

Dynamic processes in flare-hosting active regions: seismograph, metronome, or precursor?

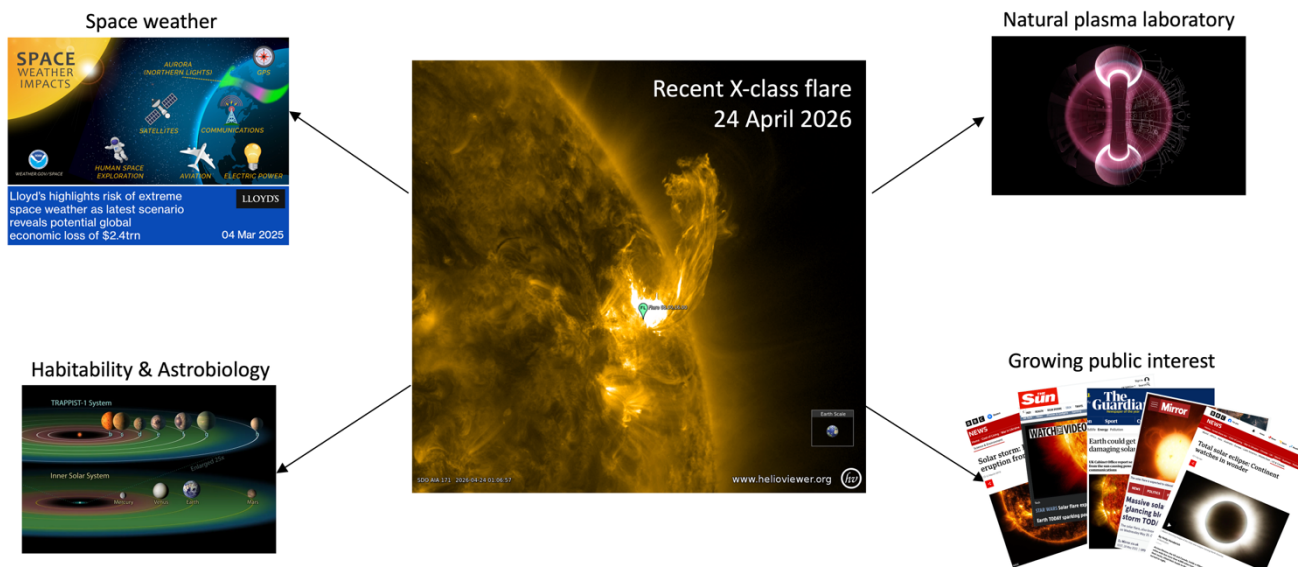
Supervisor: Dr Dmitrii Kolotkov

Centre for Fusion, Space & Astrophysics, Department of Physics

Anticipated funding: STFC (subject to confirmation of the allocation, expected in early 2027)

Anticipated start: October 2027

Solar flares are the most powerful explosive events in the Solar System, releasing up to 10^{32} erg of magnetic energy within minutes to hours across the entire electromagnetic spectrum, from radio waves to gamma-rays. They heat the coronal plasma to tens of millions of kelvin, accelerate particles to relativistic energies, and are often accompanied by coronal mass ejections. Flares are a principal driver of space weather: they disturb the Earth's ionosphere, degrading high-frequency radio communication and satellite navigation, and raise radiation hazards for spacecraft, astronauts and aviation. Beyond the Sun, stellar superflares shape the space environment and potential habitability of exoplanets. Flares also offer a natural laboratory for plasma processes, such as magnetic reconnection, particle acceleration and instabilities, under conditions unattainable on Earth and relevant to laboratory and fusion plasmas, and they attract growing public interest. Despite decades of research, the physical conditions that bring an active region to the point of flaring remain poorly understood, and flare forecasting continues to rely largely on statistical properties of the photospheric magnetic field.



Flare-hosting active regions are never at rest. Their coronal loops, fans and plumes continuously support magnetohydrodynamic (MHD) waves and oscillations, quasi-periodic pulsations and broadband fluctuations of emission, which are routinely detected in EUV, X-ray and radio observations. This project asks what these dynamic processes can reveal about the flares produced by their host regions, considering three complementary roles:

- **Seismograph.** Waves and oscillations are natural probes of the plasma in which they propagate. MHD coronal seismology uses them to estimate the magnetic field, transport coefficients and the coronal heating and cooling processes. A recent addition is the entropy mode, a non-propagating and non-oscillating MHD eigenmode which, as we have recently shown, leaves measurable imprints on compressive oscillations. Its potential for diagnosing the thermodynamic state and thermal stability of active regions is yet to be revealed.
- **Metronome.** Oscillations excited by a flare, and quasi-periodic pulsations of the flare emission, have characteristic periods determined by the physical parameters of the flaring region. They therefore provide an independent timing reference against which analytical and numerical flare models can be calibrated and tested.
- **Precursor.** The frequency content of active-region emission changes in the run-up to a flare: for example, the power-law indices of the EUV intensity power spectrum deviate from their quiet-time values from several minutes to about an hour before flare onset. We will develop this idea through the concept of the frequency response spectrum, borrowed from structural engineering, where shifts in natural frequencies, damping and

the shape of the response function are used to detect the deterioration of bridges and buildings before failure. Can an active region approaching a flare be diagnosed in the same way?

The specific research direction will be formulated together with the successful candidate, according to their interests and background: for example, observational data analysis or theory and numerical modelling, flare prediction or seismological diagnostics, or a combination of these. The project will make use of data from world-leading spaceborne and ground-based instruments (e.g. SDO, Solar Orbiter, Aditya-L1 and radio interferometers), MHD theory and simulations, and modern time-series analysis and machine-learning techniques. The student will join the Centre for Fusion, Space & Astrophysics and will benefit from its collaborations with research groups in the UK and overseas.

Applicants should hold, or expect to obtain, a first or upper-second class degree (or equivalent) in physics, mathematics or a closely related subject. Programming experience (e.g. Python) is an advantage; prior knowledge of solar physics is not required. Although funding is yet to be confirmed, interested candidates are strongly encouraged to get in touch and prepare their applications now, so that an offer can be made promptly once the studentship allocation is announced.

Eligibility: Open to UK and international applicants, subject to UKRI eligibility rules.

How to apply: Contact the supervisor before applying.

Contact: Dr Dmitrii Kolotkov, D.Kolotkov.1@warwick.ac.uk

Web page: warwick.ac.uk/fac/sci/physics/research/cfsa/people/kolotkov

Further reading:

1. Kolotkov, D. Y., Belov, S. A., & Sherif, M. (2026). Entropy-mode imprints in the solar corona: non-exponential damping and phase shifts of compressive oscillations. *ApJL*, 1004, L26. [doi:10.3847/2041-8213/ae7720](https://doi.org/10.3847/2041-8213/ae7720)
2. Zhong, S., Kolotkov, D. Y., & Nakariakov, V. M. (2026). Power-law indices of EUV intensity power spectrum in flaring coronal active regions. *ApJ*, 1000, 114. [doi:10.3847/1538-4357/ae48e5](https://doi.org/10.3847/1538-4357/ae48e5)
3. Nakariakov, V. M., & Kolotkov, D. Y. (2020). Magnetohydrodynamic waves in the solar corona. *ARA&A*, 58, 441. [doi:10.1146/annurev-astro-032320-042940](https://doi.org/10.1146/annurev-astro-032320-042940)