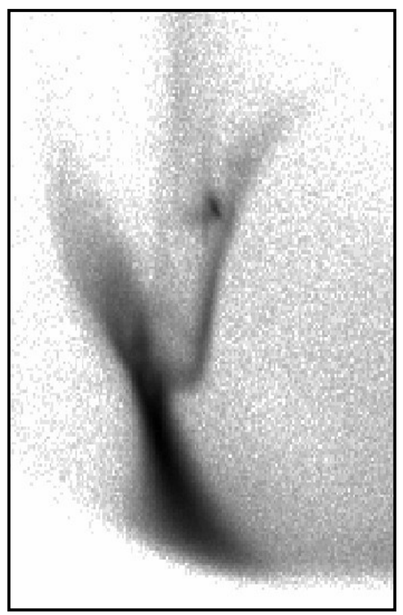
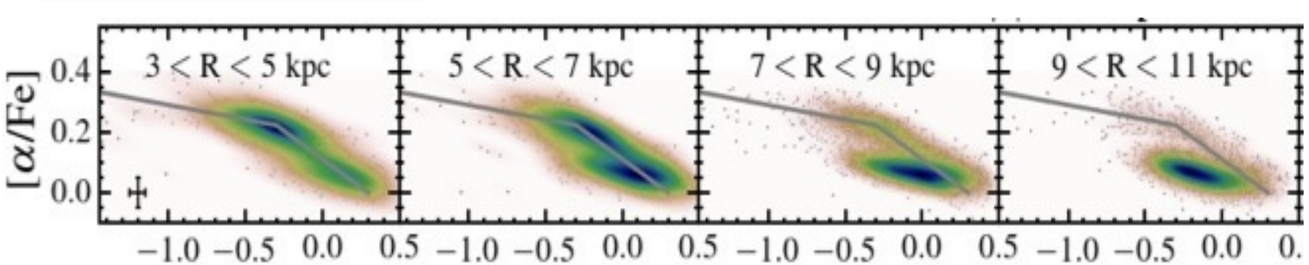
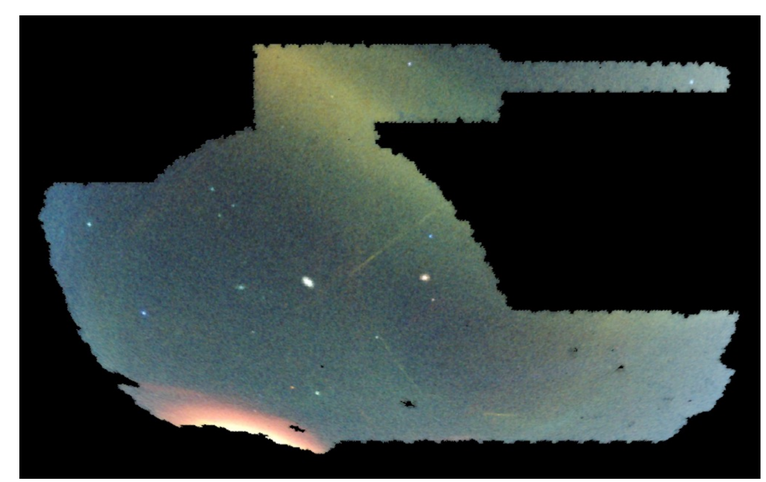
Galaxy Evolution and Resolved Stellar Populations



David Nidever

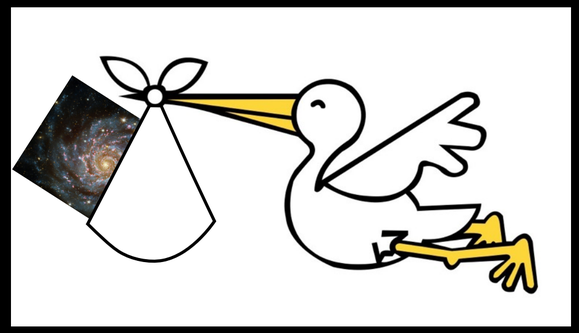
Montana State University / NOAO





How do Galaxies form?

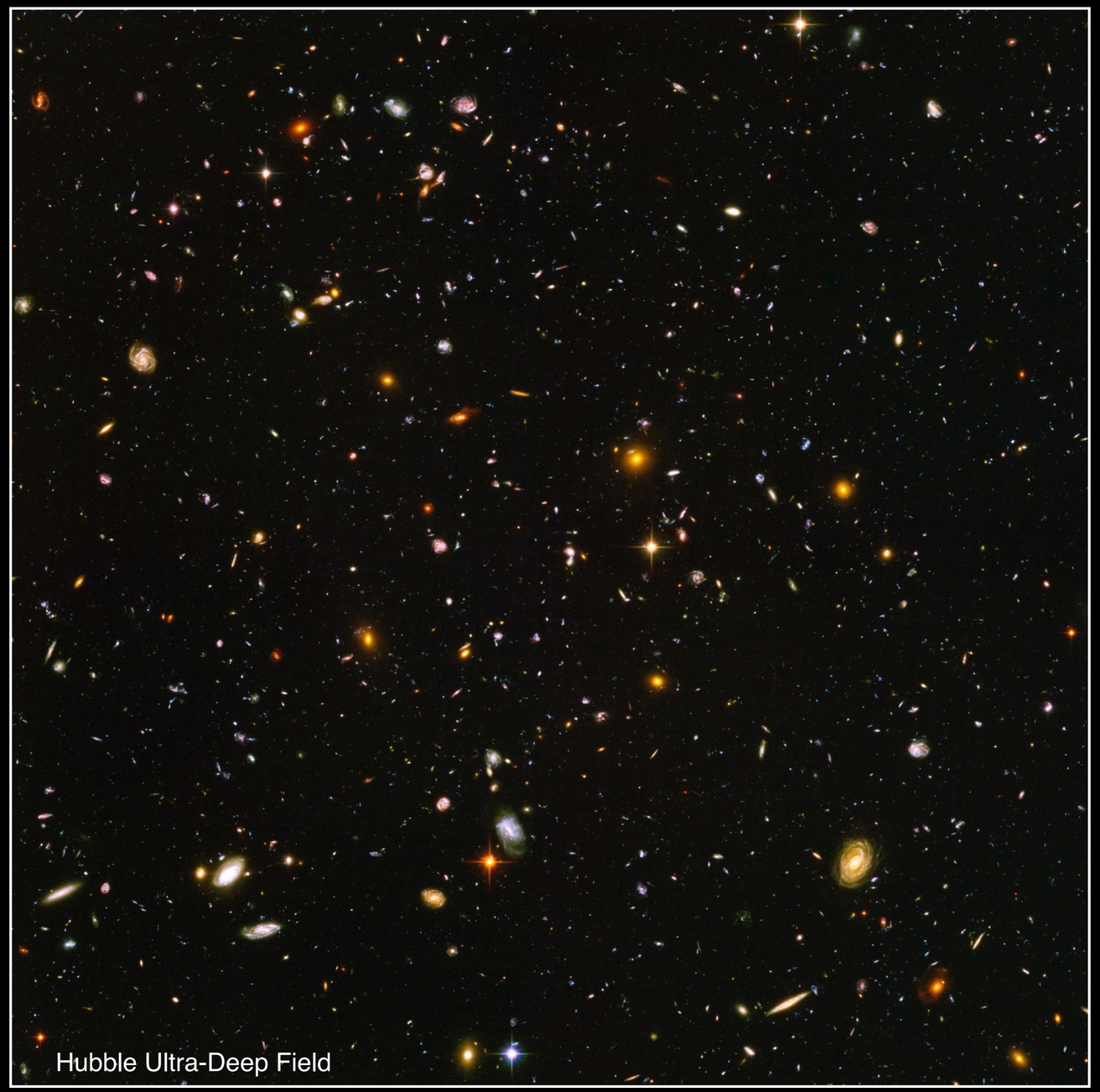
?



Galaxies the Building Blocks of the Universe

The Challenge of Studying Galaxies in Detail

Distant galaxies in *Hubble Space Telescope* Image



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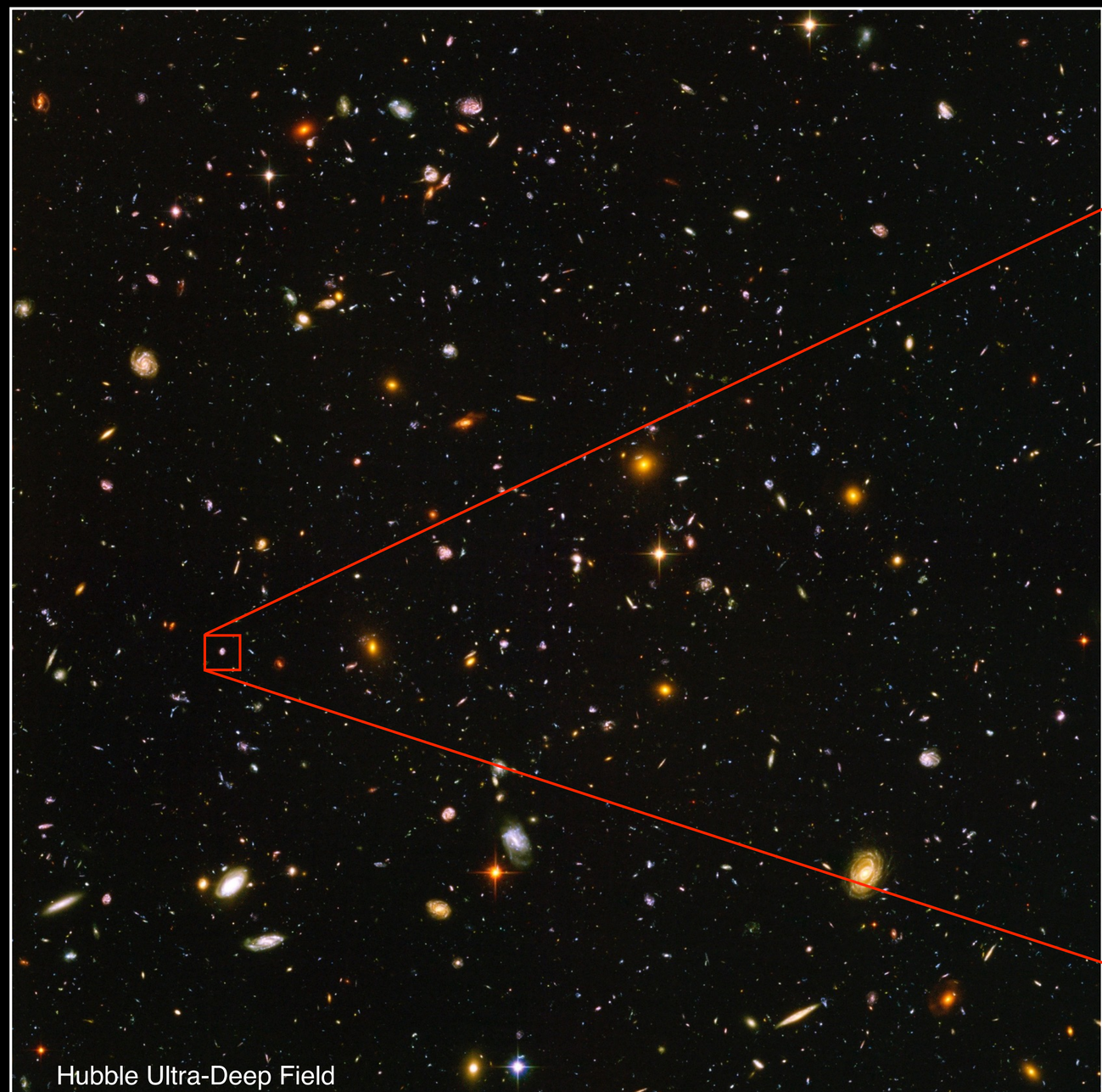

Zoom-in

giant “blob”
can’t see individual stars

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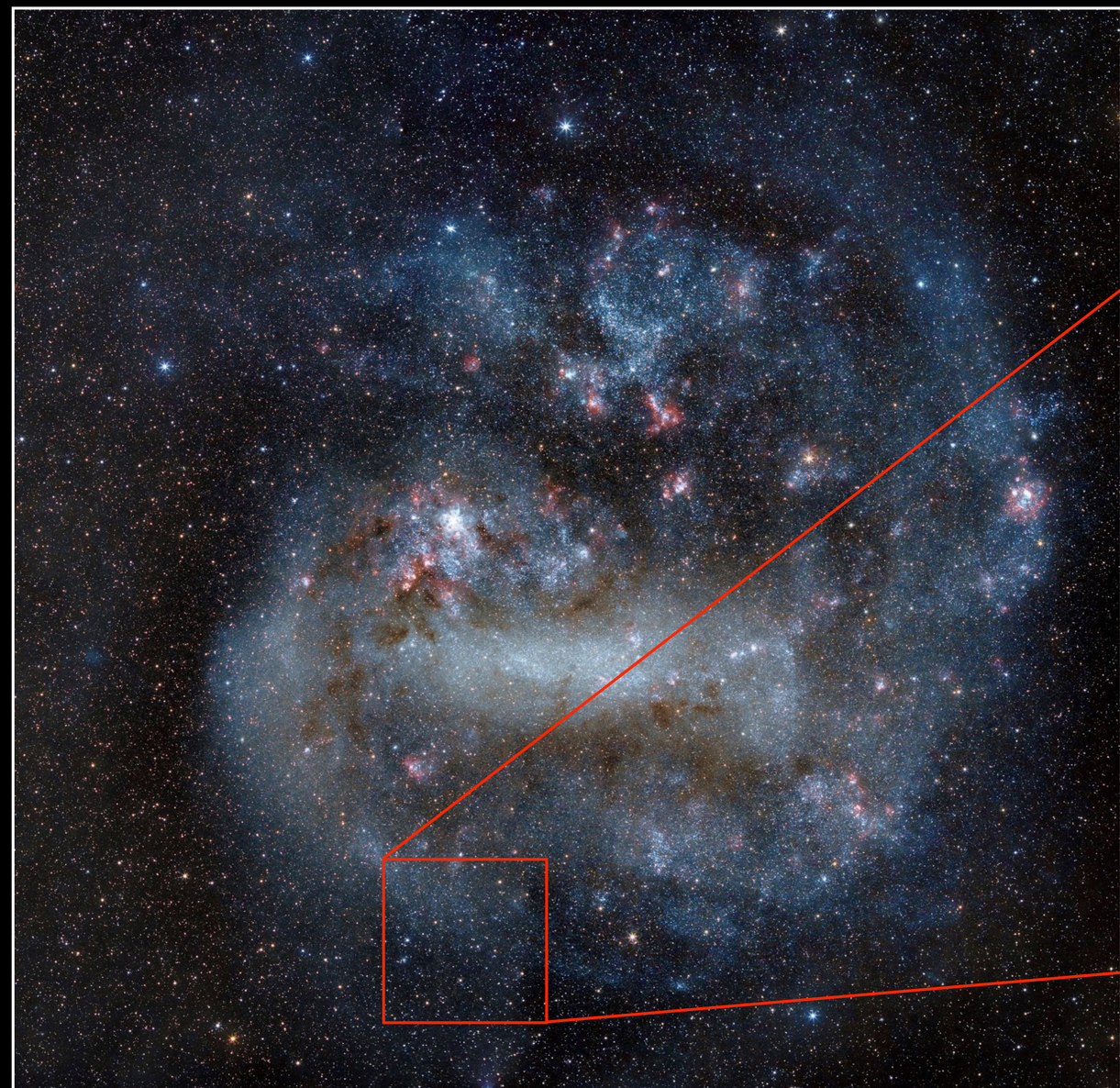

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- These are complementary approaches

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- Star formation histories and chemical evolution throughout the galaxy

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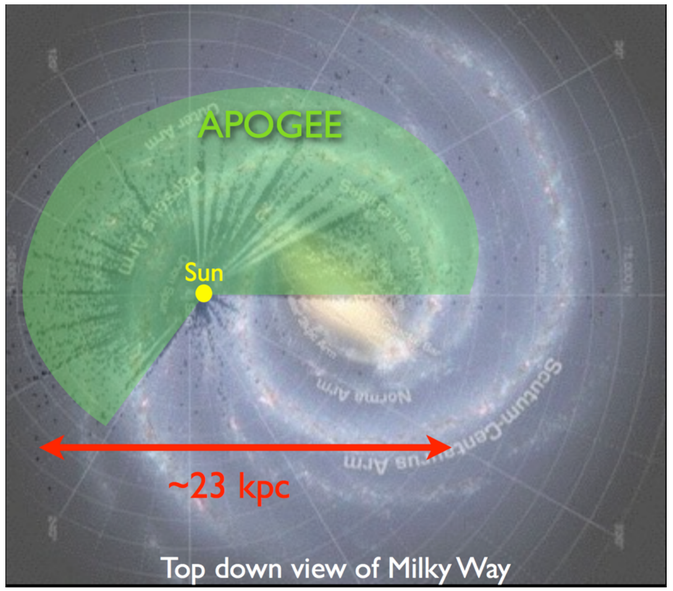
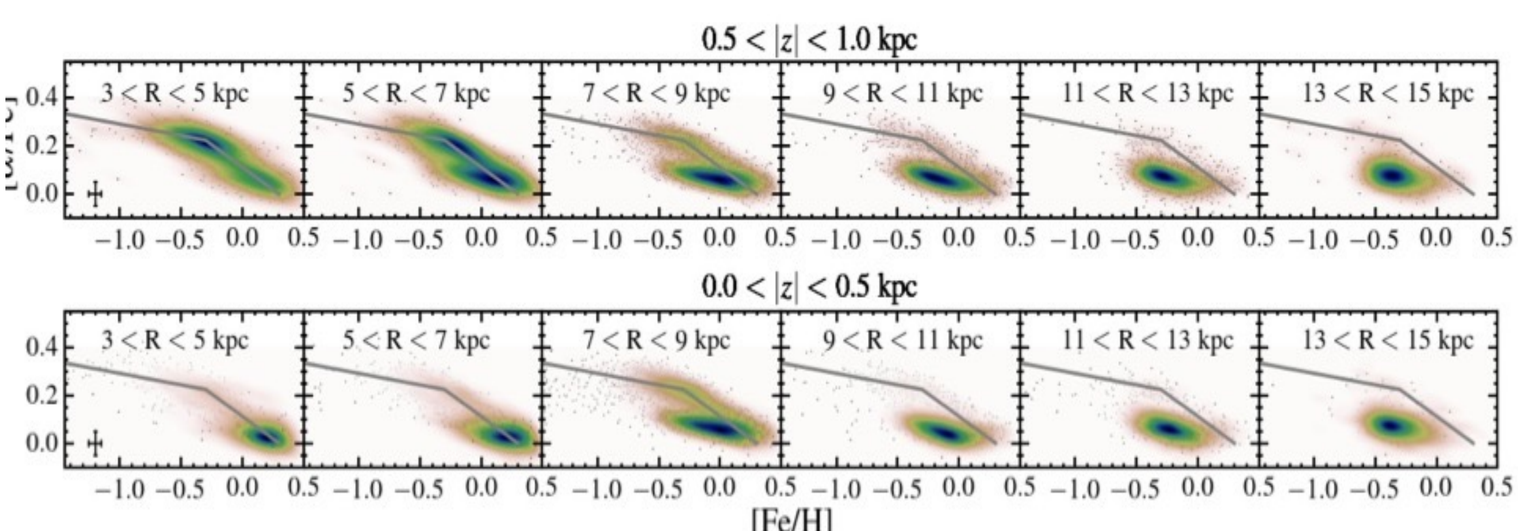
- **Models/Simulations:** important to understand the mechanisms going on in the galaxy

Important Conclusions So Far



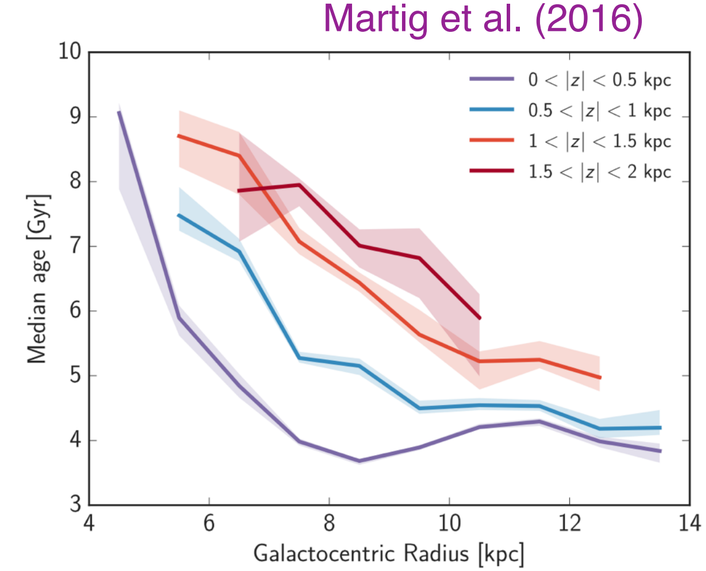
Milky Way Disk

- Detailed structural and chemical mapping of the MW disk
- α-abundance bimodality (thin/thick disk) throughout the disk
- Old, high-α, thick disk stars formed early on in inner galaxy and later dispersed throughout the disk.
- Thin disk formed more slowly later on, radial metallicity gradient
- First evidence of radial migration playing an important role in the evolution of the disk
- Origin of thick disk debated but likely not from a large stellar accretion event



Hayden et al. (2015)

Martig et al. (2016)



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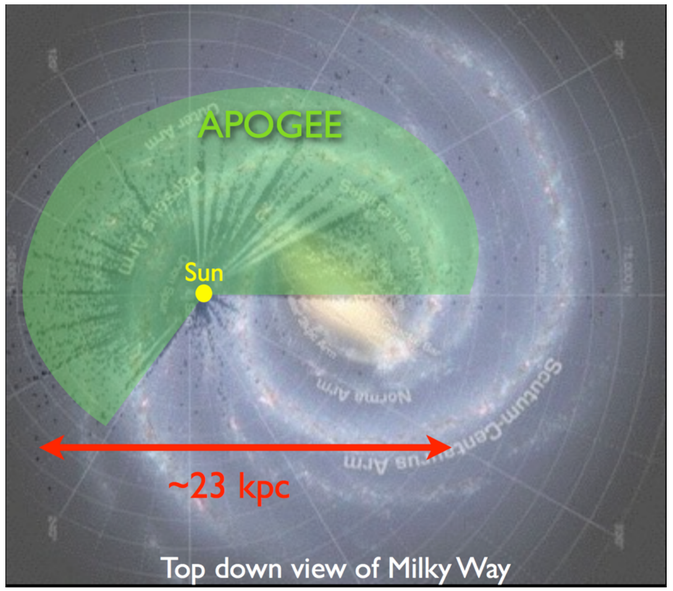

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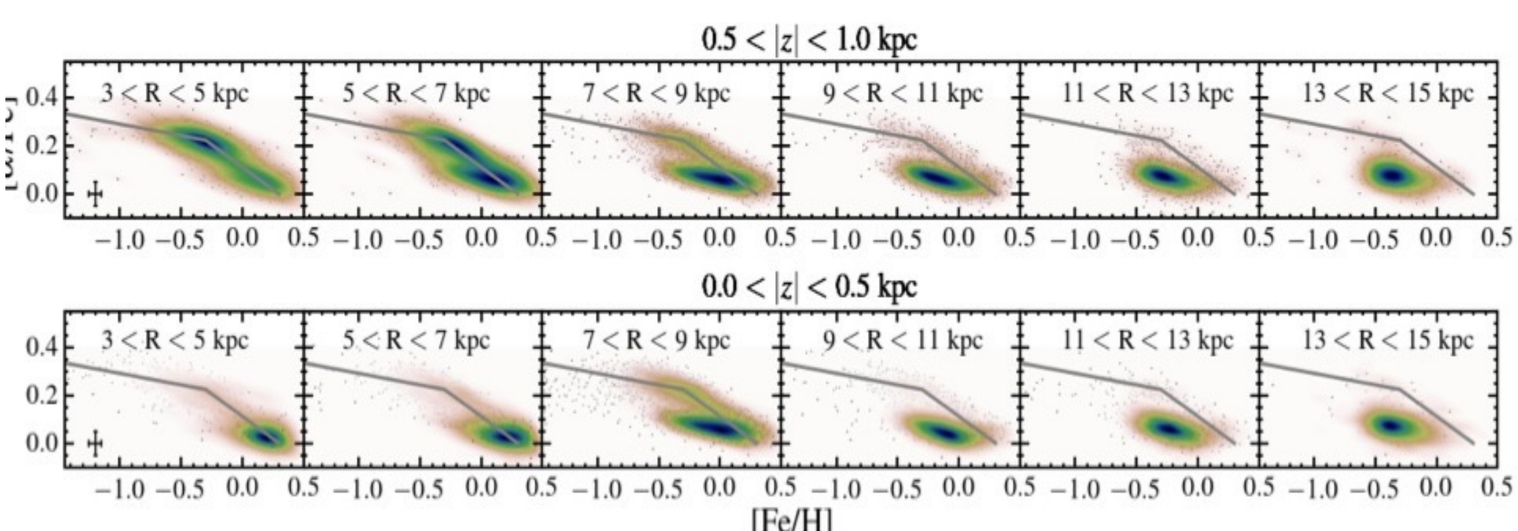

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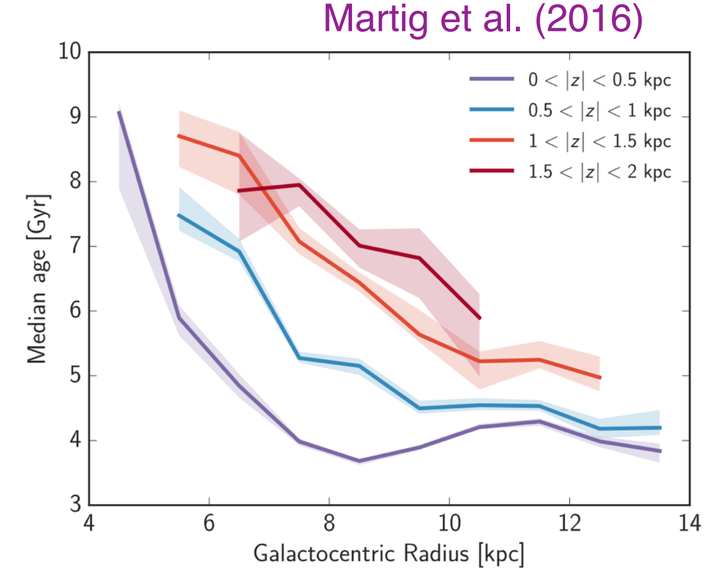
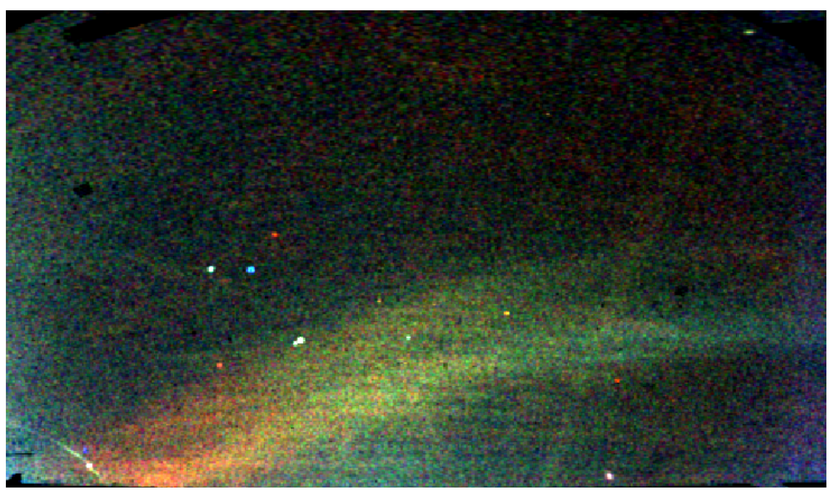


Important Conclusions So Far

Milky Way Halo

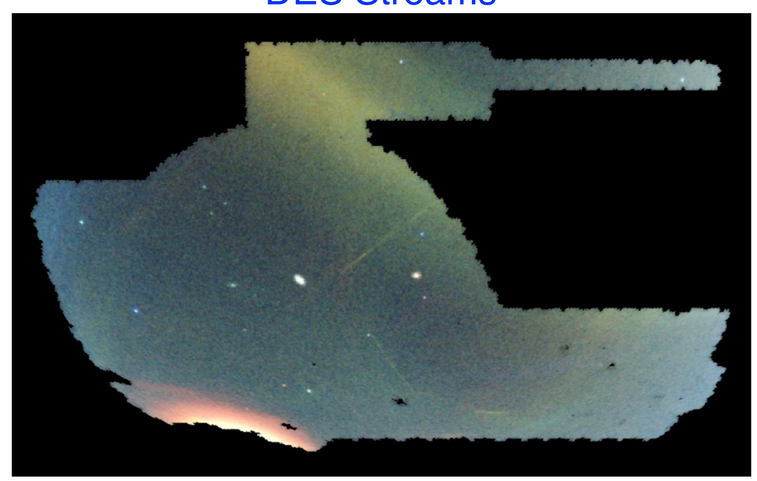
- Discovery of many new stellar streams and dwarf satellites (~45 and counting), hierarchical galaxy formation
- Still not enough to fully solve the missing satellites problem
- Halo traced to ~100 kpc. Significant fraction of halo comes from a small number of "massive" accreted satellite

SDSS Field of Streams and Dwarf Galaxies



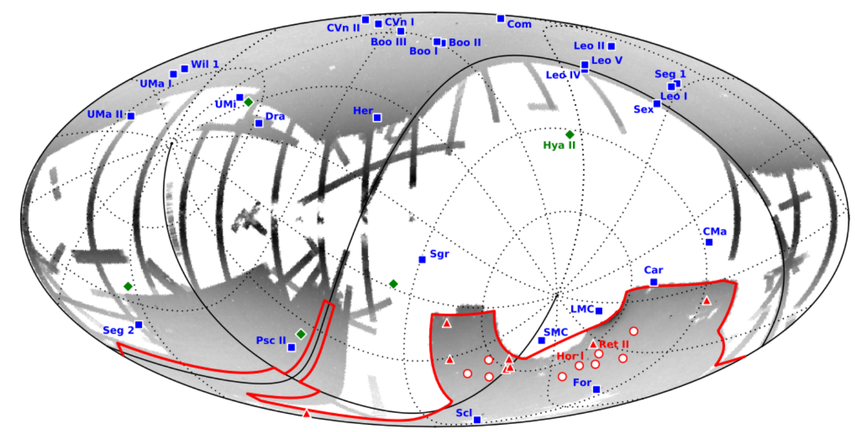
Belokurov et al. (2006)

DES Streams



Shipp et al. (2018)

Milky Way Satellites



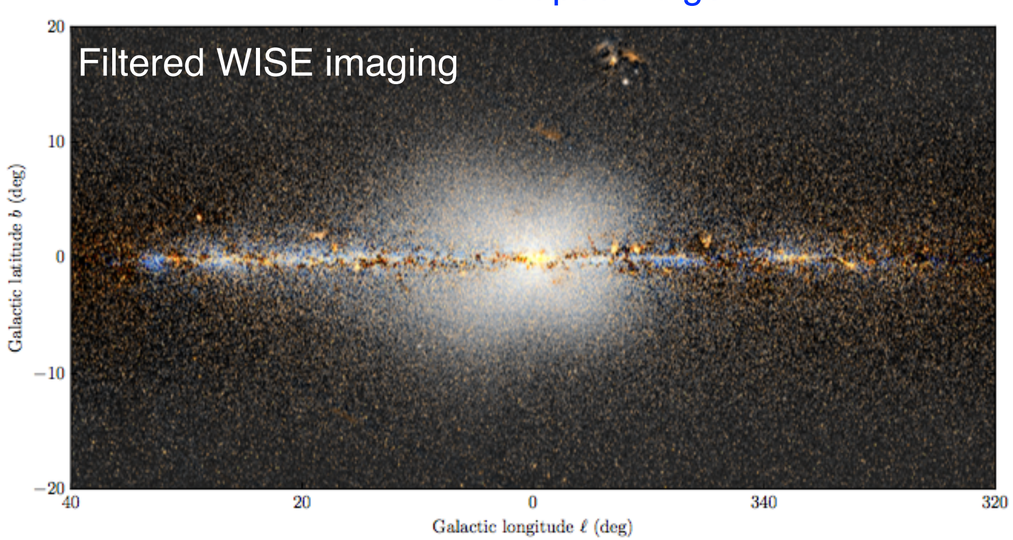
Drlica-Wagner et al. (2015)

Important Conclusions So Far

Bulges

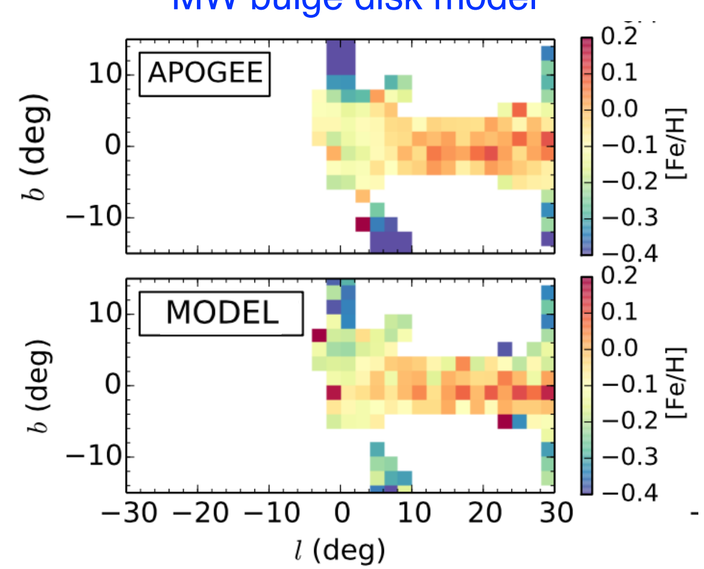
- Both MW+M31 have boxy bulges dominated by bars, MW has X-shaped bulge
- MW bulge chemistry very similar to inner thick disk
- MW bulge likely just the bar formed from thin/thick disks

MW X-shaped Bulge



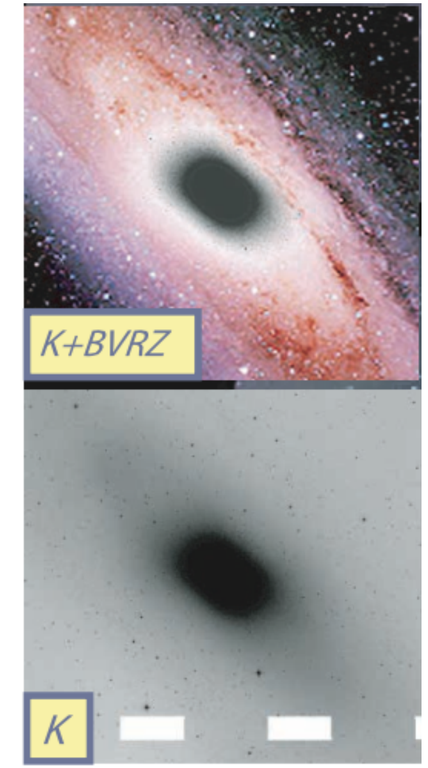
Ness & Lang (2016)

MW bulge disk model



Fragkoudi et al. (2018)

M31 Boxy Bulge/Bar



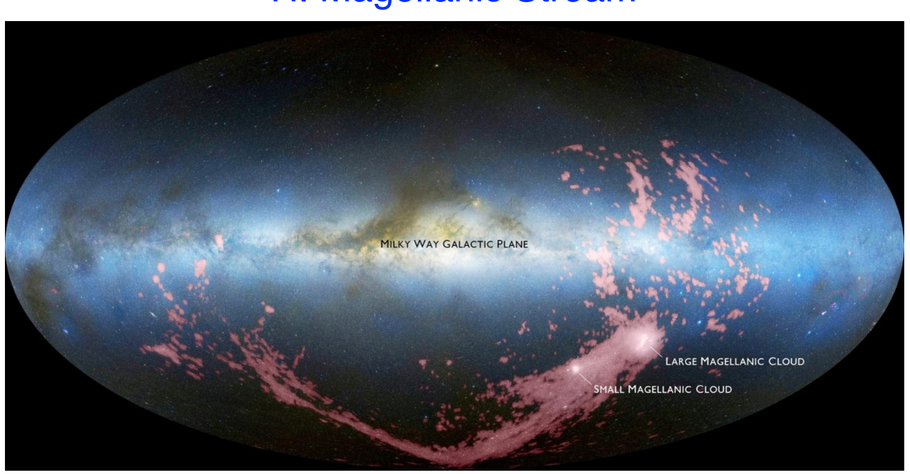
Beaton et al. (2007)

Important Conclusions So Far

Magellanic Clouds + dwarfs

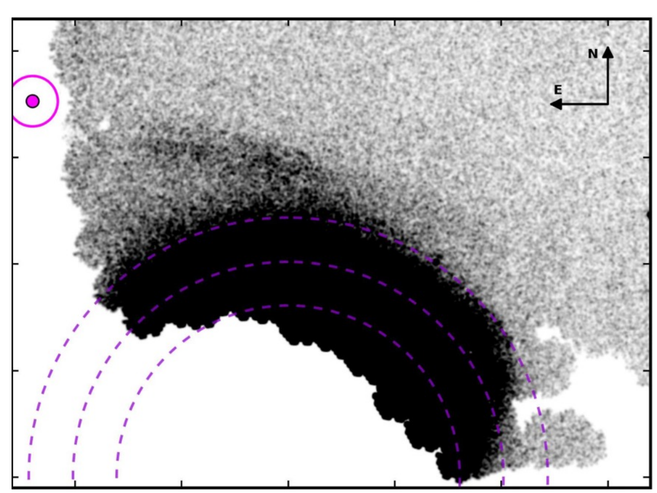
- MCs very likely have their own system of satellites, very extended stellar populations, hierarchical galaxy formation
- MCs fell into MW potential a couple Gyrs ago.
- Will contribute 10^9 $M_\odot$ masses of gas to hot halo and eventually to the MW disk
- LMC has very extended stellar component, formed “outside-in”. Very extended old disk, SF disk shrunk over time as gas used up. Same in other nearby dwarf galaxies.

HI Magellanic Stream



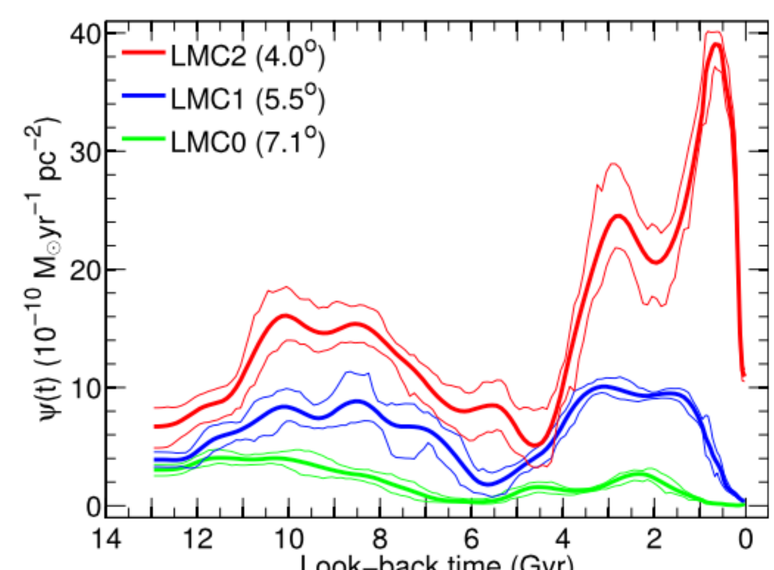
Nidever et al. (2010)

Extended LMC Stellar Populations



Mackey et al. (2016)

LMC SFH - shrinking SF disk



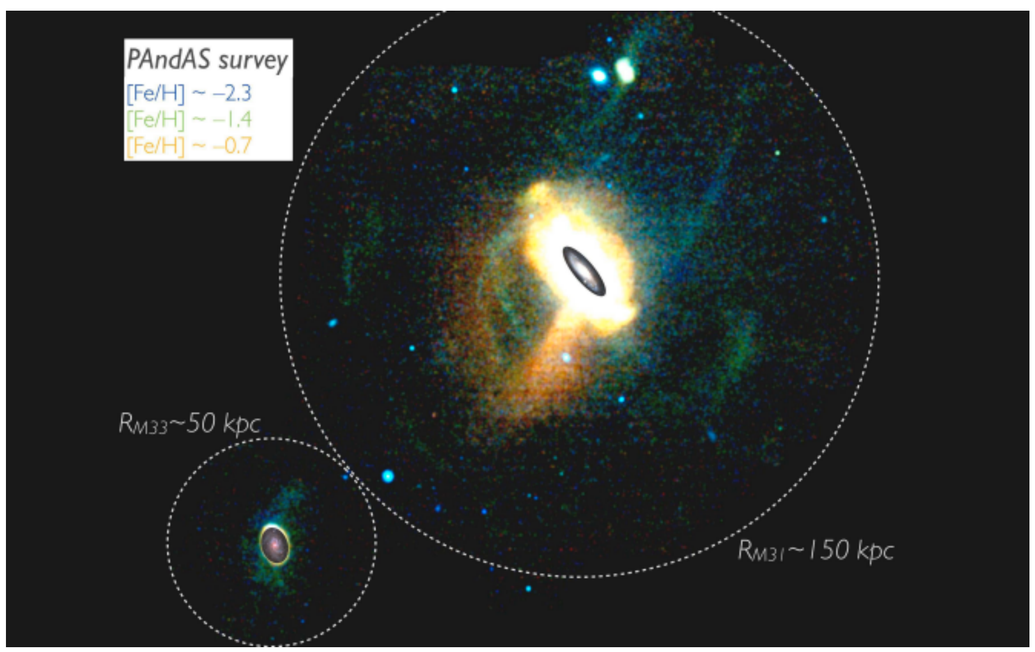
Meschin et al. (2014)

Important Conclusions So Far

M31

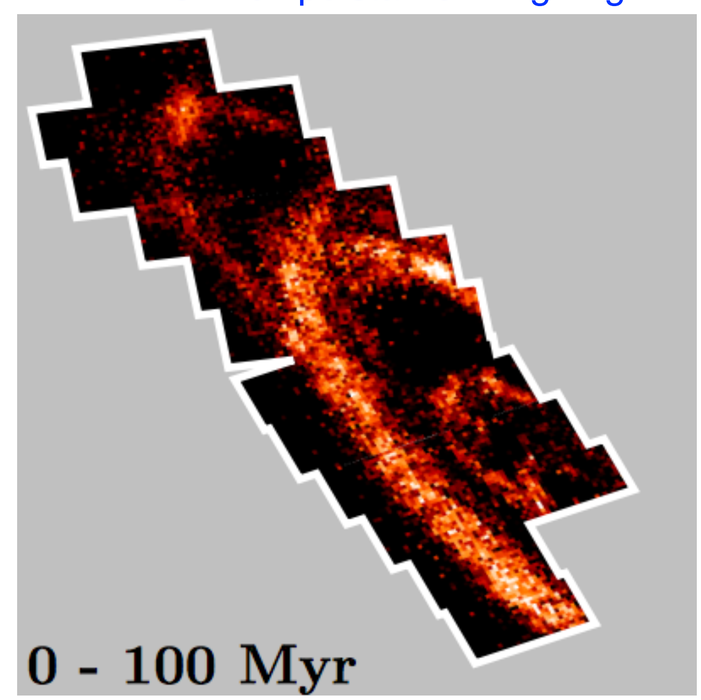
- Thickened disk with persistent star formation ring at 10 kpc over 500 Myr
- Global and massive SF event 2-4 Gyr ago likely due to to significant interaction event
- Global halo mapped, signs of multiple large interactions and debris

M31 Halo Metallicity Map



Martin et al. (2013)

M31 10 kpc star forming ring



Lewis et al. (2015)

Important Conclusions So Far

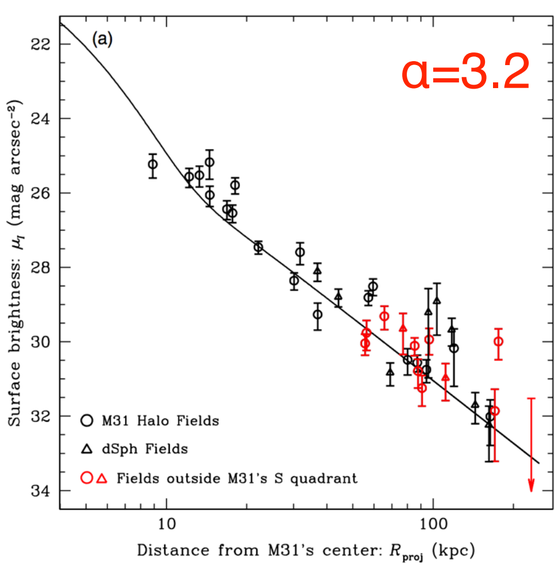
M31+MW

- Very different halo masses/shapes/metallicities, from different accretion histories, even though similar total masses and neighbors

Planes of satellites

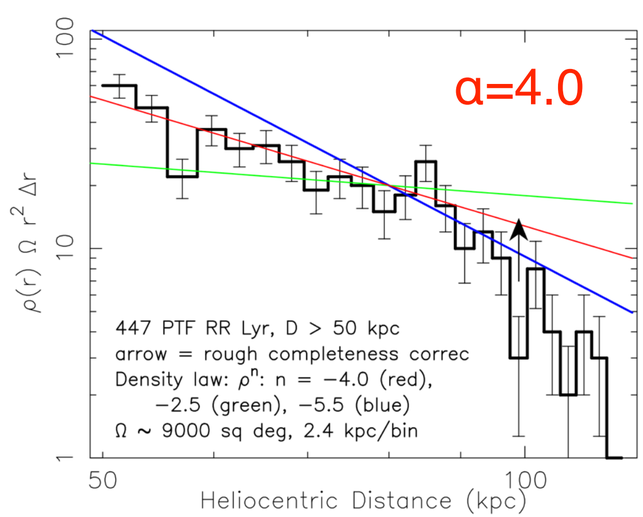
- Satellites arranged in planes (some co-rotating) around MW+M31 and other galaxies

M31 Stellar Halo - $M=8\times10^9$



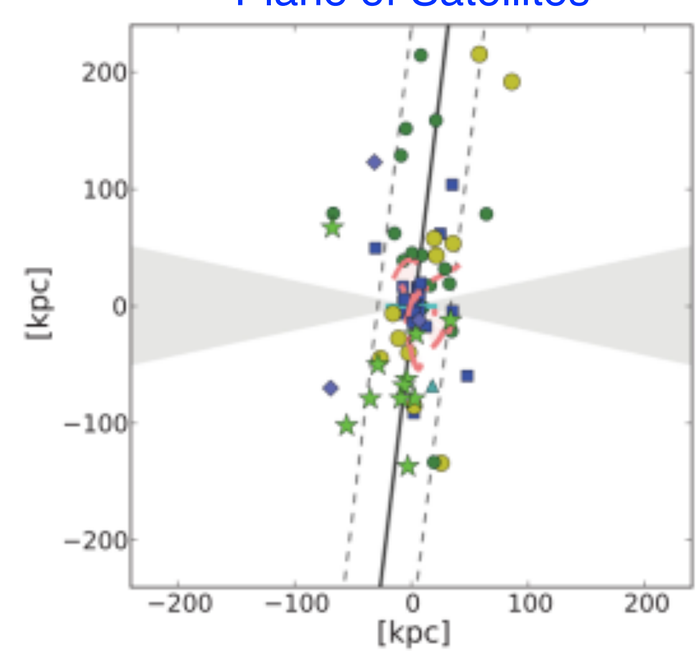
Gilbert et al. (2012)

MW Stellar Halo - $M=7\times10^8$



Cohen et al. (2017)

Plane of Satellites



Pawlowski et al. (2015)

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- **Was there a "Magellanic group" of galaxies that fell into MW.**

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  - Large spectroscopic surveys: *SDSS-V, 4MOST, MOONS, WEAVE*
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The End