LYMAN α EMISSION FROM DISK ABSORPTION SYSTEMS IN QSOS: STAR FORMATION IN YOUNG GALAXY DISKS

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The strong self-damped Lyman α absorption systems present in the spectra of high redshift QSOs represent a unique population of absorber which has recently been associated with the precursors of current disk galaxies. In a low resolution survey for what we have come to call "Lyman α disk systems" performed at Lick Observatory (Wolfe, *et al.* 1986, *Ap. J. Suppl. 61*, 249) approximately 18 systems with confirmed damped Lyman α profiles and rest frame equivalent widths greater than 5 Å were detected in a sample of 68 high redshift QSOs (Smith, Cohen and Bradley 1986, *Ap. J. 310*, 583). Subsequent higher resolution study has shown these systems to have the following properties (Turnshek, *et al.* 1988, *Ap. J.*, in press):

1. Neutral hydrogen column densities, $2 \times 10^{20} \leq N_{HI} \leq 8 \times 10^{21}$ cm^{-2}.

2. Low-mixed ionization state. Typically the low ionization states dominate the high ionization states (e.g. $CII \gg CIV$). Some enrichment has occurred, $-2 \lesssim [X/H]_{\odot} \lesssim 0$.

3. Gas density, n $\lesssim$ 1 cm^{-3}.

4. The gas shows two components, a quiescent (disk) component, $\sigma_v \lesssim 10$ km s^{-1}, and a turbulent (halo) component, $\sigma_v \gtrsim 20$ km s^{-1}. Some systems show only the low velocity dispersion component.

5. At least one system intervening toward a radio QSO (Pks 0458-020) shows 21-cm absorption. The system shows multiple cloud structure with $\sigma_v \approx 6$ km s^{-1}, $T_s \approx 100$ K, and structure extended over several kpc on the sky.

6. There is evidence that these systems may be self gravitating with scale height of the order of 300 pc.

7. These systems represent a unique population of absorber (distinct from the 'Lyman α forest' and heavy element systems) covering approximately 20% of the sky to z $\approx$ 3 and accounting for all of the baryonic matter at that redshift.

Most prescriptions for galaxy formation and evolution require an epoch of rapid star formation or higher average star formation rate during the first few gigayears. Assuming that the Lyman α disk systems do indeed represent galaxies during early

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evolutionary epochs, we have carried out a program to search for strong redshifted Lα *emission* from these absorbing systems, using specially constructed interference filters on the Lick 3-m telescope's imaging CCD spectrograph. The interference filters are typically 20 - 30 Å wide such that Lα emission from the absorber is transmitted, but the transmission curve lies within the absorption profile in the QSO spectrum, thus optimizing the contrast between faint galaxy and bright QSO. Imaging observations have now been obtained for ten systems with redshifts in the range z = 1.8-2.8. Despite observation times as long as 6 hours, no significant detection has yet been obtained to a typical flux limit:

$$l(L\alpha) \lesssim 10^{-16} \text{ erg cm}^{-2} s^{-1}$$

corresponding to a luminosity, $L(L\alpha) \lesssim 10^{42}$ erg s^{-1} depending on cosmology.

Following Kennicutt (1983, *Ap. J. 272*, 54) the star formation rate in the Lα disk systems is found by adopting a modified Miller-Scalo (1979, *Ap. J. Suppl. 41*, 513) initial mass function and calculating the mass of newly formed stars in the above prescription which would produce the Lα emission from H II regions. In this case:

$$SFR \approx \frac{L(L\alpha)}{1 \times 10^{42} \text{ erg s}^{-1}} M_{\odot} yr^{-1}$$

from which we infer star formation rates smaller than about 1 $M_{\odot}/yr$ for these systems with ages in the range 1-5 Gyr. This limit does not account for the presence of dust. The spectral energy distributions of the QSOs behind the Lα disk systems are not significantly reddened, nor do the refractory elements appear to be overly depleted in these systems. We deduce that the dust/gas ratio in the absorbing gas is perhaps a factor of ten lower than that in the Galaxy (compared to a H_2/H I ratio which is low by as much as a factor of 10^6). Adopting this limit for a plane parallel geometry would deplete the Lα emission by approximately a factor of 10, increasing our inferred limit on the star formation rate to about 10 $M_{\odot}/yr$. This may be compared with the current rate of star formation in the Galaxy which is estimated to be of the order of 5 $M_{\odot}/yr$. Our Lyman α limits are also 1-2 orders of magnitude smaller than the Lα emission from recently discovered powerful radio galaxies or QSO companions in the redshift range $z = 1.8 - 3.4$.

We conclude from the overall study that disk-like structures must form at early epochs, $z \gtrsim 3$, and that disk cross sections must be of the order of five times larger at these epochs than they are today. Possible interpretations of the low Lα emission from these disk systems include:

1. Following formation of the spheroid, active star formation in the disk does not begin until after $z \approx 2$. This is consistent with estimates for the age of the Galactic disk from the oldest existing disk clusters and cooling curves of local white dwarfs.

2. Star formation in young disks is episodic, as suggested for starburst galaxies and possibly our Galaxy, with a duty cycle $\lesssim 10\%$.

3. Even at early epochs star formation is confined to particularly dusty regions. In this case our lines of sight represent regions quite different from regions in which star formation is occurring.

DISCUSSION

VÉRON In view of the high success of the survey by Surdej *et al.* for gravitationally lensed objects among highly luminous quasars, do you think that gravitational lensing could significantly affect the quasar luminosity function at high redshift?

SMITH There are considerable uncertainties. Turner (1988) reviewed the evidence during the Tucson conference and concluded by supporting Ostriker and Vietri's (1986) view that not much distortion of the luminosity function should arise from gravitation lensing. Schneider (1987) had come to the opposite conclusion. However, effects like multiple strong scatterings have been ignored in the calculation of micro-lensing statistics.