

# Multi-wavelength study of active region loop dynamics

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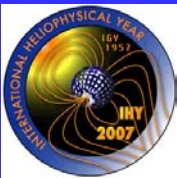
1. Indian Institute of Astrophysics, Bangalore, India

2. Armagh Observatory, N. Ireland

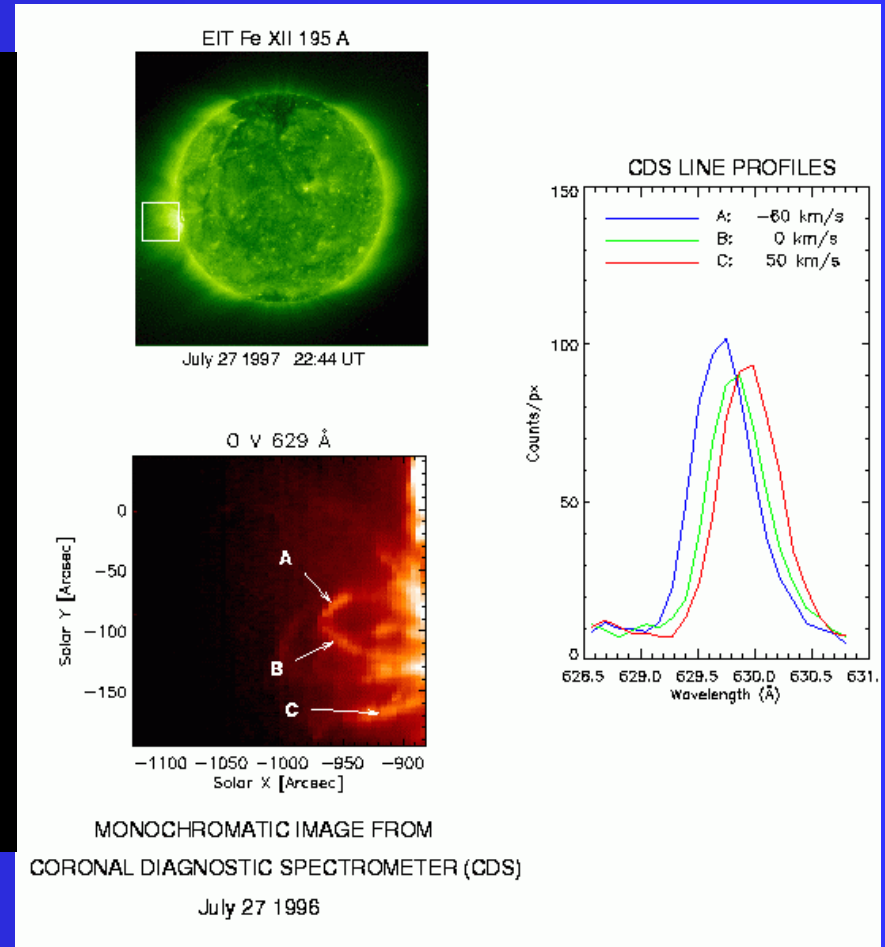
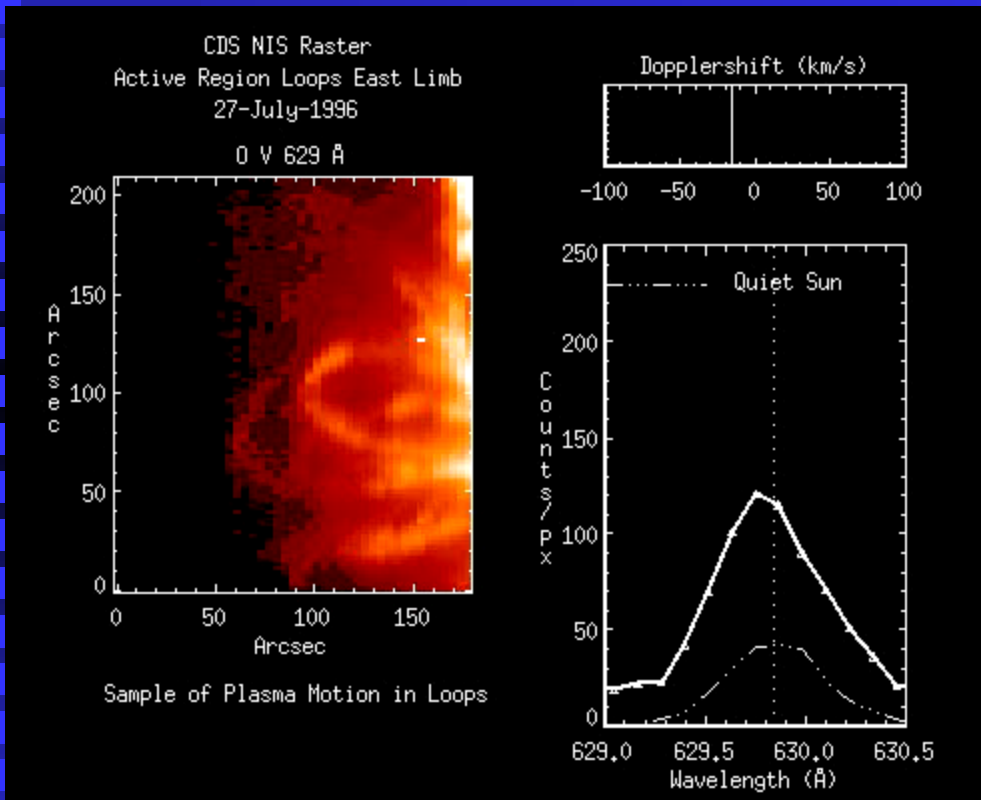


# Loop dynamics

- Even in Quiescent, non-flaring conditions, loops show strong temporal variability and substantial plasma flows
- From CDS raster Fredvik et al 2002 measures velocities 20-100 km/s at different temperatures and also observed siphon flows
- Kjeldseth-Moe & Brekke (1998) reported significant changes in coronal loops over one hour.

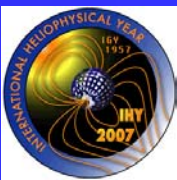


# Loop dynamics/Active region Flows



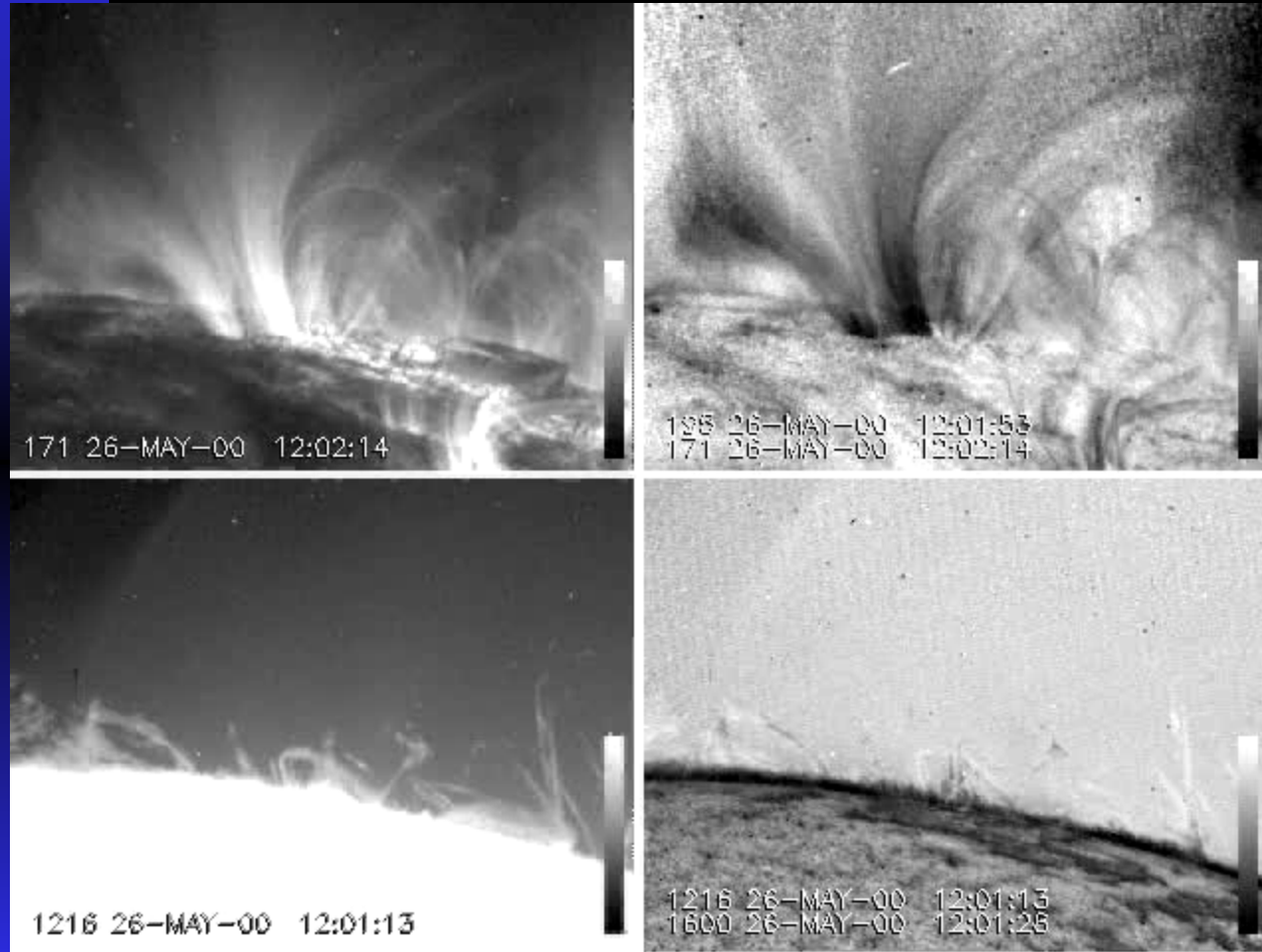
# Evacuation

- The fact that loops undergo rapid evacuation is known from Skylab era Levine & Withbroe (1977)
- ***Dramatic evacuation*** of loops triggered by rapid radiation dominated cooling



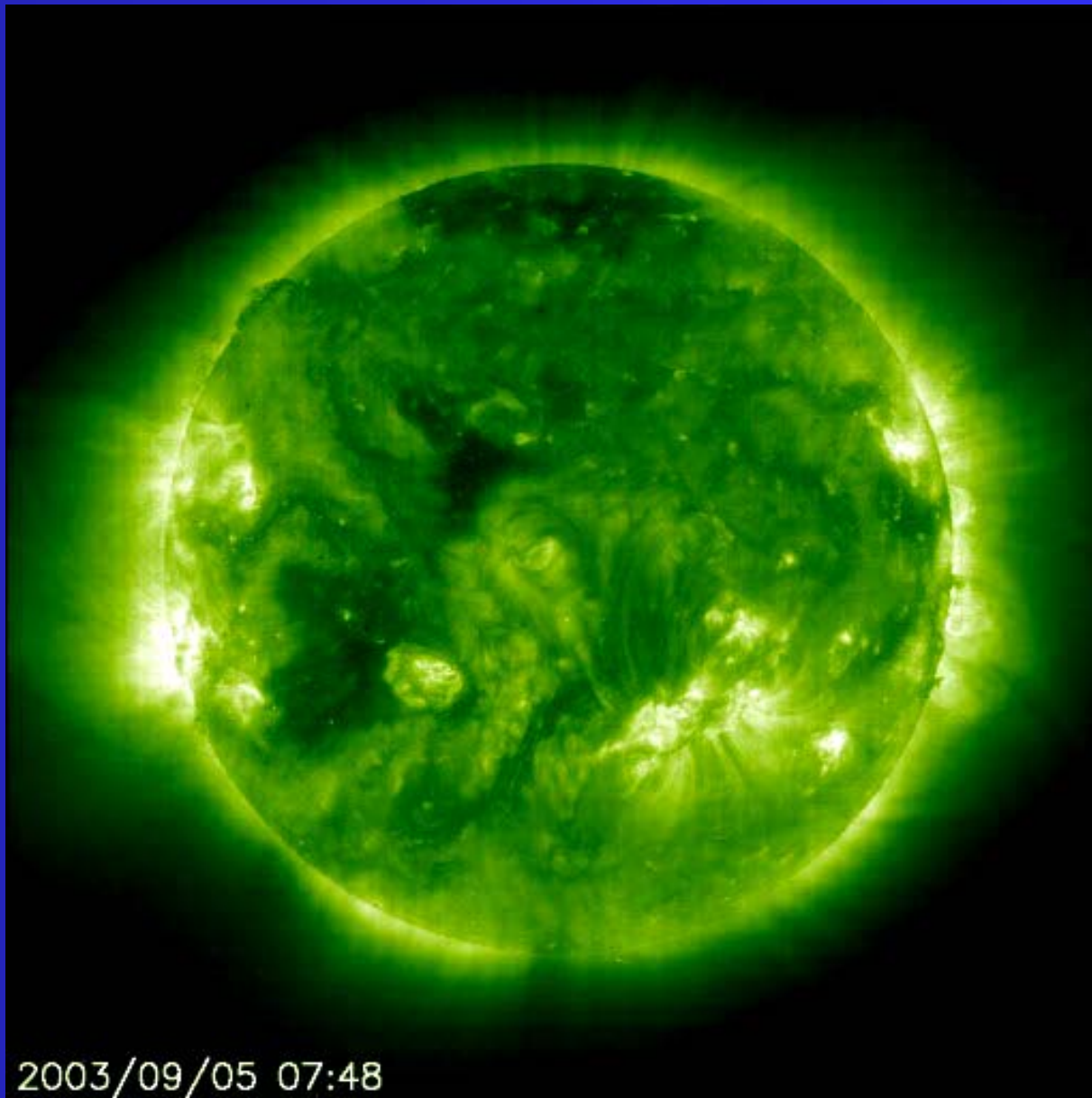
# Catastrophic Cooling and High-Speed Down-flow in Quiescent Solar Coronal Loops Observed with TRACE

## AR 9004 on 26 May 2000



four panels (clockwise from top left) show the 171 Å image, the ratio of 195 Å to 171 Å images, the ratio of 1216 Å to 1600 Å images, and the 1216 Å image. The frames nearest in time to the 1216 Å are collected in the combined images.

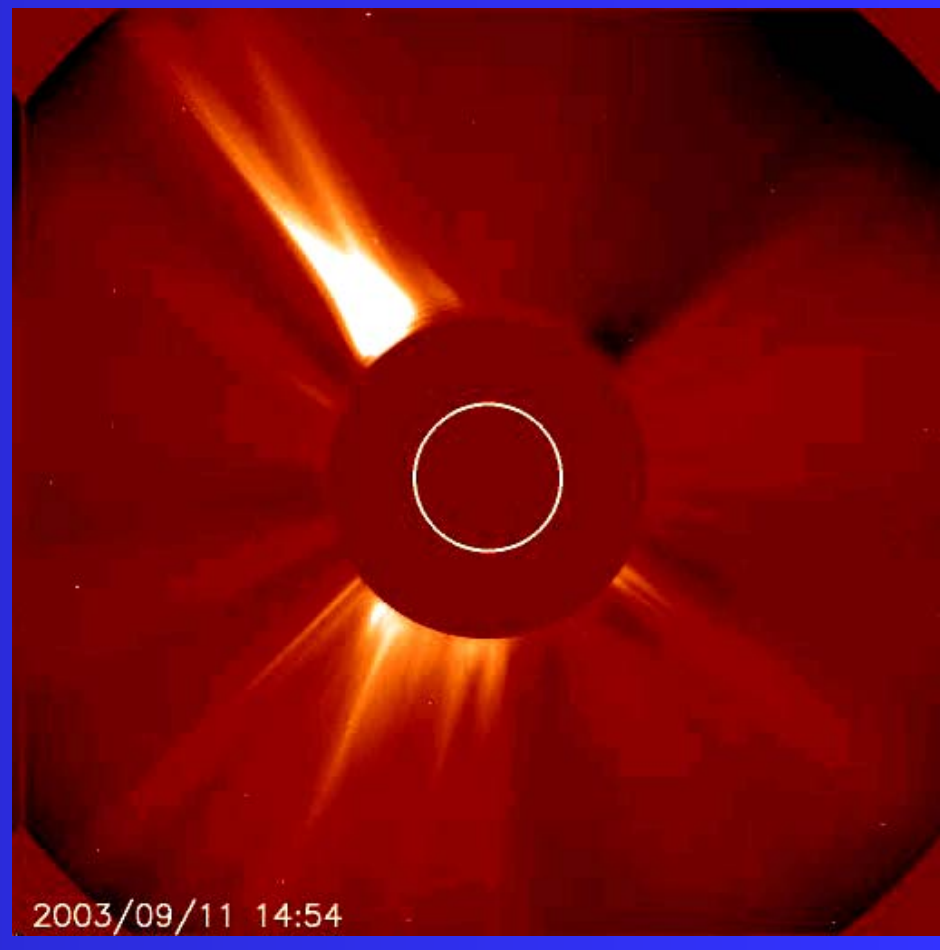
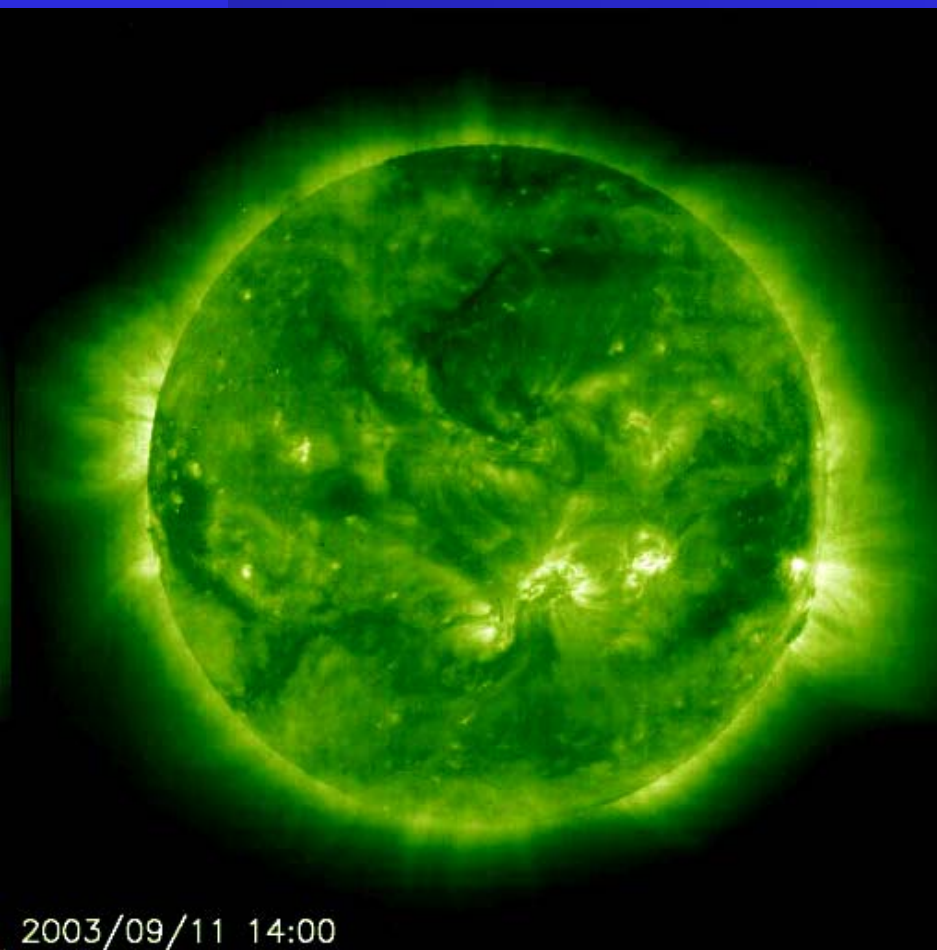
*Cool plasma is observed to slide down on both sides of the loop, forming clumps which moves with velocities upto 100 km/s*



2003/09/05 07:48



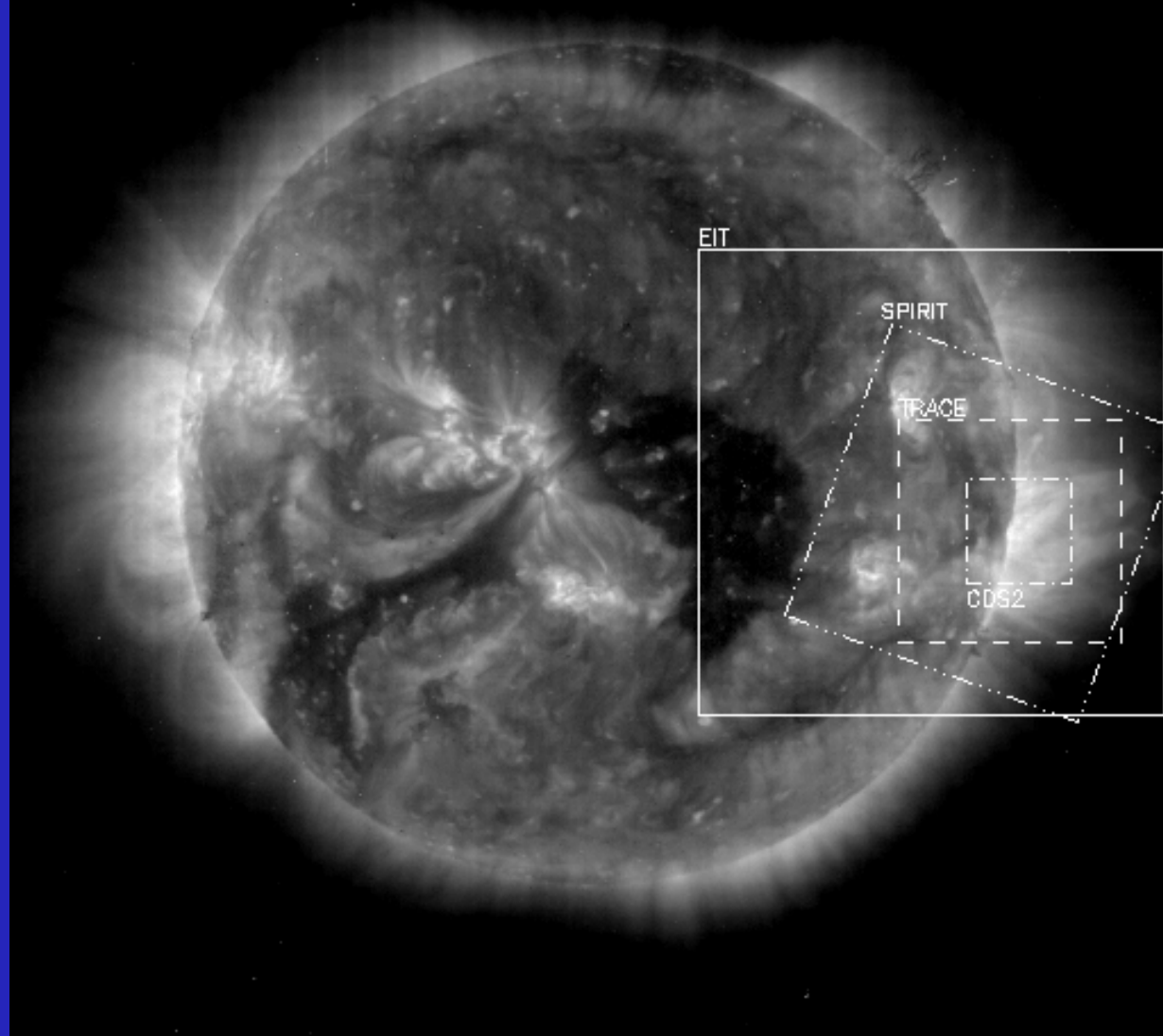
# Second half....



7



2003-09-17T16:57:56.460Z



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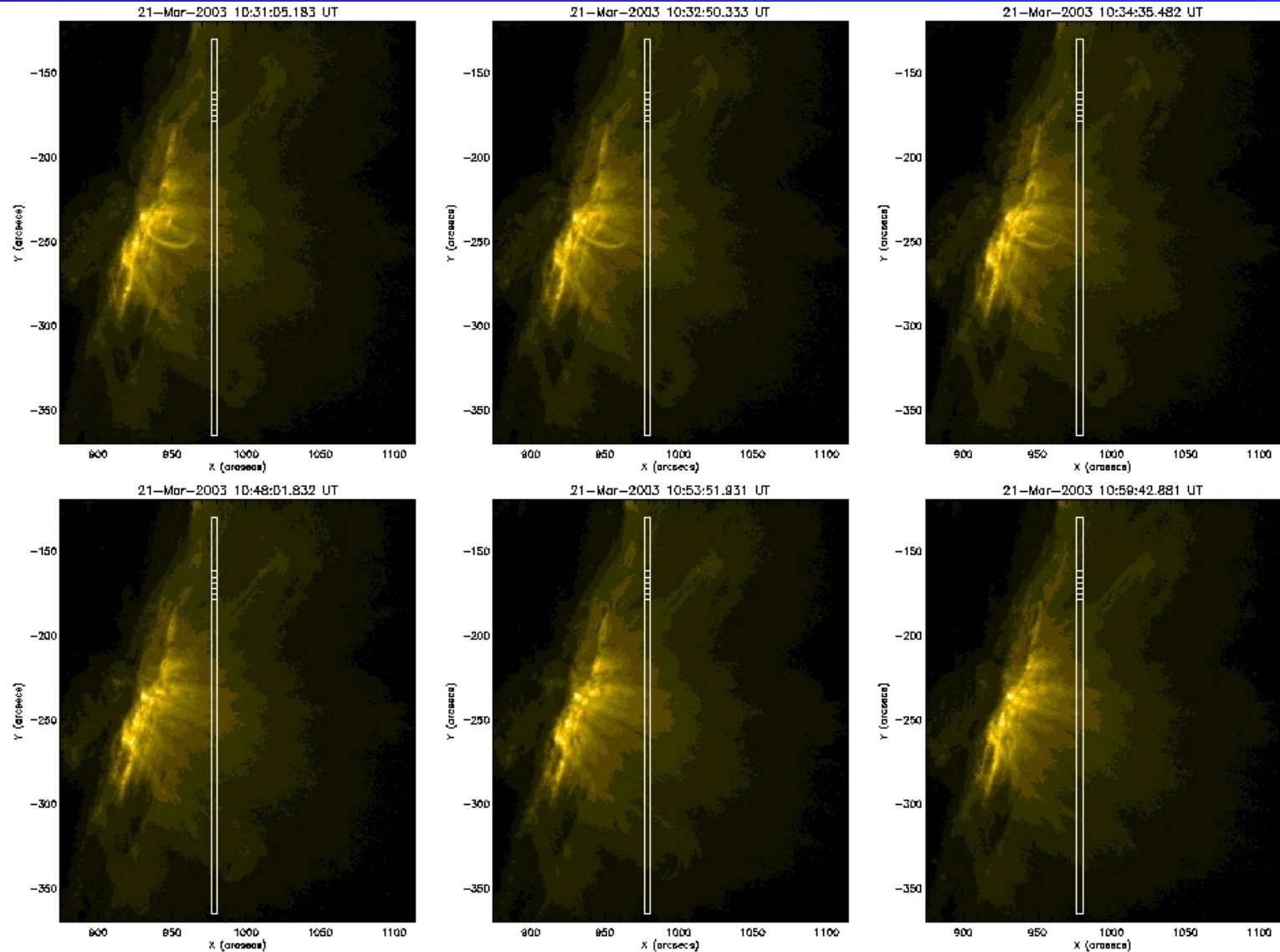


# Observations:

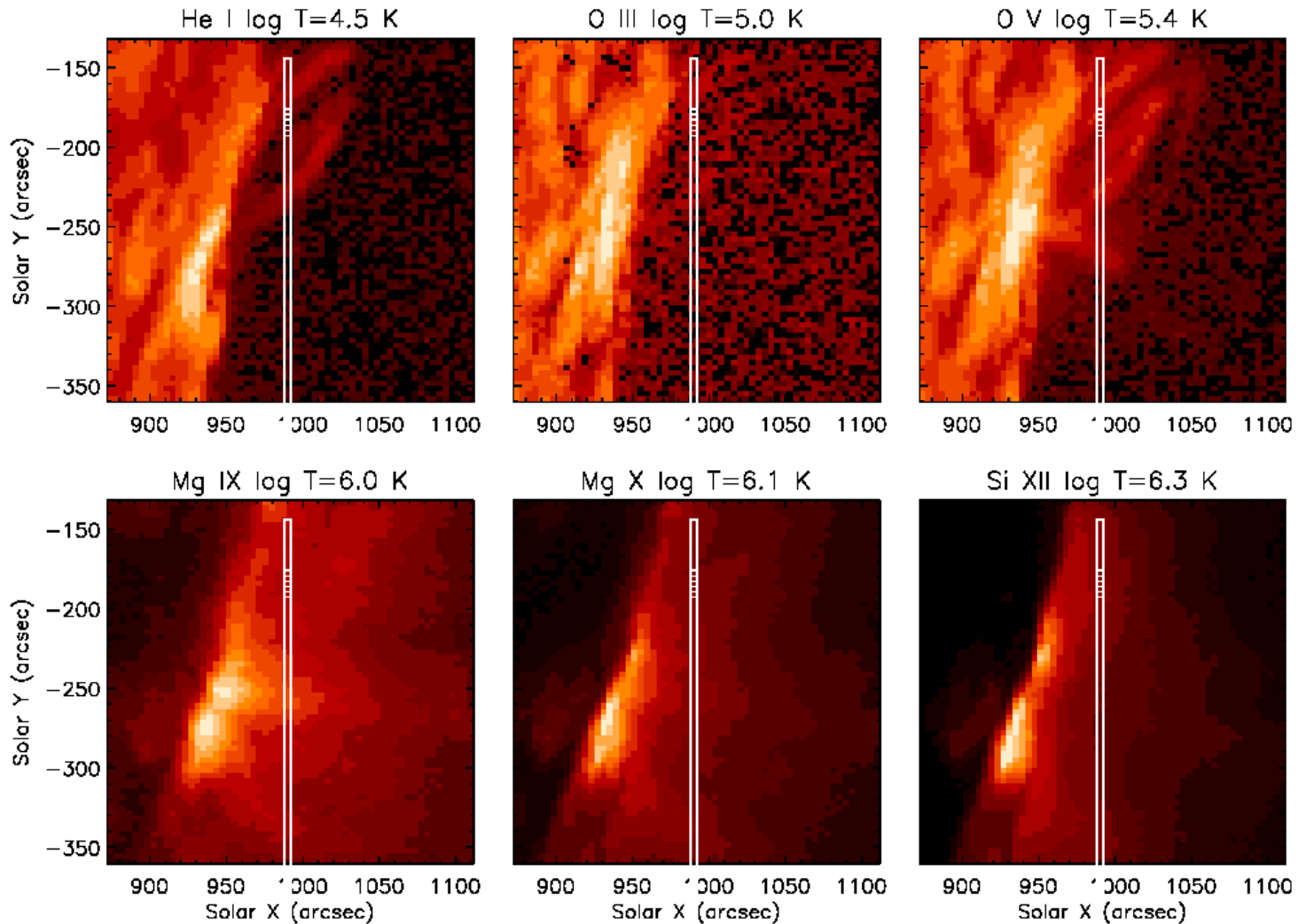
- JOP 165, 2003
- NIS/CDS. CDS temporal and raster sequences were run at several off-limb coronal loop systems over several months to investigate the dynamics of steady loops and search for coronal condensations
- For time sequences 4 x 240 arc sec slit was used with exposure times of 15s.
- Simultaneous TRACE data in the 171 filter at around 1 million K, so at the same temperature as the Mg IX line in the CDS rasters



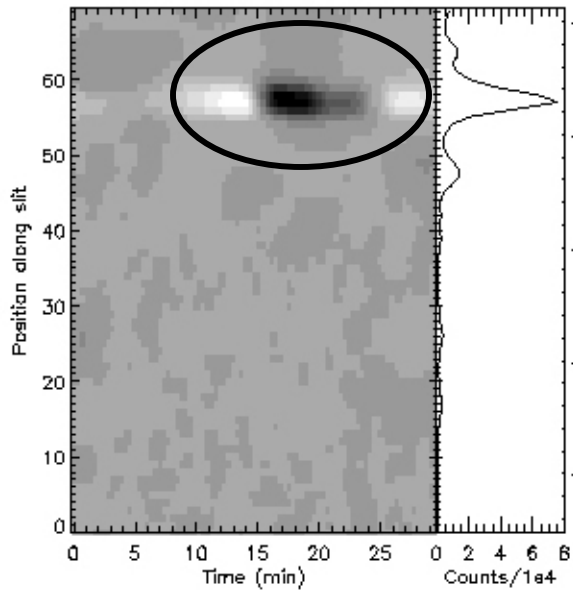
# Location of CDS slit over TRACE



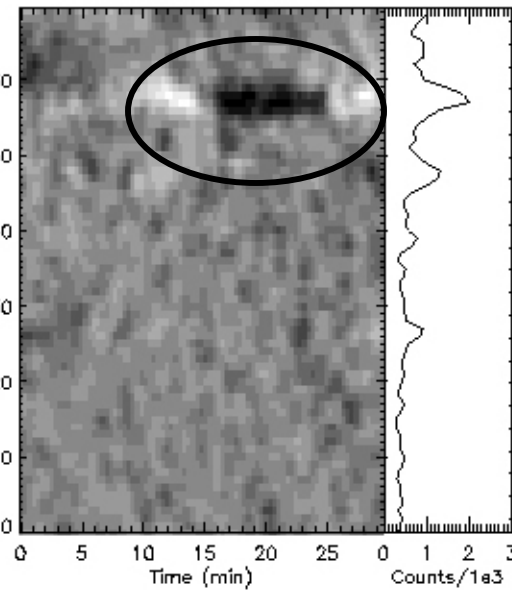
# CDS raster sequences (21 Mar '03)



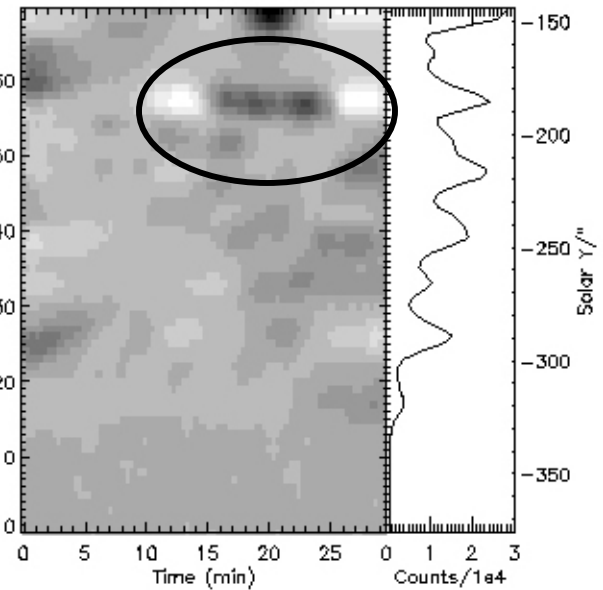
Filtered X-T - He I 584



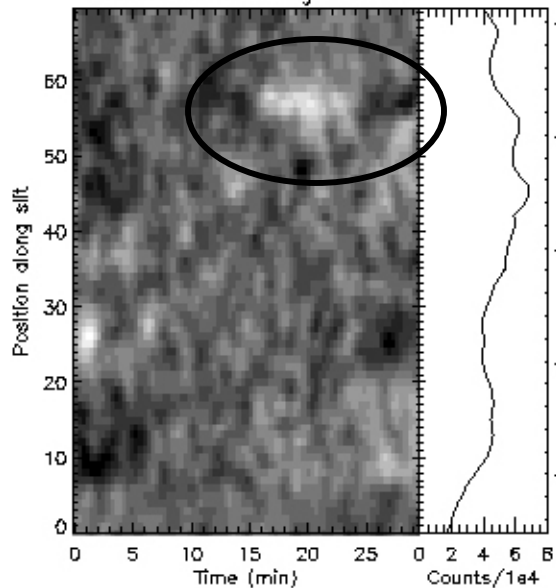
Filtered X-T - O III 599



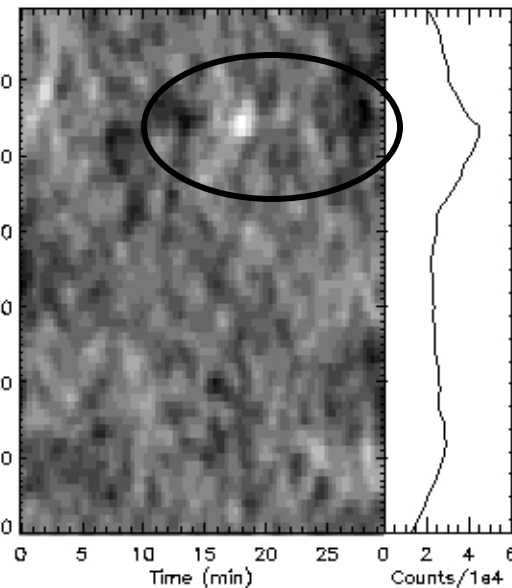
Filtered X-T - O V



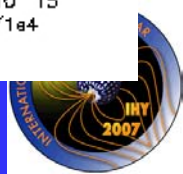
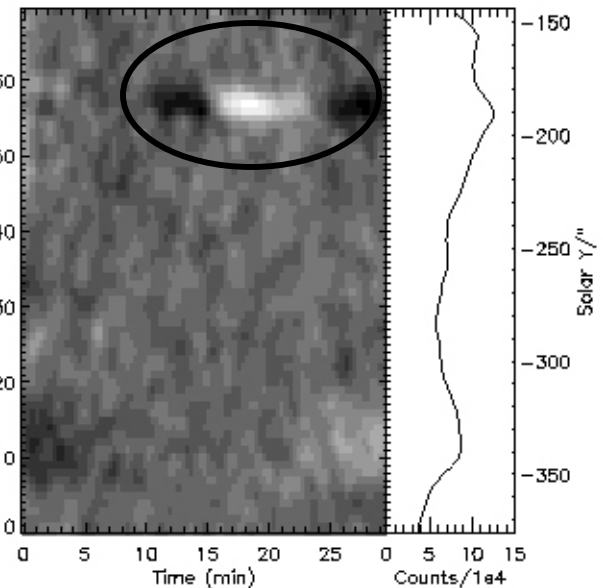
Filtered X-T - Mg X 624

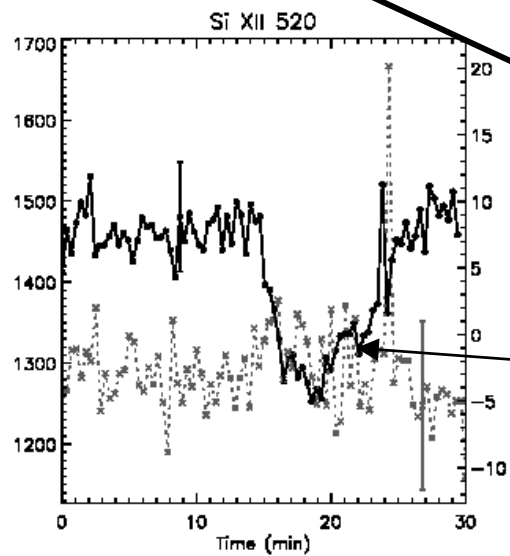
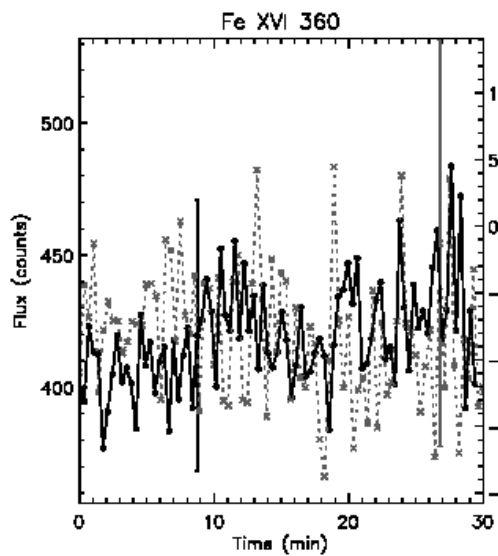
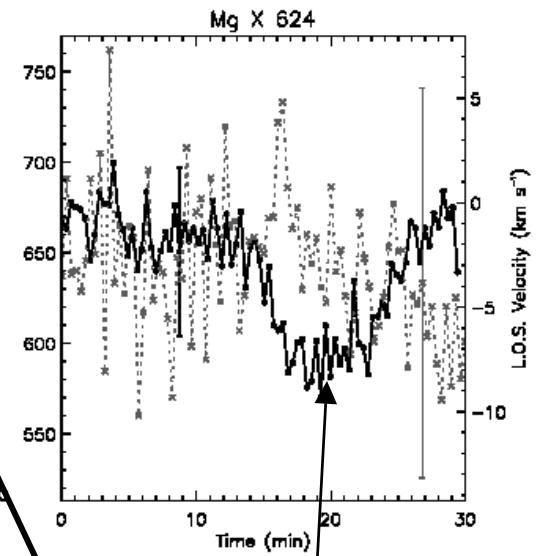
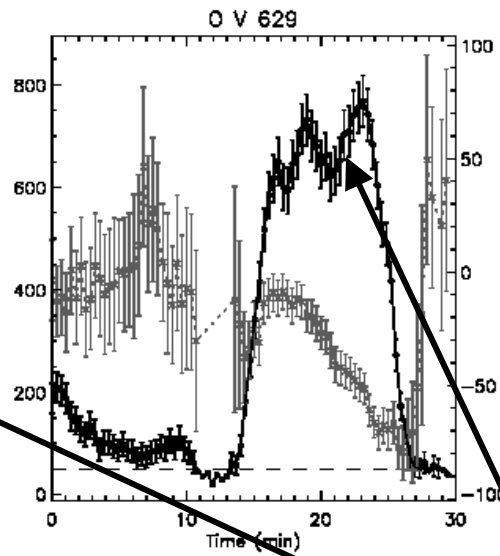
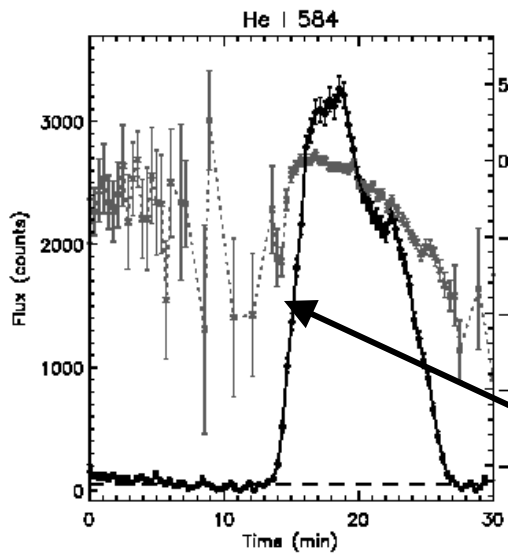


Filtered X-T - Fe XVI 360



Filtered X-T - Si XII



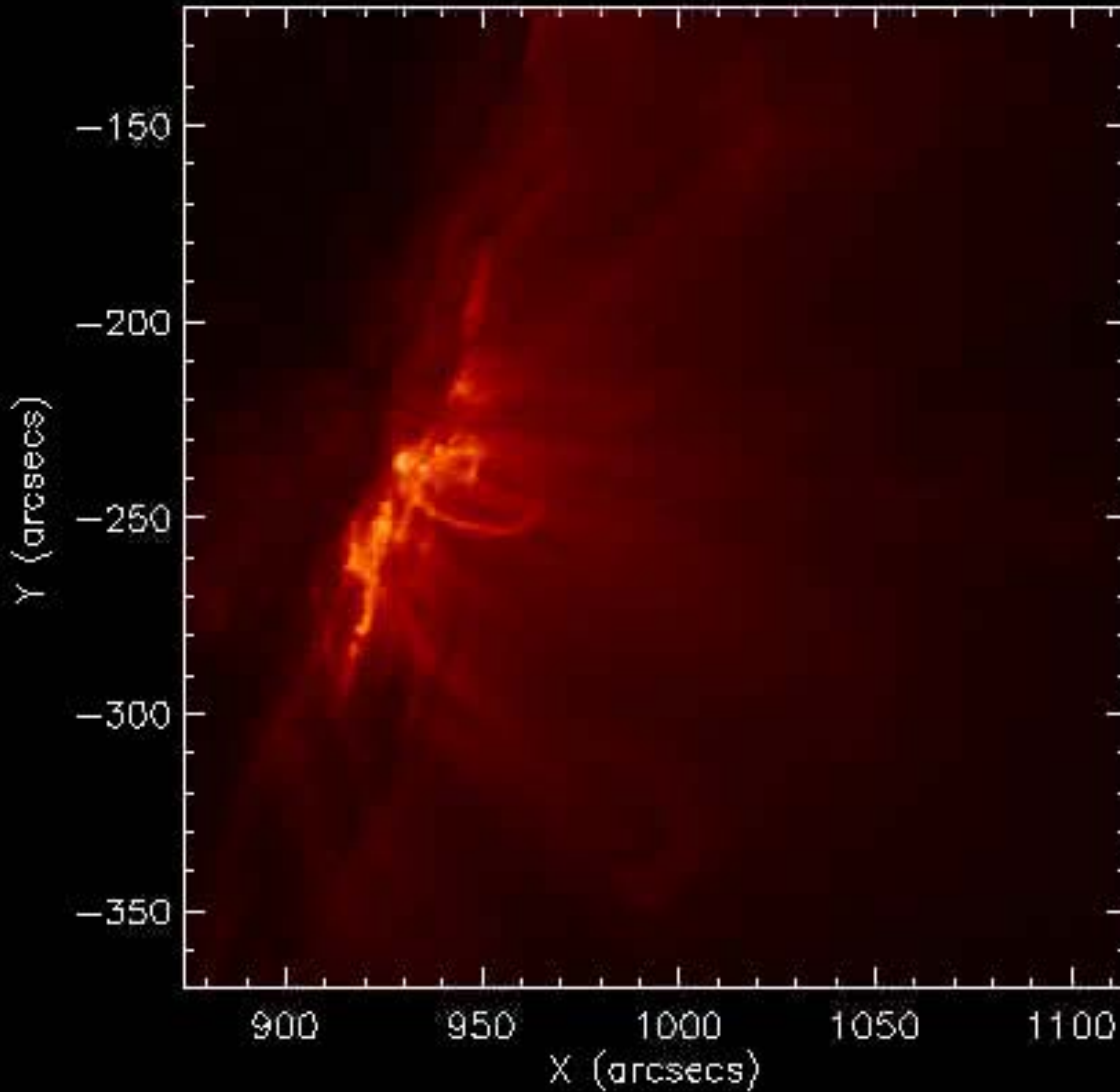


Intensity enhancements  
Plasma condensation

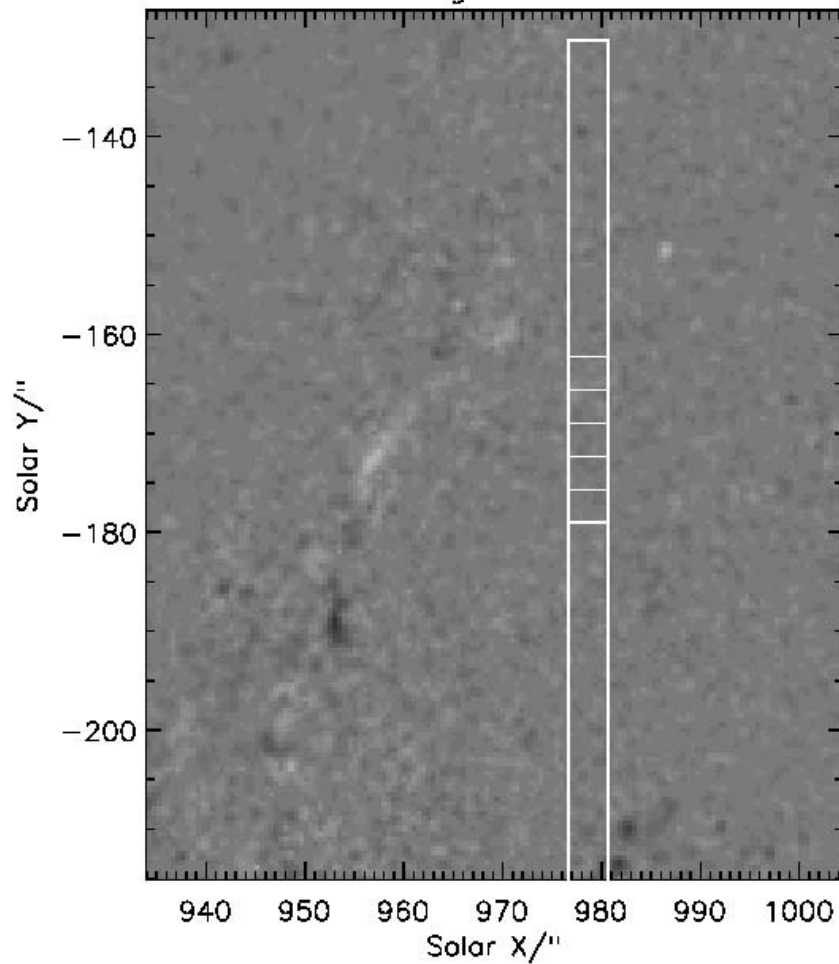
Intensity drop  
Plasma evacuation



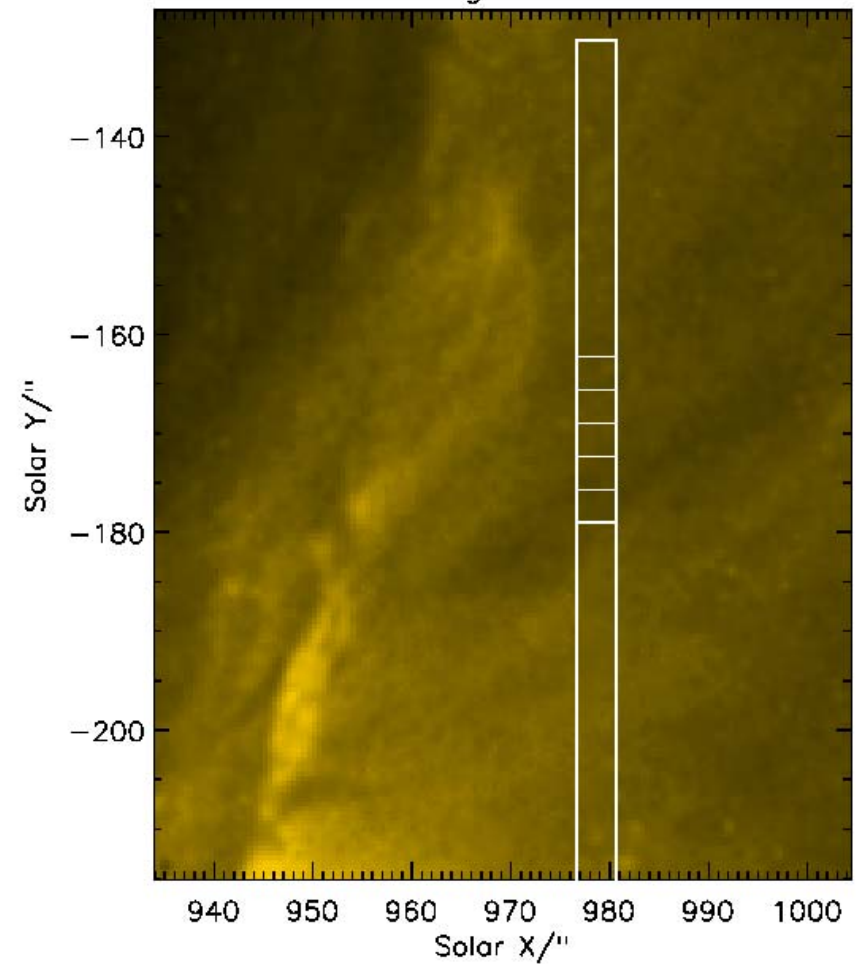
21-Mar-2003 10:30:30.132 UT



Difference image at 10:55:38 UTC



TRACE 171 image at 10:55:38 UTC



# Summary of TRACE

- From TRACE movie it can be seen that at the beginning of the sequence there is a loop draining at roughly  $X=940$ ,  $Y=-250$ .
- However, at the time of the intensity jump ( $\sim 10:48$ ) nothing much seems to be occurring.
- The location of the CDS slit was obtained by cross-correlating the CDS raster image of Mg IX with a similar size TRACE 171 image, covering the same field of view.



# Scenario

- Sudden intensity enhancement in transition region and decrease in corona within coronal loops  $\Rightarrow$  evidence of rapid evacuation of plasma
- At coronal temperatures the intensity changes are too small to be detected from TRACE movies or difference images
- These intensity enhancements are due to plasma condensation: hot coronal plasma is cooled to TR or even chromospheric temp and slide down the loop legs at speeds up to 100 km/s
- **CORONAL RAIN**



# Theory

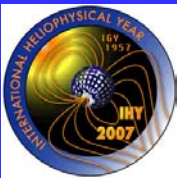
- Heating–condensation-evaporation cycle
- First described by Antiochos et al. (2000) for prominence configuration and later extended to coronal loops by Muller et al. (2003)
- A loop which is predominantly heated at the footpoints become thermally unstable and rapidly cools down at the apex. Due to the associated pressure drop high up in the loop, plasma is evaporated into the coronal loop which then cools rapidly due to loss of thermal equilibrium
- The confined region of *condensed* plasma subsequently falls down under the effect of gravity in the form of cool plasma blob



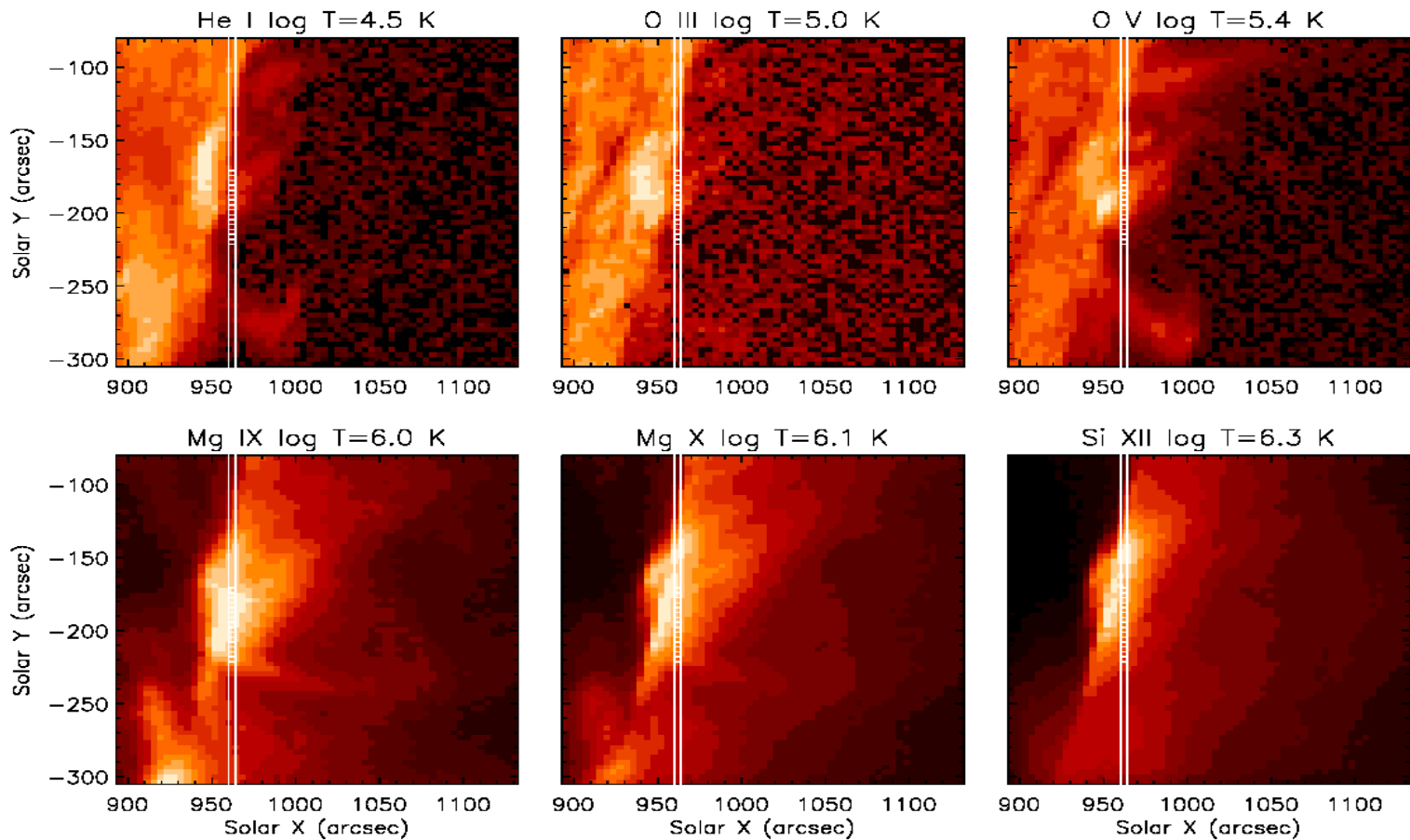
# Cycle

- When the mass blob encounters TR, it compresses the underlying plasma and thereby decelerated
- Finally the depleted loop reheats and fills up again by chromospheric evaporation and a new cycle starts.

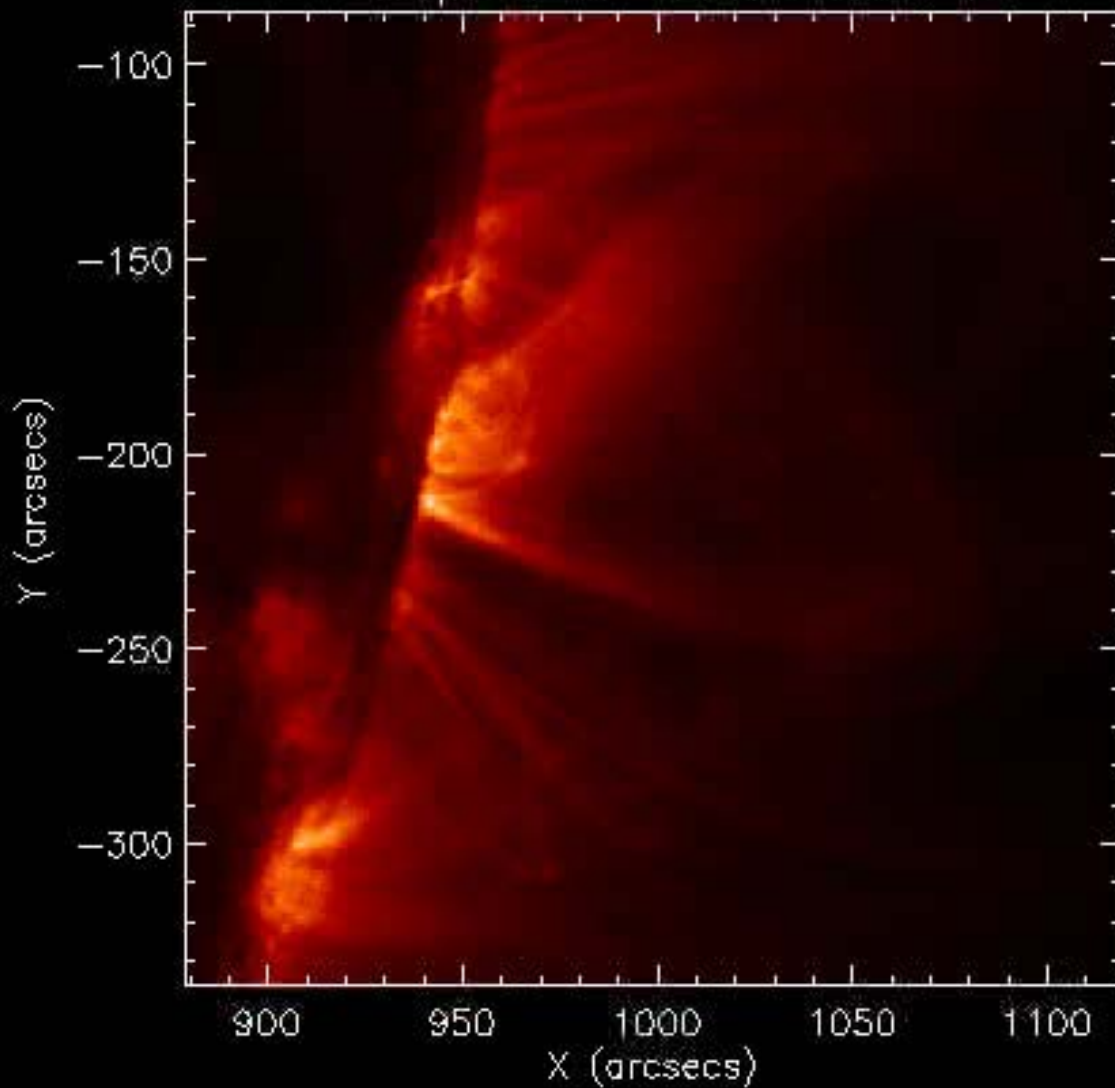
*Spectroscopic evidence of plasma condensation in coronal loops*



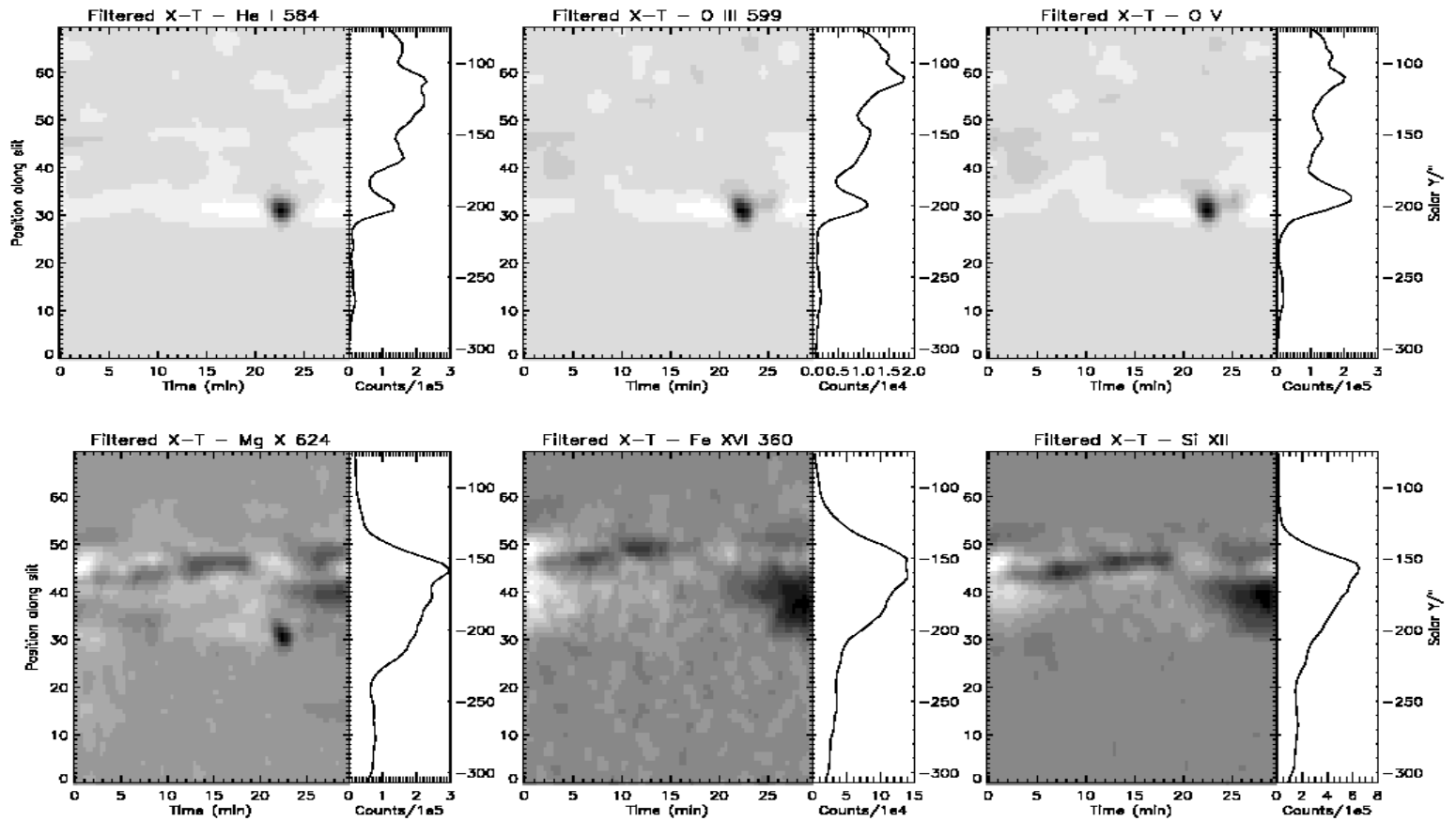
# Other examples (s28536 17 sep)



17-Sep-2003 14:00:19.000 UT



# s28536



# Intensity and velocity

For 28536 dataset the trace movie and the this plot reveals that the pixels 26-40 (corresponding to the CDS slit) are present above the location where a brightening in a small loop system occurs, e.g., at around  $X=950$ ,  $Y=-200$  and at a time of  $\sim 14:14$ . This time of 14:14 corresponds to the time of 22 minutes in the 28536 time series dataset, where we see the intensity enhancements of the He I, O III, O V and Mg X lines. The intensity and velocity results are shown for pixel 31. The small scale brightenings at the footpoints of the loops propagate upwards along the loop, these propagating disturbances originating from these brightenings propagates slowly, could be interpreted as slow mode MHD waves.

