Observing the sun in Ca II K

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Introduction

Many amateur astronomers get their first glimpses of our nearest star in white light using relatively inexpensive solar film. The wealth of information about the features seen in this wavelength (photosphere) is widely shared and easily available. As the cost of exclusive narrowband filters has decreased over the past few years, viewing the sun in the Hydrogen alpha and Ca II K line has become more common. There is a fair amount of material available to help the amateur identify features seen in hydrogen alpha but after purchasing a Coronado CaK PST telescope I became aware of how little information seemed to have been gathered to help identify features seen in this wavelength. I have tried to gather material together from scientific journals and books to give a basic spotters guide to the features commonly seen through readily available Ca II K filters. This is not a fully comprehensive guide and I can’t guarantee that all the information is totally correct in a scientific point of view but I hope it will help amateurs get more enjoyment and pleasure from observing the sun in the Ca II K wavelength.

Firstly, where on the sun are we looking at when viewing in this wavelength? Generally it is assumed that Ca II K is the lower chromosphere whilst the Hydrogen alpha band is the mid chromosphere. This illustration simplifies this very well.

http://sungazer.net/ha/ha4.html

However it is more complicated than this. For the Coronado CaK PST telescope the manufacturer states that the filter is centred at 393.4nm with a bandwidth of 0.22nm. This gives a range of 393.29nm-393.51nm. In the literature the Ca II K line is split into 3 regions, the K1, K2, and K3. Each region shows a specific area of the chromosphere and Figure 1 shows this.

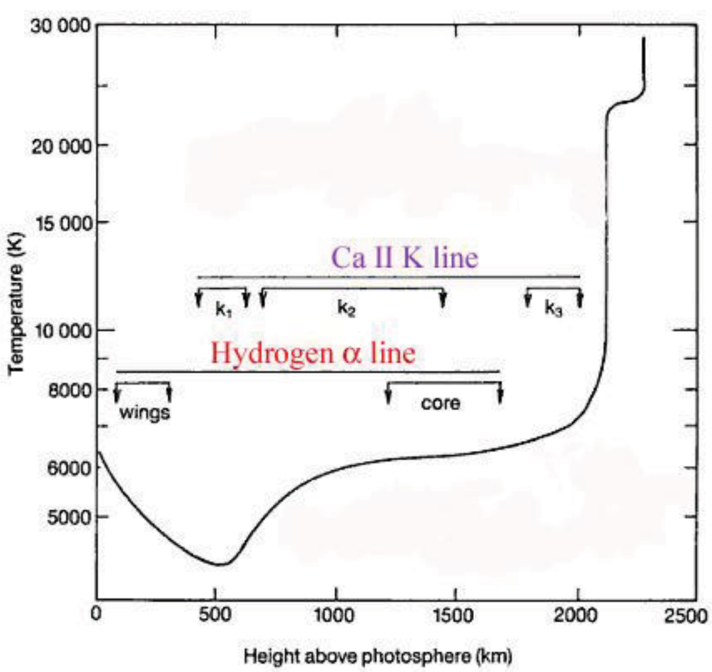

Figure 1. Graph showing the height above the photosphere of the Ca II K and hydrogen alpha line. Graph made from data gathered by (Vernazza *et al.* 1981).

With the K1 region being 393.32nm to the K3 region being at 393.37nm (where prominences can be seen) the bandwidth clearly covers the whole of this region of the chromosphere giving a general mix of heights visible in the chromosphere in Ca II K filters. The K1 or K2 region (500-1000 km) is lower than the Hα core region (1500 km) above the photosphere, but the K3 region is around 1800 km in height.

What we need also to understand with visualising in Ca II K is that this line is very sensitive to the presence of magnetic field in the material. If magnetic fields are present, absorption is less (more light is transmitted) with weaker magnetic fields showing as darker areas. Therefore, moderately strong magnetic field shows up as bright regions in our images but with the exception of very strong magnetic field, such as in a sunspot where they appear very dark.

Features

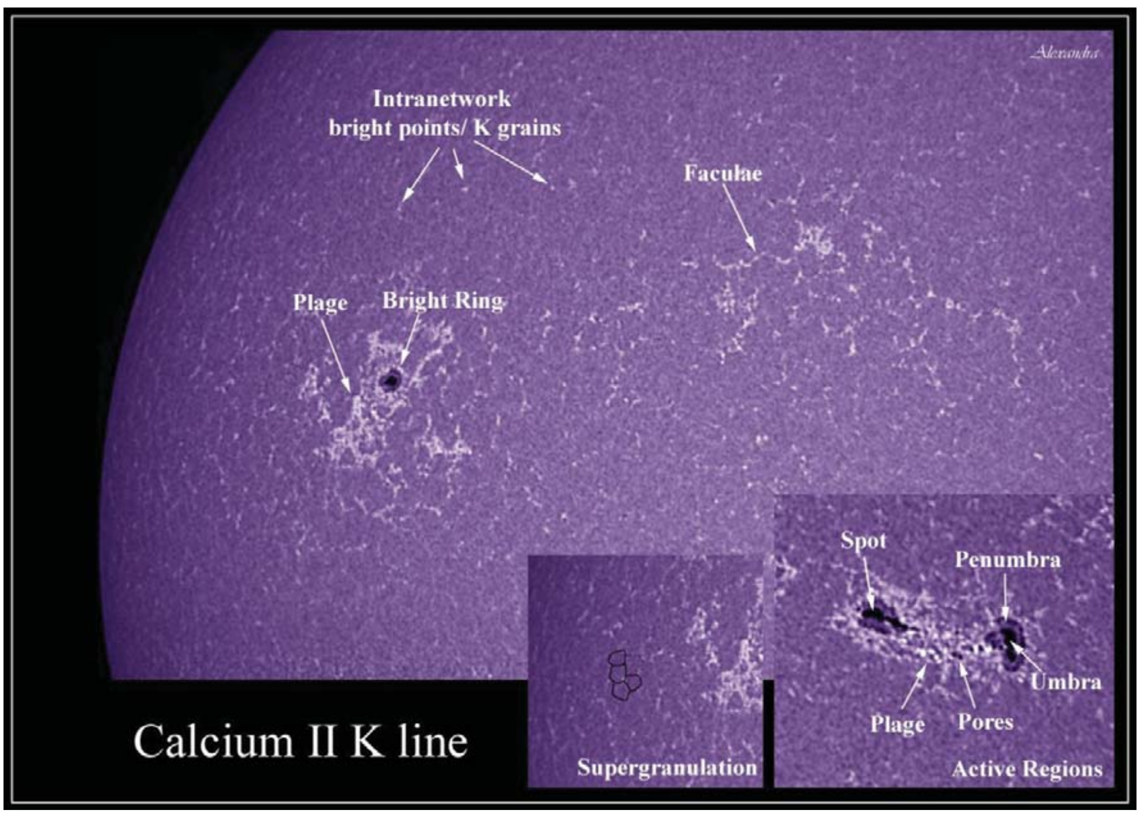

Figure 2. Features that can be observed in Ca II K line. Photographs taken using a Coronado CaK PST telescope (40mm) and an Imaging Source DMK41 monochrome camera with false colour added. Inset photographs are enlarged from the original. Telescopes with a larger aperture will see more fine detail than those shown in the photograph.

Umbra and Penumbra

Spots on the sun are areas of high magnetic field which appear dark to their surroundings (5,800K) due to their cooler temperature of around 3000-3500K. Spots consist of a dark central region (umbra) and are surrounded by an annular region of dark and bright filaments called the penumbra. Within a developing active region (sunspot group) tiny spots form initially without a developed penumbra and are called pores. These are usually relatively short lived or can develop a penumbra and become a fully developed spot. Active regions can contain either a single spot or a great number and can last from only a day up to 60 days (Bhatnager, A. 2005 and Evre, S. 1999).

The structure of these features is very similar to those seen in white light (photosphere) and more information can be found in references which concentrate on photospheric features.

Bright Ring

The Bright Ring was first observed by Waldmeier in 1939 and later again by Das and Ramanathan (1953) and more recently by Rast *et al.* 1999. It was observed that in violet and blue light, particularly in the Ca II K line that there was an area of brightening around the penumbra. This was not seen in all developed spots but was measured at around 10% brighter than the surrounding background. One theory put forward to explaining this phenomenon is that the missing energy due to suppression of convective energy transport by underlying magnetic fields in the spot shows as a bright ring around the penumbrae. Possibly around 10% of the missing energy from these regions is emitted by this ring (Bhatnager, A. 2005 p190). This would prove a good study area for the amateur astronomer with good available resolution to assess how many penumbra show this phenomenon and how bright the region is.

Chromospheric Faculae / Plage

Most of us are familiar with photospheric faculae which can normally only be observed towards the edge of the solar disc in white light when it is possible to view a higher region in the photosphere. These bright mottles can be up to 50,000km long and are caused by underlying magnetic fields. They are often a good predictor of future active region development and can also remain long after an active region has dissipated. The average lifetime of faculae is about 90 days and they are around several hundred degrees Kelvin hotter than the surroundings (therefore appear bright).

Chromospheric faculae can be observed anywhere on the solar disc and they are an extension of the photospheric faculae into the chromosphere, details of this link are still not fully understood. Areas of very dense magnetically bright faculae or plage occur in active regions and are a good predictor of the occurrence of future sunspot formation (Evre, S. 1999). Polar faculae are short lived and only observed just before and around the solar minimum.

Supergranulation cells (Chromospheric network structure)

In the quiet sun most of the chromosphere seen in Ca II K appears like a bright network pattern of irregularly shaped circles. The size of these cells is around 30,000-35,000 km in size and their average lifespan is around 20 hours. (Bhatnager, A. 2005). This is a pattern of weaker magnetic fields (the quiet network) where the magnetic elements are mixed in polarity. These are also called the intranetwork fields and the brighter edges can also be called faculae. The supergranulation cells are large scale convective horizontal flow, where material flows outwards from the centre and downward flow has been observed at the boundaries. The flow carries both polarities to the boundaries (Zirin H. 1988 p126).

K grains

K grains are 'intranetwork bright points' found in the quiet sun. Intranetwork bright points, cell flashes or cell grains, originate exclusively within cell interiors in quiet areas of the solar surface. These are observed almost exclusively in the Calcium H (396.85nm) and K lines (Rutten *et al.* 1991). They are intermittent localised brightenings which last less than a minute and often re-appear a few times at 2-4 min intervals at about the same place, and frequently occur in pairs. In Figure 2, the labelled brightenings are an example only. These bright points are tiny and good resolution is needed to observe these features. To identify them definitively, a time lapse study would need to be embarked upon and the brightenings studied to assess whether they follow the pattern of re-emergence and disappearance, again another good area for amateur study. It has been observed that these K grains do seem to correspond with G-band brightpoints observed in the intergranular lanes in the photosphere (Lite *et al.* 1998).

Microflares/Ellerman bombs

Watching and studying emerging flux regions in the Ca II K line exhibits fascinating features which seem to be poorly understood in the literature at the present time and which would provide the amateur astronomer a good target of study. The first point we need to understand is where in the chromosphere we are actually observing. Ellerman Bombs also called microflares are present in emerging highly active regions and may contribute significantly to the heating of the lower chromosphere in emerging flux regions. Ellerman bombs are most likely to be caused by magnetic flux tube reconnections that take place during the emergence of the magnetic field. They are visible in a region 600-1100km above the photosphere and can be seen in Ca II K but more commonly in the Hydrogen alpha ($H\alpha$) wings (Pariat et al 2007). In the wings of $H\alpha$ you observe from 1500km right down to the photosphere. Please see p172 Figure 7.11 of 'Astrophysics of the Sun' by Harold Zirin for a fine example of an emerging flux region with Ellerman bombs, or Figure 5
http://www.scholarpedia.org/article/Magnetic_flux_emergence
A very recent study has now identified the region where these reconnections initially occur. Using information obtained from both $H\alpha$ and Ca II K they showed that a time delay in observation of ≈3 minutes between the $H\alpha$ wing and Ca II K indicated that the observed magnetic reconnection occurs at a height of around 200 km above the solar photosphere (Jess *et al.* 2010).

With most Ca II K line filters available for amateur astronomers being a wide bandwidth it is certain that these features which can be readily observed in the K1/K2 region (500-1000km) are visible.

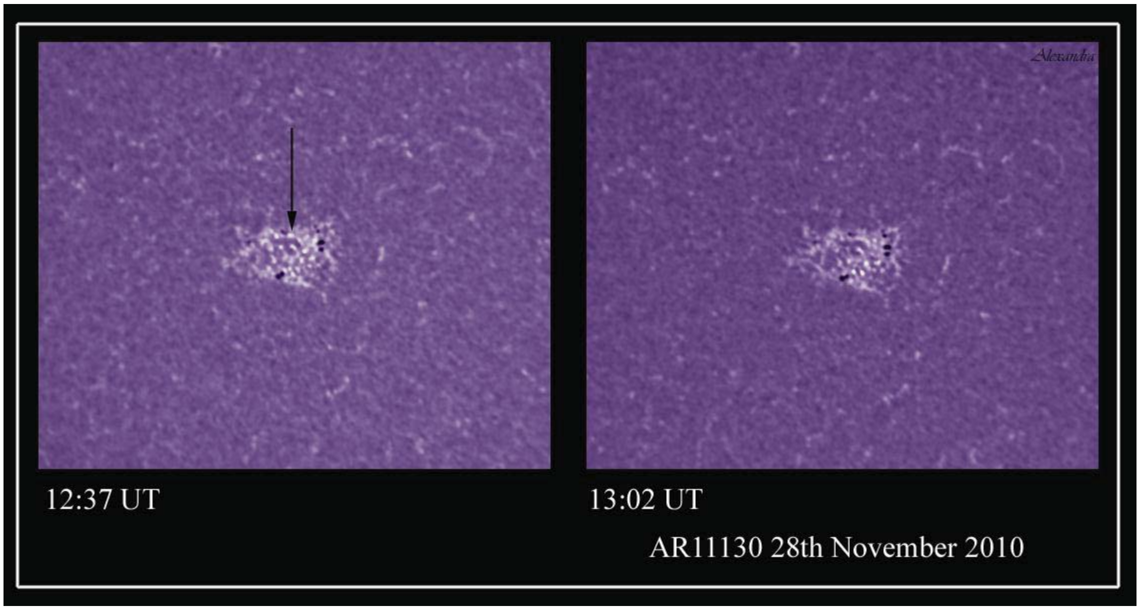

Figure 3. An emerging flux region showing bright points which emerge and disappear within 20 minutes. Photographs taken using a Coronado CaK PST telescope (40mm) and an Imaging Source DMK41 monochrome camera with false colour added.

Figure 3 shows an emerging flux region where 2 photographs were taken about 20 minutes apart. These pictures are remarkably similar to those taken in the Hα wings and show bright points which emerge and disappear within 20 minutes. Although not totally certain due to lack of data for that particular day, these bright points were identified by Dr. Werner Pötzi at the Solar Observatory Kanzelhöhe as possible microflares / Ellerman bombs.

Arch Filament Foot points

In an emerging flux region many small dark filaments are observed in Hα which are called Arch Filament systems. Here, the solar plasma is compressed by up flow of material in the flux loop and is compressed and forced downwards by gravity along the loops to the base. The base of these loops (downward flow) is the foot points where the plasma down flows at ~20-50 km/s. Most arch filament loops terminate in growing spots and are magnetically bright and are the lowest visible point (Bhatnager, A. 2005 and Zirin H. 1988). Figure 4 shows a study on an emerging flux region in both Hα and Ca II K. By merging these photographs together in Adobe PhotoShop it is possible to follow the arch filaments down to their magnetically bright foot points. Bright points (b) which do not seem to follow the arch filaments and which were previously seen to disappear within 20 minutes are the possible microflares / Ellerman bombs shown in Figure 3. This is a good subject of study for the amateur in which both wavelengths can be used.

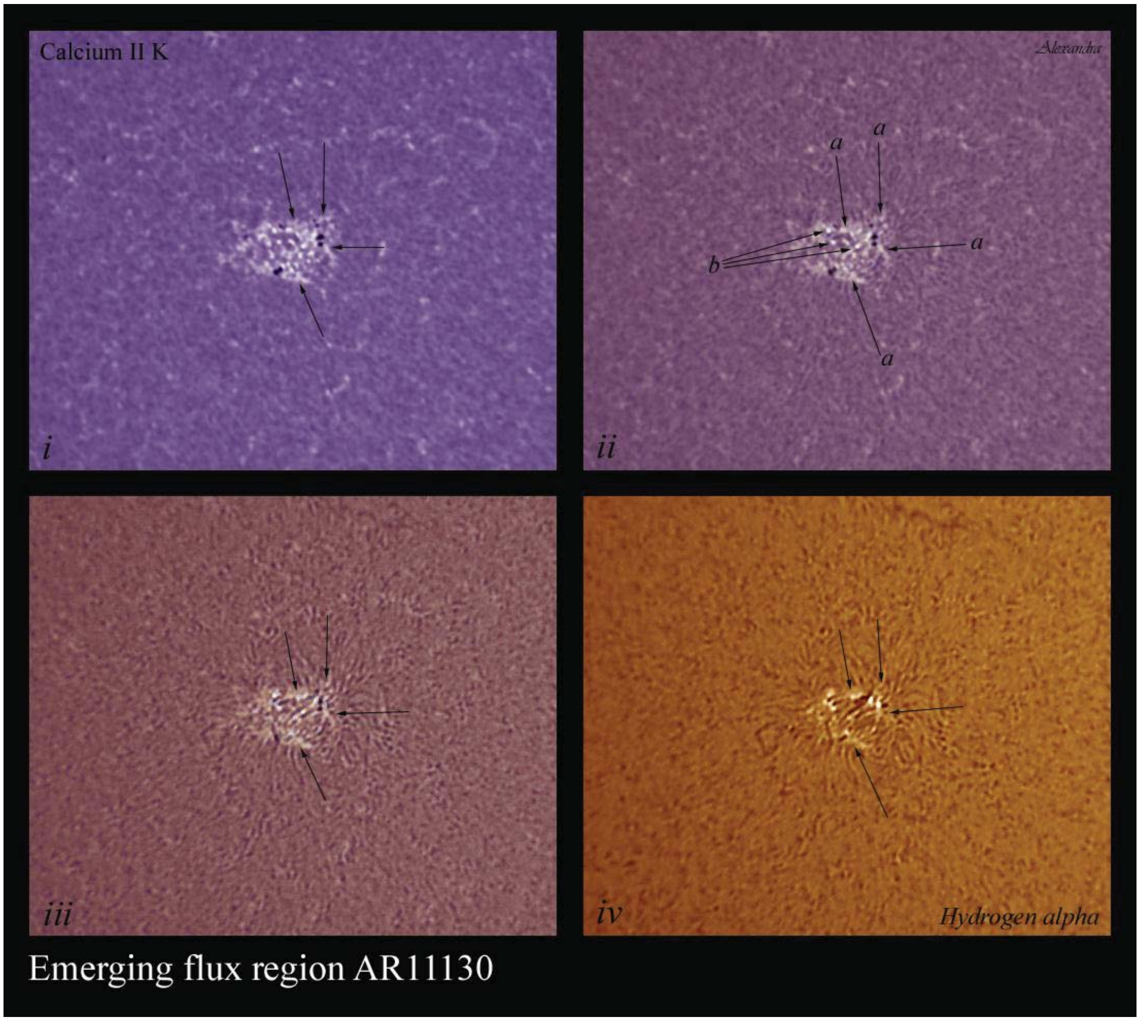

Figure 4. Emerging flux region AR11130 photographed in both Hα and Ca II K and gradually merged using Adobe PhotoShop. Initially the region was photographed in Ca II K (i) and Hα (iv). Photographs (ii) and (iii) are of increasing levels of overlay so that both features from Hα and Ca II K can be viewed together. The arrows (a) can be seen in the same places throughout all four photographs and can be used as a reference point. The arrows at (b) show 3 bright points which do not seem to be linked to the arch filaments.

Filaments and Prominences

As many Ca II K filters available to amateur astronomers have a wide bandwidth (CaK PST) being 0.22nm over the 393.4nm region, this covers all the K1, K2 and K3 region (it isn't narrow enough to define each particular region on its own). This then covers a region of the chromosphere from the temperature minimum (why we see features similar to the Hα wings) right up to the Hα core region. Therefore it stands to reason that some Hα features will be visible in Ca II K.

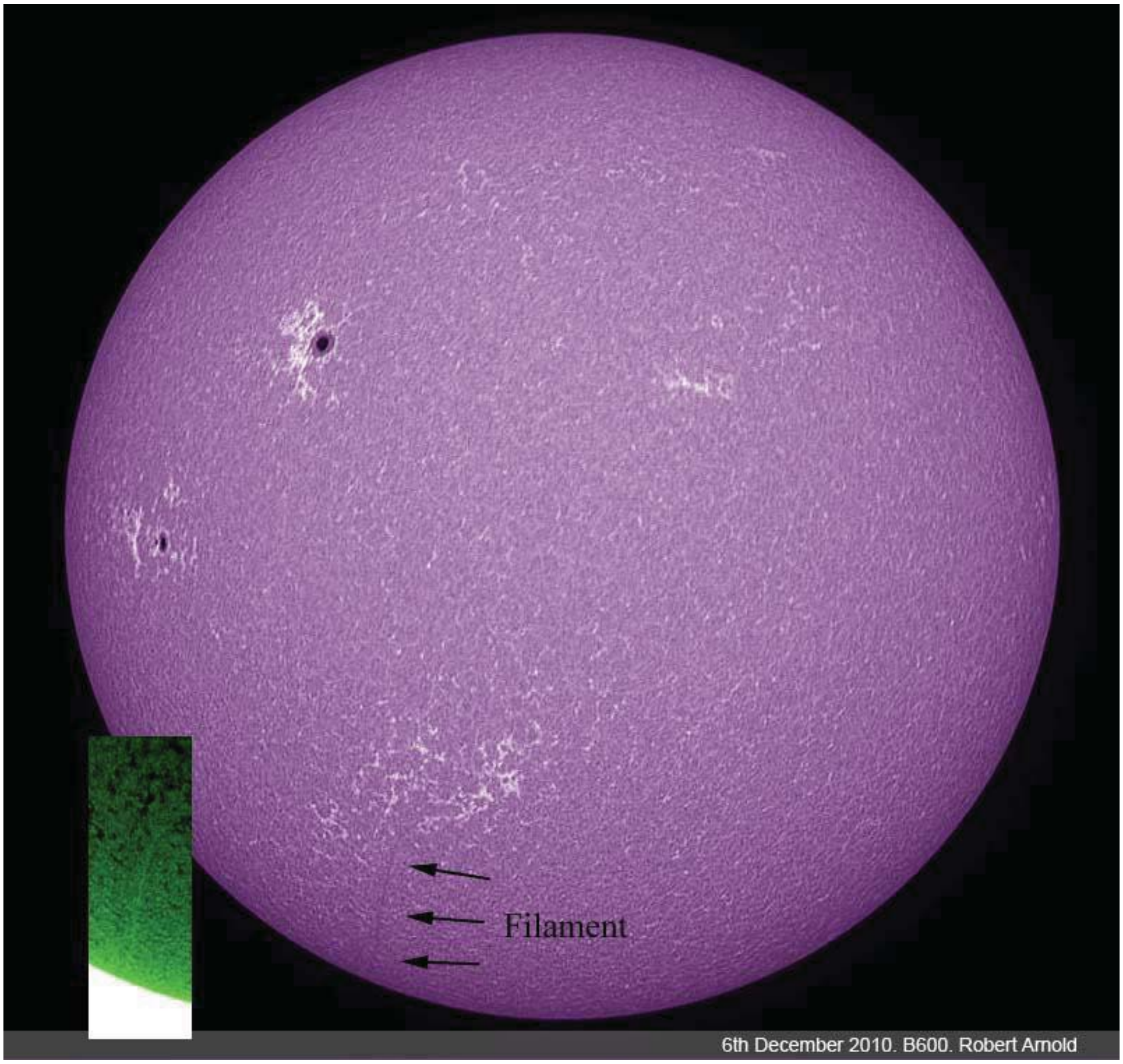

Figure 5. Full solar disc showing a large filament visible in Ca II K. The inset photograph has been inverted to allow easier visualisation of the filament. Photograph by Robert Arnold, Isle of Skye, UK.

The K3 region is where we see filaments and prominences similar to those seen in Hα but much fainter and less well defined as these features emit less light in Ca II K. Filaments separate opposite magnetic polarities with the structure running parallel to the boundary. As they are weak magnetic field they will appear darker in Ca II K emission. The size and structure of these features is very dependent on whether they will be visible and studying a solar disc at maximum, only the very largest of the filaments were visible both in Ca II K and Ha (see Figure 4.6 p115 'Guide to the Sun' by K. Phillips). Figure 5 and 6 show good examples of both of these features.

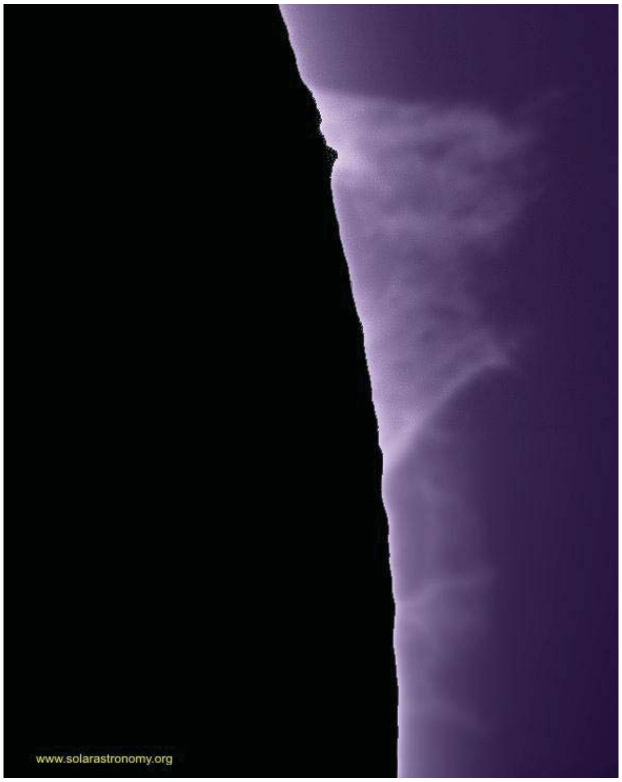

Figure 6. Solar prominences seen in the Ca II K line. Photograph by Stephen Ramsden, Atlanta, USA.

The most important part of all these features are that they can be observed with Ca II K filters available to amateur astronomers. Enjoying using them and observing with them is important. The more we see, the more we can try and understand. Have fun.

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References

Bhatnager, A., Livingston, W. 2005. 'Fundamentals of Solar Astronomy'. World Scientific Series in Astronomy and Astrophysics – Vol. 6. World Scientific Publishing Co. Pte. Ltd., Singapore.

Evre, S. 1999. 'Facular Structures on Cool Stars'. Tr. J. of Physics 23 (1999) , 383 - 390.

Jess, D. B., Mathioudakis, M., Browning, P. K., Crockett, P. J., Keenan, F. P. 2010. 'Microflare activity driven by forced magnetic reconnection'. The Astrophysical Journal Letters, 712:L111–L115, 2010 March 20

Lite, B. W., Rutten, R. J., Berger T. E. 1998. 'Dynamics of the Solar Chromosphere.II. Ca II H2V and K2V Grains versus Internetwork Fields'. The Astrophysical Journal.

Pariat, E., Schmieder, B., Berlicki, A., Deng, Y., Mein, N., López Ariste, A. and Wang, S. 2007. 'Spectrophotometric analysis of Ellerman bombs in the Ca II, Hα, and UV range'. A&A 473, 279–289

Phillips, K J H. 1992. 'Guide to the Sun'. Cambridge University Press, Cambridge.

Rutten, RJ and Uitenbroek H. 1991. 'Ca II H2v and K2v Cell Grains'. Solar Physics (ISSN 0038-0938), vol. 134, July 1991, p. 15-71.

Vernazza, J., Averett, E., and Loeser, R. 1981. 'Structure of the Chromosphere'. Ap. J. Supp., **45**, 635.

Zirin, H. 1988. 'Astrophysics of the sun'. Cambridge University Press, Cambridge.