Researching Solar Storms With Citizen Scientists: Engaging With Four Thousand Volunteer Research Assistants

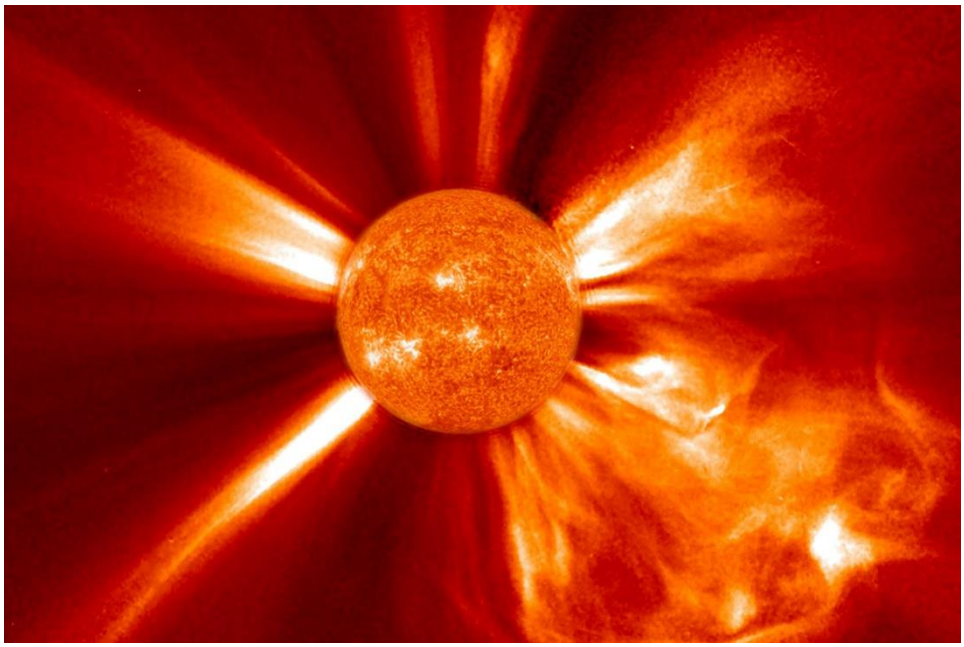
Professor Chris Scott, Dr Luke Barnard and PhD student Shannon Jones have been collaborating with a global community of thousands of citizen scientists using the Zooniverse platform, conducting open research about solar storms as they travel through interplanetary space.

Coronal mass ejections (CMEs, or solar storms) are eruptions of plasma and magnetic field from the Sun's corona. At Earth, a CME can disrupt modern technologies such as satellites, power grids and high-altitude aircraft. In order to accurately predict their arrival at Earth, it is essential that we learn as much as we can about the nature and evolution of CMEs.

Why citizen science?

These projects have provided a fantastic opportunity to engage with thousands of volunteers whose time and enthusiasm have enabled us to conduct original research that would not otherwise have been possible.

In 2006 NASA launched the twin STEREO spacecraft, whose cameras returned a huge number of images revealing the complexity of CMEs. Experts rarely have time to study more than a handful of such events, as manually combing through these data is very time-consuming, while automated algorithms still lack the capacity to accurately identify CMEs. The Solar Stormwatch citizen science project, which ran on the **Zooniverse citizen research platform** from 2011 to 2016, was developed to address this issue, asking volunteers to help identify and track CMEs. This was very successful, with over 16,000 participants enabling us to build the world's first citizen-science generated CME catalogue[1] leading to the publication of **seven scientific papers**.



Composite image showing coronal mass ejection © STEREO (NASA)

We have subsequently developed two additional projects. **Protect our Planet from Solar Storms**, created in collaboration with the Science Museum, and **Solar Stormwatch II** both use novel techniques that have enabled over 4,000 users to study the detailed structure of CMEs and trace CME 'storm fronts', in images from STEREO's Heliospheric Imagers (HI). These projects encourage users to interact via 'talk' forum pages, while a **blog** is used to keep participants up to date with the research they have helped create.

Citizen science eliminates the subjectivity of a lone expert, using instead 'the wisdom of the crowd'. For example, we combine features identified by 30 participants in each CME image, allowing us to estimate the location of the storm front with uncertainty estimates.

When creating these projects, one challenge was how to explain the task clearly to ensure consistency. For example, in pre-release tests for Solar Stormwatch II, we found that participants tended to draw around the brightest storm fronts in each image, rather than the outer, more diffuse front. The instructions were subsequently altered so that users were asked to trace both the 'brightest' and 'outermost' storm fronts, which solved the problem.

It is very rewarding to see people actively engaged in our research. We regularly interact with participants, answering questions on the forum. One high-school student from the USA was even inspired to create the first automated algorithm to trace storm fronts in HI data. We are now working with her to test the accuracy of her technique. Many participants spot unusual features in the images, which can provide unexpected avenues for future research. In the Protect our Planet from Solar Storms project, many participants have identified dust trails and 'ghost fronts', which will be used to seed future research projects.

The results of our citizen science projects are published in peer-reviewed journals. In the spirit of open collaboration, all our publications are Open Access, the most recent supplemented with code and data published online using GitHub and figshare respectively[2].

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Open at a glance

- Project developed the first ever citizen science-generated catalogue of Coronal Mass Ejections (CMEs)
- Thousands of people took part in research, making original contributions and being credited in Open Access research articles
- Members of public have developed research methods and started new lines of enquiry for future projects
- Data and code are freely available online

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References and further information

1. Barnard L. et al. (2014). The Solar Stormwatch CME catalogue: results from the first space weather citizen science project. Space Weather 12(12): 657-74. **https://doi.org/10.1002/2014SW001119** .

2. Jones, S. R. et al. (2017). Tracking CMEs using data from the Solar Stormwatch project; observing deflections and other properties. Space Weather 15(9): 1125-40. **https://doi.org/10.1002/2017SW001640**

Protect our Planet from Solar Storms **https://www.zooniverse.org/projects/lepnoir/protect-our-planet-from-solar-storms**

Solar Stormwatch II **https://www.solarstormwatch.com/**

Solar Stormwatch Blog. **https://blog.solarstormwatch.com/**