Studying the ISM of nearby galaxies through the Lyα emission line

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Outline

- Introduction

  - What is the Lyα line ? How does the Lyα line form in starburst galaxies ?

  - Why does the Lyα line encode information on an ISM ?

- Our work: studying the ISM of Mrk 1486 through the Lyα line

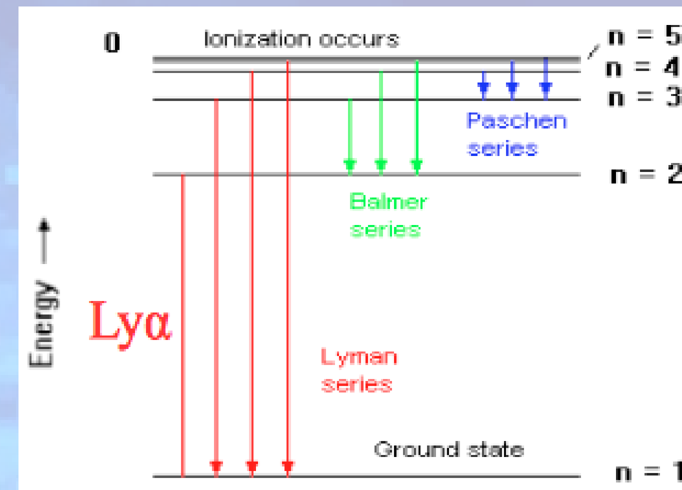
  - Lyα , UV and optical emission from Mrk 1486

  - Our numerical model

- Our results and implication for high-z galaxies
- Summary

Introduction :
The Lyα line of star-forming galaxies

The Lyman α line : the brighest emission line produced in starburst galaxies



- Lyman α line :

- A recombinaison line of the hydrogen atom

between the 2sd and the 1st energy level

- λ = 1215 A (in Far-UV)

- How does the Lyα line form in star-forming galaxies ?

Star-forming galaxy = high neutral hydrogen mass + O and B type stars

→ a *strong Lyα line is producted in HII regions (7 % of the total luminosity of the galaxy)*

- A very useful emission line to study high-redshift galaxies ?

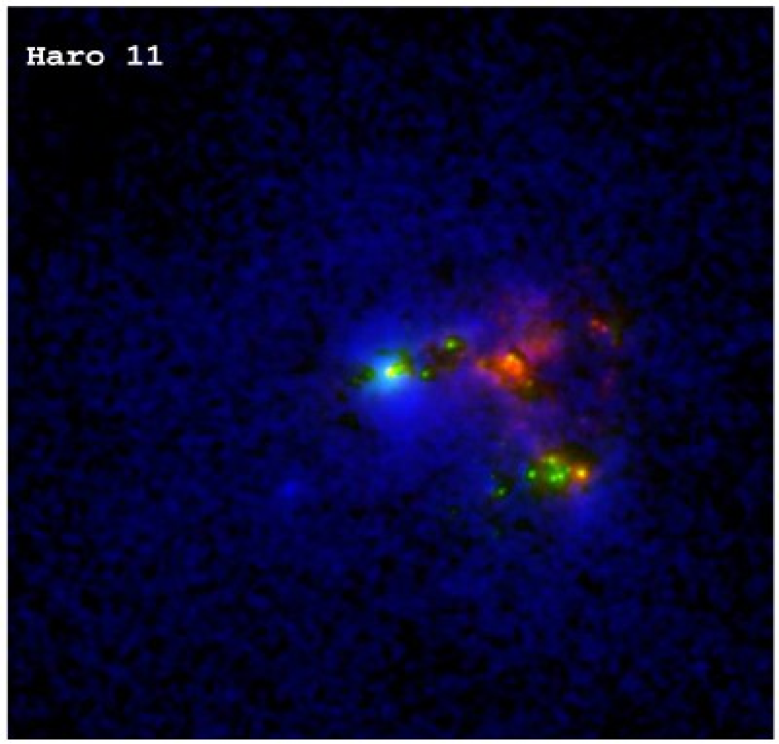
→ Numerous populations of very far galaxies have been discovered : LAE, LBG, DLA, LAB ...

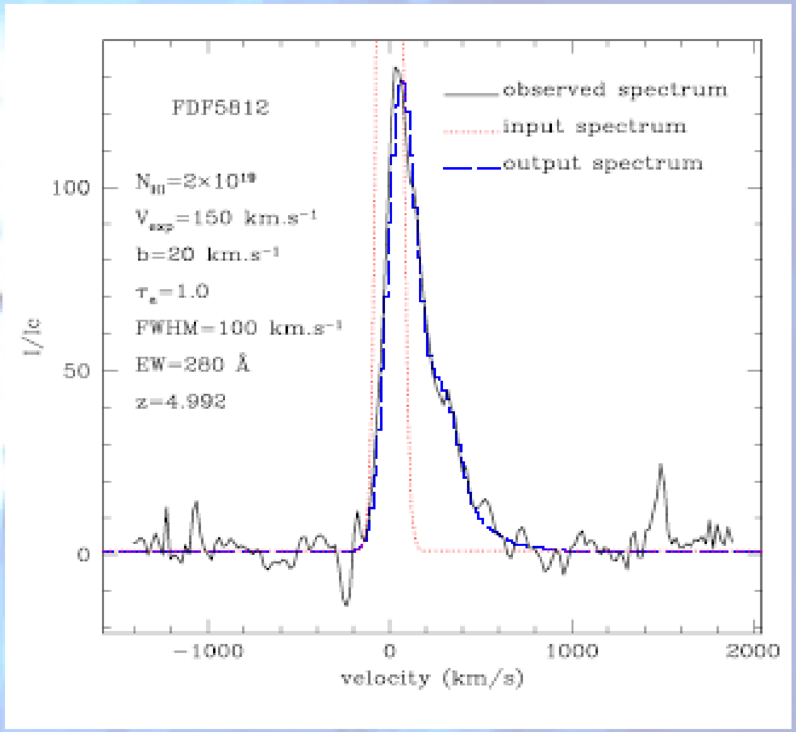
→ We can derive : s*tar Formation Rate* (SFR) , *Luminosity Function* (LF) …

However, the physics of the Lyα line is very complex

- The Lyα line is a *« resonant » line* → *in an ISM, Lyα photons are « absorbed – reemited », « absorbed – reemited » … by each neutral hydrogen atom encountered*

→ the propagation of the Lyα line in the ISM is very complex and depends on : the gas kinematics, the HI content, the dust attenuation, the ISM geometry.



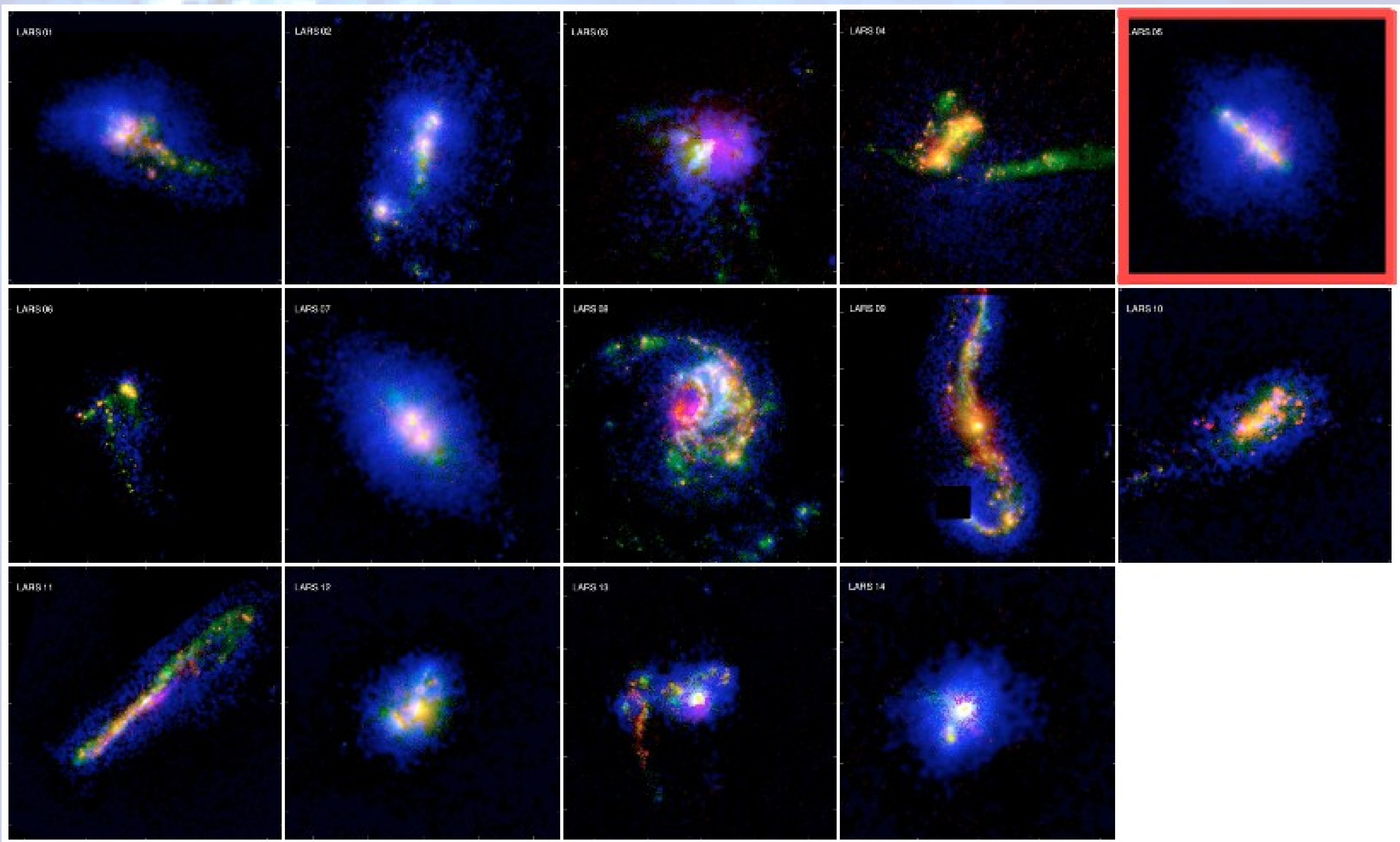


- The Lya line features (strength and line profile) encode many information on the ISM
→ the ISM physical properties can be derived from the Lya line

This work :
Studying the ISM of Mrk 1486 through the Lyα line

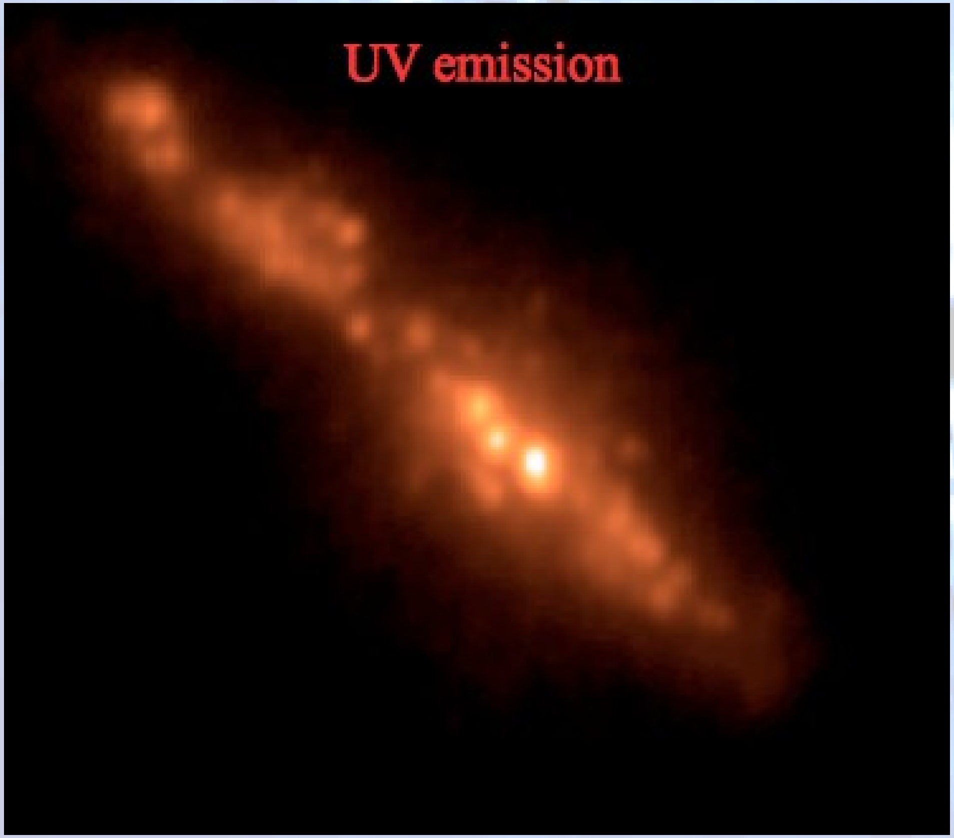
The LARS sample

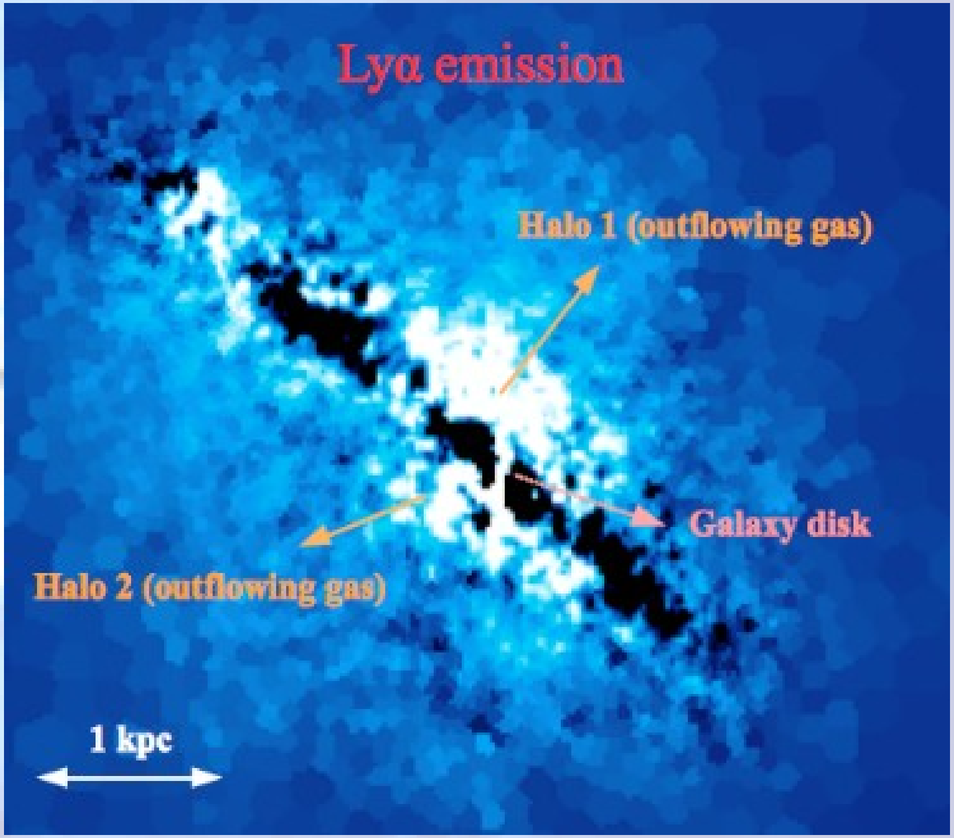
- A sample of 14 nearby starburst galaxies (0.028 < z < 0.181)
- Selected from their L_{UV} ($>10^9$ L_{O}) and EW(Hα) (> 100 Å)
- Observed in imaging (UV-optical-Near IR) and spectroscopy with the HST



Mrk 1486 : structure of the ISM

- Nearby edge-on disk starburst galaxy (z = 0.037), with SFR = 3 M_{O} yr^{-1}
- One of the brightess LARS galaxies in Lyα → goes against recent simulations that reveal that a strong Lya absorption should emerge from edge-on disk galaxies (Verhamme et al. 2013)

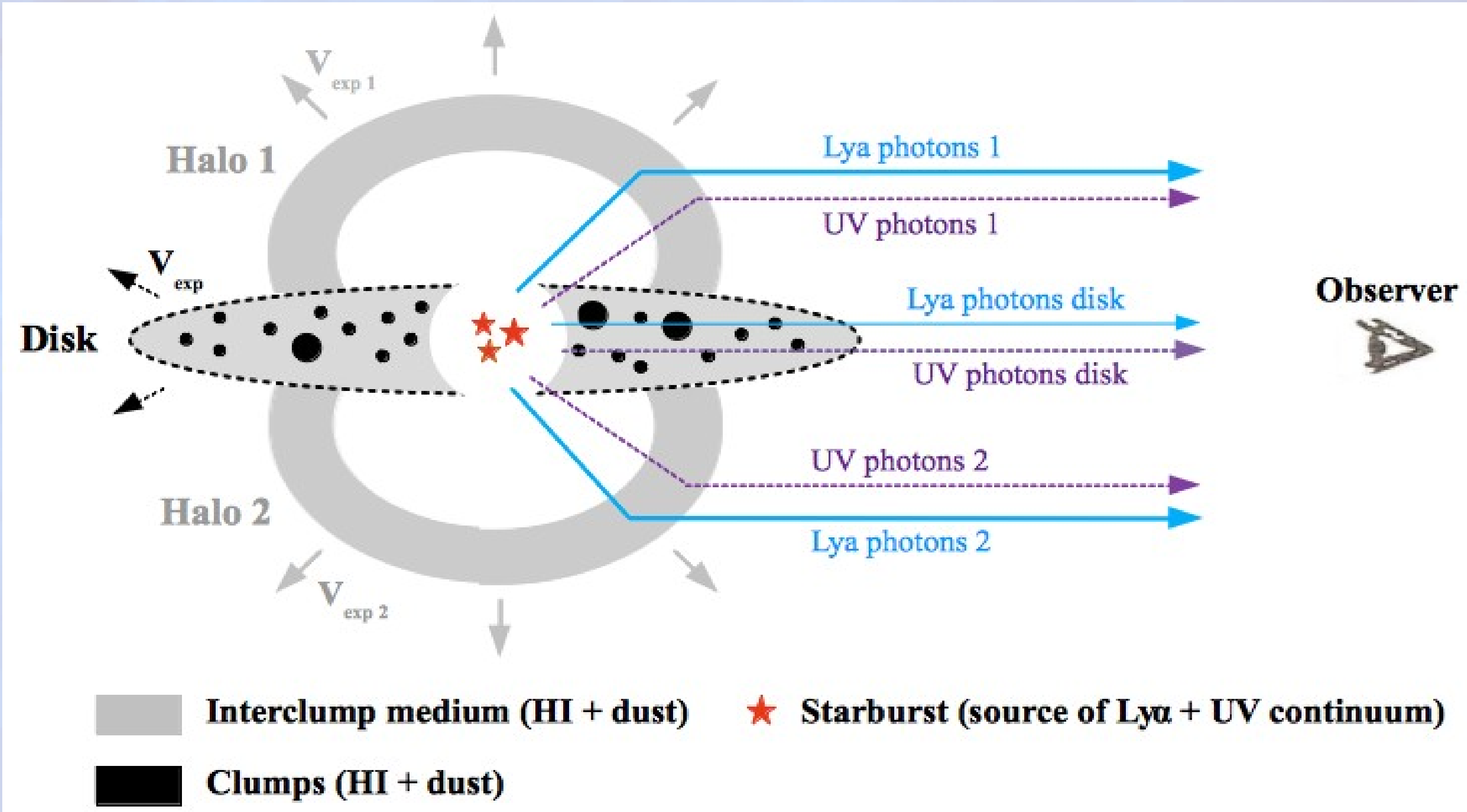




→ the ISM has a complex structure : three different components appear (the galaxy disk and two bipolar outflowing halos ; halo 1 and halo 2).

Our numerical model: 3D geometry and the MCLya code

1) 3D geometry :



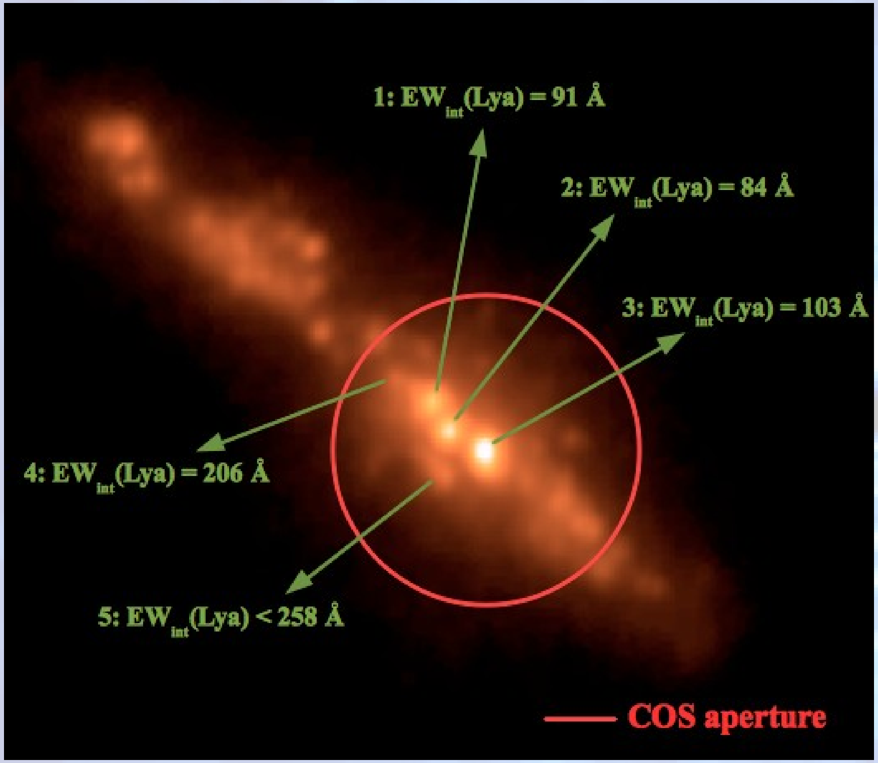
- Each component has several free parameters :

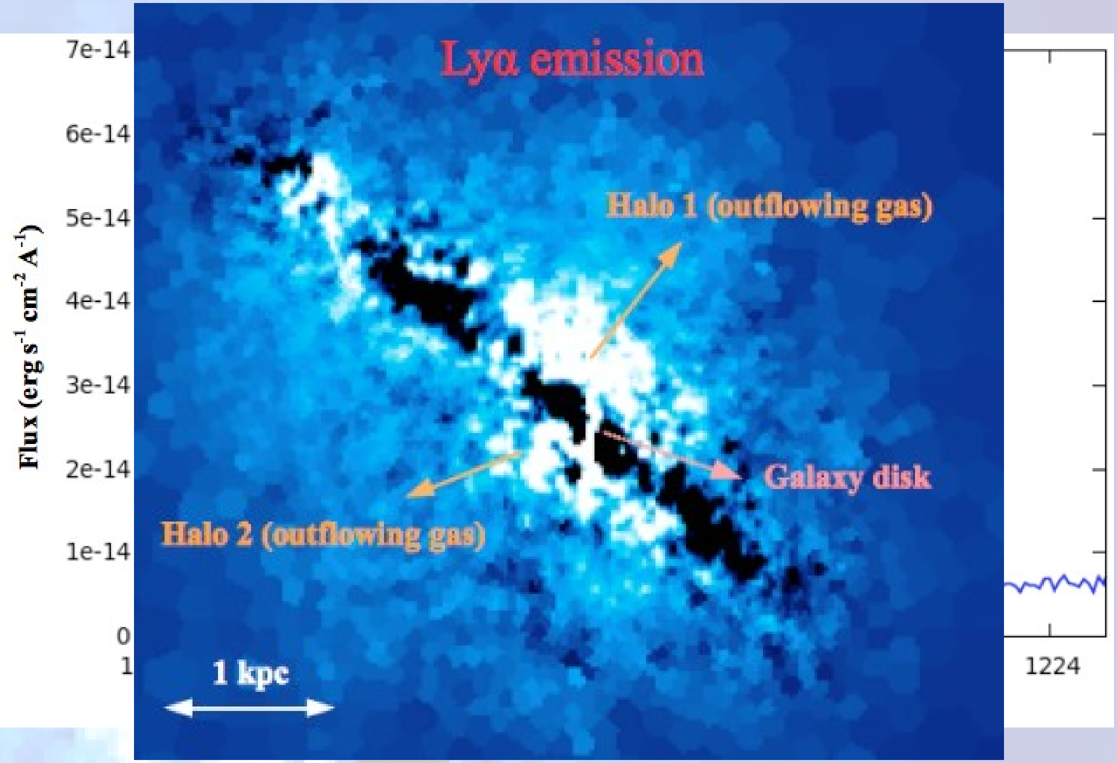
→ **Halo1, 2** : V_{exp}, N_{HI}, E(B-V) and T

→ **Disk** : V_{exp}, N_{HI}, E(B-V), T and clumpiness of the gas distribution

We constraint V_{exp}, N_{HI}, E(B-V) and T in two ways

1) Fitting the shape of the Lya line of Mrk 1486 :





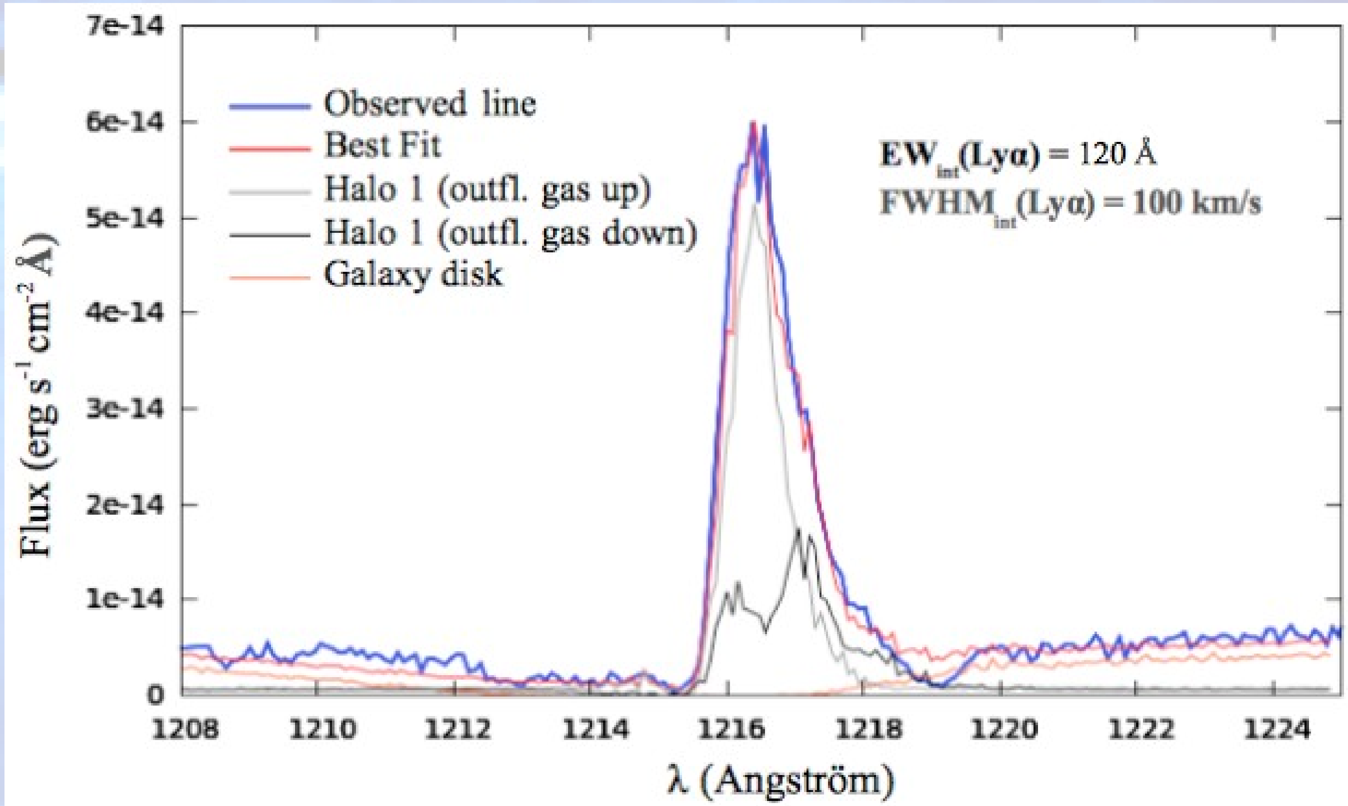
2) Reproducing the following properties of each component

Region	Lyα contribution	UV contribution	Hα/Hβ (i.e. dust content)
Halo 1	$78\%^{+1}_{-1}$	$18\%^{+3}_{-3}$	3.30 (1)
Halo 2	$22\%^{+1}_{-1}$	$5\%^{+0.5}_{-1}$	3.42 (1.6)
Galaxy disk	0%	$77\%^{+4}_{-4}$	3.85 (6.21)

Results and best fit parameters

Best Fit parameters consistent with the observed properties of Mrk 1486

- Best Lyα line fit :



- Best fit parameters :

Region	Lyα contribution	UV contribution	v_{exp} km.s^{-1}	N_{HI} cm^{-2}	E(B-V)	Temperature K
Halo 1	74% ✓	16% ✓	100^{+10}_{-10} ✓	3×10^{19}	$0.04^{+0.01}_{-0.01}$ ✓	20 000
Halo 2	26% ✓	5% ✓	190^{+10}_{-10} ✓	8×10^{19}	$0.071^{+0.01}_{-0.01}$ ✓	20 000
Galaxy disk	0% ✓	78 % ✓	130^{+50}_{-50}	$> 5\times10^{21}$	$0.40^{+0.1}_{-0.1}$	10 000

Summary

- Due to its resonant nature, the Lyα line is a useful tool to derive the ISM physical properties of nearby and high-z starburst galaxies.
- We have been able to derive the ISM properties of Mrk 1486 1) fitting the Lya line profile and 2) reproducing the observed properties of Mrk 1486.

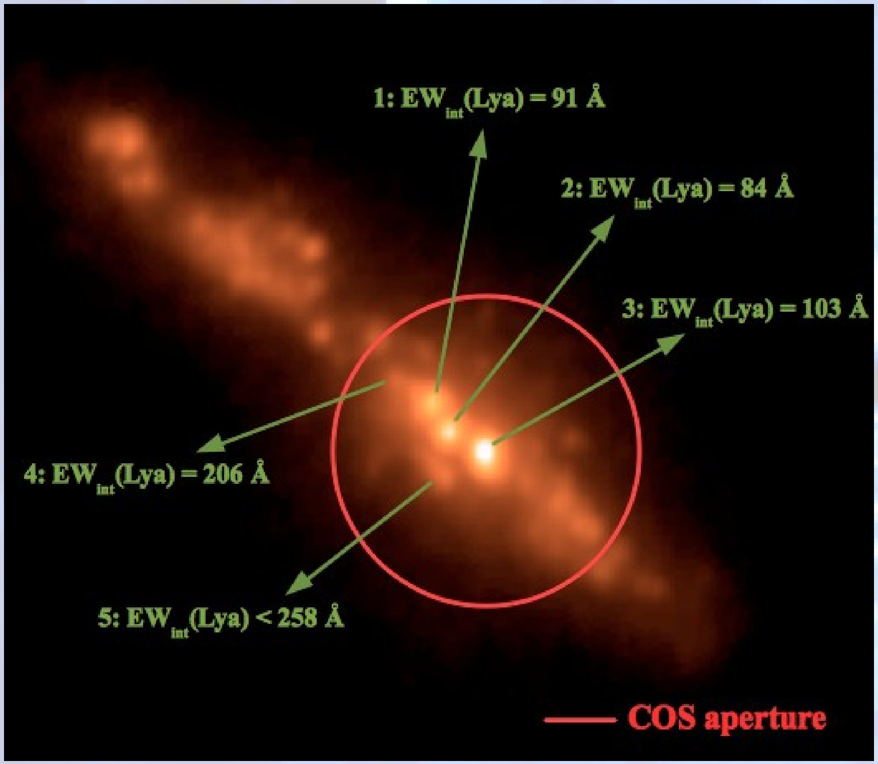
Region	Lyα contribution	UV contribution	v_{exp} km.s^{-1}	N_{HI} cm^{-2}	$\overline{\tau_a}$	Temperature K
Halo 1	74%	16%	100^{+10}_{-10}	$3x10^{19}$	$0.90\ ^{+0.01}_{-0.01}$	20 000
Halo 2	26%	5%	190^{+10}_{-10}	$8x10^{19}$	$1.40^{+0.01}_{-0.01}$	20 000
Galaxy disk	0%	78 %	130^{+50}_{-50}	$> 5x10^{21}$	$4.5^{+0.1}_{-0.1}$	10000

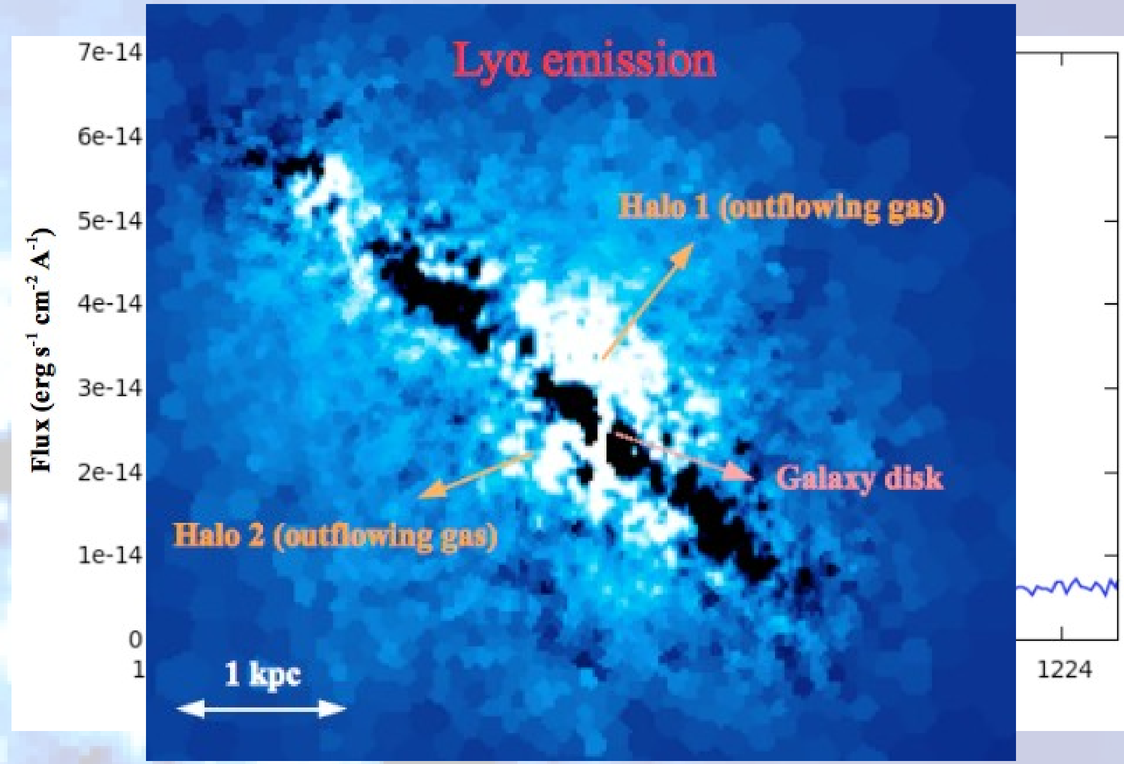
- Our work shows how Lya photons are able to escape from edge-on disk starburst galaxies (it goes against the last numerical simulation of Verhamme et al. 2013)

→ it seems that the difference between LAEs and LBGs is not only based on an effect of viewing angle

Observational data

1) Spectroscopic data





2) Photometric data

Region	Lyα contribution cm^{-2}	UV contribution	Hα/Hβ (i.e. dust content)
Halo 1	$78\%^{+1}_{-1}$	$18\%^{+3}_{-3}$	3.30 (1)
Halo 2	$22\%^{+1}_{-1}$	$5\%^{+0.5}_{-1}$	3.42 (1.6)
Galaxy disk	0%	$77\%^{+4}_{-4}$	3.85 (6.21)

The Hα emission