Astrophysical plasmas
Sun: coronal seismology
Exoplanet atmospheres

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Plasma parameters
Slow large-scale variations

$$\lambda_D = \sqrt{\frac{\varepsilon_o k_B T_e}{n_e e^2}} \langle\langle L \qquad \omega \langle\langle \omega_{pe}$$

Electrostatic vs Kinetic

$$\Lambda \rangle\rangle 1 \qquad \nu \approx \frac{\ln(\Lambda)}{\Lambda}\omega_{pe}$$

Collective behaviour

$$V_s \equiv \sqrt{\frac{\gamma p}{\rho}} \qquad V_A \equiv \frac{B}{\sqrt{\mu_o \rho}}$$

Compressible Elastic

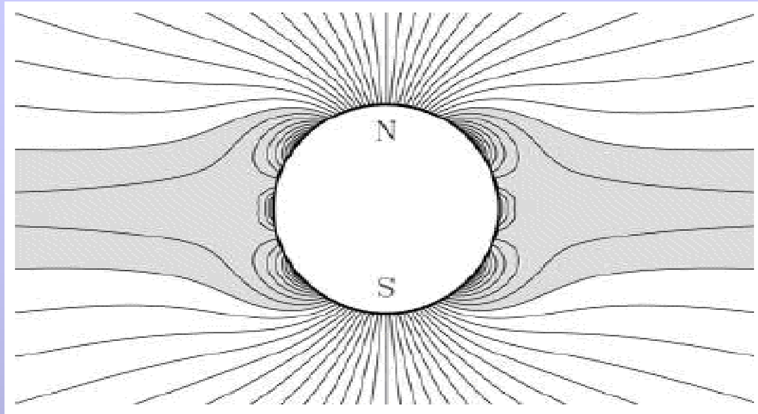
$$r_L \langle\langle L \qquad \omega \langle\langle \omega_g = qB / m$$

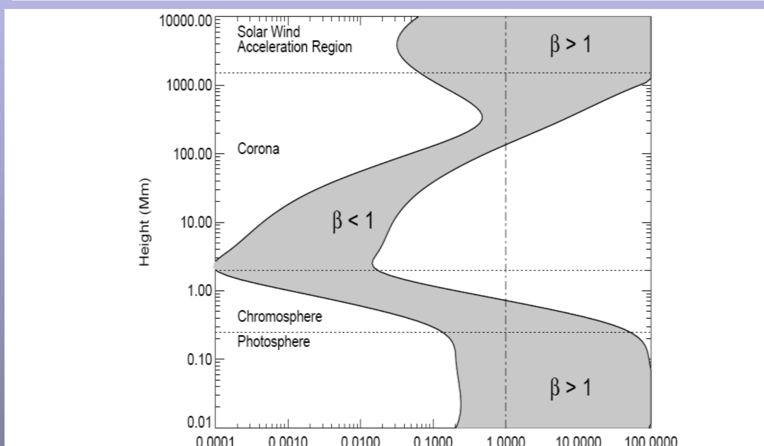
Magnetized plasma

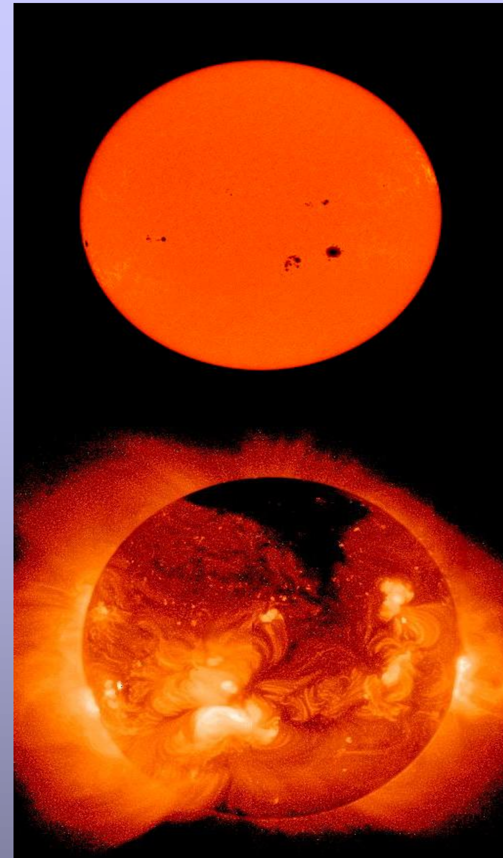
Coronal phenomenology

- Low corona magnetically highly structured system – X-Ray and EUV emission is highly structured
- Tracer of magnetic field
- The underlying chromosphere very dynamic: small scale structures and turbulent motion prevails

Coronal phenomenology- magnetized plasma







$$\beta = \frac{P_g}{P_M} = \frac{p}{B^2 / 2\mu_o} \approx \frac{c^2{}_s}{v^2{}_A}$$

- Large Reynolds number – field lines and plasma frozen
- Corona: gas pressure << magnetic pressure
- The magnetic field governs the dynamic
- Chromosphere: magnetic pressure << gas pressure
- The fluid governs the dynamic

Importance of shock wave contribution for the seismology

- Large Reynolds → frozen plasma – magnetic field
- Gas pressure << magnetic pressure
- Dynamic governed by the magnetic field
- Sound speed << Alfvén speed
- Energy: compressibility medium– elasticity medium
- Inhomogeneity of the medium couples elastic perturbations with compressible ones. In the average transfer of energy to compressible modes
- Favors the appearence of shock waves: compressive modes with Mach>1

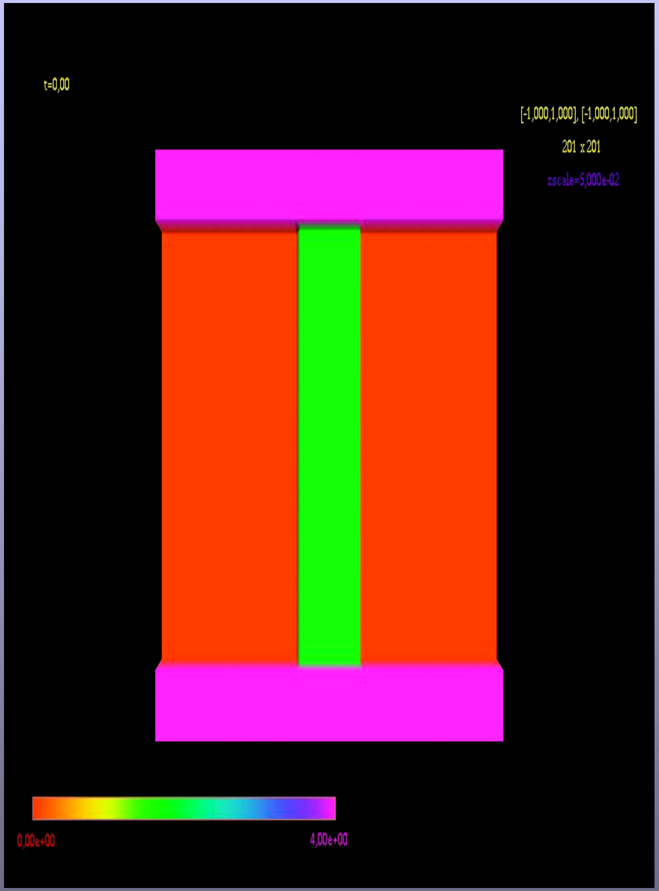
$$\beta = \frac{P_g}{P_M} = \frac{p}{B^2 / 2\mu_o} \approx \frac{c_s^{\;2}}{v_A^{\;2}}$$

Simulations fundamental and global modes

Cécere, Costa, Reula A&A, 2011

Slender tube - Logaritmic – coronal conditions

Due to chromospheric line-tied
and inhomogeneities and nonlinearities
pure modes difficult to sustain

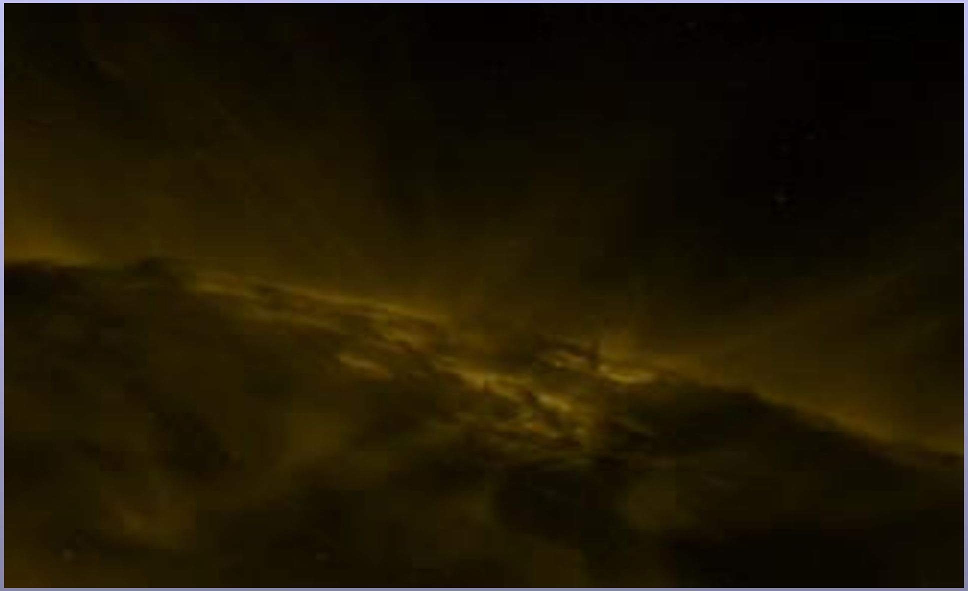


Jump conditions across the radius

amplifies the spectrum of modes
Trapped –Leaky

Evolution to a quasi-static 2nd slow harmonic state occurs via the onset of an external compressional Alfvén wave or a weak shock wave M<1.3 that triggers the sausage mode and couples the slow mode

Costa, Elaskar, Fernández, Martínez, MNRAS 2009
Fernández, Costa, Elaskar, Schulz, 2009
Schulz, Costa, Elaskar, Cid, MNRAS 2010
Maglione, Schneiter, Costa, Elaskar, A&A 2011
Costa, Pl.Phis.Contr.Fusion, 2011



Interpretations:

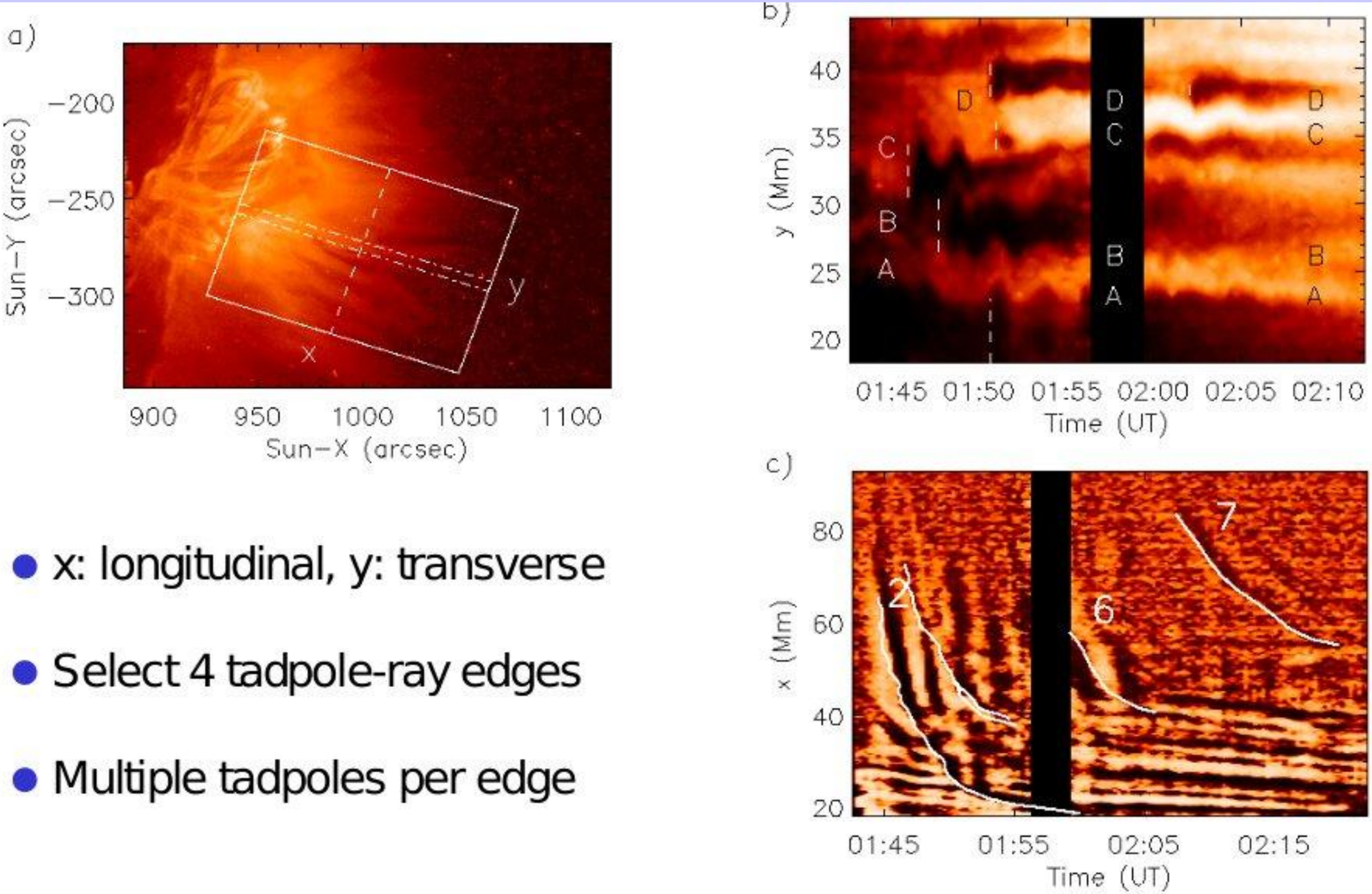
Rain of blobs of dense and cool plasma after a CME falling gravitationally back

Flux tubes linking an above current sheet retract downwards under the force of the magnetic tension

Top of colapsing loops with void tails in the wakes where reconnection occurs

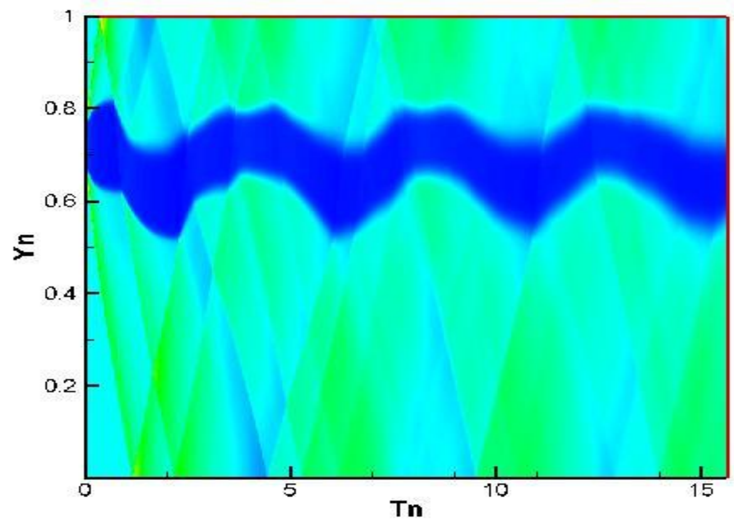
Verwichte, Nakariakov, Cooper A&A, 2005 Observational analysis

Kink wave trains guided by ray tadpole structures. However speeds ~ vs not ~vA

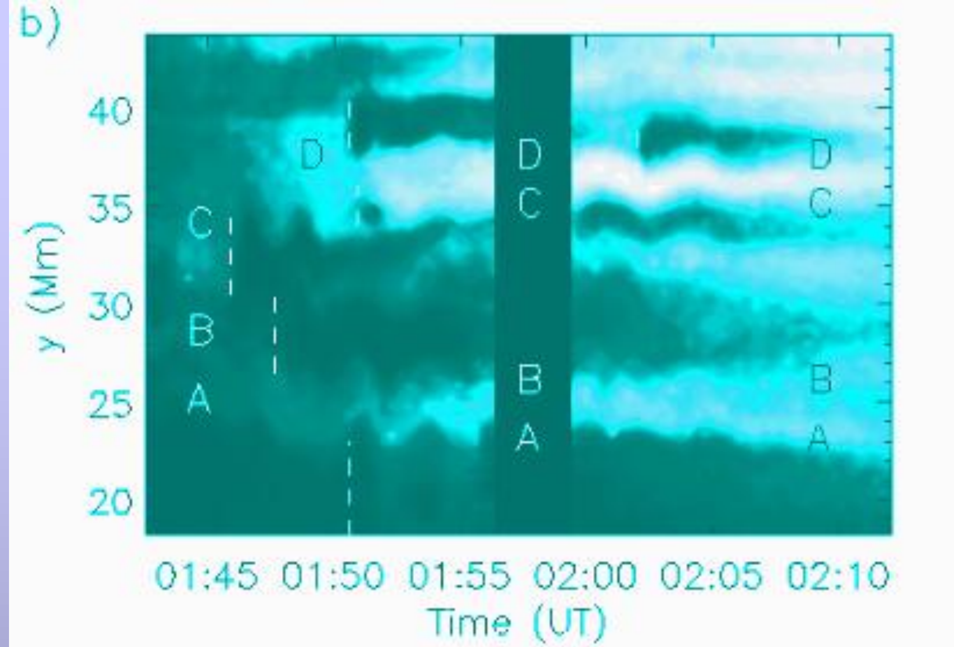


- x: longitudinal, y: transverse
- Select 4 tadpole-ray edges
- Multiple tadpoles per edge

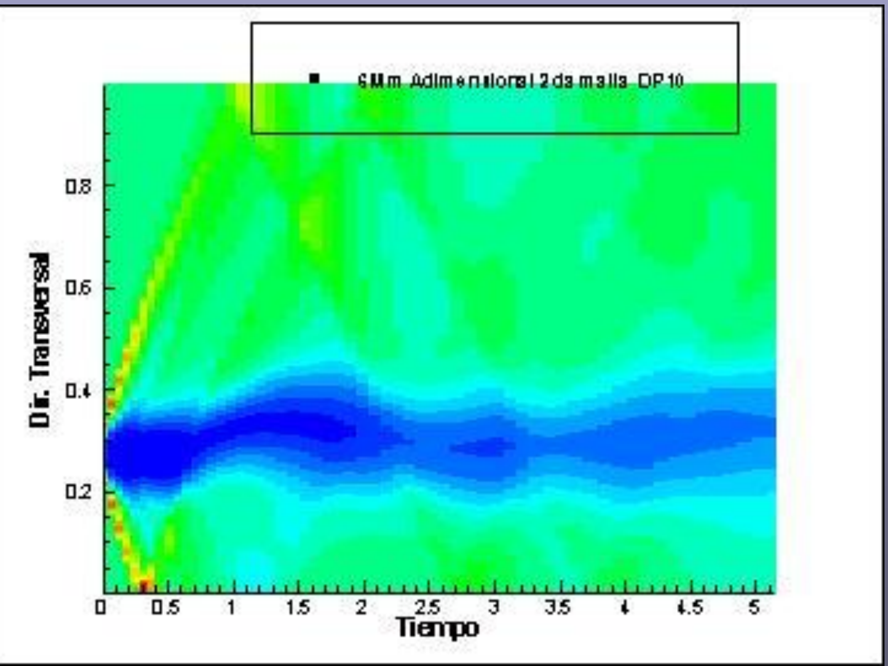
Transverse waves in a post-flare supra-arcade



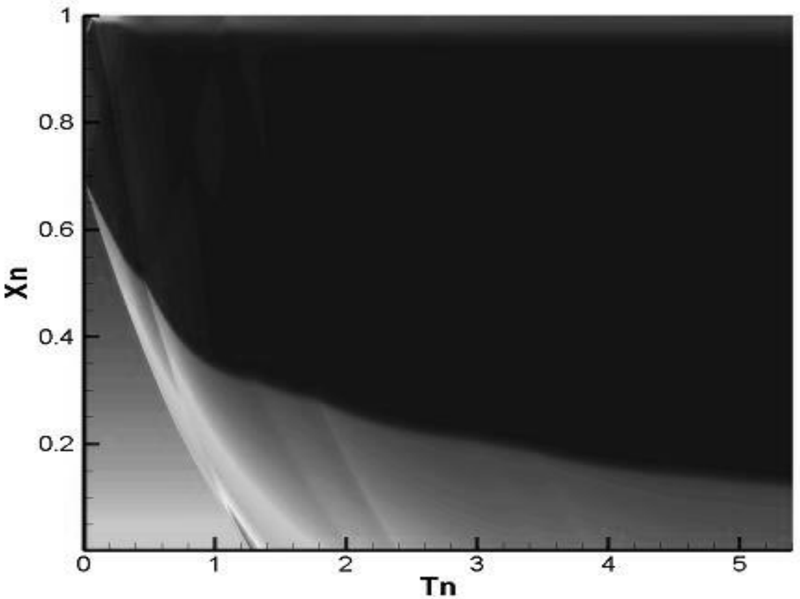
Yn
Tn
1
0.8
0.6
0.4
0.2
0
5
10
15

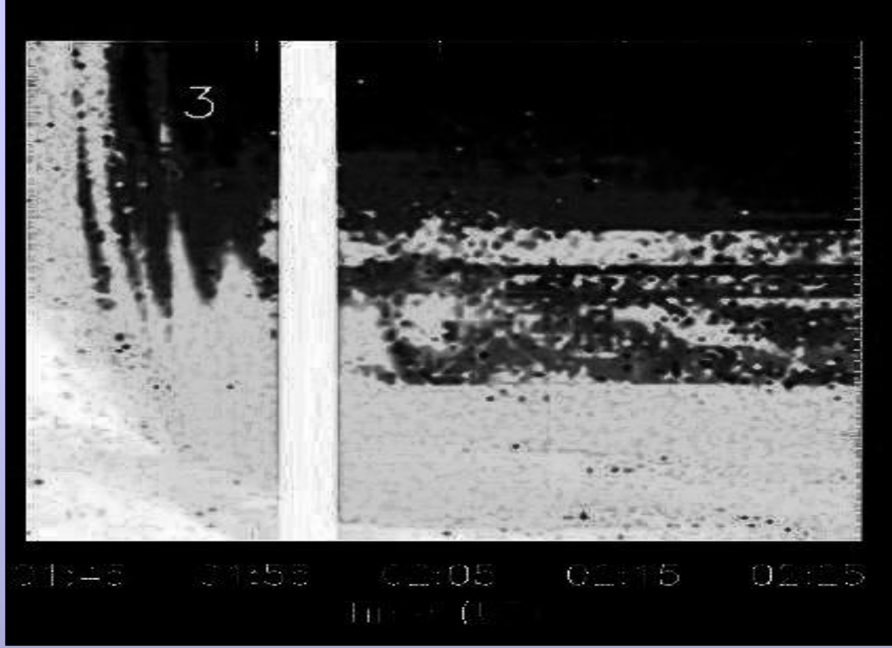


b)
y (Mm)
Time (UT)
40
35
30
25
20
01:45
01:50
01:55
02:00
02:05
02:10
D
C
B
A

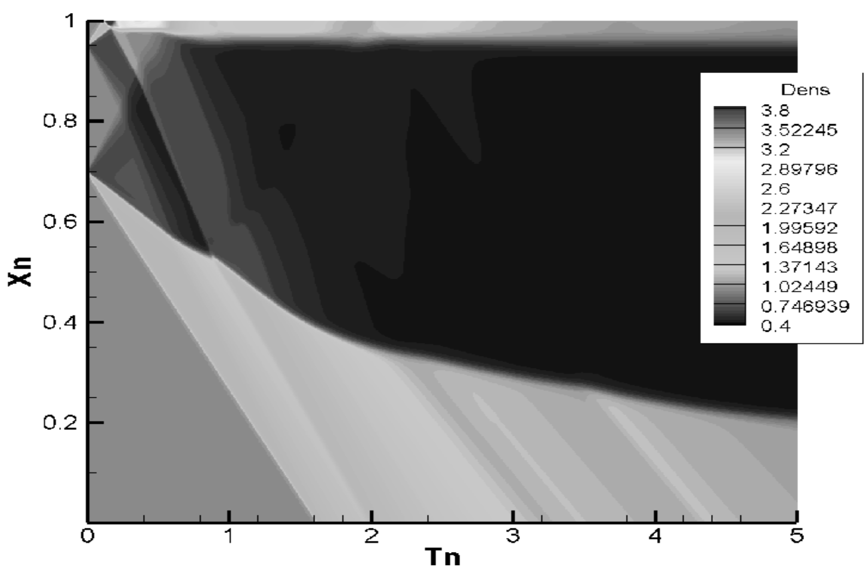


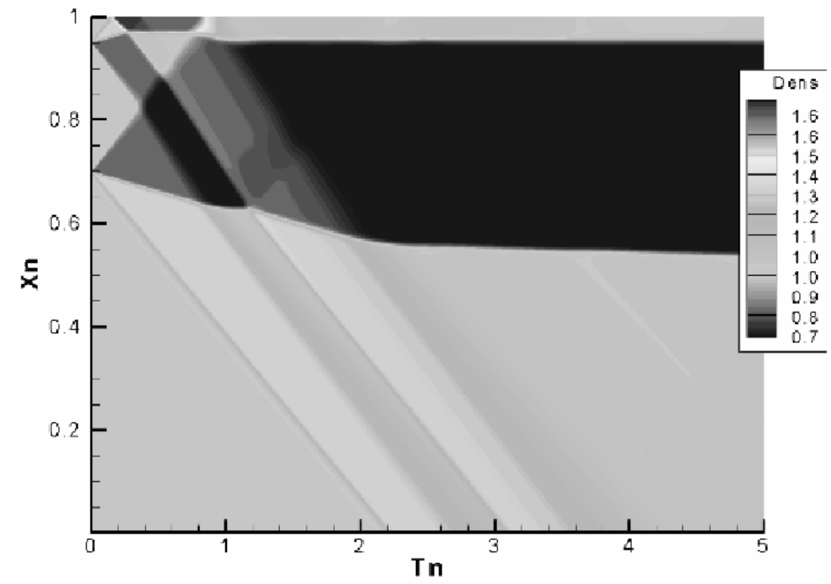
6Mm Adimensional 2da malla DP10
Dir. Transversal
Tiempo
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



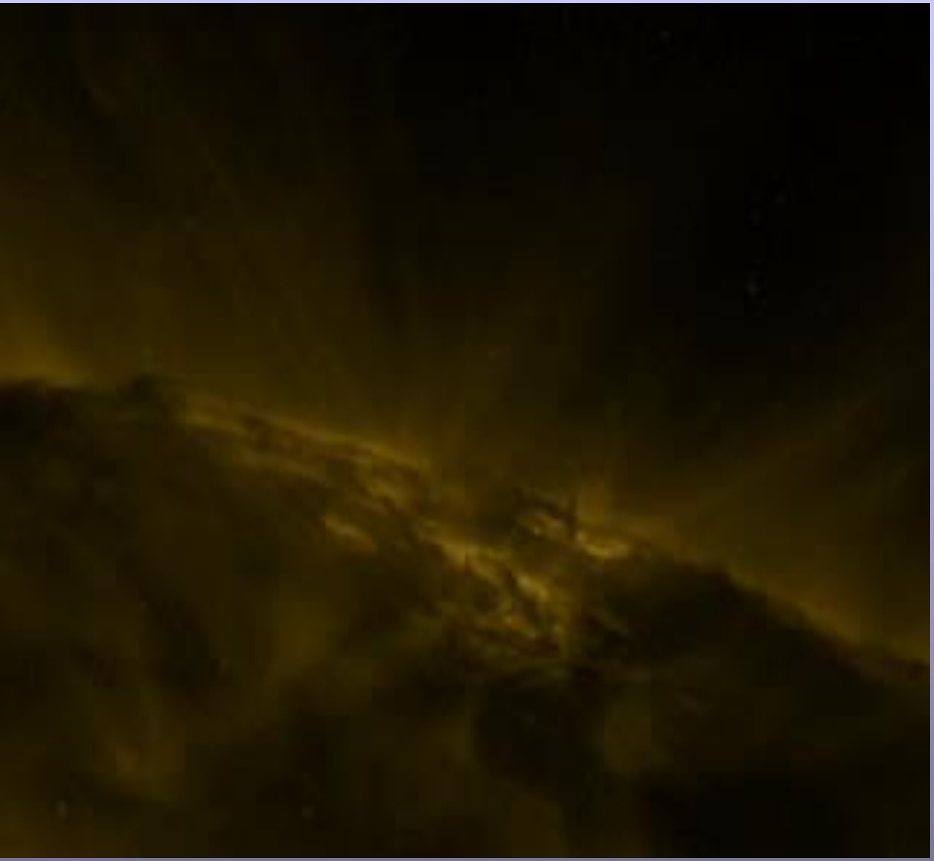


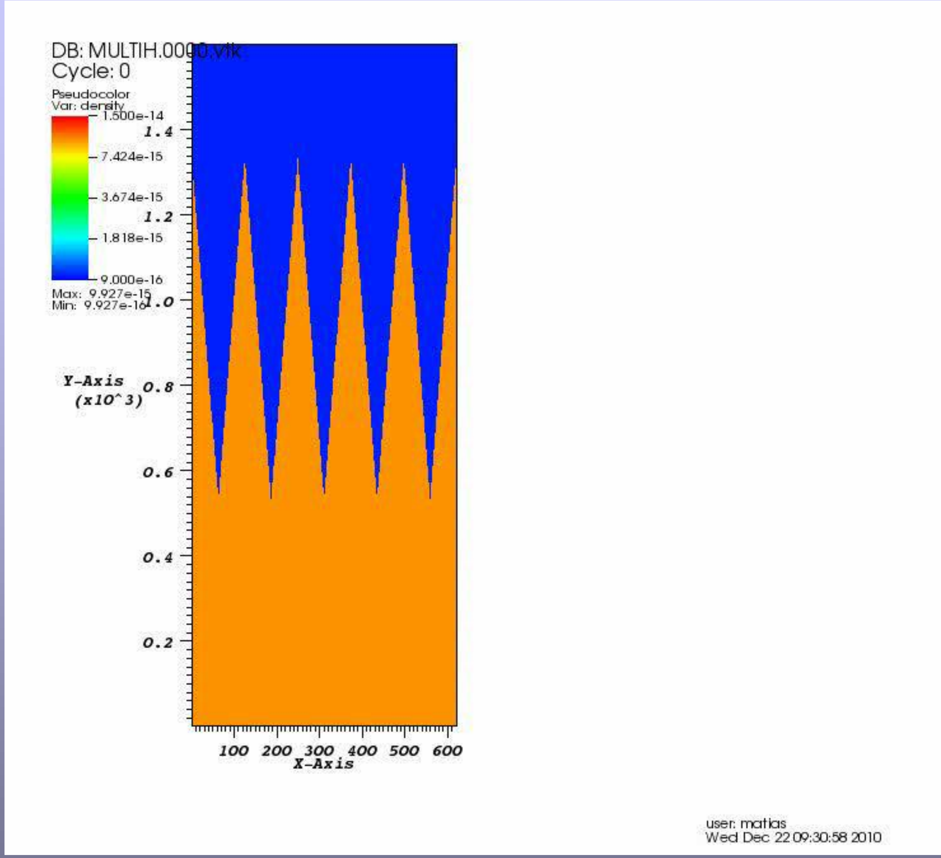
Sunward: upward rebound resembling the reconnection site absortion towards the Sun





Schneiter, Costa, Elaskar, 2011





Moreton waves

Francile, Costa, Schneiter, Elaskar, 2011

Chromospheric shock waves or fast magnetoacoustic wave

Triggered by a not stablished coronal phenomenon

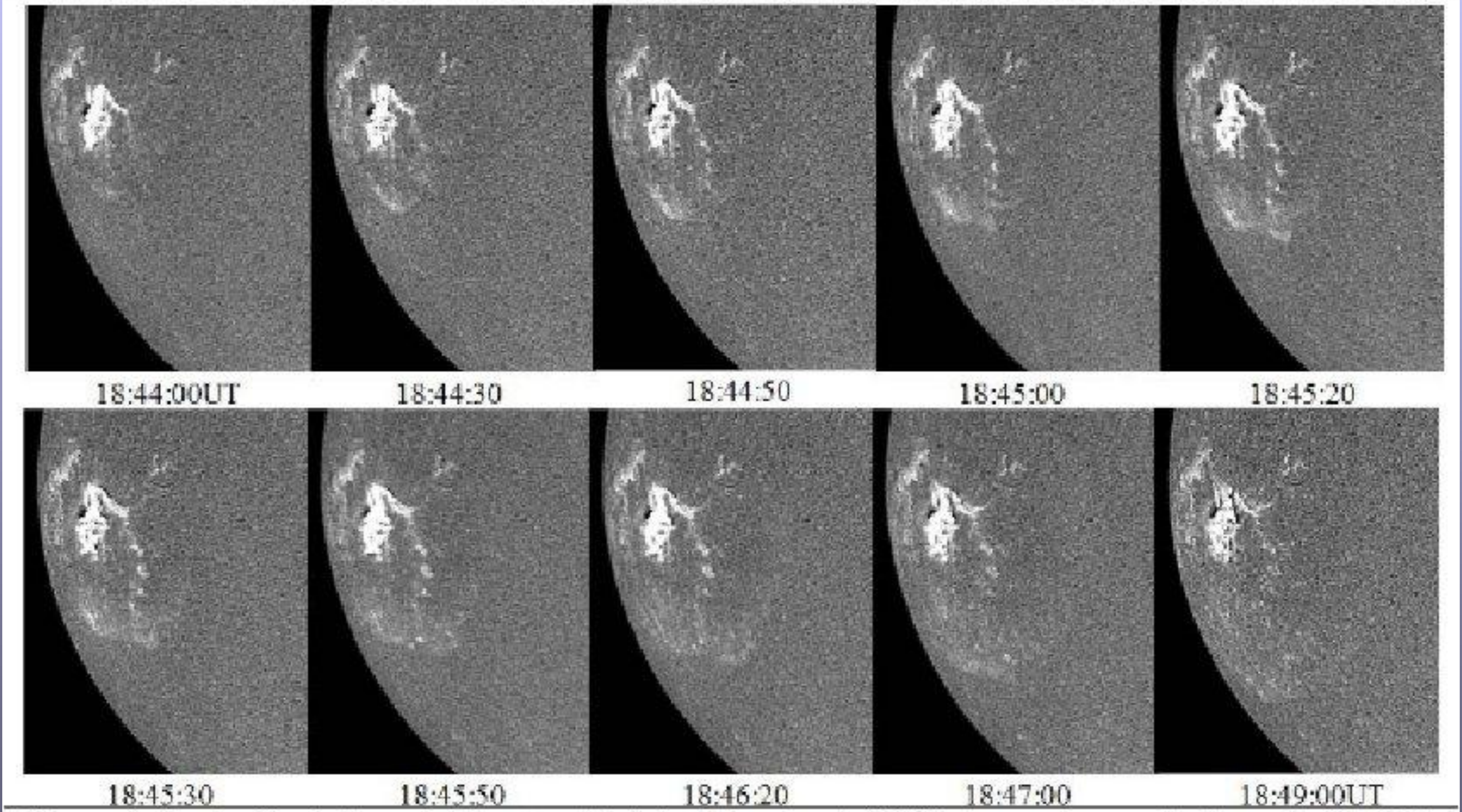
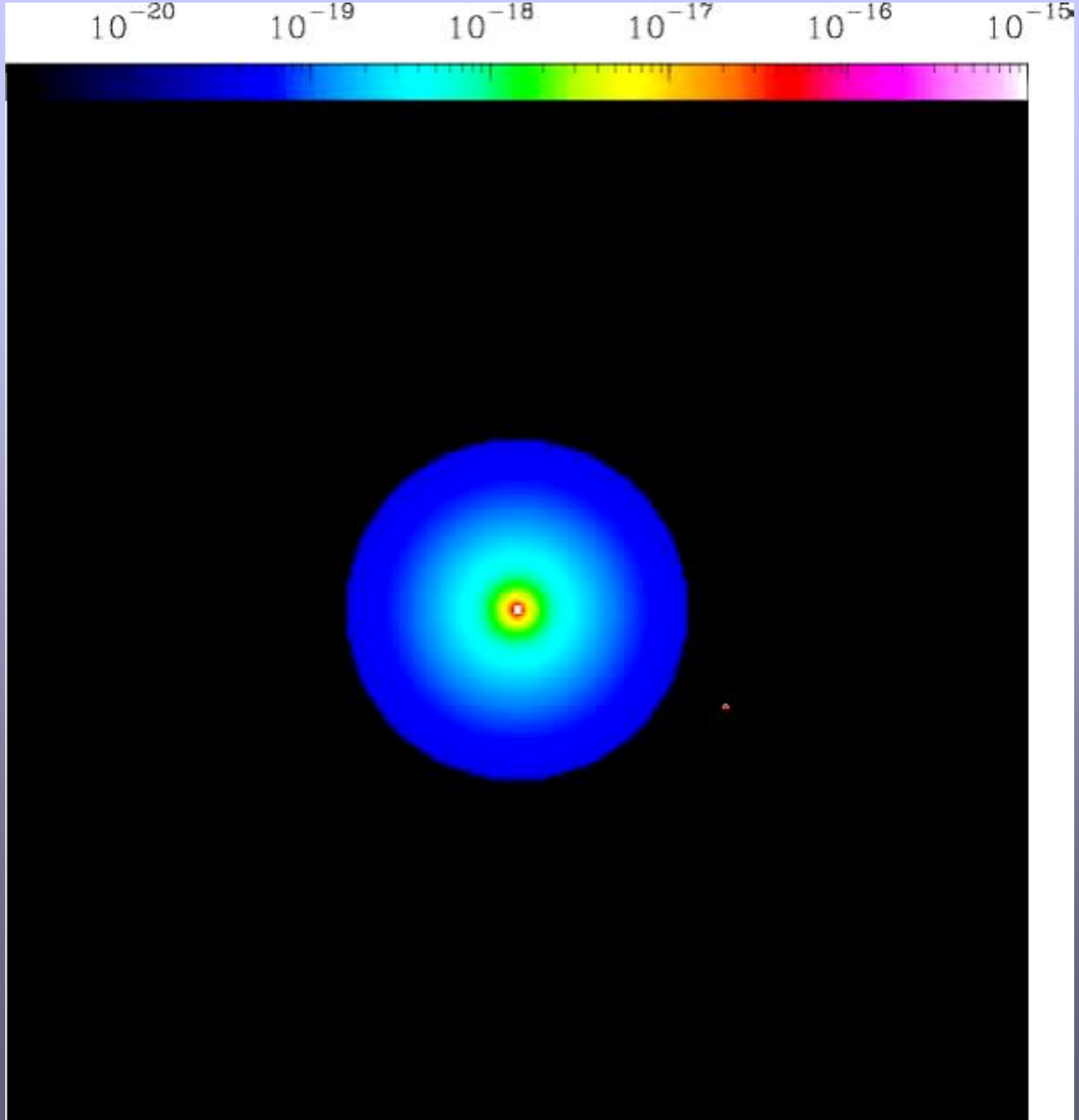


Figura 2: Evolución de la onda Moreton del 6 de diciembre de 2006 observada con el telescopio HASTA

Exoplanet atmospheres: we derive the L_Alpha absortion for different wind conditions

Schneiter,Velázquez,Raga, 2007-Villareal,Schneiter,Costa, 2011-Schneiter, Costa, Velázquez, 2011



HD209458b
HD17156b

Thank you