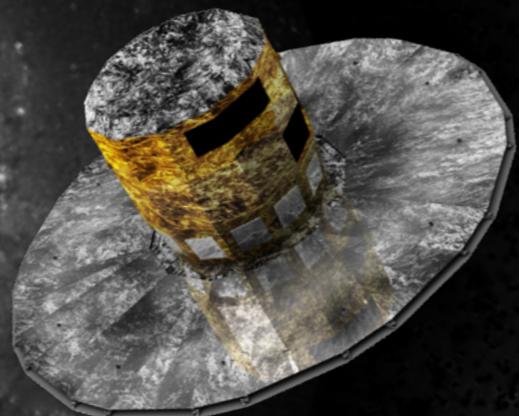


# Gaia's view of the Milky Way halo

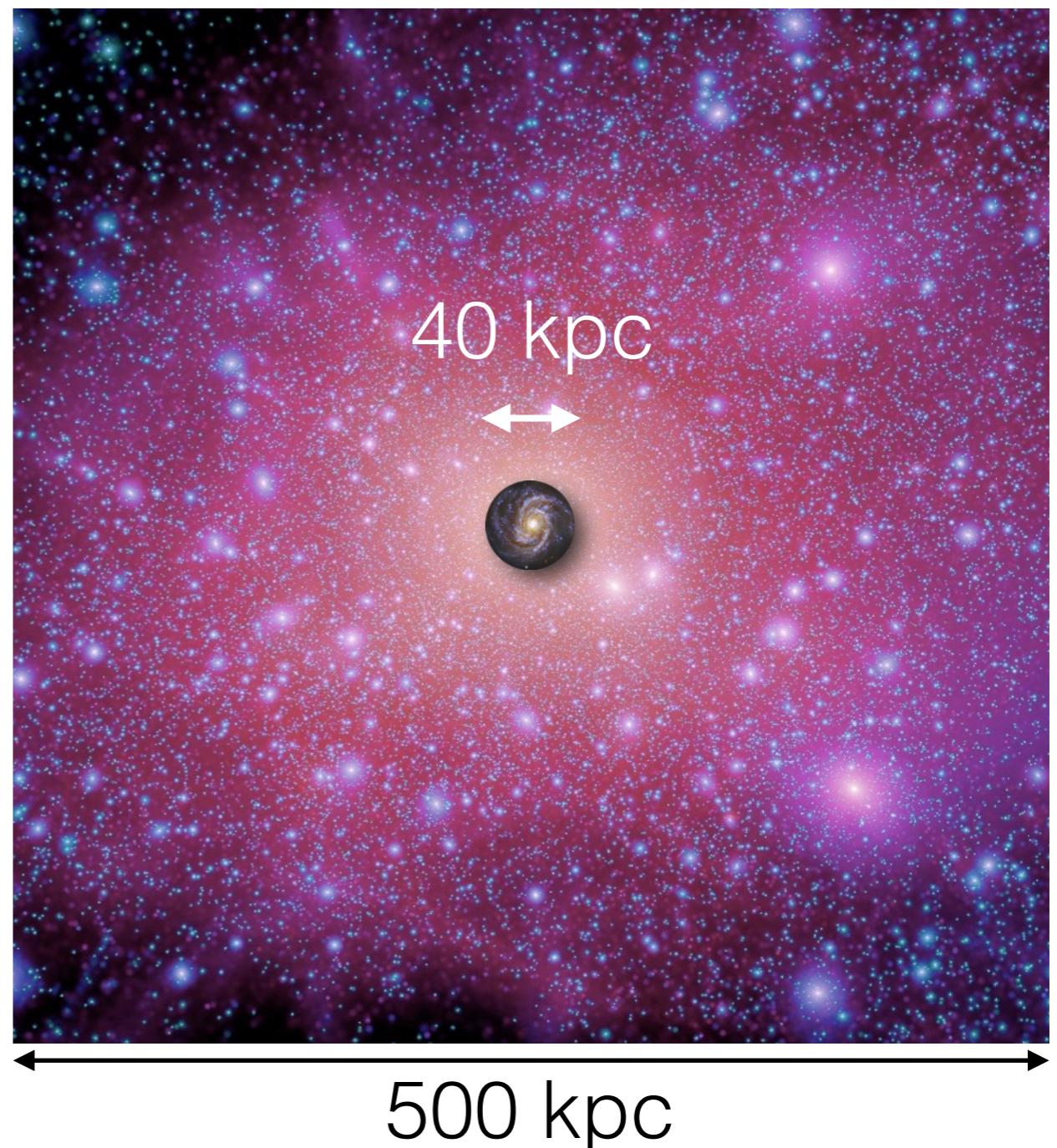
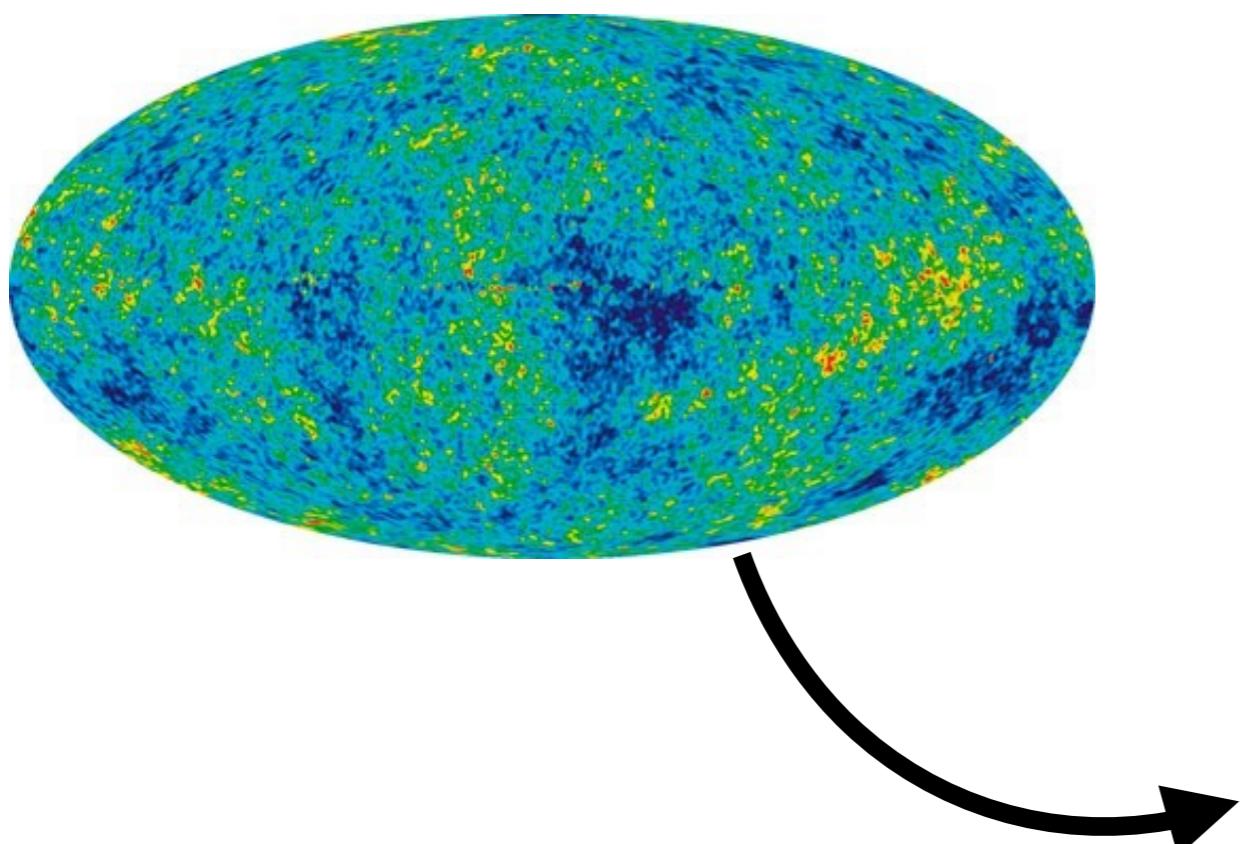


*Vasily Belokurov*  
*IoA, Cambridge, UK*

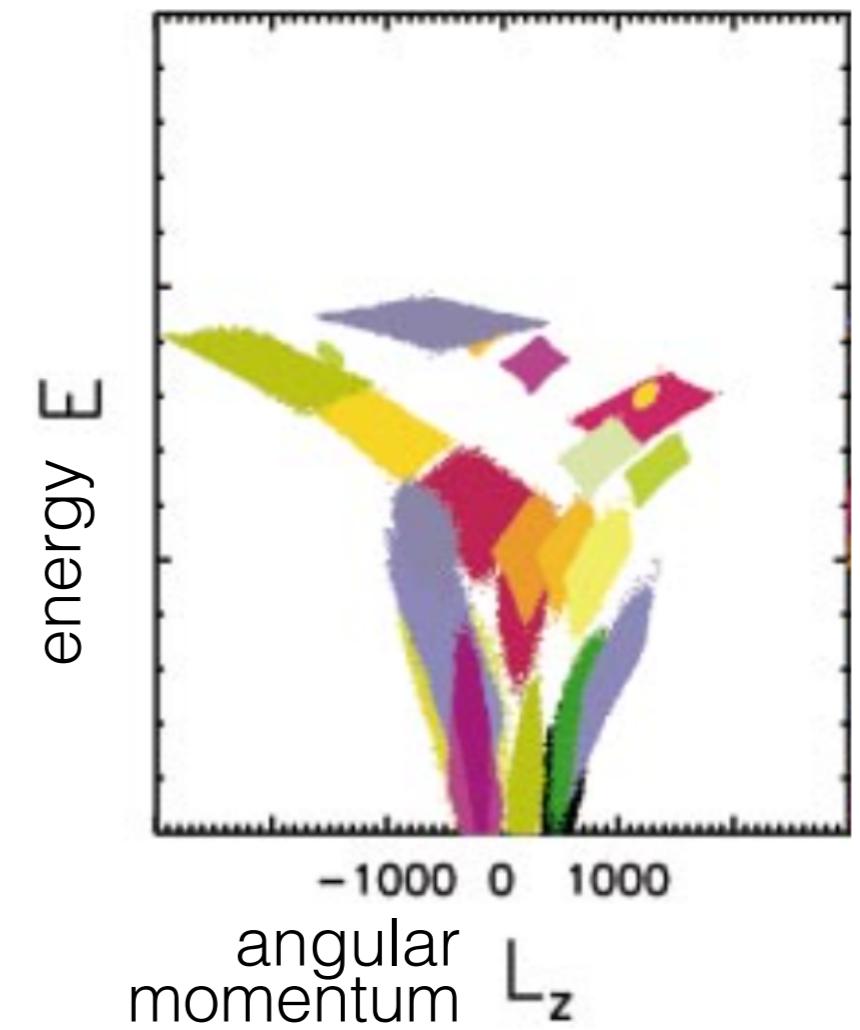
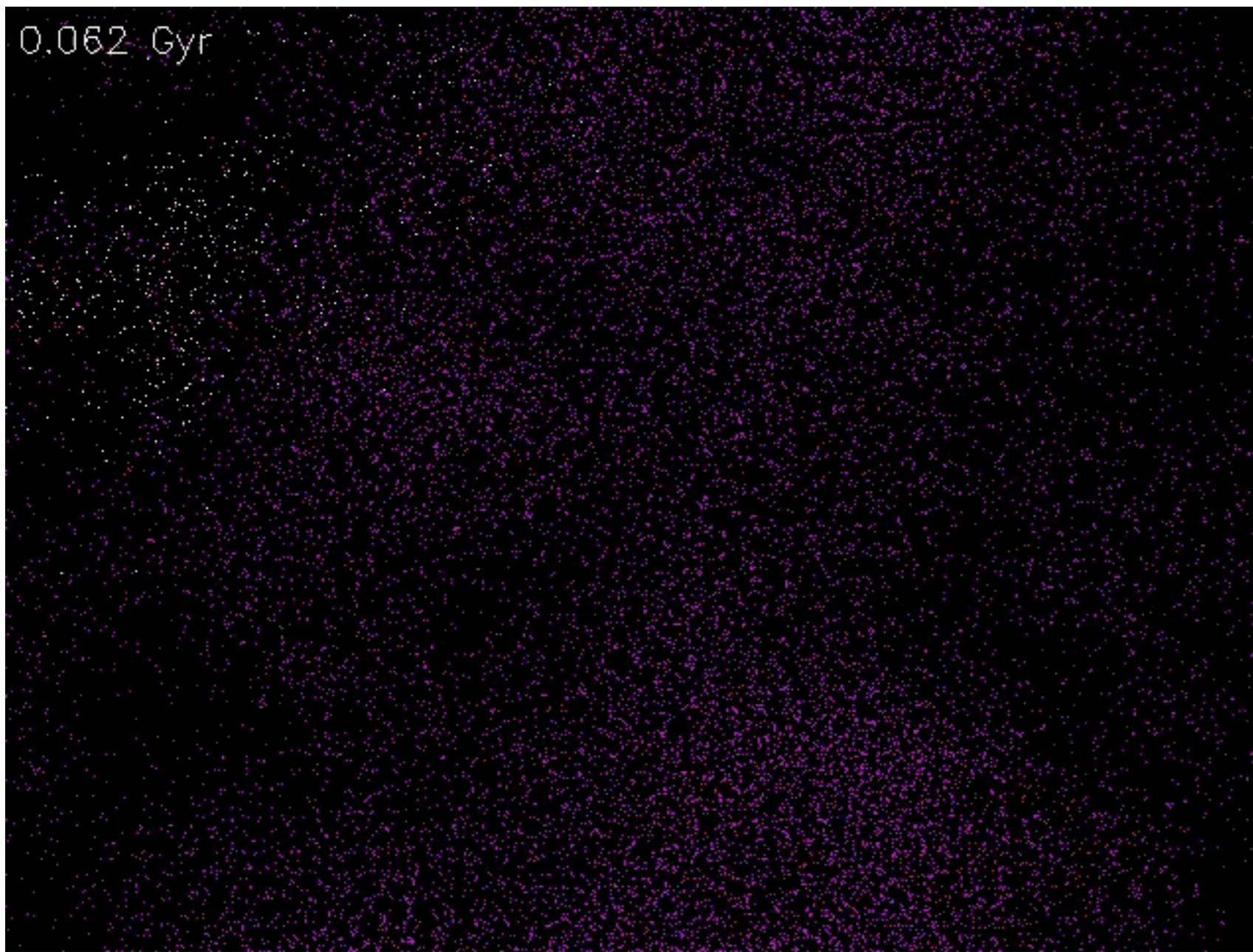
# Universal structure formation

Prediction for today's Milky Way  
dark matter density distribution

Initial conditions  
Cosmic Microwave Background

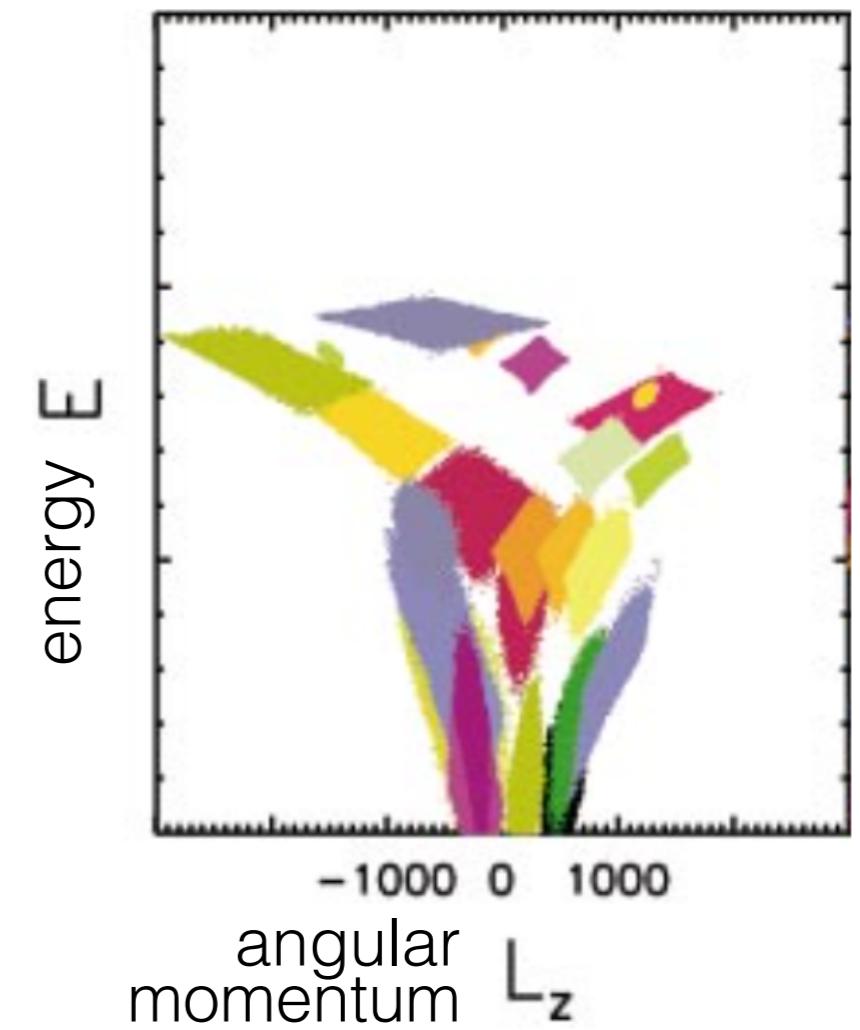
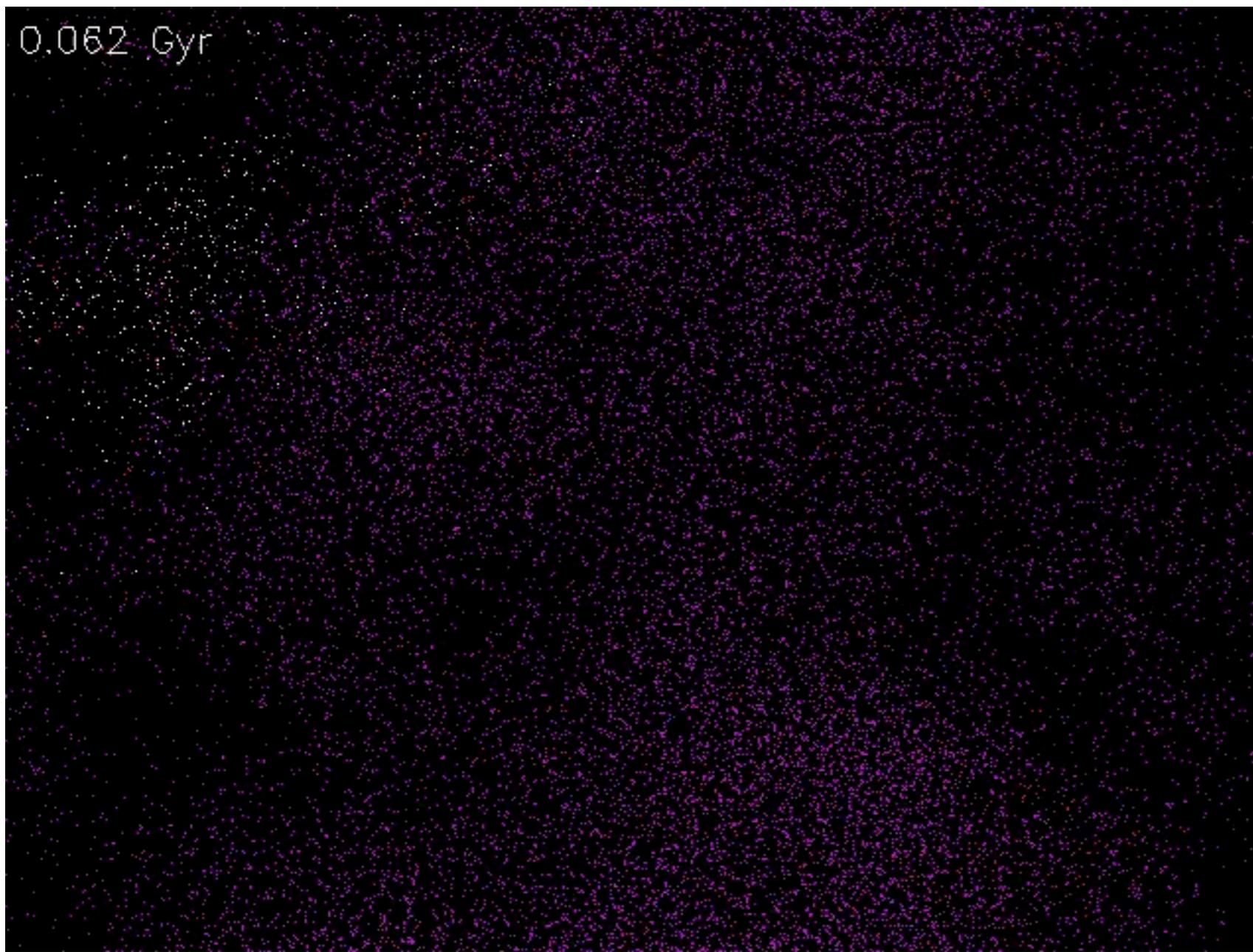


# Galactic halo formation in Cold Dark Matter Cosmology



Helmi & de Zeeuw et al 2000

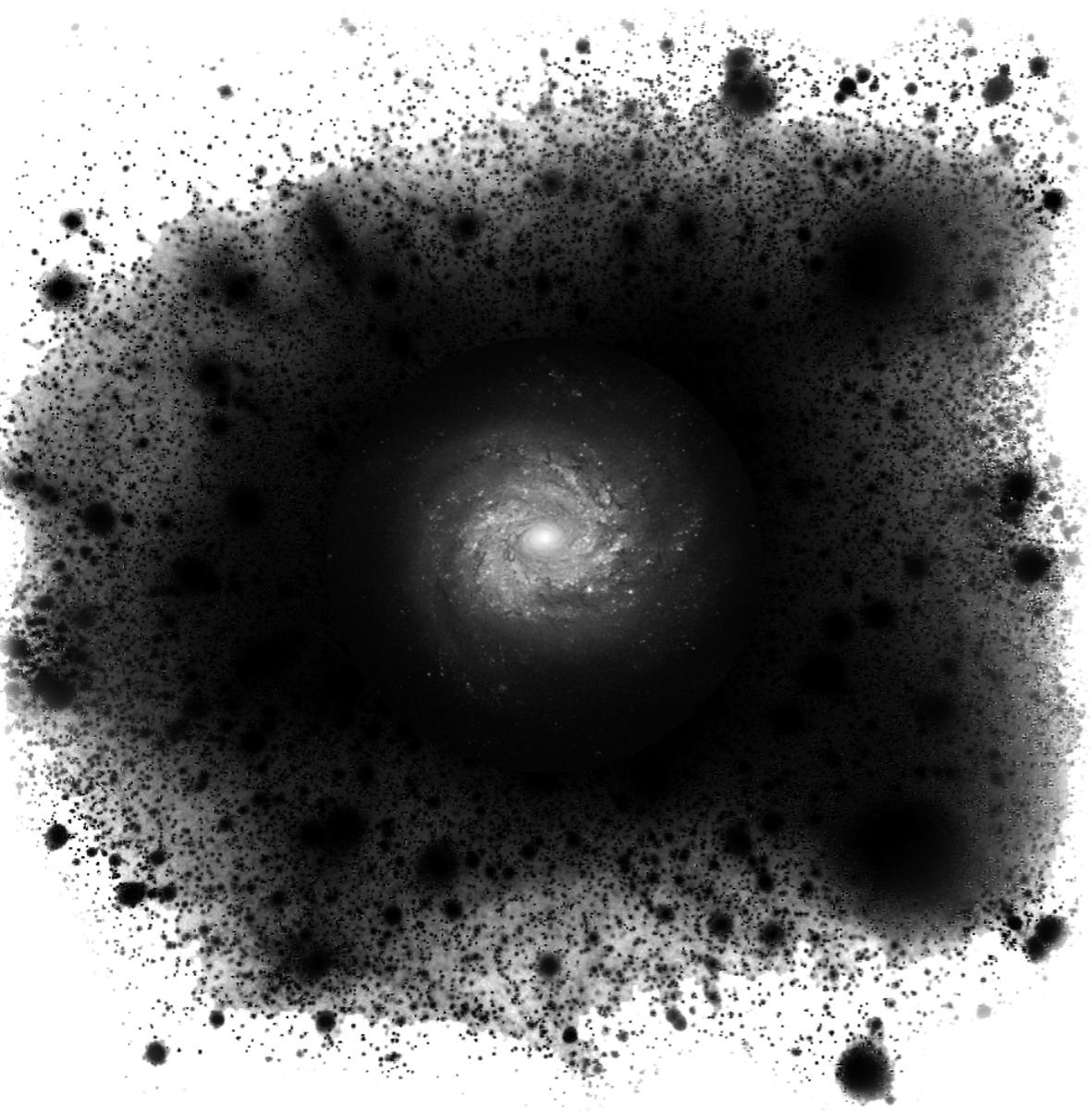
# Galactic halo formation in Cold Dark Matter Cosmology



Helmi & de Zeeuw et al 2000

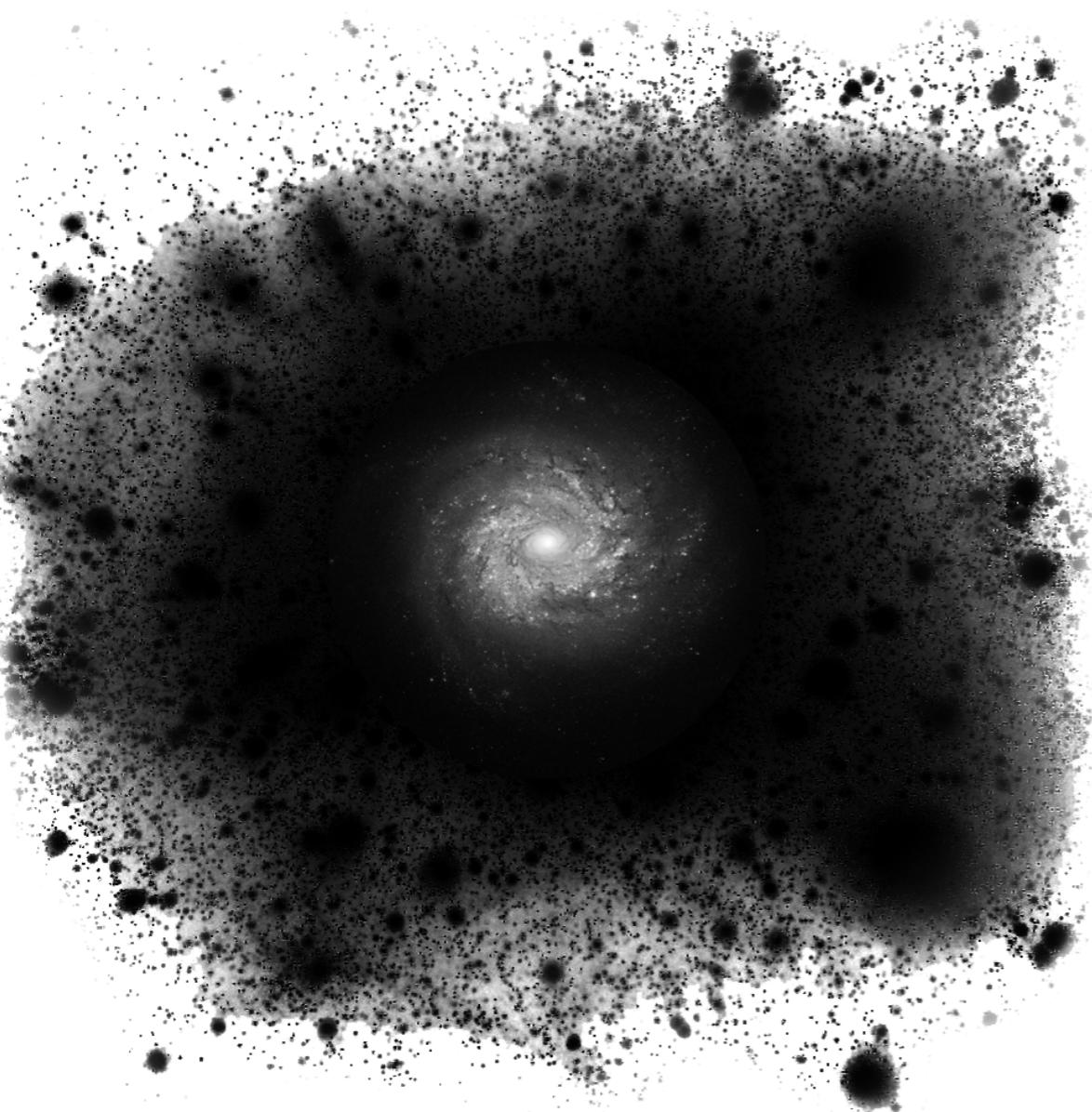
# Stellar and Dark Halos are alike

Dark Matter halo

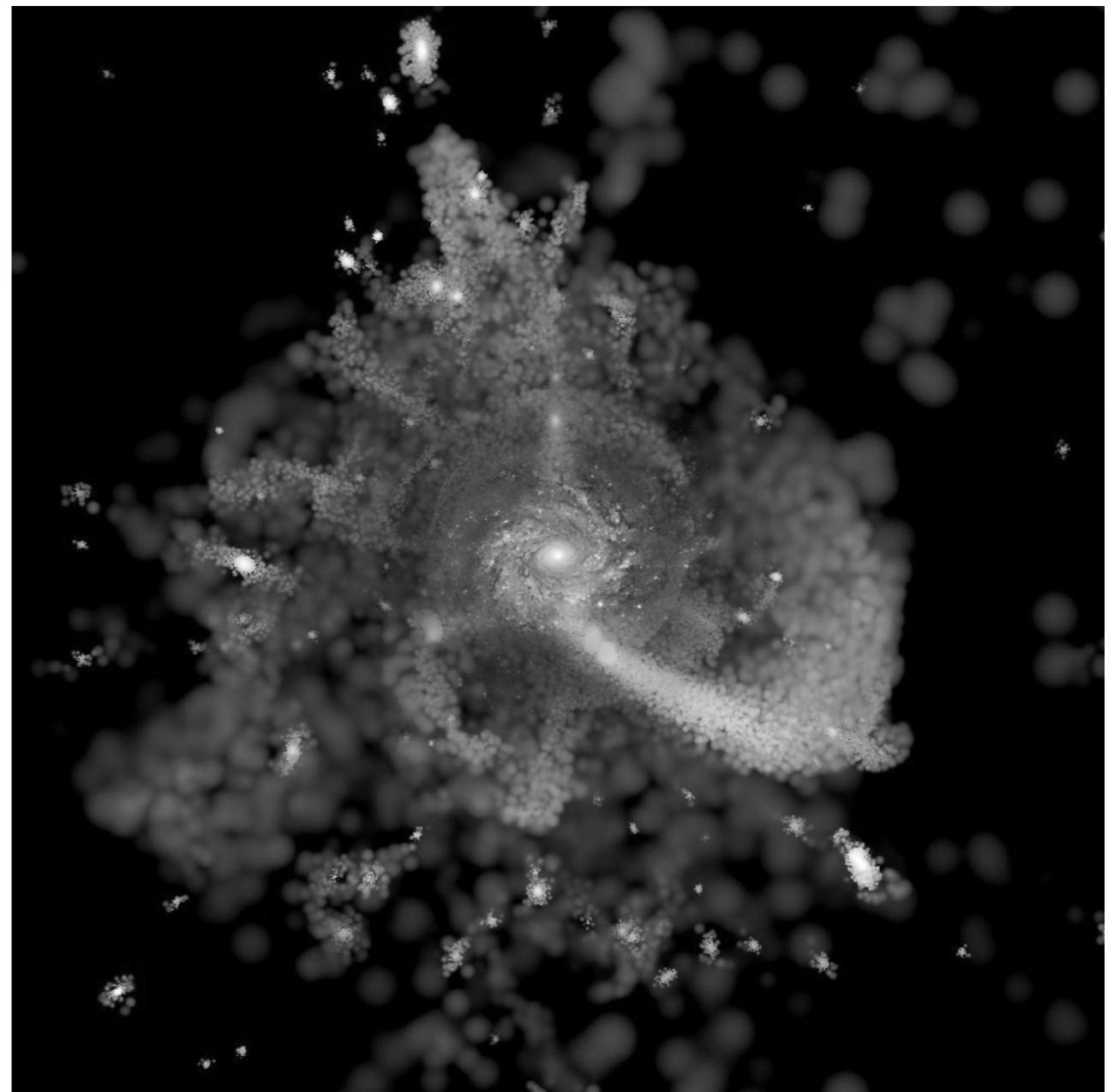


# Stellar and Dark Halos are alike

Dark Matter halo



Stellar halo



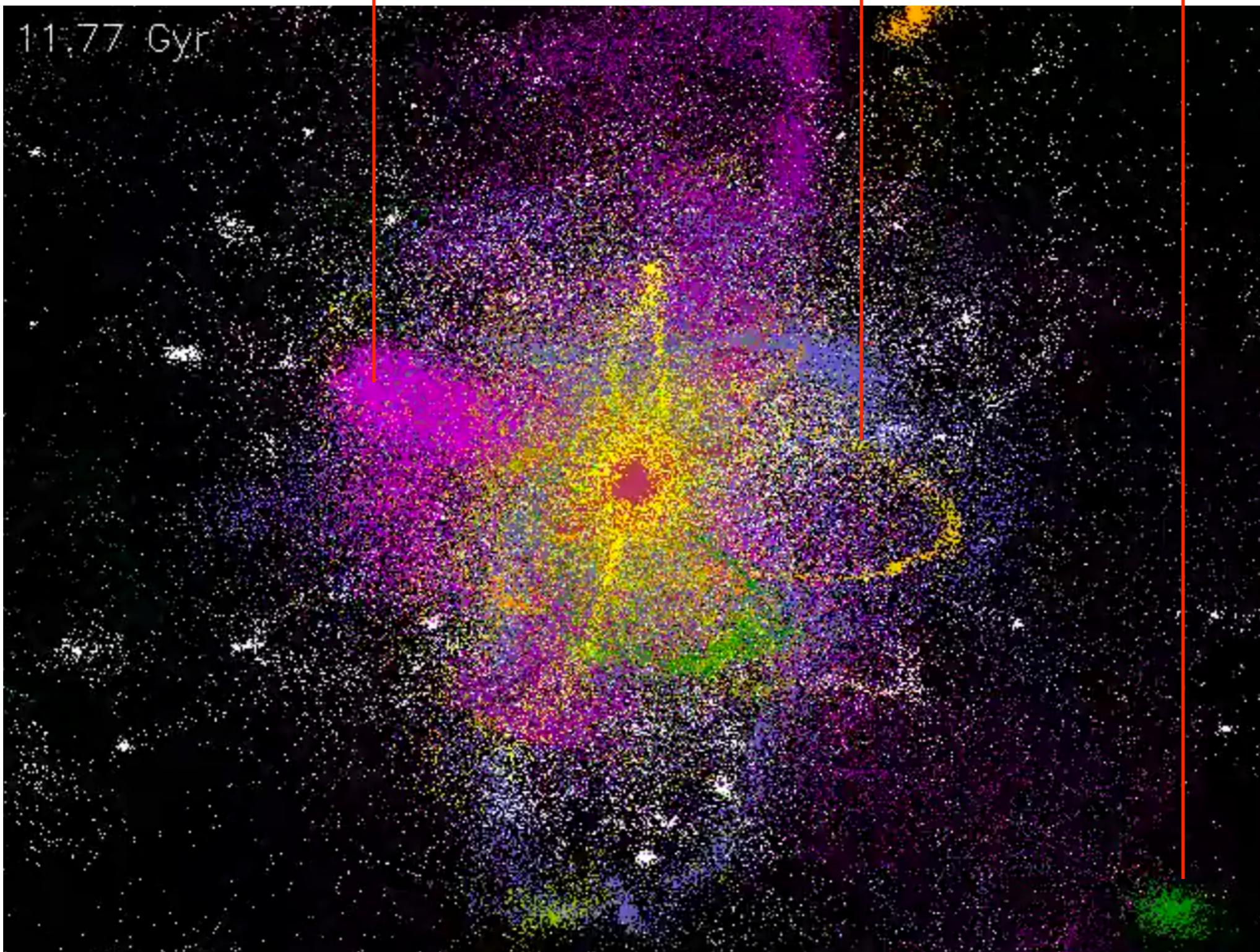
## shells/clouds

massive satellites  
radial orbits

## streams

lower-mass satellites  
tangential orbits

## satellites



# Note: Information content

- Satellites: constraints on the low(ish) end of the DM mass function, **targets for indirect DM searches**
- Streams: shape of the DM distribution, granularity of the DM distribution - **unique probes of DM**
- Shells/clouds: accretion history, major merger events in the life of the Milky Way - **likely to dominate local density, important for direct detection**

# Note: Very local stellar halo

- Locally, (most of the above) stellar halo sub-structures do not exhibit strong density gradients
- They are instead only detectable in the **velocity space** (or integrals-of-motion space)

# Note: linking stellar and DM sub-structures

- Such link requires detailed knowledge of the accretion event - most importantly of the **time and the mass** of the progenitor
- Not all DM comes from luminous progenitors, hence the link is always approximate
- Dynamical modelling of the stellar halo allows to close the loop, i.e. infer the DM density distribution

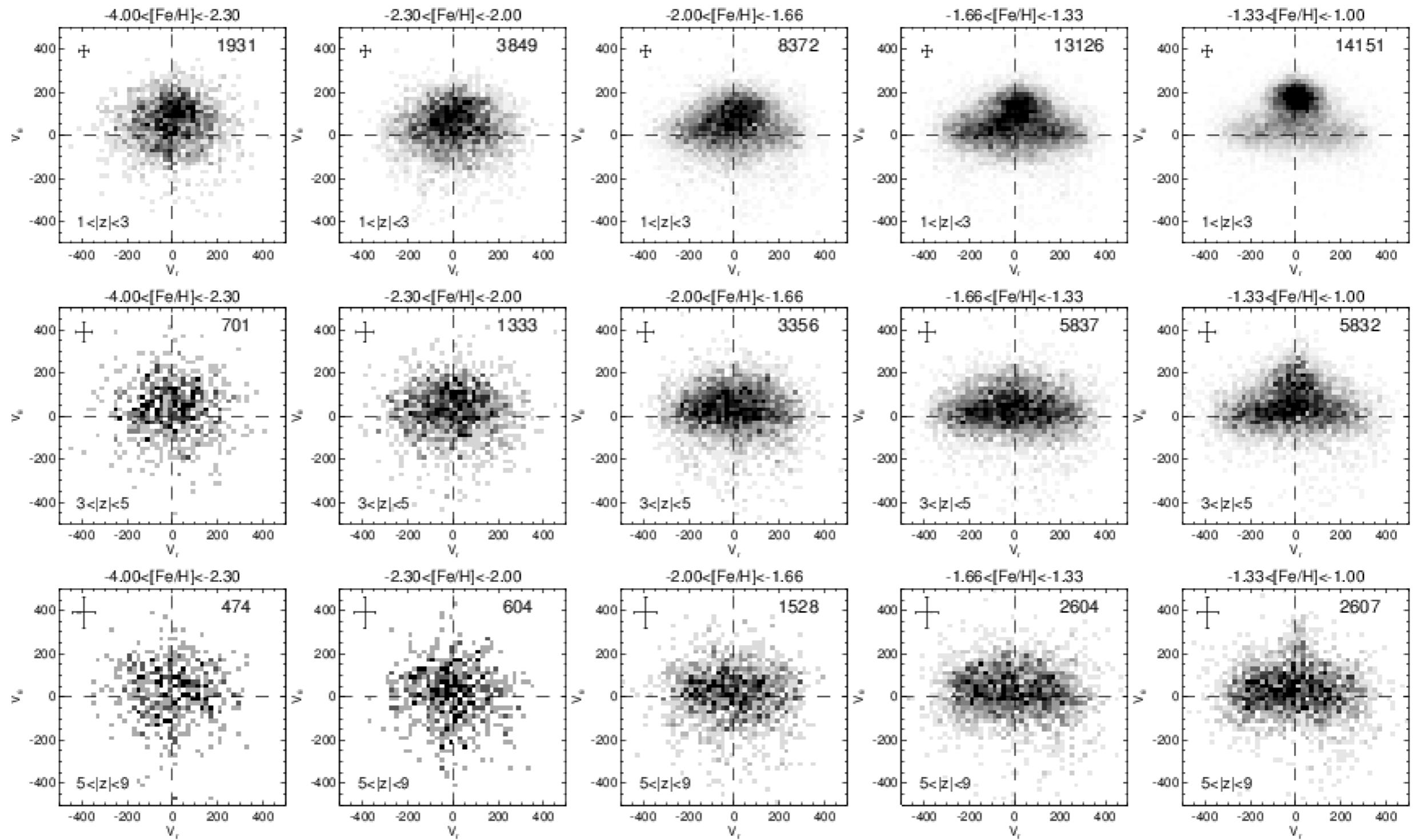
# Gaia, the halo explorer

- relatively bright magnitude limit, but
- no weather
- perfect star/galaxy separation
- artifact rejection
- whole sky
- uniform(ish) quality
- astrometry
- time domain



# Local Stellar halo in 7-D

height above the disc

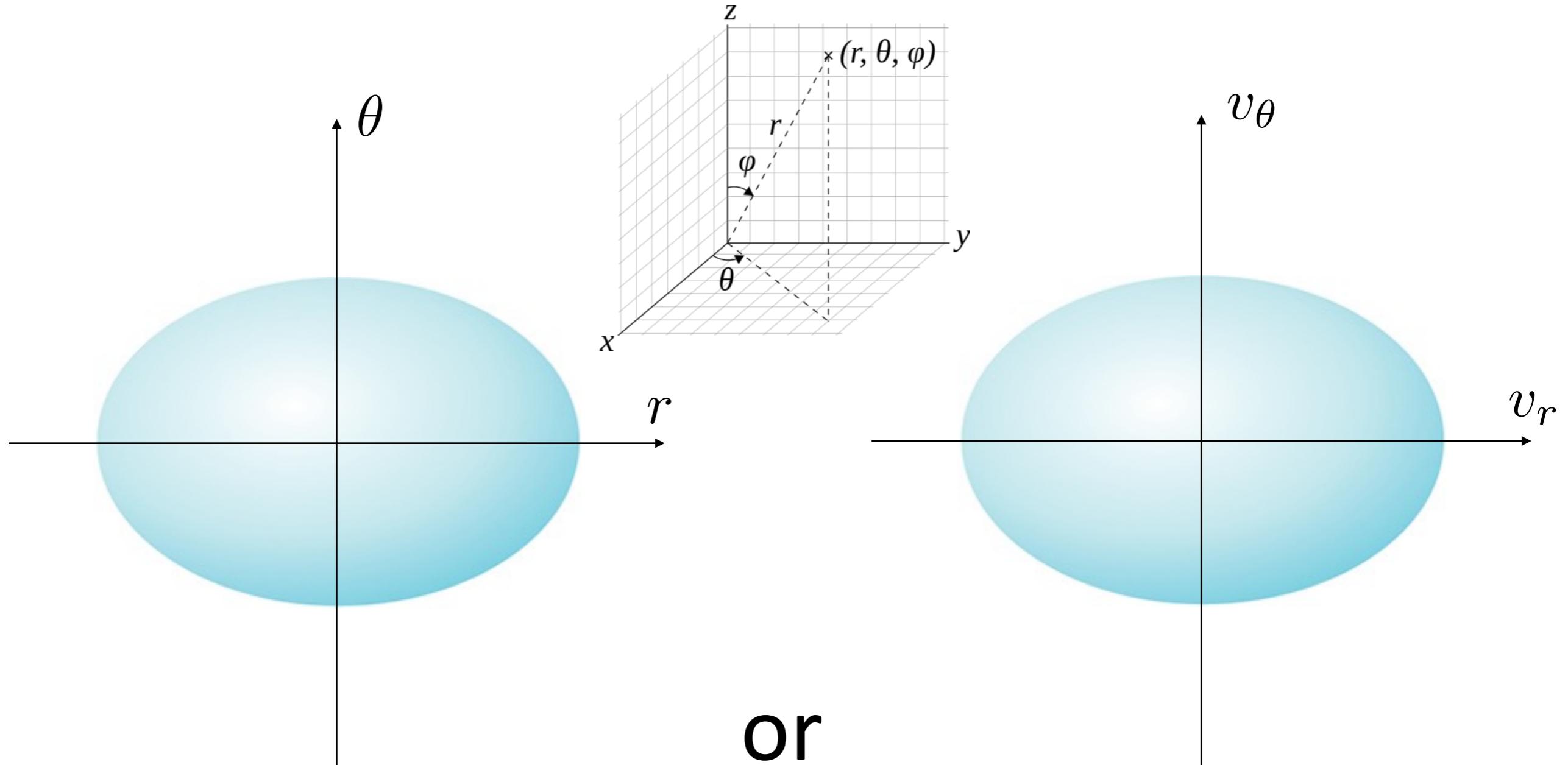


stellar metallicity

low

higher

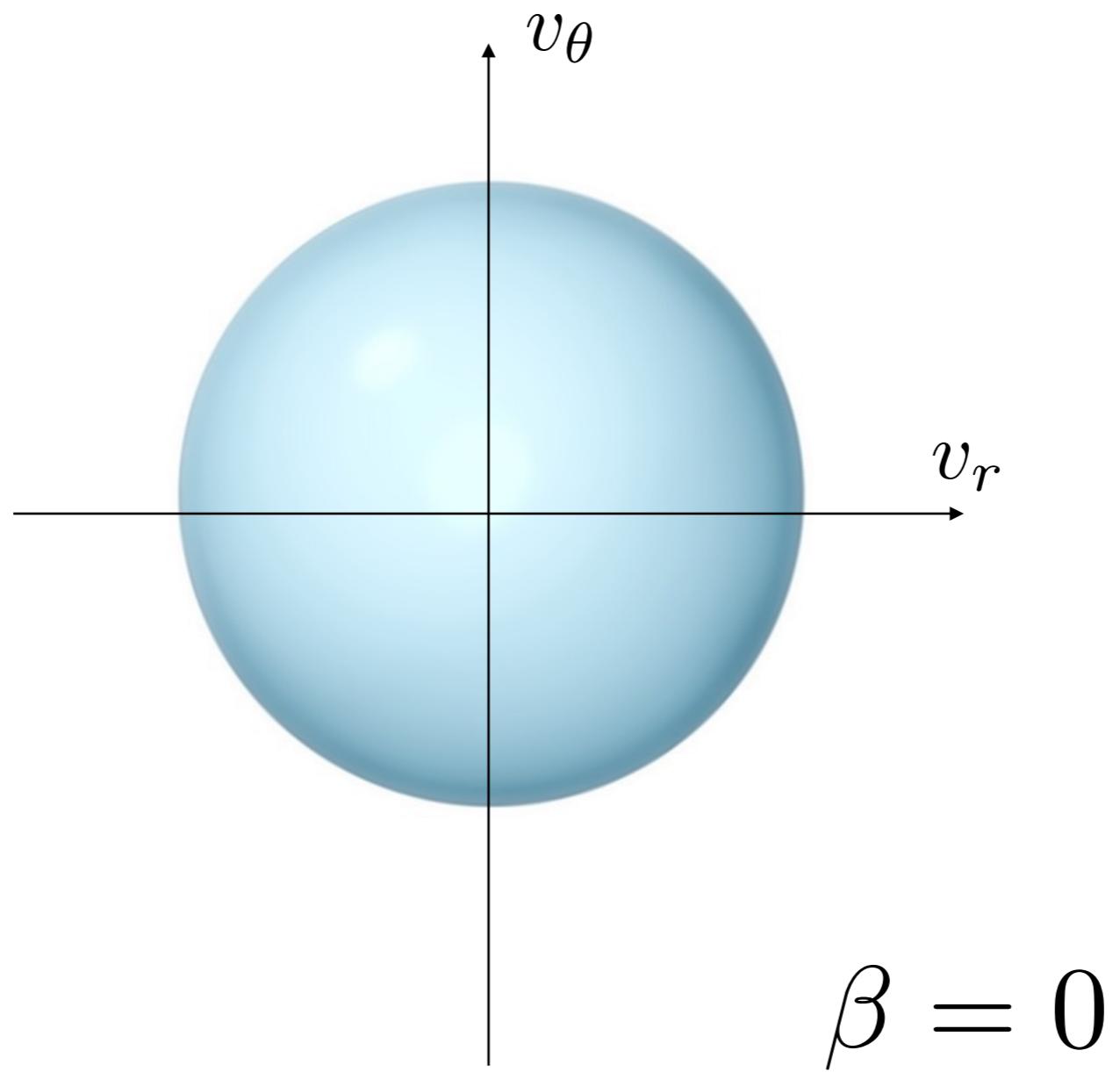
# Stellar velocity ellipsoid



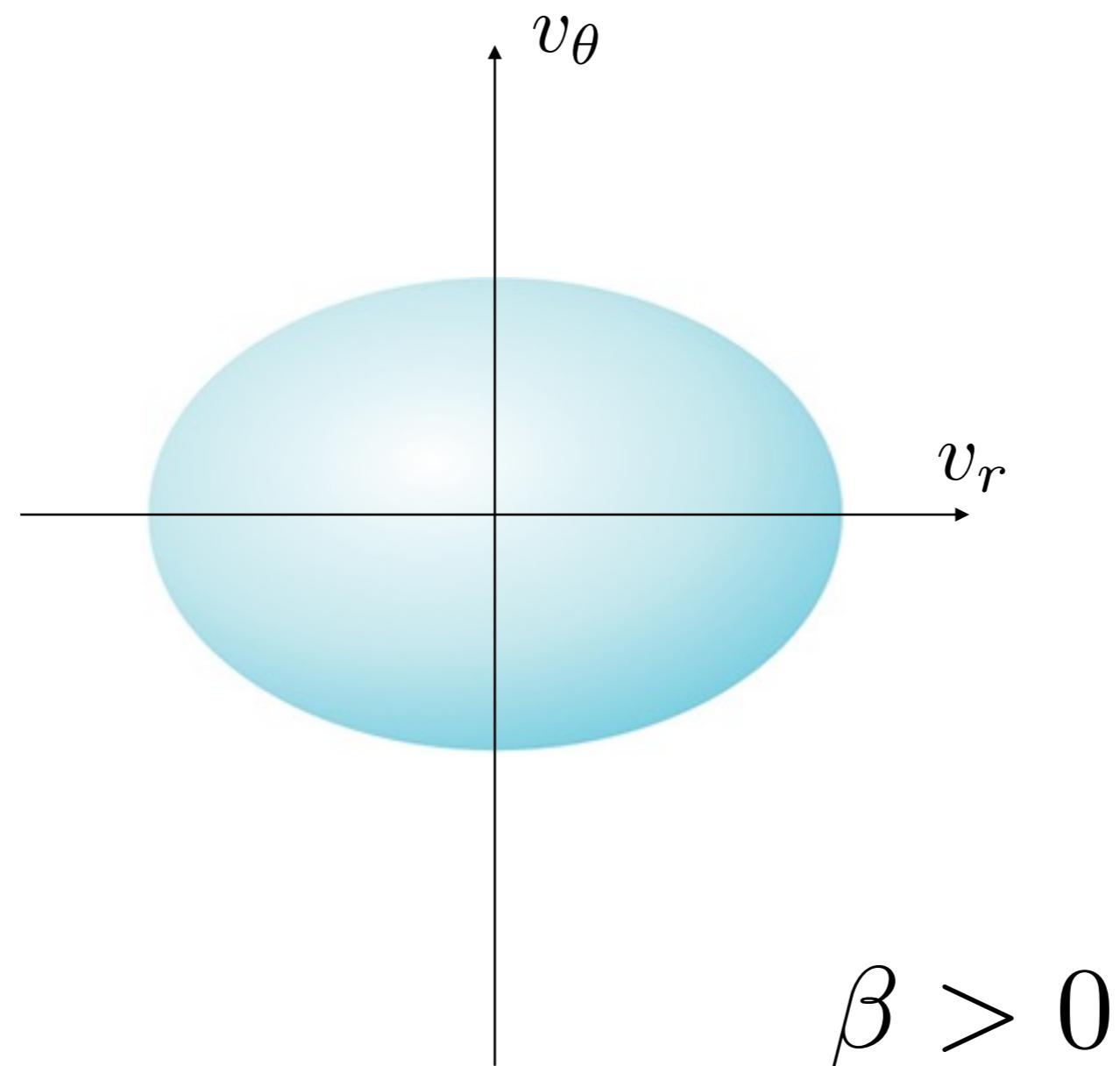
position space  
requires larger volume to be sampled

velocity space  
can be measured locally

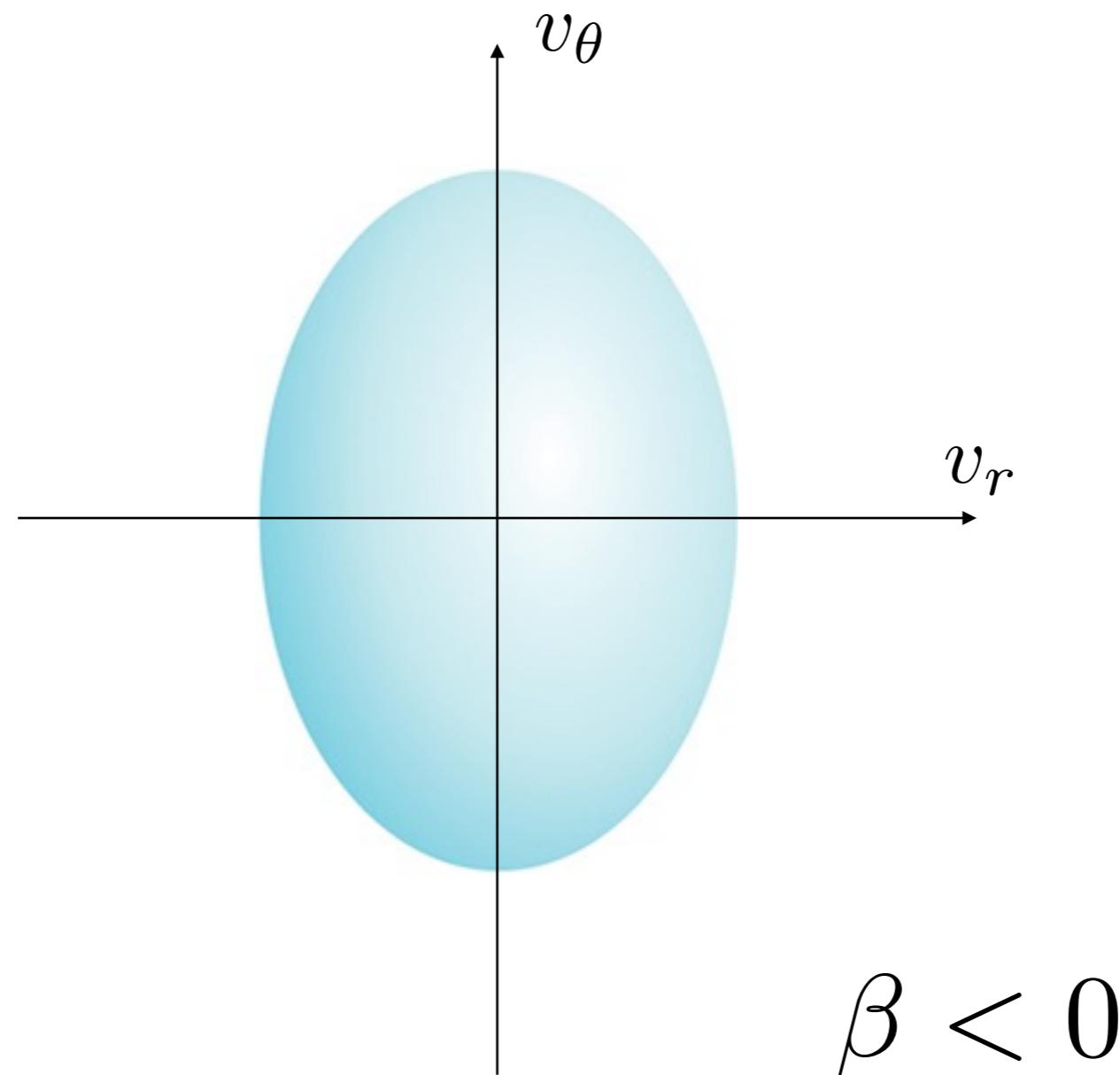
# Isotropy



# Radial anisotropy



# Tangential anisotropy



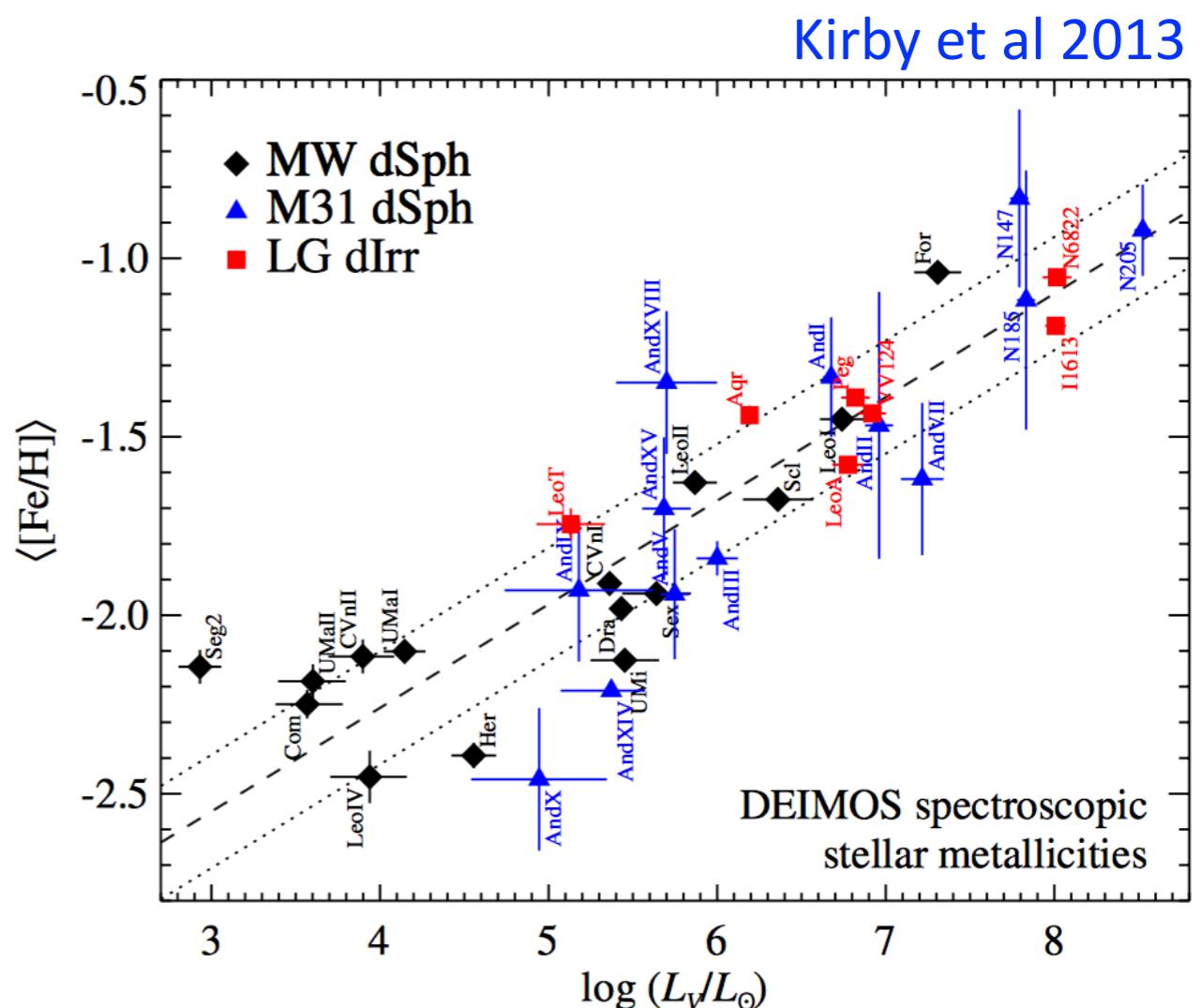
# Metallicity

- Abundance of elements heavier than H and He

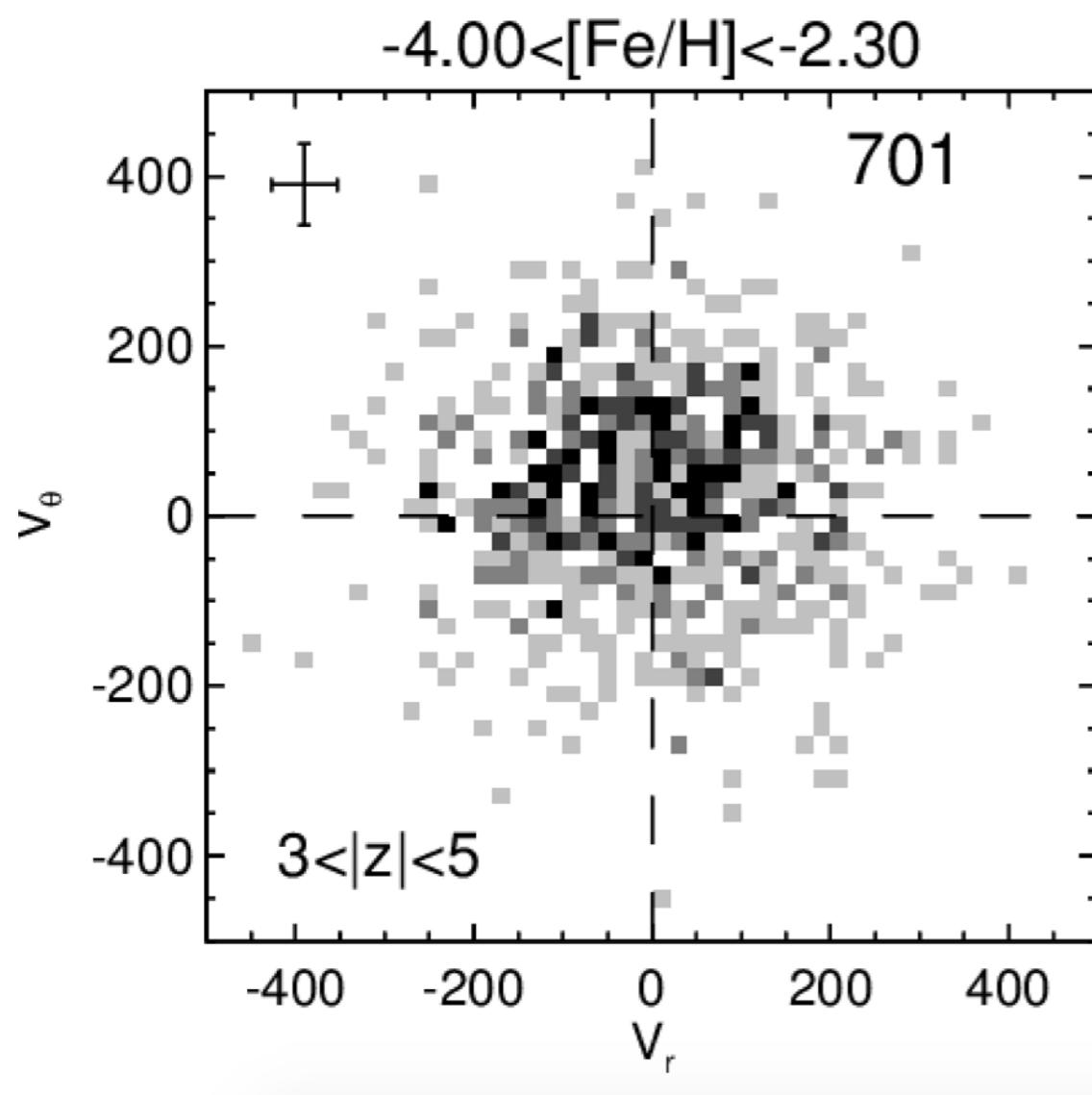
$$[\text{Fe}/\text{H}] = \log_{10} \left( \frac{N_{\text{Fe}}}{N_{\text{H}}} \right)_{\text{star}} - \log_{10} \left( \frac{N_{\text{Fe}}}{N_{\text{H}}} \right)_{\text{sun}}$$

[Fe/H]=0 i.e. Solar metallicity

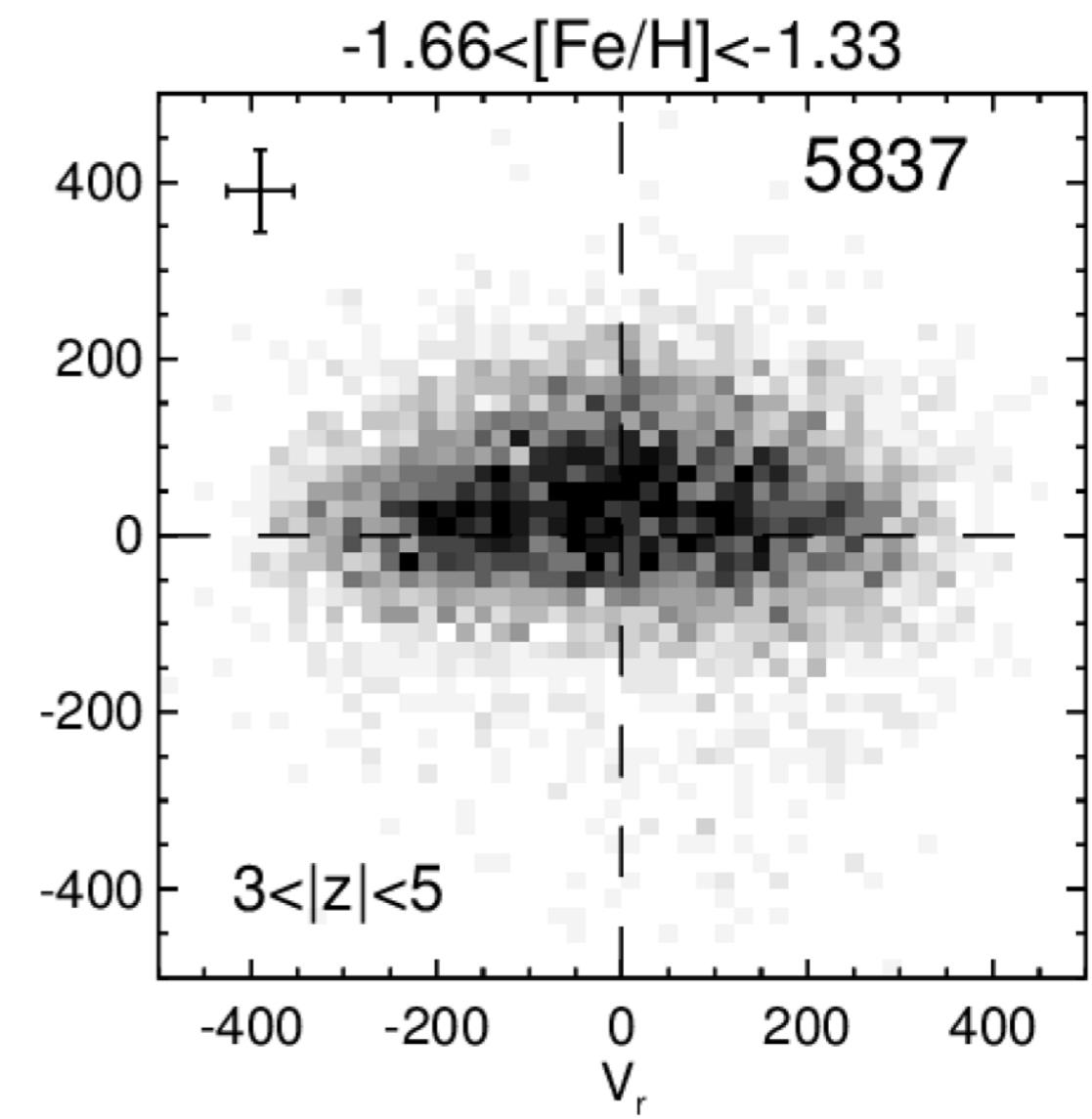
$[\text{Fe}/\text{H}] = -3$  i.e. 1000 less metal rich than the Sun



# Meatball-Sausage dichotomy

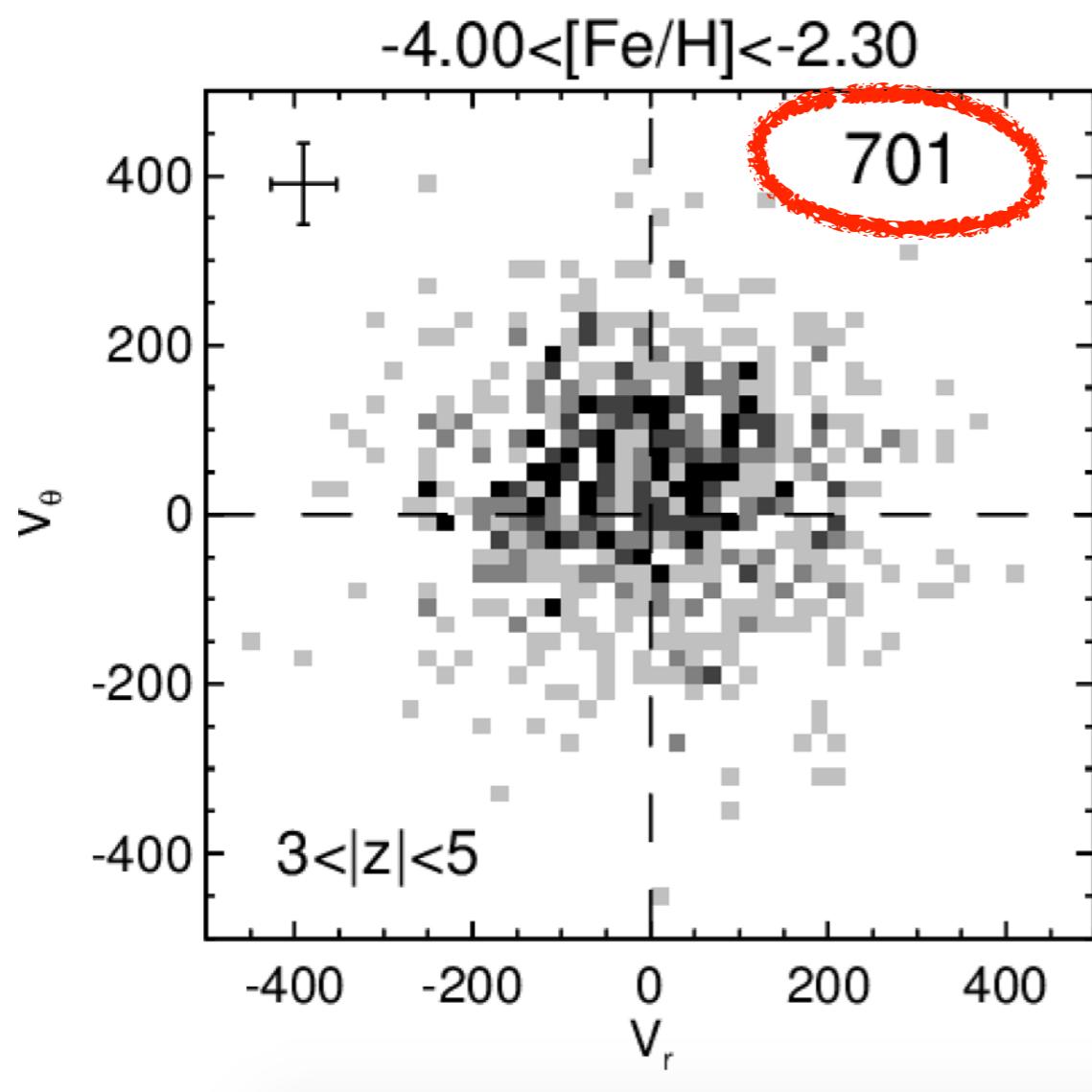


metal-poorer halo

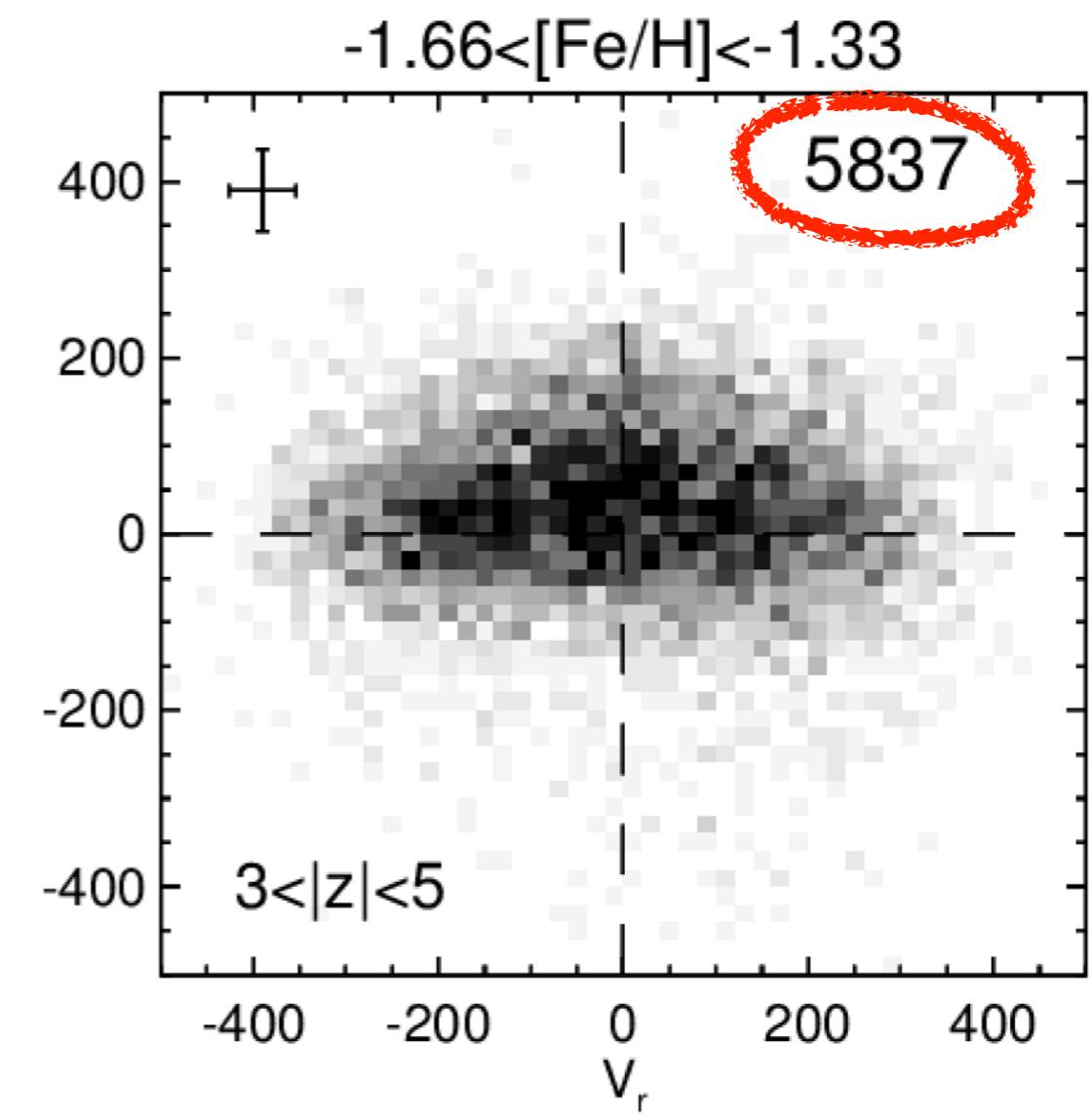


metal-richer halo

# Meatball-Sausage dichotomy



metal-poorer halo



metal-richer halo

# Orbital Anisotropy

$$\beta = 1 - \frac{\sigma_\theta^2 + \sigma_\phi^2}{2\sigma_r^2}$$

# Orbital Anisotropy

$$\beta = 1 - \frac{\sigma_{\theta}^2 + \sigma_{\phi}^2}{2\sigma_r^2}$$

Tangential motion

# Orbital Anisotropy

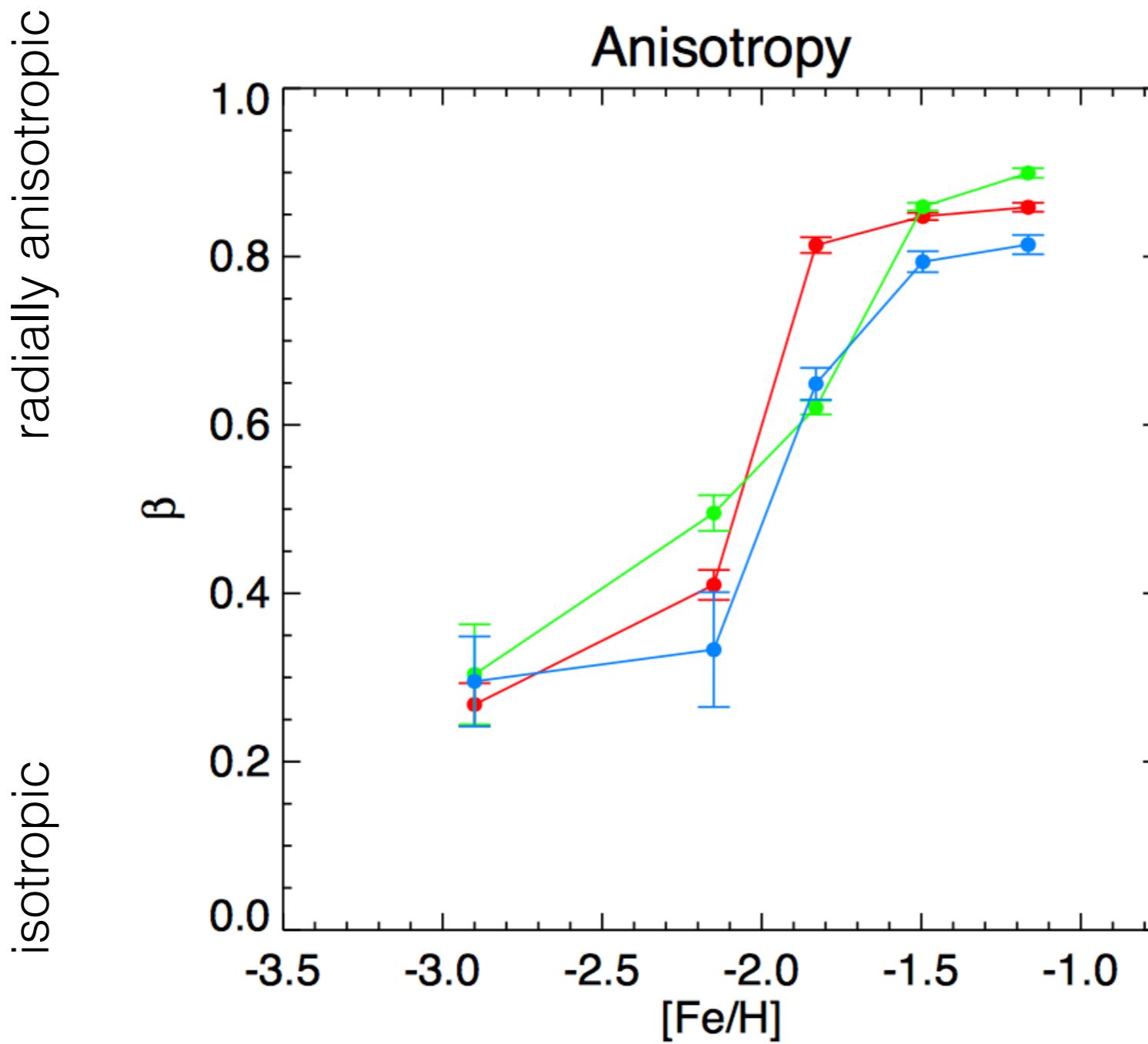
$$\beta = 1 - \frac{\sigma_{\theta}^2 + \sigma_{\phi}^2}{2\sigma_r^2}$$

Tangential motion

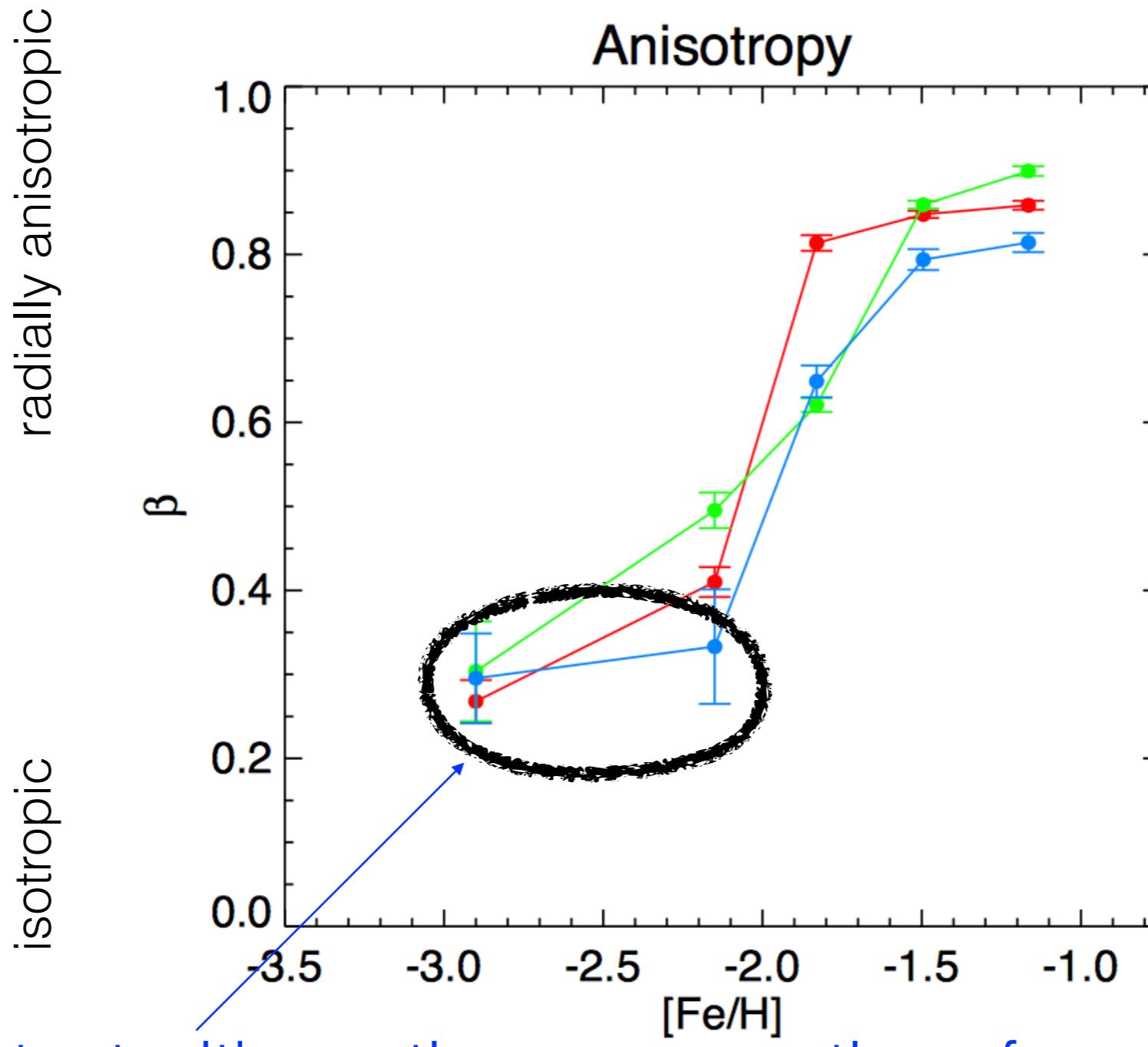
Radial motion

The diagram shows two overlapping ellipses. The top ellipse is blue and labeled "Tangential motion". The bottom ellipse is red and labeled "Radial motion". They overlap significantly. The formula  $\beta = 1 - \frac{\sigma_{\theta}^2 + \sigma_{\phi}^2}{2\sigma_r^2}$  is displayed, where the numerator is the sum of the squared standard deviations of the blue ellipse, and the denominator is twice the squared standard deviation of the red ellipse.

# Galactic stellar halo in 7-D



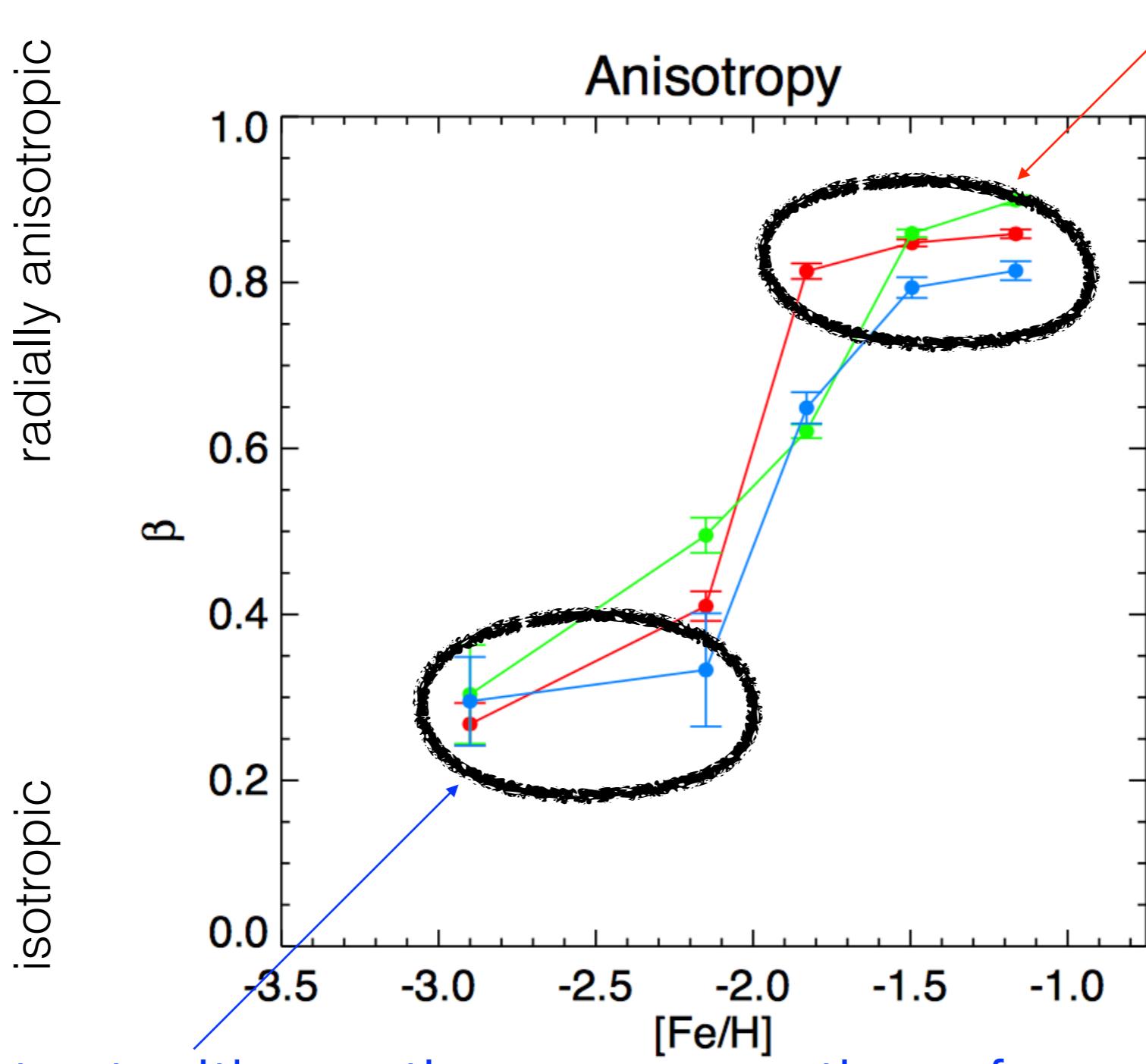
# Galactic stellar halo in 7-D



consistent with continuous accretion of small dwarfs

# Galactic stellar halo in 7-D

extreme radial anisotropy - preferred direction



consistent with continuous accretion of small dwarfs

# “Gaia Sausage”

## Summary of the discovery

- 2/3 of the (local) stellar halo in a single component
- Stars as metal-rich as 1/10 Solar
- Extreme radial anisotropy

# “Gaia Sausage”

## Summary of the discovery

- 2/3 of the (local) stellar halo in a single component
- Stars as metal-rich as 1/10 Solar
- Extreme radial anisotropy



# Co-formation of the disc and the stellar halo<sup>★</sup>

V. Belokurov,<sup>1,2†</sup> D. Erkal,<sup>1,3</sup> N. W. Evans,<sup>1</sup> S. E. Koposov<sup>1,4</sup> and A. J. Deason<sup>5</sup>

<sup>1</sup>*Institute of Astronomy, Madingley Road, Cambridge CB3 0HA*

<sup>2</sup>*Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, New York, NY 10010, USA*

<sup>3</sup>*Department of Physics, University of Surrey, Guildford GU2 7XH*

<sup>4</sup>*Department of Physics, McWilliams Center for Cosmology, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA*

<sup>5</sup>*Institute for Computational Cosmology, Department of Physics, University of Durham, South Road, Durham DH1 3LE, UK*

Accepted 2018 April 17. Received 2018 April 16; in original form 2018 February 9

## ABSTRACT

Using a large sample of main sequence stars with 7D measurements supplied by *Gaia* and SDSS, we study the kinematic properties of the local (within  $\sim 10$  kpc from the Sun) stellar halo. We demonstrate that the halo's velocity ellipsoid evolves strongly with metallicity. At the low-[Fe/H] end, the orbital anisotropy (the amount of motion in the radial direction compared with the tangential one) is mildly radial, with  $0.2 < \beta < 0.4$ . For stars with  $[\text{Fe}/\text{H}] > -1.7$ , however, we measure extreme values of  $\beta \sim 0.9$ . Across the metallicity range considered, namely  $-3 < [\text{Fe}/\text{H}] < -1$ , the stellar halo's spin is minimal, at the level of  $20 < \bar{v}_\theta(\text{kms}^{-1}) < 30$ . Using a suite of cosmological zoom-in simulations of halo formation, we deduce that the observed acute anisotropy is inconsistent with the continuous accretion of dwarf satellites. Instead, we argue, the stellar debris in the inner halo was deposited in a major accretion event by a satellite with  $M_{\text{vir}} > 10^{10} M_\odot$  around the epoch of the Galactic disc formation, between 8 and 11 Gyr ago. The radical halo anisotropy is the result of the dramatic radialization of the massive progenitor's orbit, amplified by the action of the growing disc.

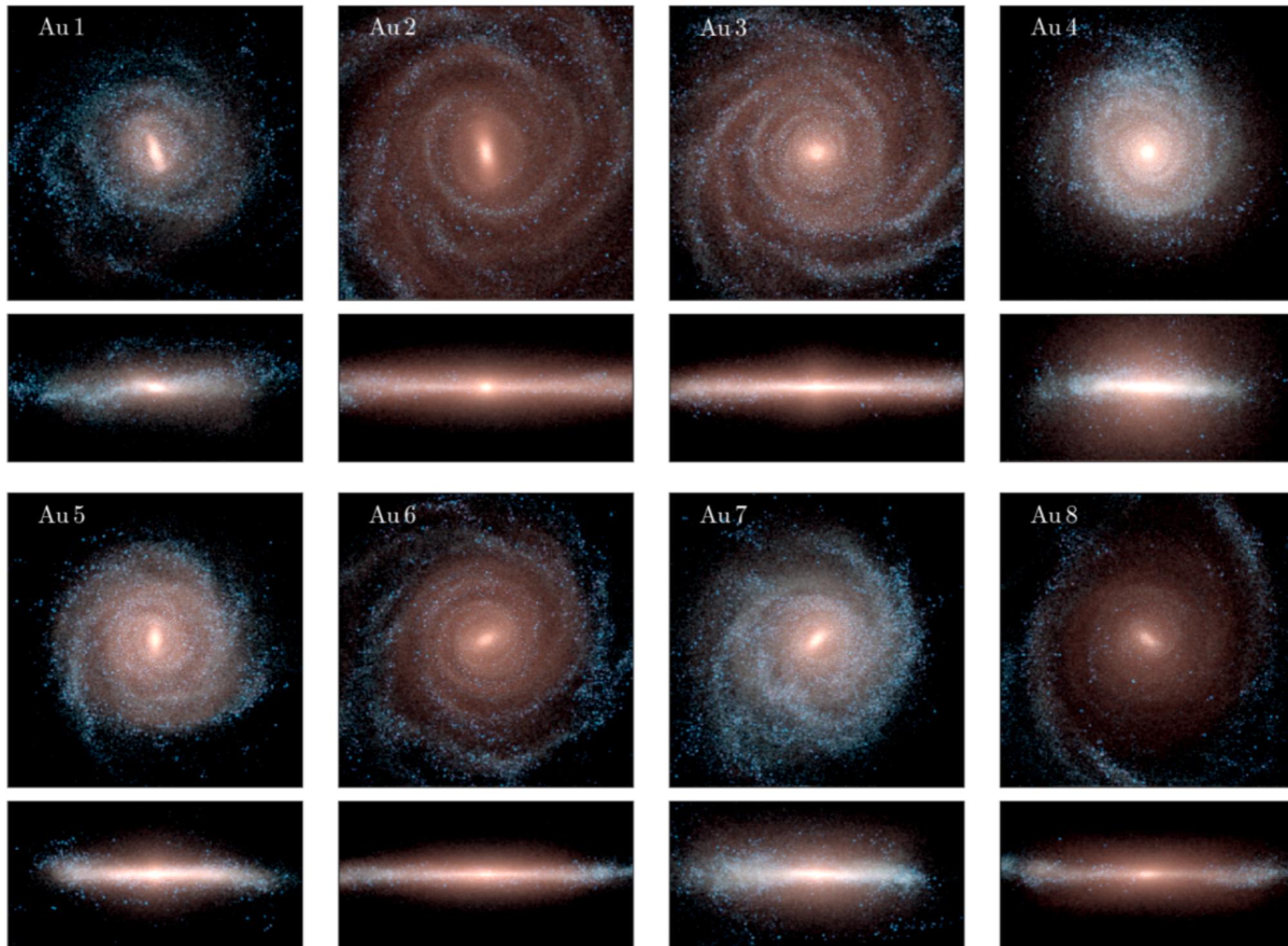
**Key words:** galaxies: dwarf – Local Group – galaxies: structure.

# When and What smashed into us?

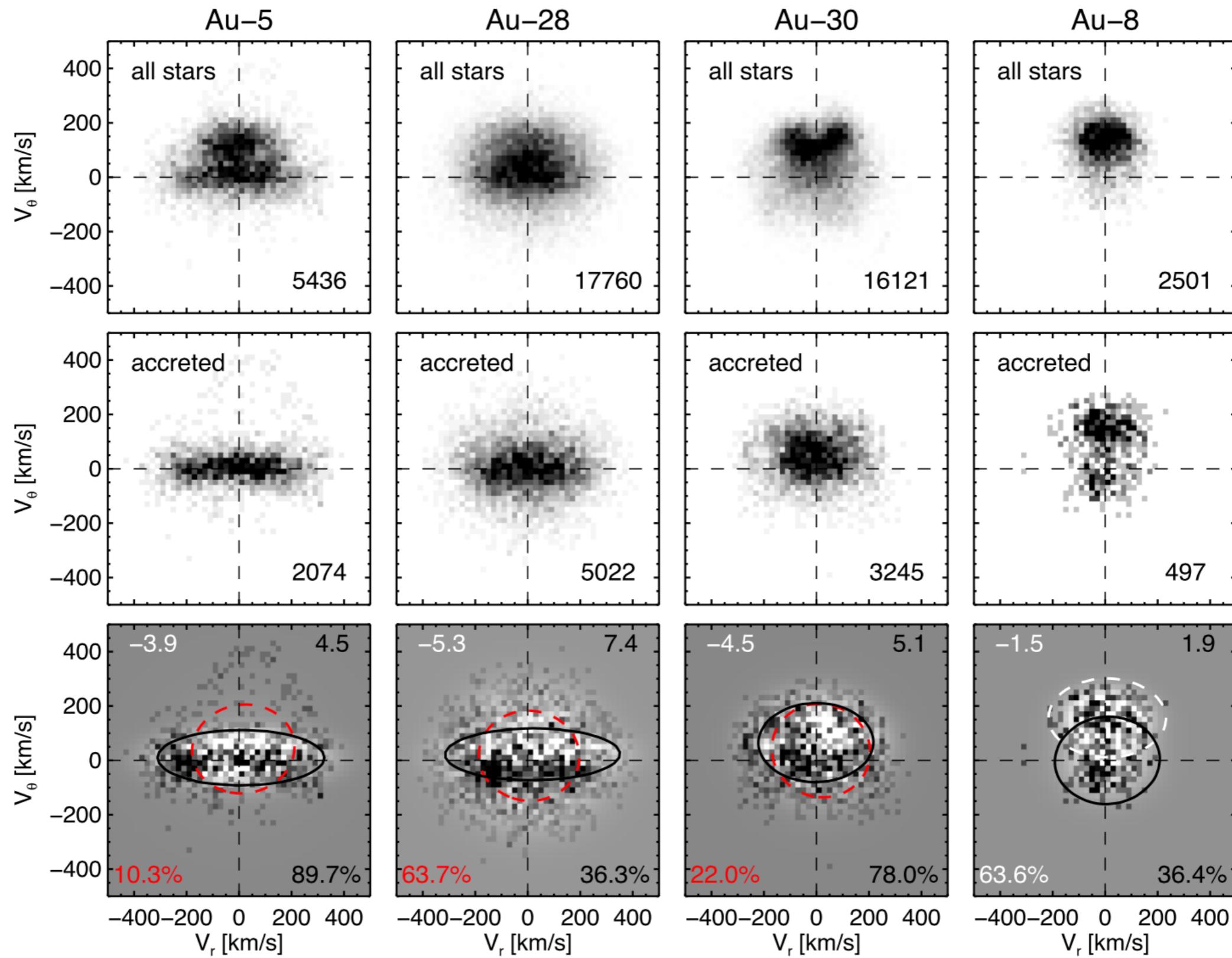
Fattahi et al 2018

# Numerical simulations

The Auriga suite ([Grand et al 2017](#)) - 30 Milky Ways

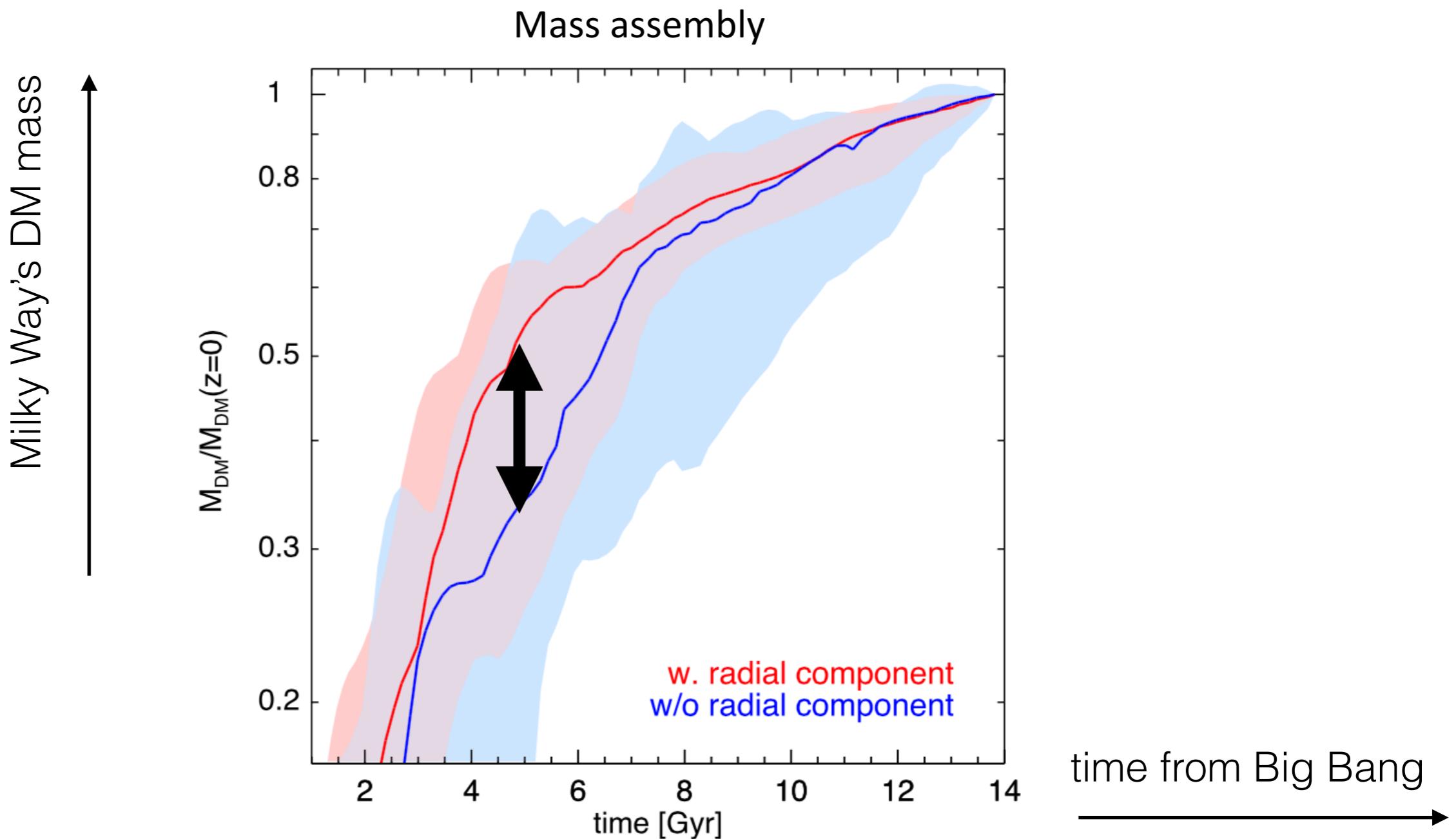


# Observing the simulations



# Variety of accretion histories

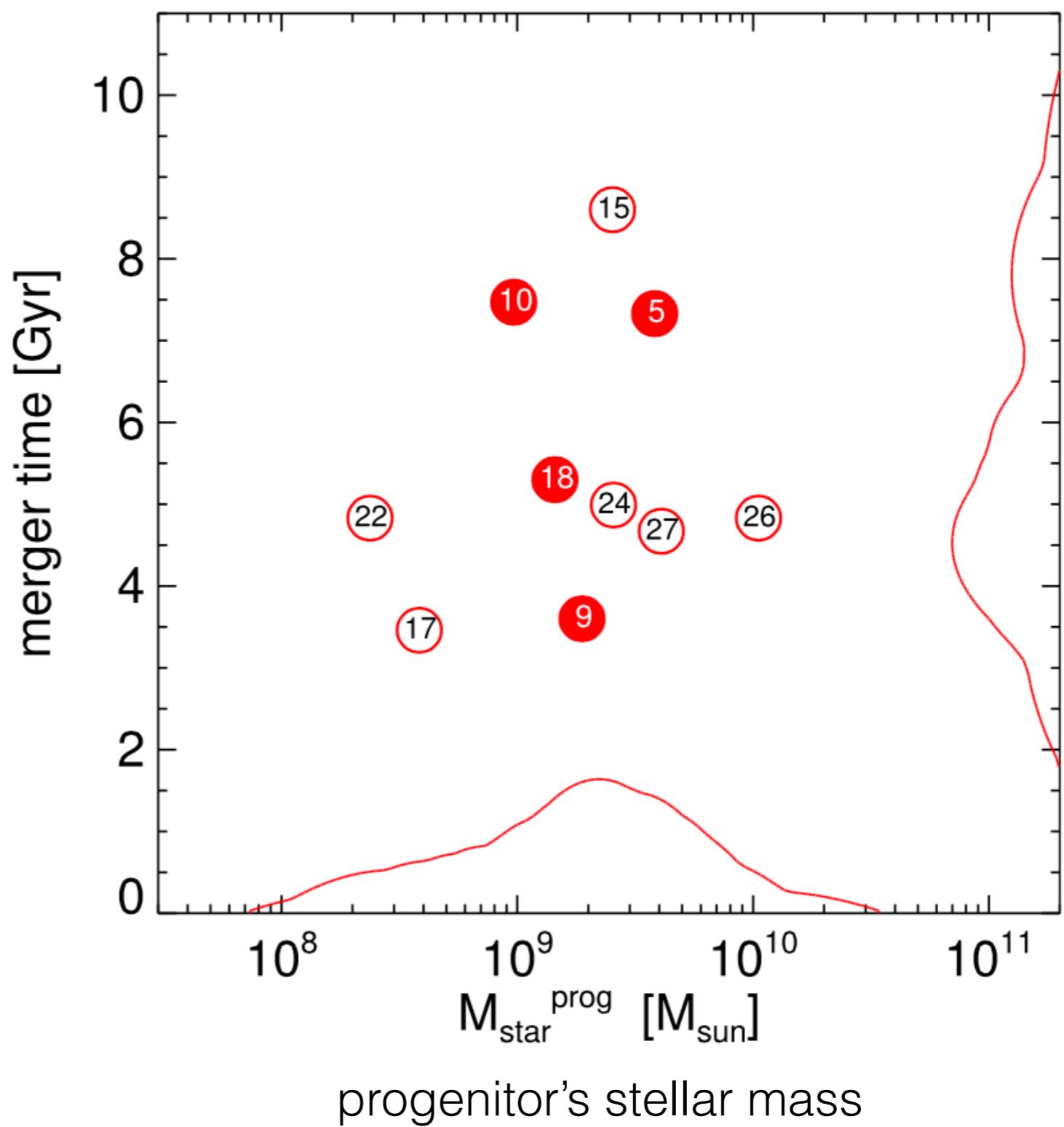
Early-peaked mass assembly is preferred



Fattahi et al 2018

# When and What smashed into us?

7-11 Gyr ago  
as big as the LMC



Fattahi et al 2018

# The origin of galactic metal-rich stellar halo components with highly eccentric orbits

Azadeh Fattahi<sup>1,2</sup>★ Vasily Belokurov<sup>1,3</sup> Alis J. Deason<sup>1</sup> Carlos S. Frenk,<sup>1</sup> Facundo A. Gómez,<sup>4,5</sup> Robert J. J. Grand<sup>1,6,7,8</sup> Federico Marinacci<sup>1,9</sup> Rüdiger Pakmor<sup>8</sup> and Volker Springel<sup>8</sup>

<sup>1</sup>Institute for Computational Cosmology, Department of Physics, University of Durham, South Road, Durham DH1 3LE, UK

<sup>2</sup>Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK

<sup>3</sup>Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, New York, NY 10010, USA

<sup>4</sup>Instituto de Investigación Multidisciplinar en Ciencia y Tecnología, Universidad de La Serena, Raúl Bitrán 1305, La Serena, Chile

<sup>5</sup>Departamento de Física y Astronomía, Universidad de La Serena, Av. Juan Cisternas 1200 N, La Serena, Chile

<sup>6</sup>Heidelberg Institut für Theoretische Studien, Schloß-Wolfsbrunnenweg 35, D-69118 Heidelberg, Germany

<sup>7</sup>Zentrum für Astronomie der Universität Heidelberg, Astronomisches Recheninstitut, Mönchhofstr. 12-14, D-69120 Heidelberg, Germany

<sup>8</sup>Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748, Garching, Germany

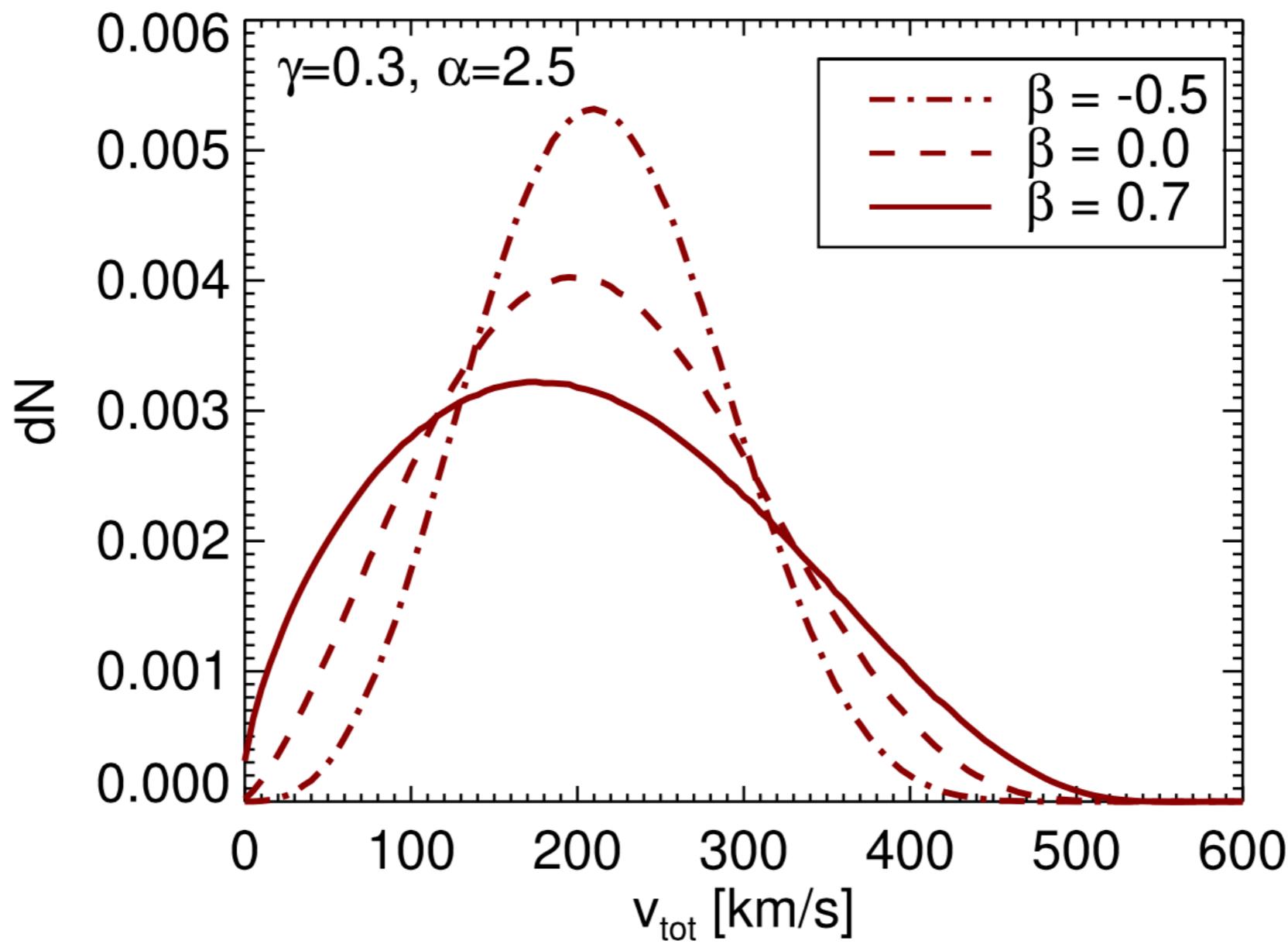
<sup>9</sup>Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

Accepted 2019 January 14. Received 2019 January 10; in original form 2018 October 17

## ABSTRACT

Using the astrometry from the ESA’s *Gaia* mission, previous works have shown that the Milky Way stellar halo is dominated by metal-rich stars on highly eccentric orbits. To shed light on the nature of this prominent halo component, we have analysed 28 Galaxy analogues in the Auriga suite of cosmological hydrodynamics zoom-in simulations. Some three quarters of the Auriga galaxies contain prominent components with high radial velocity anisotropy,  $\beta > 0.6$ . However, only in one third of the hosts do the high- $\beta$  stars contribute significantly to the accreted stellar halo overall, similar to what is observed in the Milky Way. For this particular subset we reveal the origin of the dominant stellar halo component with high metallicity,  $[Fe/H] \sim -1$ , and high orbital anisotropy,  $\beta > 0.8$ , by tracing their stars back to the epoch of accretion. It appears that, typically, these stars come from a single dwarf galaxy with a stellar mass of the order of  $10^9 - 10^{10} M_\odot$  that merged around 6 – 10 Gyr ago, causing a sharp increase in the halo mass. Our study therefore establishes a firm link between the excess of radially anisotropic stellar debris in the halo and an ancient head-on collision between the young Milky Way and a massive dwarf galaxy.

# Implications for the local speed distribution



Galacto-centric velocity

# The local high-velocity tail and the Galactic escape speed

Alis J. Deason<sup>1</sup>,<sup>1</sup>★ Azadeh Fattahi<sup>1</sup>,<sup>1</sup> Vasily Belokurov<sup>1</sup>,<sup>2</sup> N. Wyn Evans,<sup>2</sup>  
Robert J. J. Grand<sup>1</sup>,<sup>3</sup> Federico Marinacci<sup>1</sup>,<sup>4</sup> and Rüdiger Pakmor<sup>1</sup>,<sup>3</sup>

<sup>1</sup>Institute for Computational Cosmology, Department of Physics, University of Durham, South Road, Durham DH1 3LE, UK

<sup>2</sup>Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK

<sup>3</sup>Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748, Garching, Germany

<sup>4</sup>Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

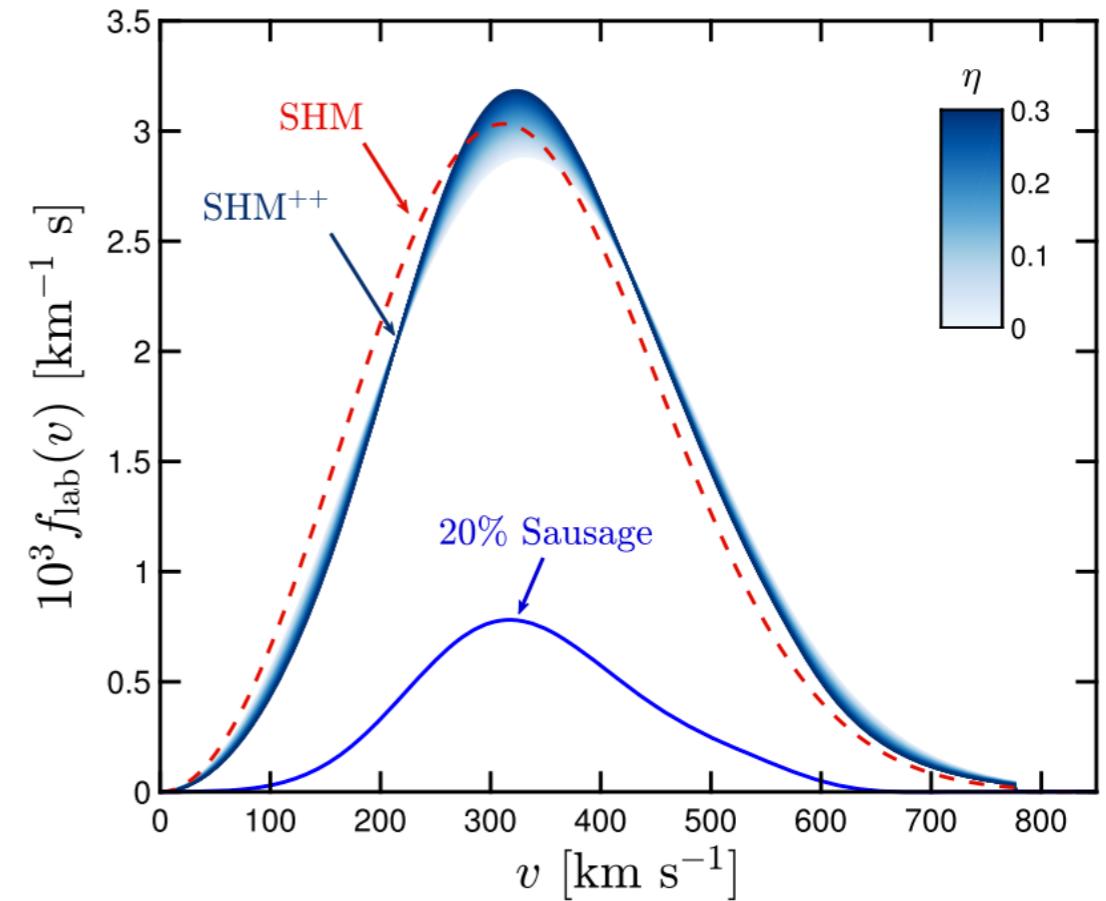
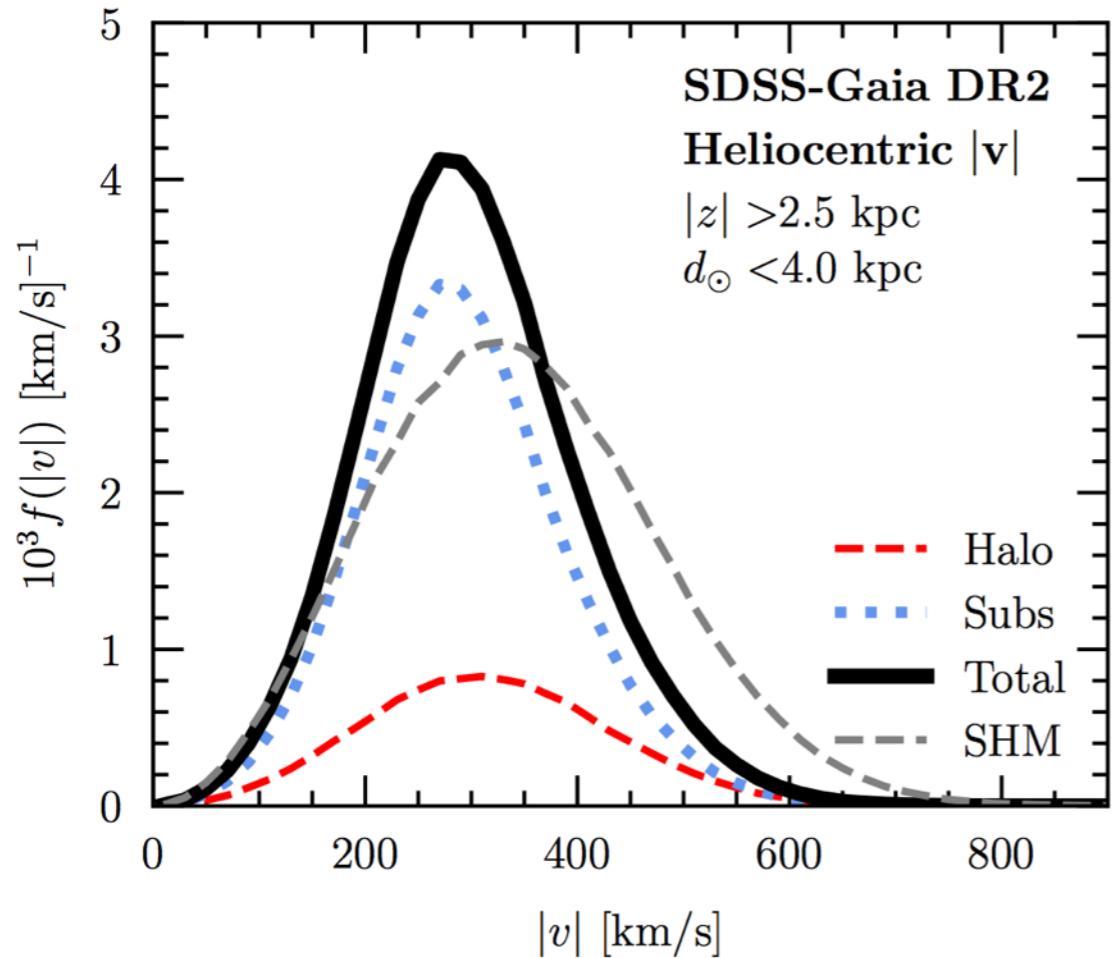
Accepted 2019 February 28. Received 2019 February 21; in original form 2019 January 7

## ABSTRACT

We model the fastest moving ( $v_{\text{tot}} > 300 \text{ km s}^{-1}$ ) local ( $D \lesssim 3 \text{ kpc}$ ) halo stars using cosmological simulations and six-dimensional *Gaia* data. Our approach is to use our knowledge of the assembly history and phase-space distribution of halo stars to constrain the form of the high-velocity tail of the stellar halo. Using simple analytical models and cosmological simulations, we find that the shape of the high-velocity tail is strongly dependent on the velocity anisotropy and number density profile of the halo stars – highly eccentric orbits and/or shallow density profiles have more extended high-velocity tails. The halo stars in the solar vicinity are known to have a strongly radial velocity anisotropy, and it has recently been shown the origin of these highly eccentric orbits is the early accretion of a massive ( $M_{\text{star}} \sim 10^9 M_{\odot}$ ) dwarf satellite. We use this knowledge to construct a prior on the shape of the high-velocity tail. Moreover, we use the simulations to define an appropriate outer boundary of  $2r_{200}$ , beyond which stars can escape. After applying our methodology to the *Gaia* data, we find a local ( $r_0 = 8.3 \text{ kpc}$ ) escape speed of  $v_{\text{esc}}(r_0) = 528_{-25}^{+24} \text{ km s}^{-1}$ . We use our measurement of the escape velocity to estimate the total Milky Way mass, and dark halo concentration:  $M_{200,\text{tot}} = 1.00_{-0.24}^{+0.31} \times 10^{12} M_{\odot}$ ,  $c_{200} = 10.9_{-3.3}^{+4.4}$ . Our estimated mass agrees with recent results in the literature that seem to be converging on a Milky Way mass of  $M_{200,\text{tot}} \sim 10^{12} M_{\odot}$ .

**Key words:** Galaxy: fundamental parameters – Galaxy: kinematics and dynamics.

# Estimates of the DM speed distribution



INFERRED EVIDENCE FOR DARK MATTER KINEMATIC SUBSTRUCTURE WITH SDSS-GAIA

LINA NECIB

Walter Burke Institute for Theoretical Physics, California Institute of Technology, Pasadena, CA 91125, USA

MARIANGELA LISANTI

Department of Physics, Princeton University, Princeton, NJ 08544, USA

VASILY BELOKUROV

Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK  
and

Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, New York, NY 10010, USA

Refinement of the standard halo model for dark matter searches  
in light of the Gaia Sausage

N. Wyn Evans,<sup>1,\*</sup> Ciaran A. J. O'Hare,<sup>2,†</sup> and Christopher McCabe<sup>3,‡</sup>

<sup>1</sup>Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, United Kingdom

<sup>2</sup>Departamento de Física Teórica, Universidad de Zaragoza,

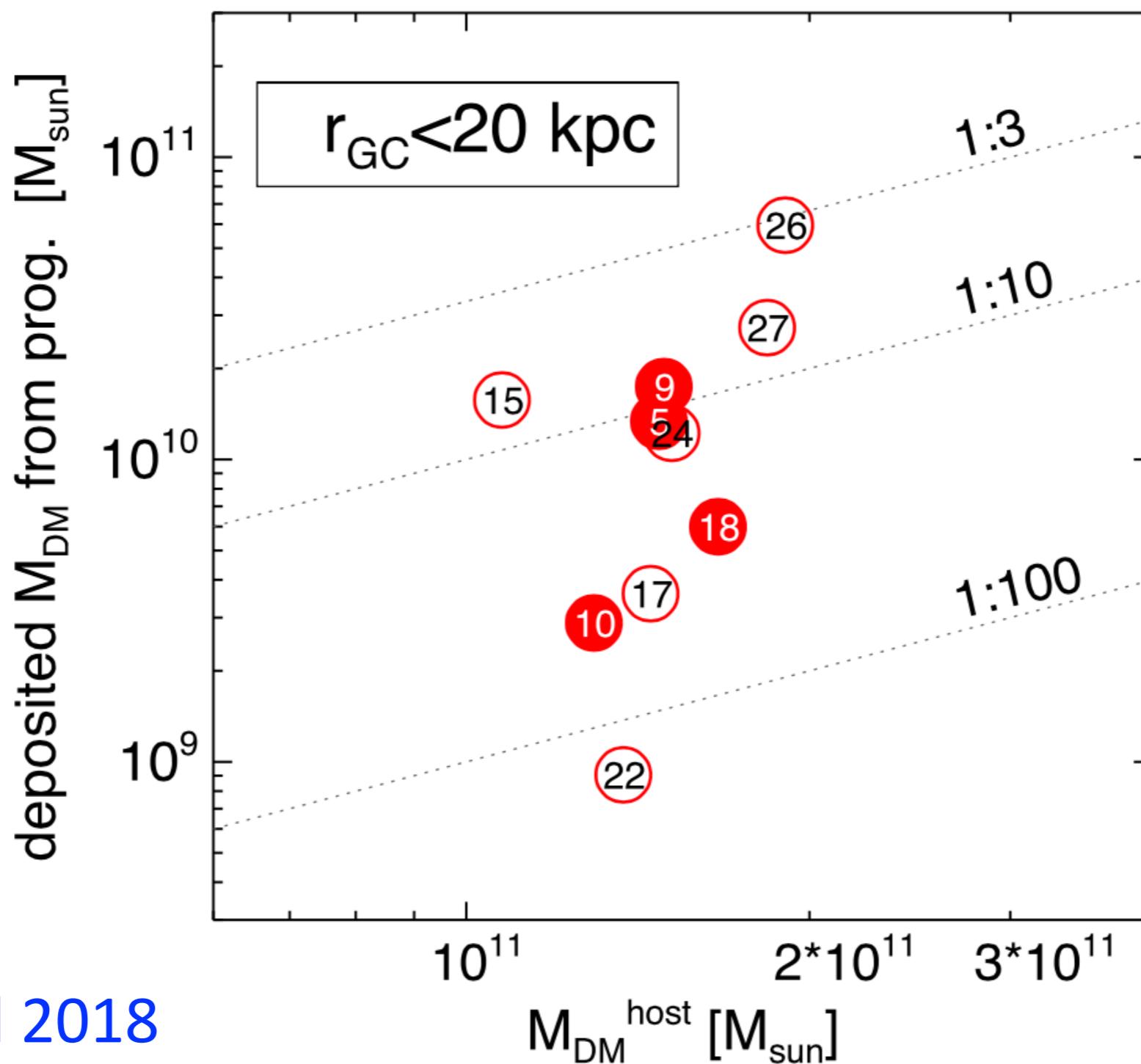
Pedro Cerbuna 12, E-50009, Zaragoza, España

<sup>3</sup>Department of Physics, King's College London, Strand, London, WC2R 2LS, United Kingdom

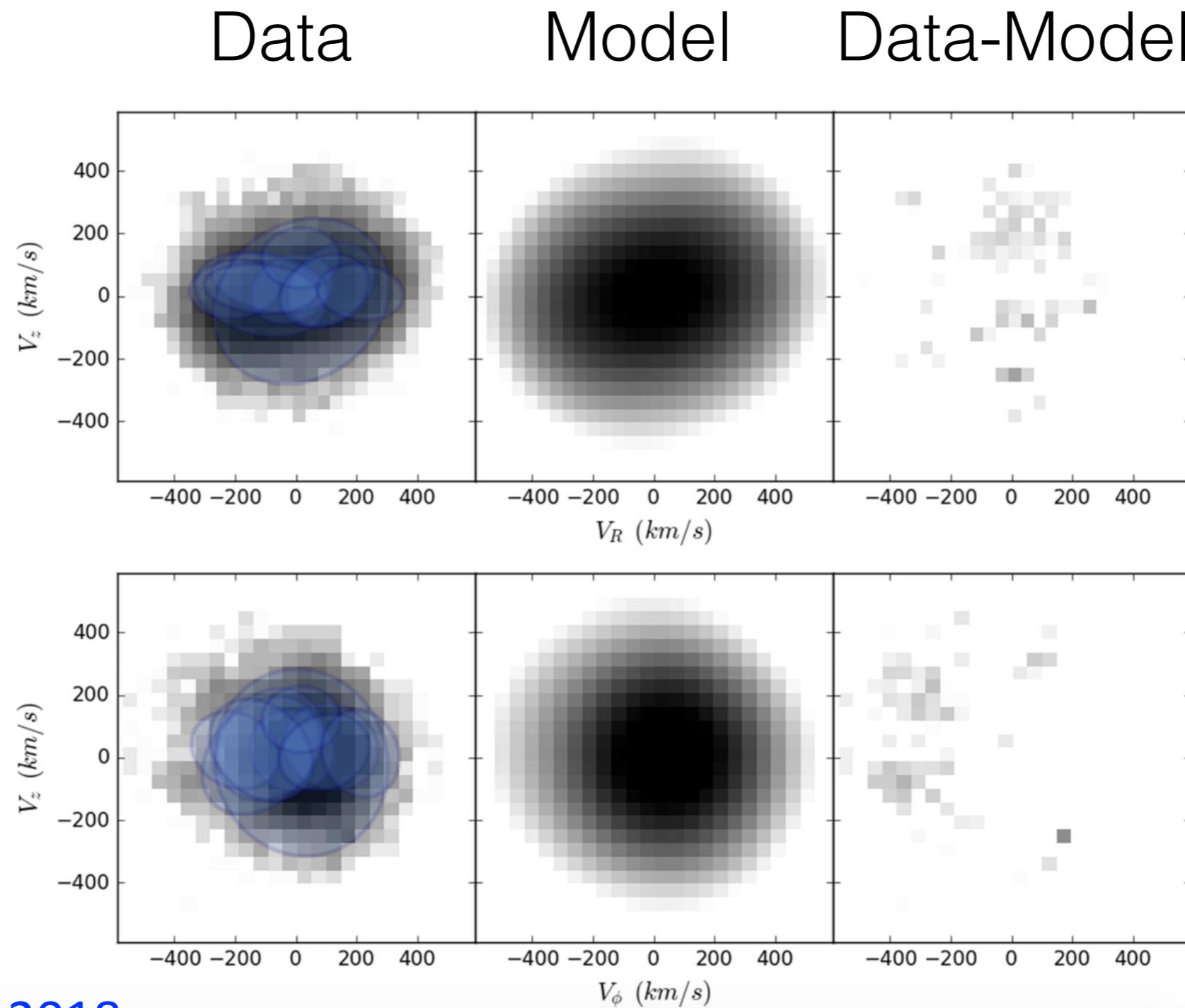


(Received 15 October 2018; published 17 January 2019)

# DM fraction deposited by a Gaia Sausage event in simulations

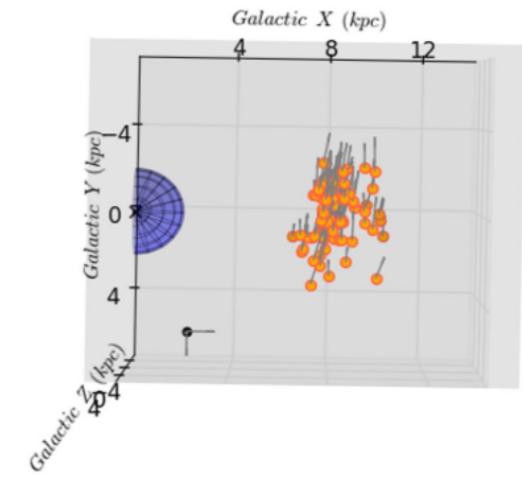
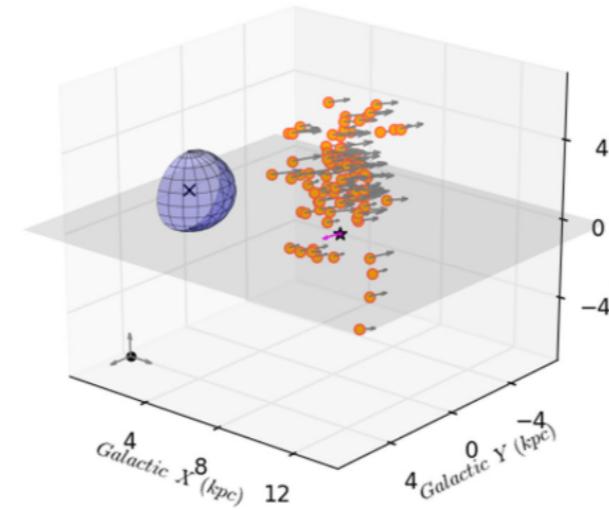
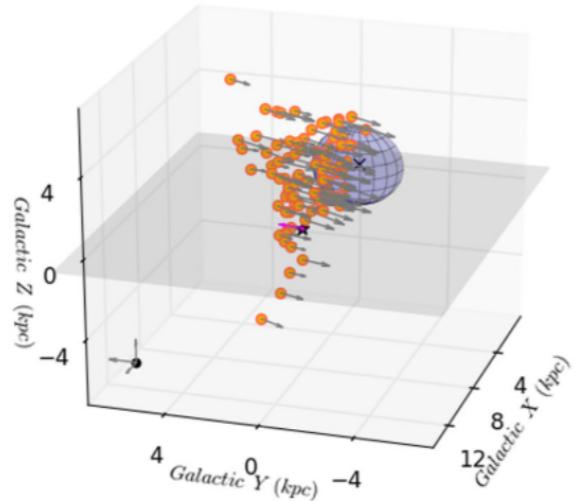


# DM substructure in the Solar neighbourhood

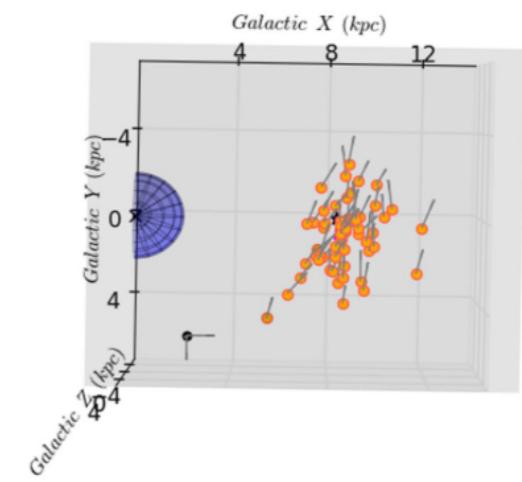
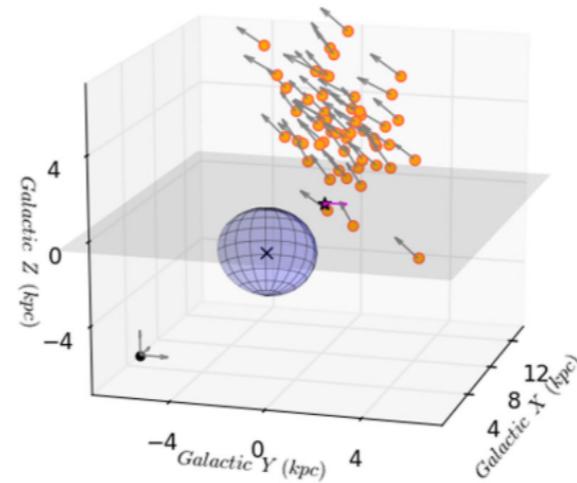
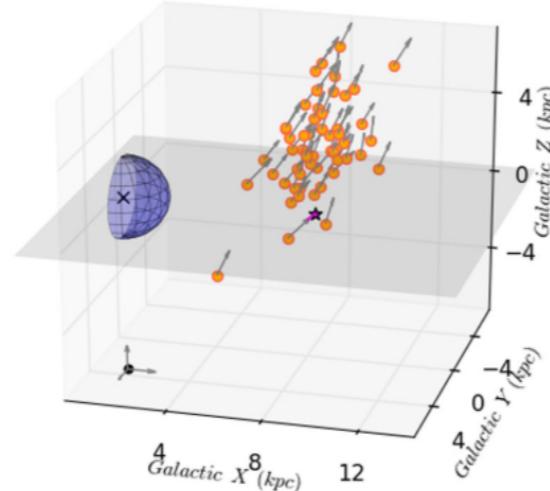


# Many new streams

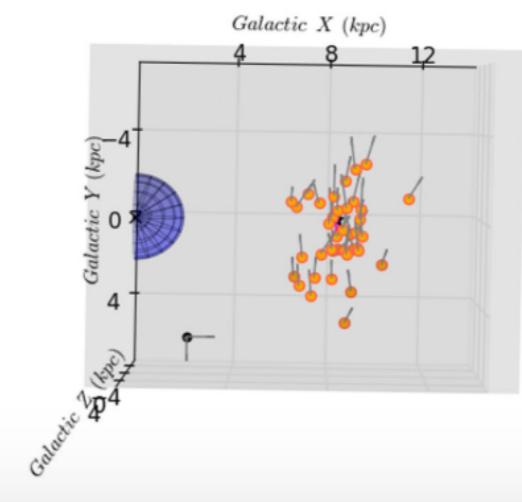
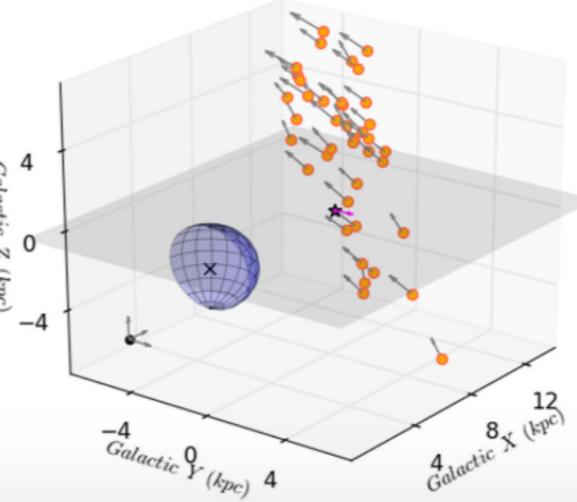
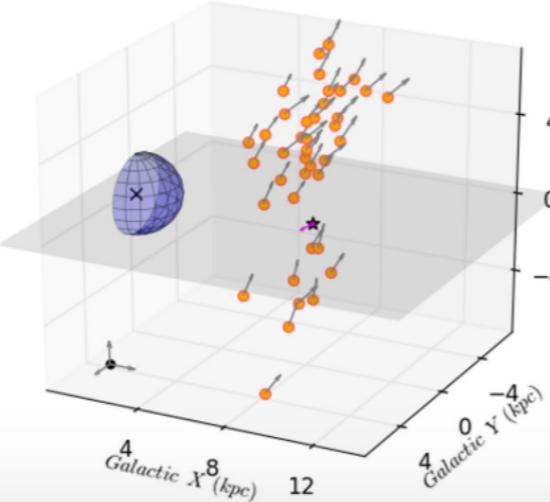
Stream 1



Stream 3



Stream 4



## Halo substructure in the SDSS–*Gaia* catalogue: streams and clumps

G. C. Myeong,<sup>1</sup> N. W. Evans,<sup>1</sup> V. Belokurov,<sup>1</sup> N. C. Amorisco<sup>2,3</sup>  
and S. E. Koposov<sup>1,4</sup>

## Discovery of new retrograde substructures: the shards of $\omega$ Centauri?

G. C. Myeong,<sup>1</sup> N. W. Evans,<sup>1</sup> V. Belokurov,<sup>1</sup> J. L. Sanders<sup>1</sup> and S. E. Koposov<sup>1,2</sup>

<sup>1</sup>Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

<sup>2</sup>McWilliams Center for Cosmology, Department of Physics, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA

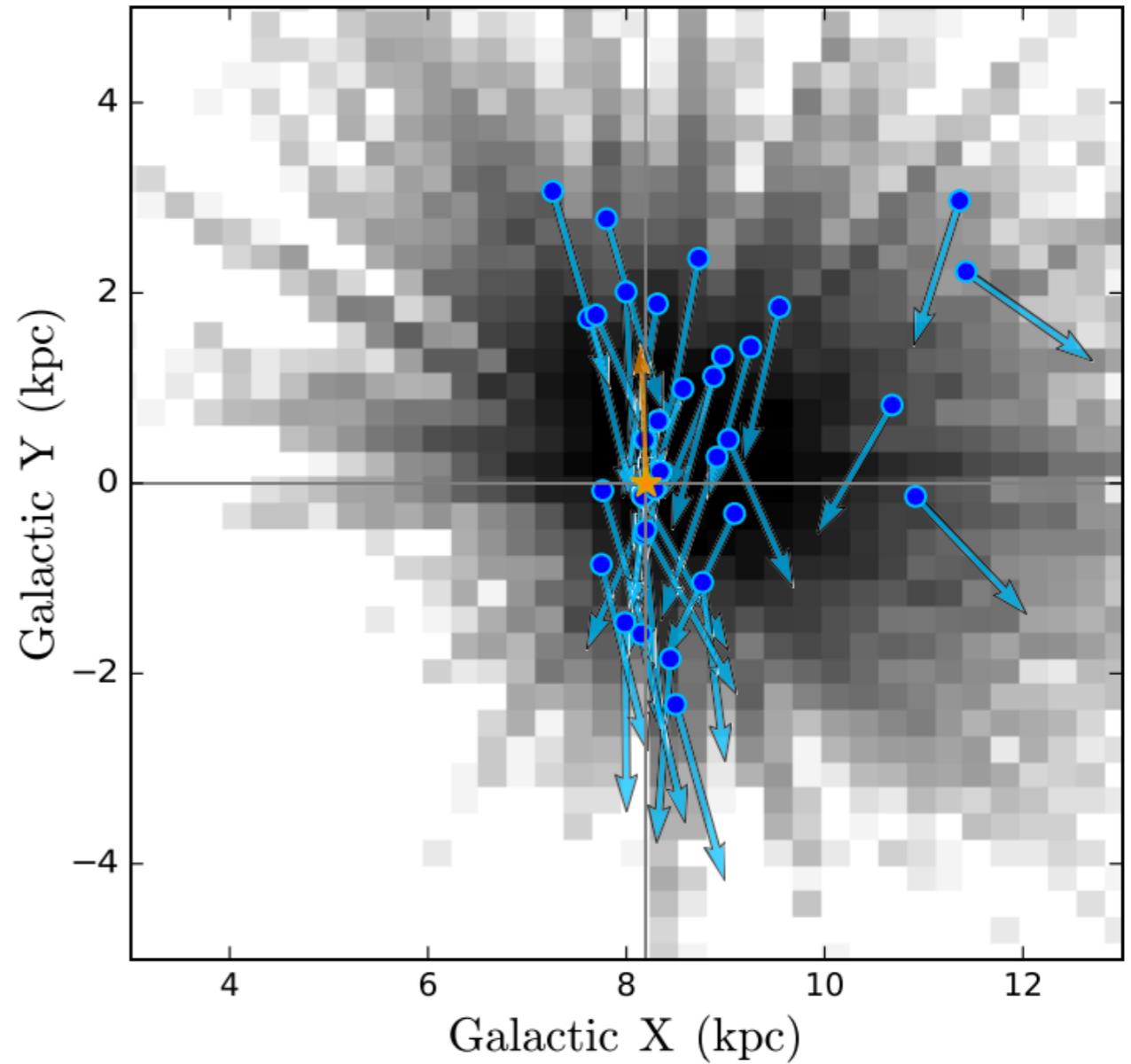
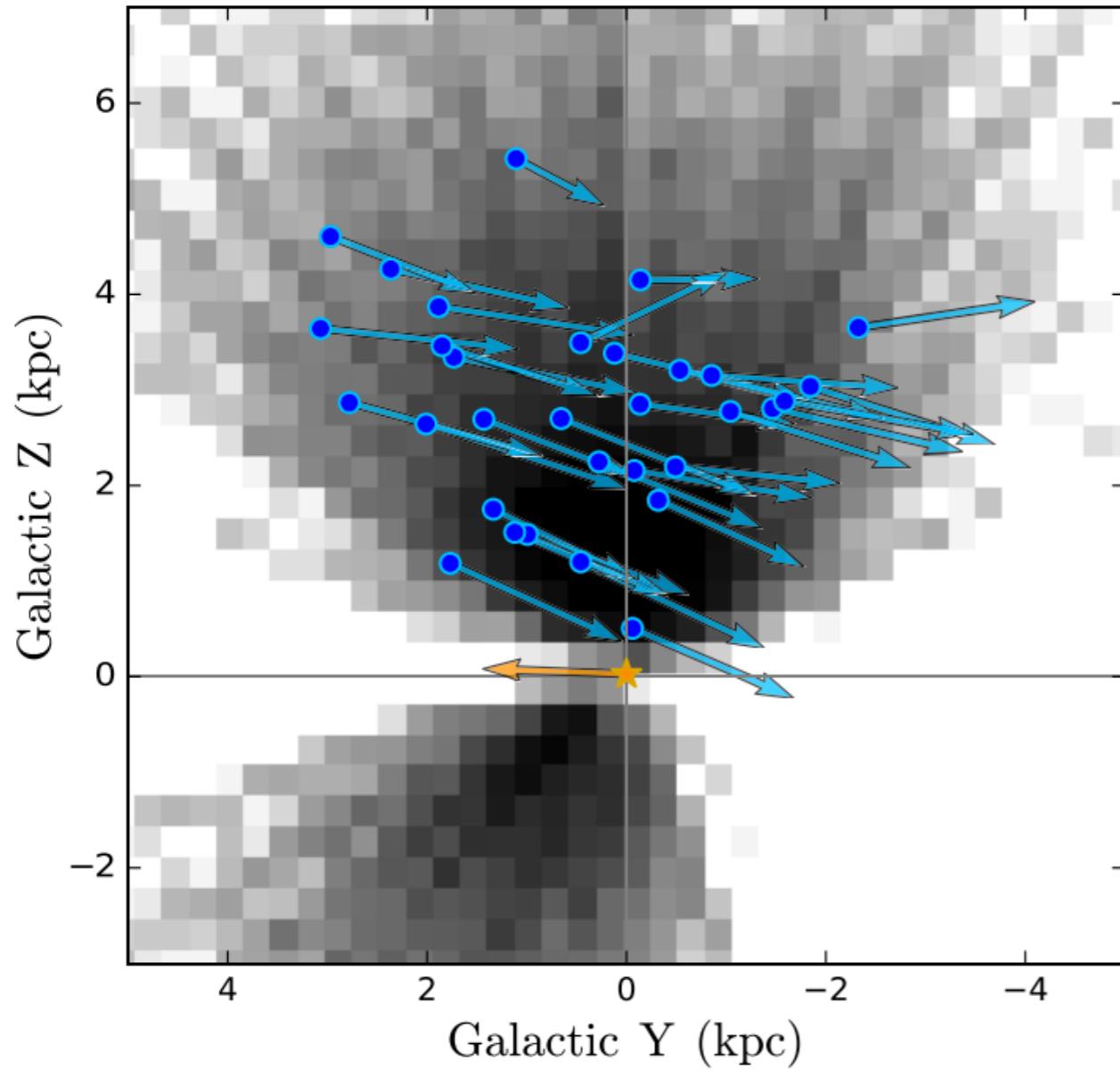
## Evidence for two early accretion events that built the Milky Way stellar halo

G. C. Myeong<sup>1</sup>, E. Vasiliev<sup>1,2</sup>, G. Iorio<sup>1</sup>, N. W. Evans<sup>1</sup> and V. Belokurov<sup>1</sup>

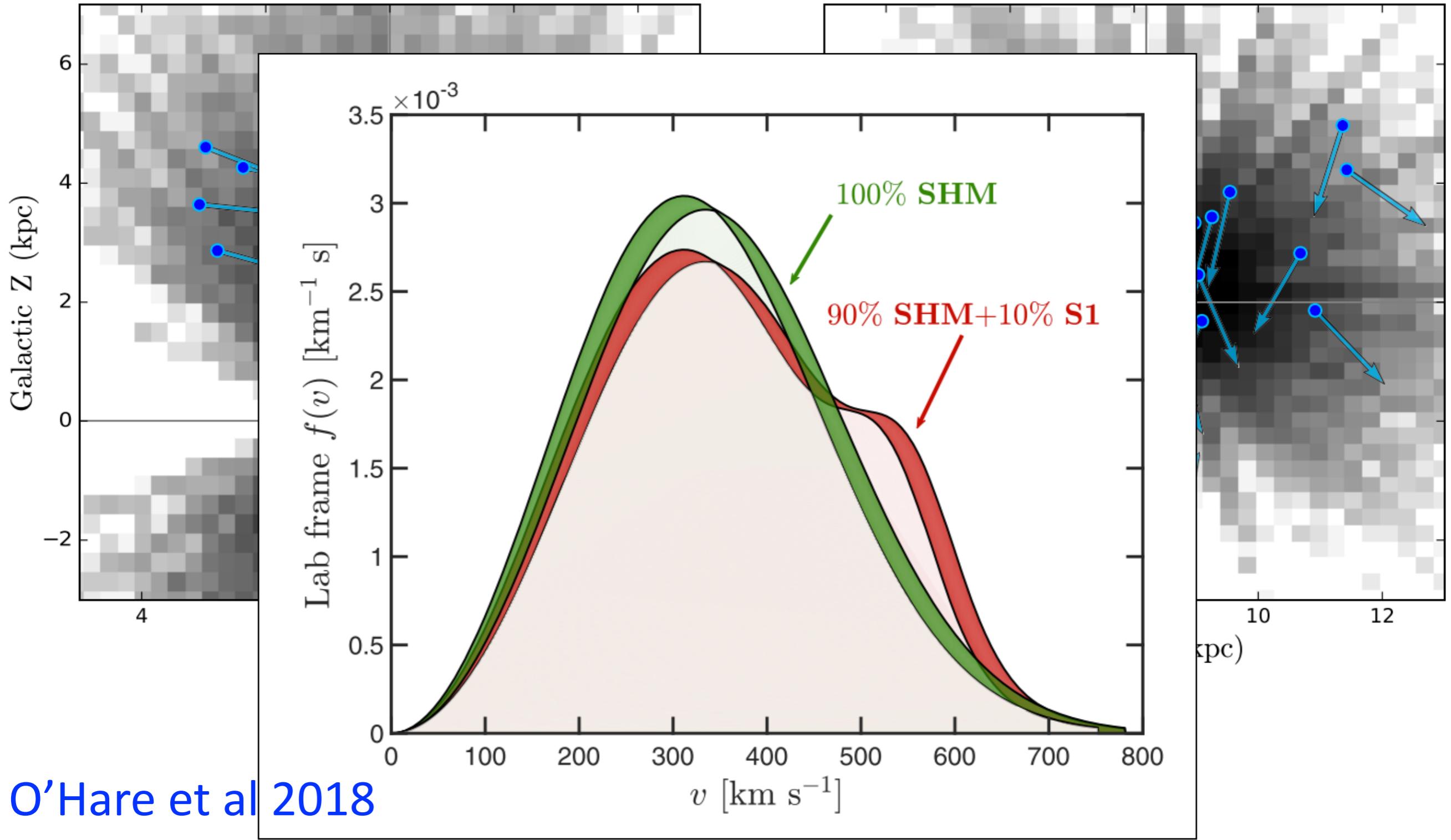
<sup>1</sup>Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK

<sup>2</sup>Lebedev Physical Institute, Leninsky Prospekt 53, Moscow 119991, Russia

# S1 - the DM hurricane



# S1 - the DM hurricane



## Dark matter hurricane: Measuring the S1 stream with dark matter detectors

Ciaran A. J. O'Hare,<sup>1,\*</sup> Christopher McCabe,<sup>2,†</sup> N. Wyn Evans,<sup>3,‡</sup> GyuChul Myeong,<sup>3</sup> and Vasily Belokurov<sup>3</sup>

<sup>1</sup>*Departamento de Física Teórica, Universidad de Zaragoza,  
Pedro Cerbuna 12, E-50009, Zaragoza, España*

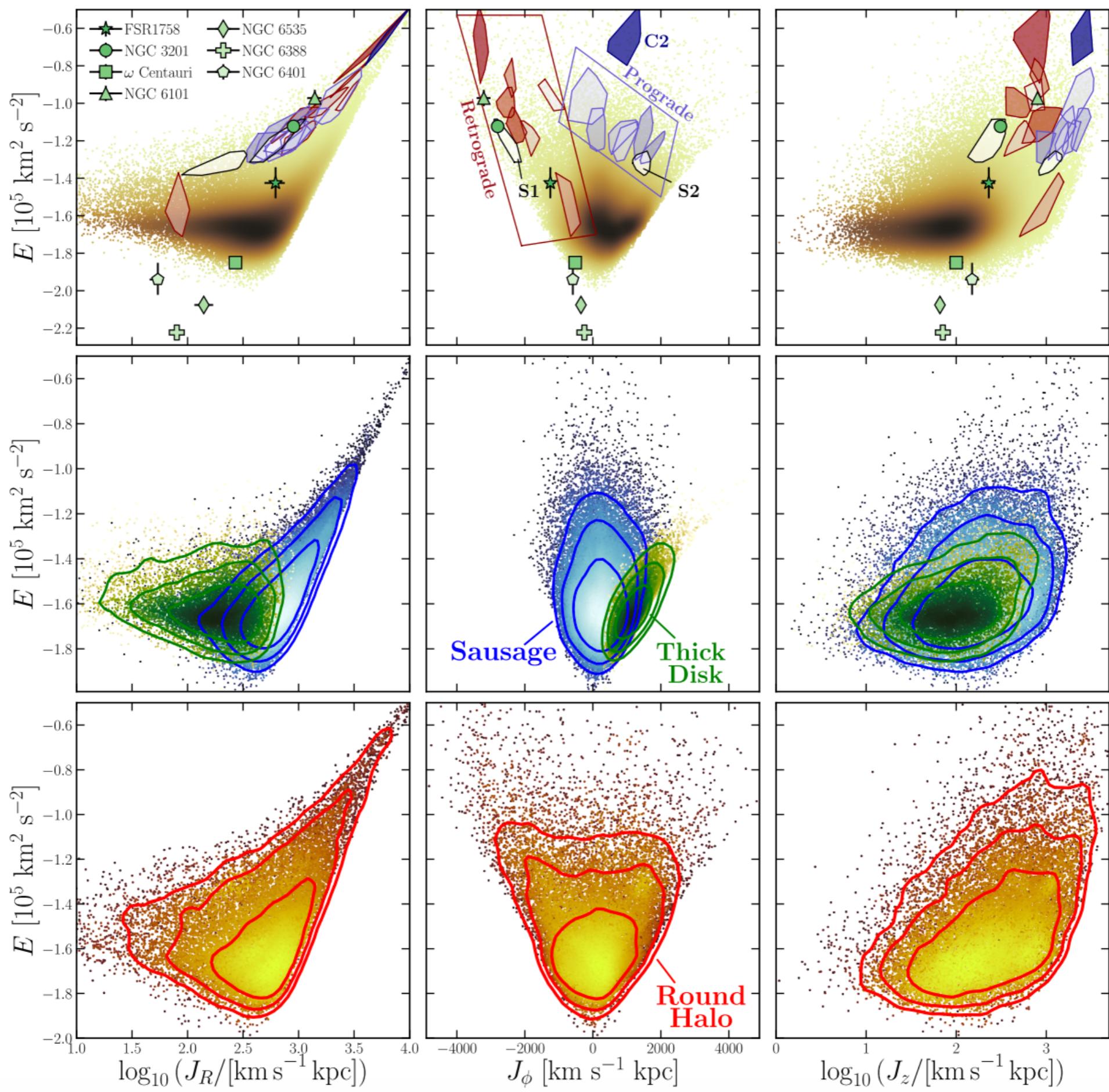
<sup>2</sup>*Department of Physics, King's College London, Strand, London, WC2R 2LS, United Kingdom*

<sup>3</sup>*Institute of Astronomy, Madingley Rd, Cambridge, CB3 0HA, United Kingdom*



(Received 13 August 2018; published 7 November 2018)

The recently discovered S1 stream passes through the Solar neighborhood on a low inclination, counterrotating orbit. The progenitor of S1 is a dwarf galaxy with a total mass comparable to the present-day Fornax dwarf spheroidal, so the stream is expected to have a significant DM component. We compute the effects of the S1 stream on WIMP and axion detectors as a function of the density of its unmeasured dark component. In WIMP detectors the S1 stream supplies more high energy nuclear recoils so will marginally improve DM detection prospects. We find that even if S1 comprises less than 10% of the local density, multiton xenon WIMP detectors can distinguish the S1 stream from the bulk halo in the relatively narrow mass range between 5 and 25 GeV. In directional WIMP detectors such as CYGNUS, S1 increases DM detection prospects more substantially since it enhances the anisotropy of the WIMP signal. Finally, we show that axion haloscopes possess by far the greatest potential sensitivity to the S1 stream if its dark matter component is sufficiently cold. Once the axion mass has been discovered, the distinctive velocity distribution of S1 can easily be extracted from the axion power spectrum.



# Dark Shards: velocity substructure from *Gaia* and direct searches for dark matter

Ciaran A. J. O'Hare,<sup>1,\*</sup> N. Wyn Evans,<sup>2,†</sup> Christopher McCabe,<sup>3,‡</sup> GyuChul Myeong,<sup>2,§</sup> and Vasily Belokurov<sup>2</sup>

<sup>1</sup>*Departamento de Física Teórica, Universidad de Zaragoza, Pedro Cerbuna 12, E-50009, Zaragoza, España*

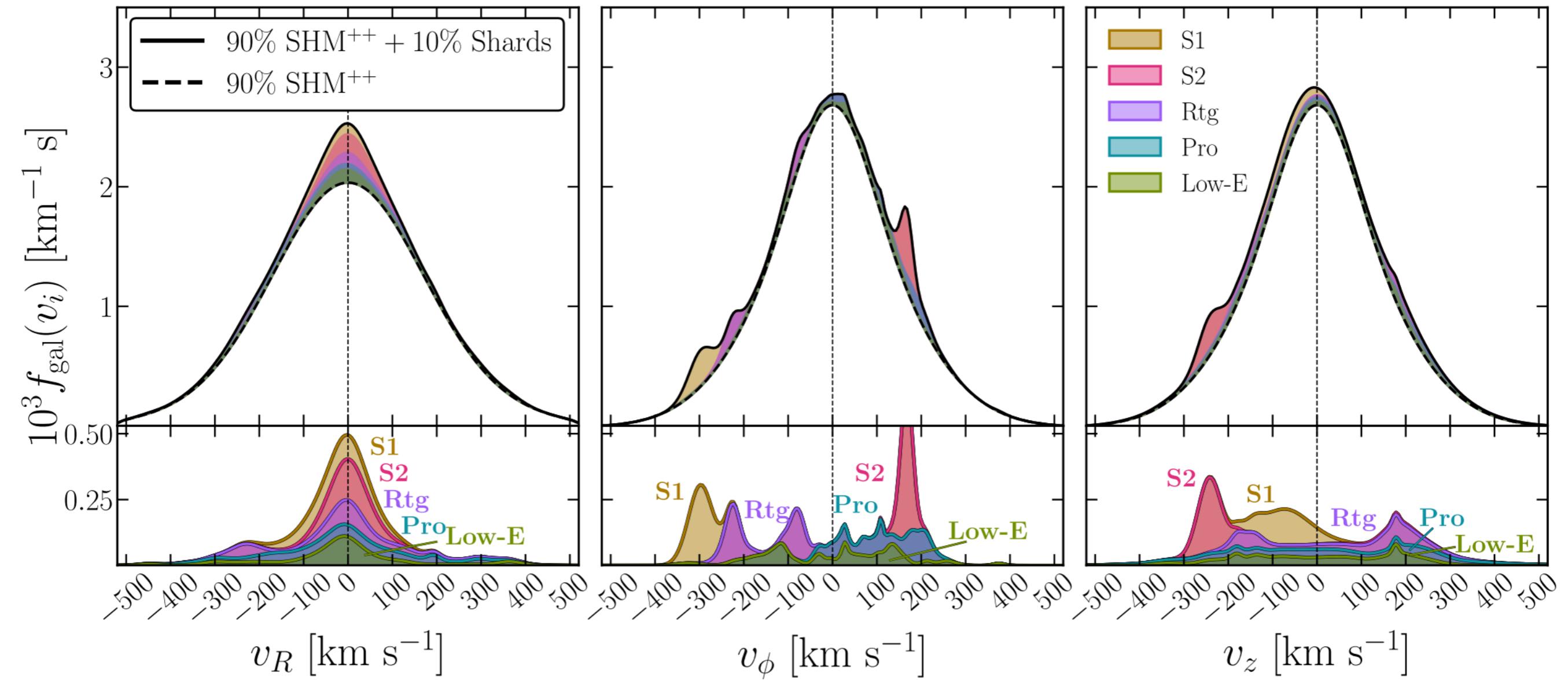
<sup>2</sup>*Institute of Astronomy, Madingley Rd, Cambridge, CB3 0HA, United Kingdom*

<sup>3</sup>*Department of Physics, King's College London, Strand, London, WC2R 2LS, United Kingdom*

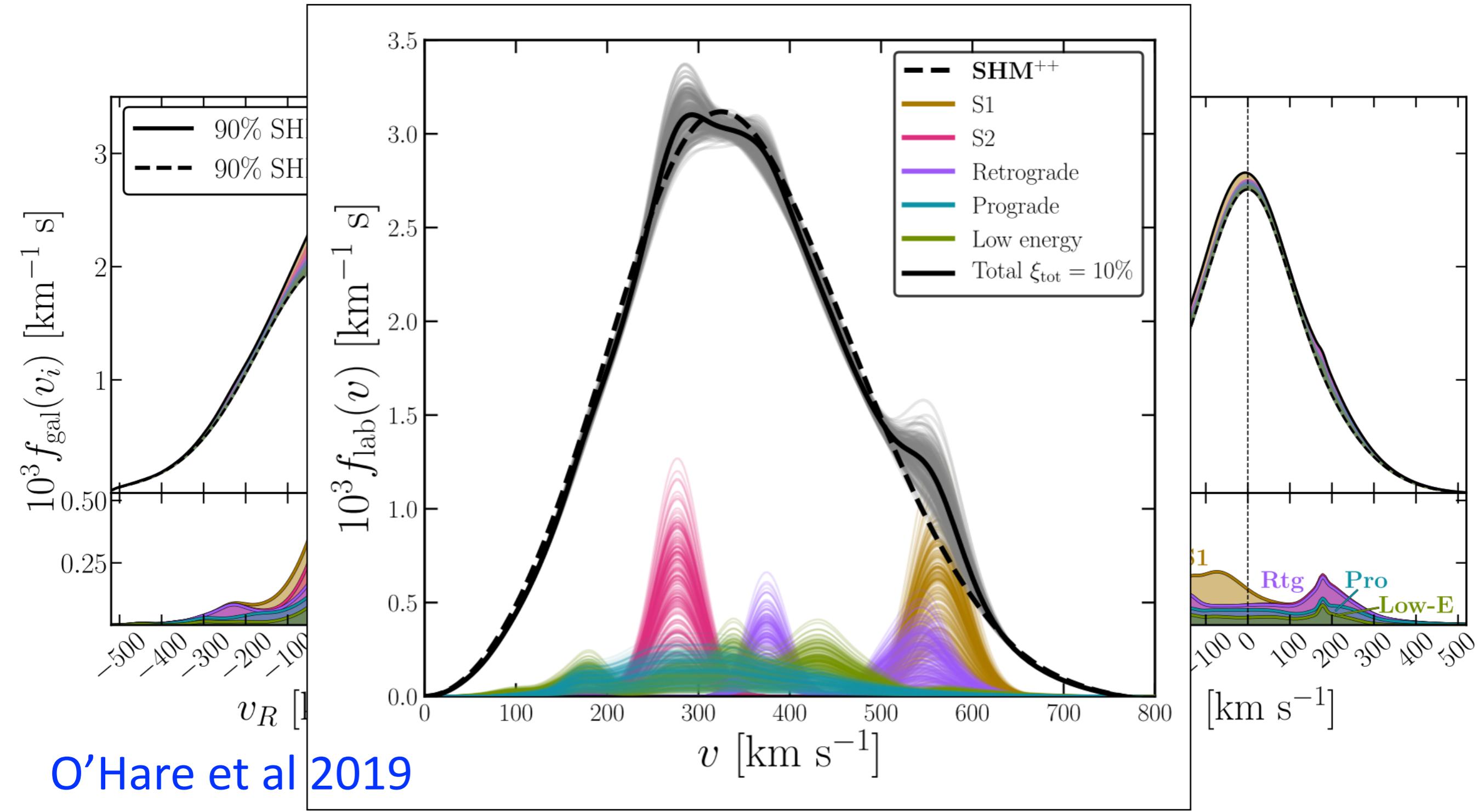
(Dated: September 12, 2019)

Data from the *Gaia* satellite show that the solar neighbourhood of the Milky Way's stellar halo is imprinted with substructure from several accretion events. Evidence of these events is found in “the Shards”, stars clustering with high significance in both action space and metallicity. Stars in the Shards share a common origin, likely as ancient satellite galaxies of the Milky Way, so will be embedded in dark matter (DM) counterparts. These “Dark Shards” contain two substantial streams (S1 and S2), as well as several retrograde, prograde and lower energy objects. The retrograde stream S1 has a very high Earth-frame speed of  $\sim 550 \text{ km s}^{-1}$  while S2 moves on a prograde, but highly polar orbit and enhances peak of the speed distribution at around  $300 \text{ km s}^{-1}$ . The presence of the Dark Shards locally leads to modifications of many to the fundamental properties of experimental DM signals. The S2 stream in particular gives rise to an array of effects in searches for axions and in the time dependence of nuclear recoils: shifting the peak day, inducing non-sinusoidal distortions, and increasing the importance of the gravitational focusing of DM by the Sun. Dark Shards additionally bring new features for directional signals, while also enhancing the DM flux towards Cygnus.

# Comprehensive view of the local sub-structures

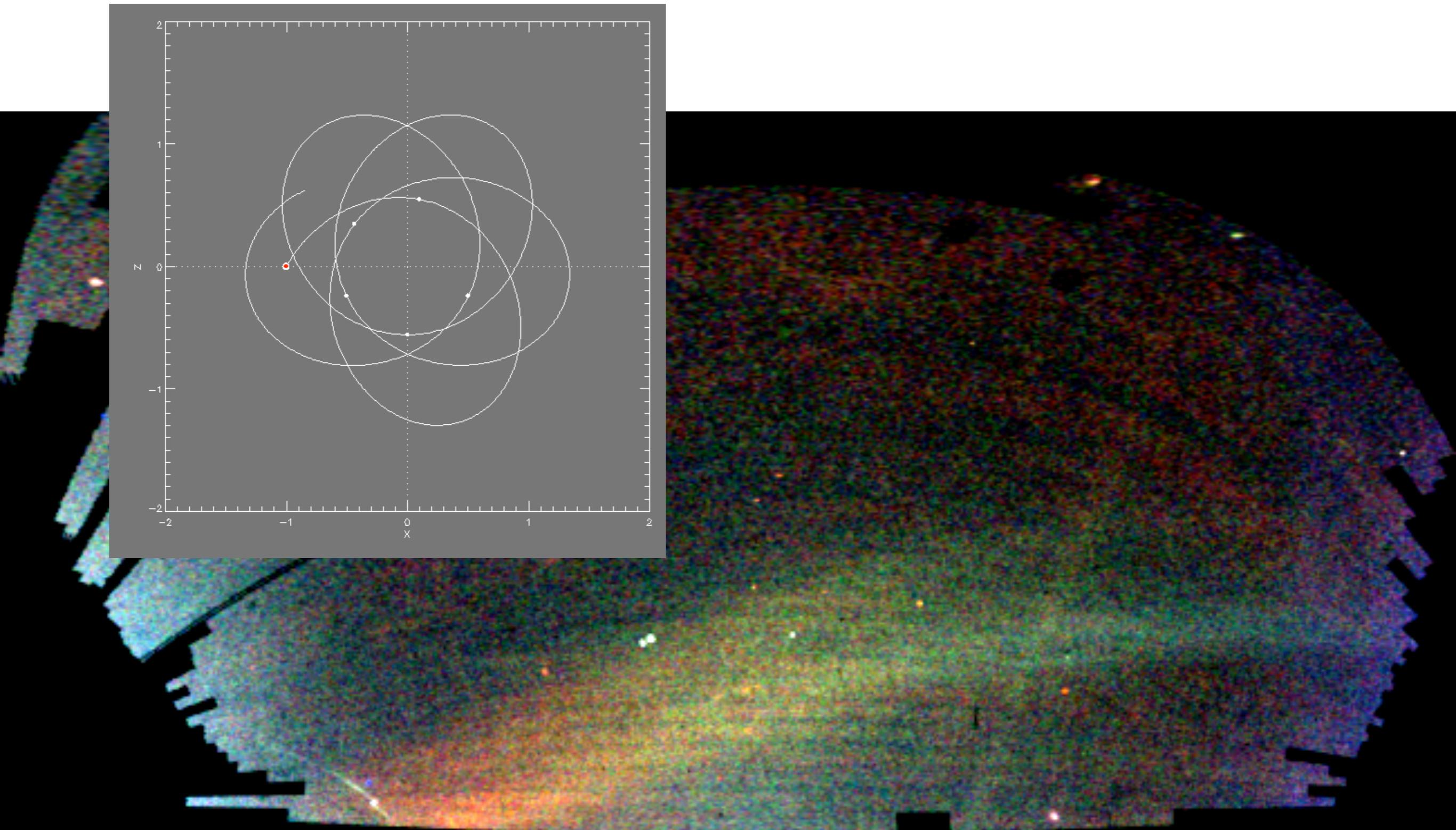


# Comprehensive view of the local sub-structures



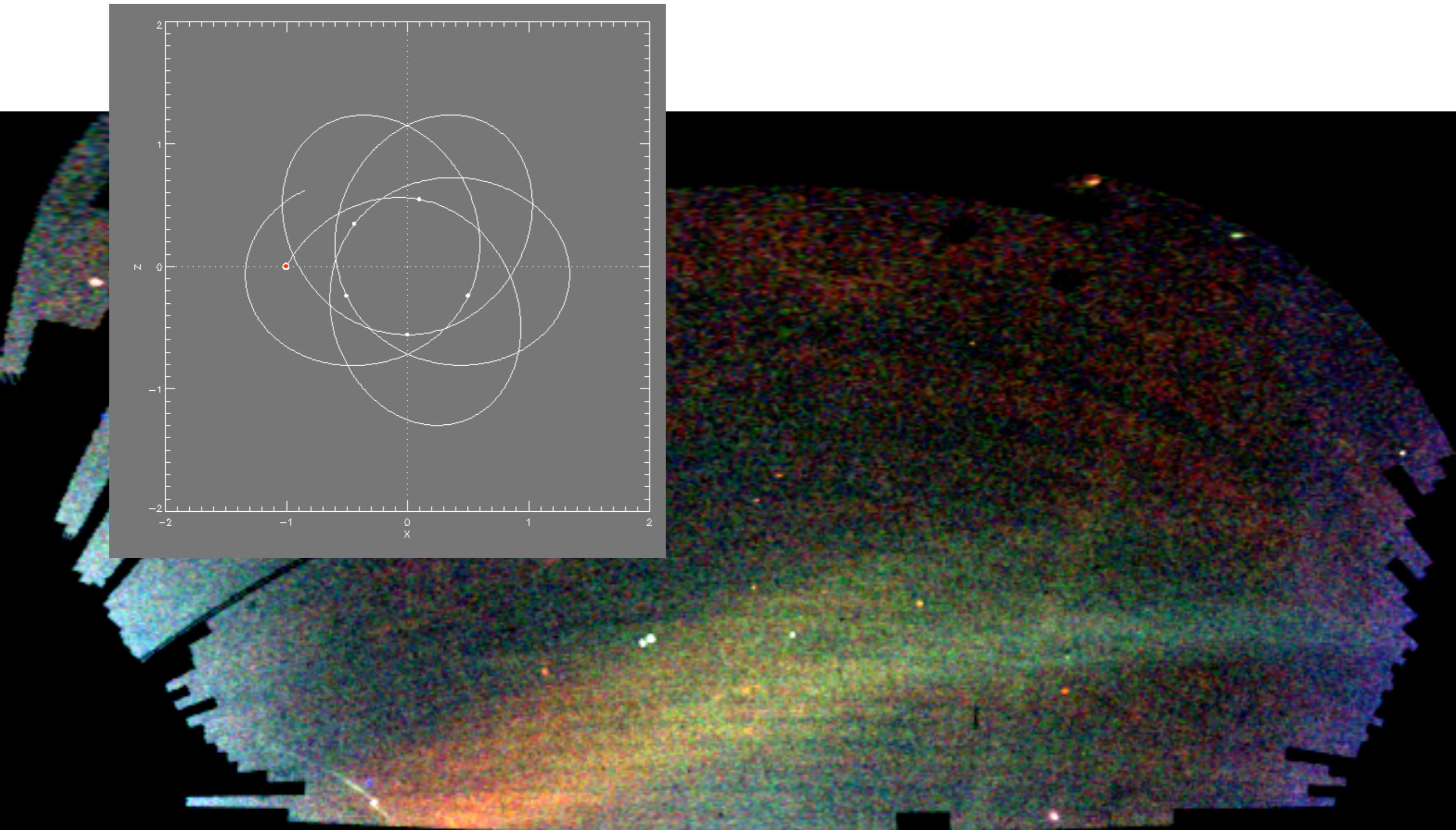
Excess of high speed local DM  
without a stellar counterpart

# Orphan Stream in the North



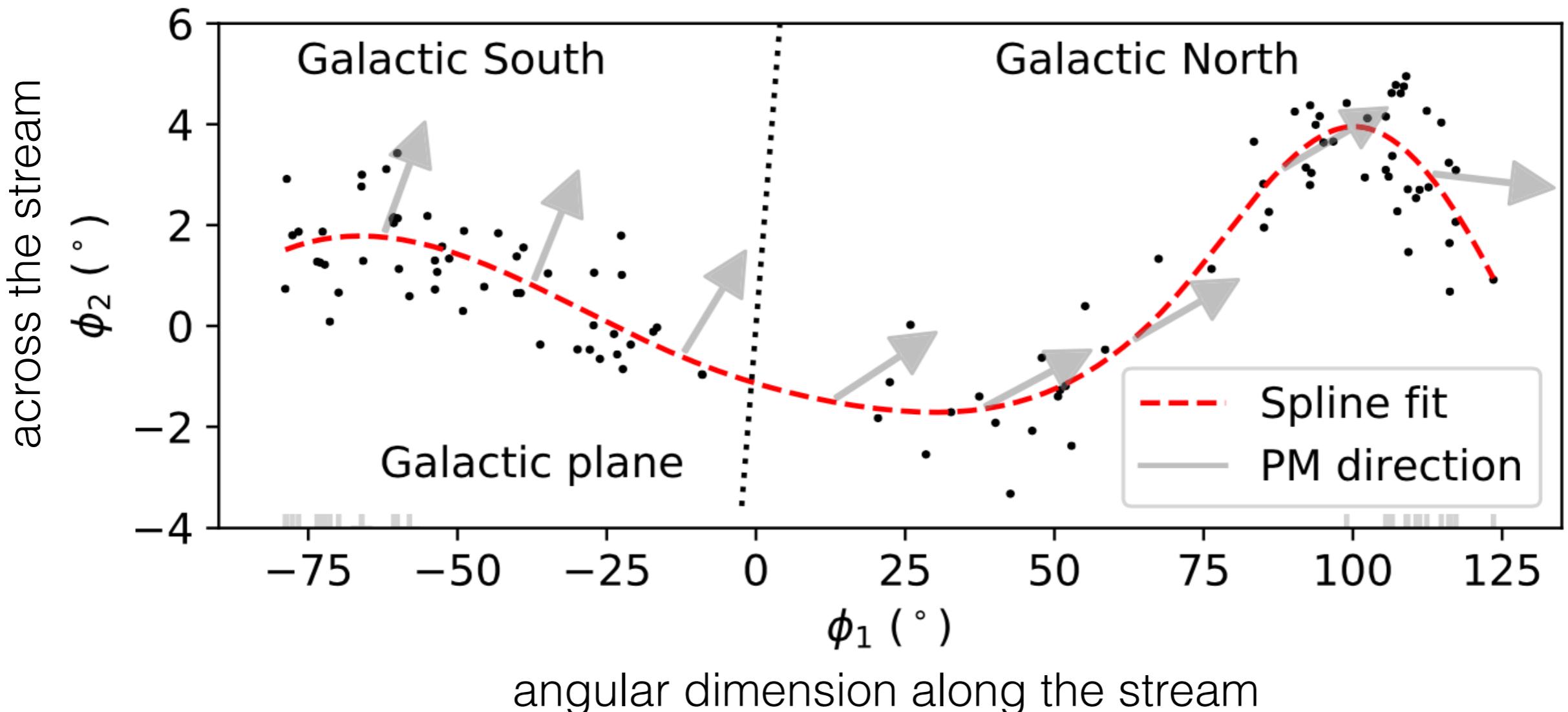
Density of SDSS Main Sequence Turn-off stars. Color ~ distance

# Orphan Stream in the North



Density of SDSS Main Sequence Turn-off stars. Color ~ distance

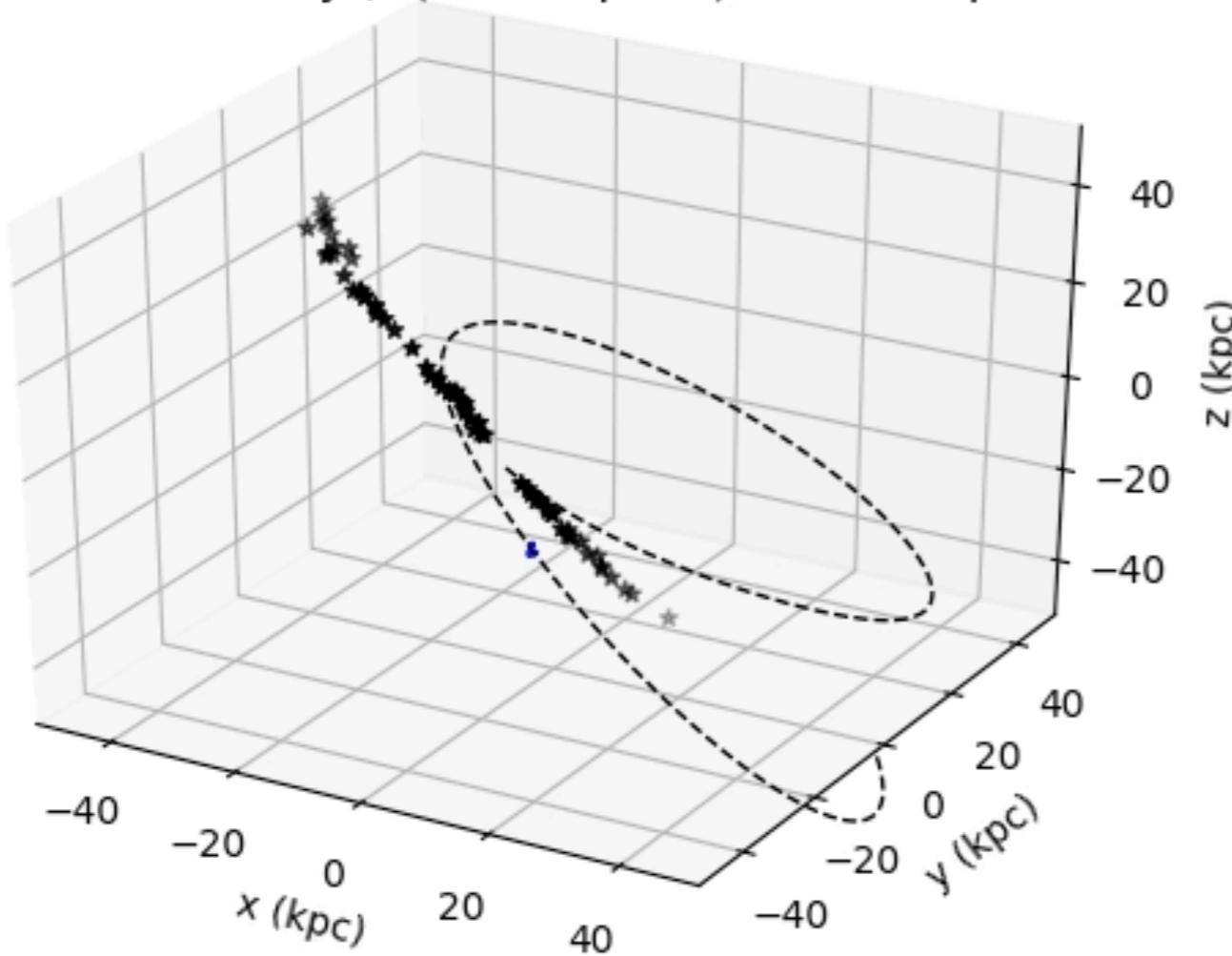
# Orphan Stream motion misalignment in Gaia DR2



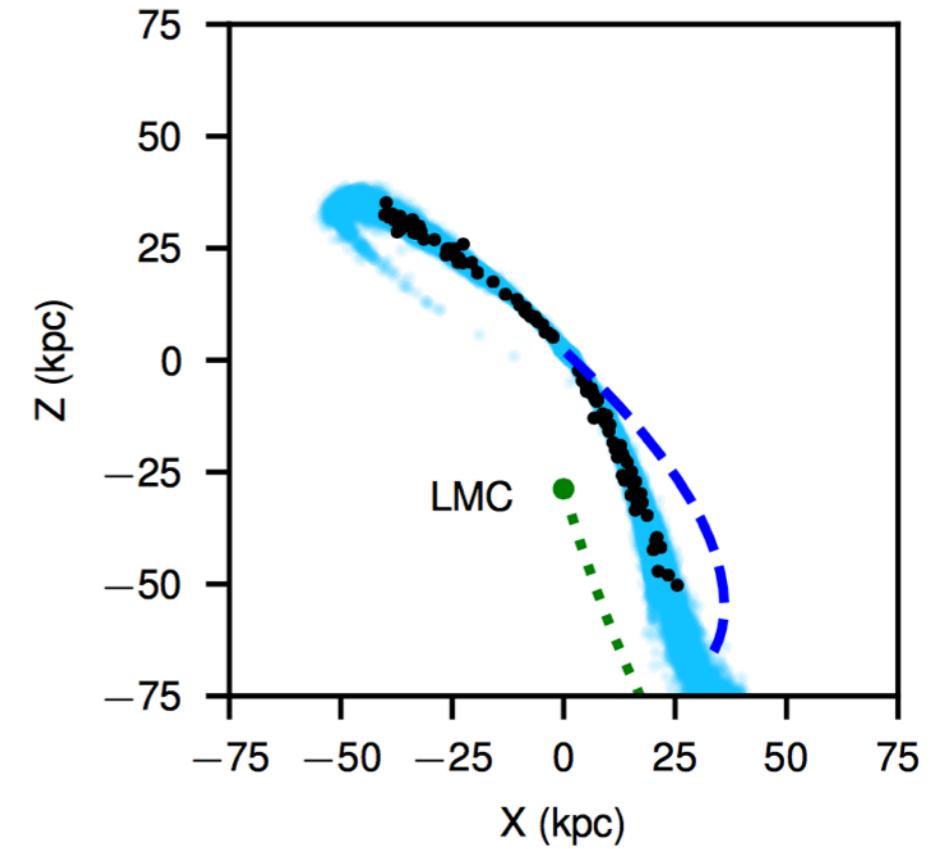
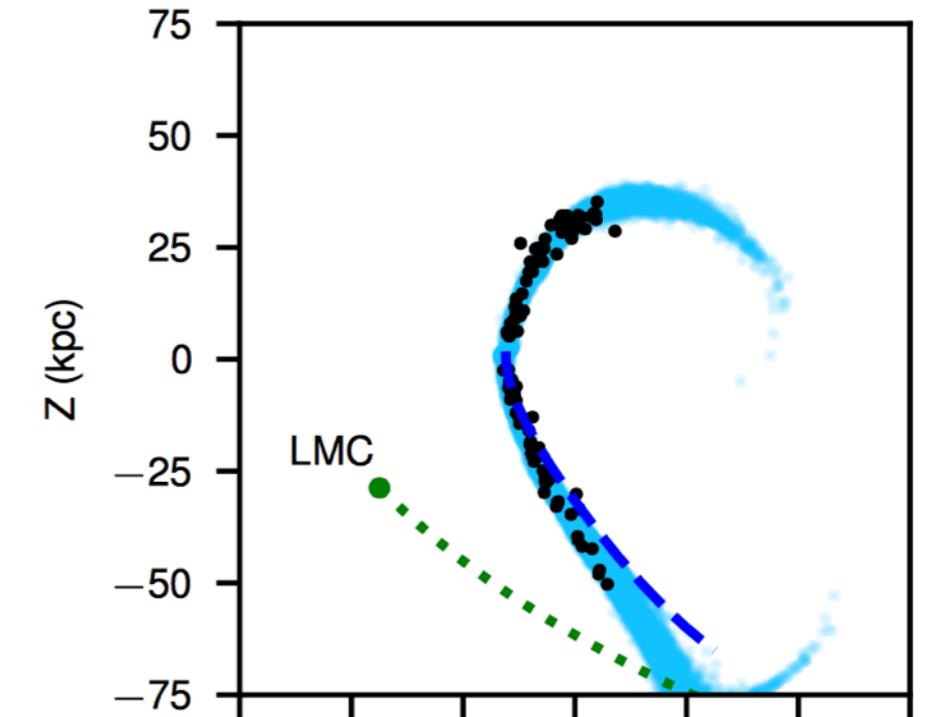
# Orphan-LMC interaction

$$M_{LMC} = 1.5 \times 10^{11} M_{\odot}$$

Milky Way + LMC  
 $t = -2.00$  Gyr,  $r(LMC\text{-Orphan}) = 507.6$  kpc



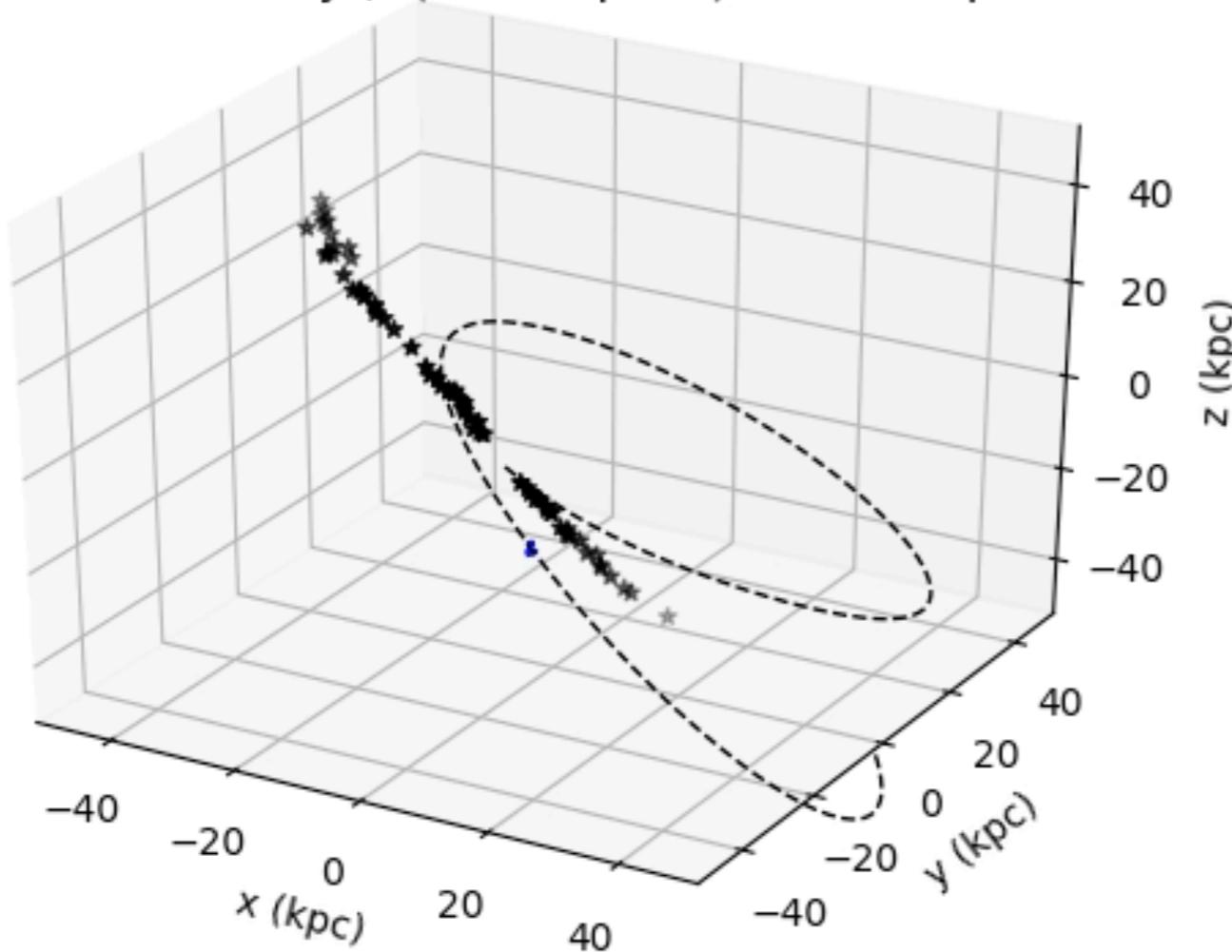
Erkal et al 2019



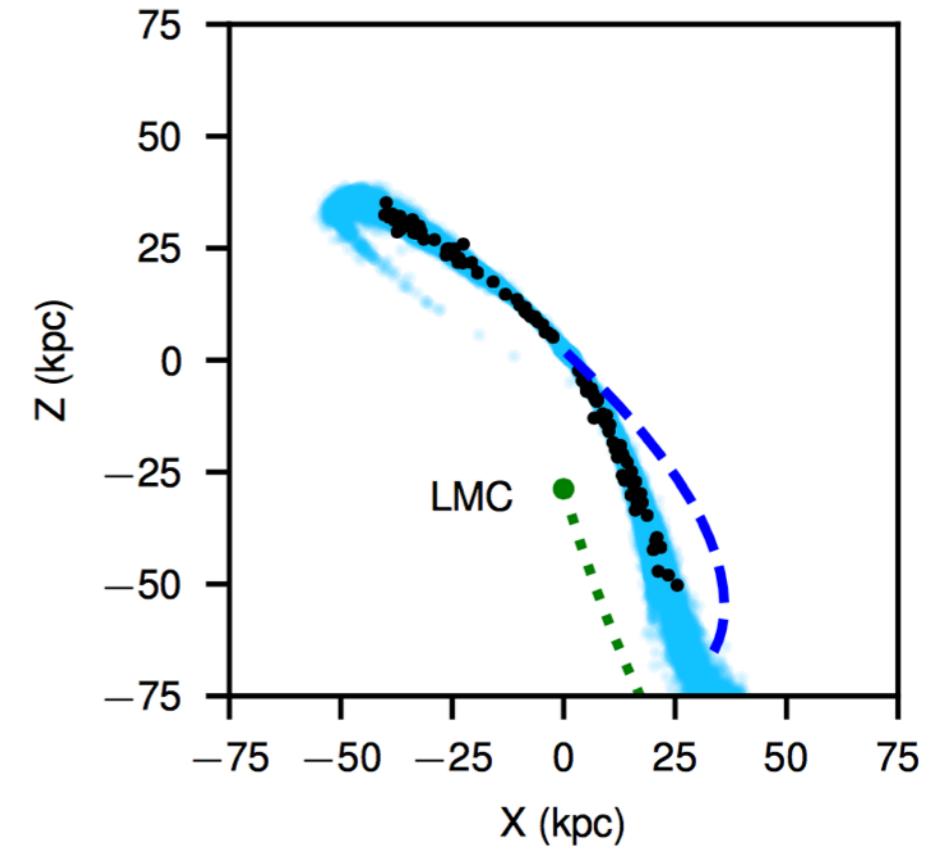
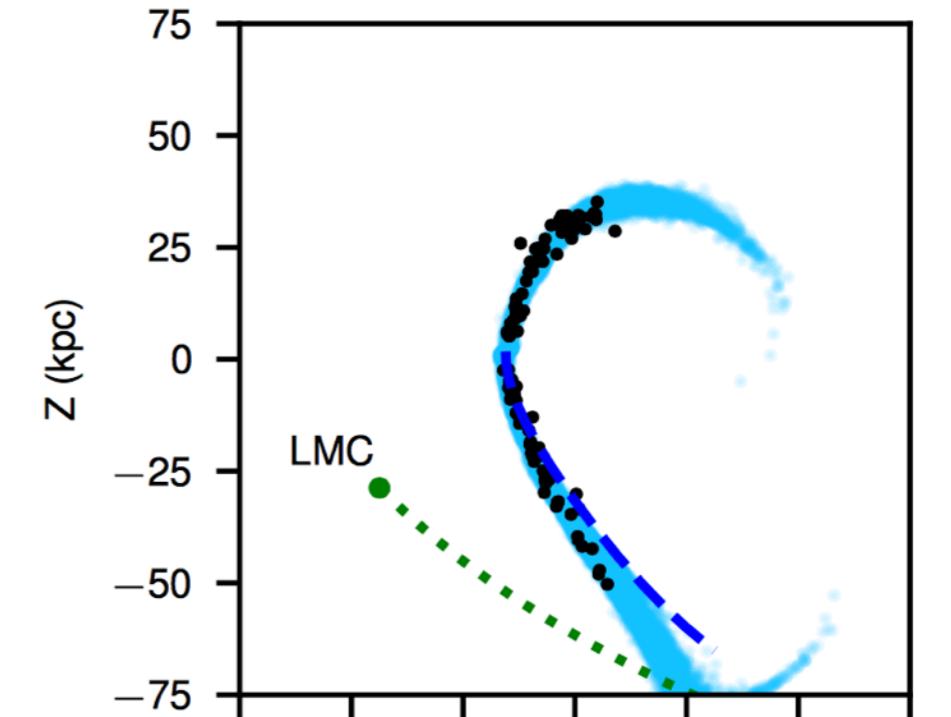
# Orphan-LMC interaction

$$M_{LMC} = 1.5 \times 10^{11} M_{\odot}$$

Milky Way + LMC  
 $t = -2.00$  Gyr,  $r(LMC\text{-Orphan}) = 507.6$  kpc



Erkal et al 2019



# The total mass of the Large Magellanic Cloud from its perturbation on the Orphan stream

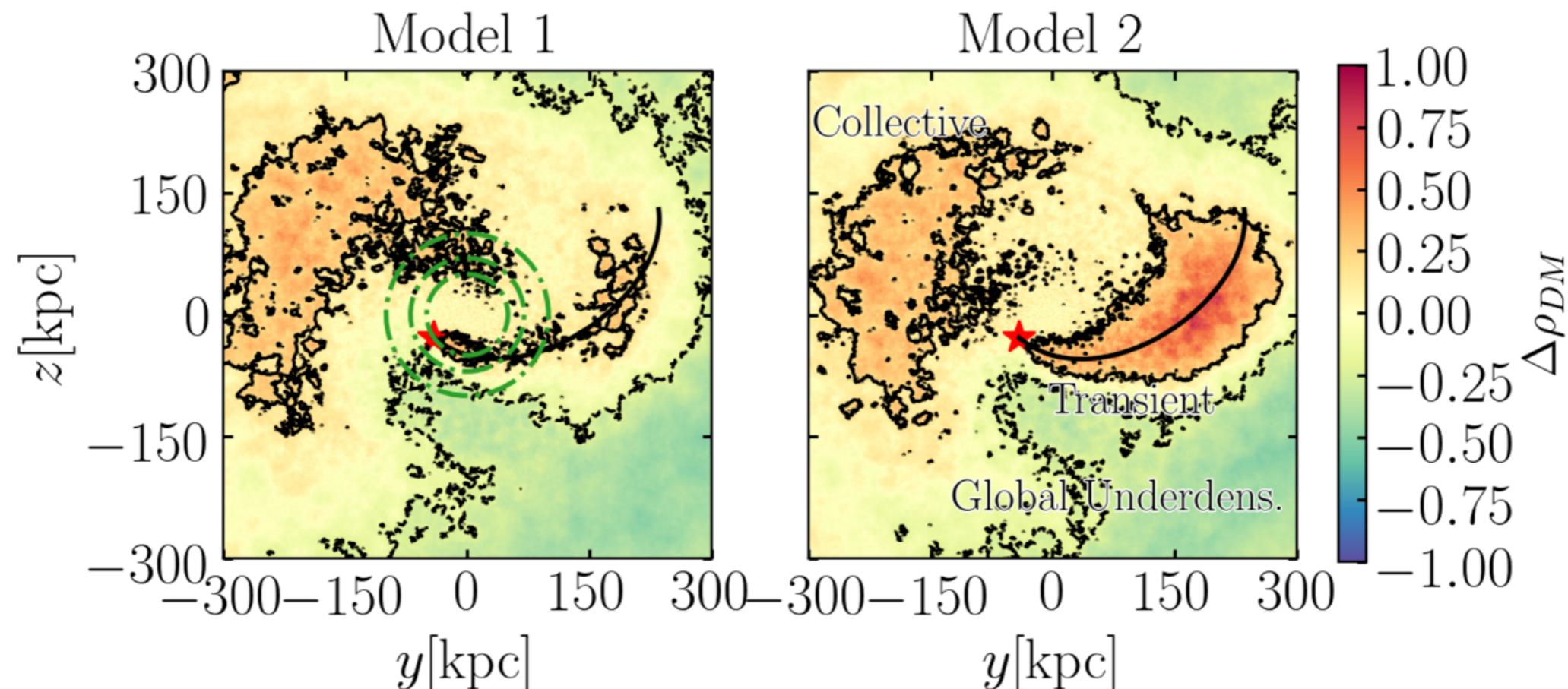
D. Erkal<sup>1</sup>,<sup>1</sup> V. Belokurov<sup>2,3</sup>, C. F. P. Laporte,<sup>4</sup> S. E. Koposov<sup>2,5</sup>, T. S. Li,<sup>6,7</sup>  
C. J. Grillmair,<sup>8</sup> N. Kallivayalil,<sup>9</sup> A. M. Price-Whelan,<sup>10</sup> N. W. Evans,<sup>2</sup> K. Hawkins<sup>11</sup>,  
D. Hendel<sup>12</sup>, C. Mateu<sup>13</sup>, J. F. Navarro,<sup>1,14</sup> A. del Pino,<sup>15</sup> C. T. Slater<sup>16</sup>  
and S. T. Sohn<sup>15</sup>

(The OATs: Orphan Aspen Treasury Collaboration)

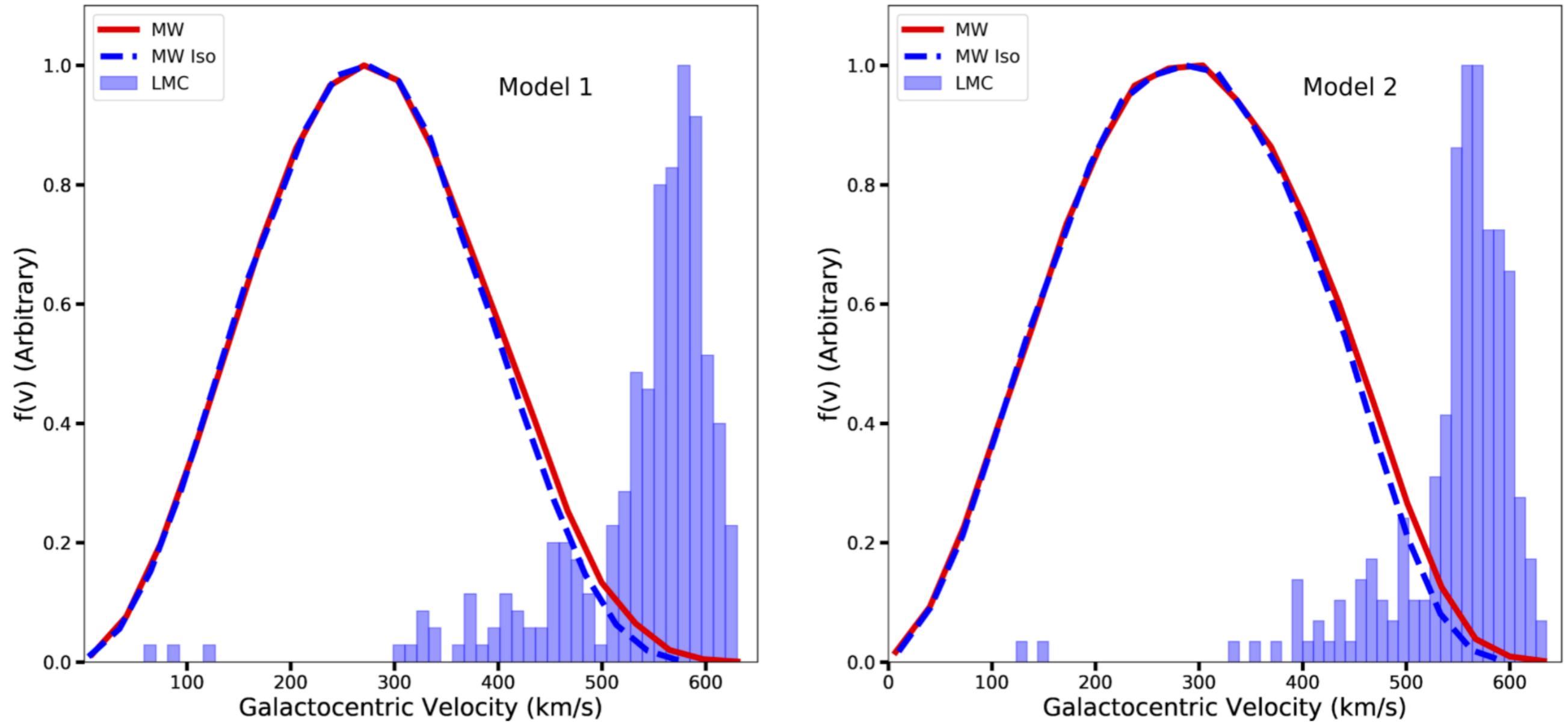
# The total mass of the Large Magellanic Cloud from its perturbation on the Orphan stream

D. Erkal<sup>1,2</sup>, V. Belokurov<sup>2,3</sup>, C. F. P. Laporte,<sup>4</sup> S. E. Koposov<sup>2,5</sup>, T. S. Li,<sup>6,7</sup>, C. J. Grillmair,<sup>8</sup>, N. Kallivayalil,<sup>9</sup>, A. M. Price-Whelan,<sup>10</sup>, N. W. Evans,<sup>2</sup>, K. Hawkins<sup>11</sup>, D. Hendel<sup>12</sup>, C. Mateu<sup>13</sup>, J. F. Navarro,<sup>1,14</sup>, A. del Pino,<sup>15</sup>, C. T. Slater<sup>16</sup> and S. T. Sohn<sup>15</sup>

(The OATs: Orphan Aspen Treasury Collaboration)



# DM particles from the LMC and accelerated by the LMC



# Conclusions. Accretion history

- Thanks to Gaia, we now have strong constraints on the mass accretion history of the Galaxy.
- It is punctuated by two major events with similar mass: the Gaia Sausage event (10 Gyr ago) and the LMC (today).
- Both have strong implications for the properties of the Galactic DM density, both globally (DM density profile, number of dwarfs etc) and locally (dis-equilibrium, shape of the velocity distribution)

# Conclusions. Local sub-structure

- Most of the local sub-structure is phase-mixed, but can be discovered with Gaia by searches through phase-space.
- Gaia has allowed to carry out a census of local DM over-densities deposited by disrupted dwarf galaxies
- Enhanced, modified signal to inform direct searches
- The exact DM content corresponding to the stellar halo sub-structures needs to be established via modelling

Thanks!