marked by crosses and absorption line galaxies by open dots. Note that there are at least three "sheets" of galaxies in this field in addition to the cluster associated with the quasar. We also found that although the field surrounding the quasar 1641 + 399 at z = 0.59 does not seem to contain a cluster of galaxies centered on the quasar, it does show a remarkably rich structure with a large number of emission line galaxies. Given that the quasar 3C 345, located 8 arcminutes away at the same redshift, also has several galaxies associated with it, this area may contain a very large and rich sheet of galaxies.

Finally, a fairly large number of galaxies in these fields are close enough to the quasar line-of-sight so that absorptions in the quasar spectra can be correlated with galaxy redshifts. The incidence of Mg II absorption from galaxies with known redshifts has been investigated by Bechtold and Ellingson (1992), and we are collaborating with members of the Hubble Space Telescope Key Project, who have taken ultraviolet spectra of several of our objects. A number of correlations have been found, which will be used to interpret the nature of metal and Lyman α absorptions also seen at higher redshifts. It is clear that these observations represent an important and necessary complement to the study of these systems.

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Magnetospheres of Helium-Peculiar Stars

Nonthermal phenomena have been known to occur in the environments of massive main sequence stars for several years. Many O stars show evidence of variable nonthermal radio emission, as well as variable soft x-ray emission, and in spite of the relatively homogeneous nature of O stars there is a wide range of radio or x-ray luminosity for a given bolometric luminosity. In addition, the UV spectra of O stars and the cooler Be stars have lines of superionized species that can only be present in plasma much hotter than the photospheric temperatures of these stars. Apparently some source of nonradiative energy and momentum is needed in the winds of most, or all OB stars. The transfer of energy from surface magnetic fields via magnetohydrodynamic waves is one possibility, and a number of investigators have also considered the possibility that the winds from massive stars are influenced directly by stellar magnetic fields. Since the winds from these stars contribute as much energy and momentum to the interstellar medium as do supernovae a firm understanding of the importance of such nonthermal processes is of widespread interest.

To date, magnetic fields have not been directly detected in the majority of hot stars showing evidence of stellar winds. This does not mean that such fields do not exist, as they could be below current detection limits or have geometries that make detection difficult with conventional polarimetric techniques. Fortuitously, globally ordered magnetic fields have been known to exist in many members of the various classes of chemically peculiar stars for almost fifty years. The hottest of these, the helium-peculiar stars, include the approximately two dozen B2-B3 helium-strong stars which have neutral helium lines too strong for their colours, and the larger group of B3 - late B helium-weak stars with abnormally weak helium lines. Both classes are spectroscopic and photometric variables, have large (> 1 kG), variable longitudinal magnetic fields, and have magnetically controlled stellar winds as demonstrated by variable UV resonance lines of CIV and SiIV. A few have also been established as non-thermal radio sources, and possibly radio variables. The helium-peculiar stars therefore display many of the same phenomena seen in massive OB stars and provide us with excellent laboratories for investigating the importance of magnetically controlled winds and magnetospheres in hot stars.

The oblique rotator model provides a satisfactory conceptual picture for understanding the observations of the helium-peculiar stars. A magnetic field (generally dipolar) inclined to the rotation axis interacts with diffusion processes as well as the stellar wind. The result is a non-uniform surface abundance consisting of belts or spots usually roughly axisymmetric with the magnetic axis. However, because of the tilt of the magnetic axis the abundance geometry is not symmetrical with respect to the rotation axis and spectrum variations, as well as photometric variations, occur on the rotation period of the star, typically a few days. The helium abundance peculiarities arise because of competition between the gravitational settling of helium and the general outflow in the stellar wind. Above the surface, the magnetic field also exerts a strong influence by trapping some of the stellar wind in a stellar magnetosphere, forming co-rotating clouds of plasma several stellar radii above the photosphere. These circumstellar clouds are the source of the Hα emission, and may also be the cause of the variable UV lines and the radio emission.

Current observations and phenomenological models of the winds and magnetospheres of the helium-strong stars suggest that these stars have mass outflows restricted to the magnetic pole regions and hot circumstellar plasma trapped in the equatorial regions of the magnetic field. A small number of helium-weak stars also show evidence for such polar outflows or magnetospheres. In addition, for some years the hottest helium-strong stars have been known to have another magnetospheric diagnostic: Hα emission. Several years ago Bolton and Fullerton (U. of Toronto) used the CFHT to obtain spectacular Hα observations of the prototypical helium-strong star, sigma Ori E, as well as several other members of the class. These data confirm that sigma Ori E has circumstellar material trapped in two clouds near the intersections of the star's magnetic and rotational equators.

Figure 20 illustrates the remarkable Hα variability of Delta Ori C. This cool (19000 K) helium-strong star has sharp lines, a constant longitudinal magnetic field of -3.4 kG (the strongest of the entire helium-strong class) and no UV spectrum variations, so the variable nature of the Hα emission is a surprise. Profile changes are obvious over time scales of an hour, and the period appears to be (unfortunately!) very close to 1.5 days. If we assume that the star's strong magnetic field forces the circumstellar material into rigid rotation about the star then the peak emission occurs at approximately 3.4 stellar radii above the surface and extends to 5.2 stellar radii. Very similar numbers are found for the emitting volume of sigma Ori E. Unlike sigma Ori E, however, the inclination of the rotation axis of delta Ori C must be on the order of 10 degrees in order to account for the star's short period but low $v \sin i$ of 32 km/s. This low inclination also explains the lack of variation in the observed longitudinal magnetic field, and is consistent with our earlier estimate of the surface field strength. These observations also provide, for the first time, evidence of low level variability in the He I λ6678 profile.

HD 35502 is an even cooler (B5) helium-weak star. This is a relatively poorly studied object, but it is known to have a strong magnetic field. Figure 21 shows that it too has variable $H\alpha$ emission, but we unfortunately have only two nights worth of data for this interesting object. Note the very pronounced changes in $H\alpha$ between the last two observations separated by 2.7 hours; these observations and the broad lines suggest that the period is likely quite short. We suspect that this object will also prove to be a radio source.

A variable shell spectrum has also been observed in the B8 helium-weak star 36 Lyn = HD 79158. Unlike the above two stars, in this case the period is well enough determined from several epochs of magnetic field observations to determine a phase relationship between the shell spectrum variations and the magnetic field: the shell phases occur precisely when the measured magnetic field is zero so that 36 Lyn also appears to have circumstellar material trapped in the equatorial region of its magnetosphere. A similar phenomena has been observed in the UV line profiles of the star.

Future observations are planned to enable us to determine which properties of a star lead to the presence of detectable magnetospheres. Obviously the magnitude of the magnetic field is of primary importance, but so far no slowly rotating, strongly magnetic stars have shown any optical evidence for trapped circumstellar gas. Rapid rotation appears to play a very important role, perhaps even more so than the effective temperature of the star. The CFHT, with its combination of large aperture and superb coudé spectrograph, will continue to be our instrument of choice for obtaining the short (< 30 minute), high S/N (200-300), and high resolution (R > 20,000) observations needed for this program.

D. Bohlender

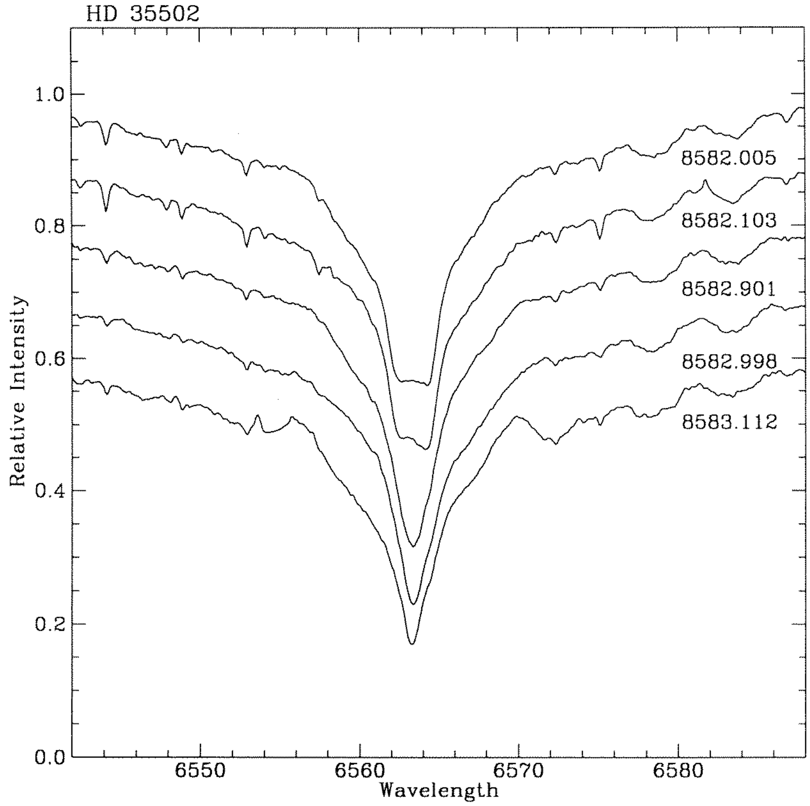

Figure 20: $H\alpha$ observations of the helium-strong star delta Ori C obtained with the CFHT coudé spectrograph and Reticon detector. Heliocentric Julian Dates (+2440000) are given below each spectrum. Note the lack of obvious variations in the CII doublet despite pronounced changes in the $H\alpha$ profile over timescales of an hour or two. Contamination by telluric lines will be removed with further processing.

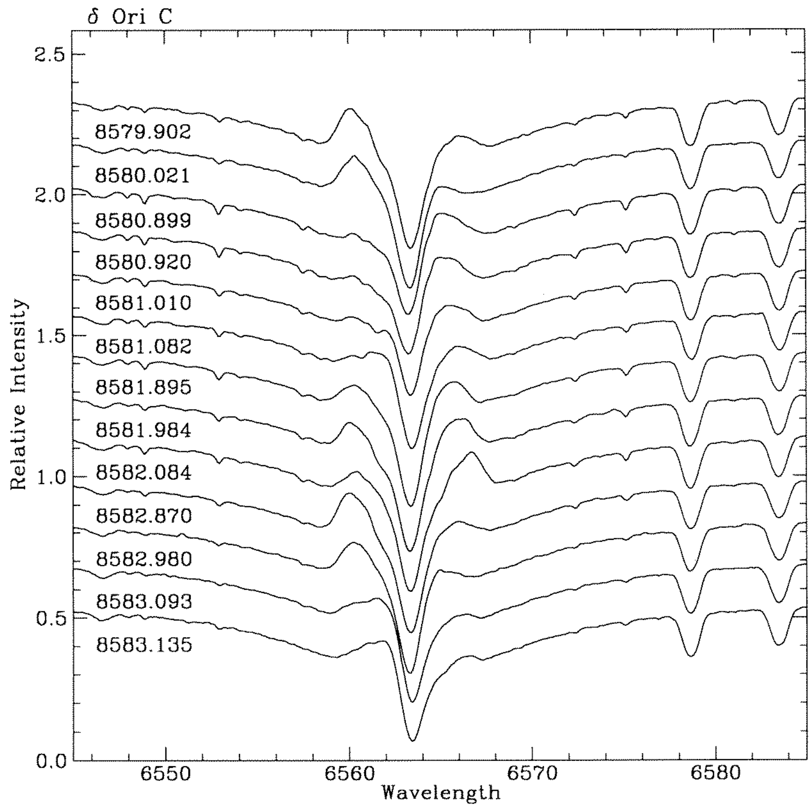

Figure 21: $H\alpha$ observations of the helium-weak star HD 35502. This is the coolest helium-peculiar star now known to have variable $H\alpha$ emission. Heliocentric Julian Dates (+2440000) are again given below each spectrum. The last two observations are separated by approx. 2.7 hours.