Can photospheric vortex flows be observed via Fourier Local Correlation Tracking (FLCT)?

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Abstract: Convection-driven turbulence in the photosphere leads to the formation of small-scale vortices between solar granular boundaries. These vortices are associated with the twisting of the magnetic field and considered to inject heat into the solar atmosphere via Poynting flux. Using Γ-functions [1], we identify rotations in MURaM-simulated photospheric velocity fields [2] and compare them to rotations in velocity fields inferred from MURaM intensity maps via FLCT [3]. We found the maximum number of vortices in the FLCT velocity field to be 11.67% of the number of vortices in the MURaM velocity field.

Introduction: Photospheric vortices have been of high interest for their potential role in the heating mechanism. Previous studies of ground-based observations report a large number of photospheric vortices [4,5]. However, the reported vortex properties have yet to be validated by synthetic data. Here, we investigate whether tracking the intensity changes are a suitable proxy to investigate photospheric vortices. We compare vortex properties within a MURaM velocity field with the ones present in the velocity fields inferred from MURaM intensity maps via FLCT.

Vortex Detection

- Cores and boundaries identified via Γ-functions.

$$\Gamma_1 = \frac{1}{N}\sum_S \frac{[(\vec{x}_j - \vec{x}_i) \times \vec{v}_j] \cdot \vec{n}_z}{\|\vec{x}_j - \vec{x}_i\|_2 \cdot \|\vec{v}_j\|_2} \qquad \Gamma_2 = \frac{1}{N}\sum_S \frac{[(\vec{x}_j - \vec{x}_i) \times (\vec{v}_j - \langle\vec{v}_i\rangle)] \cdot \vec{n}_z}{\|\vec{x}_j - \vec{x}_i\|_2 \cdot \|\vec{v}_j - \langle\vec{v}_i\rangle\|_2}$$

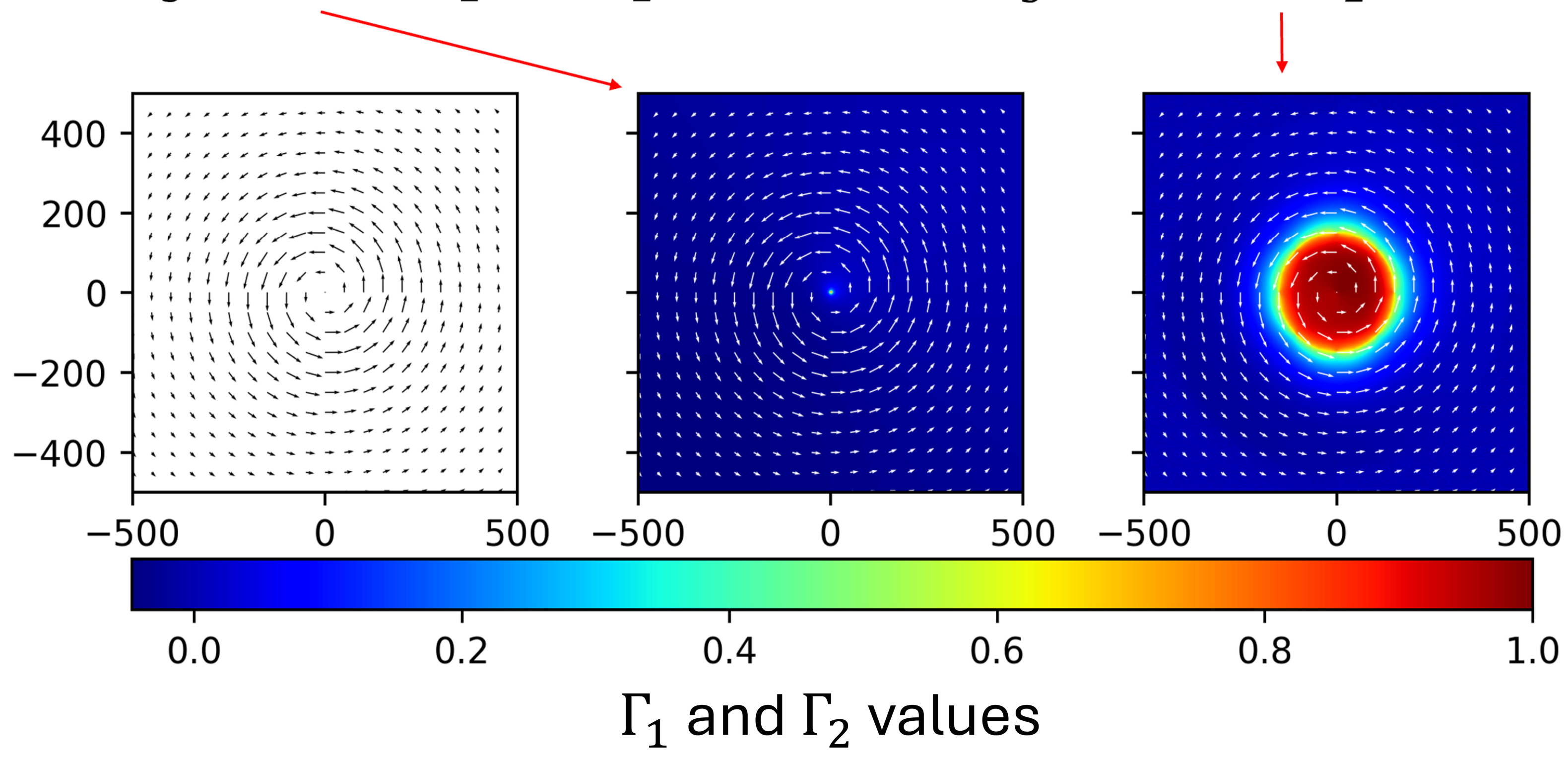

Figure 1: Example of Γ-functions application on a Lamb-Oseen vortex. Γ_1 identifies the vortex core and Γ_2 identifies the vortex boundary.

Vortex Tracking Criteria

- Cores within boundary in 2 frames labelled as same event.
- Cores closer than $v_{core}\Delta t$ also labelled as same event.

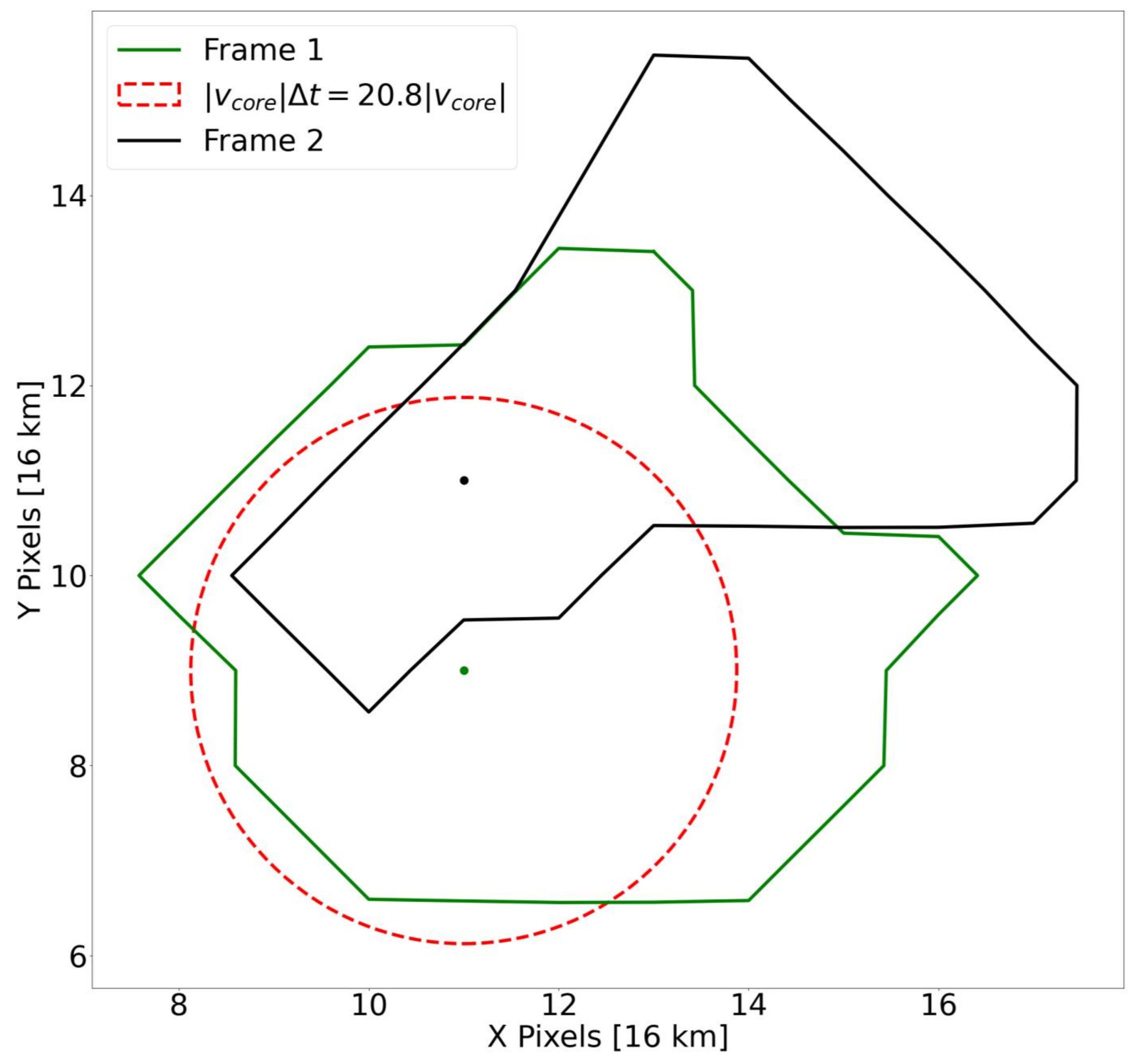

Figure 2: Graphical representation of labelling criteria.

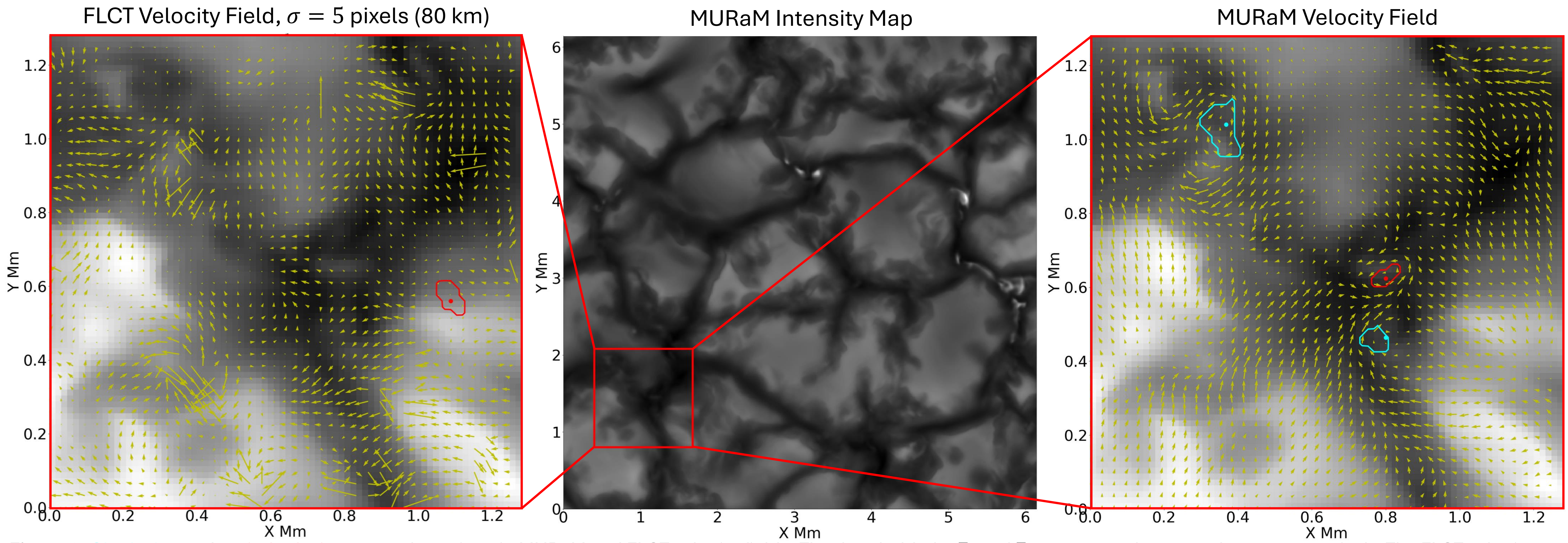

Figure 3: Clockwise and anti-clockwise vortex detections in MURaM and FLCT velocity fields. The thresholds for Γ_1 and Γ_2 were set to be 0.8 and 0.75, respectively. The FLCT velocity field was inferred using a kernel size, σ, of 5 pixels (80 km) to capture the small vortices present in the MURaM velocity field. Two similarly-sized vortices of opposite chiralities linked by a flow, i.e., a matching vortex pair, can be seen clearly in the MURaM velocity field (right panel). However, no such structures are visible in the FLCT velocity field (left panel). Other FLCT kernel sizes were also used and the properties of the vortices in the inferred velocity fields are shown in the table below.

FLCT kernel size, σ	None (MURaM)	5 pixels (80 km)	10 pixels (160 km)	15 pixels (240 km)	20 pixels (320 km)
Total number of events	12400	14111	7704	3518	1656
Multi-frame events	4603	537	494	343	222
Mean lifetime ± stdev [s]	64.06 ± 38.00	43.43 ± 6.04	44.04 ± 7.68	45.06 ± 9.38	47.50 ± 13.50
Mean area ± stdev [km²]	4157.77 ± 2287.73	7862.23 ± 4020.47	26883.67 ± 11103.78	61011.30 ± 26667.87	115215.01 ± 51672.07
Overlapping events	-	5	29	42	51

Key Results to Date

- Areas of FLCT vortices are greater than areas of MURaM vortices and are influenced by the FLCT kernel size, σ.
- FLCT vortex lifetimes < MURaM vortex lifetimes.
- Max number of FLCT detections = 11.67% MURaM vortices.
- Number of FLCT detections inversely proportional to σ.
- Very little overlap between FLCT and MURaM events.

References

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