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Intermediate- and high-velocity clouds in the Milky Way II: evidence for a Galactic fountain with collimated outflows and diffuse inflows

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ABSTRACT
We model the kinematics of the high- and intermediate- velocity clouds (HVCs and IVCs) observed in absorption towards a sample of 55 Galactic halo stars with accurate distance measurements. We employ a simple model of a thick disc whose main free parameters are the gas azimuthal, radial and vertical velocities (v_ϕ, v_R and v_z), and apply it to the data by fully accounting for the distribution of the observed features in the distance-velocity space. We find that at least two separate components are required to reproduce the data. A scenario where the HVCs and the IVCs are treated as distinct populations provides only a partial description of the data, which suggests that a pure velocity-based separation may give a biased vision of the gas physics at the Milky Way's disc–halo interface. Instead, the data are best described by a combination of an inflow and an outflow components, both characterised by rotation with v_ϕ comparable to that of the disc and v_z of $50-100\,\mathrm{km\,s^{-1}}$. Features associated with the inflow appear to be diffused across the sky, while those associated with the outflow are mostly confined within a bi-cone pointing towards ($l=220°$, $b=+40°$) and

Выборка

Understanding the nature of the HVCs and IVCs requires the knowledge of three key properties: their distance, metallicity and 3D kinematics. Considerable observational efforts have been devoted to determine the former two properties (e.g., Wakker 2001; Richter et al. 2001; Collins et al. 2003; Tripp et al. 2003; Wakker et al. 2007, 2008; Thom et al. 2006, 2008; Zech et al. 2008; Lehner & Howk 2010; Fox et al. 2016). The picture that consistently emerges from these studies is that the IVCs are nearby systems ($d < 1$–2 kpc) that have near or Solar metallicity, while the HVCs are located at larger distances ($d < 10$–15 kpc)[1] and feature metallicity in the range 0.1–1.0 $Z_{\odot}$. This dichotomy has been traditional interpreted as an evidence for a distinct origin for the two cloud populations: internal for the IVCs, external for the HVCs. While the GF is the only plausible internal mechanism that can bring gas at the DHI, several options exist for the external scenario. These include spontaneous condensation of the hot corona as a consequence of thermal instability, an option that is highly debated amongst the theoretical community (e.g., Binney et al. 2009; Nipoti 2010; Sobacchi & Sormani 2019; Sormani & Sobacchi 2019), gas stripped or ejected from satellites (e.g., Bland-Hawthorn et al. 1998; Putman 2006; Olano 2008), fragments of gas filaments accreting from the cosmic web onto the Galaxy (e.g., Kereš

- УФ-спектры 55 звезд гало с известными расстояниями (COS/HST, Gaia)
- 78 систем линий ионизованного газа (до SiIV)
- Лучевая скорость от 40 до 90 км/с – IVC, >90 км/с – HVC
- Вероятностная локализация облака в конусе

Модель

- Толстый, плоский диск: постоянная плотность по радиусу, вертикальное распределение $\sinh(z/h)/\cosh^2(z/h)$, разное h у IVC и HVC (1.0 кпк и 2.8 кпк)
- Дисперсия скоростей облаков 20 км/с
- Три свободных параметра для каждого облака: компоненты скорости в цилиндрической системе координат Галактики

Все облака дружно вращаются!

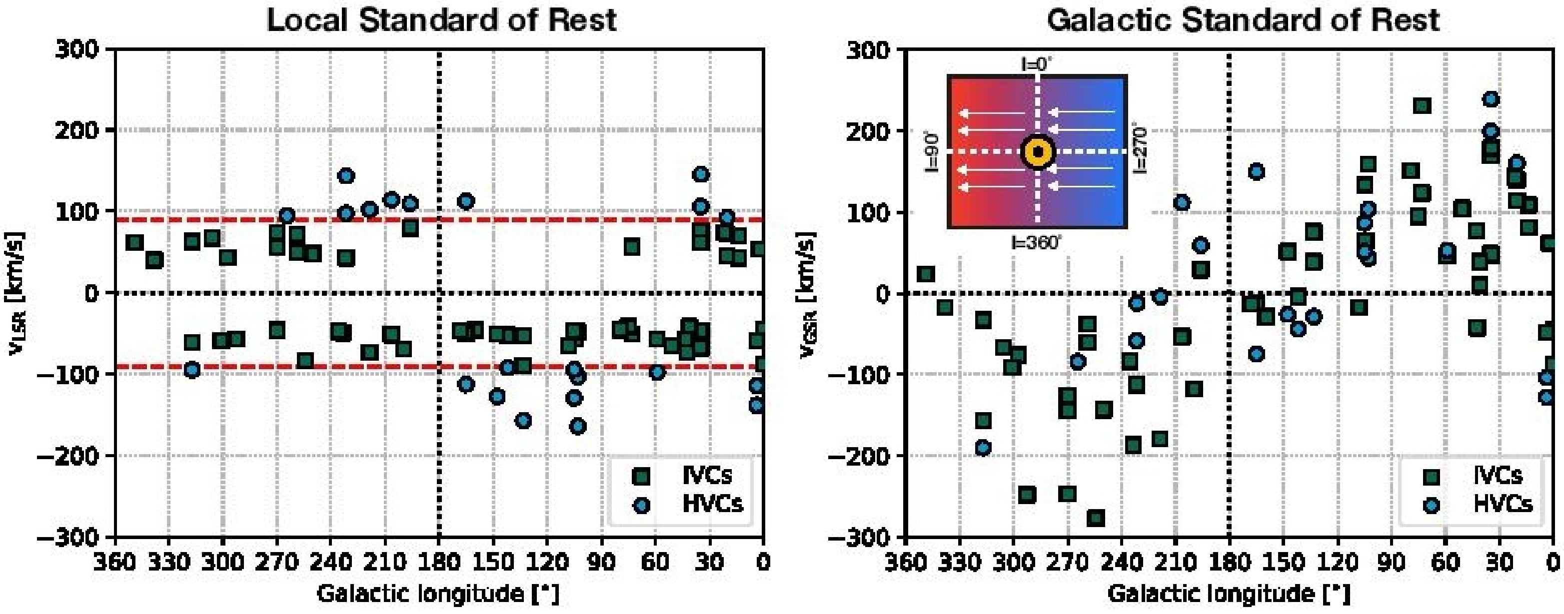

Figure 1. Longitude-velocity diagrams for the absorption features studied in this work. IVCs and HVCs are represented by green squares and blue circles, respectively. The *left* panel shows velocities in the LSR, where no significant trends with longitude is visible, suggesting the absence of strong peculiar motions in this reference frame. The *right* panel shows velocities in the GSR. The resulting sinusoidal pattern indicates that the absorbing gas streams along the same direction of the Sun motion, as illustrated in the inset on the top-left. Both panels convey the same message: the dominant motion of the absorbing material is rotation around the Galactic centre with a speed comparable to that of the disc.

Два сценария:

Table 1. Best-fit parameters for our two-component models of ionised gas in the Galactic halo. The model likelihoods are reported in the last row.

parameter	Scenario 1		Scenario 2	
	IVCs ($\mathrm{km\,s^{-1}}$)	HVCs ($\mathrm{km\,s^{-1}}$)	Inflow ($\mathrm{km\,s^{-1}}$)	Outflow ($\mathrm{km\,s^{-1}}$)
v_ϕ	224 ± 19	143^{+67}_{-33}	233 ± 18	232^{+91}_{-54}
v_z	-57^{+18}_{-13}	-102^{+33}_{-59}	-67^{+8}_{-11}	62^{+55}_{-40}
v_R	25^{+15}_{-20}	63^{+45}_{-53}	30^{+15}_{-11}	-22^{+39}_{-35}
$\log \mathcal{L}$	-203.16		-287.65	

- 1) разная природа средне- и высокоскоростных облаков – не получаются 20 из 78 систем
- 2) Комбинация вытекания и втекания – все получилось!

Главный результат: два фонтана и диффузная аккреция

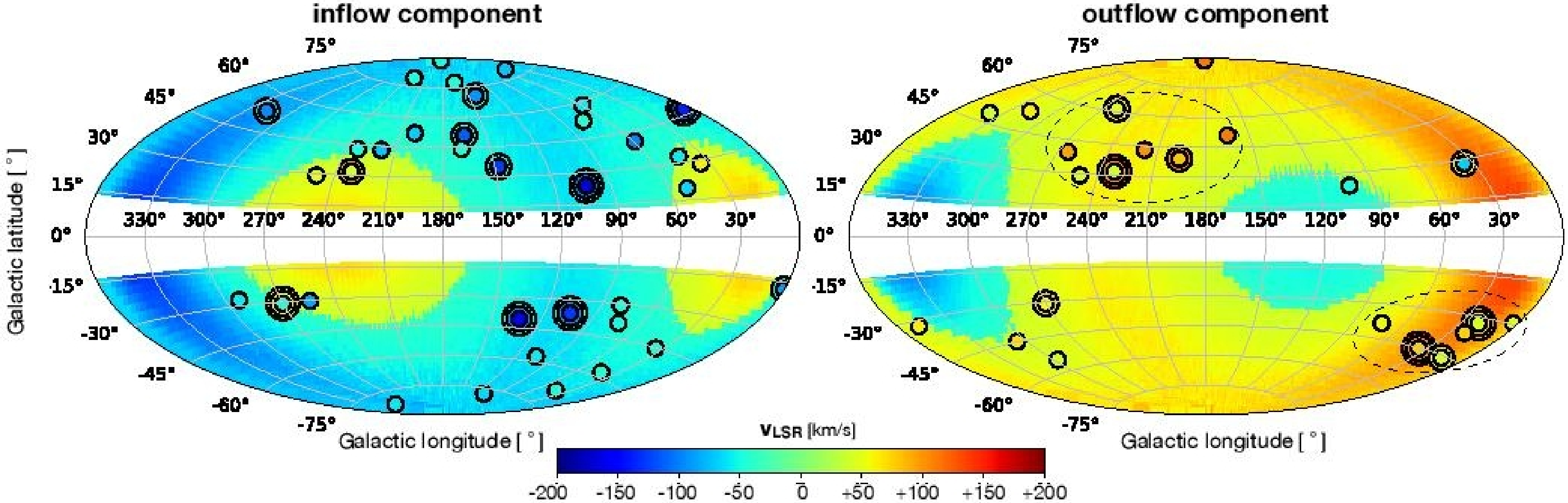

Figure 4. Comparison between the all-sky velocity fields predicted by our best-fit inflow+outflow models (background colours) and the LSR velocity of the observed absorption features (coloured circles). Concentric circles are used when multiple detections are found towards the same target star. The map on the left (right) shows the 52 (33) absorbers compatible with the inflow (outflow) component. The dashed ellipses mark the locations of the bi-conic outflow encompassing most of the observed feature associated with the outflow component.