problem, a problem involving Thomson scattering of white light, EUV line formation, and/or free-free emission of radio waves. Because the basic physics of each of these processes is apparently well established, the discrepancy must lie in their application to the solar atmosphere: some important aspect of the atmospheric constitution, density or temperature distribution, or wave propagation is probably being overlooked.

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On the Formation of Planetesimals

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Introduction

The past and present existence of smaller bodies in our solar system manifests itself in various ways through the appearance of asteroids, minor moons, planetary rings, surface cratering, etc. The occurrence of these planetesimals appears to be an integral intermediary step in the formation of the larger bodies from the initial grain state. In order to account for the discreteness and order of the planetary orbits and regular satellite systems, Prentice (1977, 1978) has suggested that the accumulation of this planetesimal material took place in a series of well defined orbits corresponding to the positions of a system of gaseous Laplacian rings that were shed by the primitive contracting parent cloud. Alfvén and Arrhenius (1975) have also drawn attention to the fact that planetesimal formation occurs far more effectively if the accumulation takes place along well defined 'jet streams'. Hourigan (1977) has previously demonstrated how such concentrated rock/ice streams or 'jet-streams' naturally form on the mean Keplerian orbit of gaseous rings that are present in the Prentice-Laplace model.

The Model

In the following, we investigate the stability of the condensate stream towards gravitational fragmentation along the mean orbit to form isolated groups of particles. The stream is assumed to be a thin, toroidal liquid having viscosity ν, density ρ and rotating with angular velocity Ω and mean minor radius R.

The deformed surface due to a varicose perturbation has the form

$$r = R + \epsilon_o \exp i(kz + \sigma t)$$

where z is the distance measured along the orbit, k and σ are the wavenumber and frequency, respectively, of the disturbance $\epsilon \ll R$.

Results

Solving the usual equations of motion and gravitational potential (see Chandrasekhar 1961) and imposing the conditions relating to vanishing of tangential viscous forces and pressure at the boundary, we obtain the following dispersion relation for the frequency of the disturbance

$$\sigma\Big[1 - [2k^2/(k^2 - p^2)]\,\Big(1 - [2kp/(k^2 + p^2)] \times [I_o'(x)I_o''(y)/(I_o'(y)I_o''(x))]\Big)\; I_o''(x)/I_o(x)\Big]$$
$$= -\,i[4\pi G\rho Rk/\nu(k^2 + p^2)]\,[K_o(x)I_o(x) - \tfrac{1}{2}]I_o'(x)/I_o(x) \qquad (1)$$

where $p^2 = k^2 + \dfrac{i\sigma}{\nu} - i\,\dfrac{2\Omega^2}{\sigma\nu}$, $x = kR$, $y = pR$

and I_o and K_o are Bessel functions for purely imaginary arguments.

In the case of zero viscosity, the critical density of the stream is

$$\rho_c = 11.06(R_o/a)^3\rho_o$$

where R_o and ρ_o are the radius and density, respectively, of the central body and a is the major axis of the torus.

The characteristic time for fragmentation is

$$\tau \sim 4.07(4\pi G\rho_c)^{-1/2}$$

For the earth, we find $\rho_c \sim 10^{-6}$ g cm^{-3} and $\tau \sim 1$ year.

It is found, from (1), that the range of wavelengths for which the stream is unstable is unchanged by viscosity. However, increasing the viscosity pushes the maximal mode of instability towards larger wavelengths which means that the stream will tend to break up at more distant points with a correspondingly longer collapse time.

Conclusions

We have found that there is a critical density for the stream of grains which, if exceeded, ensures the fragmentation of the stream into separate, self-gravitating masses or planetesimals. Subsequent interactions between the planetesimals will lead to some growth and some fragmentation. However, the majority of the mass to be accumulated will still be present in the form of small grains migrating towards the central axis of the gaseous ring. Since the rate of accretion is enhanced by gravitational focussing, a statistical runaway effect may occur leading to the formation of one predominant body within each gaseous ring. This aspect requires further theoretical study.

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An Observed Correlation between the Flux Densities of Extended Hard X-ray and Microwave Solar Bursts

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Introduction

Crannell *et al.* (1978) have reported an observed correlation between the time profiles and flux densities of *impulsive* hard X-ray and microwave solar bursts. We report here on a significant correlation between the flux density of *extended* bursts of hard X-rays and micowaves. These extended events follow after impulsive bursts and last much longer (see e.g. Fig. 1, Frost and Dennis 1971). However, as extended bursts only occur during very large flares the number of cases available for study is small. The significance of our observations follows from the suggestion of Wild *et al.* (1963) that the extended bursts are evidence for a second-phase acceleration process in the corona. We show that the observed characteristics of these extended microwave bursts (viz. a rather flat spectrum below a turnover frequency which is independent of intensity) can be explained by gyro-synchrotron radiation from the same population of energetic ($E \approx 100$ keV) electrons as those emitting (thin-target) X-ray bremsstrahlung. A detailed source model is discussed in a companion paper (Nelson and Stewart 1979 — Paper B).

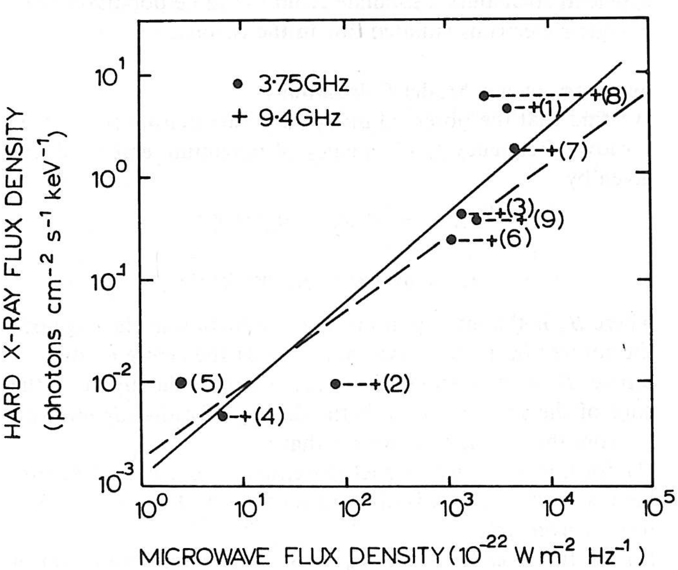

Figure 1. Observed correlation between hard X-ray and microwave flux densities near times of maxima in the nine large solar flare (extended) events listed in Table 1. Full lines show the least-mean-square fit (logarithmic) to the 9.4 GHz and long dashed lines to the 3.75 GHz data.

Observations

We have data for nine extended X-ray and microwave events listed in Table 1. Figure 1 shows that a good correlation (correlation coefficient $r^2 \approx 0.8$) exists between the 100 keV X-ray and 3.75 or 9.4 GHz microwave flux densities near the time of X-ray maximum. Figure 2 shows the spectra for the nine bursts. The spectra have two important properties. Firstly, below the turnover frequency f_M *the spectrum is much flatter,* ($S \propto f$ on the average) than that of impulsive bursts ($S \propto f^2$) (Crannell *et al.* 1978). Secondly, although the flux density varies by over three orders of magnitude (Fig. 1), *the turnover frequency remains of the same order.* Eight of the nine events (Fig. 2) have $f_M \geq 10$ GHz and four of these have $f_M \leq 20$ GHz. The remaining event (No. 5 of Table 1 and Figs 1 and 2) with $f_M \approx 1$ GHz can be explained by occultation effects (see later discussion).

Interpretation

We take the view that the observed correlation between 100 keV hard X-ray and microwave flux densities means that *both the X-ray and microwave emission come from the same population of energetic electrons in the corona.* Microwave bursts are emitted from electrons trapped in magnetic fields in the low corona. The corresponding plasma densities at these heights ($n_e < 10^{10}$ cm^{-3}) are too low for thick-target X-ray bremsstrahlung; rather they imply thin-target bremsstrahlung (Hudson 1972).

Ramaty and Petrosian (1972) have suggested that flat microwave spectra might be due to free-free absorption of gyrosynchrotron emission by thermal electrons. However, this

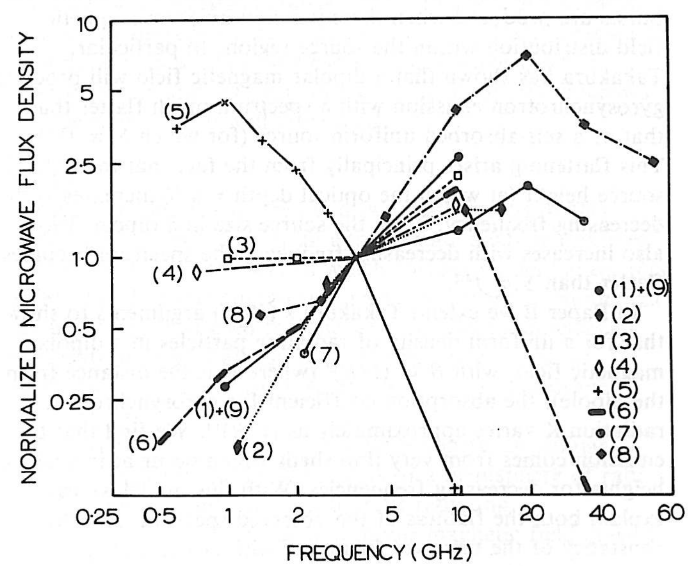

Figure 2. Microwave spectra of the nine extended solar bursts listed in Table 1 normalized to the 3.75 GHz value.