Observational results on
Exploding Granules

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Solar Granulation general properties

Field of view: 19700 x 9100 km
Duration: 40 min

Presented data:
Broad-band data, 2D-spectra
$\lambda = \text{FeI 543.4 nm}$
$\lambda = \text{FeI 557.6 nm}$
Solar Granulation general properties

Sizes:
(Fourier segmentation)

Lifetimes:
(feature tracking)

Irregular shapes:
$0.05 < 4 \pi A / P^2 < 0.8$

“Birth” and “death” by fragmentation and dissolution
Solar Granulation

$I - \nu$ correlations

- line center
- continuum

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\[\alpha = 0.707, \ \epsilon = 0.845\]
\[\alpha = 0.541, \ \epsilon = 0.862\]

\[\alpha = 0.869, \ \epsilon = 0.973\]
\[\alpha = 0.841, \ \epsilon = 0.974\]
Solar Granulation cell structure

Normalized distances of intensity and velocity maxima from cell barycenter

⇒ The larger a cell the farther out are the bright upflowing regions located

⇒ Large granules develop dark centers
Granulation is a surface phenomenon:

- Radiative cooling leads to increased density
- Upward motion declines ("buoyancy braking")
- Spontaneous downflow "plumes" form due to Rayleigh-Taylor instabilities
Solar Granulation plume formation

- Spontaneous plume formation is the primary phenomenon
- Upward gas motion is the secondary phenomenon (response in order to fulfill mass continuity)
- This explains dark centers and bright edges
- Spontaneously arising granules not observed

Rast (1995)
Solar Granulation Turbulence

Due to the high Reynolds numbers (Re~10^{12}) granular motions should be highly turbulent. High resolution observations and numerical simulations show, however, laminar motions.

⇒ In divergent flows turbulence might be suppressed by the density stratification (Nordlund et al. 1997)
⇒ Intergranular lanes should show increased turbulence

Turbulence should also appear at the granular/intergranular borders (shear motions) and as a result of supersonic flows (post-shock turbulence)

Detection: increased line widths
Requirement: high spatial + spectral resolution => difficult!
Solar Granulation explosion of granules

- common phenomenon
- discovered by Rösch in 1968
- observational difficulties
- explosion in “generations” => mesogranulation (Oda 1986)

Roudier et al. 2001:

1: granular upflow
2: generation of bright lateral plumes
3: connection
4: explosion
? : no central downflows
Solar Granulation explosion of granules

This particular example shows a lateral brightening previous to the formation of the dark center – others do not!

Disadvantage of 2d spectra: line broadening by filter causes reduction of probed $z$-range
The explosion seems to start in upper layers.
As the dark center forms in the continuum layer higher regions become bright => inverted granulation.
A reversal of the flow direction is clearly visible!
Solar Granulation plume formation

Reversal of Doppler velocities seem to proceed first in higher layers, then in lower layers => downward moving plume
Some of the dark granule centers do not increase (explosion) but move out of the granules => dark dots. (Kitai & Kawaguchi 1979) Dark dots as well indicate downward moving plumes.
Solar Granulation
dark dots

Dark dots are able to cross several granules
=> stable entities

Due to, e.g., the Coriolis force
plumes should rotate
=> “draining bathwater”
=> stabilization mechanism

Vortex motions are not confirmed observationally!
High resolution spectroscopy close to the limb may clarify
the nature of dark dots.
Solar Granulation excitation of waves

Temporary brightening of line center regions indicate upward moving waves.

Indeed, acoustic waves might be excited by turbulent motions, e.g. Lighthill mechanism (Lighthill 1952):

\[
\frac{1}{c_0^2} \frac{\partial^2 P'}{\partial t^2} - \Delta P' = \rho_0 \frac{\partial^2 T_{ik}}{\partial x_i \partial x_k} \quad \text{with} \quad T_{ik} = v_i v_k
\]

Released acoustic energy:

\[
\epsilon_{ac} \sim \frac{v^8}{c_0^5 l}
\]
Numerical simulations confirm the convective excitation of shock waves propagating into the chromosphere.

Wedemeyer et al. 2004
Wavelet analysis:

Acoustic power can be found at “all” periods (Wunnenberg et al. 2002)
Acoustic events are predominantly located in the intergranular lanes. They do not seem to be excited by exploding granules, confirming Rimmele 1995.
Exploding granules are a common phenomenon. It seems to be closely related to meso- and supergranulation. Plume formation acts as a triggering mechanism. Dark dots seem to be closely related but spatially confined, which leads to vortex motions. Exploding granules are not responsible for exciting acoustic waves.