Greenstein, Jesse L. A study of τ Ursae Majoris and other F stars.

Three hundred lines of important elements in the spectra of four F stars have been measured spectrophotometrically, on plates taken with the coudé spectrograph of the McDonald Observatory. (One star, α Canis Minoris, was measured in collaboration with Dr. W. A. Hiltner, in the Hiltner and Williams *Photometric Atlas*.) Curves of growth have been prepared using the solar values of the line strengths prepared by K. O. Wright, and by myself. Data from these curves are given in the table; the curves were also used to determine the relative number of absorbing atoms for various elements as compared to the sun. The curves of growth for other elements were prepared, and found to be similar to those for Fe I. Stellar values of $\log s_0/\kappa_\nu'$ were determined for the lines in τ Ursae Majoris; for ions these may be preferable to those in the sun, because of the greater strength of the ions. A curve of growth prepared for ρ Puppis using these new strengths in fact shows remarkably small scatter.

The apparent number of atoms above the photosphere for a given element depends on the opacity. At a representative point in the stellar atmospheres, say $\tau_0 = 0.25$, the number of atoms of a given ion will depend on the ionization equilibria, as compared to the sun, and on the abundances. Singly ionized atoms dominate in both sun and in these stars; any apparent increase in the number of ions may be ascribed to the lower opacity; if we know the source of opacity, information can be obtained beyond that given by the ionization equations. The new values of Chandrasekhar for H^- were combined with those for H , giving κ_ν' as a function of T, P_e ; the opacity and ionization in the sun were computed. Differences of numbers of atoms between sun and star are known, so that the level of ionization in the star is then known. A unique solution for T, P_e is obtained, which is given in the table. From these values, a complete set of predicted numbers of atoms for all the elements was obtained. Comparison of the observed and predicted numbers proved to be very satisfactory. Any apparent abundance changes should appear in both neutral and ionized atom, and this was found to be true.

Most of the apparent differences between the sun and three of the stars arise from the lower opacity, turbulence and pressure. The absolute magnitude effects observed are substantially the same for all elements. An interesting problem is

offered by θ Ursae Majoris, a subgiant F6 star. In spite of its well-established absolute magnitude (trigonometric and spectroscopic) it has weak lines, high opacity, and an apparently high surface gravity (shown by the large deduced $\log P_e$). The run of turbulence with absolute magnitude is most important in explaining the observed absolute magnitude effects. On the other hand, τ Ursae Majoris has a low surface gravity, very low opacity and P_e , and appreciable turbulence, v , in spite of its probable dwarf character.

The abundance changes found are of minor significance in all stars except τ Ursae Majoris. Detailed examination shows that the nomenclature "metallic-line A star" for this and such objects as 63 Tauri, 15 Ursae Majoris is not fortunate. These stars seem to be F stars with apparent abnormal abundances of certain elements. The weakness of the K line of Ca II in these stars is accompanied by many other weakenings; the great apparent observed effect in K is due to its location on the damping part of the curve of growth where the equivalent width changes relatively rapidly with the number of atoms. In τ Ursae Majoris neutral and ionized stages of a given element vary together, and the weakenings are closely the same for both stages. The numbers of atoms are reduced by a factor of nearly ten below the predicted number based on solar abundances for Ca I, Ca II, Mg I, Mg II, Sc II, Zr II; the reduction is about one-half for Ti I, Ti II, V I, V II, Sr II, Y II. On the other hand Cr I, Cr II, Mn I, Mn II, Fe I, Fe II, Co I, Ni I, Ni II, Zn I, Ba II, La II and the ionized rare earths seem substantially normal. The weakened elements are relatively light ones, except for Zr II. We are thus forced to assume a large number of abundance changes, or to find a new type of spectroscopic phenomenon which will doubly ionize Ca, Mg, Sc, Zr, Ti, V, Sr, Y atoms. The second ionization potentials of the weakened elements all lie between 11.0 and 15.0 volts. Normal elements have ionization potentials from 10.0 to 11.4 and from 15.6 to 18.4 volts. It is obvious that the Lyman lines and continuum lie not far from the energies required by the weakened elements to produce excessive second ionization. For example, if absorption lines were formed in the atmosphere free of hydrogen, and illuminated by hydrogen emission lines and continuum, the observed weakenings might be produced. The rapid decrease of emission beyond the Lyman limit would explain the normal behavior of lines with ionization potentials greater than 15.6 volts.