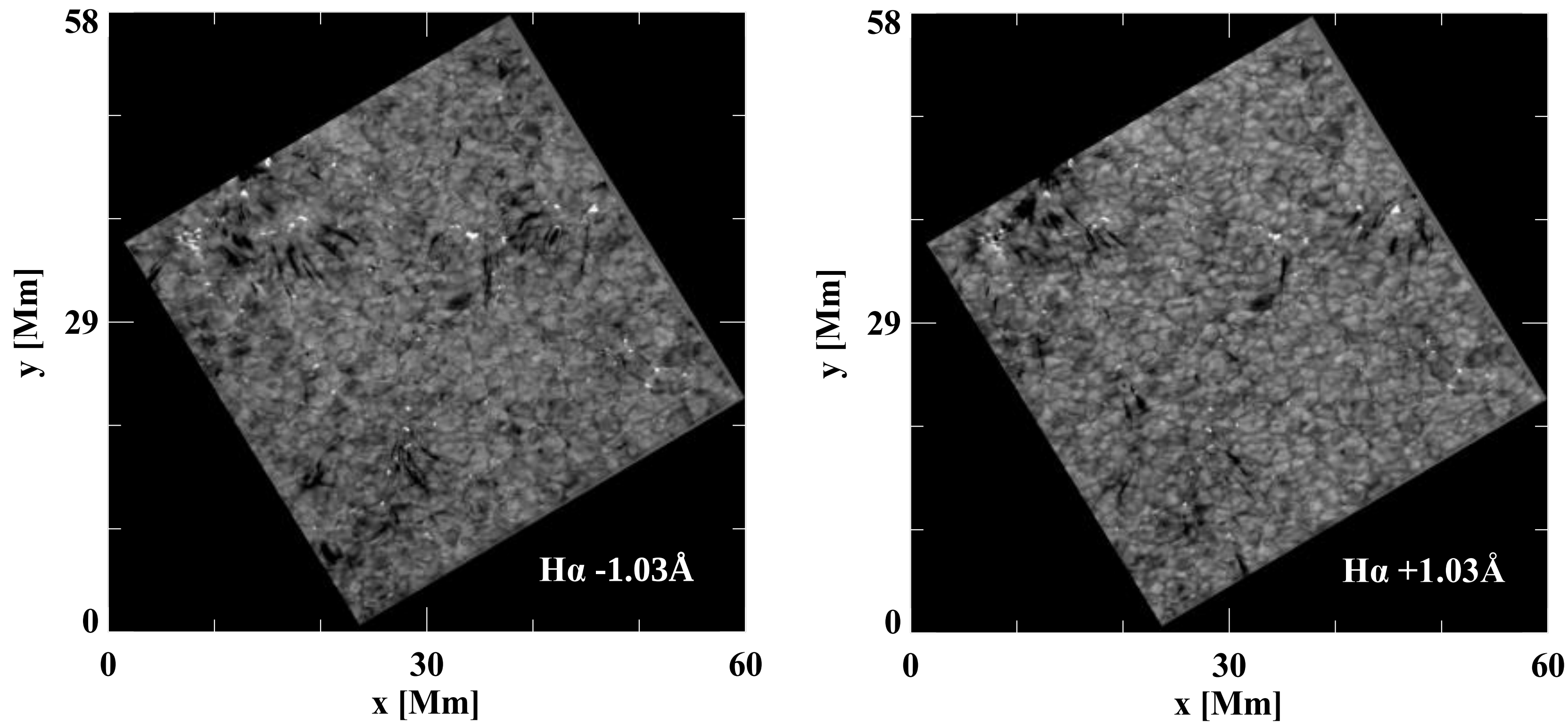
The 12th Hellenic Astronomical Conference

A granule seen in the far wings of the H-alpha line: exceptional darkening before fragmentation



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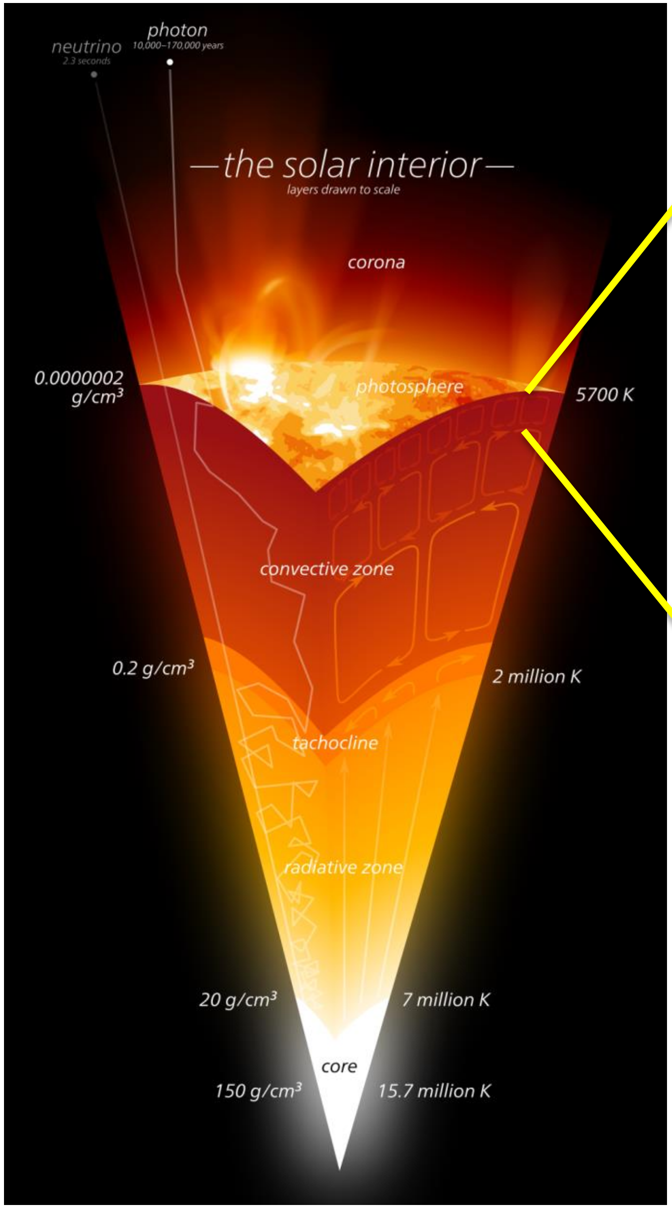
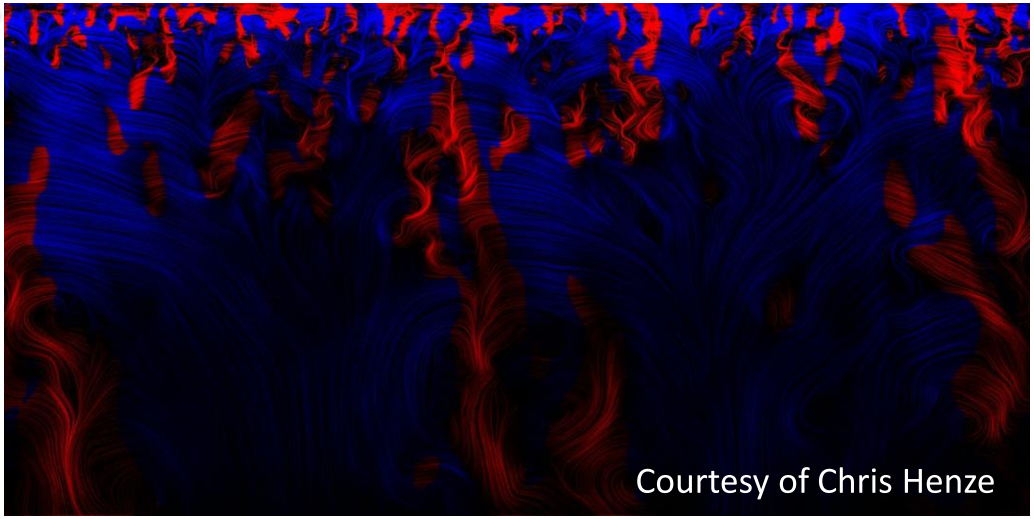
Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης
ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

1. Introduction: Solar Interior



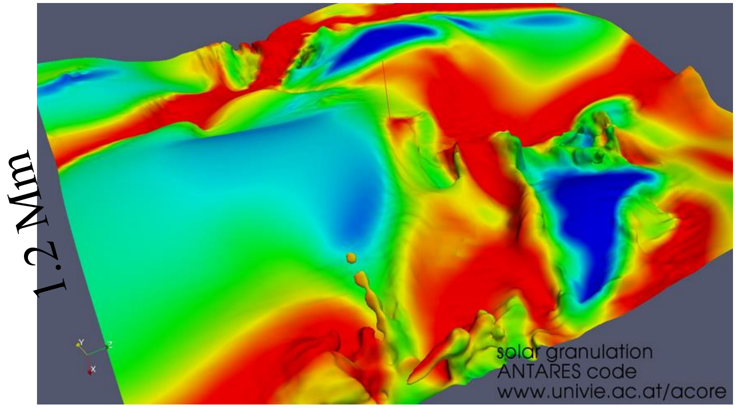
Courtesy of Kelvin Song

Solar convection (red/blue: down/up flows; 15 hours)

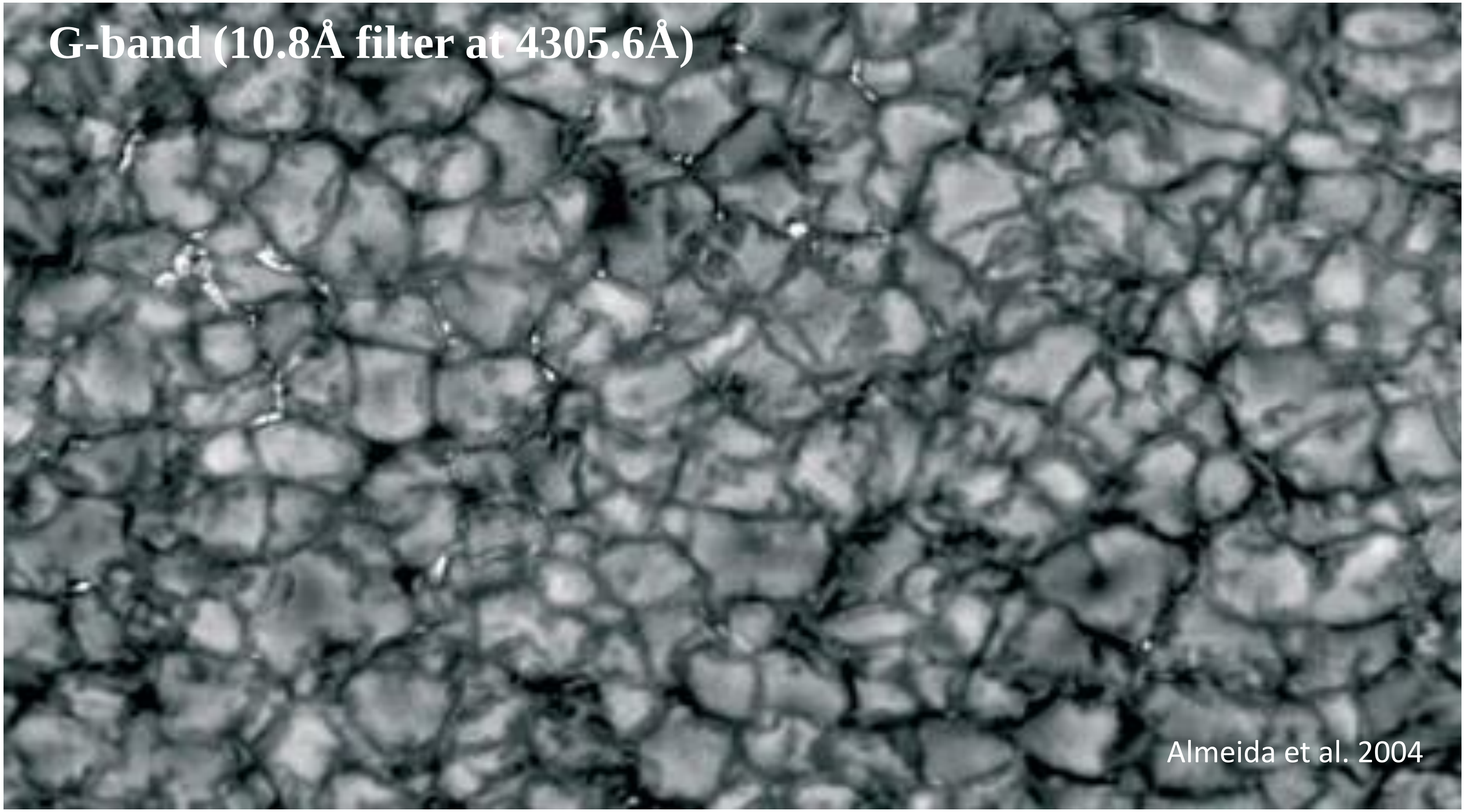


20 Mm

48 Mm



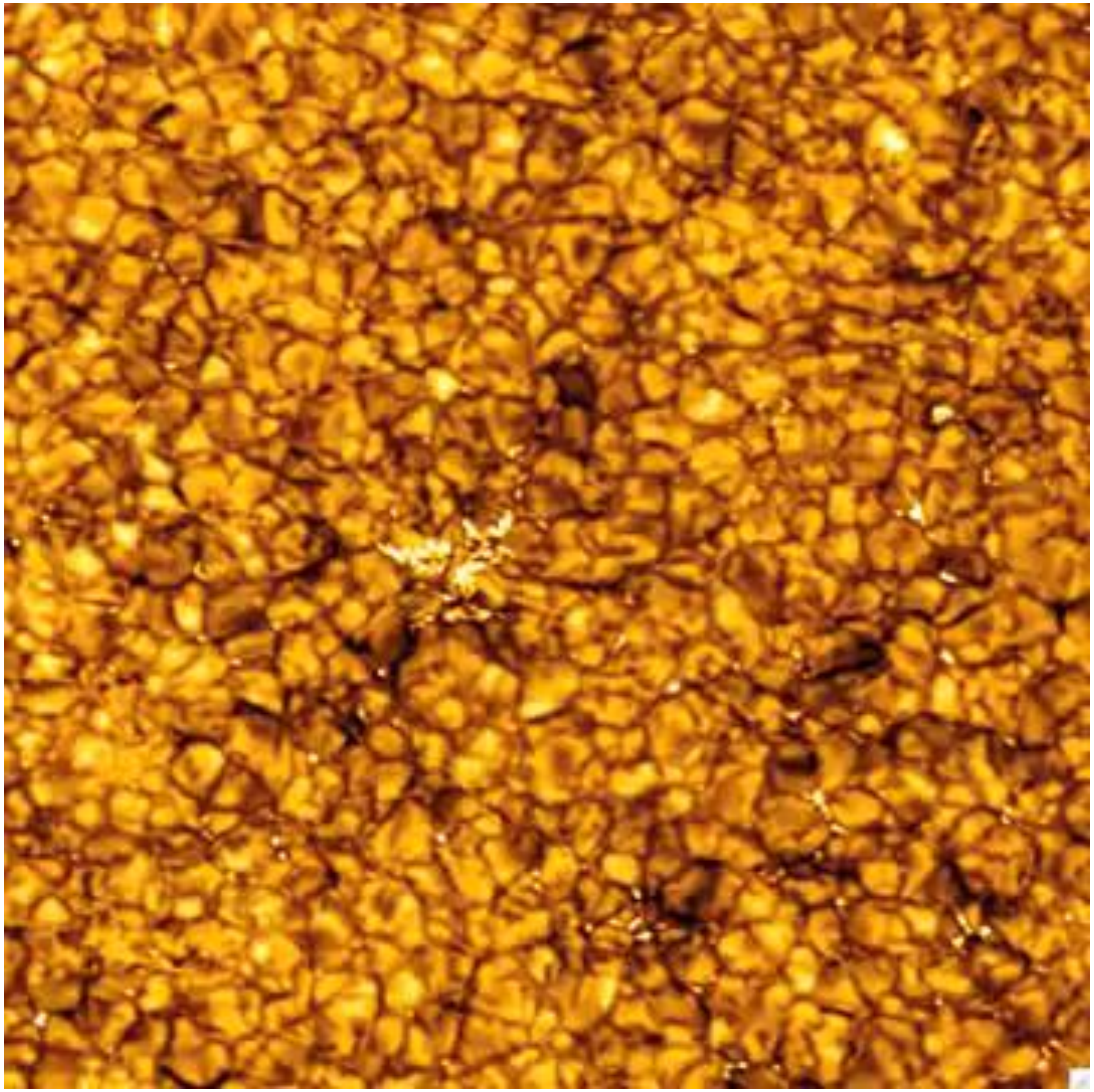
1. Introduction: Solar Granulation



Typical characteristics of granules

- Size: 1 Mm
- Doppler velocity: ~1 km/s at the disk center
- Radial expansion speed: ~1-2 km/s
- Lifetime: ~16 min
- Microturbulent velocity: ~2km/s
- Temperature: 5,000-10,000 K

1. Introduction: Evolution of Granules



SST/CRISP Hα wideband movie obtained by Luc Rouppe van der Voort

1. Introduction: Motivation & Objectives

- Although our knowledge of granules and their evolution at the bottom of the photosphere is quite precise from mainly white-light or photospheric line observations, **their temporal evolution throughout the photosphere is not well known**.

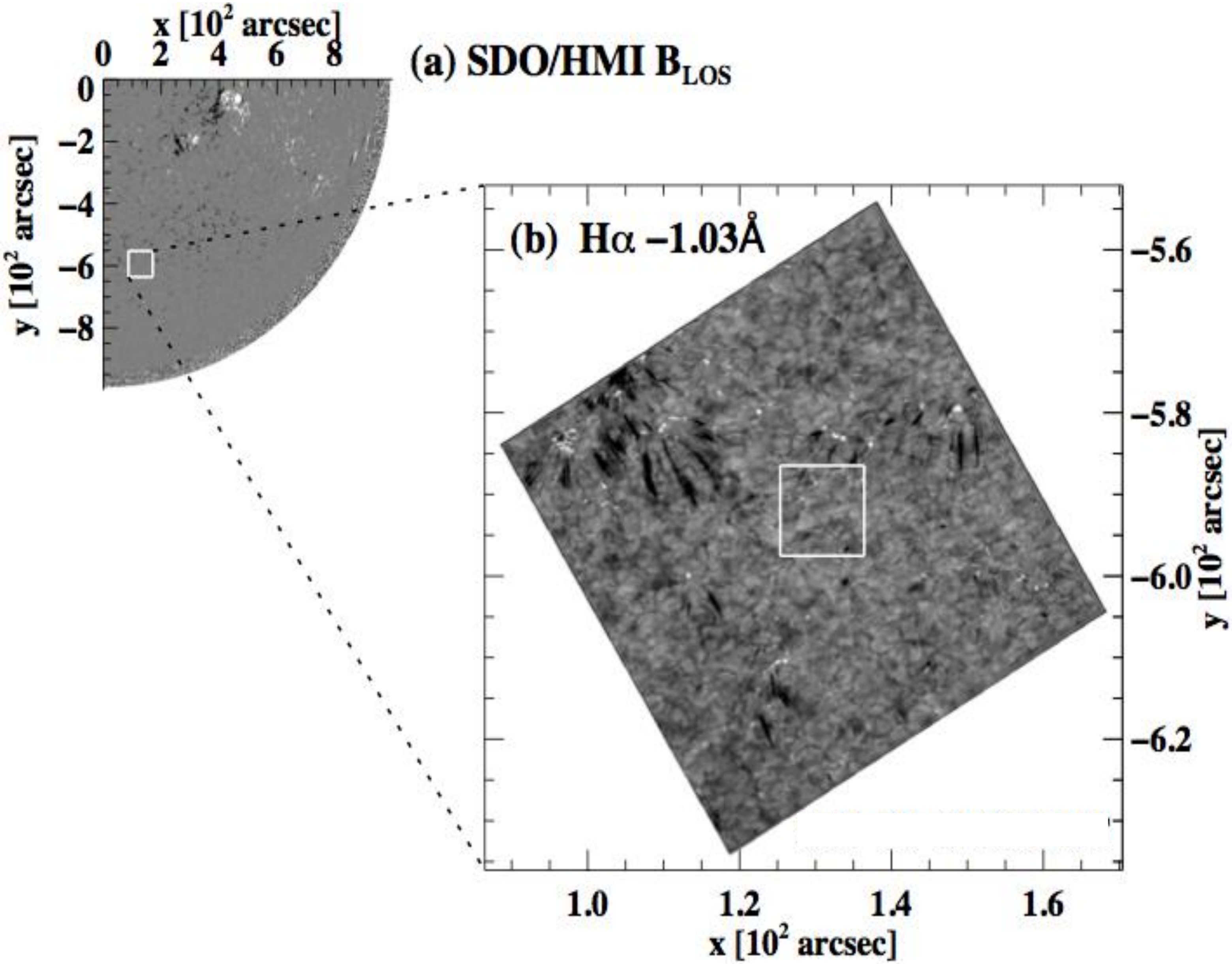
- To this extent **Hα far wing observations can be useful for the diagnosis of vertical flows and temperatures in the upper photospheric layers** of granules in relation to their evolution.

- Using time series of two-dimensional (2D) high-resolution, high-cadence, Hα observations, we investigate **temporal variations of some spectral properties** of a quiet Sun granule.

- The study will provide **a better understanding of the physics underlying the evolution of an individual granule** at the near-surface layers of the Sun.

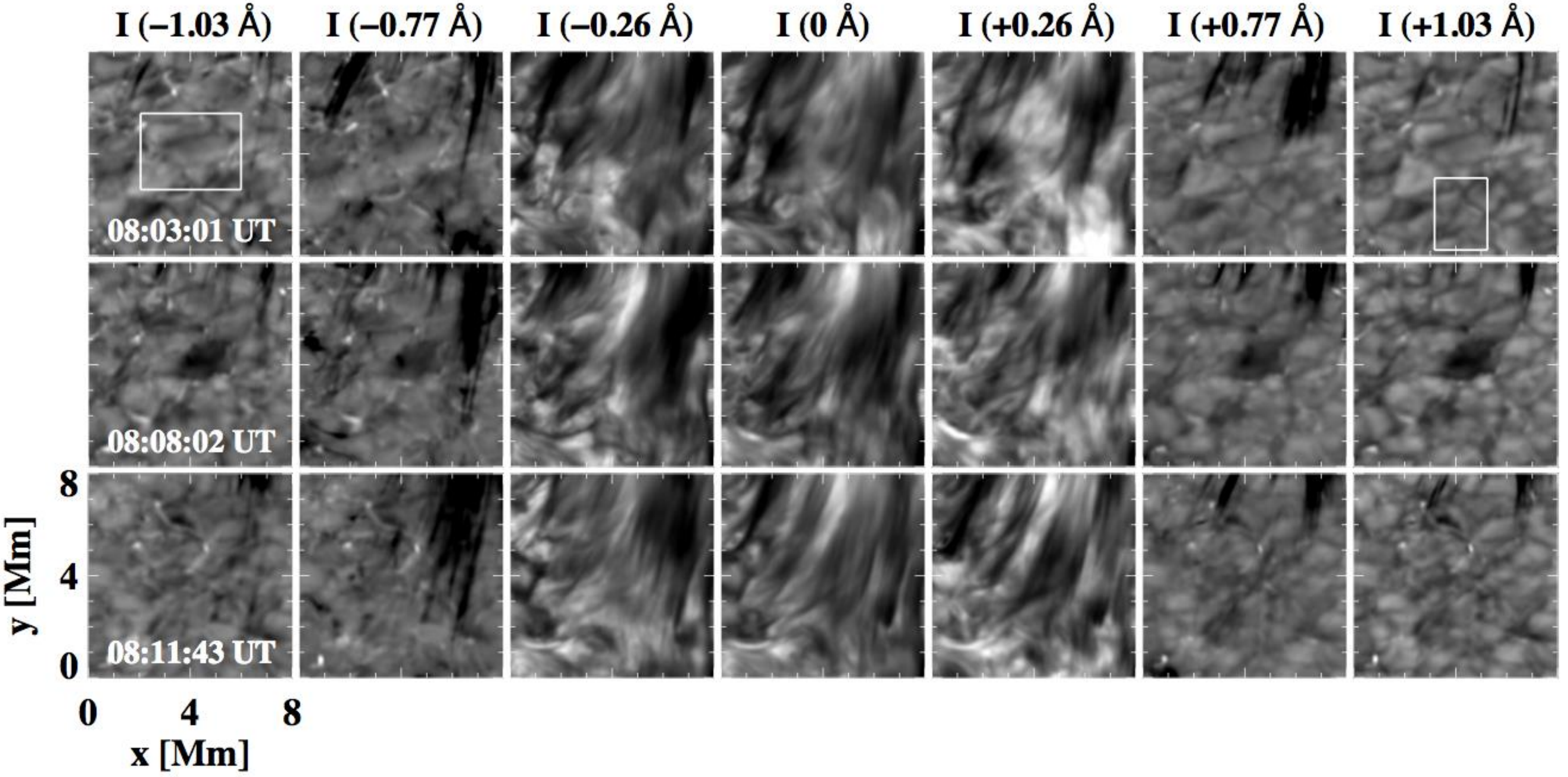
2. Observations: Swedish 1-m Solar Telescope (SST)

▪ CRISP Hα Full FOV



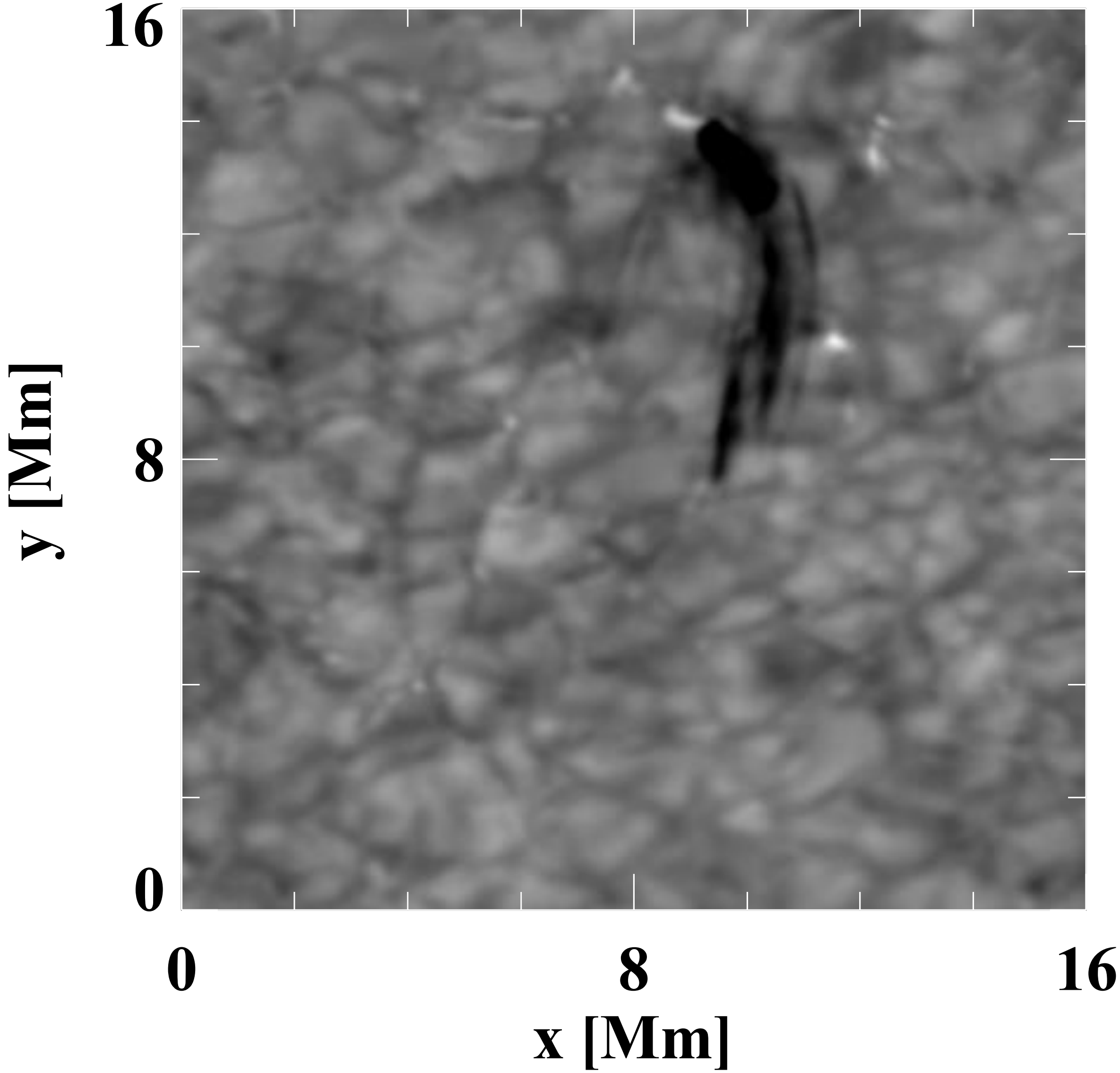
3. Results: Darkening before Fragmentation

Period of Investigation: 2014 June 07 08:03-08:12 UT (~10 min)



■ CRISP Hα+1.03Å Movie

2014 June 7 at 08:02:02 UT



Two Spectral Properties: (1) Doppler Signal

- Doppler Signal (DS) provides a qualitative picture of upward (positive DS) and downward (negative DS) moving material.

- We calculate DS from the ±0.77Å and ±1.03Å image pairs, respectively, using the following formula:

$$DS = \frac{I(+\Delta\lambda) - I(-\Delta\lambda)}{I(+\Delta\lambda) + I(-\Delta\lambda)}$$

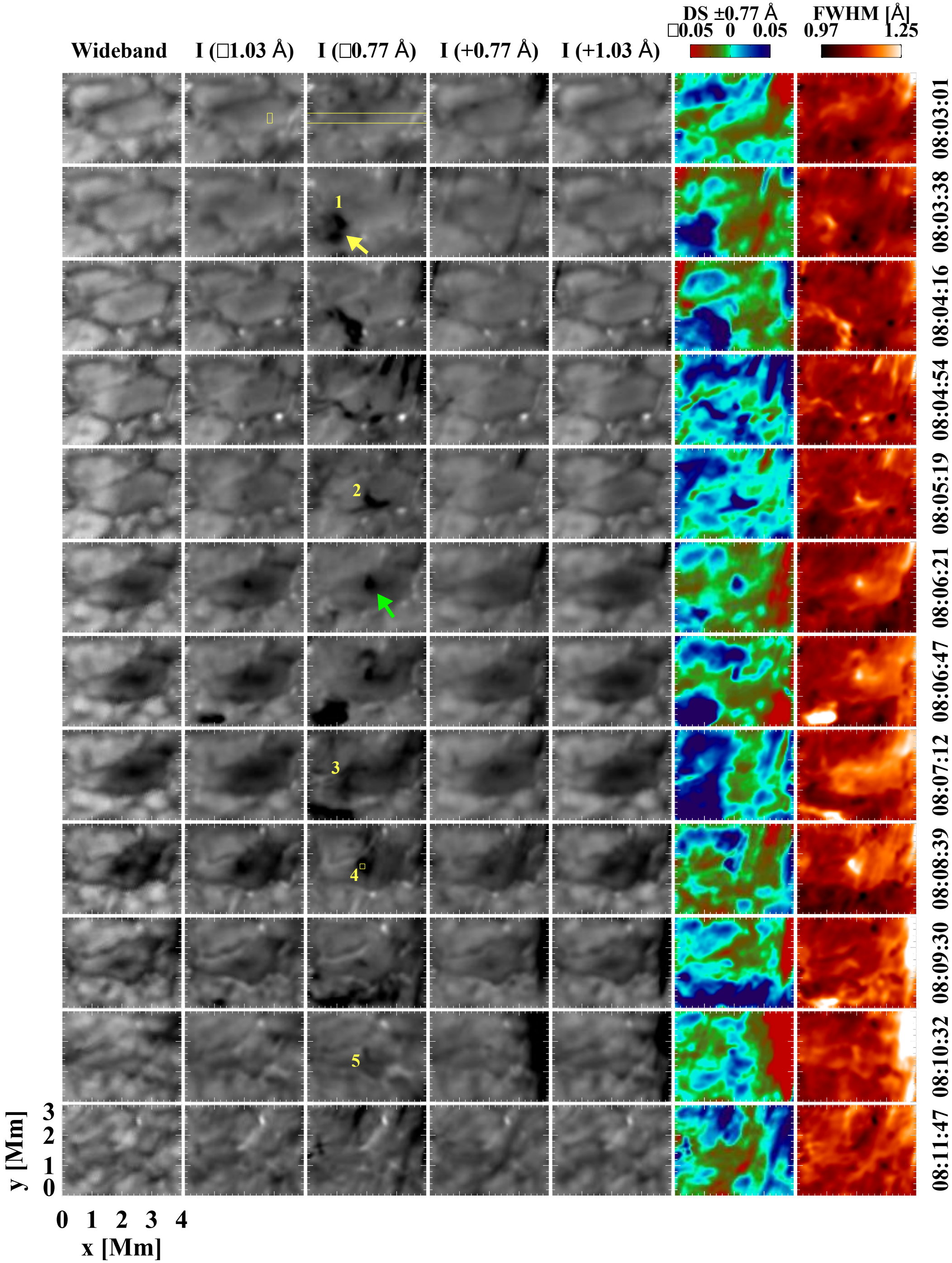
- Note that a zero reference of DS is defined as the mean DS value of a neighboring quiet Sun region.

Two Spectral Properties: (2) Full-Width at Half-Maximum

- We estimate the Full-Width at Half-Maximum (FWHM) of the Hα profiles of the granule area under study.

- The average line profile in the same neighboring quiet Sun region as used for determining the zero reference of DS is used to find the continuum intensity I_C by fitting it to a reference Hα line profile (up to ±30Å from the line centre) published by David (1961).

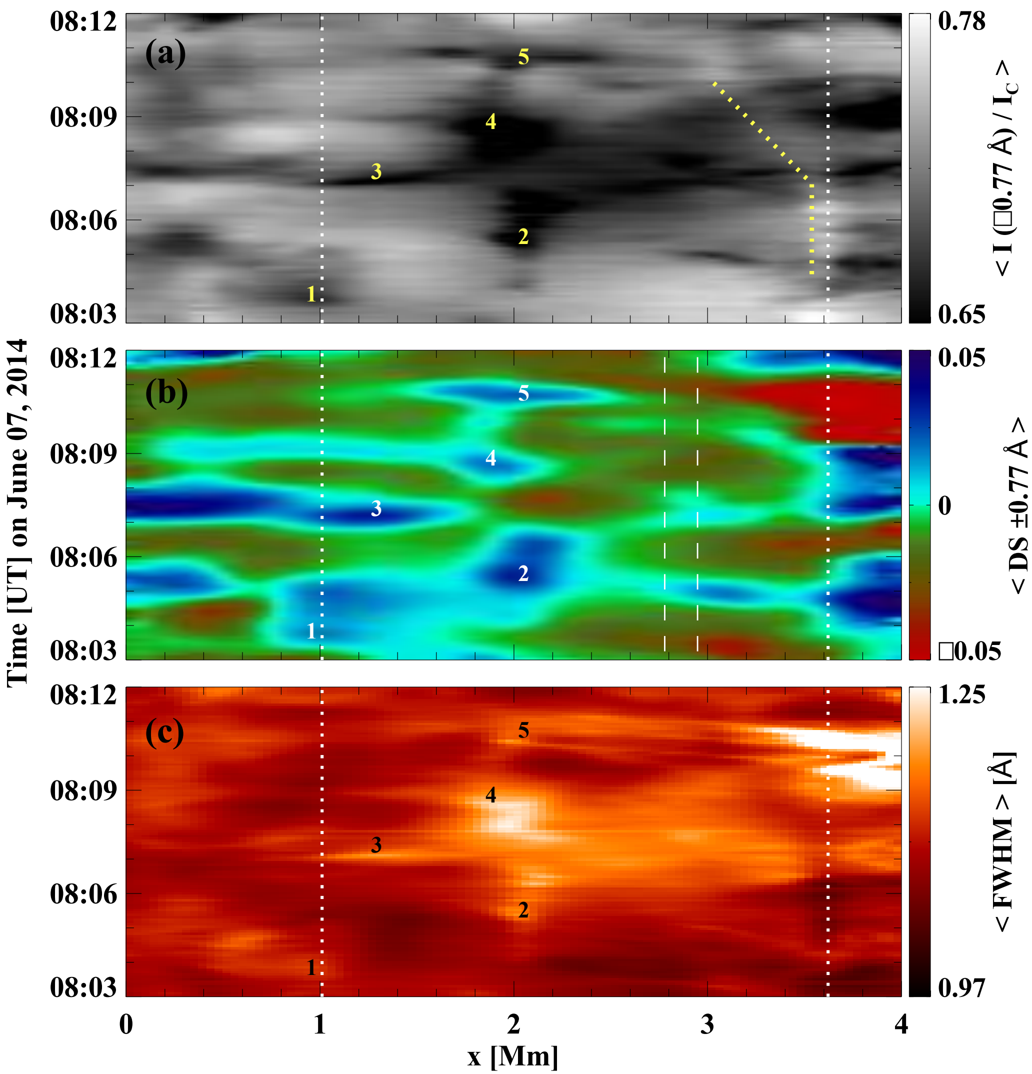
- Then, FWHM is the wavelength separation between two wavelengths on either side of the profile where the spectrum intensity $I = 0.5 \times (I_C + I_{min})$.



The Granule's Evolution I

- Formed at ~08:00 UT.
- During the initial phase (08:03 UT – 08:05 UT), the DS maps show mainly downflows in the intergranular lane, while upflows in the granule.
- From ~08:05 UT to 08:09 UT, the granule gets darker as observed in Hα wideband and far wing images. The DS and FWHM maps show downflows and important broadening of the spectral line.
- After the darkening finishes, the granule fragments into several small granules (e.g. at 8:11:47 UT).

The Granule's Evolution II: Space-time Slice Images

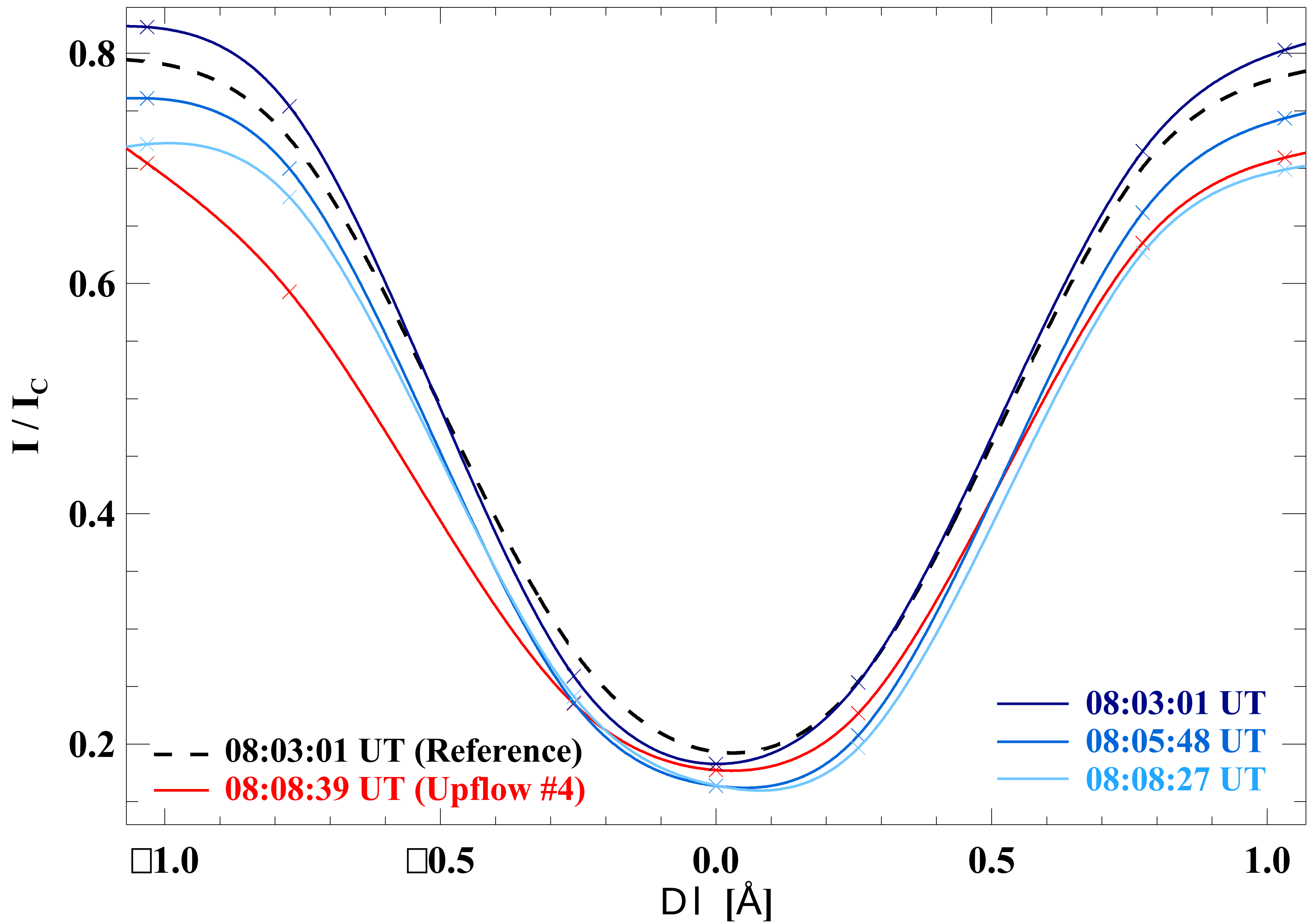


- **Cloud events (marked by 1-5)**
  very low intensity - high positive DS (high-speed upflow) - very high FWHM values

- **Granule**
  low intensity – negative DS (downflow) - high FWHM in the granule area.

- **Rapid shrinkage**
  Granule's western boundary at ~08:07 UT.

The Granule's Evolution III: Hα Line Profiles



4. Summary and Discussion

The behaviour of the Hα line profiles in the quiet Sun can be summarized as follows.

1. Initially, the granular region has its normal appearance, i.e. bright granule, dark intergranular lanes.

2. Most of the region in the granule gets dark at both far blue and red wings of the Hα line, during a period of ~5 minutes.

3. During the darkening the line profiles in the granule are redshifted, asymmetric and broader relative to a quiet Sun mean profile.

4. The granule remains constant in size for most of the time, and then it shrinks before its fragmentation.

1. After the darkening phase the granule becomes fragmented into a number of small granules, while the line profile gets closer to the quiet Sun mean profile.

Why this granule appears so dark in both Hα far wings?

- Of course, because of the broadening of the Hα line profile!
- Related to thermal and non-thermal broadening
- Non-thermal broadening is influenced by the unresolved granular motions associated with the so-called microturbulent velocities.
- Previous studies, however, indicate that granules have microturbulent velocities of the order of ~2 km/s at the photosphere that even decrease with height (see, e.g., Stodilka & Malynych 2006; Fontenla et al. 2008), so it is not expected that the increase of the FWHM is due to an increase of the microturbulent velocity.
- We conclude, therefore, that the increase of the Hα line width is mainly due to thermal broadening and thus to temperature increase caused by adiabatic compression associated with the downflowing material and the granule's rapid shrinkage.
- In addition, it is conjectured that the granular fragmentation can be associated with the downflows in the granule, as well as the shrinkage of the granule.

Thank you for your attention!
Any comments or questions are welcome.