Science with synthetic stellar surveys

Robyn Sanderson
Caltech ➤ UPenn/Flatiron CCA

OMG I’m on Twitter!? @astrorobyn

Synthetic survey of a cosmo-hydro simulation
(Sanderson et al 2018)

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Milky Way
(image credit:ESO)

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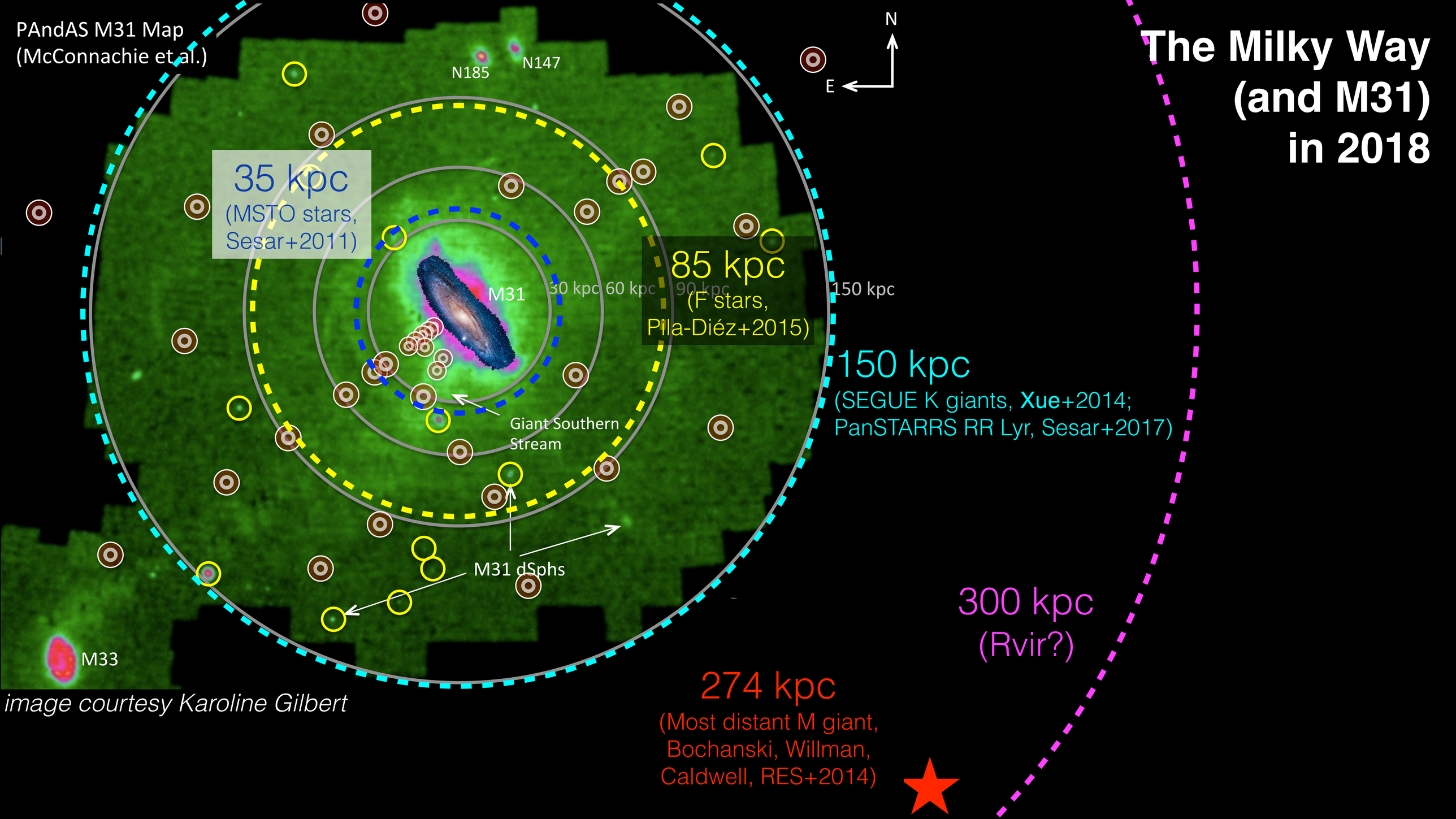
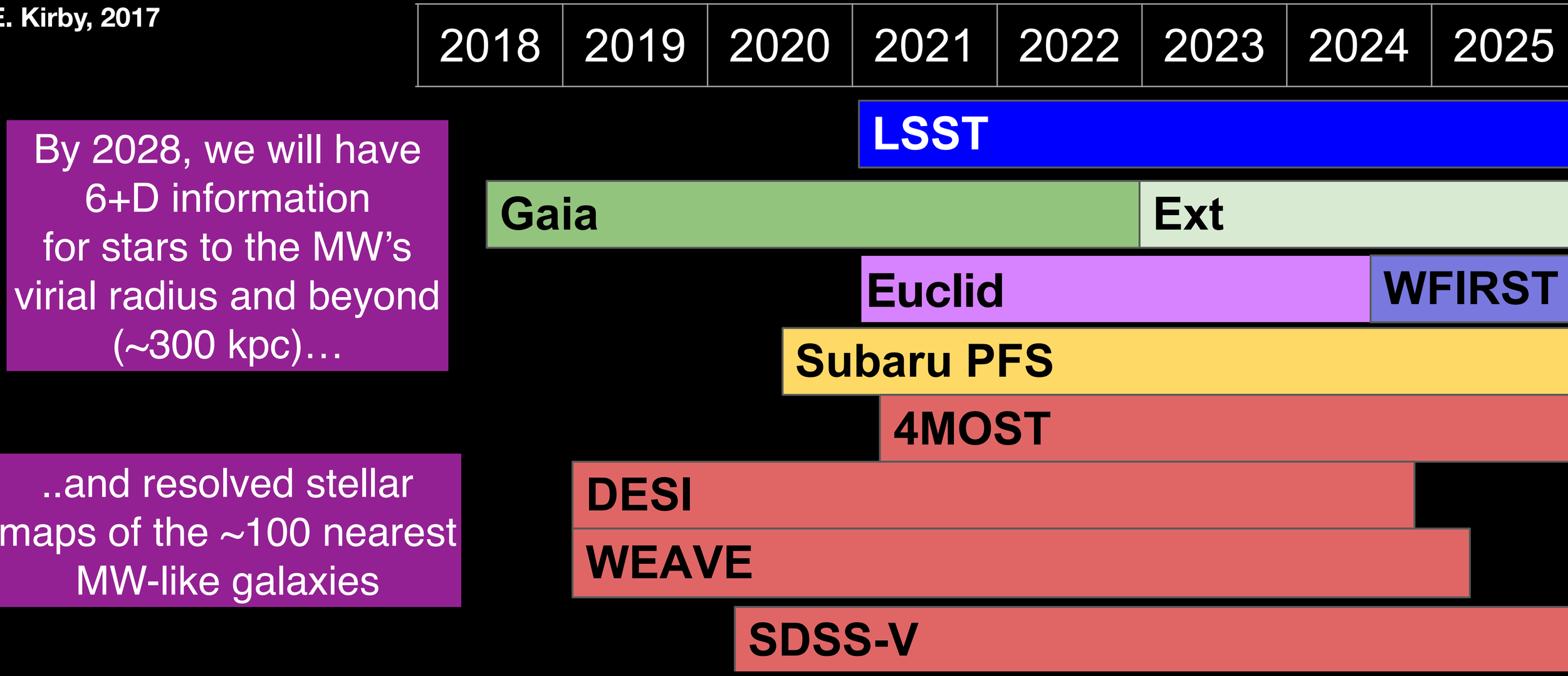

PAndAS M31 Map
(McConnachie et al.)
N185
N147
N
E
The Milky Way
(and M31)
in 2018
35 kpc
(MSTO stars,
Sesar+2011)
M31
30 kpc
60 kpc
90 kpc
150 kpc
85 kpc
(F stars,
Pila-Diéz+2015)
150 kpc
(SEGUE K giants, Xue+2014;
PanSTARRS RR Lyr, Sesar+2017)
Giant Southern
Stream
M31 dSphs
300 kpc
(Rvir?)
M33
image courtesy Karoline Gilbert
274 kpc
(Most distant M giant,
Bochanski, Willman,
Caldwell, RES+2014)

The next decade will see a Galactic renaissance[1]

[1]E. Kirby, 2017



By 2028, we will have 6+D information for stars to the MW's virial radius and beyond (~300 kpc)…

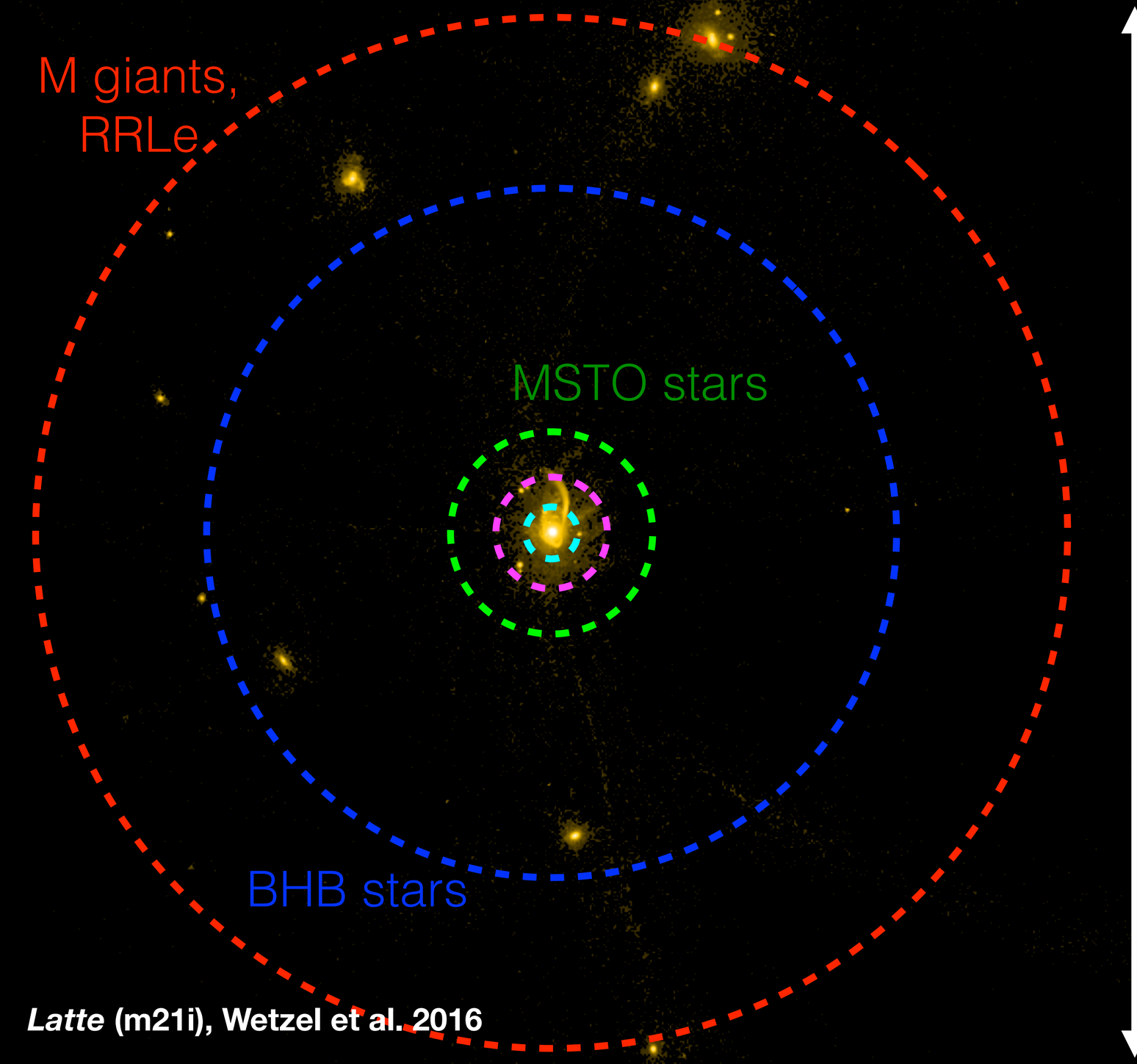
..and resolved stellar maps of the ~100 nearest MW-like galaxies

Astrometric + spectroscopic

Photometric + astrometric

Spectroscopic: <4-m class

Spectroscopic: >4-m class



Latte (m21i), Wetzel et al. 2016

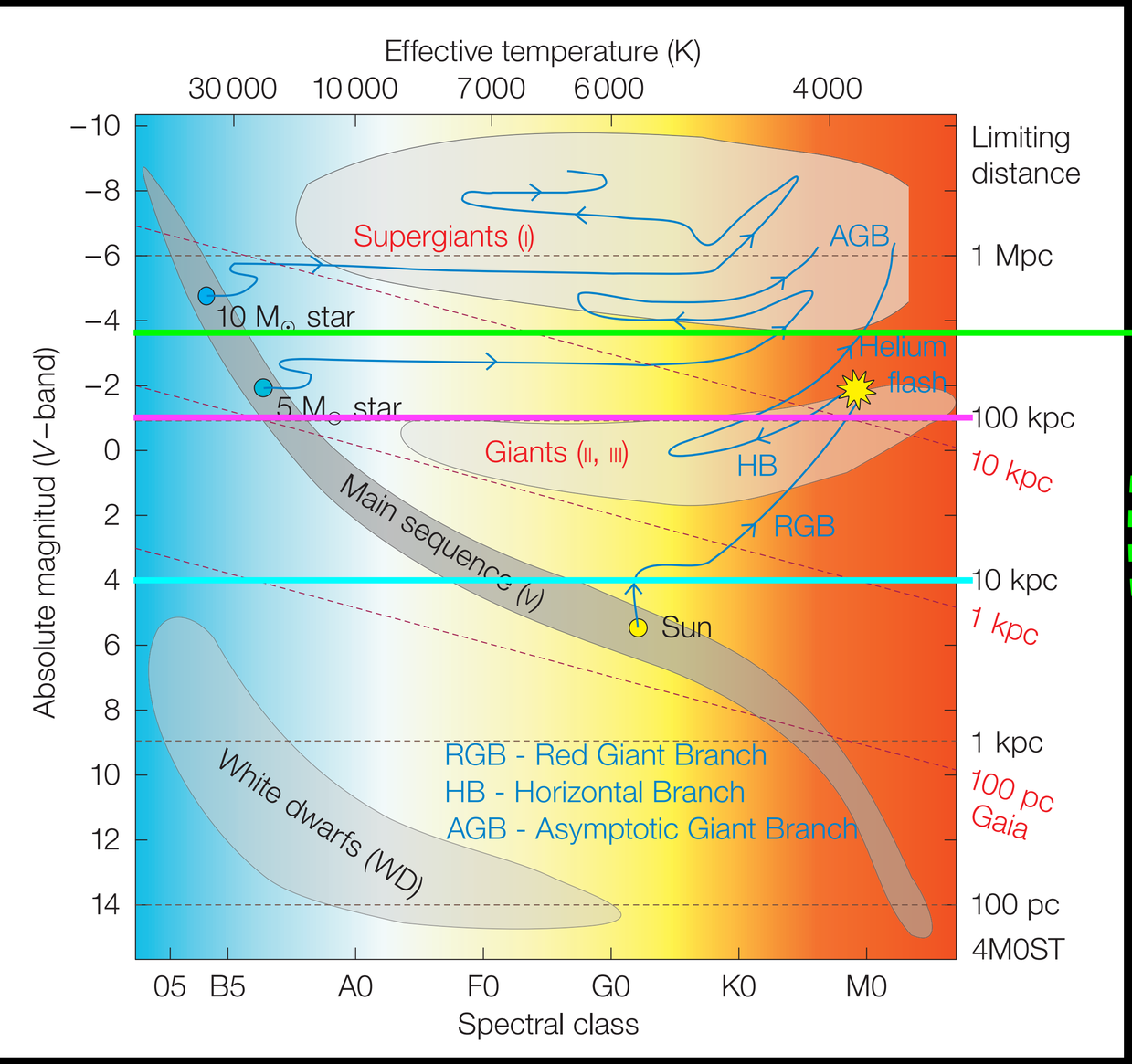
The Milky Way in 2028

LSST
coadded depth
(m=26.7)

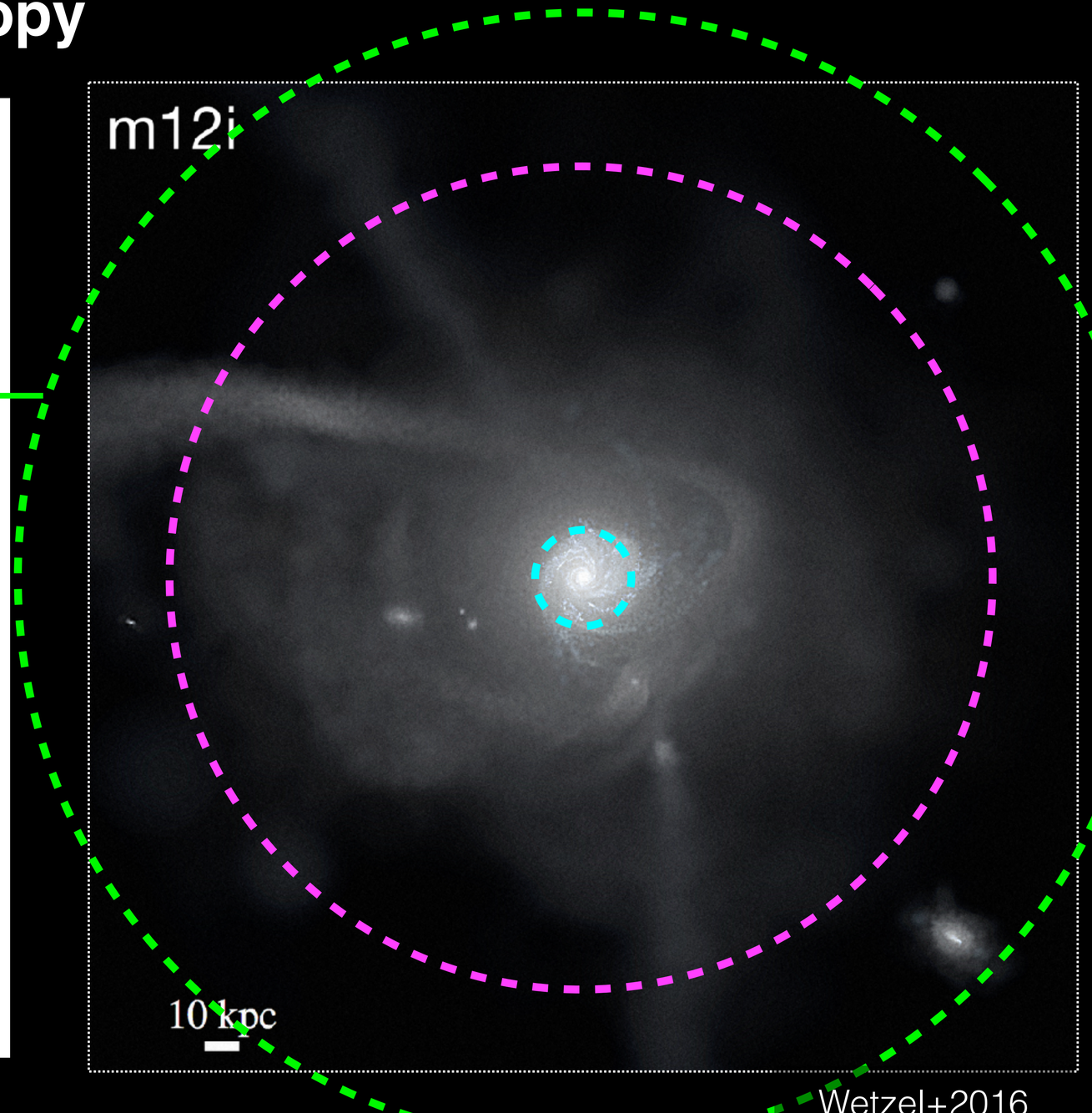
300 kpc (=Rvir?)

150 kpc
(extent of current
samples)

The Milky Way in 2028: spectroscopy

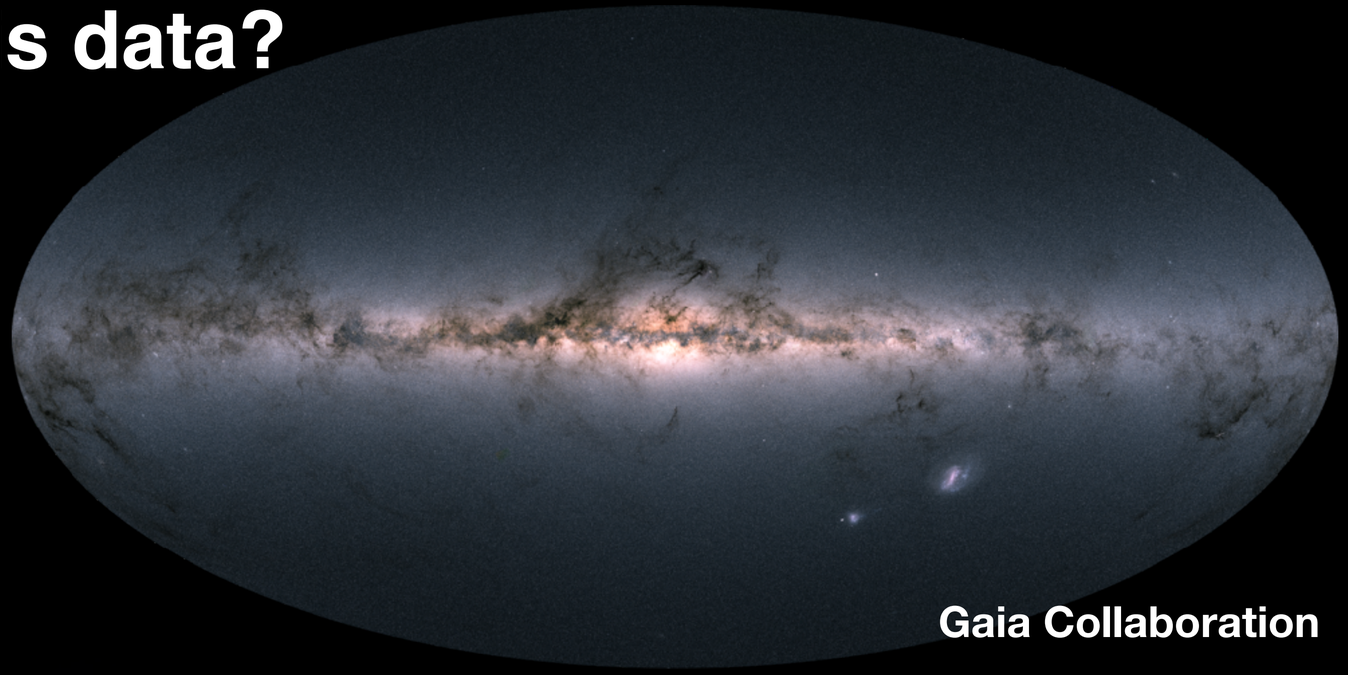


4MOST; De Jong 2011



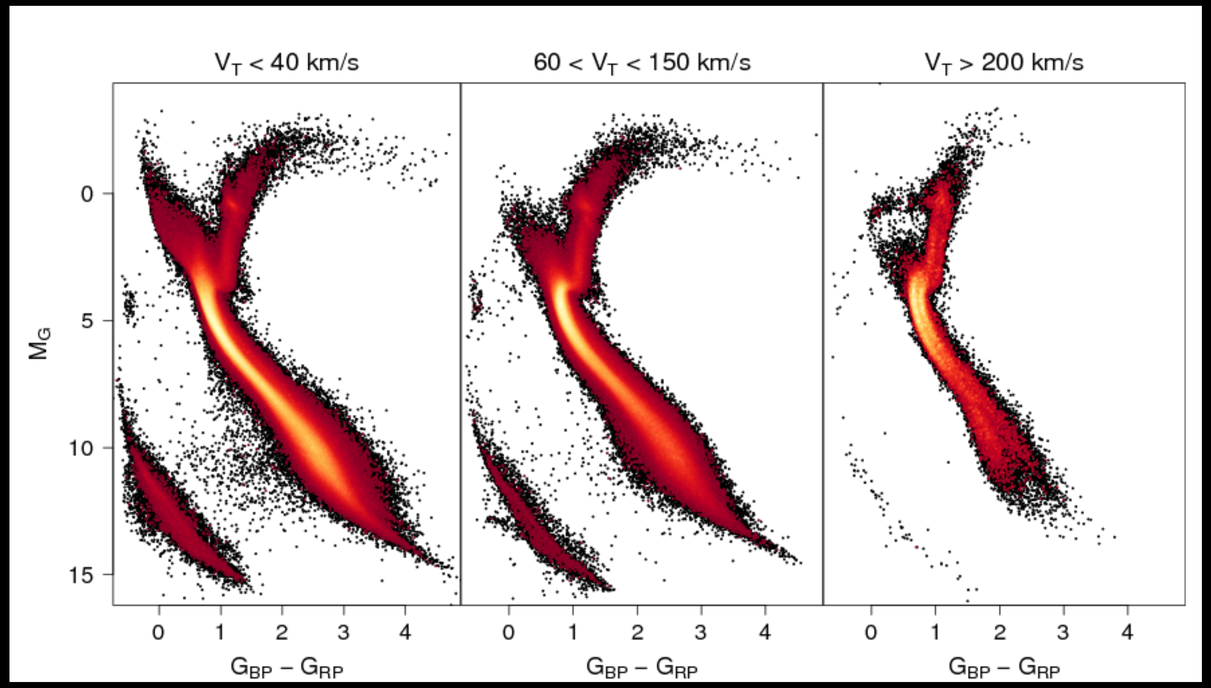
Wetzel+2016

but…what do we DO with all this data?

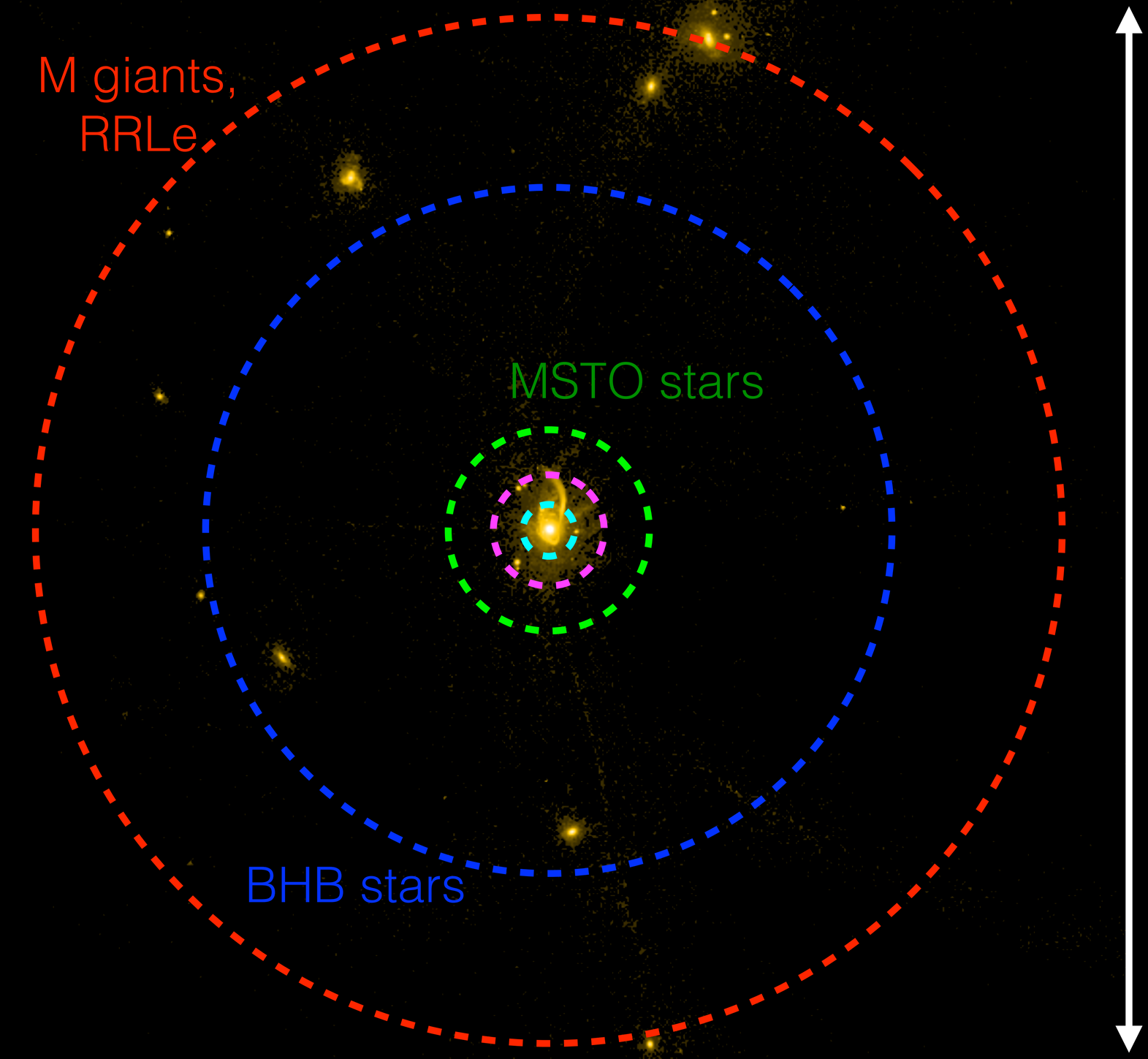


Gaia Collaboration

Wetzel et al. 2016, movie credit: Phil Hopkins



Babusiaux et al 2018



The Milky Way in 2028

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coadded depth
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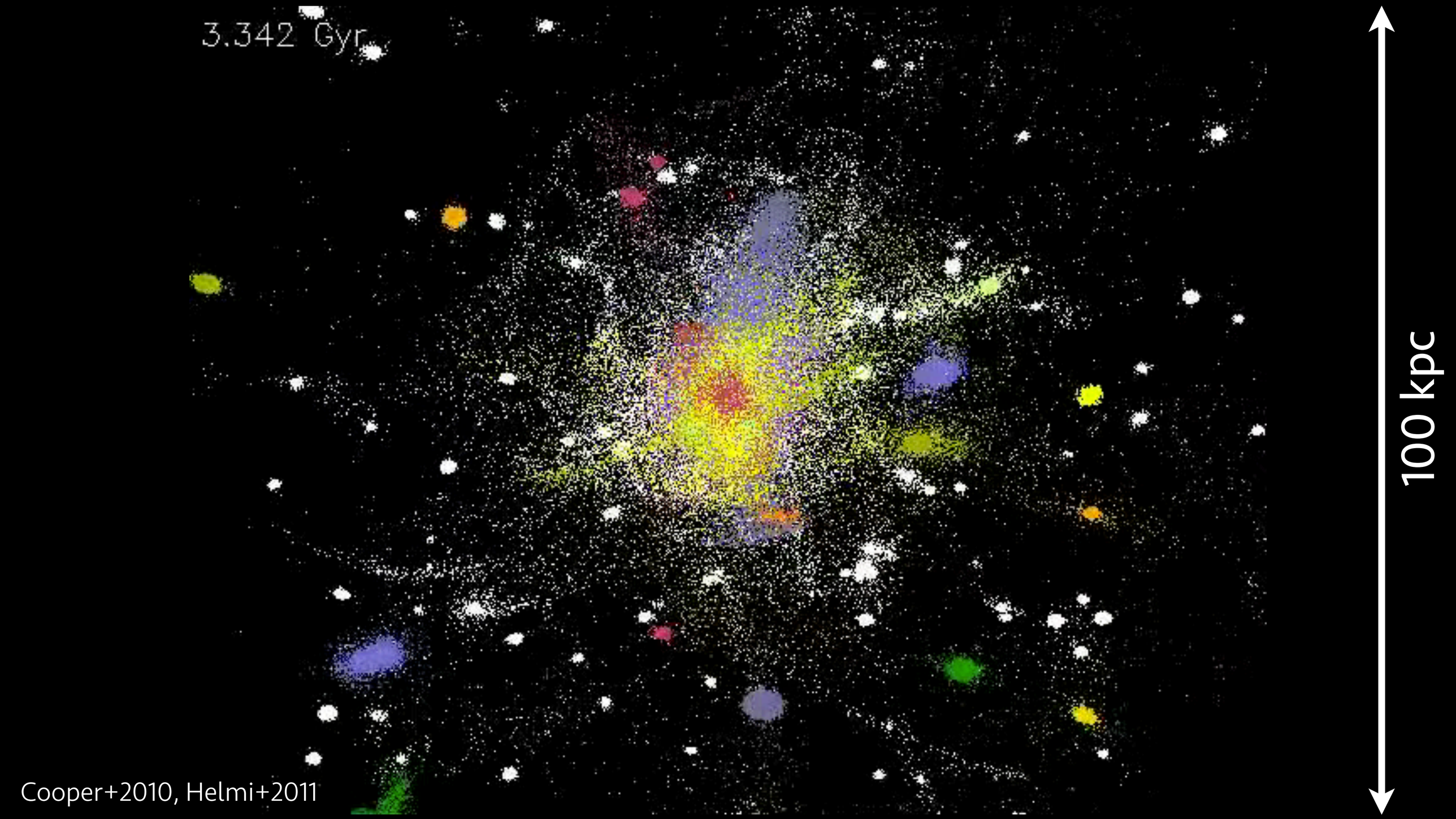
samples)

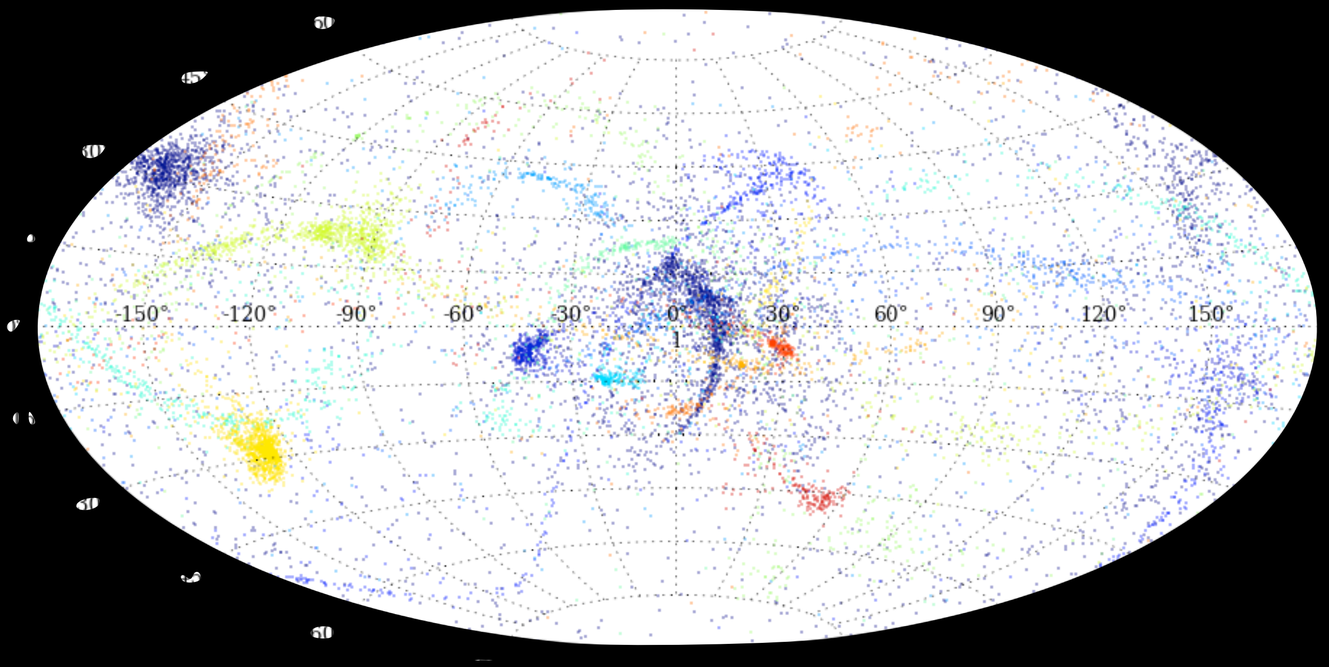
Figure courtesy Andrew Wetzel
Latte Simulation: arXiv:1602.05957



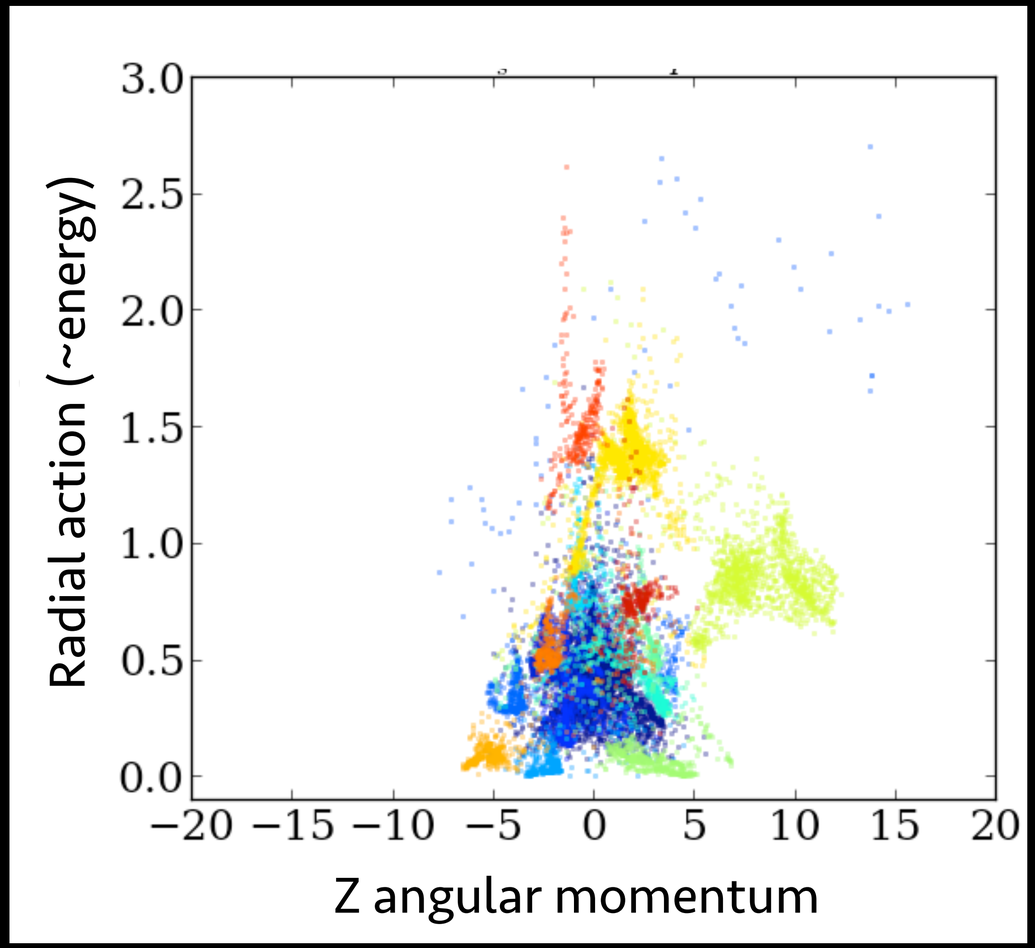
Cooper+2010, Helmi+2011

The accreted stellar halo is clumpy in constants-of-motion space

Galactic coordinates



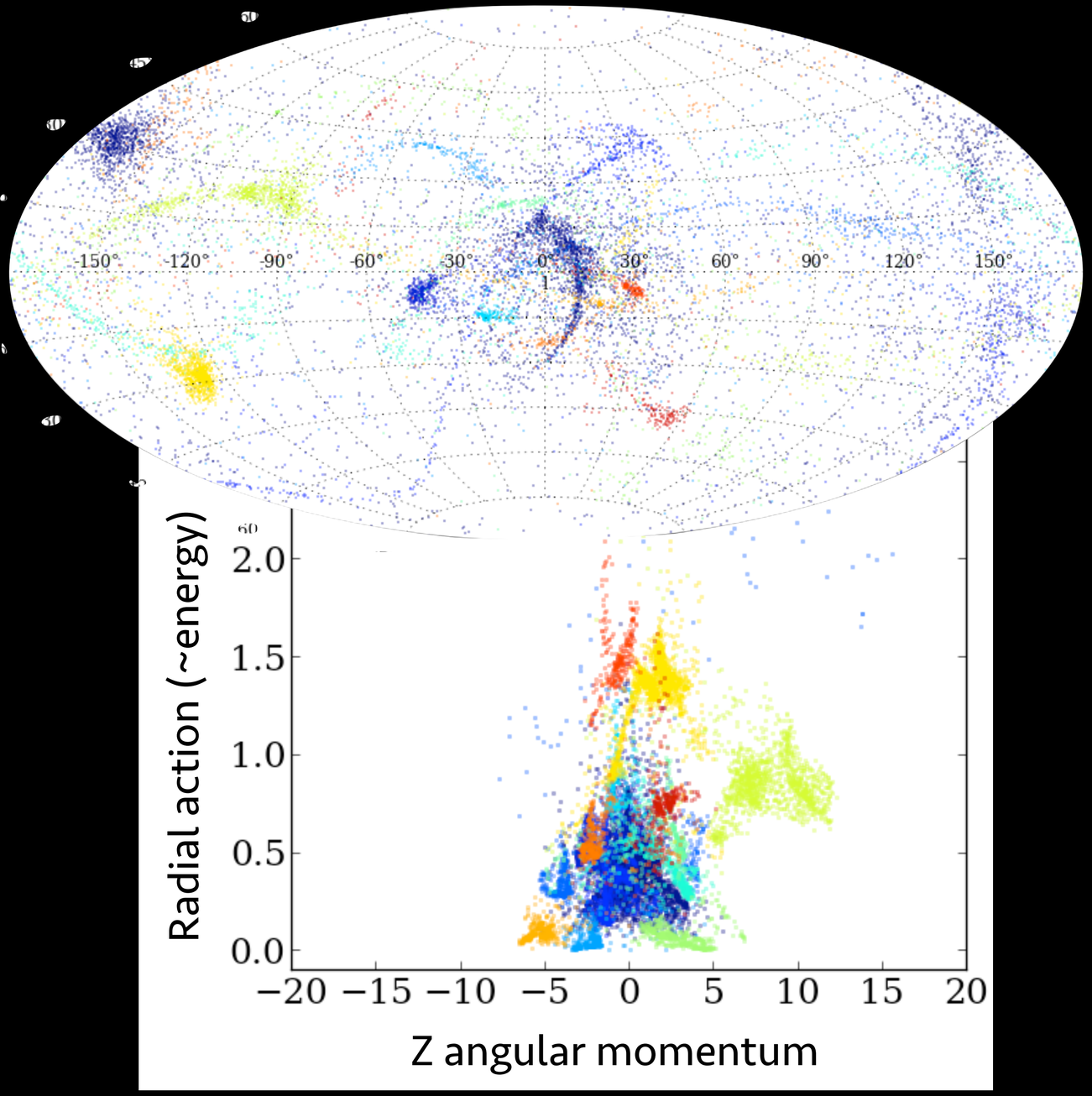
One particle = many stars

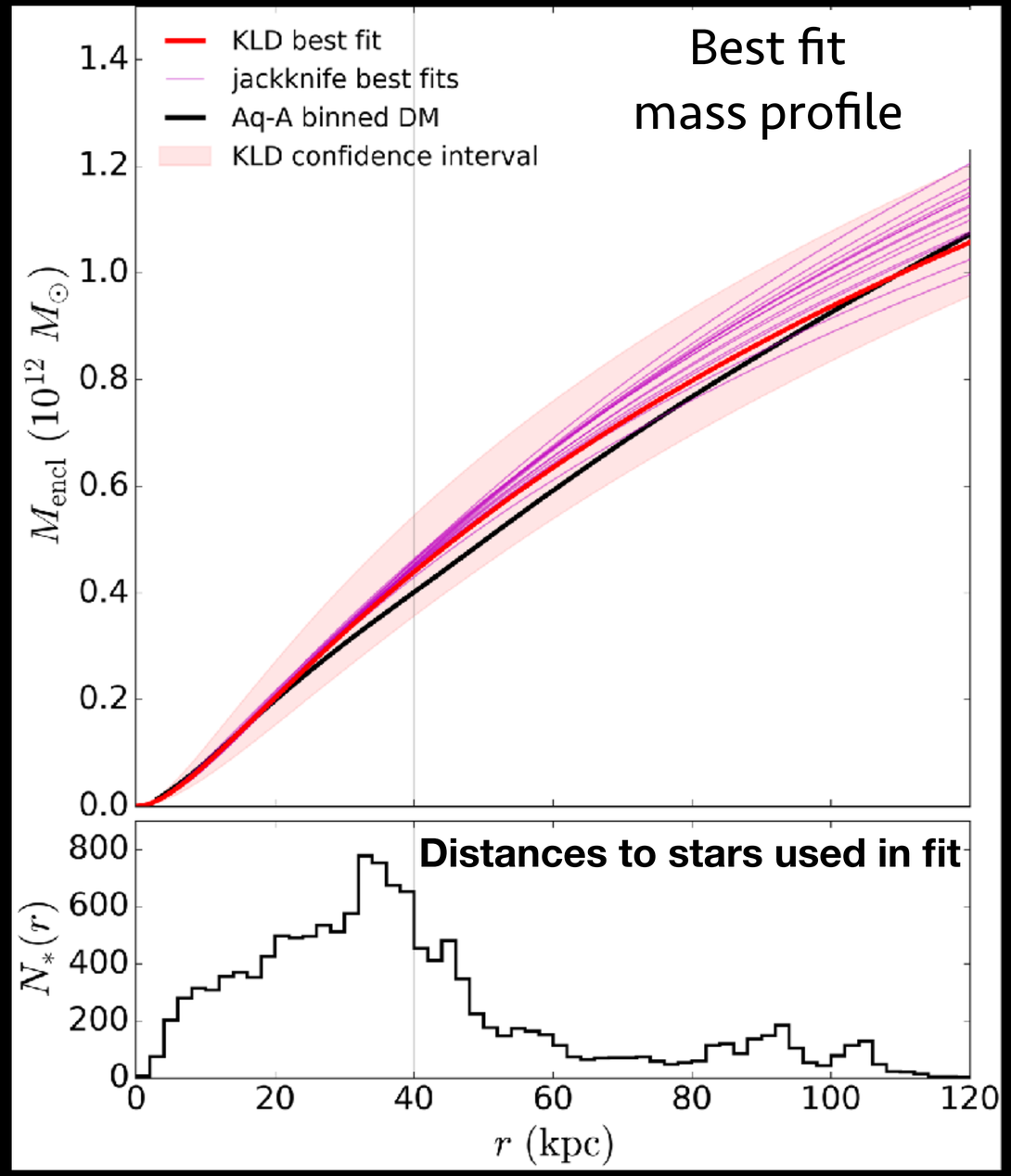


Constants of motion
(using best-fit mass model for host galaxy)

Sanderson, Helmi, & Hogg 2015
Sanderson et al. 2017a

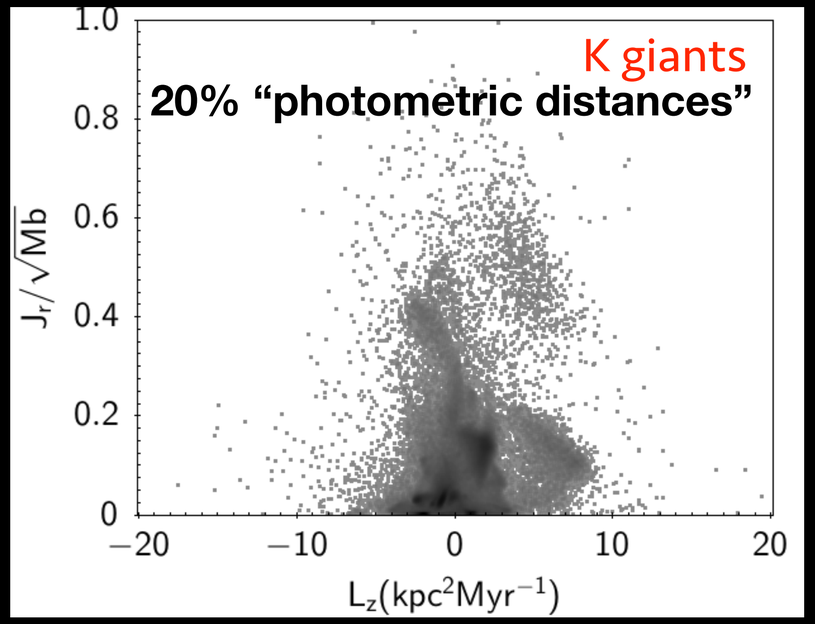
The stellar halo constrains the MW's gravitational potential

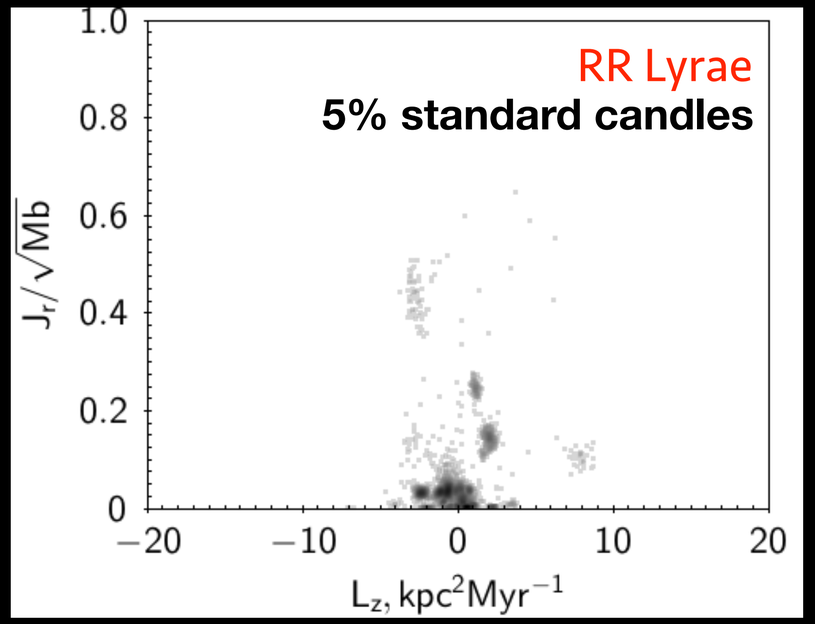




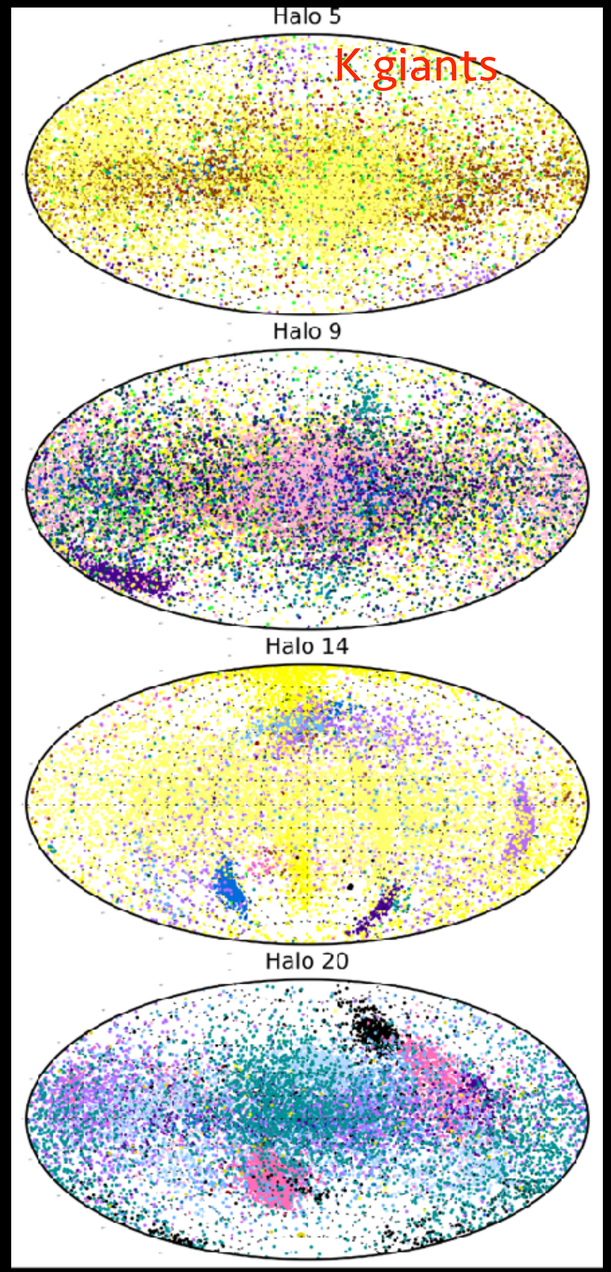
Sanderson et al. 2017a

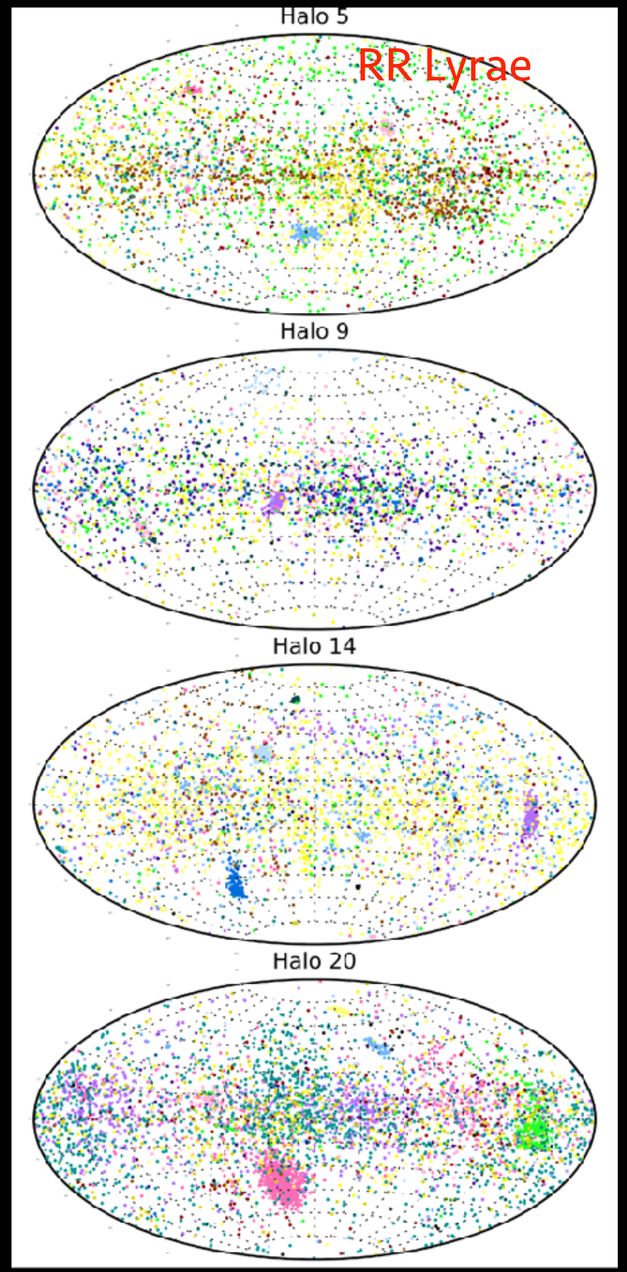
The choice of stellar tracers matters





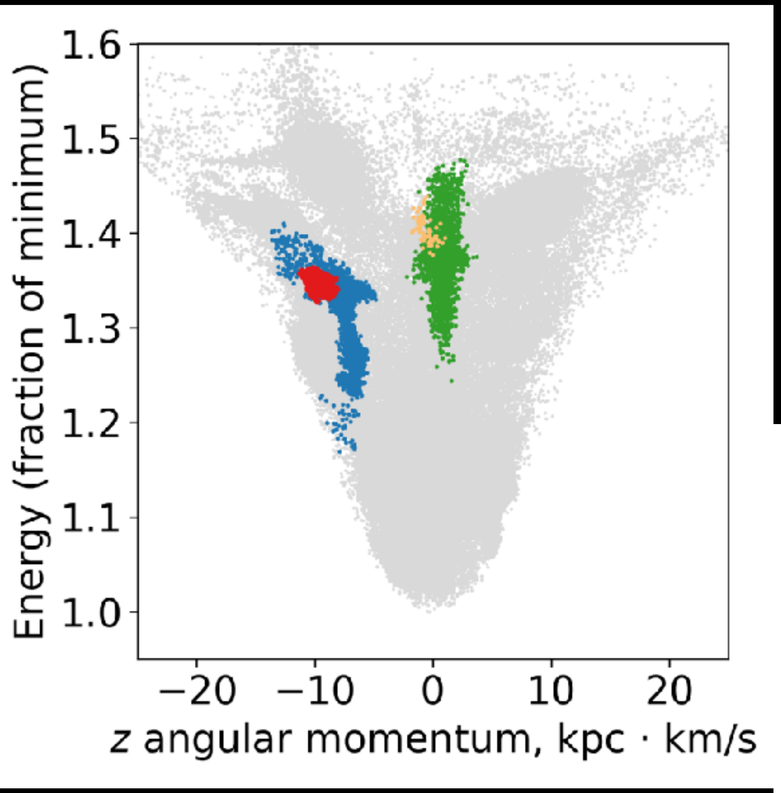
Sanderson 2016



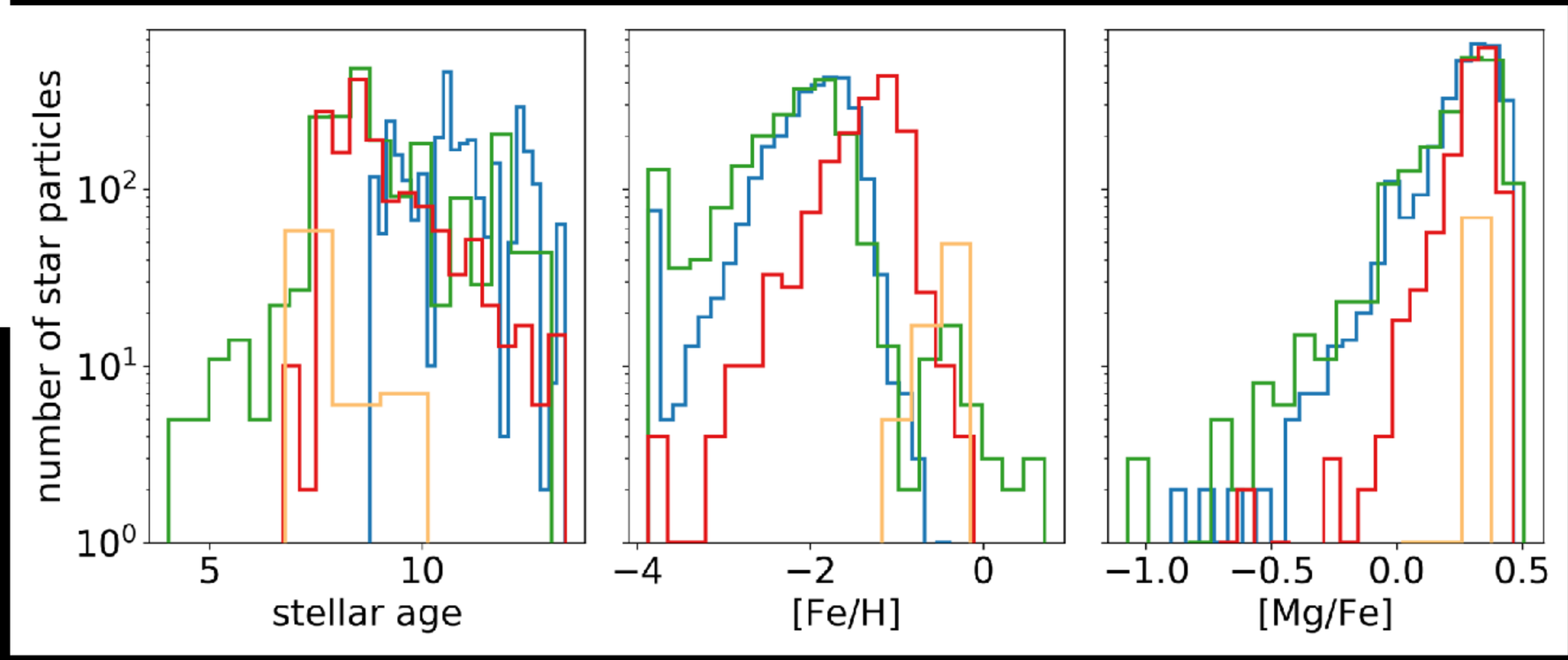


Sanderson et al. 2017b

A route to untangling the stellar halo



One particle = many stars



Sanderson et al. 2017c

Making predictions for a 6+D galaxy

Galaxy Simulation
(cosmology, DM model, gravity, gas physics, star formation, stellar feedback, …)

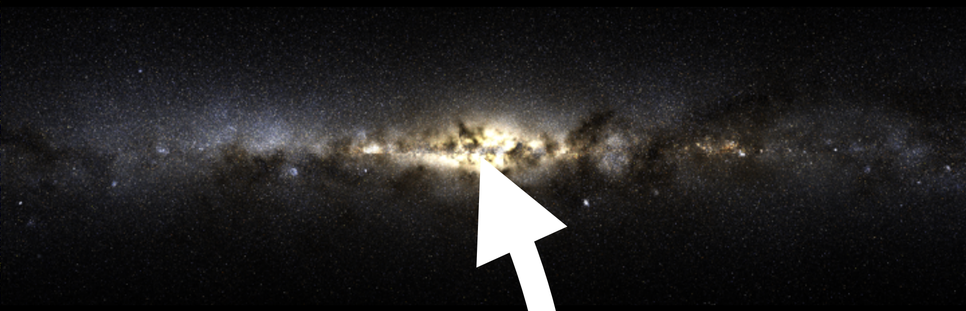
Stellar Populations
(stellar structure, stellar evolution, convection models, isochrone mapping, IMF, …)

Phase-space density estimation
(kernel dimension, smoothing scales, ages, accretion history, …)

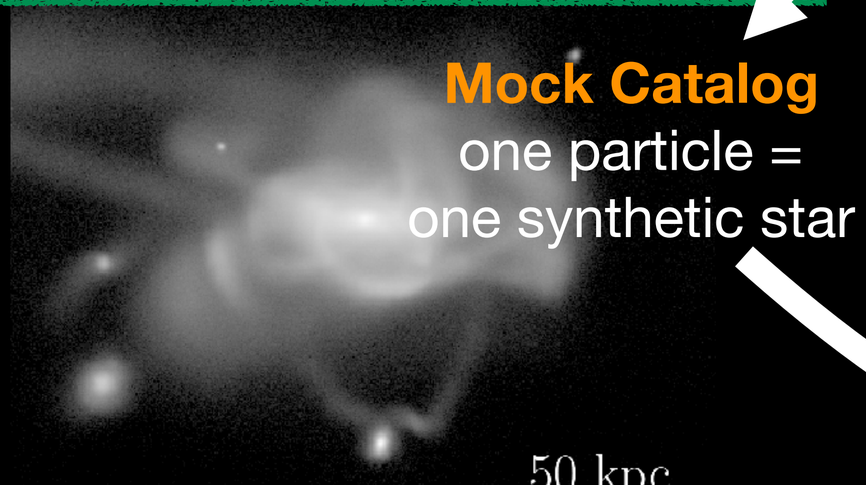
Mock Catalog
one particle = one synthetic star

Survey description
(Magnitude/color limits, extinction/reddening, selection function, error model, instrument model, …)

Synthetic Survey
one particle = one “observed” star

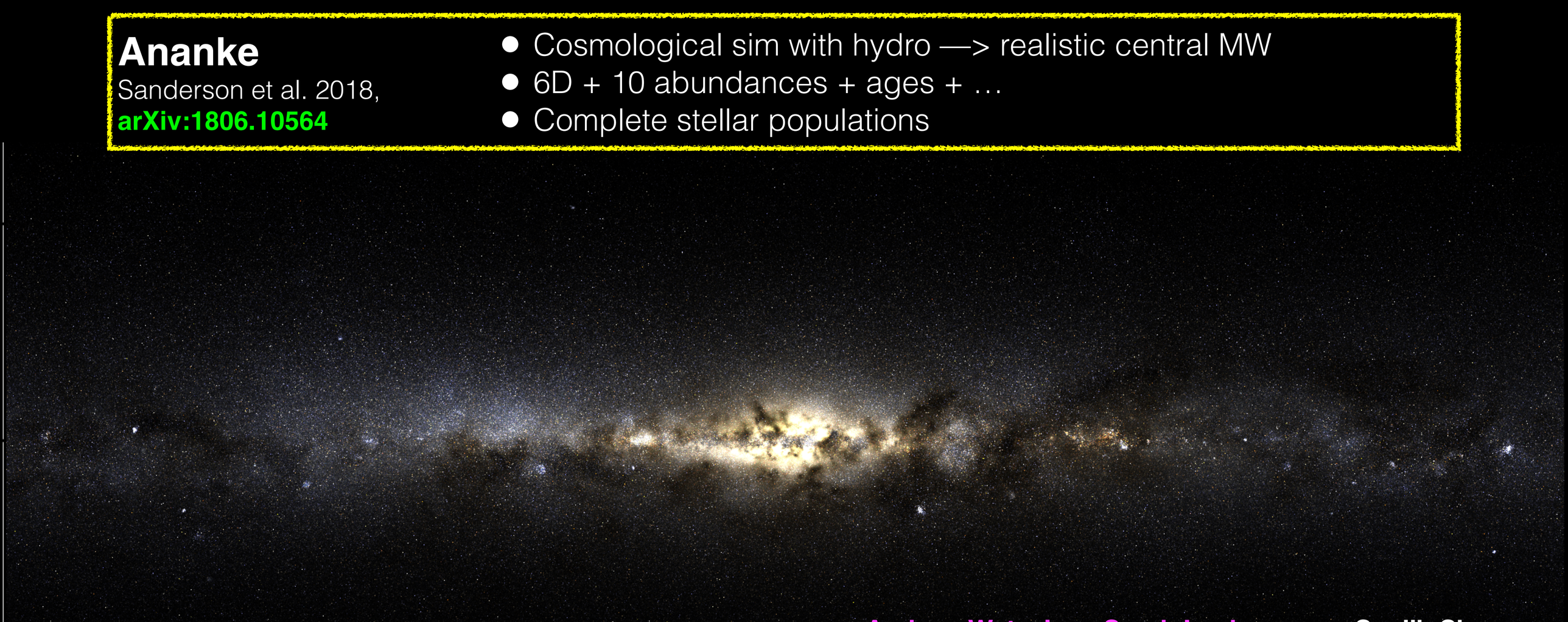


One particle = many “stars”
…with same age, abundances



Ananke
Sanderson et al. 2018,
arXiv:1806.10564

- Cosmological sim with hydro —> realistic central MW
- 6D + 10 abundances + ages + …
- Complete stellar populations



Available for Gaia DR2 on:

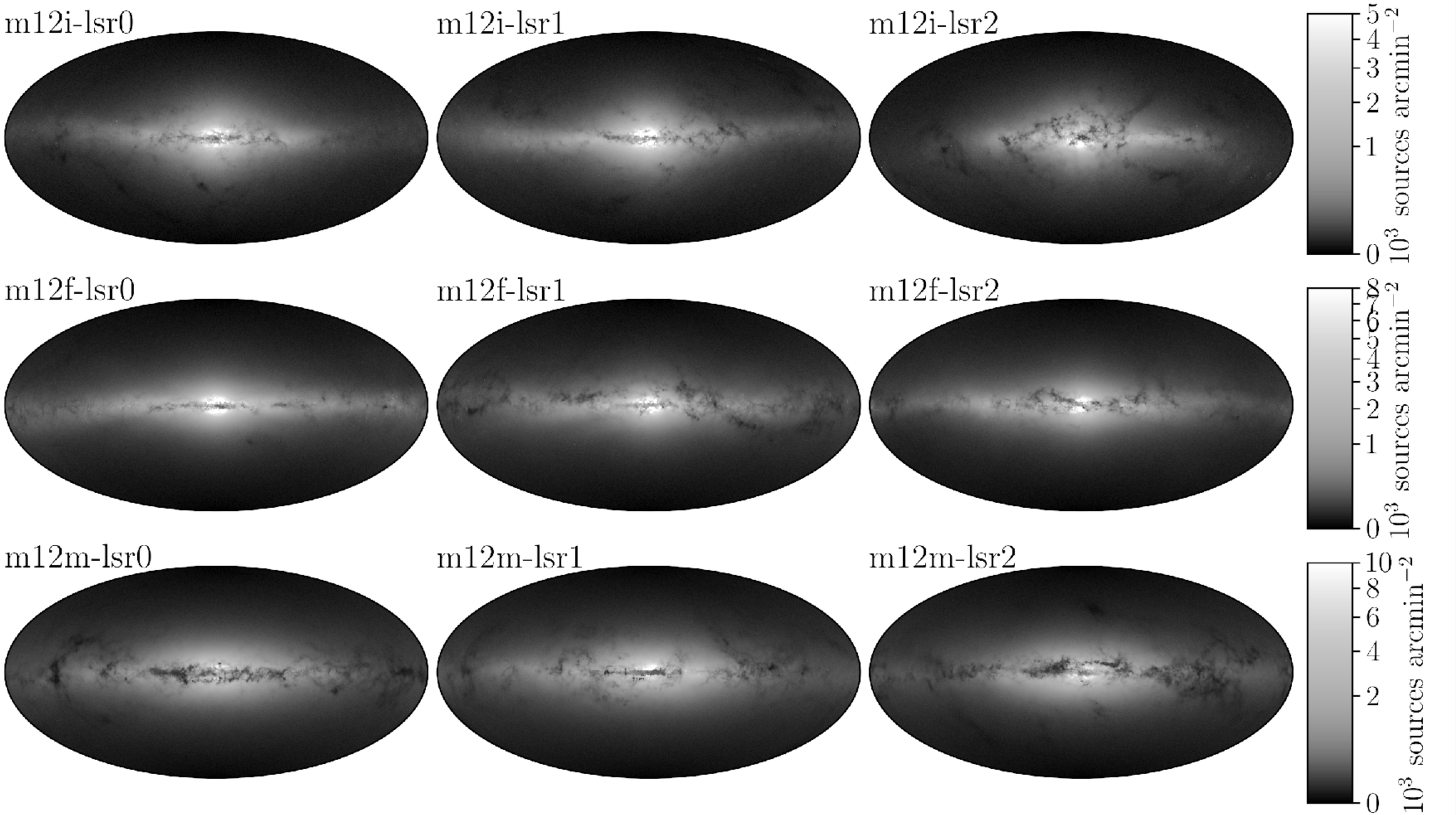
girder.hub.yt

irsa.ipac.caltech.edu

Andrew Wetzel

Sarah Loebman

Sanjib Sharma


m12i-lsr0
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m12i-lsr2
m12f-lsr0
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m12f-lsr2
m12m-lsr0
m12m-lsr1
m12m-lsr2
0
1
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3
4
5
10^3 sources arcmin^{-2}
0
1
2
3
4
6
8
10^3 sources arcmin^{-2}
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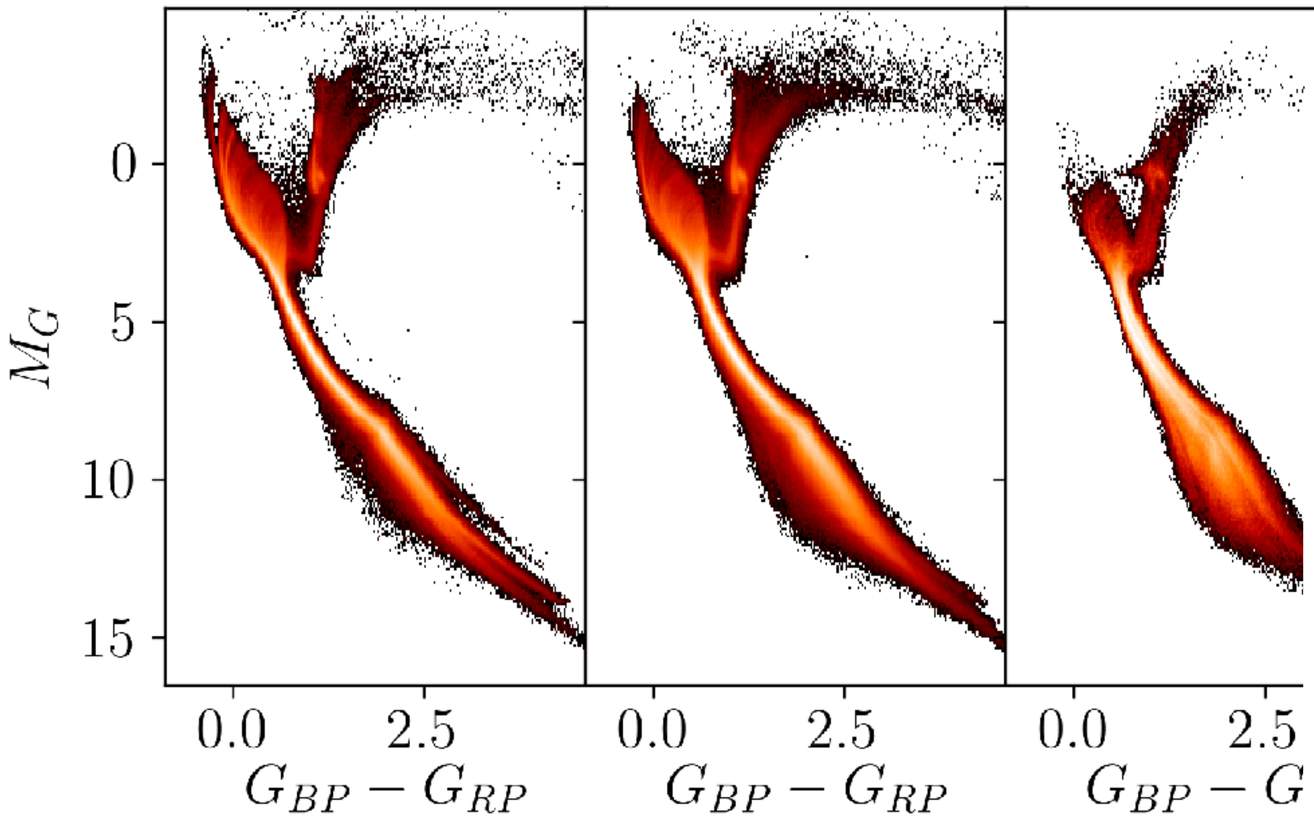
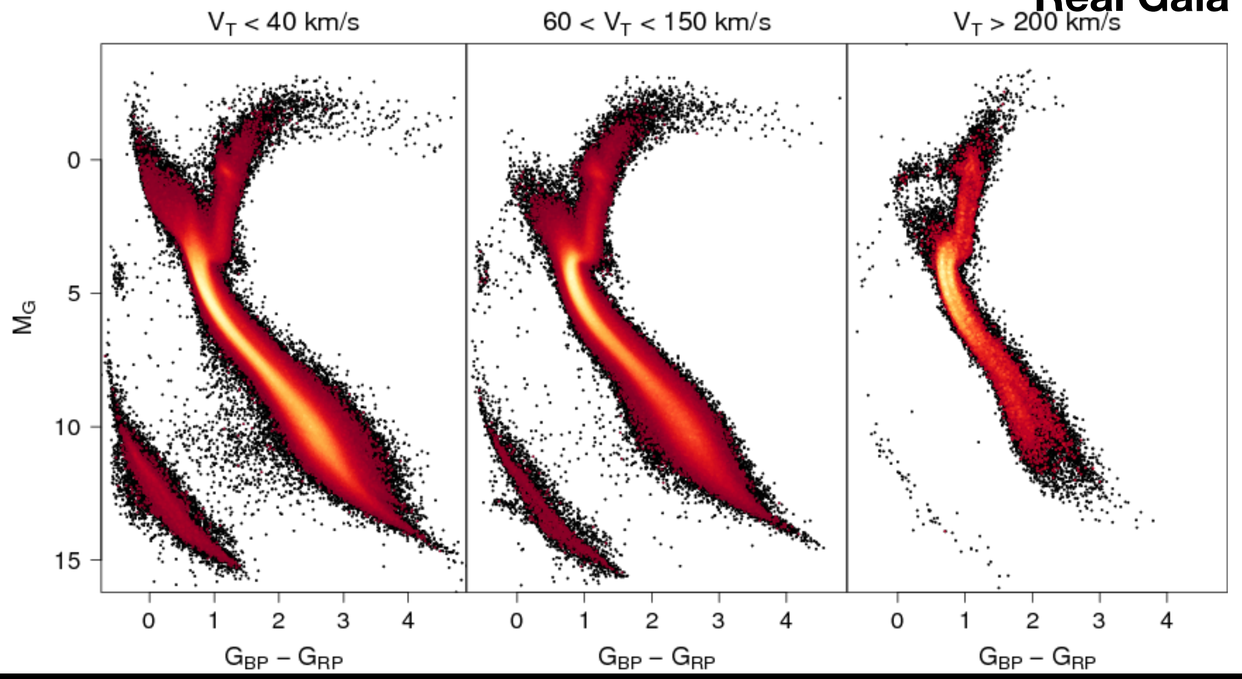
Mock Gaia $V_T < 40$ km s^{-1} $60 < V_T < 150$ km s^{-1} $V_T > 200$ km s^{-1}



Stars with:

- **10% or better parallax uncertainty**
- **extinction < 0.015 mag**
- **G mag uncertainty <0.22 mag**
- **G_{Bp}, G_{Rp} uncertainty < 0.054 mag**

Real Gaia



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Babusiaux et al 2018

Ananke
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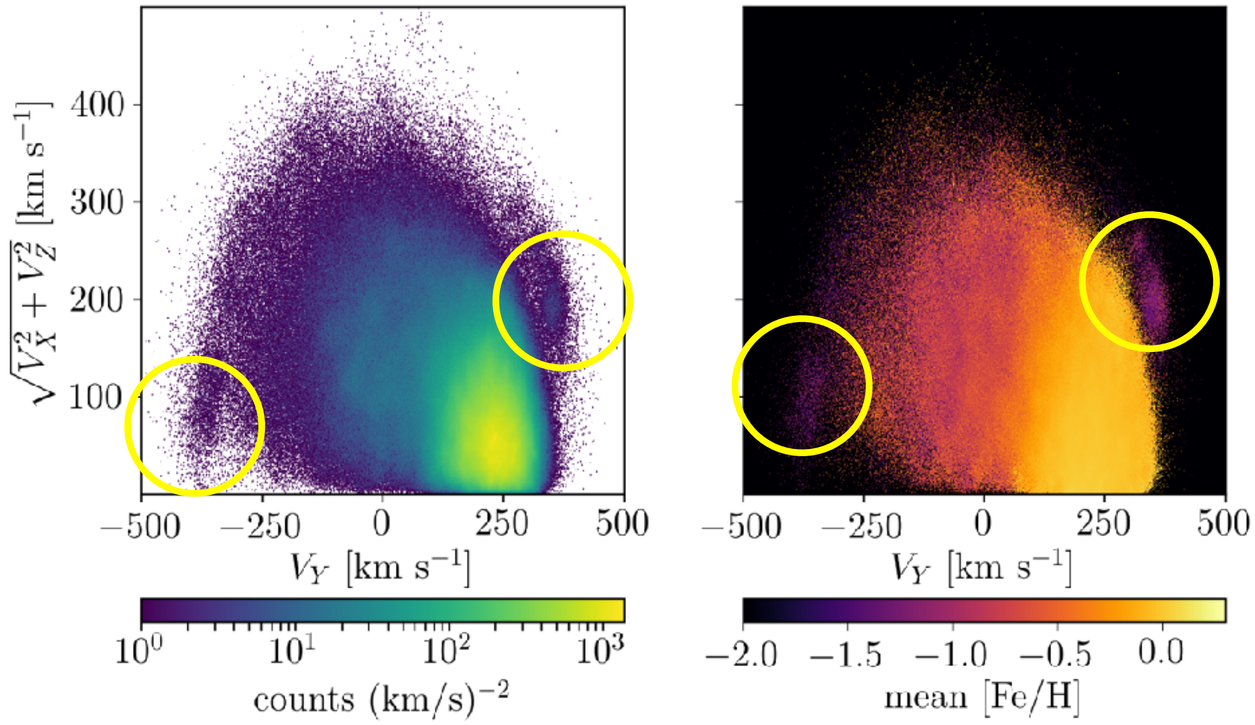
- Complete stellar populations

m12i-lsr0



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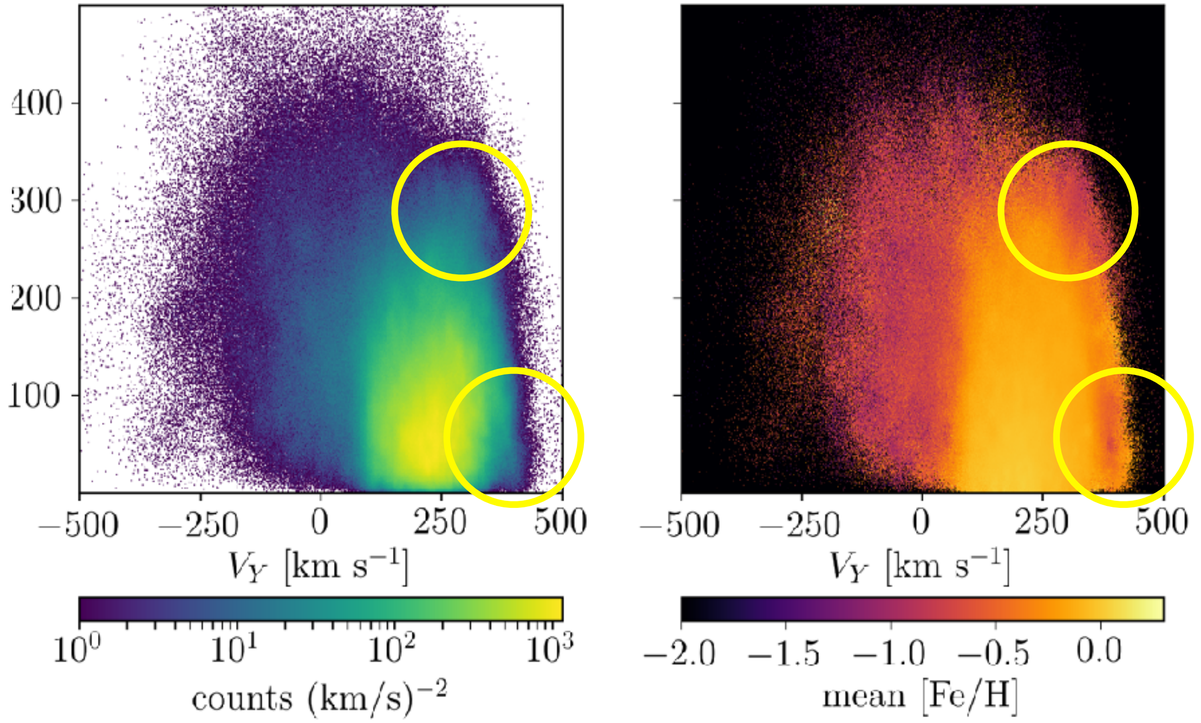
m12f-lsr2



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Things to do with ananke

- Validate your Gaia analysis technique
  (matching columns have same names)
- Train/interpret your machine-learning model
- Test & tune [some] search algorithms
- Investigate cosmic & viewpoint variance

Things NOT to do with ananke

- Estimate backgrounds/foregrounds
  (stellar mass/density are not MW calibrated)
- Study the edges of the selection function
  (the built-in error model is way too simple)
- Estimate completeness
  (crowding not treated, extinction function not MW)