AN *HST* ACS/WFC Hα IMAGING SURVEY OF NEARBY GALAXIES

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Abstract Previous studies of nearby galaxies show large discrepancies between different star formation (SF) indicators on large ($\gtrsim$100 pc, or even global) scales: the strikingly complex interplay of young stars, dust and ionized gas are the primary cause of this variance. The few galaxies in the *HST* Archive with both Hα and mid-UV images show this complex geometry to extend down to pc scales.

To provide a benchmark for understanding SF processes at spatial resolutions that are unattainable from the ground in normal and star-bursting, barred and non-barred galaxies, I am conducting an Hα SNAPshot survey with ACS/WFC of $\sim$24 galaxies of all Hubble types, that are nearby but beyond the Local Group and that were previously imaged with *HST* in the mid-UV and red.

These data can be used to address a wide range of astrophysical problems, but the immediate goals are to: (1) spatially resolve the dust clouds and filaments which strongly affect mid-UV and Hα derived SF rates, (2) test how the large-scale correlation between Hα and mid-UV flux breaks down on pc scales, and (3) model the propagation of star formation by comparing the SF over time scales of $\sim$100 Myr (via mid-UV) and $\sim$5 Myr (via Hα). This will (4) significantly improve our insight into, and calibration of SF in UV-bright galaxies at high z, and into the cosmic SF history.

Keywords: Galaxies: star formation — galaxies: ISM — galaxies: fundamental parameters — galaxies: nearby

Quantitative Star Formation Tracers

Accurate measurements of star formation (SF) in external galaxies based on tracers like the mid-UV continuum, Hα recombination line, [O II] emission line, and radio continuum emission are hampered by systematic uncertainties due to the presence of interstellar dust[26,27][9][3,4,5]. This dust is intermixed with interstellar gas and distributed in highly complex geometries down to scales that have only been resolved from the ground in the very nearest Local Group galaxies[4] but are readily apparent in *HST* images[8][12]. In their ground-based spectrophotometric study, Jansen et al. [13 – 16] showed strong

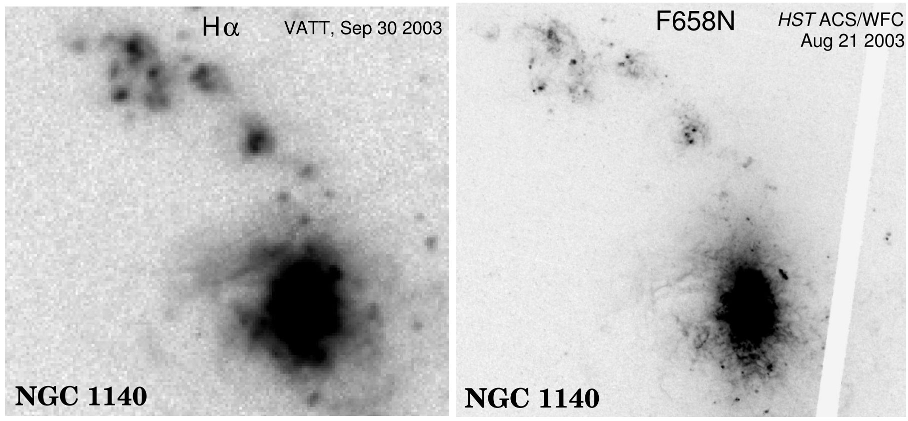

Figure 1. Hα images of star-bursting dwarf (IBm) galaxy NGC 1140 obtained from the ground under good conditions (VATT, Mt.Graham; σ=0$''\!.$9) and obtained as part of the ACS/WFC SNAPshot survey. The large uncertainties and discrepancies in global SFR calibrations can only be resolved by studying the tracers most sensitive to dust in a diverse nearby galaxy sample *at HST resolution*.

correlations between a galaxy's Hubble type, wavelength-dependent UBR morphology, luminosity and global emission line strengths of [O II] and Hα (hence the global star formation rate [SFR]), demonstrating the need for a relatively large and varied galaxy sample. However, ground-based studies are significantly limited by the seeing ($\gtrsim$0$''\!.$4), both in imaging and spectroscopy, and are therefore not suited for the study of individual SF sites beyond the Local Group. Since the emission emerging from a galaxy, especially in the UV, is dominated by regions of low obscuration[7] and may itself depend on the SFR[11], the resulting large uncertainties and discrepancies in global SFR calibrations can only be resolved by studying the tracers most sensitive to dust in a diverse nearby galaxy sample *at HST resolution*[8][21][5].

An ACS/WFC Hα SNAPshot survey of Nearby Galaxies

In Cycles 9+10, Windhorst et al. imaged a sample of 89 nearby galaxies with WFPC2 in the mid-UV F300W and red F814W filters[28,17] supplementing the 17 galaxies in the *HST* Archive for which such images were already available. The combined sample spans the Hubble sequence in morphological type, and is well represented in late-type/irregular, merging and interacting galaxies which are more common at higher redshifts.

Jansen et al. are currently conducting an ACS/WFC Hα SNAPshot survey (PID #9892) of nearby galaxies selected from this sample. 48 nearby galaxies were selected with $cz \lesssim 2500$ km s^{-1}, sampling different SF environments, for which sufficient S/N could be obtained in the F658N Hα filter in a partial *HST* orbit, and without prior WFPC2 Hα images of acceptable quality in the Archive. I chose to aim for the longer holes in the *HST* schedule (∼32–55 min) to ensure well-exposed Hα images and sensitivity to faint extended emission, even though fewer such opportunities are available. It allowed fitting three WFC exposures within a SNAP visit and therefore to also obtain a short F625W (r') exposure for continuum subtraction and to aid in selecting low-extinction sightlines (see below). As of this writing (May 2004), 19 galaxies were imaged and by the end of Cycle 12 this should be a random subset of ∼50% of the pool of 48 targets. The ACS/WFC Hα SNAPshots provide both exquisite spatial resolution and spectral information in one of the most important atomic emission lines, that has not been mapped yet in a significant number of galaxies with *HST* images in both Hα and the mid-UV.

Science goals for the Hα survey

(1) *Measure the intrinsic correlation of Hα and mid-UV flux as tracers of current high mass star formation, by distinguishing low and high extinction sight-lines at $\lesssim$10 pc spatial resolution.* We will model the Lyman continuum luminosity and corresponding high-mass SFR[18,20] for the the sight-lines with the very lowest extinction (as determined from comparison of the F300W, F625W, and F814W images) —taking into account possible changes in recent SF history or spatial propagation of the SF— and so constrain the ratio of Hα to mid-UV flux to be used in SF calibration at high z. We will study whether that ratio varies as a function of a galaxy's Hubble type, or whether it depends on (a) the distance from the galaxy center (e.g., metallicity gradients), (b) the size or luminosity of a H II-region, (c) local morphological structures, like bars, spiral arms, ridges, bubbles or filaments, and (d) on the proximity to other H II-regions.

(2) *Measure the effect of averaging over sight-lines with varying dust column densities on the derived star formation rates, calibrate lower resolution measurements, and model the SFR calibrations at higher redshifts.* The effects of dust, age and metallicity are extremely difficult to disentangle[2]. The high spatial resolution of ACS/WFC, however, helps significantly (its $0\farcs05$ pixels equal to $\lesssim$10 pc out to 37 Mpc). For the more extinguished sight-lines, we will test the interstellar extinction law[10][7][22] with simple assumptions on the dust geometry, for a much larger and more varied sample of galaxies than entered these studies, using the intrinsic Hα–mid-UV flux-ratios measured along the most transparent sightlines as reference. We will then measure the impact of averaging over varying dust column densities on the derived SFRs and properly model the SFR calibration at high z, taking into account the metal production history. Studies with this kind of detail have so far been possible only in Local Group galaxies[25][4]. This study will complement the latter (which compared

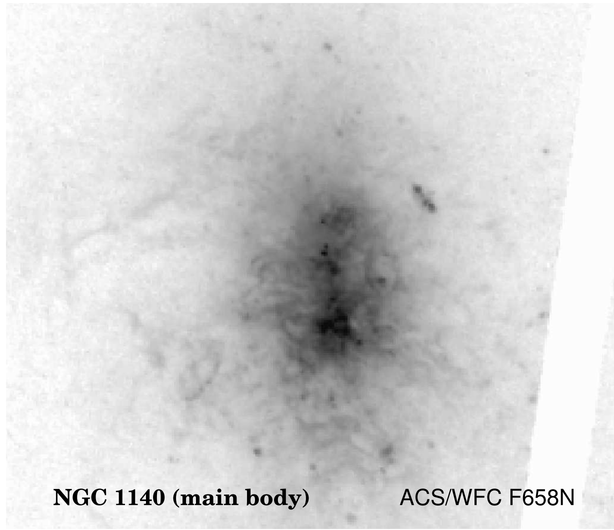

Figure 2. Detail of the full ACS/WFC Hα image of NGC 1140 centered on the high surface brightness "main body" or "bar" portion of the galaxy. The filamentary nature of the distribution of the Hα emission is apparent down to the smallest scales ($\sim$5 pc).

UIT mid- and far-UV imagery with ground-based Hα at $\sim 3''$ resolution) by spatially resolving individual SF sites.

(3) *Investigate whether the stellar populations responsible for the mid-UV emission coincide spatially with those responsible for exciting the H I gas.* Available (lower resolution) images of nearby galaxies show distinctive spatial distributions for Hα and mid-UV light. The high spatial resolution attainable with ACS/WFC allows us to examine to what extent this trend continues down to pc scales: because of different timescales probed by mid-UV and Hα light, this gives powerful insight into the mechanisms by which SF propagates within galaxies on time-scales $\lesssim$100 Myr. It also gives us the opportunity to study in detail the fraction of Hα emitted by diffuse ionized gas[24,23], and to study outflows, bubbles and superbubbles driven by SNe that have recently exploded in or near H II-regions (as seen in the Hα image of NGC 5253 [8]).

(4) *Probe the faint end of the H II-region LF — do size and luminosity depend on galaxy type?.* We will measure whether the faint-end slope of the H II-region LF depends on galaxy morphology —and if so, how— and, by comparing diameters and luminosities, what fraction of H II-regions is density bounded. For example, Kennicutt et al. [19] and Caldwell et al. [6] find systematic changes in the shape of the H II-region LF with Hubble type, as would result from differences in the intrinsic molecular cloud mass spectrum. The high end of the mass spectrum is sensitive to shear due to differential rotation, and

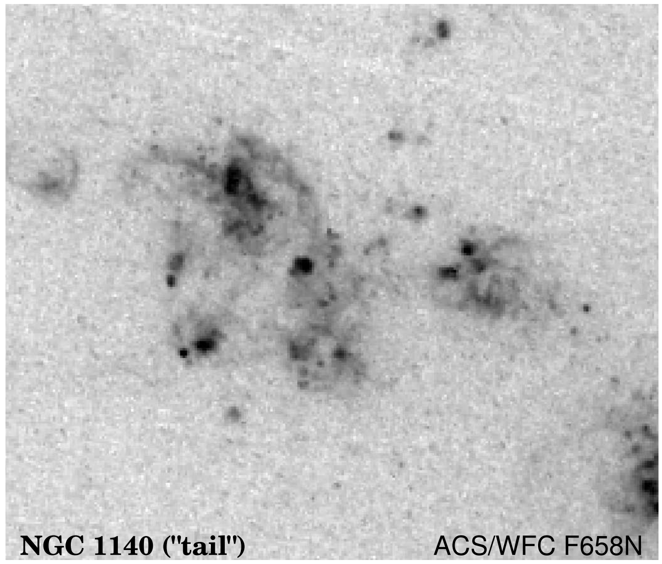

Figure 3. Detail of the full ACS/WFC Hα image of NGC 1140 centered on the "tail" of the galaxy. The knots of star formation visible in the ground based image (Fig. 1a) are resolved into the brightest stars and/or compact young clusters.

so a dependence on Hubble type could naturally emerge. Beckman et al. [1] find that the H II-region LF in several disk galaxies with Cepheid distances shows "glitches" near an apparently invariant luminosity of $L^*_{\rm H\,II} \sim 10^{38.6}$. We will investigate to what extent these results are due to the limited spatial resolution in these studies.

Acknowledgements
The author gratefully acknowledges support from NASA grant GO-9892 and thanks the team of co-Is of this program.

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