Gan, W.Q. and Fang, C.: 1987, Solar Phys. 107, 311.
Hanaoka, Y., Kurokawa, H., ans Saito, S.: 1986, Solar Phys. 108, 151.
Hofmann, A., Rendtel, J., Aurass, H., and Kalman, B.: 1987, Solar Phys. 108, 151.
Hong, W.L., Pallavicini, R., and Cheng, C.C.: 1987, Solar Phys. 107, 271.
Hudson, H.S.: 1985, Solar Phys. 93, 105.
Ichimoto, K. and Kurokawa, H.: 1984, Solar Phys. 93, 105.
Jackson, B.V: 1985, Solar Phys. 100, 563.
Kane, S.R., Love, J.J., Neidig, D.P., and Cliver. E.V.: 1985, Astrophys. J. 290, L45.
Kundu, M.R. and 5 co-authors: 1985, Astrophys. J. Suppl. 57, 621.
Kurokawa, H., Hanaoka, Y., Shibata, K., and Uchida, Y.: 1987, Solar Phys. 108, 251.
Lin, Y. and Gaizauskas, V.: 1987, Solar Phys. 109, 81.
Loughhead, R., Blows, G., and Wang, J.: 1985, Publ. Astron. Soc. Japan 37, 619.
Machado, M.E.: 1985, Solar Phys. 99, 159.
Martens, P.C.H.: 1986, Solar Phys. 107, 95.
McCabe, M.K. and 4 co-authors: 1986, Solar Phys. 103, 399.
Perez-Enriquez, R.: 1985, Solar Phys. 97, 131.
Sakurai, T.: 1985, Solar Phys. 95, 311.
Seehafer, N.: 1985, Solar Phys. 96, 307.
Simnett, G.M.: 1986, Solar Phys. 106, 165.
Somov, B.V. and Titov, V.S.: 1985, Solar Phys. 95, 141, and 102, 79.
Sturrock, P.A., Kaufmann, P., Moore, R.L., and Smith, D.F.: 1984, Solar Phys. 94, 341.
Svestka, Z. and 5 co-authors : 1987, Solar Phys. 108, 237.
Sylwester, B. and 8 co-authors: 1986, Solar Phys. 103, 67.
Tachi, T., Steinolfson, R.S., and Van Hoven, G.: 1985, Solar Phys. 95, 119.
Takakura, T.: 1986, Solar Phys. 104, 363.
Tanaka, K. and Zirin, H.: 1985, Astrophys. J. 299, 1036.
Tang, F.: 1985, Solar Phys. 102, 131.
Wang, J. and 4 co-authors: 1986, Acta Astrophys. Sinica 6, 26.
Zirin, H. Hirayama, T.: 1985, Astrophys. J. 299, 536.
Zwingmann, W., Schindler, K., and Birn, J.: 1985, Solar Phys. 99, 133.

VI. Highlights of the Solar Activity Studies Made with Instruments Aboard Spacecraft

(S. R.Kane)

A. INTRODUCTION

Although the solar activity began to decrease rapidly after 1983, the analysis and interpretation of the observations made with instruments aboard the SMM, Hinotori, P78-1, ISEE-3 (ICE), PVO, Venera, and PROGNOZ spacecraft continued to produce important scientific results. The observational results inspired new theoretical studies or extensions of the earlier studies. Several symposia and workshops were organized for presentation and discussion of coordinated studies or studies in progress.

Symposia on the results from the Solar Maximum Data Analysis (SMA) were held in Gratz, Austria (Simon 1984 (I)) and Toulouse, France (de Jager and Svestka 1986 (II)). The SMM workshops helped to bring together many solar physicists from many countries to study specific aspects of solar activity. The participants included both ground-based observers and those associated with instruments aboard spacecraft. The proceedings of the following three SMM workshops have now been published : Energetic Phenomena on the Sun (Kundu and Woodgate 1986 (III)), Coronal and Prominence Plasmas (Poland 1986 (IV)) and Rapid Fluctuations in Solar Flares (Dennis et al. 1986 (V)). The proceedings of the National Solar Observatory/SMM symposium on the Lower Atmosphere of Solar Flares have also been published (Neidig 1986 (VI)). Results related to the Sun and the Heliosphere in Three Dimensions are available in the proceedings of the 19th ESLAB Symposium (Marsden 1985 (VII)). Studies related to solar flares and particle acceleration have been reviewed by de Jager (1986).

The largest number of spacecraft observational studies were related to solar flares. This is to be expected since the instruments aboard spacecraft such as SMM and

Hinotori were designed primarily to observe solar flares. The emphasis was on the observations of high energy phenomena (involving non-thermal particles and/or high temperature plasma) with high spatial, spectral and temporal resolution. Many new results were obtained through comparative studies involving spacecraft observations of the X-ray, gamma-ray and UV emission and the ground-based observations at optical and radio wavelengths. The highlights of some of the significant results are presented below.

B. HINOTORI SATELLITE

A large number of results have been obtained with X-ray instruments on the Japanese satellite Hinotori. The impact of these observations on solar flare research has been reviewed by Tanaka (1987). Three types of flares (A, B, C) and five emission components have now been identified (Tsuneta 1984 ; Takakura et al. 1984). Evidence for chromospheric evaporation has also been found. The flare classification is based on the X-ray time profile, spectrum and morphology. The five components in the 5- 40 keV X-ray emission are impulsive, gradual-hard, soft X-ray thermal, hot thermal, and quasi-thermal.

Thermal flare with mostly gradual rise and fall in the soft X-rays and low energy (<40 keV) hard X-rays, and intense emission in Fe XXV lines is called type A flare. The microwave emission is relatively weak in this flare. The hard X-ray source is compact (<5000 km) and the spectrum is very steep above 40 KeV. Very effective heating but insufficient particle acceleration in relatively large (300 G) magnetic fields seems to result in type A flares.

The impulsive flare giving rise to rapidly varying impulsive spikes and gradual hard X-ray emission is classified as type B flare. The impulsive spectrum is hard and the source extends from the low corona to the footpoints. The gradual hard X-ray emission, if present, has a comparatively softer spectrum and the source is relatively compact and is located at higher altitudes. The associated microwave emission is intense. The flare appears to be associated with an eruptive filament. It seems to occur in complex sheared low lying magnetic fields after separation from the eruptive filament. The acceleration of particles is very rapid. The gradual phase presumably results from progressive energy release in the higher magnetic loops of an arcade.

The gradual hard X-ray flare, called type C, is a longenduring (>30 min.) hard X-ray burst with broad peaks but no impulsive emission. The X-ray spectrum is very hard and hardens systematically with time. The source is located at high altitudes (>40000 km) in the corona. The microwave emission is usually very intense. Type C flare represents a very efficient, but slow particle acceleration in relatively weak (50 G) magnetic fields.

Intense emission of iron Kα lines at 1.936 angstrom and 1.940 angstrom associated with a hard X-ray burst was observed with the Bragg crystal spectrometer. The continuum X-ray spectrum in 1.5–12.5 keV range was also measured with high spectral resolution. The observations were compared with the Kα emission expected from the collisional impact of a beam of energetic electrons and the X-ray fluorescence. It was found that the observed Kα emission can be explained by the irradiation of the photosphere by the X-ray continuum with the observed power law spectrum extending down to the threshold energy (7 keV) for K-shell ionization (Tanaka et al. 1984).

High time resolution (62.5 ms) observations of the hard X-ray emission from a flare were compared with the simultaneous observations 22 GHz radio emissions made with 1 ms time resolution at the Itapetinga Radio Observatory in Brazil. It was found that throughout the duration of the burst all the radio burst structures were delayed by 0.2–0.9 s with respect to the hard X-ray flux structures. Different burst structures showed different delays indicating independent emission sources. Also the time structure of the degree of radio polarization preceded the structure in the total microwave flux by 0.1–0.5 s (Costa et al. 1984). Rapid variation of the turn-over frequency of the microwave spectrum has also been observed in the course of some solar bursts (Zodi et al. 1986).

C. SOLAR MAXIMUM MISSION

A large variety of results regarding the energy release and energetic particle transportation processes in solar flares have been obtained with instruments aboard the SMM satellite. Many of these results have been recently reviewed by Dennis (1985).

Some of the X-ray imaging observations made with the SMM HXIS instrument have been further examined and/or reinterpreted. SMM seems to have observed mostly type B and type C flares (Hinotori classification). There are, however, several differences. In some events, type B and type C characteristics occur on different X-ray peaks of the same flare. Impulsive (type B) and gradual (type C) phases probably occur in all energetic flares, the relative importance of the two phases varying from one flare to another (Dennis 1985).

Two classes of gamma ray/proton flares have been identified by Bai (1986): impulsive and gradual. They presumably differ in the location and mechanism for acceleration of protons. Whereas the impulsive flares have the "first phase and second-step"acceleration in low lying closed magnetic loops, the acceleration in the gradual flares is by shock waves high in the corona.

A different classification of flares has been suggested by Svestka (1986). It is based on two assumptions : (1) A flare is a short-lived release of energy resulting from a rearrangement of the magnetic structure, and (2) the mode of energy release is a reconnection of magnetic field lines. They lead to two classes of flares: dynamic flares and confined flares. The large variety of observed flares are presumably caused by the differences in the boundary conditions of the flare process.

Characteristics of pre-impulsive and impulsive phases of large hard X-ray flares have been studied by Klein et al. (1986). They have found that during the pre-impulsive phase the hard X-ray emission is restricted to energies <200 keV. On the other hand, during the impulsive phase the hard X-rays over a wide energy range are emitted simultaneously. Impulsive photon emission from 40 keV to 40 MeV has been found to be essentially simultaneous within 1 s. Thus there is evidence that both non-relativistic and relativistic particles are accelerated within 1 s during the impulsive phase (Kane et al. 1986).

An analysis of the long-term variations in the occurrence frequency of energetic flares during solar cycle 21 indicates a 154 day periodicity for gamma-ray flares (Rieger et al. 1984) and a comparable period for hard X-ray flares (Kiplinger et al. 1984). Similar periodicities have been found in the soft X-ray flares observed by GOES (Rieger et al. 1984) and solar microwave bursts (Bogart and Bai 1985). At present, there is no clear understanding of this 152-158 day periodicity. Bai and Sturrock (1987) have argued that this is not a local phenomena such as interaction and alignment of local hot spots rotating at different rates.

Variation of gamma-ray flare occurrence frequency with the heliocentric angle of the flare has been used to measure the directivity of the radiation source and hence the anisotropy of the emitting particles. The earlier result for >10 MeV photons has now been extended to lower energies. Vestrand et al. (1987) have found significant center-to-limb variation in 300 KeV-1 MeV flares, both in terms of flare occurrence and spectral index, indicating an anisotropic electron distribution such as downwardly directed Gaussian beam or a "pancake" distribution that peaks in directions parallel to the photosphere. These findings are consistent with the results of the earlier computational studies by Petrosian (1985) and Dermer and Ramaty (1986).

Simultaneous observations of UV and hard X-ray emission with high (<0.1 s) time resolution have provided a better understanding of the propagation of energetic electrons from the corona to the chromosphere. The peaks in the hard X-ray, O V line, and UV continuum emissions have been found to occur simultaneously within < 0.1 s (Orwig and Woodgate 1986). Since the UV continuum is expected to be produced at depths where density ne > 10^{14} cm^{-3} and hence 20-100 keV electrons are unable to penetrate to the UV continuum source in the normal solar atmosphere, a "hole boring" scenario has been suggested. In this process, a high intensity narrow beam of electrons moving along magnetic field lines causes rapid local heating which produces laterally moving shock waves. This, in turn, creates a low density region (hole) through which the remainder of the electrons can penetrate much deeper than normally possible. An alternative photo-ionization process has been proposed by Machado and Mauras (1986) to explain the UV continuum. In this process the EUV line emission, produced by the energy deposition by electrons in the transition region, "shines" on the deeper chromospheric layers and alters the Si ionization balance. This, in turn, is expected to cause enhanced UV continuum emission.

Simultaneous high time resolution ($\leq$ 0.01 s) observations of the hard X-ray and microwave emission from an intense and fast spike-like solar burst indicate that the emission consisted of short time scale structure superimposed on an underlying gradual emission (Kaufmann et al. 1984). The radio measurements were made at the Itapetinga Radio Observatory in Brazil and the Owens Valley Radio Observatory and Sagamore Hill Radio Observatory in the U.S.A. The repetition rate for the radio line structure is 30-60 ms at the peak or 16-20 pulses per sec. The observations have been explained in terms of elementary flare bursts from multiple sources associated with interacting magnetic loops. Quasi- quantization of injected energy is also possible. In some fast radio pulses coincident with hard X-rays the radio spectrum peaks at a very high frequency ($\geq$ 100 GHz) (Kaufmann et al. 1985, 1986). It has been suggested that in these pulses ultra- relativistic electrons produce microwave emission through synchrotron mechanism and the hard X-rays through inverse Compton scattering of the electrons on the synchrotron photons (Correia et al. 1986).

D. ISEE-3 (ICE) AND PVO SPACECRAFT

Stereoscopic observations of hard X-ray and low energy gamma-ray emission from solar flares, made with instruments aboard the Third International Sun Earth Explorer (ISEE-3/ICE) and Pioneer Venus Orbiter (PVO) spacecraft, have been used to study the spatial structure of the hard X-ray source and low energy cut-off of the non-thermal electron spectrum. Significant impulsive hard X-ray and soft X-ray emission has been observed at coronal altitudes $\geq$ 1.5 x 10 5 km (Kane and Urbarz 1986). The impulsive X-ray spectrum has been found to extend down to 1 keV indicating a low energy cut-off at comparable energy for the non-thermal electron spectrum.

Properties of electron acceleration especially the density structure in the electron acceleration region, have been deduced through correlative studies of the hard X-ray bursts and decimetric type III and spike bursts. It appears that the acceleration occurs in a highly inhomogeneous region with large density variations (Benz and Kane 1986). In some flares, the electron acceleration is delayed and appears to occur in post flare loops (Kai et al. 1986 ; Cliver et al. 1986) (see also section VII).

Comparison of the hard X-ray and white light observations suggest that the hard X-ray source consists of several kernels, few arc sec in size. Energy disposition by >25 keV electrons can explain the white light observations provided the density structure in the flare is not homogeneous (Kane et al. 1985).

Several results have been obtained regarding the composition of the interplanetary solar flare particles. The heavy-ion enrichment is found to be the same (within a factor of 2) for all flares. However, the degree of heavy- ion enrichment is uncorrelated with the ^3He enrichment indicating an acceleration mechanism in which ^3He enrichment process is not responsible for the heavy-ion enrichment (Mason et al. 1986).

E. P78-1 SATELLITE

High resolution observations of 5.5-12 angstrom X-ray spectrum under a variety of solar conditions, such as flare onset, flares and non-flaring active regions, have been made with instruments aboard the US Air Force satellite P78-1. The resulting compilation of spectral lines includes many lines useful for plasma diagnostics, such as the high temperature lines of Fe XXII-XXIV and density sensitive lines Mg XI and Si XIII (McKenzie et al. 1985 ; Keenan et al. 1985). Comparison with theoretical calculations shows partial agreement.

F. VENERA AND PROGNOZ SPACECRAFT

Solar bursts of hard X-rays >100 keV have been observed simultaneously with high time resolution (2 ms) instruments aboard the Soviet spacecraft Venera 11,12,13,14, and Prognoz. A comparison of the observed X-ray flux modulation period of <1.6 s found in some solar flares with that expected from a MHD model of compact magnetic loops shows good agreement (Desai et al. 1986).

Soft and hard X-ray emission from the sun has been recorded with instruments aboard Prognoz 5-10. The data have been published in a series of publications, the latest publication being related to the data from Prognoz 10 satellite (Valnicek et al. 1987). Problems associated with the calibration of different X-ray detectors have been discussed by Valnicek et al. (1984).

References

I : Solar Maximum Analysis, Adv. in Space Res., Vol 4, N° 7, Simon, P.A. (ed), 1984.

II : The Physics of Solar Flares, Adv. in Space Res., Vol 6, N° 6, de Jager, C. and Svestka, Z. (eds) 1987.

III : Energetic Phenomena on the Sun, NASA Conf. Publ. 2439, Kundu, M., and Woodgate, B. (eds), 1986.

IV : Coronal and Prominence Plasmas, NASA Conf. Publ. 2442, Poland, A.L. (ed), 1986.

V : Rapid Fluctuations in Solar Flares, NASA Conf. Publ. 2449, Dennis, B.R., Orwig, L.E., and Kiplinger, A.L. (eds), 1986.

VI : The Lower Atmosphere of Solar Flares, Publ. of National Solar Observatory/Sacramento Peak, Sunspot, New Mexico, Neidig, D.F. (ed), 1986.

VII : The Sun and Heliosphere in Three Dimensions, D. Reidel Publ. Co., Marsden, R.G. (ed), 1985.

Bai, T.: 1986, Astrophys. J., 308, 912.

Bai, T., and Sturrock, P.A.: 1987, Preprint, Center for Space Sciences and Astrophys., Stanford University, Nature (in press).

Benz, A.O., and Kane, S.R.: 1986, Solar Phys., 104, 179.

Bogart, R.S., and Bai, T.: 1985, Astrophys. J. Lett., 299, L51.

Cliver, E.W., Dennis, B.R., Kiplinger, A.L., Kane, S.R., Neidig, D.F., Sheeley, Jr. N.R., and Koomen, M.J.: 1986, Astrophys. J., 305, 920.

Correia, E., Kaufmann, P. Costa J.E.R., Zodi Vaz, A.M., and Dennis, B.R.: 1986, Rapid Fluctuations in Solar Flares, NASA Conference 2449, Dennis B.R., Orwig, E. and Kiplinger (eds).

Costa, J.E.R., Kaufmann, P., and Takakura, T.: 1984, Solar Phys., 94, 369.

Dennis, B.R.: 1985, Solar Phys., 100, 435.

Dermer, C.D., and Ramaty, R.: 1986, Astrophys. J., 301, 962.

de Jager, C.: 1986, Space Sci. Rev., 44, 43.

Desai, U.D., Kouveliotou, C., Barat, C., Hurley, K., Niel., M., Talon, R., and Vedrenne, G.: 1986, Rapid Fluctuations in Solar Flares, eds., B.R. Dennis, L E. Orwig, and A.L. Kiplinger, NASA Conf. Publ. 2449, p. 43.

Kai, K., Nakajima, H., Kosugi, T., Stewart, R.T., Nelson, G.J., and Kane, S.R.: 1986, Solar Phys., 105, 383.

Kane, S R., Evenson, P., and Meyer, P.: 1985, Astrophys. J. Lett., 299, L07.

Kane, S.R., Chupp, E.L., Forrest, D.J., Share, G.H., and Rieger, E.: 1986, Astrophys. J. Lett., 300, L95.

Kane, S.R., and Urbarz, H.W.: 1986, Proc. STIP Symposium on Retrospective Analyses, (eds) M.A. Shea and D.F. Smart, Book Crafters, Inc.

Kaufmann, P., Correia, E., Costa, J.E.R., Dennis, B.R., Hurford, G.J., and Brown, J.C.: 1984, Solar Phys., 91, 356.

Kaufmann, P., Correia, E., Costa, J.E.R., Zodi Vaz, A.M.: 1986, Solar Flares and Coronal Physics using P/OF as a Research Tool, E. Tandberg-Hanssen and H.S., Hudson (eds), NASA Conf. Publ. 2421, p. 208.

Kaufmann, P., Correia, E., Costa, J.E.R., Zodi Vaz, A.M., and Dennis, B.R.: 1985, Nature, 313, 380.

Keenan, F.P., Kingston, A.E., and McKenzie, D.L.: 1985, Astrophys. J., 291, 855.

Kiplinger, A.L., Dennis, B.R., Orwig, L.E.: 1984, Bull. Am. Astron. Soc. 16, 4.

Klein, K.-L., Pick, M., and Magun, A.: 1986, V, p. 79.

Machado, M.E., and Mauras, P.: 1986, V, p. 271.

Mason, G.M., Reames, D.V., Klecker, B., Hovestadt, D., and Von Rosenvinge, T. T.: 1986, Astrophys. J., 303, 849.

McKenzie, D.L., Landecker, P.B., Feldman, U., and Doschek, G.A.: 1985, Astrophys. J., 289, 849.

Orwig, L., Woodgate, B., and Nakada, M.P. : 1985, Bull. Am. Astron. Soc.
Petrosian, V.: 1985, Astrophys. J., 299, 987.
Rieger, E., Share G.H., Forrest, D.J., Kanbach, G., Keppin, C., Chupp, E.L.: 1984, Nature, 312, 5995.
Svestka, Z.: 1986, The lower Atmosphere of Solar Flares, D. F. Neidig (ed), National Solar Observatory/Sacramento Peak, Sunspot, New Mexico , P. 332.
Takukura, T., Tanaka, K., and Hiei, E.: 1984, Adv. Space Res., 4, 143.
Tanaka, K.: 1987, Publ. Astron. Soc Japan, 39, 1.
Tanaka, K., Watanabe, T., and Nitta, N.: 1984, Astrophys. J., 282, 703.
Tsuneta, S.: 1984, Proceedings of Japan-France Seminar on Active Phenomena in the Outer Atmosphere of the Sun and Stars, Pecker, J.C. and Uchida Y. (eds).
Valnicek, B.., Farnik, F., Sylwester, B., and Sylwester, J.: 1984, Adv. Space Res., 4, 121
Valnicek, B., Farnik, F., Sudova, J., Kormarek, R., Likin, O., and Pisarenko, N.: 1987, Pognoz Data Part IV, Astron. Inst. Ozech. Acad. Sc, Publ. No. 63.
Vestrand, W.T., Forrest, D.J., chupp, E.L., Rieger, E., and Share, G.H.: 1987, Univ. of New Hampshire preprint, Astrophys. J. (in press).
Zodi, Vaz, A.M., Kaufmann, P., Correia E., Costa, J.E.R., Clived, E.W., Takakura, T.: 1986, V, p. 171.

VII. RESULTS FROM RADIO OBSERVATIONS
(C. Alissandrakis)

This section does not mention some results reported in sections V and VI. Other papers can be found in proceedings of CESRA Workshops (Benz 1985 (I), Pick and Trottet 1986 (II)).

A. INSTRUMENTATION

During the last three years important developments in instrumentation have taken place. A new antenna has been added to the Nobeyama solar radio interferometer increasing its one-dimensional resolution to 25" at 17 GHz (Nakajima et al, 1984). A frequency-agile receiver system has been added to the Owens Valley 2-element interferometer, operating at up to 86 frequencies in the 1-18 GHz range (Hurford et al, 1984), while a new digital, high time resolution spectrometer is in operation at Bern. The VLA and the RATAN-600 have continued to give high spatial resolution data at cm wavelengths, while the E-W branch of the Siberian Solar Radio Telescope is fully operational, giving one-dimensional scans at 5.2 cm with a resolution up to 17" (Smolkov et al, 1986). In the long wavelength range the Nançay Radioheliograph has been used as an earth rotation aperture synthesis instrument (Allissandrakis et al, 1985), while the Clark Lake Radioheliograph is operating regularly at decametric wavelengths providing instantaneous maps. A multi-frequency system has been installed in the N-S branch of the Nançay Radioheliograph. In spite of these developments the community has suffered greatly from the loss of the Culgoora Radioheliograph.

B. QUIET SUN

Just after the solar maximum, few publications refer to the quiet sun, Kosugi et al (1986) detected polar cap emission of 3-7% at 36 GHz apparently associated with coronal holes. Alissandrakis et al (1985) presented maps of the corona at 169 MHz. The maps show coronal holes with T_b~10^5 K and apparent height of .03 R_o ; the distribution of brightness at 1.15 R_o shows a gross similarity with the coronal green line. Bright features are sources of noise storm continua, while weaker emission regions are associated with neutral lines of the magnetic field. Limb synoptic charts (Lantos and Alissandrakis, 1986) are very similar to K-coronameter charts and show very well the base of the heliosheet. Kundu et al (1987a) presented coronal maps at 30.9, 50 and 73.8 MHz for one rotation. A coronal hole shows an eastward displacement at the lower frequencies. Elongated features at the limb correspond well to white light streamers. Radio synoptic charts show overall similarities with K-coronameter charts. The solar diameter at decameter wavelengths was measured by Gergely et al (1985). Observations of bright points with a lifetime of a few minutes have been reported by Habbal et al (1986) at 20 cm and Fu et al (1987) at 6 cm. Benz and Furst (1987) found little