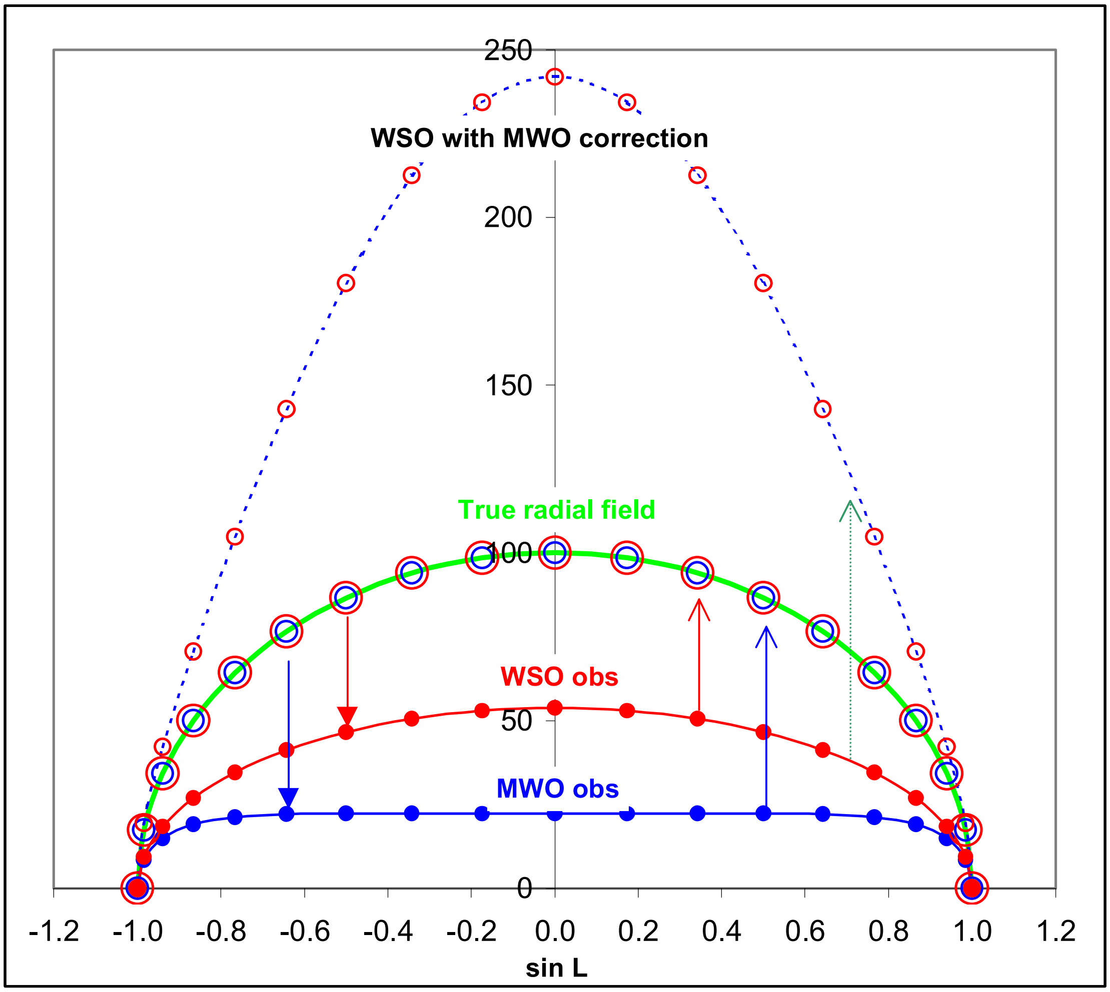
Magnetograph Saturation Factors



At WSO we find by following magnetic regions across the disk that the field is radial (to the accuracy of the observations) [Svalgaard *et al.*, 1978, Solar Phys. **58**, 225, also at `http://www.leif.org/research/The Strength of the Sun's Polar Fields.pdf`. Because we measure the line-of-sight component of the field, a field of strength B at the center of the disk will be measured as $B \cos(L)$, where L is the heliocentric angular distance. Linear position across the disk from one limb to the next varies as $\sin(L)$. The green curve in the Figure shows the field we would measure as a function of position. Because of "saturation" where the spectral line wings begin the fall outside of the slits of the magnetograph, the actual measured field is smaller depending on the size and separation of the slits and on the "true" strength, B_T, of the field in the (assumed) sub-arcsecond magnetic elements. For B_T = 1600 G = 1.6 mT, the measured field at WSO is smaller by a factor of $\delta^{-1}{}_{WSO}$ =1.86, independent of the position on the disk (deduced from the observed linear dependence on $\cos(L)$). The green curve is thus transformed into the red curve on the Figure as indicated by the downward red full arrow. Multiplying by the same factor transforms the observed field back into the "true" field (more correctly: flux density), as indicated by the upward red open arrow.

The Mt Wilson observers measure (for unknown reasons) a different field for the same given radial 100 uT = 1G field. The measured field (the blue curve on the Figure) is smaller by approximately a factor of two and is almost independent of L [e.g. Figure 2 in http://shinegroup.org/Presentations/2006/Posters/Bertello/bphot_06.pdf], The transformation is indicated by the downward blue full arrow. Multiplying by the same correction factor, $\delta^{-1}_{MWO} = 4.5 - 2.5 \sin^2(L)$, transforms the observed field back into the "true" field, as indicated by the upward blue open arrow. The corrected data are, satisfactorily, identical for both observatories (also shown by comparing real data rather than our fiducial 100 uT field).

Up to this point there are no problems for people using the data: just apply the proper correction factor for the observatory chosen. In the past ten years or so, it seems that researchers have elected to use the MWO factor for WSO data as indicated by the broken arrow transforming the red WSO curve into the broken, meaningless upper curve. The reason for this seems to be to improve the fit between model and observation. One practitioner put it to me this way: "although I agree there are problems with it [using MWO correction on WSO data], I still don't have a complete rationale for substituting another".

It should be clear that any correction factor would depend on field strength. For a sunspot of 2800 G, the magnetic signal has fallen to zero due to the saturation. Such a varying correction factor becomes an issue for magnetographs with high spatial resolution observing strong concentrated flux. The dispersed "background" flux that may be the most important for supplying flux to the source surface may all be of the same inherent strength and thus give rise to a constant correction factor. The resolution of these issues is a problem for the observers. The users of the data can with confidence use the already well known correction factor for the observatory being used.. If they don't it seems hard to make real progress.