Probing the Milky Way Halo with Stellar Streams

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Credit: Don Dixon
The Milky Way Halo

- The Galactic halo is a junkyard of old relics, preserving a history of collisions, accretions, mergers, and a few remaining, still intact structures.

- In addition to 34 dwarf or ultrafaint galaxies and ~150 globular clusters, the last decade has seen the discovery of 30+ tidal debris streams out to ~50 kpc.

- A similar number of local or nearby streams halo streams have been detected kinematically (e.g. the Helmi Stream, Arcturus, ECHOS).

- ~20% of the halo is accounted for by the Sagittarius Stream, along with perhaps 20 globular clusters.

- Current estimates of the fraction of halo stars in substructures ranges from 50 to 70%.
The Northern Galactic Cap
Bits and Pieces

Alpheus
Grillmair et al. 2013, WISE/2MASS
NGC 288?

ATLAS Stream
Koposov et al. 2014, VST ATLAS South
Pyxis?

PAndAS MW Stream
Martin et al. 2014, PAndAS
Dwarf galaxy debris?

Ophiuchus Stream
Bernard et al. 2014, Pan-STARRS 3π
Stream fanning?

Phoenix Stream
Balbinot et al. 2016, DES
Something bigger?
Phoenix + Hermus?

- Nodal precession due to the disk potential.
- Brings orbital planes into alignment in 0.5 orbits.

- 235° or ~76 kpc
- Would make it the longest cold stream yet found.

Need kinematic and chemical tagging to verify…

BHB stars with
-2.2 < [Fe/H] < -1.6
0 < log g < 3.5
-0.23 < (g-r) < -0.1
b > 0, 11 < d < 21 kpc
70 < v_{gsr} < 130 km/s
Martin et al. in prep
Individually, streams do not strongly constrain the global Galactic potential.

However, the very existence of the Pal 5 and GD-1 streams implies a large degree of regularity, or that these streams are on regular orbits (e.g. not chaotic) – Price-Whelan et al. 2015.

Pearson et al. (2015) show that the appearance and velocity of Pal 5 already rule out the triaxial potential of Law & Majewski (2010, based on modeling the Sagittarius stream), at least within 25 kpc.
Simultaneous Dynamical Modeling of Streams

- Flattening = 0.95 ± 0.05
- \( c/a = 1.05 ± 0.14 \) (expect ~0.8 for maximal disk)
- \( M(<20 \text{ kpc}) = 1.1 ± 0.1 \times 10^{11} \)

Bovy et al. 2016
Pan-STARRS1

8 kpc

15 kpc

25 kpc

Bernard et al. 2016
Summary

• The harder we look, the more we find.
  • We expect to find dozens of new streams and satellite galaxies in the next couple of years, and perhaps hundreds by the time the Gaia mission ends.

• We are learning how best to use streams for probing both the halo and its constituents.

• The stellar halo may yet challenge $\Lambda$CDM.