Background

What are Ellerman Bombs?

Ellerman bombs (EBs) are small-scale, transient brightening events observed mainly in the wings (but not the cores) of chromospheric spectral lines, such as Hα and Ca II H, occurring in the lower solar atmosphere — specifically the upper photosphere to lower chromosphere. They're mostly related to magnetic reconnection events and are observed around sunspots on the Sun. Here's a Figure from Dr Nelson's 2012 that show a clear picture associated with these events. They've "campfire" like appearance when viewed by this angle.

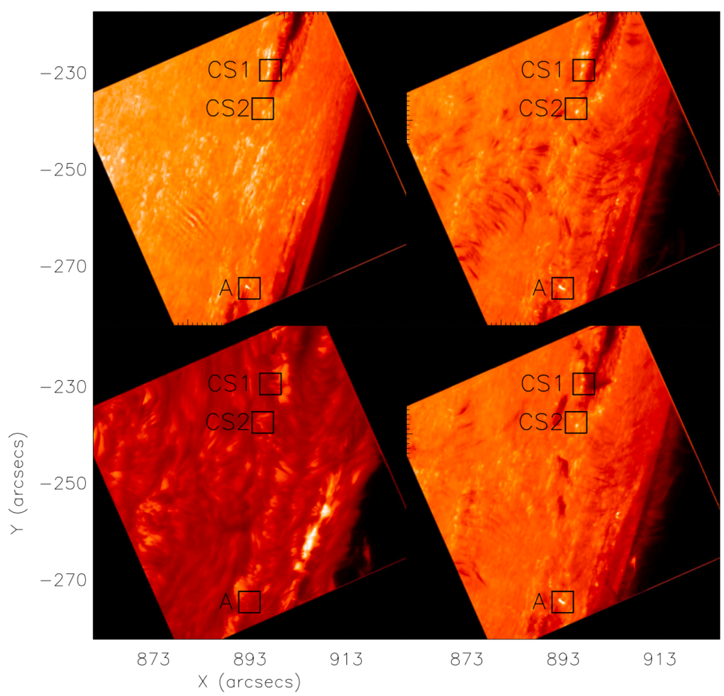

Figure 1. FOV of AR 11506 analyzed within this article (corrected for local instrumental wavelength shifts), sampled at four positions within the Hα line scan: the far blue wing (approximately -1.8 Å; top left), the near blue wing (-0.95 Å; top right), the Hα line core (0 Å; bottom left), and the red wing (+0.95 Å; bottom right). The black boxes in each image indicate the regions of interest analyzed in the following sections. A known artifact of the image reconstruction process is visible in the far blue wing at (883, -260).

CUME 488

Total Points: 49
Guaranteed Passing: 36.75
Duration: 2 hours

CUME 484 is inspired by the recent paper: *"Magnetic diffusion in solar atmosphere produces measurable electric fields"*

You will receive the paper at 09:00 am and questions by 10:00 am. You will have to hand over the answers by 12:00 noon.

To successfully complete the CUME 488, you will need basic understanding of solar atmosphere and solar phenomena. The paper should introduce you to these.

Technical details: You will need pen, paper and calculators (note: phone/ipad apps cannots be used as calculators).

Contact me in 202A from 9am to 12 noon.

Part 1: Magnetic Diffusion Basics (23 points)

1. Magnetic induction.

(a) Starting from Faraday's Law

$$\partial \mathbf{B}/\partial t = -\nabla \times \mathbf{E}$$

Where **B** is the magnetic flux density vector, **E** is the Electric field vector and t is time.

and a generalized Ohm's Law that includes both conduction and Hall effects:

$$\mathbf{E} + \mathbf{v} \times \mathbf{B} = \eta \mathbf{J} + \frac{1}{ne}(\mathbf{J} \times \mathbf{B}),$$

Where v is plasma velocity, η is the scalar resistivity, **J** is the electric-current density, n is electron (or charge-carrier) number density, **e** is the elementary charge 1.602×10−19 C.

derive **the magnetic induction equation**

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{v} \times \mathbf{B}) + \eta \nabla^2 \mathbf{B} - \nabla \times \left(\frac{1}{n_e e \mu_0} (\nabla \times \mathbf{B}) \times \mathbf{B} \right)$$

μ0 is the magnetic permeability of free space .

All units are in SI units. (Application) **(8 points)**

(b) Identify the Hall effect terms of the induction equation (Knowledge) **(1 point)**

2. Ampère's Law

(a) Write down Ampère's Law in differential form, including the displacement current term. (Knowledge) **(3 points)**

(b) Justify why the displacement current is neglected in the derivation of the magnetic induction equation for magnetohydrodynamics (MHD) (Evaluation) **(3 points)**

3. Reynold's number

(a) Identify the convection and diffusion terms from the magnetic-induction equation (Understand). **(2 points)**

(b) Derive the magnetic Reynolds number, R_m (Analyse). **(2 points)**

(c) State the conditions in the solar atmosphere where $R_m \gg 1$ and $R_m \ll 1$, and explain their physical meaning (Evaluate). **(4 points)**

Part 2: Polarisation and atomic processes. (18 points)

4. Zeeman and Stark effects

(a) Describe Zeeman splitting and the Stark effect. (Knowledge) **(2 points each) (4 points)**

(b) How will each of these differ in a Sunspot and EB (Application) **(2 points each) (4 points)**

5. Stokes' profiles

Refer to Figure 3 or Figure 4 in the paper by Anan et al. (2024).

(a) Describe the shape of the Stokes V/I profile of the Hε line shown in the figure. What makes this profile unusual compared to a typical Zeeman-induced profile (Understand)? **(4 points)**

(b) What physical mechanism do the authors propose to explain the observed profile? (Remember) **(2 points)**

6. Electric fields from VISP

For each of the two electric-field mechanisms below, name *one* clear signature you would expect to see in a ViSP Hε Stokes-V/I profile. Briefly state why that feature arises (2 pts per mechanism, **4 points total,** Application).

(i) Linear Stark broadening/shifting
(ii) Alignment-to-Orientation (A–O) conversion

Part 3: Observation and Observational techniques. (8 points)

7. (a) Describe the factors that prevented earlier observations from measuring electric fields in the solar atmosphere, and specify the particular advances of the DKIST facility that finally made such a detection achievable.
(Comprehension) **(4 points)**

(b)Using the Stokes-V/I Hε profiles in Figure 3 (or 4) of Anan et al. 2024 as your reference, qualitatively predict how the two key aspects of electric-field signatures—net circular polarization (NCP), and amplitude—would change if the data were recorded at five-times poorer spatial resolution. (Synthesis) **(4 points, 2 points per property)**