SOLAR WIND ACCELERATION FROM THE UPPER CHROMOSPHERE TO THE CORONA IN CORONAL HOLE REGIONS

NASA Grant NAG5-6183

Final Report

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Final Report on the Grant "Solar Wind Acceleration from the Upper Chromosphere to the Outer Corona in Coronal Hole Regions", NAG5-6183

1. Summary

1.1 Scope of the Investigation

The dynamic behavior of the plasma in the chromosphere/transition region /inner corona is vital for the acceleration of the solar wind. With new theoretical descriptions of the solar atmosphere and corona, and the increased observational possibilities provided by the SOHO spacecraft, it is possible to conduct an integrated study of the solar atmosphere and corona using observational and theoretical approaches.

Over the past few years a series of observational techniques have been used to estimate the solar wind densities, temperatures and flow speed in the inner corona. These estimates suggest that the solar wind has higher outflow speeds in the inner corona and lower densities than previously assumed. A comparison with densities derived from atmospheric models support these lower densities.

1.2 Progress Made During the Funding Period

We have carried out a number of supporting observations with SUMER and CDS. We have also carried out additional observations with UVCS and LASCO (covered by other grants) which were used to add to the constraints on the solar wind models. The CDS observations have been analyzed and been presented at several conferences. Several examples are shown in Figure 1.

Two sets of data are presented in the figure. The first is from a sequence of 5 repeats of the COHO22/v8 raster taken on the 23rd August, 1996, at the northern coronal hole. The COHO22 raster only takes selected lines in the CDS wave bands. Complete CDS spectra are obtained with the NISAT study which is run monthly on coronal hole regions as part of the CDS synoptic program. In the example the Mg VIII 315/317 ratio is used as density diagnostic. The solid lines represent the theoretical variations of that line ratio (from Chianti), the observed ratios, with 1-sigma error bars are plotted as squares (COHO22) and triangles (NISAT). Figure 1a is for a dilutive factor 0.0, Figure 1b for a dilutive factor of 0.43. One can clearly see that in the low density regime, it is vital to take into account the photoexcitation by the photospheric radiation field. This effect lowers the derived electron densities significantly. Using Si IX 349/345 line ratio measurements in addition, it can be shown that the coronal hole densities could be as low as 1.5 10^7 K, the typical quiet sun surrounding has densities almost one order of magnitude higher. Shown in Figure 1c is the differential emission distribution derived from the ion (Mg VII-X) line intensities of the COHO22 rasters. A single temperature does not fit the emission distribution, but it is clear from the figure that there is no plasma present at temperatures log T = 6.05. The weighted average temperature is T= 5.91.

The fact that a single temperature does not fit the emission measure indicates that different plasmas with different temperatures contribute along the line of sight to the observed emission measure. These plasmas differ most likely in other plasma parameters as well, such as flow speed and density. The emission in a given line depends on the flow speed since the maximum ionization shifts to higher temperatures for a plasma flowing in a temperature gradient. Figure 1d shows as an example the shift of the temperature for a number of Mg ions. At least in coronal holes it is expected that significant outflow exist, even close to the solar limb.

In regard to the connection between the models of the lower solar atmosphere and the solar wind models, we have made significant progress. Results for the model calculations show that we can match the observed spectra and He λ10830 line assuming an outflow starting at 1.2 10^4 K. We have also been able to connect the lower atmospheric models with the solar wind models. The link between the two codes shows that the atmospheric codes do not produce the densities at the upper chromosphere/transition region heights that are required by the solar wind expansion codes. As a result we studied a large number of different atmospheric models, steady state semi-empirical models, dynamical 1D and 3D models (Esser and Sasselov 1998). The range of densities allowed by these models without violating observed spectra is shown in Figure 2a. The highest density shown in the figure can be considered a rather firm upper limit on the electron density in that region of the atmosphere. Chosing other types of models would make the densities lower, not higher. The figure shows a comparison of the atmospheric densities with the densities typically derived from pB measurements in the corona. This comparison shows that the coronal densities seem to be too high compared to the ones allowed by the atmospheric models. The newer limits on coronal densities derived from newer SOHO observations (see above) seem to match the atmospheric densities significantly better, even though, a small discrepancy between the two sets of densities still remains. We continue to work on resolving this discrepancy. Coronal densities are extremely important in constraining solar wind outflow models, and the findings presented in the figure are now being used in our solar wind model studies.

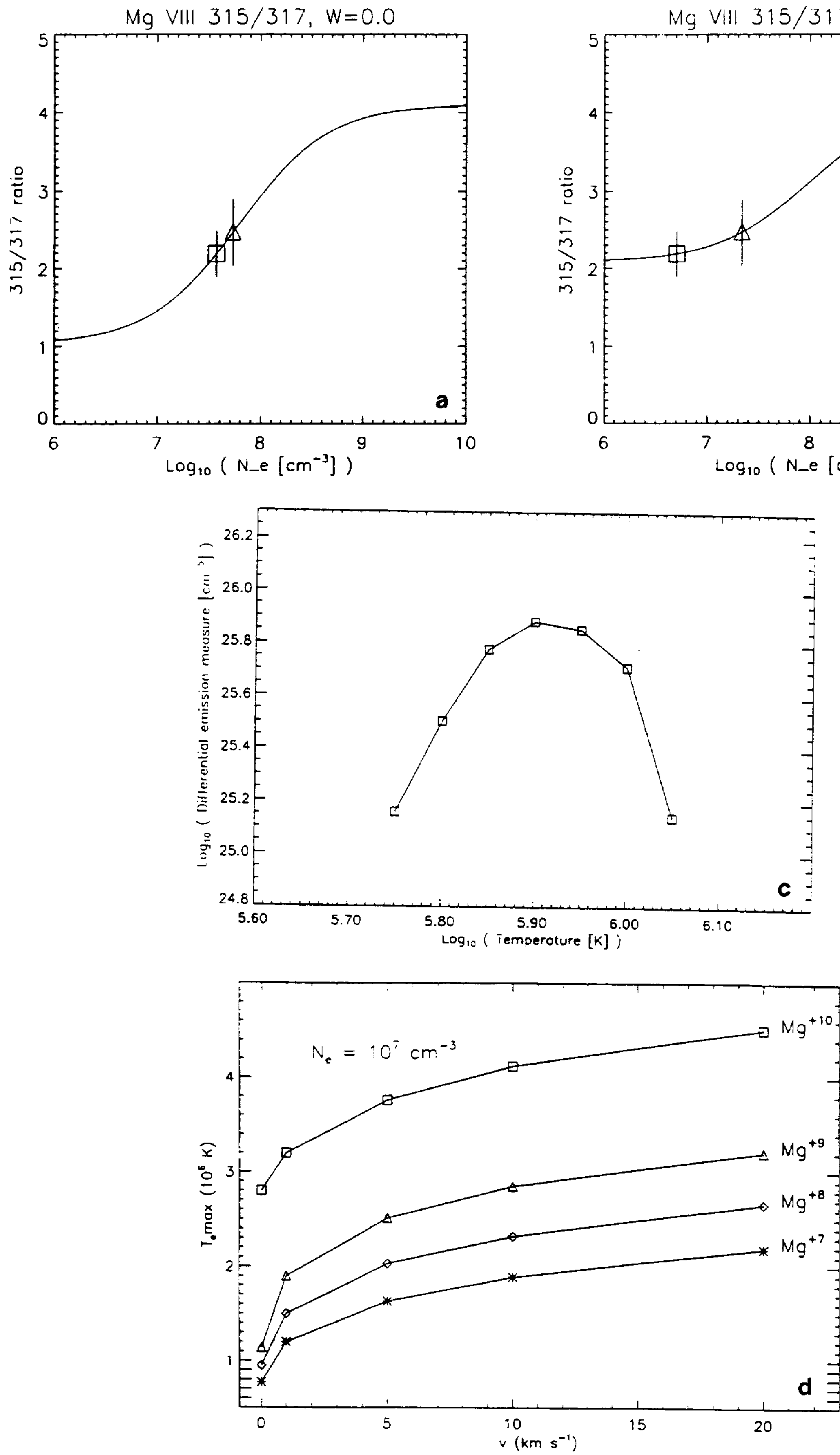
Mg VIII 315/317, W=0.0
315/317 ratio
Log10 (N_e [cm^-3])
a
Mg VIII 315/317, W=0.43
315/317 ratio
Log10 (N_e [cm^-3])
b
Log10 (Differential emission measure [cm^-5])
Log10 (Temperature [K])
c
Ne = 10^7 cm^-3
Mg+10
Mg+9
Mg+8
Mg+7
Temax (10^6 K)
v (km s^-1)
d

Figure 1

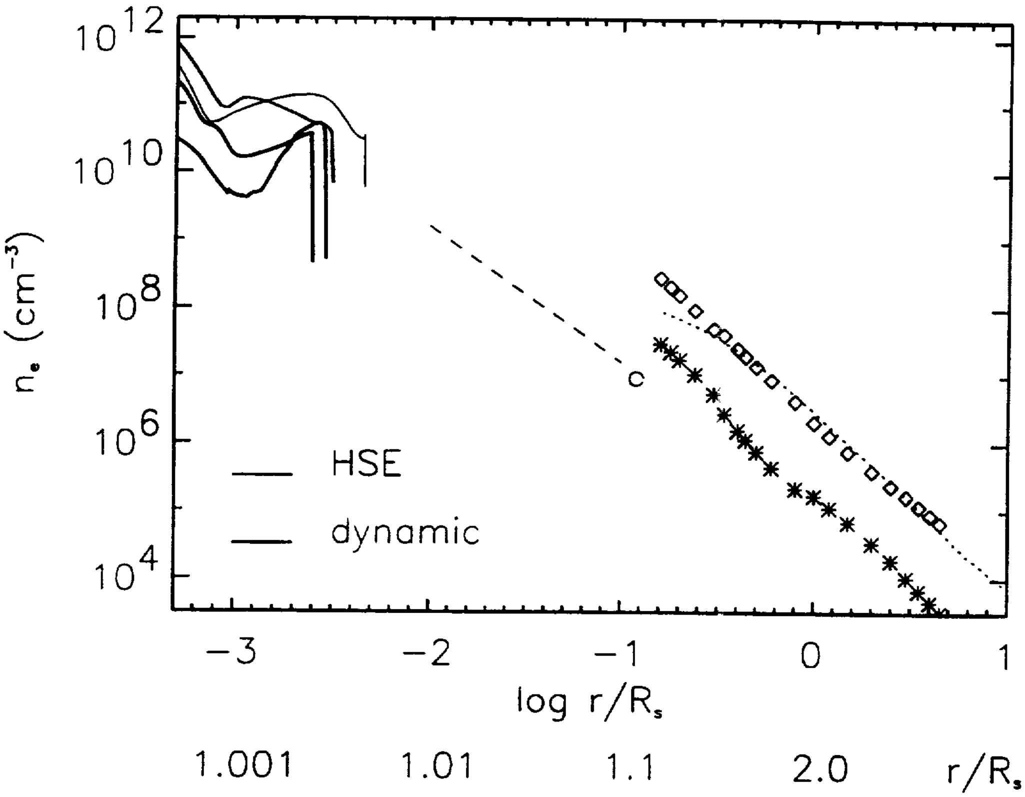
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
n_e (cm^{-3})
HSE
dynamic
c
−3
−2
−1
0
1
log r/R_s
1.001
1.01
1.1
2.0
r/R_s

Figure 2

2. Publications Fully or Partially Funded by Grant NAG5-6183

R. Esser, S. Fineschi, D. Dobrzycka, S. R. Habbal, R. J. Edgar, J. C. Raymond, and J. L. Kohl, Plasma properties in coronal holes derived from measurements of minor ion spectral lines and polarized white light intensity, *Astrophys. J. Let.*, accepted 1998.

R.Esser and D. Sasselov, Comparison between atmospheric and coronal densities, presented at SW9 conference, to be published as proceedings, 1998.

R. Esser and D. Sasselov, On the disagreement between atmospheric and coronal densities, submitted to ApJL, 1998.

P. Young, R. Esser, and H. E. Mason, CDS/SOHO: Spectral variations in and around coronal holes, presented at SOHO7 conference, 1998.

P. Young, R. Esser, and H. E. Mason, temperature and density in coronal holes - results from CDS/SOHO, presented at SW9 conference, 1998.