Structure and dynamics of cool fare loops

Petr Heinzel

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Astronomical Institute of the Czech Academy of Sciences

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Contributed Talk

4. Eruptions in the solar atmosphere

Structure and dynamics of cool flare loops

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Cool flare loops appear during the flare evolution as the result of a gradual appearance of hot loops which cool down to chromospheric temperatures. They have been observed during several flares by IRIS, and namely in MgII and CII lines, or in SiIV within hotter parts. We will present our analysis of MgII lines in such loops which exhibit significant downward flows (also called coronal rain). Using the cloud model technique we have determined the line source function which is decreasing with increasing flow velocity. This is interpreted as the effect of Doppler dimming in MgII lines. Cool lines also exhibit a strong non-thermal broadening and we will discuss its possible nature. We will present 2D non-LTE models of magnetic loops and compare the synthetic line intensities with IRIS observations, in order to estimate the electron densities in cool loops. Other observations of flare loops have been obtained recently by SDO/HMI and AIA and we will show their characteristics. Detailed non-LTE diagnostics of cool loops is needed to understand the gradual evolution of solar and stellar flares.

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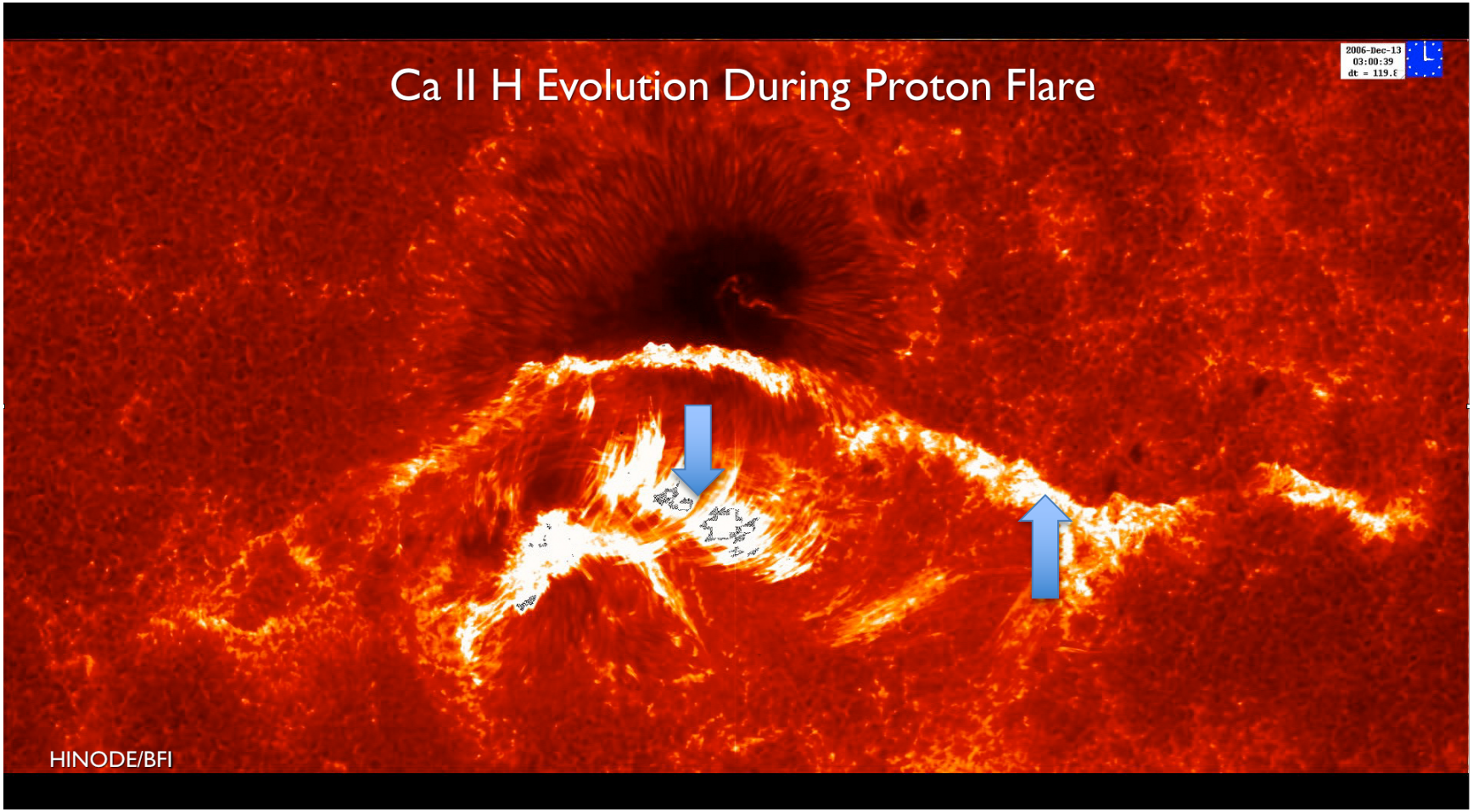
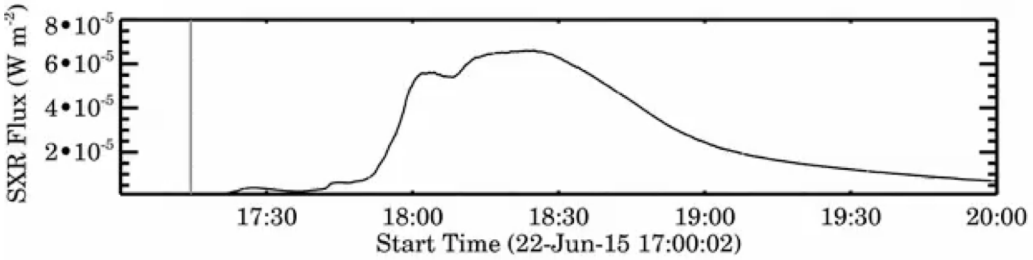

Ca II H Evolution During Proton Flare
2006-Dec-13
03:00:39
dt = 119.6
HINODE/BFI

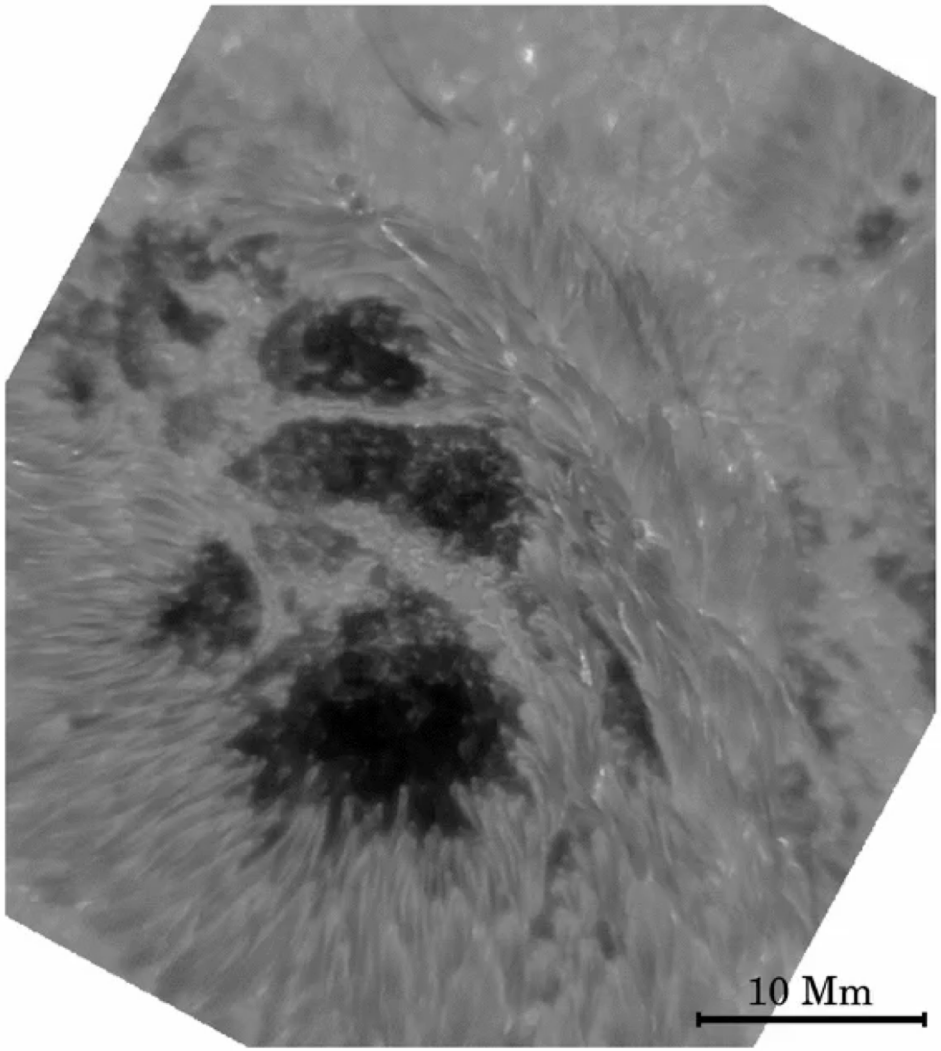
Jing+ 2016

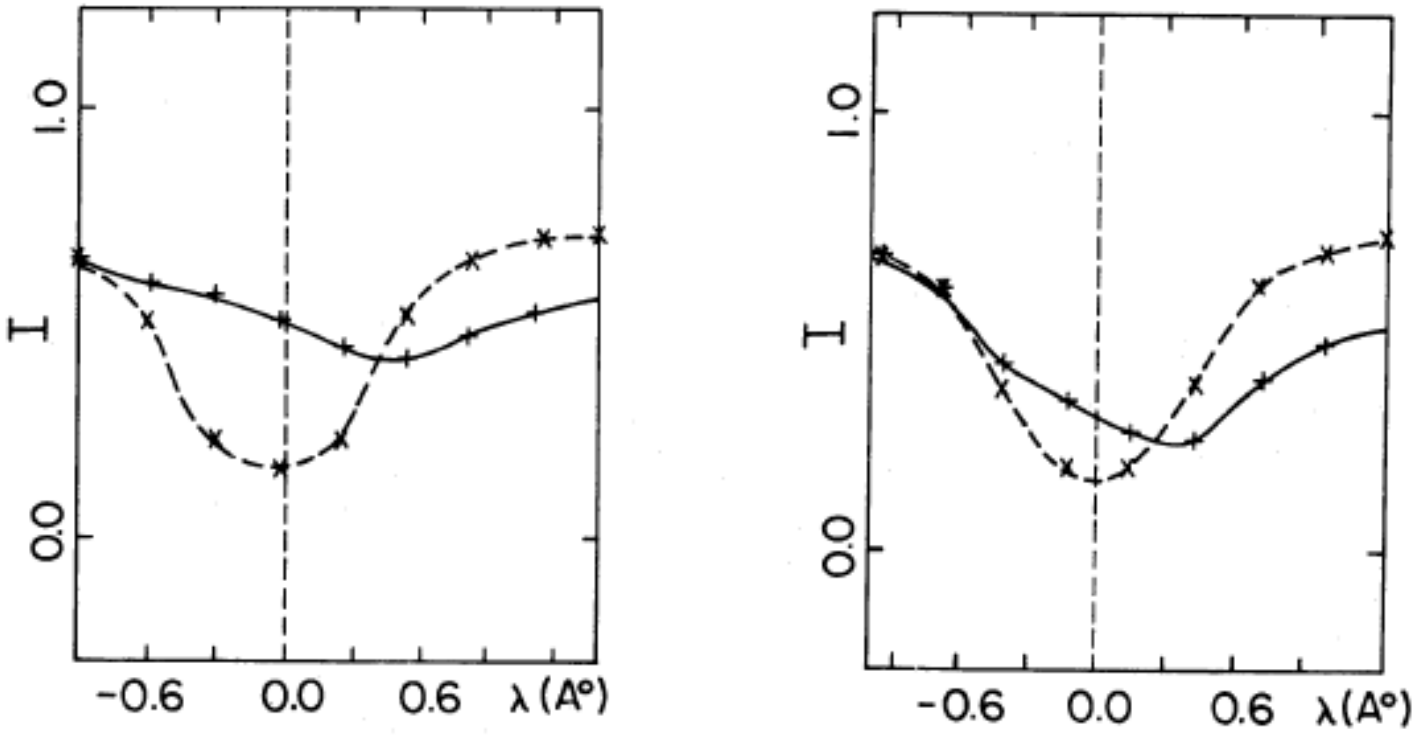
GST
22 June 2015

Hydrogen H-alpha

bright bubbles due to either higher pressure or Doppler brightening

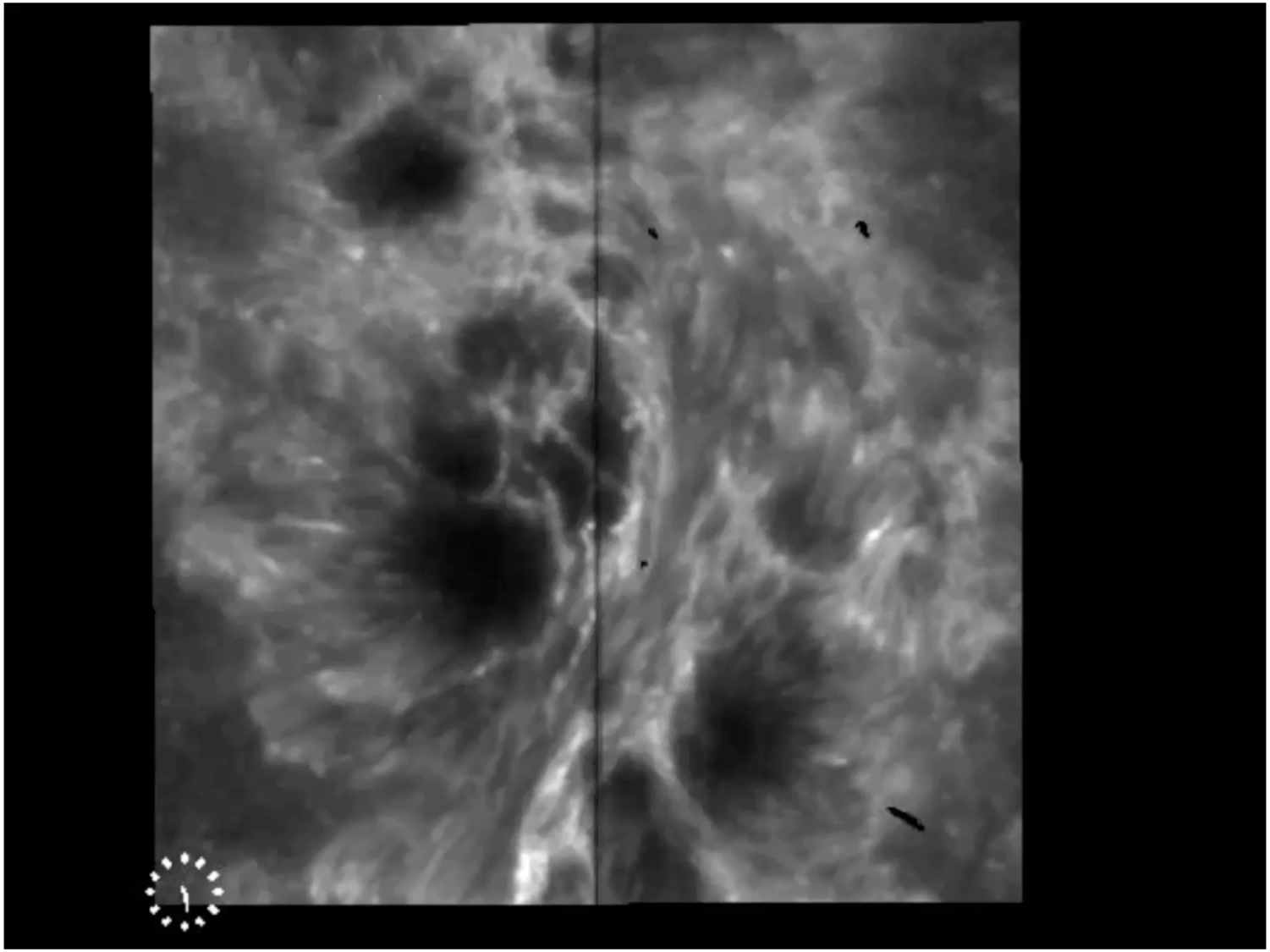


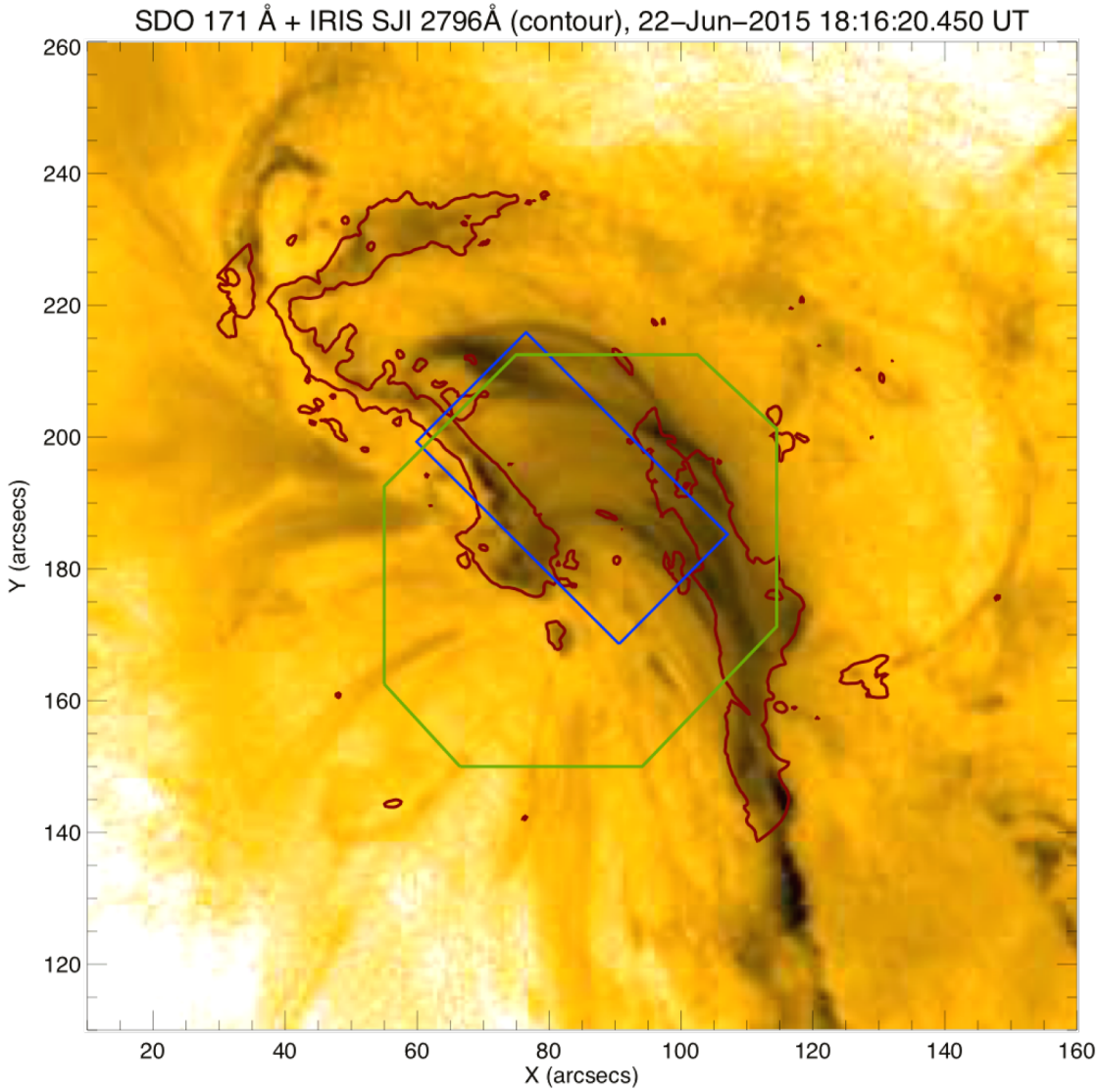




Schmieder+ 1987

MgII SJI




SDO 171 Å + IRIS SJI 2796Å (contour), 22–Jun–2015 18:16:20.450 UT
260
240
220
200
180
160
140
120
Y (arcsecs)
20
40
60
80
100
120
140
160
X (arcsecs)

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Structure and Dynamics of Cool Flare Loops Observed by the *Interface Region Imaging Spectrograph*

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An Explanation of Remarkable Emission-line Profiles in Post-flare Coronal Rain

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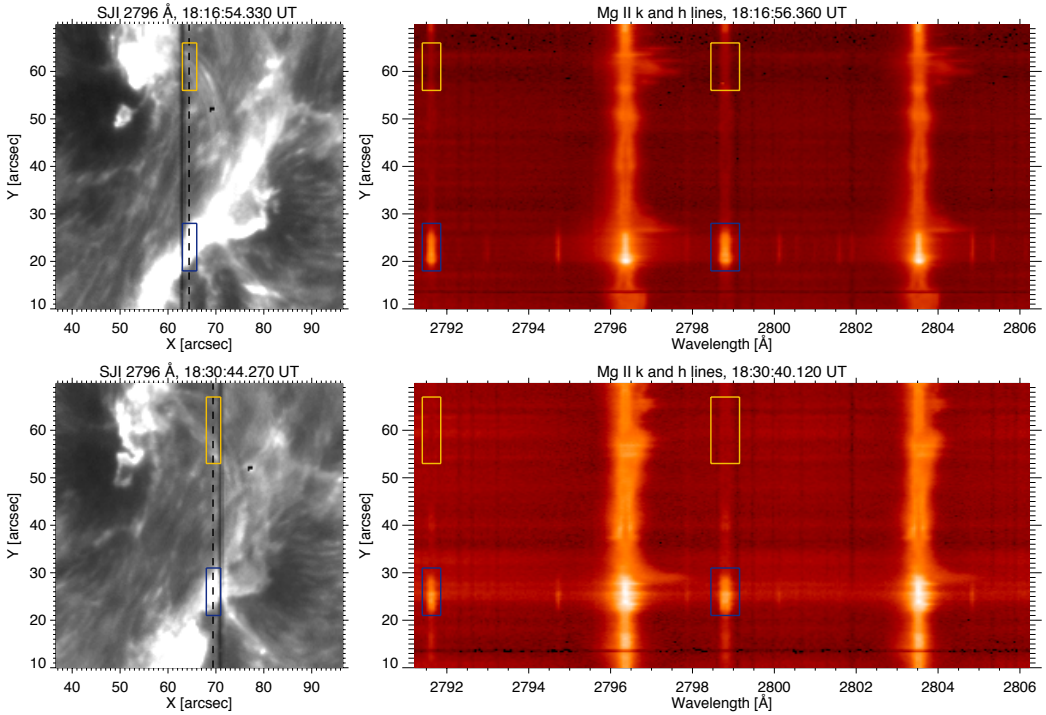
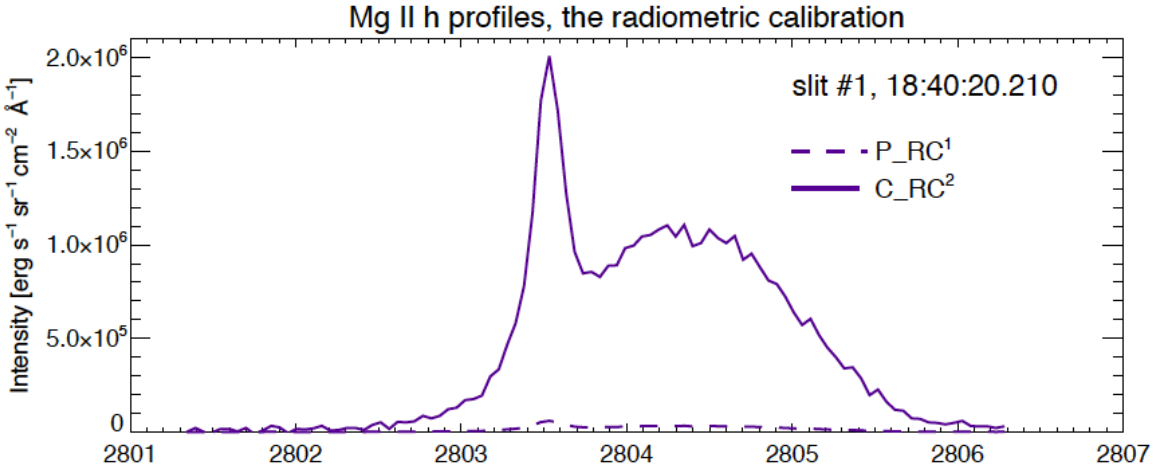
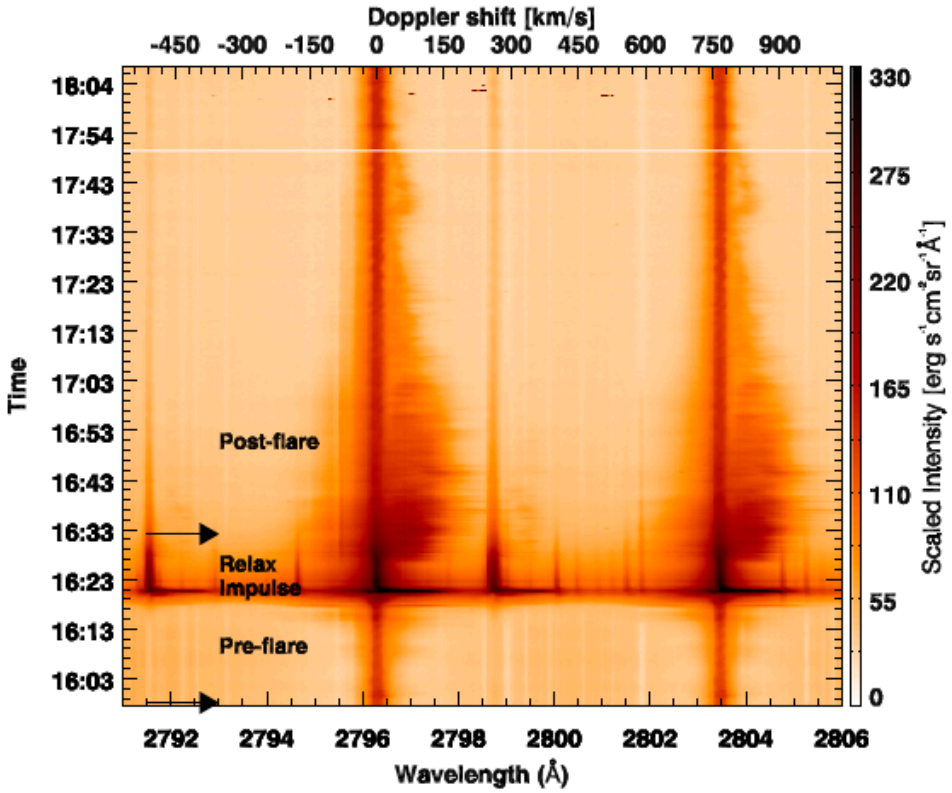
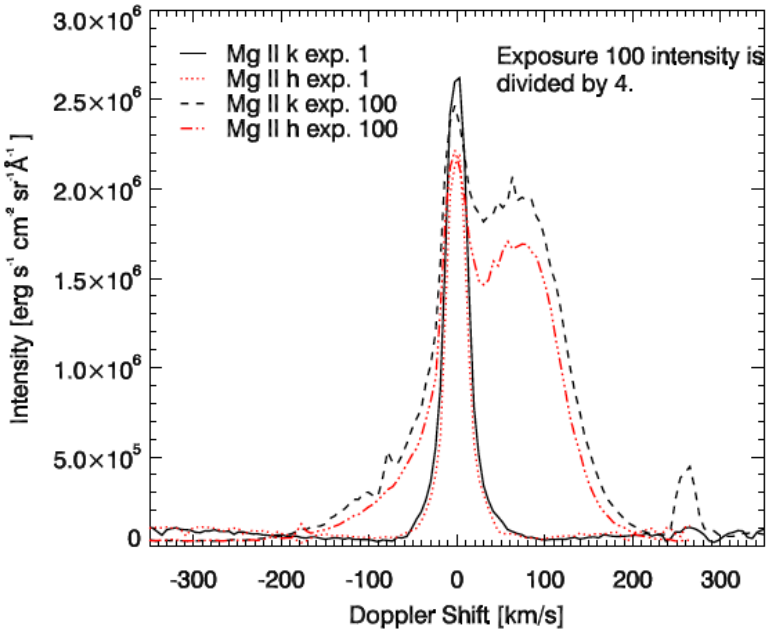

SJI 2796 Å, 18:16:54.330 UT
Mg II k and h lines, 18:16:56.360 UT
SJI 2796 Å, 18:30:44.270 UT
Mg II k and h lines, 18:30:40.120 UT
Y [arcsec]
X [arcsec]
Wavelength [Å]

Mikula+ 2017


Mg II h profiles, the radiometric calibration
slit #1, 18:40:20.210
P_RC1
C_RC2
Intensity [erg s-1 sr-1 cm-2 Å-1]

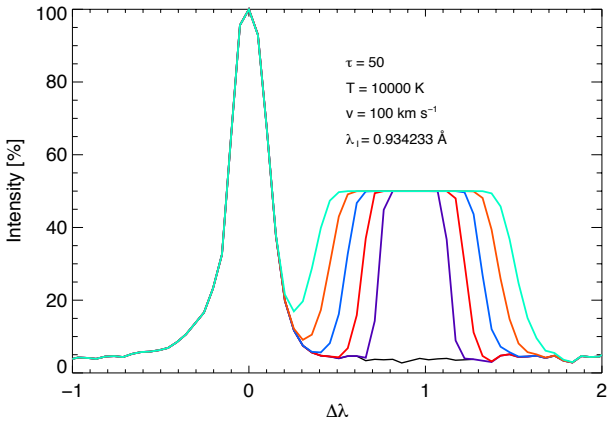


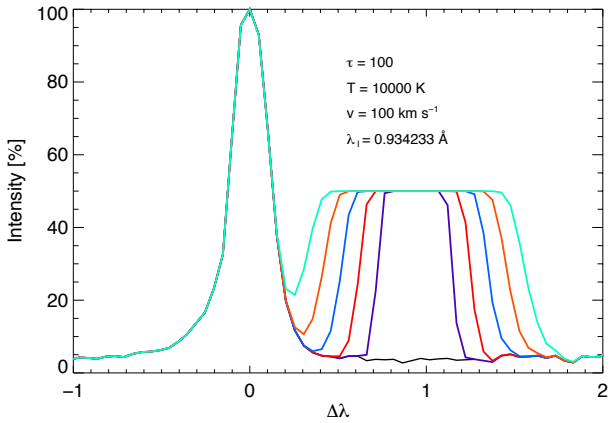


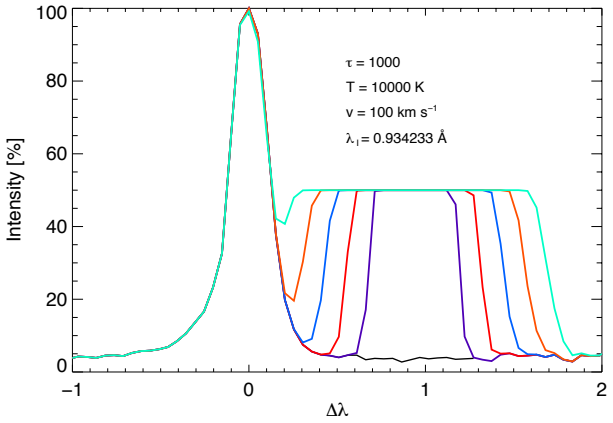
Lacatus+ 2017

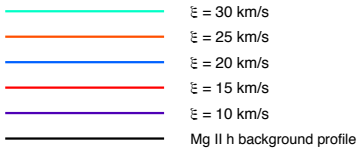
standard cloud model

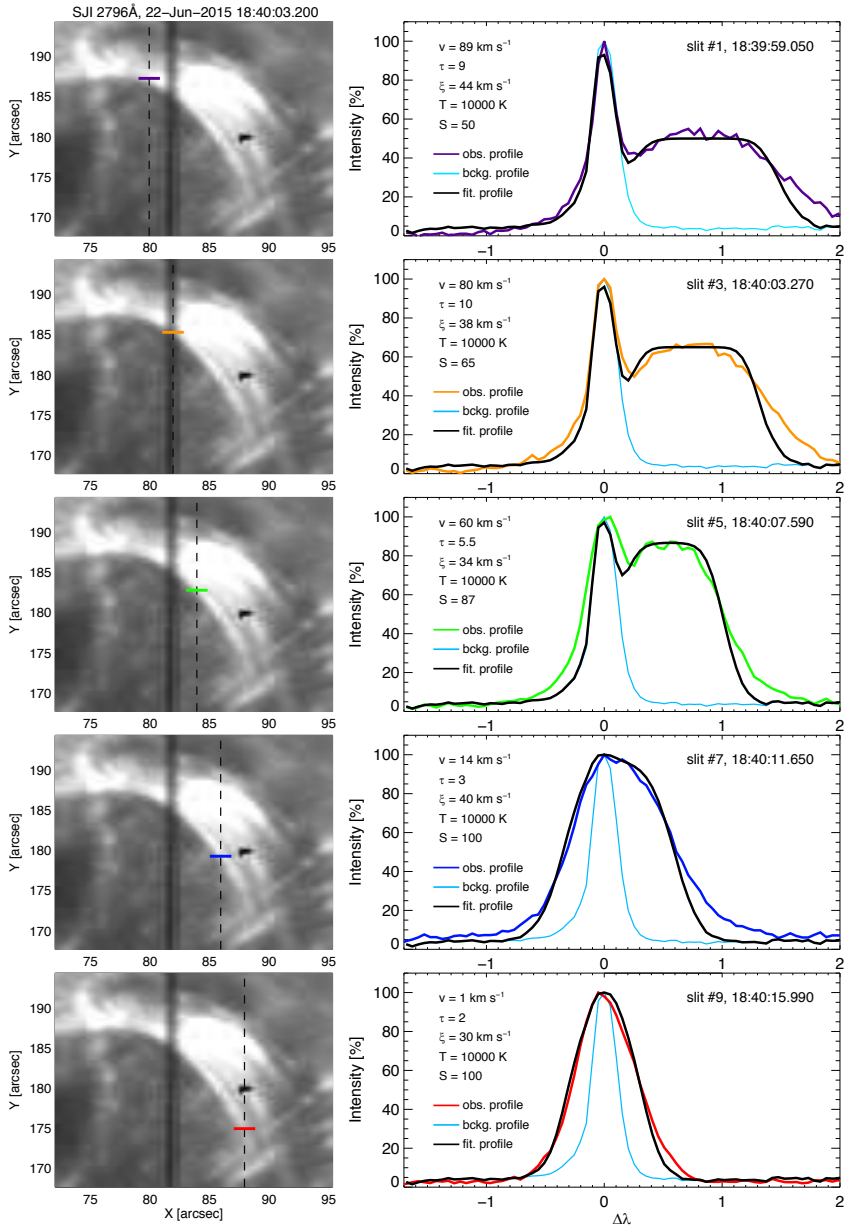
$$I(\Delta\lambda) = I_o(\Delta\lambda)exp[-\tau(\Delta\lambda)] + S(1 - exp[-\tau(\Delta\lambda)])$$











Loop dynamics with the cloud model

S is decreasing with increasing flow velocity
(Doppler dimming in MgII lines)

$$I(\Delta\lambda) = I_o(\Delta\lambda)exp[-\tau(\Delta\lambda)] + S(1 - exp[-\tau(\Delta\lambda)])$$

Conclusions

- New kind of MgII profiles detected in cool flare loops
- Downflows consistent with previous studies
- Large Doppler widths up to 100 km/sec detected
- The ‚microturbulent' broadening can be due to Alfvén-wave turbulence (Lacatus+ 2017)
- The MgII h and k line source functions decrease with increasing flow velocity which seems to be due to the Doppler dimming effect
- The radiative/collisional excitation of MgII lines will depend on the flow velocity, background radiation, gas pressure and temperature
- From 2D models we can determine the radiative cooling rates at MgII formation temperatures

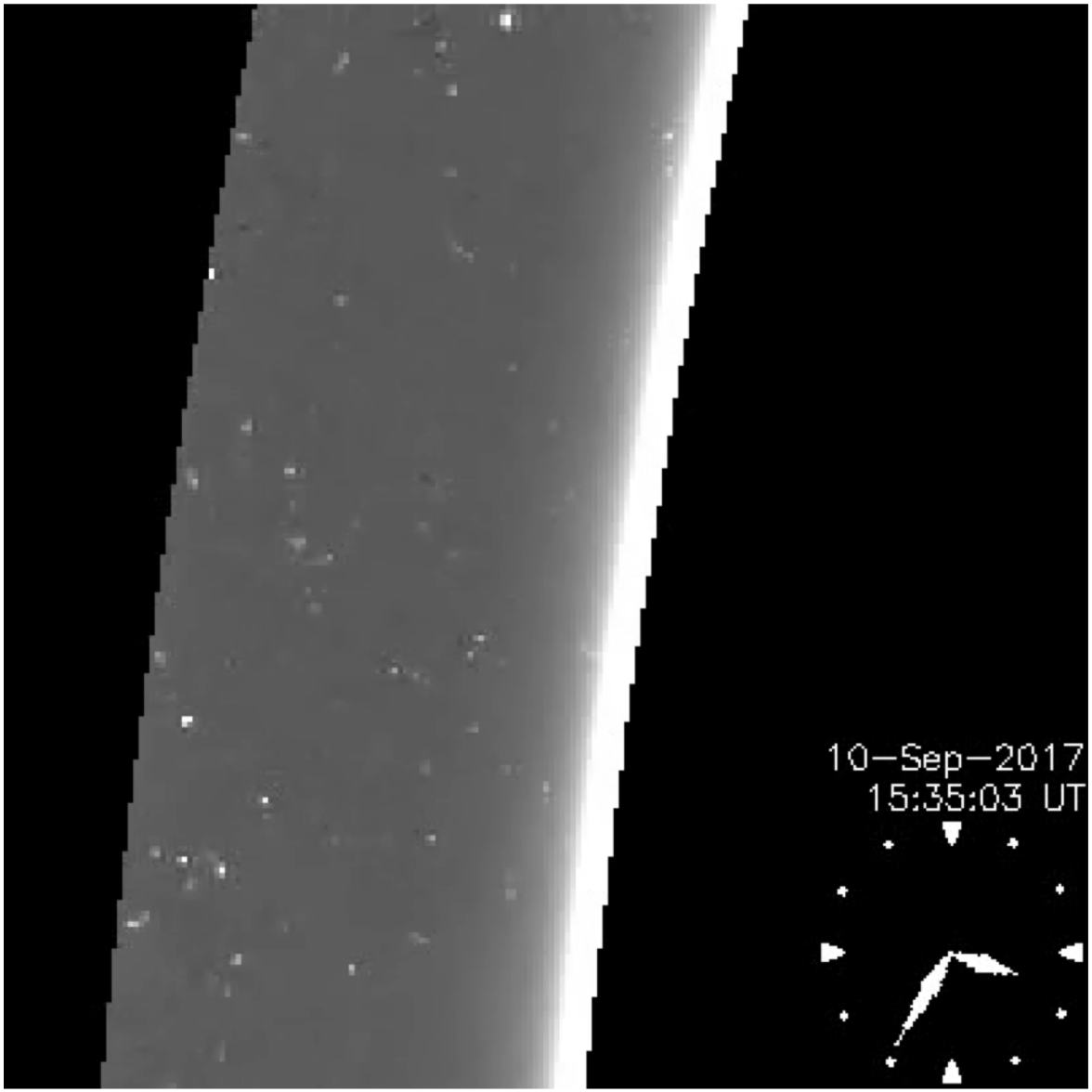
WL flare loops detected by SDO/HMI and in FUV by SDO/AIA

X8.2 class flare occured close to limb on September 10, 2017

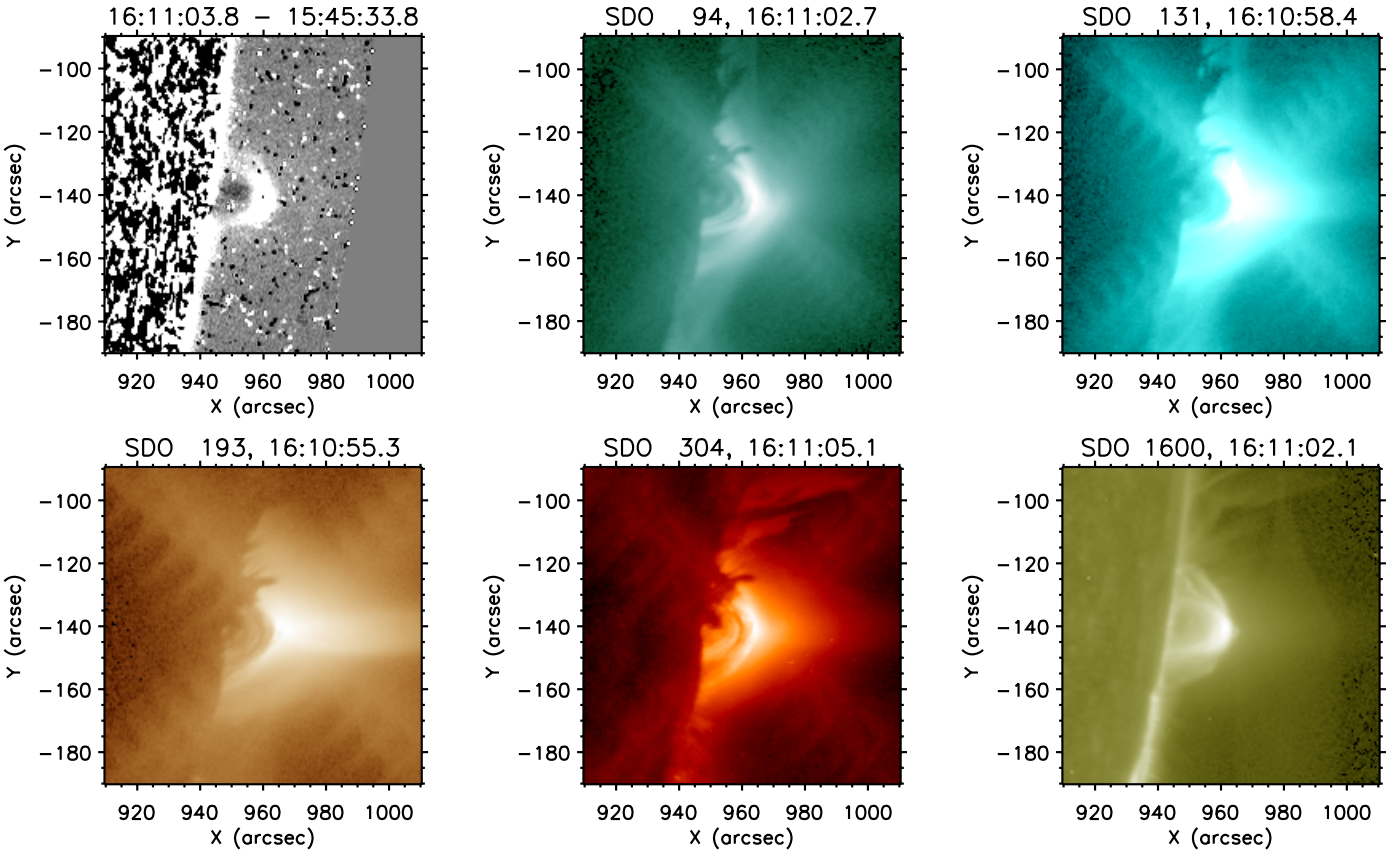
work in progress with S. Jejčič and L. Kleint

previous work by Saint-Hilaire et al. (2014) who also detected polarization due to Thomson scattering

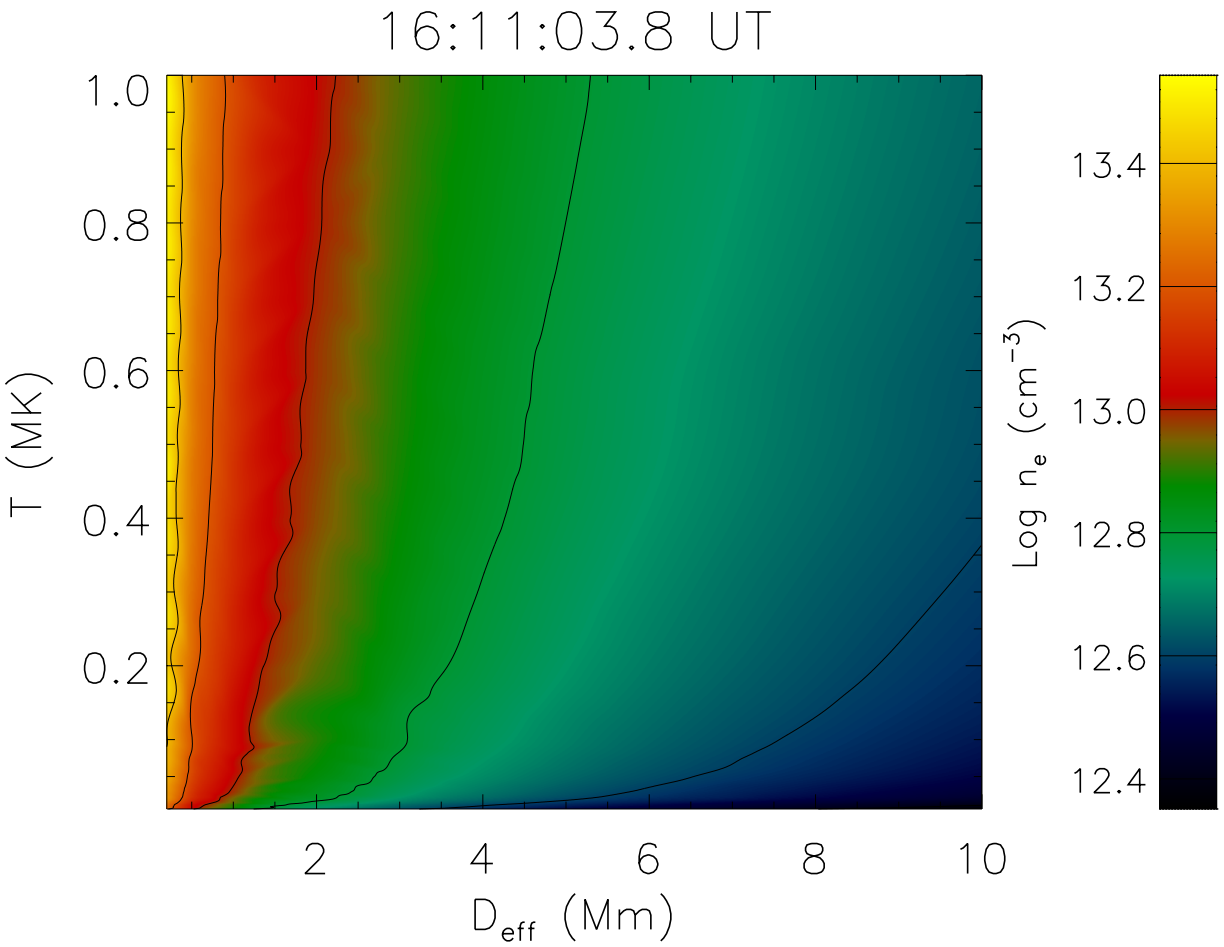
SDO/HMI
white-light loops
10 September 2017



HMI intensity is non-linear
(structures enhanced)



Multithermal structure of the loop arcade


16:11:03.8 UT
1.0
0.8
0.6
0.4
0.2
T (MK)
2
4
6
8
10
D_eff (Mm)
13.4
13.2
13.0
12.8
12.6
12.4
Log n_e (cm^-3)

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Can Flare Loops Contribute to the White-light Emission of Stellar Superflares?

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