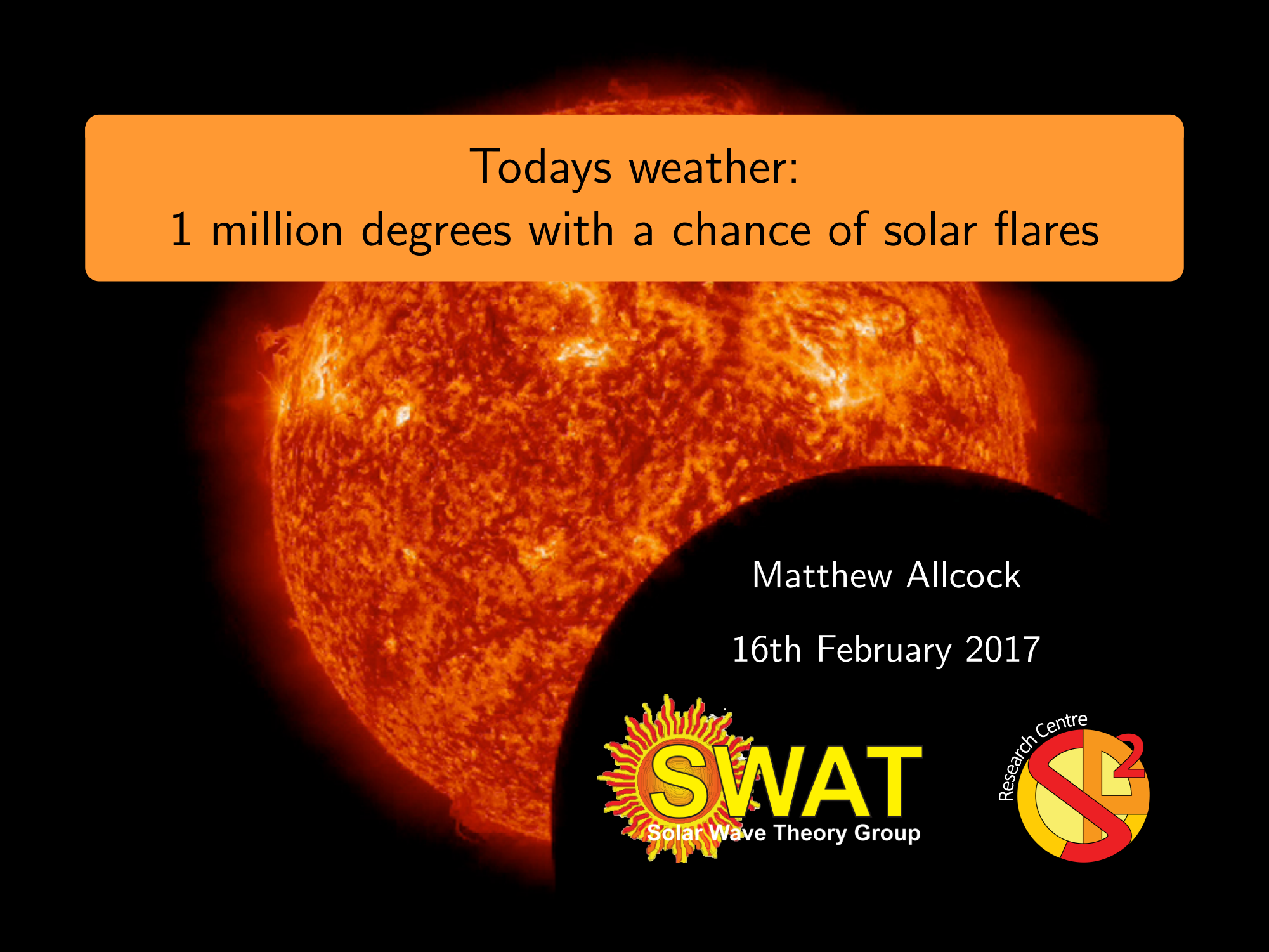
Todays weather:
1 million degrees with a chance of solar flares



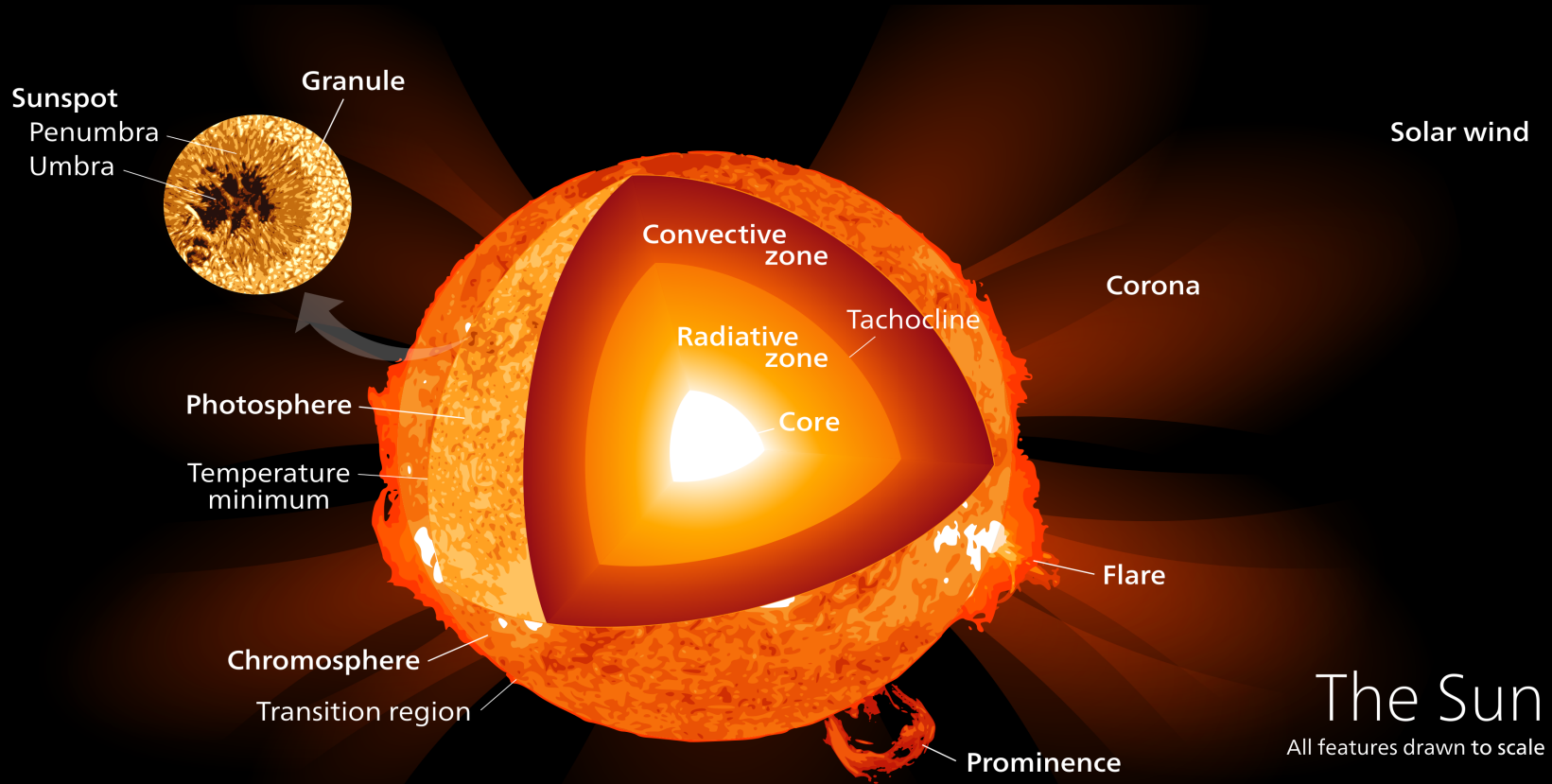
Matthew Allcock

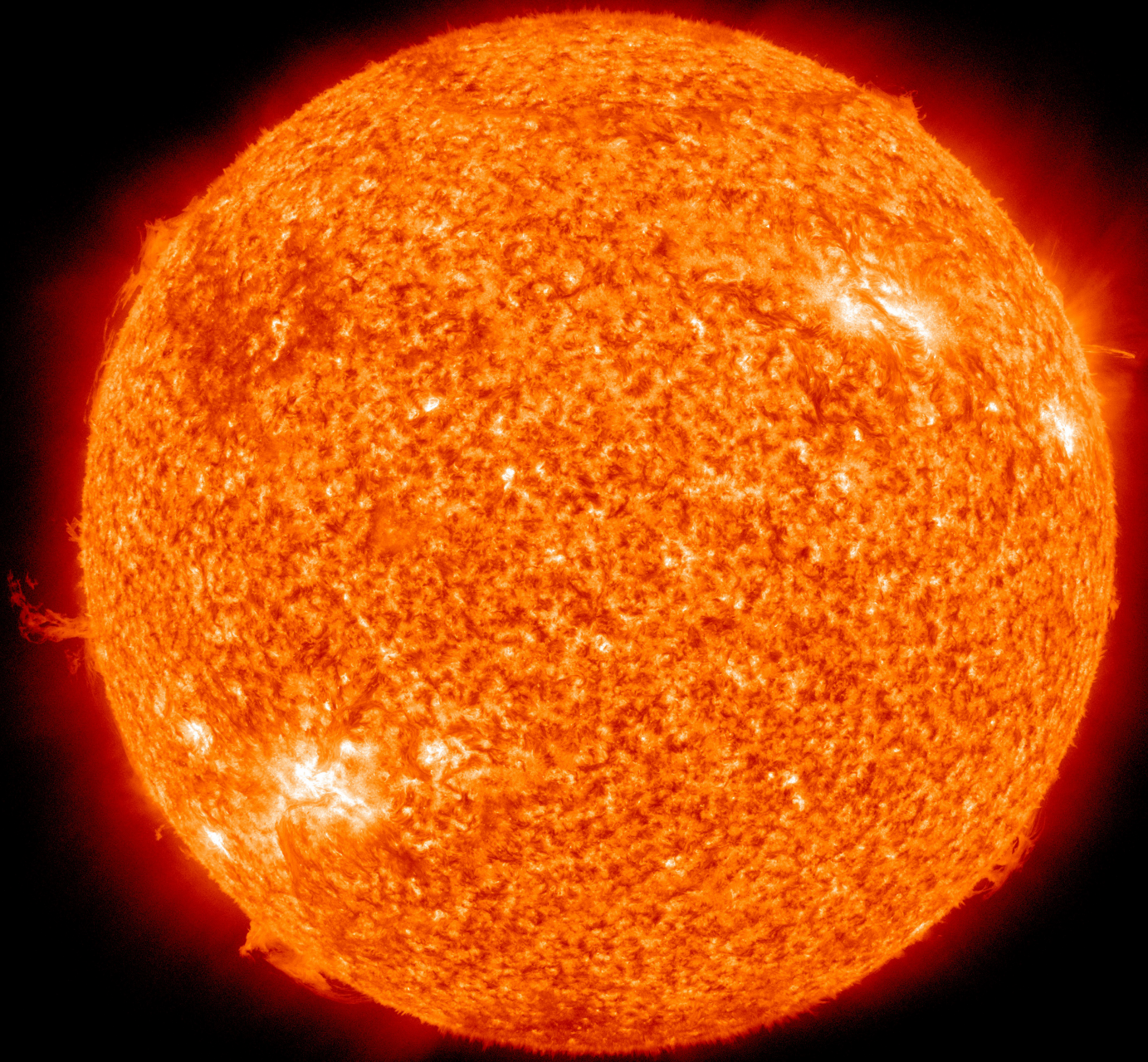
16th February 2017

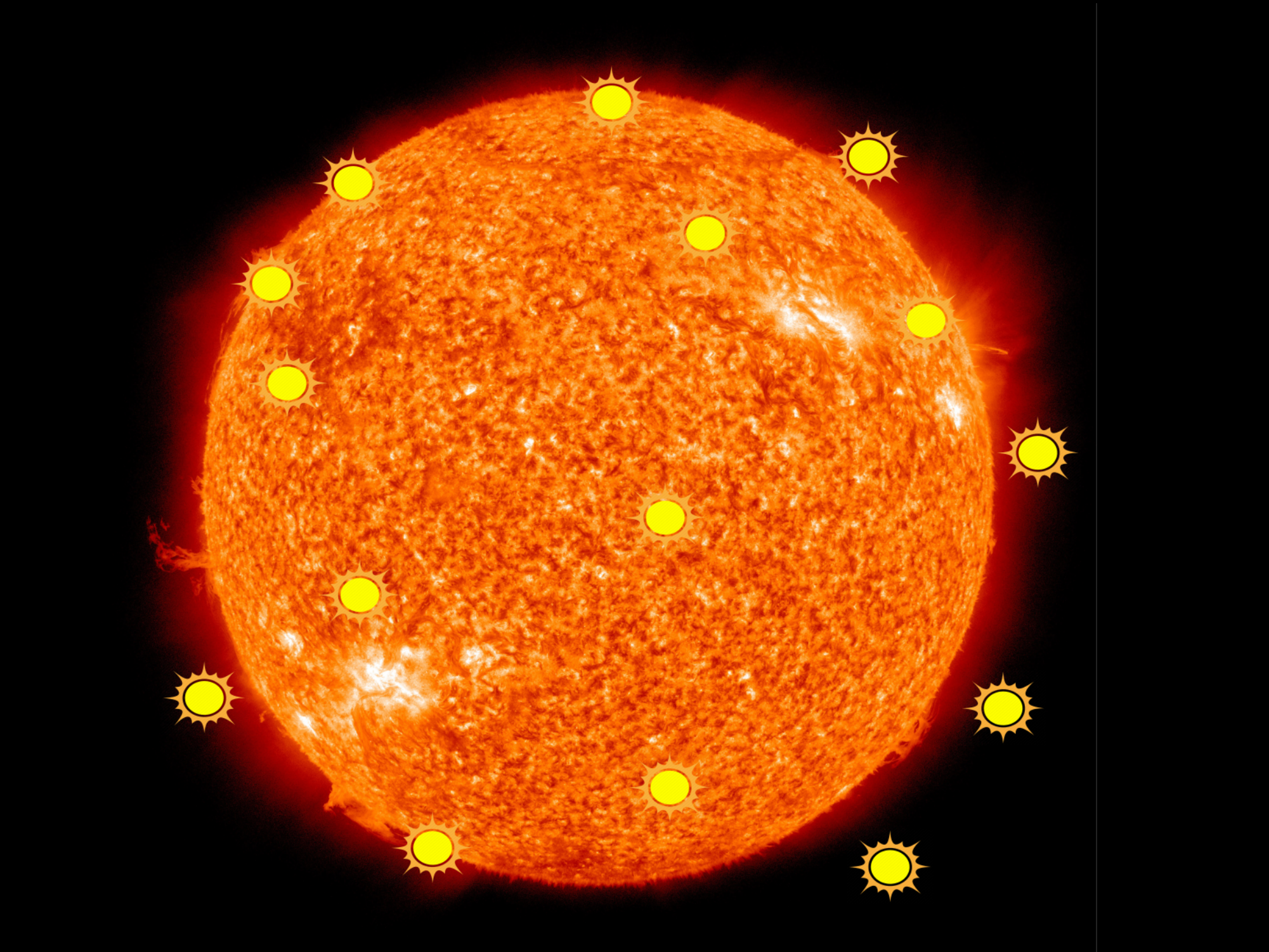
SWAT
Solar Wave Theory Group

Research Centre

The layers of an onion

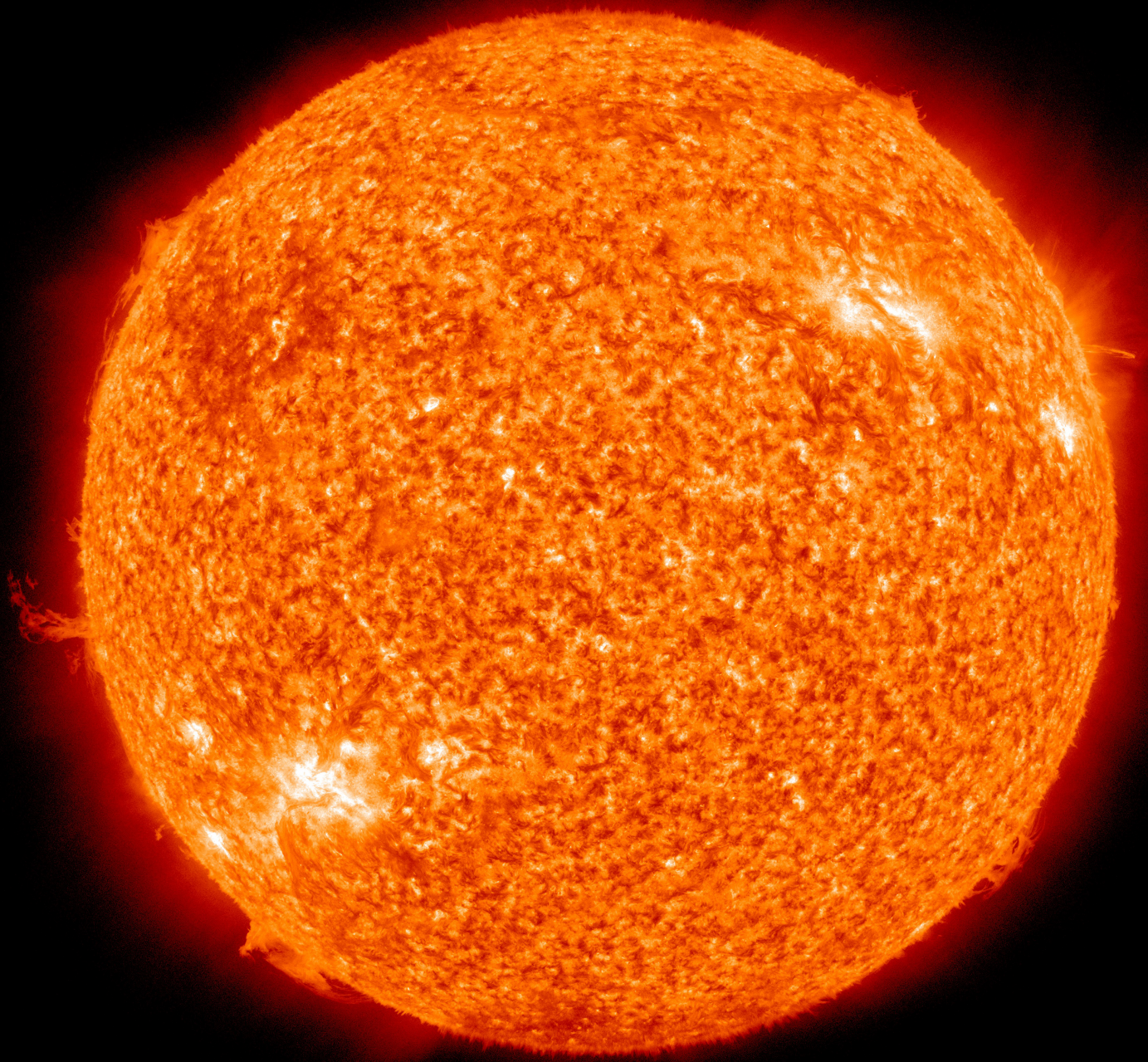


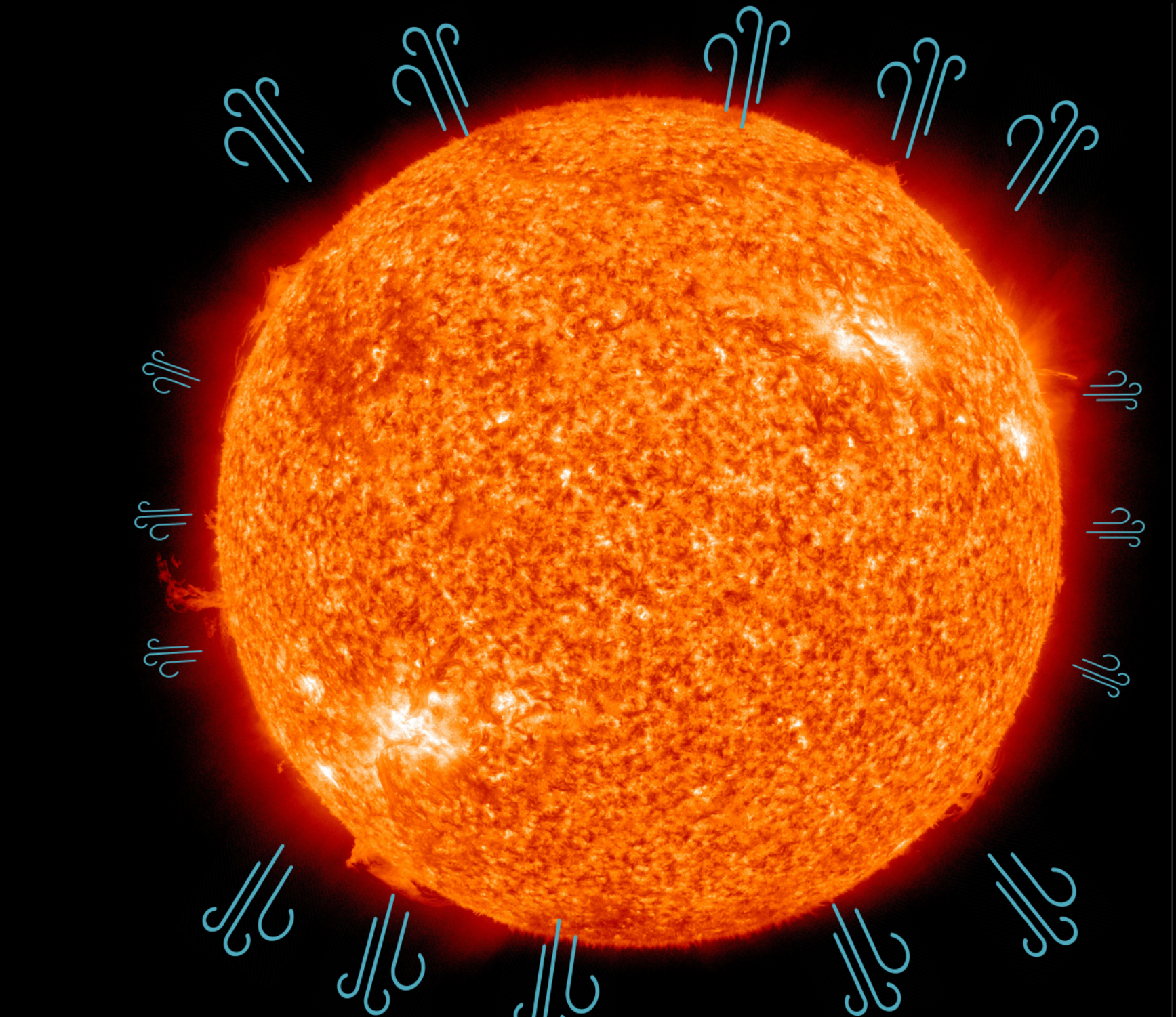




Coronal rain

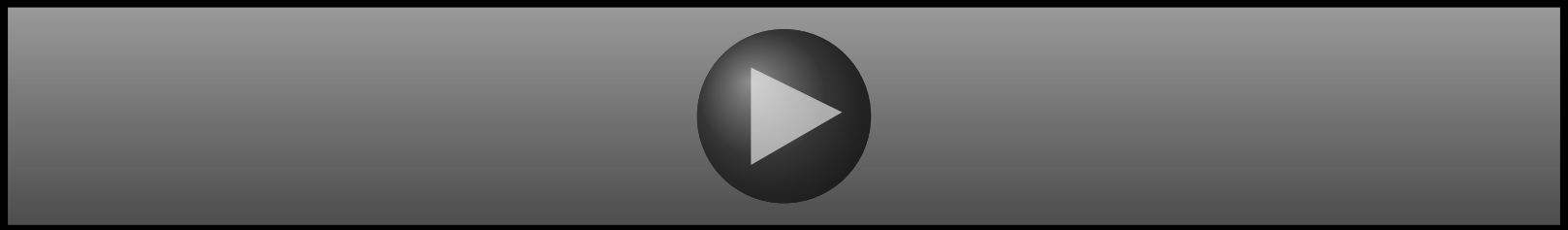
Credit: NASA, SDO



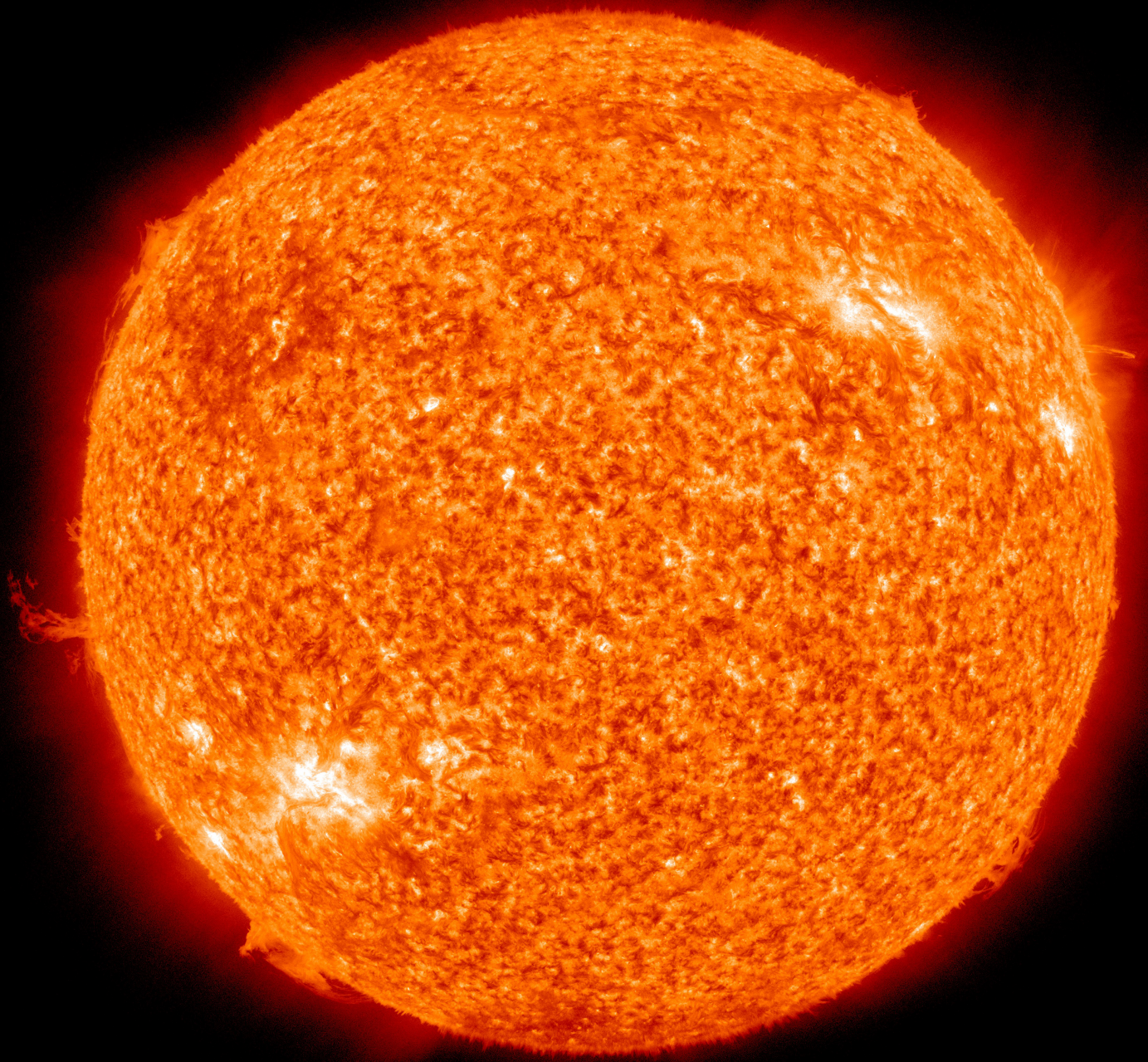


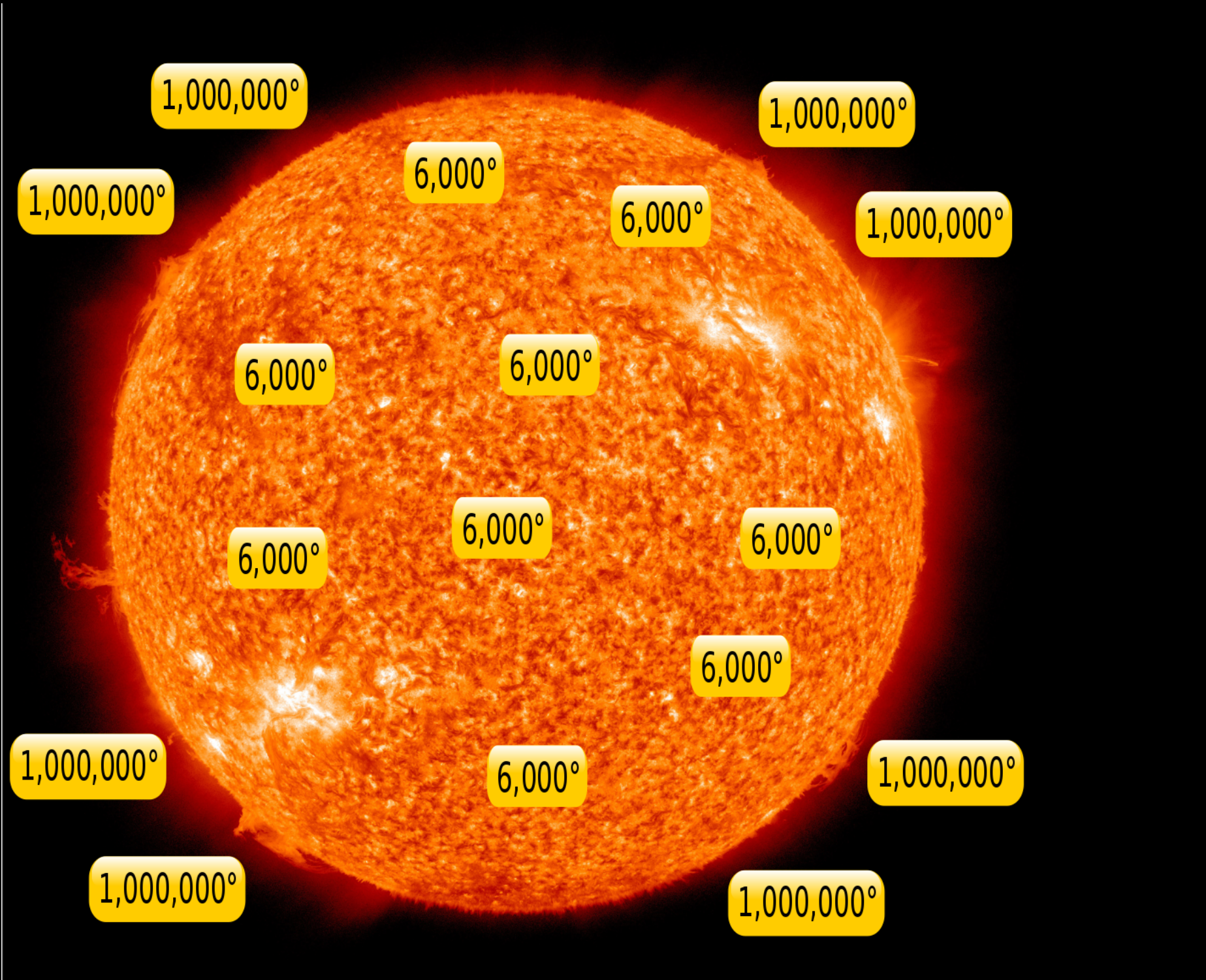
Solar wind

Coronal mass ejection



Credit: NASA, SDO

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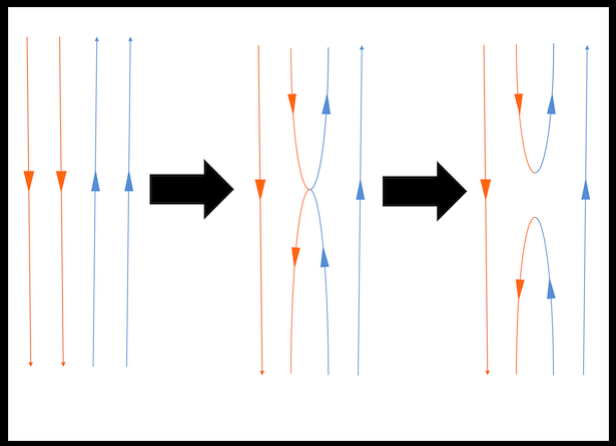
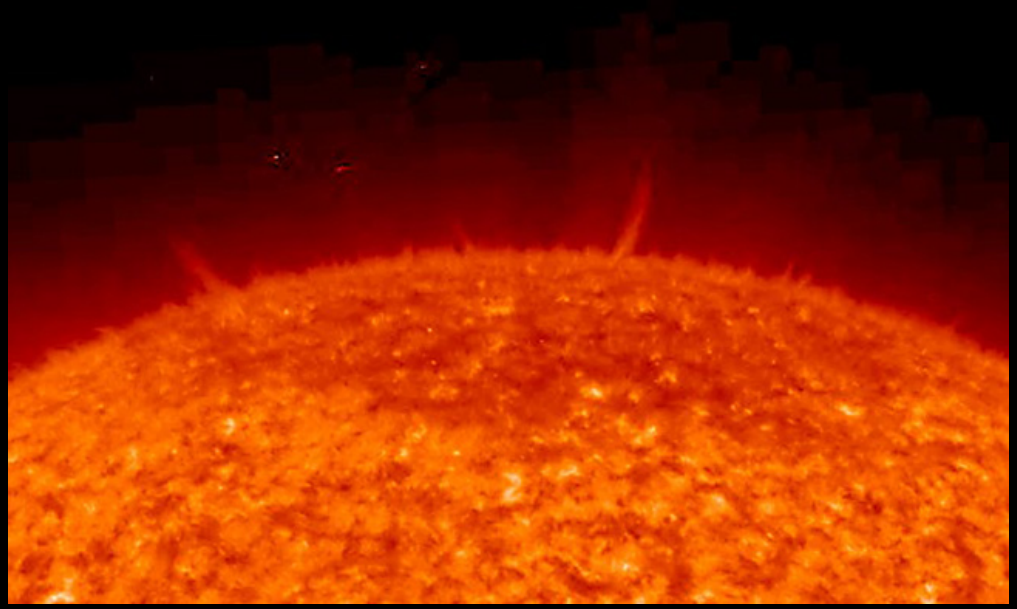
Coronal heating problem

Why is the Sun's atmosphere 1000x hotter than the surface?

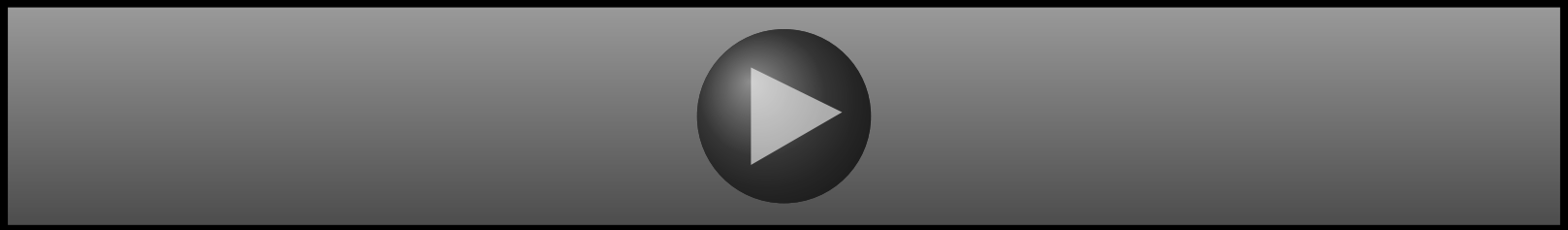
- Magnetic reconnection?
- Jets? (small or large scale?)
- Magnetohydrodynamic (MHD) waves?





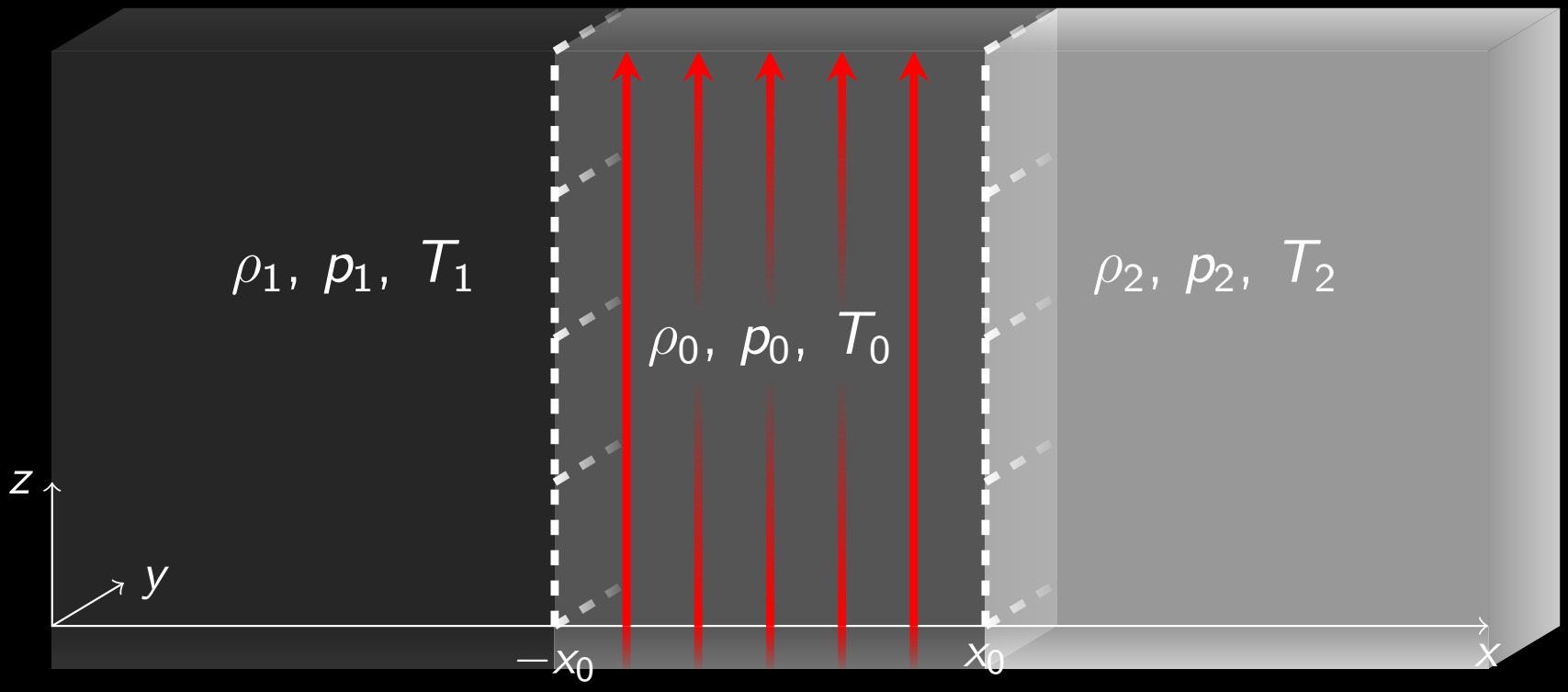
Magnetohydrodynamic waves

Coronal loop kink oscillations



Credit: NASA, SDO

Equilibrium conditions



- Uniform vertical magnetic field in the slab.
- Non-magnetised plasma outside.
- **Different** density and pressure on each side.

Governing equations

Ideal MHD equations:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0,$$

$$\rho \frac{D\mathbf{v}}{Dt} = -\nabla p - \frac{1}{\mu}\mathbf{B} \times (\nabla \times \mathbf{B}),$$

$$\frac{D}{Dt}\left(\frac{p}{\rho^{\gamma}}\right) = 0,$$

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{v} \times \mathbf{B}),$$

$\mathbf{v}$ = plasma velocity, $\mathbf{B}$ = magnetic field strength, ρ = density, p = pressure, μ = magnetic permeability, γ = adiabatic index.

Mode decomposition

Dispersion relation:

$$\frac{\omega^4 {m_0}^2}{k^2 {v_A}^2 - \omega^2} + \frac{\rho_0}{\rho_1} m_1 \frac{\rho_0}{\rho_2} m_2 (k^2 {v_A}^2 - \omega^2)$$
$$- \frac{1}{2} m_0 \omega^2 \left(\frac{\rho_0}{\rho_1} m_1 + \frac{\rho_0}{\rho_2} m_2 \right) (\tanh m_0 x_0 + \coth m_0 x_0) = 0,$$

$${m_0}^2 = \frac{(k^2 {v_A}^2 - \omega^2)(k^2 c_0^2 - \omega^2)}{(c_0^2 + {v_A}^2)(k^2 {c_T}^2 - \omega^2)}, \qquad m_{1,2}^2 = k^2 - \frac{\omega^2}{c_{1,2}^2},$$

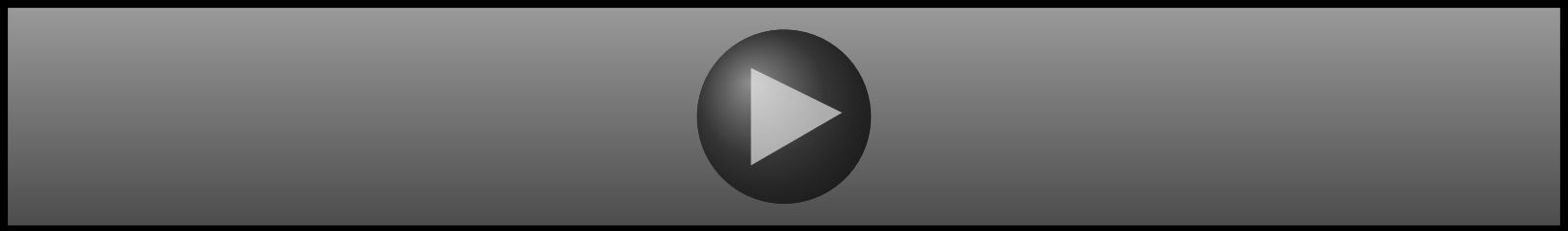
$${c_T}^2 = \frac{c_0^2 {v_A}^2}{c_0^2 + {v_A}^2}, \qquad v_A = \frac{B_0}{\sqrt{\mu \rho_0}},$$

We can identify modes present in observations and use this to

- Identify the structure of solar phenomena,
- Estimate difficult-to-measure parameters such at the magnetic field strength,
- Run more realistic simulations.

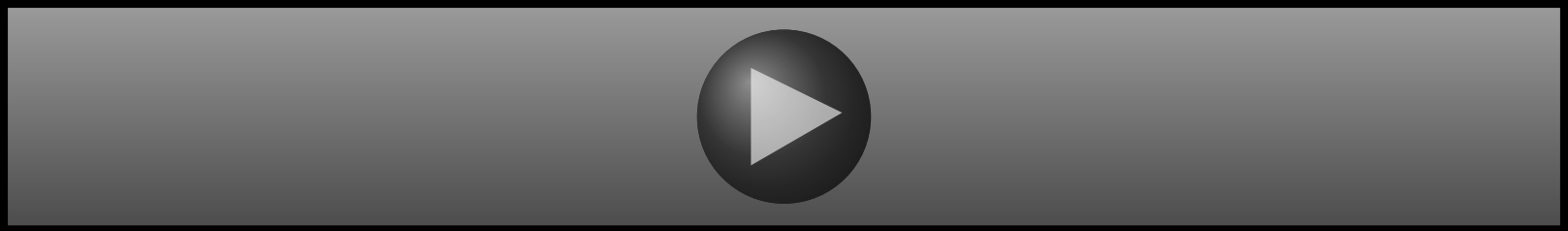
Magnetohydrodynamic waves

Kink mode



Magnetohydrodynamic waves

Sausage mode



Thank you!