Photospheric Magnetic Field Changes in the Active Regions Observed during October 2003 Leading to Flares

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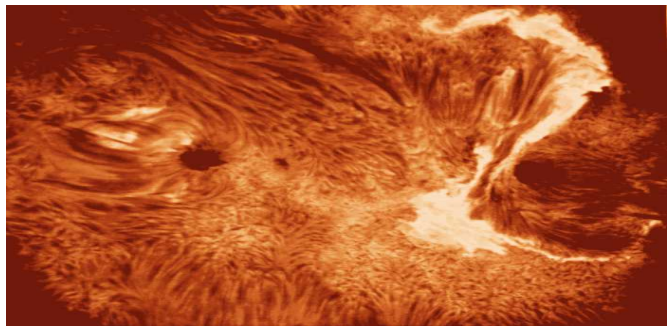
1. Introduction

• Solar Flares



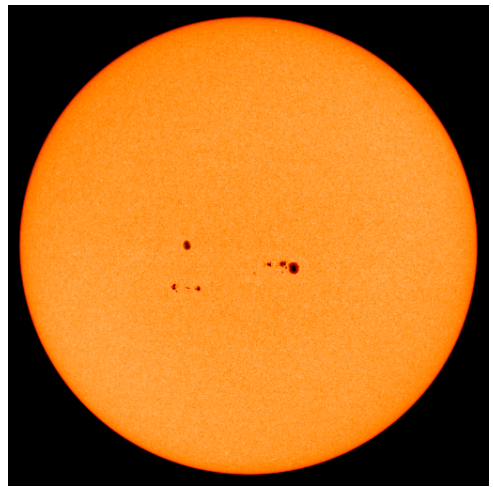
• Energetic Phenomena – solar atmosphere – sudden outburst of energy released in a short interval of time

• Active Regions – manifestations of the mag. fields that are observed all through the solar atmosphere

•Energy released – must be derived from magnetic fields – other sources are energy are totally inadequate

• How the energy gradually accumulated before getting released – is not yet fully understood

2. Photospheric magnetic fields and flares



- **Mag fields emerge into the solar surface as a pair of opp. polairty patches**
- **Sunspots – ARs observed in the photosphere**
- **Flares occur not only with large AR sunspots but also with smallest resolvable regions**
- **There are cases of spotless flares**
- **Size or strength of the ARs are not important factors for the occurrence of flares**
- **Many cases of flares are reported during the evolution of the sunspots**
- **Mag. strucutre and evolutionary changes in the photosphere are often associated with the flares**
- **Evolutionary changes are slow that takes place hours or days before the flares**

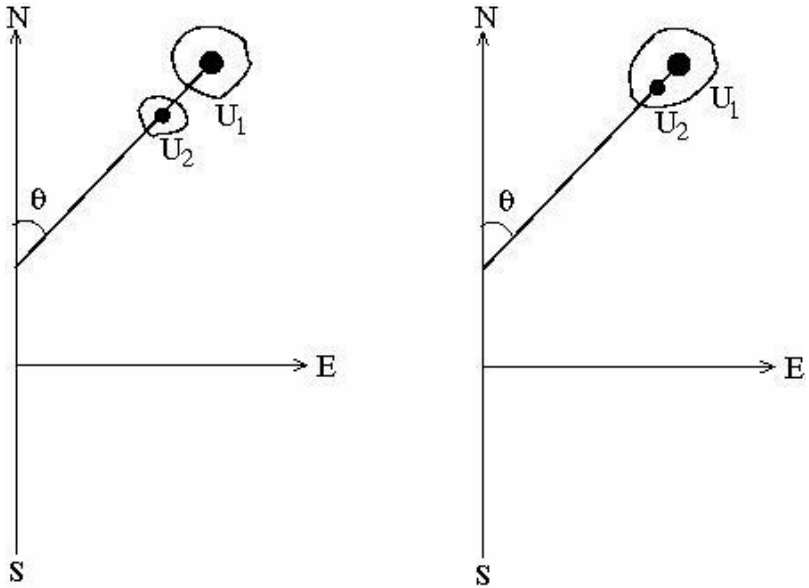
(2. Continued)

- **Shown on many occasions that slow changes AR – precede a flare**
- **Sunspot motions are the consequences of the evolutionary changes in sunspots**
- **sunspot motions – energy buildup of at least some flares**
- **Horizontal shear motions in sunspots (K S Raman et al 1998, Moon et al 2002)**
- **Many studies – proper motion of sunspots (see Yang et al 2004)**
- An AR sunspot – appears – due to the eruption of twisted subphotospheric flux tube
- After the tube penetrates – photosphere – corona – subphotospheric portion to unwind the twist and transmits the same through the photosphere into corona
- **Produces rotation in the photosphere including a high shear along the neutral line**
- **Shear – notable property of the flare producing regions**

3. Magnetic Shear

- **Process of pre flare energy – shearing of magnetic fields**
- **Longitudinal component of the magnetic field may not show much change**
- **Therefore, the transverse component of the stressed mag. field is much related to the occurrence of the flares**
- **Vector magnetograms – twisted or sheared nature of mag. fields in the photosphere – alignment of the transverse field – neutral line – before flare**
- **Hagyard et al 1984 – defined angular shear – large angular variation of photospheric neutral line**
- **Many contradictory results relating mag. shear and flares**
- **May be due to the fact – shear may be present above and near the photospheric neutral line**

4. Umbral orientation changes in solar flares

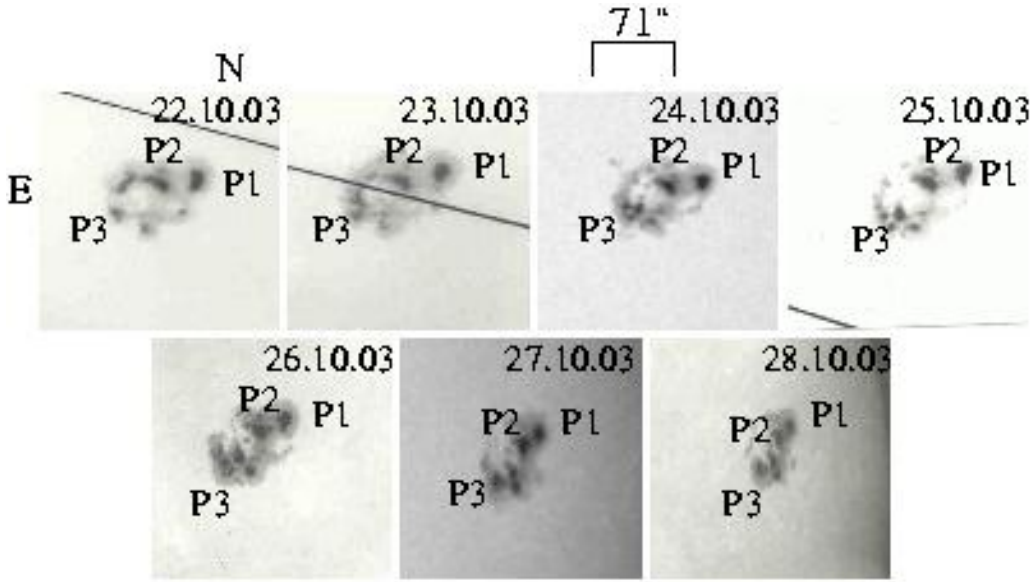


- Carefully monitored the changes in the orientation of umbral position – bipolar
- Umbral rotation – relative motion of the umbrae – shear developed in the AR

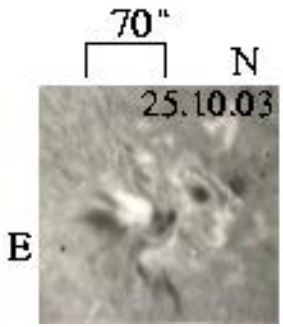
- Coronal levels – flare sites – mag.field measurements difficult
- Mag. Field measurements in both photosphere and chromosphere – information on flare triggering mechanisms
- Sunspot evolves – complexity in the field structure increases – induces stress – changes in the mag. field pattern
- Changes in the mag field pattern of AR – plasma motions – outline the storage of energy

5. October 2003 Flare Events

i) NOAA 0484

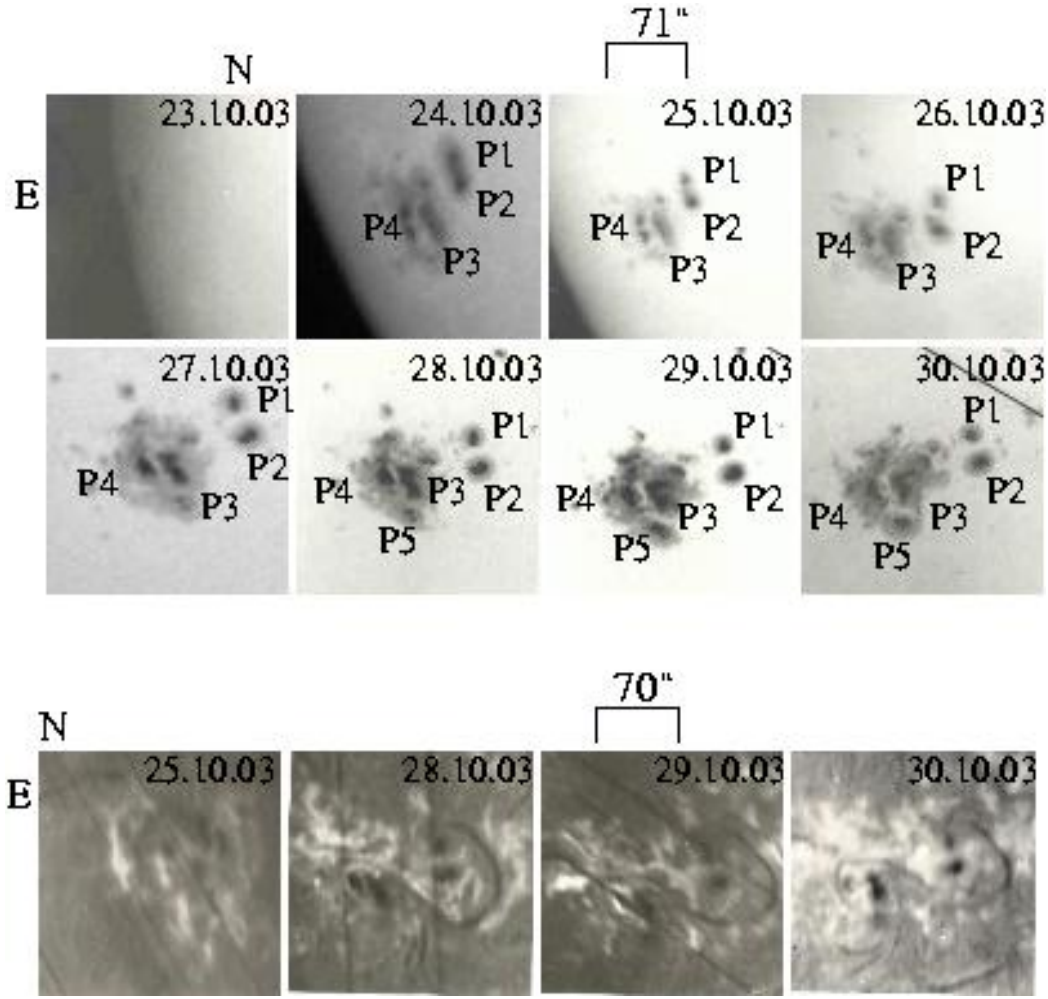


White light photoheliogram of the AR 10484 observed at Kodaikanal. The umbrae P1, P2 & P3 are taken for caluculating the changes in umbral orientations



H alpha spectroheliogram observed at Kodaikanal on flare day

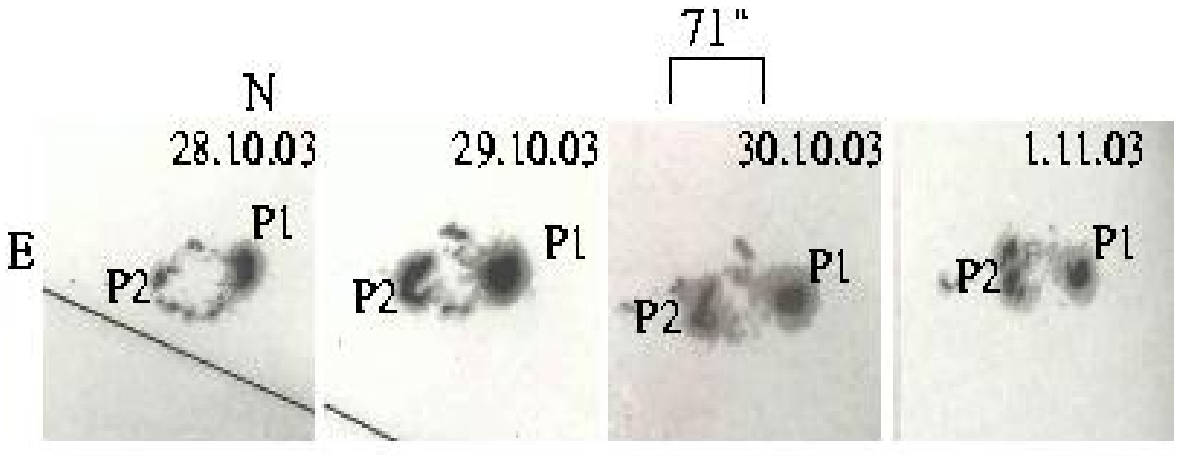
ii) NOAA 10486



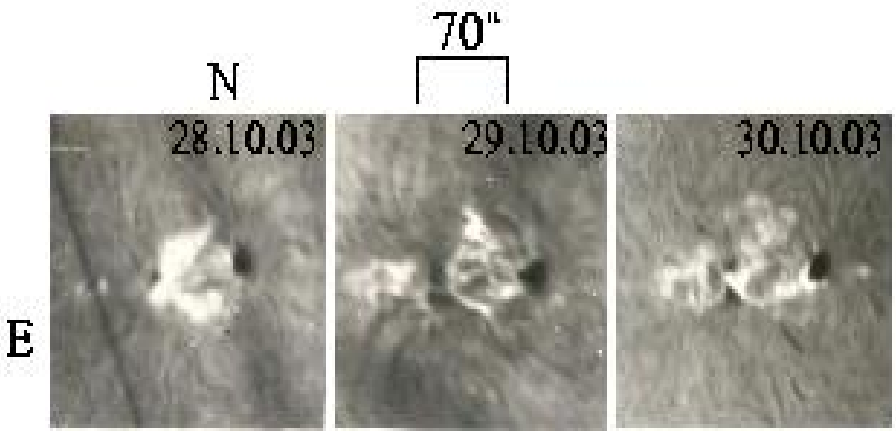
White light photoheliograms of the AR 10486 observed at Kodaikanal. The umbrae P1, P2, P3 & P4 are taken for calculating the changes in the orientations

H alpha spectroheliograms observed at Kodaikanal on flare days

iii) NOAA 10488

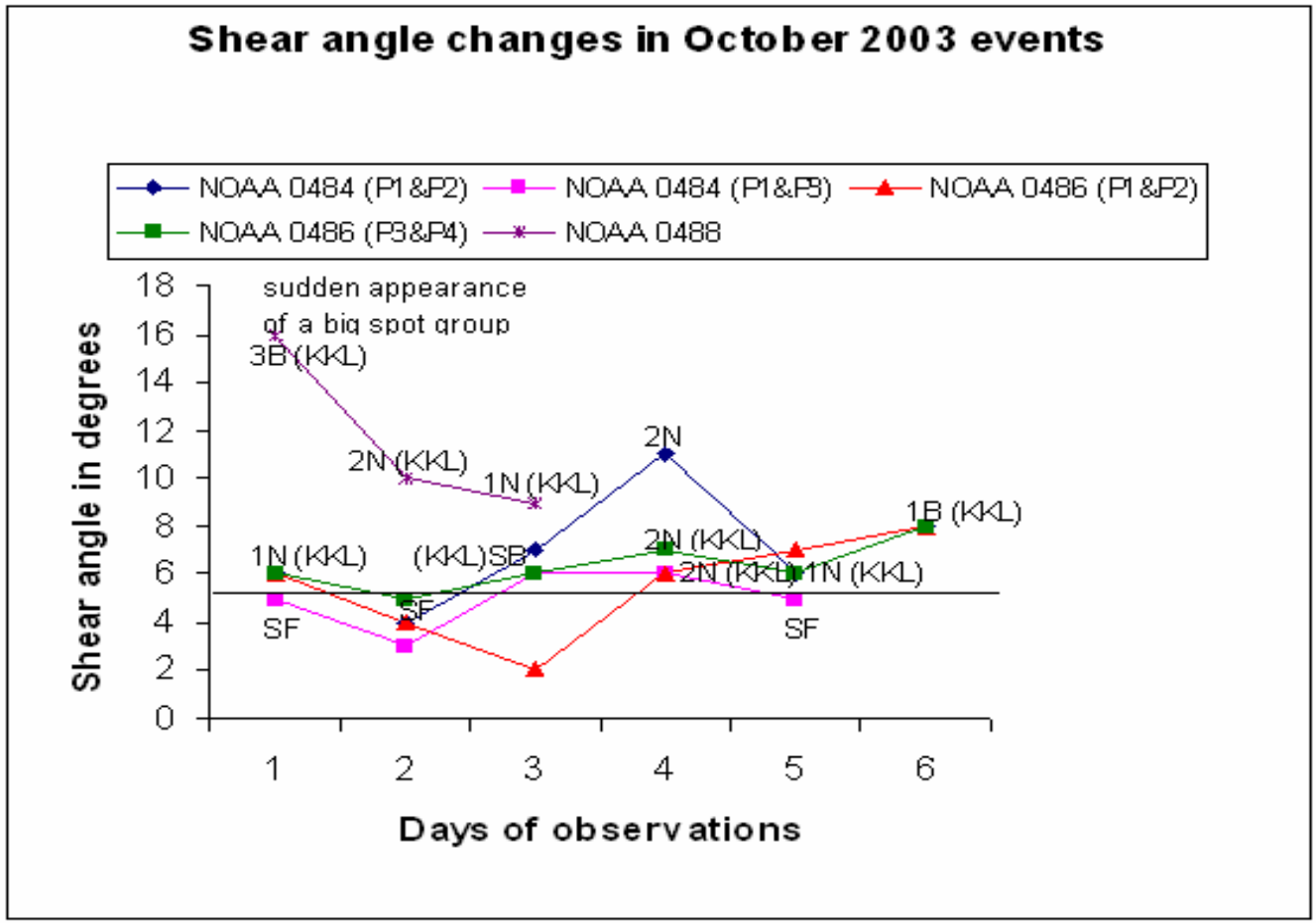


White light photoheliogram of the AR 10488 observed at Kodaikanal. The umbrae P1 & P2 are taken for calculating orientation changes



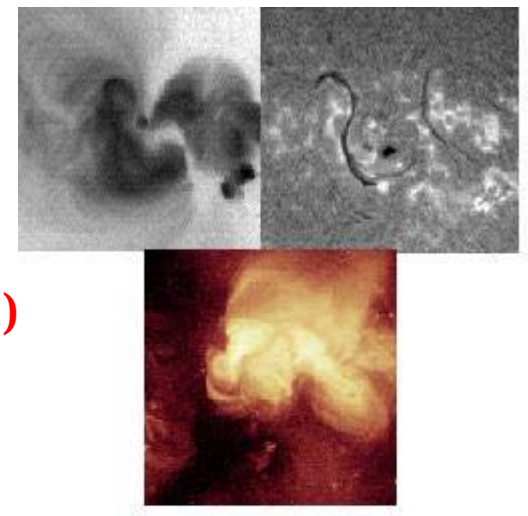
H alpha spectroheligrams observed at Kodaikanal on flare days

Table showing umbral orientation changes on the three major events observed during October 2003



6. Conclusions

- Theoretical studies – mag reconnection – observation difficult
- **Mag field emerge on the solar surface – dynamo process – appear as opposite polarity sunspots**
- **The rearrangements of these opp polarity mag fields in AR – mag reconnection**
- Mag fields – AR – break out to solar atmosphere forming loops – connect subphotospheric regions to corona
- **Sigmoids – twisted flux loops – observed in the corona sunspots or filaments**
- umbral rotation – sigmoidal eruption **(KS Raman et al 2001)**
- As the mag field emerge – already in a twisted state (Rust & Kumar 1995)
- **Any small additional twist that is developed in an AR – transmitted to the corona – conditions are favorable for reconnection**



(Conclusion Contd.)

- **Umbral rotation – shear developed in the AR sunspot – builds up twist in ARs (van Ballegooijen 1999)**

- **Threshold value of 5° in the umbral rotation for the flare onset**

- **Umbral rotation – caused by the change of flux observed during the development of sunspots - additional energy stored in excess of potential**

- **It is the propagation of twist from one flux system in the photosphere to another in the corona until the conditions are favourable for mag reconnection**

- **Our observations support the twisted flux bundle model – flare process**

- **More attention to WL observations – Interpretation is straight forward**

- **High cadence space data – flare research hot topic**

- **Multi wavelength observations – High time sequence WL observations coupled with VMs – more light on the process involved in flares**