Dark halos around Active Regions in the Solar Atmosphere

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Abstract

Active regions (ARs) on the solar disk are frequently surrounded by annular, relatively dark regions. These "dark halos" (hereafter DHs) seem to vary greatly in shape and size, are not radially symmetric and are observed during different phases of the solar cycle. Even if this phenomenon was first identified in chromospheric lines, halos are observed as relatively dark areas in many wavelengths, including some SDO/AIA wavebands. However, today little is known about their nature and we do not even have a clear and comprehensive characterization of their emission properties across of the electromagnetic spectrum.

Herein we present a preliminary analysis through a systematic characterization of the dark halo around AR12706 in various wavelengths, by analyzing IRIS full-Sun mosaics and SDO/AIA images. In particular, we evaluated the average intensity of the halo and related it to quiet Sun emission. As a result, we report the existence of a halo in all IRIS mosaics and in all SDO/AIA images. Also we provide a spectral comparison with the Coronal Holes (CHs) present on the disk at the same time of AR12706. The analysis shows that for our observation CHs have a stronger emission than the halo for all IRIS images, while a comparable, and sometimes weaker, emission for AIA images. This seems to confirm the theory according to which dark halos and CHs are originated by different physical phenomena.

Introduction

The so called "Dark Halos" (a.k.a. "dark moat", "circumfacular regions" or "dark canopies") are a phenomenon first identified in chromospheric lines, as observations of dark regions around Ca II K-line 393.4 nm plages (Hale & Ellerman 1903; St. John 1911). D'Azumbuja (1930) found them to be strikingly prominent also in spectroheliograms made with the core of the Ca II 854.2 nm line. Nothing more was done until Bumba & Howard (1965) found that Ca II K-line circumfacules are closely associated with the Hα fibril vortex around ARs. The dark areas were shown to coincide approximately with the vortex pattern of Hα fibrils, that rapidly appears around emerging active regions, also by a number of authors (see e.g. Veeder & Zirin 1970, Reardon et al. 2009). As a result, it seems clear that DHs are closely related to chromospheric fibrils. However, DHs are also observed in wavelengths corresponding to Transition Region (TR) and corona, including some SDO/AIA wavebands. For example, in Fig. 1 some dark areas are well seen around the central AR for both SOHO/SUMER O V 629 Å and S VI 933 Å.

More recently, there has been a new interest in DHs and some hypothesis have tried to explain their nature:

- According to Wang et al. (2011), the 171 Å canopies consist of 171 Å EUV-absorbing "fibrils", that might be the coronal counterparts of the fibrils as seen in the Hα chromospheric data.
- Singh et al. (2021) argue that DH exists because the pressure from the strong magnetic field that splays out from the AR presses down on underlying magnetic loops, flattening those loops to a low altitude. Those loops, which would normally emit the bulk of the 171 Å emission, are restricted to heights above the surface that are too low to have 171 Å emitting plasmas sustained in them, according to Antiochos & Noci (1986).

As noted by Andretta & Del Zanna (2014), Wang et al. (2011) explanation is not consistent with the observations of SUMER, as it observes halos in wavelengths > 911 Å (S VI 933 Å, see Fig. 1), the Lyman continuum absorption threshold. On the other hand, the explanation by Singh et al. (2021) is difficult to reconcile with the appearance of DHs in chromospheric lines.

Therefore further investigation are needed.

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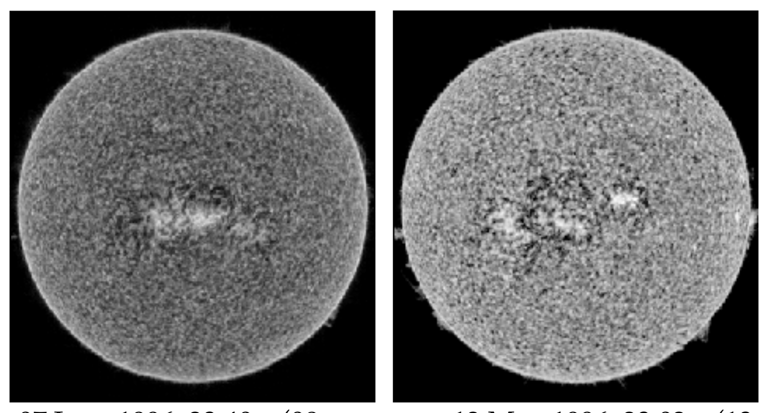


07 June 1996, 23:40—(08 June) 03:24 UTC, O V 629 Å, dt = 2 s

12 May 1996, 23:02—(13 May) 07:33 UTC, S VI 933 Å, dt = 3 s

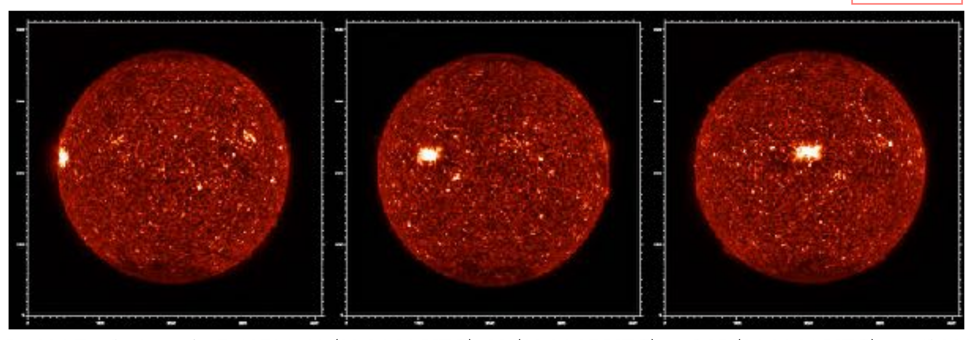
Figure 1

Present Work

With the present work, we aim to contribute presenting a preliminary study of the emission properties of a halo

- AR12706 —> one of the seven ARs studied by Singh et al. (2021)
- Large-scale structures in chromosphere + TR —> IRIS full-Sun mosaics
- Need for co-spatial and co-temporal TR + Corona data —> SDO/AIA images
- Structures relatively stable on the time scale of the evolution of ARs (~ days), as can be seen in Fig. 2 —> Possibility to analyze images/rasters taken over a period of ~ hours.

Figure 2



AIA 304 Evolution of AR 12706: 19 (23:24:31 UTC), 22 (19:24:07 UTC) and 25 (06:04:31 UTC) April 2018

IRIS Analysis

- **Main idea:** evaluate the average intensity of the halo and compare it with QS and CHs
- Halo average intensity in a box of 45″ x 35″ (Box 1 in Fig. 3, bottom left panel)
- AIA 193 Å "Frankenmap"(*) to visually select where to evaluate CH and QS on the disk —> it visually allows a clear identification of CHs and bright areas
- CH box: 50″ x 50″ in the southern CH
- QS box: 250″ x 445″ in the upper hemisphere (see Fig. 4)

(*) A "FrankenMaps" is a pseudo-mosaic showing the SDO signal at the time when IRIS was sampling each portion of the disk.

IRIS full-disk mosaic Data Info

- From 2018-04-22 10:41:50 UT to 2018-04-23 04:05:45 UT
- Exposure time: 2s
- Raster on AR12706 lasts ~ 4h

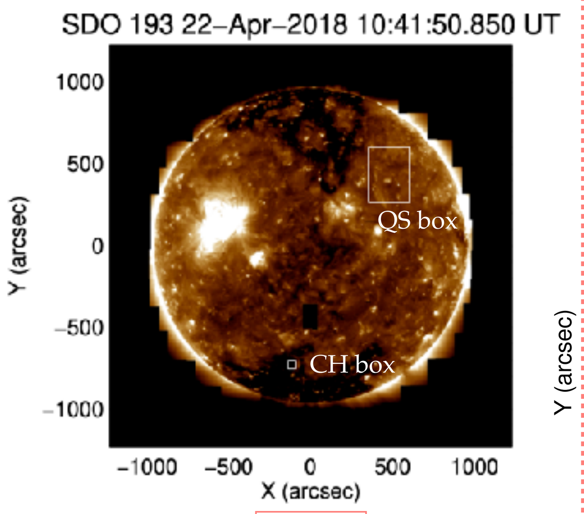


Figure 4

A halo is nicely seen. Fibril-like structures are seen in Mg II h & k lines

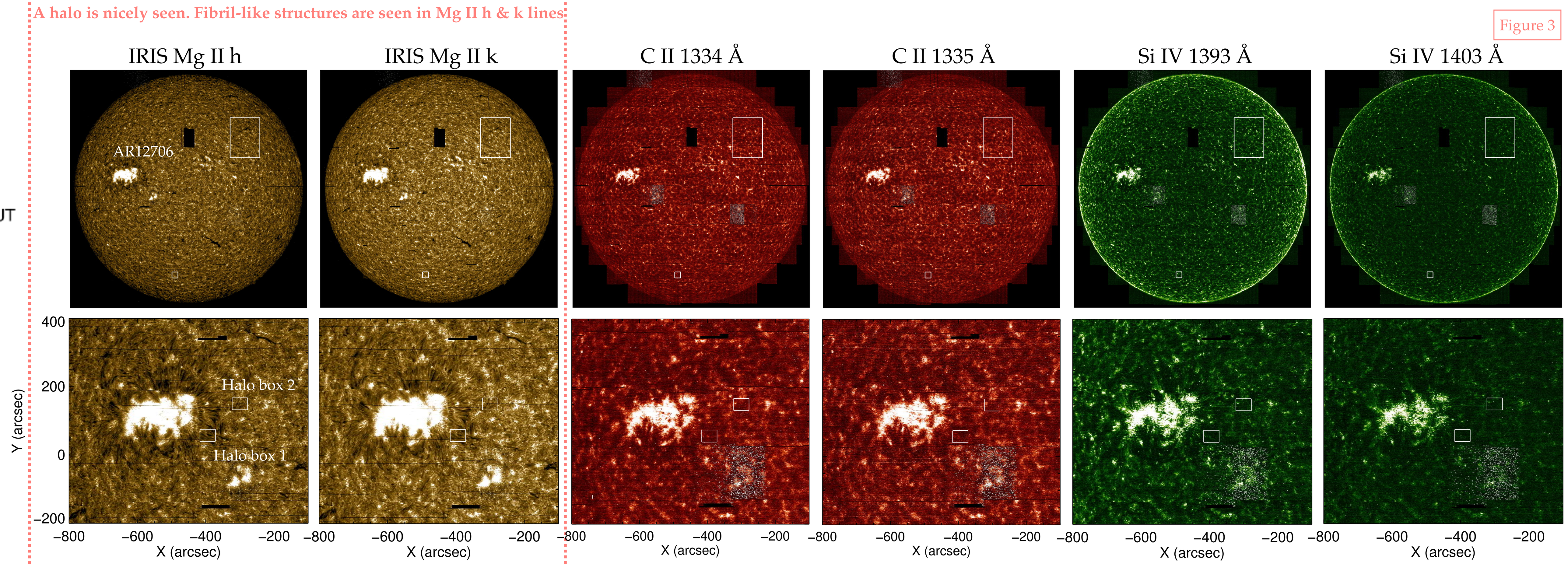


Figure 3

AIA Analysis

- AIA images —> 2018-04-22 19:23:59 UT, within 4-hour time frame in which IRIS created AR12706 raster
- Average intensity in Halo Box 1 (same as in IRIS) —> it fell over bright loops fanning out from AR
- We use a second halo box (see Fig. 3, 5) in a relatively dark area near the AR largely free from bright coronal loops
- Box 2 falls outside the halo area as identified in IRIS Mg II k images (see Fig. 3)

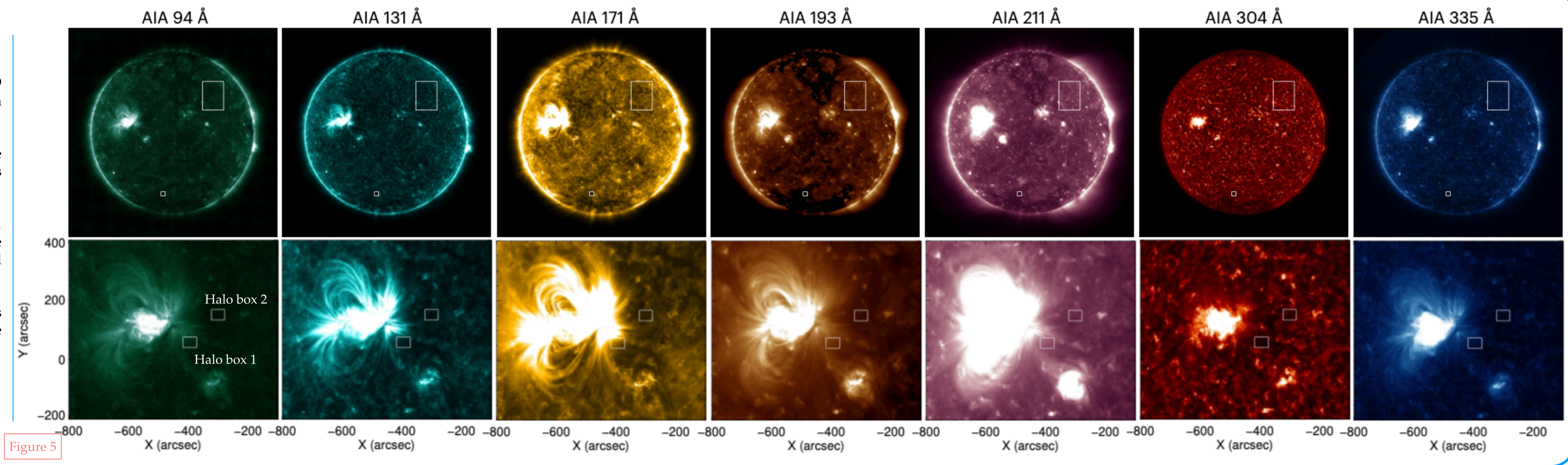
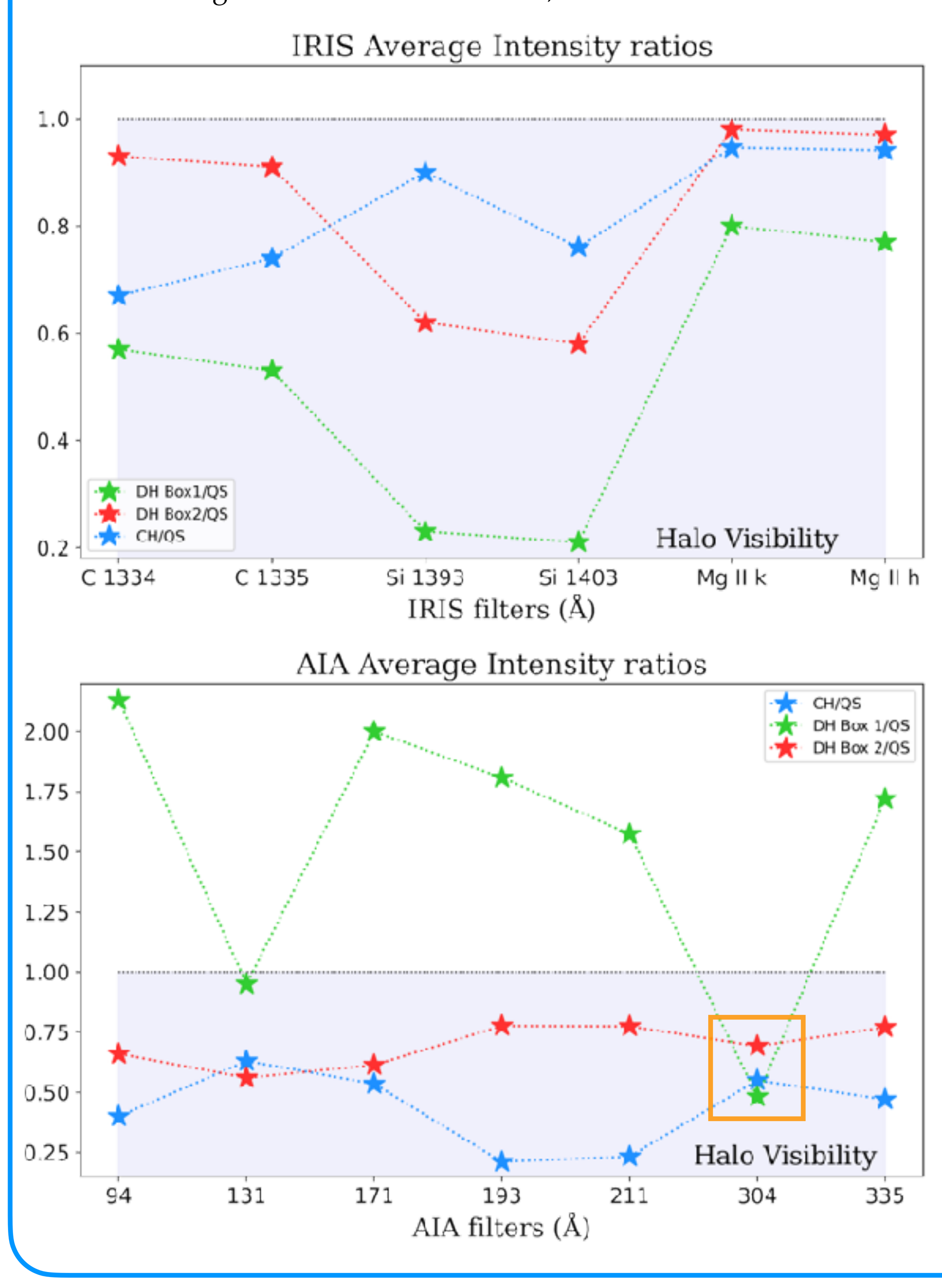


Figure 5

Results

Fig.6: Upper panel: IRIS average intensities for DH Box 1, DH Box 2 and CH Box. Bottom panel: SDO/AIA average intensities for DH Box 1, DH Box 2 and CH Box.



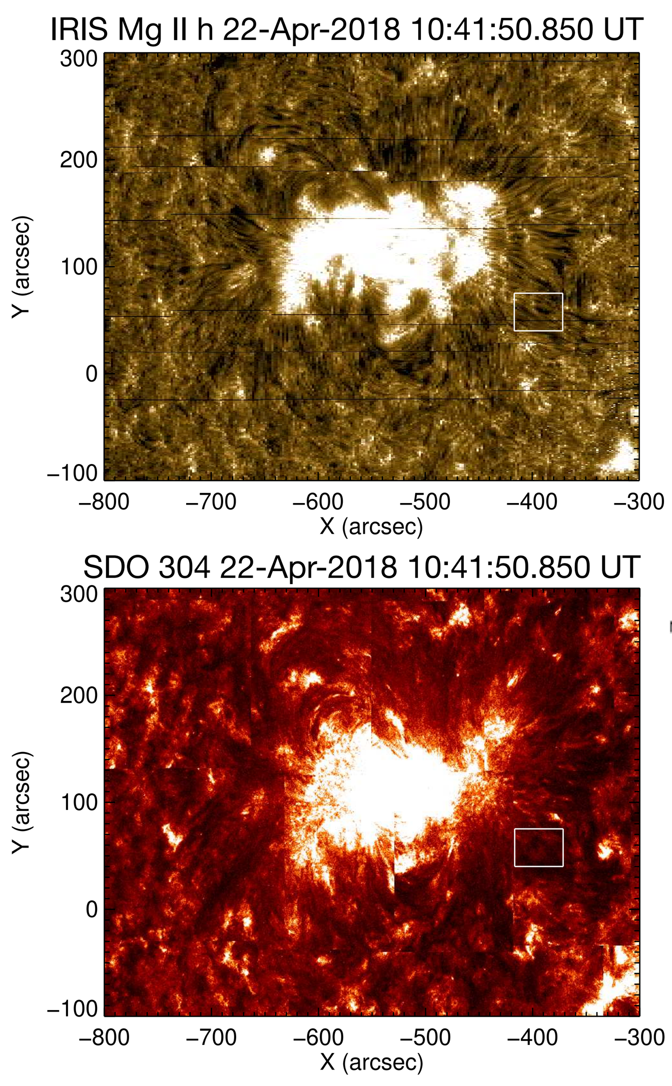
IRIS results

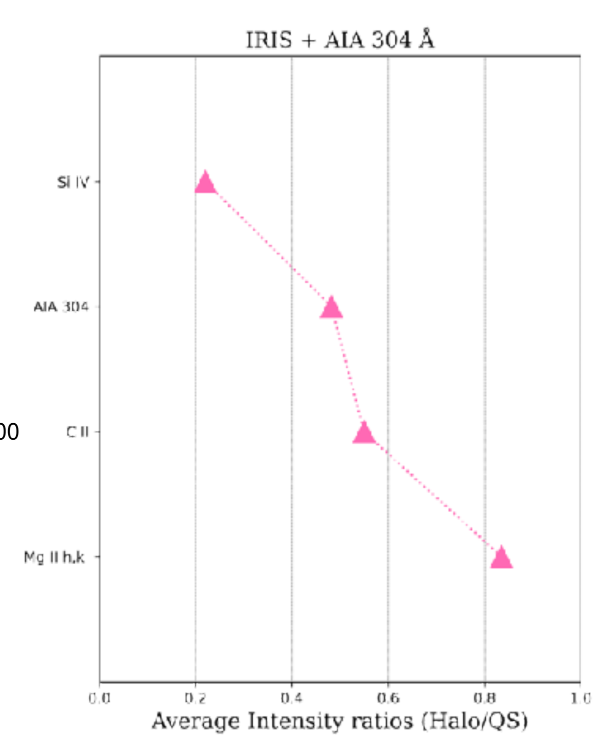
- In DH Box 1 and 2 the ratio is always less than one —> **A halo is actually observed in all IRIS filters**
- All ratios for DH Box 1 are less than for Box 2 —> Box 1 fall within the visually observed fibrils halo, while Box 2 fall outside IRIS halo
- **DH is darker than CH**

AIA results

- No halo is observed in Box 1 —> Box 1 fall over the AR overlying loop-filled area
- **In** Box 2 the average intensity ratio is less than one —> **A halo exists in all AIA filters**
- **Possible enlargement of the DH with the temperature?**
- AIA DH is similar to CH

- Only AIA 304 Å sees a halo in Box 1 —> it is the only within the IRIS temperature ranges (see Fig. 7)





An increasing trend in the relative visibility of the halo approaching the Transition Region is found.

Figure 7

Future Works

- Compare the DH evolution with AR evolution
- Magnetic Field Extrapolation above the area
- Propose dedicated IRIS rasters of an entire AR also in other IRIS lines (e.g O IV in TR) —> with higher exposure time
- Analyze several ARs to build a statistic for:
  - emission properties —> is there really an enlargement with T?
  - dynamic (evolution) properties
  - differences with CHs —> What happens for anemon ARs?

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