

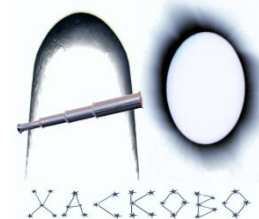


Magnetic Field and the Prominences

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Magnetic Field of the Sun

For many years in the Astronomical observatory in Haskovo are conducted regular solar observations. Recently we own solar telescope PST Coronado and this enables us to follow the solar activity based both on its sunspots and prominences.

Observing the Sun in the H-alpha line gives us the opportunity to investigate in details the active regions on the disc of the Sun. Significant alteration of an object such as changes in its speed, density, temperature or even radiation may be observed in a trek of images. However, the cause of all activity in the Sun's atmosphere is its magnetic field.

A question often asked is how exactly the magnetic field and the hot plasma in the Sun's atmosphere interact. Let's imagine a gas which consists only of neutral molecules. In that case the magnetic field doesn't have an influence on them, nonetheless, all stars consist not only of neutral particles but also of equal number positive and negative ions (referred to as plasma). That is what makes the magnetic field such an important part of the studies of these active regions since it has a great influence on their movement.

Unless there was magnetic field, the Sun would have been a "quiet" star without sunspots, eruptions and prominences. Moreover, the Sun's magnetic field is created as a result of a dynamo effect. This can happen only when there is a moving fluid in a conductive area which will form a current and a magnetic field as an effect.

However, how does this magnetic field influence on the formation, life and eruption of a prominence? As it is well-known, the prominences are located in the Sun's corona despite having a hundreds times lower temperature and hundreds times higher density than the surrounding corona. Because of that fact it can be said that the prominences and the corona are in a balance. In order to remain in that state for a long time the prominence has to be maintained by a magnetic arc system with deformed upper side where the prominence "lay". This structures highly resembles to leaves situated vertically to the Sun's surface. Prominences always form on the neutral lines which separates the two magnetic fields with different polarity.

To answer the question which force prevents the prominences from heating and full dissipation, we have to look deeper in the effects of the strong magnetic field. Not only does it cool down their temperature, but also it protects the plasma from the mechanic power of the corona. Prominences are observed in these regions where the magnetic field is parallel to the Sun's surface.

One of the theories of the creation deformed upper side of the magnetic field is considered to be due to strong eruptions which firstly inflates it and then forms an open magnetic field. The prominences are formed in the current sheet where they condense. Therefore, the plasma decreases its temperature while increasing its magnetic field, magnetic heating and density. After a while, the field stops increasing which results in the appearance of magnetic "loops". The place where the prominences is located is called coronal helmet region. The force of the magnetic fields and the magnetic loops keep the plasma above the surface despite the gravitation of the Sun.

Here are some fundamental equations for the plasma velocity (v), magnetic field (B), plasma density (ρ), electric current (j), plasma pressure (p) and temperature(T) are the induction equation:

$$\frac{\Delta B}{\Delta t} = \nabla \times (v \times B) + \eta \nabla^2$$

The equation of motion:

$$\rho \frac{dv}{dt} = -\nabla p + j \times B + \rho g$$

The mass continuity equation:

$$\frac{dy}{dx} = -\rho (\nabla \cdot v)$$

The energy equation (for optically thin radiation):

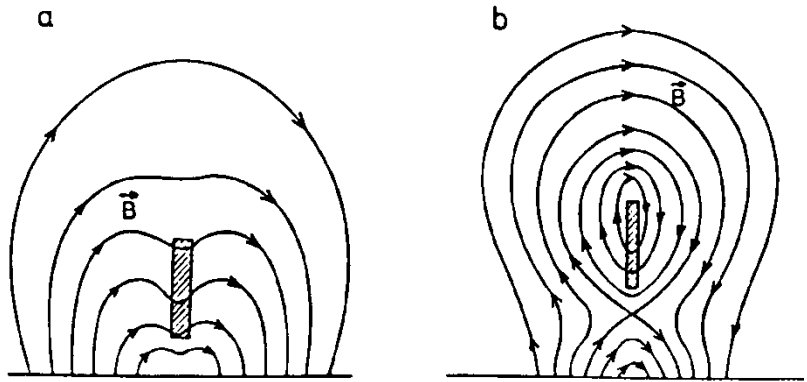
$$\frac{\rho \gamma}{\gamma - 1} \frac{d p}{dt} = -\nabla \cdot (k \nabla T) - \rho^2 Q T + \frac{j^2}{\sigma} + h \rho$$

Where $B \cdot \nabla = 0$:

$$j = \nabla \times B / \mu$$

is Ampere's law, μ is the magnetic permeability and:

$$p = \frac{k_B}{m} \rho T = n k_B T = \frac{R}{\mu} \rho T$$



The formation and the maintenance of a prominence is not only influenced by its own magnetic field, but also from the magnetic field of the Sun. The relation between these two magnetic fields forms two configurations – “normal” (N) and inversive (I). On the first image above (a) you can see the polarity of a N type prominence where the magnetic field of the prominence is same as the photospheric magnetic field. On the second image (b) you can see the I type where the two polarities differ.

Prominences (or filaments when they are observed on the disk) is used to describe a variety of objects ranging from relatively stable structures with lifetime of many month, to transient phenomena that last a few hours or less. They can be separated in two big groups: quiescent and plage filaments.

Plage filaments or active regions filaments are located in the active regions. They are lower and not so extended (10×10^6 m high, 50×10^6 m long). They lie along a neutral line of the photospheric magnetic field and appear to consist of different extended low-lying loops limited by footprints, anchored either near a sunspot or between faculae.

Quiescent prominences are located outside active regions. They migrate towards latitude higher than 45° where they are called polar prominences. Their characteristics dimensions are 200×10^6 m long, 50×10^6 m high, 10×10^6 m wide. Their lifetime can reach several months. They are anchored in the photosphere at footprints which are periodically separated (30×10^6 m). Observations on the disk show that quiescent filaments structures with footprints are connected by large arches visible only when there is enough thickness.

During the last few decades some surveys of the polarization of emission lines of prominences provided the needed data to explore the connection between them and the magnetic field. The quiet prominences are always located on the neutral lines which separate two areas with opposite polarity. Magnetic neutral lines are those lines in the photosphere where the magnetic field is parallel ($B=0$). Because of that fact they are assumed to be tracers of the general solar magnetic field. Their importance is significant when it comes to exploring the magnetic structures. Following their lifetime. They become aligned in an East-West direction due to differential rotation. Following their trajectory through the solar cycle, large-scale azimuthal magnetic structures have been found.

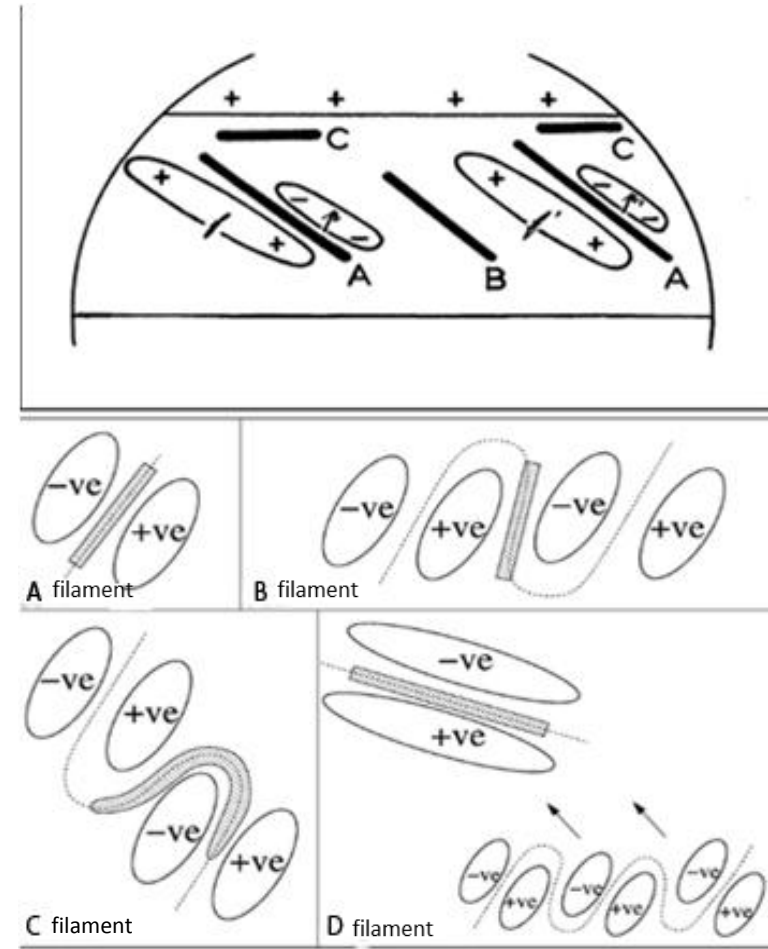
Tanberg-Hansen and Mackay

Classifications

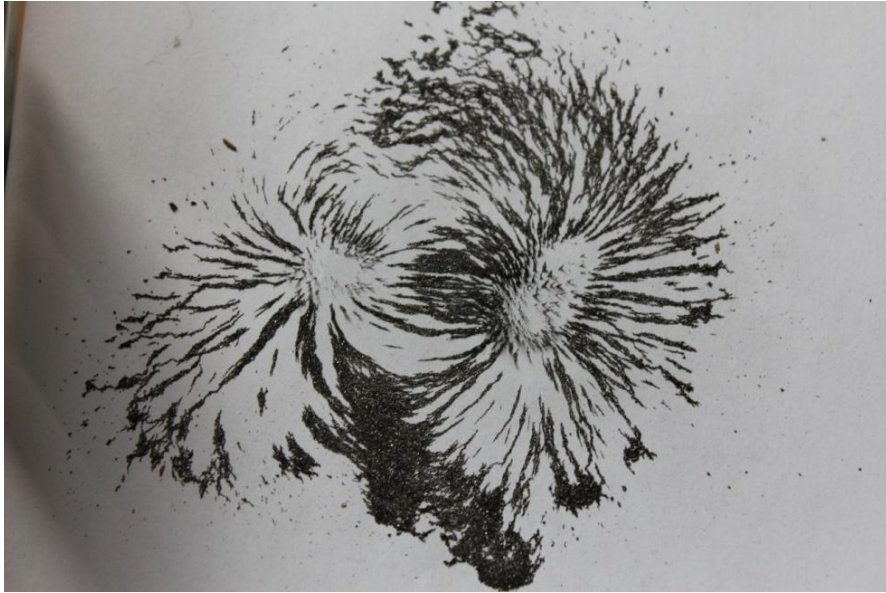
There is a specific filaments classification based on where they are located on the neutral lines. That classification is conducted by Tanberg-Hansen (1984). Firstly, it consisted of three types of filaments. Further in the this project we will use the renewed classification (introduced by Mackay et al., 2008) to study the filaments we have observed.

The filaments now are separated in four big groups:

- **A type** – filaments formed on neutral lines between bipolar regions.
- **B type** – filaments formed on neutral lines between two bipolar regions
- **C type** – filaments' one part is formed between the neutral lines between two regions while the other part is between two bipolar regions.
- **D type** – polar filaments which are formed between diffusive magnetic lines on high heliographic altitude.

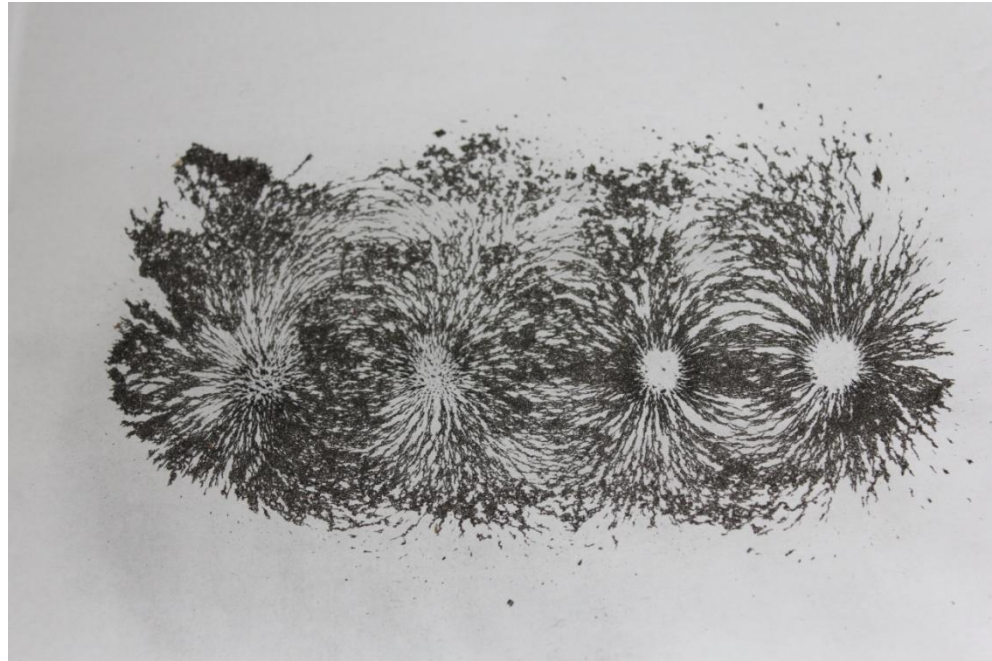


Our Experiments



While exploring the different properties of the magnetic field we have decided we make our own experiments. Firstly, we tried to recreate a bipolar group with magnet and iron filings. Between the two sides of the magnet, there is a neutral magnetic field where the A type filaments are formed.

Another experiment that we have done is recreating the neutral lines between two bipolar groups using two magnets. Between these two groups it can be seen that more iron filings placed. On these regions B type filaments are formed.



Our Working Set-up

Depending on the circumstances we put the CORONADO PST on a tripod or on a German equatorial mount.



For photographing sunspots and prominences we use the following cameras: CANON EOS 350D and CANON EOS 60D.

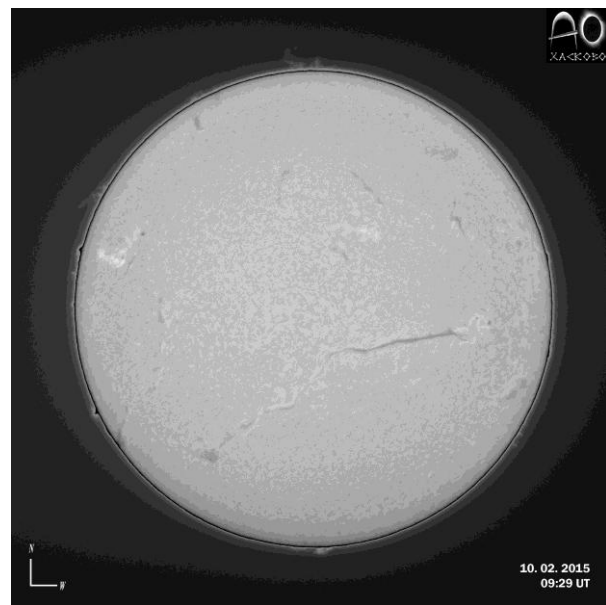
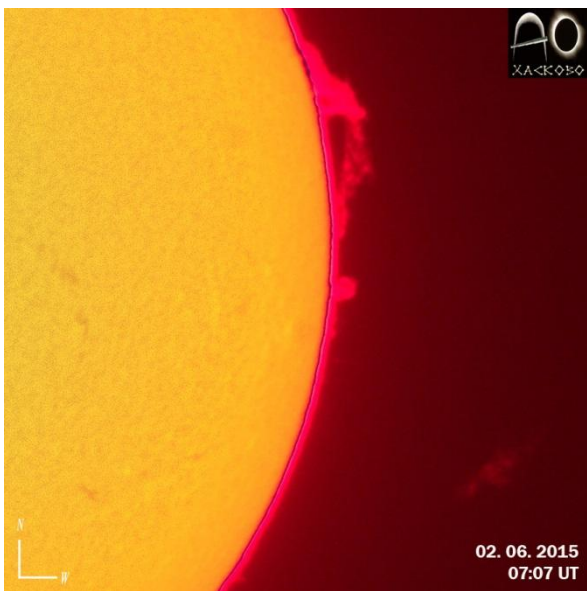
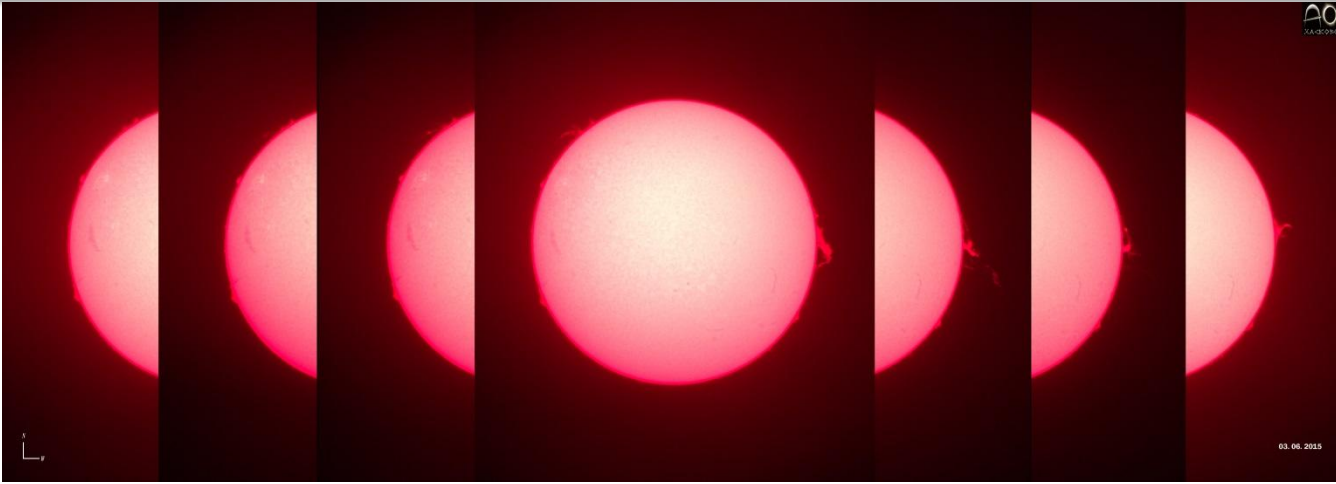


Mostly we simultaneously photograph prominences with CORONADO PST and sunspots in white light with Carl-Zeiss refractor telescope 80/1200, supplied with a standard solar filter SFO.

We photograph the solar prominences using a x2 Barlow lens.

Our Observations

Throughout the years we have observed and photographed the Sun in H alpha occasionally. We had the opportunity to observe not only quiet prominences, but also eruptive prominences, flares, flocculi and different active formation on the Sun. On this page we show you a quick summary of our previous work which we have presented in different projects in the past.



REALTIME IMAGE GALLERY

The X1 Flare On The Sun

Taken by Yoanna Kokotarskova on November 19, 2013 @ Haskovo, Bulgaria

Last viewed by a user in:
Haskovo, Khaskovo, BG
at 3:37pm UT

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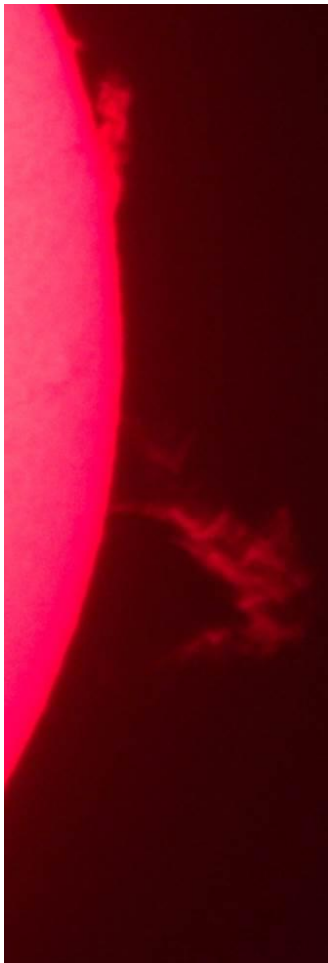
A screenshot of a webpage showing an H-alpha image of the Sun with a blue arrow pointing to a bright spot on the right limb. The webpage includes a logo 'AO XA-KO-BG' in the top right corner, the date and time '19.11.2013 10:29 UT' in the bottom right corner, and various navigation and advertising buttons.

Our Prominences

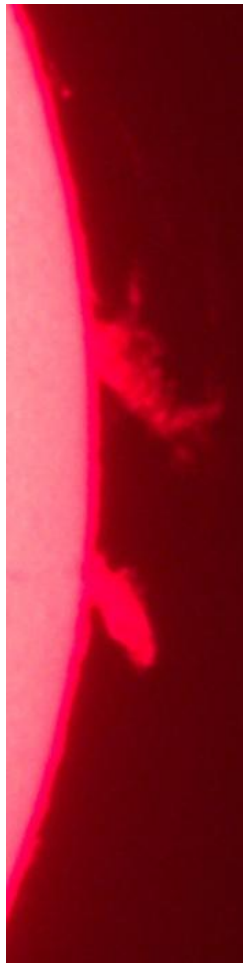
We have the opportunity to photograph extremely distinctive prominences in height and form. We are glad to be able to observe these whimsical events almost everyday.



17.06.2013



11.09.2013



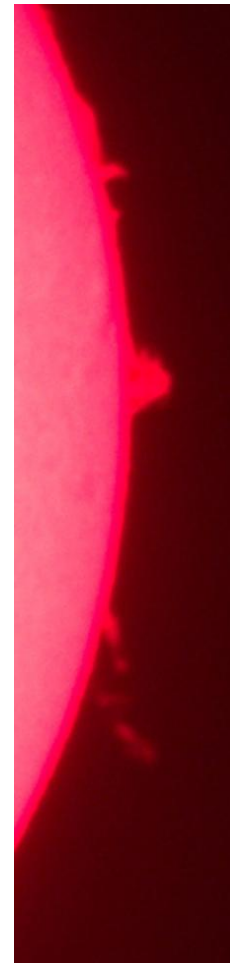
31.10.2013



25.11.2013



11.01.2014



26.02.2014



13.03.2014

Our Publications



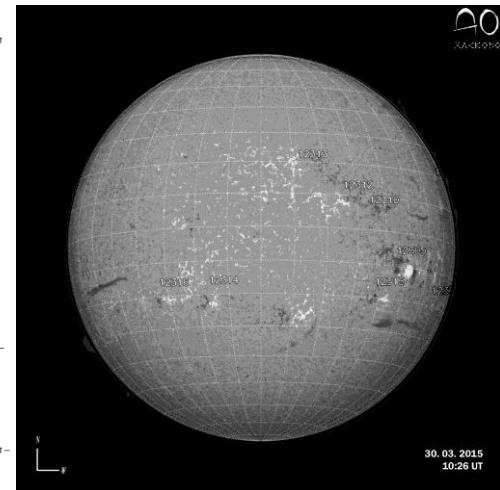
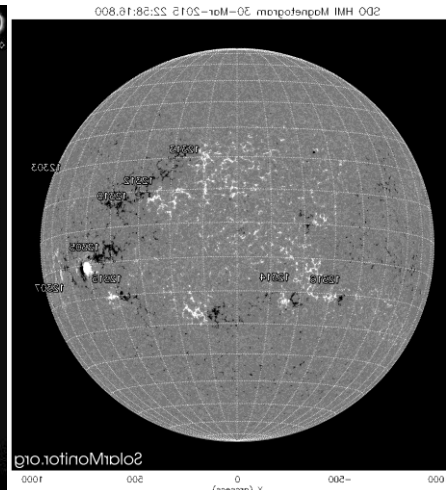
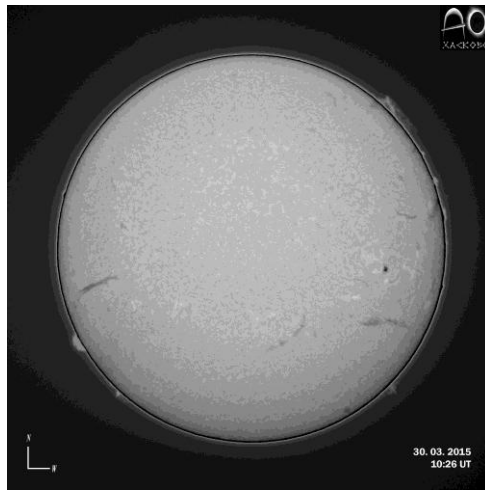
After shooting the Sun, we process our photos and then we publish them in our Facebook page :
(<https://www.facebook.com/ao.haskovo>)



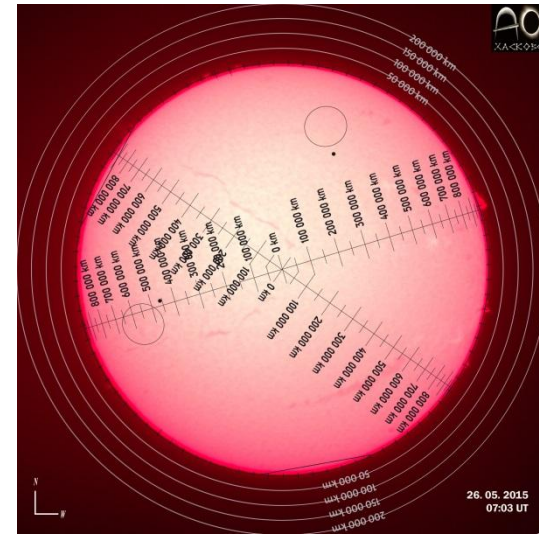
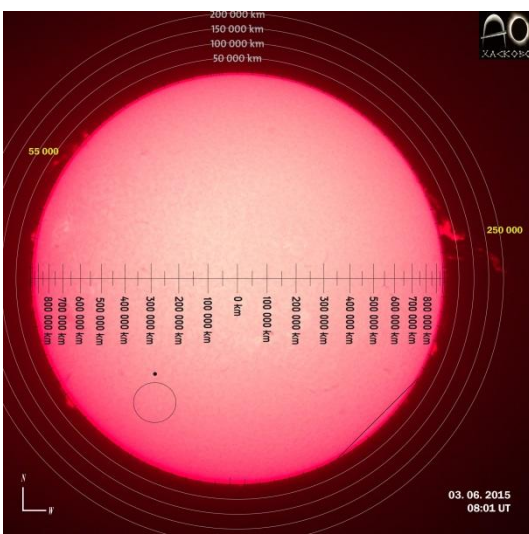
The main purpose of this processing is to clean our photos (if it need), to crop it and primarily to orientate them correctly to directions N-S-E-W.

The images of the Sun are shot in „jpeg” and „raw” format. This allows to us to made additional processing of the pictures in different channels. We are making this processing so that we can get a better quality.

Our Results



One of our main aims in the last one year was to investigate the magnetic field of the Sun and to identify filaments on our own observations. For this reason everyday, when we were able to observe and take photos of the Sun, we have downloaded pictures of the HMI magnetographs of SDO. These pictures allows us to see where exactly the bipolar groups are and when we stack them to our photos we able to identify which is the type the filaments on the disc.

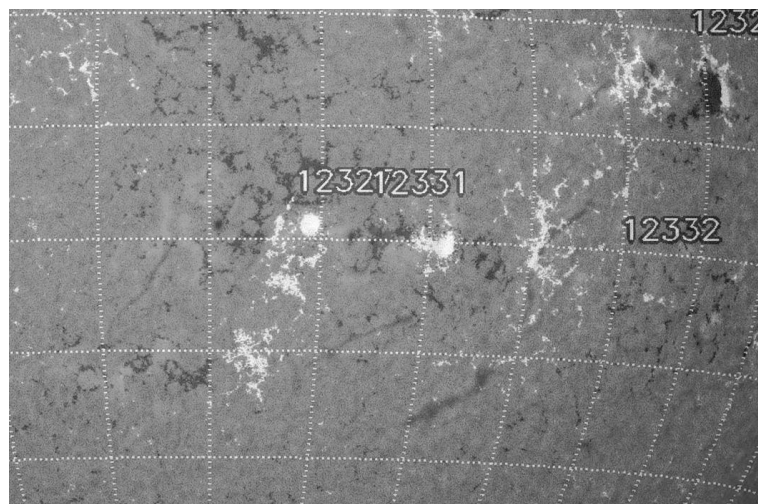
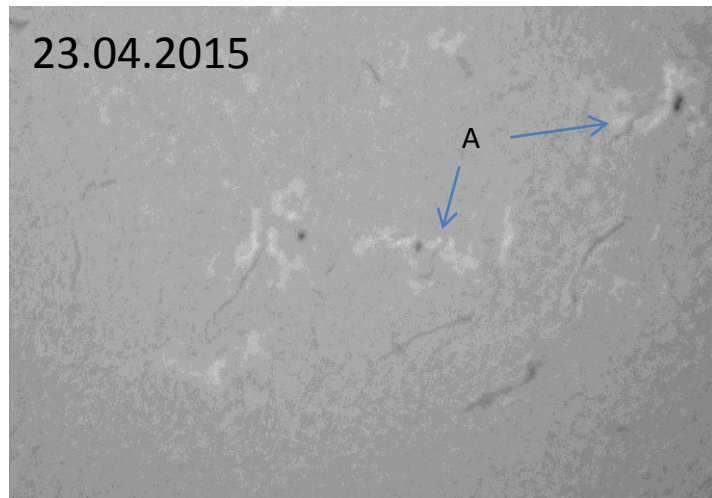
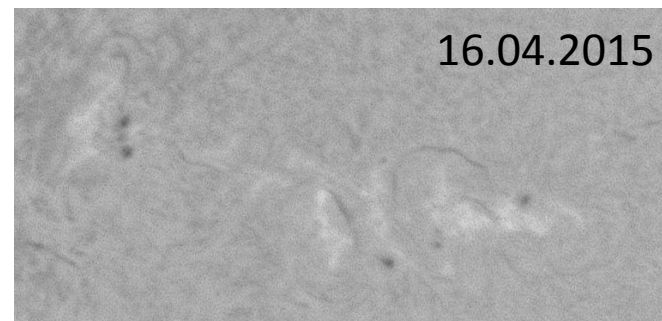
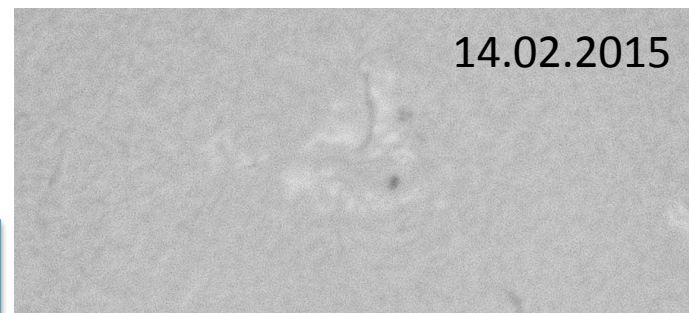


Another edit that we have done was to use this specific ruler (suggested and given permission to use by Guy Buhry) and which can be stacked to the Sun's disc so we can estimate the height of the prominences and the length of the filaments. The ruler is adjusted to the spherical form of the Sun. By this images we have made different assumptions about the prominences' characteristics formed on the four neutral lines. This method is not very accurate when it is used on filaments with high heliographic latitude.

The next part of the project we will present identification of filaments based on the classification of Mackay we have done on our own observation.

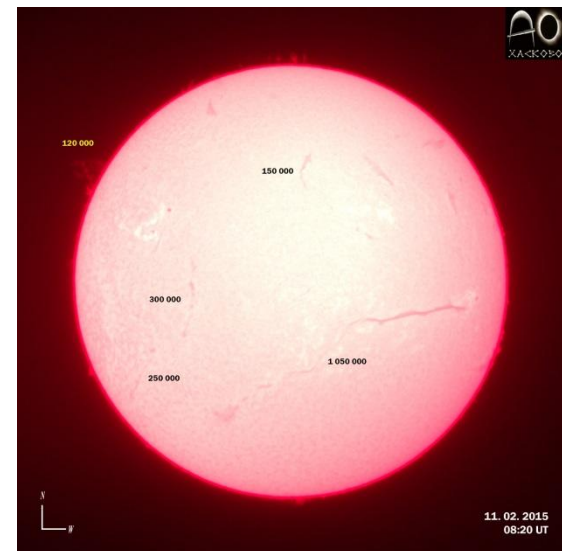
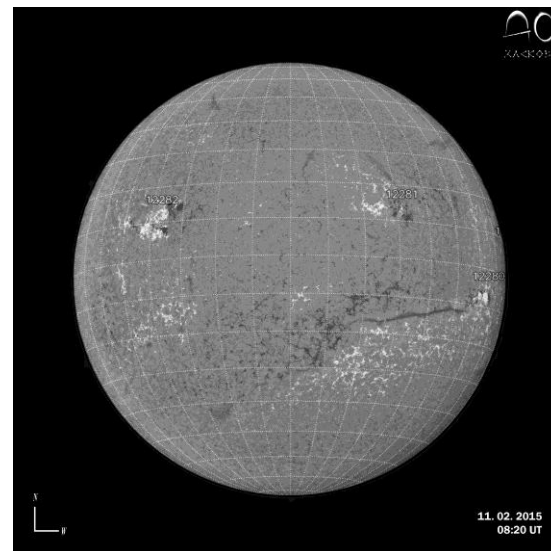
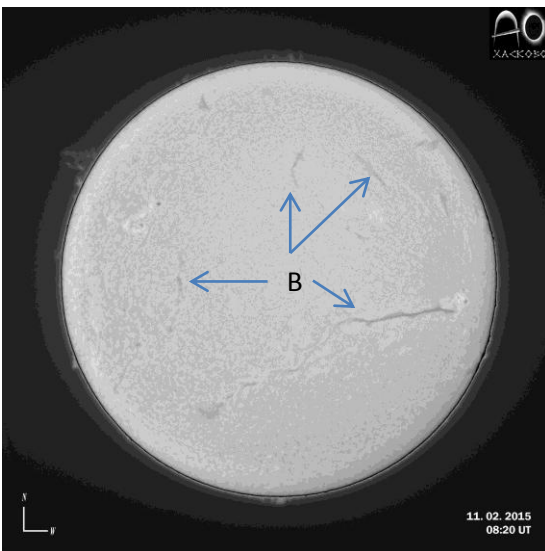
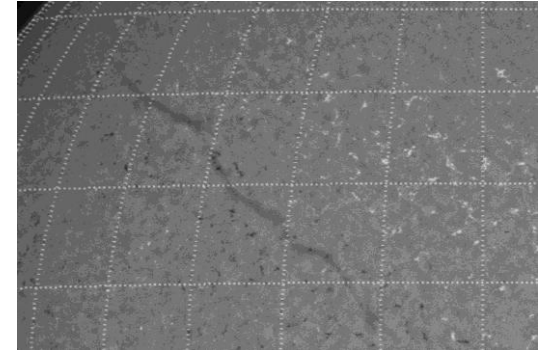
A type filaments

From our observation we can conclude that most A type filaments are small, with not so long a lifespan and mostly vertical on small heliographic latitude. Due to this facts, they are not easy to photograph. These conclusions support and the thesis that A type filaments have a N type magnetic structure.



B type filaments

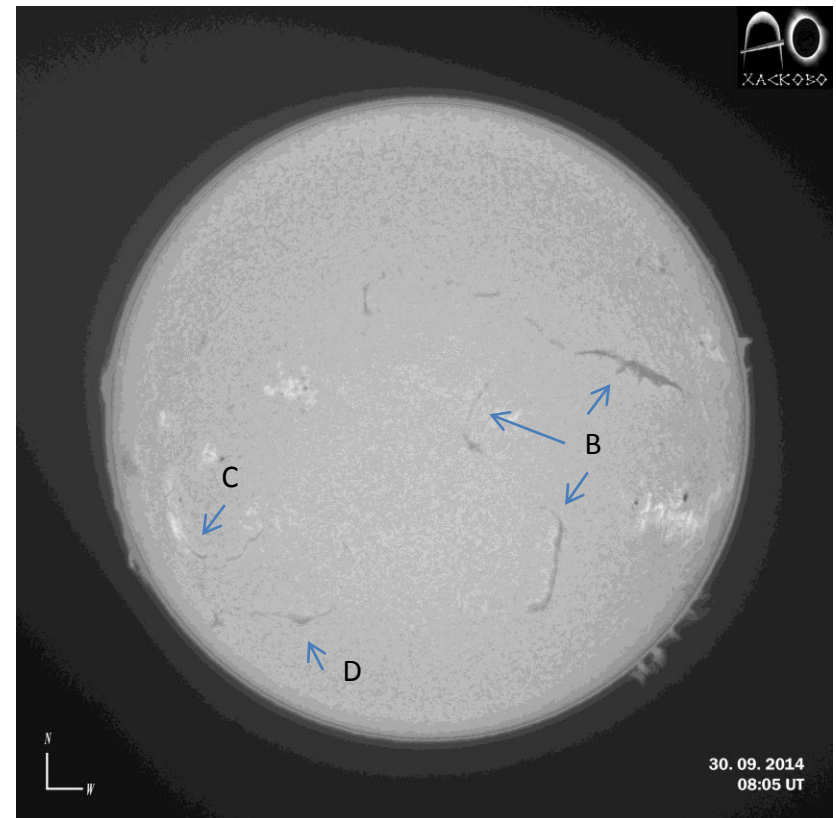
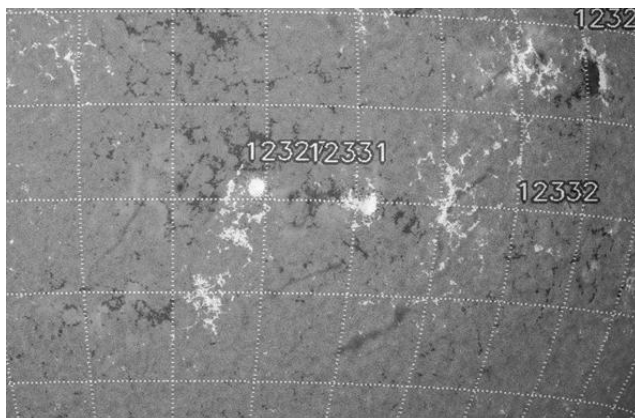
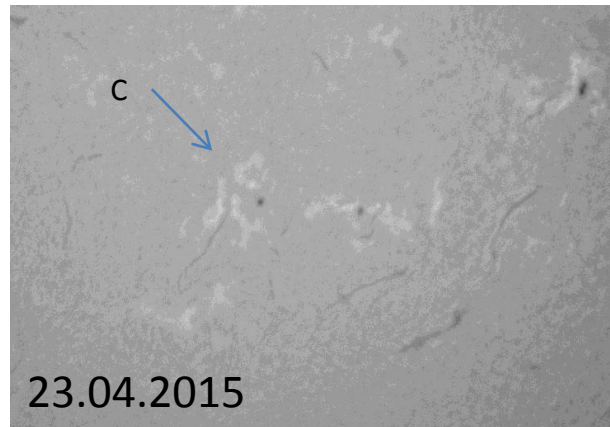
The B type filaments we observed were most distinctive from each other, with long lifespan and great variety in length, width and location.



C type filaments

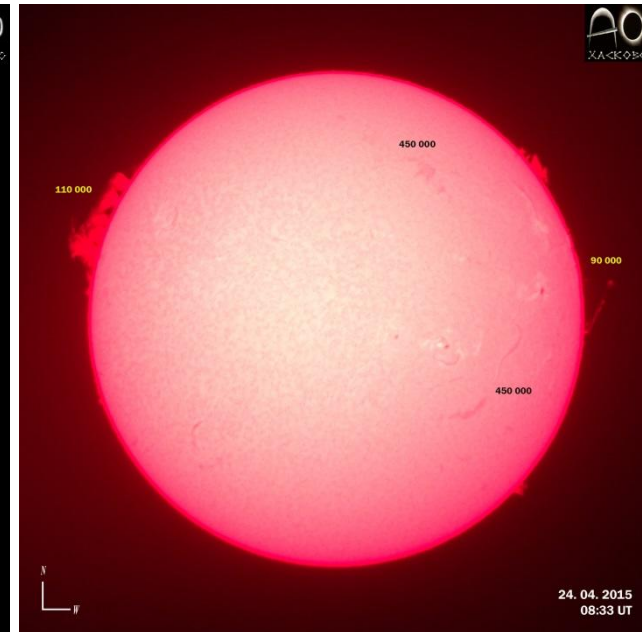
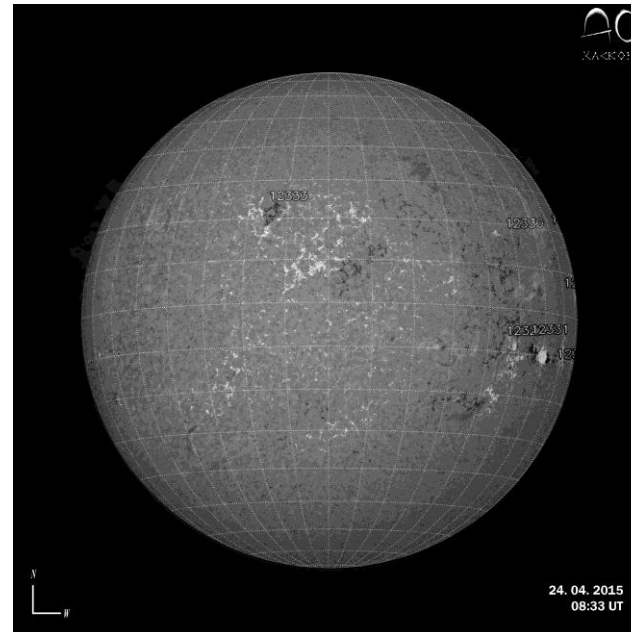
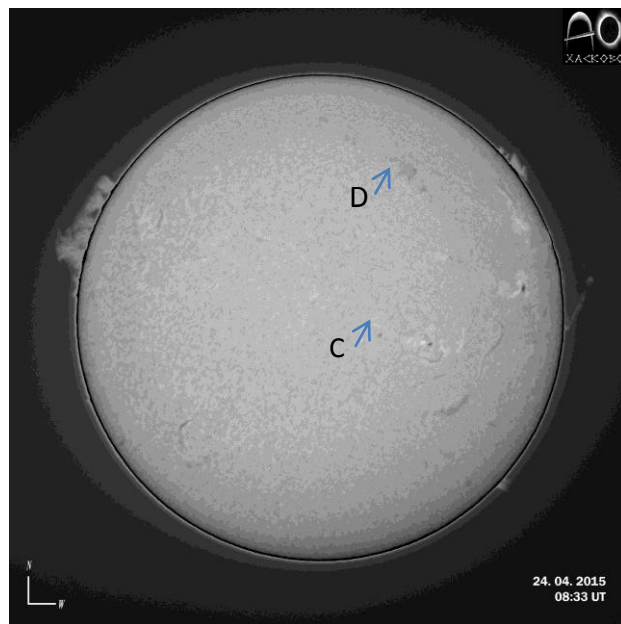
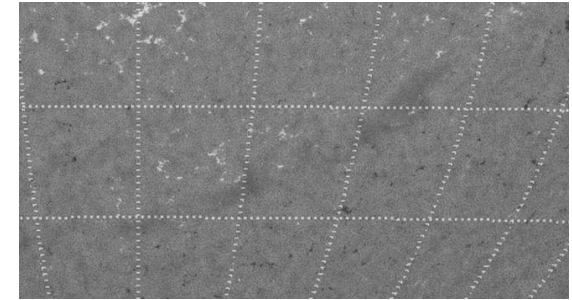
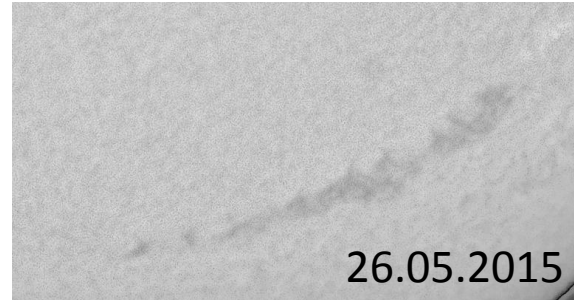
This type is newly distinguished. They are not observed so much because of the difficult configuration they are in which leads to a short life. Their length is difficult to estimate cause most of them have oval or semi oval forms.

12.06.2015



D type filaments

D type filaments are observed on high heliographic latitudes. They are mostly horizontally slanted. Even though their magnetic field is not so strong they are relatively wide.



Our Conclusions

As it is said before in the project, there is relation between the type of the neutral line where the filaments are formed and their magnetic configuration. It is considered that N type prominences are located on A type neutral line while I type on D neutral line.

The magnetic configuration of B type neutral line is still open for discussion. Theoretically, they are expected to be I type. Firstly, the magnetic field of B type neutral lines are less powerful than of the A type. Secondly, the most observed prominences are from I type and as Tangerg concluded prominences on B types are most observed. As conclusion, prominences prefer neutral lines between two bipolar groups where the surrounding of neutral line is quadruple.

| A | B | C | D |
|----|----|----|----|
| 17 | 54 | 15 | 28 |

On the table above you can see the numbers of different prominences by type identified on our own observation for the last one year. Even though this task was not so easy as we expected it would be, we are satisfied by our result because they are in full accordance with the literature on that theme.

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