

Title:

Feasibility study of the use of I-LOFAR radio astronomy to analyse and predict solar weather

Background:

I chose this research project as I felt it had a real importance to both Ireland and the World. The Space Weather phenomena explained below can be extremely dangerous, costing Billions if not Trillions of dollars and potentially hundreds of thousands of lives should certain infrastructure be damaged. I hope that through this project I can incite research into our country's preparedness for Space Weather and promote that Irish-Based Telescopes can be self-sufficient in doing so. While some systems are in place, redundancy in the ability to predict these events is of vital importance, especially as during them, many systems are damaged or offline for protection.

The Sun is a very hostile, violent environment, which ejects huge amounts of hot material into the Solar System. The Earth has a magnetic field which protects us from these powerful emissions of radiation during normal Solar activity. This protection is weaker at the poles and so the aurorae borealis and australis occur. However, rare events occur which are much more powerful than normal Space Weather.

Space Weather includes the Solar Wind in which particles are constantly emitted on a day to day basis and do not impact infrastructure. Solar Flares are large eruptions of electromagnetic radiation, these happen more rarely and can be accompanied by Coronal Mass Ejections(CMEs) which are large emissions of plasma and magnetic field from the Sun's Corona. CMEs eject at minimum a billion kilograms of material. These events profoundly impact technology both in orbit and on the ground. Thankfully there is causality to these processes and predictive capability is achievable from studying the Sun.

The importance of satellites in our current lives is obvious. From predicting weather and analysing climate change for agriculture, GPS navigation and communicating all over the globe, they play a vital role in our society. These satellites, and their insights, are at risk from Space Weather. Solar phenomena impact communications with satellites due to perturbations in the Ionosphere. They damage sensitive electrical components and damage Solar panels.

Solar Weather also impacts important systems and infrastructure on the ground. Radio communications use the Ionosphere, allowing them to reach past the horizon. Changes in the Ionosphere affect its absorption of radio waves and lead to possible radio blackout.

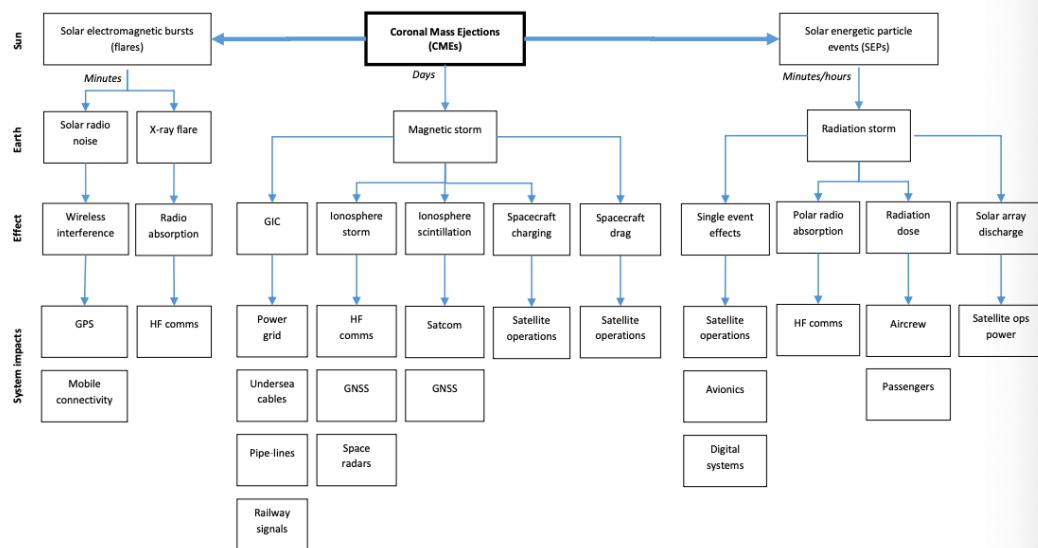
The most concerning effect of Solar Weather on ground infrastructure is Geomagnetically-Induced Currents (GICs). Like their namesake suggests, this is when a current is induced in a conductor, for example a power line or oil pipeline, by the Earth's magnetic field. These GICs are driven by geomagnetic disturbances resulting from Solar Weather.

There are many examples of GICs causing damage. The most famous of which is the Carrington event which happened in September 1859. Telegraph communications around the globe failed. Operators were badly shocked by arcing electricity spewing out of the machines. Platinum contacts, with a melting point of over 1,700°C were close to melting. Even much later, the GICs were so powerful that operators could send messages with their telegraphs unplugged [1]. Thankfully in the Victorian era technology was sparse and had little impact on the lives of those at the time.

A more recent and much less powerful Solar Flare and CME was in 1989 when transformers in Quebec's power grid were damaged. Leading to a power outage which caused \$13.2 Million damage to infrastructure and economic loss of \$2.9 Billion [2]. Another CME in 2012 barely missed Earth. Had it erupted one week earlier the economic impact could have been \$2 Trillion[3]. These figures are similar to others found in literature which warn of the devastating impact of CMEs. The Human cost of losing power for an extended period is likely to be high.

This table shows the effects of Space Weather:

Figure 2 Space weather impact tree (Adapted from Hapgood et al. 2016)



[4]

While these events are thankfully rare, they still warrant investigation into analysis and predictions of Space Weather. Most of these predictions are done via satellite on missions such as SOHO(Solar and Heliospheric Observatory) and SDO(Solar Dynamics Observatory). These satellites rely heavily on chronograph data to determine eruption velocities and to track CMEs through space, yet I believe radio astronomy should be used as a reliable backup and supplement. During these events systems can go offline, so a ground based redundancy should be investigated.

Aims and Methodology:

In this research project I aim to use the Irish Low Frequency Array (I-LOFAR) radiotelescope to analyse both historical and current Space Weather data, cross reference this with data from satellites and develop a system to predict Solar Activity which may affect Earth, in particular Ireland. I will also conduct research into the Irish Power Grid (EirGrid) and how well protected it is from Space Weather events, and make recommendations on how we can protect EirGrid.

Research Supervisor:

Professor Evan Keane, Associate Professor of Radio-Astronomy. During this project he will support me with the use of the telescope and analysis of data. He is also on-site in Birr with other researchers to repair and operate the telescope safely. Professor Keane has established contact with Professors in the Dublin Institute for Advanced Studies who have offered their support and had input on this project’s goals and feasibility.

Timeline:

Week 1: Develop an understanding of the use of the telescope, how to access and process historical data from I-LOFAR. Establish contact with EirGrid operators/engineers and substations.

Week 2: Continue to develop skills in data analysis of the telescope and develop software to analyse data.

Week 3: Visit Substation and interview engineers on their opinion of the impact of Space Weather. Use my software to detect Space Weather in historical data.

Week 4: Cross reference data from SOHO and SDO with radioastronomy data ie. test the model.

Week 5: Combine SOHO, SDO data with I-LOFAR data to predict Solar Activity.

Week 6: Conduct feasibility study into the benefits of radio astronomy in predicting Space Weather and as a redundancy for chronograph data.

Outcomes:

After 2-3 weeks I plan to have a working, predictive model. In the second 3 weeks this model will be tested with other datasets from satellites. At the end of the project I will combine this research with information gathered about the grid to conduct a feasibility study on the use of radio astronomy for predicting space weather and to make recommendations on how we should better prepare for these events.

Contingency:

All of this project is possible to be done at home. Problems with the telescope would not be an issue as the vast historical data is sufficient.

References:

1. Carlowicz, Lopez, 2002, National Academic Press
2. Bolduc, 2002
3. Baker, University of Colorado, 2014
4. Oughton, University of Cambridge (adapted)