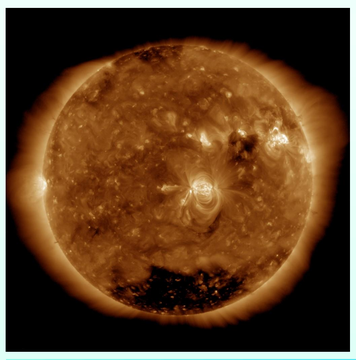

Multiple EUV wave reflection from a coronal hole

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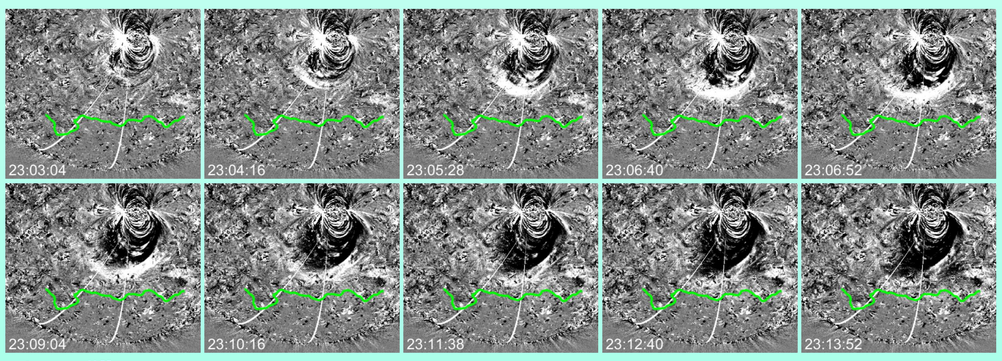
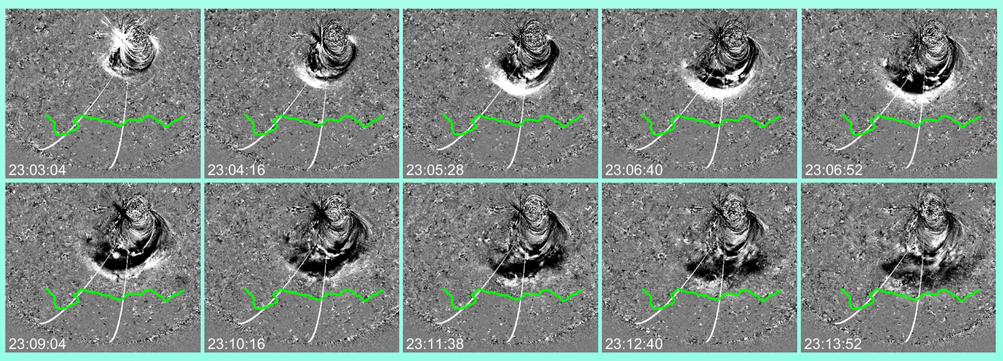
EUV waves are large-scale propagating disturbances in the solar corona initiated by coronal mass ejections. We investigate the multiple EUV wave reflections at a coronal hole boundary, as observed by SDO/AIA 195 Å on 1 April 2017. The EUV wave originates from Active Region (AR) 12645 close to the disk center and propagates toward the south polar coronal hole with an average velocity of 346 km/s. The interaction of the EUV wave with the coronal hole, which represents a region of high Alfven speed, is observed as a splitting into two wave components: one continues propagation inside the coronal hole with an increased velocity of 1300 km/s (transmitted wave), while the other one moves back toward the AR, also with an increased velocity of 609 km/s (reflected wave). The reflected EUV wave is subsequently reflected again from the AR and propagates toward the coronal hole, where it is reflected for the second time at the coronal hole boundary and propagates again toward the AR with a velocity of 406 km/s. These events are observed over an interval of 40 minutes. The high cadence SDO imagery allows us to study in detail the kinematics of the direct and multiple times reflected EUV wave. In addition, its multi-wavelength EUV imagery allows us to derive the plasma properties of the corona and the EUV wave pulse via Differential Emission Measure analysis.

Direct EUV wave propagation from the source region to the coronal hole

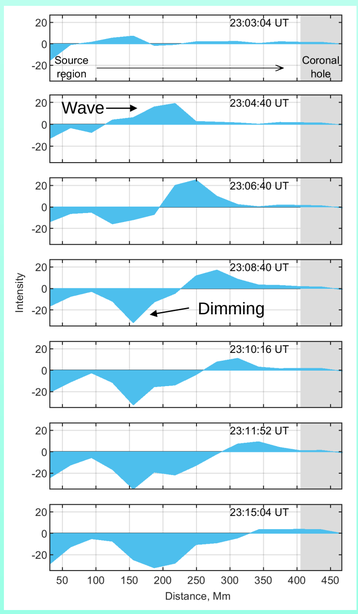
We observe quasi circular propagation of EUV wave in the sector of interests.
At 23:13:52 UT the wave reaches the border of south coronal hole.



Base difference



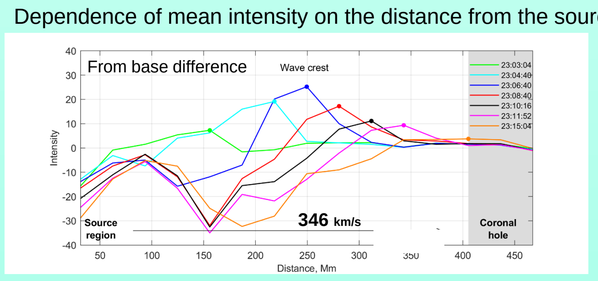
Running difference



The high cadence SDO imagery allows us to determine almost continuous EUV wave profile.

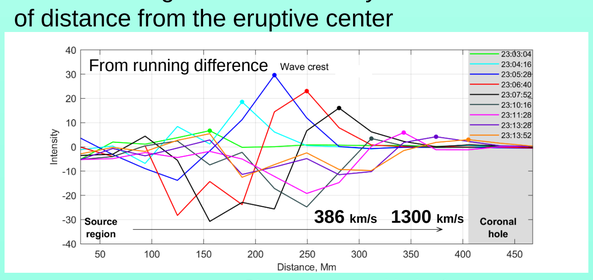
Kinematics of the direct EUV wave propagation

Dependence of mean intensity on the distance from the source region



We determine the kinematics of EUV wave propagation in SDO/AIA images by analyzing intensity perturbation profiles (ring analysis method, Podladchikova and Berghmans, 2005). The solar sphere is divided into a number of rings around the eruptive center as well as separated into angular sectors along great circles through the eruptive center. Then the mean intensity of all pixels in a sector of interest is determined.

Relative change of mean intensity as a function of distance from the eruptive center



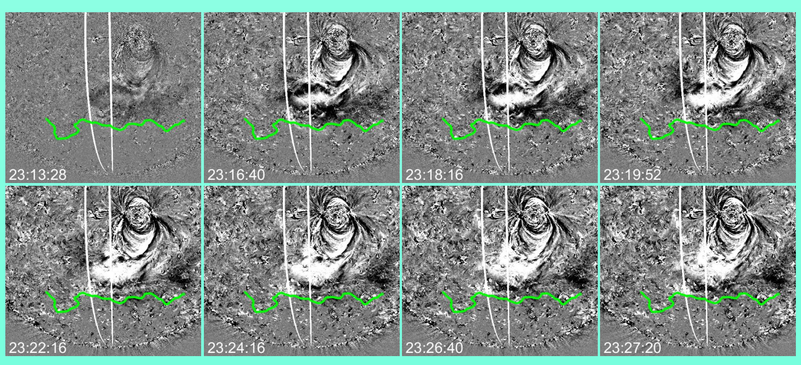
Analysis of base difference images and corresponding perturbation profiles allows us to detect the EUV wave crest moving with average speed of **346 km/s.**

Analysis of running difference images and corresponding perturbation profiles opens a possibility to study the relative change of intensity. At the beginning of propagation from the source region its average speed is **386 km/s.** However, approaching coronal hole, fragments of EUV wave move much faster with the speed of **1300 km/s**.

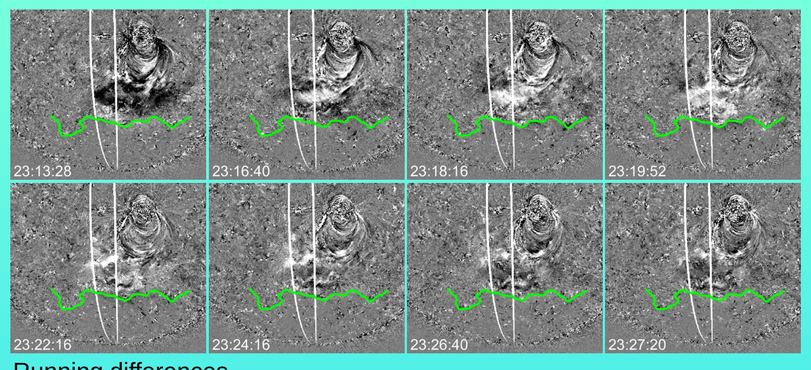
Closer to coronal hole, fragments of EUV wave move much faster

First EUV reflection from the coronal hole

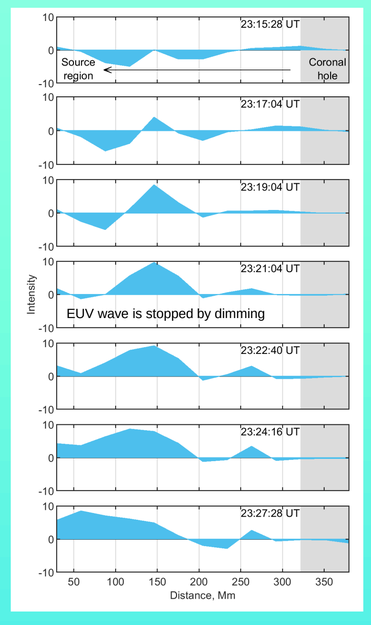
Kinematics of the first EUV wave reflection



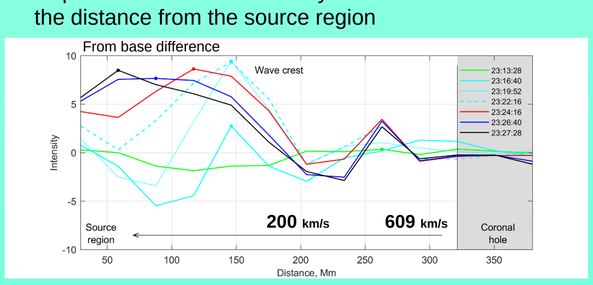
Base difference images



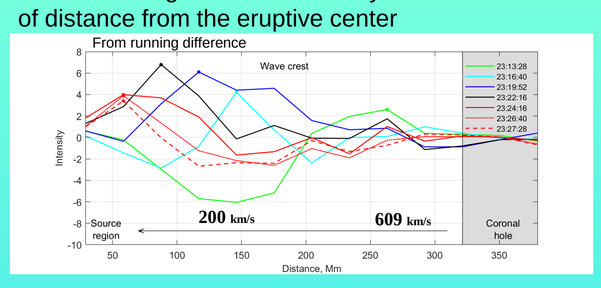
Running differences

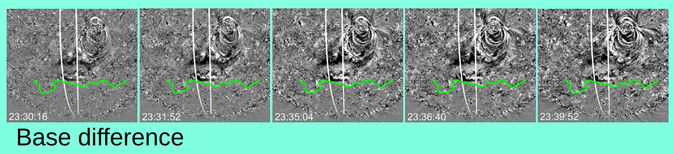


Dependence of mean intensity on the distance from the source region

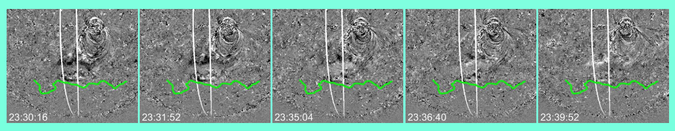


Relative change of mean intensity as a function of distance from the eruptive center

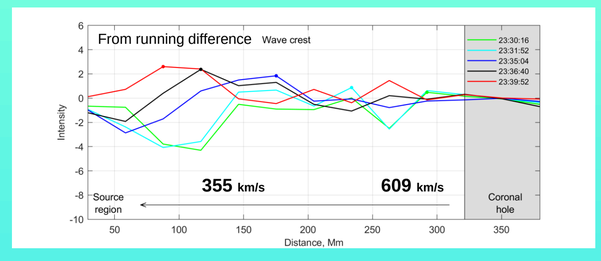




Base difference



Running differences



The EUV wave reflected from the coronal hole propagates mainly to North and Northeast. However its propagation is stopped by the dimming associated with the direct EUV wave. Wave crest doesn't move for some time, while its intensity is increased. Later it goes over dimming back to the source region and coronal hole.

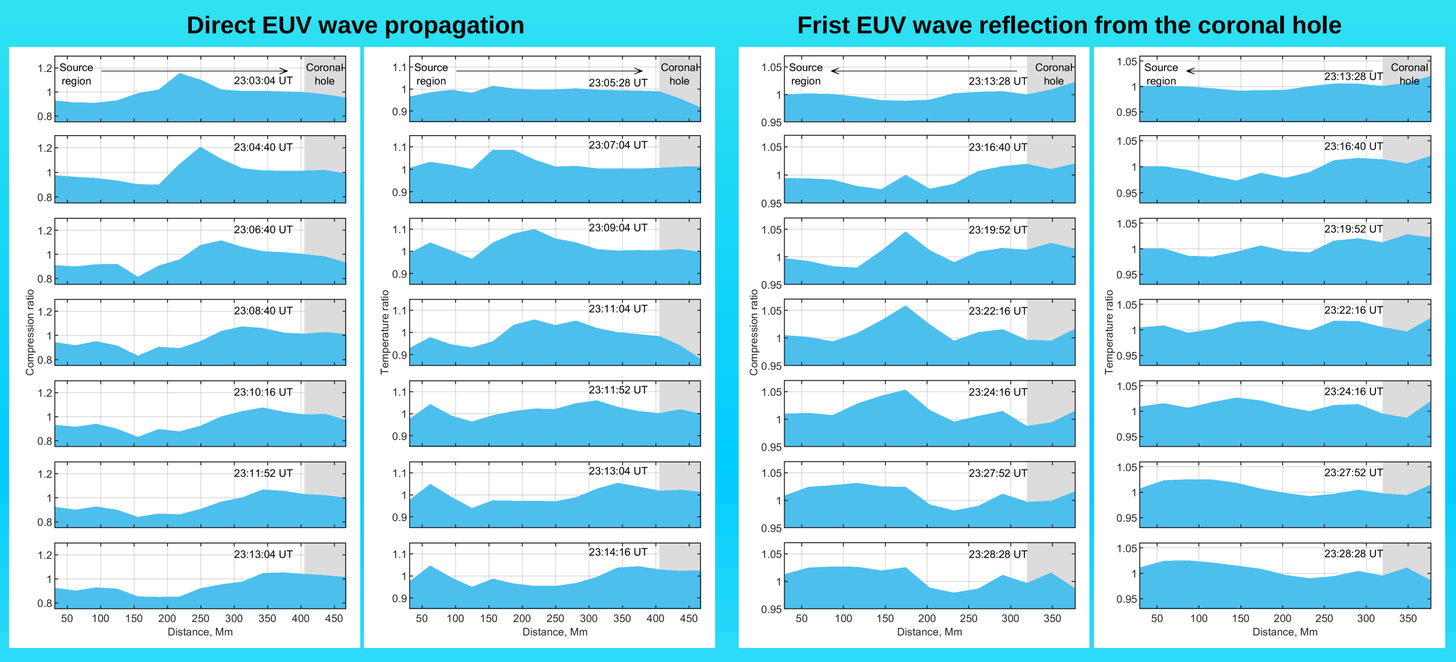
EUV wave crest is reflected with the speed **of 609 km/s** from the coronal hole. However later it doesn't move for some time being stopped by the coronal dimming. At the same time its intensity is increased and EUV wave is extended in two directions (toward coronal hole and source region). Further its moves over the diming toward the source region with the mean speed of **200 km/s.**

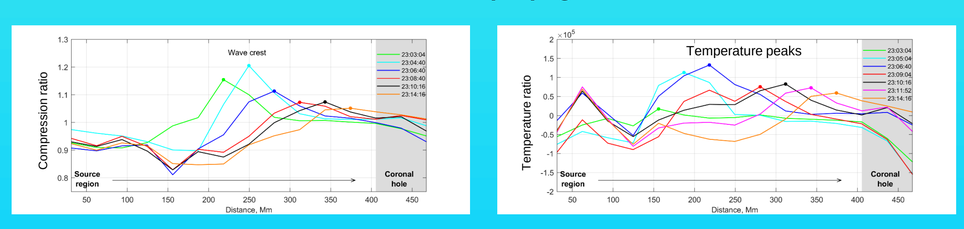
The reflected EUV wave is subsequently reflected again from the active region and propagates toward the coronal hole, where it is reflected for the second time at the coronal hole boundary and propagates again toward the AR with a velocity of **355 km/s.**

Differential Emission Measure analysis

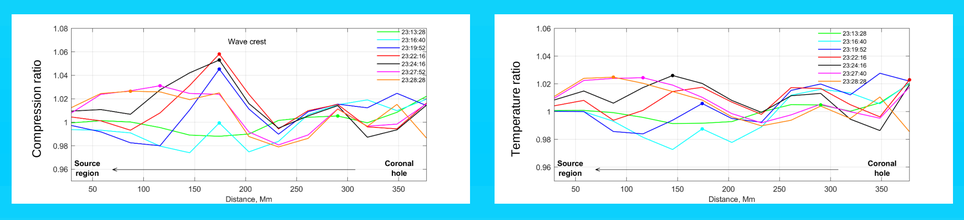
Dynamics of density compression and temperature ratio

Direct EUV wave propagation | **Frist EUV wave reflection from the coronal hole** | **Direct EUV wave propagation**





Frist EUV wave reflection from the coronal hole



Multi-wavelength EUV imagery allows us to derive the plasma properties of the EUV wave pulse via DEM (Hannah & Kontar, 2012). The dynamics of density compression and temperature ratio repeats that one of the EUV wave. The strongest decrease of intensity corresponds to the deepest part of dimming. Maximal increase of density corresponds to the increase of wave crest.

The density enhancements corresponding to the direct EUV wave propagation and the first reflection from the coronal hole are around **22% and 5%** correspondingly.

Conclusions

- ✓ **The EUV wave propagates** directly toward **the South coronal hole** with average speed of **340 – 390 km/s.**
- ✓ The border of **South coronal hole** is located on **a short distance of ~ 300 – 400 Mm** from **the source region.**
- ✓ Closer to **coronal hole boundary**, fragments of EUV wave move much **faster**.
- ✓ The propagation of EUV wave is constrained **from the both sides** (the source region and the coronal hole).
- ✓ The propagation of reflected EUV wave **is constrained by the dimming** associated with the direct EUV wave. However, with increase of intensity it is extended. **in two directions:** toward source region and back toward the coronal hole.
- ✓ With the propagation of EUV wave **the dimming ahead or dark front is intensified** (also found in Piantschitsch at. al. 2018).