Formation of chromospheric and coronal loops as a result of flux emergence

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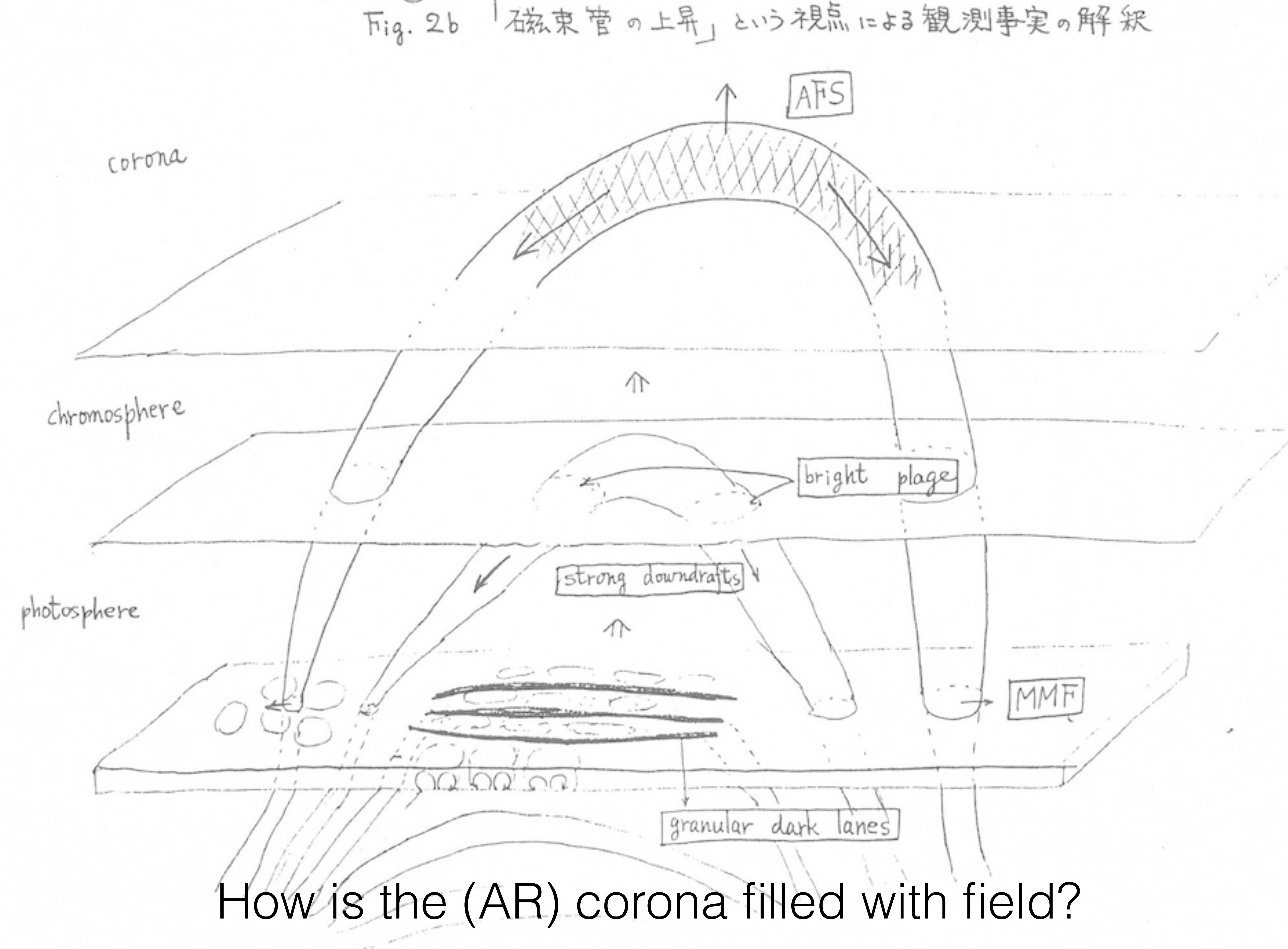
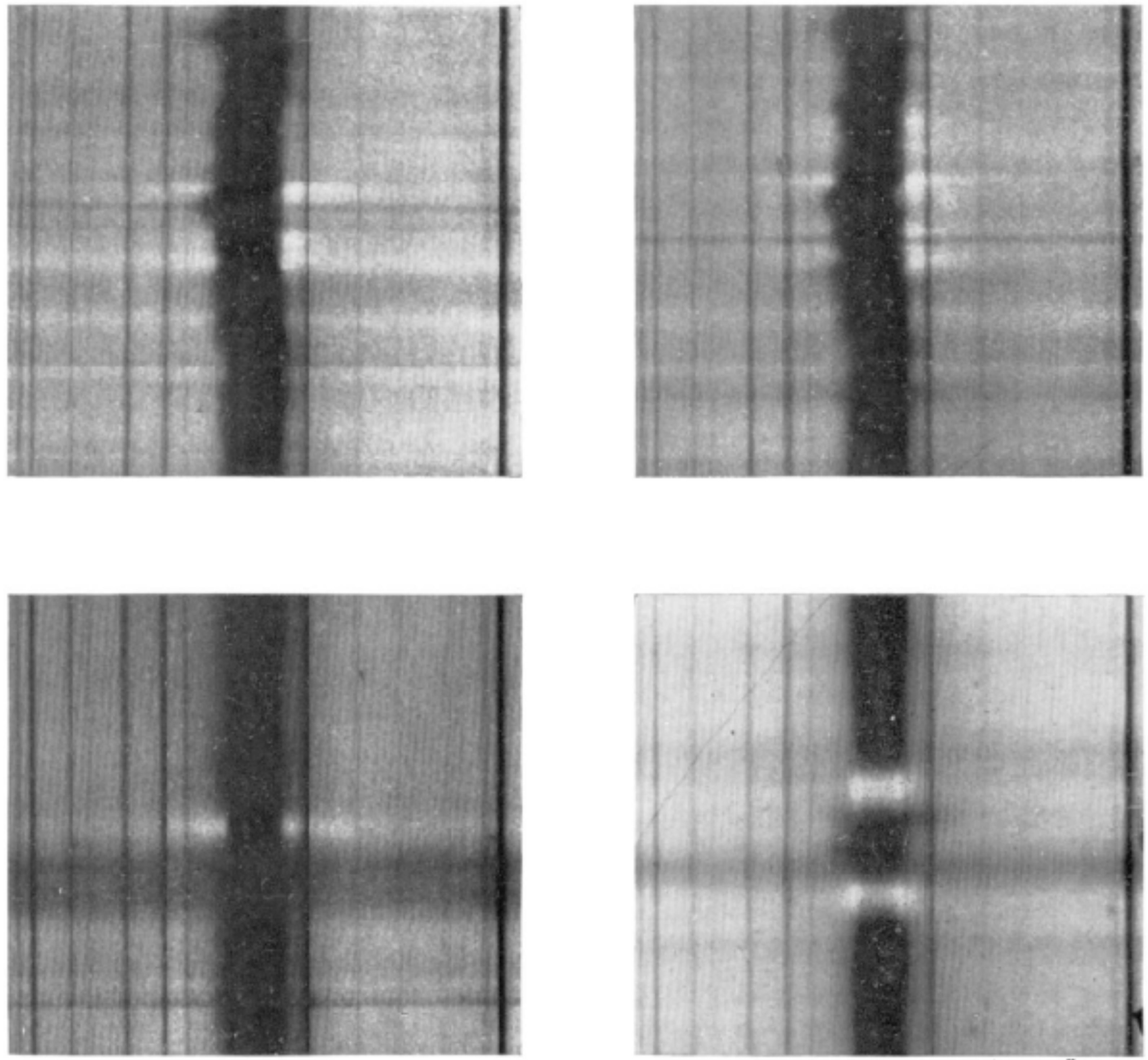
Shibata 1979



How is the (AR) corona filled with field?

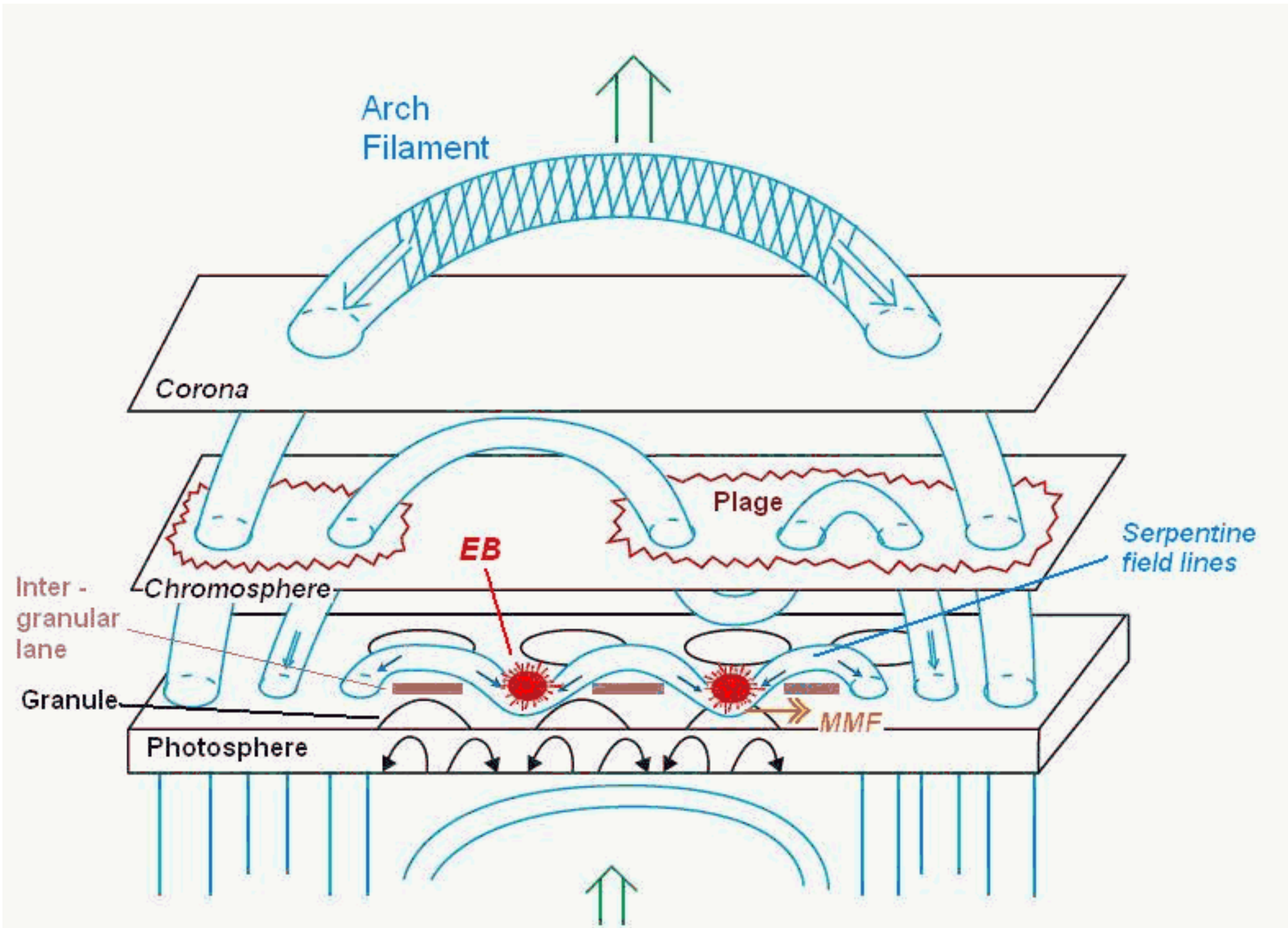
PLATE XVI



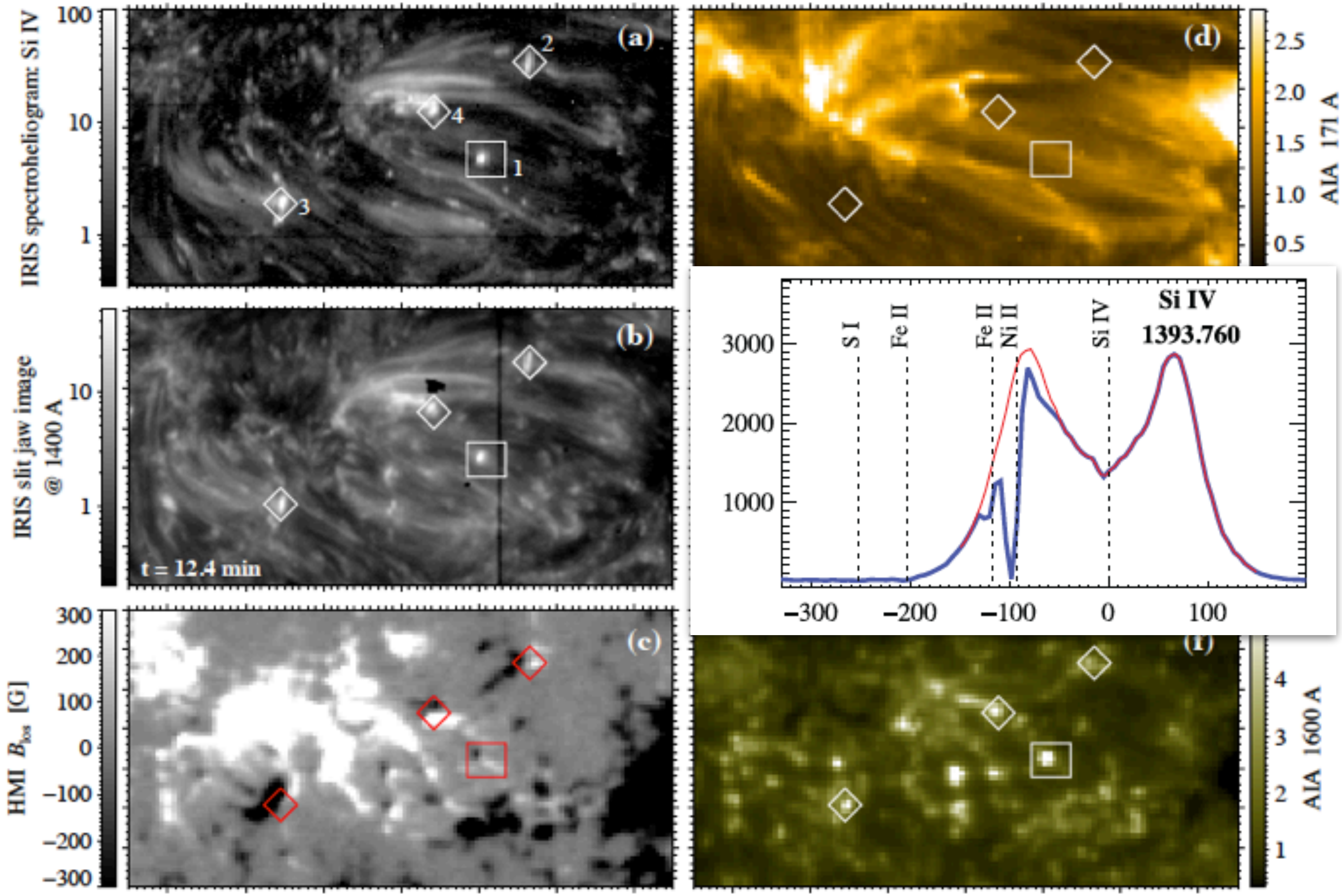
a and *b*. Appearance of the Hα line in an active sun-spot region, showing the bands of "bombs" and the distortions of the line.

c. Spectrum of a "bomb" (close to the dark Hα line) superposed on the spectrum of a facula.

…complex evolution as field and plasma rise into outer

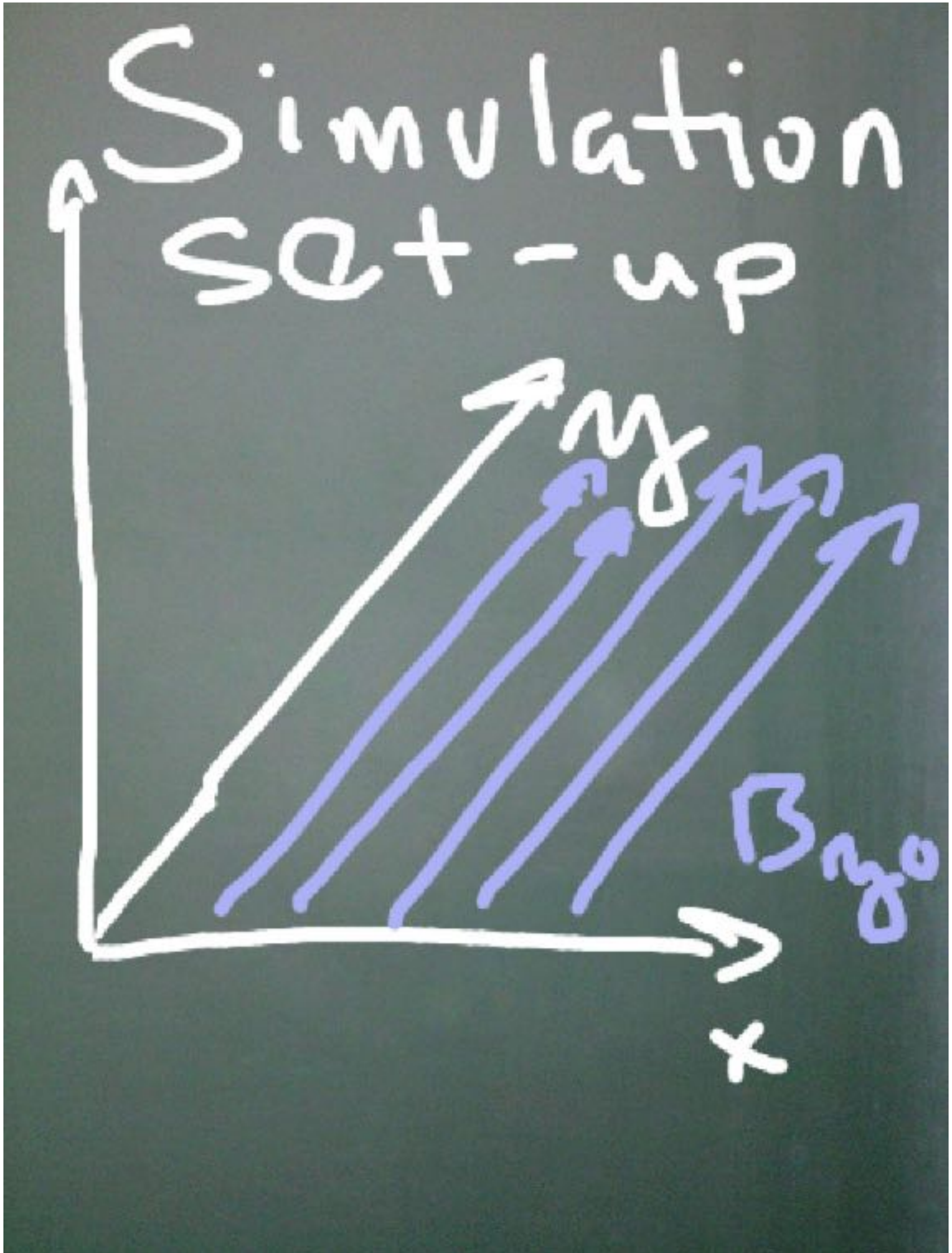


Schmieder & Pariat 2007 [Scholarpedia] 2(12):4335 (Shibata's cartoon, slightly modified)



Ellerman bombs and "UV bursts" (IRIS bombs)
high Si IV intensities, large line shifts/widths,
hot gas below cold

Hardi Peter 2014, "Hot explosions in the cool atmosphere of the Sun", Science 346, C315

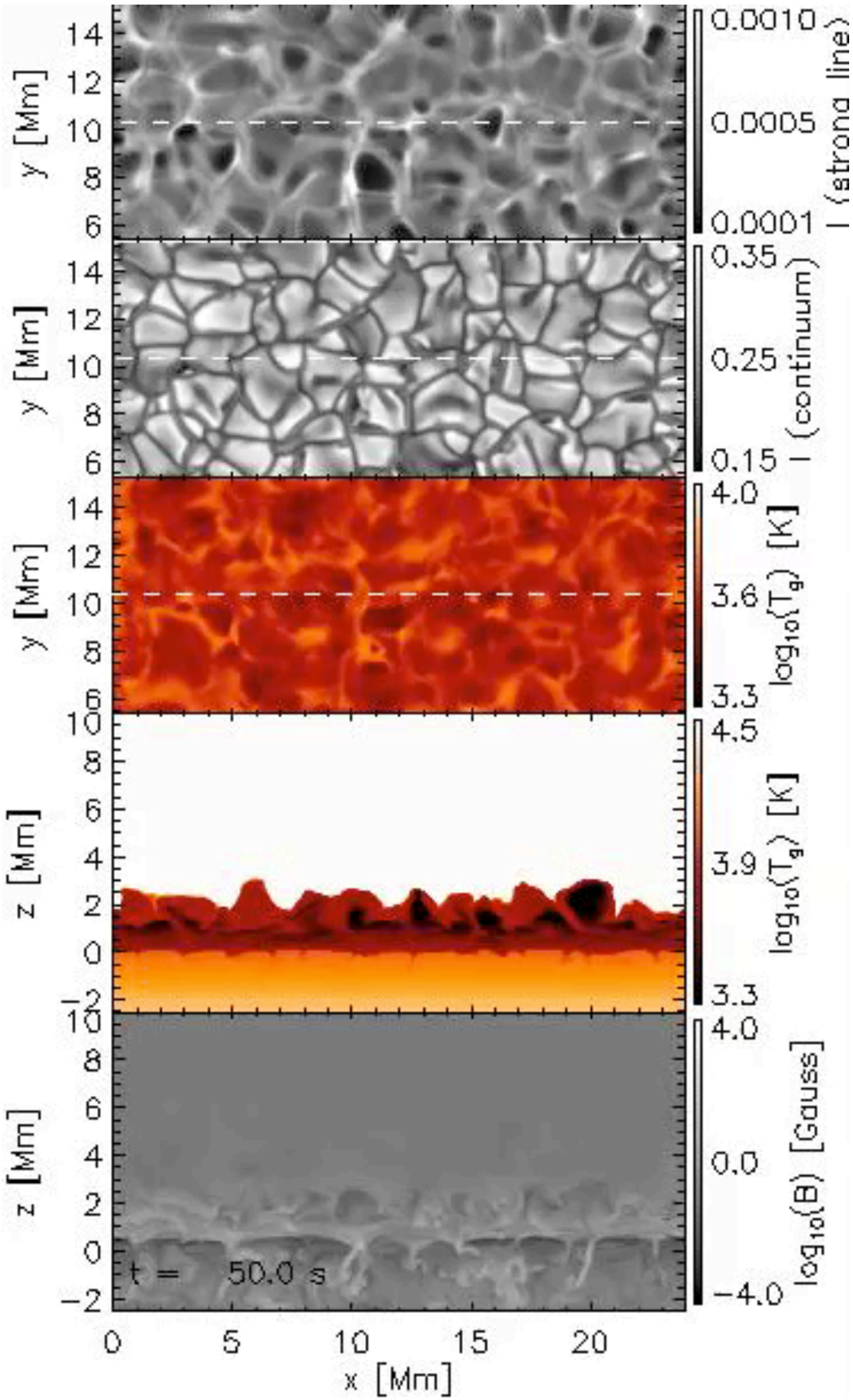


Bifrost Models with flux emergence

Domain 24x24x17 Mm^3 (504,504,496 grid points), 2.5 Mm below photosphere 14.5 Mm above

Weak initial field B < 0. 1G, inclination 45°

Flux sheet with By = 3360G in domain [0–24, 3–16] Mm for a period of 105 minutes.



Photospheric and chromospheric intensity little changed by emergence of flux sheet through convection zone.

Some large granules appear towards end of this animation.

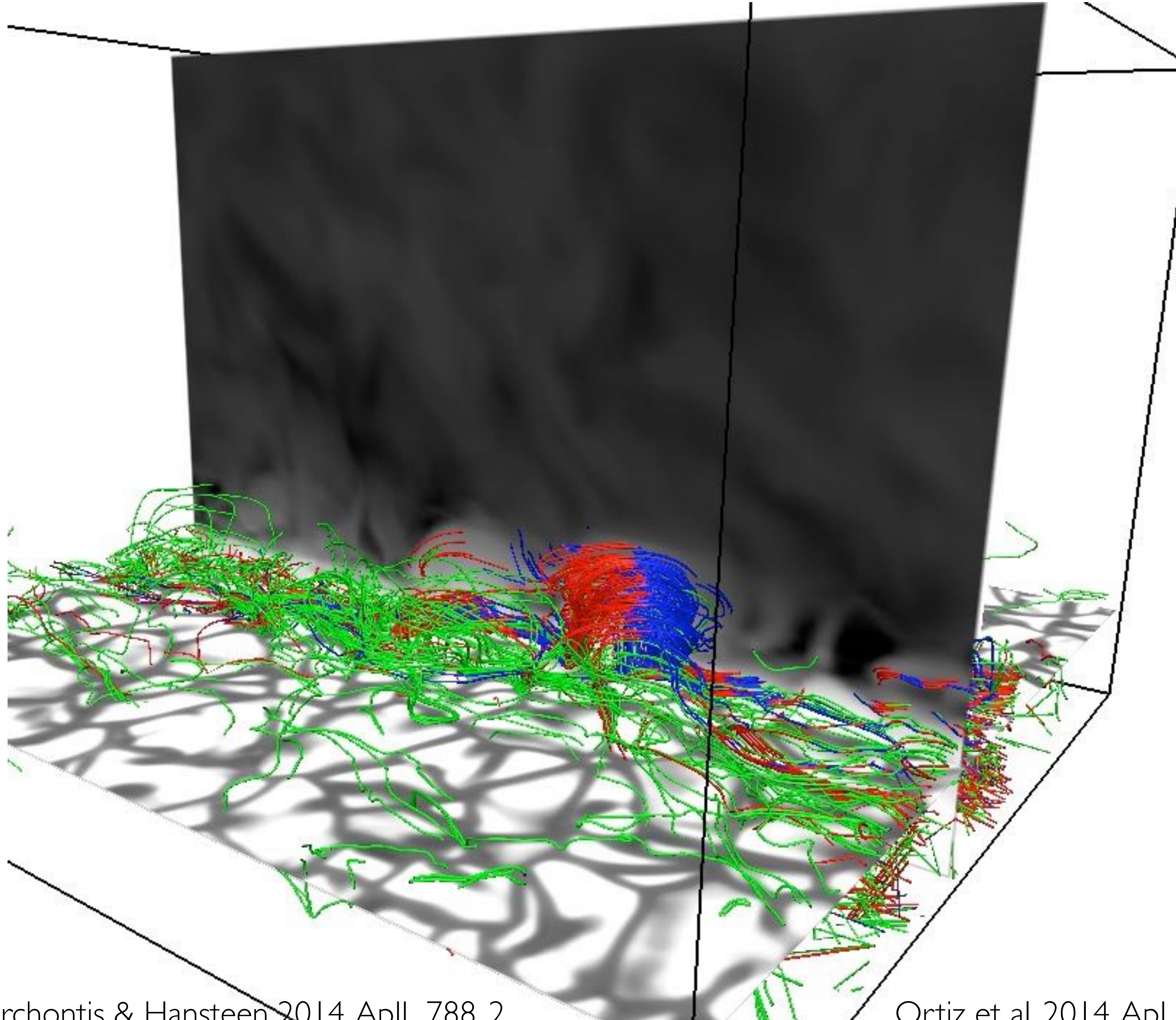
Horizontal panel at z=700 km above photosphere. Chromospheric vertical extent initially some 2 Mm.

Chromospheric temperature structure set by acoustic shocks until magnetic field emerges into outer atmosphere.

Flux sheet (B=3300 G at bottom boundary) steadily rises to photosphere... Where it stalls.

Initial ambient field of B=0.1 G with inclination of 45° with respect to z axis.

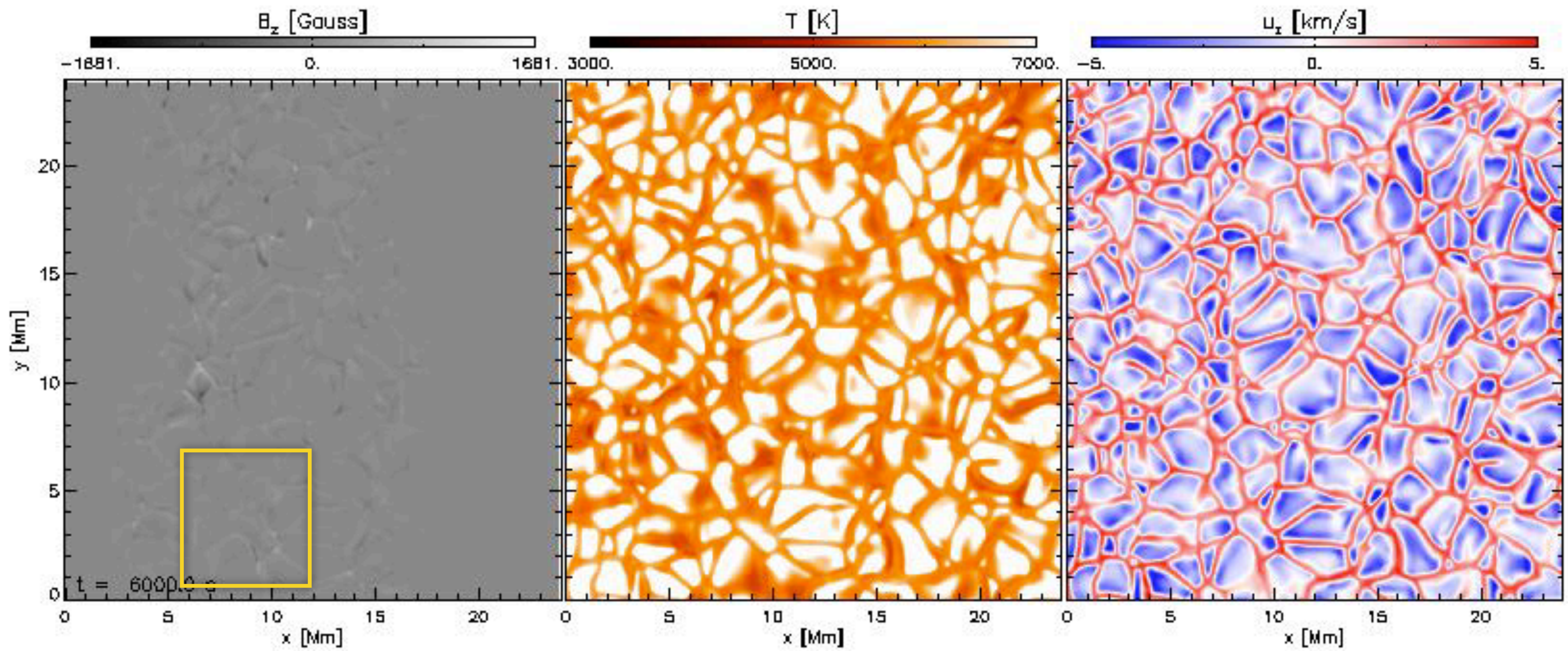
Archontis & Hansteen 2014, ApJL 788, 2



Archontis & Hansteen 2014, ApJL 788, 2

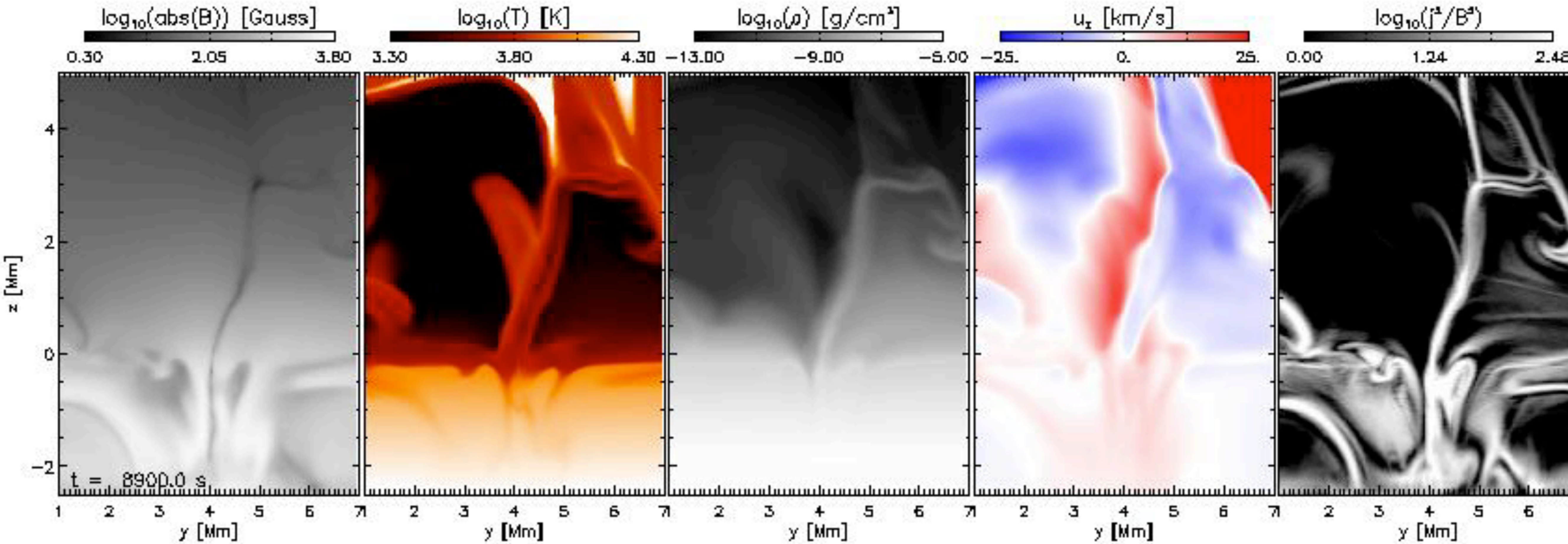
Ortiz et al. 2014, ApJ 781, 126

Photospheric reconnection



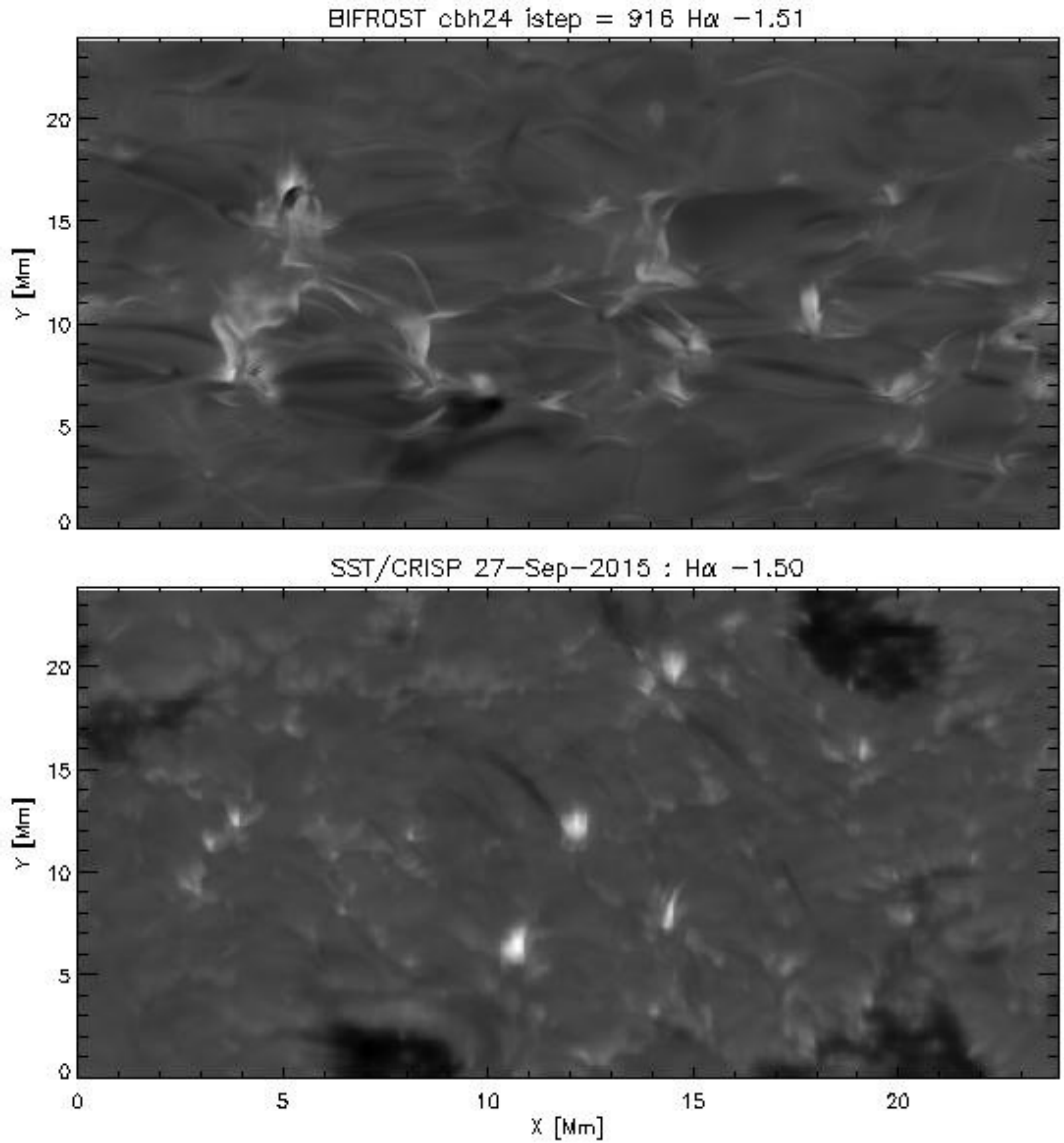
- strong field concentrations
- very low temperatures (convective collapse)
- strong down-flows in regions of strong field
- reconnection where opposite polarities meet

Photospheric jet - 20 km/s ($\sim v_a >> c_s$) at current sheet



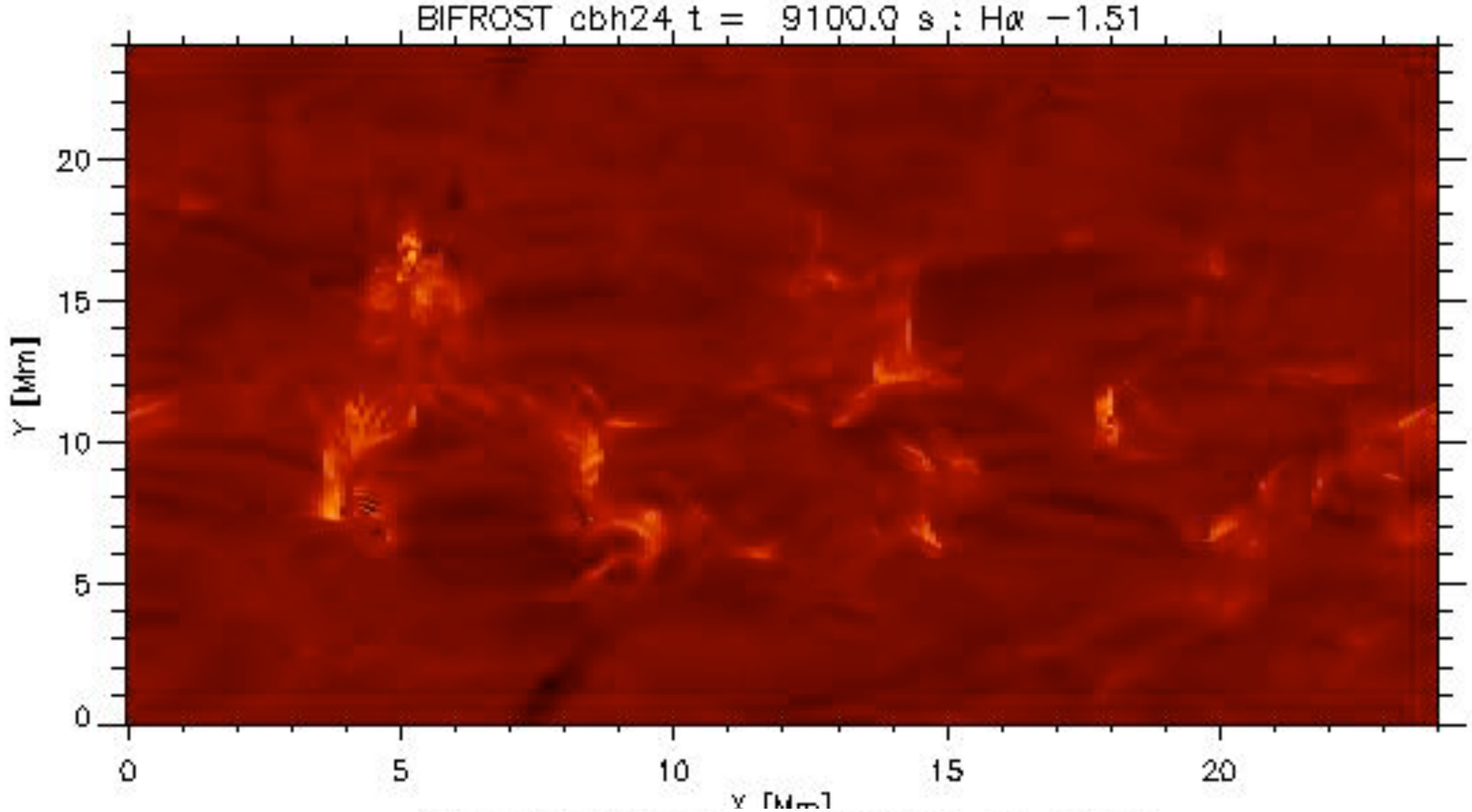
- jet extends some 1000 km below; 2000 km above photosphere
- duration some hundreds of seconds
- strong heating in current sheet

Hα wing
μ = 0.5

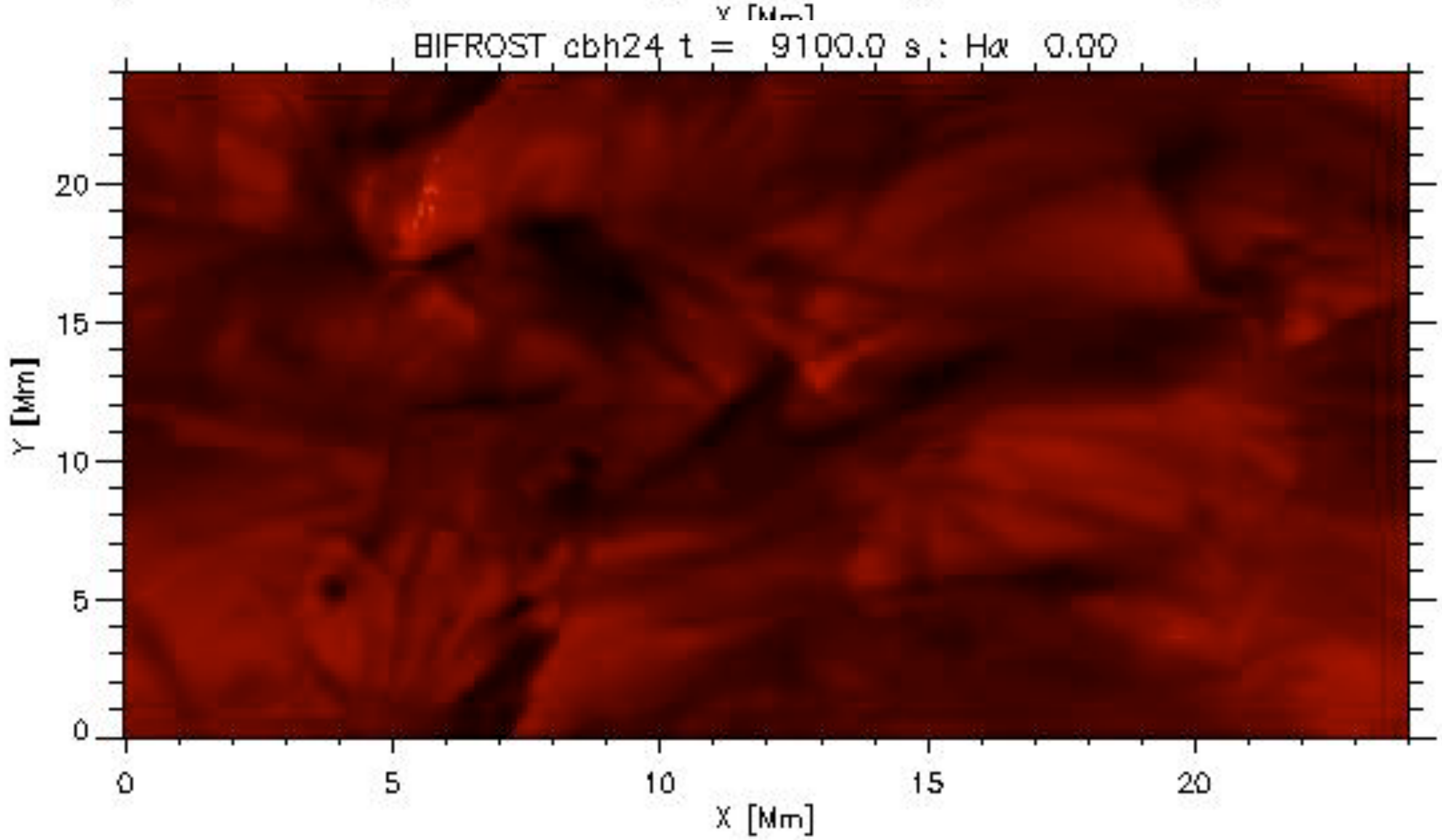


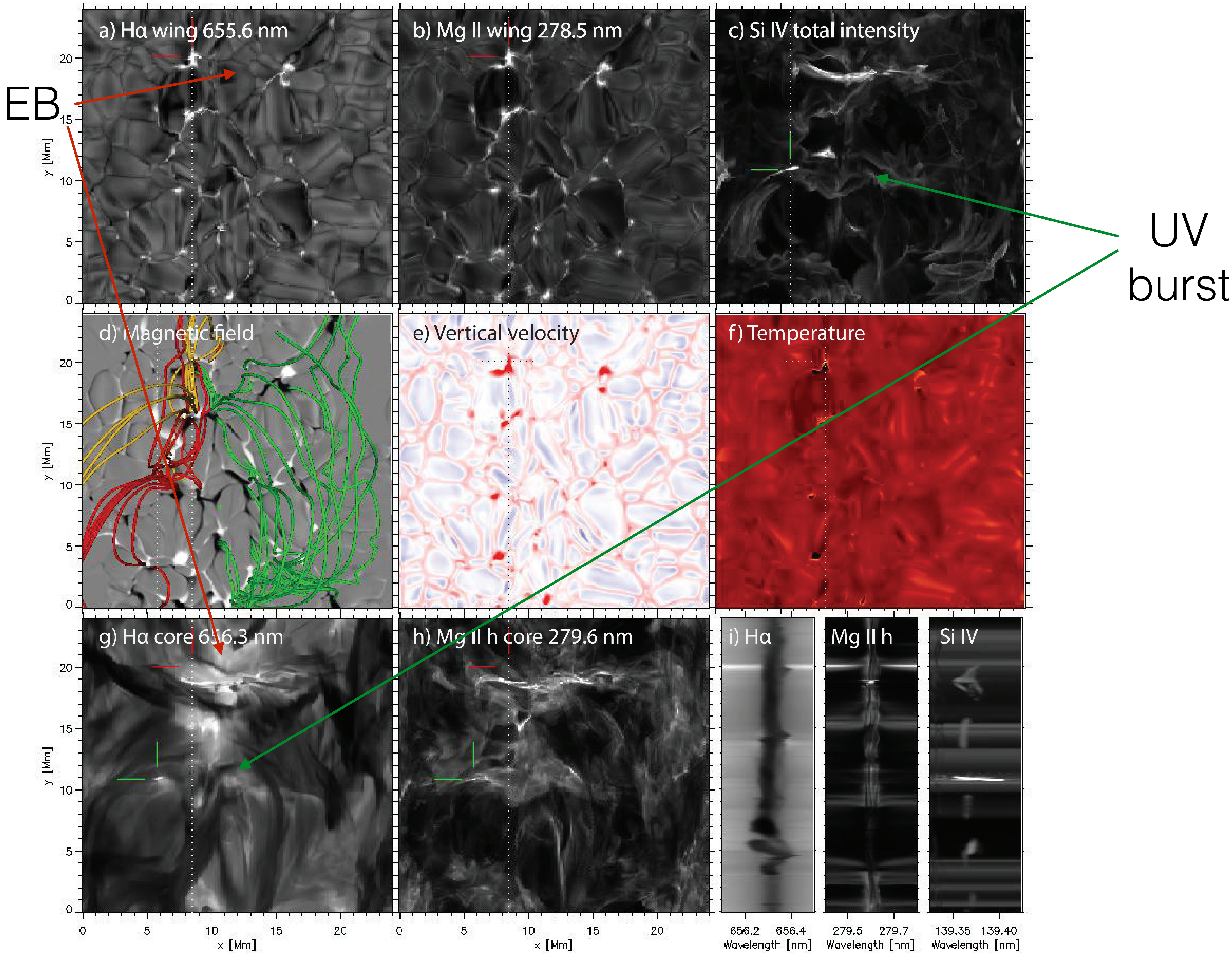
BIFROST cbh24 istep = 916 Hα −1.51
Y [Mm]
0
5
10
15
20
SST/CRISP 27−Sep−2015 : Hα −1.50
Y [Mm]
0
5
10
15
20
0
5
10
15
20
X [Mm]

Hα line
wing -1.51Å
μ=0.5

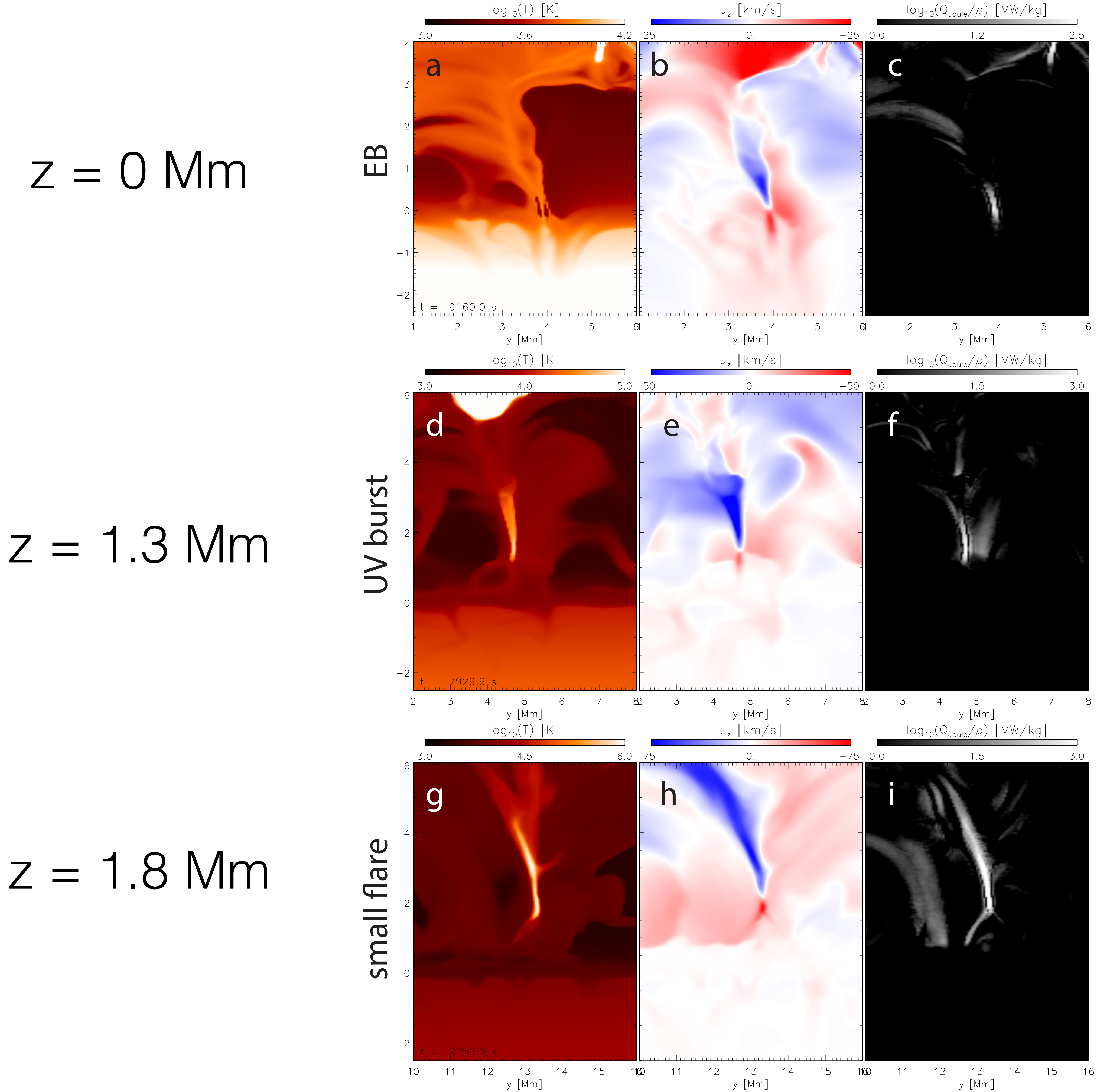


Hα line
core
μ=0.5

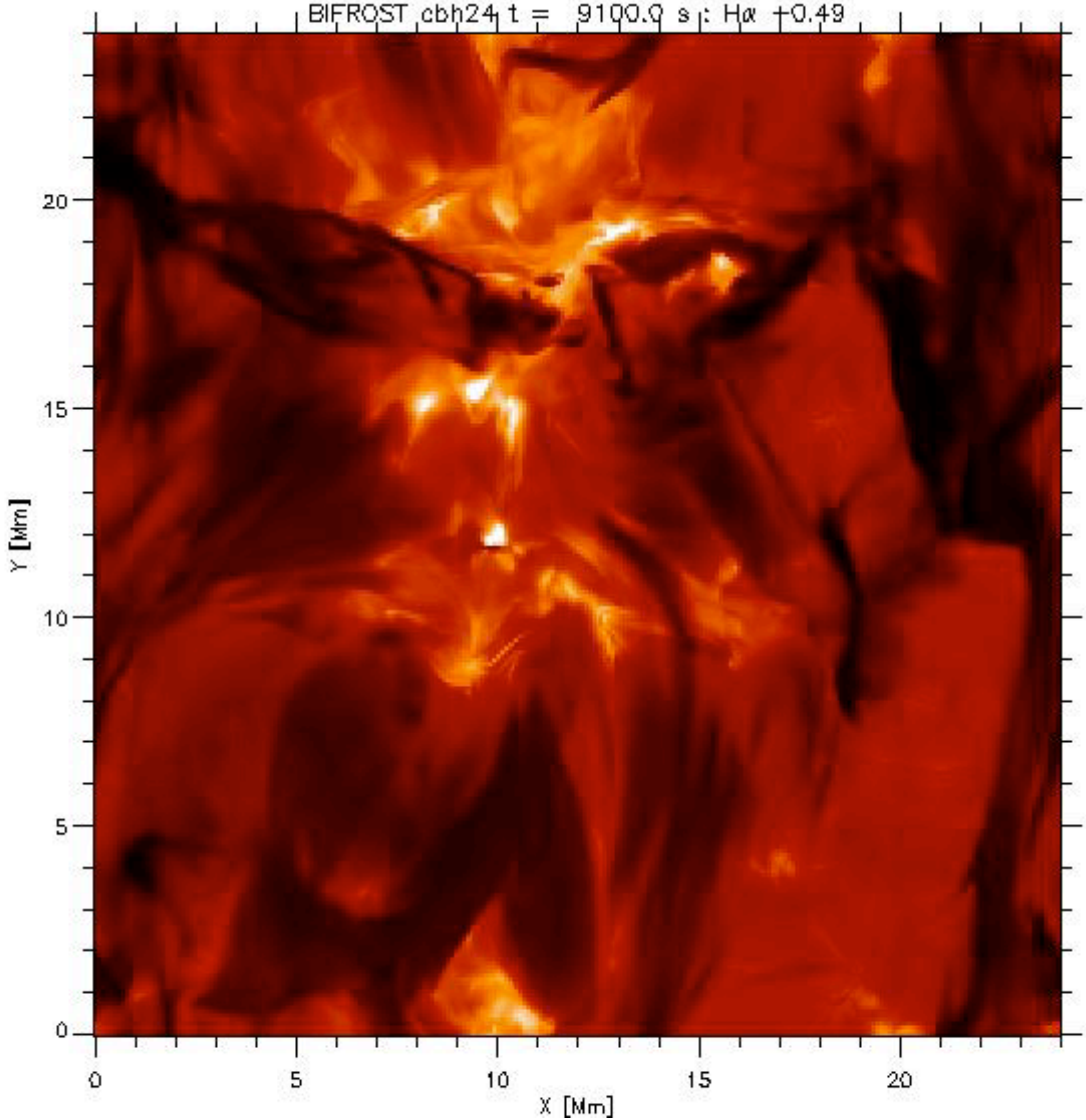




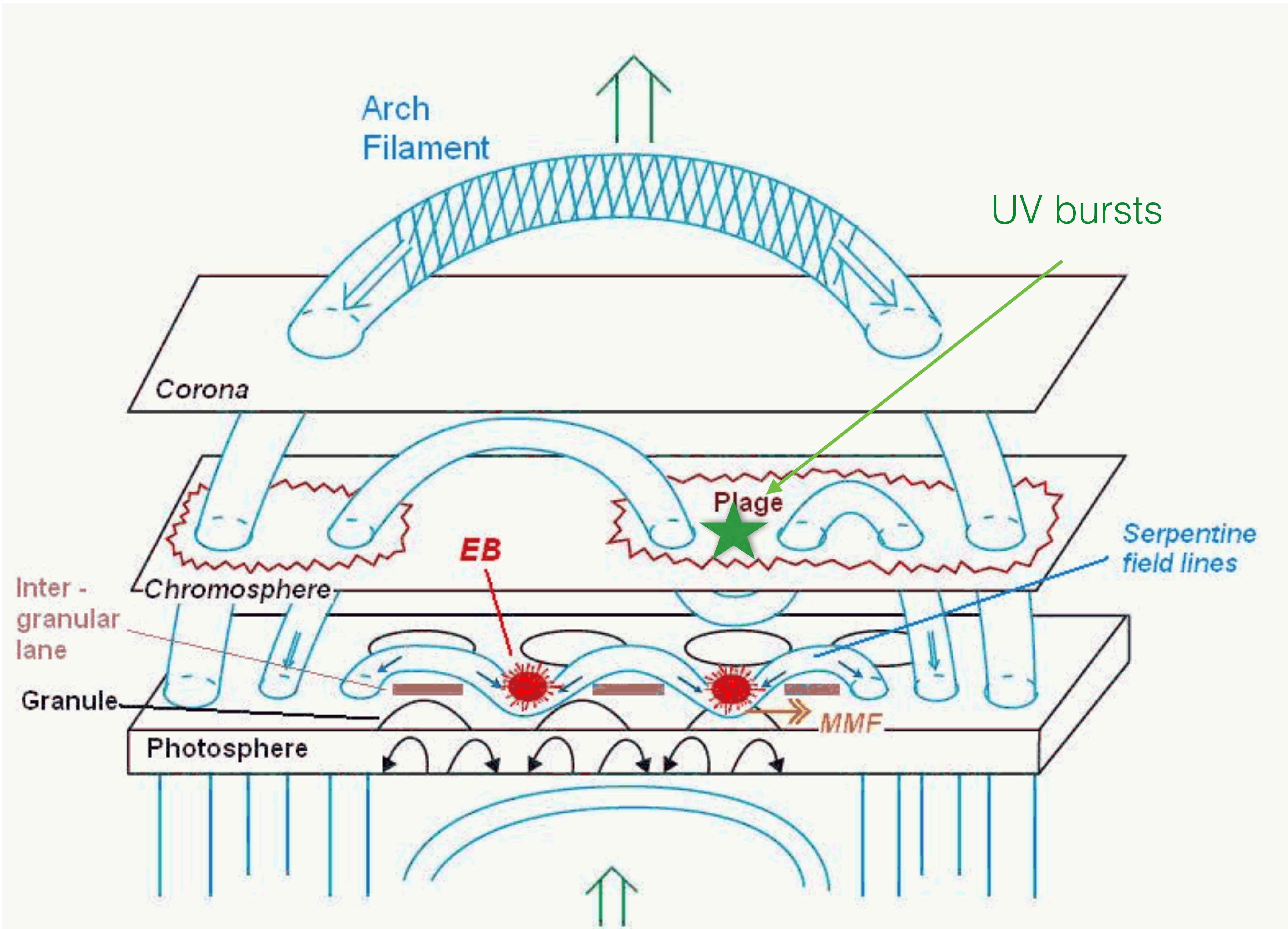
a) Hα wing 655.6 nm
b) Mg II wing 278.5 nm
c) Si IV total intensity
d) Magnetic field
e) Vertical velocity
f) Temperature
g) Hα core 656.3 nm
h) Mg II h core 279.6 nm
i) Hα
Mg II h
Si IV
EB
UV burst
y [Mm]
x [Mm]
Wavelength [nm]


z = 0 Mm
z = 1.3 Mm
z = 1.8 Mm
EB
UV burst
small flare
log10(T) [K]
uz [km/s]
log10(QJoule/ρ) [MW/kg]
a
b
c
d
e
f
g
h
i
t = 9160.0 s
t = 7929.9 s
t = 9250.0 s
y [Mm]

Hα line
+0.5 Å
μ = 1.0
Formation
of fibrils



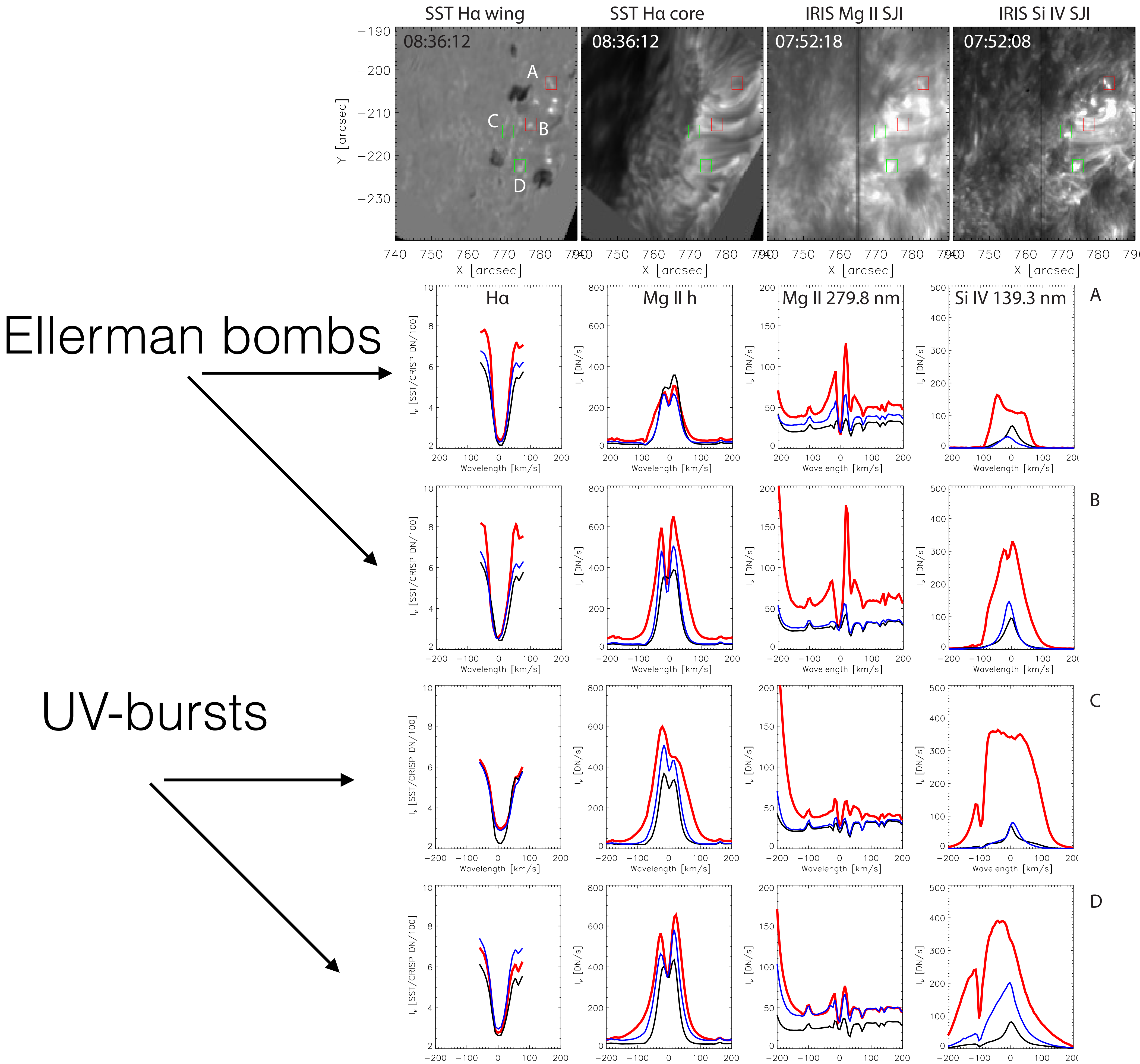
…complex evolution as field and plasma rise into outer



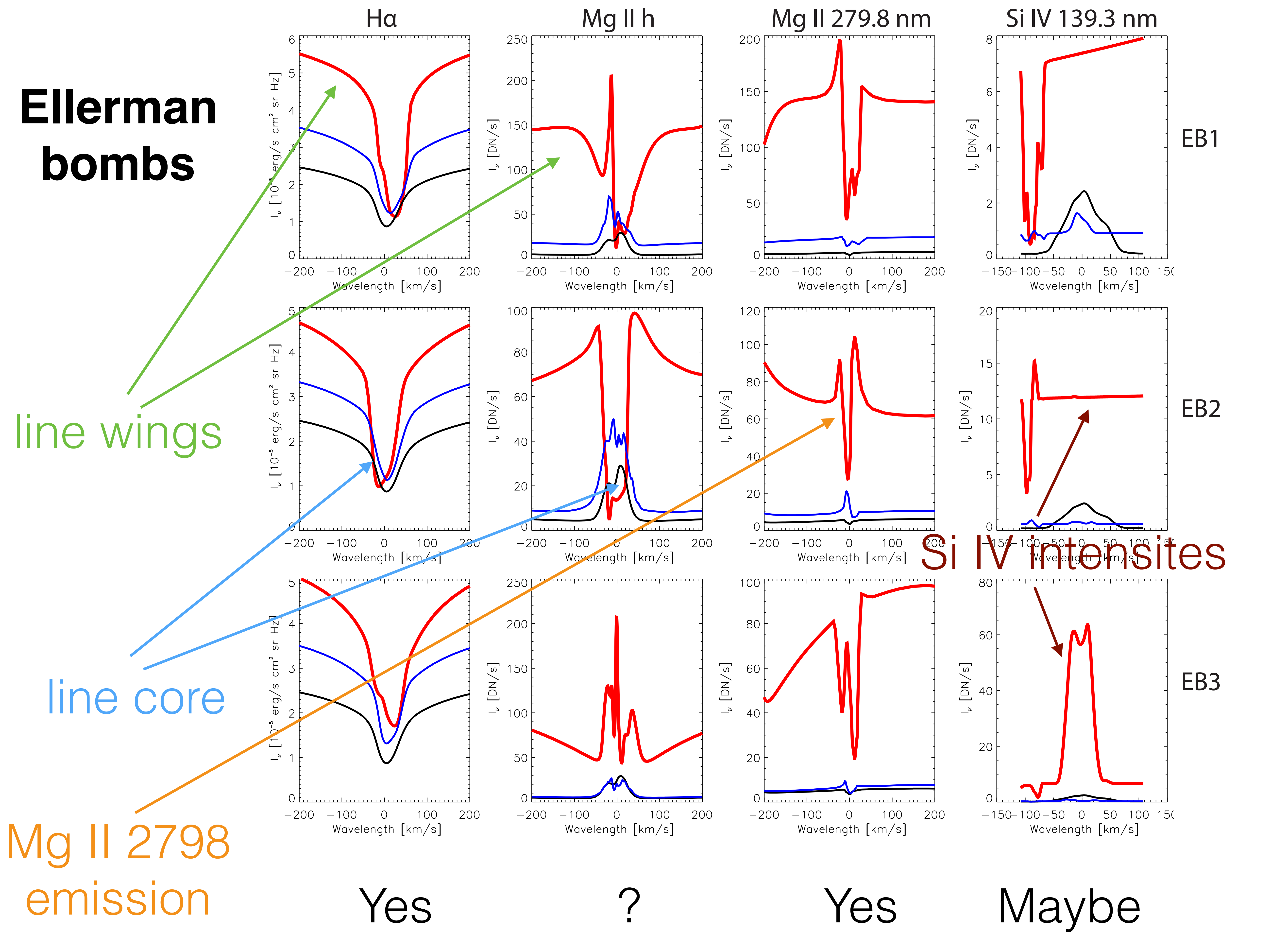
Schmieder & Pariat 2007 Scholarpedia 2(12):4335 (Shibata's cartoon, slightly modified)

Discussion/Summary

- Flux emergence carries high density cold material high into chromosphere.
- “Ellerman bombs” reproduced through reconnection at photospheric level.
- Temperature rise of some 2-5000 K above photosphere.
- Large velocity (20 km/s in photosphere) jet.
- Hα emission looks right, little Si IV emission from photospheric EB.
- “Hierarchical” reconnection/jets as field expands into corona forming long fibrils/coronal loops - UV bursts (and Hα microflares?) arise at chromospheric heights (“level 2”)?
- Densities high enough even at 2000 km to reproduce measured Si IV intensities.
- “Level 2” jet velocities of order 200 km/s or higher.

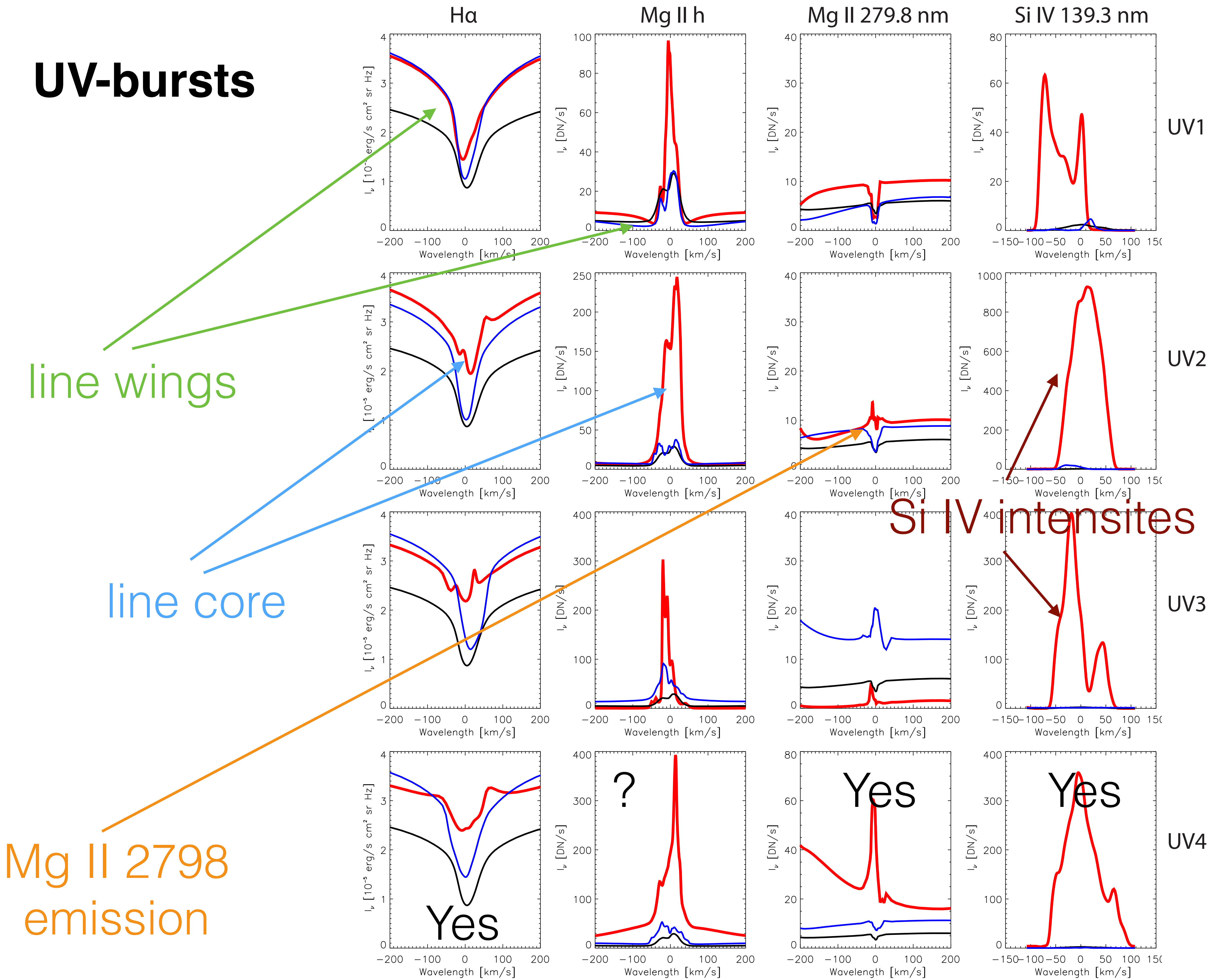


SST Hα wing
SST Hα core
IRIS Mg II SJI
IRIS Si IV SJI
08:36:12
08:36:12
07:52:18
07:52:08
A
B
C
D
Y [arcsec]
X [arcsec]
Ellerman bombs
UV-bursts
Hα
Mg II h
Mg II 279.8 nm
Si IV 139.3 nm
Wavelength [km/s]
I [SST/CRISP DN/100]
I [DN/s]



Ellerman bombs
Hα
Mg II h
Mg II 279.8 nm
Si IV 139.3 nm
EB1
EB2
EB3
line wings
line core
Mg II 2798 emission
Si IV intensites
Wavelength [km/s]
I_ν [10⁻⁵ erg/s cm² sr Hz]
I_ν [DN/s]
Yes
?
Yes
Maybe

UV-bursts


Hα
Mg II h
Mg II 279.8 nm
Si IV 139.3 nm
UV1
UV2
UV3
UV4
line wings
line core
Mg II 2798 emission
Si IV intensites
Yes
?
Yes
Yes
I_ν [10^{-5} erg/s cm² sr Hz]
I_ν [DN/s]
Wavelength [km/s]