

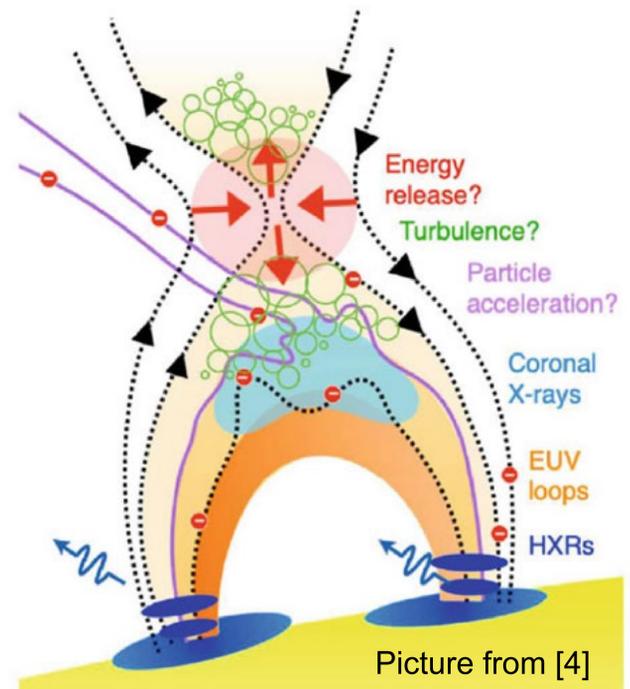
Unveiling particle acceleration in solar flares: the crucial role of X-ray polarimetry and future Italian space missions

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1. Solar flares: a particle acceleration laboratory yet to be discovered

The study of **solar flares** offers a unique laboratory for investigating **high-energy plasma physics and magnetic reconnection** processes. A central open question in solar physics concerns the mechanisms responsible for **particle acceleration** during the **impulsive phase of flares**. Particle acceleration acts nearby the flare loop top source and it has been proposed as consequence of:

- stochastic acceleration (second-order Fermi)** [1];
 - first-order Fermi process at the fast shock** [2], under some circumstances
 - reconnecting current sheet (RCS)** where magnetic reconnection occurs [3].
Precipitating of electrons through the plasma in the magnetic loop could cause also return currents of plasma electrons that contributes to the HXR emission [3].
- Regardless of the specific mechanism, accelerated **electrons propagate along the magnetic loop**, producing **bremstrahlung hard X-ray (HXR)** emission at both the **foot points** and the loop-top source.



2. X-ray polarization as a direct diagnostics of particle acceleration and magnetic field properties

Solar flares **HXR energy spectrum above 15-20 keV is dominated by non-thermal Bremsstrahlung** emission from accelerated electrons. The **soft X-rays (SXR)** are dominated by **thermal emission** due to **plasma heating**.
HXR polarimetry is able to solve degeneracies in flare models arising from imaging and spectroscopy [5].

High polarization is expected:

- from the non-thermal HXR component, up to tens of % of polarization degree [3,5]
- from regions with a low or negligible turbulence [5]



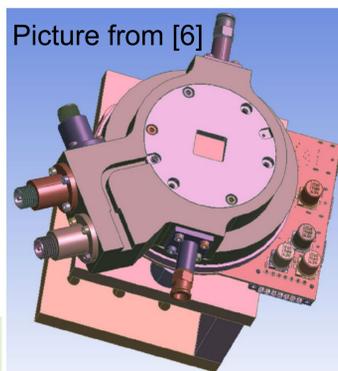
HXR polarization is a direct diagnostics for:

- non-thermal electron population fraction
- level of turbulence in the flaring region

3. High Yield Polarimetry experiment in X-rays (HypeX)

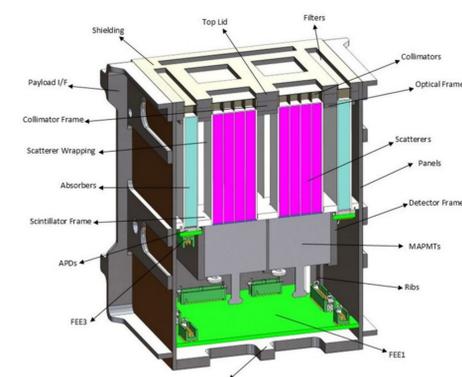
A new **gas polarimeter** based on the **photoelectric effect** effective in the **10-35 keV energy range (Ar based gas mixture)** is under development by **INAF-IAPS in collaboration with Bonn University** with the support of the Ministry of University and Research (**MUR**), Ministry of Foreign Affairs and International Cooperation (**MAECI**) and **ASI**. The HypeX polarimeter is based on the **TimePix3**

technology to perform **3D reconstruction** of the **photoelectron track** in a gas cell. Coupling this polarimeter with a multilayer X-ray optical module enables imaging polarimetry, providing a polarimetric map (and thus the magnetic field) of the flaring region [6].



4. CUBeSat Solar Polarimeter (CUSP)

CUSP [7], led by INAF-IAPS, is designed to measure the linear polarization of hard X-rays (25–100 keV) from solar flares with a dual phase Compton scattering polarimeter on board a 6U XL CubeSat from a SSO LEO orbit. The CUSP project is funded by the **Italian Space Agency (ASI)** for a **phase B (started in December 2024)** in the framework of the **Alcor program** implemented by ASI to develop innovative CubeSats.



6. Future developments

A future solar mission concept:

- broad-band X-ray polarimetry** with both photoelectric and Compton polarimeters;
- Imaging polarimetry** of the flaring source (few arcsec angular resolution is needed)
- breakthrough concept** : two satellites for **stereoscopic X-ray polarimetry** to break degeneracies due to single satellite line of sight observation

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