High-resolution N-body Simulations of Galactic Cannibalism

The Magellanic Stream

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Swinburne University of Technology

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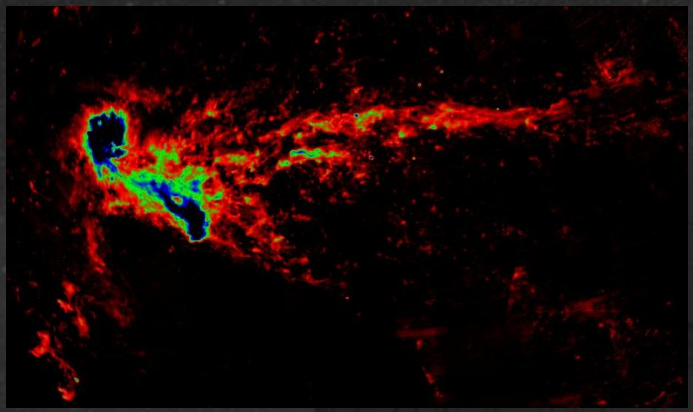
Abstract

Through the investigation of the closest obvious group of interacting galaxies, the Magellanic Clouds and the Milky Way Galaxy, we hope to understand the process of hierarchical clustering in detail.

1. Introduction

1.1. Introduction – Magellanic System



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Magellanic System is Large and Small Magellanic Clouds and the spectacular gas streams – MS and LAF.

Close example of Galactic Cannibalism – an example of Hierarchical Clustering.

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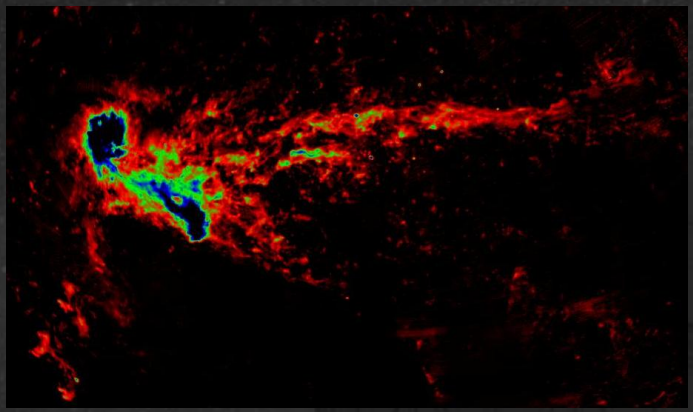

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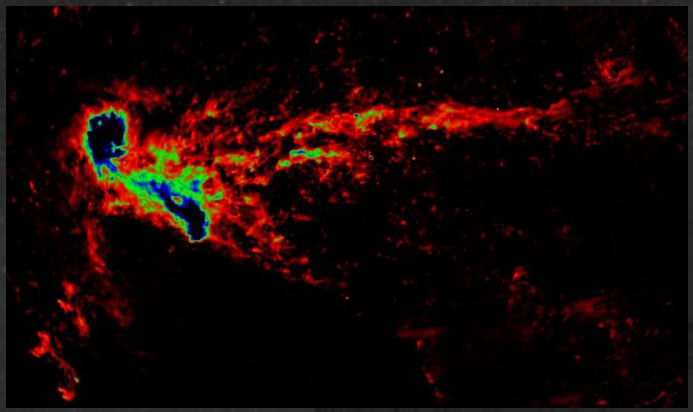

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Favourable position $\Rightarrow$ Best chance of untangling physics, as can resolve individual stars, proper motions and distances. Not a stellar stream; shaped by hydrodynamical & tidal forces

1.2. Motivation

Best laboratory for study of

- Formation of tidal streams
- Effect of interaction and SNe feedback on SF in cannibalised dwarfs.

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First, this study allows us to hunt down allowable parameters

We investigate how pure tidal forces influence stream, and find what the formation process of Magellanic Stream is

2. N-body simulation of SMC and Magellanic Stream

Backwards integrate orbit using modified Noguchi's (1996) ubiquitous code.

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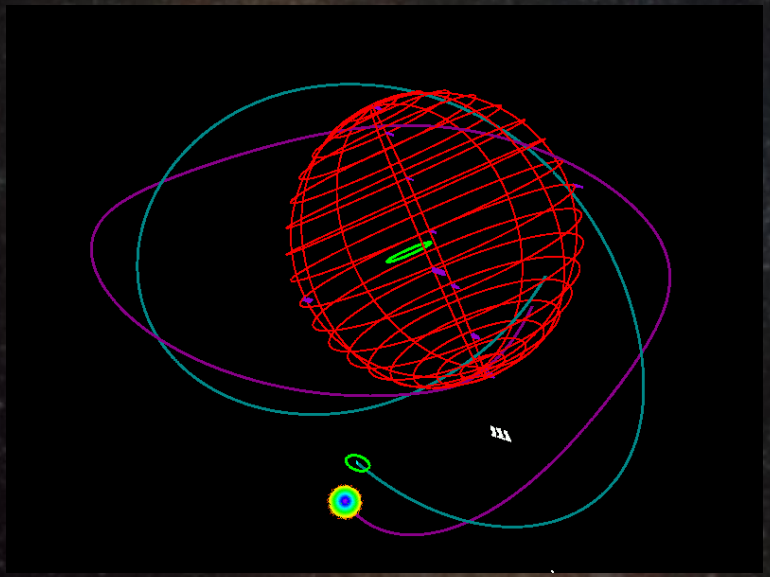

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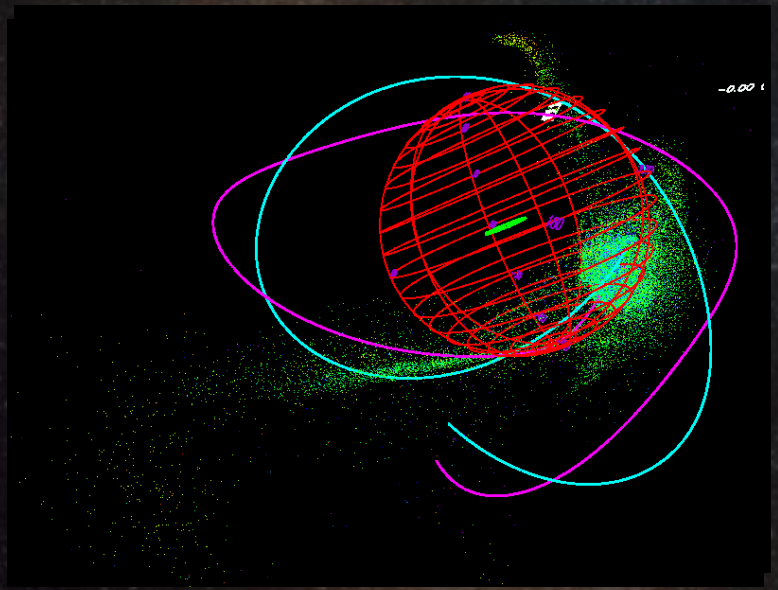

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Use GCD+: 3D vector/parallel tree N-body/SPH code: Includes hydrodynamics, radiative cooling, star formation, SNe feedback, metal enrichment

3. Modelling Strategy

A step-by-step model construction
A: N-body model of SMC
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Almost completed — Connors et al. 2004 already published

B: Include hydrodynamics/Star Formation/Chemodynamical evolution

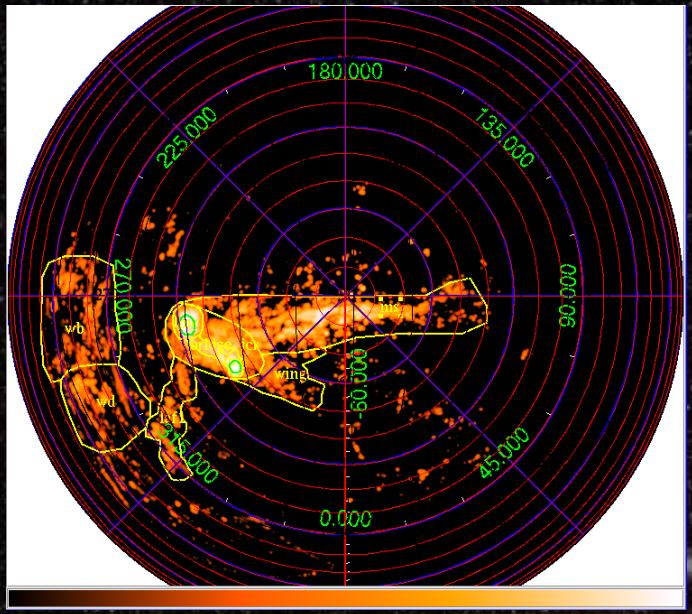
Based on best model determined in A, find star formation history within SMC

SNe feedback is most complicated and poorly understood

SMC is good laboratory for such study

4. Parameter survey

Best model determined by both spatial and kinematical agreement with:



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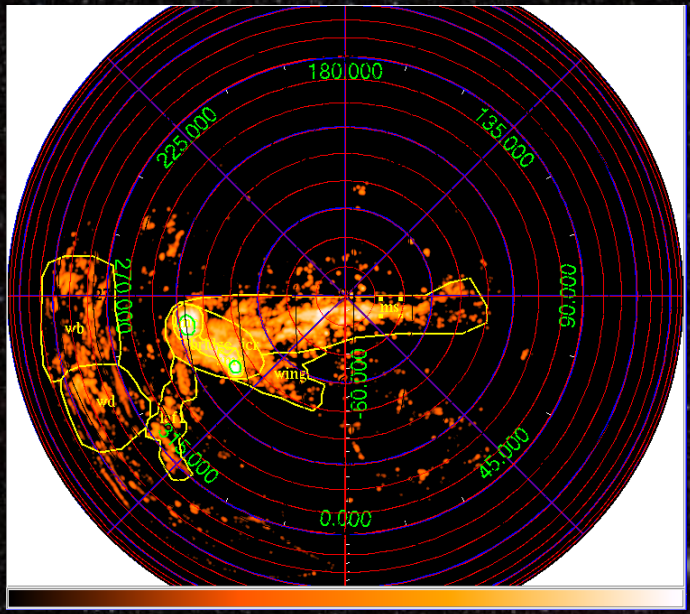

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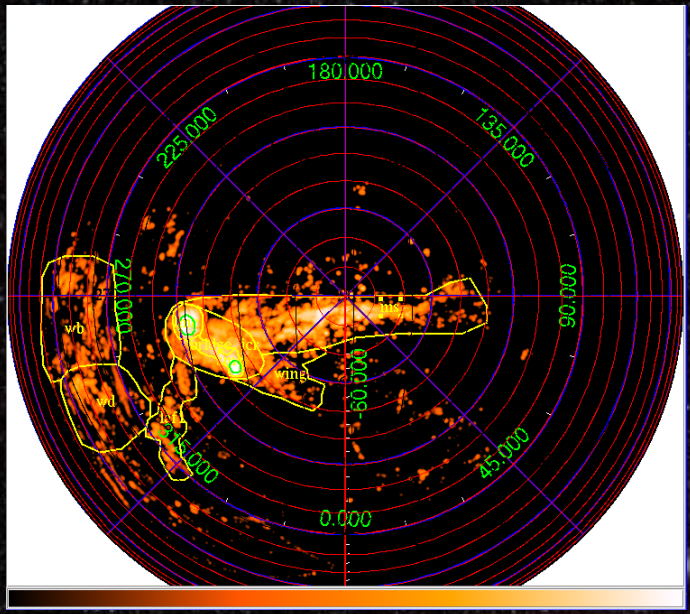

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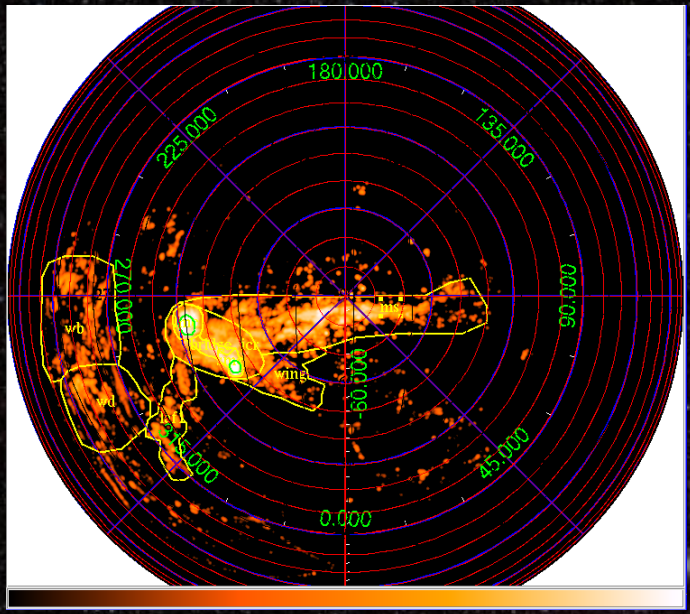

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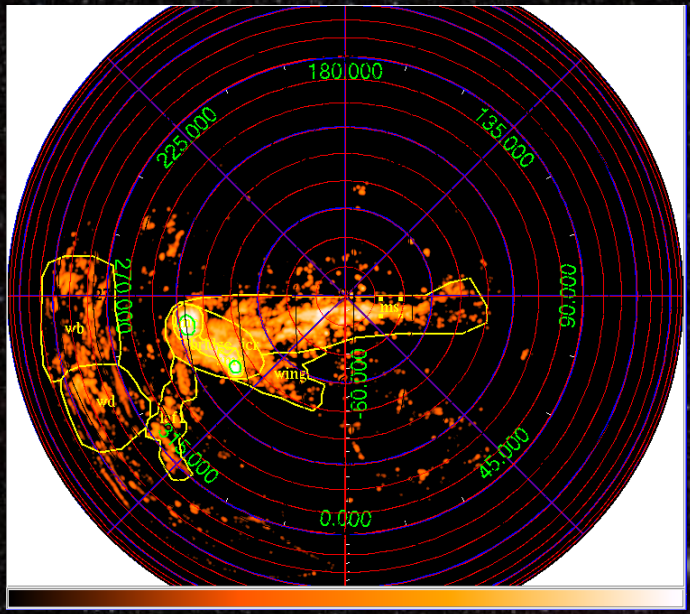

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- mass of SMC disk / mass of SMC halo

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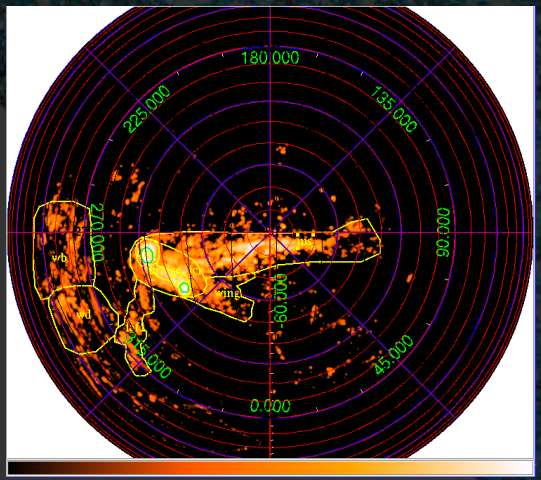

Observation ⇔ Simulation (ZEA coordinates)

Overall features of LAF and MS reproduced

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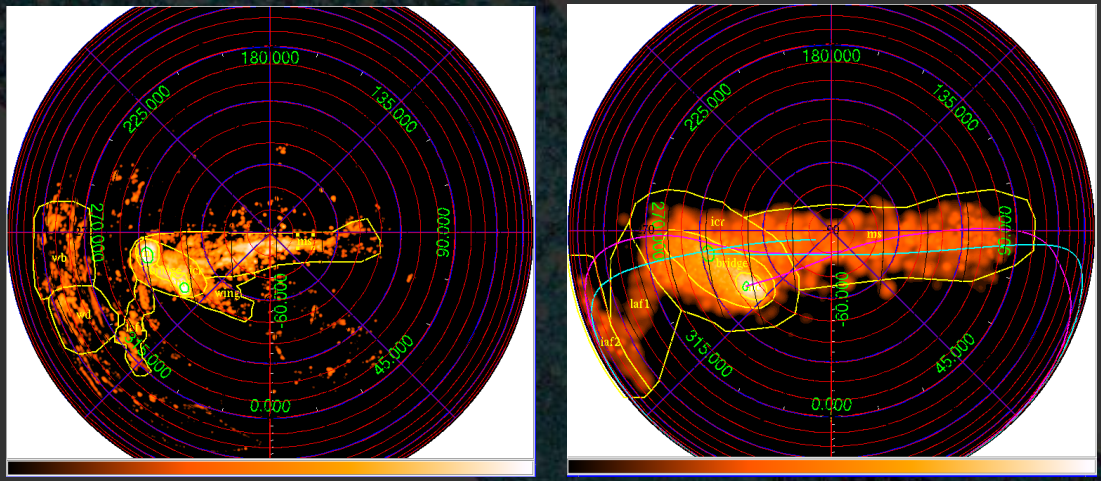

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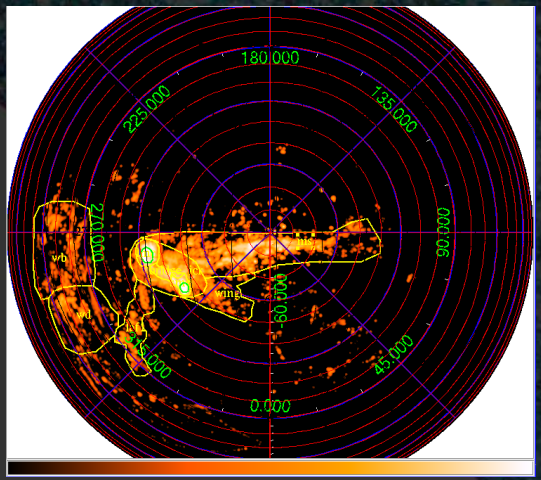

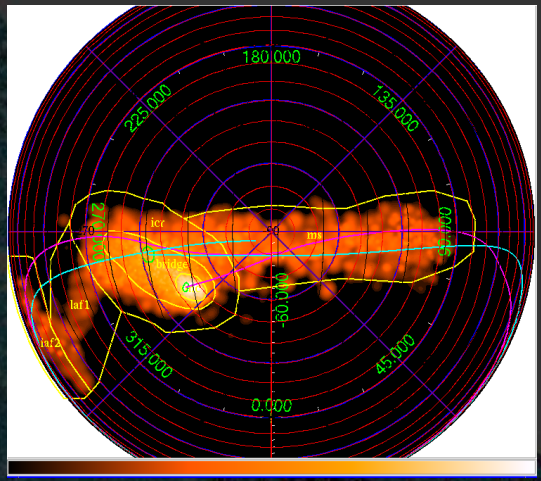

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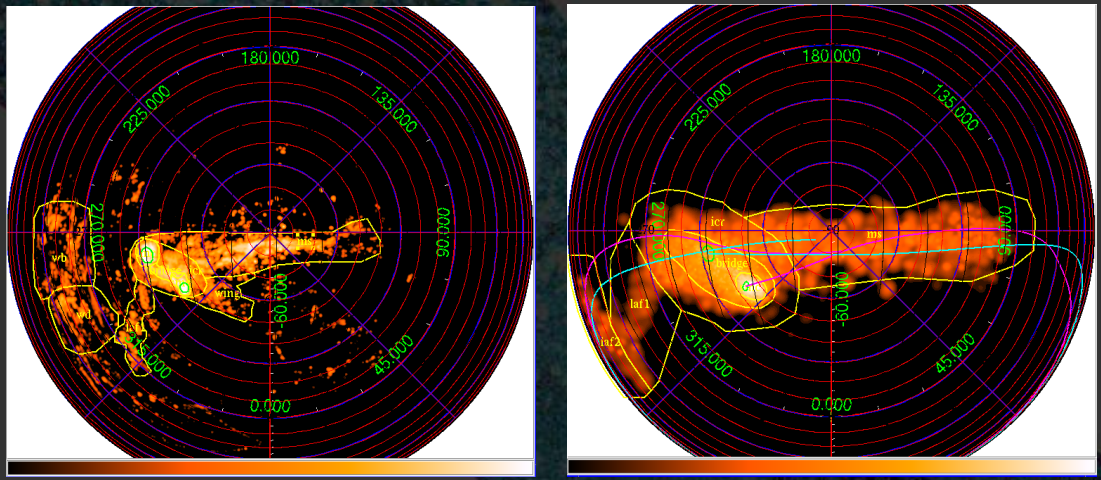

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Adding drag (ram pressure from Galaxy halo) may fix these.

6. Best model: Kinematics ("v_{Sub}")

$800\,\mathrm{km\,s^{-1}}$ velocity LSR range: Too hard to see any small scale differences

Subtract trend from observational data equally Velocity in

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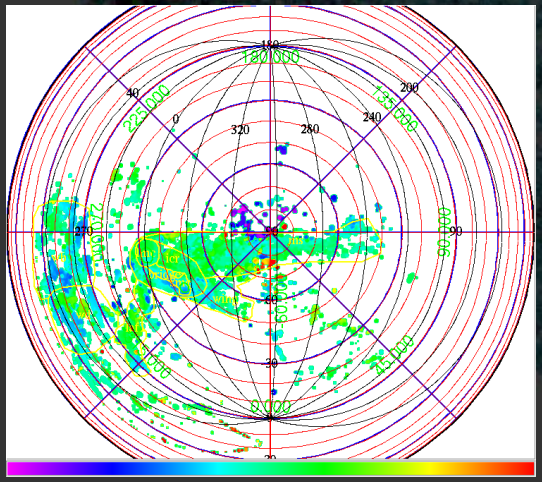

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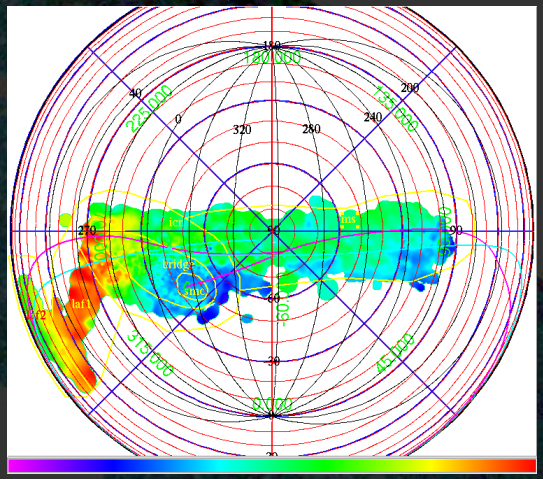
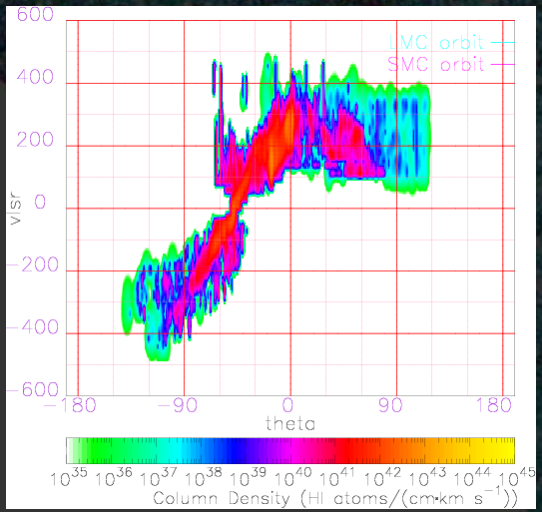


Simulation

Mostly consistent, except for residuals around LAF

7. Best model: Kinematics (v_{LSR} vs l_{Mag})

Another projection:



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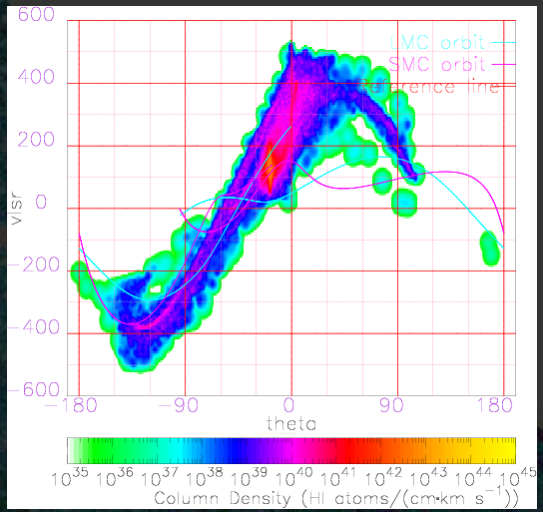
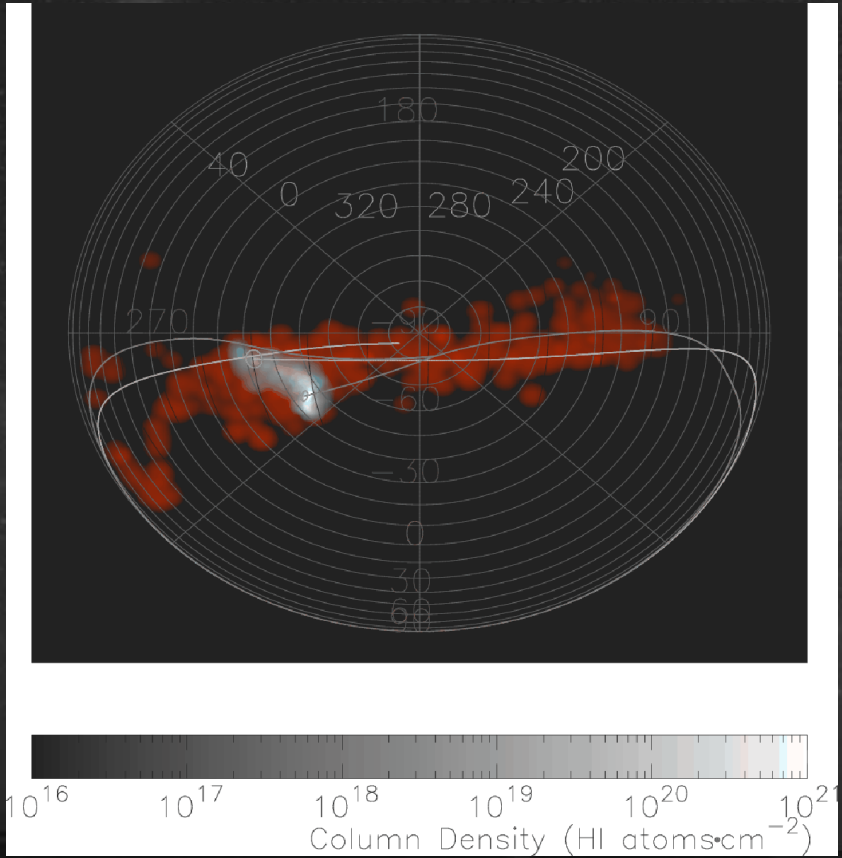


Simulation

Simulation: Clear bifurcation in v_{LSR} vs l_{Mag} - not so clear in low resolution simulations

Observations: Difficult to tell: Christian Brüns has same data with different reduction technique

8. Hydro/Star formation



No stars observed in MS and LAF

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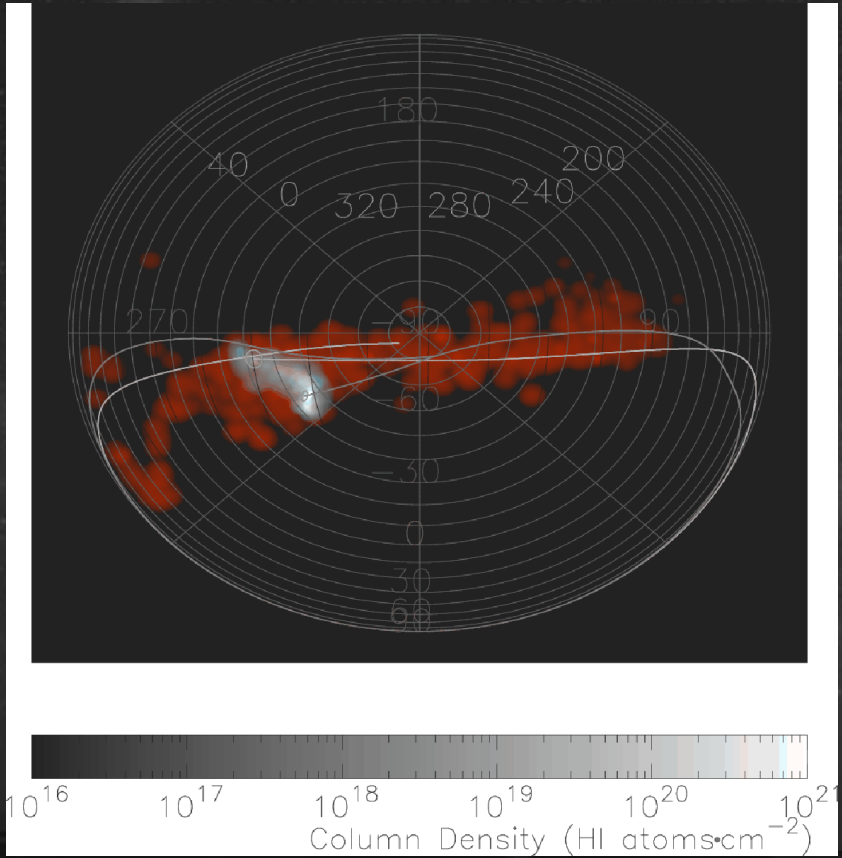

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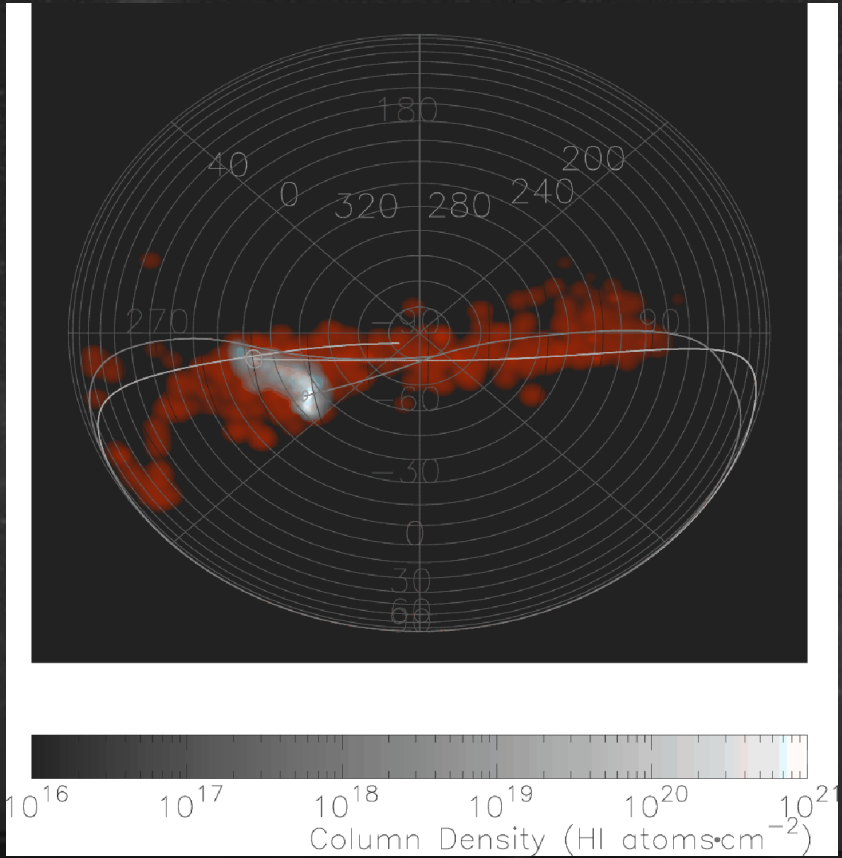

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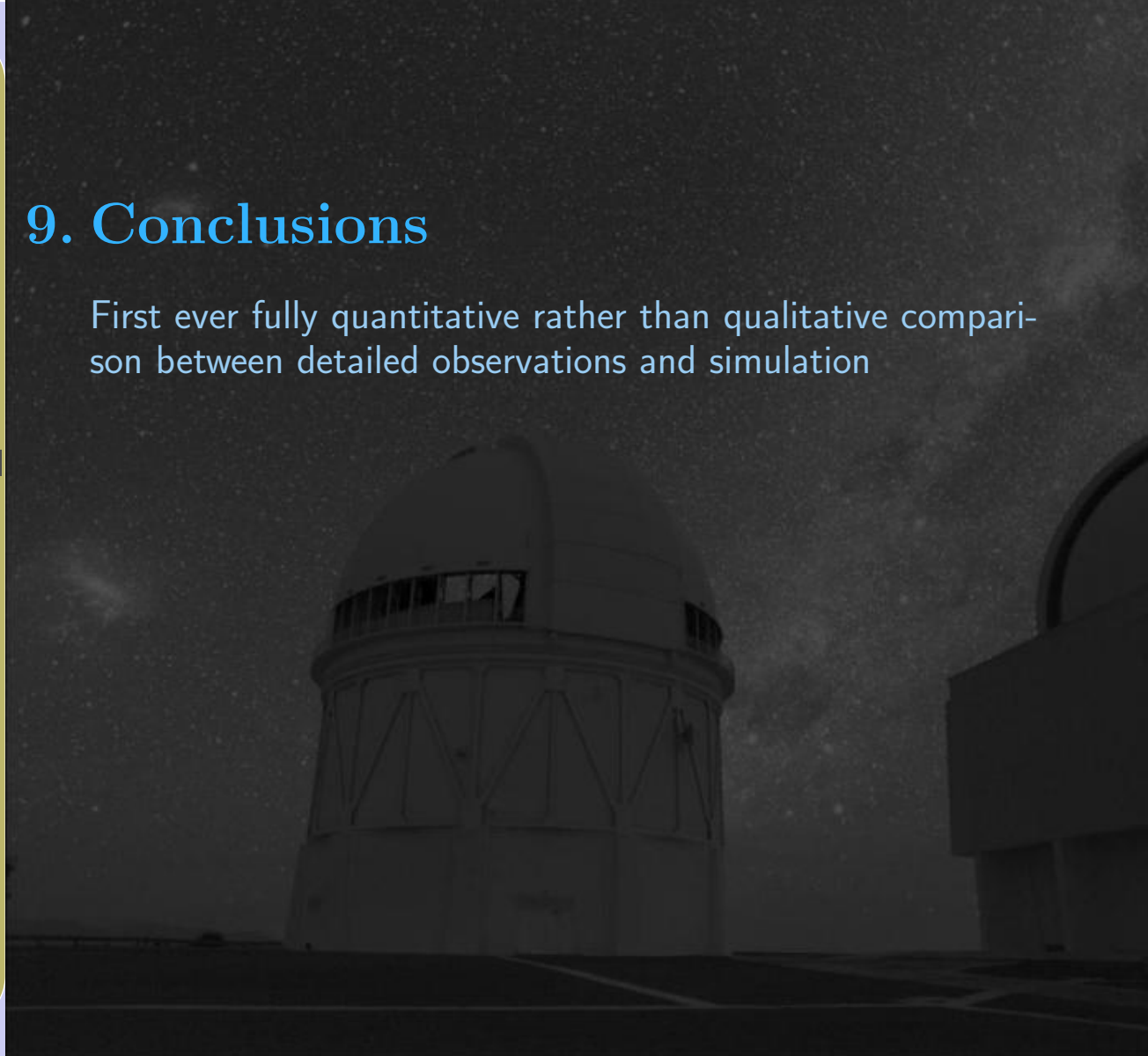
More analysis in progress

9. Conclusions

First ever fully quantitative rather than qualitative comparison between detailed observations and simulation



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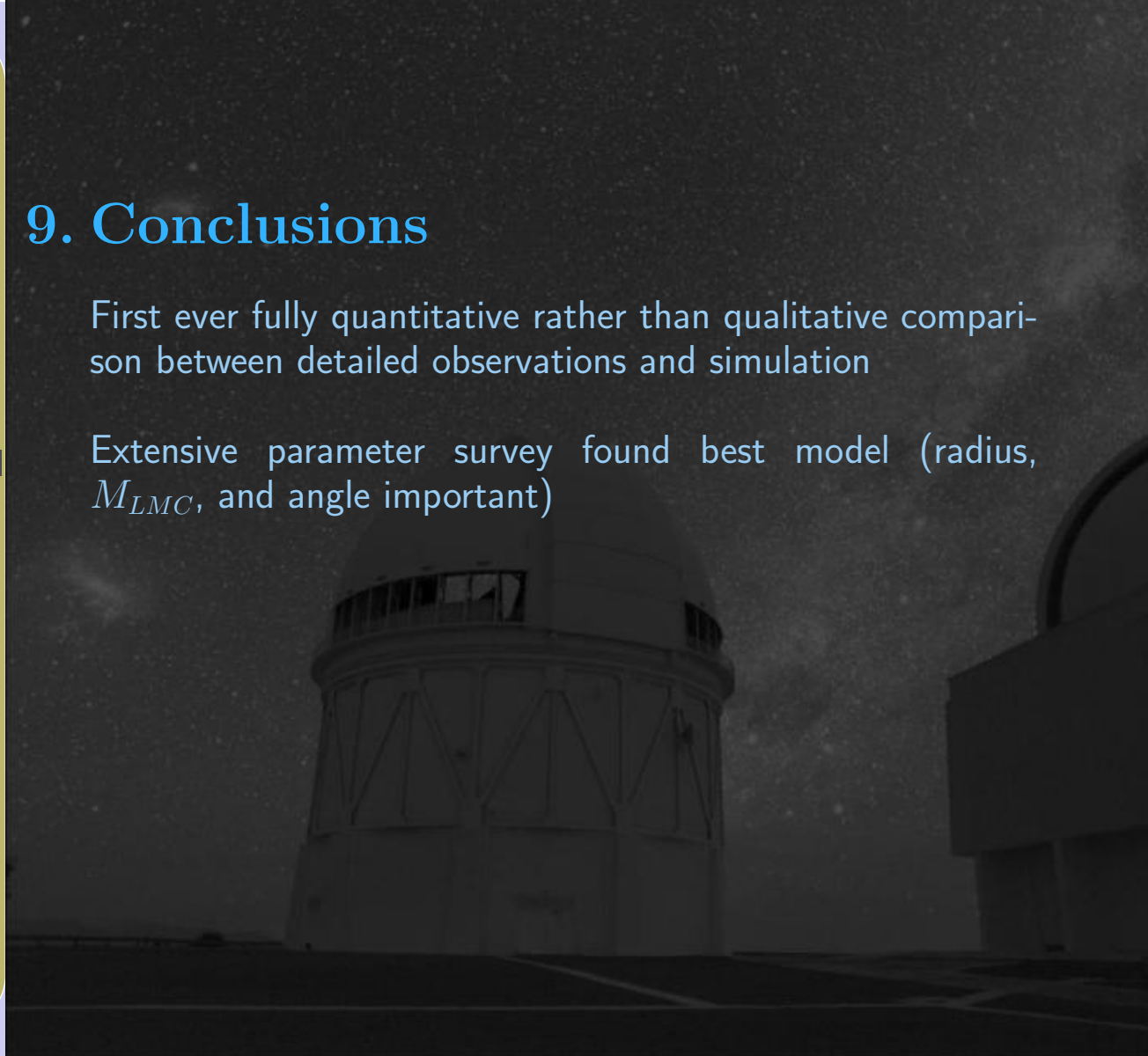
Extensive parameter survey found best model (radius, M_{LMC}, and angle important)



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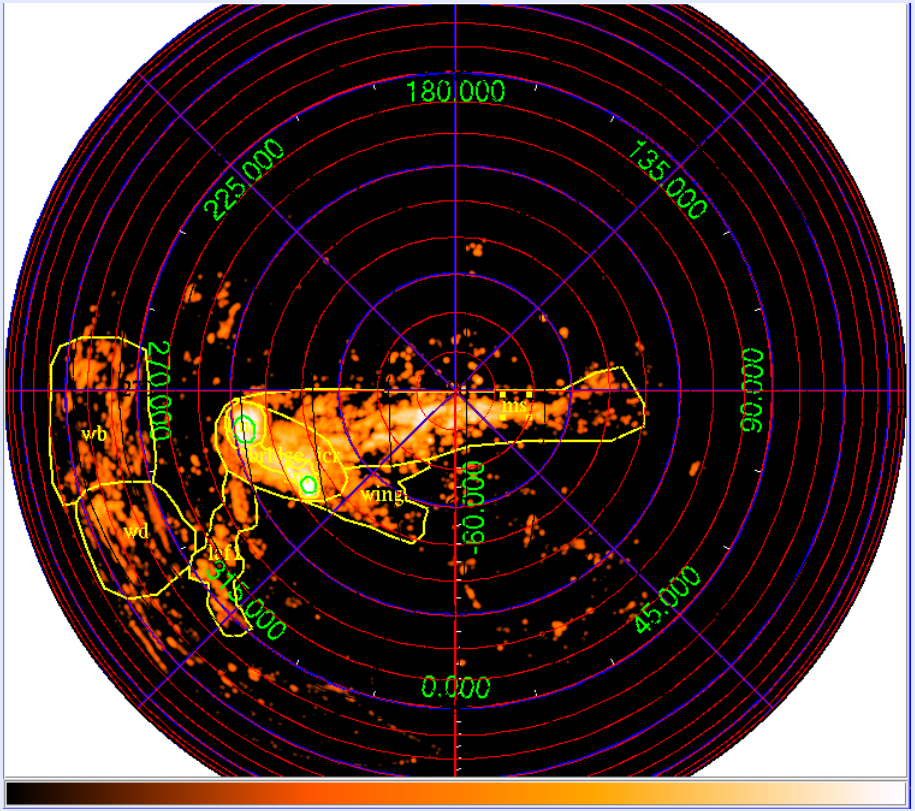
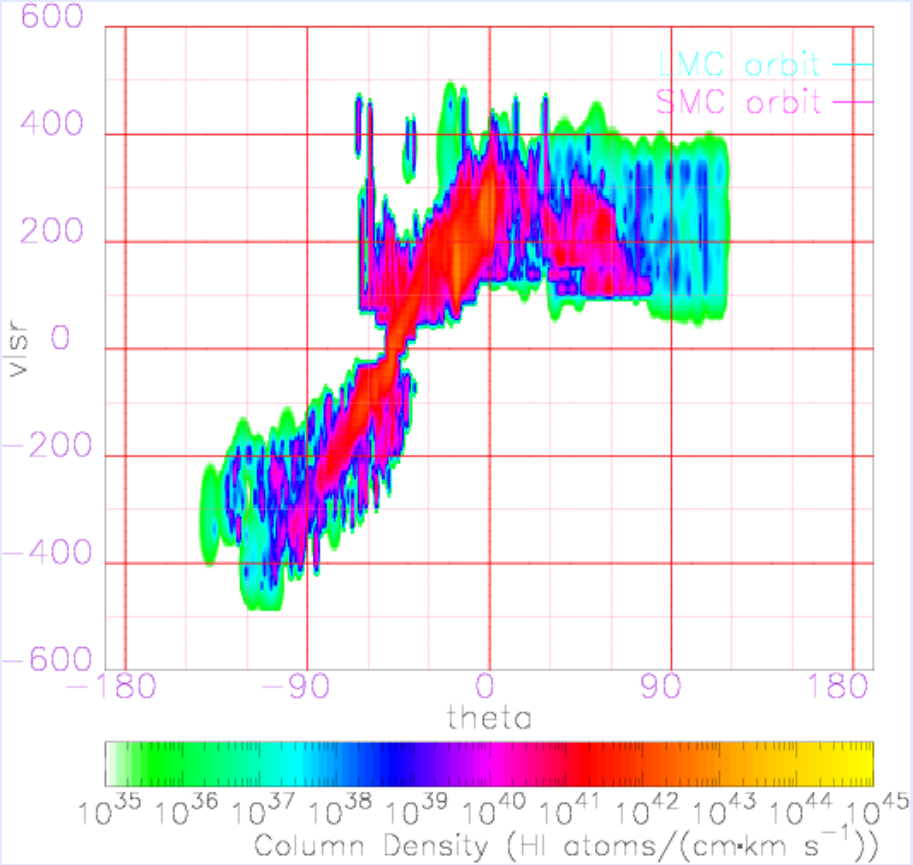
N-body parameter survey nearing completion, leads to full gas treatment

Done



Magellanic Stream in HI



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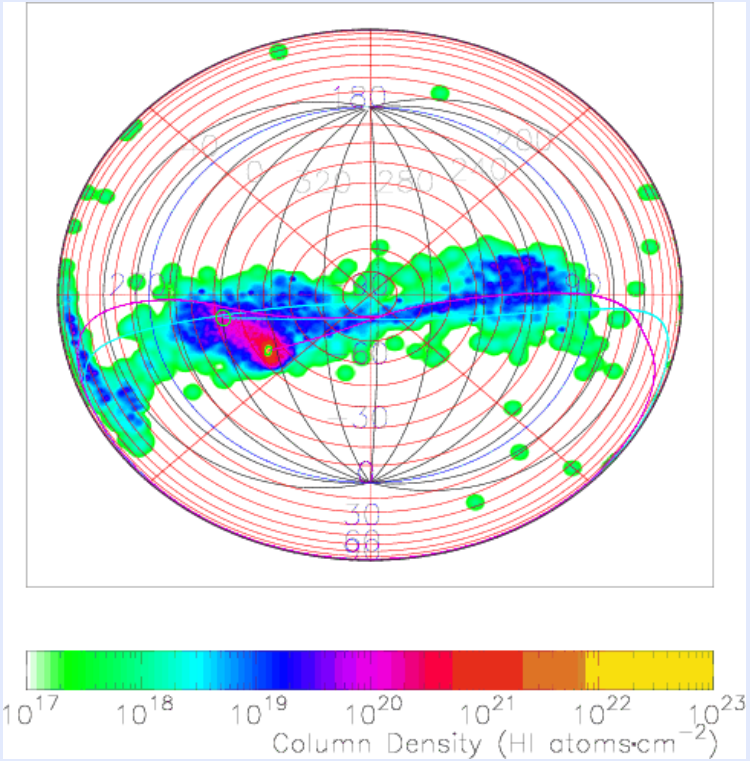

Gardiner Noguchi 1996 (re-rendered)

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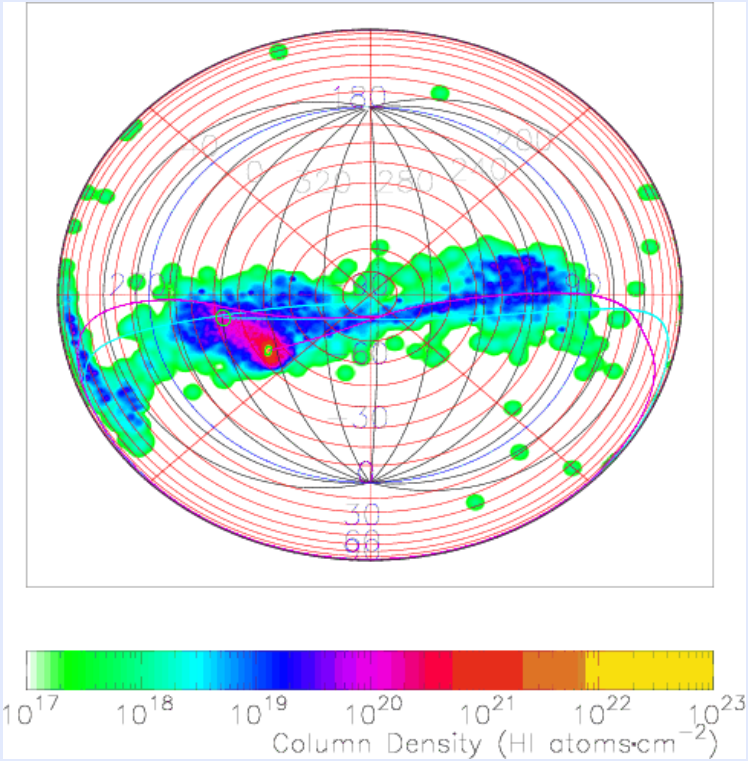

Noguchi 1999; Yoshizawa & Noguchi 2003

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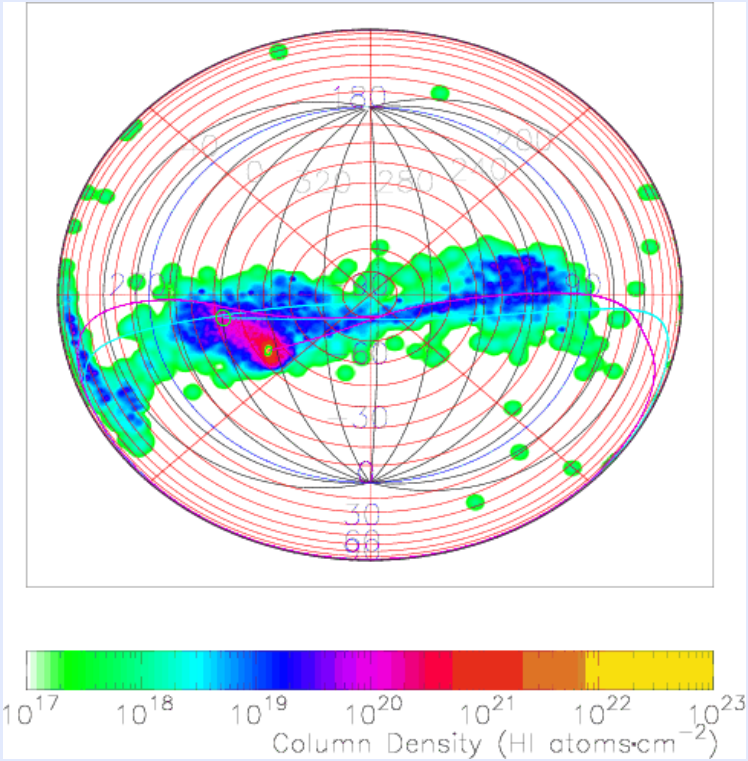

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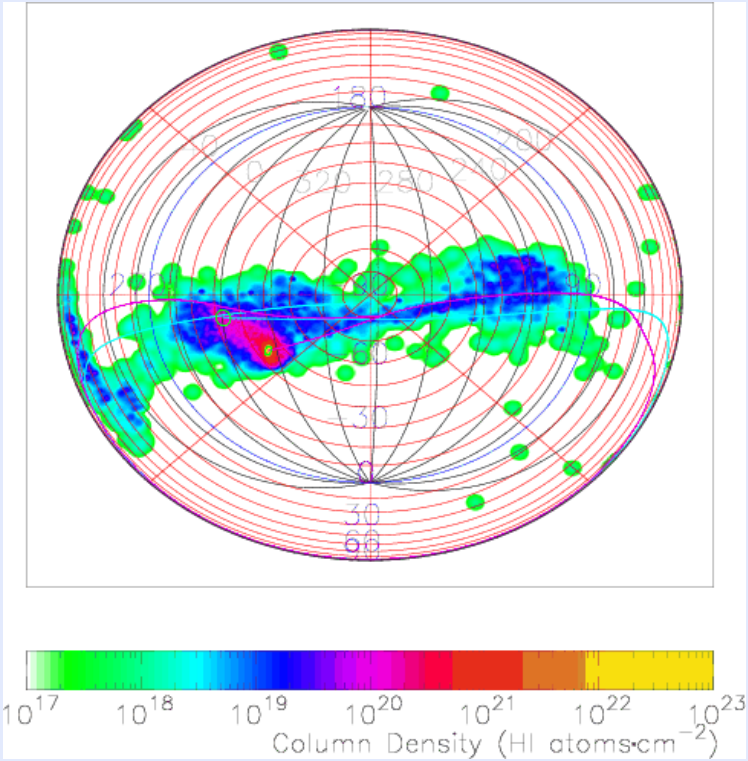

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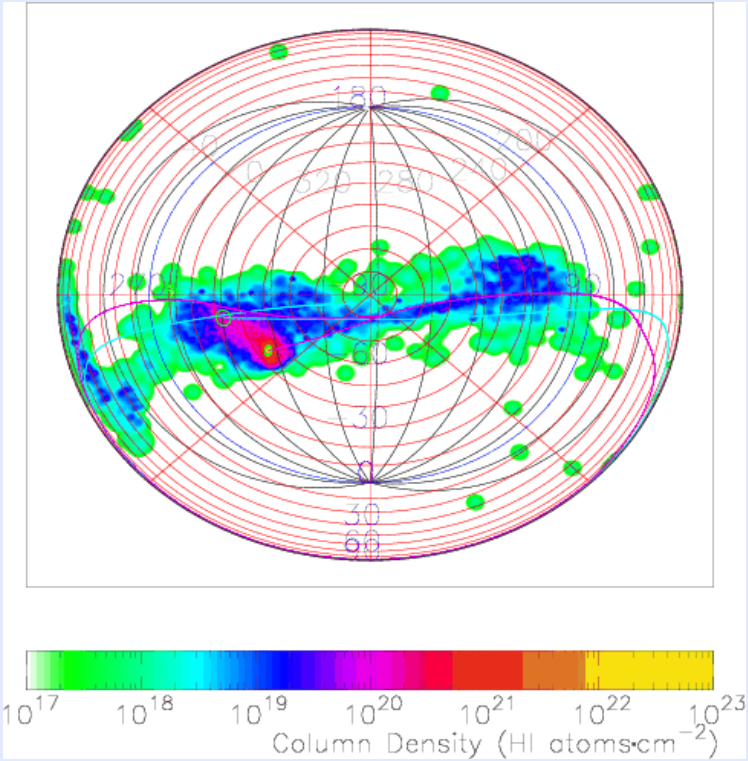

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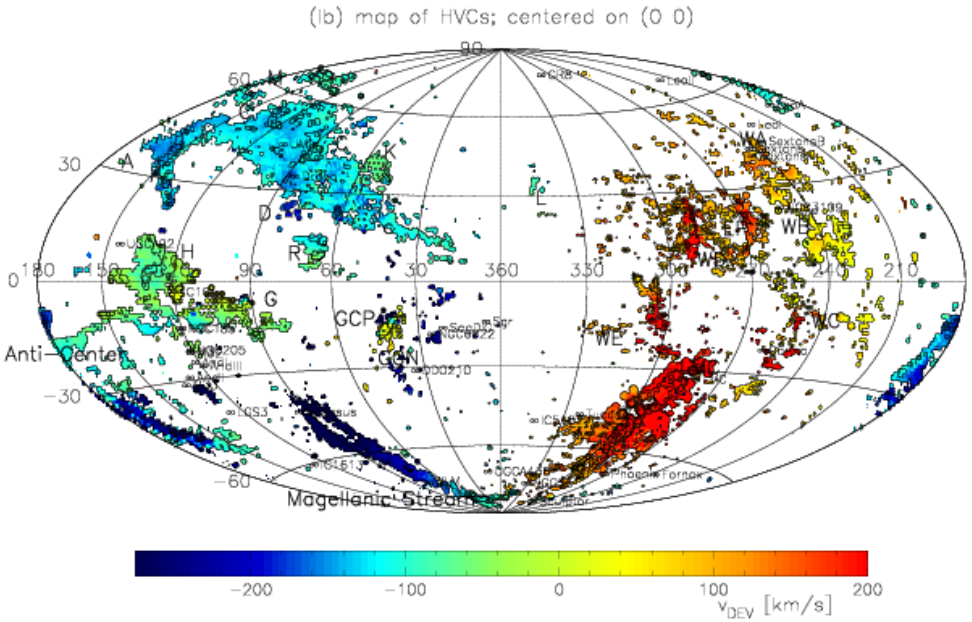
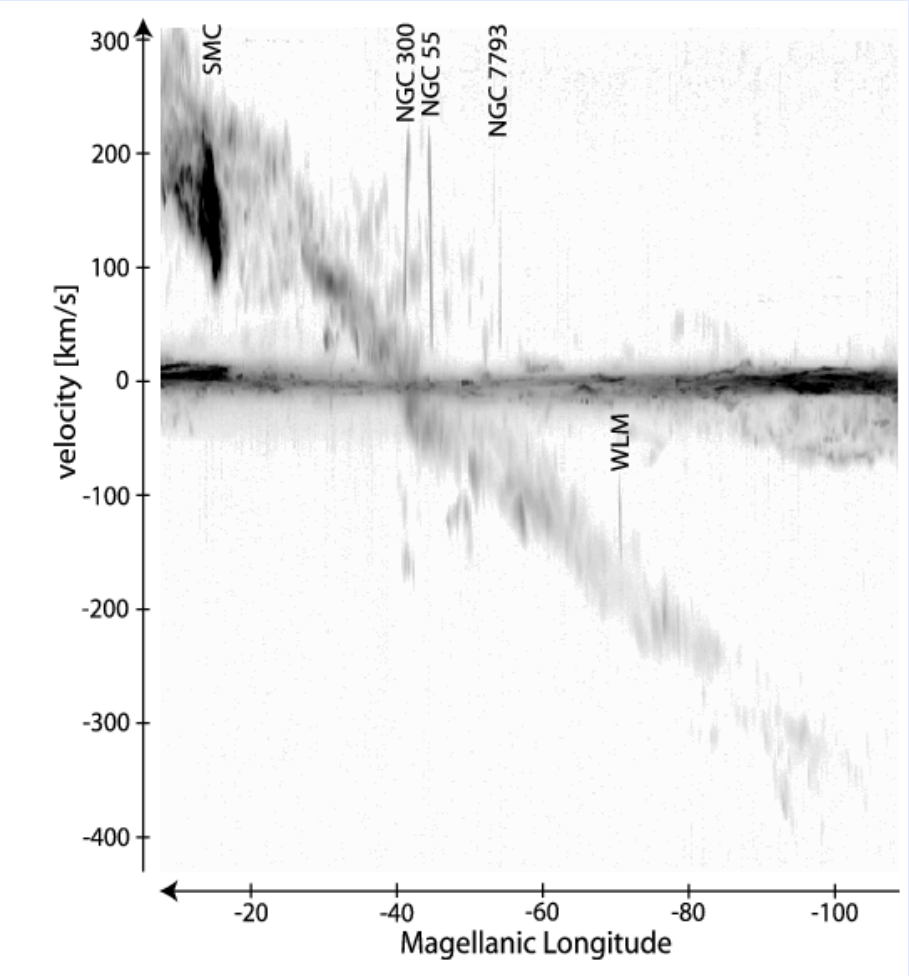
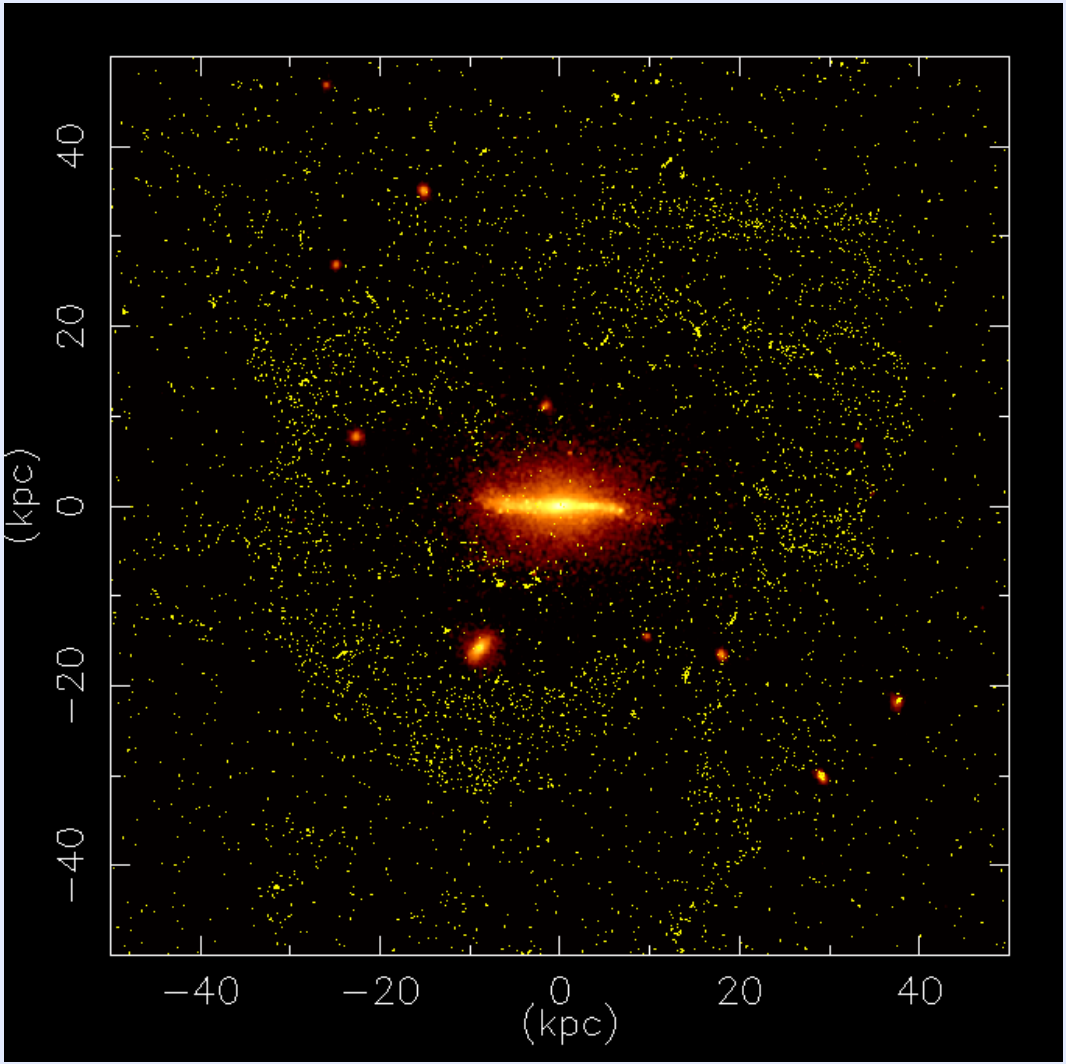
Movie of low res MS

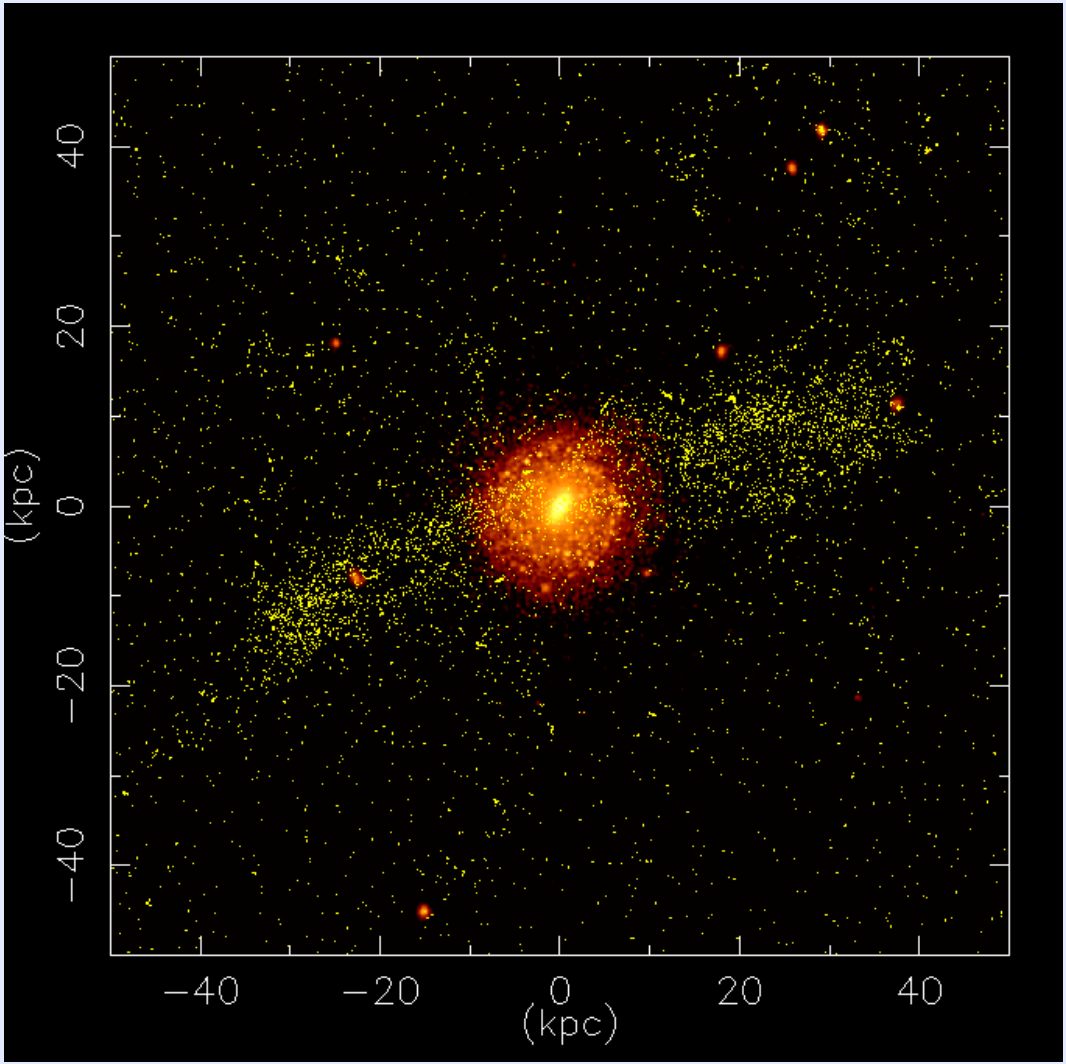


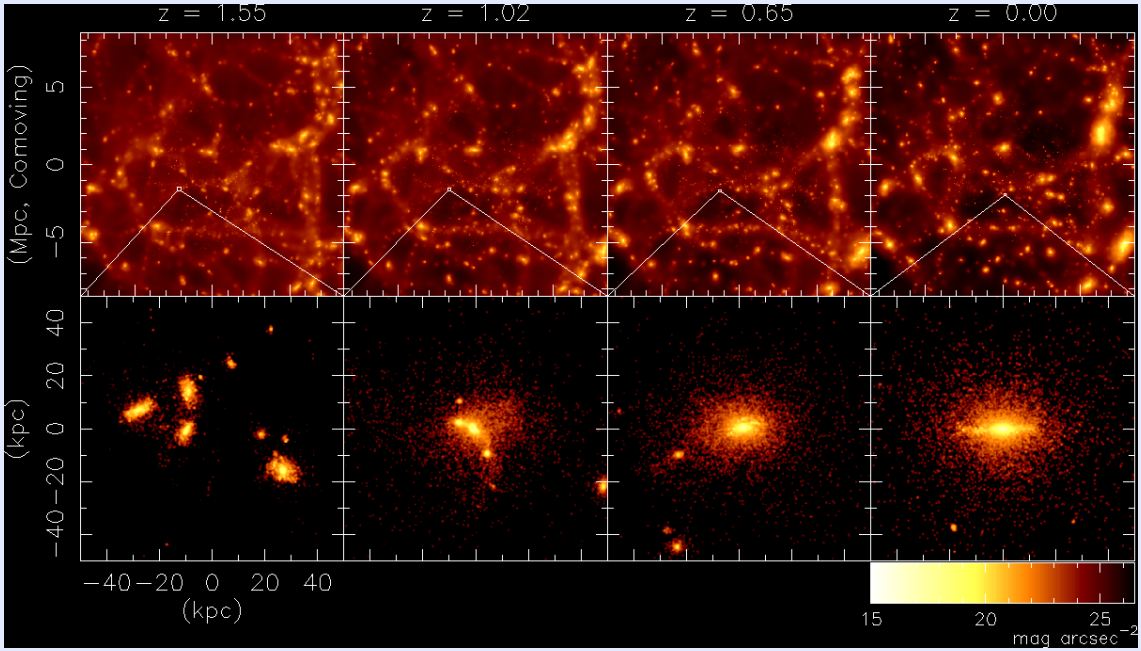
Full sky image of the HVCs.

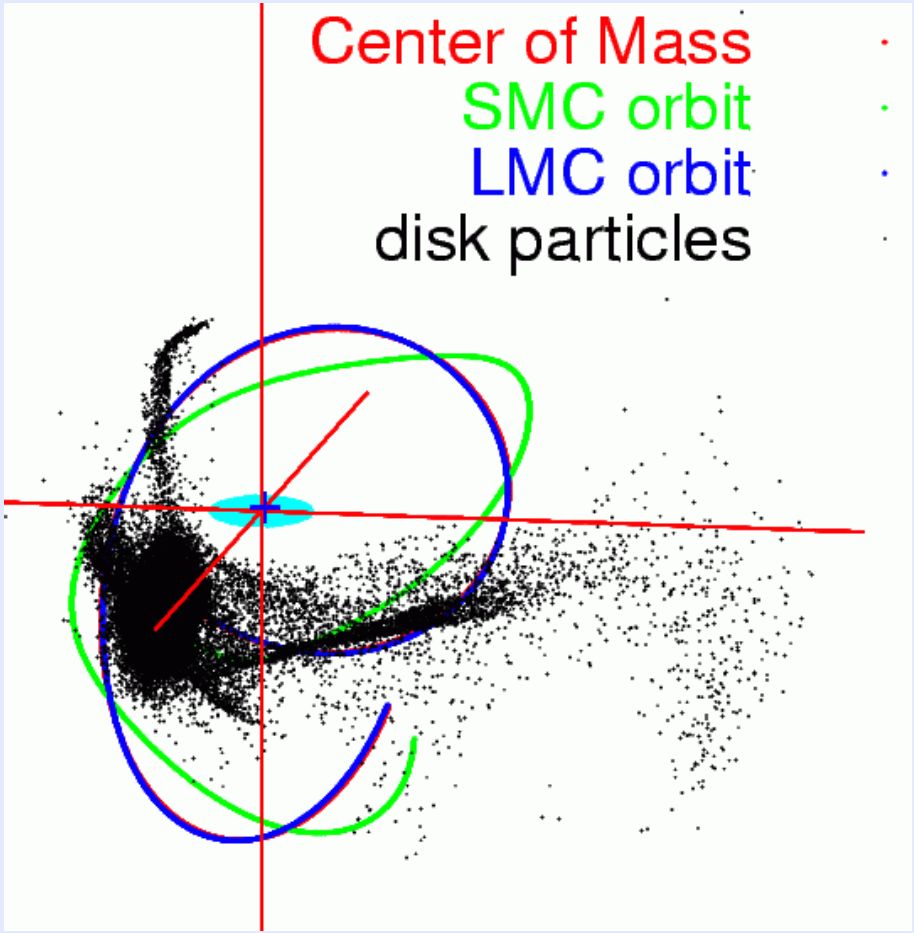


Brüns, Kerp, Stavely-Smith (2004)

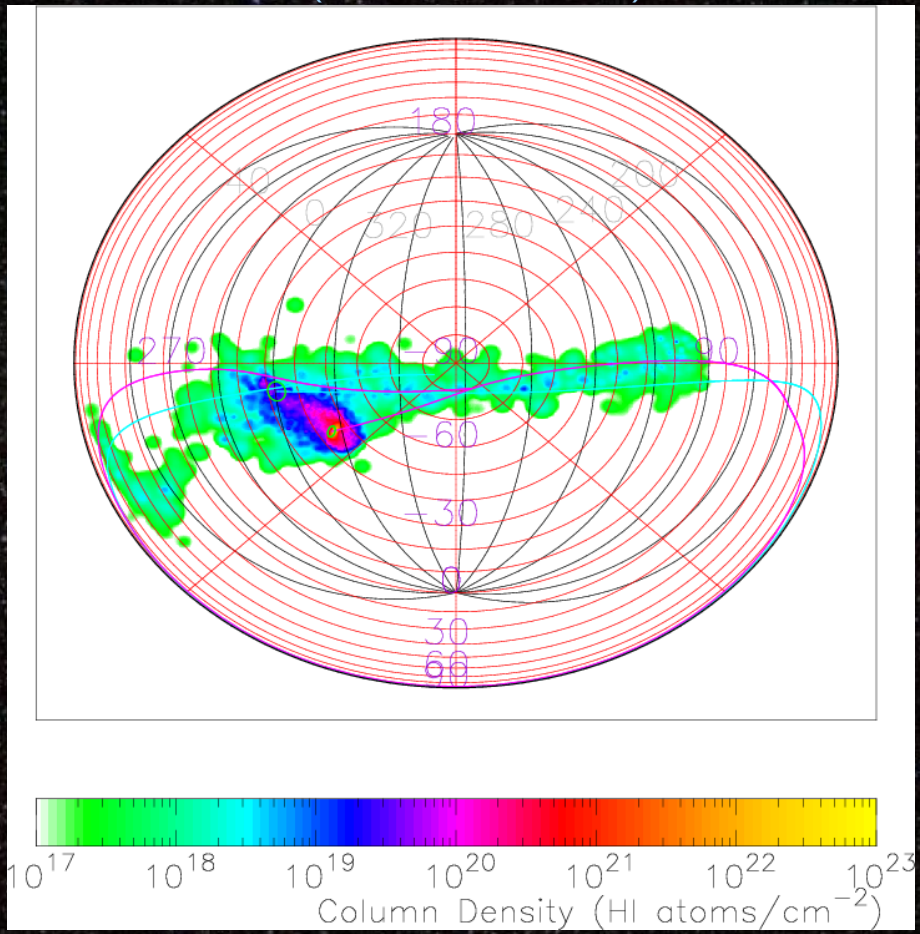








First, the radius (5.5 kpc – fiducial)



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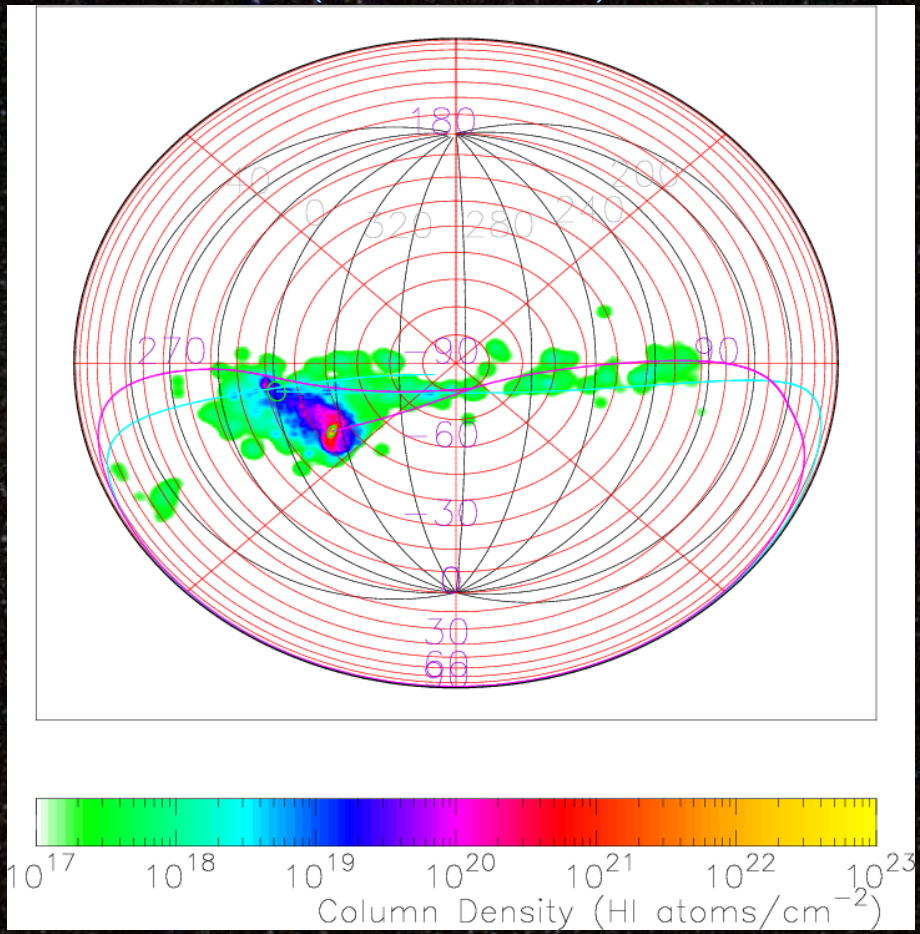
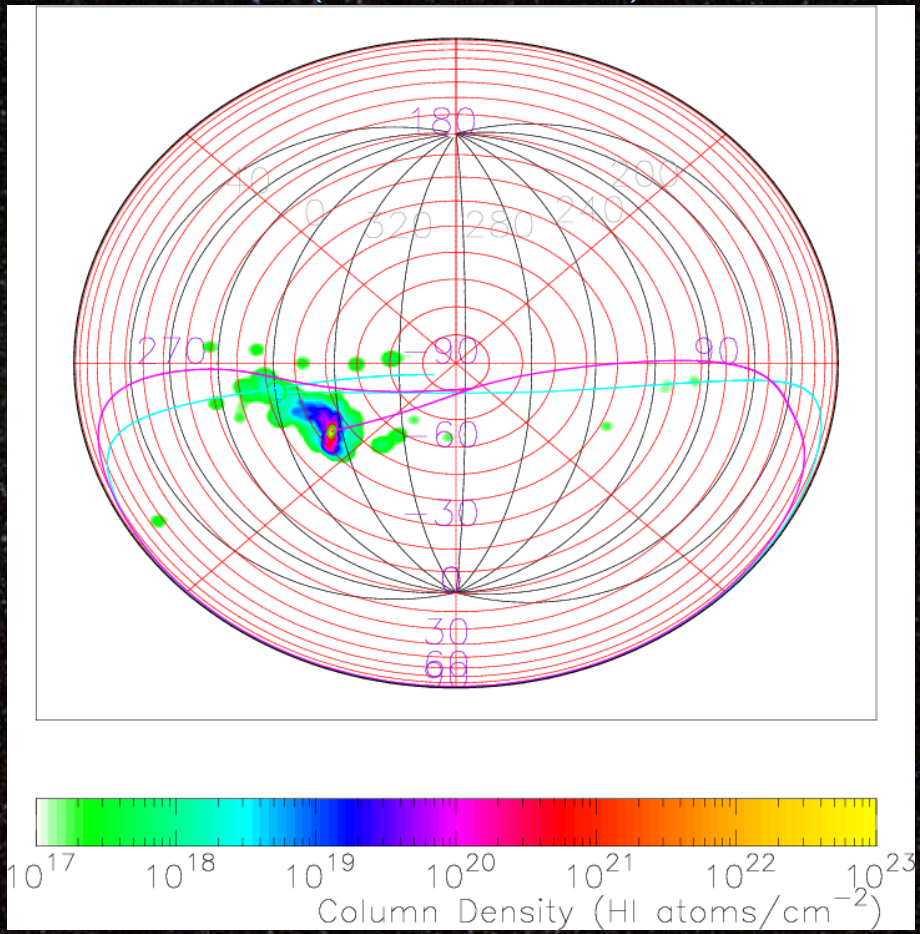
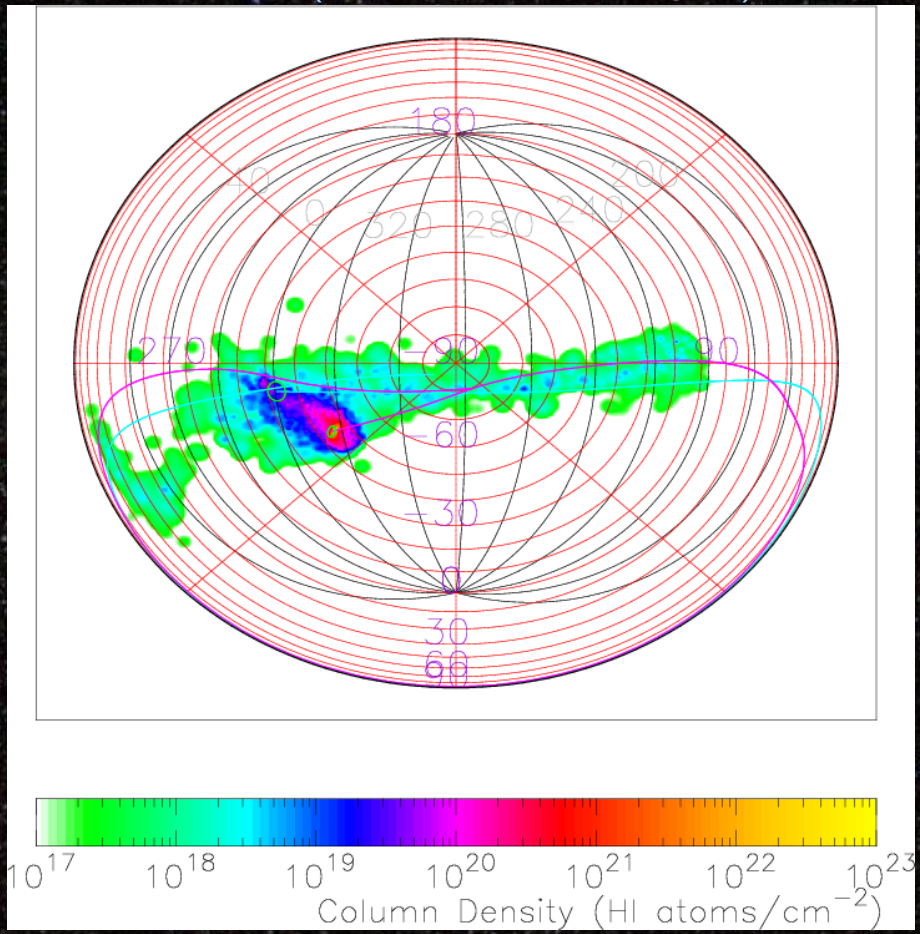
First, the radius ($4.5\,\mathrm{kpc}$ – small)



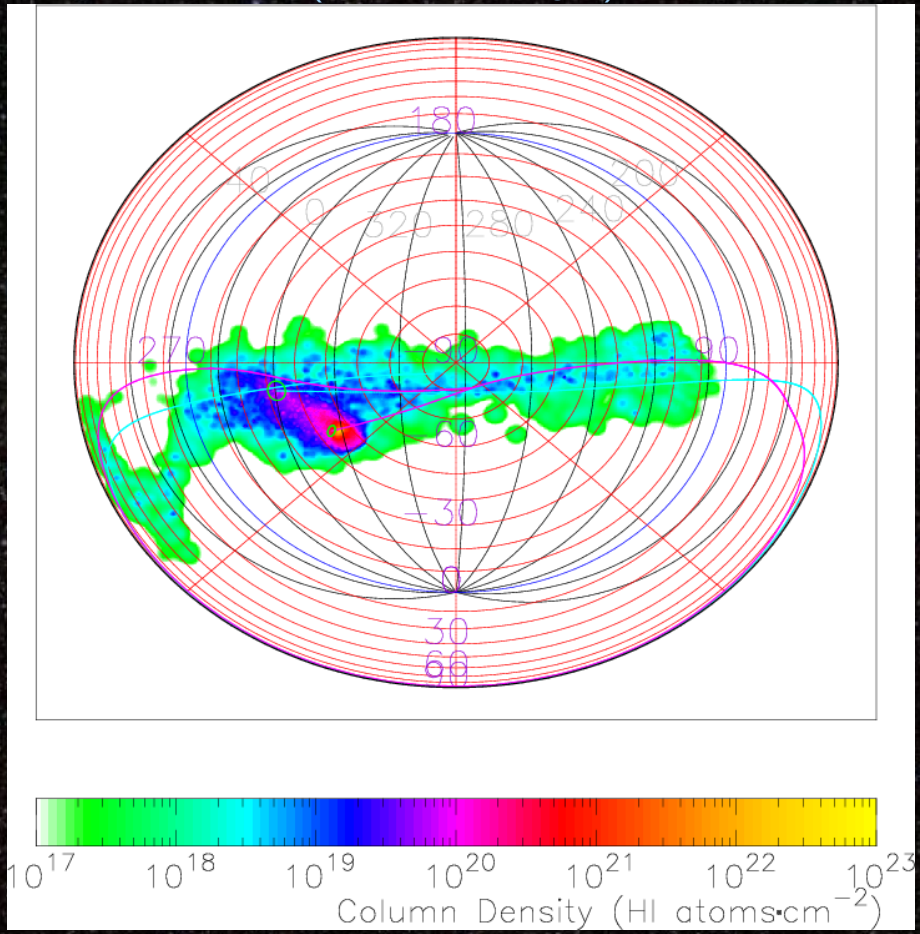
First, the radius ($3.0\,\mathrm{kpc}$ – smaller)



First, the radius (5.5 kpc – fiducial again)



First, the radius ($7.0\,\mathrm{kpc}$ – larger)



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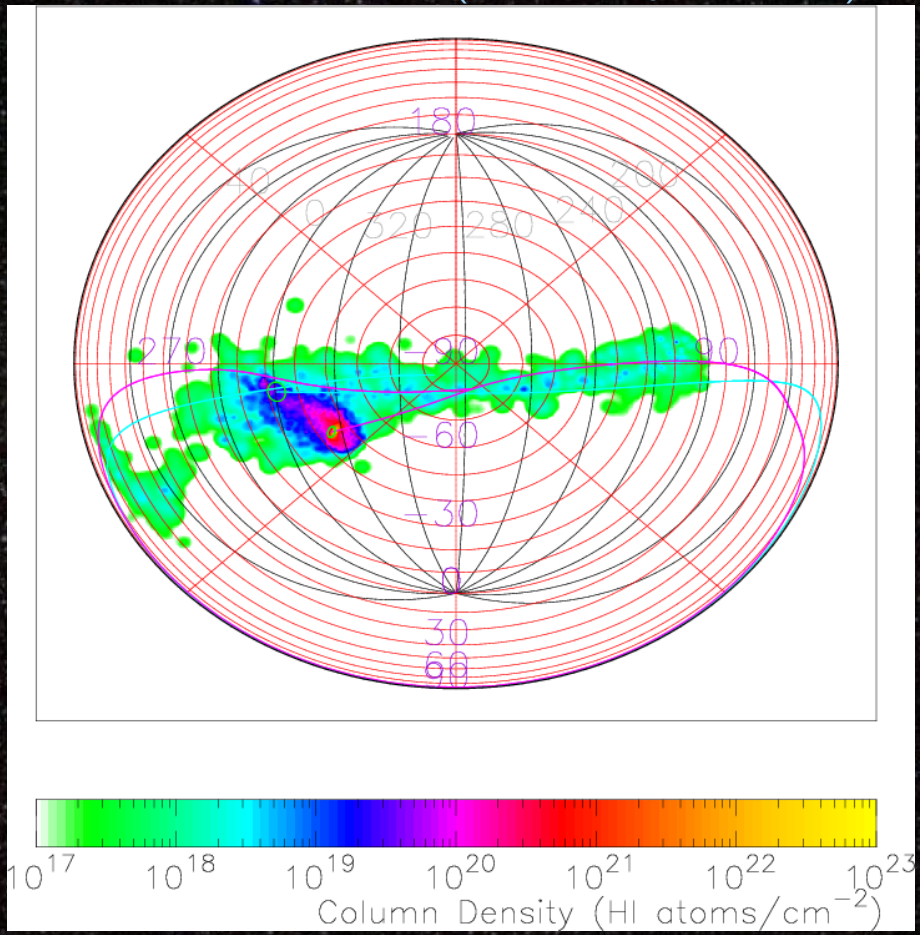
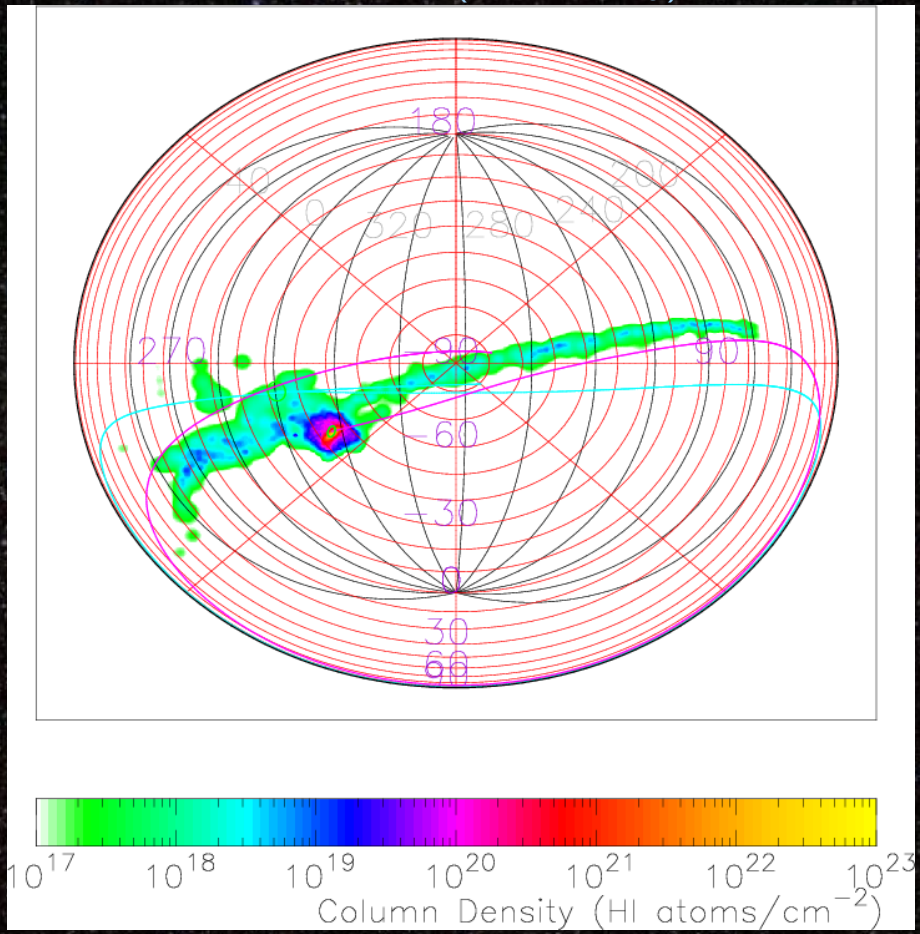
Then, the mass of LMC ($2\times10^{10}M_{\odot}$ – fiducial)



Then, the mass of LMC ($1\times10^{10}M_{\odot}$)



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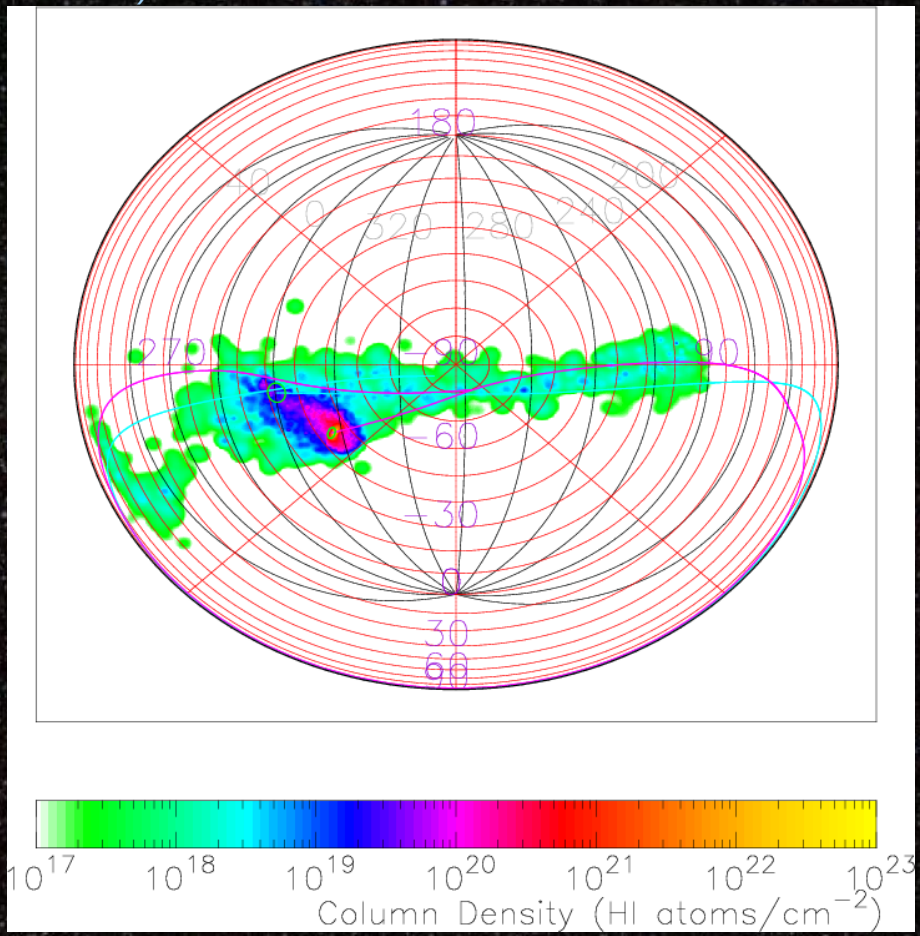
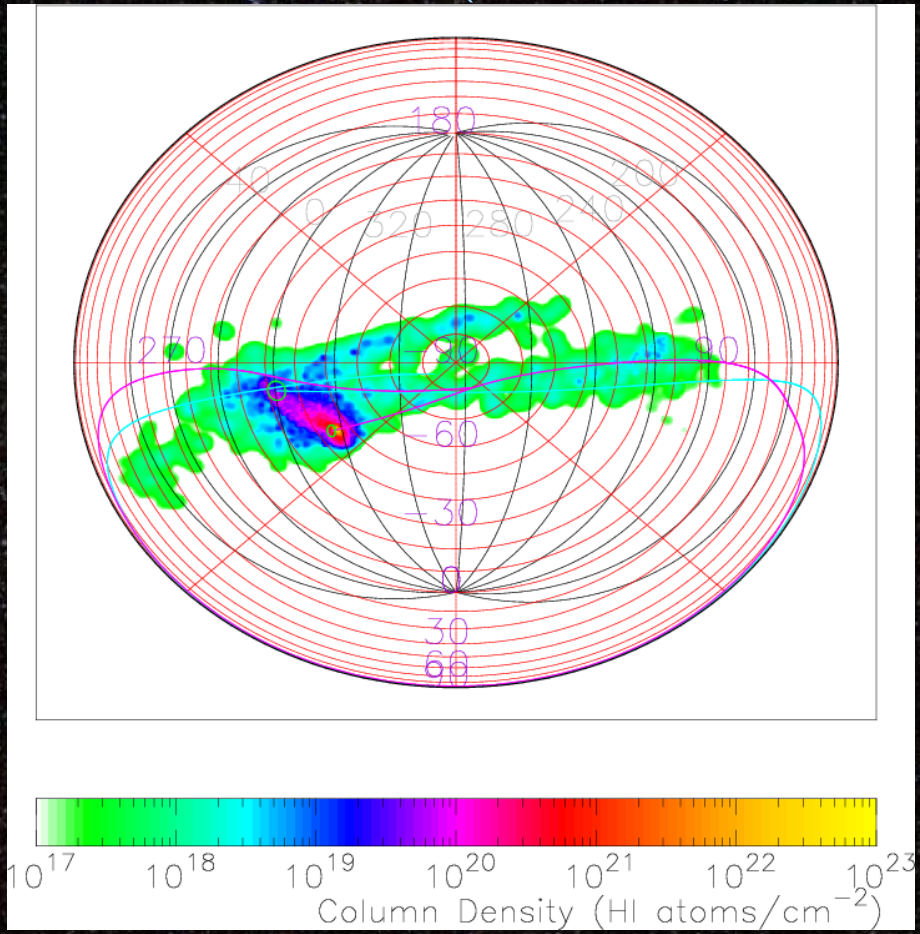
Then, angle of SMC disk – 2 degrees freedom ($45, 210^\circ$ – fiducial)



Then, the angle of SMC $(30, 210^\circ$ – only 15° different)



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