The effect of gas bulk rotation on the morphology of the Lyα line.

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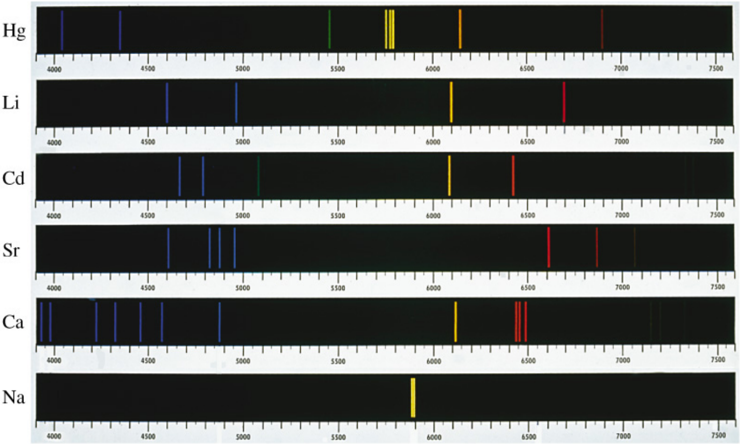
In collaboration with Mark Dijkstra.

Emission lines: Transitions from higher to lower energy levels in the atoms.



Wavelenght($\AA$)

Hydrogen is the most abundant element in the Universe.

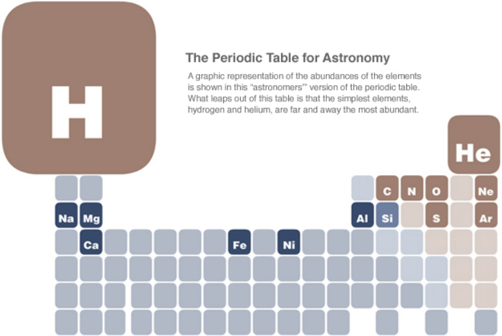
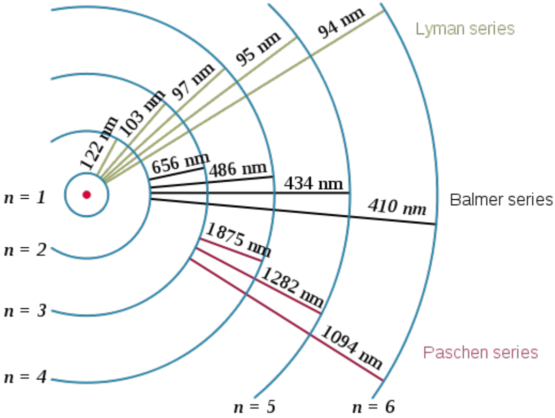


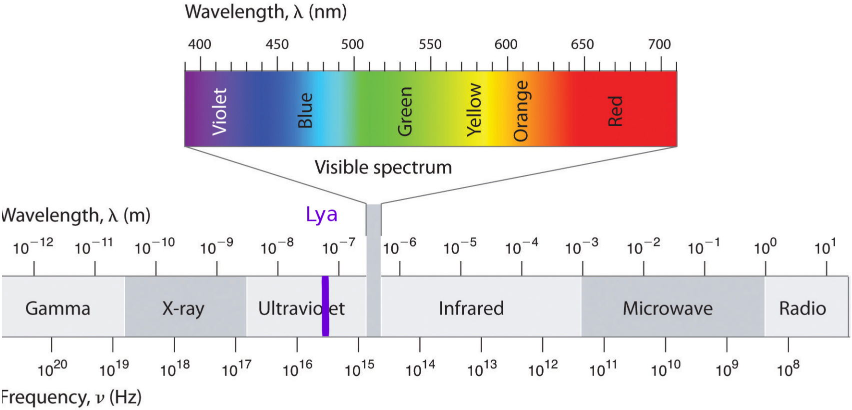
Figure : Astronomers periodic table. Image credit: http://chandra.harvard.edu

The Lyman α emission line is the transition from the first state to the ground state in the Hydrogen atom.

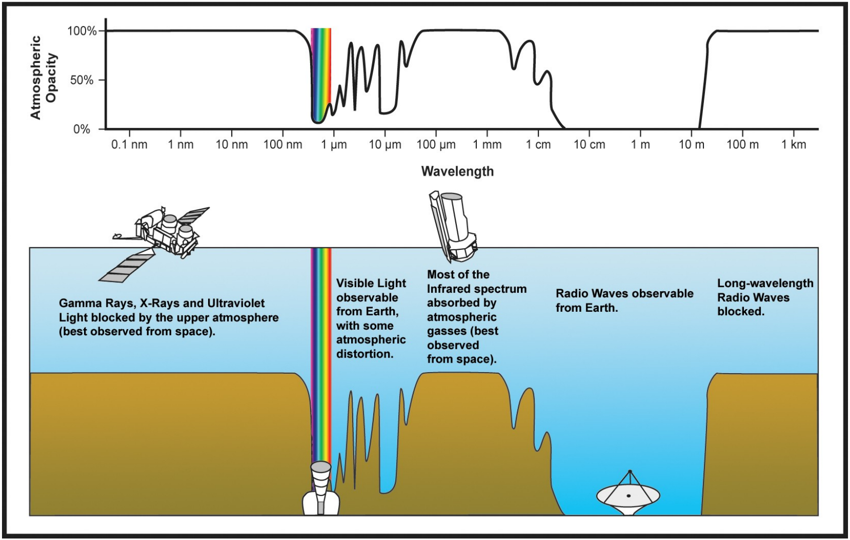
A Lyα photon is emitted with a $\lambda = 121.56nm$.



$Ly\alpha$ *is in the UV part of the EM spectrum.*



The Ly α is no observable from earth.



Atmospheric radiation absorption

Due to the cosmological redshift LAEs are visibles from earth.

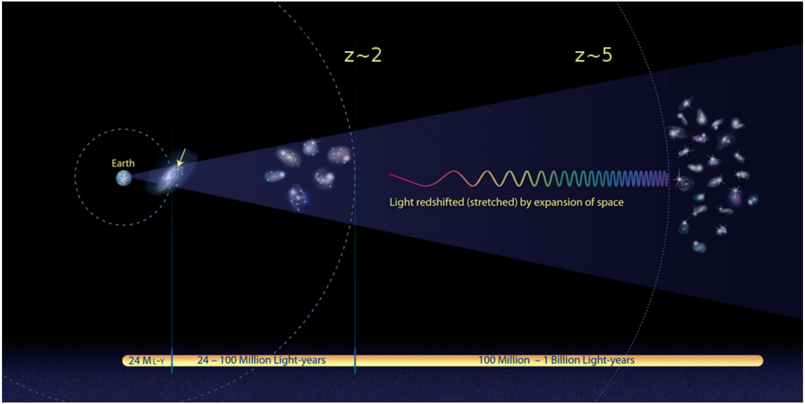


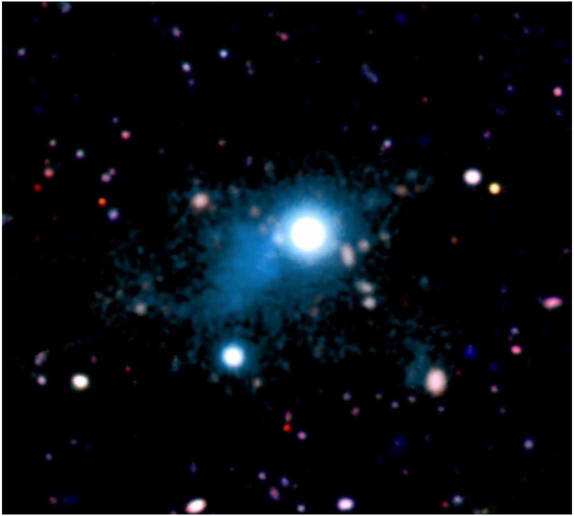
Image credit: NASA, ESA, and A. Feild (STScI).

How galaxies radiate Lyα photons:

UV radiation mechanisms and sources:

1. **UV stellar radiation.**

Gravitational cooling & UV background radiation:



Cantalupo, e.a. MNRAS 2012

ARE YOUNG GALAXIES VISIBLE?

R. B. PARTRIDGE AND P. J. E. PEEBLES
Palmer Physical Laboratory, Princeton University
Received August 5, 1966; revised September 8, 1966

ABSTRACT

The purpose of this paper is to assess the general possibility of observing distant, newly formed galaxies. To this end a simple model of galaxy formation is introduced. According to the model galaxies should go through a phase of high luminosity in early stages of their evolution. The estimated luminosity for a galaxy resembling our own is $\sim 3 \times 10^{46}$ ergs/sec, roughly 700 times higher than the present luminosity. The bright phase would occur at an epoch of about 1.5×10^{8} years, corresponding to a redshift between 10 and 30, depending on the cosmological model assumed.

The possibility of detecting individual young galaxies against the background of the night sky is discussed. Although the young galaxies would be numerous and would have sufficiently large angular diameters to be easily resolved, most of the radiation from the young galaxies would arrive at wavelengths of 1–3 μ where detection is difficult. However, it seems possible that the Lyman-α line might be detected if it is a strong feature of the spectra of young galaxies.

It is also shown how such an experiment might help us to distinguish between various cosmological models.

25 years later ...

SEARCHES FOR PRIMEVAL GALAXIES

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ABSTRACT. We review primeval galaxy searches based on the Lyα line emission. Simple arguments are given which suggest that primeval galaxies (interpreted here as ellipticals and bulges undergoing their first major bursts of star formation) should be detectable with present-day technology. Many active objects are now known at large redshifts, which may be plausibly interpreted as young galaxies, but there is so far no convincing detection of a field population of forming normal galaxies. This suggests that either primeval galaxies were obscured, and/or are to be found at higher redshifts, $z_{gf} > 5$.

Hubble deep field.

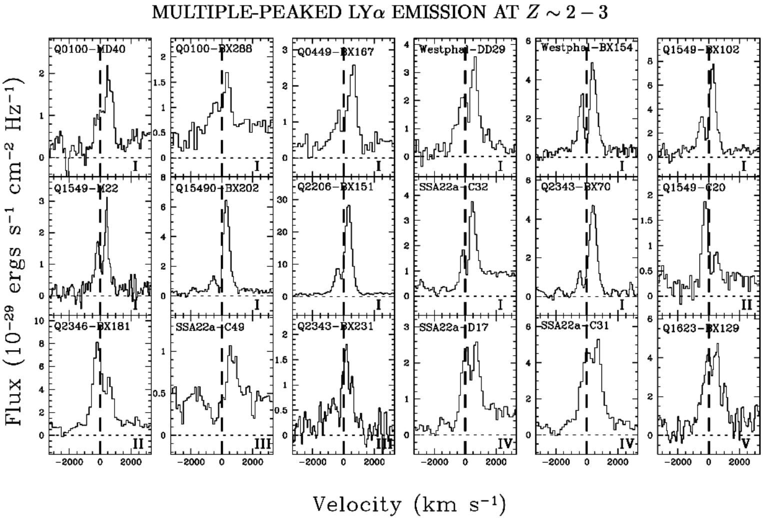
Units convention:

$$x = \frac{\nu_{obs} - \nu_\alpha}{\Delta\nu_D}$$

$$\Delta\nu_D = \frac{v_{th}}{c}\nu_\alpha$$

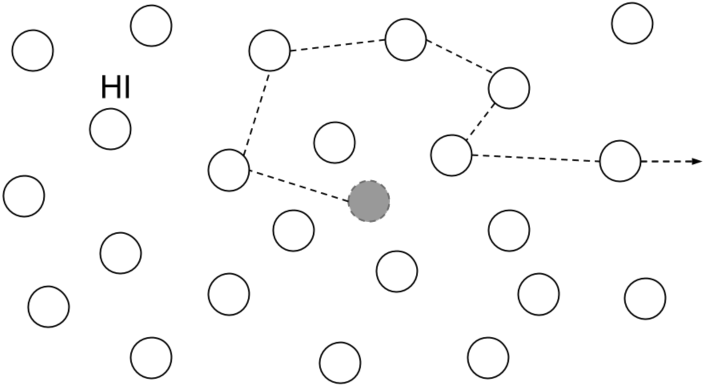
$$V = x v_{th} = \frac{(\nu_{obs} - \nu_\alpha)}{\nu_\alpha} c$$

LAEs spectra are diverse:

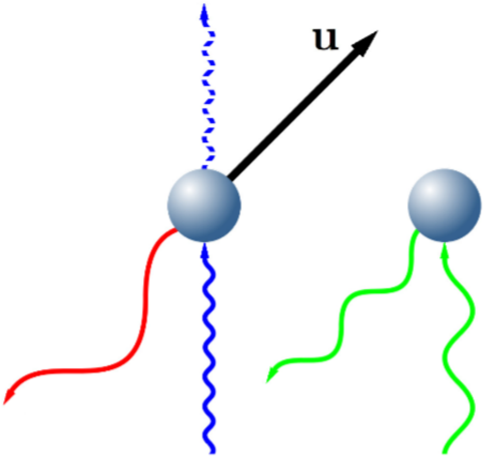


Kulas e.a ApJ, 2012.

Radiative transfer is more complex than usual:

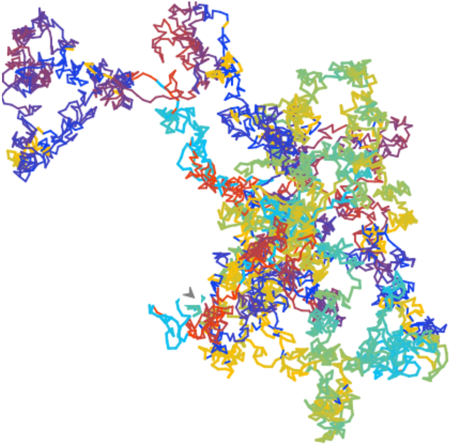


Radiative transfer in a non-static medium induces shifts on the line:



Laursen, P. PhDT, 2010.

Lyα line is shaped by density, temperature and velocity



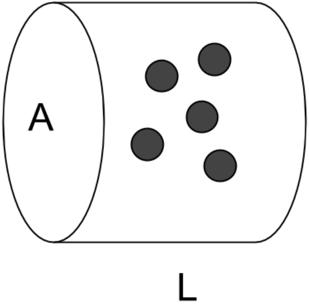
Dust absorbs Lyα photons

Dust grains can either absorbe or scatter Lyα photons. The probability of these events is given by the **Albedo (A)**.

$$A = \frac{\sigma_{scatt}}{\sigma_{dust}}$$

Optical depth:

$$\tau = nL\sigma$$



Radiative transfer as diffusion process:

$$\frac{dJ(\nu)}{d\tau} = \frac{(\Delta\nu_D)^2}{2}\frac{\partial}{\partial\nu}\phi(\nu)\frac{\partial J(\nu)}{\partial\nu} \tag{1}$$

Where ν is the frequency of the photons, $\phi(\nu)$ is the Voigt profile and τ the optical depth.

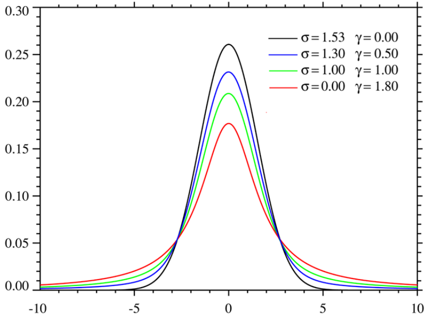
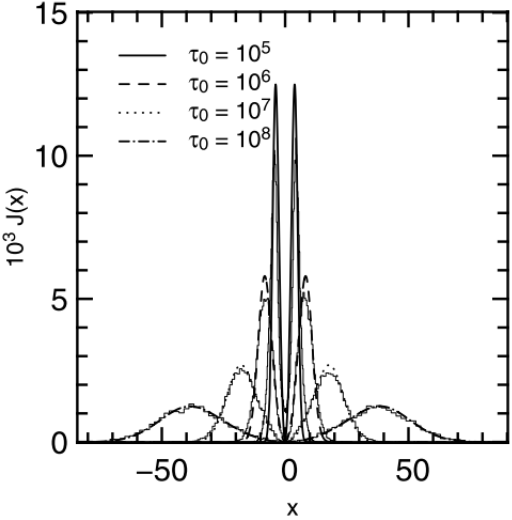


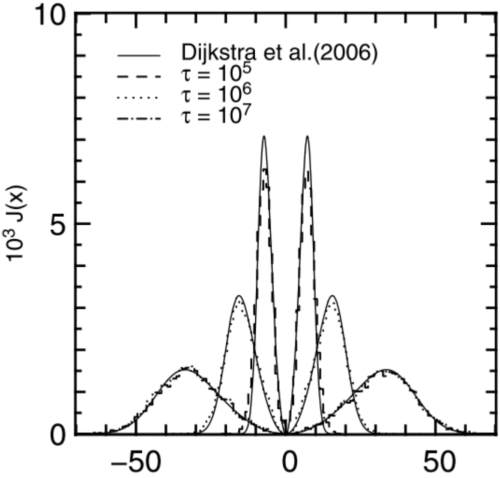
Figure : Voigt profile

A slab geometry induces a double-peak in the line:



Forero-Romero e.a 2011.

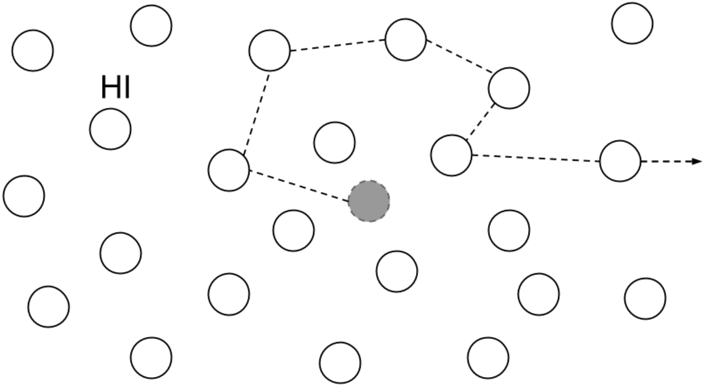
A spherical distribution induces a double-peak in the line:



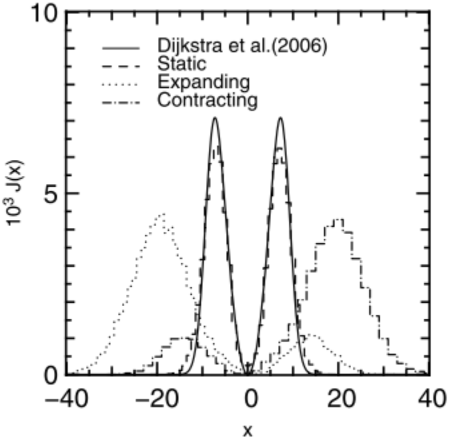
Forero-Romero e.a 2011.

Monte-Carlo approach:

Radiative Transfer via Monte-Carlo methods:

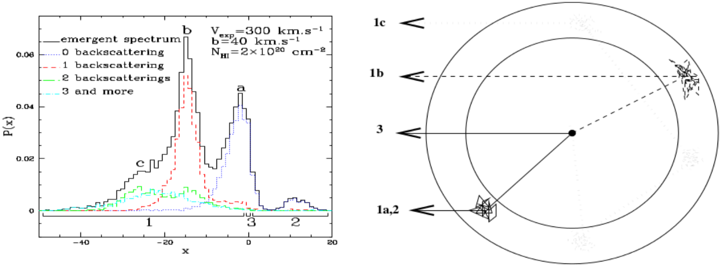


Asymmetries in the line can be induced by kinematics:



Forero-Romero e.a 2011.

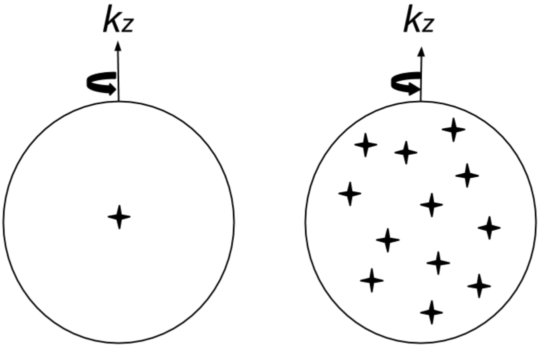
Thin shell model:



Verhamme, A. e.a, A&A, 2006.

Different geometries and kinematics of the gas has an impact on the morphology of the Lyα spectrum.

What would be the effect of rotation on the morphology of the Lyα line?
Is this effect observable?


k_z
k_z

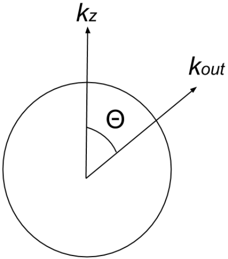
Models:

Physical Parameter (units)	Symbol	Values
Velocity (km/s)	$V_{\max}$	0, 100, 200, 300
Hydrogen Optical Depth	τ_H	10^5, 10^6, 10^7
Dust Optical Depth	τ_a	0,1
Photons Distributions		Central, Homogeneous

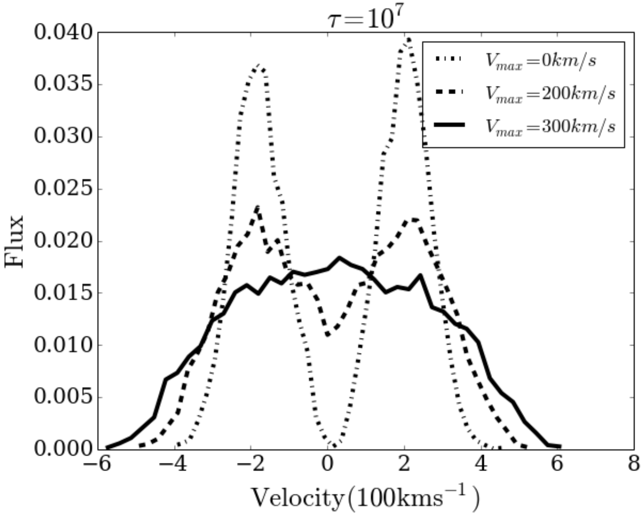
Table : Summary of Physical Parameters of our Monte Carlo Simulations.

Rotation has an effect on the morphology of the line:

We measure the impact of rotation and viewing angle θ for the main line characteristics.

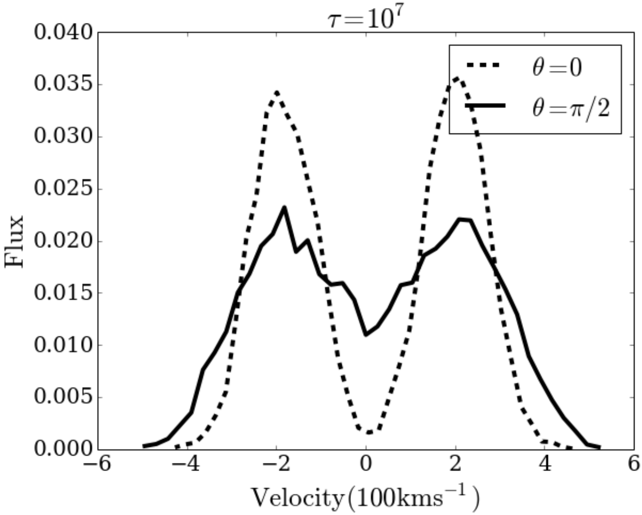


The morphology of the line is affected by rotation



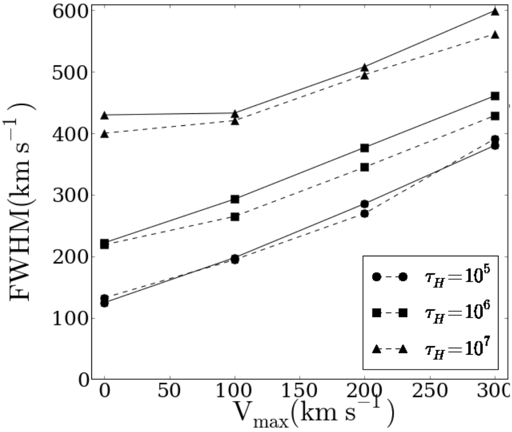
Garavito-Camargo e.a 2014

The morphology of the line changes for different observers



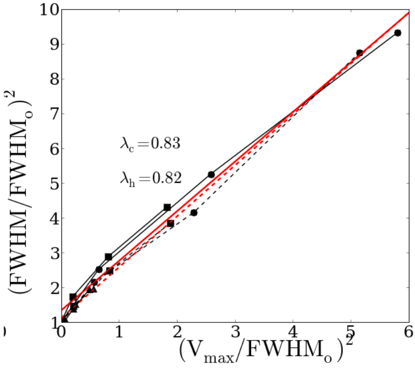
Garavito-Camargo e.a 2014

The line width increases proportional to the rotation velocity.



Garavito-Camargo e.a 2014

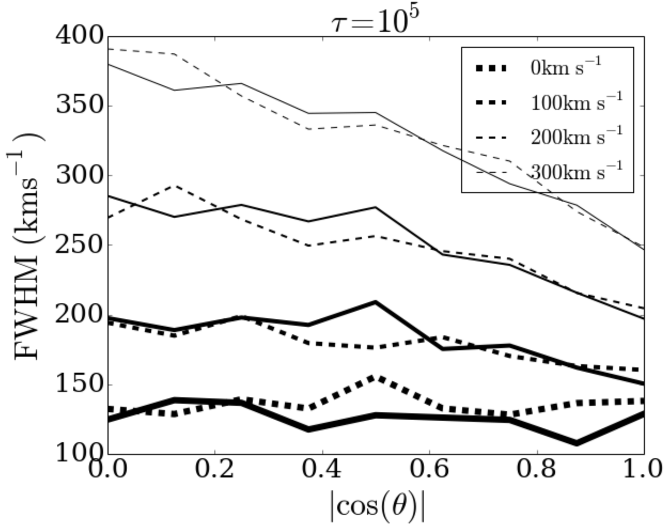
The line width increases proportional to the rotation velocity.



Garavito-Camargo e.a 2014

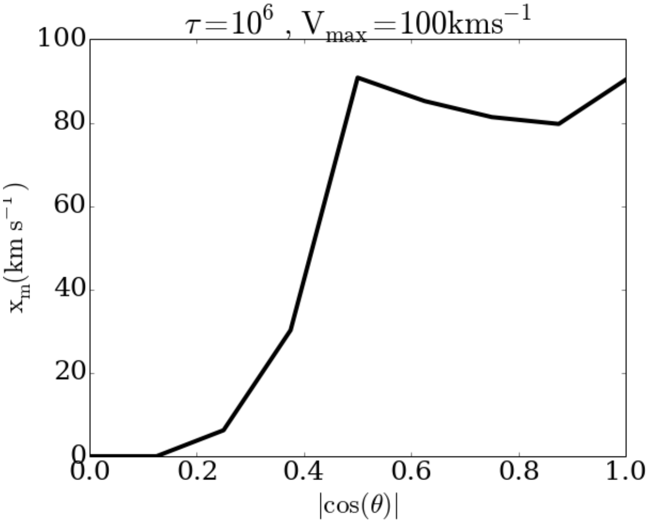
$$FWHM^2 = FWHM_0^2 + \left(\frac{V_{max}}{\lambda}\right)^2$$

The line width increases proportional to the viewing angle θ



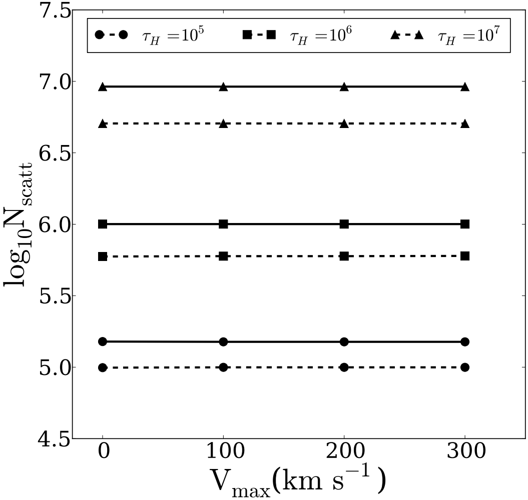
Garavito-Camargo e.a 2014

The flux at the line center increases with the rotation velocity and the viewing angle θ.



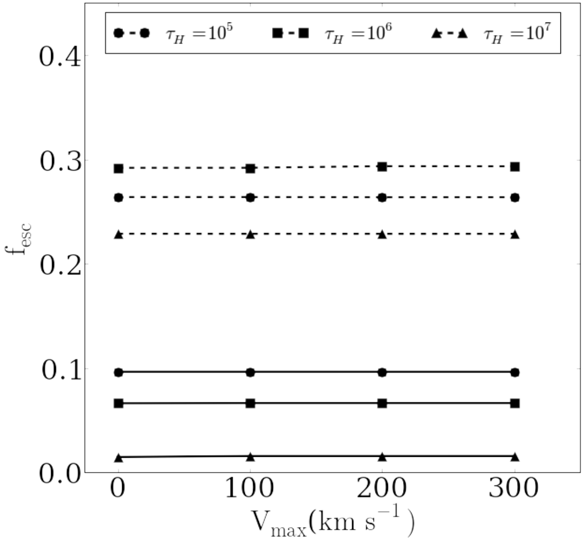
Equator Garavito-Camargo e.a 2014 Poles

The average number of scatterings is unaffected by rotation and viewing angle.



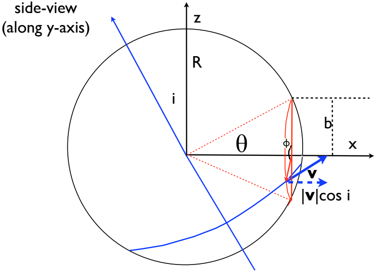
Garavito-Camargo e.a 2014

The escape fraction of Lyα is unaffected by rotation and viewing angle.



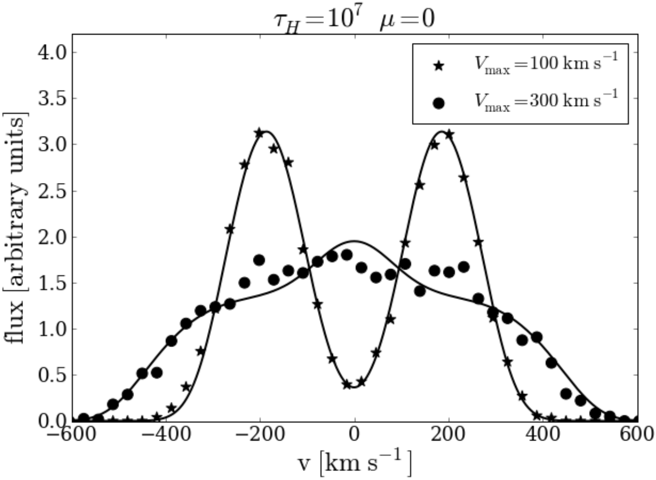
Garavito-Camargo e.a 2014

Analytic approximation:



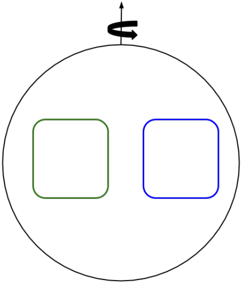
$$J(x,i) = 2\pi \int_0^R dbb \int_0^{2\pi} d\phi S(b,\phi) J(x,b,\phi,i) \approx 2\pi \int_0^R dbb \int_0^{2\pi} d\phi J(x,b,\phi,i) \tag{2}$$

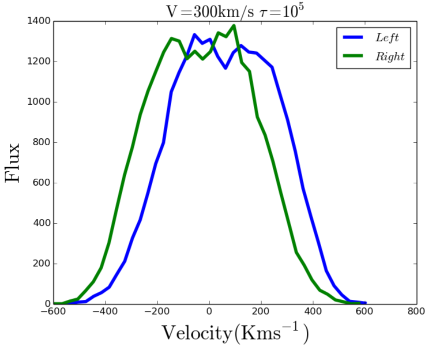
Analytic approximation:

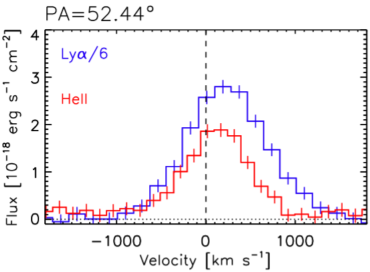


Garavito-Camargo e.a 2014

Lyman alpha observed in rotation:





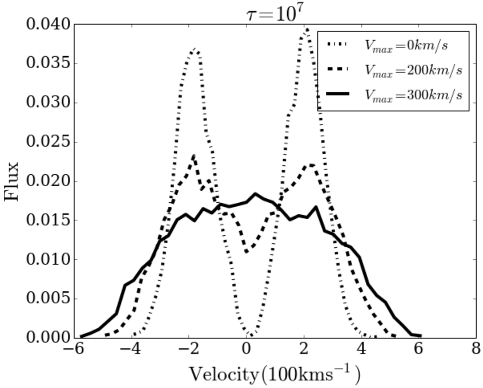


Prescott e.a, ApJ, 2014.

Conclusions:

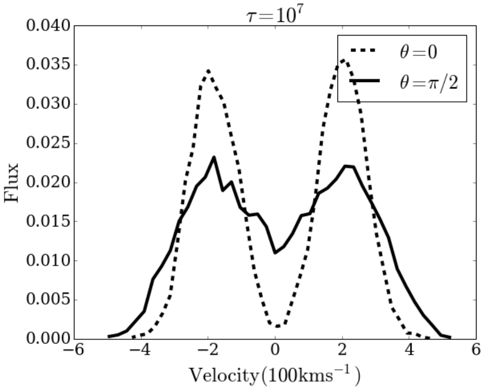
1. Rotation has an impact in the Lyα line morphology; the width and the relative intensity of the peaks and the center of the line are affected.

$$FWHM^2 = FWHM_0^2 + \left(\frac{V_{max}}{\lambda}\right)^2$$



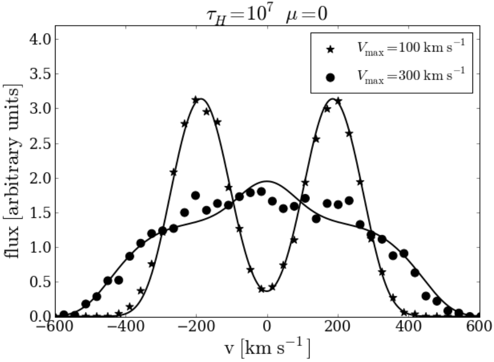
Conclusions:

2. Rotation induces an anisotropy for different viewing angles.

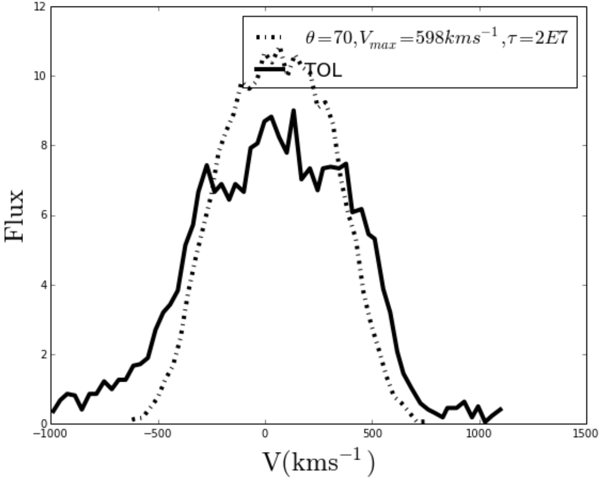


Conclusions:

3. An analytical approximation could be derived.



In progress:



$\theta=70, V_{max}=598kms^{-1}, \tau=2E7$
TOL
Flux
$V(kms^{-1})$
12
10
8
6
4
2
0
−1000
−500
0
500
1000
1500