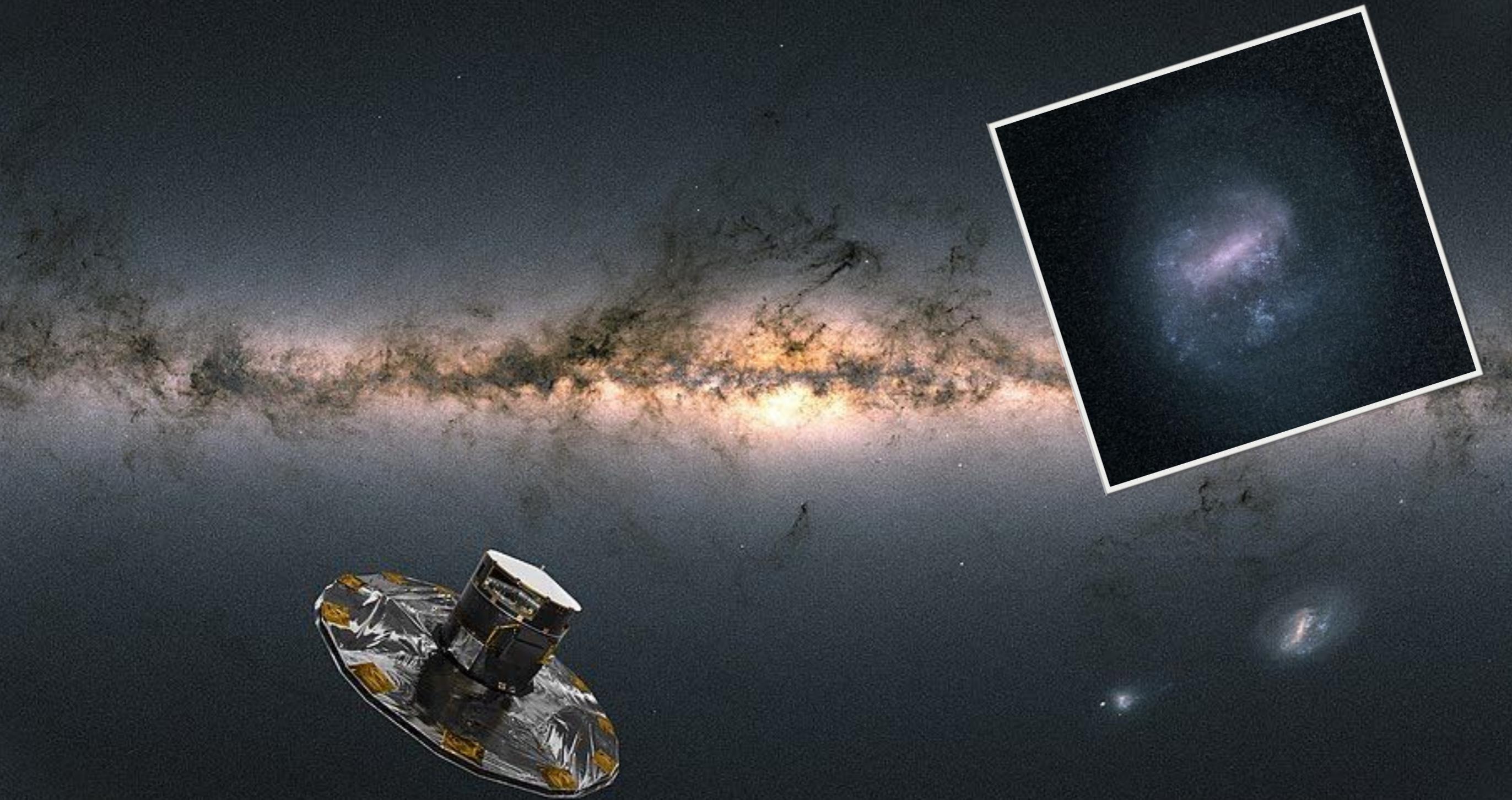


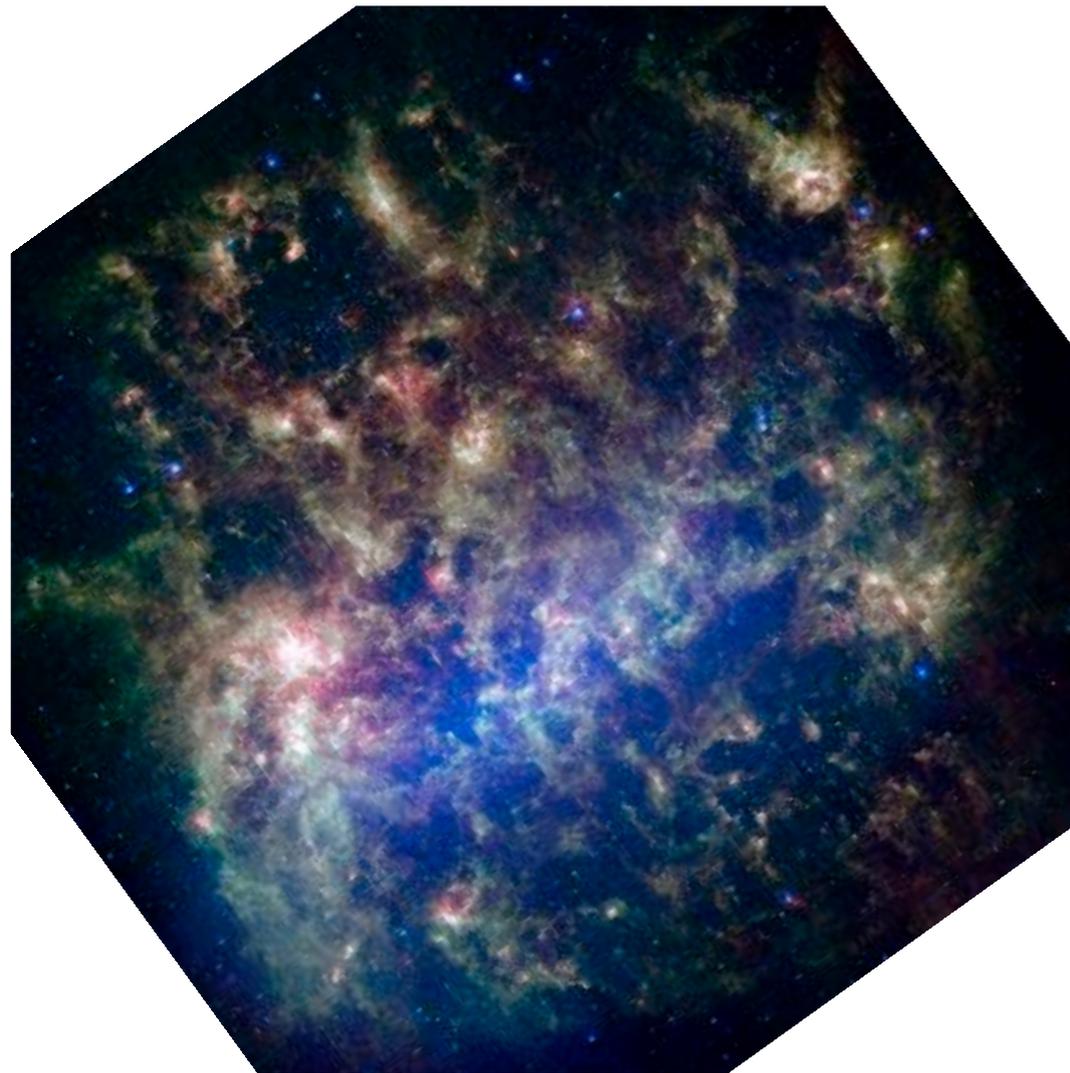
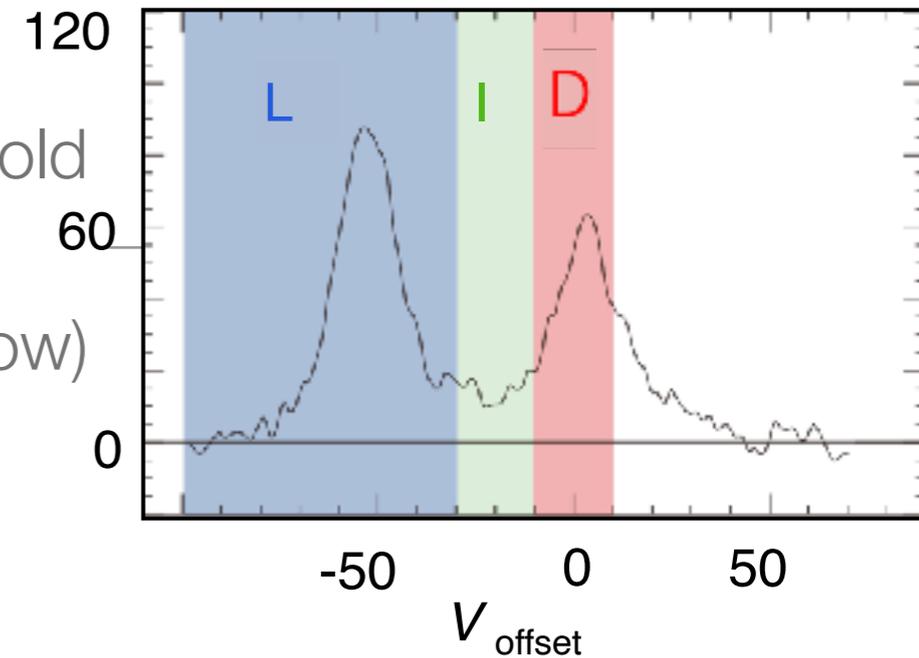
# A Study of Massive Star Cluster Formation in the Large Magellanic Cloud from Their Kinematic Properties



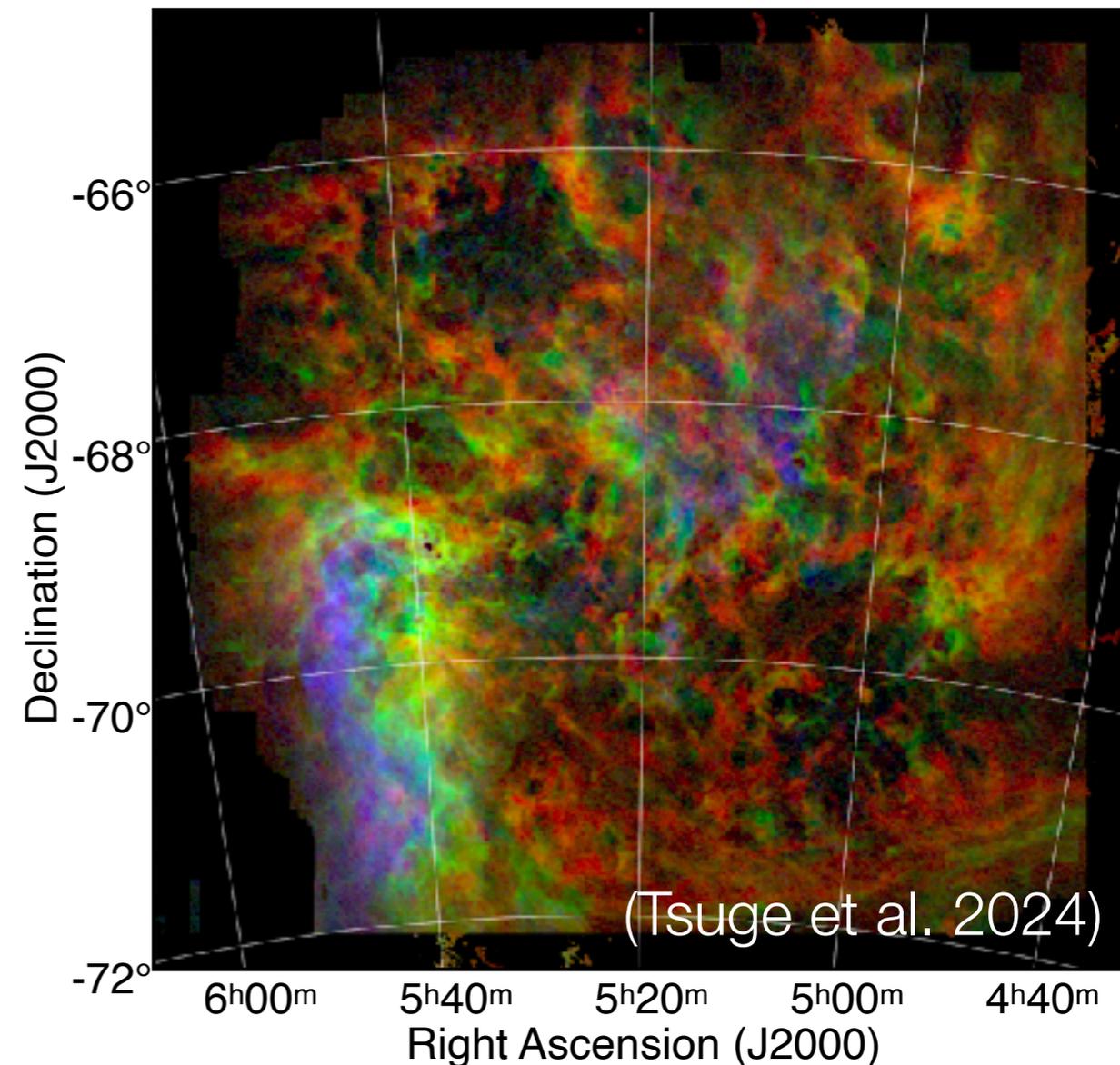
Kengo Tachihara (Nagoya University)

# ISM in the Large Magellanic Cloud

- Surveyed in HI (ATCA), CO (NANTEN and Mopra), hot/cold dust (Spitzer and Herschel)
- HI has 2 velocity components (by feedback / colliding flow)
- Formations of 30 Dor and N44 have been triggered (Fukui+ 2017; Tsuge+ 2019, 2024)

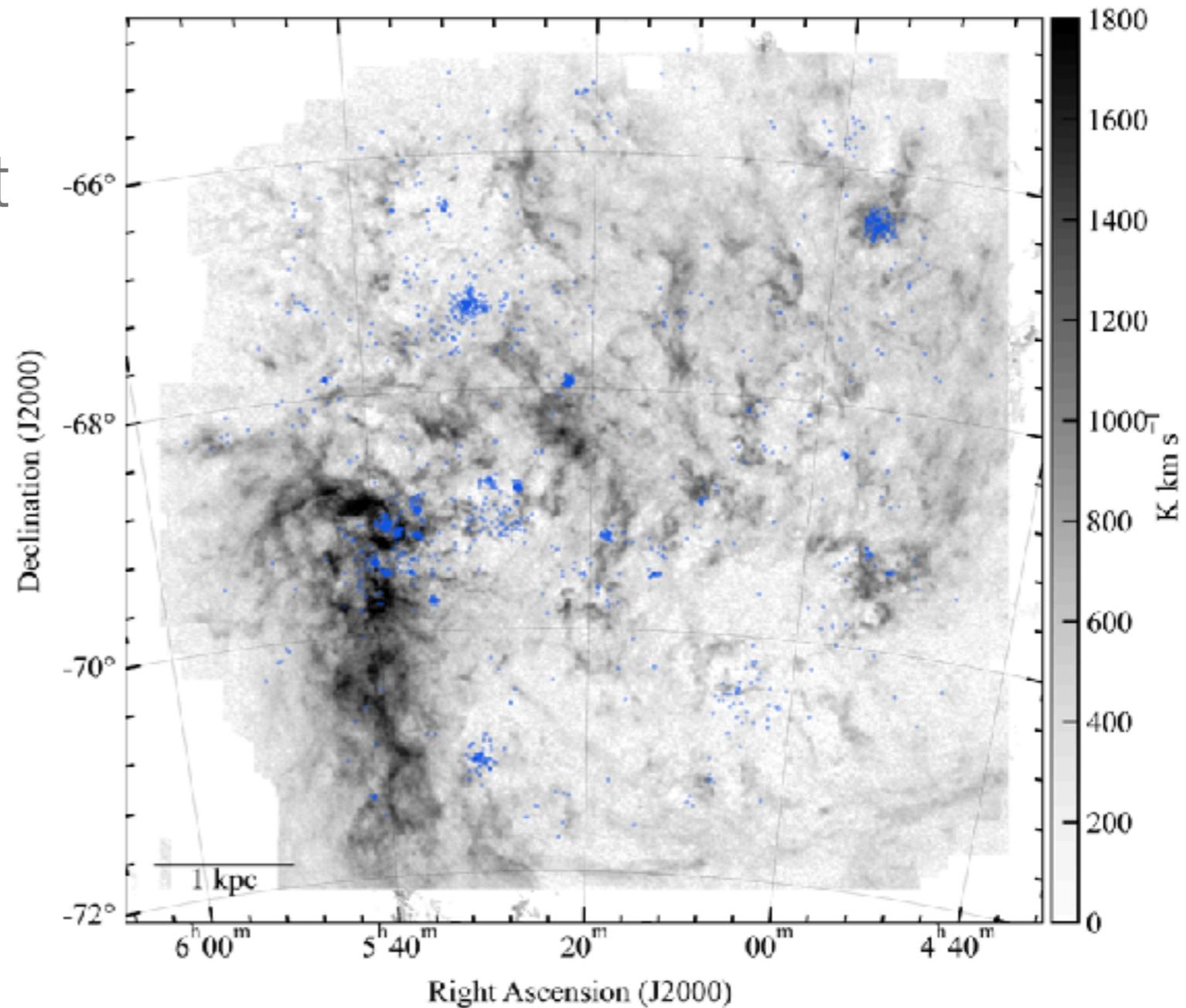


(Spitzer image: Meixner et al. 2006)



# Massive stars in the Large Magellanic Cloud

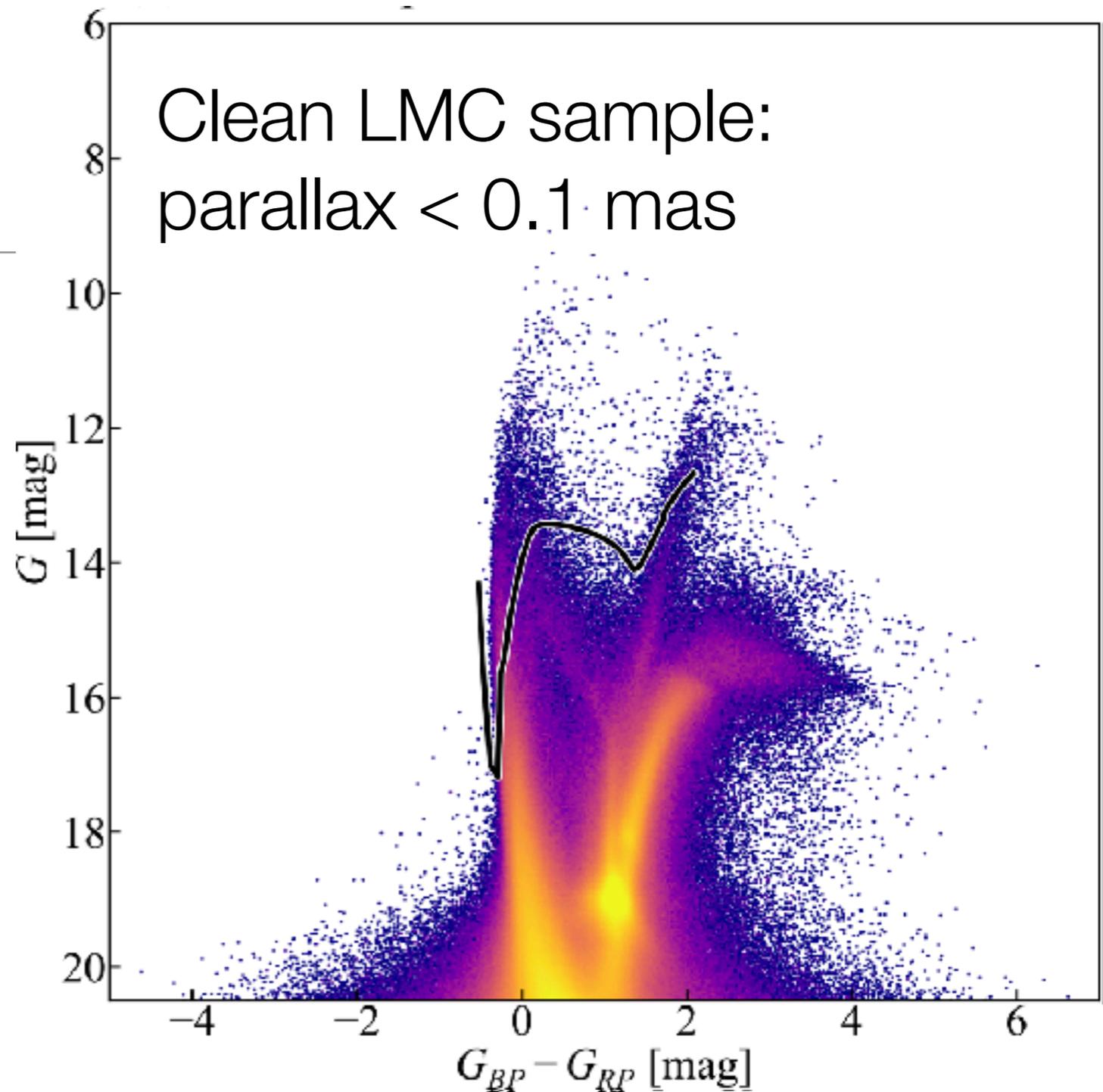
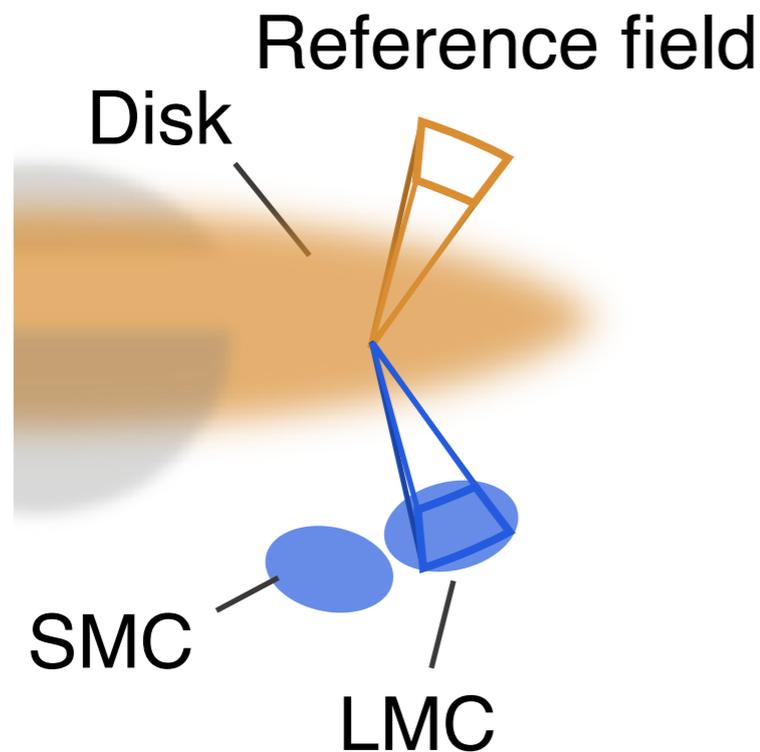
- Massive star catalog compiled by Bonanos et al. (2009)
- 1750 massive stars by spectroscopy
- Most comprehensive to date, but non-uniform
- Uniform catalog is required for statistics



(Bonanos et al. 2009)

# Massive star Identification

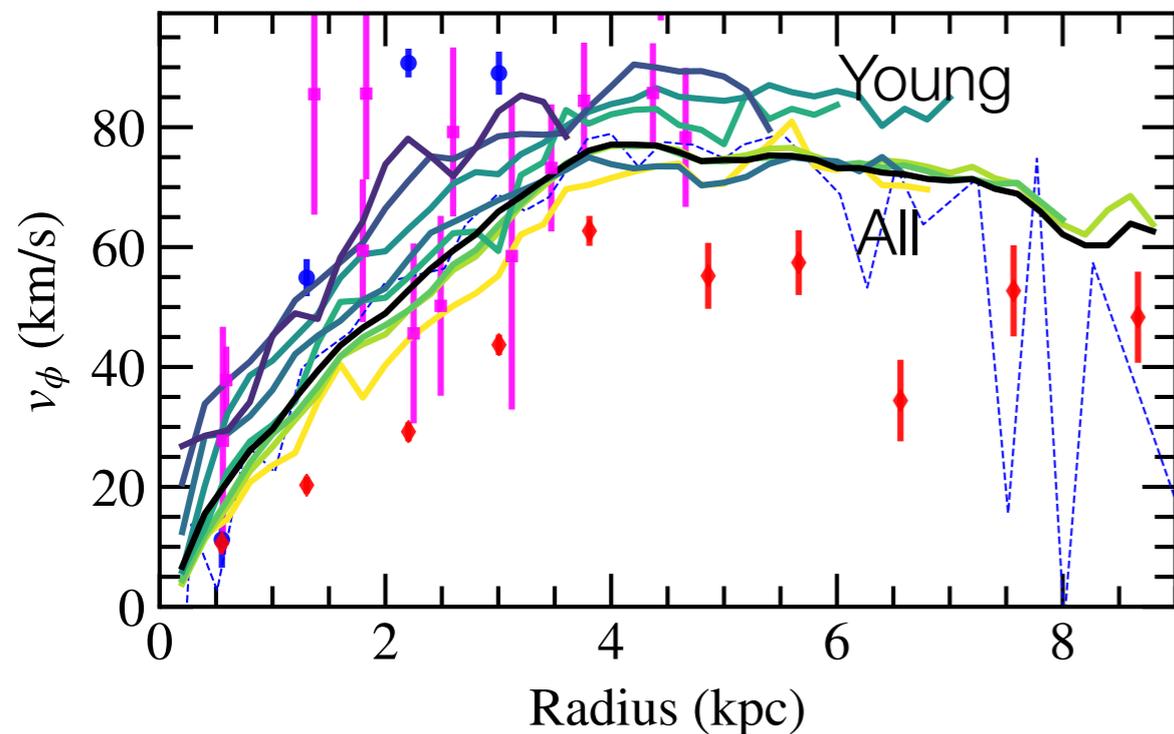
- Sample selection by CMD
  - Gaia DR3



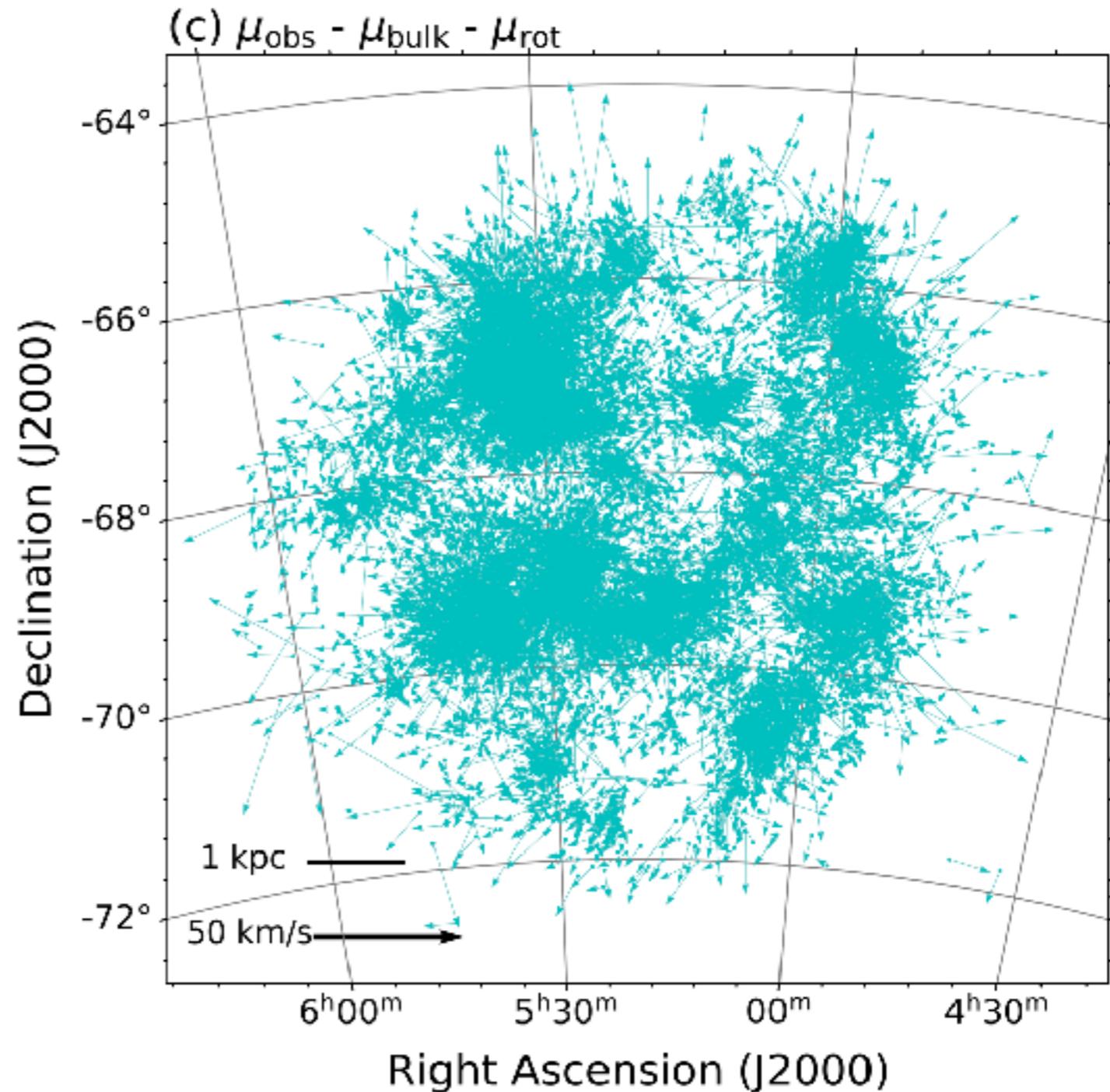
- Above the evolutionary track of  $8 M_{\odot}$  star from the PARSEC model
- Remove foreground stars
- Less than 0.4% contamination to the massive stars

# Proper motions

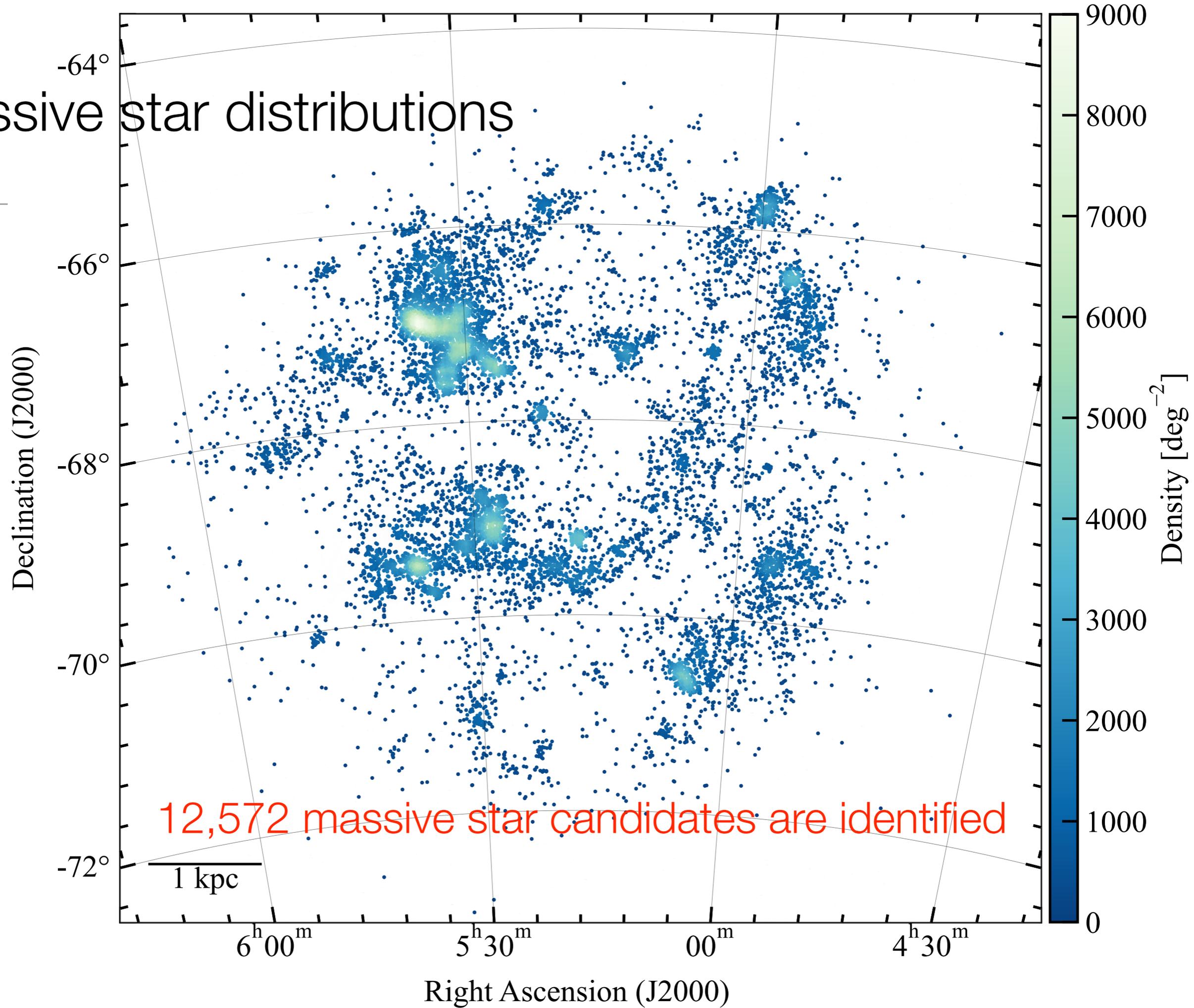
- Subtract
  - the bulk motion
  - galaxy rotation x1.3 faster than overall
- Internal PM



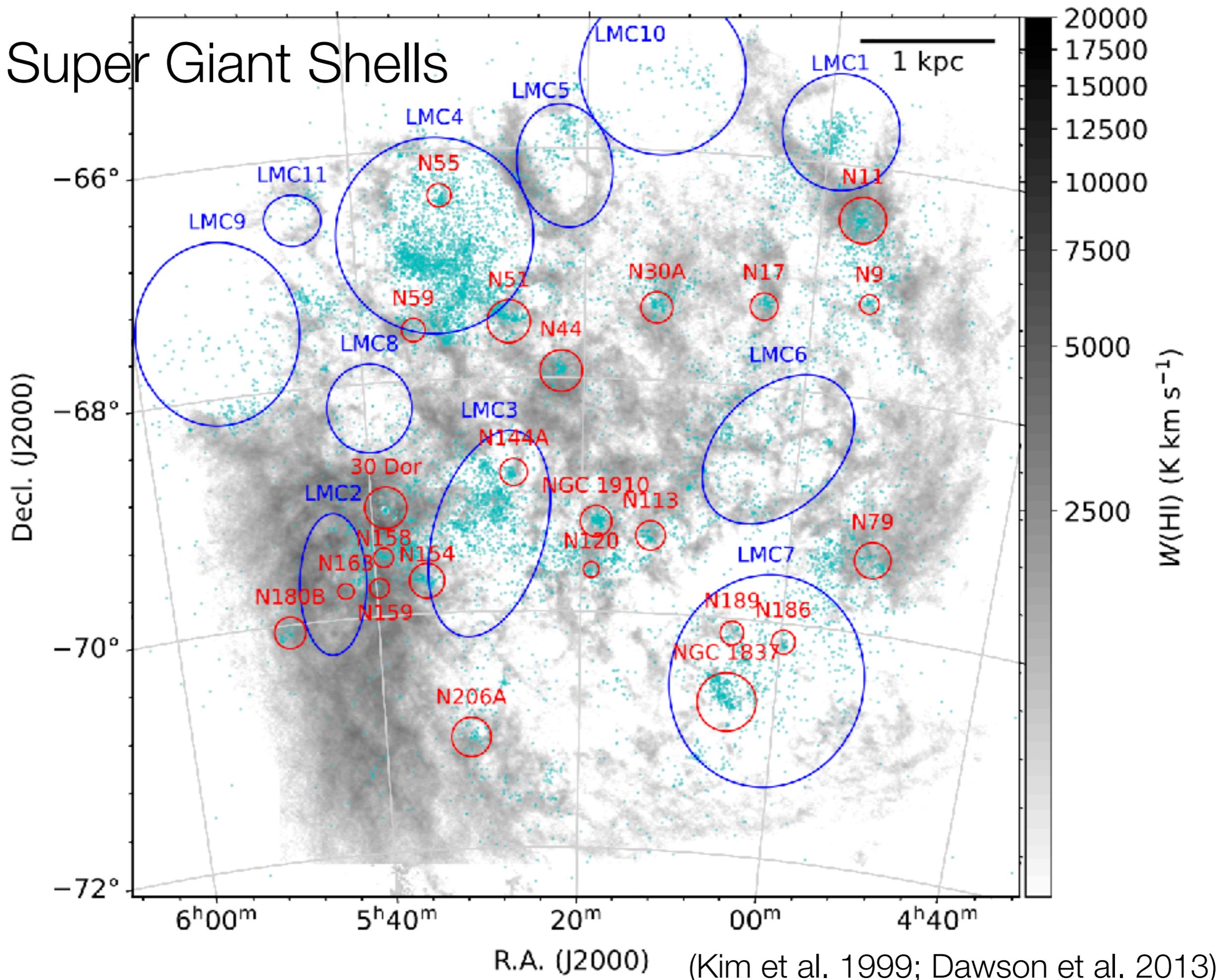
Rotation curve (Gaia collaboration 2021)



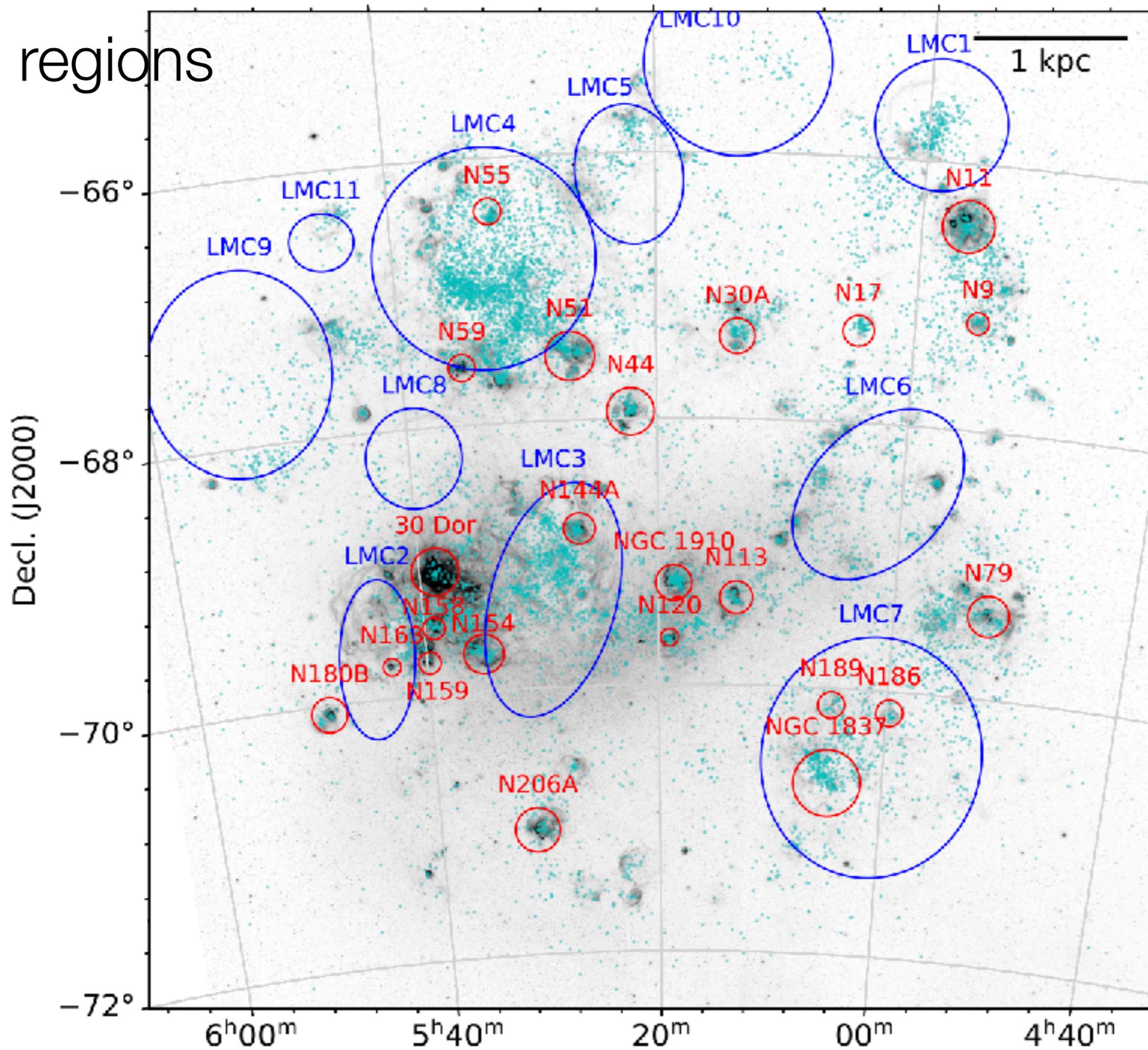
# Massive star distributions



# HI Super Giant Shells

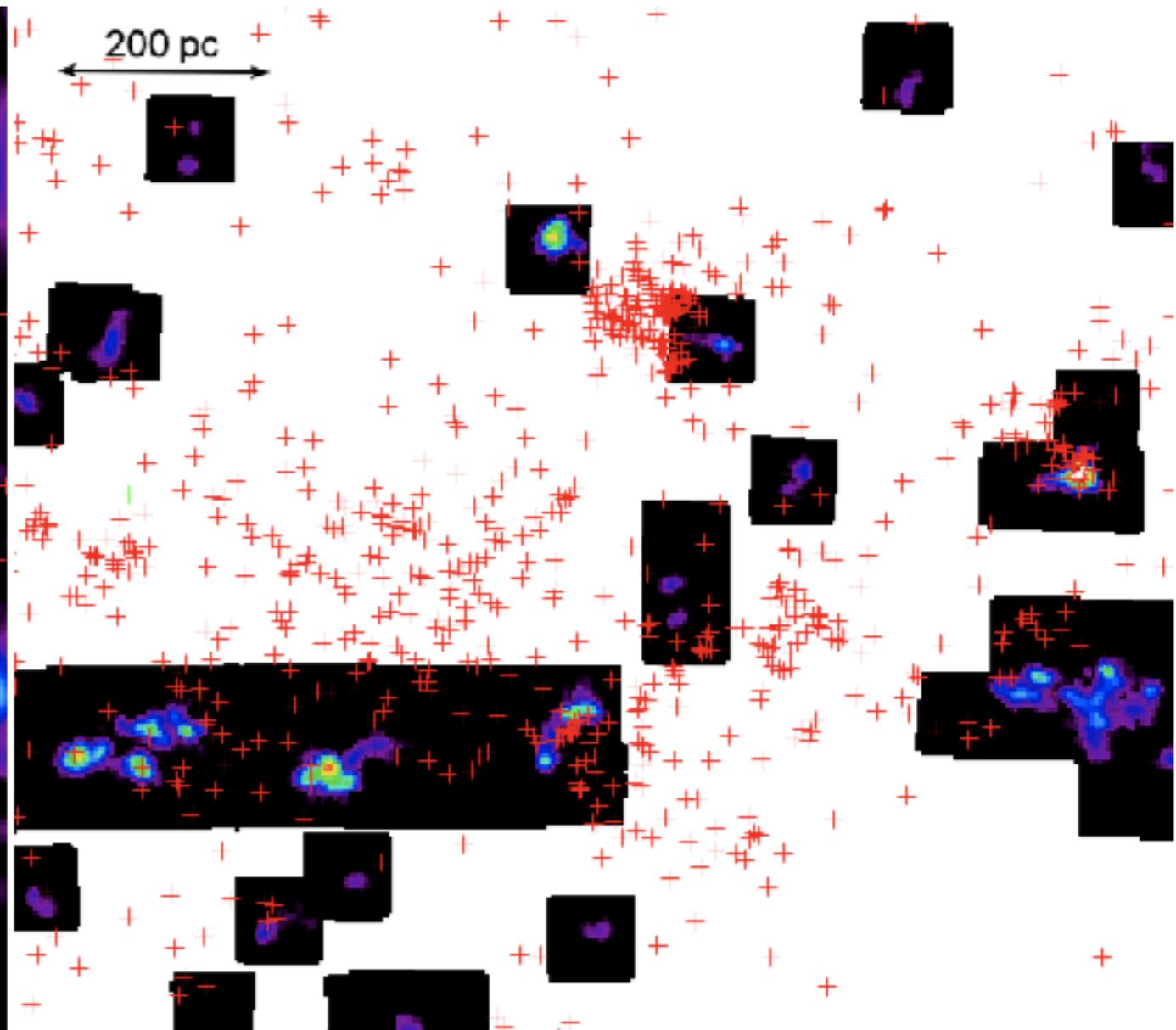
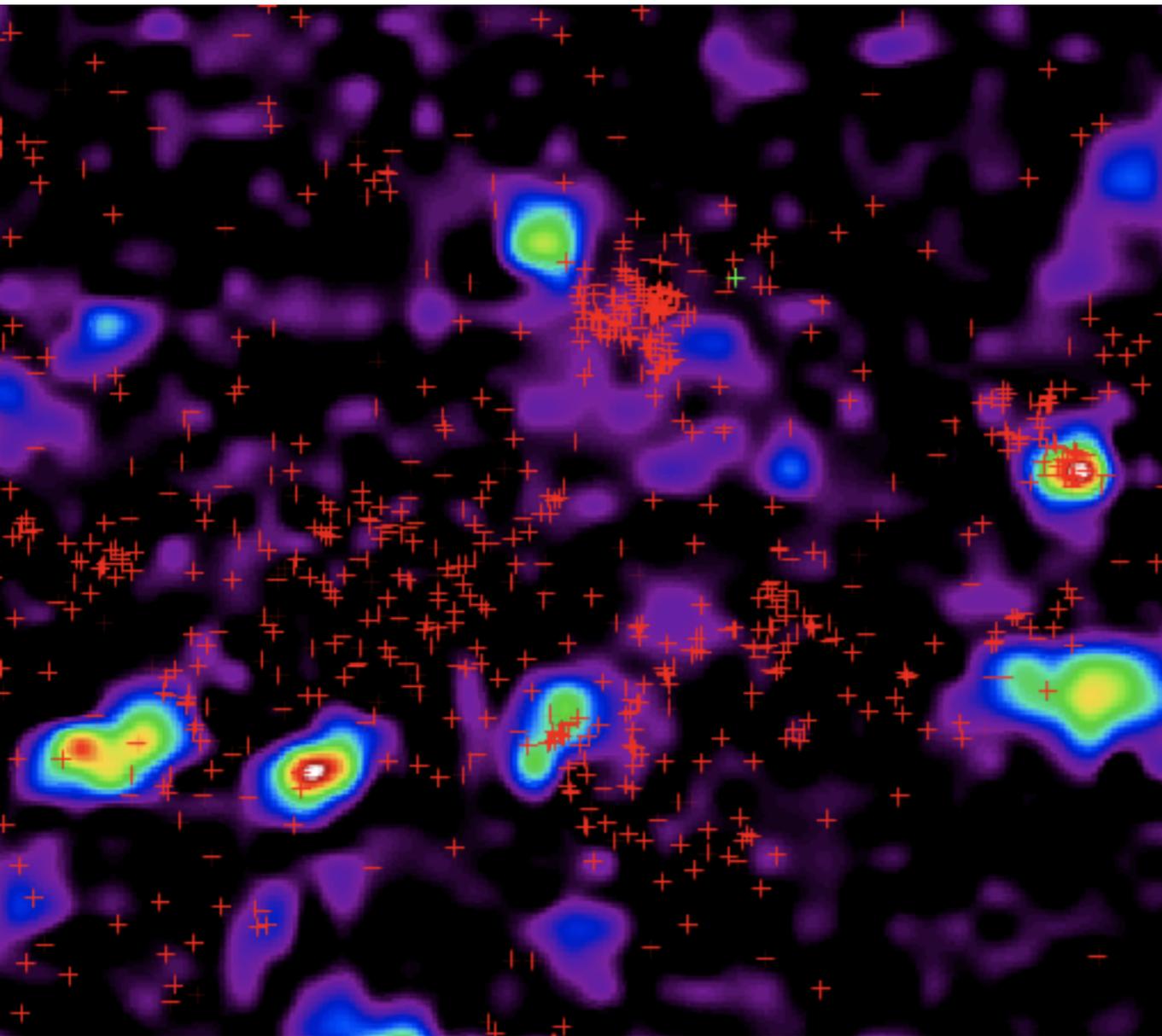


# HII regions



R.A. (J2000) (MCELS H $\alpha$  image: Smith et al. 1999)

# Association with CO clouds



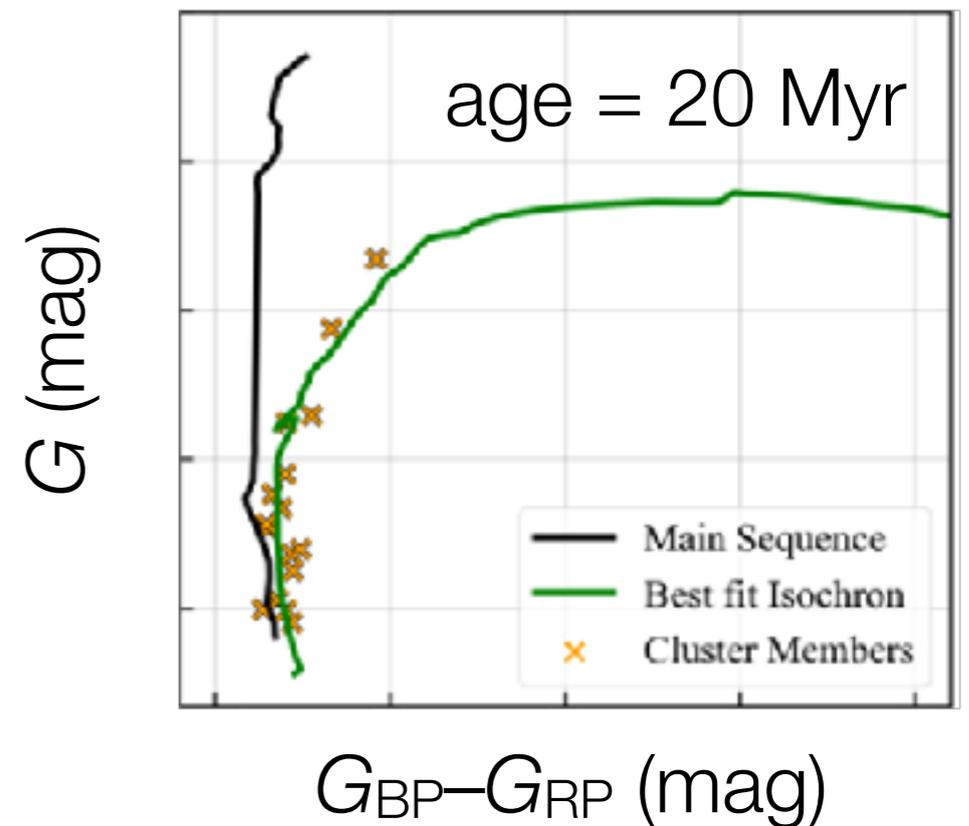
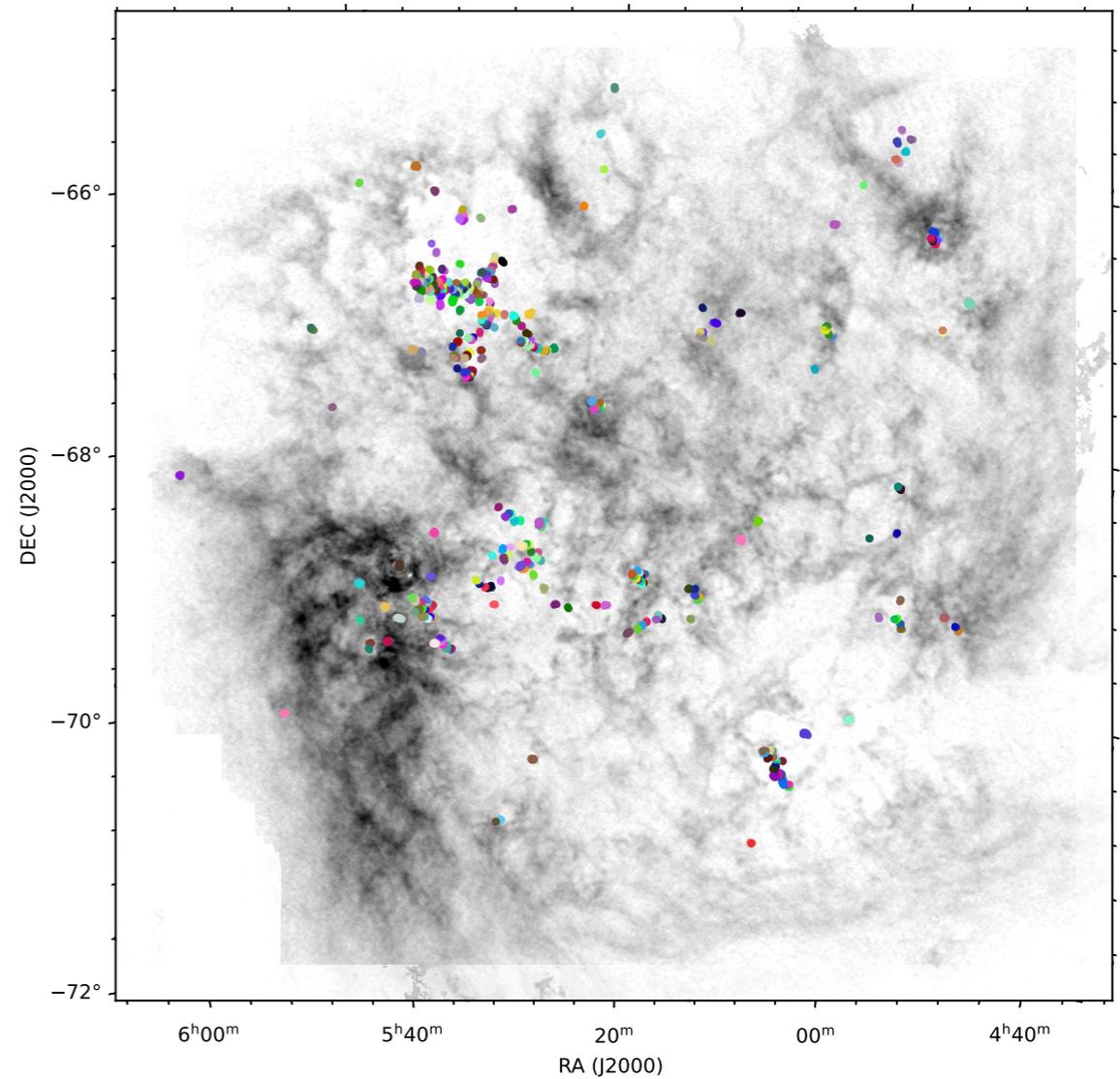
(NANTEN: Fukui et al. 1999, 2008)

(Mopra MAGMA survey: Wong et al. 2011, 2017)

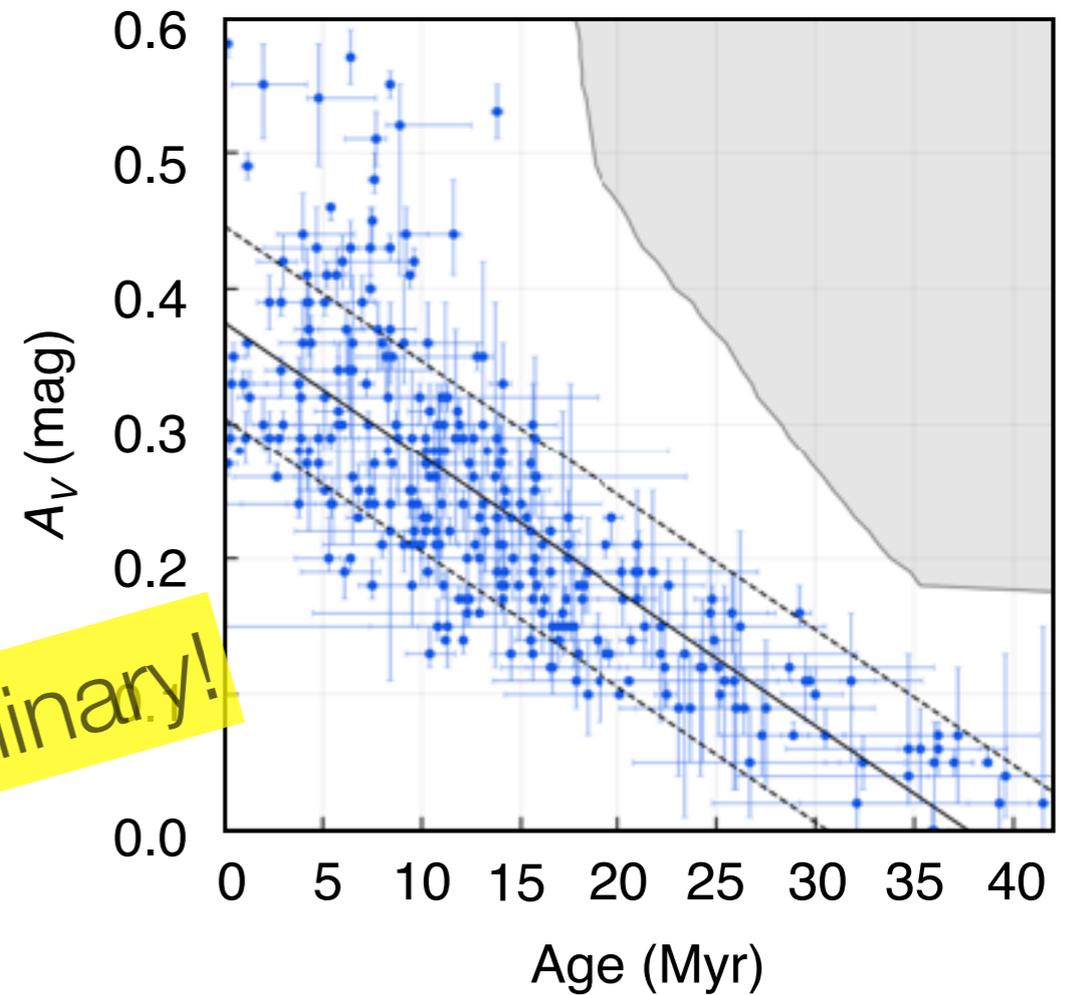
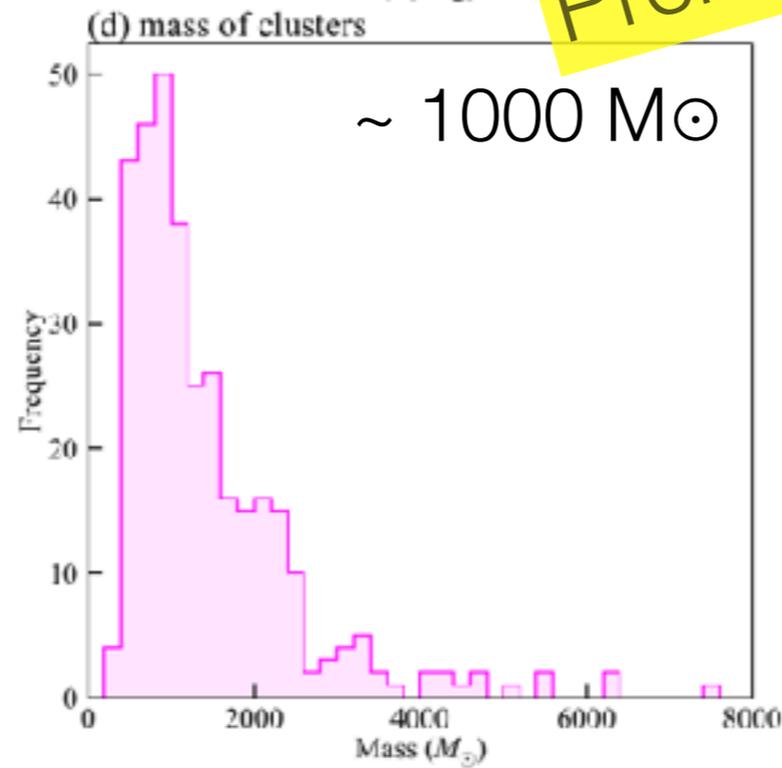
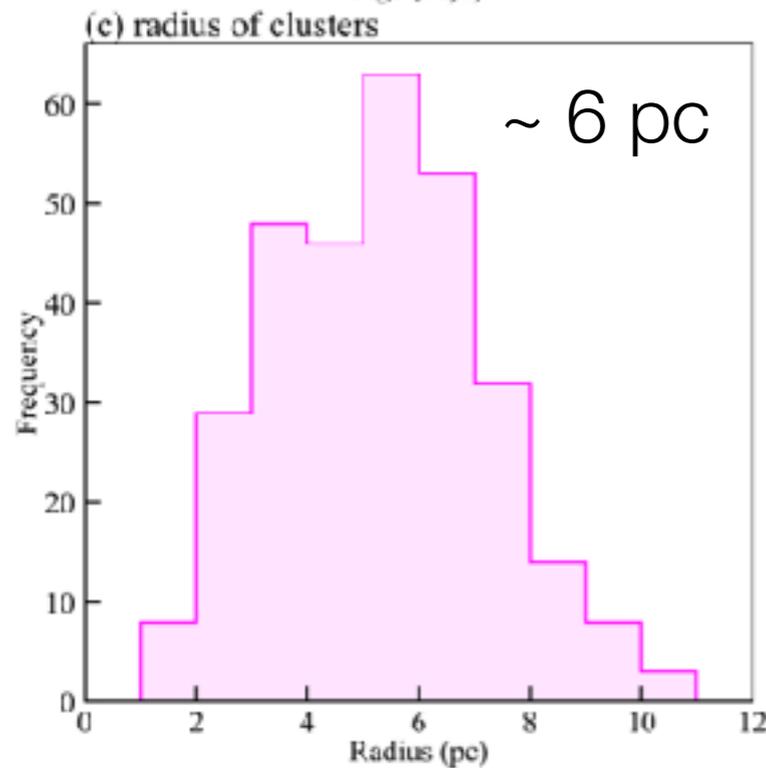
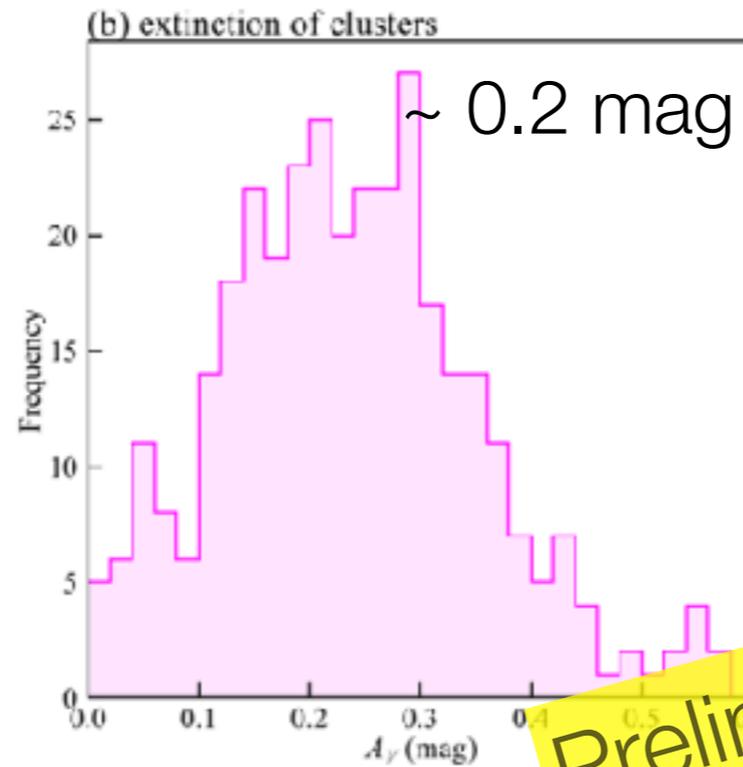
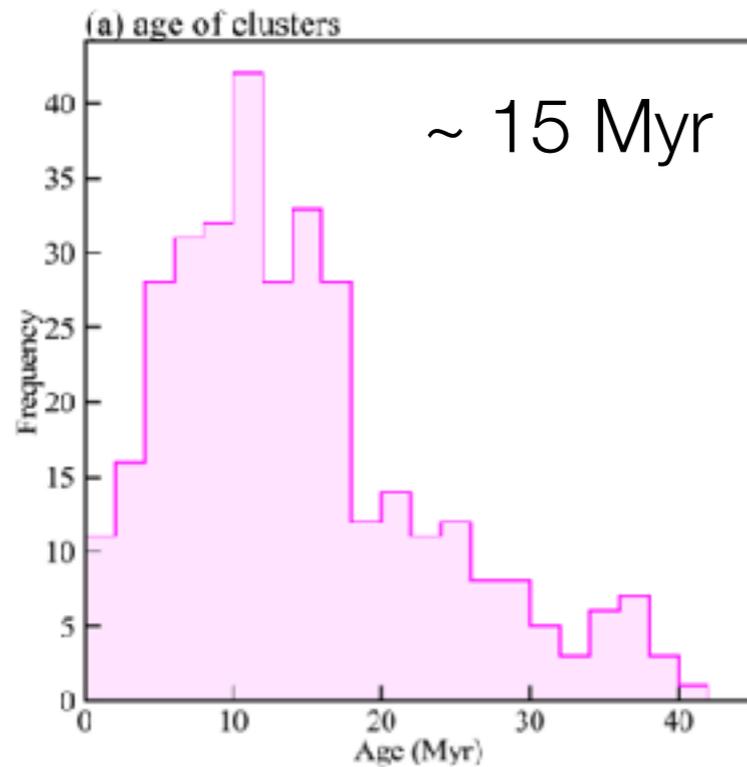
- Some are associated with CO clouds, but many others are separated.
- They are destroying molecular clouds.

# Cluster identifications

- Apply the DBSCAN algorithm
- Identify 339 cluster candidates
- Apply isochrone fitting with age and  $A_V$  as free parameters
- By the  $\chi^2$  test, **304 coeval clusters**



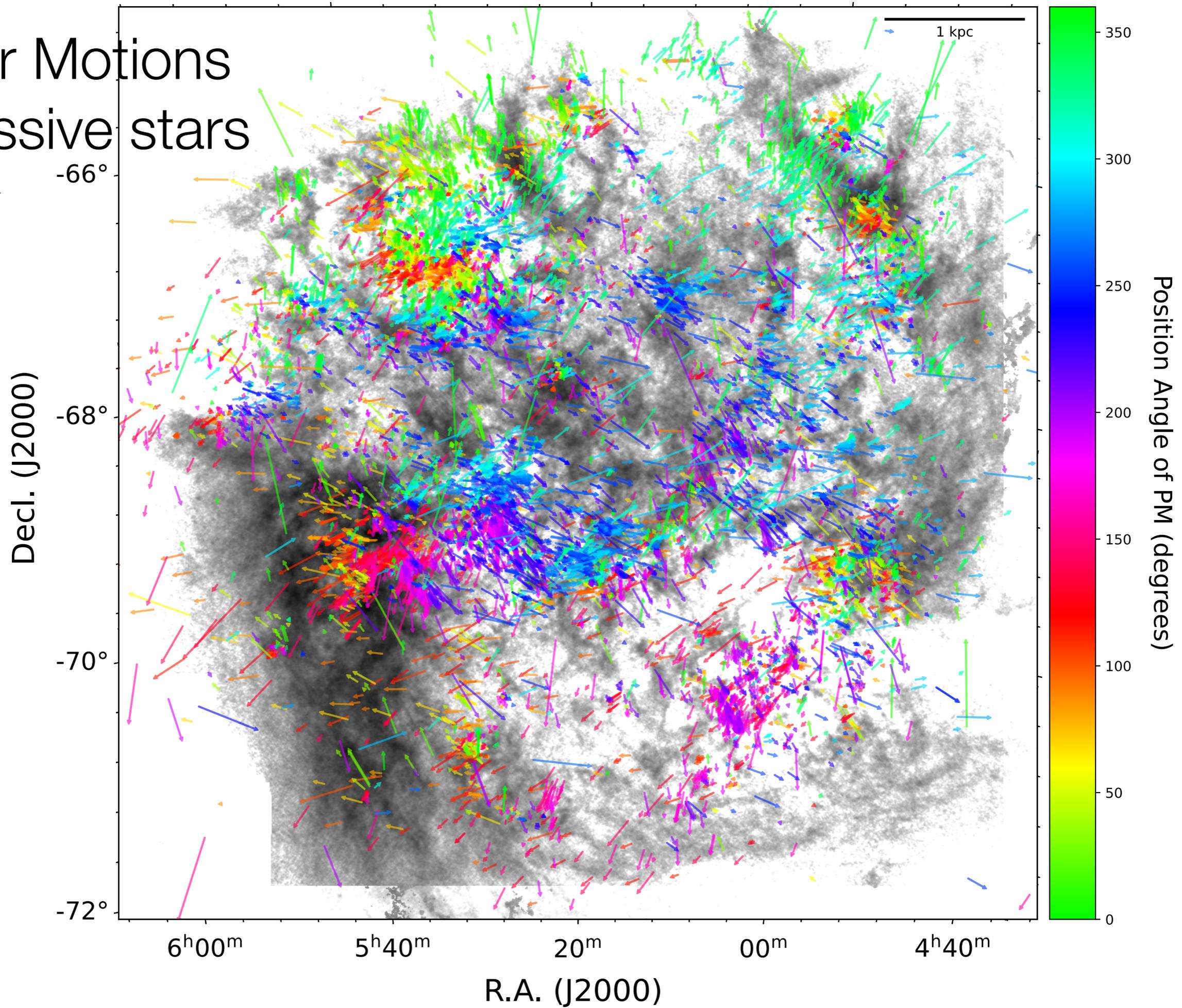
# Properties of the clusters



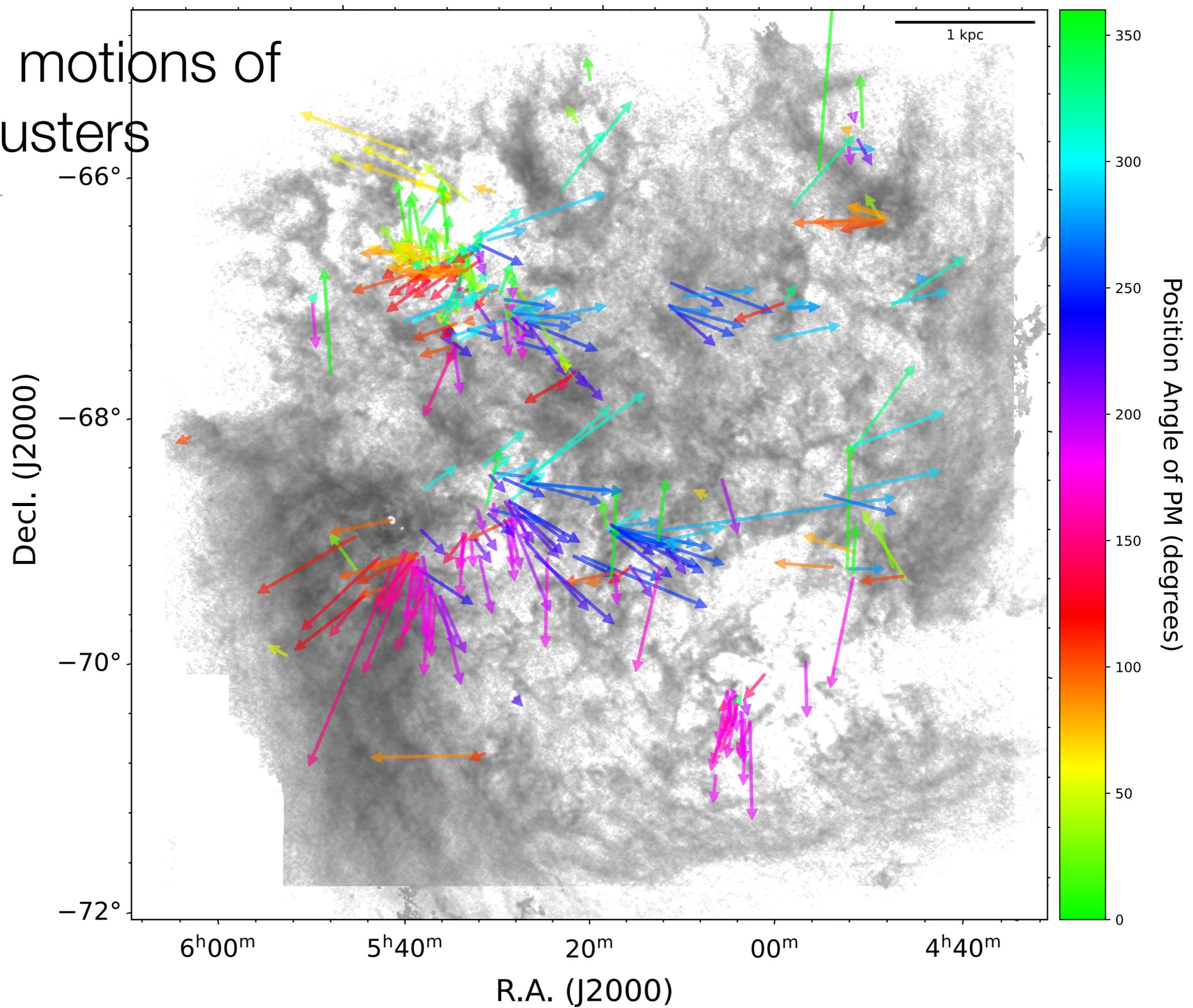
Preliminary!

Cloud dissipation timescale  
~ 30 Myr

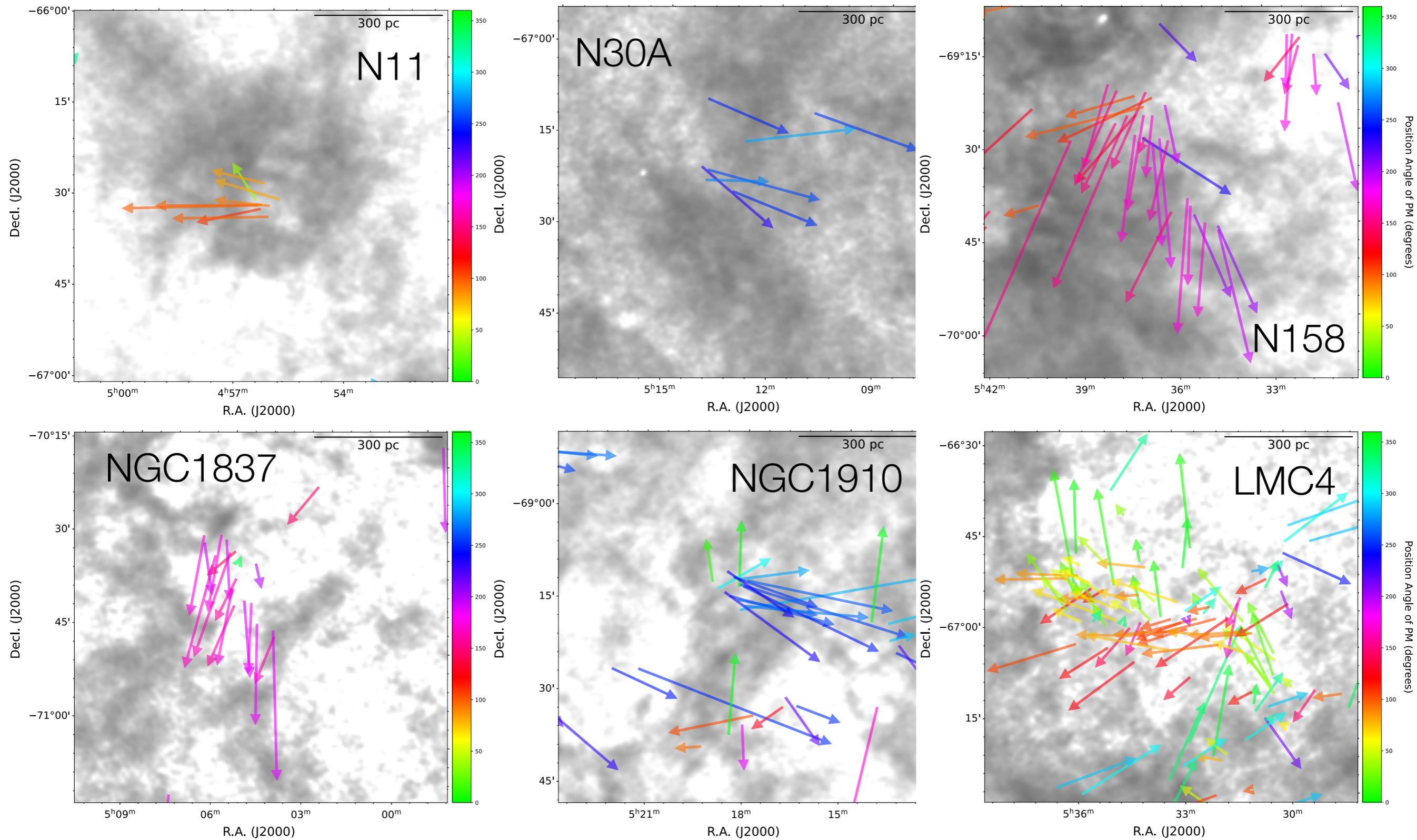
# Proper Motions of Massive stars



# Mean motions of the clusters

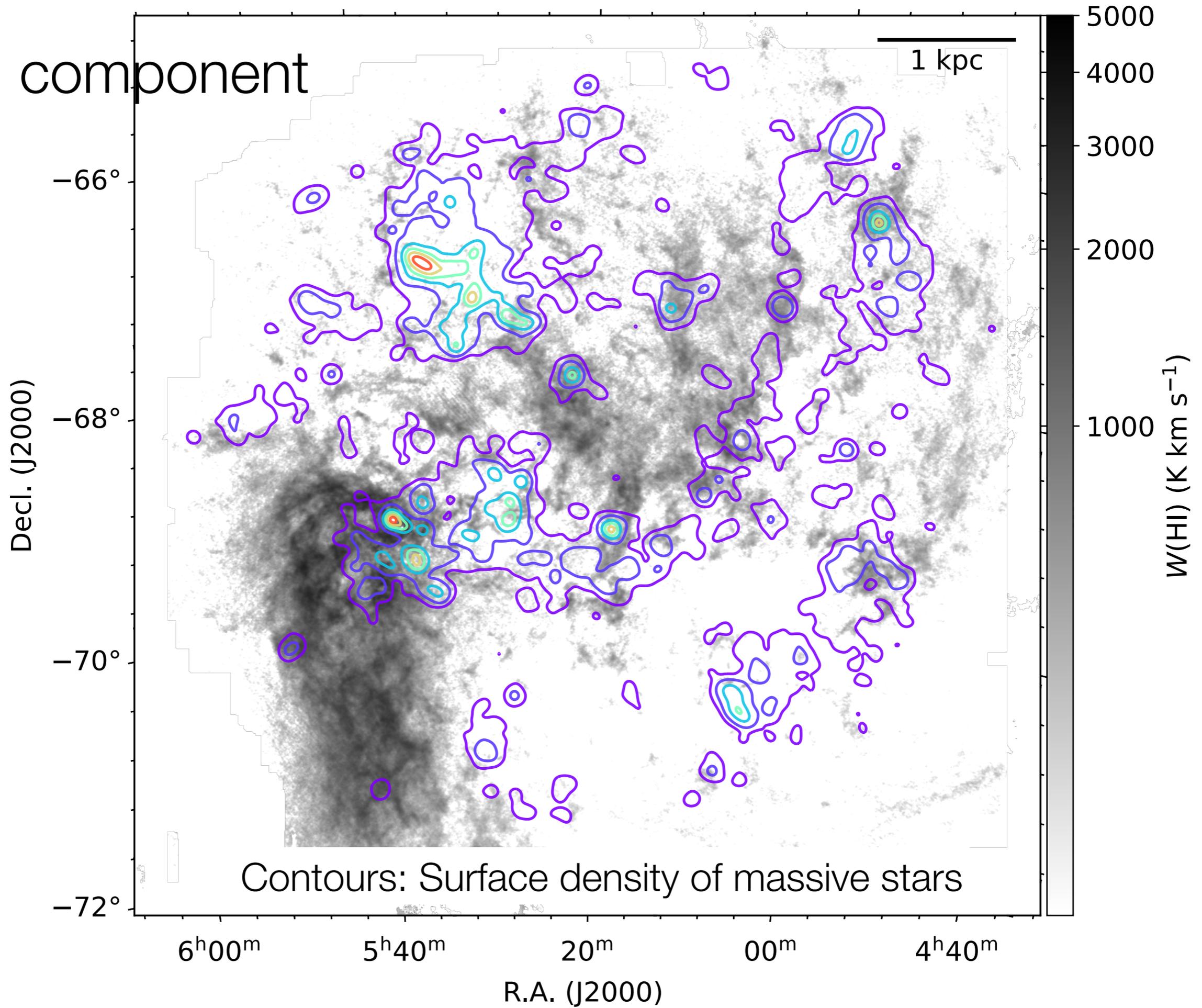


# A few-100 pc scale co-moving clusters

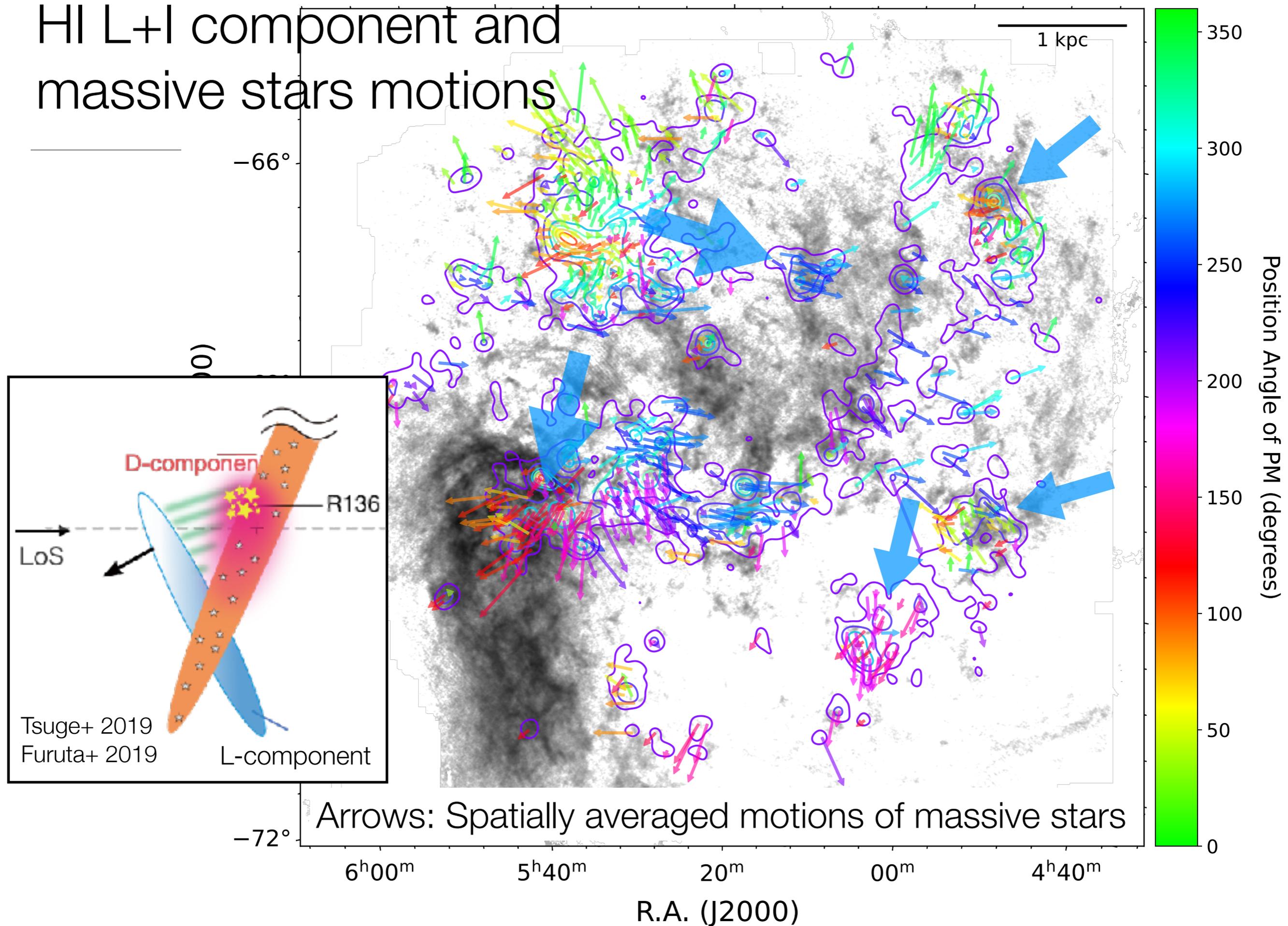


Each arrow shows mean motion of single cluster

# HI L+I component

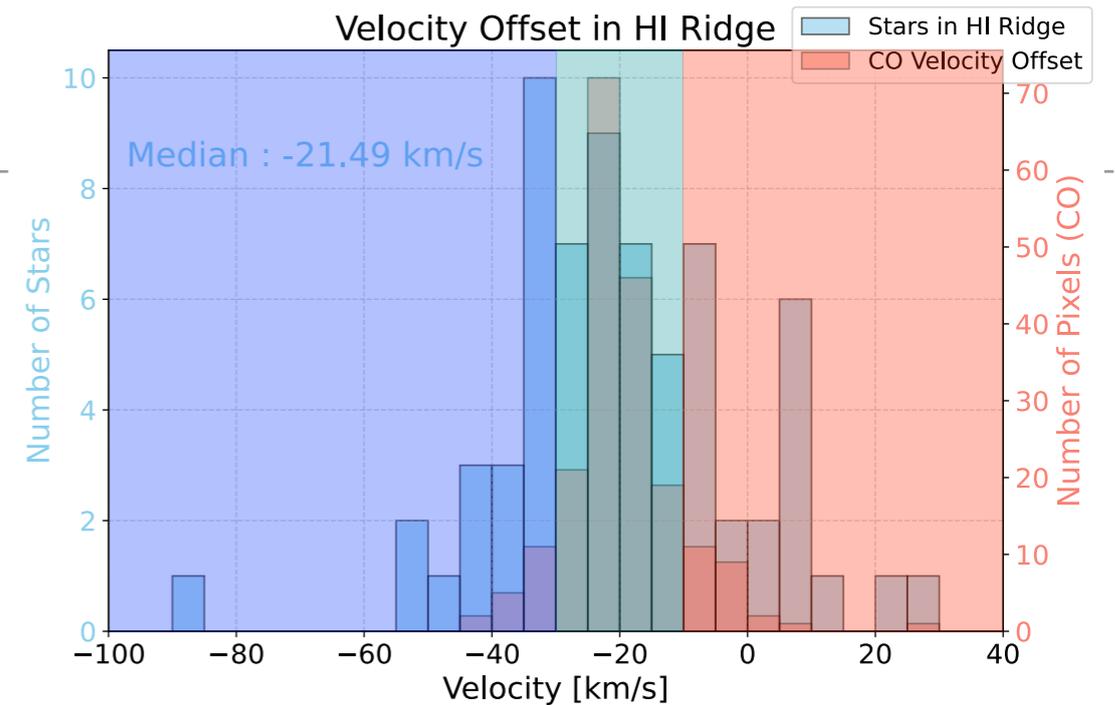


# HI L+I component and massive stars motions

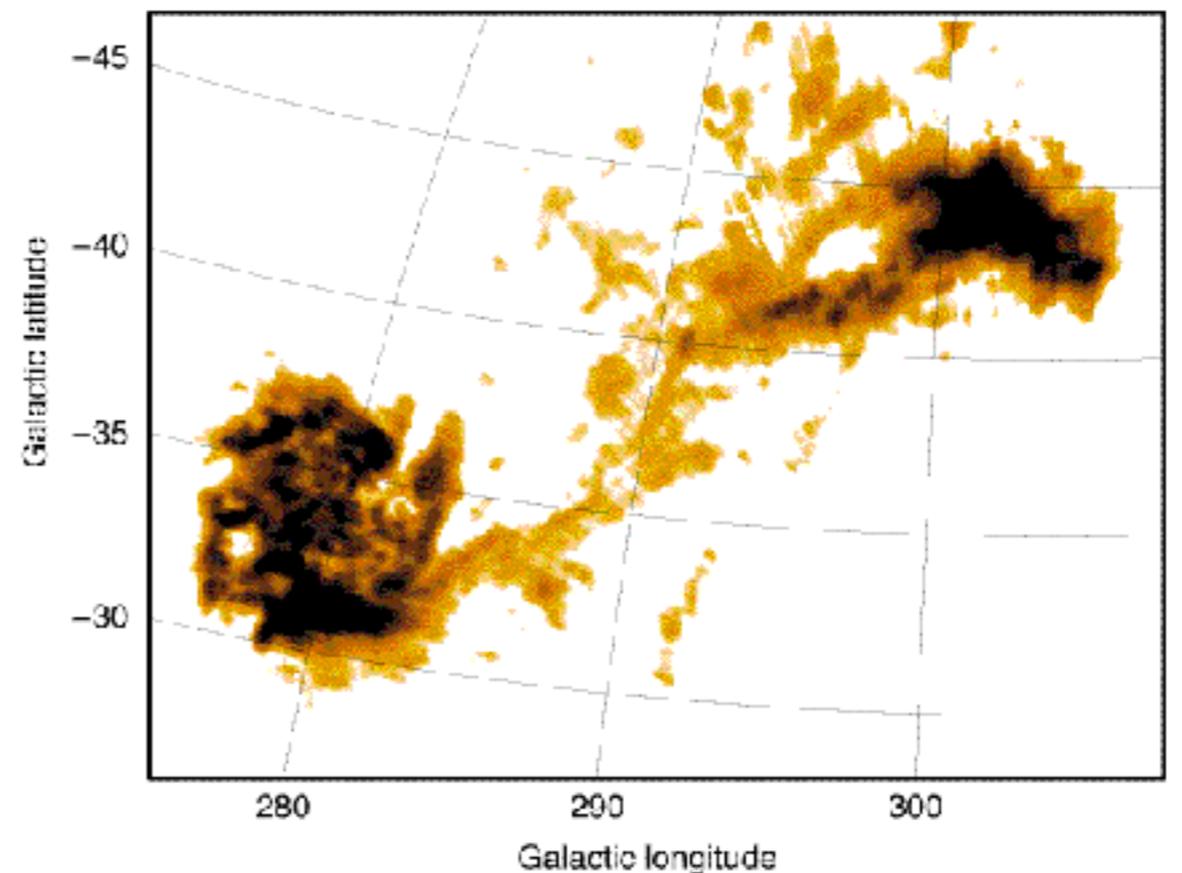


# Triggered star formation by interaction with SMC

- Massive stars in LMC are
  - concentrated on the edge of the HI L+I components
  - moving away from L+I HI gas
  - have similar radial velocity to CO clouds between the HI L- and D-components
  - suggested to be **formed by triggering of accreting gas flow from the SMC.**

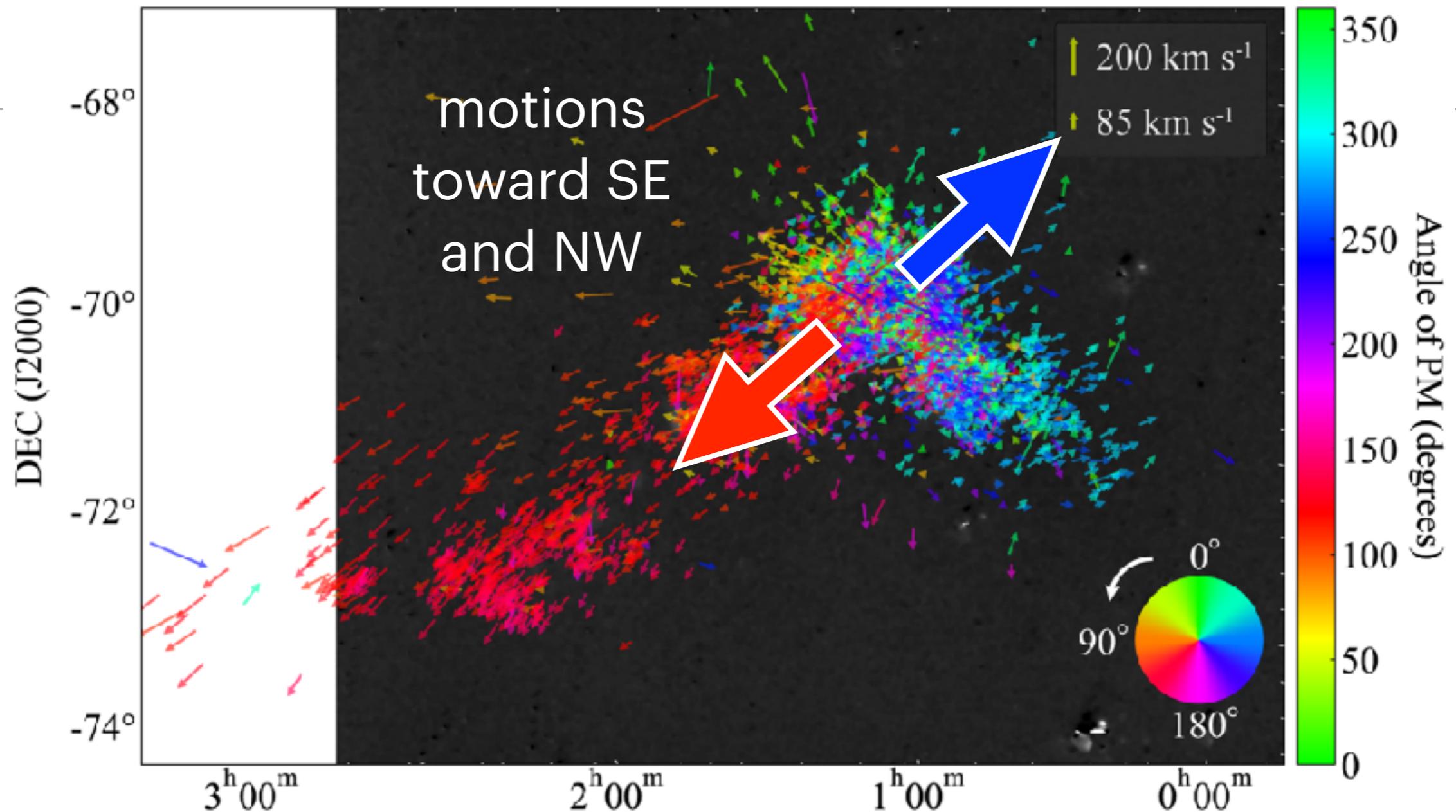


Radial velocity of CO and Gaia stars in the HI ridge



The Magellanic Bridge (Putman et al. 1998)

# What about SMC?



SMC is not rotating, but being destructively stretched.  
Total mass derived from the HI rotation might be wrong!

Nakano, Tamashiro & Tachihara 2025, ApJS, 277, 62

Nakano & Tachihara 2025, ApJL, 985, 5L

# Summary

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- Using the Gaia DR3 data, 12572 massive stars are identified in the LMC.
- $\sim 300$  clusters of  $\sim 1000 M_{\odot}$ , 15 Myr and 6 pc are identified.
- Co-moving clusters and massive stars over a size scale of a few 100 pc.
- Large-scale HI gas flow are colliding the LMC disk and triggering the massive star and cluster formation.