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Study of shocks in the solar corona with METIS

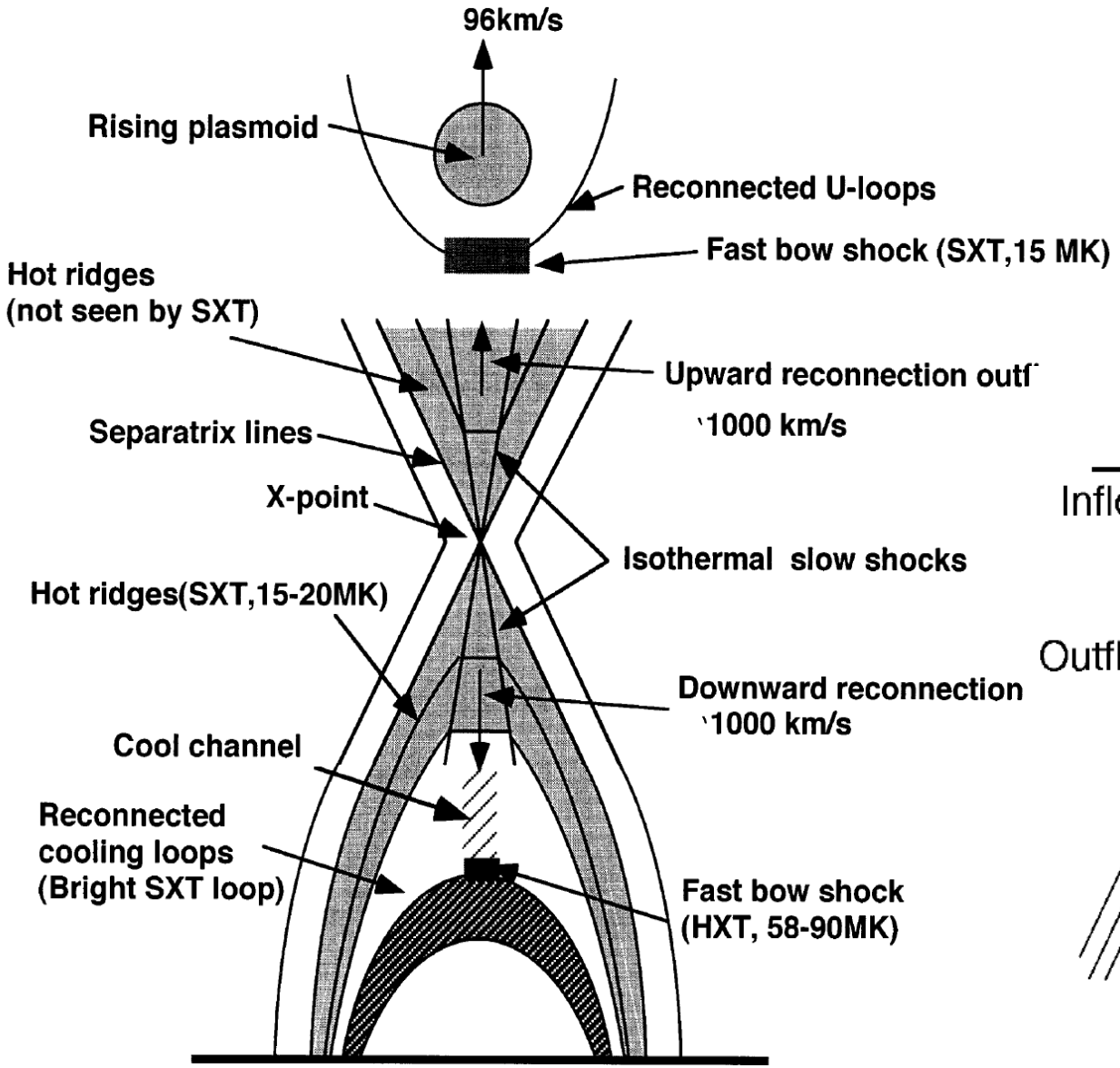
G. Zimbardo (1), G. Nisticò (2), S. Perri (1)

(1) Dipartimento di Fisica, Università della Calabria, Italy
(2) Institut für Astrophysik, Georg-August-Universität, Göttingen, 37077, Germany

Plan of Presentation

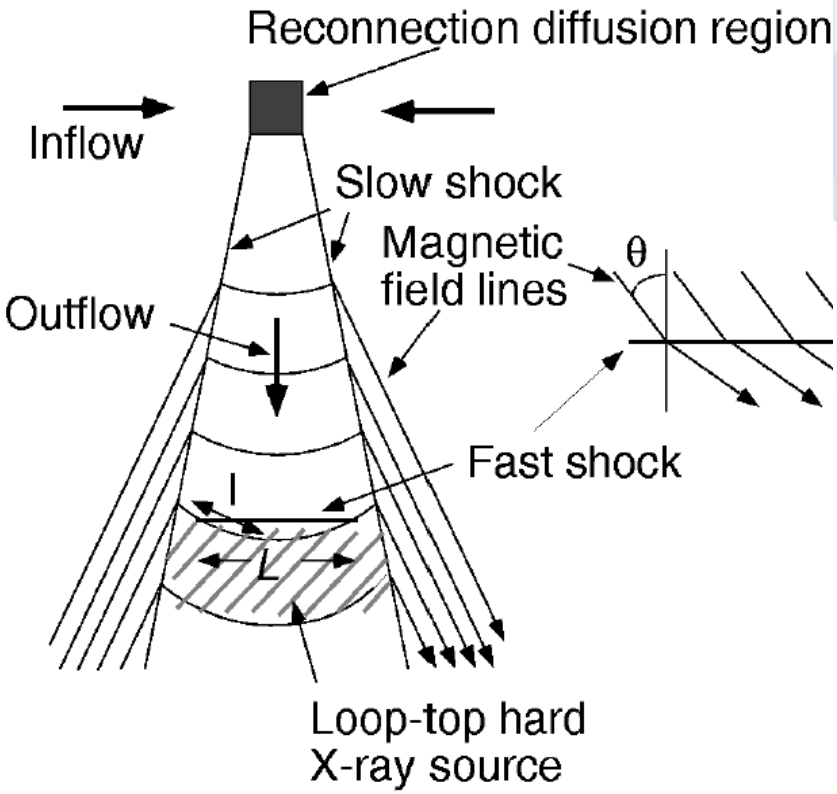
- Magnetic reconnection and shock waves
- CME Shocks as the source of solar energetic particles (SEPs)
- Jets and small scale shocks for preferential heating of heavy ions
- How many shocks in low-middle corona? A quest for METIS …

Magnetic reconnection in flares creates fast shocks:

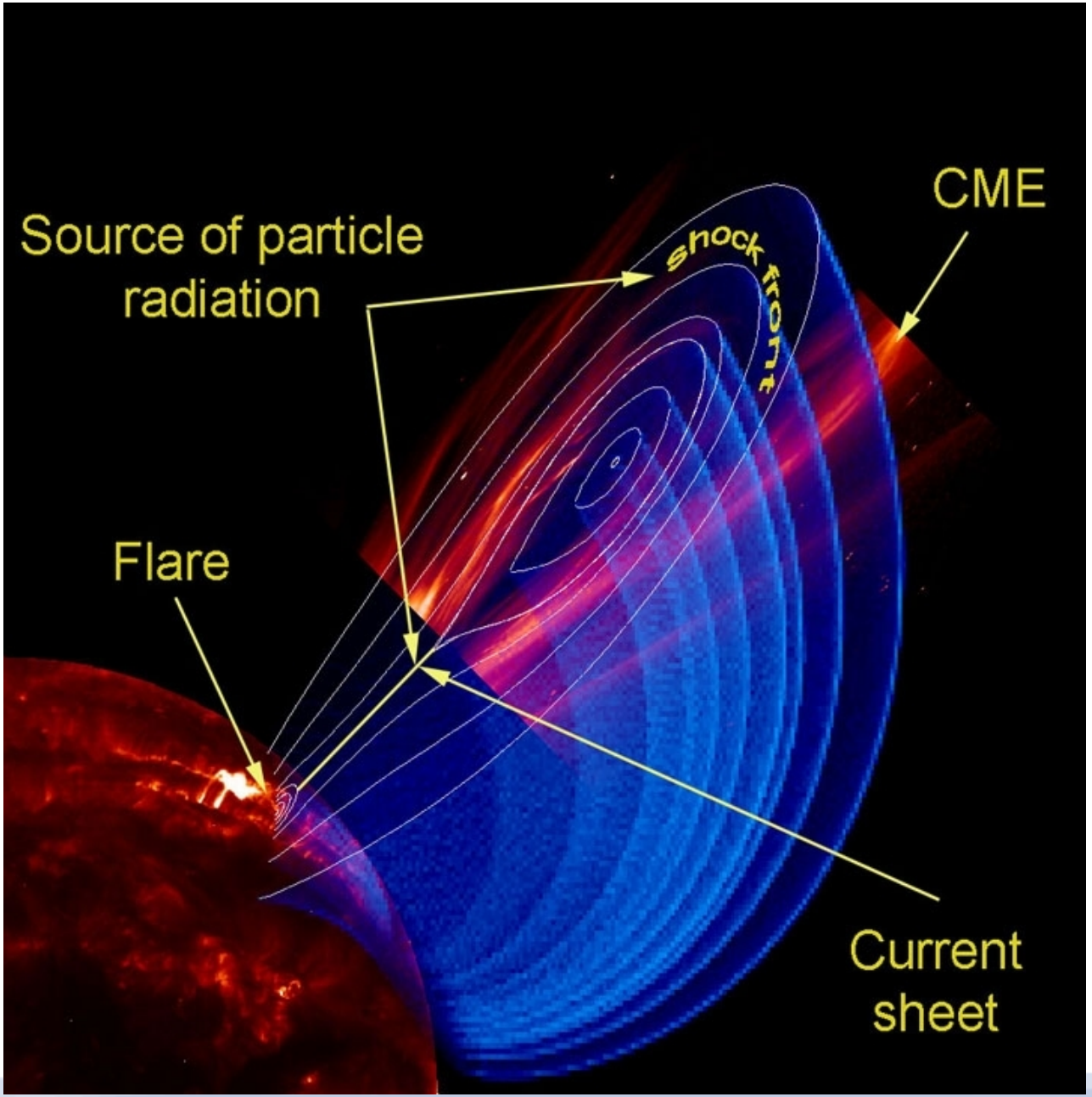


Tsuneta, ApJ, 1997.

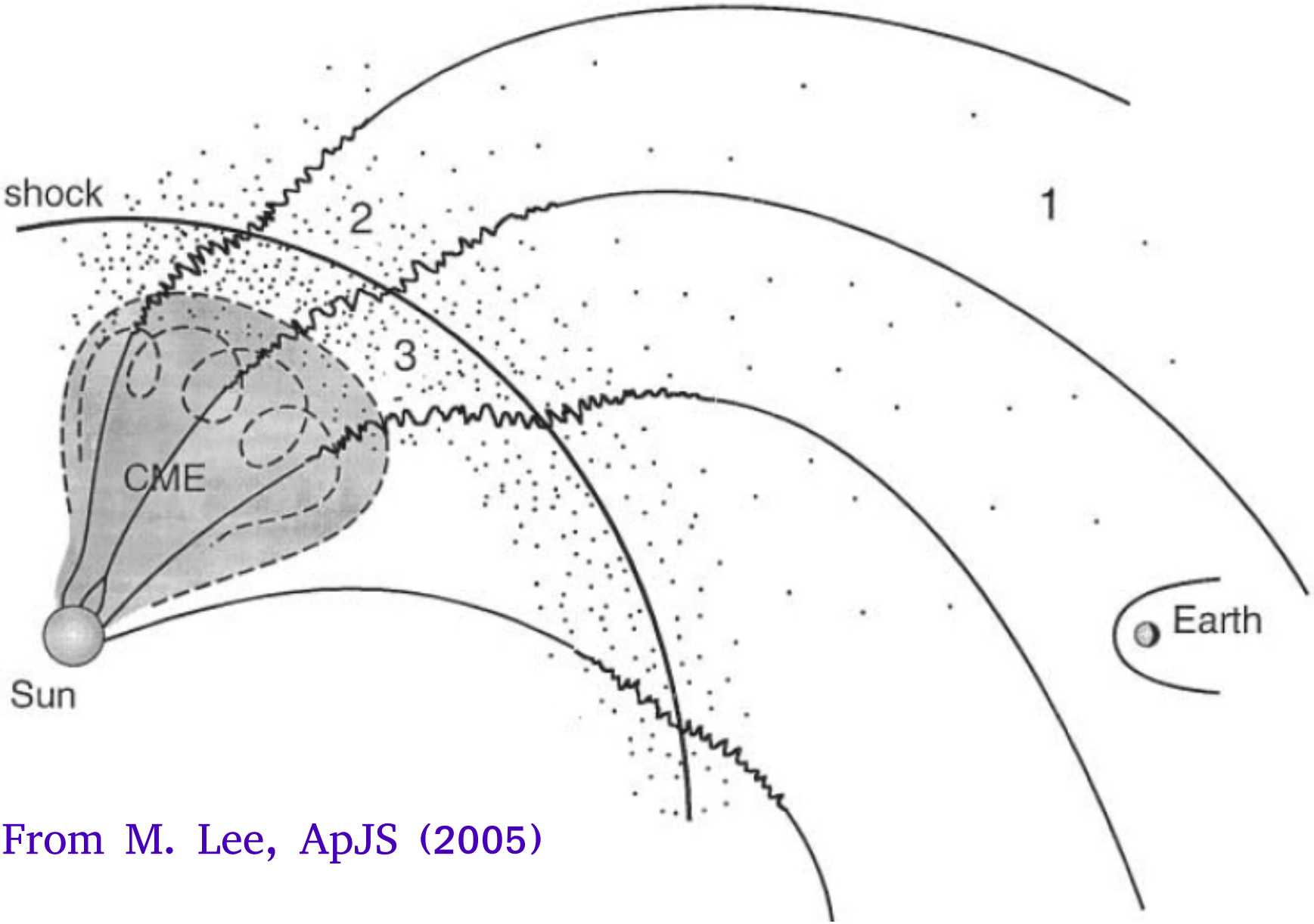
Tsuneta and Naito, ApJ, 1998



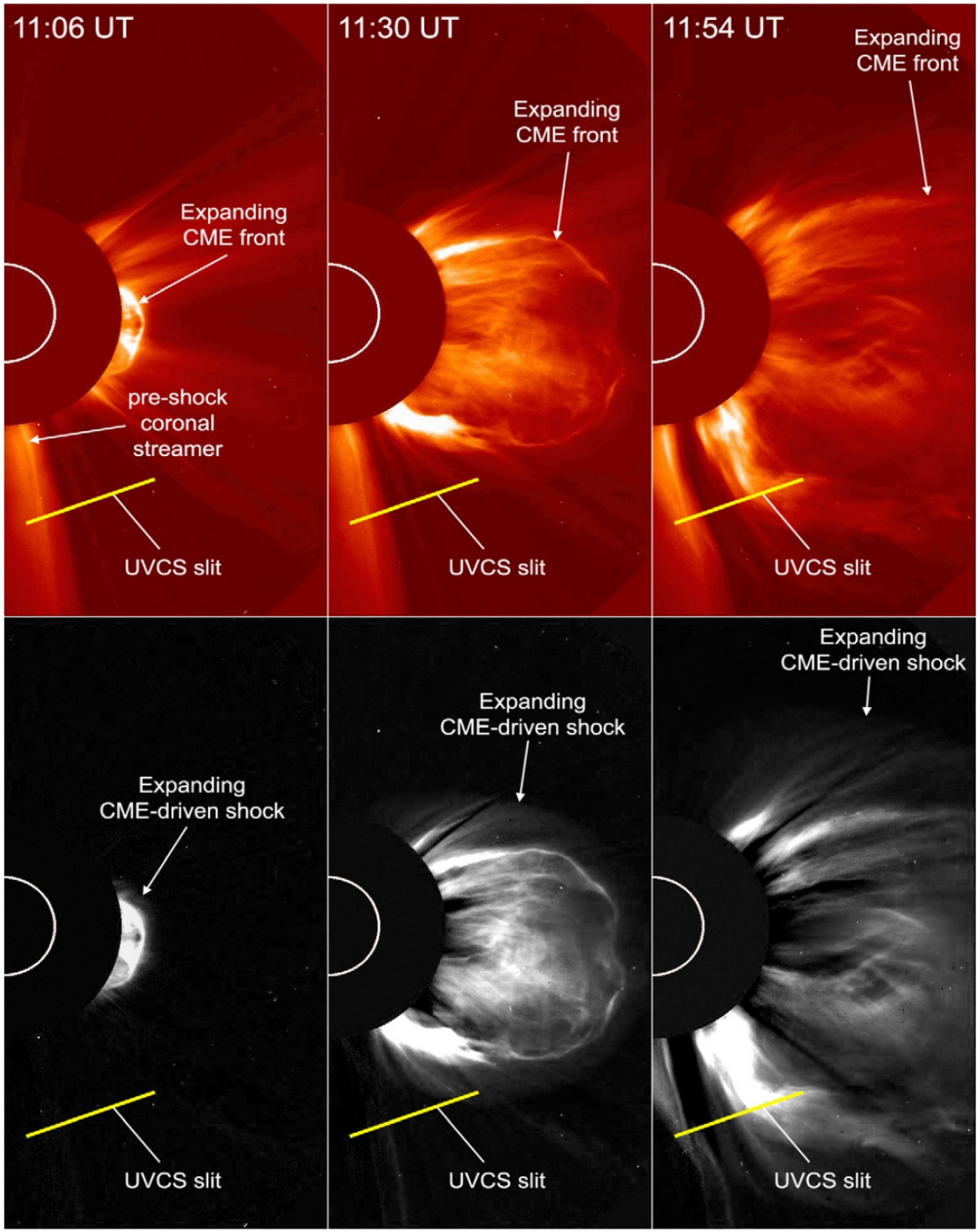
CME shocks are the source of solar energetic particles



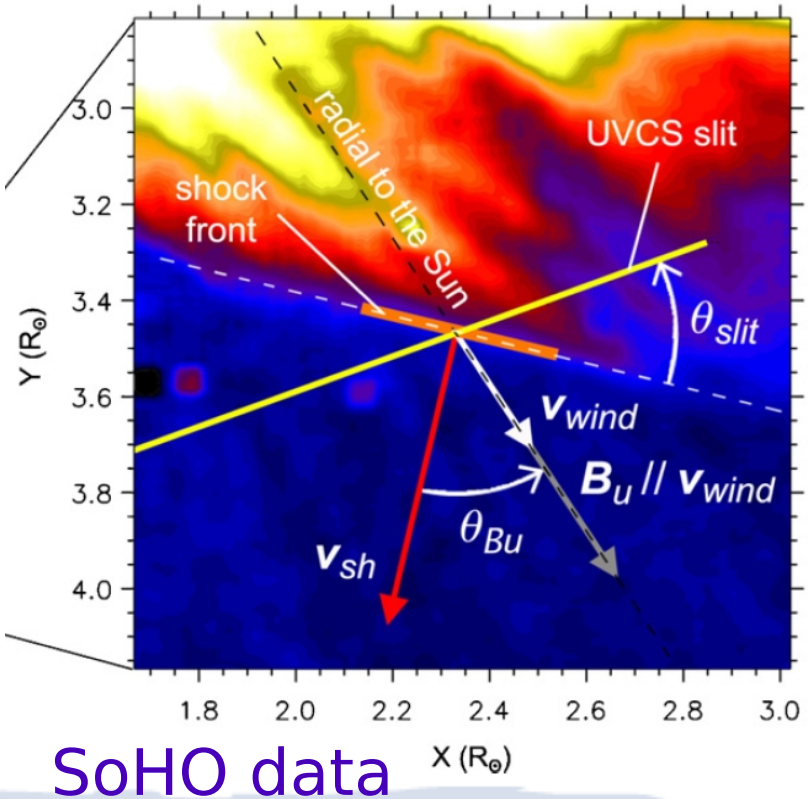
SEPs acceleration depends on the physical parameters **local to the shock**



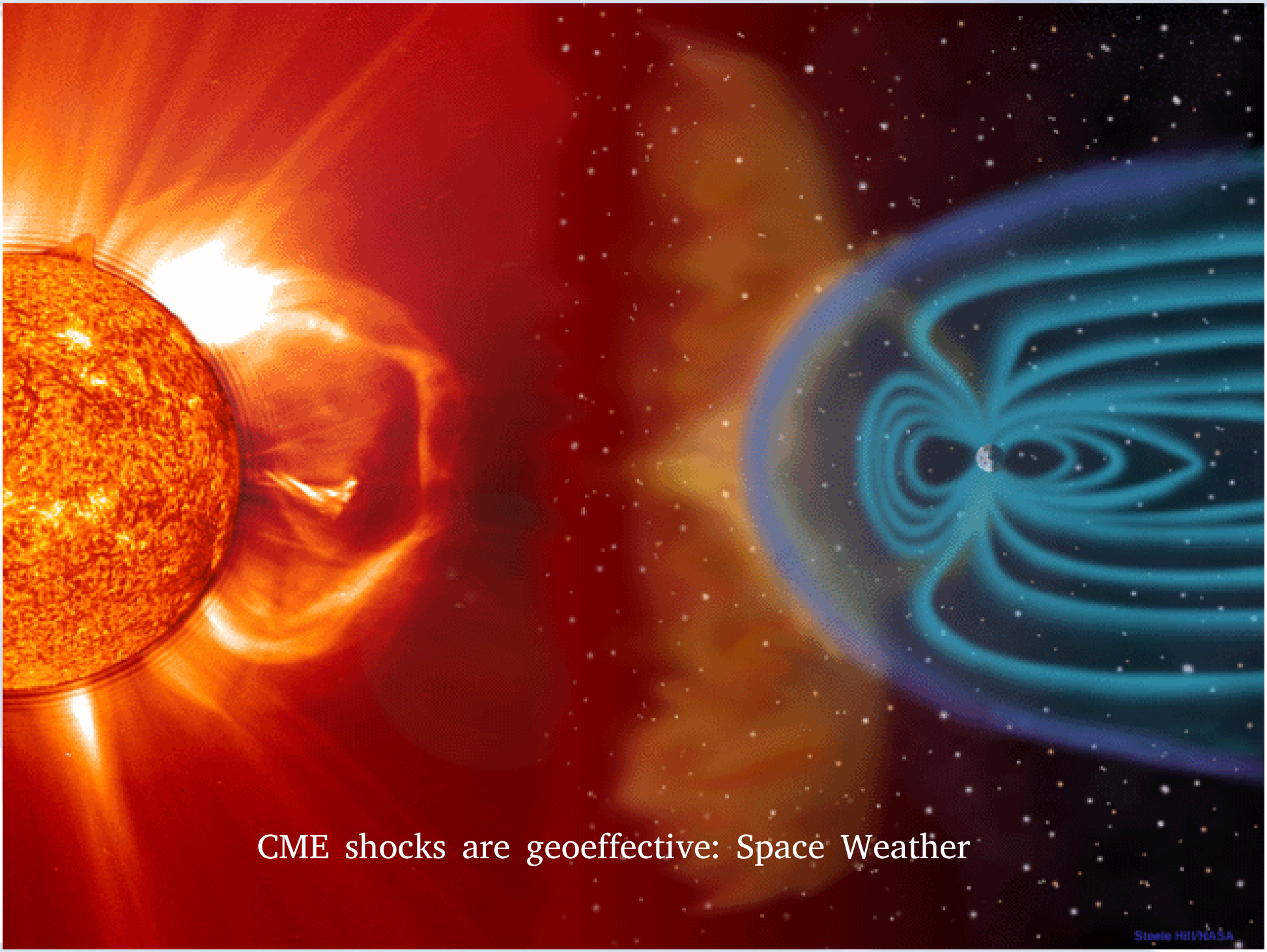
From M. Lee, ApJS (2005)



CME shocks have been studied in detail by Bemporad and Mancuso, ApJ (2010, 2011)



SoHO data

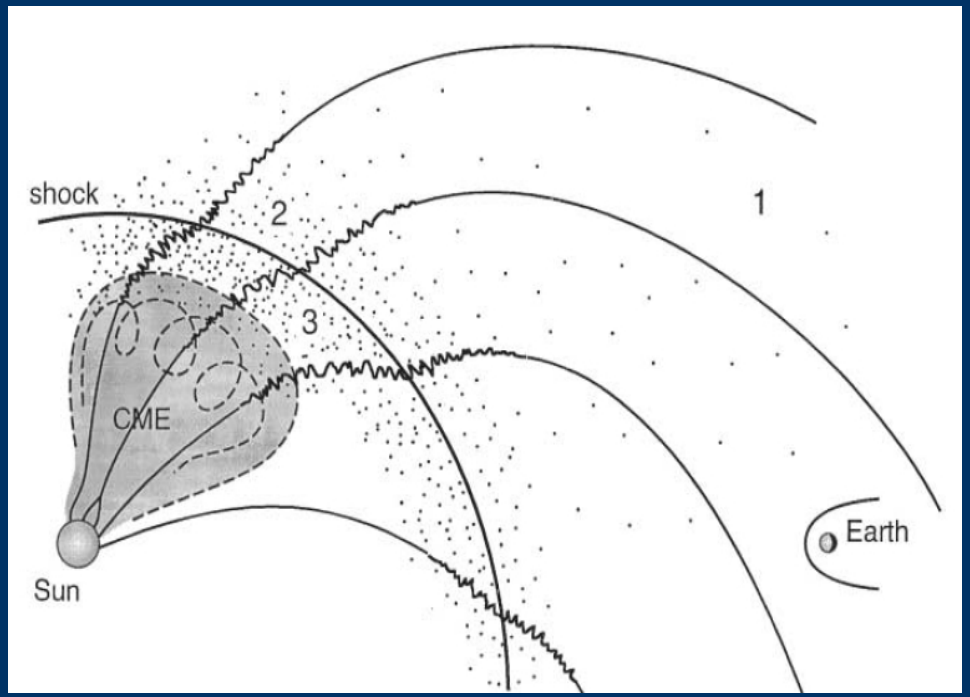

CME shocks are geoeffective: Space Weather
Steele Hill/NASA

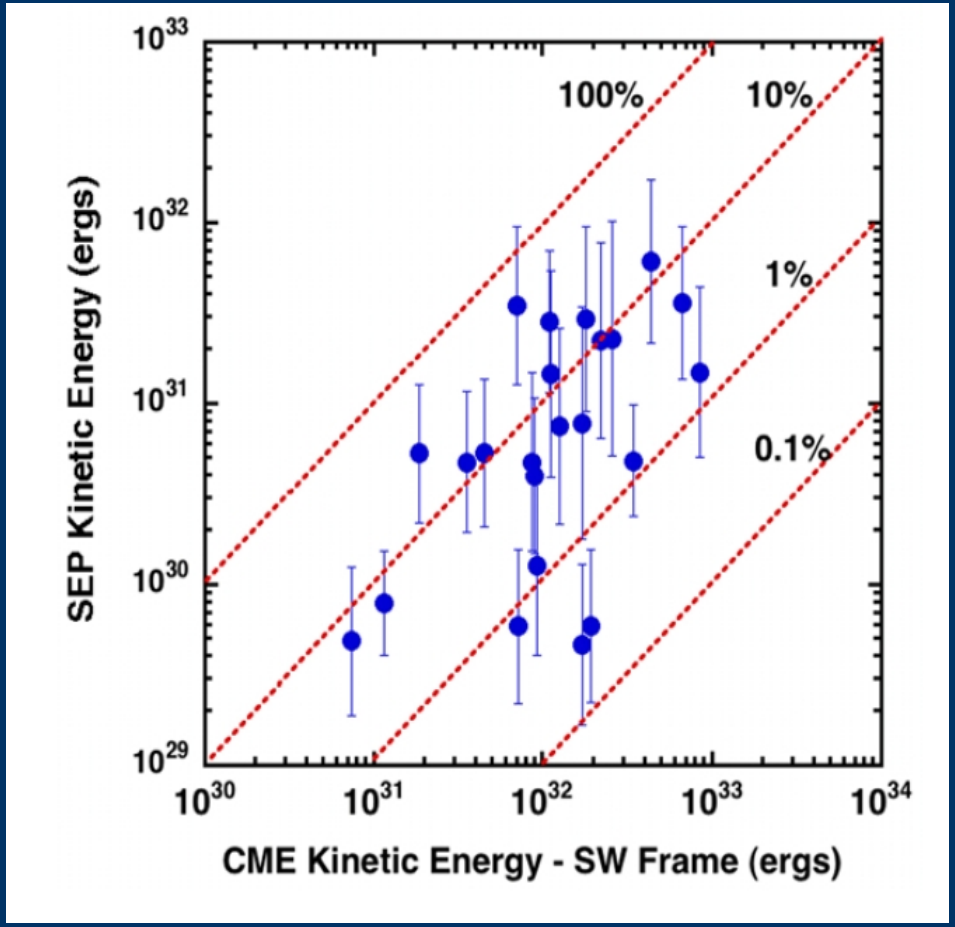
Many details of the acceleration process are not clear

From the Solar Orbiter Science Objectives:

- Where and when are shocks more efficient in accelerating particles ?
- What are the influences of magnetic field orientation and turbulence ?
- How can SEPs be accelerated so rapidly ?
- Why is the peak intensity varying over four orders of magnitude (e.g., Lee et al., SSRv, 2012) ?

Particle acceleration at coronal shocks



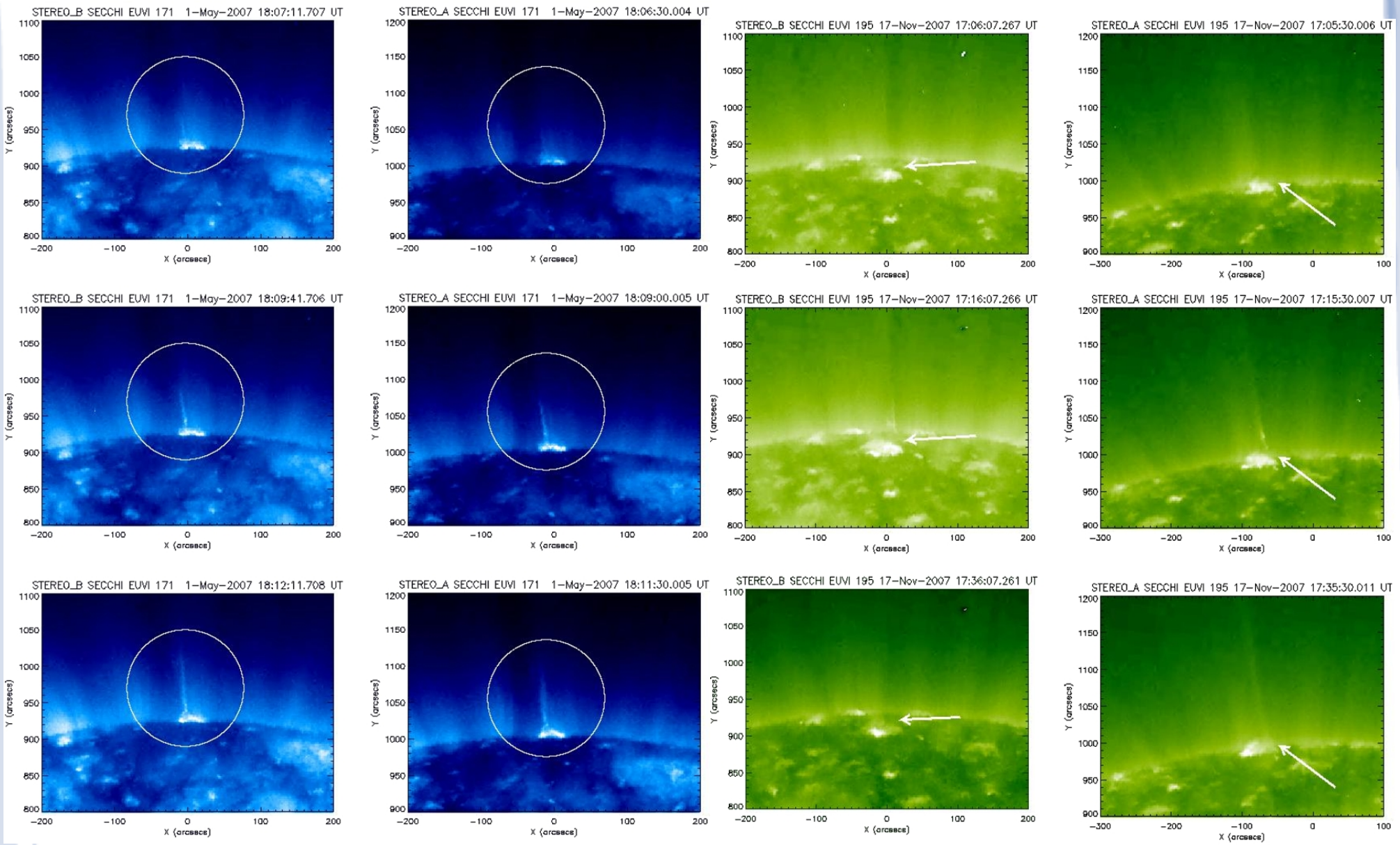


Mewaldt et al., 2008

while there is considerable scatter, and the uncertainties are large, on average ~5 %–10 % of the CME kinetic energy apparently goes into accelerating energetic particles. It is interesting that a similar acceleration efficiency is required of supernova shocks if they are to keep the Galaxy filled with galactic cosmic rays over their ~15 million year lifetime (e.g., Ptuskin 2001).

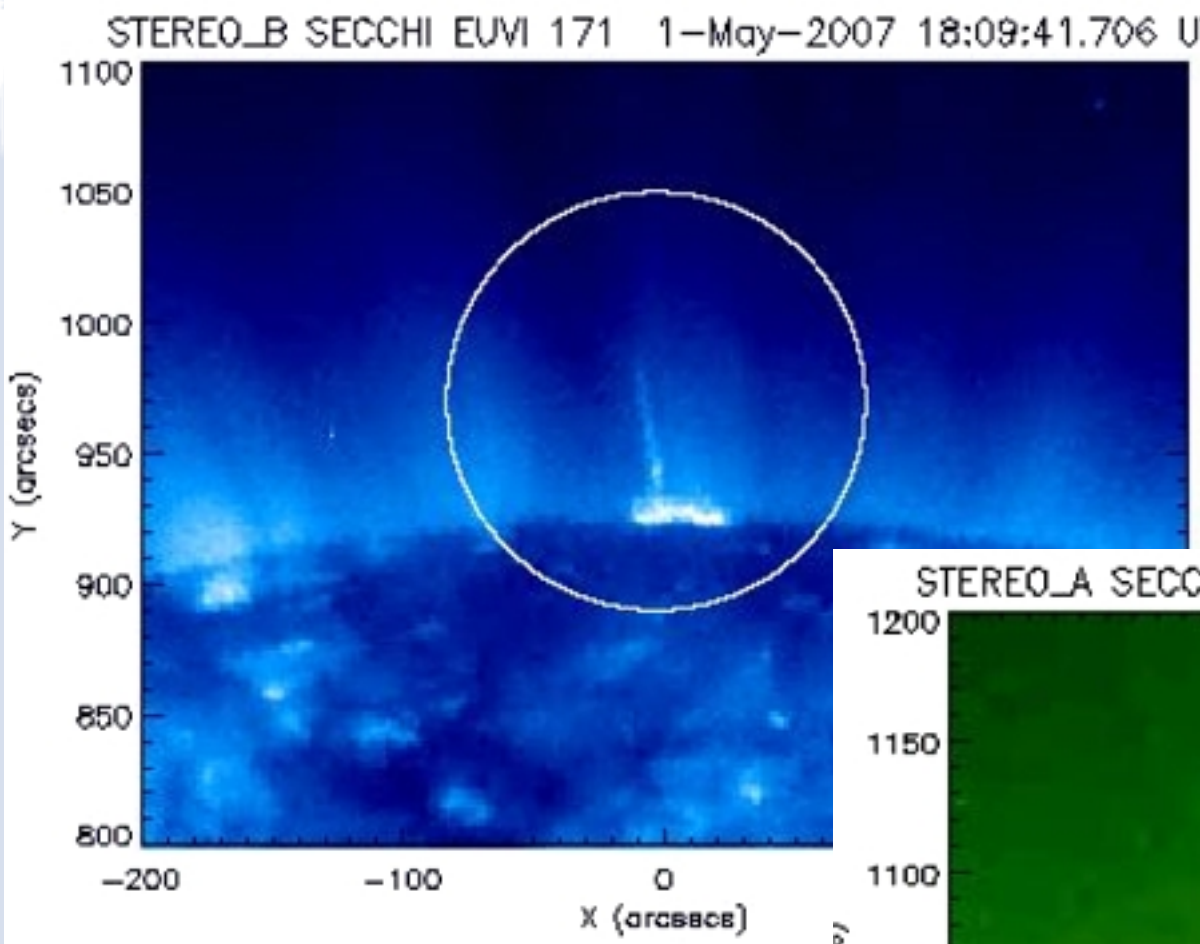
Lee et al., 2012

Smaller scale mass ejections: coronal hole jets

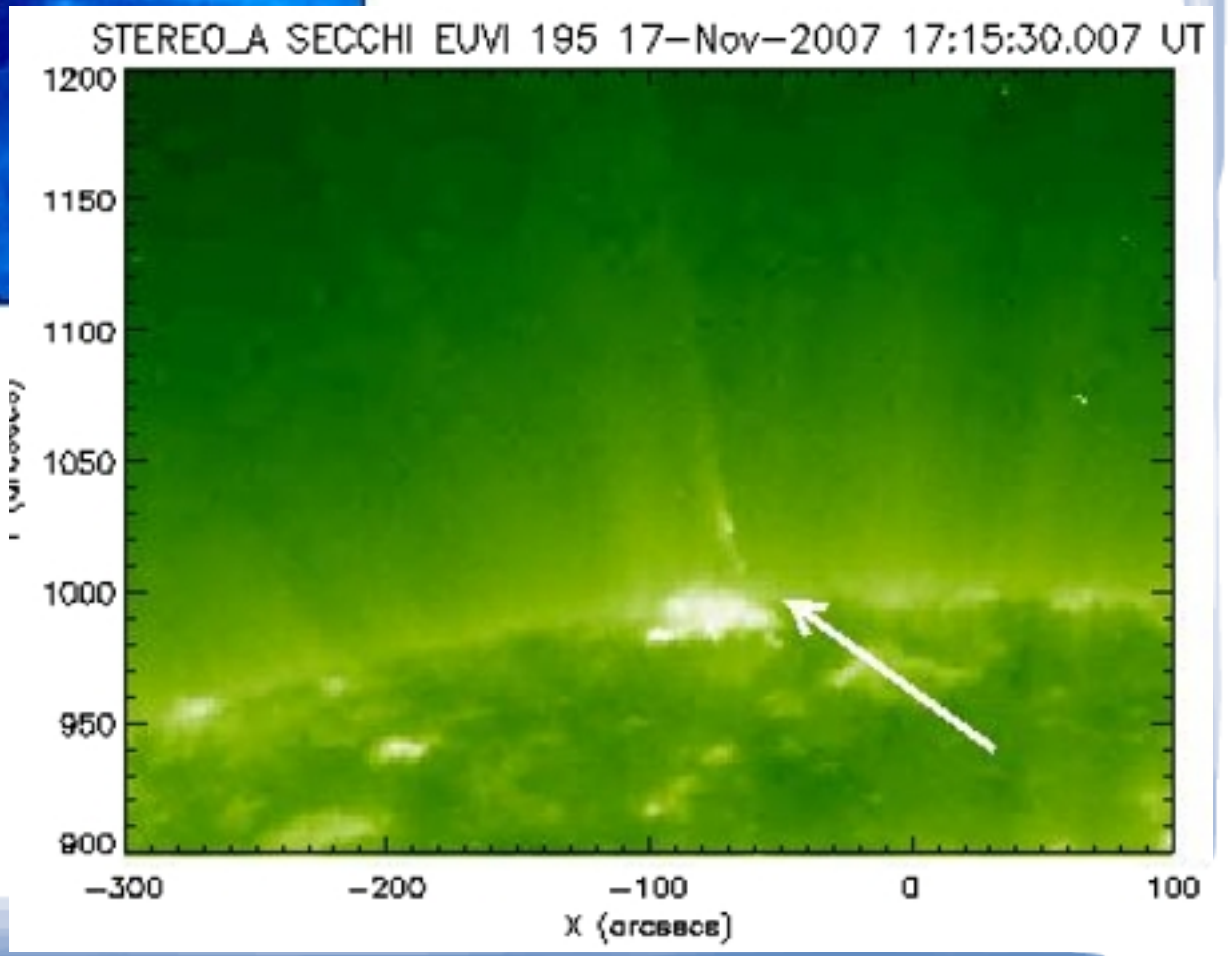


Nistico' et al., Solar Phys., 2009

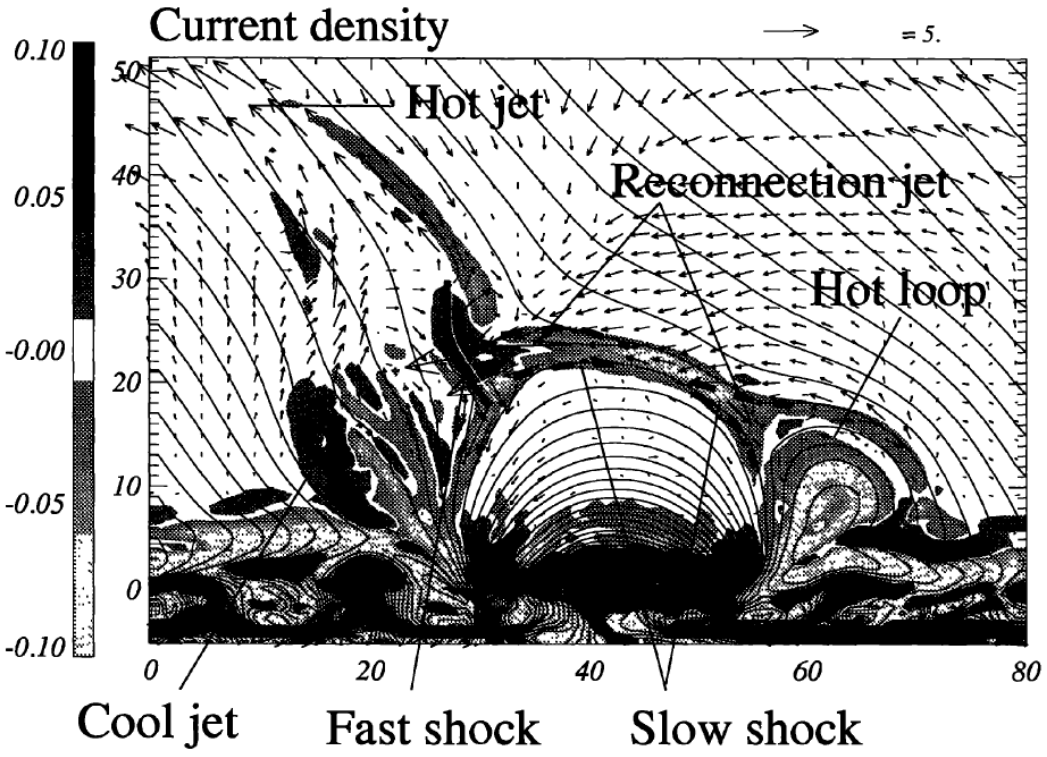
STEREO data



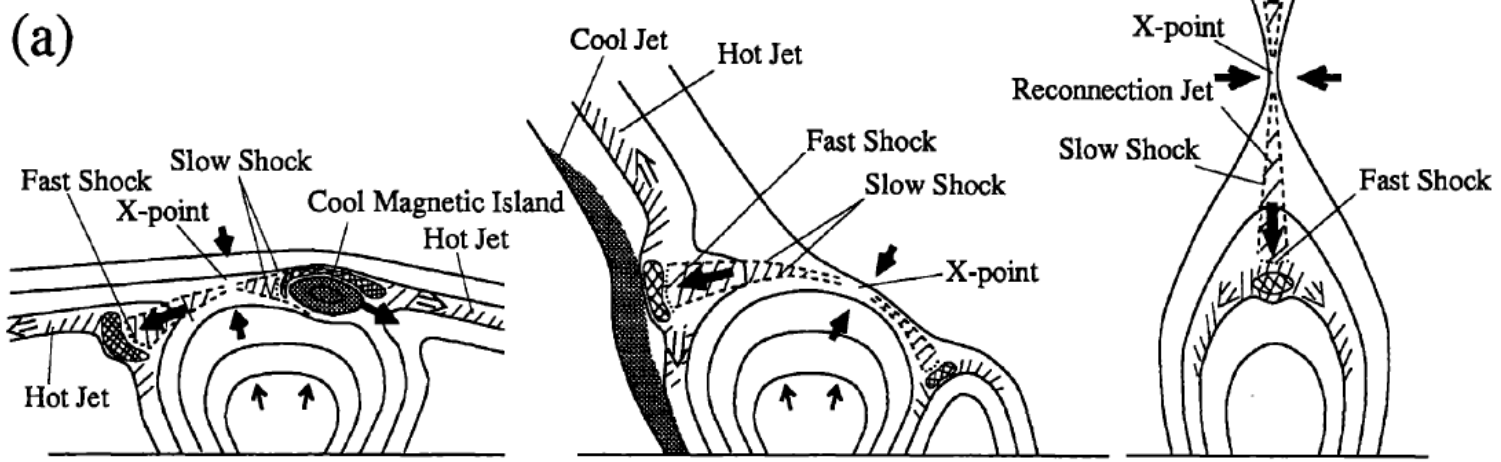
Blow ups of jets seen by STEREO:



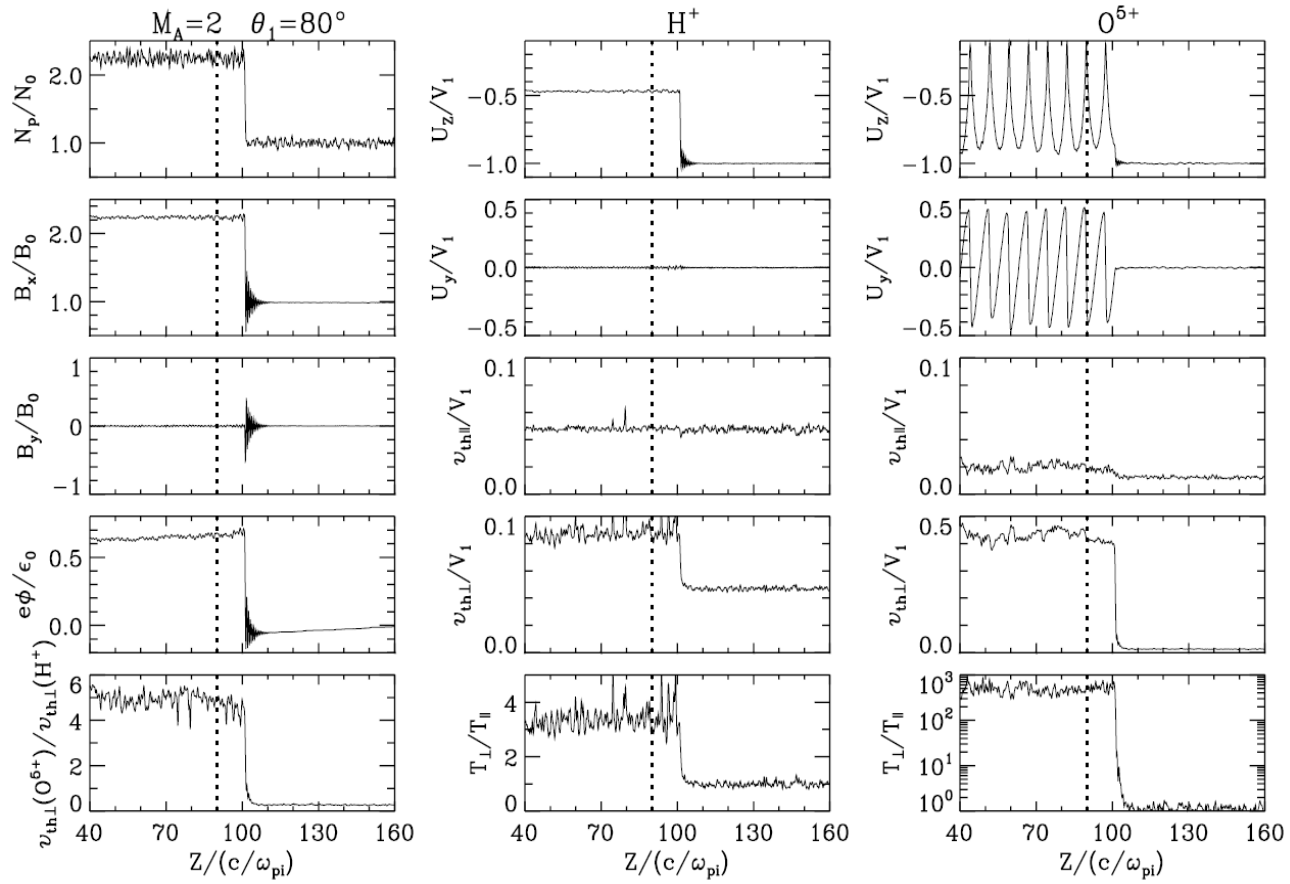
Numerical simulations by Yokoyama and Shibata show that coronal hole jets create fast shocks:

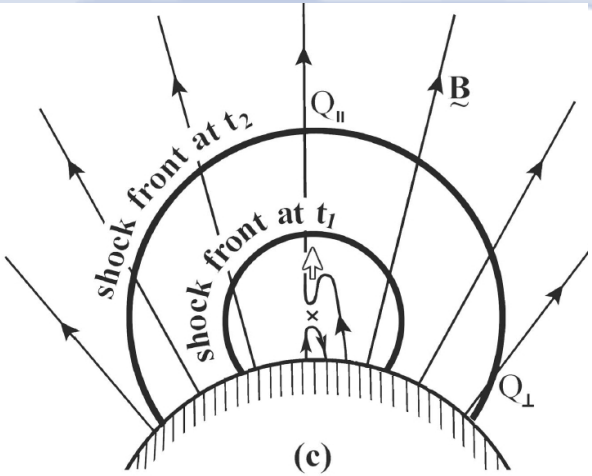


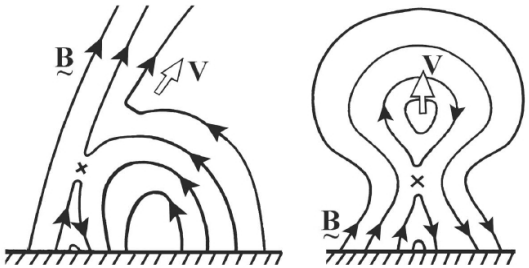
Yokoyama and Shibata, PASJ (1996)



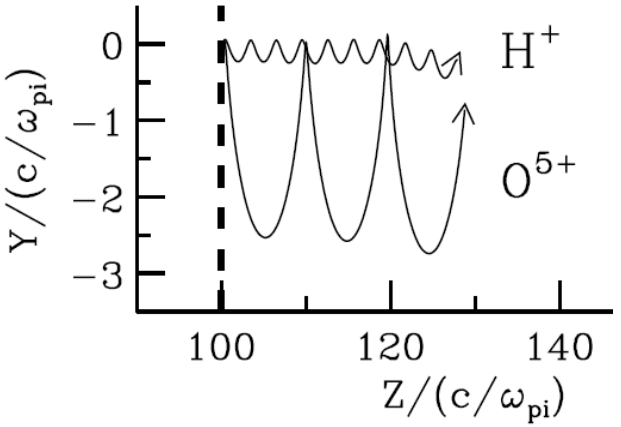
Consider quasi-perpendicular shocks: both subcritical and supercritical shocks can explain the preferential heating of heavy ions in the solar corona (Lee and Wu, ApJ, 2000):



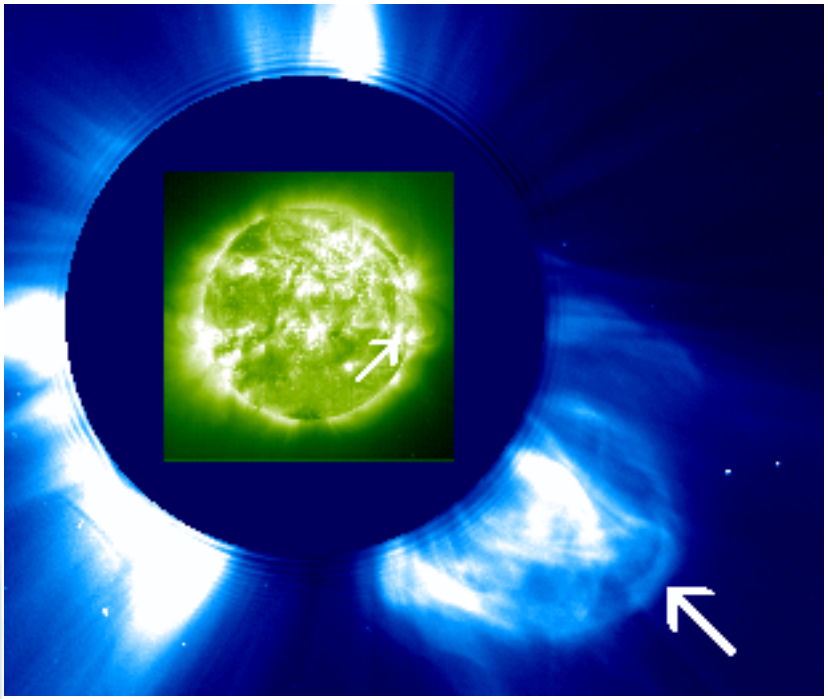


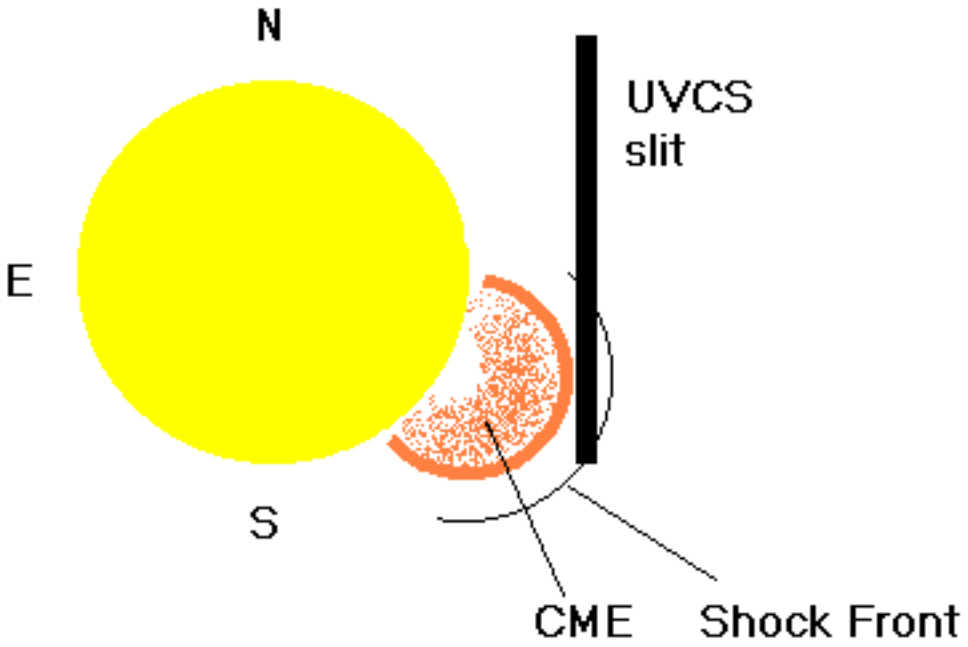


shock
at $\Omega_{ci}t = 0$

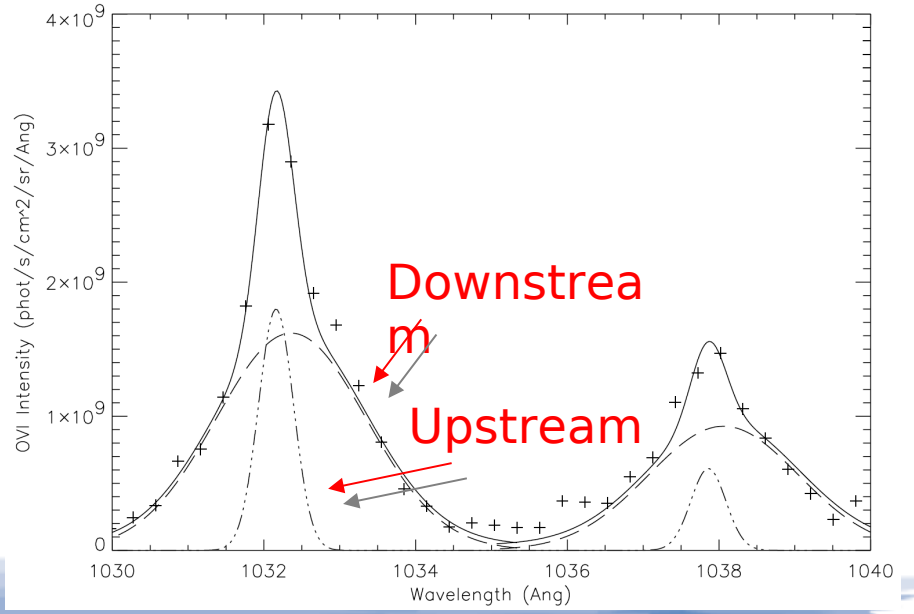


Enhanced heating of oxygen ions at shock passage was reported by Mancuso et al., A&A (2002), using SoHO UVCS data:





The observed line broadening of O VI is consistent with the model of Lee and Wu (2000) and with in situ observations by Berdichevsky et al., JGR (1997)



How common are small scale shocks in the low corona ?

METIS will allow to study coronal shocks and reconnection jets at lower altitudes than before, thanks to improved resolution in both the visible and the UV lines.

Search strategy:

1. Look for shocks and jets in METIS images;
2. Find the corresponding source in the EUI images
3. Determine the physical parameters by the METIS Ly-alpha analysis.

This will help to determine the energy flow from reconnection to shock dissipation.

Conclusions

- Solar Orbiter represents a fantastic opportunity to increase our knowledge of the Sun and of the heliosphere.
- High resolution measurements by METIS will allow to study in detail magnetic reconnection outflow jets and shocks.
- The possibility that a large enough number of shocks exists in the low corona will boost our understanding of energy dissipation and heavy ion preferential heating in solar corona.