

Models

We propose several models which include different rotational velocities and optical depths. We also take into account the dust within the gas and two different initial distributions of the photons, central and homogeneous. At the end we study 48 models, those are resumed in Table[1]

Velocity(km/s)	50, 100, 200, 300
Optical Depth	$\tau = 10^5, 10^6, 10^7$
Photons Distributions	Central, Homogeneous

Table 1: Models, If we take into account all these possible combinations we get 24 models with dust and 24 without dust for a total of 48 models.

We later study these models taking into account the position of the observer respect to the axis of rotation of the cloud.

Rotational Effect

Due to the resonant nature of the Lyman alpha line, gas kinematics play an important role in the shape of this line. In particular we study the case in which this gas is spherically symmetric and is rotating.

In cartesian coordinates the rotational velocity around the z-axis is defined by:

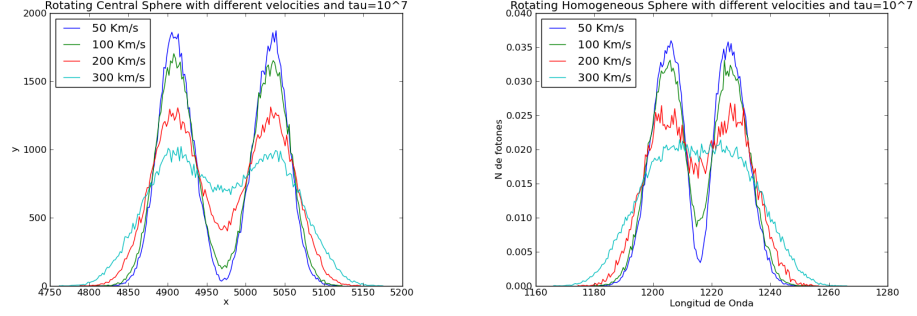
$$v_x = -\frac{y}{R}v \quad (1a)$$

$$v_y = \frac{x}{R}v \quad (1b)$$

Where x and y define the position of the gas atoms and dust particles. The minus sign in the x-component of the velocity is due to the direction of rotation, in this case we assume that as seen from the top, the rotation is anticlockwise.

In Figure[1] the effect that rotation has in the spectra is shown, for both distributions central (Left) and homogeneous (right). This is a general case in the sense that it is independent of the position of an external observer.

Figure 1: Shape of the lyman alpha line for differents velocities. The left panel show the central distribution while the right panel show the homogeneous distribution.



Now if we take into account the position of the observer and compute this for differents angles of observation θ the outcoming spectra is modified as is shown in figure[2]. The main feature here is that as the angle increases the line high decreases. It means that a observer in the poles will observe a higher double peak than a observer in the ecuator. We will understand this in more details when we present the resaults of the scape fraction in section[].

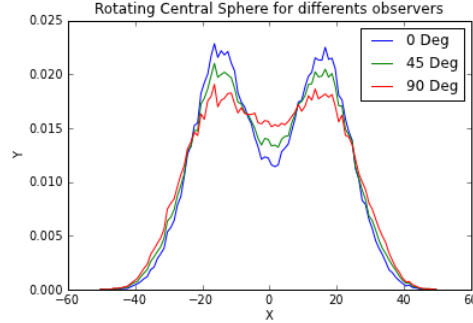


Figure 2: Spectra for different observers. Model: $V = 300 \text{ km/s}$, Optical Depth $\tau = 10^7$ and Central Distribution without dust.

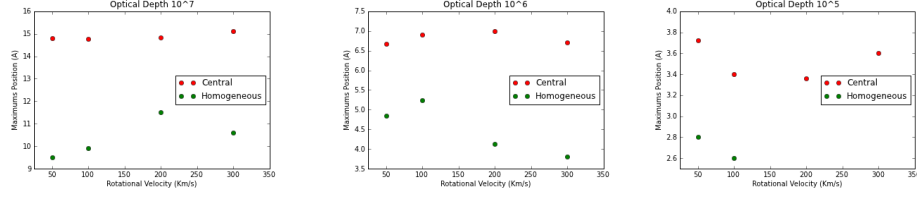
Resaults and Discussion

In the previous section we describe the models that we study the effect of rotation in the Lyman alpha line and see the effect of rotation in the spectrums. Now we show the main resaults that we obtain, in particular we pay spetial attention to the position of the maximums, the width of the line and the escape

fraction in function of the rotational velocity and the angle of observation θ .

Maximums Position

Figure 3: Width of the lyman-alpha line for all the models.

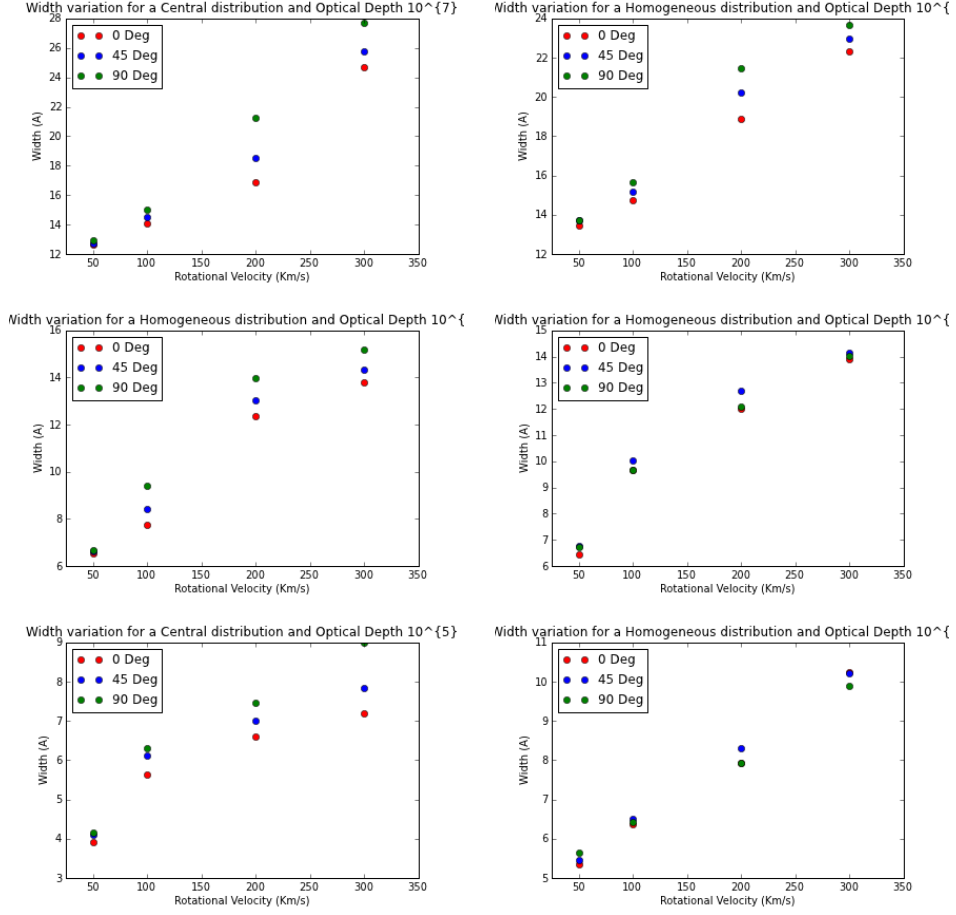


The maximum position gives information about the wave length of the majority of the outgoing photons after they interact with the gas, in addition as a photon have more scatterings its wave length would be larger than the initial which is 1216 Å. As we can see in Fig.[3] the position of the maximums does not change with rotational velocity. But it change from homogeneous and central.

Line Width

Another effect that the rotation of the gas produce is in the width of the lyman alpha line. The width of the line provide information of the the how many photons scape with a particular wave length, in the ideal case in which all the photons scape with the same wave length the outgoing spectrum would be narrow. For all the models we study we found that as the rotational velocity increase as the line width increase this is show in Fig.[4].

Figure 4: Width of the lyman-alpha line for all the models.



We also found that the width for a particular model is not the same for different angles of observation in particular as the angle increases the width also increases, it means that as the angle increases the number of scatterings of the photons increases for this reason we see a broader line. Fig.[5]

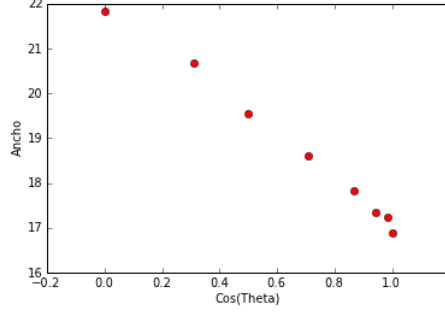


Figure 5: Width variation in function of theta

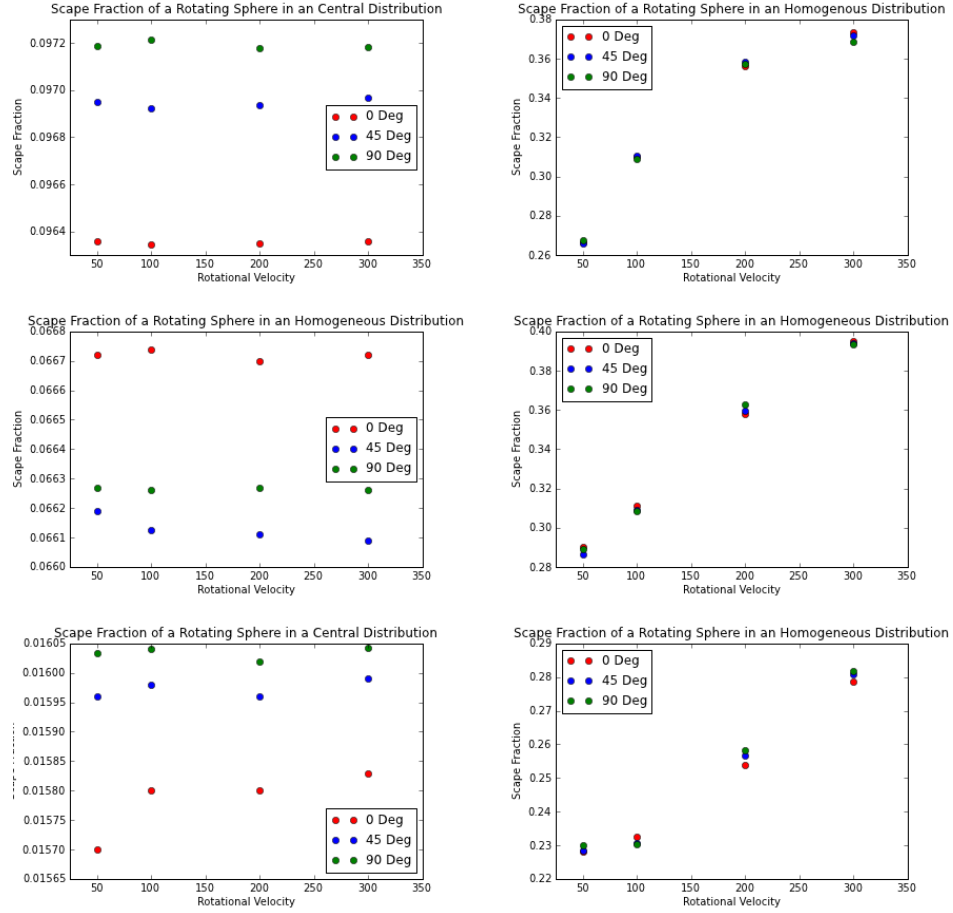
Escape Fraction

The fraction of photons that escape from de cloud of gas and dust is defined as:

$$F_e = \frac{\Sigma_{NI} \vec{k} \cdot \vec{o}}{\Sigma_{NF} \vec{k} \cdot \vec{o}} \quad (2)$$

Where NI is the initial number of photons and NF is the final. This escape fraction is computed for all the models which resaults are shown in Fig.[6]

Figure 6: Escape fraction for all the models. Left panels show the central distribution, while right panels show the homogeneous distribution



When the distribution is homogeneous the effect of velocity in the escape fraction is clear while in the central model the effect is not noterous. The main effect is that the escape fraction increase as the velocity increase.

Observational effect.

Tables

Maximos

Velocity (Km/s)	Maximum 1 position	Maximum 2 position
50	-16.2695	16.23705
100	-15.66496	15.33504
200	-16.93149	14.56851
300	-13.40048	16.09952

Table 2: Optical Depth $\tau = 10^7$, Central Distribution

Velocity (Km/s)	Maximum 1 position	Maximum 2 position
50	-7.46286	6.53714
100	-7.53357	6.96643
200	-8.17453	7.32547
300	-6.81487	6.18513

Table 3: Optical Depth $\tau = 10^6$, Central Distribution

Velocity(Km/s)	Maximum 1 position	Maximum 2 position
50	-4.33708	3.66292
100	-4.27326	3.72674
200	-3.7737	3.7263
300	-3.84903	4.15097

Table 4: Optical Depth $\tau = 10^5$, Central distribution

Line width

Velocity(Km/s)	FWHM	θ
50	12.62	0°
50	12.72	45°
50	12.93	90°
100	14.07	0°
100	14.48	45°
100	15.00	90°
200	16.90	0°
200	18.51	45°
200	21.24	90°
300	24.69*	0°
300	25.79*	45°
300	27.73*	90°

Table 5: Lines Widths for a Central Distribution and $\tau = 10^7$

Scape fraction

Model	Velocity (km/s)	θ	Dust $\sum(s)$	$\sum(s)$
Homogeneous	50	0°	13293.06	49939.53
Homogeneous	50	45°	13291.04	50001.59
Homogeneous	50	90°	13348.76	49922.73
Homogeneous	100	0°	15527.69	50114.11
Homogeneous	100	45°	15511.56	49967.17
Homogeneous	100	90°	15401.71	49833.65
Homogeneous	200	0°	17830.85	50078.69
Homogeneous	200	45°	17932.87	50064.42
Homogeneous	200	90°	17830.85	49931.748
Homogeneous	300	0°	18687.33	50048.33
Homogeneous	300	45°	18572.12	49922.67
Homogeneous	300	90°	18421.79	49979.37

Table 6: Escape fraction for a Homogeneous Distribution and optical depth 10^5 .

Model	Velocity (km/s)	θ	Dust $\sum(s)$	$\sum(s)$
Central	50	0°	4809.881	49917.069
Central	50	45°	4829.21	49811.79
Central	50	90°	4845.108	49853.039
Central	100	0°	4809.665	49921.30
Central	100	45°	4828.65	49820.13
Central	100	90°	4846.45	49854.0
Central	200	0°	4809.63	49917.64
Central	200	45°	4829.25	49818.49
Central	200	90°	4844.89	49856.66
Central	300	0°	4810.56	49922.98
Central	300	45°	4831.16	49823.33
Central	300	90°	4845.33	49858.48

Table 7: Escape fraction for the central Distribution and optical depth 10^5 .