FINAL REPORT

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Archival Research on Absorption Lines in Violently Star–Forming Galaxies

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FINAL TECHNICAL REPORT - NAG 5-989
IUE STUDY OF ULTRAVIOLET INTERSTELLAR ABSORPTION LINES IN VIOLENTLY STAR-FORMING GALAXIES

INTRODUCTION

Recently a number of ground-based studies have been undertaken with the objective of revealing the nature of objects responsible for metal absorption lines seen in the ultraviolet spectra of high redshift quasars. These investigations, including those by Co-Investigator D. York and his collaborators, show that emission line galaxies are found with the same redshifts as metal absorption lines towards many quasars. We may then ask how the properties of the intervening emission line galaxies are linked to quasar metal absorption line characteristics, including ionization levels, equivalent widths, and velocity structures.

Galaxies with the high equivalent widths of the [O II] 3727 Angstrom emission line found towards some quasars must either contain active galactic nuclei or excess populations of massive OB stars. In the latter case the current star formation rate is likely to be enhanced (a "starburst" galaxy) or the galaxy could be young. In this project we have extended our exploration of the starburst model by using archival IUE data to measure UV interstellar absorption line properties of nearby starburst galaxy candidates for comparison with metal absorption lines in quasars.

The project achieved only limited success due to the modest signal-to-noise ratios of IUE spectra of mostly apparently faint starburst galaxies. A list of target galaxies for this archival research project is given in Table 1

TECHNIQUE

Absorption lines due to or with large interstellar components were measured in IUE SWP, LWP, and LWR spectra of blue galaxies. Only about 1/2 of the objects in Table 1 had spectra of sufficient quality to attempt absorption line equivalent width determinations.

IUE spectra were analyzed on the Lowell Observatory Sun 4 computer with the NOAO IRAF software package. In addition to limits imposed by signal-to-noise, the choice of continuum is an important source of error. For this study an empirical approach based on reasonable choices over large spectral intervals was adopted, but eventually a more sophisticated

approach would be worthwhile. A sample spectrum with some lines chosen for measurement is illustrated in Figure 1. For example, following on the approach of R. W. O'Connell and collaborators as well as some experiments that J. Gallagher and D. York have carried out with their colleagues, a better method might involve differencing observed spectra from those predicted by theoretical stellar population models.

RESULTS

That blue galaxies can have very strong interstellar absorption lines is an established fact based on low resolution IUE spectra of a number of nearby examples (including the studies by J. Gallagher in collaboration with S. Lamb and D. Hunter) and a high resolution IUE spectrum of the high surface brightness amorphous galaxy NGC 1705 (York et al. 1989, Ap.J., in press). The issue lies in understanding which physical process controls the absorption equivalent widths of interstellar lines in these types of objects.

For UV resonance lines absorption equivalent widths will depend more strongly on gas velocity dispersions than ion column densities. This occurs because resonance lines become saturated and thus on the flat part of the curve of growth even for small column densities and therefore are insensitive to column density. However, the equivalent width will increase roughly linearly with the number of clouds having velocity Doppler shifts exceeding the intrinsic line width that are found along the line of sight. This is exactly what seems to be happening in quasars, where high velocity resolution spectra have shown that metal absorption features break up into multiple components, usually spread over a velocity range of hundreds of km/s.

An issue, however, remains as to where these velocity shifted absorption components originate. The standard model locates absorption features in galactic halos, while more recently York and his collaborators have suggested that multiple velocity components occur in and around regions of active star formation. This idea motivated the successful grond based optical search for violently star forming galaxies associated with quasar absorption line systems by York and his collaborators. In this model quasar metal absorption features often arise in objects having multiple centers of star-forming activity spread over large areas. Such systems would have many of the properties expected of young galaxies forming in a universe dominated by cold dark matter.

If star formation is responsible for quasar absorption line velocity spreads, then simple physical arguments also

predict that a relationship might exist between the level of star forming activity and the velocity spread of interstellar gas. Large, energetic starbursts such as those found in the central regions of some galaxies should produce wider velocity spreads and therefore higher absorption line equivalent widths than are found in more modest star forming complexes, such as giant HII regions.

In this project we undertook a test of this specific model, that absorption line equivalent width should scale with level of star forming activity, by analyzing archival IUE spectra of luminous blue galaxies to compare with previous IUE observations of extragalactic HII regions and low luminosity galaxies.

The comparison of measured equivalent widths of ultraviolet absorption lines can be summarized as follows (including results from luminous blue galaxies from this study; other data from York et al 1989):

OBJECT	CII -1335	Si IV - 1400
Low ionization, strong line QSO absorber	1.3	0.4
Medium ionization, strong line QSO absorber	1.2	1.8
Extragalactic HII regions	1.9	2.5
Luminous blue galaxies	2.8	2.7

DISCUSSION

Interstellar absorption lines in luminous blue galaxies are similar in equivalent width to those found in extragalactic HII regions. This suggests that the scaling between equivalent width and level of star forming activity as measured by estimates of OB star luminosity is not linear. We are currently exploring the implications of this result in terms of velocities expected to be produced by OB stellar clusters of varying sizes. Numerical models suggest that the scaling between OB stellar population richness and expansion velocities of the superbubbles they produce could be rather flat, which would be consistent with our observational results.

The offset in absorption equivalent widths measured in the IUE spectra of galaxies and HII regions and those in quasars could have two causes: (1) Stars may be contributing to equivalent widths of "interstellar lines" in blue galaxies. (2) The IUE spectra of blue galaxies average over a large regions in the target galaxies (set by the sizes of OB associations with low obscuration--- 10 pc to ~1 kpc) as compared to that sampled by the lines of sight to quasars (< 1 pc).

PUBLICATIONS

We plan to submit a short paper reporting the results from this study for publication in a refereed journal.

TABLE 1
PROGRAM GALAXIES FOR IUE ARCHIVAL STUDIES

GALAXY	POSITION	COMMENTS
Mich 239	00 22 19.0 -02 10 10	SWP7495,LWR6481
MK347	00 45 18.0 22 06 00	SWP27190, optical data
Haro 15	00 46 04.0 -12 59 25	SWP11259, optical data
MK357	01 19 56.6 22 54 33	SWP18199
MK1027	02 11 28.4 04 56 24	SWP21604, interacting
MK7	07 22 19.0 72 40 00	SWP11139,LWR 10572, optical data
MK8	07 23 38.0 72 14 00	SWP7286,LWR10976, optical data
Haro 1	07 33 39.4 35 21 15	SWP11269, optical data, underexp?
N2537	08 09 43.1 46 08 33	SWP22359,SWP10473,SWP11270, MK86
MK702	08 42 45.3 16 16 46	SWP6706,LWR6730, 8-28A
MK19	09 12 53.5 59 58 53	SWP18237, interacting?
IC2458	09 17 26.0 64 27 00	SWP13396,LWR10955 saturated?
MK25	10 00 22.0 59 40 33	SWP22785,LWP3174
N3125	10 04 18.0 -29 41 00	LWR9894, optical data
Haro 2	10 29 22.5 54 39 30	SWP10471
N3310	10 35 39.0 53 45 54	SWP13529,SWP17323,LWR13568, optical data
Haro 3	10 42 16.4 56 13 20	SWP10483, MK35, optical data
MK153	10 46 03.8 52 35 50	SWP17314
MK1267	10 50 28.6 04 53 21	LWP1769, type?
MK170	11 23 56.0 64 25 00	SWP6255, low lum obj
MK171	11 25 42.9 58 50 25	SWP6656-7-8,LWR5710, classic starburst interact., opt. data
POX 36	11 56 24.3 -18 45 03	SWP18113
N4194	12 11 39.9 54 48 19	SWP22784, LWP3412
MK52	12 23 09.0 00 51 00	SWP9341,LWR8097
MK209	12 23 50.6 48 46 07	SWP10484,SWP10495
MK213	12 29 01.0 58 14 00	LWR10631
MK54	12 54 32.0 32 43 00	SWP3472,SWP9793,LWR3018
MK59	12 56 38.4 35 06 54	SWP5691-2,LWR3052,LWR4937, low lum
POX124	13 04 44.9 -12 56 00	SWP25348
MK66	12 23 57.7 57 30 38	SWP24384
Tol 89	13 58 25.0 -32 50 00	SWP16971-2,LWP1554
N5430	13 59 10.0 59 33 34	7 SWP spectra, 6 LW spectra, interacting
MK487	15 35 48.3 55 25 33	SWP19697, optical data, low lum
MK691	15 44 43.2 18 02 22	SWP19291, LWR15208
MK496	16 10 24.0 52 35 00	SWP17305
MK499	16 47 02.7 48 47 43	SWP26961
MK309	22 50 09.9 24 27 51	SWP24383
MK325	23 25 11.0 23 19 00	SWP7303,LWR9670, optical data

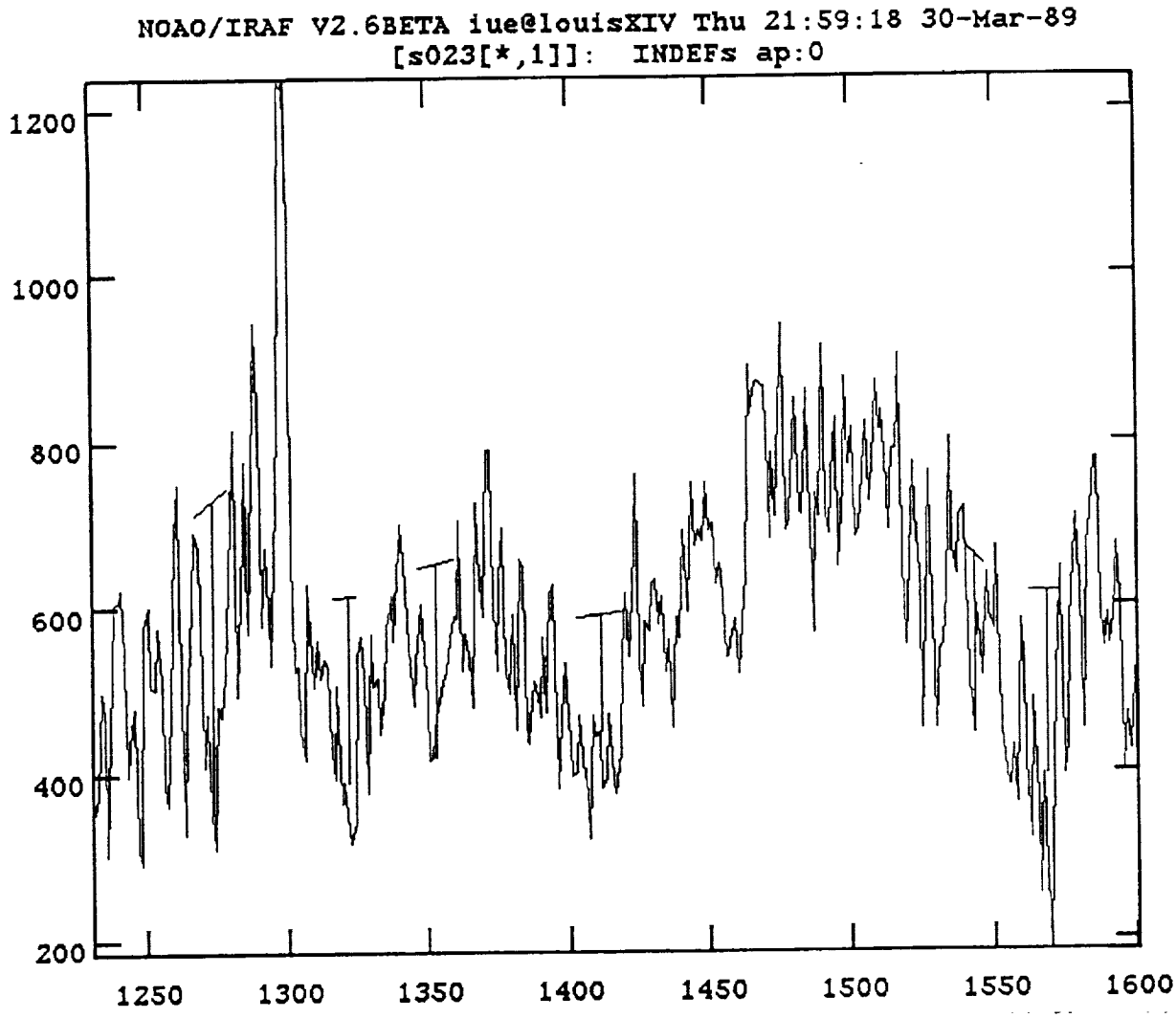

FIGURE 1. IUE low resolution SWP spectrum of the starburst nucleus system Haro 1. Wavelength in Angstroms is plotted against relative intensity. Regions for equivalent width measurements are marked. These data are typical of IUE spectra of the intrinsically fainter luminous blue galaxies. Once the data have been reprocessed as part of the program to make an ultimate IUE archive, better S/N will be achievable on absorption line equivalent widths.