ABSTRACT

We are conducting a study over nine regions of high-mass star formation and prominent photo-dissociation regions (PDR's) to investigate their content and structure. The observations include Spitzer/IRAC and IRS observations, ground-based optical and NIR imaging, and optical spectra of objects and locations in the molecular clouds. The objective of the study is to have a better understanding of the processes involved in high mass star formation by determining the characteristics of the stars detected in these regions, by studying the massive young stars, their interaction with the surrounding interstellar medium (ISM) and investigating the properties of the ISM in which these stars form.

We present our first Spitzer, ground-based optical and NIR imaging data on 3 of our regions; AFGL4029, AFGL437 and S255, and optical spectra for AFGL4029. From the data shown we will determine the properties of the constituent stars using 1-8 um infrared spectral energy distributions. Also we will use the spectral types of stars and spatial distribution of Class 0 and I objects to investigate the evolutionary state of the regions.

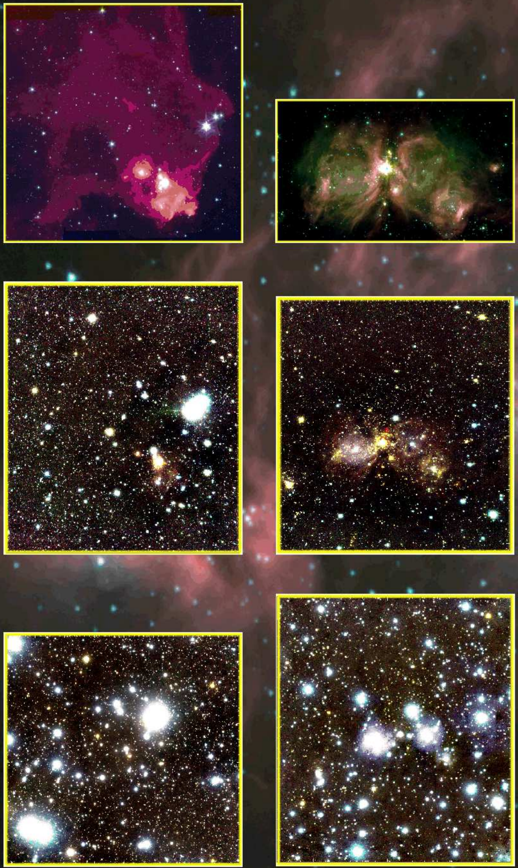

Figure 1. *Left;* AFGL437 (top) IRAC color image, where 3.6μm is blue, 4.5μm is green, and 8μm is red; (middle) NIR color image where J band is blue, H is green and K is red; (bottom) optical color image where R band is blue, I is green and z' is red. *Right;* The same for S255.

Figure 2. AFGL4029, (Left:) NIR color image where J band is blue, H is green and K is red; (Right:) optical color image where R band is blue, I is green and z' is red. For IRAC color image see the poster "Investigating the Properties of the Interstellar Medium Near Massive Star Forming Regions" (Hora J. et al.) in this Symposium.

DATA AND OBSERVATIONS

We selected 9 regions of massive star formation at distances between 2 and 3 kpc and angular sizes between 15' and 25' (Table 1). These regions were selected because: a) they have predominant Photo-dissociation Regions (PDRs) in a broad range of morphologies, b) they are located near to the Sun compared with the most of the massive star forming regions in the Galaxy.

Table 1. Source List

Name	α (J2000) hh:mm:ss	δ (J2000) dd:mm:ss	Distance (kpc)
AFGL4029	03:02:00.00	60:33:49.0	2.2
AFGL437	03:07:53.00	58:35:03.0	2.0
S235	05:41:00.00	35:48:04.0	1.8
S252	06:09:04.70	20:35:09.0	2.2
S255	06:12:46.00	18:00:38.0	2.4
S76	18:56:07.00	07:56:03.0	2.1
S87	19:46:17.00	24:39:03.3	2.1
S88	19:46:43.00	25:12:14.0	2.5
NGC7538	23:13:42.00	61:30:10.0	2.8

Our observations currently include four bands Spitzer/IRAC images (at 3.6, 4.5, 5.8 and 8.0 microns) for almost all our regions, ground-based optical I, R, z', and Hα bands (using Minicam mounted at 48 inch telescope in Mount Hopkins) and near-IR J, H and K bands (using Flamingos mounted at 2 meter telescope in Kitt Peak) imaging for our winter regions. Also we acquired optical spectra for AFGL4029 and S235 using Hectospec at MMT.

All the images were taken in dithering mode. To combine the images and create the final mosaics in each filter we implemented a routine which uses IRAF Geomap and Geotran tasks to correct field distortion and World Coordinate System Tools to obtain accurated ($\sim$ 0.1 arcsec) positions of the stars using 2MASS catalogue RA and DEC.

FIRST RESULTS

Figures 1 and 2 show the resulting mosaics for several of our regions after the first NIR and optical observations. Also, we include 3 color (3.6, 4.5 and 8.0 microns) IRAC mosaics. We detected in general more optical than NIR stars because the final size of the optical band mosaic is bigger than the size of the NIR mosaic. The number of stars detected in J,H and K bands in AFGL4029 with photometric error below 0.1 mag is $\sim$ 3600 compared with $\sim$ 2300 stars detected by 2MASS in the same field of view. We used standard stars to calibrate the magnitudes in the optical data and 2MASS stars to calibrate fluxes in NIR data.

Our research is most advanced for AFGL4029 (Figure 3). We used IRAC, optical and NIR photometry in order to select sources to be observed with Hectospec at MMT. First we selected all the stars which are classified as Young Stellar Objects (YSO) according to their IRAC colors (Allen et al 2004, Megeath et al 2004, Hartmann et al 2005 in press, Figure 4.) and which have an optical counterpart. Second, we selected stars which show reddening excess in the NIR + 4.5μm data and which have an optical counterpart. Finally we selected stars which are located in the path described by the stars already chosen in the optical color-magnitude diagram.

To determine spectral types we used an IRAF plus IDL code which classifies the spectra based on the intensity of several absorption lines like the Balmer series, He I and Fe I lines (Hernández, J. PhD Thesis 2005). In Figure 5 we show preliminary results of spectral types for AFGL4029. With the time allocated for these observations, we were just able to detect stars brighter than 19 mag in I band.

The upper part of Figure 5 shows the distribution of stars by spectral type in the I v/s R-I color-magnitude diagram. At the bottom we show the spatial ditribution of the same stars on the I band mosaic. At first glance, all the types are distributed uniformly over the field. We need deeper observations to obtain spectra of Class I and Class II objects (Fig. 4) with optical counterparts (90 % of these objects are faintness than 18 mag in I band).

REFERENCES

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We are in process of putting the stars with spectral types in the HR digram, and will estimate their ages and masses by comparison with pre-main sequence evolutionary tracks. We hope to extend the spectroscopic survey to lower masses in future observing runs with Hectospec. At time of writing, we are checking in more detail the spectral classifications in order to continue our progress on this region.

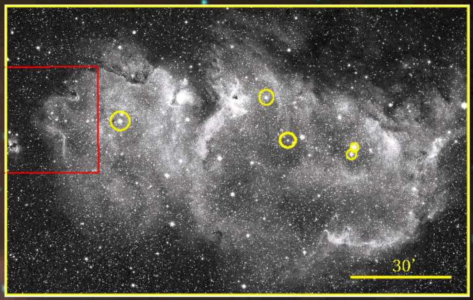

Figure 3. The W5 HII Region. AFGL 4029 is part of this region (the observed optical area is marked in red, to the left), which in total is more than 2 x 1 degrees in size. The ionizing stars are marked in yellow. The size- and timescales in this region are consistent with a triggered star formation scenario (Karr & Martin, 2003). We are currently obtaining optical spectra of stars in this region so that we can place them in the HR diagram and estimate their ages as a function of position. (Image from Digital Sky Survey).

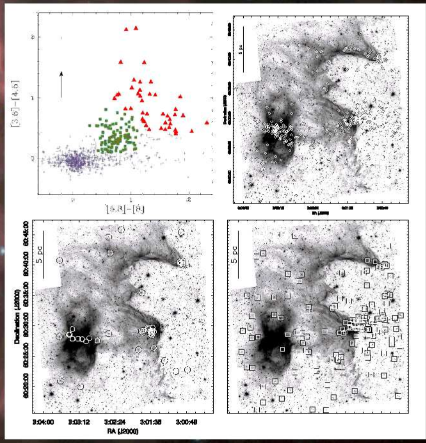

Figure 4. *Upper left:* IRAC color-color diagram for AFGL4029. Red triangles are Class I objects, green squares are Class II objects, the reddening vector is for 30 A_v (Indebetouw et al 2004). *Upper right:* Spatial distribution of stars with IR excess in the K-4.5μm v/s H-K diagram. *Lower:* Spatial distribution of Class I (left) and Class II (right) sources in AFGL4029.

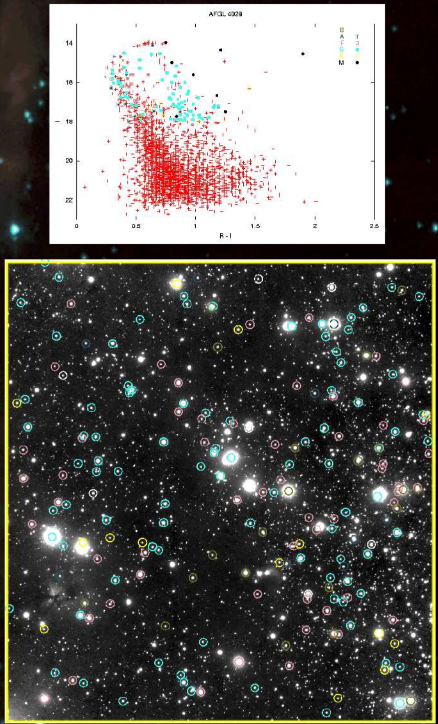

Figure 5. *Up:* Color-magnitude diagram for AFGL4029. We include all the stars with spectral classification separated by color. *Down:* Spatial distribution of stars with spectral classification on the I band mosaic in AFGL4029, the color indices are the same as the upper part except by M= class which is white.

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