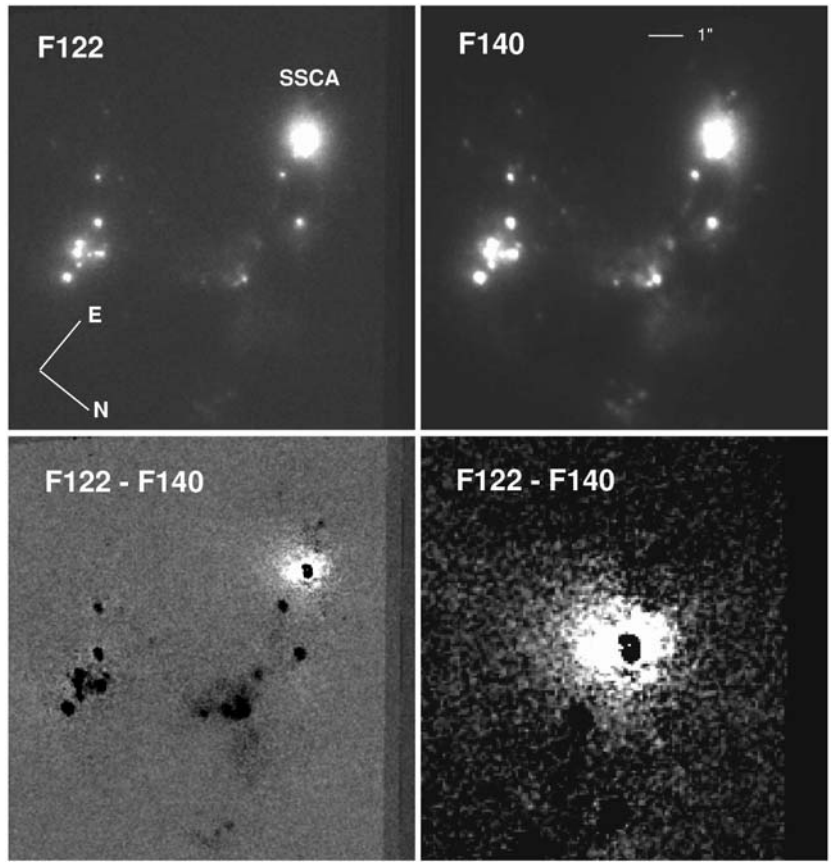
Lyman α emission in starbursts: from GHRS to ACS

J. Miguel Mas-Hesse
CAB (CSIC-INTA)

in collaboration with

D.Kunth, G.Tenorio-Tagle, C.Leitherer, R. Terlevich, E. Terlevich, G.Östlin, A.Petrosian



IUE and the origin of the *'Lyman α problem'*

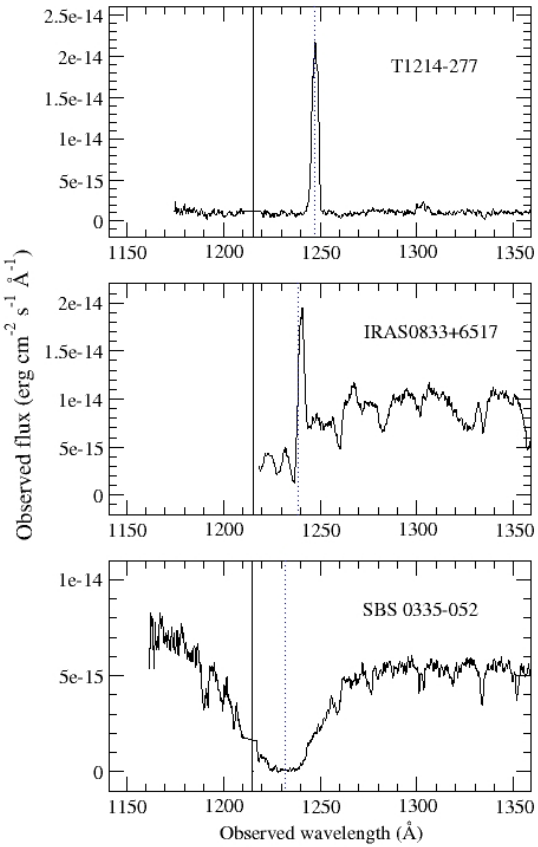
- HII regions should emit a prominent Lyman α line
  L(Lyman α) / L(Hβ) ~ 33 in typical conditions

- But IUE showed a variety of situations:
  - When Lyman α was detected, its intensity was frequently well below the theoretical value, even allowing for reddening.
  - In many cases, the line was not detected at all in emission.
  - In some cases, a strong, damped absorption line was visible instead.

What was driving the visibility of the line?

GHRS results: the effects of kinematics

- A sample of 8 Blue Compact Galaxies was observed with high resolution.
- When Lyman α was detected, it showed in most cases a prominent P Cigny profile.
- The neutral metallic lines appeared in these cases blueshifted by 200-400 km/s. Lequeux et al. (1995), Kunth et al. (1998).
- Pure emission was found by Thuan & Izotov (1997).

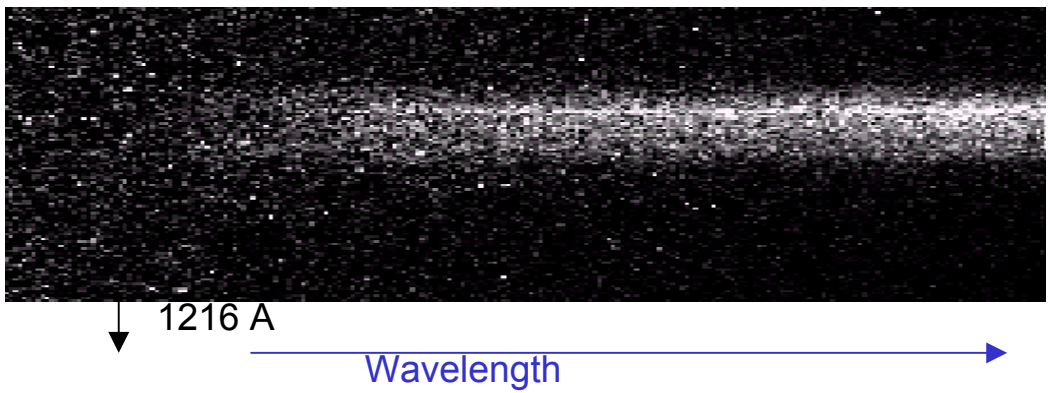


GHRS results: the effects of kinematics

- Main conclusions from GHRS data:
  - In some cases (at least 1!), Lyman α was detected without traces of absorption distorting the profile.
  - In the most frequent cases, the neutral gas along the line of sight was *flowing with 200-400 km/s velocities* from the HII region, producing a prominent P Cygni profile.
  - When the neutral gas was static w.r.t. the HII region, a damped broad absorption profile was detected.
- Next step: 2-D analysis with STIS:

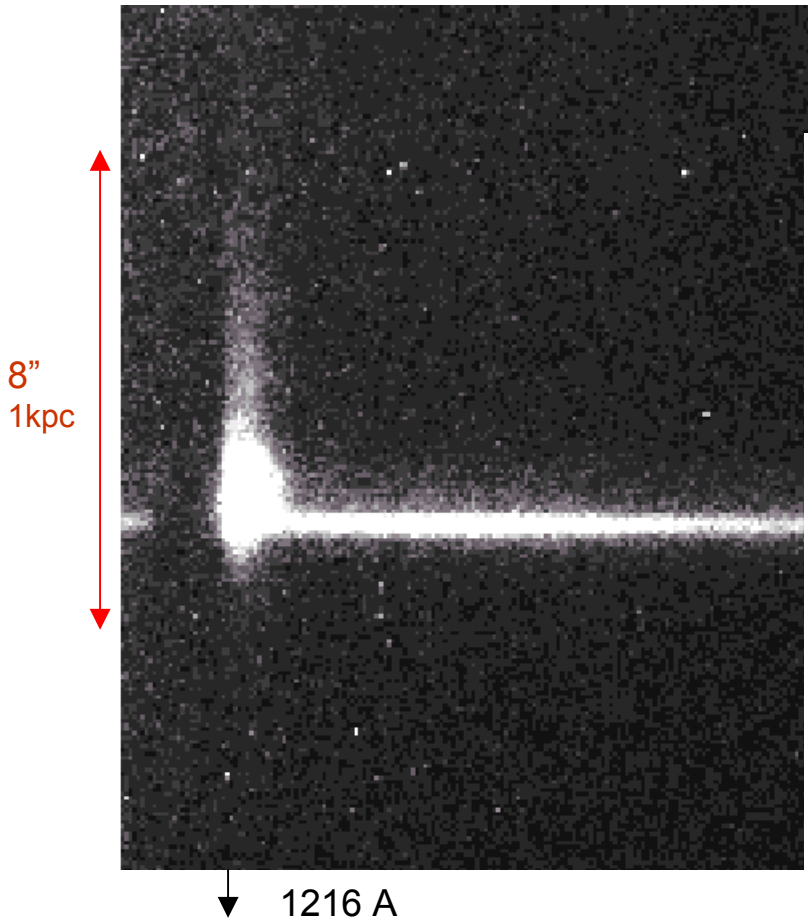
The 2-D view: STIS observations

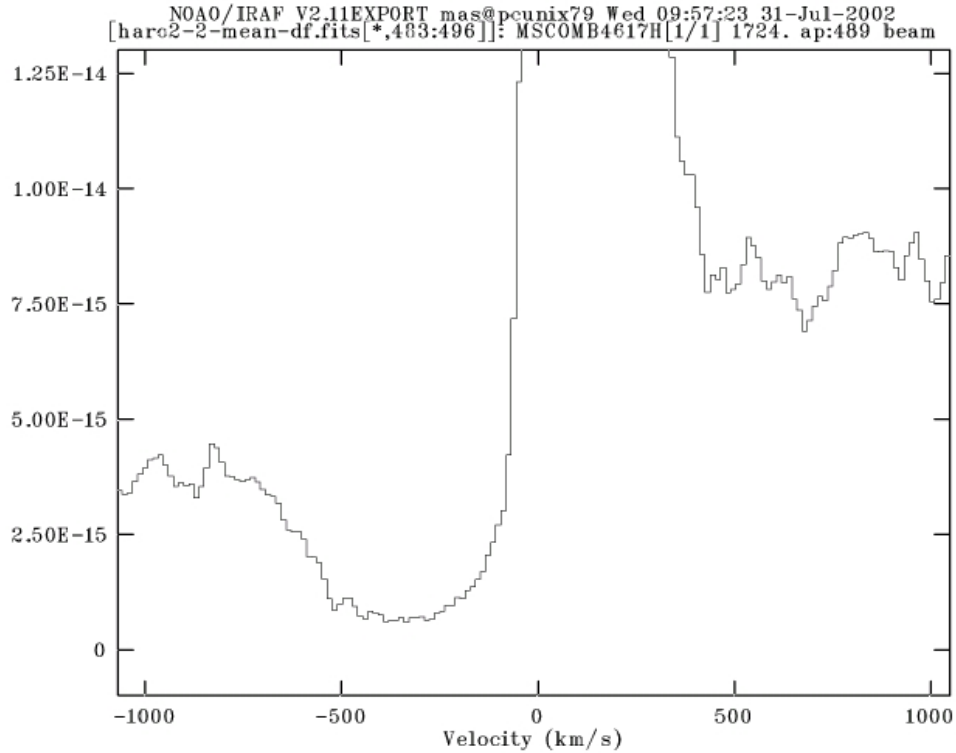
- Observations with STIS were performed on 3 objects, 2 showing a strong Lyman α P Cygni profile (**Haro 2** and **IRAS 0833**) and 1 showing a damped absorption (**IZw 18**), aiming to:
  - Analyze the spatial structure of the emission
  - Look for leaking areas in IZw18



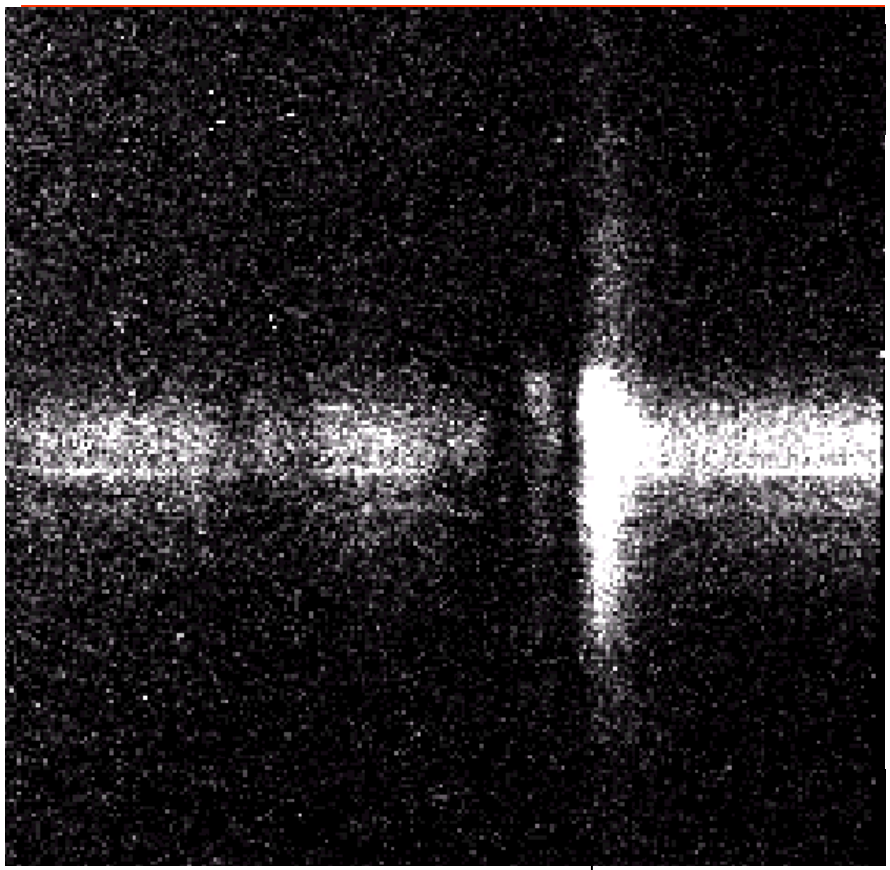
IZw 18

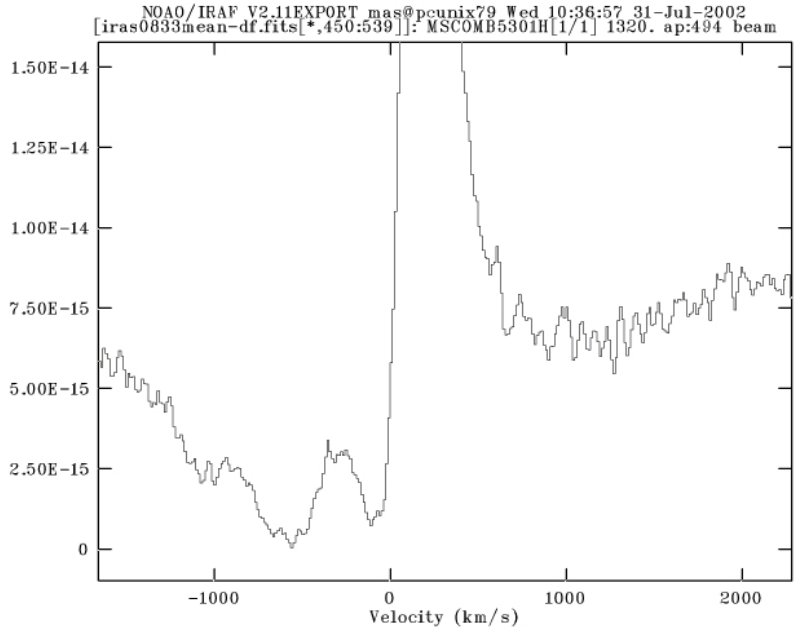
Haro 2


8”
1kpc
1216 A
Wavelength


NOAO/IRAF V2.11EXPORT mas@pcunix79 Wed 09:57:23 31-Jul-2002
[haro2-2-mean-df.fits[*,483:496]]: MSCOMB4617H[1/1] 1724. ap:489 beam
1.25E-14
1.00E-14
7.50E-15
5.00E-15
2.50E-15
0
-1000
-500
0
500
1000
Velocity (km/s)

IRAS 0833


10”
5 kpc
1216 A
Wavelength


NOAO/IRAF V2.11EXPORT mas@pcunix79 Wed 10:36:57 31-Jul-2002
[iras0833mean-df.fits[*,450:539]]: MSCOMB5301H[1/1] 1320. ap:494 beam
1.50E-14
1.25E-14
1.00E-14
7.50E-15
5.00E-15
2.50E-15
0
-1000
0
1000
2000
Velocity (km/s)

The 2-D view: STIS results

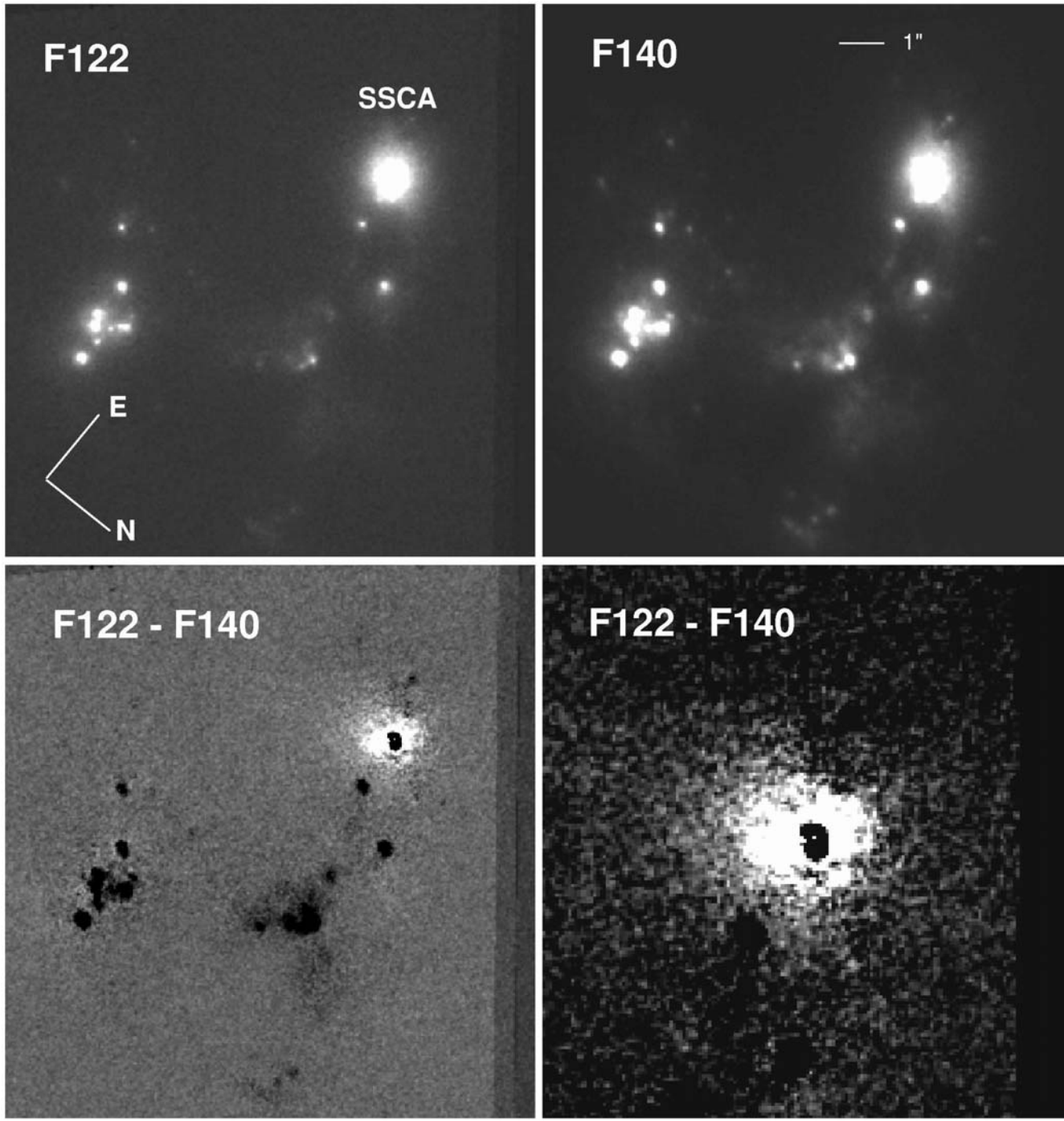
- Summary of main observational results:
  - No velocity structure on the sharp edge of the P Cygni profile on scales of 1-5 kpc.
  - Large neutral Hydrogen column densities of gas outflowing from the HII region at velocities of 200 - 400 km/s, acting practically as a moving plane-parallel slab on kpc scales.
  - Presence of broad and extended emission components of low intensity.
  - Spatial decoupling between Lyman α emission and UV continuum.
- Evolutionary view: the different profiles could be correlated with the evolutionary status of the starburst.
  Mas-Hesse et al. 2003
- Next step: HST-ACS Lyman α imaging

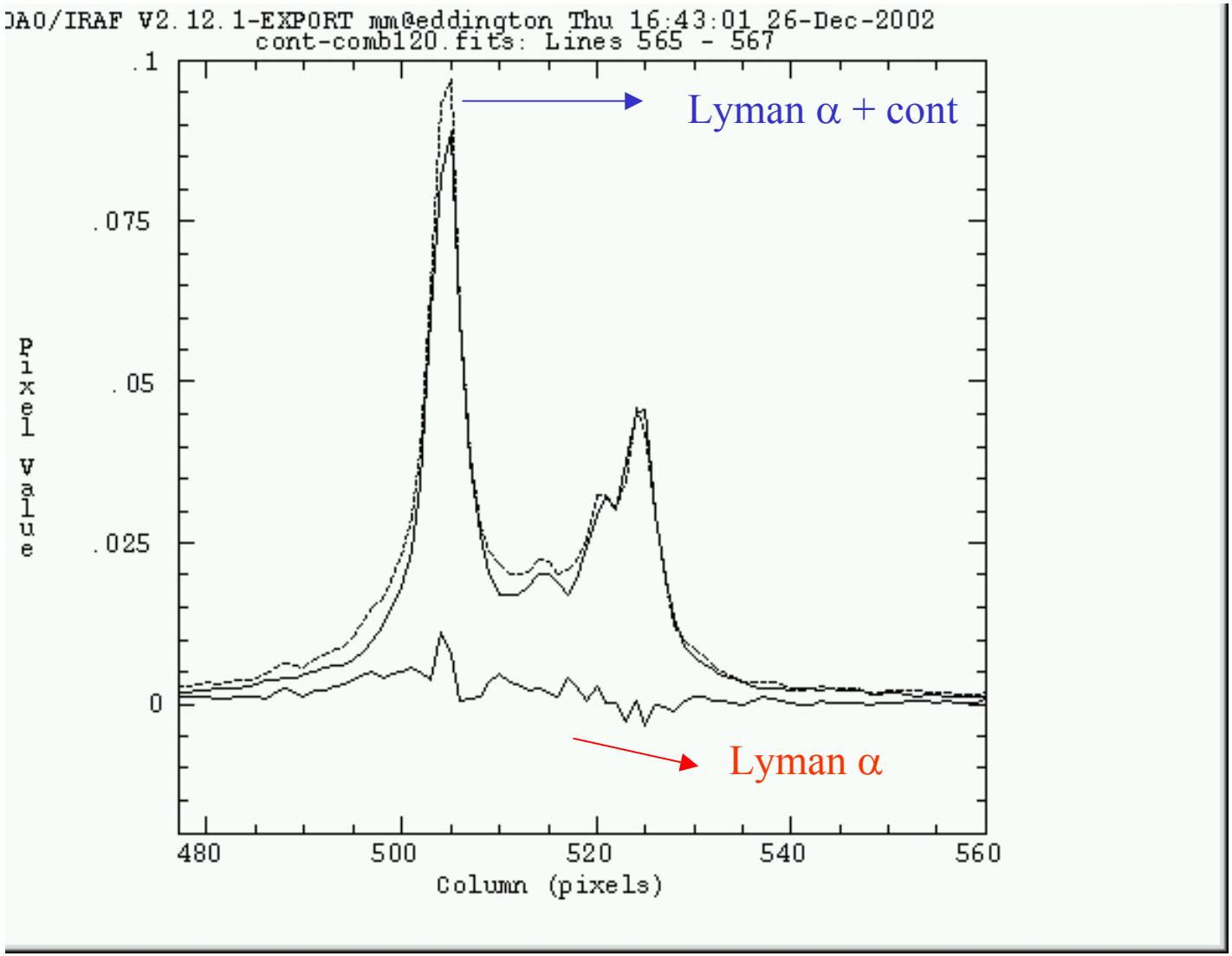
ACS Imaging: The data

- Observations with ACS are being performed for a sample of 5 starburst galaxies, some known to be Lyman α emitters, and some showing broad absorptions.
- Objectives:
  - Analyze the spatial distribution of Lyman α emission, in comparison with Hα and Hβ
  - Look for regions where Lyman α photons could leak (low HI column density, expanding shells, ...)
- Present status:
  - 2 starburst galaxies have been observed and analyzed
  - 3 more will be done during 2003.

  Kunth et al. 2003

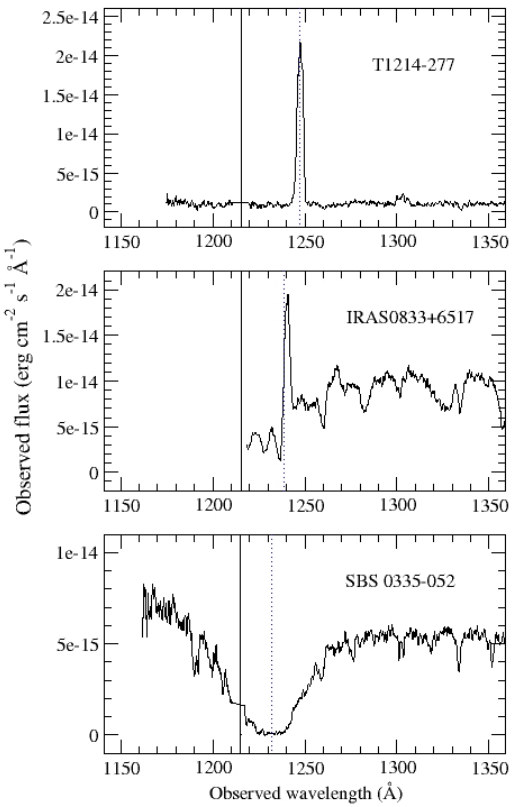
ESO350

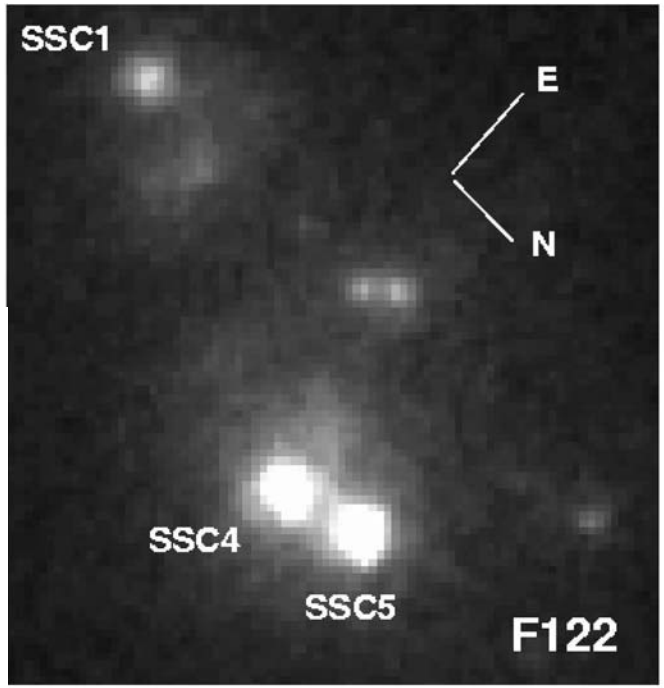


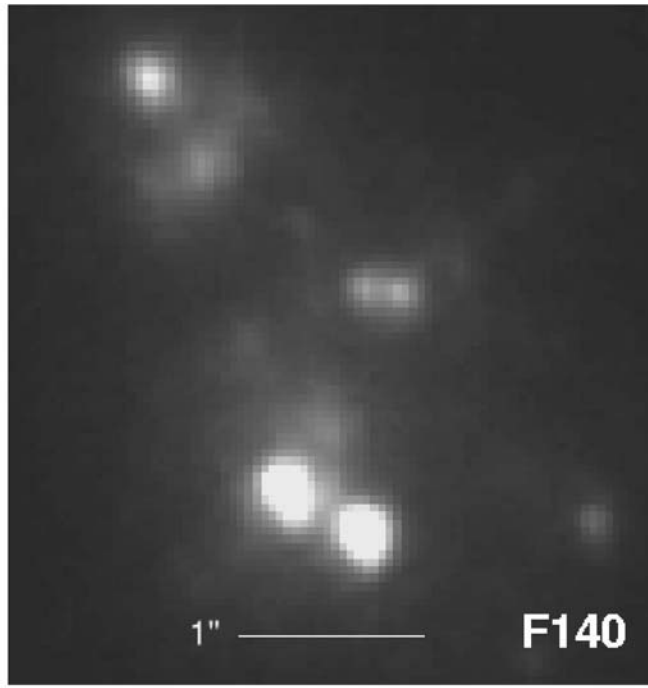


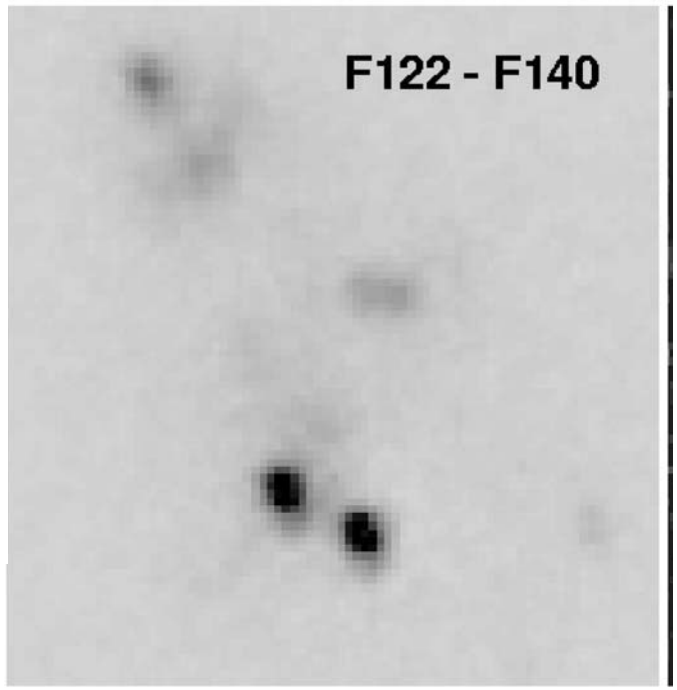
There maybe some Lyman α photons leaking in this region!

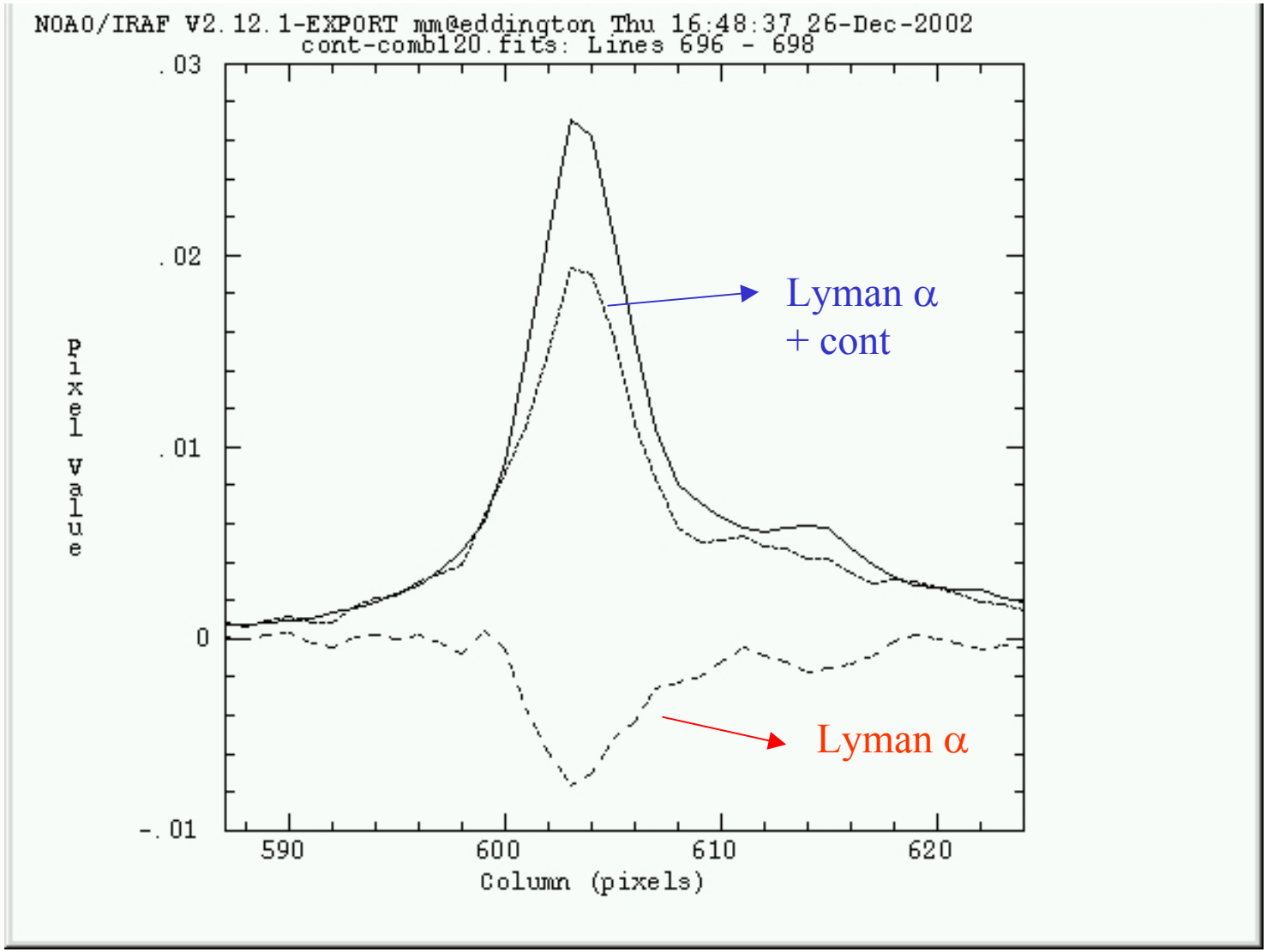
SBS0335-052


T1214-277
IRAS0833+6517
SBS 0335-052
Observed flux (erg cm^{-2} s^{-1} Å^{-1})
Observed wavelength (Å)

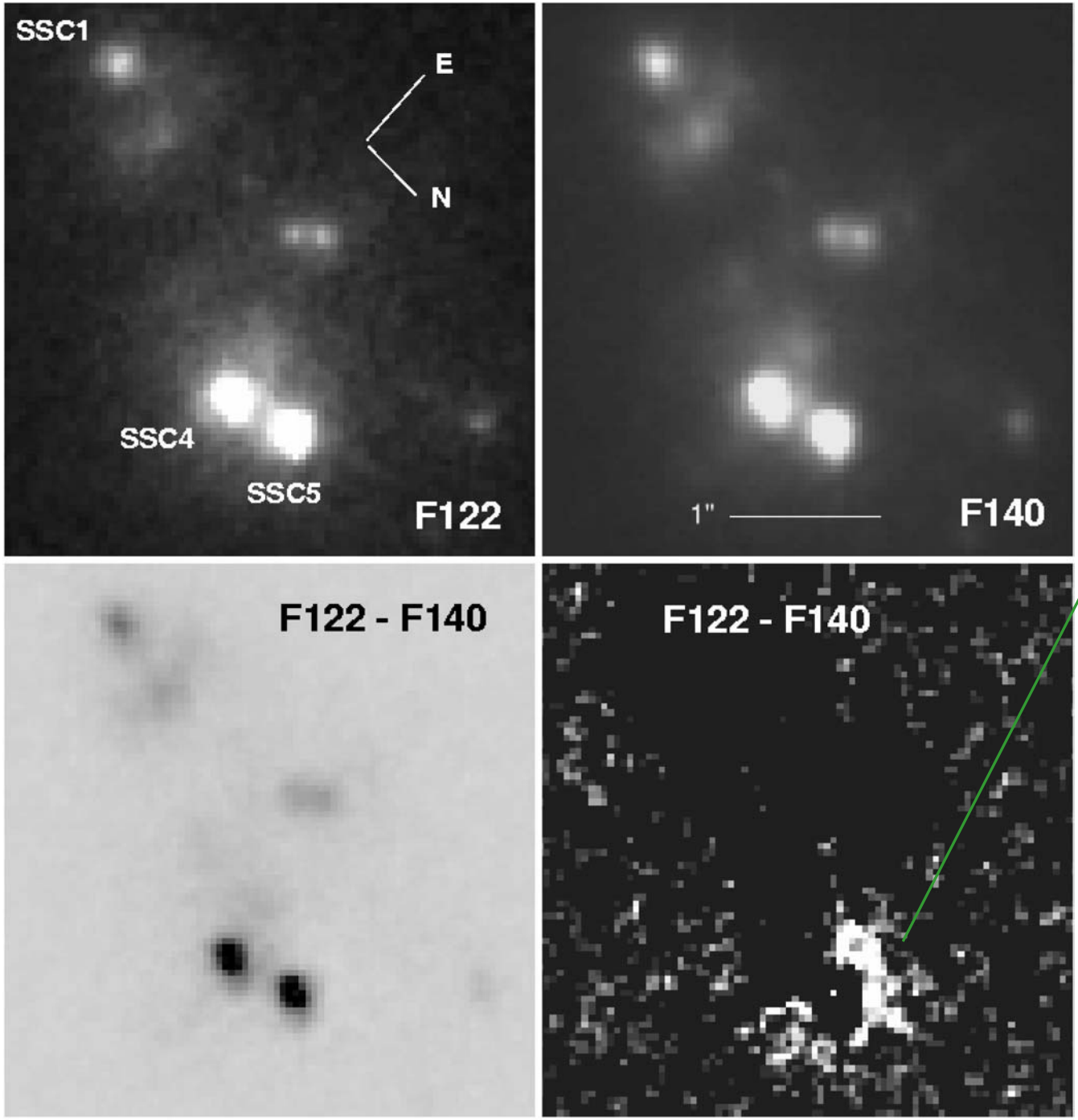

SSC1
E
N
SSC4
SSC5
F122


1"
F140


F122 - F140



There is a clear lack of photons within the Lyman α filter!



Lyman α photons are leaking in the region surrounding the SSC !!

ACS Imaging: Preliminar results

- ACS imaging through the F122M and F140LP filters allows to analyze the spatial structure of the Lyman α emission.
- The brightest knots of ESO350 show a strong emission, with a minimum at the center of the SSC. This minimum is attributed to the knowm P Cygni properties of this region.
- The brightest knots of SBS0335, on the other hand, show a significant lack of photons wirhin the F122 filter, due to the broad absorption profile.
- ***But some weak leaking of Lyman α photons can be detected in extended regions of both objects!!***

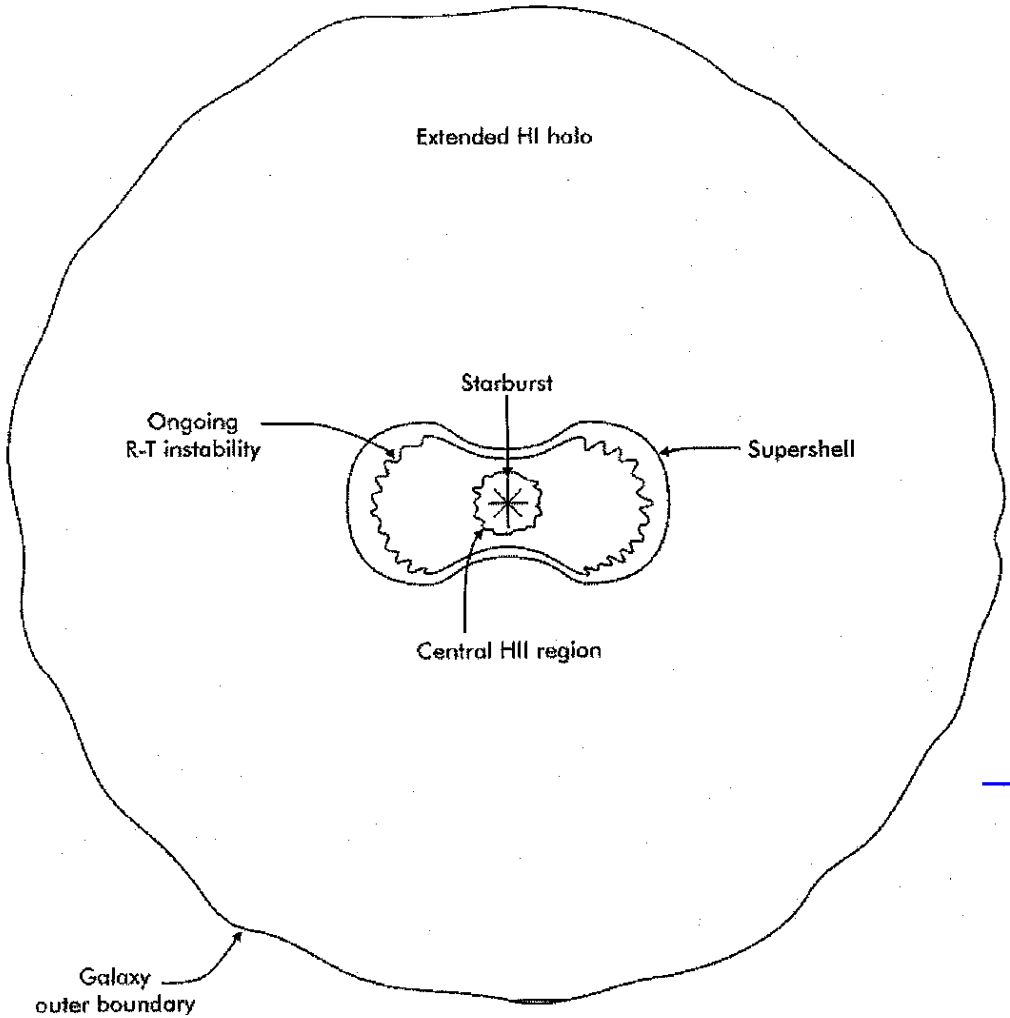
Lyman α visibility: an evolutionary view

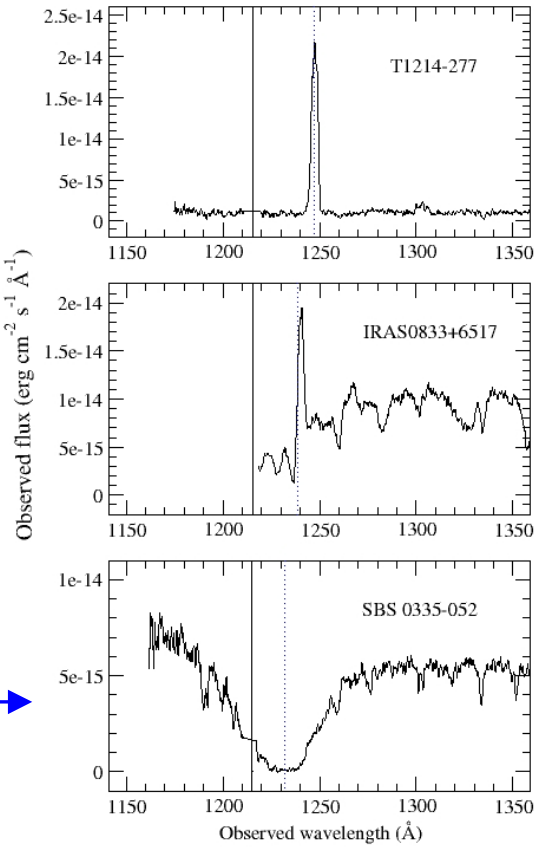
- Observational results suggest that the starbursts are driving a huge expanding shell of neutral gas.

- The interaction of the ionizing flux and the shell itself with the surrounding medium can lead to different configurations which could explain the variety of Lyman α profiles.

  These scenarios could be correlated with the evolution of the starburst.

First phase: damped absorption



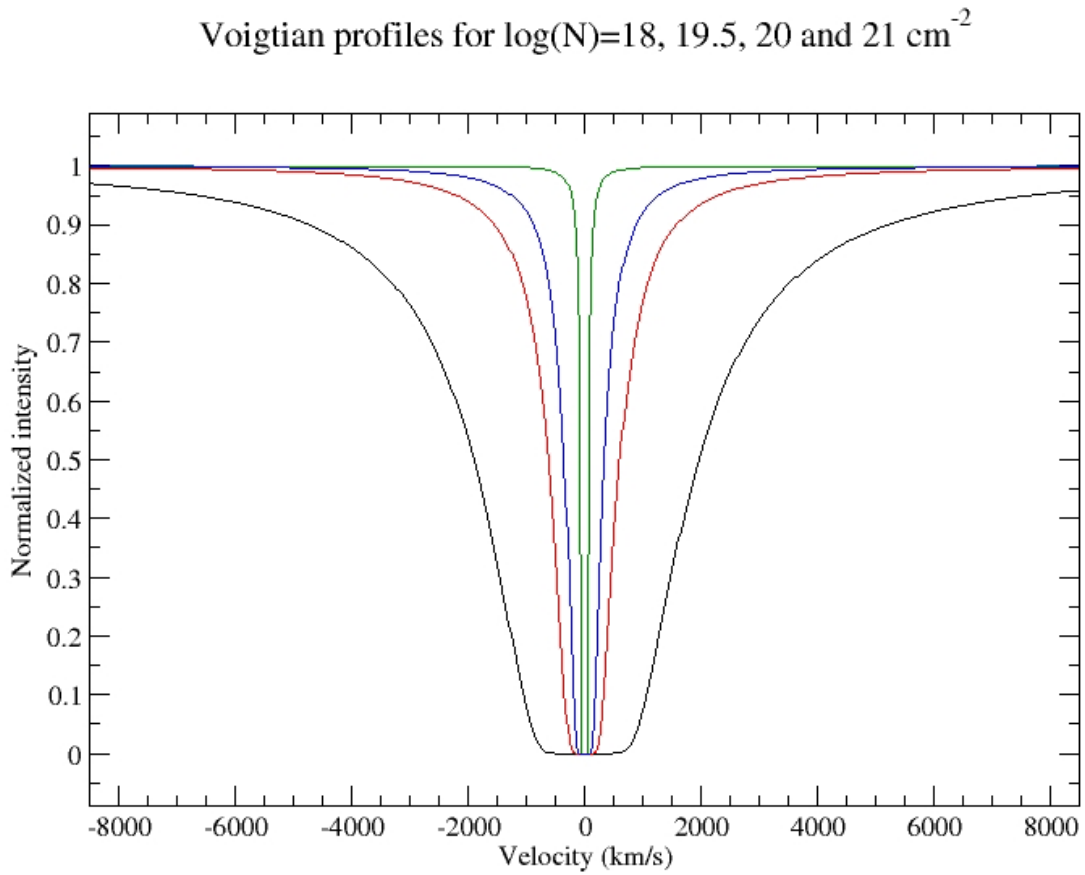


Lyman α destruction

For HI column densities $> 10^{18}$ cm^{-2}, resonant scattering starts to affect 100% of the photons at the nominal Lyman alpha wavelength.

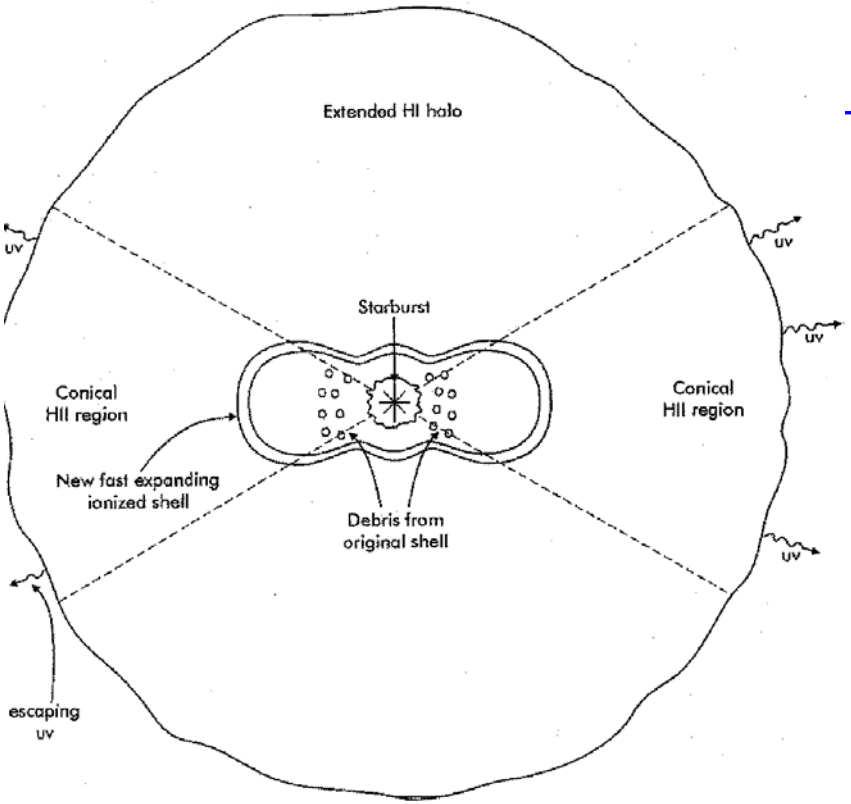
Resonant scattering increases exponentially the probability of absorption by dust, even if scarce.

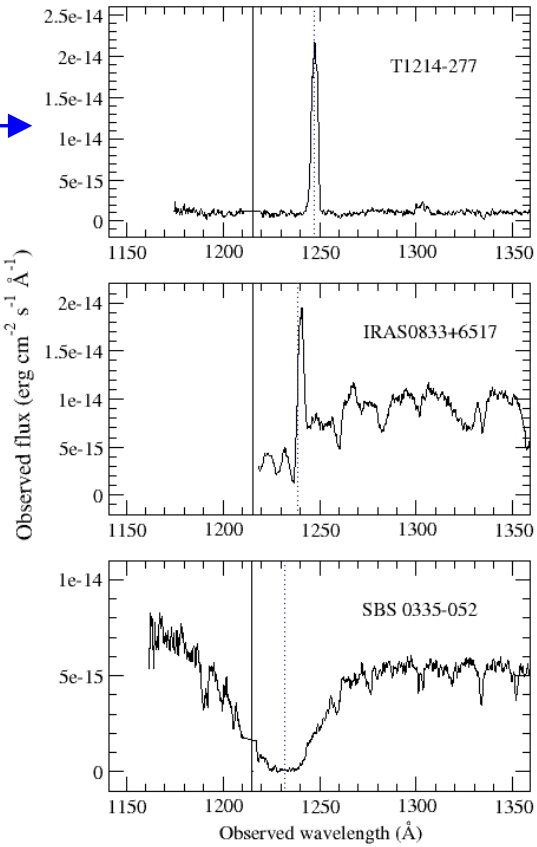
At higher column densities, photons with broader energy ranges are affected.



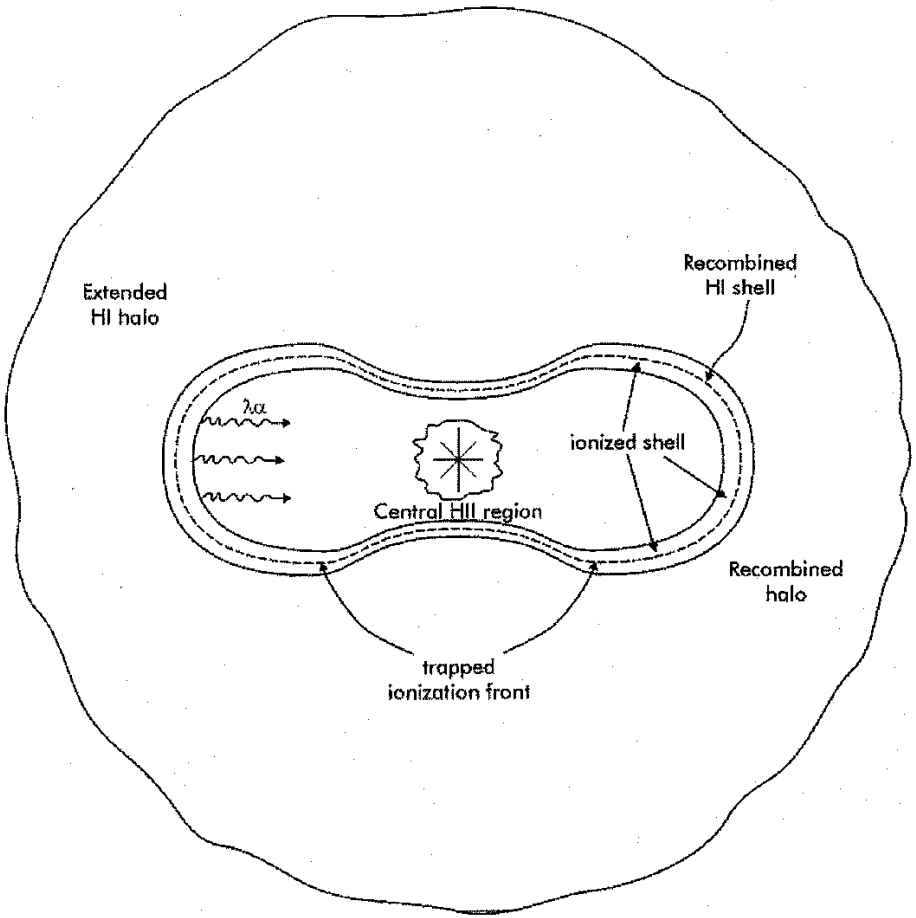
Young phases: strong and pure emission line

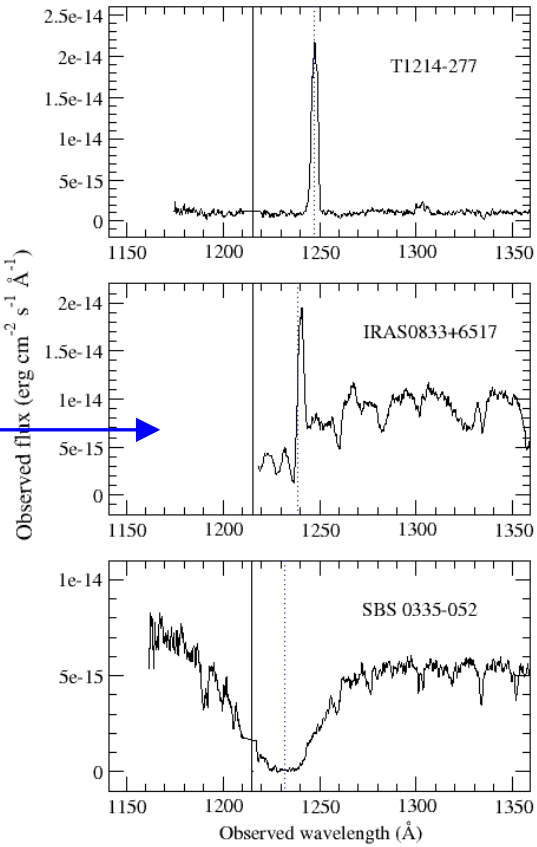
but visibility depends on line of sight!





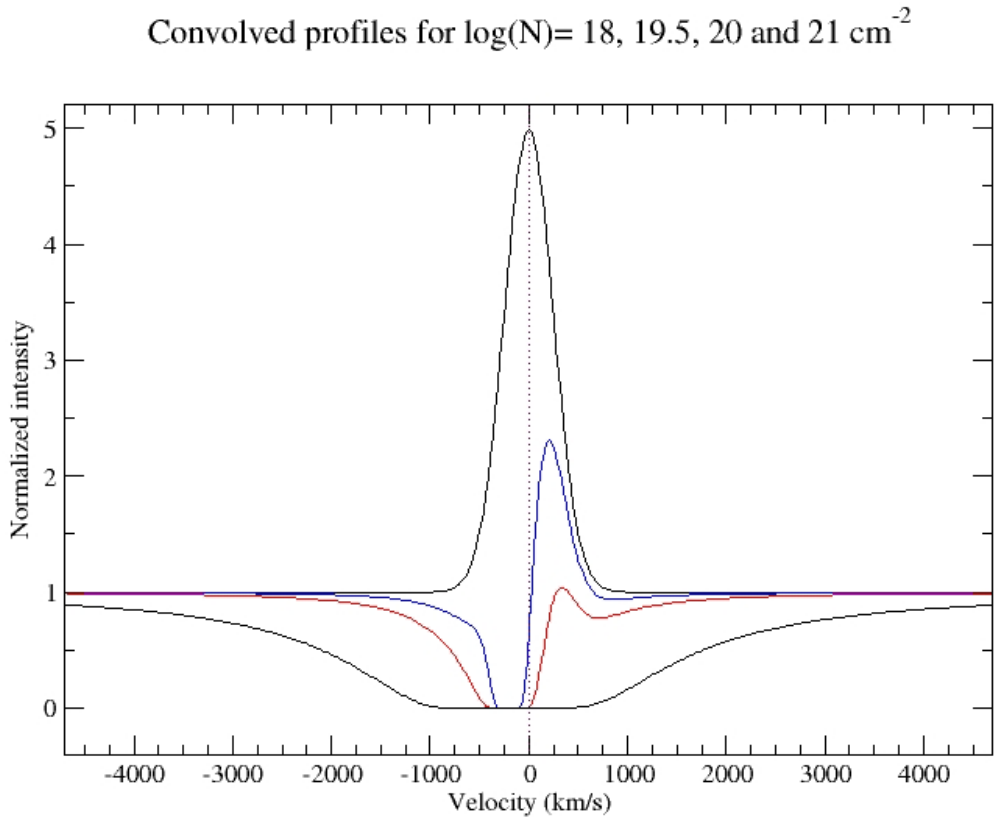
Evolved starburst: outflowing HI layers induce marked P Cygni profiles





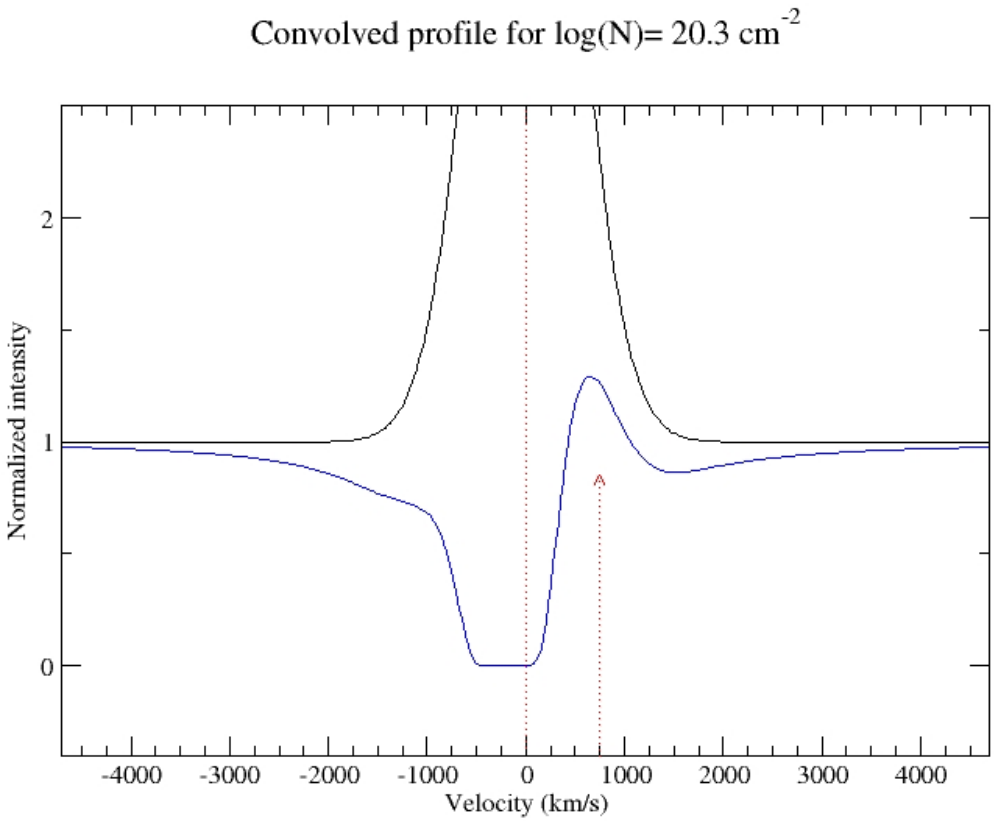
The effects of an expanding shell:

P Cygni and/or absorption profiles

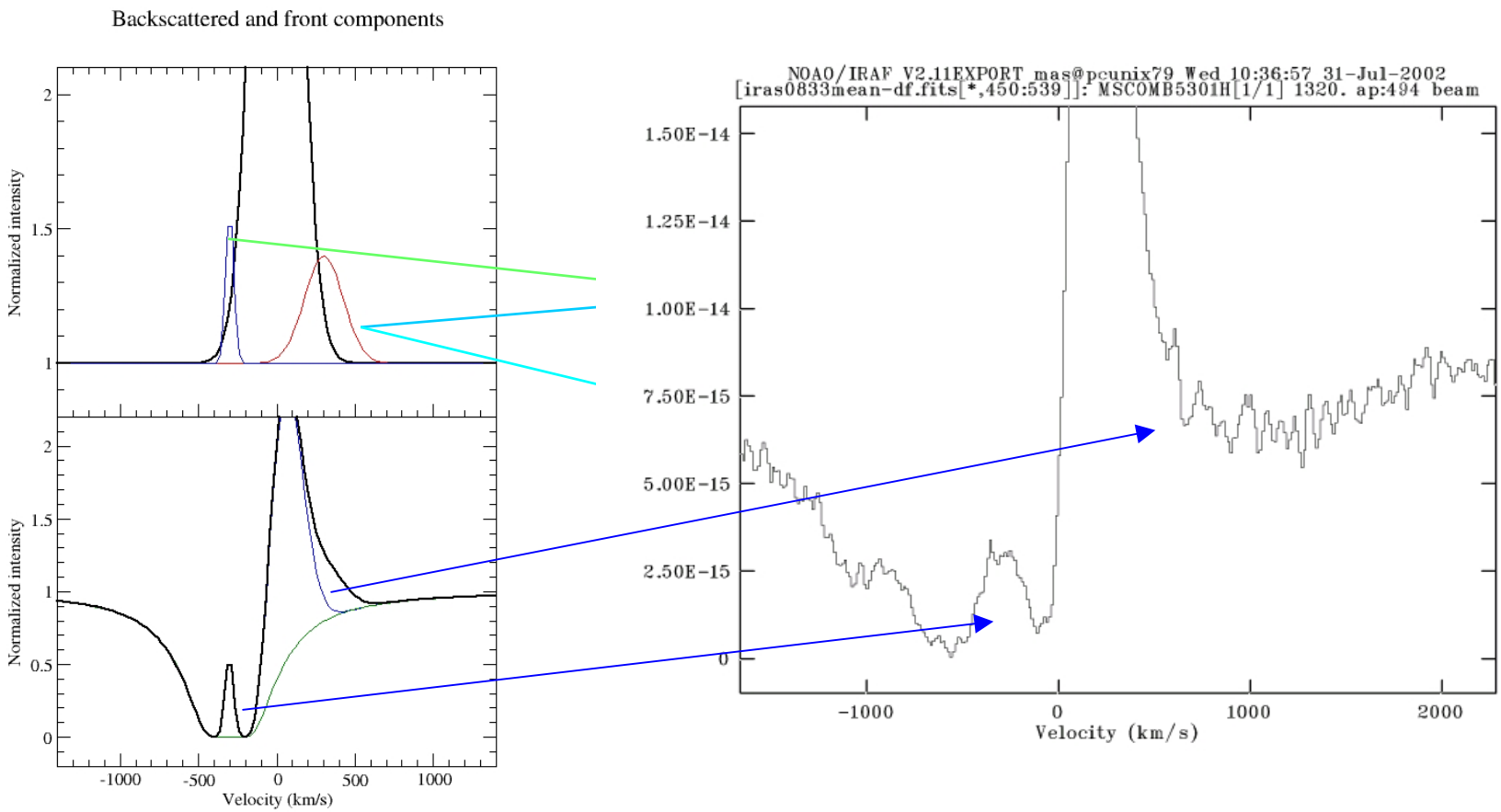


HI layer moving at -200 km/s

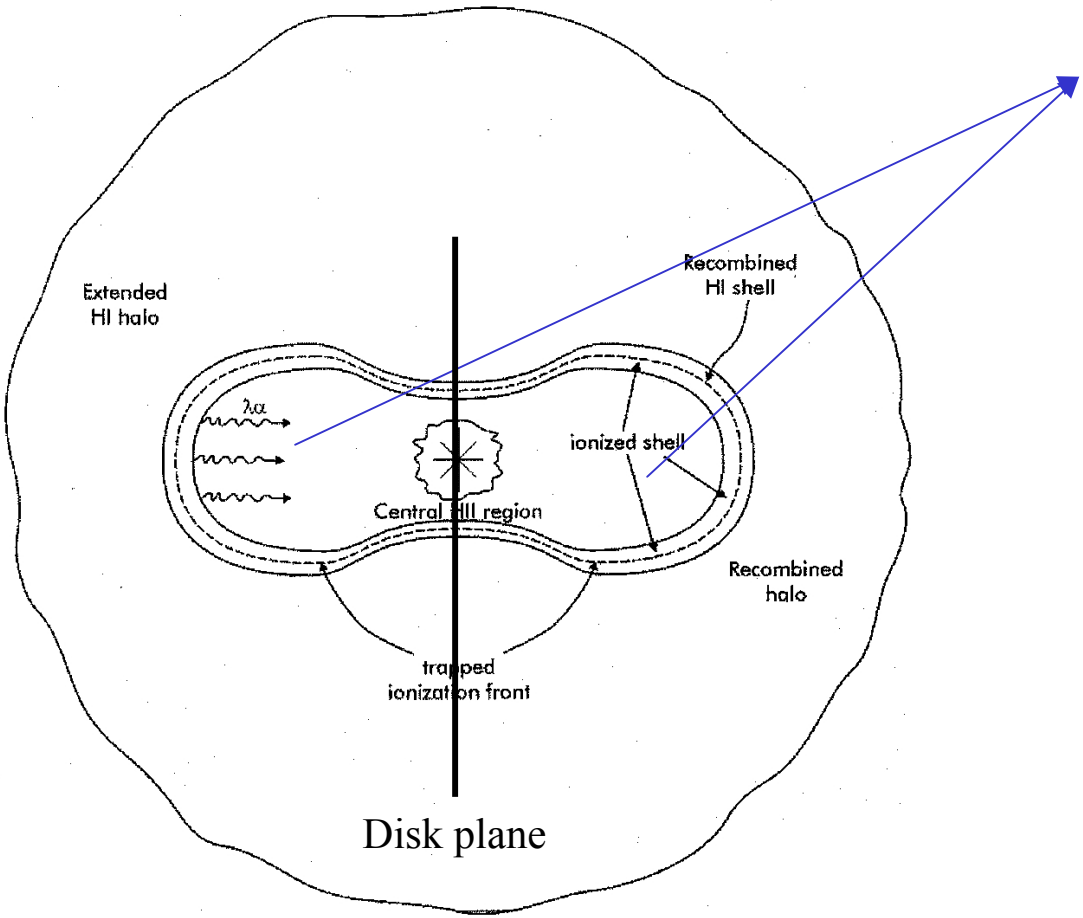
The effects of an expanding bubble:
artificial 'redshift' of the emission peak



The effects of an expanding bubble:
backscattered and front components



Where are the newly formed metals?



The hot, metal enriched gas might still be confined within the expanding shell!

Implications for galaxies at high redshift

- Observed profiles suggest the same mechanisms are present in massive starbursts at high redshift (z = 2-3).
- Thererefore, derived parameters might be wrong by significant amounts:
  - Intensities would be underestimated, and therefore so will be SFRs....
  - Even worse, many galaxies forming intensively massive stars, but not showing Lyman α, will be counted as inactive.

    Star formation densities at high redshift might be severely underestimated if based only on Lyman α.

  - Redshift determinations will also be wrong by up to 1000-2000 km/s.

Conclusions

- The properties of the observed Lyman α profiles are driven by:
  - Kinematical effects: presence of a neutral/ionized expanding shell.
  - Orientation effects.
- The properties of this shell are linked to the evolutionary state of the starburst. We are now to understand 2nd order effects.
- The P Cygni properties suggest that the shells are expanding into a low density, extended halo, and haven´t therefore blown-out (*yet*) into the intergalactic medium.
- A similar scenario shall be applicable to high redshift starbursts.
- Parameters derived from Lyman α can be misleading if these effects are not considered.