CONCLUDING REMARKS

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Before presenting my concluding remarks, I would like to repeat a comment made to me by the late Steve Smerd concerning the name «noise storms». Steve held strong views on many things, politics in particular, and he expressed his dislike of the name «noise storms» in characteristically forceful terms to me. The name «noise storms» was coined by C.W. Allen in 1947. Ruby Payne-Scott, who made the first detailed study of the phenomenon, called it «enhanced radiation». Later (in 1950) Paul Wild introduced his classification «Type I» for the phenomenon. Steve Smerd argued that we should refer to «type I storms», «type I continuum», «type I-III storms» and so on. The argument against the use of «noise storms» is simple : the phenomenon shows clearly defined frequency structure and hence cannot reasonably be described as «noise».

I have collected my concluding remarks around four rhetorical questions.

1 — What are we attempting to explain ?

To understanding what we are attempting in connection with type I bursts let us consider existing ideas on type II and type III bursts. Already in 1950, when he classified the bursts, Paul Wild proposed a qualitative theory for type III bursts : the emission occurs at the local plasma frequency and the existing agency is a stream of electrons. Within a few years a qualitative theory for type II bursts had emerged : the emission mechanism is similar to that in type III bursts and the exciting agency is an MHD shock wave. Subsequent observational developments have confirmed these qualitative ideas. In 1957 V.L. Ginzburg and V.V. Zheleznyakov presented a quantitative theory for the emission process : the stream of electrons generates Langmuir waves which are converted into transverse waves at the fundamental and second harmonic of the plasma frequency through nonlinear processes in the thermal plasma. These authors developed the nonlinear plasma theory themselves, and their papers, besides their astrophysical significance, were amongst the first in nonlinear plasma theory.

Those familiar with the theory of the plasma emission processes, as these emission processes are called, will be aware that most of the details in Ginzburg and Zheleznyakov's early works are now outdated. However, I would like to emphasize that their theory was (and is) valid from an astrophysical viewpoint. The basic ingredients in their theory remain in modern-day theories ; only the details of the plasma processes need to be updated. A similar comment could be made regarding the MHD shock hypothesis for type II : the details are not understood (the shock cannot be collisional, and there is no known collisionless shock structure with the appropriate properties) but it is universally agreed that an MHD-like shock is the exciter.

Now consider the situation with type I. As is obvious from our discussions here, there is no wide agreement on the nature of the exciter or driver, nor on the emission mechanism.

In answer to Q1 : we are attempting to formulate a theory for type I which provides the same level of understanding as was achieved for type III and type II in the 1950's.

2 — What can we reasonably expect of a theory of a solar radio phenomenon ?

It is important to recognize that a theory for a solar radio phenomenon has a status which is qualitatively different from that of a theory for a laboratory plasma phenomenon or even from that of a magnetospheric phenomenon. The purpose of a theory is to explain facts, and the nature of the facts is qualitatively different in these different contexts.

Laboratory plasmas are small scale and transient. The phenomena observed are often strongly dependent on initial conditions and/or boundary effects. The phenomena may be described in great detail due to the great variety of plasma diagnostics which are available. Data relating to a magnetospheric plasma phenomenon are similar in some ways to the data on a laboratory phenomenon, but there are important differences : one can probe the magnetospheric plasma only in the immediate vicinity of the trajectory of a spacecraft. Thus data on magnetospheric emissions are highly detailed but highly localized. The major distinction between the magnetosphere and the solar corona, from the viewpoint of the data available to us, is that we are inside the former and outside the latter. Data on the magnetosphere relates primarily to trapped particles and waves. Data relating to the solar corona depends entirely on escaping radiation (i.e. electromagnetic radiation and escaping particles). We are unable to probe the solar corona to test our hypotheses directly.

In answer to Q2 : the most we can expect of a theory of a solar radio phenomenon is that (a) it explains the observational data, (b) it is consistent with existing (plasma) theory, and (c) it is compatible with other solar phenomena.

3 – Why should we attempt to explain type I ?

There are several answers we could give to this question, e.g. because we wish to understand type I better, so that we may predict new phenomena associated with type I, in order to relate type I to other solar and non-solar phenomena (e.g. certain magnetospheric emission, emissions from flare stars), and so on. I think there is a more general justification for attempting to explain solar radio phenomena. As I have already suggested, the plasma processes of interest on the Sun are large scale and long lived, and the relevant phenomena usually cannot be simulated in the laboratory. Plasma astrophysics is complementary to laboratory plasma physics and can reasonably be expected to produce new results. Indeed, it already has : Ginzburg and Zheleznyakov's theory for type III emission introduced new ideas in plasma theory. Paul Wild has pointed out that the study of the Sun had led to major contributions to physics : «There were, for instance, Galileo and Newton who gave us mechanisms and gravitation ; Fraunhofer who gave us atomic spectra ; Eddington and Bethe who pointed the way to nuclear energy ; and Alfvén who gave us magneto-hydrodynamics».

I regard it as certain that the study of solar radiophysics will lead to significant contributions to our understanding of plasma physics.

4 – What have we achieved here ?

The answer to this question is necessarily a personal one, because clearly we have not solved any major problems. I have learnt several things :

– The driving agency for type I is related to emerging magnetic flux and Dr Brueckner has shown us data relating directly to emerging flux. Thus the exciting agency for type is partly identified.

– There is a separation of active regions into those which produce flares and those which produce type I. This leads to the interesting idea that in flaring regions free energy is stored and released explosively, and in type I-emitting regions the same free energy is released slowly with type I bursts as a signature.

– The driver for a type I burst is likely to be a perpendicular current associated with reconnection.

– Although not directly relevant to type I, the concept of non-equilibrium in MHD structures is obviously relevant to active regions.

– Understanding the directivity of type I and interpreting its source size seems to require a major departure from existing ideas on the source structure.

– Lastly I would like to mention the emission mechanism, which is my particular interest. We have three independent groups supporting the idea of coalescence of low-frequency waves with Langmuir waves as the emission mechanism. This idea is relatively new in connection with type I, and I would warn against accepting it as the established mechanism. Dr Mangeney has not pushed his (and Dr Veltri's) mechanism hard here, and there are other alternatives which I mentionned in my prepared talk on Tuesday.

In closing I would like to thank Jean-Louis Bougeret for his work in organizing the workshop, Arnold Benz for his organization of the scientific program, the CNRS for financial support, and the group leaders Drs Roberts, Wentzel and Zlobec.

EPILOGUE