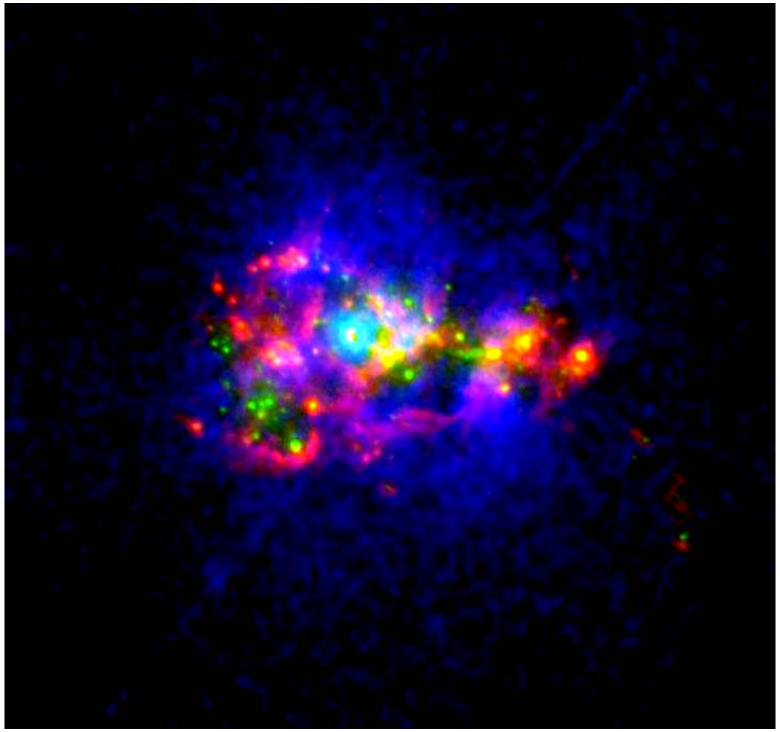
Local galaxies as seen in Lyman-alpha



HST Workshop – Bologna, Jan 31 2008

Hakim ATEK
Daniel Kunth, Matthew Hayes, Claus Leitherer, J. Miguel Mas-Hesse,
Göran Östlin, Artashes Petrosian, Daniel Schaerer, Anne Verhamme

The Lyman-alpha Puzzle

- Early observations with IUE:
  - Lyα was not detected in many cases
  - A damped absorption was observed instead
  - When detected, Lyα was well below the theoritical value predicted by recombination theory

Which factors are actually driving the visibility of Lyman-alpha emission in star-forming galaxies ?

This question will remain unclear after the IUE era …

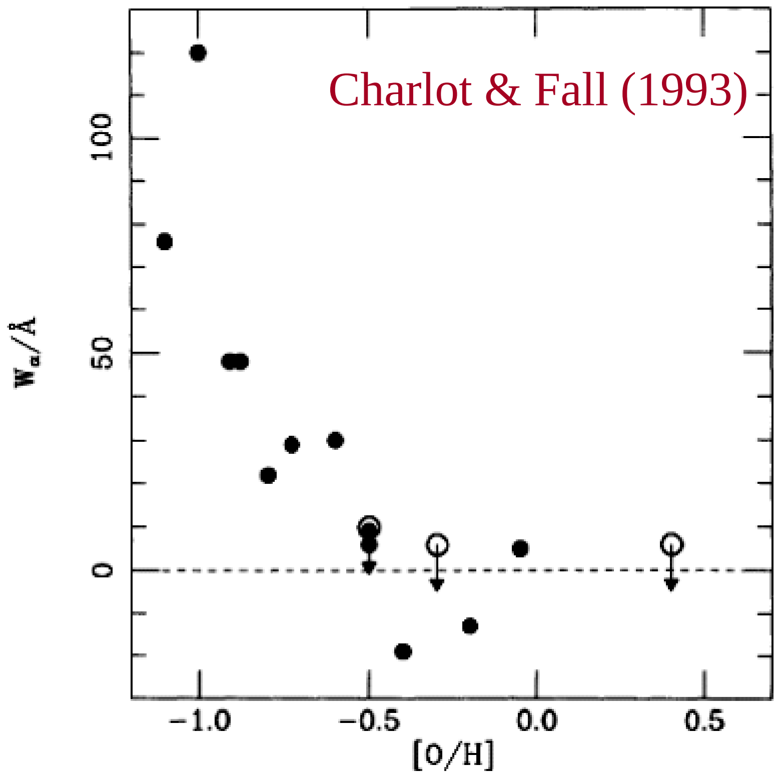
The Lyman-alpha Puzzle

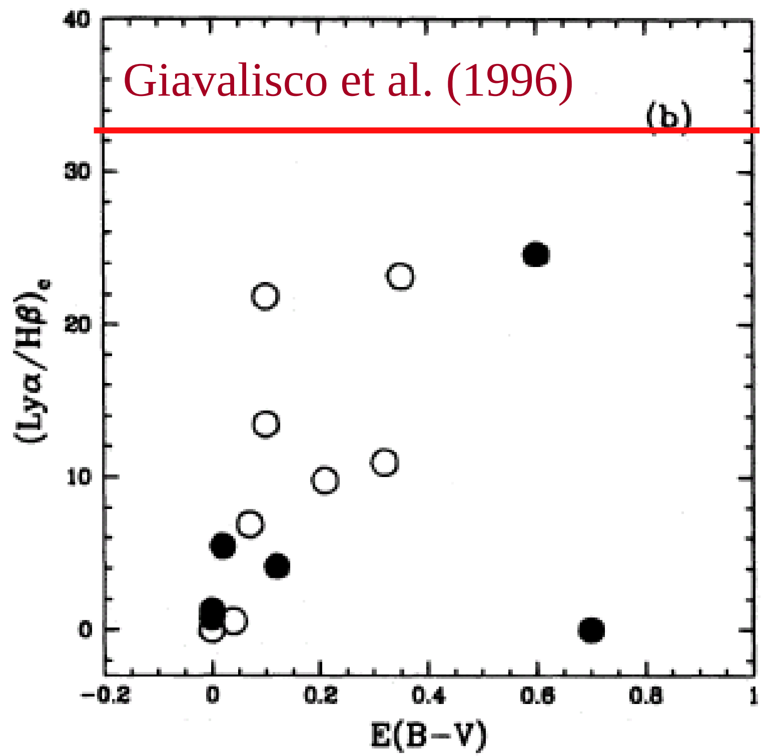
- Attempts to solve the puzzle in the early 90's

✓ Attenuation by dust :
Only very early starbursts are detectable ?

-- Lyα NOT correlated with dust

-- Lyα emission, even after extinction correction, is still below CASE B





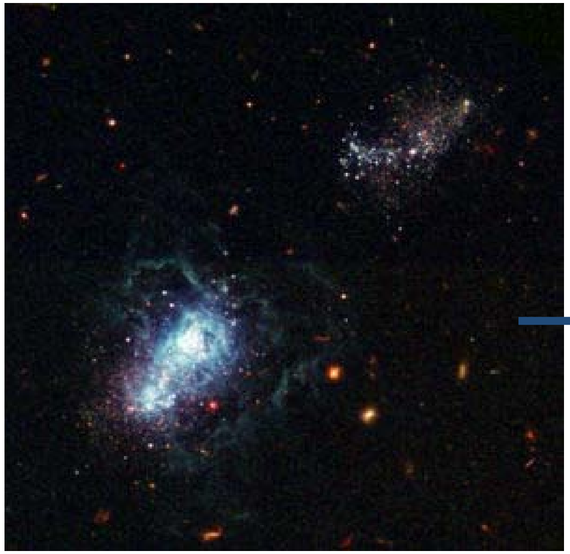
New Insight with HST/GHRS

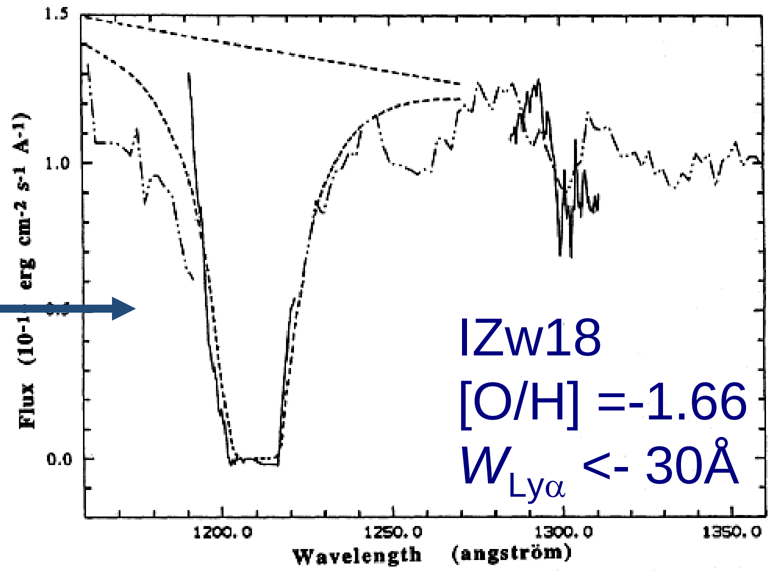
High resolution spectroscopy with HST/GHRS of local BCGs:

- First results by Kunth et al. (1994) :

Very low metallicity and dust deficient galaxy IZw 18 :

- A prominent Lyα emission is expected for a young unevolved starburst

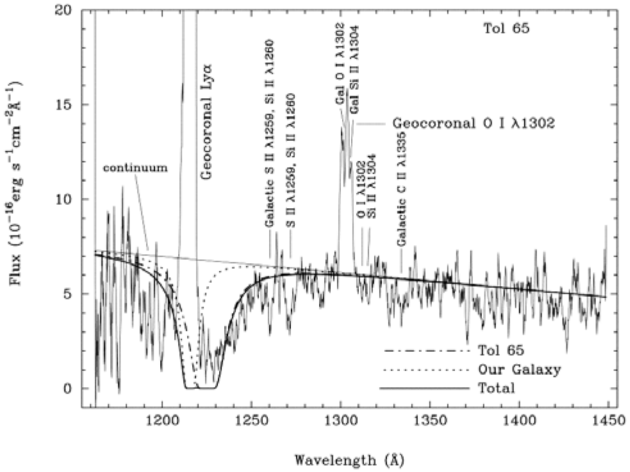


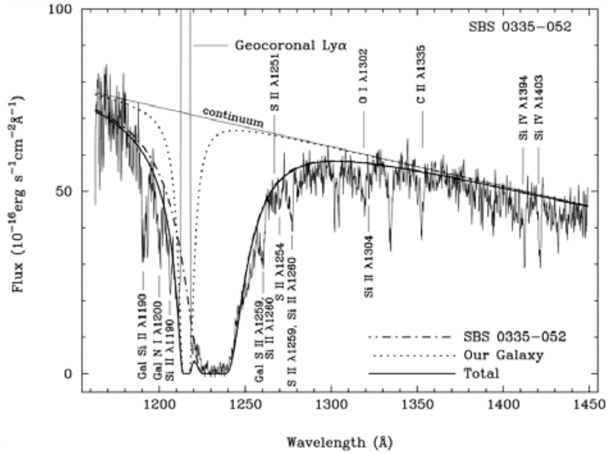


Suprisingly, a strong damped absorption is observed

New Insight with HST/GHRS

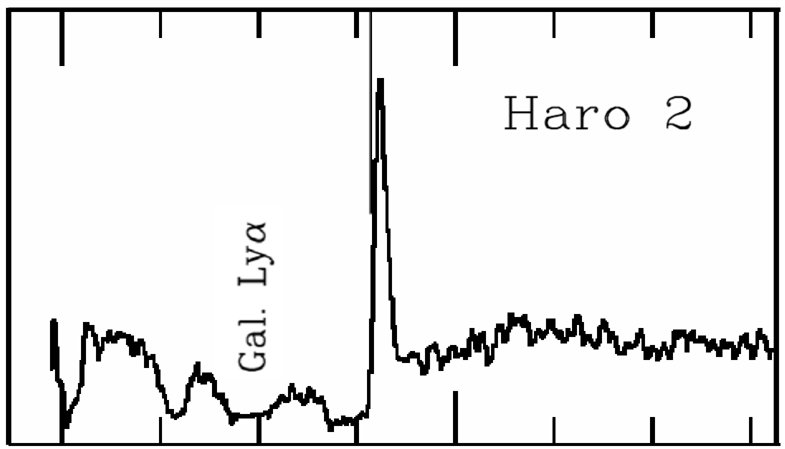
- Similar results by Thuan and Izotov (1997) :
  Low metallicity BCGs SBS 0335-052 & Tol 65





A prominent Lyα emission was found in a more metallic and dusty starburst Haro 2

Lequeux et al. 1995



GHRS Sample of BCGs: The Role of Kinematics

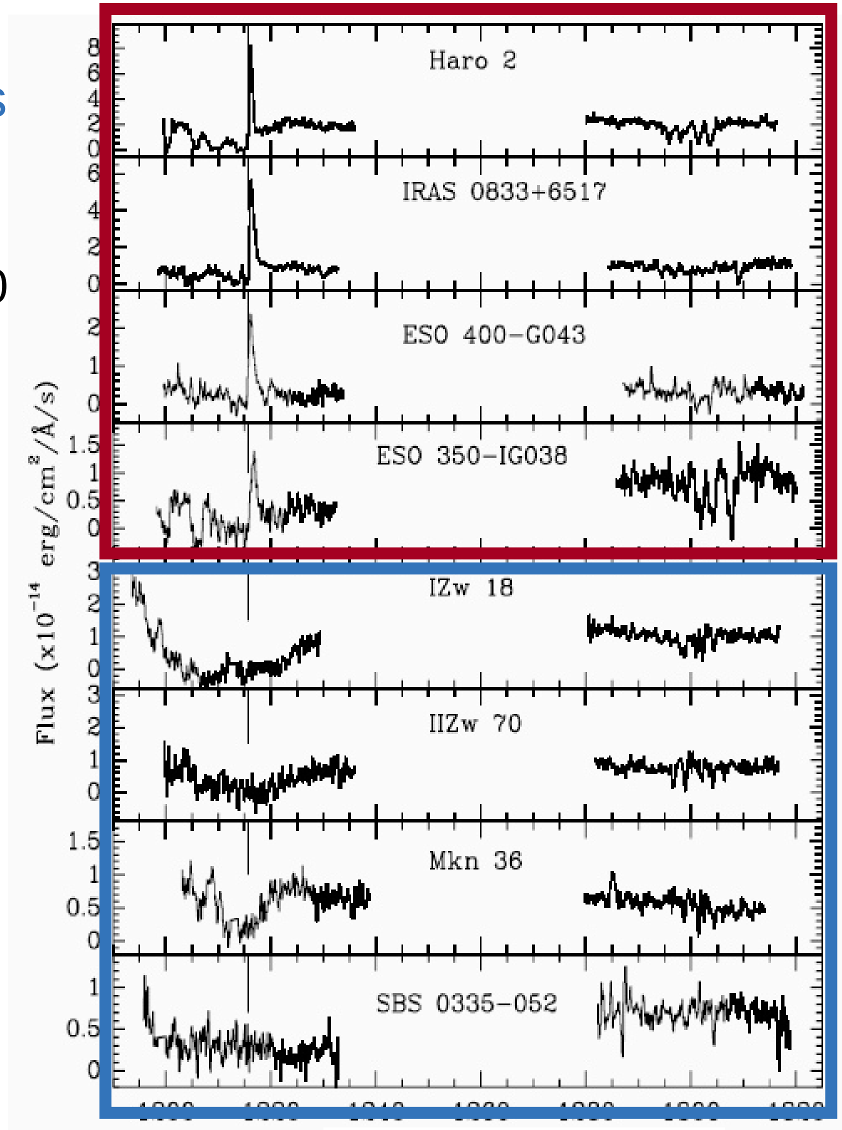
➤ 8 local BCGs: 4 Lyα emitters, 4 absorbers

- In all Lyα emitters the neutral, metallic absorption lines were blueshifted by 100-400 km/s.

- In the damped systems, the neutral absorptions were always at the systemic velocities

- All Lyα emission lines showed a clear P Cyg profile, indicating the presence of an expanding shell of neutral gas.

→ The profiles could be well fitted assuming the measured expansion velocity



Kunth et al. 1998

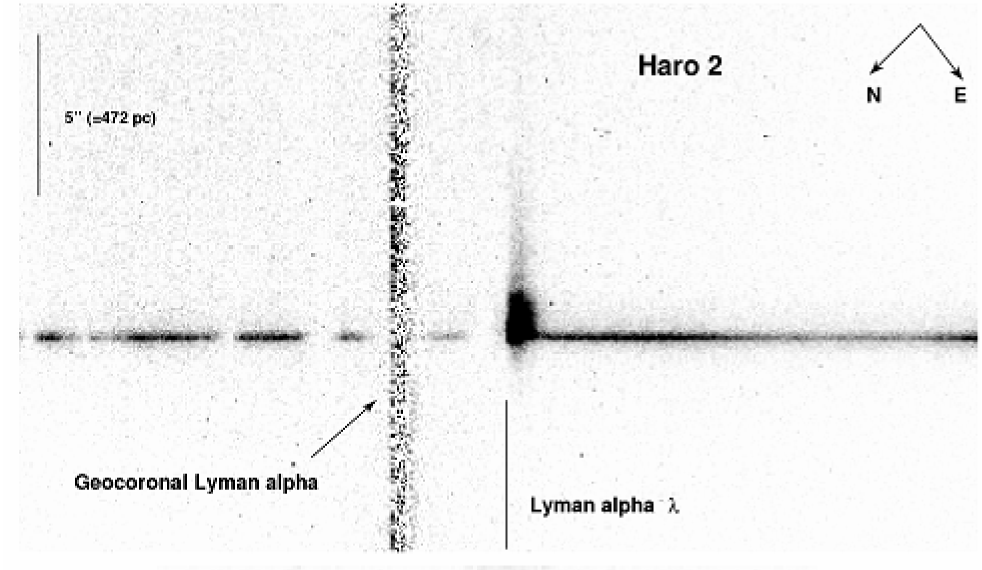
HST/STIS: Spatial Analysis

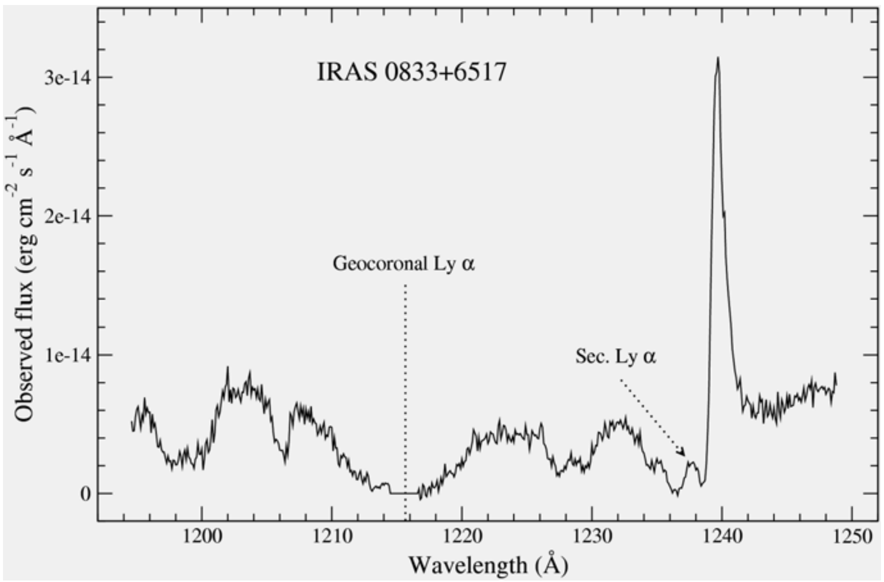
➤ Long slit spectroscopy with STIS
To map the kinematics of the neutral gas
In 3 galaxies: Mas-Hesse et al. (2003)

- Lyα emission extends over more than 10" (~1 kpc)

- Large expanding shell in 2 cases with
An ionised front in IRAS 08+65 associated with a secondary Lyα emission

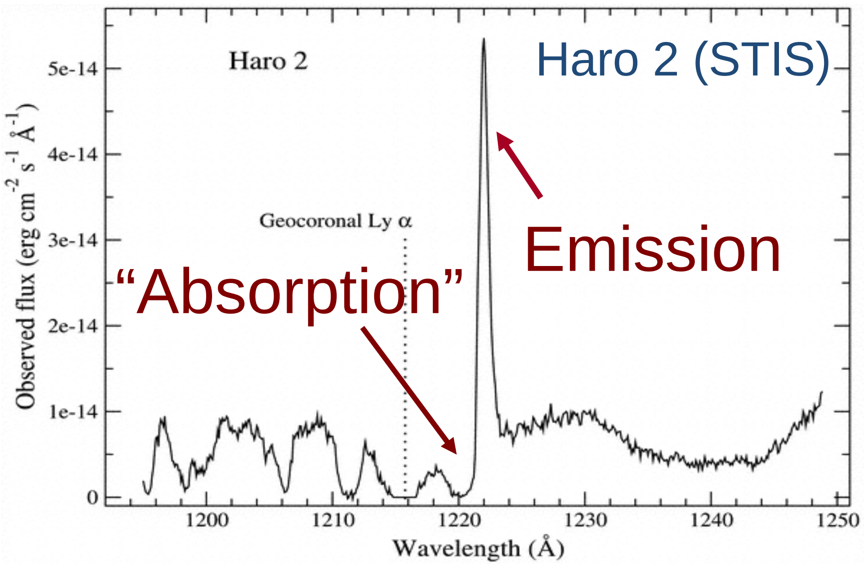
The visibility of Lya might be driven mostly by the neutral gas distribution (porosity) and kinematics



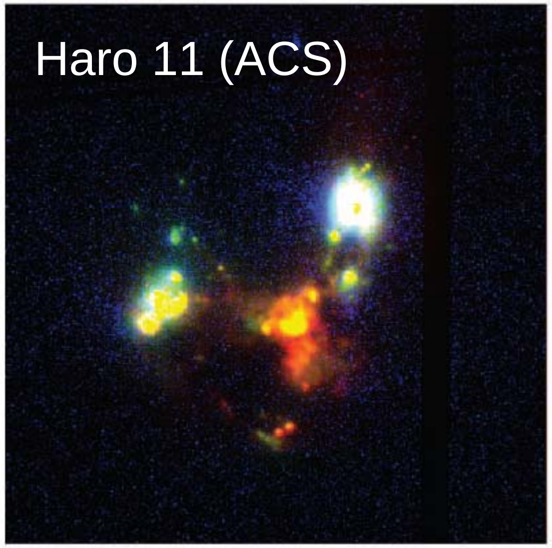


HST/ACS Imaging of Local Starburst Galaxies

- Need to map the diffuse Lya emission: complementary to UV-bright targeted spectroscopic studies
- Resonant scattering → Emission and absorption at small scale
- To infer the relative importance of the factors regulating the detectability of Lya emission



Kunth et al. 2003



HST/ACS Imaging : Pilot Study

- 6 selected local galaxies :
  - 0.009 < z < 0.029
  - 40 orbits in total
  - 0.03" sampling

- span a range of :
  - Lya morphology and profiles
  - Luminosity and metallicity
  - dust

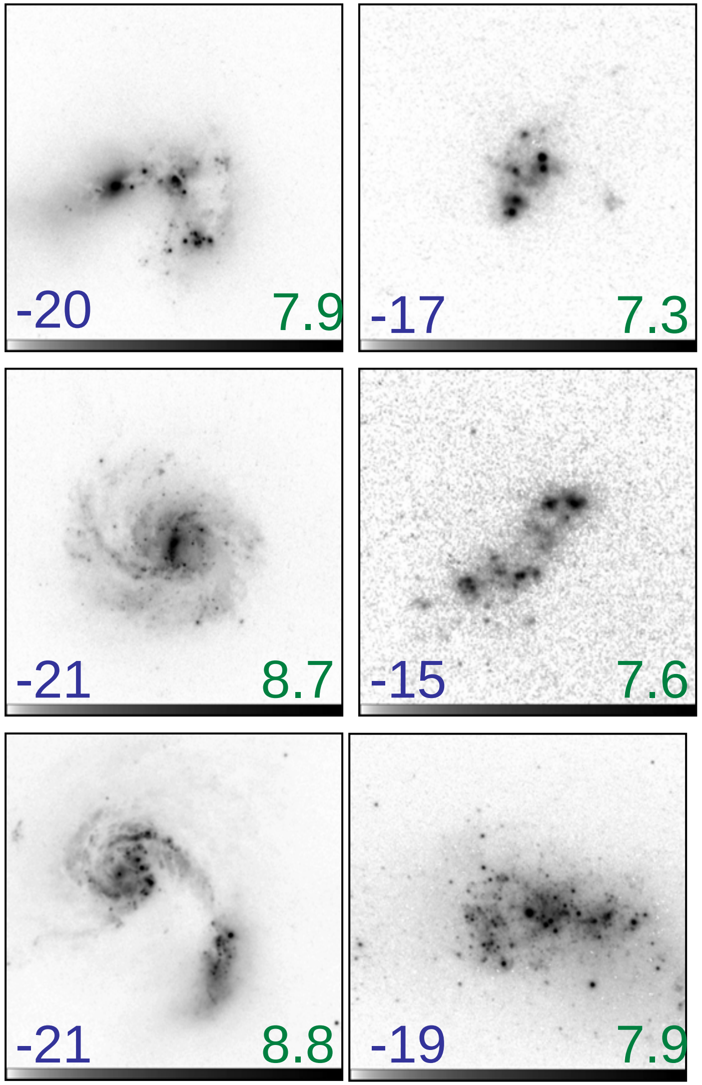
- Preliminary results:
  - Complex emission + absorption
  - Lya emission with no continuum counterpart
  - Global damped absorption

➡ Continuum subtraction issue

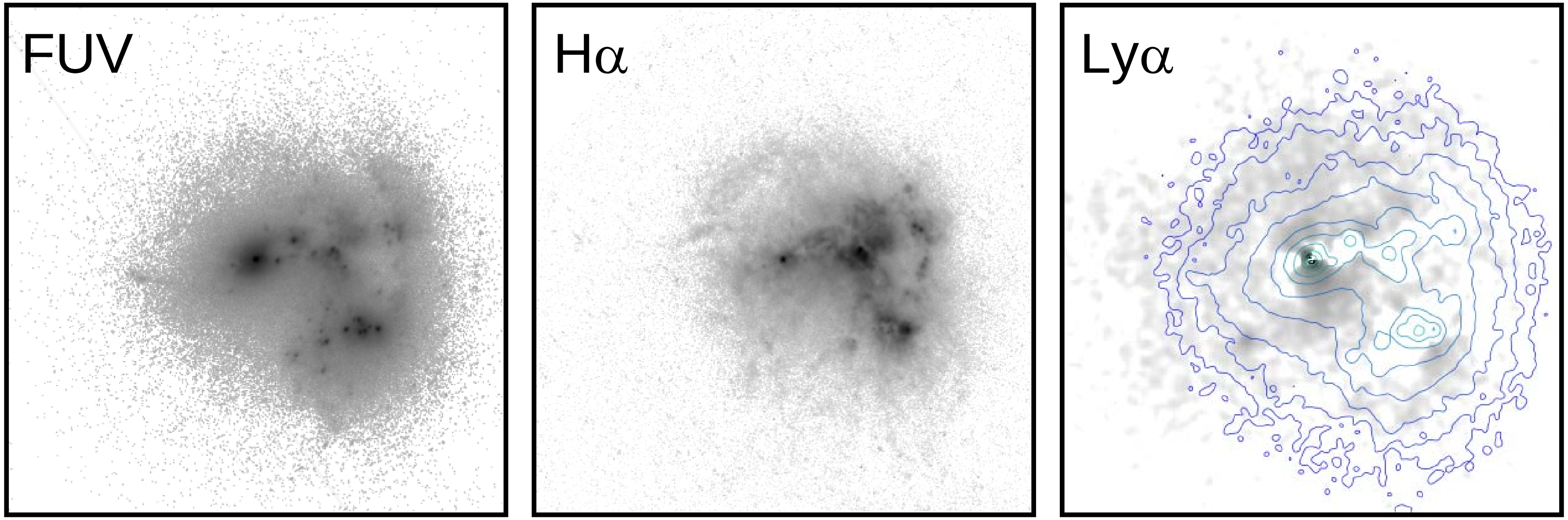
Kunth et al. 2003

M_B Z

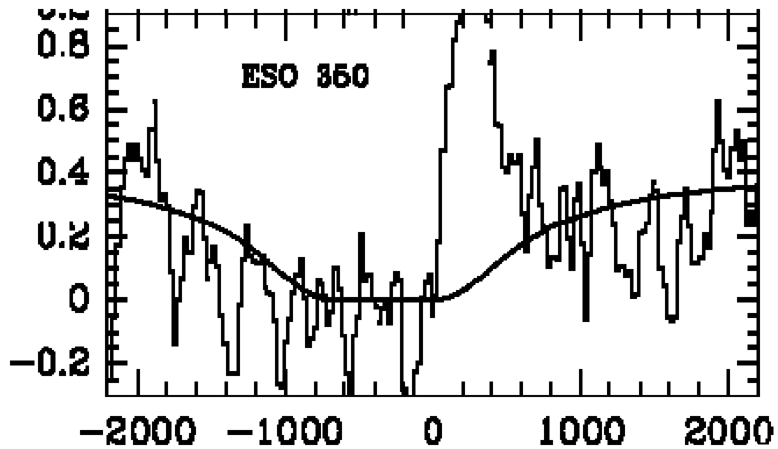
HST / ACS / F550M



HST/ACS Imaging Results: Haro 11

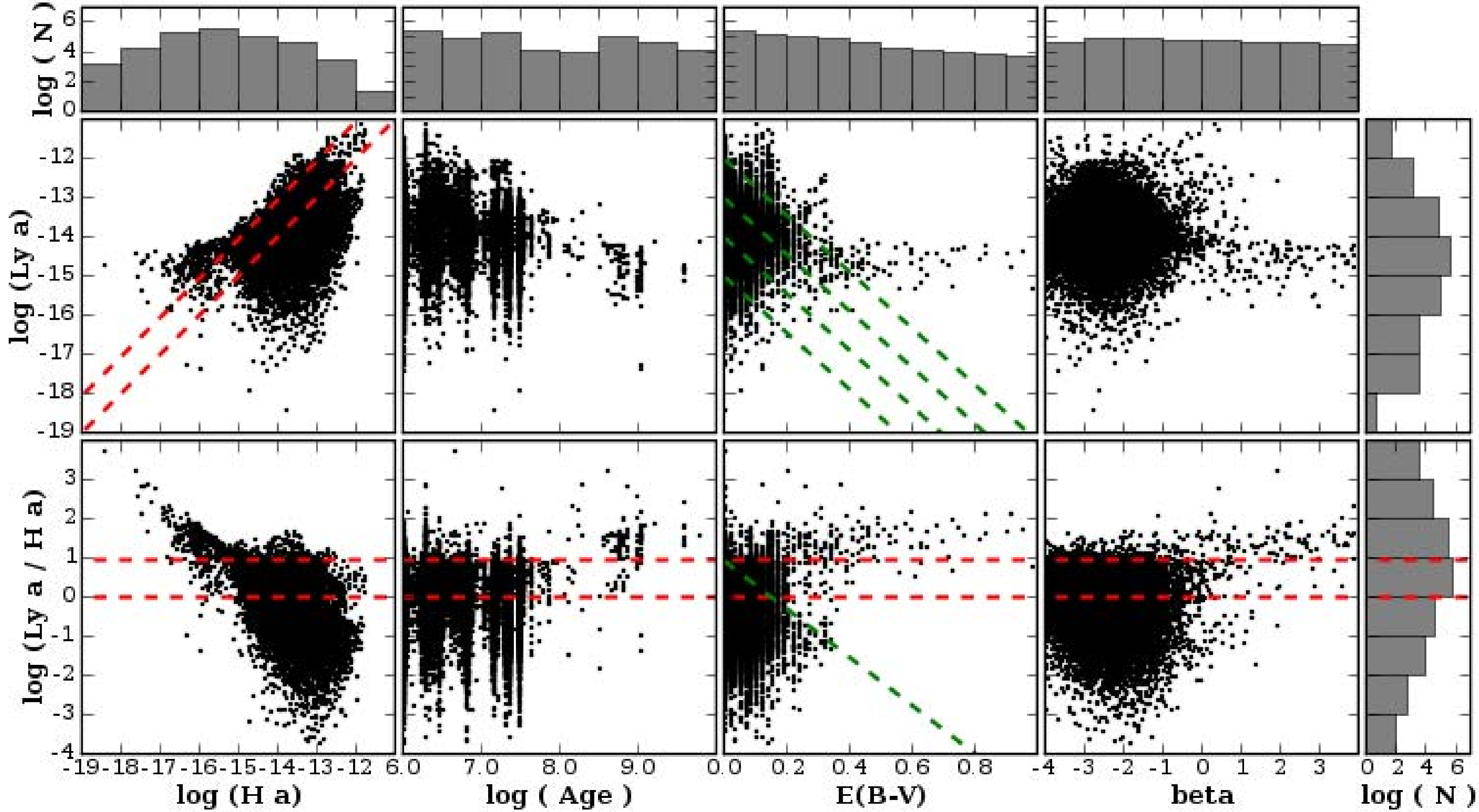


- Net Lyα emitter
- Lyα does NOT resemble FUV
- Lyα does NOT resemble Hα
- 90% of flux in diffuse compnt.

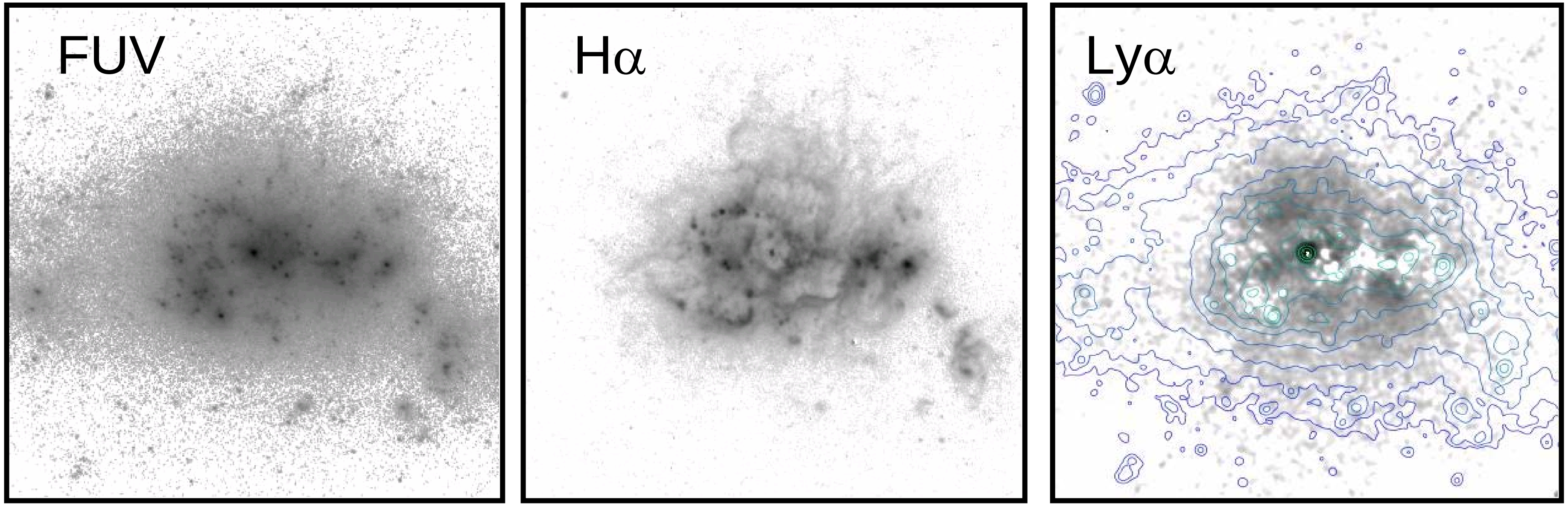


(Hayes et al. 2007a; Östlin et al. 2007)

HST/ACS Imaging Results: Haro 11

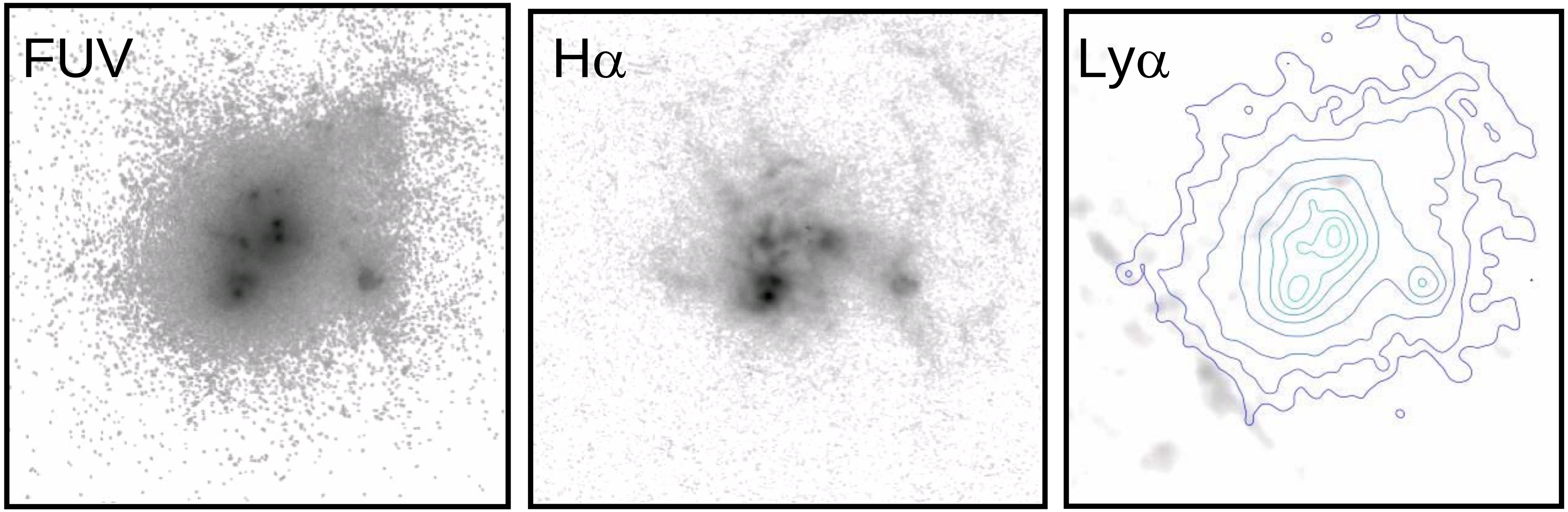


HST/ACS Imaging Results: ESO 338-04

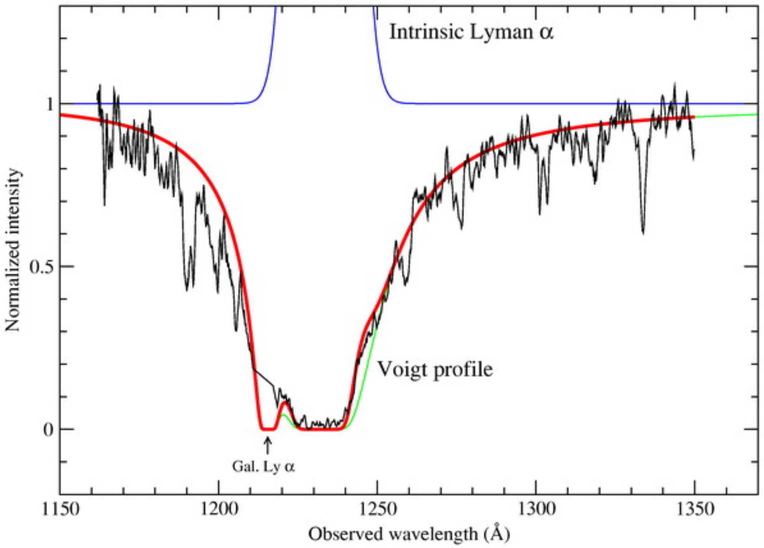


- Net Lyα emitter
- Lyα largely symmetric around one knot
- Lyα uncorrelated with Hα

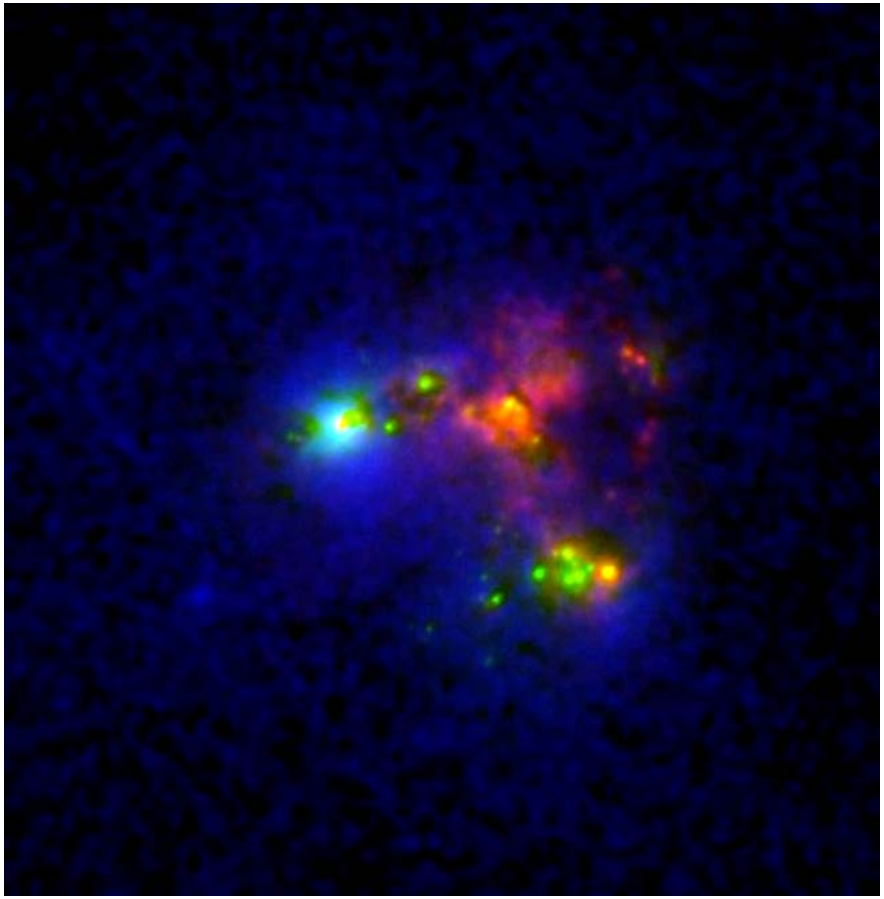
HST/ACS Imaging Results: SBS 0335-052

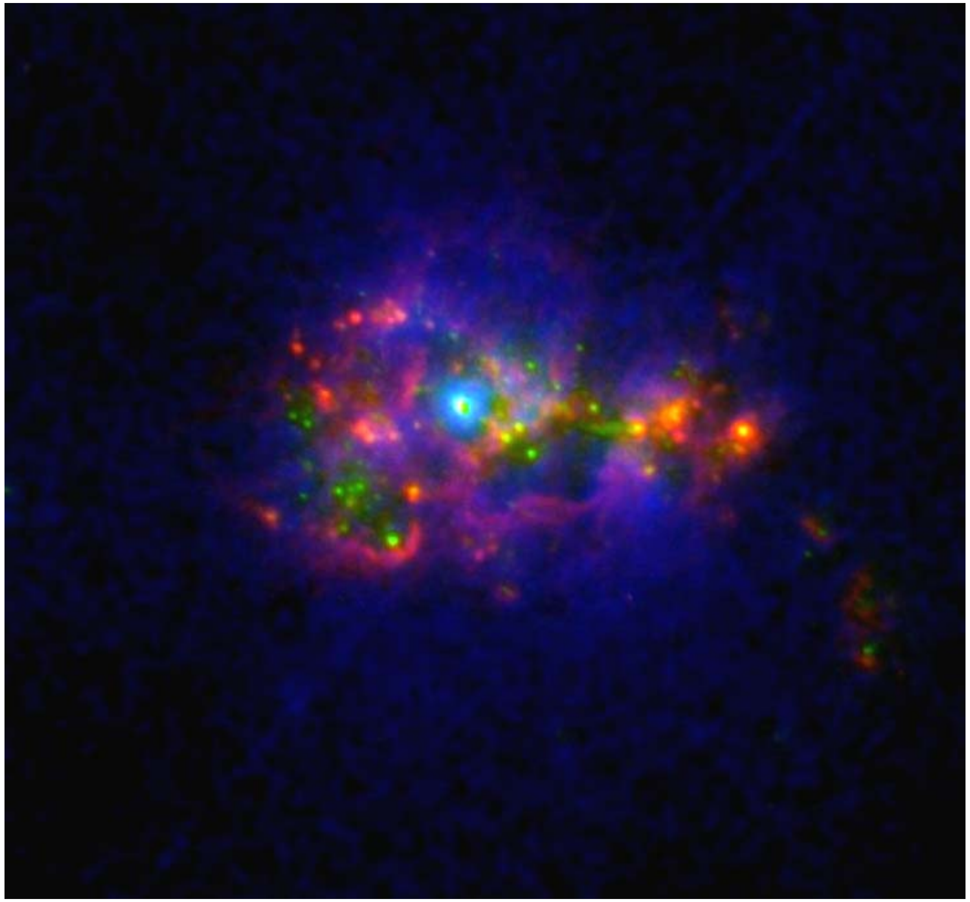


- Net Lyα absorber
- Ha follows FUV tightly
- Lya almost exact mirror

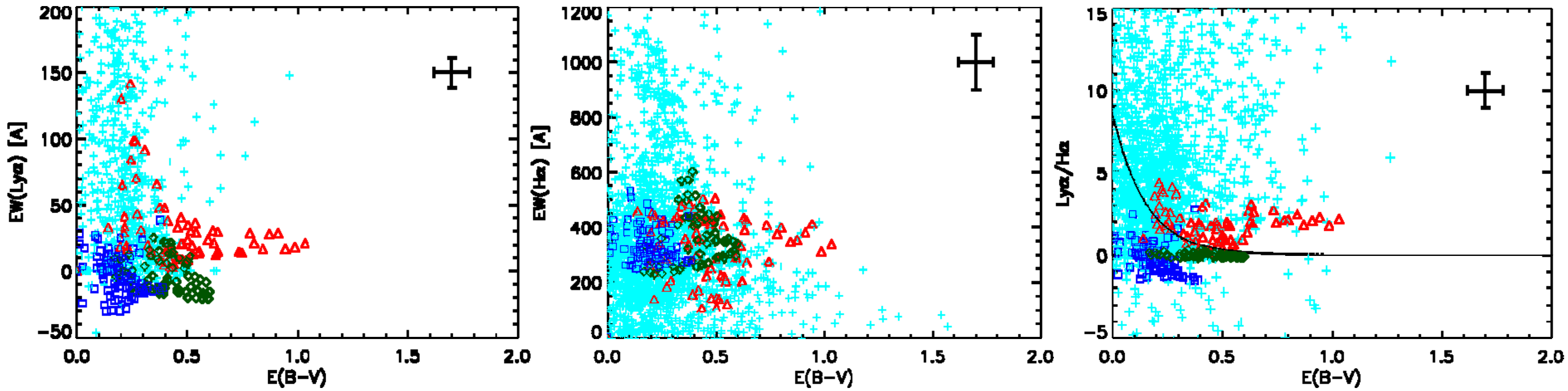


HST/ACS Imaging Results

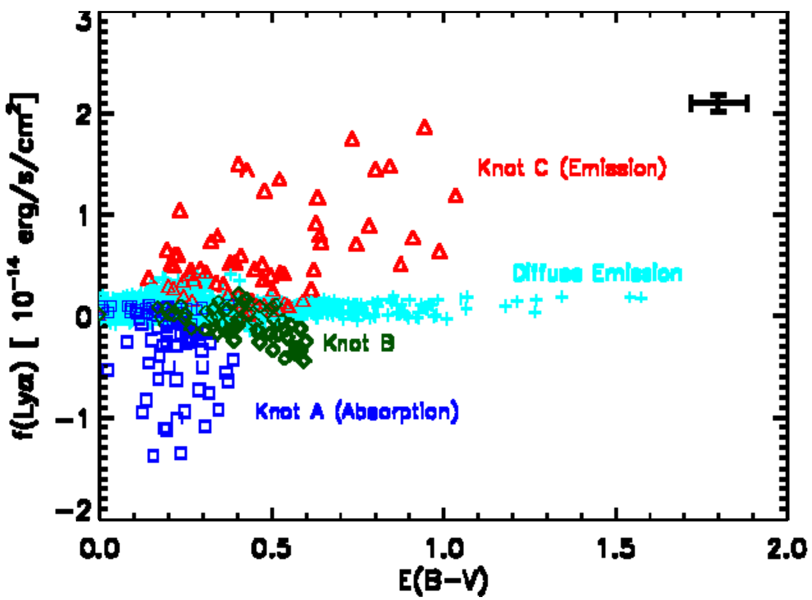




The Role of Dust in Lya Obscuration: Haro 11



Atek et al. 2008

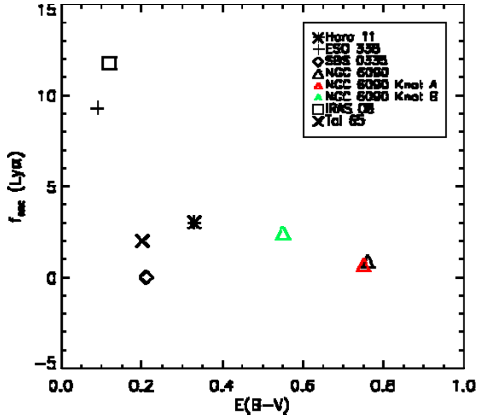


- Diffuse emission component independent of the dust
- Emission from knot C with E(B-V) ~ 0.4
- Absorption from knot A with E(B-V) ~ 0.2
- EW(Lyα) *vs* EW(Hα)
- Lyα/Hα above the theoretical value (8.7 case B extinction corrected)

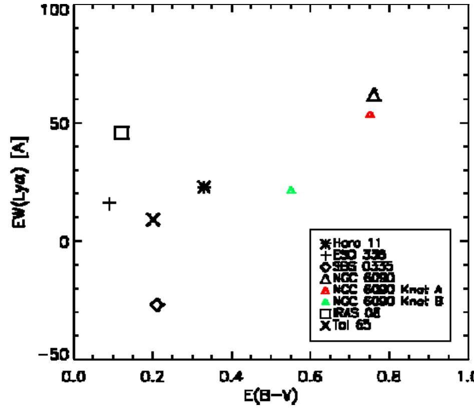
  → enhanced Lyα/Hα ratio

HST/ACS Imaging Results

- Escape fraction decreases with dust



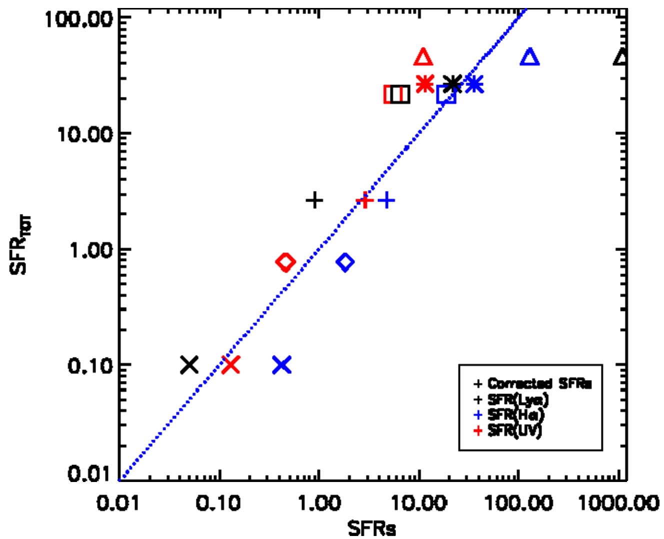
No clear correlation between EW(Lyα) and dust



- Star Formation Rate calibration :

 - What fraction of Lyα photons actually escape from the starburst ?

 - Simple dust correction of Lyα luminosity fails to recover the intrinsic SFR !



Summary

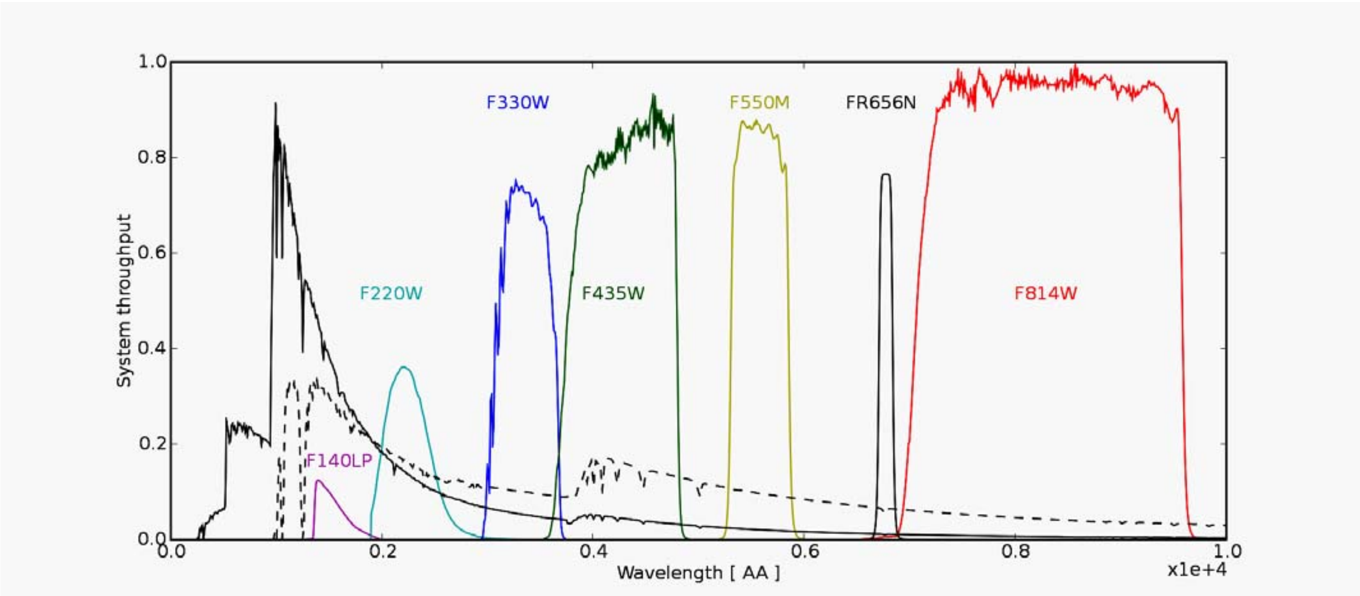
- First calibrated Lyα maps produced: spatial resolution ~10 - 20 pc
  soon to be released to public
- Different escape mechanisms : Direct or diffuse emission
  Emission through outflowing medium
  Scattering into inhomogenous ISM
- Low escape fractions (< 15%) -- dust corrections fail
- When Hα strongest (starburst youngest) Lyα weakest

Demonstrates the need for a detailed,
statistically significant investigation

The prospect of a “new” HST

- Need generalize the results to high-z with an homogeneous sample and a high spatial resolution (orders of magnitude better than high-z obs.)

- repaired ACS/SBC (F125LP and F140LP for Lyα)
- ACS or/and WFC3 (Balmer lines and continuum obs.)



The prospect of a “new” HST

- Spatial analysis of the ISM kinematics in Lyα emission starbursts : Need for a high spatial and spectral resolution

- STIS, COS : complementary spectroscopy for an insight in both accelerated media and diffuse emission regions

Lyα will remain a very important, probably the dominant, probe of the distant universe even with the advent of ELTs and the JWST.

This is a unique opportunity to better understand the Lyα escape physics and interpret correctly future high-z observations

Lyα Team

- Hakim Atek & Daniel Kunth (*IAP, France*)
- Matthew Hayes (*Observatoire de Genève, Switzerland*)
- Göran Östlin (*Stockholm obsevatorium, Sweden*)
- J. Miguel Mas-Hesse (*LAEFF, Spain*)
- Daniel Schaerer & Anne Verhamme (*Observatoire de Genève, Switzerland*)
- Claus Leitherer (*STScI, USA*)
- Artashes petrosian (*Buyrakan observatory, Armenia*)