Chromospheric Waves

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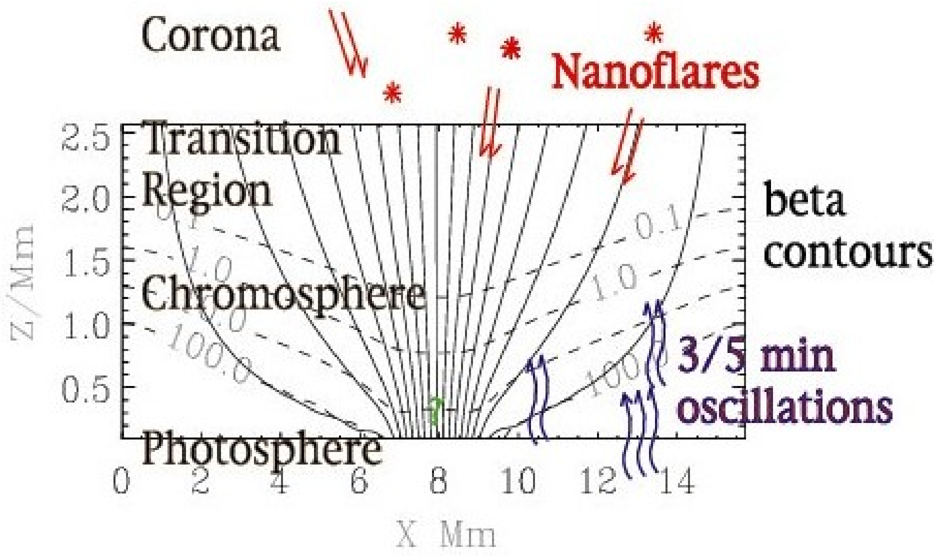
Lindau, Friday 2.9.2005

Chromospheric waves

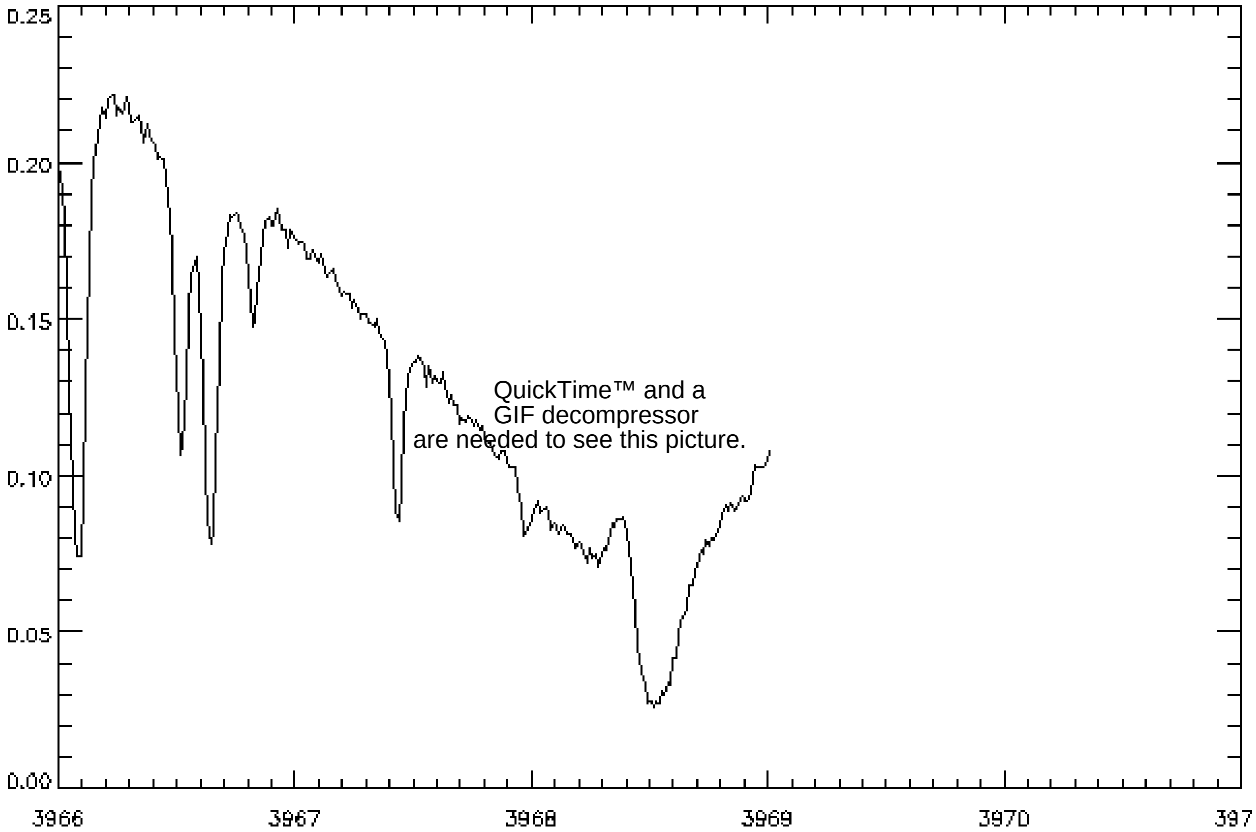


Energetics

Diagnostics

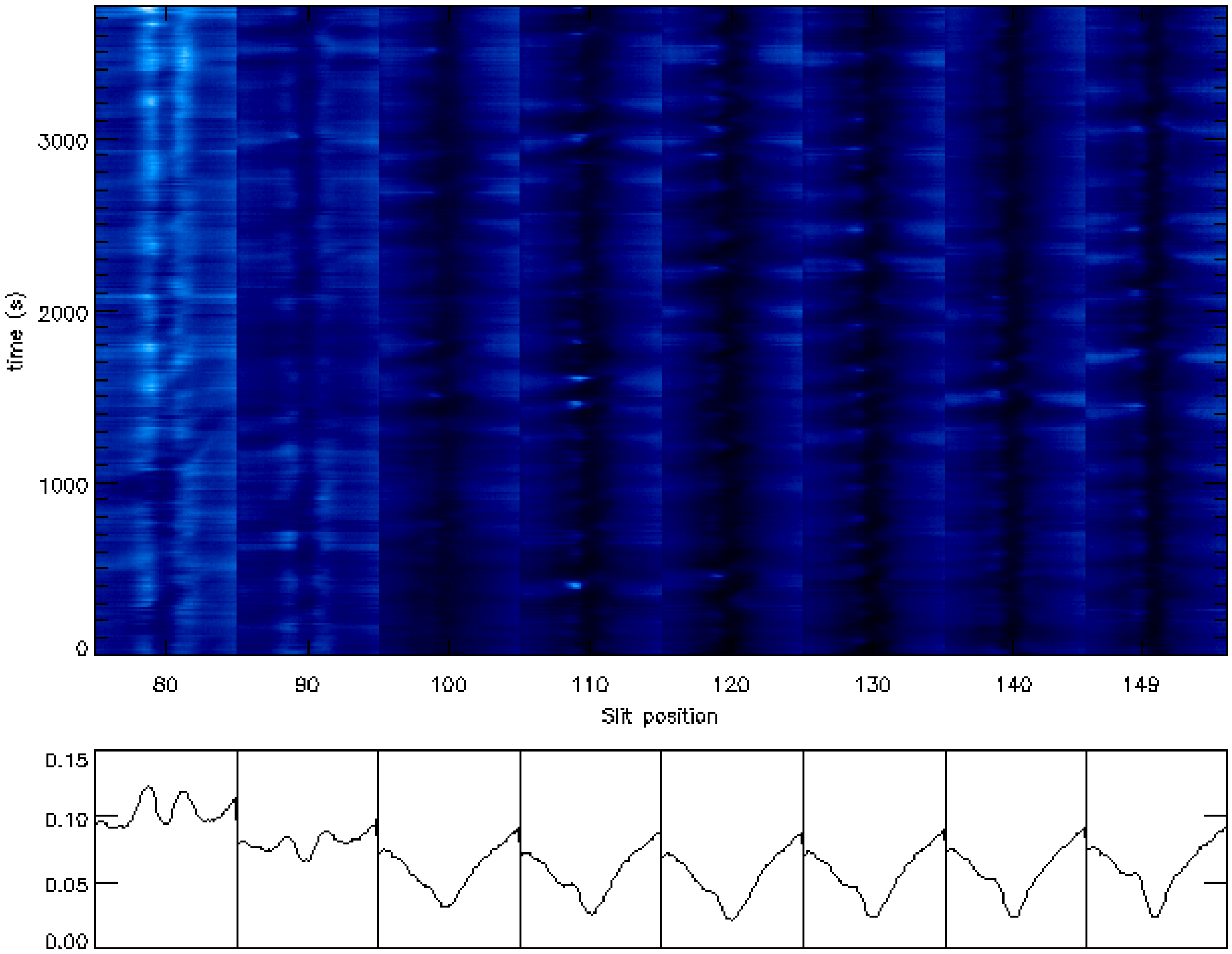
- Observations
- Simulations

Ca II H-line



0.25
0.20
0.15
0.10
0.05
0.00
3966
3967
3968
3969
3970
3971
QuickTime™ and a
GIF decompressor
are needed to see this picture.

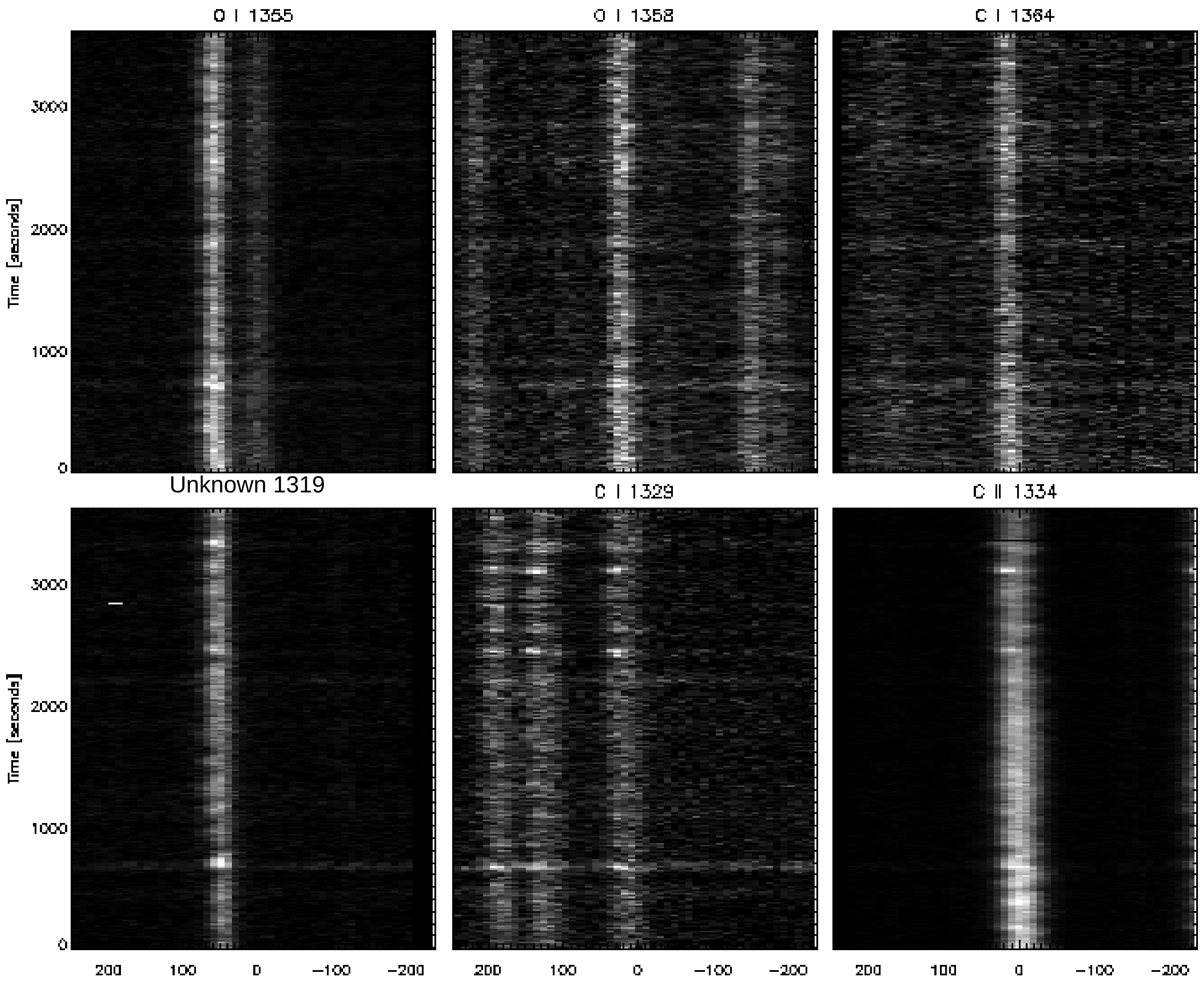
Ca II H-line observations



- 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

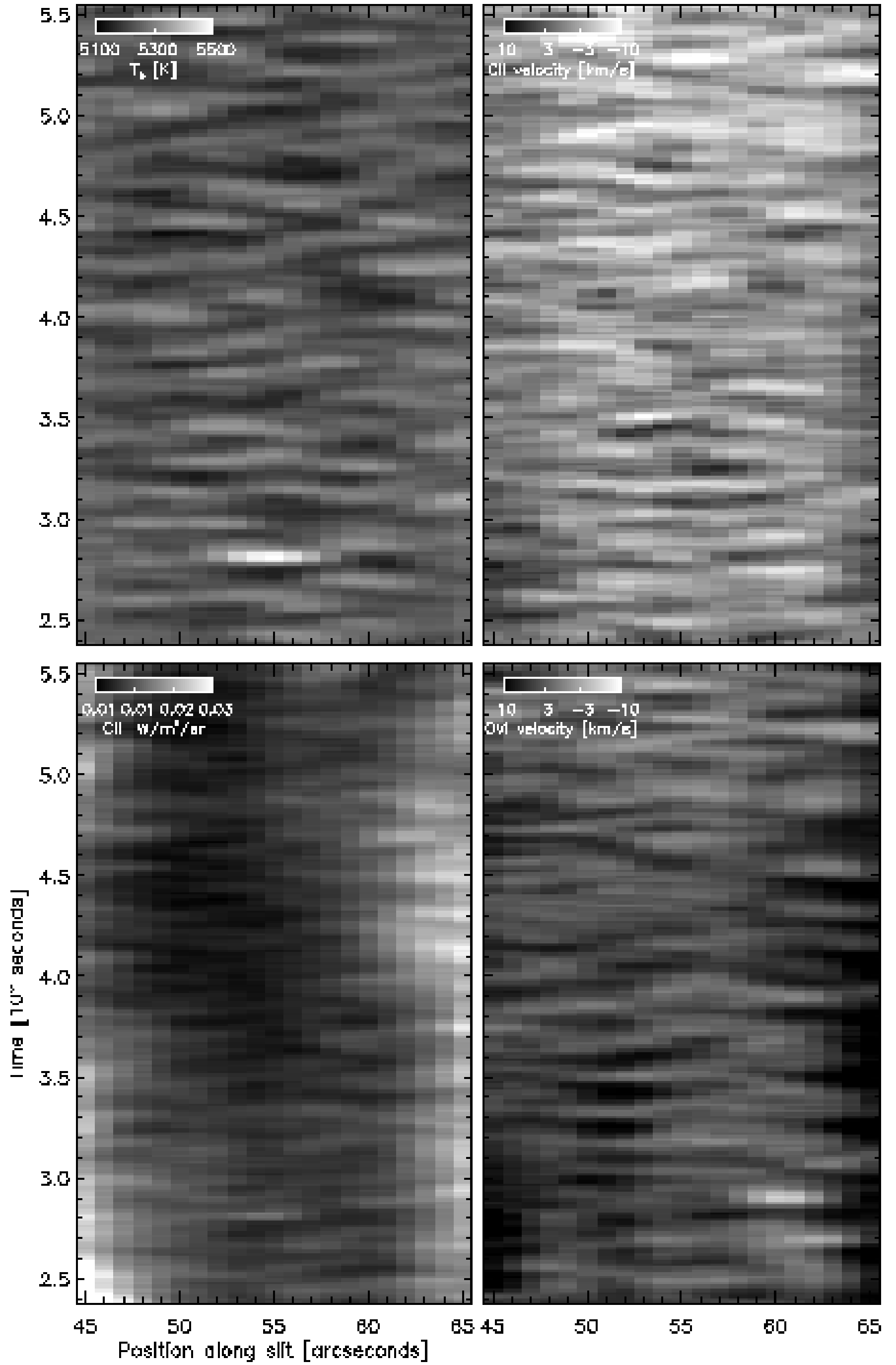
Lites, Rutten, Kalkofen 1993

SUMER observations



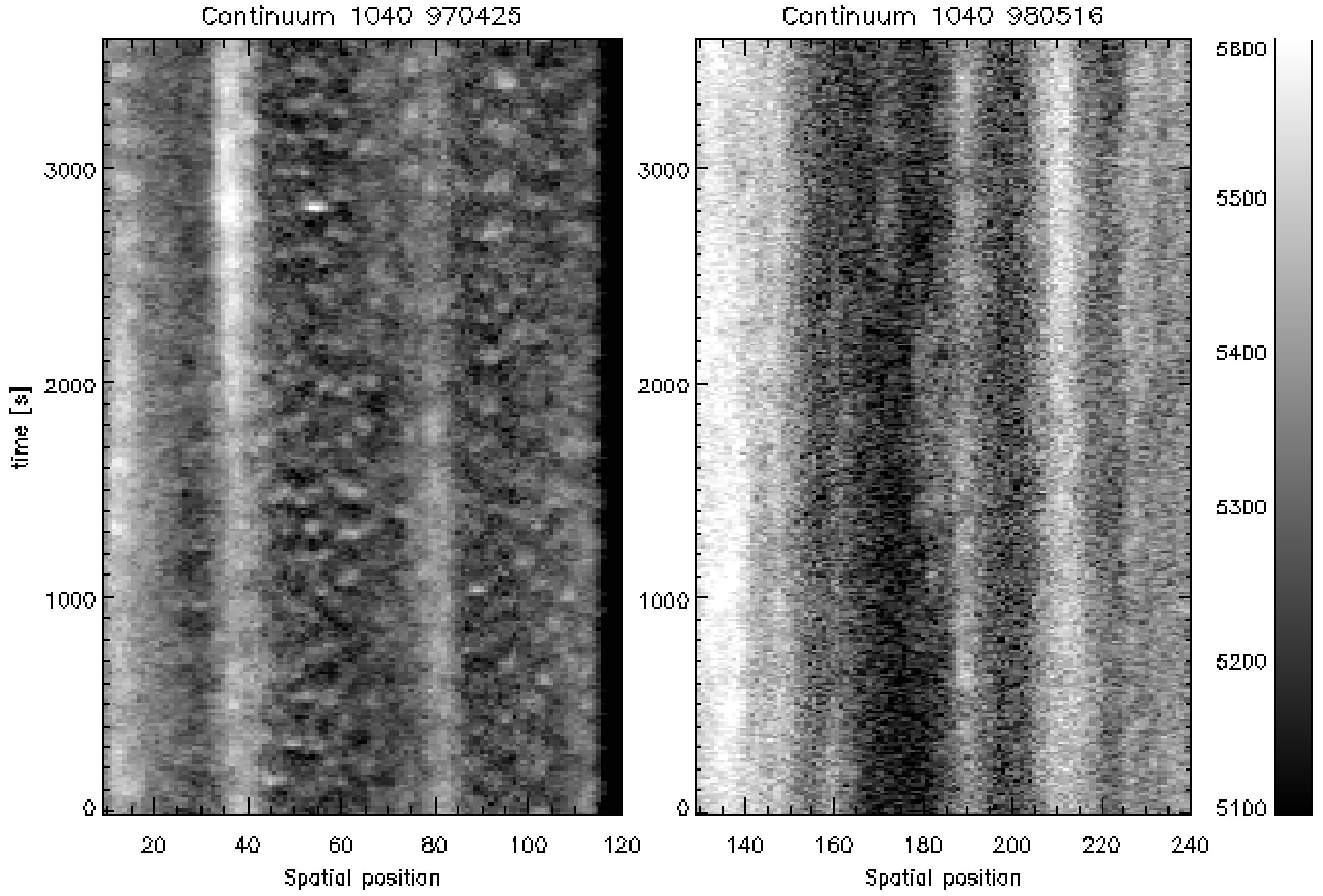
- Emission all the time
- Brightenings in the continuum
- Blue shifted emission

SUMER observations, upper chromosphere



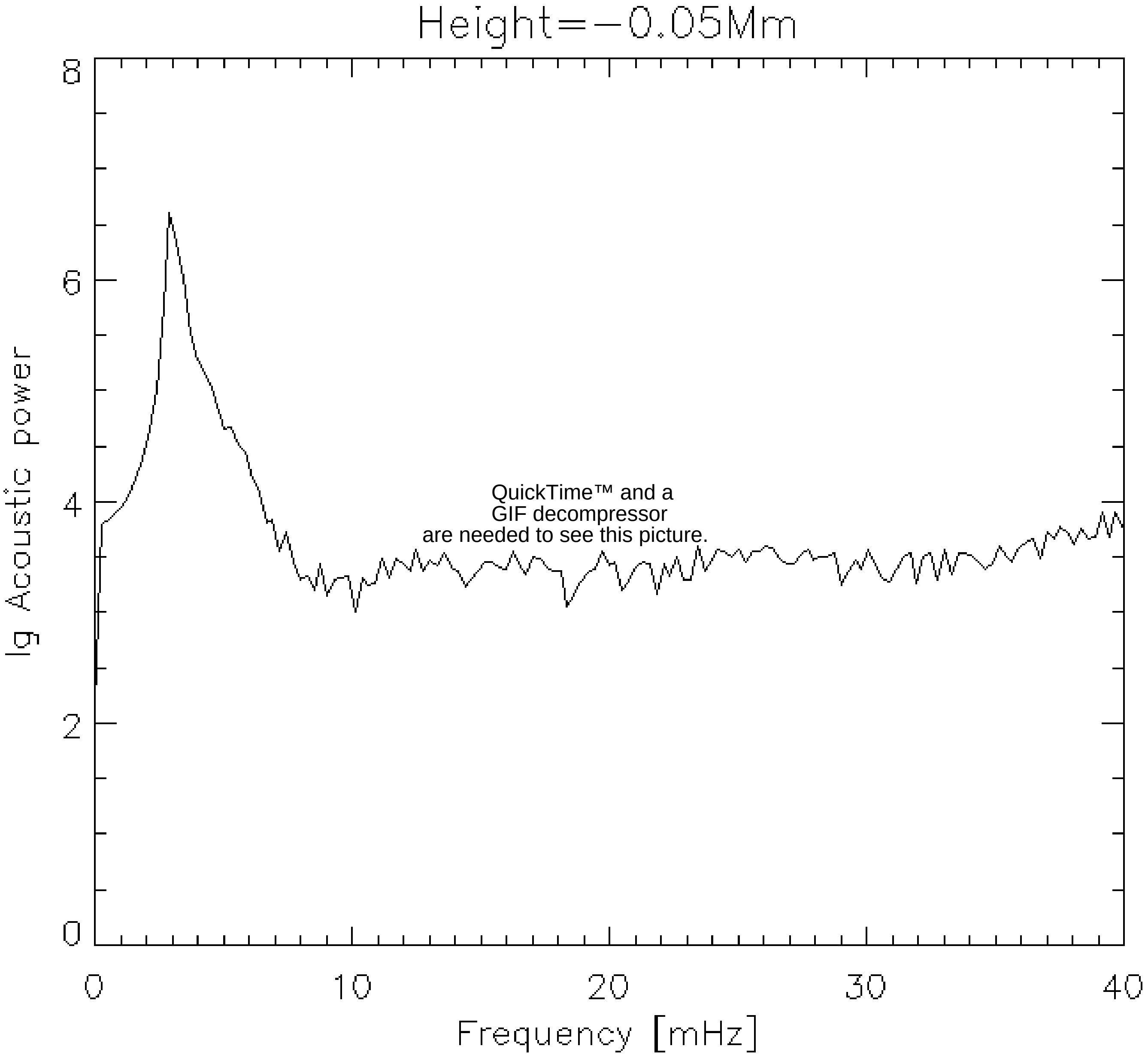
- Oscillatory signal
- more in V than in I
- No strong saw-tooth form
- Extends to Transition-region

UV continua

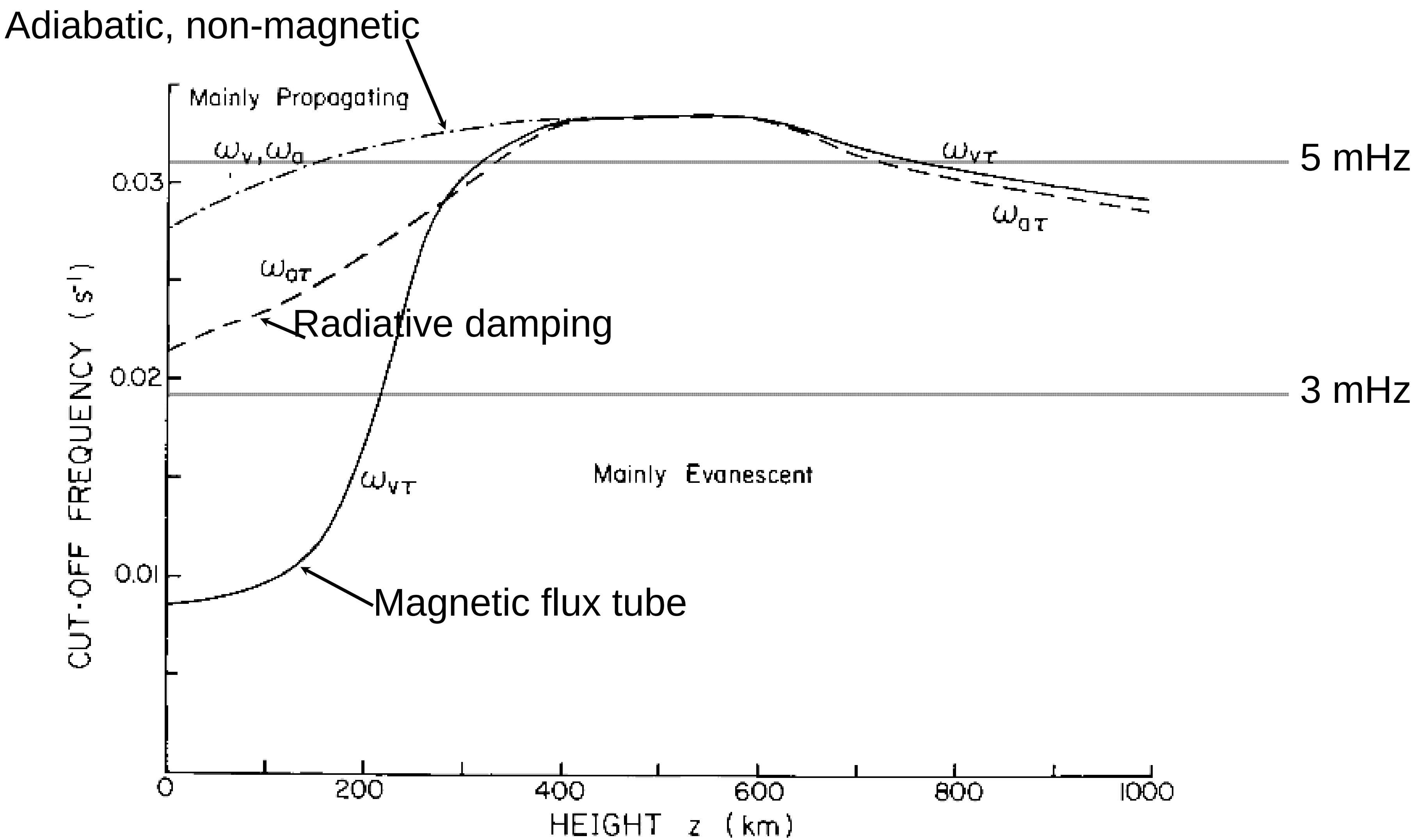


Behaviour varies with position and time

Wave energy flux as function of height

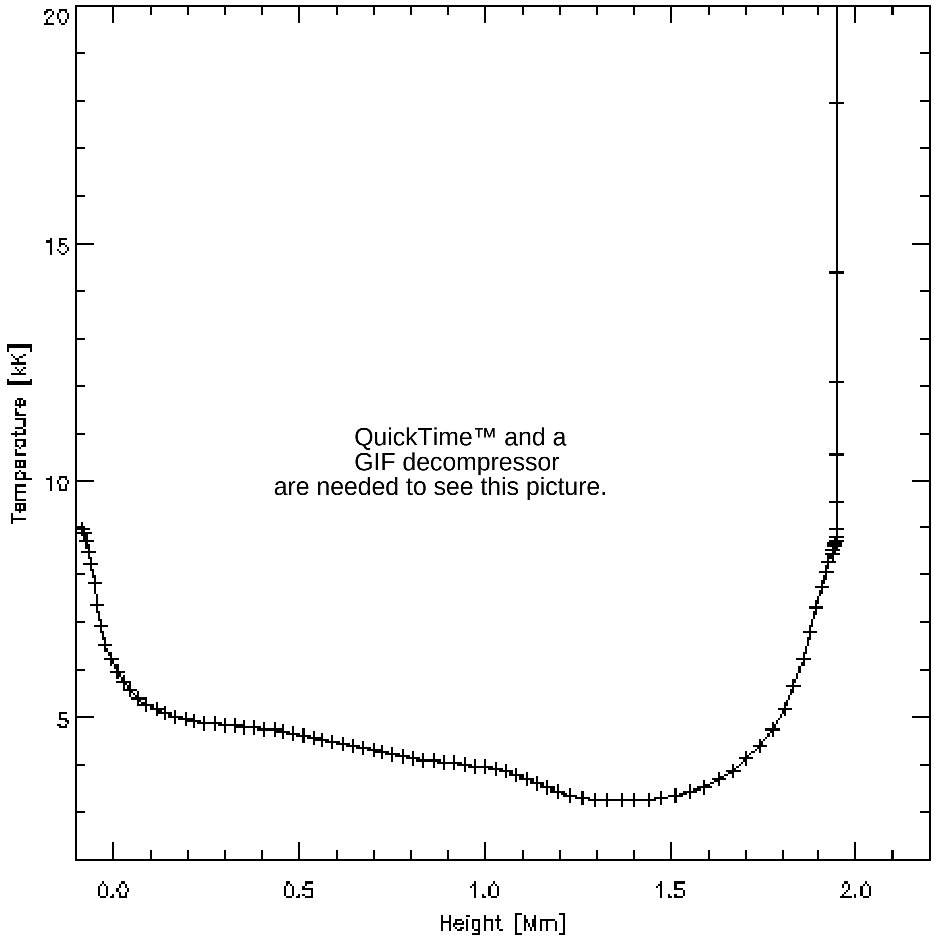


Cut-off frequency

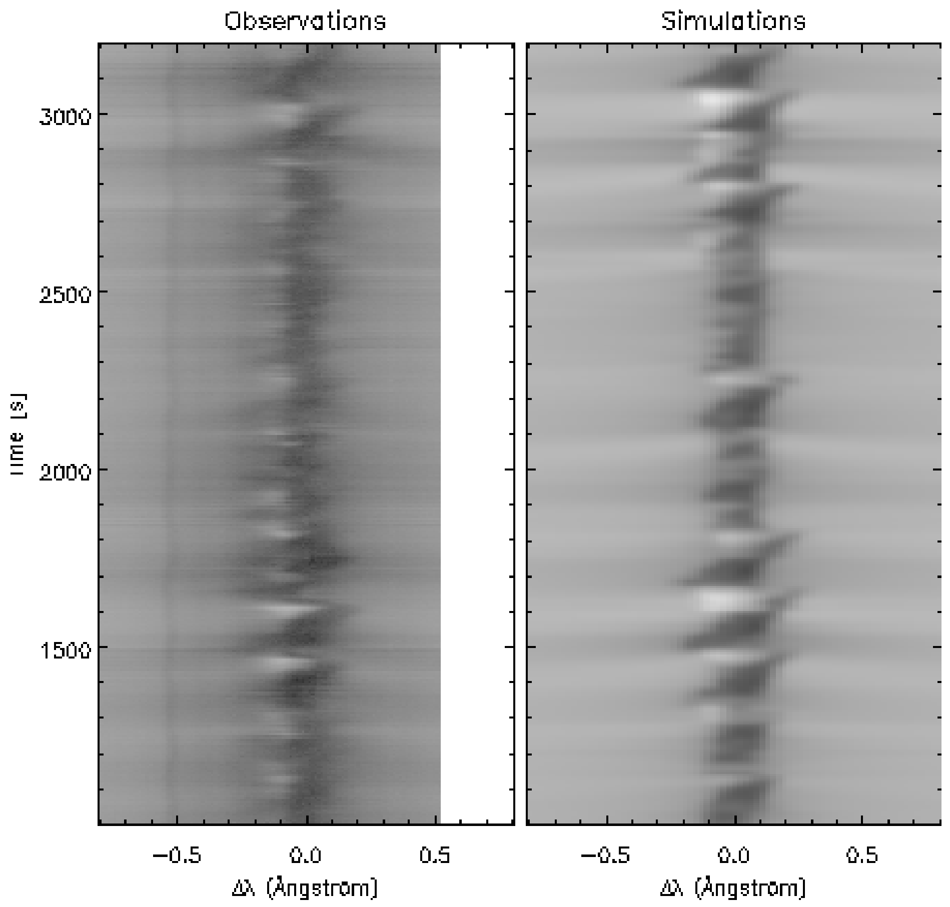


Roberts, 1983, Solar Physics 87,77

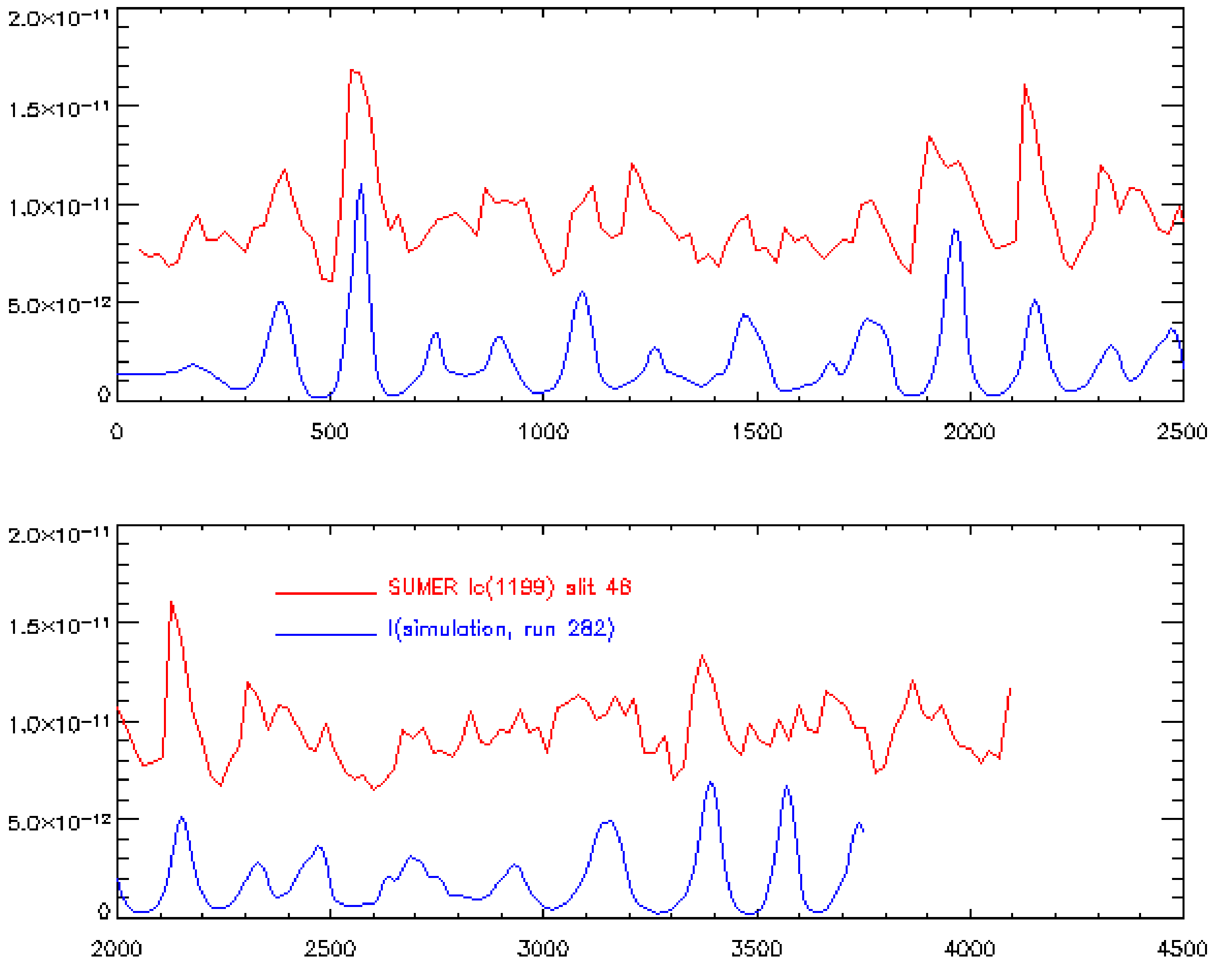
Dynamic behaviour, Temperature



Ca II H-line intensity

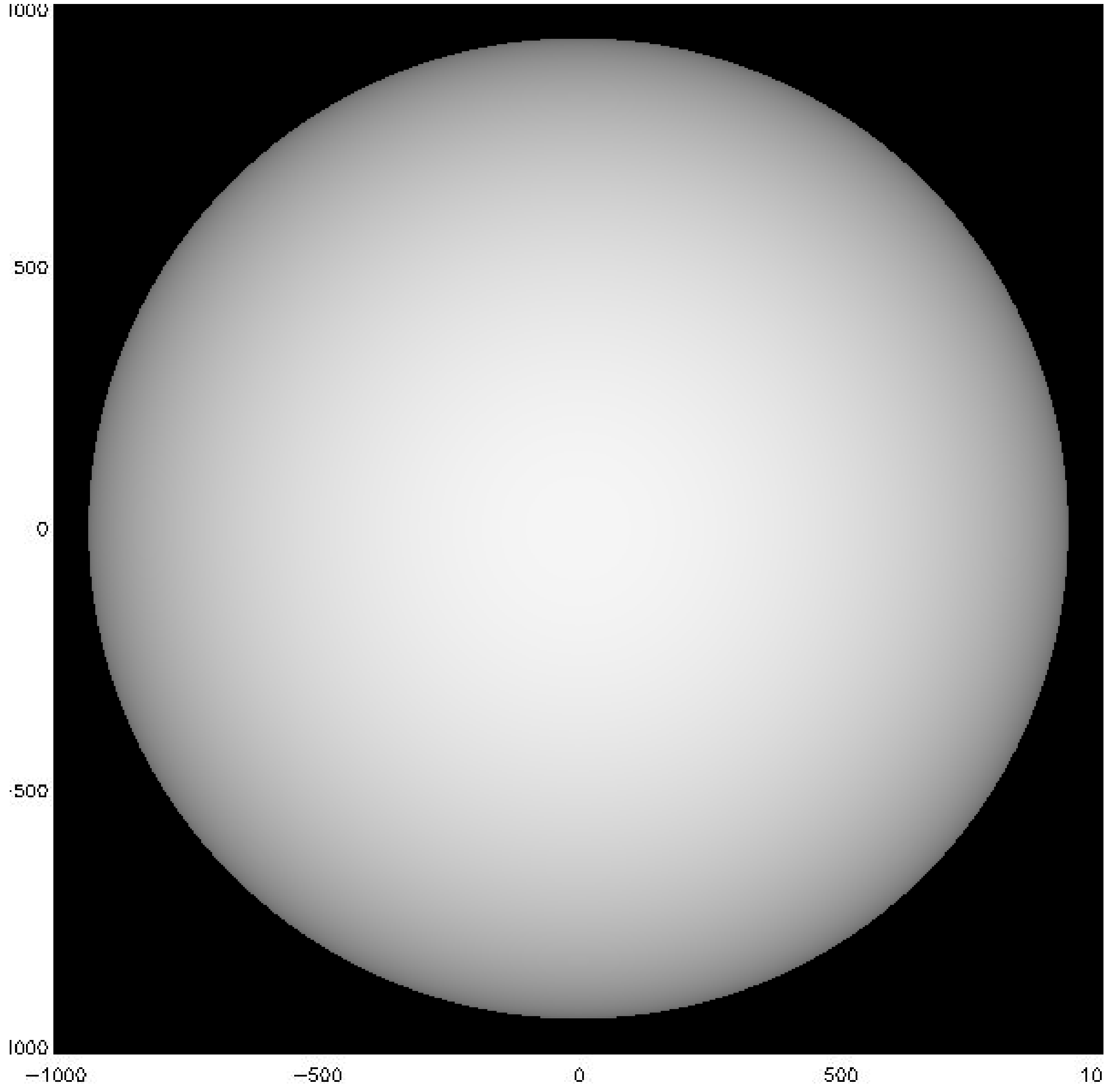


Comparison, mid-high chromosphere

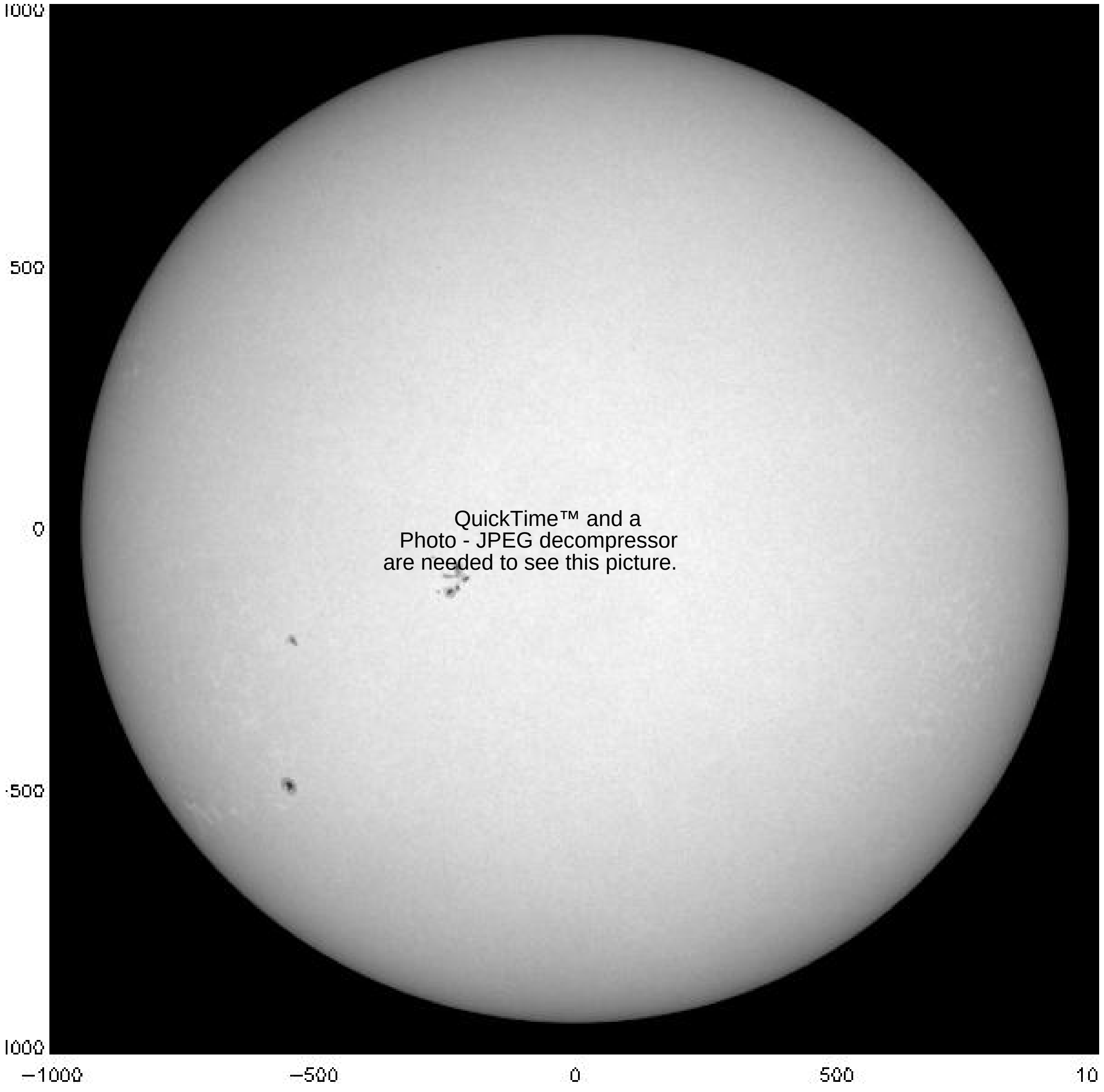


- Intensity variations OK, Mean level much too low.
- Agreement gets worse with height
- Where have all the shocks gone?

Model



Sun: 25 May 2003, 11:22:32 UT

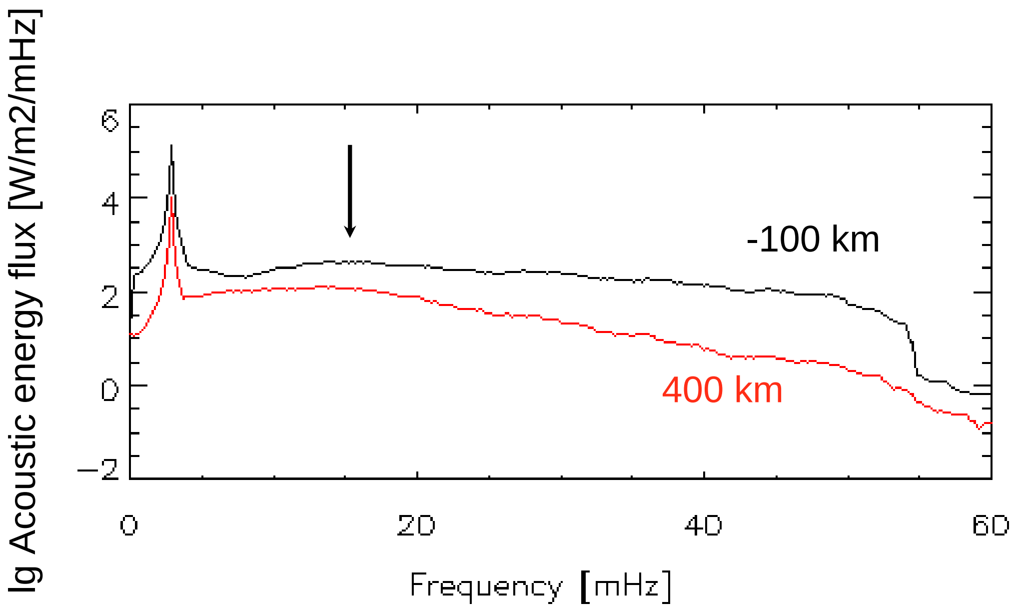


Restrictions

- 1D
- lacking processes (NLTE line blanketing, Mg II, CO)
- CRD
- no magnetic fields
- no high frequencies in piston

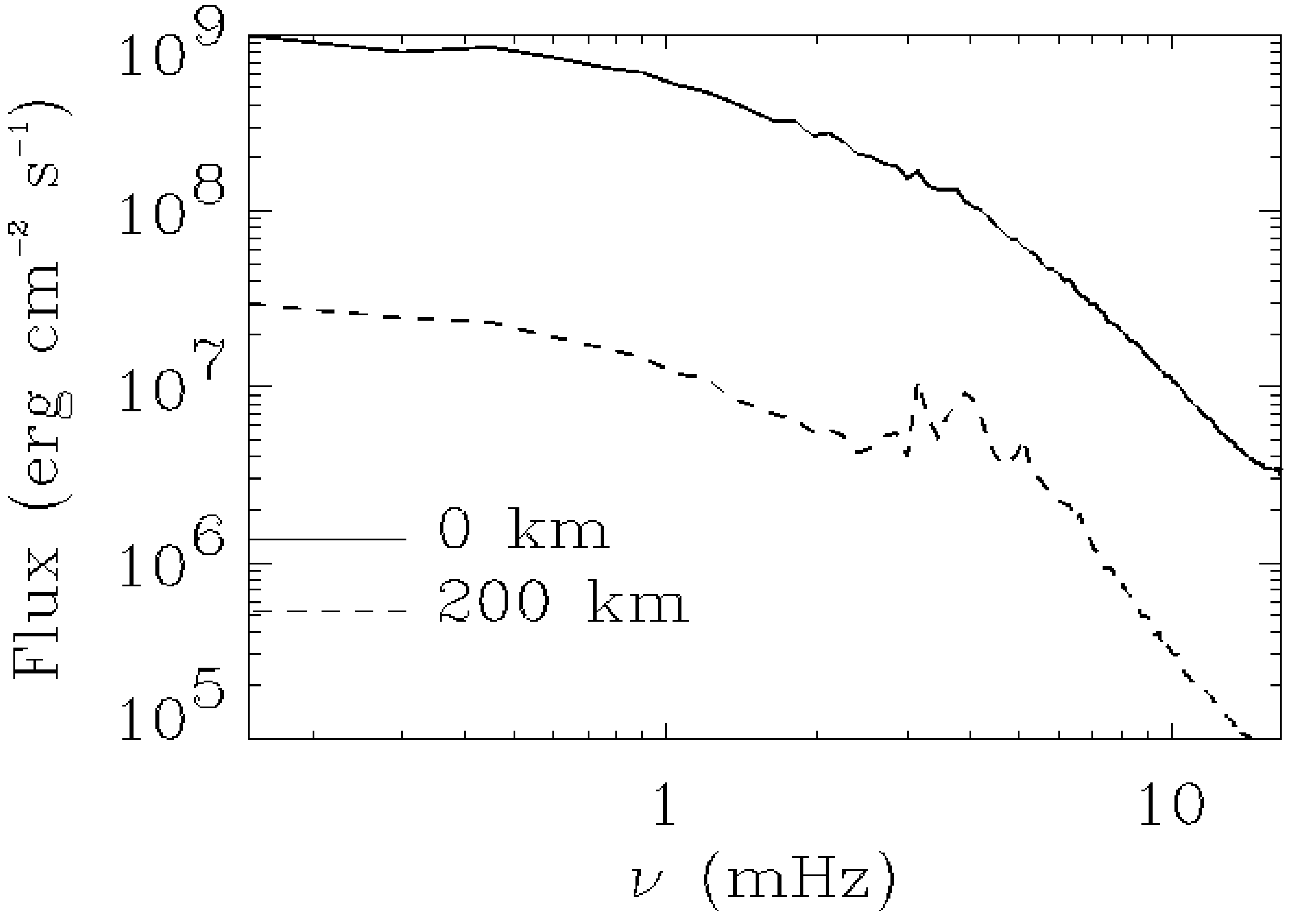
Generation of acoustic waves

1D: high frequency peak (15mHz)



Musielak, Rosner, Stein, Ulmschneider 1994

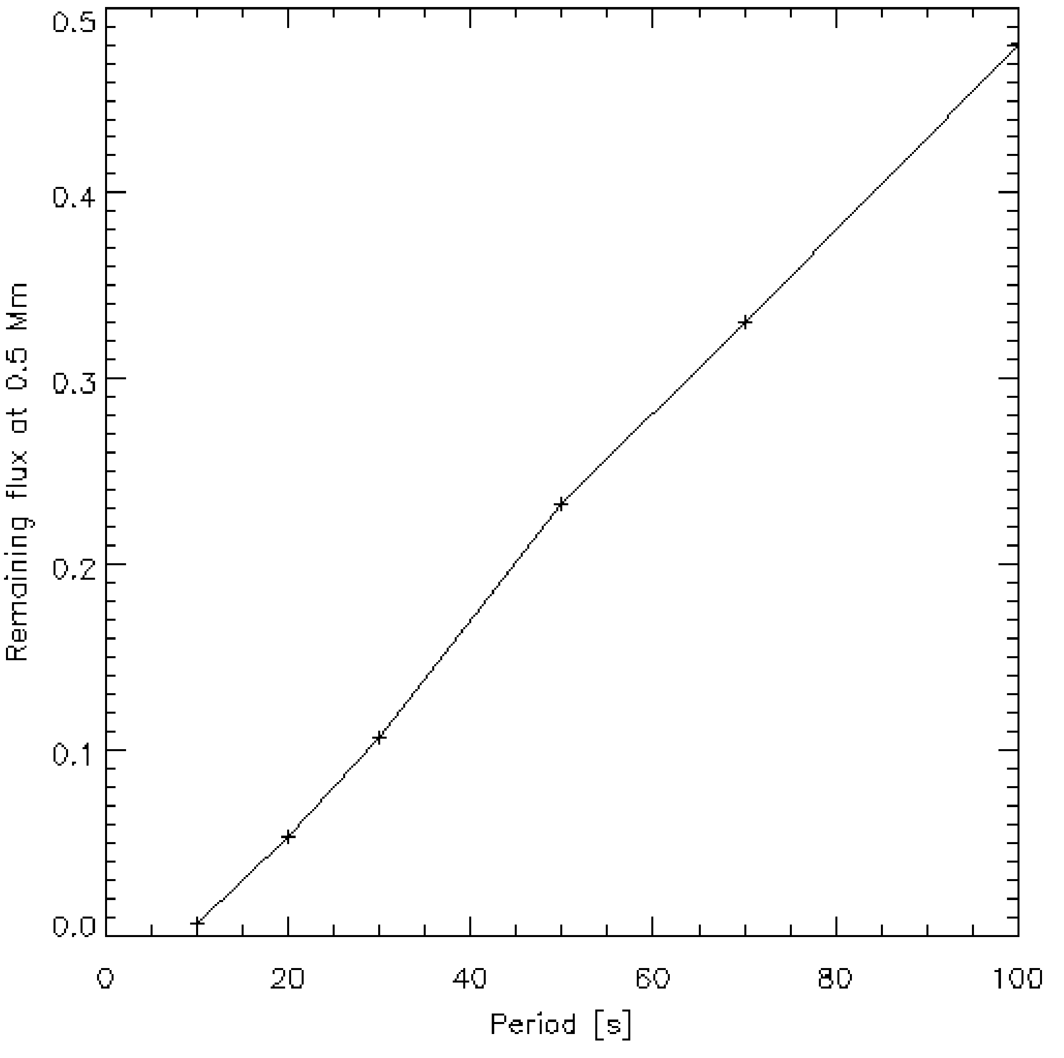
3D HD convection simulations: no peak



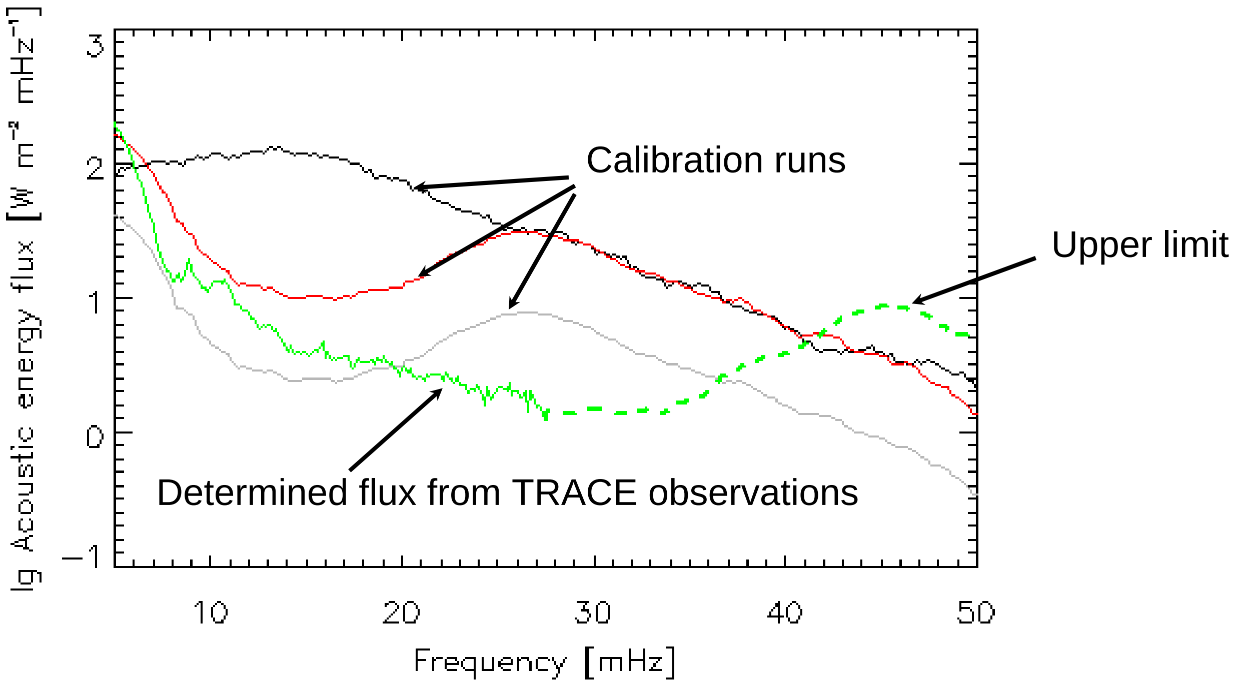
Goldreich, Murray, Kumar 1994

Stein, Nordlund, 2001

Strong damping



Acoustic flux determined from observations



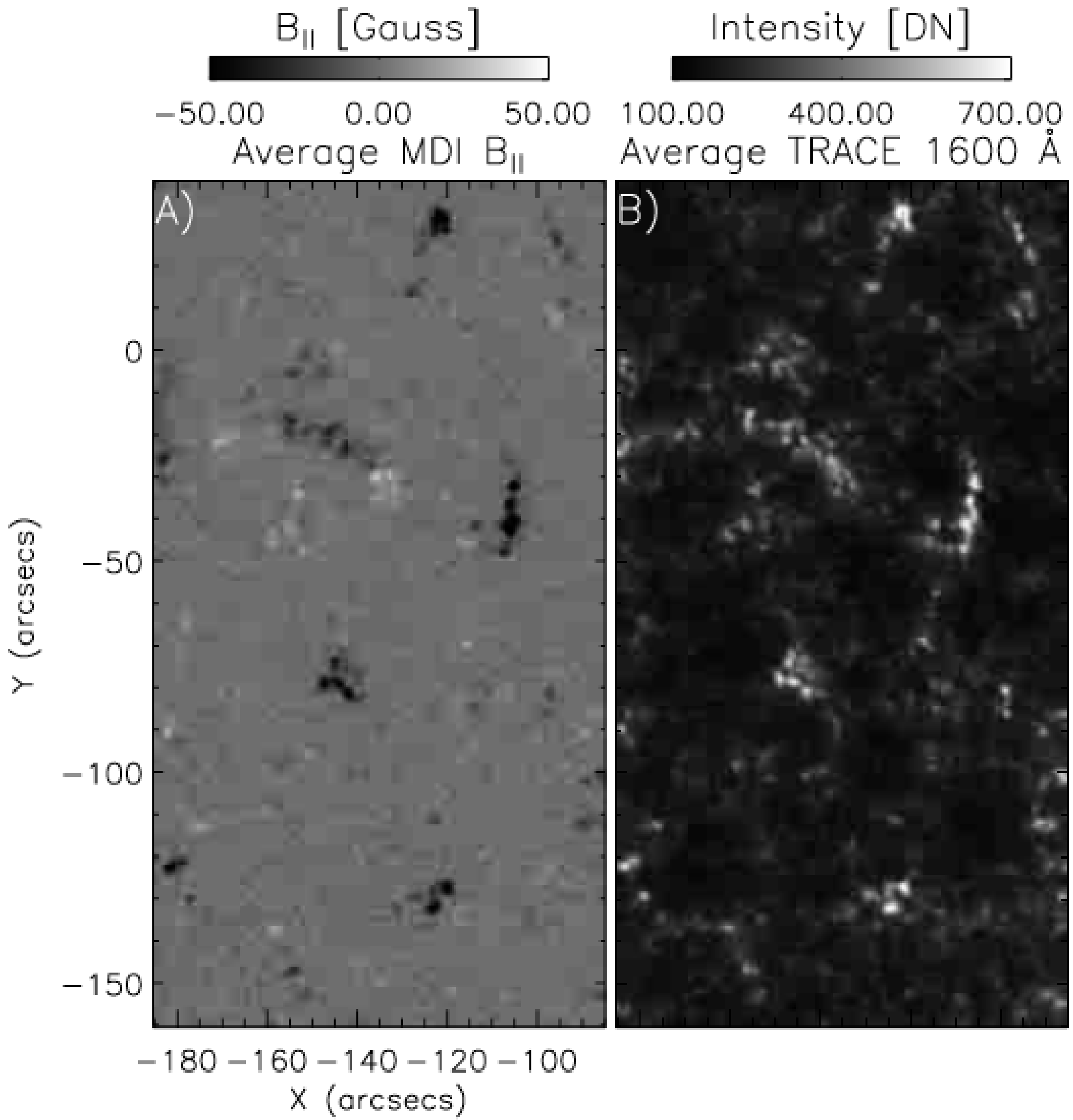
Fossum, Carlsson 2005, Nature 435,919

Total flux at 400km: 0.4 kW/m2

What have we learnt?

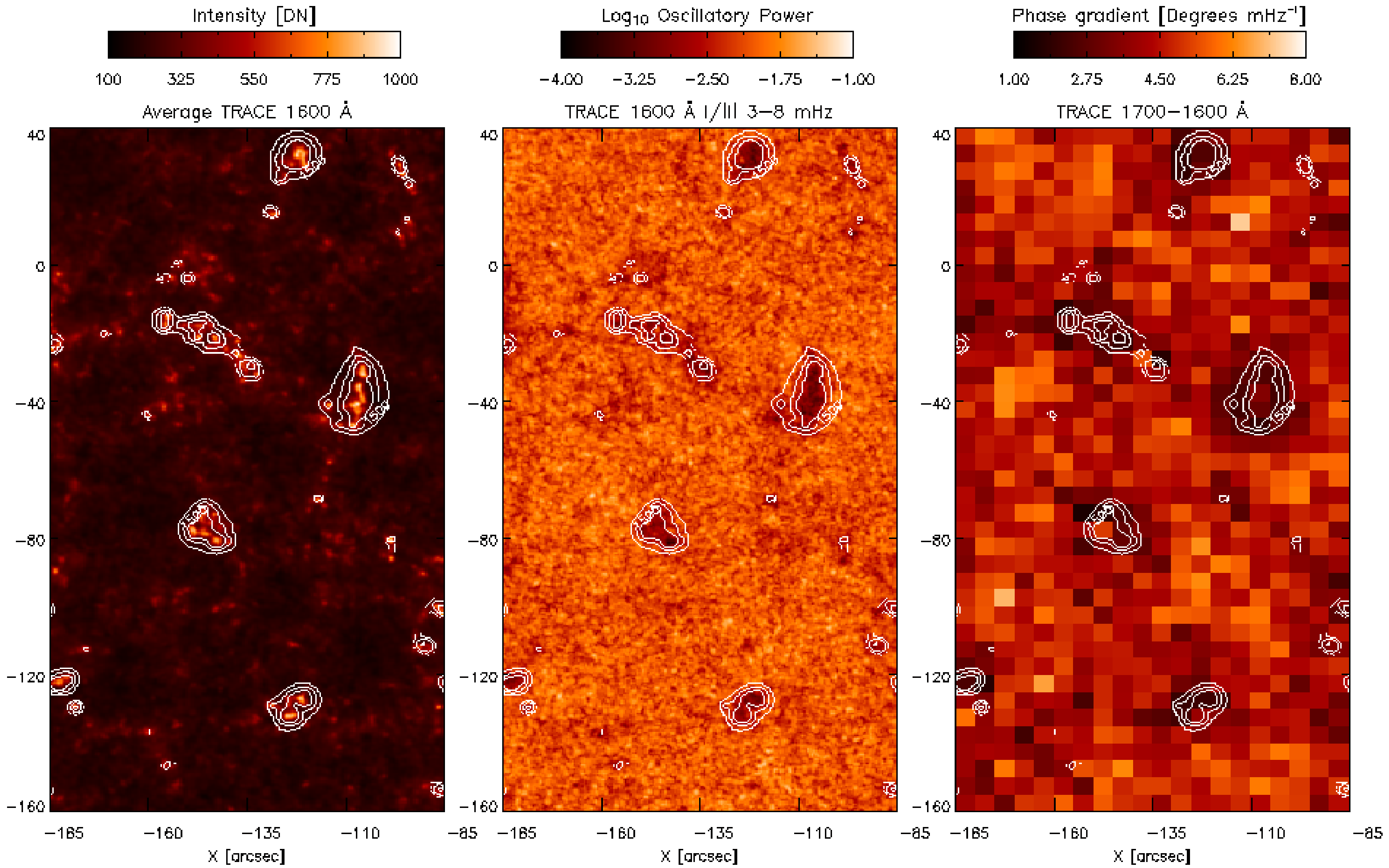
- Ca II grains explained by acoustic waves
  - only way to get strong blue-red assymetry is through a strong velocity gradient
- 3min waves present already in photosphere
- Non-magnetic chromosphere very dynamic.
- Acoustic waves not enough to explain mid-upper chromosphere in internetwork

Chromosheric seismology



McIntosh et al, 2003, AA 405, 769

Correlation with Magnetic canopy height



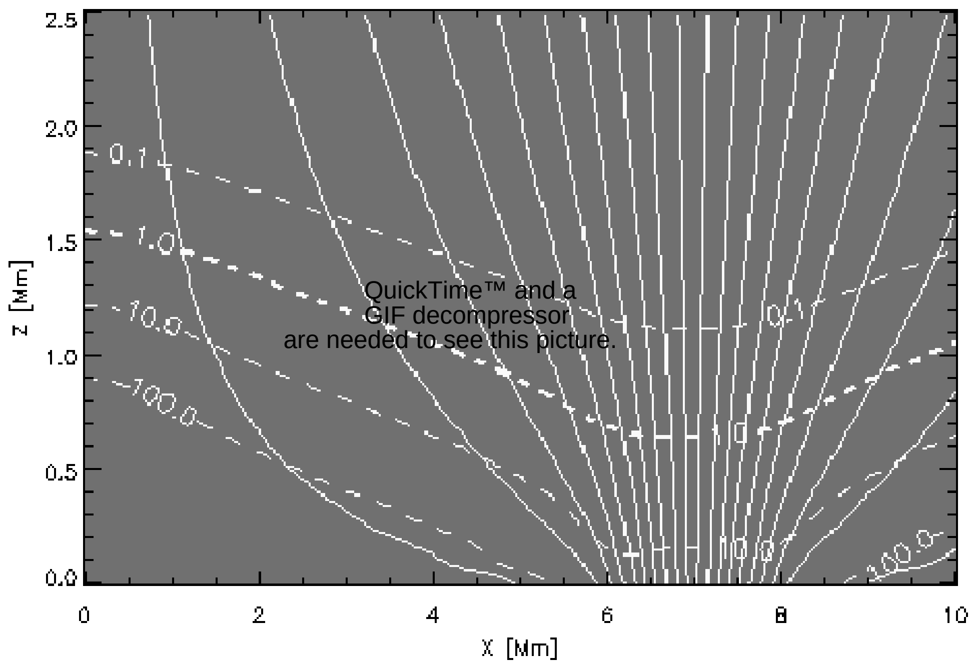
See also poster P.12 by Fleck et al

Wave interaction with magnetic fields

Rosenthal et al 2002 ApJ 564,508

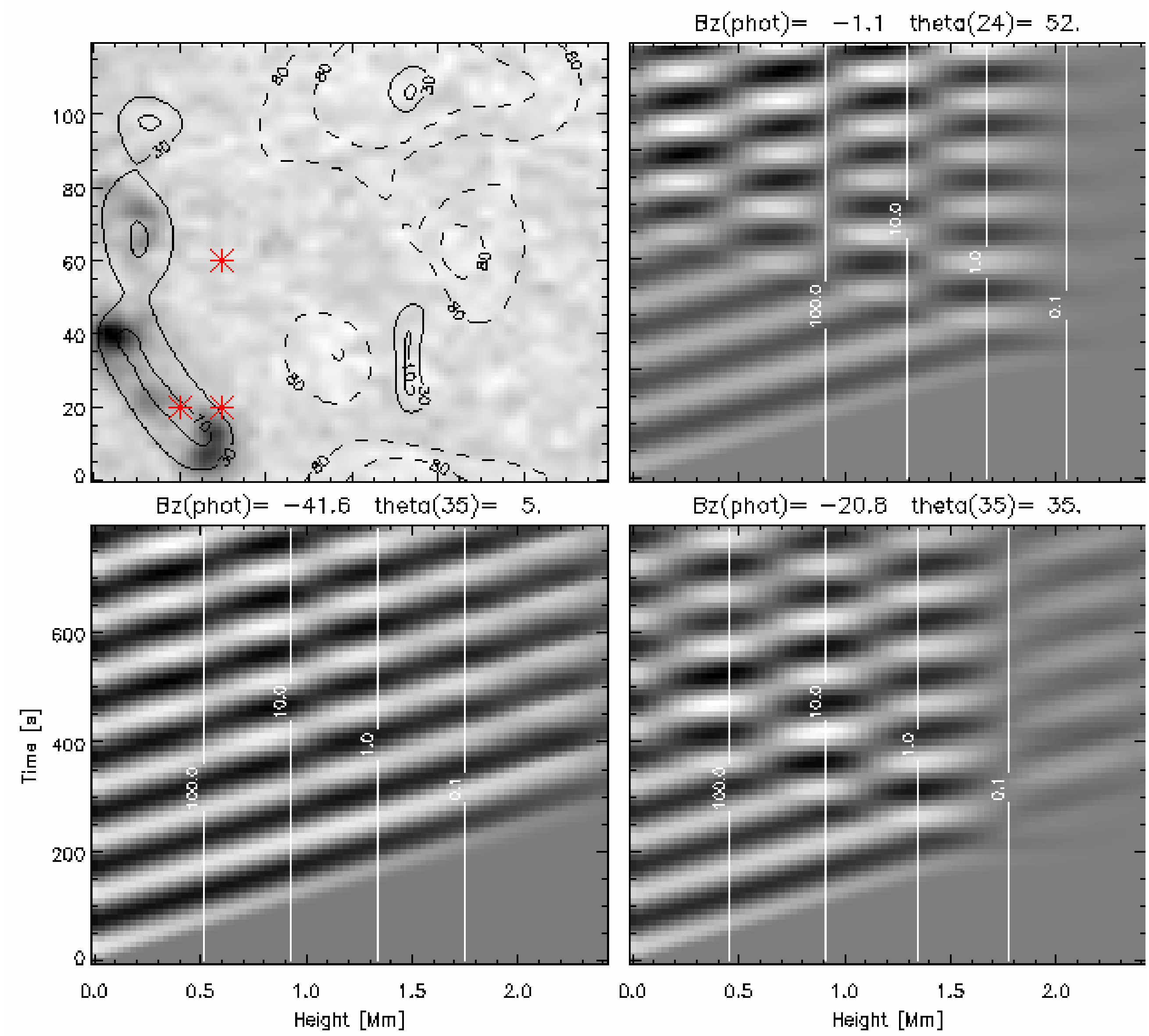
Carlsson & Stein 2002, ESA SP-505, 293

Bogdan et al 2003 ApJ 599,626



- 2D/3D wave studies

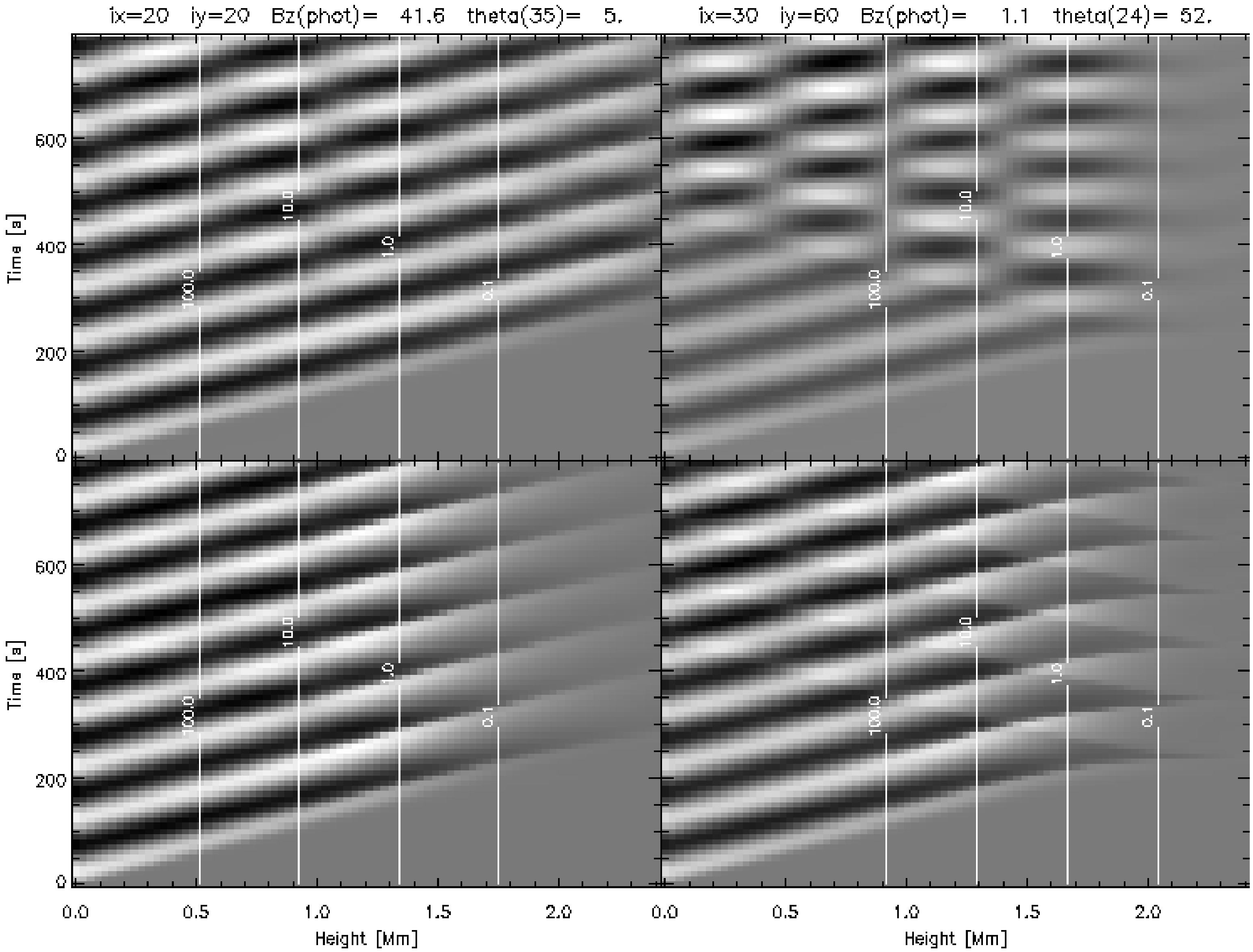
Mode conversion and reflection



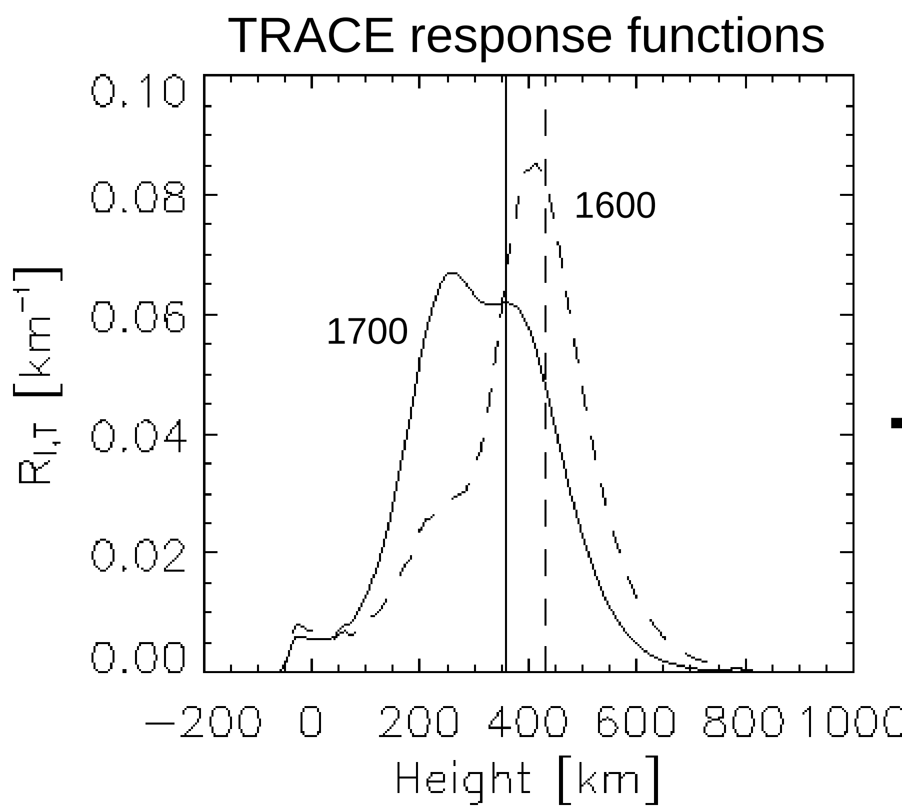
Small attack angle - full mode conversion - no reflection

Large attack angle - refraction - standing wave pattern

Radiation and shocks



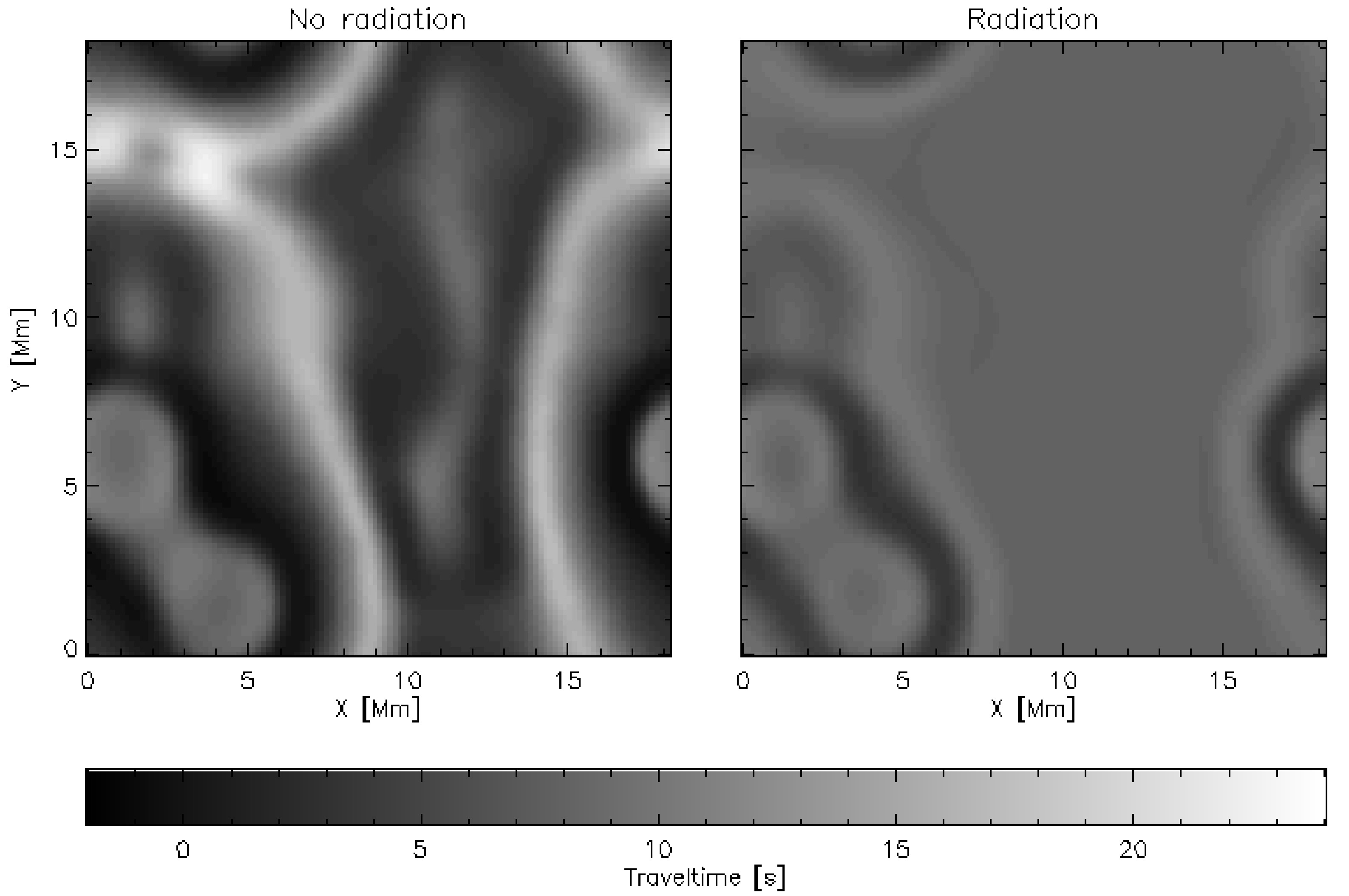
Traveltime analysis



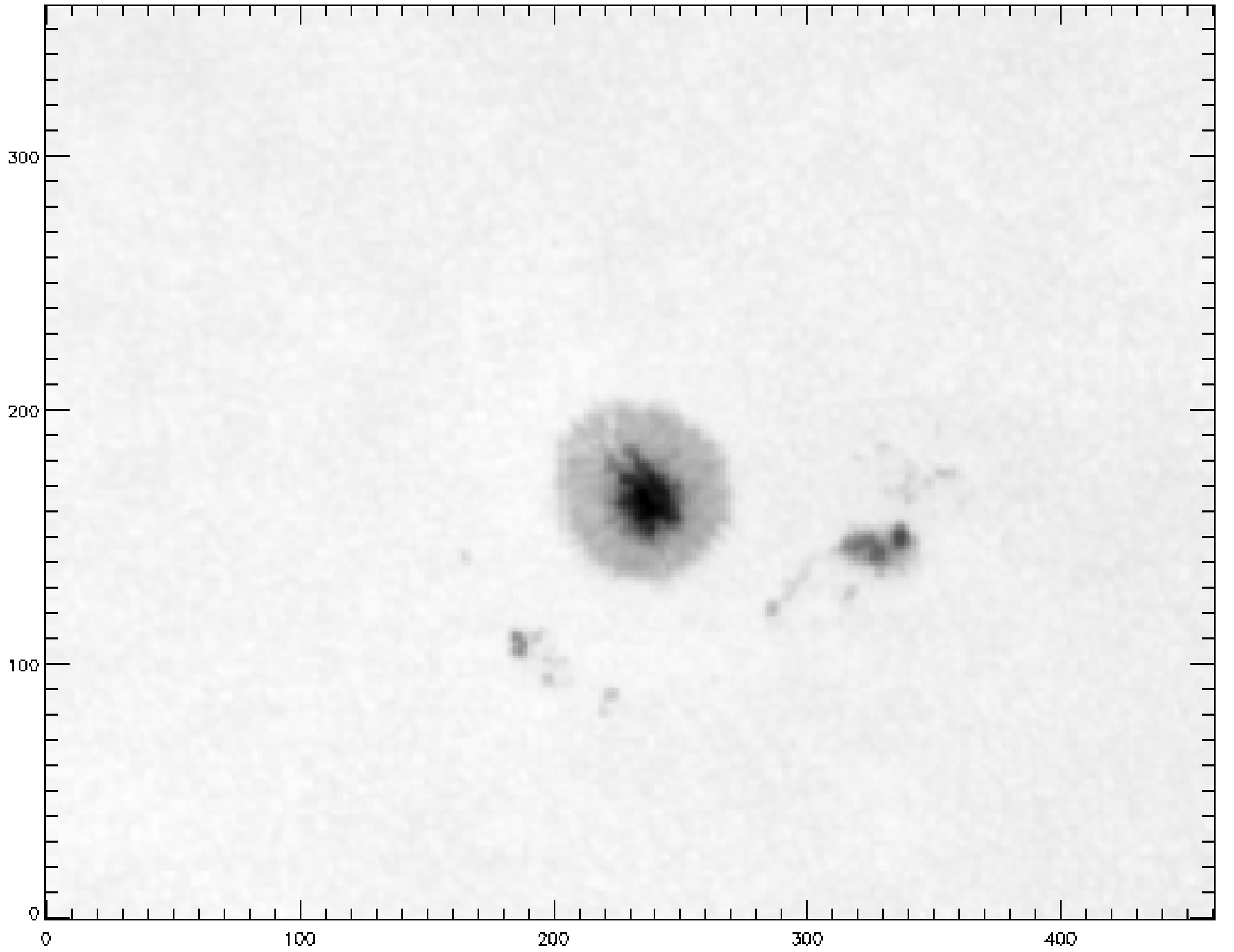
T(x,y,z,t) ⟶ (chart above) ⟶ $\Delta I/I_{1600,1700}$

$$C(\Delta I/I_{1600}, \Delta I/I_{1700}) \longrightarrow$$ traveltime (x,y)

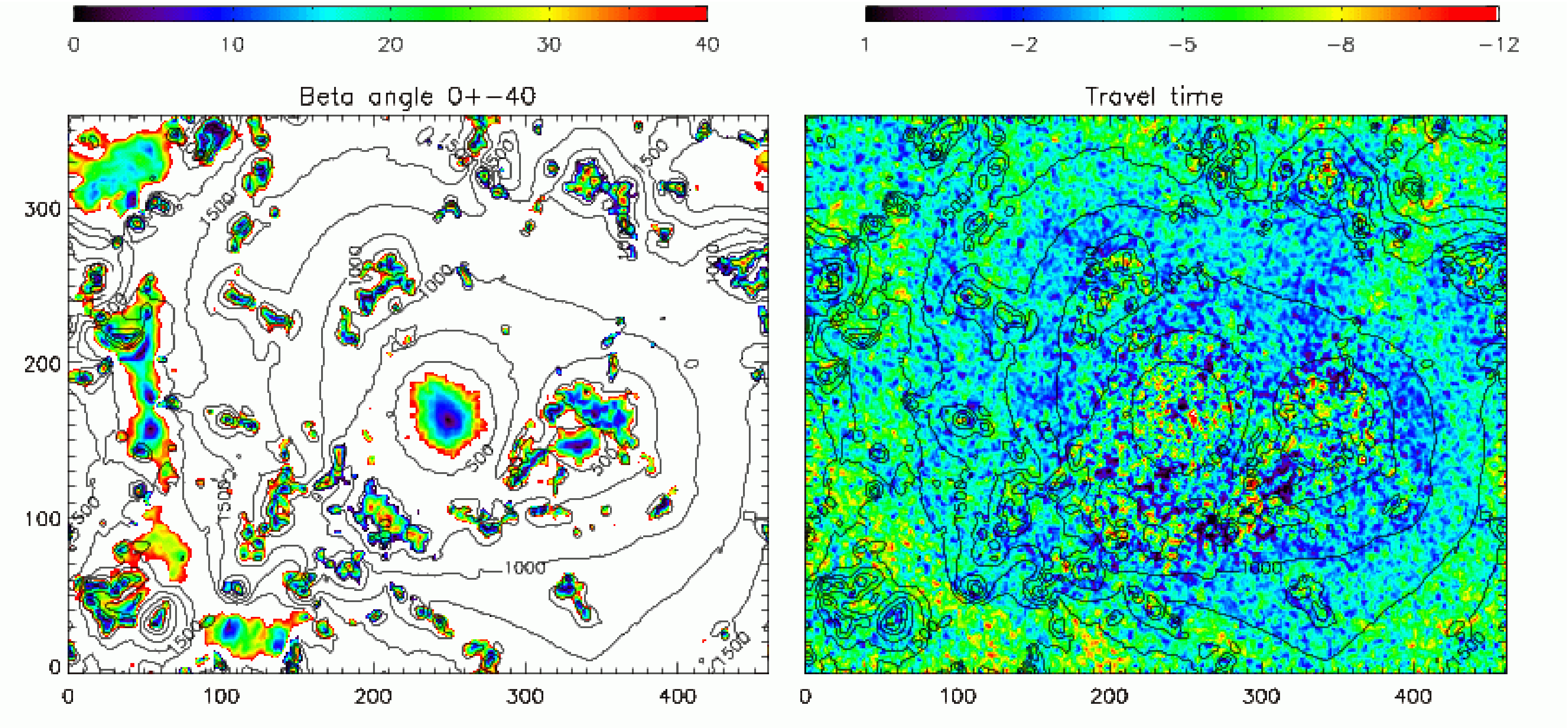
Traveltime analysis



Active region wave propagation

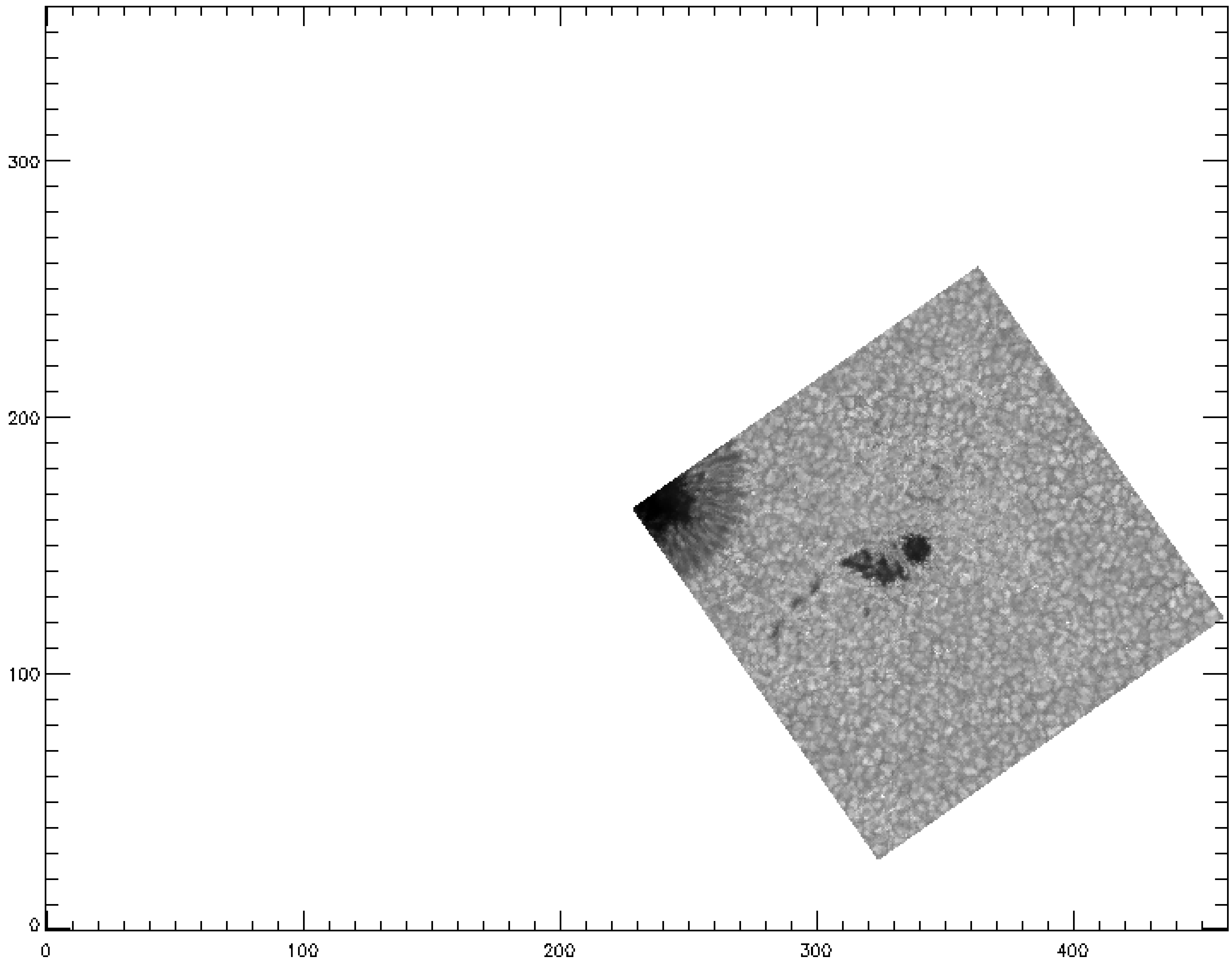


Active region wave propagation

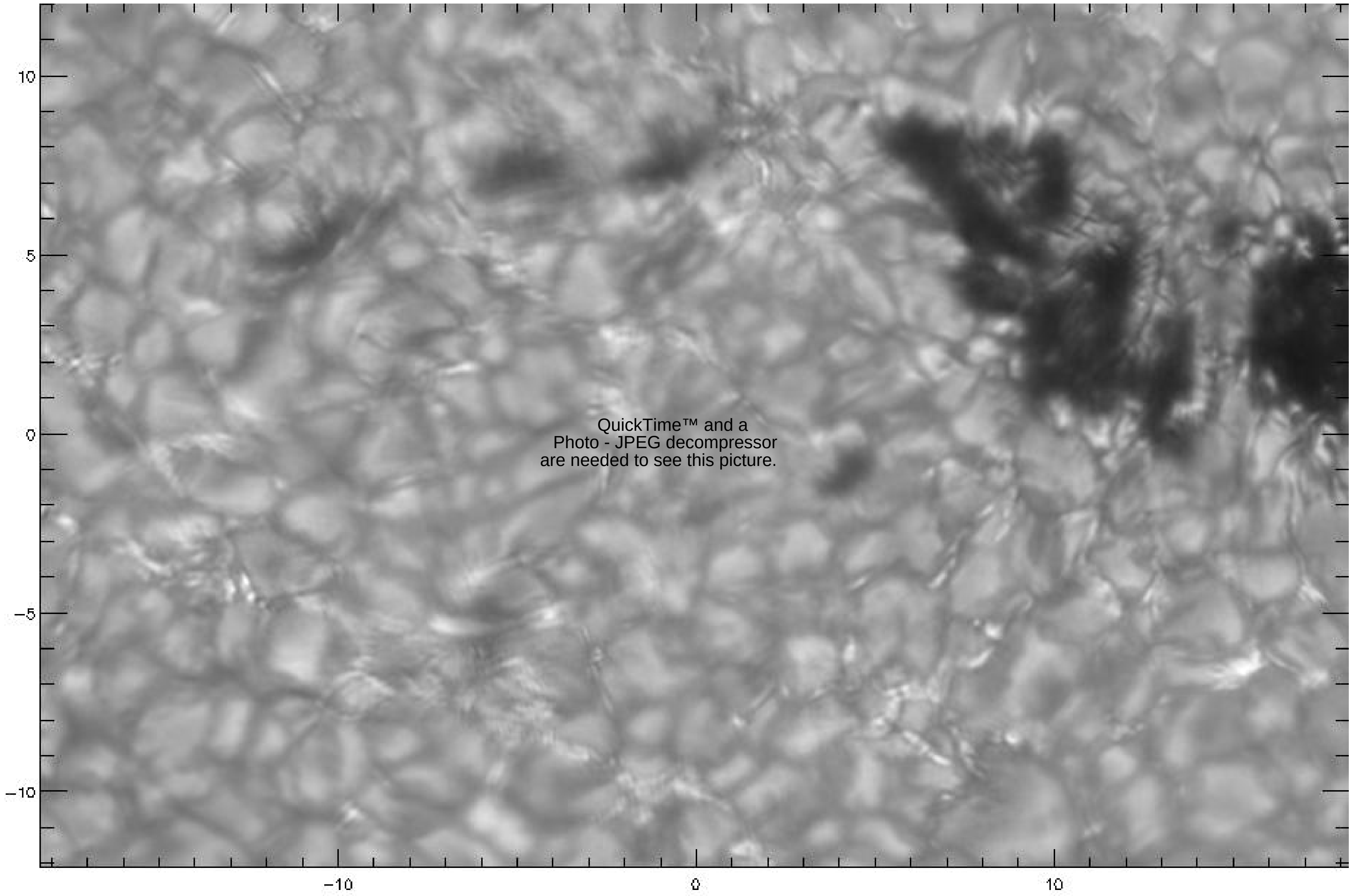


Fossum, A, 2005

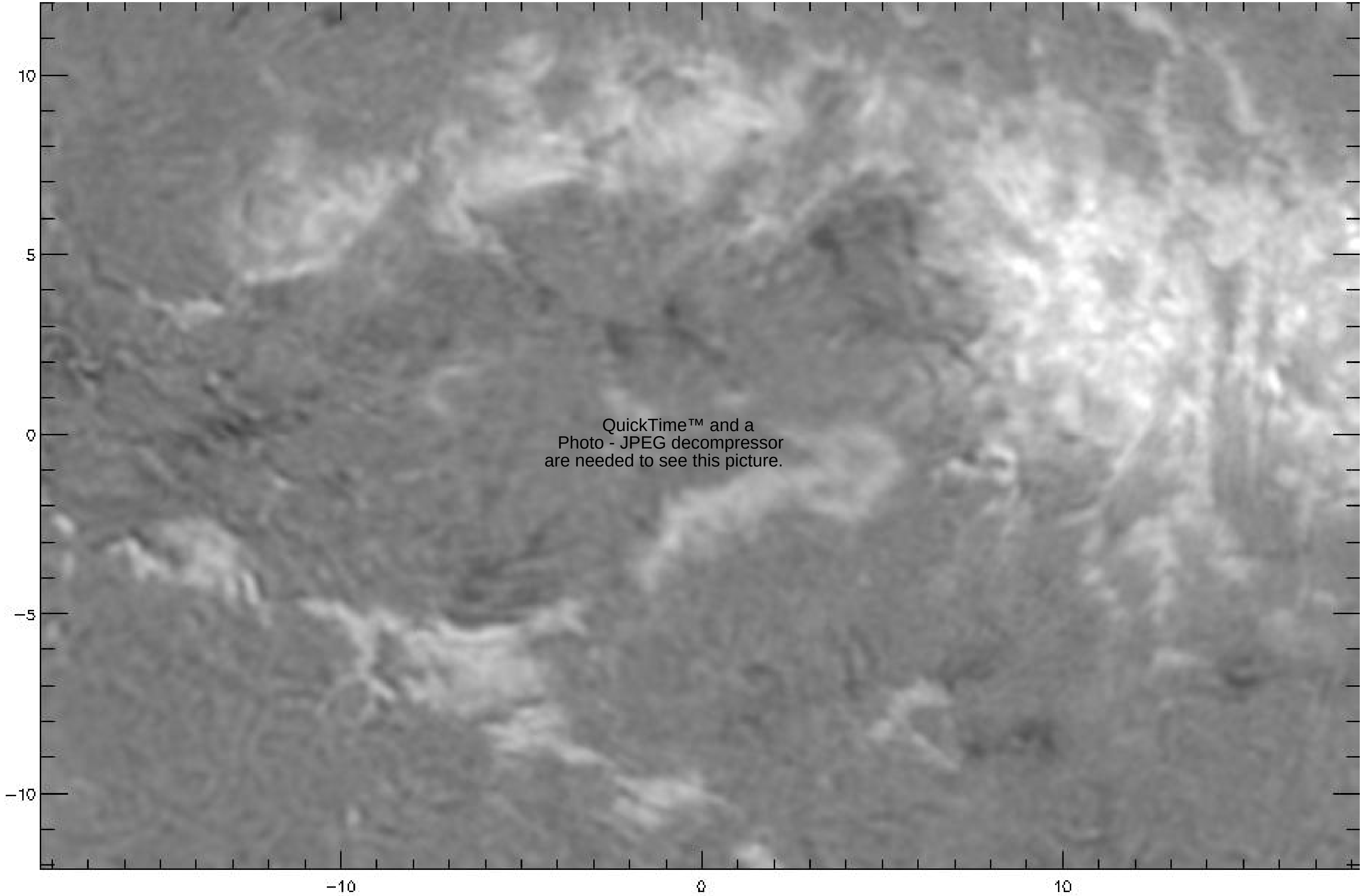
Higher resolution needed



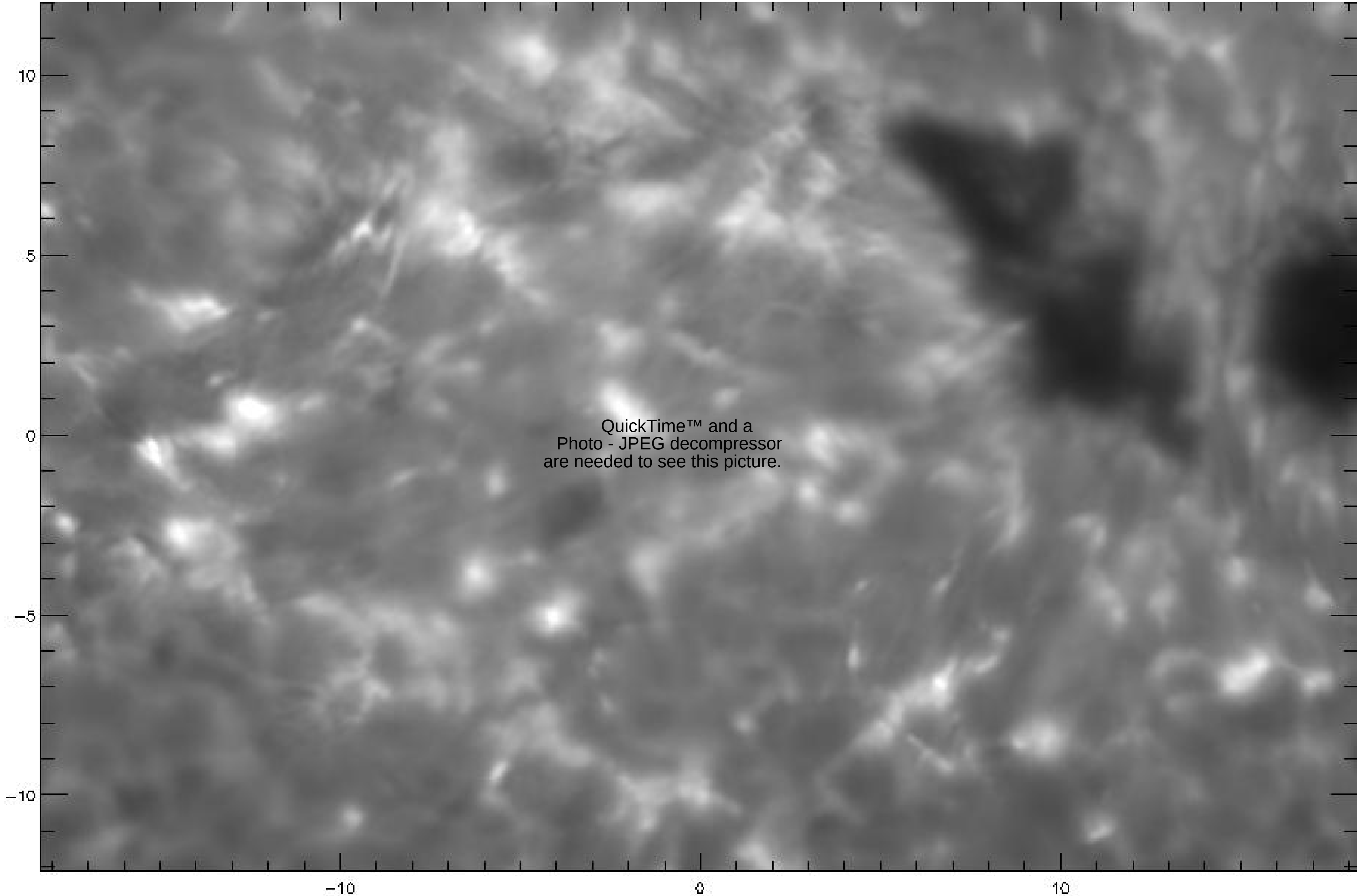
02 June 2003, G-band



02 June 2003, Magnetogram



02 June 2003, Ca H

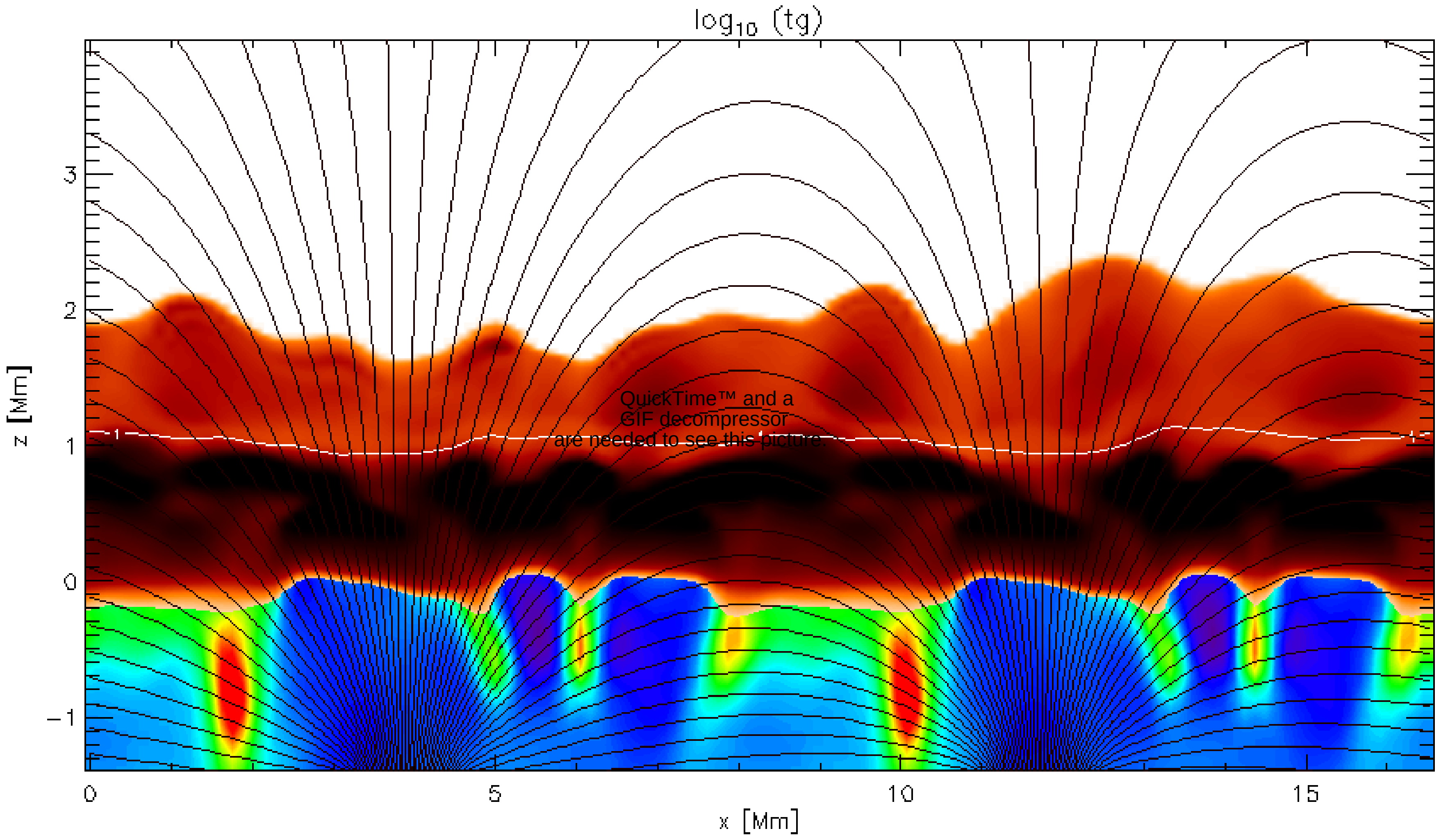


Piecing it all together

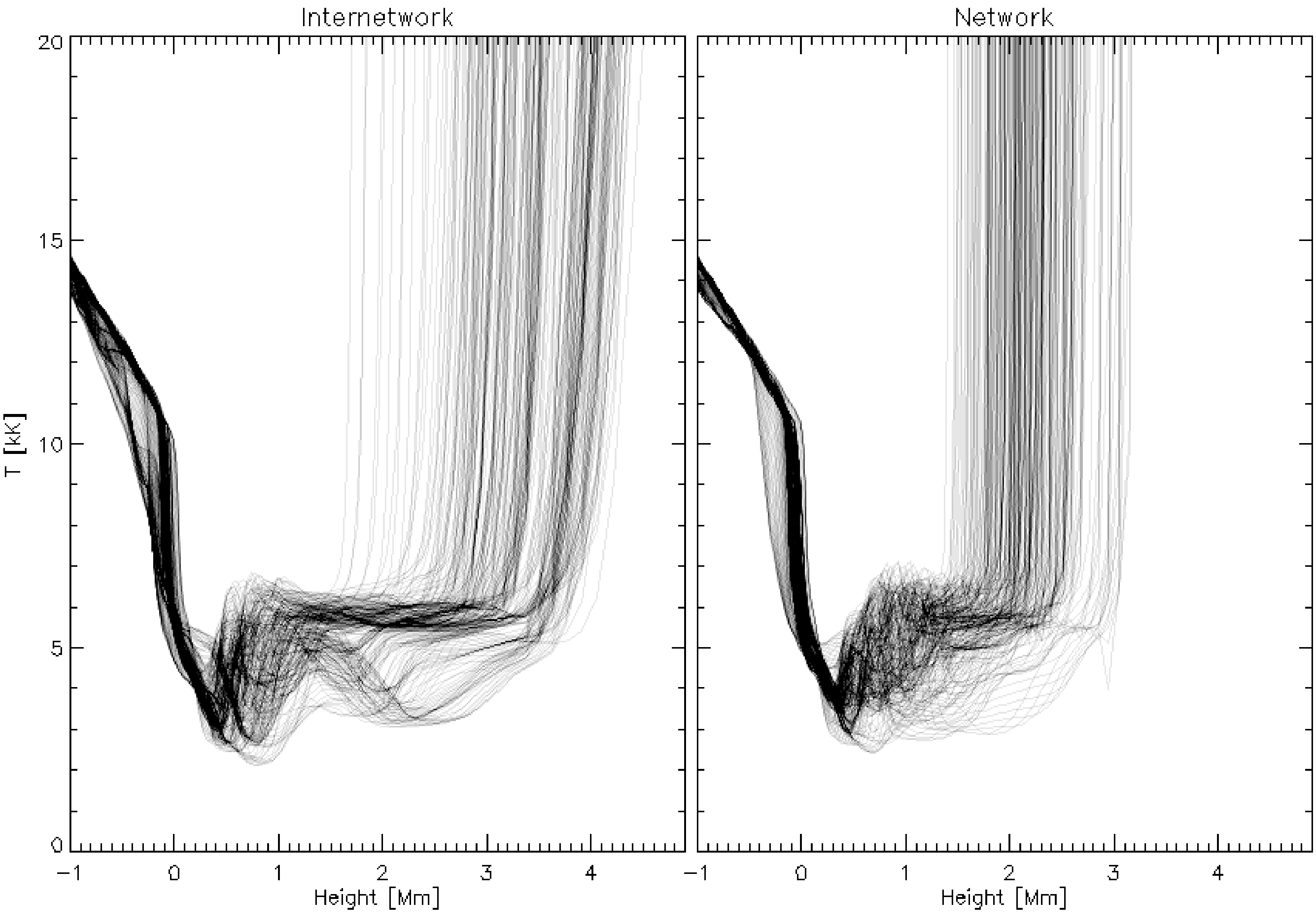
Hansteen 2004

- 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

2D version

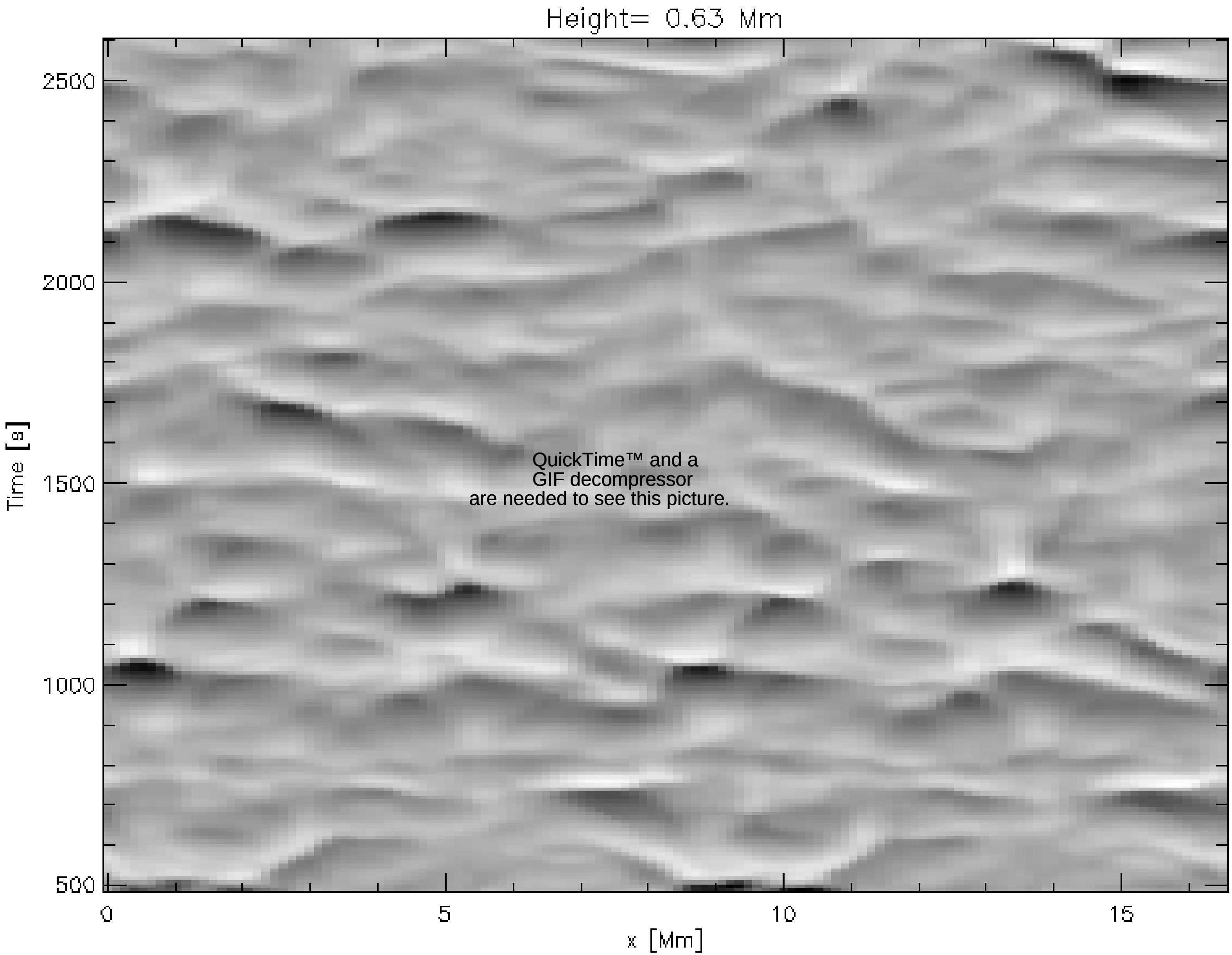

log10 (tg)
z [Mm]
x [Mm]
0
5
10
15
−1
0
1
2
3
QuickTime™ and a
GIF decompressor
are needed to see this picture.

2D model



Internetwork
Network
T [kK]
20
15
10
5
0
−1
0
1
2
3
4
Height [Mm]
Height [Mm]

Waves



Height= 0.63 Mm
Time [s]
2500
2000
1500
1000
500
0
5
10
15
x [Mm]
QuickTime™ and a
GIF decompressor
are needed to see this picture.

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?