Haro 11 as seen by FUSE -

first detection of Lyman leakage from a local starburst galaxy*

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Background.

The dominating reionization source of the intergalactic medium in the young universe has yet to be identified. Possible candidates include metal poor starburst dwarf galaxies but because of their apparent faintness at high redshifts these are not accessible for direct studies. Important information can however be obtained from local counterparts. Among these we find the Blue Compact Galaxies (BCGs). While all previous observations have indicated that these galaxies are opaque in the Lyman continuum (LyC), Haro 11 seems to be an exception. It is one of the brightest local BCGs, having low chemical abundances and an extremely high star formation efficiency. Surprisingly, HI has not been detected. One may therefore suspect that the conditions for LyC leakage are unusually favourable and therefore make Haro 11 particularly relevant as a possible template of high redshift reionization sources.

The galaxy.

Haro 11 (Fig.1) is one of the brightest BCGs in the local universe. It is involved in a global starburst with a star formation rate, assuming a Salpeter IMF, of about 20 $M_\odot$/yr. Its optical spectrum (Fig. 3) shows strong WR features from a very young stellar population. It has neither been detected in HI nor CO and the upper mass limit of neutral hydrogen is ~10^8 $M_\odot$. The corresponding gas consumption time scale is thus very short, < 10^7 yr. ISO [CII]λ158Å observations (Bergvall et al. 2000, A&A 359, 41) and the high IRAS temperature (see Fig. 2) indicate a low optical depth in the carbon line, supporting the idea that most of the gas is in ionized form with the photodissociation region as the outermost shell. Table 1 summarizes the basic properties. The mass estimates are discussed in Bergvall et al. (2000, A&A 359,41; 2002, A&A 390, 891) and Östlin et al. (2001, 274, 800).

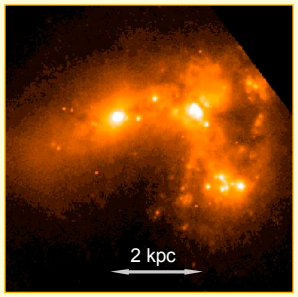

Fig. 1 Haro 11. HST WFPC2/F606W (Malkan et al. 1998, ApJS 117, 25)

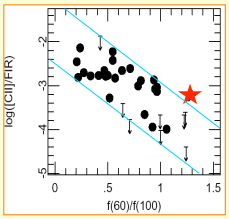

Fig. 2 IRAS and ISO data for starforming galaxies over a large range of luminosities, including a few ULIRGs at high IRAS temperatures. Haro 11 (star) shows an excess in [CII], indicating a low column density (Bergvall et al. 2000, A&A 359,41).

Table 1. Basic data of Haro 11

m_B: 14.3	M_B: -20.5
Scalelength: 9 kpc	12+[O/H]: 7.9
L(Lyα): 9x10^{35} W	L(Hα): 3x10^{35}W
L_{FIR}: 7x10^{10} $L_\odot$	$f_{60\mu}/f_{100\mu}$: 1.5
Log(L_{CO}/L_{FIR})< -8.5	M_{dyn}: 2x10^9 $M_\odot$
M(H_2)< 10^8 $M_\odot$	M(H I)< 10^8 $M_\odot$
M(H II): 10^8-10^9 $M_\odot$	M(H I)/L_B < 0.01
M(PDR) ~ 2x10^8 $M_\odot$	M_{phot}: 1.5x10^{10} $M_\odot$

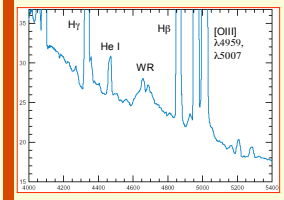

Fig 3 Optical spectrum of the central 4"x4" showing a steep continuum and WR features from massive stars with ages ~3-5 Myr. *ESO 3.6m telescope.*

FUSE observations

We obtained LWRS spectra of Haro 11 with the Far Ultraviolet Spectroscopic Explorer (FUSE) with the aim of determining the LyC escape fraction.. A weak signal shortwards of the Lyman break (Fig. 4) was identified as LyC emission escaping from the ongoing starburst. From profile fitting to weak metal lines we derive column densities of the low ionization species corresponding to a hydrogen column density of a few times 10^{19} cm^{-2}. This relatively high value indicates that most of the LyC photons escape through transparent windows in the interstellar medium.

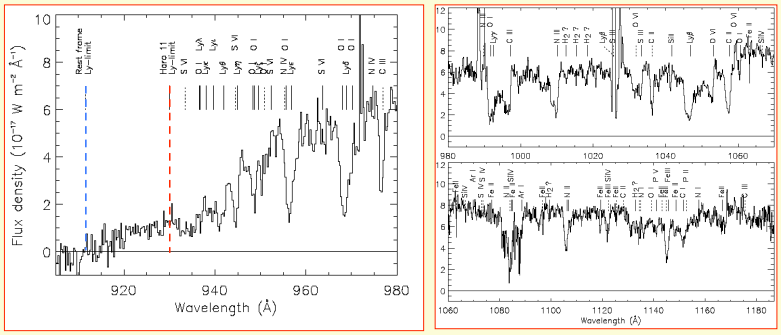

Fig. 4 FUSE LWRS spectrum of the central 30"x30" of Haro 11. Local ISM features are marked with hatched lines. The Lyman absorption lines are unsaturated and show extended wings towards shorter wavelengths, indicating outflows of neutral gas with velocities of several hundred km s^{-1}. Notice also the P Cygni profiles of O VI at 1054 and 1059 Å, originating from the global outflows and winds from O and B stars. The Lyman limits in the rest frame and in the Haro 11 frame are indicated with blue and red lines in the diagram on the left. The region in between shows a weak but significant signal, indicating that part of the LyC photons are escaping into the intergalactic space.

Results and conclusions

Here we report on the first detection of Lyman continuum photon escape from a local galaxy. Spectral evolutionary models were used to constrain the escape fraction. Assuming a normal Salpeter initial mass function we obtain a LyC escape fraction of f_{esc} ~ 4-10%. We argue that in a hierarchical galaxy formation scenario, the upper limit we derive for the escape rate allows for a substantial contribution to cosmic reionization by starburst dwarf galaxies at high redshifts.

**) Based on observations made with the NASA-CNES-CSA Far Ultraviolet Spectroscopic Explorer. FUSE is operated for NASA by the Johns Hopkins University under NASA contract NAS5-32985.*

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