The Wisconsin H-Alpha Mapper Northern Sky Survey
Data Use Documentation
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1. Introduction

The Wisconsin H-Alpha Mapper Northern Sky Survey (WHAM-NSS) is available for public download at http://www.astro.wisc.edu/wham/. WHAM was built and has been supported through funds from the National Science Foundation since 1992. Use of the data is free to all researchers; however, we ask that you attempt to properly attribute all use of this data. As of the writing of this document, the formal survey paper is still being written, but may be referenced for now as:

Haffner, L. M., Reynolds, R. J., Tufte, S. L., et al., in preparation

We also request that you insert a line in your acknowledgments to the effect of:

The Wisconsin H-Alpha Mapper is funded by the National Science Foundation.

Until the final documentation is ready, preliminary information about WHAM and the survey can be found in:

Reynolds, Tufte, Haffner, Jaehnig, & Percival. 1998, Publ. Astron. Soc. Aust., 15, 14
Tufte, 1998. PhD Thesis, University of Wisconsin
Haffner, 1999. PhD Thesis, University of Wisconsin

Please check back at this site for future reference information, especially before you submit your work for publication. We hope to submit the survey paper early in 2002.

The WHAM-NSS consists of 37565 spectra taken around Hα (-100 km s$^{-1} \lesssim v_{\rm LSR} \lesssim +100$ km s^{-1}) on a grid with approximately 1° resolution. The northern survey covers the sky down to $\delta = -30°$. More technical details are provided in the sections below.

2. Data Format

The data is available from our website in several formats. A velocity integrated (-80 km s^{-1} $< v_{\rm LSR} < +80$ km s^{-1}) version of the survey is available as an ASCII table, FITS binary table, and IDL save file. The full kinematic survey is available only as a FITS binary table and IDL save file. We are not providing FITS images or cubes at this time due to the regular-grid interpolation required to provide such a format. Our data were taken on an irregular grid optimized for large sky coverage over a short observing time. We instead wish to present the reduced data in its most unadulterated form.

All intensity units are given in Rayleighs. 1 R $= 10^6/4\pi$ photons cm^{-2} s^{-1} ster^{-1} $= 2.4 \times 10^{-7}$ ergs cm^{-2} s^{-1} ster^{-1}; 1 R ≈ 2.25 pc cm^{-6} at $T = 8,000$ K.

2.1. Integrated Survey

Each of the integrated survey distributions contains a short `README` with a summary of the column contents. The following data are included:

GAL-LON: The Galactic longitude of the pointing in degrees.

GAL-LAT: The Galactic latitude of the pointing in degrees.

INTEN: The Hα intensity of the pointing over the integration range -80 km s^{-1} $< v_{\rm LSR} < +80$ km s^{-1}. Note that in certain directions, especially those toward the inner Galaxy at low Galactic latitudes, this range does not fully include all Galactic emission. This uniform range was chosen to avoid arbitrary bias and to give a fairly accurate representation of the relative intensity over the whole sky. Nearly all pointings contain at least this velocity range (see §3.1 below). Units are Rayleighs.

ERROR: The calculated error in the Hα intensity. This value is simply derived from the measured error in each contributing spectral data point. No additional error is included due to systematic or calibration uncertainties. If this field is zero, this pointing is potentially contaminated by a bright star and the original intensity of this pointing has been replaced with and average of nearby neighbors. The original intensity is provided in the OINTEN field for reference. About 10% of the pointings are contaminated.

BLOCK: Most WHAM survey data is collected in groups of 30–50 spectra called a "block". Within each block, each consecutive pointing exposure is only one degree away from the last, minimizing large changes in the background from spectrum to spectrum. Each block has been numbered and is provided here to help aid in discriminating between real Galactic features and residual systematic effects that we are unable to remove. These effects are typically quite faint, near the 0.1 R level. More details can be found in §3.3

OINTEN: WHAM observations are contaminated by stars in the one-degree beam brighter than about 6th magnitude. For the integrated survey release, we have replaced the INTEN value for these pointings by an average of nearby neighbors. The original integrated intensity is provided here as a reference.

Various pre-generated Hα sky maps are also provided on our website in a variety of graphic formats and projection centers.

2.2. Kinematic Survey

The kinematic survey represents the full WHAM-NSS product and is as close to pure Galactic emission profiles as we can provide. The fields from the integrated survey are also provided in this release as a convenience. The data provided are:

GAL-LON: The Galactic longitude of the pointing in degrees.

GAL-LAT: The Galactic latitude of the pointing in degrees.

VELOCITY: The velocity vector of this pointing in km s^{-1}.

DATA: The Hα intensity vector of this pointing in R (km s^{-1})$^{-1}$.

VARIANCE: The variance vector of this pointing in (R (km s^{-1})$^{-1}$)^2.

BLOCK: See the description of BLOCK in §2.1 above.

POINTING: The individual pointing index within this block. See the description of BLOCK in §2.1 above.

VLSR: The deviation of the Local Standard of Rest from geocentric zero velocity in km s^{-1}. This value is exact for the time and direction of this observation. This field is provided to allow location of the geocoronal Hα line that has been removed from the spectrum. In the LSR velocity frame provided by the VELOCITY vector, the geocoronal line is centered at ($-$VLSR – 2.33) km s^{-1}. See §3.3 for more details.

ZDIST: The zenith distance of the observation. Atmospheric intensity corrections have been applied already.

ODATE: The UT date of the observation in standard FITS format: DD/MM/YY.

OTIME: The UT time of the observation in decimal hours.

INTEN: The total Hα intensity as calculated for the integrated survey (see §2.1 above).

ERROR: The total intensity error as calculated for the integrated survey (see §2.1 above).

STAR: Whether or not a star was determined to contaminate this spectrum. Unlike the integrated release, no modification has been made to the spectral vectors above. This field is provided as a reference to denote which pointings we have changed for the integrated release. As in the integrated release, the INTEN, ERROR, and OINTEN fields are changed.

OINTEN: The original intensity of the pointing if a star contaminated the field (see §2.1 above).

3. Notes

Full information about our reduction procedures and issues with the data will be presented in a forthcoming survey paper. In the meantime, we provide some tidbits below to be aware of when working with WHAM data.

3.1. Velocity

WHAM spectra are velocity calibrated by our fits to the geocoronal Hα line present in each observation. These fits result in a velocity registration better than 1 km s^{-1}. As it is excited primarily by solar Lyβ and does not contain the full assortment of recombination cascade components, the geocoronal Hα line is offset 2.33 km s^{-1} to the blue of the geocentric Hα zero-point. This offset as well as a correction for the standard solar motion ($v = 20.0$ km s^{-1} toward $\alpha_{1900} = 18\overset{\mathrm{h}}{.}0$, $\delta_{1900} = +30\overset{\mathrm{d}}{.}0$; contained in the VLSR field above) are used to translate the velocity frame to the LSR.

WHAM survey data is taken with the spectrometer velocity range fixed in only two geocentric positions (depending on the sign of VLSR). This decision was made to allow us to characterize and subtract atmospheric lines, the major source of contamination in our spectra, as accurately as possible. As a result, the actual LSR velocity range (i.e., the endpoints of the VELOCITY vector) of pointings varies. For this reason, the integrated release employs the slightly limited range of ± 80 km s^{-1}. We chose this option rather than integrating each pointing fully over its 202 km s^{-1} velocity vector.

In addition, there is a second order component to the velocity dispersion in WHAM spectra. Thus, data points are not spaced equally in velocity space. Δv between data points in a spectrum ranges from 1.988 at the red end to 2.059 at the blue end (an approximately 3.5% change). The effect is small, but one should be aware of this when combining or subtracting spectra with large differences in velocity ranges where high precision is desired.

3.2. Intensity

The WHAM intensity calibration is based on a Fabry-Perot calibration of the North American Nebula made by F. Scherb (1981, ApJ, 243, 644). An estimated correction has been made for the difference in the beam between the instrument used for the calibration and WHAM ($50'$vs. $60'$). However, we intend to repeat these calibration measurements with WHAM during the next year. Preliminary comparison of WHAM survey data with radio (Heiles, C. 2000, ApJ, 536, 335) and optical data (Gaustad, J., et al. 2001, PASP, 113, 132) suggest that our calculated intensity calibration is very good. We conservatively estimate a systematic error of $\pm 10\%$ in our absolute calibration at this time.

Atmospheric extinction curves were calculated for each night where multiple nebular calibration observations were available. An empirically determined, seasonally varying transmission was applied to nights where insufficient data was available. The average transmission at Kitt Peak during the survey was computed to be 0.924.

Two very minor corrections have also been applied. Slow degradation of the transmission of the optical coatings was also detected over the duration of the survey and a correction has been applied to account for the effect. Finally, a small correction has been applied based on the Fabry-Perot tune used during an observation. Th seems to be related to whether a narrow (i.e., geocorona) or broad (i.e., nebular) line source was used to tune the spectrometer prior to science observations. Since galactic emission is broad, tuning on a narrow source seems to result in slightly reduced efficiency, most likely due to small spatial variations in the spacing of the etalon gap over the field.

3.3. Atmospheric Lines

Atmospheric lines are the most significant source of uncertainty in our reduced Galactic emission profiles. In addition to the bright (2–13 R) geocoronal Hα line, numerous fainter (30–150 mR) lines span the entire spectral range. These lines are dense enough that no true 'flat' continuum is seen in our spectra at our spectral resolution (10–12 km s^{-1}). Through the work of N. Hausen, et al. (2002, ApJ, in press) these lines have been characterized allowing an atmospheric template to be created that aids in removing these features from our spectra.

Each observational block of pointings was combined to form a high signal-to-noise (1500 s) spectrum. For each of these block sums, the atmospheric template was fit by hand to provide the best match to the faint features. The parameters from this fit are then used to subtract the template from each of the original observations.

The geocoronal line, although noticeably variable among our short exposure observations (30 s), is well characterized by a single Gaussian at our spectral resolution and is easily fit and removed from all but the brightest Galactic profiles. The VLSR parameter can be used to locate the location where the line was removed. This area will have slightly higher noise due to the higher signal that was originally there.

3.4. Zodiacal Light

As somewhat of a surprise to us, but as a testament to WHAM's power at detecting faint features, many spectra taken near the beginning or end of the night show evidence for a zodiacal absorption feature near Hα. Although observations were only taken with the moon down and after astronomical twilight, a residual absorption feature is present after subtracting the geocoronal line from these observations. Most of the feature is hidden by the geocoronal Hα line and is removed with that line in our subtraction procedure. However, a wing of absorption that remains and is present only on the blue or red side of the geocoronal line depending on the look direction of the observation (due to solar system rotation of the zodiacal dust along the line of sight).

Work by G. Madsen in our group determined that the strength and location of the absorption in a spectrum correlated quite well with ecliptic direction and measured distributions of zodiacal light. He derived a synthetic absorption profile whose strength was based on this distribution and the direction of an observation. This profile was then subtracted from each spectrum. The method does not remove all the absorption in all cases, but it does significantly reduce some of the systematic residuals (≈ 0.1 R) that were present in our maps.

4. FAQ

Coming soon...