

Are the Magellanic Clouds on their First Passage about the Milky Way?

Gurtina Besla

Harvard CfA

Collaborators:

Nitya Kallivayalil

Lars Hernquist

Brant Robertson

T.J. Cox

Roeland P. van der Marel

Charles Alcock

Outline

- Motivation for this Orbital Re-analysis:

- **New Proper Motions vs Old**

- Kallivayalil et al (2006a,b)

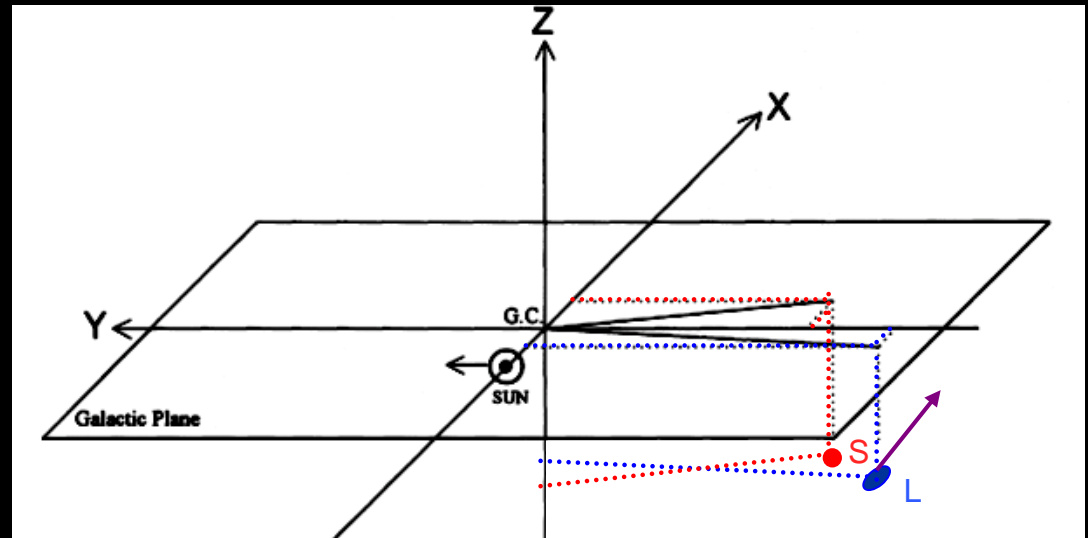
- **Milky Way (MW) model**

- Isothermal vs NFW

- Model

Dependences:

- MW Mass
 - Role of the SMC



- Implications for the formation of the Stream

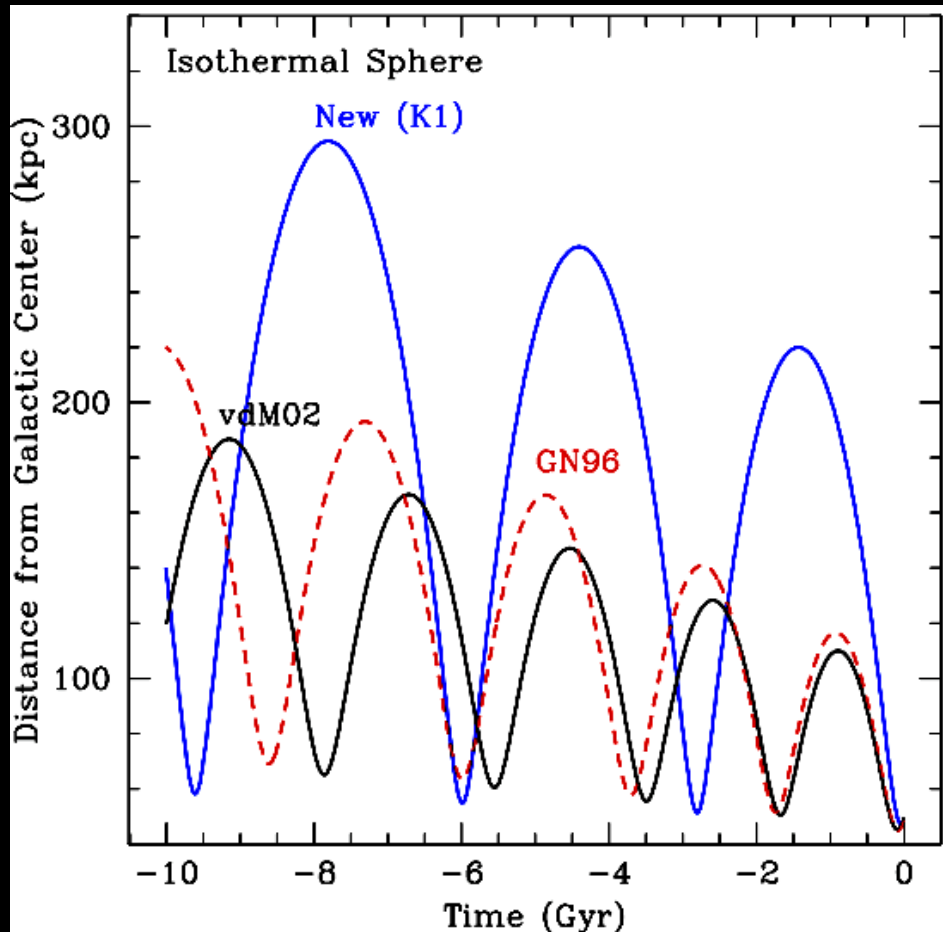
LMC Proper Motions:

	Kallivayalil et al 2006a	Van der Marel et al 2002	Gardiner & Noguchi 1996
μ_N is not consistent with 0			
μ_W (mas/yr)	-2.03 (± 0.08)	-1.68 (± 0.16)	-1.72
μ_N (mas/yr)	0.44 (± 0.05)	0.34 (± 0.16)	0.12
Total Vel. (km/s)	378 (± 18)	293 (± 39)	297
Radial Vel. (km/s)	89 (± 4)	84 (± 7)	82
Tangential Vel. (km/s)	367 (± 18)	281 (± 41)	287

New velocity ~1.3 times higher

Implications of the K1 results for the Classical Picture

Isothermal sphere model



GN96, vdM02 :

Apo = 110-120 kpc

T = 1.5 Gyr



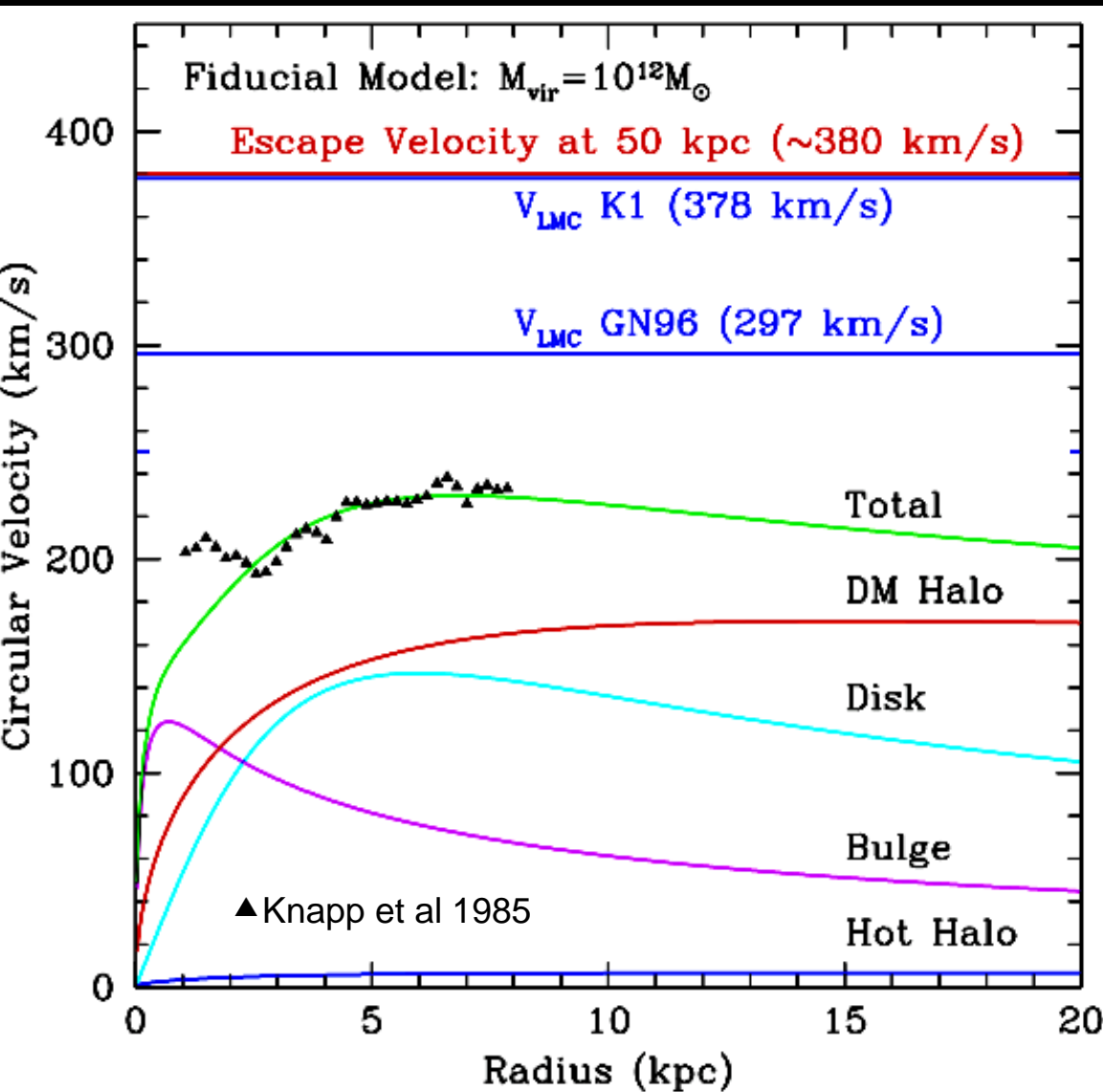
K1 mean:

Apo = 220 kpc

T = 3 Gyr

An isothermal sphere model is likely inaccurate at large distances.

4-component MW model

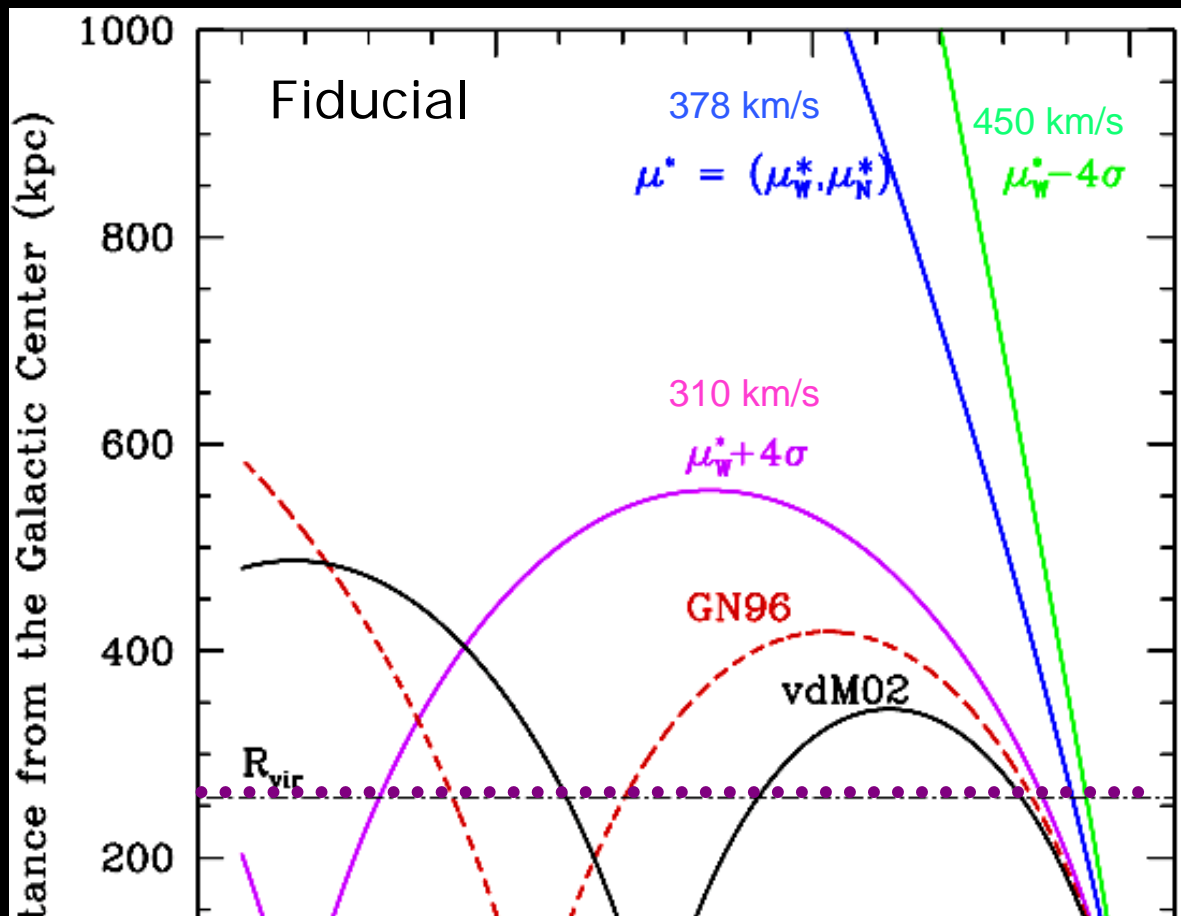


$$M_{\text{vir}} = 10^{12} M_{\odot}$$

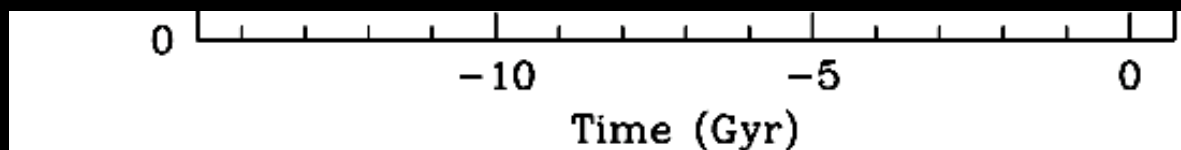
Consistent with
Klypin et al (2002)

Consistent with
known obs.
constraints

New MW model (static) + new PM:



The LMC is on its FIRST passage about the MW



Assumptions by GN96:

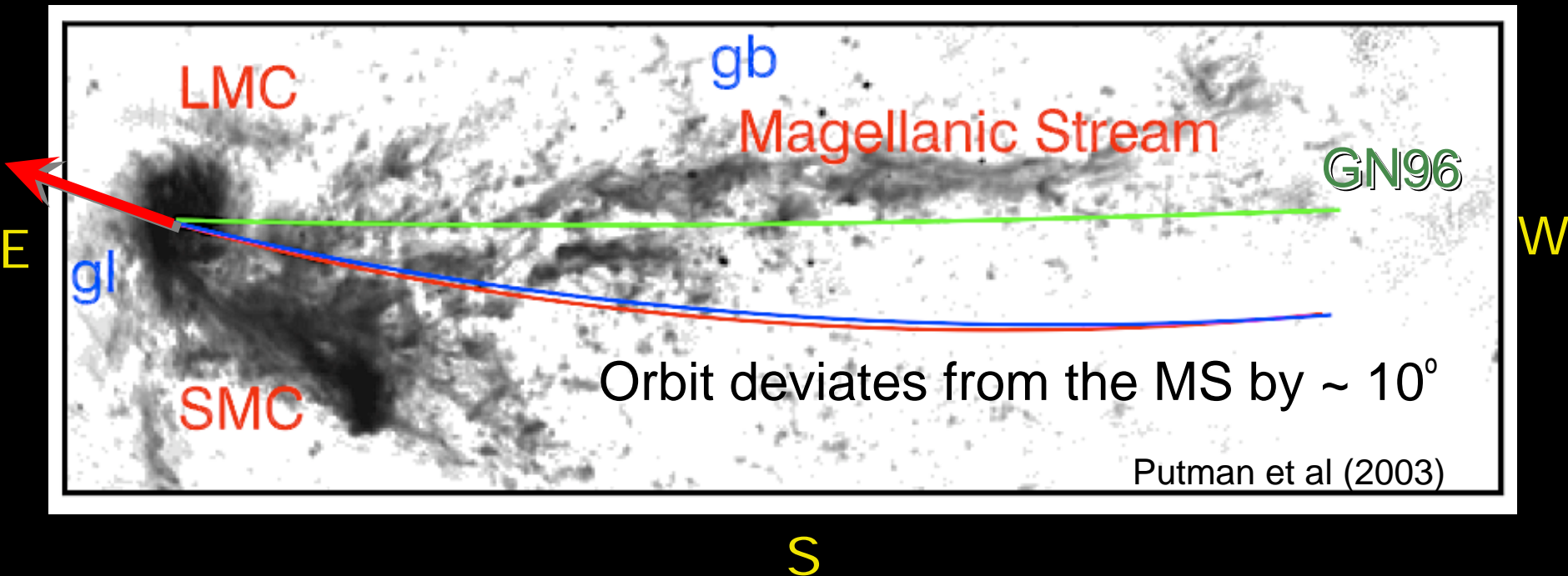
1) The LMC's past orbit does NOT trace the current location of the MS on the plane of the sky

2) Orbital $V_{\text{LSR}} \cong V_{\text{LSR}}$ of the MS (specifies μ_W)

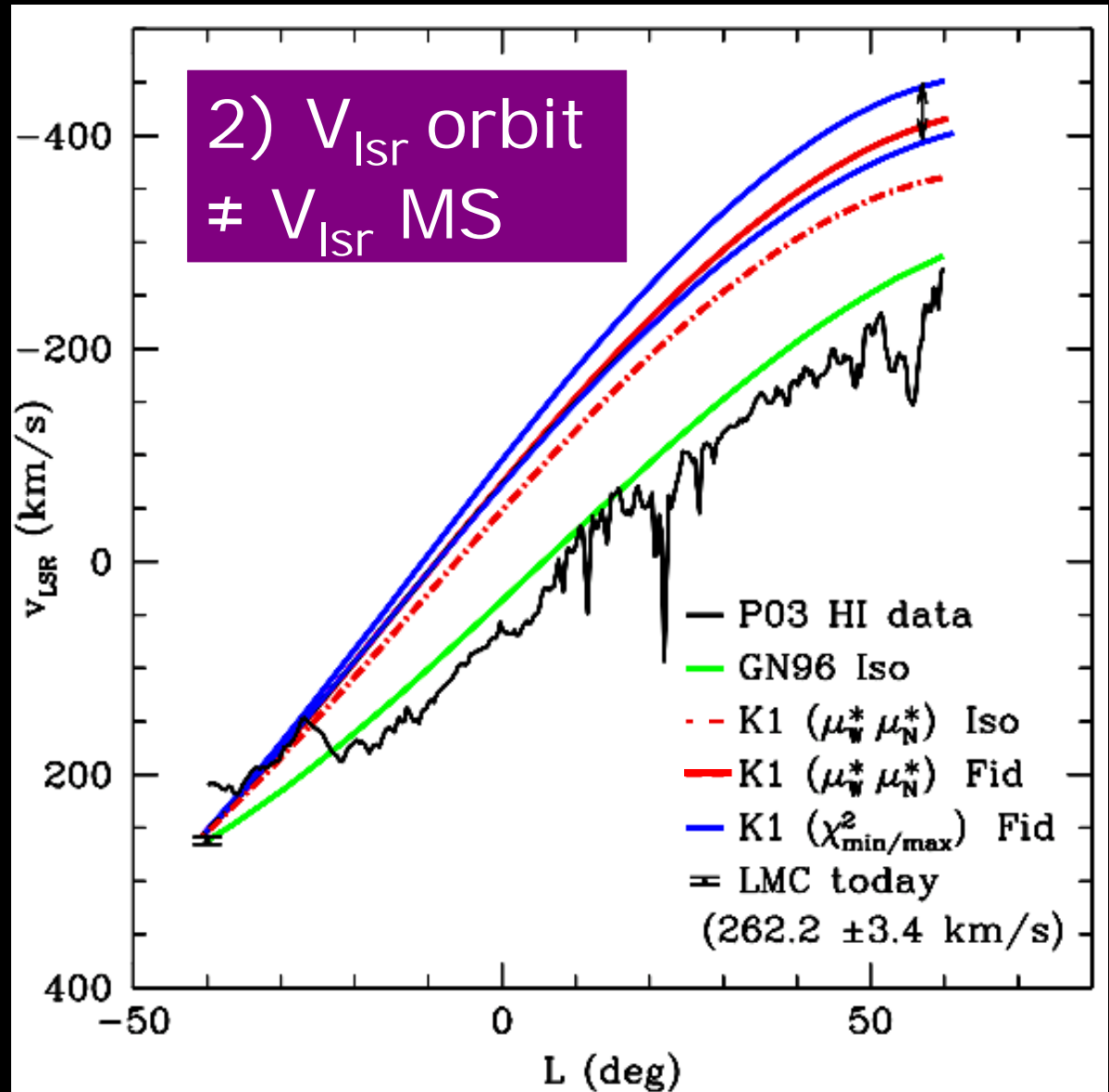
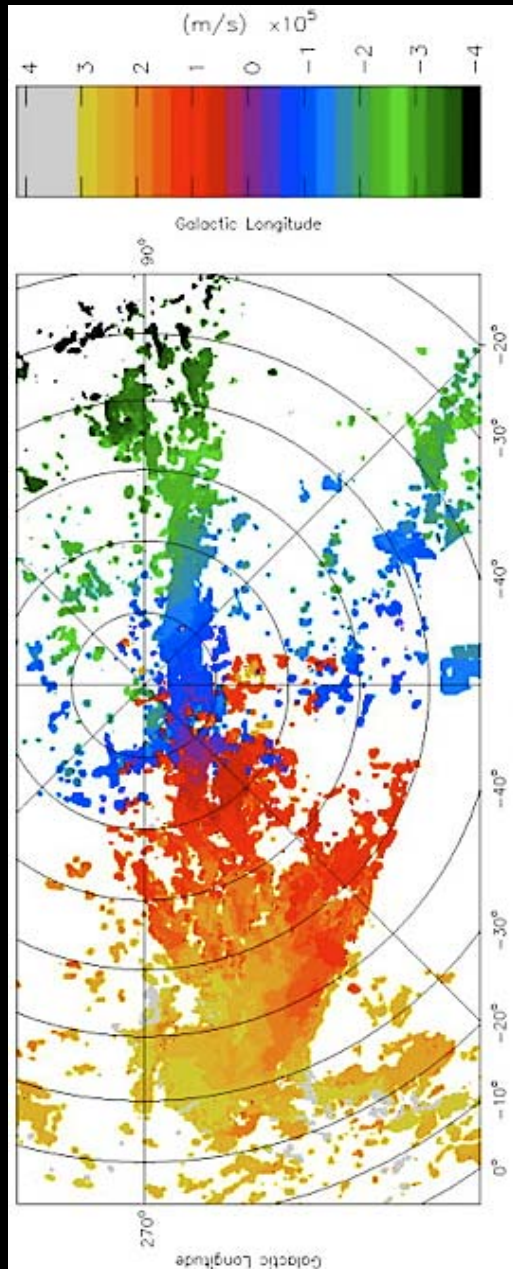
3) Clouds form a binary system ($V_{\text{tan}}^{\text{SMC}} \sim V_{\text{tan}}^{\text{LMC}}$)

(μ_W, μ_N) K1; vdM02

N

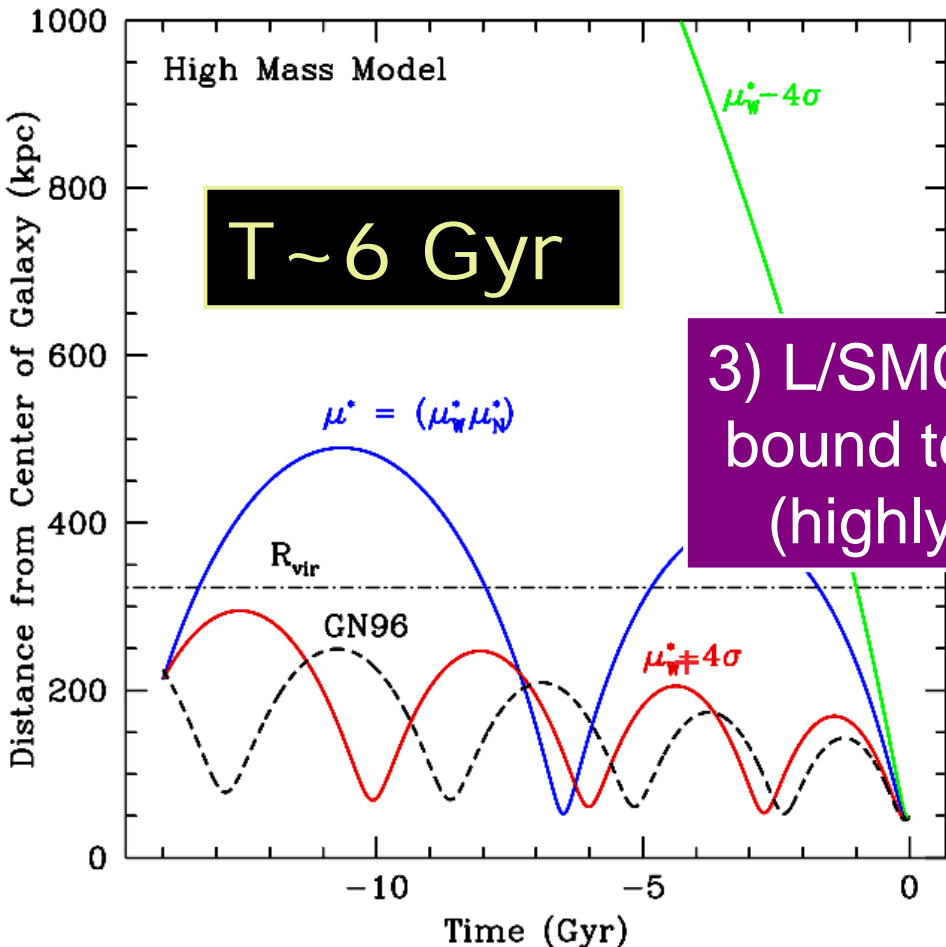


Velocity Gradient



Putman et al (2003; P03)

Model Dependences:

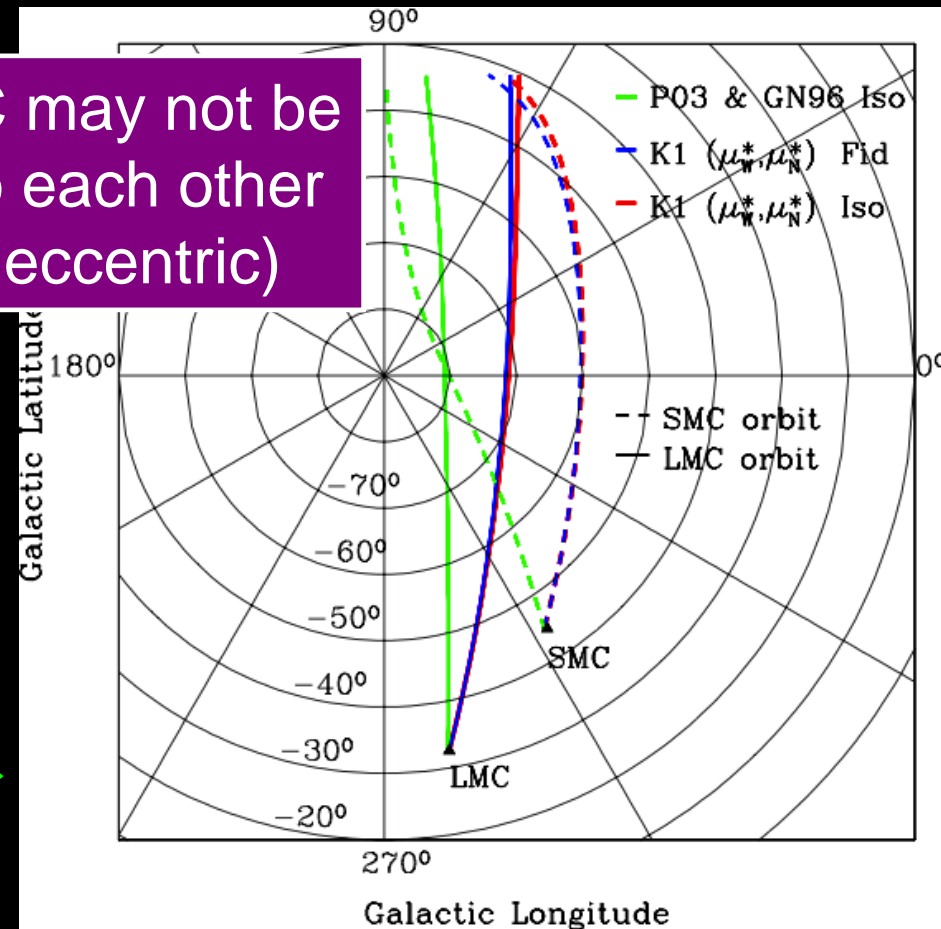


High Mass Model:
 $M_{\text{vir}} = 2 \times 10^{12} M_{\odot}$
 STATIC MODEL

3) L/SMC may not be bound to each other
 (highly eccentric)

Perturbations from SMC
 are negligible:

$$M_{\text{SMC}}/M_{\text{LMC}} \sim 1/10$$



Implications for the Magellanic Stream (MS)

Issue: the strength of the MW/L/SMC interaction is severely limited

Tidal Stripping: NOT VIABLE

- No stars associated with the MS
- Tidal radius is too large along fiducial orbits.
- Most of the mass is lost at PERICENTER

Ram Pressure Stripping (ρv^2): NOT VIABLE

- Requires high gas densities & no Leading Arm Feature
- Instantaneous ram pressure is insufficient.

SMC bound: Stellar Feedback ?

- see Olano (2004) & Nidever et al (2007)

SMC unbound: Stream originates from SMC ?

Conclusions

The new PM measurements by Kallivayalil et al (2006) **strongly** suggest that the Clouds are on their **first** passage about the MW.

OR

The MW is **substantially more massive** than previously believed ($>2 \times 10^{12} M_{\odot}$) **and** the **proper motions are discrepant by 4σ** .

The past orbits of the Clouds **DO NOT** trace the line of sight velocities or location of the MS unless the **SMC is not bound to the LMC**.

All formation scenarios for the MS need to be re-evaluated in light of the new orbital history.