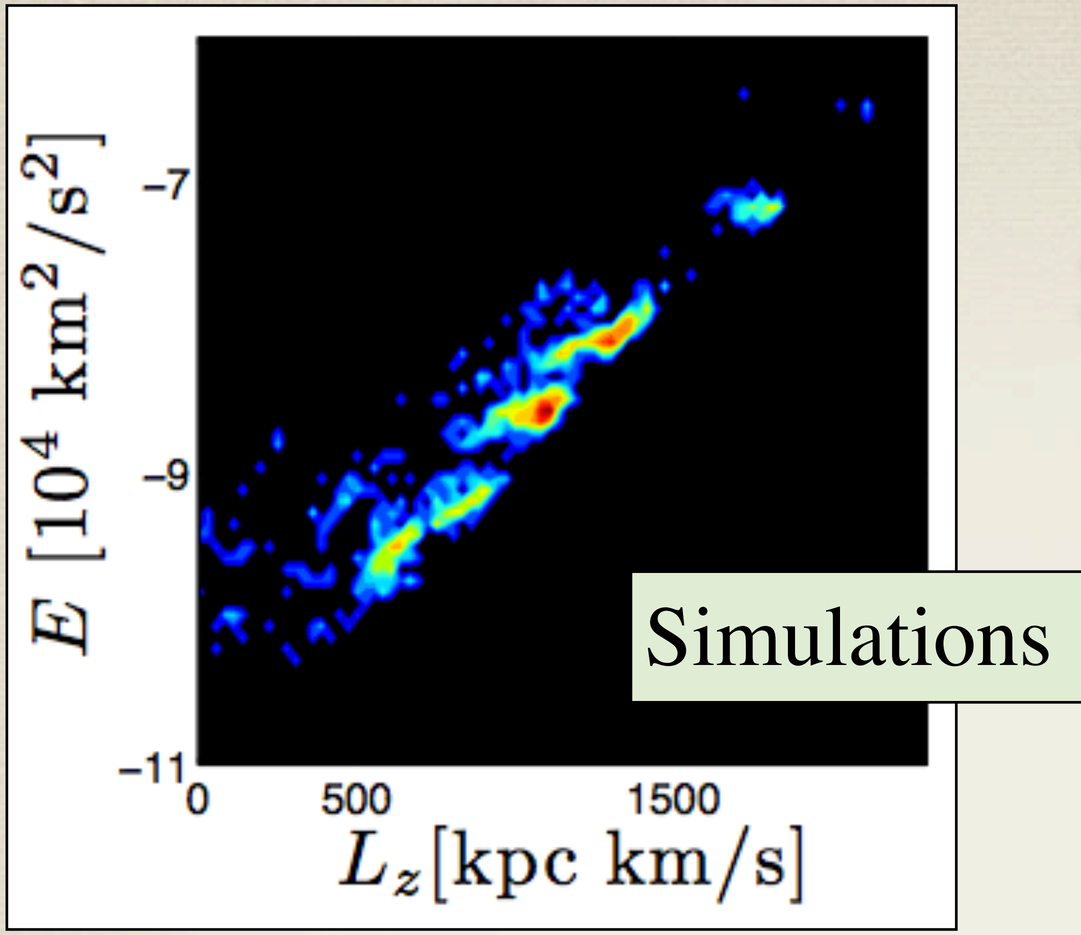


Diagnostic confirmed in N-body simulations



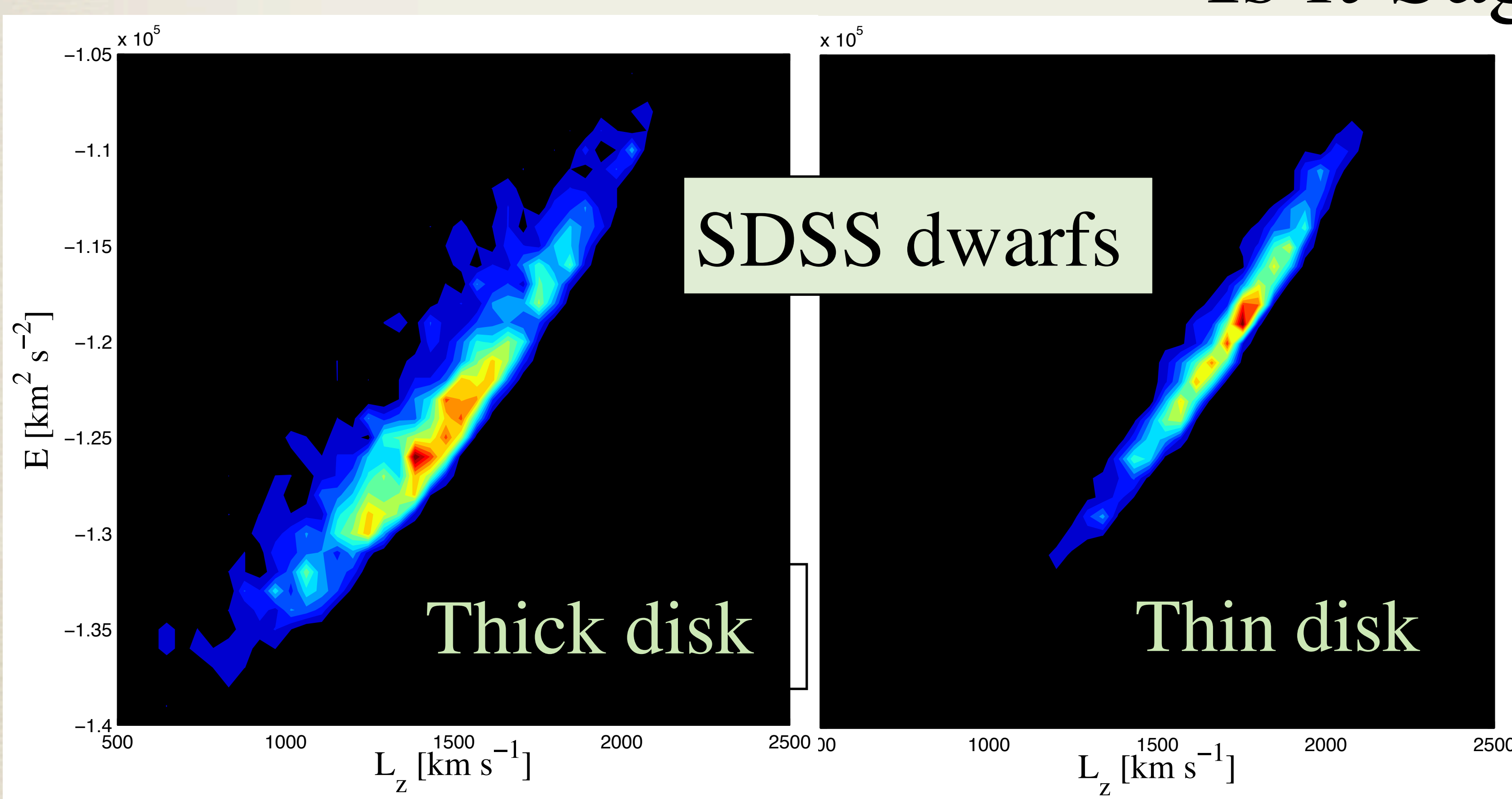
Gomez, Minchev et al. (2011)

Search for signatures of ringing in SDSS



Gomez, Minchev et al. (2012)

Is it Sagittarius?



Conclusions

- With Gaia, complemented by 4MOST RVs, we can study THE TOTAL DISK AREA visible from the southern hemisphere, ~12000 square degrees.
- Science requirements: **RV precision of 2 km/s and Distance errors better than 15%.**
- We need to observe **>6.6x10^{6} F,G Dwarfs** at **14<V<16** for studying velocity field **in the extended solar neighborhood** (d < 2 kpc).
- To study the global disk structure we require >**7.2x10^{6}** dwarfs and giants at 2<d<15 kpc, which will come from **14<V<16** and **17<V<20** observation.