Contribution of Solar Chromospheric Fine Scale Features to UV Irradiance Variability

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Layout of the Talk

- Introduction
  - -- background & highlight the current problems
- Observations & Analysis
  - -- Call K & Hell images
- Results & Discussions
  - -- full-disk indices
  - -- intensity & area of individual features
- Conclusions
- What Next ?

Introduction

- Since the radiative output of the Sun is one of the main driving forces of the terrestrial atmosphere and climate system,

---- study of the changes in the solar energy flux has become of quite interest.

- Although the long-term change in total solar irradiance (the solar energy flux integrated over the entire spectrum) can be considered to be one of the major natural forces of Earth's climate system,

---- study of UV irradiance variability is an equally important issue in solar physics.

- **For more than 2 to 3 decades, solar irradiance (both bolometric and at various wavelengths) have been monitored "Sun as a star" from several satellites.**

- **Solar energy flux changes over a solar cycle.**

- **Long-term irradiance variations are attributed to the changing emission of bright magnetic elements, (Foukal and Lean, 1988; Kariyappa & Pap, 1996, 1999, 2000; Worden & White, 1998)**

- **Short-term irradiance variations are directly associated with active regions as they evolve and move across the solar disk,**
(Lean, 1987)

- **Difference between the observed and model irradiance variability has not been fully understood yet:**
---- Observed > Model & this will depend on the phases of the solar activity cycle

- Current irradiance models are based on full-disk integrated flux: such as Radio flux, CaII K 1A index, HeI equivalent width equivalent width

---- but not from spatially resolved features of the Sun

- To identify and understand the underlying physical mechanisms of solar irradiance variability and to estimate the contribution of various chromospheric features to UV irradiance

---- detailed analysis of spatially resolved data both from ground and space is required.

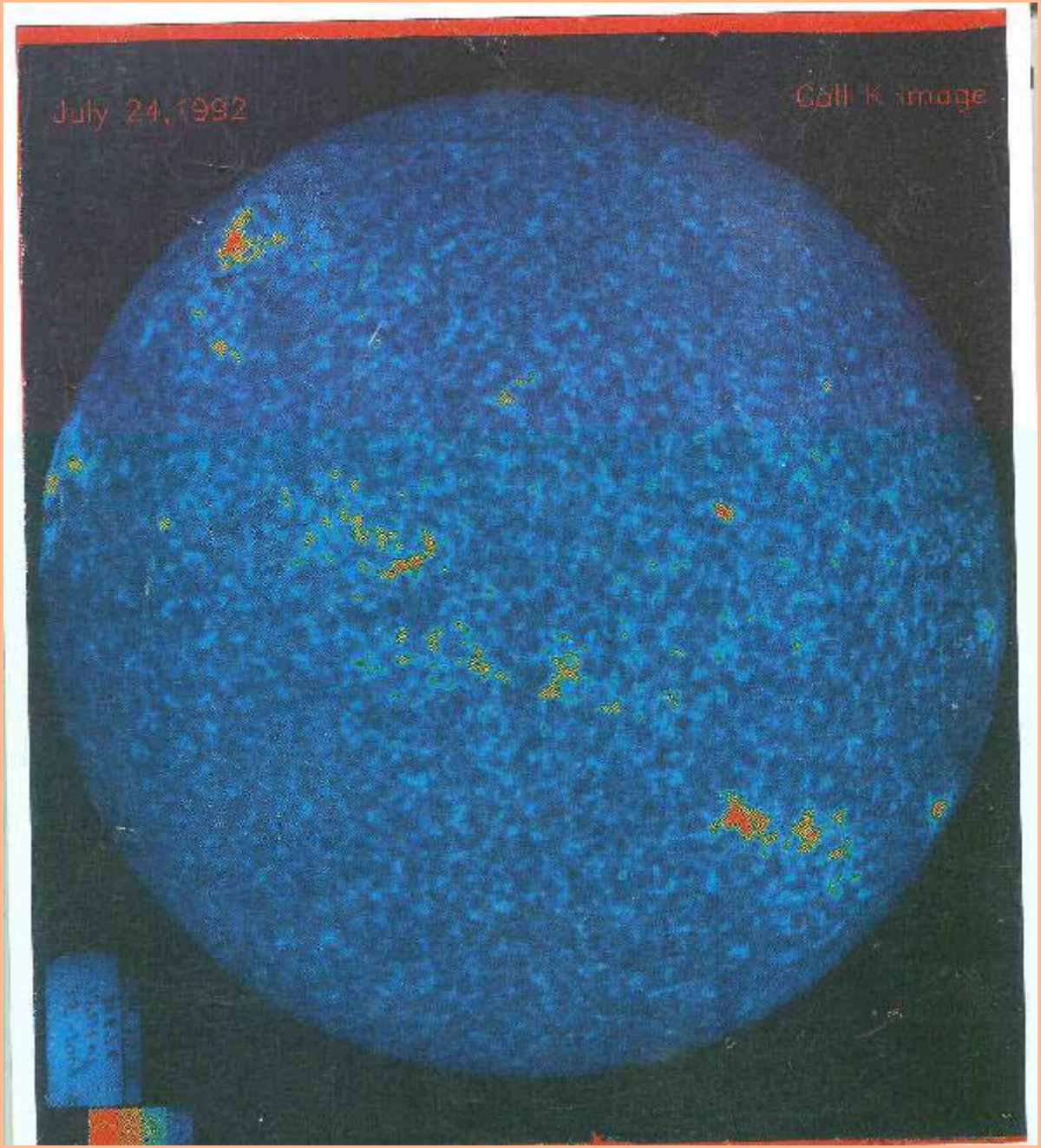
- **CaII H and K resonance lines are widely used to study the solar chromospheric structures.**

- **HeII (304 A) is similar to these lines representing the main features of the chromosphere.**

- **All these lines are very sensitive to the variations in temperature and the magnetic field strength, therefore they are excellent indicators of the chromospheric structural changes related to solar magnetic activity.**

Analysis of two-dimensional solar images in the CaII H & K and HeII lines demonstrate that the main features responsible for chromospheric emission are:

- **the bright plages;**
- **the network elements, which are co-spatial with the boundaries of supergranular cells in the underlying photospheric levels;**
- **the internetwork bright points – 1-2 arcsec features; &**
- **the background chromospheric emission regions**


July 24, 1992
CaII K image

Separating out these features from the images is ONE OF THE IMPORTANT & BIGGEST PROBLEM ???

- **CaII H & K, HeII & MgII h & k lines –**
  formed in the middle & upper chromosphere.

- **UV irradiance measured in MgII h & k lines to**
  compare with spatially resolved features

- **Solar UV flux cause significant changes in the Earth's climate & in space weather,**
  ---- understanding the physical origin of UV irradiance changes from spatially resolved images is an extremely important issue in Solar & Space Physics.

Observations & Image Analysis

- CaII K images observed at NSO/Sac Peak – Spectroheliograph 1.2 mm/A around 3934 A
- Selected the daily images for 6-years representing different phases of the solar activity
- Images have been digitized & calibrated
- Analyzed the images of 1980,1985, 1987 & 1992
- HeII 304 A images for 2004 from SOHO/EIT instrument - Very preliminary analysis

Following parameters derived from these calibrated images using the Histogram Method in IDL:

i.) Histogram plots for the full-disk

- **(a) Full Width at Half Maximum (FWHM)**
- **(b) Peak pixel numbers**
- **(c) Peak intensity**

ii.) Intensity in quiet region at the disk center

iii.) Full-disk CaII K index (Spatial K Index)

iv.) Intensity of plages, network, & internetwork regions.

v.) Number pixels of plages, network and inter-network

Results and Discussions

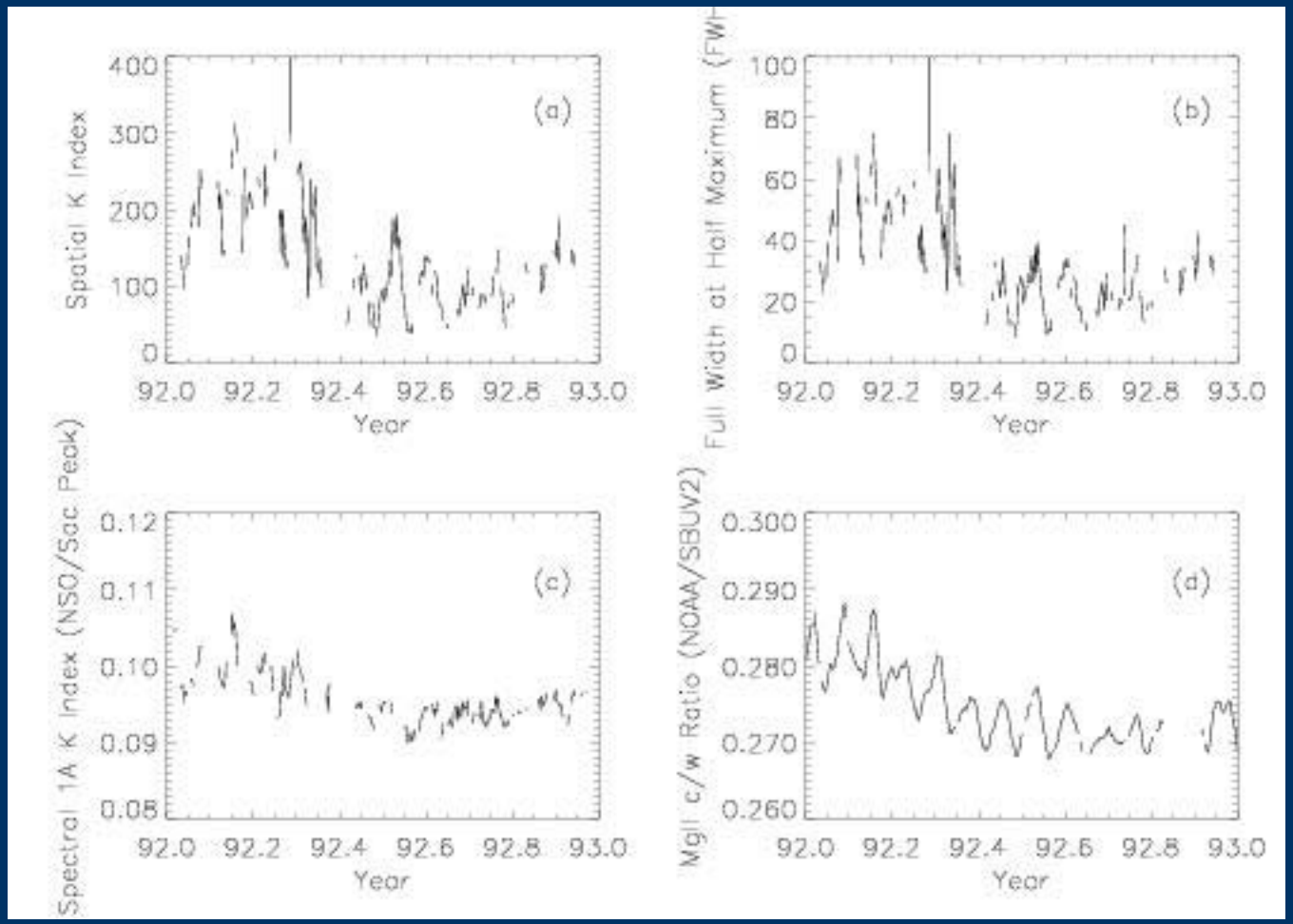
Full-Disk Indices:

- **Full-disk intensity (Spatial K Index): – derived from spatially resolved images (Kariyappa et al. 1996, 2000, 2006).**

- **Spectral K 1A index : – derived from CaII K line profile (White & Livingston, Sivaraman & others).**

- **Full Width at Half Maximum (FWHM) of the histogram taken for the full-disk image.**

- **Compared Spatial K index, spectral 1A K index & FWHM with UV irradiance measured in MgII h & k lines**

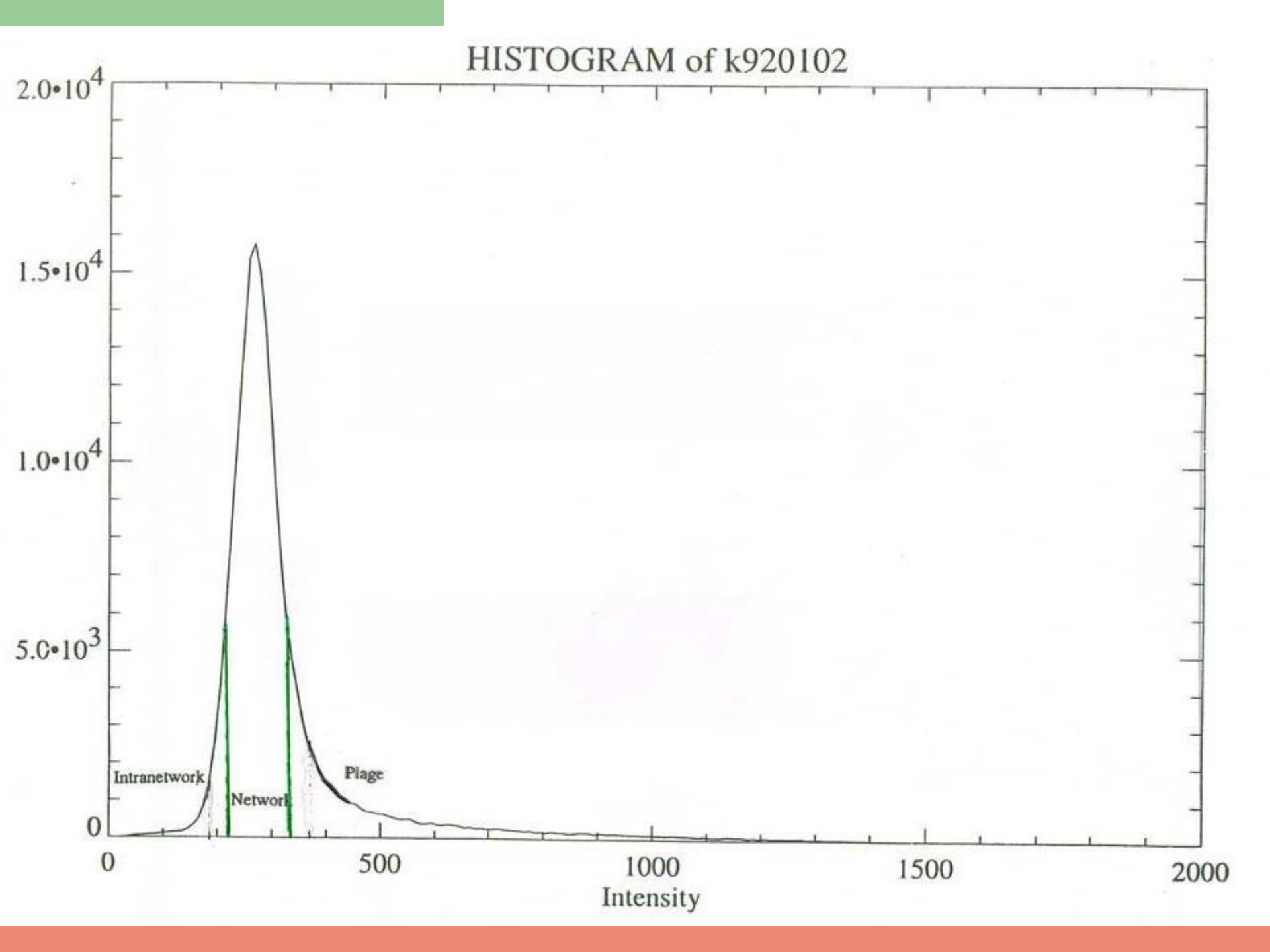

(a)
Spatial K Index
400
300
200
100
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
(b)
Full Width at Half Maximum (FWH
100
80
60
40
20
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
(c)
Spectral 1A K Index (NSO/Sac Peak)
0.12
0.11
0.10
0.09
0.08
92.0 92.2 92.4 92.6 92.8 93.0
Year
(d)
MgII c/w Ratio (NOAA/SBUV2)
0.300
0.290
0.280
0.270
0.260
92.0 92.2 92.4 92.6 92.8 93.0
Year

- **FWHM & Spatial Index are :**

(a) good indices for describing the variability of the chromospheric flux;
(b) provide a new method to estimate the full-disk flux in K & HeII
(c) good parameters to determine and understand the variability of UV irradiance

Segregation of Chromospheric Features:

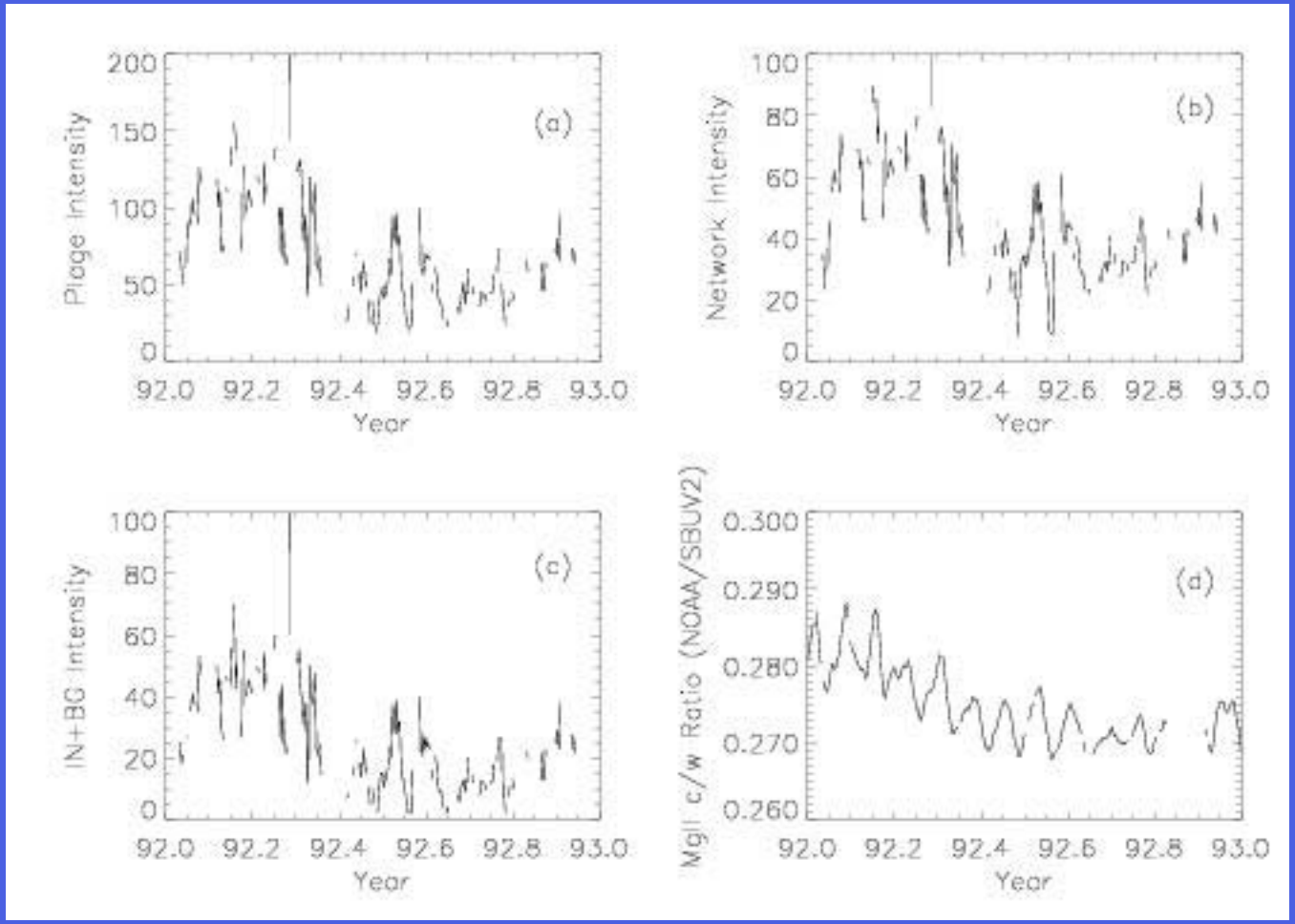
- **Taken histogram for the full-disk image;**
- **pixed the intensity level for plage, network, internetwork & background in the histogram plot**

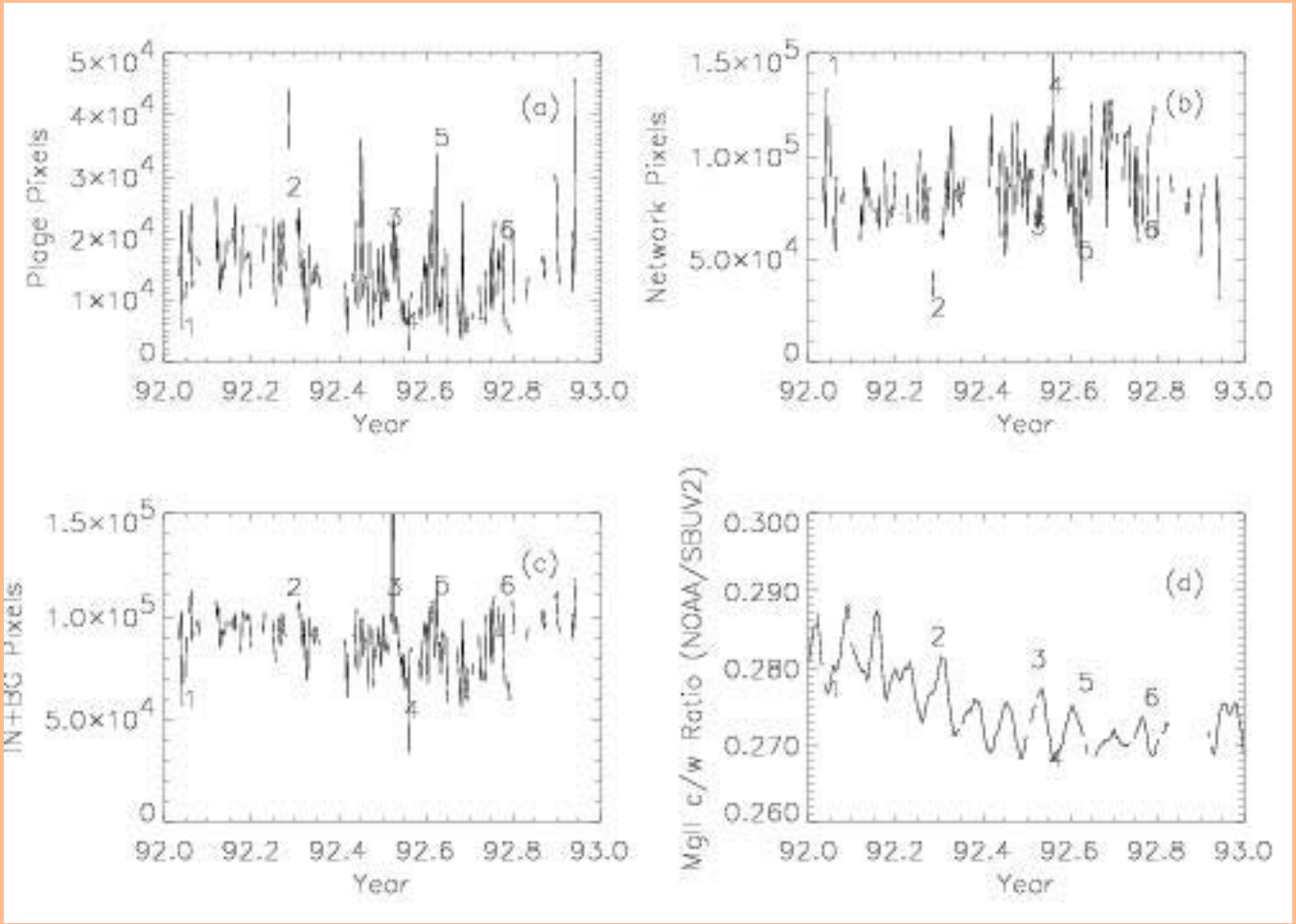

HISTOGRAM of k920102
2.0•10^4
1.5•10^4
1.0•10^4
5.0•10^3
0
Intranetwork
Network
Plage
0
500
1000
1500
2000
Intensity

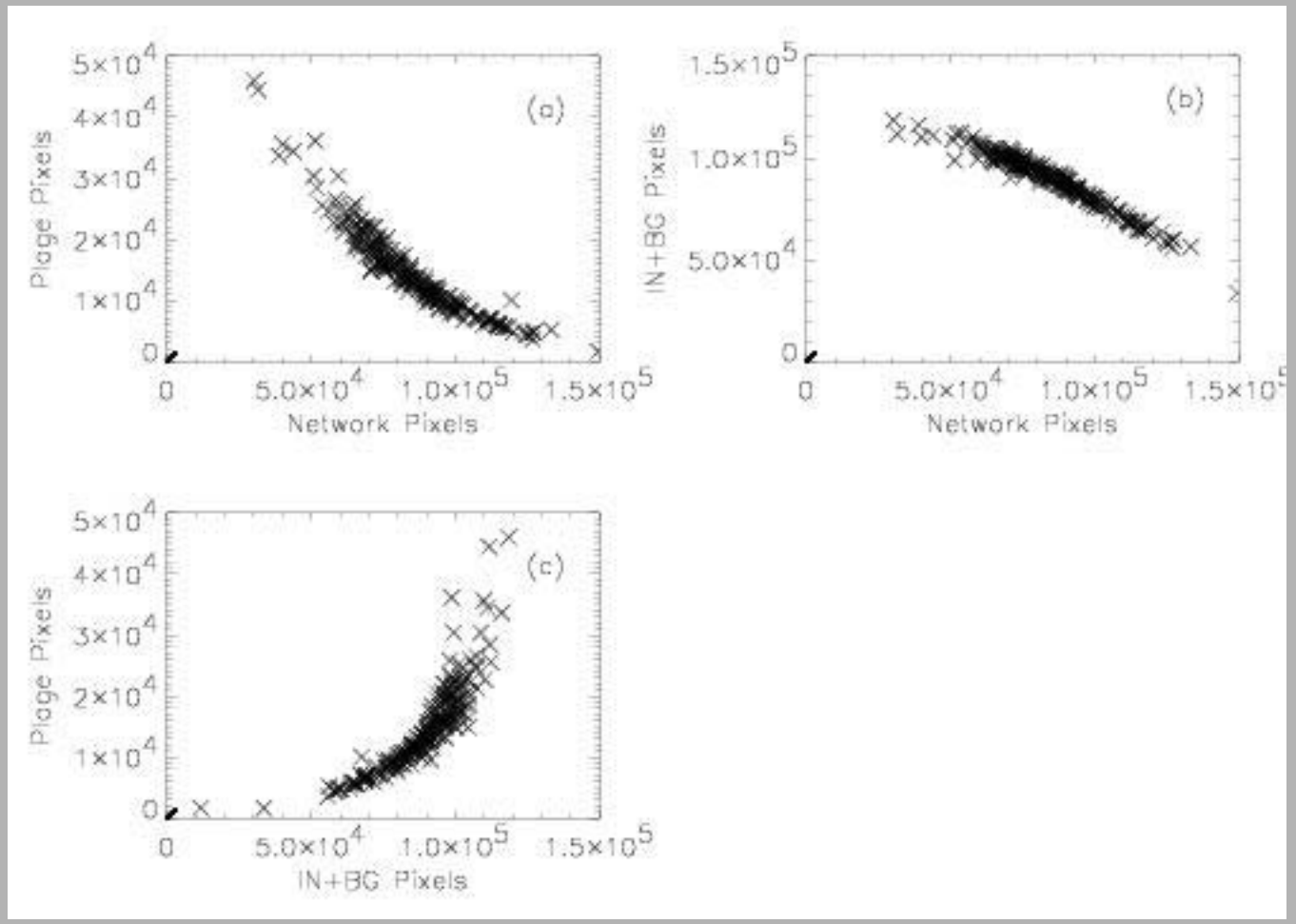
- **Main criteria used: (a) intensity level & (b) morphological structure:**

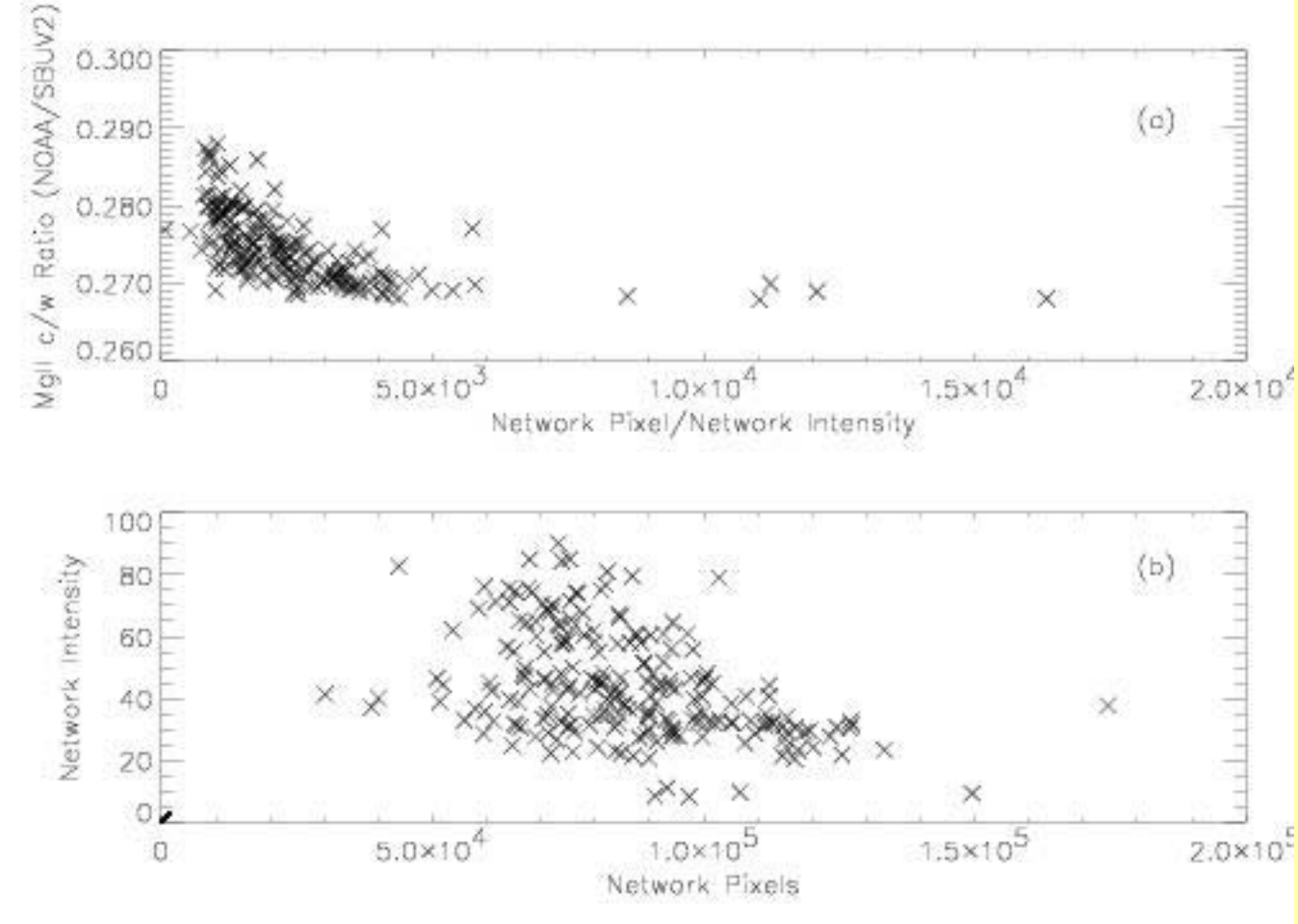
- **plages are bright, large & compact structures;**
- **network resembles the cellular structures; &**
- **remaining belong to internetwork + background regions.**

- **Derived the intensity and pixel number of plages, network and internetwork + background regions from the images using histogram plots.**


Plage Intensity
(a)
200
150
100
50
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
Network Intensity
(b)
100
80
60
40
20
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
IN+BC Intensity
(c)
100
80
60
40
20
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
MgII c/w Ratio (NOAA/SBUV2)
(d)
0.300
0.290
0.280
0.270
0.260
92.0 92.2 92.4 92.6 92.8 93.0
Year


(a)
Plage Pixels
5×10^4
4×10^4
3×10^4
2×10^4
1×10^4
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
(b)
Network Pixels
1.5×10^5
1.0×10^5
5.0×10^4
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
(c)
IN+BG Pixels
1.5×10^5
1.0×10^5
5.0×10^4
0
92.0 92.2 92.4 92.6 92.8 93.0
Year
(d)
MgII c/w Ratio (NOAA/SBUV2)
0.300
0.290
0.280
0.270
0.260
92.0 92.2 92.4 92.6 92.8 93.0
Year


(a)
Plage Pixels
Network Pixels
0
5.0×10^4
1.0×10^5
1.5×10^5
2×10^4
3×10^4
4×10^4
5×10^4
1×10^4
(b)
IN+BC Pixels
Network Pixels
5.0×10^4
1.0×10^5
1.5×10^5
(c)
Plage Pixels
IN+BC Pixels


MgII c/w Ratio (NOAA/SBUV2)
0.300
0.290
0.280
0.270
0.260
(a)
0
5.0×10^3
1.0×10^4
1.5×10^4
2.0×10^4
Network Pixel/Network Intensity
Network Intensity
100
80
60
40
20
0
(b)
0
5.0×10^4
1.0×10^5
1.5×10^5
2.0×10^5
Network Pixels

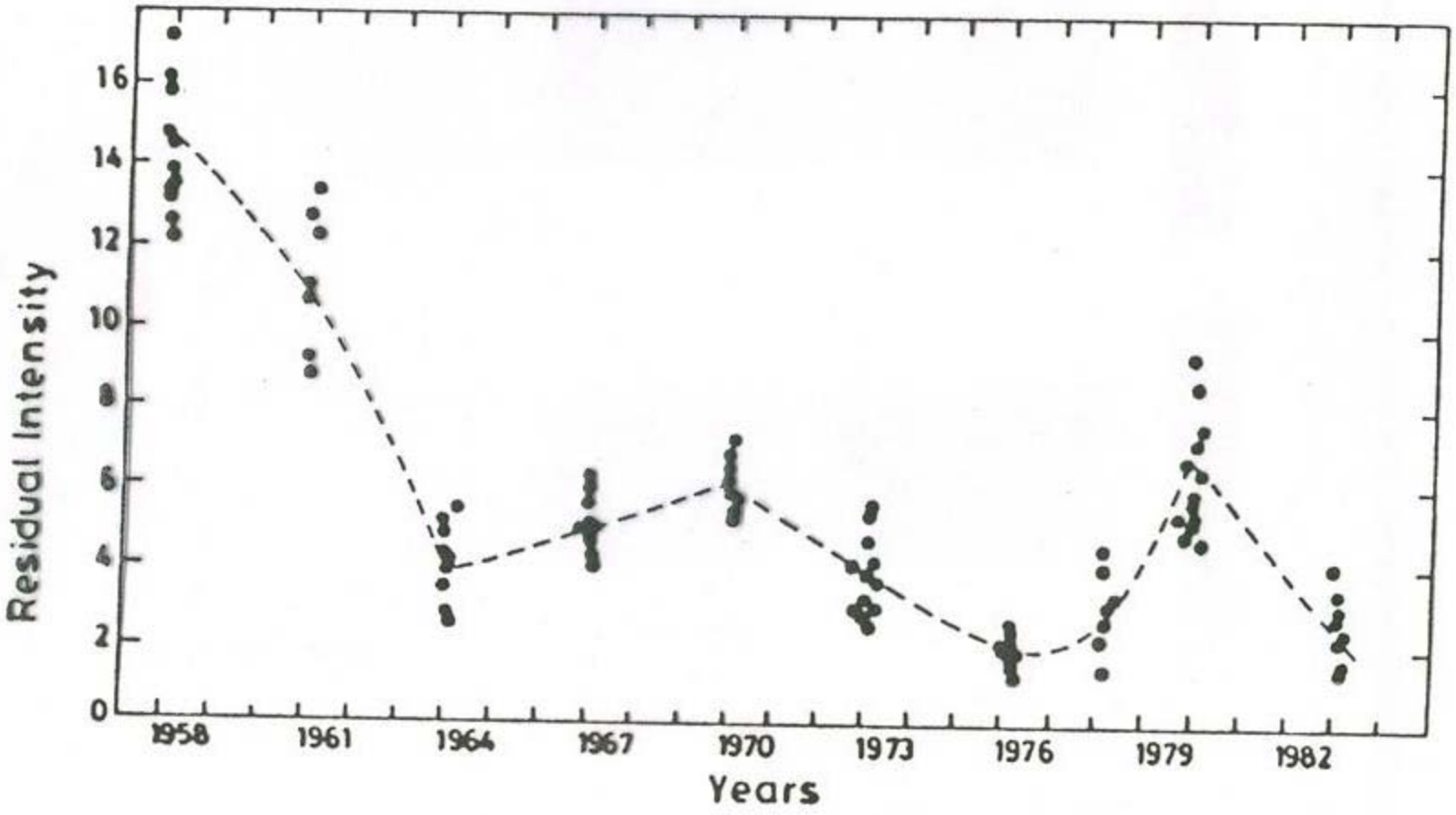


Fig. 1. The cycle variation of residual intensity of network elements.

Kariyappa & Sivaraman (1994)

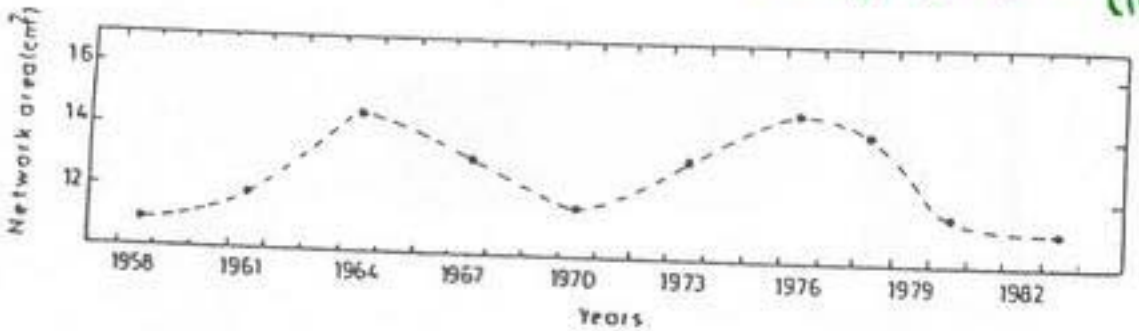


Fig. 2. The cycle variation of area of the network elements. The image scale on the intensity plot is about 0.65 arc sec /mm.

Muller & Roudier (1994)

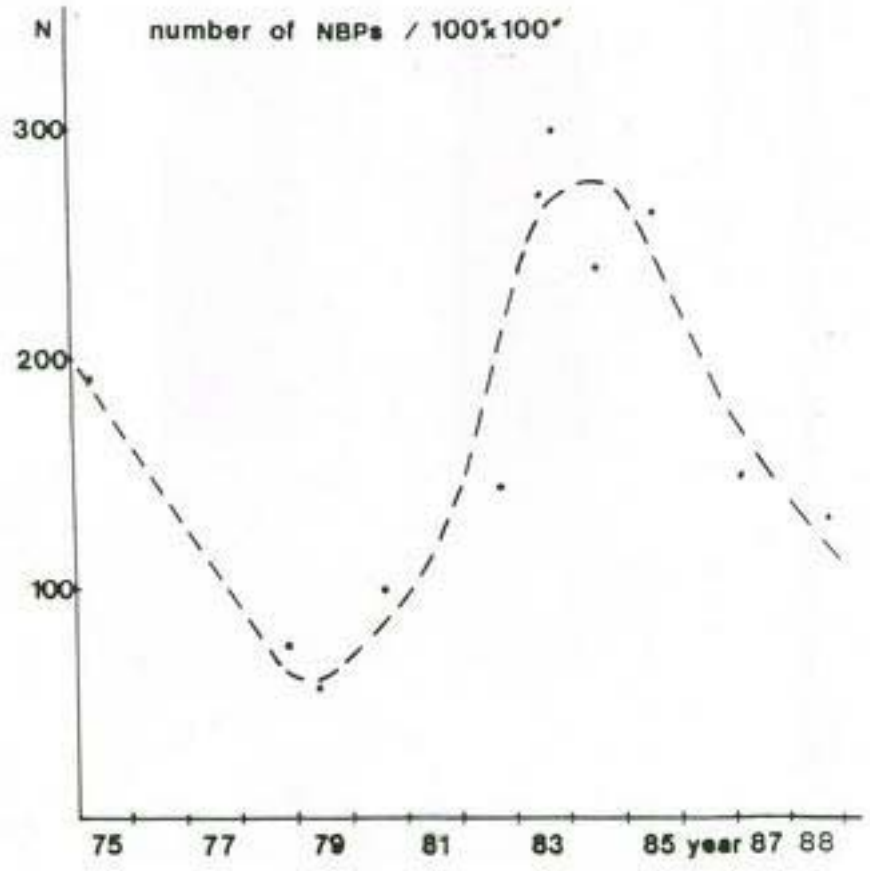
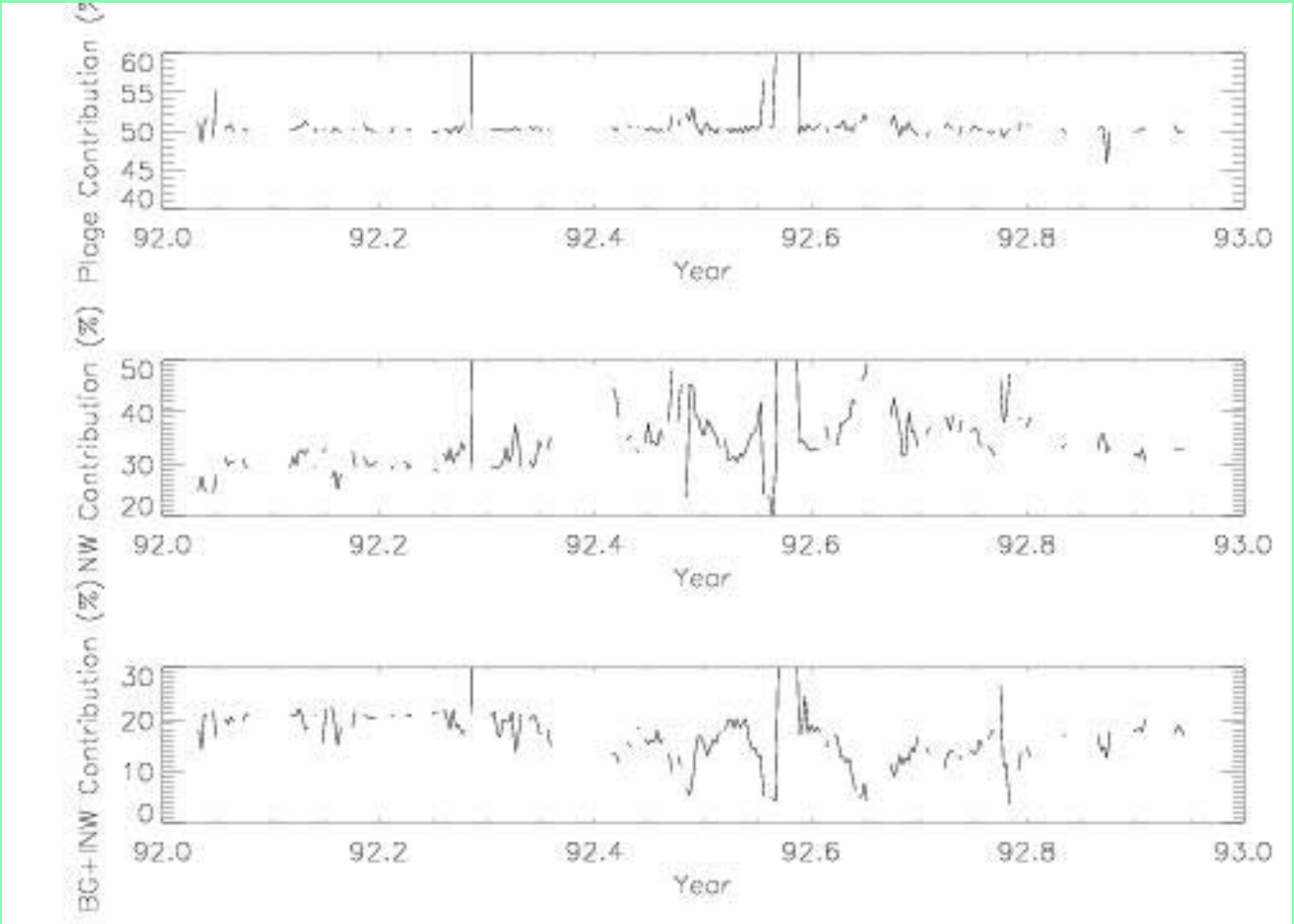
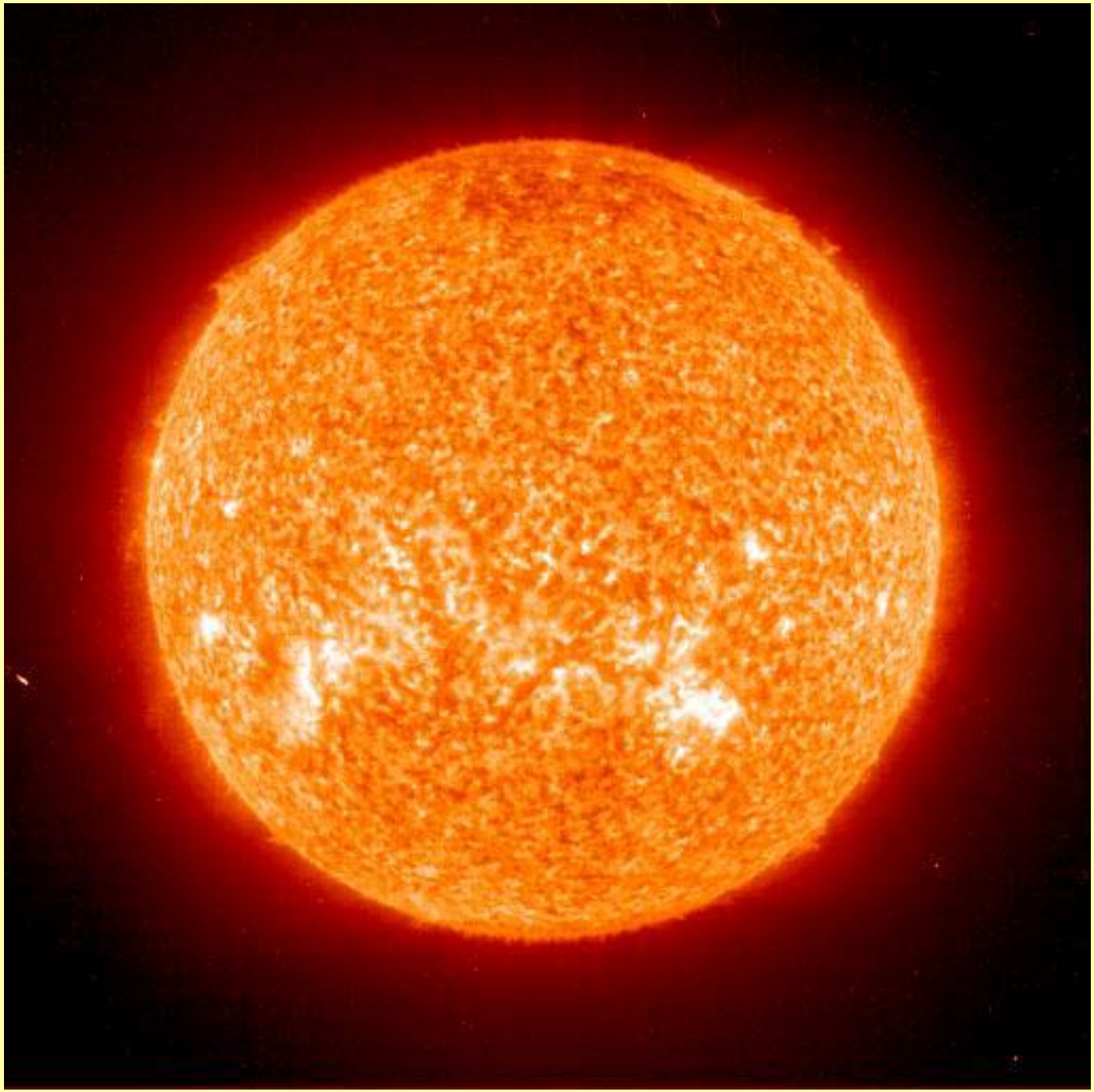
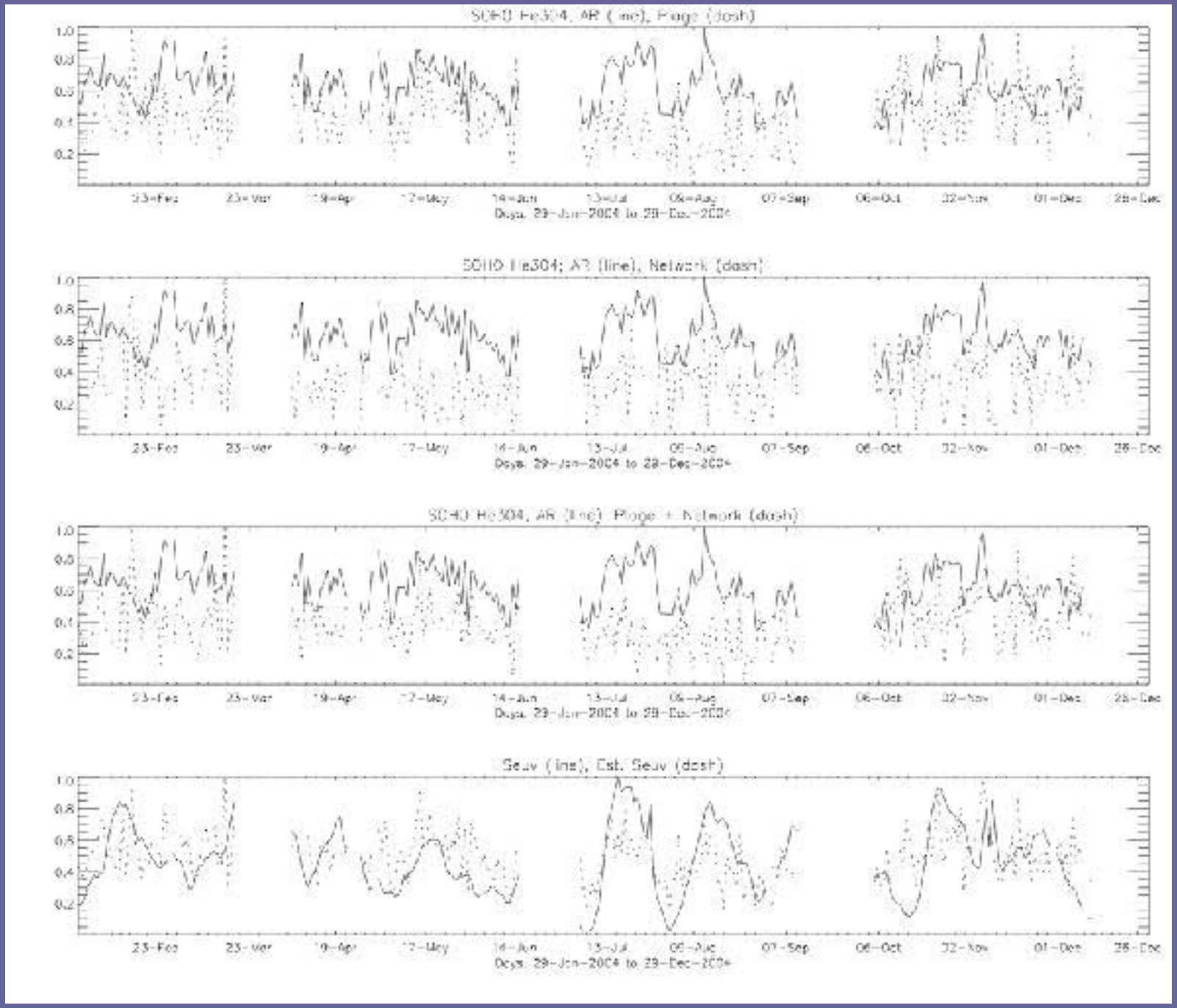


Figure 2 : Time variation of the number of Network Bright Points (per surface unit of 100" x 100") at the solar disk centre.

- **Network intensity is correlated with the solar activity**
- **Network area is anticorrelated with network intensity & also with the solar activity.**
- **There are independent evidences to these results from earlier investigations using different sources of data: (Kariyappa & Sivaraman, 1994, Kodaikanal CaII K spectroheliograms; Muller & Roudier, 1994, Pic du Midi Observations; Berrilli et al. 1998, 1999, PSPT CaII K imags)**
- **Physical reasons for the existence of anticorrelation is not known.**


Plage Contribution (%)
60
55
50
45
40
92.0
92.2
92.4
92.6
92.8
93.0
Year
NW Contribution (%)
50
40
30
20
92.0
92.2
92.4
92.6
92.8
93.0
Year
BG+INW Contribution (%)
30
20
10
0
92.0
92.2
92.4
92.6
92.8
93.0
Year




SOHO He304, AR (inc), Plage (dash)
SOHO He304; AR (line), Network (dash)
SOHO He304, AR (inc) Plage + Network (dash)
Seuv (ins), Est. Seuv (dash)
23-Feb
23-Mar
19-Apr
17-May
14-Jun
13-Jul
06-Aug
07-Sep
06-Oct
02-Nov
01-Dec
28-Dec
Days 29-Jan-2004 to 28-Dec-2004

Conclusions

- **Histogram Method has been used to segregate the different chromospheric features from CaII K & HeII images.**

- **FWHM derived from the histograms has been introduced as a new index to measure the chromospheric activity and to understand the UV irradiance variability.**

- **We estimated from the intensity time series data that about 50% of the CaII K solar cycle variability results from plage, about 32% from network, and about 18% from internetwork + background features.**

- **Quiet-Sun variability is very dynamic, NOT QUIET, & is crucial for understanding of the chromosphere itself.**
- **The intensity & area of the network elements are anticorrelated and it indicates that during solar minimum the network is fainter but it covers a larger area &therefore it may give a significant contribution to irradiance changes.**
- **Besides the plage, a significant portion of the variations observed in UV irradiance is related to the changing emission of the network and internetwork regions and hence may also play a significant role in their contribution to the variation in UV irradiance.**

What Next ?

- *We have done ONLY a very preliminary analysis on HeII images, but a detailed analysis will be carried out.*
- *A similar analysis will be done on SOHO/MDI full-disk magnetograms to determine the underlying photospheric magnetic field corresponding to the chromospheric emission features observed in CaII K and HeII lines.*
- *This research effort will help us to understand & clarify the role of magnetic field in UV irradiance variability.*
- *Measure the solar diameter from MDI & HeII images & clarify whether the variations in solar diameter are contributing to irradiance variability ?*

Thank You !!!