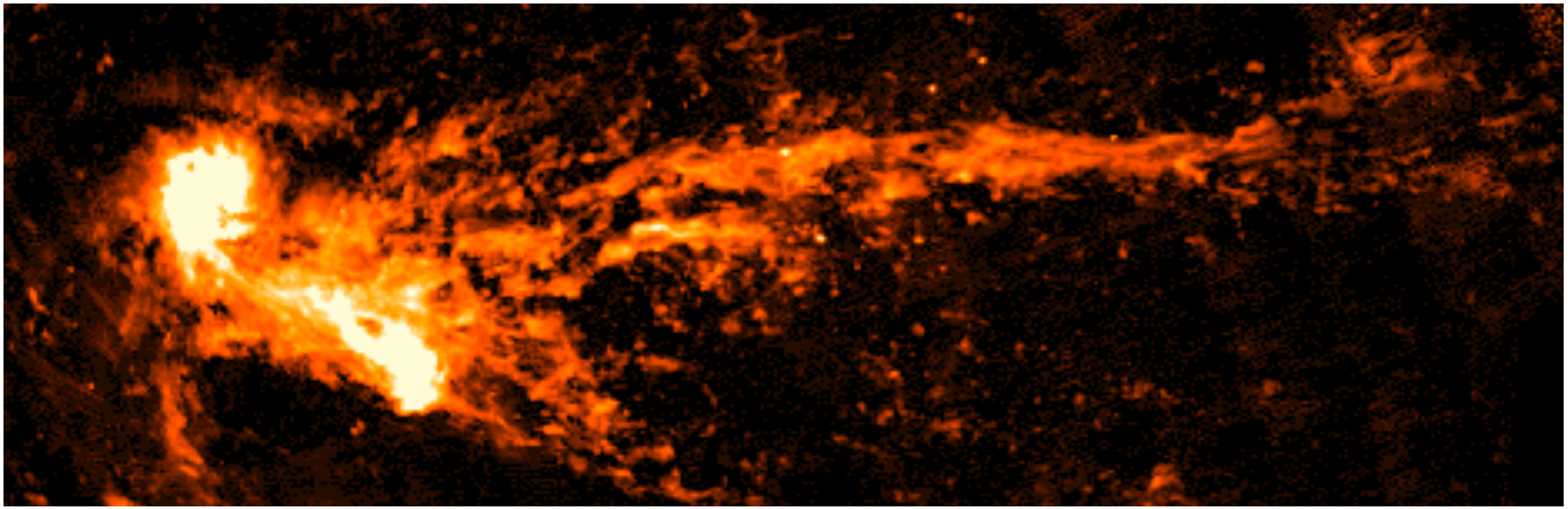
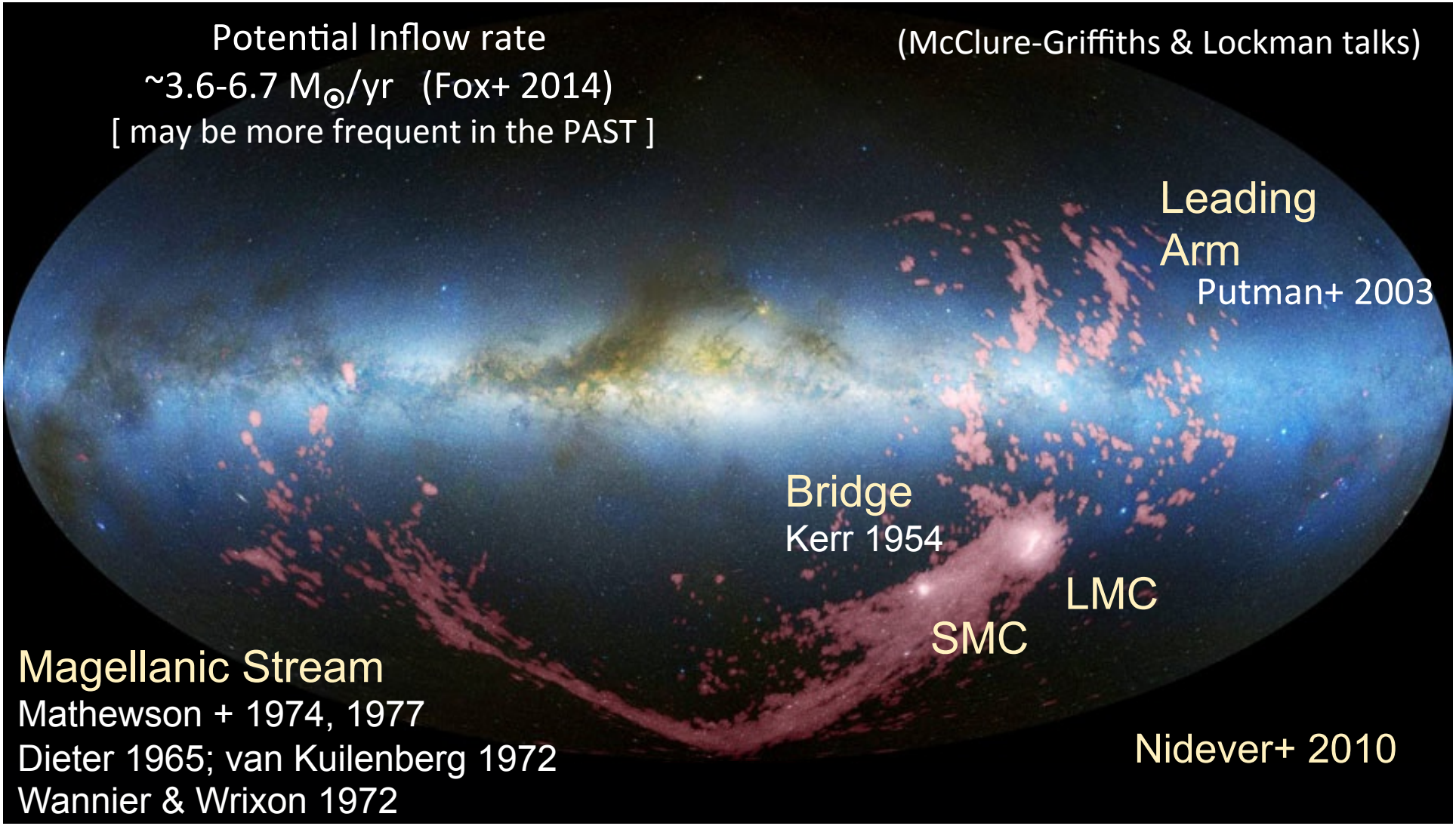
The Evolution of the Gaseous Magellanic System



Gurtina Besla, Munier Salem

Greg Bryan, Mary Putman, Roeland van der Marel,
Nitya Kallivayalil, Dusan Keres, Lars Hernquist, TJ Cox

The Magellanic System



$M_{Gas\ outside} \sim \mathbf{2 \times 10^9\ M_\odot} (d/55\ kpc)^2 > 2 \times M_{Gas\ LMC+SMC}$ Fox + 2014

What is the Dominant Formation Mechanism of the Extended HI Structures?

1. **MW Tides**

   Murai & Fugimoto 1980, Lin+1995, Gardner & Noguchi 1996, Yoshizawa & Noguchi 2003, Bekki & Chiba 2005, Connors+ 2005, Ruzicka+2010

2. **Ram Pressure Stripping of LMC (Marasco Talk)**

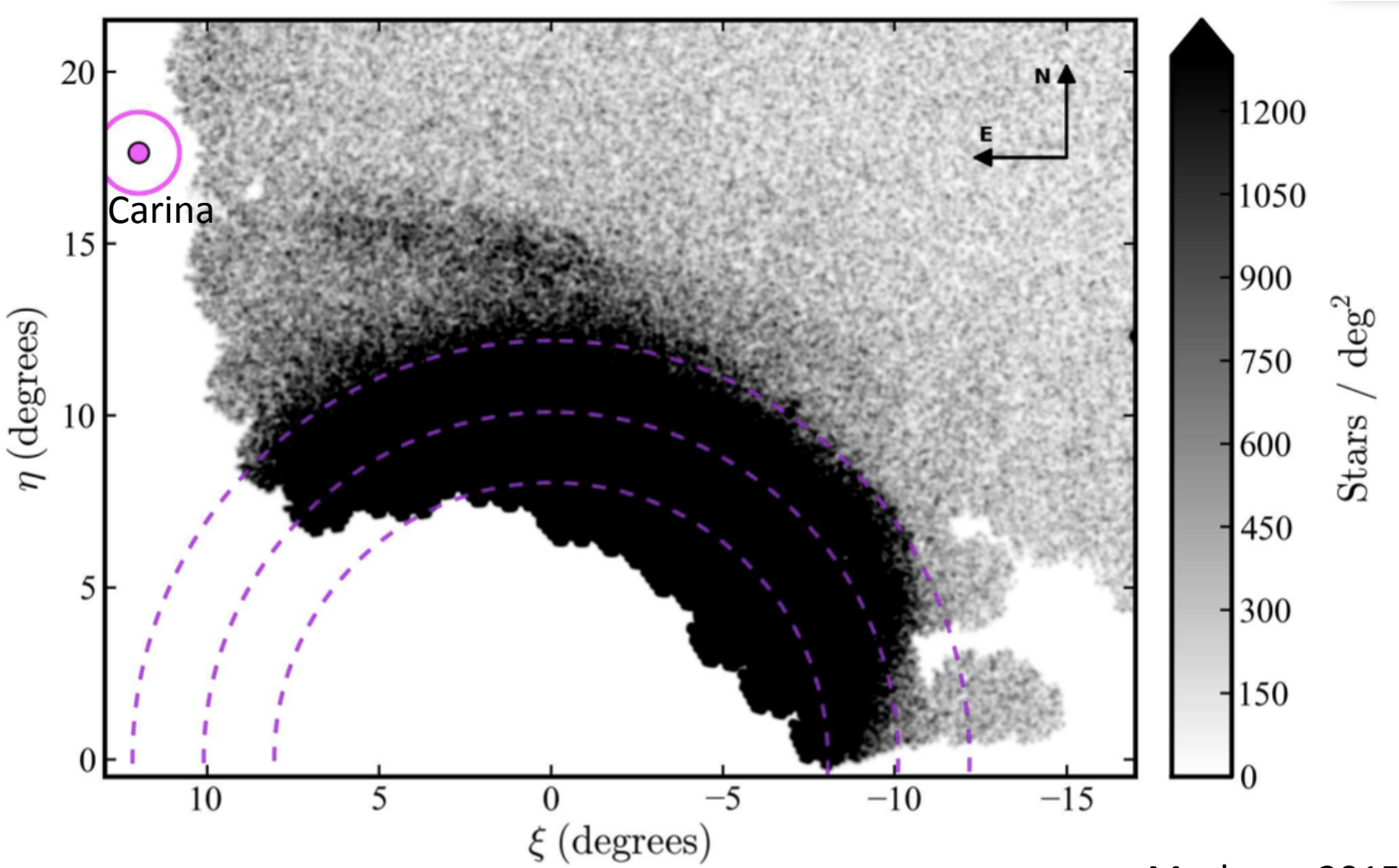
   Moore & Davis 1994, Heller & Rohlfs 1994, Mastropietro + 2005, 2009

3. **LMC-SMC Interactions (Bridge)**

   Besla + 2010, 2012, 2013, Diaz & Bekki 2012

But the LMC Tidal Radius > 18.5 kpc

SMC also has an extended stellar component ~11 kpc (Nidever + 2011)



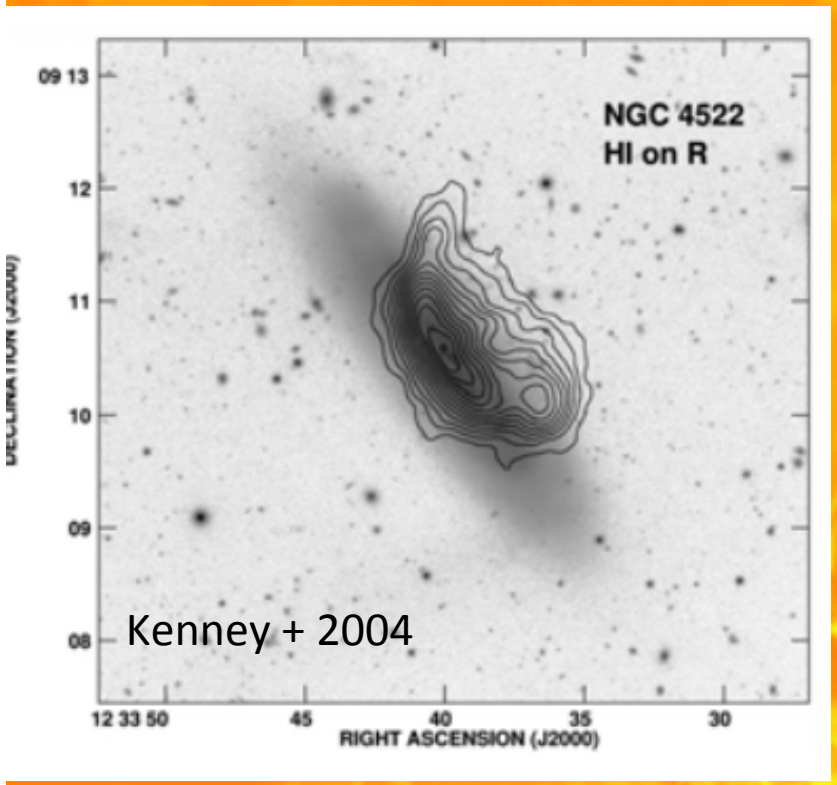
See also: Balbinot et al. 2015; Saha et al. 2010

Mackey + 2015

temperature map: 10^4 - 10^7 kelvin

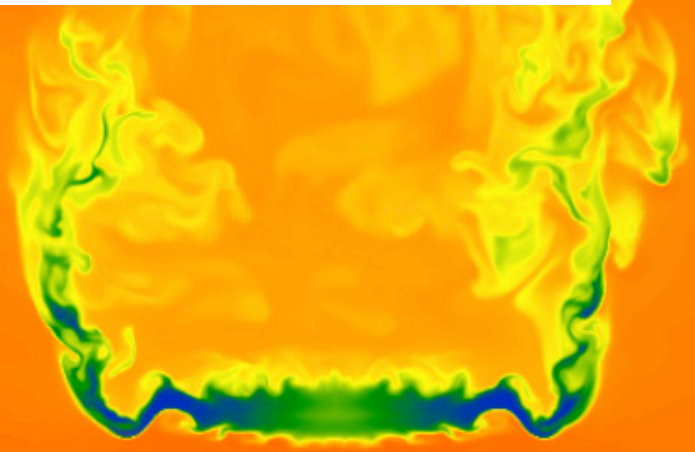
Ram Pressure Stripping Probes the Ambient Medium

(Braun Talk)



Kenney + 2004

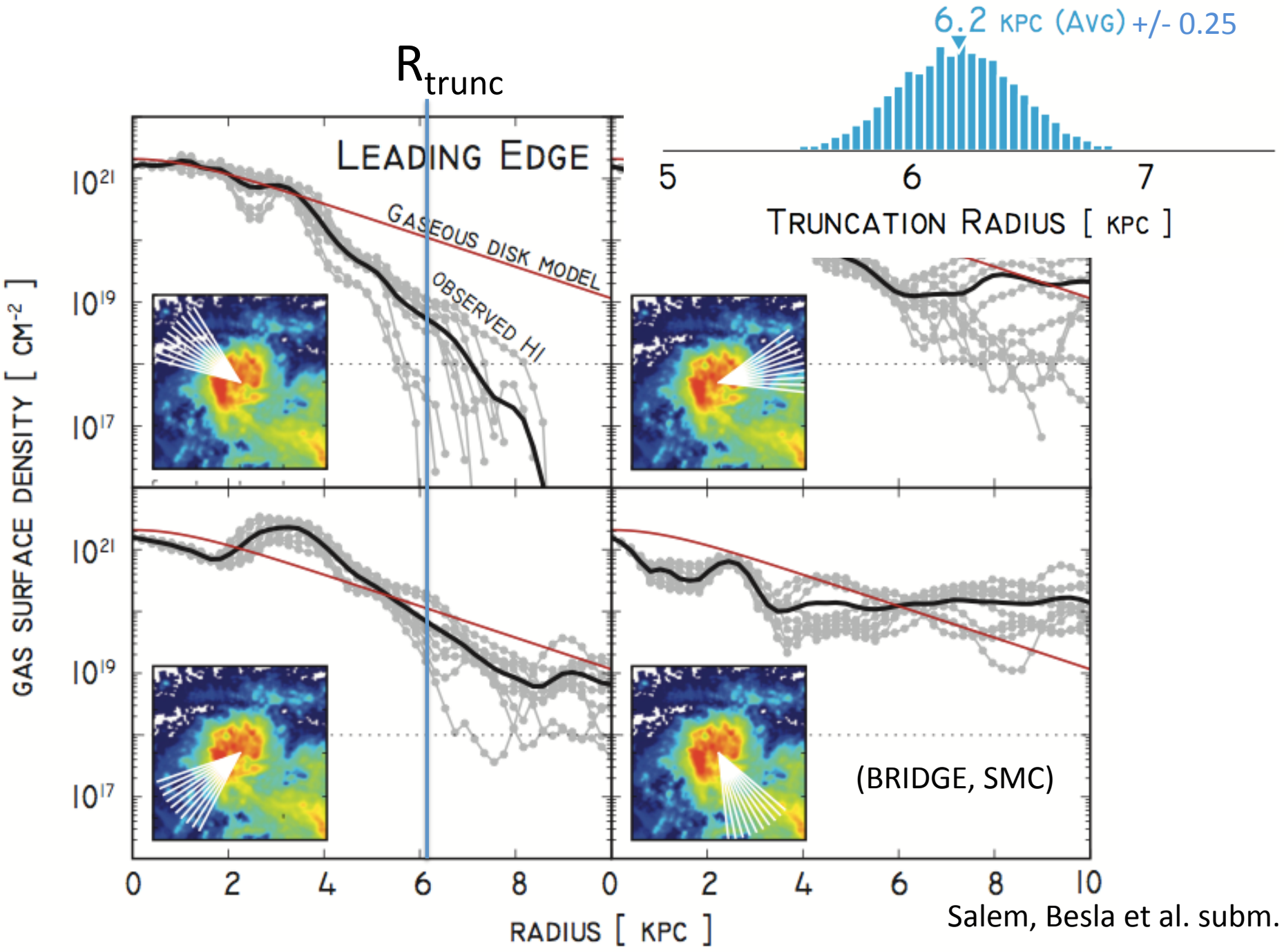
Ram Pressure =
Wind Density * (Wind Speed)^2



Tonnesen & Bryan 2009

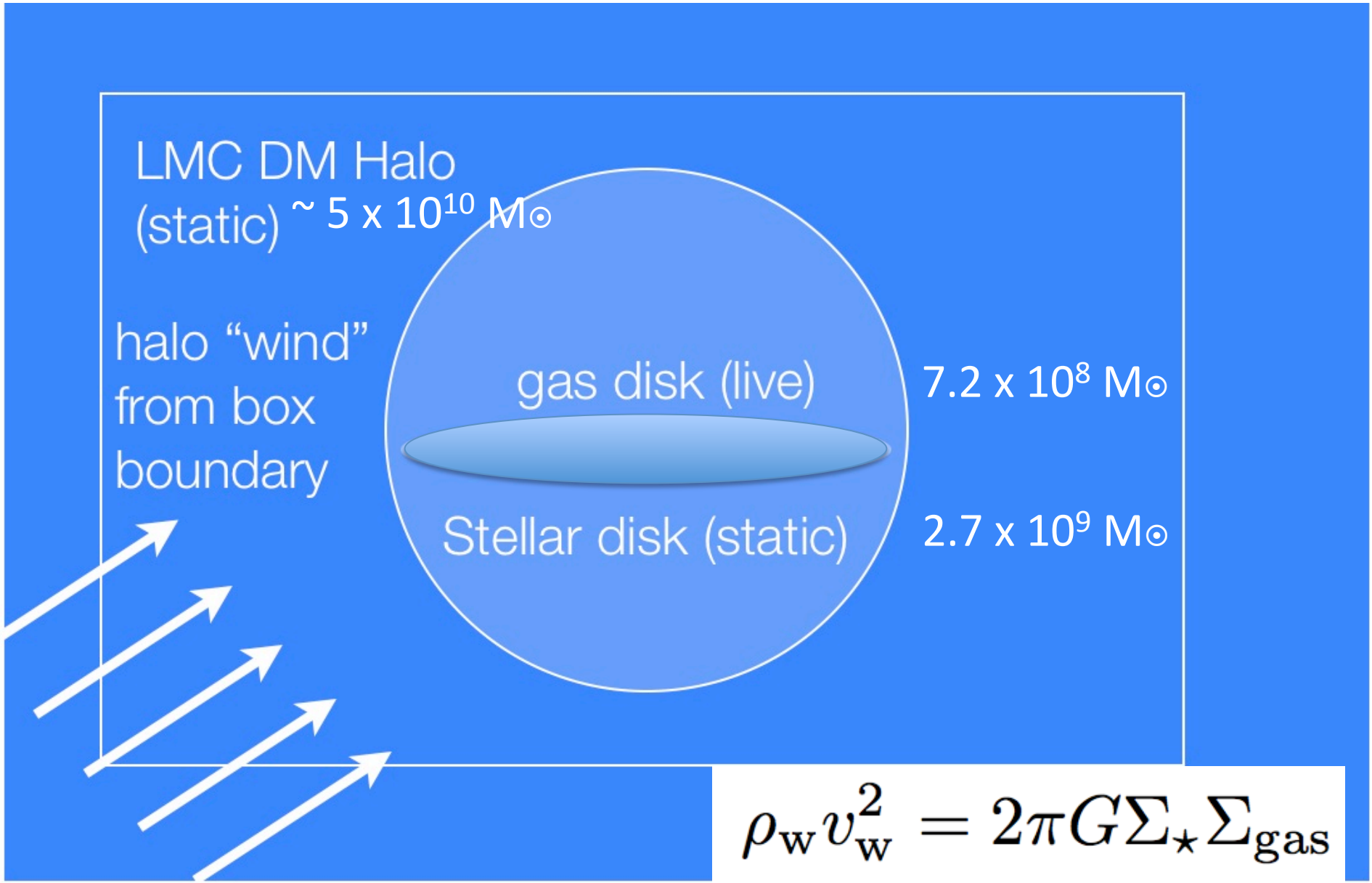
26 kpc

$M_{tot} = 10^{12} M_{sun}$, $v_{circ} = 200$ km/s



Salem, Besla et al. subm.

Simulation Set Up

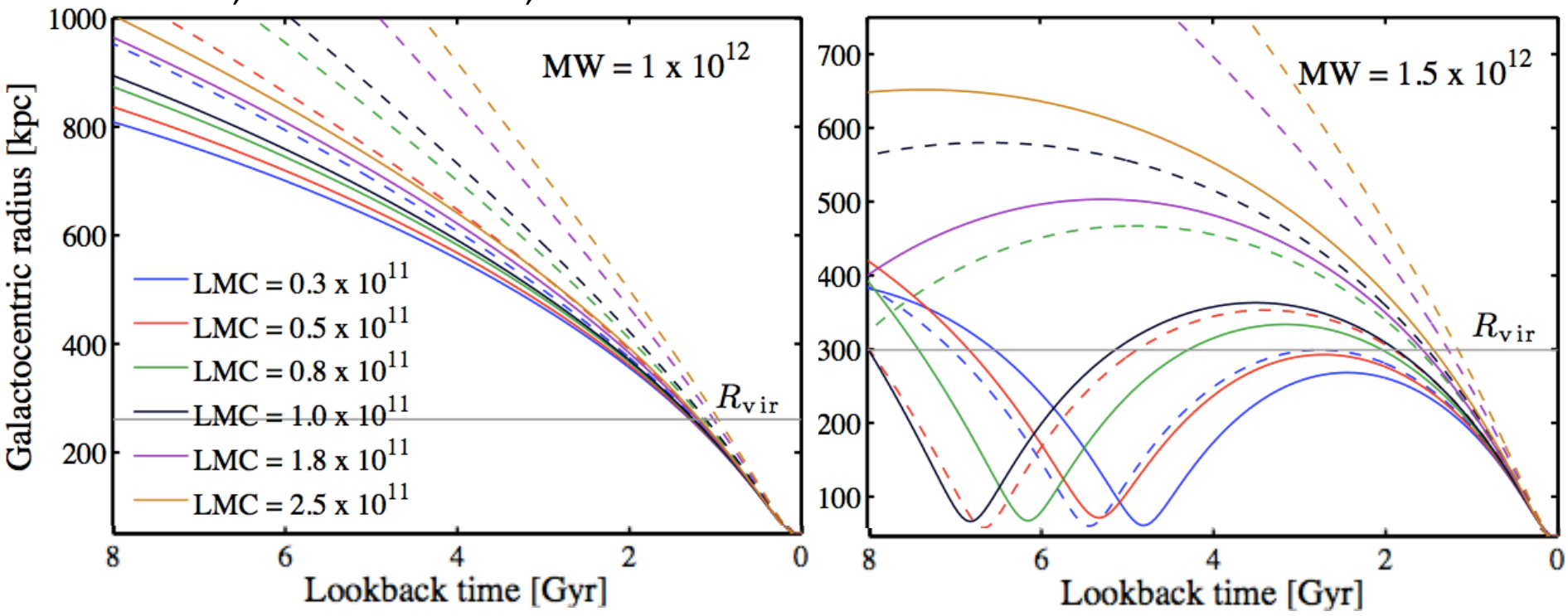


$$\rho_{\rm w} v_{\rm w}^2 = 2\pi G \Sigma_\star \Sigma_{\rm gas}$$

Gunn & Gott 1972

The Recent Pericentric Passage of the LMC about the MW is Model Independent

Gomez, Besla et al. 2015 ;



$r_p = 48.1 \pm 2.5$ kpc $\quad v_p = 340 \pm 19$ km/s

$t_p = 46.4 \pm 8.5$ Myr

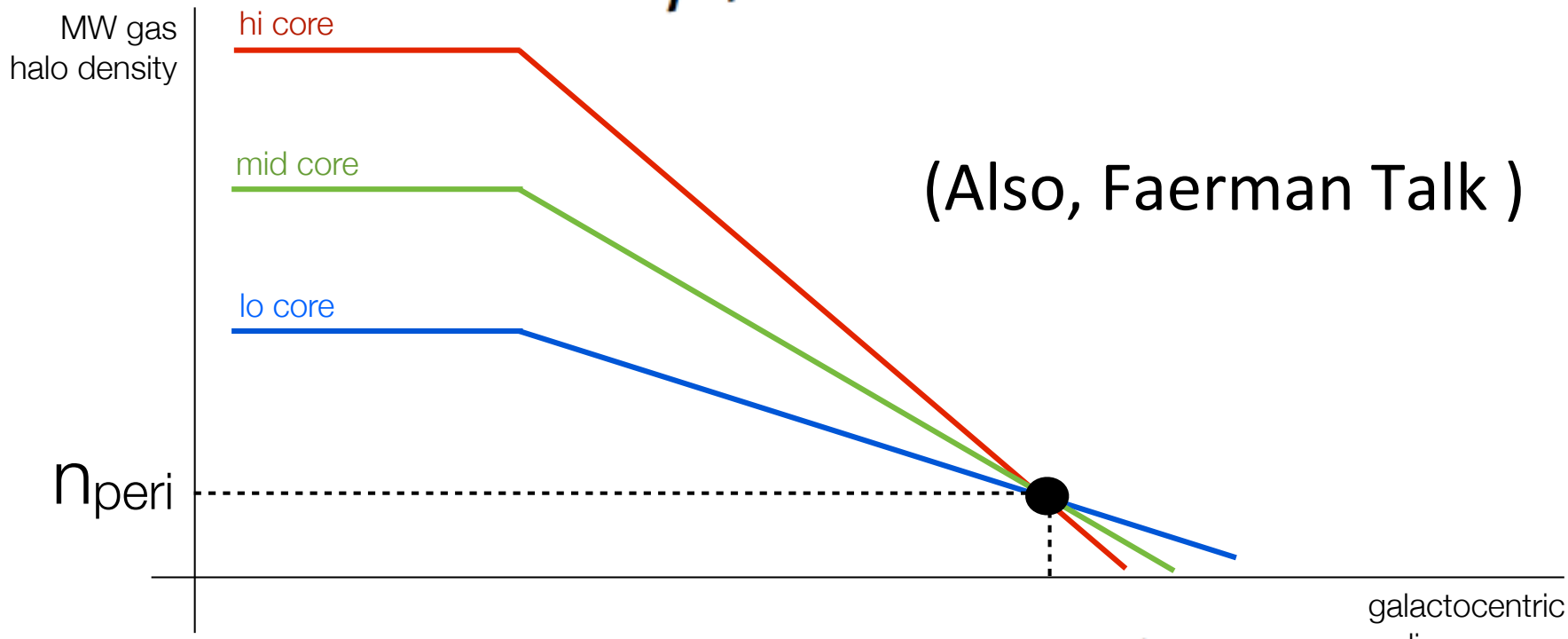
Kallivayalil, van der Marel, Besla et al. 2013

Maximal Stripping at Peri: $\rho_{(peri)} v^2_{(peri)} = 2\pi G \Sigma_\star \Sigma_{gas(Rtrunc)}$

KNOWN

Following Miller & Bregman 2015
Beta Profile:

$$n(r) \approx \frac{n_0 r_c^{3\beta}}{r^{3\beta}}$$



(Also, Faerman Talk)

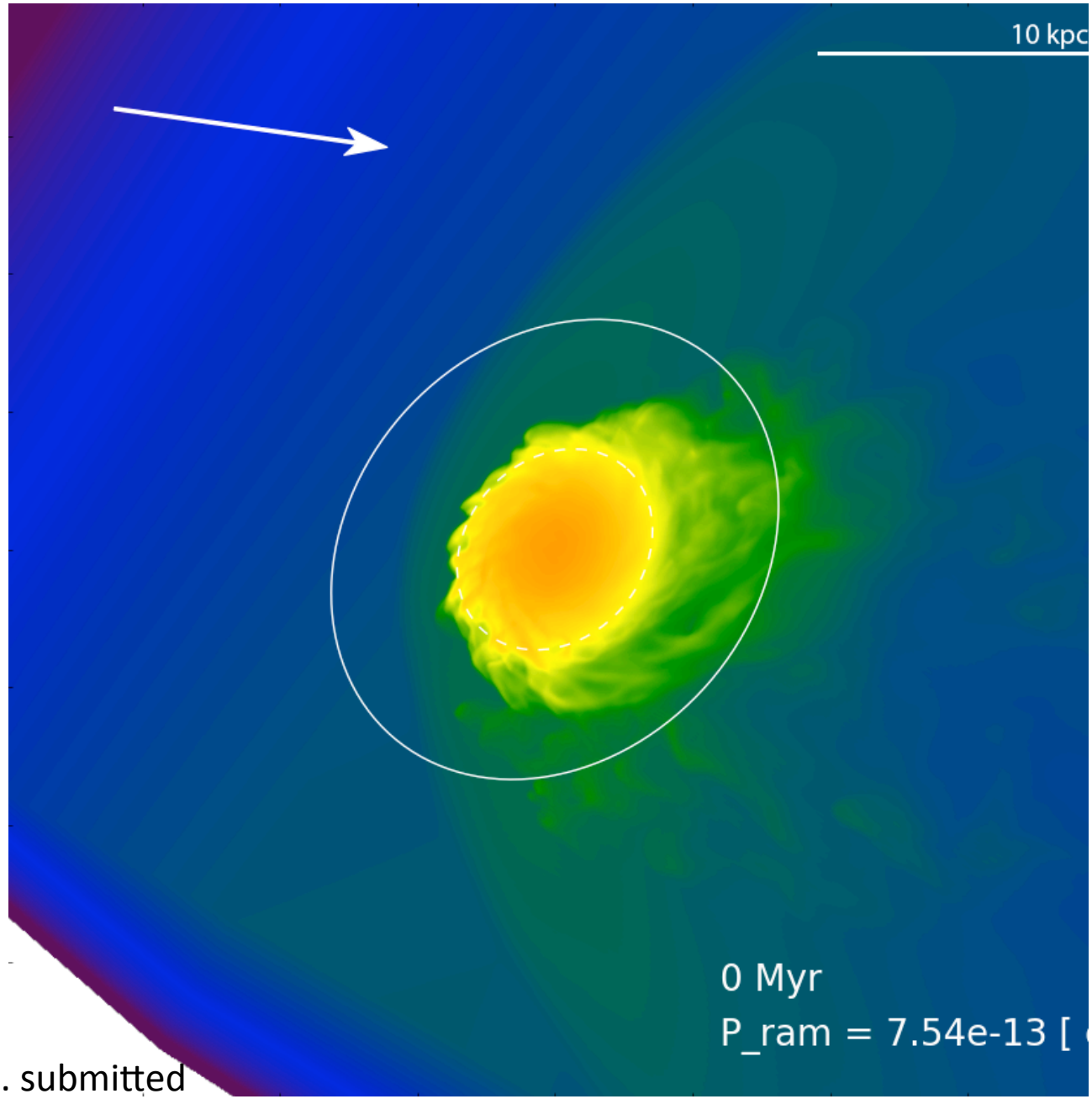
Temp profile: Hydrostatic equilibrium
(10^{12} M⊙ halo) Makino 1998

48.1 ± 2.5 kpc

Resolution:
30 pc

No cooling

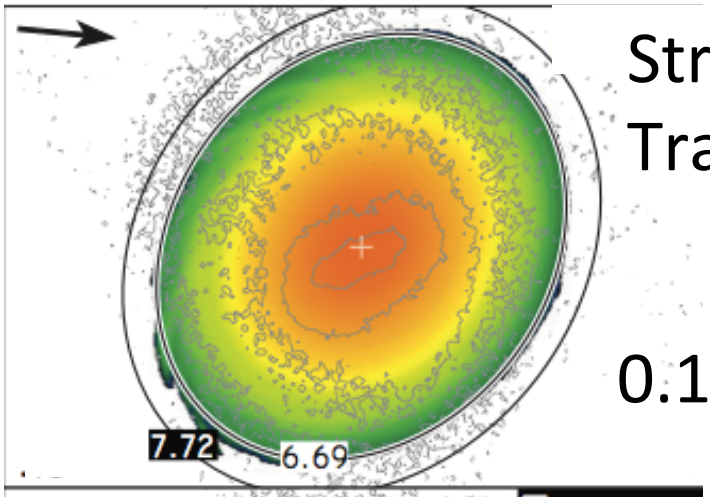
See also Roediger & Hensler 2006



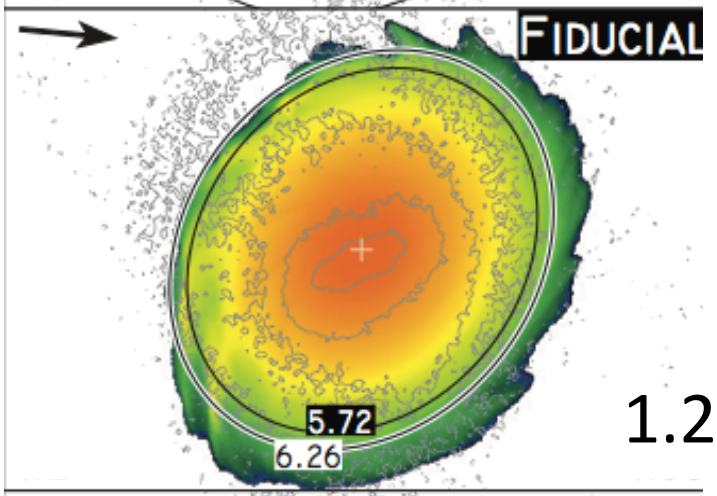
Salem, Besla et al. submitted

Enzo AMR Simulations

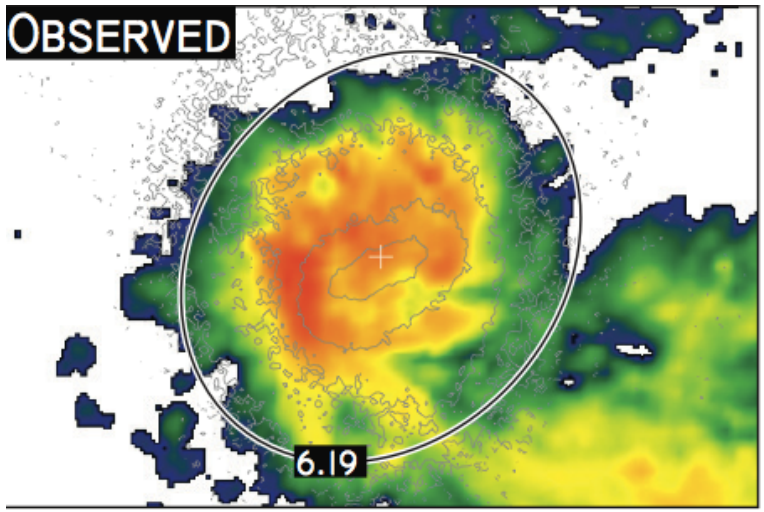
Stripping is insensitive to halo gas profile
Traces density at pericenter

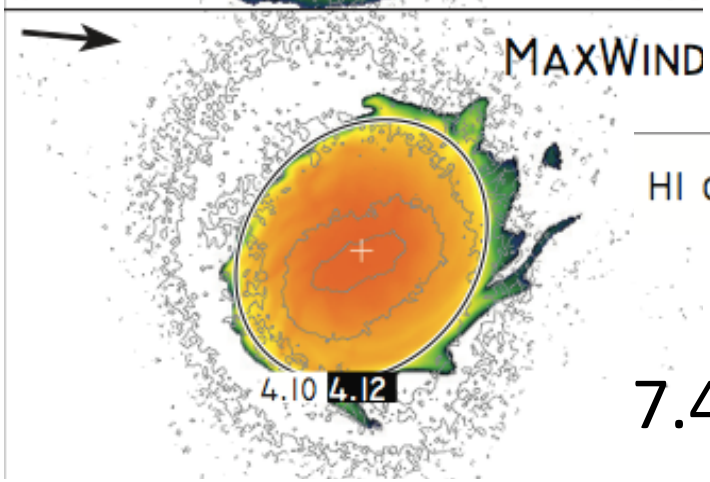


0.13×10^{-4} /cm^3



1.2×10^{-4} /cm^3





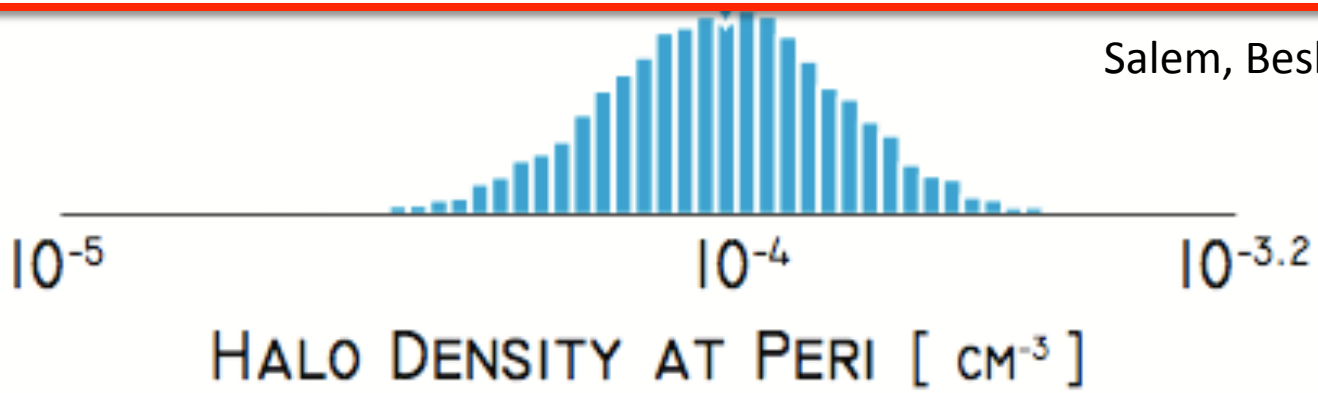
7.44×10^{-4} /cm^3

Salem, Besla et al. subm.

Constraints on CGM density at ~ 48 kpc

$$n_{\rm MWHalo}(R = 48.2 \pm 2.5\ {\rm kpc}) = 1.1^{+.44}_{-.45} \times 10^{-4}\ {\rm cm}^{-3}$$

Salem, Besla et al. subm



Estimates at ~ 50kpc from stripping simulations of other MW Satellites:

Gatto, Fraternali et al. (2013) $(1.3 – 3.6) \times 10^{-4}$ /cm^3

Grcevich & Putman (2009) $(0.1\text{-}10) \times 10^{-4}$ /cm^3

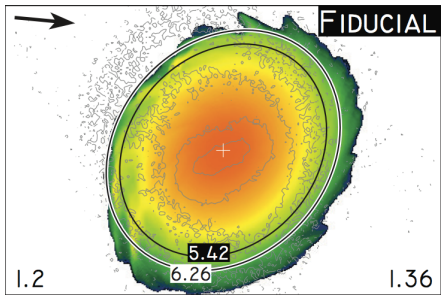
IF BETA PROFILE: (BUT SEE FAERMAN TALK)

$$M_{\rm gas\ \mathbf{smooth}}\ (R < 300\ {\rm kpc}) = 2.6\ (+/- 1.4) \times 10^{10}\ M\odot$$

(7-24% of Expected Baryons in 1e12 halo)

Similar to that inferred for M31 (Lehner et al. 2015)

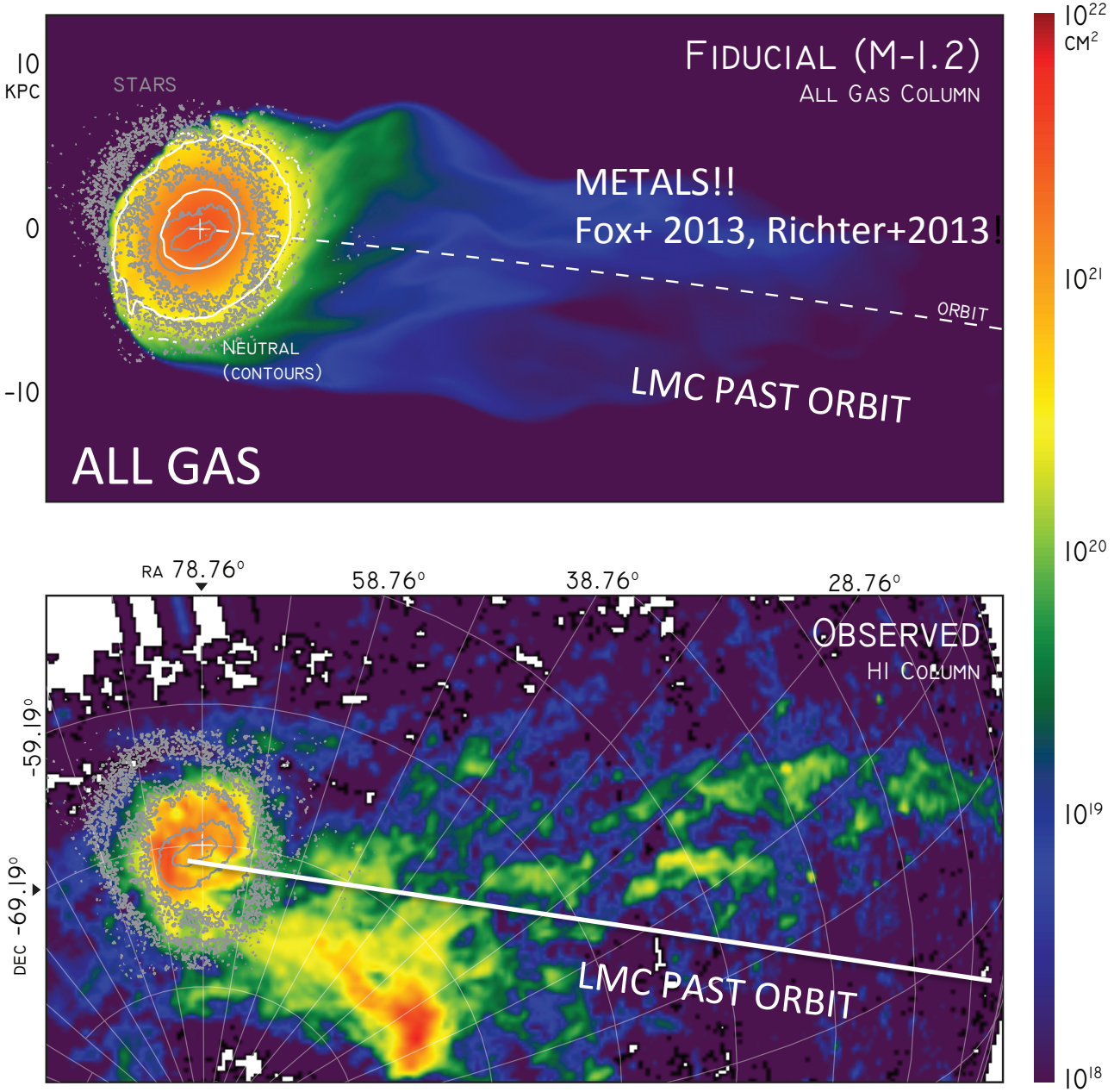
Contribution to the Mag. Stream/CGM?



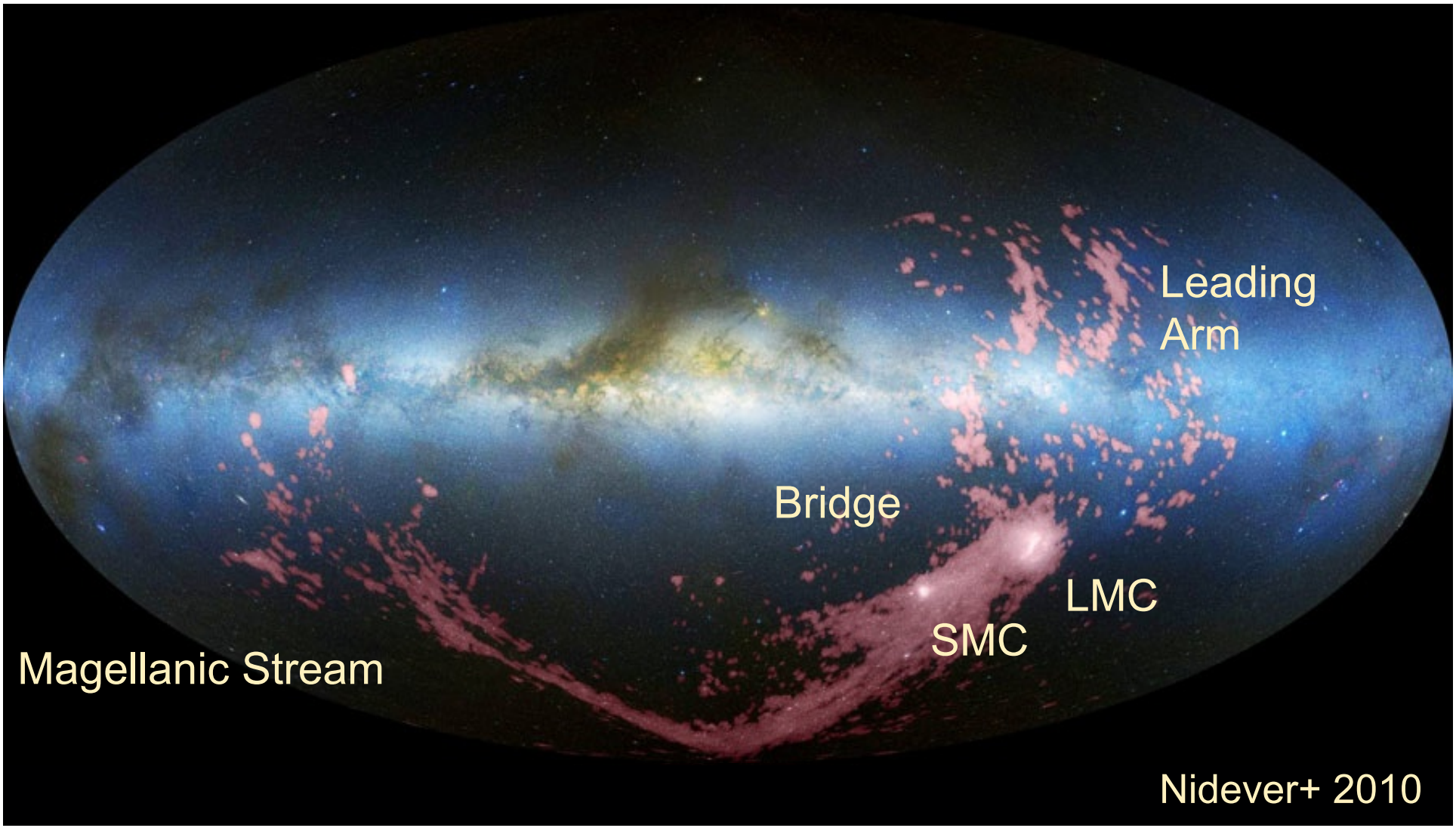
"HI" Gas

~ 7×10^6 $M_\odot$

~ 1% of MS



Origin of Extended HI Structures?

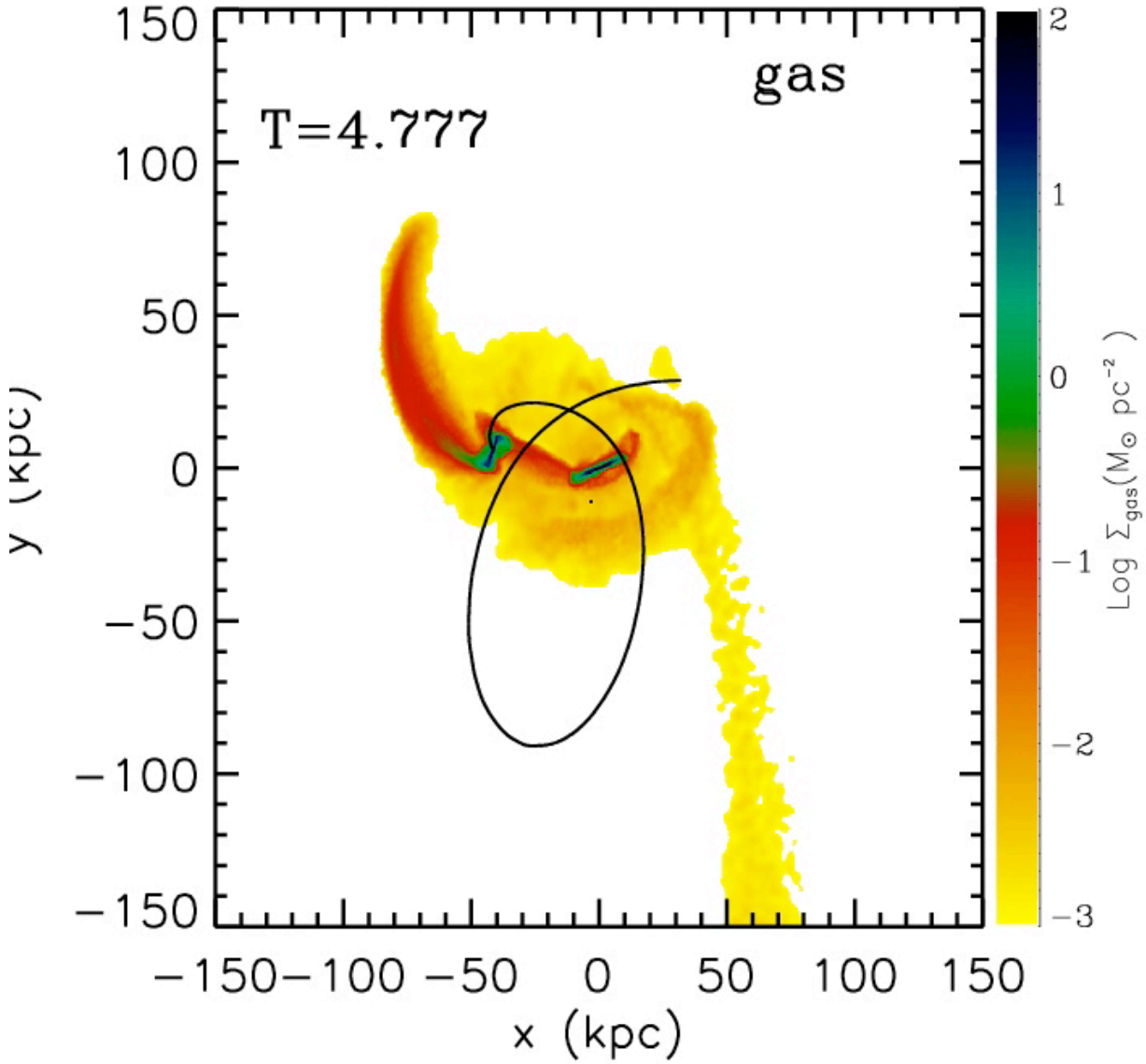


The SMC - LMC Interactions Before Capture by the Milky Way

LMC tides form bridges and tails

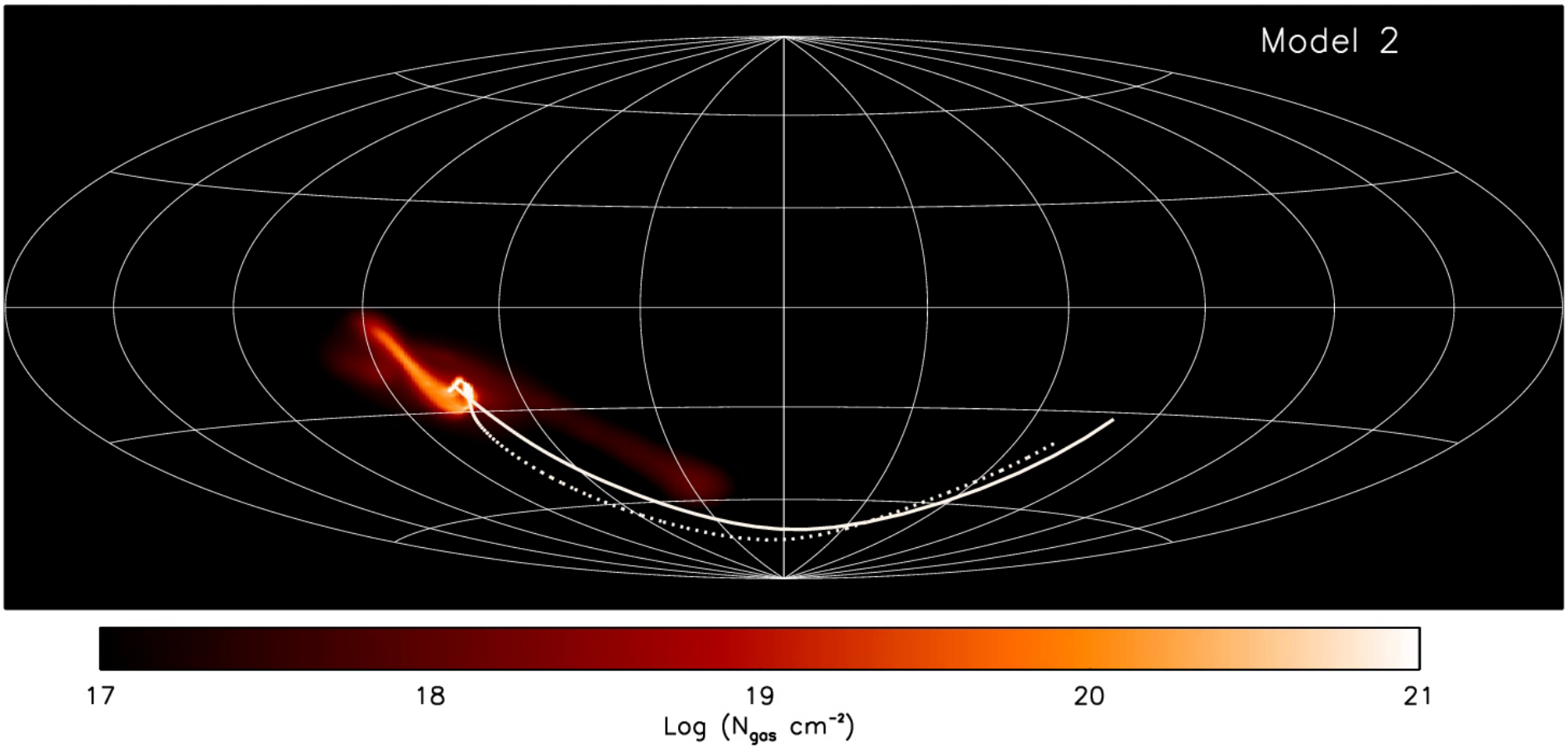
Bridges feed the outer LMC gas disk

(Burkhart talk)

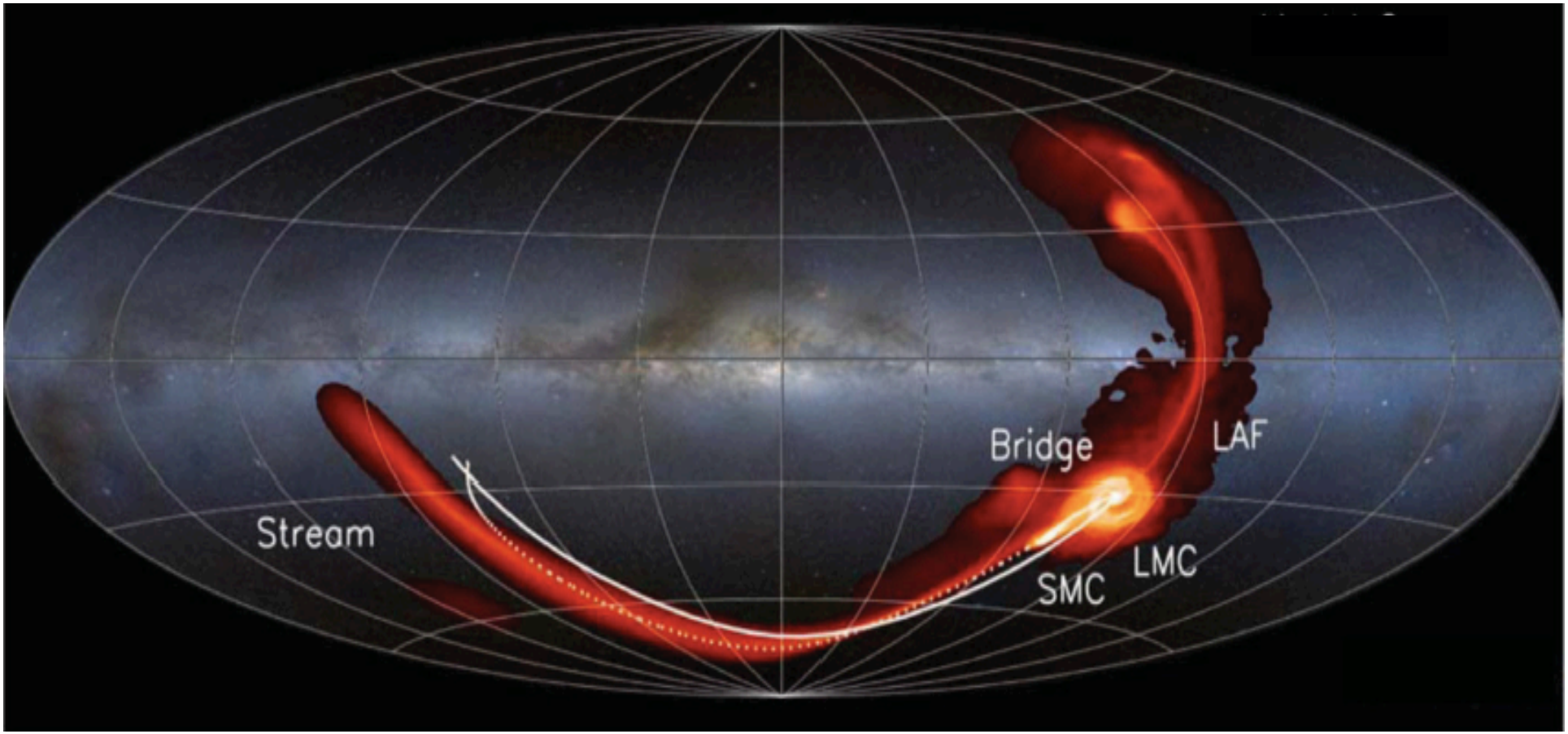


L/SMC Binary in Orbit about the MW:

MW as a static NFW potential: $1.5 \times 10^{12}\ M_{\odot}$



Besla + 2010, 2012



Besla+2012, 2010

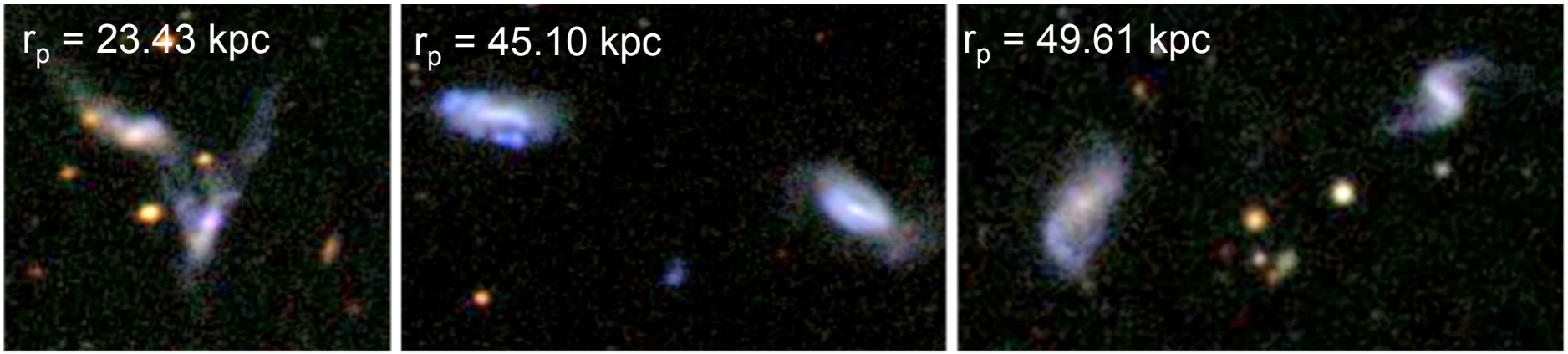
It is possible to form the Stream in a first infall scenario, where MW tides and ram pressure are minimal.

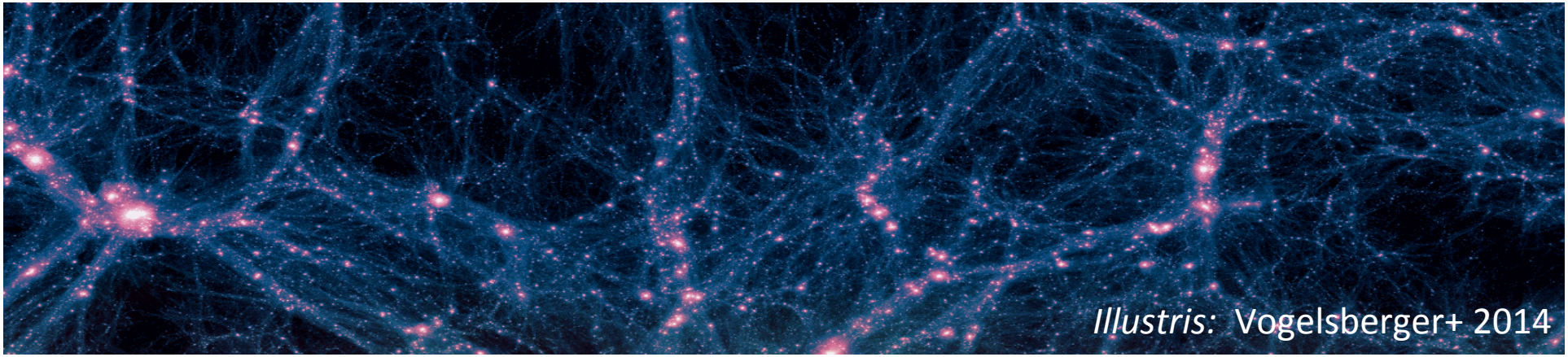
The TiNy Titans (TNT) Survey

Numerical Simulations and multi-wavelength observations of Dwarf groups found in SDSS & the Local Volume

Besla, Pearson, Stierwalt, Kallivayalil, Johnson, Putman, Patton, Privon, Patel & Liss

Stierwalt, Besla+2015





Conclusions

- The LMC's HI disk shows evidence of truncation by ram pressure stripping in the direction of motion (r_{trunc}= 6.2 +/- 0.25 kpc)
- **This provides a direct constraint on the gas density of the MW's CGM at ~ 48 kpc**

$$n_{\rm MWHalo}(R = 48.2 \pm 2.5\ {\rm kpc}) = 1.1^{+.44}_{-.45} \times 10^{-4}\ {\rm cm}^{-3}$$

- However, ram pressure stripping contributes negligibly to the mass content of the HI Stream
- Instead, the HI Leading Arm, Bridge and Stream form primarily via LMC tides stripping material from the SMC