Introduction

We present the first all-sky, kinematic survey of Hα from the Milky Way, combining survey observations taken with the Wisconsin H-Alpha Mapper (WHAM) from Kitt Peak (1997–2007) and Cerro Tololo (2009–present). The WHAM Sky Survey (WHAM-SS) is the first and perhaps only all-sky WHAM survey. It is designed primarily to study the large-scale distribution and kinematics of ionized gas in the Milky Way, combining survey observations taken with the Wisconsin H-Alpha Mapper (WHAM) from Kitt Peak (1997–2007) and Cerro Tololo Inter-American Observatory (CTIO) to complete the Milky Way survey and begin study of ionized gas throughout the Magellanic System (e.g., Barger et al. 2013; Smart et al. 2016).

WHAM-SS data is obtained in “blocks” of 30–33 one-degree pointings organized into a roughly 7° × 7° grid. Tracing full sampling for full sky coverage in a tractable span of time (≈2 years), we use a beam spacing of Δv = 0.85, Δl = 0.89 × cos l. In each direction, WHAM integrates for 30 s capturing a spectrum approximately 100 km s⁻¹ × 100 km s⁻¹ around Hα. Geocoronal Hα emission distinct in all but the brightest Galactic regions provides a consistent, absolute velocity reference. Measurements are calibrated by frequent observations of standard nebular targets, which not only track instrumental performance, but also measure atmospheric transmission from night to night.

Apart from the geocorona, faint (f < 0.1 R) atmospheric emissions line are present throughout the 200 km s⁻¹ window (Hausen et al. 2002b). In most directions above |b| > 20°, accurate removal of these lines is essential to recover Galactic internuclear and trace structures in the faint background. Haffner et al. (2003) details the procedure we followed for the Northern Sky Survey to clean and calibrate that data. The pattern of faint lines around Hα is the same at CTIO, allowing us to use the same methods to subtract atmospheric lines from the southern portion of the survey.

We attempt to observe blocks at a time of the year that gives us the best chance to extract accurate Galactic emission. In particular, we try to (1) maximize the separation between the geocorona and expected Galactic emission, particularly near 124° = 0 km s⁻¹; (2) minimize the zenith distance of the observation; and, for directions near the ecliptic plane, (3) maximize the angular distance of the target from the sun. This final requirement helps to minimize the level of background contamination by zodiacal light, which adds the Hα Fraunhofer absorption line to the spectrum and complicates data reduction. These survey requirements lead to an LSR velocity range that varies with position and observing date, as evident in Figure 3. With some Galactic emission missed by a single pass of WHAM’s 200 km s⁻¹ coverage, we are beginning observations to extend the survey range to at least ±150 km s⁻¹. The extent of the emission in the first and fourth quadrants (1 ≤ |b| ≤ 90°, 0° ≤ l ≤ 270°) has been surprising and particularly impressive. In some directions, WHAM is tracing diffuse ionized gas structures beyond the solar circle with distances approaching 10–12 kpc.

The Hα Sky Survey

The wealth of spectral information contained in the WHAM-SS is only touched on by Figure 1 (above). A full integration map that highlights structure to emission well below 3 R. In Figure 3 (at right), four slices of the velocity-longitude plane at specific Galactic latitudes are shown. Intensities are logarithmically scaled to highlight structure to emission well below 1 R. In Figure 3, only touched on by Figure 1 (above), a full integration map that adds the Hα line of sight to the spectrum and complicates data reduction. These survey requirements lead to an LSR velocity range that varies with position and observing date, as evident in Figure 3. With some Galactic emission missed by a single pass of WHAM’s 200 km s⁻¹ coverage, we are beginning observations to extend the survey range to at least ±150 km s⁻¹. The extent of the emission in the first and fourth quadrants (1 ≤ |b| ≤ 90°, 0° ≤ l ≤ 270°) has been surprising and particularly impressive. In some directions, WHAM is tracing diffuse ionized gas structures beyond the solar circle with distances approaching 10–12 kpc.

Observations

To fully map the extent and kinematics of the WIM, we designed and built a dedicated instrument that excels in observations of faint, diffuse optical emission. WHAM (Figure 2) consists of a steerable siderostat with a 0.6-m primary lens coupled to a 15-cm, dual-etalon Fabry-Perot spectrometer. This optical configuration (R = 30,000) delivers a spatially integrated spectrum from a one-degree beam on the sky covering 200 km s⁻¹ around the Local Standard of Rest (LSR) with 12 km s⁻¹ spectral resolution. Aside from many large-scale, locally-ionized regions, much of this emission arises from the diffuse, thick WIM and extends several kiloparsecs into the Galactic halo with a kinematic signature that traces the gaseous spiral arms of the Galaxy.

First detected through the absorption of diffuse, low-frequency radio synchrotron emission commonly used to study warm, dense, “classical” H II regions, WHAM integrates for 30 s capturing a spectrum approxi- mately 100 km s⁻¹ × 100 km s⁻¹ around Hα. Geocoronal Hα emission distinct in all but the brightest Galactic regions provides a consistent, absolute velocity reference. Measurements are calibrated by frequent observations of standard nebular targets, which not only track instrumental performance, but also measure atmospheric transmission from night to night.

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The Hα Sky Survey

The wealth of spectral information contained in the WHAM-SS is only touched on by Figure 1 (above), a full integration map that highlights structure to emission well below 3 R. In Figure 3 (at right), four slices of the velocity-longitude plane at specific Galactic latitudes are shown. Intensities are logarithmically scaled to show the full extent of detected emission. The oscillation of the intensity-weighted center of each column around 0 km s⁻¹ as a function of longitude is the imprint of Galactic rotation on distant (f > 1 kpc) gas components and traces spiral arms. A component at

References


Acknowledgments

The observations presented in this paper were taken with the Wisconsin H-Alpha Mapper (WHAM) at the Kitt Peak National Observatory, the Cerro Tololo Inter-American Observatory, and the La Silla Observatory in Chile. The observations presented in this paper were taken with the Wisconsin H-Alpha Mapper (WHAM) at the Kitt Peak National Observatory, the Cerro Tololo Inter-American Observatory, and the La Silla Observatory in Chile.