Testing cosmic-ray acceleration in the Galactic halo

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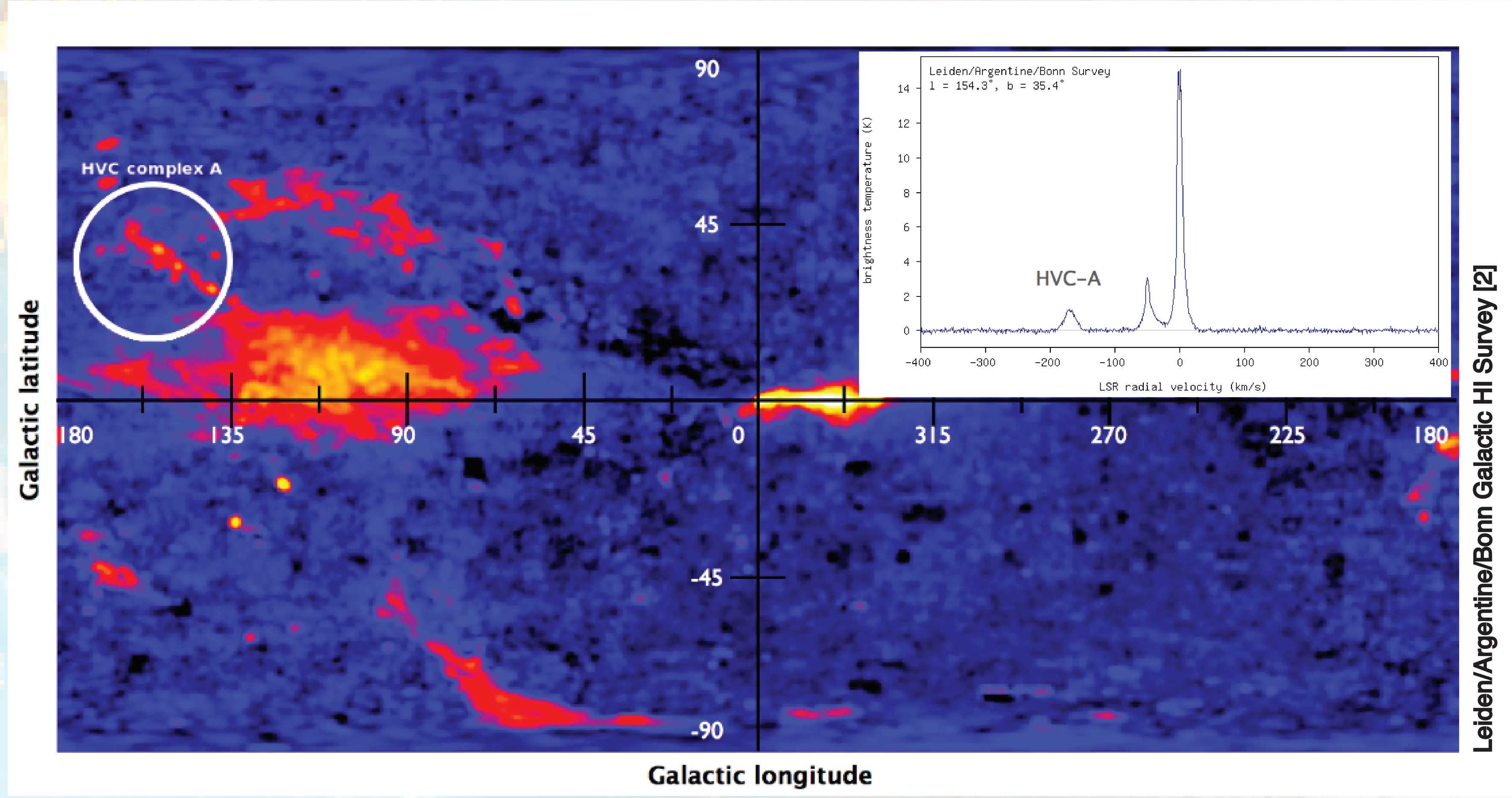
Abstract

We use gamma-ray emission from HI high-velocity clouds as probes of the cosmic-ray spectrum in the Galactic halo.
While conventional cosmic-ray (CR) propagation models predict a negligible gamma-ray flux, alternative scenarios such as large-scale acceleration at the Galactic-wind termination shock [1] suggest a significant irradiation of high-velocity clouds with particles at energies exceeding 100 GeV, resulting in very hard gamma-ray emission that may be detectable with Fermi. We report on a search for such emission from the high-velocity cloud complex A (HVC-A), and discuss the implications of our findings.

Background



The Medvedev and Melott model [1] revisiting the mechanism of CR propagation, predicts a substantial flux of CRs at Galactic north. The model exploits the observation of the Galactic wind-like outflow of hot, ionized gas, that is permeated with clouds of infalling gas [3]. Convincing evidence for the existence of this Galactic wind comes from X-ray data [4]. A Galactic wind substantially modifies CR transport in a number of ways: advection, acceleration by turbolence and shocks in the Galactic wind and at the termination shock, which is imposed by the interaction of the Galactic wind with the intergalactic medium. The Galaxy's infall towards the Virgo cluster pushes the wind termination shock close to the north Galactic face. Therefore, the flux of TeV-ish CRs in the northern Galactic halo may be substantially larger than in the southern Galactic halo, making northern HVCs a much better probes for our studies than, e.g. the Magellanic Clouds. The HVC-A is located +35° Galactic latitude. Distance brackets are available for it, placing it between 2 kpc and 7 kpc above the Galactic plane [5], ideally placed to study CRs in the halo. These CRs at TeV energies interact with the interstellar gas in the clouds producing pions.

Analysis

Observations.
For the analysis we used the LAT Science Tools package version 9.18.6, with the P6_V3 instrument response function (IRF). We selected only photons in the *dataclean* class events, to minimize the non-photon background contamination. From the data sample we excluded photons coming from a zenith angle larger than 105°, to reduce the background from Earth albedo gamma rays. The analysis was performed using 730 days of data and selecting all events within a region of interest of size 40° x 40°, centered on (l = 154.38, b = 35.46).

Method.
Data have been analyzed using a binned maximum-likelihood procedure on a spatial grid of 0.2° bins. The analysis was performed both for a wide energy band (1 GeV - 100 GeV) and for four smaller continguous energy bands (1 GeV - 3.16228 GeV, 3.16228 GeV - 10 GeV, 10 GeV - 31.62278 GeV, 31.62278 GeV - 100 GeV).

Background modelling.
The background gamma-ray model includes 70 point sources from the 11 months catalog of Fermi-LAT sources, the Galactic diffuse emission and the Extragalactic isotropic component.

HVC-A template.
The spatial distribution of the high-velocity cloud complex A, has been extracted from the LAB Galactic HI survey [2]. We converted the integrated flux over spectral line into HI column density under the assumption that the gas is optically thin,

$$N_{HI} = 1.823 \times 10^{18} \int T_B \, dv$$

and then we translated the HI column density into gamma-ray intensity above 100 MeV. Figure 1 shows the resulting map.
The energy spectral of the cloud was modeled with a simple power law,

$$\frac{dN}{dE} = N_0 \left(\frac{E}{E_0}\right)^{\gamma}$$

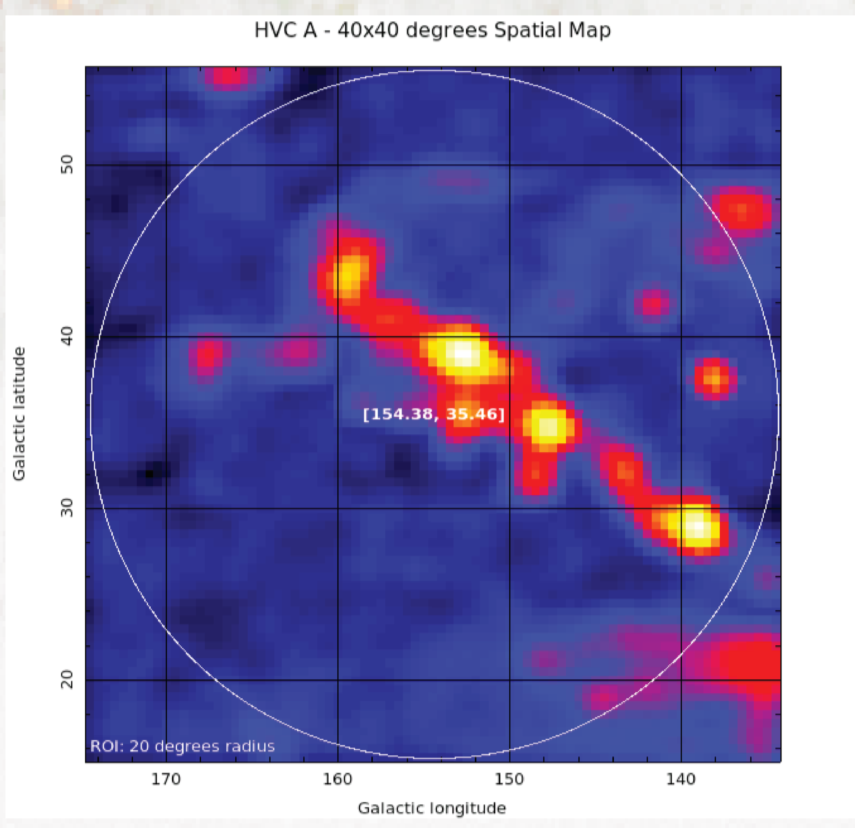


Figure 1.
Spatial map of the high-velocity cloud, complex A.

Discussion

The analysis is ongoing, in particular concerning possible systematic errors in fitting a weak component in the presence of intense diffuse emission from the Galactic and the Extragalactic background. At this time we do not find a significant gamma-ray signal associated with the HVC-A.
Anyway, any excess related to the HVC-A would provide a strong evidence for the CRs acceleration efficiency in the Galactic halo.

References:

[1] M.V. Medvedev, A.L. Melott, ApJ **664**, 879 (2007)
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[3] B.A. Keeney *et al.*, ApJ **646**, 951 (2006)
[4] J.E. Everett *et al.*, ApJ **674**, 258 (2008)
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