NATIONAL RADIO ASTRONOMY OBSERVATORY
VERY LARGE ARRAY PROGRAM
SOCORRO, NM 87801

VLA Scientific Memorandum No. 139

VLA Hybrid Configuration U,V Plane Coverage

R. A. Perley
November, 1981

I. Introduction

The VLA was designed to operate in one of four "standard" configurations. The placement of antennas in these configurations was carefully chosen to optimize the u,v plane coverage over an observing period of 6 to 12 hours. Stated another way, the antenna placements were chosen to give the minimum sidelobe level possible in the synthesized beam. The price of this optimization is that the range of angular scales over which a single VLA configuration is sensitive is somewhat limited. This range is approximately:

$$\frac{\text{maximum spacing}}{\text{minimum spacing}} \approx 40$$

meaning that emission on a scale $\gtrsim 40$ times the synthesized beam will not be accurately represented in the map. Currently, the only way to gain this missing information is to obtain more data in a more compact configuration.

A second method enabling greater u,v coverage at a single observing session is to configure the array in a "hybrid" mode which would combine long and short spacings, thus giving a greater range in spatial frequency sampling, while still maintaining the original resolution. A number of applications of this hybrid configuration can be listed. Some (but probably not all) are:

1. To increase efficiency by observing a wider range of spacings than those available in any single configuration. A well-designed hybrid configuration should provide as good a u,v coverage in one day as could be gained in two half-day observations in two different standard configurations. This use may be particularly important for sources whose flux varies significantly on time scales shorter than reconfiguration times (say, 2 weeks).

2. To aid in self-calibration by supplying a few long spacings for sources whose interesting information lies in short spacings and which contain a bright unresolved core.

3. To provide a circular beam at modest resolution for far southern ($\delta < -20^{\circ}$) sources.

There is no general solution which answers all these needs. The best solutions for #2 and #3 are simple and quite different. In the former case, one antenna at the end of each arm, with the remaining antennas in a standard 'B' or 'C' configuration, seems optimal. For the latter, placing the North arm in the next larger configuration than the East and West arms is an obvious solution which is currently in use at the VLA. In Fig 1a is the u,v plane coverage for a full synthesis of a source at $\delta=-40^{\circ}$ in this hybrid configuration, while Fig 1b shows the standard u,v coverage. The improvement in this hybrid array is obvious. Tests show that this improvement is obtained only for declinations south of -20°.

The solution for use #1 requires a more careful study of u,v coverage. This report concerns this study.

II. A Suitable Hybrid Configuration

I have assumed that the purpose of a hybrid configuration would be to provide short spacing coverage in a basically high resolution array. The tests started with the 'A' configuration, and the effect of moving some antennas near the center was noted. The goal was to provide good u,v coverage in the center without seriously depleting the long-spacing coverage. All tests used full 12^{h} tracks, unless limited by elevation constraints. To improve antenna move efficiency, only stations used by 'A' or 'C' arrays were considered. An obvious scaling change will allow configurations combining 'B' and 'D'.

The judgement of a "good" hybrid configuration is difficult and quite subjective. I have chosen not to attempt to parameterize this decision, but rather to trust intuition based on uniformity and smoothness of the u,v plots. Qualities judged as good are an absence of "holes" on all scales, and the uniformity of track density.

It must be emphasized that the presence of "holes" in the u,v plane sets the limit on the largest angular scale structure which can accurately be reconstructed. The "hole" need not be located at the center to be considered serious - if, in filling the center hole, a hole of equal size appears elsewhere, then serious errors in the structure on the same angular scale will occur in the map. Although the "total flux" may be gained, the detail may be lost. It is debatable which loss is the greater.

The freedom one has in designing hybrid configurations is limited by the following considerations:

1. Because of the need to maintain high resolution, the outer two antennas on each arm must be left on stations 64 and 72.

2. To adequately cover the short spacings, about 3 antennas on each arm must be placed inside station 8.

3. The remaining four antennas on each arm must be redistributed to cover the missing center spacings.

In essence, the problem is how to place the inner and central antennas. Too many inner antennas create large gaps in the high-resolution u,v coverage, while too few leave inadequate coverage of the short spacings.

To examine the u,v plane coverages of the various hybrid arrays, the coverages were displayed on three scales, or resolutions: (a) high - corresponding to the resolution of the 'A' array, (b) medium - an 8-fold expansion, and (c) low, a 32-fold expansion.

The initial tests were made for $\delta = 60°$. For some of the 'better' configurations, plots at other declinations were made to test the variation of coverage with declination.

Fig. 2 shows, for reference, the u,v coverage in the 'A' array at $\delta = 60°$ for full 12^h tracks. Note that the coverage is good for the high and medium scales, but is very poor at low resolution. This is especially a problem at northern declinations where the benefit of foreshortening is lost. It is this 'hole' we need to fill to gain a good hybrid configuration.

Approximately ten different hybrid configurations were studied. The best, judged by the criteria mentioned above, is that given by:

W arm	2	6	10	16	24	40	48	64	72
E arm	4	8	12	18	24	40	48	64	72
N arm	6	10	14	16	24	40	48	64	72

The u,v plots for $\delta = 60^o$, 12^h tracks, are shown in Fig. 3. This configuration, however, is only marginally better than others that were tested. Stated another way, the optimization is very broad; small deviations from the placements given above will not change the coverage appreciably. Finally, Figs. 4 and 5 show the u,v coverage at $\delta = 10^o$ and $\delta = -20^o$, respectively.

III. Comparison with Combining 'A' and 'C' configurations

An important comparison is how this "best" hybrid array fares against a combination of 'A' and 'C'. To nullify any arguments based on observing time, the comparison is made between 12^h of hybrid configuration and 12^h of A + C: 6^h in 'A' plus 6^h in 'C'. UV plots were made for six declinations ($+60^o$, 30^o, 10^o, -05^o, -20^o, -40^o). For all declinations and all resolutions, the combined A and C had equal or (usually) better u,v coverage. We give, for example, the coverages at $\delta = 60^o$, 10^o and -20^o in Fig. 6, 7 and 8. Little change is noted at other declinations. In terms of u,v coverage, then, no hybrid array is as good as combining the A and C (or B and D with obvious scale changes) arrays, even under the restriction of using the same total observing time.

IV. Conclusions

For special purpose cases, such as southern sources and small, core-dominated sources, simple and effective hybrid arrays are clearly possible. For these cases, suggested solutions are given in Section I. Note, however, that it is not clear that long-baseline self-calibration techniques are any better than self-calibration of a standard or combined configurations using the newer, more powerful, and more efficient algorithms.

A hybrid configuration whose intent is to fully and evenly cover the u,v plane at resolutions varying over a factor greater than 40 is possible. A good solution is given in Section II. An important conclusion is that the optimization of this hybrid configuration is very broad - the placement of the antennas is not critical providing that the general guidelines given in Section II are followed.

Finally, the u,v coverage given by the "best" hybrid configuration is inferior to that given by a combination of standard arrays. This conclusion is true even for the same total observing time (i.e. 12^h in hybrid vs. 6^h in 'A' plus 6^h in 'C'), and is true at all declinations.

In view of these results, it appears that the only valid reason for adopting a hybrid configuration is for observations of sources whose structure changes appreciably on time scales less than ∿2 weeks, and for observations of far southern sources.

RP/tr

FIGURE CAPTIONS

Fig 1a: The u,v coverage at $\delta = -40^{o}$ in the 'B' configuration
1b: The u,v coverage at $\delta = -40^{o}$ with the East and West arms in 'B" configuration, and the North arm in 'A' configuration. Note the greatly improved N-S coverage.

Fig. 2 The u, v coverage at $\delta = 60^{o}$ with 12 hour tracks in standard 'A' configuration: (a) Full resolution, (b) X 8, and (c) X 32. Note the lack of information in the largest expansion.

Fig. 3 The u,v coverage for the "best" hybrid configuration at $\delta = 60^{o}$. The expansions are as in Fig. 2. Note the improvement in coverage at short spacings.

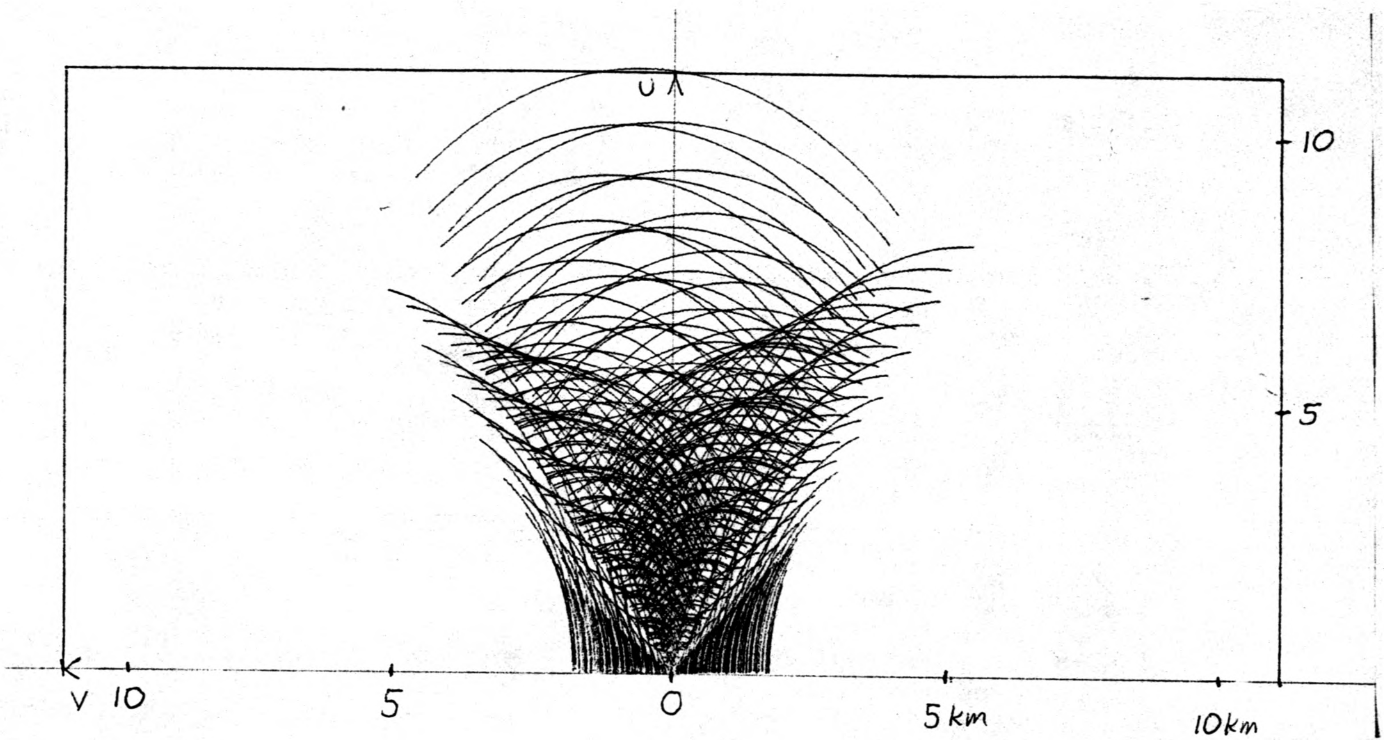
Fig. 4 Hybrid array u,v coverage for $\delta = 10^{o}$.

Fig. 5 Hybrid array u, v coverage for $\delta = -20^{o}$.

Fig. 6 The u,v coverage at $\delta = 60^{o}$ when 6^{h} of 'A' configuration are added to 6^{h} of 'C' configuration. Compare this to Fig. 3.

Fig. 7 As in Fig. 6 for $\delta = 10^{o}$. Compare to Fig. 4.

Fig. 8 As in Fig. 6, but for $\delta = -20^{o}$. Compare to Fig. 5.



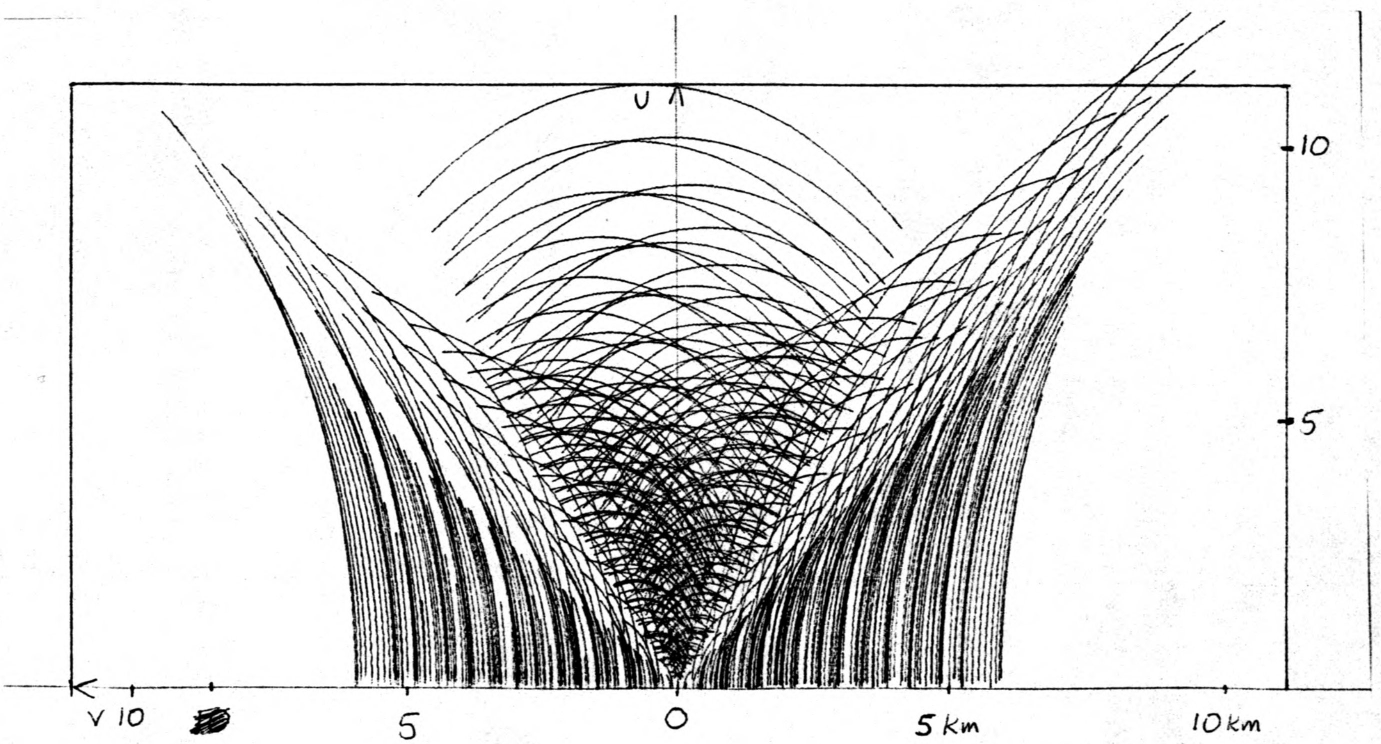


Fig 1

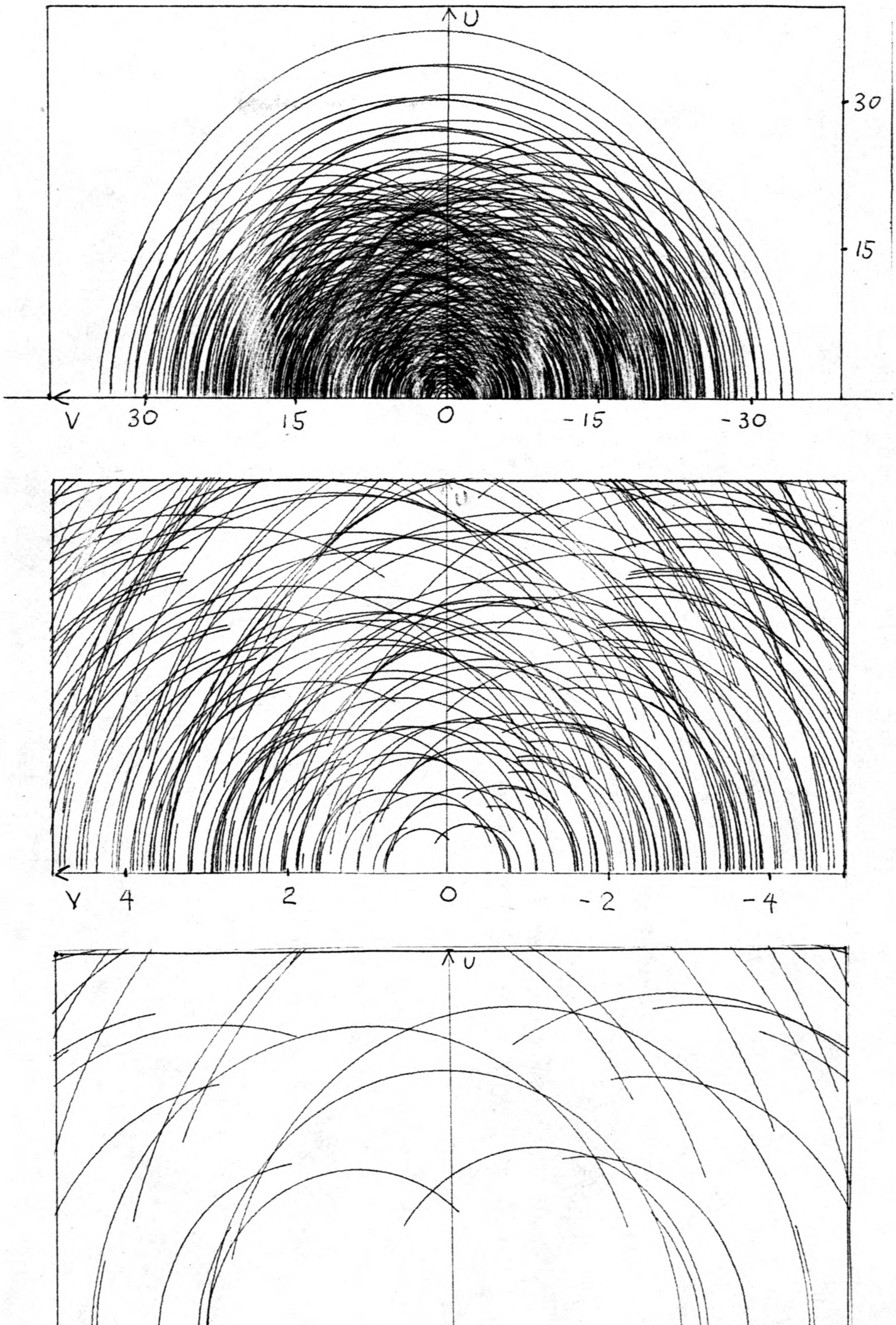
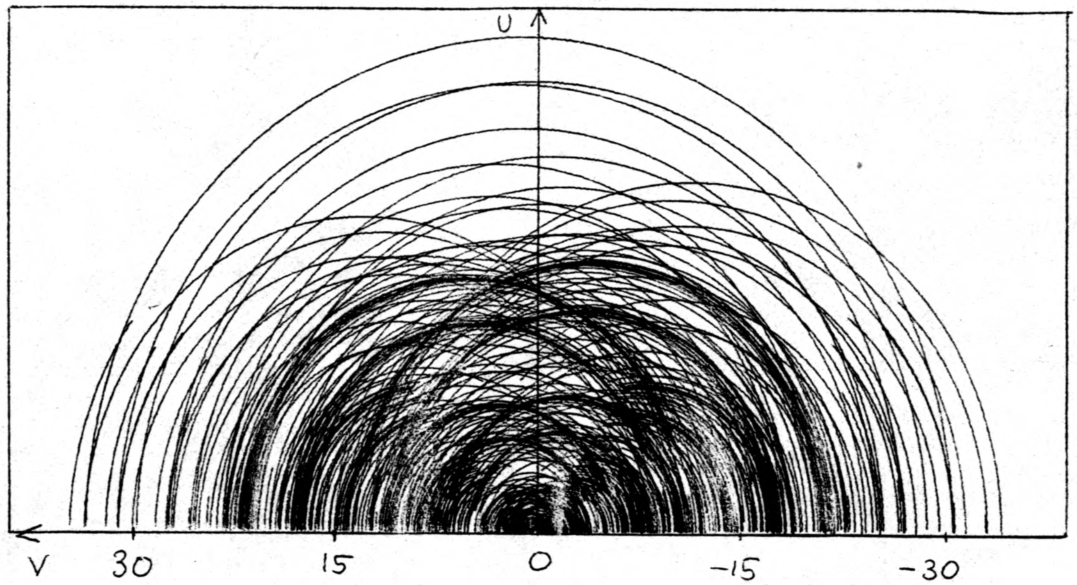


Fig 2



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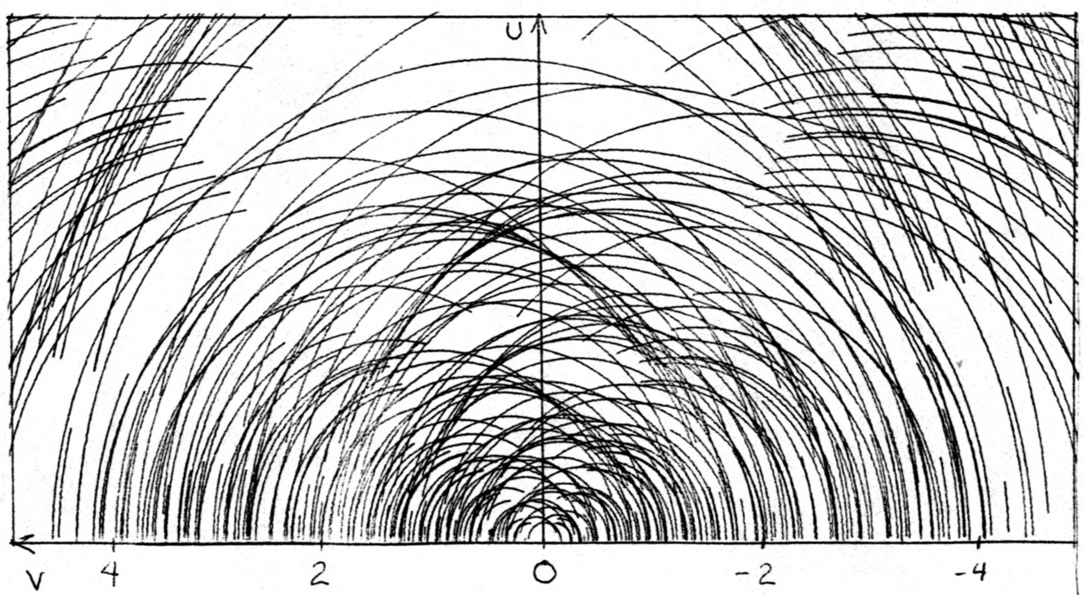

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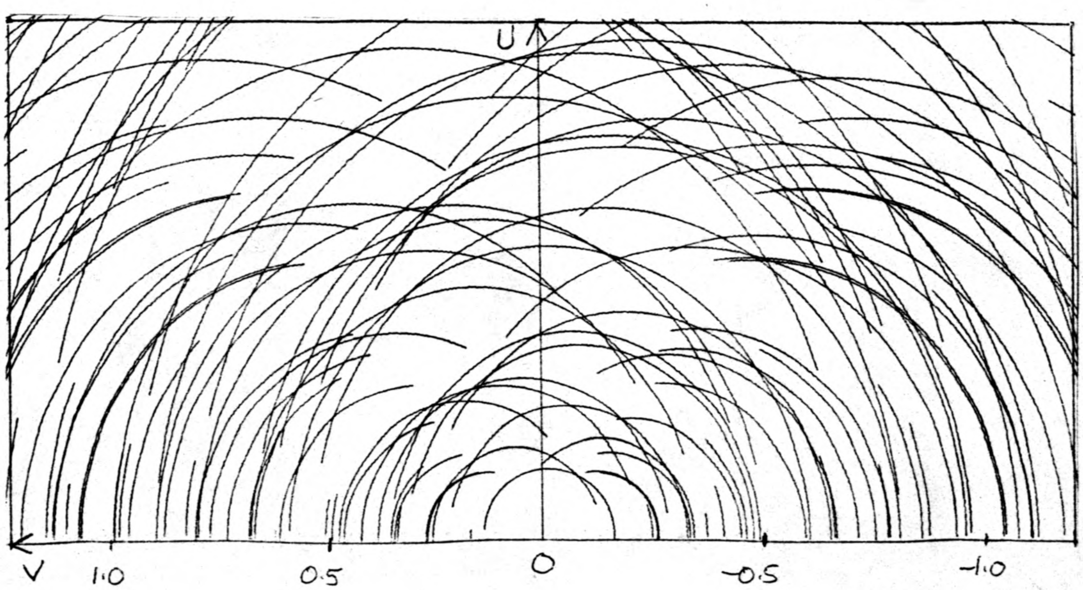

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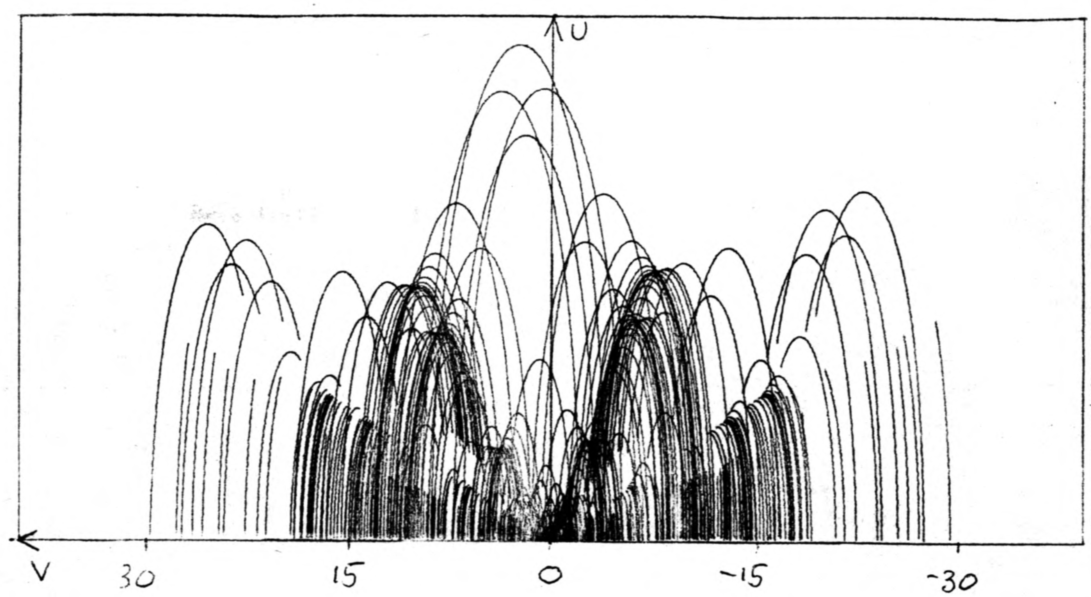
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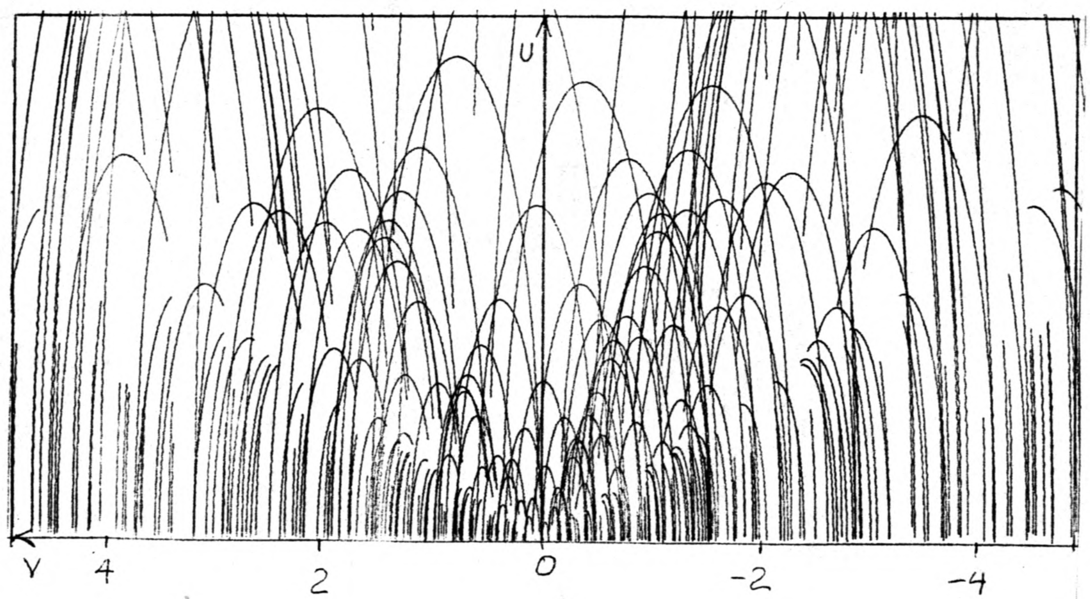
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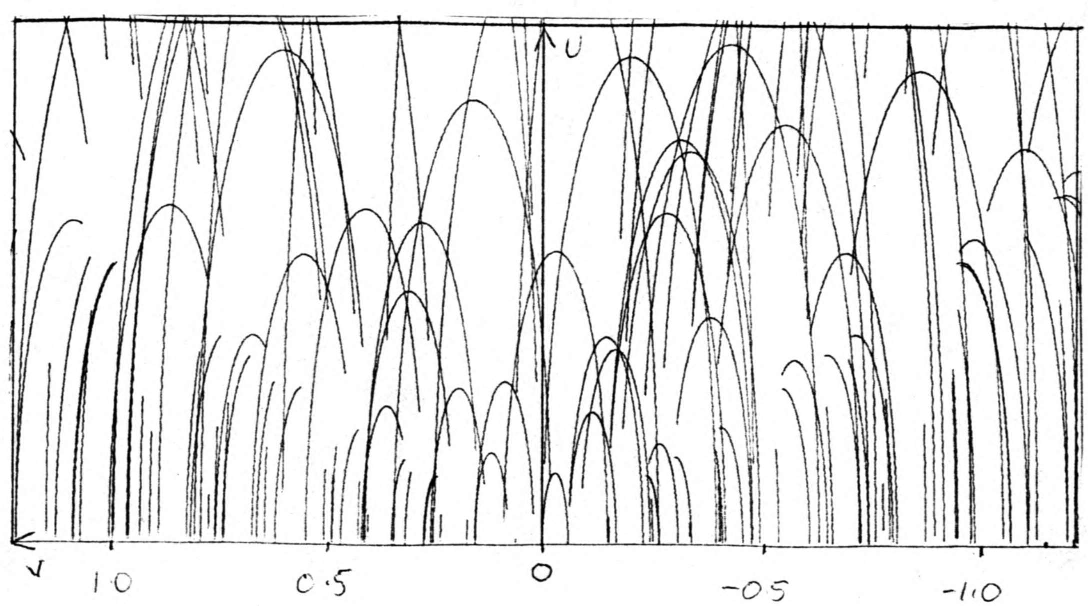
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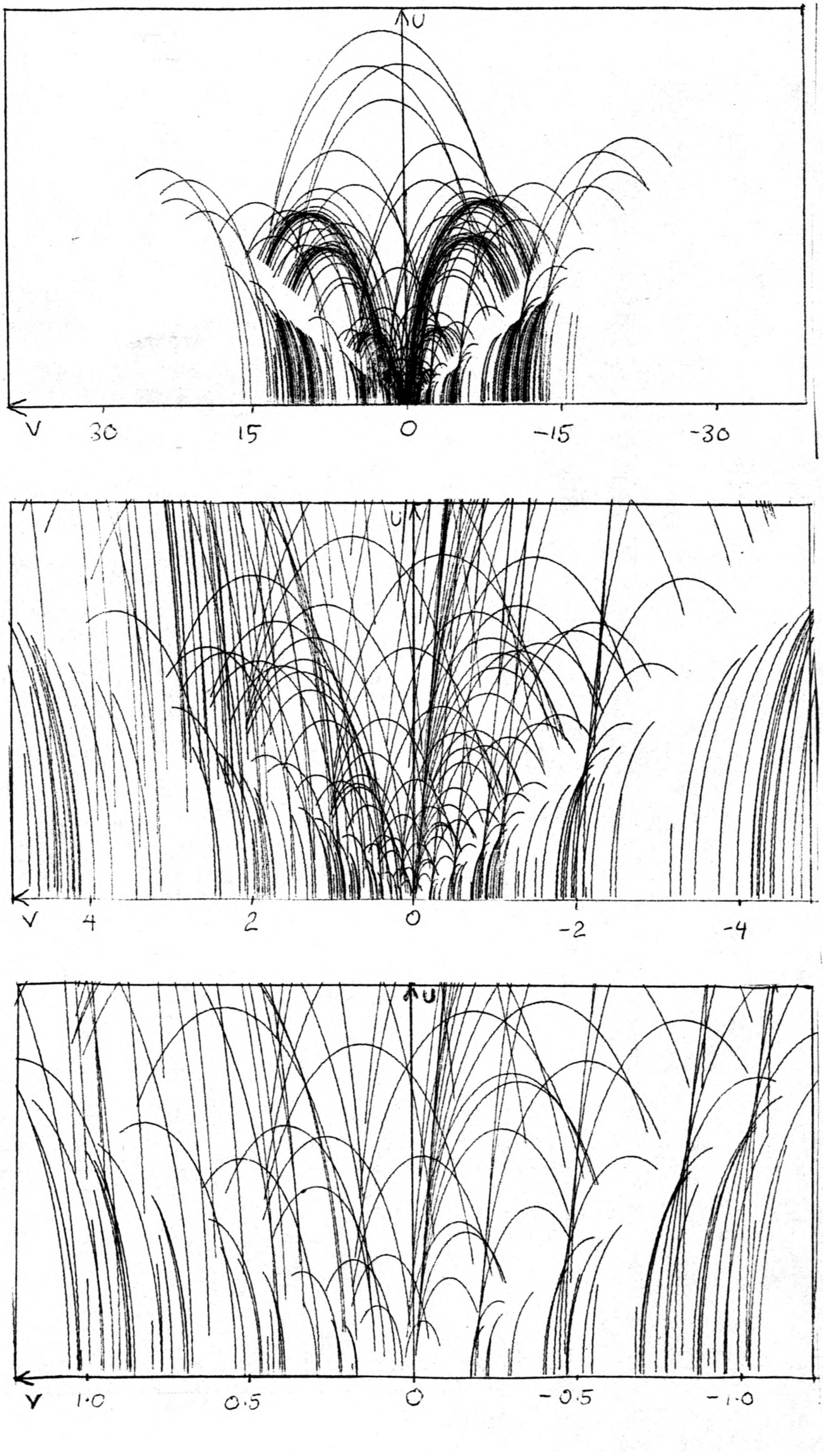
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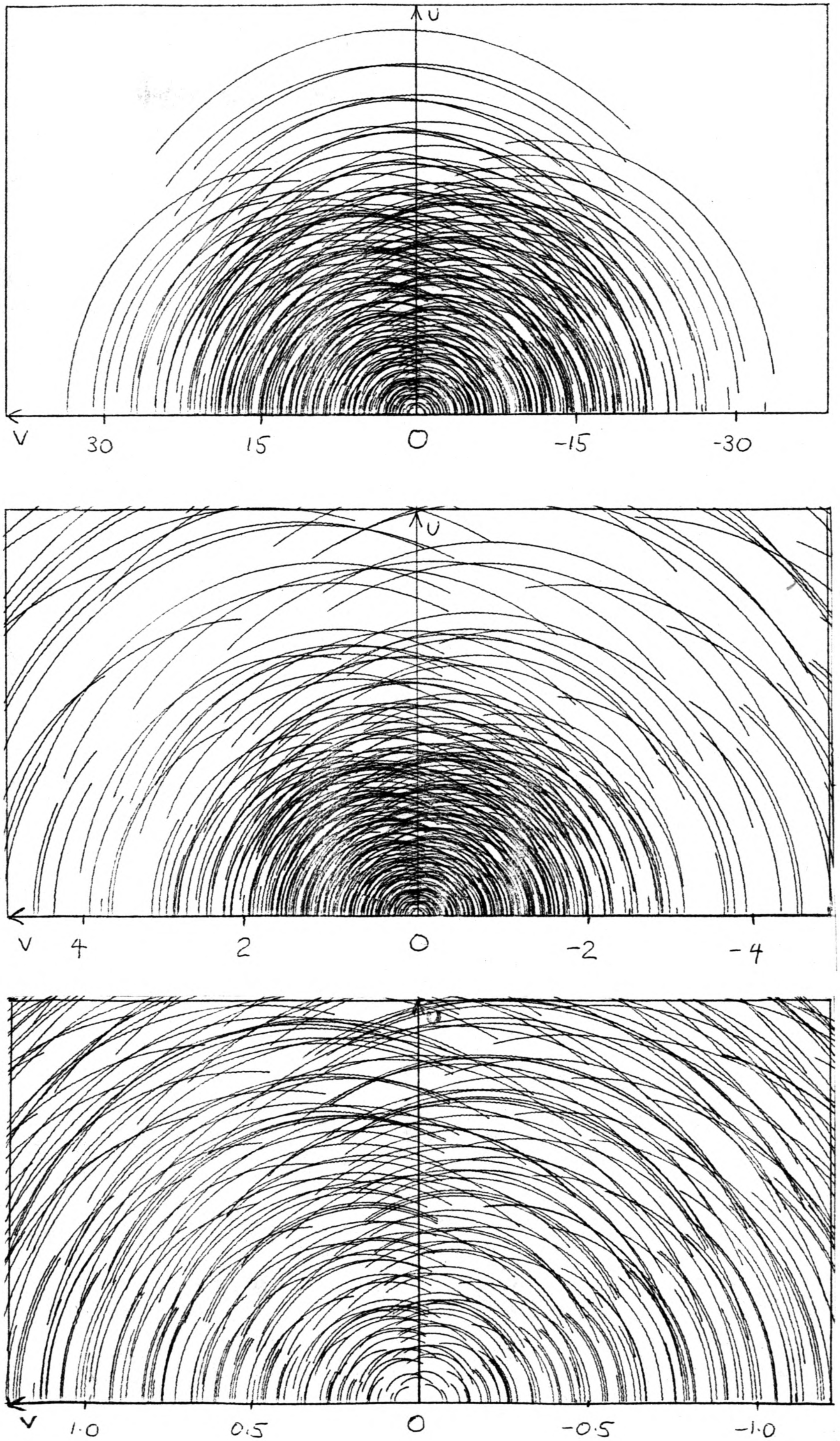

Fig 6.

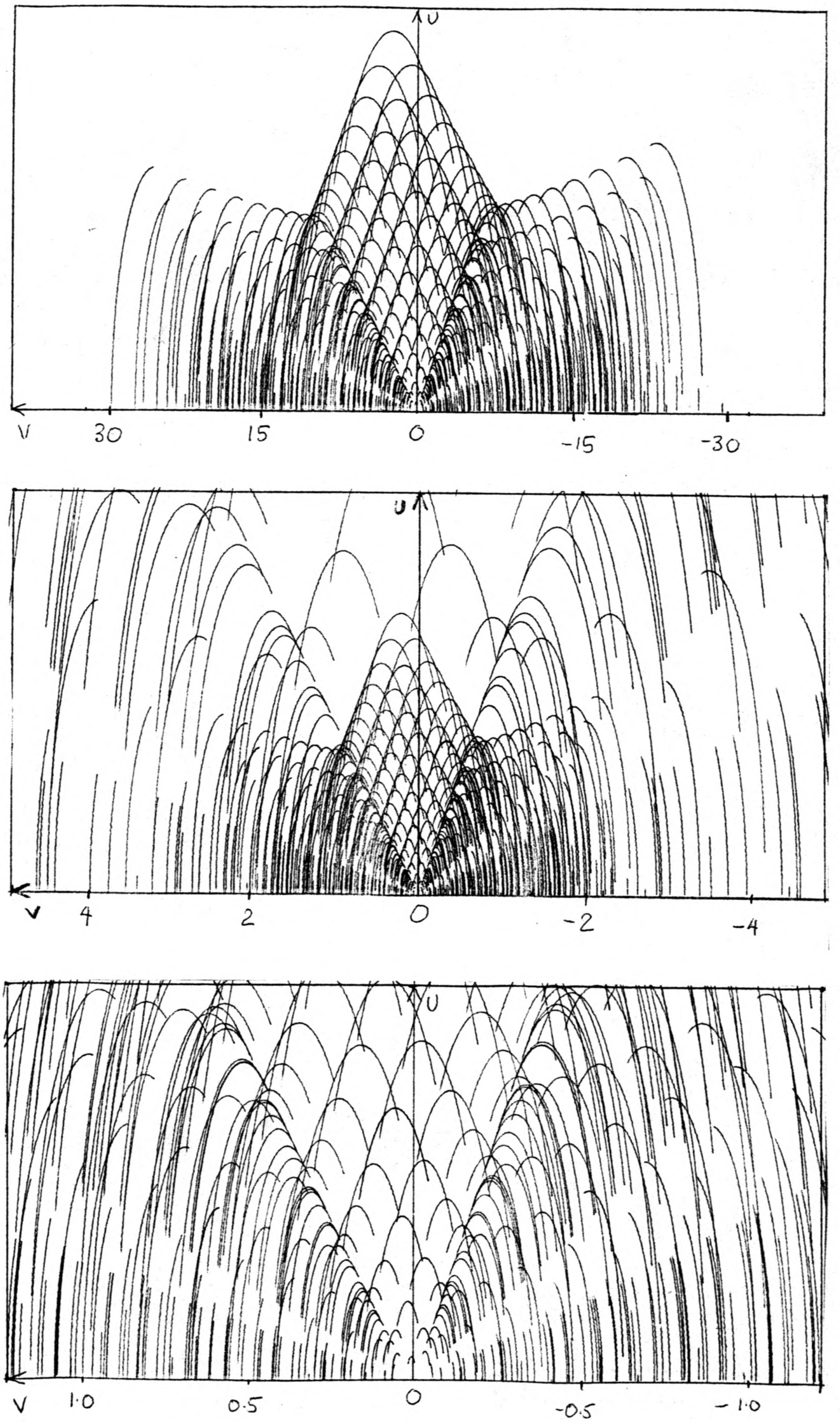

Fig 7

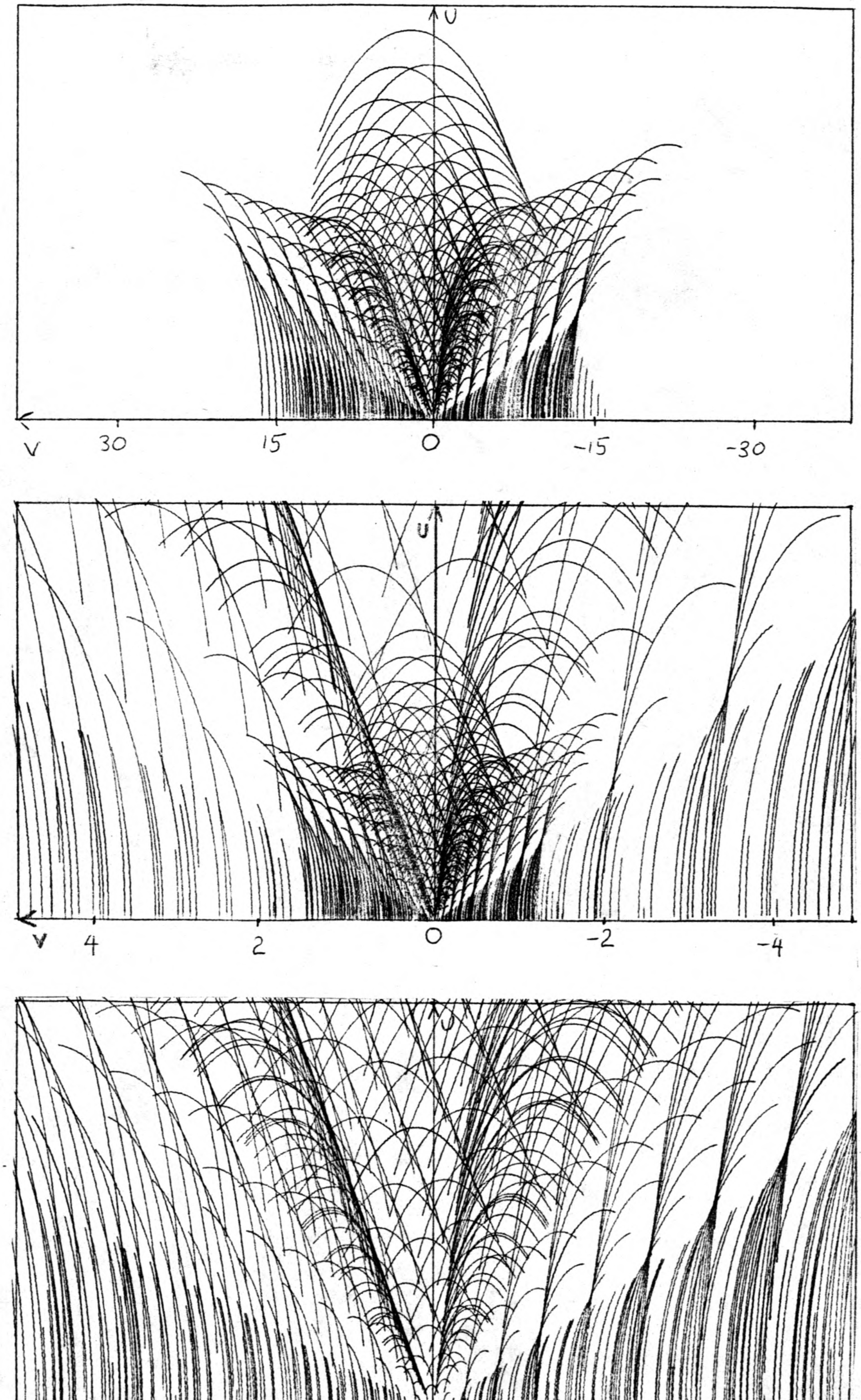

Fig 8