The Smith Cloud and its dark matter halo

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ABSTRACT

The Smith Cloud is an extraordinary gas structure with a cometary tail being accreted onto the Galaxy (Lockman et al. 2008). Using hydrodynamical simulations, we find that it could not have survived a passage through the Galactic disk unless the cloud is encapsulated by dark matter. As it stands, the Smith Cloud might represent the best testing ground for dark matter content and confinement in these puzzling gaseous systems surrounding our Galaxy. We determine flux upper limits to the gamma-ray emission around a hypothesized dark matter core in the Smith Cloud, and set constraints on the dark matter annihilation cross section (Nichols et al. 2014)

DYNAMICAL HISTORY

Under conservative assumptions, the derived velocity of the Smith Cloud indicates that it will have undergone at least one passage of the Galactic disk. Without arising from the disk and a tidal event being unlikely, the origin of the Smith cloud is likely to be from extragalactic infalling gas (Fig. 1). Given its relative proximity, derivable orbit and large mass it appears as the ideal astrophysical site to study dark matter confinement of HI clouds (Mirabal 2013).

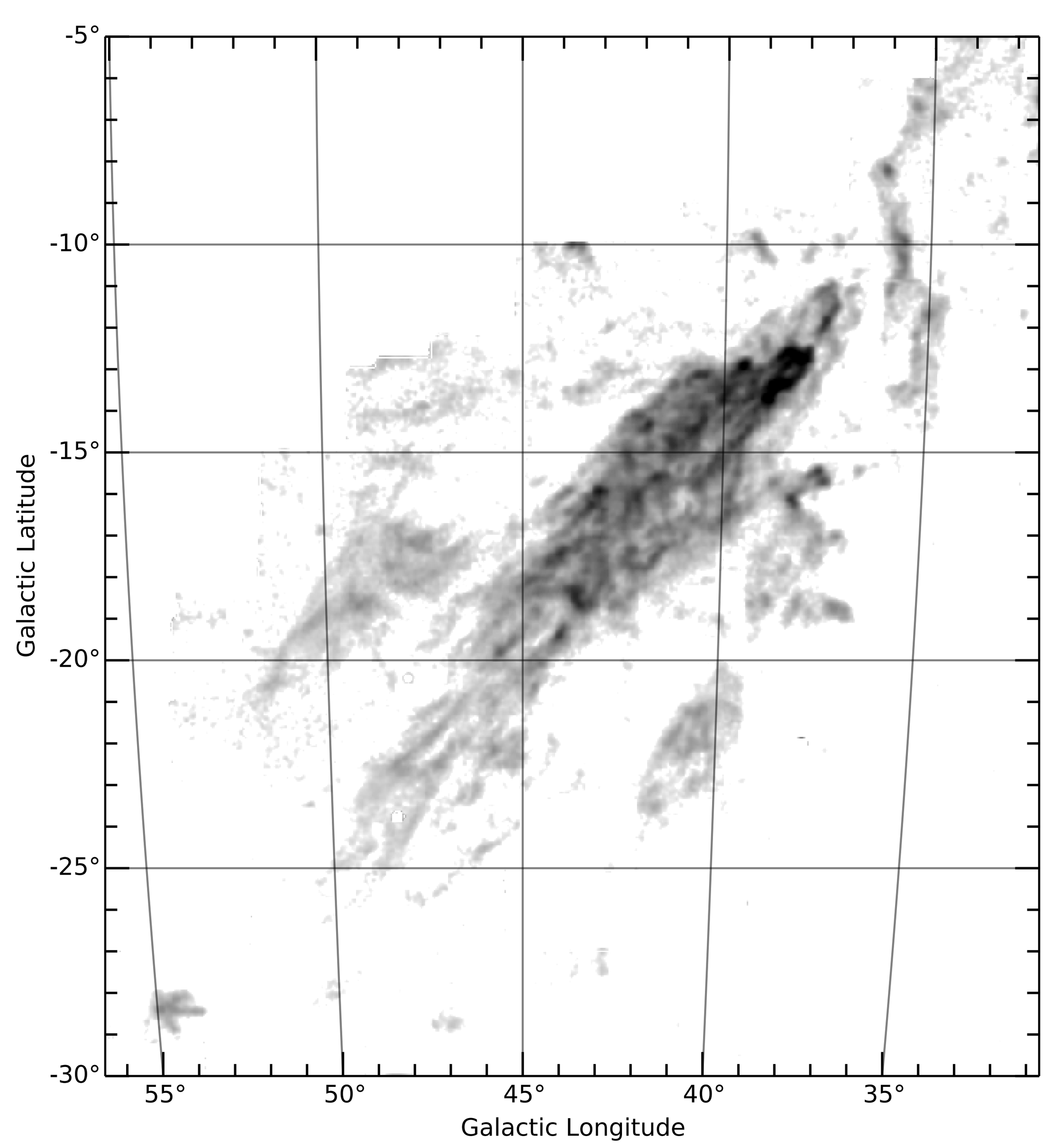

Fig. 1. Observed HI 21 cm GBT image of the Smith Cloud.

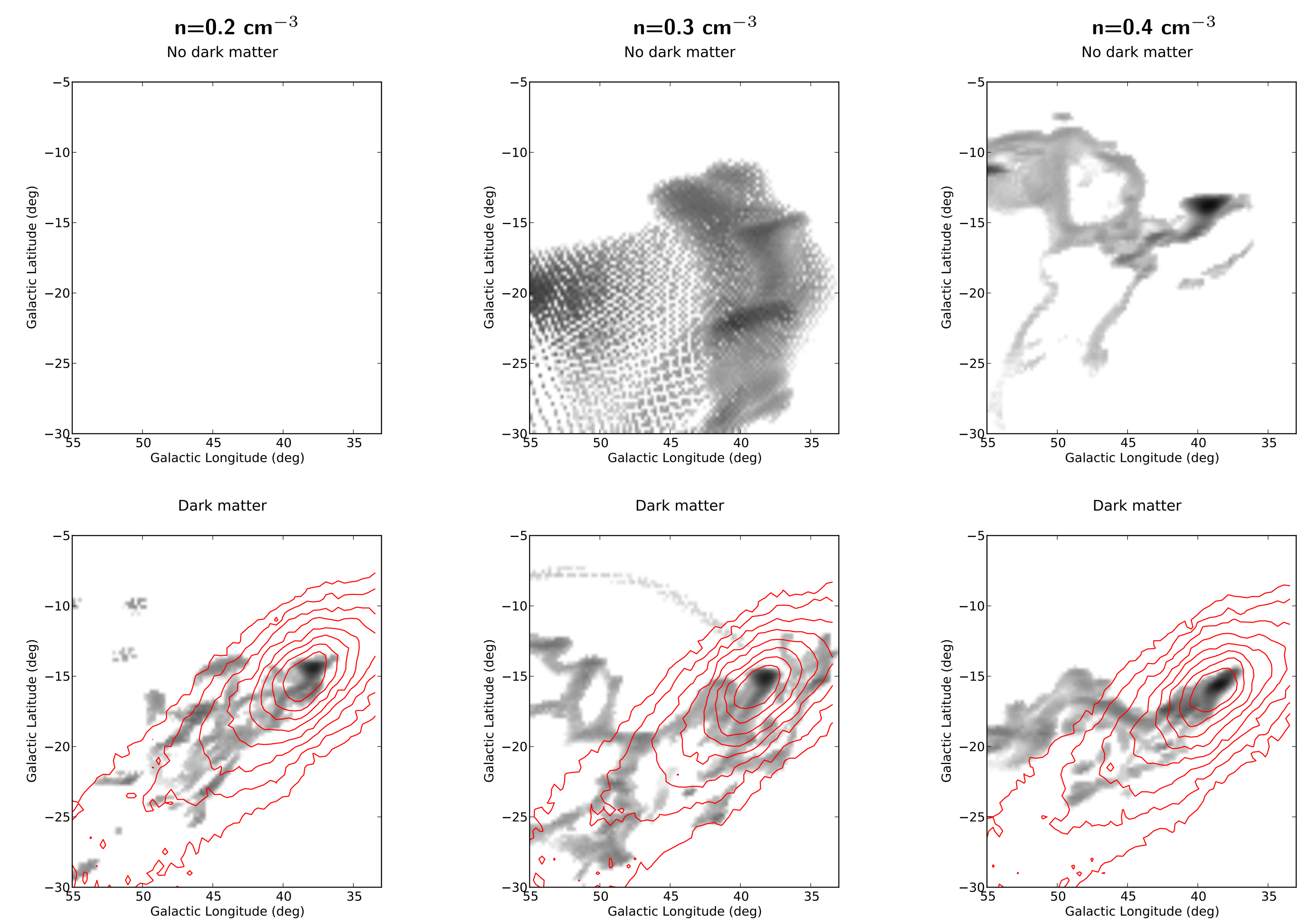

Fig. 2. Simulated HI intensity for a HVC that has passed through the Galactic disk, without dark matter (top row), or encapsulated by a dark matter halo (bottom row). Dark matter is shown in red.

NUMERICAL SIMULATIONS

In an attempt to replicate the observed mass, morphology and HI distribution of the Smith Cloud today (Fig. 1), we use the Adaptive Mesh Refinement (AMR) code RAMSES (Teyssier 2002). Using RAMSES we simulated the disk passage of both a dark matter enclosed HI cloud and a dark matter free cloud, along the Smith Cloud's expected orbital path from peak height above the disk 204 Myr ago and compared it to new HI observations. We include a realistic progenitor to the Smith Cloud and a realistic model of the Milky Way which includes live stellar and gaseous disks and dark matter halo. The Smith Cloud progenitor is modeled over a range of densities. In Fig. 2 we show the expected HI density today (rescaled to maximum density in each case) for both dark matter free clouds (top row) as well as dark matter encapsulated clouds (bottom row). With a dark matter halo, a cloud is able to survive the passage through substantially intact.

FERMI-LAT OBSERVATIONS AND DARK MATTER LIMITS

To search for potential gamma-ray emission from the dark matter annihilation of weakly interacting particles (WIMPs) around the Smith Cloud, we used Fermi-LAT observations carried out between 2008 August 4 to 2013 June 11 (~4.85 years of data). The analysis is performed using the v9r27p1 Fermi Science tools. With the current Fermi data, we do not see obvious correspondence between the gamma-ray emission and the observed HI morphology (Fig. 3). We exclude WIMPs annihilating into b quarks with an annihilation cross section of 3 x 10^{-25} cm^3 s^{-1} for masses around 10 GeV (see also Drlica-Wagner et al. 2014).

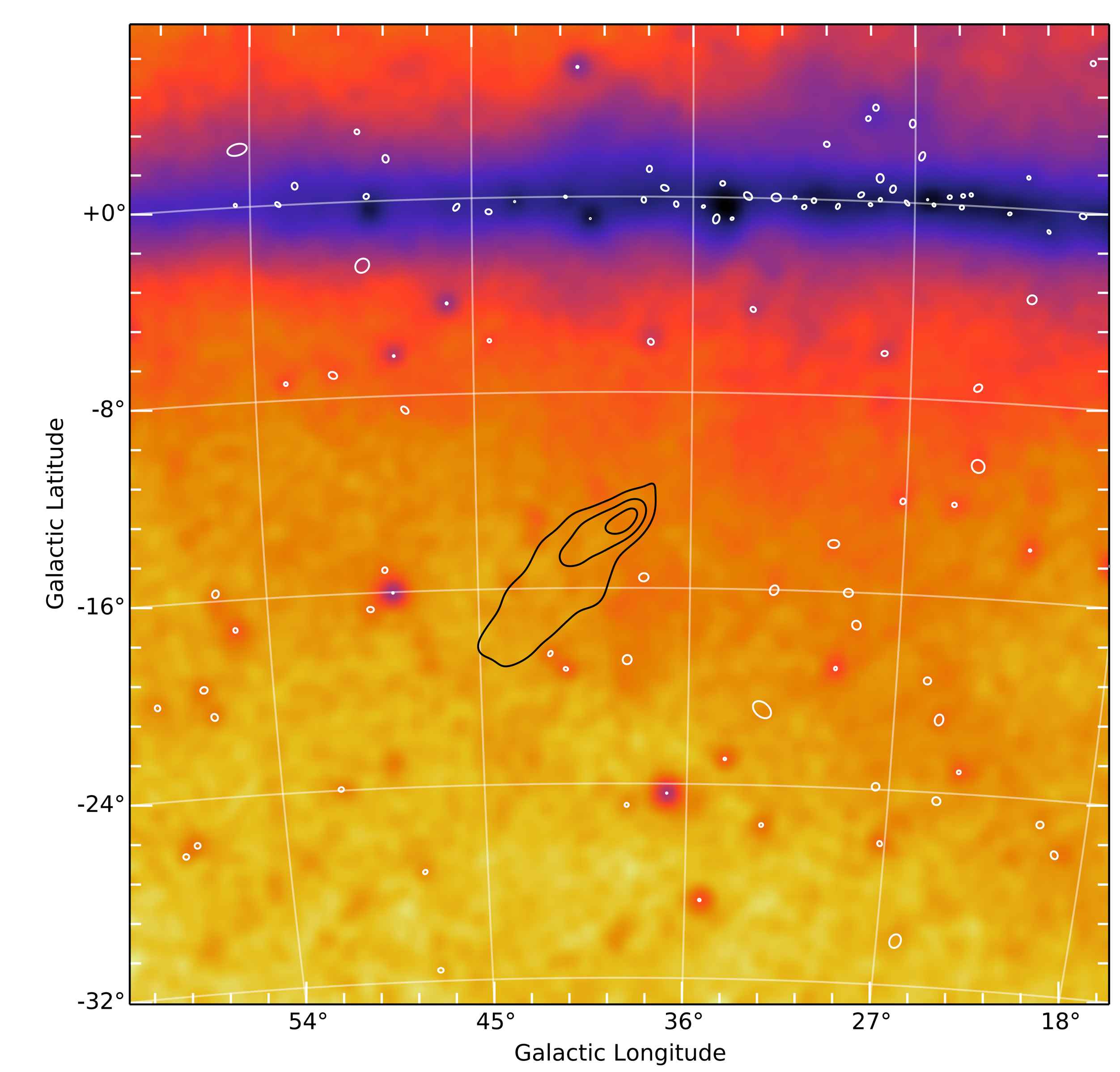

Fig. 3. Smoothed Fermi-LAT 1-300 GeV count map. HI contours for the Smith Cloud are overlaid. 2FGL point sources are shown in white.

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References

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