Visible wavelength broad band imager

Some observations of the solar atmosphere can be done using the broad band imager. A few broad band imagers can be used as a proxy to probe the magnetic features in the solar atmosphere. The main component in the broad band imager system is a spectral filter with a bandwidth of 3-10 Å. Even though the broad band imager can image the solar atmosphere, it generally provides an image integrated over a range of temperatures, within the solar photosphere and low chromosphere. These images can be converted into a movie format to study the dynamics of the magnetic features in the solar atmosphere. In addition, the broad band imager is also important for the follow up studies using the narrow band imaging system and vector magnetic field measurements.

The Kodaikanal Observatory of IIA has been doing photographic observations of the sun since 1900. These observations are made using the spectroheliograph as well as broad band imager (e.g. Sivaraman, Gupta,and Howard, 1993). Mainly they used Ca II K 3934 Å filter to observe the plage and network regions. The Observatory has a large collection of white light data and Hα data. There is huge demand for the archived data from the solar community across the world. Udaipur Solar Observatory and Aryabhatta Research Institute of Environmental Sciences (ARIES) also have archival Hα data obtained from the broad band imager (Bhatnagar et al., 1980, Uddin and Verma, 1998).

A great amount of research work has already been published in reputed journals using these data sets. Similarly, if we have broad band imaging system for the high resolution it not only gives the archival data, it also gives a supplementary data to the other two instruments (see below). So, we have a history of using broad band imager data since 50 years in India. Most of the data sets are full disk solar images and a few of them are of high resolution type (1″). For NLST, we are planning to provide the broad band images to the user community not only at high temporal cadence but also give the data at very high resolution (~0.063 arcsec).

Wavelengths selection for the broad band imager: There are several broad band filters that can be used to observe the solar atmosphere. In practice, the broadband imager is used to observe the solar photosphere and low chromosphere. The instrument will be capable of observing the sun at any wavelength with high throughput. Since the throughput is very high it is possible to obtain the images at high cadence hence these images can be used to study the dynamics of the solar atmosphere. The wavelength will be chosen such that the observation can be carried out from photosphere to the chromosphere. A list of possible filters along with the observation level in the solar atmosphere and their scientific purpose is presented in the following table.

Ca II K 3934 filter of about 2-3 Å band pass will be used to observe the low chromosphere. The large band pass will allow higher amount of flux that can be useful to study the oscillations. Since the cadence will be very high one can use the speckle reconstruction technique to get high contrast images.

Details of broad band imaging filters, the height covered in the solar atmosphere and objects of scientific interests.

Wavelength	Height	Purpose
Ca II K 3934 Å	Low chromosphere	Chromospheric dynamics, morphology, heating etc.,
G-band 4305 Å	Photosphere	Magnetic elements morphology, evolution etc.
Blue continuum 4500 Å	Photosphere	Granular contrast and photospheric dynamics etc.,
Red continuum 6600 Å	Photosphere	Granular contrast and photospheric dynamics and for image registration etc.
Hα 6563 Å	Chromosphere	Chromospheric morphology and dynamics
CN band 3883 Å	Photosphere	Bright points morphology and dynamics, magnetic network

G-band images are obtained in the band of CH molecule. The images have very good contrast for the magnetic features. The pass band of the filter is about 10 Å. Blue and red continuum filters will have a band pass of 5 Å. The images taken from these filters will have a better contrast to the granulation than the G-band images. These images can be used to align the different types of images obtained from various telescopes across the world. These images are also useful to find the horizontal velocity in the granulation and pores. The Hα filter will have a band pass of about 0.25 Å. The Hα images have very good contrast for the higher chromosphere. This is the only line that shows the fibril nature of the chromosphere and hence also shows the direction of the magnetic fields, chirality etc. CN molecular band images are similar to the G-band images and have very good contrast for the magnetic elements. The band width of the filter is about 5-10 Å.
Further, there will be some options to include filters like TiO (7058 Å), Ca II 8542 Å, Na I 5896 etc. to observe the sunspot umbra, upper chromosphere and lower chromosphere.

Instrument and data: In order to cover the wide wavelength range, we would require two CCD cameras with optimized response in the blue and the red region. The diffraction limited sampling will be implemented at the shortest wavelengths and images are acquired at over sampled rate in the longer wavelengths. The optical path and the optics are same for both the wavelength setup. The broad band filters will be kept in the collimated beam to avoid any variation in the pass band for the different angle of incidence. The final image will be focused on the CCD camera. The whole set up will be placed on the rotating platform to cancel the effect of image rotation. The detailed specifications of the broad band imager are shown in the following table. The filters will be kept on the filter wheel and the whole assembly will be kept in the air-conditioned room.

Detailed specifications of the filter.

Specification	Quantity
Diameter of the filter	6 cm
Operating temperature	25^{o} Celsius
Angle-of-incidence	Parallel beam
Cavities	Two
Variation in transmission	<5% over the aperture

The data will be acquired at fast rate. There will be many modes of operation to acquire the data. For example, a single frame can be obtained to check the region of interest, burst mode to watch any changes in the active region flows during flare or eruption and binning mode to collect enough photons for better signal to noise ratio. Broad band imager can be used to get a correct focus of the optics on the CCD camera. The software package will be developed in-house to correct the pixel-to-pixel gain variation, dark current etc. In the end, a fully calibrated data will be made available to the end users for scientific studies. In summary, this broad band imager can be used as a first light focal plane instrument. The high resolution images obtained at various wavelengths will also be used to test the telescope optics and image quality.