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2. The results of scientific research on completed space missions obtained by Russian scientists in 2014-2015

2.1 The Observations of Hot Arcades

The observations of hot arcades made with the Mg XII spectroheliograph onboard the **CORONAS-F** mission were presented.

The arcades were observed to form above the polarity inversion line between active regions NOAA 09847 and 09848 at four successive episodes: at 09:18, 14:13, and 22:28 UT on 28 February 2002, and at 00:40 UT on 1 March 2002. The evolution of the arcades can be described as:

a) a small flare (precursor) appeared near the edge of the still invisible arcade,
b) the arcade brightened in a wave-like manner - closer loops brightened earlier, and
c) the arcade intensity gradually decreased in {≈} 1 h.

The estimated wave speed was {≈} 700 km s^{-1}, and the distance between the hot loops was {≈} 50 Mm. The arcades formed without visible changes in their magnetic structure. The arcades were probably heated up by the instabilities of the current sheet above the arcade, which were caused by a magnetohydrodynamic wave excited by the precursor.

Reference:

Reva, A.; Shestov, S.; Zimovets, I.; Bogachev, S.; Kuzin, S., “Wave-like Formation of Hot Loop Arcades”, Solar Physics, Volume 290, Issue 10,

pp.2909-2921 (2015)

2.2 The Observations of a CME that Occurred on May 2009

The results of the observations of a coronal mass ejection (CME) that occurred on 2009 May 13 were presented.

The most important feature of these observations is that the CME was observed from the very early stage (the solar surface) up to a distance of 15 solar radii (R ⊙). Below 2 R ⊙, we used the data from the TESIS extreme-ultraviolet telescopes obtained in the Fe 171 Å and He 304 Å lines, and above 2 R ⊙, we used the observations of the LASCO C2 and C3 coronagraphs.

The CME was formed at a distance of 0.2-0.5R ⊙ from the Sun's surface as a U-shaped structure, which was observed both in the 171 Å images and in the white light. Observations in the He 304 Å line showed that the CME was associated with an erupting prominence, which was not located above—as the standard model predicts—but rather in the lowest part of the U-shaped structure close to the magnetic X point. The prominence location can be explained with the CME breakout model. Estimates showed that CME mass increased with time. The CME trajectory was curved—its heliolatitude decreased with time. The CME started at a latitude of 50° and reached the ecliptic plane at distances of 2.5 R ⊙. The CME kinematics can be divided into three phases: initial acceleration, main acceleration, and propagation with constant velocity. After the CME, onset GOES registered a sub-A-class flare.

Reference:

Reva, A. A.; Ulyanov, A. S.; Bogachev, S. A.; Kuzin, S. V., “Initiation and Early Evolution of the Coronal Mass Ejection on 2009 May 13 from Extreme-ultraviolet and White-light Observations”, The Astrophysical Journal, Volume 793, Issue 2, 12 (2014)

2.3 The Detailed Extreme Ultraviolet Spectra of Four Large Solar Flares

The detailed extreme ultraviolet (EUV) spectra of four large solar flares: M5.6, X1.3, X3.4, and X17 classes in the spectral ranges 176-207 Å and 280-330 Å were presented. These spectra were obtained by the slitless spectroheliograph SPIRIT onboard the CORONAS-F satellite. To our knowledge, these are the first detailed EUV spectra of large flares obtained with a spectral resolution of ~0.1 Å.

We performed a comprehensive analysis of the obtained spectra and provide identification of the observed spectral lines. The identification was performed based on the calculation of synthetic spectra (the CHIANTI database was used), with simultaneous calculations of the differential emission measure (DEM) and density of the emitting plasma. More than 50 intense lines are present in the spectra that correspond to a temperature range of T = 0.5-16 MK most of the lines belong to Fe, Ni, Ca, Mg, and Si ions. In all the considered flares, intense hot lines from Ca XVII, Ca XVIII, Fe XX, Fe XXII, and Fe XXIV are observed. The calculated DEMs have a peak at T ~ 10 MK. The densities were determined using Fe XI-Fe XIII lines and averaged 6.5×10^{9} cm^{-3}.

We also discuss the identification, accuracy, and major discrepancies of the spectral line intensity prediction.

Reference:

Shestov, S.; Reva, A.; Kuzin, S., “Extreme Ultraviolet Spectra of Solar Flares from the Extreme Ultraviolet Spectroheliograph SPIRIT Onboard the CORONAS-F Satellite”, The Astrophysical Journal, Volume 780, Issue 1, 16 (2014).