

TYPE III SOLAR RADIO BURSTS AND  $^3\text{He}$ -RICH EVENTS

D. V. Reames and R. G. Stone  
NASA/Goddard Space Flight Center,  
Greenbelt, MD 20771 USA

## ABSTRACT

We investigate the kilometric radio data for  $^3\text{He}$ -rich events during the 1979-82 time period. Type III bursts are present for each event as expected from the previous electron/ $^3\text{He}$ -event association. A list of identified solar events is presented.

1. Introduction The association of solar  $^3\text{He}$ -rich events and non-relativistic electron events by Reames, von Rosenvinge and Lin (RvL, 1985) allowed the precise timing and velocity dispersion of the electron data to be used to identify the solar events responsible for the acceleration of particles with such anomalous isotopic abundances. However, these non-relativistic electron data are only available for the first 15 months of the ISEE-3 mission while many of the larger and more interesting  $^3\text{He}$  events occurred during the next several years of the mission. Fortunately, these same electrons are responsible for the rapidly drifting radio features called Type III bursts as they propagate at high velocity through the decreasing density of the interplanetary medium.

In this paper we show the relationship between the Type-III radio observations and the particle data in  $^3\text{He}$ -rich events and then use this association to identify the source region for many of the events.

2. Observations and Analysis The helium observations described in this paper were obtained with the very-low-energy telescope (VLET) in the GSFC cosmic-ray experiment on ISEE-3. In a few events it was possible to observe energetic (0.25 to 2 MeV) electron increases in the high-energy telescope of the same experiment.

The kilometric radio data used to study the interplanetary portion of the Type III radio emissions were obtained from the Radio Astronomy Experiment aboard ISEE-3. These radio observations provide not only timing of the electron release at the sun but also directional information that can track the electron population in interplanetary space and locate the solar longitude of the source within 10 to 20 degrees.

A list of  $^3\text{He}$ -rich time periods (Kahler et al., 1985) was re-examined for well-defined particle increases during the Dec. 1979 to Aug. 1982 study period. Dynamic radio spectra and single-frequency time histories were then examined during each of these events for the related Type III emission and the onset

times and spectral characteristics of the events were determined.

In Figure 1 we show the particle and radio data for two  $^3\text{He}$  time periods in 1982. Two events are seen in Fig. 1a, the Type III emission for the first event begins at 0533-0536 UT on June 25. There is no obvious increase in the energetic electrons from this event but the 2.2 - 3.4 MeV/AMU He nuclei begin to increase at 0745 and the 1.3 - 1.6 MeV/AMU nuclei arrive at 0830. The second event in Fig 1a begins in the radio data at 1945 and is seen minutes later (particle data are averaged in 15-min intervals) in the energetic electron data but He-nuclei from the event are not seen until after the data gap at about 2330.

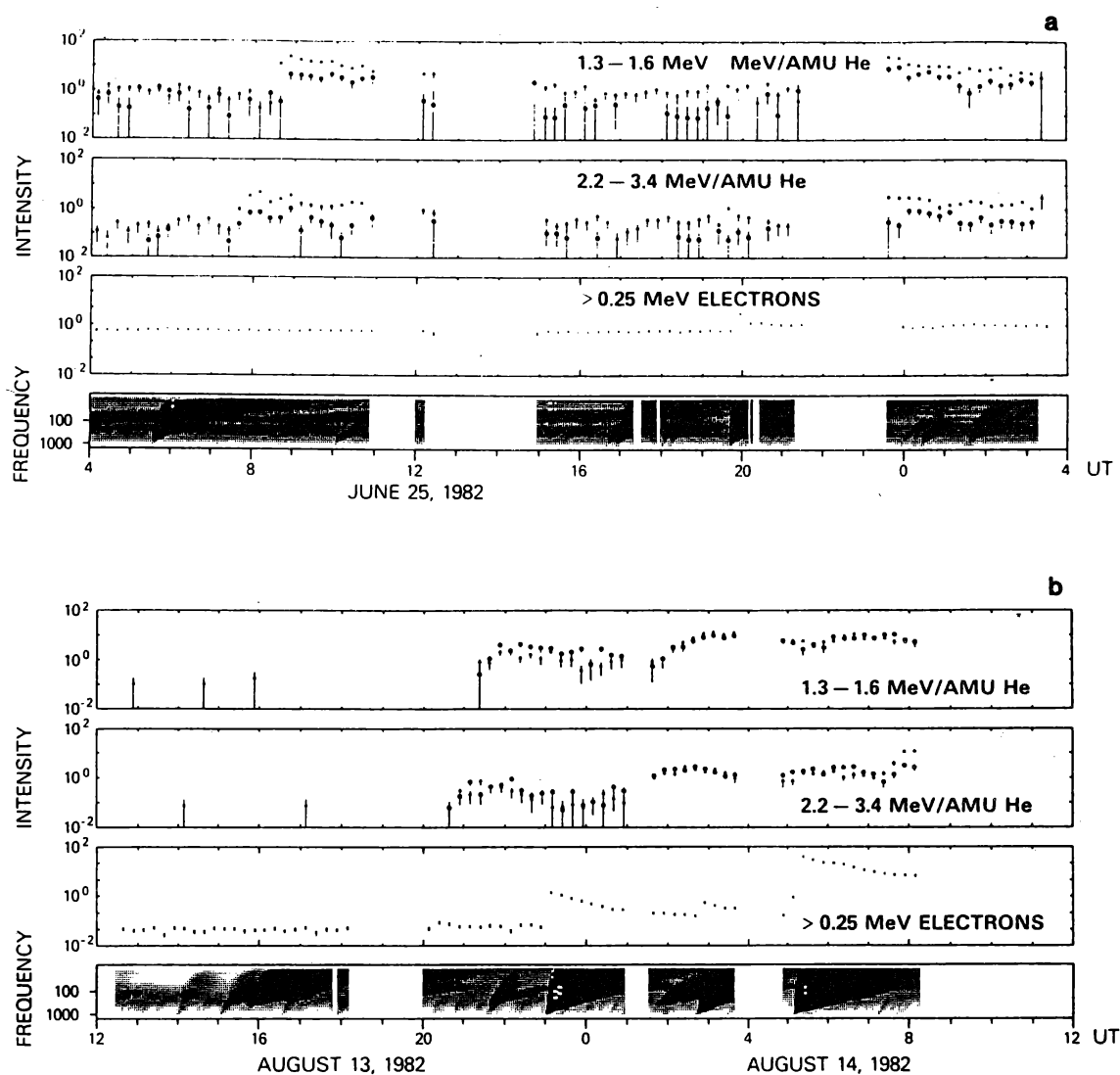


Fig. 1 Dynamic radio spectra and electron and He time histories for (a) Jun 25-26, 1982 and (b) Aug 13-14, 1982.

In Fig. 1b we show the striking series of  $^3\text{He}$ -rich events on Aug 13 - 14, 1982 that include the gamma-ray event (also  $^3\text{He}$  rich) at 0506 on Aug 14. The first Type-III event, is masked by the ubiquitous data gap at 1800-2000. Helium in the two energy intervals arrive at 2030 and 2115. The next three events beginning in the radio data at 2302, 0241 and 0509 each inject energetic electrons that are seen at 1 AU, and each inject fresh He nuclei that are observed after they propagate to 1 AU 2-3 hrs later as described by RvL (1985). Only the higher-energy He nuclei are seen from the large gamma-ray event before the data gap; all energies are seen again at 1200, just off the plot.

Note the difference in size and character of the Type III dynamic spectra in Fig. 1b for those events that contribute electrons and He at 1 AU and for those that do not. The other, weaker events in the same time period drift slowly to low frequencies because they lack sufficient intensities of faster, more-energetic electrons that would propagate outward more rapidly. Lacking energetic electrons, these events also lack measurable intensities of  $^3\text{He}$  (see also Reames and Lin, 1985).

Note also the quiet conditions in the particle observations prior to the first Aug 13 event. During the first 6 hrs in Fig 1b (excluding data gaps seen as white areas in the radio data) only 5  $^4\text{He}$  particles enter the telescope in both energy bands. In fact, no  $^3\text{He}$  particles enter the telescope in the 24-hr period prior to the first event.

The major  $^3\text{He}$ -rich events in the Dec 1979 to Aug 1982 for which we can identify the likely radio onset time are shown in Table 1. Also shown are the metric-radio and H-alpha flare data for most of the events. Many of the events occur in groups from the same active region, a fact that greatly simplifies their identification. In a few cases, where other candidate events do exist, they are always smaller events from the same active region.

3. Conclusion In conclusion we have shown that the solar electron- $^3\text{He}$  event association can be extended considerably by use of the kilometric radio data. Each  $^3\text{He}$ -rich event we examined was found to have a candidate Type III event and in most cases an unambiguous identification could be made. Of course these data do not provide the continuous and direct extrapolation of the velocity dispersion provided by the direct observation of non-relativistic electrons. On the other hand, the directional capability of the radio experiment provides the added spatial information that was only partially exploited in this work.

The prevalence of multiple events, usually with different isotope ratios, from the same solar active region is, once again, a striking result of this study. Each event is itself composed of groups at much higher time resolution in the radio data.

Table 1. Type III and Flare Associations of  $^3\text{He}$ -Rich Events

| Date        | 1.3 He |      | 2MHz<br>Time | Metric |      | Flare   |           |      |
|-------------|--------|------|--------------|--------|------|---------|-----------|------|
|             | Onset  | 3/4  |              | Time   |      | Time    | Site      | Imp. |
| 1979 Dec 14 | 2000   | 1.5  | 1552         | 1550   | 2GG  | 1553    | N10W51    | 1B   |
|             |        |      | -1605        | -1559  |      | -1643   |           |      |
| 1980 Nov 9  | 1930   | 0.9  | 1621         | 1620   | 3G   | 1621    | S14W44    | -N   |
|             |        |      |              | -1623  |      | -1633   |           |      |
| Nov 10      | 0000   | 1.4  | 2035         | 2033   | 2GV  | 2028    | S12W48    | -N   |
|             |        |      |              | -2035  |      | -2054   |           |      |
| Nov 10      | 0830   | 1.8  | 0448         | 0448   | 2GV  | 0446    | S09W51    | -N   |
|             |        |      |              | -0449  |      | -0508   |           |      |
| Dec 16      | 1830   | 0.5  | 1455         |        |      |         |           |      |
| 1981 Sep 15 | 2315   | 1.2  | 1935         | 1933   | 3GGV |         |           |      |
|             |        |      |              | -1937  |      |         |           |      |
| Nov 20      | 1330   | 0.2  | 1045         | 1041   | 2GG  | several |           |      |
|             |        |      |              | -1043  |      |         |           |      |
| 1982 Mar 10 | 1615   | >1.4 | gap          | 1220   | 3GG  | 1213    | S06W32    | 1B   |
|             |        |      |              | -1255  |      | -1308   |           |      |
| Mar 10      | 2300   | 0.7  | 1845         | 1844   | 3GGV | 1845    | S06W34    | 2B   |
|             |        |      |              | -1850  |      | -1908   |           |      |
| Jun 25      | 0830   | 0.3  | 0533         | 0530   | 3SIS | 0528    | N13W50    | 1B   |
|             |        |      | -0536        | -0535  |      | -0615   |           |      |
| Jun 25      | 2330   | 0.4  | 1945         | 1944   | 3GGV | 1941    | N17W56    | 2B   |
|             |        |      |              | -1945  |      | -2010   |           |      |
| Jun 30      | 1315   | >1.0 | 0915         |        |      |         |           |      |
| Aug 13      | 2130   | 2.0  | gap          | 1813   | 2GG  |         |           |      |
|             |        |      |              | -1820  |      |         |           |      |
| Aug 14      | 0200   | 0.8  | 2302         | 2259   | 3GV  | 2301    | N13W59    | -N   |
|             |        |      |              | -2303  |      | -2334   |           |      |
| Aug 14      | 0600   | 1.2  | 0241         | 0238   | 2GV  | 0237    | N11W60    | 1B   |
|             |        |      | -0245        | -0244  |      | -0315   |           |      |
| Aug 14      | 0800   | 0.2  | 0509         | 0506   | 3GV  | 0507    | N11W62    | 1B   |
|             |        |      |              | -0515  | II   | -0525   | gamma-ray |      |

The event identifications begin to show a link between the impulsive electron-rich  $^3\text{He}$  events and the impulsive electron-rich solar gamma-ray events with the Aug 14 event.  $^3\text{He}$  has been observed in two other gamma-ray events by Van Hollebeke et al. (1985). The distinction between particle events with impulsive and long-duration X-ray events has been clearly demonstrated by Cane et al. (1985).

#### References

- Cane, H. V., R. E. McGuire and T. T. von Rosenvinge, 1985, XIX ICRC paper SH 1.2-12 and *Astrophys. J.* (to be published).  
 Kahler, S. et al., 1985, *Astrophys. J.* **290**, 742.  
 Reames, D. V., and R. P. Lin, 1985, XIX ICRC paper SH 2.2-5.  
 Reames, D. V., T. T. von Rosenvinge and R. P. Lin, 1985, *Astrophys. J.* **292**, 716.  
 Van Hollebeke, M. A. I., F. B. Mc Donald and J. H. Trainor, 1985, XIX ICRC paper 2.2-3.