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Title

Detection and Analysis of Jupiter's Decametric Micropulses

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I. SCIENTIFIC BACKGROUND

The occurrence of Jupiter's decametric radio emission (discovered by Burke and Franklin in 1955) can be correlated with the central meridian longitude of Jupiter as if the active regions were radio transmitters placed at fixed longitudes on its surface. These active regions are commonly called sources and are labelled "Source A" (Jovian longitude ($\lambda_{III} = 200^{\circ}$), "Source B" ($\lambda_{III} = 100^{\circ}$) and "Source C" ($\lambda_{III} = 300^{\circ}$).

These sources are not always active. However, they can be "turned-on" if Jupiter's innermost Galilean moon, Io, is in the right phase. In fact, if Io is found 90° from superior geocentric conjunction (maximum eastern elongation) and if source B is simultaneously on the central meridian, source B radiation is almost guaranteed, whereas source C radiation is highly likely when Io is found 240° from superior geocentric conjunction. Source A radiation is largely independent of Io's position.

Interestingly, the Io-related radio storms contain unusually rapid events that can only be properly studied using wide-band techniques.

The University of Florida radio astronomy group began its wide-bandwidth studies as early as 1966.

Using a 100-kHz bandwidth receiver, and photographing burst envelopes, it was discovered in March, 1966 that some millisecond Jovian bursts (S-bursts) had leading and trailing edges lasting 10μ seconds or less. If the emitting source is capable of turning on or off in 10μ seconds, then it is suggested that the source diameter can be no larger than 10 light-microseconds, i.e., 3 km.

Figure 1 -- Oscilloscope photographs of a Jovian S-burst (center trace) and an isolated micropulse (top trace). These photographs represent 100 kHz-bandwidth IF output of an 18 MHz receiver as recorded in 1967.

Very short isolated pulses - believed to be of Jovian origin - were also discovered. These pulses which have durations on the order of 25μ seconds occur very infrequently.

Figure 1 shows one msec long S-burst on the center trace which exhibits bandwidth limited leading and trailing edges. The bottom trace contains an isolated "microsecond" burst.

In 1968 a 300 kHz bandwidth receiver was constructed having a Base-Band detected output which preserved the spectral characteristics of the received signals. The receiver output was recorded on a high speed instrumentation tape recorder.

Frequency drift measurements on the "microsecond" pulses were made by slowing the recorded data down by a factor of 4096:1 and making strip chart records of the slowed down data after it had been passed through a tuneable filter.

An analysis of the microsecond bursts in Jupiter's decametric radio emission showed that these pulses had an average duration of about 25 micro-seconds and drifted in frequency at a rate on the order of GHz/sec.

The pulses appeared to belong to two different populations; one having an average upward drift rate of 16. 7 GHz/sec, the other drifting downward at an average rate of 8. 5 GHz/sec. The difference in these rates is attributed to the observed drifts being compounded of a source-produced drift, which can be both positive and negative, and a negative drift due to dispersion by the plasma in the propagation path. Based on the difference in these average observed rates, the magnitude of the average drift rate at the source (11.3 GHz/sec) and that due to dispersion (34.6 GHz/sec) were determined. Such dispersion would require a columnar electron density of about 1.2×10^{18} electrons/m^2. Since 1×10^{17} e^-/m^2 reside in the terrestial ionosphere and about six times this amount in interplanetary space, then the remainder, 5×10^{17} e^-/m^2, must be in the Jovian magnetosphere. If one assumes that (1) the electron density profile obeys a power law, (2) that the electron density at the top of Jupiter's ionosphere is 5×10^{11} e^-/m^3, and (3) that the magnetopause is at about 50 Jovian radii, then the exponent in the power law is -3.6. Using this density model and the value given above for the integrated density between the source and magnetopause, it was found that the source is between the planet and Io at approximately four Jovian radii.

During the period 1966-1970 wide-bandwidth observations were made with considerable difficulty due to interference from terrestial radio signals.

II. PROJECT PROGRAM

When the Project was approved by NASA in 1970, we opened the field observatory near Huanta, Chile which had been constructed in 1964 using NASA funds. This site, in a deep Andean valley of north central Chile, was chosen for its interference-free environment. NASA and the University of Florida shared in the cost of the project; NASA supplying travel operating expenses (NASA grant NGR 10-005-149) and the University of Florida supplying salary, capital equipment and data analysis expenses.

The equipment, a tape recording system and a receiving system consisting of a 15-24 MHz log-periodic antenna and six 500 kHz bandwidth receivers, was shipped to Chile through NASA channels in January 1971. The observatory became operational April 11, 1971 and was "on-the-air" until June 29, 1971.

The observatory was operated by Richard Flagg, an engineer from the radio astronomy staff at the University of Florida, Dolores Kraushe, a graduate student and Vladimir Papic, a Chilean who acted as observing assistant, local business manager and interpreter. Jorge May and Juan Aparici, scientists from the Maipu Radio Observatory which is located near Santiago and which is operated jointly by the University of Florida and the University of Chile, aided in initial construction and check out procedures and helped our shipments through customs.

Each night during the period April 11, 1971 to June 29, 1971, Jupiter was monitored when it was above the horizon. Special attention was given to the times of predicted Io-related radiation. On the nights from April 26, 1971 to May 12, 1972, no observations were made as one of the motors in the tape system failed in the extremely dry, dusty environment.

After June 29, 1971, the observatory was dismantled. The receiving and tape systems were moved to the Maipu observatory. The tape system and some of the receivers were shipped back to the University of Florida. The remaining components remain at Maipu.

III. SCIENTIFIC RESULTS

Although there was more station interference than had been anticipated, it was possible to record more high-resolution spectral information at Huanta than had been obtained during all of the preceeding apparitions at the Florida site.

It was possible to synthesize a 3 MHz system bandwidth by choosing receiver center frequencies in adjacent 500 kHz channels. The product-detected outputs of the six receivers were recorded simultaneously along with a reference timing signal on a 7 track, portable, high speed instrumentation recorder.

The spectral and temporal character of the data are now being analyzed using a real time spectrum analyzer after the data have been slowed down into audio frequency domain.

The output of the spectrum analyzer is photographed producing a record of both spectral and temporal characteristics of the Jovian burst structure.

Examples of this data reduction and presentation method are seen in Figures 2-5.

Analysis of the Hunata data is still not complete after almost two years of intensive study due to the very time consuming nature of the data reduction and analysis techniques which must be employed. Important clues as to the nature of the Jovian radiation mechanism are however beginning to emerge.

Figure 2 shows spectra of quasi-periodic S-bursts having an average separation of 90 msec. The average drift rate of these bursts is -18.5 MHz/sec.

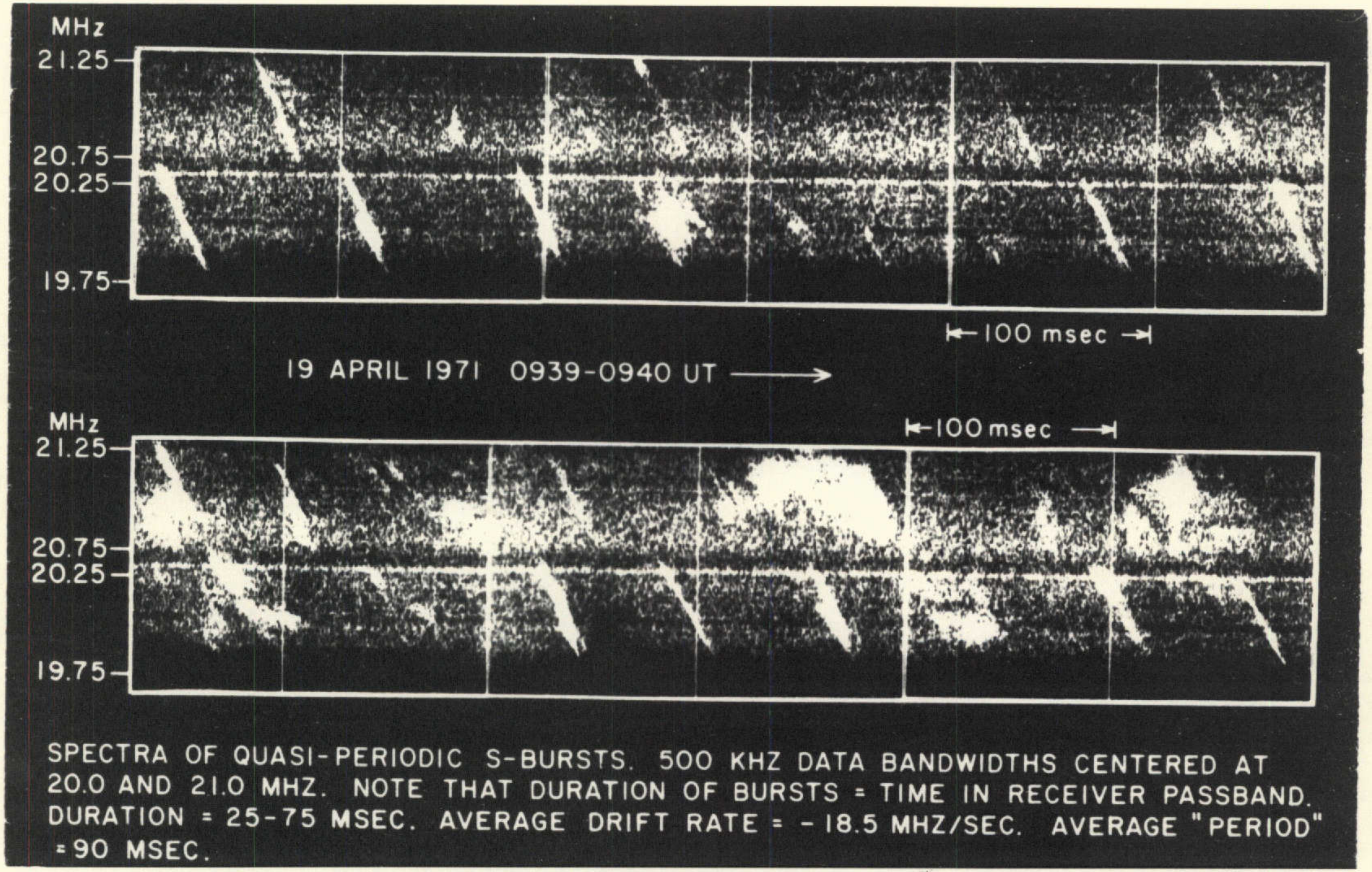

Figure 2 -- Spectra of two 500-kHz-bandwidth channels as recorded in Huanta, Chile in 1971.

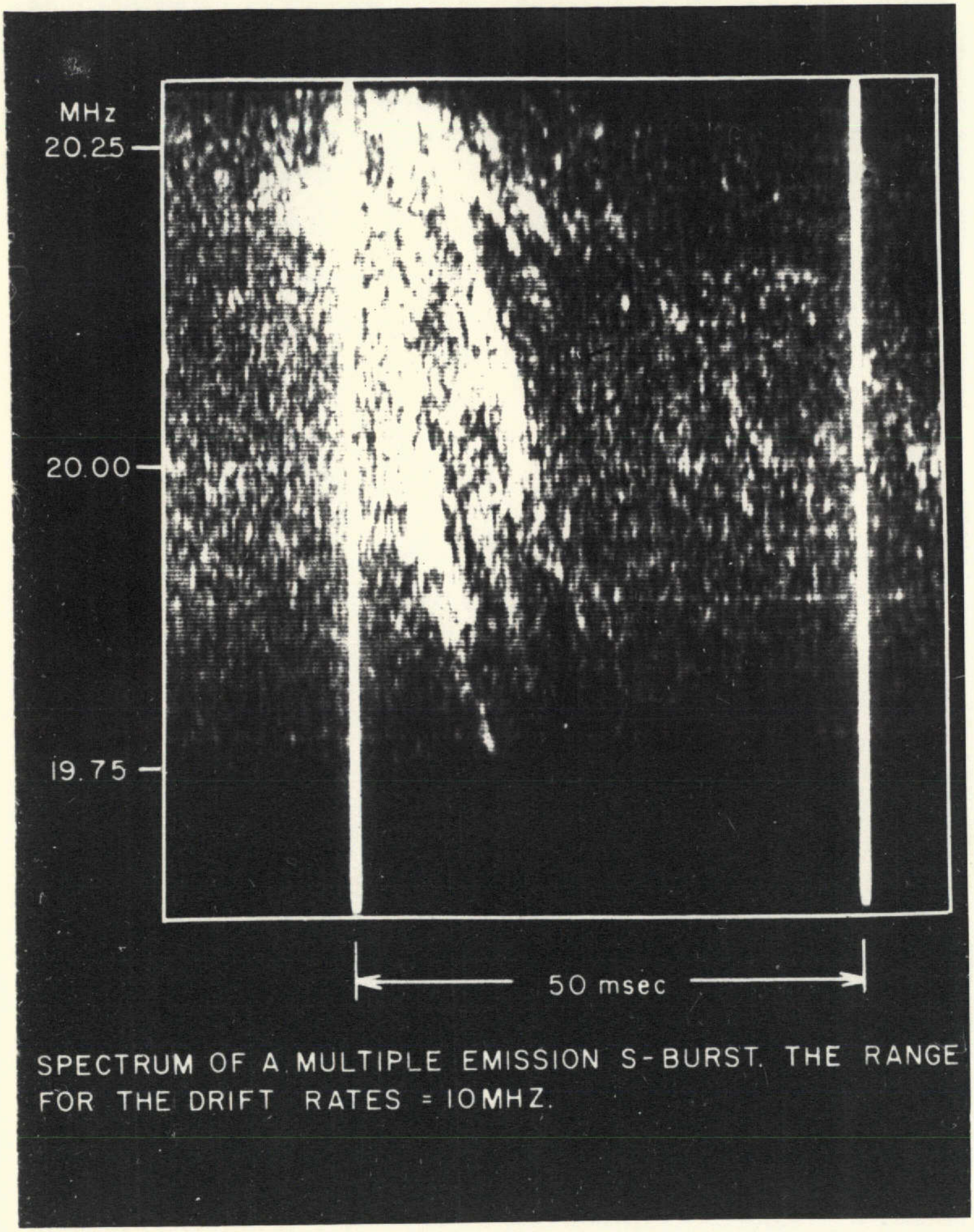

Figure 3 -- Spectra of a complex Jovian S burst as recorded in Dixie County in 1970.

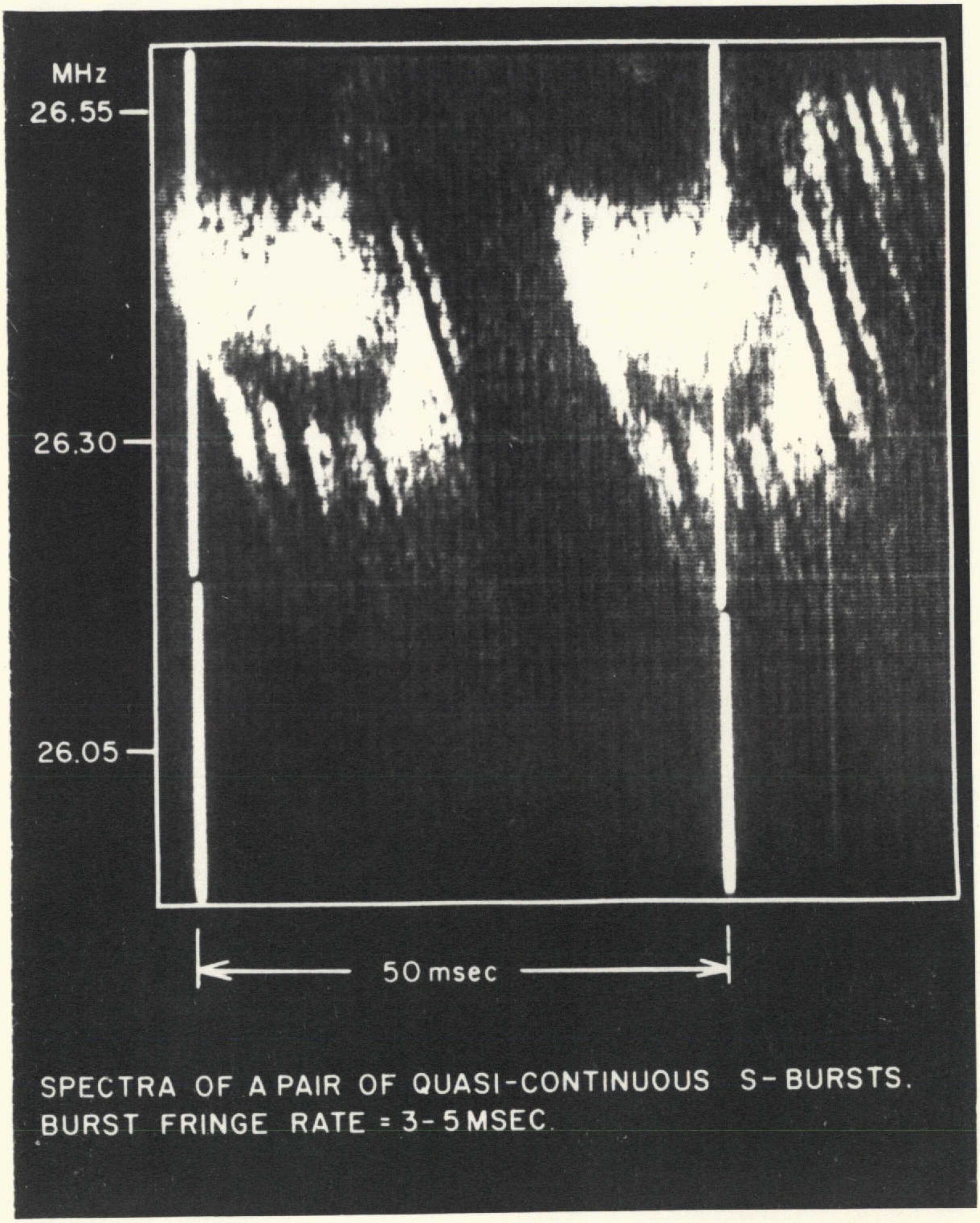

Figure 4 -- Spectra of two Jovian S bursts showing nearly identical characteristics. These data were recorded using the 640 element array at the University of Florida Radio Observatory during the 1971 apparition of Jupiter.

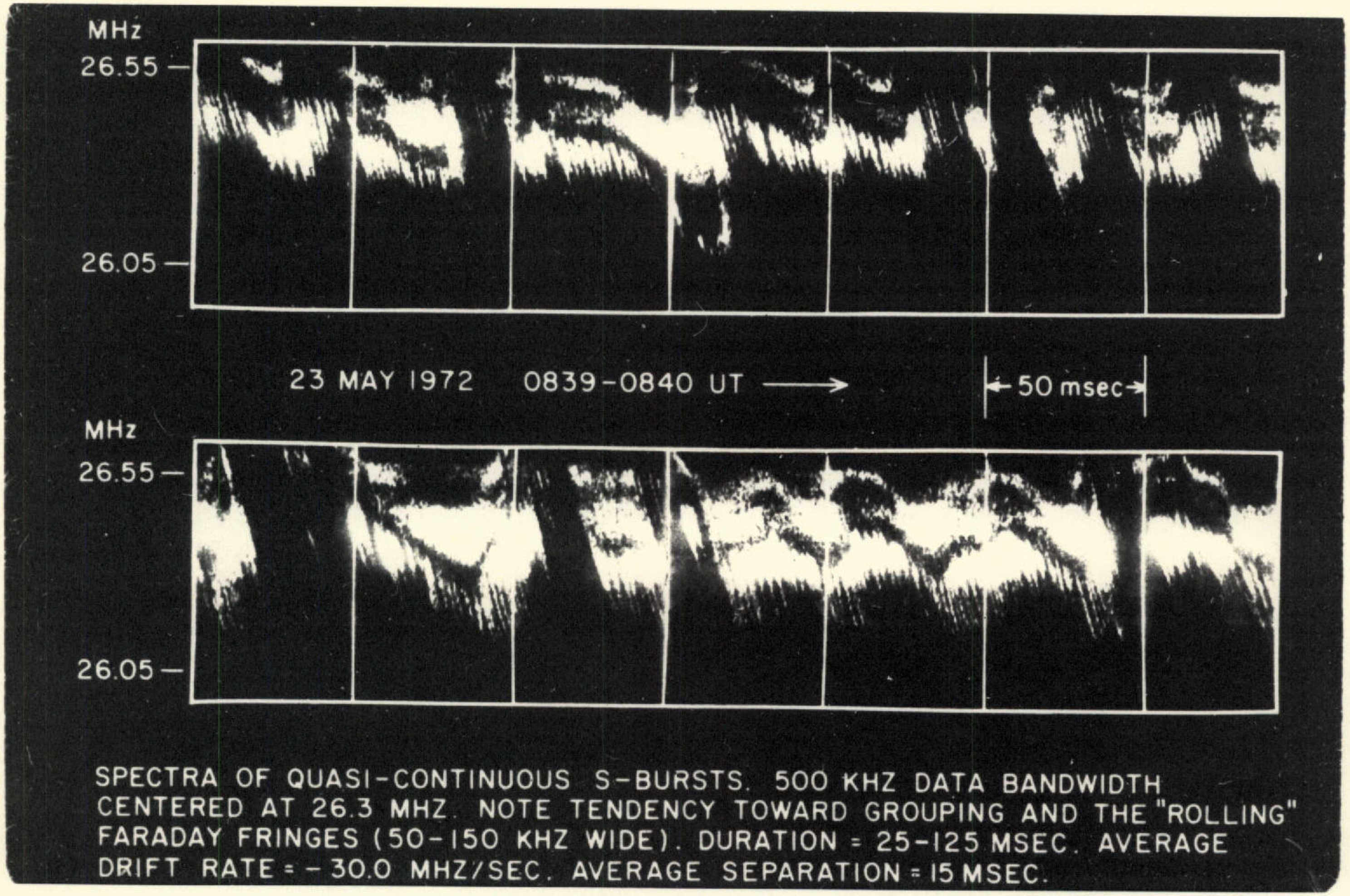

Figure 5 -- Spectra of continuous Jovian S-burst activity showing Faraday Rotation lanes. These data were recorded using the 640 element array at the University of Florida Radio Observatory during the 1971 apparition of Jupiter.

Figure 3 shows the spectra of a much more complex event. Numerous drift rates are evident with the rates decreasing as time progresses suggesting some type of decay process in the emission mechanism.

Figure 4 shows a pair of practically identical S-bursts. The probability is high that the second burst is an "echo" - the first burst having propagated directly to earth from the source, while the second burst is produced by a reflection in the Jovian ionosphere.

If this explanation is correct then it should be possible using computer modeling to locate the source position in the Jovian magnetosphere.

Figure 5 depicts differential Faraday rotation observed in the spectra of quasi-continuous S-bursts.

Differential Faraday measurements will yield values of $\int Nf(B)\, dr$ along the propagation path.

Measurements of the dispersion of "microsecond" bursts will produce values of $\int N\, dr$ along the propagation path.

The data shown in Figures 4 and 5 was taken in 1972 at the University of Florida's Dixie County radio observatory.

The antenna used was the recently completed 640 dipole phased array operating at 26.3 MHz; the receiver was one of those constructed for the Huanta experiment.

Wide bandwidth observations, of Jupiter's decametric radiation, have produced preliminary estimates of source size and location. They have also been responsible for the discovery of the "microsecond" burst component of

Jovian radiation. Further analysis of the differential Faraday measurements will yield values of $\int Nf(B)\, dr$. Measurements of "microsecond" burst dispersion produces values of $\int N\, dr$ along the propagation path. "Microsecond" burst dispersion measurements are providing a method of studying the solar wind electron content.