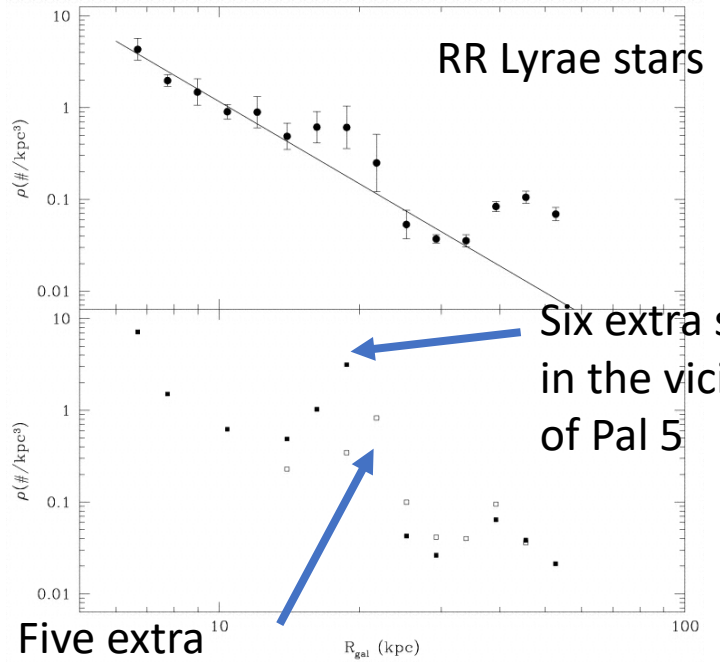
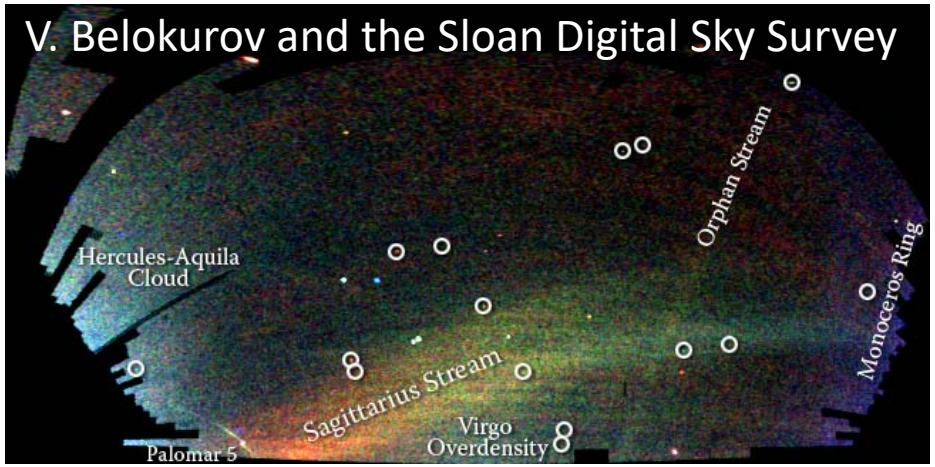
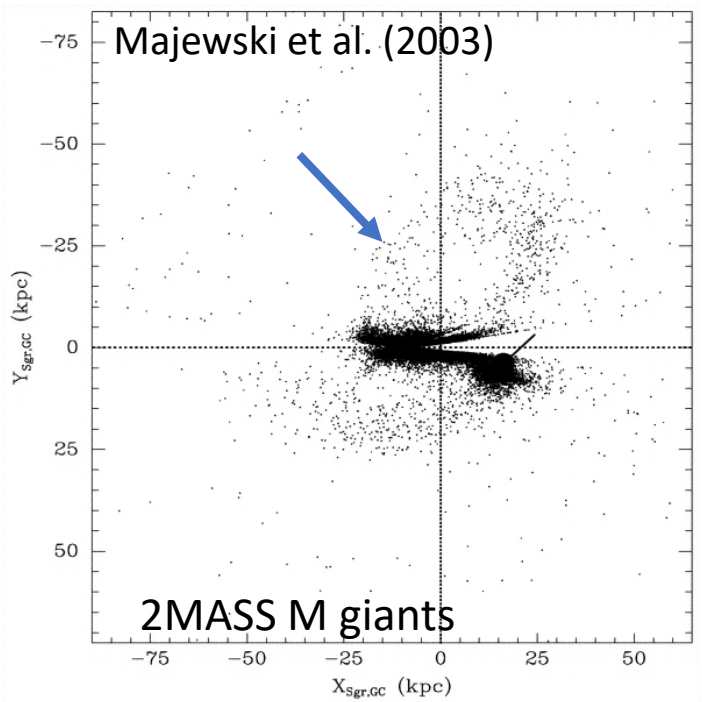
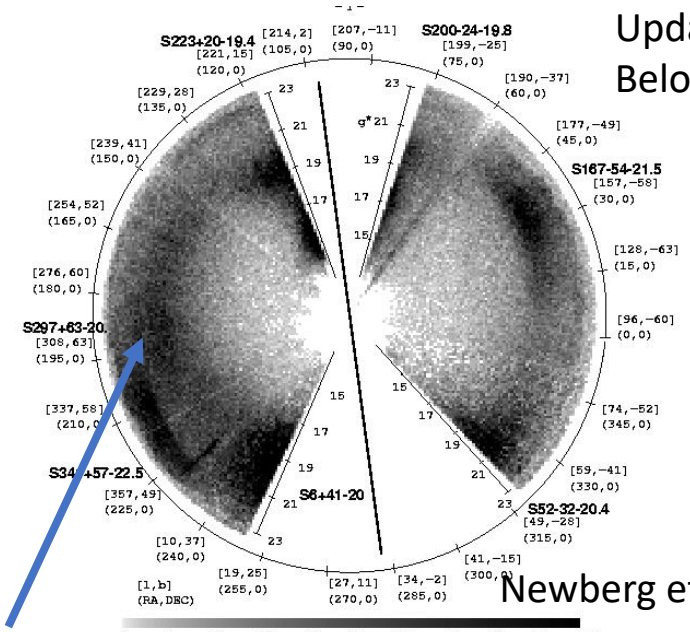
The Virgo Overdensity Explained

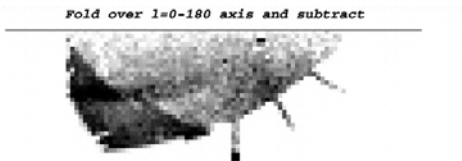






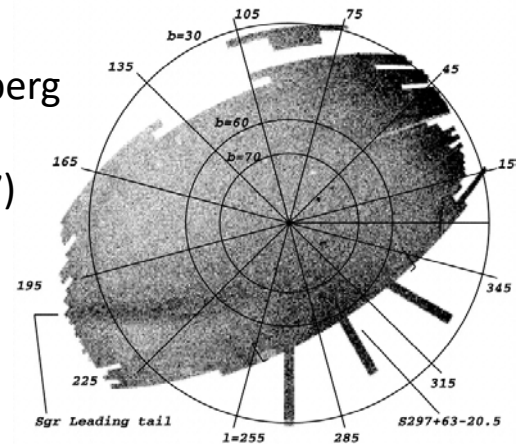


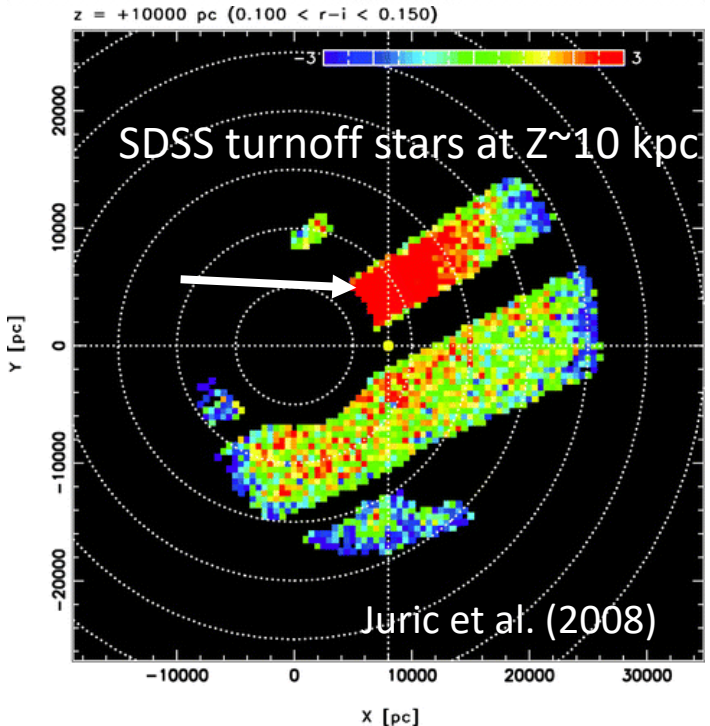
Updated from Belokurov et al. (2006)

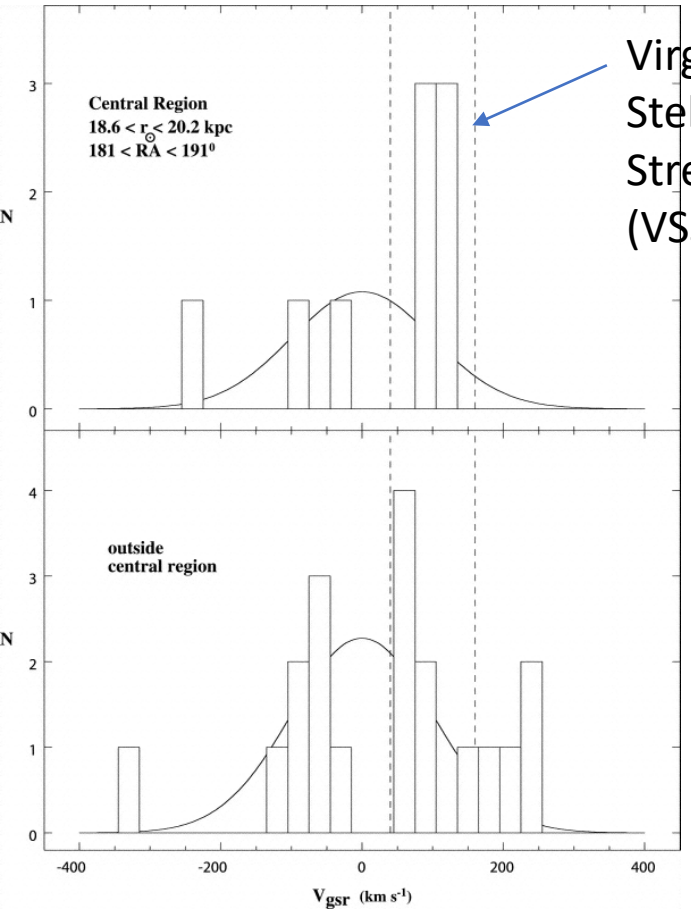


SDSS turnoff stars with 20<g0<21

Newberg et al. (2007)

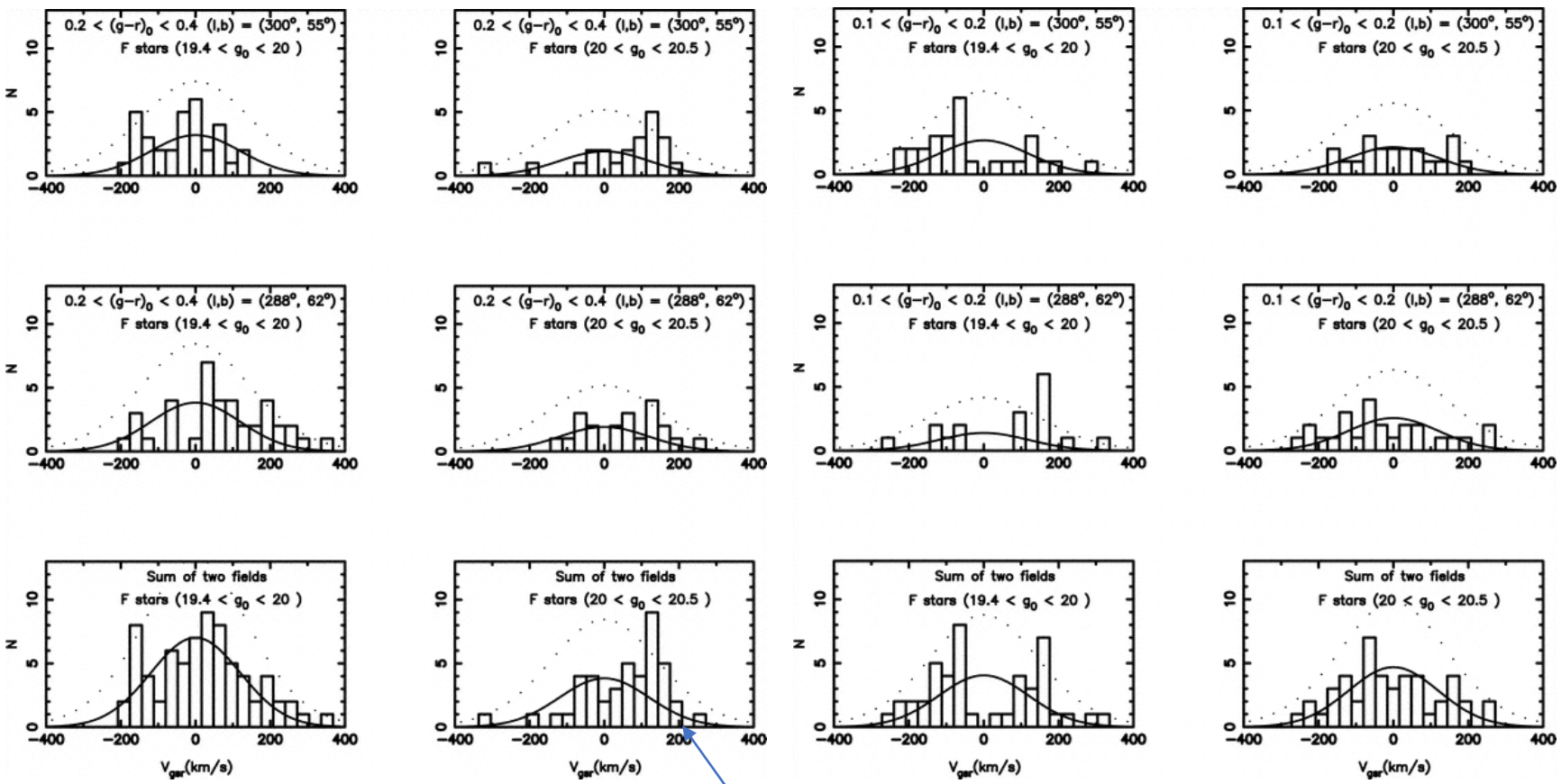






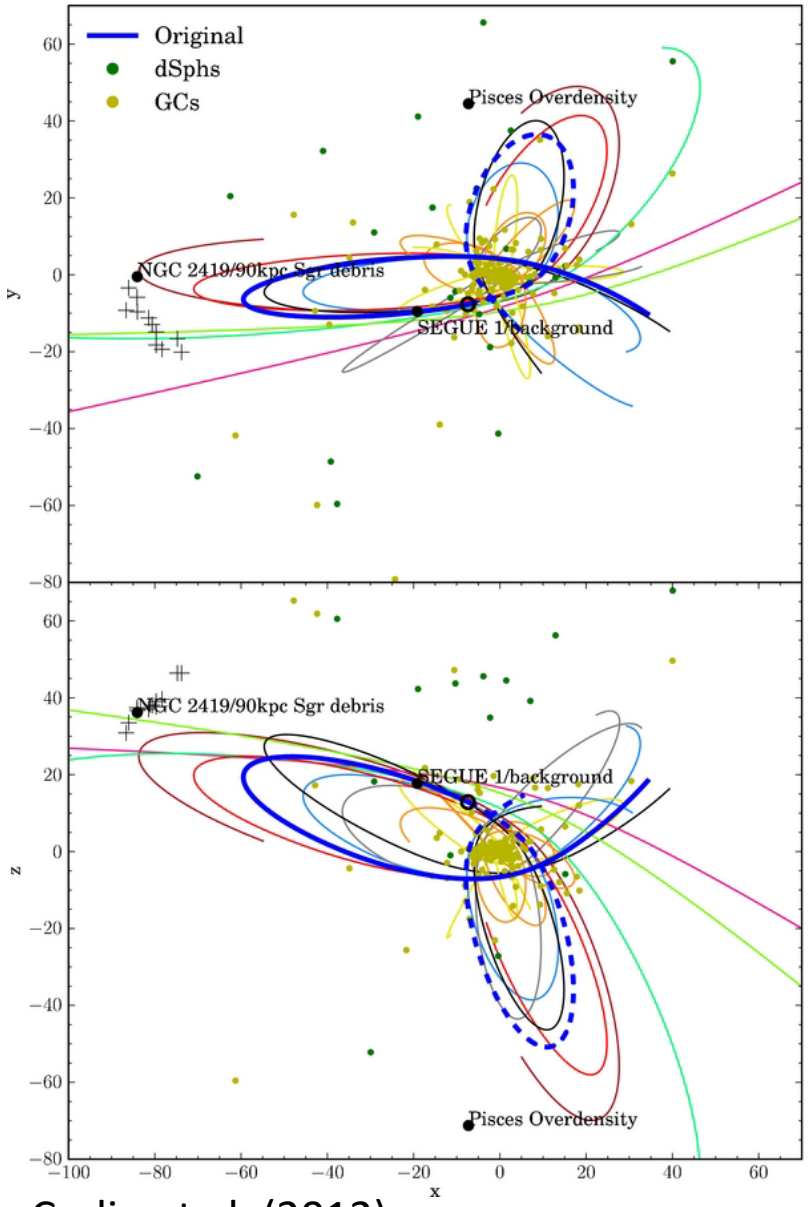
Virgo Stellar Stream (VSS)

Duffau et al. (2006)



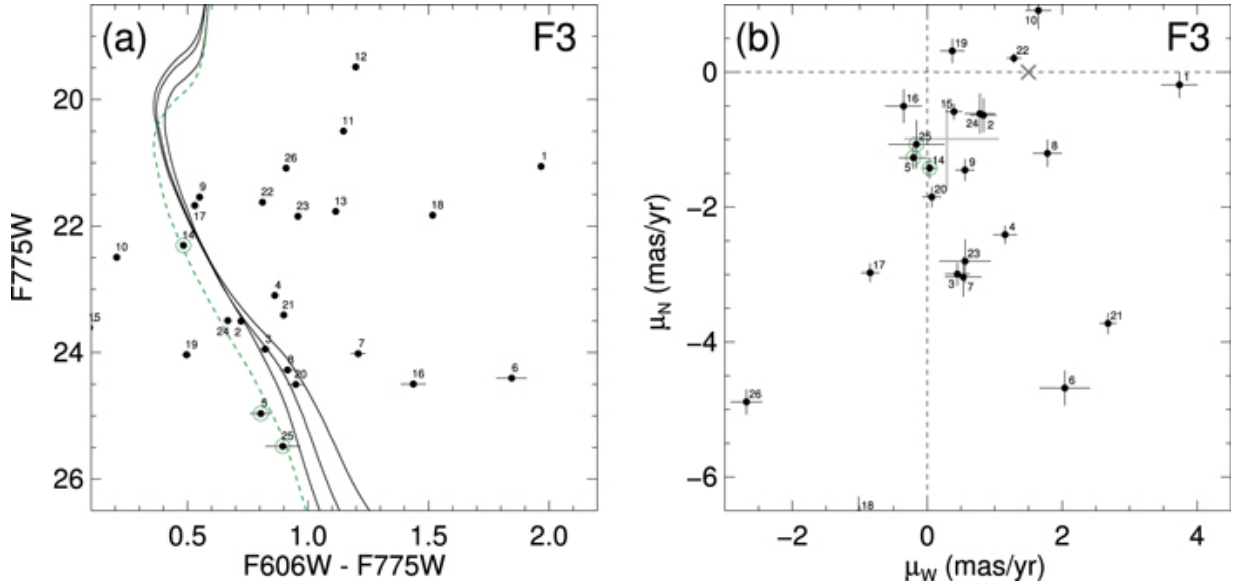
Newberg et al. (2007)

Virgo Overdensity

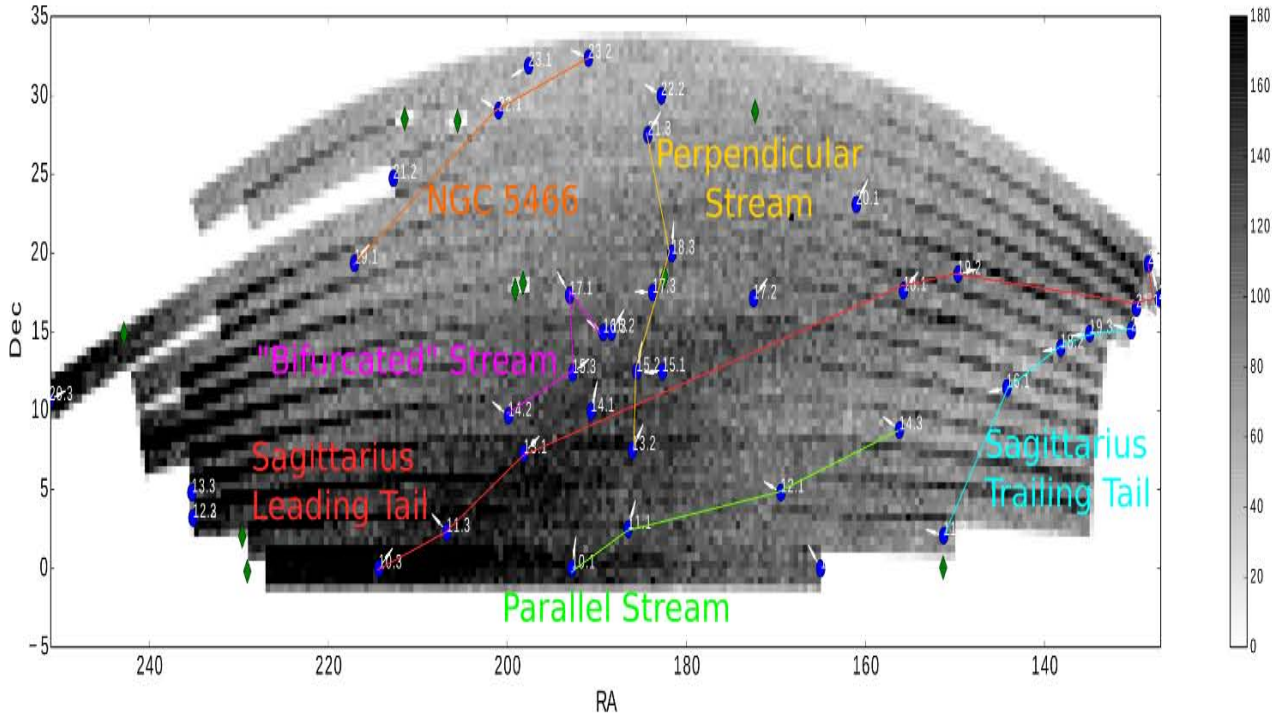


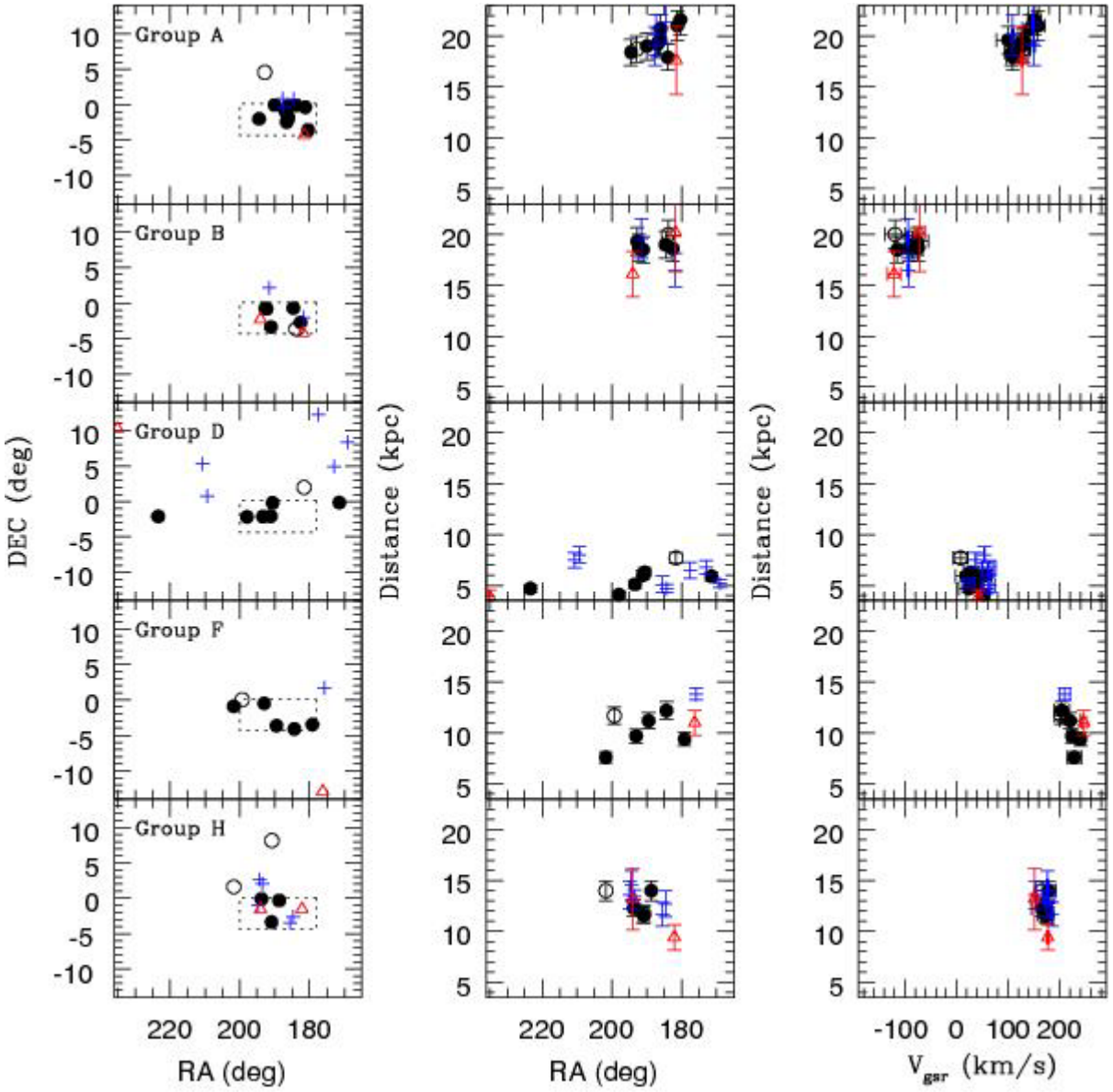
Carlin et al. (2012)
Blue line is fit to Virgo Stellar Stream, and other lines show orbits that fit within the errors.

Sohn et al. (2016)
Green circles show stars in the Parallel Stream.

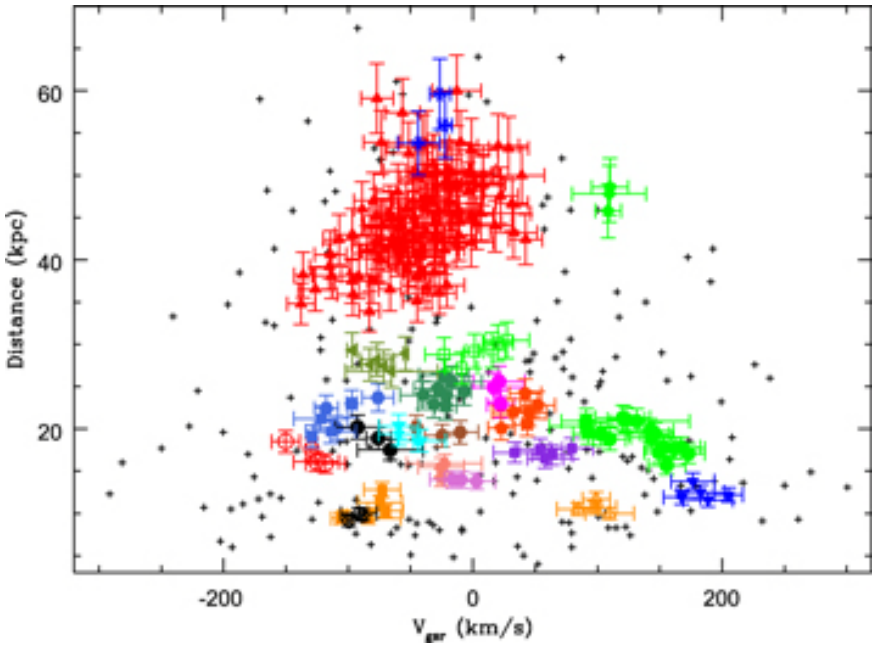


Weiss et al. (2018)
Found Parallel Stream in density, and matched to Sohn. Identified a Perpendicular Stream



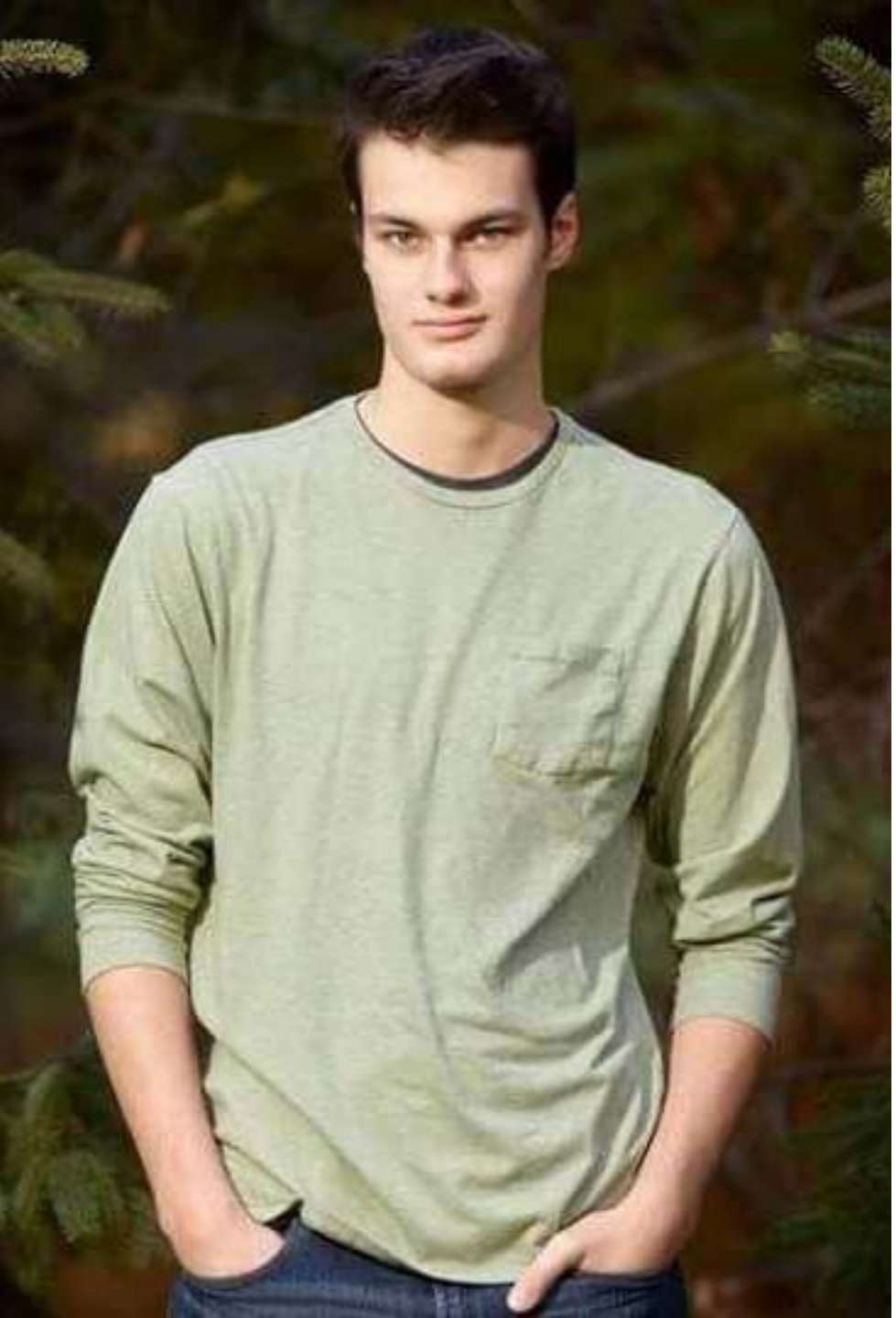


Duffau et al. (2014)



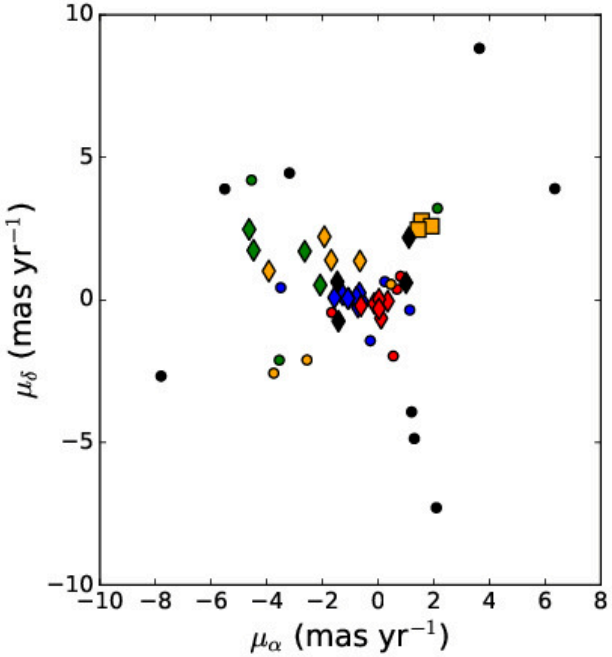
Vivas et al. (2016)

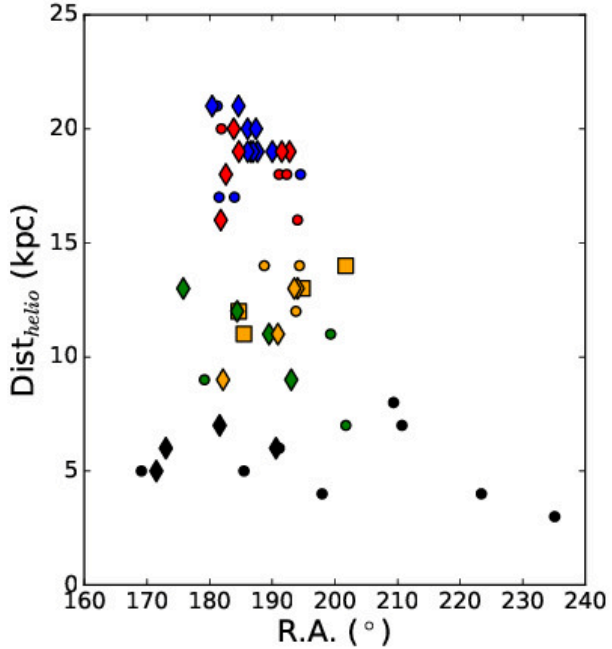
Duffau finds five moving groups in the Virgo region in RRL/BHB stars. Vivas et al (2016) finds 22 groups but only 6-10 of the groups are thought to be significant.

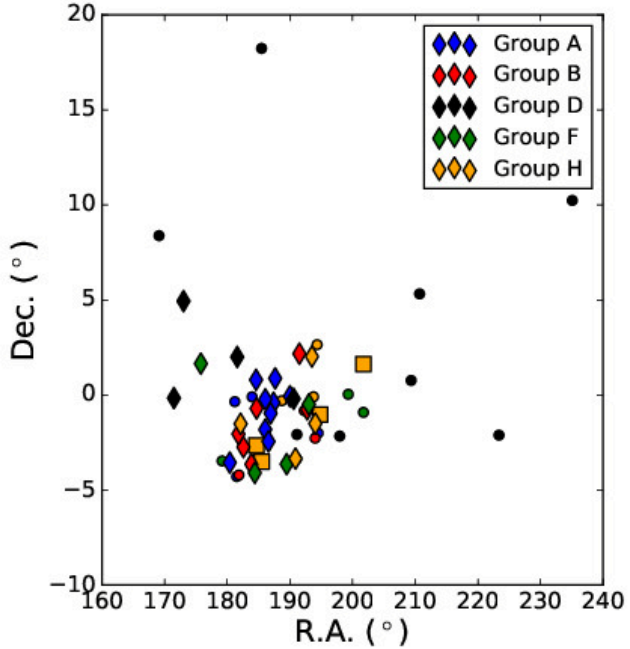


The rest of the talk is the work of undergraduate student Tom Donlon.

The paper is submitted and should be available on arXiv next week.

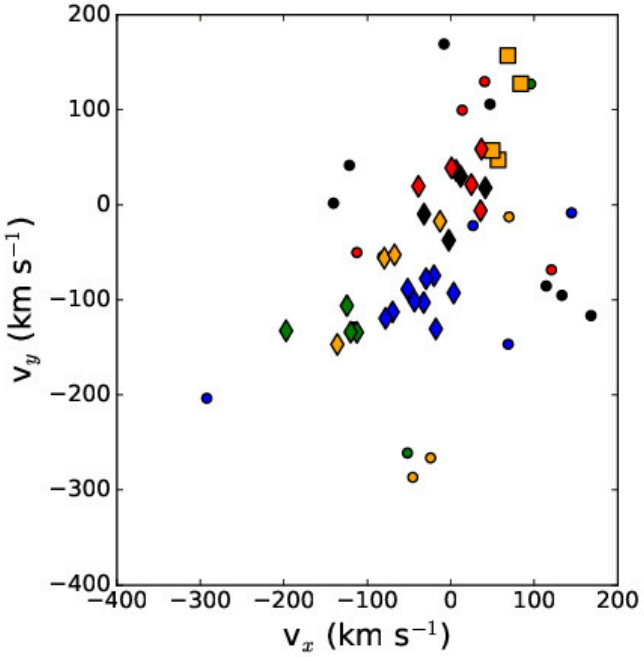


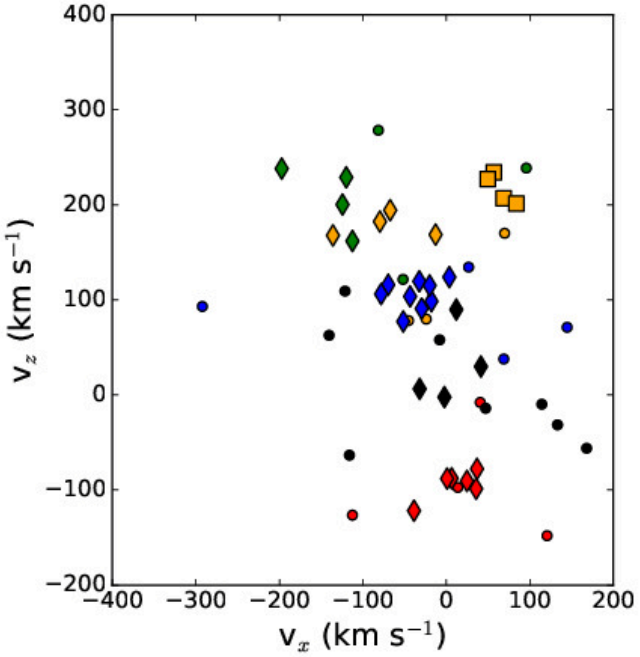


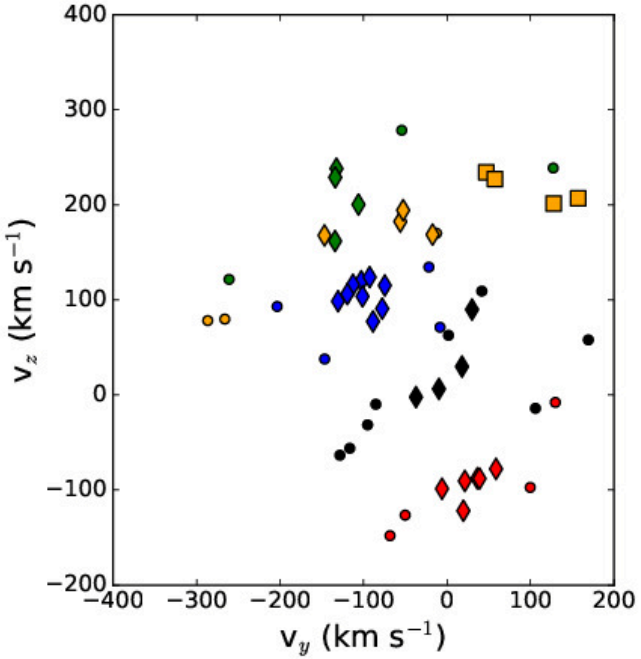


Add Gaia proper motions to Duffau groups

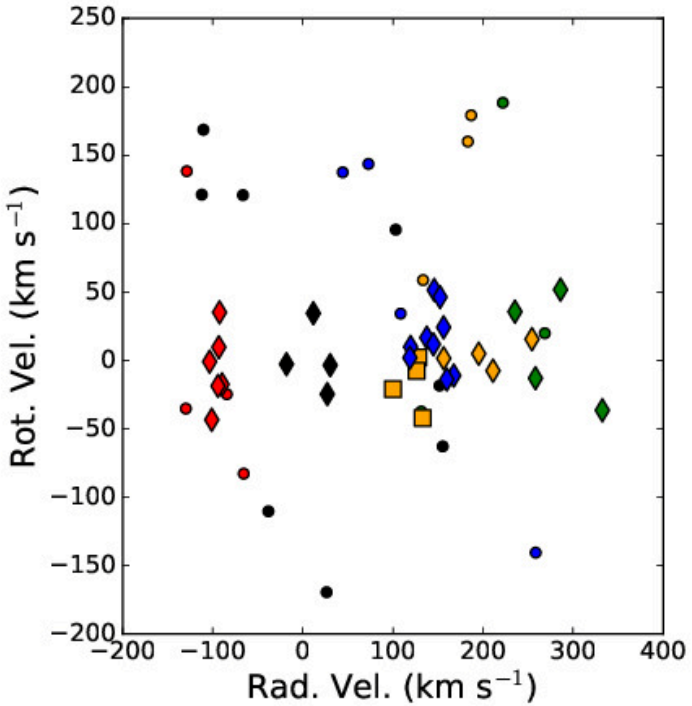
Groups are all from the same area on the sky. The more distant groups are more clustered in proper motion (as one would expect).

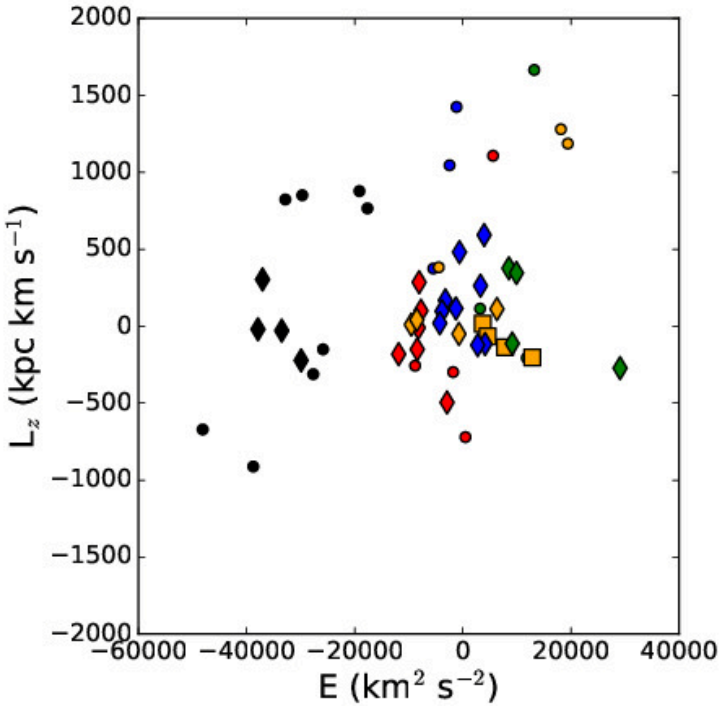


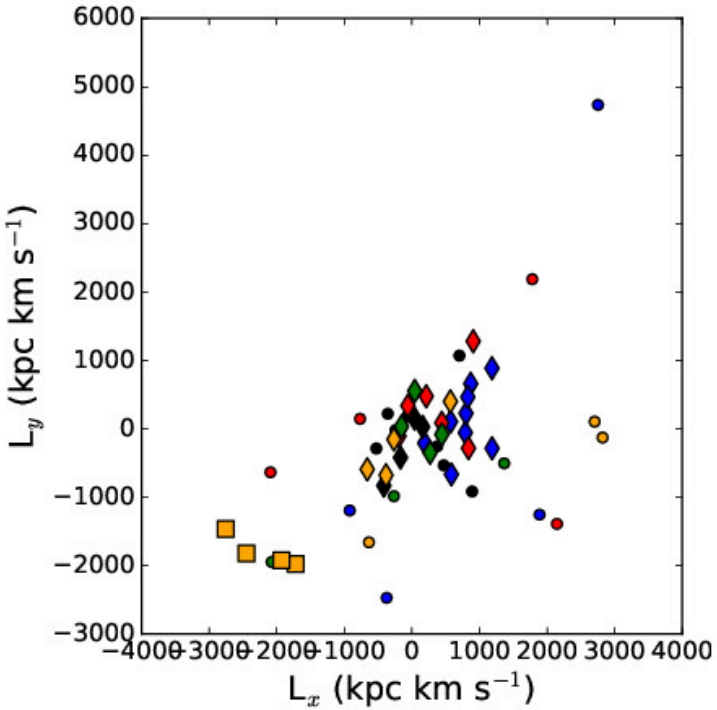


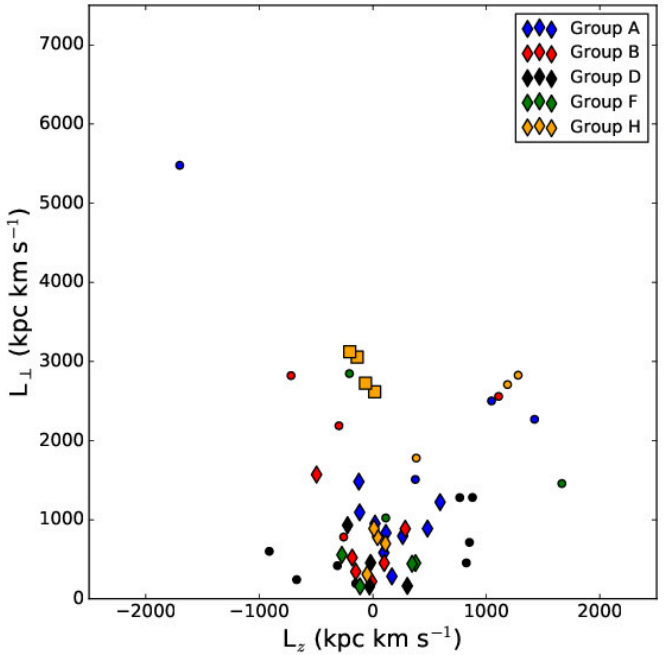


We identified stars within each group that were clustered in velocity. Group H was split into one tight group (yellow squares) and one group that looks more like group F.

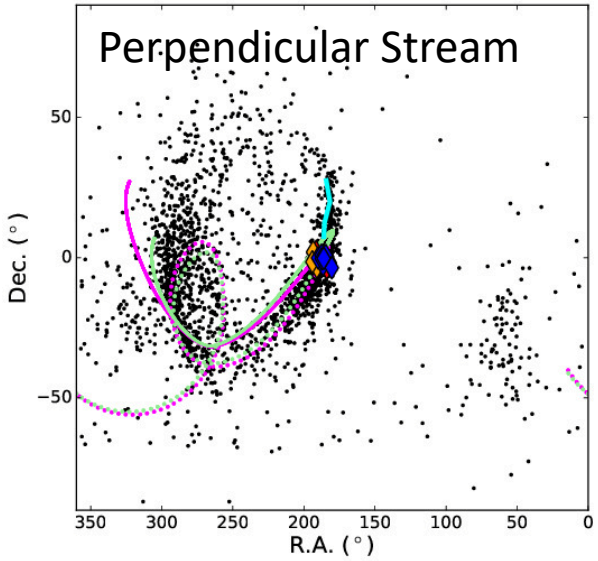


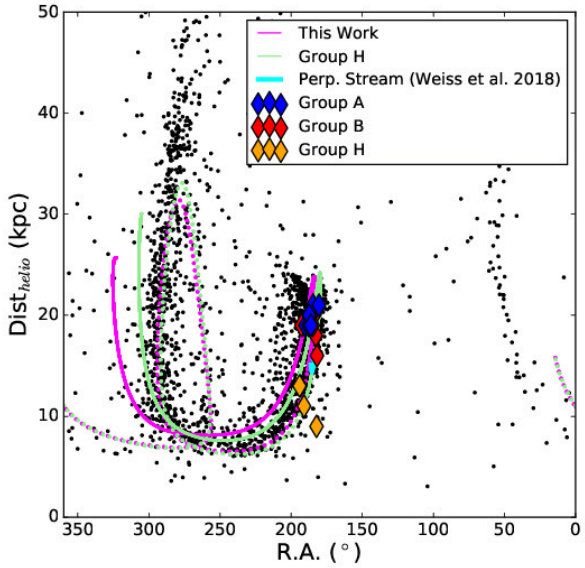


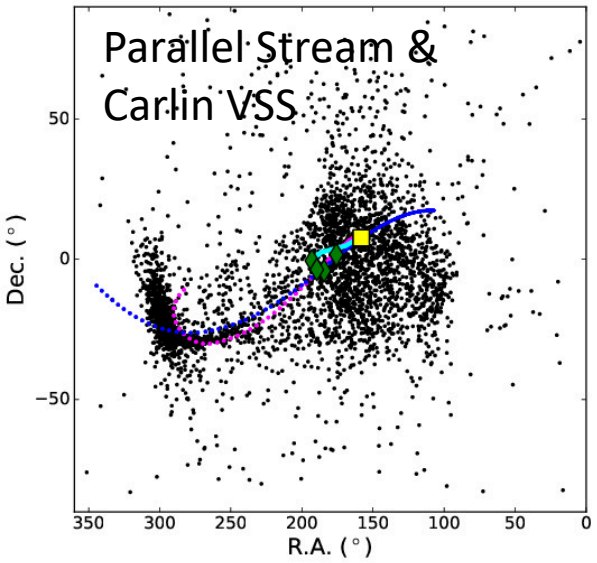


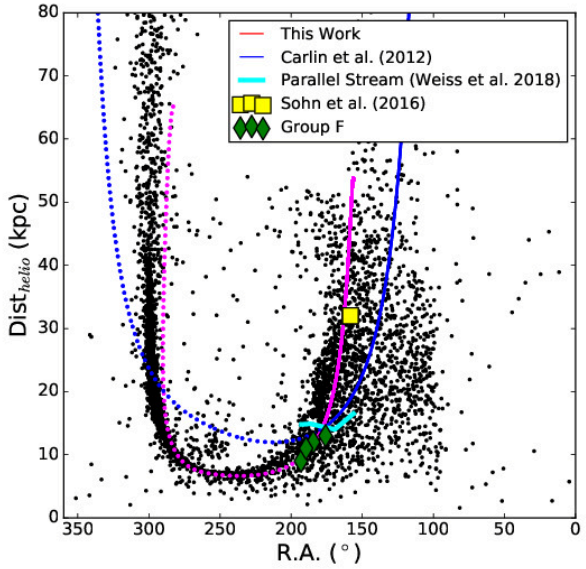


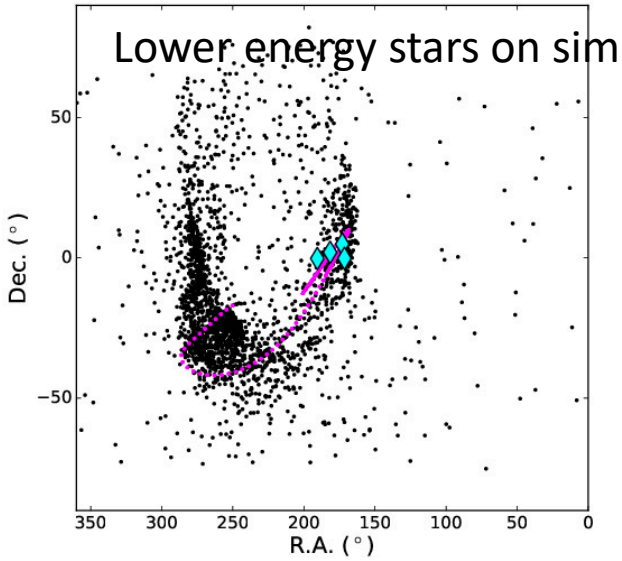
The yellow squares are completely different in angular momentum than the stars in the other groups.
The groups represented with diamonds have similar (nearly zero) rotational velocity/Lz, and are therefore on highly radial orbits. These stars cover a range of energies.
If you remove the diamonds from the sample, there is no clustering on radial orbits.
There is possibly an excess at positive rotational velocities.

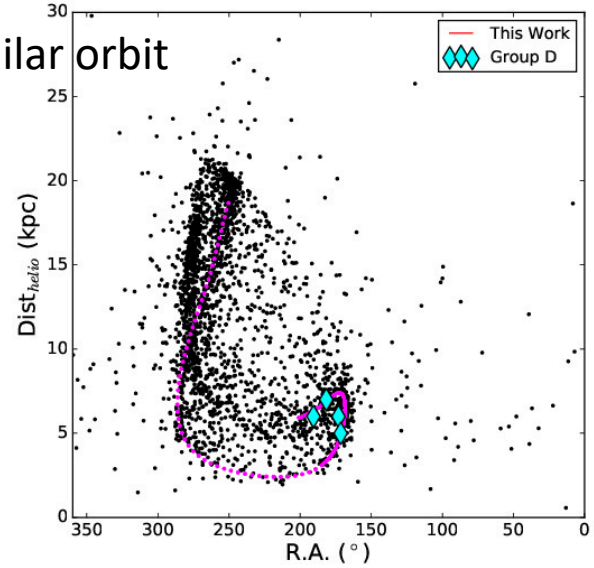


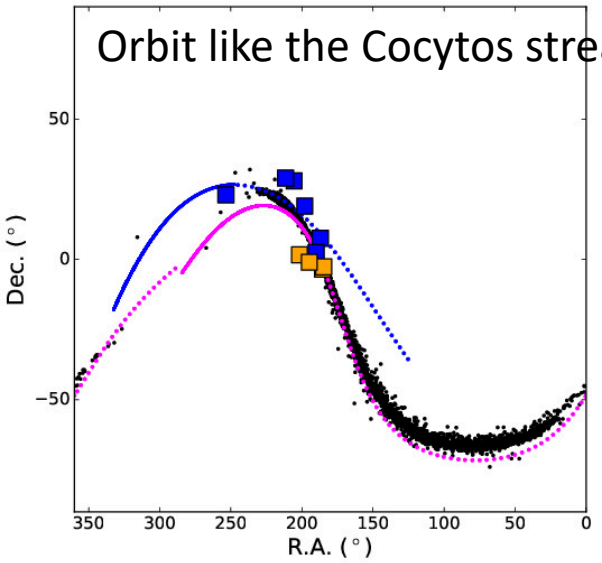


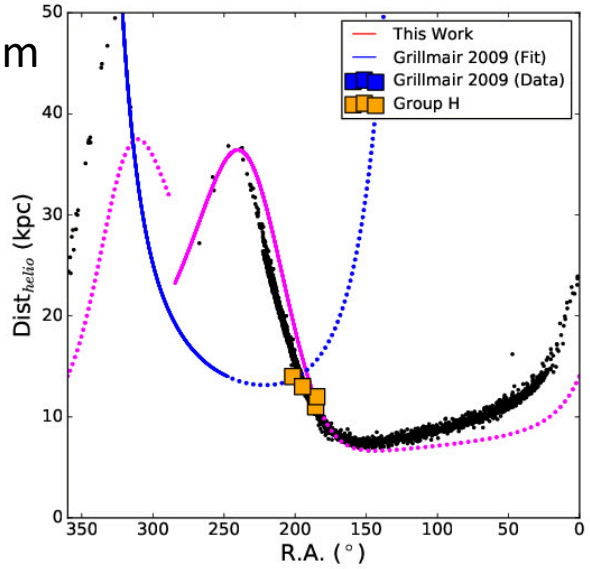






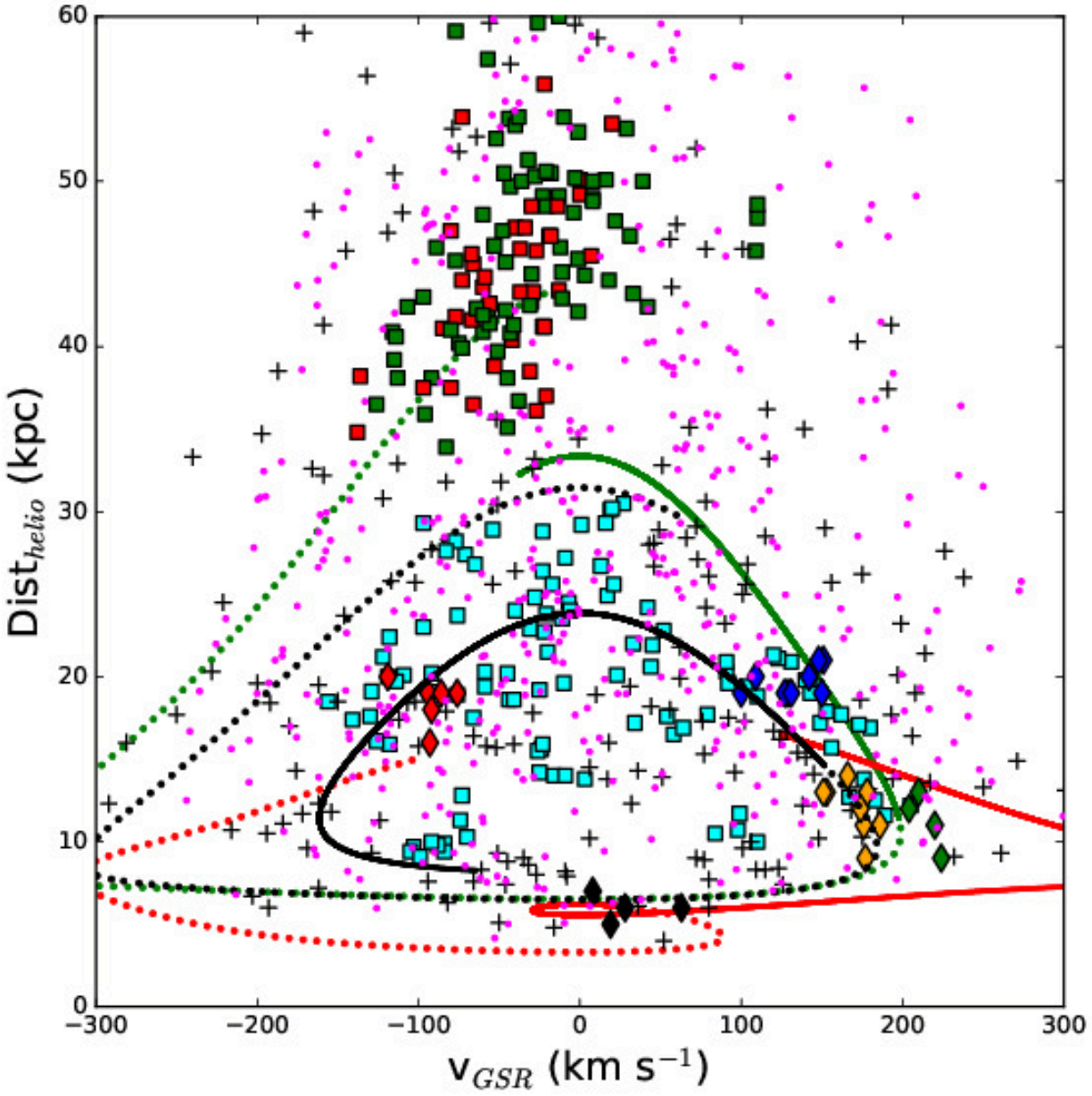


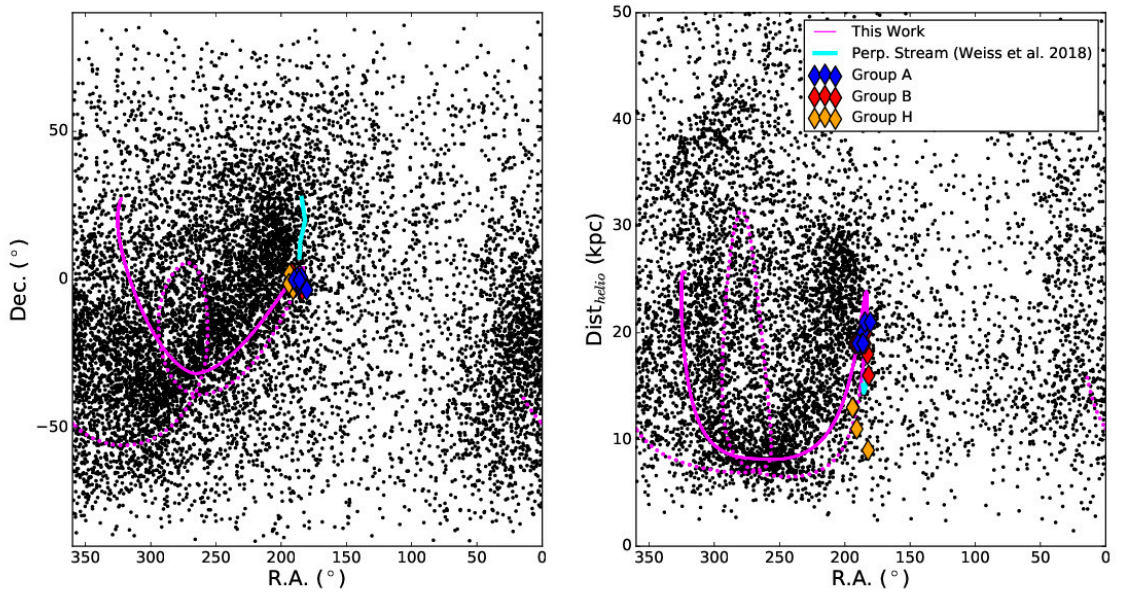




Orbit fits to stars in the Duffau groups are shown as magenta lines. N-body simulations along that orbit have 10^7 $M_\odot$, 0.4 kpc scale length, and 2 Gyr evolution time. HAC is at (RA, dec) = (285°, 6°) and EriPhe is at (RA, dec) ~ (30°, -55°)

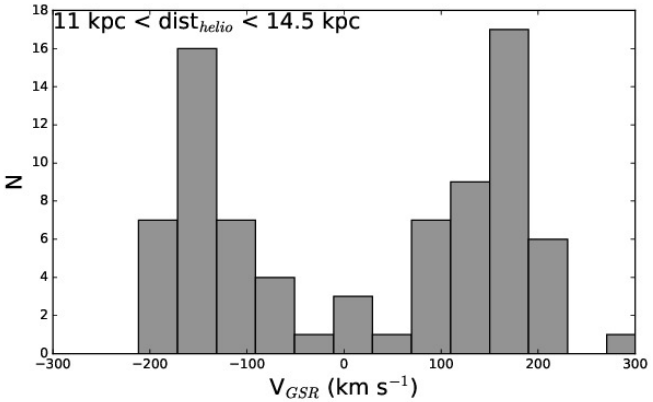
The Virgo Radial Merger

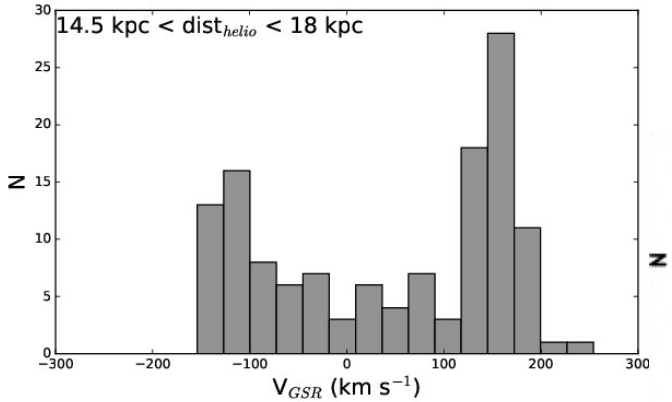


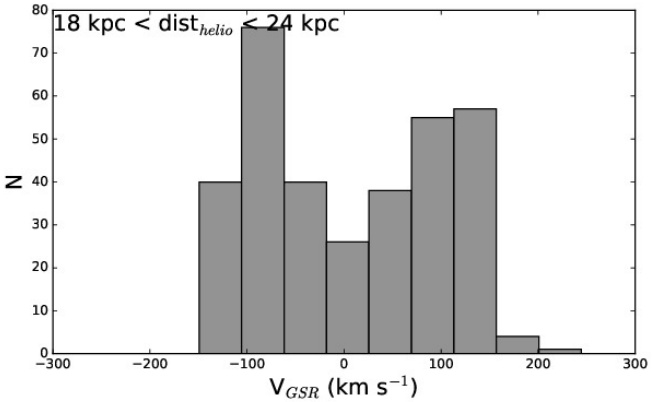


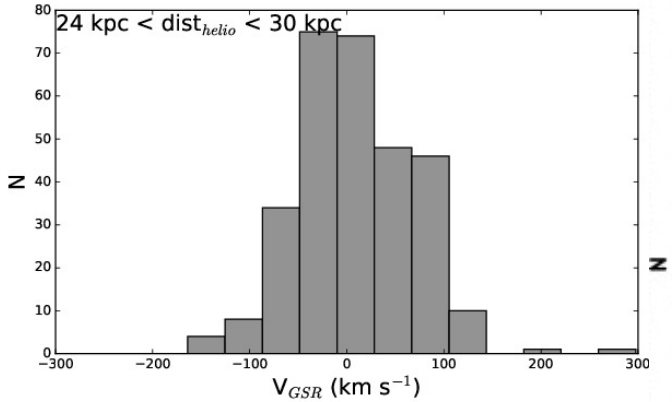
We sent a 10^9 $M_\odot$ dwarf galaxy with a scale radius of 3 kpc along the Perpendicular Stream orbit, then selected only the bodies in the Virgo region of the sky, and plotted as magenta points. The squares show RRL/BHB stars from Vivas et al. (2016). The diamonds are the RRL in groups from Duffau et al. (2014). The red, black and green orbits are group D, the Perpendicular Stream, and the Parallel Stream. Note that the larger galaxy N-body does not follow the orbit fit to the debris well. The effect on the disk/GC is not included. The dG model is a Plummer sphere. But:

We can fit the range of distances and velocities of the groups and streams in the Virgo region with one dG.

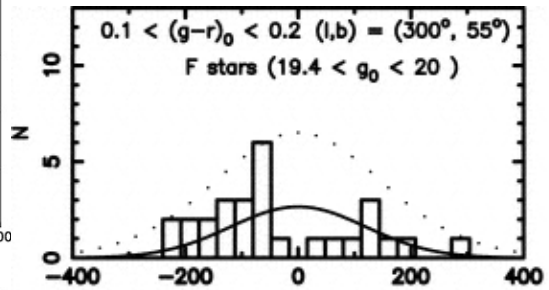


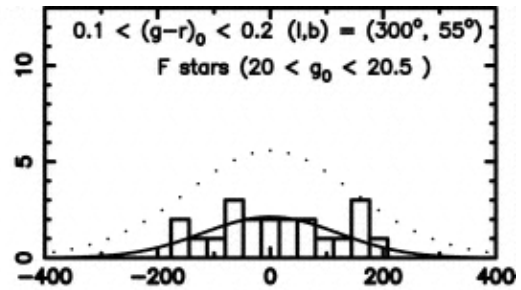


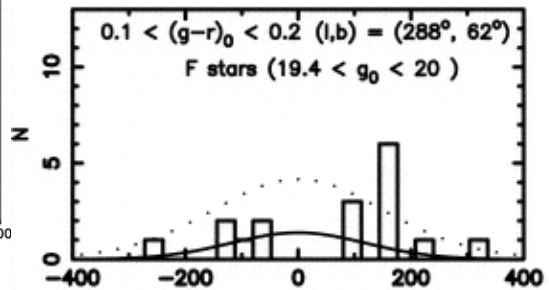


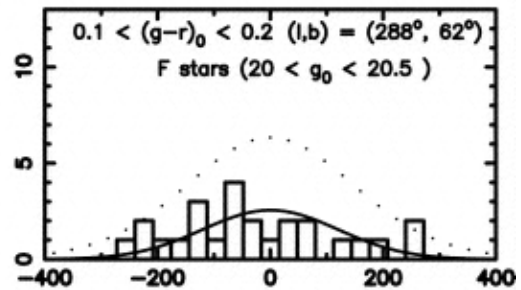


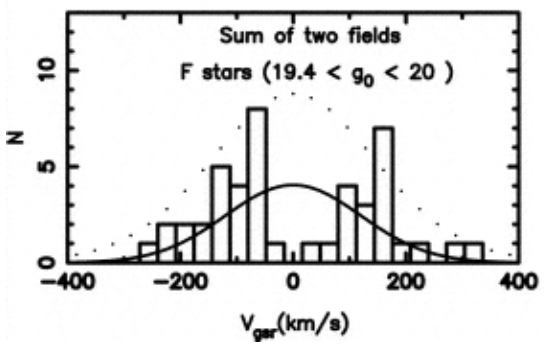
Newberg et al. (2007)

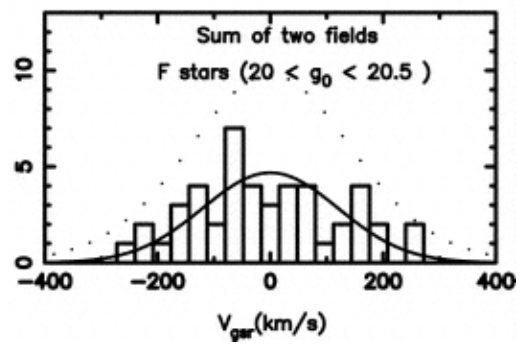




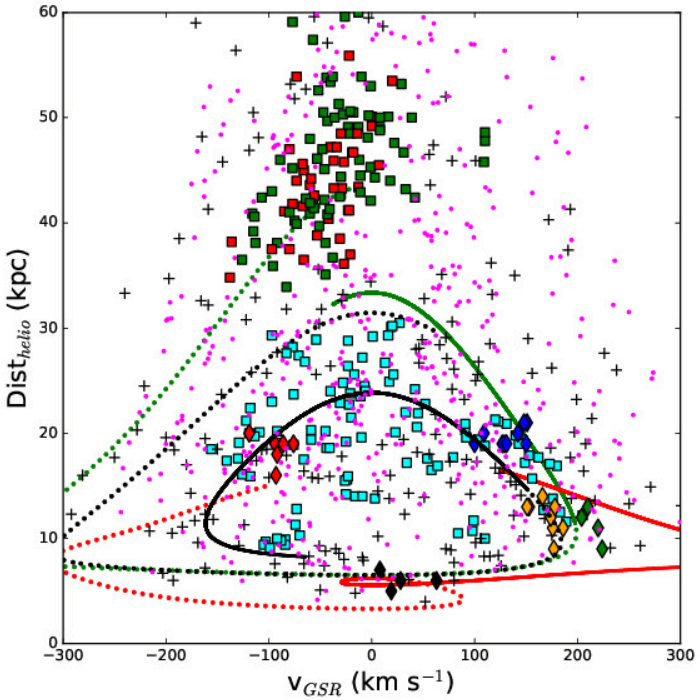


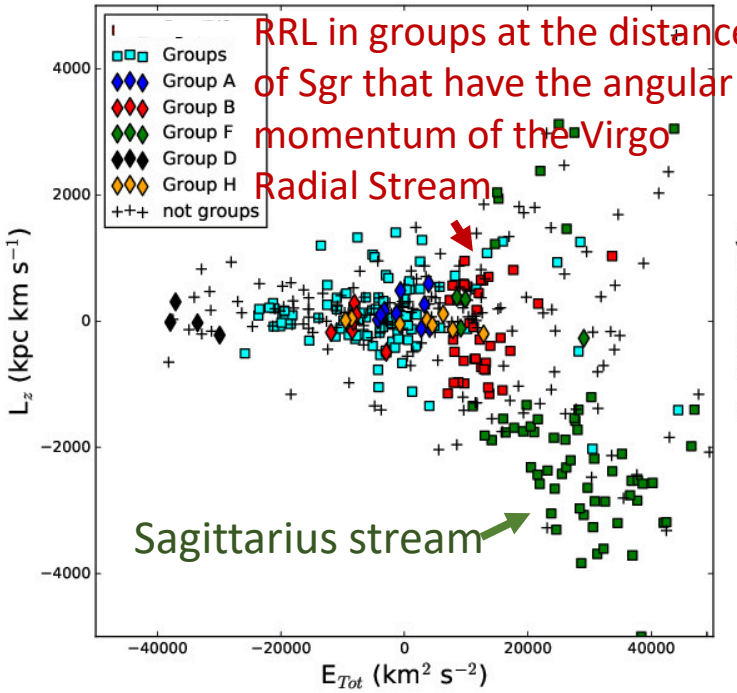






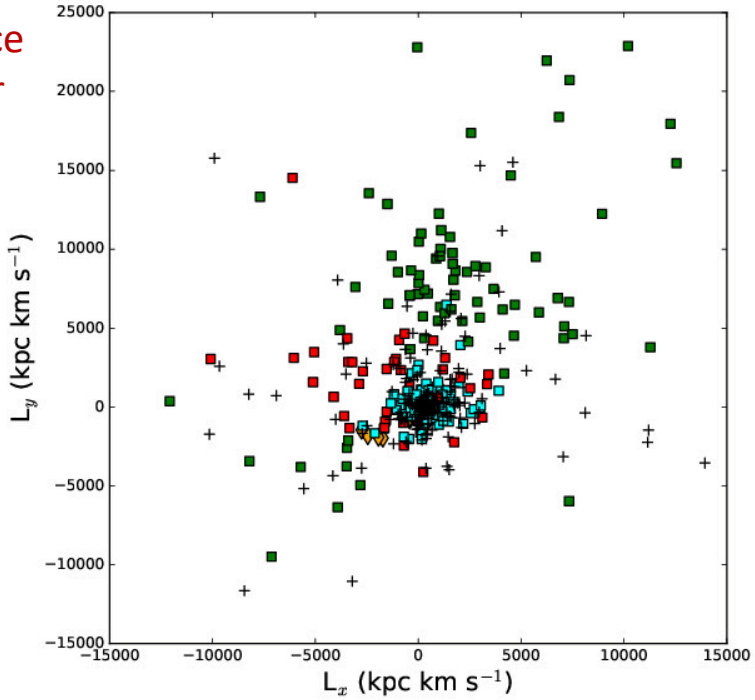
Only bodies within the VOD region analyzed in Newberg et al. (2007) (180◦ < RA < 200◦, -10◦ < Dec < +5◦) are shown.

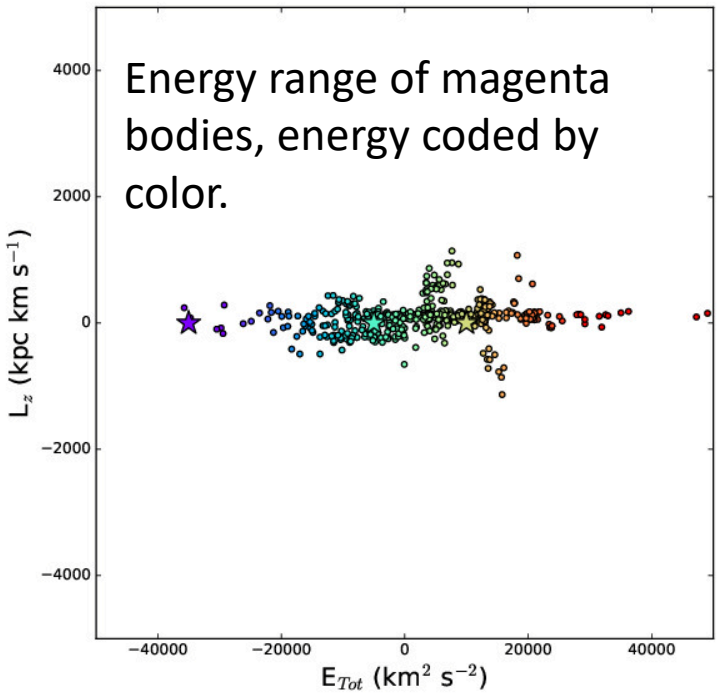




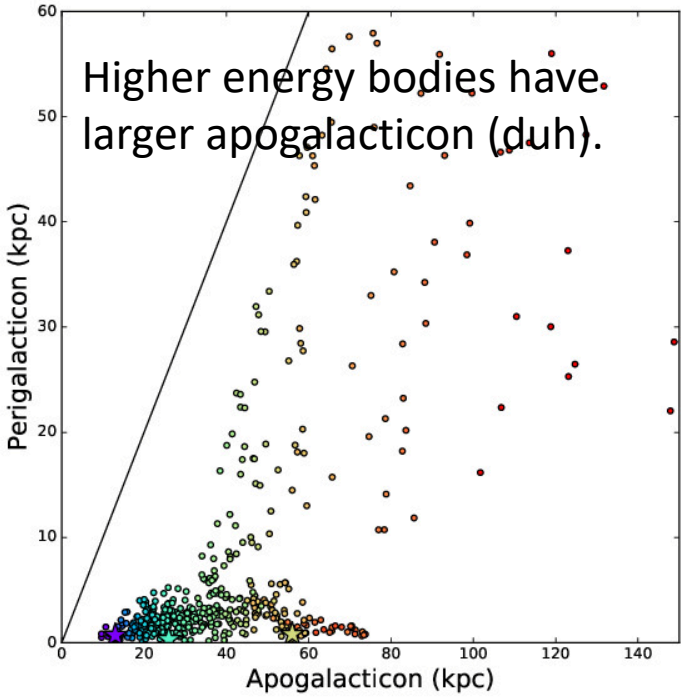
RRL in groups at the distance of Sgr that have the angular momentum of the Virgo Radial Stream

Sagittarius stream

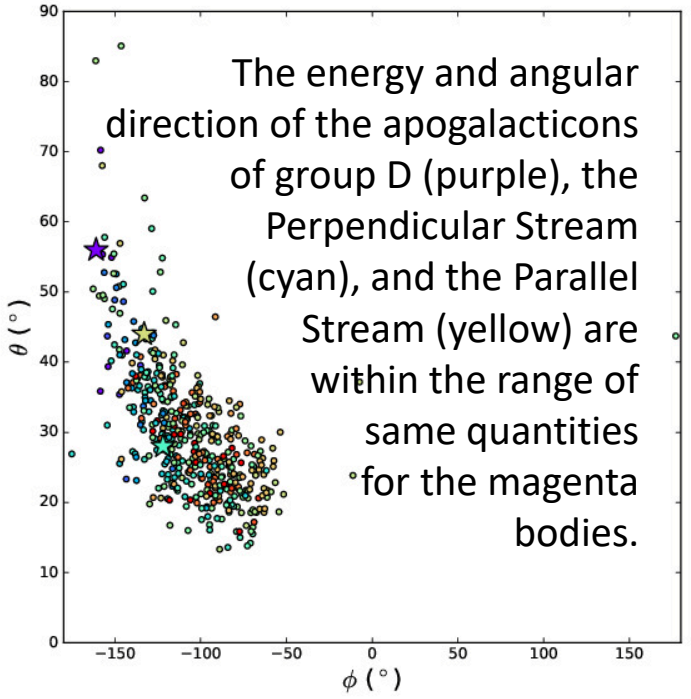




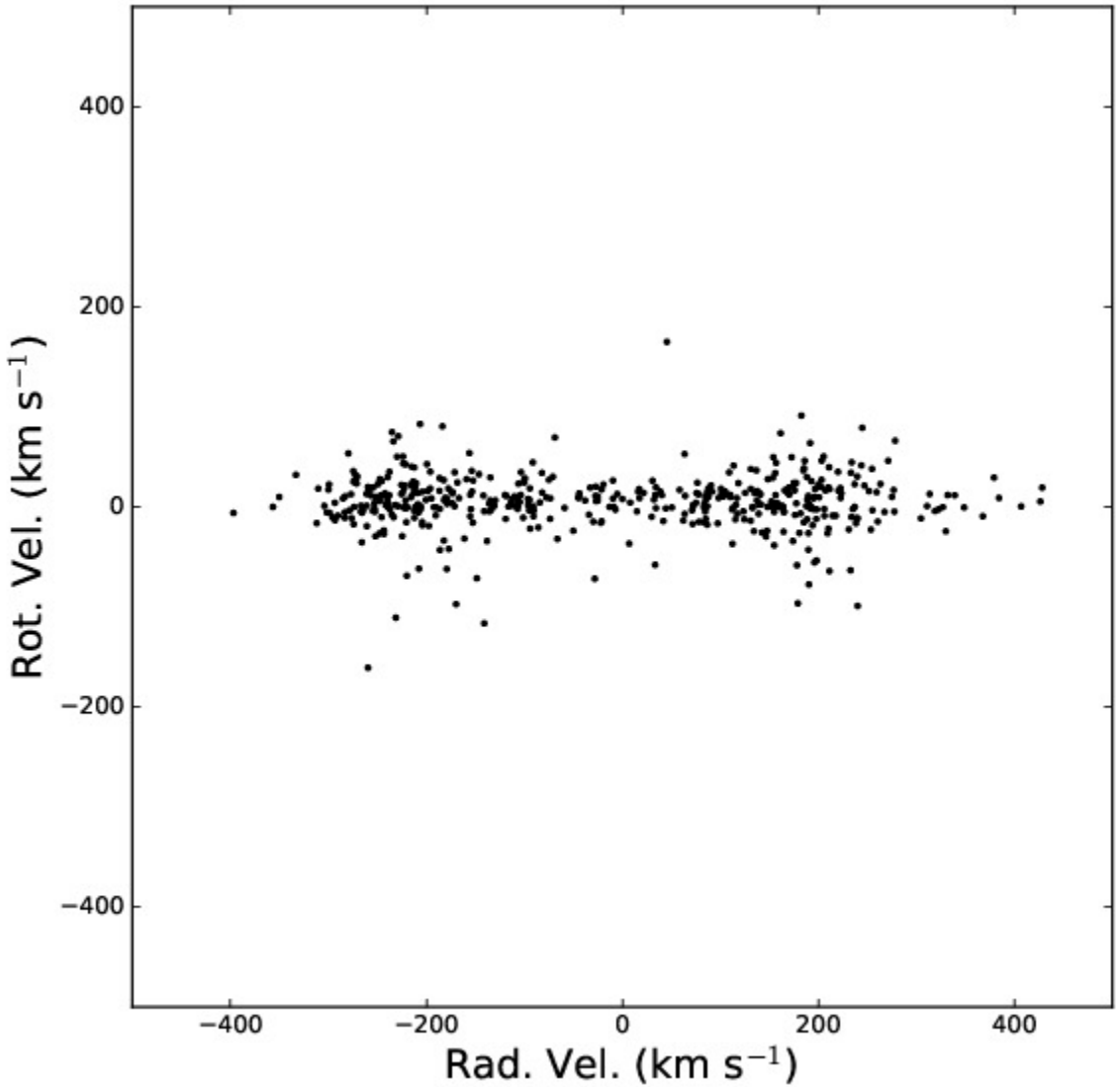
Energy range of magenta bodies, energy coded by color.

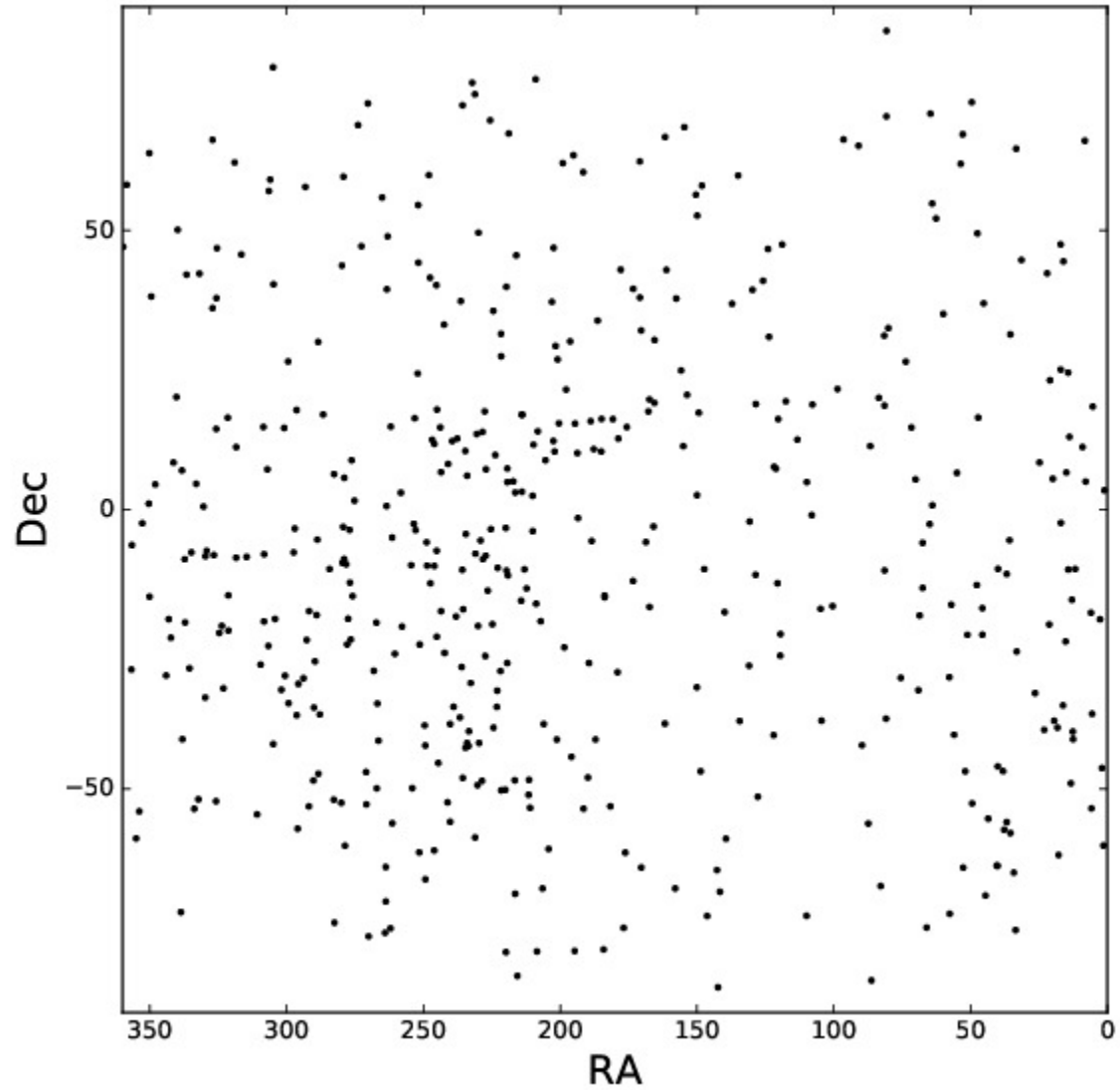


Higher energy bodies have larger apogalacticon (duh).



The energy and angular direction of the apogalacticons of group D (purple), the Perpendicular Stream (cyan), and the Parallel Stream (yellow) are within the range of same quantities for the magenta bodies.





Bodies from the Virgo Radial Merger simulation that are within 5 kpc of the Sun. They look a lot like the Gaia-sausage or Gaia-Enceladus Merger, even though the simulation is only 2 Gyr.