TP General Physics / M1

High Velocity Cloud Analysis in HI4PI Data

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Chapter 1

Introduction

The study of our own galaxy (the Milky Way) is especially complex by the fact that we are located inside. The sun is approximatly at 8.5 kpc from the galactic center (noted G) and have a radial velocity due to the rotation around G of $220\,km.s^{-1}$. As a fist approximation, we can discribe the galactic plane as a sum of three components : Gas (HI, neutral hydrogen), Star and Dark Matter. All around the galactic plane are located an important gas reservoir called the Milky Way Halo. To better understand how this reservoir constraint the physics of our galaxy, we must study it in detail.

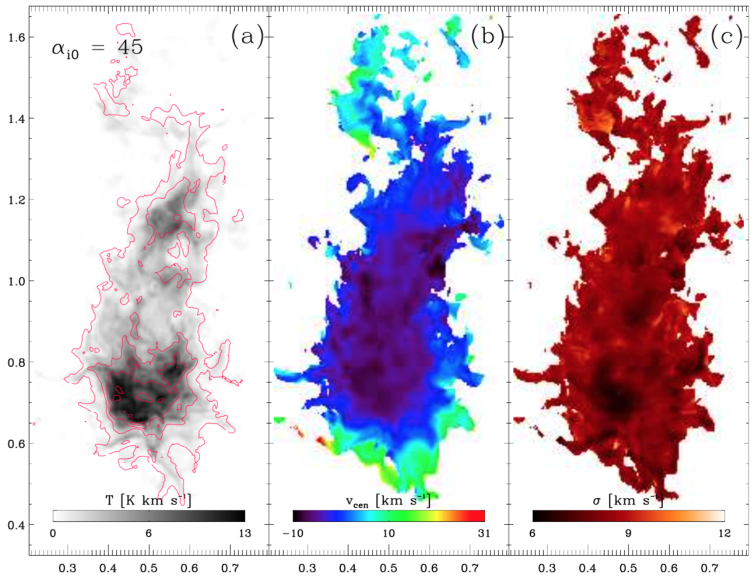

Figure 1.1: (a) Integrated intensity, (b) centroid velocity, and (c) velocity dispersion of a model CHVC (model Wb1a15b of Heitsch Putman (2009)), traveling at 45∘ to the observer. Contours are given at [1, 5, 9, 13] K km s1. / (from Heitsch et al, 2016)

Since their discorevy by Muller et al (1963), High Velocity Clouds are studied as isolated objects. They are defined as neutral atomic hydrogen with radial velocity (typically $V_r \approx 200\,km.s^{-1}$) that cannot be explained by the rotation of the Milky Way (Wakker 1991). We present figure 1 an HVC view from numerical simulation. The neutral hydrogen is very well observed since many years through the 21cm hyperfine structure line, and the latest full sky survey is the result of the HI4PI collaboration. More details are present in the recent article (in free access) : https://arxiv.org/abs/1610.06175 . This work is based on a single HVC cloud name HVC125+41-207 present in HI4PI. From the original data release, we develop a simple method to obtain some approximations of the physical properties of this cloud and its environment.

Physical constants :

- Atomic mass of hydrogen : $m_H = 1.6737236 \times 10^{-27}\,kg$
- Definition of a parsec : $pc = 3.085677581467192 \times 10^{16}\,m$
- Mass of the Sun : $M_{\odot} = 1.9891 \times 10^{30}\,kg$
- Mean mass per particle within the sphere : $\mu \approx 1.25\,m_H$
- Boltzmann constant : $k = 1.38064852 \times 10^{-23}\,m^2.kg.s^{-2}.K^{-1}$

Chapter 2

Manipulation of hyperspectral data

2.1 Reading Data from FITS Files

This work is based on Hyperspectral imaging (see representation figure 2.2). For each pixel of the projected plan of sky we have an associated spectrum.

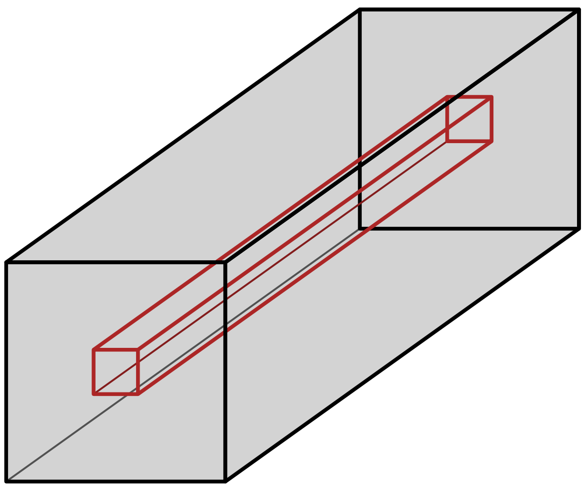

Figure 2.1: 3D representation of a hyperspectral cube. All the points on a straight line in this cube compose a spectrum. We can select a sub-regoin of this cube which corresponds to a smaller part of the sky.

We propose to read the hyperspectral cube which is formatted in FITS using the python programming. A good documentation is available on the following link: http://docs.astropy.org/en/stable/io/fits/

2.2 High Velocity Cloud research

First, in order to understand the kind of data we use, we can visualize the total integreted column density map of the field using the equation 3.2. There is no clear evident of an HVC because we are totaly dominated by the galactic emission. Indeed, the HVC HVC125+41-207 is located in the following spectral range : $v_{rad}(km.s^{-1}) = [-225, -185]$. From the article describing the HI4PI survey, we can clean the cube considering the rms value. For exemple we keep all values greater than $3 \times \sigma_{rms}$, with σ_{rms} the sensitivity of HI4PI.

After selecting the spectral range, we can plot the HVC using the 'imshow' function in the matplotlib library (see http://matplotlib.org)
Note that the galactic longitude range and the galactic latitude range of the cube are respectively $l(deg) \in [119, 141]$ and $b(deg) \in [19, 51]$.

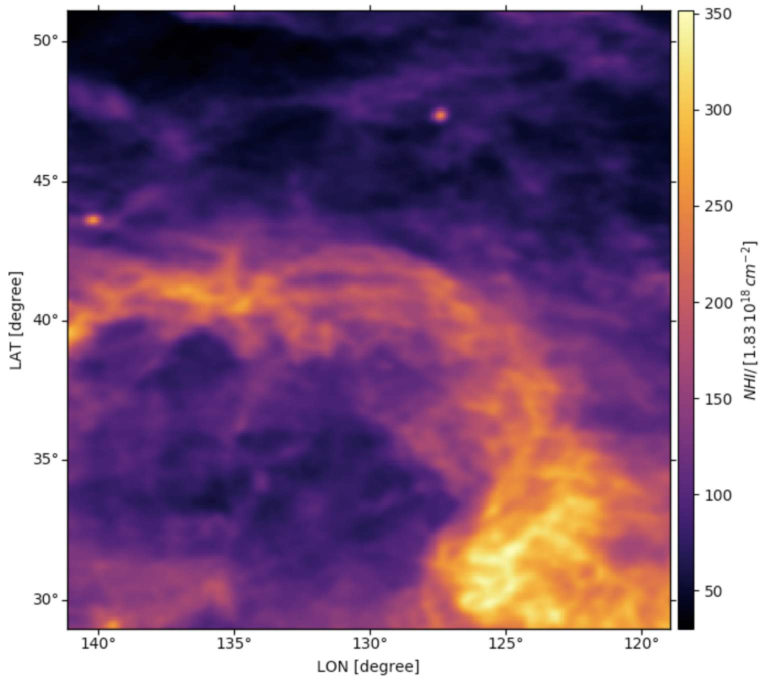

Figure 2.2: Total integreted column density map of the field. Note that the coordinates are in the galactic coordonate system.

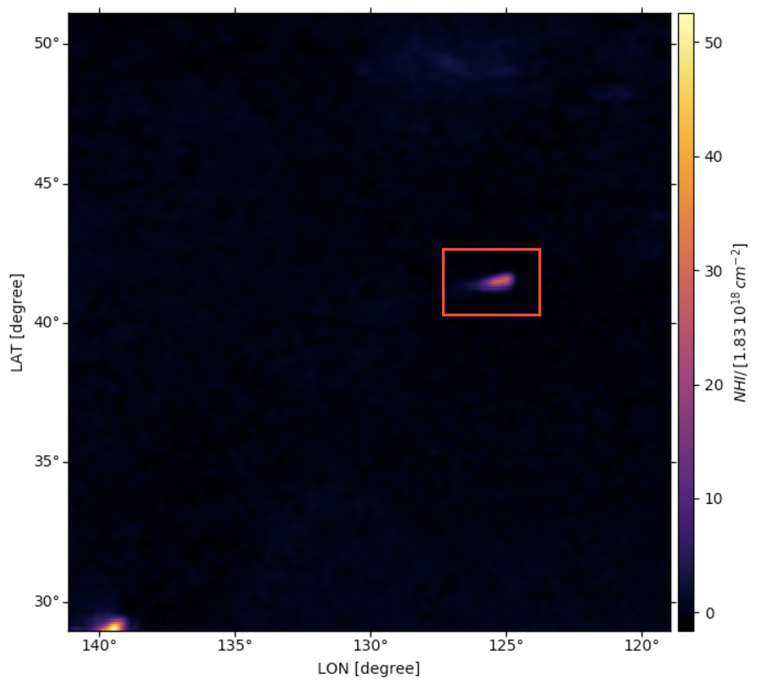

Figure 2.3: Integrated intensity map of HVC125+41-207 High Velocity Cloud, i.e integration perform in the velocity range of the cloud.

Chapter 3

Physical properties of the HVC

3.1 Mean spectra of the HVC

To obtain some physical properties of this clump, we can analize the mean spectrum of the data. We graphically represent the numerical calculation of the passage of hyperspectral data to the mean spectrum of the cloud figure 3.1.

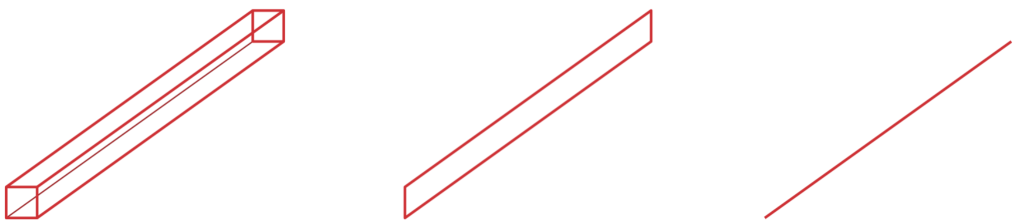

Figure 3.1: Representation of the passage of hyperspectral data to the mean spectrum of the cloud

3.2 Spectral analysis

As a first approximation, we can applied the Virial equilibrium to obtain the pressure outside the HVC as a function of the distance d (preferentialy expressed in kpc which is a unit of length used in astronomy and astrophysics). This is actually nothing more than the pressure equilibrium between the inside medium and the outside medium.

$$\frac{P_s}{k} = \underbrace{\frac{\langle N_{HI}\rangle \; T_k}{d\,\theta}}_{\text{kinetic pressure}} \underbrace{- \frac{\mu^2 \, G \, \pi \, \langle N_{HI}\rangle^2}{15\,k}}_{\text{gravitational pressure}} \tag{3.1}$$

where θ is the observed angular diameter in radian, T_k is the kinetic temperature of the gas, d is the distance of the clump, G and k and respectively the gravitational constant and the Boltzmann constant, $\langle N_{HI}\rangle$ is the mean value of the column density and μ the mean mass per particle within the sphere.

Tools to calculate the quantities that we have to get to compute the pressure as function of the distance of the cloud :

From the mean sprectra of the clump, we estimate $\langle N_{HI} \rangle$ from 21 cm measurements.

$$\frac{\langle N_{HI} \rangle}{cm^{-2}} = 1.82243 \times 10^{18} \times \int_{-\infty}^{+\infty} \left(\frac{T_b(v)}{K} \right) d \left(\frac{v}{km.s^{-1}} \right) \tag{3.2}$$

where T_b is the mean brightness temperature and v is the the radial velocity.

Note that we can direclty get the surface density :

$$\Sigma = \frac{\langle N_{HI} \rangle \, m_H \, pc^2}{M_{\odot}} \tag{3.3}$$

where m_H is the atomic mass of hydrogen, pc is the definition of a parsec, and $M_{\odot}$ is the mass of the Sun.

If we consider that the temperature of our system is only due to the kinetic temperature (without turbulence for exemple), T_k can be written as :

$$T_k = \frac{m_H \, \sigma_v^2}{k} \, (K) \tag{3.4}$$

σ_v is obtained by fitting a gaussian function on the mean spectra that we calculated previously.