First Semester Report

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“Nonlinearities and Stochastic Perturbations in Dynamo Models”

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Introduction

Nonlinearities and/or stochastic variations in the parameters of solar dynamo models (R. H. Cameron, 2016) induce cycle-to-cycle variations in the resulting dynamo-generated magnetic field. The study of stochastically perturbed nonlinear dynamos is therefore a research topic intimately linked with studies of long-term variations of solar activity. Indeed, the 11-year solar cycle is an irregular, quasi-periodic phenomenon, the lengths and amplitudes of individual cycles varying between rather wide limits. Long-term variations are also present, including the Maunder Minimum (Eddy, 1976), a period of very low activity in the late 17th century, and the Modern Maximum, a series of particularly strong solar cycles in the second half of the 20th century. In addition to its theoretical interest, the problem of understanding and predicting such variations has great practical importance, given the increasing vulnerability of human civilization to space weather disturbances.

During my Ph.D. research I will perform a systematic analysis of the effects of different types of (physically well motivated) nonlinearities and stochastic perturbations of the dynamo equations. The objective is to find the signatures in the statistical properties of long term activity variations that correspond to particular types of nonlinearities or perturbations. This might offer observational clues regarding which nonlinear effects or perturbations actually determine the long-term behavior of the solar dynamo.

Description of research work carried out in current semester

By the beginning of the semester, my supervisor (Prof.Petrovay) gave me an outline for our work, according to that I started to prepare myself, the first step was to make a full review for python programming language, since our work was about MHD theory simulation by python, so I started by reading

1- Python for Astronomer (An introduction to scientific computing) book by Imad Pasha and Christopher Agostin (I. Pasha, 2015), this book describes the python language in astronomical point of view, and include many examples one can start with.
2- Because our work was about a theory so some mathematics needed, especially the partial differential equations, so I step farther and made a full review for the PDEs, then using Numerical Methods for the Solution of Partial Differential Equations by Luciano Rezzolla (Rezzolla, 2011) I learned how one can solve the PDEs numerically using schemes like Upwind method, Lax Fredrich method, McCormack method, ...etc.
3- I was interested in solving complicated PDEs, so I searched for more complicated scheme like Finite Volume Methods, and to get deeper and to see more about stabilities for the schemes and how one can choose the correct one, I watched a full class lectures (Computational Fluid dynamics) online for Prof. (Barba, 2012), where she illustrated the schemes in amazing way and made everything simpler.
4- A full review for the Magnetohydrodynamics theory was needed, so I started with some basics about Plasma physics using the book (Introduction to Plasma Physics and Controlled Fusion by Francis F. Chen (Francis, 1984)) and

sometime using the online resources, moving forward to the MHD by reading lectures in Magnetohydrodynamics by Dalton D. Schnack (Schnack, 2009) and using some slides and presentations like Introduction to MHD theory by Stefaan Poedts and chapter three from the physical foundations of theoretical astrophysics by K.Petrovay (K.Petrovay, 2016), then to be more specific, the solar dynamo theory, where I used two reviews, What makes the sun tick? The origin of the solar cycle by K. Petrovay (Petrovay, 2000) and Solar Dynamo Theory by P. Charbonneau (Charbonneau, (2014)).

With these reviews a began to see what kind of work I need to do, and every sentence was clearing the path for me.

During this semester I had three jobs to do,

1- To solve the integrated toroidal flux equation, which was a PDE, and to prove that the solution is in the form of the oscillator equation with the parameters of the updated Leighton model, with Petrovay instructions I completed the work and sent it as an overleaf project.
2- Write a python script which solve the surface flux transportation equation, using the numerical methods that I learnt them before, so I started with simple techniques and schemes, under the supervision of Petrovay and his instructions again we solved the equation in one dimension by python and produced figures for four solar cycles.
3- The next step is to add a rogue Active Region as a spatially and temporally localized peak added to the source term, then to see the effect on the polar field using our source code, so I started to read The Effect of Rogue Active Regions on the Solar Cycle by M. Nagy et al. (M. Nagy, 2017) and then I will study in details how the model of the rogue active region influences the effect.

Educational activities in current semester

In this semester, I studied three subjects in the department, as a review, I took Introduction to Astronomy (2 Credits), the Radio Astronomy course (6 Credits) and the Infrared Astronomy course (6 Credits), also I registered for Guided Research Work (18 Credits).

1- I started the Introduction to Astronomy course in the 14th of September as first lecture with Prof. Petrovay, in this course we refreshed our knowledge in the astronomy in general, we began by studying the history of the observations and knowing our exact location in universe also to study some specific features about the earth, after that we moved to the orientation in the sky topic, where we review the models for the celestial spheres and how one can determine the exact location for a celestial objects, then a study for the conceltaion and how they defined and their locations after that the notion of the starts.

   The next topic was our sun, we started by describing some important values for the sun, moving forward to the content of the sun as Hydrogen and Helium major compositions, after that we look more in details to the structure of the sun from the core up to the corona, the composition and the phenomenon for each layer, concentrating on the upper part of the sun the photosphere and the corona which gave a lot of information about the sun as a whole.

Real and apparent motion in the solar system was the next topic, where Kepler's laws studied in detail, the rotation of the planets around the sun and how the perturbations and resonance happen to the planets' orbits.

Moving forward to the solar system as a whole and the age of the solar system, and the most important features for each planet, also the origin of the solar system was studied and some theories discussing the formation of the Earth-like planets and the giant planets.

A special topic to study was our Moon, starting from the rotation of the moon and the eclipses produced, then a complete study for the structure of the moon were taken and how the creators can give some information about the age, a theory to explain the born of the moon was introduced as well. At last, an intense look to the rocky and giant planets, all the information about these planets were displayed and reviewed, the small solar system bodies were studied, where I used the recommended reference Fundamental Astronomy by H. Karttunen et al. (Karttunen, 2016), learning with Prof. Petrovay was very amusing specially the videos and pictures for the universe, that he prepared them during the lectures.

2- Radio Astronomy, with Dr. Frey and Dr. Gabányi, I attended all lectures in the Konkoly Observatory, we started the lectures with a brief history of radio astronomy as an introduction to the course, after that the definitions such as the radio windows, bands, specific intensity and many other, used in radio astronomy were previewed, which gave a deep understanding to the topic, then we began to move deeper to some emission mechanisms in radio astronomy, getting familiar with the radio emission from the sky, and how one can represent it using the Planck's law for black body spectrum, the second part of the lecture was about MASEREs introduced by Gabor Orosz, he illustrated the atomic energy levels and the Einstein coefficient, we saw how MASEREs are very important in observations and how one can use it to observe the universe.

In the third lecture, Dr. Kristina illustrated the interferometry in a professional way, starting from the single dish telescope to Very Long Baseline Array Telescopes (VLBA) including the historical and theoretical backgrounds, also she introduced most of existing radio telescopes in the world with some nice photos.

The last part of the lectures was about astrometric and geodetic applications of VLBI, where I learnt about QUASARs and how it can be observed using VLBI, the second part was about Imaging techniques using VLBI, moving forward to the steps on how we can enhance the pictures by some methods such as CLEAN algorithm and Hybrid mapping.

The next two lectures were set to be seminars by the students, each student worked on a scientific paper and introduce it as 20 minutes presentation, I worked with another Ph. D. student (Nofoz Sulieman) on a simulation program for radio astronomy (APSYNSIM), where one can set up a whole system of radio telescopes, also the program gives the possibility to CLEAN the taken images by CLEAN algorithm, it was quite interesting experience being in the observatory and work with such professionals.

3- Infrared Astronomy was the last subject in the semester, with Dr. Toth we begin by a brief history and the discovery of Infrared, the Herschel experiment, the black body experiment, then moving to the history of the infrared observatories, the two-micron sky survey, the balloon-borne observatories, the rocket flights and Cosmic Background Explorer (COBE) were also discussed.

The third topic was some necessary definitions and the origin of infrared, bands, radiation (Radiation of Molecules and Dust), were investigated in this chapter. After that the infrared photometry method was introduced, what are the steps for color correction of infrared images.

In the next chapter, a quick view for All-sky surveys including IRAS, MSX, AKARI, WISE and PLANCK with their properties and specifications for each one. In chapter seven we studied about three of the most important Infrared satellite observatories the Infrared Space Observatory (ISO), Spitzer Space Telescope and Herschel Space Observatory, features and the uses for each one and some Most important scientific results from these telescopes.

The last two topics were about the interstellar medium in infrared and Young stellar objects, what are the infrared emission regions and what are their classifications, for young stellar objects topic we studied the molecular clouds and how a whole solar system can form from them step by step.

I used the book Infrared Astronomy by V. Toth (Tóth, 2013) as a main reference, learning withe Dr. Toth was very exciting way and gave one a different angle of view, especially with his mind scratching questions.

Conferences in current semester

During the semester I attended many seminars and presentations

1- The 15th European Solar Physics Meeting which was held in Gólyavár Conference Center, Budapest. the latest research in the field of solar physics were presented.
2- Every Wednesday there were the Astrophysical lunch in the department, where a discussion for the latest experiments, observations, researches.
3- On Monday, November 6th I attended a special event was held in the Hungarian Academy of science (MTA) as a special series of talks commemorating the 50th anniversary of the discovery of pulsars
4- Next June, I am planning to attend a special summer school for Magnetohydrodynamic theory, which will be held in Udine, Italy. In this school 'ADVANCED TOPICS IN MHD' a full review for the MHD theory by scientists from different places (UK, France, Japan, Spain), it will be a good place to invest the time in the summer, and to reorganize the work, I hope that this school will move me forward to the next step of the work.

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