INTERSTELLAR MATTER AT HIGH GALACTIC LATITUDES

H_α-EMISSION IN DIRECTIONS TOWARD HIGH VELOCITY 21cm CLOUDS

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Summary

Measurements of H_α-emission in fields known to emit 21cm radiation at intermediate and high velocities are presented. The observations are partial results of a survey being carried out at the Calar Alto Observatory with a dedicated Fabry-Perot spectrometer of 15cm aperture, providing velocity and angular resolutions of 11km s^{-1} and 0.5 deg^2. The limited material available indicates that the H_α-emission, when detected at a radial velocity nearly the same as that measured in 21cm, appears more extended in the sky than the HI-radiation.

1. Introduction

The presence of extended galactic H_α-emission, from almost all over the entire sky, has become known through the pioneering observations carried out with the 2-etalon PEPSIOS spectrometer of the University of Wisconsin (Reynolds, Roesler and Scherb, 1974 and 1977; Reynolds, 1980, 1981 and 1983). The H_α intensities measured by Reynolds (1984) in 9 fields with galactic latitude $|b|>45°$ are very low, corresponding to emission rates 0.5<ER<1.7R (1R = 1 Rayleigh = 2.47(-7) $erg.cm^{-2}s^{-1}sr^{-1}$ at H_α), but imply an average hydrogen recombination rate of 2 to $7x10^6$ s^{-1} per cm^2 of the galactic disk, large enough to raise an important unsolved problem in regard to the nature of the ionization agents. The small number of sample fields in the Reynolds (1984) survey, chosen in directions to known pulsars, clearly cannot provide information about the porosity of the H_α emitting medium or about its likely geometrical relation to the 21cm features. In order to answer such questions and provide theoreticians with an idea of how unrealistic their modeling of the thermal phases of the interstellar medium may be (Shull, 1987), many thousands of observing hours with large thruput spectrometers, such as PEPSIOS and field widened Michelsons, will be required. In consideration of the fact that at present only the Wisconsin PEPSIOS is operational, under non-optimal conditions of atmospheric transparency, we undertook the construction of a spectrometer similar to PEPSIOS, to be used at the Calar Alto Observatory.

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In this communication we shall present, in a condensed form, some results of our H_α measurements in fields where 21cm line emission at intermediate and high velocities has been mapped. Although our survey is far from completed, it suffices to show that, at least in some cases, there exists a positional and kinematical correspondance between the HI and HII distributions.

2. Instrumentation

The essential difference between our instrument and the PEPSIOS is that the high resolution master etalon of 15cm aperture, manufactured by Queensgate Instruments Ltd., is piezoelectrically scanned and servo-controlled for plate parallelism. The etalon gap was chosen to deliver a resolving power of 30,000 and can be varied as to provide a continuous scan range of 850km s^{-1}, around a manually set nominal zero. As it will become apparent below, such a large scan range is of great value to fix the background "continuum" against which the faint galactic emission lines have to be discriminated. The off-order suppressing slave etalon, also piezoelectrically scanned and controlled for parallelism, has an aperture of only 50mm and, correspondingly, it has been lens coupled to the master with a gap ratio 1:8.12. The field stop, generally chosen to be 0°8 in diameter, is placed at the intermediate focus between etalons, while the interference prefilter, of FWHM=15A, is located in the parallel beam entering the slave etalon. The price we have paid for the high reproducibility and stability in plate parallelism provided by the piezoelectric system, is a relatively low finesse (no more than 14), due to imperfect dielectric coatings and master flats deformation at the feet of the cemented piezoelectric transducers. The effective resolution, nevertheless, is near 11km s^{-1}, as it can be seen in Fig. 1 by the profile of the Th I 6554 line from a hollow cathode discharge.

The instrument has a vertical optical axis and is enclosed in a 6m long sea-going container, admitting sky-light from a polar siderostat through a trap side door. Light and heat tight partitions separate the spectrometer from the "room" containing observer, control electronics and system microcomputer. We use Ga:As photomultipliers as detectors for the scanned signal and for a co-aligned fixed wide band signal from the sky, which serves only as monitor of sky conditions.

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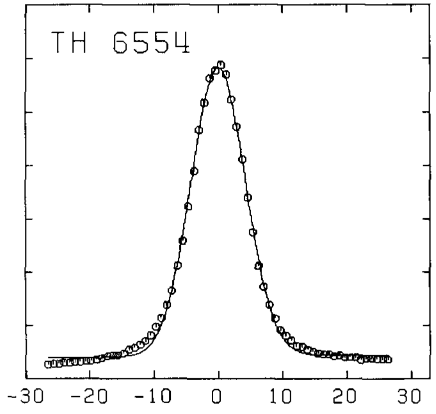

Fig. 1. Intensity profile of the Th I 6554.15A line with abscissae in km s^{-1}. The Gaussian fit drawn as a continuous curve, with a dispersion of 4.23km s^{-1} fits well the core of the line. At distances from line centre $|\Delta V|>10$km s^{-1} the extended wings of the 2-fold Airy profile become apparent. The slight slope of the baseline is due to curvature in the pre-filter transmission.

3. **Procedures**

The main difficulty encountered in the measurement of galactic H_α-lines with emission rates ER at the 1R level arises from the presence of the much stronger geocoronal H_α (GCH_α) and of its first order ghosts shifted $\pm$ 136km s^{-1}, which the slave etalon suppresses only to an intensity of 4.8% with respect to the parent. The airglow OH lines P_1(3)6553.66 and P_2(4)6568.78 of the (6,1) band, only partially suppressed by the pre-filter and slave etalon, also have ghosts in the range of interest. By choosing a master spectral free range of 136km s^{-1} we managed to place the ghosts of those OH lines near the H_α ones, in such a way that relatively extended spectral ranges became available for the search for faint galactic H_α features.

The dependence on time and position in the sky of the GCH_α and the OH line intensities severely constrains the time available to scan a chosen range with a S/N-ratio sufficient to allow recognition of faint galactic emission. Even under optimum "photometric" conditions of atmospheric transparency, it is impossible with a single beam instrument to "subtract" completely from a scan the night sky features by comparison with another scan not obtained simultaneously on a neighbouring field. On the basis of these considerations, as a general strategy in our survey for faint galactic H_α emission with shifts $|\Delta V|<100$ km s^{-1}, we have set a limit of 30 minutes for the duration of one scan, sampling a range not larger than 300km s^{-1} with about 50 points. The implied 30sec integration time per sample provides then $S/N\approx20$, due to photon arrival statistics for a single sample in the "continuum" of a typical scan at $|b|>30°$. A line with height above the continuum equal to the r.m.s. PM- dark noise of $2s^{-1}$ can then still be recognised in a 3σ-sense.

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4. **Results**

a) *OYM 190, a cloud at intermediate latitude*

As an example of a fairly strong displaced galactic H_α emission we show in Fig. 2a the spectrum of the 21cm cloud OYM190 of Meng and Krauss (1970) with V_{LSR}=-50km s^{-1}, which happens to be near the star HD215733 (l=85°.2, b=-36°.4), long known (Münch and Zirin, 1961) to show 4 interstellar CaII components with LSR shifts of -57, -44, -26 and -11km s^{-1}. The H_α spectrum of Fig. 2a is a coaddition of 2 scans obtained in the same night, to which 3 Gaussians with free parameters have been fitted. The subtraction from Fig. 2a of the Gauss fitted GCH_α and of its ghost, taken with fixed height, position and dispersion, respect to the parent, gives the spectrum of Fig. 2b. While "removing" the GCH at V_{LSR}=+15.7km s^{-1}, it is very likely that some of the low velocity galactic H_α has also been subtracted. The subtraction of the GCH_α ghost has also not removed the faint nearby OH ghosts. Nevertheless, the complex character of the residual galactic spectrum is apparent in Fig. 2b, which is confirmed by other scans secured at the same position. The Gaussian fit shown in Fig. 2b has two components with LSR peaks at -43.7 and -0.4km s^{-1} and FWHM-widths of 24 and 36km s^{-1}, respectively. Adopting as photometric standard an emission rate of 850R, as determined by Scherb (1981) and independently confirmed by our own measurements, we find for the two galactic components emission rates of 0.6 and 2.3 R.

The scans of Fig. 2 were obtained at the centroid of the OYM190 cloud as drawn by Meng and Krauss (1970). A few other scans secured beyond the 21cm boundaries definitely show galactic H_α extending to -60km s^{-1} and more, but somewhat weaker and with a different shape from those of Fig. 2. Pending a detailed comparison of the 21cm and H_α profiles within the OYM190 cloud and in its extended neighbourhood, however, the apparent enhancement of the -44km s^{-1} component in Fig. 2b cannot prove the side by side coexistence of the HI and HII emitting gases. In this regard it is of interest to remark that the high resolution 21cm profile obtained by Lockman, Hobbs and Shull (1986) at HD215733 shows a broad displaced component peaking at -47km s^{-1}, but weaker than and well separated from the near zero velocity component. The H_α profile we observe has a component at -44km s^{-1}, but it is not well separated from the nearby zero velocity component. We believe this is an effect not due to the smaller beam width (21 arcmin) of the 21cm profile or to the larger thermal width of the HII emission, but rather to the relatively greater extension of the ionized emitting volume.

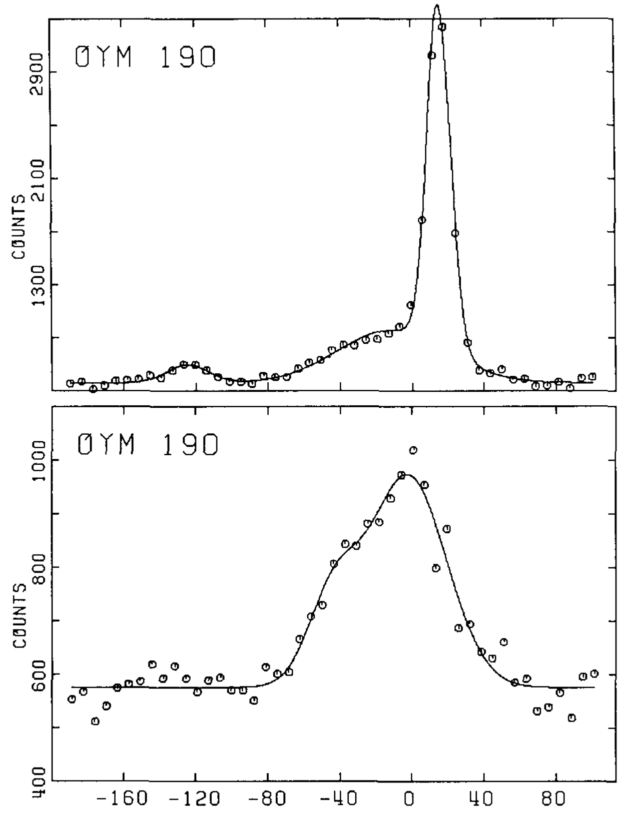

Fig. 2. H_α spectrum of the 21 cm cloud OYM190 (104°,-29°) from two scans, each with 30s integrations. Above (a) is shown the raw data fitted with 3 Gaussian components. Below (b) is shown the spectrum obtained upon subtracting from (a) the Gaussian fitted geocoronal H_α and its ghost, with a two component Gaussian fit for the residual galactic emission. Notice that the count scale below is x4 times greater than above.

b) *OMM360 and OLH393, high latitude clouds*

The OMM360 field of Meng and Krauss (1970), with V_{LSR}=-50km s^{-1}, attracted our attention because of its large extension in the sky and its neighbourhood to other closed contours in HI column density at similar "intermediate" velocity. One of such nearby clouds, OLM351 with V_{LSR} between -45 and -66km s^{-1}, covers completely the "high" velocity cloud OLH393 (185°, +65°) with V_{LSR}=-86km s^{-1}, also called MII by Hulsbosch (1986). It was thus thought that the detection in the OMM360 field of an H_α component at about -50km s^{-1} and at the position of OLH393 of components at -85 and -50km s^{-1} would by itself offer strong evidence for the close relationship between the HII and HII emitting gases. We have scans in 10 fields in and around the OMM360 complex, all of which unmistakably show galactic H_α in the range -60 to -40km s^{-1}. Shown in Fig. 3 is the average of two scans obtained on the brightest condensation (201°, +62°) appearing in the high resolution map of Giovanelli, Verschuur and Cramm (1972), after subtraction of the GCH_α and its ghost in the manner explained for Fig. 2. The residual galactic spectrum clearly shows evidence of complexity, again amply confirmed by many other scans. The Gaussian fit of 2 components, shown in Fig. 3, has peaks at -54 and -14km s^{-1}, widths of 26 and 34km s^{-1}, and emission rates of 0.35 and 0.85R, respectively. Spectra obtained in fields outside the 21cm boundaries of OMM360 and the other nearby clouds also show the shifted galactic H_α, somewhat but not much weaker than within. Especially, the western boundary of OMM360 in the map of Meng and Krauss (1970) appears at RA=$10^h 0^m$, Dec=+30°, but shifted galactic H_α begins to be noticeable in scans taken at $9^h 20^m$ and the same declination.

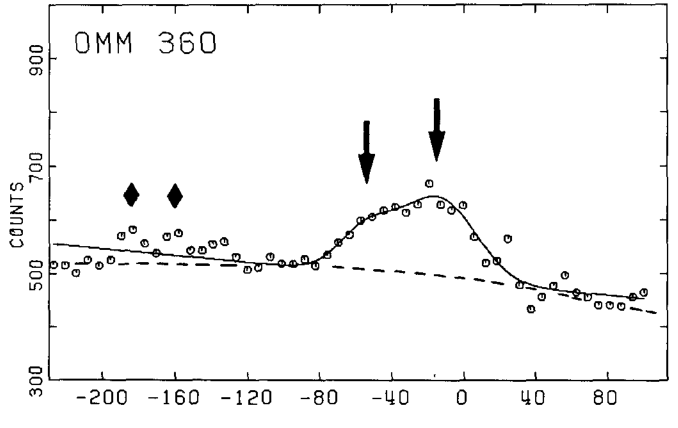

Fig. 3. Spectrum of the galactic H_α emission in OMM360 from two co-added scans, each with 30s integration time per sample. The geocorona H_α at 15.8km s^{-1} (LSR) and its ghost have been subtracted from the raw spectrum.

Unlike OMM360, the OLH393 or MII cloud is relatively compact and small (4°x8°) (Giovanelli, Verschuur and Cramm, 1972), although it probably belongs, together with MI=OMH425, to an elongated "chain" of clouds extending to the North East. Two spectra of OLH393, obtained in Jan. 1989 and Dec. 1988, each representing the coaddition of 2 single

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scans are shown in Fig. 4, a and b, with the GCH and ghost removed. The comparison of Fig. 4a with Fig. 3 immediately shows the existence of radiation in the range -80 to -40km s^{-1}, while hardly any can be seen around zero velocity. In the spectrum of Fig. 4b, obtained at larger zenith distance and angle from the antisolar point, the subtraction of the GCH_α has not been as complete as in Fig. 4a, but the existence of line emission in the same range can also be noticed. The shape of the emission feature, with a secondary minimum around -65km s^{-1} appears to be similar in the two spectra, suggesting the reality of two components, one at -80 and the other at -50km s^{-1}, which we ascribe to OLH393 and OLM351, respectively.

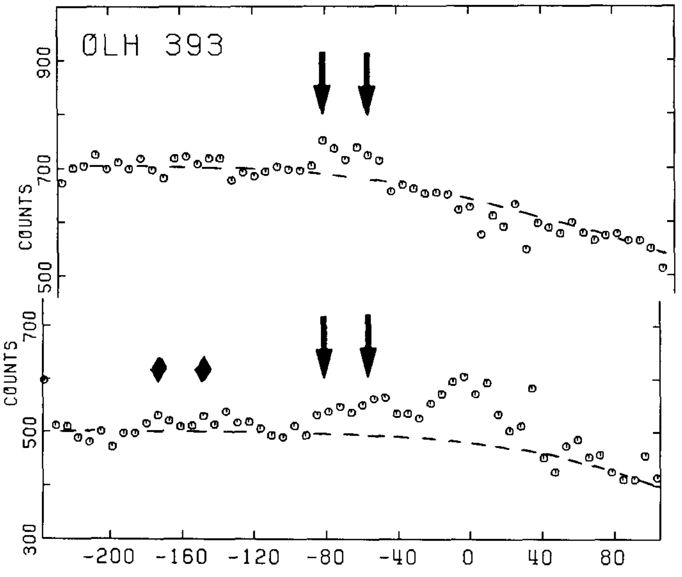

Fig. 4. Two spectra of OLH393, each obtained from the coaddition of 2 scans, with the geocoronal H_α and its ghost subtracted, and so aligned as to have common abscissae. Above is shown the spectrum (a) obtained in Jan. 89, while below appears the one (b) secured one month earlier. The baselines of the two spectra (dashes) are not identical because of differing contributions of atmospheric scattering (from stars, zodiacal light and artificial illumination). The emission peaks marked with a filled diamond in (b) are due to OH. The features highlighted by arrows are assigned to galactic H_α emission at LSR-velocities of -80 and -50km s^{-1}, to which correspond emission rates of 0.15 and 0.2R.

In this context we should mention that Reynolds (1987) has unsuccessfully searched for H_α associated with the cloud OMH323 (177°.0, +67°.0) with V_{LSR} (21cm)=-82km s^{-1}, to the North-East of and very close to OLH393. We do not yet have scans at OMH323, but we believe that the

S/N ratio of the scan shown by Reynolds (Fig. 1, 1987) would not suffice to detect a shifted galactic H_α as weak as that we see in OLH393.

Our selection of the two clouds OLH393 and OLM351 for study was to some extent conditioned by the presence of the 09V type star HD93521 (183°2, 62°2) just at the 21cm boundaries of both clouds. The star has an interstellar CaII absorption component at -56km s^{-1} (Münch 1952) and the 21cm profile at the star also has a well defined broad component peaking at -55km s^{-1} (Lockman, Hobbs and Shull, 1986), with no significant signal around -80km s^{-1}. The few scans we have at the position of HD93521 show unmistakably signal of H_α radiation only around -50km s^{-1}. We believe the negative result found by Reynolds and Ogden (1982) for the same star must again be due to insufficient S/N. The conclusion to be drawn from the presence of a CaII absorption component at the velocity of the 21cm and Hα emissions is not profound or new, namely, that the height above the galactic plane of the absorbing/emitting mass is smaller than that (1800pc) of the star (Hobbs, Morgan and Ebert, 1982). Nevertheless, it serves as another indicator for the spatial association between the HI and HII gases.

5. **Concluding remarks**

The positional and kinematical correspondance between the H_α and 21cm emissions in the few clouds with V_{LSR}>-100km s^{-1} we have studied demonstrates the possibility of studying the interstellar gas at large heights above the galactic plane through H_α observations. On the basis of the observations available, we cannot draw general conclusions about the state of ionization, relative spatial distribution between HI and HII gas, etc. Rather, we can only draw a program for further studies. The experience we have gained in regard to the observing time and S/N needed to gather reliable information about line emission with ER<0.2R leads us to estimate that in two years of observations at most we could survey the Galactic Polar caps with about 200 samples, quite insufficient for a complete coverage. The need for other dedicated installations, especially in the Southern Hemisphere, to participate in an extensive survey seems to us obviously urgent. The recent announcement by Kutyrev and Reynolds (1989) of the H_α detection in a -300km s^{-1} 21cm cloud in Cetus, also speaks for the important results waiting to be gained by an enlarged group of observers.

The possibility of improving the instrumentation is also open. Most valuable would be to build an instrument with two (or more) independent beams, mounted equatorially, which could be achieved with piezoelectrically servoed etalons.

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Discussion:

DANLY: I would like to comment that although your Ca components in HD93521 are seen only out to -55 kms^{-1} the more sensitive ultraviolet absorption lines extended all the way to -80 kms^{-1}. Perhaps the gas giving rise to emission at -80 kms^{-1} has too small a column density to be seen in CaII, but is nonetheless present in front of the star, as seen in CII ot SiII, for example.

MŬNCH: You are quite right. As I said, the absence of a high velocity line in absorption does not necessarity imply that the star is nearest to us than the cloud, because of the small "filling factor" or porosity of the material in CaII. The gas in CII and SiII, however, may have less porosity as the ionization potencials for C and Si are higher than of Ca.

COURTES: The reason of the difficulty to obtain an optical identification of the HVCs is likely due to the fact that the structure of the emission clouds is mainly filamentary (as it is in the diffuse Hα emission of M33 for example, 6 m telescope observations (Courtes et al. 1987). The large aperture etalon technics integrates structures that are maybe hundred times brighter than the mean background, killing the lest hope of contrast. The best should be to use the same interference technics but with a high resolution imagery permited by the new CCD detectors and, of course a minimum sized telescope.

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MÜNCH: The surface brightness I am meaning - say, 0.1 Rayleigh - are at least one order of magnitude lower than those you can reach with imaging techniques at small pixel size because of the solid angle factor which can not be gained back by "binning" n pixels because while doing so you increase the r.m.s. readout noise as $\sqrt{n}$. For the low level of detection we have to pay the price of low angular resolution, for a given etalon size. An increase in collecting area indeed would bring higher angular resolution, which could be achieved by using a mosaic of parallel servo-controlled etalons, say 6 to 8 of them, each with 10 cm diameter mounted in front of a fast all reflecting steerable "light bucket" with ~40 to 50 cm aperture.