

# **SHOCKING AFFAIRS**



**Hydraulic  
jump**

## Mass conservation

$$\rho v_1 h_1 = \rho v_2 h_2$$

## Momentum conservation

$$\rho v_1^2 h_1 + \frac{1}{2} \rho g h_1^2 = \rho v_2^2 h_2 + \frac{1}{2} \rho g h_2^2$$

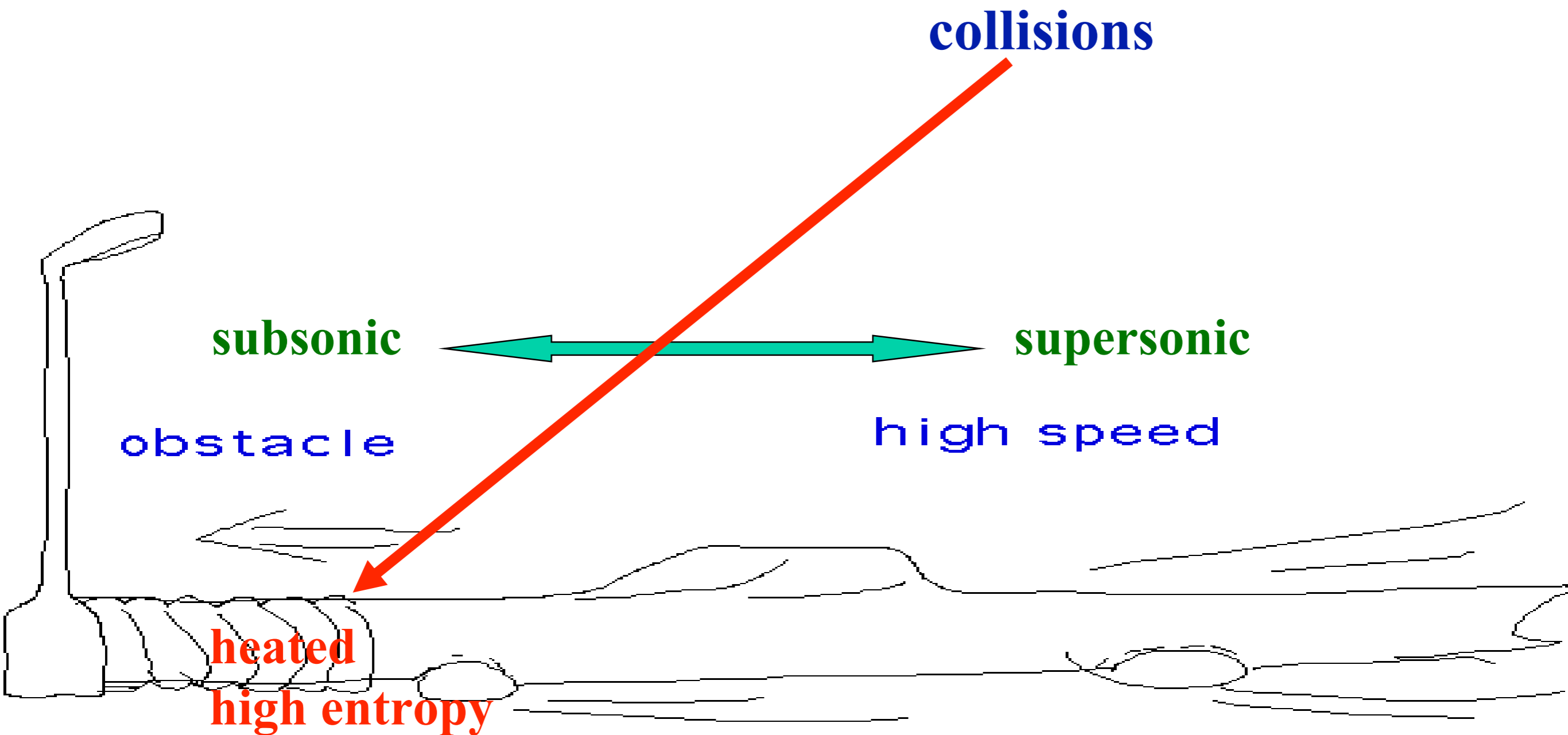
## Jump condition

$$Fr = \frac{v_1}{\sqrt{gh_1}} > 1$$

# TIDAL BORE



# SHOCKS IN COMPRESSIBLE GASES



# SHOCK IN GAS VISUAL CONDENSATION

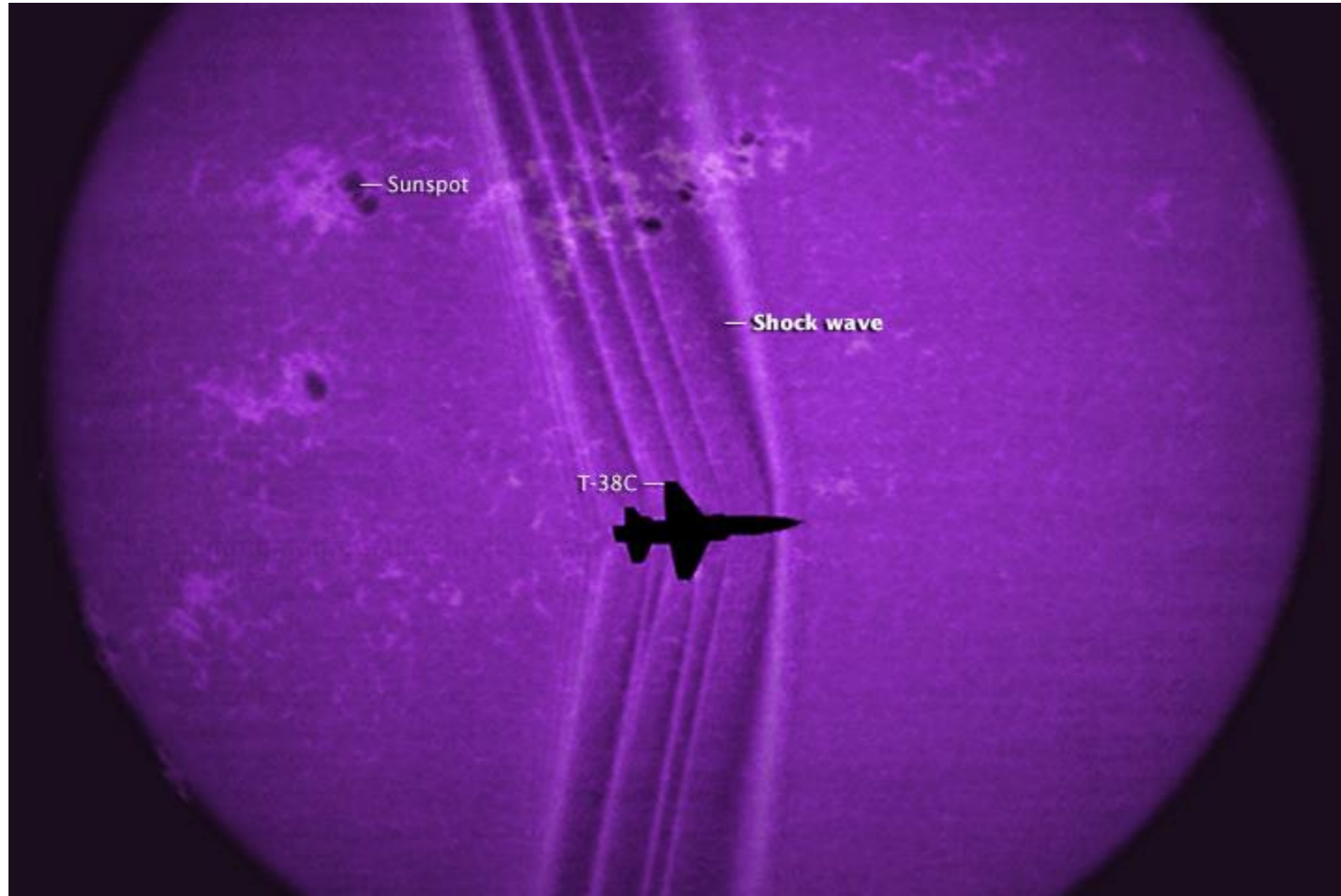


# TROMBONE SHOCKS

## VISUAL CHANGE OF REFRACTION INDEX



# MACH CONE VISUAL CHANGE OF REFRACTION INDEX





# **SHOCKS - COLLECTIVE MOTION**

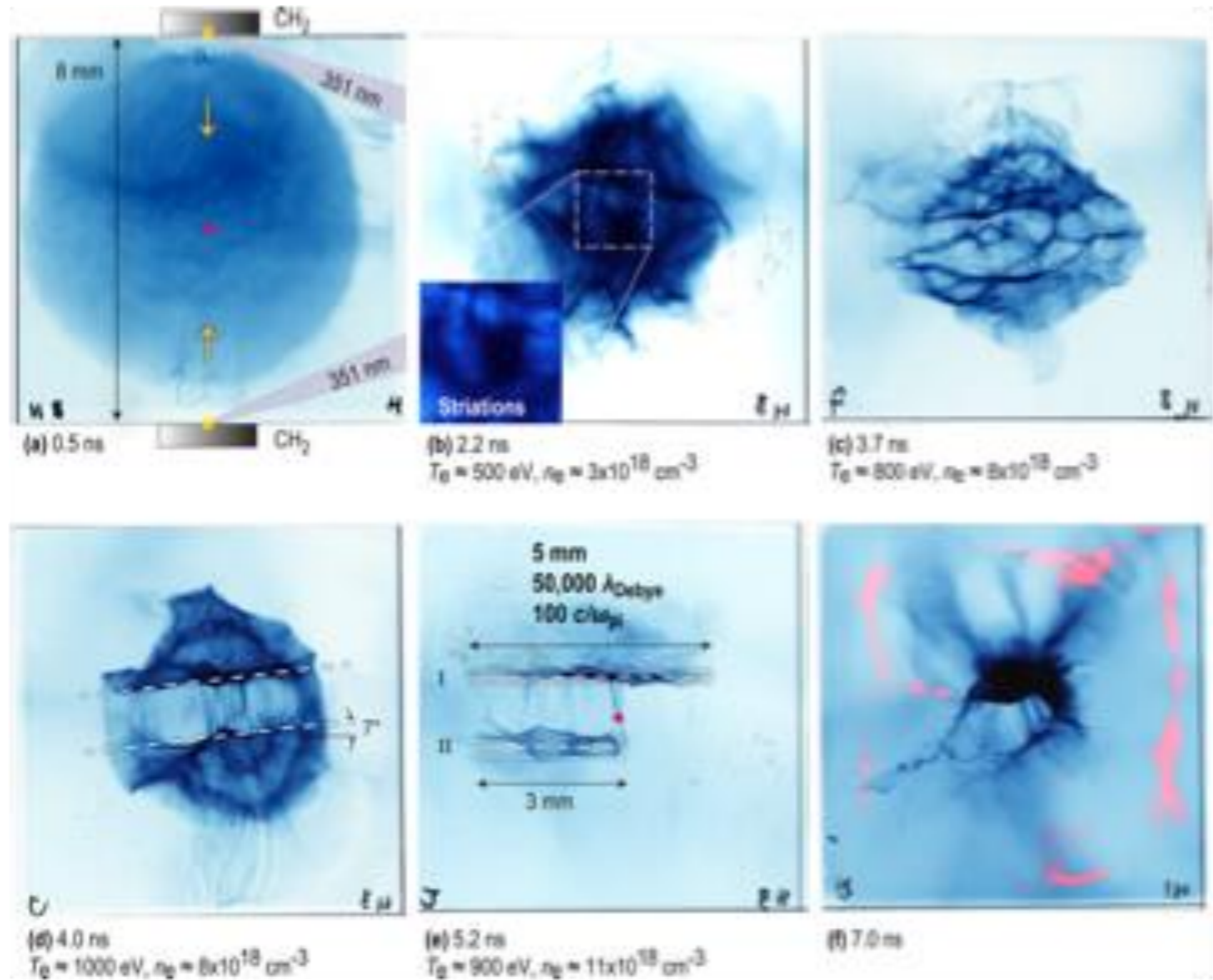
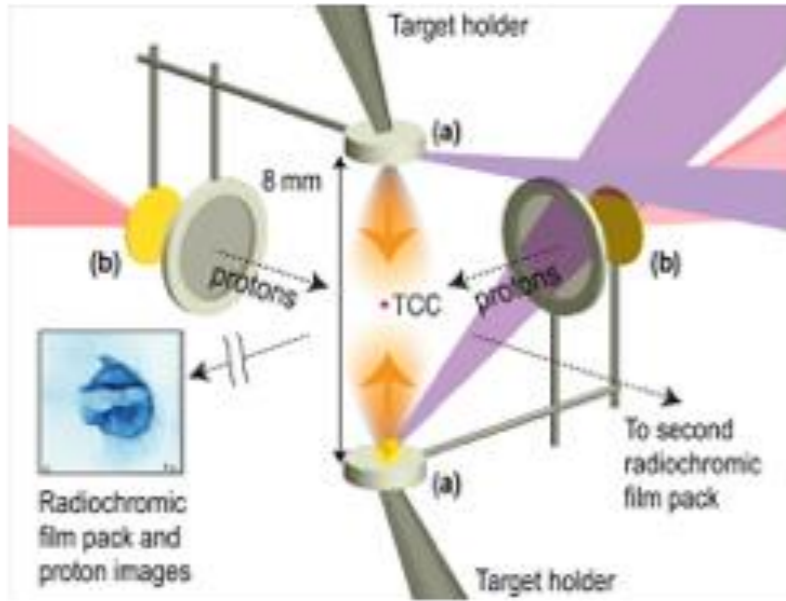
**LIQUID - STRONG COUPLING OF  
MOLECULES**

**GAS - PLENTY OF COLLISIONS**

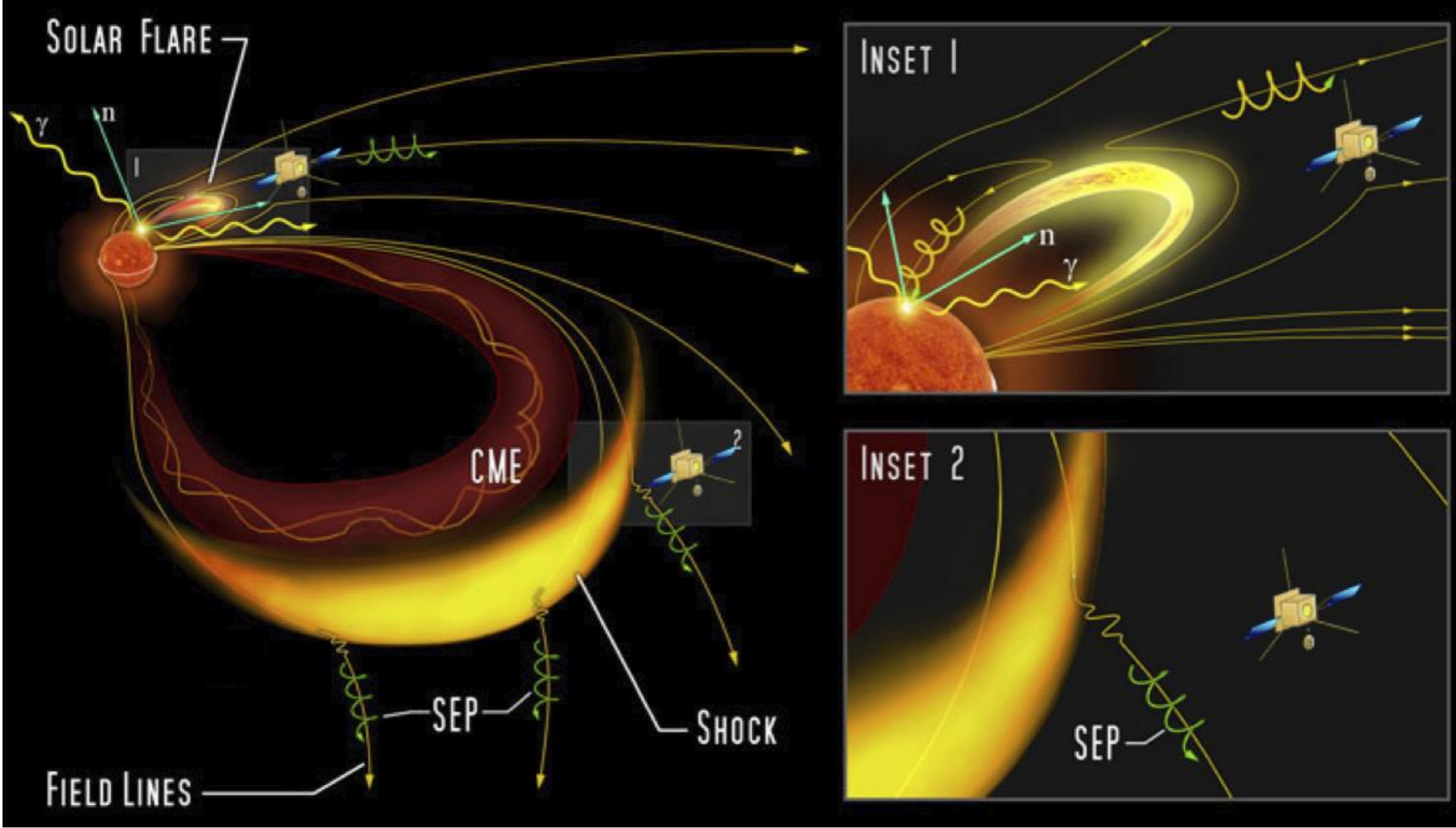
**VERY DILUTE GAS - IONIZED, NO  
COLLISIONS, COUPLING VIA SELF-  
CONSISTENT FIELDS**

**COLLISIONLESS SHOCKS IN PLASMA  
THROUGHOUT THE UNIVERSE**

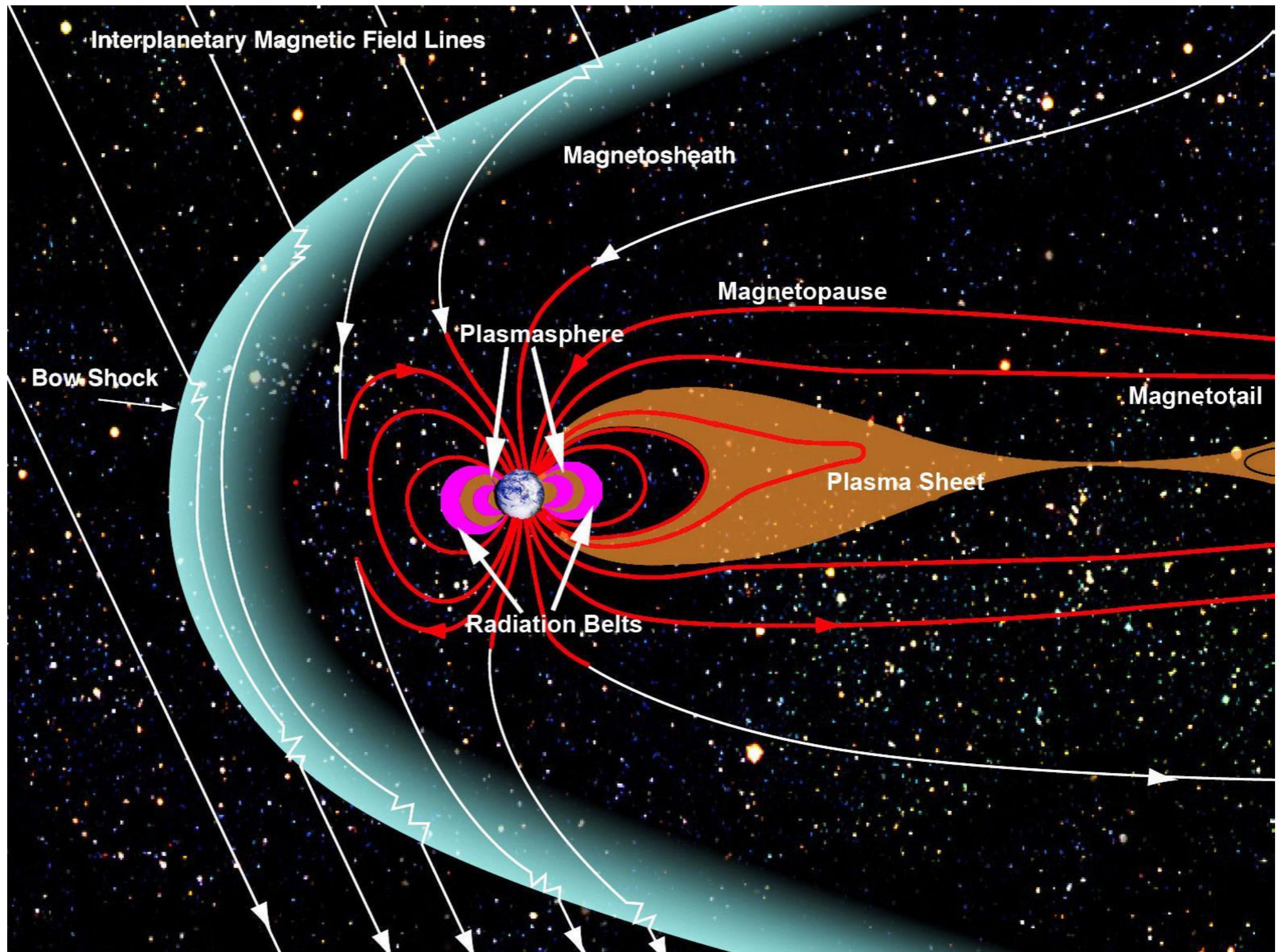
# Lab shocks - tiny



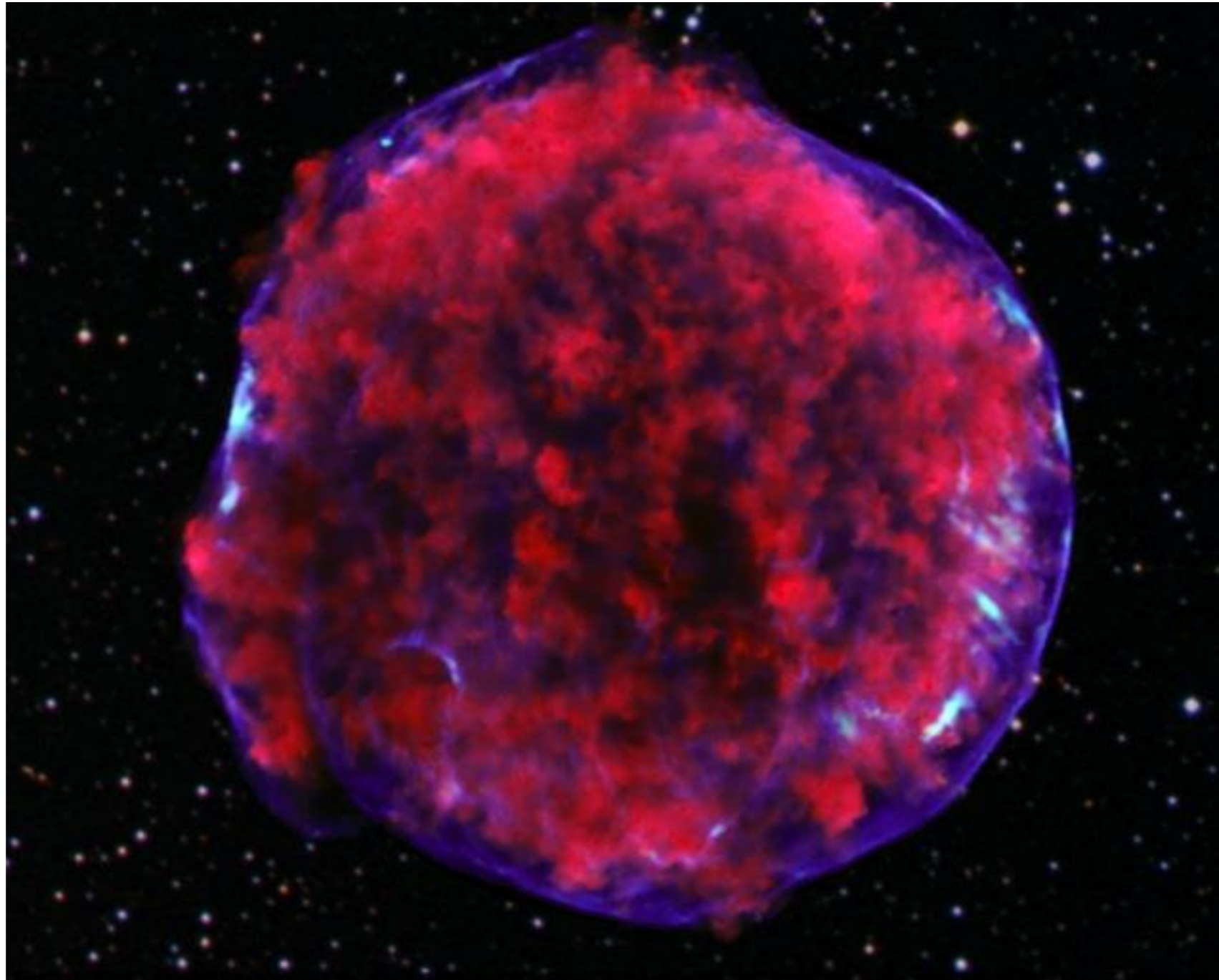
# Heliospheric shocks - CME



# Heliospheric shocks - bow shocks



# SNR shocks



**Heating** - all particles  
gain some energy

**Acceleration** - some particles gain  
high energies,  
dimensions important

**Cosmic rays** - shocks in space  
as much as  $10^{18}$  eV

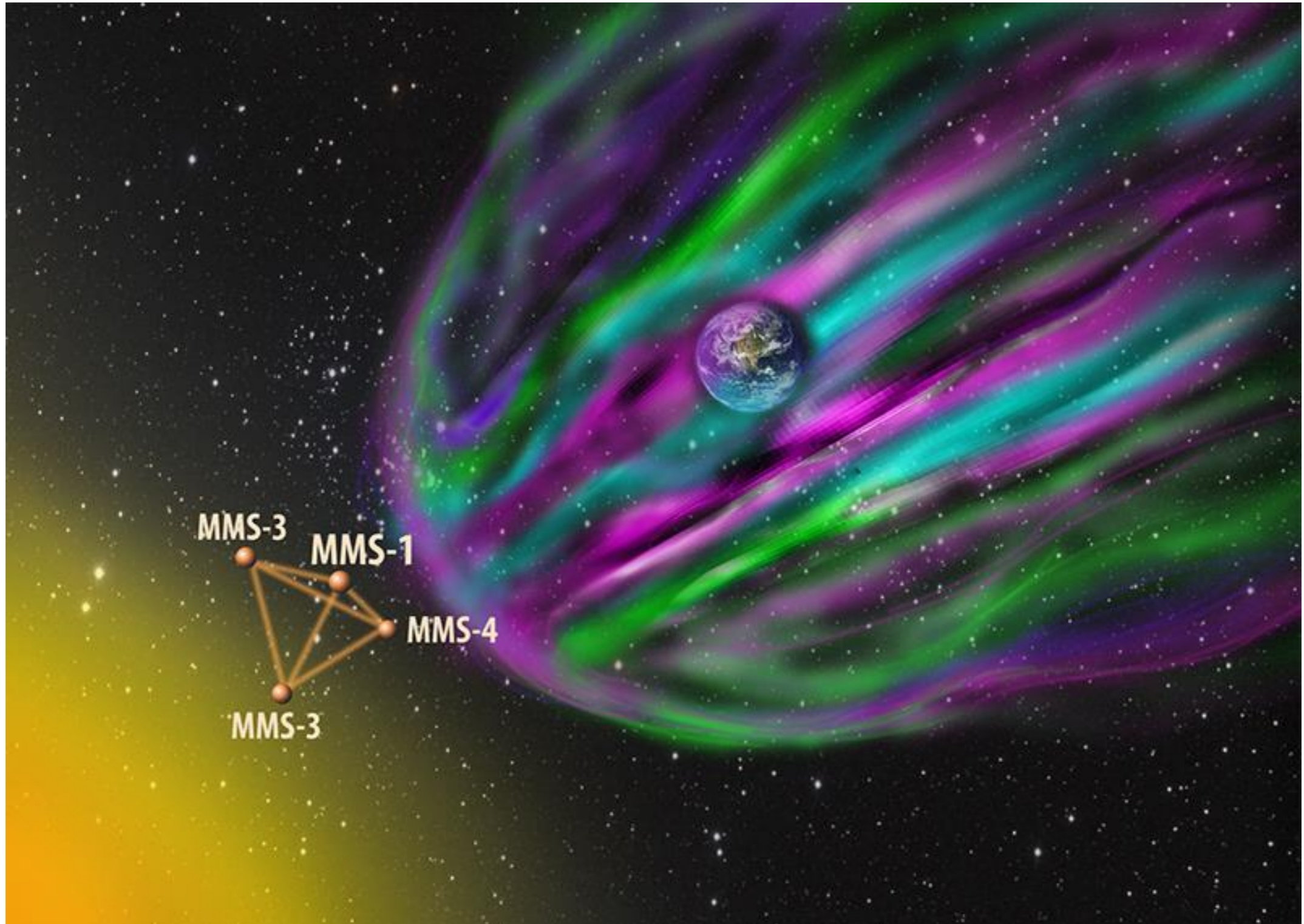
**LHC**  $< 10^{15}$  eV

# **OBSERVATIONS**

- 1. Astrophysical shocks - indirect - enhanced emission and cosmic rays**
- 2. Heliospheric shocks - in situ observations and high energy particles**
- 3. Earth bow shock - detailed in situ measurements**

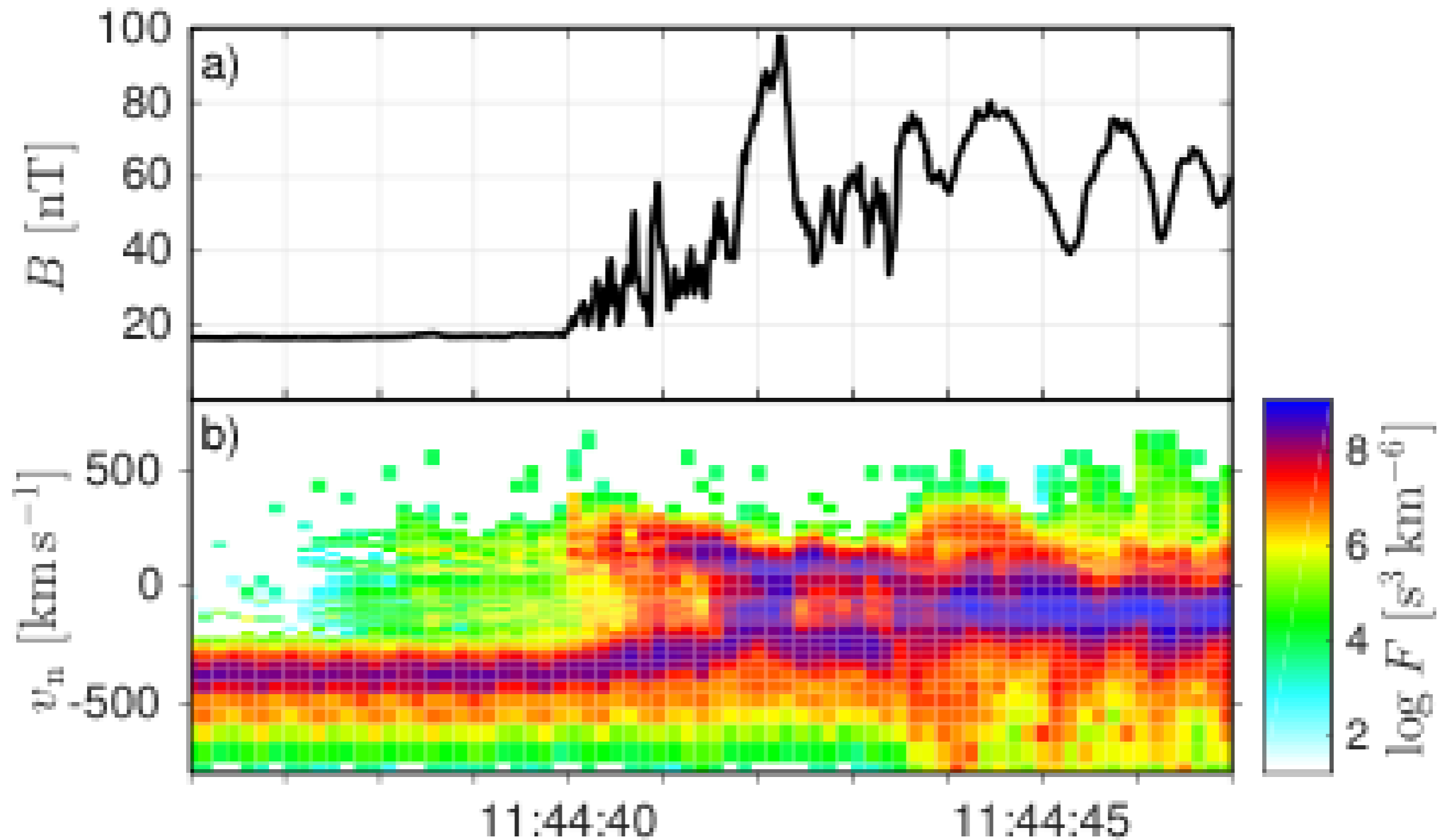
# INSIDE THE SHOCK

## Magnetospheric Multiscale Mission





# Magnetospheric Multiscale Mission measurements



**NO END**

**EVERLASTING STORE**