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16. Abstract:

We report on progress made with IUE observations of stars located in the Galactic halo and either inside or near the 3 kpc spiral arm. These observations were obtained to study the absorption due to highly ionized interstellar halo gas. The observations were reduced and combined with previous ones to produce high signal-to-noise spectra. The interstellar lines were converted into optical depth profiles and compared to model predictions. It was apparent that the analysis of individual program stars was incapable of achieving our science goals, so we developed a method to analyze all of the program stars, plus supplementary data, simultaneously. We have made considerable progress along these lines, and preliminary results are presented.

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Final Report

Title: A Survey of Interstellar Gas Inside the 3 Kpc Arm

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Our objective was to determine the nature of the halo gas inside the region of the 3 kpc spiral arm. Previous work had suggested that its motion was anomalous, so we proposed to obtain higher quality data for stars suspected to be in the region. We obtained spectra of our program objects and reduced them. In most cases, this involved combining the new data with existing spectra in order to increase the signal-to-noise.

Profiles for the program stars were compared to synthetic ones produced by a computer model of the Galactic halo. This model has been employed by Savage, Massa and Sembach (1990), and Sembach, Savage and Massa (1991), to analyze a few kinematically interesting lines of sight using similar, high quality IUE observations obtained by adding several spectra taken at different locations in the IUE large aperture to reduce the effects of fixed pattern noise. The interstellar absorption profiles were converted into "Tau plots". These are derived by taking the log of the residual intensity of the line profile and they can be compared directly to the predictions of a model for the kinematic and density structure of the absorbing gas along the line of sight. The details of the models are given in the papers cited above. In fact, it was these two papers which suggested that gas in the halo decouples from disk gas near a Galactic altitude of 1 kpc, instigating the current study.

It soon became apparent that we were not going to be able to achieve our science goals from the results of any one program star, so we had to come up with a means to incorporate all of the observational data, fitting several lines of sight simultaneously in an unbiased manner. Therefore, the problem had to be recast into a form which could be tested via a χ^2 statistic. Thus, we constructed a computer routine which allows us to analyse all of the data at once. The input to the program is a set of parameters which express the density of the gas, the RMS velocity dispersion of the gas, and the rotation of the gas about the Galactic center as arbitrary functions of the distance above the Galactic plane and Galactocentric radius. We also input the distance to the program star, its Galactic coordinates, and the observed properties of the absorption (rest wavelengths and f values are also needed). The output of this portion of the program is the optical depth of the gas as a function of line of sight velocity. This is used to produce an absorption line which is then convolved with the IUE high resolution spread function. This represents an observed profile. The model can be used to fit the observed profiles directly, or to extract simple measurements such as the equivalent

width of the profile and its half intensity velocities. These quantities can then be compared to the observed values.

Currently, the comparison between the model and observed parameters is weighted by a combination of the expected measurement uncertainties and the uncertainties in the observed quantities which result from the expected error in the distance to the star. The latter effect can be quit large for certain lines of sight, overwhelming the simple measurement errors. We are currently also looking into weighting schemes which account for the fact that the absorption probably occurs in discrete entities, or "clouds".

We treat each line from a given ion separately, since each represents an independent set of observations. For example, if both components of the C IV λ1550 doublet can be measured, this gives us two independent measurements for the given line of sight, and we take full advantage of the difference in f values (this is very much like the advantage gained in curve of growth analyses).

The program is designed to produce a χ^2 statistic from the weighted differences between the observed and model quantities squared. The parameters of the model are then adjusted so that this statistic can be minimized using the amoeba simplex algorithm.

Clearly, there is a wealth of parameters which can be chosen as variables, so we have begun with a very simple case, where we can determine whether the model results meet our expectations and, therefore, is working properly. Figure 1a shows the observed equivalent widths of C IV λλ1548, 1550 (this is for the Savage and Massa ,1987 sample of stars, supplemented by the new observations -- about two thirds of these had measurements for both components) versus those of a model in which the mid-plane density and scale height were optimized (corotation was assumed, and we adopted an RMS velocity dispersion of 26 km/s for the gas, in accordance with Jenkins 1978 results). Figure 1b shows similar results for a static model, in which a constant velocity dispersion of 26 km/s was used. The effects of Galactic rotation on the fits is clearly apparent. The RMS dispersion for the two models are 0.21 and 0.29 dex for the dynamic and static models respectively. The former is close to the expected measurement error, ~50% or 0.18 dex, while the latter represents an error nearly twice this large.

The parameters derived from the optimization scheme differ significantly from those derived by Savage and Massa (1987) from essentially the same sample of stars. The Savage and Massa mid-plane density and scale height were 7.0E-9 cm^{-3} and 3.0 kpc, while the optimization scheme gives 1.02×10^{-8} and 5.62 for these same quantities. It is interesting that both are larger, and that they combine to produce a vertical column density of 1.8×10^{14} cm^{-2} as opposed to 6.5×10^{13} which results from the Savage and Massa parameters -- more than a 60% difference. In addition, the "dynamic" value is more closely in accord with the values deduced by Savage et al. (1990) and Sembach et al. (1991) from detailed profile fitting. Therefore, this increase may be typical of how analyses which ignore the inherently dynamic nature of the gas could systematically

underestimate its abundance.

To demonstrate that we have not exhausted the data with this simple model, Figure 2 shows a plot of the observed half intensity velocities versus those from the dynamic model. There is clearly unaccounted for structure present in the data and, hence, additional information can be extracted. Whether this can be accounted for by employing different density structures, such as a "transition region" near $|z| = 1$ kpc, or if it is necessary to invoke kinematical influences remains to be seen.

We are currently improving upon the preceding analysis. Now that we have tested the software on simple measures of the profiles and determined that additional information resides in the data, we are proceeding to modify the program so that it accepts detailed profiles as well as derived parameters. This should help constrain the models considerably.

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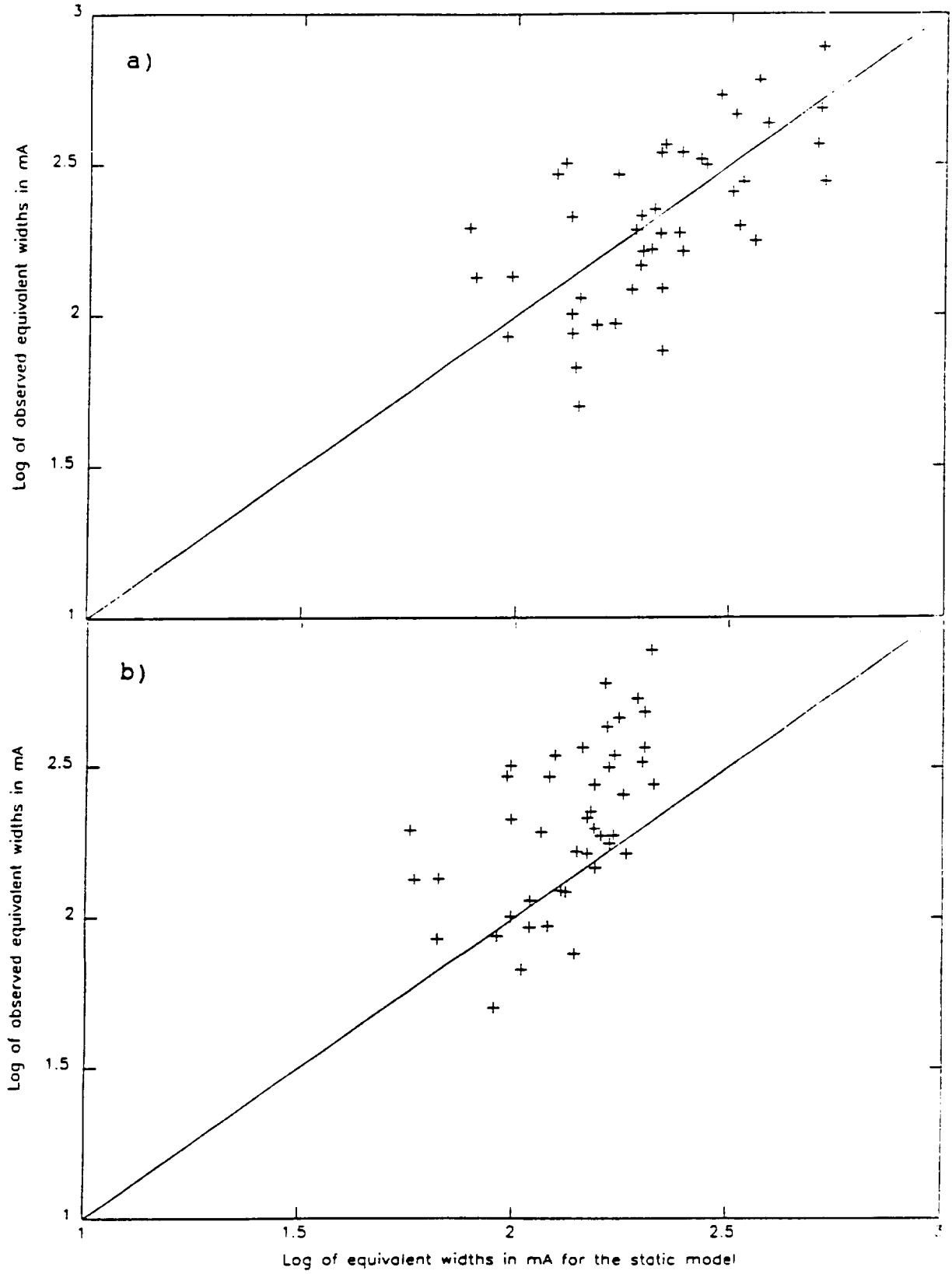

Figure 1. Log of the observed C IV equivalent widths in mA versus those derived from models. The line in each figure has a slope = 1 (all the points would lie on the line if the model were perfect). Figure 1a is the best fit for a model which includes Galactic rotation, assumes corotation in the halo, and has been optimized to determine the mid-plane density and scale height of the gas. Figure 1b shows the same data plotted against a model which ignores Galactic rotation.

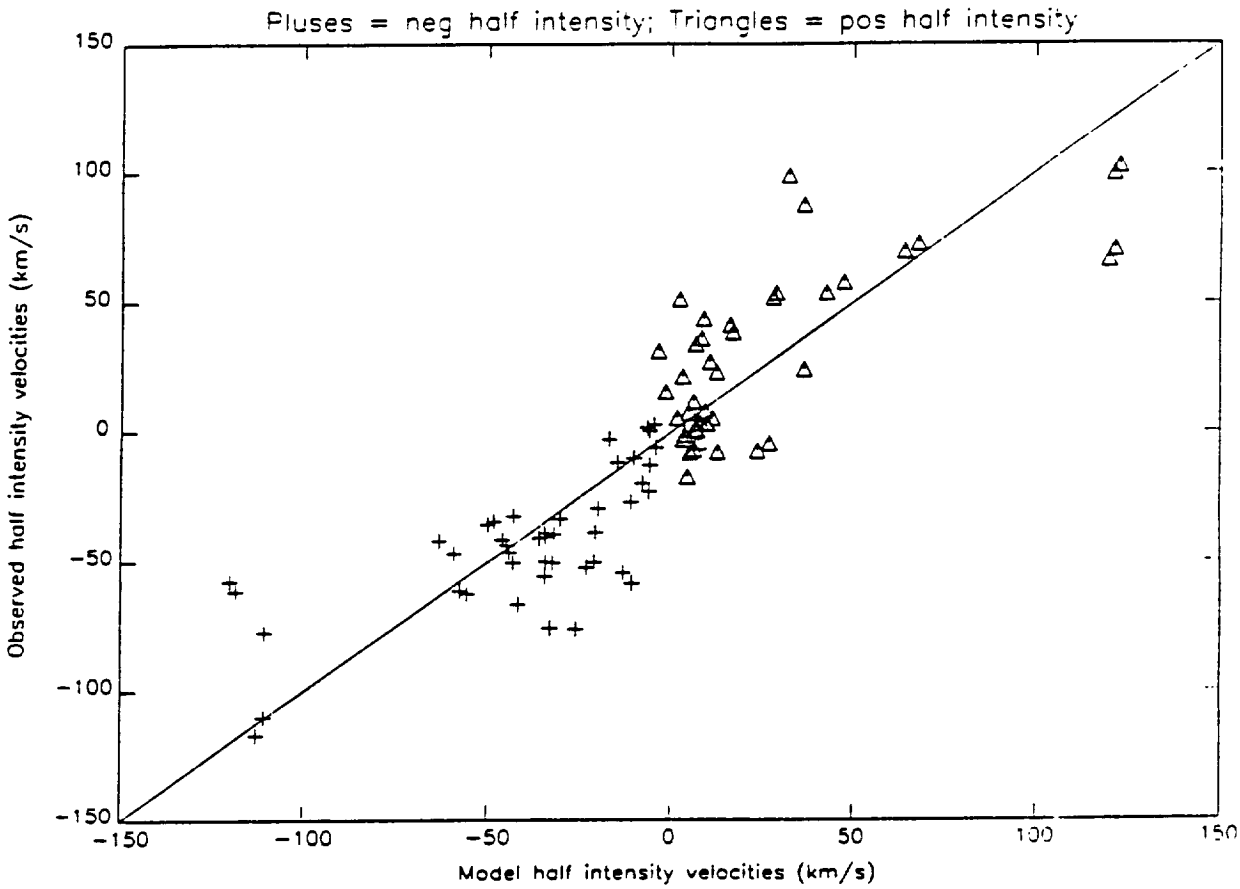

Figure 2. The observed C IV half intensity velocities versus those derived from a best fit model which includes Galactic rotation, assumes corotation in the halo, and has been optimized to determine the mid-plane density and scale height of the absorbing gas. The crosses and triangles represent the negative and positive half power points, respectively, and the line shown has slope = 1. Notice that the deviations about the line have a distinct "S-shaped" pattern which is unaccounted for by the simple model.