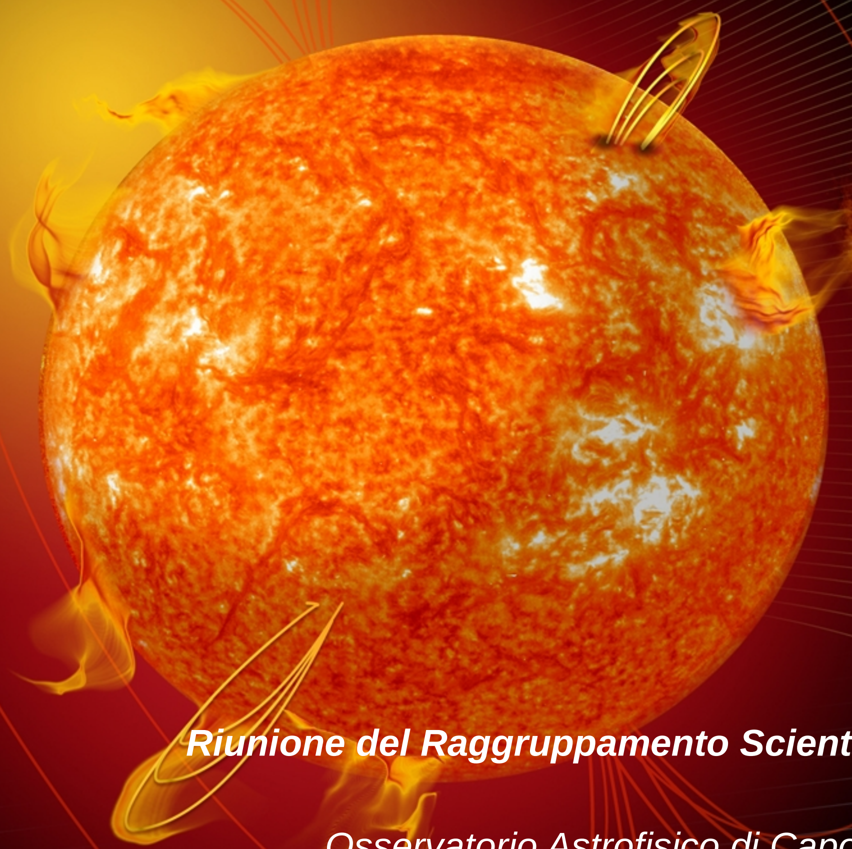
Study the formation and evolution of CME-driven shocks with space and ground-based instrumentations



Federica Frassati
INAF - Istituto Nazionale di Astrofisica
OATo – Osservatorio Astrofisico di Torino

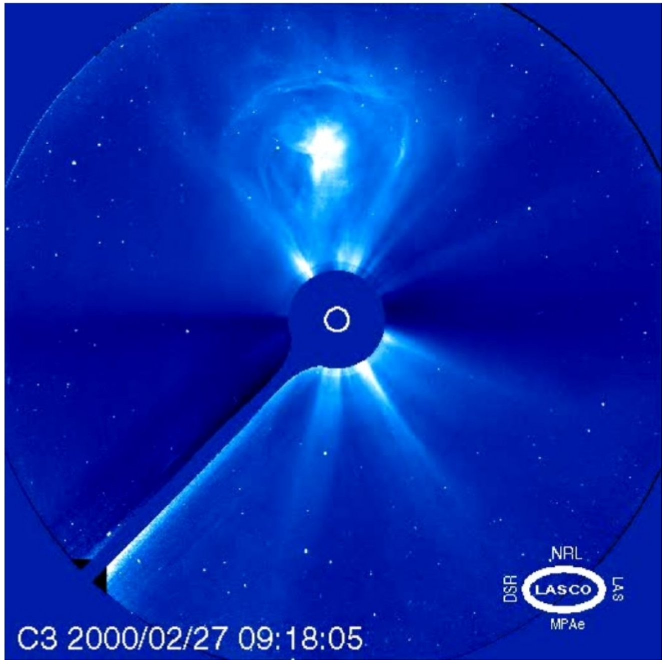
Riunione del Raggruppamento Scientifico Nazionale 3 - "Sole e Sistema Solare"

Osservatorio Astrofisico di Capodimenote (NA) 18 – 19 Ottobre 2022

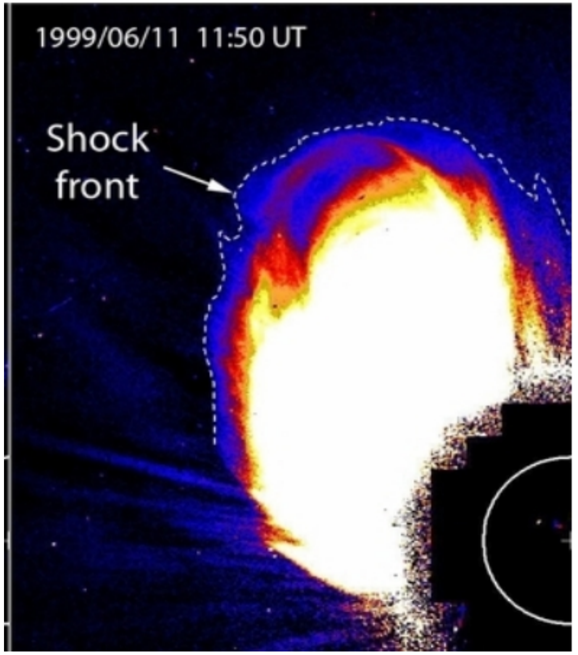
Solar transient phenomena – CME and Shocks

Many transient phenomena happen every day on Sun, including eruptions, flares, and CMEs that can drive interplanetary shocks and SEP events.

CMEs are expulsions of huge quantities of magnetized plasma (masses up to 10^{16} g) with speeds from 500 km/s up to 2500 km/s and dragging an expanding magnetic field and propagate from the Sun into the heliosphere;



A shock is formed in a medium when its main parameters (density, temperature, pressure, and velocity) suffer a discontinuity. When the CME speed > sound speed, a shock can be formed.



Why is it important to study CME-driven shocks?

The study of Shocks (origin and evolution) associated with major solar eruptions continues to be a very **important topic in Solar Physics**.

Scientific reasons (examples):
- to understand the dynamics of solar eruptions;
- to provide a better understanding of fundamental plasma physical processes (as plasma heating, acceleration of energetic particles at collisionless shock waves, …).

Technological and Biological reasons (examples):
- Energetic particles produced in the solar corona and propagating in the solar wind and toward the Earth, often generate significant radiation hazards, a major threat for spacecraft operations, technological systems, and astronauts.

Understanding the origin, propagation and physical properties of **coronal shocks is crucial** to improve our scientific **knowledge** and therefore for possible applications to **Space Weather** services.

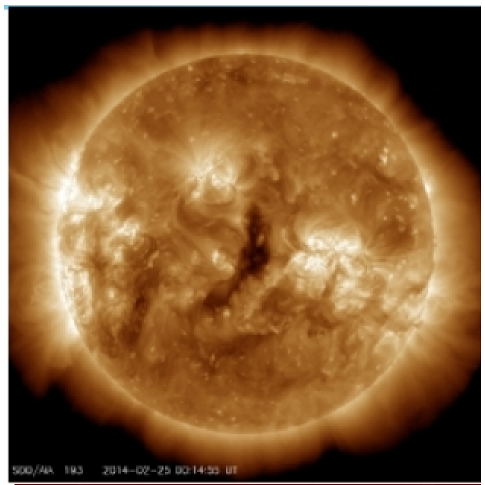
How to observe a CME-driven shock?

Observations from space are useful because:
- 24/7 Solar observations possible;
- EUV coronal emission, X – ray emission, and low radio emission are fully absorbed by our atmosphere;

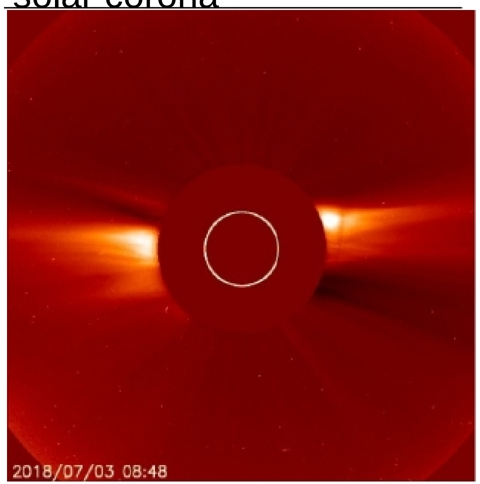
Observations from ground – based instrumentation can be complementary to space-based ones (examples: WL coronagraph, Radioheliograph).

Instrumentation - examples

EUV IMAGER → Images of high dynamic low solar corona (< 1,6 Rsun)



CORONAGRAPHS → a disk blocks the Sun's bright surface, revealing the faint solar corona



Space-based instrumentations

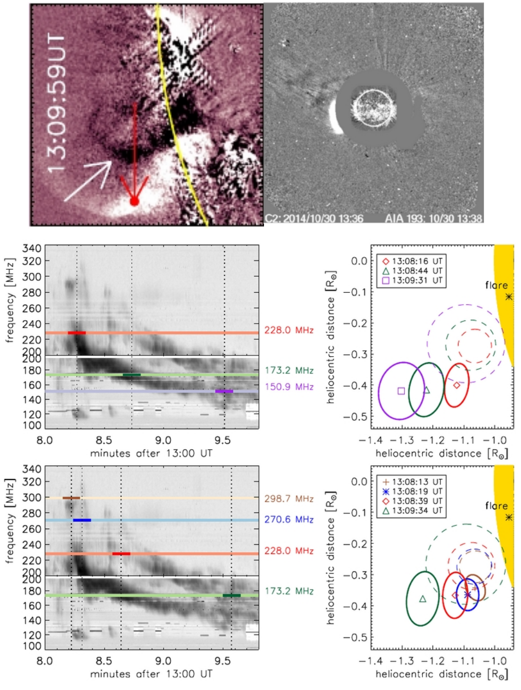
RADIO SPETTROMETRI / HELIOGRAPHS → reveal solar radio emissions from 10 MHz to ~2 GHz. They are very useful to detect physical processes at different heliocentric distances.

Ground-based instrumentations

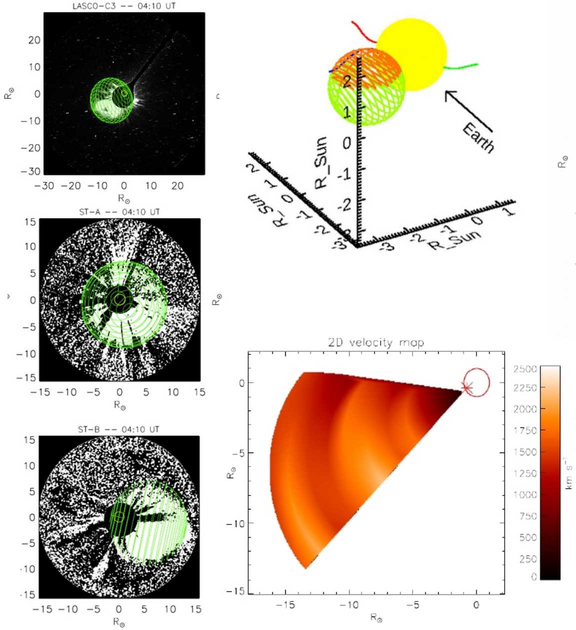
How to study a CME-driven shock? Principal steps

1 – Detection of EUV wave/CME/CME-driven shock front from images;
2 – Detection of Type II radio (the shock can be present even if the Type II is absent.) in radio dynamics spectra.
3 – Cinematics study : lateral expansion and 2D velocity map on POS and 3D front recostruction (by stereoscopic observations).
4 – Dynamics analysis: Intensity profile evolution, pre-event 2D plasma density map reconstruction (DEM, pb inversion) and/or 3D density reconstruction using time-dependent Solar Rotational Tomography; estimation of plasma temperature.
5 – Electron density compression ratio calculation from EUV, WL, and Radio data → Comparison between radio data and imaging data to infer the location of shock formation

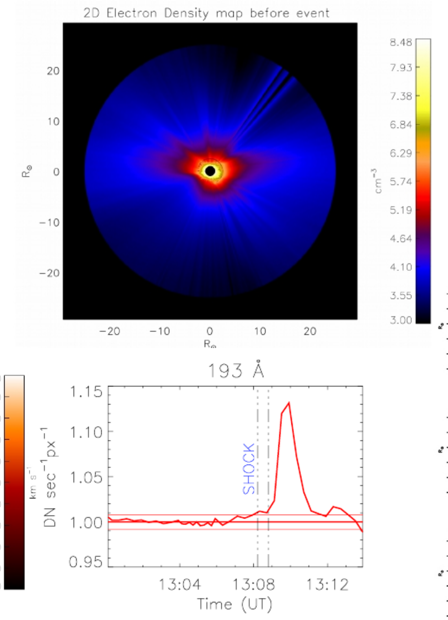
Step 1-2



Step 3



Step 4



Step 5