Evolutionary state of the Lyman Alpha Emitter Haro 2

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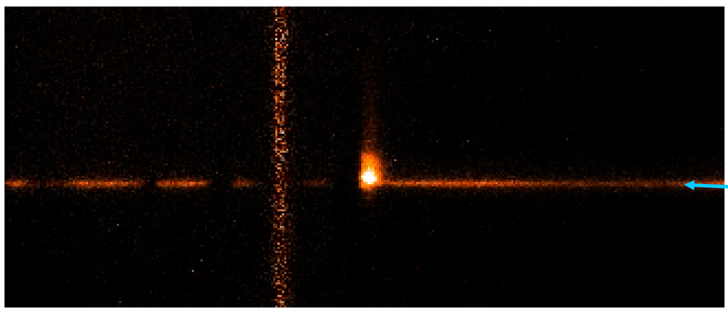
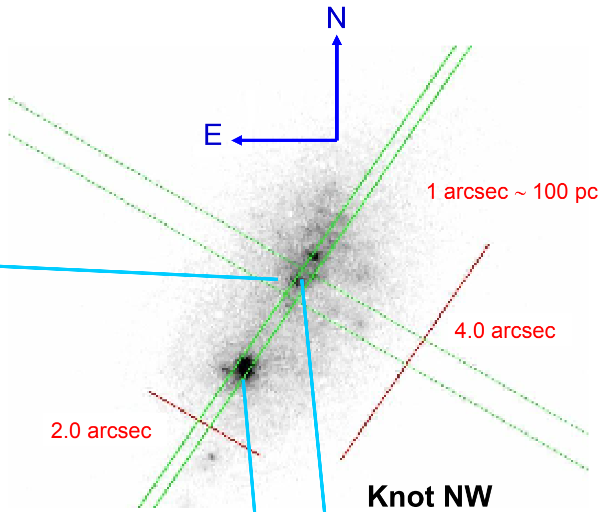
Haro 2 is one of the few galaxies of the local universe which shows a prominent Lyα emission. We have performed X-ray and UV spectral analysis on Haro 2 with spatial resolution, using Chandra and HST data. Our results show that the two starbursts present in the central region of the galaxy are in different evolutionary states, with a difference in age >~1 Myr. Attending to the CIV and SiIV line profiles, evolutionary synthesis models yield ages of ≤~4 Myr and ≥~5 Myr for each one of them. We have also investigated the Lyα spatial profile, which turns out to be rather complex, showing three Lyα-emitting components decoupled from the young stellar clusters, together with absorption regions. One of these Lyα-emitting regions appears as a diffuse emission to the NW, extending ≥6 arcsec (≥600 pc). Each burst contributes to X-ray emission in a different energy range, since it is observed that the younger burst emits mainly in the high energy range 1.5-8 keV, whereas the older burst does it in the soft range 0.2-1.5 keV.

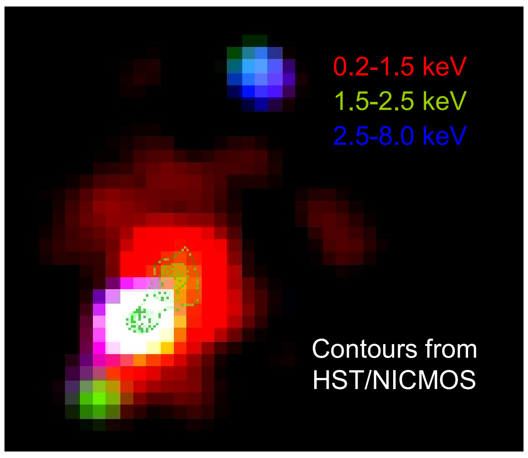
All the facts described, the somewhat evolved state of the starbursts and the Lyα emission found, together with its decoupling from stellar emission, are compatible with the current model for the outflow of neutral gas in galaxies with Lyα emission, which states that mechanical energy released by the central starbursts must have been injected into the medium, sweeping up the surrounding neutral gas, allowing Lyα photons to escape.

HST/STIS high resolution spectrum





Chandra image



In the nucleus of the galaxy we observe two bursts. Starburst99 evolutionary synthesis models (Leitherer et al. 1999) yield

- their ages through the fitting of SiIV and CIV lines
- E(B-V) assuming SMC extinction law (Prévot et al. 1984)
- their mass values, normalized by the UV flux measured by HST/FOC and assuming a Salpeter IMF (α=-2.35) with mass range 2-120 M_o

Knot SE

Age ~ 3.85 Myr

M ~ 7.2×10^5 M_o

E(B-V) ~ 0.060

Knot NW

Age ~ 5.3 Myr

M ~ 1.4×10^6 M_o

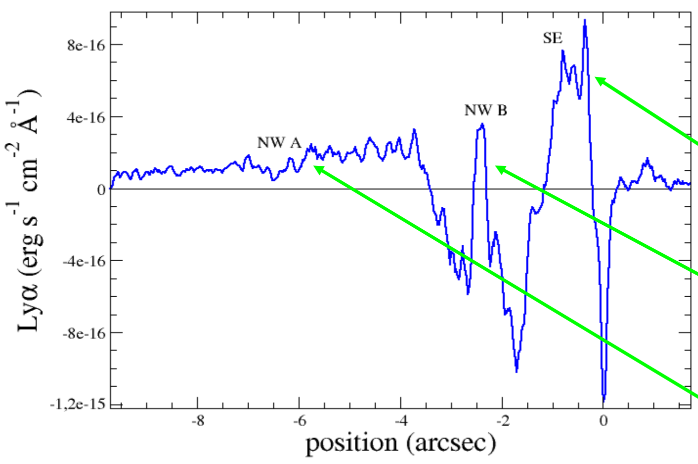
E(B-V) ~ 0.020

In the X-ray image of Haro 2 we observe that hard emission is mainly originated in the younger burst SE, whereas both knots contribute to the soft component. Also, an extended, soft, diffuse component is seen northward of knot NW, which can be linked to the spatially-extended Lyα emission NW A. This fact agrees with knot NW being older than SE, and hence the bubble created by the burst, having had more time to expand. On the other hand, this detached component might be due also to the ~20 Myr population reported by Fanelli et al. (1988).

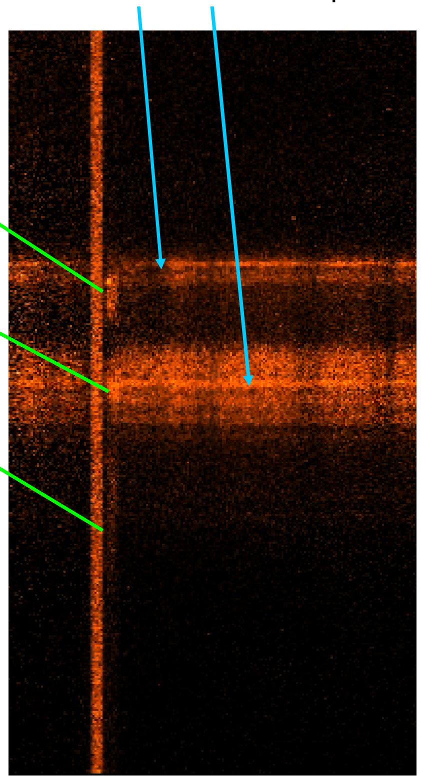
It was found that a model with a hot-plasma emission, a power-law component and Galactic absorption could account for the observed spectrum of the source. Although its statistical significance is not conclusive, an intrinsic absorption was included too, driven from our results in the UV-optical range, as well as from previous analysis in the literature. The value obtained for the plasma temperature (*kT*=0.8 keV) is somewhat high, but consistent with diffuse thermal emission in BCGs.

The soft X-ray luminosity value found agrees with CMHK02 models (Cerviño et al. 2002) for an efficiency value ε_{Xeff}=1-5 %, which lies in the range observed in other starbursts (Summers et al. 2004). However, the hard X-ray emission is underestimated by one order of magnitude. This may be due to the presence of an active binary star with *L*(2-10 keV)~10^{39} erg s^{-1}, which might be the cause of the hard, point-like structure located in knot SE, contributing with a power-law component to the X-ray spectrum. The value obtained for the spectral photon index (Γ=2.0) lies within the range of those found for this kind of objects.

Spatial distribution of Lyα



HST/STIS low resolution spectrum



We observe three Lyα-emission components in the low-resolution slit direction, together with absorption regions. This spatial profile shows that the distribution of the HI kinematics and its structure are rather complex.

- **NW A:** a diffuse and extended (>600 pc) component northward of knot NW. It turns out that, although being diffuse, it is the strongest component, as found by Hayes et al. (2007) for Haro 11. $L_{Ly\alpha}$=9.1×10^{38} erg s^{-1}, *EW*(Lyα)~13 Å
- **NW B:** the weakest component lies somewhat in the direction of knot NW. $L_{Ly\alpha}$=2.8×10^{38} erg s^{-1}, *EW*(Lyα)~5 Å
- **SE:** clearly detached from the stellar emission of knot SE. $L_{Ly\alpha}$=8.5×10^{38} erg s^{-1}, *EW*(Lyα)~13 Å

All Lyα spectral profiles from these regions show the typical blue-edge absorption, as well as the redshifted peak emission due to the presence of HI.

X-RAY ANALYSIS

Values of the fixed parameters

Galactic absorption: *N*(HI)=7×10^{19} cm^{-2}

Intrinsic absorption: *N*(HI)=8×10^{19} cm^{-2}

Values of the free parameters

Hot plasma temperature: *kT*=0.8±0.2 keV

Power law index: Γ=2.0±0.4

Values of the luminosities (D=20.5 Mpc)

When integrating over the whole region:

L(0.2-1.5 keV)=2.4×10^{39} erg s^{-1}

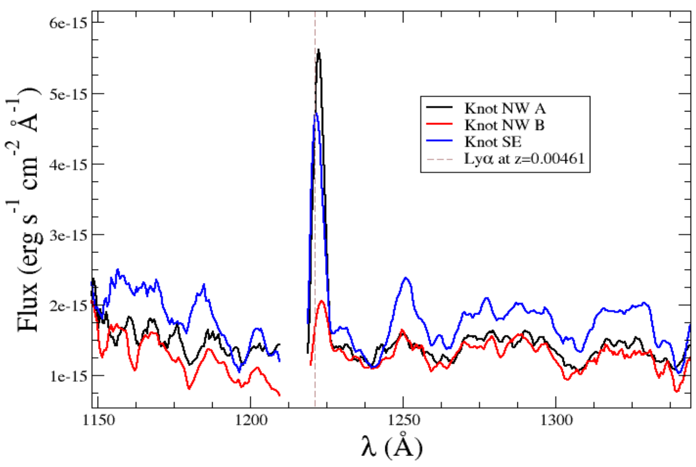
L(1.5-2.5 keV)=5.1×10^{38} erg s^{-1}

L(2.5-8.0 keV)=1.0×10^{39} erg s^{-1}

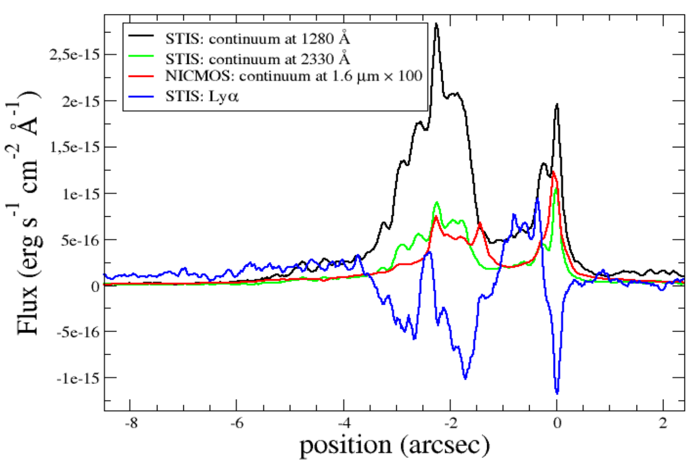
L(0.2-2.0 keV)=2.7×10^{39} erg s^{-1}

L(2.0-10.0 keV)=1.4×10^{39} erg s^{-1}

Spectra of the different Lyα-emitting regions



Spatial distribution of continuum and Lyα



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