Element Diffusion in the Solar Interior
A.A. Thoul, J.N. Bahcall, A. Loeb (IAS)

We study the diffusion of helium and other heavy elements in the solar interior, using the flow equations developed by Burgers (1969) for a multi-component fluid. The set of equations is solved exactly, including the residual heat flow terms. No approximation is made about the relative concentrations and no restriction is placed on the number of elements considered. For helium diffusion, we compare our results with those obtained by Bahcall and Loeb (1990) using a simplified treatment with heat flows neglected. We find that the inclusion of the residual heat flow terms leads to a significant increase in the helium diffusion velocity. However, we also find that the temperature and charge-dependence of the Coulomb logarithm has the opposite effect, leading to a decrease in the helium diffusion velocity. By coincidence, the two effects partially cancel each other out throughout most of the solar interior. Our complete treatment of element diffusion could be directly incorporated in a standard stellar evolution code, but, for convenience, we also give simple analytical fits of our numerical results.


Variability of the Solar Limb-Darkening Function with Latitude
R. Kroll, H. Hill (U. Arizona), K. Beeson (Pima Community College)

Variations in the brightness of the quiet solar photosphere, in addition to sunspots and faculae, could contribute significantly to solar total-irradiance changes. To determine the extent to which this occurs, a long-term project is underway which is capable of measuring changes in solar limb darkening near the extreme edge of the Sun by monitoring the differential radius, a quantity characterizing the slope of the limb-darkening function. The differential radius is the difference between two edge locations of the Sun determined by the Finite Fourier Transform Definition for two different scan amplitudes, and thus has a reduced sensitivity to atmospheric seeing. Beginning in 1988, observations were made at 24 limb positions, and at 36 positions since 1990. Each limb position includes approximately 5.7° of the solar circumference. The observations consist of intensity profiles of the outermost 32 arc-seconds of the solar limb made in the continuum at 550 nm. This allows limb darkening to be studied as a function of both position and time. The average differential radius at each position for an observing season is obtained from the daily observations that are not affected by regions of solar activity. For the nine seasons under consideration, the average deviations from the seasonal means range from 11 to 22 milliarcseconds, corresponding to latitudinal changes in the limb-darkening function of approximately 0.8 to 1.5 at \( \cos \theta = 0.28 \). These results suggest a mechanism that causes perturbations to the temperature gradient which are localized in latitude and persist for several months. This work was supported in part by the U.S. Department of Energy.

Measurement of the Height of the Solar CO Layer During the 11 July 1991 Eclipse

"Normal" chromospheric indicators such as Ca II H & K, MgII h & k, HI Lyα and the UV and far IR continue all show the presence in the solar atmosphere of a distinct temperature inversion with a minimum temperature of about 4300 K at 550 km above the photosphere and a temperature rise in the lower chromosphere. In distinct contrast, the characteristics of lines in the V-R bands of CO show the presence of cool plasma extending over this height range, with \( T < 3800 \) K. Present models suggest that the CO exists only in clouds of limited vertical extent above supergranular cells, surrounded by a hotter chromospheric network containing embedded magnetic flux tubes. One remaining uncertainty is the height and vertical extent of these CO clouds.

Near IR total eclipse observations from Mauna Kea on 11 July 1991 have provided a clear indication of the limb extension of CO emission in the fundamental V-R band between 4.4 & 5.4 μm compared to both the IR continuum and visible limbs. The CO "limb" is found to be \( 125 \pm 15 \) km above this visible limb, or 465 km above \( r_0 = 1 \), which places the main CO concentration just below the temperature minimum but above the \( r_0 = 1 \) level of 430 km in the semi-empirical "hot chromosphere" model of Avrett but below the equivalent level of 560 km in the "cool" radiative equilibrium model of Anderson.

Comparison between Yohkoh Soft X-ray Images and 3D MHD Simulations of Solar Emerging Flux Regions

The soft X-ray telescope on the Yohkoh mission enabled us to observe the evolution of emerging flux regions (EFR) in coronal X-rays with high spatial and temporal resolution. Furthermore, we now have enough computing capability to perform three-dimensional MHD simulation of EFRs with sufficient spatial resolution to study details of the flux emergence process. These new tools provide the opportunity to investigate the physics involved in the formation of coronal loops in much more detail.

We carried out 3D MHD simulations of emerging magnetic flux regions under various initial conditions: (1) a horizontal magnetic flux sheet, (2) a bundle of horizontal flux tubes, and (3) a flux sheet with sheared magnetic fields. Numerical results show that coronal magnetic loops are formed due to the enhanced buoyancy resulting from gas precipitating along magnetic field lines. The interchange modes help to produce a fine fibrous structure perpendicular to the magnetic field direction in the linear stage, while the nonlinear modes determine the overall loop structure. We observe in 3D simulations that during the ascendancy of loops the bundle of flux tubes, or even the flux sheet, develops into dense filaments pinched between magnetic loops. We also find that magnetic field lines are twisted by the vortex motion produced by the horizontal expansion of magnetic loops.

Our numerical results may explain the observed signatures such as (1) the spatial relation between soft X-ray loops and Ho arch filaments obtained by coordinated observation between Yohkoh and ground-based observatories (Kawai et al. 1992), (2) the rate of increase in size of soft X-ray loops in EFRs (Ishido et al. 1992), (3) emergence of twisted magnetic loops, and (4) the threshold flux for formation of chromospheric arch filament systems (APF).

Fine Structure at the Limb in a Coronal Hole
M. Karovska, S.R. Habbal, F. Bundelli (CIA)

We present examples of the application of an image enhancement algorithm, developed by Koutchmy et al. (1987), to limb observations in a polar coronal hole. The data consist of spectrally integrated observations taken simultaneously in six different wavelengths through the same instrumental slit, by the Harvard/UEUV spectrometer on Skylab, scanning temperatures characteristic of the chromosphere and the corona. The spatial resolution of the data is \( 5'' \).

The algorithm, MADMAX, replaces each pixel in an image by the second derivative of the intensity, maximized over eight directions. Several levels of block-average smoothing may be applied prior to the derivative, and the results may be blended to emphasize features at various scales. By applying this technique to limb observations, we find that there is a fine structure emerging from the solar limb into the adjacent space with a characteristic spatial scale of approximately \( 10'' \). In addition, we find that different temperature fine structures which have the same characteristic scale are not co-planar.