On the origin of anomalous velocity clouds in the Milky Way

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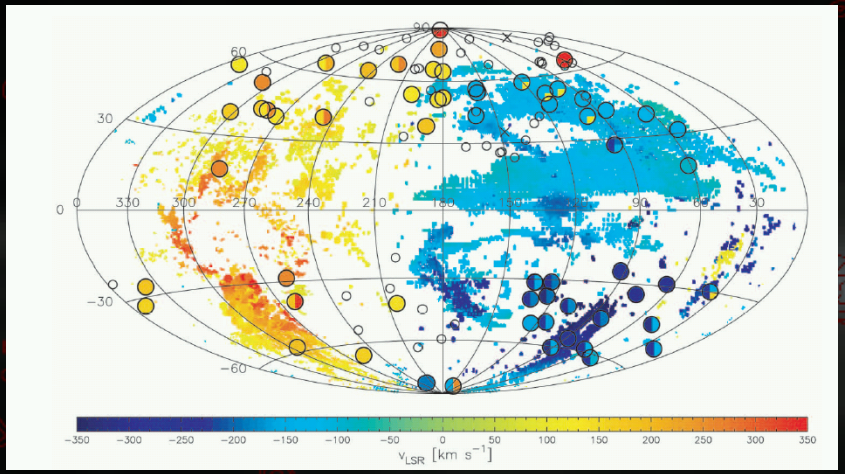
July 15, 2005

Abstract

Within a cosmological context, we show the occurrence of HVCs with properties similar to those of the Milky Way is the norm

1. Introduction



Sembach et al. (2003)
H I column density
$> 2 \times 10^{18}/\mathrm{cm}^2$

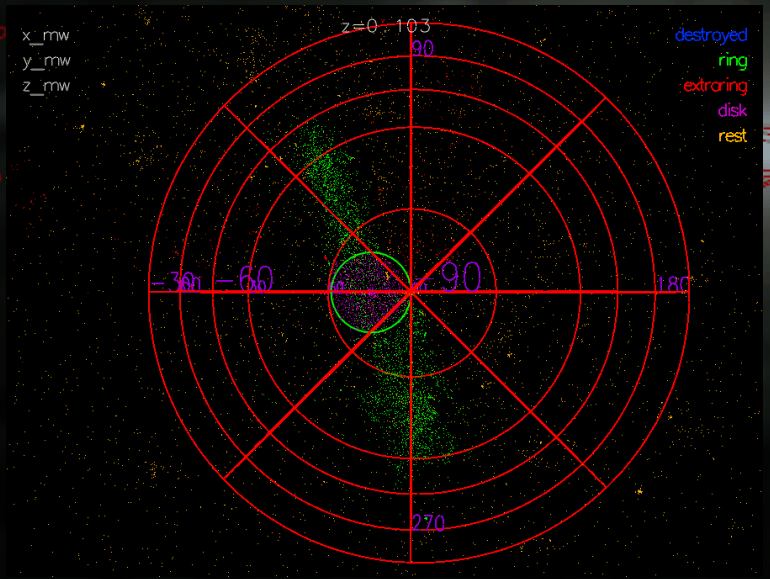
High Velocity Clouds incompatible with galactic rotation
High Velocity Clouds first observed in H I – whole sky covered
Other elements have now being observed – just sightlines
Origin, location and nature of HVCs still largely unknown

2. Cosmological Disk Simulation

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

Normal $L_\star$ galaxy, but not MW specifically

Anomalous velocity features



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Normal $L_\star$ galaxy, but not MW specifically

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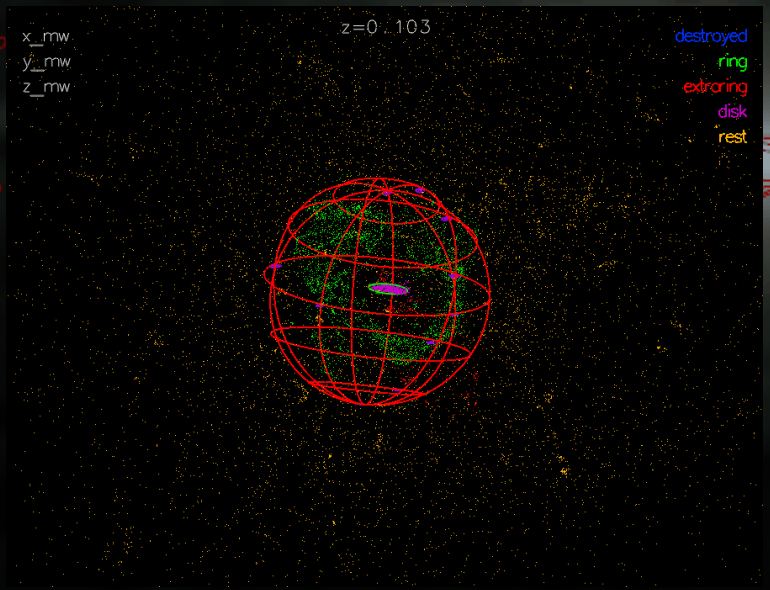


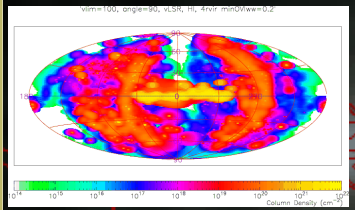
Polar ring particles came from filaments

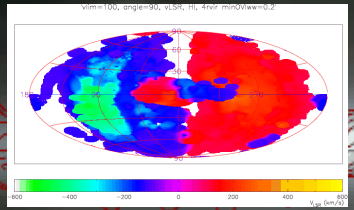
Other high column density HVCs have collapsed earlier (but lower metallicity)

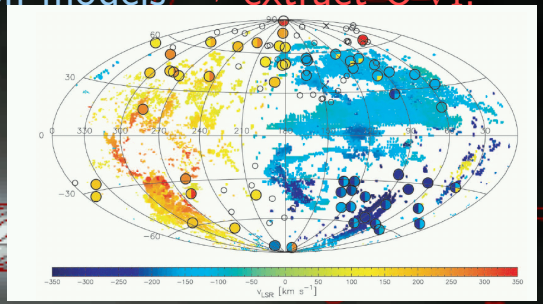
3. Observation comparisons

3.1. Moment maps

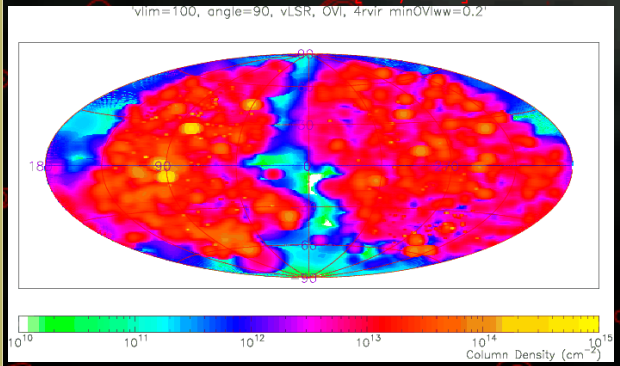
Use "solar" projection ($220\,\mathrm{km\,s^{-1}}$, $7\,\mathrm{kpc}$).
Use CLOUDY collisional ionisation models → extract O VI, C IV and H I etc.

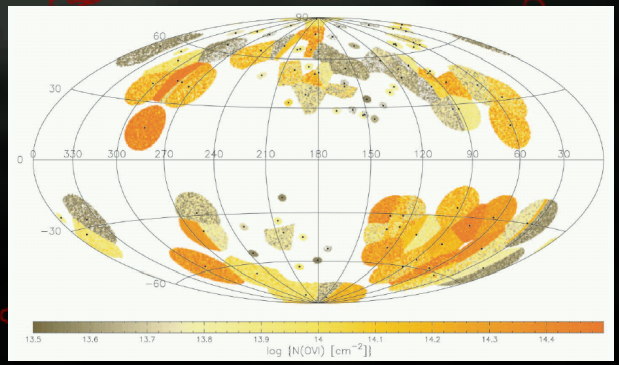






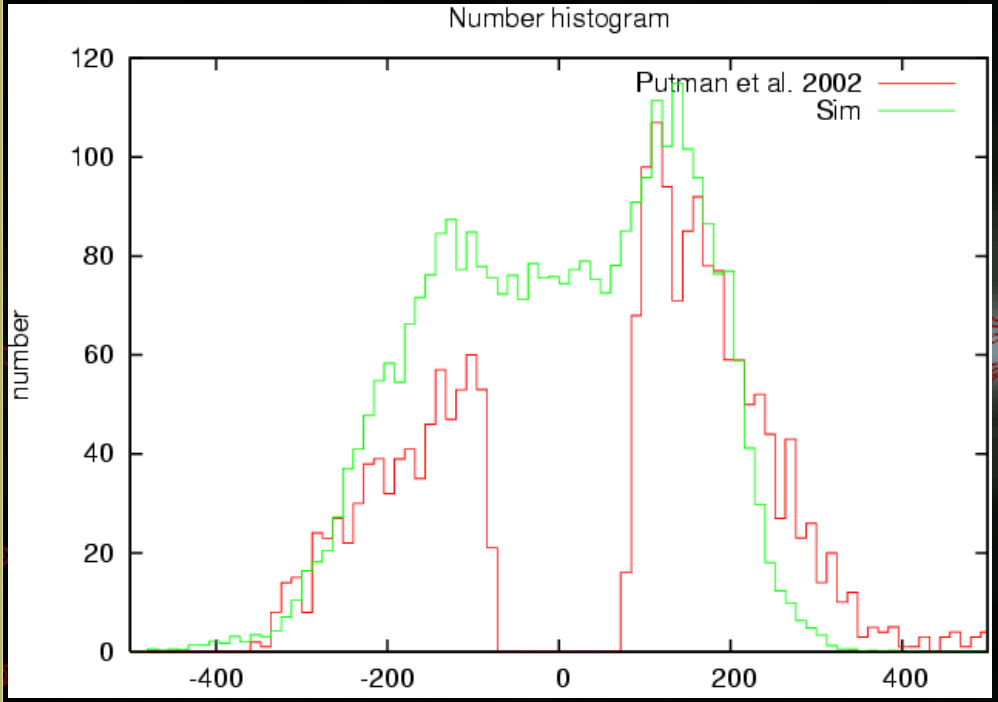
$V_{\mathrm{lim}} = \pm 100$, $[O/H] > -0.7$





H I/O VI Observations/Simulations

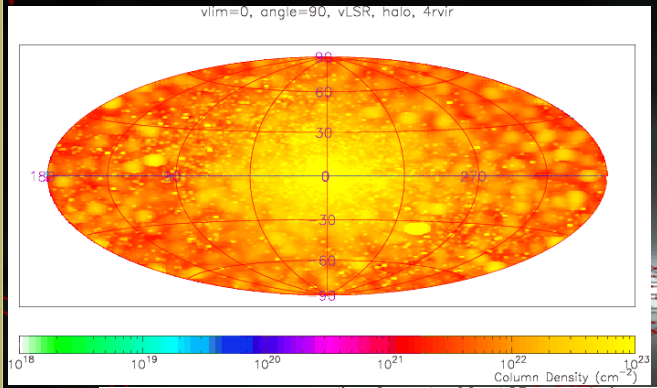
3.2. Velocity and sky coverage distributions

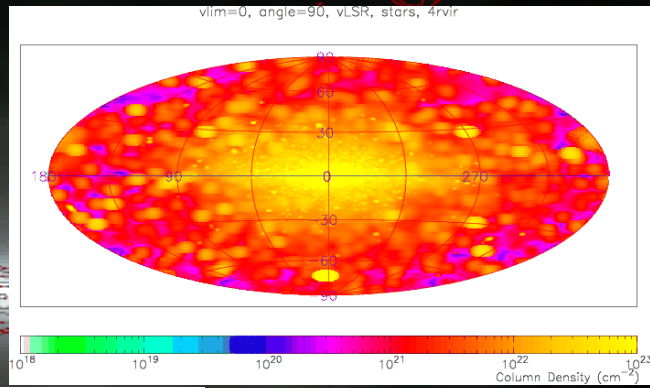


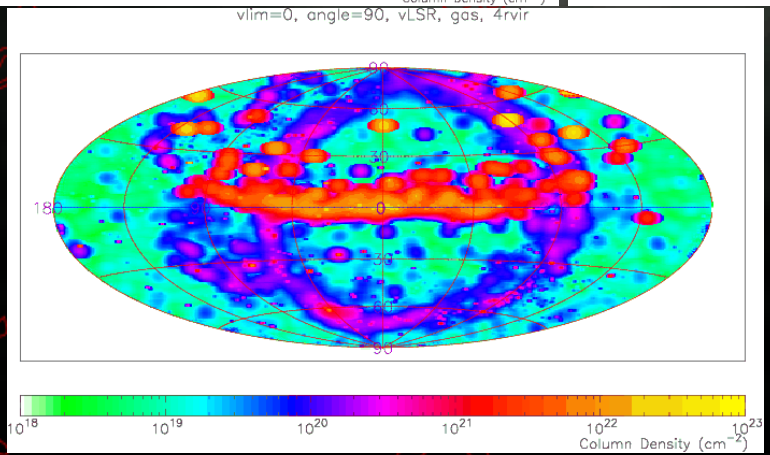
Sky coverage as function of limiting column density:
H I within an order of magnitude
O VI within two orders – but not MW!

4. Predictions

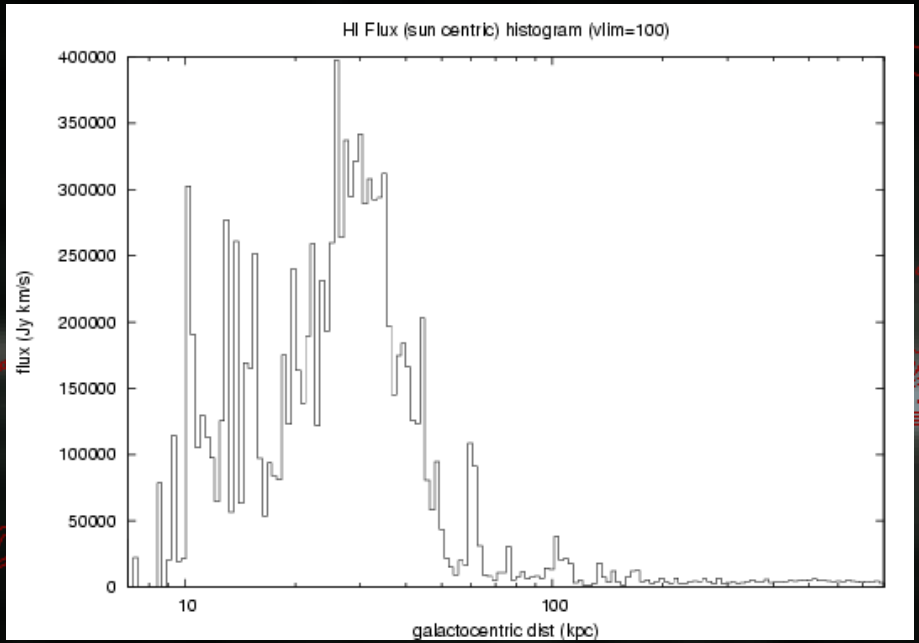
4.1. Sky distributions – column density (no cuts)







4.2. Flux weighted distance distributions



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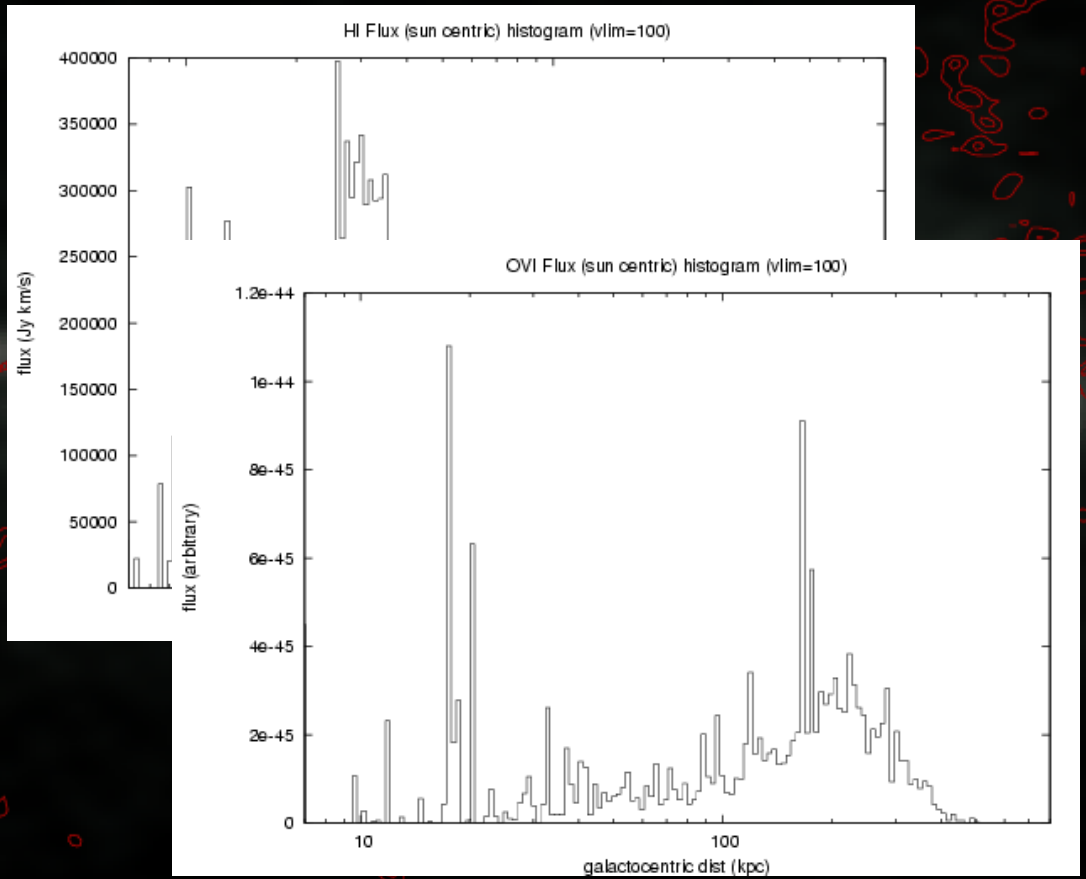


5. Conclusions

- Proof of concept: Self consistent simulation with gas dynamics, cooling, star formation, feedback, yielding a single $L\star$ disk galaxy in cosmological context
- Presence of H I and O VI HVCs (not associated with DM and stars) with roughly similar properties to MW HVCs
- Distances to H I consistent with Pisano et al. 2004; O VI diffuse and further out
- Unresolved problems – O VI column density too low (too low [O/H]; add UVB; just natural differences between galaxies?)
  → More galaxies

6. Extras

H I observations
O VI observations
H I moment maps
O VI moment maps
O VI $v_{\rm LSR}$ distributions
Sky coverage distributions
Full sky velocity (Wakker)
$v_{\rm LSR}$ flux/number histograms
O VI Ionisation fractions
[O/H] gas and stars
DM/Stars/Gas distance distributions
DM/Stars/Gas column dens

6.1. H I Observations

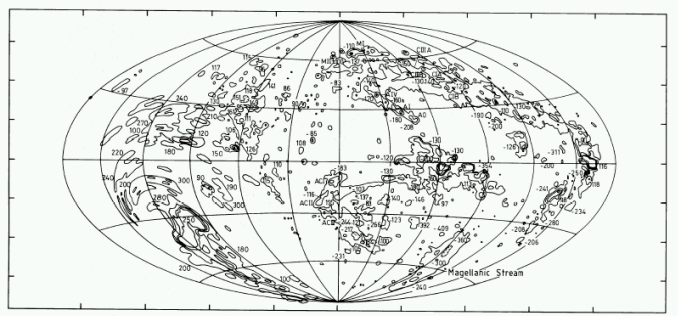
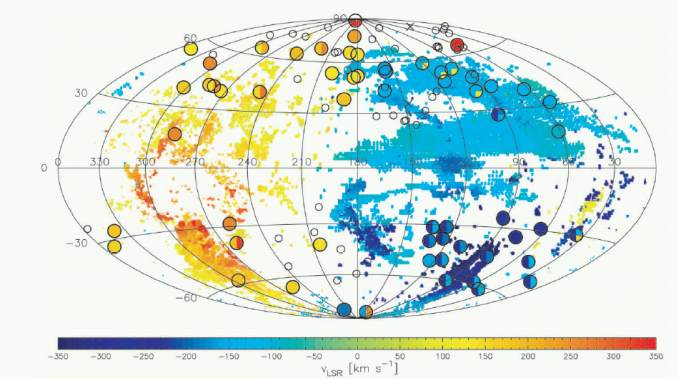


Fig. 2. Total column density map for high-velocity clouds, using both the northern and the southern survey data, in Aitoff projection, centered on $(l, b) = (180°, 0°)$. Contours are drawn at column density levels $2\ 10^{18}$, $5\ 10^{18}$, $5\ 10^{19}$ and 10^{20} cm^{-2}. The commonly used names of several complexes and clouds are indicated, as are approximate velocities at selected positions. The outer arm has been left out



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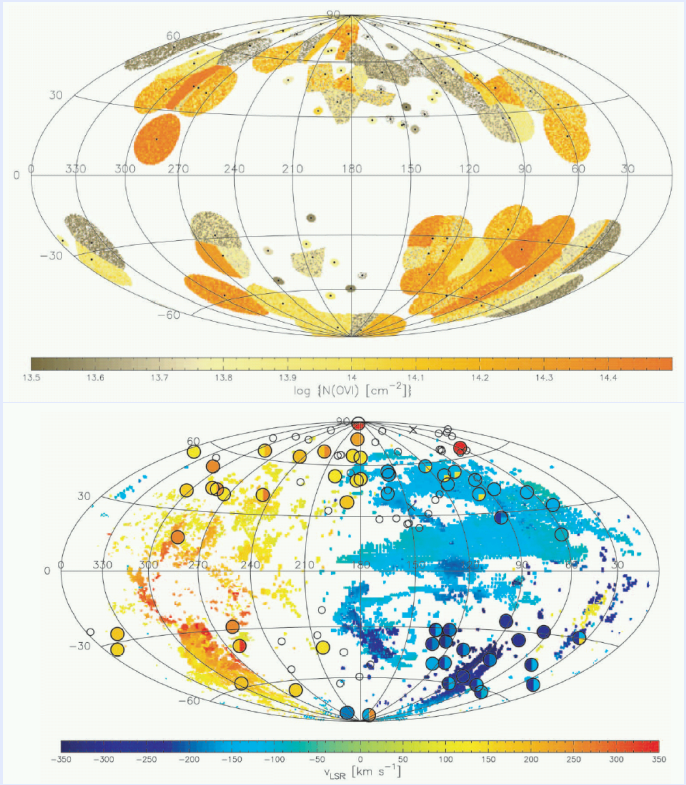
6.2. O VI Observations



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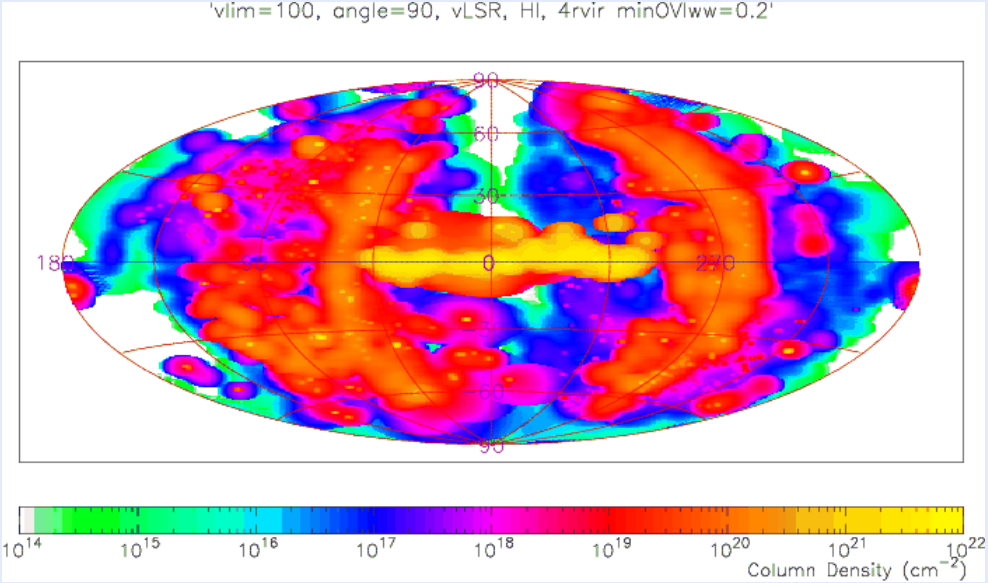
6.3. H I Moment 0 (column density)

$V_{\rm lim} = \pm 100$



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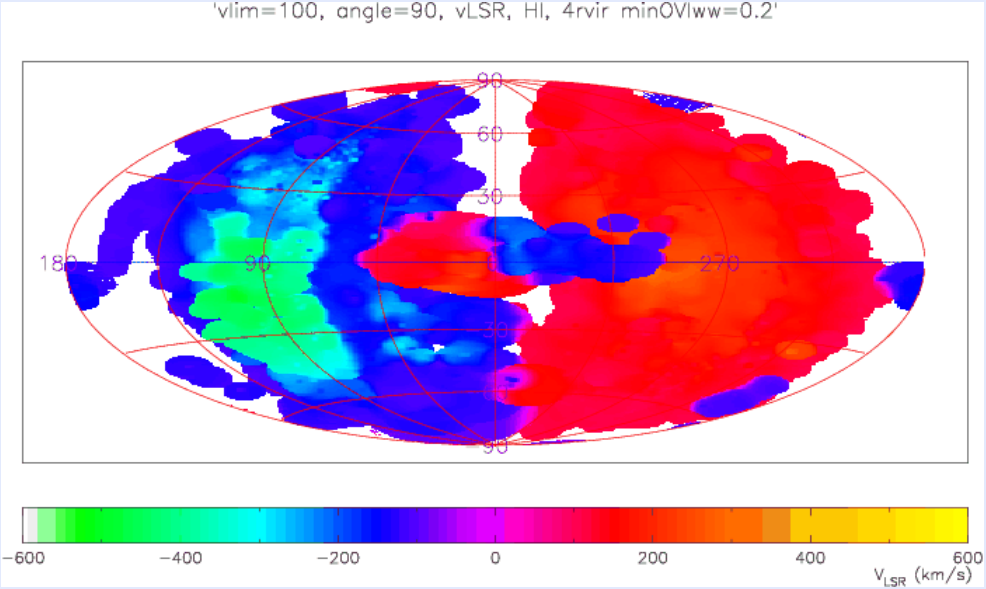
6.4. H I Moment 1

$V_{\rm lim} = \pm 100$



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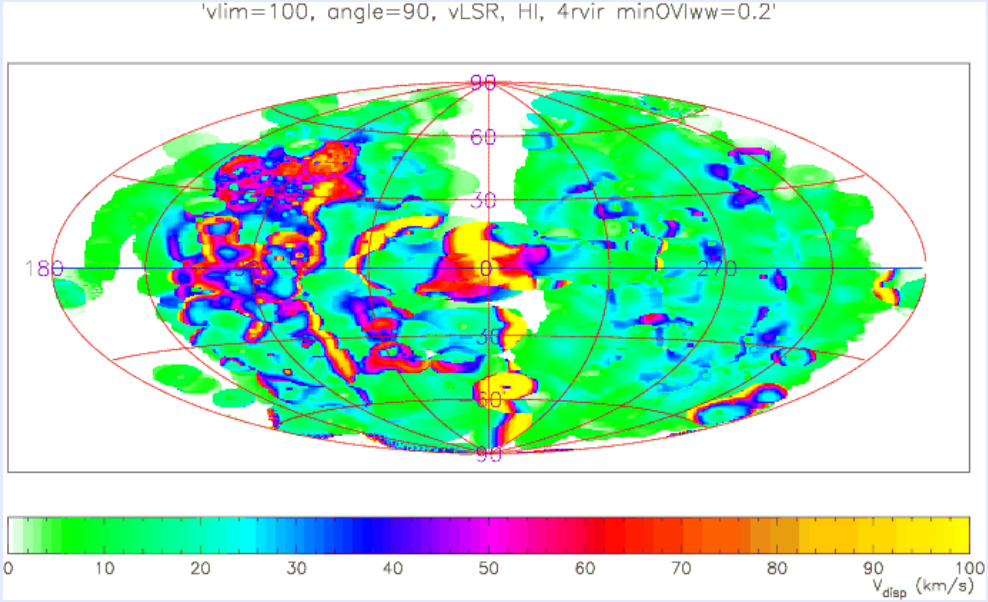
6.5. H I Moment 2

$V_{\rm lim} = \pm 100$



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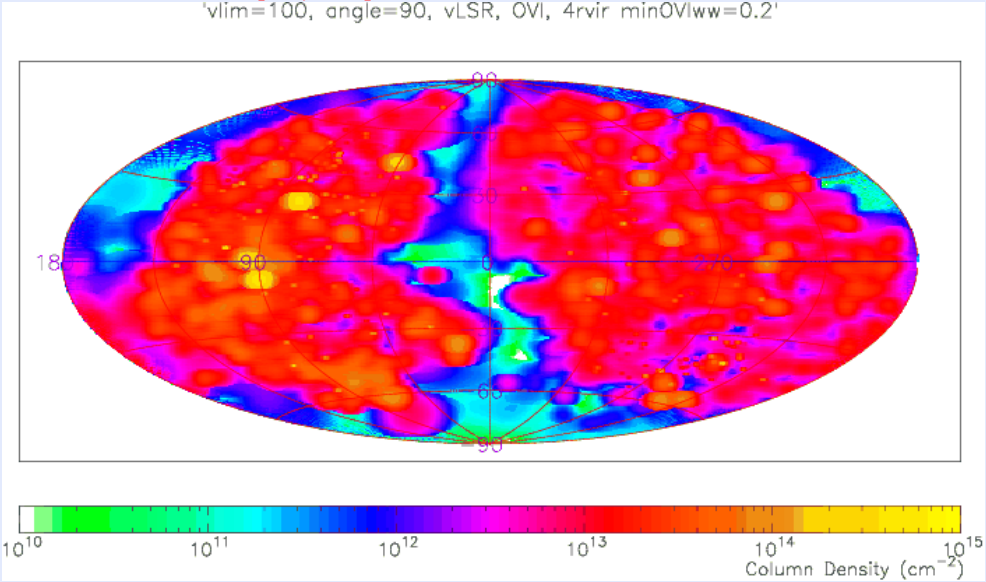
6.6. O VI Moment 0

$V_{\rm lim} = \pm 100,\ [O/H] > -0.7$



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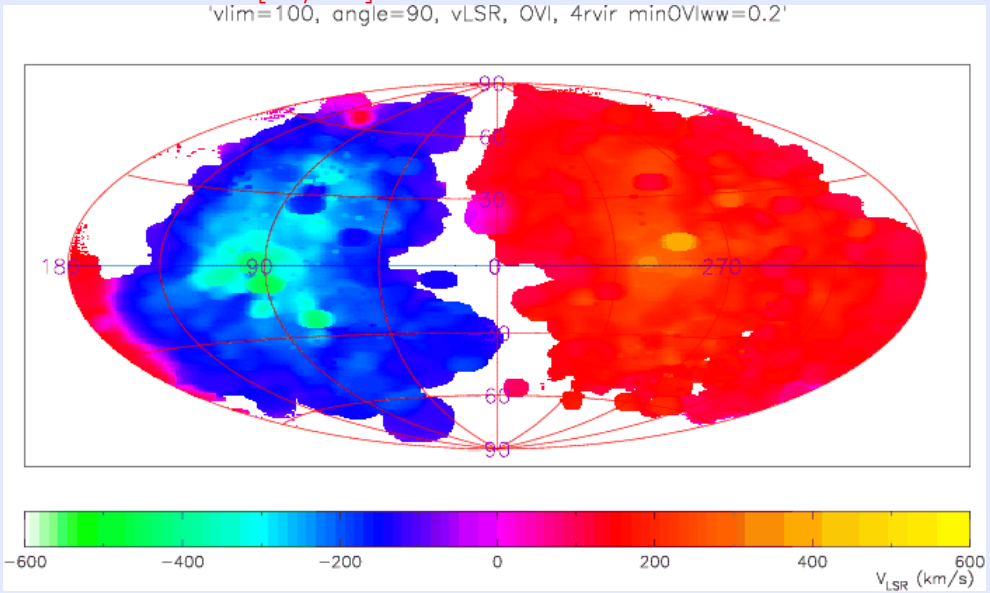
6.7. O VI Moment 1

$V_{\rm lim} = \pm 100,\ [O/H] > -0.7$



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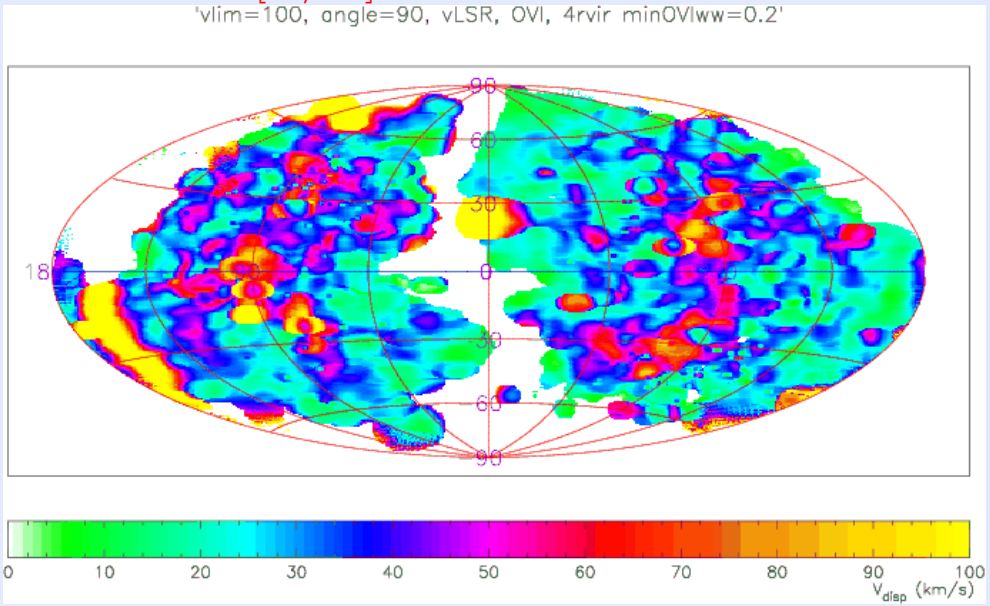
6.8. O VI Moment 2

$V_{\rm lim} = \pm 100,\ [O/H] > -0.7$



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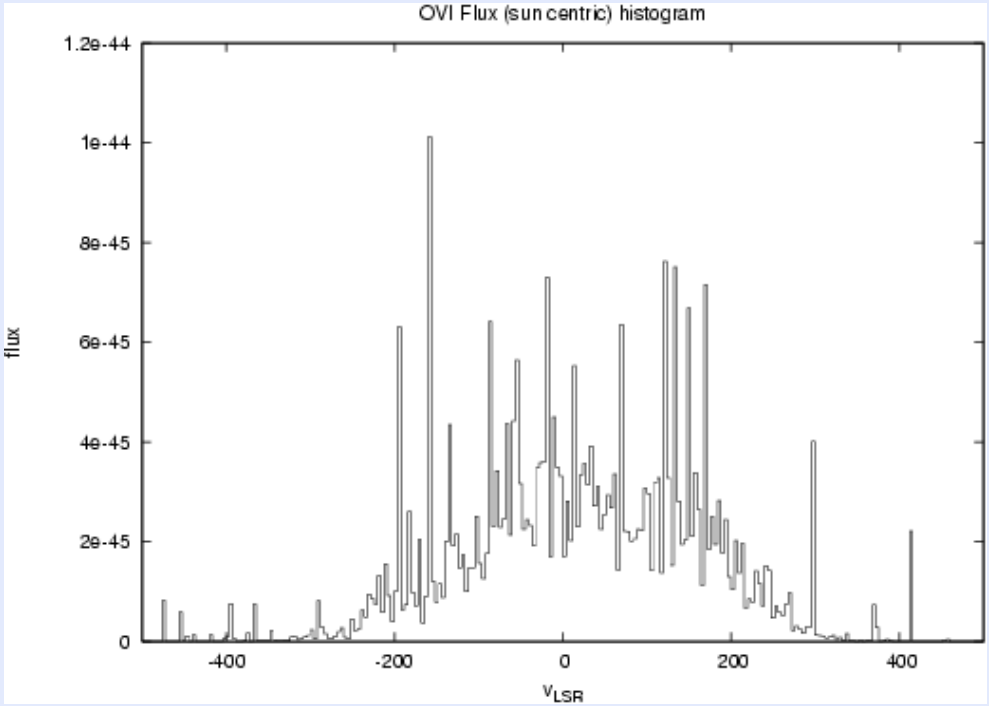
6.9. O VI v_{LSR} distributions



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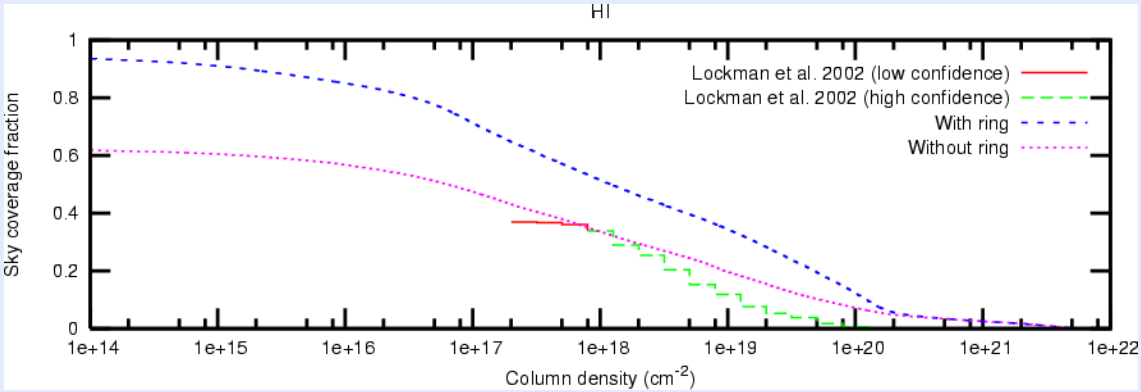
6.10. H I Sky coverage distribution



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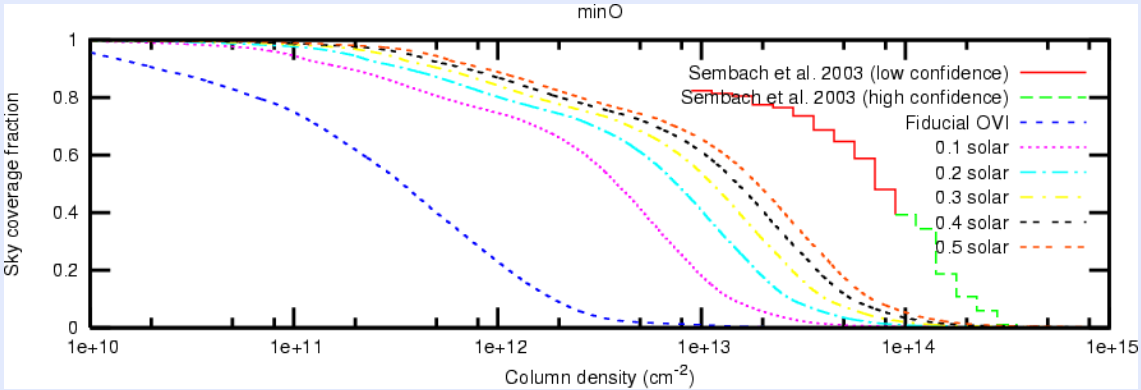
6.11. O VI Sky coverage distribution



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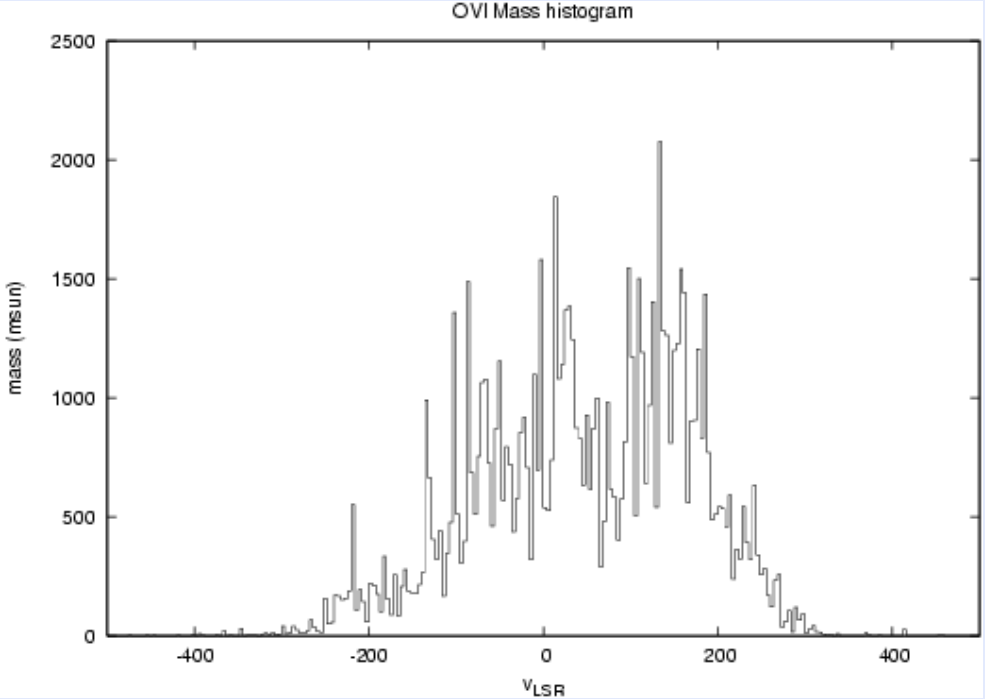
6.12. O VI v_{LSR} distributions



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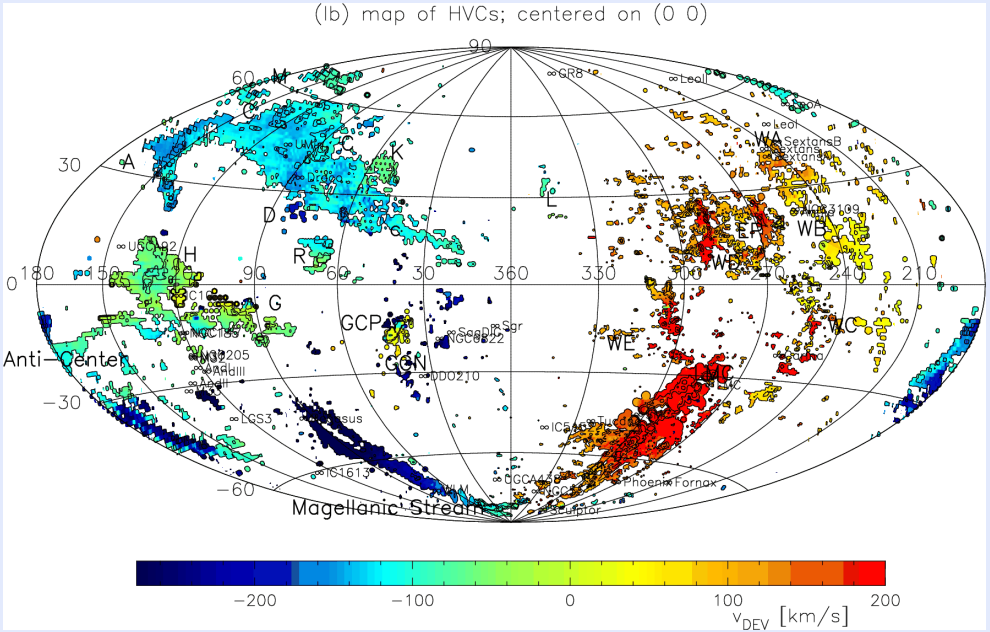
6.13. Whole sky velocities (Wakker)



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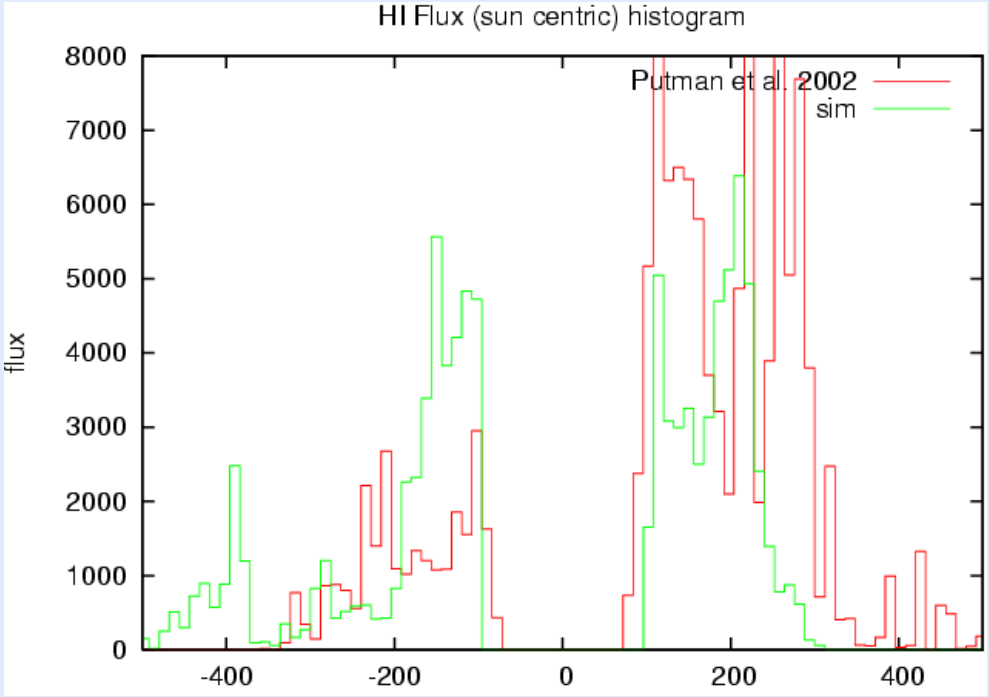
6.14. H I v_{LSR} flux histograms



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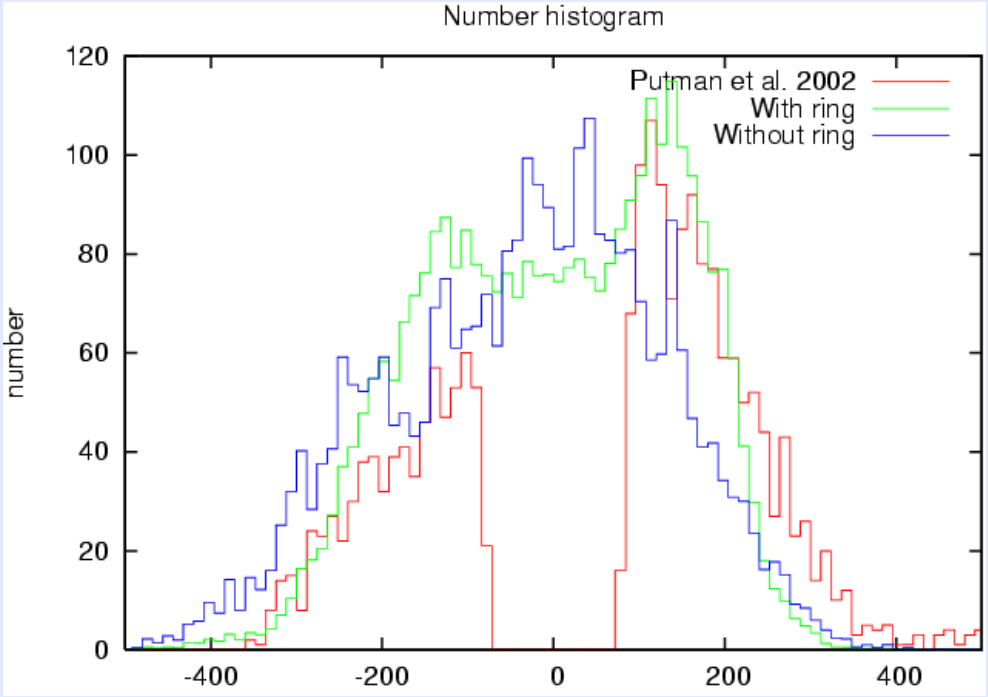
6.15. v_{LSR} number histograms, with ring cuts



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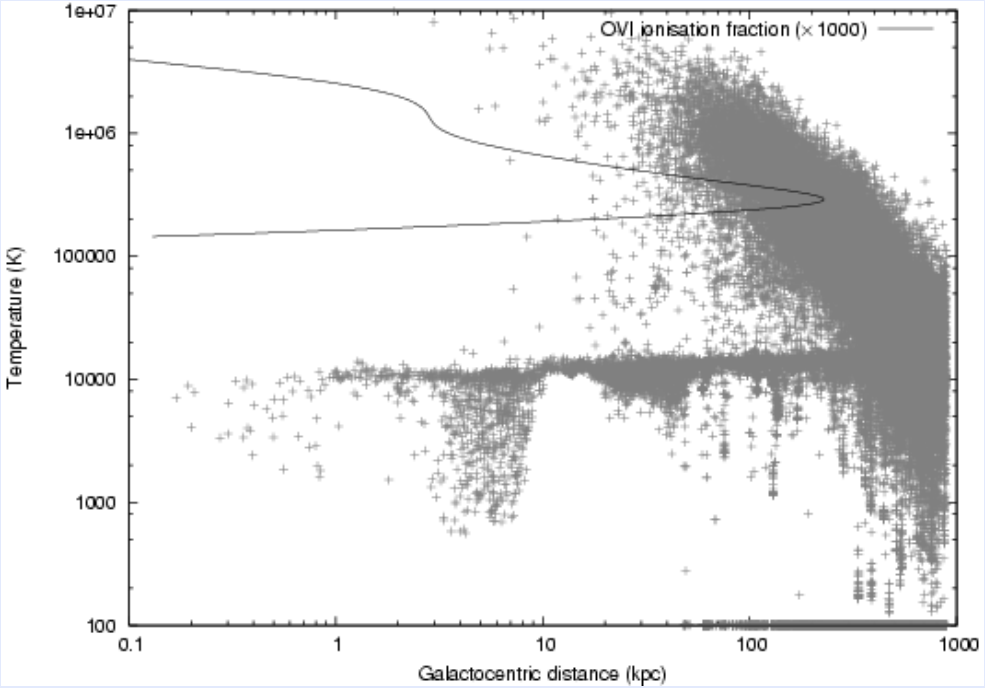
6.16. O VI Ionisation fractions, temperature gas particles

No cuts



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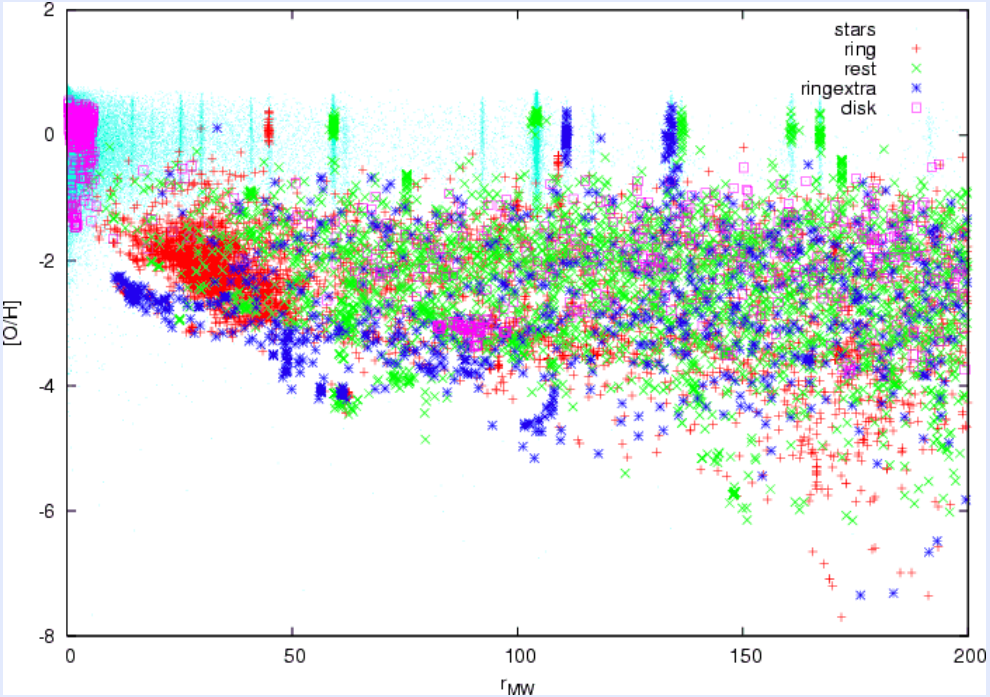
6.17. [O/H] gas and stars

$V_{\rm lim} = \pm 100$



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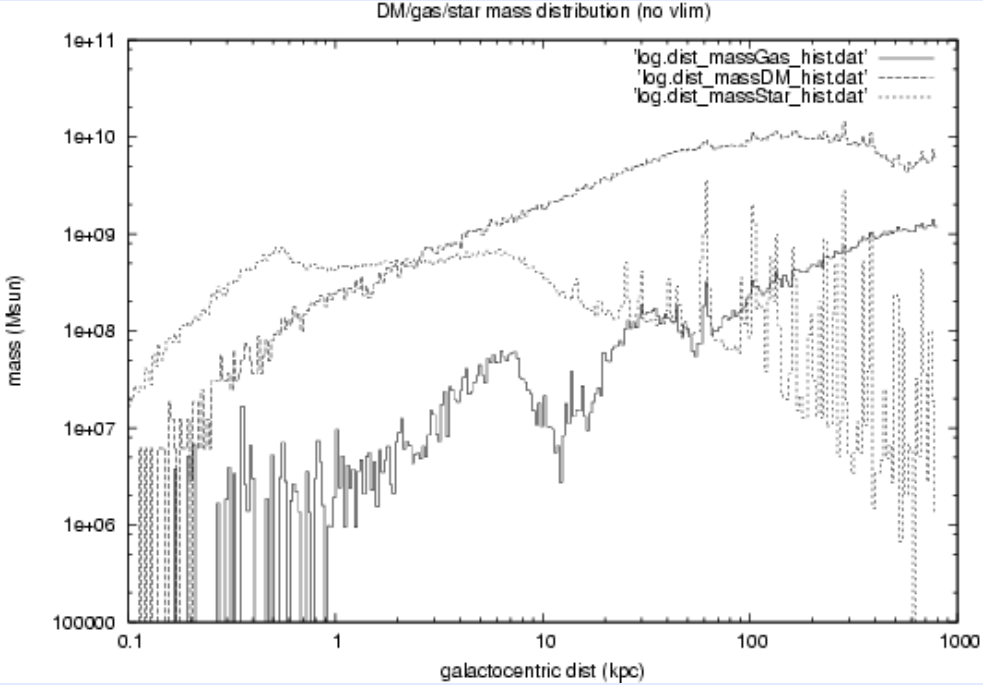
6.18. DM/Stars/Gas distance distributions



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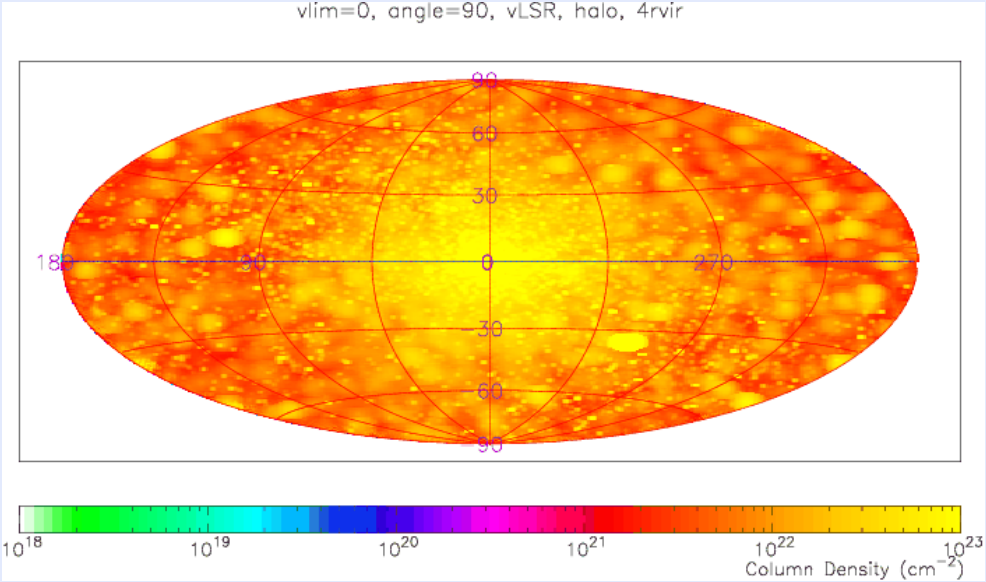
6.19. DM column density, no cuts



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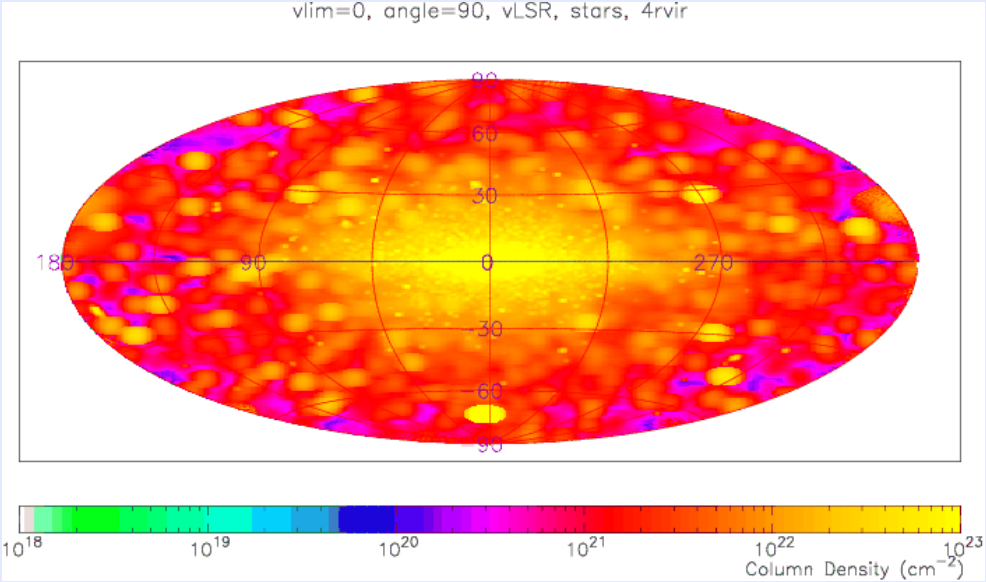
6.20. Stellar column density, no cuts



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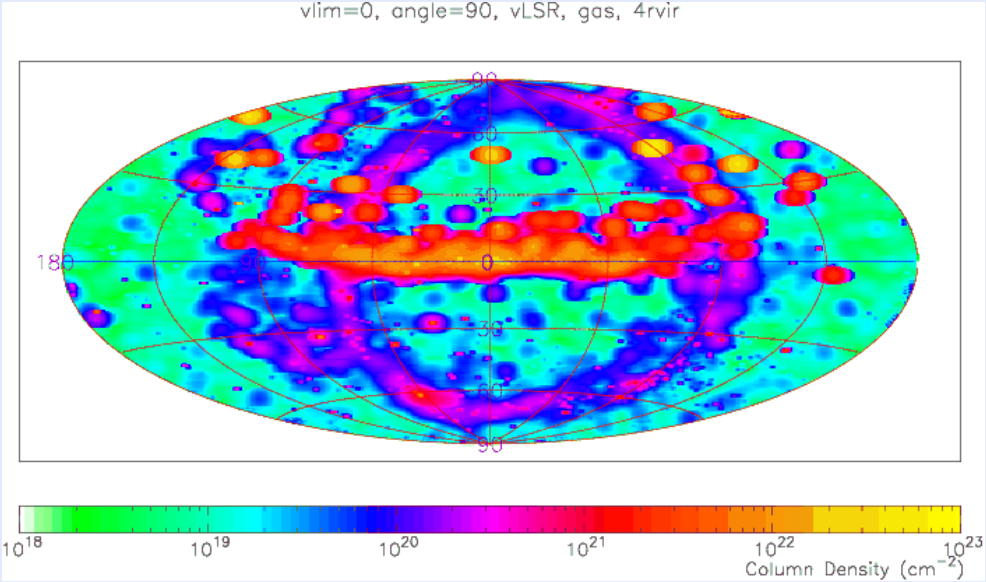
6.21. Gas column density, no cuts



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