Local galaxies as seen in Lyman-alpha

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The Lyman-alpha Puzzle

➢ Early observations with IUE:

• Ly$\alpha$ was not detected in many cases

• A damped absorption was observed instead

• When detected, Ly$\alpha$ was well below the theoretical 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

Charlot & Fall (1993)

Giavalisco et al. (1996)
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

IZw18
\[ [\text{O/H}] = -1.66 \]
\[ W_{\text{Ly}\alpha} < 30\text{Å} \]

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 Ly$\alpha$ emitters, 4 absorbers
  - In all Ly$\alpha$ 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 Ly$\alpha$ 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)

  - Ly$\alpha$ 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 Ly$\alpha$ 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 $\rightarrow$ Emission and absorption at small scale
- To infer the relative importance of the factors regulating the detectability of Lya emission

Kunth et al. 2003

Haro 2 (STIS)  
Haro 11 (ACS)
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

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HST/ACS Imaging Results: Haro 11

- Net Ly\(\alpha\) emitter
- Ly\(\alpha\) does NOT resemble FUV
- Ly\(\alpha\) does NOT resemble H\(\alpha\)
- 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 $E(B-V) \sim 0.4$
- Absorption from knot A with $E(B-V) \sim 0.2$
- $EW(\text{Ly} \alpha) \text{ vs } EW(H \alpha)$
- $\text{Ly} \alpha/H \alpha$ above the theoretical value (8.7 case B extinction corrected)
  $\Rightarrow$ enhanced $\text{Ly} \alpha/H \alpha$ ratio
HST/ACS Imaging Results

- Escape fraction decreases with dust
- No clear correlation between EW(Ly\(\alpha\)) and dust

Star Formation Rate calibration:

- What fraction of Ly\(\alpha\) photons actually escape from the starburst?
- Simple dust correction of Ly\(\alpha\) luminosity fails to recover the intrinsic SFR!
Summary

- First calibrated Ly\(\alpha\) 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 H\(\alpha\) strongest (starburst youngest) Ly\(\alpha\) 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 Ly\(\alpha\) 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

Ly\(\alpha\) 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 Ly\(\alpha\) escape physics and interpret correctly future high-z observations.
Lyα Team

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