Kinematics of the Local Group gas and galaxies in the Hestia simulations

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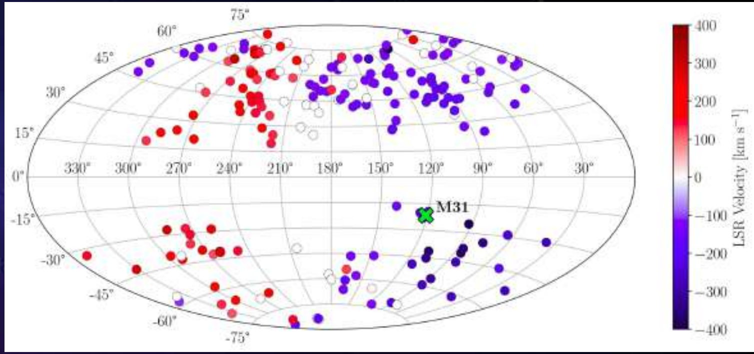
- **The Milky Way (MW) and Andromeda (M31) are the two main constituents of the Local Group (LG). Both are on a collision course due to the general motion of LG galaxies towards the group's barycenter.**

- **Observational evidence from Cosmic Origins Spectrograph (COS) onboard the Hubble Space Telescope (HST) determines the existence of a velocity dipole of high-velocity absorbers (as seen from the Local Standard of Rest or LSR), interpreted as gas streaming towards the LG barycenter [Richter P. et al. (2017)].**



Sky distribution of COS sightlines in a Hammer-Aitoff projection of Galactic coordinates. The average gas velocity in each sightline is color-coded. A velocity dipole is observed even at high latitudes, where Galactic rotation doesn't play an important role.

Richter P., et al., 2017, A&A
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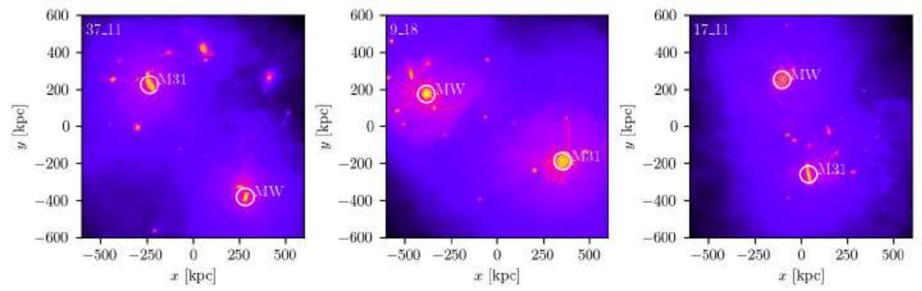
Hestia simulations emulate the LG including main cosmographic features such as the Virgo cluster, the local void and the local filament. We focus on the three high resolution runs 37_11, 9_18 and 17_11.

The three runs have increasingly higher infall velocity: 9, -74 and -102 km s^{-1} for 37_11, 9_18 and 17_11 respectively (negative velocities mean that the two main galaxies are approaching).



Gas mass projection for the three simulations used in this work, the two main galaxies (MW and M31) are the main constituents of the LG, while several other galaxies can be seen in the Intragroup Medium (IGrM) or as satellites to MW and M31.

To simulate observations, we choose a Sun position in each simulation so that M31 position matches the observed Galactic longitude l = 121°.

We approximate the Sun's motion around the MW as being purely tangential. We approximate this velocity by the galaxy's circular velocity at the observer radius, which we set as r = 8 kpc.

This motion of the Sun around the MW imprints a dipole velocity pattern in the sky, though at high galactic latitudes this effect plays a minor role. We generate sky velocity maps from this simulated LSR.

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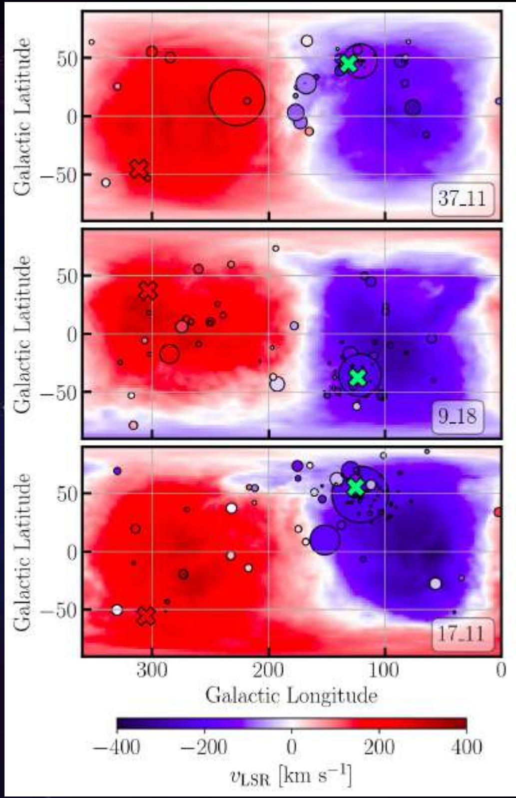
- **Simulations in which the MW and M31 are approaching (9_18 and 17_11) show a velocity dipole even at high Galactic latitudes, supporting the interpretation that the existing dipole is in part due to the overall infalling motion of the LG gas towards the barycenter.**

- **Galaxies of the LG show a similar dipole pattern than that of the intragroup gas.**

➔ **This brings up the question, what happens if we eliminate Galactic rotation from the velocity field?**



Radial velocity of the gas as seen from the LSR. Galaxies are marked with circles and the barycenter (anti-barycenter) direction is marked with a green (red) cross.

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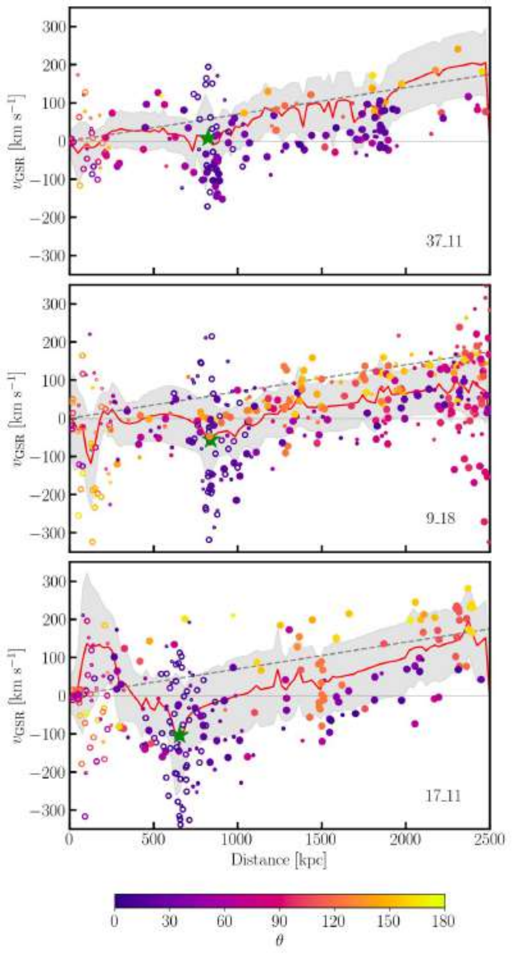
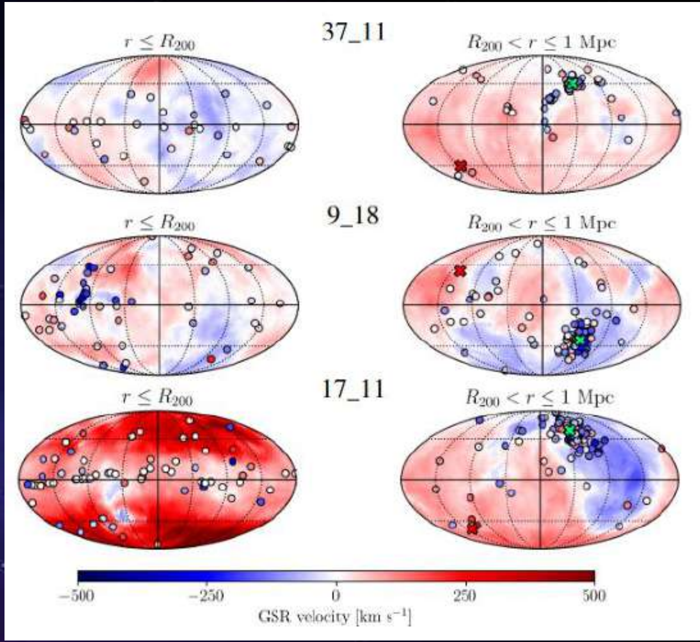
- When transformed to the Galactic Standard of Rest (GSR, that is velocities referred to that of the MW), there is a clear relation between galaxies velocities and their position in the sky.
- We define theta for each galaxy as the angle between M31 and its position in the sky. When plotting the GSR velocity of LG galaxies as a function of distance, it is clear that galaxies in the general direction of M31 tend to have more negative velocities than the ones in the opposite direction (theta is color-coded in the figure to the right).
- This goes in line with the interpretation that material in front of the MW is being rammed into by the MW itself, while material behind tends to lag. The red line shows the average IGrM gas velocity, and the grey shade goes up to one standard deviation. Simulations show an increasingly wider spread with higher infall velocities.





Mollweide projection of mean mass-weighted gas and galaxies GSR velocities in the LG for the three Hestia high-resolution simulations. Circles indicate galaxies (also color-coded) and the green (red) cross indicates the barycenter (anti-barycenter) direction.

For distances greater than R_{200}, the dipole pattern is evident even when the Galactic rotation component has been removed, particularly in 9_18 and 17_11 in which the MW and M31 are approaching each other.

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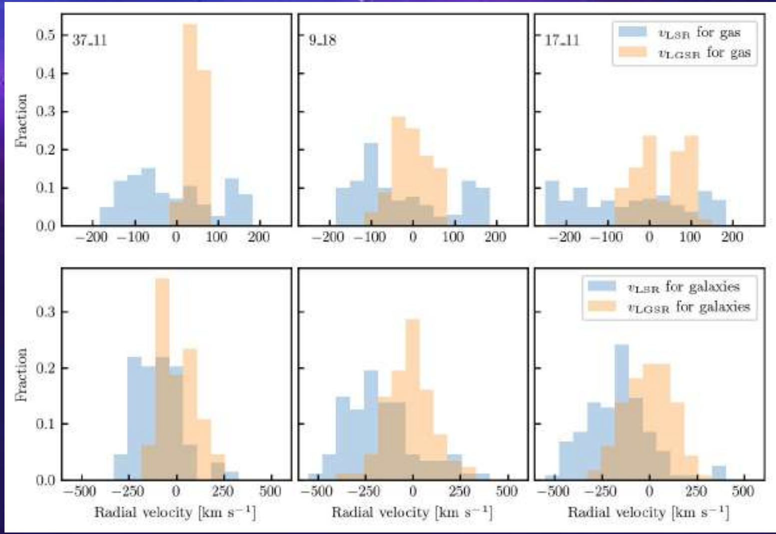
If we refer velocities to the Local Group Standard of Rest (LGSR) we also eliminate the MW peculiar motion through the LG.

When considering velocities of gas and galaxies outside the virial radius and in the quadrants containing the barycenter and anti-barycenter, there is a substantial narrowing of the distributions when transforming from the LSR frame to the Local Group Standard of Rest (LGSR).



Conclusions

- The dipole velocity pattern is visible from the LSR in the three simulations.
- When removing Galactic rotation and referring velocities to the GSR, the dipole pattern persists in simulations in which the galaxies are approaching (9_18 and 17_11)
- From these three simulations, we consider 17_11 to be the one that best resembles the LG kinematically. We attribute this to the radial velocity between MW and M31 being the most similar to it's measured value (-109 km s⁻), making the dipole velocity pattern more evident.

In a follow-up work we will examine quantitatively how different ion species contribute to the gas flow at z = 0.

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