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Formation of Photospheric Vortices and its-Associated Hα Surges in a Solar Light Bridge

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Hα surges, which are jets of cool chromospheric plasma, are protruding into the solar corona 10–100 Mm above the photosphere. Their promising driving energy source is 1) energy release via magnetic reconnection in the low atmosphere, or 2) MHD waves from the photosphere. But the mechanism is still elusive due to the lack of high-resolution observations.

We report on the successive occurrence of 0.5 asc wide photospheric vortices with strong transverse shear flows at the edge of a sunspot light bridge (LB), and the subsequent ejection of chromospheric Hα surges observed using a Visible Interferometry Spectrograph and a Fast Imaging Solar Spectrograph of the Goode Solar Telescope operating at Big Bear Solar Observatory.

The photospheric horizontal flow of about 0.7 km/s on average was observed at the LB. The west directional horizontal flows were dominant at the edge of the LB. When a strong horizontal flow of about 3-5 km/s reached the edge, one of the filamentary structure of the LB began to protrude into the umbral region, forming a vortex.

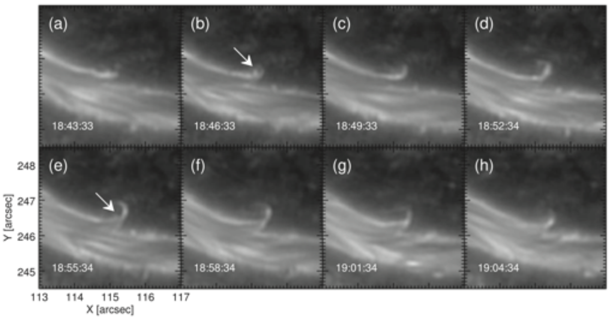

Figure 1. Formation of a filamentary vortex observed in the TiO broadband images. The white arrows represent secondary vortices when the vortex forms.

The Hα surges were observed in one-to-one association with the vortex formation. One interesting observation is that these surges appeared as a pair of narrow jets, which are likely that they have a hollow tube structure so that the edge of the tube is optically thicker than the center. Or, they seem to spurt out from the photospheric vortices preserving the round shape of the vortices.

At the bottom of the surges, or at the location of the vortices, vortex-associated bright Hα plasma blobs were observed quasi-periodically. They moved upward with a speed of up to 4 km/s. The average time gap between the blobs was about 80-110 sec.

In view of the strong transverse velocity shear flow between the LB and the umbral region may trigger the Kelvin–Helmholtz instability resulting in the appearance of vortices. Even though the vertical magnetic field at the sunspot region is strong, they may not play a role in stabilizing the KHI.

After forming the vortices by the KHI, they can be strengthened by the bathtub effect. The strong photospheric convective downflow observed at the locations of the vortices can gather the surrounding angular momentum and strengthen the vortices efficiently. The surges may result from the magnetic tension generated after magnetic reconnection. Magnetic reconnection taking place right above the vortex represented by bright upward propagating blobs can release the magnetic helicity to the upper atmosphere. The nonlinear torsional Aflvénic waves may play a role to accelerate the plasma.

Another possible mechanism of observed surges is that the surge plasma can be accelerated by nonlinear waves developing from the acoustic or Alfvén waves, not by magnetic reconnection. The waves can be produced by the photospheric vortices. The enhancement of the gas and magnetic pressure near the root of the vortex tube will generate the acoustic shocks squeezing out the plasma into the corona. The untwisting motion of the twisted vortex tubes can also produce the torsional Alfvénic waves. The Alfvénic waves can be amplified as traveling along with the stratified medium, and they may generate surges.

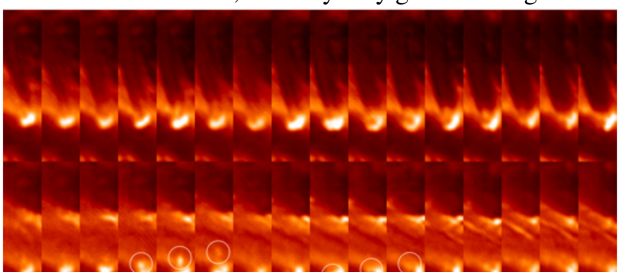

Figure 2. Evolution of the brightenings at the bottom of a surge. White circles outline two bright blobs ejected sequentially from the middle of the vortex. The FOV is 1'' × 6''.

References

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