A ROBOTIC WIDE–ANGLE H_α SURVEY OF THE SOUTHERN SKY

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We are conducting a wide-angle imaging survey of the southern sky at 656.3 nm wavelength, the H_α emission line of hydrogen. Each image of the survey covers an area of the sky 13° square at an angular resolution of approximately one arcminute, and reaches a sensitivity level of 0.5 Rayleigh (3×10^{-18} erg cm^{-2} s^{-1} arcsec^{-2}), corresponding to an emission measure of 1 cm^{-6} pc, and to a brightness temperature for microwave free-free emission of 3 μK at 30 GHz. The survey is being done with a CCD detector, a commercial camera lens, and narrow-band interference filters, mounted on a robotic telescope platform located at Cerro Tololo Inter-American Observatory in Chile. As of June 2000 the data-gathering phase of the survey was 96% complete, and publication is expected by early 2001.

SCIENTIFIC PURPOSE

This survey will produce detailed information on the structure of the diffuse, warm, ionized component of the interstellar medium, information necessary for understanding the dynamics and evolutionary history of the interstellar gas. Since the survey will cover the entire southern sky south of +10° declination, and reach a fainter intensity level than does any previous survey, we expect to discover several new structures, such as stellar wind bubbles, supernova remnants, bow shock nebulae, planetary nebula shells, and other interesting objects.

Even where H_α emission is not seen, the images will be scientifically useful. The intensity of the microwave free-free emission from Galactic hydrogen is directly proportional to the brightness at H_α. The production of both kinds of emission results from the interaction of a proton with an electron, in the one case leading to a transition to another unbound energy state with emission of a microwave photon, and in the other case leading to recombination at a high energy level, followed by a cascade down through the third and second energy levels with emission of an H_α photon. The ratio of intensities of the free-free and H_α emission thus depends primarily on quantum-mechanical factors, with only a slight dependence on temperature and no dependence on density (Bennett *et al.*, 1992). Thus, these images will allow accurate measurement of anisotropies in the Galactic free-free emission at microwave wavelengths (or proof that these are negligible), emission which must be subtracted from satellite or ground-based measurements to obtain the true cosmic background fluctuations. For example, in an early pilot study for this project (Gaustad *et al.*, 1996) we showed that no more than 7% of the 44 μK anisotropy in the CMBR measured in the Saskatoon experiment (Netterfield *et al.*, 1995) could be due to contamination by Galactic free-free emission.

INSTRUMENTATION AND OPERATIONS

The survey is being conducted from Cerro Tololo Inter-American Observatory (CTIO) near La Serena, Chile, located at longitude W 70°49′, latitude S 30°10′, and elevation 2200 m. The system is housed in a 10-foot dome (from Technical Innovations, Inc.) on a concrete pad located near the 1-meter telescope building at CTIO.

Our CCD camera, from SpectraSource, Inc., contains a 1024 × 1024 TI chip with 12-μm pixels. The sky is imaged onto the chip with a 52-mm f.l. Canon lens operated at f/1.6, yielding a field of view of 13°×13° and a scale of 48″/pixel.

The advantage of the small lens over a large telescope, of course, is the field of view. The CTIO 4-meter telescope has the focal length of 11.2 m compared to the 52-mm focal length of our camera lens, and thus has

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an angular scale 215 times smaller. It would take 46000 times longer to survey the sky to the same sensitivity with this large telescope (if operated at the same focal ratio and with the same CCD), although of course one would get much higher angular resolution. (The small size of the instrument and dome has caused the CTIO staff to give our instrument the nickname of El Enano–The Dwarf.)

A filter wheel mounted in front of the lens contains an H_α filter of 3-nm bandwidth and a dual-band notch filter, which excludes H_α but transmits two 6-nm bands of continuum radiation on either side of H_α. The filter wheel is encased in Styrofoam and maintained at a constant 25 C temperature to provide wavelength stability of the filters and to prevent condensation on the filters or the lens.

The camera is attached to a Byers Series 2 German mount with microstepping motors and Dynamics Research encoders on each axis. The pointing resolution is better than 0.25 arcseconds, and the accuracy is better than 5 arcseconds up to Z = 75 degrees. The unguided tracking accuracy is better than 2 arcseconds per hour. Thus, no external guider is needed.

Since the twilight sky is not uniform over our wide field of view, we have built a lightbox, for obtaining calibration flats, containing a translucent screen illuminated by incandescent light bulbs and by hydrogen emission lamps.

A Texas Weather Instruments weather station completes the system. Two PCs running scheduling and control programs written in Visual Basic under Windows 95 control the camera, mount, dome, weather station, and light box. Data is recorded on disk during operations, and later transferred to DAT tape.

One of the robot's computers positions of the telescope and dome while the other operates the camera, schedules the observations, and runs the ftp and e-mail communication links. A log of the night's operations and sample images are sent to the PI at Swarthmore each morning via e-mail and ftp, but the full data set is recorded on disk and then transferred to magnetic tape during the day. We can inquire of the status of the robot via e-mail, and make changes in the program or observing schedule via ftp. But we do not operate the camera in real time – it is a true robot. The robot has its own weather station and will not attempt observations if humidity or wind conditions exceed safe limits, but as an extra precaution it also asks permission (via e-mail) of the 4-meter telescope operator before opening the dome. The operator can also close the dome via e-mail command. The only other human intervention, during normal operations, is for weekly tape-changing and preventive maintenance.

OBSERVATIONS AND DATA REDUCTION

All observations are taken after twilight and with the moon below the horizon. A normal set of scientific observations consists of five 20-minute exposures through the H_α filter interspersed among six 5-minute exposures through the dual-band continuum filter. Between observations of each science field, we take a few exposures pointed at the pole to obtain data on changes in extinction during the night. We also take occasional short exposures of bright standard objects for intensity calibration. Biases, darks, and flats are taken during twilight at the beginning and end of each night.

Reduction of the calibration exposures is done on site automatically, but all science images are shipped to Swarthmore on tape for later processing. The H_α and continuum images are aligned and coadded separately. Then, after scaling to make the star images the same brightness, the continuum image is subtracted from the H_α image, divided by the transmission function for the H_α filter, and smoothed to remove residual stars. In Figure 1, images of the Orion region are shown as an example of the process.

SURVEY STATUS

The survey consists of 283 fields covering the sky from $-90°$ to $+15°$ declination, with the same centers as those in the IRAS Sky Survey Atlas. In order to reduce the noise and to confirm objects discovered at the faintest brightness levels, we repeat all fields with 5° offsets. As of June 2000, we had completed 96% of the survey. A mosaic consisting of all images obtained so far is shown in Figure 2. When the data are fully processed, the survey will be made available to the scientific community on the web and on CD-ROM. We expect the data-gathering phase of the project to be finished towards the end of 2000, and the survey to be published in early 2001.

PRELIMINARY RESULTS

Images of the Large Magellanic Cloud have already been published (Gaustad *et al.*, 1999). Several other preliminary results have also been obtained. For example, some cirrus dust clouds show a rim of ionized hydrogen on the side towards the Galactic plane (McCullough *et al.*, 1999). A filamentary bubble just north of the Gum Nebula may be a new supernova remnant (McCullough *et al.*, 2000). Planetary nebulae often have the extended ionized regions surrounding their bright cores (Hall, 1999). Abell 36, for example, has an ionized halo 5° in diameter, formed by ultraviolet photons escaping through its optically thin shell (McCullough *et al.*, 2000).

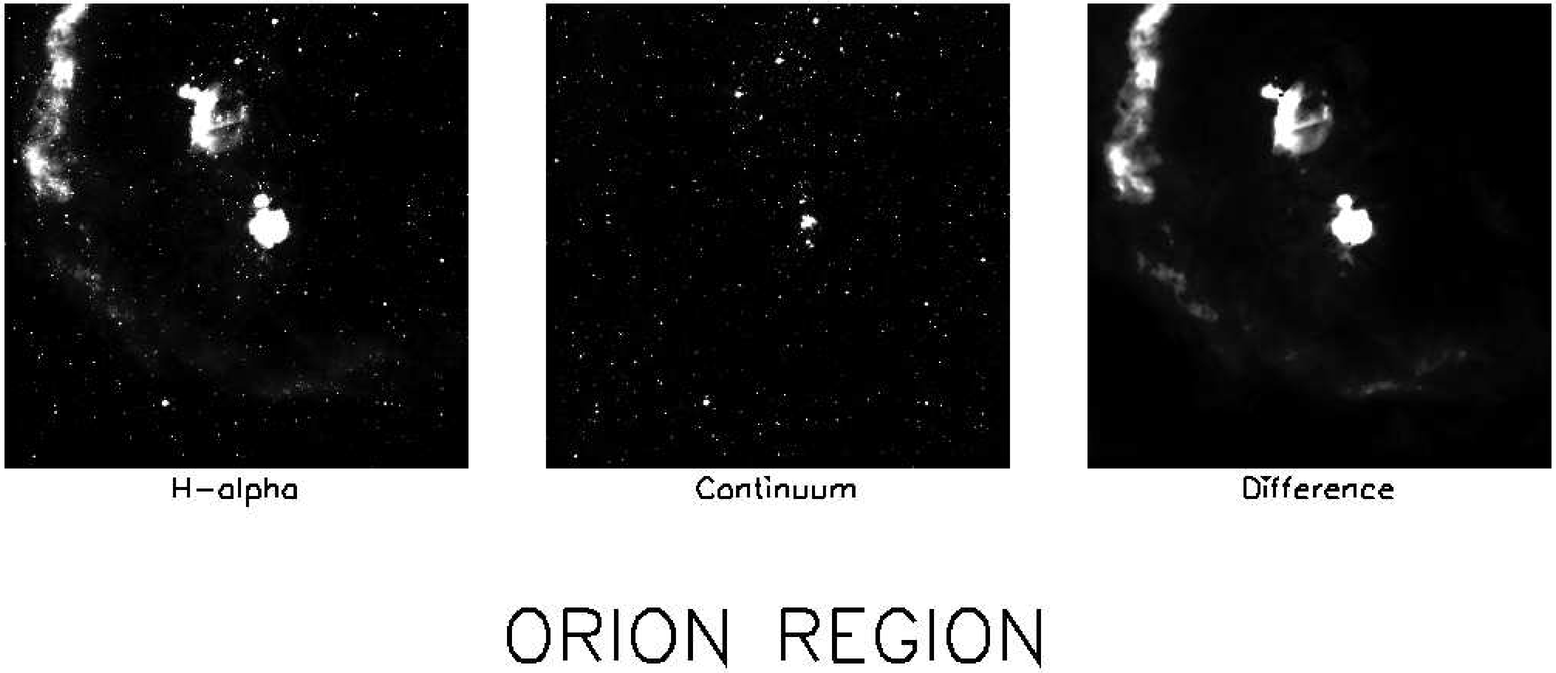

Figure 1: Three images of the southern region of Orion, showing Barnard's Loop and the Orion Nebula:
left – taken through the H_α filter, showing both stars and nebulosity;
center – taken through the continuum filter, showing only the stars;
right – the difference of the two images, showing only the nebulosity

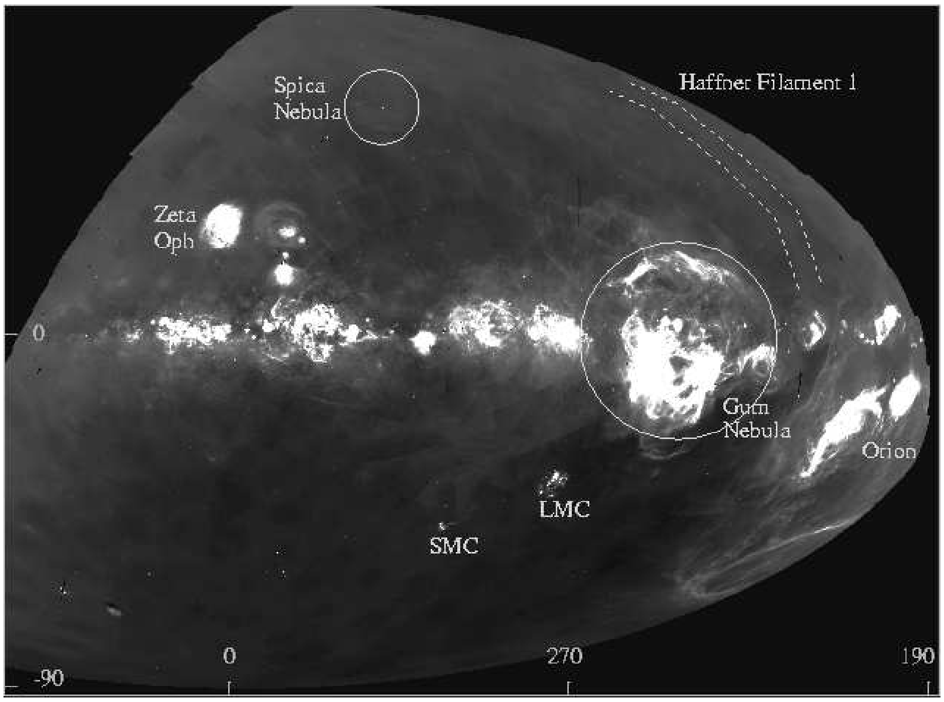

Figure 2: A mosaic of the southern sky in H_α

ASTRONOMY IN UKRAINE

What does this project have to do with the theme of this conference? Nothing, really, other than that the fact that the data have been gathered in Chile, analyzed in the United States, and reported in Ukraine shows that astronomy does not recognize national boundaries. Astronomy in Ukraine is Astronomy in the World. We invite Ukranian astronomers, and in fact all astronomers, to make use of our survey once it is complete, and the data are fully reduced, calibrated, and published.

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