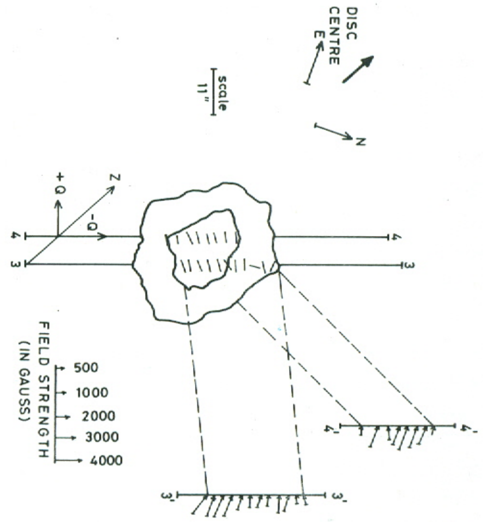
Newsletter
Quarterly Newsletter of the Indian Institute of Astrophysics

Volume 4 Number 3 July 1989

Stokes Polarimetry and the Measurement of Vector Magnetic Fields in Solar active regions

The measurement of Stokes polarization profiles and the deduction of vector magnetic fields in solar active regions has been one of the goals in understanding the nature of the solar atmosphere. We have attempted to devise a way to measure the Stokes profiles of Zeeman-sensitive spectral lines and to infer the vector magnetic fields from such measurements. Using the Kodaikanal solar telescope and spectrograph, not originally meant for such measurements, this study aimed to exploit the feasibility of such telescopes to make the measurements, given the limitations.

First, a detailed study of the instrumental polarization of the tower/tunnel coelostat system and the limitations imposed by it was made and a computer code for the off-line corrections of the instrumental polarization was developed. A prototype ellipsometer was designed and developed to measure the complex refractive indices of aluminized mirror surfaces–a vital ingredient for the knowledge of instrumental polarization due to reflections. This was followed by a choice of reasonable Zeeman-sensitive spectral lines that will be required to make the measurements. The Zeeman spectral lines used are the FeI 6302.5 Å (Lande $g=2.5$) and FeI 6301.5 Å (Lande $g=1.667$). Next a polarimeter was designed and constructed to measure all the four Stokes profiles based on the logistical and mechanical constraints imposed by the existing set-up. Using the polarimeter-spectrograph, the Stokes profiles are recorded in the form $I+Q$, $I-Q$, $I+V$, $I-V$, $I-U$, $I+U$. The spectra are registered on a 35 mm spectroscopic emulsion as density fluctuations, each frame covering a



A vector magnetic field representation for a sunspot KKL-18303 for observations on 1987 May 12, for two slit positions 3 and 4. The sunspot is of south polarity with $\mu=0.88$. N and E represent the solar north and east, respectively. Thick arrow represents the direction to the disc centre. The field strength and inclination are projected along lines 3′ and 4′. The inclination is to be visualized in the Z-plane (perpendicular to the plane of the paper) for each corresponding point along the length of the slit. The length of the arrows represent the total field strength, their levels are indicated at the bottom left. The $+Q$, $-Q$ plane (in the plane of the paper) represents the azimuthal plane. The azimuth directions are shown along the length of the slit. Arrows are not indicated due to the 180° ambiguity.

spatial extent of about 130 arcsec in the spectral region of λλ6299–6306 Å.

Daily observations on sunspots KKL-18303 (NOAA-4810), KKL-18313 (NOAA-4811) and KKL-18315 (NOAA-4812) were made between the period 1987 May 12–29. These spectra have been converted to digital intensities using a PDS-1010 M 1 microdensitometer.

Using the VAX-11/780 computer at the Vainu Bappu Observatory and the spectroscopic reductions package RESPECT, a spectral reduction scheme has been developed to convert the digital densities of the spectrum to a usable form of intensities, with proper wavelength calibration and reduction of the spectrum to line-to-continuum ratios. The spectra have then been corrected for the instrumental polarization and finally the true *I, Q, U* and *V* spectra have been obtained.

A non-linear least-squares technique of fitting the observed profiles with those generated from the analytical solutions of the equations of polarized radiative transfer has been adopted and modified to simultaneously fit all the three polarized spectra *Q, U* and *V* in order to derive the parameters: the magnetic field strength, the inclination and the azimuth of the vector magnetic field and other parameters such as the Doppler width, slope of the source function, line-centre wavelength, damping constant and opacity ratio. Repeated tests have been made on the algorithms using both synthetic and observed profiles before they have been used in the data reduction.

Using the above technique, the Stokes profiles of the sunspot KKL-18303 have been reduced to derive all the 8-parameters of the spectral line forming region, thus establishing the capabilities and the constraints that are present in attempting to measure the vector magnetic fields with the said telescope.

K. S. Balasubramanian

(*Synopsis of a thesis submitted to the Joint Astronomy Programme, Department of Physics, Indian Institute of Science, towards a PhD degree*).

Magnetic field induced metal-insulator transition in a one-dimensional chain

For a system of noninteracting electrons in a solid, the electrical property is known to be decided by the level of band-filling, *e.g.* the solid is metallic if the highest band be half-filled and insulating if the band-filling be complete. Thus a solid with odd number of electrons in the valence state of the atom is known to be metallic, there being two degrees of spin degeneracy for the electrons. In what follows, we show that this metallic state can be destroyed if we apply an external magnetic field $H > E_B/\mu_B$, where E_B is the band width and μ_B is the Bohr magneton.

Let us consider a chain of N atoms with separation a between the neighbours and let every atom have a single electron in its outer shell. This implies that the system is metallic. We now consider *a* magnetic field to be applied to the system, which we consider to be acting along the chain. The energy band dispersion relation for wave-vector k, in the tight-binding approximation, then reads to be,

$$E_{\pm}(k) = \varepsilon(H) - 2t(a, H) \cos ka \pm (1/2) \mu_B H$$

where $\varepsilon(H)$ is the energy eigenvalue of the atomic orbital state, $t(a, H)$ is the hopping integral and the last term denotes the interaction energy between the spins and the external magnetic field. It is seen that this last term lifts the degeneracy of the spins and breaks the band into two. We ask here the question: if we have to accommodate all the N electrons, how do we have to fill the band?

Electrons being Fermions, we are permitted to put one electron per state. It can be seen that we have to begin by filling in the '−' band first till the energy $\mu_B H$ is reached and then onwards electrons can be kept, in both bands. This shows that the '−' band will have larger number of electrons than the '+' one. This results in the well-known Pauli paramagnetism. But if $\mu_B H > E_B = 2t(a, H)$, all the electrons in the system can be accommodated in the '−' band filling it upto $k = \pi/a$, *i.e.* up to the band edge. This results in a completely filled band and hence an insulating phase is obtained.

It is known that $t(a, H)$ has a very weak dependence on H while the spin term is linear in H. Thus the condition $\mu_B H > E_B$ can be satisfied if the field be very high. For neutron star atmospheres, for particle density less than 10^{27} cm^{-3} and $H \sim 10^{12}$G, the magnetic polymer states will be insulating, in contrast to the existing understanding. The electrical and thermal conductivities of these magnetic polymers will thus be very low.

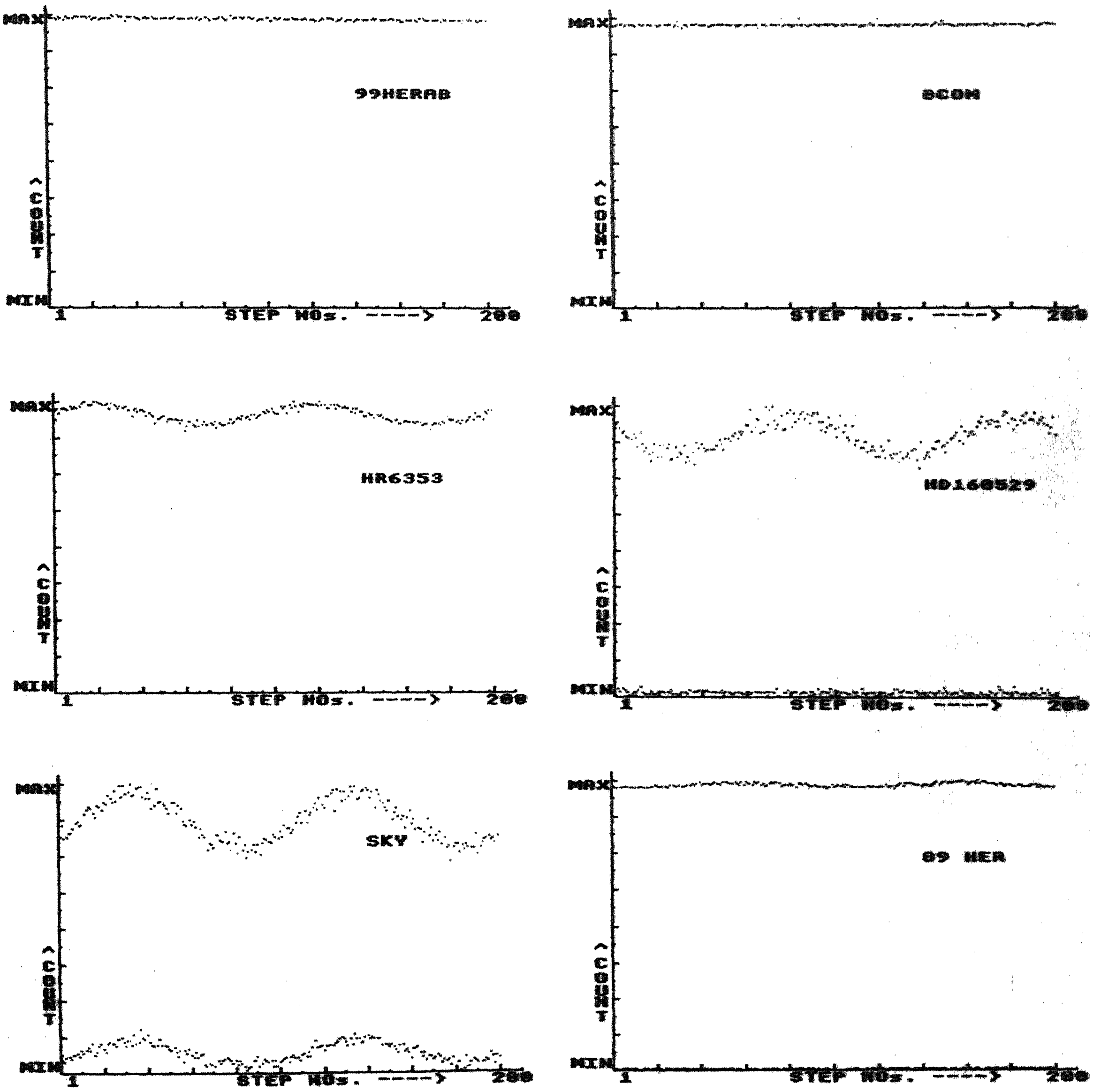
Similar effects can be expected in the narrow-band conductors or in electron-hole droplets though the existing fields are too low to achieve the transition in the above systems. This phenomenon can have application as sensitive relays for controlling very high magnetic fields.

Electron system in a strong magnetic field can have several other transitions to insulating phase, like the Wigner crystalline phase and the Peierls distorted phase. The competition between these different effects can result in an interesting phase diagram for the system.

A more detailed version of the work will be published elsewhere.

S. Chatterjee

Some samples of polarimetric observations with the Star-and-Sky-Chopping Polarimeter



Distribution of photon counts in star and sky channels at 200 steps (equivalent to one complete revolution) of the polarizer. To accommodate the large dynamic range on the monitor, scaling has been done. Thus, sky counts are not seen in brighter objects like 99 Her AB and β Com. 99 Her AB: unpolarized standard, $P=0.03\pm0.01\%$; β Com: unpolarized standard, $P=0.03\pm0.02\%$; HR 6353: polarized standard, P (V-band) $=3.67\pm0.05\%$; HD 160529: polarized standard, P (B-band) $=7.18\pm0.17\%$; Sky: moon about 30° away; 89 Her: Peculiar F supergiant, P (V-band) $=0.61\pm0.02\%$.

S. K. Jain

newsline

K. S. Balasubramanian has been awarded the PhD degree under the Joint Astronomy Program, Department of Physics, Indian Institute of Science, for his thesis on *Stokes Polarimetry and the Measurement of Vector Magnetic Fields in Solar Active Regions*. A summary of the work is presented in this issue. He has now been awarded the National Research Council Research Associateship, USA, for a year and will be working with the Solar Physics Group at NASA Marshall Space Flight Centre, Huntsville, Alabama, USA, beginning 1989 June.

out of context

Both of these roads of attack fall prey to severe interpretive problems.

Uranus and Neptune, NASA CP 2330, p. 3.

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The IAU participated in "Anti-space junk activities" . . . .

IAU Information Bulletin, No. 60, p. 23.

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The viral theorem.

Rep. Prog. Phys., (1981), **44**, 1077–1122.

Editors: T. P. Prabhu & A. K. Pati
Editorial Assistant: Sandra Rajiva
Published by the Editors on behalf of the Director, Indian Institute of Astrophysics, Bangalore 560 034.

Newsletter
Quarterly Newsletter of the Indian Institute of Astrophysics
Vol. 4, No. 3, July 1989.

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