Microwave Oscillations in a solar flare

Rohit Sharma[1], Marina Battaglia[1], Sijie Yu[2], Bin Chen[2]
[1]Fachhochschule Nordwestschweiz, Bahnhofstrasse 6, 5210 Windisch, Switzerland
[2]Center for Solar-Terrestrial Research, New Jersey Institute of Technology, Newark, USA

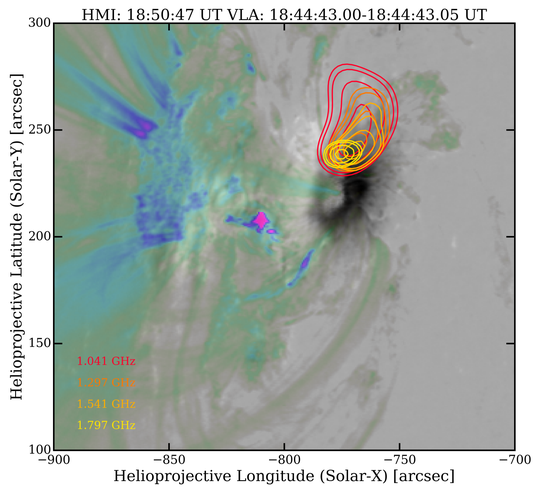
Introduction

During solar flares, particles are accelerated to relativistic energies producing radio bursts at a large range of frequencies. The intensity of these radio bursts depends on their emission mechanism and the local conditions such as magnetic field strength, plasma density and the distribution of accelerated electrons. However, the presence of MHD waves in the loops can periodically change the local magnetic fields, resulting in modulations and oscillations of the observed radio bursts.

Objective

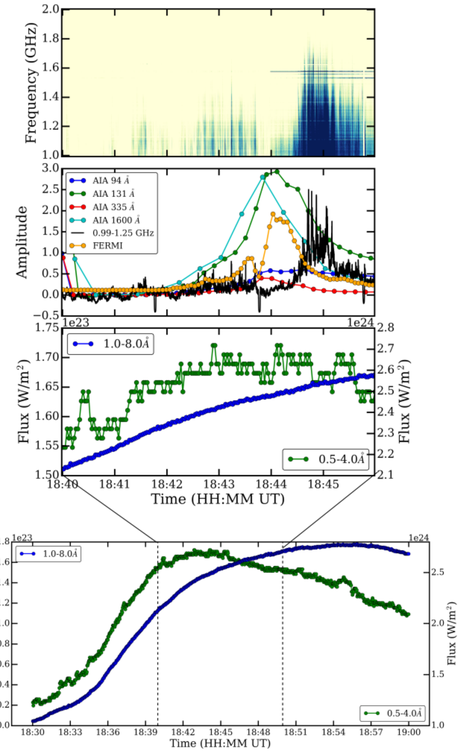
We study microwave pulsations that occurred after a GOES C1.5-class flare and were observed with the Karl G. Jansky Very Large Array (VLA) at 1–2 GHz. VLA's high temporal resolution (50 ms), along with imaging spectroscopy, provides a detailed view of the pulsations. We also utilise the Solar Dynamics Observatory in extreme ultraviolet (EUV) and magnetic extrapolation to build a coherent picture.

Radio Sources Location



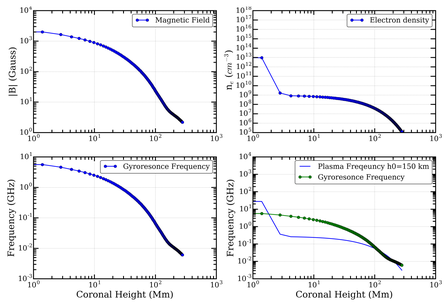
The background gray image shows the HMI magnetogram super-imposed with the AIA 171 map along with the VLA radio contours. We note that the radio sources are extended at low frequencies and their location are non-co-spatial with flare location.

Multi-wavelength Observation



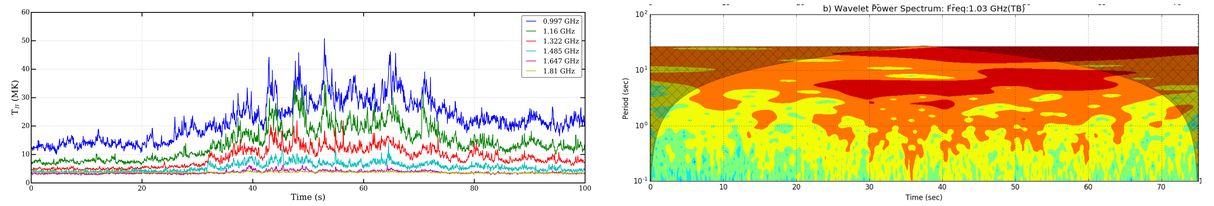
Temporal evolution of radio and EUV emission during the C1.5-class flare on 2016 April 9. The top panel shows the VLA dynamic spectrum. The second panel from the top shows the frequency-averaged line VLA plot along with FERMI X-rays (10-14 keV) lightcurve and EUV flare region-averaged line-plot for various wavelengths. The bottom panels show the GOES X-ray lightcurves. The FERMI curves show two peaks coincides with the EUV flare. The radio bursts occur post EUV flare. The radio oscillations can be seen in the bursts.

Electron Cyclotron Emission Mechanism (ECM)

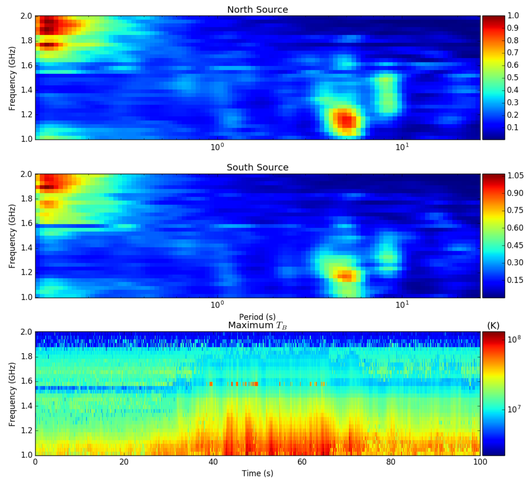


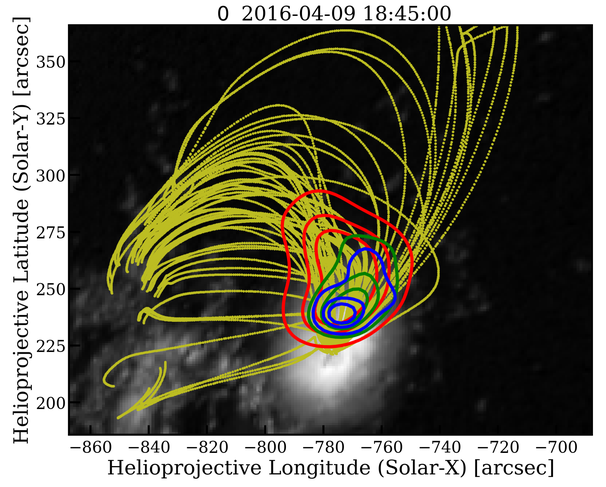
Coronal density and magnetic field model for the line-of-sight corresponding to the radio source. We note that computed gyroresonance frequency exceeds plasma frequency for 11 Mm to 100 Mm coronal heights, thus providing necessary conditions for ECM source.

Wavelet Analysis and Magnetic Extrapolation



Left Panel shows the radio source brightness temperature for various frequency bands obtained by averaging 50% and greater in the map. The 5 sec oscillations are clearly seen. We do wavelet analysis for the timeseries for each frequency element. The right panel shows the wavelet power for the 1 GHz timeseries. We note that power at 5 sec dominates between 20 sec to 45 sec, while power dominates at 7 sec from 45 sec to 65 sec.





Left panel shows the global wavelet power spectrum for each frequency band. Here top and middle panel shows the power spectrum for the northern and southern extension of the sources. We note that the 5 sec period occurs at low frequencies (higher heights) and 7 sec at middle frequencies (lower heights).The right panel shows the magnetic extrapolation at the location of the radio source. We note that the field lines converges at the sunspot and coincides with radio sources.

Conclusions

Using simultaneous radio and EUV observations, we present a scenario of pulsating ECM source with multiple periods, possibly in different magnetic loops since, even though the EUV flare emission occurred at the other end of the loop footprint as shown by the magnetic extrapolation.

- High brightness temperature (10^8 MK), polarisation properties accompanied by suitable magnetic field strengths, and coronal density suggest Electron-Cyclotron Emission (ECM).
- The imaging shows multiple source locations non-co-spatial with flare location. The magnetic extrapolation reveals the magnetic connectivity from the flare location to the microwave sources providing channels for the energetic particles from the flare site to the radio source location.
- The microwave pulsations are observed from 1 GHz to 1.5 GHz exhibit two 5 secs and 7 secs for all frequency channels, most likely caused by Sausage mode oscillations. During pre-bursts time 7 sec periods were observed for all frequencies from 1 GHz to 2 GHz suggesting multiple electron transport channels oscillating with different periods.