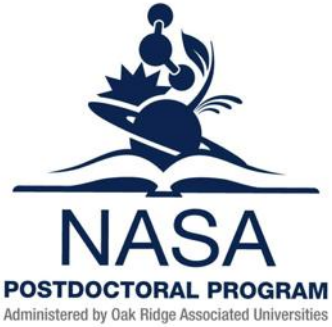
Suppression of Heating of Coronal Loops Rooted in Opposite Polarity Sunspot Umbrae

Sanjiv K. Tiwari,

(J. K. Thalmann*, A. R. Winebarger, N. K. Panesar#, R. L. Moore#)

NASA Marshall Space Flight Center, Huntsville, AL, USA
*Institute for Physics/IGAM, University of Graz, Austria
#Center for Space Plasma and Aeronomic Research, UAH, Huntsville, AL, USA

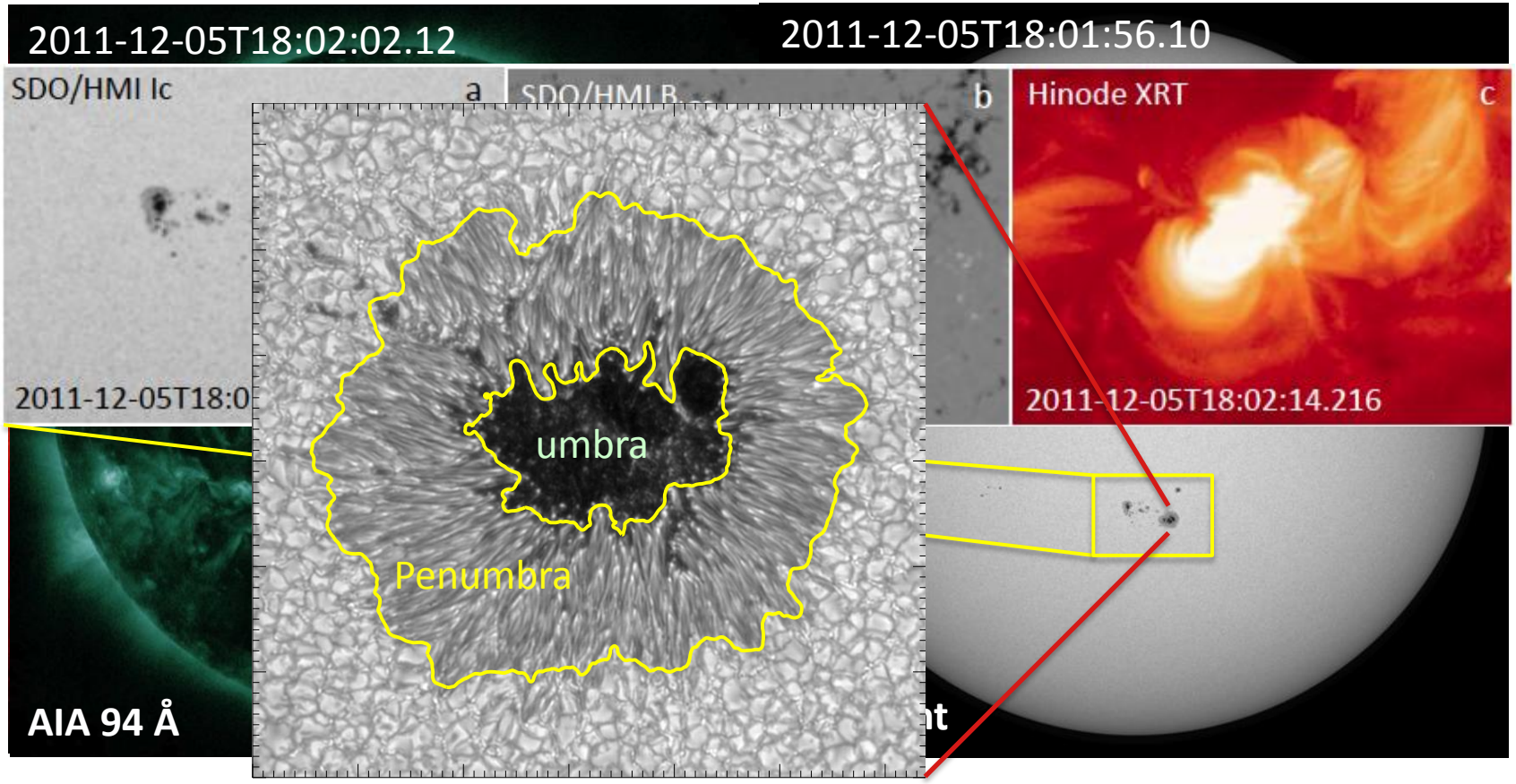
Marshall Space Flight Center



21 Jul 2015 Loops VII, Univ. of Cambridge

sanjiv.k.tiwari@nasa.gov

Background



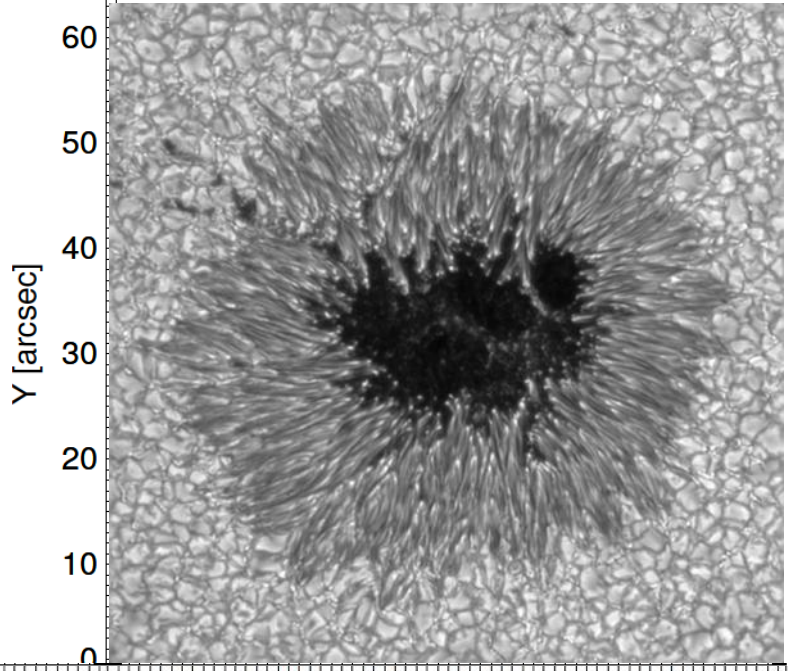
- Active regions are the brightest features in EUV and X-ray corona of the Sun
  Sounding rockets and Skylab (Vaiana et al. 1973, 1975) onwards….

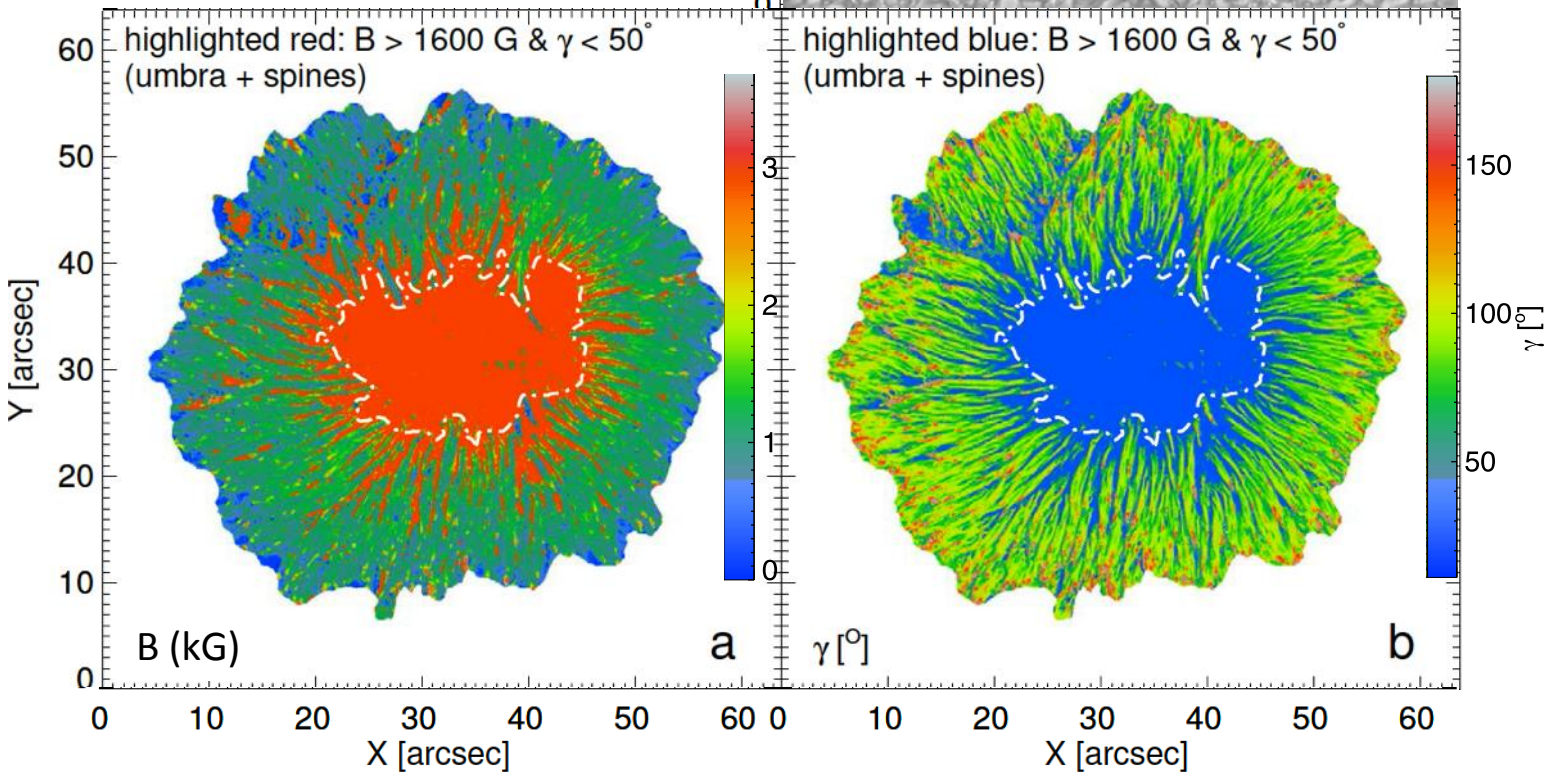
(For a recent review, see, Reale 2014, LRSP)

Background..

Part of sunspot penumbra (spine field) is an outward extension of umbra

Tiwari, van Noort, Solanki, Lagg, 2015, *A&A*, under review





Background..

- Sunspot umbrae have no or little X-ray and/or coronal EUV emissions
  (Pallavicini et al. 1979, Webb & Zirin 1981, Webb et al. 1983)

- None of the bright loops originate in sunspot umbrae
  (Sams III et al., 1992)

- Sunspots are dark on the surface and in the (X-ray) corona
  (Golub, Zirin & Wang, 1994: NIXT sounding rocket X-ray images)

Inconsistent with the following…

- Loops rooted in sunspot umbra are the brightest ones among others
  (Foukal et al., 1974; Foukal, 1975; Webb & Zirin 1981)

1975SoPh...43..32

THE TEMPERATURE STRUCTURE AND PRESSURE BALANCE OF MAGNETIC LOOPS IN ACTIVE REGIONS

P. FOUKAL
Center for Astrophysics, Cambridge, Mass. 02138, U.S.A.

(Received 2 January; in revised form 7 May, 1975)

Abstract. EUV observations show many active region loops in lines formed at temperatures between 10^4K and 2×10^6K. The brightest loops are associated with flux tubes leading to the umbrae of sunspots. It is shown that the high visibility of certain loops in transition region lines is due principallly

Webb & Zirin 1981

- All flaring loops end in umbrae

Golub, Zirin & Wang, 1994

- The brightest features are the remains of small flares

Falconer et al. 1997

- Brightest loops are rooted near neutral lines
- Flux cancellation at feet might induce loop's coronal brightness

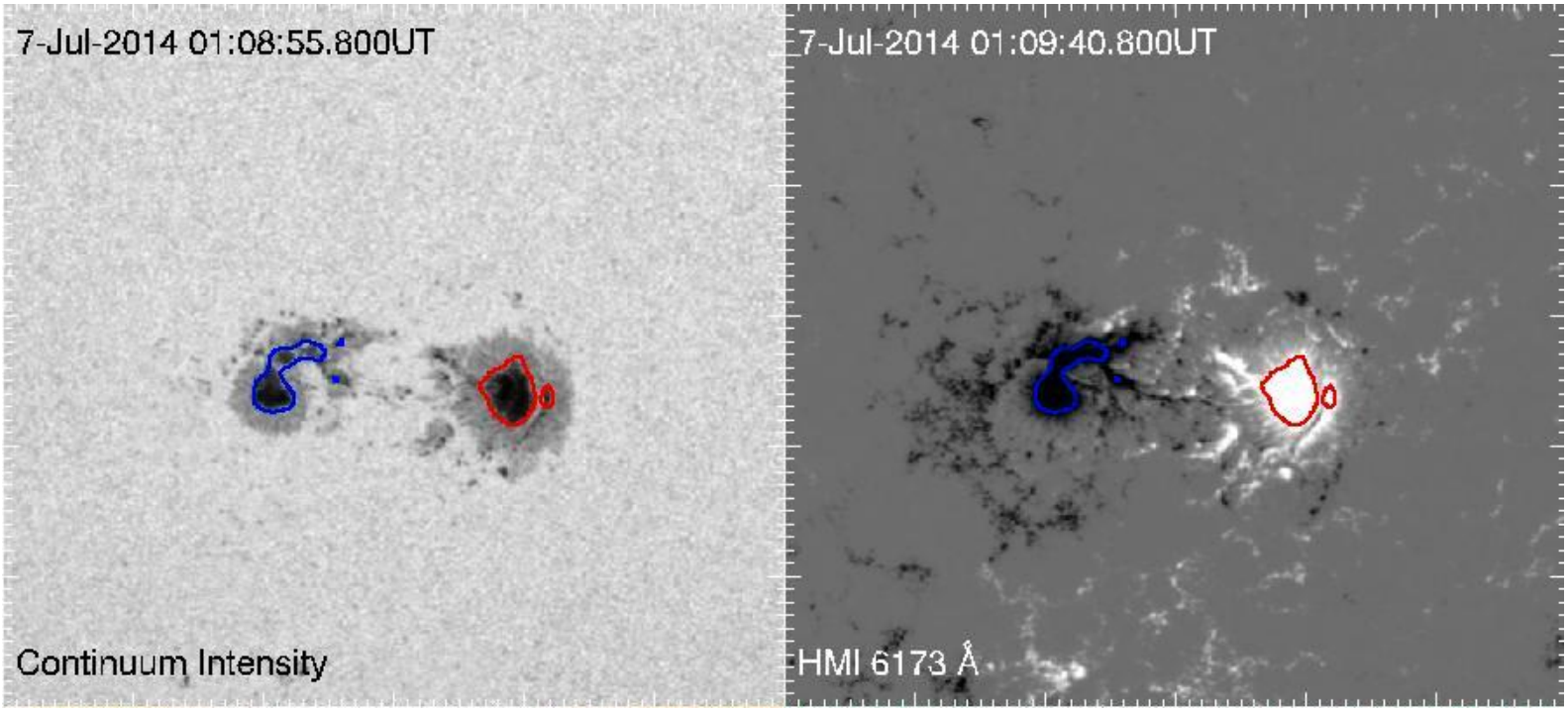
Some obvious questions

- Why sunspots, particularly umbrae, are usually dim in coronal EUV and X-ray?

- What's special about some loops that stem from an umbra but are the AR's brightest loops in coronal EUV and X-ray at a given time?

- Does loop's rooting pattern, magnetic setting on the photosphere, tell us something about their coronal brightness?

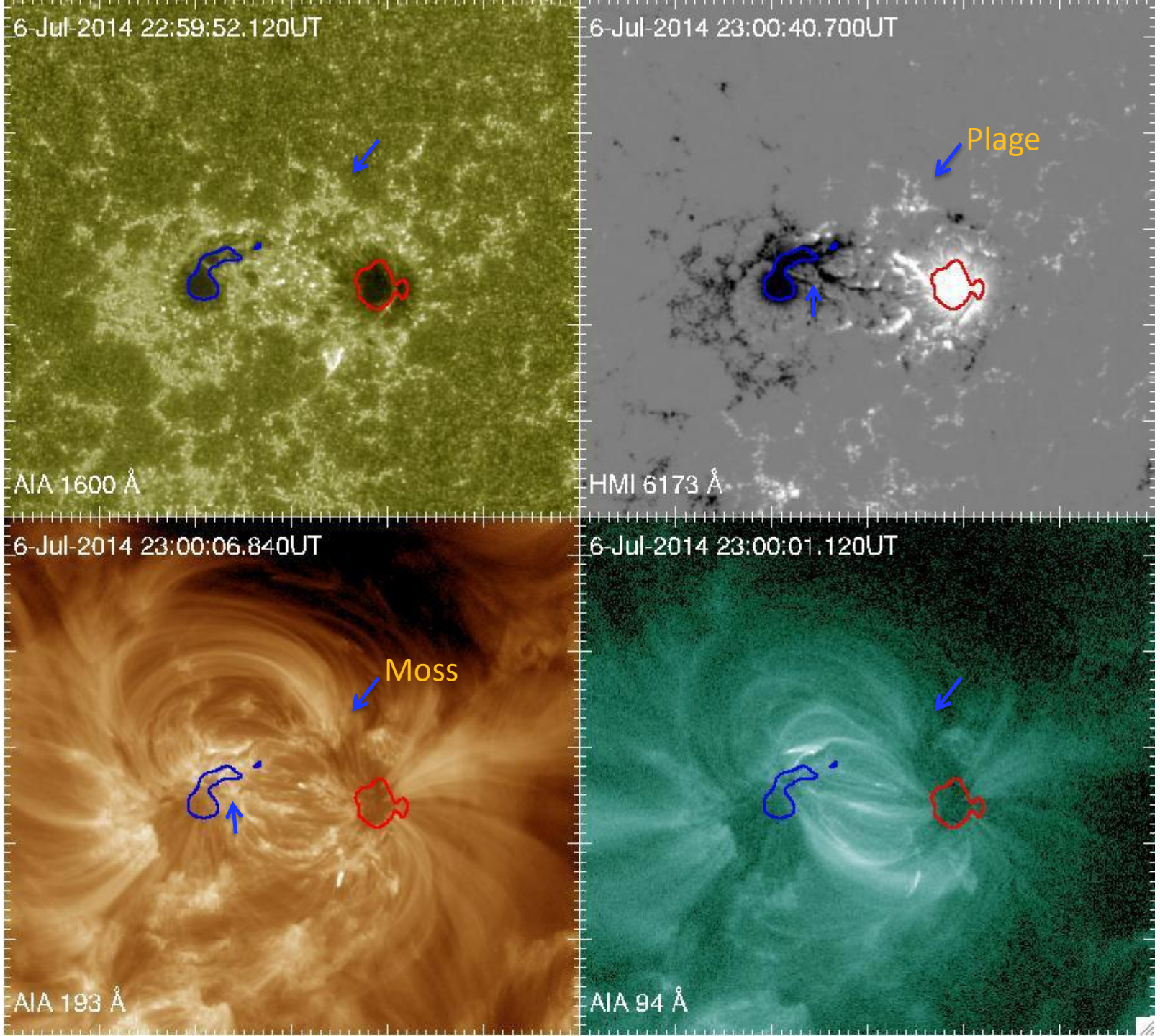
Example active region:



- Developed sunspots in both polarity
- Close to disc center
- Non-flaring (no more than B-class flares 24h before and after)

6-7 Jul 2014; AR12110
E/W ± 7deg; S −15deg

25h movie @3m cad.



AIA 94 Å movie reveals that:

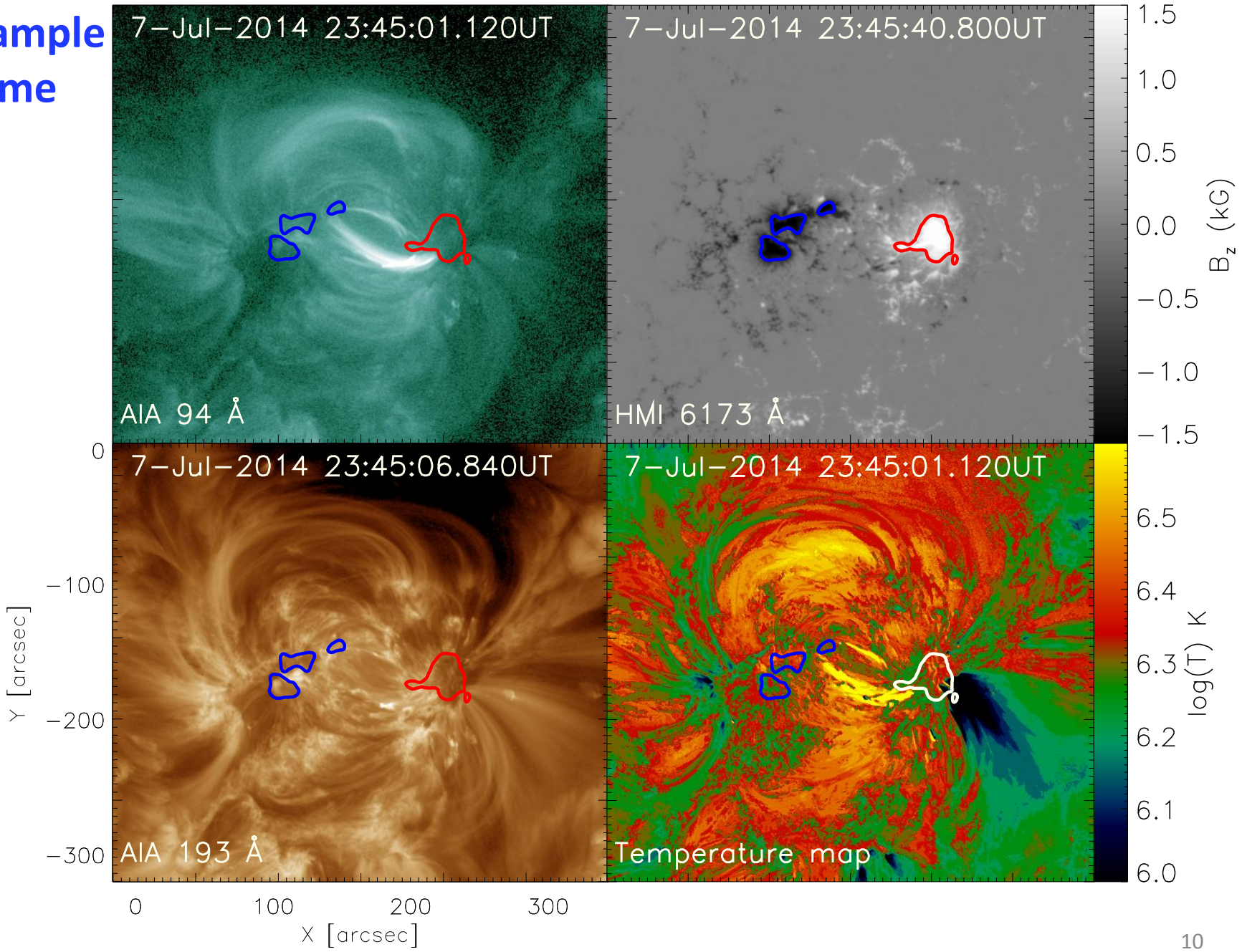
- Bright loops are episodic (~1-2h); repeated subflares are seen in sets of loops with a given rooting pattern

- The brightest loops are rooted in umbra at one of their feet with their other foot in plage or penumbra of opposite polarity, and they never end in opposite polarity umbra.

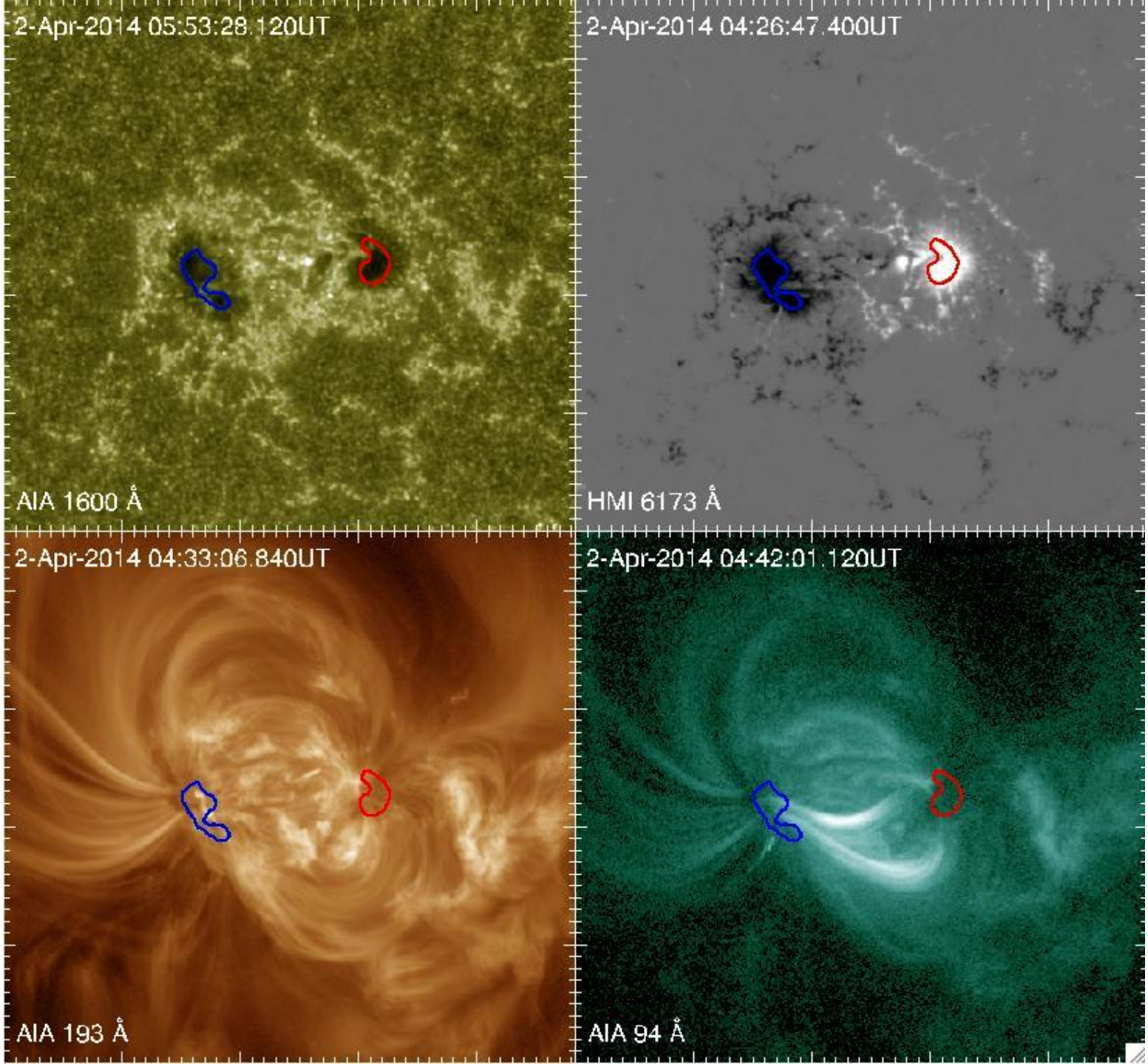
- The plage-to-plage loops have only intermediate brightness

- AIA 94 images are dim in umbrae-> not all umbral loops are strongly heated; most umbral loops are weakly heated

Example frame



AR
Ex.2


2-Apr-2014 05:53:28.120UT
AIA 1600 Å
2-Apr-2014 04:26:47.400UT
HMI 6173 Å
2-Apr-2014 04:33:06.840UT
AIA 193 Å
2-Apr-2014 04:42:01.120UT
AIA 94 Å

Umbra-to-umbra loops?

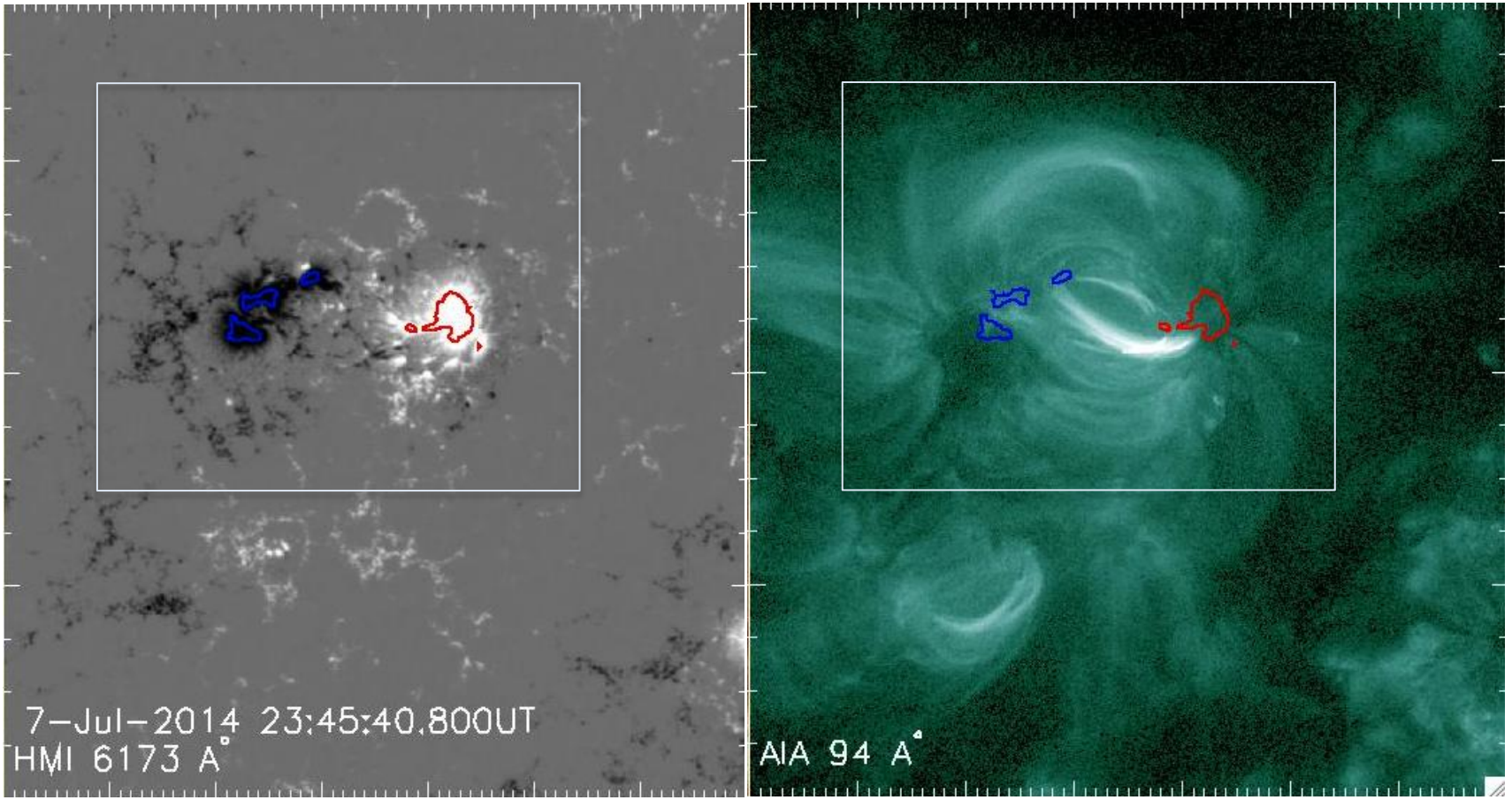
To test whether there are umbra-to-umbra coronal loops not visible in any AIA channel:

we performed a NLFFF extrapolation
(Wiegelmann et al. 2006; Wiegelmann & Inhester, 2010)

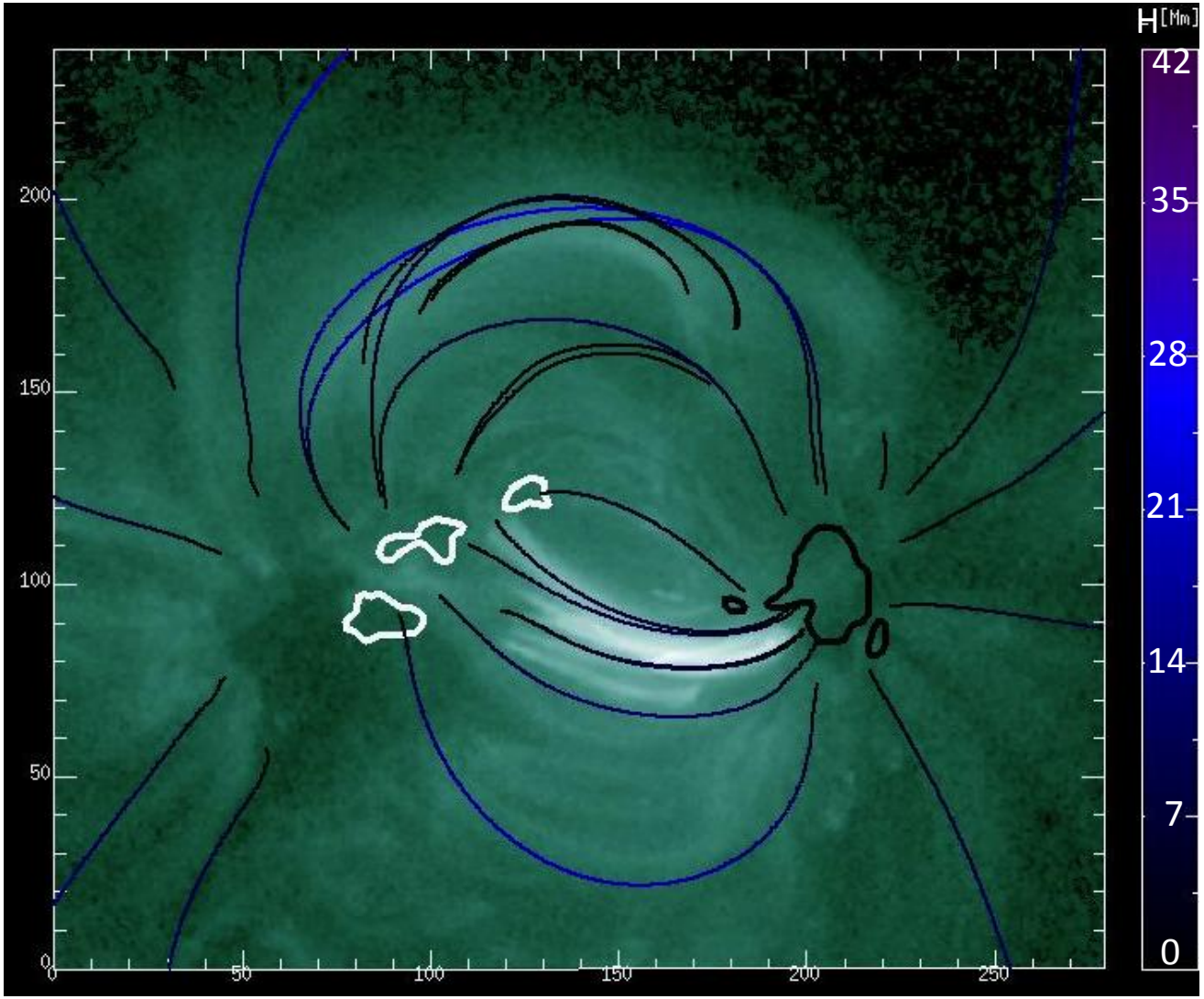
- preprocessing applied to HMI vector magnetograms to achieve force-free boundary conditions for the modeling

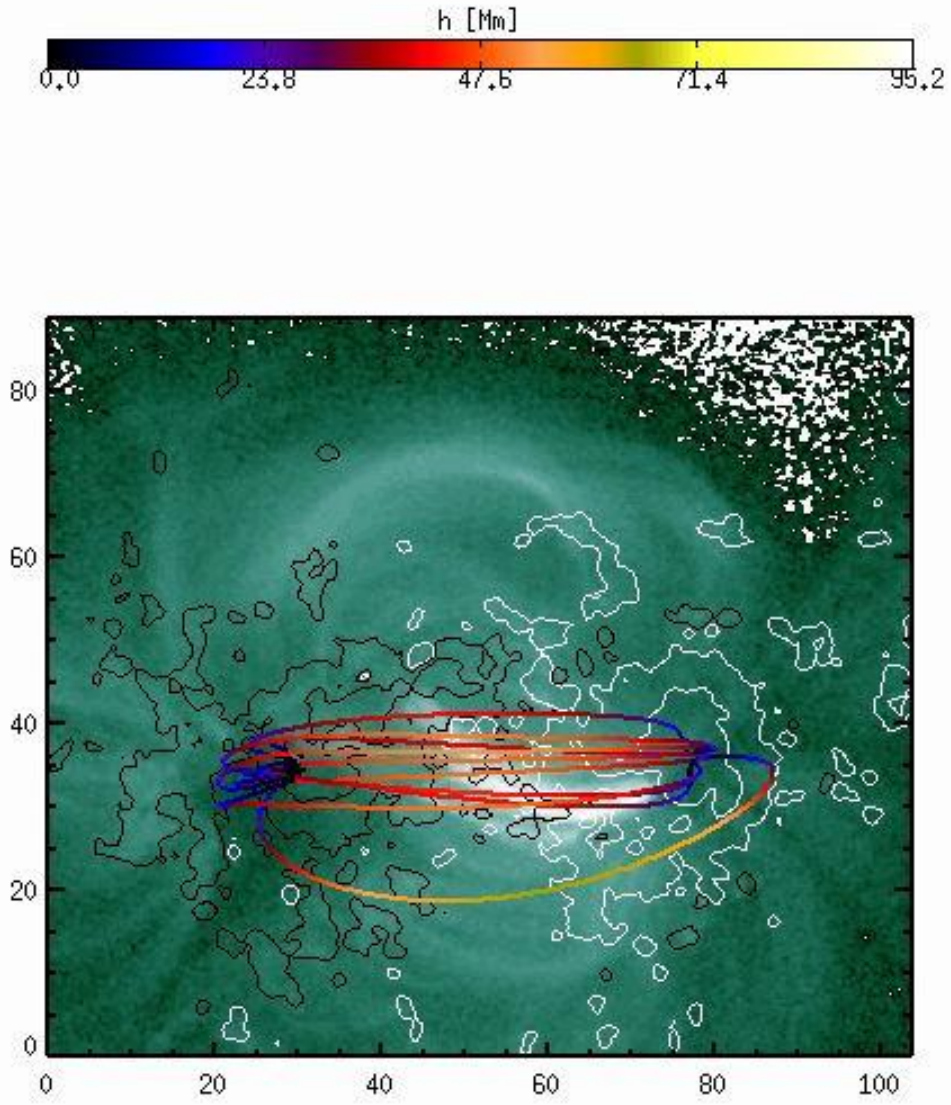
(performed by our collaborator Julia K. Thalmann)

FOV selected for the NLFFF extrapolation

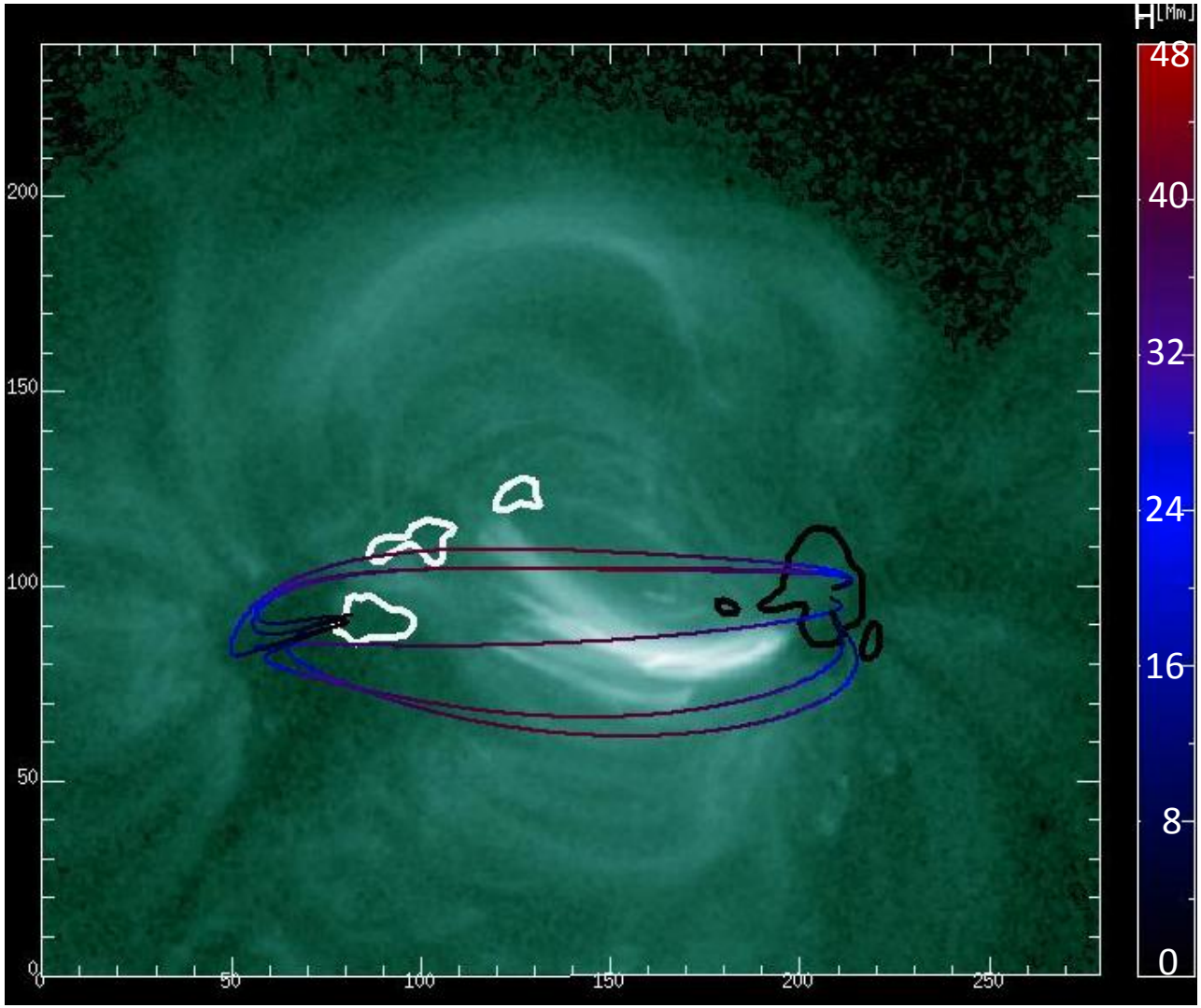


NLFF model field lines

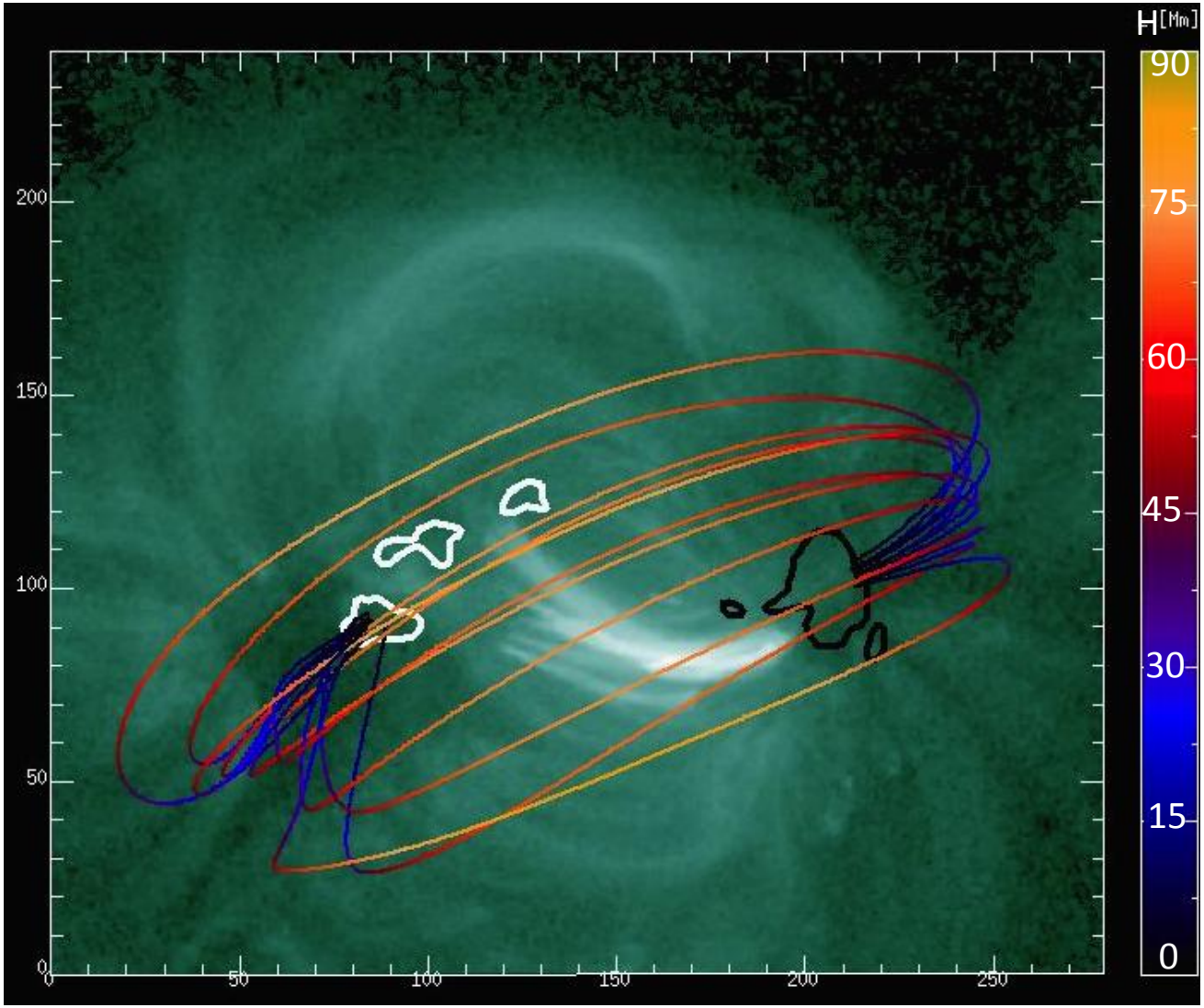



h [Mm]
0.0
23.8
47.6
71.4
95.2
0
20
40
60
80
0
20
40
60
80
100

Modeling results: lower umbral loops

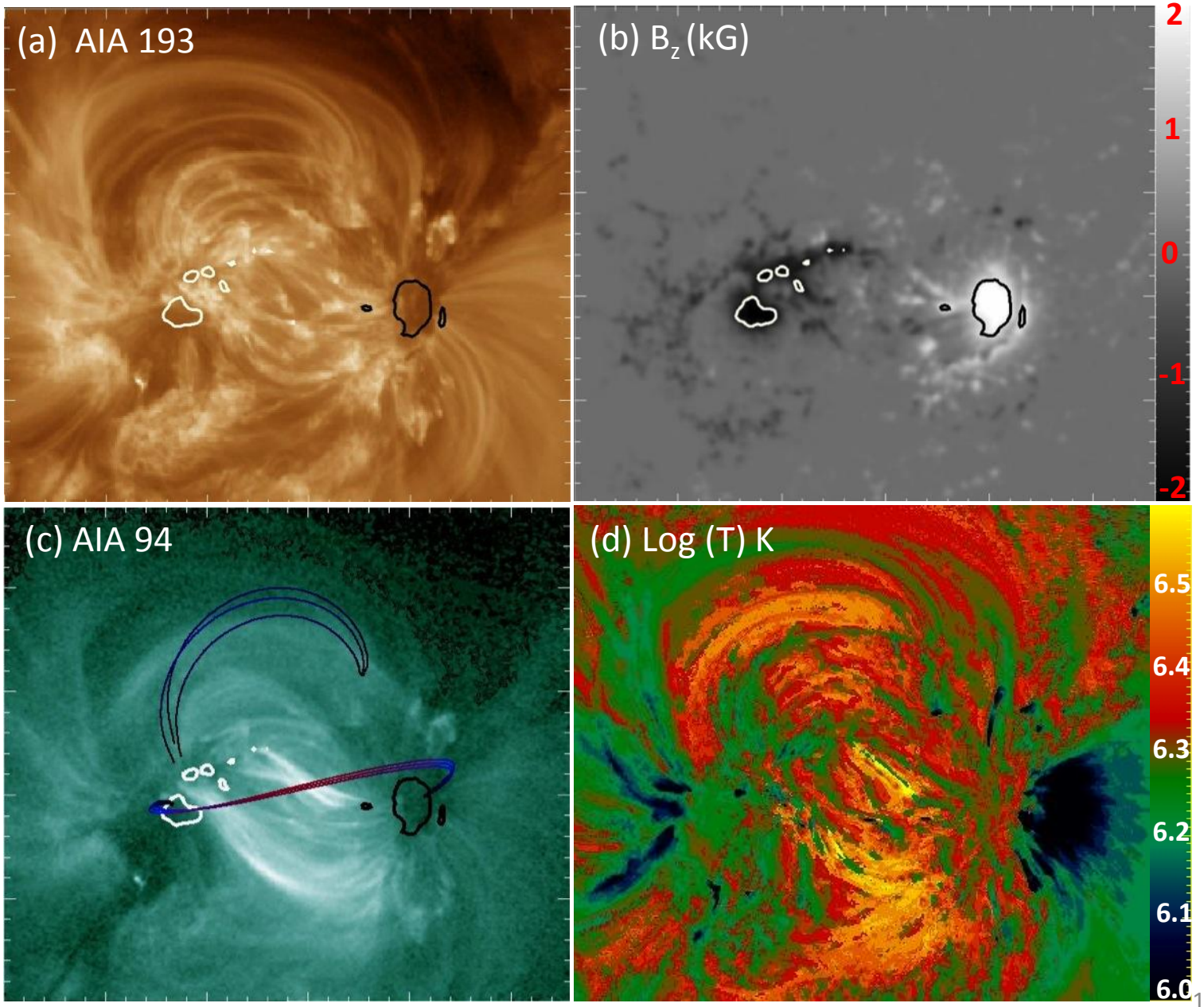


Modeling results: high umbral loops



Another Time Frame

07 Jul 2014 10:24 UT



Summary of the preliminary results

- Most of the brightest loops are transient (micro/sub-flaring loops) and have the following magnetic rooting pattern:

  - Umbra-to-plage/penumbra loops have the strongest heating

  - Plage-to-plage loops have intermediate heating

  - Umbra-to-umbra loops have the weakest heating

- Lack of coronal emission in umbra-to-umbra loops is new evidence supporting Parker's idea that convection at loop footpoints drives coronal heating in ARs

Our hypothesis

Magnetic field strength together with the convective freedom at the feet of the loops mostly determines their coronal temperature

- Umbra-to-umbra loops have the lowest temperature because they have least convective freedom at their feet, either to induce braiding in the coronal loops, or to generate Alfven waves.

- Only umbra-to-plage and/or penumbra loops have the highest temperature because they have strong magnetic field and one of their feet has moderate convection

- Plage-to-plage loops have only intermediate temperature because they have rather weaker field, although they have moderate convective freedom at their feet

Loop length might be important: work in progress!!

Thanks for your attention!