

The Nature and Physics of Vortex Flows in Solar Plasmas
ISSI International Team, K. Tziotziou and E. Scullion conveners
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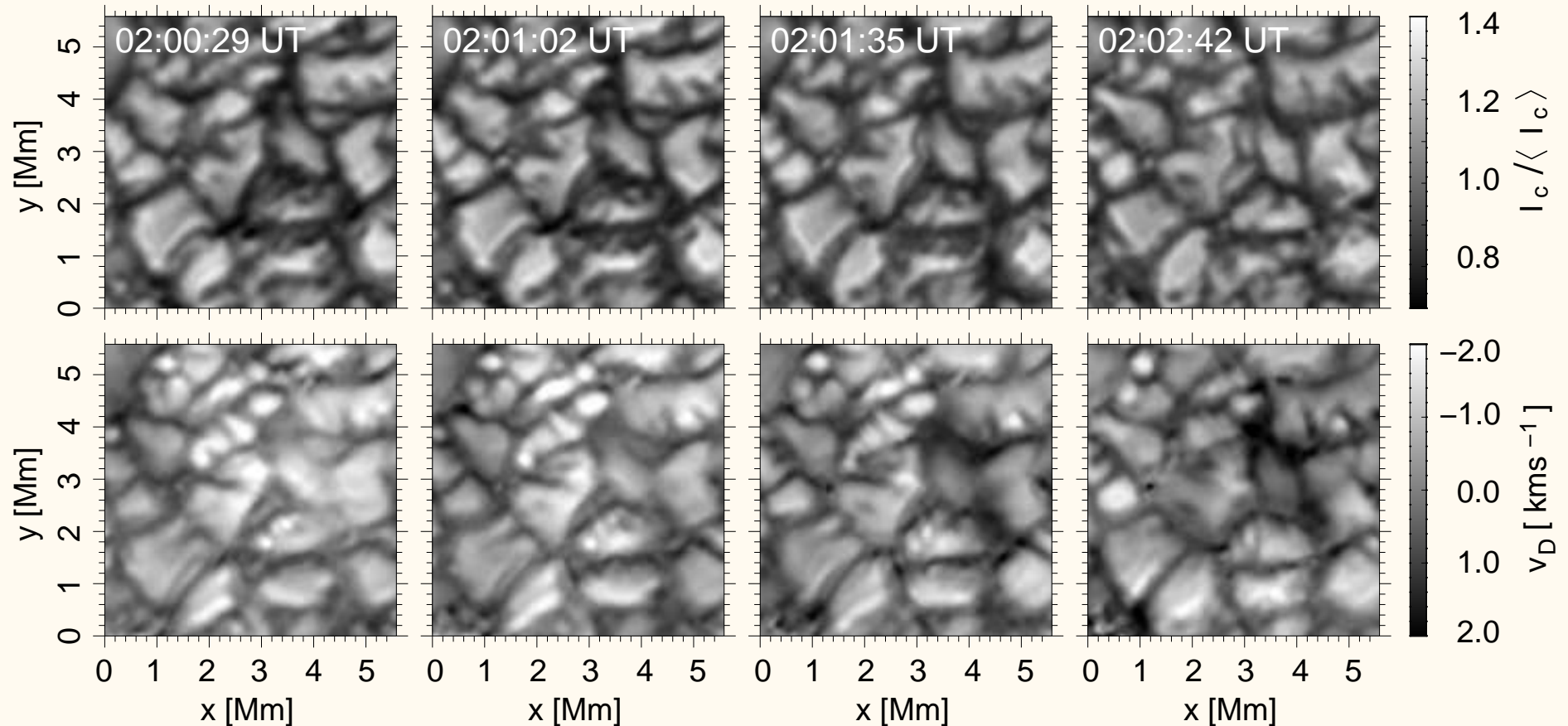
Horizontal vortex tubes at the edges of solar granulation

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^a via zoom teleconference

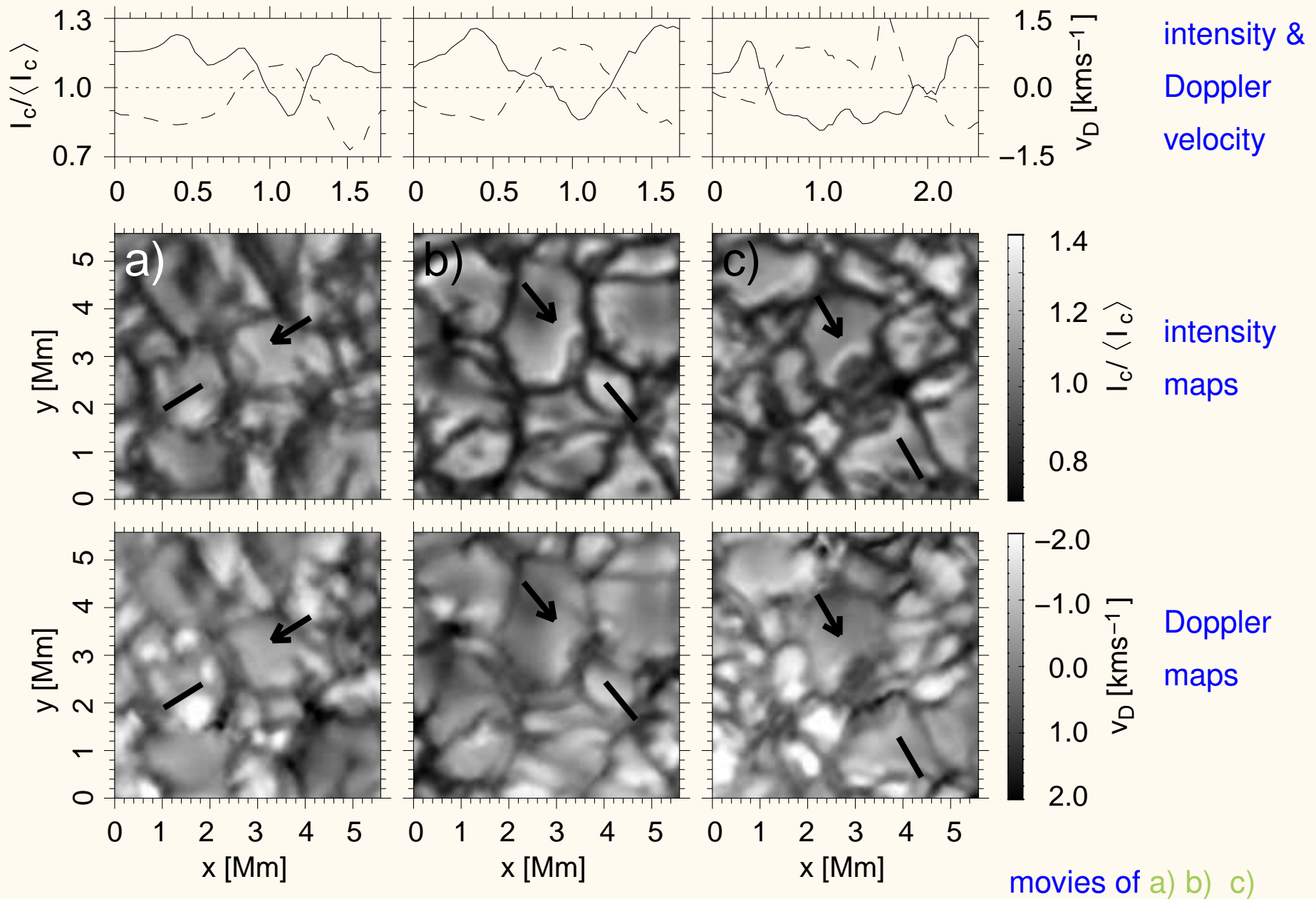
1. Observation with *IMaX* onboard *Sunrise*



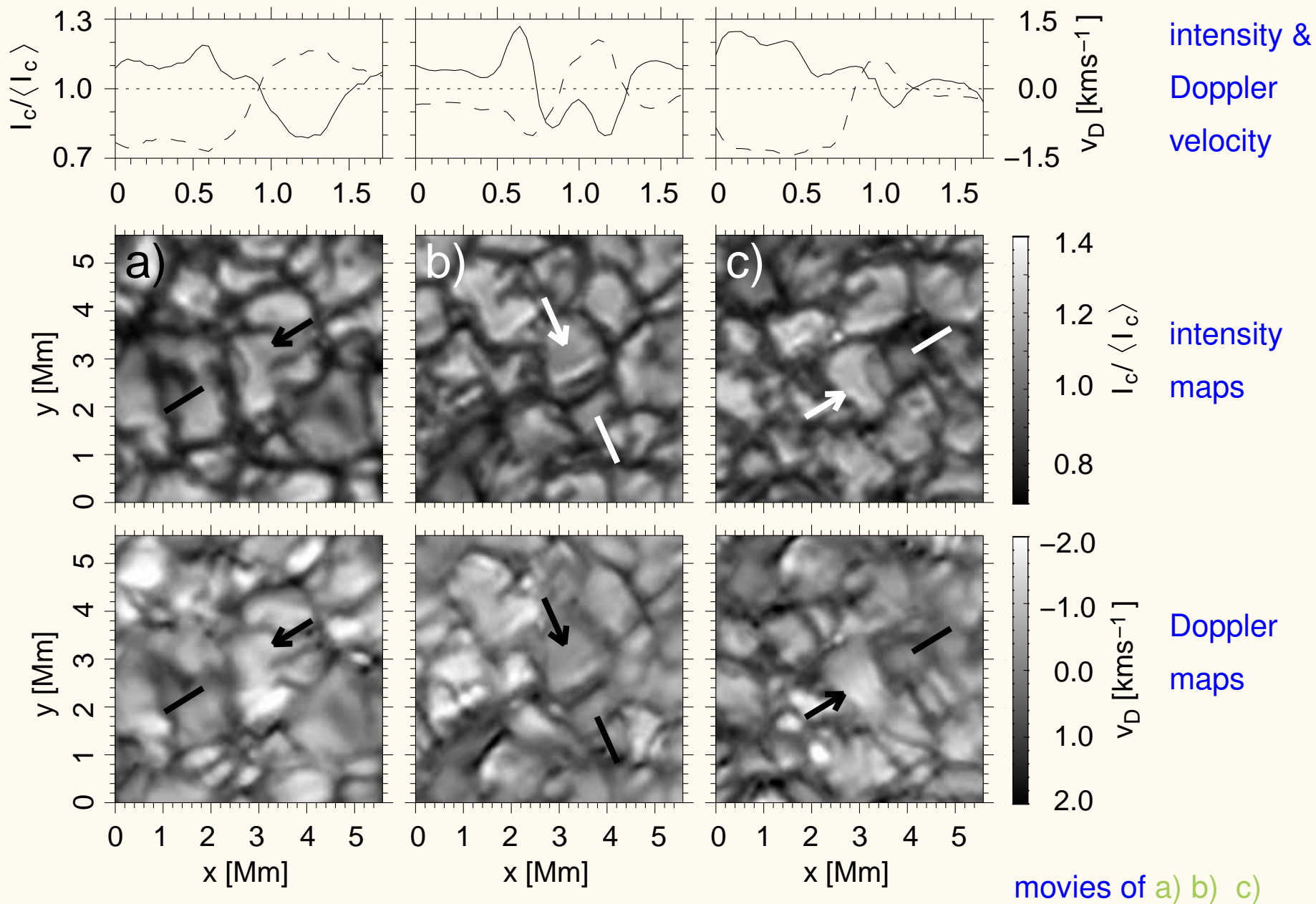
Time series of subfields of 5.6×5.6 Mm in the continuum intensity at $\lambda = 5250.4$ Å.

Top row: sequence of reconstructed images. *Bottom row:* sequence of Doppler maps.

1. Observation with *IMaX* onboard *Sunrise* (cont.)

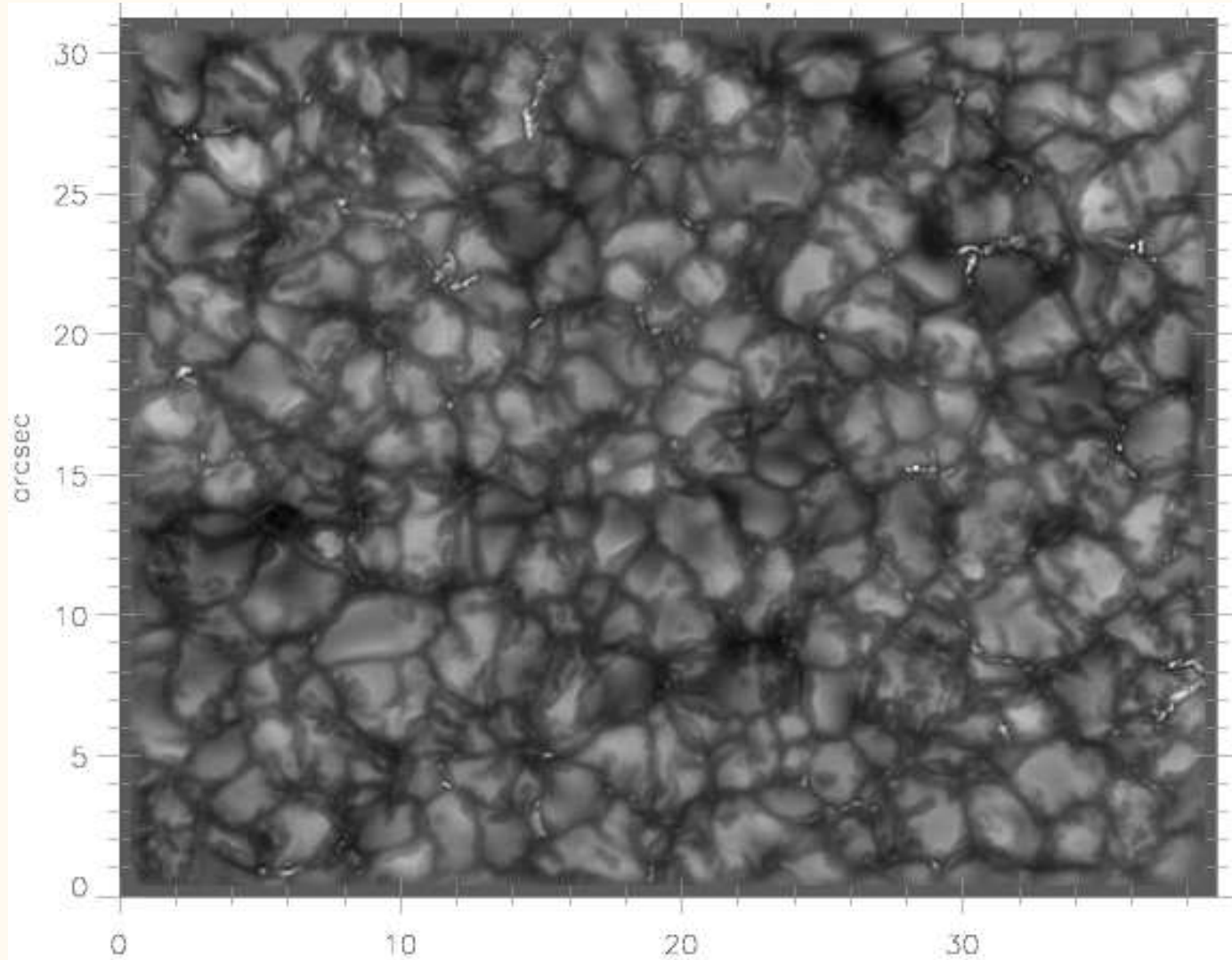


1. Observation with *IMaX* onboard *Sunrise* (cont.)



1. Observation with *IMaX* onboard *Sunrise* (cont.)

Similar events in other data

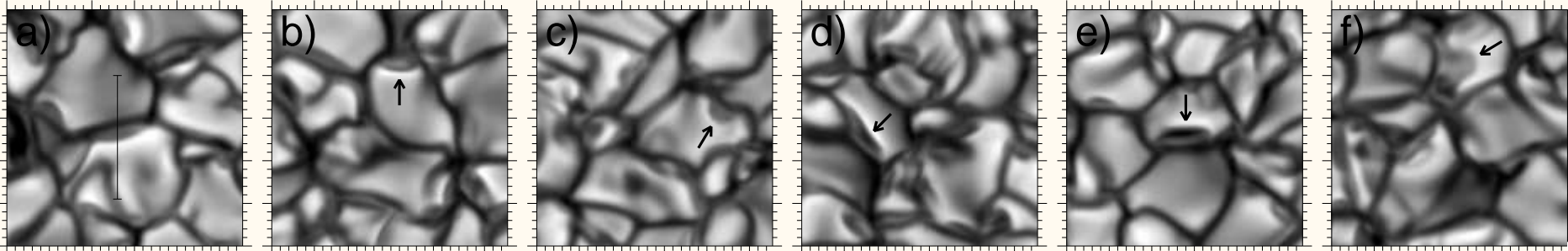


VTT with AO and speckle reconstruction. Continuum at 395 nm. Courtesy, O. von der Lühe et al. (KIS)

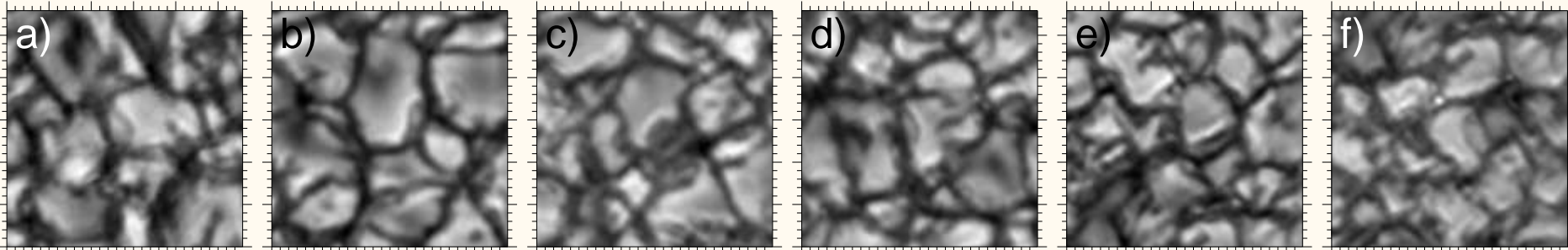
Hinode G-band

SST G-band: Courtesy L. van der Voort

2. Simulation with CO⁵BOLD



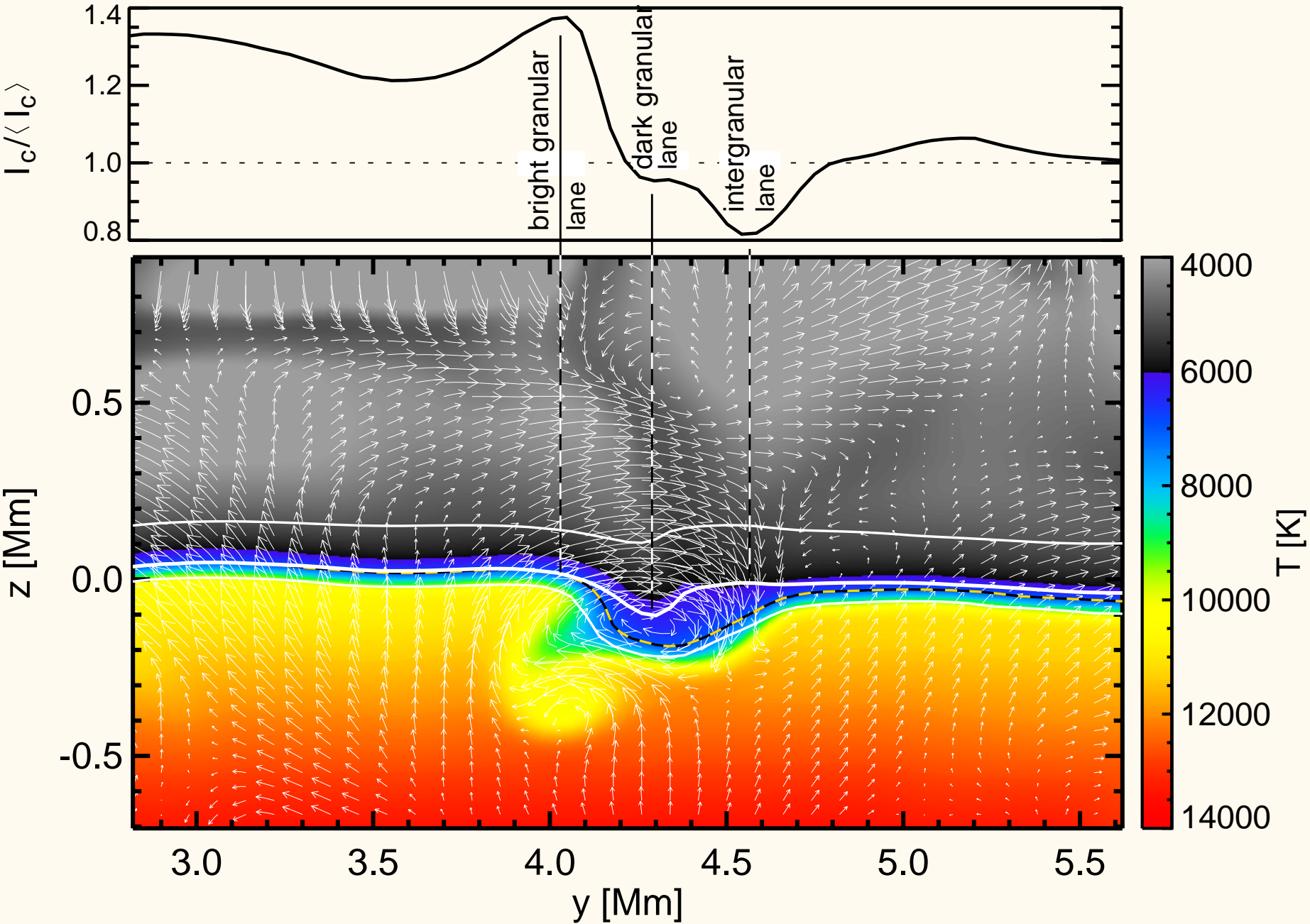
Instances of *granular lanes* (marked by arrows) from the *numerical simulation*...



...in comparison to *observations*

movies of a) b) c) d) e) f)

2. Simulation with CO⁵BOLD (cont.)



2. Simulation with CO⁵BOLD (cont.)

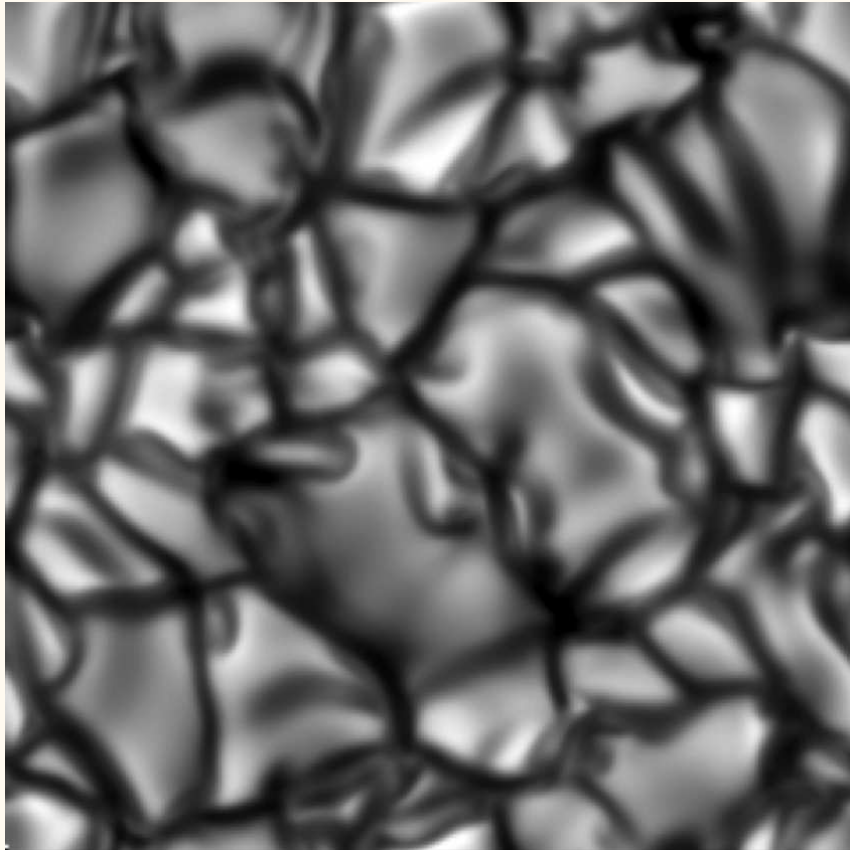
The equation of *vorticity* $\boldsymbol{\omega} = \nabla \times \boldsymbol{v}$ for a inviscid, compressible medium is

$$\frac{D\boldsymbol{\omega}}{Dt} = \nabla(\boldsymbol{v} \cdot \boldsymbol{\omega}) + \underbrace{\frac{1}{\rho^2} \nabla \rho \times \nabla p}_{\text{baroclinic term}} .$$

The baroclinic term can act as a source of vorticity.

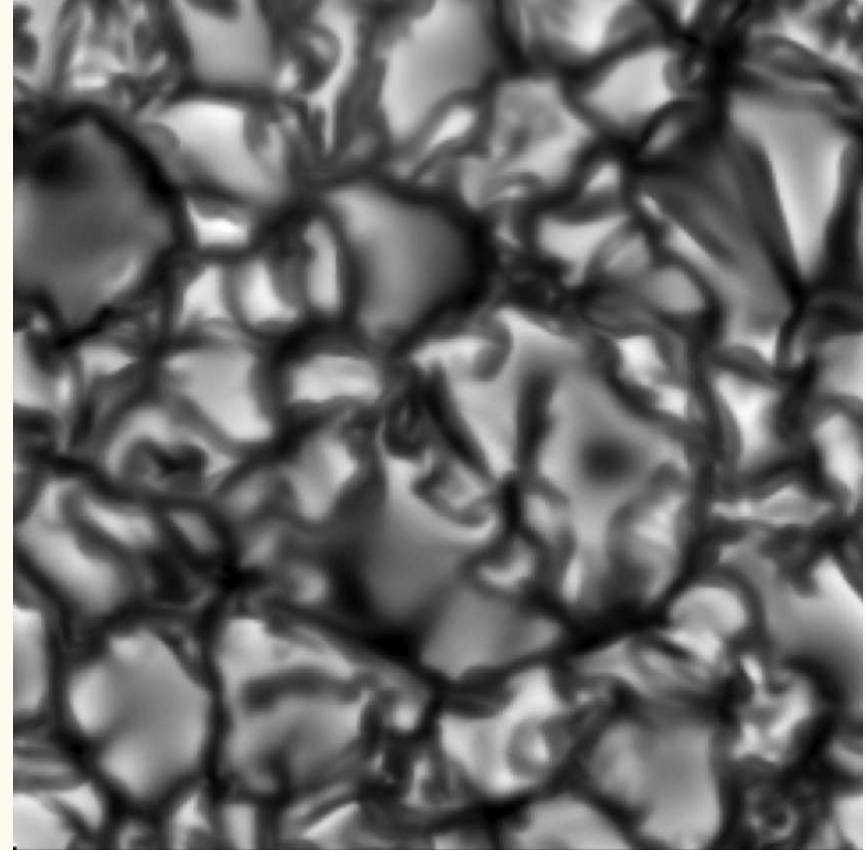
2. Simulation with CO⁵BOLD (cont.)

Run with HLL solver
+ numerical viscosity



Role of numerical viscosity.

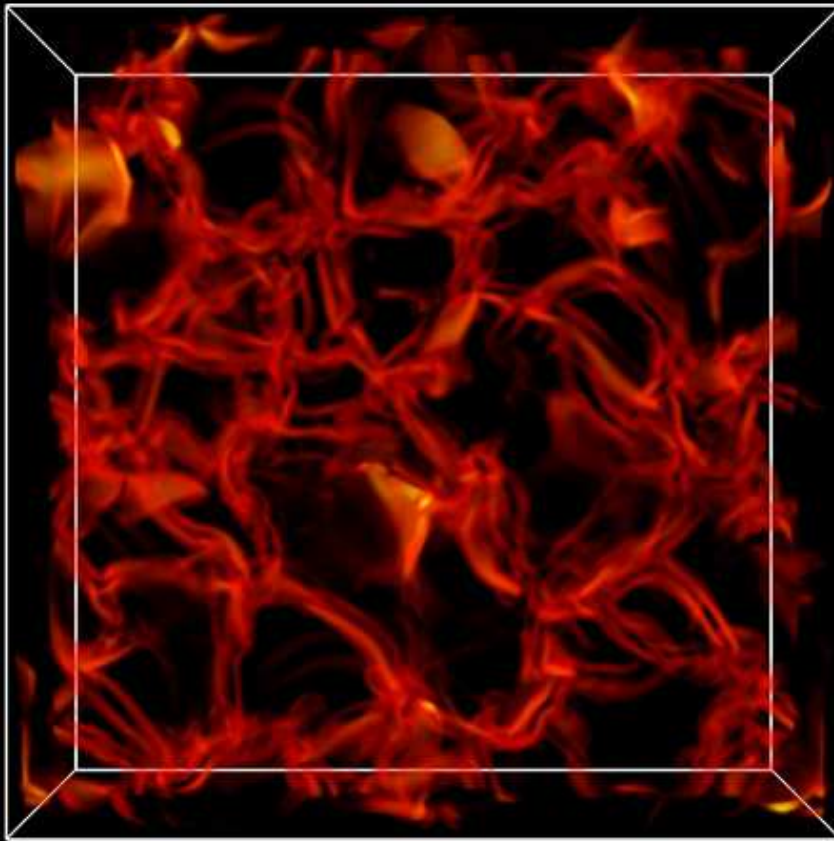
Run with Roe solver
without numerical viscosity



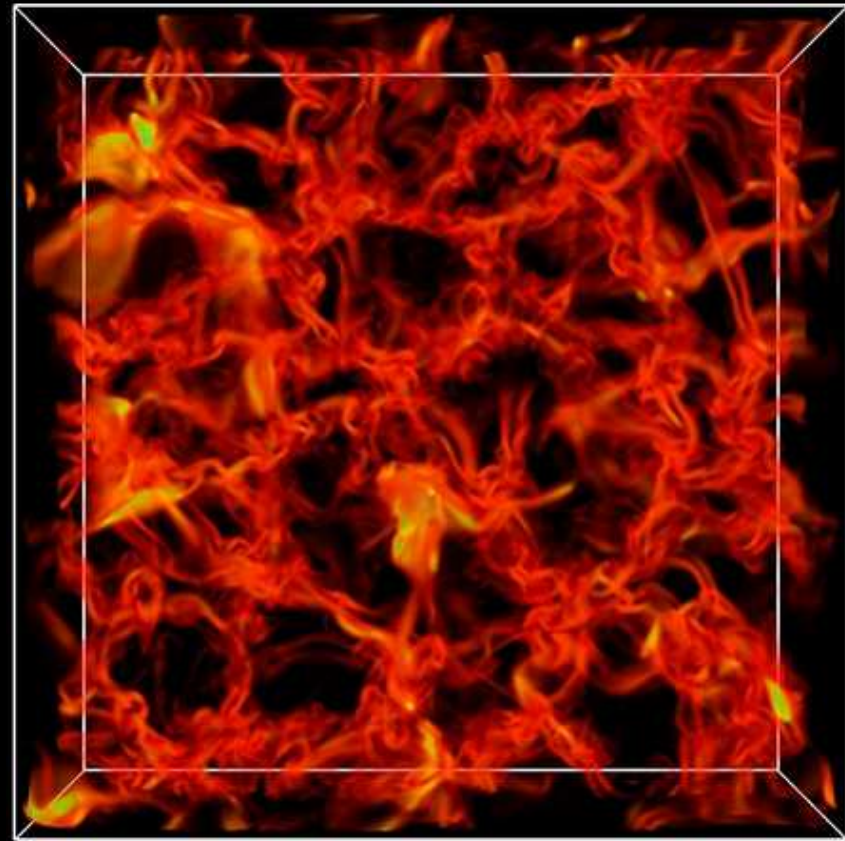
2. Simulation with CO⁵BOLD (cont.)

Vorticity

Run with HLL solver
+ numerical viscosity



Run with Roe solver
without numerical viscosity



3. Conclusions

- We find *granular lanes*, which are (usually) composed of a leading bright rim and a trailing dark edge or darkish area. They move from the border of a granule into the granule itself.
- With the help of numerical simulations of solar surface convection we identify these objects as *vortex tubes*.
- The size of the vortex tubes is close to the spatial resolution limits of both the observation and the numerical simulation. We expect *vortex tubes on smaller scales*.
- The Sun seems to provide an unique opportunity for the study of vortex tubes in a baroclinic and gravitationally highly stratified medium.

Table of content

1. Observation with *IMaX* onboard *Sunrise*

2. Simulation with CO⁵BOLD

3. Conclusions

References

References

Steiner, O., Franz, M., Bello González, N., Nutto, Ch., Rezaei, R., Martínez Pillet, V., Bonet Navarro, J. A., del Toro Iniesta, J. C., Domingo, V., Solanki, S. K., Knölker, M., Schmidt, W., Barthol, P., and Gandorfer, A.: 2010, *Detection of vortex tubes in solar granulation from observations with SUNRISE*, ApJL 732, L180-L184