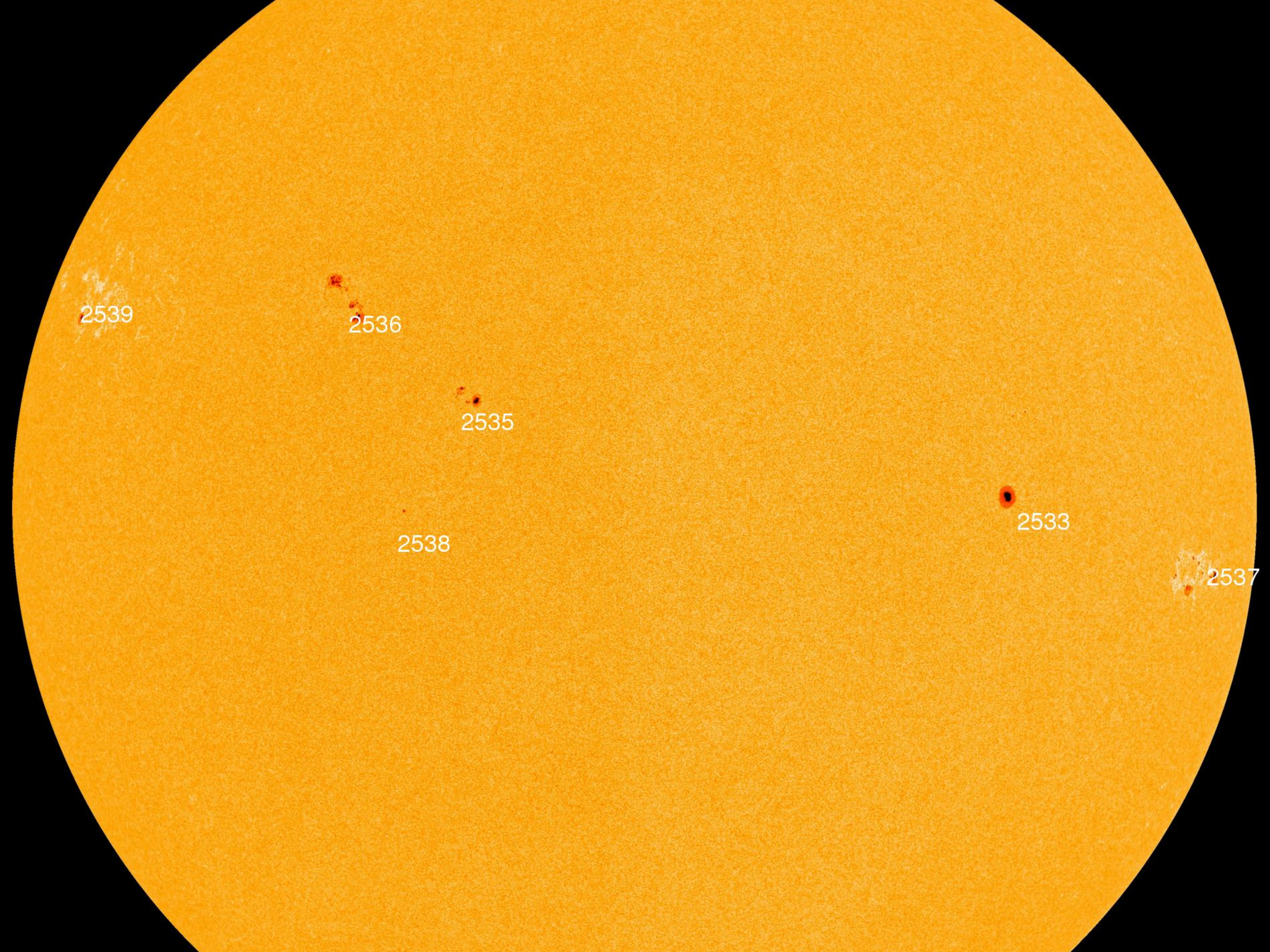

2016/04/27
UFOCaptureV2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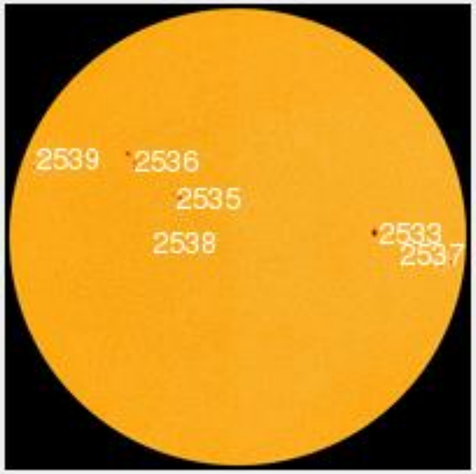
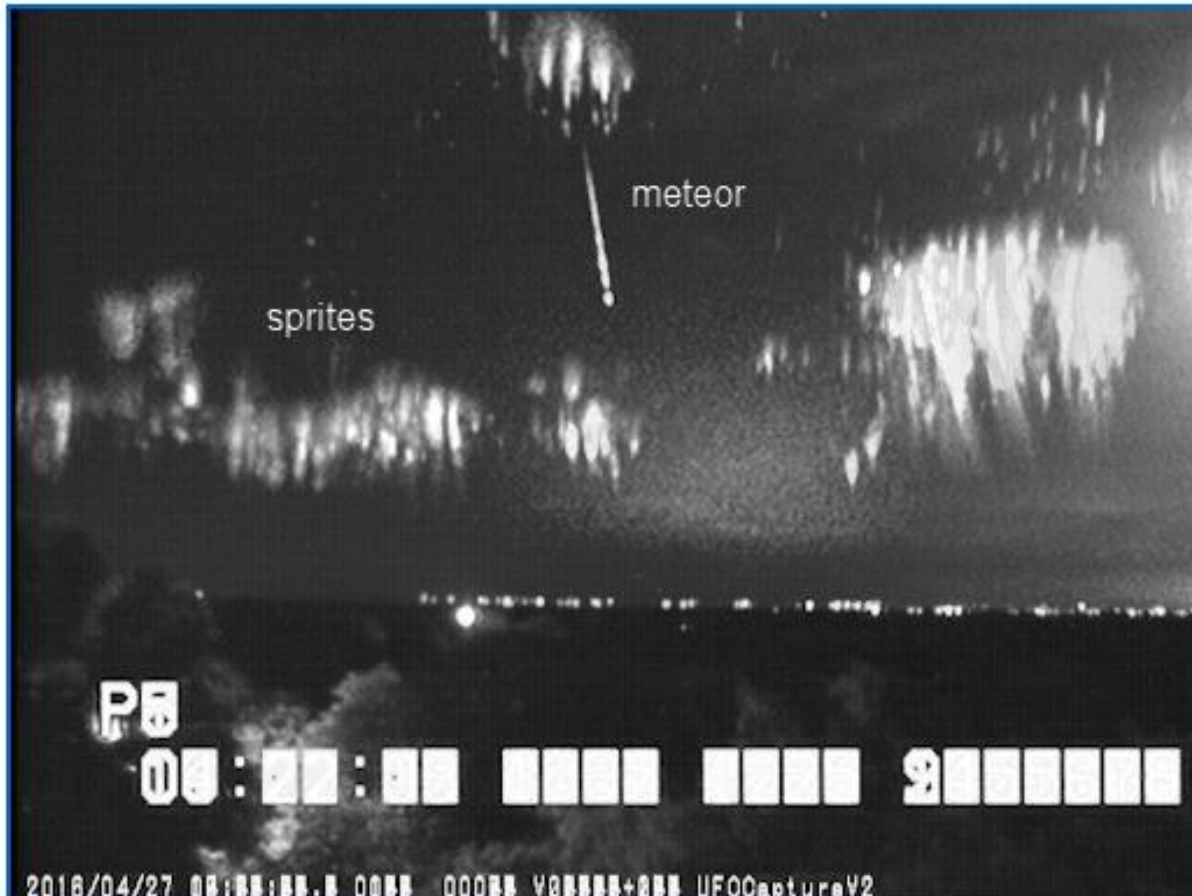


Sunspot AR2535 iscrackling with [C-class](#) solar flares. One of those flares hurled a CME in the general direction of Earth on April 28th. Forecasters say the CME could deliver a glancing blow to Earth's magnetic field on May 1st. Credit: SDO/HMI

Sunspot number: 84
[What is the sunspot number?](#)
Updated 29 Apr 2016

Spotless Days
Current Stretch: 0 days
2016 total: 0 days (0%)
2015 total: 0 days (0%)
2014 total: 1 day (<1%)
2013 total: 0 days (0%)
2012 total: 0 days (0%)
2011 total: 2 days (<1%)

"SPACE LIGHTNING" OVER TEXAS: You know what comes out of the bottom of thunderstorms: lightning. On April 27th, Kevin Palivec of Hawley, Texas, saw something coming out of the *top*. "Storms moving across Texas produce more than just rain, wind, hail and tornadoes!" says Palivec. "They also produce a lot of space lightning called '[sprites](#).' This is a stacked image of all the sprites I caught over storms as they moved across Texas towards Dallas/Ft Worth--with one meteor thrown in!"



Because sprites are associated with thunderstorms, they tend to occur in late spring and summer. Palivec's photo shows that **sprite season is now underway**.

Last time…

- More on final report
  - Relation to other work (introduction)
  - Where to go from here (conclusions)
- Results so far

Lecture 40

- Review & questionnaire
- More on final report
- Results so far
- Final words

Lecture 2

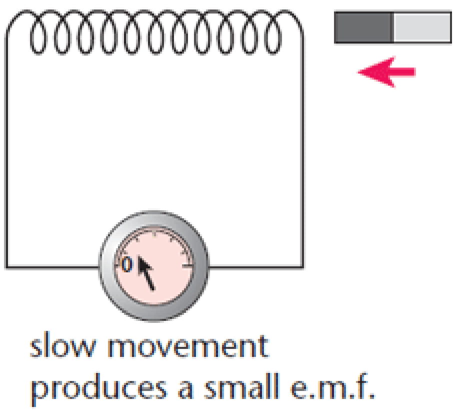
$$I_\nu(\nu,T) = \frac{2\nu^2}{c^2} k_{\mathrm{B}} T$$

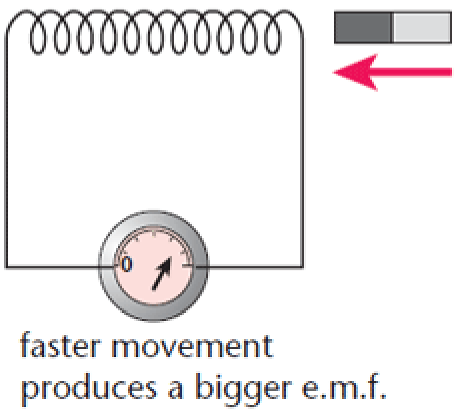
$$I_\lambda(\lambda,T) = I_\nu(\nu,T)\frac{c}{\lambda^2} = \frac{2\nu^2}{c^2}\frac{c}{\lambda^2} k_{\mathrm{B}} T$$

$$= \frac{2c}{\lambda^4} k_{\mathrm{B}} T$$

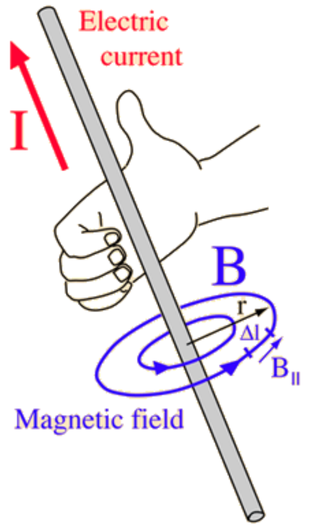
Lecture 5

Q1: Faraday's law





Q2: Ampere's law



A. $$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}$$

B. $$\nabla \cdot \mathbf{B} = 0$$

C. $$\mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} = +\nabla \times \mathbf{B} - \mu_0 \mathbf{J}$$

D. $$\nabla \cdot \mathbf{E} = \rho_c / \varepsilon_0$$

Stokes U = Stokes I

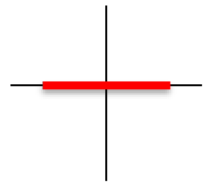
$$E_x = \xi_x \cos\phi, \quad E_y = \xi_y \cos(\phi + \varepsilon)$$

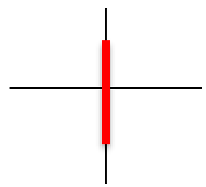
$$I = \xi_x^2 + \xi_y^2$$

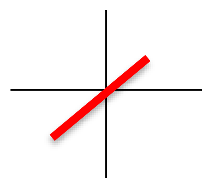
$$Q = \xi_x^2 - \xi_y^2$$

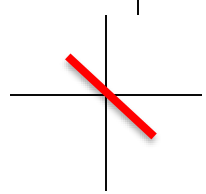
$$U = 2\xi_x \xi_y \cos\varepsilon$$

$$V = 2\xi_x \xi_y \sin\varepsilon$$

A. 

B. 

C. 

D. 

Lecture 6

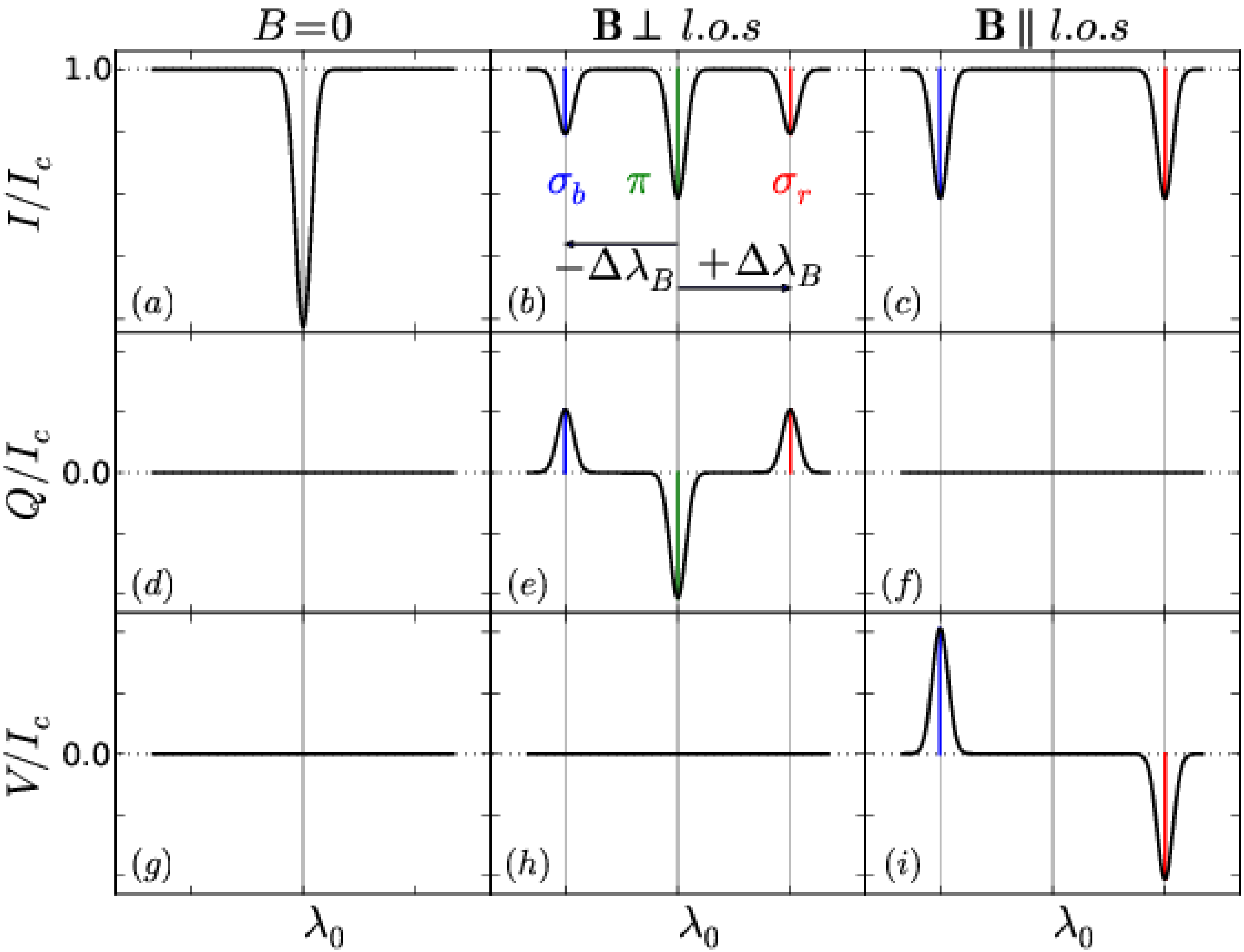
$$\varepsilon_{123} = \varepsilon_{231} = \varepsilon_{312} = 1$$
$$\varepsilon_{321} = \varepsilon_{213} = \varepsilon_{132} = -1$$
$$\varepsilon_{ijk} = 0 \text{ otherwise}$$

Also: totally antisymmetric tensor

what is $\varepsilon_{ijk}\varepsilon_{ijk}$??

A. 0
B. 1
C. 3
D. 4
E. 6

Lecture 8



$B = 0$
$\mathbf{B} \perp l.o.s$
$\mathbf{B} \parallel l.o.s$
1.0
0.0
0.0
I/I_c
Q/I_c
V/I_c
σ_b
π
σ_r
$-\Delta\lambda_B$
$+\Delta\lambda_B$
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
λ_0
λ_0
λ_0

What is $e^{-3i\pi/4}$?

A. $(1+i)/\sqrt{2}$

B. $(1-i)/\sqrt{2}$

C. $(-1+i)/\sqrt{2}$

D. $-(1+i)/\sqrt{2}$

Lecture 11

Expand continuity eqn:

$$\frac{\partial\rho}{\partial t} = -\nabla\cdot(\rho\mathbf{u}) = -\mathbf{u}\cdot\nabla\rho - \rho\,\nabla\cdot\mathbf{u}$$

Momntum eqn (isothermal):

$$\rho\frac{\partial\mathbf{u}}{\partial t} = -\rho\mathbf{u}\cdot\nabla\mathbf{u} - \frac{\Re T}{\mu}\nabla\rho + \ldots$$

Linearized form

$$\frac{\partial\rho_1}{\partial t} = -\rho_0\nabla\mathbf{u}_1$$

$$\rho_0\frac{\partial\mathbf{u}_1}{\partial t} = -\frac{\Re T}{\mu}\nabla\rho_1$$

Trial solution

$$\rho_1(z,t) = \hat{\rho}_1 e^{ik_z z - i\omega t} + \text{c.c.}$$

$$u_{1z}(z,t) = \hat{u}_{1z} e^{ik_z z - i\omega t} + \text{c.c.}$$

$$\begin{pmatrix} i\omega & -ik_z\rho_0 \\ -ik_z\dfrac{\Re T}{\mu} & i\omega\rho_0 \end{pmatrix}\begin{pmatrix}\hat{\rho}_1 \\ \hat{u}_{1z}\end{pmatrix} = 0$$

Dispersion relation $\omega^2 = \dfrac{\Re T}{\mu}k_z^2$

$c_s = \sqrt{\Re T/\mu}$ Sound speed

Lecture 12

Dispersion relation of Lecture 11

$$\omega^2 = \frac{\Re T}{\mu} k_z^2$$

In 3-D

$$\omega^2 = c_s^2 \, (\underbrace{k_x^2 + k_y^2}_{k_{\mathrm{hor}}^2} + \underbrace{k_z^2}_{k_{\mathrm{vert}}^2})$$

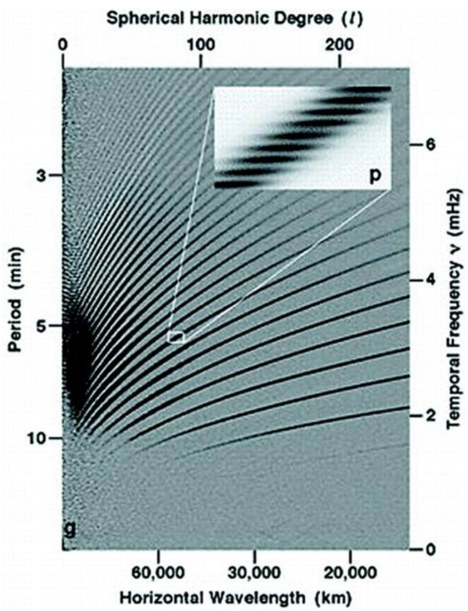
“Solve” for k_z

$$k_z^2 = \frac{\omega^2}{c_s^2} - k_{\mathrm{hor}}^2$$

Consider $c_s = c_s(\mathrm{r})$ [oops?]

In quantum mechanics:
WKB approximation

→ Jeffreys-Wrentzel-Kramers-Brilloin
→ Tunnel effect → Gamow!!



Example

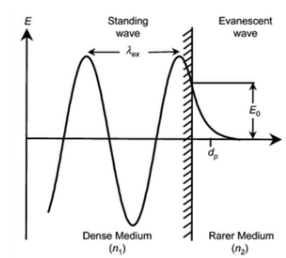
$$\omega = \frac{2\pi}{300\mathrm{s}} = 0.02\mathrm{s}^{-1}$$

$$k_{\mathrm{hor}} = \frac{\ell}{R} = \frac{100}{700\,\mathrm{Mm}}$$

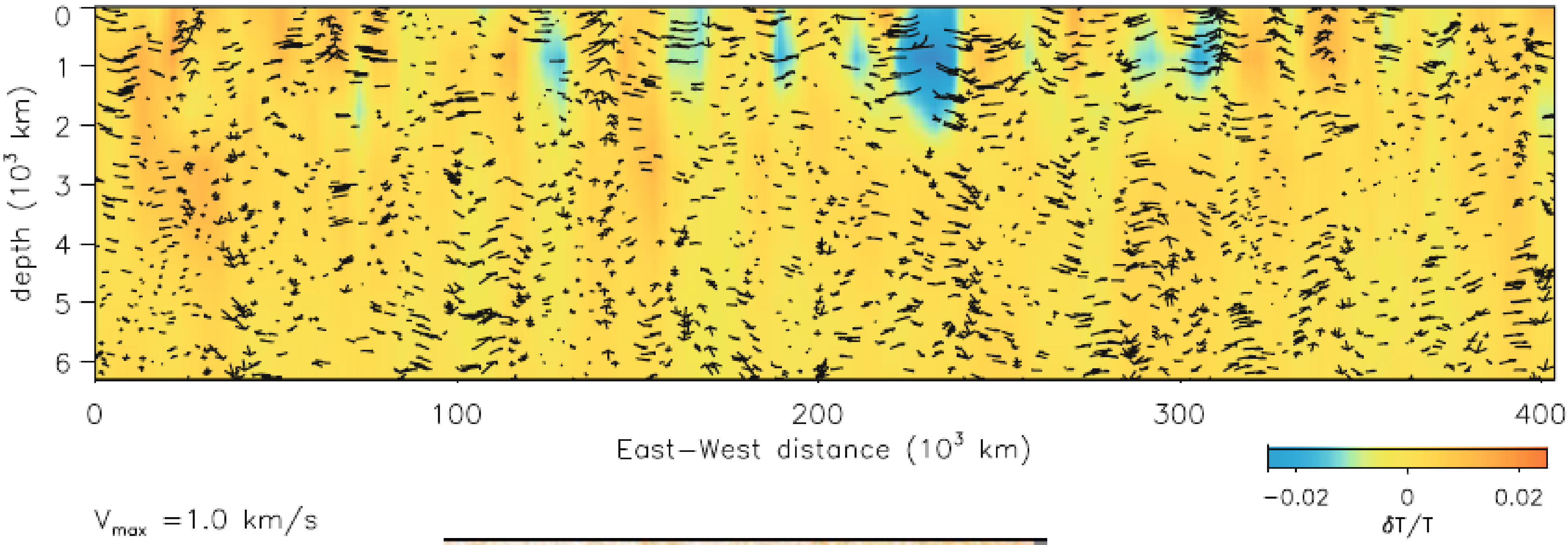
$$c_{\mathrm{s}} = \frac{\omega}{k_{hor}} = 0.02 \times 7\,\frac{\mathrm{Mm}}{\mathrm{s}} = 140\,\frac{\mathrm{km}}{\mathrm{s}}$$

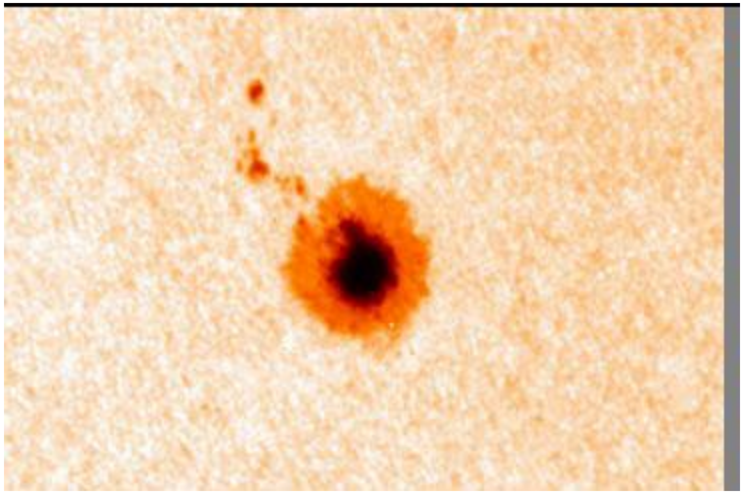
Deeper down: k_z imaginary!?

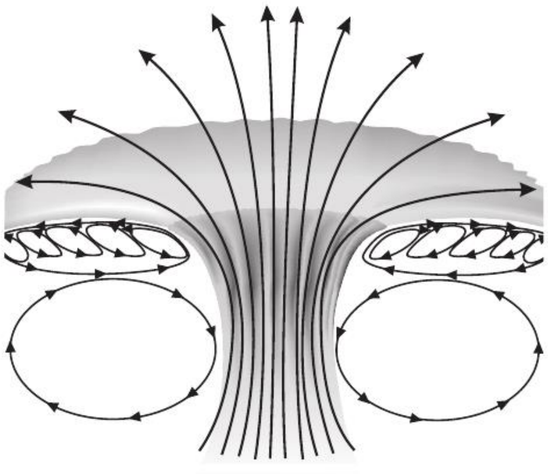
$$e^{ik_z z} = e^{\mp |k_z| z}$$



Lecture 13







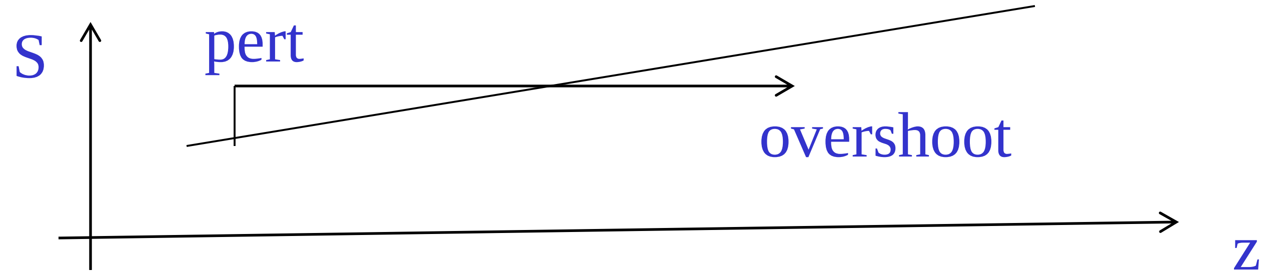
Sunspot imaging
…but uncertain!

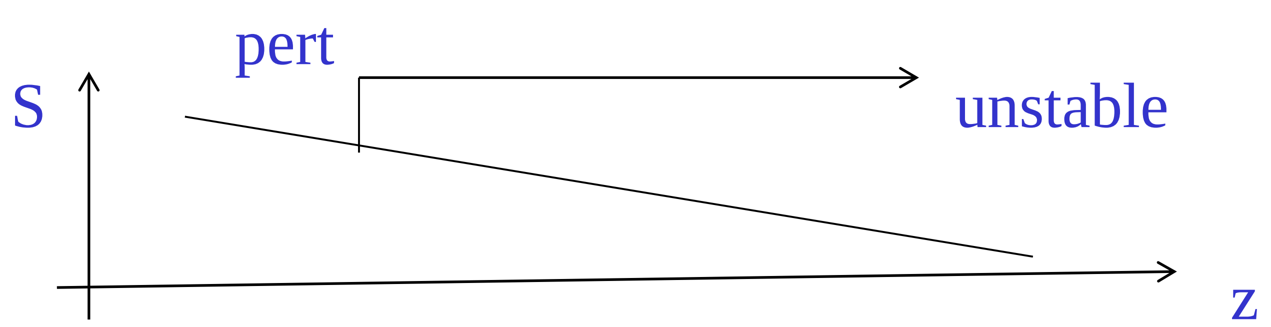
Lecture 15

$$s / c_p = \frac{1}{\gamma} \ln P - \ln \rho$$

Adiabatic changes: S=const

P equilibrium: S+ → buoyant





Lecture 16

Momentum equation

$$\rho \frac{D\mathbf{u}}{Dt} = -\nabla P$$

Multiply by ***u***

$$\tfrac{1}{2}\rho \frac{D\mathbf{u}^2}{Dt} = -\mathbf{u}\cdot\nabla P$$

Internal energy equation

$$\rho c_v \frac{DT}{Dt} = -P\nabla\cdot\mathbf{u} + \rho T \frac{Ds}{Dt}$$

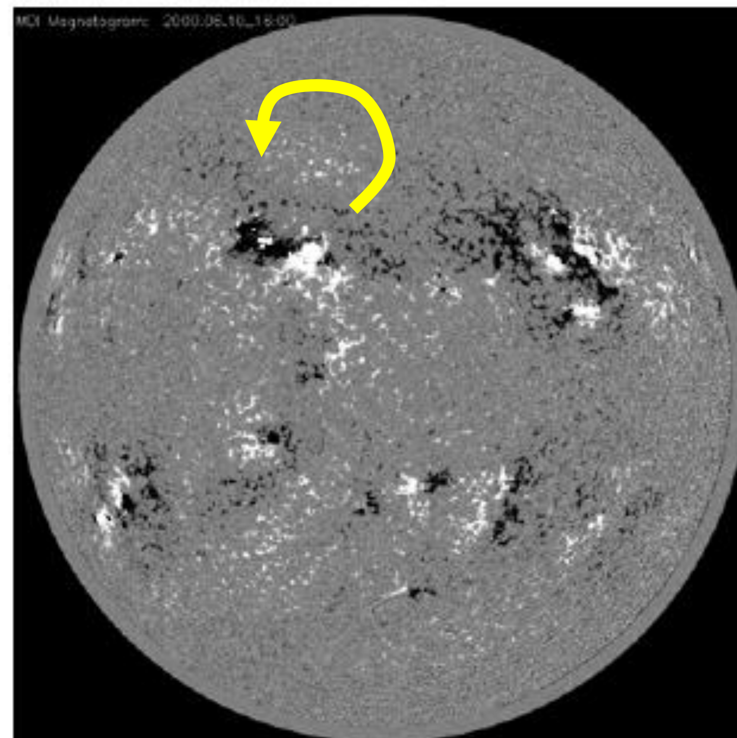
Add the two to get one part of total energy equation

$$\tfrac{1}{2}\rho \frac{D\mathbf{u}^2}{Dt} + \rho c_v \frac{DT}{Dt} = -\nabla\cdot(\mathbf{u}P) + \rho T \frac{Ds}{Dt}$$

Lecture 17
The Sun today and 9 years ago

Solar magnetograms:

Line of sight B-field from circularly polarized light



Lecture 19

Insert ansatz

$$u_y = \hat{u}_y \sin(kx - \omega t)$$

$$b_y = \rho\mu_0 \hat{b}_y \sin(kx - \omega t)$$

into

$$\frac{\partial u_y}{\partial t} = B_x \nabla_x b_y / \rho\mu_0$$

$$\frac{\partial b_y}{\partial t} = B_x \nabla_x u_y$$

Linearize **B → B+b**

$$-\omega \hat{u}_y \cos(k_x x - \omega t) = B_x k_x \hat{b}_y \cos(k_x x - \omega t)$$

$$-\omega \hat{b}_y \cos(k_x x - \omega t) = B_x k_x \hat{u}_y \cos(k_x x - \omega t)$$

insert

$$-\omega \hat{u}_y = B_x k_x \hat{b}_y / \rho\mu_0$$

$$-\omega \hat{b}_y = B_x k_x \hat{u}_y$$

Dispersion relation

$$\omega^2 = B_x^2 k_x^2 / \rho\mu_0$$

Lecture 22

Momentum eqn:

$$\rho_0 \frac{\partial \mathbf{u}_1}{\partial t} = -\nabla p_1 + s_1 \mathbf{g} / c_p + \nu \nabla^2 \mathbf{u}_1 \ldots$$

Entropy equarion:

$$\frac{\partial s_1}{\partial t} = -\mathbf{u}_1 \cdot \nabla s_0 + \chi \nabla^2 s_1$$

here: χ is the thermal (radiative) diffusivity

Assume $\nu=\chi$ for simplicity

$$\begin{pmatrix} -\lambda - \nu k_z^2 & -g/c_p \\ -ds_0/dz & -\lambda - \nu k_z^2 \end{pmatrix} \begin{pmatrix} \hat{u}_{1z} \\ \hat{s}_1 \end{pmatrix} = 0$$

$$\left(\lambda + \nu k_z^2\right)^2 - g \frac{ds_0/c_p}{dz} = 0 \quad \left(\lambda + \nu k_z^2\right)^2 = \left(g \frac{ds_0/c_p}{dz}\right)$$

Lecture 26

Frequent collisions: electric, kinetic, and thermal energies similar

$$k_\mathrm{e}\frac{e^2}{r} \sim \tfrac{1}{2} m_\mathrm{e} v_\mathrm{e}^2 \sim k_\mathrm{B} T$$

$$k_\mathrm{e} = \frac{1}{4\pi\varepsilon_0}$$

permittivity

Coulomb
(1736-1806)

Coulomb cross-section

$$\sigma_\mathrm{cross} = \pi r^2 = \pi\left(\frac{k_\mathrm{e} e^2}{k_\mathrm{B} T}\right)^2$$

Mean-free path

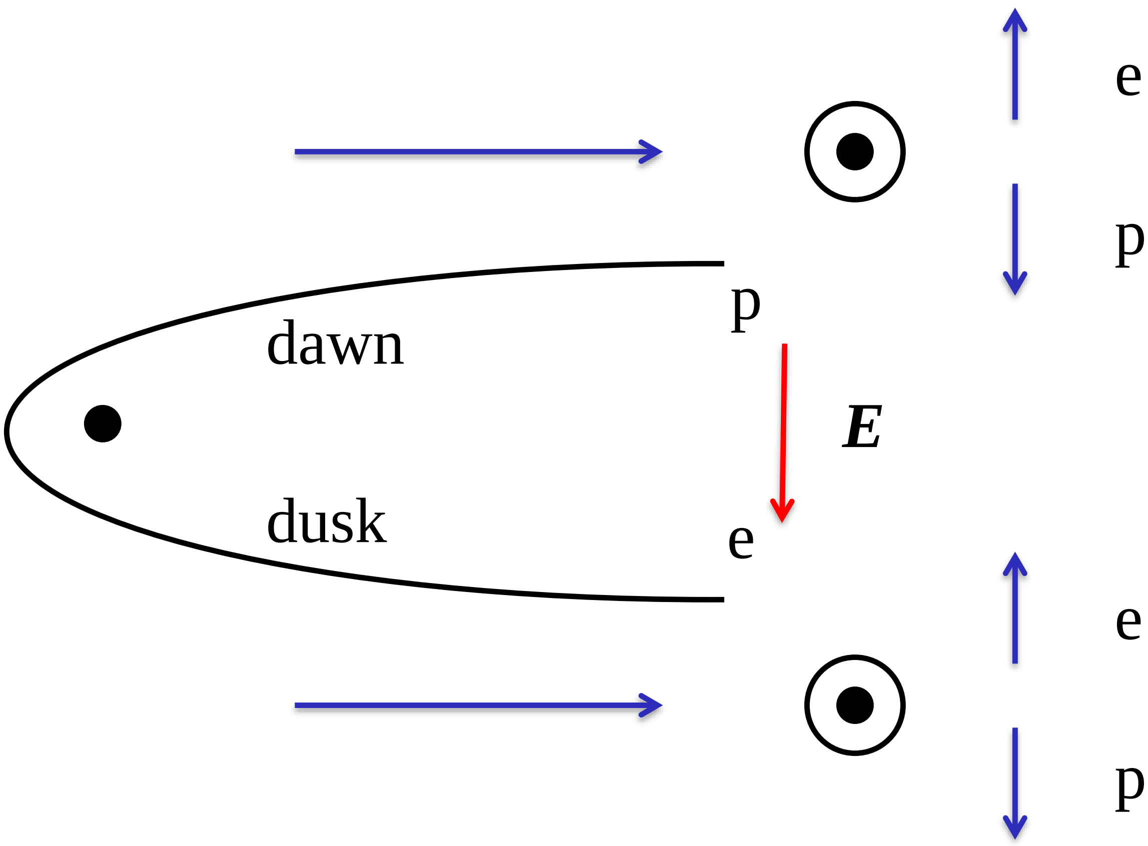
$$\ell = \frac{1}{n\sigma_\mathrm{cross}} \propto \frac{T^2}{n}$$

Heat diffusivity

$$\chi \sim \ell v_\mathrm{e} \sim T^{5/2}$$

Also true for viscosity $\nu \sim \ell v_\mathrm{e} \sim T^{5/2}$

Lecture 34:
Cross-tail electric field



What we did today

- Review & questionnaire
- Final report & Results so far

- Final words:
  – Comment about straylight
  – Deadline: May 5, 11:59pm, Q&A session 4:30-7
  – Thanks to Baylee for her help & dedication
    - Thanks also to Fabio for preparations behind the scene
  – For future: recommendation letters
  – Summer projects?