

AURORAL BUMPS

Understanding non-monotonic truncation of scale-free fluctuations in Earth's aurora and other systems

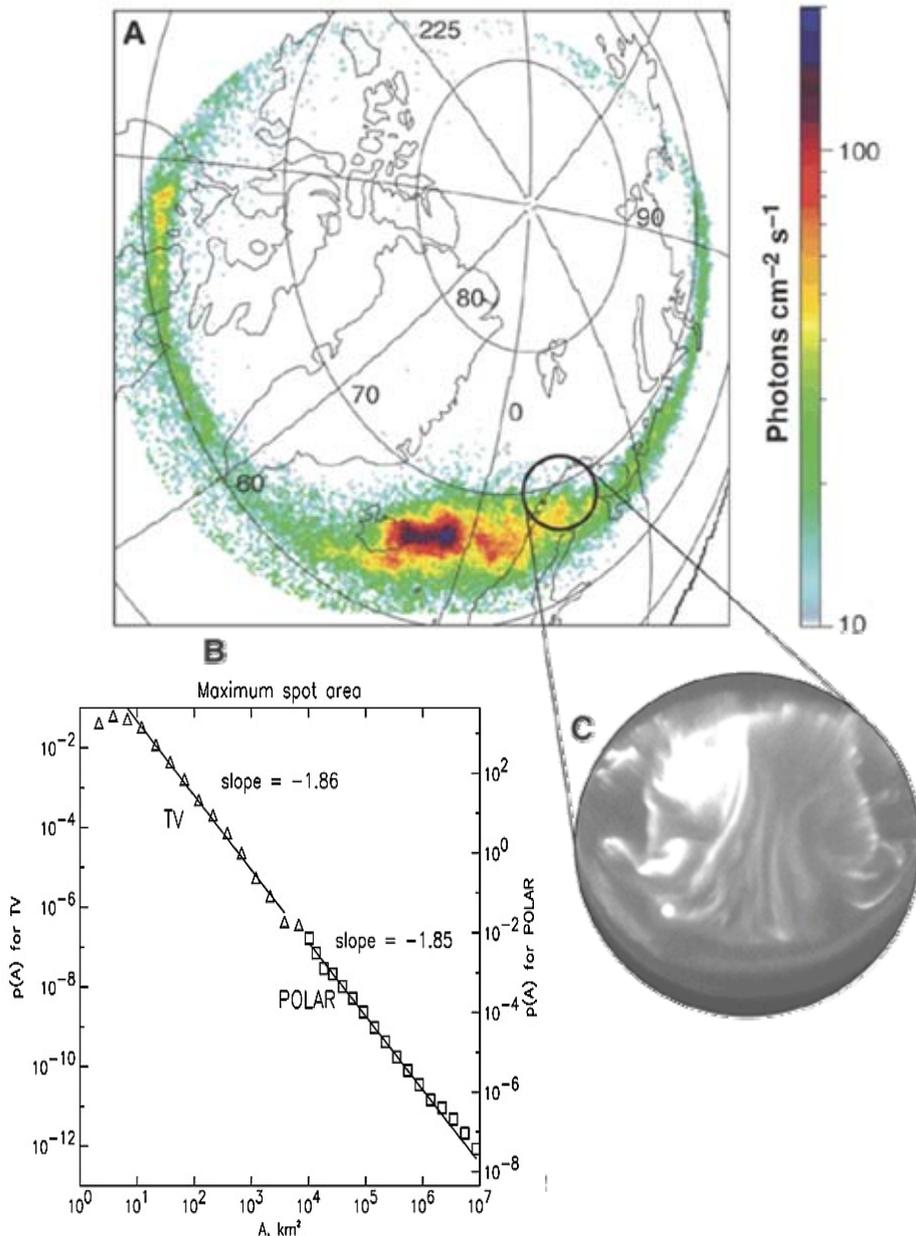
with Dr Mervyn Freeman at the British Antarctic Survey, Cambridge

The aurora (aka the northern lights) has long been an object of beauty and fascination, but increasingly it has also become a target for scientific investigation. This is not only to resolve its mysteries but also because its fluctuations influence radio communications, navigation systems, and electricity supply networks, and also provide a window on processes happening further out in space that affect satellites and astronauts.

Dramatic auroral displays over Earth's polar regions reveal a range of intricate patterns. Over the years, certain auroral structures have been identified at different spatial and temporal scales and been given names such as spirals, curls, westward-travelling surges, omega bands, etc. However, more recently, attention has begun to focus on whether there may be universal aspects to auroral structure, of the type observed in many complex natural systems. Indeed, if we look at the aurora as a whole it appears that the auroral structures such as spirals and curls are in fact part of a fractal landscape of fluctuations with no characteristic scale in time and space – a power law probability distribution of fluctuation durations and areas (see figure).

Eventually this distribution must be truncated when fluctuations reach time and space scales corresponding to the size of the system. However, it appears that the truncation is not simple and that, rather than decrease monotonically, there is a bump in the distribution at the largest scale (you might just be able to see this in the graph in the figure). Similar bumps may also be present in the scale-free fluctuations of other natural phenomena. One idea for explaining this is provided by non-ideal cellular automata models of self-organised criticality in finite size systems.

This mini-project will explore the different types of truncation of scale-free fluctuations in natural systems and the reasons for them. This will be done by a combination of literature review, analysis of experimental data from the earth's aurora and possibly other natural systems, computational experiments using cellular automata and/or mathematical analysis. The results are expected to lead to the publication of a paper in the peer-reviewed scientific literature. The mini-project will also introduce the student to the Natural Complexity research group at the British Antarctic Survey with a view to identifying a PhD project of mutual interest and benefit.



Complex beauty. (A) Ultraviolet image of Earth's aurora viewed from space by NASA's Polar satellite at 21:19:23 universal time (UT) on 16 February 1997. Structures in the auroral luminosity are seen on many scales from the global to the image resolution (~ 20 km) and evolve on many different time scales. (C) An optical image of the aurora taken from the ground at about the same time (21:20:20 UT) as (A) reveals details of auroral structures to even smaller scales. The image radius is ~ 200 km centered above Kilpisjärvi, Finland. North is at the top of the image; the bright round spot in the southwest sky is the Moon. (B) When different evolving auroral spots above a given luminosity threshold were tracked, the probability distribution of fluctuation area is a power law for spatial scales from ten to a million square kilometres (a straight line when plotted with logarithmic axes). This means that there is no typical bright spot size – for any given area there are always 13 times fewer patches that are four times bigger and 13 times more patches that are four times smaller. (Similarly for fluctuation duration and other measures.)

[Adapted from Freeman, M. P., and N. W. Watkins, *Science*, volume 298, 1 November 2002]