

Understanding facular granules and facular lanes

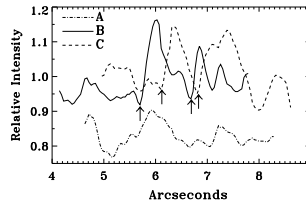
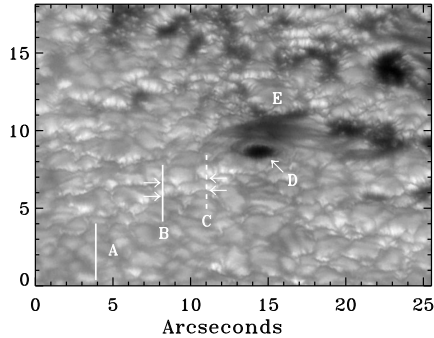
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Poster available under <http://www.kis.uni-freiburg.de/~steiner> in A4/PDF format



1. Recent observations of faculae

Recent observations by *Lites et al. (2004)* with the newly commissioned 1-m Swedish solar telescope on La Palma show details of *facular granules* at 0.12" spatial resolution, including dark *facular lanes*.



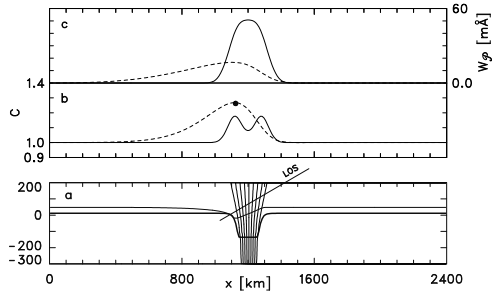
— 8 nm passband filtergram at 487.7 nm of a *facular region*. The limb is towards the top. From Lites et al. (2004)

- At heliocentric angle $\mu = 0.54$, the facular *size* (\perp to the limb) is $\approx 0.5''$ and more.
- *Facular brightening* occurs at the disk center side of granules just *limbward* of the corresponding facular magnetic field.
- Images reveal a thin *dark facular lane* at the disk center side of the facular brightening separating it from the granule immediately centerward of it.

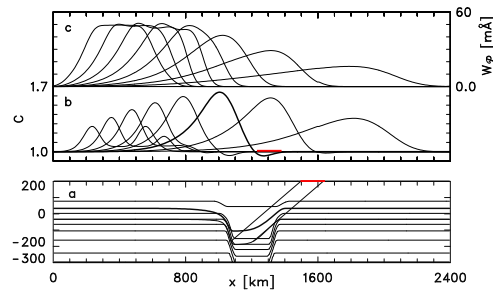
2. Results from a basic model and from numerical simulations

We construct a basic facular model consisting of a *magnetic flux sheet* embedded in a plane parallel atmosphere. The atmosphere within the flux sheet is similar to the external one but shifted in the downward direction to result in a "*Wilson depression*" of 150 km. The upper

layers are in thermal equilibrium, $T_i = T_e$, while in deep layers, the tube interior is cooler than the external atmosphere at equal geometrical height: in between the two regimes there is a 300 km wide transition around $\tau_c = 1$.



a) Magnetic flux sheet with two surfaces of optical depth $\tau_c = 1$. Thick curve: $\tau_c = 1$ for vertical lines of sight (disk center). Thin curve: $\tau_c = 1$ for lines of sight running from the top right to the bottom left under an angle of $\theta = 60^\circ$ to the vertical (heliocentric angle $\mu = 0.5$). b) Continuum contrast, $C(x) = I_c(x)/I_{c,0}$, for disk center ($\mu = 1$, solid curve) and for inclined lines of sight with $\mu = 0.5$ (dashed curve). All values of the dashed curve left of the black dot are from lines of sight left of the one indicated in panel a). c) Equivalent width of the total polarization of Fe I 630.25 nm, for $\mu = 1$ (solid) and $\mu = 0.5$ (dashed)

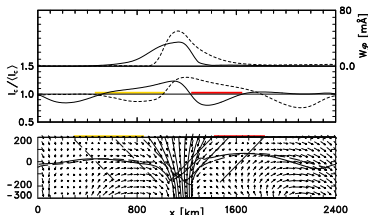


a) Magnetic flux sheet with isothermal contours and two surfaces of optical depth $\tau_c = 1$ and $\tau_c = 5$, both for lines of sight running from the top right to the bottom left under a zenith angle of $\theta = 50^\circ$. b) Continuum contrast, for lines of sight with $\theta = 0^\circ \dots 70^\circ$ in steps of 10° . The thick profile belongs to $\theta = 50^\circ$, for which the region where $C < 1$ is bounded by the two lines of sight indicated in panel a) (red bars). c) Equivalent width of the total polarization for the same azimuth angles as in panel b)

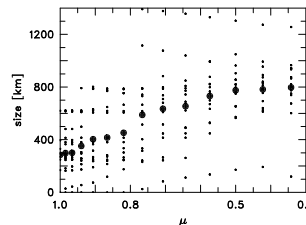
Result: At disk-center side, *steep increase in facular brightness due to the "hot wall" of the flux-sheet depression*. Limbward of the flux-sheet, *wide, limbward gently fading brightening due to reduced opacity of the rarefied flux-tube atmosphere*. One can say: From a location at the solar surface and sideways of the flux sheet the *sky is more transparent in the direction across the flux sheet* compared to an equal altitude direction away from it, leading to enhanced radiation escape in this direction. \Rightarrow A single flux sheet/tube influences the radiative escape from the neighbouring granules surrounding it. \Rightarrow *Facular granules*.

Result: On the disk-center side of the magnetic flux sheet $C < 1$, leading to a *narrow, dark facular lane*. It arises from the low temperature gradient of the flux-sheet atmosphere in the height range of optical depth unity (see isotherms). \Rightarrow The facular lane offers a *glimpse at the "cool bottom" of the magnetic flux sheet*.

The above given results provide a good understanding of a fully consistent but more complex numerical simulation of a *non-stationary flux concentration* in dynamic interaction with convective motion of which a snapshot is shown below.



Surfaces of optical depth $\tau_c = 1$ (bottom), contrast profiles (middle), and equivalent widths of total polarization of Fe I 630.25 nm (top) for two viewing angles, $\theta = +45^\circ$ (solid) and $\theta = -45^\circ$ (dashed). Also shown in the bottom panel the two lines of sight that limit the facular lane region where $C < 1$ together with the line of sight of least intensity



Size of contrast enhancement (where $C > 1.05$) measured parallel to the solar surface and \perp to the limb as a function of disk position μ from 16 directions of 8 simulation snapshots. The heavy dots show arithmetic means. The *facular size increases from center to limb* and encompasses about half a granular diameter at $\mu > 0.5$

3. Conclusion

Faculae are the manifestation of magnetic flux concentrations. Their brightness comes from the "hot wall" of the "Wilson depression" and from the surroundings limbward of the facular magnetic field from where radiation escapes more easily in the direction of the

rarefied, less opaque flux tube or sheet. The dark facular lane is the manifestation of the cool deep layers of the magnetic flux concentration.