## Onset of penumbra formation







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## Data and methods

On 9 July 2009, **GFPI**/VTT (Tenerife) recorded the leading sunspot in NOAA 11024, which was located at a heliocentric angle  $\theta \sim 28^{\circ}$ .

Full-Stokes polarimetric scans in the Fe I 617.3 nm photospheric line were inverted with a Milne-Eddington inversion code (VFISV<sup>[1]</sup>). Previous investigations have used this dataset<sup>[2],[3],[4],[5],[6]</sup>.

## 1. Bi-directional flow in elongated granules

#### Segment at the **centre side**.

Before the onset of the penumbra, we observe a configuration loop (or sea-serpent): we detect an elongated granule in  $I_{GB}$ , embedded in weak B, whose extremes are characterised by **redshifts-blueshifts** in  $v_{
m LOS}$  and  $\gamma_{
m LRF}$  of opposite polarity. During the onset of the penumbra, B strengthens,  $I_{
m GB}$  darkens,  $\gamma_{
m LRF}$  flattens and the EF (blueshift) sets in.



In this work<sup>[7]</sup>, we studied the **temporal evolution** of three 5pixel-wide segments where penumbral filaments with an Evershed flow (EF) formed from **three different preceding magnetic and plasma flow conditions**.

## Protospot with analysed segments



## 2. Transient filament with counter-Evershed flow

#### Segment at the **limb side**.

Before the transient filament, we see the edge of a penumbra with EF, which contains blueshifts (upflows of penumbral grains). transient filament The **CEF** has a **fast** with (dis)appearance, with a weaker B and more horizontal  $\gamma_{\text{LRF}}$ . After the transient filament, the magnetic properties and flows return to their previous values and the penumbral filament enlarges.

#### time (and slice width) 1.5 <sup>1</sup>/<sub>9</sub> <sup>9</sup>/<sub>9</sub> 1.5 <sup>1</sup>/<sub>9</sub> <sup>9</sup>/<sub>9</sub>

## Conclusions

- Only the center-side segment shows the real mangetic configuration.
- Limb-side inferred magnetic fields and  $v_{\text{LOS}}$  are affected by projection effects and  $\theta$ .
- The onset of penumbral filaments is independent of the previous flows.
- Penumbral filaments form at the umbral boundary and expand outwards, radially.



## 3. Granular pattern

#### Segment at the **limb side**.

Beforetheonsetofthepenumbra,weobserveagranulationpatternin $I_{GB}$ ,withgranulessmaller



• Evershed flows appear as soon as the penumbral filaments form.

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than those observed in the quiet Sun, and a blueshifted filamentary structure in  $v_{LOS}$ , as a CEF. Short filaments with heads with weak blueshifts that move towards the spot boundary. <u>During</u> the formation of the penumbra, the magnetic gradient decreases gradually and the EF sets in within minutes.

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