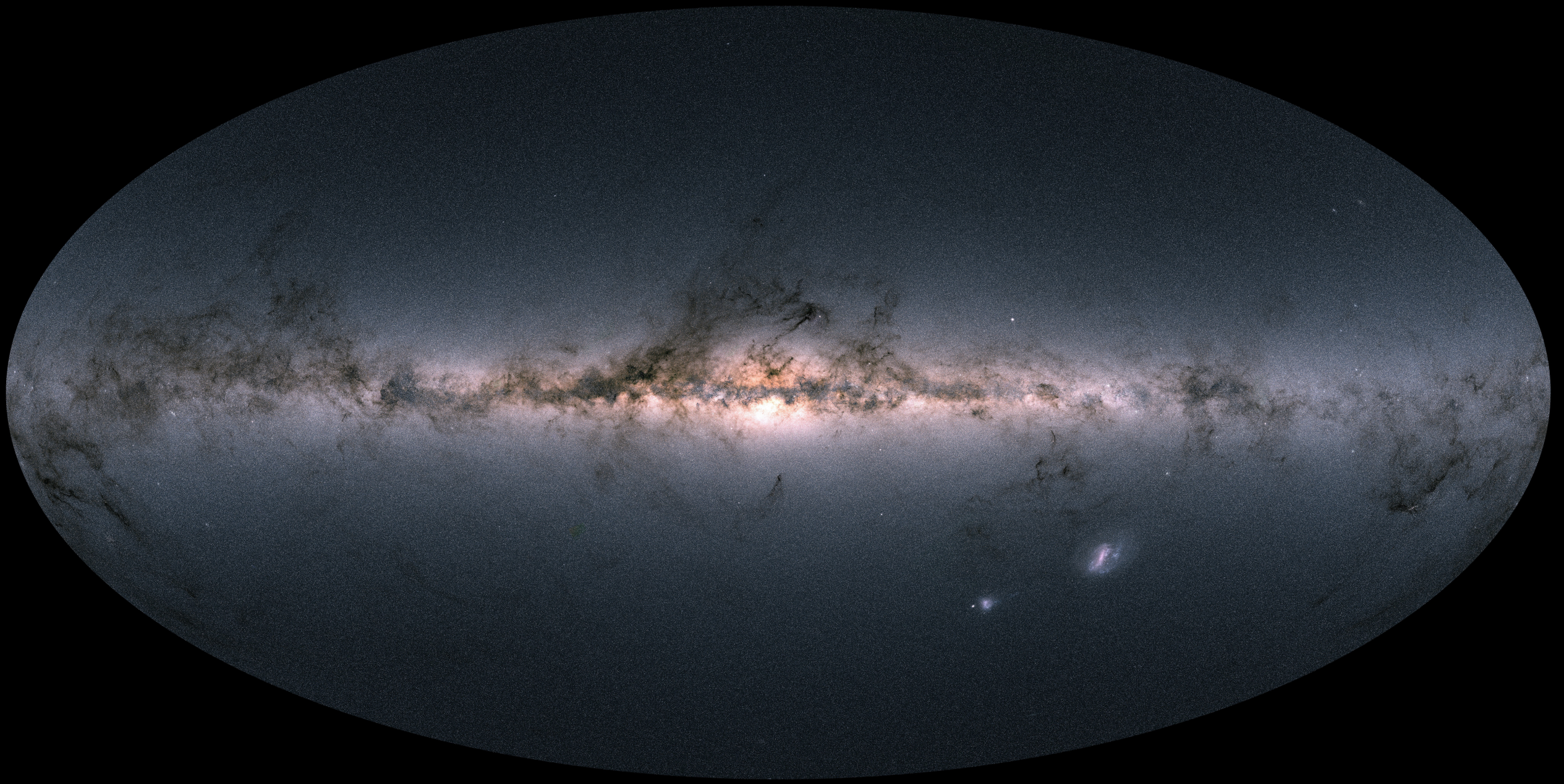
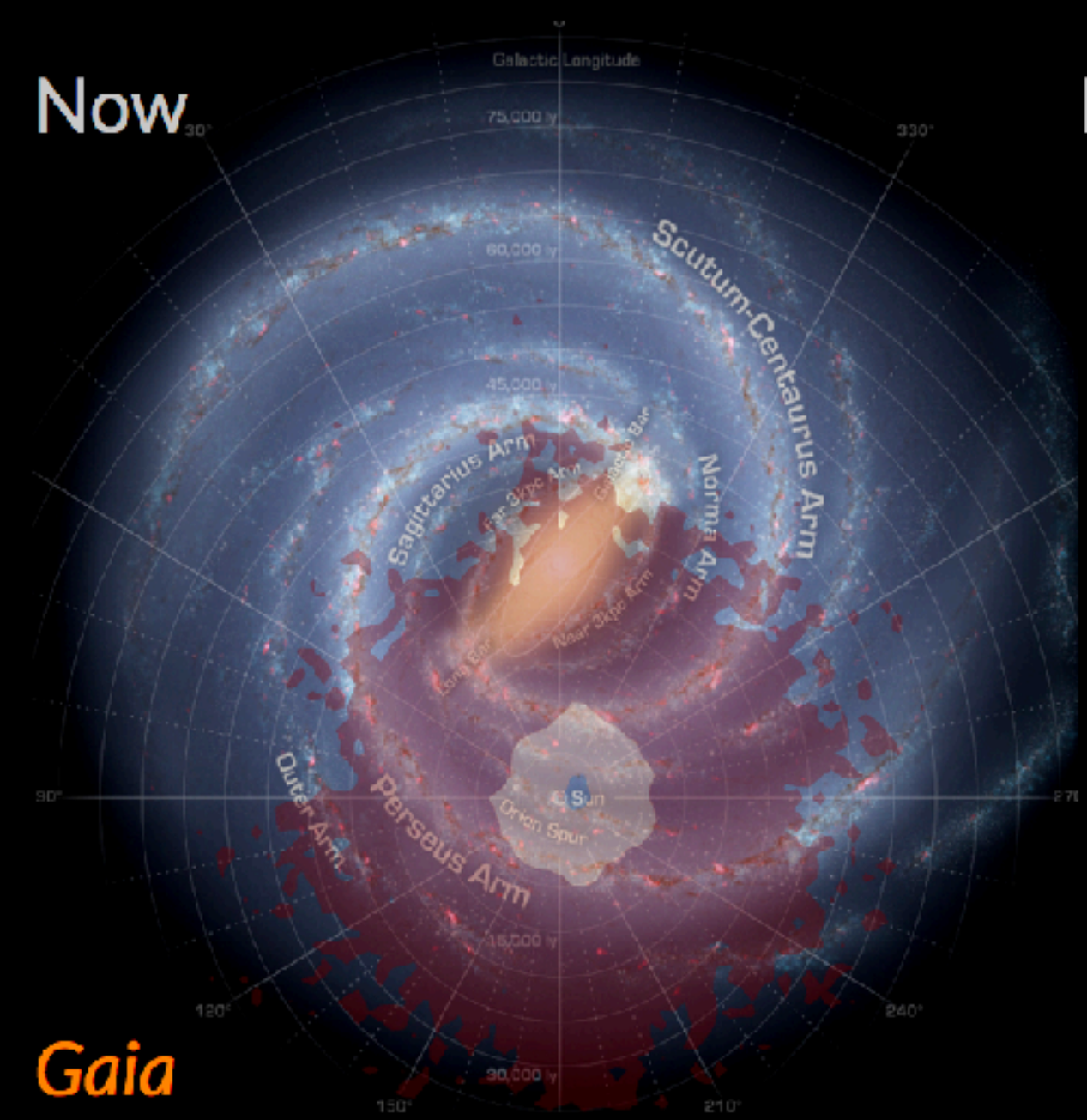
The *Milky Way* in Seven Dimensions



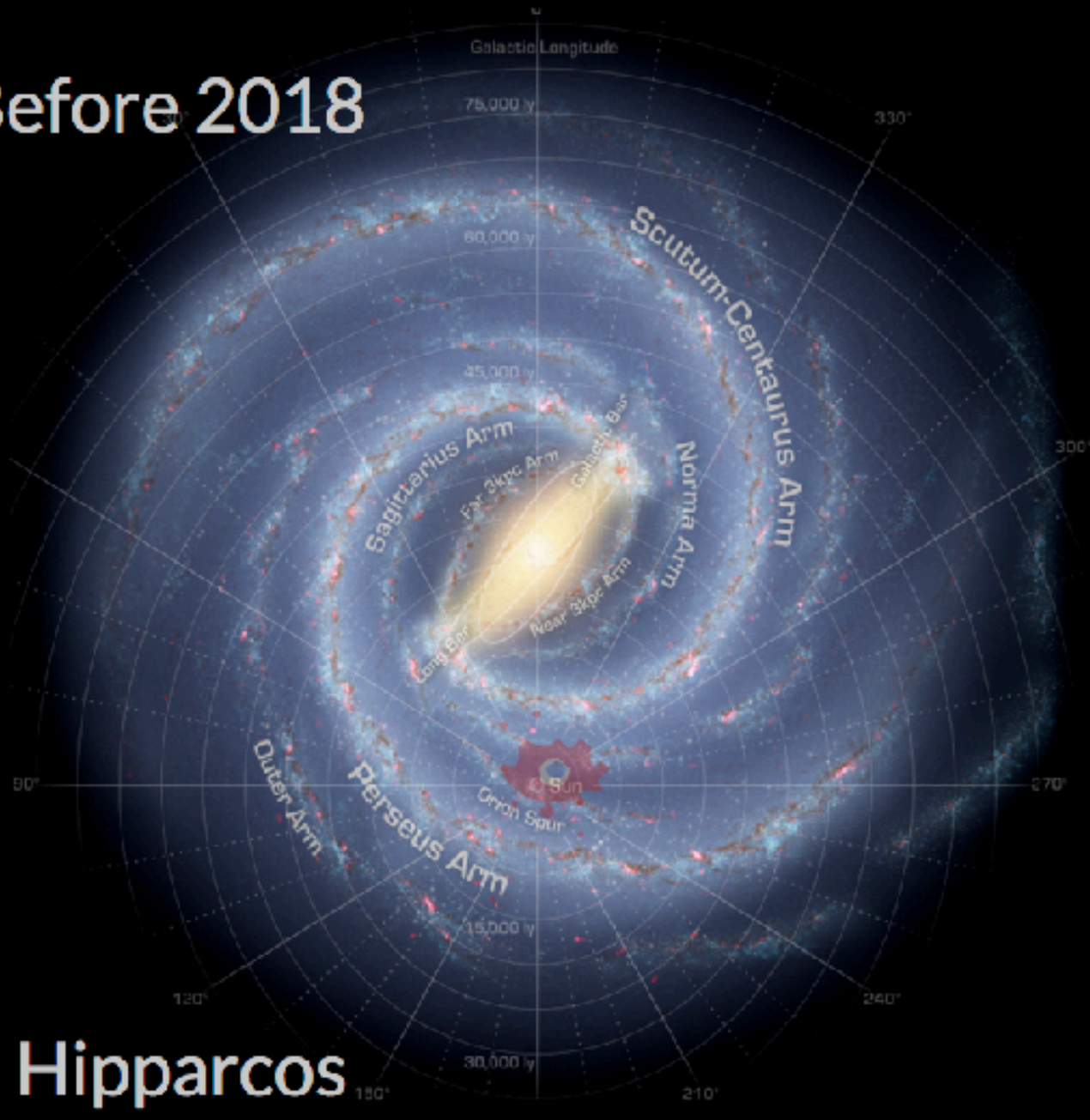
Harshil Kamdar

The *Gaia* Revolution



Gaia

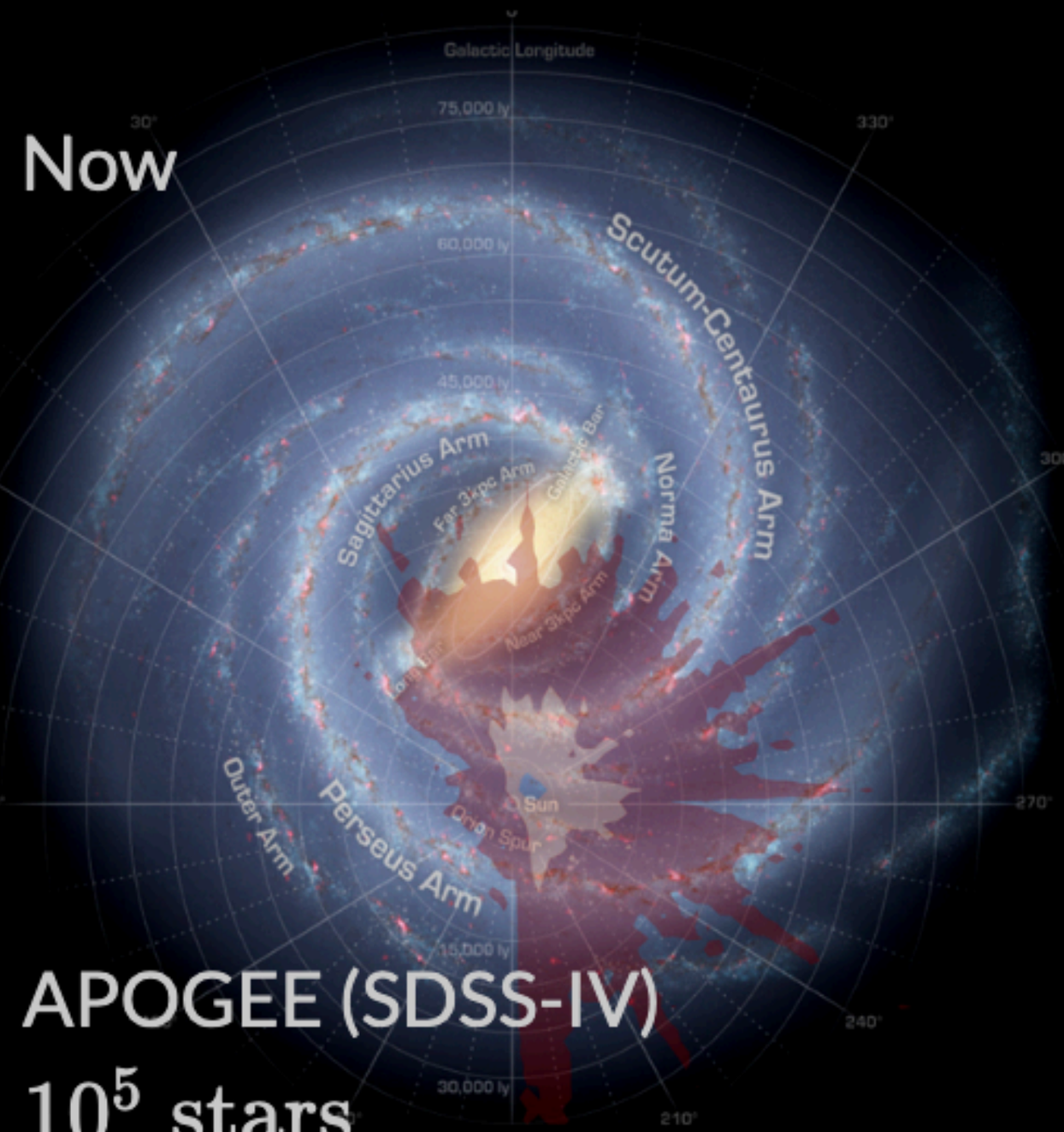
10^9 stars



Hipparcos

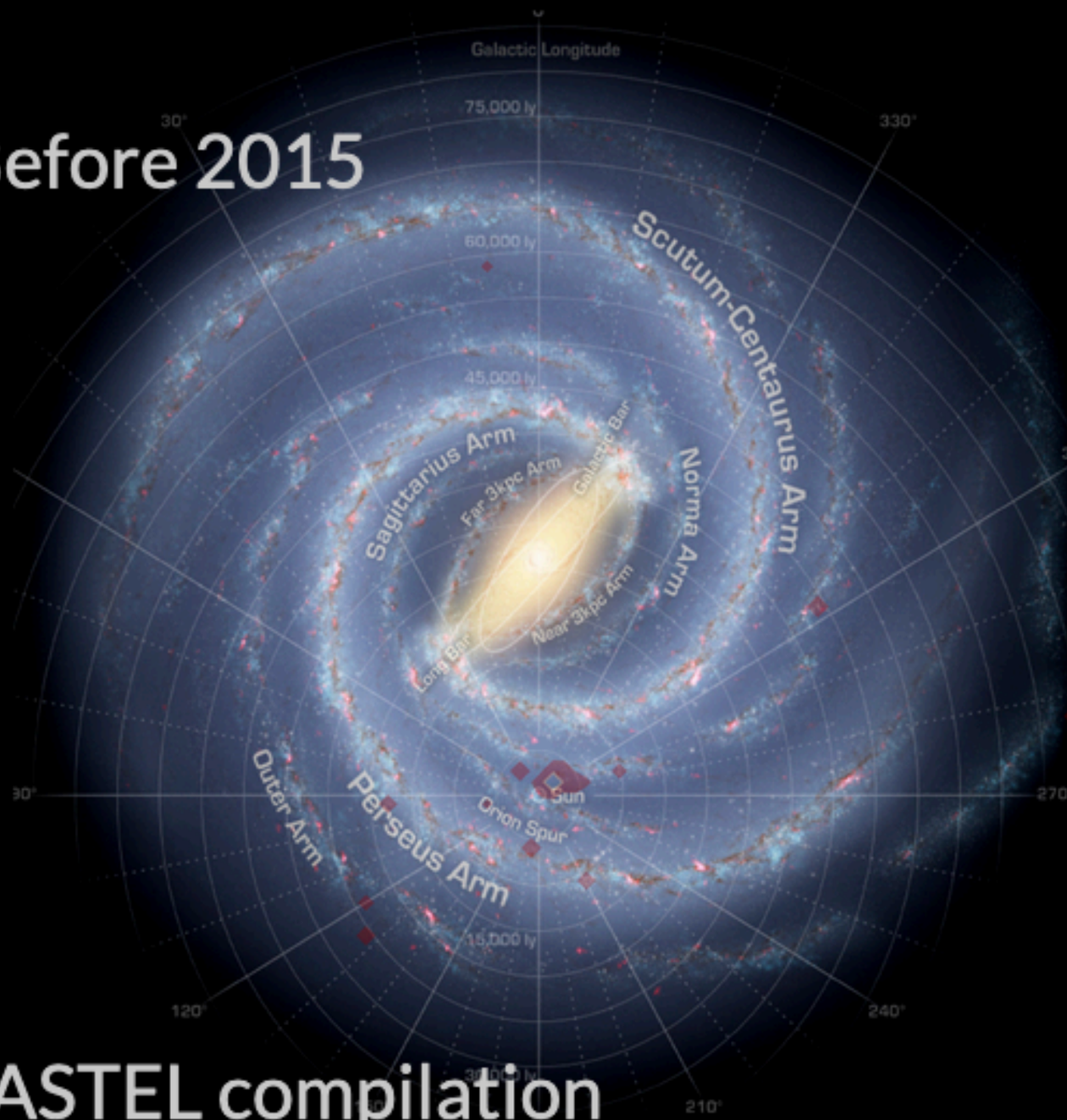
10^5 stars

Stars with Chemical Composition Information



APOGEE (SDSS-IV)

10^5 stars



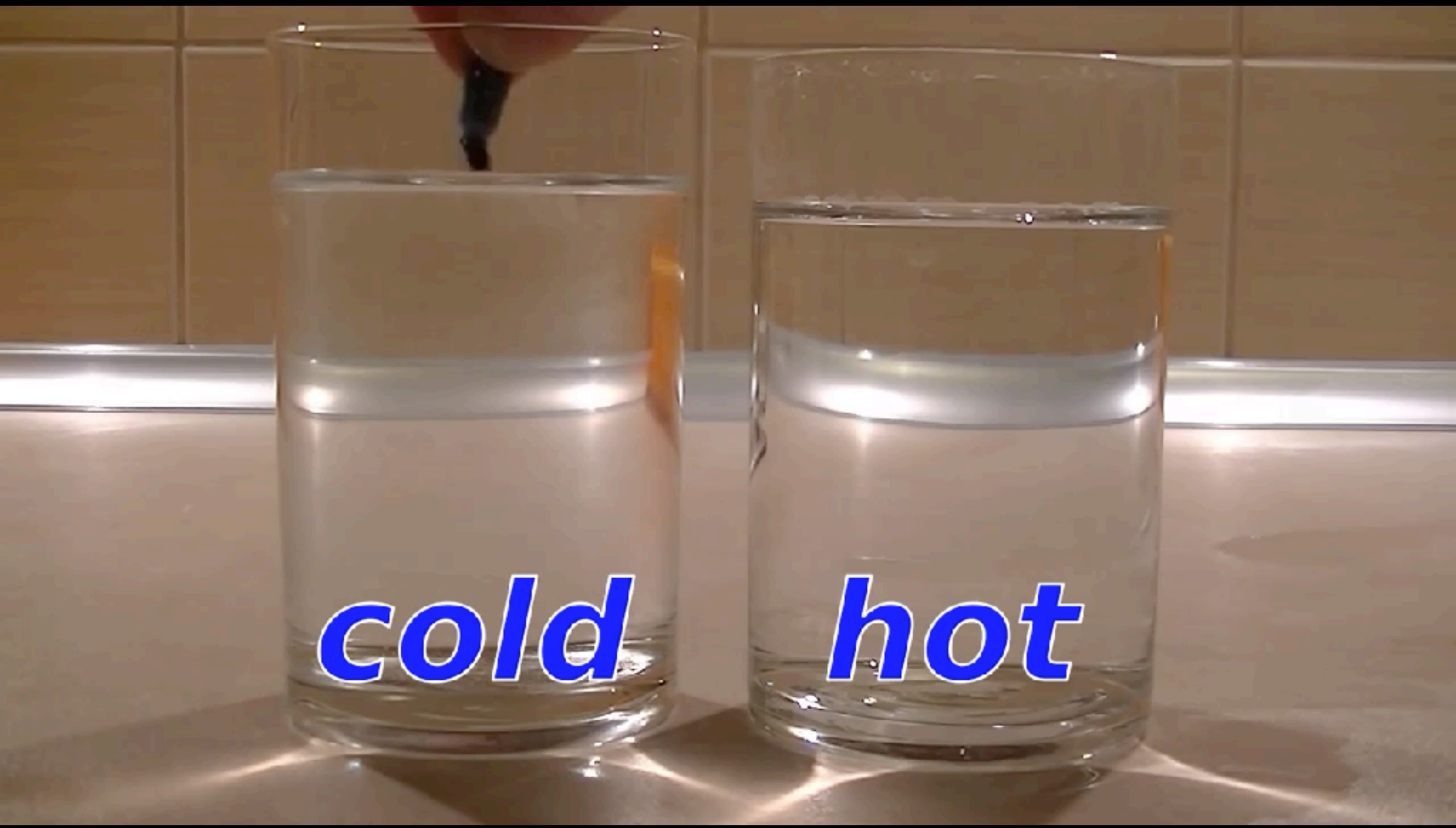
PASTEL compilation

Galactic Archaeology

The **position**, **velocity**, and **chemical make-up** of stars today holds valuable clues about our Galaxy's history.

- What is the history of star formation in our Galaxy?
- How did the Galaxy assemble and what can we learn about other galaxies by studying our own?

Galactic Archaeology



The Need for Another Model

Cosmological simulations &
N-body simulations

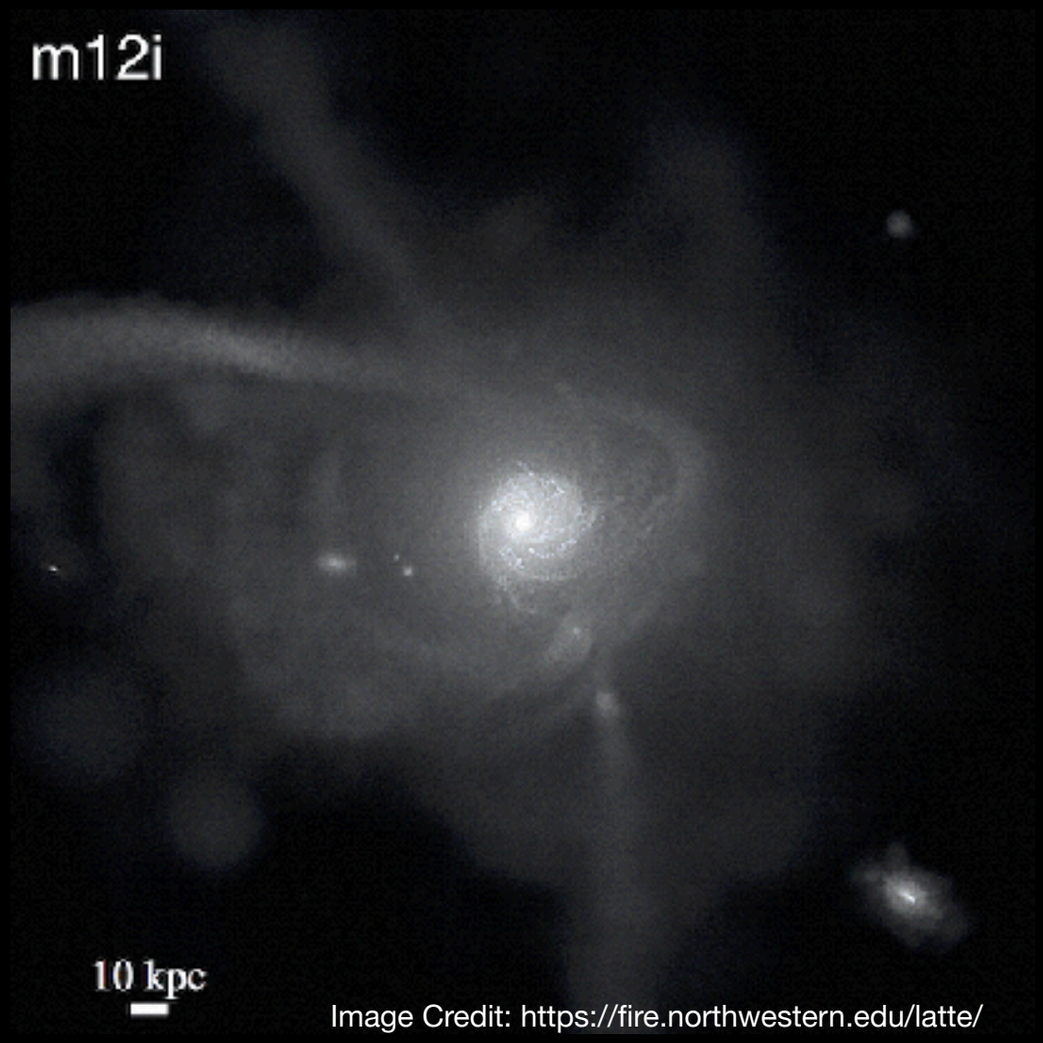


Image Credit: https://fire.northwestern.edu/latte/

Latte Simulations (Wetzel+ 2017)
~$10^{3\text{-}4}$ $M_\odot$ resolution
~10^{12} $M_\odot$ galaxy

The Need for Another Model

Cosmological simulations &
N-body simulations

m12i

The highest resolution in current simulations is ~500-1000 times the mass of the sun.

The average mass of a ***star cluster*** born in the MW today is 500 times the mass of the sun.

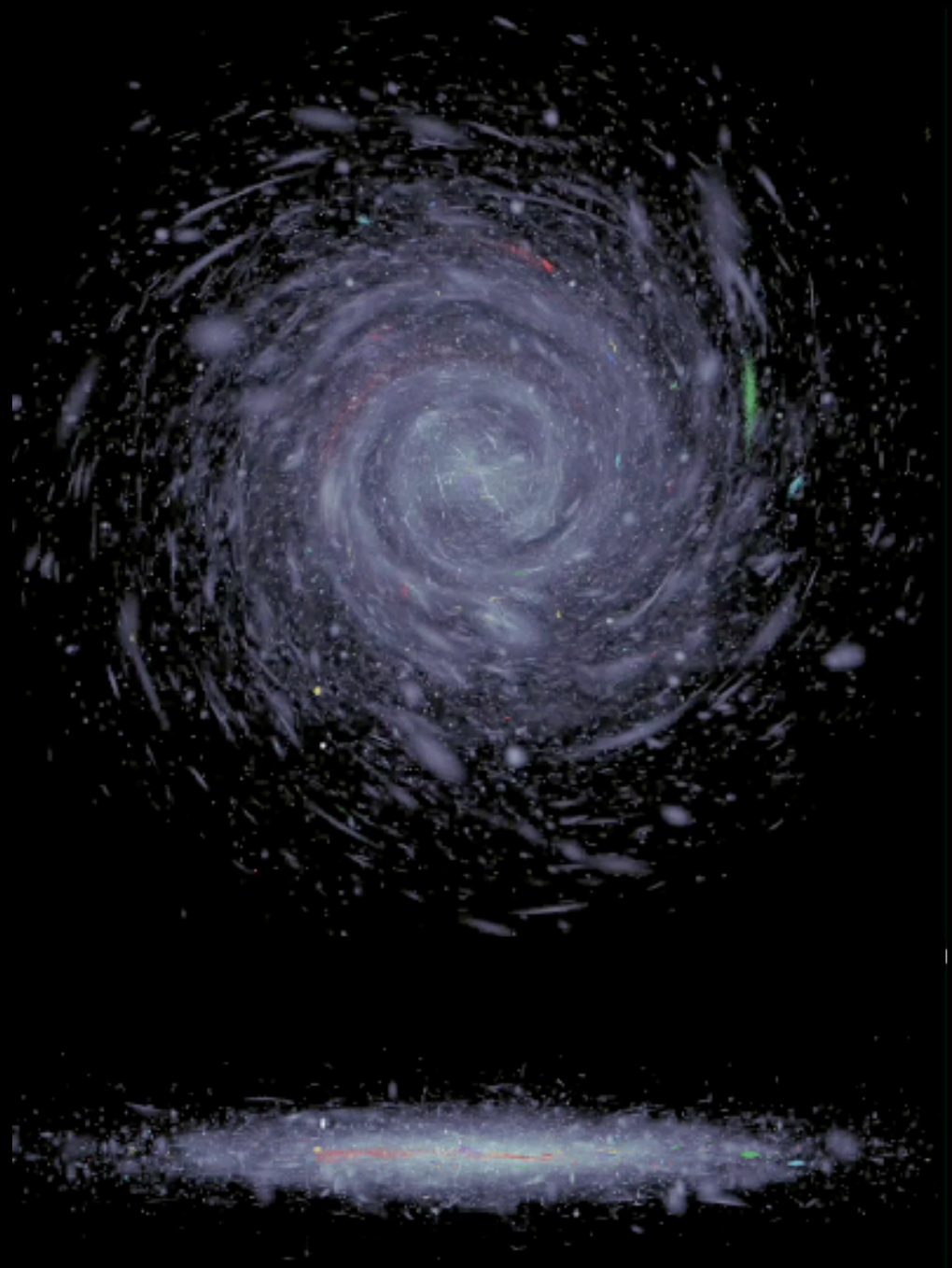
10 kpc

Image Credit: https://fire.northwestern.edu/latte/

Latte Simulations (Wetzel+ 2017)
~$10^{3\text{-}4}$ $M_\odot$ resolution
~10^{12} $M_\odot$ galaxy

Building an *Approximate* Milky Way

- ~1 solar mass resolution.
- Analytical prescription for the lifecycle of star clusters.
- Analytical prescription for the potential of the Galaxy.
- Realistic error model
- Control simulations
- Takes ~a few days vs ~a few months.



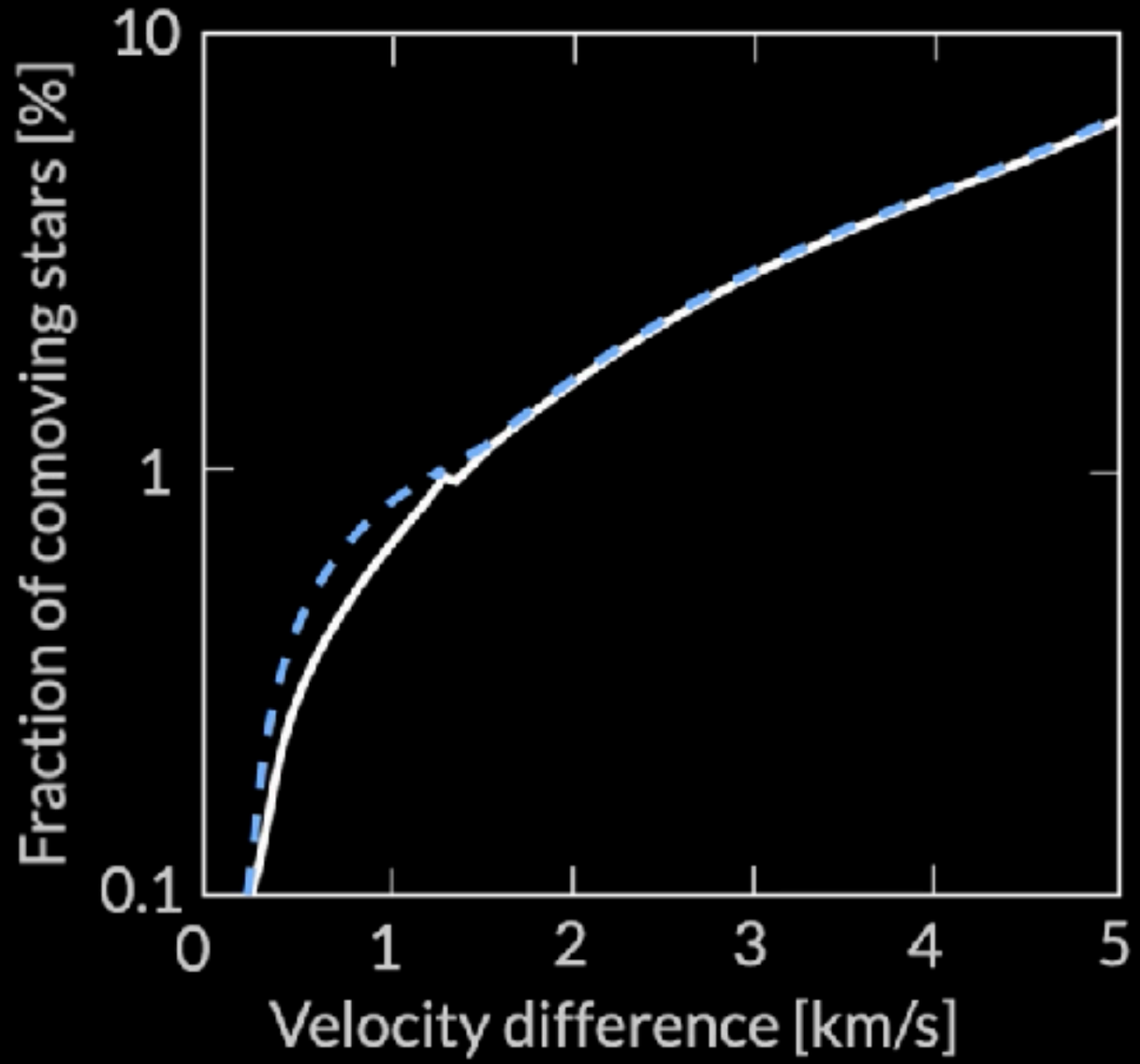
Colors are individual stars from different star clusters being disrupted in the disk. 4 billion stars evolved over 5 Gyr

Case Study: Co-moving Pairs

Stars that are *close* together and moving at a *similar velocity*.

Oh+ (2017), Andrews+ (2017a,b), Oelkers+ (2017), Simpson+ (2018), Bochanski+ (2018), El-Badry+ (2018), Jiménez-Esteban+ (2019)

Number Density of Co-moving Pairs

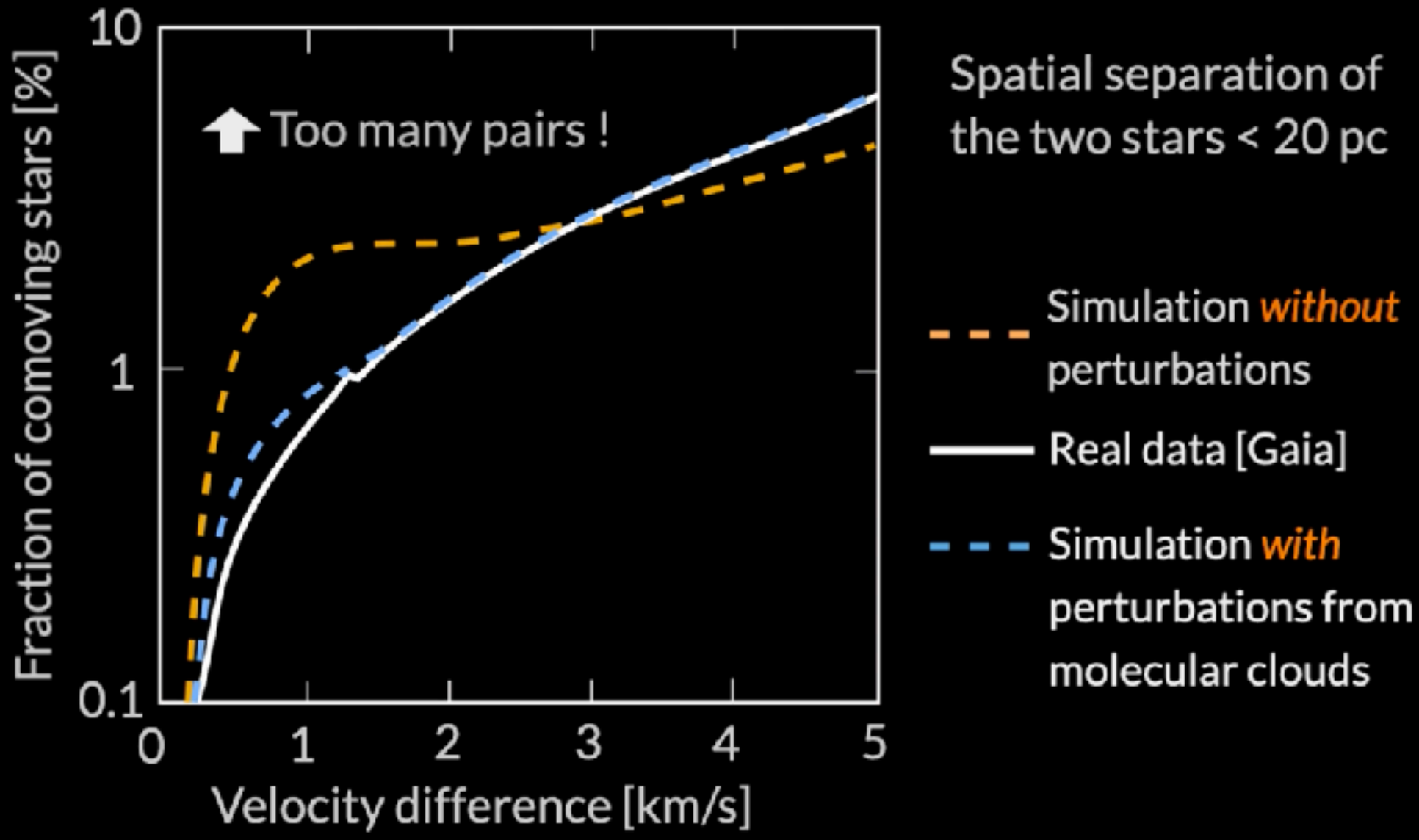


Spatial separation of the two stars < 20 pc

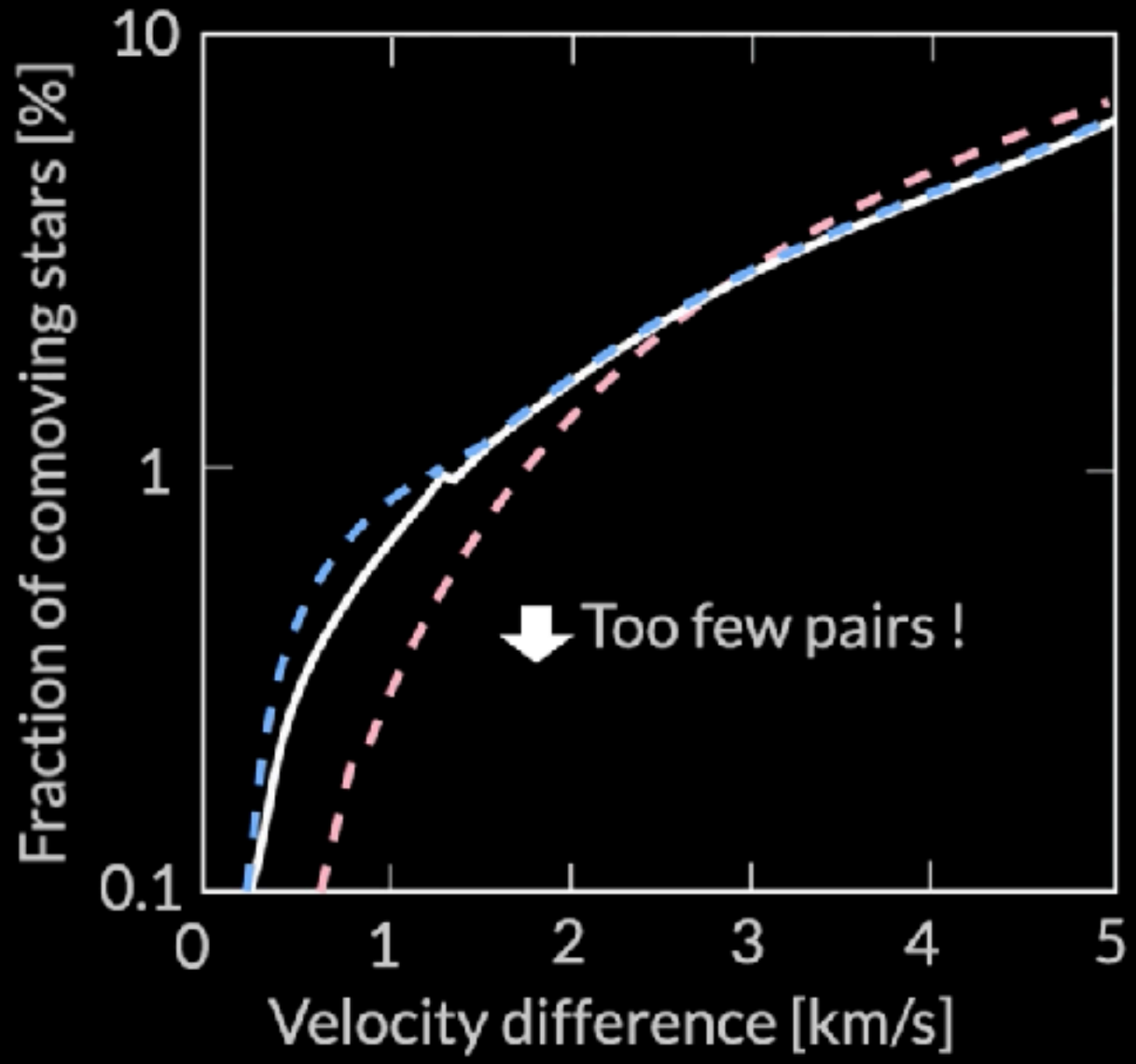
Real data [Gaia]

Simulation *with* perturbations from molecular clouds

Number Density of Co-moving Pairs



Number Density of Co-moving Pairs



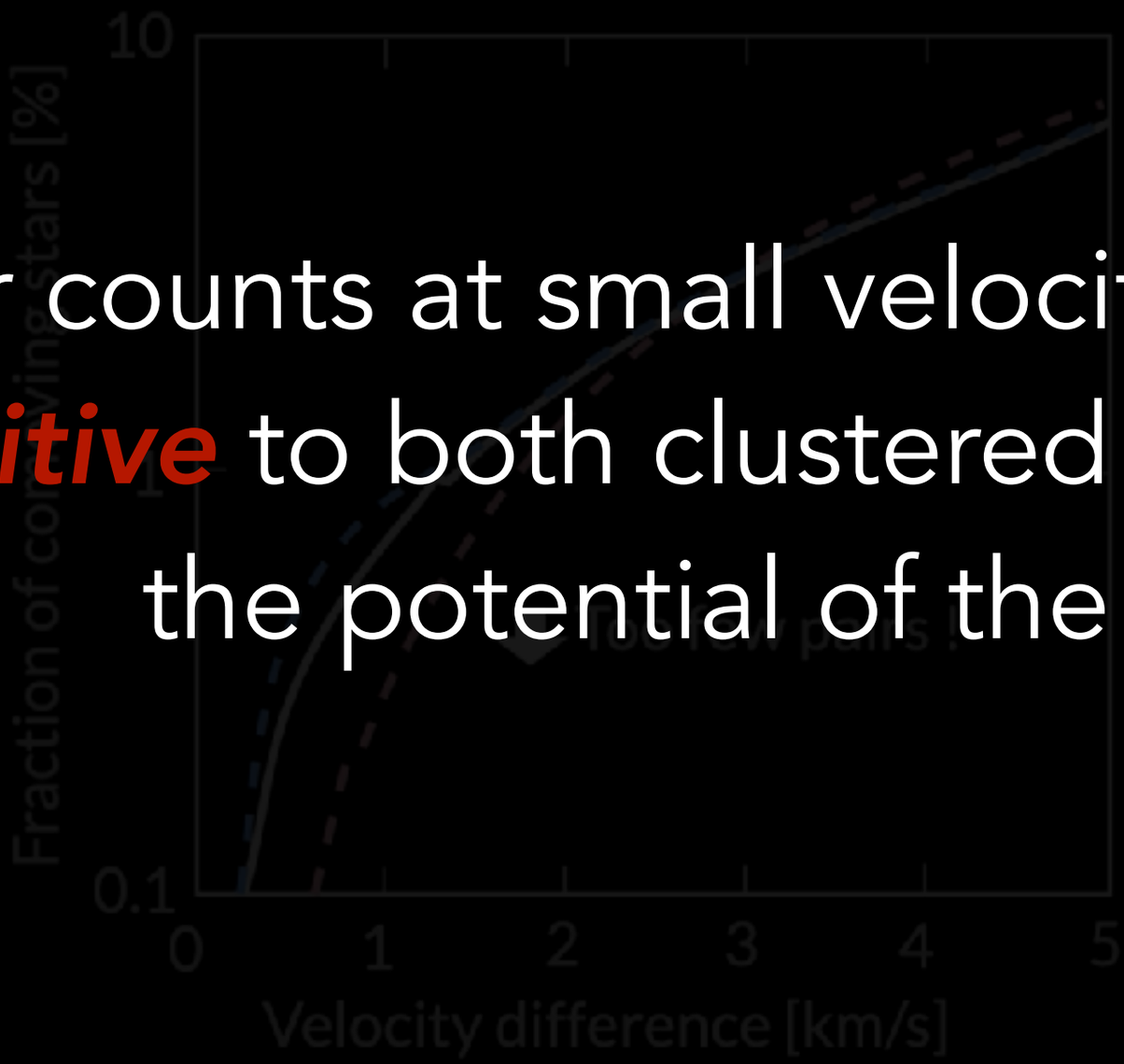
Spatial separation of the two stars < 20 pc

Without clustered star formation

Real data [Gaia]

Simulation *with* perturbations from molecular clouds

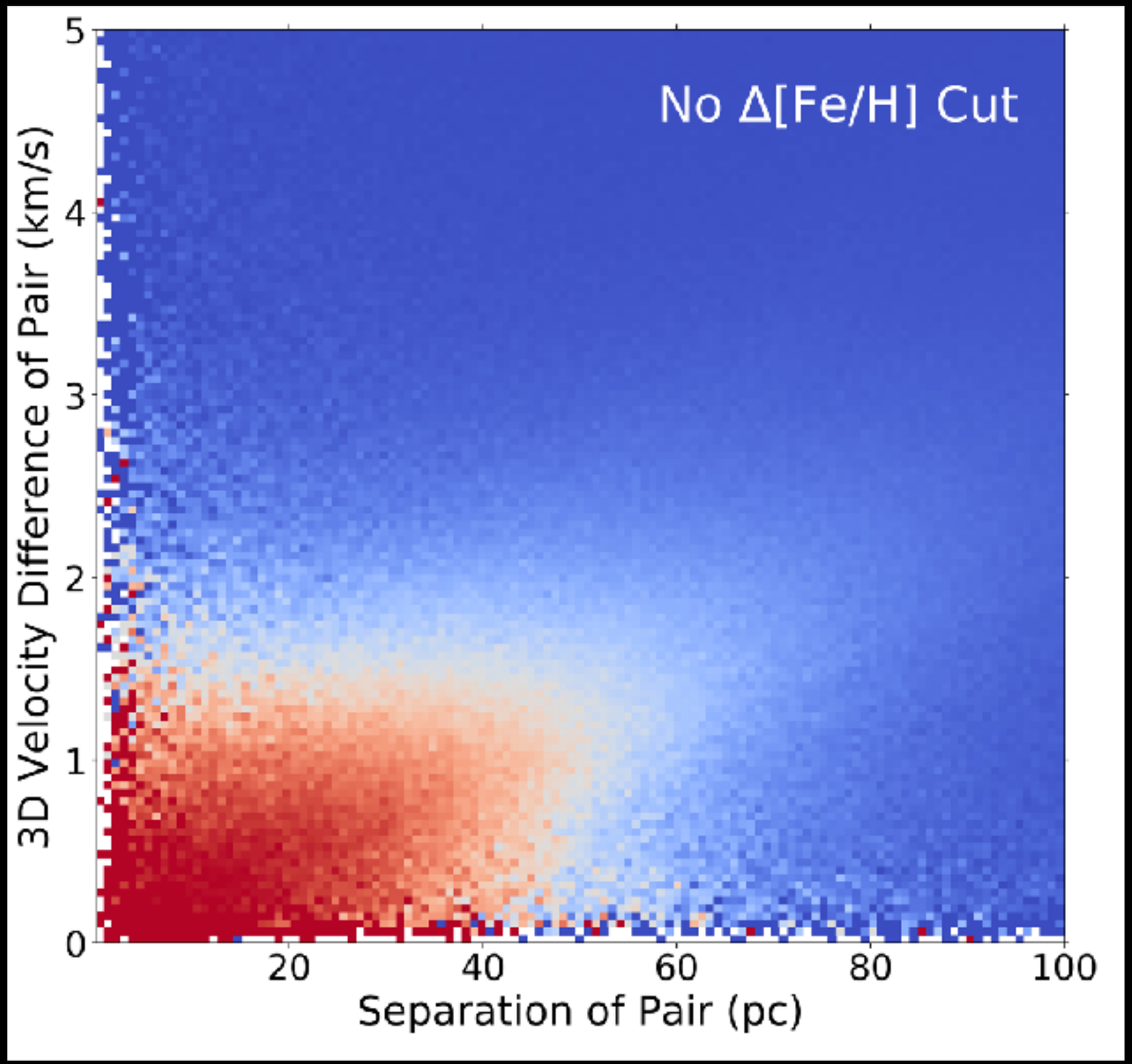
Number Density of Co-moving Pairs



Pair counts at small velocity separations are ***sensitive*** to both clustered star formation and the potential of the Milky Way!

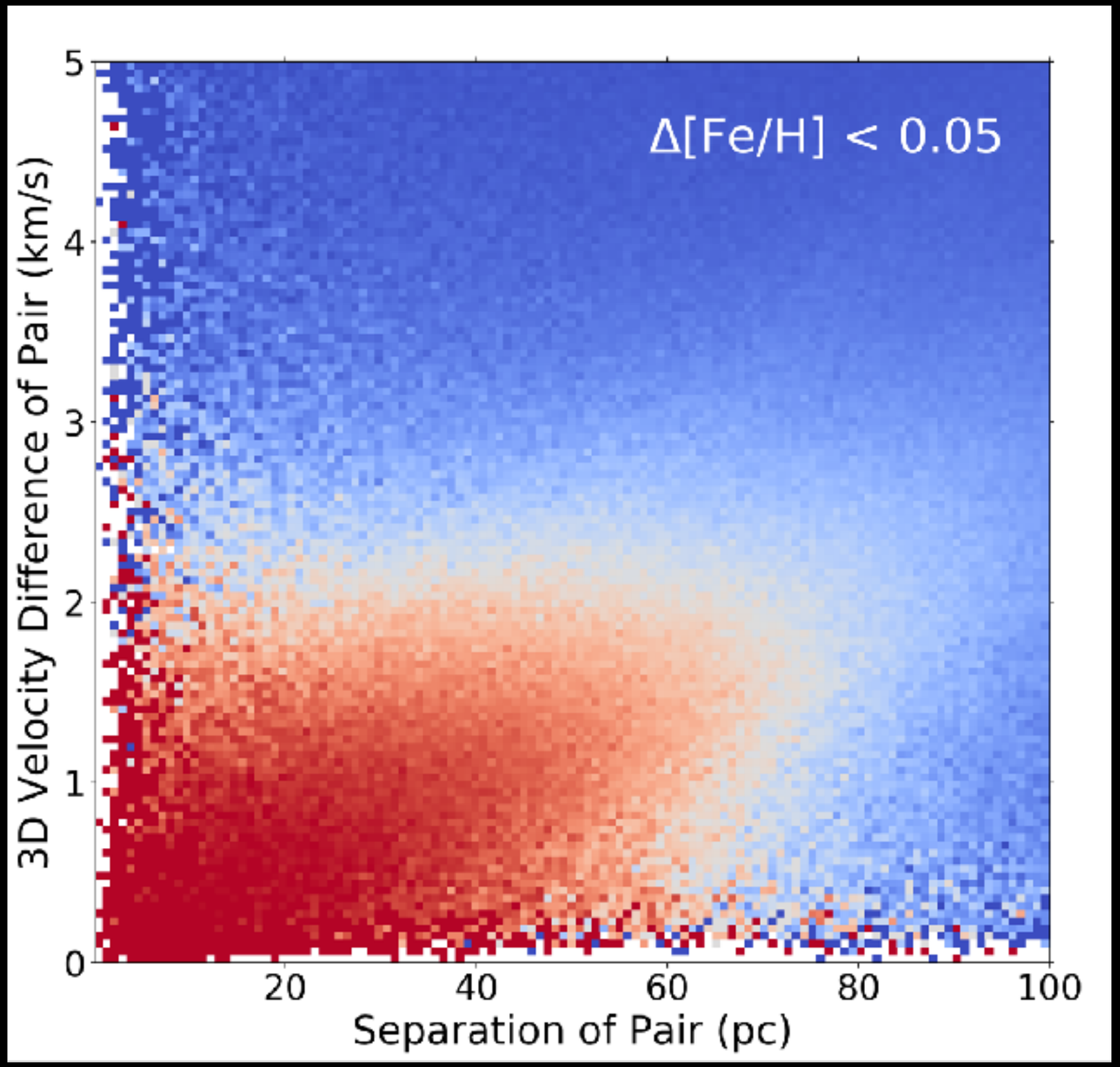
What Fraction of Pairs were Born Together?

No chemistry information

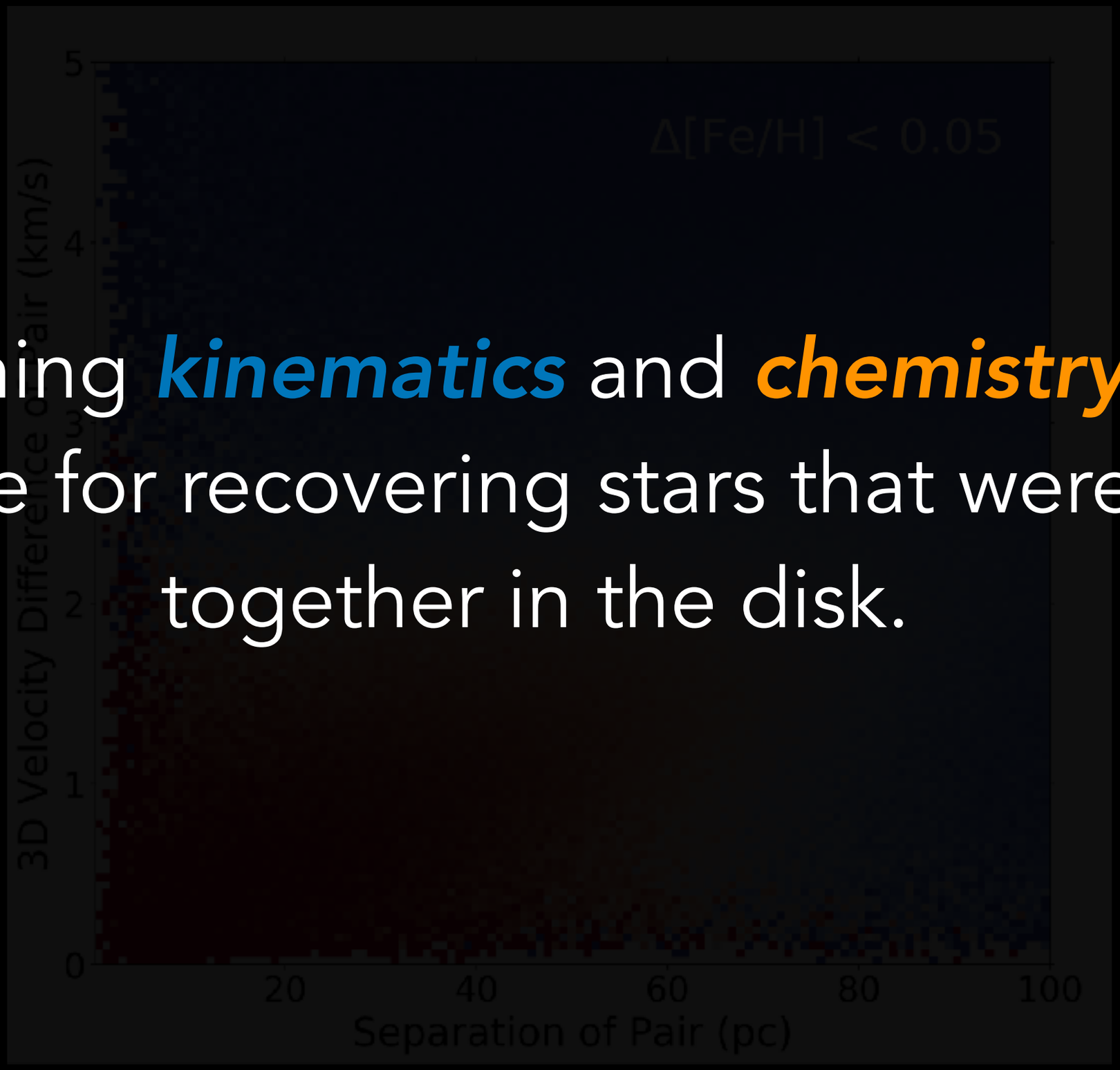


What Fraction of Pairs were Born Together?

With chemistry!

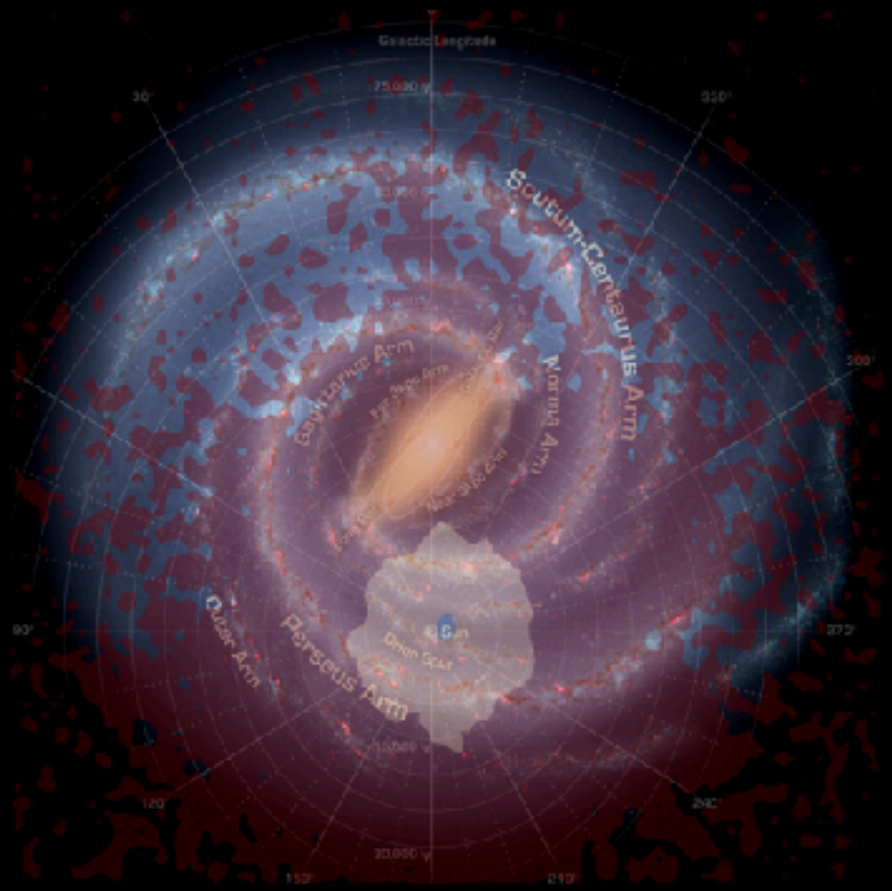


What Fraction of Pairs were Born Together?



Combining ***kinematics*** and ***chemistry*** holds promise for recovering stars that were born together in the disk.

The Future is Bright for Galactic Archaeology



10^7 stars

In the next 10-15 years:

>10x stars with chemistry
(~10 million)

>10x stars with positions
and velocities
(~100 million)

SDSS V Footprint (image credit: Yuan-Sen Ting)

Acknowledgments

Conroy Group at Harvard University

Dr. Caleb Phillips & NREL

Everyone at Krell!