Mapping stellar substructure in the Milky Way

*bound & unbound*

Bell et al (2008)
Grillmair et al (2009)
Willman (2010)
median [Fe/H], n=2.5 million with 0.2<g−r<0.4 and 0.8<Δ/kpc<9

Mon stream

HALO

galactic center

DISK
Figure 12 from Juric et al (2008)
$0.10 < r - i < 0.15$ (bluest color bin)

Slices in height above Galaxy midplane: 17.5, 15.0, 12.5, 10.0 kpc

Yellow dot is the Sun’s location.
Center of circles is Galactic center

Massive asymmetry above/below $Y = 0$ line
Figure 13 from Juric et al (2008)

$0.10 < r-i < 0.15$ (bluest color bin)

Slices in height above Galaxy midplane: 5, 4, 3, 2 kpc

Can see Monocerous stream near $X = 16$ kpc and $Y = 0$

They used redder stars to look at nearby disk structure (300, 600, 900 pc slices) - no discernible substructure.
The Virgo Overdensity  (Juric et al 2008)
Major Features:

- Sag stream dominates in all distant maps
- Low-latitude stream prominent nearby and towards anti-center
- Virgo overdensity, prominent esp. in 19.5 - 20.0 slice

Figure 10 from Bell et al (2008)

Halo structure remaining after subtracting best fit smooth model

Spatially smoothed with 42’ Gaussian filter
number density map of stars with g-r < 0.4
red: 21.33 < r < 22.0
green: 20.66 < r < 21.33
blue: 20.00 < r < 20.66

updated version of Belokurov et al. 2006
Matched filter based on the SDSS observation of stars in globular cluster M13, but with the stellar luminosity function of Ω Cen. (Grillmair 2009).
“Stretch is logarithmic, and darker areas indicate higher surface densities. For panel (a), a fifth-order polynomial fit has been subtracted from the surface densities for presentation purposes. For the other three panels, a seventh-order polynomial surface fit has been subtracted. All fields have been smoothed with a Gaussian kernel of width 0.2 degrees.” (Grillmair 2009)
Boxcar color-magnitude filter based on Dotter isochrones of a range of old and metal-poor stellar populations. (Stars inside filter are accepted, outside filter are rejected).

Width based on color and magnitude measurement uncertainty as a function of magnitude.

Example taken from Willman 2010
• Color-magnitude filter projected to numerous distances is applied to SDSS dataset.
• 2D spatial histogram of number density is generated across footprint and then spatially smoothed.
• Locally, statistically significant overdensities are automatically identified by a computer algorithm.
• Overdensity shown is the Ursa Major I dwarf (Willman et al 2005)
Milky Way dwarfs known in 2004
red = post-SDSS dwarfs

distances from ~30 kpc to 400 kpc (~100,000 LY - 1 million LY)

Figure and table made by M. Geha (Yale)
Future Challenges: Unresolved galaxies

Stars

Mock MW field
1 deg$^2$, (l, b) = (45,40)
35,000 stars
Future Challenges: Unresolved galaxies

Stars

Mock MW field
1 deg², (l, b) = (45, 40)
35,000 stars

Galaxies

Mock LSST galaxy catalog
0.01 deg², 25,000 galaxies