The substructure of the stellar halo as measured with SDSS turnoff stars and MilkyWay@home

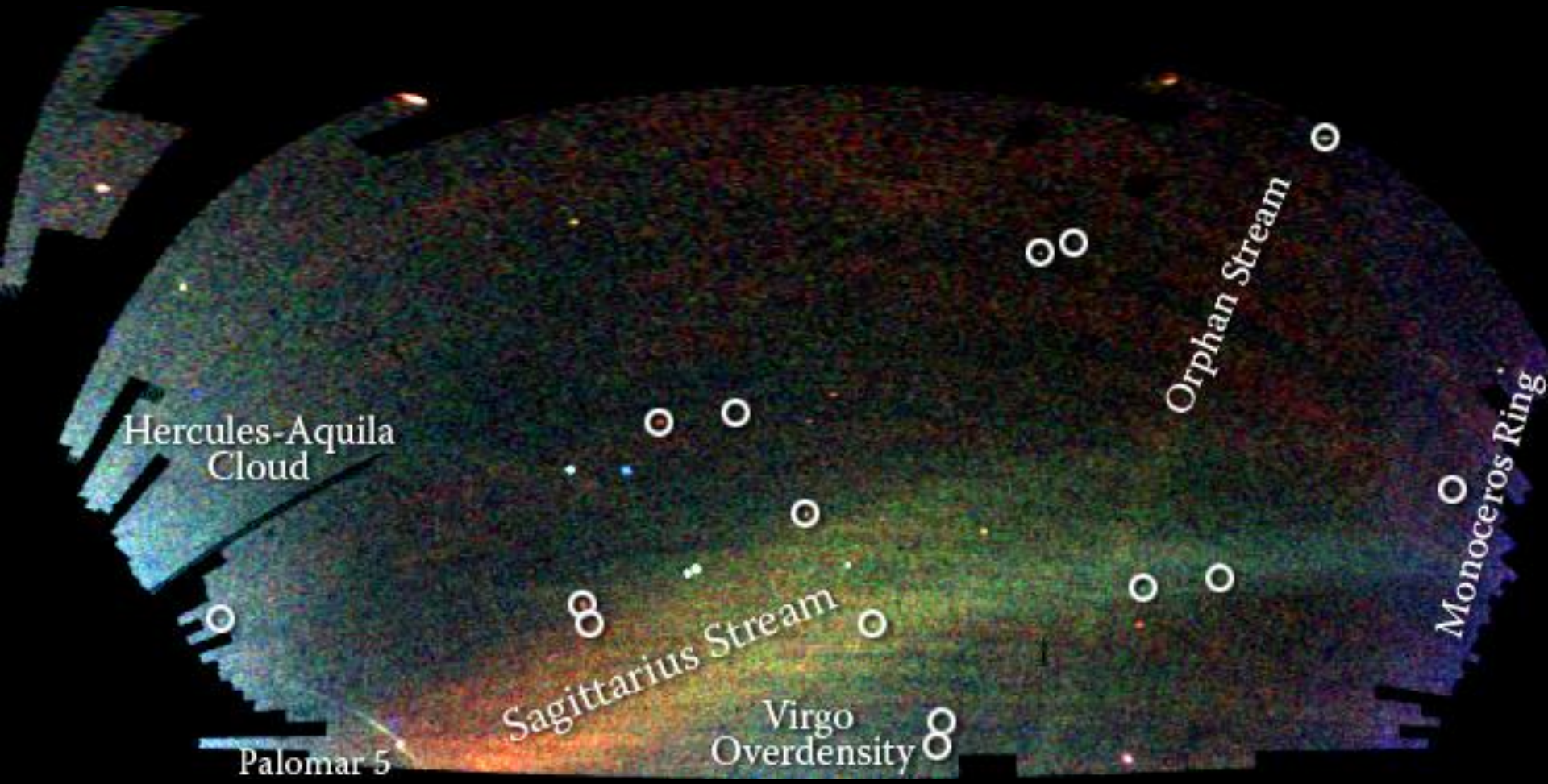
Simulation: Stefan Gottlöber/AIP

Image Credit: Heidi Newberg

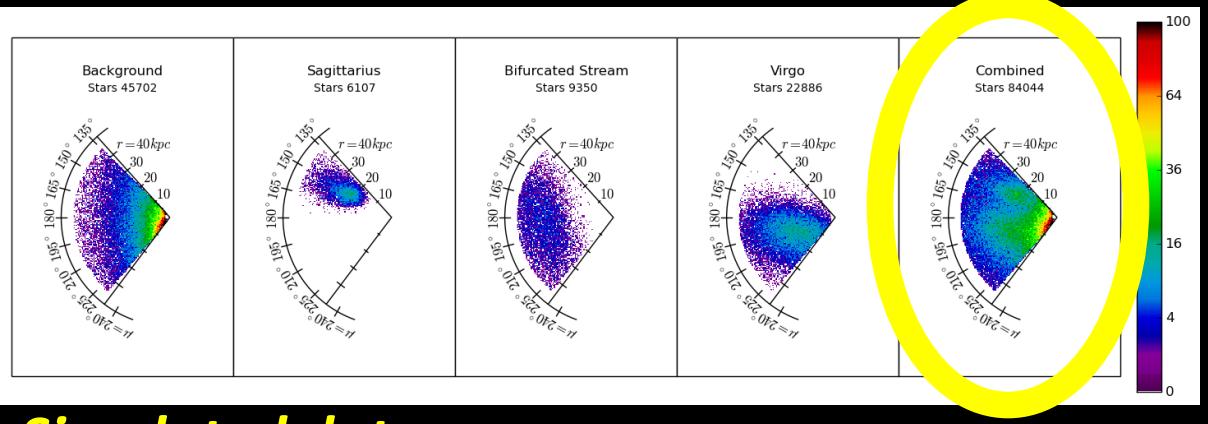
Heidi Jo Newberg

Rensselaer Polytechnic Institute

Field of Streams



Analyze density of the stars in one SDSS stripe at a time.
Credit: V. Belokurov and the Sloan Digital Sky Survey.

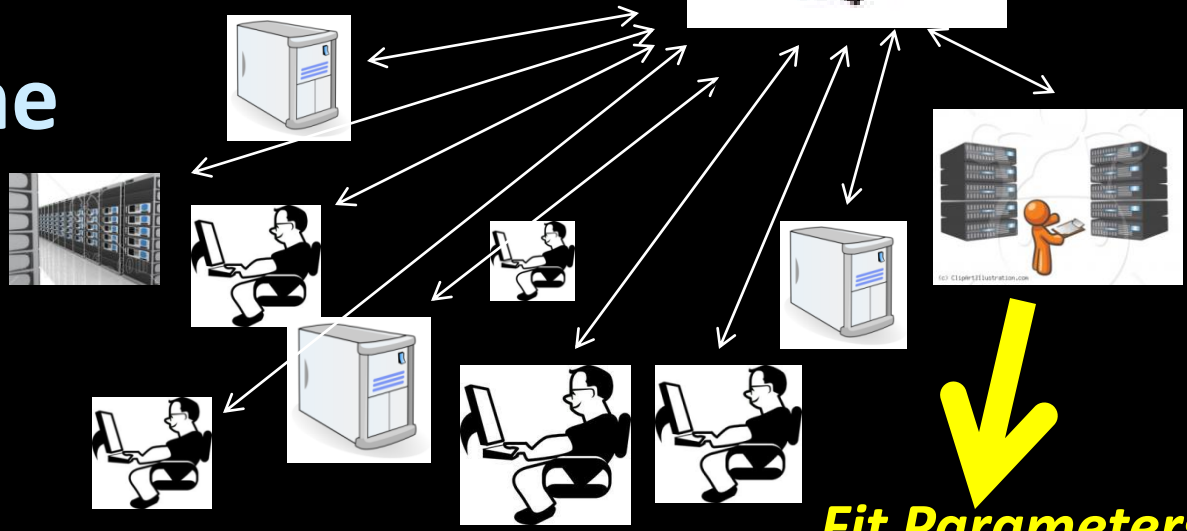


Simulated data

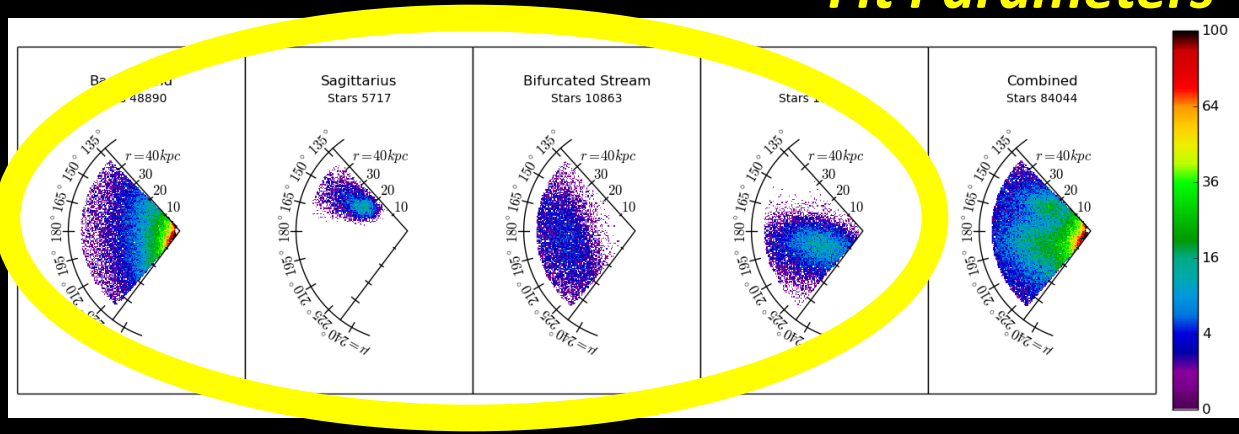
Jake Weiss

MilkyWay@home

uses the power of volunteer computing to successfully fit ***20 parameters*** *(6 x 3 streams plus two background) in the spatial density of tidal streams in the Milky Way halo.*



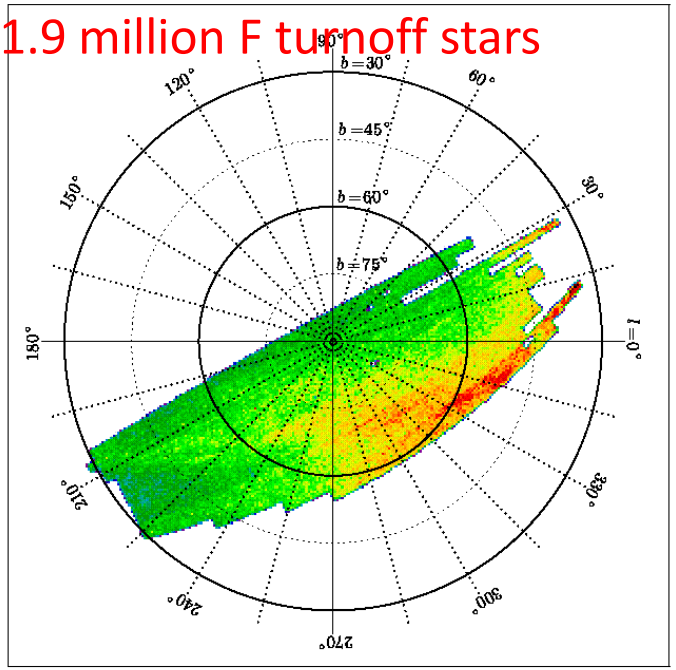
Fit Parameters

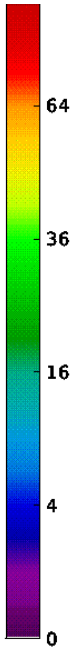


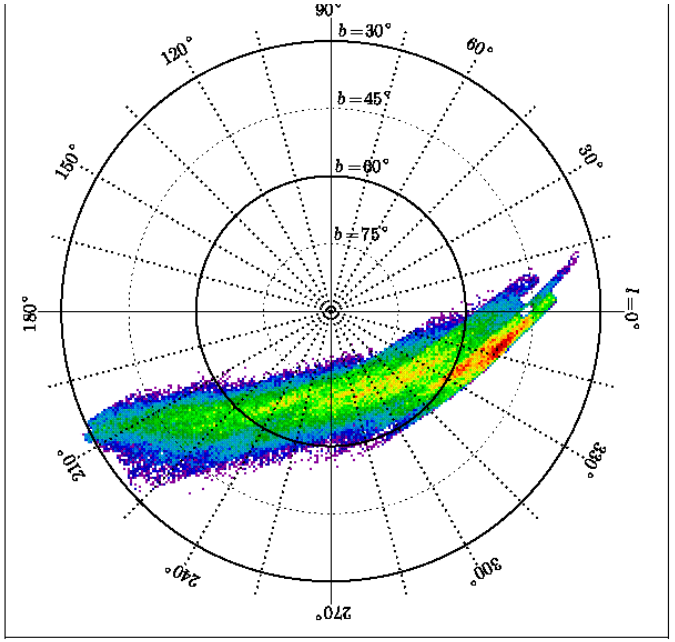
Mapping the Sgr Tidal Stream

Polar plots of SDSS F turnoff stars in the north Galactic Cap (top). Using our density model, we place each star in either the Sgr (lower left) or non-Sgr panel (lower right), with the probability given by the model. The stars in the Sgr panel are not guaranteed to be from the stream, but they collectively have the spatial properties of the Sgr stream. **Newby et al. (2013)**

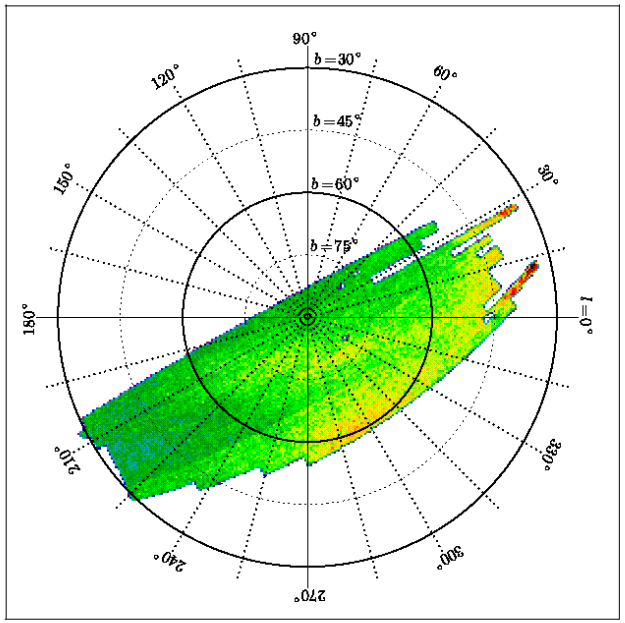
1.9 million F turnoff stars

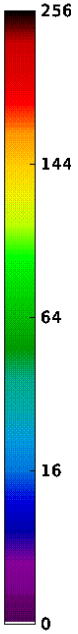




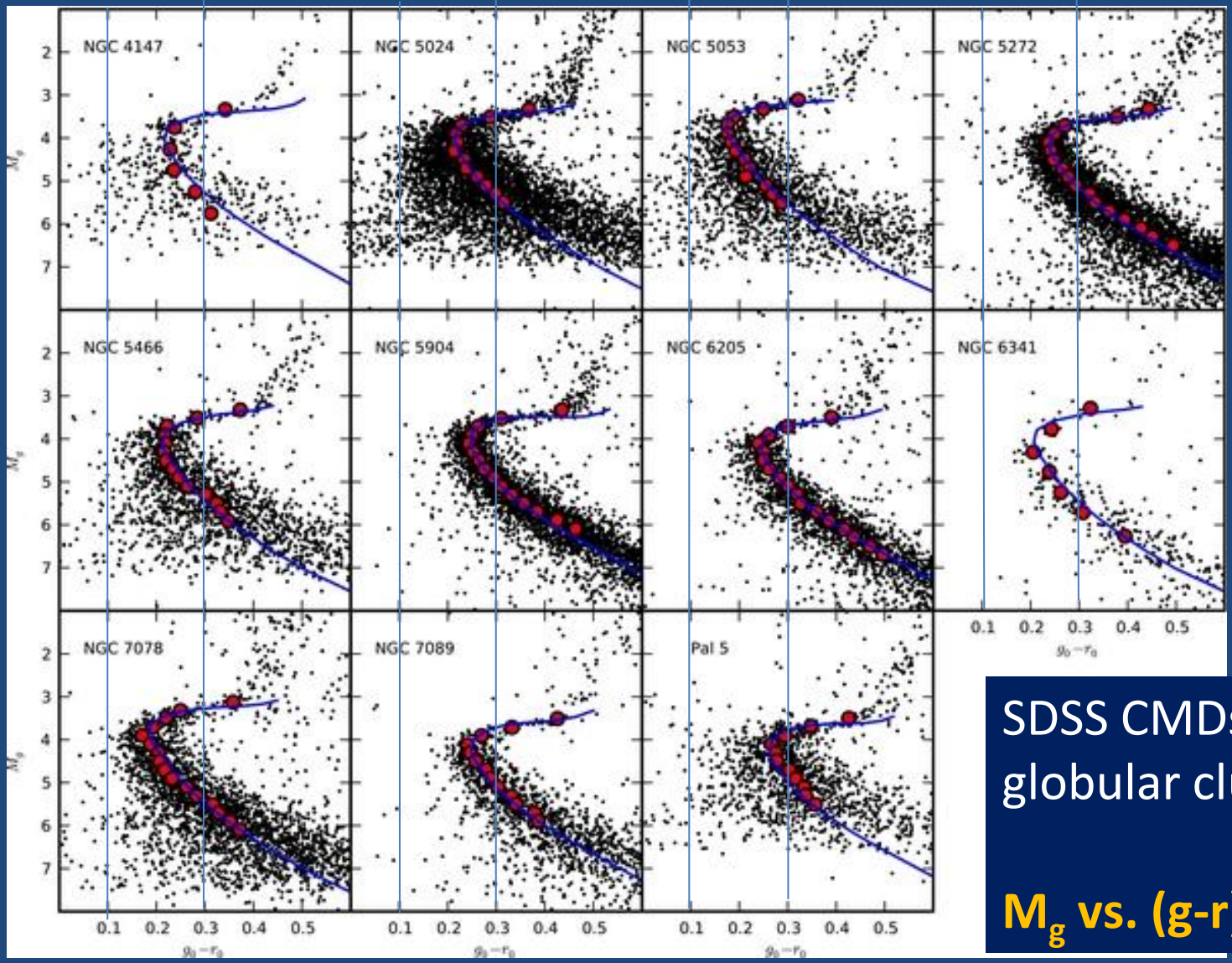


160,000 stars with Sgr density





1.7 million non-Sgr stars



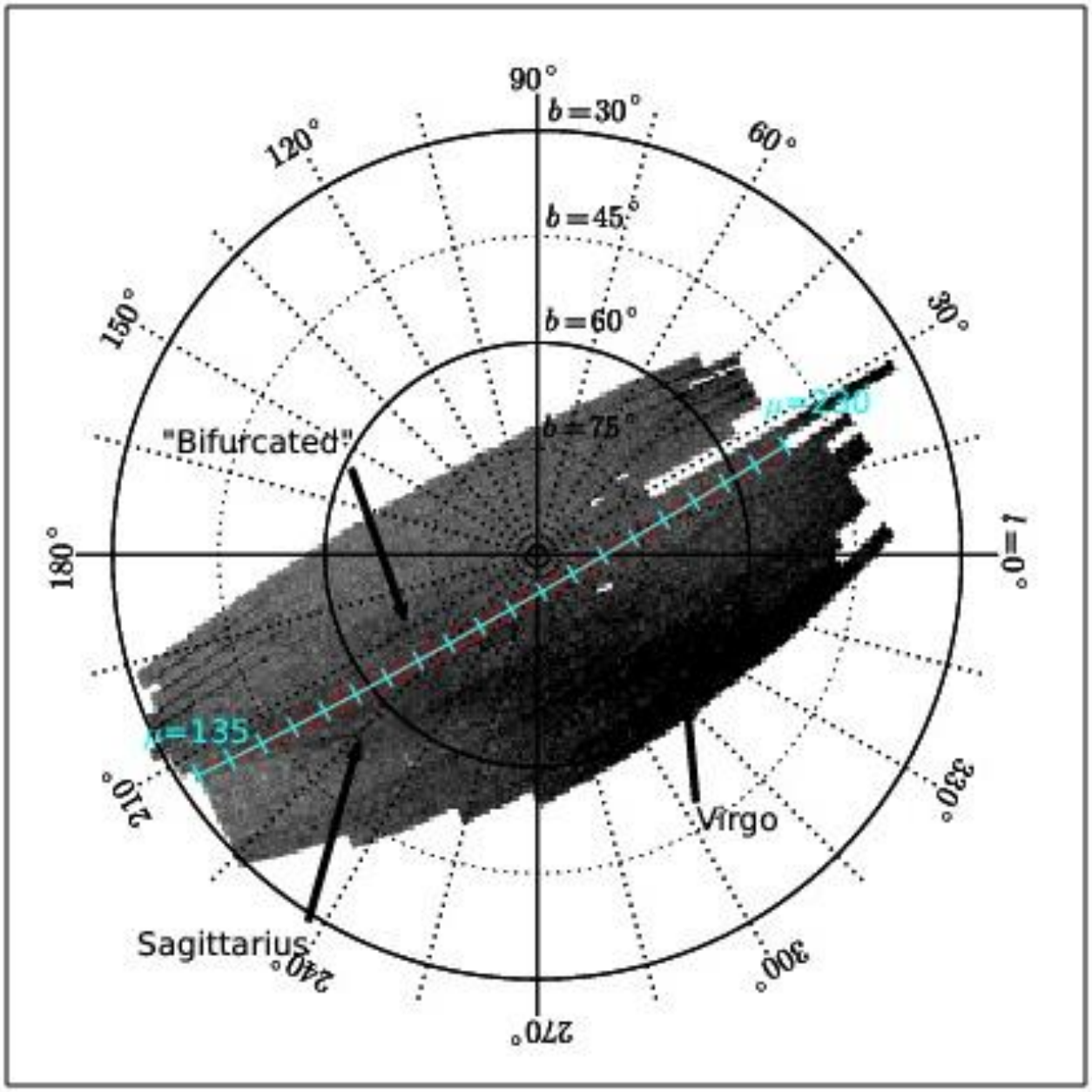
Matthew Newby

SDSS CMDs for 11 globular clusters studied

M_g vs. (g-r)

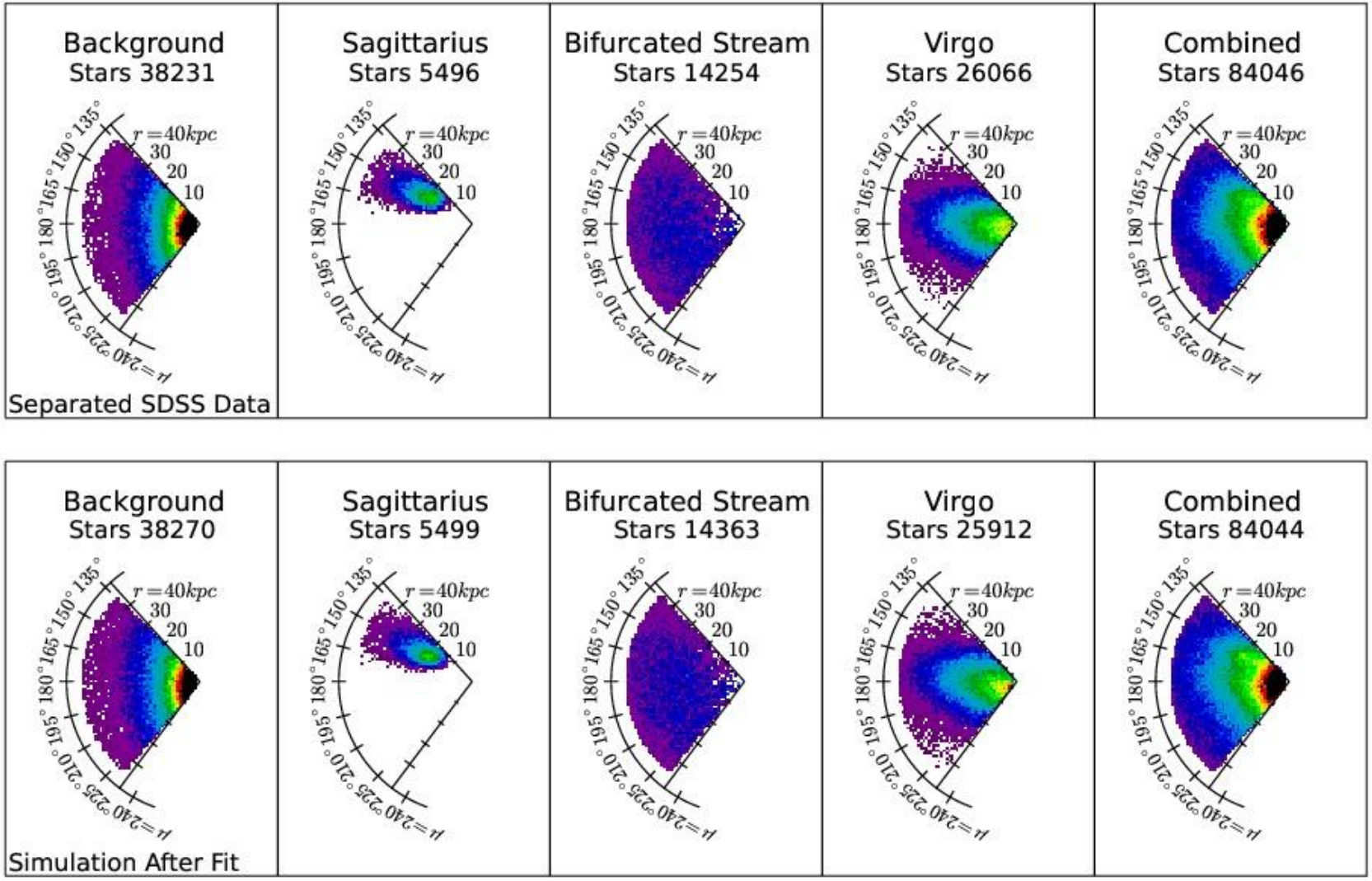
Newby et al. (2011)

All halo GCs have the same turnoff at g=4.2!



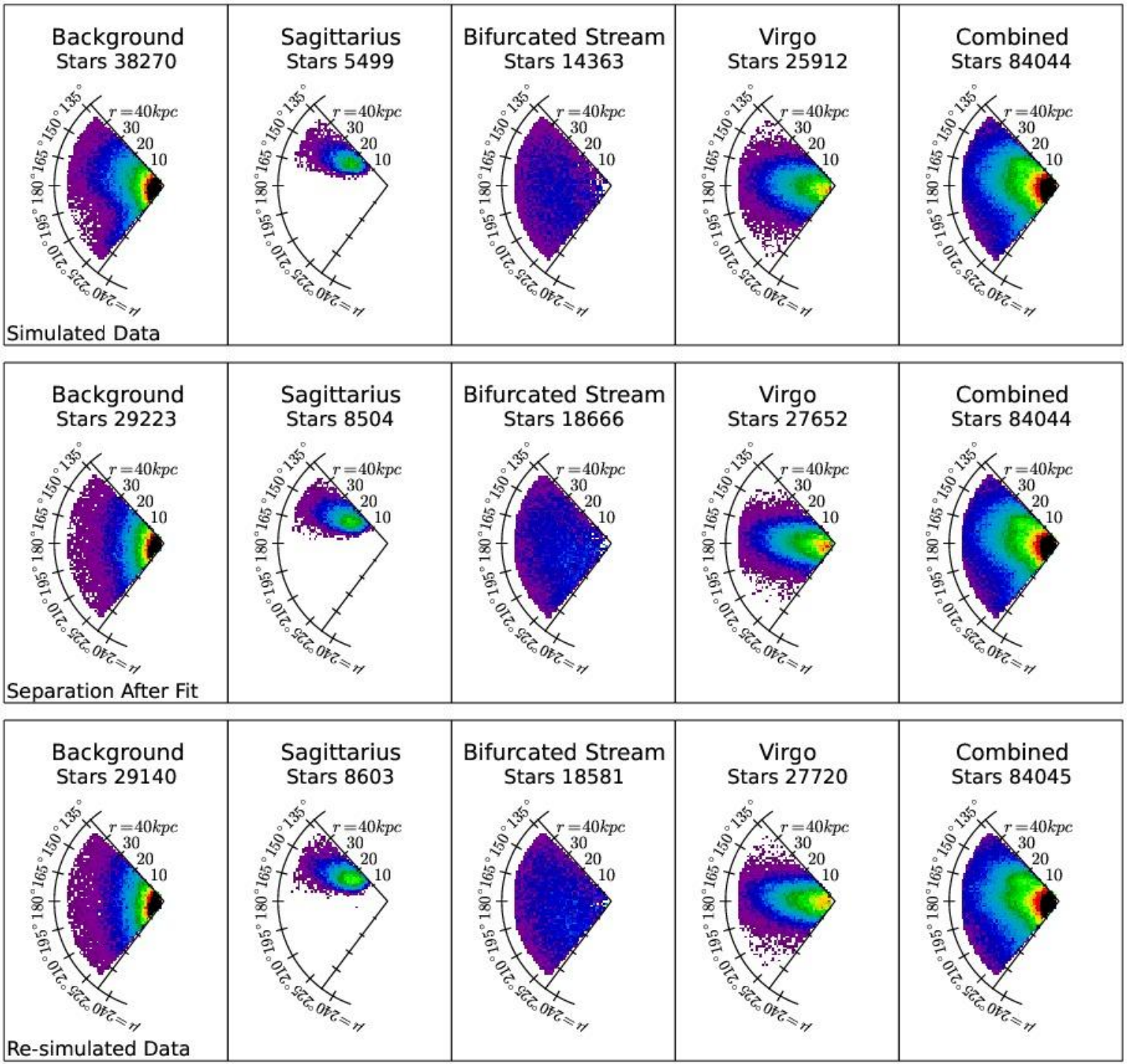
Weiss et al. (2018)

Now, we have a better model for the absolute magnitude distribution, better parameters in our optimizer, and better code optimization, and we attempt to fit all three major substructures in this portion of the north Galactic cap.

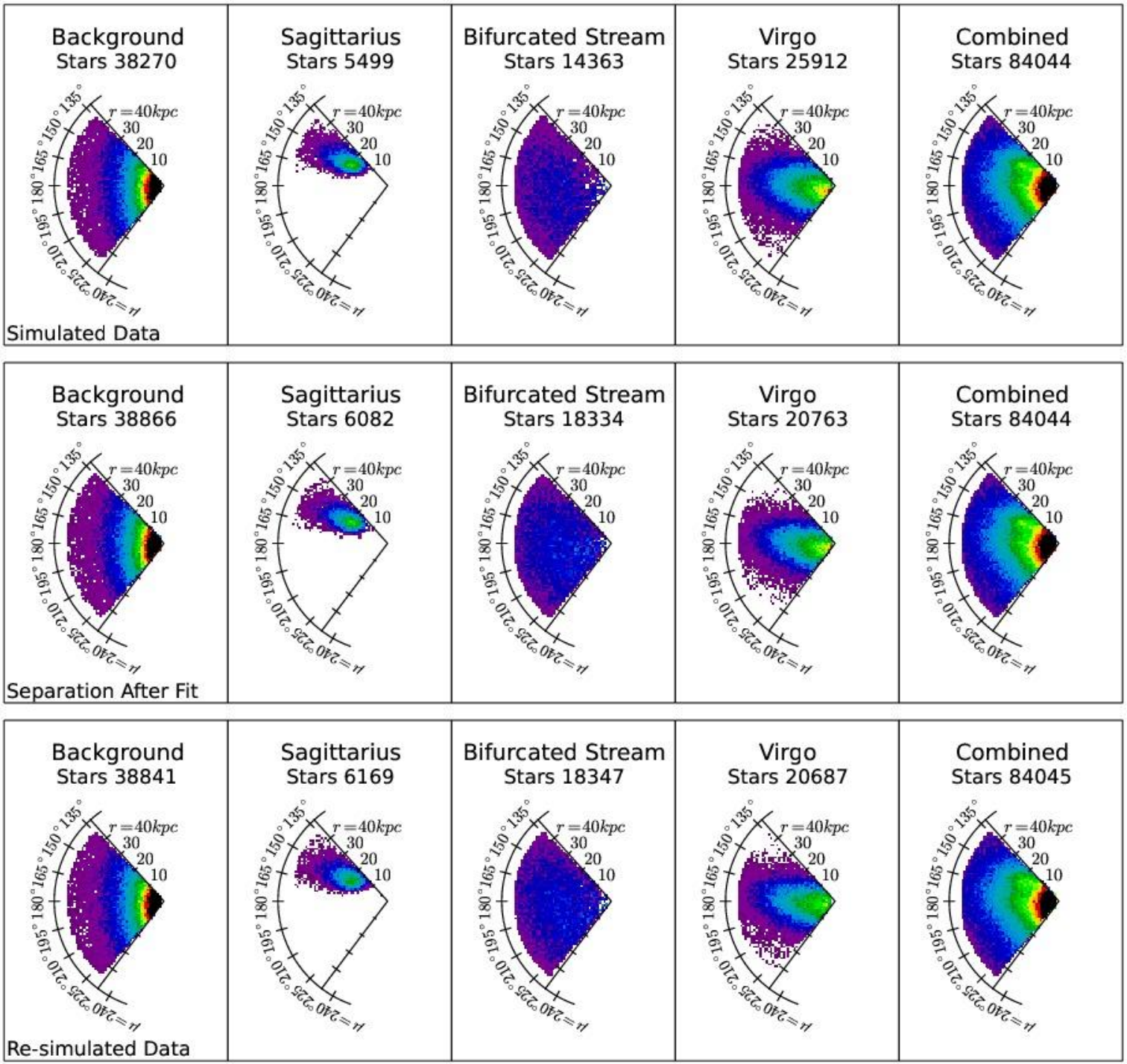


The top row shows the actual SDSS data. The first four panels are separated probabilistically into three streams and the smooth component.

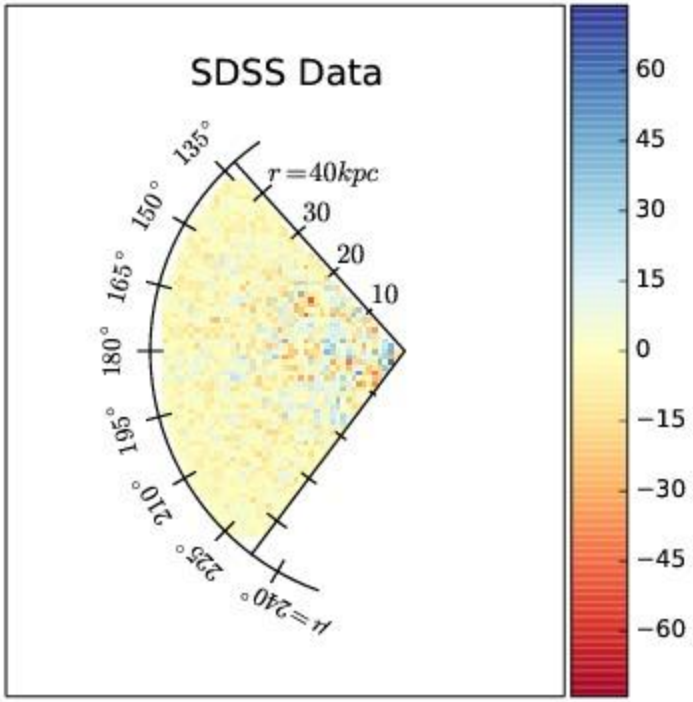
The lower panel shows simulated stars with the density profile that was fit to the data.



Correct Background model



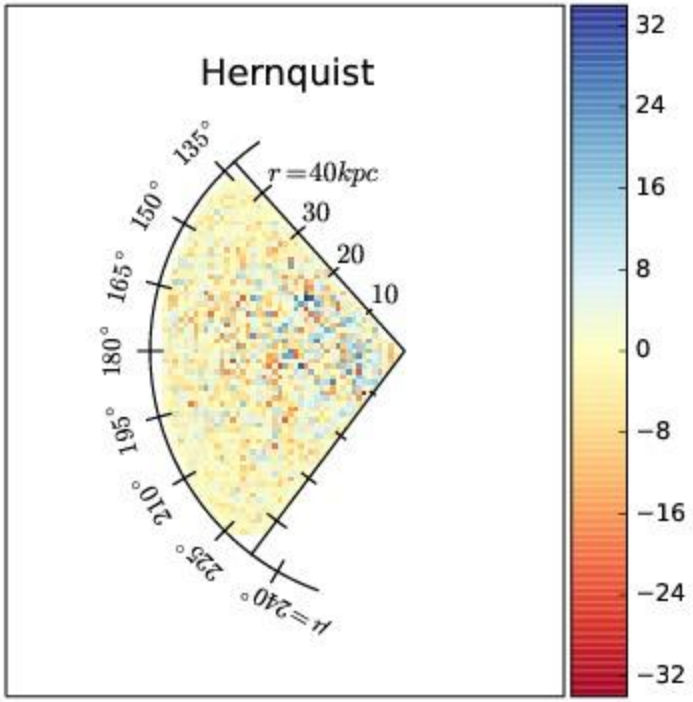
Incorrect Background model

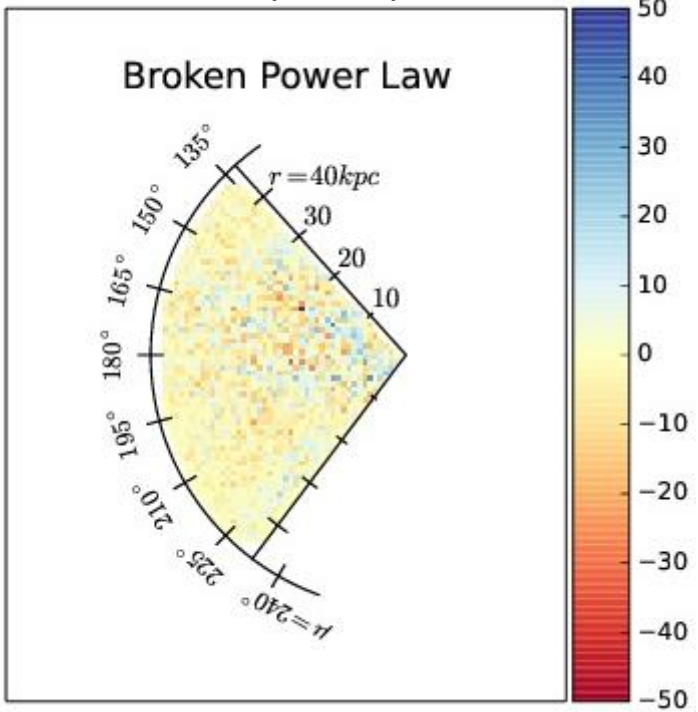


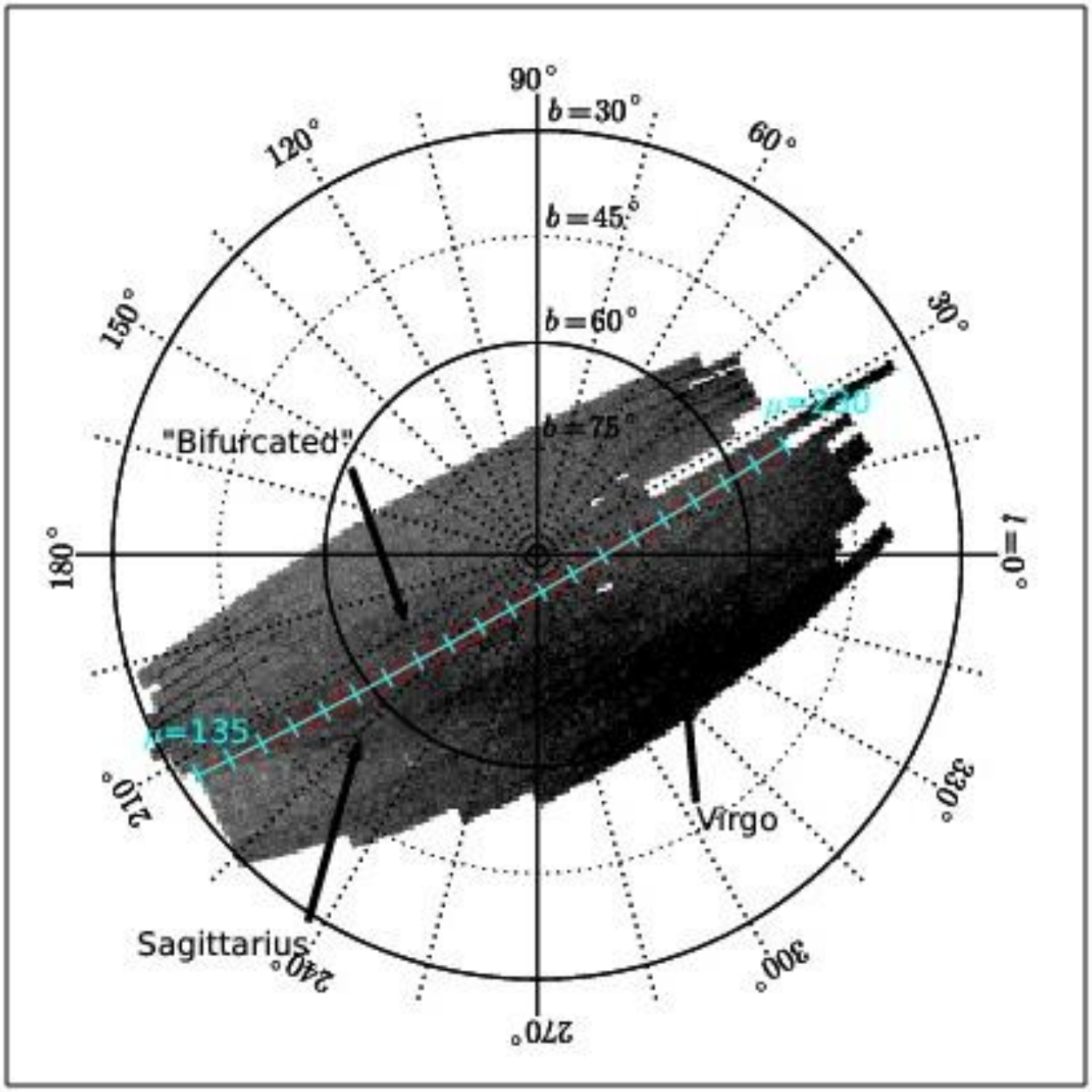
We subtract the simulated stripe, with the same parameters as were fit to the data, from the data.

The Hernquist subtraction fits the same background model as was simulated in the “data” and the Broken Power Law subtraction uses a different power law

Weiss et al. (2018)



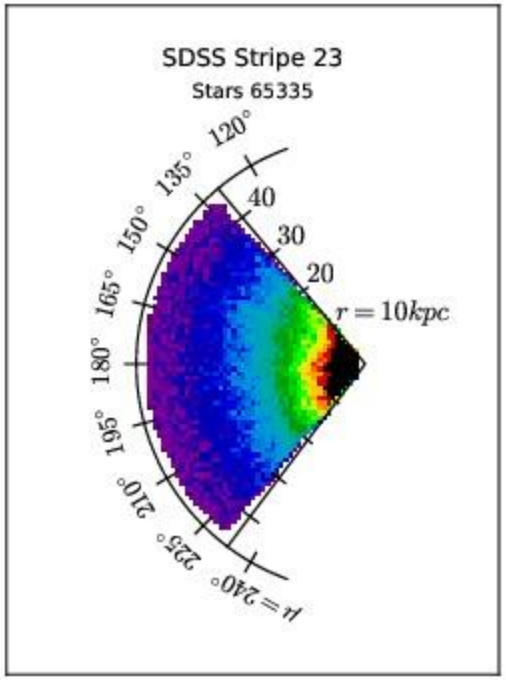


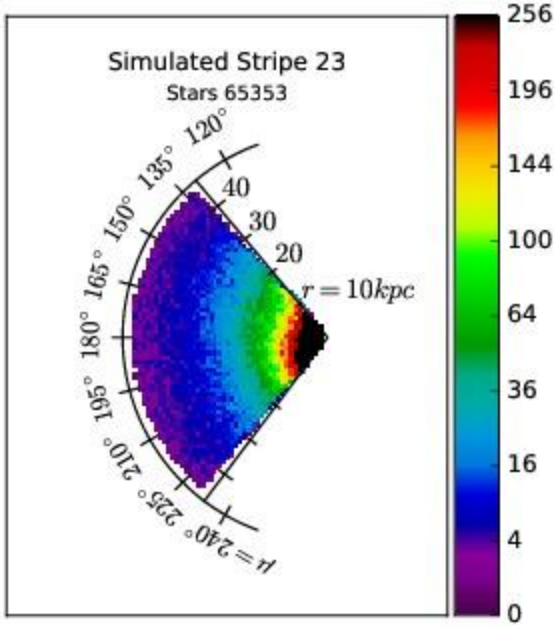


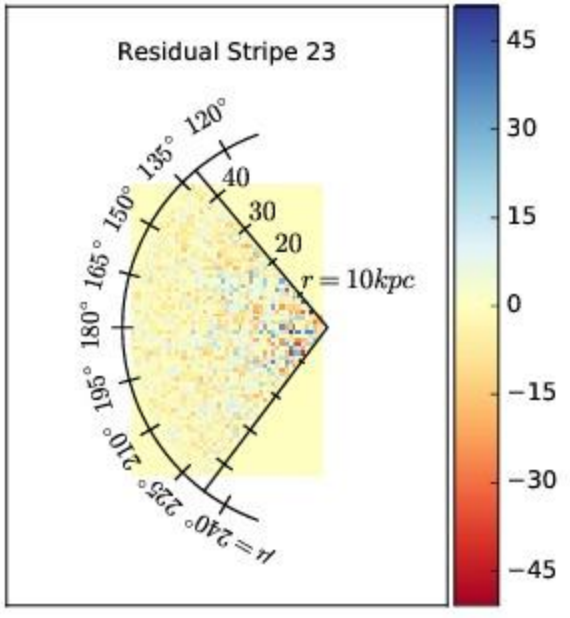
Weiss et al. (2018)

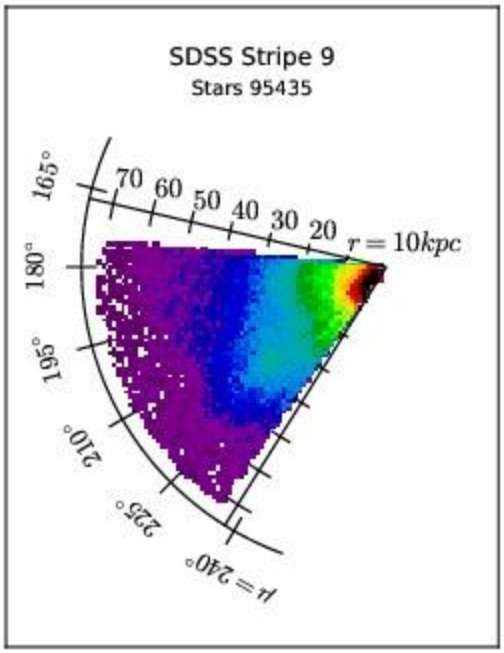
Now, we have a better model for the absolute magnitude distribution, better parameters in our optimizer, and better code optimization, and we attempt to fit all three major substructures in this portion of the north Galactic cap.

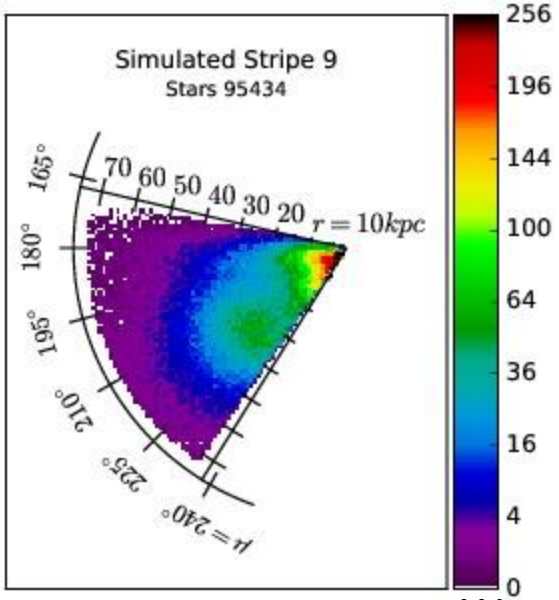
Best residual is highest stripe number

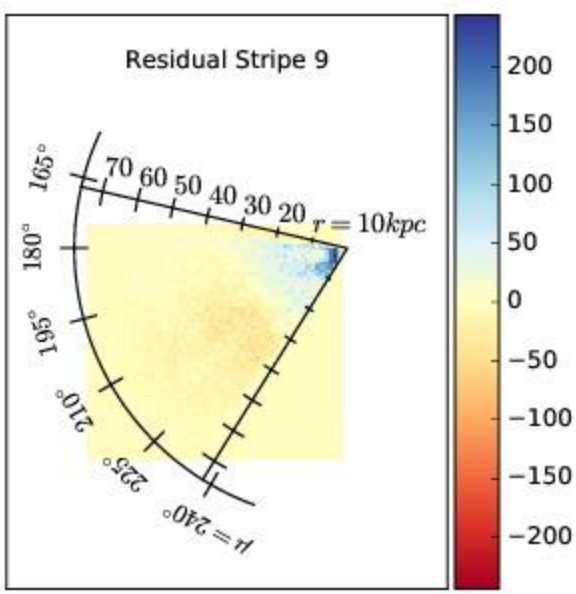




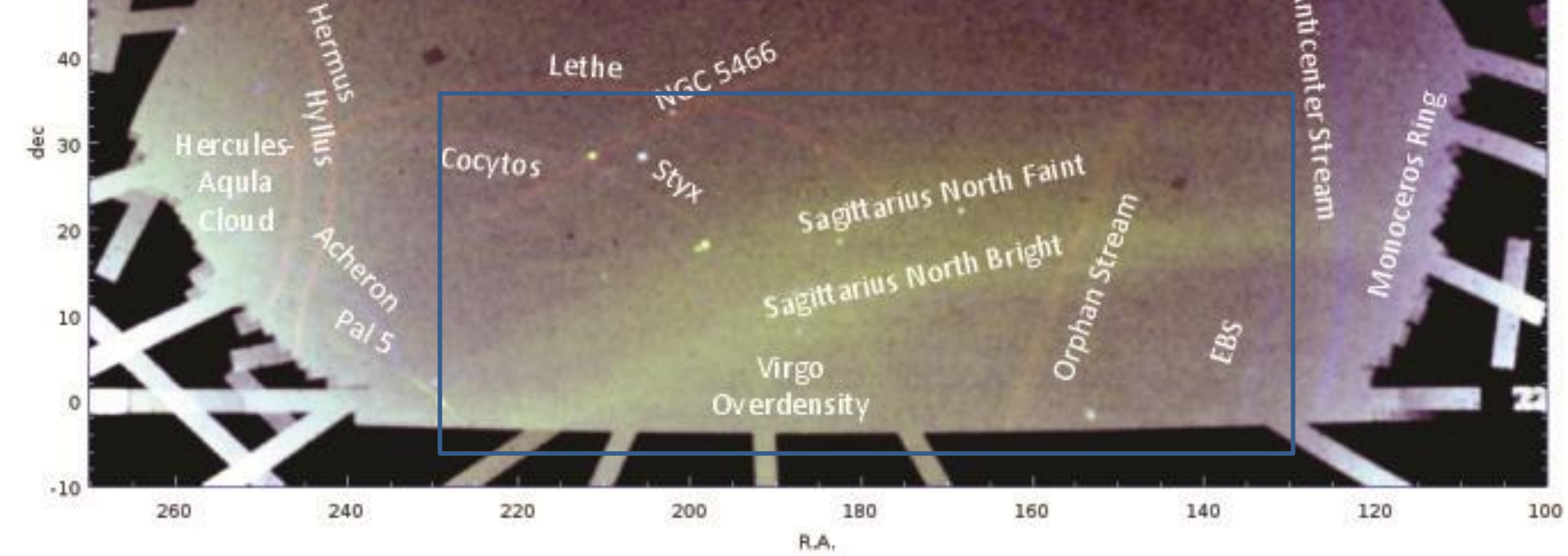


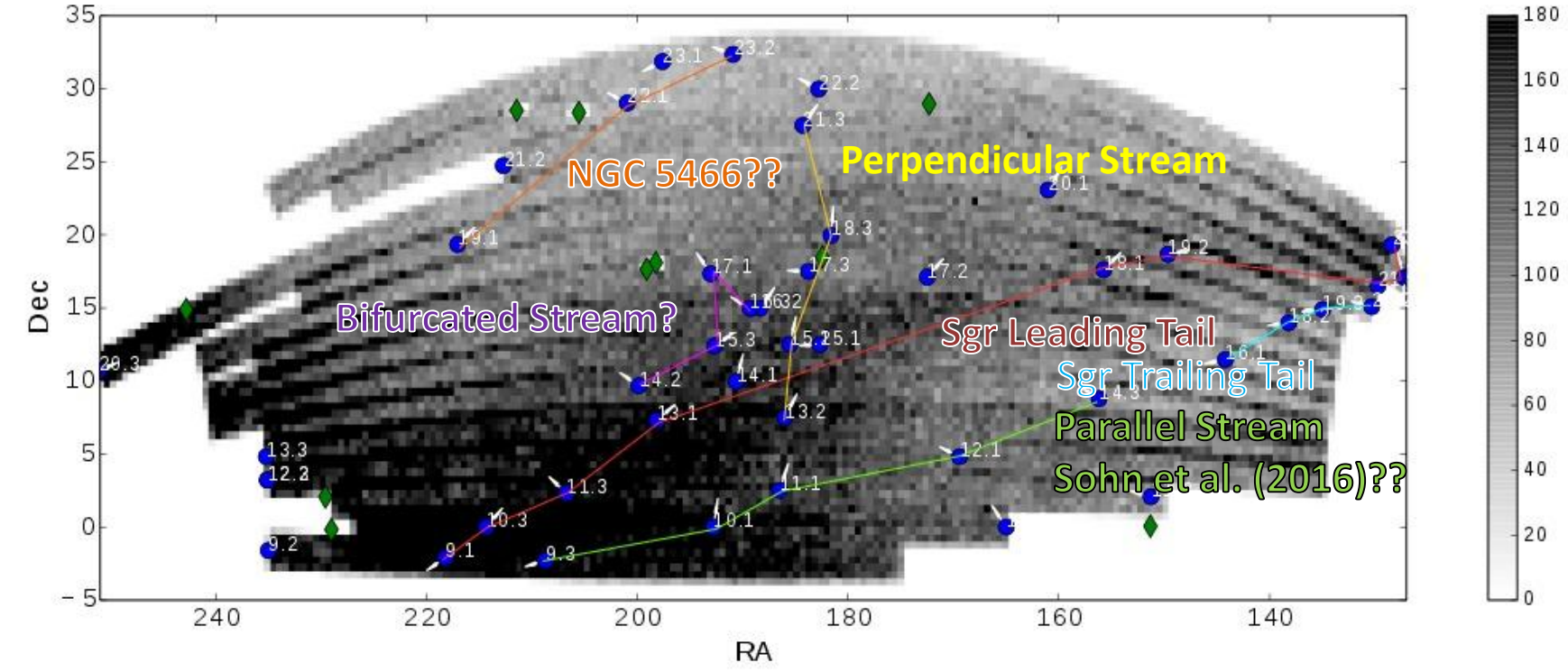


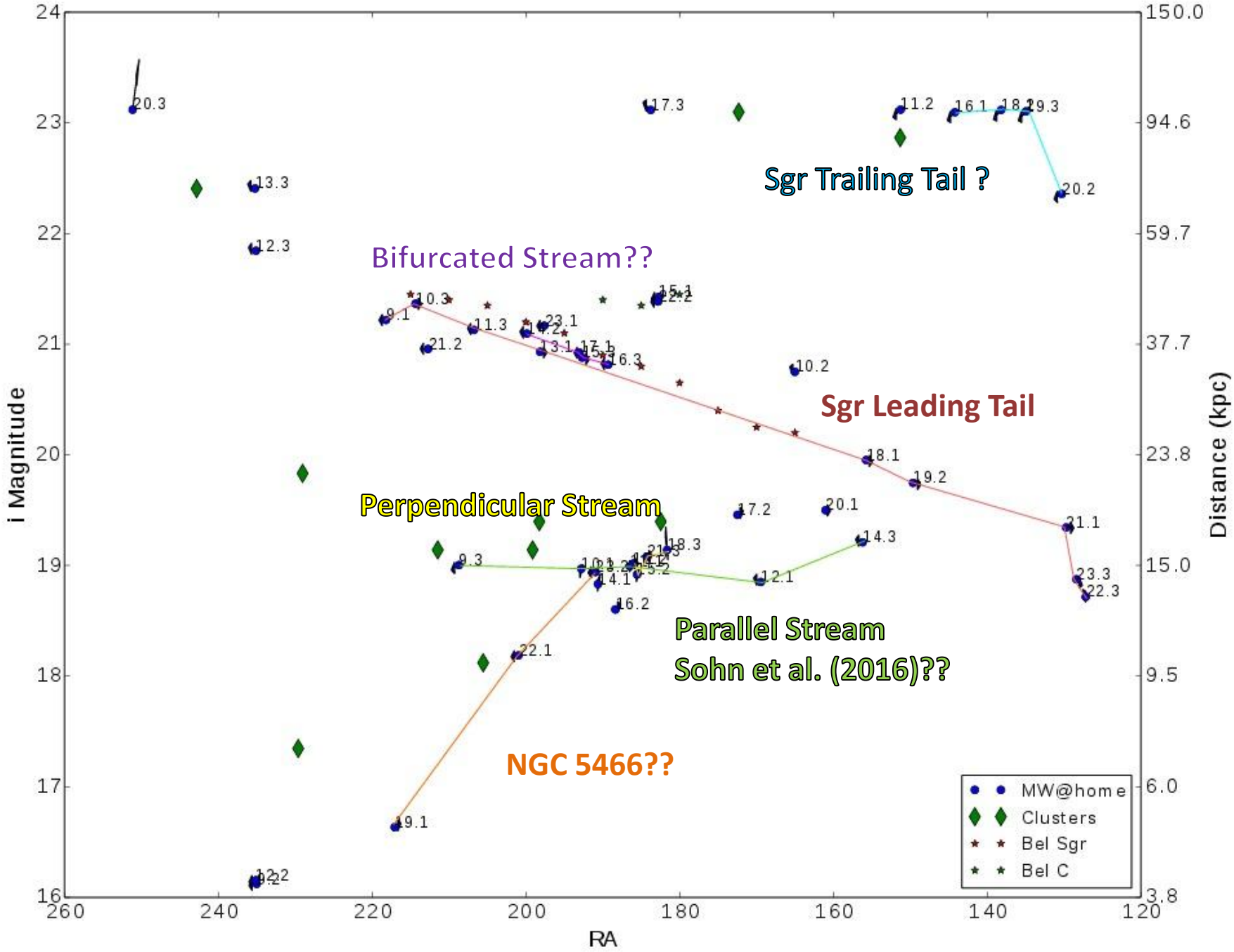


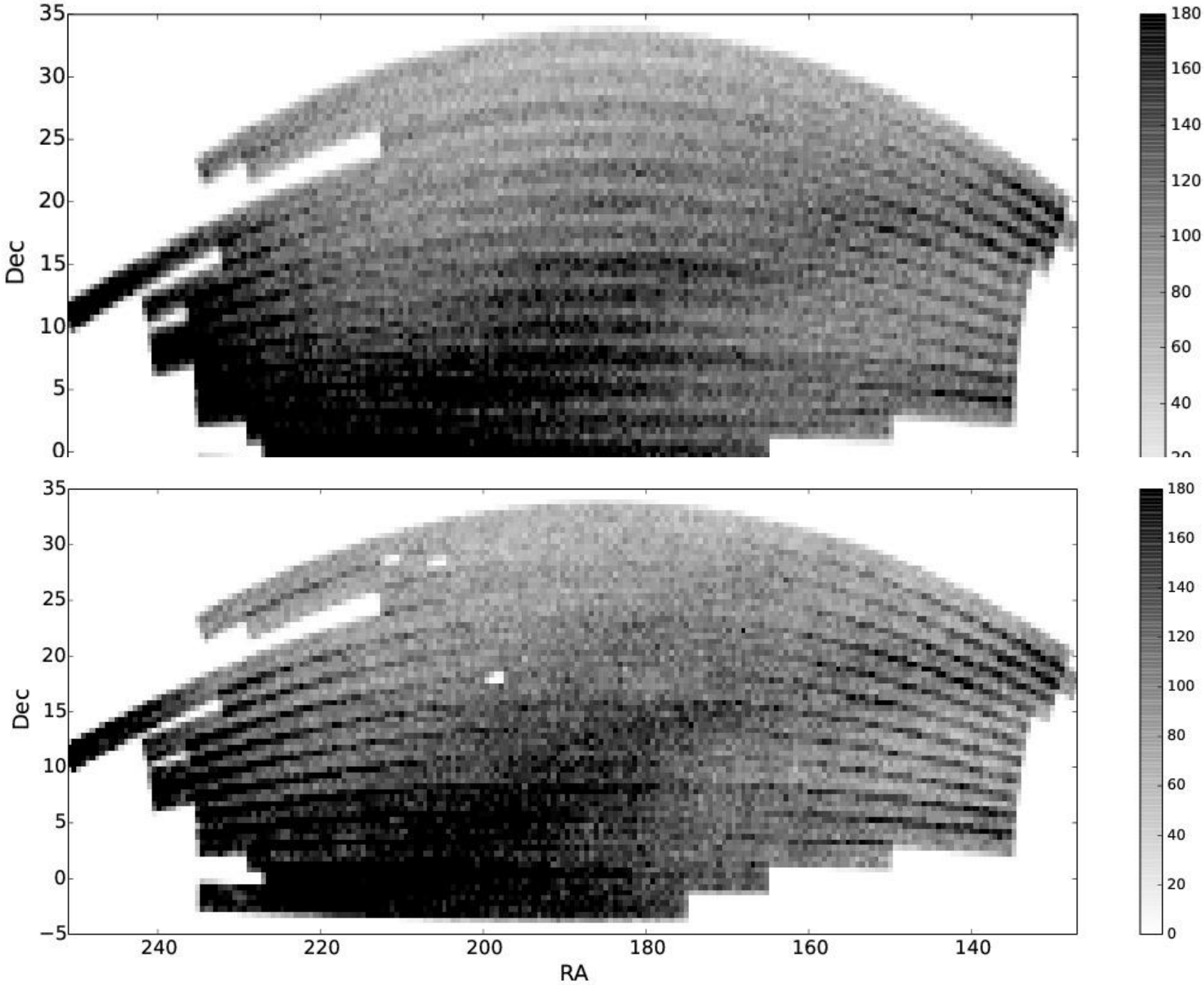


Worst residual is lowest stripe number


Hercules-
Aquila
Cloud
Hermus
Hyllus
Acheron
Pal 5
Lethe
NGC 5466
Cocytos
Styx
Sagittarius North Faint
Sagittarius North Bright
Orphan Stream
EBS
Virgo
Overdensity
Monoceros Ring
dec
R.A.

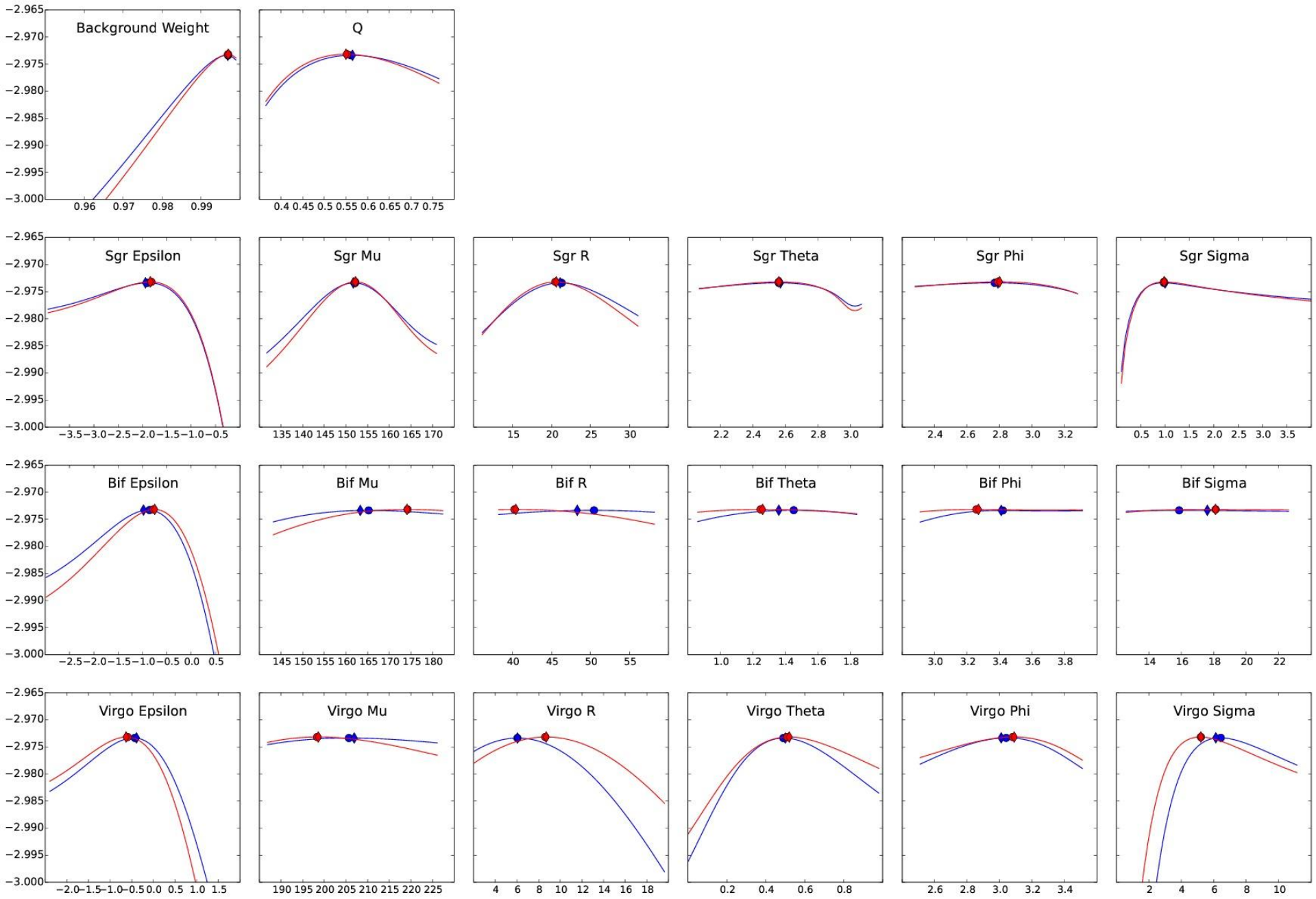

NGC 5466??
Perpendicular Stream
Bifurcated Stream?
Sgr Leading Tail
Sgr Trailing Tail
Parallel Stream
Sohn et al. (2016)??
Dec
RA

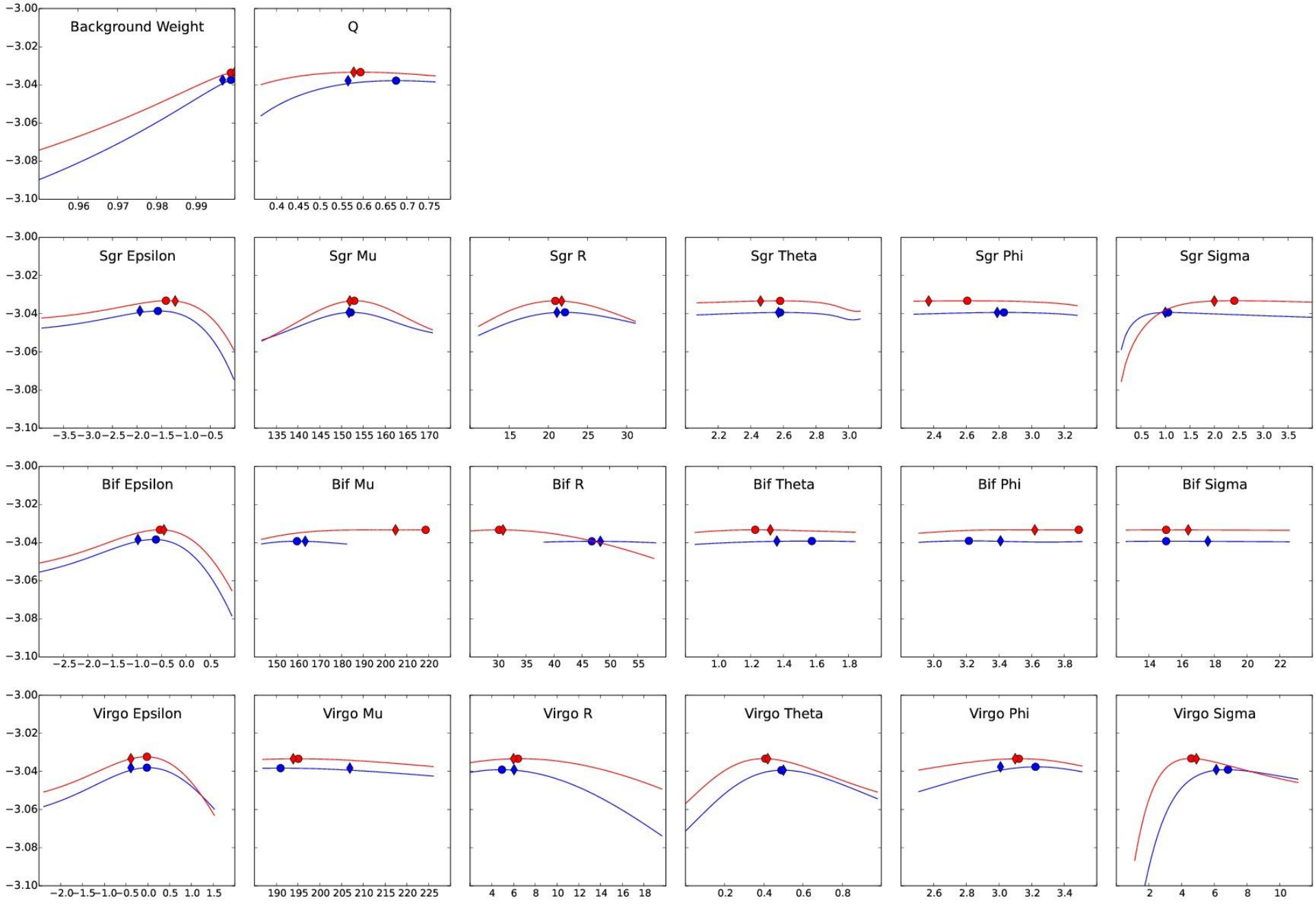

Sgr Trailing Tail ?
Bifurcated Stream??
Sgr Leading Tail
Perpendicular Stream
Parallel Stream
Sohn et al. (2016)??
NGC 5466??
MW@home
Clusters
Bel Sgr
Bel C
i Magnitude
RA
Distance (kpc)
24
23
22
21
20
19
18
17
16
260
240
220
200
180
160
140
120
150.0
94.6
59.7
37.7
23.8
15.0
9.5
6.0
3.8


Dec
RA
35
30
25
20
15
10
5
0
−5
240
220
200
180
160
140
180
160
140
120
100
80
60
40
20
0

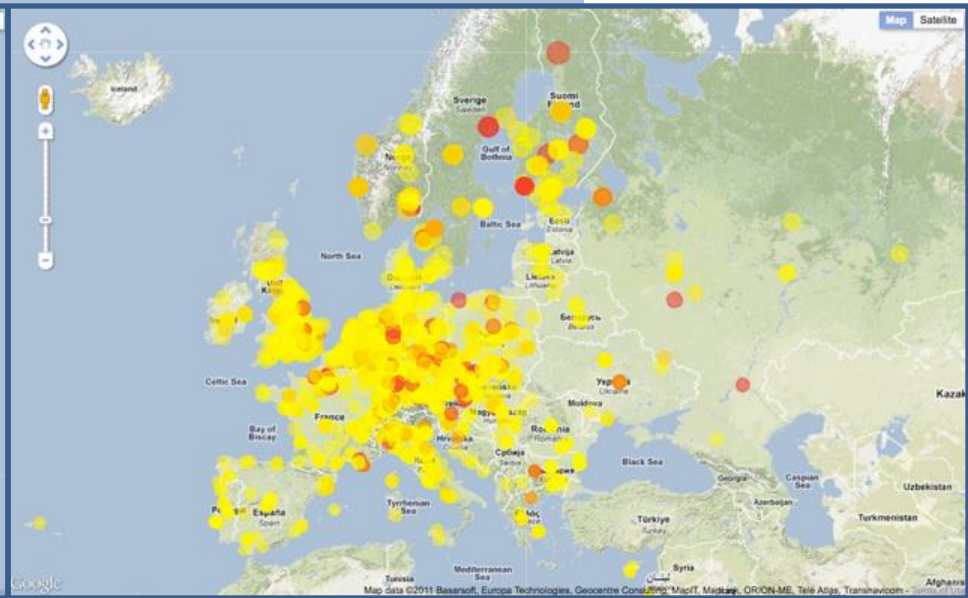
Conclusions

- We have improved the statistical photometric parallax algorithm so that it can fit at least three streams plus a smooth component.
- We have run this algorithm on 15 stripes and identified the Parallel Stream, bits of the Sgr leading tidal tail, possibly bits of the bifurcated stream, something at the angular position of the NGC 5466 stream, possibly the distant part of the trailing tidal tail, and a stream that is perpendicular to the parallel stream that is at the distance at which stars are usually attributed to the Virgo Overdensity.
- Questions are raised about the form of the smooth background, and we definitely need to fit additional streams in most of the stripes. Currently we are attempting 4 tidal streams (26 parameters) per stripe.


Background Weight
Q
Sgr Epsilon
Sgr Mu
Sgr R
Sgr Theta
Sgr Phi
Sgr Sigma
Bif Epsilon
Bif Mu
Bif R
Bif Theta
Bif Phi
Bif Sigma
Virgo Epsilon
Virgo Mu
Virgo R
Virgo Theta
Virgo Phi
Virgo Sigma

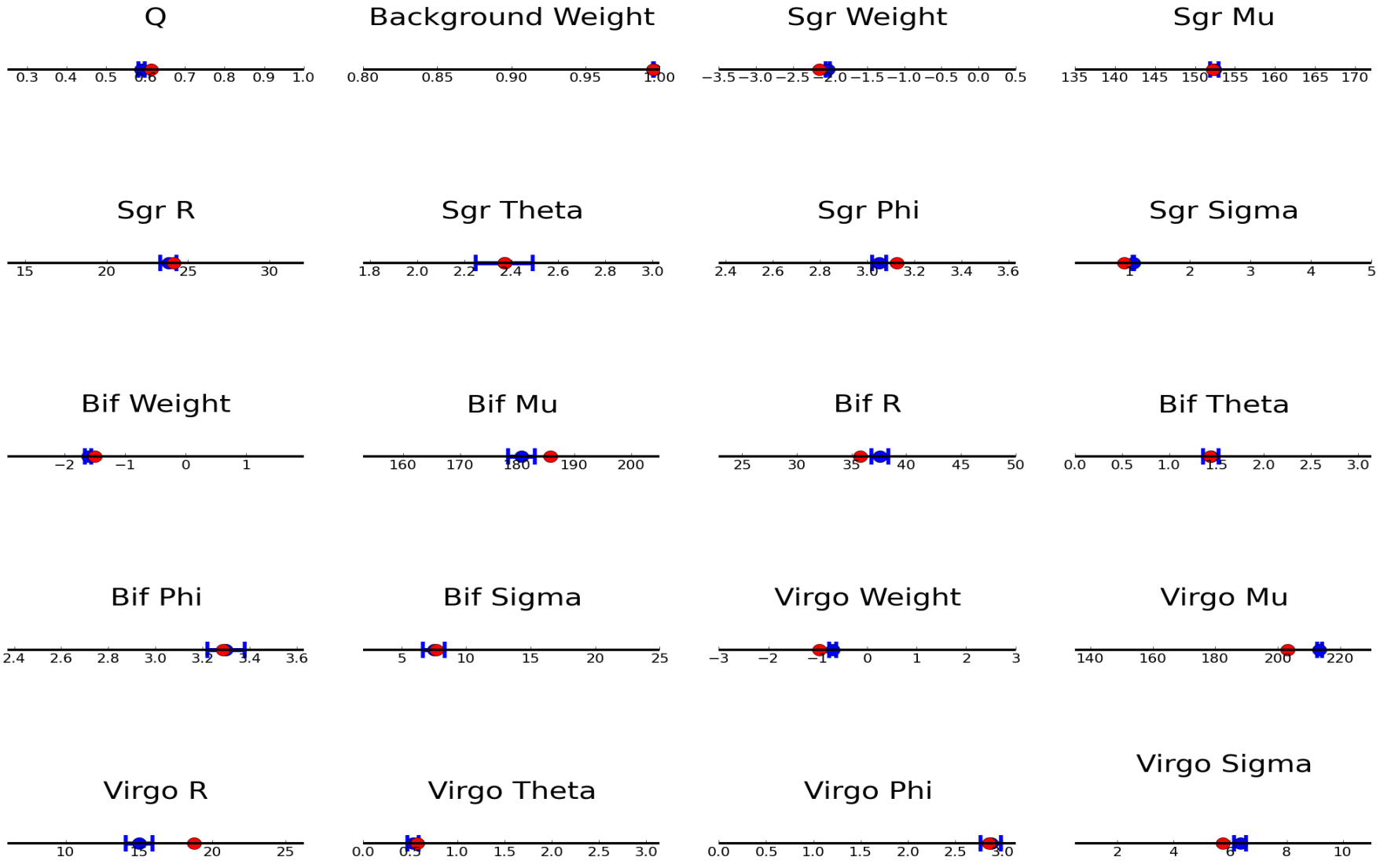

Background Weight
Q
Sgr Epsilon
Sgr Mu
Sgr R
Sgr Theta
Sgr Phi
Sgr Sigma
Bif Epsilon
Bif Mu
Bif R
Bif Theta
Bif Phi
Bif Sigma
Virgo Epsilon
Virgo Mu
Virgo R
Virgo Theta
Virgo Phi
Virgo Sigma

Distribution of Milkyway@home processors



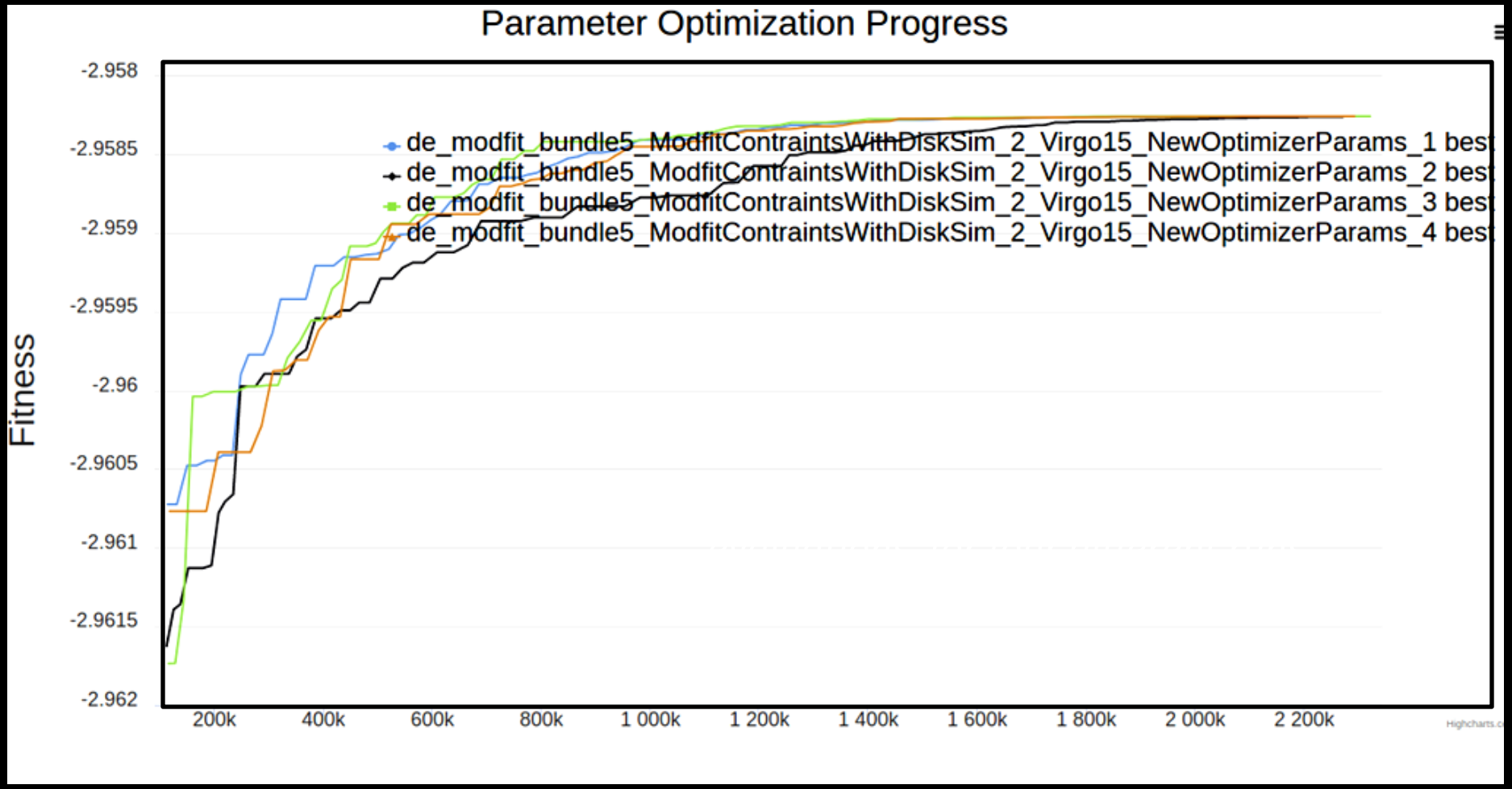
206 countries (of which 193 are United Nations members)

MilkyWay@home found the simulated parameters!!

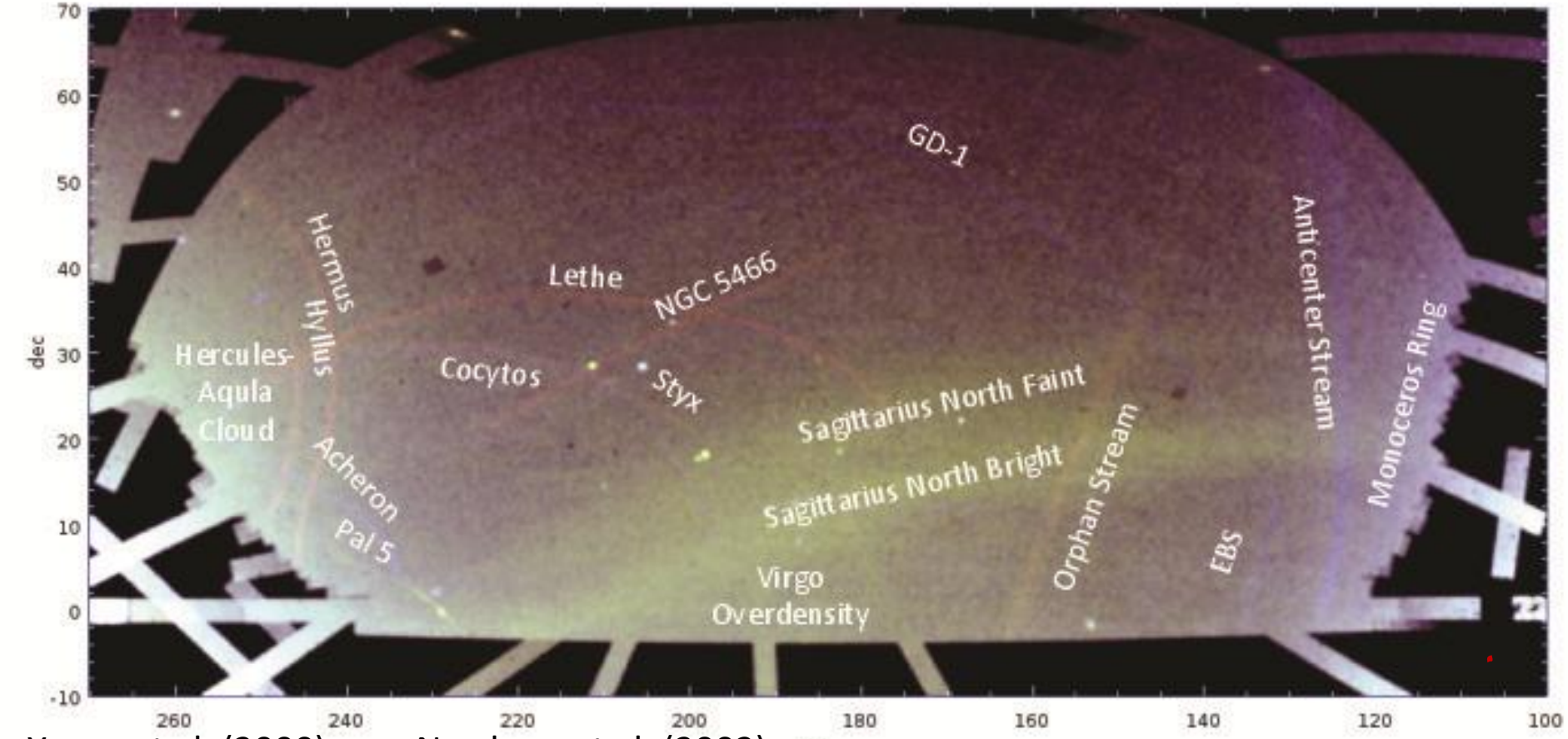


Red: simulated parameter value

Blue: parameter value found by MilkyWay@home



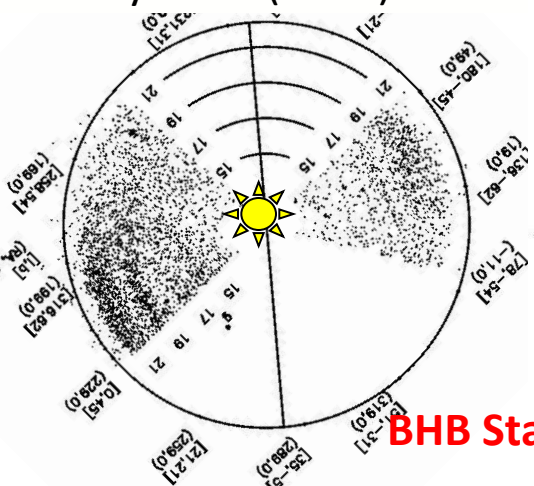
The parameter space is searched using a differential evolution method with a population of 200 trial parameter sets maintained at any given time. About 2M likelihood evaluations for the algorithm to converge; this takes about a week or two, and ~six optimizations can be run simultaneously with little change in the time to convergence.

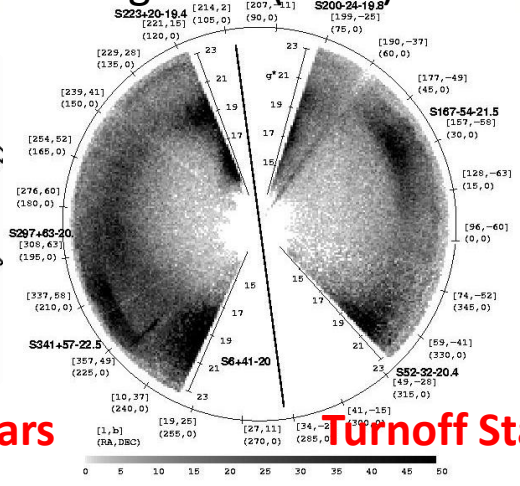


Yanny et al. (2000)

Newberg et al. (2002)

Grillmair & Carlin (2016)





BHB Stars

Turnoff Stars

Having higher density stellar tracers, and having tracers that are present in all populations, makes a big difference.