



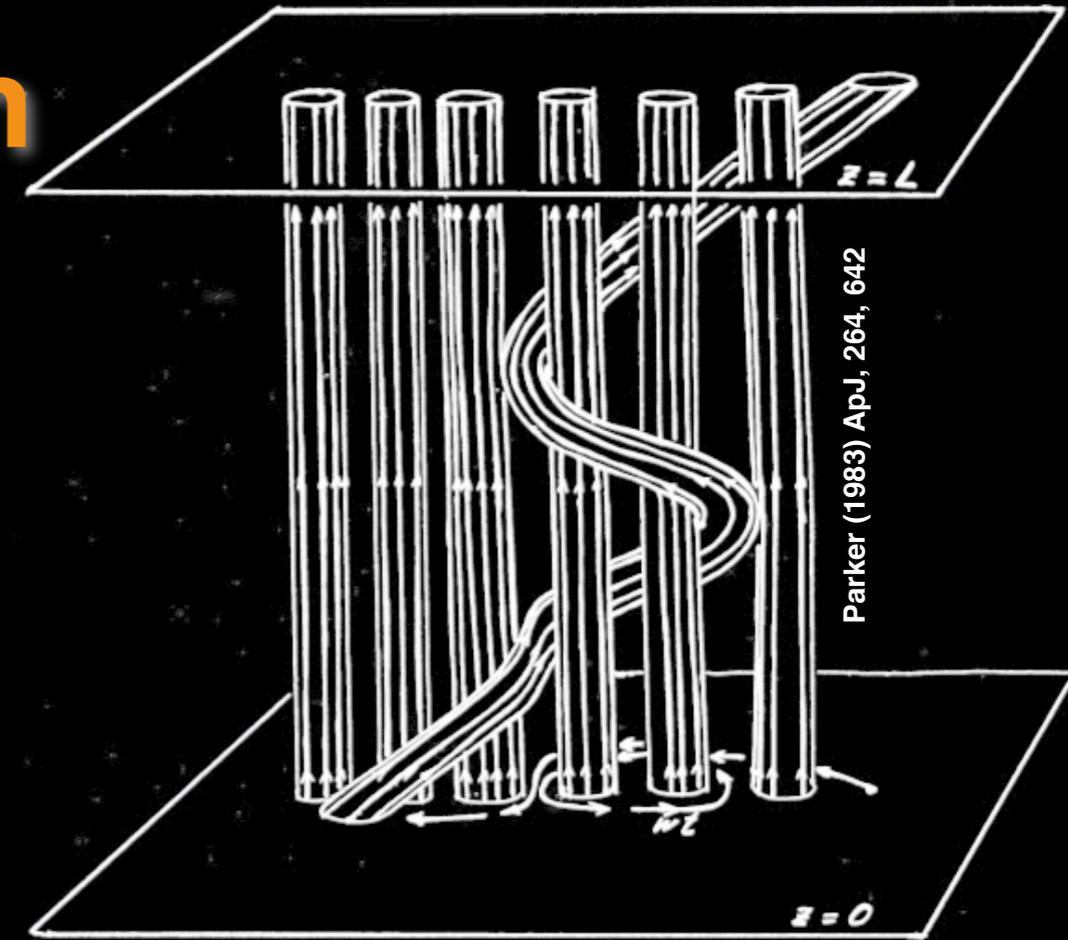
MAX-PLANCK-GESELLSCHAFT



Horizon 2020 MSCA
No. 707837



Magnetic coupling through the solar atmosphere



Lakshmi Pradeep Chitta

chitta@mps.mpg.de

Max Planck Institute for Solar System Research

Invited Talk

3. Magnetic coupling and mass flux through the atmosphere

Magnetic coupling through the atmosphere

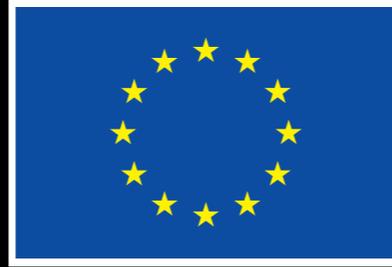
L. P. Chitta¹

¹*Max Planck Institute for Solar System Research, Göttingen, Germany*

Probing the magnetic coupling through the solar atmosphere is central to deciphering a wide range of plasma dynamics observed above the visible surface of the Sun. The Interface Region Imaging Spectrograph in coordination with the current fleet of ground- and space-based telescopes provides unprecedented details of the magnetic processes and magnetic-field-regulated mass and energy transport through the solar atmosphere. In this talk, we will review some recent studies that highlight the complex nature of magnetic coupling at the chromospheric interface of coronal loops. The role of apparent chromospheric magnetic reconnection at the base of coronal loops in the heating of discrete hot structures in active region cores will be discussed.



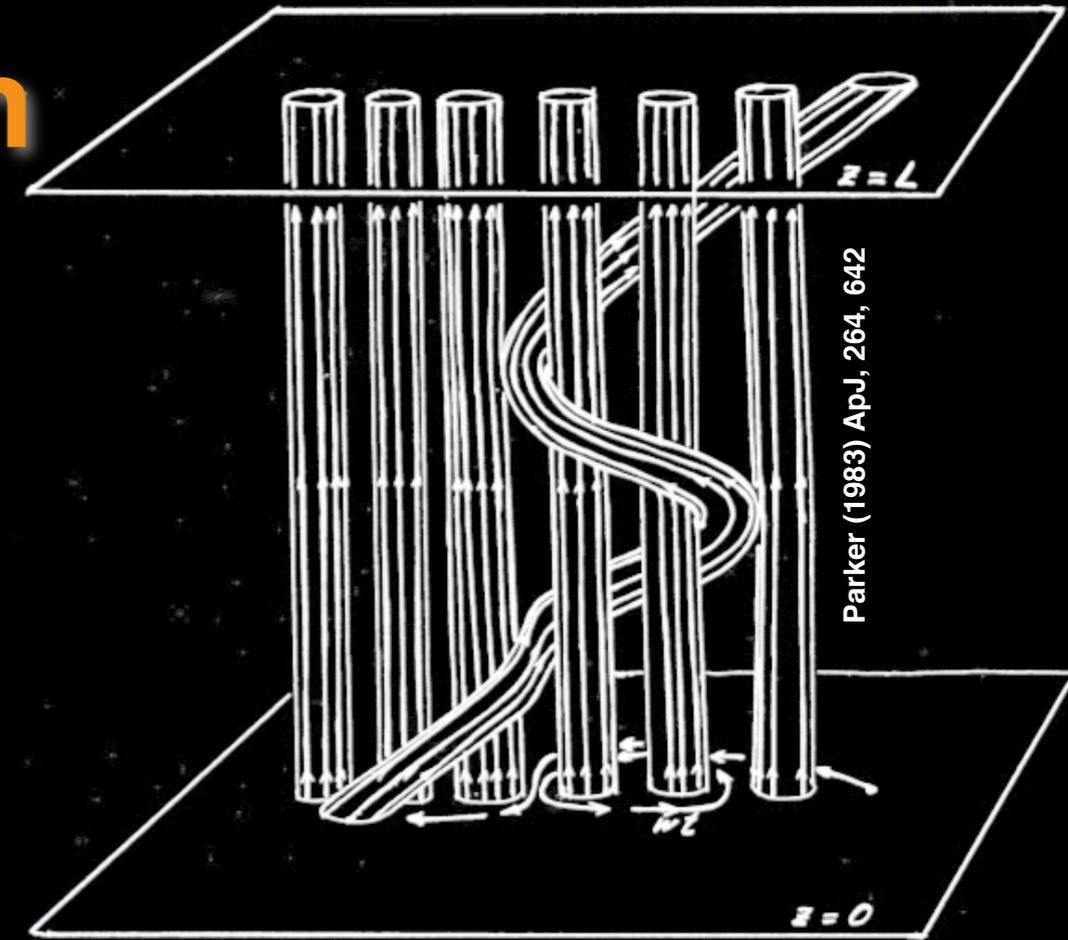
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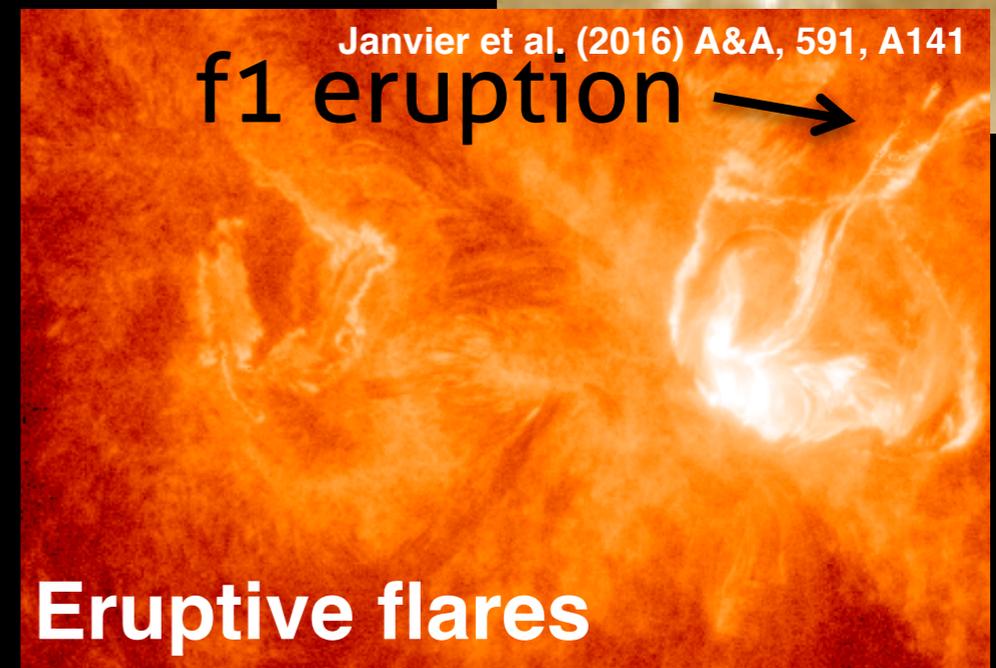
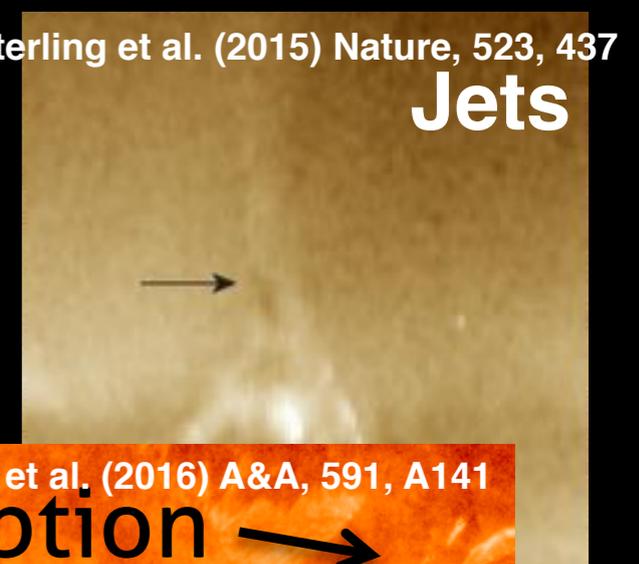
Max Planck Institute for Solar System Research

Magnetic coupling and solar structures

Magnetic coupling

Confined events

Eruptive events

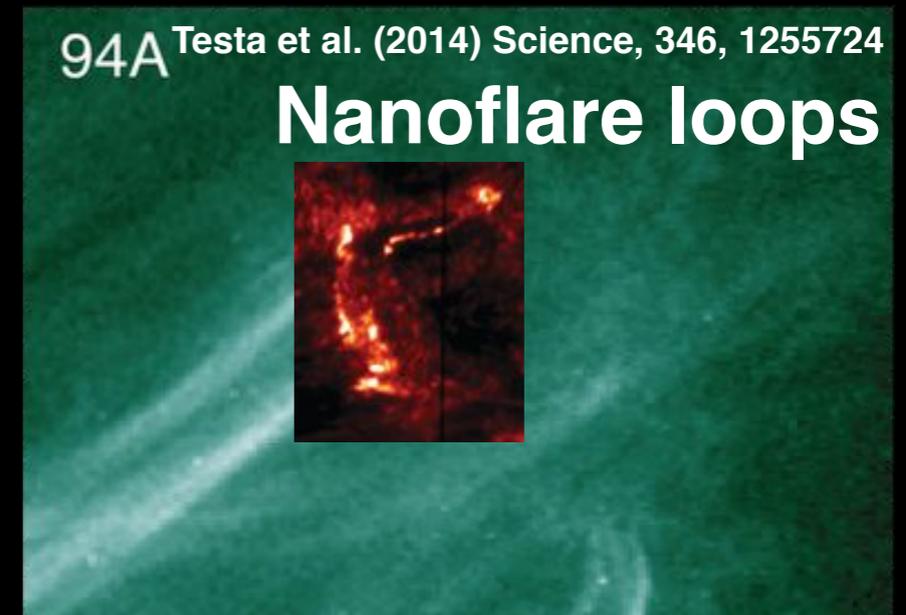
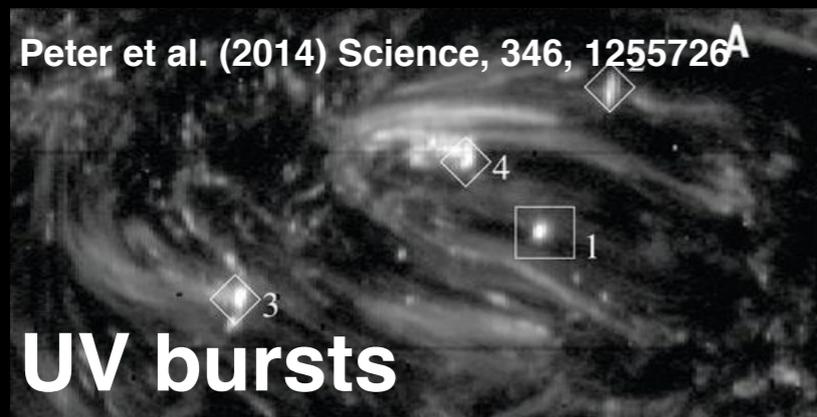


Thermal coupling \leftrightarrow Observed structures

Magnetic coupling and solar structures

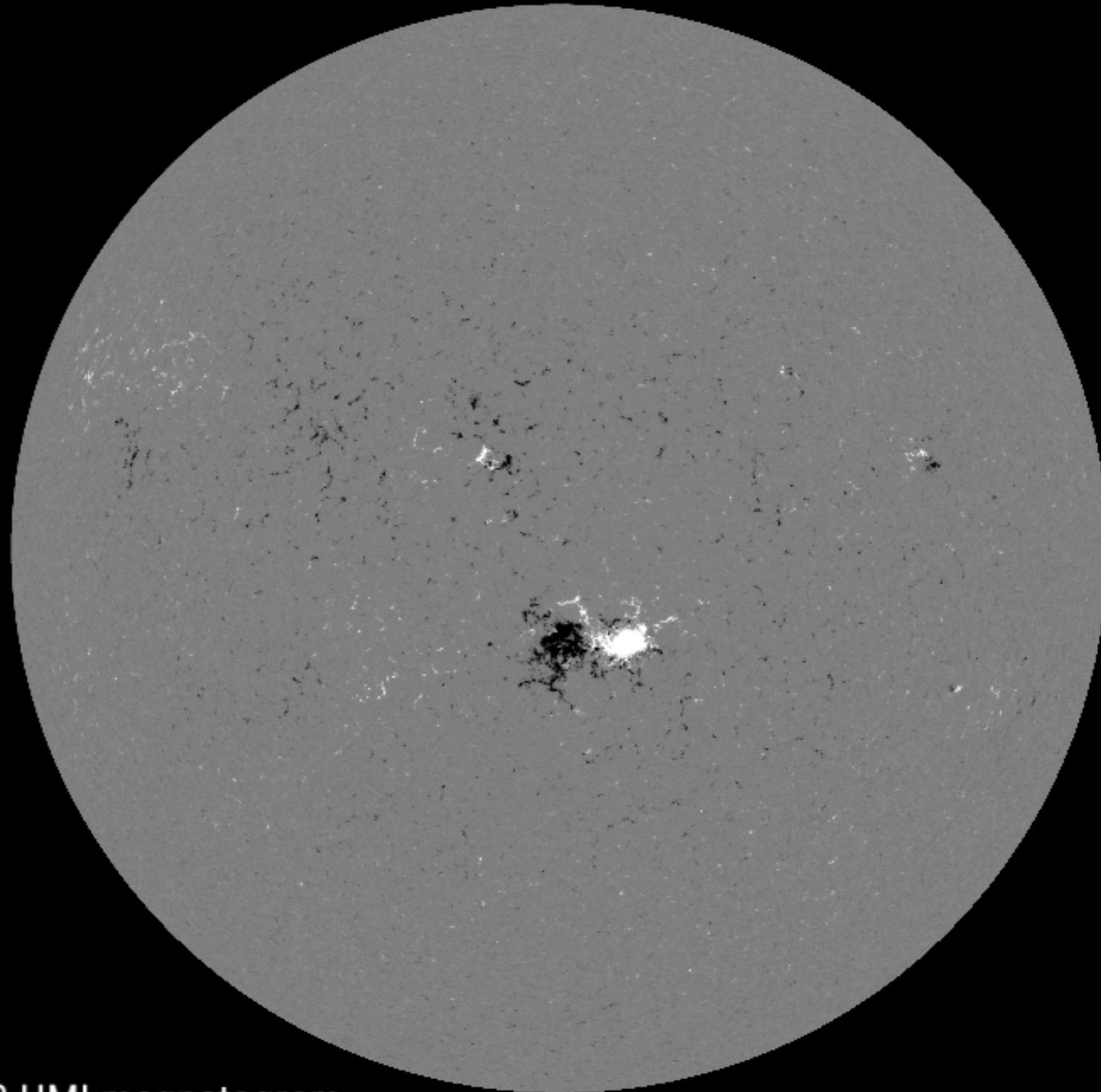
Magnetic coupling

Confined events



Thermal coupling \longleftrightarrow Observed structures

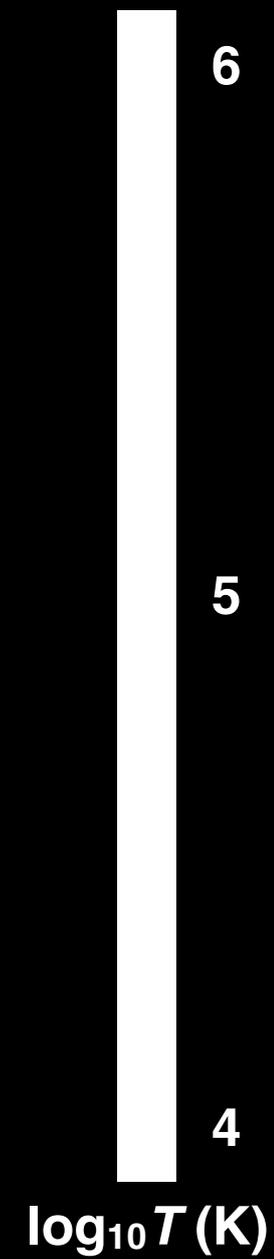
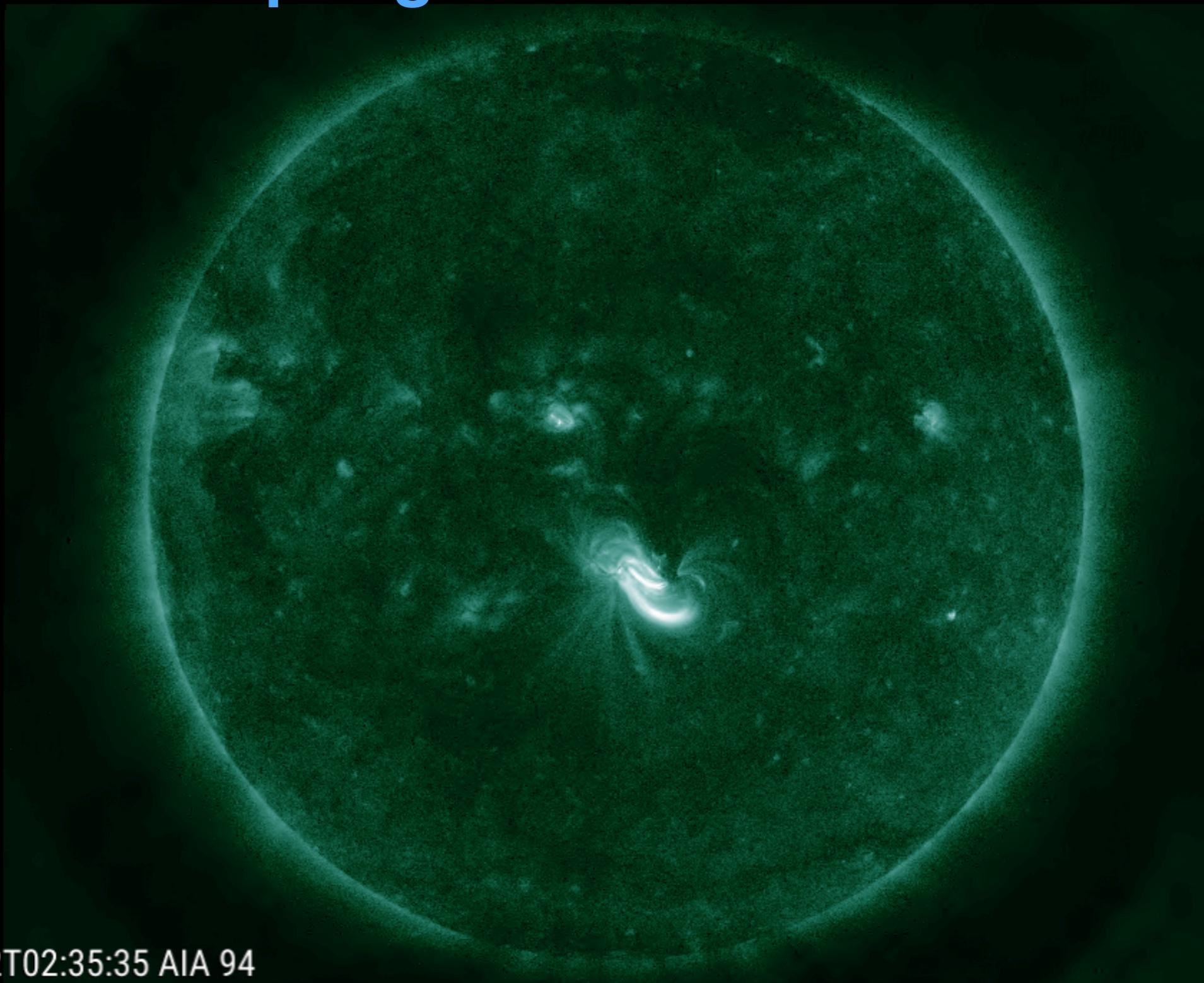
Magnetic coupling and solar structures



4
log₁₀ T (K)

2017-07-12T02:35:08 HMI magnetogram

Magnetic coupling and solar structures

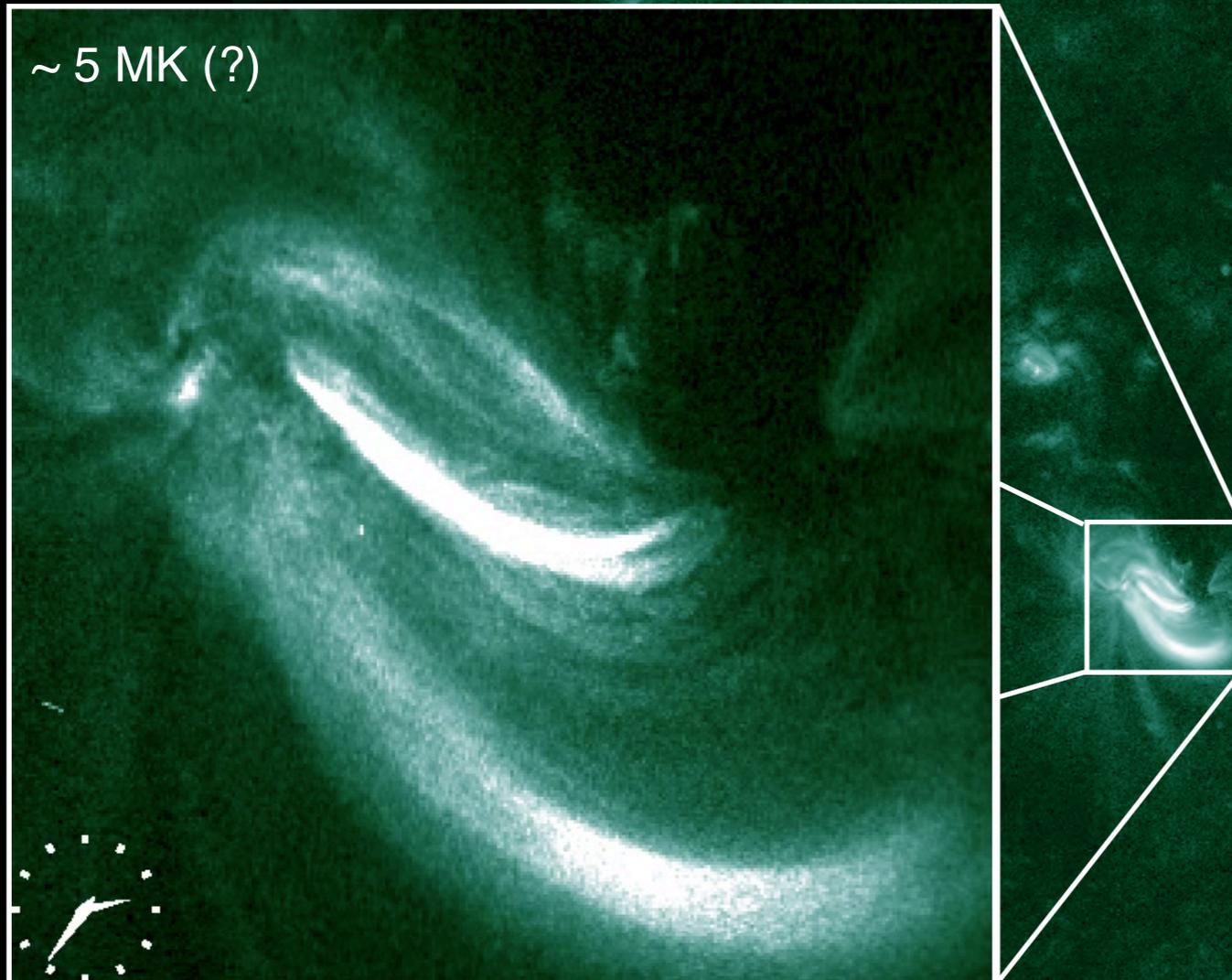


2017-07-12T02:35:35 AIA 94

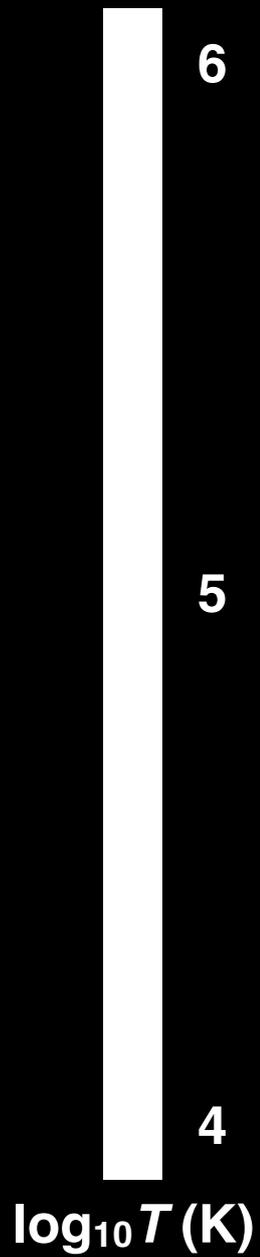
Magnetic coupling and solar structures

What governs the energy release, its location, and frequency?

The role of magnetic field?



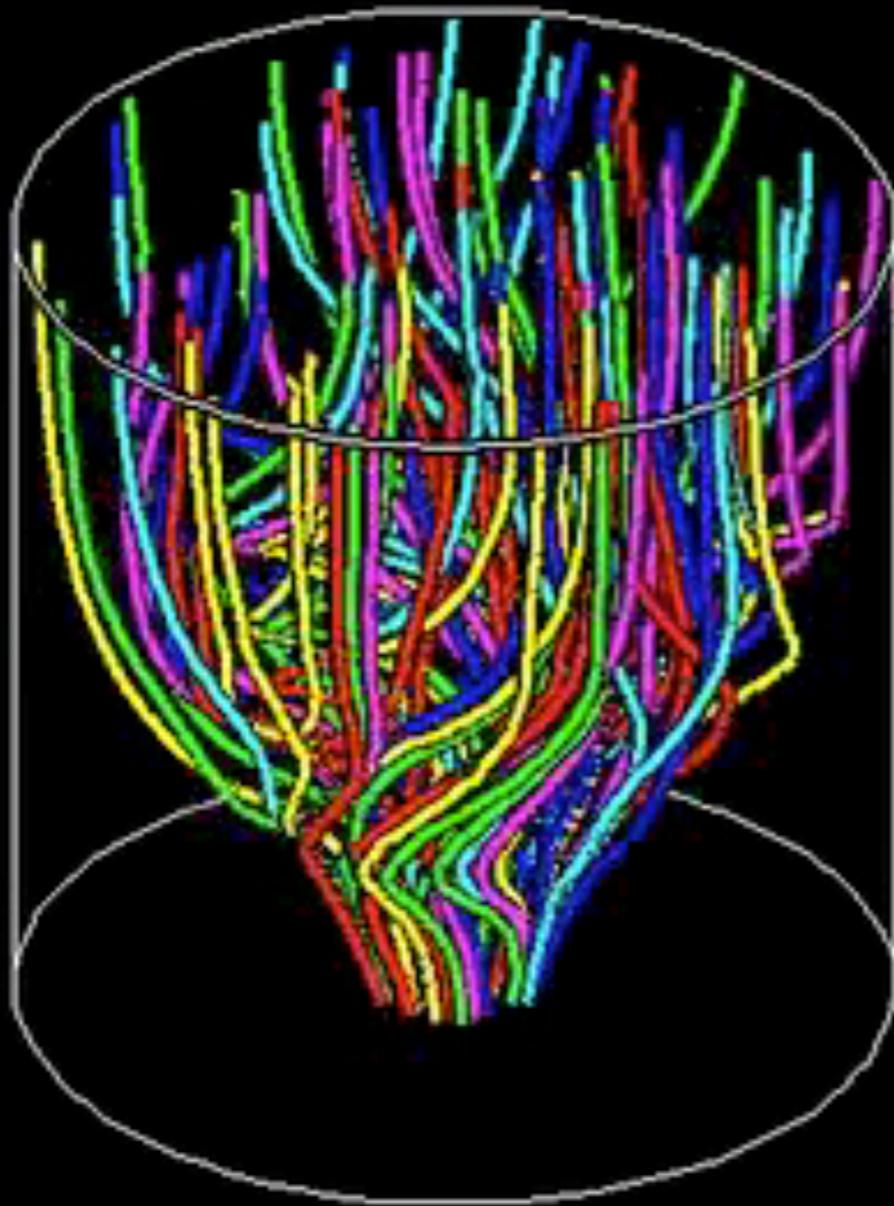
Evolution of loops in an active region



Magnetic coupling and solar structures

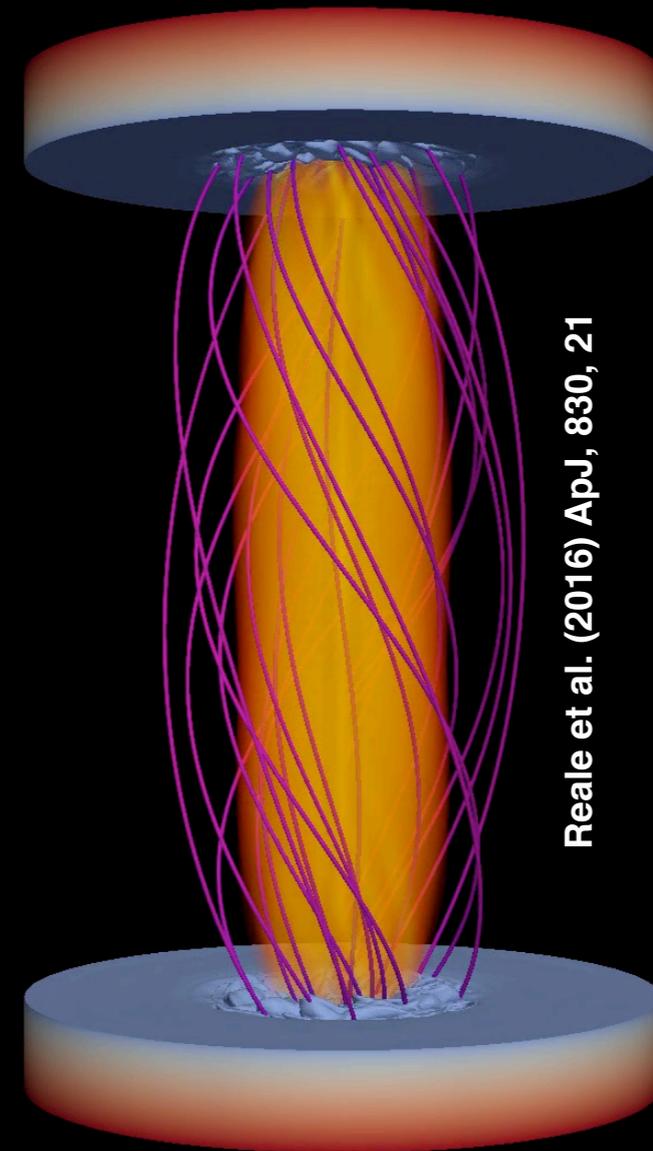
AC - wave models

van Ballegoijen et al. (2011) ApJ, 736, 3



DC - braiding models

T (MK)
4
3
2
1
0.5

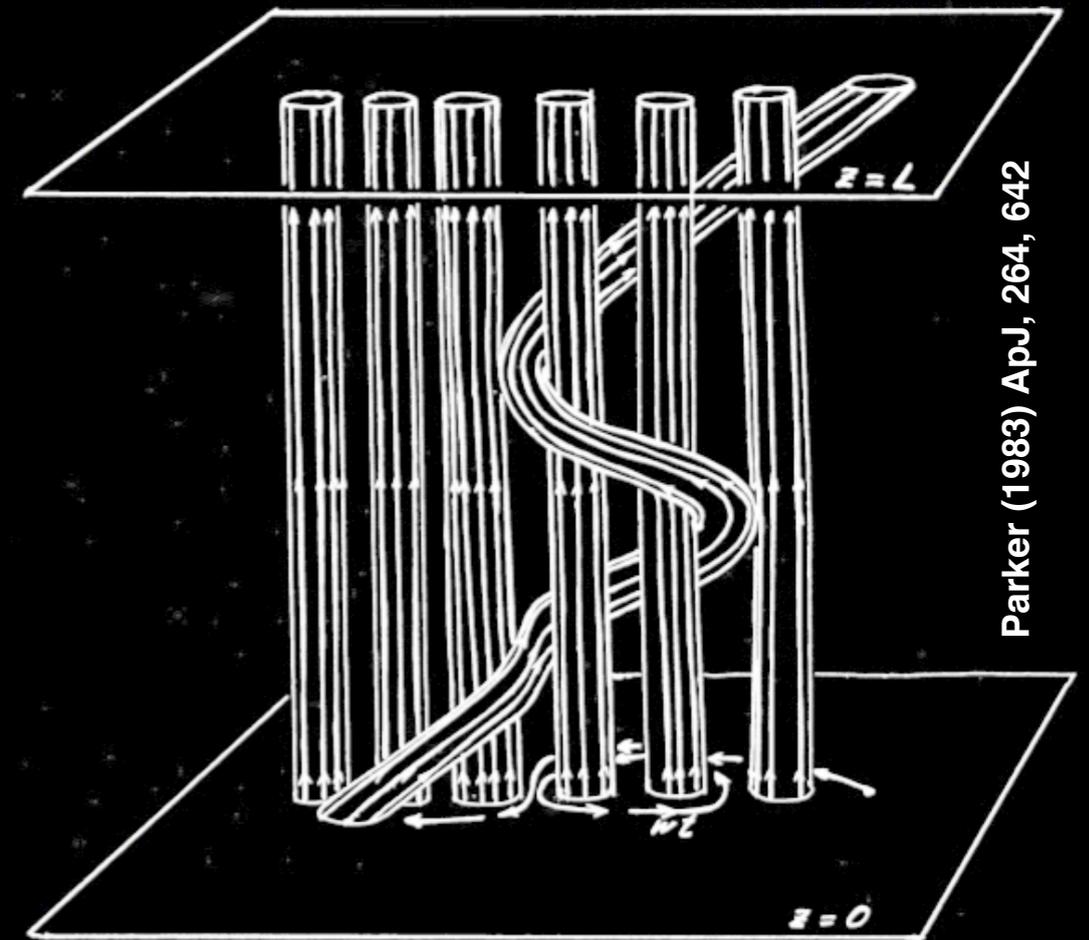
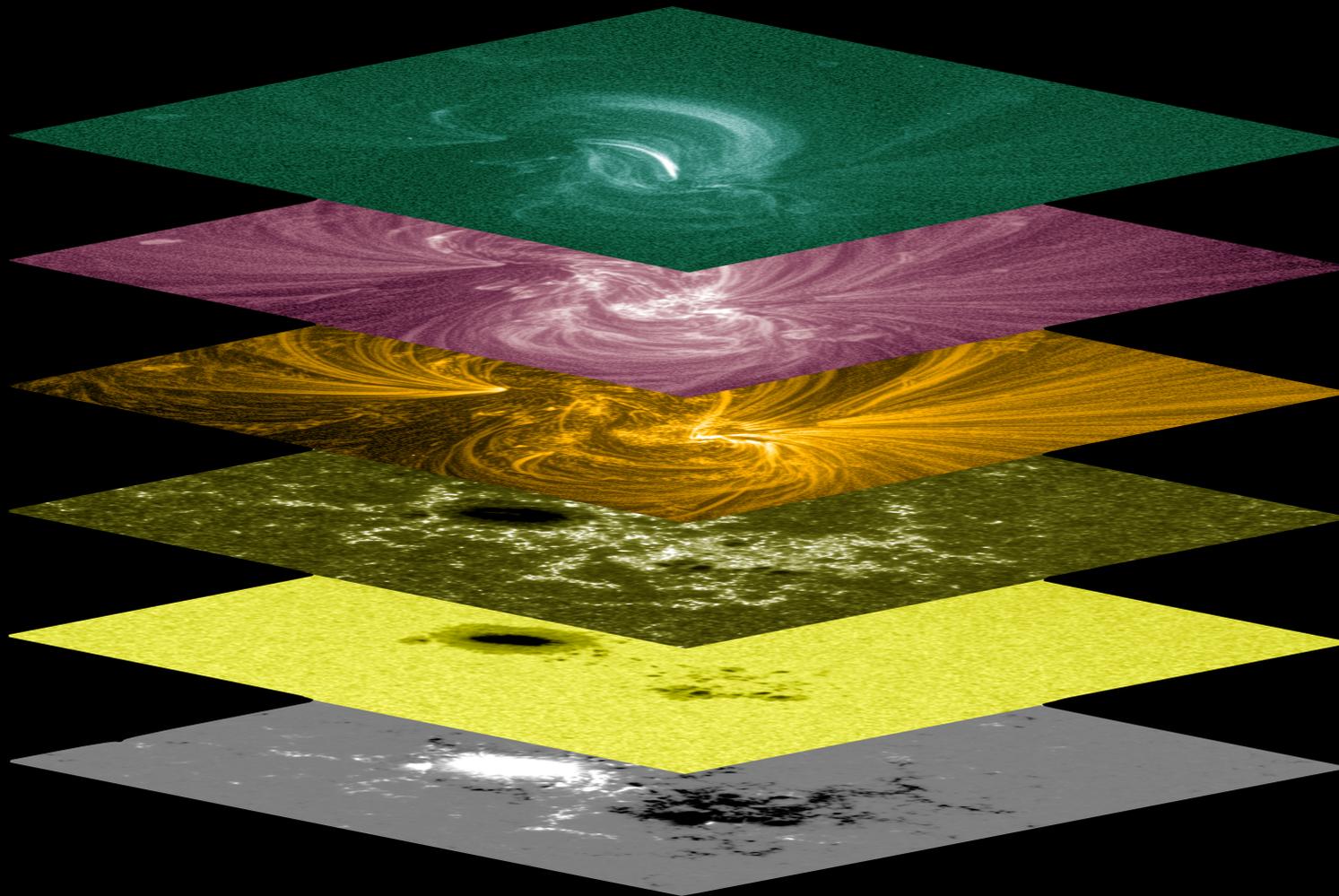


Reale et al. (2016) ApJ, 830, 21

Time: 2000 s

Magnetic coupling through footpoint motions

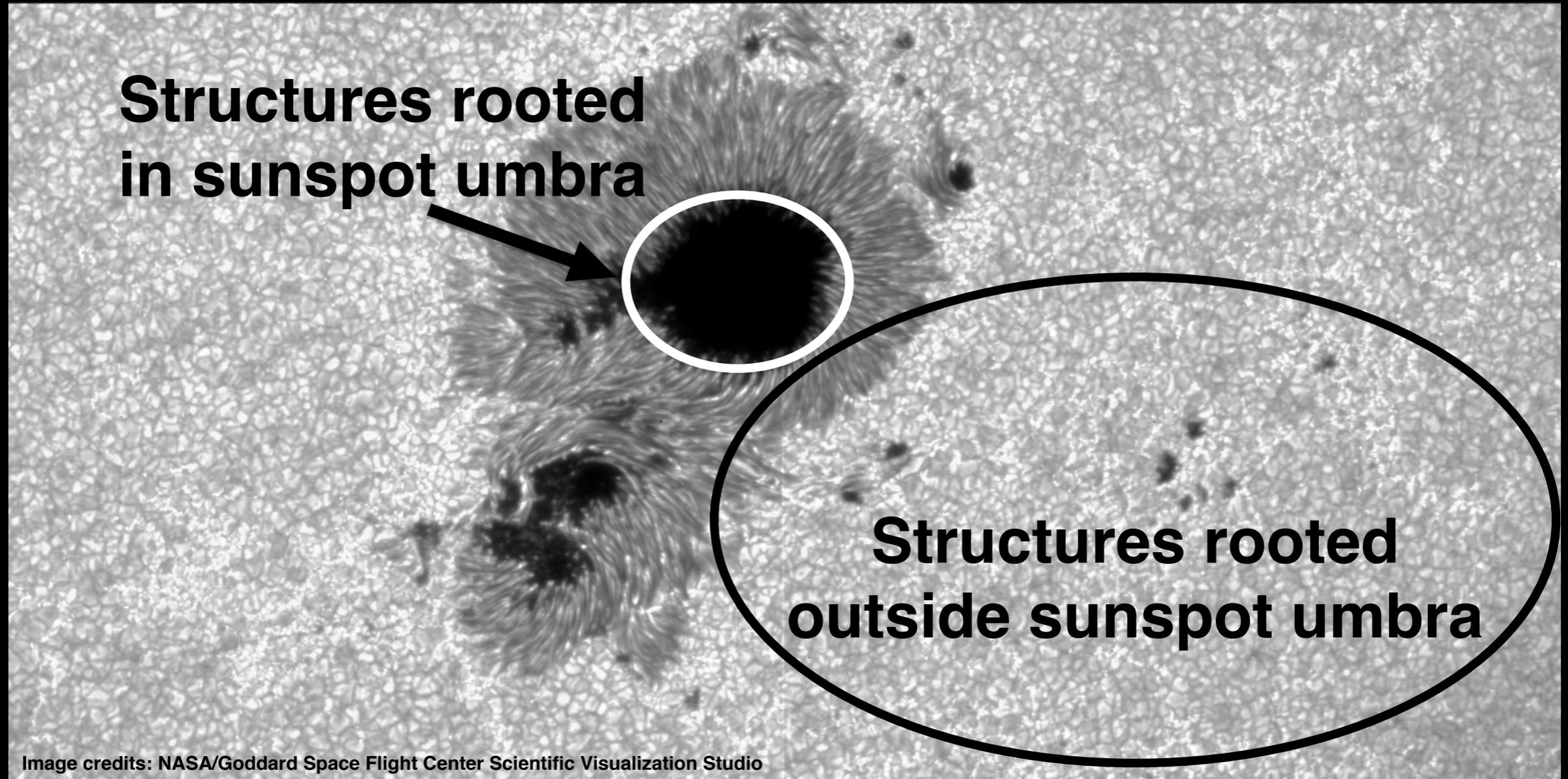
Magnetic coupling and solar structures



Parker (1983) ApJ, 264, 642

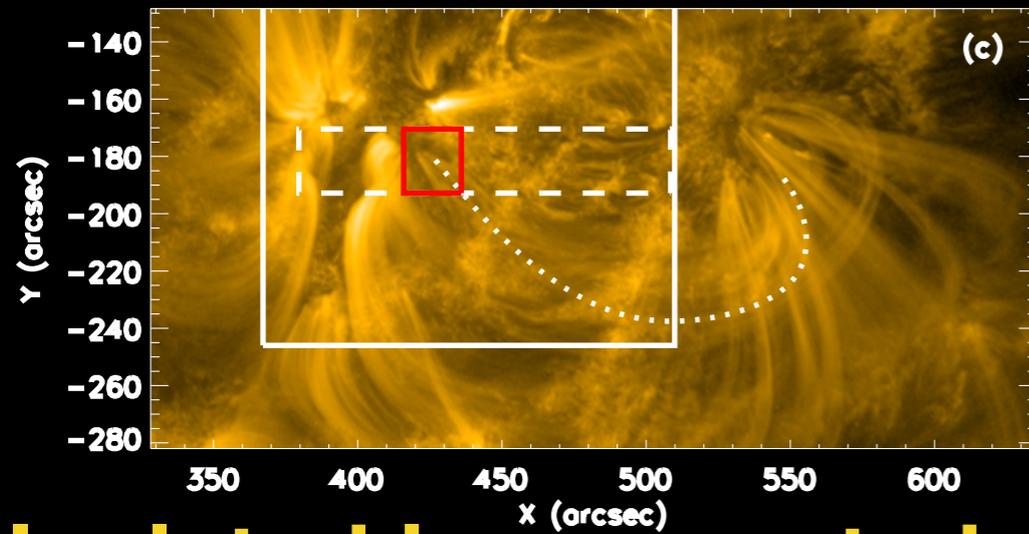
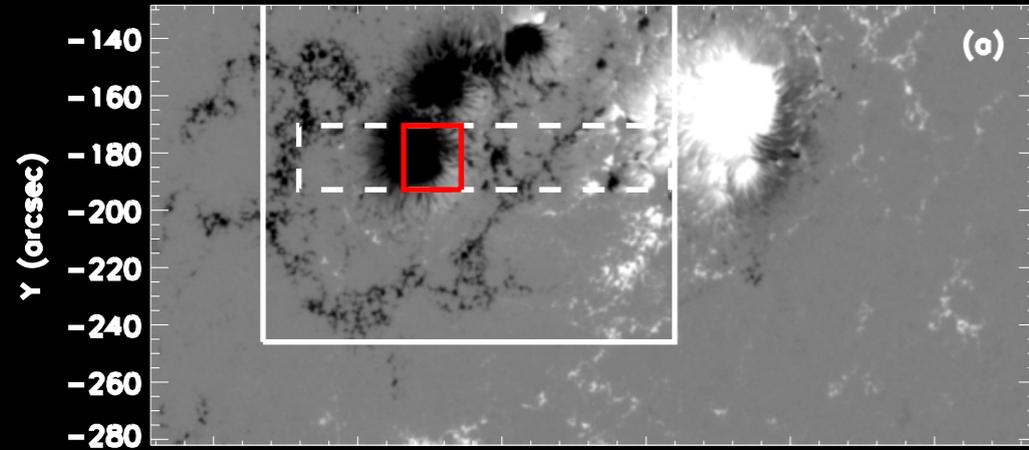
Current space and ground based telescopes provide valuable observations to probe the magnetic coupling through the solar atmosphere

Context



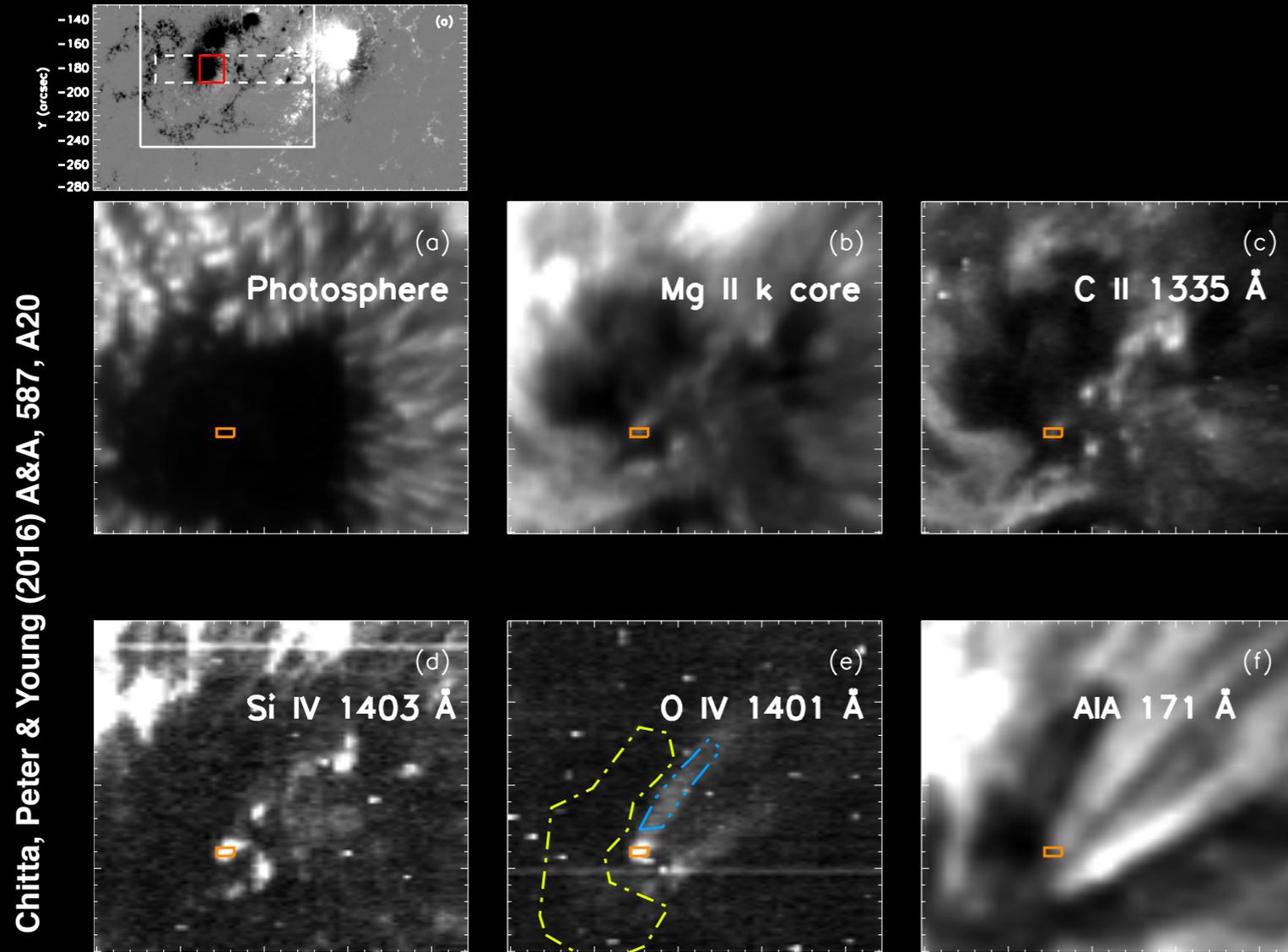
Sunspot loops

Chitta, Peter & Young (2016) A&A, 587, A20



**Isolated loops rooted
in a sunspot umbra**

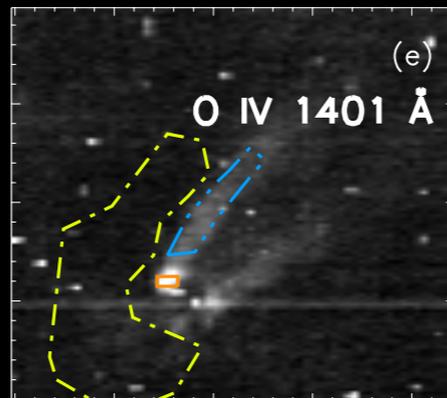
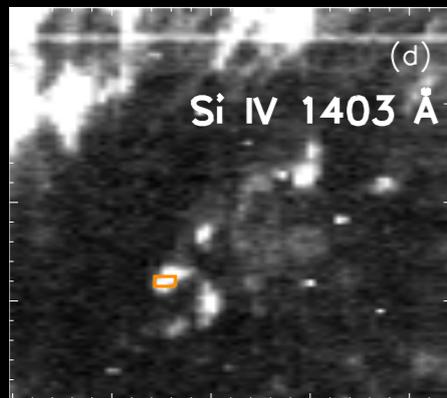
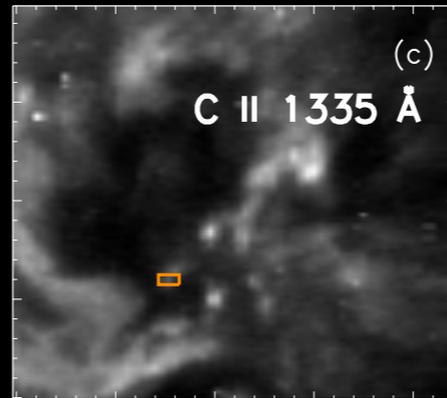
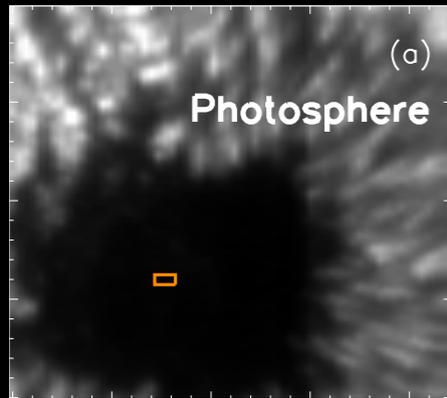
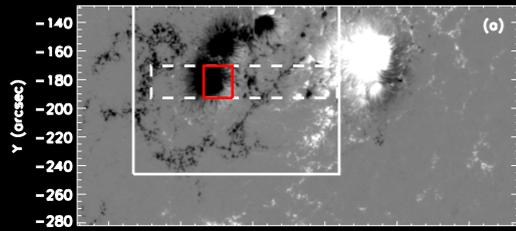
Sunspot loops



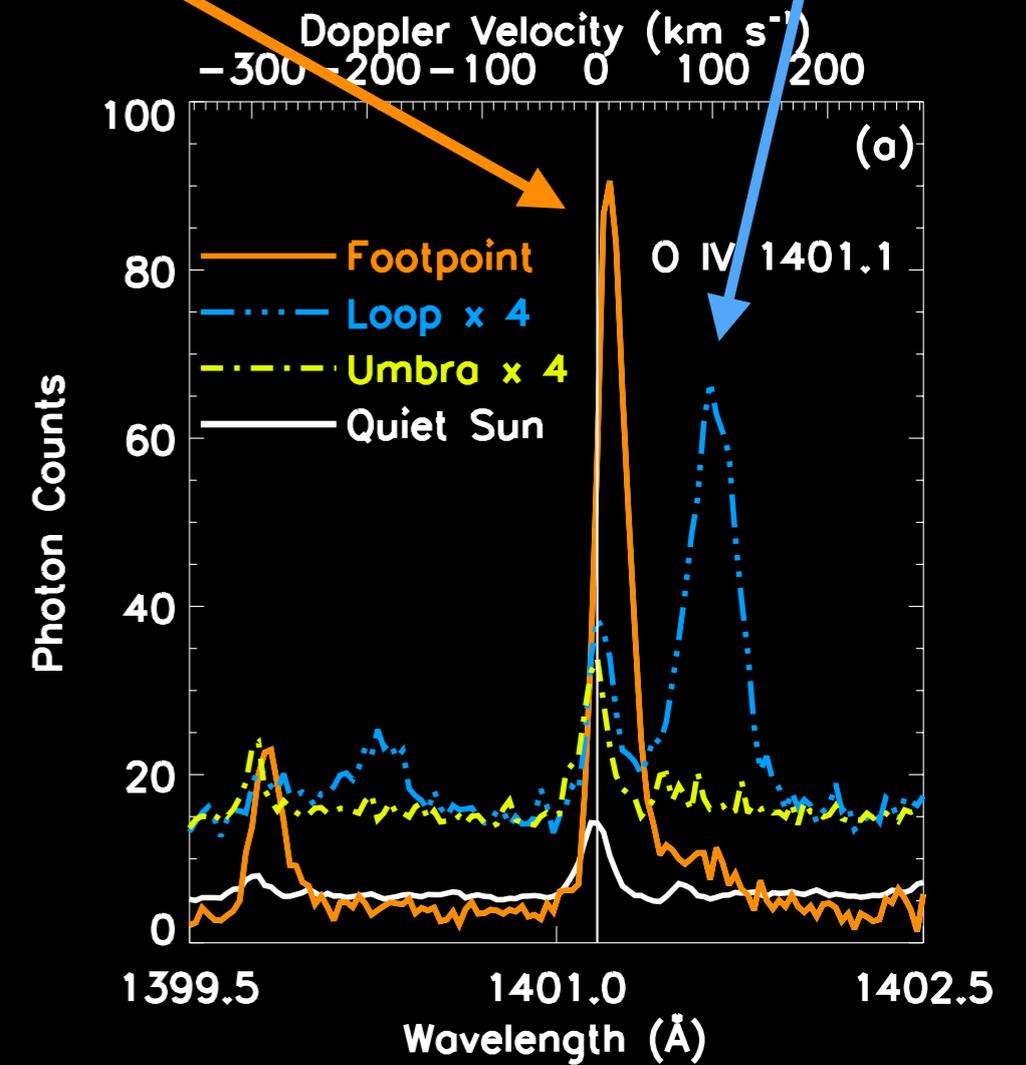
Clear identification of footpoints due to weak emission from the umbra

Sunspot loops

Chitta, Peter & Young (2016) A&A, 587, A20



Subsonic flow **Supersonic flow**

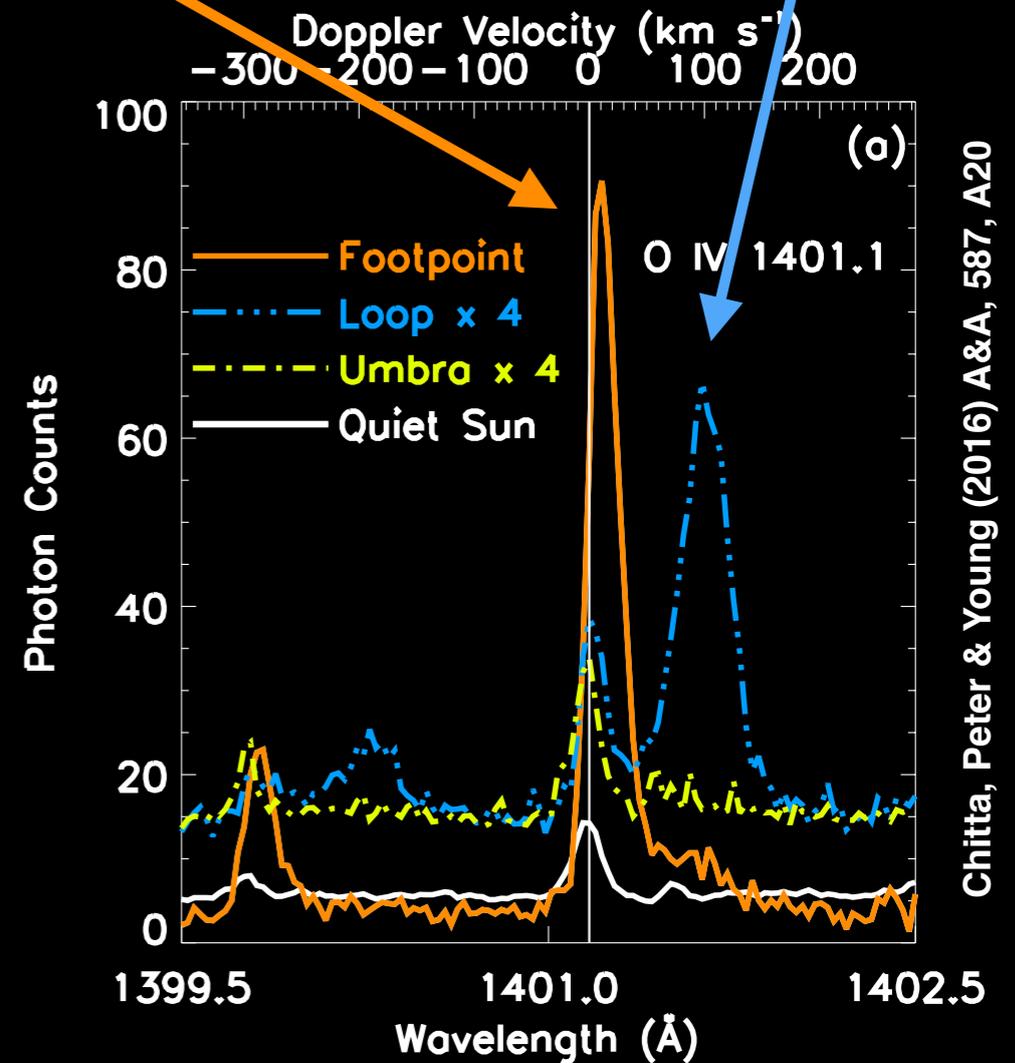
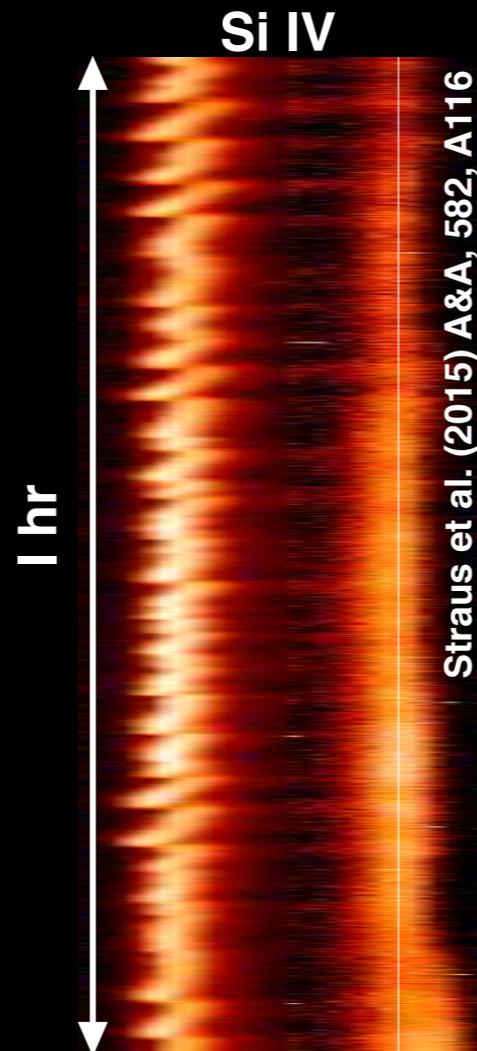
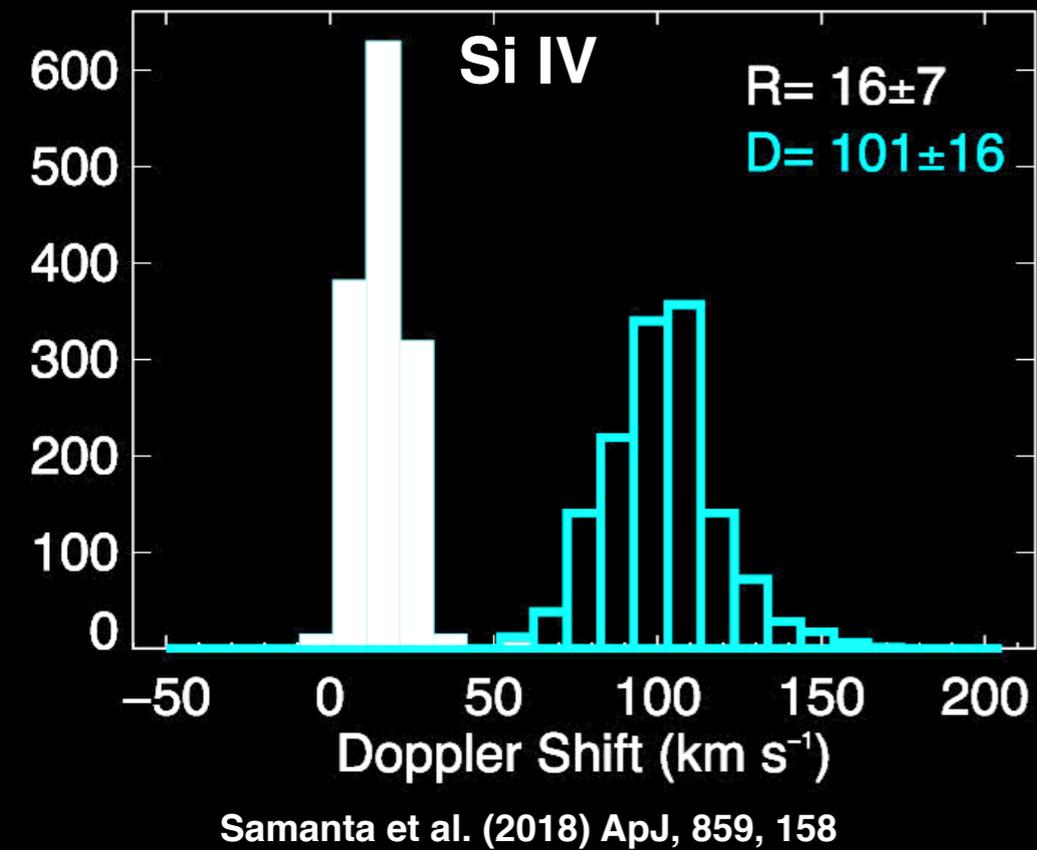


Sunspot loops

Sunspot loops

Subsonic flow

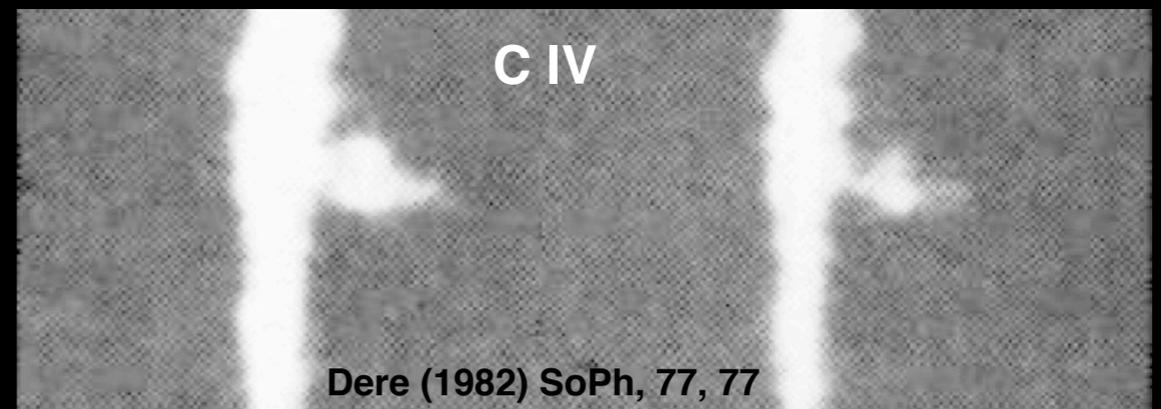
Supersonic flow



A general property Steady downflows Sunspot loops

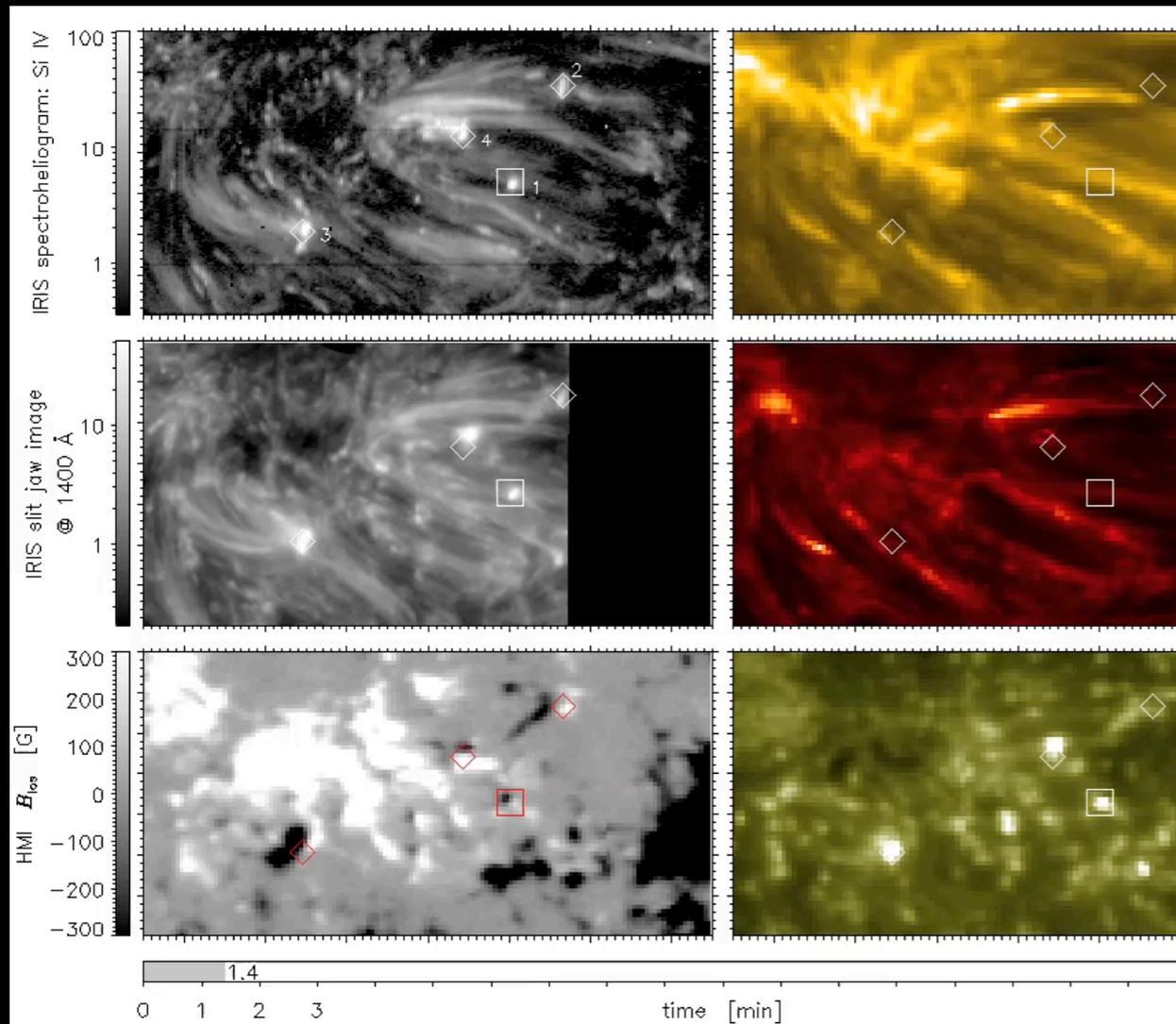
Sunspot loops

- Supersonic downflows in sunspot loops**
- **Suppressed convection and Poynting flux**
- **Signatures of cooling**
- **Known since 1980s**
- **IRIS is able to provide spatial connection of flows to the loops and footpoints**

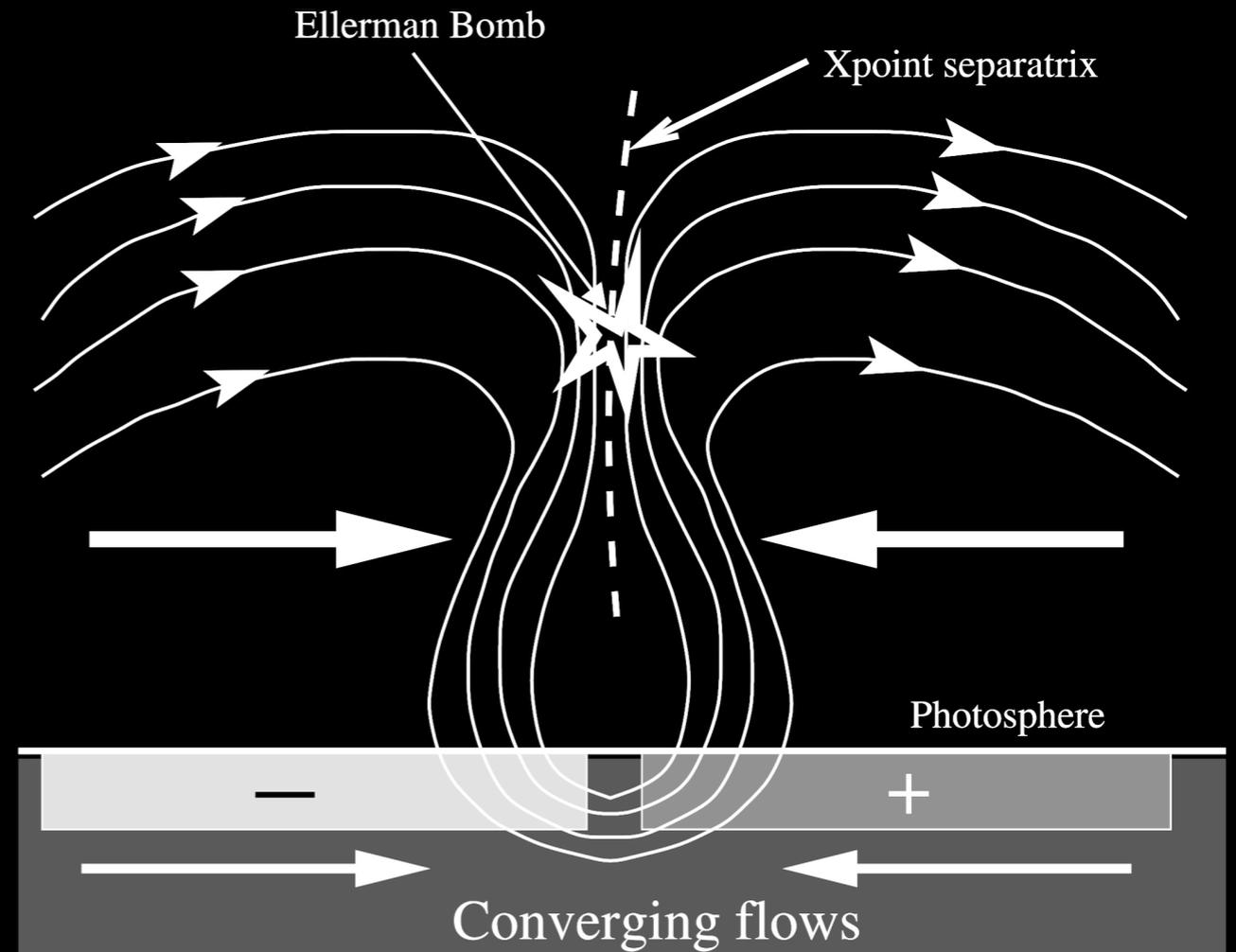


Structures rooted outside sunspot umbrae

UV bursts: Diamonds in the rough



Peter et al. (2014) Science, 346, 1255726



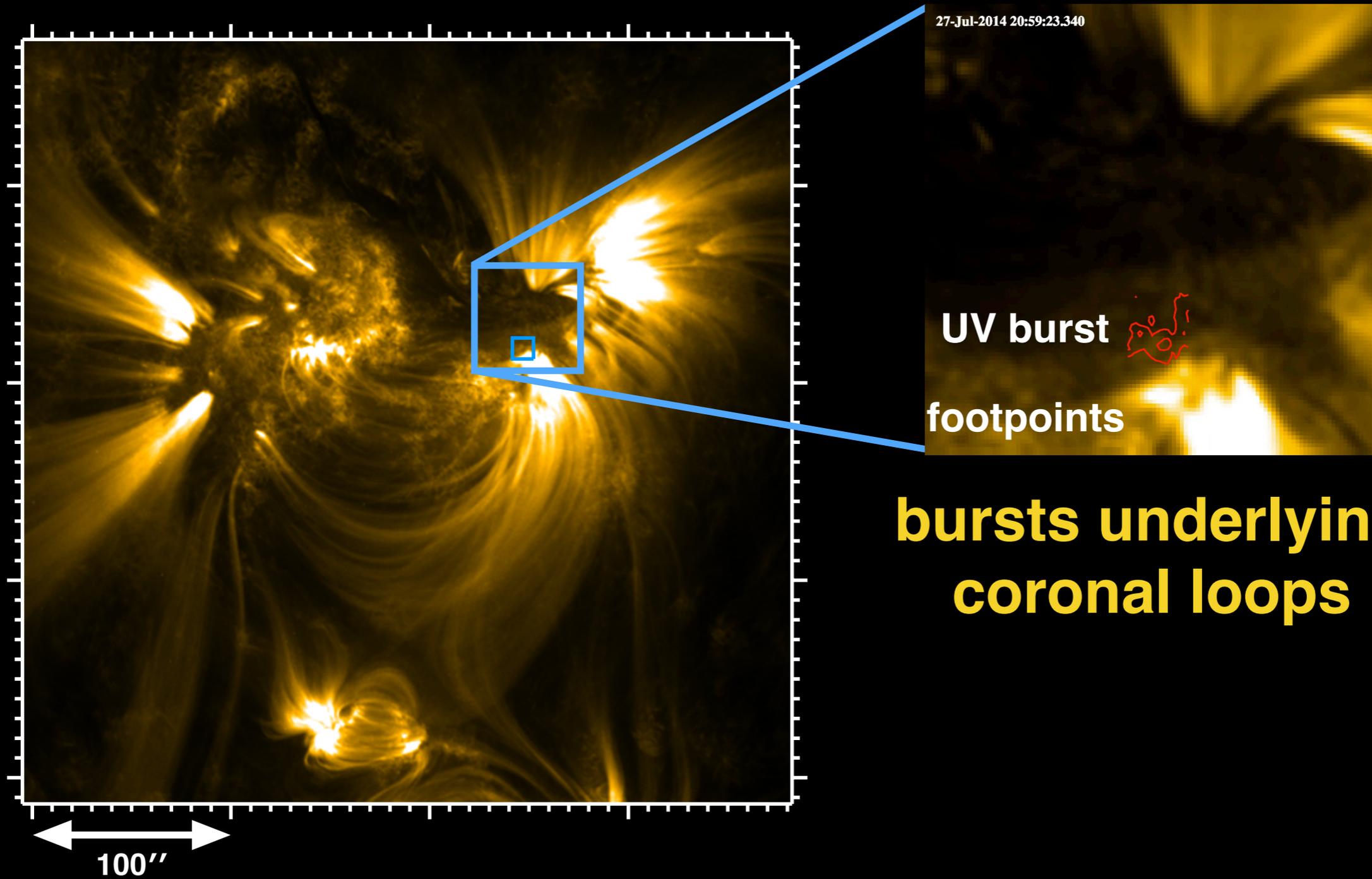
Georgoulis et al. (2002) ApJ, 575, 506

Form over flux cancellation — magnetic reconnection
Confined to low heights — Lack of coronal emission —
but...

What if the UV bursts are triggered at the feet of coronal loops?

Hidden bursts underlying loops

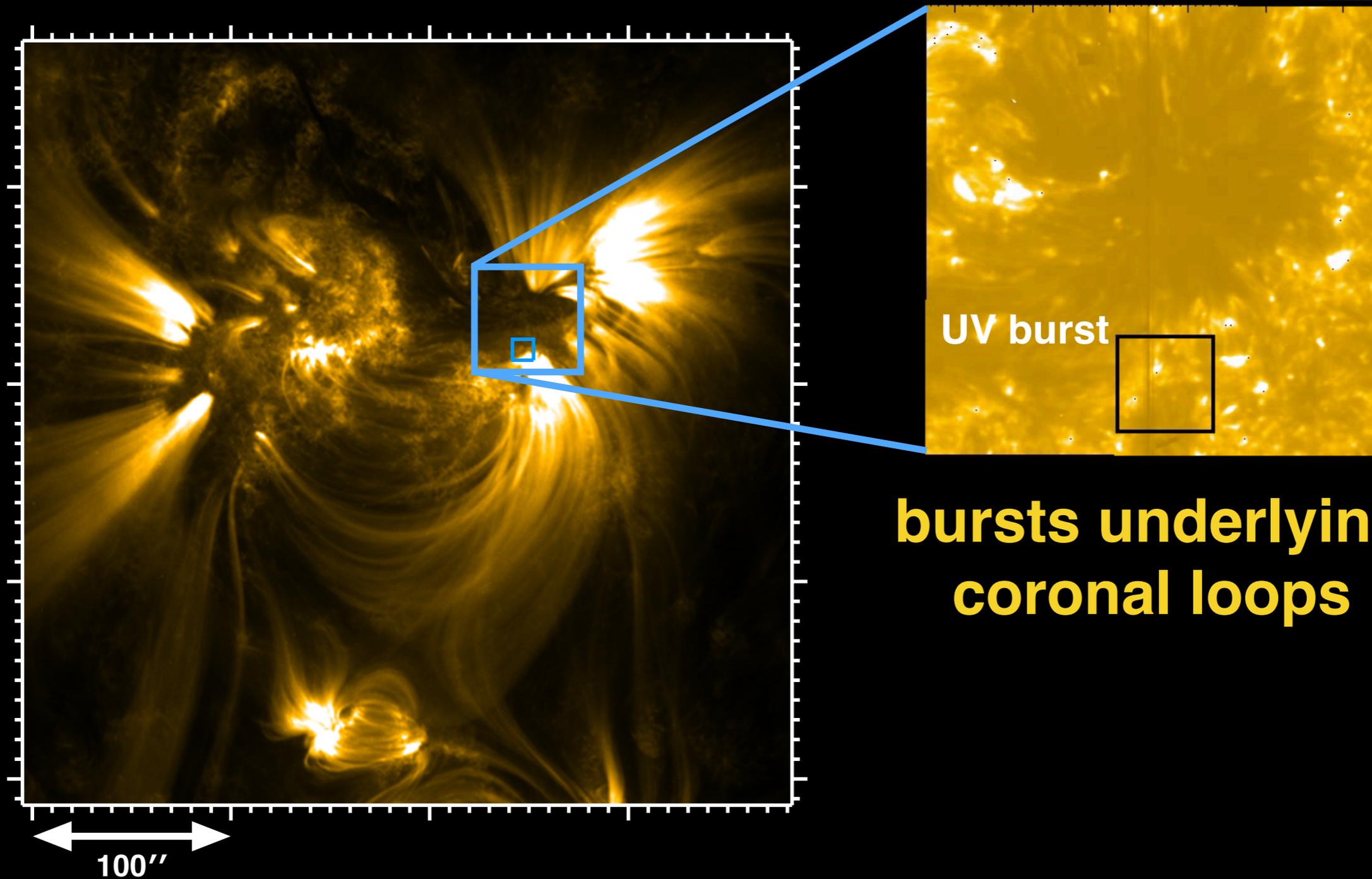
Chitta et al. (2017b) A&A, 605, A49



**bursts underlying
coronal loops**

Hidden bursts underlying loops

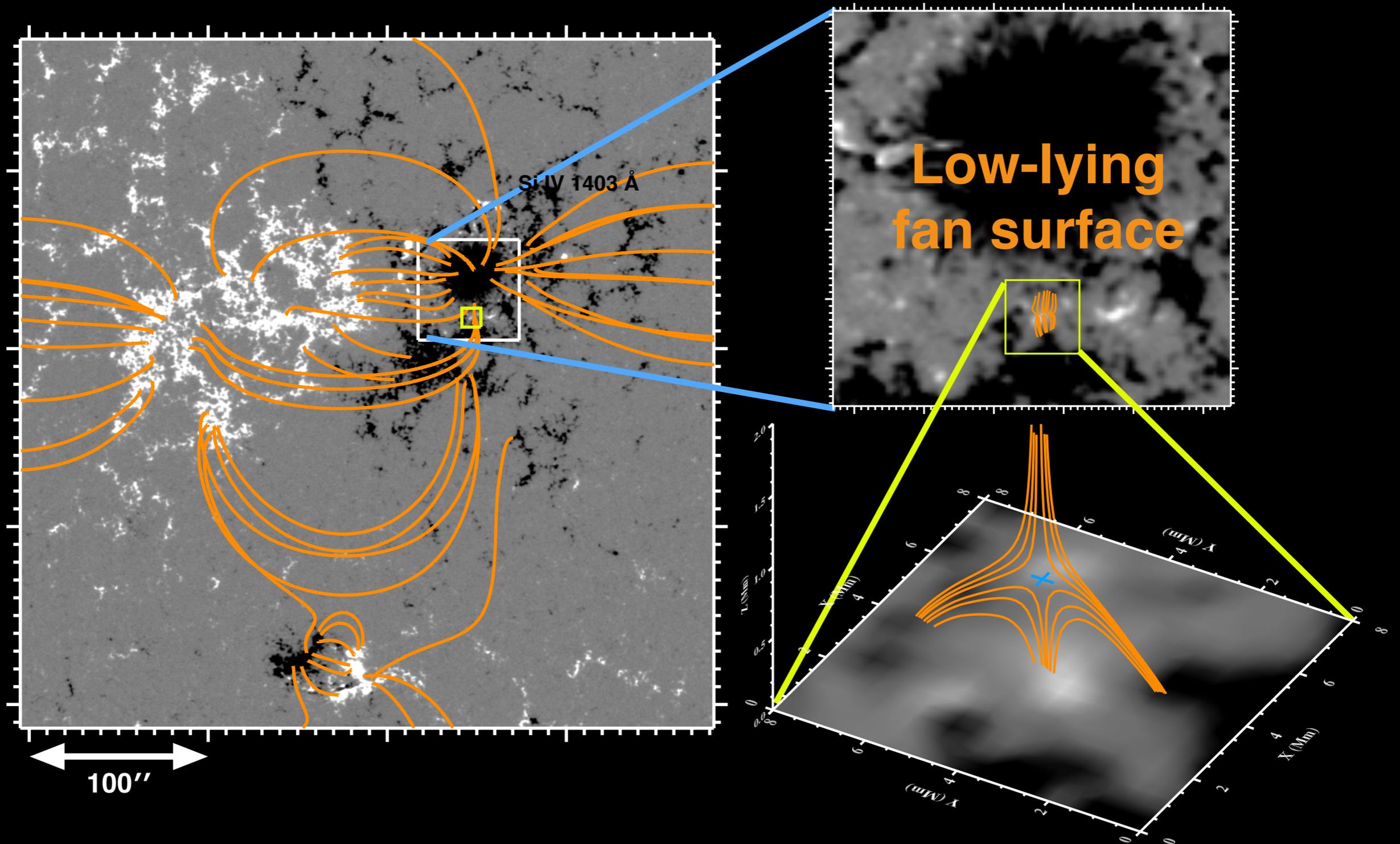
Chitta et al. (2017b) A&A, 605, A49



**bursts underlying
coronal loops**

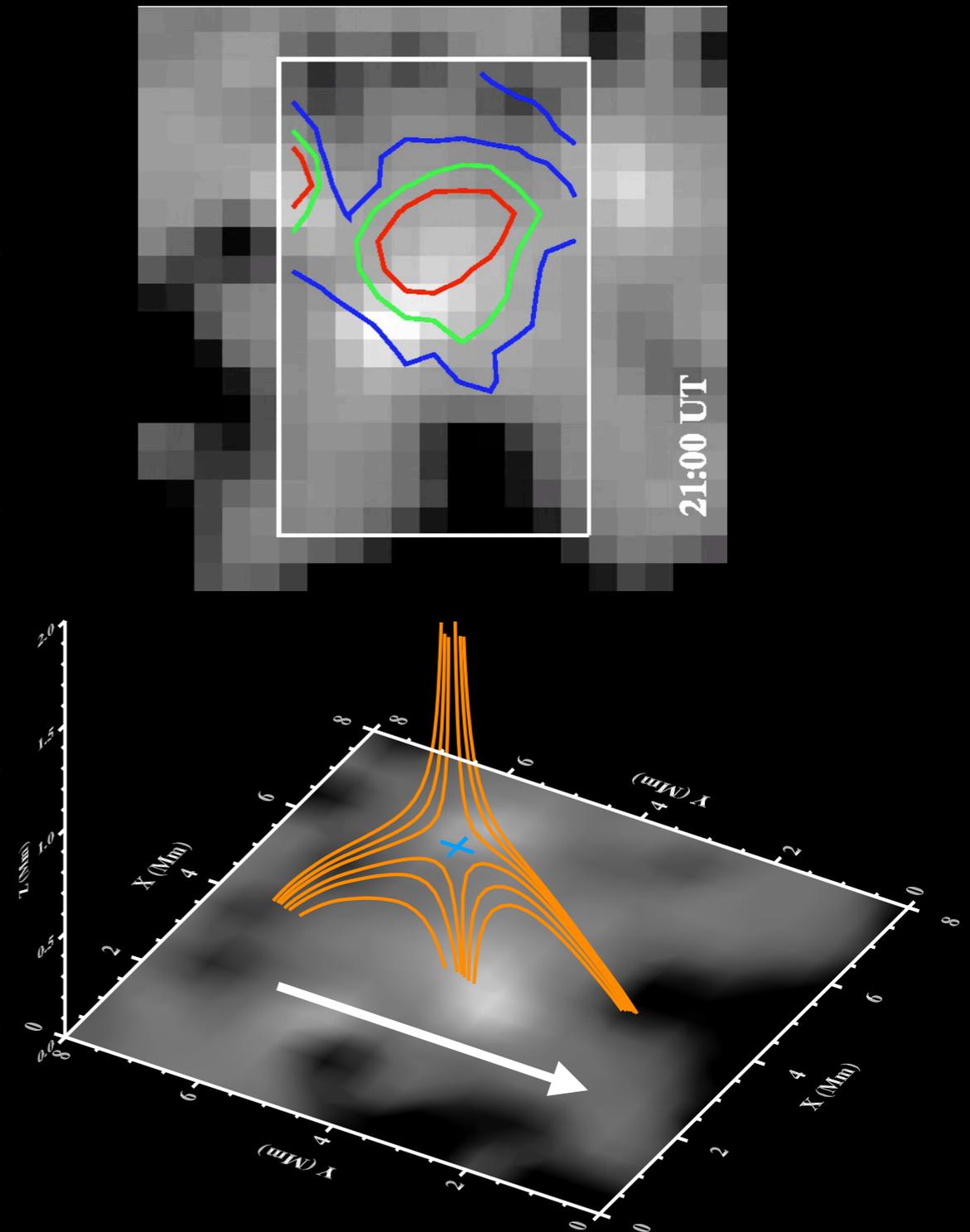
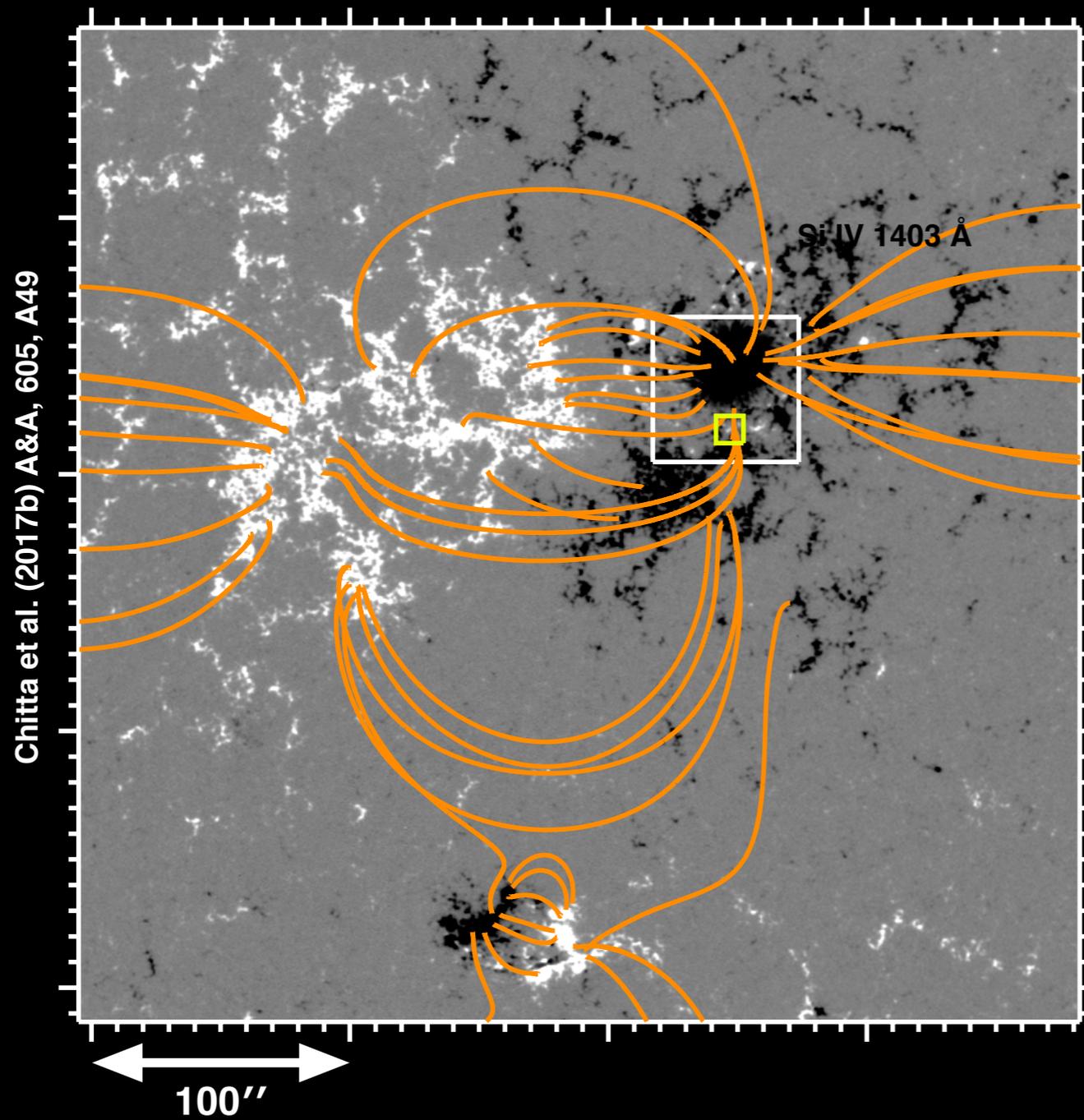
Magnetic coupling

Chitta et al. (2017b) A&A, 605, A49



3D magnetic topology surrounding the burst

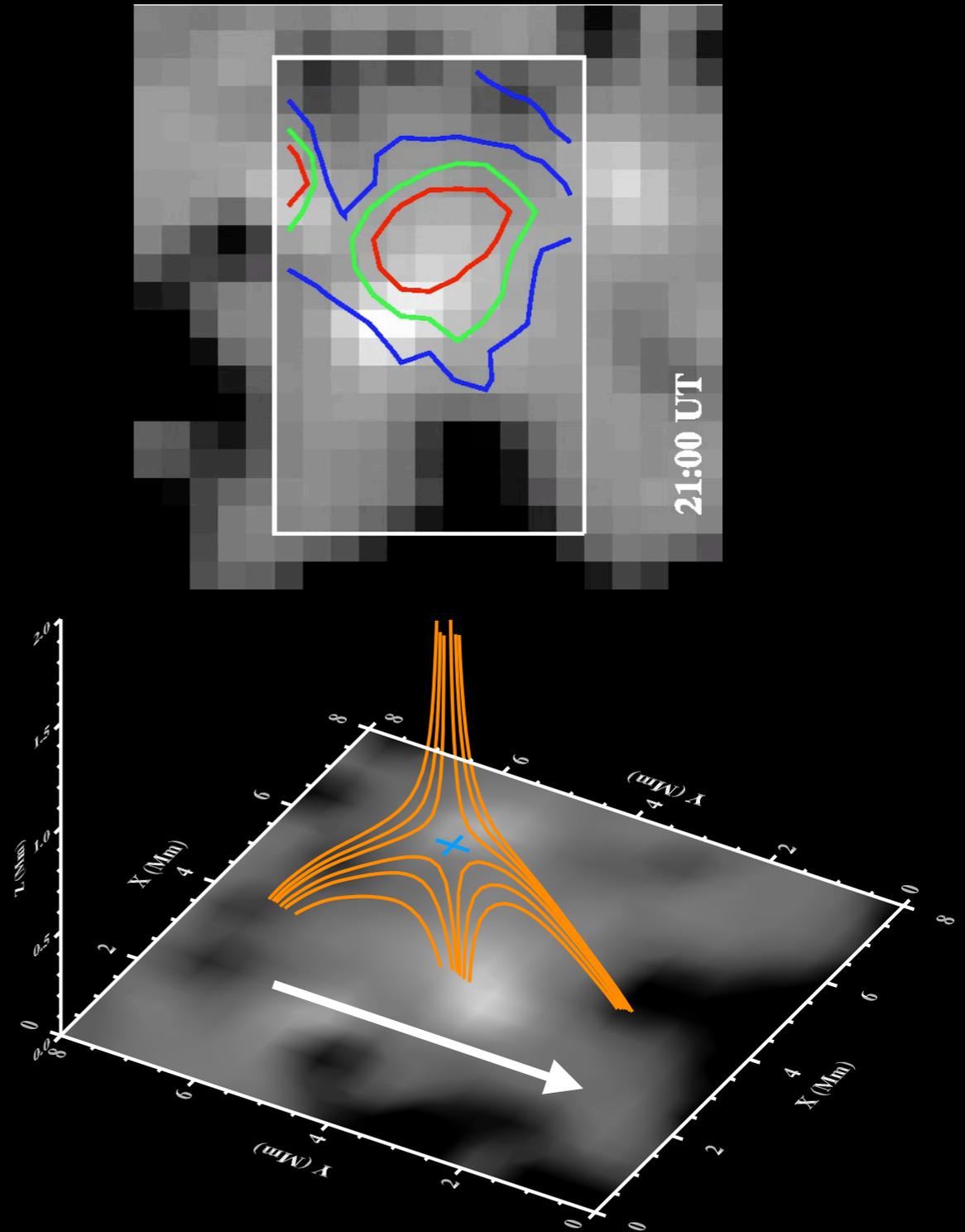
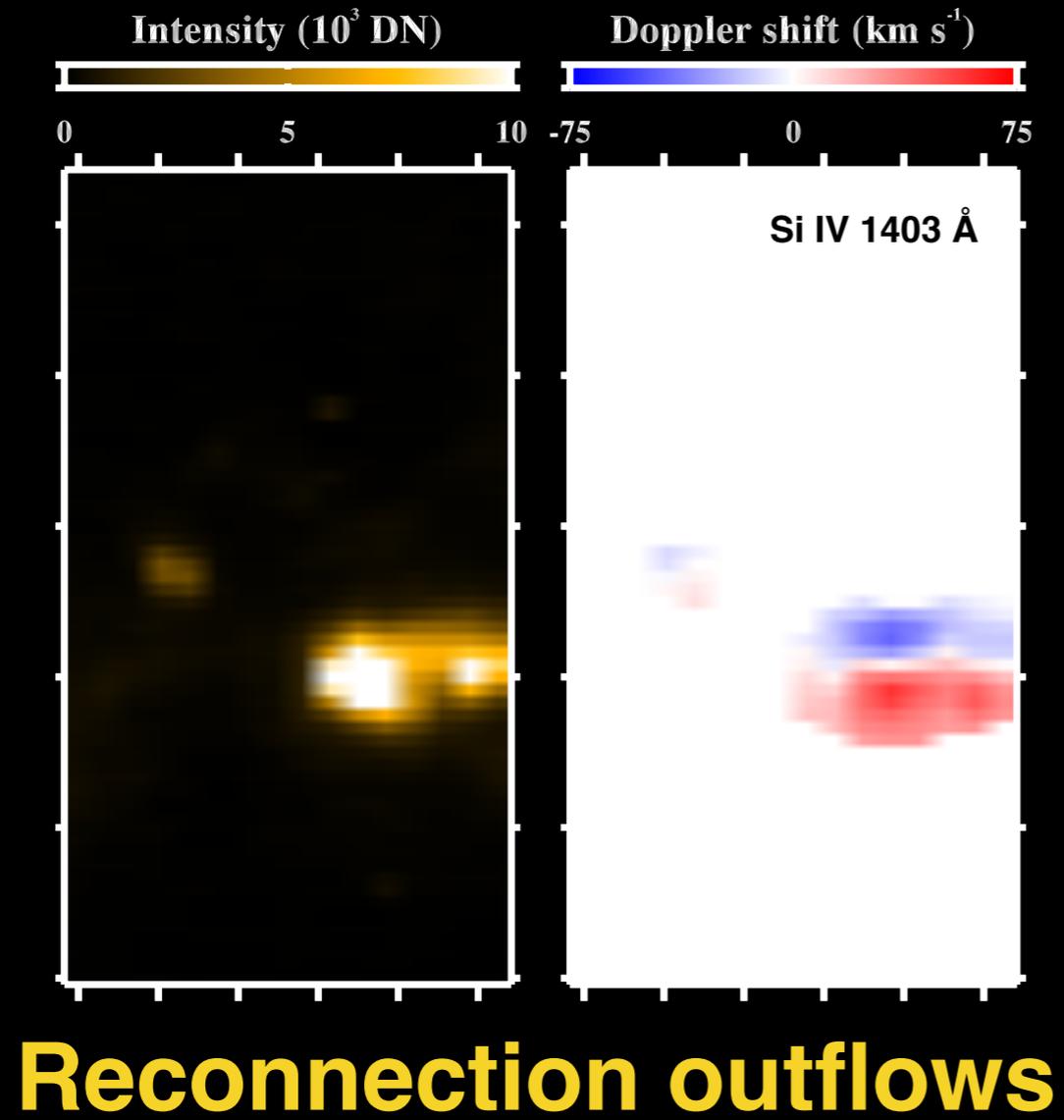
Magnetic coupling



Magnetic reconnection due to null-point shear

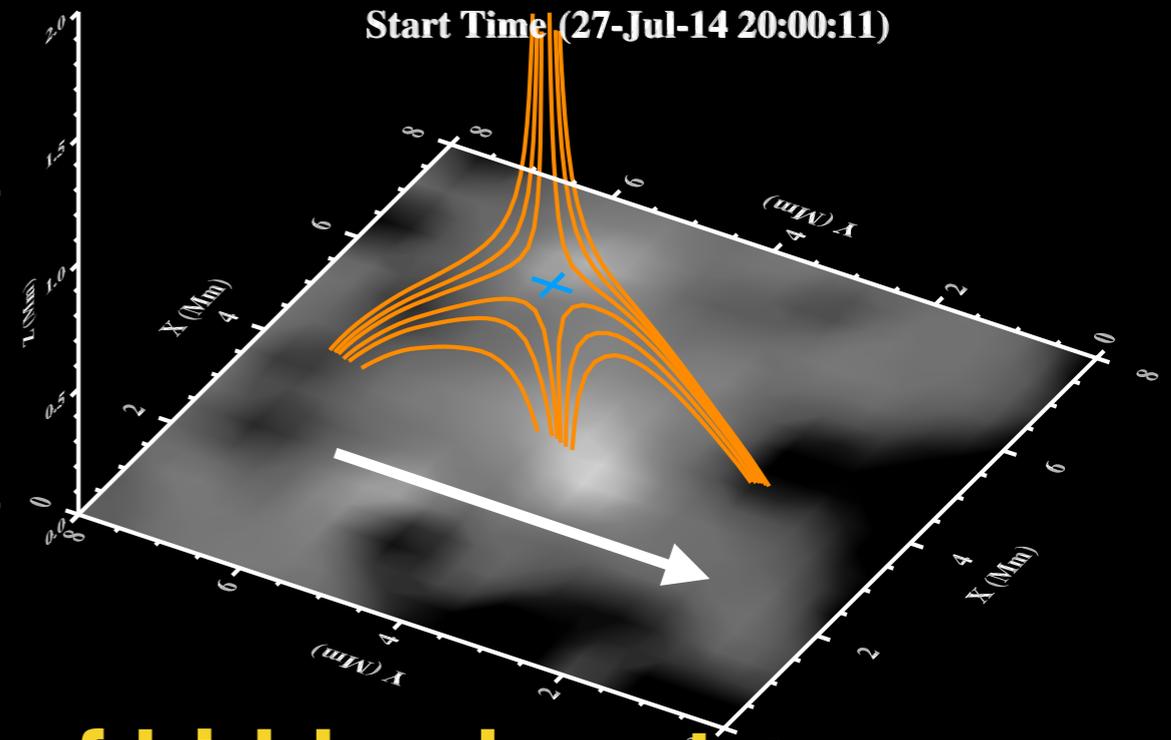
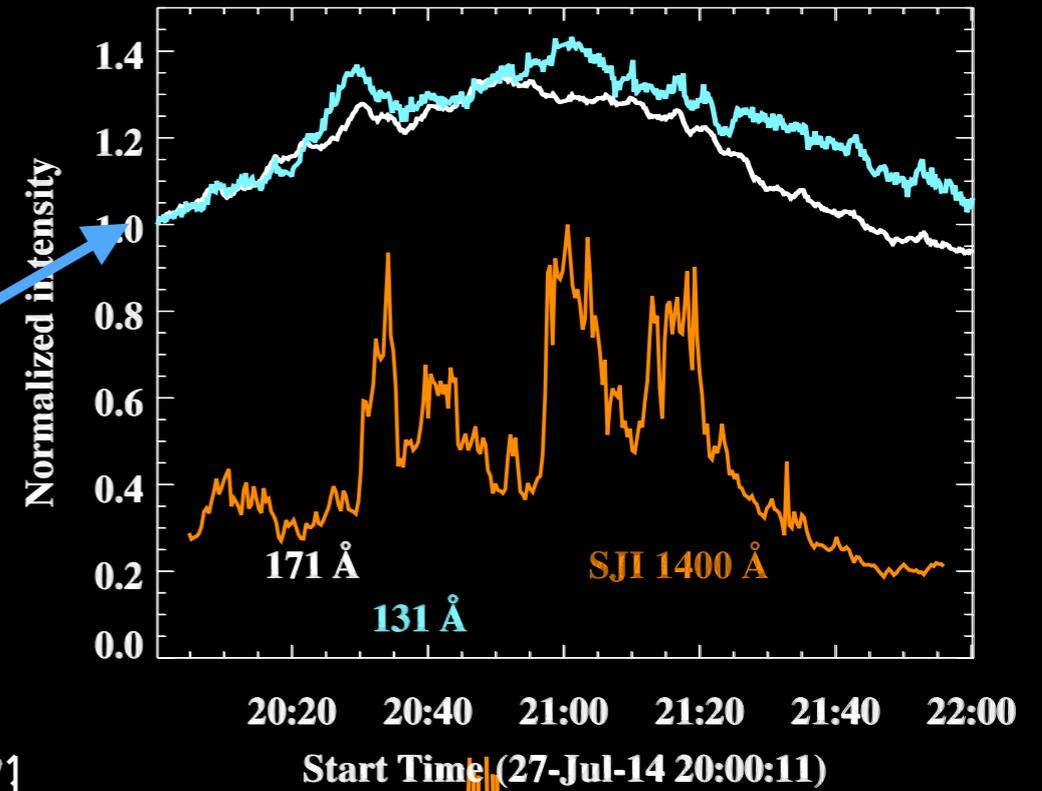
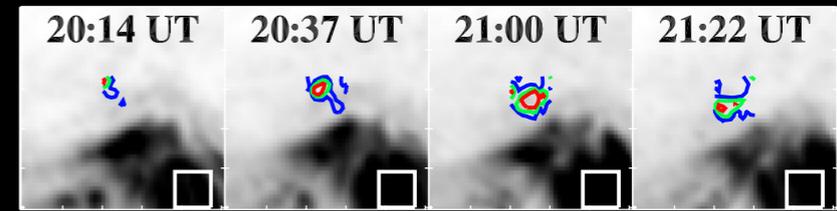
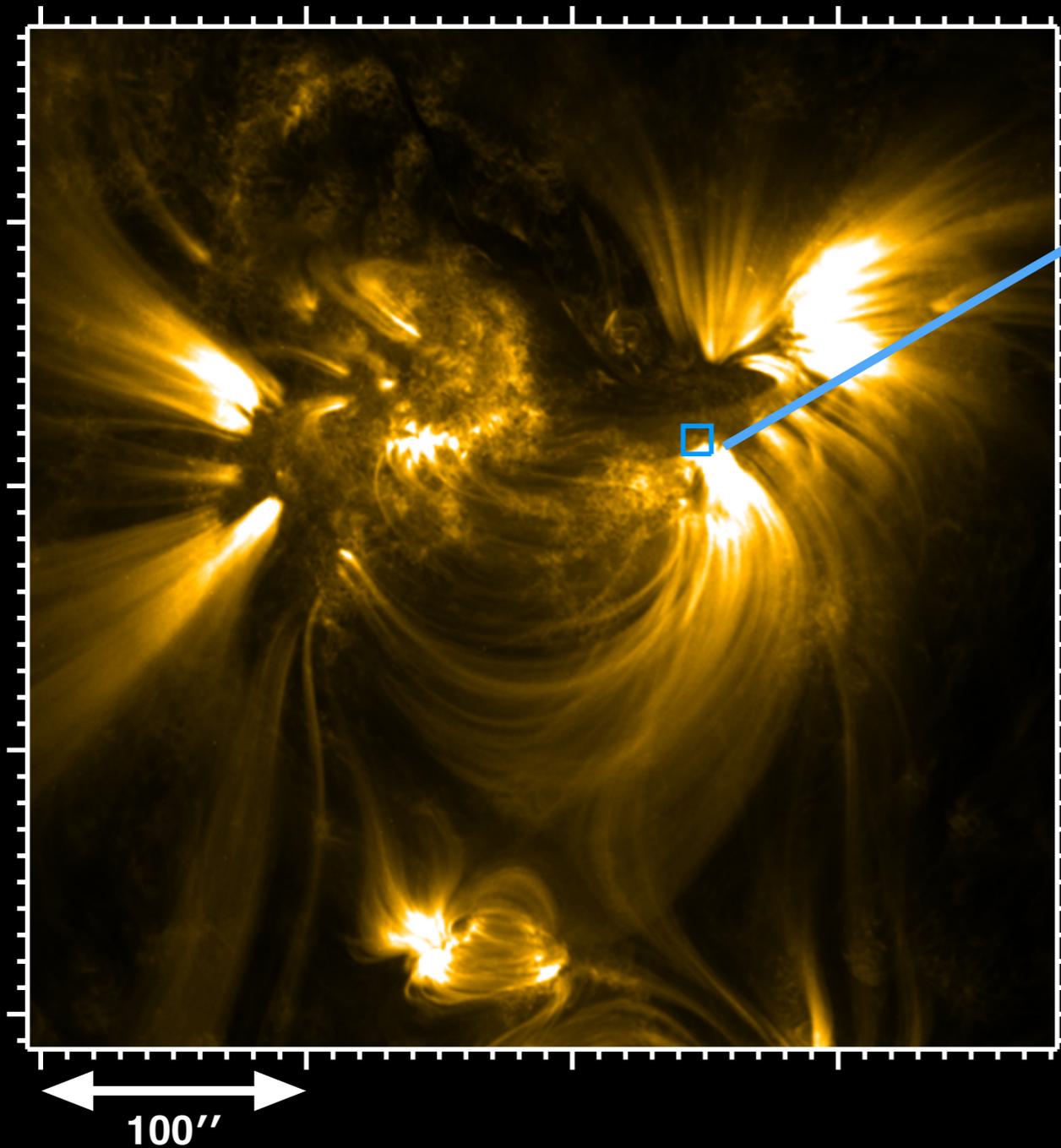
Magnetic coupling

Chitta et al. (2017b) A&A, 605, A49



Magnetic coupling

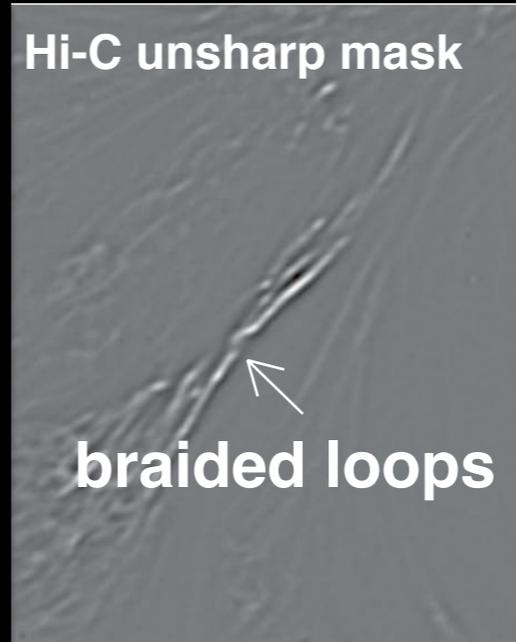
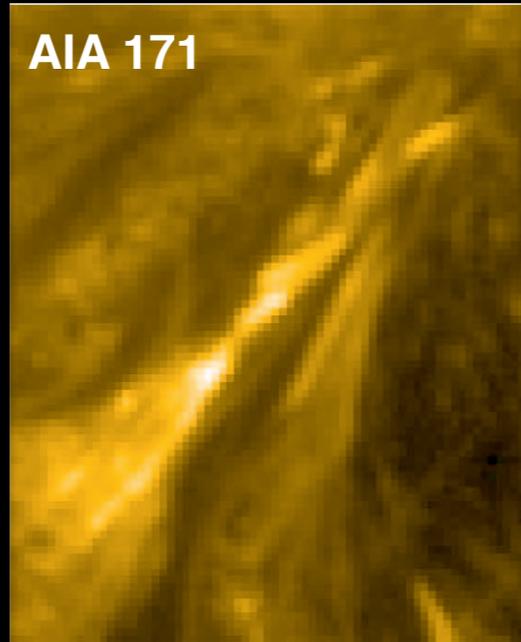
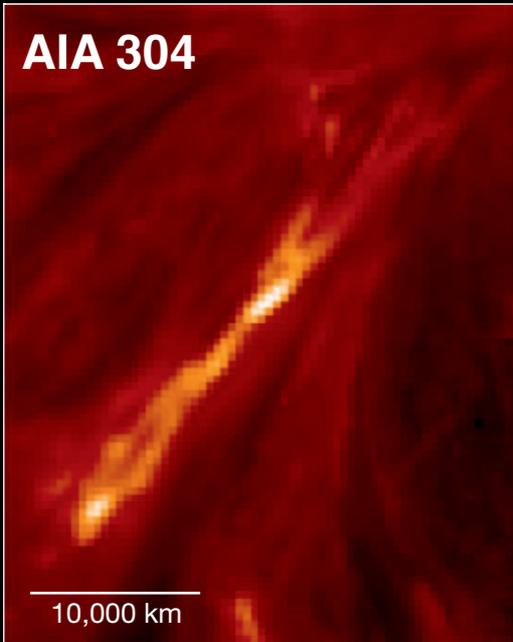
Chitta et al. (2017b) A&A, 605, A49



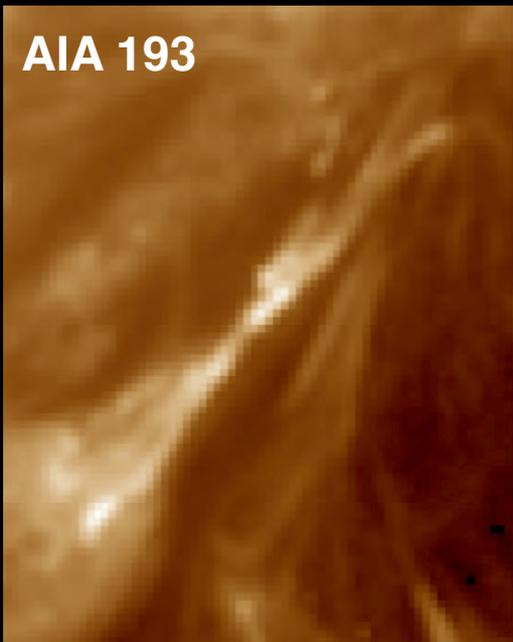
Coronal connection of hidden bursts through magnetic coupling

Bursts along (Hi-C) braided loops

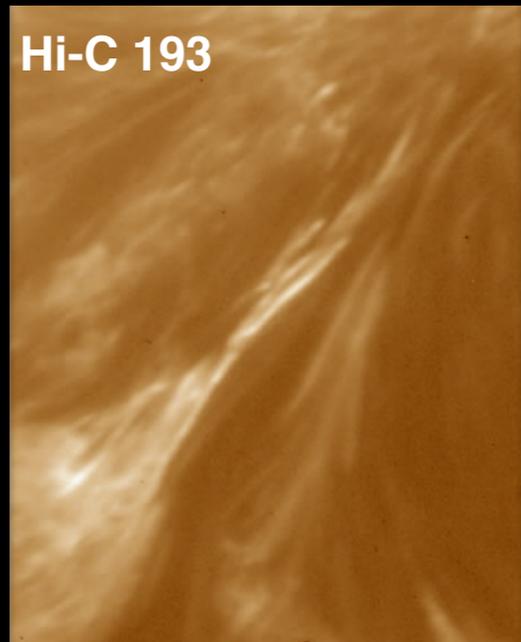
Cirtain et al. (2013) Nature, 493, 503



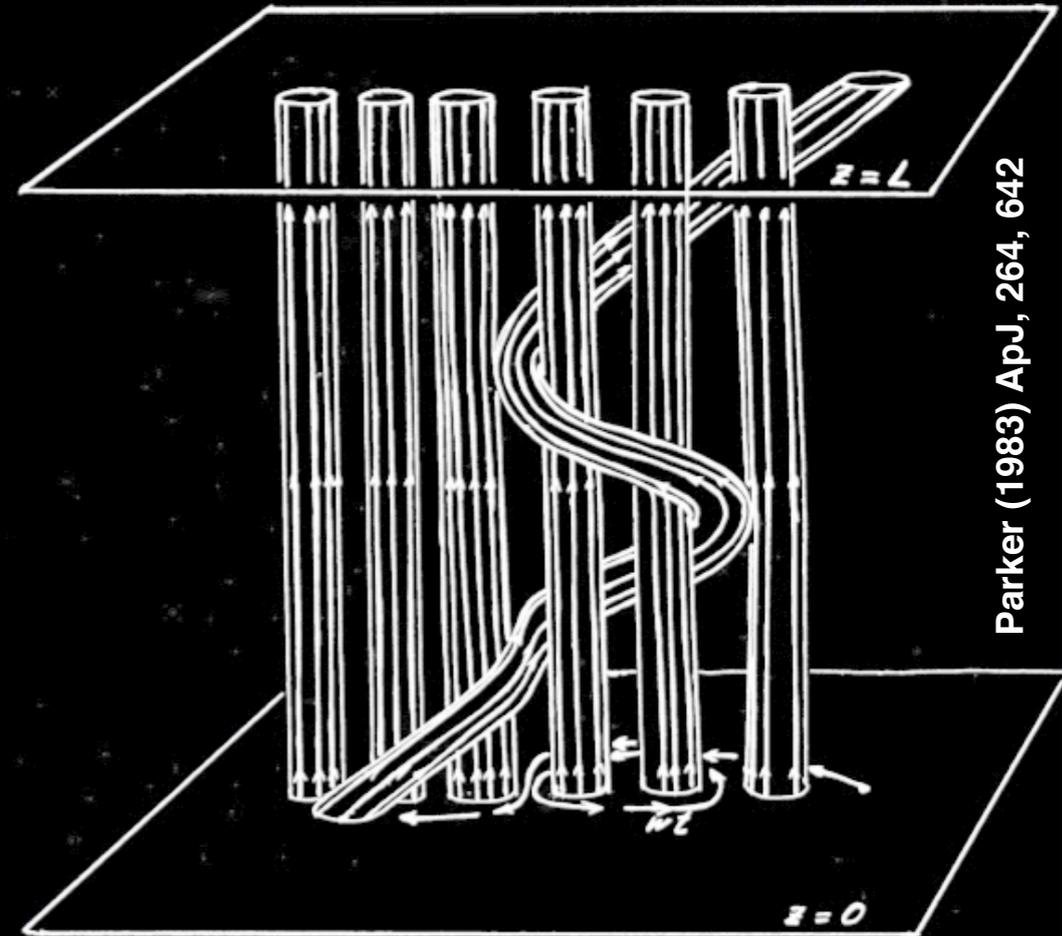
d AIA 193 Å: Fe XII (1.5 MK) 18:55:19



e Hi-C 193 Å: Fe XII (1.5 MK) 18:56:04



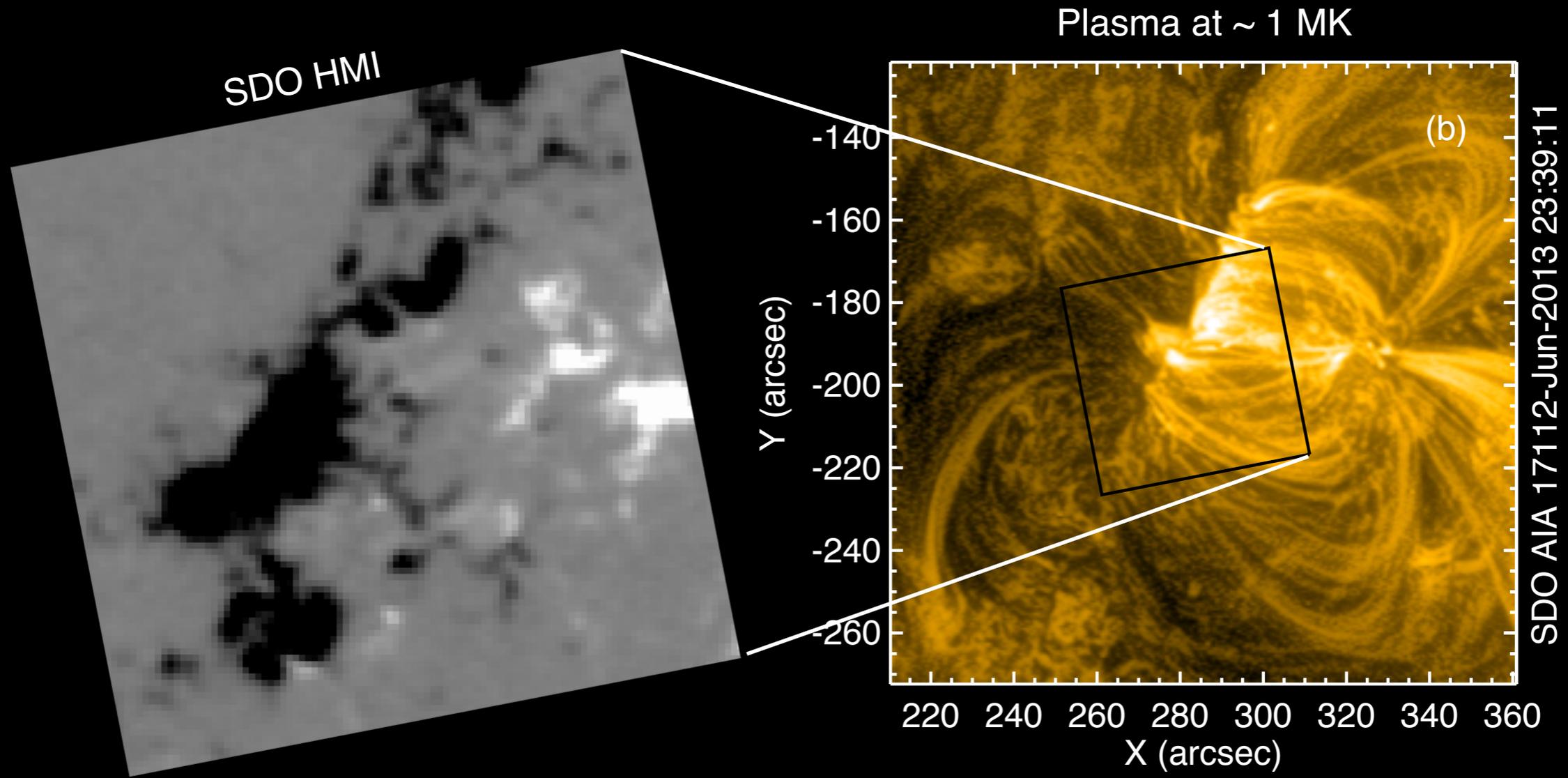
f AIA 94 Å: Fe XVIII (6.3 MK) 18:55:26



Magnetic roots of coronal loops

Where are coronal loop rooted?

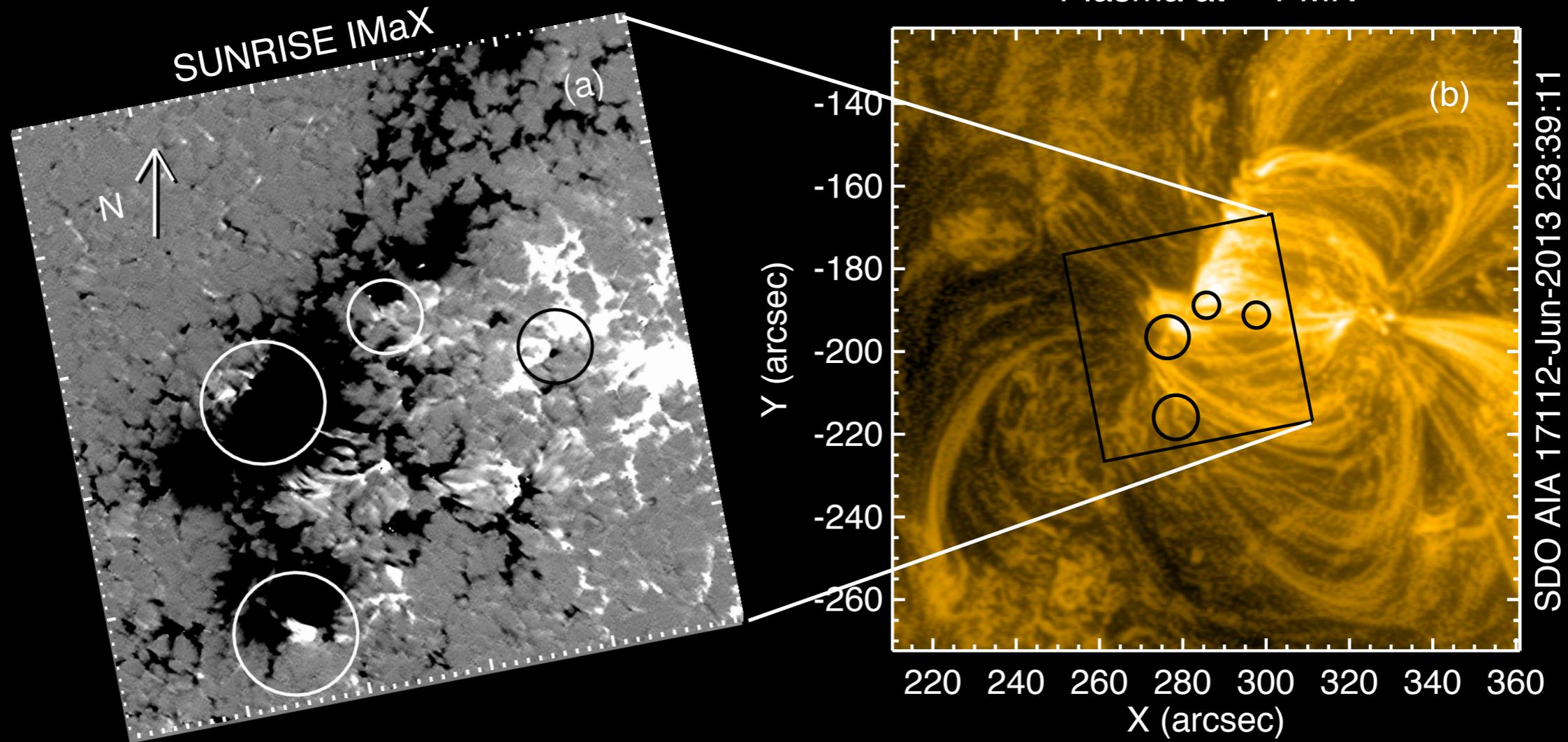
Chitta, Peter, Solanki et al. (2017a) ApJS, 229, 4



IMaX observed an emerging active region

Where are coronal loop rooted?

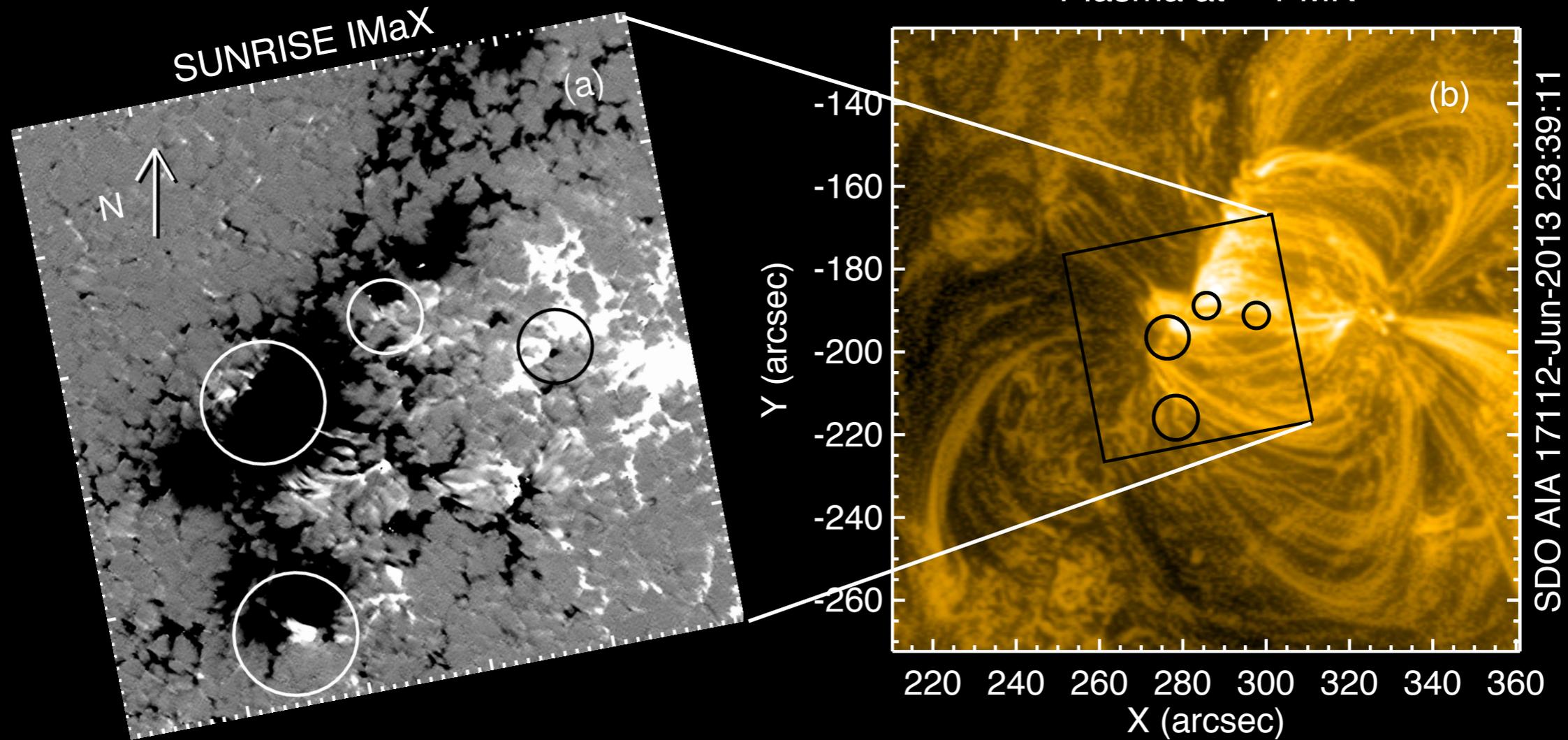
Chitta, Peter, Solanki et al. (2017a) ApJS, 229, 4



IMaX revealed a rich structure of the magnetic field in the photosphere which is not detected by HMI

Where are coronal loop rooted?

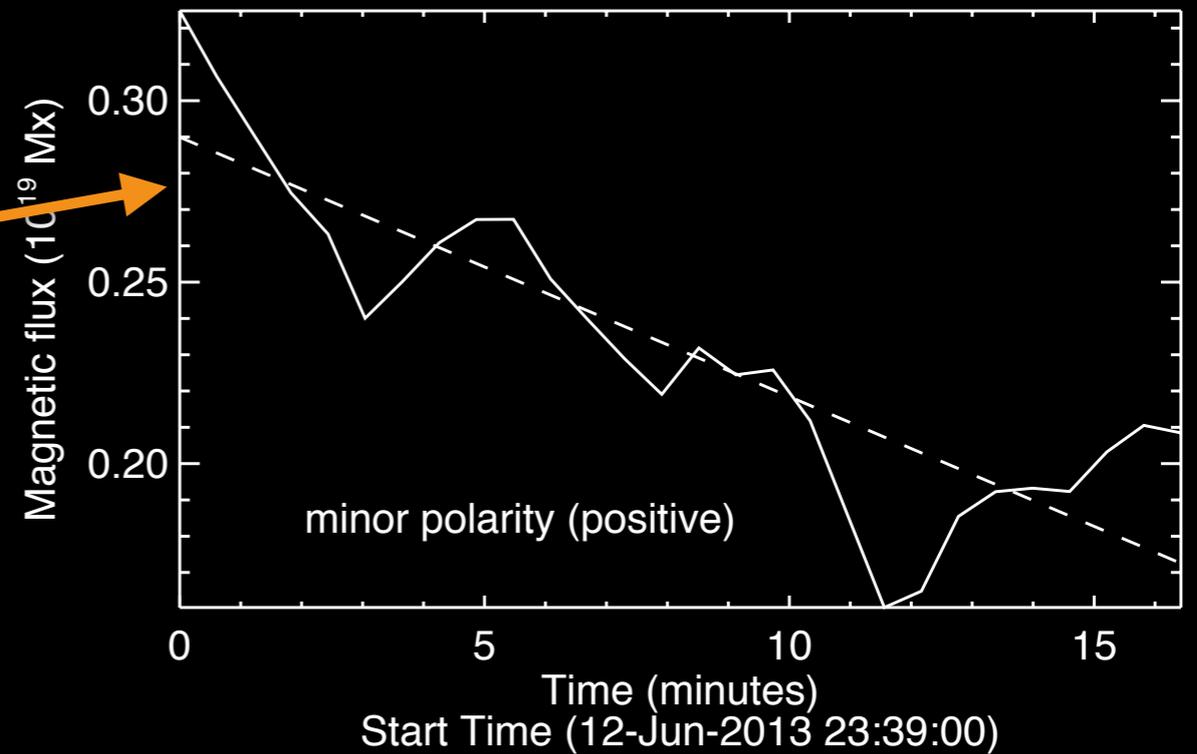
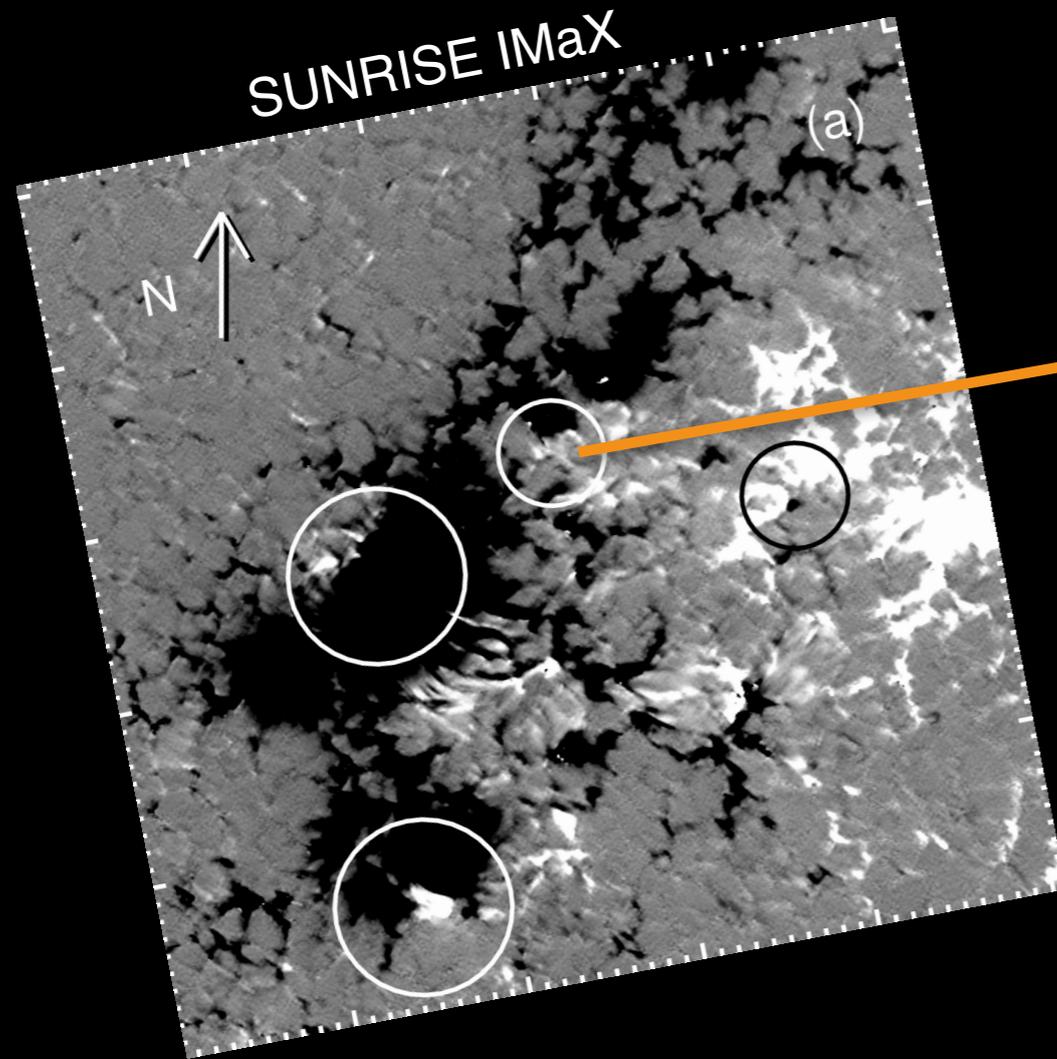
Chitta, Peter, Solanki et al. (2017a) ApJS, 229, 4



Mixed polarity magnetic field at coronal loop footpoints

Where are coronal loop rooted?

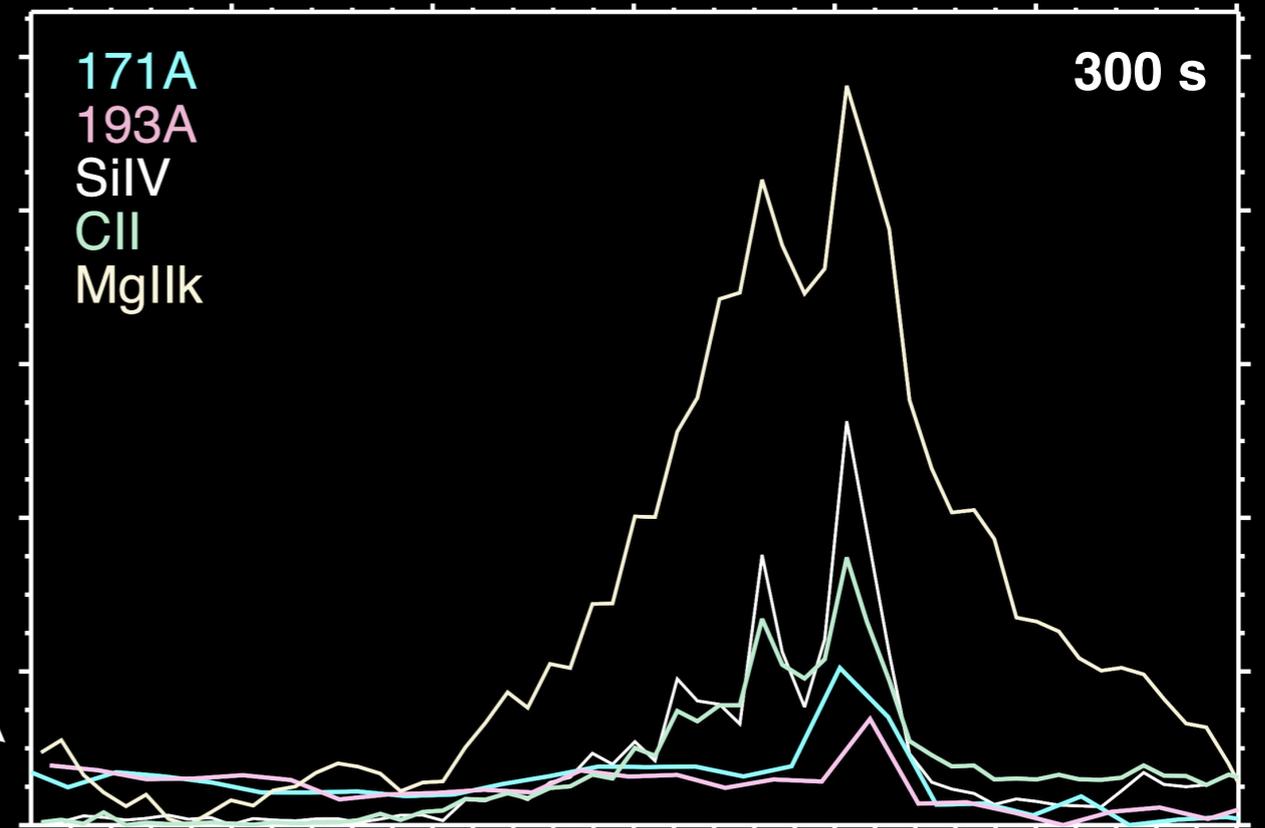
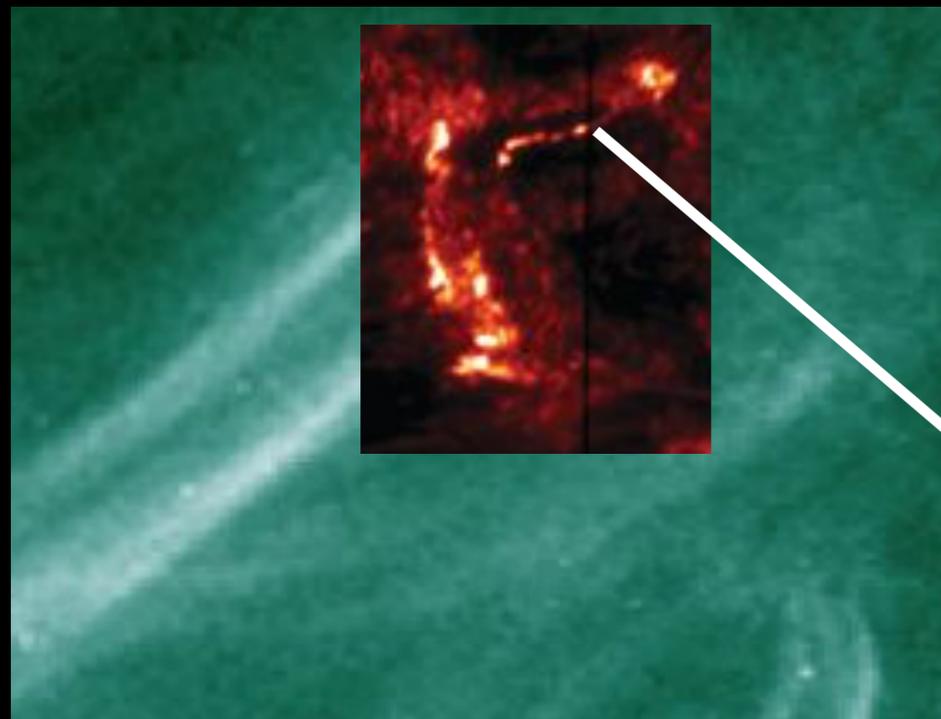
Chitta, Peter, Solanki et al. (2017a) ApJS, 229, 4



**Magnetic flux cancellation at coronal loop footprints
— similar to the case of UV bursts**

Flux cancellation in action

Flux cancellation in active region cores

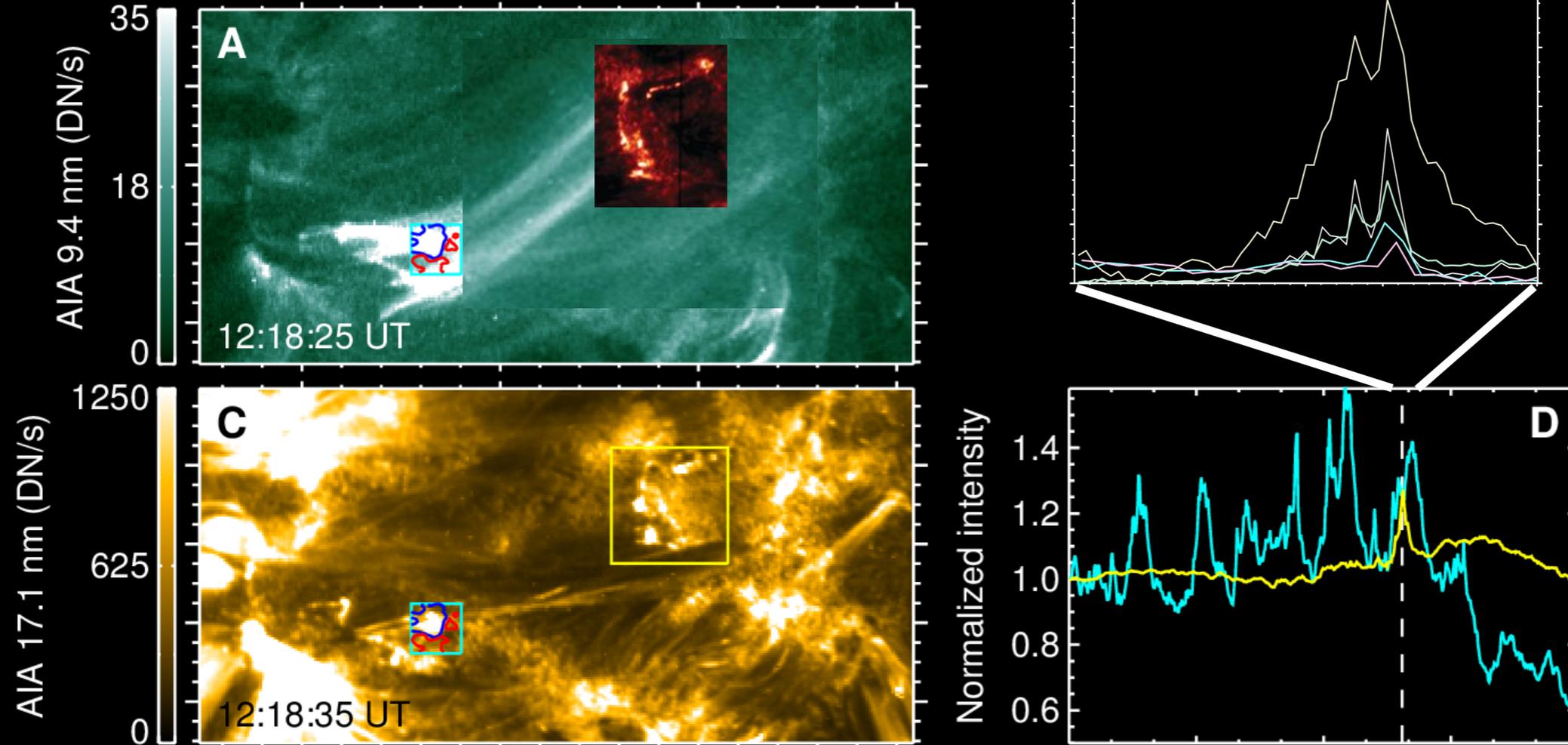


Testa et al. (2014) Science, 346, 1255724

Highly variable emission from the footpoint of a nanoflare driven coronal loop

Flux cancellation in active region cores

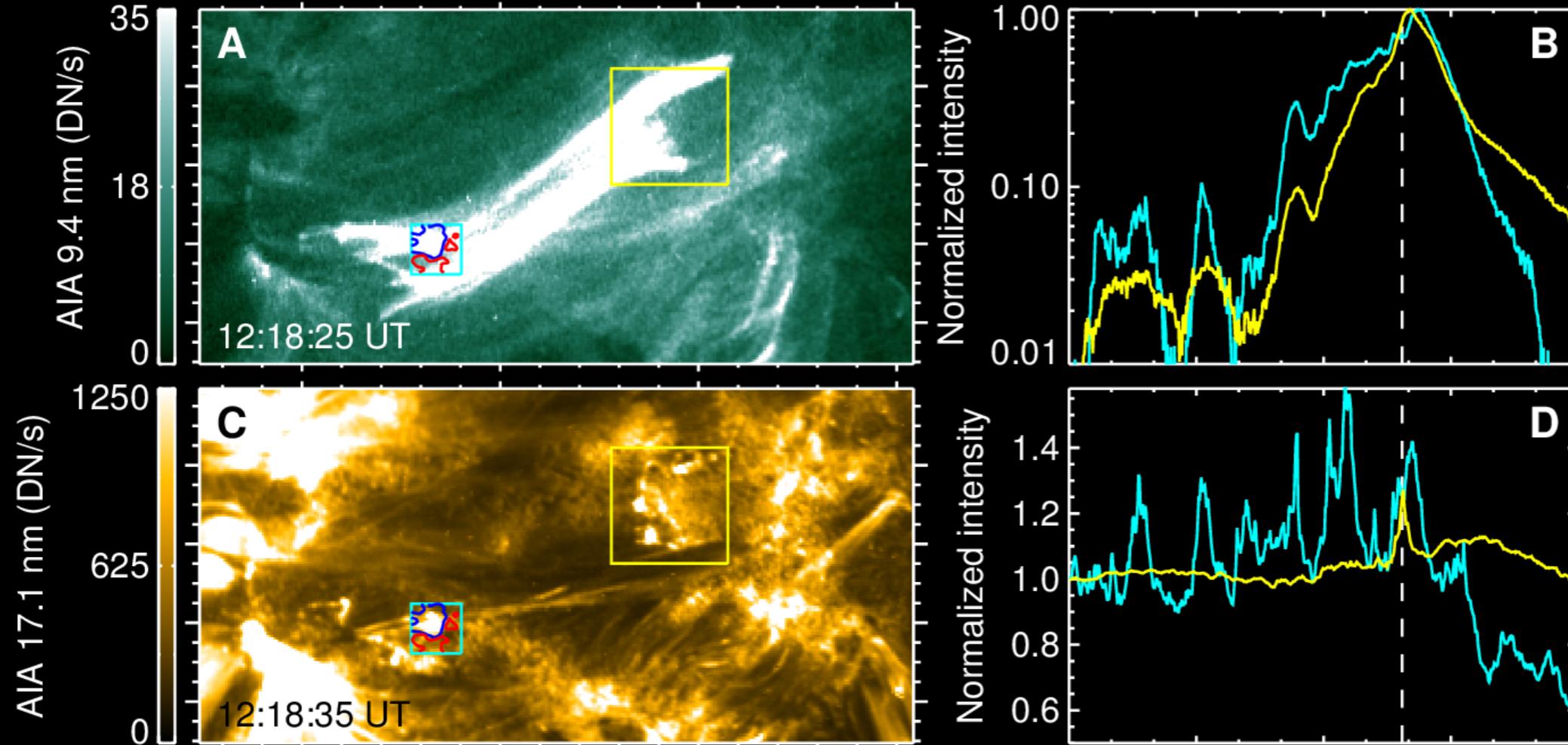
Chitta, Peter & Solanki (2018; to appear in A&A Letters; ArXiv e-prints 1806.11045)



Emission from both the footpoint

Flux cancellation in active region cores

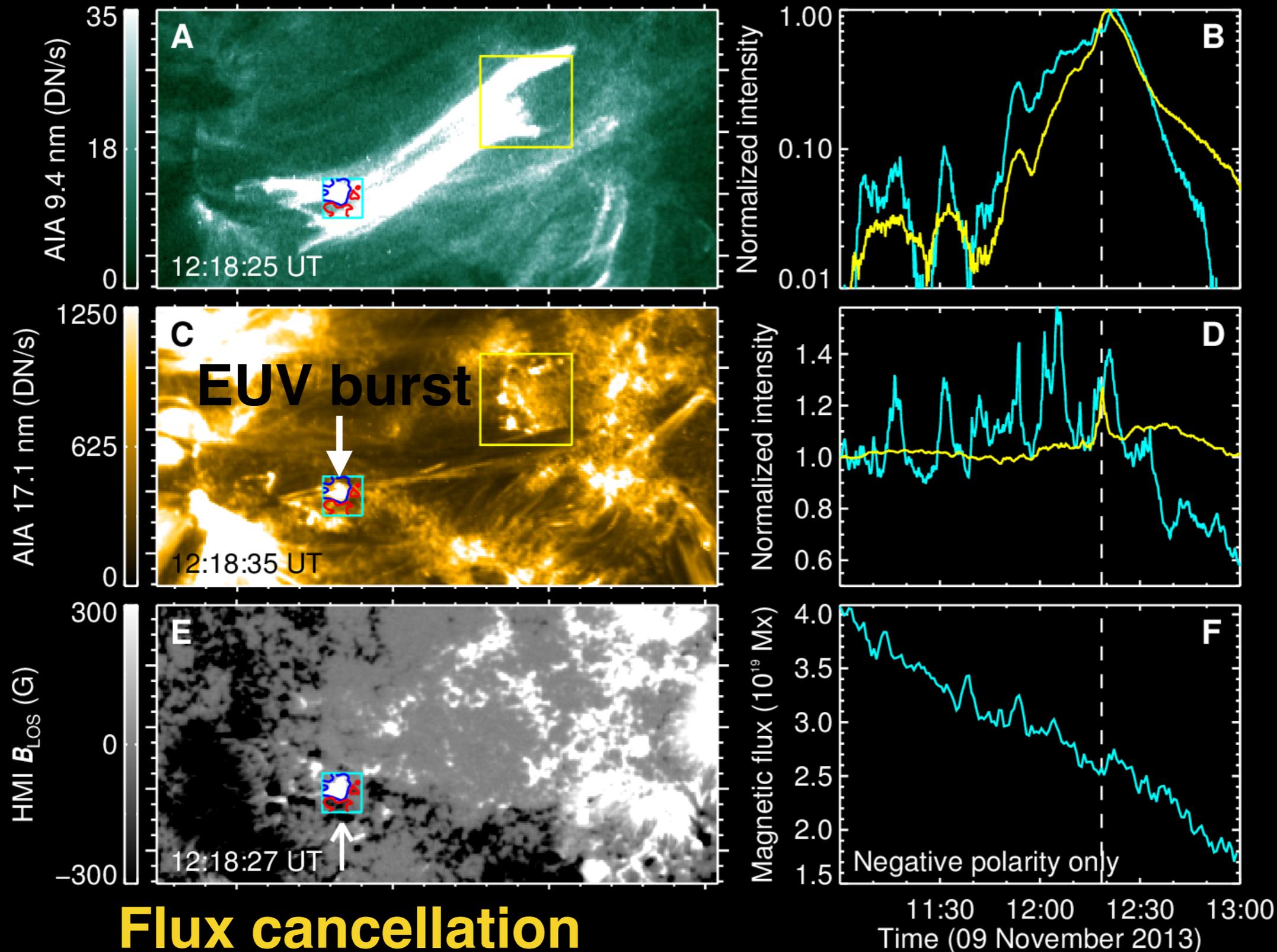
Chitta, Peter & Solanki (2018; to appear in A&A Letters; ArXiv e-prints 1806.11045)



Emission from both the footpoint

Flux cancellation in active region cores

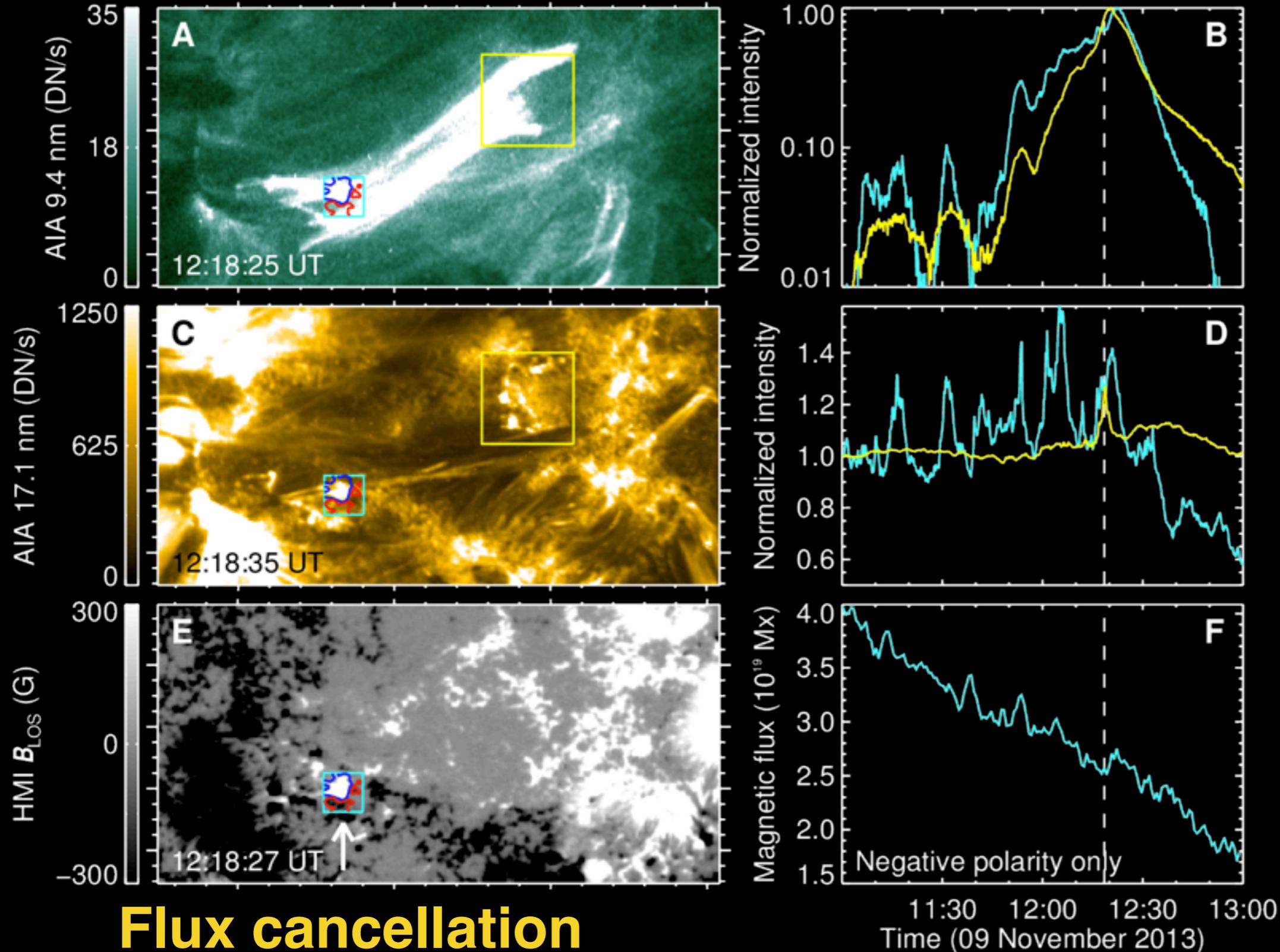
Chitta, Peter & Solanki (2018; to appear in A&A Letters; ArXiv e-prints 1806.11045)



Flux cancellation

Flux cancellation in active region cores

Chitta, Peter & Solanki (2018; to appear in A&A Letters; ArXiv e-prints 1806.11045)

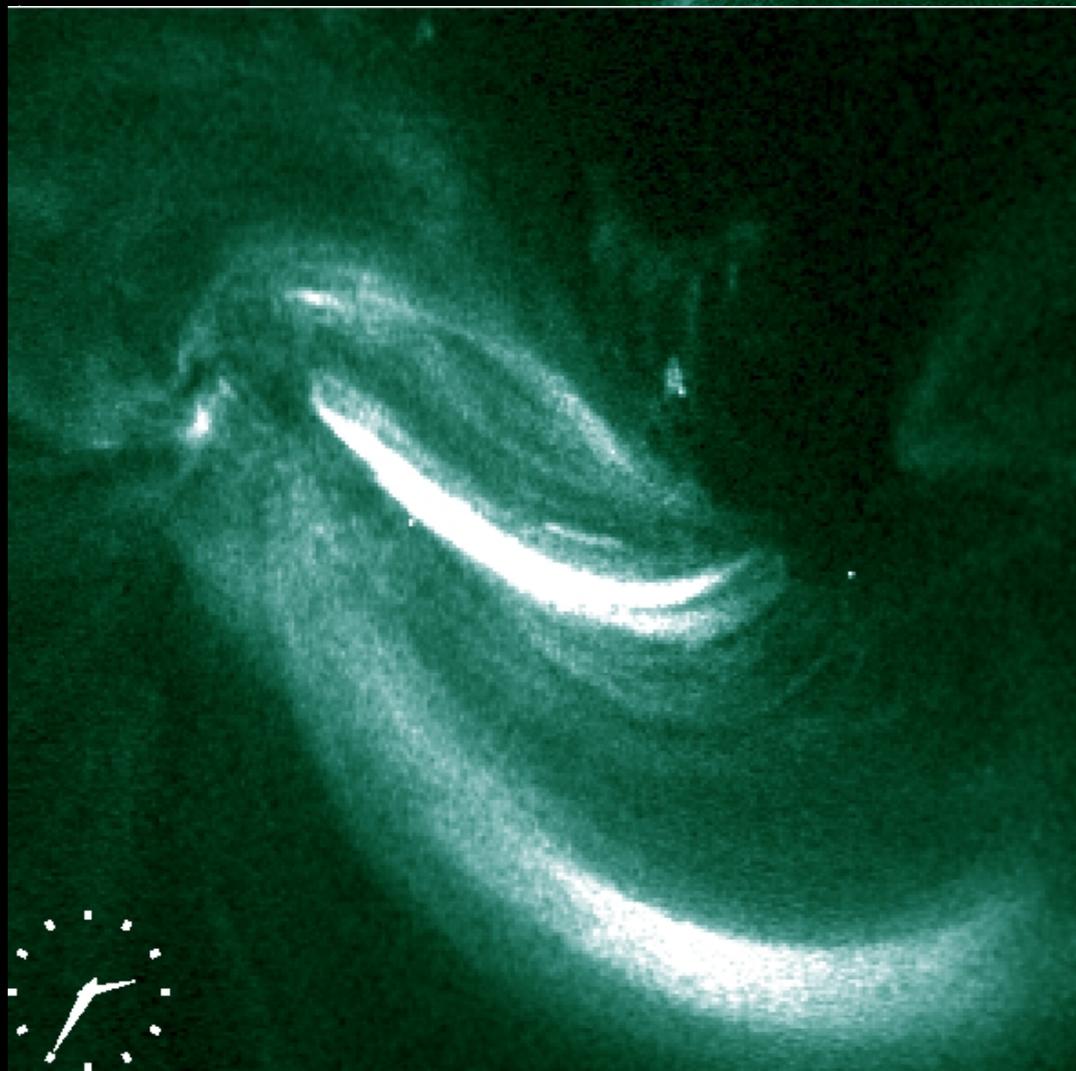


Magnetic coupling and solar structures

What governs the energy release, its location, and frequency?

- Flux cancellation and reconnection at footpoints

- Reconnection height and dynamics



Flux cancellation and reconnection

- **a process discrete in space and time in contrast to braiding and waves**
- **can explain the spatial structuring and temporal evolution of the atmosphere**
- **generate high heat input to power the loops in active region cores**

Summary

Bursts and coronal loops are governed by the underlying magnetic landscape

- **Sunspot loops — supersonic downflows — cooling due to suppressed energy input**
- **Flux cancellation and signatures of reconnection (EUV bursts and jets) at the feet of coronal loops**
- **Towards a unified picture of bursts and loops — driven by magnetic reconnection**