Growth of post-flare supra-arcades by instabilities at the head of reconnection jets

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Supra-Arcade downflows SADs
Observations

- Supra arcades are bright fans of hot plasma (10 MK) above flare arcades
- Dark tadpole shaped structures descend with velocity up to 300 km/s
- These are low density regions
- They push arcade emission away
- High Doppler velocities in fan seen by SUMER and EIS
SUMER density observations

![Diagram showing SUMER density observations]
Absorbing material would show in second order not first order.
Continuum emission due to Bremsstrahlung
$I \sim 1/\lambda^2$
KBr almost all first order $\sim 1350$ A
Bare almost all second order $\sim 675$ A
If absorption see a difference in the bare and KBr intensities across structures

$log$ column density $< 17$
Much too small to account for the darkening in TRACE 195 A

$=>$ low density
"voids"
The current sheet

For the “voids” to be visible the fan of emission must be narrow ie not much thicker than the width of the voids. The standard flare models predicts a thin current sheet above the arcade.

Downflows are in the current sheet.
Interpretations

Retracting loop (McKenzie, Warren)  Wake behind retracting loop (McKenzie, Savage)

The wakes should disappear on a sound crossing time $\sim 30$ s but they last for up to 20 min
**Interpretation**

Rarefactions behind shocks

Brightening at head of SAD

Shocks and rarefactions bouncing in sunward directed flux tubes

Temperature of ambient only 1 MK should be 10 MK

Scott et al 2013

Cecere et al 2012
Interpretation

Multiple reconnection jets

Asai et al. 2004

Density

instability at head of a reconnection jet

Cassak et al. 2013

Asai et al. 2004
Observe flares with different orientations

Face-on

Edge-on

Top-view

SDO/AIA 131 A

STEREO/EUVI 195 A
Face – on current sheet
Close-up of some of the SADS

SAD develops at the top of fan spike

Forking at the head of one of the large SADS

Forking at the head of smaller SADS
Edge-on current sheet
Close-ups

SAD forms at the head of spike

SAD at tip of current sheet.
Seems to be connected with retracting loop below
Edge-on current sheet viewed from above

SAD from at top of spike
Key properties

1. SADs often form near the top of fan spikes
2. Some SADs split at their head as they evolve
3. Some SADs are seen above and maybe connected to retracting loops
4. SADs are not loops
5. Most SADs do not have brightening at their heads when the form - in any of the AIA filters
Recall the development of dense falling plasma in the 7 June 2011 prominence eruption.

High density plasma falling through low density wind.

Evolution may be related to Rayleigh Taylor instability.
Or low density wind expanding into high density

The Crab supernova remnant.
Low density pulsar wind expands into high density ejecta
Proposed scenario
Simulations

3D resistive MHD
Initial condition – Harris sheet
$B_x = \tanh(z/a)$, $a$ – width of current sheet
$P_g + P_b = \text{Const}$
Constant Temp condition $P_g = nT$
Density, $n$, increases to center of current sheet

Guo, Bhattacharjee, Huang 2013
Emissivity

Some aspects look similar

Too small wavelength
Summary

We are starting to investigate the properties of supra arcade downflows.
The current model looks promising

Need to consider
Role of guide field (directed along the current sheet in the Y direction)
Importance of flows and inhomogenities in the fan and reconnection jet.
Boundary conditions