Summary of Involvement for the Thomas Metcalf SPD Travel Award

Bidya Binay Karak

NASA LWS Workshop on solar dynamo frontiers: Helioseismology, 3D Modeling, and data assimilation – June 9-12, 2015

Bidya is a post doctoral fellow at NORDITA, working on solar dynamo. He received his PhD (2009-2009) from Indian Institute of Science under the guidance of Prof. Arnab Rai Choudhuri. Major contribution of his thesis was to explain the reasons of the irregularities of solar cycle, particularly the grand minima. Presently, he is working on magneto-convection simulations of solar cycle and large-scale flows and turbulence simulations to understand the interaction between small-scale and large-scale dynamos with Axel Brandenburg, Petri Kapyla and Maarit Kapyla.

In recent years, the flux transport dynamo model has become a popular paradigm for modeling the solar cycle. In this model, the Babcock-Leighton process is conisidered for the generation of poloidal field near the surface and a meridional circulation—poleward near the surface and equatorward near the base of the convection zone—is required for advecting the fields. Under certain conditions this dynamo model reproduces many observed features of the solar cycle, including the 11 year period, the equatorward migration of sunspots, the polarity reversal etc.

In the presentation: **Flux transport dynamo models: fluctuations and grand minima,** I mainly focused on whether this flux transport dynamo model is capable of reproducing the irregular solar cycle, including grand minima of extended low activity. I argued that the Babcock-Leighton process and the meridional circulation are two major ingredients in this dynamo model which can have variations. I showed that due to large variations in active region properties, particularly the tilt angles, locations and inflows, fluctuations in the Babcock-Leighton process can be large enough to make the poloidal field sufficiently weak to push the dynamo into grand minima events. Furthermore, when the meridional circulation becomes sufficiently weak, it allows the fields to diffuse more and makes the dynamo weaker to trigger grand minima. However, when we want to reproduce the observed frequency and the durations of grand minima in past, we need to feed the correct level of fluctuations in poloidal field and meridional circulation of regular dynamo model. I have shown that the crude estimates of the fluctuations in the strength of the poloidal field and the meridional circulation can be obtained from the existing sunspot cycle strengths and durations, respectively. Another way to estimate the fluctuations of poloidal field is to measure it from the observed properties of active regions. Using these estimates of fluctuations, a flux transport dynamo model allows us to reproduce the correct statistic of observed grand minima resonably well.

In addition to oral presentation, I had a poster contribution on: **Magnetically controlled stellar differential rotation near the transition from solar to anti-solar profiles**. In this poster, I presented our results of large-scale flows from global compressible MHD simulations in spherical geometry. When we decrease the Coriolis number, differential rotation changes from solar-like to anti-solar. We find that the magnetic field helps to produce solar-like differential rotation. We do not find any evidence of the bistable states of differential rotation which has been previously observed in hydrodynamic simulations. In all cases, speed of the poleward propagating meridional circulation near the surface is close to the observed value. The large-scale flows show significant temporal variations which are also in observational ranges.

Furthermore, with people in the meeting I informally discussed my recent/ongoing projects particularly, on the variation of small-scale magnetic field due to the global dynamo. Besides presenting my works, I learnt a lot from other presentations and discussion—all these help to devlope a global view of solar and stellar dynamo. Overall, it was a great opportunity to participate in this workshop.