Lecture 20

- Sommers-Bausch Observatory sessions
- Ohmic diffusion
- sunspots

Last time

- Alfven wave dispersion relation
- Ohmic diffusion
- Reynolds numbers
- Prandtl numbers

Data taking at SBO

- Center to limb variation
  - at ifferent wavelengths
- Record spectrum
- Estimate opacity
  - at different wavelength dependence
- Timing, clouds, etc

Alfven speed

2 equations with
two unknowns

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

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

$$v_{\mathrm{A}}^2 = B^2 / \rho\mu_0$$

B=2000 G, $\rho=10^{-6}$ g/cm^3: v_{A}=6 km/s

Ohmic diffusion

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times \left(\mathbf{u} \times \mathbf{B} \right) + \eta \nabla^2 \mathbf{B}$$

No flow: **u=0**

$$B_x = B_0 e^{ik_x x - i\omega t}$$

Dispersion relation

$$-i\omega = -\eta k_x^2$$

Sunspots

What do you need to derive:

$$\oint_{4\pi R^2} \mathbf{B} \cdot d\mathbf{S} = 0$$

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

What does it mean

$$\oint_{4\pi R^2} \mathbf{B} \cdot d\mathbf{S} = 0$$

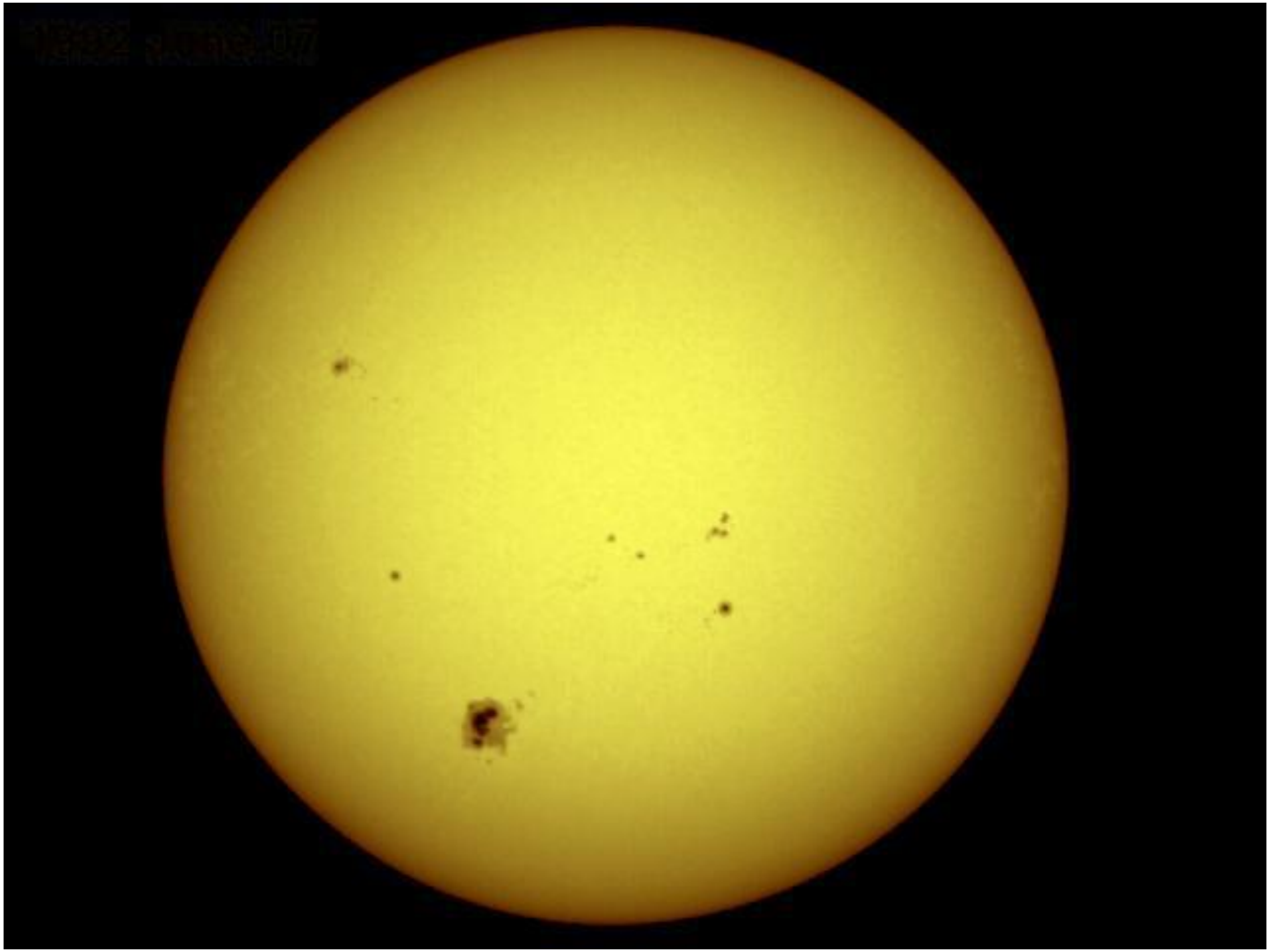
A. There must be spots

B. There must be an even # of spots

C. Spots must always be bipolar

D. Spots tend to be bipolar

Sunspots

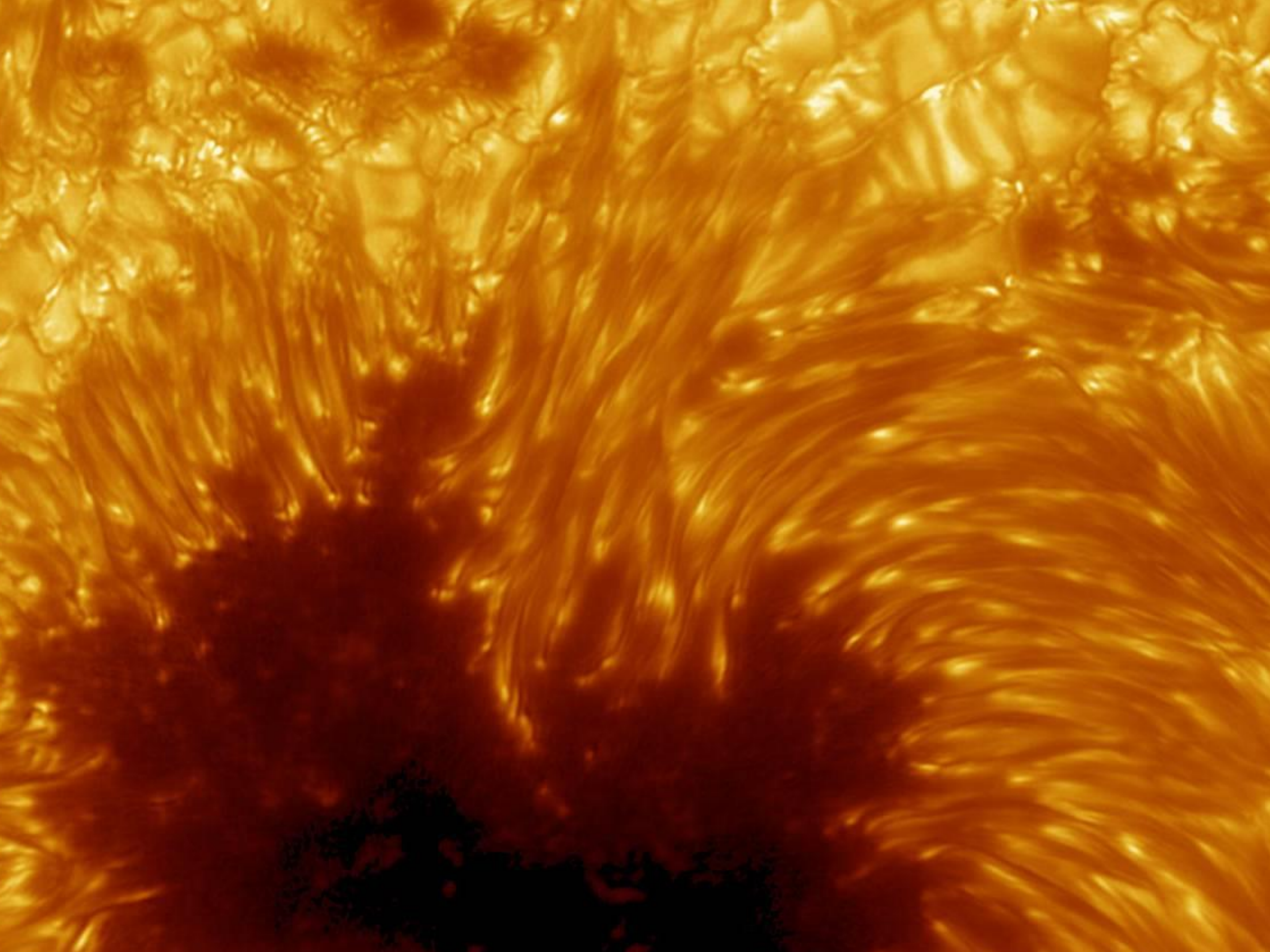


1992 June 07

Properties

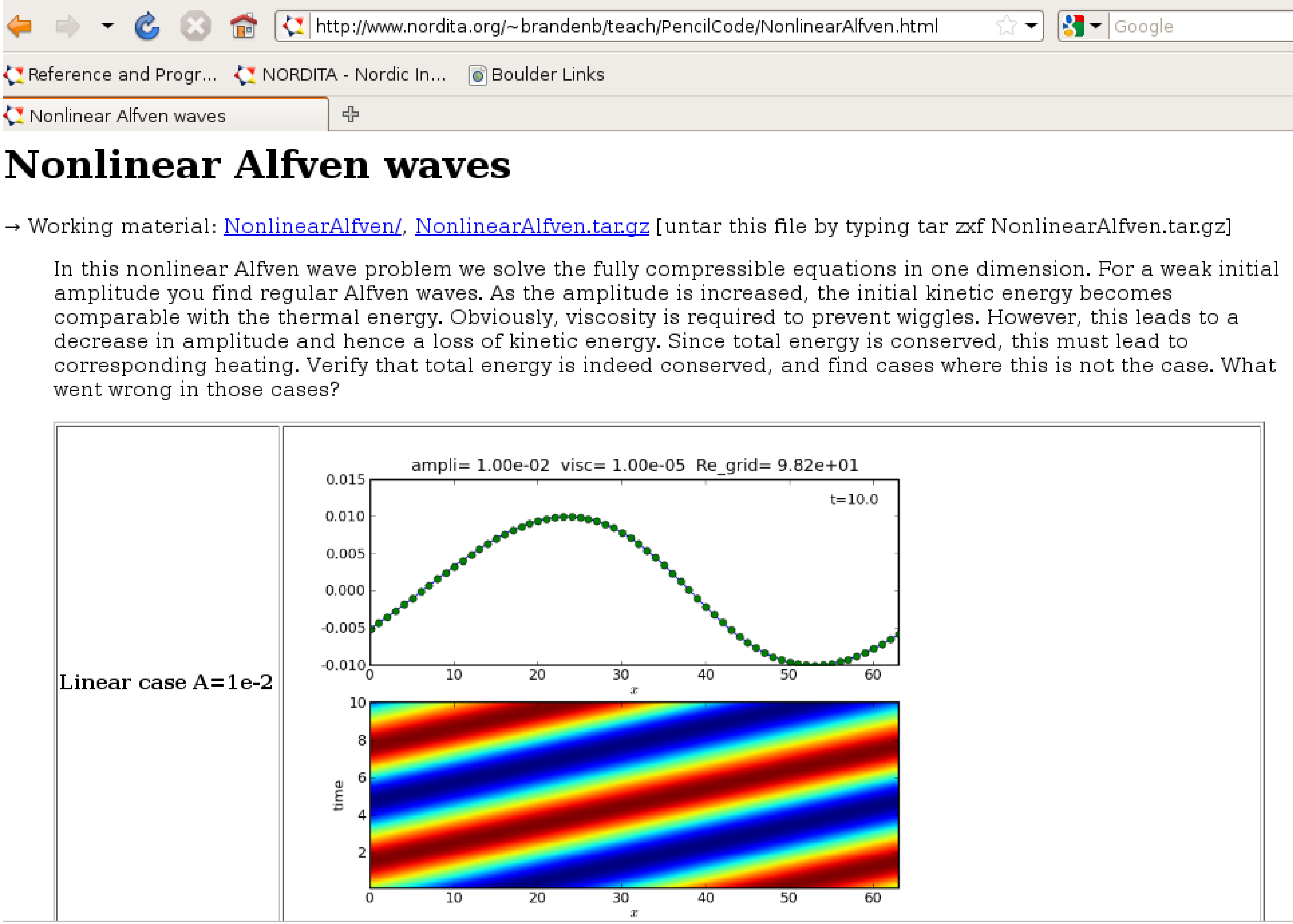
- Life time ½ day – 3 months
- Sunspot area decay, $dS/dt = -1.5 \times 10^8$ m^2/s
- Comparison with what?

A. Ohmic decay time
B. Turbulent velocity
C. Turbulent velocity and scale height
D. Turbulent diffusivity
E. Surface density



Why are they dark

A. Because gas pressure is lower
B. One cannot see deep enough
C. Convection suppressed
D. Opacity is increased



Nonlinear Alfven waves

→ Working material: NonlinearAlfven/, NonlinearAlfven.tar.gz [untar this file by typing tar zxf NonlinearAlfven.tar.gz]

In this nonlinear Alfven wave problem we solve the fully compressible equations in one dimension. For a weak initial amplitude you find regular Alfven waves. As the amplitude is increased, the initial kinetic energy becomes comparable with the thermal energy. Obviously, viscosity is required to prevent wiggles. However, this leads to a decrease in amplitude and hence a loss of kinetic energy. Since total energy is conserved, this must lead to corresponding heating. Verify that total energy is indeed conserved, and find cases where this is not the case. What went wrong in those cases?

Linear case A=1e-2

What we learned

(& talked about)

- SBO data taking
- Ohmic diffusion
- sunspots