Iberian Space Science Summer School

SUMMER SCHOOL WORK REPORT

2nd i4s Iberian Space Science Summer School, Madrid, Spain 06-10 June 2022

Submitted by

Dr. Shirsh Lata Soni

Research Associate
Planetary Science Branch
Space Physics Laboratory
Vikram Sarabhai Space Center
Trivandrum, Kerala, India

Content

1. i4s Iberian Space Science Summer School

The objective of the school is to provide professional development for young researchers in the domain of Space Weather, with an emphasis on the fundamental science of the Sun-Earth system, modeling, and forecasting. This school will provide high-level professional development for early career, scientists, students, and entrepreneurs in the domain of Space Weather, with an emphasis on the fundamental science of the Sun-Earth system, modeling and forecasting, and its impact on society. The school is also an opportunity to promote scientific collaboration between researchers, to stimulate the vocations of young researchers, and to help disseminate the results of research in Space Science.

A wider objective is to create an "Iberian Space Science Summer School" to be held annually, alternating between Portugal and Spain in different universities. In this way, the school will contribute to the spread of study of Space Science, Space Weather, and the Sun-Earth interactions and attract the academic community to this subject, as well as provide information to the civil society and young entrepreneurs.

This school has the support of the **International Space Weather Initiative(ISWI),** the **Institute for Space-Earth Environmental Research (ISEE)** and the **Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)**, being in line with their aims in providing training in the domain of Space Science.

This school propose a 5 daysworkshop, to be held in 06-10 June 2022. The course is open to Iberian Post-doctoral and PhD students, as well as international students.

1.1 Venue

University of Alcala,
Pl. de San Diego, s/n, 28801
Alcalá de Henares, Madrid, Spain
Phone: +34 918 85 40 00, **+34 91 885 50 00**
Website: **ciu@uah.es**

1.2 Organizers

The ScientificProgramme Committee
Antonio Guerrero, University of Alcala, Spain
NatchimuthukGopalswamy, NASA GSFC, USA
Kazuo Shiokawa, ISEE, Nagoya University, Japan

Programme Committee Members:
Consuelo Cid, University of Alcala, Spain
Patricia Doherty, Boston College, USA
George Maeda, Kyushu Institute of Technology
Christine Amory-Mazaudier, IPP, France
Ivan Dorotovič, Slovak Central Observatory, Slovakia
Shing Fung, NASA GSFC, USA
Bernd Funke, Instituto de Astrofísica de Andalucía, CSIC, Spain
Anna Morozova, University of Coimbra, IA, Portugal
Teresa Barata, University of Coimbra, IA, Portugal
Rui Pinto, IRAP, France
Ramon Lopez, University of Texas, USA
Karl-Ludwig Klein, Observatoire de Paris, France
Daniel Marsh, NCAR/University of Leeds, USA/UK
Antonio Guerrero, University of Alcala, Spain

The Local Organization Committee:
Antonio Guerrero, University of Alcala, Spain
Consuelo Cid, University of Alcala, Spain
Elena Saiz, University of Alcala, Spain
Manuel Flores-Soriano, University of Alcala, Spain
Carlos Larrodera, University of Alcala, Spain
Teresa Barata, University of Coimbra, IA, Portugal
Anna Morozova, University of Coimbra, IA, Portugal
Rui Pinto, IRAP, France

1.3 Project Group member:

During school we all participants divided in five groups of six participants in each. Following participants of group which assigned to me.

S.N.	Name of Participant	Affiliation	Country
1.	Shirsh Lata Soni	Vikram Sarabhai Space Center	India
2.	Nicholas Larsen	University of Oulu	Finland
3.	Karmen Martinic	Hvar Observatory, University of Zagreb	Croatia
4.	Liwei Chen,	ISEE, Nagoya University	Japan
5.	Tre’Shunda James	University of Texas Arlington	US
6.	Chaoran Gu	University of Kiel	Germany

2 Introduction of Project work

This Summer School is mostly focused on space weather observations and prediction techniques. During this School we had lecture series which covered the topic of solar physics, space weather, interplanetary disturbances, geo-magnetospheric and ionospheic responses due to solar eruption and associated social risks. These lectures were performed simultaneously with hands on training. The participants were divided in to five groups containing six students in each with one particularspace weather event.

We have assigned with a intense geo-magnetic storm event which occurred on 22 June 2015.This geo-magnetic storm is associated with a series of CME events which occurred 2-4 days back. In the middle of June 2015, the Sun's activity increased in one of the biggest sunspot active regions (AR) (NOAA AR 2371) directly facing Earth. We studied this event in detailed from near Sun to Earth.

2.1 Data Sources

i) We have used different filter images observed by Atmospheric Imaging Assembly (AIA), Solar Dynamic Observatory (SDO) for analyze the early signature of source region of CME events.
ii) We have traced the propagation of CMEs in interplanetary space from the observation taken from C2 and C3 coronagraph onboard SOHO/LASCO space craft.
iii) To analyze the impact of these CMEs/ICMEs at interplanetary and 1 AU, we used ACE and WIND spacecraft data.
iv) To observe geo-magnetic disturbances, we collect data from World Data Center, Kugi, Kyoto.

2.2 Near Sun Observations

On 18 June 2015 active region 12371 displayed a beta-gamma magnetic configuration, and was located at N09E50 (solar disc coordinates). It produced a long duration M3.0-class solarflare. The flare started at 16:30 UT, peaked at 17:36 UT and ended at 18:25 UT. A full halo CME was produced in thisevent. It was observed by SOHO at 17:24 UTC on 18 June (Figure 1).The second CMEoccurred at 19 June 2015 06:42 with the initial speed of ~584 km/sec. This particular eruption associated with filament present at SE section of visible solar disk, which is indicated by arrows in Figure 2. A coronal hole was present just above to this filament, which cause the open magnetic field and high speed of solar wind.The 2015 June 21 CME originated from NOAA AR 12371 located close to the disk center (N12E13) (Figure 3). This CME was observed from SOHO/LASCO C2 and C3 coronagraphsat 02:48 and 04:06 UT respectively.

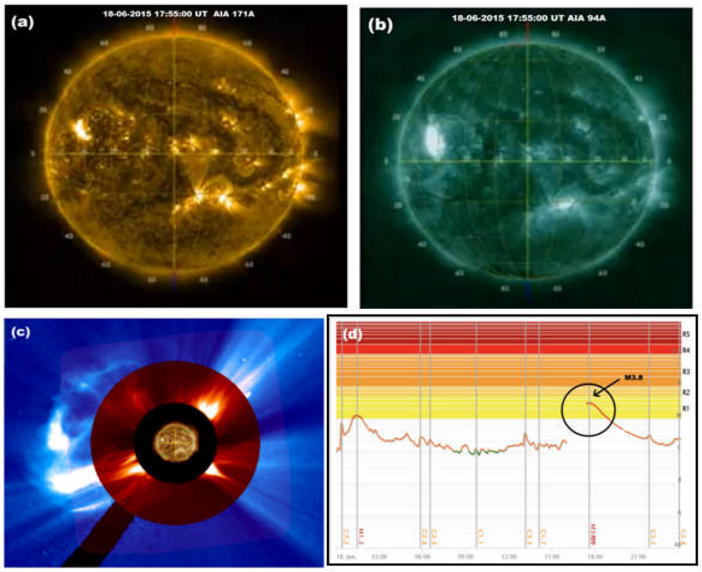

Figure 1: (a) SDO-AIA 171A image shows the eruption origin of CME 3 which occurred on 18 June 2015 17:35 UT. (b) source active region NOAA AR 12371 in SDO-AIA 94 A image. (c) Combined image of SDO-AIA 171A, SOHO-LASCO C2 (red) and C3 (blue) shows the eruption of CME 3. (d) GOES X ray profile presenting the association of CME-1 with M3.8 class flare.

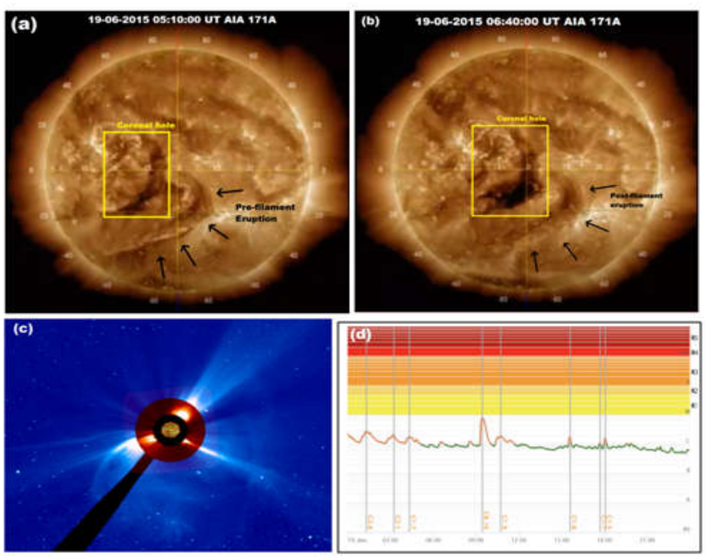

Figure 2: (a) Image is taken by SDO AIA 171A filter at 19 June2015 05:10 UT. showing the coronal hole present in visible solar disk and clear signature of pre-filament eruption. (b) Image observed by SDO AIA 171A filter shows presence of a coronal hole and signature of post-filament eruption. (c) Combined image of SDO-AIA 171A, SOHO-LASCO C2 (red) and C3 (blue) shows the eruption of CME 2. (d) GOES X ray profile presenting the association of flare, but as this particular CME associated with filament eruption so there is no associated flare.

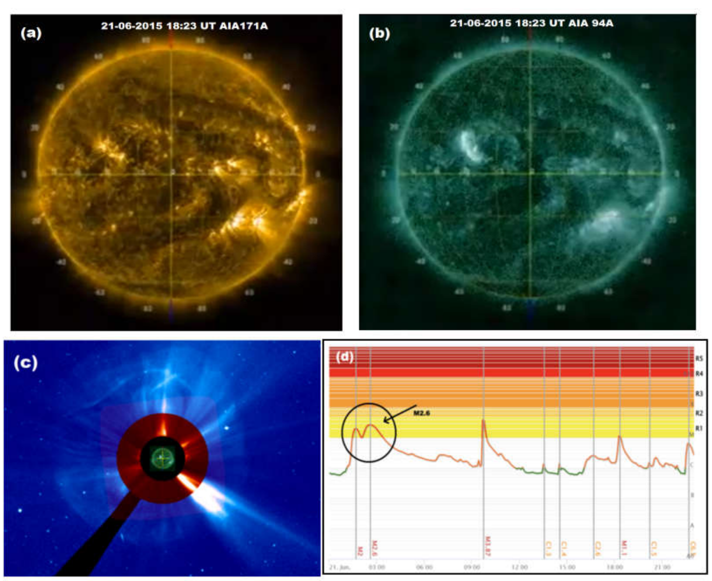

Figure 3: (a) SDO-AIA 171A image shows the eruption origin of CME 3 which occurred on 21 June 2015 02:48 UT. (b) source active region NOAA AR 12371 in SDO-AIA 94 A image. (c) Combined image of SDO-AIA 171A, SOHO-LASCO C2 (red) and C3 (blue) shows the eruption of CME 3. (d) GOES X ray profile presenting the association of CME-3 with M2.6 class flare.

2.3 Prediction with model

In this section of analysis we look for the interplanetary disturbances due to these merge CMEs. For that we run the WSA-ENLIL-Cone model ofheliospheric condition. By observing this model, we reported interaction of high stream solar wind with Earth magnetic field at 21 June 2015 07:00 UT. Following this shock associated with merged CME event reached to the Earth at 22 June 2015 10:00UT. With this model, we can also predict the interaction height of CME1, CME2 and CME3. We also observed that the all three CMEs interacted each other with their fronts and straight arrival towards the Earth. Figure 4 (right corner plot) shows the number density of solar wind at 1 AU. Here red line indicates the simulated data, blue line indicates the measured data and vertical blue line shows the location of Earth.

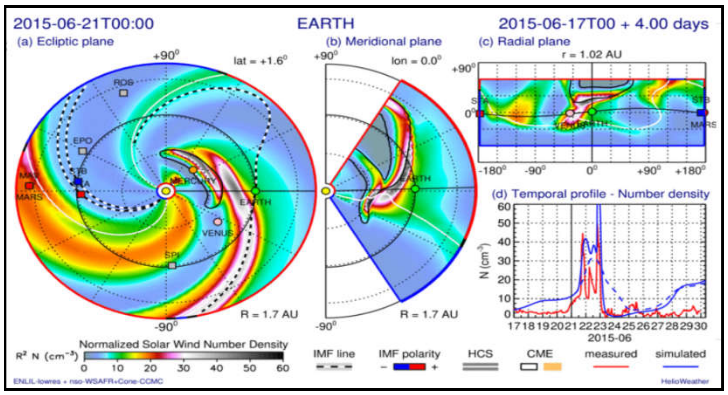

Figure 4:WSA-ENLIL-Cone model shows heliospheric condition. Second section shows the

2.4 Interplanetary Observation

As we can see from WSA-ENLIL-Cone model that the Earth was interacting with a high stream solar wind just before shock arrival. Figure 5, shows plots ofinterplanetary magnetic (IMF herewith) field and solar wind (SW herewith) parameters (speed, temperature, pressure, density etc) at 1 AU. Mild fluctuation in IMF and SW parameters are indication of high speed stream with Earth's magnetosphere. Observations show the clear enhancement in all the IMF and SW parameter at 22 June 2015 08:20 UT, which is the signature of shock arrival following to this shock. We can trace the signatures of sheath with fluctuation in almost all the parameters. Considering total magnetic field and southward component of IMF, we can observe smooth rotations in total magnetic field and corresponding negative rotations in Bz. These are the foot prints of CME1, CME2 and CME 3 respectively, indicated by arrow sign in Figure 5.

Figure 6 shows the plots for ion composition parameter with in solar wind at 1 AU observed from ACE spacecraft. We can clearly see the enhancement in Ion components Fe and O8/O6, which are the signatures of arrival of ICME.

2.5 Geo-magnetic storm

Figure 7 shows the geo-magnetic response for June 2015 month.Here we plot averaged Dst values obtained from four ground-based magnetometers. The circled signatures indicate the sudden enhancement in Dst. It presents compression of Earth's magnetic field due to arrival of shock. After this re-connection of southward Bz and Earth's magnetic field, Dst starts decreasing and reached to a minimum magnitude, which decide the strength of geo-magnetic storm. Our reported CME events occurred on late June 2015.

So here we observe second geo-magnetic storm present in Figure 7. In figure 7, circled section shows the sudden storm commencement due to shock arrival and then Dst value start decreasing and reached at minimum value about - 198 nT at 23 June 2015 with in very short period. Rectangle section shows the rising phase of storm, after that storm starts recover slowly.

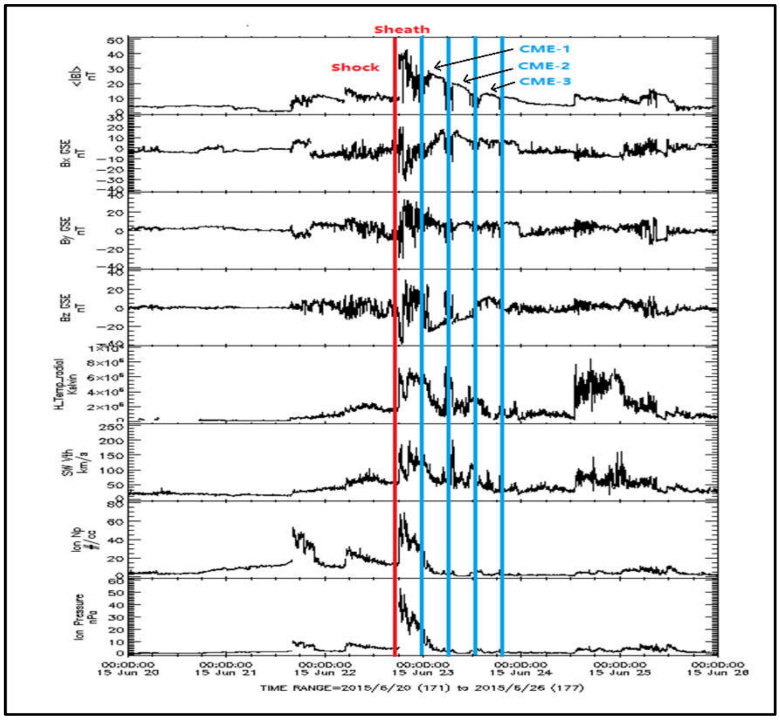

Figure 5: From top to bottom: total magnetic field parameter of Interplanetary medium, Bx, By and Bz component of interplanetary magnetic field, Temperature profile of solar wind, solar wind velocity, Ion density in solar wind and ion pressure at the bottom panel. Red vertical line indicates the arrival of shock, the section between red and first vertical blue lines presents the signature of sheath. we also indicate the footprints of CME1, CME2 and CME3 with arrow and vertical blue lines.

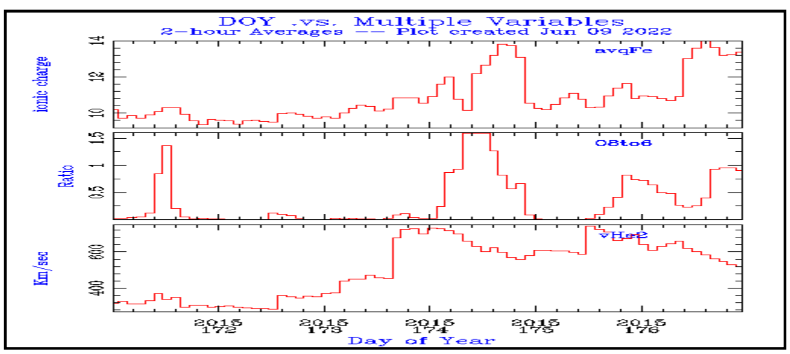

Figure 6: Ion composition in solar wind during storm period. Top to bottom: Ionic charge of average Fe, Ratio of O8 to O6 and He.

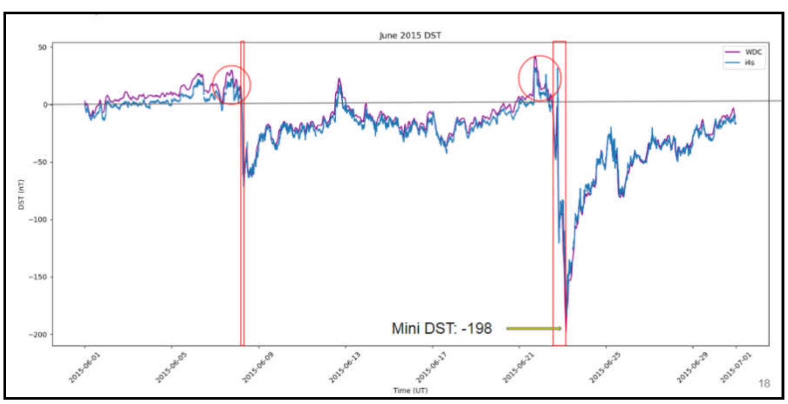

Figure 7: Averaged geo-magnetic DST values obtained from four stations.

2.6 Ionospheric study

Injection of energy into the magnetosphere from the incoming solar wind can lead to significant increases and decreases in ionosphere density, associated with the main and recovery phase of geomagnetic storm respectively. To analyze how the ionosphere responds we look at how the total electron content (TEC) changes over the period of a storm.

Obtaining ΔTEC:

1. Calculate the mean TEC during each hour of the day during quiet days of the same month.
2. Subtract this quiet value from the hourly TEC value recorded by satellites during the entire month.

Selection of quiet days:Quiet Days Picked: 1st, 2nd, 3rd, 4th, and 6th (0 flares detected on these days)Days Omitted Due to high number of flares or noticeable disturbances: 8th, 9th, 13th, 14th, 18th, 19th, 22nd, 23rd, 24th, 25th, and 26th.

- 2 large increases in ΔTEC followed by significant decreases between the dates of 22 - 26 June.
- Evidence that the ionosphere was impacted by some space weather event/s during this time period.

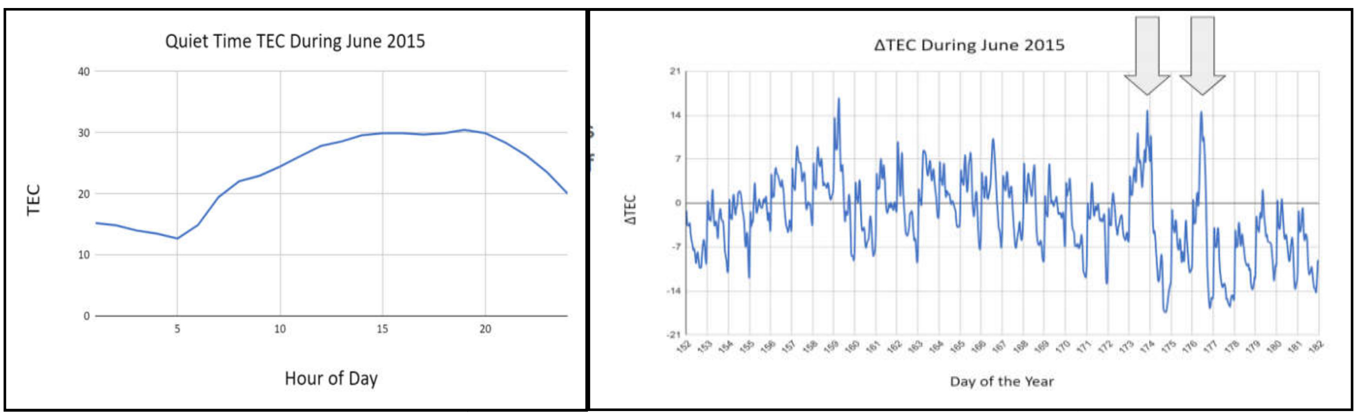

Figure 8: (Left) Quiet time TEC during a quiet day in June 2015. (Right) observed TEC over the month of June 2015.

3. Further work

During this Summer School, interaction with eminent scientists/experts working on this field from all over the globe provided wide vision of new possibilities and insights of space weather and space plasma for my further research work. We (all group members) are still working on this event for detailed analysis and trying to understand the complex interaction process of CME events at interplanetary medium. Regarding this, we are discussing with mentors of the School. Additional to this reported event, I have discussed other ideas for further work and collaboration with Prof. Nat Gopalswamy (GSFC, NASA), Dr. G. Antonio and Dr. C. Cid (Alcala University). Received very important feedback, kind suggestions and support from them. I am sure this collaboration will be of great use for my ongoing research work and would provide new dimension to the problem in which I am working on (kinematical behavior of solar transients).

4 Visits during School

There were two official trips during Summer School. The first trip was on 07 June 2022 to University of Alcala. The University of Alcala is a public university located at Alcala de Henares, a city 35 km northeast of Madrid in Spain and also the third-largest city of the region. It was founded in 1293 as a Stadium General for the public. We got to know about their study patterns, culture and rituals. The architecture of building is fantastic.

On Thursday, 09 June 2022, organizers arranged another professional visit to European Space Agency (ESA), Madrid. We have visited data center and solar observatory of ESA. We experienced the work culture of space center. The Scientists from ESA explained about their past, present future missions and discussed about techniques and scientific advantage etc.We acknowledge the organizers for the interesting and knowledge-full trips.