CHARACTERISTICS OF NEAR-FIELD GROUND MOTIONS DURING THE IMPERIAL VALLEY EARTHQUAKE OF 1979

Saburoh MIDORIKAWA (I)
Hiroyoshi KOBAYASHI (II)
Jean-Yves LE DOARE (III)
Presenting Author: Saburoh MIDORIKAWA

SUMMARY

The near-field ground motion records during the Imperial Valley Earthquake of 1979 were analyzed to investigate the characteristics of the strong ground motions in near-field. The records show the wide variations on the peaks, duration, spectral content and spatial distribution of the horizontal motions. Such wide variations of the near-field ground motions, except on the amplitudes of the short period motions, could be explained by the effects of finite moving source due to smooth rupture propagation. However, to explain the higher peak accelerations near the epicenter, the irregular rupture process would be considered at several kilometers north-west of the epicenter.

INTRODUCTION

To predict strong ground motions in near-field is one of the important problems for anti-seismic design of important structures. The attempts for synthesizing the near-field ground motions by theoritical fault model have been performed. However, short period ground motions, that would be related to the complexity of rupture process, have not been synthesized successfully. For the empirical prediction of near-field ground motions, the difficulties still remain, because the number of the near-field ground motion data is not enough for the statistical analysis.

Recently, the amount of the near-field ground motion data is gradually increasing owing to the dense array network of strong motion accelerographs. Especially, during the Imperial Valley Earthquake of 1979, numerous strong motion accelerograms including in near-field were obtained by the efforts of U.S.G.S., C.D.M.G., U.C.S.D. and U.N.A.M. Using these records, the fault models of this earthquake have been proposed [1],[2]. The fault models well explain the observed near-field records in rather-long period range, but not in short period range that is shorter than 1 or 2 second. The nature of near-field ground motions in wide period range and the detailed rupture process should be investigated further. The interest of this study is the characteristics of near-field horizontal ground motions in short and rather-long period ranges with related to the rupture process.

(I) Research Associate, The Graduate School at Nagatsuta, Tokyo Institute of Technology, Yokohama, JAPAN

(II) Professor of Earthquake Engineering, ditto.

(III) Research Student, ditto.

NEAR-FIELD GROUND MOTIONS DURING THE IMPERIAL VALLEY EARTHQUAKE OF 1979

A moderate earthquake (M_L=6.6) occured near the U.S.A.-Mexico border on the Imperial fault. The earthquake was shallow one and the dislocation was the right-lateral strike slip. The rupture started at about 2 kilometers south of the border [3], and propagated about 30 kilometers to the north-west direction and about 10 kilometers to the south-east direction [2]. Several strong motion accelerographs were installed within a few kilometers of the Imperial fault, as shown in Fig.1. EC7 and MEL are located on the north-west of the epicenter. BNC is near the epicenter. ARP and AGR are on the south-west of the epicenter.

The ground velocities at these stations were drawn in Figs.2. At EC7 and MEL, the pulse with rather-long period is simply remarkable. The duration of the motion is less than 10 seconds. At BNC, the high frequency motion is dominant and the duration of the motion is rather long. At ARP and AGR, the wave form is not simple and some S-phases are recognized. These phases suggest that this earthquake might be a multiple event. As shown in Fig.3, the peak ground accelerations and velocities at these stations range from 310 to 770 gals and from 43 to 115 kines, respectively. Note that the peaks of these near-field ground motion records vary twice or more. For peak ground velocity, the amplitude is much enhanced toward the north-west from the epicenter and also little enhanced toward the south-east from the epicenter. It could be explained as the effect of source directivity of finite moving source, as mentioned by Singh [4]. For peak ground acceleration, the highest amplitude is observed at BNC near the epicenter. The source directivity effect could not be recognized in the distribution of peak ground accelerations.

The velocity response spectra at these stations were shown in Fig.4. The spectral shapes at EC7 and MEL are simple with a remarkable peak at period of 3 to 4 second. The peak value of the velocity response spectra with 5 percent damping exceeds 200 kines. At BNC, the spectrum has several peaks over the wide period range. The highest peak is at period of 0.6 second. At ARP and AGR, the spectral shapes are rather similar to that at EC7 or MEL. However, the period of the highest peak is little shorter than that at EC7. In short period range that is less than about 1 second, the spectral amplitude at BNC is much larger than those at the other stations. In rather-long period range, the amplitude at BNC is much smaller than that at EC7 or MEL, and almost same or little smaller than that at ARP or AGR. The spectrum at BNC is completely different from those at the other stations.

These stations are on deep sediments of the Imperial Valley. The site subsurface conditions at these stations would be considered as fairly uniform. The spectra of the aftershock (M_L=5.2) were compared to examine the effect of site conditions (See Fig.5). The spectra at these stations are similar to each other, and the difference of the site conditions would be negligible. Then, the different spectral contents at EC7 and BNC could not be explained by the effects of the site conditions alone.

NEAR-FIELD GROUND MOTIONS IN HORIZONTAL PLANE

To examine the characteristics of the near-field horizontal ground motions further, the spatial distribution of the horizontal ground motion was investigated. The particle orbits of the horizontal ground velocity were drawned in Fig.6. At EC7, MEL and AGR, the motions are strongly polarized in a direction perpendicular to the fault strike. However, at BNC, the particle motion is complicated and shows no particular polarization.

Two-dimensional response spectrum analysis was performed to check the polarization of horizontal motions at each period range. The method has been already described by authors [5]. In Figs.7, the directions of the major axis at the peak periods of the spectrum were plotted. The radial direction of the figure means the period. At EC7, MEL and AGR, the direction of the major axis is perpendicular to the fault strike in short and rather-long period ranges. At BNC, the major axis is parallel to the fault strike in rather-long period range, but perpendicular in short period range. The numerical calculation of the near-field ground motions was performed for the strike-slip and unilateral faulting with vertical fault plane by simple dislocation theory. It shows that the major axis of the near-field motion is perpendicular to fault strike, whereas the motion near the epicenter is not polarized to particular direction (See Fig.8). The results from simple fault model are in accord with the major axis of the observed near-field motions. The polarization of the near-field motions has been already pointed out in case of the Parkfield Earthquake of 1966 [6]. It would be expected that the buildings or structures near strike-slip fault suffer the severer ground motion in a direction perpendicular to fault strike.

DISCUSSION

As mentioned above, the variation in the near-field ground motions along the fault trace is considerable. The differences of the amplitudes in rather-long period range and the duration could be explained by the source directivity effects due to smooth rupture propagation. However, large amplitude of the BNC record in short period range could not be explained by the source directivity nor site conditions. Then, the other records obtained at the neighboring stations of BNC were examined. Near the epicenter, two other strong motion records were obtained at CLX and MXC (See Fig.1). These stations are about 10 kilometers far from the fault trace. The velocity response spectra of these records were shown in Fig.9. The spectral amplitude in short period range is relatively higher than in rather-long period range. On the contrary, the spectrum at HLT, which is located about 15 kilometers north of the epicenter, have a peak at period of 3 to 4 second. The peak ground accelerations at CLX and MXC are higher than that at HLT, but the peak ground velocities at CLX and MXC are lower than that at HLT (See Fig.3). The record at ARP contains larger high frequency content than that at AGR, nevertheless the wave forms of the both records are similar to each other. The high frequency content seems to be concentrated near the U.S.A.-Mexico border. These results might lead the existence of the source, which would generate the high frequency motions, on the north-west side of the epicenter.

The moving window spectrum was calculated for the BNC record to check the hypothesis of the source for the high frequency motions. Three different phases are recognized from the moving window spectrum of the BNC record, as shown in Fig.10. The first one would be due to the starting of the rupture. The second one which caused the peak acceleration occured at 4 second after the first one. The first and third ones contain smaller high frequency content. If the shock with the high frequency motion was assumed at several kilometers north-west from the epicenter and at a few seconds later, the second phase with peak acceleration could be comprehended well.

CONCLUDING REMARKS

The near-field ground motion records during the Imperial Valley Earthquake of 1979 showed the wide variations on the peaks, duration, spectral content and spatial distribution of the horizontal motions. The strong polarization of the horizontal near-field motions, except near the epicenter, was recognized in a direction perpendicular to fault strike. The source directivity effect of smooth rupture explained the distribution of the amplitudes in rather-long period range, but not in short period range. To explain the amplitudes in short period range such as peak ground acceleration, the source which would generate the high frequency motion was proposed at several kilometers north-west of the epicenter. The source would be a result of the irregular rupture process. For the prediction of the near-field ground motions for engineering purpose, it would be indispensable to grasp the complexity of the rupture process physically and quantitatively through the observation of the near-field ground motions.

ACKNOWLEDGEMENTS

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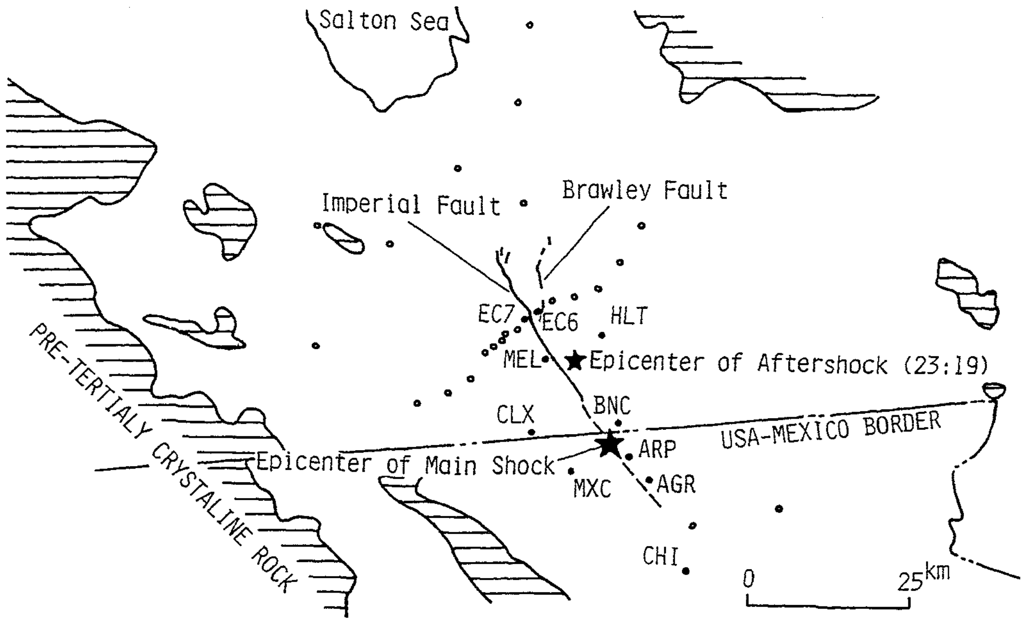
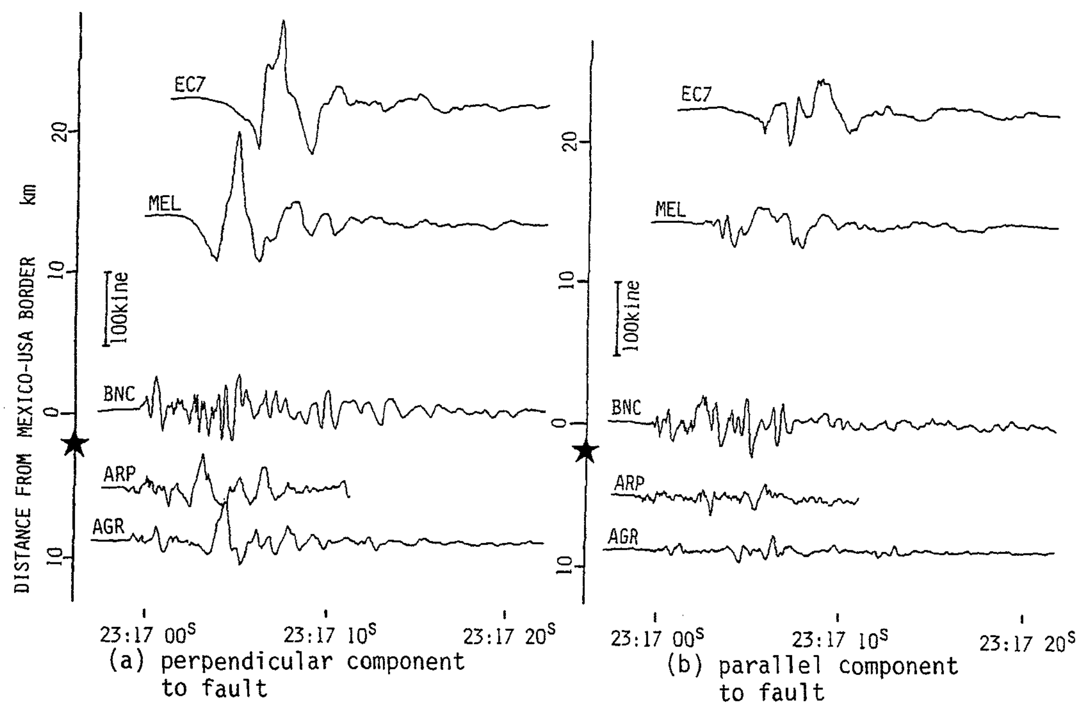


Fig.1 LOCATION OF STRONG MOTION ACCELEROGRAPHS



Figs.2 GROUND VELOCITIES OF NEAR-FIELD MOTIONS

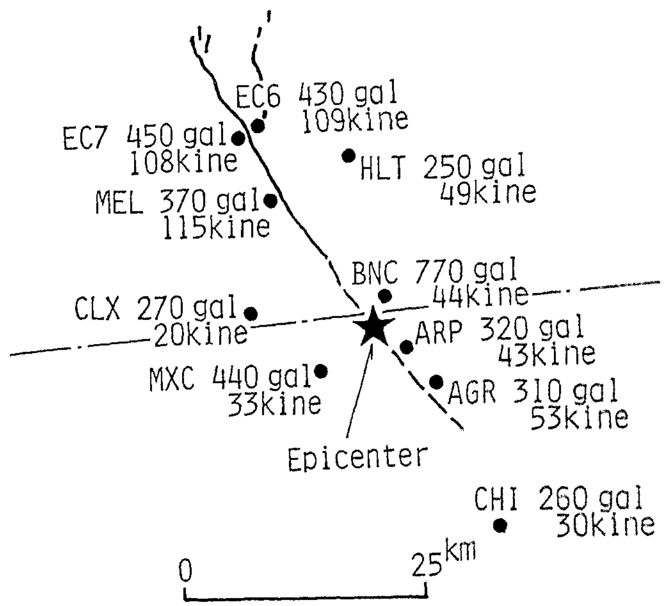


Fig.3 DISTRIBUTIONS OF PEAK GROUND ACCELERATION AND VELOCITY

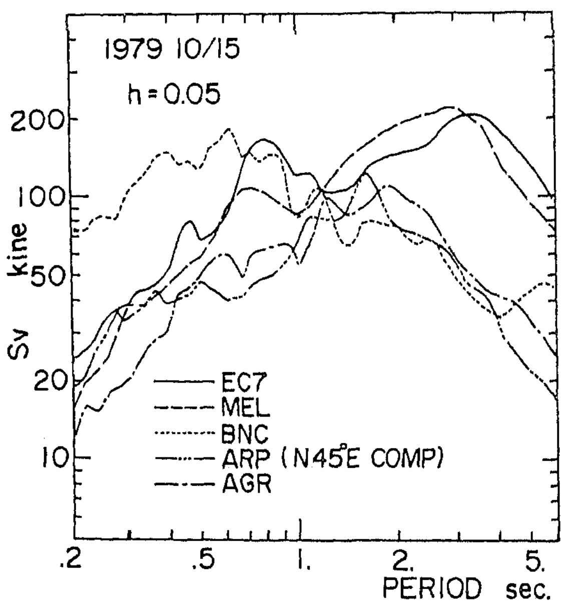


Fig.4 TWO-DIMENSIONAL VELOCITY RESPONSE SPECTRA FOR MAIN SHOCK

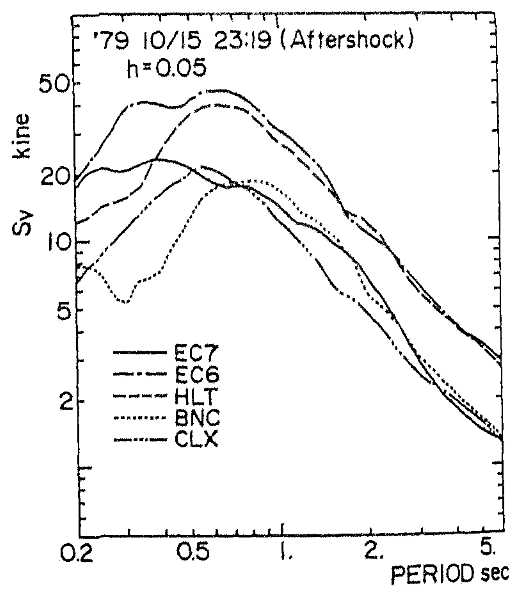


Fig.5 TWO-DIMENSIONAL RESPONSE SPECTRA FOR AFTERSHOCK

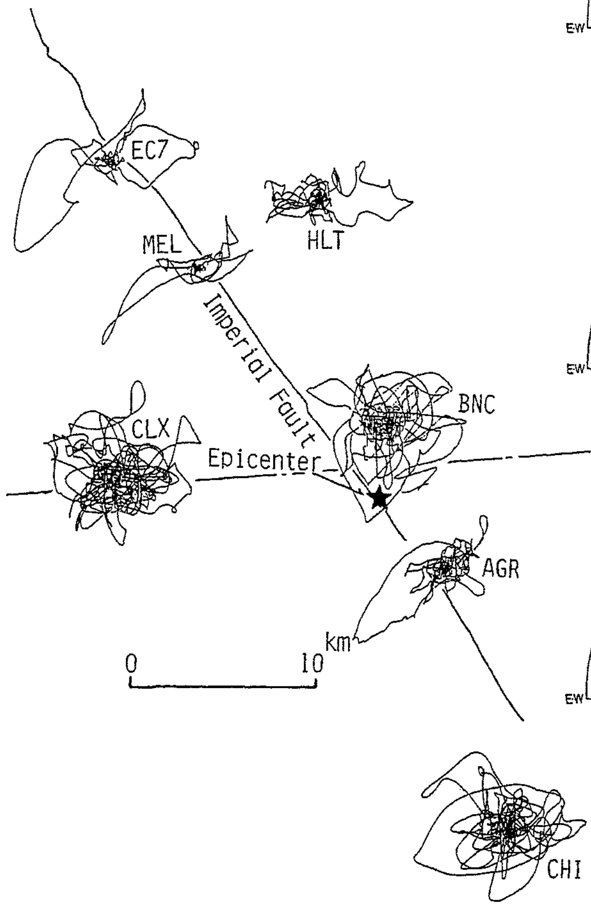
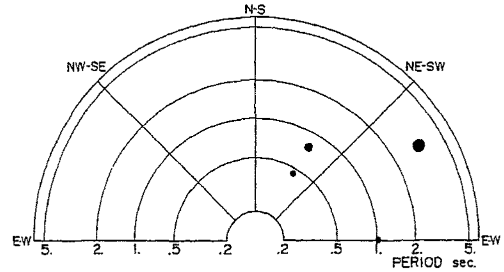
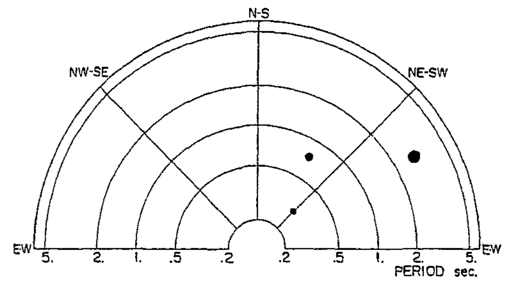


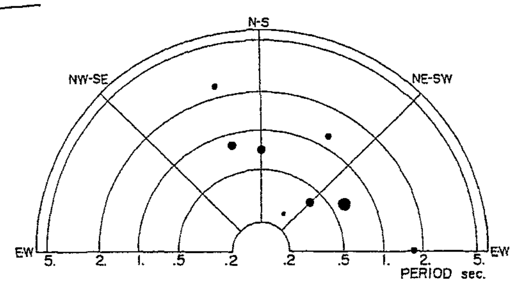
Fig.6 PARTICLE ORBIT OF HORIZONTAL GROUND VELOCITY



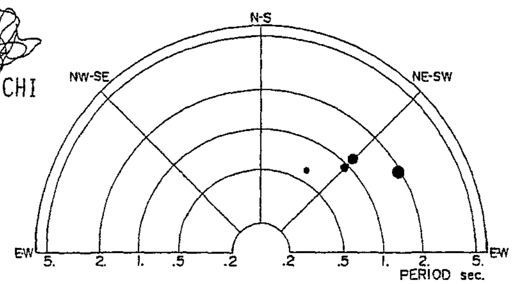
(a) EC7



(b) MEL



(c) BNC



(d) AGR

Figs.7 MAJOR AXIS OF HORIZONTAL GROUND MOTION

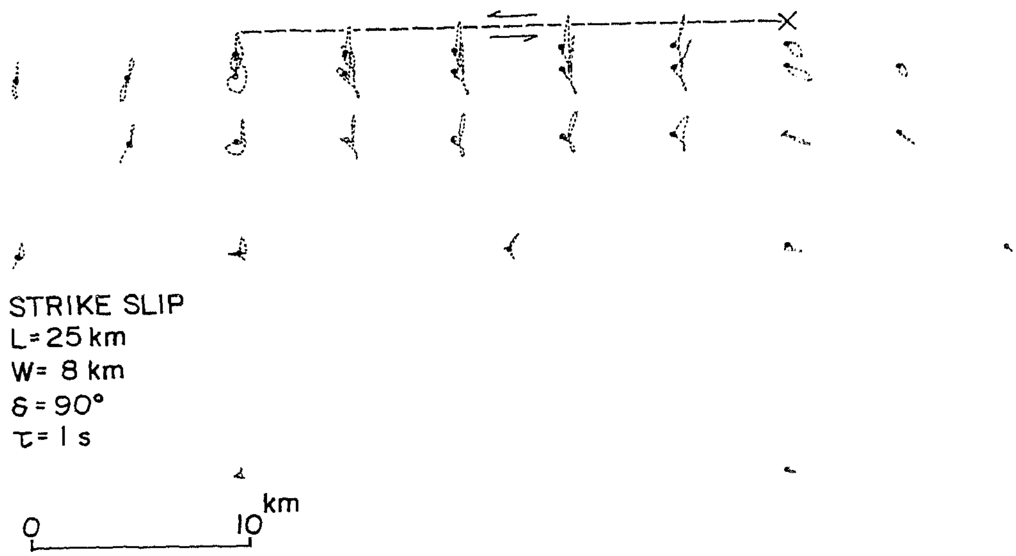


Fig.8 PARTICLE ORBIT OF SYNTHESIZED GROUND VELOCITY

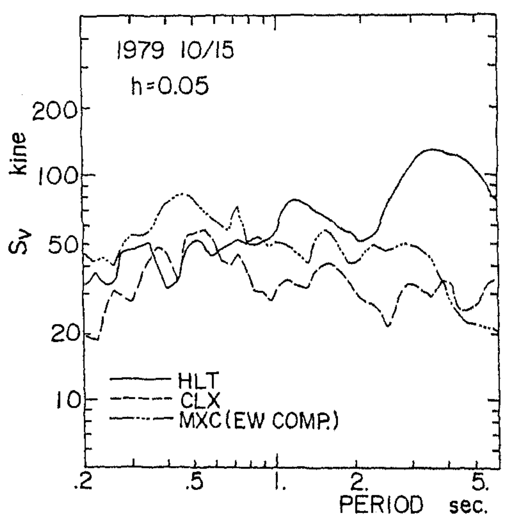


Fig.9 TWO-DIMENSIONAL VELOCITY RESPONSE SPECTRA

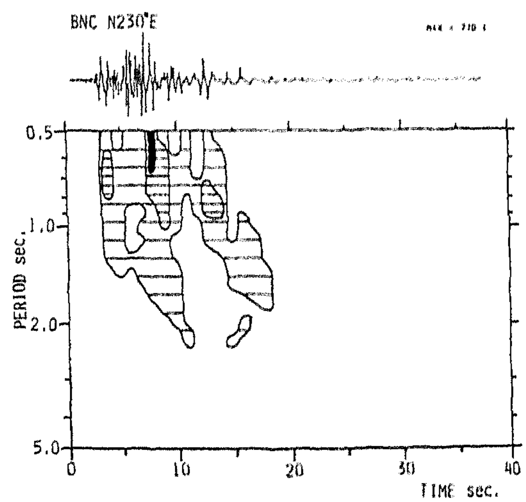


Fig.10 MOVING WINDOW SPECTRUM