



# *Particle acceleration as seen by Solar EUV imagers*

SIDC, ROB, Belgium

Lucky observations during SWAP off-pointing campaign  
01-03 April, 2017

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# *PREAMBULA*

- ➔ EUV observations of middle solar corona **ALREADY** provide precious information about the region where solar wind is heated and accelerated !

## *SWAP off-pointing campaign is:*



This is the region of solar wind heating and acceleration. Can we study this region using EUV observations?



# Long-term goal



Electron density

- 15 R\_Sol
- LASCO C2 – 2 Sol\_Rad

?



electron + ion  
(M. Mierla analysis)



We are **ALREADY** able to extract  
EUV signal from the middle  
corona



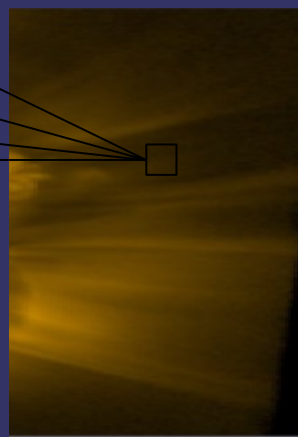
# Two-fluid MHD equations

$$\frac{\partial \rho_e}{\partial t} + \nabla \cdot (\rho_e \vec{v}_e) = 0,$$

$$\frac{\partial (\rho_e \vec{v}_e)}{\partial t} + \nabla \cdot (\rho_e \vec{v}_e \vec{v}_e^\top + p_e \mathbf{I}) = -\frac{\lambda_m}{\hat{r}_g} \rho_e (\vec{E} + \vec{v}_e \times \vec{B}),$$

$$\frac{\partial \rho_i}{\partial t} + \nabla \cdot (\rho_i \vec{v}_i) = 0,$$

$$\frac{\partial (\rho_i \vec{v}_i)}{\partial t} + \nabla \cdot (\rho_i \vec{v}_i \vec{v}_i^\top + p_i \mathbf{I}) = \frac{1}{\hat{r}_g} \rho_i (\vec{E} + \vec{v}_i \times \vec{B}),$$

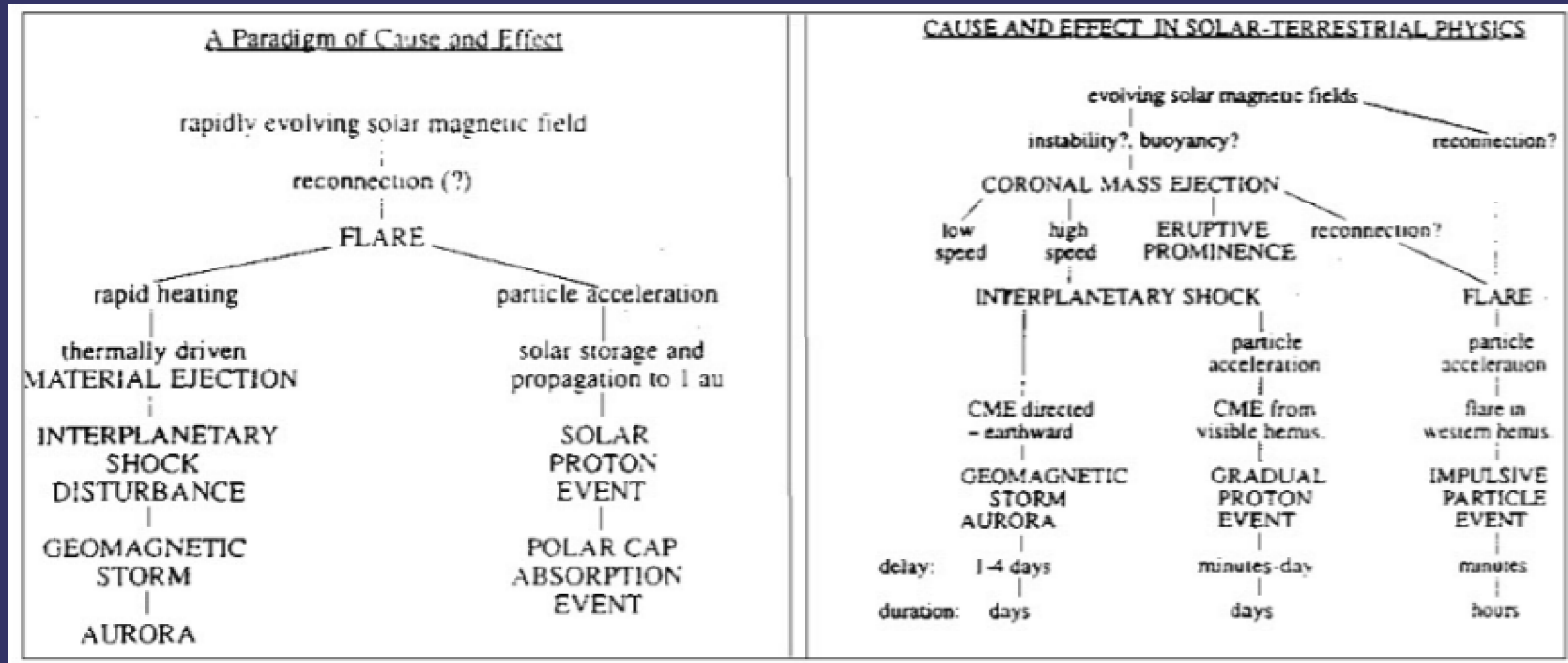


Knowledge of electron and ion  
density evolution in middle corona  
can give us self-consistent  
description of fluid dynamics of  
the solar wind

## *View on Solar-Terrestrial relations*

- ➞ Study of solar magnetic energy release at all scales.

## *“Old view” on space weather*

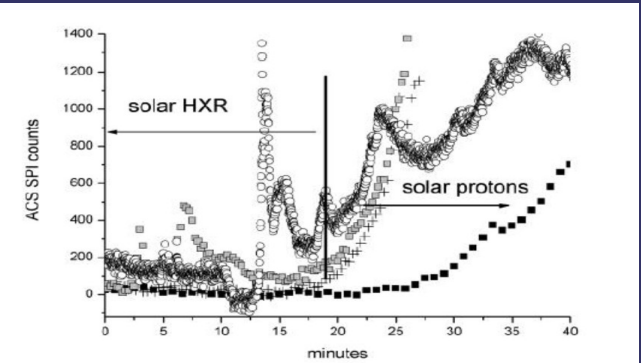
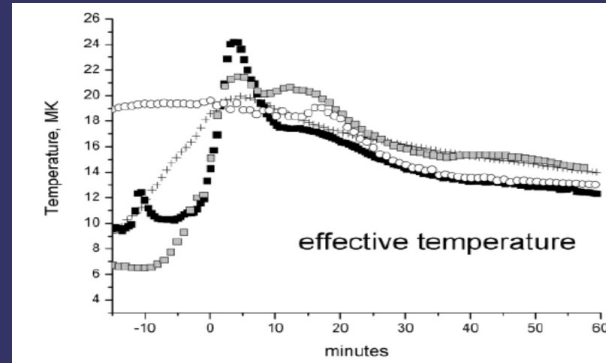


Gosling, 1993.

Flare ignition  
scenario

CME ignition  
scenario

# *Particle Acceleration is also important!*



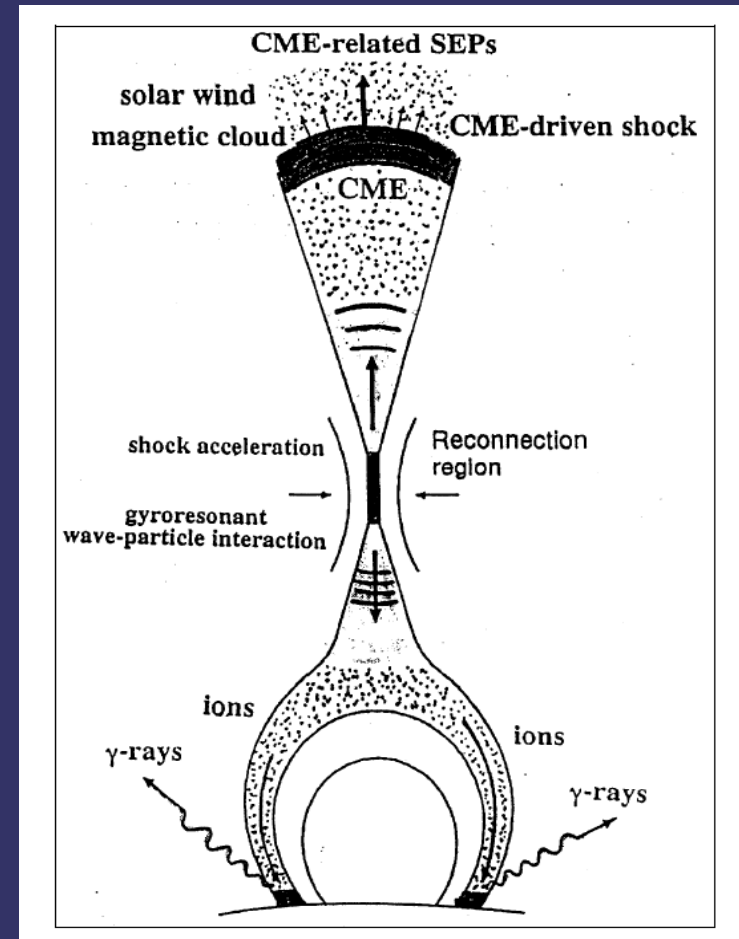
Flare observations by NASA/Swift satellite, 25/04/2008, EV Lacertae

- 2 types of flares
- Accelerated particles: 10-500 MeV



# *Particle Acceleration on the Sun*

➡ Solar flares: electron, protons, heavy ions, (up to 10 GeV for protons)



Generation scheme of high-energy particles taking into account the process of magnetic reconnection in a solar atmosphere (Yoshimori et al., 2000).

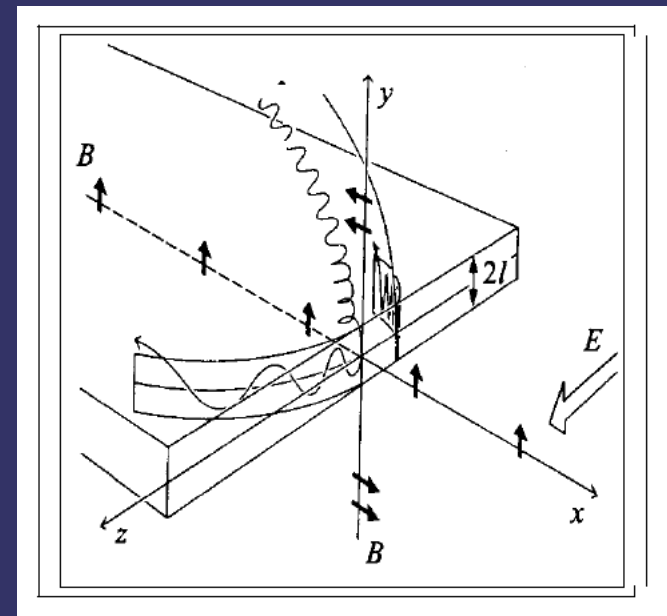
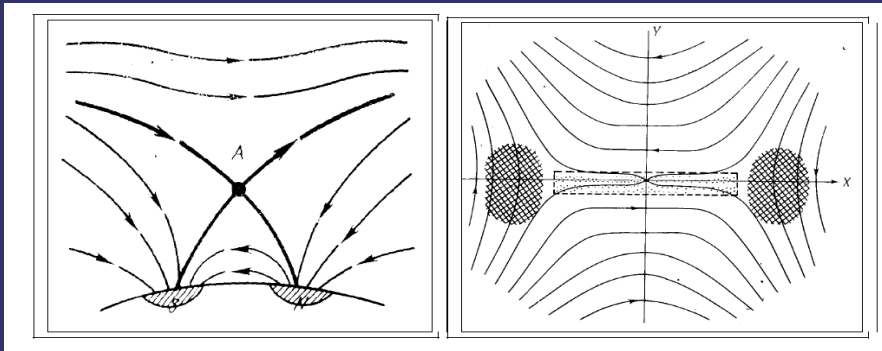
- ➔ *The main reason that nature avoids uniform distribution for energetic particles is: they meet extremely rare other particles.*

## ***Particle Acceleration on the Sun***

- ➔ If we decompose them into the most simple processes:
- By electric field (related to reconnection)
- Acceleration by the shock waves
- Stochastic acceleration by the turbulence (Fermi... particles accelerate while propagating between inhomogeneous islands)

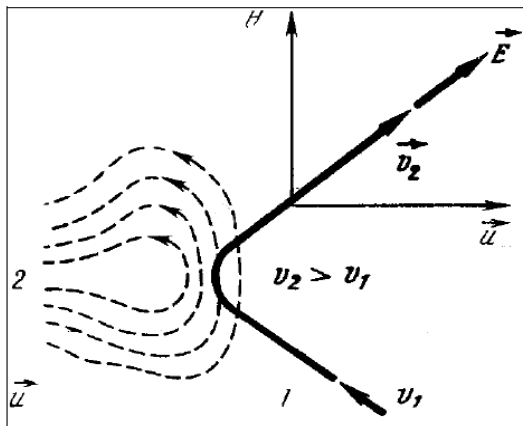
# Particle Acceleration on the Sun

ION AND ELECTRON BEAMS  
FROM RECONNECTION,  
Were observed in solar wind  
magnetosphere, but never YET on  
the Sun



Spicer, 1965, Priest and Forbes (2000)

Fermi, 1949

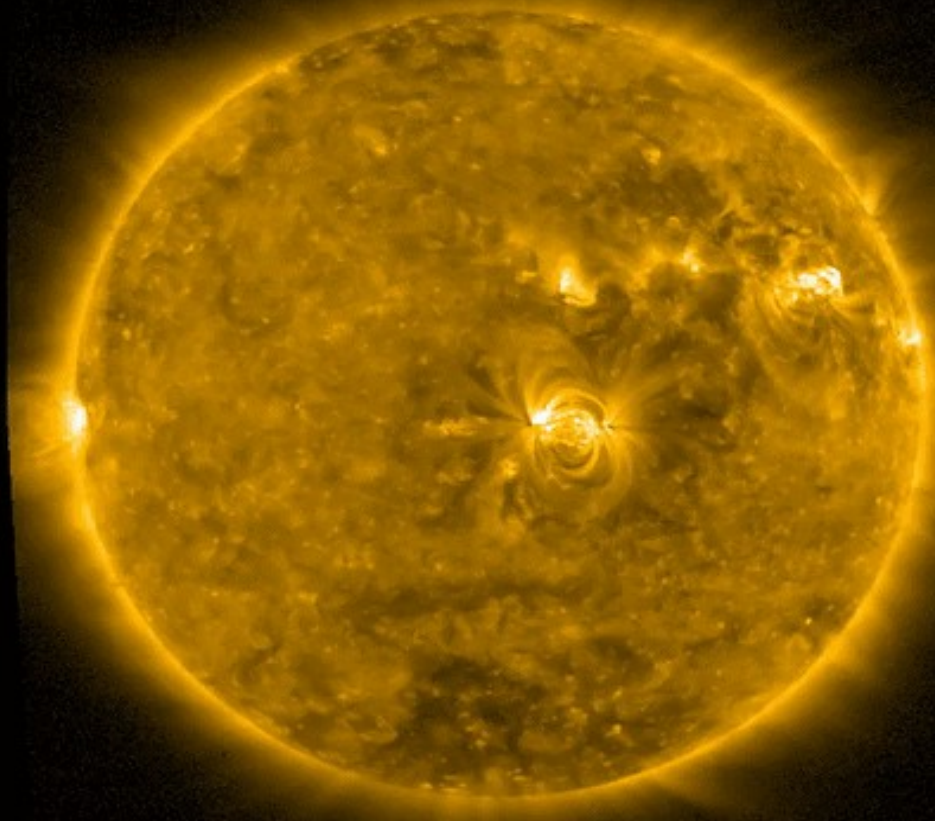


# *Summary*

	electrons	ions	
shock		20 minutes	
reconnection	sec	1-2 min	
geometry	Fron side	Aside...	

Electrons acceleration is very fast  
processes with respect to ion  
acceleration

# *SWAP acceleration event*

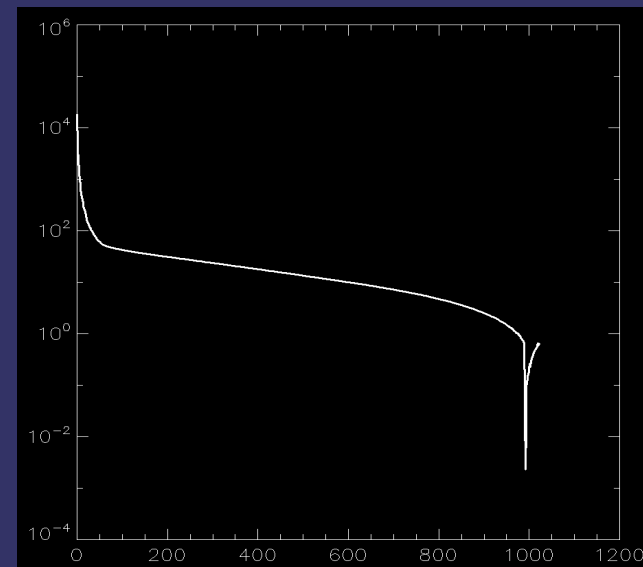
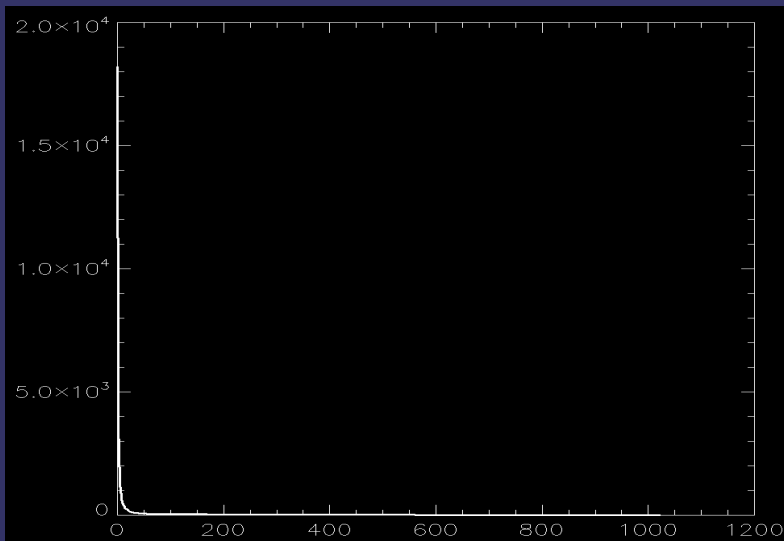


This event is too narrow.  
We demonstrate that it  
correspond to direct  
observation of  
ION BEAM, produced by  
flare reconnection.



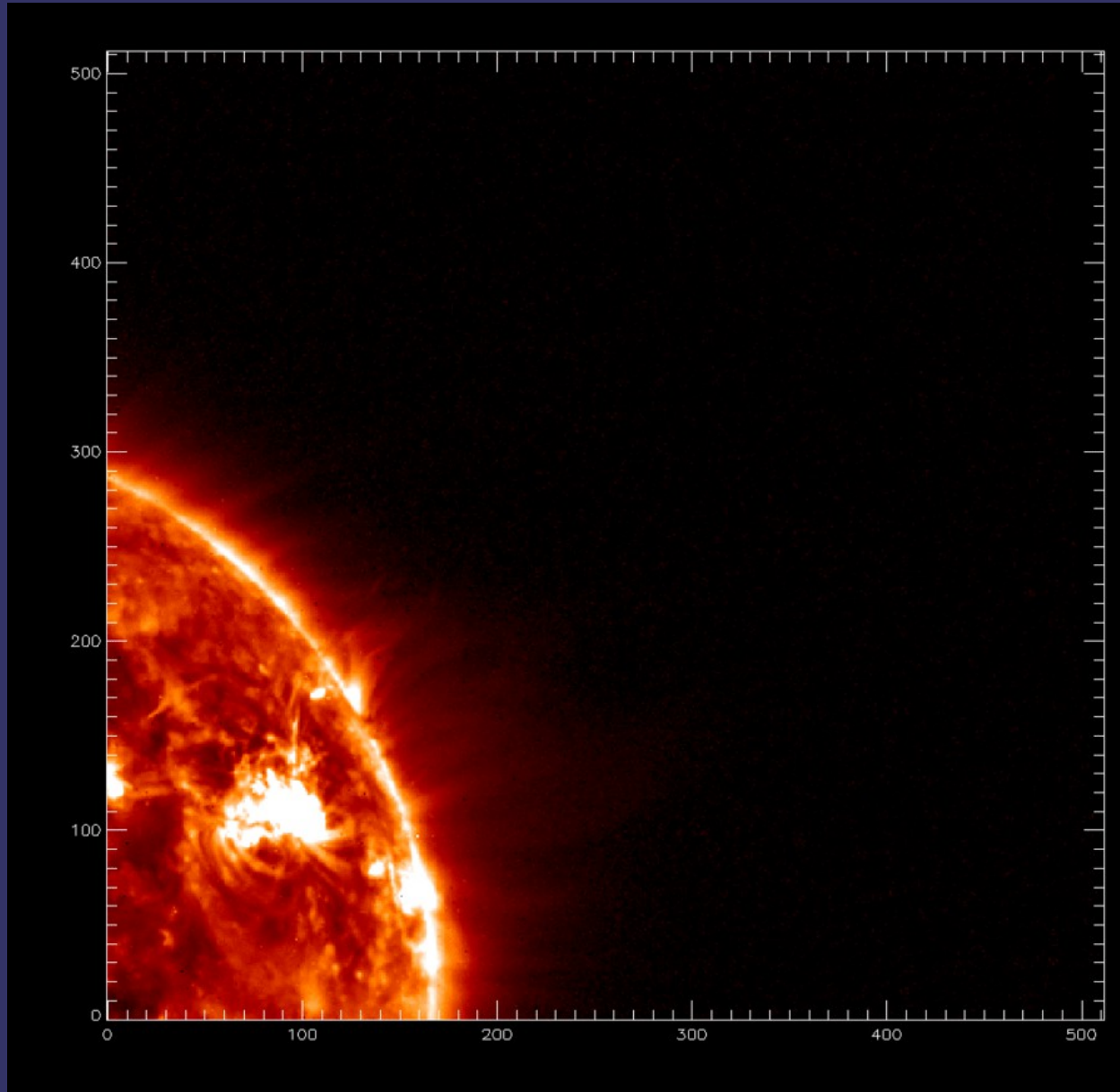
# *Image Processing*

- ➔ Images are calibrated to level 1 data using latest swap\_prep subroutines.
- ➔ In addition we remove some extra-noise using principal component analysis technique.

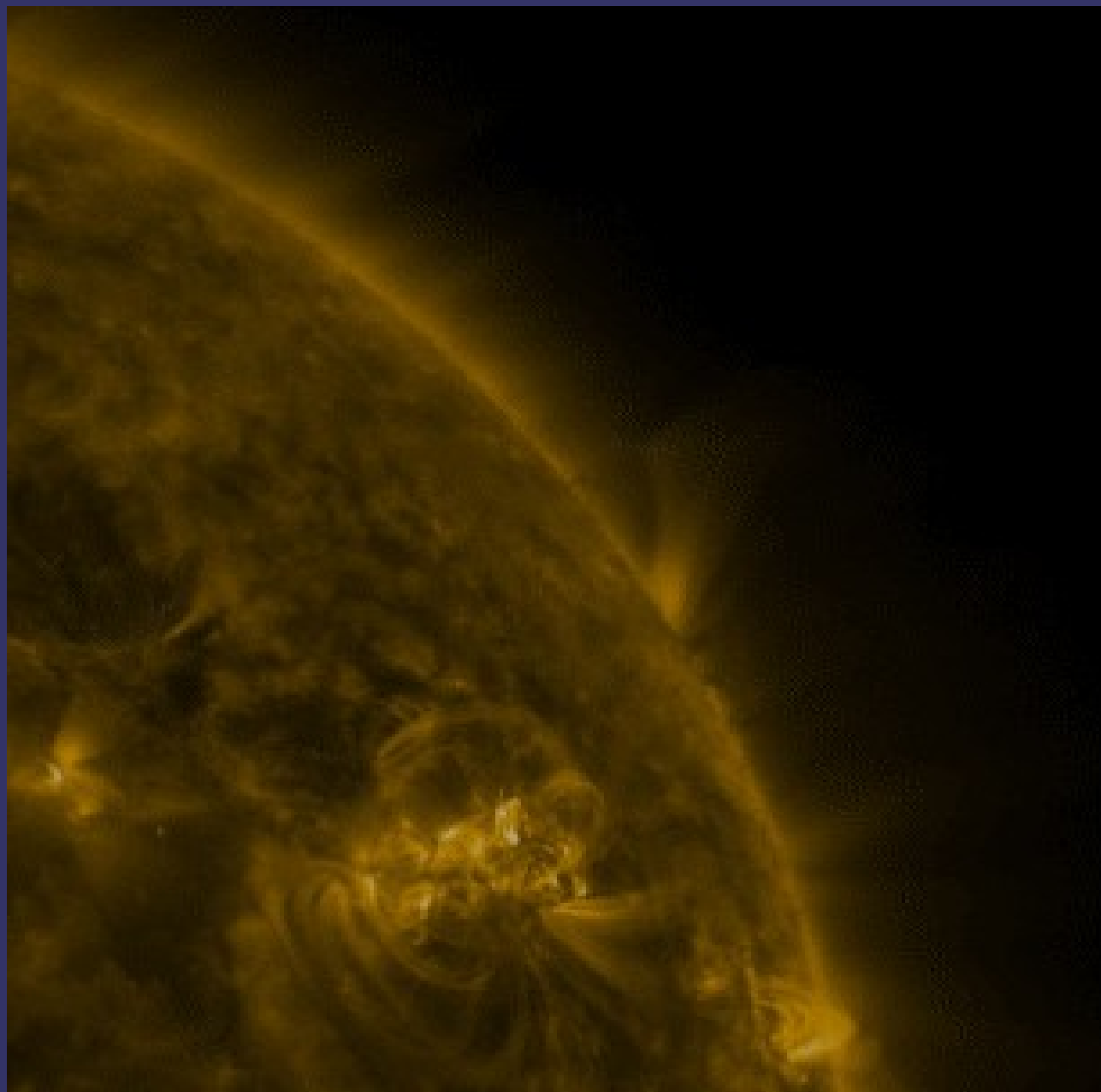


Proper values of swap image.  
First 40 ( from overall 1024)  
modes are enough to  
reconstruct the image.  
**EFFICIENT NOISE FILTER**

# *After Calibration and SVD*



Using SWAP off-pointed campaign data we observe ION beam propagation till  $1.35 R_{\text{sol}}$



SDO observed the  
same event till  
 $0.8 R_{\text{sol}}$

# Results & Conclusion

- ➔ Observation of ion beam acceleration in the middle corona till  $1.3 R_{\text{Sol}}$

450 km/s	20-40 km/s
550 km/s	-
650 km/s	-
750 km/s	-
760 km/s	-
730 km/s	-
690 km/s	-
660 km/s	-
550 km/s	-
475 km/s	-
	-

# *Conclusions*

- ➔ Using SWAP off-pointed campaign we identify the narrow acceleration event propagating till  $1.35 R_{\text{Sol}}$  in the MIDDLE solar corona.
- ➔ Spatio-temporal and physical characteristics of the event unambiguously indicate our event is:
  - ION BEAM acceleration event, firstly identified already in the solar corona.



# *Next Step*

- ➔ In the paper following this presentation we present detailed characteristics of ion beam acceleration event.
- ➔ We discuss importance of MIDDLE corona EUV observations for fundamental processes of solar wind heating and acceleration