Chromospheric Waves

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Lindau, Friday 2.9.2005
Chromospheric waves

• Observations

• Simulations

Energetics
Diagnostics
Ca II H-line

QuickTime™ and a GIF decompressor are needed to see this picture.
Ca II H-line observations

• Emission all the time in the network, rather symmetric

• Most of the time no emission in internetwork

• Brightening from wing progressing to line center

• Brightening on the violet side of line center

• 3 min periodicity

Lites, Rutten, Kalkofen 1993
SUMER observations

- Emission all the time
- Brightenings in the continuum
- Blue shifted emission
SUMER observations, upper chromosphere

- Oscillatory signal
- more in V than in I
- No strong saw-tooth form
- Extends to Transition-region
UV continua

Behaviour varies with position and time
Wave energy flux as function of height

Height = -0.05 Mm

QuickTime™ and a GIF decompressor are needed to see this picture.
Cut-off frequency

Adiabatic, non-magnetic

Radiative damping

Magnetic flux tube

Roberts, 1983, Solar Physics 87,77
Dynamic behaviour, Temperature

QuickTime™ and a GIF decompressor are needed to see this picture.
Ca II H-line intensity
• Intensity variations OK, Mean level much too low.
• Agreement gets worse with height
• Where have all the shocks gone?
Restrictions

• 1D
• lacking processes (NLTE line blanketing, Mg II, CO)
• CRD
• no magnetic fields
• no high frequencies in piston
Generation of acoustic waves
1D: high frequency peak (15mHz)

Musielak, Rosner, Stein, Ulmschneider 1994
3D HD convection simulations: no peak

Goldreich, Murray, Kumar 1994
Stein, Nordlund, 2001
Strong damping
Acoustic flux determined from observations


Total flux at 400km: 0.4 kW/m²
What have we learnt?

• Ca II grains explained by acoustic waves
  • only way to get strong blue-red asymmetry is through a strong velocity gradient

• 3min waves present already in photosphere

• Non-magnetic chromosphere very dynamic.

• Acoustic waves not enough to explain mid-upper chromosphere in internetwork
Chromospheric seismology

McIntosh et al, 2003, AA 405, 769
Correlation with Magnetic canopy height

See also poster P.12 by Fleck et al
Wave interaction with magnetic fields

Carlsson & Stein 2002, ESA SP-505, 293

• 2D/3D wave studies
Mode conversion and reflection

Small attack angle - full mode conversion - no reflection
Large attack angle - refraction - standing wave pattern
Radiation and shocks

\[\text{ix}=20 \quad \text{iy}=20 \quad Bz(\text{phot})=41.6 \quad \text{theta}(35)=5.0 \]

\[\text{ix}=30 \quad \text{iy}=60 \quad Bz(\text{phot})=1.1 \quad \text{theta}(24)=52.0\]
Traveltime analysis

\[ T(x,y,z,t) \rightarrow R_{IT} \quad \text{[km]} \rightarrow \frac{\Delta I}{I_{1600,1700}} \]

\[ C(\frac{\Delta I}{I_{1600}}, \frac{\Delta I}{I_{1700}}) \rightarrow \text{traveltime (x,y)} \]
Active region wave propagation
Active region wave propagation

Fossum, A, 2005
02 June 2003, G-band

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.
02 June 2003, Ca H

QuickTime™ and a Photo - JPEG decompressor are needed to see this picture.
Piecing it all together
Hansteen 2004

• 16x8x12 Mm (2 Mm below, 10 Mm above)
• Open boundaries
• Multi-group opacities (4 bins) with scattering
• Conduction along field-lines
• Optically thin losses in corona
• Various initial magnetic field configurations
QuickTime™ and a GIF decompressor are needed to see this picture.
2D model

Internetwork

Network

$T$ [K]

Height [Mm]

Height [Mm]
Waves

Height = 0.63 Mm

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Conclusions

• Chromosphere pervaded by waves
  • Determine the chromospheric structure

• Mode conversions where Cs=Ca
  • Attack angle crucial

• Diagnostics very difficult - forward modeling necessary for interpretation
  • Chromospheric seismology possible but long “integration” times - is the average structure interesting?