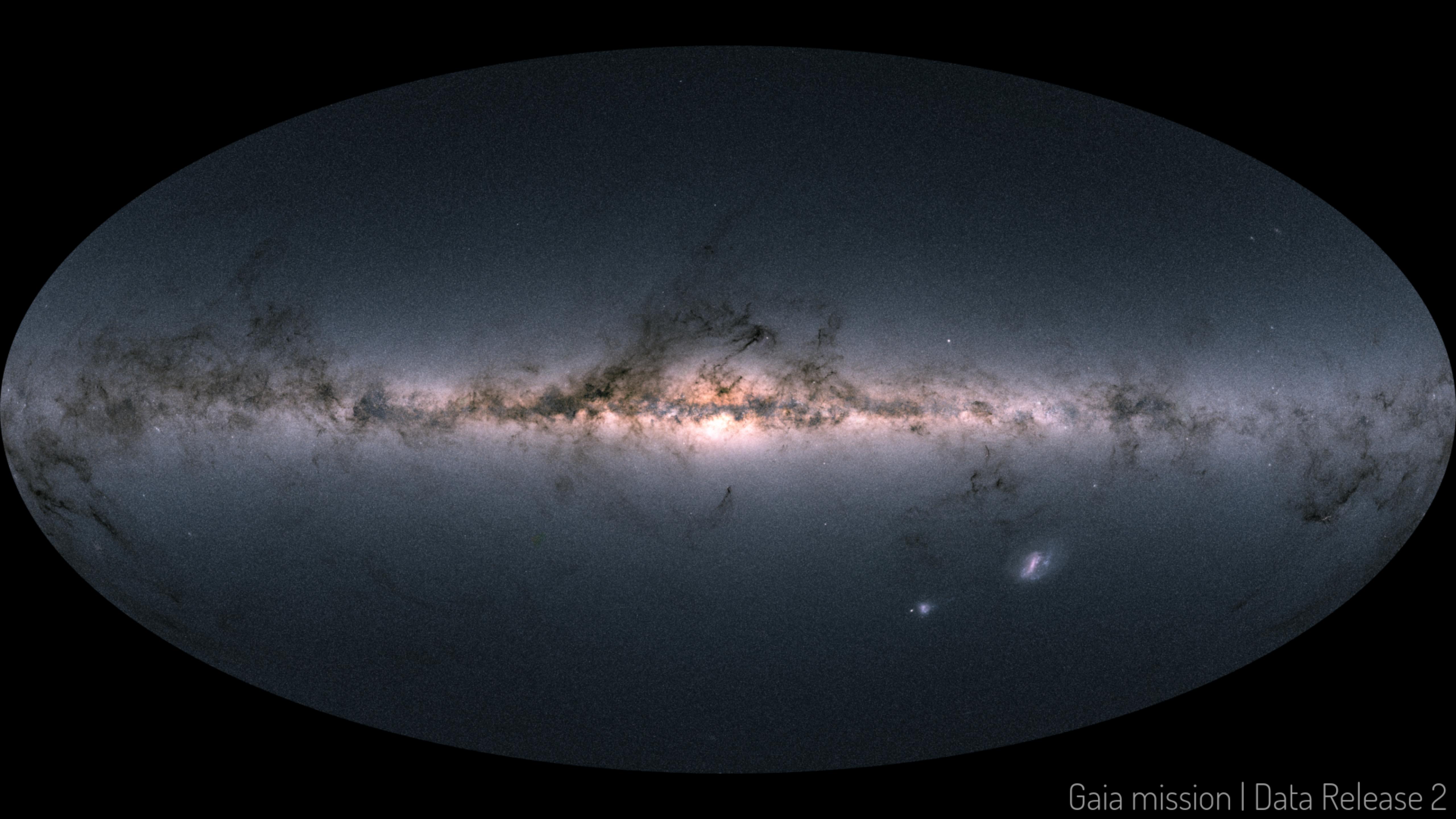


# Reconstruction of the dark matter distribution in the Milky Way with Gaia

Ana Bonaca ITC Fellow | Harvard

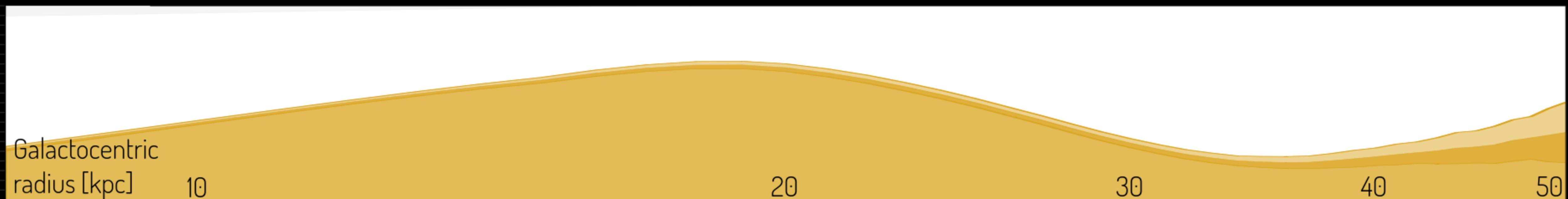
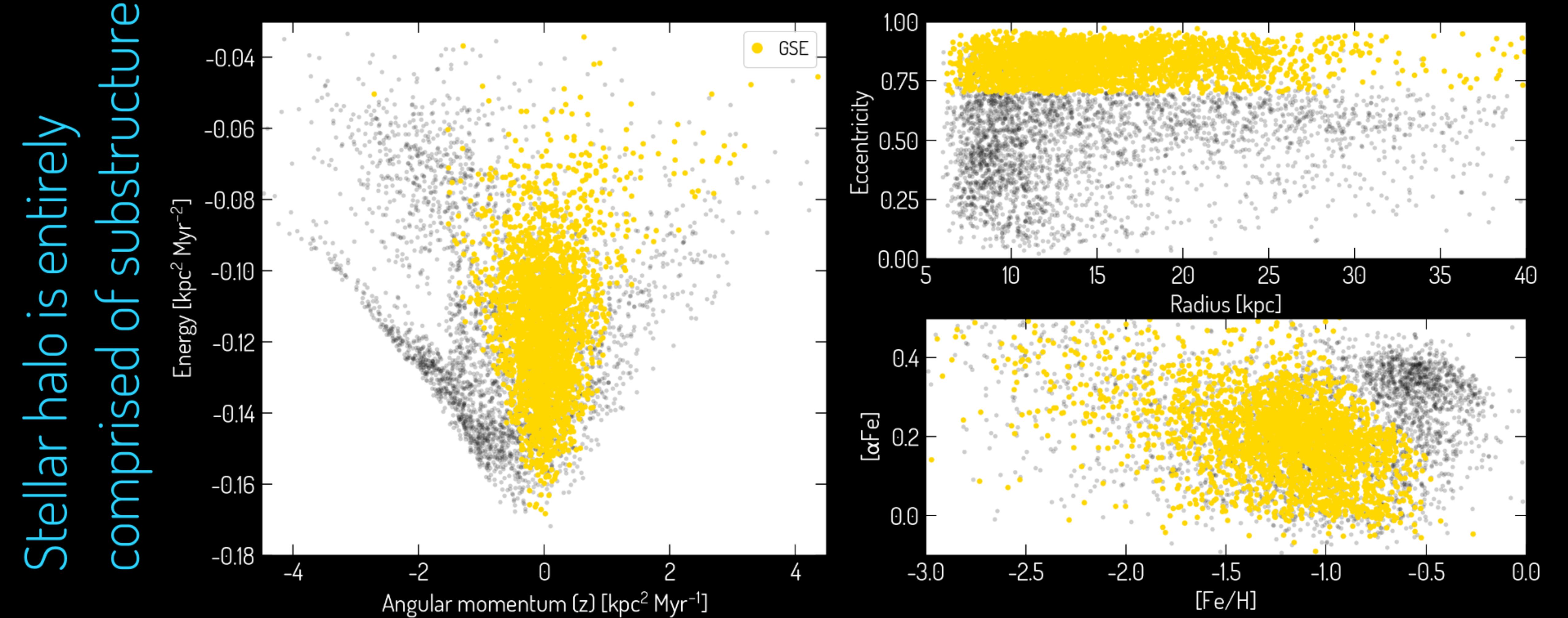
A circular map of the night sky centered on the Milky Way galaxy. The map shows a dense band of stars and interstellar dust, appearing as a bright, multi-colored band of light (blue, white, yellow, orange) against a dark background. The map is set against a dark, textured background that suggests the surface of the Earth or a celestial sphere.

Gaia mission | Data Release 2



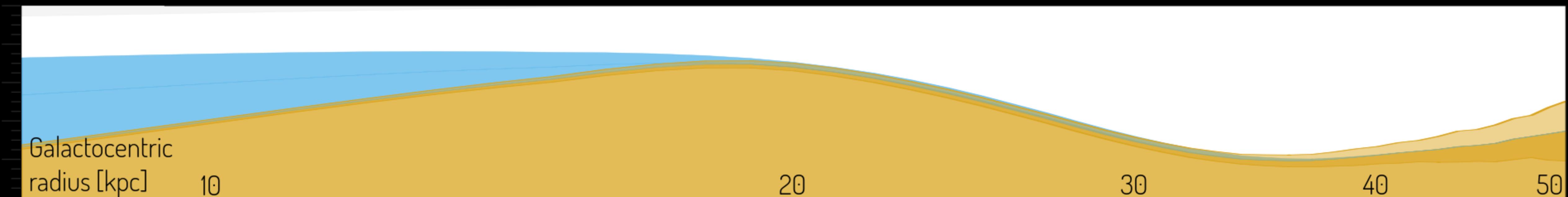
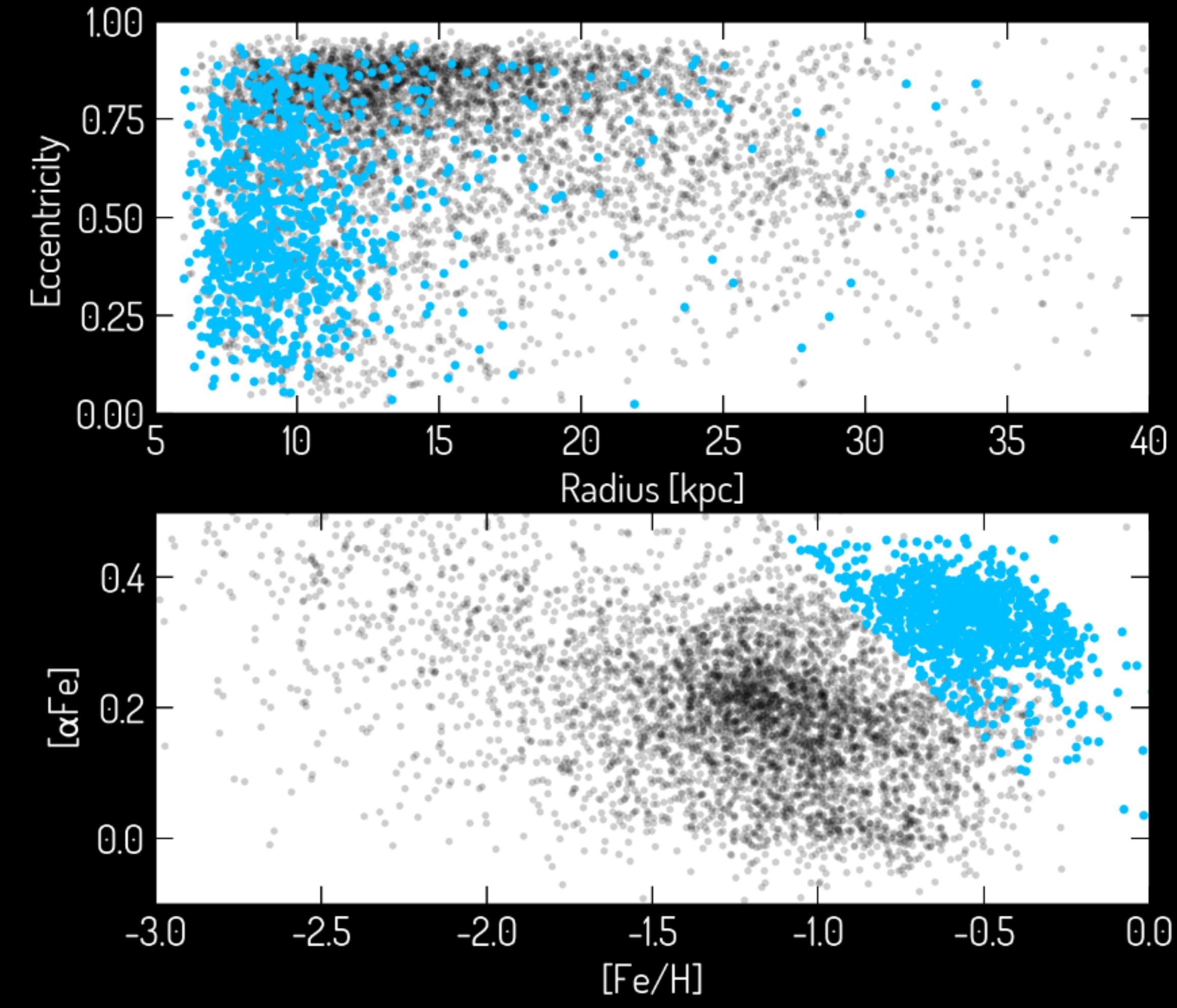
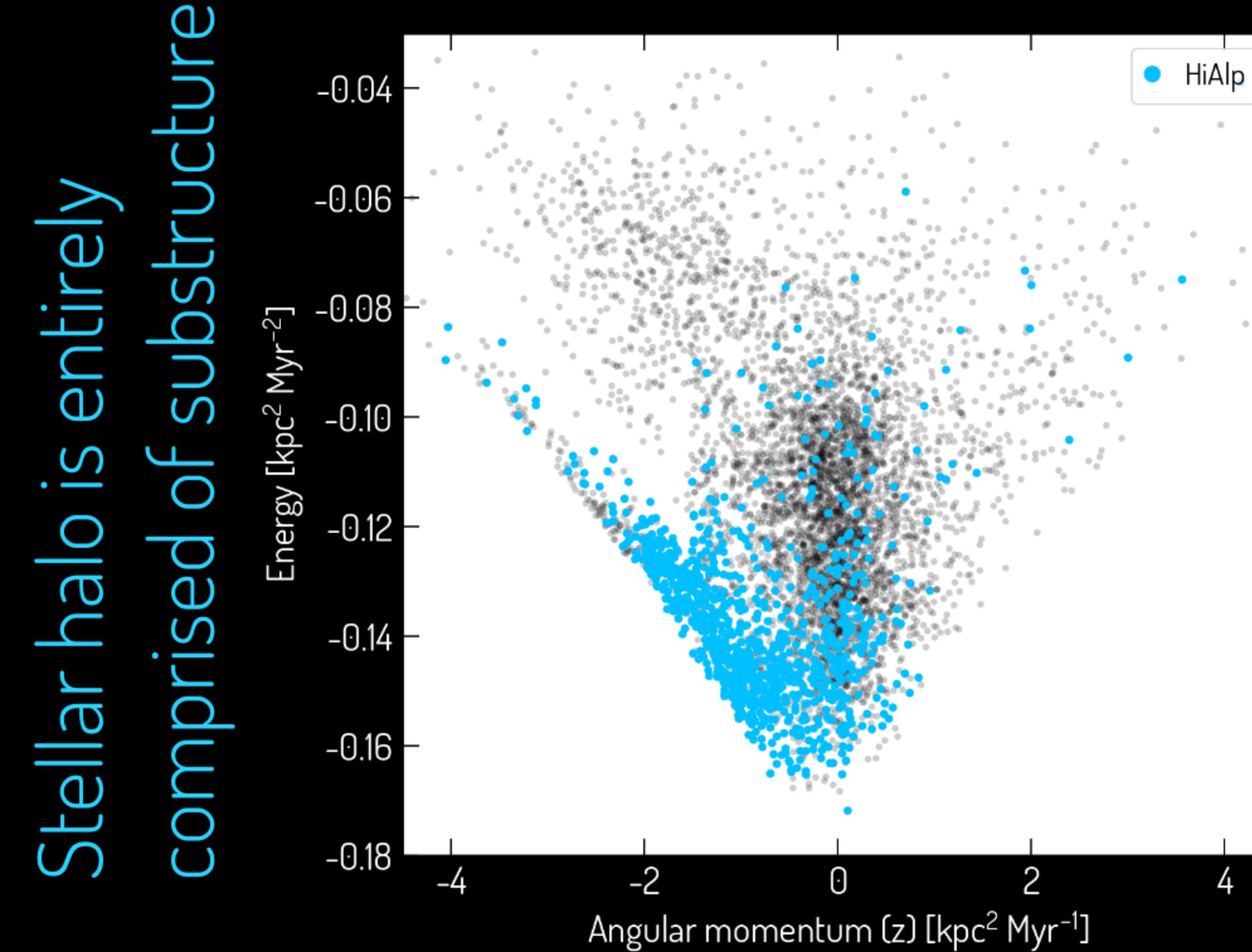
# Giant stars in Gaia and H3 spectroscopic survey

Naidu et al. (2021)



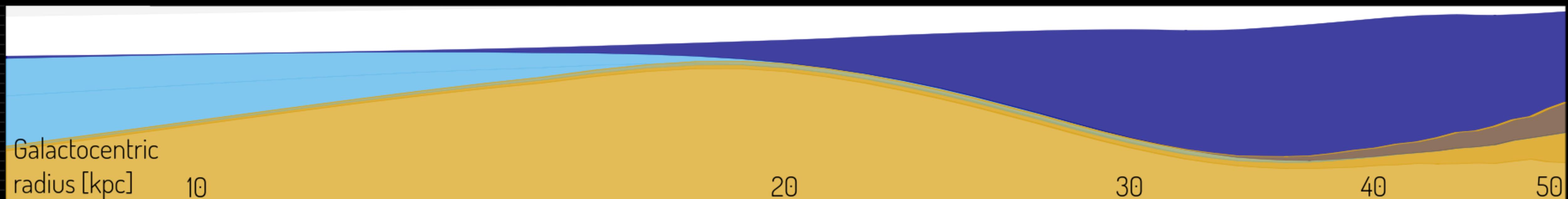
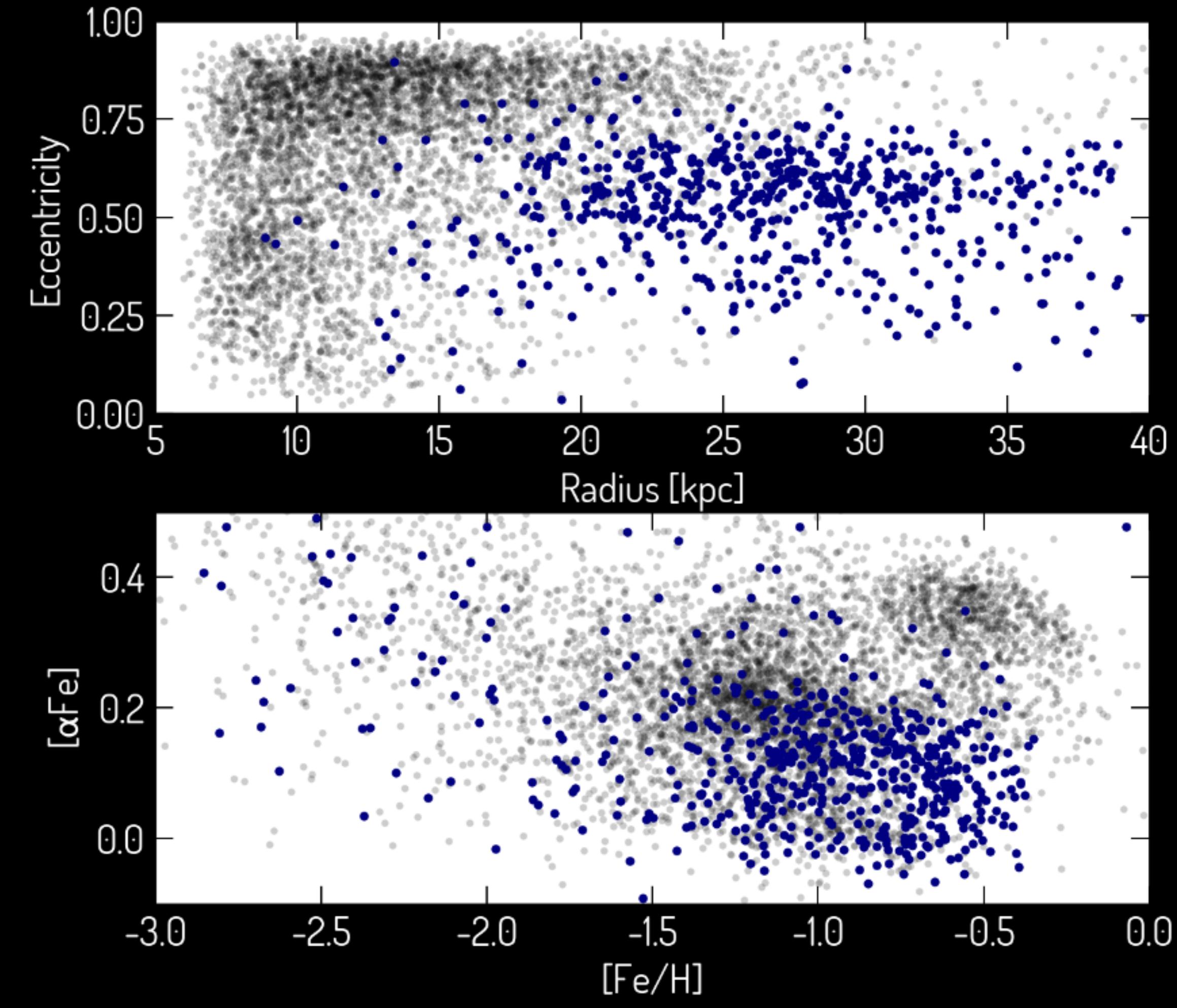
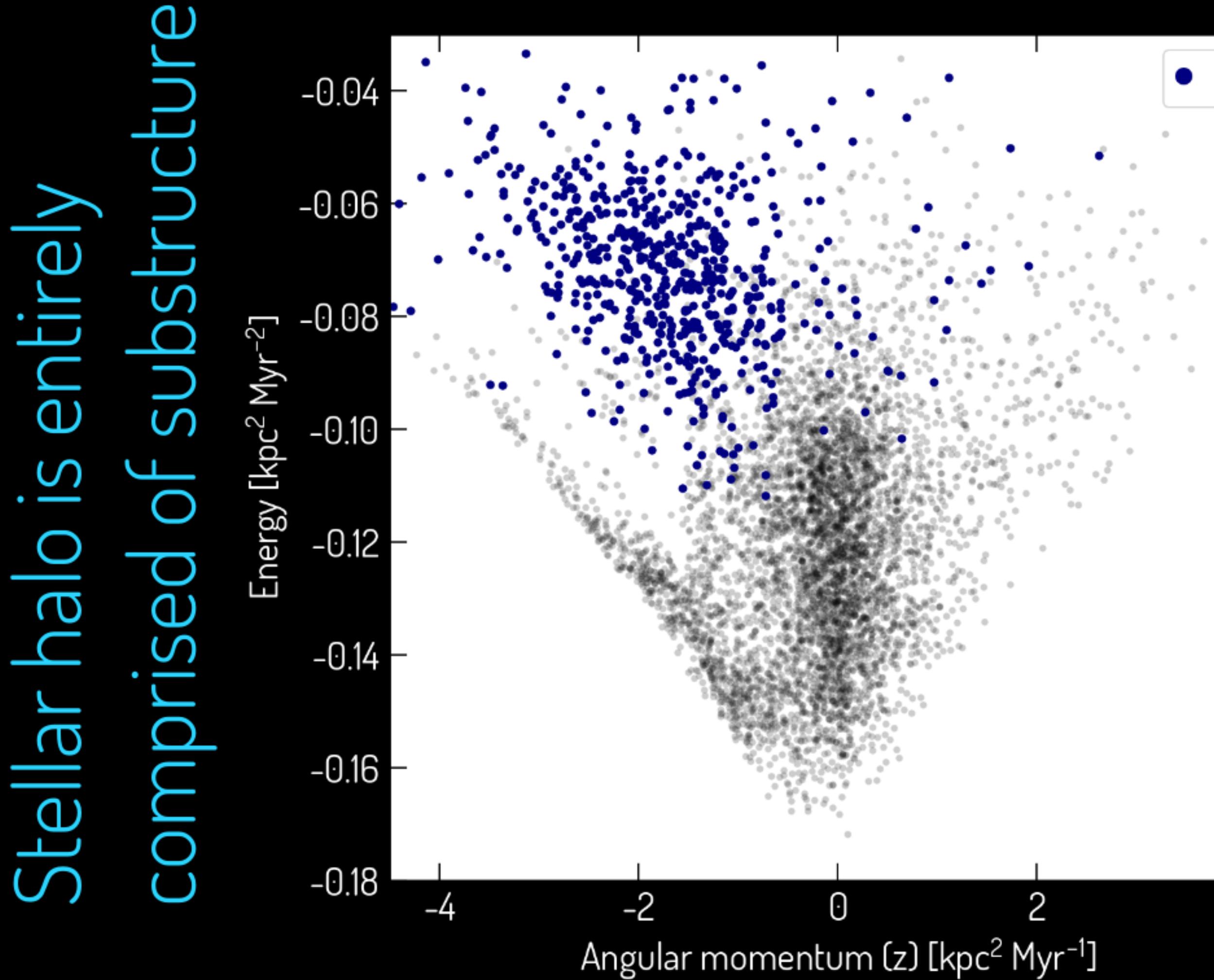
# Giant stars in Gaia and H3 spectroscopic survey

Naidu et al. (2021)



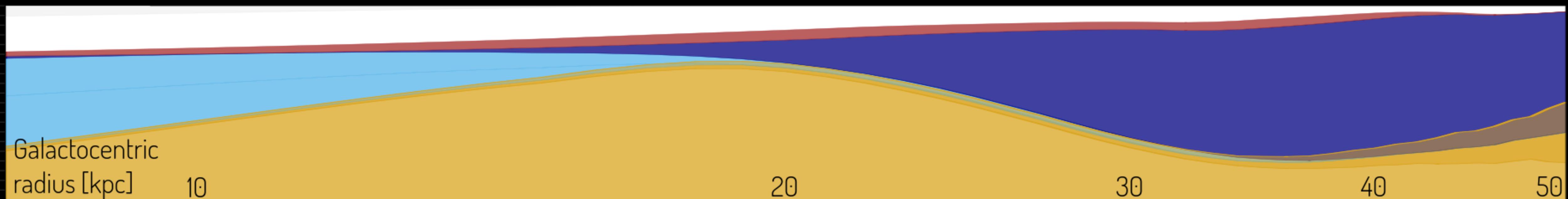
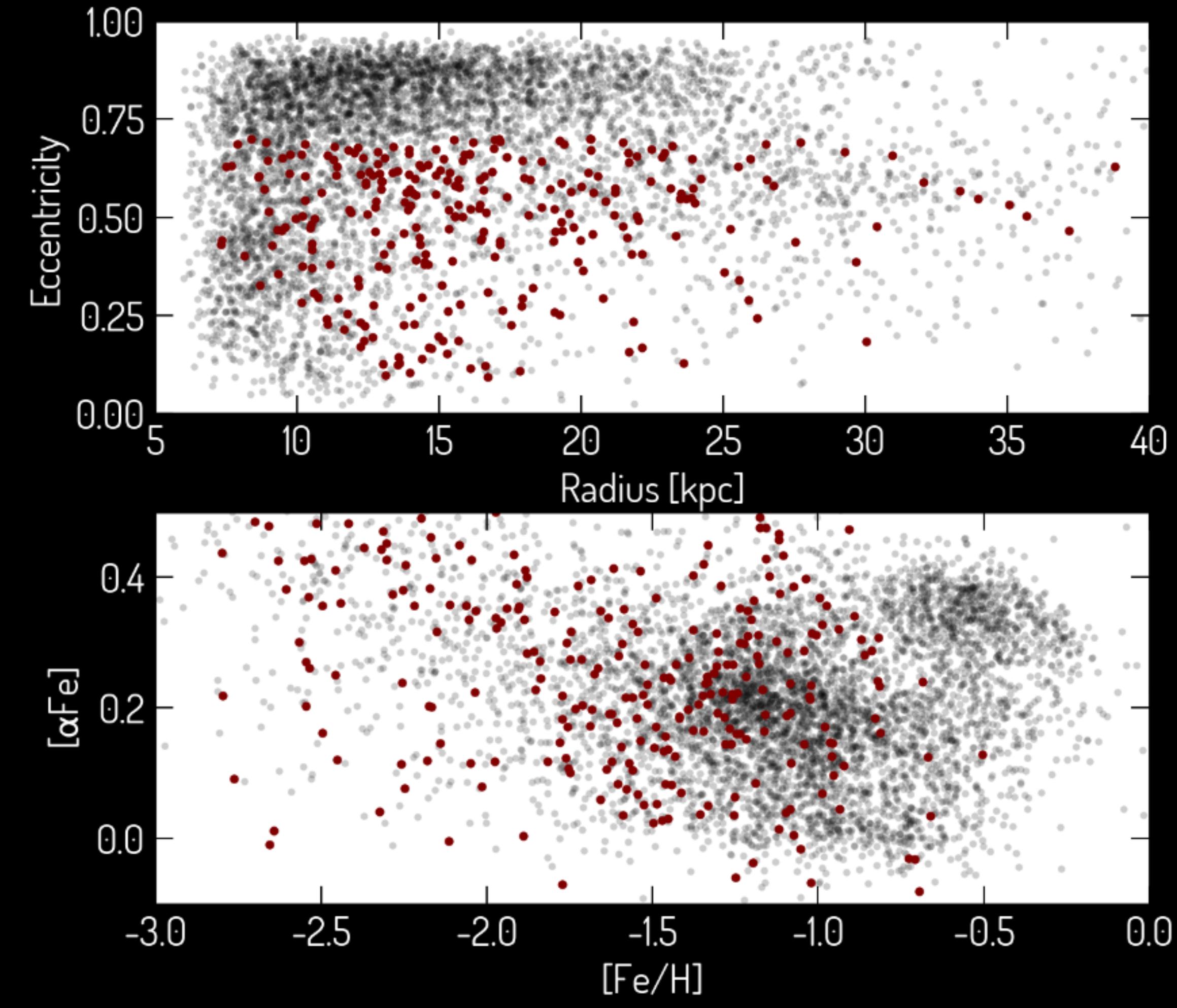
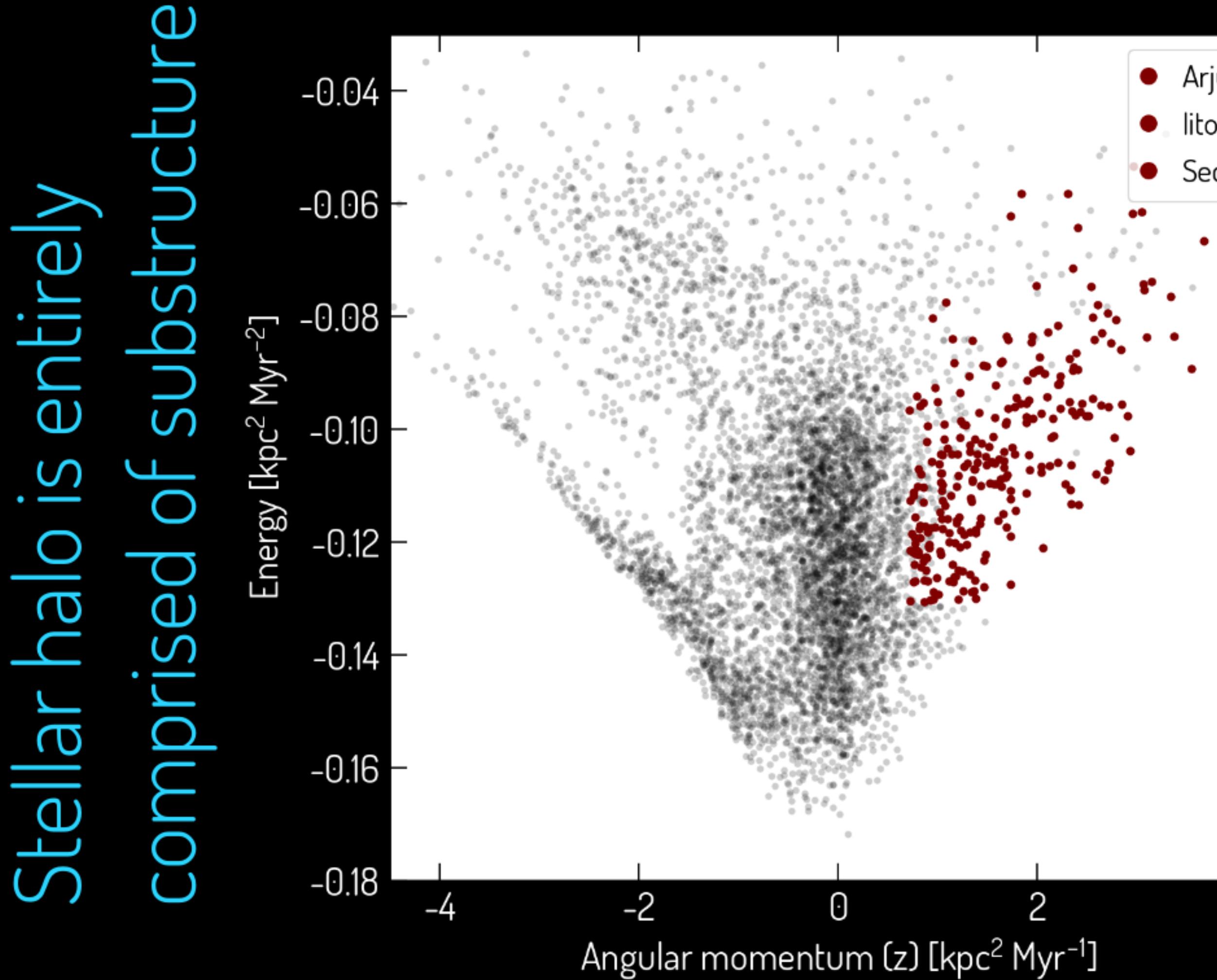
# Giant stars in Gaia and H3 spectroscopic survey

Naidu et al. (2021)



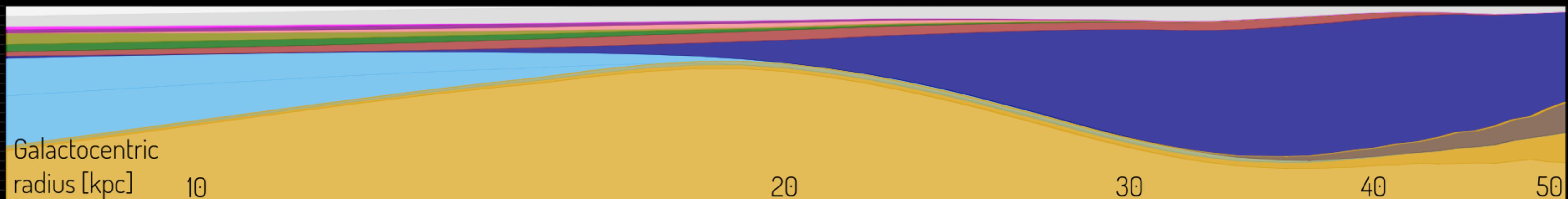
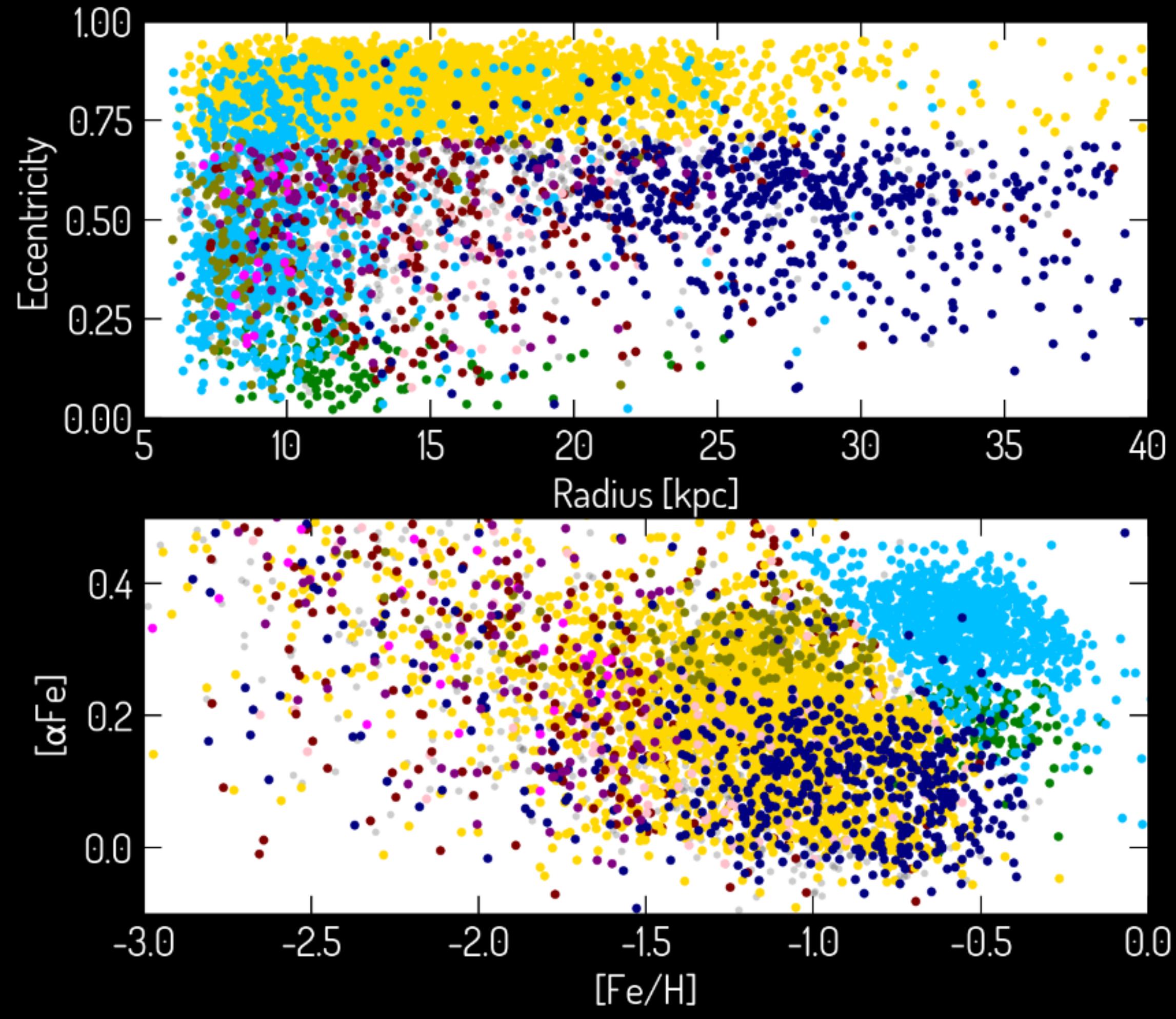
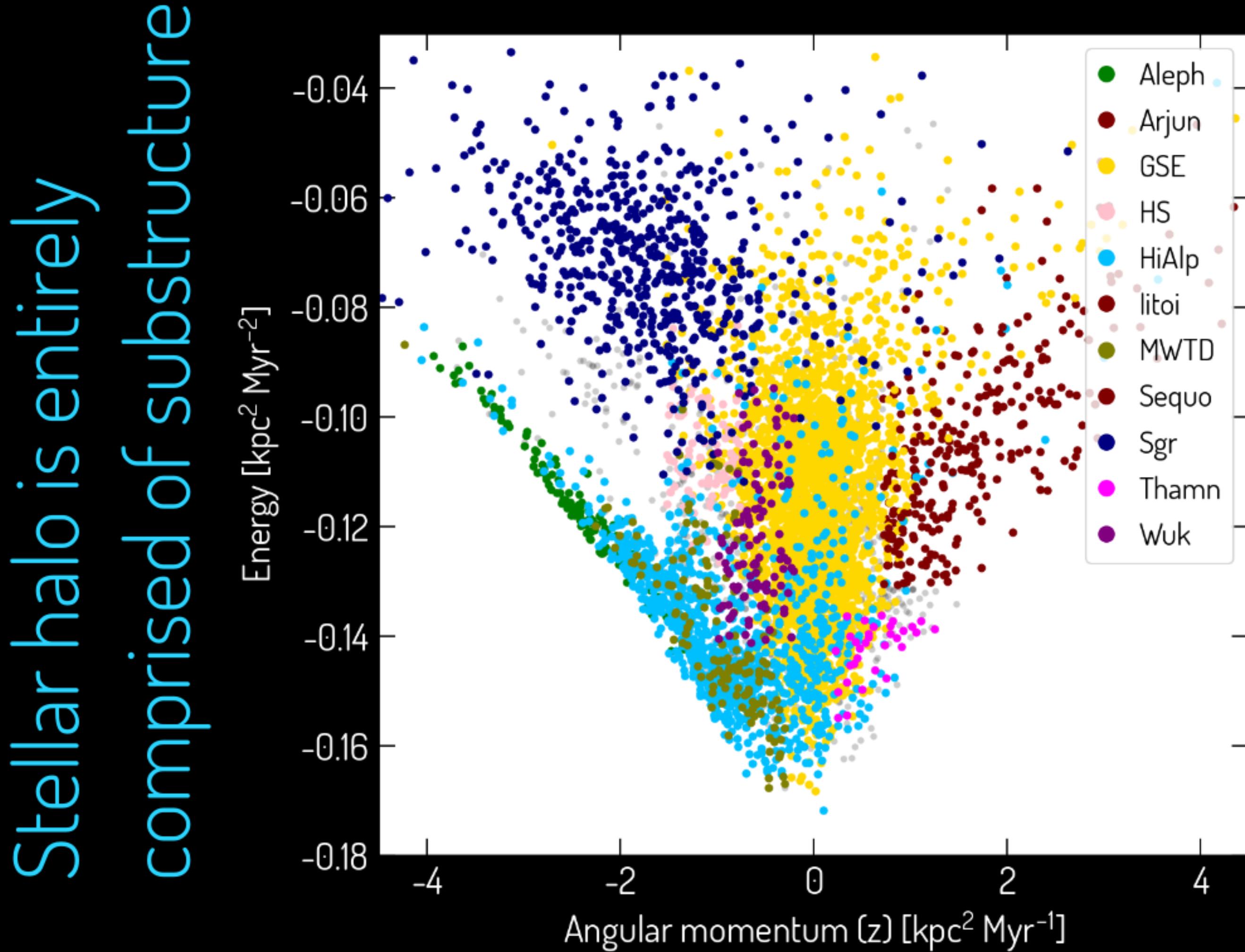
# Giant stars in Gaia and H3 spectroscopic survey

Naidu et al. (2021)

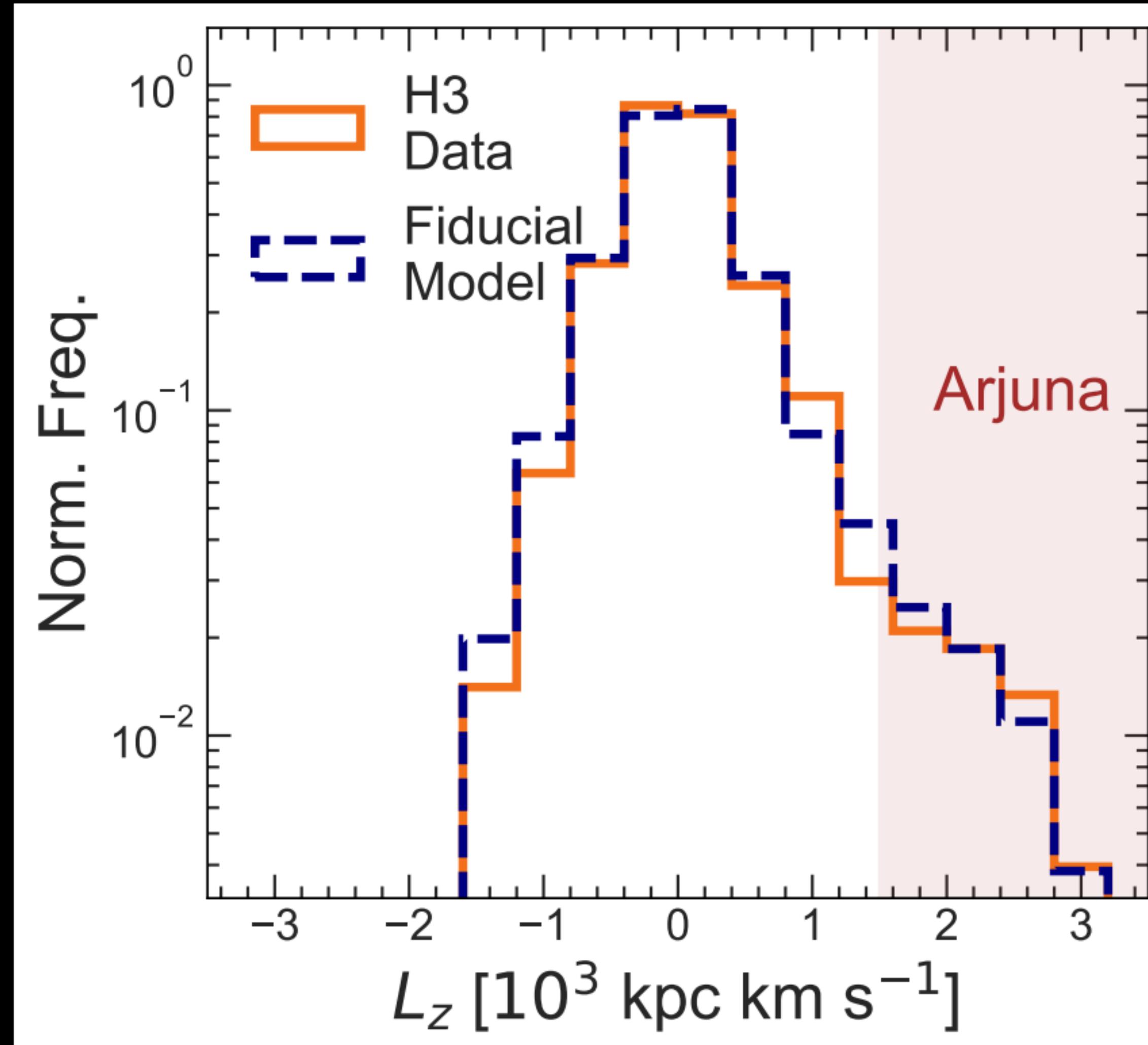


# Giant stars in Gaia and H3 spectroscopic survey

Naidu et al. (2021)

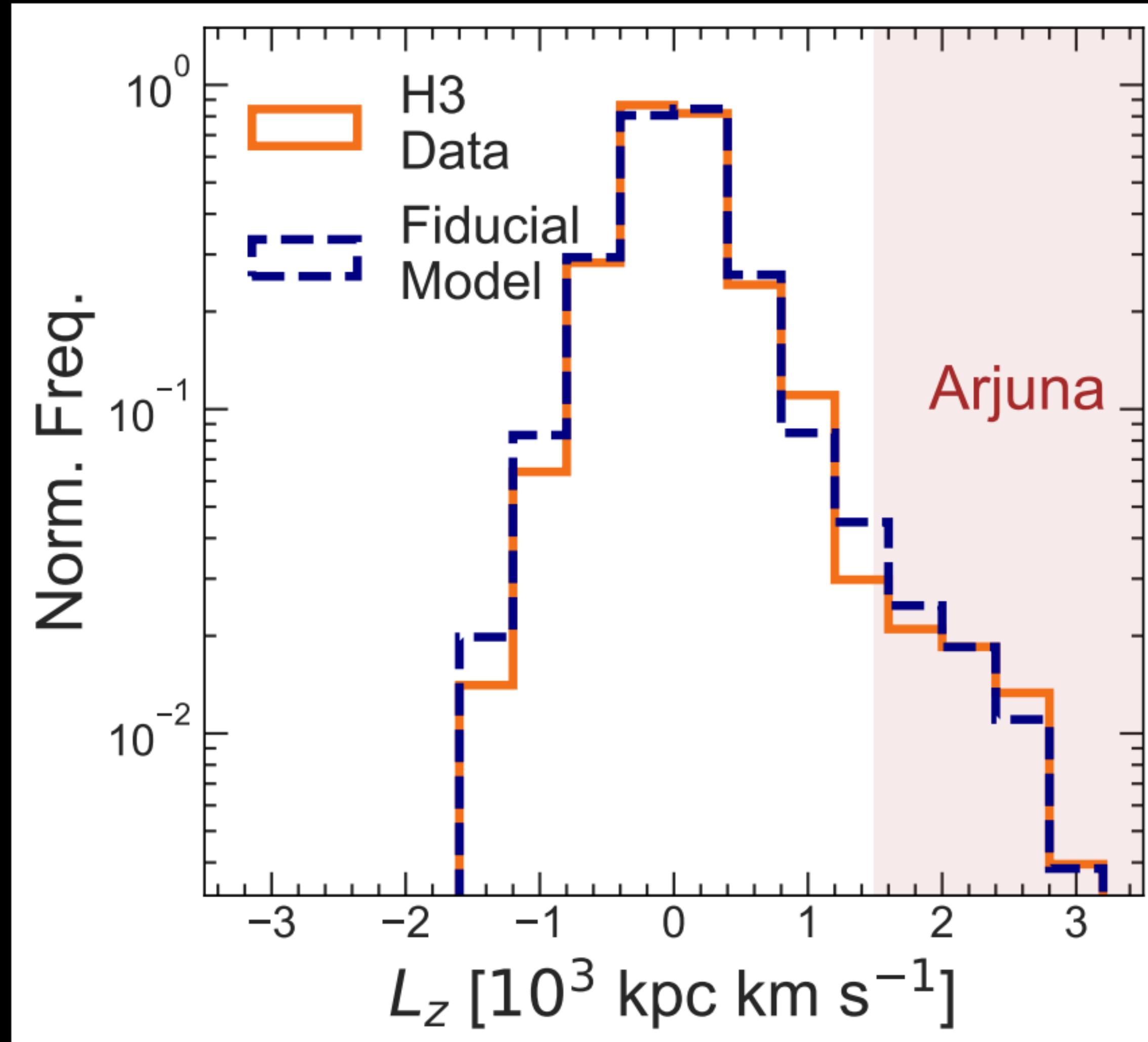


The dark-matter halo may be tilted due to ancient mergers

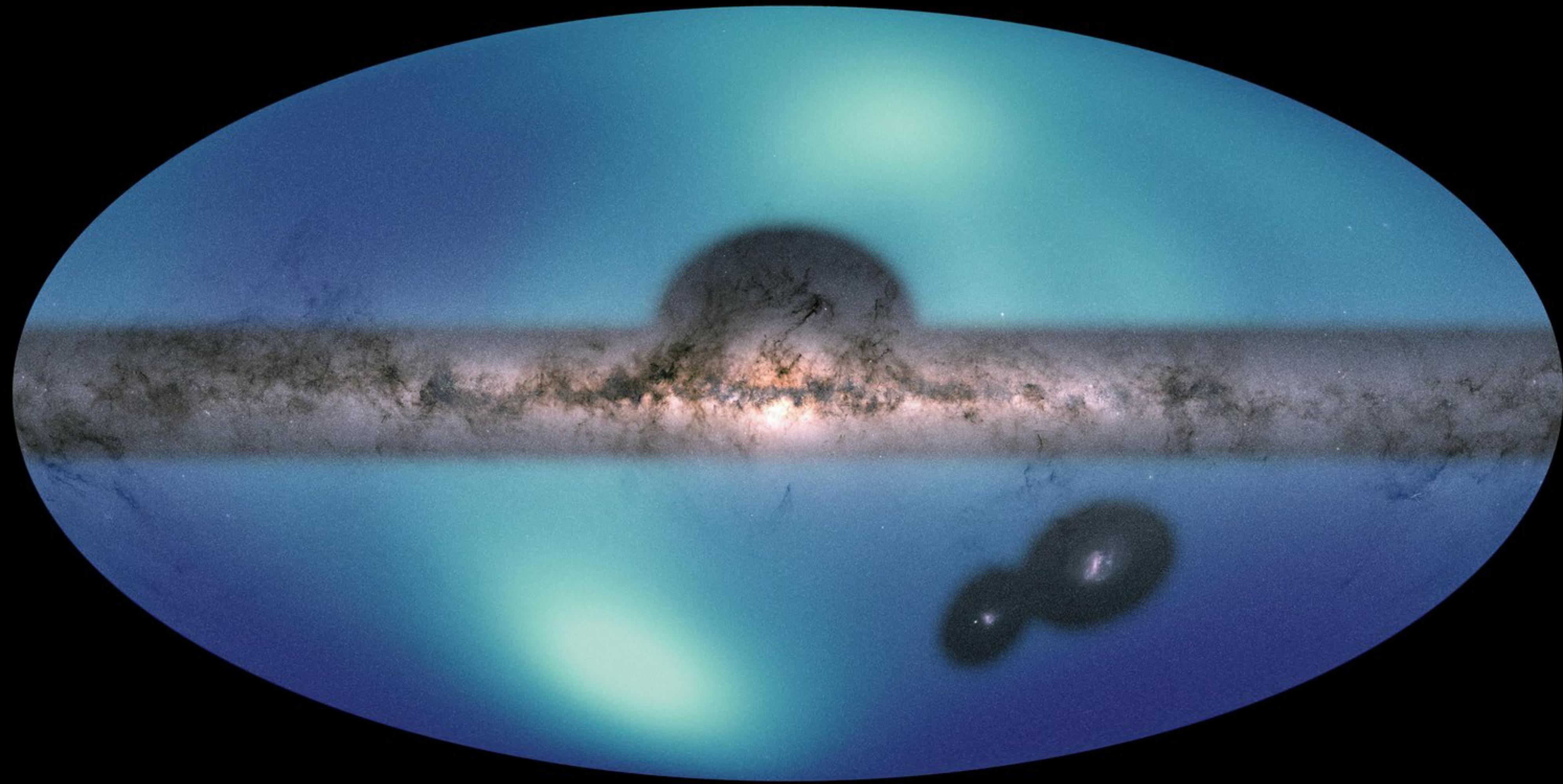


# The dark-matter halo may be tilted due to ancient mergers

Naidu et al., arXiv:2103.03251



# The outer halo of the Milky Way is highly asymmetric



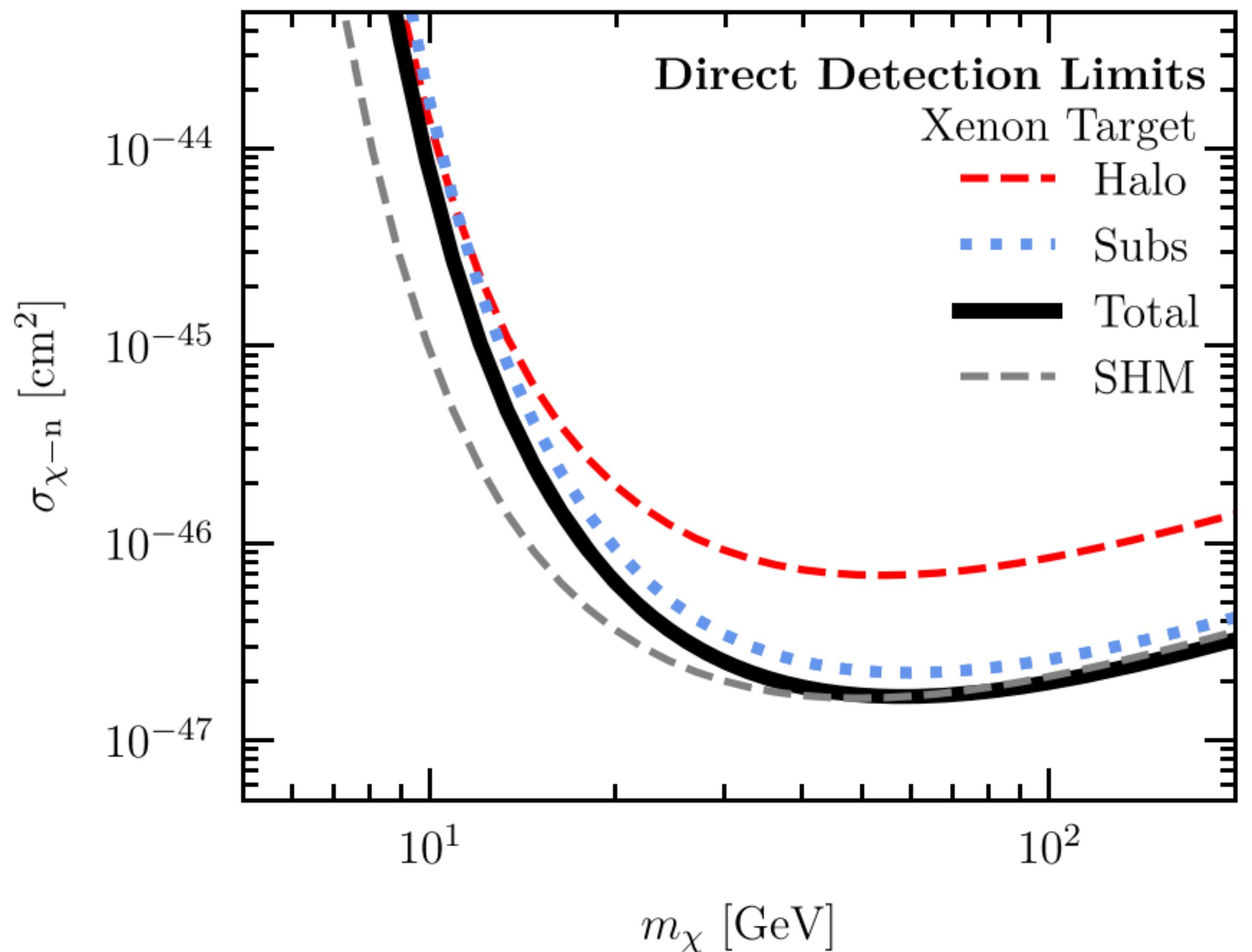
Density map of Gaia/WISE-selected K giants between 60 kpc and 100 kpc      Conroy et al. (2021)

See also: Belokurov et al. (2019) | Garavito-Camargo et al. (2019, 2020) | Petersen & Penarrubia (2020)



# DM direct detection rates are affected by velocity substructures

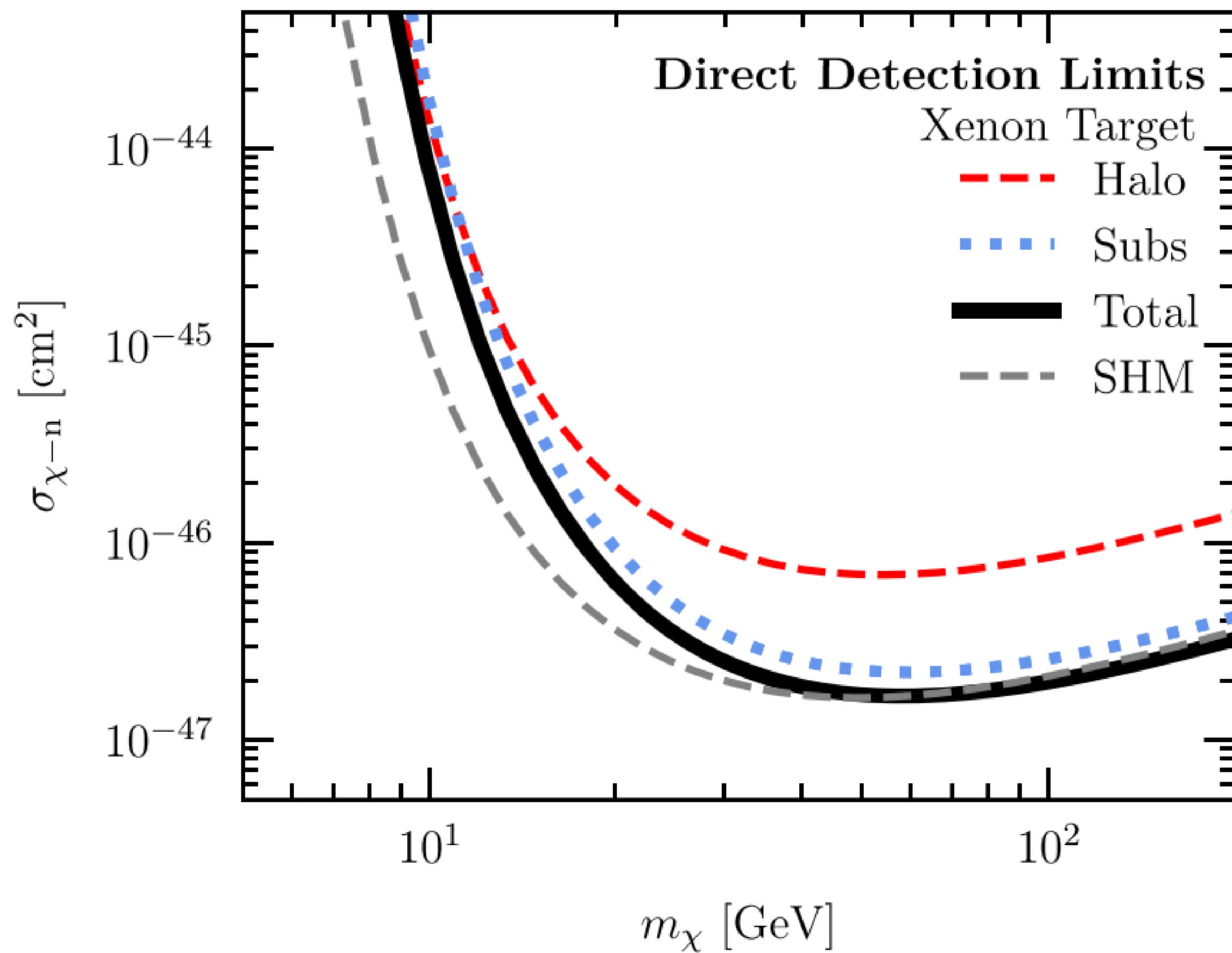
Necib et al. (2019, Gaia-Sausage-Enceladus)



see also Evans et al. (2019), O'Hare et al. (2020)

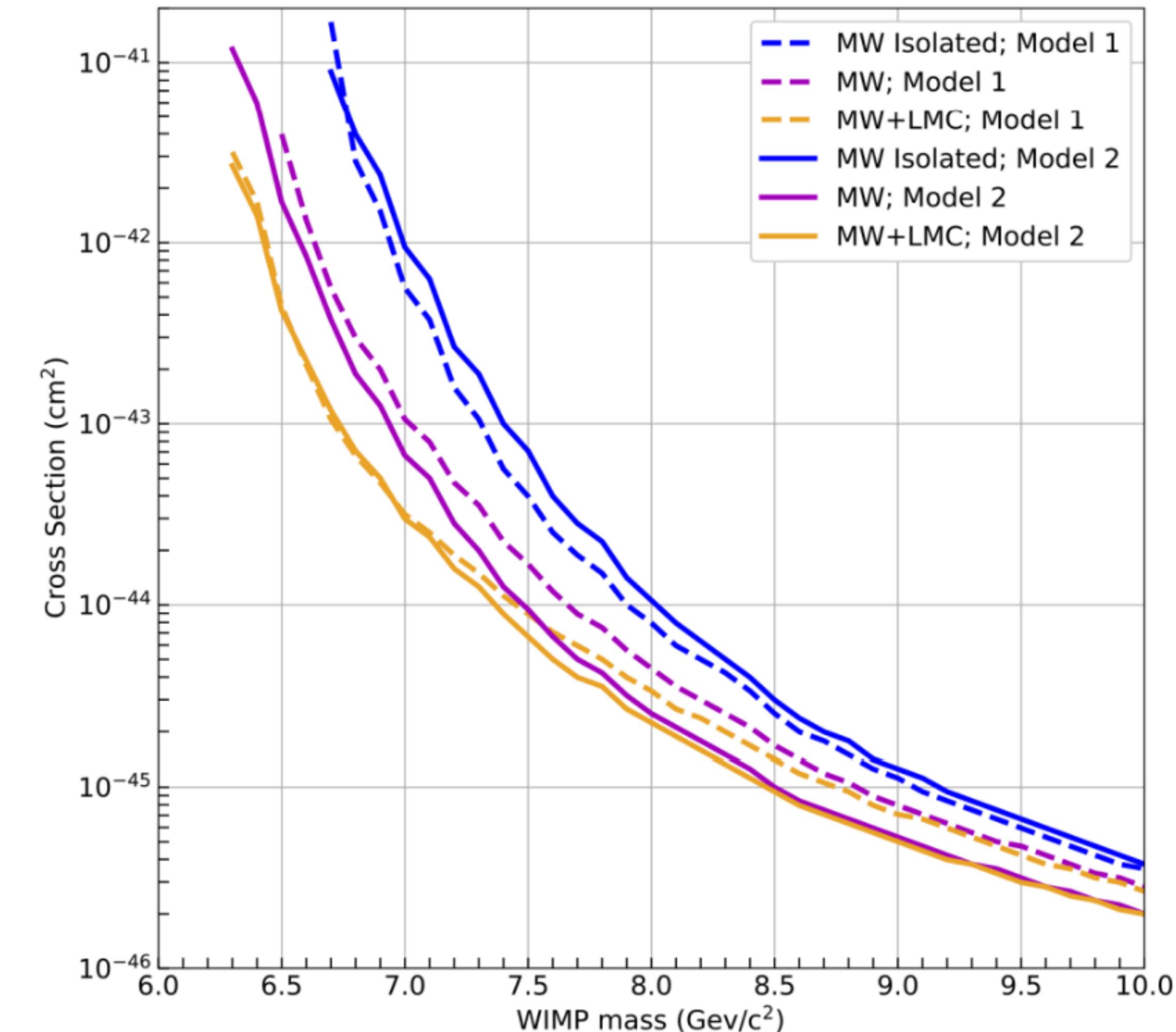
# DM direct detection rates are affected by velocity substructures

Necib et al. (2019, Gaia-Sausage-Enceladus)



see also Evans et al. (2019), O'Hare et al. (2020)

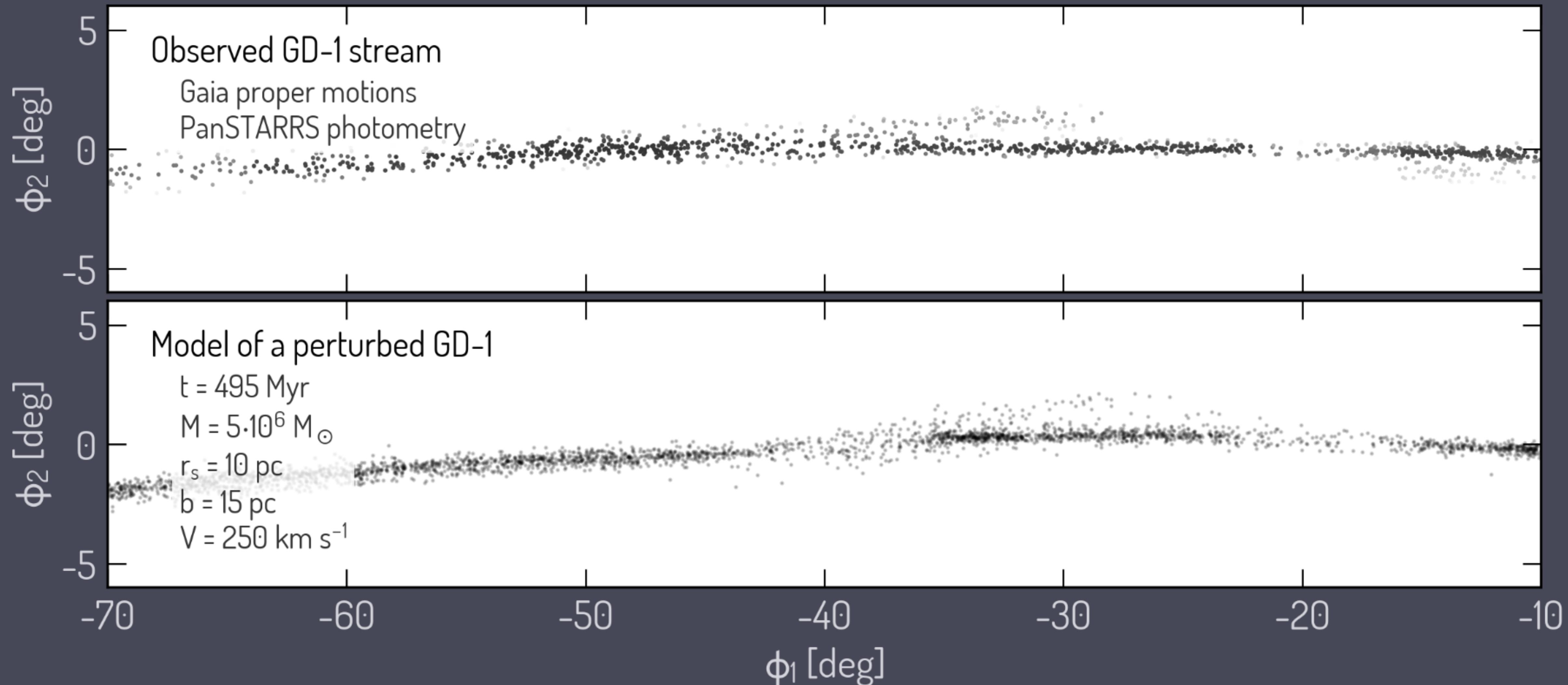
Besla et al. (2019, Large Magellanic Cloud)



Stellar streams are gravitational  
antennae sensitive to impacts  
of dark-matter substructure

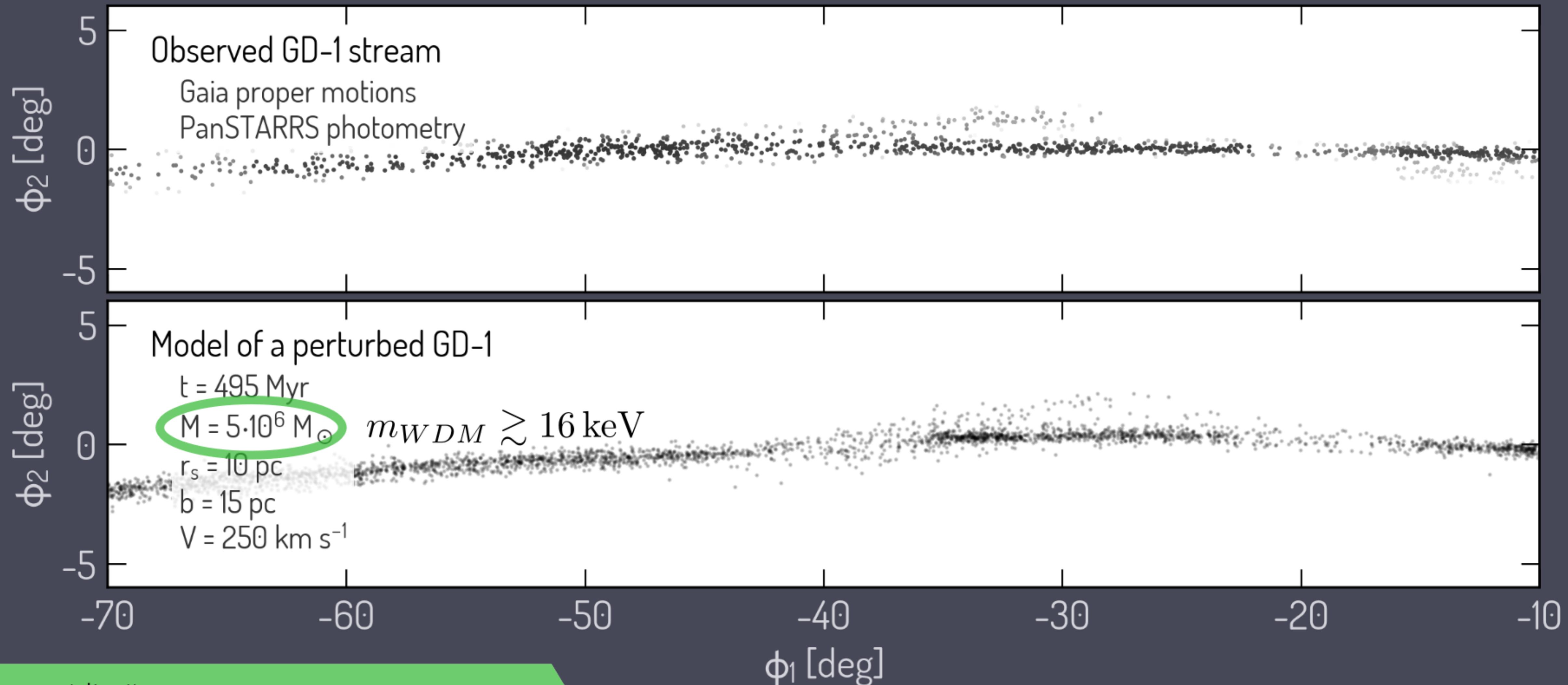
# Possible first detection of a dark dark-matter subhalo

Bonaca et al. (2019)



# Possible first detection of a dark dark-matter subhalo

Bonaca et al. (2019)

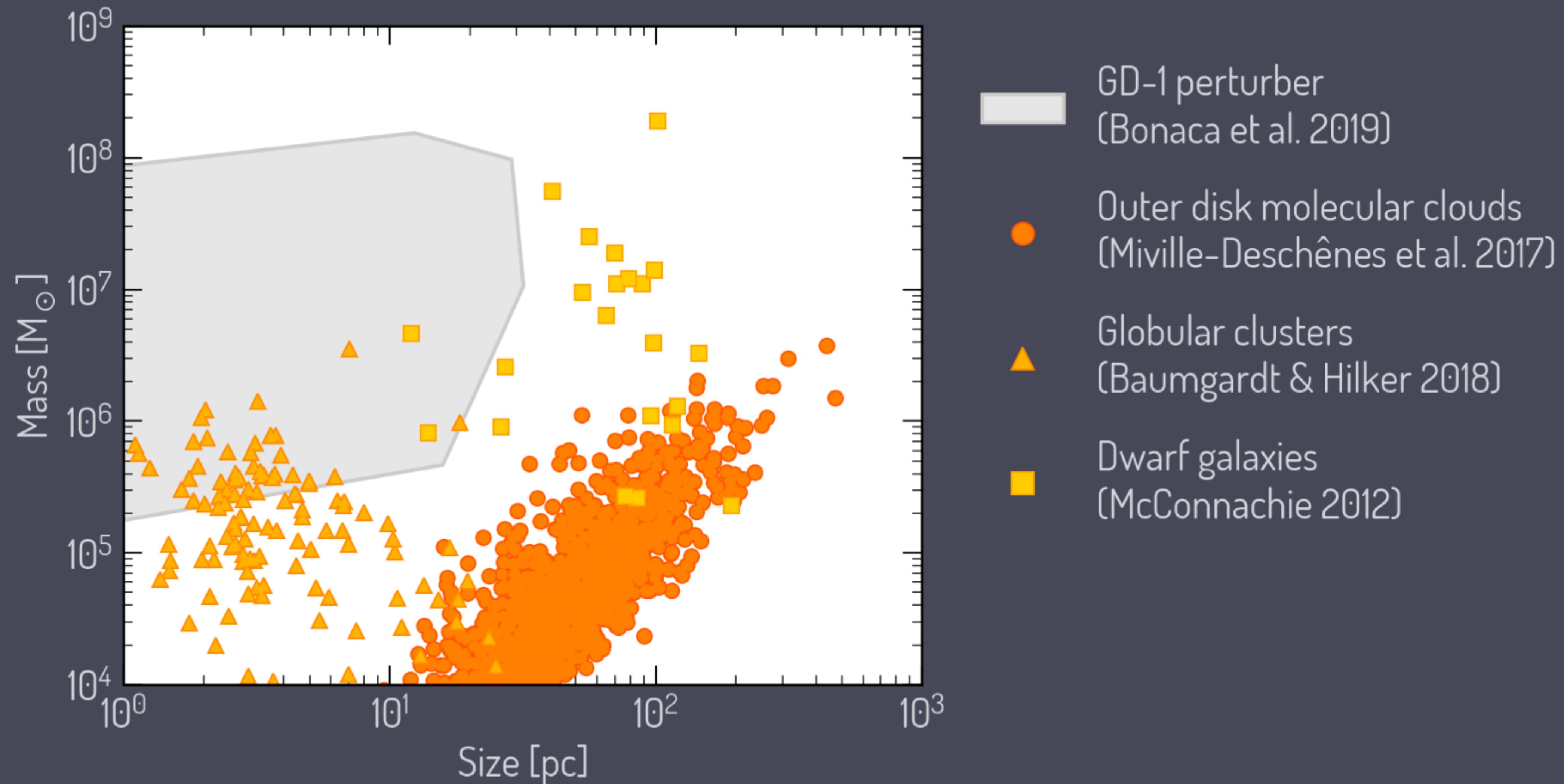


Current limit

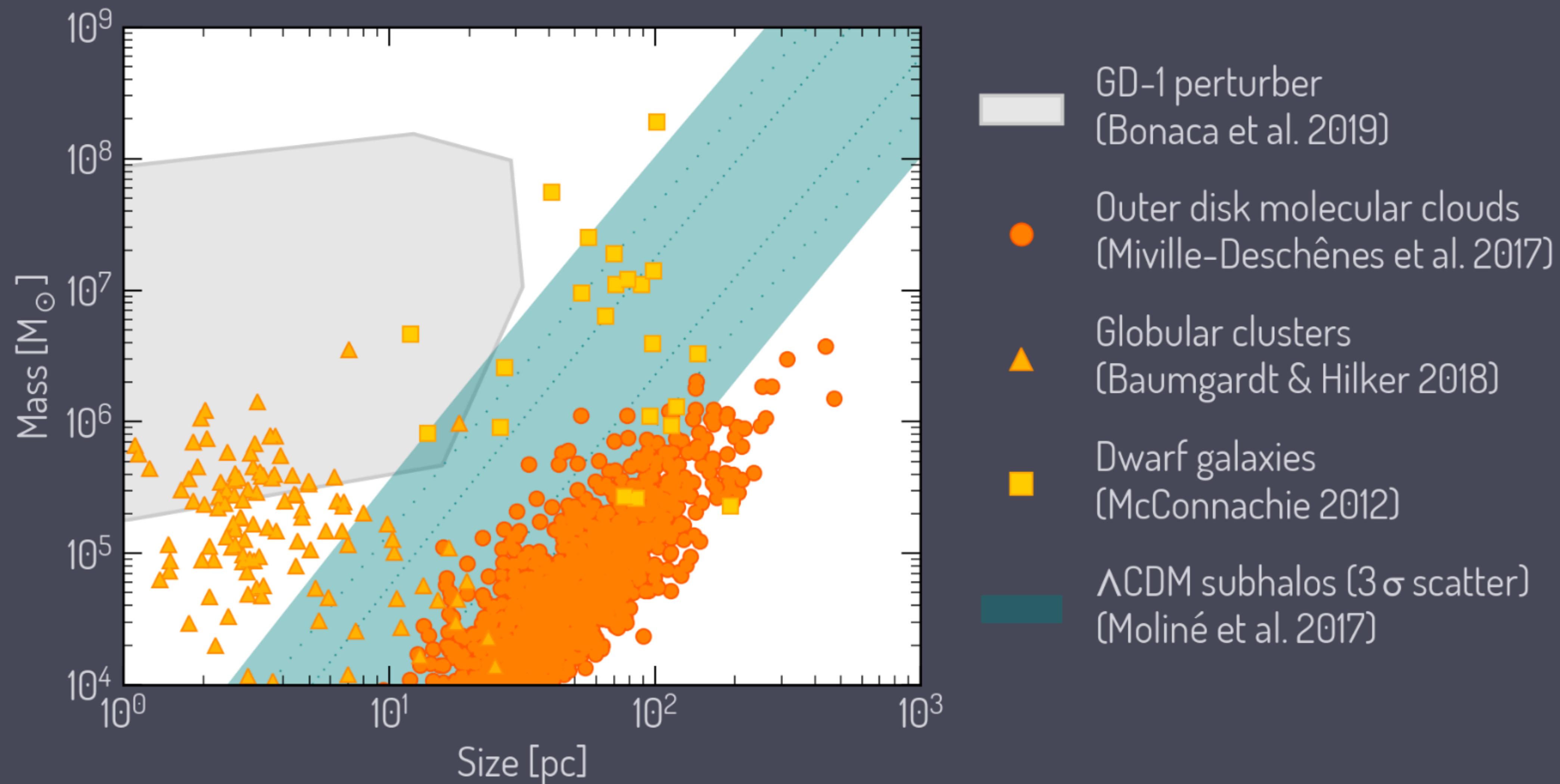
(Nadler et al. 2020)

$m_{WDM} \gtrsim 6.5$  keV

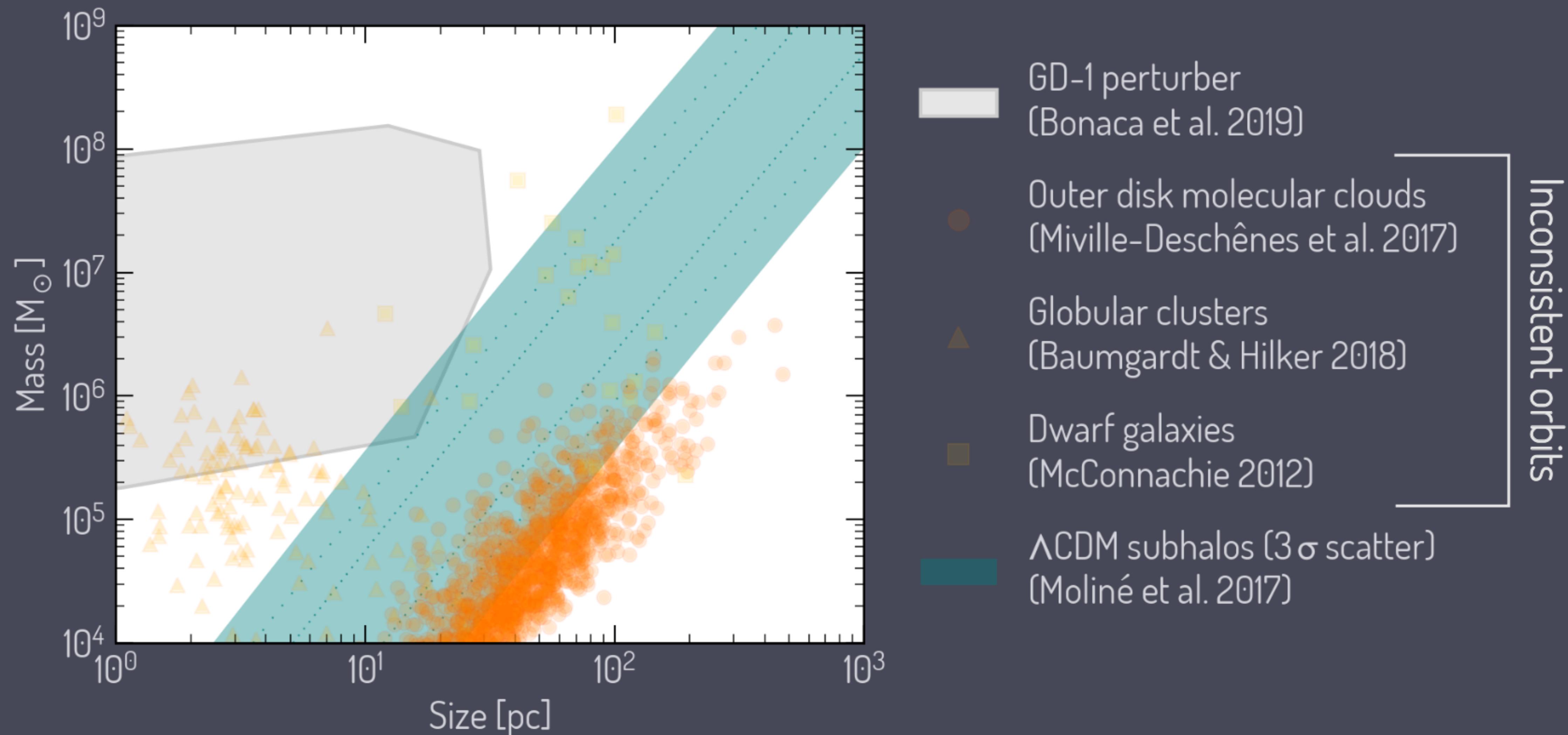
# Stream impact sites can constrain the structure of DM subhalos



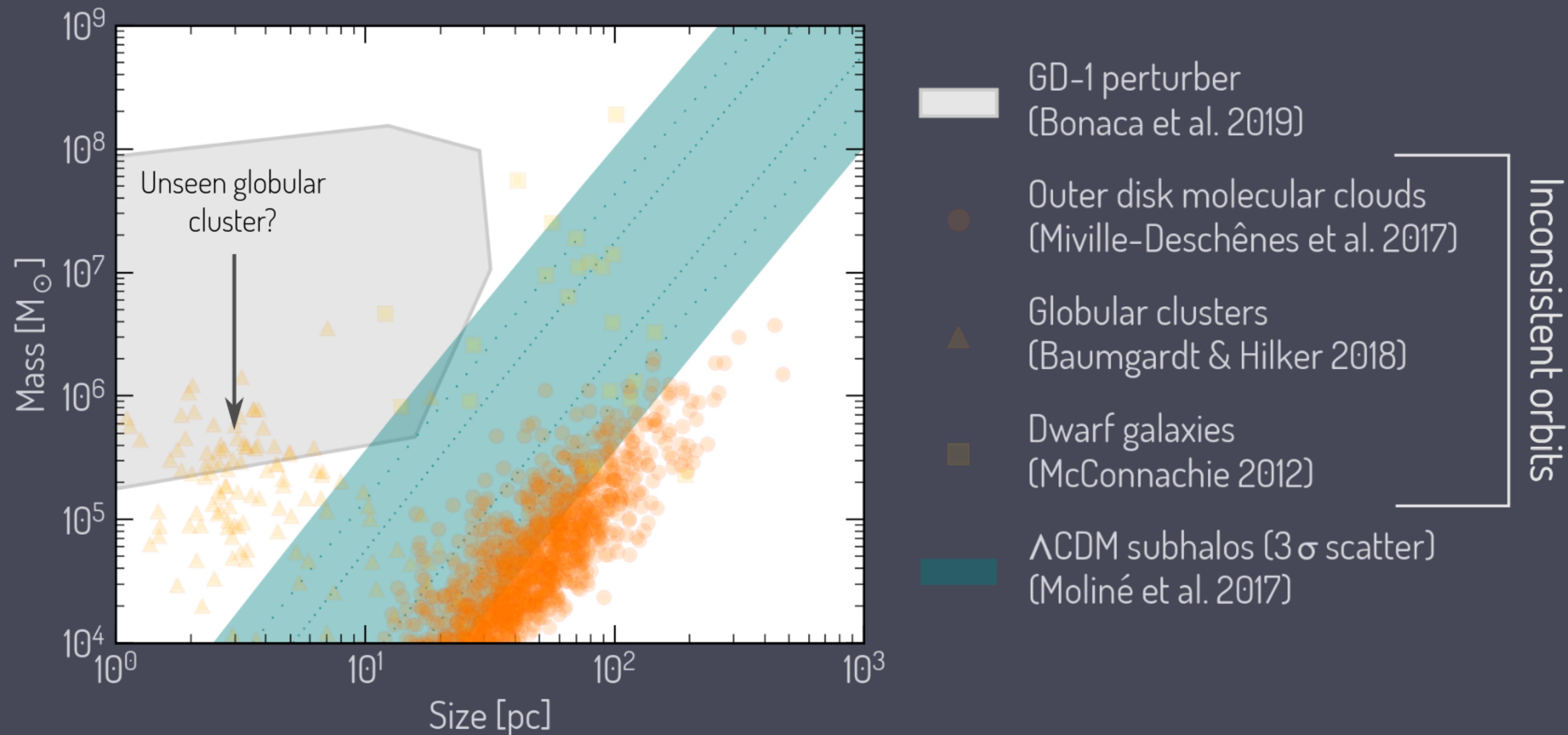
# Stream impact sites can constrain the structure of DM subhalos



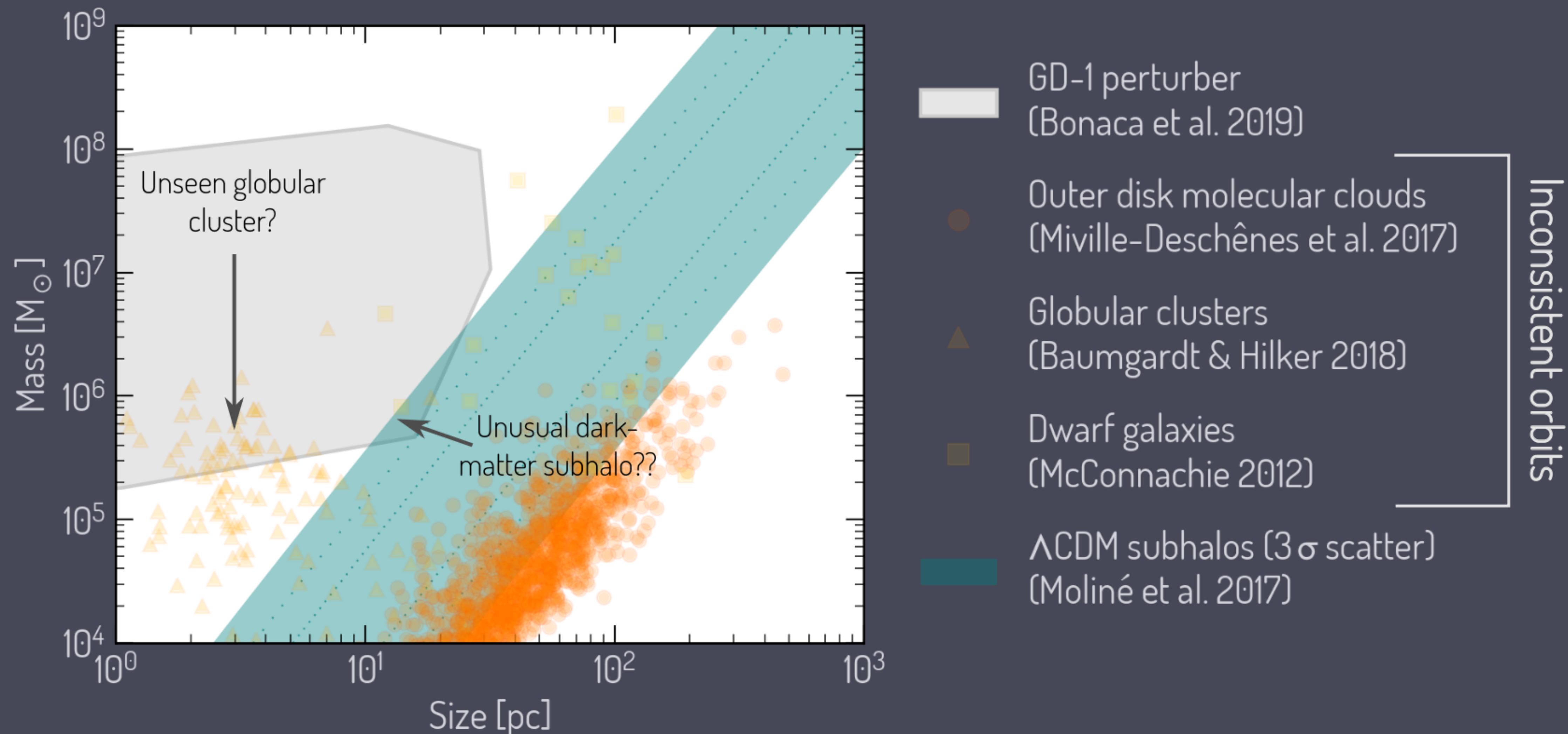
# Stream impact sites can constrain the structure of DM subhalos



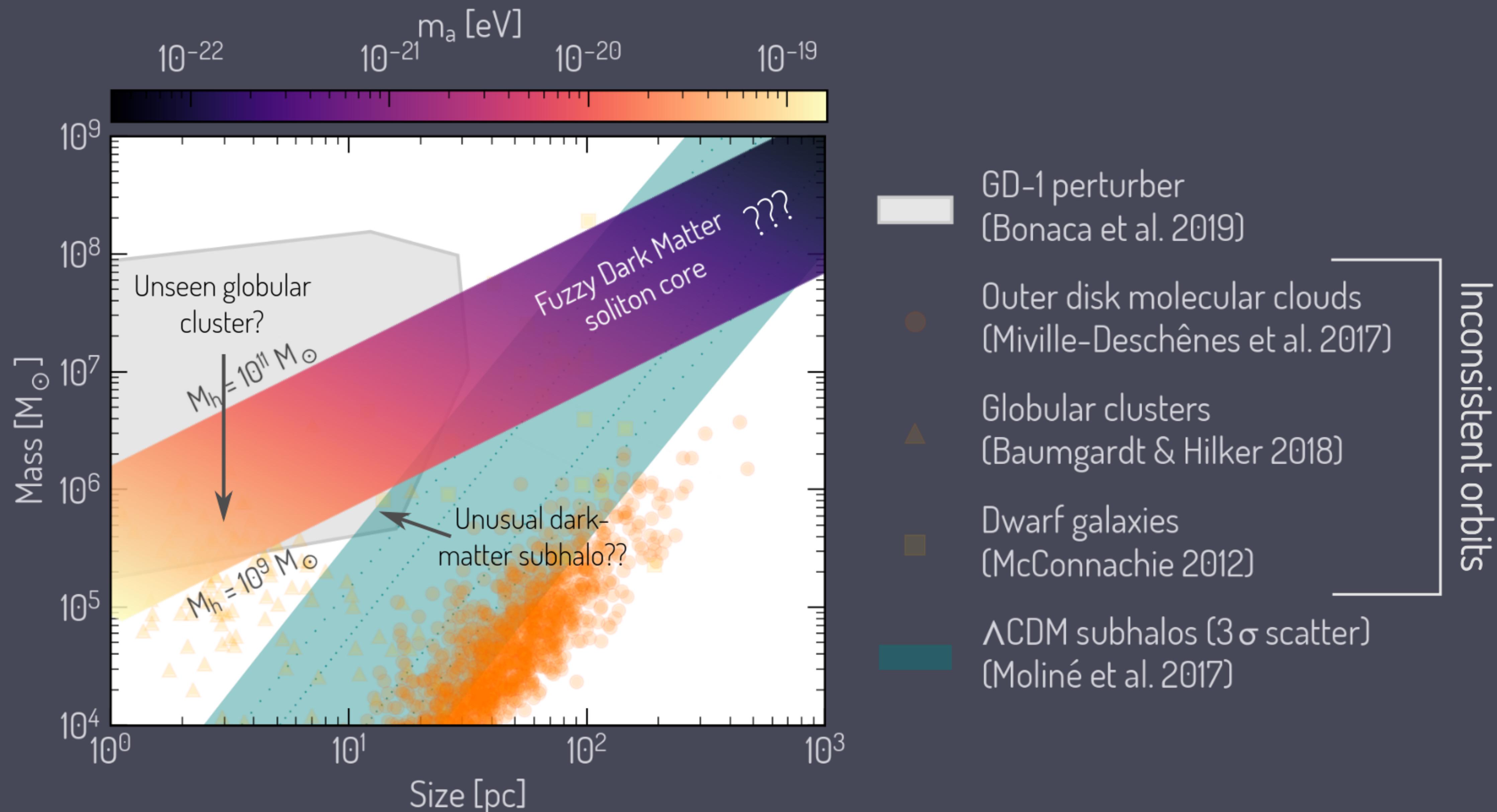
# Stream impact sites can constrain the structure of DM subhalos



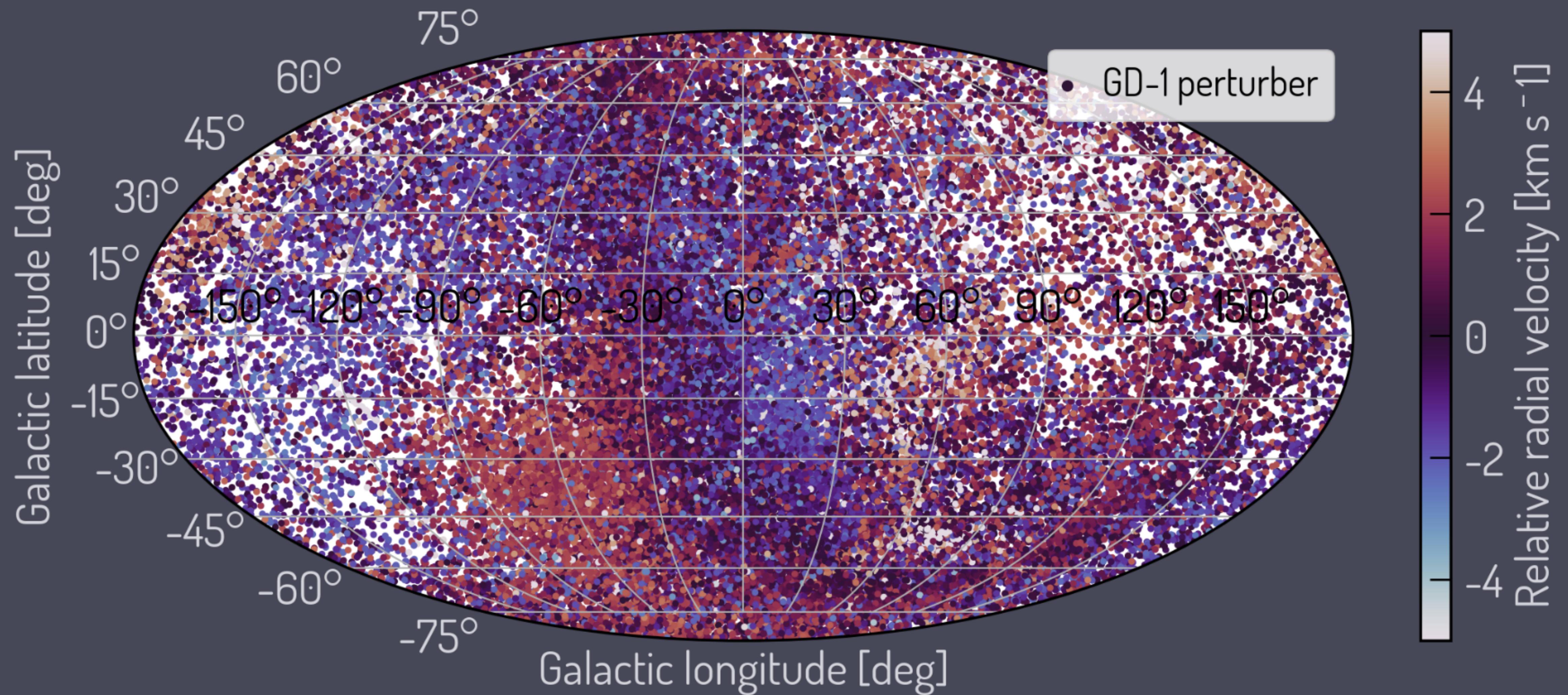
# Stream impact sites can constrain the structure of DM subhalos



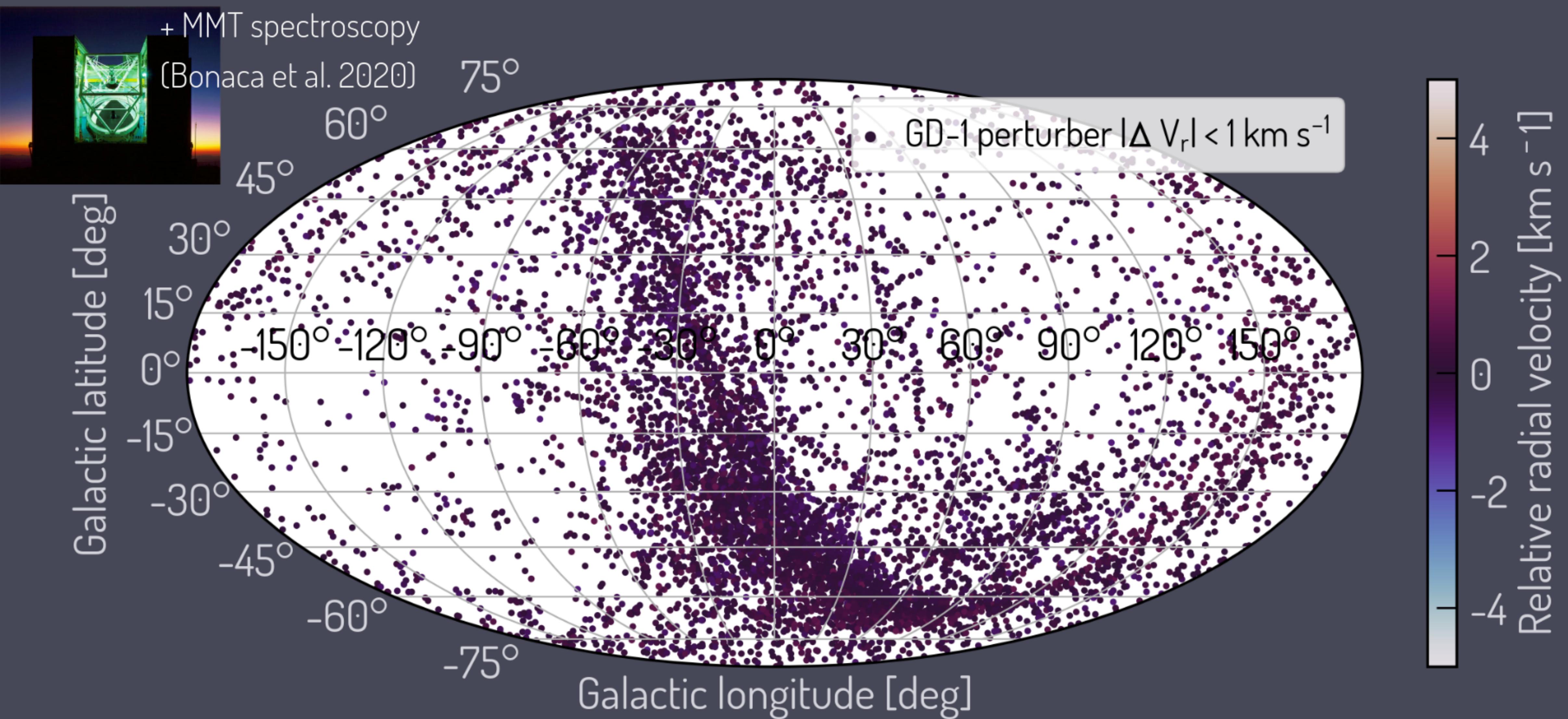
# Stream impact sites can constrain the structure of DM subhalos



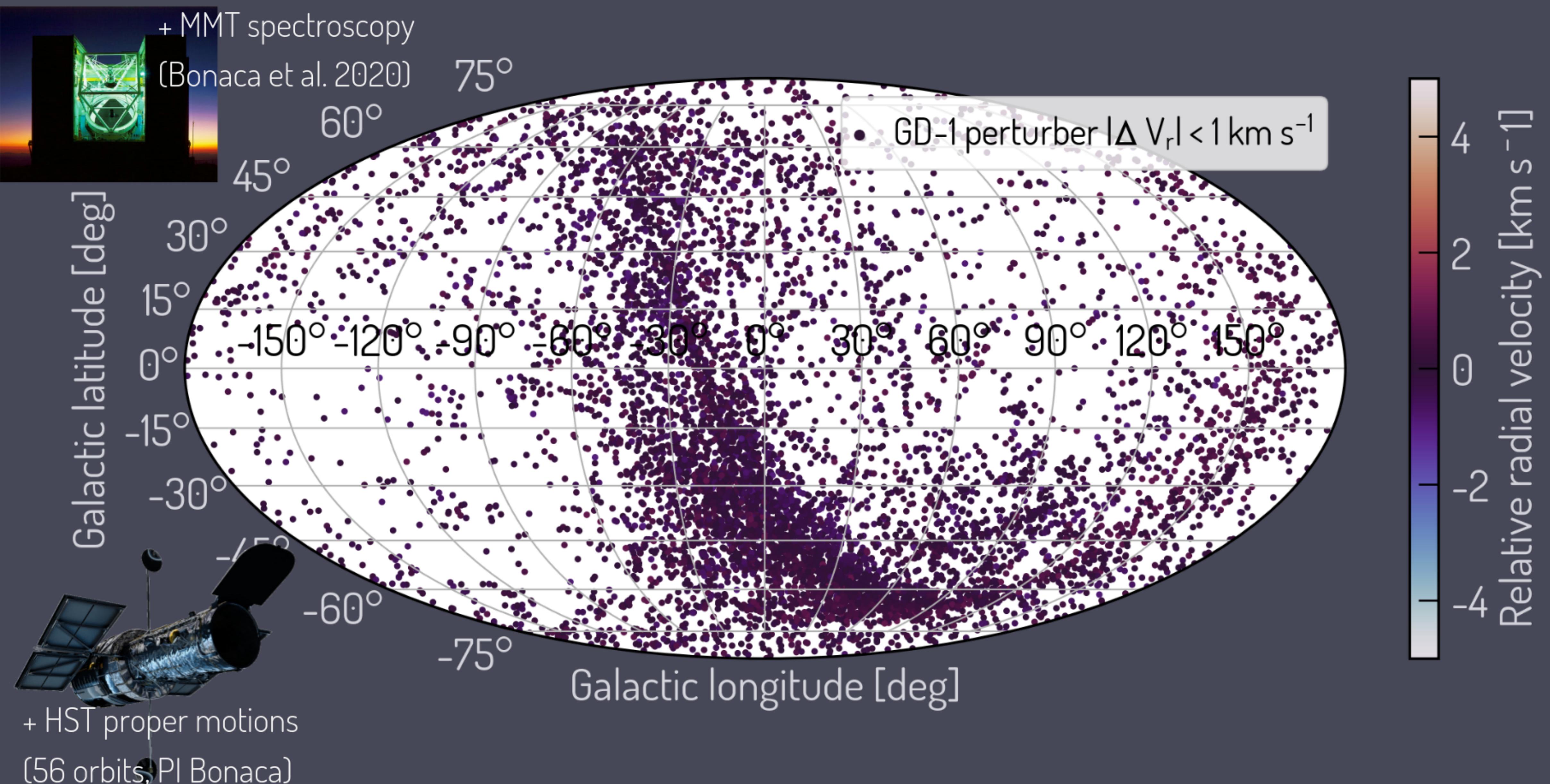
# Precision dynamics of streams can localize dark-matter structures



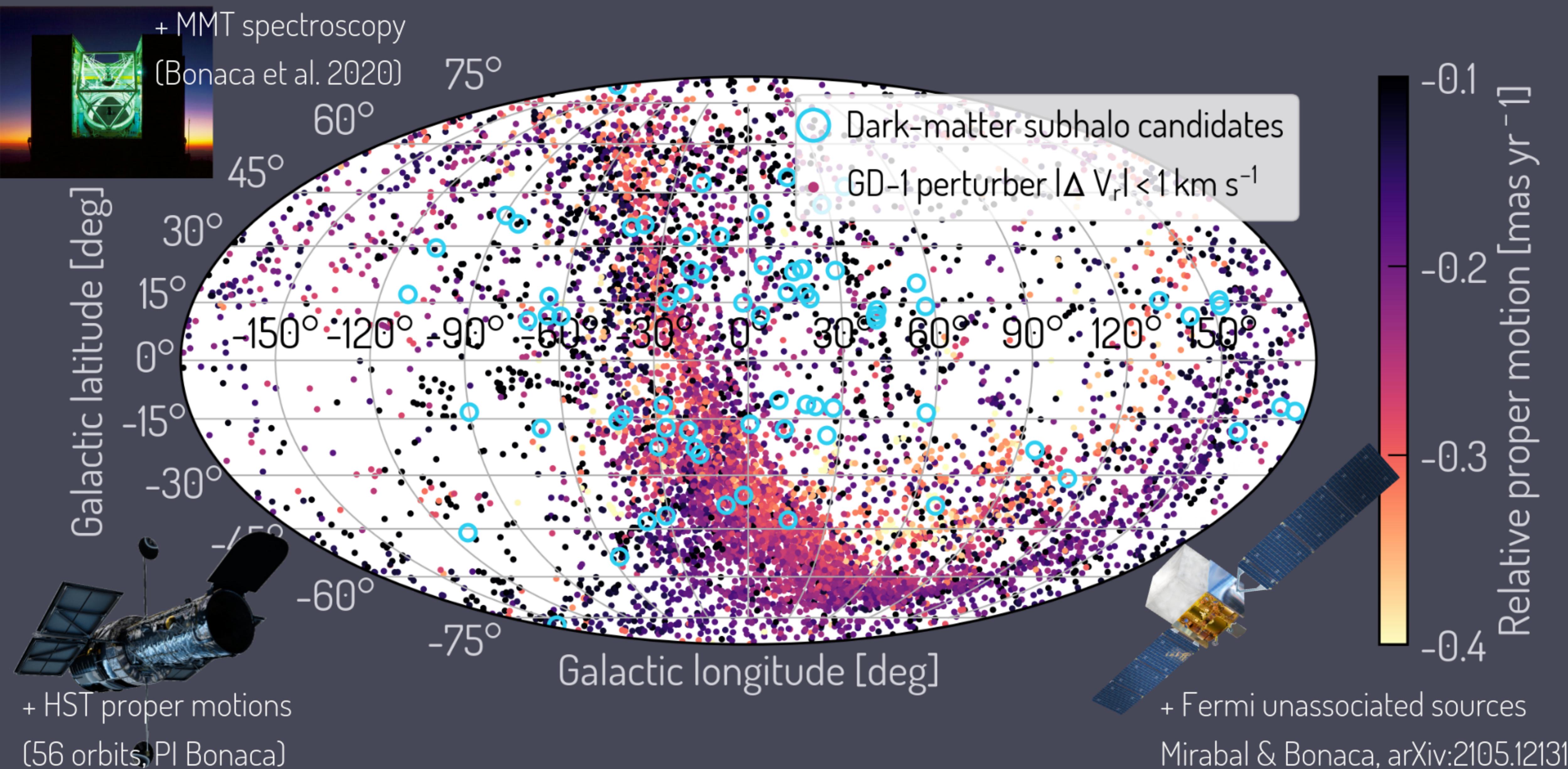
# Precision dynamics of streams can localize dark-matter structures



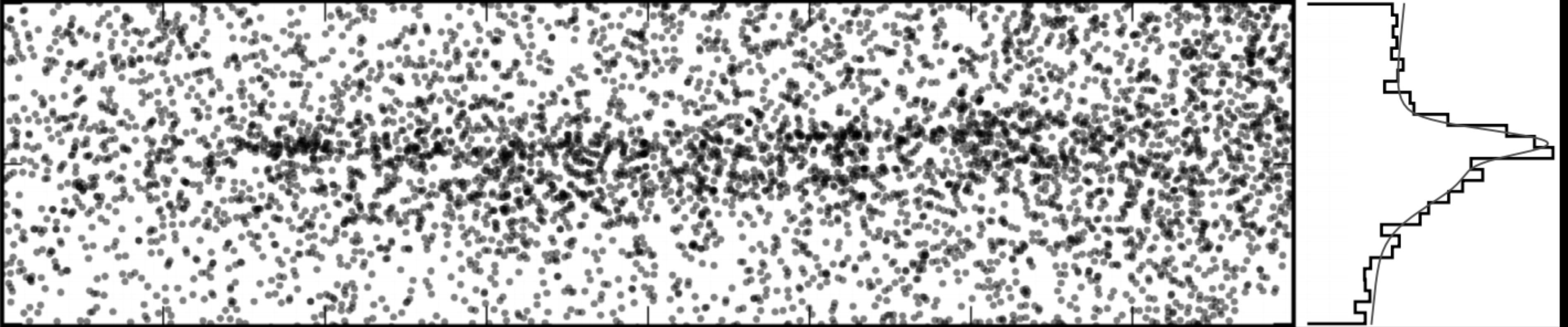
# Precision dynamics of streams can localize dark-matter structures



# Precision dynamics of streams can localize dark-matter structures

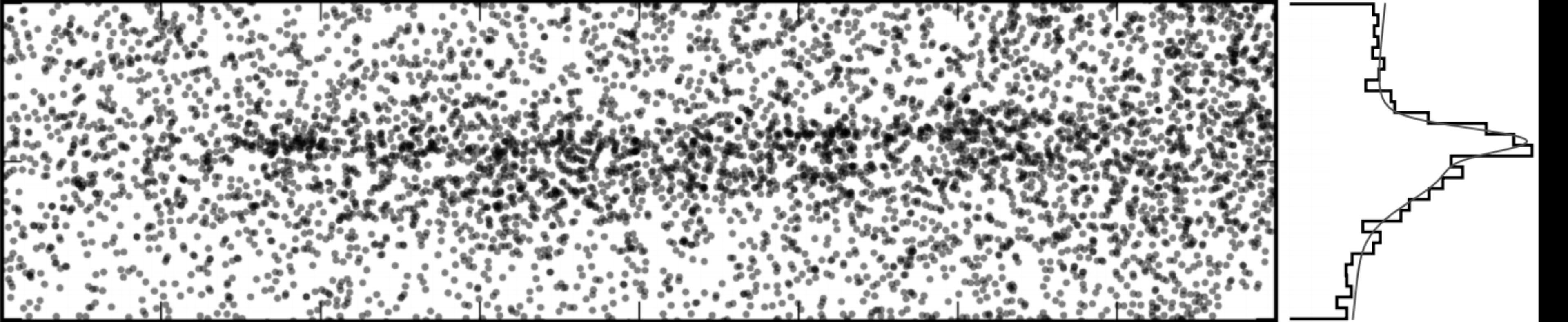


Stream  
perturbations  
are common

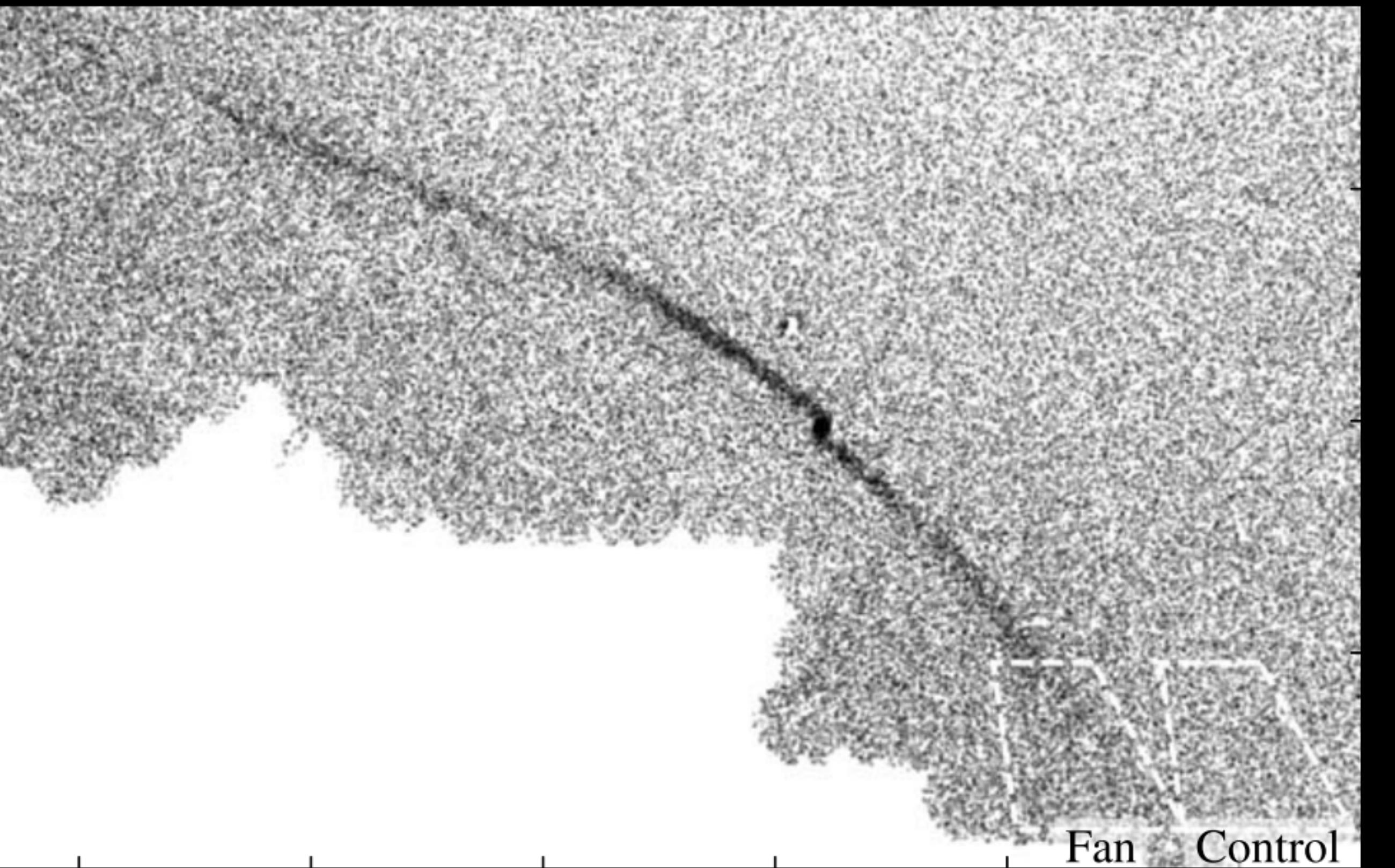


"Multiple Components of the Jhelum Stellar Stream" Bonaca et al. (2019)

Stream  
perturbations  
are common

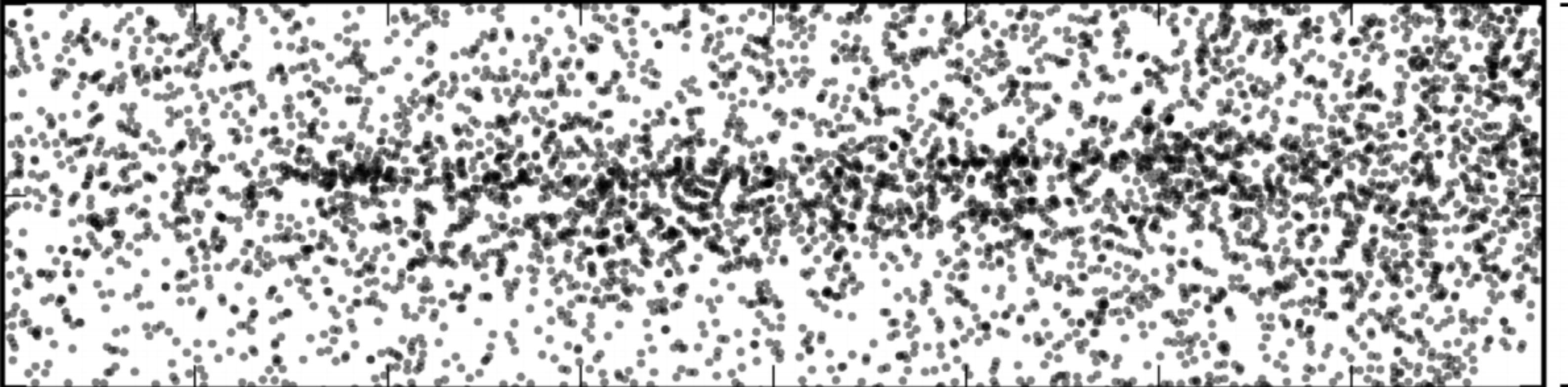


"Multiple Components of the Jhelum Stellar Stream" Bonaca et al. (2019)

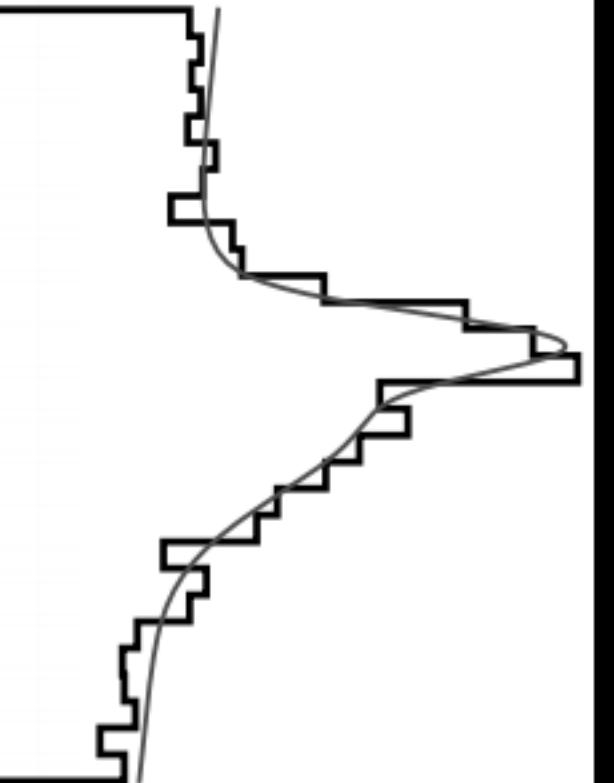


"Variations in the Width, Density, and Direction of the Palomar 5 Tidal Tails"  
Bonaca, Pearson, Price-Whelan et al. (2020)

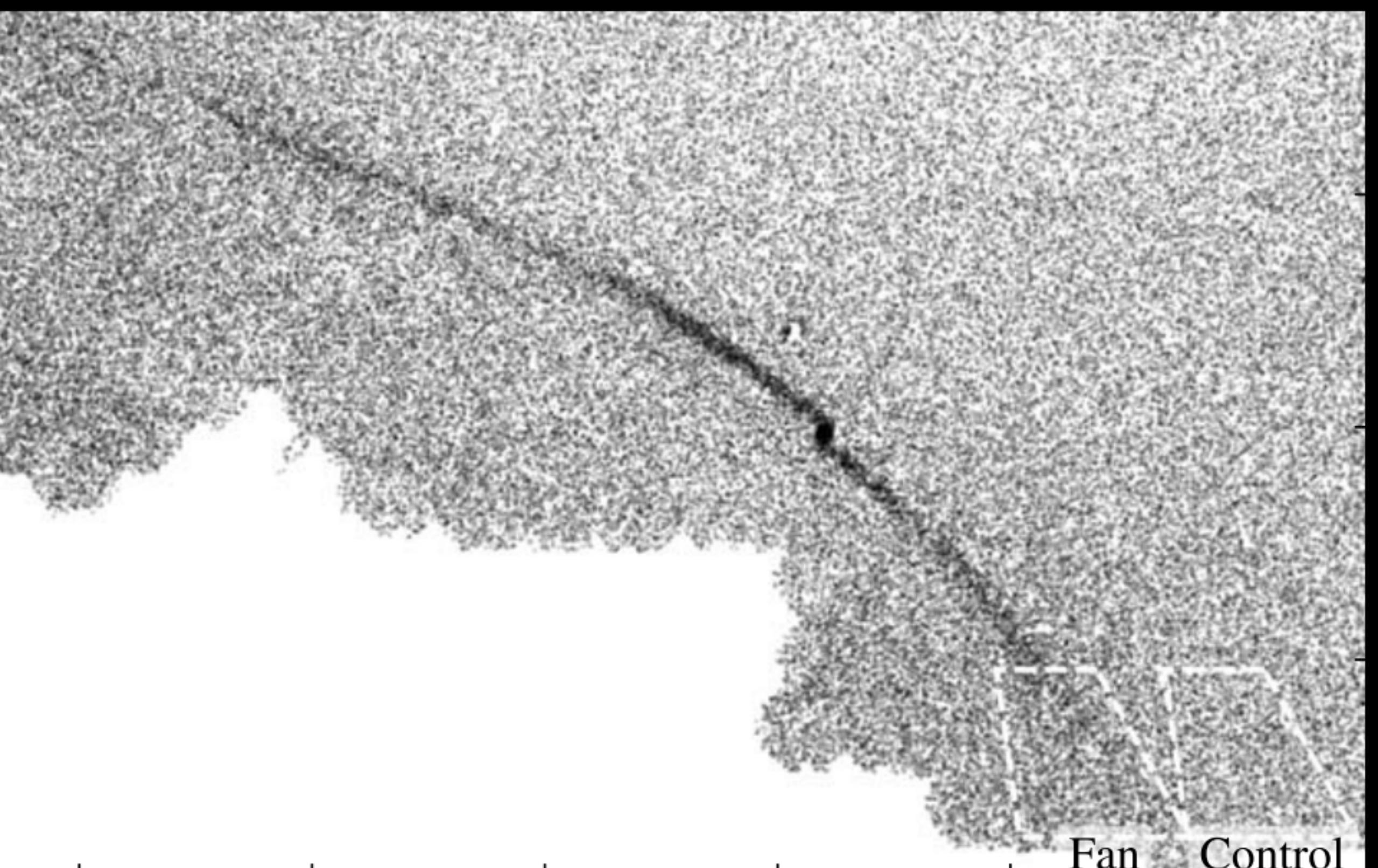
# Stream perturbations are common



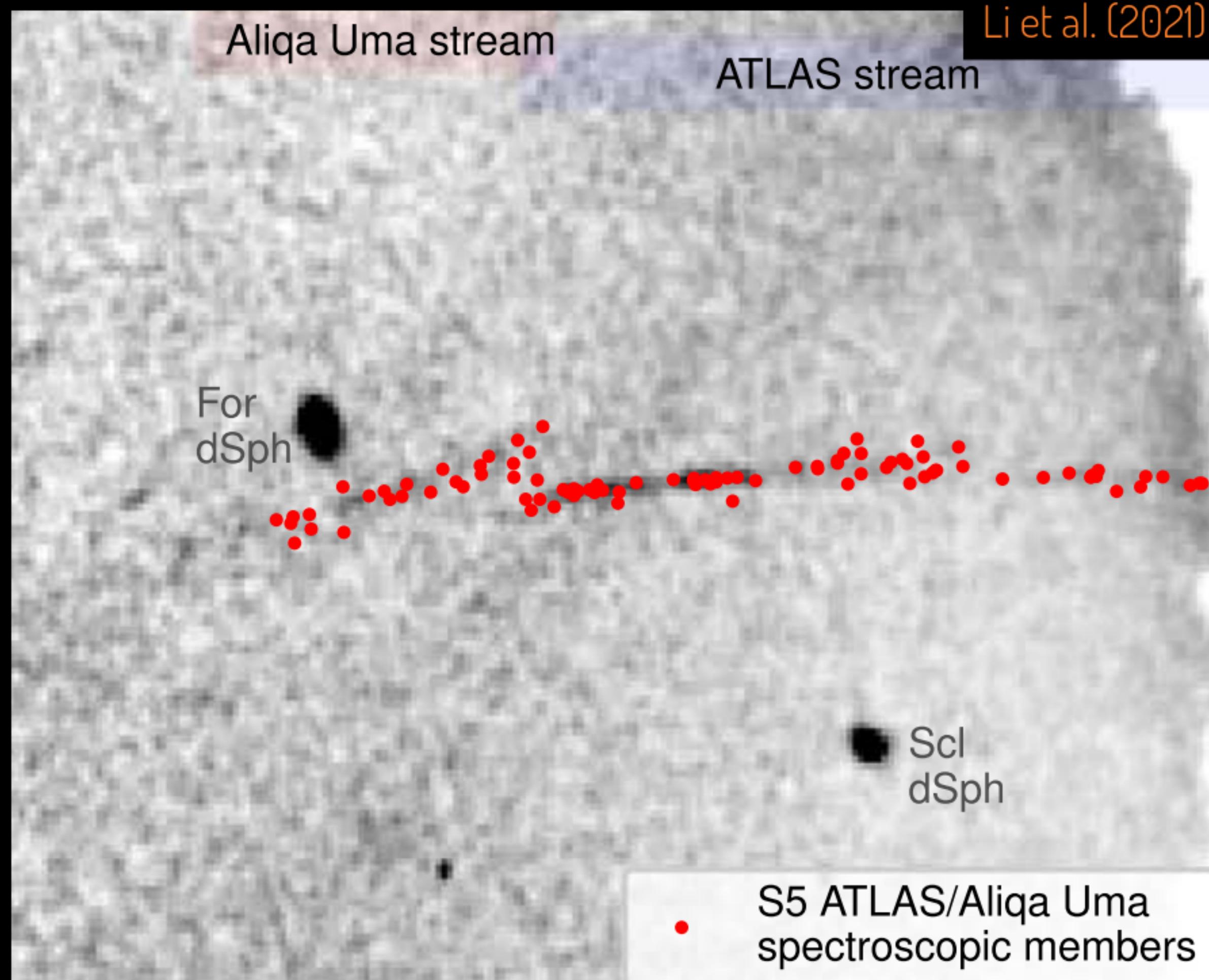
"Multiple Components of the Jhelum Stellar Stream" Bonaca et al. (2019)



"Broken into Pieces: ATLAS and Aliqa Uma as One Single Stream"



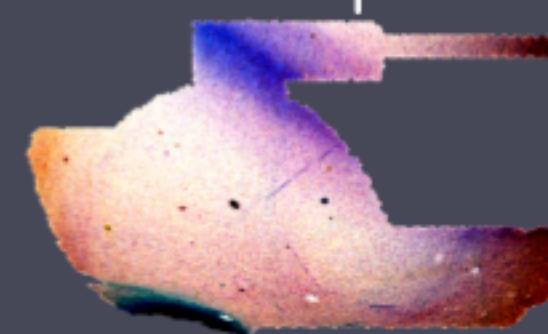
"Variations in the Width, Density, and Direction of the Palomar 5 Tidal Tails"  
Bonaca, Pearson, Price-Whelan et al. (2020)



# The statistics of stream gaps can limit the DM particle mass

[1] streams in the LSST footprint:

13 known (Shipp et al. 2018)



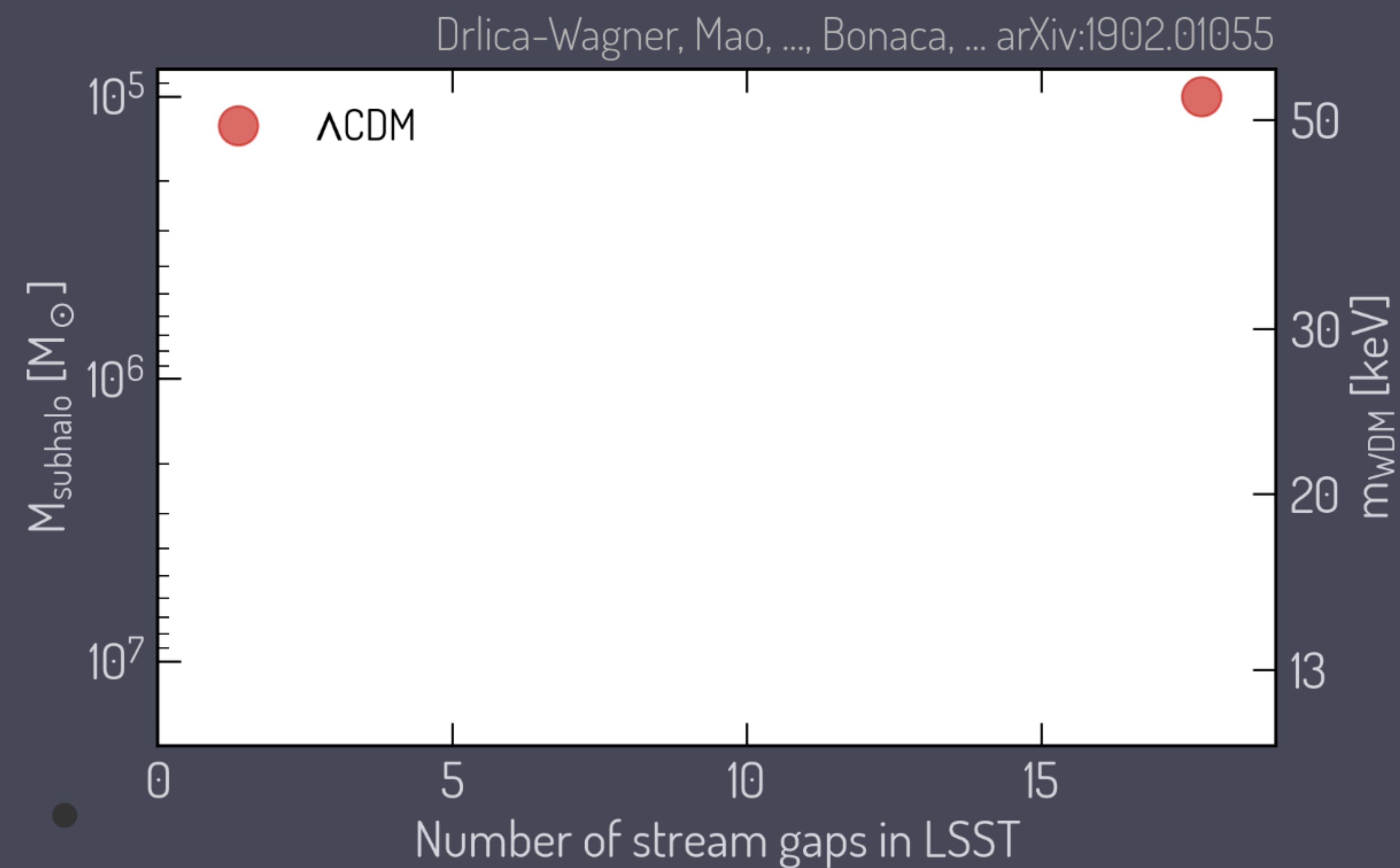
[2] minimum detectable subhalo:

$\gtrsim 10^5 M_\odot$   
(Nora Shipp)



[3] subhalo encounter rates:

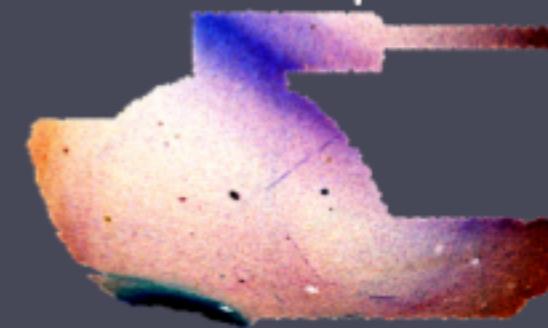
N-body + disk (Erkal et al. 2016)



# The statistics of stream gaps can limit the DM particle mass

[1] streams in the LSST footprint:

13 known (Shipp et al. 2018)



[2] minimum detectable subhalo:

$\gtrsim 10^5 M_\odot$   
(Nora Shipp)

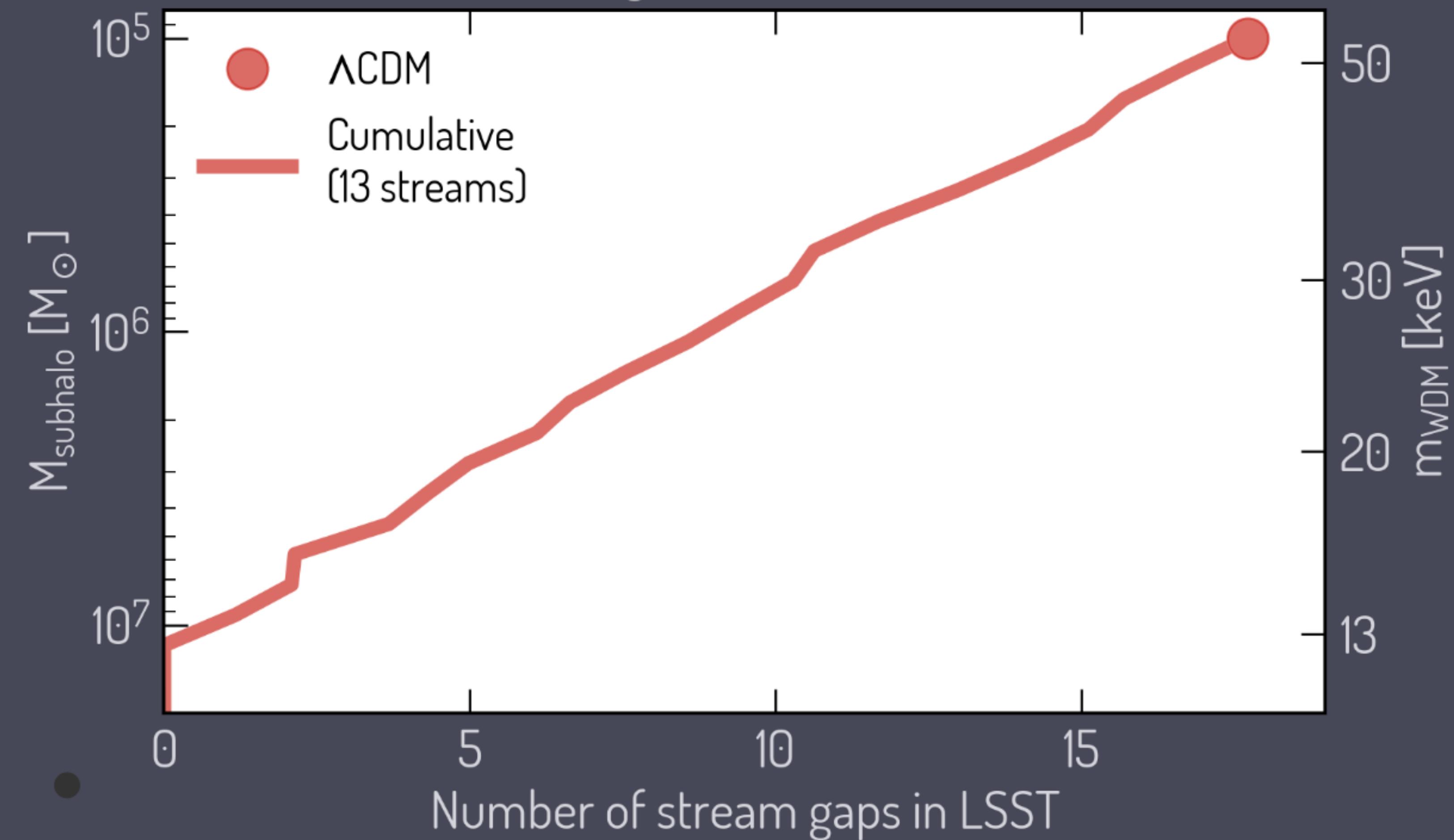


[3] subhalo encounter rates:

N-body + disk (Erkal et al. 2016)



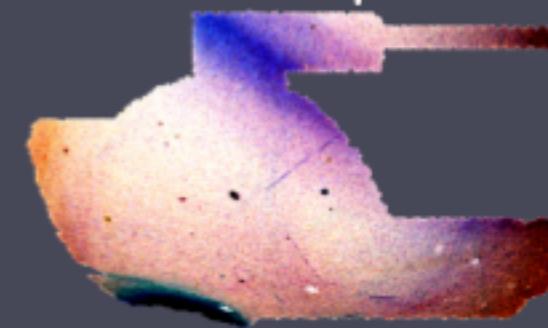
Drlica-Wagner, Mao, ..., Bonaca, ... arXiv:1902.01055



# The statistics of stream gaps can limit the DM particle mass

[1] streams in the LSST footprint:

13 known (Shipp et al. 2018)



[2] minimum detectable subhalo:

$\gtrsim 10^5 M_\odot$   
(Nora Shipp)



[3] subhalo encounter rates:

N-body + disk (Erkal et al. 2016)



Drlica-Wagner, Mao, ..., Bonaca, ... arXiv:1902.01055

