High resolution analysis of a magnetic bubble emerging through the solar atmosphere

Ada Ortiz[1]
Luis Bellot Rubio[2]
Viggo H. Hansteen[1]
Jaime de la Cruz Rodriguez[3]
Luc Rouppe van der Voort[1]

[1]Institute of Theoretical Astrophysics, UiO, Oslo
[2]Instituto de Astrofisica de Andalucia (CSIC), Granada
[3]Dept. Physics and Astronomy, Uppsala U.

Hinode 7

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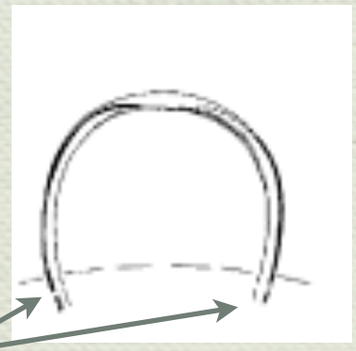
Present work:

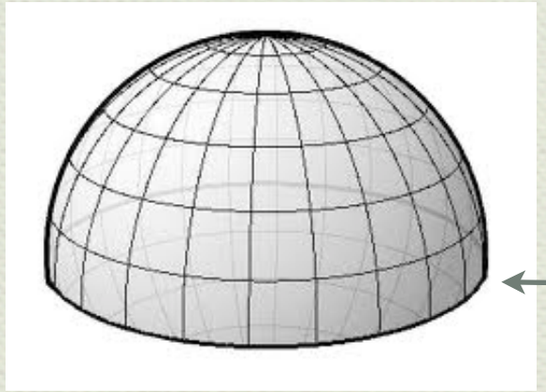
- Granular-size flux emergence events inside an AR at **very high resolution**.
- These events are different from others reported in the literature: not loop shaped, but have a 3D **semi-spherical** shape.

Magnetic loop



VS.

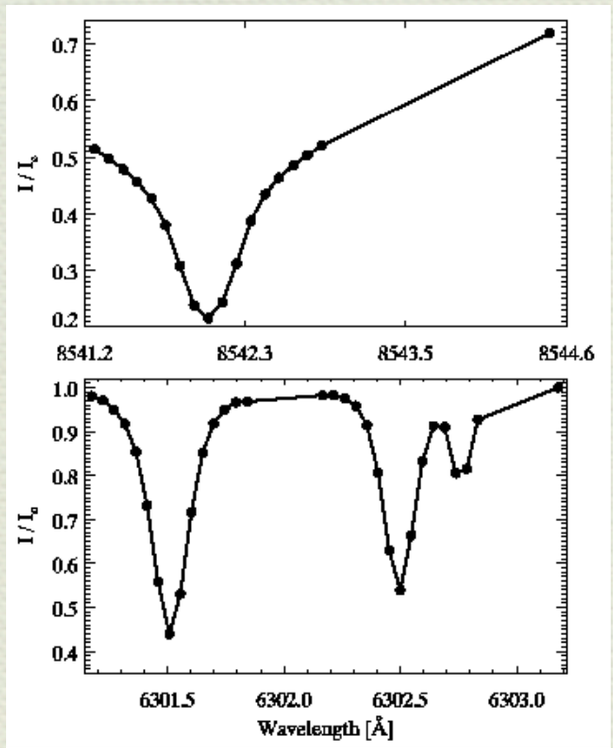
Magnetic "bubble"



- Numerous phenomena occur simultaneously to the emergence of the magnetic bubble:
  - abnormal granulation,
  - separation of opposite polarities feet,
  - appearance of brightenings in Ca 8542,
  - ... and most remarkably appearance of a **dark bubble** in the wings of Ca 8542.

July 2009 campaign: spectropolarimetry

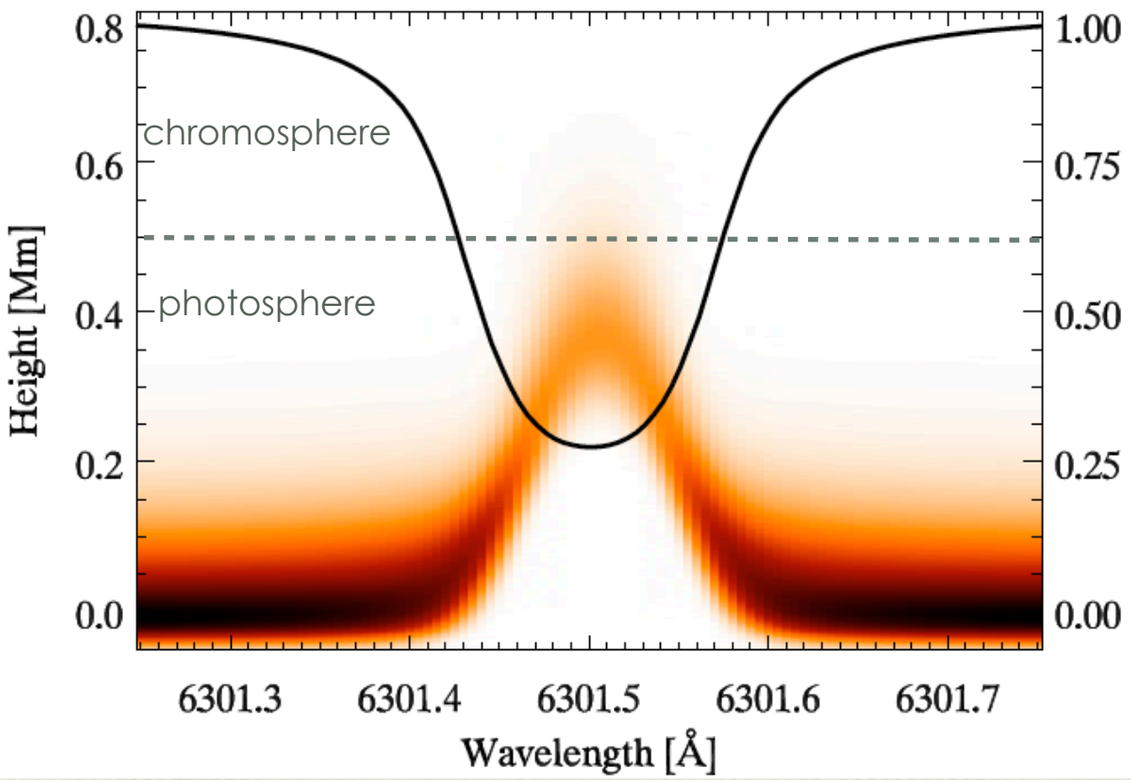
- CRISP @ 1-m SST: 5 July 2009
- Full Stokes scans of **Fe I 6301.5, 6302.5 Å** and **Ca II 8542 Å**:
    - 15 + 15 + 1 point in the continuum (-336 to 336 mÅ)
    - 17 points + 1 point in the continuum at 2.4 Å (-800 to 800 mÅ)
- sampling = 48 mÅ for Fe I
- sampling = 100 mÅ for Ca IR
- 9 frames/ pol. state
- time interval to complete all scans: 61 s.
- FOV=60" x 60"
- image scale = 0.059"/pixel



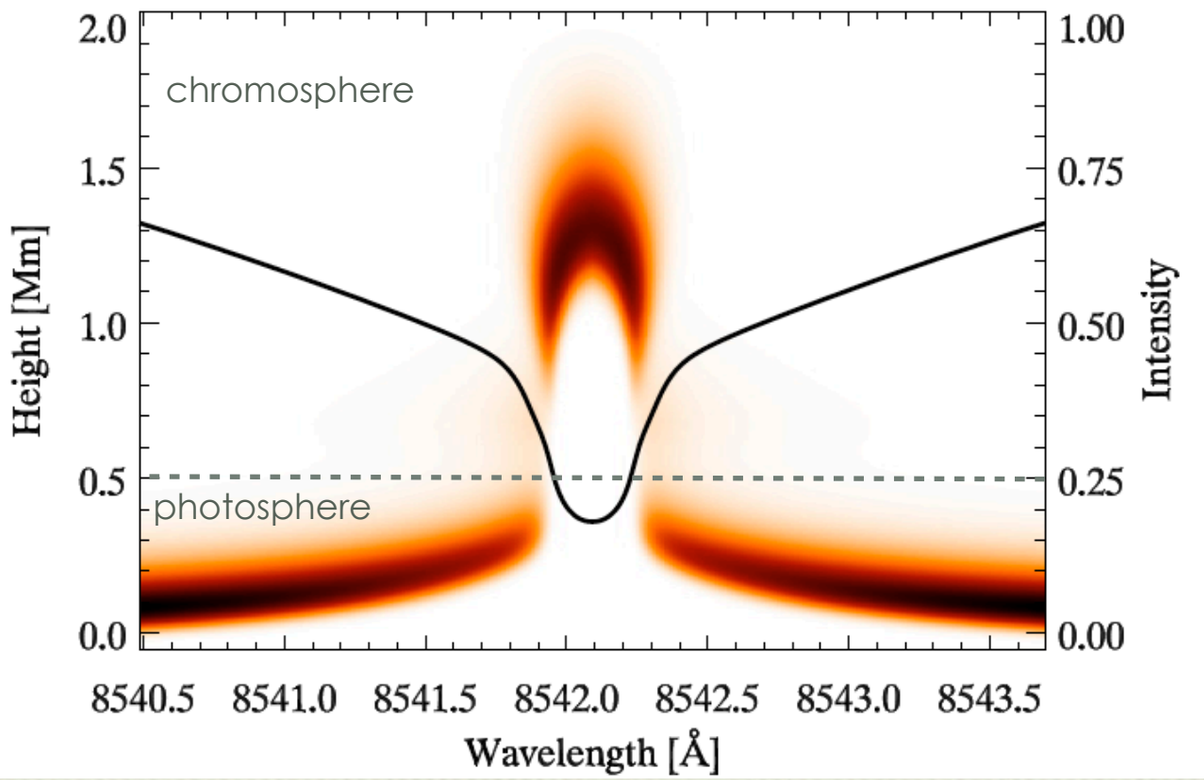
Nearly diffraction limited observations: 0.14" (at Fe I)

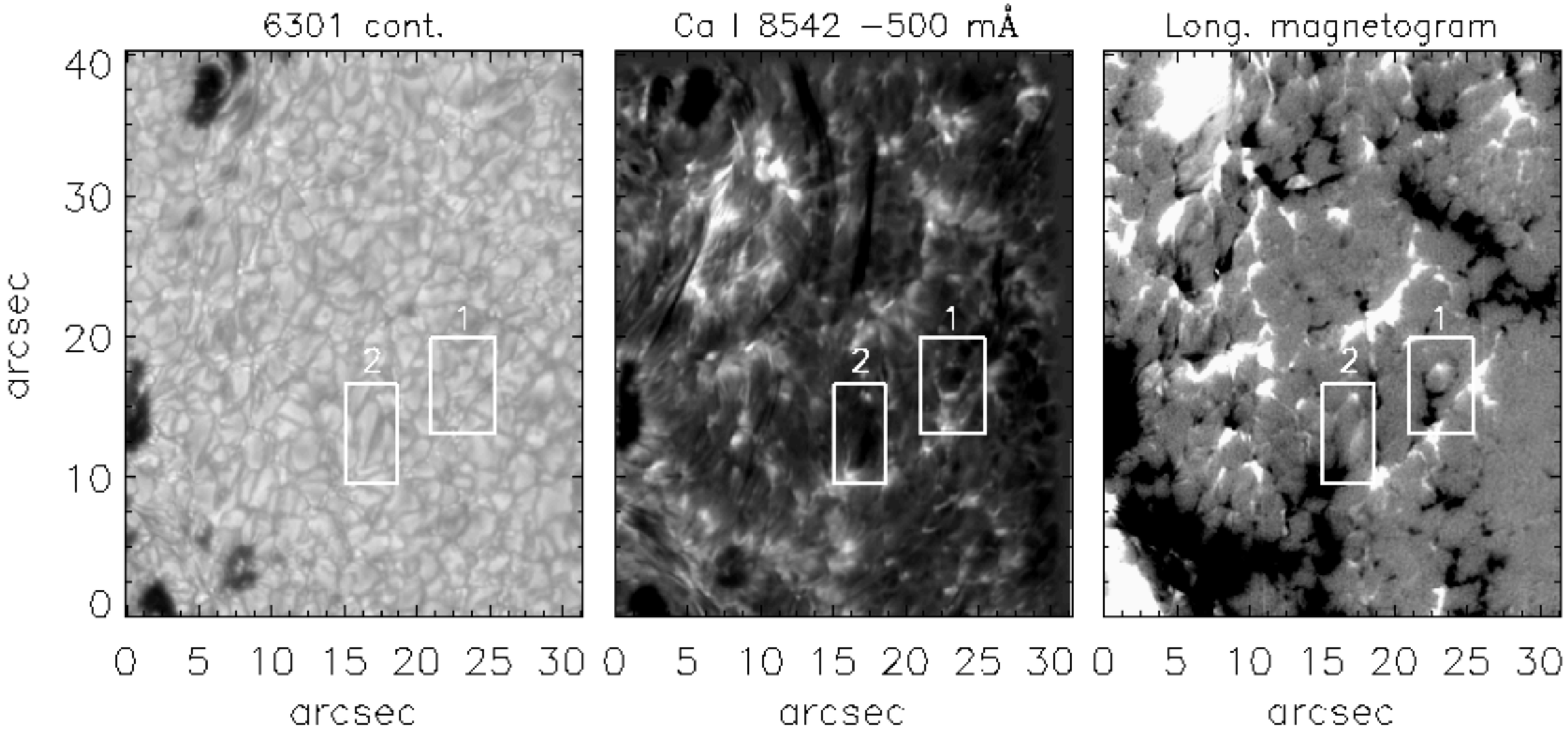
Which heights are we talking about?: Contribution functions for Fe I 6301 and Ca II 8542

Fe I 6301

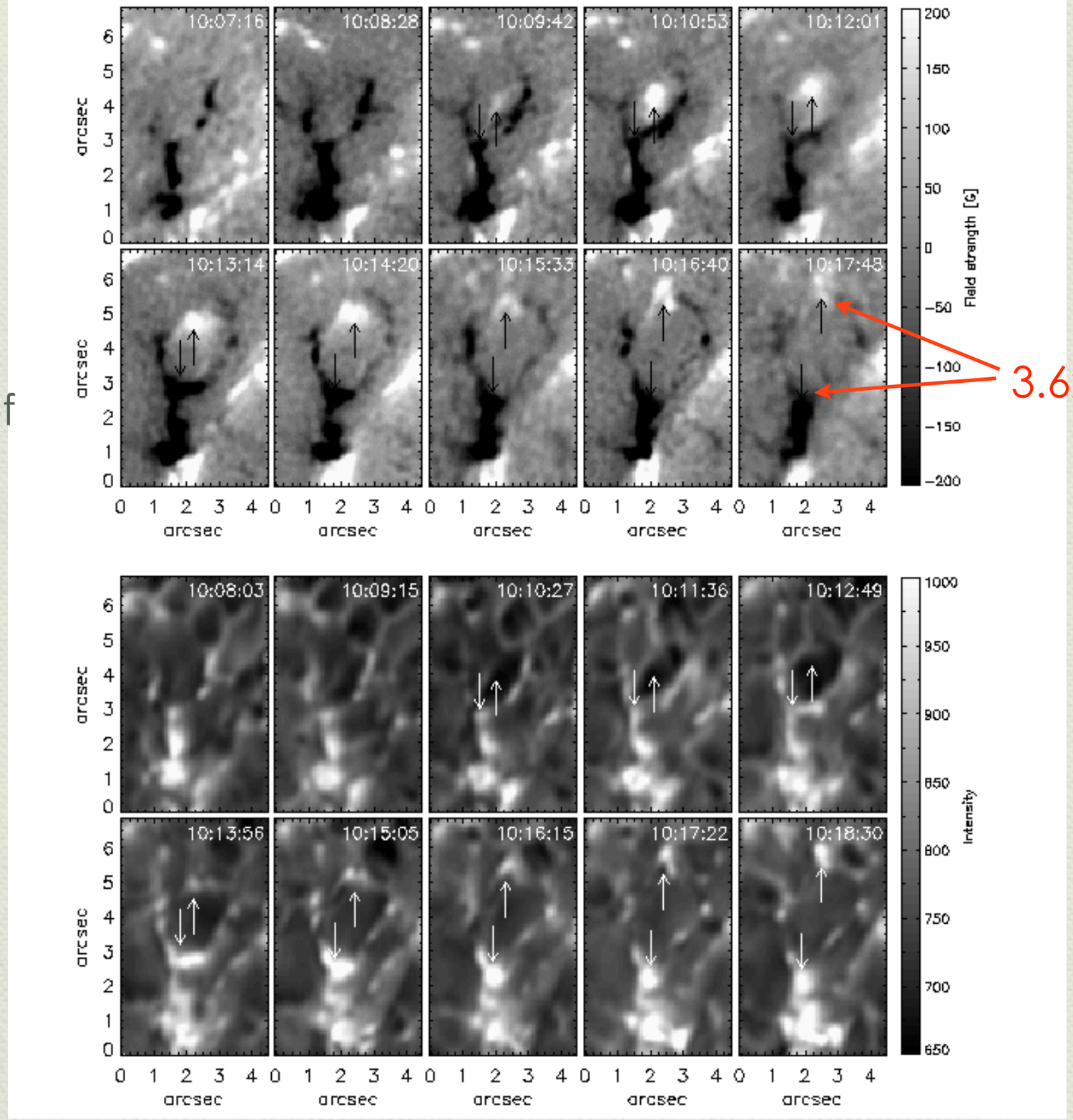


Ca II 8542




6301 cont.
Ca I 8542 −500 mÅ
Long. magnetogram
arcsec
0
10
20
30
0 5 10 15 20 25 30
arcsec
1
2

- Max. Speed of leg separation: 5km/s.



- Slowing down to 2.7 km/s

Dark bubble definition: Ca II 8542 -800 mÅ $<0.7I_C$

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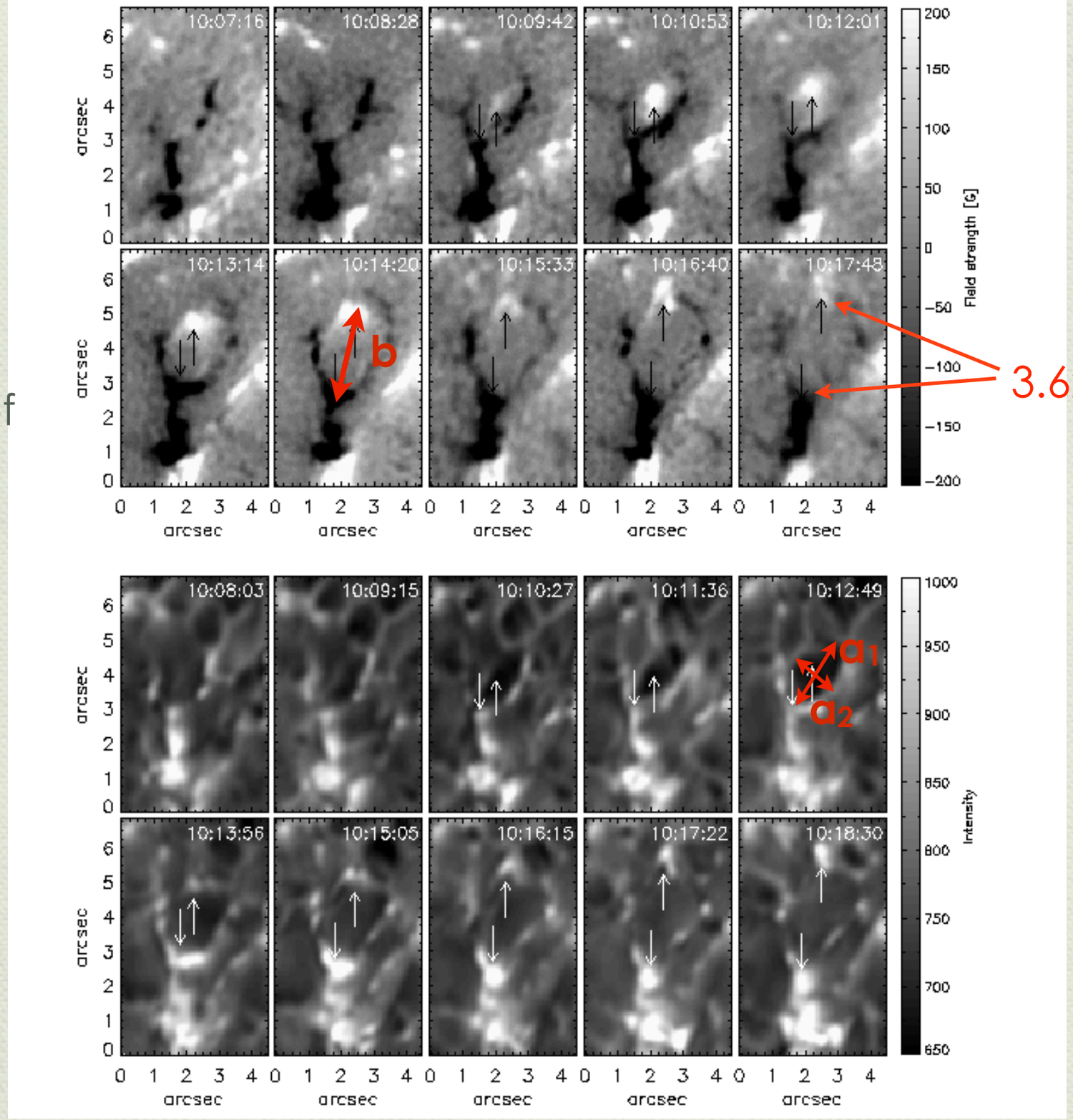

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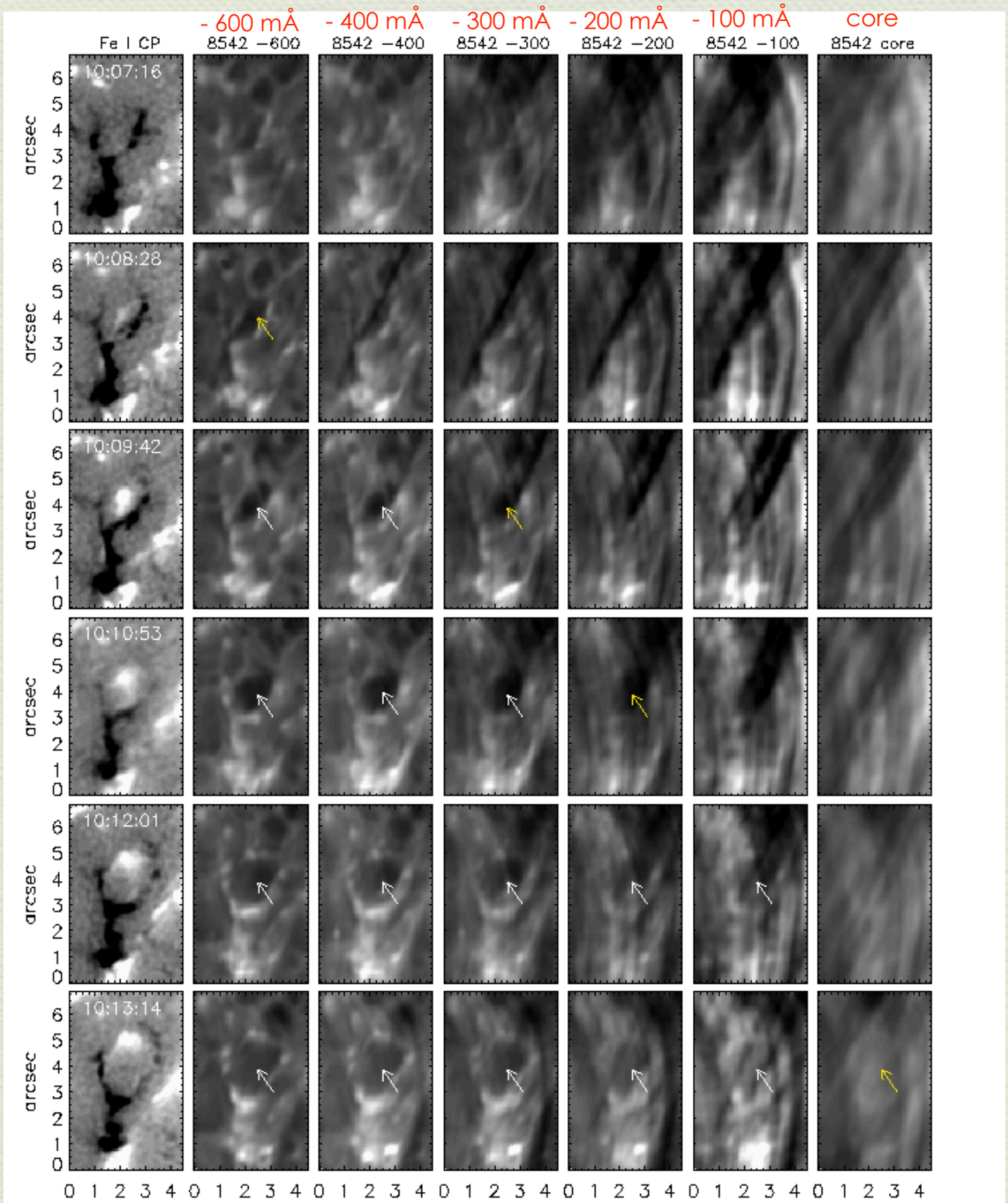
Dark bubbles

Wavelength

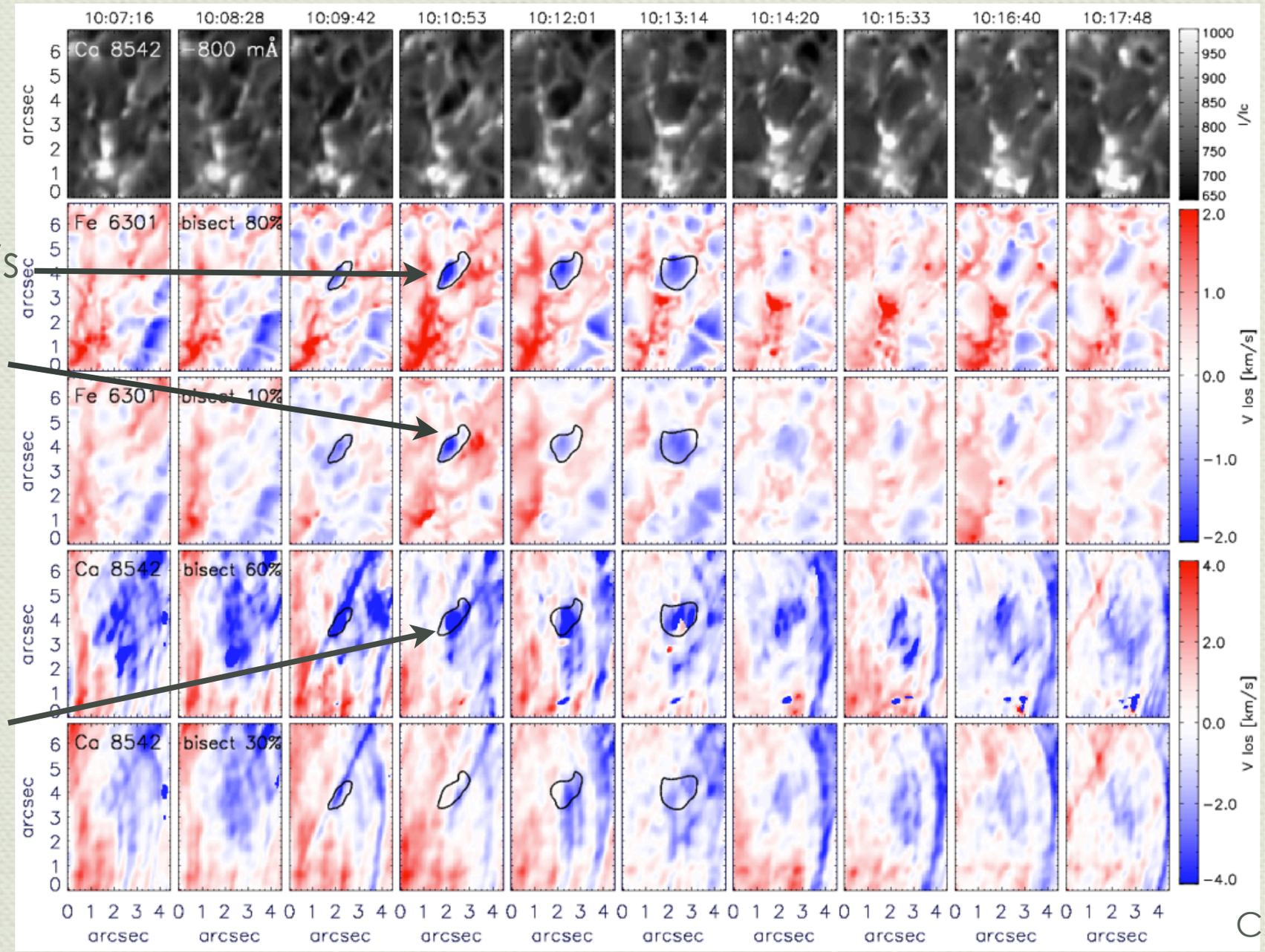
Photosphere → Chromosphere

Time: 6 minutes
1 min. / time step



Velocities

Time



upflow: -2.4 km/s

upflow: -2 km/s

downflows:
2-3.5 km/s

chromospheric
upflows: -5 km/s

Height

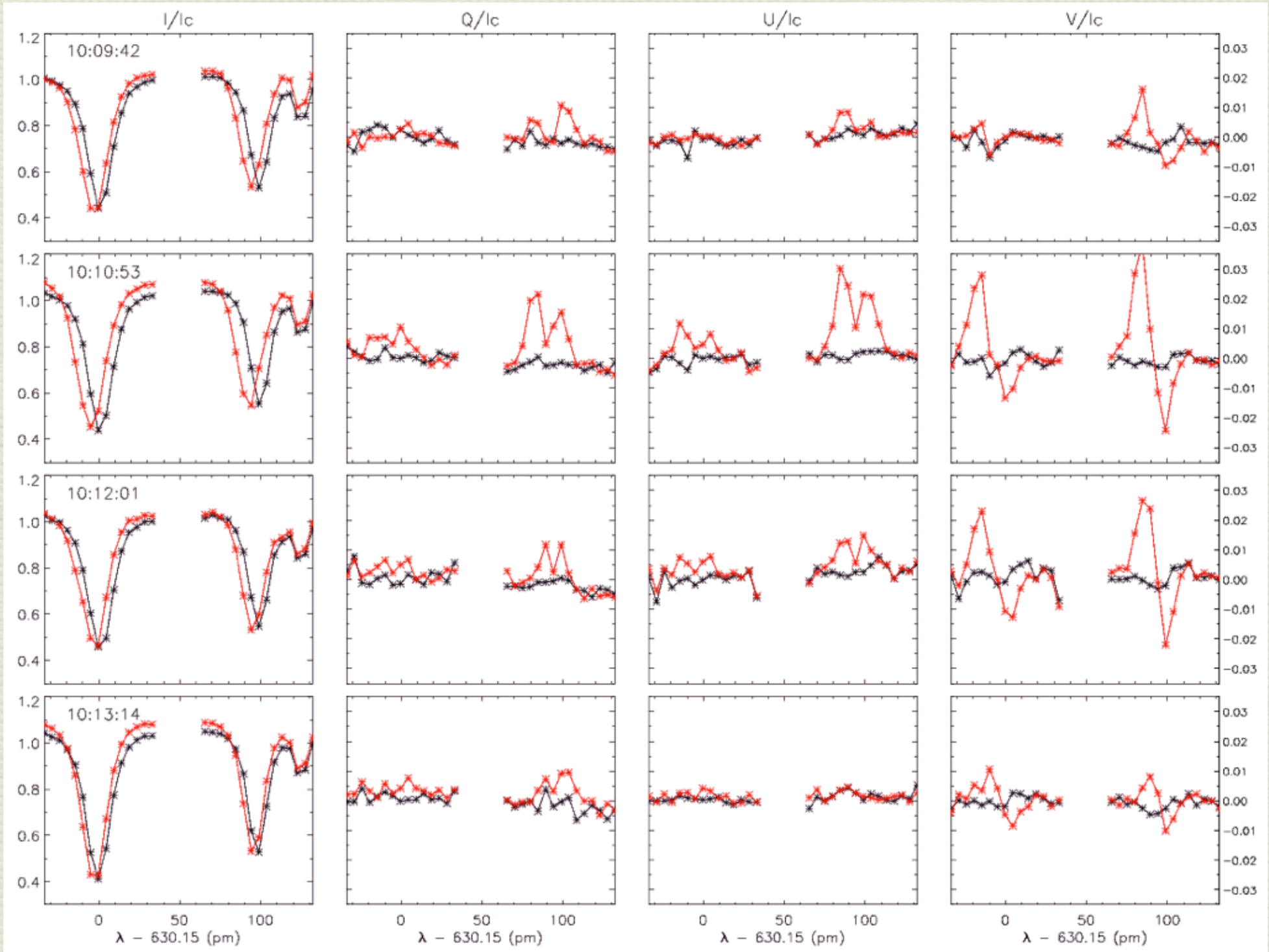
Photosphere

Chromosphere

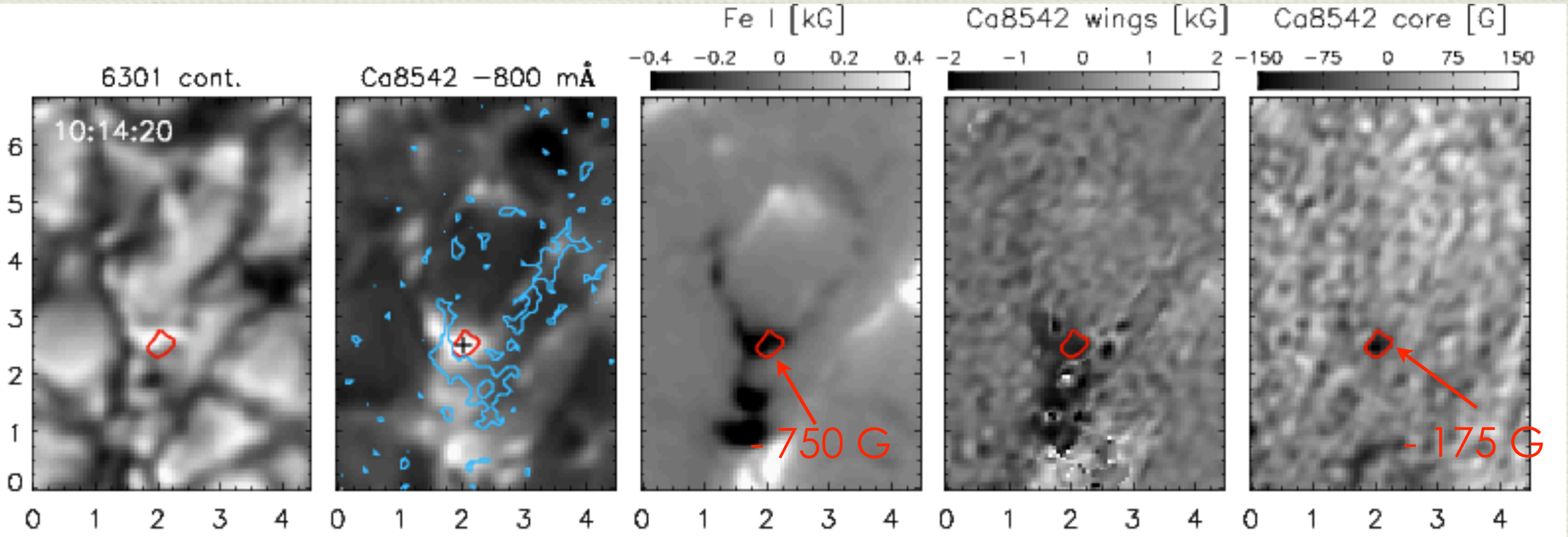
Inside vs. outside

Fe I 6301

Outside dark bubble
Inside dark bubble

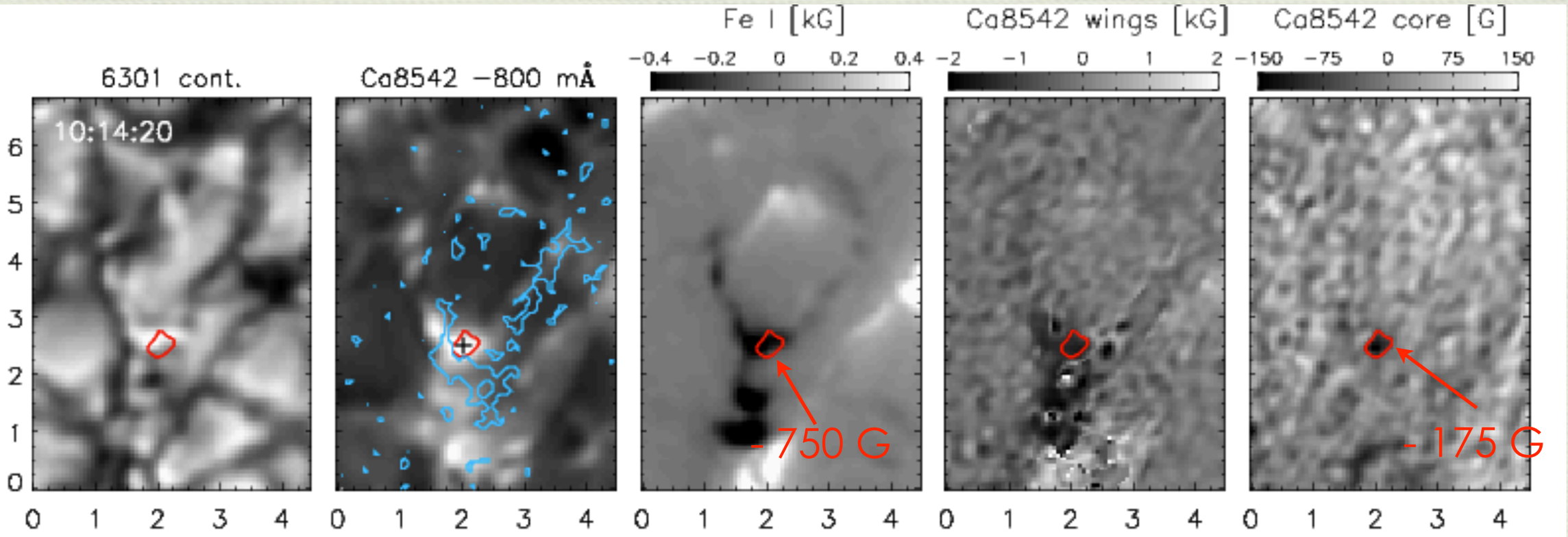


Chromospheric field



- No Q or U signals in Ca II 8542. Only Small V signals.
- Chromospheric field obtained through **weak field** approximation (Zeeman < broad.). Max field retrieved = - 175 G
- Photospheric field from SIR inversion. Max. field retrieved = - 750 G
- We can follow the magnetic bipolar feet from the photosphere to the high chromosphere. **Same** polarity in both layers with **exceptions** (blue contours). Change in polarities = emission profiles?

Chromospheric field



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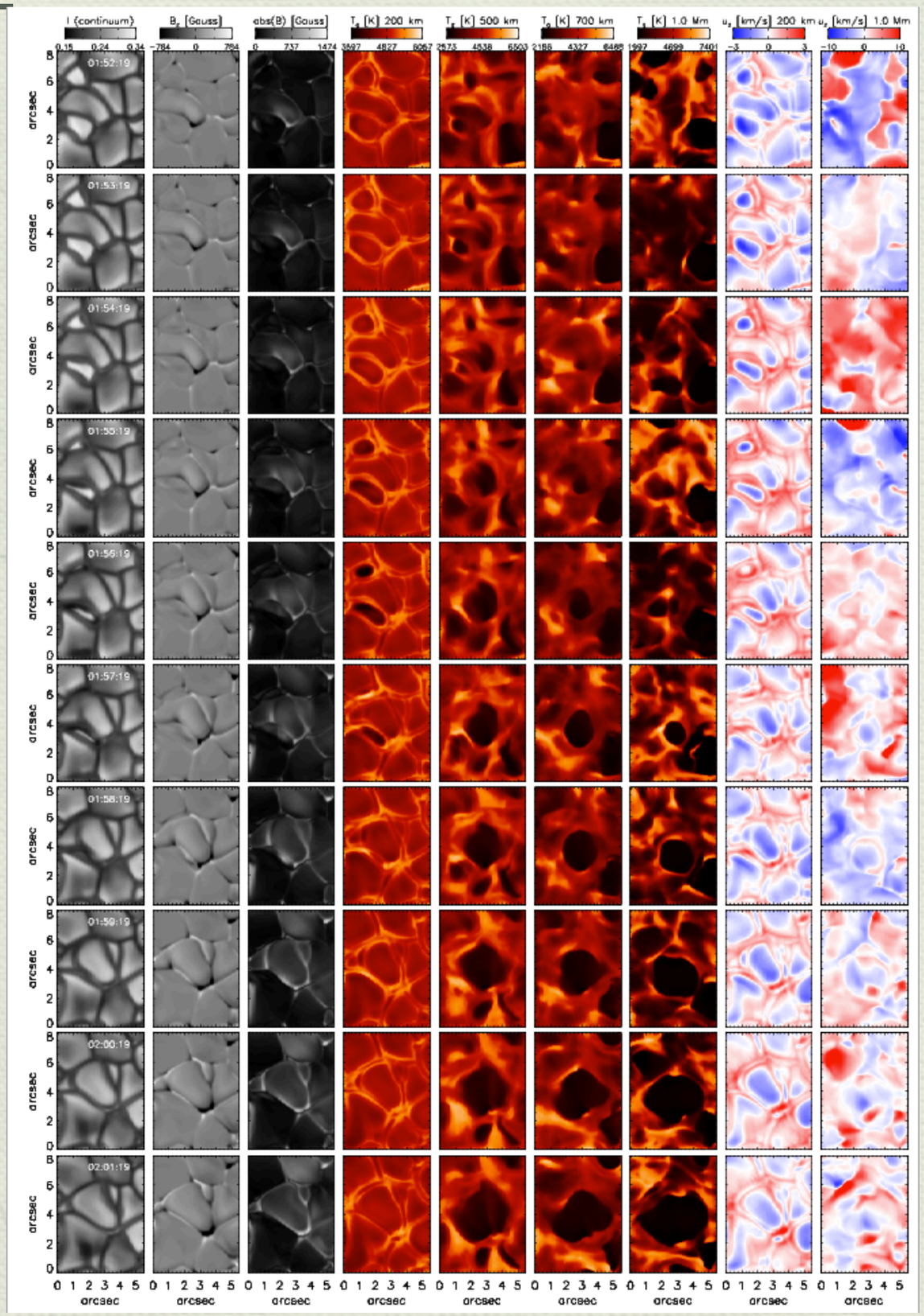
Strong flows!! Strong heating??

Simulations

Time: 9 minutes

1 min. / time step

Height



- BIFROST: MHD+RT
- 24x24 Mm box
- Vertical range: -2.5 Mm to +14 Mm above
- 3360 G flux sheet injected at lower boundary for 105 min

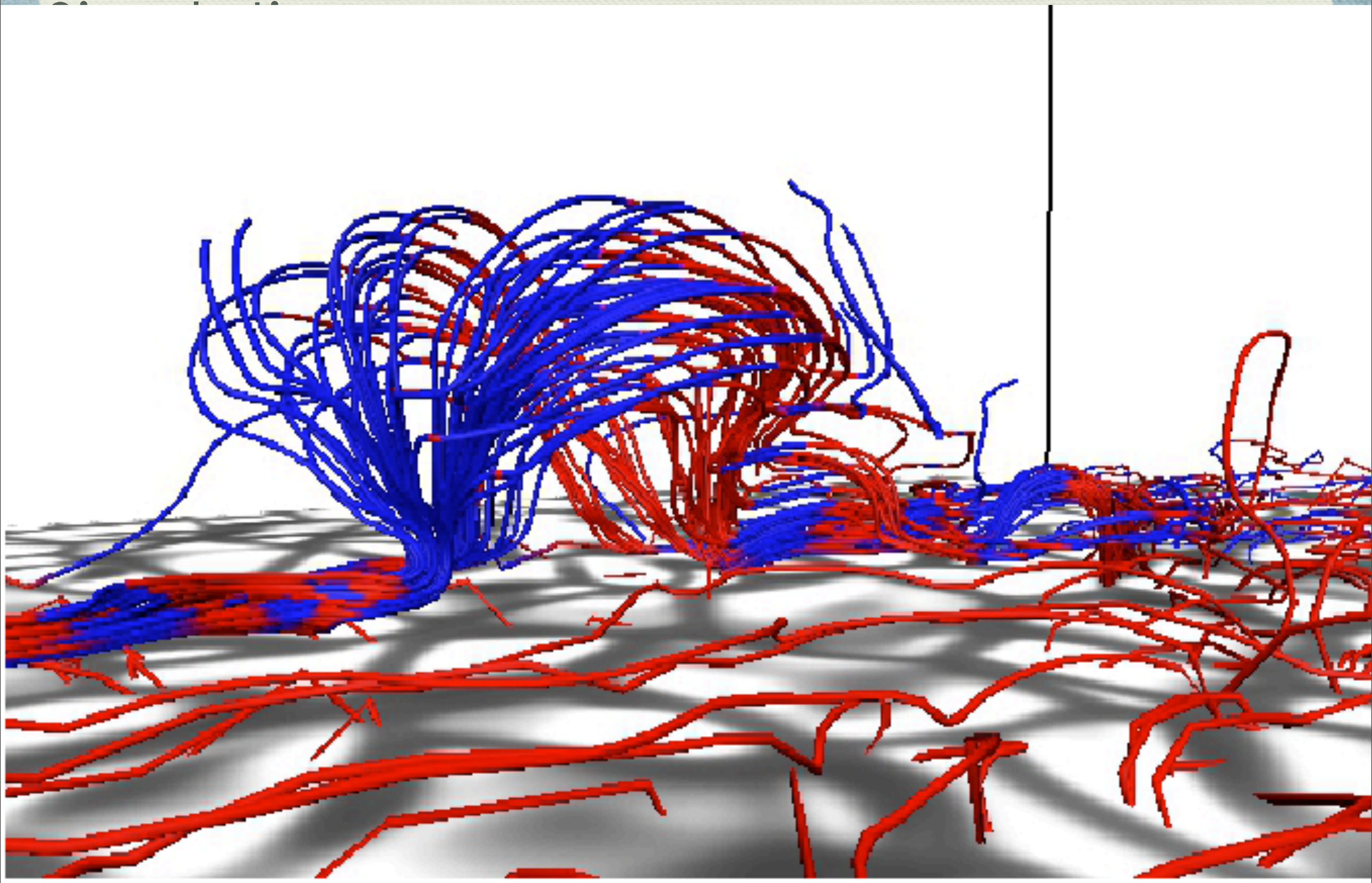
upflows (200 km): -3 km/s

upflows (1000 km): -10 km/s

- 1200 G < B_{long} < 600 G

B_{long} (700 km) ~ 100 G

T bubble (1000km)< 2000 K

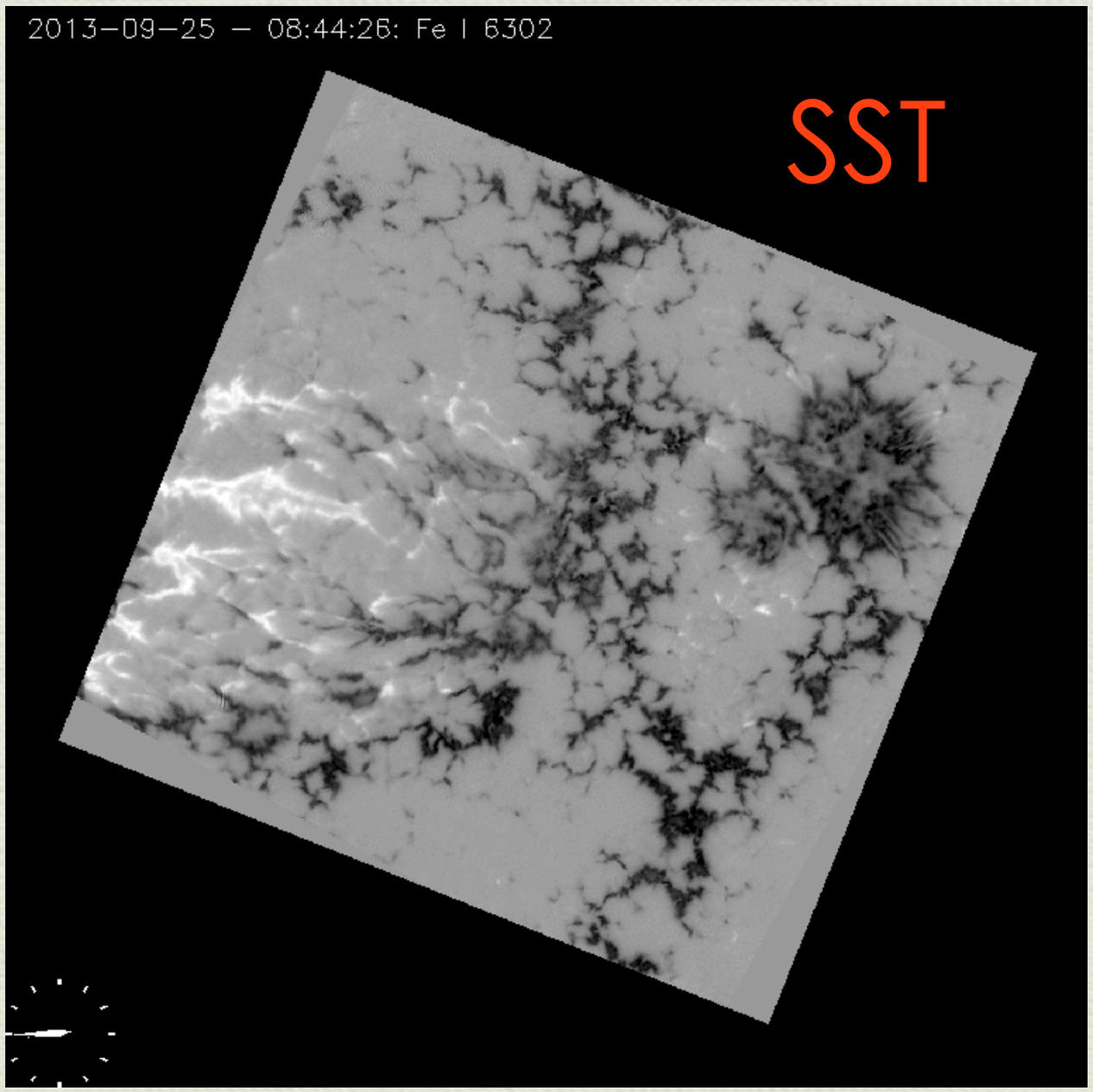


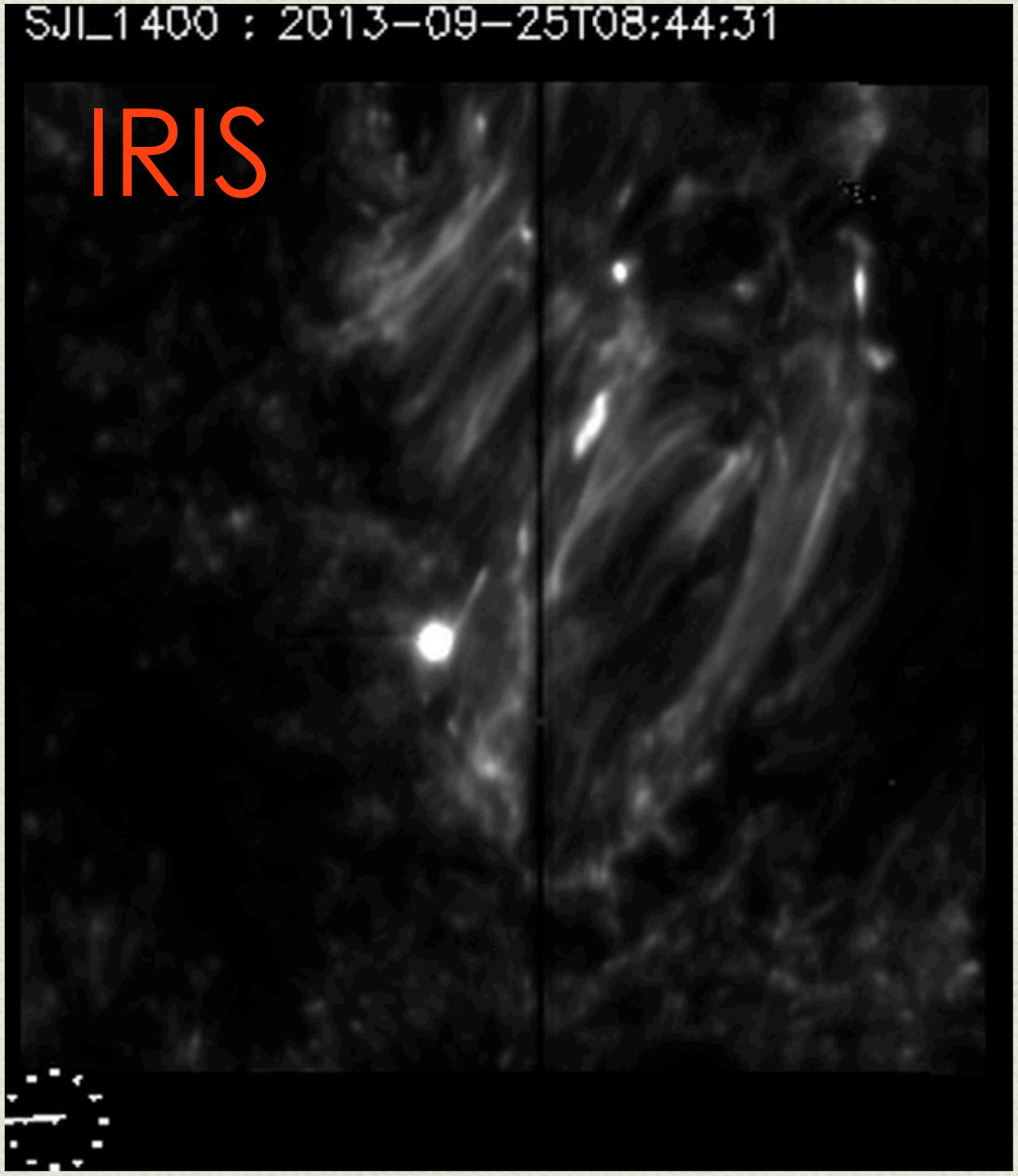
Conclusions, so far ....

- We have observed granular size flux emergence events inside AR at **very high resolution** and at **different layers** in the solar atmosphere.
- Several phenomena are observed: abnormal granulation, separation of opposite polarity feet, brightenings, but ...
- **Novelty**: appearance of a **magnetized dark bubble** that rises through the atmosphere. Observed **from the wings to the core** of Ca II 8542.
- Observed previously by simulations of Martinez-Sykora et al. 2008 and Tortosa Andreu & Moreno Insertis 2009. Realistic numerical simulations of flux emergence events **can reproduce** the dark bubble properties: diameter, time of formation, velocities and magnetic fields.

Coming soon to a theater near you!

This season ...
the most awaited romance





2013 SST - IRIS coordinated campaign: flux emergence