First two decades of the stellar magnetism - a personal view

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1 When and how it all started?

In 1892 C.A. Young noted that some lines appear doubled in spectra of sunspots. This was probably the first observation of an effect in solar spectrum described and explained four years later by Pieter Zeeman. Young was not able at that time to offer a correct interpretation of the doubling but only a few years later George E. Hale noted that it results very likely from the magnetic splitting of spectral lines. At the turn of century Hale built a new, very accurate instrument for solar observations — a spectroheliograph which provided him with a large number of images of the solar surface obtained in selected spectral lines. He often obtained a long time sequence of exposures enabling him to follow the dynamics of sunspots. The observations showed spiral motions around spots and Hale believed that the electric currents associated with these motions should produce vertical magnetic fields, just as observed in solenoids. In 1905 he attempted to detect visually a plane polarization, expected from the Zeeman effect, in spectra of sunspots lying close to the solar limb, but he failed. When he later introduced a photographic plate as a detector for the Zeeman analyzer, the accuracy of measurements increased and in 1908 (Hale, 1908) he could announce the detection of a kilogauss field in sunspots. In consecutive years Hale observed both, the linear and circular polarization in spectra of sunspots, in agreement with theoretical predictions of a vertical magnetic field.

One should note that his basic idea of a magnetic field generated by circular motions observed on spectroheliograms was wrong. According to the present view, sunspot fields are caused by currents having nothing to do with the motions observed by Hale, and flowing deep below the visible surface. And yet his idea resulted in an important discovery and demonstrated usefulness of the Zeeman effect for detecting and measuring cosmic magnetic fields. By the way: Hale (1908) refers to the Preston law, $\Delta\lambda/\lambda^2$ = const. It could not have been George W. Preston, born 22 years later, but it is interesting to note that stellar magnetism works on some names stronger than on others.

At the beginning of XXth century scientists believed that the terrestrial magnetic field results from the Earth rotation. Assuming the same mechanism for the Sun and using a simple scaling law Hale estimated that the general solar magnetic field should be about 400 times stronger than terrestrial. After a few attempts he succeeded indeed in measuring it (Hale, 1913). Its intensity at the pole was about 50 G, i.e. weaker than expected. Again, a wrong idea that rotation of a conductive sphere is sufficient to maintain a general, dipole-like magnetic field resulted in an important discovery. Pure accident? Certainly not. When you build a new instrument increasing substantially the accuracy of your measurements or measuring a new effect, you will always do new discoveries, no matter what are your detailed theoretical ideas. This was the case of George Hale — one of the greatest instrumentalists ever working in astronomy.

In some of his papers he refers to his collaborator H. Babcock. Could it be Horace W. Babcock? Very unlikely, because in 1913 Horace was only one year old. Another name strongly attracted by stellar magnetism? Yes, but this time it was not a pure coincidence of names. H. Babcock collaborating with Hale was Harold D. Babcock, father of Horace, who greatly influenced the scientific interests of his son.

The first published observations of the Zeeman effect in a stellar spectrum were obtained by

W. H. Wright (1910). Guess which star it was! Well, he unsuccessfully tried to detect a polarization within the H_γ line of Mira Ceti. A few years later P. W. Merill (1913) looked for the Zeeman effect in spectra of B stars (warm, warm!), but he also failed. The subject was abandoned for the next 30 years.

2 Babcock's decade

In the forties Horace W. Babcock started a new search for stellar magnetic fields. He built a very accurate Zeeman analyser and selected a group of apparently rapidly rotating stars. He was convinced that the intensity of the surface magnetic field should be correlated with rapid rotation. He argued that a star rotating 30 times faster than the Sun should possess a field 30 times stronger, i.e. about 1500 G although the simple idea that rotation alone suffices to generate strong stellar magnetic fields was in the meantime proven to be incorrect (Cowling, 1934). Because rotationally broadened lines could mask Zeeman shifts, Babcock selected a group of B, A and F stars with narrow lines assuming that they are rapid rotators seen nearly pole-on. Several of these stars showed chemical peculiarities which seemed to be a pure accident.

It turned out later that nearly all steps in his reasoning were wrong: a dipole part of the solar field is order of magnitude weaker than measured by Hale, rotation of early type stars is not related to their magnetic fields, and chemically peculiar stars are slow rotators on average. And yet Babcock succeeded in discovering the first stellar magnetic field! The same, old recipe: take an instrument measuring something new, which is beyond reach of old instruments, and observe the sky — satisfaction (i.e. new discoveries) guaranteed or money back!

The first star outside of the Solar System with a measured magnetic field was 78 Virginis (Babcock, 1947). The star was observed on April 24, May 7, 8 and June 15, 16, 1946, i.e. exactly 50 years before the time of our conference. Babcock demonstrated a presence of the magnetic field in a figure where the observed shift between left- and right-polarized line components is plotted against the theoretically expected shift. The lines with larger expected shifts show indeed the larger observed shifts. For comparison, Babcock shows the results of observations of ϵ Peg where the observed shifts are comparable with errors and are uncorrelated with theoretical values. This means a null magnetic field. Since then such diagrams have become standards for discussing the presence of stellar magnetic fields.

In the end of his decade Babcock (1958) published a famous catalogue where he summarizes his magnetic field measurements obtained over 11 years.

3 Preston's decade

When I first thought of writing this review I assumed that while the fifties was the Babcock's decade, the sixties can be called a Preston's decade in stellar magnetism. After a closer inspection of available data I found out, however, that the Preston's decade actually lasted only 5 years. He began magnetic field measurements in July 1963 (Preston and Pyper, 1965), whereas in summer 1968 he left the Lick Observatory. It is remarkable how much had been done within these 5 years.

In 1965 Preston received a prestigious award — the Helen B. Warner prize, and in December of that year he presented the Helen Warner Lecture on "Studies of Stellar Magnetism — Past, Present and Future" (Preston, 1967a). He summarized in it the unsolved problems of the stellar magnetism. Probably the most important of these was the question about the correct model of magnetic field variations. Several theories existed of which two were best known and elaborated: the magnetic oscillator (Schwarzschild, 1949; Ledoux, 1967) and the oblique rotator (Stibbs, 1950; Deutsch, 1954; 1958). The strongest arguments in favor of the oblique rotator were the existence of the cross-over effect, discovered and interpreted by Babcock, and the relation between the variability period and

$v\sin i$ of a magnetic star. The strongest argument against it was the existence of apparently irregular variables.

Preston understood that the key to solution of the problem of a correct model is a good instrument. He put a lot of effort to build an analyser of the best possible quality. Together with the coude system of the 3 m telescope, which was, due to a better grating and a lower number of reflections, superior to the system of the 5 m telescope, he was able to obtain a large number of sharp, well widened and well separated Zeeman spectra of several magnetic stars. In all cases when a significant magnetic field was detected, the star turned out to be a periodic variable (e.g. Preston, 1967c), although the period was in some cases unexpectedly long. Concurrent photometric observations showed a lack of any phase preference between magnetic and light extrema (Preston and Stepien, 1968a, b) which strongly supported the oblique rotator model. Improved values of variation periods and $v\sin i$ showed a strict correspondence of these two parameters. Based on the oblique rotator model a distribution of inclination of magnetic to rotation axis was determined (Preston, 1967b), the main mechanism of light variations resulting from a redistribution of flux due to a nonuniform element distribution was identified (Wolff, 1967) and first detailed maps of chemical element distributions were obtained (Pyper, 1969). Preston noted an importance of the so called null lines (insensitive to magnetic broadening) for the correct determinations of $v\sin i$ values, and measured the mean surface magnetic field H_s (in addition to the mean effective field H_e) for a number of stars. Since then the oblique rotator has become generally accepted as the only correct model of magnetic stars.

Not all results were a success — there were also failures. The most notable one was probably a detection of a 5 days period for light and magnetic field variability of a HgMn star κ Cnc (Preston et al., 1969). The observed amplitudes of this star are close to measurement errors and the best interpretation of the observations is by assuming zero magnetic field and constancy of light. Later observations did not confirm the announced period.

If we adopt the Helen Warner Lecture as an opening bracket of the Preston's decade, the review article in Publ. of the Astr. Soc. of Pacific can be taken as a closing bracket (Preston, 1971). In the list of references to the first article only one paper by Preston is given whereas about one third of papers listed in the second article was published by Preston and his collaborators. This is a measure of the importance of the Preston's half-decade to the studies on stellar magnetism.

At the end let me call your attention to authors of two papers listed in the Preston's review article, both published at the turn of sixties and seventies: Landstreet (1970) and Michaud (1970). These two astronomers became leaders of research on stellar magnetism in the next decades.

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