1. INTRODUCTION

How do galaxies evolve? Such a broad query covers a wide variety of current research interests. One specific approach to answering this question lies in tracking the volume density of the cosmic star-formation rate as a function of redshift. Early pioneering efforts by Lilly et al. (1996), Madau et al. (1996), and Steidel et al. (1996) forged a scenario in which the population of star-forming galaxies evolves out to a redshift of approximately unity, and beyond this redshift the star-formation rate density plateaus or slowly declines. This general picture has since been confirmed through various imaging and spectroscopy surveys carried out at ultraviolet, optical, infrared, and submillimeter wavelengths (e.g., Blain et al. 1999; Rowan-Robinson 2001; Jones & Bland-Hawthorn 2001; Tresse et al. 2002; Balderay et al. 2002; Wilson et al. 2002; Mann et al. 2002; Glazebrook et al. 2003; Hubble et al. 2003; Heavens et al. 2004; Gabasch et al. 2004; Pérez-González et al. 2005; Le Floc’h et al. 2005; Thompson et al. 2006; Babbedge et al. 2006; Sawicki & Thompson 2006; Ly et al. 2007; Shioya et al. 2007; Westra & Jones 2008). The rate of this drop-off provides an important constraint to cosmologists—understanding the physical processes involving stellar birth, life, and death, and how these processes feed back into the interstellar medium is crucial to our overall understanding of galaxy formation and evolution (e.g. Somerville et al. 2001; Ascasibar et al. 2002). Galaxy merger rates, the frequency of starburst galaxies compared to active galactic nuclei, the production of heavy metals and dust, and the origin of the cosmic background levels (Dole et al. 2006) are also closely linked to the cosmic star-formation rate.

While the decrease in the cosmic star-formation rate density since \( z \sim 1 \) has been empirically parameterized as \((1 + z)\gamma\), the strength of this evolution is not well determined. Values for the exponent range from \( \gamma \approx 1.5 \) (e.g. Cowie et al. 1999; Wilson et al. 2002) to \( \gamma \approx 4 \) (e.g. Lilly et al. 1996; Blain et al. 1999; Tresse et al. 2002; Pérez-González et al. 2005; Le Floc’h et al. 2005; Babbedge et al. 2006), a discrepancy of a factor of 6 in the change in the star formation rate from \( z = 0 \) to \( z = 1 \). Constraining galaxy evolution through measuring changes in the star formation rate density at even higher redshifts is a viable and important goal. However, a deep understanding of galaxy evolution, from the era of galaxy formation until now, requires an accurate foundation that is based on observations of the most recent epochs.

The current conflict over the strength of the evolutionary trend can be addressed by carrying out a uniformly sensitive survey for star formation in hundreds of galaxies at each of several epochs. The Wyoming Survey for Hα, or WySH, is a large-area, uniform survey for star-forming galaxies at several different epochs that span the latter half of the age of the universe. The specific aim of the survey is to utilize narrowband imaging of Hα-emitting galaxies to conclusively determine the strength of the evolution in the cosmic star-formation rate density since \( z \sim 0.8 \), to provide a firm, low-redshift baseline for studies of star-forming sources at higher redshift. The purpose of this paper is to introduce the survey, in particular the optical imaging program, and to present initial results from the two most recent epochs studied. Though only preliminary results are presented in this contribution, the survey will ultimately cover volumes at each epoch large enough to minimize cosmic variance due to large-scale structure and to robustly quantify any dependences on environment.

In this paper we outline the optical portion of the survey in Section 2, present initial results from \( z \sim 0.16 \) and \( z \sim 0.24 \) in Section 3, and summarize in Section 4. The cosmology assumed is \( H_0 = 70 \, \text{km} \, \text{s}^{-1} \, \text{Mpc}^{-1}, \Omega_m = 0.3, \) and \( \Omega_k = 0.7. \)
The optical portion of the survey is being carried out via large blocks of dark time on the Wyoming Infrared Observatory 2.3 m telescope (WIRO). Unlike many previous efforts which piece together the star-formation history using disparate surveys and techniques/tracers at different epochs, the data are being uniformly obtained over the same fields and to the same sensitivity to luminosity over the different epochs. The survey is being carried out over 3.5–4 deg$^2$ from multiple “blank” fields selected to minimize foreground contamination (see Section 2.2). By design, these fields are additionally pre-selected to overlap with the target areas of deep infrared and ultraviolet surveys. Not only will this survey provide a statistically robust measure of the evolving star-formation history of the universe, it will also enable important parallel science to be pursued. For example, combining H$_\alpha$, ultraviolet, and infrared data will help us to understand the extent to which the standard individual star-formation rate indicators are biased (Wilson et al. 2002), and to study the evolution of ultraviolet and optical extinction by interstellar dust over time (e.g., Reddy et al. 2006; Burgarella et al. 2008; Iglesias-Páramo et al. 2007; Moore et al. 2008, in preparation). In addition, a large-volume, multi-epoch survey will sample well the cluster, group, and field environments, leading to strong constraints on the environmental threshold that provides the balance between star-formation inducement and truncation that occurs in the vicinity of clusters (e.g., Dale et al. 2001; Balogh et al. 2002; Finn et al. 2005).

2.1. H$_\alpha$ as a Star Formation Tracer

Astronomers rely on a wide range of observational approaches for quantifying star formation. The ultraviolet, infrared, and radio restframe continua all provide useful measures of the star-formation rate, as do line fluxes in the ultraviolet, optical, infrared, and sub/millimeter (Kennicutt 1998; Calzetti et al. 2007; Kennicutt et al. 2007). However, for local universe systems H$_\alpha$ photons, indicative of ionized gaseous regions and hence directly related to the massive stellar population, provide the conventional standard by which to gauge star formation (Kennicutt 1998). H$_\alpha$ is typically the intrinsically strongest optical emission line and it suffers less extinction than other traditional indicators that lie at shorter wavelengths. Moreover, H$_\alpha$ fluxes are technically much simpler to obtain than star-formation measures at longer wavelengths. Thus a feasible and direct route to measuring galaxy evolution, one that is well calibrated by local universe measurements and is accessible from a 2 m class ground-based telescope equipped with a wide-field camera, would be to survey the universe in H$_\alpha$ at several different epochs.

2.2. Field Selection

In addition to carrying out H$_\alpha$ observations over multiple epochs, we are observing multiple fields (Table 1; Figures 1–3). Three separate fields help to dampen the effects of cosmic variance (Davis & Huchra 1982; Oliver et al. 2000; Huang et al. 2007). Moreover, the spacing of the fields in right ascension and their high declinations enable year-round observations from Jelm Mountain, located at a terrestrial latitude of +41° and an elevation of 9656 feet (2943 m) above sea level, thus maximizing the number of usable nights. These fields have been chosen to minimize foreground contamination by zodiacal and Galactic dust, bright stars, and nearby galaxies. Our pointings in the ELAIS-N1 and Lockman Hole fields overlap

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Table 1

| Target Fields | R.A. & decl. (J2000) | $I_{\nu}$(100 $\mu$m) (MJy sr$^{-1}$) | Observing window |
|---------------|---------------------|--------------------------------------|------------------|
| WySH 1        | 00 12 40 +32 49 00  | ~1.0                                 | Jul–Nov          |
| Lockman Hole  | 10 47 10 +58 23 00  | ~0.9                                 | Nov–Jun          |
| ELAIS N1      | 16 11 10 +45 22 00  | ~0.4                                 | Feb–Sep          |

Note. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

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3 The near-infrared portion of the survey ($z$ ~ 0.81) is being completed as a collaborative effort with J. Lee, R. Finn, and D. Eisenstein using the Bok 2.3 m and Mayall 4 m telescopes on Kitt Peak. Results from that effort will be presented elsewhere.
with deep surveys that have been carried out in the infrared and ultraviolet. The Spitzer Wide-Area Infrared Extragalactic Survey (SWIRE) Legacy project provides maps of these regions at 3.6, 4.5, 5.8, and 8.0 μm by the SWIRE program is outlined in bold, while the 11.0 deg² mapped at 24, 70, and 160 μm by SWIRE is outlined with a thinner line. Fields from the GALEX Deep Imaging Survey are shown as circles with a radius not covered by any other current deep-field work.

2.3. Observations and Data Processing

Optical observations for the survey utilize the WIRO 2.3 m telescope. The WIRO is equipped with a 2048×2048 CCD camera at prime focus that has 0.523 pixels and hence a 17.9 field of view (Pierce & Nations 2002). While most narrowband imaging surveys rely on broadband imaging for the estimation of the continuum flux levels, we use wavelength-adjacent narrowband filters (∼60 Å FWHM) to optimize the continuum subtraction. Note that this approach leads to a more efficient observing program, since no time is “wasted” on obtaining broadband imaging. The filter transmission profiles for the optical portion of this survey are provided in Figures 4 and 5. The filter widths and central wavelengths in Table 2 are computed via

\[ \Delta \equiv \int T(\lambda) d\lambda \]

(1)

\[ \bar{\lambda} \equiv \frac{\int \lambda T(\lambda) d\lambda}{\int T(\lambda) d\lambda} \]

(2)

where \( T \) reflects the combined transmittance of the filter and the quantum efficiency of the CCD, normalized to peak at unity (see Pascual et al. 2007). Note that these values are for the typical observing temperature of 0 °C.

The basic unit of observation is a 300 s frame, though several are taken for each filter at each location; the individual 300 s frames are slightly dithered to improve image reconstruction. IRAF/CCDPROC is used to run the images through the standard preliminary data processing routines. Bias levels and dark counts are removed, the images are trimmed to their usable regions (2048×2037 pixels), and the images are flat-fielded using twilight sky flats. Fringing affects our images primarily at wavelengths of 8132 Å and longer, and all images suffer from non-uniform illumination that induce a mild halo effect if not removed. The amplitude of fringing is at the 10% level or smaller in terms of sky fluctuation, whereas the non-uniform illumination results in 1–2% variations in the sky level across the field. CCDPROC is also used to correct for both of these effects, relying on the science frames themselves for fringe removal and on median skyflat images for the non-uniform illumination.

The data presented here were obtained under generally good observing conditions during several observing runs spanning 2005, 2006, and 2007. The seeing at Jelm Mountain is typically 1′–1′.5 FWHM; the observed stellar point-spread functions (PSFs) from 300 s frames range from 1′.2 to 2′.0 for this survey. Flux calibration is obtained via 30 s observations of spectrophotometric standards (Bohlin et al. 2001). Based on numerous repeated measurements...
of the same set of standard stars, the uncertainty in the flux calibration is 5%. In addition to frequently monitoring the night sky conditions by eye, the photometric quality for each frame is based on the relative fluxes in five foreground stars distributed across the field of view. Ninety percent of the 300 s frames used in this presentation were obtained under photometric conditions (in which foreground stellar fluxes agree to within 2–3% from frame to frame). For the remaining 10% of the frames taken in “nearly photometric” conditions, the median flux correction to account for thin cirrus cloud cover is a factor of 1.07. Such a correction is applied to each image that is based on the photometric quality described above. Coordinate solutions are written to each stack header via IRAF/XYEQ and IRAF/CCMAP, based on the coordinate solutions in Digitized Sky Survey (DSS) imaging and the pixel coordinates for several matched field stars in DSS and WySH frames. Inspection of numerous sources spread across the fields of view of several stacks shows that WySH coordinates match DSS coordinates to within an arcsecond.

2.4. Survey Sensitivity

The sensitivity of the survey is estimated in two ways, with the first based on the fluctuation of sky counts and the second based on the observed distribution of detections (the identification of sources is described in Section 2.5). In the first method, assuming a 3” diameter aperture and using the observed 3σ sky fluctuations of $\sim 6.2 \times 10^{-20}$ and $\sim 3.7 \times 10^{-20}$ W m$^{-2}$ at 7597/7661 Å and 8132/8199 Å, respectively, we find that the 3σ
limiting sensitivity to continuum/continuum+line luminosity in our survey is \( \sim 5 - 7 \times 10^{33} \text{ W} \).

The noise characteristics within a fixed circular aperture does not necessarily capture the full sense of the survey sensitivity. The seeing PSF is, of course, not constant from night to night, nor do we even utilize fixed aperture photometry for our source extraction (Section 2.5). Figure 6 shows the relevant figure for the second method of estimating survey sensitivity. In this figure we show the observed distribution of signal-to-noise ratio for continuum luminosity for all narrowband detections at the targeted redshifts. As can be seen from the distribution, the 3\( \sigma \) sensitivity to luminosity is \( 6 \times 10^{32} - 3 \times 10^{33} \text{ W} \). In short, the two techniques give consistent values for the survey sensitivity to continuum/continuum+line luminosity. The sensitivity to line detections is \( \sim \sqrt{2} \) poorer since we derive line strengths via subtraction of two narrowband luminosities, as described in the following section.

2.5. Source Identification and Flux Extraction

SExtractor (Bertin & Arnouts 1996) is used to identify sources and to extract their fluxes. Extensive simulations were performed to optimize the extraction approach for our imaging program; key parameter settings include DETECT_THRESH = 1.5 and DETECT_MINAREA = 300.523 pixels. The FLUX_AUTO output parameter (with the default PHOT_AUTOPARAMS = [2.5, 3.5]) is used for the flux extractions, as it effectively recovers simulated fluxes for the variety of source morphologies and sizes typical of this survey. Narrowband filter pairs are employed at each epoch, and it is unknown in advance whether a particular source will produce line emission appearing in ‘Filter A’ or ‘Filter B’ of a given filter pair. Thus, SExtractor is used in “dual” mode twice for each stack. First, sources are identified and fluxes are extracted from the Filter A stack, then SExtractor is rerun on the Filter B stack using the same positions and apertures that were determined from Filter A imaging. The procedure is then repeated in the reverse order: identifications and extractions are based on Filter B imaging, and then the Filter A image is processed using Filter B positions and apertures. In this way two goals are accomplished: fluxes are consistently extracted from Filter A and Filter B imaging, and line emitters with weak continuum levels are not overlooked.

Traditionally, narrowband imaging surveys rely on broadband imaging to infer and subtract off the underlying stellar continuum. Since two wavelength-adjacent but otherwise nearly identical narrowband filters are used at each epoch for this survey, the line emission is derived from a simple subtraction of the flux from Filter A and the flux from Filter B (after accounting for the slightly different filter widths):

\[
\begin{align*}
\Delta f(\text{H}\alpha + [\text{N} \alpha]) &= f_A - f_B \frac{\Delta A}{\Delta B} & \text{if} & & f_A > f_B \frac{\Delta A}{\Delta B} \ (3) \\
\Delta f(\text{H}\alpha + [\text{N} \alpha]) &= f_B - f_A \frac{\Delta B}{\Delta A} & \text{if} & & f_B > f_A \frac{\Delta B}{\Delta A} \ (4) \\
f(\text{H}\alpha) &= 0.8 f(\text{H}\alpha + [\text{N} \alpha]) \ (5) \\
L(\text{H}\alpha) &= 4\pi D_L^2 f(\text{H}\alpha) \ (6) \\
S/\text{N}(\text{H}\alpha) &= f(\text{H}\alpha + [\text{N} \alpha])/\sqrt{\epsilon(f_A)^2 + \epsilon(f_B)^2} \ (7)
\end{align*}
\]

where a correction for [N\alpha] that is typical of star-forming galaxies is employed (Kennicutt 1992; Jansen et al. 2000). The above expressions include the luminosity distance \( D_L \) and filter fluxes derived as the filter width times the flux density, e.g., \( f_A = \Delta A f_A \). While our dual-narrowband imaging is more accurate than a traditional narrowband+broadband observational approach, there still may be a selection effect working against low equivalent width sources. Hanish et al. (2006) show that 4.5% of their H\alpha luminosity density comes from galaxies with equivalent widths smaller than 10 Å. Figure 7 displays the H\alpha
equivalent width distributions for the two epochs studied in this work, showing that a significant portion of our sources have equivalent widths below 10 Å. The distributions are qualitatively in agreement with that presented in the literature (e.g., Gronwall et al. 2004; Haines et al. 2007), though there is evidence for larger equivalent widths at redshift \( z \approx 0.24 \) than at \( z \approx 0.16 \). The median equivalent widths are 8.5 Å and 23 Å at redshifts 0.16 and 0.24, respectively.

The redshift of each line emitter is not known \textit{a priori} and thus detections from galaxies outside of the target epochs could bias to high levels the \( \mathrm{H}^\alpha \) detection rate and thus the inferred starformation rate density at each epoch; other prominent optical emission lines such as \([\mathrm{O} \, ii] 3727\), and \( \mathrm{H}\beta 4861 \) could be reddshifted into the filter bandpasses (e.g., Fujita et al. 2003). Photometric redshifts are used to cull the contaminants. Multiple photometric redshift catalogs are or soon will be available for the fields pursued in this work: Rowan-Robinson (2001) from SWIRE, Csabai et al. (2003) from the Sloan Digital Sky Survey (SDSS), and Moore et al. (2008, in preparation) from WIRO observations. The SWIRE survey utilizes a suite of optical and infrared fluxes along with a variety of spiral, elliptical, and AGN SED (active galactic nucleus spectral energy distribution) templates to determine photometric redshifts. The Sloan survey uses a similar technique with \( ugriz \) data, and our WIRO-based catalog employs \textit{UBVRI} imaging in addition to our narrow/band data. In regions where the coverage overlaps (e.g., Lockman Hole), we have compared the impact of using photometric redshifts from the various surveys. Survey products such as the parameters and integrals of the \( \mathrm{H}^\alpha \) luminosity functions are fairly insensitive to which survey is utilized for photometric redshifts (Moore et al. 2008, in preparation). However, for the sake of uniformity SWIRE photometric redshifts are used where available, with SDSS and our own photometric redshifts employed to supplement the SWIRE coverage.

The uncertainty on these photometric redshifts is a function of redshift, flux, the number and rest wavelengths of the broadband detections, the SED models, etc. The typical photometric redshift used in this work has an uncertainty of \(-5\%\). A source is considered to be at one of the targeted redshifts if its photometric redshift falls within one of our filter’s effective bandpasses, i.e., within \( \Delta z/2 \) of one our filter’s central wavelengths (see Section 2.3). The sample of \( \mathrm{H}^\alpha \) emitters is created after applying a 3\( \sigma \) cut based on the \( \mathrm{H}^\alpha \) signal-to-noise. The large number of sources detected in our survey leads to a robust \textit{statistical} representation of the star formation rate at each cosmic epoch, but the reliance on photometric redshifts implies a certain level of error in tagging \textit{individual} sources as residing within the targeted redshift ranges. The impact of relying on photometric redshifts will be more fully explored in a future contribution that presents a larger fraction of the survey.

3. RESULTS

A primary tool for understanding the basic characteristics of a galaxy population is the luminosity function (Schechter 1976). The \( \mathrm{H}^\alpha \) luminosity function is constructed for each epoch assuming a Schechter profile:

\[
\Phi(z, \log L) d\log L = \phi(z, L) dL = \phi_*(z) \left( \frac{L}{L_*(z)} \right)^{\alpha(z)} e^{-L/L_*(z)} \frac{dL}{L_*(z)},
\]

where \( \alpha(z) \) conveys the shape of the function, \( L_*(z) \) sets the luminosity scale, and \( \phi_*(z) \) represents the overall normalization. The computation of the \( i \)th bin of the luminosity function and its uncertainty follows,

\[
\Phi(z, \log L_i) = \frac{\sum_j (V(z_j, L_j)^{-1})}{\Delta \log L},
\]

\[
\epsilon[\Phi(z, \log L_i)] = \frac{\sqrt{\sum_j (V(z_j, L_j)^{-2})}}{\Delta \log L},
\]

where \( V(z_j, L_j) \) is the comoving volume for the \( j \)th galaxy in the summation, \( |\log L_j - \log L_i| < \frac{1}{2} \Delta \log L \), and the bin width \( \Delta \log L \) spans 0.4 dex. The \( \mathrm{H}^\alpha \) luminosity functions for each epoch are presented and discussed after a brief description below of corrections that are first applied to the data.

3.1. Accounting for Observational Biases

3.1.1. Non-Rectangular Filter Transmission Profiles

If each filter bandpass were to follow a “tophat” profile, then the comoving volume computed in Equation (9) would be simply a product involving the filter width \( \Delta \) and the number of square degrees surveyed (see Table 2). However, since the filter bandpasses are not tophats, it is more difficult to detect faint galaxies over the full bandpass. Hence, the volume in Equation (9) for faint galaxies is somewhat smaller than \( \Delta \). The volume correction factors, \( \xi(z)_{\text{filter}} \), where

\[
V(z, L)_{\text{cor}} = \xi(z)_{\text{filter}} V(z, L),
\]

can be as large as 10–20\%, but the median volume correction factors are \( \xi_{\text{filter}} = 0.985, 0.981, 0.990, \) and 0.988, respectively for filters centered at 7597 Å, 7661 Å, 8132 Å, and 8199 Å.

A second effect is related to the non-rectangular nature of the filter bandpass profiles. If spectra were available to provide accurate measures of individual galaxy redshifts, then each \( \mathrm{H}^\alpha \) luminosity could be corrected by the inverse of the normalized filter transmission at the appropriate wavelength, \( T(\lambda)^{-1} \). Since such spectra are not available for this survey, galaxies that are detected in the low-transmission wings of the filter profiles are measured to have artificially faint \( \mathrm{H}^\alpha \) luminosities. A statistical correction, \( \eta_{\text{filter}} \), can be applied to all \( \mathrm{H}^\alpha \) luminosities to remedy this effect. The correction is derived by calculating the average inverse normalized transmission for each filter, weighted by the survey’s distribution of detectable \( \mathrm{H}^\alpha \) luminosities (assuming a Schechter luminosity function). Monte Carlo simulations of the effect indicate \( \eta_{\text{filter}} \approx 1.10 \pm 0.08 \).

3.1.2. Extinction

Fluxes are corrected for foreground Milky Way extinction, an effect on the order of 1\% for these regions of low Galactic cirrus emission. More importantly, the \( \mathrm{H}^\alpha \) data are also corrected for the internal extinction within the survey galaxies. A standard recipe is to assume 1 mag of extinction at either \( V \) band (a factor of \( \sim 2.1 \) at 6563 Å) or at the \( \mathrm{H}^\alpha \) wavelength (a factor of \( \sim 2.5 \) at 6563 Å). Another approach is to employ an extinction that varies with galaxy luminosity. Hopkins et al. (2001), for example, suggest a transcendental equation for the extinction based on the galaxy star-formation rate:

\[
\log \text{SFR}(\mathrm{H}^\alpha)_{\text{hs}} = \log \text{SFR}(\mathrm{H}^\alpha)_{\text{int}} - \alpha \log \left[ \frac{\beta \log \text{SFR}(\mathrm{H}^\alpha)_{\text{int}} + \gamma}{\delta} \right].
\]
where $\alpha = 2.360$, $\beta = 0.797$, $\gamma = 3.786$, and $\delta = 2.86$ if a Cardelli et al. (1989) reddening curve is assumed (see Ly et al. 2007). This approach is adopted for the WySH survey. Table 3 lists the extinction correction factor, $\theta(L)_{\text{ext}}$, for the relevant bins in the luminosity function. The corrected Hα luminosity and star formation rate are thus expressed as

$$ L(H\alpha)_{\text{cor}} = \eta_{\text{filter}} \theta(L)_{\text{ext}} L(H\alpha)_{\text{obs}} $$

(12)

$$ \epsilon(\text{SFR}) = \frac{SFR}{\text{SFR}} = \frac{\sqrt{\epsilon(H\alpha)}}{f_H} + \epsilon(H\alpha) + B^2 + 0.02^2 + 0.15^2 + 0.05^2 + 0.20^2 $$

(13)

$$ \Phi(z, \log L)_{\text{cor}} = \kappa(z, L)_{\text{inc}} \Phi(z, \log L)_{\text{obs}} $$

(15)

Extensive Monte Carlo simulations are employed to quantify the impact of incompleteness. For each luminosity bin in the luminosity function, IRAF/mkobject is used to create several mock images with the same noise as the actual survey image stacks described in Section 2.3. These mock images incorporate typical seeing effects and generate sources with distributions similar to those of actual sources in spatial density, equivalent widths, Hα diameters (Dale et al. 1999), and of course the luminosity of the particular luminosity bin being simulated. Table 3 provides a compilation of incompleteness factors $\kappa(z, L)_{\text{inc}}$ for samples that are selected with a 3σ cut based on the Hα signal-to-noise. The uncertainties in the incompleteness are based on the ranges in incompleteness for a variety of simulation parameters (e.g. 500 versus 1500 versus 4500 sources in a simulated image; $1 < \text{EW}(\lambda) < 10$ versus $10 < \text{EW}(\lambda) < 50$, etc). For brighter luminosities the incompleteness reaches an asymptotic value of $\sim 0.95$ due to the effects of sources overlapping one another. Additional pseudo-empirical simulations, whereby artificial sources are added to actual image stacks, indicate consistent results with the “pure” simulations.

### 3.1.4. Active Galaxies and Star-Forming Galaxies Lacking Hα Emission

A main goal of this survey is to derive the volume-averaged star formation rate at several epochs, $\dot{\text{SFR}}(z)$. If $\dot{\text{SFR}}(z)$ is to be interpreted as being solely due to star-forming galaxies, then contributions from AGN galaxies will have to be removed. Brinchmann et al. (2004) and Salim et al. (2007), for example, respectively use multi-wavelength data for $\sim 150,000$ and $\sim 50,000$ galaxies to derive a $\sim 4\%$ AGN contribution to $\dot{\text{SFR}}(z)$. However, these same studies estimate between $\sim 1$ and $11\%$ of the cosmic star formation rate stems from galaxies lacking obvious optical line emission. These two effects have a counteracting impact on $\dot{\text{SFR}}(z)$, and in light of their uncertainties and relatively small impact on the final outcome, we do not invoke any corrections to account for them.

### 3.2. Preliminary Luminosity Functions at $z \sim 0.16$ and 0.24

Figure 8 shows the initial luminosity functions at $z \sim 0.16$ and 0.24 for the WySH survey. Open circles indicate the data corrected for all issues described above except incompleteness; the filled circles also include corrections for incompleteness. The thick solid lines show the Schechter fits for all luminosity bins except $L(H\alpha) = 10^{33.2} \text{W}$ at $z \sim 0.24$. The parameters for the displayed fits are listed in the first two rows of Table 4; for comparison with the literature (e.g., Table 5 of Ly et al. 2007), we also include in Table 4 fit parameters assuming 1 and 2 mag of internal extinction at the Hα wavelength. Tentatively, we observe a significantly higher luminosity function amplitude $\phi_0$ at $z \sim 0.24$ than at $z \sim 0.16$. It is difficult to compare the characteristic luminosity $L_*$ between the two epochs since it is poorly defined at $z \sim 0.16$. Error bars in Figure 8 reflect the uncertainty in the luminosity function amplitude according to Equation (9), summed in quadrature with the uncertainties in the incompleteness corrections. Also included in Figure 8 are Hα-based luminosity functions from the literature, largely consistent with our preliminary results.

### 3.3. The Cosmic Star-Formation Rate Density at $z \sim 0.16$ and 0.24

The volume-averaged cosmic star-formation rate can be computed by integrating under the fitted Schechter function and multiplying by the Kennicutt (1998) star-formation rate calibration:

$$ \dot{\text{SFR}}(b_{70} M_\odot \text{yr}^{-1} \text{Mpc}^{-3}) = 7.9 \times 10^{-35} \mathcal{L} \text{(W)} $$

(16)

where an analytical expression for the luminosity density is

$$ \mathcal{L} = \int_0^\infty dLL\Phi(L) = \phi_0 L, \Gamma(\alpha + 2). $$

(17)

The larger $\phi_0$ and brighter $L_*$ at $z \sim 0.24$ lead to an overall larger cosmic star-formation rate density at that redshift, by a factor of 1.5 for the canonical fits displayed in Figure 8. Table 4 provides the integrated cosmic star-formation rate densities. For comparison with other extinction-corrected, Hα-based cosmic star-formation rate densities, we are comfortably within a factor of 2 of the values published by Sullivan et al. (2000) at $z \sim 0.16$ and Pascual et al. (2001), Fujita et al. (2003), Hipplelein et al. (2003), Ly et al. (2007), Westra & Jones (2008), and Shioya et al. (2007) at $z \sim 0.24$ (see Ly et al. 2007 for values converted to the common cosmology also assumed in this work).
The overall scientific goal of the survey is to accurately calibrate changes in the \( \alpha \) luminosity function due to fluctuations in the cosmic star formation rate densities in these two fields differ by \( \sim 25 \% \) at each epoch, indicating a modest impact due to cosmic variance.

### 4. SUMMARY

We report first results from the two most recent epochs of WySH, the Wyoming Survey for H\( \alpha \), on hundreds of galaxies at each epoch using narrowband filter pairs for improved continuum subtraction. Preliminary results from approximately 2 deg\(^2\) from two fields indicate a clear evolution in the volume-averaged cosmic star-formation rate, a decrease by a factor of \( \sim 1.5 \) from a redshift of \( z \sim 0.24 \) to a redshift of \( z \sim 0.16 \). Our value at \( z \sim 0.16 \) is comparable to that found from H\( \alpha \) work at \( z = 0 \) by Gallego et al. (1995) and Hanish et al. (2006), so more substantial evolution appears to have occurred between redshifts of 0.16 and 0.24 compared to what has occurred after a redshift of 0.16, but additional data are needed to more robustly assess this claim.

By separately analyzing these initial data from the Lockman Hole and ELAIS-N1 fields, we see a \( \sim 25 \% \) “cosmic variation” in our cosmic star formation rate densities at \( z \sim 0.16 \) and 0.24. The estimate of the cosmic variance in our survey will be more accurately estimated in future work, after more data are added from ELAIS-N1 and Lockman, and data are included from our third field (“WySH 1”).

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