FULL TITLE
*ASP Conference Series, Vol. **VOLUME**, **YEAR OF PUBLICATION***
NAMES OF EDITORS

The Spitzer View of M101: Preliminary Results

Karl D. Gordon, George Rieke, Charles Engelbracht, Robert Kennicutt, Joannah Hinz, Pablo Pérez-González, Karl Misselt, and J.D.T. Smith

Steward Observatory, Univ. of Arizona, Tucson, AZ 85721

Abstract. New Spitzer images of M101 from 3.5 to 160 μm are presented. Preliminary analysis focusing on the dependence of the infrared spectral energy distribution of HII regions as a function of metallicity finds that the mid-infrared PAH features become weak or absent between metallicities of 8.5 and 8.1. There is also a trend towards hotter dust temperature as metallicity decreases.

M101 is a large ($> 30'$diameter), face-on spiral galaxy at a distance of 6.7 kpc (Freedman et al. 2001). It has one of the largest metallicity gradients known with metallicities [log(O/H) + 12] ranging from $\sim$9.2 in the nucleus to 7.5 in an HII region 41 kpc from the center (Zaritsky et al. 1994; van Zee et al. 1998; Kennicutt et al. 2003). This large apparent size, numerous HII regions, and large metallicity gradient makes M101 the ideal galaxy for studying the dependence of the physics of star formation as a function of metallicity. Past studies of M101 in the infrared have concentrated on radial gradients as the spatial resolution was not high enough to study all but the few brightest HII regions (eg. Hippelein et al. 1996; Popescu et al. 2005).

Sufficient infrared spatial resolution and sensitivity to study bright and faint HII regions in M101 is now possible with the launch of the Spitzer Space Telescope (Spitzer, Werner et al. 2004). Our program utilizes the imaging and spectroscopic capabilities of Spitzer to study the metallicity dependence of the spectral energy distributions (SEDs) in M101 HII regions. Spitzer imaging of M101 has been obtained with the Infrared Array Camera (IRAC, Fazio et al. 2004) at 3.6, 4.5, 5.8, 8.0 μm and with the Multiband Imaging Photometry for Spitzer (MIPS, Rieke et al. 2004) at 24, 70, and 160 μm. In addition, targeted spectroscopic observations of a handful of HII regions are planned with the InfraRed Spectrograph (IRS, Houck et al. 2004). Preliminary results from the IRAC and MIPS images are presented here. A more detailed analysis of the Spitzer images is given in Gordon et al. (2005).

This study M101 HII regions is complimentary to the Spitzer program on starburst galaxies as a function of metallicity lead by Charles Engelbracht (Engelbracht et al. 2005a,b).

Images

The IRAC and MIPS images of M101 are shown in Fig. 1. The reduction of the IRAC images was done with SSC pipeline S9.5.0 and the mosaicking was done with MOPEX v101504. The 5.8 μm images suffered from poor dark subtraction and flat fielding (which will be corrected in the future with S11 reductions)

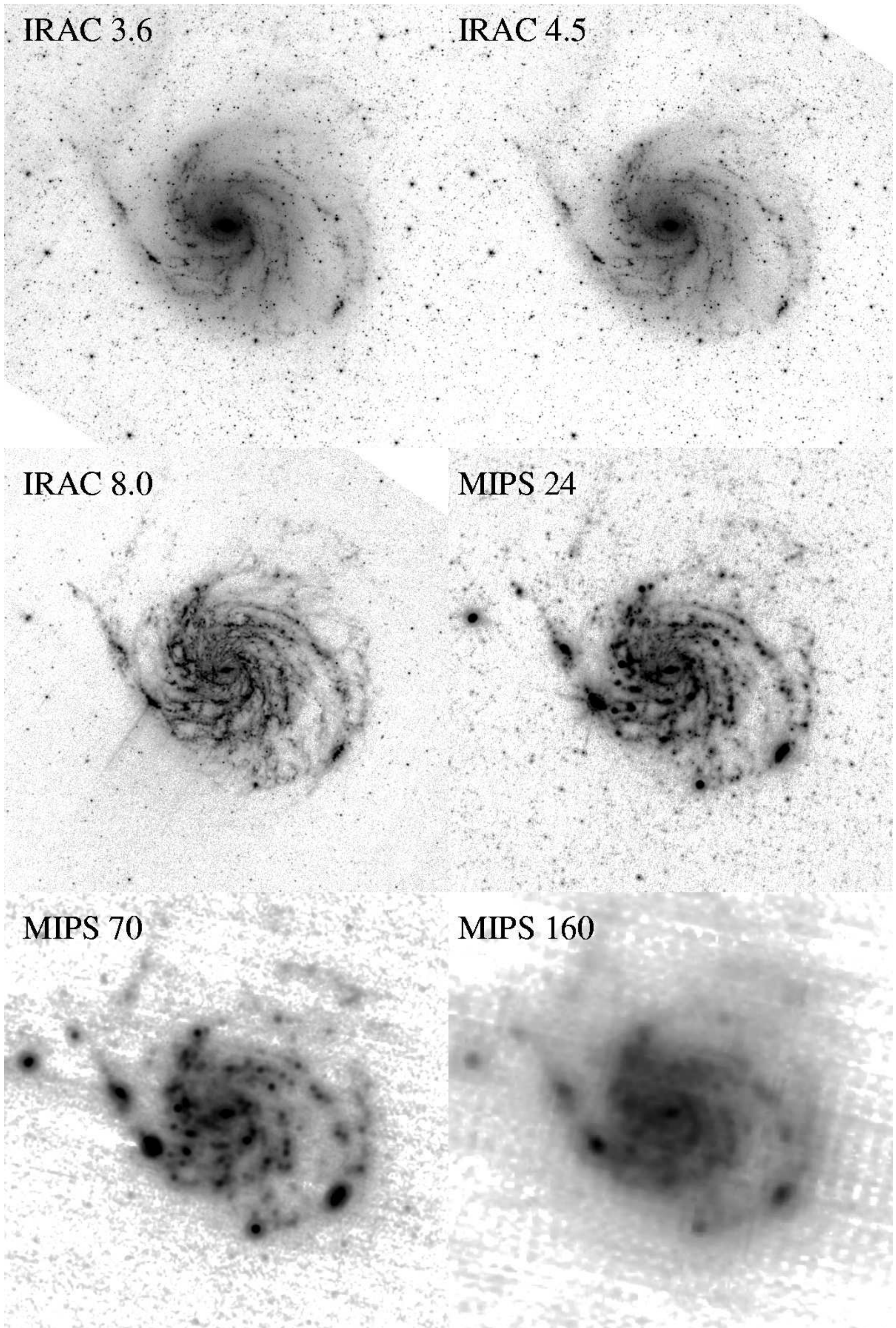

Figure 1. Spitzer IRAC and MIPS images of M101 are shown for a region $25' \times 25'$.

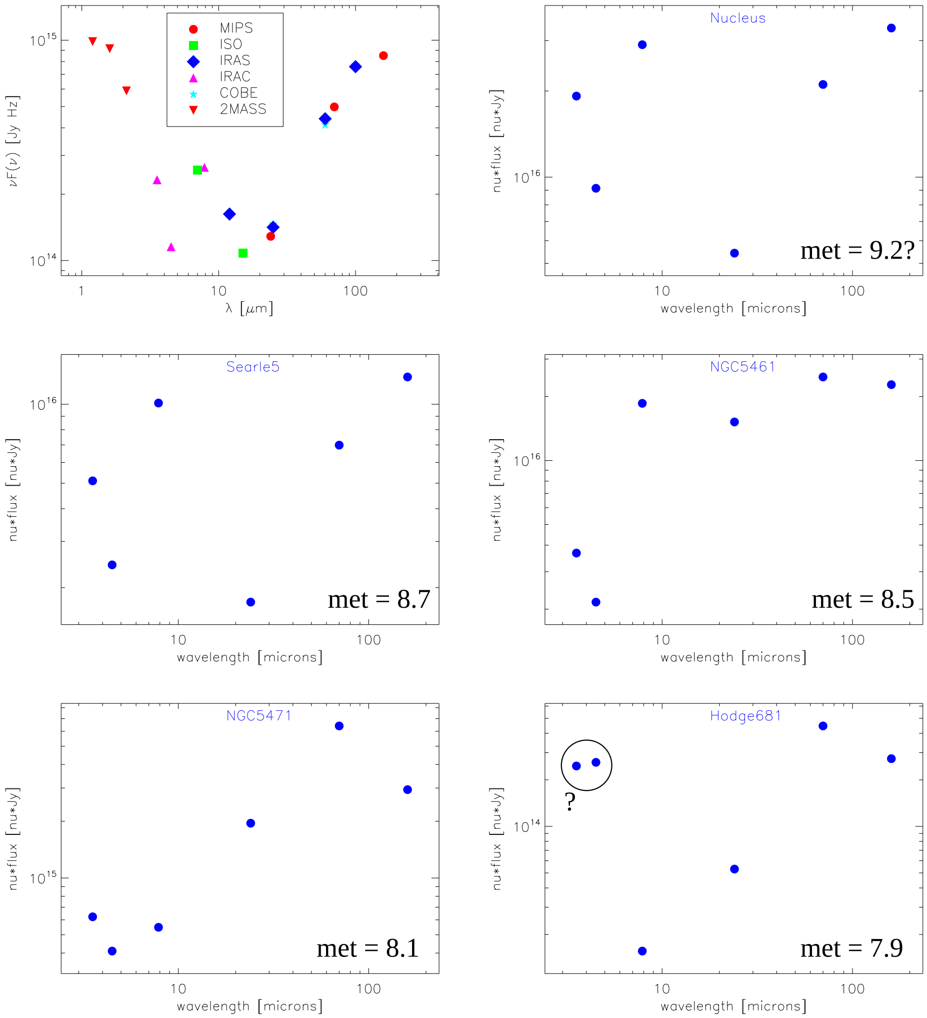

Figure 2. SEDs of M101, the nucleus, and selected HII regions. The literature data for 2MASS are from Jarrett et al. (2003), IRAS are from Rice et al. (1988), COBE are from Odenwald et al. (1998), and ISO from Roussel et al. (2001).

and so was not considered for this preliminary analysis. The reduction of the MIPS images was done with the MIPS Instrument Team Data Analysis Tool (DAT, Gordon et al. 2005) with additional processing steps to remove detector transients and sky background. In addition to numerous compact sources, diffuse emission is detected in all bands.

Spectral Energy Distributions

The infrared spectral energy distribution (SED) of M101 is shown in the upper left panel of Fig. 2. The global SED exhibits a stellar continuum ($\lambda < 5$ μm), PAH emission ($5 < \lambda < 15$ μm), and thermal emission ($\lambda > 15$ μm). The IRAC and MIPS photometry match well with previous measurements which exhibits the superb calibration of Spitzer.

Infrared SEDs of 5 HII regions selected to span the range of metallicities seen in M101 are also shown in Fig. 2. These SEDs were determined from the IRAC and MIPS images after convolving them all to the MIPS 160 μm resolution (FWHM $\sim 40''$) using custom convolution kernels (Engelbracht et al. 2004) to ensure that the same physical regions were probed at each wavelength. Fluxes in each band were determined using apertures with diameters of $100''$ with a single background for each image subtracted determined far from the galaxy. Determining local backgrounds was not possible at 160 μm resolution.

The clear signature of PAH features in the global SED of M101 is seen in some, but not all of SEDs of the HII regions. While it is not possible to say if the PAH features are truly absent from NGC 5471 or Hodge 681 without spectra, it is clear from the SEDs that the PAH features are much weaker in these HII regions than in Searle 5, NGC 5461, or the nucleus. The change in PAH feature strength seems to happen between metallicities of 8.5 and 8.1 which is consistent with the recent results in starburst galaxies (Engelbracht et al. 2005a). This change in the PAH feature strength can also be clearly seen in the ratio image of IRAC 8 μm/MIPS 24 μmfor all HII regions beyond a radius corresponding to this transition metallicity.

In addition, the peak of the IR SEDs shifts to shorter wavelengths as metallicity decreases. Thus, the dust temperatures near low metallicity HII regions are hotter than those with higher metallicities.

Acknowledgments. We thank the entire Spitzer Team for their extraordinary efforts to design, build, and fly such a superb telescope.

References

Engelbracht, C. W., et al. 2004, ApJS, 154, 248
—. 2005a, ApJ, submitted
—. 2005b, ASP Conf. Ser., this book
Fazio, G. G., et al. 2004, ApJS, 154, 10
Freedman, W. L., et al. 2001, ApJ, 553, 47
Gordon, K. D., et al. 2005, ApJ, in prep.
Gordon, K. D., et al. 2005, PASP, in press
Hippelein, H., et al. 1996, A&A, 315, L82
Houck, J. R., et al. 2004, ApJS, 154, 18
Jarrett, T. H., et al. 2003, AJ, 125, 525
Kennicutt, R. C., Bresolin, F., & Garnett, D. R. 2003, ApJ, 591, 801
Odenwald, S., Newmark, J., & Smoot, G. 1998, ApJ, 500, 554
Popescu, C. C., et al. 2005, ApJ, 619, L75
Rice, W., et al. 1988, ApJS, 68, 91
Rieke, G. H., et al. 2004, ApJS, 154, 25
Roussel, H., et al. 2001, A&A, 369, 473
van Zee, L., et al. 1998, AJ, 116, 2805
Werner, M. W., et al. 2004, ApJS, 154, 1
Zaritsky, D., Kennicutt, R. C., & Huchra, J. P. 1994, ApJ, 420, 87