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# Analysis of an Umbral Flare Observed from Antarctica

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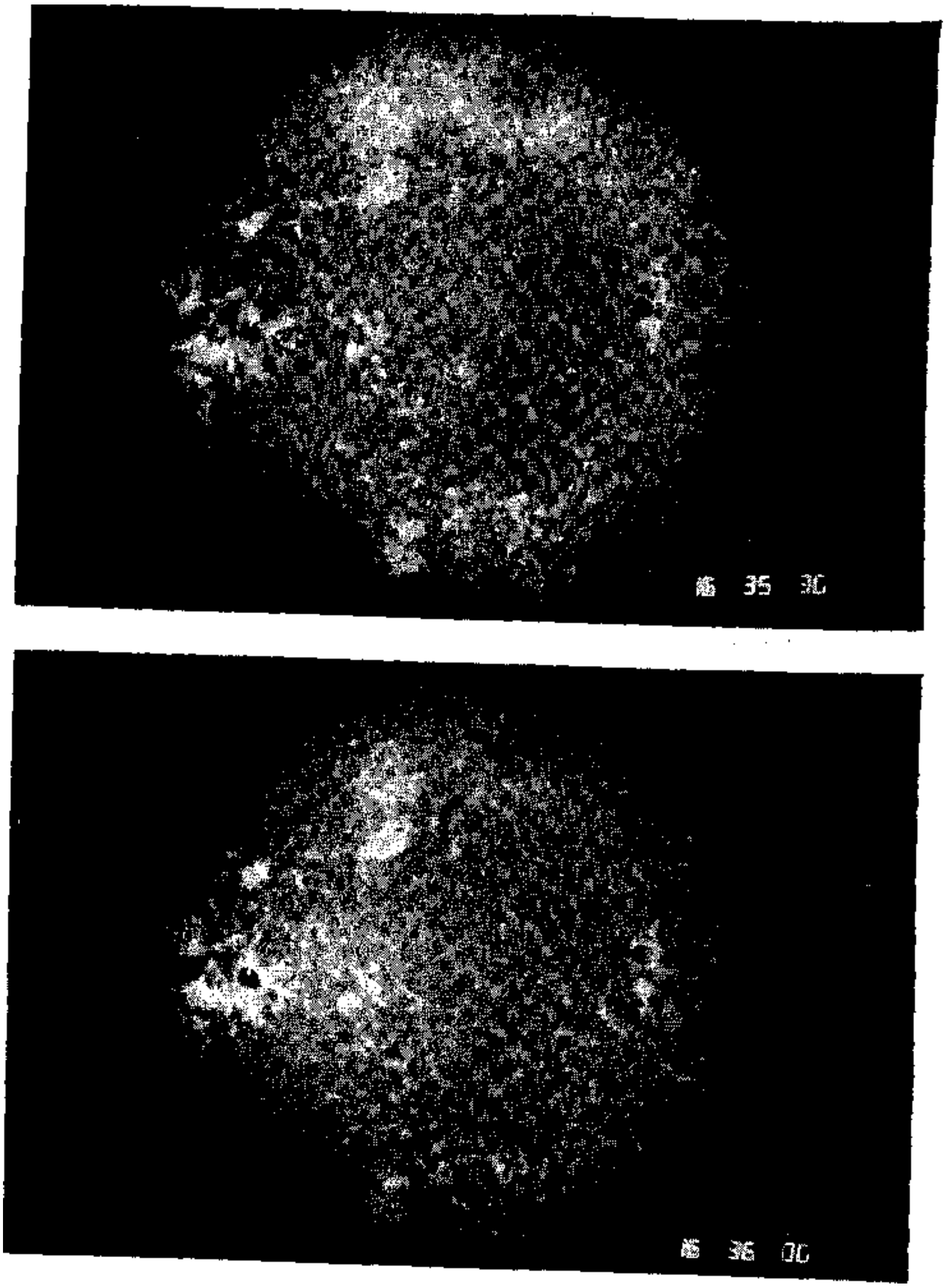
**Abstract**

We report here the observations in Call K of an umbral solar flare of optical importance class SF (subflare) which occurred on 12 Feb, 1990 . These observations have been correlated with the ones taken in H-alpha and in the radio region reported in Solar Geophysical Data (SGD). Though the umbral flare was small, it showed the impulsion behaviour in microwave region. We conclude that this is a special and very rare class of an umbral flare which is more energetic in microwave and radiowave regions than in the optical region.

## Introduction

When the sun is observed in white light, the centres of activity on the solar disk (photosphere) are visible as the well known groups of sunspots. Central dark part of the sunspot is known as umbra where strong magnetic field exists and the outer less dark part is known as the penumbra. If we observe the sun through a filter having a very narrow pass band of about, say 1 A or less, centred on the H-alpha line (the first line of the Balmer series of hydrogen, 6563 A) or of the Call K (singly ionized calcium, 3934 A), the centres of activity are seen as bright plages surrounding the sunspot groups (cf., Figs 1a and 1b). We then observe the higher layers in the chromosphere above the sunspots which are at about $10^4$ K temperature. An optical flare is seen as a rapid brightening of a part of such a plage in the active centres where the magnetic field strength is more and its gradient higher than outside this region.

Solar flares are violent explosions of energy (about $10^{32}$ ergs) that occur in the solar atmosphere leading to the emission of electromagnetic radiations (radio, visible, ultraviolet, X-rays and y-rays). From flares energetic particles (electrons, protons, neutrons and heavier nuclei), mass ejections and shock waves also have been observed. On the earth, these phenomena cause radio blackouts, failures in long distance power lines, changes in the terrestrial magnetic field, produce aurora in the polar regions and can even endanger astronauts in space. Their origin is not yet understood even after more than a century of study since the first recorded observations (Sweet, 1969). At present, the study of flare origin has a great importance for solar astronomers. An extensive study has been carried out by a large



*Figs 1a and 1b. Call K filtergrams at the maximum phase of umbral flare; it is a bright patch near the major sunspot.*

number of investigators, see, e.g. Svestka (1976), Sturrock (1980), Tandberg-Hanssen and Emslie (1988) for details.

In the present analysis, we have carried out a study of a special and very rare class of an 'umbral flare' which we observed on 12 Feb. 1990, in NOAA active region 5927. The calcium K (3934 A) line filtergrams were obtained with an interval of 30 seconds and spatial resolution of about 2 arcsec. The details of the experimental set up, observing conditions and telescope location at Maitri — the Indian permanent station in Antarctic region, are given separately by Jagdev Singh in this technical report. It may be noted that the prime objective of this program was to study the evolution and decay of the large convective cells known as supergranules.

## Data Analysis

The observations of the NOAA active region 5927 (N 19°; E 34°) on 12 Feb. 1990 were carried out regularly at the rate of 1 filtergram every 30 seconds for 5 hours from 12 29 30 to 17 29 20 UT. Spot class and magnetic class of this active region are reported as CKO type and bipolar type respectively in SGD, 1990 and magnetic field strength 2800 gauss has been reported for the major spot with south magnetic polarity in which the flare occurred (Solar Data, 1990, in Russian). In the active region, magnetic neutral line shows highly twisted or kinky shape near the major spot (cf., Fig. 2). Here sunspots, filaments and flare are shown near the spot by filled, hatched and blank areas respectively. Thick solid lines represent neutral lines drawn with the help of Mount Wilson Observatory magnetograms. The Call K filtergrams of the flare taken at the maximum phase are shown in Figs la and lb. In these

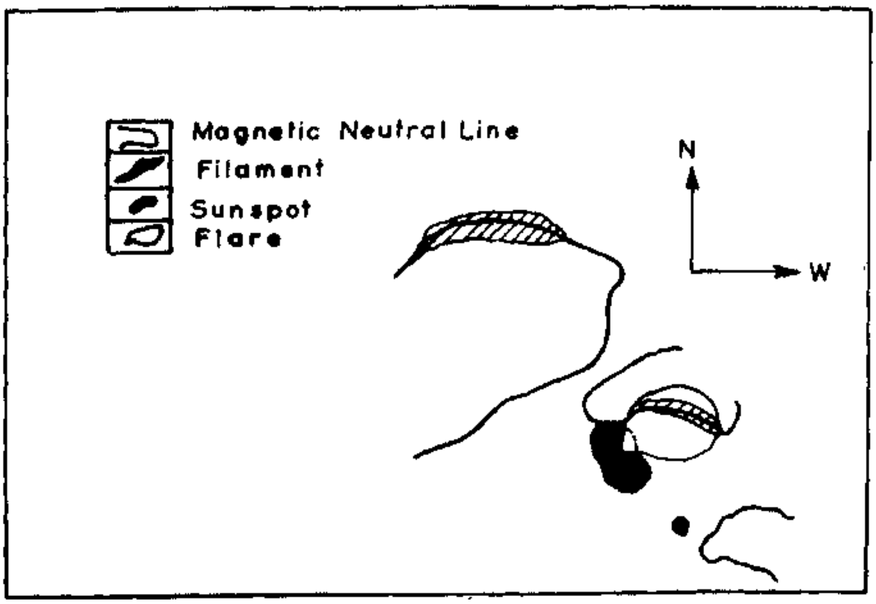



*Fig.2. Composite diagram of Call K, H-alpha filtergrams and magnetogram of the flaring region.*

figures, the flare is visible as a bright patch near the major spot marked by an arrow and the umbra is partially covered by the flare which is clearly visible in Figs la, lb and 2. The plage brightness increased slowly and around 16 28 00 UT it brightened to a flare. The flare reached its maximum brightness within few minutes at 16 36 00 UT, fading out slowly around 16 50 00 UT. Careful inspection of Call K observations showed that there are two bright knots in the flare, with a small knot penetrating the umbral region and their knot just outside the border of the major spot, but they seemed to be one whole flare patch at the maximum phase. Furthermore, in the high temperature region i.e. in the radio region, Sagamore Hill Solar Observatory, U.S.A. recorded microwave burst of high importance class 49 GB and spike type burst of 4 minutes and 1 minute durations respectively in different frequencies and one type V radio burst of 1 minute duration during the maximum phase of the flare (SGD 1990). The association of microwave and type V radio burst with the flare shows that a stream of relativistic electrons were responsible for these bursts. According to Wild *et al,* (1959), the occurrence of type V radio burst is probably the manifestation of rich stream of relativistic electrons of which a fraction is trapped in the corona i.e. in the upper layer of solar atmosphere becoming visible either through synchrotron radiation or through plasma waves (Weiss and Stewart, 1965).

## Results and Discussions

The observed flare is an umbral flare (cf., Figs 1a, 1b and 2) of SF importance class in optical region.

Generally flares avoid sunspot umbrae because they are the centres of very strong magnetic field. Only very energetic flares expand oyer the sunspot umbrae during their evolution (Joshi and Uddin, 1992). However, there is a special and very rare class of 'umbral flares' when one of the ribbons of the two ribbon flare is formed, inside a sunspot umbra as is the case in the above mentioned flare seen in Call K. Only four such flares have been observed in detail so far (Tang, 1978); all being subflares, and all occurred in a simple magnetic configuration with a large dominant 'preceding' spot and tiny and or non-existing 'following' spots (cf., Figs 1 and 2). Using H-alpha observations, Dizer (1969) has shown that subflares very often occur at places that were brighter than the surroundings. Prior to the subflare onset, he called these bright preflare patches as live points. An analysis of subflares, which were observed during CINOF (Compaign for the Integrated Observation of Solar Flares) in June 1972 was carried out by de Jager (1975). The analysis showed that such type of flares were associated with surges and/or filament activities, radio bursts and particle acceleration to higher energies. The existence of the filament near the major sunspot and the sharp kink in the neutral line near the same place show that the magnetic field is sheared in thatregion (Uddin *etal.,* 1986; Moore, 1988; Sivaraman *et al.,* 1992), since every filament marks a sheared neutral line. Magnetic energy is stored in that region which later on is released during the flare occurrence. It seems that the flare is triggered by the activation of existing filament near the spot. During the flare occurrence, this filament erupted with high velocity and the flare was also accompanied with the active filament SGD (1990).

As mentioned earlier flares generally avoid strong magnetic field areas (sunspots). If a flare penetrates a spot, which sometimes happens with large flares and with exceptional flares of small size (as in the case of present Call K flare), that flare as a rule, is very productive in X-ray and radio microwave radiations (Dodson and Hedeman, 1960; Martres and Pick, 1962; Malville and Smith, 1963; Hagen and Neidig, 1971). Generally, the hardness of the spectrum of an impulsive microwave burst increases with the flares closeness to the spot umbra (Neidig, 1977).

## Conclusions

The umbral flare of SF importance class observed from Antarctica seems a very interesting event. This flare of a low importance class in optical region is a small two ribbon umbral flare. From the occurrence of impulsive microwave bursts and type V radio burst during the maximum phase, it is clear that the flare is very energetic in high temperature region about $10^6$ K (in the corona) as compared to the low temperature region about $10^4$ K (in the chromosphere). It is clear from Fig.l that flare area is small which is about 26 millionth of solar disk, so we can say that this is a special and a very rare class of umbral flare.

Data on such type of flares in various wavelengths are very useful for the study of their origin. In our view, quantitative analysis of the data would lead to more fruitful results for the flares.

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## References

de Jager, C. (1975): Phenomenology of the subflare; A synthesis of CINOF, *Solar Phys..* v. 40, pp. 133-140.

Dizer, M, (1969): Isophotal photometry and morphological changes in the flares. *Solar Phys..* v. 10, pp. 416-428.

Dodson, H.W. and Hedeman, E.R. (I960): Flareof July 16, 1959, *Astron. J.* . v. 65, p. 51.

Hagen, J .P. and Neidig, D.F. (1971): Identification of two distinctive types of centimeter radio bursts with flare location, *Solar Phys.,* v. 18, pp. 305-310.

Joshi, A. and Uddin, W. (1992): Analysis of solar flare in Call K on March 13, 1989 *Bull. Astron. Soc. India,*v. 20, pp. 231-241.

Malville, J.M. and Smith, S.F. (1963): Type IV radiation from flares covering sunspots. *J. Geophys. Res.,* v. 68, pp. 3181-3185.

Martres J M. and Pick, M. (1962): Caracteres Propres aux eruptions chromospheriques associees a des emissions radioelectriques (in French), *Ann. Astrophys.,* v, 25, pp. 293-300.

Moore, R.L, (1988): Evidence that magnetic energy shedding in solar filament eruptions is the drive in accompanying flares and coronal mass ejections, *Astrophys. ].,* v. 324, pp. 1132-1137.

Neidig, D.F. (1977): Microwave burst spectra and solar flare magnetic fields, *Solar Phys.,* v. 54, pp. 165-168,

Sivaraman, K.R., Rausaria, R.R. and Aleem, S.M. (1992): Magnetic shear in flaring regions, *Solar Phys., v.* 138, pp. 353-360.

*Solar Data (in Russian)* (1990): No. 2.

*Solar Geophysical* Data,( 1990):Part I, No. 548 and Part II, No. 552, U.S. Department of Commerce, Boulder, Colorado, U.S.A.

Sturrock, P.A. (ed.) (1980): *Solar Flares, A Monograph from Skylab Solar Workshop II,* Colorado Associated University Press, Boulder, Colorado, U.S.A.

Svestka, Z. (ed.) (1976): *Solar Flares,* D. Reidel Publishing Company, Holland.

Sweet, P.A. (1969): Mechanisms of solar flares, *Annual Reviews of Astronomy and Astrophys.,* v. 7, pp. 149-176.

Tandberg-Hanssen, E. and Emslie, A.G. (eds.) (1988) *The Physics of Solar Flares,* Cambridge University Press.

Tang, F. (1978): Umbral flares, *Solar Phys.,* v. 60, pp. 119-122.

Uddin, W., Pande, M.C. and Shelke, R.N. (1986): Association of solar flares with twisting of magnetic neutral lines, *Bull Astron. Soc. India,* v. 14, pp. 91-94.

Weiss, A.A. and Stewart, R.T. (1965): Solar radio bursts of spectral type V, *Australian J. Phys.,* v. 18, pp. 143-165.

Wild, J.P., Sheridan, K.V. and Noylan, A.A. (1959): An investigation of the speed of the solar disturbances responsible for type III radio bursts, *Australian J. Phys.,* v. 12, pp. 369-398.