# The Evolution of the Magellanic System: Implications for Satellites & Streams

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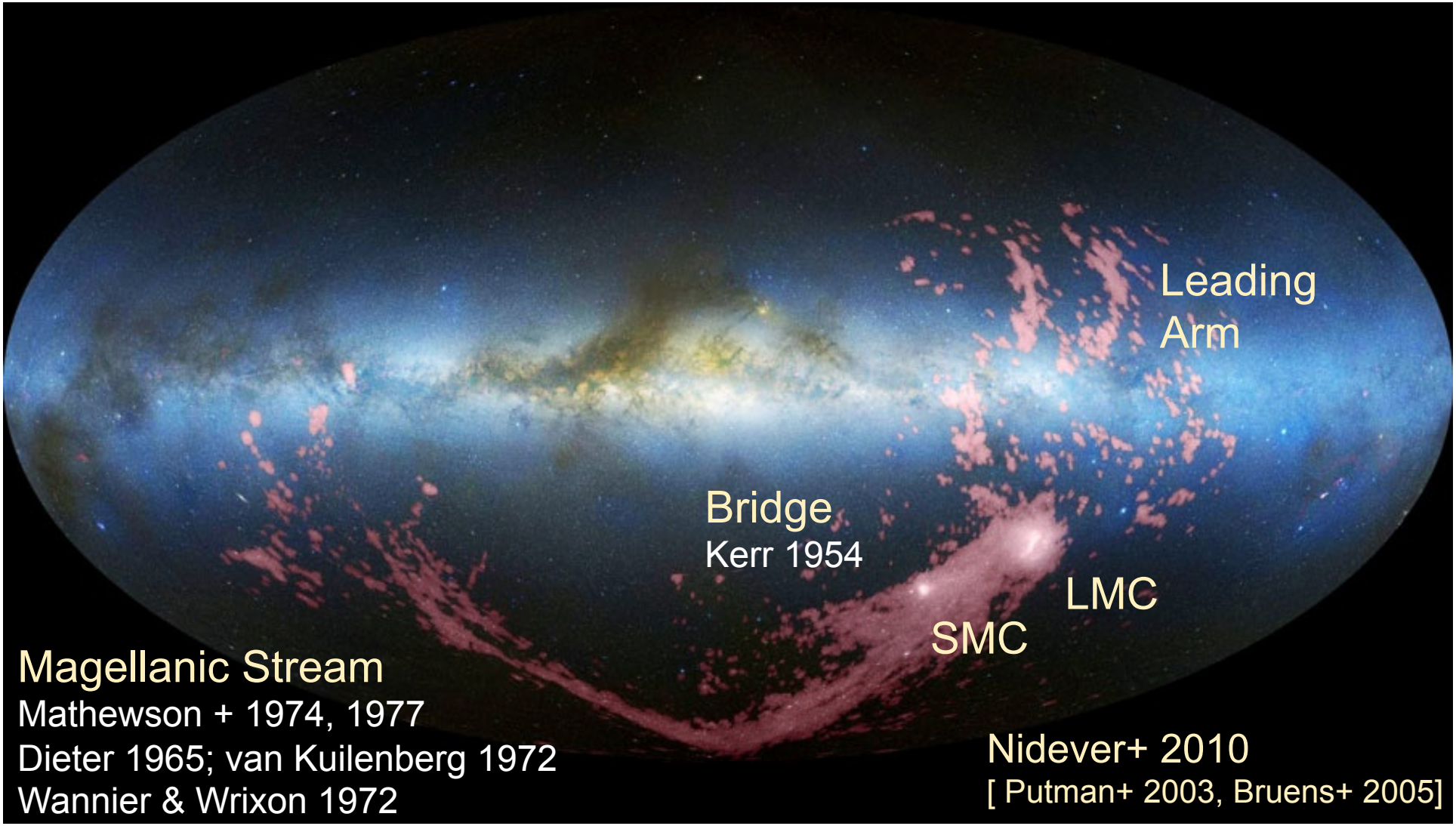
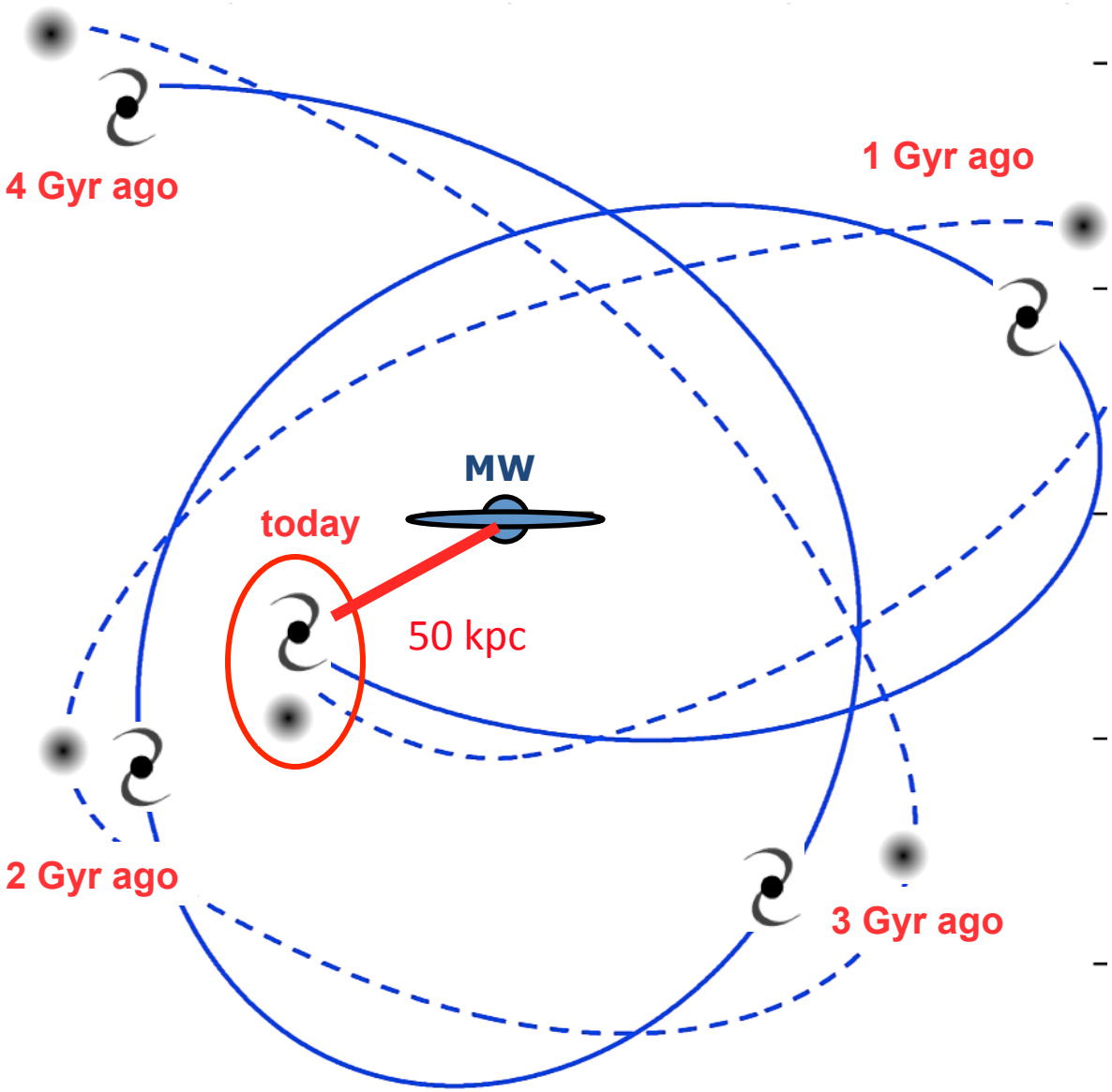
Image Credit: Miloslav Druckmuller
(Brno University of Technology)

# 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

# Traditional Orbital History




**Isothermal Sphere**
model for the MW

**$V_{LMC}$ = 300 km/s**

**SMC in a circular orbit about the LMC**

**$T_{orb}$ = 2 Gyr**

Ruzicka+ 2010
Connors+ 2005
Bekki & Chiba 2005
Sawa & Fujimoto 2005
Yoshizawa & Noguchi 2003
Gardiner & Noguchi 1996
Lin+ 1995
Heller & Rohlfs 1994
Murai & Fujimoto 1980

# New Orbital History

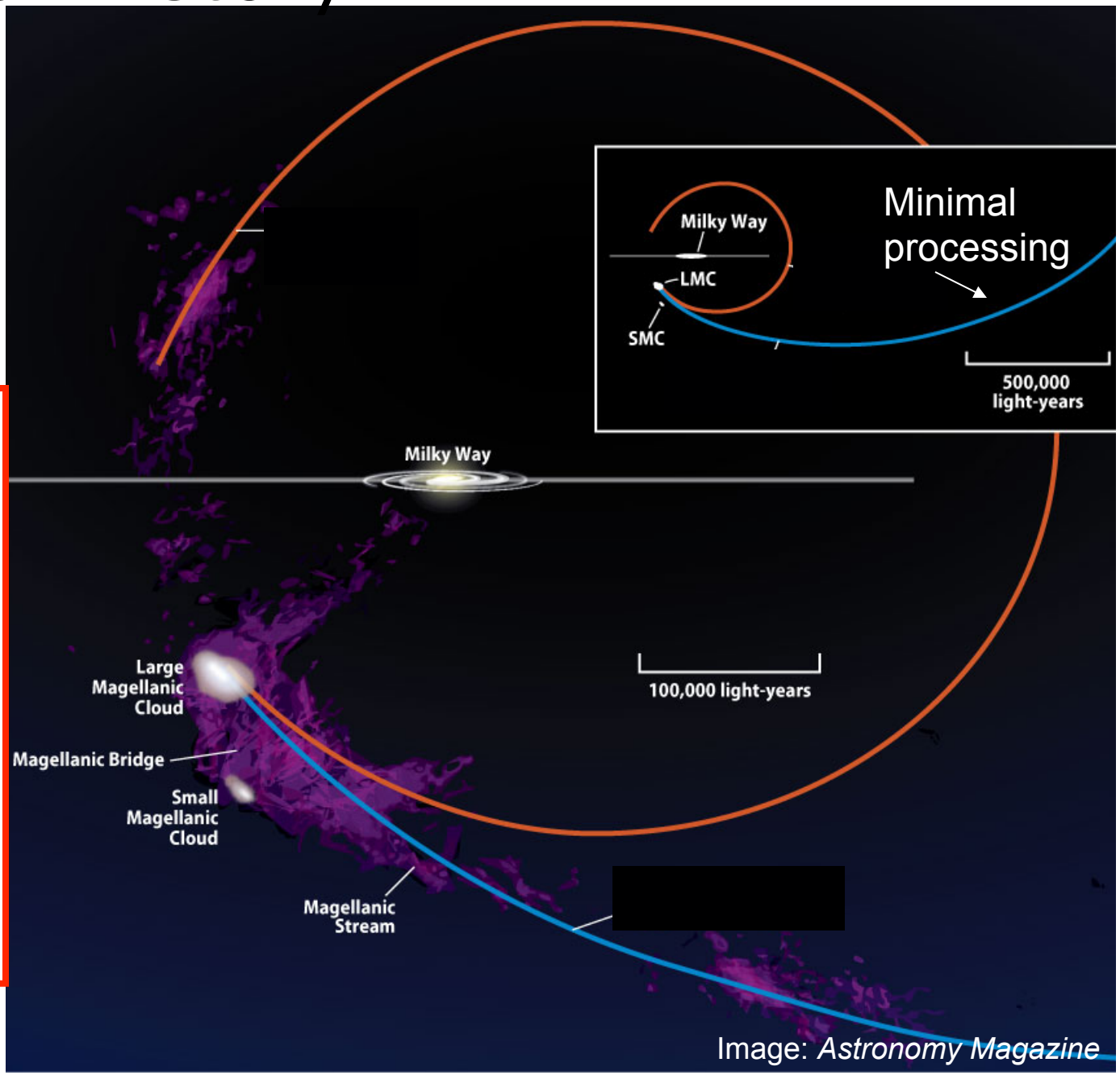
NFW potential

Higher Speeds (320 km/s Kallivayalil+2013)

**First passage, OR a long period orbit (> 5 Gyr, e>0.7)**

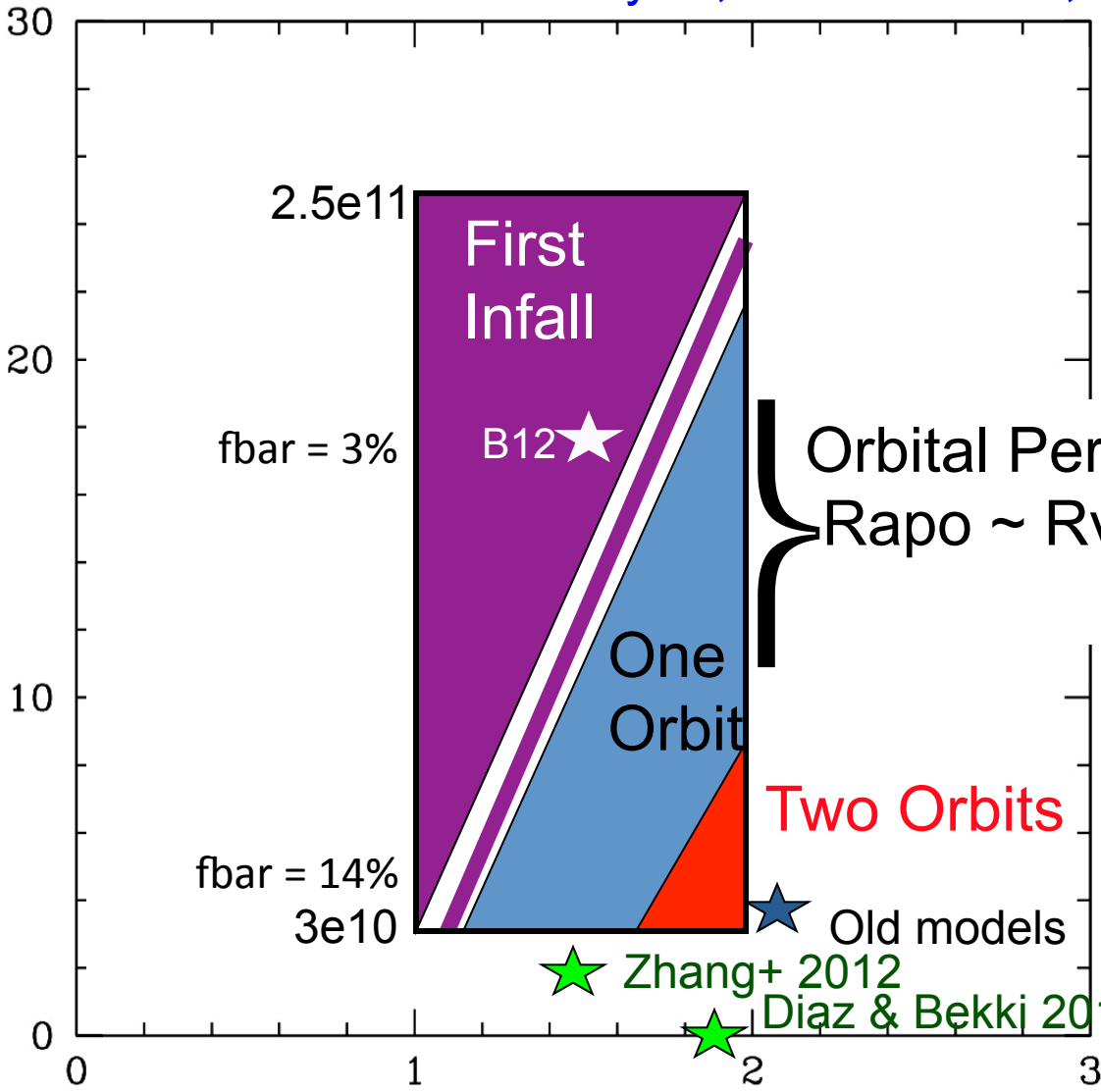
Besla +2007

(see also: Shattow & Loeb 2009, Diaz & Bekki 2012, Zhang+ 2012)



# 3rd Epoch PMs for LMC:

**$V_{LMC}$ = 321 +/- 24 km/s** Kallivayalil, van der Marel, Besla+ 2013

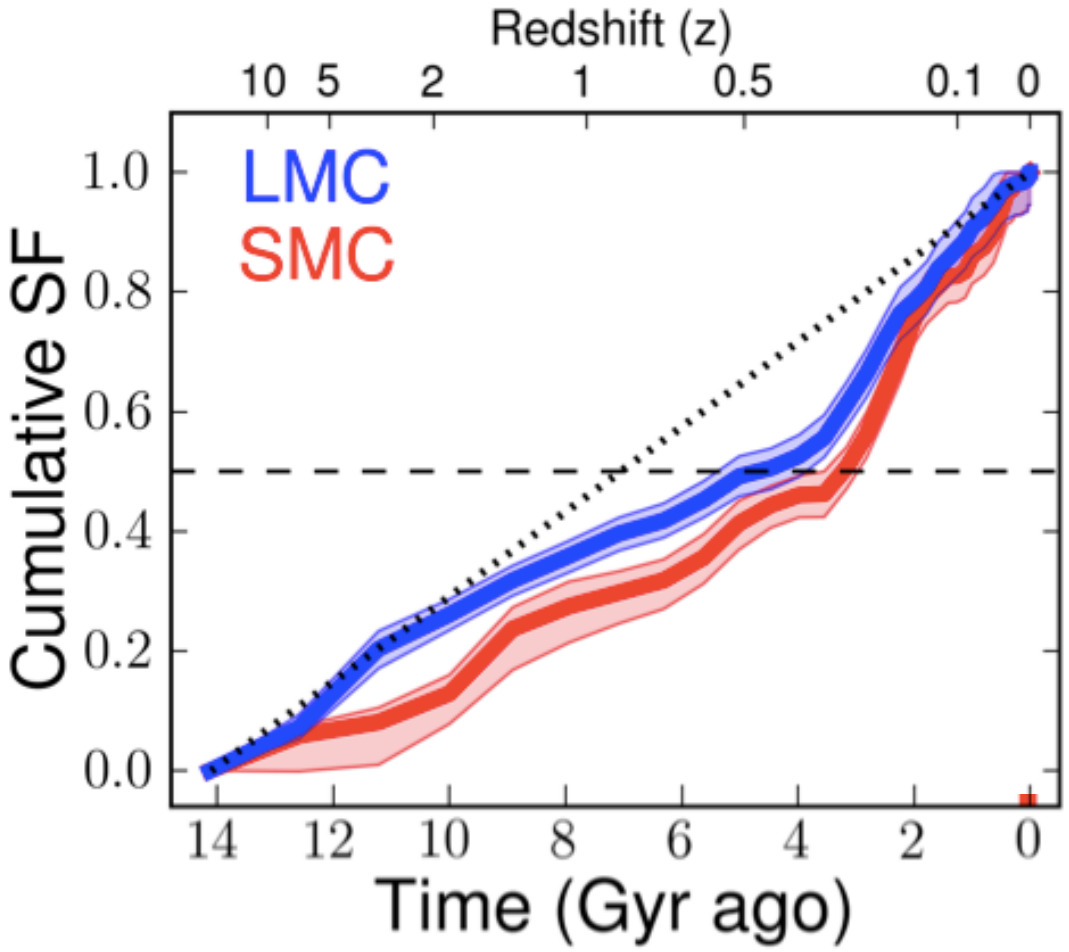



**LMC MASS ($10^{10}$ $M_\odot$)**

**MW Virial MASS ($10^{12}$ $M_\odot$)** STATIC

# Longevity of LMC-SMC binary?

**Kallivayalil 2013, 2006:** **$V_{rel}$ = 128 +/- 32 km/s**



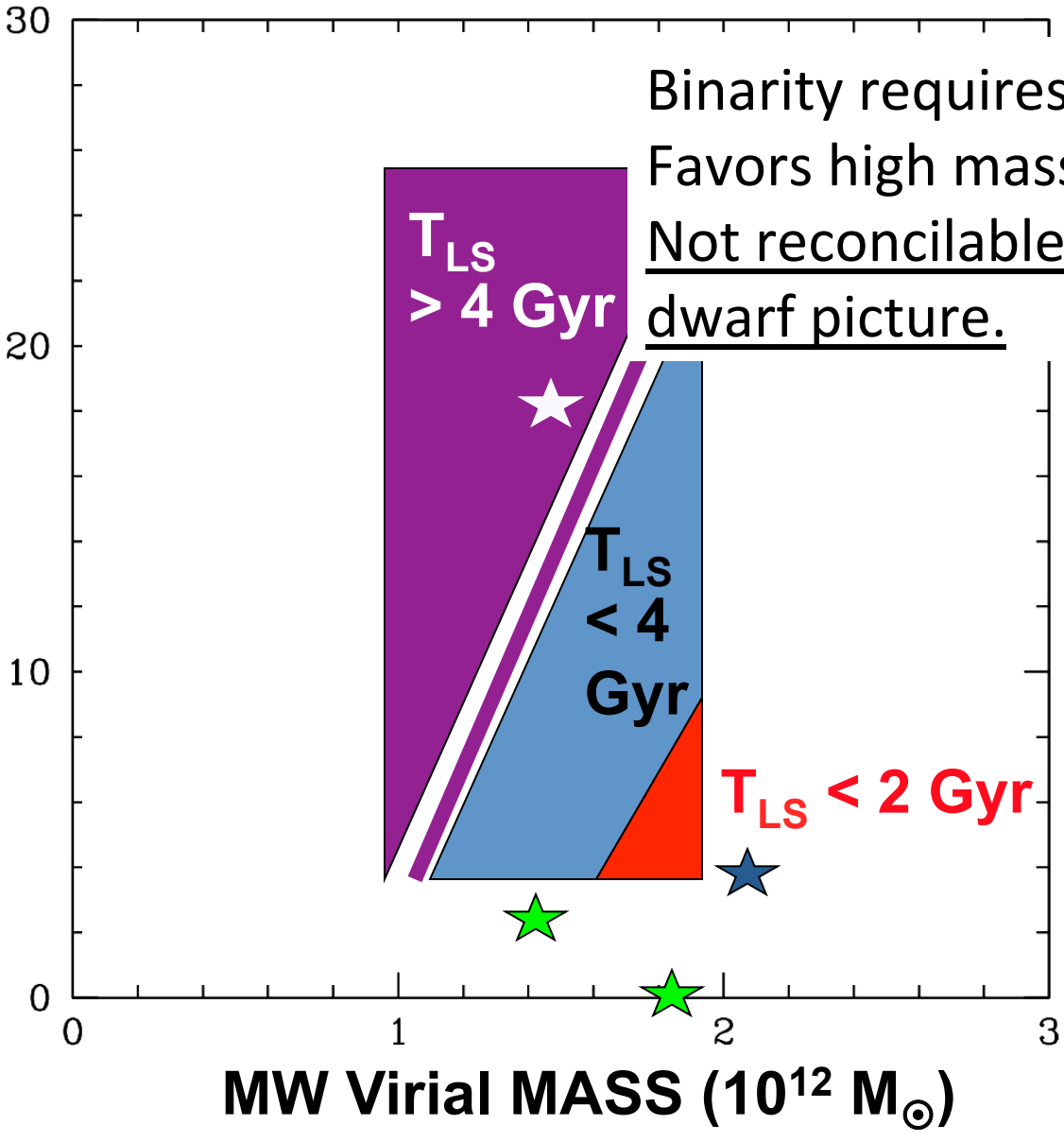

~ 4 Gyr

(Weisz et al. 2013)

# Longevity of the LMC-SMC Binary:

**$V_{rel}$ = 128 +/- 32 km/s** Kallivayalil, van der Marel, Besla+ 2013

Old: ~65 km/s

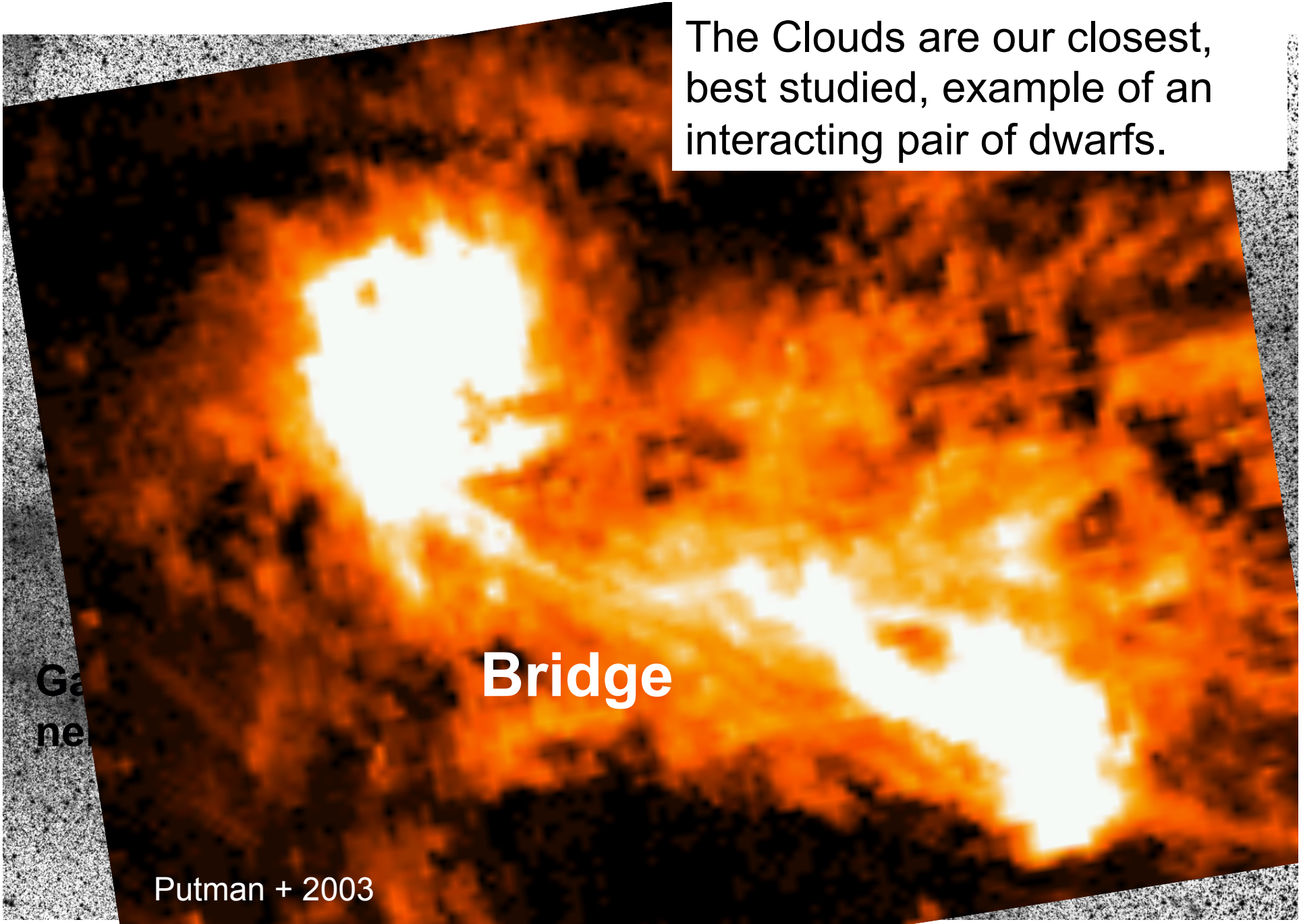



Binarity requires First Infall
Favors high mass LMC > 5e10
Not reconcilable in a tidal dwarf picture.

**(See Poster 17 by Gonzalez et al.)**

# What are the consequences of a high mass LMC/SMC pair on first infall about our MW?

- For pre-processing of satellites in groups?
- For stellar streams?
- For other MW satellites ?




The Clouds are our closest, best studied, example of an interacting pair of dwarfs.

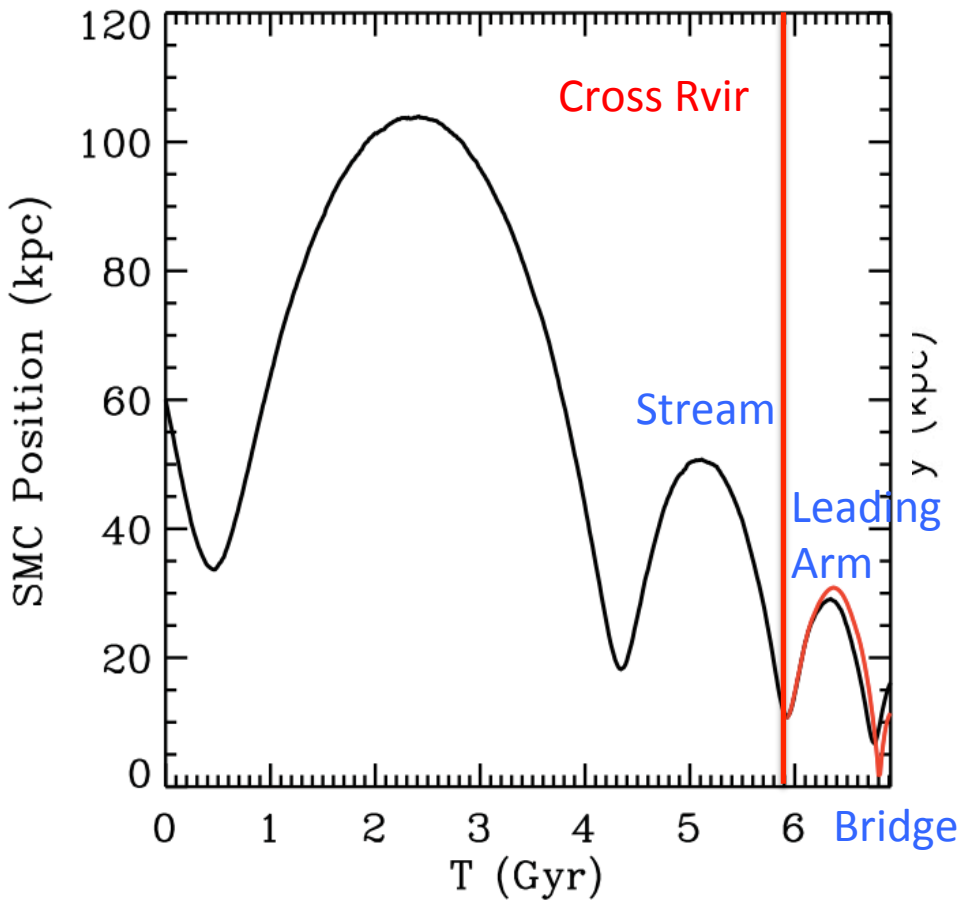
Besla, van der Marel in prep

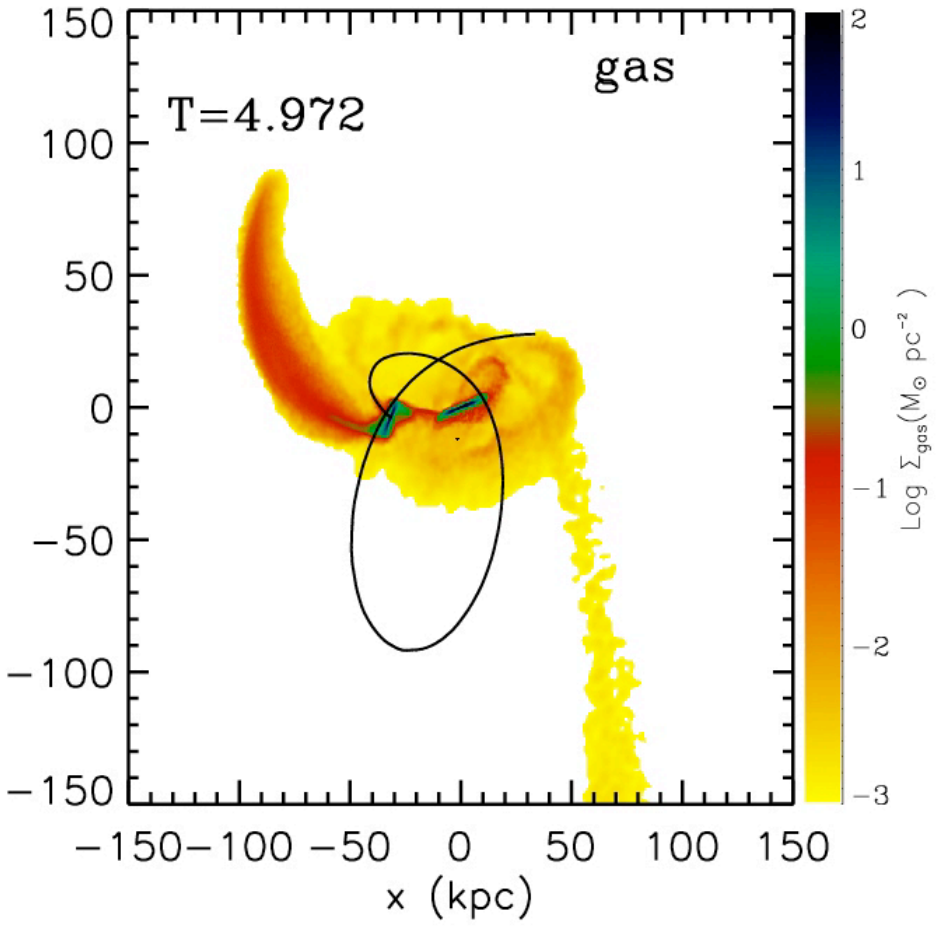
# SMC in orbit about the LMC (no MW)

GADGET2 (Springel 2005) SPH simulations

SMC 2.5 X $10^{10}$ ; LMC 1.8 X $10^{11}$

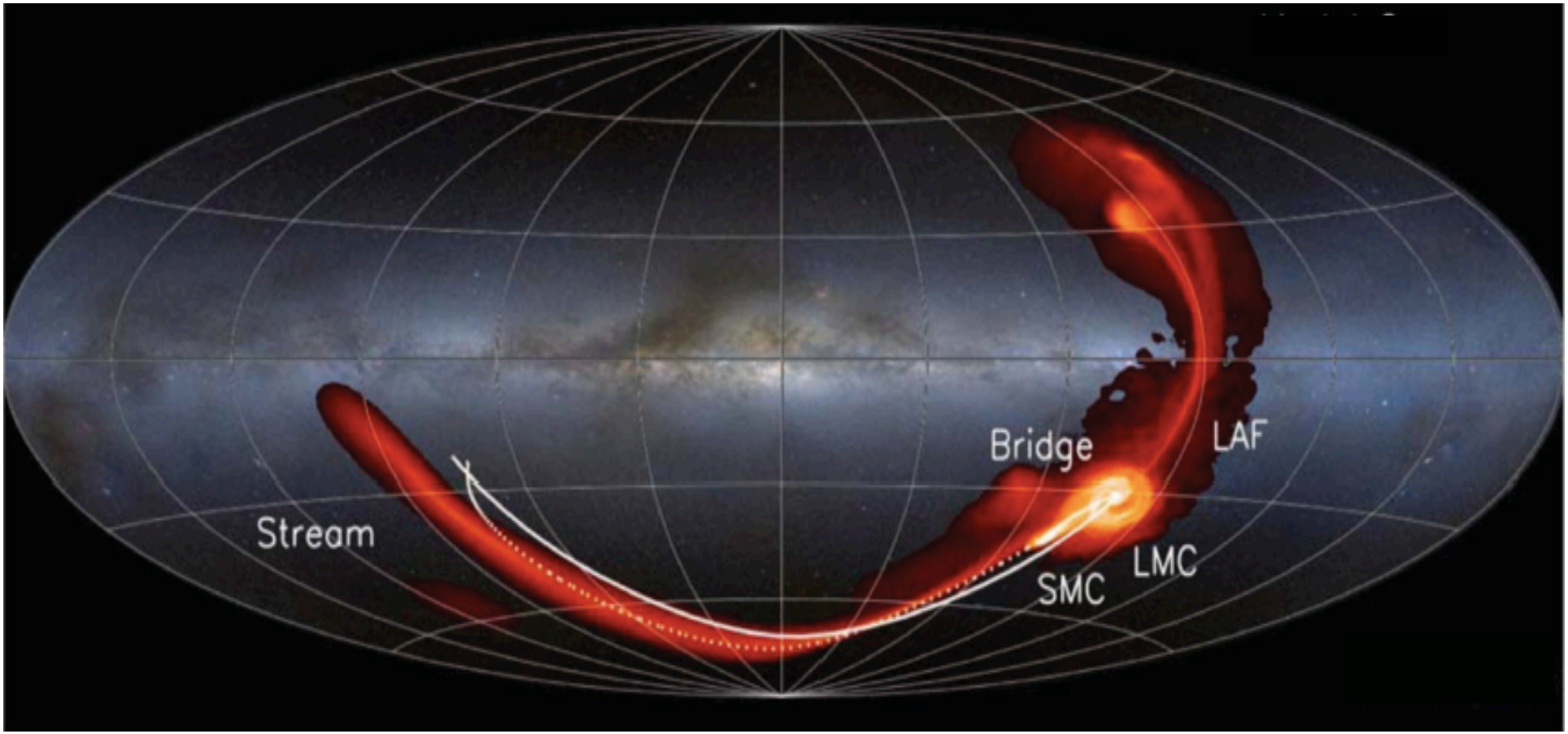
PROGRADE encounter




LMC tides remove an extended tail of gas from the SMC without the aid of MW tides (**Besla**+ 2010)

# LMC/SMC interactions form the Magellanic Stream, Leading Arm and Bridge




Besla+2012, 2010

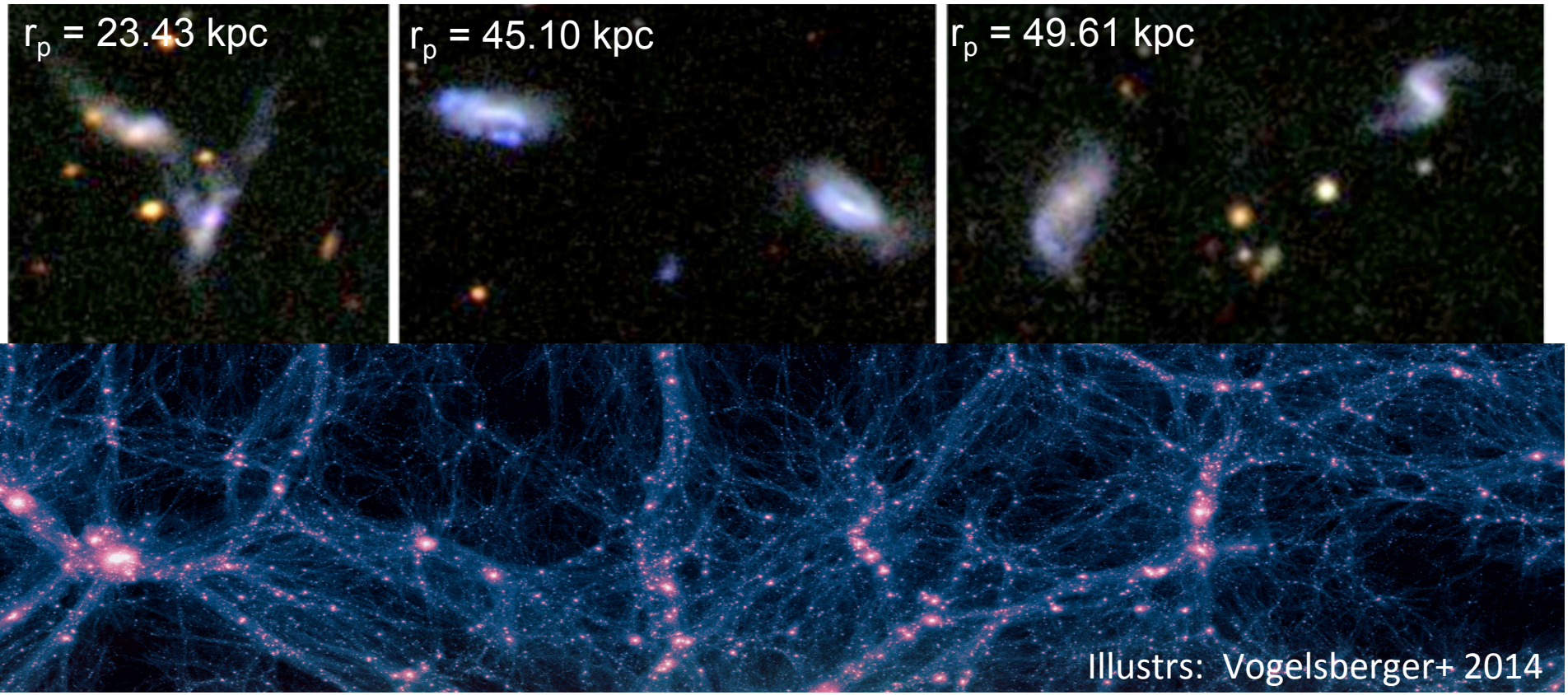
It is possible to form the Stream in a first infall scenario, where MW tides and ram pressure are minimal.

# The TiNy Titans (TNT) Survey

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

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

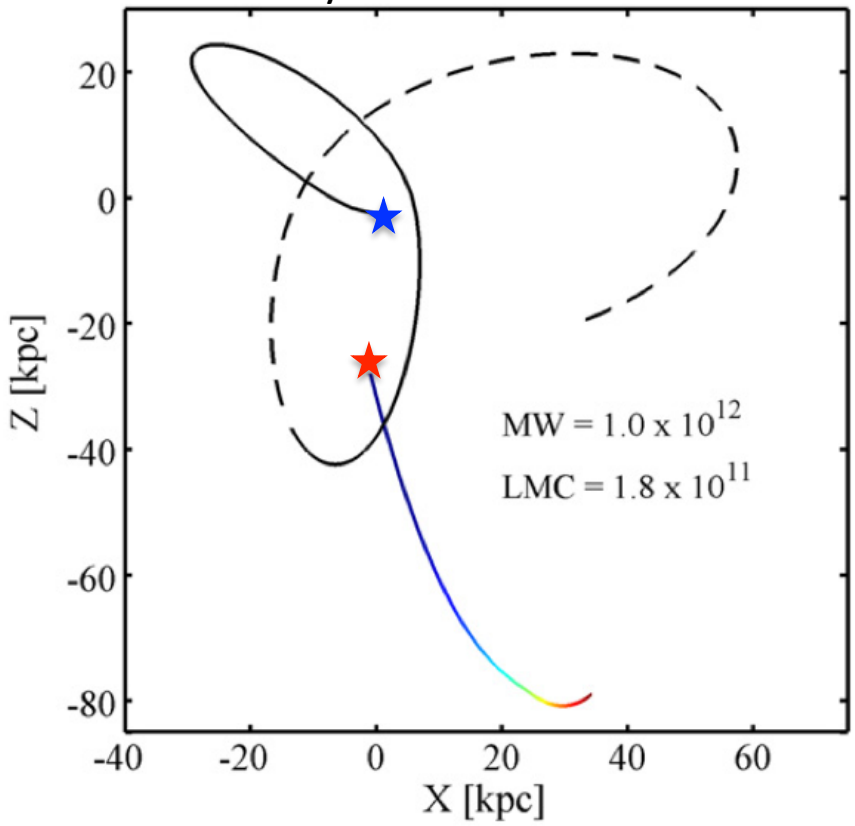
**Stierwalt, Besla+2015**

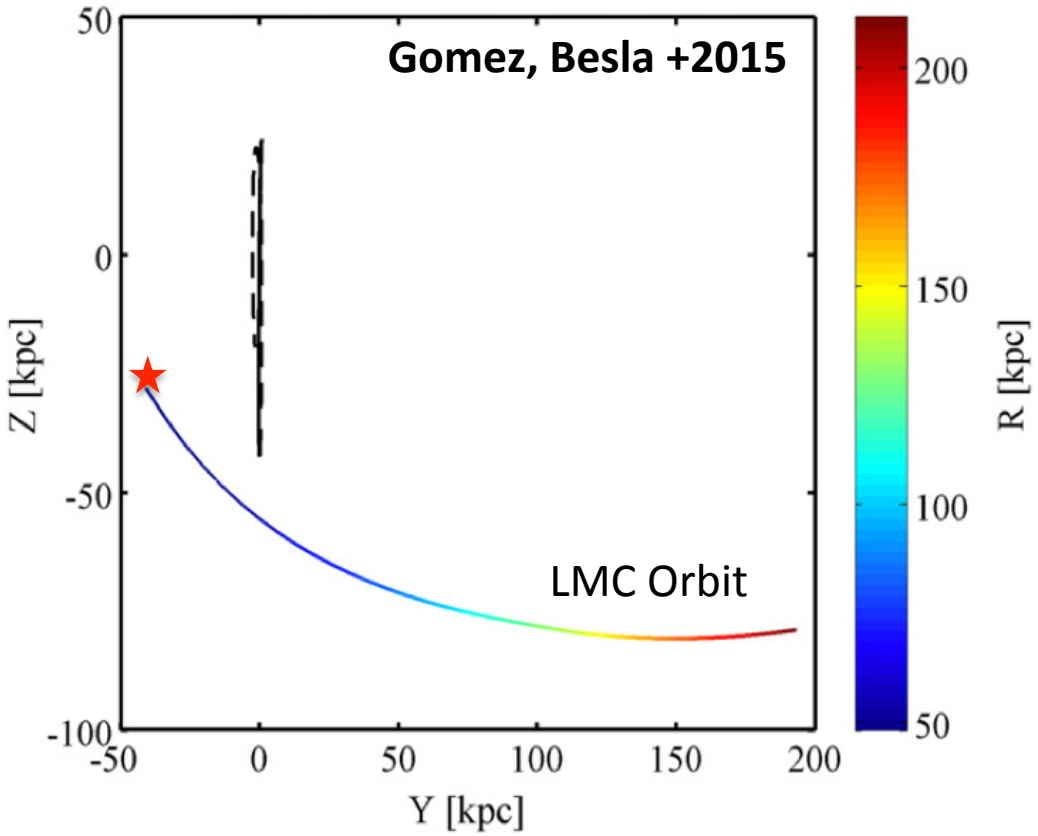


# Consequences for Streams?

## Torques from the LMC on the Orbit of The Sagittarius Dwarf

Solid Line : 1 Gyr of Evolution



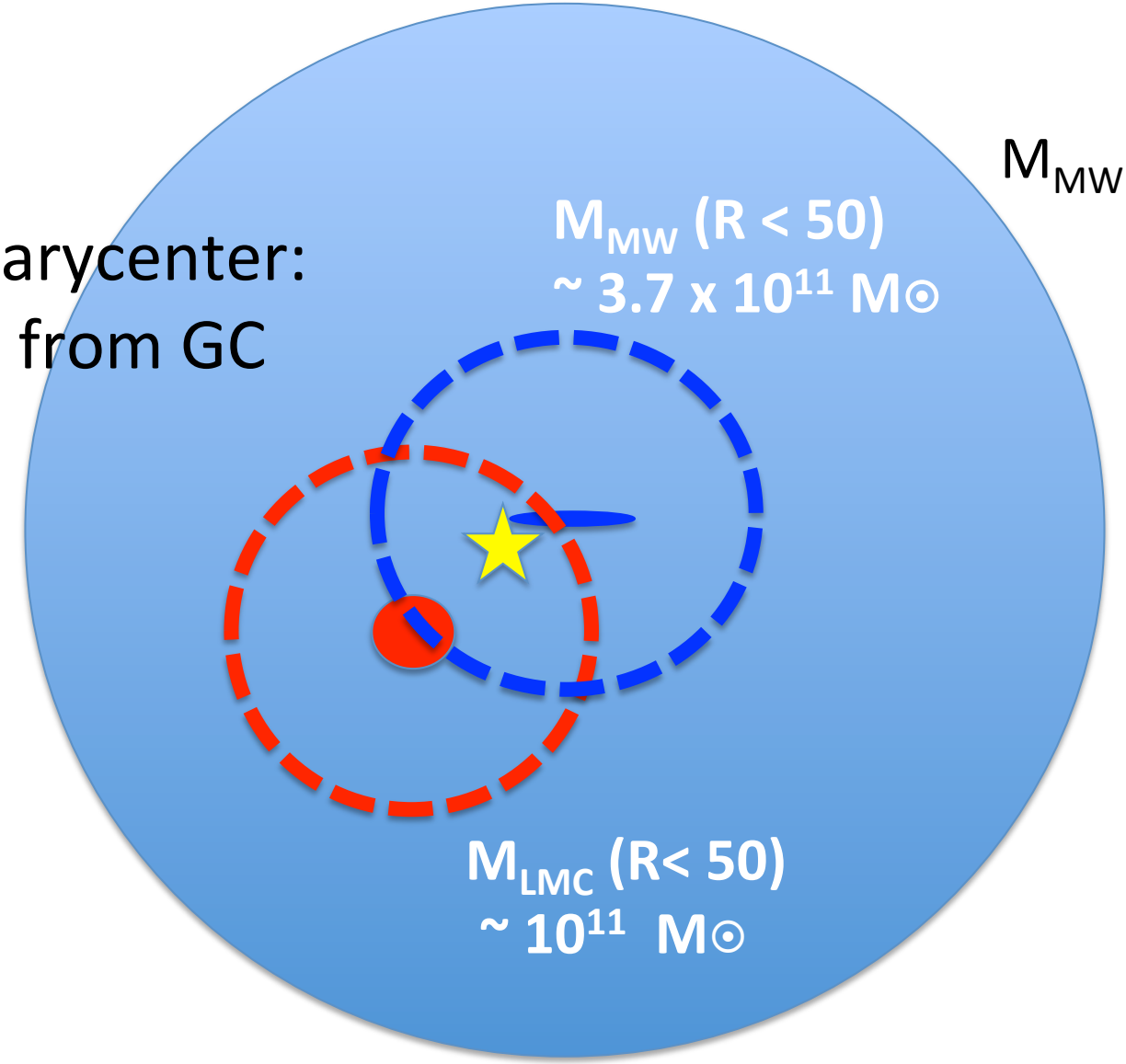




**Vera-Ciro & Helmi 2013 (LMC 1e11)**

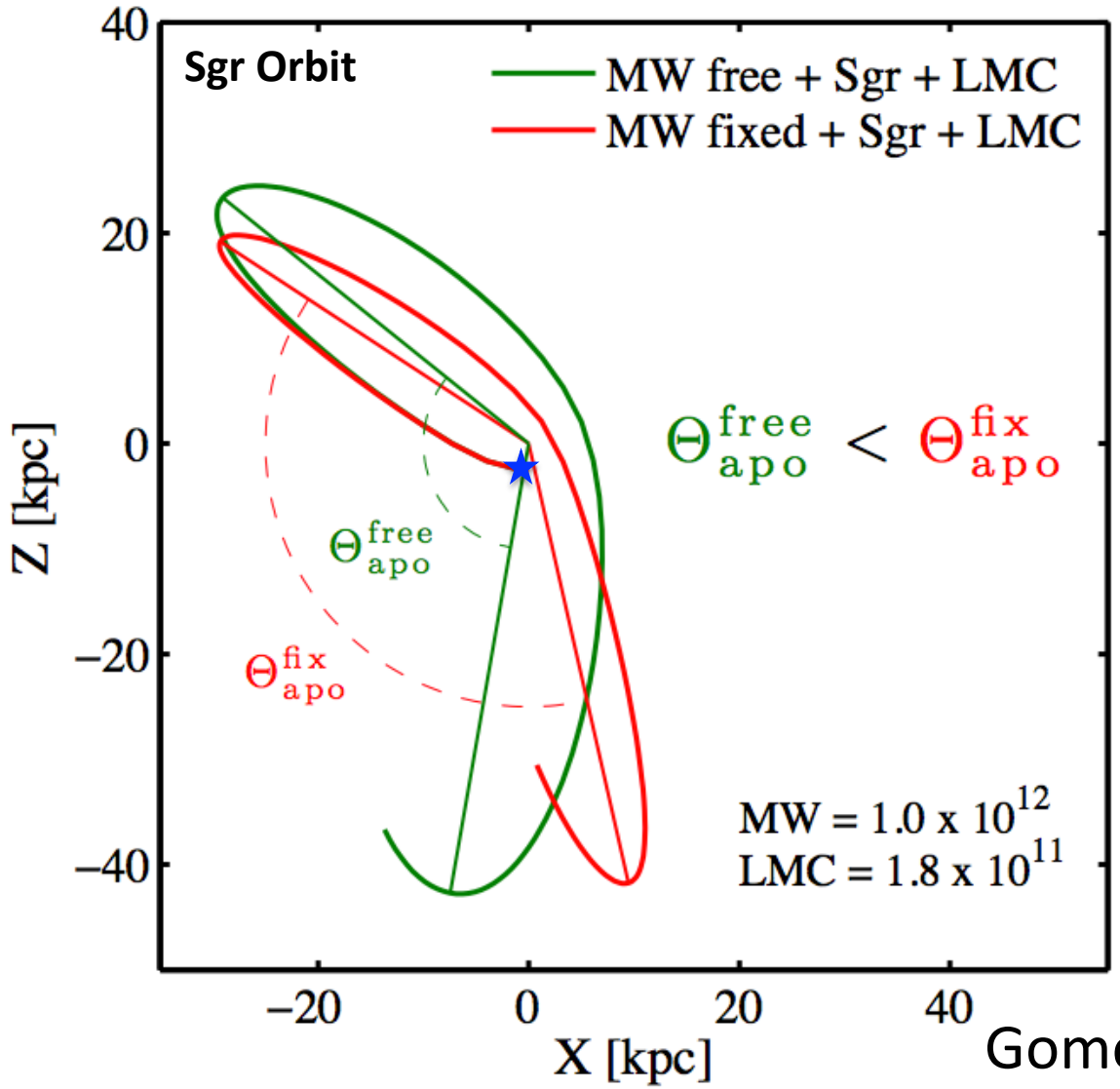
**Law & Majewski 2010**

# Consequences for Streams?

Where is the orbital barycenter of the MW + LMC system?



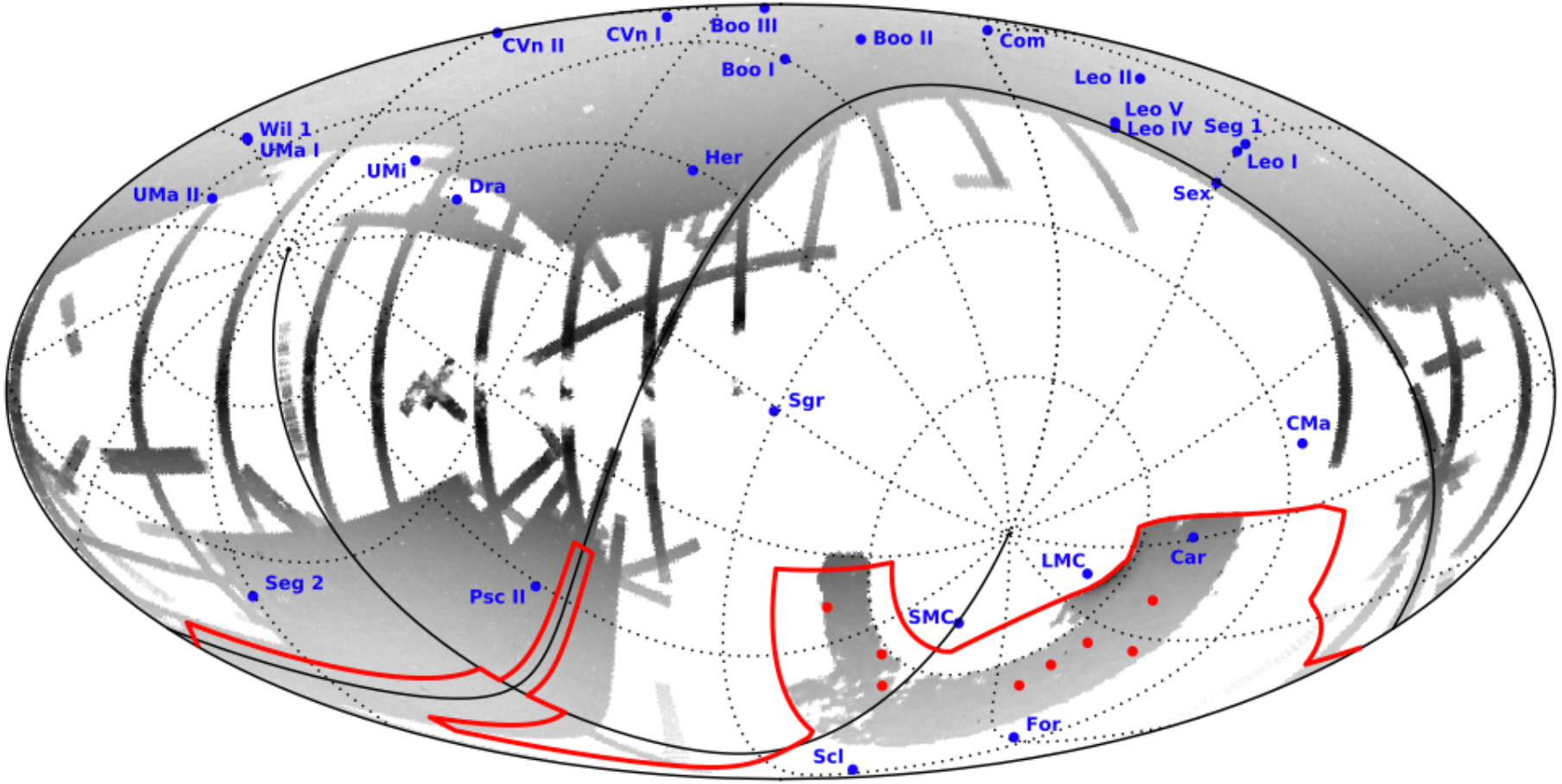
# Ignoring the LMC will force artificial adjustments in the MW gravitational potential




Gomez, Besla + 2015

# Consequences for Satellites?

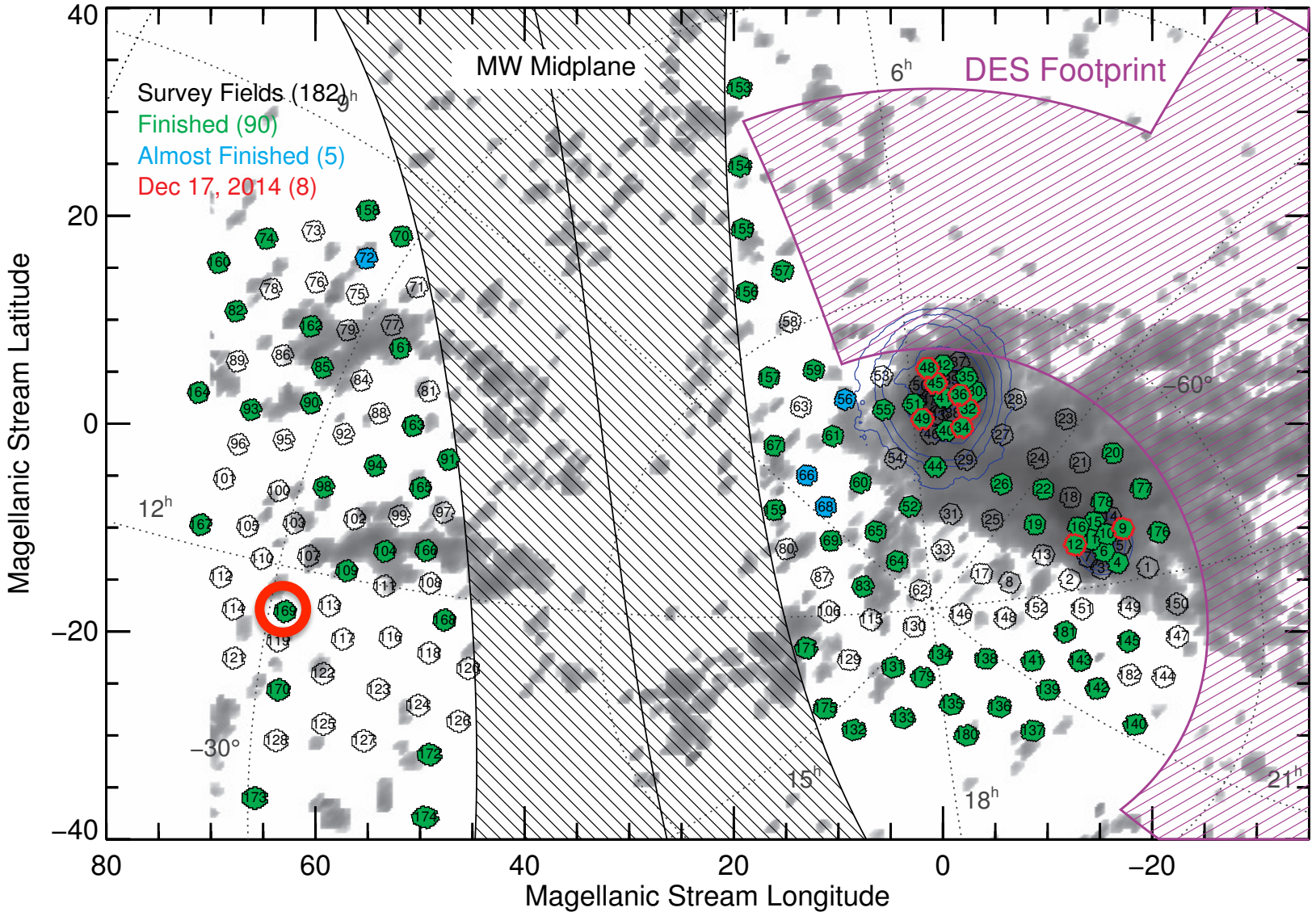
New Surveys of the Southern Sky!




DES, Bechtol + 2015 : Dark Energy Survey

Koposov + 2015

# Survey of the MAgellanic Stellar History (SMASH)
# Hydra II : Martin, Nidever, Besla, Vivas + 2015 (Poster 35)

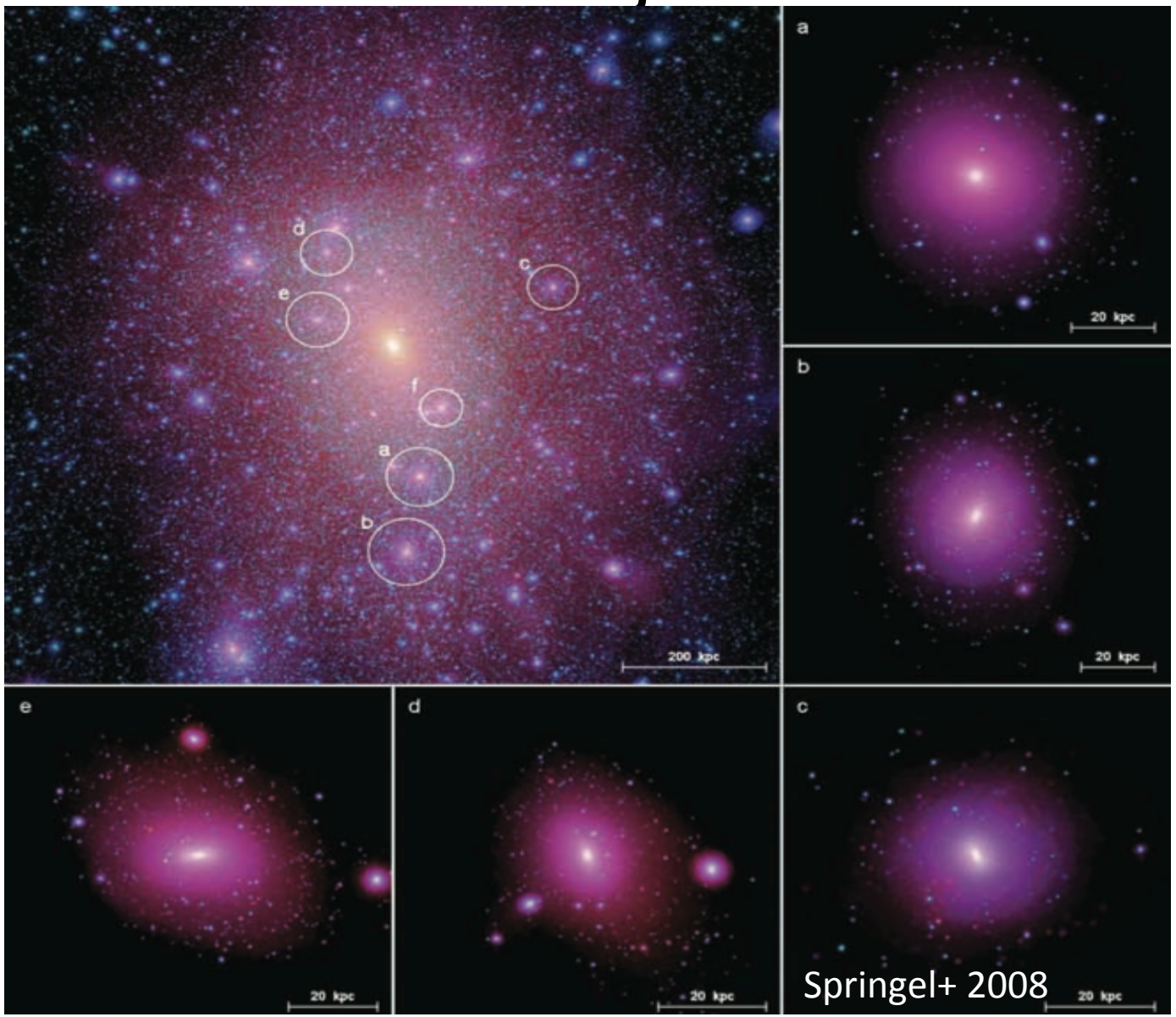


# Self-similarity implies the LMC should have more satellites than just the SMC

If $M_{dark\ LMC} \sim 10^{11}$

**Then ~ 7 satellites with Vmax > 20 km/s** (Sales+2011)

(Also, Talk by Coral Wheeler)



# HSTPROMO

## The HST Proper Motion Collaboration

(http://www.stsci.edu/~marel/hstpromo.html)

Both Gaia & HST in concert are needed to develop a model for the dynamics o
our Local Group.

| | ΔPM (km/s) | |
|---|---|---|
| **Galaxy** | **HST** | **Gaia (2017)**/2018 |
| Horologium I | 23 | 45 |
| Pictoris II | 24 | 119 |
| Phoenix II | 25 | 125 |
| Hydra II | 27 | 138 |
| Grus I | 26 | 138 |
| Eridanus III | 23 | 151 |
| Tucana II | 24 | 59 |

< 30 kpc: Gaia

30-80 kpc: Gaia & HST

> 80 kpc: HST

# Satellites & Streams are affected by the presence of the Clouds

- If the LMC-SMC are a long-lived binary, the Clouds must be on their first passage
- LMC-SMC binarity & baryon fraction favor a massive LMC

  ~ 0.5 - 2 x $10^{11}$ $M_{\odot}$
- **Dwarf Groups:** Interactions between the Clouds form the Magellanic Stream & Bridge – dwarf interactions are important to part of the baryon cycle (TiNy Titans Survey)
- **Streams:** Massive LMC can affect the orbits of satellites over the past Gyr: ***modeling cold, young streams without taking the LMC into account will lead to artificial adjustments to the gravitational potential of the MW***
- **Satellites:** A massive LMC should have satellites – HST PMs & orbital histories of the new UFDs are our best chance to test this.