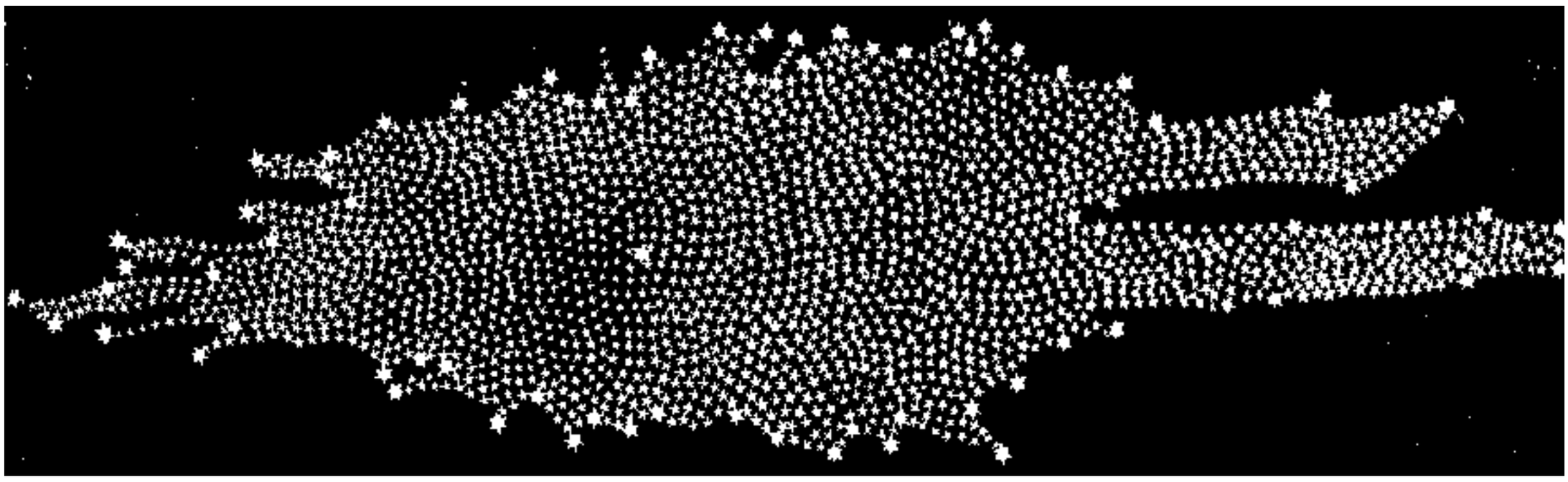
“disk”

(kinematics)

(Ivans & Schiavon 2009)

Connie Rockosi

UC Santa Cruz, UCO/Lick Obs.



Herschel 1785

“disk”

(kinematics)

(Ivans & Schiavon 2009)

Connie Rockosi

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- old (no moving groups of younger stars)
- stellar (no gas kinematics)
- almost certainly incomplete
- squander opportunity to link extragalactic observations
- focus on data, derived quantities and techniques

Why Disk Kinematics?

- Stellar disks have an irresistible likeness to relaxed, axisymmetric systems
  - kinematics → mass distribution
- Disks are (even) more interesting than that
  - bar, spiral structure, warp effect kinematics near and far
- The old disk has a long memory and lived in interesting times
  - stubborn disk formation issues in galaxy formation theory

Data

- Hipparcos
- RVs of Hipparcos stars:
  - Geneva-Copenhagen (Nordstrom et al. 2004, Holmberg et al. 2007)
  - Famaey et al 2005
- PM: UCAC (Zacharias et al. 2004), USNOB+SDSS (Munn et al. 2004)
- RV: RAVE (Steinmetz et al. 2006), SDSS/SEGUE (Yanny et al. 2009)
  - both come with PM catalogs
- R>Rsun:
  - open clusters (Carraro et al. 2007)
  - Cepheids (Pont et al. 1997)
  - @ d = 10 kpc, b = 5°, Z ~ 1 kpc

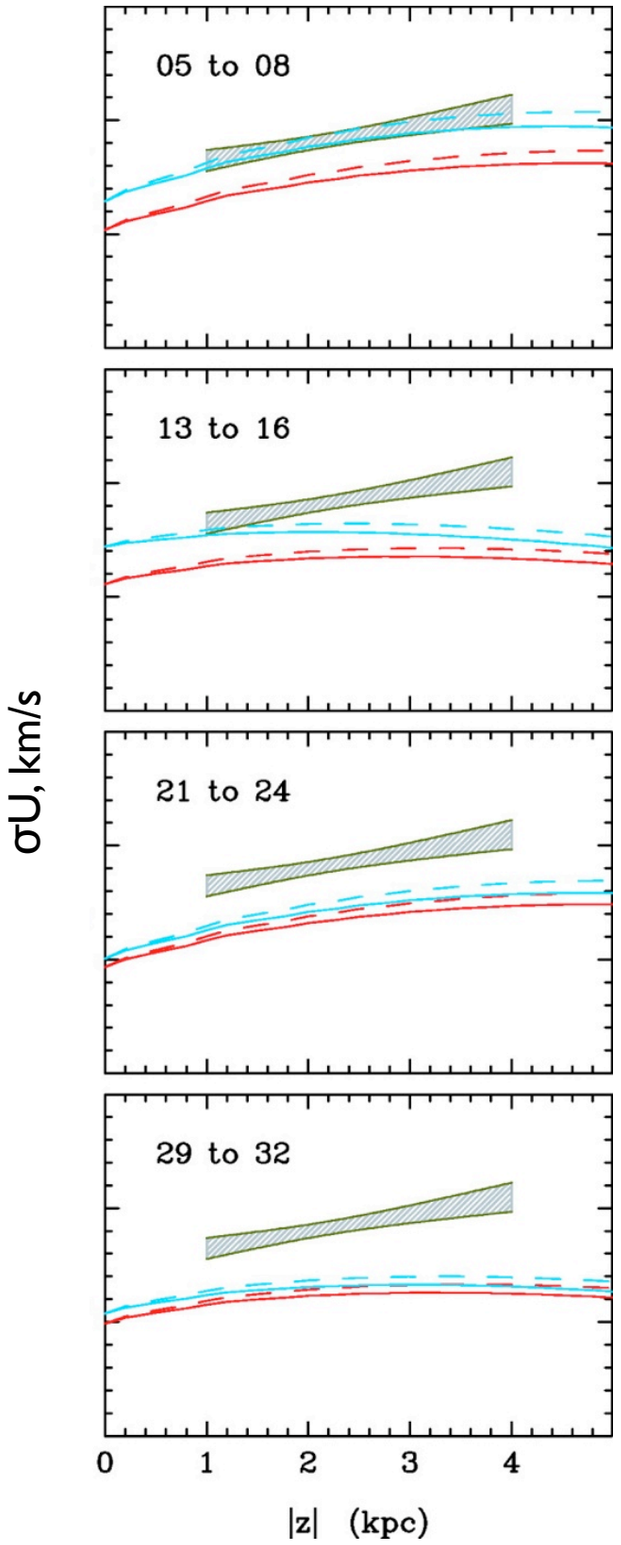
    ➡ velocities in the disk (and muck) would get to larger R in the plane

Kinematics and Mass

- Oort Constants: local circular velocity, R0
  - Feast and Whitelock 1997, from Hipparcos data
  - Now have R0 from SgrA* obs, Eiesenhaur et al 2003, Reid et al. 1999
- Surface mass density at R0 from σz, $\rho(z)$
  - Kuijken & Gilmore (1989,1991), Gould, Bahcall & Flynn (1997)
- Velocity ellipsiod: $\sigma Rz \rightarrow$ DM halo flattening+disk scale length
  - Siebert et al. 2008 (RAVE), Fuchs (SDSS/SEGUE, arXive0902.2324)
  - Siebert et al. find 2-3 kpc depending on halo shape
- $\sigma(R,\varphi,z)$, asymmetric drift $\rightarrow$ disk scale length

In-Situ Kinematics

- <V>, σ^2 at large |Z| to boost fraction of thick disk stars
- RV, PM, PM+RV all useful kinematic data
- thick+think disk decomposition
  - scale heights
  - self-consistent models for density, kinematic distributions (need mass profile, structural parameters)
  - recently, Siebert et al. 2008 (RAVE)
  - ...and many people in this room...
- Velocity, dispersion gradients



Equilibrium disk models
Girard et al. 2006
Lines: models, Hatched: data
blue, red scale heights 5,3.5 kpc

Deviations from Axisymmetry

- Deviations from axisymmetry → measurable kinematic features

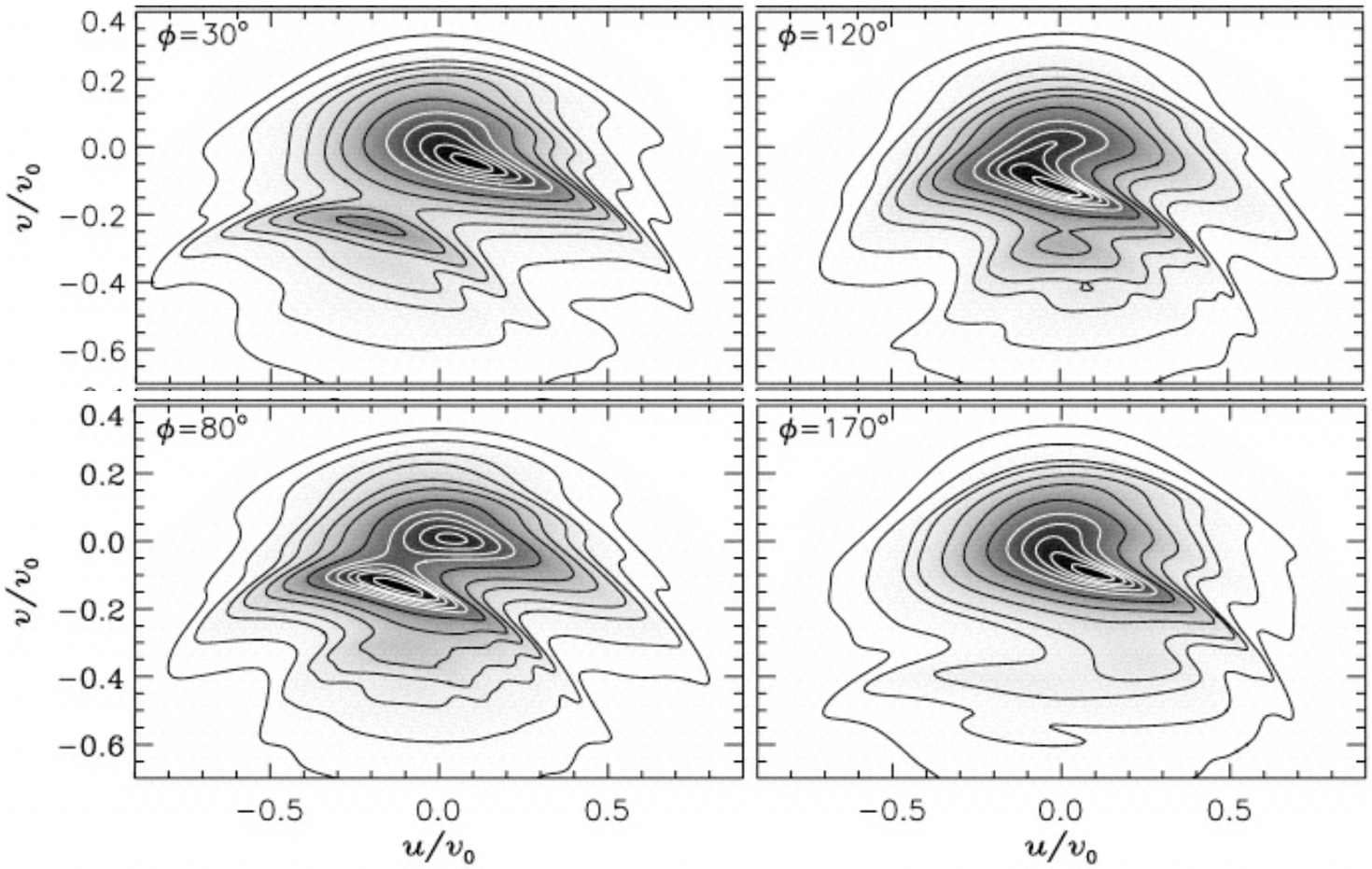
- Dehnen 2000: second peak in u,v distribution caused by OLR of bar

  - constraint on bar pattern speed and radius of OLR

- Same kind of predictions for spiral structure from Minchev & Quillen 05

- Signatures of non-axisymmetry are bigger in the region of the structures

  - want kinematics at large distances in the disk

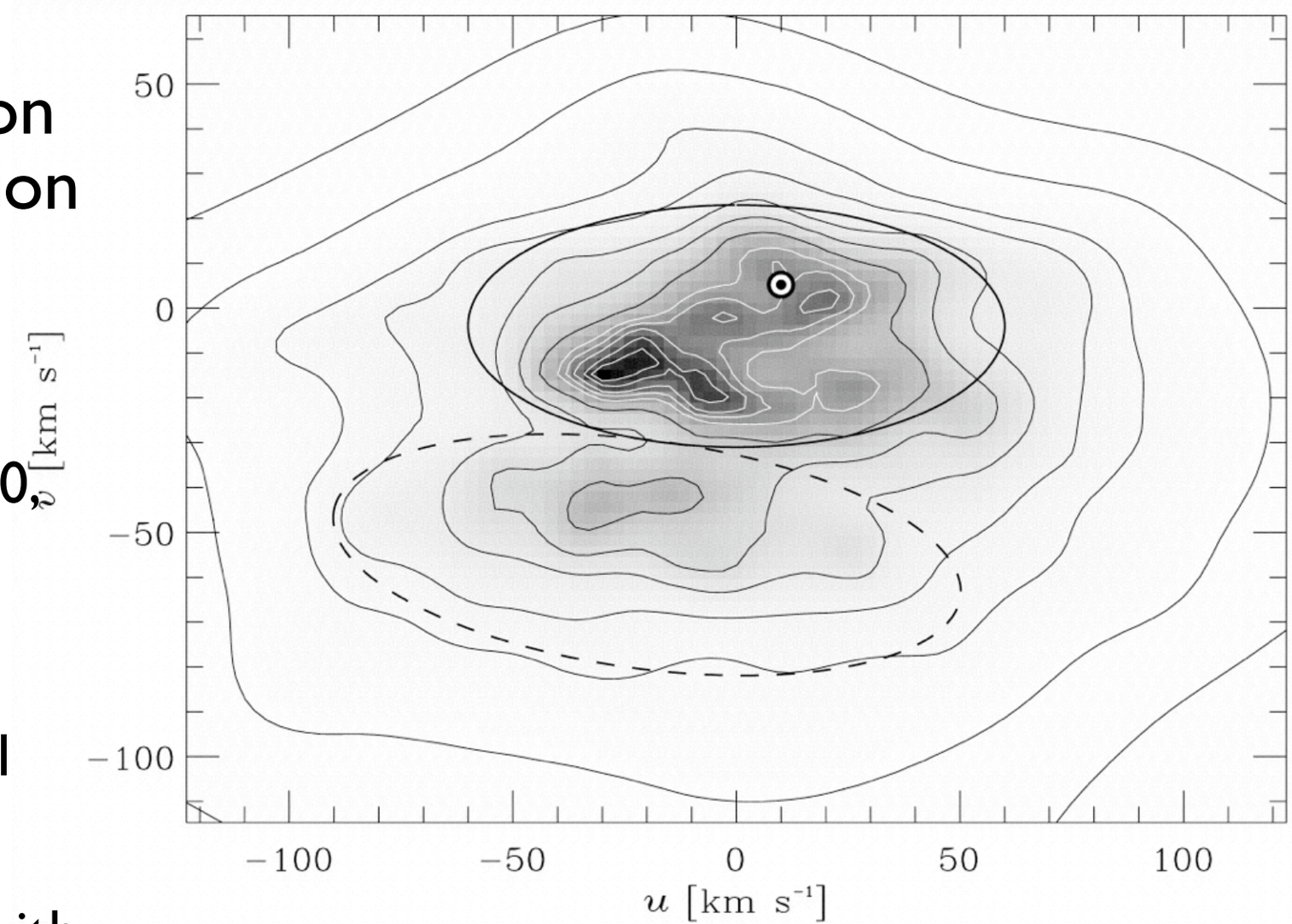


Dehnen 2000: Models

3D Kinematics from 3-N Components

- Not usually in the happy situation of having all three velocity components
- Large datasets with well characterized errors: statistical reconstruction of the full 3D distribution

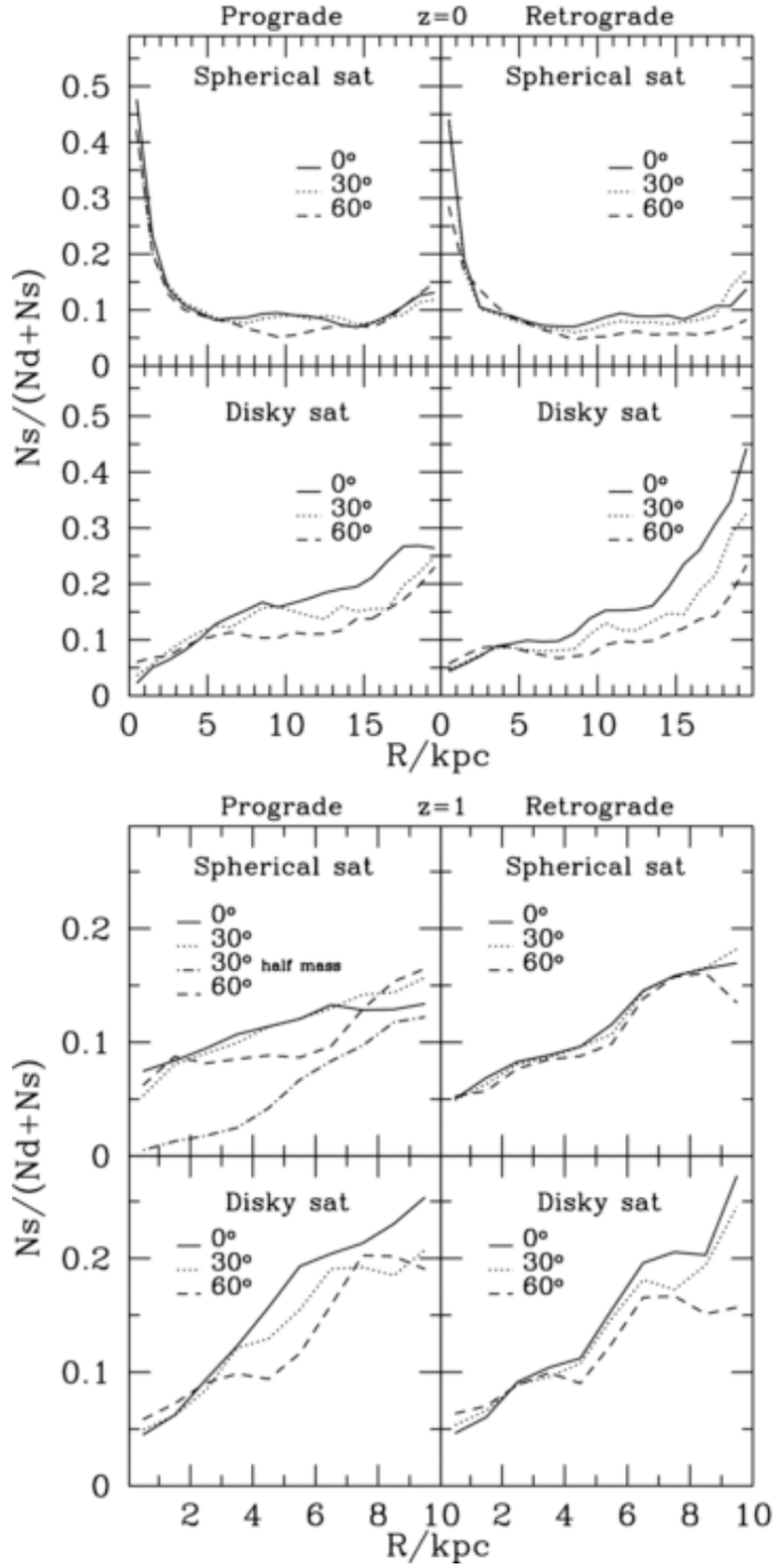
  - Dehnen & Binney 1998: moments of projection equations to get <v>, σ
  - ~like Frenk & White 1980, but NOT unbiased estimator for individual stars
  - Dehnen 2000: ML reconstruction of the full distributions
  - requirement is that velocities uncorrelated with position (careful...)



Dehnen 2000: Reconstructed velocity distribution

Disk Kinematics vs. Galaxy Formation Theory

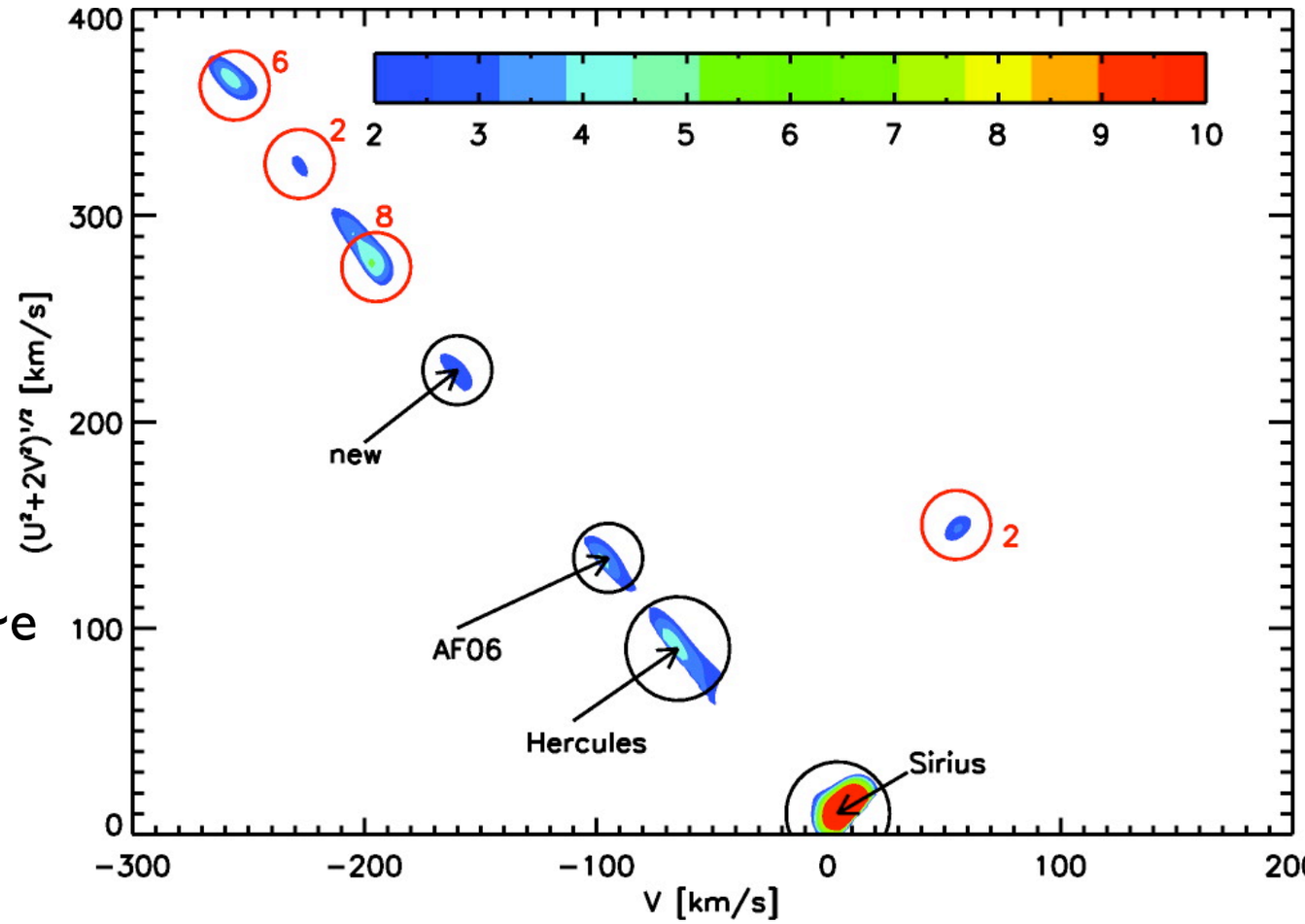
- The local thick disk is really old: 10+ Gyrs
- The old thin disk is old, too: 8 Gyrs
- Structure formation simulations: the MW probably had a 10:1 merger since z~1 (Stewart et. al 2008)
- Destructiveness:
  - probably depends on gas fraction (Stewart et al. 2009)
  - upon further simulation, might not be so bad (Villalobos & Helmi 2008)
- This dynamical history should leave traces, and maybe stars from the culprits (eg, Abadi et al. 2005), in old disk kinematics



Villalobos & Helmi 2008

Disk Kinematic Substructure Zoo

- Photometric detections, RV follow-up: Monoceros/GASS
- Bulk motion test: Seabroke 2008 (RAVE+local)
- Helmi et al. 2006
  - G-C N04 data
  - apo-peri-Lz search
- Klement et al. 2008
  - RAVE data, d<400 pc
  - eccentricity,Lz search ~e



Summary

- We are not saturated in kinematic data:
  more at all distances in the disk would improve
  mass profile and structural parameters,
  characterization of deviations from axisymmetry, ...
- Constraints on the mass distribution from local
  kinematics will improve multicomponent modeling,
  sensitivity to substructure in conserved variables
  from kinematics at larger distances
- Non-parametric reconstruction of 3D velocity
  distributions and moments are promising
  techniques: don't design them out of surveys