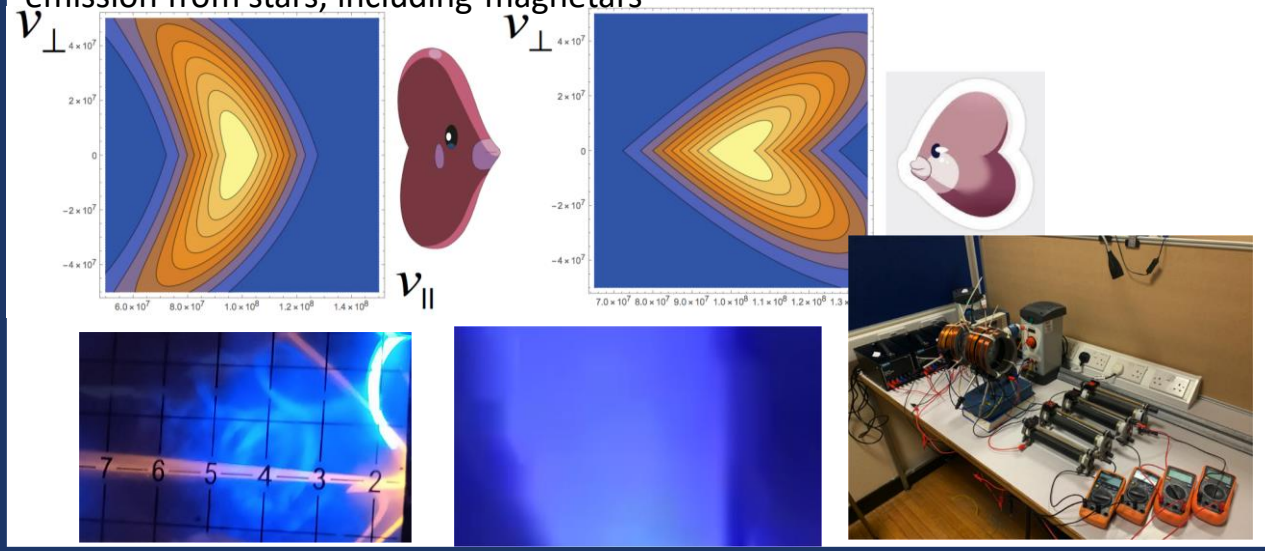
New cyclotron maser instability in electron beams due to magnetic field varying with time: theory and a simple experiment

Author(s): Irena Vorgul, Max Ayling, Conor Straub, Daniel MacKay, Joseph Houghton, & Gavin Lamb
Institution(s): University od St Andrews
Funder(s): School of Physics and Astronomy, University of St Andrews

Abstract
Last summer, we were doing a summer project research with five students from St Andrews. The project was a pilot research into developing a new experimental and theoretical framework to examine kinetic beam instabilities arising from a *magnetic field gradually changing with time*. It is relevant to laboratory/tokamak plasma diagnostics and to a wide class of astrophysical plasmas.

Luvdisk distribution in theory and experiment, and a sketch of a resultant emission from stars, including magnetars



Project Description
We combined theory and experiment, using a simple desktop set-up with a cathode tube and up to six pairs of magnetic coils allowing changing the magnetic field.
We found a new type of beam instability which can cause a cyclotron maser emission with distinct properties. Its frequency is conventionally close to the local cyclotron one, but the direction of radiation varies over a wide range. This change of direction can be responsible for deviations from periodicity in pulsars and magnetars.. We suggest the available data for gamma-rays emission from magnetars fits the properties of the above cyclotron emission. For a laboratory plasma, with cyclotron maser emission being the only non-invasive diagnostic tool, the found properties could refer change of the emission's direction to the time variations of local magnetic field.

Key Results, Conclusions, Comments
- a new type of instability found from theoretical derivations, which we called a *Luvdisk instability* (after a Pokemon ☺);
- evidences of this instability seen happening in the experiment involving an electron beam in a cathode tube trapped in gyrations by a set of six pairs of magnetic coils, the field of which we were changing in time;
- Looking for evidence of the effects in astrophysical observations, we found a relevance to magnetars' high-frequency (gamma-rays) emission.

Refs: I. Vorgul, M. Ayling, C. R. Straub, D. M. MacKay, J. Houghton, & G. A. Lamb, *New kinetic cyclotron instability for electron beam in time-changing magnetic fields*, Journal of Plasma Physics, Volume 86, Issue 3, 2020, http://dx.doi.org/10.1017/S002237782000046X.
Two more papers in preparation.