SLOVAK RESEARCH AND DEVELOPMENT AGENCY

Chromospheric evidence of a small-scale loop emerging in the quiet Sun

P. Gömöry[1], H. Balthasar[2], K.G. Puschmann[2]

1) Astronomical Institute, Slovak Academy of Sciences, Slovakia
2) Leibniz-Institut für Astrophysik Potsdam (AIP), Germany

3rd International workshop on small scale solar and stellar magnetic fields
Bairisch Kölldorf, April 3-5, 2013

Introduction

- small-scale loops emerging in the quiet photosphere have recently come to the center of attention
  - new generation of instruments providing data with very high spatial resolution and polarimetric signals
- fraction of these features can reach chromospheric heights and heat up sufficiently to be detected in e.g. Hα emission (Martínez González & Bellot Rubio 2009, Yurchyshyn et al. 2010)
- simulations indicate that the magnetic energy stored in the quiet photosphere is sufficient to balance chromospheric radiative losses (Trujillo Bueno et al. 2004, Isobe et al. 2008)
  → small-scale loops could be a good candidate for transport and dissipation of the magnetic energy to heat the chromosphere
  - Interesting possibility especially in the light of results showing a lack of total energy flux transported to the chromosphere by acoustic waves (Carlsson et al. 2007)
- simulations of magneto-convection (Stein & Nordlund 2006) predict that small-scale loops should disintegrate as they rise to the chromosphere
  → energy transport by small-scale loops should be implausible
- mentioned discrepancy → the main motivation for our study

Data

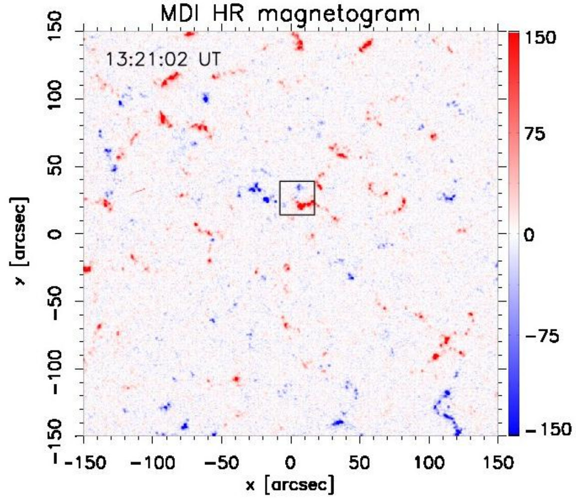
- target: quiet solar atmosphere near disk center
- date / time: October 25, 2005 / 13:17-13:56 UT

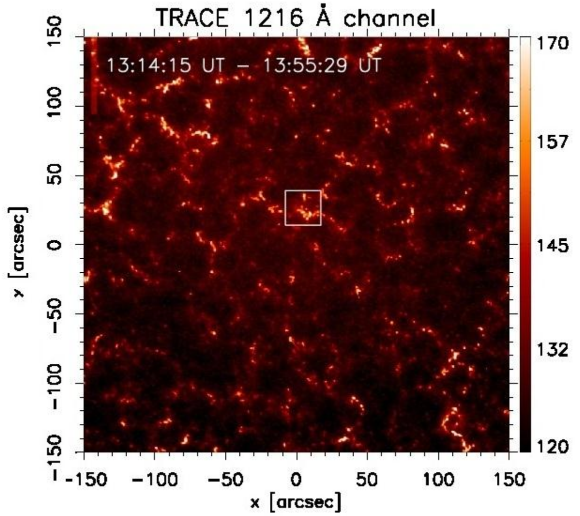
- SoHO/MDI data:
  - high-resolution magnetograms
  - spatial / temporal resolution: 0.6"×0.6“ / 1 min
  - no data between 13:45-13:53 UT

- TRACE data:
  - filtergrams taken in the 1216 Å channel
  - spatial / temporal resolution: 0.5"×0.5“ / ~45 s
  - **problem:** data from TRACE 1216 Å channel → not pure Lyα emission, contaminated by local UV continuum and longer wavelength emission → only ~60% of the recorded signal from Lyα line (Handy et al. 1999a)

    temperature coverage of the 1216 Å channel → $T[K] = 1.0\text{-}3.0 \times 10^4$, i.e. chromospheric temperatures

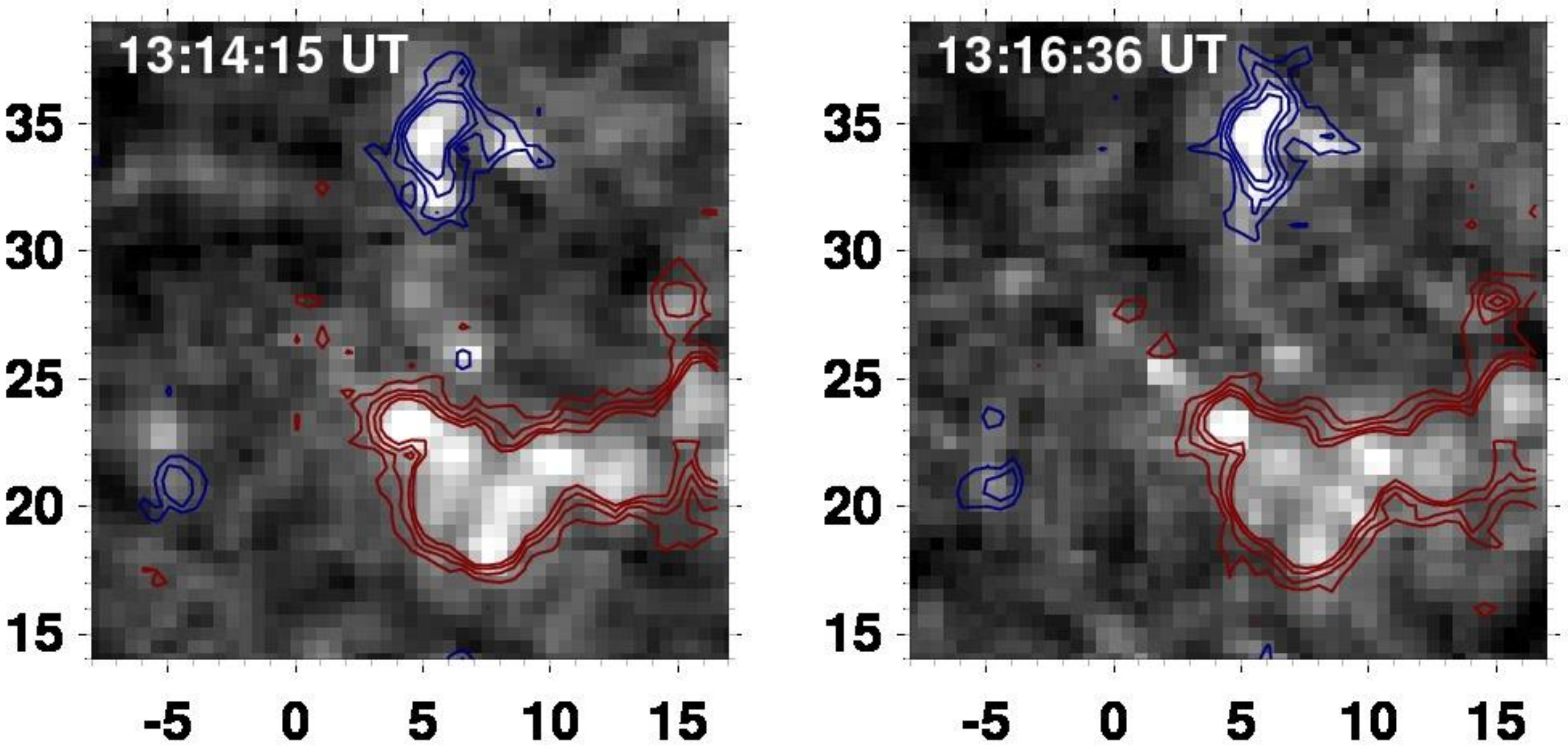
    1216 Å channel data used only as a proxy of chromospheric emission → no conclusions about absolute intensity changes





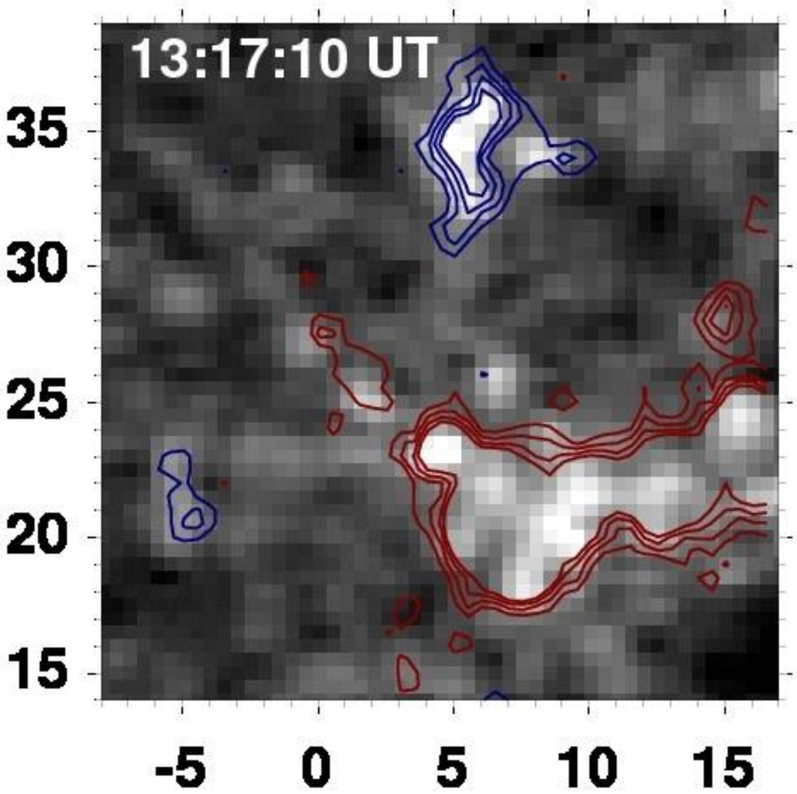
Results

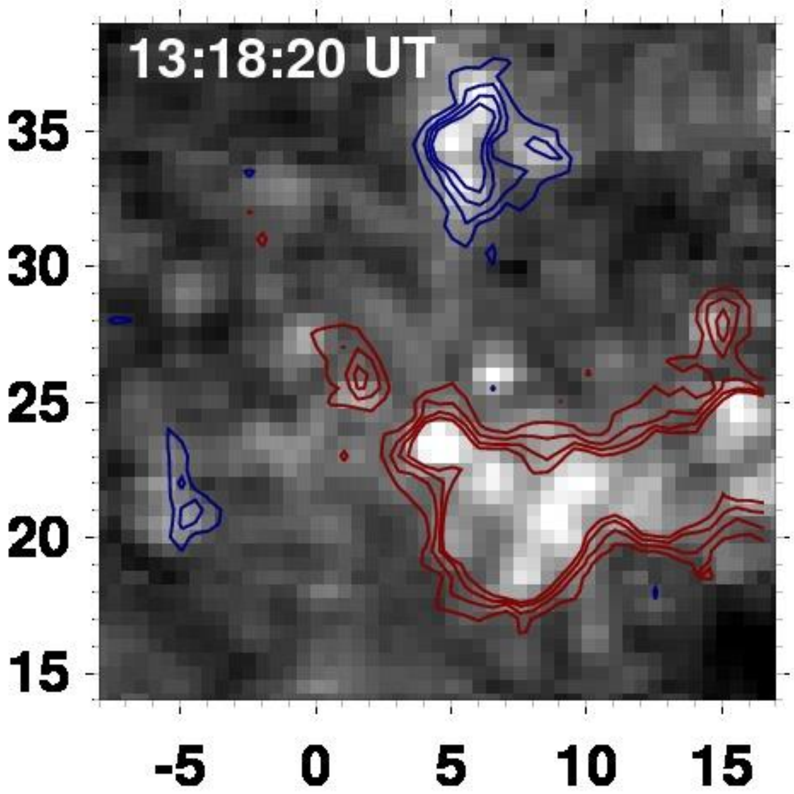
- temporal evolution of the emerging dipole:
  - 13:14:15-13:16:36 UT: pre-existing flux visible



Results

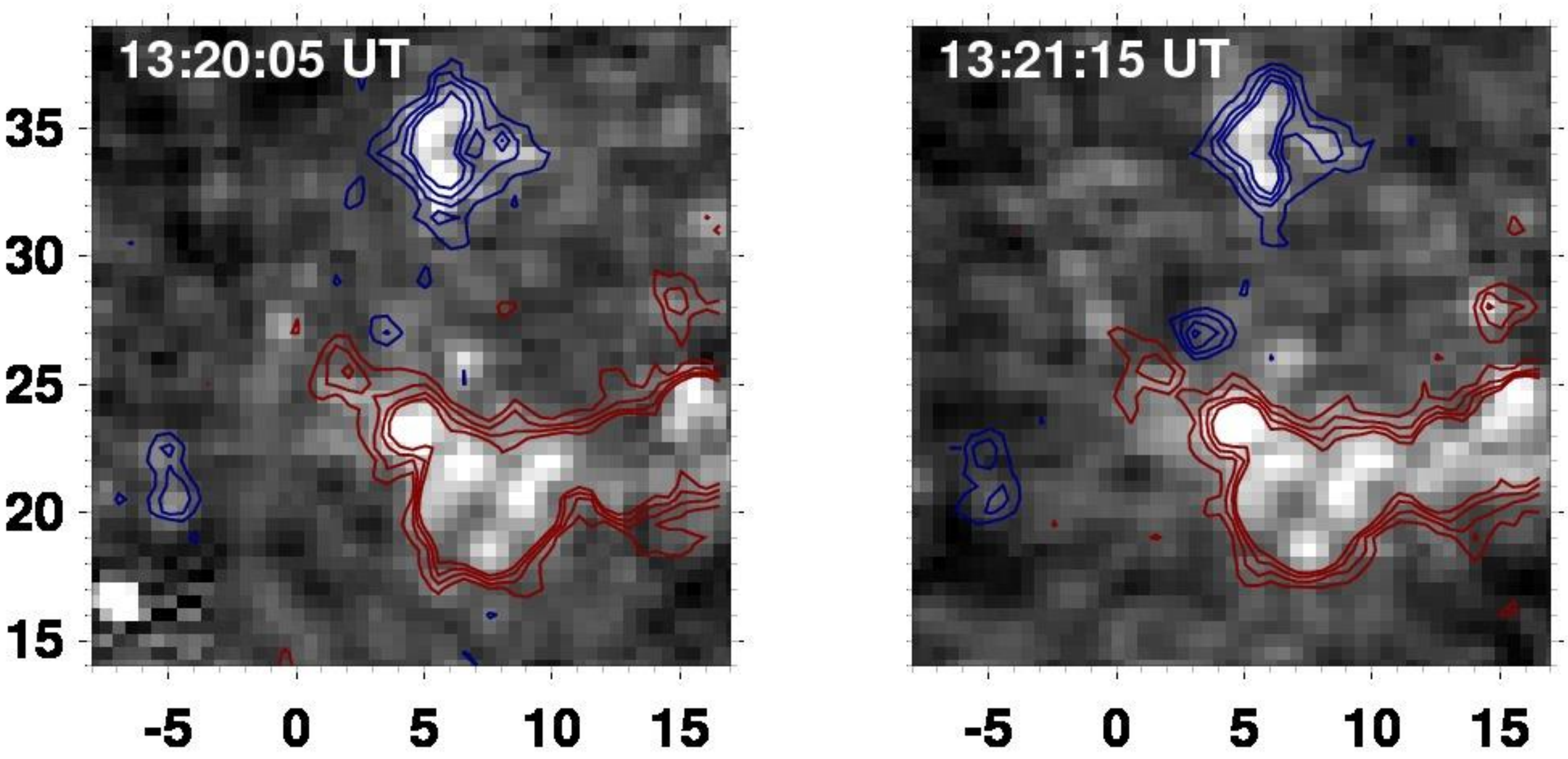
- temporal evolution of the emerging dipole:
  - 13:17:10-13:18:20 UT: patch of positive polarity appears





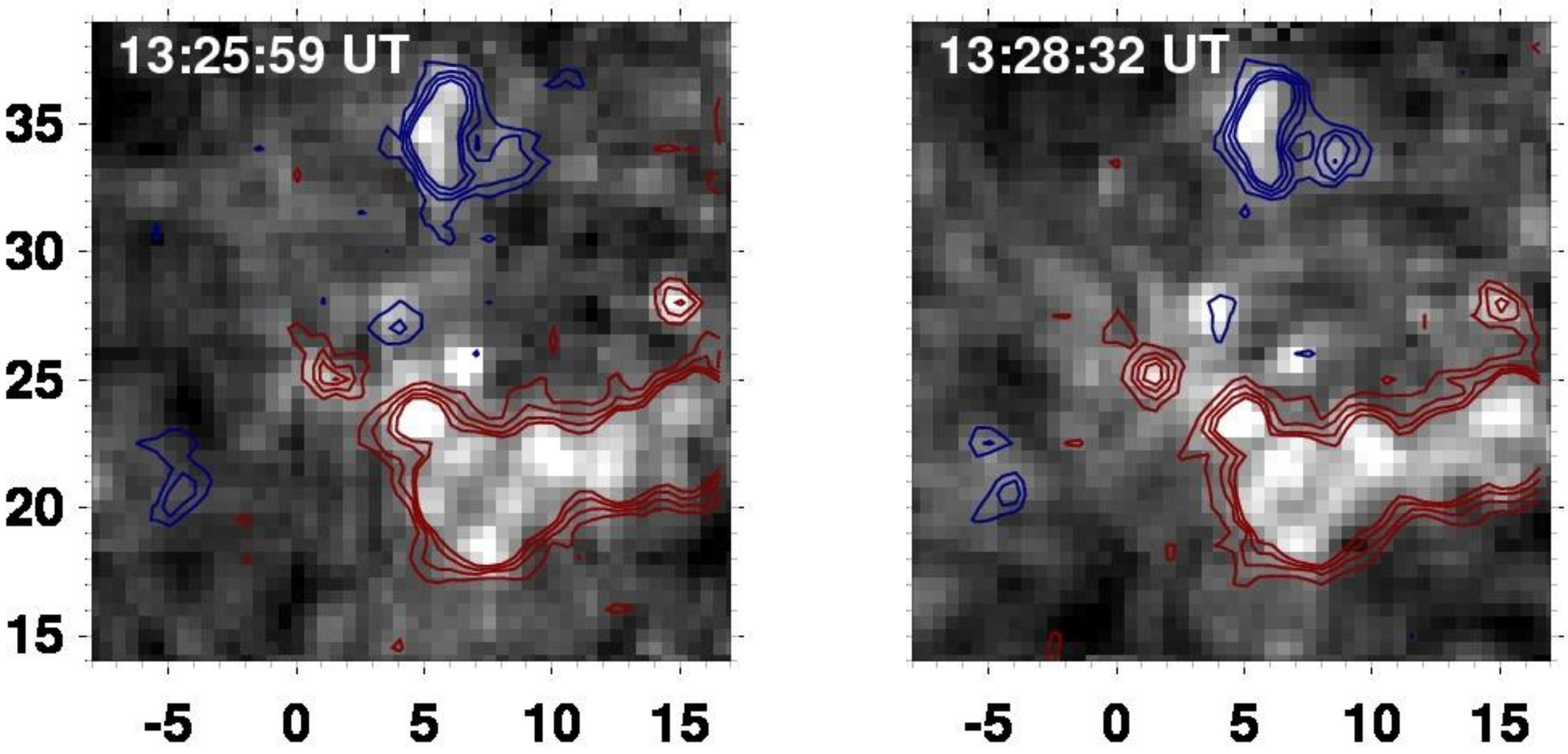
Results

- temporal evolution of the emerging dipole:
  - 13:20:05 UT: negative polarity becomes apparent
  - 13:21:15 UT: the new magnetic structure well visible → possible topology: emerging ∩-like loop or submerging U-like structure



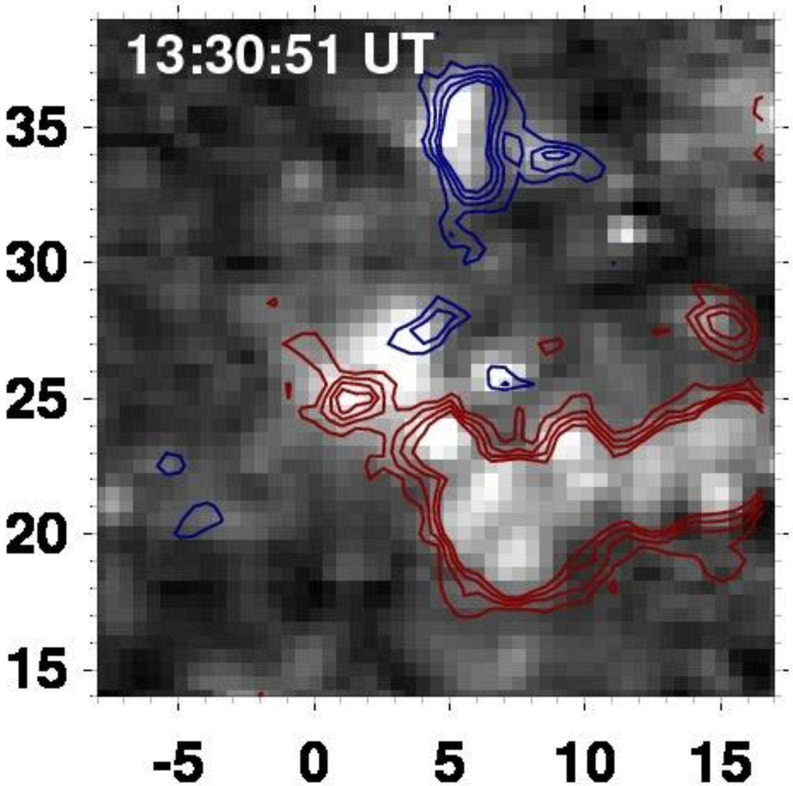
Results

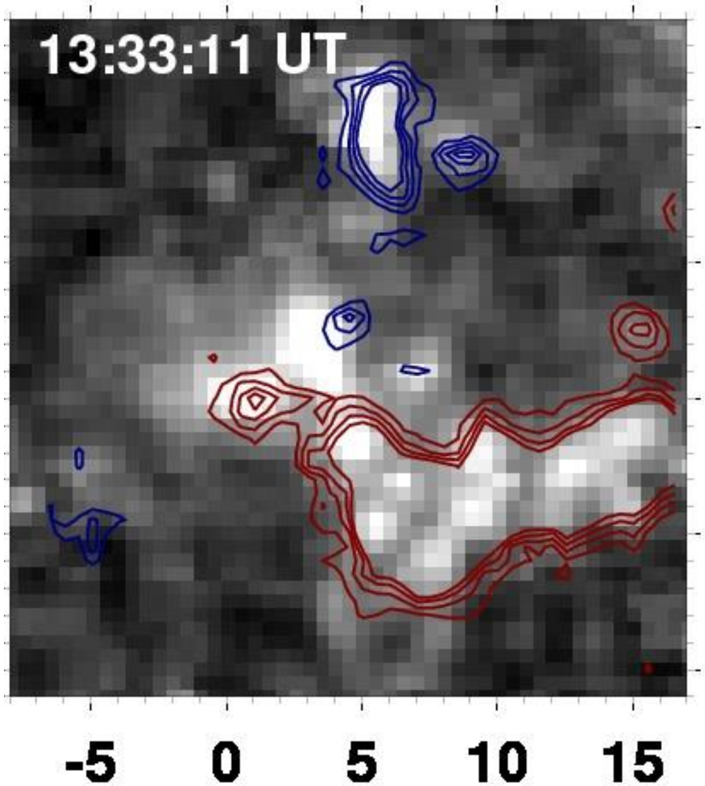
- temporal evolution of the emerging dipole:
  - 13:25:59 UT: chromospheric brightenings co-spatial with the new patch of negative polarity appear
  - 13:28:32 UT: enhanced chromospheric emissions visible also in regions covered by the patch with positive polarity



Results

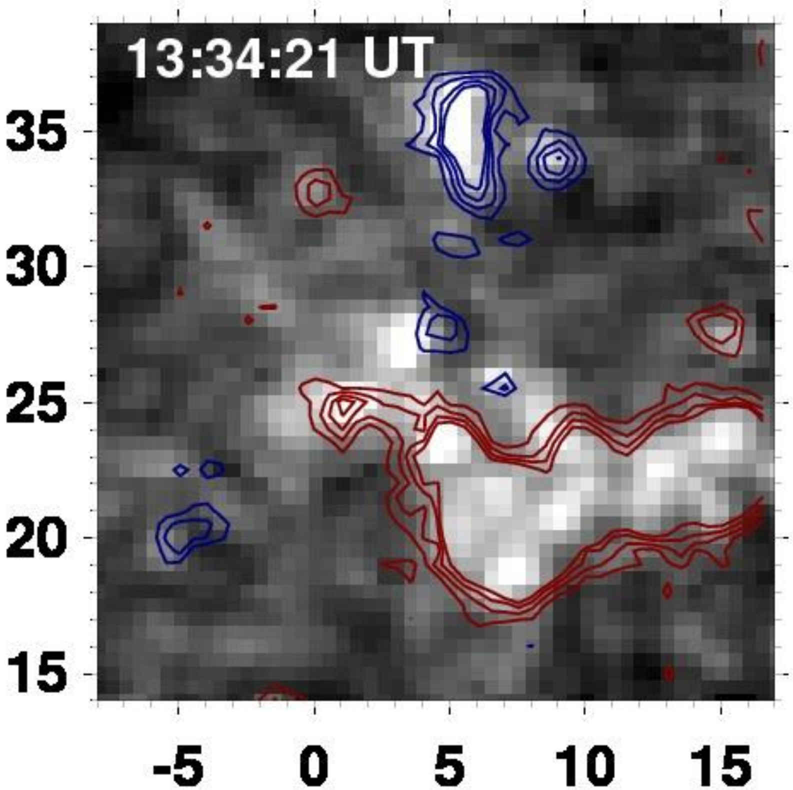
- temporal evolution of the emerging dipole:
  - 13:30:51-13:33:11 UT: enhanced chromospheric activity is already apparent along the whole axis of the new structure
  - 13:30:51 UT: onset of an interaction and consecutive merging of the positive polarity with the nearby located network boundary

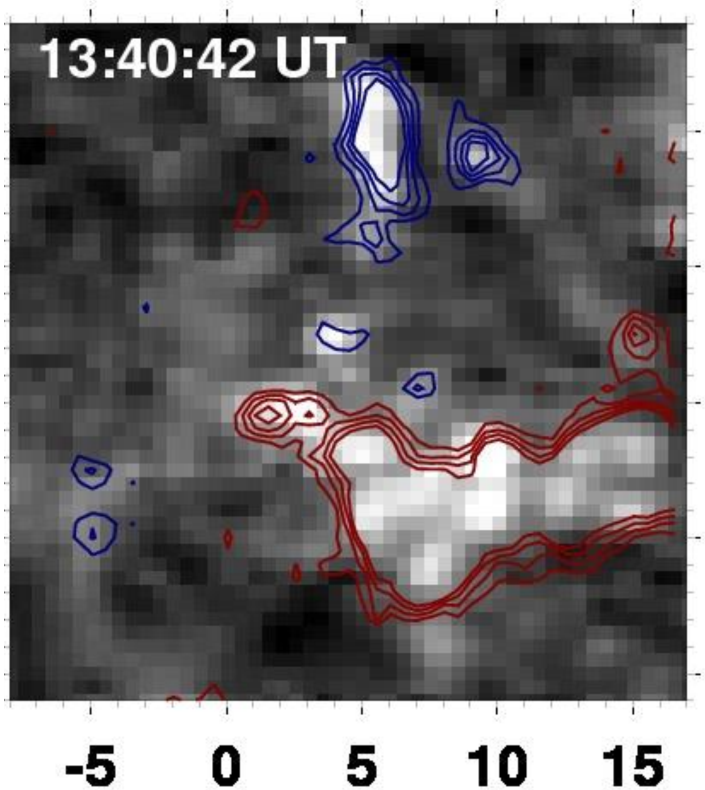




Results

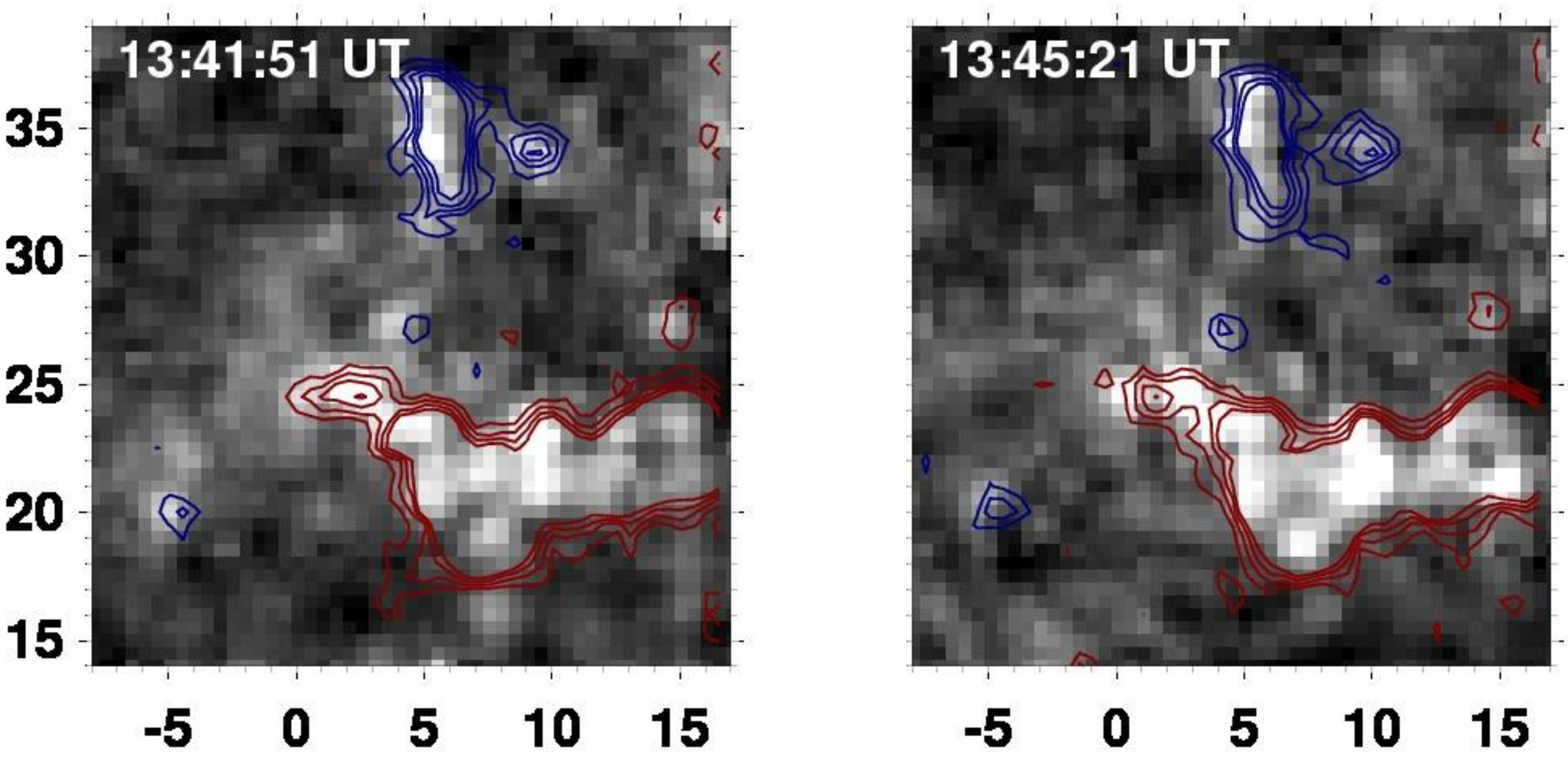
- temporal evolution of the emerging dipole:
  - 13:34:21-13:40:42 UT: the 1216 Å cannel emission becomes again spatially separated and brightenings related to the negative patch start to weaken at the end of this period





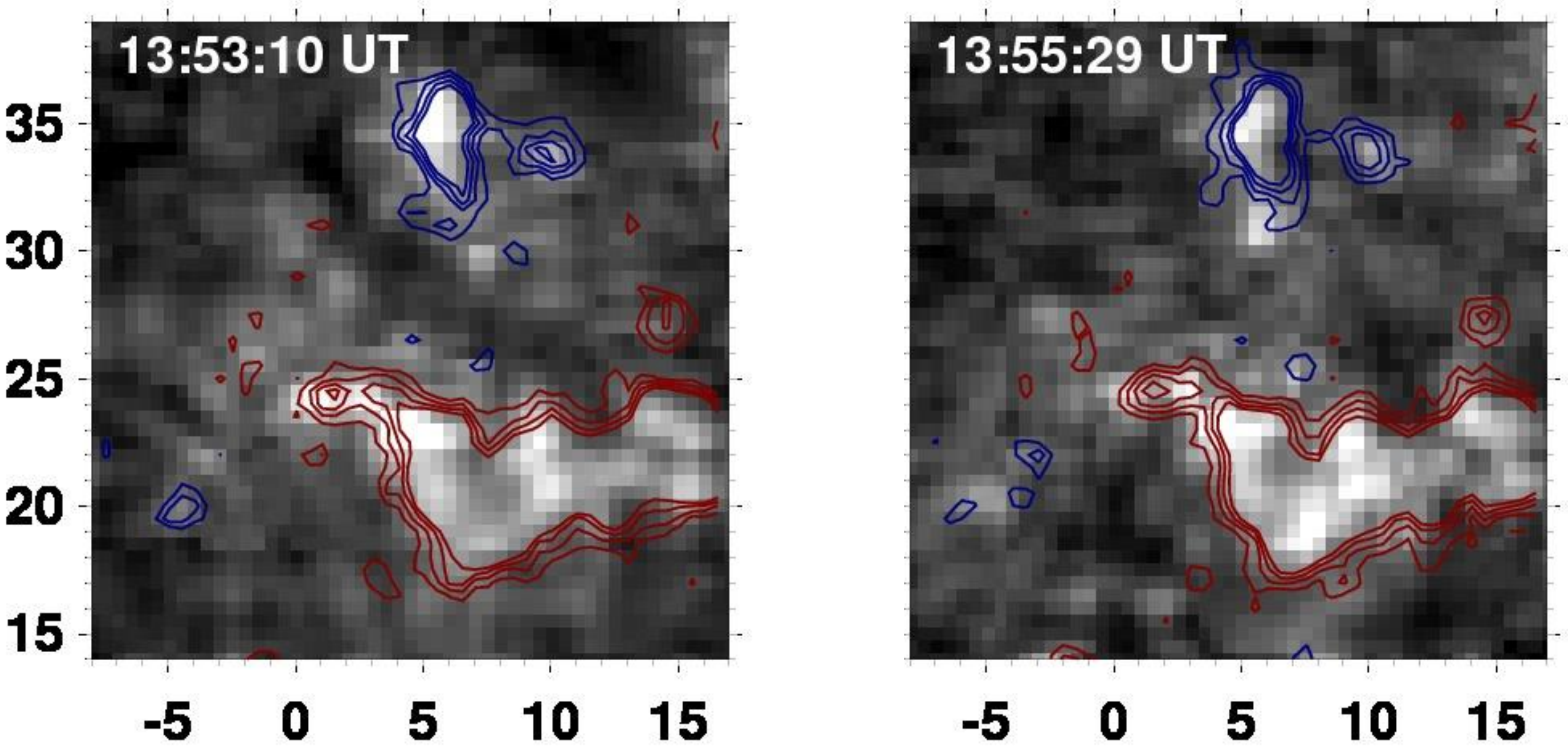
Results

- temporal evolution of the emerging dipole:
  - 13:41:51-13:45:21 UT: the northern footpoint is still visible in the magnetograms, but is rather not longer detectable in the chromosphere



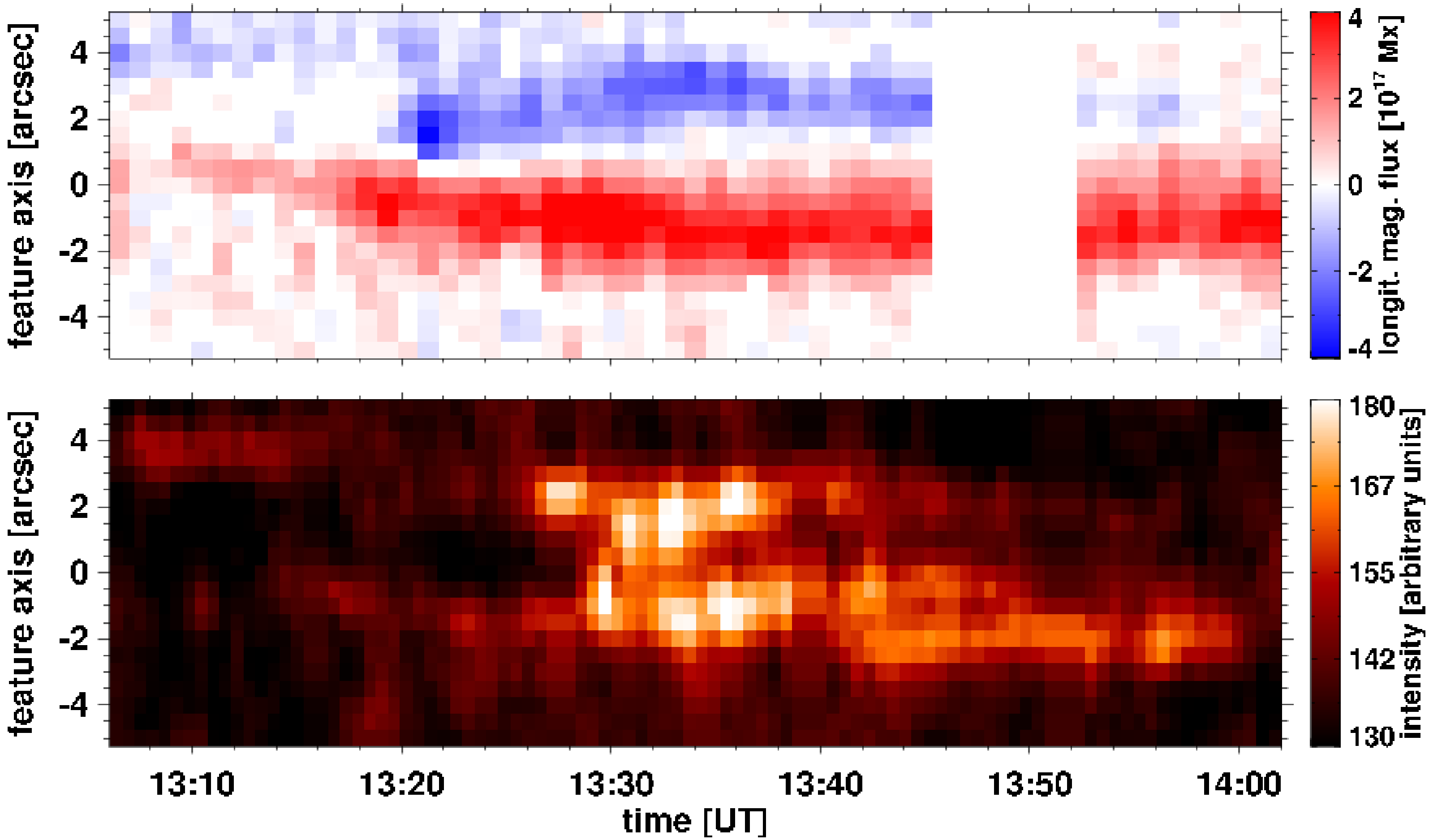
Results

- temporal evolution of the emerging dipole:
  - 13:53:10 UT and later: no clear evidence of the negative footpoint or its recurrent appearance (13:45-13:53 UT: gap in the MDI data)



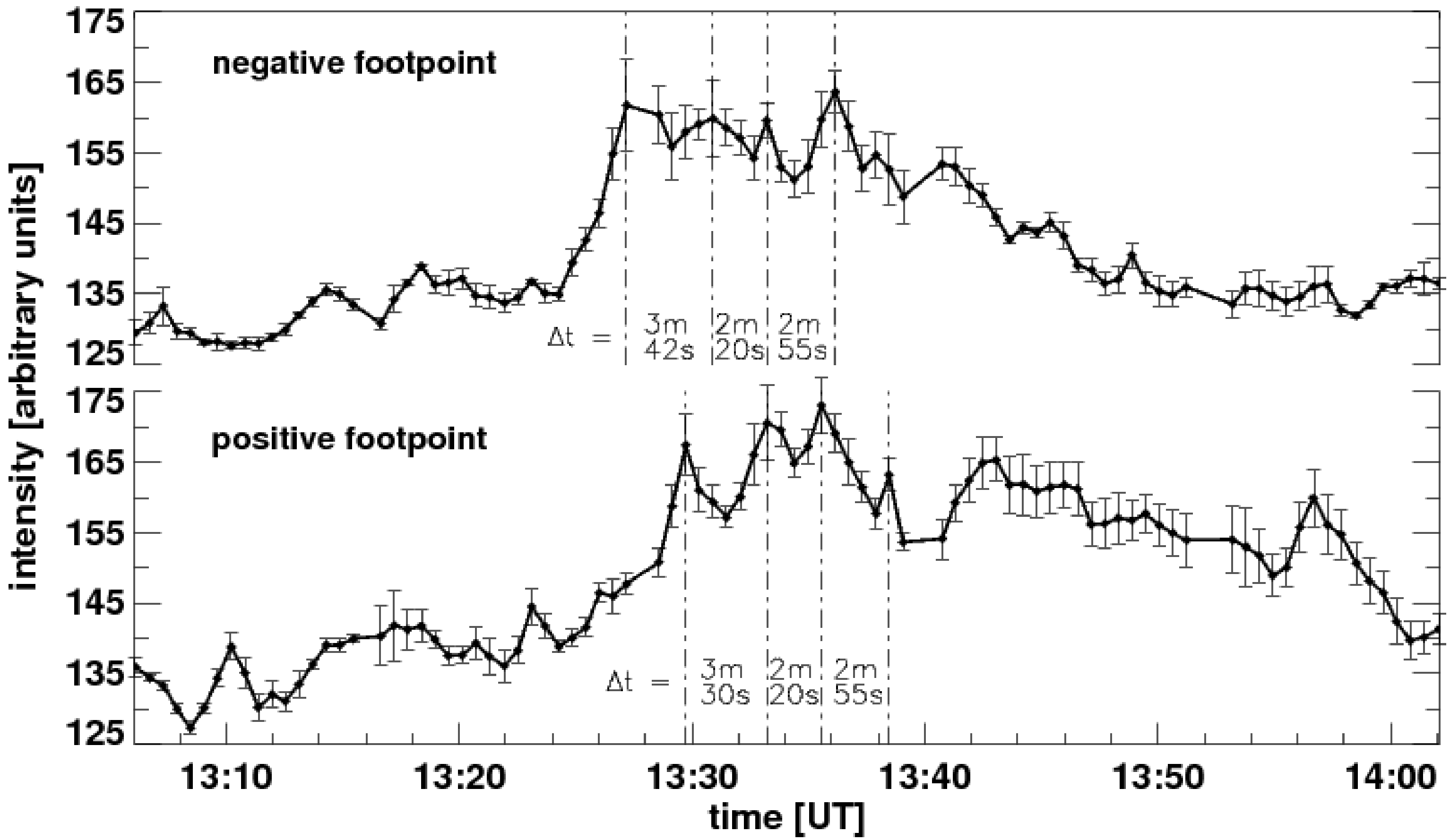
Results

- evolution of the longitudinal magnetic flux and chromospheric emission along the axis of the emerging dipole



Results

- evolution of the chromospheric emission related to the positions where the dipole exhibits the strongest magnetic flux



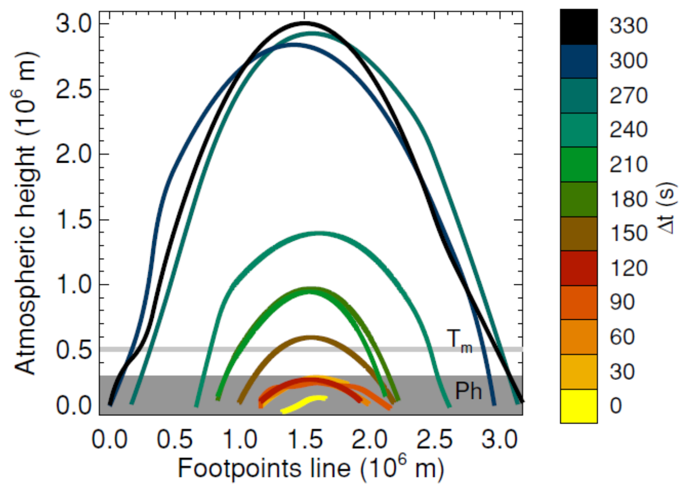
Discussion and conclusions

- parameters estimated for the emerging dipole are consistent with typical characteristics of small-scale magnetic loops reaching chromospheric heights

	emerging dipole	Martínez González et al. (2009)
- longitudinal magnetic flux:	4×10^{17}, -2×10^{17}	$2\times10^{16} - 2\times10^{17}$ / 1.9×10^{18}
- spatial extent:	from 2.5” to 5.0”	0.6” – 5.5”
- lifetime:	<36 min	2.0 – 40 min
- delay between photosph. and chromosph. activity:	~9,0 min	5 – 13 min

→ Observed dipole can be identified as a rising small scale magnetic loop which exhibits activity in the chromosphere.

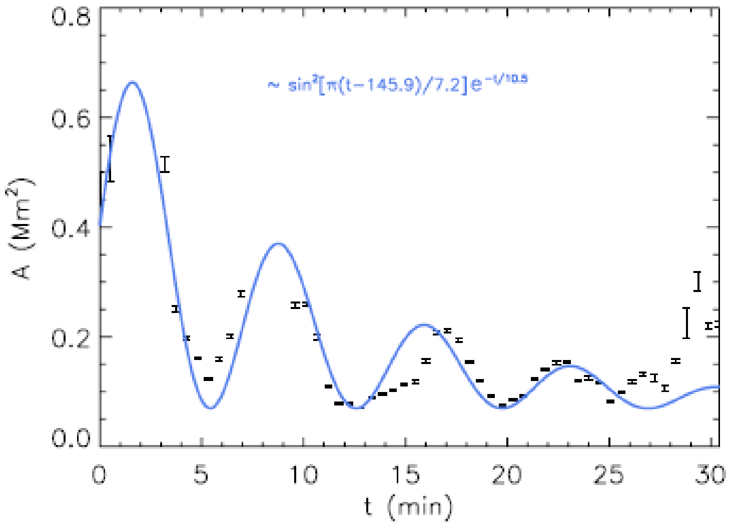
- co-spatiality of the magnetic polarity patches with the 1216 Å emission → how it fits with the expected quasi-circular topology of the detected small-scale loop

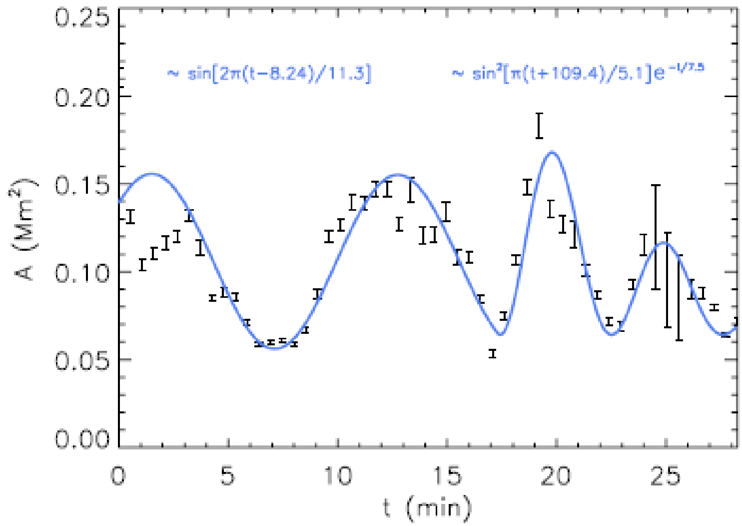


Martínez González et al. (2010)

Discussion and conclusions

- footpoint areas of the small-scale loops which contain constant magnetic flux oscillate → magnetic flux density fluctuates in antiphase (Martínez González et al. 2011)
  - there is not a characteristic period for these oscillatory patterns
  - typical periods: 4 – 11 min. (weak loops); 3 – 5 min. (stronger structures)
  - damping time: 5 – 30 minutes





- we detected a quasi-periodic oscillations in the 1216 Å channel
  - determined periods: 2.3 – 3.7 minutes / damping time: ~14 minutes

→ pattern detected in the 1216 Å intensities reflects oscillations of the magnetic flux density at the footpoints of our loop which cause the propagation of waves into the chromosphere

Open questions

- asymmetry of the detected loop → total magnetic flux of the of the emerging feature seems to be unbalanced
  - might be an artifact caused by the difficulty in separating the positive footpoint of the loop from the strong network element with which it interacts
  - alternative explanation could be the different spatial extension of both footpoints: for the positive polarity patch, the magnetic flux could be concentrated within a much smaller area, implicating flux densities well above the detection threshold, while for the negative polarity the opposite could be the case

  similar conditions can even lead to measurements of unipolar fields in quiet Sun (Lamb et al. 2008)

- small decrease of the spatial loop extension after 13:36 UT
  - possible indication of a submergence of the loop that is also supported by a co-temporal weakening of chromospheric emission
  - or it could just reflect the noisy behavior of the SoHO/MDI magnetograms.

Thank you for your attention!