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SUMMARY OF RESEARCH INTEREST

I am interested in studying the fundamental processes in the solar and stellar atmosphere associated with magnetic fields and their role in the heating of chromosphere and coronae. Apart from other research projects that I will be assigned to work on, I am also interested in pursuing the following research problems.

Numerical study of magnetic field intensification in stellar photospheres

The magnetic fields in the solar atmosphere are believed to be generated by a dynamo process operating below the surface. The magneto-convective motions in the photospheric and sub-photospheric layers play an important role in further structuring these magnetic fields. The generated fields are amplified due to flux expulsion by granular motions and further downdraft results in kilogauss field strength. But the plausible mechanism by which different stars maintain concentrated intense magnetic fields on their surface is not clearly understood.

The contribution to the luminosity variation of the Sun as a result of its magnetic activity mainly comes from the small scale magnetic features (Solanki 1993). It is now believed that the brightness variation in stars is due to a similar periodic magnetic activity and it varies as a result of its evolution across the HR diagram. The rotation plays a very crucial role in maintaining the dynamo and hence in the generation of magnetic field. Studies of the rotation-activity correlation in Sun-like stars give us a better insight into the stellar dynamo process. The photospheric and chromospheric activity strongly depend on the strength of the surface magnetic field and also show variation as a function of age and surface temperature of the star. The younger, faster rotating and more active stars grow photospherically darker as activity increases, thereby resulting in an anti-correlation between the photospheric and chromospheric activity measures, whereas the older stars show positive correlation between these two quantities (Radick et al. 1990; Lockwood et al. 1992).

It has been shown that the photospheric magnetic field varies as a function of surface temperature as a result of the changing superadiabaticity (Rajaguru et al. 2002). Since, the magnetic field plays a crucial role in the photospheric microvariability, it is important to understand the surface structuring across a range of different stellar parameters. In order to address this issue, we propose to study the various magnetic field intensification scenarios in different stellar atmospheric models using the radiation-magnetohydrodynamic codes currently available. In the light of recent progress in the area of high-precision photometry and Zeeman-Doppler Imaging, it is now possible to make a comparison of the numerical models with observations. This work, along with new and upcoming observations from CoRoT (see for e.g. Michel et al. 2008) and KEPLER missions, will give a better understanding of the magneto-convective processes in stars and their variability (Ludwig et al. 2009).

MHD wave coupling in magnetically structured solar atmosphere: 3D numerical approach

Two dimensional numerical simulations of wave propagation in a gravitationally stratified, magnetized atmosphere, show that the region with comparable magnetic and thermal energy density (the plasma $\beta = 1$ region) acts as a wave conversion zone (Bogdan et al. 2003) Recent two-dimensional numerical studies (Vigeesh et al. 2009) of wave propagation in small scale magnetic flux concentrations show that the nature of the modes excited depends on the value of plasma beta of the region where the excitation takes place. Mode conversions and transmissions occur in the region where $\beta = 1$ and energy is exchanged between various MHD modes. These simulations suggest that flux tubes provide minimal acoustic energy to the chromosphere in the network, however, are an efficient source of acoustic heating to the surrounding non-magnetic regions. But these studies are limited by the fact that they use simple idealistic pulses for the wave excitation, they are in 2D and hence do not give a clear picture.

In order to overcome the various limitations of these studies, like the restrictions of 2D, idealistic atmosphere, unavailability of more realistic sources of drivers to generate waves, etc., we would like to use observational data as direct input and carry out 3D MHD simulations of wave propagation from lower atmosphere to corona. This will help in recognising the role played by the wave conversion zone and establishing the energy budget of the solar atmosphere. Most importantly, 3D is needed to identify the Holy Grail of MHD waves: Alfvén waves. Large scale initial 3D MHD simulations focusing mainly on the wave coupling between longitudinal and transverse waves in this region is very demanding (Fedun et al. 2009).

Most of the MHD simulations have not really concentrated much on this aspect, and the energy transport by these waves. We are particularly interested in exploring the detailed dynamics and energy transport by a wide range of MHD waves in a realistic 3D solar atmosphere which will considerably improve our understanding of their role in the heating of the solar chromosphere and corona (Vigeesh et al. 2012).

Seismology of small-scale magnetic features using numerical simulations

Seismic waves are commonly used to infer the internal structures of large feature like sunspots present on the Sun. Recent studies have shown that these waves are also influenced by magnetic inhomogeneities of much smaller spatial scales. However, the interaction of these waves with small-scale entities like flux tubes in the solar magnetic network are not clearly understood. Using 3D magneto-hydrodynamic simulation we model the propagation of artificially excited p and f-mode waves through a solar atmosphere. We plan to study the interaction of these waves with isolated structures present in our model that are representatives of magnetic flux concentrations on the Sun. This will help us to better understand the effects of travel time perturbations due to small-scale magnetic features in the interpretation of helioseismic inversions.

Reference

Bogdan, T. J., Carlsson, M., Hansteen, V. H., et al. 2003, ApJ, 599, 626

Fedun, V., Erdélyi, R., & Shelyag, S. 2009, Sol. Phys., 258, 219

Lockwood, G. W., Skiff, B. A., Baliunas, S. L., & Radick, R. R. 1992, Nature, 360, 653

Ludwig, H., Samadi, R., Steffen, M., et al. 2009, A&A, 506, 167

Michel, E., Baglin, A., Auvergne, M., et al. 2008, Science, 322, 558

Radick, R. R., Lockwood, G. W., & Baliunas, S. L. 1990, Science, 247, 39

Rajaguru, S. P., Kurucz, R. L., & Hasan, S. S. 2002, ApJL, 565, L101

Solanki, S. K. 1993, Sp. Sci. Rev., 63, 1

Vigeesh, G., Fedun, V., Hasan, S. S., & Erdélyi, R. 2012, ApJ, 755, 18

Vigeesh, G., Hasan, S. S., & Steiner, O. 2009, A&A, 508, 951