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IV. Results from Hinotori and P78-1

(K. Tanaka)

Hinotori observed 720 flares through its operation February 1981-October 1981. General discussions of the results were given in two symposia: the Hinotori Symposium (ISAS 1982) and the U.S.-Japan Seminar (de Jager & Švestka 1983). The hard x-ray imaging made at the effective energy 20-35 keV showed a wide variety of morphology. Many flares (22 out of 30 events) showed single source structure, either compact (12) or extended (10) in the spatial resolution of 15 arc sec (Takakura et al. 1983a, Ohki et al. 1983, Takakura 1984). Evidences are given in some limb events that the main source is located in the high corona (1-4 x 10^4 km) (Takakura et al. 1983b). The extended single source could be the whole coronal loops which may include footpoints, but the maximum brightness is near the loop top. In some events (8 out of 30), weak subsource(s) which sould be identified with the footpoint(s) appear intermittently (Tsuneta et al. 1983). Takakura et al. (1984) found that the extended single source becomes compact and slightly shifts to higher altitudes in later phases of the impulsive burst (5 out of 10 events). Tanaka (1984), Takakura (1984), and Tanaka & Zirin (1984) argued that the hard x-ray morphology of the impulsive burst is consistent with the non-thermal electron beam model in high density corona. Sakurai (1983) investigated magnetic field structures of the hard x-ray sources based on the potential field calculations. Timing between the hard x-ray and microwave in the impulsive bursts was examined by Takakura et al. (1983c), who found correlated subsecond time structures and also by Takakura et al. (1983d), who found a long (5-10 s) delay of the peaks at 17 GHz and E > 300 keV to the peak at E < 100 keV. Kurokawa (1983) showed detailed coincidence between the hard x-ray spikes and Hα brightenings.

The flares observed from Hinotori were classified into three types (Types A, B, and C) according to combined characteristics of the morphology, spectrum, and time profile (Tanaka 1984, Tanaka et al. 1983). With contrast to the impulsive burst (Type B), the gradual hard burst (Type C) shows an extended duration without impulsive spike component, and a spectral hardening is observed with a large delay (30 s-1 min) of the gamma-ray peak to the hard x-ray peak (Yoshimori et al. 1983). Tsuneta et al. (1984a) showed that its hard x-ray image is an extended, stationary source located high in the corona. Microwave interferometric (one-dimensional) observations by Kawabata et al. (1983) showed the microwave structure co-spatial with the hard x-ray source suggesting that the high-energy electrons in the MeV range are trapped due to magnetic mirroring. Kai et al. (1985) found a larger microwave to hard x-ray flux ratio for this type compared with the impulsive burst. Nitta et al. (1983) studied dynamic spectra of the hard x-ray burst and found a characteristic change from the exponential to power law spectra in the initial phase of the impulsive burst, but the spectrum in the gradual hard burst remains power law all the time. The hot thermal burst (Type A) is characterized by a gradual enhancement in the low-energy (17-40 keV) hard x-ray flux of thermal origin from the middle phase of flare (Tsuneta et al. 1984b). Tanaka et al. (1982a) found strong emission of Fe XXVI lines whose spectrum and intensity show an electron temperature of 30-40 million K and a large emission measure of the order of 10^{49} cm^{-3}, and showed that this component is responsible for the low-energy, hard x-ray excess. This hot thermal component shows different temporal behavior from the previously known hot plasma which is diagnosed from the Fe XXV spectrum to have electron temperature in the range of 13-25 million K, and can be found in about half (7 out of 13) of large flares (Tanaka & Akita, 1984). Independently Lin et al. (1981) discovered this new thermal component from the balloon observation of very high-resolution, hard x-ray continuum spectrum. Tsuneta (1984) proposed a mechanism to explain the formation of this hot thermal component by direct energy conversion from the magnetic field due to the joule heating in the high density region in the corona, while Tanaka & Zirin (1984) attributed the origin to the collisional heating by low-energy electron beams.

A wealth of data have been obtained for the high-resolution, soft x-ray line spectra from P78-1 (Doschek et al. 1979, McKenzie et al. 1980), SMM (Culhane et al. 1981), and Hinotori (Tanaka et al. 1982a). Doschek et al. (1980) and Feldman et al. (1980) derived general spectral properties of X and M class flares, respectively. The electron temperature for Fe XXV (Ca XIX) is constant near 22 (16) million K or increases somewhat during the rise phase for the X class flare and is 13-20 million K in the M class flare. Blue shifted (400 km/s) components and large non-thermal broadenings (130 km/s) were discovered during the rise phase. The results from SMM and Hinotori confirmed these, and Hinotori's Fe XXVI spectra revealed an existence of an abundant higher temperature (30-40 million K) component (Tanaka et al. 1982a, Tanaka & Akita 1984). From line ratios of the density-sensitive line (O VII), Doschek et al. (1981) found a rapid increase in the electron density to 10^{12} cm^{-3} for the 3 million K plasma before the peak flux in the Fe XXV and Ca XIX lines. Using the same line McKenzie & Landecker (1982a) found the densities of non-flare active regions to be in the range of 3-13 x 10^{9} cm^{-3}. Feldman et al (1982a) studies impulsive soft x-ray flares with the rise and decay times less than 1 min and concluded that the 20 million K plasma cools by radiation in the high-density ($>10^{12}$ cm^{-3}) corona. From these results Feldman et al. (1982b) discussed observational constraints for a soft x-ray flare model. On the other hand Tanaka et al. (1983) found that the soft x-ray source thermal energy agrees with the electron energy deposition above 30-50 keV, the threshold depending on the preflare coronal density, and Tanaka et al. (1982b) showed a casual relationship between soft and hard x-ray flux increases for the elementary flare bursts. Tanaka & Zirin (1984) studied the temporal behavior of the blue shifts in Fe XXV lines and showed that mass of the stationary hot cloud emitting Fe XXV line is explained by the mass input from the rising plasma. They argue that the chromposheric evaporation caused by the electron (50 keV) bombardment provides the coronal hot cloud. Akita et al. (1983) derived the upper limit for the mean polarization of Fe XXV line in six flares, which is 4% and seems to contradict the high polarization degree obtained from the Intercosmos measurement (Krutov et al. 1981). In a very impulsive flare observed by Hinotori a high (10%) polarization was reported for a short period (30 s) by Tanaka et al. (1982c). An unusually intense Fe Kα emission well correlated with an impulsive hard x-ray burst was reported by Tanaka et al. (1984), who attributed it to the fluorescence from the non-thermal (power law) flux extending to 7 keV observed from the continuum spectra. Watanabe et al. (1983) studied thermal evolution of many small flares from the high-resolution, soft x-ray (1-25 keV) continuum spectra which resolve line emissions. McKenzie & Landecker (1982b) identified many lines from ionized Ca and Cr ions in the 15-23 A region from the spectra obtained from P78-1.

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V. Sunspots

(V. Bumba)

Several proceedings of scientific meetings on sunspots appeared during the 1981-1984 period [The Physics of Sunsots, Cram and Thomas (eds.) 1981; see also reports of regional meetings, e.g., Third European Solar Meeting, Oxford 1981; Nordic Astronomy Meeting, O. Hauge (ed.), Oslo 1983; 11th Regional Consultation on Solar Physics, L. Dezsö and B. Kalman (eds.), Debrecen 1983]. New interest in sunspots was aroused through observations of EUV sunspot spectra from space and was also inspired by the growing number of observations of starspots and other stellar activities [IAU Symposium No. 102, Solar and Stellar Magnetic Fields: Origin and Coronal Effects, J.O. Stenflo (ed.) 1983; Colloquium IAU No. 71 Activity in Red Dwarf Stars, Catania 1982]. Other reasons for the increased interest in sunspots and their energetics were prompted by the correlation between sunspot occurrence and the variations of the solar constant (Hudson et al. 1982) and by the use of sunspot positions for determining solar differential rotation and its change with latitude, depth, and time (Howard et al. 1984, Godoli & Mazzucconi 1982, Balthasar et al. 1984, Tuominen & Kyröläinen 1982, Adam 1983, Koch 1984).

A. EVOLUTION OF SUNSPOTS IN THE FRAME OF ACTIVE REGION'S MAGNETIC FIELD

Current studies define with more precision than before the modes of sunspot development from individual nuclei, sunspot rotation, and the course of penumbral formation, strongly dependent on field topology, etc. (Bumba & Suda 1983a, 1984a,b, Liggett & Zirin 1983). The studies describe the complicated changes in umbral and penumbral forms due to the action of colliding magnetic entities of the same or opposite polarities (Bumba et al. 1982). The structure of the magnetic field and its evolution around sunspots visualized in photospheric and chromospheric fine structures has been studied during the normal development of sunspots (Gopasyuk & Kartashova 1981), in cases of more complicated magnetic situations (Karlicky & Suda 1983), during the appearance of "δ spots" (Patty 1981, Tang 1983), and during still more complex magnetic field topologies (Lin & Wang 1982, Yang & Chang 1983), as well as in association with flare occurrence (Ikhsanov 1982). The investigation of the behavior of sunspot magnetic flux during the time of sunspot disappearance brought a new enigma concerning the manner in which sunspot magnetic fields vanish. Some observers (Wallenhorst & Howard 1982, Wallenhorst & Topka 1982) do not see any evidence for spreading or diffusion of the field into the supergranular network, although others see small