HII Regions in the Outer Disk and Tidal Arms of M81

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Introduction

The outer disk spiral arms of M81, caused by the interaction with M82 and NGC3077, are fertile grounds for exploring star formation in low density environments. The area is characterized by extended HI arms and filaments (Yun et al. 1993; Walter et al. 2002) within which are found HII regions and dwarf galaxies, including HoIX. Much attention has focused in past years on the evidence for star formation and on the properties of the stellar populations detected in these HI features, especially from recent GALEX and HST observations (de Mello et al. 2008; Sabbi et al. 2008; Weisz et al. 2008; Chiboucas et al. 2009; Davidge 2009.) We report on a study of the HII region population over a 1.5 degree field, derived from a Burrell-Schmidt Hα composite (Thilker et al. 2002) supplemented with ARC 3.5-m telescope emission line images. We discuss the luminosities and morphologies of the HII regions and compare the current massive star formation with the recent and past rates inferred from the stellar populations detected in the outer disk features.

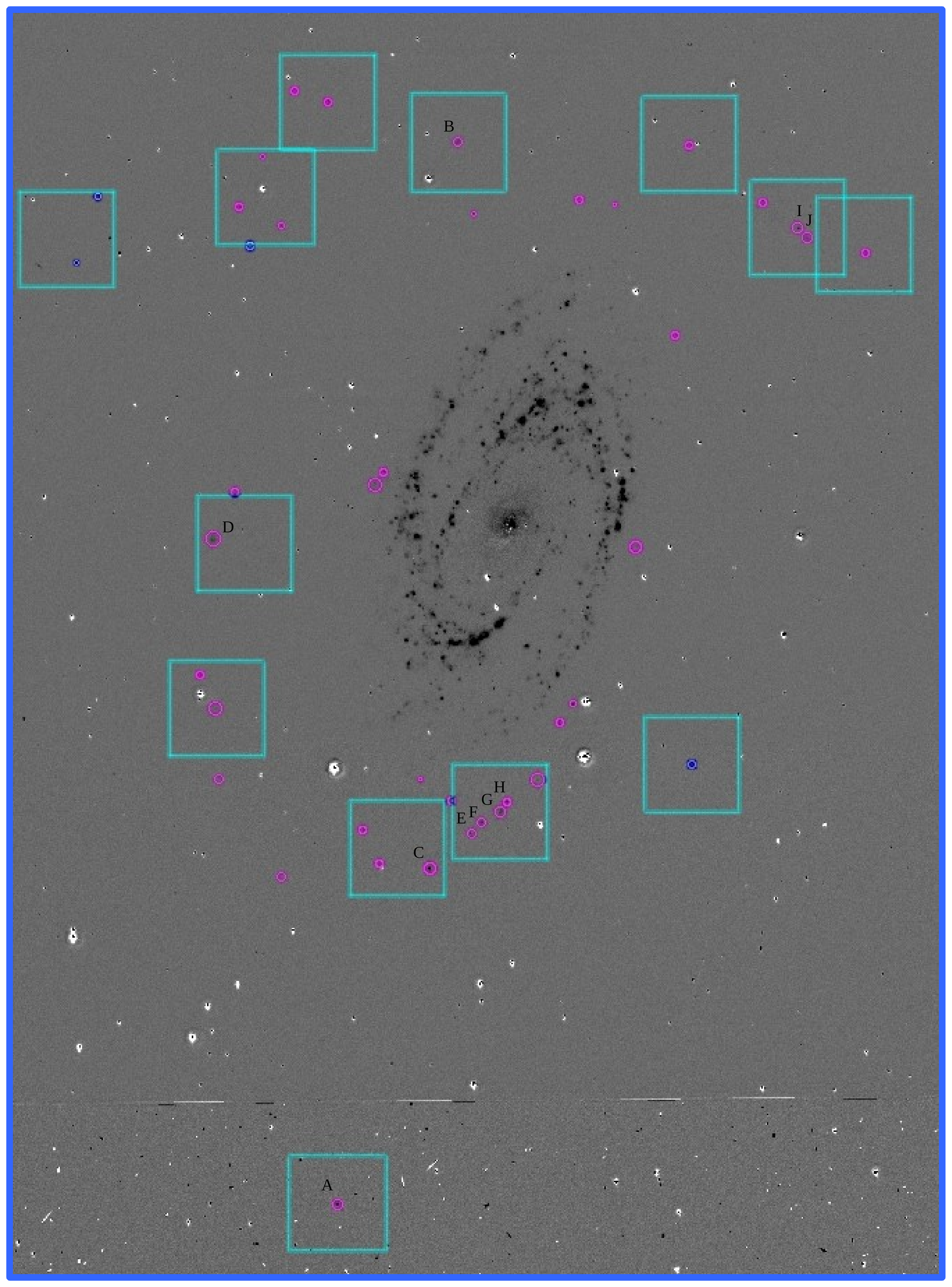

Fig. 1

A portion of the Hα + [NII] continuum-subtracted composite image taken with the KPNO Burrell-Schmidt telescope showing the HII region population around M81 . Each of the regions are enclosed by circles corresponding to the aperture size used. The 36 purple regions signify a 5σ or greater detection. The 4 blue regions signify a detection below 5σ but greater than 4σ. The cyan boxes show the fields imaged with the 3.5-meter telescope.

Observations

The field around M81 was observed on the Burrell-Schmidt telescope at KPNO with 2" pixel size for a total exposure time of 3.5 hours in Hα. We used 75 Angstrom wide filters for both the Hα and continuum images, which is wide enough to include [NII] λλ(6548+6584) lines in the Hα image.

Candidate HII regions were found by visual comparison of the Hα + [NII] image to the continuum image. We used a photometry task from Coughlin (NMSU) to obtain fluxes for the HII regions. The aperture sizes chosen are shown by the size of the purple circles in Figure 1. Only candidate regions with signal to noise greater than 5 were kept. We found 36 HII regions at a 5σ confidence level.

We verified our flux calibration by comparison with the fluxes of several HII regions in the main disk given by Lin et al. (2003) and Pérez-González et al. (2006), using the aperture sizes quoted in each paper. To convert to Hα luminosities, we assumed the [NII]/Hα ratio to be 0.4 and a distance to M81 of 3.63 Mpc. Fig. 3 shows the distribution of Hα luminosities for these regions.

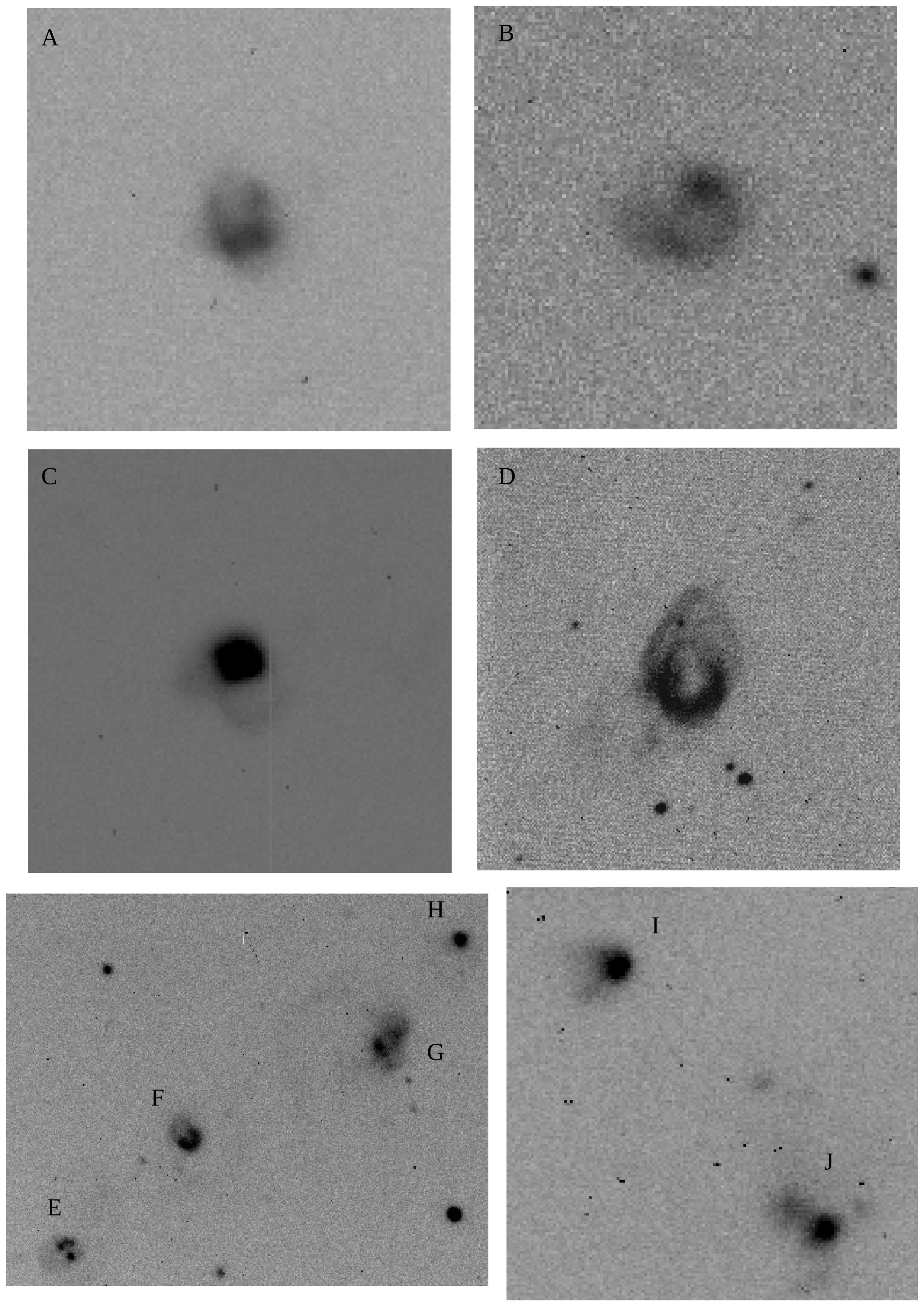

Fig. 2

TOP LEFT: (A) HII region associated with the dwarf spheroidal galaxy KDG 61 (not shown to the lower right.) It has a horseshoe shape morphology with a cavity-like feature to the north.

TOP RIGHT: (B) HII region to the North of M81 with a comma shape morphology.

MIDDLE LEFT: (C) Bright (1.5×10^{38} ergs s^{-1}) HII region in the Southern tidal arm of M81. It has two prominent loops of gas protruding from a bright central region.

MIDDLE RIGHT: (D) HII region associated with the tidal dwarf HoIX, whose main body is outside this image to the lower right. It has a similar horseshoe morphology to KDG 61.

BOTTOM LEFT: String of HII regions in the Southern tidal arm of M81. **(E)** has four visible knots of gas. **(F)** has a horseshoe shape similar to KDG 61 and HoIX. **(G)** has a very flocculent morphology. **(H)** appears smooth and round.

BOTTOM RIGHT: (I) and **(J)** are two HII regions in the Northern tidal arm of M81. **(I)** has a bright concentration with extended tail features. **(J)** has a bright region with several flocculent tufts of gas.

Results

The Hα luminosities for the HII regions observed with S/N > 5 range from 4.2×10^{36} ergs s^{-1} to 1.5×10^{38} ergs s^{-1}. To calculate a star formation rate for these outer disk HII regions we relate it to the total Hα luminosity by

$$\mathrm{SFR}(M_\odot\ \mathrm{year}^{-1}) = 7.9\times10^{-42}\ L(\mathrm{H}\alpha)\ (\mathrm{ergs\ s}^{-1})$$

(Kennicutt 1998). The total Hα luminosity for the HII regions is $\sim1.1\times10^{39}$ ergs s^{-1}, which gives a total star formation rate in these regions of $\sim8.7\times10^{-3}$ $M_\odot$ yr^{-1}.

Thirteen fields around M81 imaged in Hα with the ARC 3.5-meter telescope are shown by the 4'×4' cyan boxes overlain in Fig. 1. We selected ten regions within these fields to show in Fig. 2. The seeing was typically 0.9-1.2". The images show interesting structure in the HII regions. Several have arc or horseshoe shaped dense concentrations of gas or looped structures.

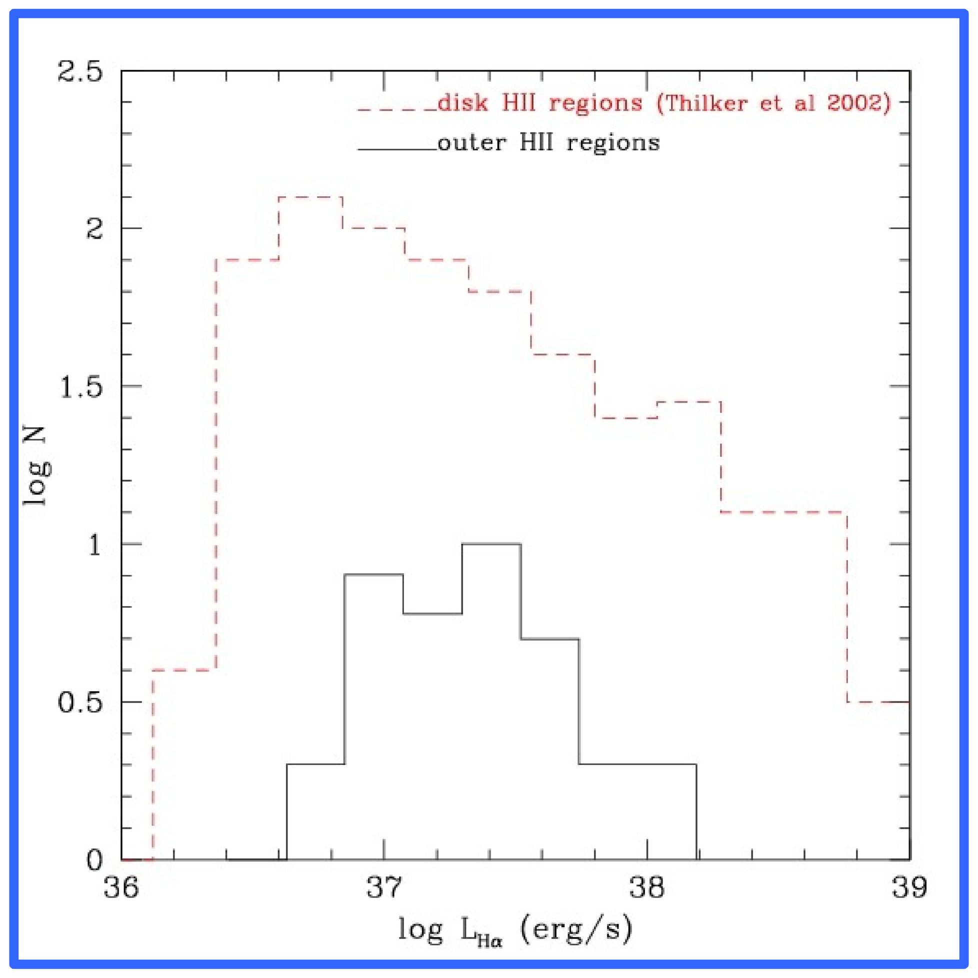

Fig. 3

Histogram of the derived Hα luminosities for the 36 outer disk HII regions plotted for comparison with inner disk HII regions from Thilker et al. 2002. The average Hα luminosity is $\sim2.9\times10^{37}$ ergs s^{-1}. The total Hα luminosity for all 36 HII regions is $\sim1.1\times10^{39}$ ergs s^{-1}. The brightest regions seem to be associated with HoIX, KDG 61, and the Southern and Northern tidal arms.

Summary

From Hα + [NII] observations of the outer disk and tidal arms of M81, we detect 36 HII regions with S/N>5. We show the morphologies of ten of these regions from follow-up Hα imaging. The Hα luminosities we derive for the 36 outer disk HII regions range from 4.2×10^{36} ergs s^{-1} to 1.5×10^{38} ergs s^{-1}, as shown in the histogram in Fig. 3 compared to HII regions in the inner disk (Thilker et al. 2002.) We derive a total star formation rate for the outer disk HII regions of $\sim8.7\times10^{-3}$ $M_\odot$ yr^{-1}, which is much smaller than the global star formation rate of M81 (0.4-0.8 $M_\odot$ yr^{-1}; Devereux et. al. 1995; Lin et. al. 2003; Gordon et. al. 2004).

From observations of the M81 outer disk as part of the HST ACS Nearby Galaxy Survey Treasury (ANGST), Gogarten et al (2008) derive the recent star formation histories of two ~0.5 kpc-sized areas with HII regions in the Northern tidal arm. They conclude that the HII regions were forming stars 10-16 Myr ago, possibly more recently, and experienced an increase in star formation rate during that time to $\sim1.5\times10^{-3}$ $M_\odot$ yr^{-1}.

The Burrell-Schmidt image of M81 shown in Fig. 1 is a section of a larger 1.5 degree field additionally encompassing M82 and NGC3077. We will extend the search for HII regions into this area. We also have additional ARC 3.5-meter emission line images for more fields. In addition, we have spectroscopic data from the MMT for several of these HII regions for abundances determinations. This will allow us to compare the abundances in the HII regions in the disk with those in the outer spiral arms not clearly associated with dwarf galaxies, and with those in HoIX and K61 to further study the recent suggestion by Croxall et al. (2009) that these two galaxies differ from normal dwarfs in that they lie well off the metallicity-luminosity relation suggesting their likely tidal origin.

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