Weathering solar storms

An Irish solar physicist is unravelling the causes of gas eruptions from the sun in an attempt to improve daily space weather forecasts. **Andrew Read** reports

An Irish scientist wants to understand massive eruptions on the sun that can play havoc with satellites, communications systems and power grids. The solar explosions produce "space weather" that batters our planet in the same way that waves batter a coastline.

These are no ordinary explosions. They spew out billions of tonnes of electrically charged gas that rush from the sun at tremendous speeds, says Dr Peter Gallagher, who works in the US space industry.

Called coronal mass ejections (CMEs), the eruptions can knock out satellites and communication systems if their particles plough into Earth. "Part of my job is to forecast space weather for military and commercial clients, warning them if and when we'll be hit," he says. "The other part of my job is to improve the forecasts, and this requires a better understanding of the solar physics responsible for CMEs."

The ejections, which move at up to eight million kilometres an hour, can occur once a week or three times a day, depending on the solar cycle, says Dr Gallagher. They are too faint to see from Earth and were discovered only three decades ago, using spacecraft.

They typically occur with a solar flare. Solar flares, which can be seen from Earth, are explosions in the sun's atmosphere. "Big ones have the power of a million megatons of TNT," says Dr Gallagher.

"Flares and the CMEs usually occur within a few seconds of each other. What's not been clear is whether the flares cause the CMEs or the reverse. It's been a classic chicken-and-egg question." His recent work now provides the answer.

Dr Gallagher, originally from Dublin and a graduate of University College Dublin and Queen's University Belfast, has been working at Goddard Space Flight Center near Washington DC for two years.

He and his collaborators used three spacecraft to watch a single ejection. "This was the first time we were able to identify and study in detail the region on the sun where the initiation and acceleration of a CME occurs," he says.

"The sun has an intense magnetic field. From a distance it looks like a well-organised bipole, just like the Earth's. But, up close, on the sun's surface the field is extremely complicated," he says.

The convective motion of gas generates the complicated field. "It's like a pot of porridge churning away. The magnetic fields are embedded in the porridge. When the fields bump into each other they snap and release energy into the atmosphere."

The new data show that when the fields snap – "reconnect", in the jargon – the resulting energy release causes gas to be ejected from close to the sun's surface. If there is enough energy the result is a solar flare, which can punch a hole through the magnetic fields that "keep the lid on things", he says. Gas escapes through the hole to become a coronal mass ejection.

"So the chicken-and-egg question was the wrong question. Both the flare and the CME are a consequence of the large-scale restructuring of the magnetic field," he says.

"The challenge for the next few years is to move that level of analysis to operational forecasting," he says. "We are currently able to forecast the arrival at the Earth of CME and flare-related radiation and particles to within half a day's accuracy. But at the moment we can't say much about how big – how energetic – the blast will be."

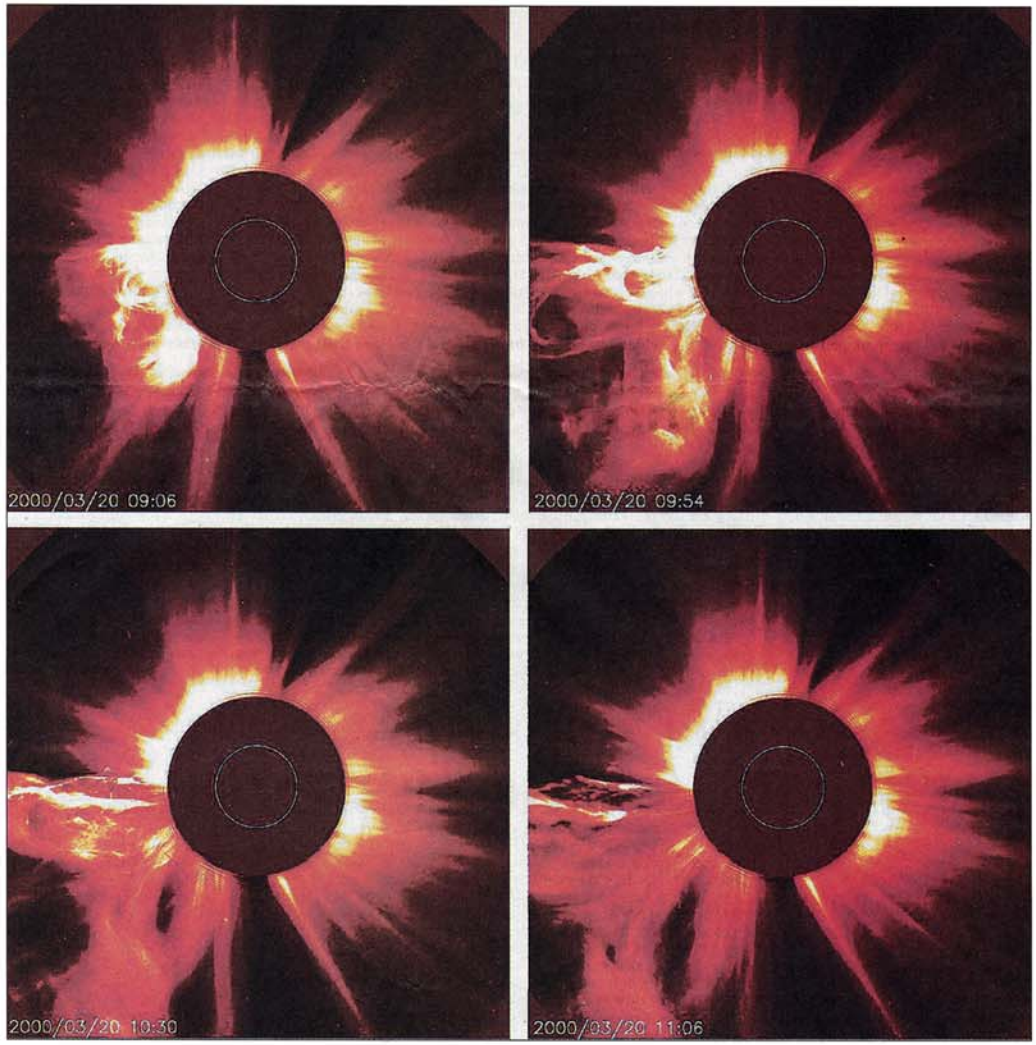
The ejections' effects on human activity can be substantial. "The electronics of satellites can be disrupted or destroyed. Some satellites have been completely lost."

The accuracy of the Global Positioning System can also be temporarily affected, generating positioning errors of several hundred metres. This can have serious consequences for aircraft navigation.

"The most famous disruption caused by CMEs happened in 1989, when a huge charge dumped into the Earth's upper atmosphere caused a current surge in some electrical grids. Quebec was plunged into darkness."

NASA is particularly interested in the forecasts because coronal mass ejections affect its extra-vehicular activity – spacewalks.

"It could be fatal to astronauts if they are hit by the ejecta," says Dr Gallagher.



Seeing red: a CME spews particlesinto space. The sun is indicated by the inner circle (NASA/ESA)

Hundreds of people were involved in supporting the spacecraft involved. Two of the spacecraft, *RHESSI* and *TRACE*, are in low Earth orbit. The third, *SOHO*, is parked at L1, about 1 per cent of the distance to the sun, at the point where Earth's and the sun's gravity balance.

SOHO is a $1 billion collaboration between NASA and the European Space Agency. The three spacecraft each brought different instrumentation to bear. "It took six months to properly analyse the data," he says.

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